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NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

LXX INTERNATIONAL CONFERENCE

«NUCLEUS-2020»

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Объединенный институт ядерных исследований

LXX МЕЖДУНАРОДНАЯ КОНФЕРЕНЦИЯ

«ЯДРО-2020»

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СБОРНИК ТЕЗИСОВ

Онлайн часть.
12 – 17 октября 2020

Санкт-Петербург

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СЕМЬДЕСЯТ ЕЖЕГОДНЫХ ЯДЕРНЫХ КОНФЕРЕНЦИЙ

(70-е совещание по ядерной спектроскопии и структуре атомного ядра)

Авторы: М.А. Листенгартен[1], А.К. Власников[1]

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В наступившем 2020-м году мы в семидесятый раз проводим традиционную конференцию по ядерной физике.

Семьдесят лет, без единого пропуска, физики-ядерщики нашей страны имеют возможность встречаться ежегодно и обсуждать самые насущные проблемы ядерной науки. На первых порах это были Всесоюзные ежегодные совещания, но они быстро превратились в Международные конференции по физике ядра, сначала фактически, а потом и официально.

В первую очередь, наш долг сегодня вспомнить Бориса Сергеевича Джелепова - замечательного ученого, инициатора, организатора и вдохновителя этих традиционных встреч людей науки. На сорока четырех конференциях он был председателем Оргкомитета, а в последние годы жизни - почетным председателем (четыре конференции). Он выступал с докладами и сообщениями вплоть до 1995 года включительно. И сейчас, через двадцать два года после его кончины, наша конференция, одно из его творений, живет, и, надеемся, еще послужит отечественной науке.

Конечно, сейчас созывается много различных конференций, как российских, так и международных. Но полвека тому назад в условиях закрытости, в которых жила страна, ядерные конференции представляли собой уникальное явление. Ни в одной отрасли советской науки еще не было тогда возможностей для встреч ученых со столь завидной регулярностью. Правомерно было бы назвать Джелеповские Совещания в какой-то мере продолжением традиции довоенных Всесоюзных съездов по ядерной физике (а их было пять).

Первое Совещание по ядерной спектроскопии состоялось в Москве в феврале 1951 *г.* Материалы Совещания, опубликованные в "Известиях АН СССР, сер. физ. ", т. 16, № 3, 1952, содержали всего пять докладов, причем все - из Ленинграда. Перечислим их, так как это пионеры наших конференций, их тоже не надо забывать, они внесли ощутимый вклад в становление традиций совещания и в развитие науки. Это работы А.А.Башилова, Н.М.Антоньевой, Б.С.Джелепова (спектроскопия ^{192}Ir), Э.Е.Берловича (спектроскопия ^{214}Po), Л.А.Слива и Л.А.Слива с Л.Н.Зыряновой (выбор взаимодействия в теории бета-распада) и А.З.Долгинова (теория угловых корреляций конверсионных электронов - заметим, на год раньше появления аналогичных работ за рубежом).

Далее случился прямо-таки "большой взрыв": как число участников конференции, так и число представляемых докладов стали стремительно возрастать. Со второго Совещания активно включились в его работу физики Москвы. С четвертого (1954 г.) появились украинские ядерщики, а на седьмом Совещании (первом, состоявшемся в Ленинграде), как свидетельствует Ежегодник БСЭ, присутствовали уже несколько сот человек, в том числе представители из многих городов России, большинства союзных республик, а также ученые из Болгарии, ГДР, Китая, Польши, Франции, Чехословакии, Югославии. Как уже отмечалось в печати, Б.С. Джелепов чутко уловил, что настоятельная необходимость созыва представительных конференций отвечает созревшим объективным потребностям развития науки в стране. И потому появление всесоюзного форума - "Джелеповских совещаний" - было с энтузиазмом встречено всеми, кто активно работал в области ядерной физики низких энергий.

Помимо Москвы и Ленинграда, очередные конференции стали организовываться на базе научных учреждений союзных республик (1959 г., Харьков), а затем и в других городах (Рига, Киев, Тбилиси, Минск, Ереван, Баку, Ташкент, Самарканд, Алма-Ата), что в громадной степени содействовало развитию ядерной науки во всей стране. В ряде случаев эти конференции были знаменательными или даже небывалыми событиями для научной общественности на местах. Например, как вспоминали участники, конференция 1964 г., проходила под непосредственным патронажем Совета Министров Грузии, со всеми вытекающими отсюда следствиями. Автобусы с участниками конференции следовали по городу в сопровождении эскорта машин с милицией под оглушительный вой милицейских сирен. Еще бы! Возможно, впервые город принимал такое созвездие: крупных ученых из США, Англии, Франции, Германии и ряда других стран (Престон, Расмуссен, Вилкинсон и многие другие), а также из социалистических стран, Москвы и Ленинграда.

В первые годы рост числа участников можно проследить по числу публикаций в "Материалах конференций" в "Изв. АН СССР". К пятому Совещанию появилась машинописная "Предварительная

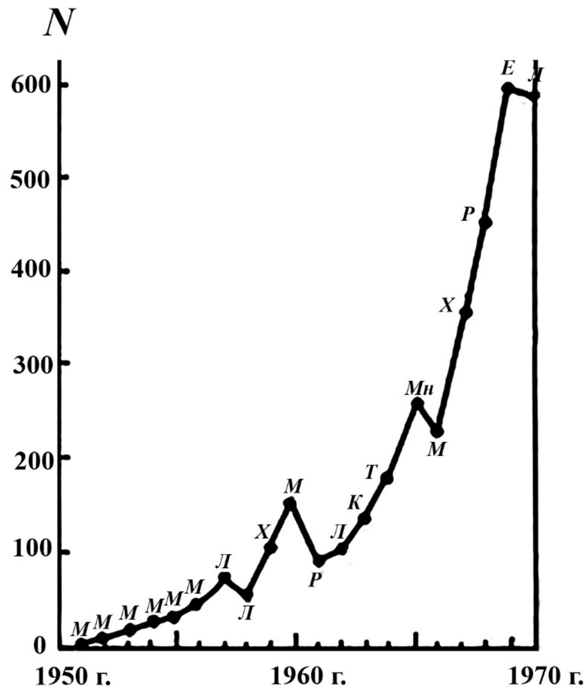

Рис. 1: Число докладов, включенных в программу ежегодных совещаний. Буквы возле точек означают место проведения конференции (М — Москва, Л — Ленинград, Х — Харьков, Р — Рига, К — Киев, Т — Тбилиси, Мн — Минск, Е — Ереван).

программа и тезисы", размноженные на ротапринте, а с шестого Совещания начала печататься привычная всем книжка тезисов.

Судя по этим источникам, первые 18 лет (1951 – 1969) число представленных докладов возрастало по экспоненте с периодом удвоения 3.1 года.

Затем в течение 20 лет (1969 - 1989) число представляемых тезисов докладов оставалось почти постоянным (максимум - 618, Самарканд, 1981). Число приезжавших участников также достигало в большинстве случаев 500 - 600 человек. Этому в немалой степени способствовала сознательная политика Б.С.Джелепова, который старался создать такие условия, чтобы молодые физики, в том числе и аспиранты, могли лично встретиться с корифеями, обсудить свои научные работы, а иногда и доложить их, если руководитель секции найдет их заслуживающими такой чести. Приезжающих студентов старались разместить бесплатно в студенческих общежитиях.

В девяностые годы экономические проблемы страны, к сожалению, сказались и на наших конференциях. С 1990 года число докладов начало снижаться с периодом полураспада $T_{1/2}$ ~ 18 лет. Так, книжка 1997 года содержала всего 287 тезисов докладов. Из-за уменьшения государственной поддержки и роста цен число российских ученых, приезжающих на конференцию, снизилось почти в три раза, а число физиков из стран бывшего СССР сократилось еще больше. Зато увеличилась относительная доля гостей из дальнего зарубежья и возросло число стран, из которых стали появляться доклады (Италия, Япония, Бельгия, Португалия, Греция и др.). Однако следует отметить, что в последнее время наблюдается увеличение количества участников конференции, что особенно заметно, когда местом проведения становятся крупные научные центры (Дубна, Санкт-Петербург).

Огромную роль в работе конференции сыграл К.А.Гриднев. С 1995 года вплоть до кончины в 2015 году Константин Александрович был главным организатором конференции в разных городах страны. В этот труднейший период он сумел не только сохранить конференцию, но и обогатить ее новыми темами, привлечь к участию крупнейших ученых, как из Российской Федерации, так и из других стран.

Семидесятилетняя история конференций по структуре атомного ядра хорошо отражает процесс развития и изменение приоритетов в ядерной физике за эти годы. В последнее время возрос интерес к экзотическим состояниям атомных ядер, к ядрам на границе стабильности, к ядерной физике сверхвысоких энергий, а также к прикладным аспектам ядерной физики. Приоритетно развиваются Mega Science проекты. Все это находит отражение в тематике представляемых докладов.

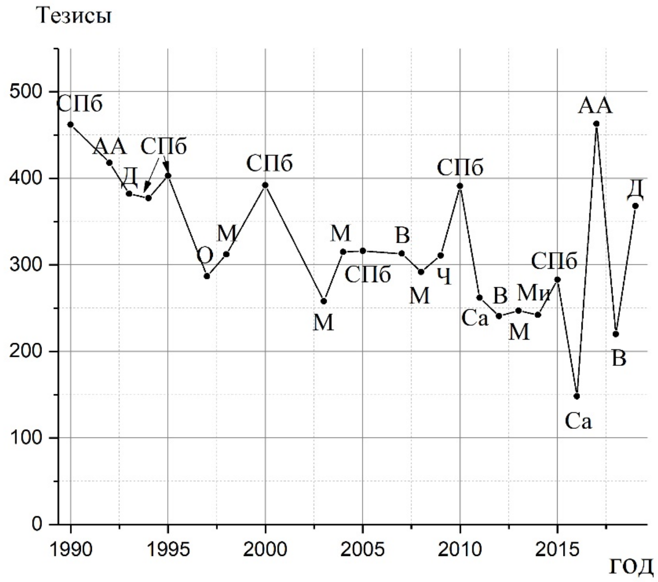

Рис. 2: Изменение количества докладов, включенных в программу ежегодных совещаний в 1990-2019 г.г. Буквы возле точек означают место проведения конференции (М — Москва, СПб — Санкт-Петербург, Д — Дубна, АА — Алма-Ата, О — Обнинск, В — Воронеж, Ми — Минск, Ч — Чебоксары, Са — Саров).

В работе конференции принимали участие крупные ученые. Результаты многих важнейших исследований были доложены и обсуждены на наших конференциях.

Среди основных достижений, представленных на заседаниях конференции, можно упомянуть:

- открытие несохранения четности в гамма-процессах (В.М.Лобашов, В.А.Назаренко, Ю.Г.Абов, П.А.Крупчицкий);
- создание модели неаксиального ядра (А.С.Давыдов, Г.Ф.Филиппов);
- открытие сверхтяжелых элементов вплоть до 118-го (Г.Н.Флеров, Ю.Ц.Оганесян);
- открытие эффекта теней (А.Ф.Тулинов);
- открытие более сотни ранее неизвестных нейтронно-дефицитных изотопов и изучение их свойств в ходе выполнения первой в мире программы исследования ядер, удаленных от области стабильности (Б.С.Джелепов, К.Я.Громов и их многочисленные соратники);
- фундаментальные работы по теории внутренней конверсии (Л.А.Слив и его сотрудники);
- важные экспериментальные исследования кулоновского возбуждения (И.Х.Лемберг и его команда);
- создание теории конечных ферми-систем с приложением к структуре ядер (А.Б.Мигдал и большое число его последователей);
- детальное изучение глубоконеупругих процессов (В.В.Волков и другие);
- разработка квазичастично - фононной модели ядра В.Г.Соловьевым;
- создание ядерной теории бозонных разложений (С.Т.Беляев, В. Г. Зелевинский, Р.Джолос)

и много других.

В работе конференций принимали участие выдающиеся ученые нашей страны. В их числе академики: В.И.Гольданский, Я.Б.Зельдович, Л.Д.Ландау, П.И.Лукирский, Ю.Ц. Оганесян, Б.М.Понтекорво, П.А.Черенков, чл.-корр. АН: А.И.Алиханян, Д.А.Варшалович, В.П.Джелепов, М.В.Ковальчук, П.Е.Спивак, О.И.Сумбаев, И.С.Шапиро и другие, а также такие широко известные своими классическими трудами физики, как А.И.Базь, Д.П.Гречухин, Р.В.Джолос Д.Д.Иваненко, А.А.Оглоблин, К.А.Петржак, Я.А.Смородинский, В.М.Струтинский, и многие другие. Активное участие в работе конференции принимали академики республиканских АН бывшего СССР: Р.Б.Бегжанов, И.Н.Вишневский, И.И.Залюбовский, В.М.Кельман, А.П.Комар, Г.Д.Латышев, В.И.Мамасахлисов, О.Ф.Немец, М.В.Пасечник, П.Т.Прокофьев и большое число видных зарубежных ученых: Ш.Бриансон, Р.Вален, Ц.С.Ву, Дж.Гамильтон

(США), В.Д.Гамильтон (Англия), Ж.Желев, Х.Клапдор, М.Младженович, Г.Мюнценберг, Ж.Т.Юван, В. Грайнер и многие замечательные физики- ядерщики как российские, так и зарубежные. Приведенный список известных имен далеко не полный. С трибуны конференций было доложено еще о многих выдающихся научных достижениях, но перечислить здесь все достойные работы невозможно.

В чем же причина долгой жизни конференции? Скорее всего, таких причин две: универсализм и гибкость программы. Широта тематики, охватывающей практически все разделы физики атомного ядра и элементарных частиц, делает конференцию интересной для исследователей из самых разных областях науки. А гибкость программы позволяет ученым обсудить самые актуальные проблемы ядерной физики.

В заключение подчеркнем еще раз, что семьдесят Всесоюзных и Международных конференций по физике атомного ядра сыграли большую положительную роль в развитии ядерной физики в нашей стране во второй половине XX и в начале XXI веков. Можно выразить уверенность, что отечественные ученые, которые трудятся в области ядерной физики, приложат весь свой талант и энергию, чтобы обогатить науку новыми открытиями и достижениями.

СОВЕЩАНИЯ
ПО ЯДЕРНОЙ СПЕКТРОСКОПИИ И СТРУКТУРЕ АТОМНОГО ЯДРА
(МЕЖДУНАРОДНЫЕ КОНФЕРЕНЦИИ ПО ФИЗИКЕ АТОМНОГО ЯДРА,
МЕЖДУНАРОДНЫЕ КОНФЕРЕНЦИИ ПО ЯДЕРНОЙ ФИЗИКЕ «ЯДРО»)

1.	1951 г.	Москва	36.	1986 г.	Харьков
2.	1952 г.	Москва	37.	1987 г.	Рига
3.	1953 г.	Москва	38.	1988 г.	Баку
4.	1954 г.	Москва	39.	1989 г.	Ташкент
5.	1955 г.	Москва	40.	1990 г.	Ленинград
6.	1956 г.	Москва	41.	1991 г.	Минск
7.	1957 г.	Ленинград	42.	1992 г.	Алма-Ата
8.	1958 г.	Ленинград	43.	1993 г.	Дубна
9.	1959 г.	Харьков	44.	1994 г.	С.-Петербург
10.	1960 г.	Москва	45.	1995 г.	С.-Петербург
11.	1961 г.	Рига	46.	1996 г.	Москва
12.	1962 г.	Ленинград	47.	1997 г.	Обнинск
13.	1963 г.	Киев	48.	1998 г.	Москва
14.	1964 г.	Тбилиси	49.	1999 г.	Дубна
15.	1965 г.	Минск	50.	2000 г.	С.-Петербург
16.	1966 г.	Москва	51.	2001 г.	Саров
17.	1967 г.	Харьков	52.	2002 г.	Москва
18.	1968 г.	Рига	53.	2003 г.	Москва
19.	1969 г.	Ереван	54.	2004 г.	Белгород
20.	1970 г.	Ленинград	55.	2005 г.	С.-Петербург
21.	1971 г.	Москва	56.	2006 г.	Саров
22.	1972 г.	Киев	57.	2007 г.	Воронеж
23.	1973 г.	Тбилиси	58.	2008 г.	Москва
24.	1974 г.	Харьков	59.	2009 г.	Чебоксары
25.	1975 г.	Ленинград	60.	2010 г.	С.-Петербург
26.	1976 г.	Баку	61.	2011 г.	Саров
27.	1977 г.	Ташкент	62.	2012 г.	Воронеж
28.	1978 г.	Алма-Ата	63.	2013 г.	Москва
29.	1979 г.	Рига	64.	2014 г.	Минск
30.	1980 г.	Ленинград	65.	2015 г.	С.-Петербург
31.	1981 г.	Самарканд	66.	2016 г.	Саров
32.	1982 г.	Киев	67.	2017 г.	Алма-Ата
33.	1983 г.	Москва	68.	2018 г.	Воронеж
34.	1984 г.	Алма-Ата	69.	2019 г.	Дубна
35.	1985 г.	Ленинград	70.	2020 г.	С.-Петербург

Plenary

PHYSICAL CRITERIA OF DATA RELIABILITY AND SYSTEMATIC UNCERTAINTIES OF PHOTONEUTRON REACTION CROSS SECTIONS

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The problem of significant disagreements [1] between partial photoneutron reaction cross sections obtained using the method of neutron multiplicity-sorting at Livermore (USA) and Saclay (France) was investigated in detail. As a rule for 19 nuclei from $^{51}\mathrm{V}$ to $^{238}\mathrm{U}(\gamma, 1\mathrm{n})$ reaction cross sections are larger at Saclay, but $(\gamma, 2n)$ cross sections vice versa larger at Livermore. The averaged Saclay/Livermore ratio $\mathrm{R} = \sigma_{\mathrm{S}}^{\mathrm{int}} / \sigma_{\mathrm{L}}{}^{\mathrm{int}}$ of integrated cross sections is equal to $\mathrm{R}_1 = 1.08$ for $(\gamma, 1\mathrm{n})$ reaction but $\mathrm{R}_2 = 0.83$ for $(\gamma, 2\mathrm{n})$ reaction.
Using the objective physical criteria for data reliability [2] it was found that there are several quite different reasons for systematic uncertainties obtained. For many nuclei it was shown that the main reason of those is unreliable sorting of many neutrons between $1\mathrm{n}$, $2\mathrm{n}$ and, $3\mathrm{n}$ channels because of definite shortcoming of the method of neutron multiplicity-sorting [1,2].
Four very interesting cases were investigated in detail: data for three nuclei for which the differences between R_1 and R_2 are very large $\left({}^{127}\mathrm{I}\,(\mathrm{R}_1 = 1.34 \text{ and } \mathrm{R}_2 = 1.08)\,, {}^{181}\,\mathrm{Ta}(1.25 \text{ and } 0.89),\right.$ and $\left.{}^{208}\mathrm{Pb}(1.22 \text{ and } 0.77)\right)$ and for $^{75}\mathrm{As}$ for which those ratios are also large but very close to each other, $\mathrm{R}_1 \approx \mathrm{R}_2 \approx 1.22$. For all four nuclei mentioned the neutron yield reaction cross sections $(\gamma, \mathrm{xn}) = (\gamma, 1\mathrm{n}) + 2(\gamma, 2\mathrm{n}) + 3(\gamma, 3\mathrm{n}) + \ldots$ obtained at Saclay and Livermore are significantly different at photon energies before the threshold B2n of $(\gamma, 2n)$ reaction, where one has no multiplicity sorting problems. Using the experimental-theoretical method for evaluation of partial photoneutron reaction cross sections [2] it was shown that the main reason of such type significant differences of data is that at Livermore many neutrons from the reaction $(\gamma, 1\mathrm{n})$ were lost.
In the case of nucleus $^{51}\mathrm{V}$[3,4] it was found that additionally to unreliable sorting of many neutrons between $1\mathrm{n}$, $2\mathrm{n}$ and, $3\mathrm{n}$ channels because of definite shortcoming of the method of neutron multiplicity-sorting the another reason for systematic disagreements is that the contribution of proton reaction $(\gamma, 1\mathrm{n}1\mathrm{p})$ was not taken into account.

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MECHANISMS OF MULTY-STAGE NUCLEAR DECAYS WITH TAKING INTO ACCOUNT REAL AND VIRTUAL STATES OF INTERMEDIATE NUCLEI

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The sequential n-stage ($n \geq 2$) decay of the compound nucleus A: $A \to b_1 + A_1 \to \ldots \to b_1 + \ldots + b_n + A_n$ with the formation of the real particles $b_1, \ldots, b_n$, intermediate nuclei $A_1, \ldots, A_{n-1}$ and the final nucleus A_n with internal energies $E_{b_1}, \ldots, E_{b_n}$ and $E_{A_1}, \ldots, E_{A_n}$, correspondingly, has been considered. It has been proved that the width of mentioned decay can be presented by the integral of productions of the i-stage widths, corresponding to the real and virtual processes. If the i-th stage of the decay has the decay heat $\left(E_{A_i} - E_{A_{i+1}} - E_{b_{i+1}}\right) < 0$, then this decay stage has virtual character and can be described using the formalism [1]. If the i-th stage of the decay has the positive decay heat $\left(E_{A_i} - E_{A_{i+1}} - E_{b_{i+1}}\right) > 0$, then this decay is really observed and can be described by the R-matrix theory of nuclear reactions [2].
In [3] it was shown that the experimental characteristics of spontaneous ternary fission of ^{248}Cm, ^{250}Cf, ^{252}Cf [4] with emission of $\alpha-$particle as the third particle, are adequately described using the representation about two-stage character of this fission, when on the first stage the long-ranged α-particle is emitted from the neck of the fissile nucleus A and the virtual state of the intermediate nucleus $(A-4)$ is formed, and on the second stage this nucleus $(A-4)$ decays onto two fission fragments. In present paper by usage of methods [3] it has been demonstrated that the characteristics of the induced by thermal neutrons ternary fission of ^{233}U and ^{235}U are successfully described on the base of virtual mechanism. It has been obtained that fissile nucleus neck radii r_A for induced fission of compound nuclei ^{234}U and ^{236}U are close to the analogous neck radii for spontaneous fission of ^{248}Cm, ^{250}Cf, ^{252}Cf and are in good agreement with the estimations of the theoretical models considering fissile nucleus deformations. The differential cross section $\sigma(\theta)$ of the ternary fission of actinide nuclei by cold polarized neutrons can be presented as a sum of the terms of null order $\sigma^0(\theta)$ and the first order $\sigma^1(\theta)$ on the neutron polarization vector $\vec{p}_n$: $\sigma(\theta) = \sigma^0(\theta) + \sigma^1(\theta)$ (1), where θ is an angle between the directions of flights of the third particle and light fragment. In general case $\sigma^1(\theta)$ can be presented as sum of the triple $\sigma_3^1(\theta)$ and quinary $\sigma_5^1(\theta)$ correlators, which satisfy the conditions: $\sigma_3^1(\theta) = \sigma_3^1(\pi - \theta), \sigma_5^1(\theta) = -\sigma_5^1(\pi - \theta)$ (2). These components $\sigma_3^1(\theta)$ and $\sigma_5^1(\theta)$ can be calculated using experimental differential cross sections $\sigma(\theta)$ and $\sigma^0(\theta)$ in (1) and formula (2). In quantum fission theory [5,6] $\sigma_3^1(\theta)$ and $\sigma_5^1(\theta)$ have forms: $\sigma_3^1(\theta) = \Delta^{odd}\frac{d\sigma_0^{odd}(\theta)}{d\theta}$, $\sigma_5^1(\theta) = \Delta^{even}\frac{d\sigma_0^{even}(\theta)}{d\theta}$ (3), where $\sigma_0^{odd}(\theta)$ and $\sigma_0^{even}(\theta)$ are components of σ_0 defined by sums over spherical functions with odd and even orbital momenta, correspondingly, and Δ is an angle, which characterizes the changing of the angle θ, which takes into account the influence of the connected with the collective rotation of the fissile nucleus Coriolis interaction on the directions of the light fragment and ternary particle flight. Using the experimental values of the cross section $\sigma^0(\theta)$ it is possible to calculate by formulae (3) the angles Δ^{odd} and Δ^{even} for various ternary fission types. In [5,6] it has been shown that for the ternary fission of ^{233}U and ^{235}U with the emission of the α-particle the angles Δ_α^{odd} are positive, but the angles Δ_α^{even} change their sign under the transition from ^{235}U to ^{233}U. At the same time the calculation on the base of the trajectory methods [7] use the parametrization: $\sigma_3^1(\theta) = C$; $\sigma_5^1(\theta) = \sigma^1(\theta) - C$, where C is a constant, and $\sigma_5^1(\theta)$ concides with (3), the angles Δ_α^{even} and Δ_α^{odd}, are correctly describe the signs of Δ_α^{odd} for ^{233}U and ^{235}U, but conserve the same signs of Δ_α^{odd} for ^{233}U and ^{235}U that critically contradicts to the fact of sign changing in the experiment. For the ternary fission accompaning with evaporative neutrons and γ-quanta from the fission fragments the σ^0 have only even orbital momenta, and the angles Δ_n^{even} and Δ_γ^{even} are defined by the influence of the Coriolis interaction onto fission fragments because of its small values in the region of these neutrons and γ-quanta emission. Using the experimental data [8] of the Δ_n^{even} and $\Delta_\gamma^{\text{even}}$ change the value under the transition from ^{233}U to ^{235}U, that is in agreement with the experimental sign change of Δ_α^{even} for α-particle. This fact approve the correctness of the experimental results [8].

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HAWKING RADIATION FROM STRANGE QUARK NUGGETS, RELICS OF THE QCD PHASE TRANSITION

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It is entirely plausible that during the primordial quark – hadron phase transition, microseconds after the Big Bang, the universe may experience supercooling accompanied by mini inflation leading to a first – order phase transition from quarks to hadrons. The relics, in the form of quark nuggets, with baryon number beyond a critical value will survive the evolution of the universe. The quark nuggets are candidates of strange quark matter.
It is conjectured that colour confinement turns the physical vacuum to an event horizon for quarks and gluons. The horizon can be crossed only by quantum tunnelling. The process just mentioned is the QCD counterpart of Hawking radiation from gravitational black holes. Tunnelling of neutrons from the nuggets is equivalent to Hawking radiation from the gravitational black hole. Thus, when the Hawking temperature of the quark nuggets gets turned off, tunnelling will stop and the nuggets will survive forever. The baryon number and the mass of these nuggets are derived using this theoretical format. The results agree well with the prediction using other phenomenological models. Further, the variation of Hawking temperature as a function of baryon number and mass of the nugget mimics chiral phase transition, somewhat similar to the QCD phase transition. Finally the strange quark nuggets may well be the candidates of baryonic dark matter.

SPECTROSCOPIC FACTORS: MEASURABILITY AND OBSERVABILITY

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Spectroscopic factors are intensely used in the analysis of nuclear reactions. However, spectroscopic factors are absent in the rigorous theory of nuclear reactions. They arise only within the standard version of the distorted-wave Born approximation (DWBA) as a result of the replacement of a rigorous many-particle overlap function by a two-body wave function. This approach has no serious theoretical justification and is essentially a convenient method for approximate modeling of experimental data on direct nuclear reactions. Even within this approach, the accuracy of the spectroscopic factors extracted from the experimental data is low, especially in the case of the removal of composite objects, say, α-particles. Spectroscopic factors are off-shell quantities. They are not determined by the S matrix unlike on-shell quantities, such as phase shifts, binding energies, etc. It should be noted that, in contrast to spectroscopic factors, asymptotic normalization coefficients, which are currently actively used in the physics of nuclear reactions, are on-shell quantities. Spectroscopic factors are non-invariant under the unitary transformations of nuclear forces conserving the S matrix. Therefore, they are 'non-observables' which can only be defined within a special convention, like a particular form of the nuclear Hamiltonian which is used to derive or calculate them [1, 2]. Thus determining spectroscopic factors from experimental data is of rather limited value. Spectroscopic factors can be calculated in the framework of microscopic approaches. However, comparing the results of such calculations with the phenomenological values of spectroscopic factors is unlikely to provide any significant information.
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OVERVIEW OF RECENT HEAVY ION RESULTS FORM CMS EXPERIMENT

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The CMS detector at the LHC was designed originally as a particle physics experiment but has performed exceptionally well in the high-multiplicity environment of heavy-ion collisions. Over the past decade, the CMS collaboration had delivered multiple ground-breaking results on quark-gluon plasma produced in such collision events. In this talk, I will review the recent CMS results from the Heavy Ion program, covering a wide range of topics, from bulk medium properties to tomographic probes. I will emphasize the new results from jets, heavy flavor, and quarkonia studies, and will close with an outlook for the future running and upgrades.

NEW INNER TRACKING SYSTEM (ITS) FOR OPEN CHARM DIRECT MEASUREMENTS BY ALICE AT THE LHC: STATUS AND PERSPECTIVES

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One of the main goals of the ongoing upgrade of ALICE during the second long LHC shutdown (LS2) is to significantly improve the charged particle tracking and secondary vertex reconstruction, as well as the readout rate capabilities of the detector system. The ALICE physics programme of measurements of low momentum charm and beauty hadrons and low-mass dielectrons in heavy-ion collisions at the LHC requires the development of an entirely new Inner Tracking System (ITS2) with the increased capabilities in readout speed, impact parameter resolution and the reduced material budget. These requirements are met in the ITS2 design by the application of arrays of novel coordinate-sensitive CMOS Monolithic Active Pixel Sensors (MAPS) with the sensor matrix and readout integrated in a single chip, named ALPIDE (ALice PIxel DEtector). Besides MAPS, large improvements of the tracking precision and efficiency of registration of particles with low transverse momentum were achieved by a large reduction of the material budget of the ITS2 in the region close to the interaction point. As a result, the record low level of 0.38% radiation length (X/Xo) per layer for each of three innermost layers is achieved, ensuring the overall improved efficiency for heavy-flavor measurements at low pT.
The first part of the talk is devoted to the general physics motivation, requirements and status of the ITS2 preparations for the start of RUN3 at the LHC. The second part of the presentation will cover new ideas of the ALICE upgrade during the next Long Shutdown 3 (LS3) in the period 2023-2024 and the ongoing R&D on the development of a high granularity fast detector (ITS3) which will further reduce the material to X/Xo below 0.05% per layer, will be presented. This will include the concept of the ITS3, the status of very thin ($\sim$20 μm) MAPS sensor developments as well as the ongoing studies of the extra-light-weight mechanics and gas-cooling issues.
Acknowledgement: This work was partially supported by Funds of Ministry of Science and Higher Education of the Russian Federation and by the National Research Center "Kurchatov Institute".

CANCER AND EUROPEAN NETWORK FOR LIGHT ION HADRON THERAPY (ENLIGHT)

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Cancer is a critical societal issue. Worldwide, in 2018 alone, 18.1 million cases were diagnosed, 9.6 million people died and 43.8 million people were living with cancer. Current projections anticipate an increase with approximately 24,6 million newly diagnosed patients, 13 million related deaths by 2030.. The efforts that are currently carried out worldwide to improve the effectiveness of RT have the potential to change the forecasts for the upcoming years. The main goal of Advanced Radiotherapy Treatment is to maximise the damage of ionising radiation to the tumour cells while minimising exposure of the surrounding normal tissue and critical organs& To achieve this goal, RT has considerably progressed with the development of new technologies and methodologies able to increase the conformity of the dose delivered to deep-seated tumours. While the most frequently used modern RT modalities still rely on high energy (MeV) X-rays, there is a rapidly growing interest and adoption of accelerated charged particles.
Radiotherapy using charged hadrons (protons and light ions), with their unique physical and radiobiological properties, allows highly conformal treatment of various kinds of tumours, while delivering minimal doses to large volumes of surrounding healthy tissues. Harnessing the full potential of hadron therapy requires the expertise and ability of physicists, physicians, radiobiologists, engineers, and information technology experts, as well as collaboration between academic, research, and industrial partners.
It was in response to these challenges that ENLIGHT – the European Network for Light Ion Hadron Therapy (http://www.cern.ch/enlight) – was launched which had its inaugural meeting at the European Organization for Nuclear Research (CERN) in February 2002, today has more than 1000 participants from over 30 countries in Europe and beyond. Harnessing the full potential of particle therapy requires the expertise and ability of physicists, physicians, radiobiologists, engineers, and information technology experts, as well as collaboration between academic, research, and industrial partners.
The given report highlights the status and the main new directions of hadron therapy in Europe and in the world with the emphasis on the international cooperation that is of crucial importance in combat of the disease.

NEW RADIONUCLIDES FOR PERSONALIZED MEDICINE (THERANOSTICS)

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The investigations of the processes and mechanisms of medium-range nuclear systems (formed in reactions with protons) formation, with the evaporation of one or more nucleons in the final stages, are not only the significant fundamental task, but also have practical importance. These tasks become particularly relevant for production of medical radionuclides which are used for effective early diagnosis and treatment of various localized oncological tumors. Applying these radionuclides in

radiotherapeutic and diagnostic (Positron Emission Tomography and Single Photon Emission Computed Tomography) methods one can realize unique techniques for non-surgical treatment of tumors with their precise visualization. The merging radionuclide imaging methods with methods of radionuclide therapy to Theranostics, it can give us an excellent result for the treatment and diagnosis of a cancer with minimal side effects. Therefore in present work the experimental and theoretical studies of the nuclear reactions excitation functions with the targets of 117Sn and 119Sn in energy range 6-20 MeV were carried out. For these reactions the cross-sections of antimony radionuclides (can be considered as the prospective for Theranostics methods) which are formed in the output channels have been obtained.
Acknowledgments: the reported study was supported by RFBR, research project No. 20-02-00295.

STATUS AND PROSPECTS OF JIANGMEN UNDERGROUND NEUTRINO OBSERVATORY

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The Jiangmen Underground Neutrino Observatory (JUNO) is a next generation multi-purpose liquid-scintillator neutrino experiment under construction in South China. Exploiting the anti-neutrinos produced by the nearby nuclear power plants, JUNO will be able to study the neutrino mass hierarchy, one of the open key questions in neutrino physics. The JUNO detector structure consists of a large acrylic sphere ($34.5\mathrm{m}$ diameter), containing almost 20 kton of ultra pure linear alkylbenzene with proper additives. The light produced by the scintillator will be seen by about 18,000 large photomultiplier tubes (PMT) (20") and about 25,000 small PMTs (3"). The described central detector will be placed inside an instrumented water pool that will act both as a Cherenkov muon veto and as a shield against environmental radiation coming from the rock. A key ingredient for the measurement of the neutrino mass hierarchy is an excellent and challenging energy resolution of the central detector: 3% at $1\mathrm{MeV}$ or better is required. Beyond mass hierarchy and precision determination of the three active neutrino oscillation parameters, JUNO can give access to valuable data on many topics in physics, like supernova burst and diffuse supernova neutrinos, solar neutrinos, atmospheric and geo-neutrinos, nucleon decay, indirect dark matter searches and a number of additional exotic searches. During the presentation, the status of the design, construction and the JUNO prospects on physics will be reported.

THE NEUTRAL PION RADIATIVE WIDTH MEASUEREMENT: RESULTS FROM PRIMEX (JLAB)

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The neutral pion two gamma decay amplitude is determined by the Chiral anomaly. Recent calculations made within Chiral Perturbation Theory predict this value at percent level accuracy. Precise determination of this decay width gives a possibility to check the theoretical calculations. The PrimEx experiment used the Primakoff effect to measure neutral pion radiative decay width. The final result

of the PrimEx experiment performed in Hall-B at Jefferson Lab will be presented in the talk. The ongoing Primakoff-Eta experiment, measuring the eta meson radiative decay width at Jefferson Lab will be discussed as well. The project was supported in part by RFBR-18-02-00938.

STRONG INTERACTIONS AND THE EMERGENCE OF MASS

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Having uncovered the explicit source for <2% of the mass of visible matter, attention is now shifting to searches for the origin and the explanation of the remaining >98%. That emergent mass is contained within atomic nuclei, which lie at the core of everything we can see. At the first level of approximation, the atomic weight of a nucleus is simply the sum of the masses of all the neutrons and protons (nucleons) it contains. Each nucleon has a mass mN ≈ 1 GeV, i.e. approximately 2000-times the electron mass. The Higgs boson produces the latter, but what produces the masses of the neutron and proton? This is the pivotal question: the vast bulk of the mass of a nucleon is lodged with the energy needed to hold quarks together inside it; and that is supposed to be explained by quantum chromodynamics (QCD), the strong-interaction piece within the Standard Model.
QCD is unique. It is the only known fundamental theory with the capacity to sustain massless elementary degrees-of-freedom, viz. gluons and quarks. Yet gluons and quarks are predicted to acquire mass dynamically, and nucleons and almost all other hadrons likewise, so that the only massless systems in QCD are Nature's composite Nambu-Goldstone (NG) bosons, the pions and kaons. Simultaneously reconciling the emergence of mass in the bulk of hadron systems and the screening of mass generation in the pion and kaon is one of the greatest challenges in modern physics.
This presentation will canvass the potential for a coherent effort in QCD phenomenology and theory, coupled with experiments at existing and planned facilities worldwide, to reveal the origin and distribution of mass and expose and explain its manifold expressions in hadrons and nuclei. This international programme addresses a diverse range of issues, e.g. How do hadron masses and radii emerge for light-quark systems from QCD; What is the interplay of the strong-mass and Higgs-mass generation mechanisms; What are the basic processes that determine the distribution of mass, momentum, charge, spin, etc., within hadrons, and how are these things expressed in observable deformations of the basic building blocks of nuclei?

HISTORY OF ONE CALENDAR DATE TO THE 80-TH ANNIVERSARY OF THE DISCOVERY OF SPONTANEOUS FISSION

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In 2020, we celebrate 80 years since the discovery of the fundamental phenomenon - spontaneous fission of uranium - a type of radioactive decay that defines the boundaries of the Periodic system of elements. The paper with the results of research carried out by K. Petrzhak (Radium Institute) and

G. Flerov (Leningrad Institute for Physics and Technology) was sent to Physical Review on June 14, 1940 and published on July 7, 1940.
The questions of the creation and development of nuclear physics in the 20-30th XX century at the Radium Institute are considered. Little-known documents and historical facts are examined to estimate the contribution of the Radium Institute - the cradle of comprehensive studies of radioactivity in Russia - to the world atomic science and technology.

NUCLEAR FORCE FROM QCD POINT OF VIEW

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In the talk, it is surveyed the path how to construct the nuclear force theory starting from Quantum Chromodynamics (QCD) which is considered now as a basic theory of strong interactions in physics. Historically, since the pioneer Yukawa's work by 1935 the nuclear interactions were considered as those originated from meson exchange between nucleons (or, more generally, between baryons). But until the end of 90ies, there was no consistent meson-nucleon theory that could derive the nuclear force from a unified meson-nucleon Hamiltonian. Instead, there were many phenomenological models for NN interactions with parameters values fitted to empirical NN phase shifts. In 80ies, however, Weinberg suggested some new way in this area to treat consistently strong NN-interaction in terms of the Chiral Perturbation Theory (ChPT) or Effective Field Theory (EFT). In this approach, one calculates the successive terms of the perturbative expansion, order by order, and remained unknown short-range terms are found from the fit to the NN empirical phase shifts. So, from the general physical point of view, the EFT is also not a complete theory in a proper sense.
The consistent theory of nuclear force must be based on QCD which is the theory of strong interactions. But QCD is operating with quark, gluon and string degrees of freedom (d.o.f.) while the EFT and similar meson-exchange approaches operate with mesons and nucleons. And first of all, one has to build a bridge between nuclear physics d.o.f. and QCD d.o.f. and then to formulate the nuclear force using some hybrid model which is based just on the quarks and gluons.
In the present review, we will survey our recent work devoted to the new way how to build the above bridge connecting QCD and nuclear physics. This path is based on dibaryon (six-quark) resonances dressed with meson fields. In this picture, these resonances transmit the strong interaction between nucleons in free space and in nuclei. In principle, the dibaryon resonances can be calculated purely theoretically using well known QCD-lattice calculations in different NN-partial waves. In our recent works [1,2], we demonstrated how to realize the second crucial step in this way: i.e. how to construct in a quantitative manner, starting with experimentally found dibaryon resonances, both elastic and inelastic NN phase shifts in a very broad energy range from zero energy till 1 GeV. We will review also the various implications for nuclear physics of this new paradigm for nuclear force.

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OBSERVATION OF STERILE ANTINEUTRINO OSCILLATION IN NEUTRINO-4 EXPERIMENT AT SM-3 REACTOR

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The experiment Neutrino-4 had started in 2014 with a detector model and then was continued with a full-scale detector. All steps of preparatory work on this experiment are presented. Measurements were carried out in two phases. The first phase measurements with reactor under operation had started in June 2016 and were continued till June 2018. The second phase from September 2018 to July 2019 was carried out mainly in near positions to the reactor, where the signal to background ratio is significantly better. It enabled to increase the statistical accuracy of measurements by factor 1.4. Measurements with the reactor ON were carried out for in total 720 days, and with the reactor OFF - for 417 days. In total, the reactor was switched on and off 87 times. Were obtained the results of measurements of reactor antineutrino flux and spectrum dependence on the distance in the range 6-12 meters from the center of the reactor core at SM-3 reactor (Dimitrovgrad, Russia). Using all collected data, we performed the model independent analysis on the oscillation parameters m_{14}^2 and $\sin^2 2\theta_{14}$. The method of coherent summation of results of measurements allows us to directly observe the effect of oscillations. We observed an oscillation effect in vicinity of $\Delta m_{14}^2 = \left(7.25 \pm 0.13_{\text{stat}} \pm 1.08_{\text{syst}}\right) eV^2$ and $\sin^2 2\theta = 0.26 \pm 0.08_{\text{stat}} \pm 0.05_{\text{syst}}$ We provide a comparison of our results with results of other experiments on search for sterile neutrino. Combining the result of the Neutrino-4 experiment and the results of measurements of the gallium anomaly and reactor anomaly we obtained value $\sin^2 2\theta_{14} \approx 0.19 \pm 0.04$ (4.6σ). Also was performed comparison of Neutrino-4 experimental results with results of other reactor experiments NEOS, DANSS, STEREO, PROSPECT and accelerator experiments MiniBooNE, LSND and results of the IceCube experiment.
Mass of sterile neutrino obtained from data collected in the Neutrino-4 experiment (in assumption $m_4^2 \approx \Delta m_{14}^2$) is $m_4 = (2.68 \pm 0.13)$eV. Using the estimations of mixing angles obtained in other experiments and our new results we can calculate, within 3+1 neutrino model, masses of electron, muon, and tau neutrinos: $m_{\nu_e}^{\text{eff}} = (0.58 \pm 0.09)$eV, $m_{\nu_\mu}^{\text{eff}} = (0.42 \pm 0.24)$eV, $m_{\nu_\tau}^{\text{eff}} \leq 0.65$eV. Extended PMNS matrix for (3 + 1) model with one sterile neutrino is provided, neutrino flavor mixing scheme with sterile neutrino and global fit of reactor experiments.

LATEST RESULTS ON (ANTI-)HYPERNUCLEI PRODUCTION AT THE LHC WITH ALICE

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Heavy-ion collision experiments offer a unique opportunity to study the production of (anti-)hyperon-baryons bound systems, called (anti-)hypernuclei. ALICE at the LHC measured the production of (anti-)hypertriton analyzing data collected in Pb-Pb collisions at the two center-of-mass energies of 5.02 and 2.76 TeV. The analysis was performed by exploiting the excellent particle identification performance of the ALICE detector, by measuring the energy loss of the charged tracks in the Time Projection Chamber. In addition, the Inner Tracking System was used to separate (anti-)hypertriton's weak decay daughters from primarily produced tracks through the precise determination of secondary vertices.

The results on (anti-)hypertriton production will be discussed and compared to model predictions, based on coalescence and statistical hadronization approaches, and to experimental results obtained at lower energies. The latest results of the (anti-)hypertriton lifetime measurement will be shown as well. Plans for the future LHC Run 3, scheduled to start in 2021, with the improvements in statistics and precision will be also presented.

STAR RECENT RESULTS ON HEAVY-ION COLLISIONS

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Exploration of the hot and dense nuclear matter produced in collisions of heavy ions is one of the main goals of modern relativistic nuclear physics. The Relativistic Heavy Ion Collider (RHIC) provides a unique opportunity to map the QCD phase diagram colliding different nuclei species and varying the energy of collisions. RHIC has already begun the second phase of the Beam Energy Scan (BES) program, which will allow us to cover energy range for gold-gold collisions $\sqrt{s_{NN}} = 7.7 - 27$ GeV. The Fixed-target Program (FXT) will extend collision energy range available for the analysis down to $\sqrt{s_{NN}} = 3.0$ GeV. BES-II along with FXT will dramatically enhance our understanding of the QCD phase diagram in the broad range of baryon chemical potential, μ_B, up to 720 MeV.
Recent detector upgrades increase STAR's acceptance both in rapidity and low transverse momentum, and extend its particle identification capabilities. With new detectors STAR can explore phase diagram with even higher precision hopefully reaching both the onset of deconfinement as well as the onset of fireball.
In this talk, we will present the most recent results and future plans from the STAR experiment.

NUCLEAR RESPONSE AT ZERO AND FINITE TEMPERATURE

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Recent developments of the relativistic nuclear field theory (NFT) on the fermionic correlation functions will be presented. The general non-perturbative equation of motion framework is formulated in terms of a closed system of non-linear equations for one-body and two-body propagators. The present formulation provides a direct link to ab-initio theories and extends the explicit treatment of many-body correlations beyond the standard NFT level. The novel approach to the nuclear response, which includes configurations with two quasiparticles coupled to two phonons (2q⊗2phonon), is discussed in detail for electromagnetic excitations in medium-mass nuclei. The proposed developments are implemented numerically on the basis of the relativistic effective meson-nucleon Lagrangian and compared to the models confined by 2q and 2q⊗phonon configurations, which are considered the state-of-the-art for the response theory in nuclear structure calculations. The results obtained for the dipole response of ^{42,48}Ca and ^{68}Ni nuclei in comparison to available experimental data show that the higher-complexity configurations are necessary for a successful description of both gross and fine details of the spectra in both high-energy and low-energy sectors.
The approach confined by the 2q⊗phonon configurations has been extended recently to the

case of finite temperature for both neutral and charge-exchange nuclear response. Within this approach, we investigate the temperature dependence of nuclear spectra in various channels, such as the monopole, dipole, quadrupole and spin-isospin ones, for even-even medium-heavy nuclei. The special focus is put on the giant dipole resonance's width problem, the low-energy strength distributions and the influence of temperature on the equation of state. The temperature dependence of the Gamow-Teller and spin dipole excitations will be discussed in the context of its potential impact on the astrophysical modeling of supernovae and neutron-star mergers.

COMPTON IONIZATION OF ATOMS NEAR THRESHOLD AS A METHOD OF SPECTROSCOPY OF OUTER SHELLS

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Recently unique experiments have been carried out to measure the fully (FDCS) and single (SDCS) differential cross sections of Compton ionization of helium atoms near the threshold of single ionization [1]. The photon energy was about 2 keV, and the energy of the detected electrons did not exceed 10 eV.
An adequate theoretical description in this energy range can be carried out in the framework of the so-called A^2 approximations. The corresponding matrix element looks exactly like the usual first Born approximation (FBA) in the case of ionization of an atom by a fast particle (electron, proton, heavy ion). This analogy allows us to treat the process under consideration on a par with such well-known methods of spectroscopy of the outer shells of atoms and molecules as (e, 2e), (p, pe), etc. It should be noted that the contribution to the second-order matrix element of the term including two sequential dipole transitions is extremely small in this kinematic region, which makes Compton ionization a valuable spectroscopic tool.

ALICE UPGRADE FOR RUN 3 AND 4 AT THE CERN LHC

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During the ongoing Long Shutdown of the LHC, ALICE is installing detector upgrades that will allow to collect the full 50 kHz interaction rate of the LHC, collecting 2 orders of magnitude more events than in run 1 and 2. This, together with the improved track-resolution will allow ALICE to significantly improve the precision of measurements of rare signals such as heavy flavour and di-lepton production at low pt, where they probe the QGP at the scale of the temperature.
To cope with this challenge, ALICE is implementing new hardware and software solutions. The Time Projection Chamber (TPC) – the main ALICE tracking detector – has been refitted with the new GEM-based readout chambers and three new detectors are being installed: the Inner Tracking System (ITS), the Muon Forward Tracker (MFT) and the Fast Interaction Trigger (FIT) detector. The new silicon trackers are based on ALPIDE (ALICE Pixel Detector) – a custom designed sensor incorporating the requirements imposed by the physics program including a high-granularity and low material budget of the non-active elements. The new sensor will improve vertexing and tracking, especially at low pT values. The use of ALPIDE by the Muon Forward Tracker will add vertexing capabilities to the Muon Spectrometer covering a broad range of transverse momenta and allowing ALICE to measure beauty down to pT ~0 from displaced J/Ψ vertices and to have

an improved precision for the Ψ (2S) measurement. It will also add high-granularity data to the forward multiplicity information acquired by FIT. In addition to providing inputs for the new Central Trigger Processor, FIT will serve as the main luminometer, collision time, multiplicity, centrality, and reaction plane detector for the ALICE experiment.
In this presentation the main goals of the upgraded ALICE experiment and a brief status of the construction, installation and commissioning of the major ALICE detectors will be summarized. The talk will conclude with the outline of the future plans being discussed by the collaboration.

TERMONUCLEAR EXPLOSIONS AND NUCLEOSYNTHESIS OF HEAVY ELEMENTS

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The artificial r-(rapid)-process of nucleosynthesis goes under high neutron flux densities: the obtained neutron fluencies in the irradiated volume of thermo-nuclear devices reach ~1025 neutrons/cm2 during the time interval ~10-6 s. Under (thermo) nuclear explosions the obtained conditions in neutron flux and temperature (~ 108 °K) reach extreme values. The creation of transuranium nuclides under pulsed neutron fluxes of thermonuclear explosions is investigated by means of dynamical model (as in the kinetic model of the astrophysical rapid r-process) taking into account the time dependence of the external parameters and the processes accompanying the beta decays of neutron-rich nuclei. Time dependent neutron fluxes in the interval ~ 10-6 s (prompt rapid pr-process) were simulated within the framework of the developed adiabatic binary model (ABM) [1]. The results of calculation on the base of the ABM model are compared with the experimental date for all mass numbers in the region A = 239 – 257.
Calculations of transuranium nuclides yields Y(A) are made for six large scale explosion USA experiments ("Mike", "Anacostia", "Par", "Barbel" "Vulcan" and "Kankakee" and it were obtained good or satisfied agreement. The corresponding root-mean-square deviations (r.m.s.) of the model yields compare to the experimental data are: 91% (for "Mike"); 70% ("Anacostia"); 33% ("Par"); 29% ("Barbel"); and 45% ("Vulcan"). The beta-delayed processes are taken into account for isotope yields correction after the pulse neutron wave. The calculations include the processes of delayed fission (DF) and the emission of delayed neutrons (DN), which determine the "losing factor" – the total loss of isotope concentration in the isobaric chains. The DF and DN probabilities were calculated in the microscopic theory of finite Fermi systems [2]. Thus, it is possible to describe the even-odd anomaly in the distribution of concentrations N(A) in the mass number region A = 251 – 257. It is shown qualitatively also that the odd-even anomaly may be explained mainly by DF and DN processes in very neutron-rich uranium isotopes.
The work is supported by the Russian Foundation for Basic Research (Grant no.18-02-00670_a).

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MODIFICATION OF HADRON PROPERTIES IN A DENSE AND HOT BARYONIC MATTER

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One of the main questions relating to heavy ion collisions "How much of incident energy is converted into a compression of nuclear matter?" has not found a definite answer yet. Equation of State (EoS) which describes density dependence of the energy density achieved in a hot and dense nuclear matter is not specified yet for heavy ion collisions. High compression should change both the initial state of colliding nuclei consisting of protons and neutrons and the properties of produced secondary particles. Starting with the Strongly Correlated Quark Model of a hadron structure, SCQM [1, 2], we demonstrate how the properties of mesons and baryons can be modified in hot and dense nuclear environment. It is shown that at these conditions nucleons are converted into delta-isobars, hyperons and their excitations, and mesons are produced predominantly via vector resonances. Moreover, the properties of vector mesons consisting of light quarks changes drastically. Their masses drop and widths are widening. These in-medium modifications can lead to the observable effects in heavy ion collisions, especially in NICA energy range, such as enhancement of strangeness, like "horn-effect", and enhancement of dilepton invariant mass spectra at 0.2 – 0.7 MeV.

PHENIX HIGHLIGHTS

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The primary goal of the PHENIX experiment at RHIC is the experimental study of the quark-gluon plasma (QGP) using relativistic heavy ion collisions. In recent years, the unique set of small collision systems has provided evidence for collective flow in such systems that is driven by the initial state geometry. Hydrodynamical models, which include the formation of a short-lived QGP droplet, provide a simultaneous description of these measurements. Thermal photon measurements also indicate that the temperature achieved in the central collisions of small systems is high enough to form QGP. The scaling behavior of direct photon production in the large systems is verified by the new measurement of thermal photons using the Au+Au data set collected by PHENIX in 2014. From these measurements, multiplicities at which QGP effects turn on could be indicated. The study of particle collectivity and hard probes from large to small systems, in order to understand the bulk and fine structure of the QGP, will be discussed.

INVESTIGATION OF REACTION CROSS SECTION FOR BEAM OF ^{8}Li, ^{8}He ON ^{28}Si, ^{59}Co, ^{181}Ta TARGETS

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Total reaction cross sections for interaction of ^{8}Li and ^{8}He secondary beam with ^{28}Si, ^{59}Co, ^{181}Ta target nuclei in the energy range 25–45 A MeV were measured. Modified transmission method

based on registration of prompt n, γ radiation by a multi-detector γ-spectrometer [1, 2] was used. Energy dependences of total reaction cross sections were obtained. Theoretical analysis of experimental data was performed in the microscopic model based on numerical solution of the time-dependent Schrödinger equation for the outer weakly bound neutrons of the projectile nucleus [3]. Agreement with experimental data was obtained. The role of the cluster structure of projectile nuclei [4] in the reaction mechanisms was analyzed.

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HIGHLIGHTS FROM THE ALICE EXPERIMENT AT THE LHC

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An overview on the most recent results by the ALICE collaboration at the LHC is presented for both heavy-ion collisions (Pb–Pb and Xe–Xe) and small systems (pp and p–Pb). A broad range of topics is covered, which includes bulk particle observables and particle chemistry, heavy flavour and quarkonia production, jet-medium interaction and electromagnetic probes. Motivations and status of the ongoing upgrade of the ALICE detector are discussed.

SELF-CONSISTENT APPROACH TO BETA-DECAY OF NEUTRON-RICH NUCLEI

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The global beta-decay calculations are presented which are based on the Density Functional developed by Fayans *et al.* [1] and Continuum Quasiparticle Random-Phase Approximation. The DF3+CQRPA model [2] describes the data on the half-lives and probabilities of delayed neutron emission for more than 200 (quasi) spherical nuclei with Z = 18 - 52 and T1/2 < 5c within the factor of 2 and 3 correspondingly (Fig.1). A detailed comparison with modern self-consistent models: spherical RHB + RQRPA [3], deformed FAM [4] and HFB + QRPA [5] is performed. The"sudden shortening" of the β-decay half-lives found in RIKEN for the Ni isotopes crossing the major neutron shell at N=50 [6] are addressed (Fig.2). The performance of "beyond the QRPA models" in explaining beta-decay acceleration in the ^{78,79}Ni is discussed. Supported by the grant of Russian Foundation

for Basic Research (RFBR 18-02-00670).

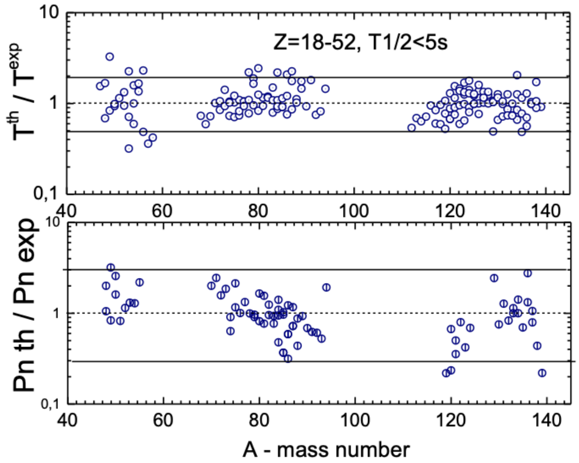

Figure 1: The T1/2 th/T1/2exp ratio and (bottom) The Pn th/Pn exp ratio, as the functions of the mass number.

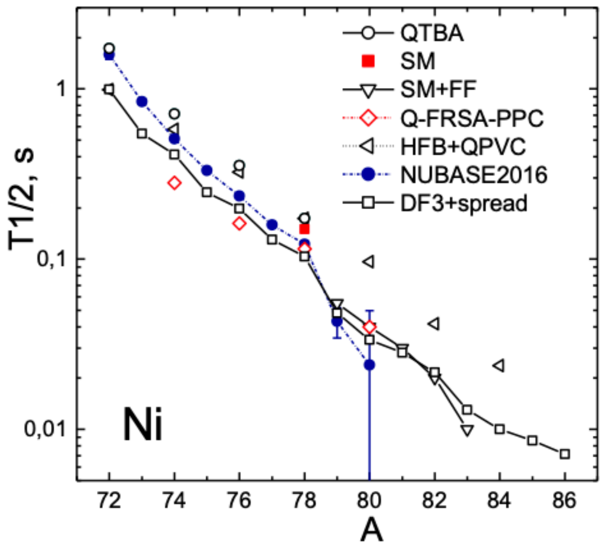

Figure 2: The experimental half-lives of the Ni isotopes [6] compared to the ones predicted by different beyond the QRPA models (indicated in the legend of Fig.2).

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PHASE TRANSITIONS IN ATOMIC NUCLEI

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A structure of atomic nuclei have many examples of a phase transitions with increase of the excitation energy, rotational moment and changing of the number of nucleons. These are phase transitions in the equilibrium shape and structure of the ground and low-lying excited states related to symmetry changed. The problem of phase transitions has caused of new wave of researches of the structure of atomic nuclei. In the review are considered different examples of nuclear phase transitions. Description of phase transitions in collective nuclear model and microscopic aspects of phase transitions are discussed.

RECENT RESULTS FROM NA61/SHINE STRONG INTERACTION PROGRAMME

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The research programme of the NA61/SHINE Collaboration covers a wide range of hadronic physics in the CERN SPS energy range (beam momentum $13A$ - $158A$ GeV/c), encompassing measurements of hadron-hadron, hadron-nucleus as well as nucleus-nucleus collisions. Data are analysed to better understand the properties of hot and dense nuclear matter. This talk will present the energy dependence of quantities inspired by the Statistical Model of Early Stage (kink, horn and step) as well as recent results of particle production properties in p+p and centrality selected Be+Be, Ar+Sc at the SPS energies. Moreover, the current achievements and future plans related to the measurement of open charm production will be presented.

NEW NUCLEAR PHYSICAL PHENOMENON - SPONTANEOUS NUCLEAR SYNTHESIS

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For the first time, a new nuclear-physical phenomenon is described - the flight out from complex nuclei of the lightest clusters with mass numbers from 1 to 4. The interpretation of the phenomenon consists in the assertion that the multiclusters recently experimentally discovered in the volume of nuclei [1] spontaneously enter into thermonuclear fusion reactions with each other. While they

have the indicated lightest clusters with noticeable kinetic energies in the output channels.
Until now, only the spontaneous fission of nuclei discovered in 1940 by Petrzhak K.A. and Flerov G.N. and alpha-decays were known. An experimental search for spontaneous fusion of nuclei was not carried out, first of all, due to the lack of physically reasonable initial premises. Currently, such physical conditions have arisen in connection with the experimental discovery in the volume of nuclei of spatially separated clumps of nuclear matter — multiclusters with mass numbers A = 1, 2, 3, 4 [1] and measurements of their cluster widths.
In fact, with an asymptotic giant mean density of nuclear matter of 0.147 Fm^{^(-3)}, it turned out that spatial clusters coexist in the volume of complex nuclei in the form of deuterons (d), tritons (t), helium-3 nuclei (h) and helium-4 nuclei (α) [2]. Naturally, this gives rise to a noticeable probability of their fusion in various combinations, including exothermic ones, which in modern terminology can be described as the implementation of "spontaneous thermonuclear fusion" in the solid phase of a substance. Note that until now they are trying to carry out controlled thermonuclear fusion only in the gas-plasma phase, for example, in installations of the Tokamak type.
In this work, the calculation of the spectra of spontaneous thermonuclear particles emitted as a result of spontaneous nuclear fusion between multiclusters inside the volume of complex nucleus was performed under the condition that the effective number of clusters (multicluster widths), which are given in [1], are equal. Theoretical spectra of spontaneous intranuclear synthesis for gamma quanta, neutrons, protons, deuterons, tritons, helions, alpha ions (intranuclear α-particles) and heavy ions are calculated. The calculated spectra contain only high-energy components for each output channel, without taking into account the loss of their energy in nuclear matter inside the nucleus volume. Comparison with experiment shows satisfactory agreement. It should be noted that in the world literature there is no information about the search for deuteron, triton and helion radioactivity of complex nuclei. Therefore, these sections of the physics of stable and radioactive nuclei are relevant for research.

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NUCLEAR PHYSICS IN MEDICINE: PRESENT AND PROSPECTS

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Modern medicine has a large arsenal of equipment for diagnostic and therapeutic purposes, which uses sources of ionizing radiation - these are x-ray tubes, natural and artificial isotopes, accelerators. The science of physical radiation and devices, medical diagnostic devices, facilities and technologies, the ability to diagnose and treat diseases of the human body using methods and means of physics, mathematics and technology is called medical physics.
Modern medical physics includes a number of major areas of application of physical methods in medicine: physics of remote and contact radiation therapy, nuclear medicine, radiation diagnostics, physics of non-ionizing methods of diagnosis and therapy and radiation safety.
A coordinated interaction between a doctor and a medical physicist is necessary for successful work

on radiation treatment of patients.
Very specific and deep training requires for successful work of such a specialist in the field of radiation therapy.
The training in the educational program of professional retraining of specialists in the field of radiation therapy for the development, operation and use of high-tech systems in clinical institutions was developed and provides based on the Faculty of Physics, Moscow State University, the Department of Physics of Accelerators and Radiation Medicine.
At the end of the full-time lecture module of the program, students attend internships are trained in the departments of the P. Herzen Moscow Oncology Research Institute, Academician N. N. Burdenko Main Military Clinical Hospital, European Medical Center. In addition, an internship is offered in clinics in Germany. Practical exercises and internships are conducted using modern medical accelerators, dosimetry monitoring and patient fixation tools, computer dosimetry planning systems and other radiotherapy equipment.
After graduation, graduates gain skills for professional activity in physical and mathematical support of radiotherapy treatment methods as a medical physicist.

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PROJECT KATRIN FIRST RESULT ON THE NEUTRINO MASS

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The KArlsruhe TRItium Neutrino experiment (KATRIN) is designed to improve the existed direct limit on the effective electron antineutrino mass by an order of magnitude, with a projected sensitivity of 0.2 eV/c2 at the 90% confidence level. To achieve this KATRIN is using a windowless gaseous tritium source containing up to 100 GBq activity and electrostatic spectrometer with adiabatic magnetic collimation with resolution up to 1 eV. In spring 2019 first 521.7 hour long data taking run was performed. Data analysis provided new upper limit on the electron antineutrino effective mass 1.1 eV (90% confidence level), published at Phys. Rev. Lett. 123, 221802, November 2019. In 2020 Neutrino-4 experiment presented evidence of a sterile neutrino signal observation of with parameters sin22θ14≈0.35±0.07(5σ) and Δm214≈(7.3±0.7)eV2. KATRIN experiment is sensitive to sterile neutrino with these parameters. Last results from KATRIN project and common analysis with Neutrino-4 are presented.

PHYSICS AND ASTROPHYSICS OF ULTRA-HIGH ENERGY COSMIC RAYS: RECENT RESULTS FROM THE PIERRE AUGER OBSERVATORY

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Ultra-high-energy cosmic rays (UHECRs) are the highest energy messengers in the universe, with energies up to 10^{20} eV. Studies of astrophysical particles (nuclei, electrons, neutrinos and photons) at their highest observed energies have implications for fundamental physics as well as astrophysics. The primary particles interact in the atmosphere (or in the Earth) and generate extensive air showers. Analysis of those showers enables one not only to estimate the energy, direction and most probable mass of the primary cosmic particles, but also to obtain information about the properties of their hadronic interactions at an energy more than one order of magnitude above that accessible with the current highest energy human-made accelerator.
The Pierre Auger Observatory, located in the province of Mendoza, Argentina, is the biggest cosmic ray experiment ever built. The Observatory was designed as a hybrid detector covering an area of 3000 km^2 and it has been taking data for more than twenty years.
In this talk a selection of the latest results is presented: the cosmic ray energy spectrum, searches for a directional anisotropy and studies of mass composition (including the photon and neutrino searches). Finally, the current upgrade ("AugerPrime") of the Observatory, which is mostly aimed at improving the sensitivity to the particle type and mass of ultra-high energy cosmic rays, is described.

DERICA PROJECT: DUBNA ELECTRON – RADIOACTIVE ION COLLIDER FACILITY

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Development of radioactive ion beam (RIB) facilities is the highway of the low-energy nuclear physics development in the world the last 3 decades. RIB studies in Russian Federation at the moment are conducted only in one place – ACCULINNA/ACCULINNA-2 facility at Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research. However, scientific opportunities of these instruments are lower than those expected for the modern RIB center. It is proposed to develop powerful RIB facility DERICA (Dubna Electron – Radioactive Ion Collider fAcility) covering broad range of modern nuclear physics aspects (new isotope synthesis and production, its masses, lifetimes and decay modes, nuclear reactions and spectroscopy). The emphasis of the project is storage ring physics with ultimate aim of electron-RIB scattering studies in the collider experiments.
The DERICA concept combines in-flight production of RIBs by projectile fragmentation technique (primary beams up to uranium with energy ~100 AMeV), stopping RIBs by gas catcher, reacceleration by LINAC-synchrotron combination, usage of reaccelerated RIBs for reaction studies and for storage ring experiments.
Status of DERICA project and the most recent information can be obtained at http://derica.jinr.ru. Letter-of-Intent for DERICA project is published in [1].

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SEARCH FOR NEUTRINOLESS DOUBLE BETA DECAY WITH GERDA

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The GERDA (GERmanium Detector Array) experiment, located at the Laboratori Nazionali del Gran Sasso (LNGS) of the Istituto Nazionale di Fisica Nucleare (INFN) in Italy, searches for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge. During Phase II, 35.6 kg of bare high purity germanium diodes enriched in ^{76}Ge have been deployed in liquid argon; they serve both as source and detector. The use of active background rejection methods, e.g liquid argon scintillation light read-out and pulse shape discrimination of germanium detector signals, has allowed to achieve a background index of $6{\cdot}10^{-4}$ cts/(keV·kg·yr). No evidence for $0\nu\beta\beta$ decay has been found establishing the up-to-date most stringent half-life limit for this process in ^{76}Ge with a sensitivity of $1.1{\cdot}10^{26}$ yr at 90% C.L. The experimental setup, the analysis procedures and the latest results of GERDA are summarized in the present work.

Section 1. Experimental and theoretical studies of the properties of atomic nuclei

$\Delta I = 1$ "STAGGERING" EFFECT IN THE SPECTRUM OF BAND OF EVEN-EVEN NUCLEI

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A non-adiabatic collective model that takes into account the relationship of rotational motion with longitudinal and transverse vibrations of the quadrupole type of the surface of the nucleus allows us to explain a number of patterns observed in the excitation spectra of deformable non-axial even-even nuclei.
Various well-known types of deviations of nuclear collective motion from purely rotational are known. As a result of these deviations, high-order effects such as "squeezing", "backbending" and "staggering" occur in the structure of the nuclear rotational spectrum.
In particular, the "staggering" effect represents the branching of rotational bands in a sequence of states that differ by several units of angular momentum. The use of discrete approximations of high-order derivatives of a given nuclear characteristic as a function of a particular physical quantity shows various forms of even-odd "staggering" effects that carry information on the fine properties of nuclear interaction and the corresponding high-order correlations in the collective dynamics of a system.
Collective excitations of even-even nuclei of a quadrupole type were studied in the framework of the approximation with arbitrary nonaxiality. In the framework of this approximation, the zigzag behavior of the $\Delta I = 1$ "staggering" effect in the energy spectrum of the collective excitation of the γ-band of heavy even-even nuclei of ^{152}Sm, ^{156}Dy, ^{164,166}Er and ^{230}Th is considered. Moreover, the first and second order terms in the expansion of the rotational energy operator in the variable γ are taken into account in the description of the energy of the levels of the nuclei under consideration. It was shown that the $\Delta I = 1$ "staggering" effect occurs in the case of strong coupling of the ground and γ-bands in the framework of the SU(3) dynamic symmetry.

TRIAXIALITY OF EVEN-EVEN NUCLEI WITH QUADRUPOLE AND OCTUPOLE DEFORMATIONS

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The real observed excitation spectrum of deformed nuclei is complex and contains levels having both a rotational nature and levels arising from collective vibrations. The collective spectra of atomic nuclei with axial-symmetry quadrupole and octupole deformations are characterized by rotational bands with alternating parity.
Earlier energy sequences with alternating parity of deformed axial-symmetry even-even nuclei described within a collective model with non- adiabatically coupled quadrupole and octupole degrees of freedom. Satisfactorily reproduced the structure of the yrast and first non-yrast alternating-parity sequences in the rare-earth nuclei ^{150}Nd, ^{152,154}Sm, ^{154,156,158}Gd, ^{156}Dy, ^{162,164}Er and the actinides ^{224}Ra, ^{228}Th, $^{232;234;236;238}$U, ^{240}Pu. It should be noted that in the experiments one can observe energy bands, which cannot be explained framework the nuclei models with axially-symmetric multipole deformations. For example, the spectrum of γ–band energy levels. In present work we are attempt to describe energy spectrum of yrast-, non-yrast- and γ-bands even-even nuclei framework the model with trixial-asymmetric multipole deformations.

ENERGY SPECTRUM OF COLLECTIVE STATES OF ODD-ODD NUCLEI

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The presence of an energy gap in the spectrum of single nucleon states of even-even nuclei facilitates the identification of collective excitations corresponding to a change in the surface shape and rotation of atomic nuclei. In odd atomic nuclei, the energy of single-nucleon excitations usually differs little from the energy of collective excitations; therefore, their separation is possible only in some special cases. The interaction between the rotation of the nucleus and the external nucleon, on the one hand, changes the structure of the rotational spectrum corresponding to the adiabatic approximation, on the other hand, this interaction changes the spectrum of single-particle excitations. The above circumstances make it difficult to classify the excited states of odd nuclei by analogy with the classification of the excited states of even-even nuclei. And the excited collective states of odd-odd nuclei are even more complex and is an interesting subject, and this phenomenon has been little studied.
In the non-adiabatic collective model, where the Hamilton operator includes the operators of longitudinal and transverse vibrations of the surface of an even-even remainder and the energy operator of an external proton and neutron in the core field, the interactions of an external proton and neutron are also taken into account. However, the general solution of the Schrodinger equation by such a Hamiltonian is complex. Therefore, the present work attempts to describe the collective excitations of odd-odd nuclei in the framework of a non-adiabatic collective model with effective non-axiality. The rotationally single-nucleon spectrum of the excited states of odd-odd nuclei is determined. These states were calculated and compared with experimental data for nuclei ^{100}Y, ^{104}Rb, ^{162,164}Ho, ^{242}Am.

ЭНЕРГЕТИЧЕСКИЙ СПЕКТР И СТРУКТУРА СОСТОЯНИЙ ИЗОТОПА ^{156}Gd

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^{156}Gd-одно из изученных ядер. Причиной этого является то, что величина сечения (n, γ) - реакции дает богатые возможности для изучения спектра излучения. Наиболее полные результаты по этому ядру представлены в работах [1,2]. В реакции (n, γ) получены данные об уровнях ротационных полос с $K = 0_1^+$ - до 26^+, 0_2^+ до 14^+, 2_1^+ до 14^+, 0_3^+ до 10^+, 0_4^+ до 6^+, 0_5^+ до 4^+ и 2_2^+ до 4^+. Из имеющихся результатов можно сказать, что в ^{156}Gd обнаружены почти все уровни до энергии возбуждения 2 МэВ.
В данном ядре известны пятнадцать состояния с $K = 1_1^+$. Абсолютно большинство из них принадлежат ножничной моде и экспериментально определены вероятности M1-переходов [1,3]. Электрические характеристики низколежащих коллективных состояний экспериментально исследовались в работах [2,4], а магнитные свойства этих уровней изучались в [1,5]. Эти экспериментальные данные указывают на наличие отклонения от адиабатической теории.
В данной работе в рамках феноменологической модели [6], рассматривающей смешивание состояний низколежащих ротационных полос, описываются неадиабатические эффекты,

проявляемые в энергиях и электромагнитных характеристиках. Вычислены спектр энергии, структура состояний и вероятности электромагнитных переходов.
Показано, что неадиабатические эффекты, проявляемые в энергиях и электромагнитных свойствах состояний, является результатом кориолисово смешивание состояний адиабатических полос, имеющих одинаковые моменты инерции. Ранее эта модель была применена для изучения смешивание полос состояний положительной четности изотопов ^{158,160}Gd [7,8].

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NUCLEAR MATTER DENSITY DISTRIBUTIONS OF THE LIGHT WEAKLY BOUND NUCLEI

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The study of nuclear matter is one of the most interesting branches of nuclear physics from a theoretical and experimental point of view. Especially it goes quite capacious when the internal structure of studying nuclei is extraordinary. As an example can be nuclei in follow: ^{6}He and ^{6}Li, which are unstable and have a Borromean structure; ^{9}Be having also Borromean structure, it is stable and has relatively significant deformation in the ground state, has the first excited state with positive parity pointing to the non-applicability of the standard shell model.
In this work, the densities of the nuclear matter of the listed nuclei are studied within the framework of the three-body model. An analytical expression is derived using the three-body wave function based on the Gaussian function for the density distribution function of nuclear matter. Comparisons with available data and other theoretical models are made.

ENERGY SURFACE AROUND A DEFORMED EVEN-EVEN NUCLEI WITH 150<A<190

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If an ideal energy surface around a deformed nucleus with even N and Z existed and were linear and quadratic in deviations s and t from N and Z respectively $(|s|/N \ll 1, |t|/Z \ll 1)$

$$E(N+s,Z+t) = M(N+s,Z+t) - m_n(N+s) - m_p(Z+t) = \mathscr{E}(N,Z) + d_{1n}s + d_{1p}t + \\ + d_{2n}s^2/2 + d_{2p}t^2/2 + d_{1n1p}st$$

(E, M are nuclear energy and mass, m_n, m_p are nucleon masses), then parameters $\mathscr{E}(N,Z)$ and d_{inkp} should not depend on those adjacent nuclei which are used for calculations of these parameters. In particular, a measured $E(N,Z)$ has to coincide with a calculated parameter $\mathscr{E}(N,Z)$. For determination of $E(N,Z) - \mathscr{E}(N,Z)$ and other parameters three groups of even-even nuclei are applied: s -Appr. (Approximation, $s = \pm 2, \pm 4, t = 0$, i. e. isotopes); t -Appr. ($s = 0$, $t = \pm 2, \pm 4$, i.e. isotones) and $(st)-$ Appr. in which $s = \pm 2, t = \mp 2; s = \pm 4, t = \mp 4$

Calculated quantities $E(N,Z) - \mathscr{E}(N,Z)$ are given in Table [1], which shows that these quantities are sign variable in different approximations and a maximum divergence attains $\simeq 120\text{keV}$. Approximately the same difference is found in other parameters. Thus, description of the energy surface around a deformed even-even nucleus by Eq. (1) is rather approximate. This information is useful for prediction of unknown masses and calculations of the pairing energies.

Nucleus	$E(N,Z) - \delta$(N, Z)		
	s -Appr.	t -Appr.	(st) -Appr.
$^{154}_{64}$Gd$_{90}$	128.6± 2.0	−8.9± 19.2	121.8± 10.3
$^{160}_{66}$Dy$_{94}$	−29.6± 8.6	−53.1± 9.2	−68.2± 18.4
$^{70}_{170}$Yb$_{100}$	37.7± 1.4	29.9± 16.9	−8.8± 33.9
$^{180}_{74}$W$_{106}$	74.6± 13.6	77.6± 11.3	−55± 61
$^{188}_{76}$Os$_{112}$	−21.0± 1.1	−179.0± 7.2	12.4± 9.7

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COLLECTIVE STRUCTURE IN ^{116}Sb

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Structure of nuclei near Z=50 proton magic shell closure and neutron number near Z=64 subshell closure are found to exhibit the single-particle structure that coexist with the collective structure and therefore, gives the possibility to investigate both the structures within the single nuclear system [1-3]. The collective band structures have been systematically observed in both odd-odd and odd-even Sb (Z=51) isotopes along with the single particle structure [4-5]. The collective structures are understood as due to promotion of proton from β-upsloping 1g$_{9/2}$ to the β-downsloping 1d$_{5/2}$, 1g$_{7/2}$ and 1h$_{11/2}$ orbitals. In particular, due to presence of negative parity 1h$_{11/2}$ orbital, collectivity is further induced in the system. The aim of present work is to study the structure of ^{116}Sb nucleus.
The excited states of the ^{116}Sb have been populated by using the reaction ^{115}In(α, 3n)^{116}Sb, at a beam energy of 40 MeV from the K-130 Cyclotron at VECC, Kolkata, and the de-exciting γ-rays were detected with the Compton suppressed clover detector setup of the Indian National Gamma

Array (INGA) coupled to a digital data acquisition system.
A new level scheme of ^{116}Sb has been proposed with significant extension of level scheme compared to previous work [6-9]. The deformed bands have been extended to higher spin. Earlier a band like structure of strong M1 transitions with missing crossover E2 transitions was observed, and predicted to be a magnetic rotational band [9]. In the present work, the corresponding E2 transitions of this band have been found and placed in the level scheme. The neutron pair breaking has also been found to occur in one of the bands.
The INGA collaboration for their support during the experimental campaign, UGC for financially supporting my work and the Cyclotron operators of VECC, Kolkata for providing a good quality Alpha beam, are gratefully acknowledged.

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PROPERTIES OF ISOSCALAR GIANT MULTIPOLE RESONANCES IN MEDIUM-HEAVY CLOSED-SHELL NUCLEI: A SEMIMICROSCOPIC DESCRIPTION

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The particle-hole (p-h) dispersive optical model (PHDOM) developed recently [1] is adopted and implemented for describing main properties of Isoscalar Giant Multipole Resonances (ISGMPR) up to L=3 in medium-heavy closed-shell nuclei. The overtones of monopole and quadrupole isoscalar giant multipole resonances are also studied. Being considered in a large excitation-energy interval, the main properties include the following energy-averaged quantities: the strength function related to an appropriate probing operator; the projected (i.e., related to the mentioned operator) one-body transition density; partial probabilities of direct one-nucleon decay. Unique abilities of PHDOM are conditioned by a joint description of the main relaxation modes of high-energy p-h configurations associated with a given giant resonance. Two modes (Landau damping and coupling of mentioned configurations to the single-particle continuum) are described microscopically in terms of Landau-Migdal p-h interaction and a phenomenological partially selfconsistent mean field. Another mode, coupling to manyquasiparticle states (the spreading effect), is described phenomenologically in terms of the imaginary part of the properly parameterized energy-averaged p-h self-energy term. The imaginary part determines the real one via a microscopically-based dispersive relationship. Using previous studies of the isoscalar giant monopole resonance in ^{208}Pb [2, 3] as a base, we specify and markedly extend the above-outlined PHDOM description of mentioned giant resonances in closed-shell nuclei ^{40,48}Ca, ^{90}Zr, ^{132}Sn, ^{208}Pb. The model parameters related to a mean field and p-h interaction are taken from independent data accounting for the isospin symmetry and translation invariance of the model Hamiltonian. Parameters of the strength of self-energy term imaginary

part are adjusted to reproduce in PHDOM-based calculations of ISGMPR total width (full width at half maximum (FWHM)) in each nucleus under consideration. The calculation results are compared with available experimental data. Some of results are compared with those obtained in microscopic Hartree-Fock calculations [4]. These comparisons confirm the statement that PHDOM is a powerful tool for describing ISGMPR in medium-heavy closed-shell nuclei. Extension of the model on taking nucleon pairing into account in open-shell spherical nuclei is in order.

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PARTICLE-HOLE DISPERSIVE OPTICAL MODEL FOR OPEN-SHELL NUCLEI. IMPLEMENTATIONS FOR DESCRIBING 0^+ GIANT RESONANCES IN TIN ISOTOPES

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The semi-microscopic particle-hole dispersive optical model (PHDOM), in which main relaxation modes of high-energy particle-hole-type nuclear excitations are together taken into account [1], has been implemented for describing various giant resonances in medium-heavy closed-shell nuclei (see, e.g., Refs. [2,3]).

A lot of experimental data concerned with giant resonances in medium-heavy open-shell spherical nuclei makes reasonable an extension of PHDOM for taking nucleon pairing into account. In the present work, an extended PHDOM version is developed in a "high-energy limit" employing the simplest BCS-model.

The proposed version is implemented for describing main properties of Isoscalar Giant Monopole Resonance (ISGMR) and Isobaric Analog Resonance (IAR) in a number of tin isotopes.

From studies of ISGMR in a chain of tin isotopes one gets information about isotopic dependence of nuclear-matter incompressibility coefficient (see, e.g., Ref. [4]).

Existence and properties of IAR are closely related to the isospin and symmetry in nuclei. Using previous studies of ISGMR [2], IAR and its overtone [3] as a base, we employ the extended PHDOM version for describing strength function, projected transition density, probabilities of direct one-nucleon decay of ISGMR, and main relaxation parameters of IAR (partial proton and spreading widths, resonance-mixing phase).

The obtained results are compared with respective experimental data related to ISGMR (Ref. [4] and references therein) and IAR [5].

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THE STRUCTURE OF HIGH-SPIN (9+) ISOMERS AND THE NATURE OF ROTATIONAL BANDS IN ODD-ODD Ho NUCLEI WITH A = 156, 158, 160

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The report considers the structure of high-spin (9+) isomers and the nature of rotational bands in Ho and Dy nuclei with A= 156, 158, 160.
A detailed comparative analysis of the decay of holmium isomers into dysprosium levels (Ho ⟶ Dy) for A= 156, 158, 160 (see Fig. 1.).

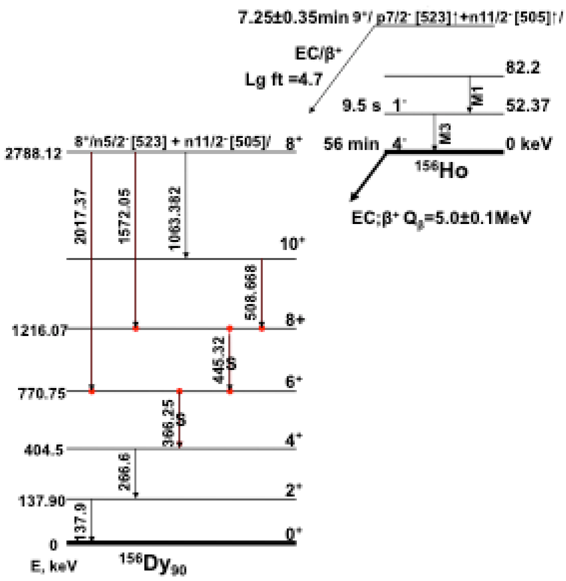

Figure 1: Decay of isomer 9+ in ^{156}Ho nucleus.

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NON-STATISTICAL EFFECTS IN BETA & GAMMA DECAYS AND BETA-DELAYED FISSION ANALYSIS

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The β-transition probability is proportional to the product of the lepton part described by the Fermi function $f(Q_\beta - E)$ and the nucleon part described by the β-decay strength function $S_\beta(E)$, where E is the excitation energy in daughter nuclei and Q_β is the total energy of β-decay.
The previously dominant statistical model assumed that there were no resonances in $S_\beta(E)$ in Q_β-window and the relations $S_\beta(E) = Const$ or $S_\beta(E) \sim \rho(E)$, where $\rho(E)$ is the level density of the daughter nucleus, were considered to be a good approximations for medium and heavy nuclei for excitation energies $E > 2 \div 3MeV$. The effect of the non-statistical resonance structure of the $S_\beta(E)$ on the probability of delayed fission was first investigated in [1]. Then the method developed in [1] for the description of delayed processes by considering the $S_\beta(E)$ structure was used to analyze delayed fission of a wide range of nuclei [2–6]. Ideas about the non-statistical structure of the strength functions $S_\beta(E)$ have turned out to be important for widely differing areas of nuclear physics [4].
When studying delayed fission, (i.e., fission of nuclei after the β-decay) one can obtain information on fission barriers for nuclei rather far from the stability line [1-3]. The delayed fission probability substantially depends on the resonance structure of the $S_\beta(E)$ both for β^- and β^+/EC-decays [1-6]. It can therefore be concluded from this analysis of the experimental data on delayed fission [1-6] that delayed fission can be correctly described only by using the non-statistical β-transition strength function reflecting nuclear-structure effects.
In β-decay the simple (non-statistical) configurations are populated and as a consequence the non-statistical effects may be observed in γ-decay of such configurations. In delayed fission analysis the γ-decay widths Γ_γ calculated using the statistical model, which, in general, can only be an approximation. Non-statistical effects in (p, γ) nuclear reactions in the excitation and decay of the non-analog resonances, for which simple configurations play an important role, were analyzed in [5]. The strong non-statistical effects were observed for $M1$ and $E2$ γ-transitions. Because the information about γ-decay is very important for delayed fission analysis, it is necessary to consider the influence of non-statistical effects on delayed fission probability not only for β-decay, but also for γ-decay.
In this report some features of β-delayed fission probability analysis are considered. It is shown that only after proper consideration of non-statistical effects both for β-decay and γ-decay it is possible to make a quantitative conclusion about fission barriers.

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A SEARCH FOR RARE NUCLEAR AND INDUCED DECAYS IN HAFNIUM

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A low-background measurement of hafnium foil using a modified ultra-low-background high purity detector with optimized sample-to-detector geometry was performed at Laboratori Nazionale del Gran Sasso. Radiopurity of the stock Hf foil was studied in detail, in addition to an analysis of data collected over 310 day to search for rare processes that can occur in natural Hf isotopes. Firstly, leading limits on alpha decays of all natural Hf isotopes to the first excited state of the daughter nuclides were established in the range of 10^{16}–10^{19} a (90% C.L.). Secondly, a search for modes of double electron capture and electron capture with positron emission in ^{174}Hf was performed, yielding half-life limits 10^{15}–10^{18} a (90% C.L.). Lastly, novel dark matter-induced nuclear excitations in hafnium isotopes were investigated. For dark matter with 1 TeV/c^2 mass, leading limits on the inelastic dark matter–nucleon cross section are set for mass splitting's in the range 430 keV < $\delta M\chi$ < 465 keV.

ROLE OF DIBARYON RESONANCES IN ELASTIC AND INELASTIC NN SCATTERING

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The recent results [1,2] of the dibaryon model for nucleon-nucleon (NN) interaction are presented. The model is based on a mechanism with the intermediate six-quark (dibaryon) state formation. Thus, the total Hamiltonian of the system has a two-channel matrix form where the external channel corresponds to the ordinary relative motion of two nucleons and the internal channel takes into account non-nucleonic degrees of freedom. Alternatively, one can solve the initial problem in the external channel only with the effective energy-dependent non-local interaction which arises after exclusion of the internal channel [2].
It is shown that in the particular NN channels, the model allows reproducing simultaneously the positions of the experimentally detected dibaryon resonances [3] and the partial scattering NN phase shifts up to energies far above the inelastic threshold [1,2]. By including a possibility of the decay of the intermediate dibaryon state, the inelasticity parameters for the discussed partial NN channels are reproduced as well. At the same time, one may consider some particular inelastic processes within the model, such as a near-threshold single pion production.
It is also discussed how to employ the above two-channel NN interaction in 3N system within the Faddeev framework. Here the Faddeev equations for the basic objects such as the total resolvent, the scattering wave function and transition operators for this type interaction are derived explicitly [2].

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THEORETICAL STUDY OF WEAKLY-BOUND TRIATOMIC SYSTEMS WITH FADDEEV EQUATIONS IN TOTAL ANGULAR MOMENTUM REPRESENTATION

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The long-lived interest to weakly-bound triatomic systems is stimulated by their connection with Efimov physics [1]. While the most studied system is the Helium trimer [2], there is a variety of other systems [3,4] like helium-alkali triatomic molecules under investigation. Although their bound states with zero total orbital momentum lie very close to the breakup threshold, some of those systems have also bound states with nonzero orbital momentum. These latter states are much less studied than the former due to the computational complexity. In order to deal with this computational complexity a theoretically sound and computationally effective method is required. Here we present a method for solving the Faddeev equations in the total angular momentum representation. The method makes accurate calculations of bound states with arbitrary total orbital momentum value viable. We illustrate the method implementation with calculations of different weakly-bound triatomic systems.

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RESONANCES IN THE SYSTEM WITH AN INTERNAL DEGREE OF FREEDOM

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The Hamiltonian of the system with an additional internal degree of freedom is studied. For this purpose, the coupled channel formalism with the total Hilbert space consisting of two subspaces is used. Here, the external subspace corresponds to the relative motion of two particles and the internal one takes into account some other degrees of freedom. In the simplest case, the internal subspace is a single intruder state $|\alpha\rangle$ with energy E_0. Then, the total two-channel Hamiltonian has a form:

$$H = \begin{pmatrix} h_{\rm ext} & \lambda|\phi\rangle\langle\alpha| \\ \lambda|\alpha\rangle\langle\phi| & E_0|\alpha\rangle\langle\alpha| \end{pmatrix}.$$

Here, $h_{\rm ext}$ is the external Hamiltonian which defines mainly the peripheral relative motion of particles, λ is the strength of coupling with the internal channel, and $|\phi\rangle$ is the coupling formfactor. The main goal of this research is to develop a method for calculating resonances in such systems

and to study their properties according to the model parameters. An interesting problem here is a possibility for the formation of a bound state in continuum (BIC). Although the presence of the BIC does not lead to a resonance-like sharp behavior of amplitudes, it may have a significant impact on observables.
As a practical example, we consider the dibaryon model [1] for nucleon-nucleon (NN) interaction in which coupling to the internal state corresponds to account of the intermediate six-quark (dibaryon) state formation. This model allows [1] to reproduce the positions of the experimentally detected dibaryon resonances [2] and the partial scattering phase shifts, in particular, the partial NN channels. In the present study, a special attention is paid to two main NN channels $^1S_0$ and $^3S_1$-$^3D_1$ where experimental evidences for high lying dibaryon resonances have been found very recently [3].

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QUANTUM SPEED LIMITS FOR TIME EVOLUTION OF A SYSTEM SUBSPACE

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One of the fundamental physical limits on the speed of the time evolution of a quantum state is known in the form of the celebrated Mandelstam-Tamm inequality. This inequality gives an answer to the question on how fast can an isolated quantum system evolve from its initial state to an orthogonal one. Extensions of the Mandelstam-Tamm inequality give optimal speed bounds for the evolution between non-orthogonal initial and final states as well as for the evolution of mixed states. In the present work, we are concerned not with a single state but with a whole (possibly infinite-dimensional) subspace of the system states that are subject to the Schr\"odinger evolution. By using the concept of maximal angle between subspaces we derive an optimal bound on the speed of such a subspace evolution that may be viewed as a further generalization of the Mandelstam-Tamm inequality.

This is a joint work with Sergio Albeverio.

EFIMOV STATES IN THREE-ATOMIC SYSTEMS

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Three-atomic molecules at ultralow energies are of a great interest in both experiment and theory. The ability to control the scattering length in ultracold gases make these systems ideal candidates for experimental study of Efimov [1]. After the first successful observation of Efimov states in an ultracold Cesium gas [2], a lot of the experimental evidence for the Efimov states in three-atomic

systems consisting of He, Li, K, Rb, Cs atoms and its combinations were reported (see review [3]).
The properties of ultracold triatomic systems are determined by the van der Waals interaction. Analyzing interaction potentials between different species we discuss the possible existence of Efimov states in three-body systems. Some our results obtained using Faddeev calculations [4] and a short review of other calculations will be presented.

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METASTABLE STATES OF DIATOMIC BERYLLIUM MOLECULE

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Calculation of vibrational-rotational bound states and metastable states of a diatomic beryllium molecule important for laser spectroscopy [1] are presented. The solution to the problem is performed using the potential curve given in [2,3] and the authors' software package that implement the iteration Newton method and the high-accuracy finite element method [4].
The efficiency of the proposed approach is demonstrated by calculated for the vibrational-rotational bound states and the first time sharp metastable states with complex eigenenergies (with negative imaginary parts of order $10^{-20} \div 10^{-3}$ cm^{-1}) in a diatomic beryllium molecule.

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RADIAL ASYMPTOTIC OF THE WAVE FUNCTION OF FEW-PARTICLES IN THE CONTINUUM

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The asymptotic form of the wave function of a few-particle system in the continuum is described. The contribution of the rescattering processes in the leading terms of the asymptotic behavior of the wave function is analyzed. The hyperradial asymptotic behavior of the wave function is found after averaging over the hyperspherical angular variable. The perspective of applications to the analysis of the few neutron system is discussed.

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ELECTROMAGNETIC TRANSITIONS IN HEAVY ODD-A NUCLEI

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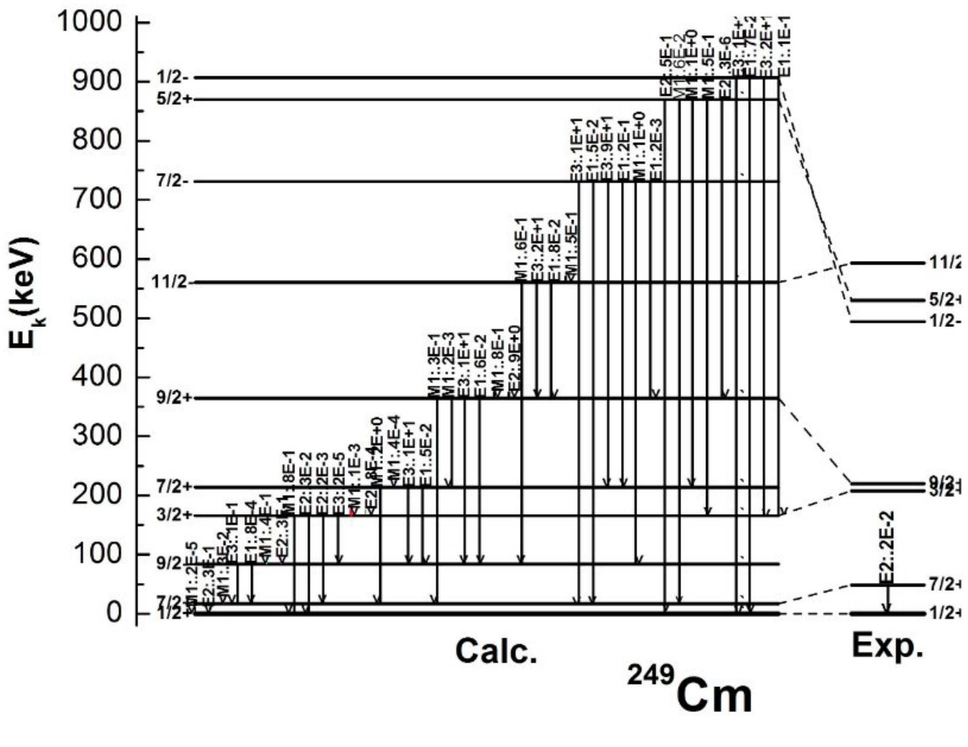
The reduced probabilities B{[Eλ(,Mλ); IπK(K=μ) ⟶ (IπK)'} of electro-magnetic transitions from excited states into the ground and excited states, as well as structure of low-lying states were calculated for odd-A nuclei: in the region of A=243-269 and Z=96-109. The interaction of quasiparticles and phonons was taken into account. The calculations are performed at equilibrium deformation of the nuclei. The spectra of non-rotational states were studied in the present work in the same way as in Ref. [1] using a theoretical formalism based on a microscopic-macroscopic approach and a Quasiparticle-Phonon Model [2,3]. The calculations do not contain any free parameters. The figure shows the results for the 249Cm nucleus (in Weiskopf's units, W.u.↓).



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FOUR-NEUTRON DECAY CORRELATIONS

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Mechanism of simultaneous non-sequential four-neutron ($4n$) emission (or "true" $4n$-decay) has been considered in phenomenological five-body approach.
This approach is analogous to the model of the direct decay to the continuum often applied to $2n$- and $2p$-decays. It is demonstrated that $4n$-decay fragments should have specific energy and angular correlations reflecting strong spatial correlations of "valence" nucleons orbiting in their $4n$-precursors. Due to the Pauli exclusion principle, the valence neutrons are pushed to the symmetry-allowed configurations in the $4n$-precursor structure, which causes a "Pauli focusing" effect.
Prospects of the observation of the Pauli focusing have been considered for the 4n-precursor ^{7}H. Fingerprints of it nuclear structure or/and decay dynamics are predicted.

RESEARCH OF ISOBAR: Yb-Tm-Er-Ho WITH A=157

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During the decay of Yb and Tm, Er with A = 157, the structure and isomerism of daughter isotopes levels were studied. An investigation of ^{157}Er decay made it possible to establish a scheme of ^{157}Ho excited states in the energy range up to 3 MeV. The spectra of gamma rays, electrons, and gamma-gamma coincidence were studied. The obtained experimental results were compared with theoretical calculations.

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USE OF MOLECULES TO EXTRACT FUNDAMENTAL PROPERTIES OF NUCLEI

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Recently a strong disagreement between the theoretical prediction [1] of the specific difference of hyperfine splittings in H-like and Li-like ^{209}Bi ions and the experiment was found [1]. This problem was called the "hyperfine puzzle". We have shown [3] that the reason of the discrepancy was caused by the inaccurate "standard" value of the magnetic moment of the ^{209}Bi nucleus, which is

given in reference books. This magnetic moment was obtained from the nuclear magnetic resonance experiment on the bismuth nitrate solution. We show that in the previous interpretation of the experiment the uncertainty of the shielding constant required to extract the nuclear magnetic moment was strongly underestimated. For this we have adapted the relativistic 4-component coupled cluster method to calculate the shielding constant in molecules at a new level of accuracy [3]. Using this method, the interpretation of the new nuclear magnetic resonance experiment on $[BiF_6]^-$ was performed [3]. In the present report we will outline the approach as well as the results of its application to other systems. In particular, the refined value of the magnetic moment of the ^{207}Pb nucleus will be presented.
Also, we will briefly mention related problems to search for other nuclear properties such as the quadrupole distribution of neutrons inside the nucleus in the ^{177}HfF+ cation [4]. This can be done by studying the parity violation effects.
The study of the magnetic moment of the ^{209}Bi nucleus was supported by the Foundation for the advancement of theoretical physics and mathematics BASIS grant No. 18-1-3-55-1. Calculation of the Breit interaction contribution to the Bi shielding constant was supported by the RFBR grant № 20-32-70177. The study of the magnetic moment of the ^{207}Pb nucleus was supported by the grant from the Russian Science Foundation (project No. 19-72-10019).

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STRUCTURE OF ^{10}Li IN ONE-NEUTRON TRANSFER REACTION ^{2}H(^{9}Li,p)

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Beside of the general interest to structure of the light exotic nuclei ^{10}Li attracts attention of theoreticians as well as experimentalists because this nucleus is a binary subsystem of famous halo-nuclei ^{11}Li. Last time many experiments were devoted to study the structure of low energy spectrum of ^{10}Li but to the moment the status is far from consensus, even the spin-parity of the ground state is still an open question. We perform the experiment aimed to study the low energy spectrum of the ^{10}Li populated in one-neutron transfer reaction ^{2}H(^{9}Li,p) at 28 MeV/nucleon beam energy. That is one of the first experiments at new fragment separator ACCULINNA-2. The data analysis is in progress and here we present the preliminary results clarifying the structure of ^{10}Li low energy spectrum.

INFLUENCE OF CHARGE-EXCHANGE RESONANCES ON THE CAPTURE OF SOLAR NEUTRINO BY MOLYBDENUM 98 AND 100

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The work presents calculations of the solar neutrino capture cross-section σ(E) by ^{98,100}Mo nuclei. In calculations experimental data on strength function S(E), received in charge-exchange reactions

(p, n) [1] and (^{3}He, t) [2, 3] were used. Calculations of the charge-exchange strength function S(E) for these nuclei were performed as part of the self-consistent theory of finite Fermi-systems. The resonance structure of the strength function S(E) was analyzed and Gamow-Teller (GTR) [4], Analog (AR) [5] and Pigmy resonances (PR) [6] were isolated. The effect of the resonant structure S(E) on the calculated solar neutrino capture section σ(E) was studied. The question of changing the neutrino capture cross section due to taking into account the effect of neutron emission from the daughter nucleus is considered. It was noted that the capture of solar neutrinos by the ^{100}Mo nucleus is a background process in the study of double beta decay of this nucleus.

The work is supported by the Russian Foundation for Basic Research (Grant no.18-02-00670_a).

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STRUCTURE OF LIGHT Λ-HYPERNUCLEI NEAR NUCLEON DRIP LINES AND BARYONIC INTERACTION

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Hypernuclei provide an excellent opportunity to investigate the properties of baryon-baryon interaction. Exotic systems with a neutron or proton excess are of particular interest. The response of weakly bound nuclear states to hyperon addition is determined by the core polarization by the hyperon [1]. Due to the glue-like role of the Λ-hyperon, there is a chance to stabilize loosely bound nucleon systems and even get bound hypernuclei with unstable core nucleus [2].

We address the structure of light Λ-hypernuclei in the framework of Hartree-Fock approach with effective potentials in the Skyrme form. This phenomenological approach allows us to analyze the hypernuclear properties in relation to both nucleon-nucleon and hyperon-nucleon components of the general baryonic interaction. Hyperon binding energies, as well as radii of nuclear cores are calculated using several Skyrme parametrizations in order to verify the sensitivity of these quantities to the interaction properties. In particular, we study hypernuclei ${}^{9}_{\Lambda}$C, ${}^{12}_{\Lambda}$N and ${}^{13}_{\Lambda}$O with unbound nuclear cores.

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THE PROPERTIES OF THE $^4He_3$ AND $^3He^4He_2$ THREE - ATOMIC SYSTEMS

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Clusters of gas atoms are a large class of molecules interacting via van der Waals type potentials. Some weakly bound clusters show universal characteristics and scale invariants related to the famous Efimov effect [1], which was experimentally confirmed in an ultracold gas of the Cs atoms [2]. The helium trimer system has been long considered as an ideal candidate for observing Efimov states. Only recently, after a long and continued research, the Efimov state as the excited state of the $^4He_3$, was detected [3]. Also, the wave function of the ^{4}He dimer has been measured via Coulomb explosion technique which enabled to determine its very small binding energy - 151.9 (13.3) neV [4].
There are many realistic He-He potential models which are more and more accurate reproduce two-body data [5]. Very accurate calculation needed in order to evaluate the effect of potential models on the characteristic of three-body system. One of the effective methods for studying triatomic clusters is based on the differential Faddeev equations.
In this work we develop an application based on the Faddeev differential equations for studying the properties of the $^4He_3$ and $^3He^4He_2$ three - atomic systems using modern realistic potentials constructed by M. Przybytek *et al.* in 2010 [6] and 2017 [7] years, as well as older potentials – LM2M2 [8] and TTY [9]. The calculated results we compare with the results obtained using different methods by other authors and with the experiment.

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ABOUT THE DEPENDENCE OF NUCLEAR SURFACE DIFFUSENESS ON NEUTRON-PROTON ASYMMETRY AND ITS INFLUENCE ON THE EVOLUTION OF SINGLE-PARTICLE SPECTRA

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The evolution of single-particle energies E_{nlj} of near to spherical medium and medium- heavy nuclei as they approached neutron drip line was studied within the dispersive optical model (DOM) [1]. The main attention was paid on the dependence of the diffuseness parameter a_{HF} of the Hartree-Fock component of the potential on neutron-proton asymmetry and its influence on the

evolution. It was shown that the agreement with the available experimental data was improved if a_{HF} depended on neutron-proton asymmetry:
$a_{HF} = a^{0}_{HF} \pm a^{1}_{HF}(N-Z)/A$, + for n, – for p . (1)
In other words, the diffuseness a_{HF} increased when the Fermi energy goes up. The dependence (1) differs from that of the global diffuseness parameter a_V^{KD} of the traditional optical model potential [2]. The parameter a_V^{KD} decreases with increasing mass number A of the nucleus for both neutrons and protons. The dependence (1) leads, in particular, to the following: more pronounced inversion of the $2s_{1/2}$–$1d_{3/2}$ proton levels in stable Ca isotopes and the $1g_{7/2}$–$2d_{5/2}$ proton levels in stable Sn isotopes; more pronounced evolution of the energy gap between the neutron states $1f_{5/2}$ and $2p$ in the stable $1f-2p$– shell nuclei; better agreement with the experimental energies E_{nlj} of the $1d_{3/2}$ neutron state in neutron-rich Si isotopes [3] comparing to the parameter $a_{HF} = a_V^{KD}$ (see fig). Thus, dependence (1) improves the predictive power of DOM with respect to the nuclei far from the β-stability valley.

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INVESTIGATION OF EXOTIC ^{7}He NUCLEUS WITHIN THE SS-HORSE-NCSM APPROACH

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We present *ab initio* calculations of resonances for exotic ^{7}He, a nucleus with no bound states, using the realistic nucleon-nucleon interactions Daejeon16 [1] and JISP16 [2]. For this, we evaluate the $n-^6$He elastic scattering phase shifts obtained within an S-matrix analysis of no-core shell model results for states in the continuum (SS-HORSE-NCSM approach [3]).
Results with Daejeon16 and preliminary results with JISP16 for $3/2^-$ and $5/2^-$ states are in reasonable agreement with experimental data. We obtain and discuss $1/2^-$ resonance. There is contradictory information about energy and width of this resonance in different experiments. Also we predict new broad resonances likely related to fragmentary experimental evidence.

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NUCLEAR SHELLS REFLECTION IN NUCLEAR MASSES

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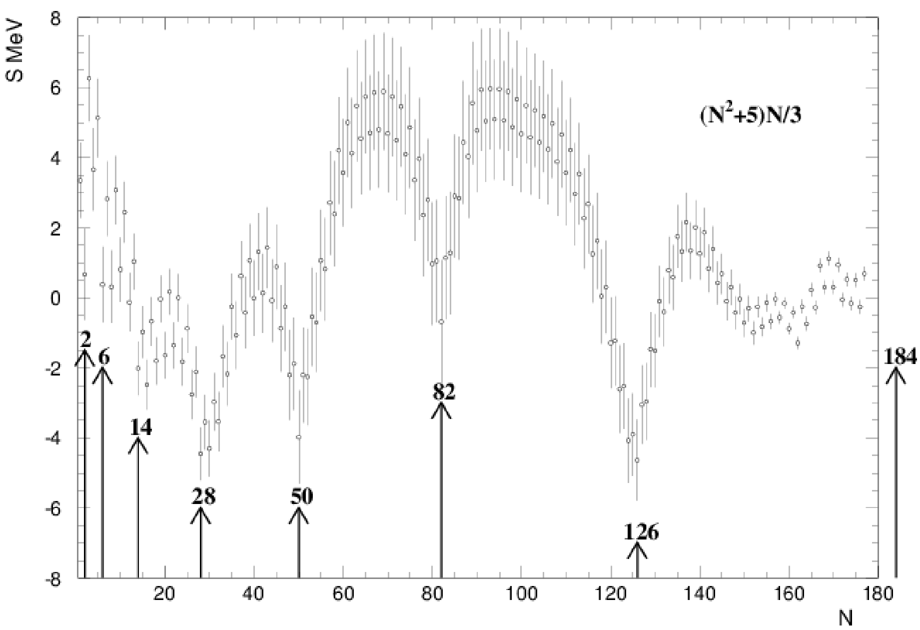
The shell corrections to the nuclear masses are discussed for decades. Since the classic Weizsacker mass formula a lot of formulas have been proposed, which include the shell corrections. But there is a simple method to extract the shell factors from the nuclear masses.
An internal nuclear mass fit of the CHIPS [1] model by a simple formula

$$M\text{-}A = \alpha_1 Z^2 A^{-1/3} + \alpha_2 Z^2/A + \alpha_3 (N\text{-}Z)^2/A^p + \alpha_4[(1+e^{k(N-Z)})^{-1}-0.5] + V(Z) + V(N)$$

calculates unmeasured masses with approximately 1 MeV accuracy. For each Z and each N (A=N+Z) there are special parameters V(Z) and V(N) in the formula (Z_{max}=118, N_{max}=177). All 3353 masses from [2] were used for the fit.



The longest function V(N) was approximated by a formula

$$U(N)=(34-6.8\cdot N)/[1+(27.44/N)^{0.743}] \text{ (MeV)}.$$

The N-dependence of the S(N)=V(N)-U(N) function is shown in the figure. The minima of the S(N) function correspond to the magic numbers calculated as $\mathbf{n\cdot(n^2+5)/3}$.

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DISCRETE VARIABLE REPRESENTATION METHOD IN THE STUDY OF FEW-BODY QUANTUM SYSTEMS WITH A LOW BINDING ENERGY

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Systems of particles with a low binding energy and a wave function that is widely distributed in space are considered in this work. The study of these systems is not an easy task and requires different approaches, solution methods and additional computational recourses. Extensive studies of weakly bound systems have been conducted in recent times [1,2,3].
The goal of the work is the development and implementation of the discrete variables representation method [4,5], which allows to carry out calculations with smaller computing resources without loss of accuracy, reduce the calculation runtime, and as a result, conduct scientific research faster and with lower financial costs. Initially, the method was developed and implemented for systems with zero orbital momentum; the decomposition was performed according to functions constructed from Legendre polynomials.
The algorithm was generalized to perform high accuracy and quick calculation for systems with non-zero total orbital momentum. Also in order to perform calculations faster, the discrete-variable representations (DVR) of different kinds are used in this work.
The DVR method is based on constructing function with the well known functions such as Legendre polynomials P_n:
$\varphi_i(z) = \frac{P_n(z)}{P'_n(z_i)(z-z_i)}$, $\varphi_i(z_k) = \delta_{ik}$,
where z_k are defined by $P_n(z_k) = 0$. Due to the properties of the DVR functions the calculations of the potential energy may be simplified. That allows to gain speed and accuracy for solving the problem.
Algorithm was used to calculate binding energies of the systems Ne_3, He_3, Li—He_2. The method allows to decrease runtime significantly without loss of accuracy.

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COLLECTIVE STATES AND BANDCROSSING IN EVEN CERIUM ISOTOPES

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On the base of microscopic version of the IBM1 plus other bosons of positive parity with spins from 0^+ to 10^+ properties of yrast-band states in even Ce isotopes are studied. Parameters of the boson Hamiltonian and interactions of the collective quadrupole bosons with other bosons are calculated microscopically. This study is a continuation of similar works on the isotopes Xe and Ba [1], in which the possibilities of the microscopic theory have been investigated in the description of increasingly deformed nuclei.
In all considered even Ce isotopes in which there are developed yrast-bands theoretical calculations show that at spin $I\text{cr} = 12^+$ in $^{122-128}$Ce and at $I\text{cr} = 10^+$ in ^{130,132}Ce the band-crossing takes

place just as in even Ba isotopes [1]. The back-bending in moment of inertia (expect ^{122}Ce) at corresponding rotational frequency and minima in $B(E2;\ I \to I-2)$ values at $I = I$cr serve experimental confirmation of such calculations. In ^{122}Ce because of a strong interaction between two bands the moment of inertia up to $I = 14^+$ retains the square dependence on frequency.
The suggested theory satisfactory describes these experimental facts: fig.1 present yrast-band energies (theoretical quantities distinguish from experimental ones not more then by 60 keV), fig.2 $B(E2)$'s for ^{128}Ce.

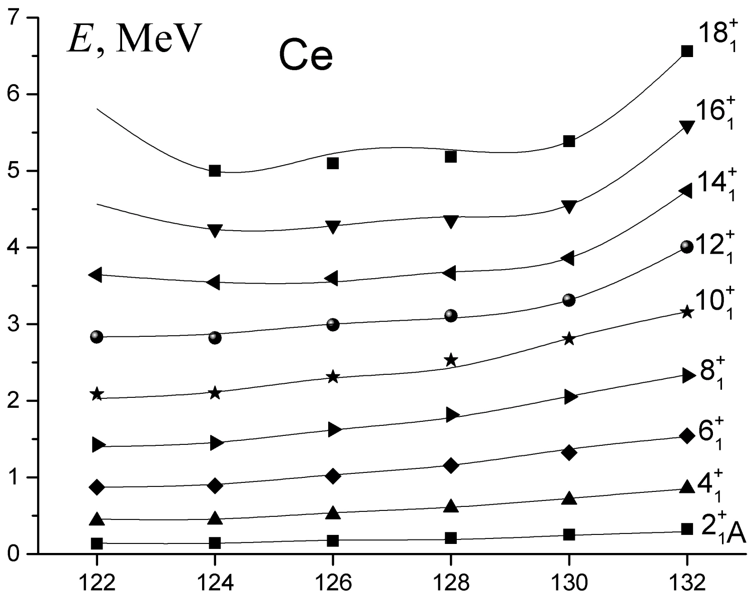

Figure 1: Yrast-band energies for ^{128}Ce.

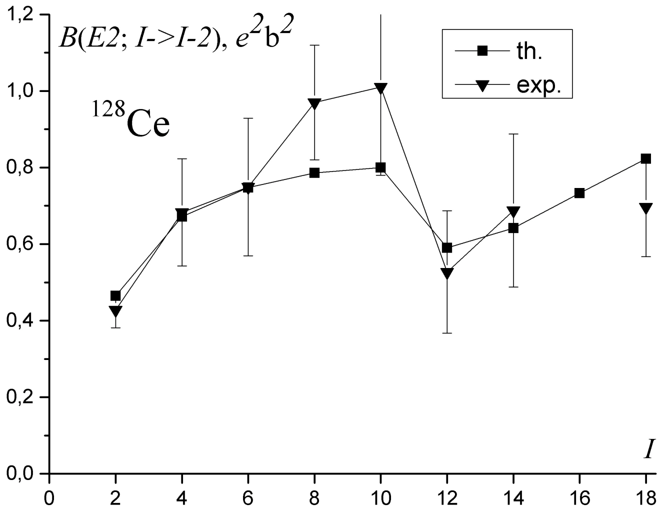

Figure 2: $B(E2)$'s for ^{128}Ce.

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STUDY OF NUCLEAR MAGNETIC QUADRUPOLE MOMENTS AT TRIATOMIC MOLECULES

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Search for spatial parity and time-invariance violation is one of the most topical fields of particle physics. Observation of P,T-invariance violation at atomic and molecular physics may lead to some new restrictions for Standard Model extensions and even be indirect evidence of unknown particles existence. So, precise theoretical and experimental study of molecular electronic structure is necessary for construction of fundamental physical interactions theory.
At the present work the electronic structure of ytterbium monohydroxide molecule YbOH [1] and its isoelectonics is considered. Recent suggestion to perform this kind of experiments on triatomic molecules [2,3] promises to lead to new restrictions for electron electric dipole moment (eEDM) and other P,T-odd constants. Here we consider nuclear magnetic quadrupole moment (NMQM) of 173Yb nucleus as such a constant. Its interaction with molecular electrons leads to energy shift, which is proptional to NMQM value. Calculation of proportionality constant is the main goal of the work, however, expected value of the energy shift is also estimated.
Solution of FSCC equations was supported by the Russian Science Foundation Grant № 19-72-10019. Calculation of Gaunt correction was supported by the Russian Foundation for Basic Research Grant №20-32-70177. Electronic structure calculations were performed at the PIK data center of NRC "Kurchatov Institute" – PNPI.

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THE MODERN CONCEPT OF THE CLUSTER SPECTROSCOPIC CHARACTERISTICS

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The subject of the talk is the theory of the cluster and nucleon spectroscopic factors. A mathematical proof of the necessity for taking into account the channel wave-function renormalization generated by the exchange terms of the antisymmetrization operator is given. This property was ignored in earlier approaches. Unfortunately, the 'old" version is in use up to now through habit. The correct procedure was first time recommended in [1].
In the present study it is reliably demonstrated that the use of the "new" spectroscopic characteristics, which are defined, following by the prescriptions of Ref. [1], with allowance for renormalization makes it possible to meet the unitarity conditions for the set of amplitudes for the formation of various states of a compound nucleus. Owing to this, the cross sections of compound nuclear reactions becomes consistent with regularities inherent in the statistical theory. The averaged values of alpha-particle spectroscopic characteristics obtained in the framework of the

discussed approach turn out to be in a good agreement with the alpha-particle strengths deuced from the analysis of wide-range measurements of the cross-sections of (n,α) reactions.
The technique of calculations of the discussed characteristics in advanced shell-model approaches including ab initio ones is also presented. The types of nuclear decays and reactions which could be described more or less adequately in the framework of traditional "non-renormalized" approaches are considered.

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PHONON-EXCHANGE NUCLEAR INTERACTIONS IN THE THEORY OF NUCLEAR POLARIZABILITY

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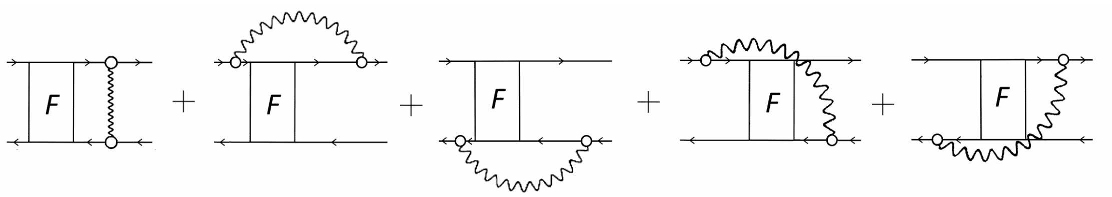

Figure 1: Phonon-exchange interactions between nucleons. The rectangle means the effective interaction F of Landau-Migdal. Straight and wavy lines correspond to single-particle and phonon Green functions, circles with a wavy line stand for the amplitude of phonon production g.

The phonon-exchange nuclear interactions (see Fig.1) are investigated and compared to the effective interaction F of Landau-Migdal. They have been obtained in order to consistently take into account the phonon coupling in the equation for the effective field, which determines nuclear polarizability. This generalization of the self-consistent theory of finite Fermi systems considers only complex 1p1hxphonon configurations. The interactions shown in Fig.1 contain the interaction F and square of the phonon creation amplitude g. They have very similar structures and, at the first sight, they should be comparable to each other. Since 1983 [1], the first graph has been always considered within the Green function method in the known "time blocking approximation" [2] including the latest articles (for example, see [3]). The other graphs are new. The contributions of these phonon-exchange nuclear interactions to the characteristics of M1 resonance in ^{208}Pb are estimated.

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ON THE MICROSCOPIC PYGMY- AND GIANT RESONANCES THEORY ACCOUNTING FOR COMPLEX 1P1H⊗PHONON CONFIGURATIONS

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An extension of the self-consistent theory of finite Fermi systems [1,2] to the energy region of pygmy- and giant resonances in magic nuclei is performed with the aim to consider particle-hole (ph) and complex 1p1h⊗phonon configurations and to consistently account for the phonon coupling (PC) .
A new equation for the effective field, which determines nuclear polarizability, has been derived. Quite new PC contributions to the effective field, which are of interest in the energy regions of PDR and GMR, have been obtained. These contributions are the following. 1) The tadpole effect in the standard ph-propagator. In order to calculate dynamic tadpole contributions, it is necessary to solve the equation for the two-phonons creation amplitude or, maybe, to use the known estimations for the tadpole. 2) Two new interactions induced due to phonon exchange in the second ph-channel (in addition to the old phonon-exchange interaction in the first ph-channel) and the phonon-exchange interactions in the pp- and hh-channels, 3) The effects of the first and second variations of the effective interaction in the phonon field. Such an extension allows us to describe on the equal footing both the ground states and the whole region of nuclear excitations up to giant resonances energies (30-35 MeV). The qualitative analysis and discussion of the new terms are performed.

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SELF-CONSISTENT STUDY OF NUCLEAR CHARGE RADII WITHIN THE FAYANS FUNCTIONAL

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Fully self-consistent calculation of the Odd-Even Staggering (OES) of the charge radii in the long isotopic chains is presented. The nuclei around the neutron shells at N=20, 28, 50 including non-magic ones with pairing in both neutron and proton sectors are treated in the Density Functional Theory. Well-established Fayans functional DF3-a developed in [1] is used. A comparison with its new options Fy(stand) [2] and more recent Fy(Δr,HFB) [3] is performed. The performance and flexibility of the DF3-a are demonstrated. Namely, it describes better the unexpected OES reduction which was observed in the CERN-ISOLDE experiments on the charge radii of the 58-78Cu isotopes approaching the N=50 shell [3] (Fig.1). Also, the DF3-a allows one to simultaneously describe the total beta-decay energies. The latter (presented as the 3-point OES parameters in Fig.2) are more

sensitive "markers" than the binding energies used in [3]. Still, the problem of the charge radii OES needs a more detailed study. A rather strong dependence of the pairing on the density gradient is needed in order to comply with the experimental data on nuclear radii [3]. Supported in part by the grant of Russian Scientific Foundation (RSF 16-12-10161).

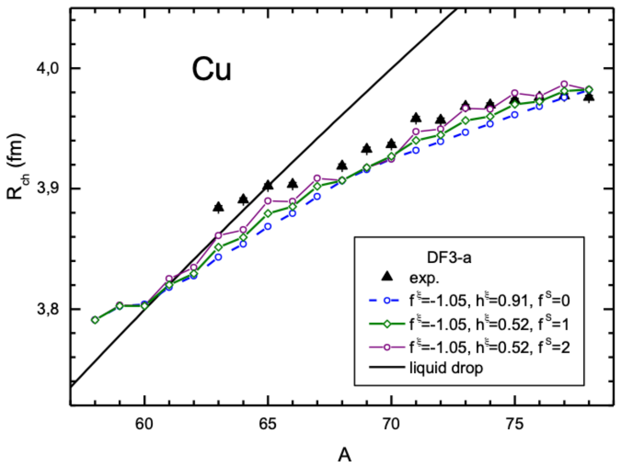

Figure 1: The "liquid drop" charge radii of 58-78Cu compared to the data [3] and calculation within the DF3-a functional for a few different strengths of the gradient paring term.

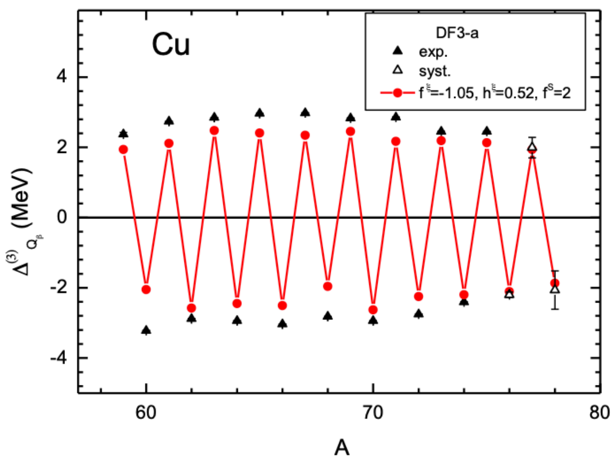

Figure 2: The 3-point OES parameters Δ(3)=1/2(QA+1 -2 QA+ QA-1) for the measured total beta-decay energies Qβ and ones calculated with DF3-a for the Cu isotopic chain.

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SHAPE COEXISTENCE IN ^{96}Zr WITHIN GEOMETRICAL COLLECTIVE MODEL

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Shape coexistence is a remarkable phenomena consisting in the presence in the same nucleus, within the narrow energy range, of two or more states which have distinct properties and can be interpreted in terms of different intrinsic shapes [1]. Recently accumulated experimental data have shown that ^{96}Zr has coexisting spherical and deformed structures with small mixing amplitudes. The observed properties of the low-lying collective states in ^{96}Zr was investigated in the frame of the geometrical collective model by diagonalization of the quadrupole collective Bohr Hamiltonian. Good agreement with the experimental data on the excitation energies, B(E2) and B(M1) reduced transition probabilities is obtained. It is shown that the low-energy structure of ^{96}Zr can be described in a satisfactory way within the geometrical collective model with a potential function supporting shape coexistence without other restrictions of its shape [2].

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SELF-CONSISTENT CALCULATIONS OF TRANSITIONS BETWEEN THE FIRST ONE-PHONON 2+ AND 3- STATES IN SN ISOTOPES

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The self-consistent calculations with the use of functionals of both Skyrme and Fayans have been performed for the probability of E1-transitions between the first one-phonon 2^+ and 3^-states in Sn isotopes. Good agreement with the available experimental data has been obtained. As in our previous calculations for the quadrupole moments of the first 2^+ [1], and 3^- states [2], and for the EL transitions between first 2^+ and 3^- states in magic nuclei [3], we have found that two dominant contributions to observed characteristics come from new three-quasiparticle ground states correlations (GSC), which are largely due to tadpole effects, and from the nuclear polarizability. The polarizability effects reduce the E1 transition probabilities by one order of magnitude. An opposite effect of similar magnitude proves to arise from the three-quasiparticle GSCs. So, in contrast to E2 transitions, the E1 transition probability is determined by the difference between the large effects of nuclear polarizability and three-quasiparticle GSCs.

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STUDY OF CLUSTER DECAY CHANNELS CHARACTERISTICS OF LOW-LYING AND HIGHLY-EXITED STATES OF LIGHT NUCLEI USING AB INITIO METHODS

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The study of cluster properties of various nuclear states is extremely important for nuclear physics as they are manifested at nuclear decay, fusion of colliding nuclei, reactions of knockout and transfer of clusters, etc. As in other fields of light nuclei theory ab initio approaches are actively developing for studying them. [1, 2, 3] These methods are based on solving A-nucleon Schrödinger equation using realistic nucleon-nucleon potentials. Nevertheless all the existing schemes of such a type have rather narrow ranges of applicability.
Being motivated by that we developed [4, 5] a theoretical scheme and the corresponding computer codes adopted for investigating of clustered (A+X)-nucleon states of light nuclei. This scheme is rather universal and in this study it is used for ab initio calculations of the quantities of traditional nuclear reaction theory such as spectroscopic factors, reduced widths, and asymptotic normalization coefficients.
In the present talk we present this method on the example of calculation of cluster decay channels characteristics of low-lying and highly exited states of ^{7}Li and ^{8}Be, both strongly and weakly clustered. These results turn out to be in a good agreement with the known experimental data containing in the spectroscopic tables.

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DISCRETE TRANSFORMS IN QUANTUM CHAOS

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We had suggested in our previous publications (see, e.g. [1-2]) the definition of quantum chaos based on the Liouville-Arnold theorem. It states that a system featuring N degrees of freedom is regular if it has M = N linearly independent first integrals of motion in involution. First (global, isolating) integrals of motion are those that, by Noether's theorem, are associated with the symmetry of the system (that is, with the presence of a group of transformations under which the Hamiltonian of

the system is invariant). Therefore, it is natural to define a chaotic quantum system as that whose symmetry is so low that the number M of its good quantum numbers is smaller than the number N of its degrees of freedom. We had also stressed [3] that only the Wigner distribution law might be a true signature of the system's hard chaos, while the popular belief about the Poisson level distribution for the regular system is wrong and misleading.
Therefore, we suggested a rather simple way to find whether the quantum system under consideration is chaotic: just to compare the number N of its degrees of freedom with the number M of its integrals of motion (good quantum numbers). If the system's symmetry is so low that the number of its integrals of motion is smaller than the number of its degrees of freedom, then it is chaotic.
However, Noether's theorem is proved only for continuous transforms while in quantum mechanics we face also symmetries arising from discrete transforms, like space and time inversion. The question is whether presence of these symmetries should be taken into account in the above analysis of system's chaoticity.
We demonstrate that an additional good quantum number of parity plays a role of an integral of motion and should be taken into account in calculating M. Time-reversal invariance does not generate any corresponding good quantum number (or integral of motion).

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TWO-PHONON STRUCTURES FOR β-DELAYED γ-SPECTROSCOPY

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The β-decay properties are very important for understanding the nuclear structure evolution at extreme N/Z ratios, for analysis of radioactive ion-beam experiments, and modeling of the astrophysical r-process. For this reason, the β-decay properties of r-process “waiting-point nuclei” ^{129}Ag, ^{130}Cd, and ^{131}In provides valuable information, with important tests of theoretical calculations. One of the successful tools for nuclear structure studies is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived from the Skyrme interaction. The framework allows to relate the properties of the ground states and excited states through the same energy density functional. On the other hand, it would be desirable to overcome the discrepancies between the theoretical predictions low-energy 1^+ spectrum using the one-phonon QRPA wave functions of the daughter nucleus and the measurements [1]. We have generalized the approach to the coupling between one- and two-phonon terms in the 1^+ wave functions and the tensor force effects on the β-decay rates of neutron-rich nuclei [2]. We applied the influence of the phonon-phonon coupling on the multi-neutron emission probabilities [3]. The new calculation is extended by enlarging the variational space for the 1^+ states with the inclusion of the two-phonon configurations. The dominant contribution to the additional 1^+ states comes from the $[3^+ \otimes 2^+]_{QRPA}$ two-phonon configurations constructed from the charge-exchange 3^+ phonons. A correlation is found between the low-lying E2 transition strengths of the parent and daughter isobaric companions. Using the same set of parameters this correlation is studied for ^{126,128,130}In and ^{126,128,130}Cd.

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DELINEATING THE KINK: LASER SPECTROSCOPY AND THEORETICAL CALCULATIONS OF MERCURY ISOTOPES ACROSS THE N = 126 SHELL CLOSURE

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Neutron rich mercury isotopes have been studied at CERN-ISOLDE by in-source resonance ionization spectroscopy, determining the change in the mean-square charge radii of ^{207,208}Hg and magnetic dipole moment of ^{207}Hg. These results reveal a doubling of the growth rate of the mean-square charge radii of mercury isotopes across the N = 126 neutron shell closure. Kinks in charge radii systematics at the crossing of neutron shell closures have been found to be universal, indicating an origin that is general and independent of the local microscopic phenomena in the nuclear chart. The location and gradient of experimentally measured kinks provide an excellent benchmark for testing nuclear theory: facilitating the comparison of different theoretical approaches. This work provides a complementary benchmark for the validation of theoretical calculations in addition to the commonly used lead isotope chain.
In order to investigate the mechanisms driving these results, theoretical calculations of the ground states of $^{200-210}$Hg and $^{198-214}$Pb have been performed. This has included both nonrelativistic Hartree-Fock-Bogolyubov (HFB) calculations with energy density functionals (EDF) M3Y-P6 and M3Y-P6a and relativistic calculations within the framework of covariant energy density functional theory (CDFT) and employing a range of EDFs (NL3*, DD-PC1, DD-ME2 and DD-ME2). Of the approaches considered, the CDFT approach with the DD-ME2 forces was found to agree best with experimental data. There is a strong dependence of calculated values on the choice of the EDF. Thus, the experimentally determined kink parameter appears a good candidate for optimization of the EDF parametrization. Crucially the CDFT approach is also demonstrated to reproduce the kink and odd-even staggering (OES) independent of pairing effects, suggesting for the first time an approach that could be capable of reproducing all aspects of the kink and OES at N = 126. Based on the experimental measurements and the theoretical results, our interpretation of the kinks and odd-even staggering in charge radii is in contradiction to that suggested in [1], where pairing is the dominant contributor to both these effects.

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MICROSCOPIC DESCRIPTION OF ISOSCALAR GIANT MONOPOLE RESONANCE IN $^{118-132}$Sn

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The study of nuclear giant resonances has long been a subject of extensive theoretical and experimental research. The multipole response of nuclei far from the β-stability line and the possible occurrence of exotic modes of excitation present a growing field of research. In particular, the study of the isoscalar giant monopole resonances (ISGMR) in neutron-rich nuclei is presently an important problem not only from the nuclear structure point of view [1] but also because of the special role they play in many astrophysical processes such as prompt supernova explosions [2]

and the interiors of neutron stars [3]. One of the successful tools for describing the ISGMR is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived from Skyrme energy density functionals (EDF) [4]. Such an approach can describe the properties of the low-lying states reasonably well by using existing Skyrme interactions. Due to the anharmonicity of the vibrations there is a coupling between one-phonon and more complex states [5]. The main difficulty is that the complexity of calculations beyond standard QRPA increases rapidly with the size of the configuration space, and one has to work within limited spaces. Using a finite rank separable approximation for the residual particle-hole interaction derived from the Skyrme forces one can overcome this numerical problem [6-8].
In the present report, we analyze the effects of phonon-phonon coupling (PPC) on the E0 strength distributions of neutron-rich tin isotopes. Using the same set of the EDF parameters we describe available experimental data for ^{118,120,122,124}Sn [9] and give prediction for ^{130,132}Sn [10]. The effects of the PPC leads to a redistribution of the main monopole strength to lower energy states and also to higher energy tail.

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STUDY OF LEVEL STRUCTIRE OF HEAVY HELIUM ISOTOPE 8HE IN STOPPED PION ABSORPTION

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An overview of experimental results on the level structure of heavy helium isotope 8He, obtained in the reactions of the stopped pion absorption by light nuclei, is presented. Excited states of the 8He were observed in several reaction channels on the ^{9}Be, ^{10,11}B and ^{12}C nuclei: ^{9}Be(pi-,p)^{8}He, ^{10}B(pi-,pp)^{8}He, ^{11}B(pi-,pd)^{8}He, ^{11}B(pi-,^{3}He)^{8}He, ^{12}C(pi-,p^{3}He)^{6}He, ^{14}C(pi-,d^{4}He)^{8}He and ^{14}C(pi-,t^{3}He)^{8}He. The results of measurements of the ^{9}Be(pi-,p)^{8}He are presented for the first time. Important advantage of this method is the possibility to study with high statistics a wide range of excitation energies up to Ex = 40 MeV.
Several levels with high excitation were found only in our measurements. Channels with correlated neutrons make a significant contribution to the continuous spectrum of studied reactions. Note that similar neutron correlations were observed in reactions of formation of heavy helium isotopes ^{6,7}He.
A comparison with experimental and theoretical data other works is performed.

DESCRIPTION OF THE $M1$ RESONANCE IN ^{208}Pb WITHIN THE SELF-CONSISTENT PHONON-COUPLING MODEL

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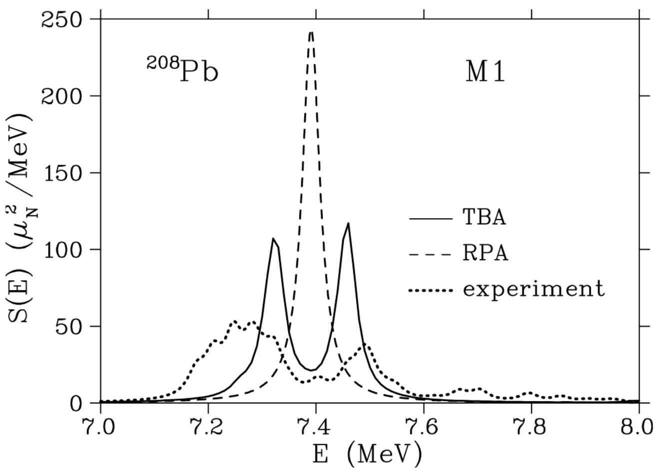
The theoretical description of nuclear magnetic excitations within self-consistent models is hampered by the fact that the parameters of the underlying energy-density functionals (EDF) are determined without accounting for magnetic properties which leaves the EDF's spin parameters uncertain. In a recent paper [1] we have explored low-lying M1 excitations in ^{208}Pb within a self-consistent random-phase approximation (RPA) based on a Skyrme EDF. By re-tuning the spin parameters we managed to reproduce the experimental key quantities: energy and the strength of the 1_1^+ state as well as mean energy and summed strength of the M1 resonance in ^{208}Pb in the interval 6.6-8.1 MeV.
However, the observed fragmentation of the M1 resonance and its total width are not described within the RPA. Here we have to go beyond RPA by proceeding to the self-consistent time blocking approximation (TBA) which includes particle-phonon coupling and which we use actually in its renormalized version [2]. The Skyrme EDF with the basis parametrization SKXm [3] was used both in the RPA and in the TBA. The spin-related EDF parameters x_W, W_0, g and g' were refitted as explained in [1]. The theoretical and "experimental" strength functions were obtained by folding the discrete spectra with a Lorentzian of half-width Δ = 20 keV. The results are shown in the figure. The TBA, in contrast to the RPA, reproduces the experimental splitting of the M1 resonance into two components separated by the dip near 7.4 MeV. But the total width of the resonance is still underestimated and the detailed fragmentation structure of the experimental curve is not quantitatively reproduced.



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INFLUENCE OF NEUTRON SHELLS ON SURFACE TENSION IN NUCLEI

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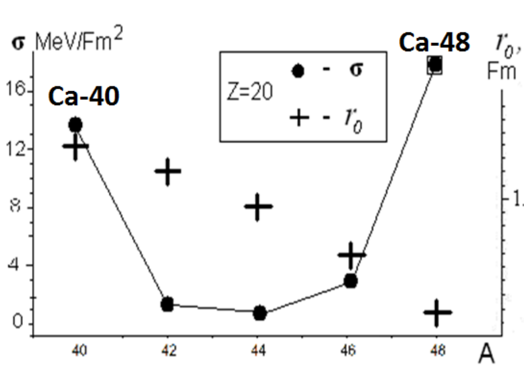
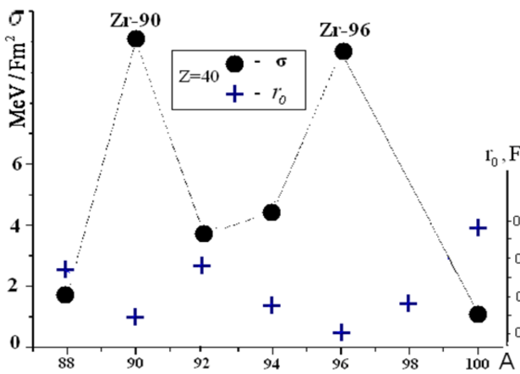
Estimation of the surface tension coefficients in the even-even nuclei could be performed due to connection of surface tension and nuclear rigidity [1]. The values of rigidities are connected with the mean squared deformations of nuclei [2]. The estimation of the surface tension coefficients in the even-even nuclei were presented in [3]. The coefficients σ show great fluctuations: from $\sigma \approx$ 1.0÷1.8 (for 150<A<198) up to $\sigma \approx$ 34 MeV/fm^2 (for ^{208}Pb, ^{210}Pb). The comparison of these values with the data on nuclear charge radii reveals the impact of the filled out neutron shell peculiarities on σ.

In the figures the calculated [3] surface tensions for Calcium and Zirconium isotopes together with the values of r_0 coefficients are shown. The surface tension in nuclei is highly influenced by the shell structure, especially of the neutron subshells near the surface: $(1d_{3/2})^4_n(1f_{7/2})^8_n$ for ^{48}Ca and $(1g_{9/2})^{10}(2d_{5/2})^6$ for ^{96}Zr . The highest σ corresponds as well to the highest values of pressure p (according to the Laplace formula $p \approx \frac{2\sigma}{R}$). It is obvious that filling out two near neutron subshells leads to grow of pressure on the proton component of the nuclei and, as consequence, to decreasing of the charge radii.

For ^{208}Pb and ^{210}Pb the surface tension is close to the maximum among all even-even nuclei ($\sigma \approx$ 34 MeV/fm^2). It is approximately $0.75 \cdot 10^{20}$ higher than σ for water at 20 °C.





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FORMATION OF HEAVY HELIUM ISOTOPE ^{9}He IN ^{11}B(π^-,pp)X REACTION

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The unbound heavy helium isotope ^{9}He was discovered in pion double charge exchange reaction ^{9}Be(π^-,π^+)^{9}He at E$_\pi$ = 194 MeV [1]. Despite a significant number of experiments performed to

date, the problem of the level structure of ^{9}He remains open [2, 3]. In particular, the energy and quantum numbers of the ground state are undefined. The studied range of excitation energies is limited to 5 MeV, while the parameters of states lying above 3 MeV do not agree in different works. In this situation, new experimental information is needed to resolve existing contradictions and discover new levels.
In this work a search for ^{9}He was performed in the reaction of stopped pion absorption ^{11}B(π^{-},pp)X. The experiment was taken at low energy pion channel of LANL with two-arm multilayer semiconductor spectrometer. In these measurements missing mass resolution was 1 MeV and error of absolute energy calibration did not exceed 0.1 MeV. These values were determined from measurements of the reaction ^{10}B(π^{-},pp)^{8}He carried out in the same experimental run. The studied excitation energy ranges up to about 50 MeV.
In these measurements we do not observed s-wave resonance just above threshold in ^{9}He. The lowest lying state in our measurements has the following resonant parameters: E_r =1.3(3) MeV and $\Gamma \leq$ 0.5 MeV, which are in agreement with a number of experiments [2, 3]. Highly excited state with E_r =10.5(2) MeV and Γ = 1.5(5) MeV has been observed for the first time.

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INVESTIGATING THE KAONIC ATOMS AND K^{-} NUCLEAR ABSORPTION AT LOW-ENERGY: SIDDHARTA-2 AND AMADEUS

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The SIDDHARTA-2 and AMADEUS collaborations aim to provide experimental information on the low-energy strong interaction between antikaons and nucleons. The investigation of the antikaons dynamics in nuclear medium is fundamental for understanding the non-perturbative QCD in the strangeness sector, with implications going from the domain of nuclear physics to astrophysics. The DAΦNE collider provides a unique source of monochromatic low-momentum kaons ($p_{\mathrm{K}} \sim 127$ MeV/c) from the ϕ-meson decay nearly at-rest, ideal to explore the interactions of the kaons at low-energy or to stop them in the targets. SIDDHARTA-2, which is the upgraded experiment of SIDDHARTA, studies the physics of kaonic atoms. The goal is to measure the X-rays emitted in the atomic transitions of the kaonic deuterium, the energy shift and the width of the 1s level will allow to extract for the first time the isospin dependence of the KbarN scattering amplitude at the energy threshold. AMADEUS explores the absorptions of the K^{-} in light nuclei (H, ^{4}He, ^{9}Be and ^{12}C) in order to extract information about the possible existence of kaonic bound states with nucleons and the properties of hyperon resonances in the nuclear environment. As a first step, the hadronic interactions of the negatively charged kaons with the materials of the KLOE detector, used as an active target, are investigated by reconstructing hyperon-nucleon/nuclei (YN) and hyperon-pion (Yπ) pairs emitted in the final state.

FINE STRUCTURE OF β-DECAY STRENGTH FUNCTION

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The β-decay strength function $S_\beta(E)$ governs [1,2] the nuclear energy E distribution of elementary charge-exchange excitations and their combinations like proton particle (πp)-neutron hole (νh) coupled into a spin-parity I^π: $[\pi p \otimes \nu h]I^\pi$ and neutron particle (νp)-proton hole (πh) coupled into a spin-parity I^π : $[\nu p \otimes \pi h]I^\pi$. The strength function of Fermi-type β-transitions takes into account excitations $[\pi p \otimes \nu h]0^+$ or $[\nu p \otimes \pi h]0^+$. Since isospin is a quite good quantum number, the strength of the Fermi-type transitions is concentrated in the region of the isobar-analogue resonance (IAR). The strength function for β-transitions of the Gamow–Teller (GT) type describes excitations $[\pi p \otimes \nu h]1^+$ or $[\nu p \otimes \pi h]1^+$. At excitation energies E smaller than Q_β (total β-decay energy), $S_\beta(E)$ determines the characters of the β-decay. For higher excitation energies that cannot be reached with the β-decay, $S_\beta(E)$ determines the charge exchange nuclear reaction cross sections, which depend on the nuclear matrix elements of the β-decay type.

Successful applications of the total absorption γ-spectroscopy ($TAGS$) for $S_\beta(E)$ resonance structure study, methods of $TAGS$ spectra interpretation, and results of analysis of $S_\beta(E)$ structure for the GT β^+/EC and GT β^--decays were summarized in [1]. Development of experimental technique allows application of methods of nuclear spectroscopy with high energy resolution for $S_\beta(E)$ fine structure measurement [2-4]. First results of the $S_\beta(E)$ fine structure study were summarized in [2]. The combination of the $TAGS$ with high resolution γ-spectroscopy may be applied for detailed decay schemes construction [2]. It was shown [2-5] that the high-resolution nuclear spectroscopy methods give conclusive evidence of the resonance structure of $S_\beta(E)$ for GT and first-forbidden (FF) β-transitions in spherical, deformed, and transition nuclei. High-resolution nuclear spectroscopy methods [2-4] made it possible to demonstrate experimentally the reveal splitting of the peak in the $S_\beta(E)$ for the GT β^+/EC-decay of the deformed nuclei into two components.

Resonance structure of the $S_\beta(E)$ for β-decay of halo nuclei was analyzed in [6-8]. It was shown that when the parent nucleus has *nn* Borromean halo structure, then after GT β^- - decay of parent state or after $M1$ γ-decay of IAR the states with *np* tango halo structure or mixed *np* tango + *nn* Borromean halo structure can be populated.

In this report the fine structure of $S_\beta(E)$ is analysed. Resonance structure of $S_\beta(E)$ for GT and FF β – decays, structure of $S_\beta(E)$ for halo nuclei, quenching of the weak axial-vector constant $g_A{}^{eff}$, and splitting of the peaks in $S_\beta(E)$ for deformed nuclei connected with the anisotropy of oscillations of proton holes against neutrons (peaks in $S_\beta(E)$ of GT β^+/EC–decay) or of protons against neutron holes (peaks in $S_\beta(E)$ of GT β^- – decay) are discussed.

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DEEP NEURAL NETWORKS AND THE PHENOMENOLOGY OF SUPER-HEAVY NUCLEI

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In recent years, several successful applications of the Artificial Neural Networks (ANNs) have emerged in nuclear physics, high-energy physics, and other fields of science. These works have already shown, that modeling of nuclear data with ANNs provides a valuable complementary approach to theory-driven models of the systematics of nuclear data (see e.g. [1] and references therein). A significant effort to exploit these novel methodologies is motivated by aspirations toward experimental and theoretical exploration of nuclei far from stability.
In our work we aimed at predicting the binding energies $\{B/A\}$, as well as the two-proton and two-neutron separation energies (S_{2p}, S_{2n}) of super-heavy nuclides, specifying only their proton and neutron numbers (Z, N) together with the numerical parity of the latter. Given a body of training data [2] the iRPROP (improved resilient backpropagation) and Adam (adaptive moment estimation) learning algorithms have been used to adjust the parameters of the deep ANN, determining (without any further theoretical assumptions) the mapping from the proton and neutron numbers to the properties of the nuclear ground state.
The predictive power of the neural network emerging from simulations done within the Keras+TensorFlow framework is compared with that of traditional phenomenological models. The obtained results show not only excellent learning performance of our network (with the MSE deviation between the ANN output and the 2498 experimentally known binding energies at the level of 70 eV), but are also very promising in predictions of various properties of both super-heavy nuclei as well as nuclei far from stability. It is found that the purely phenomenological models, based on deep ANNs can match or even surpass the predictive performance of conventional models for nuclear systematics (e.g. in grasping the existence of shell structure) and accordingly should provide a valuable additional tool for exploring the expanding nuclear landscape.

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Section 2. Experimental and theoretical studies of nuclear reactions

OBSERVATION OF THE 3.82 MeV STATE FROM THE ^{9}Be(d,d')^{9}Be REACTION AT E(d) = 23 MeV

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The experiment ^{9}Be(d,d')^{9}Be at E(d) = 23 MeV was carried out at the HI-13 tandem accelerator, China Institute of Atomic Energy (CIAE), Beijing. Two different method of detection were used: Q3D spectrometer at forward angles and strip detectors (ΔE-E) at medium and large angles. Following excited states are seen in experimental spectra: g.s, 2.43, 2.78, 3.05, 3.82, 4.7, 5.59, 6.38, 6.76 and 7.94 MeV. Existence of the 3.82 MeV state with Γ = 1240 keV, previously observed in [1], is confirmed. The analysis is in progress.

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EXPERIMENTAL INVESTIGATION OF THE (N, γF)–REACTION IN RESONANCE NEUTRON-INDUCED FISSION OF U-235

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The new experimental investigation of the (n,γf)-reaction, neutron-induced fission after preliminary emission of gamma-rays [1], have been done in neutron resonances of U-235 in the energy range from thermal to 300 eV. The measurements of fission gamma-ray and prompt neutron multiplicities as well as energy spectra of fission gamma-rays in separated neutron resonances were carried out at the neutron time-of-flight spectrometer GNEIS based on the SC-1000 proton synchrocyclotron used as a "spallation" neutron source [2]. Fission gamma-rays and neutrons were detected in coincidence with fission fragments registered by means of the fast parallel-plate ionization chamber which contained 1.8g of 90% enriched U-235. Two large NaI(Tl) scintillation detectors d150 x h100 mm^2 of size were used for registration of gamma-rays, while a couple of medium-sized d50 x h50 mm^2 stilbene scintillators were used for registration of prompt fission neutrons by applying a pulse-shape discrimination to separate gamma-rays and neutrons. The signals from all detectors were processed using 8-bit Acqiris DC-270 and 14-bit CAEN V1274 digitizers, which provided 1E6 time channels (2 – 10 ns width) with a practically "zero" dead time.
The correlations observed between the fission gamma-ray as well as prompt neutron multiplicities and reciprocal fission widths in the isolated 3- and 4- resonances of U-235 have been analyzed to subtract the pre-fission widths. The values obtained from the experiment were compared with those calculated using various theoretical models adopted for description of the radiation strength

function, shape of the fission barriers and transition states structure. Taking into account the data obtained from the analysis of measured pre-fission gamma-ray spectra, the conclusions about the nature of gamma transitions between the highly exited states in the compound nucleus U-236 were inferred.

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NEW RESULTS OF THE INVESTIGATION OF THE ANGULAR DISTRIBUTION OF FRAGMENTS IN NEUTRON-INDUCED FISSION AT ENERGIES UP TO 200 MEV

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Angular distributions of fragments from the neutron-induced fission have been measured for a number of heavy target-nuclei in the energy range 1-200 MeV at the neutron time-of-flight spectrometer GNEIS [1] based on the 1-GeV proton synchrocyclotron of the NRC "Kurchatov Institute" - PNPI (Gatchina). As a result, the anisotropy of fission fragments W(0)/W(90) deduced from the experimental data on angular distributions for ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{237}Np, natPb and ^{209}Bi [2-6] have been presented and discussed.

Recently, the measurements have been carried out for the neutron-induced fission of ^{240}Pu. Main features of the experiment and first results are presented in this work. In the neutron energy range above 20 MeV. the energy dependence of the anisotropy of fission fragments was obtained for the first time. In lower neutron energy range the comparison with the results of other authors is performed and demonstrates a general agreement between them. However, unlike data given in literature, our data are obtained in a wide neutron energy range, from the reaction threshold up to the energy of second-chance fission that gives the possibility to perform theoretical description of the angular distribution of fission fragments and to obtain new information about the fission of ^{240}Pu. This analysis is presented in the other report.

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RECENT RELATIVISTIC FADDEEV CALCULATIONS OF POLARIZATION OBSERVABLES FOR ELASTIC PD SCATTERING WITH KHARKOV POTENTIAL

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We have extended applications [1] of unitary clothing transformations (UCTs) [2,3] in quantum field theory. Such transformations connect the representation of "bare" particles (BPR) and the representation of "clothed" particles (CPR), i.e., the particles with physical properties. The Kharkov potential is a recent field theoretical model of nucleon-nucleon (NN) interaction that has built up in the framework of the instant form of relativistic dynamics starting with the total Hamiltonian of interacting meson and nucleon fields in the CPR. Unlike many available NN potentials each of which is the kernel of the corresponding nonrelativistic Lippmann-Schwinger (LS) equation this potential being dependent in momentum space on the Feynman-like propagators and covariant cutoff factors at the meson-nucleon vertices is the kernel of relativistic integral equations for the NN bound and scattering states. As in Ref. [4] we have employed a transition from the relativistic Lippmann-Schwinger (LS) equation for the two-body t-matrices to the so-called boosted LS one. The theoretical predictions based on the Kharkov and CDBonn potentials are compared to recent precise data for the analyzing powers iT_{11}, T_{20}, T_{21} and T_{22} in the pd scattering. Special attention has paid to finding from the contemporary n-p phase shift analysis [5] reliable optimum values of the adjustable parameters involved in the covariant meson-nucleon cutoff functions in momentum space.

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MECHANISM OF THE ^{11}B(α, T)^{12}C REACTION AT AN ENERGY OF 40 MEV

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The experiment was performed on a α-particle beam extracted from the isochronous cyclotron U-150M of the Institute of Nuclear Physics (Almaty, Kazakhstan).
The differential cross sections of tritons from the ^{11}B (α, t) reaction with transitions to the ground (0+) and to excited states of the ^{12}C nucleus at Ex = 4.44 MeV (2+), 7.65 MeV (0+), 9.64 MeV (3-) and 14.08 MeV (4+) MeV have been measured at the beam energy of 40 MeV. A typical energy spectrum of tritons is shown in Fig. 1. Analysis of the measured angular distributions was carried out in the framework of the coupled reaction channels method [1] with considering the contribution of the ^{8}Be cluster exchange mechanism. It is shown that the direct mechanism with proton transfer dominates at energy of 40 MeV, and the heavy particle transfer is noticeable only at large angles. An exception is the transition to the 14.08 MeV (4+) state, which is possible

only by the transfer of the ^{8}Be cluster. It is established that the couplings between the excited states of ^{12}C, arising from the non-sphericity of the nucleus, have little effect on the (α, t) reaction cross sections in the forward hemisphere, but strongly affect the cross sections at large angles.

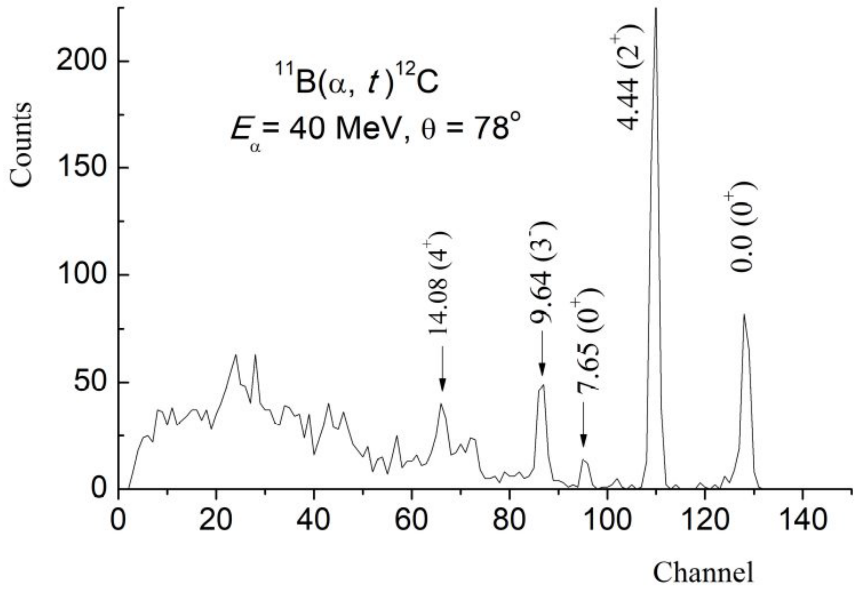

Figure 1: The energy spectrum of the tritons from the reaction (α, t) on the 11B nuclei measured at 78° at the beam energy of 40 MeV.

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RANGES OF RADON AND MERCURY ISOTOPES WITH ENERGIES OF 0.12-0.25 MEV/AMU IN ALUMINUM

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The ranges in aluminum of radon and mercury isotopes, produced in *xn*-evaporation channels of the complete fusion reactions ^{40}Ar+^{144}Sm, ^{36}Ar+^{148}Sm, ^{40}Ca+^{144}Nd, ^{48}Ca+^{142}Nd and ^{40}Ar+^{166}Er, have been measured in energy range of $0.12 - 0.25$ MeV/amu. The energies of the primary beams, delivered by the cyclotron U-400M, were measured by the time-of-flight method with an accuracy of 0.5% (FWHM). The evaporation residua energies and their energy spreads were calculated proposing consecutive neutron evaporation cascades from the compound nuclei produced at some depths in the target. The beam interruption method was applied for the isotope identification. Five thin aluminum absorbers were installed on a linear pneumatic actuator. In the accumulation mode, the foils were placed one under another, so that the reaction products were stopped at different depths in the proper foils. In the measurement mode, the foil array was extended to its full width so that each foil was placed opposite to the corresponding silicon detectors registered α-decays of short-lived

radon and mercury isotopes. The measured ranges have been compared with the predictions of SRIM code.

MECHANISMS OF THE T-ODD ASYMMETRIES FORMATION IN REACTIONS OF TERNARY FISSION OF NUCLEI BY COLD POLARIZED NEUTRONS WITH THE EMISSION OF ALPHA PARTICLES

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It was proved [1] that P-even T-odd asymmetry in differential cross sections of nuclear ternary fission reactions by cold polarized neutrons with the flight of α-particles can be represented in common case through the sum of triple $\sigma_3(\Omega) = A_3(\theta)(\sigma_n[\mathbf{p}_{LF}, \mathbf{p}_\alpha])$ and quinary $\sigma_5(\Omega) = A_5(\theta)(\sigma_n[\mathbf{p}_{LF}, \mathbf{p}_\alpha])(\mathbf{p}_{LF}, \mathbf{p}_\alpha)$ scalar correlators, depending from spin σ_n of polarized neutron, oriented along the axis Y, momentum of light fission fragment $\mathbf{p}_{LF}$, oriented along the axis Z, and momentum of α–particle $\mathbf{p}_\alpha$ emitted in solid angle $\Omega(\theta, \varphi)$). Coefficients A_3 and A_5 are connected with sums of quantities $(\mathbf{p}_{LF}, \mathbf{p}_\alpha)^n = \cos^n(\theta)$ with even values *n*. For the case of α-particle emission in plane (Z,X) when $\varphi = 0$, this correlators are presented as $\sigma_3(\theta) \sim \sin\theta$ and $\sigma_5(\theta) \sim \sin\theta\cos\theta$ and satisfy the symmetry condition: $\sigma_3(\theta) = \sigma_3(\pi - \theta), \sigma_5(\theta) = -\sigma_5(\pi - \theta)$. Then investigated correlators can be expressed through the coefficient of researched above asymmetry [2]: $D(\theta) = [\sigma_3(\theta) + \sigma_5(\theta)]/\sigma_0(\theta)$, where $\sigma_0(\theta)$ is the differential cross section of analogous reaction with cold polarized neutrons, as $\sigma_{3,5}(\theta) = 1/2\ [D(\theta)\sigma_0(\theta) \pm D(\pi - \theta)\sigma_0(\pi - \theta)]$ (1). Using experimental values $D^{exp}(\theta)$ and $\sigma_0^{exp}(\theta)$ for target nuclei ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu [2], the values of triple $\sigma_3^{exp}(\theta)$ and quinary $\sigma_5^{exp}(\theta)$ correlations were calculated. Taking into account the mechanism of the T-odd asymmetries formation, due to the influence of quantum rotation of the compound fissile system around an axis perpendicular to its symmetry axis on the angular distribution of fission fragments and α–particles, these correlators can be represented as $\sigma_3^{th}(\theta) = \Delta_3\left(d\sigma_{odd}^0(\theta)/d\theta\right)$, $\sigma_5^{th}(\theta) = \Delta_5\left(d\sigma_{ev}^0(\theta)/d\theta\right)$(2), where σ_{ev}^0 and σ_{odd}^0 are the components [1] of the differential cross section $\sigma_0(\theta)$, connected accordingly with even and odd orbital moments of α-particles, and Δ_3, Δ_5 are the effective rotation angles of $\mathbf{p}_\alpha$ relative to $\mathbf{p}_{LF}$. A comparison of the correlations from formulae (1), (2) allows to find the values of the angles Δ_3, Δ_5 by the χ^2-method, and using them to calculate the correlators σ_3^{th} and σ_5^{th}. The calculated angles Δ_3 are comparable with the angles obtained in the classical approach [2] and have a positive sign for all nuclei. At the same time, it is possible to achieve acceptable agreement between the correlators for ^{235}U, ^{239}Pu and ^{241}Pu, however, these correlators are very different from each other for ^{233}U. A reasonable agreement of $\sigma_5^{th}(\theta)$ and $\sigma_5(\theta)$ is observed for all nuclei, but the sign of Δ_5 is positive and coincides with Δ that is calculated in the framework of the classical approach [2], but when switching from ^{235}U, ^{239}Pu and ^{241}Pu to ^{233}U, the sign changes.The differences obtained above for the classical and quantum approaches of the studied T-odd asymmetries can be used in the analysis of the reliability of these approaches.

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THE QUATERNARY FISSION AS A VIRTUAL PROCESS

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In experimental papers [1, 2] the yields, angular and energy distributions of the pairs of light third and fourth particles formed with the highest probability, such as α-particles pair (α_1, α_2), were obtained for the spontaneous quaternary fission of the nucleus ^{252}Cf. Using the theoretical concepts [3-5] of ternary and quaternary fission as virtual processes [6], we consider spontaneous quaternary fission from the ground states of even-even actinides [1,2] with the sequential emission of two α-particles from the virtual states of nuclei A and $(A-4)$ and the subsequent binary fission of the residual fissile nucleus $(A-8)$ into light and heavy fission fragments. These α-particles, in contrast to the α-particles that fly out in the sub-barrier α-decay of the studied nuclei A and $(A-4)$, when the energies $Q^A_{\alpha_1}$ and $Q^{(A-4)}_{\alpha_2}$ of this decays are close to 6 MeV, are long-range, since their asymptotic kinetic energies $T_{\alpha_1} \approx 16$ MeV and $T_{\alpha_2} \approx 13$ MeV, are markedly larger than energy values $Q^A_{\alpha_1}$ and $Q^{(A-4)}_{\alpha_2}$. Using the formula [4] for the width $\Gamma^A_{\alpha_1\alpha_2 f}$ of the virtual quaternary fission of nucleus A, formulae for the widths $\Gamma^A_{\alpha_1}(T_{\alpha_1})$ and $\Gamma^{(A-4)}_{\alpha_2}(T_{\alpha_2})$ for α-decays of nuclei A and $(A-4)$ are constructed:
$\Gamma^A_{\alpha_1}(T_{\alpha_1}) = 2\pi W_{\alpha_1}(T_{\alpha_1})(Q_{\alpha_1} - T_{\alpha_1})^2; \Gamma^{(A-4)}_{\alpha_2}(T_{\alpha_2}) = 2\pi W_{\alpha_2}(T_{\alpha_2})(Q_{\alpha_2} - T_{\alpha_2})^2;$
where $W_{\alpha_1}(T_{\alpha_1})$ and $W_{\alpha_2}(T_{\alpha_2})$ are the energy distributions of the first and second α-particles, normalized by the ratio of the widths of these α-particles emission to the width of the binary fission of the nuclei A and $(A-4)$. The widths $\Gamma^A_{\alpha_1}$ and $\Gamma^{A-4}_{\alpha_2}$ take into account the fact that the emitting α-particles are formed in such configurations of the fissile nuclei A and $(A-4)$ that occur during their deformation motion from the ground states through the internal and external fission barriers and reach a pear-shaped forms corresponding to the appearance of two deformed fission prefragments connected by a neck. If we consider the ratio $\Gamma^A_{\alpha_1}/\Gamma^{(A-4)}_{\alpha_2} = \sqrt{T_{\alpha_1}}P_1(T_{\alpha_1})/\sqrt{T_{\alpha_2}}P_2(T_{\alpha_2})$ and take into account the fact that the probabilities of formation of the α_1 and α_2 particles are close to each other, and the radii of the neck of the nucleus r_A before the emission of α_1-particle does not differ much from the radius of the neck r_{A-4} before the emission of the α_2-particle, one can get the ratio of the Coulomb barrier penetrabilities $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ for the first and second α-particles. Using the experimental values of the kinetic energies T_{α_1} and T_{α_2} and maximum values of energy distributions $W_{\alpha_1}(T_{\alpha_1})$ and $W_{\alpha_2}(T_{\alpha_2})$, the specified estimation of $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ is 0.03 for spontaneous quaternary fission of ^{252}Cf. This estimation $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ demonstrates that the virtual decay of nucleus $(A-4)$ with α_2 particle flight has subbarrier character in contrast to the virtual decay of nucleus A with α_1 particle flight.

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A STUDY OF REACTIONS WITH THE EMISSION OF CHARGED PARTICLES AT EMAX = 55 MEV ON NATURAL TANTALUM AND TUNGSTEN TARGETS

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A research of the cross-sections and level filling yields of high-spin isomeric states in reactions with the emission of charged particles allows one to obtain diverse information both about the structure of excited levels in the continuous and discrete regions of excitation and about the mechanisms of nuclear reactions. Therefore, the aim of our work is to study the production yields of ^{178m}Ta, ^{180m}Hf, and ^{182m}Hf isomers in reactions with bremsstrahlung with energies exceeding the giant dipole resonance energy.
The weighted average yields were measured by the activation method using bremsstrahlung of electrons with a 55 MeV maximum energy and natural tantalum and tungsten targets.
The spectra of irradiated targets were measured by Canberra and Ortec gamma spectrometers with ultra-pure semiconductor detectors with a (15–40)% detection efficiency compared to a 3′×3″ NaI(Tl) detector. The energy resolution of the spectrometers was 1.8–2.0 keV on the 1332 keV ^{60}Co γ-line.
In the studied spectra, γ transitions from the decay of ^{178m,g}Ta, ^{180m}Hf, ^{182m}Hf, and ^{185}Ta are reliably identified.
For the first time, the weighted average filling level yields of ^{182m}Hf in the ^{186}W(γ, α)^{182m}Hf-reaction and of ^{180m}Hf in the ^{184}W(γ, α)^{180m}Hf-reaction were measured at a 55 MeV maximum energy of bremsstrahlung gamma quanta.
The bremsstrahlung simulation was carried out with the Geant4 software code.
The following weighted average yields were obtained: for ^{181}Ta(γ, 3n)^{178g}Ta-reaction – 1.6(1) mbn, for ^{181}Ta(γ, 3n)^{178m}Ta-reaction – 420(25) mbn, for ^{186}W(γ, α)^{182m}Hf-reaction – 3.5(8) μbn, for ^{184}W(γ, α)^{180m}Hf reaction – 3.6(2) μbn, for ^{181}Ta(γ, p)^{180m}Hf reaction – 36(4) μbn and for ^{186}W(γ, p)^{185}Ta- reaction – 660(30) μbn. With such energy of bremsstrahlung, the isomeric yield ratio for the reaction ^{181}Ta(γ, 3n)^{178m,g}Ta is Y_m/Y_g = 0.26(3). It was measured for the first time.
According to the modeling results, within the TALYS-1.9 and EMPIRE-3.2 program codes, non-statistical processes dominate.
A discussion of the findings is ongoing.

THEORETICAL DESCRIPTION OF FRAGMENT ANGULAR ANISOTROPY IN NEUTRON-INDUCED FISSION OF EVEN-EVEN NUCLEI ^{232}Th, ^{238}U, ^{240}Pu AT ENERGIES UP TO 200 MeV

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During the past few years, we have measured the angular distributions of fragments in neutron-induced fission of a number of isotopes at energies of 1–200 MeV. The studies were performed at the NRC "Kurchatov Institute" – PNPI using a TOF neutron spectrometer GNEIS at the 1 GeV proton synchrocyclotron (see [1] and references therein). Now we are adding to previously studied nuclei ^{209}Bi, Pb (nat), ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu (see [2] and references therein) the isotope ^{240}Pu. For energies above 20 MeV, the results are obtained for the first time, their analysis is presented in a separate report. In the region of intermediate energies exceeding 20 MeV, similar data on the angular anisotropy of fission fragments of ^{232}Th, ^{235}U, ^{238}U nuclei were also obtained in [3-6].

We developed a method for theoretical description of the angular distribution of fragments as function of the energy of incident neutrons. Our approach is based on the use of the modified TALYS program [7] and is applicable in a wide range of energies, including the interval of 1–200 MeV. In [2] the results of calculations were presented for the ^{237}Np (n,f) reaction. It was shown that even with the use of some simplifying assumptions; the method correctly describes the gross structure of the energy dependence of the angular anisotropy of fission fragments.

In this work, we apply our method to the theoretical description of the angular anisotropy of fission fragments of even-even nuclei ^{232}Th, ^{238}U, ^{240}Pu by low and intermediate-energy neutrons. The first two isotopes are of particular interest. First, in the intermediate energy region, we use not only our data, but also the results of other authors [3-5]. Secondly, just for ^{232}Th and ^{238}U, only an estimate [3] of the energy dependence of angular anisotropy above 20 MeV was previously performed. Generally, our results confirm that data on the angular anisotropy of fission fragments are a valuable source of information on both the transition states at the barriers and the role of pre-equilibrium processes.

This work was partially supported by the Russian Foundation for Basic Research (Grant No. 18-02-00571).

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STUDY OF TA-178M AND HF-180M IN REACTIONS WITH RELEASED CHARGED PARTICLES

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A study of the cross-sections and level filling yields of high-spin isomeric states provides information about the structure of excited levels in the continuous and discrete regions of excitation, as well as about the mechanisms of nuclear reactions. Therefore, the aim of our work is to study the ^{178m}Ta and ^{180m}Hf yields in reactions with bremsstrahlung with energies ranged in the giant dipole resonance energy region.

The study of the weighted average yields was carried out by the activation method using a bremsstrahlung γ-beam of electrons with a 20 MeV maximum energy and natural tantalum targets. The spectra of irradiated targets were measured by Canberra and Ortec gamma spectrometers with ultra-pure semiconductor detectors with a (15–40)% detection efficiency compared to a 3′×3″ NaI(Tl)

detector. The energy resolution of the spectrometers was 1.8–2.0 keV on the 1332 keV ^{60}Co γ-line. The gamma transitions from the decay of ^{178m}Ta and ^{180m}Hf are reliably identified in the spectra. The bremsstrahlung simulation was carried out with the Geant4 software code.
For the first time, the weighted average level filling yield of ^{178m}Ta in the ^{180}Ta(γ, $2n$)^{178m}Ta-reaction and the weighted average level filling yield of ^{180m}Hf in the ^{181}Ta(γ, p)^{180m}Hf-reaction at a 20 MeV bremsstrahlung maximum energy were obtained. For ^{180}Ta(γ, $2n$)^{178m}Ta-reaction weighted average yield is equal 48(5) mbn and for ^{181}Ta(γ, p)^{180m}Hf-reaction weighted average yield is equal 60(4) mbn.
According to the simulation results, within the TALYS-1.9 and EMPIRE-3.2 program codes, the dominance of non-statistical processes is established. The theoretical integral cross sections are significantly lower than the experimental values.
A discussion of the findings is ongoing.

B-10 (γ, T)-REACTION STUDY

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Currently, the most studied are (γ, n)- and (γ, γ')-reactions. Reactions with the release of charged particles, especially for light nuclei, are much less studied. The main reason for this is the lower cross-sections of these channels in comparison with the (γ, n)-reactions due to the Coulomb barrier. At the same time, the study of photonuclear reactions with the release of charged particles is of considerable interest in connection with the excitation of other states, often inaccessible for the (γ, n) channel. In addition, for such reactions, we can expect a significant contribution of direct and semi-direct processes.
The weighted average yield for the ^{10}B(γ, t)-reaction was obtained by the activation method using a bremsstrahlung γ-beam of electrons with E_{max} = 20 MeV and natural boron targets. The duration of irradiation of natural boron and the tantalum monitor targets was 40 minutes.
The spectra of irradiated targets were measured by Canberra and Ortec gamma spectrometers with ultra-pure semiconductor detectors with a (15-40)% detection efficiency compared to a 3′×3″ NaI(Tl) detector. The energy resolution of the spectrometers was 1.8–2.0 keV on the 1332 keV ^{60}Co γ-line. Gamma transitions from ^{7}Be decay are reliably identified in the studied spectra.
The bremsstrahlung spectrum was simulated using the Geant4 software code.
For the first time, the weighted average yield of ^{10}B equal to 7(2) μbn in the ^{10}B(γ, t)^{7}Be-reaction was obtained at a 20 MeV maximum energy of bremsstrahlung γ-quanta, while the reaction threshold is 18.7 MeV.
According to the modeling results, within the TALYS-1.9 and EMPIRE-3.2 program codes, non-statistical processes dominate.
A discussion of the findings is ongoing.

ALPHA CLUSTER STRUCTURE IN ^{19}F

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The nucleosynthesis of 19F was investigated over the past several years [1]. The synthesis of fluorine occurs by ^{14}N(α,γ)^{18}F(β+)^{18}O(p, α)^{15}N(α,γ)^{19}F reaction chain in the asymptotic giant branch

stars [1-2]. For that reason, the studies of the abundance of 19F can be useful as a probe of stellar nucleosynthesis [1,3].

Several experimental groups also have been studied the properties of levels in 19F nuclei [1,4,5]. The aim of these studies was the knowledge of cluster structure in N>Z nuclei. Still, the information on the alpha cluster structure of 19F is scarce because of the experimental difficulties of the studies of elastic scattering of alpha particles at a gas target at low energy in the backward hemisphere [4].

We made the measurements of the 15N+α elastic scattering using the Thick Target Inverse Kinematic [6] method in a broad angular range including 180 degrees in c.m.s. at heavy ion accelerator DC-60 [7-8] (Nur-Sultan, Kazakhstan) and analyzed the available experimental data using R-matrix formalism [9]. This study presents a comprehensive analysis of the experimental data and reveals an interesting relation between level structure in 19F and 20Ne.

Fig.1. demonstrates the quality of the new fit for θc.m. = 149.5 [4] in the energy range 2.0-4.4 MeV.

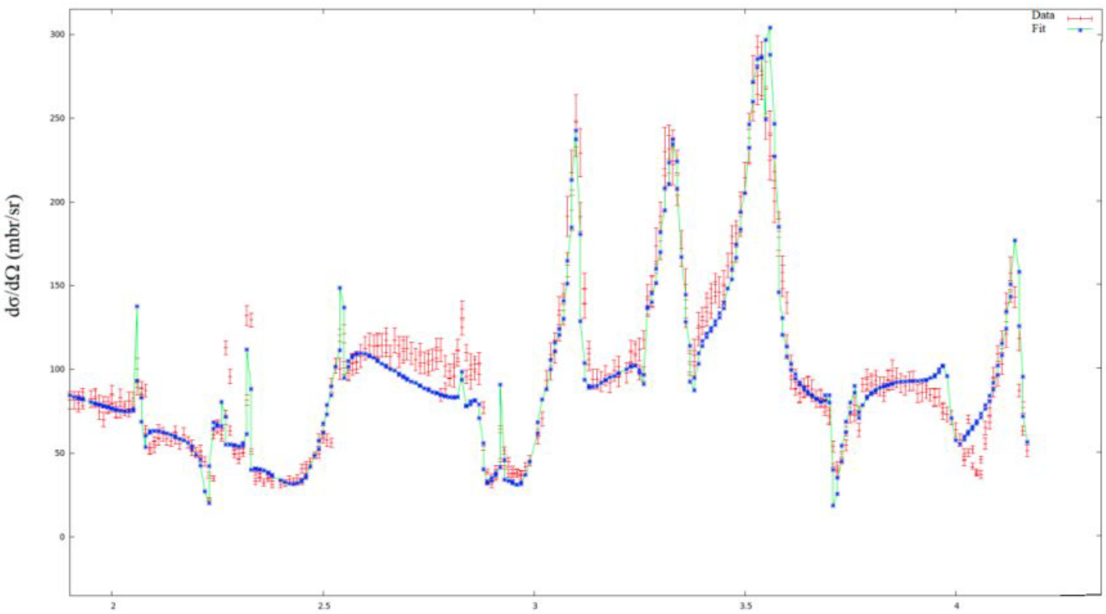

Figure 1: The excitation function for the 15N(α, α)15N elastic scattering. The blue points are the R-matrix fit.

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POSSIBLE HALO STATES IN ^{12}N

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Experiment was done by our group on ^{12}C(^{3}He,t)^{12}N reaction. The measurements were conducted at the University of Jyväskylä (Finland) using the K130 cyclotron to produce a ^{3}He beam at E(^{3}He)=40 MeV. The 150 cm diameter Large Scattering Chamber was equipped with three ΔE-E detector telescopes, each containing two independent ΔE detectors and one common E detector. So each device allowed carrying out measurements at two angles. The differential cross sections of the (^{3}He,t) reaction on ^{12}C were measured in the c.m. angular range 8°–70°. Self-supported ^{12}C foils of 0.23 and 0.5 mg/cm^{2} thicknesses were used as targets. It should be mentioned that, before starting measurements, beam monochromatization was done [1], which made it possible to diminish beam energy spreading up to three times and obtain a total energy resolution about 140 keV. Triton angular distributions for the g.s. and three first excited states of ^{12}N: 0.96-MeV 2^{+}, 1.19-MeV 2^{-}, and 1.80-MeV 1^{-} were measured. Modified Diffraction Model (MDM) analysis [2] of (^{3}He,t) experimental data was done. Enhanced rms radii were obtained for the 2^{-} (1.19-MeV) and 1^{-} (1.80-MeV) states of ^{12}N. It can be an argument for existence of halo in these states.

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^{6}Li(d,xt) REACTION TOTAL CROSS SECTION MEASUREMENTS BY SECONDARY ACTIVATION METHOD

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^{6}Li(d,xt) reaction total cross sections were measured at electrostatic tandem accelerator EGP-10 (RFNC-VNIIEF) at 2.5-12 MeV deuteron energy (fig.1). Secondary activation method proposed by B.Ya. Guzhovskii was used. Cross section was determined by registration of 18F collected yield from ^{16}O(t,n)18F reaction (β+, T1/2=109 min.) produced by ^{6}Li(d,xt) tritons in three quartz tubes situated along deuteron beam direction. 4π-geometry registration was achieved. Li(3)N targets at 250-400 mu-g•cm^2 thickness with different lithium isotope composition (^{6}Li - 91.2% and ^{7}Li - 8.8%, ^{7}Li - 99.5% and ^{6}Li 0.5%) on thin (10-15 mu-g•cm^2) hydrocarbon (C(8)H(8)) backings were used. ^{16}O(t,n)18F and 17O(d,n)18F reaction yields from thick quarz disks were measured for implementation of the method. The obtaining of the results was possible after our 6,^{7}Li+d reaction spectral measurements have been performed [1]. ^{6}Li(d,xt) reaction cross section measured by different methods are presented in fig. 1. for comparison.

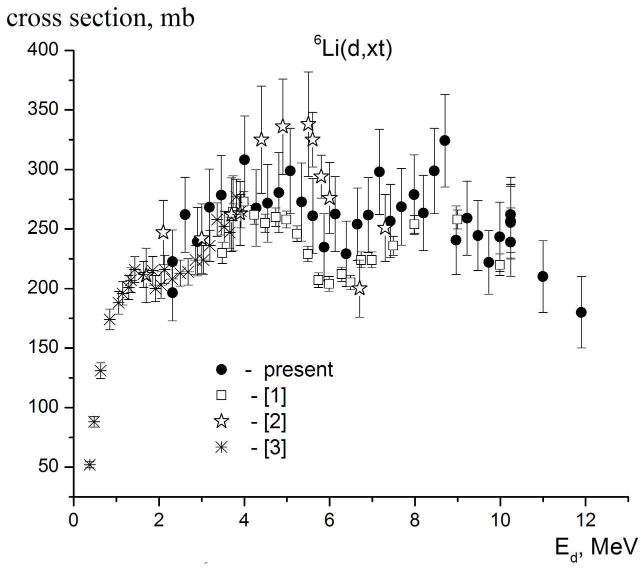

Figure 1: ^{6}Li(d,xt) reaction total cross section.

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OPTICAL-MODEL ANALYSIS OF PROTON ELASTIC SCATTERING ON ^{6,7}Li AND ^{9}Be NUCLEI WITH RESONANCE PART

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Performed an optical-model analysis (description) of proton elastic scattering at 50 keV to 200 MeV proton energy Ep on 6,7Li and ^{9}Be nuclei. There was used an optical-model code OptModel (developed at RFNC-VNIIEF) where resonance part of elastic scattering was taken into account. Energy dependences of optical potential parameters from [2] with our modifications were used. All obtainable data on differential and total cross sections and polarization were analyzed simultaneously. Evaluated data from ENDF/B-VII, SaBa [3] were used as well as experimental ones. The interruption of the scattering matrix unitarity was observed at several energetic points and was no more than 7%. Energy dependences of volume real potential radius rV, diffuseness aV and amplitude VV of ^{6}Li+p reaction are shown in fig. 1 (a-c). ^{6}Li+p and ^{9}Be+p reaction total cross sections are demonstrated in fig. 2,3.

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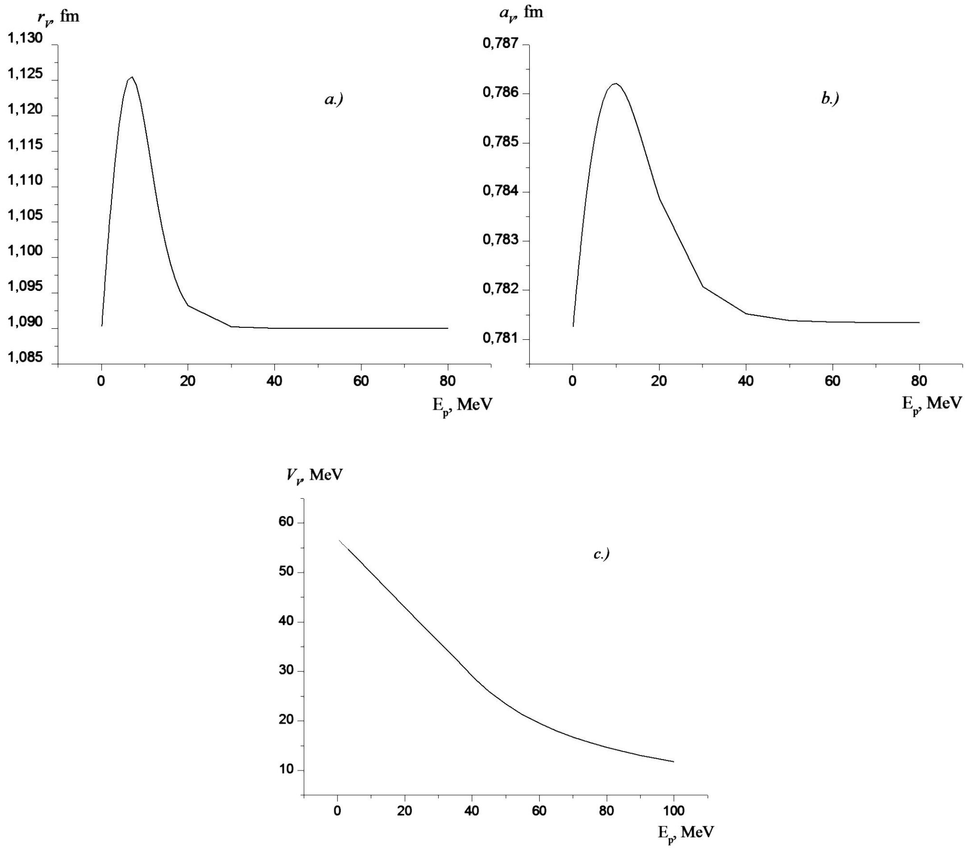

Figure 1: Energy dependences of volume real potential radius r_V (a), diffuseness a_V (b), and amplitude $V_V(c)$ of ^{6}Li + p reaction

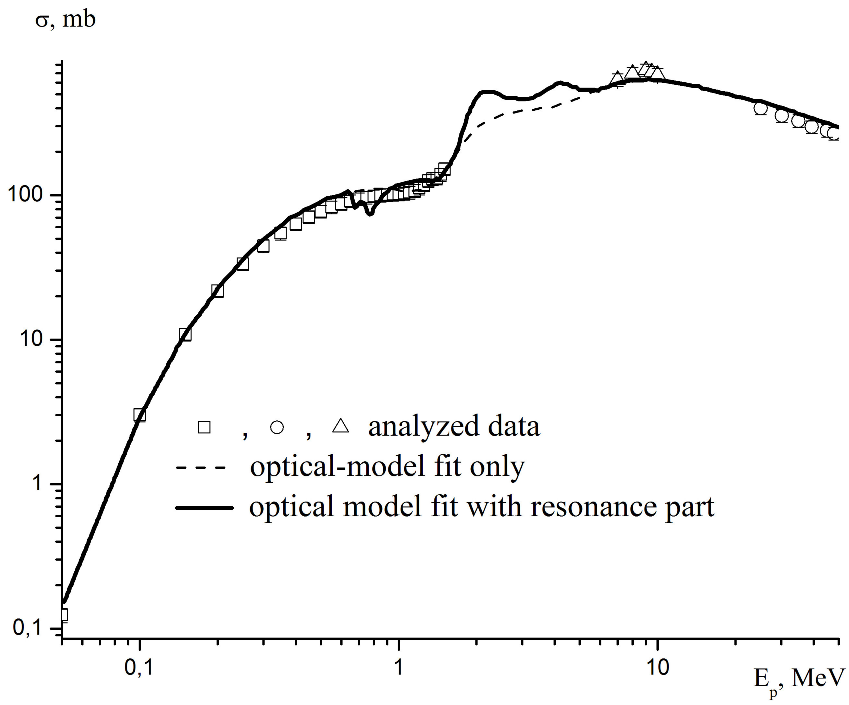

Figure 2: ^{6}Li + p reaction total cross section

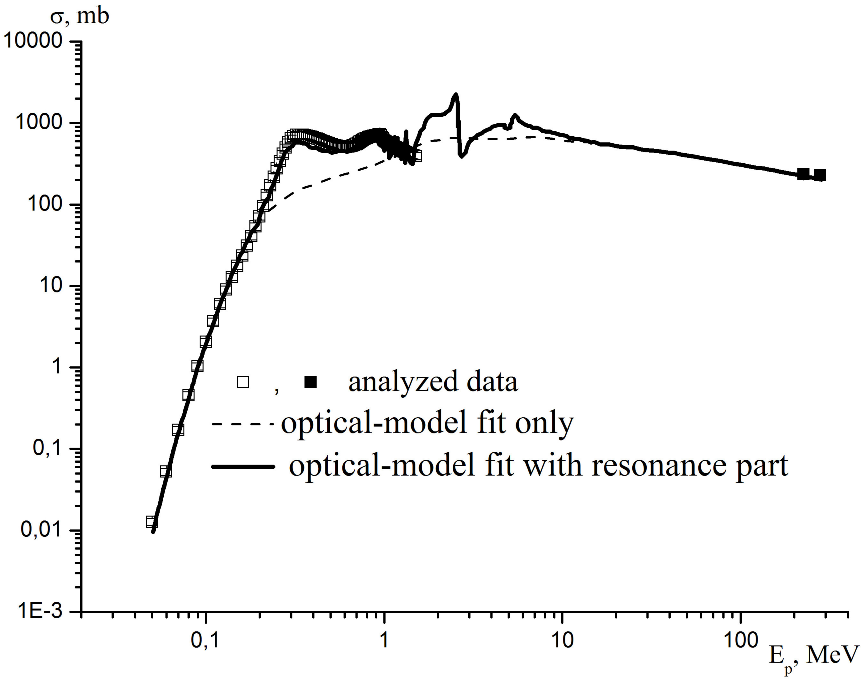

Figure 3: ^{9}Be + p reaction total cross section

A POSSIBILITY OF DETERMINING CLUSTER STRUCTURE OF ^{6}Li EXCITED STATES IN INELASTIC SCATTERING OF α-PARTICLES

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The study of the cluster structure of light nuclei is one of the fundamental problems of nuclear physics. The cluster structure of ^{6}Li nucleus was a subject of many experimental and theoretical studies, for example [1-3]. The cluster configurations of ^{6}Li excited states can be either two-cluster (^{4}He + d, ^{5}He + p, ^{5}Li + n, ^{3}He + t), or three-cluster (^{4}He + p + n) ones.
To determine the contribution of various configurations to the structure of excited states, we propose the study of inelastic scattering of α-particles on the ^{6}Li nucleus, provided that the scattered α-particle coincides with the particle from the breakup of the excited state. Kinematical simulation of this reaction was performed at $E_\alpha = 30$ MeV for various excited states of ^{6}Li nucleus. The simulation results show that registration of the scattered α-particle in coincidence with various particles (n, p, t, α) from the breakup of excited ^{6}Li states will allow us to determine the cluster structure of these states.

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STUDY OF HADRON SCATTERING ON BORON ISOTOPES WITHIN THE GLAUBER THEORY

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Hadron scattering on light nuclei at intermediate energies is a good test of investigation of both the structure of nuclei and the mechanisms of interaction. From the scattering of various hadrons, both experimentally and theoretically, proton scattering has been studied in more detail. At the same time, the study of the scattering of other particles, for example, mesons with the same kinematics, in the same nuclei, provides additional interesting information. In the same approach, we previously studied carbon and nitrogen nuclei [1].
In this work, we study the scattering of π±- and K+-mesons at intermediate energies at 9,10B nuclei in the framework of Glauber's theory. In our calculations, we used the wave function of the ^{9}B nucleus in the 2αN-model [2], calculated with paired α α- and αN-interactions with states forbidden by the Pauli principle. In calculating the wave function, two versions of the α α interaction were used: the l-dependent α α-Ali-Bodmer potential and the deep attractive α α-potential of Buck. In both models, the αN potential with the exchange Majorana component was chosen, which leads to even-odd splitting of the phase shifts, which reproduces phases well with l = 0, 1, and 2.
To describe the state of the ^{10}B nucleus, the wave function was used in the model of shells with an intermediate coupling [3] with the following components: – 0.418 [42] 13D1 + 0.679 [42] 13D2 – 0.481 [42] 13F .
The reaction matrix element is calculated based on the Glauber diffraction theory of multiple scattering. The Glauber operator takes into account all the multiplicities of collisions on α particles and a proton on the ^{9}B nucleus and one- and two-fold collisions on the ^{10}B nucleus. The differential cross section on the ^{9}B nucleus was calculated with two variants of the wave function and it was shown how sensitive the cross section to the structure of the nucleus.
Differential scattering cross sections of π±- and K+-mesons were calculated at several energies: 135, 180, and 220 MeV. The choice of data for the energy value is related to comparing our calculations with the available calculations and experimental data on proton scattering on the same nuclei.
This work was carried out as part of the scientific project AP05132620.

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MEASUREMENTS OF THE γ RAY EMISSION CROSS-SECTIONS IN Fe($n, x\gamma$)-TYPE REACTIONS

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Iron-based alloys are important construction materials which are widely used in science and industry. Information about cross-sections of different nuclear reactions on iron is needed to accurate modeling of different nuclear facilities, elemental analysis and other applications. From theoretical point of view, experimental cross-sections are needed to ajust optical potentials for incoming and outgoing particles.
Measurements of the γ ray emission cross-sections in Fe($n, x\gamma$) were performed using TANGRA facility with high-purity germanium (HPGe) detector [1]. Neutron generator ING-27 with embedded 64-pixel α-detector was used as 14.1 MeV neutron source. In this experiment 17 γ-transitions were observed; for 13 γ-transitions cross-sections were measured and compared with data obtained in other experiments and results of calculations in TALYS. Data processing procedure and discrepancy between our results and previous measurements[2-5] will be discussed.

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INVESTIGATIONS OF THE EXCITED STATES OF 1P SHELL NUCLEI IN INTERACTION WITH DEUTERONS AT LOW ENERGIES

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The differential cross-sections of the elastic and inelastic d + ^{13}C scattering were measured at E(d)=14.5 and 18 MeV on U150M cyclotron of Institute of Nuclear Physics (Almaty, Kazakhstan).

The first 3.09 MeV $(1/2^+)$ excited state of ^{13}C nucleus is of special interest because, it is a state with increased radius, where we can talk about a neutron halo-like structure.

The most probable candidate having the structure of α-particle condensate is still considered a known Hoyle state of 7.65 MeV (0_2^+) in the ^{12}C nucleus. In the context of α-particle hypothesis, the level of 7.65 MeV in the ^{12}C nucleus is the simplest example of α-particle condensate state and plays an important role in Astrophysics problem. In the work [1], it is proposed that similar Hoyle state can be detected in some neighboring nuclei, such as excited state 8.86 MeV $(1/2^-)$ in the ^{13}C nucleus.

In this paper we show the results of the calculations of the radii of the excited states: 3.09 $(1/2^+)$ and 8.86 $(1/2^-)$ which were determined by the Modified diffraction model (MDM)[2] at E(d)=14.5 MeV.

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ANGULAR DISTRIBUTION OF GAMMA RAYS FROM THE INELASTIC SCATTERING OF 14.1 MeV NEUTRONS ON SODIUM AND CHLORINE

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For investigation of 14.1-MeV neutron-induced nuclear reactions, at Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR), a project TANGRA (Tagged Neutrons & Gamma Rays) was created [1].
In the framework of this project, we are investigating the energy and angular distributions of the characteristic gamma-rays raising from the inelastic scattering (INS) of 14.1-MeV neutrons on a number of nuclei, using tagged-neutron method (TNM). As a source of tagged neutrons, we are using a portable neutron generator ING-27 of VNIIA (Moscow), in which 14.1-MeV neutrons are generated in T(d,n) 4 He fusion reaction. The tagging of the neutrons is done by registering the alpha-particles with a multipixel charge-particle detector. The gamma-rays from the INS-reactions are registering in coincidence with the signals from the alpha-detector, by 18 BGO-detector array "Romasha", significantly reducing this way the influence of the background scattered radiation.
In this article we are reporting the results obtained in the measurements of the gamma-ray angular distributions from the INS of 14.1-MeV neutrons on 23 Na and 35 Cl nuclei, in comparison with the data of other authors [2].

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SCATTERING FEATURES ON NON-SPHERICAL POTENTIAL

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An actual problem in studying the interaction of nuclei is the assumption of the non-spherical shape of a particle [1]. Of particular interest is the variation in the scattering cross section. As an example, we consider neutron scattering at ^{238}U.

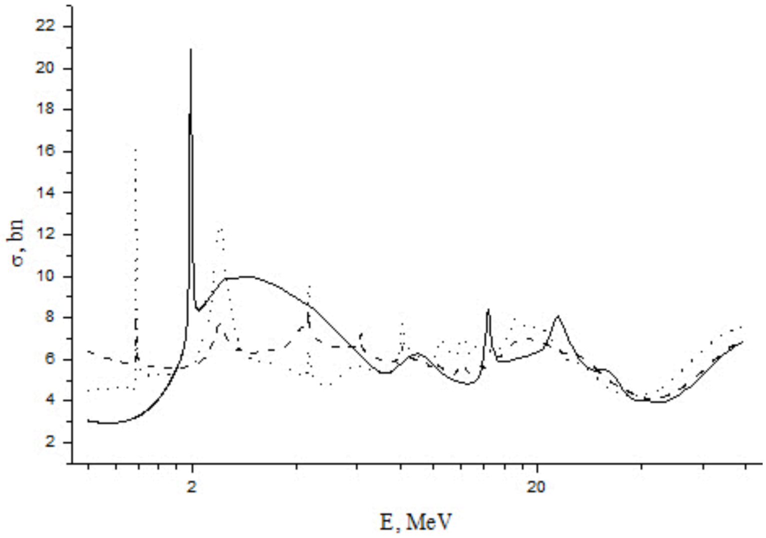

Figure 1: Elastic scattering of neutron at uranium. The solid line represent scattering at spherical potential; the dashed line is result of averaging for axial-symmetrical potential; the dotted line is one component of the previous data, scattering at the axial-symmetrical potential for angle π/2.

In Figure 1 the results of calculation for spherical and axial-symmetrical potential are presented. The base of axial-symmetrical potential is ellipsoid with Wood-Saxon potential as in [2].
It can be seen that obtained features of the scattering do weakly correlate. Particularly, the positions of resonances that appear due to the combination of attractive and centrifugal potentials are shifted regarding the one with the axial-symmetrical potential.

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CROSS-SECTIONS FOR THE ^{27}Al(γ,2pn)^{24}Na MULTIPARTICLE REACTION AT Eγmax = 31.5-100 MeV

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The possibility of using the photonuclear multiparticle reaction ^{27}Al(γ,2pn)24Na (Eth = 31.4 MeV) as a monitor of the flux of γ-quanta with the bremsstrahlung end-point energies Eγmax up to 140 MeV

was studied. The aluminum targets were activated by the bremsstrahlung beam at Eγmax = 30-100 MeV using the LUE-40 RDC "Accelerator" NSC KIPT. The γ-radiation spectra of the irradiated ^{27}Al targets were registered using a semiconductor HPGe-detector with the 20% absolute efficiency and with the 1.8 keV energy resolution at the 1332.5keV γ-line of 60Co. The γ-line with Eγ = 1368.6 keV was used to obtain cross-sections <σ(E)> of the ^{27}Al(γ,2pn)24Na reaction.
The experimental <σ(E)> results from [1-3] and the cross sections <σ(E)> estimated using the "photon difference" method showed a significant scatter of data near 0.2 mb. The experimental value of <σ(E)> found in the present work at the maximum of cross section of the reaction under study is near 0.2 mb and is consistent with the data [2,3]. The theoretical <σ(E)> value obtained with the TALYS 1.9 program code is 0.12 mb.

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DATA ANALYSIS FROM CATCHER FOIL EXPERIMENT FOR MEASUREMENT OF CROSS SECTIONS OF FUSION REACTION LEADING TO HG ISOTOPES

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Yields from the complete fusion reaction of ^{40}Ar + ^{144}Sm => 184-xnHg were measured by the catcher foil method [1] (on the U400M cyclotron at the Flerov Laboratory of Nuclear Reactions). Cross sections for neutron channels of complete fusion were calculated from measured yields. The catchers were made out of five aluminum foils (0,8 μm thick) stacked downstream from the target. The experiment was carried out in repetitive short cycles (10 s). The foils were periodically moved from the beam position to the detector position. Data from the detector were analyzed to obtain α-spectra of implanted isotopes.
The talk will be focused on the data analysis of the above mentioned reaction. As a rule, the α-particle spectra produced in these types of experiments have a very complicated structure. The problem of resolving them into separate lines attributed to specific decaying nuclides can be rather complicated. To make it easier, new software written in LabVIEW was developed. It allows one to calculate the cross sections of the reaction studied by taking into account all essential corrections: half-life and α-decay probability of the registered isotopes, and also the influence of measurement cycles. Geometric efficiency of the detectors was simulated using GEANT4 software. The current of the incident ion beam was measured. The energy of the ion beam from the cyclotron was decreased by a degradation foil upstream of the target. Straggling of the ion beam in both the degradation foil and the target itself were experimentally measured.Measured energy dispersion was higher than what theory predicted. Therefore, deconvolution of the incident excitation function was applied on the obtained results. Experimental results were compared with theoretical excitation functions from the channel coupling model.
Experimental results were compared with results obtained on the MASHA setup (Mass Analyzer of

Super-Heavy Elements) [2] to allow estimation of time and separation efficiency of mass spectrometer MASHA.

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EXTRACTION OF NN-SCATTERING LENGTH IN ND-BREAKUP REACTION AT NEUTRON ENERGY OF 10-80 MEV

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One of the main few-body reactions, in which data on *nn*-interaction are obtained, is the *nd*-breakup reaction $n + {}^2\mathrm{H} \longrightarrow n + n + p$. However, the data on main *nn* interaction parameter - *nn* scattering length, extracted from this reaction at different energies, have a large scatter of values that exceeds the experimental errors. In [1], it was assumed that this dispersion is related to the unaccounted contribution of 3N forces depending on the energy of primary neutrons. Moreover, at low energies, the contribution of 3N forces is relatively large, while at high energies it is negligible, and we can assume that the extracted scattering length value is independent on the 3N interaction. To verify this assumption, it is necessary to obtain data for various energies.
The advantage of RADEX channel of the Moscow Meson Factory (INR RAS) is a possibility of studying *nd*-breakup reaction in a wide range of neutron energies. Although the energy spectrum of neutrons formed in the beamstop of INR linear proton accelerator is wide and includes all energies up to the limit ones equal to the energy of the proton beam, the energy of the primary neutron may be reconstructed from the kinematics of the reaction and, thus, the data may be obtained in a wide range of primary energies.
In [2], data on *nn*-scattering length were obtained in *nd*-breakup reaction at energy of 60 MeV. In this work, the reaction was studied both at low energy ~ 10 MeV and at high one ~ 80 MeV. Two neutrons were detected in the kinematic region of FSI at neutron opening angle of $\Delta\Theta = 5°$. The proton was detected in the active C_6D_6 scintillator target. The energies of secondary neutrons were determined by the time of flight, and the relative energy of the *nn*-pair was calculated for each event using the energies of two neutrons and their opening angle.
In this experimental setup, the neutron-neutron interaction in the final state manifests as a maximum in the dependence of reaction yield on the relative energy of two neutrons, the shape of which is sensitive to the scattering length a_{nn}. To determine a_{nn}, the experimental dependence of *nd*-breakup reaction yield was compared with the simulation results.

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RADIATIVE CAPTURE IN THE ^{4}He + ^{2}H SYSTEM IN THE FRAMEWORK OF A MICROSCOPIC APPROACH

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The nuclear ^{4}He + ^{2}H system is of great importance to nuclear astrophysics. Radiative capture proceeding in this system is responsible for production of the ^{6}Li nuclei during the primordial nucleosynthesis. In this work, the ^{4}He + ^{2}H radiative capture is considered from the microscopic viewpoint within a developed approach [1, 2] based on cluster aspects of nuclear structure and dynamics and formalism of expansions over the oscillator basis. Cross section and astrophysical S factor of the reaction are calculated. Low-energy dependence of these quantities serves as a source of information that can be useful for the so-called second "lithium puzzle". A comparison of the calculated results with experimental data is performed.

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EXTRACTION OF SINGLET pp-VIRTUAL STATE ENERGY IN d+^{1}H→$p + p + n$ REACTION

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Earlier in [1], it was suggested that the reason of discrepancies in experimental a_{nn} values (from −16 to −22 fm) may be connected to a large effect of $3N$ forces. It can also be assumed that the values of the proton-proton scattering length a_{pp} and the energy of the virtual $^1S_0$ state E_{pp} extracted from the experiment with three particles in the final state will differ from the values obtained in the free pp scattering. We plan to test this idea studying the d+^{1}H→$p + p + n$ reaction.
Simulation of this reaction showed that studying the energy spectrum shape of single proton in coincidence with the neutron will allow us to determine the energy of the virtual state of the pp-pair. Parameters of the experimental setup were also determined by simulation.
The experiment was started at 15 MeV deuteron beam of the SINP. A solid deuterated polyethylene target was used. To determine the spectrum of protons, we used a three-detector ($\Delta E - E_1 - E_2$) telescope of silicon surface-barrier detectors. The advantage of such a system is a separation of events with coincidences in two ($\Delta E - E_1$) and three ($\Delta E - E_1 - E_2$) telescope detectors, which greatly simplifies the analysis of energy loss diagrams (the absence of inverse loci in $\Delta E - E_1$ and $E_1 - E_2$ diagrams). With this in mind, a technique was developed for reconstructing the energy spectrum of charged particles from energy losses of particles in detectors. The basis of this technique is the kinematical simulation of the passage of charged particles through matter. The neutron energy is determined by the time of flight using liquid-hydrogen scintillation detector. At that, it is possible to separate neutron events from those caused by gamma rays by the pulse shape. Preliminary data on the shape of the spectrum of protons in coincidence with neutrons are obtained.

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TIME-DEPENDENT CALCULATION FOR PROCESSES OF NEUTRON TRANSFER AND NUCLEAR BREAKUP IN ^{11}Li+^{28}Si REACTION

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The results of theoretical calculation of the neutron transfer and nuclear breakup for the ^{11}Li+^{28}Si reaction at energy range 1–55 MeV/nucleon are presented. The total cross sections for the ^{11}Li+^{28}Si reaction are calculated based on a numerical solving of the time-dependent Schrödinger equation for the external weakly bound neutrons of the projectile nucleus ^{11}Li. Based on probabilities of neutron transfer and nuclear breakup obtained from an exact solving of time-dependent Schrodinger equation, we calculated two-neutron removal cross sections σ_{-2n}. In the low-energy region for the nuclear reaction with weakly bound nucleus ^{11}Li, the neutron transfer process gives a large contribution to the two-neutron removal cross sections σ_{-2n} [1]. Contributions of reaction channels to the total cross sections were defined.

The shell model of spherical nuclei without spin-orbit interaction was used for description of outer neutrons in the ^{11}Li nucleus and states of transferred neutron in the target nucleus ^{28}Si. To confirm the applicability of this principle for calculating reaction cross sections with weakly bound nuclei, we compare calculations taking into account the spin-orbit interaction [2] and without it. The approach without taking into account the spin-orbit interaction does not lead to significant differences in the results.

Enhancement of the total cross section for reactions with light weakly bound lithium nuclei ^{8,9,11}Li nuclei as compared to with reactions with ^{6,7}Li arouse great interest. Mechanisms leading to increase in the total cross section at low energies for ^{11}Li+^{28}Si reaction will enable us to explain important problems of nucleosynthesis (nuclear astrophysics) [2-6]. This effect is especially strongly manifested for light nuclei with a neutron halo [7].

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FEW-BODY DYNAMICS AND FEW-BODY CORRELATIONS IN THE DRIPLINE NUCLEI

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Studies of nuclear systems close to and beyond the driplines is an important field of the modern radioactive ion beam studies. Because of paring and clusterization effects the lowest threshold in the dripline systems are often few-body thresholds (2p, 2n, 4p, 4n, etc.). This lead to emergence near such thresholds of states having expressed few-cluster structure or/and corresponding few-body cluster decay channels. Such states may demonstrate complicated forms of few-body dynamics. These forms of nuclear dynamics are often poorly understood and their studies could be challenge for theory. I review several examples of theoretical studies focusing on various qualitative few-body phenomena near the driplines.

(1) **Two-proton radioactivity and "true" three-body decay**. In the last decade high-quality data was obtained for two-proton decays of light 2p emitters ^{6}Be and ^{16}Ne. This allowed to validate accurate description of these decays in a broad range of excitation energies [Egorova *et al.*, Phys. Rev. Lett. 109, 202502 (2012); Brown *et al.*, Phys. Rev. Lett. 113, 232501 (2014)]. Recently a detailed data on the excitation spectrum of 12O became available [Webb *et al.*, Phys. Rev. C 100, 024306 (2019)]. It was a challenge to provide precise description BOTH of three-body core+p+p correlations for decays of 12O states and their Thomas-Ehrman shifts with respect to corresponding states in the isobaric mirror partner system 12Be.

(2) **"Transitional dynamics" in the three-body decays**. This is specific case of topic (1) concerning the decay dynamics available on the borderline between "true" 2p decay and sequential 2p decay. This decay regime has features typical for phase transition enabling in-depth studies for parametric dependencies of three-body and two-body decays [T.A. Golubkova *et al.*, Phys. Lett. B 762 (2016) 263]. There is experimental evidence that the decays of the recently discovered 2p emitters ^{30}Ar and ^{67}Kr belong to transitional dynamics [I. Mukha *et al.*, Phys. Rev. Lett. 115, 202501 (2015); L.V. Grigorenko *et al.*, Phys. Rev. C 95, 021601(R) (2017)]. The prospects to observe the transitional dynamics in various systems beyond the proton dripline is discussed.

(3) **Soft dipole (E1) excitations in three-body systems**. In the halo nuclei the extreme radial extent of the wavefunction may lead to extreme low-energy concentration of E1 strength above the first breakup threshold. This concentration (the so-called soft dipole mode) can be crucial for understanding of the reciprocal processes of radiative capture in astrophysical environments [Parfenova *et al.*, Phys. Rev. C 98, 034608 (2018)]. Studies of soft dipole excitation in three-body systems (^{17}Ne, ^{6}He, ^{11}Li) are specifically complicated and there are important controversies both in theory and experiment. The new high-precision theoretical studies of soft dipole excitation in 6He resolve several puzzling issues of the previous studies. The obtained three-body core+n+n correlation patterns provide insight in the mechanism of the soft dipole excitation [Grigorenko *et al.* submitted].

(4) **Five-body decays**. Studies of such extreme neutron-rich systems as ^{7}H or ^{28}O are very complicated from experimental side. This complexity is to large extent connected with their unique 5-body (4n emission) decay channel. Such decay processes are poorly studied theoretically so far. The recent experimental results on ^{7}H [Bezbakh *et al.*, Phys. Rev. Lett. 124, 022502 (2020)] underline importance of understanding of correlations in such decays. It was demonstrated theoretically that potentially a detailed information of the structure of the decaying system can be extracted from the 5-body correlation data [Sharov *et al.*, JETP Letters, 110, 5(2019)].

DECAY DYNAMICS OF ^{221}Ac* FORMED IN ^{16}O+^{205}Tl REACTION AT ABOVE BARRIER ENERGIES

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The study of heavy ion induced reactions provides an opportunity to extract the knowledge of nuclear dynamics and related structural effects of nuclear systems belonging to different regimes of isotopic chart. Significant theoretical and experimental work have been done to understand the dynamical processes associated with variety of nuclear reactions, but still there is an enigma among the investigators due to complex nuclear properties and associated aspects. In view of this, the present work aims to analyse the decay of 221Ac* nucleus formed in ^{16}O+^{205}Tl reaction at Ec.m.=76.2-104.5 MeV. In reference to the experimental finding of Gehlot *et al.* [1], the evaporation residue (ER) cross sections are calculated using Dynamical Cluster decay Model (DCM) [2,3]. The corresponding decay properties are investigated by analysing the fragmentation potential and preformation probability of decaying fragments. Note that, the calculations are performed using quadrupole(ß2) deformations of decay fragments with optimum orientations (θiopt). We intent to present comprehensive analysis of decay dynamics associated with the chosen reaction at time of conference.

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THE EFFECT OF THE ELECTRON SCREENING IN THE D(^{3}He, p)^{4}He REACTION IN DEUTERATED METALS

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In recent decades, the issue of increasing cross sections of the thermonuclear reactions in the low-energy region has become relevant. This phenomenon is associated with the effect of the electron screening, which consists in reducing the Coulomb energy between interacting nuclei by the electrons of the surrounding substance. The study of this phenomenon is important in the astrophysics, since research in this area can shed light on the issues of the Big Bang Nucleosynthesis [1], as well as resolves a number of questions in the field of a stellar dynamics. At the same time, the application of this effect can be found in the design and material science of the thermonuclear reactors.
A specific feature of light nuclei synthesis reactions in the astrophysical energy region is that the electron screening potentials obtained in the experiments are higher than those calculated in the adiabatic limit. This has not been explained in theoretical studies so far [2]. The situation is even more dramatic in the study of reactions to solid targets [3,4]. In this work we present the results of

the study of D(^{3}He, p)^{4}He reactions using deuterated Ti and Zr targets.
The D(^{3}He, p)^{4}He reaction was investigated at the pulsed plasma Hall accelerator (Tomsk) in the ^{3}He+ energy range EHe = 16÷34 keV (E = 6.41÷13.61 keV in the center-of-mass system) with a step of 2 keV. The aim of this work was to experimentally determine the enhancement factor of the D(^{3}He, p)^{4}He reaction and the electron screening potential of Ue using TiD and ZrD targets. In this work, two types of targets with different crystal structures were used: channeling and screening with Miller indices [100] and [111], respectively. Targets were placed on a stainless steel substrate 50 μm thick. The registration of protons from the D(^{3}He, p)^{4}He reaction (Ep = 14.7 MeV) was carried out by the detector based on a plastic scintillator BC-404 (d = 115 mm, thickness 4 mm). The pulse operation mode of the accelerator and the background events measurement in the intervals between pulses of the accelerator made it possible to suppress the background events registration.
The measured screening potentials of the D(^{3}He, p)^{4}He reaction in deuterated Ti and Zr metals are almost an order of magnitude higher than for gas targets and reach values of the order of Ue = 1255 eV for the conditions of the present experiment. The enhancement factor obtained on a TiD target with a Miller index [100] reaches 8.1 for E = 6.51 keV, which is ~ 2 times greater than the value obtained for the ZrD target [100]. At the same time, the values of the enhancement factors obtained for ZrD and TiD targets with the Miller index [111] differ by only 20% and amount to ~ 3, which is 3 times more than for the calculated curve. These results clearly indicate of the channeling effect on the reaction yield. In this case, energy behavior of the enhancement factor of the D(^{3}He, p)^{4}He reaction is not described by the classical exponential formula.

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DESCRIBING PION PRODUCTION IN COLLISIONS OF HEAVY IONS AT INTERMEDIATE ENERGIES IN THE HYDRODYNAMIC APPROACH WITH A NON-EQUILIBRIUM EQUATION OF STATE

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In progress of a hydrodynamic approach with a non-equilibrium state equation for describing heavy ion collisions [1], we consider the emission of pions both at sub-threshold energies and at the SIS (GSI) accelerator energies. The emission of pions at sub-threshold energies is possible due to the collective intra-nuclear movement of nucleons. The influence of this motion is naturally taken into account in the framework of the hydrodynamic approach, which clearly includes the multiparticle nature of colliding heavy ions. In this case, nuclear hydrodynamics must be modified by the non-equilibrium equation of state to account for the transition from the initial non-equilibrium state to the state of local thermodynamic equilibrium. In this approach, highlighting the compression stage, the expansion stage, and the freeze-out stage with the formation of secondary particles, we described experimental inclusive double differential cross sections of pion emission for collisions of different nuclei at sub-threshold energies [2, 3]. Agreement with experimental data is achieved without introducing fitting parameters. We have extended this approach to the SIS energy domain and suggest using it in research at the NICA accelerator complex under construction in Dubna.

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ELECTRON SCREENING IN NUCLEAR REACTIONS AT LOW ENERGIES

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In nuclear reactions induced by low-energy charged particles, atomic electrons can participate in the process by screening the nuclear charge and so, effectively reduce the repulsive Coulomb barrier. Consequently, the measured cross section is enhanced by an effect called electron screening. In numerous experiments, different research groups [1-4] obtained extremely high values of electron screening, that are in several cases (depending on target-nuclei environment) more than an order of magnitude above the prediction based on available theoretical model in adiabatic limit [5].
Nevertheless, even as a considerable amount of experimental data was collected over the past twenty years, a suitable theory, which can give an explanation of this effect, has not yet been found. However, electron screening is very important in nuclear astrophysics. For nucleosynthesis calculations, precise reaction rates should be known at very low energies. At these energies charged-particle-induced reaction cross sections become difficult to measure due to their sharp drop with decreasing energy. Nowadays, the energies of astrophysical interest can only be reached in underground laboratories with high-current low energy accelerators [6]. In spite of that, even when the lowest energies are reached, the measurements do not give the nuclear cross section, since the reaction rate in the laboratory is always influenced by the atomic electrons that surround the reacting nuclei.
Trying to understand this process, the effect of electron screening has been investigated by our group [7-9]. We measured the highest value of electron screening in a graphite target. The measured value is about a factor of 50 above the adiabatic limit prediction and much higher than any potential measured so far. Further, our results pointed out that the Z dependence of the screening is even higher than Z^2 instead of expected linear dependence. This rules out the theory based on static electron densities. In order to explain our data, we proposed a new model assuming that an electron is caught in the attractive potential of the two approaching nuclei, similar to the potential of the hydrogen molecular ion [8].
At the moment, our group is focusing on studying the electron screening effect in deuterium implanted titanium targets using the ^{19}F(d,p)^{20}F reaction. Titanium is particularly suitable because it can absorb deuterium up to the stoichiometric ratio of 1:2. It is also very interesting for our investigations due to particular dependence of the electron screening potential on the concentration of deuterium in titanium [3]. Deuterium depth profiles of Ti targets were analysed by nuclear reaction analysis. In order to get a better insight into the condition of the titanium lattice itself, targets were additionally analysed by X-ray diffraction, thermal desorption and Raman spectroscopy. Our goal is to find a different value of the screening potential in two titanium targets and then to understand which parameters of those targets differ and cause high electron screening. An overview of our work will be given and our latest results will be presented.

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ANGULAR DEPENDENCIES OF THE DEUTERON ANALYZING POWERS IN dp-ELASTIC SCATTERING AT LARGE TRANSVERSE MOMENTA

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The results on the vector Ay and tensor Ayy and Axx analyzing powers in deuteron-proton elastic scattering at large transverse momenta are presented. These data were obtained at internal target at JINR Nuclotron in the energy range 400-1800 MeV using polarized deuteron beam from new polarized ion source. New data on the deuteron analyzing powers in in the wide energy range demonstrate the sensitivity to the short-range spin structure of the isoscalar nucleon-nucleon correlations.

POLARIZED DD FUSION EXPERIMENT (POLFUSION) IN PNPI

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The $^2H(d,p)^3H$ and $^2H(d,n)^3He$ fusion reactions at low energies are relevant in pure and applied physics. These reactions took place in the first minutes during the Big Bang nucleosynthesis and occur in the early phases of stellar burning. Active discussion [1] is being made to encourage scientists in research in the field.
The low-energy regime (tens to hundreds of keV) typical for nucleosynthesis and fusion plasmas is challenging to probe because of exponentially decreasing in the reactions cross section and therefore lowering counting rates. However due to sreening effects of electrons and polarizing reactants [2] fusion reaction rates can be increased significantly.
The dd fusion is the reliable source of thermonuclear energy and tritium fuel for future reactors without an external tritium source [3]. Handling of neutron production and the by-products emission direction can be achieved by polarizing deuterium in specific ways [2].
The world's first colliding-beam experiment with both polarized beams PolFusion [4] has been started in PNPI, Gatchina, in collaboration with Forschungszentrum Juelich, Germany, and INFN University of Ferrara, Italy.
The experiment aims to study fusion reactions of $^2H(d,p)^3H$ and $^2H(d,n)^3He$ with the beam energy at 10-100 keV and various spin combinations. Fusion by-products are detected by using the 4π central detector with 51\% filling based on 600 silicon pin-diodes to measure its energy.
We plan to measure different spin-correlation parameters such as assymetry, vector and tensor analyzing powers, spin-correlation coefficients, polarization transfer coefficients, and also differential and total cross sections of the reactions at given energy range.

The experimental setup is described. Results of the test-run in 2019 are presented. Details of future plans are discussed.

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STUDY OF DEUTERON-PROTON ELASTIC SCATTERING AT INTERMEDIATE ENERGIES

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Nowadays, a significant amount of the experimental data in GeV energy range was accumulated both with unpolarised and polarised beams. However, a description of the data faces problems because well developed Faddeev calculation technique cannot be applied at these energies.

In this report we consider deuteron- proton elastic scattering in the relativistic multiple scattering expansion framework [1]-[3]. We start from the AGS-equations and iterate them up to second-order terms of the nucleon-nucleon t-matrix. The four reaction mechanisms are included into consideration: one-nucleon exchange, single scattering, double scattering, and the term with the Δ- excitation in the intermediate state.

The deuteron-proton elastic scattering is considered in a whole angular range at two deuteron energies, 880 Mev and 1200 MeV. The obtained theoretical predictions are compared with the existing experimental data for the differential cross section, vector A_y and tensor A_{yy} analysing powers. Effects of the different reaction mechanisms are analysed. It is shown that the inclusion of the double scattering and Δ- excitation terms into consideration significantly improves the agreement between the experimental data and theoretical predictions at the scattering angles larger than 60^0.

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POPULATION OF EXCITED STATES IN ^{45}Ti AND ^{197}Hg NUCLEI IN CHARGE-EXCHANGE REACTIONS ON LOW-ENERGY ^{3}He BEAMS

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Studying charge-exchange reactions allows one to study the structure of a nucleus and understand the mechanism of the ongoing reaction.
In the charge-exchange reactions (p, n) and (^{3}He, t) at low energy of bombarding particles on nuclei

with even mass, isobar-analog and other excited states have been observed and identified. The reaction (^{3}He, t) has certain advantages over the (p, n) reaction due to the possibility of measuring the energy of emitted particles (t). It was found that the cross sections for reactions (^{3}He, t) are almost an order of magnitude lower than the cross sections for (p, n) reactions on the same target nuclei. Nevertheless, the cross sections for reactions (^{3}He, t) on nuclei with an odd mass (45Sc and 197Au) reach relatively large values (up to 100 mb) at bombarding particle beam energy close to the reaction Coulomb barrier [1].
One of the first reactions on odd nuclei, in which excited states were studied, was the reaction ^{9}Be (^{3}He, t) ^{9}B. In the ^{9}B nucleus, only one excited state has been observed at ^{3}He energy of 30 MeV [2]. In this work, we continued the study of the reaction (^{3}He, t) on the odd 45Sc and 197Au target nuclei. In this work, for the
(^{3}He, t) reaction, differential cross sections for the population of excited states in 45Ti and 197Hg product nuclei were obtained at ^{3}He energy of 30 MeV. The angular distribution of the formed tritium was also studied.
The experiments showed that the maximum values of the cross sections for these reactions correspond to grazing angles. This indicates the peripheral nature of charge-exchange reactions.

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SUPERASYMMETRIC FISSION MODE IN ^{254}Fm NUCLEUS POPULATED BY ^{16}O+^{238}U REACTION

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The search for super-asymmetric fission, has been receiving increasing interest due to its possible interest in producing exotic neutron rich nucleus [1]. Among the four main fission modes prescribed by Brosa [2], the supershort mode manifests itself only when light and heavy fission fragments are close to the double magic tin with A~132 in their nucleon composition. Though the possibility of the fission asymmetry of the pre-actinides had been predicted in 70's [3], it took a decade to substantiate this prediction experimentally [4]. Recently, the superasymmetric mode due to the influence of double magic Ca (Z = 20, N = 28) and double magic Pb (Z = 82, N = 126) has been observed at a mass yield level of 10-3 and 10-5, in fission of excited ^{260}No compound nucleus, populated by the reactions ^{12}C+^{248}Cm and ^{22}Ne+^{238}U, respectively [5, 6]. The fission mass distributions of the fermium isotopes showed a marked transition from asymmetric to symmetric as the mass number increases from 254 to 258 [7]. Additionally, Lustig *et al.* [8] predicted super-asymmetric fission modes in ^{253}Fm(n,f) ^{254}Fm(sf). So, further investigations at the lower excitation energies of Fm isotope and to discern super-asymmetric fission mode and its characteristics out of all other fission modes, was of paramount importance.

The mass-energy distributions of fission fragments of ^{254}Fm compound nucleus formed in the reaction ^{16}O+^{238}U have been measured at two lab energies E_{lab} = 89 and 101 MeV, using the two-arm time-of-flight spectrometer CORSET [9]. The contribution from quasifission is negligible in the reaction ^{16}O+^{238}U [10]. At the energy close to the Coulomb barrier (corresponding excitation energy E CN~ 45 MeV), where the shell effects still exist, the enhancement of the mass yield in the region 60-70 u for the light fragment is observed. This can be explained by the influence of double magic

Ni (Z=28, N=50). The mass yield is found to be around 10-2 %. This signature of super-asymmetric fission goes away at the higher excitation energy (E CN~ 56 MeV).

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PROBING FISSION FRAGMENTS OF ^{182,183}Hg NUCLEI AT ENERGIES AROUND COLOUMB BARRIER

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Asymmetric fission of mercury nuclei was initially observed in low energy region [1-3]. Sub-lead region is the region where it is noticed that the fission fragment shell property is over-ruled by the ridges and valleys present from saddle to scission point in the potential energy surface. These ridges and valleys are the result of shell correction, which vanishes with increase in excitation energy. In recent years several experiments have been performed in this direction to investigate the asymmetric behaviour of Hg nuclei which supported the influence of shell effects on the asymmetric fission process [4-6].
Spherical shells are more stable towards asymmetric fission in comparison to deformed nuclei. It has been observed that the three odd nuclei 181,183,185Hg have highly deformed charged radii in comparison to other mercury isotopes, due to quadrupole and monopole moment [7]. Thus, one may expect for 183Hg to show more asymmetry in fission fragments mass-energy distribution in comparison to ^{182}Hg.
An experiment is performed using CORSET [8] setup, where we investigate mass and energy distributions of fragments and fission characteristics of oblately deformed 182 Hg ($\beta 2$ = 0.147) and prolate deformed 183Hg ($\beta 2$ = 0.313) nuclei formed by 40Ca+142,143Nd, at three different lab energies Elab= 172, 192, 212 MeV. Observing their $\beta 2$ value we understand that ^{182}Hg is lightly deformed in comparison to 183Hg.The energies taken into consideration are at different difference from the Coulomb barrier, so that we can study the behaviour in different regions. We are expected to get higher asymmetry for 183Hg but we find a contradicting result where there is no huge variation in mass-energy distribution of ^{182}Hg and 183Hg at any of the measured energies. This gives us an outlook regarding influence of shell structure, charge radii deformation and factors associated in the potential energy surface that are responsible for fission in Hg region.

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ON THE PROTON SPECTRA IN COLLISIONS OF HEAVY IONS ^{12}C + ^{9}Be AT ENERGIES OF 0.3–2.0 GEV/NUCLEON IN THE FRAMEWORK OF THE HYDRODYNAMIC APPROACH

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In the progress of the hydrodynamic approach with a non-equilibrium equation of state [1], collisions with a beryllium target of nuclei ^{12}C at energies of 0.3-2.0 GeV/nucleon with proton emission at an angle of 3.5 degrees, which were studied at the ITEP accelerator [2], are considered. The experimental proton spectra contain a high-energy cumulative part, as well as a soft part, to which fragmentation contributes. We could describe the cumulative part of the spectra within the framework of a non-equilibrium hydrodynamic approach, taking into account the nuclear viscosity and correction for the microcanonical distribution [3]. In this work, in accordance with experimental data, our calculations are supplemented by taking into account the contribution of protons from fragments in the region of overlapping parts of colliding nuclei and in the region of non-overlapping parts on the basis of the statistical fragmentation mechanism proposed earlier in [4, 5].

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POTENTIAL DESCRIPTION OF α+^{208}Pb ELASTIC SCATTERING

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The last two decades have seen the considerable success of non-monotonic (NM) and modified single-folded (MSF) potentials in describing the alpha-induced elastic scattering and non-elastic processes

which exhibit a distinctive feature of anomaly in large angle scattering (ALAS). The ALAS effect cannot be explained by the Woods-Saxon type of optical model (OM) potential in a consistent manner. This work reports the analyses of the experimental angular distributions of alpha+208^Pb elastic scattering in terms of two types of OM potentials, namely the complex NM and modified form of single-folded potentials. Two sets of real NM potentials have been found through the analysis of the data, which are termed as set-1 and set-2 potentials. The closeness of the fits to the data using set-1 potential with unshifted repulsive core and set-2 potential with shifted repulsive core suggests that the effect of the potential shape in the central region of the target ^{208}Pb nucleus is not that significant in determining the angular distribution of cross-sections at low incident energies and the scattering is dominated by the nuclear potential at the nuclear surface. The MSF potential, without any renormalization, satisfactorily describes the alpha+208^Pb elastic scattering data for the energies considered here. The number of nucleons making alph-like clusters is deduced as 4A_α=180 and the number of unclustered nucleons found is A_N=28. The rms radius of the target 208^Pb has also been deduced.

TEMPERATURE DEPENDENCE OF THE PROTON EMITTING DECAY HALF-LIVES USING DOUBLE-FOLDING POTENTIAL

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Using temperature dependent nuclear potential the temperature dependence of proton emitting decay half-lives were analyzed in framework of WKB method with inclusion of quantization conditions. The temperature dependent double-folding and proximity potentials were used in calculations. In temperature independent calculations, in contrary to Prox77, very good agreement between calculated half-lives with double-folding and experiment were observed. Considering temperature dependent potentials and Q-value showed decreasing behavior of half-life with increase of the temperature.

HOYLE STATE AND UNSTABLE NUCLEI IN RELATIVISTIC NUCLEI DISSOCIATION

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The phenomenon of dissociation of relativistic nuclei observed with a unique completeness in the nuclear track emulsion (NTE) makes it possible to study ensembles of nucleons and lightest nuclei of interest to nuclear cluster physics and astrophysics [1]. The advantages of the NTE technique include a record space resolution in determining emission angles for recognition relativistic ^{8}Be and ^{9}B decays among the He and H projectile fragments. The decays are identified by the invariant mass M^{*} defined by the sum of all products of 4-momenta P_i of relativistic fragments He and H. The components P_i are determined by the fragment emission angles under the assumption of conservation a projectile momentum per nucleon. Recently, in the events of relativistic dissociation of ^{9}Be, ^{10}B, ^{10}C, ^{11}C nuclei were identified unstable ^{8}Be and ^{9}B nuclei by invariant mass approach [2]. The successful identification of ^{9}Be nuclei allowed us to cross to the problem of identifying triples of alpha

particles in the Hoyle state (HS) in the dissociation of relativistic nuclei. Production of α-particle triples in the HS in dissociation of ^{12}C nuclei at 3.65 and 0.42 A GeV in NTE was investigated [3]. Contribution of the HS to the dissociation $^{12}C \rightarrow 3\alpha$ is (11 $\pm$ 3) %. Analysis of data on coherent dissociation $^{16}O \rightarrow 4\alpha$ at 3.65 A GeV is revealed the HS contribution of (22 $\pm$ 2) %. These observations indicate that it is not reduced to the unusual ^{12}C excitation and, like ^{8}Be, is a more universal object of nuclear molecular nature. Reanalysis of data on dissociation of heavier nuclei (Ne, Si, Kr and Au) pointed out to significant contribution of HS in the nα-channels. The analysis of the NTE layers exposed to relativistic ^{14}N nuclei is resumed in the HS context. Video collection of relativistic nuclei dissociation events in NTE obtained using a microscope and a digital camera can be found [4].

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ENERGY DEPENDENCE OF THE FISSION MODE PROBABILITY OF ^{234}U BY NEUTRONS

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Mass distribution of the fission fragmnets of ^{234}U fission by neutrons can be described using three fission modes: S1 (Standard 1), S2 (Standard 2) and SL (Super Long). Yields of these modes can be calculated using the form of the potential barriers along three different paths in the configuration space of nuclei deformation. Vibrational resonance at neutron energy about 0.7 MeV influence the cross section and angular distribution of fission fragments at this energy. We test the hyphothesis that the resonance is occurring only for one fission mode after the bifurcation. The result of the calculation are comparing with experimental data of work [1] about mass distribution of fission fragments.

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INVESTIGATION OF THE EXCITATION OF ISOMERIC STATES IN THE REACTIONS (,n), (,2n) AND (n,2n) ON THE NUCLEUS ^{197}Au

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In the present work the results of the experimental study of the photoexcitation of isomeric states ^{196m}Au(J=12$^-$) and ^{195m}Au(J=11/2$^-$) in reactions (,n), (,2n) and (n,2n) on the nucleus ^{197}Au in the range 10-35 MeV are presented.
The isomeric yield ratios were measured by the induced radioactivity method. Samples of natural

Au have been irradiated in the bremsstrahlung beam of the betatron SB-50 in the energy range of 1035 MeV with energy step of 1 MeV. For 14,1 MeV neutron irradiation, we used the NG-150 neutron generator.
The gamma spectra reactions products were measured with a spectroscopic system consisting of HPGe detector CANBERRA with energy resolution of 1,8 keV at 1332 keV gamma ray of ^{60}Co, amplifier 2022 and multichannel analyzer 8192 connected to computer for data processing. The filling of the isomeric and ground levels was identified according to their γ lines.
Isomeric ratios for ^{197}Au(,n)^{196m,g}Au reaction yields are measured in the 12-30 MeV energy range with 1 MeV energy step. The obtained E_{max} dependence of the isomeric ratio yields for the (,n) reaction, d, looks like a saturation curve. In the saturation region d=(5,60,4)10^{-4}. Using the isomer yield ratio and the total cross section of the (, n) reaction on ^{197}Au [1] we estimated the cross sections of $(,n)^m$ and $(,n)^g$ reactions. For $(,2n)^m$ reaction cross sections are obtained at first. The cross section isomeric ratios of E_m= 17 MeV are estimated.
In the case of the reaction (n, 2n), the cross sections for the formation of the isomeric and ground states and their isomeric ratios σ_m/σ_g were determined. To obtain the absolute values of the cross sections of the ground and isomeric states, methods were used to compare the yields of the test and monitor reactions.
The experimental results have been discussed, compared with those of other authors as well as considered by the statistical model [2]. Theoretical values of the isomeric yield ratios have been calculated by using code TALYS-1.8.

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THE ^{12}C(^{10}B,^{9}Be)^{13}N REACTION STUDY FOR ANC ^{13}N→^{12}C+p EVALUATION

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In this work the measurement of the differential cross sections (DCS) of the proton transfer reaction ^{12}C(^{10}B,^{9}Be$_{g.s.}$)^{13}N$_{g.s.}$. has been carried out (Fig. 1) for the ANC ^{13}N$_{g.s.}$→^{12}C+p obtaining. The experiment was fulfilled at ^{10}B ions beam of the C-200P cyclotron of the Heavy Ion Laboratory (University of Warsaw) at the energy E_{10B}=41.3 MeV. At this energy the proton transferring process is practically peripheral what is suggested by behavior of the testing function $R(b)$ of the MDWBA method [1] in which the single DCS calculated using the LOLA computer code [2]. So the DCS of the reaction is expressed via the product of the ANCs squares $(C_{10B\to 9Be+p})^2$×$(C_{13N\to 12C+p})^2$. The ANC $(C_{13N\to 12C+p})^2$ = 2.6±0.3 fm^{-1} was preliminary evaluated from the analysis (the solid curve in Fig.1), as the ANC $(C_{10B\to 9Be+p})^2$ is rather well known from [3,4]. The channel coupling was found to be negligible by evaluation with the FRESCO code. More correct value will be found by analysis of the data in the frameworks of the developed asymptotic reaction theory [5] along with a careful selection of parameters of the optical potentials.

The derived ANC for ^{12}C+p→^{13}N will be applied for calculation of the nuclear-astrophysical ^{12}C(p,γ)^{13}N reaction rates at stellar temperatures.

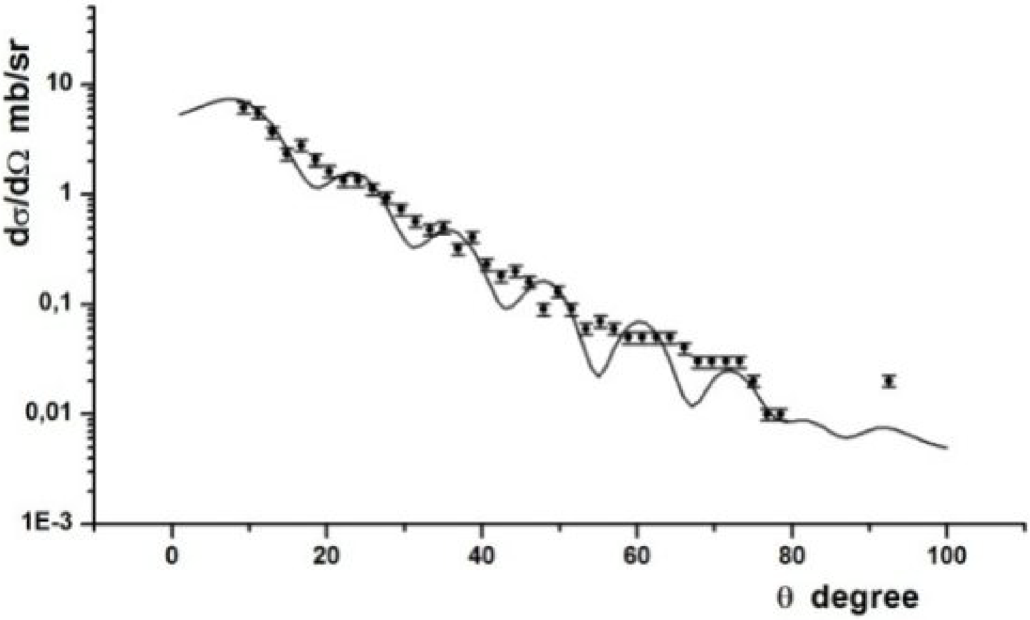

Figure 1: Differential cross section of the reaction ^{12}C(^{10}B,^{9}Be$_{g.s.}$)^{13}N$_{g.s.}$ The solid curve is the result of the calculations.

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INVESTIGATION OF T(^{1}H, γ)^{4}He REACTION IN THE ASTROPHYSICAL ENERGY RANGE

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The study of reaction T(^{1}H, γ)^{4}He is of interest both for nuclear physics and nuclear astrophysics. In nuclear astrophysics, it is necessary to get more accurate data about the rates of primordial synthesis reactions, which cause the synthesis of ^{4}He [1,2]. In nuclear physics, there are several theoretical predictions of this reaction cross-section and S-factor behavior in tens of keV energy range, which are in significant disagreement [3]. Therefore, it is necessary to provide more accurate experimental study of this reaction cross-section in the astrophysical energy range.

The reaction T(^{1}H, γ)^{4}He was investigated in E_{lab} = 12 - 34 keV (E_{cm} = 7.8 – 20.1 keV) energy range using pulse Hall accelerator (Tomsk, Russia) with placed solid state TiT target. Produced γ-quanta with energy E_γ = 19.8 MeV are registered by the assembly of 8 NaI(Tl) detectors placed radially around the target chamber.
In order to determine the efficiency of γ-quanta registration by detectors assembly, a Geant4 simulation was performed. This simulation was also used to imitate the experimental spectrum taking into account the neutron background. To estimate the possible influence of residual gases in vacuum chamber on the value of neutron background generated in neutron-producing reactions, a quadrupole mass analyser was used.
The experimental cross-sections values for different energies of proton are used to determine the behavior of the T(^{1}H, γ)^{4}He reaction S-factor in dependence on energy. Our results do not correspond with theoretical results presented in [3]. The details of the experimental setup and simulation, as well as the results of the experiment will be presented.

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INVESTIGATION OF MASS-ENERGY DISTRIBUTIONS OF FRAGMENTS FORMED IN THE ^{32}S+^{232}Th→^{264}Sg REACTION AT ENERGIES BELLOW AND NEAR THE COULOMB BARRIER

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The present work is focused on exploring the features of fission of ^{264}Sg formed in the reaction ^{32}S+^{232}Th at energies near and below the Coulomb barrier. The detailed study of properties of Sg fission will enrich the information on fission in the transition region of transactinide nuclei. The experiment was carried out at the K-130 accelerator of the University of Jyväskylä (Finland) at energies of ^{32}S ions of 165, 181 и 200 MeV. The mass-energy distributions of the reaction fragments were measured using the double-arm time-of-flight spectrometer CORSET. As a result of the analysis of experimental data, the dependence of width of mass-energy distributions on the excitation energy was obtained. In the symmetric mass region (A/2±20), the contribution of the quasifission process was found at energies both below and above the Coulomb barrier.

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SCATTERING PROCESSES IN FEW-BODY SYSTEMS WITH NON-ZERO ANGULAR MOMENTUM

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Scattering problems for few-body systems are of great importance for many physical processes. The complicated boundary conditions at large distances, especially for slowly decreasing potentials, are a major difficulty for these problems [1]. While several methods have been developed for constructing solutions to the three-body scattering problem, mathematically sound and computationally effective approaches to this problem are still in demand.
Here we present an approach based on splitting the reaction potential into a finite range part and a long range tail part to describe few-body scattering in the case of the Coulomb interaction [2.3]. The solution to the Schroedinger equation for the long range tail of the reaction potential is used as an incoming wave. This reformulation of the scattering problem into an inhomogeneous Schroedinger equation with asymptotic outgoing waves makes it suitable for solving with the exterior complex scaling technique [4]. The potential splitting approach is illustrated with calculations of scattering processes in atomic and molecular systems with non-zero angular momentum. The validity of the approach is analyzed and demonstrated numerically.
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INVESTIGATION OF BINARY PROCESSES IN REACTIONS ^{36}Ar+$^{144,\,154}$Sm and ^{68}Zn+^{112}Sn LEADING TO THE FORMATION OF NEUTRON-DEFICIENT $^{180,\,190}$Hg COMPOSITE SYSTEMS

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Asymmetric fission process observed in decay of neutron-deficient nuclei lying in sub-lead (Pb) region provoked intensive investigations of fission process of these nuclei [1, 2]. Mass-energy and angular distributions of fission fragments of neutron-deficient $^{180,\,190}$Hg composite systems formed in the reactions ^{36}Ar + $^{144,\,154}$Sm, ^{68}Zn + ^{112}Sn were measured using two-arm time-of-flight spectrometer CORSET [3] at energies near and above the Coulomb barrier. Analysis of the experimental data

showed that in fission of these nuclei at the excitation energies up to 75 MeV both symmetric and asymmetric fission modes are clearly observed.

It was found that mass distributions of fragments formed in the reaction ^{68}Zn + ^{112}Sn have wide two humped shape with maximum yield at 70/110 amu for light and heavy fragments, respectively, and differ significantly from the distribution obtained in the reaction ^{36}Ar + ^{144}Sm leading to the formation of the same composite system of ^{180}Hg. Difference of entrance channel properties in these two reactions leads to appearance of quasifission process in the reaction with ^{68}Zn ions.

At highest incident energies fast fission process was observed [4] for composite systems of ^{180,190}Hg. This occurs due to vanishing of fission barrier of formed composite system at large angular momenta. Fast fission process also widens the mass and energy distributions of fission fragments.

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STUDIES OF THE LOW ENERGY RESONANCE REACTIONS IN THE MEDIUM MASS NUCLEAR SYSTEMS

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Today, one of the fundamental problems in physics of nuclear reactions is a quantitative description of the elements formation in the Universe. These studies lead to an understanding of the mechanisms and processes that occur in stars. When analyzing the nuclear reaction experimental data, playing a key role in astrophysical studies it becomes necessary to use interaction potentials. These potentials allow with good accuracy to take into account the effects of particles transfer and particles (clusters) interaction [1]. The building of these potentials is also associated with an important fundamental problem - the explanation (prediction) of the astrophysical spectroscopic factor behavior for the nuclear fusion reactions near the Gamow window. It was experimentally obtained that during the fusion of carbon and oxygen nuclei in this mass region one can observe the resonance behavior of the reaction cross section. Such resonances have been not yet fully described by the existing nuclear models [2]. In addition, due to the ambiguity of the potential choice, the theoretical predictions for low energies have different values (by several orders of magnitude) in this energy range.
In present work the nuclear reaction ^{12}C + ^{16}O was studied in the framework of a potential model. Several types of potentials obtained in the cluster [3], semi-microscopic [4] and phenomenological approaches [5] were discussed. It was shown that the excitation function may contain "false" resonance states. In addition, the discrete uncertainty of potentials was eliminated by using the analysis of the cross section in the low-energy region.

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A NOVEL ALGORITHM FOR CALCULATING PROTON, NEUTRON, AND CHARGE NUCLEAR DENSITIES: COMPARISON WITH THE EXPERIMENTAL DATA

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The Strong nucleus-nucleus Potential (SnnP) is of principal importance for understanding nuclear molecules [1] and for the synthesis of the superheavy nuclei [2]. Nucleon density distributions are known to play a crucial role in finding the SnnP by means of the double folding model [2], [3]. The best way is to calculate the densities in a microscopic manner, i.g. by the Hartree-Fock approach [4]–[6]. However, such calculations are rather complicated and computer resources consuming.
That is why in the present work we develop a novel fast algorithm for evaluating the proton and neutron densities for spherical nuclei. The algorithm is based on five benchmarking densities coming from the Hartree-Fock approach: ^{12}C, ^{16}O, ^{36}S, ^{92}Zr, ^{144}Sm, ^{208}Pb. Each of these microscopic densities is approximated by a combination of a Woods-Saxon profile with an exponential tail having a variable (i.e. radial dependent) diffuseness (WST profile). For the nuclei with the charge number between the benchmarking ones we perform a linear interpolation of the parameters defining the WST profile.
As a test for the WST-algorithm we find the nuclear charge density distributions for several spherical nuclei and compare those with the experimental Fourier-Bessel distributions from [7]. The agreement seems to be rather good.
Then we calculate the barrier height and radii for several fusion reactions involving two spherical nuclei using the well-known M3Y nucleon-nucleon interaction. The calculated barrier parameters are compared with the experimental ones from [8]. The calculated barriers are systematically higher than the experimental ones indicating importance of the dissipative phenomena in the above-barrier collision process [5], [6].

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RELATIVISTIC MEAN-FIELD EFFECTIVE NN FORCES IN DYNAMICAL MODELING OF HEAVY-ION FUSION

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In the analysis of heavy-ion fusion cross-sections, the relativistic effects are usually ignored [1]. However, it is known that the fastest nucleons in a nucleus have the velocity close to a quarter of the speed of light. The relativistic mean-field (RMF) theory accounting for the effects of high nucleons velocity was successfully applied to reproduce the binding energies and astrophysical S-factors for proton-induced reactions [2].
In the present work, we demonstrate the results of the application of the RMF theory for describing the heavy-ion above-barrier fusion process of complex nuclei. The modeling is performed within the framework of a trajectory model [3-5] based on the double-folding approach and accounting for energy dissipation. We employ six different RMF parameter sets for the effective nucleon-nucleon (NN) forces. The forces as well as the resulting potentials and cross-sections are compared with those obtained using the non-relativistic M3Y NN-forces.
It turned out that several of the RMF parameter sets appeared to be inapplicable for the dynamical calculations of the fusion cross-sections. For the feasible parameter sets, we perform a quantitative comparison of the calculated above-barrier fusion excitation functions with the experimental ones for reactions involving spherical colliding nuclei.

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SUPERASYMMETRIC FISSION MODE OF ^{248,250}Cf, ^{254,256}Fm AND ^{260}No

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This work devoted to the study the mass and energy distributions of fission fragments to investigate the role of closed proton and neutron shells in the fission of 248,250Cf, *254,256Fm*, and ^{260}No nuclei [1,2,3,4] at excitation energies of 40–55 MeV. Experiments are performed on the U-400 cyclotron at the Flerov Laboratory of Nuclear Reactions (Dubna, Russia) using the CORSET double-arm time-of-flight spectrometer [5].
To study the role of the multimodal fission the mass and energy distributions of fission fragments formed in the reactions ^{16,18}O+^{232}Th, ^{238}U, and ^{22}Ne+^{232}Th, ^{238}U at energies around the Coulomb barrier have been measured. It was found that at these energies the mass and energy distributions

of fragments exhibit the multimodal structure, which results in the larger variance of the mass distributions.

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SPECTROSCOPIC STUDY OF DECAY PROPERTIES OF TRANSFERMIUM ISOTOPES IN DUBNA

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Important information on the structure of Super Heavy Elements (SHE) can come from the study of lighter deformed transfermium (Z ~ 100–106) elements. The cross-section for the formation of these nuclei is many orders of magnitude higher than for Z ≥ 110 so that detailed spectroscopy becomes possible.
The opportunity to have high intensity (>1 pμA) accelerated beams with A ≤ 50 together with the use of exotic targets provide the possibility to study many aspects of heavy ion induced reactions exploiting new generation of high efficiency, high resolution experimental setups.
In recent years α-, β- and γ- spectroscopy of heavy nuclei at the focal plane of recoil separators ("decay spectroscopy") has been very intensively developed. The mixing of α decay with γ and β decay spectroscopy allows to investigate single particle states behavior as well as the structure of little known elements in the Z = 100–104 and N = 152–162 region.
Using SHELS recoil separator and GABRIELA (Gamma Alpha Beta Recoil Invetsigations with the ELectromagnetic Analyser) detector set-up the experiments aimed to the gamma and electron spectroscopy of the Fm – Db isotopes, formed at the complete fusion reactions with heavy ions ^{22}Ne, ^{48}Ca, 50Ti and 54Cr were performed at FLNR JINR.
At the years 2017–2019 we performed model experiments using method of high resolution alpha, EC and γ spectroscopy to study decay properties of 254,255,256,257Rf in the reactions 50Ti + ^{206,207,208}Pb $\longrightarrow$ ^{256,357,258}Rf, ^{250,252,254}No in the reactions ^{48}Ca + ^{204,206,208}Pb $\longrightarrow$ $^{252,354,256}No$ and ^{256}No in the reaction ^{22}Ne + ^{238}U $\longrightarrow$ ^{260}No*.
Future developments and perspectives of experimental studies in spectroscopy of heavy and superheavy elements are discussed.

REGISTRATION OF DELAYED NEUTRONS FROM ^{238}U PHOTOFISSION AT E_{max} ≈ 10 MeV IN INTERVALS OF ~ 1.5 ms AFTER BEAM PULSES OF THE ELECTRON ACCELERATOR

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Studies of production and properties of nuclei near the stability boundary with respect to neutron emission are an important part of modern nuclear spectroscopy (see, e.g., [1]). In fission of actinide nuclei, neutron-rich nuclei are produced (especially in short-lived light fragments formed in asymmetric fission at low energies of bombarding particles). In small part of beta-decays of these fragments-precursors (with values of their half-lives T1/2) highly excited states of daughter-nuclei are populated, for which in some cases it may be possible to emit delayed neutrons. Usually, for convenience of description, several groups of nuclei-precursors are introduced according to their T1/2 values of which until now have been not less than 0.2 s [2, 3]. But for an adequate description of critical systems (e.g., their reactivity) it is very important to look for precursors with T1/2 down to ~1 ms [3].
In our previous work [4] the measurement was performed from 4.5 ms after the beam pulse. And it seemed that for photofission of ^{238}U at Eg max about 10 MeV there is indication for existence of short-lived nuclei-precursors with T1/2 ~ 1 ms. In the present work we continued studies in this direction.
Measurements were made at the pulsed linear electron accelerator LUE-8-5 of the INR RAS [5] at the energy of incident electrons Ee about 10 MeV and beam repetition rate 100 Hz. The scintillation fast neutron spectrometer with pulse shape discrimination of background g-quanta (see [6] and references therein) was used. The controlled divider of photomultiplier tube of the scintillation detector [7] had to be used to decrease negative influence of big light output near the beam pulse time. Delayed neutrons and g-quanta were registered in interval from 1.5 ms after beam pulse to 9 ms with average beam currents about 16 nA.
The statistical uncertainties of the data, obtained so far in this way, do not allow us to distinguish existence of nuclei-precursors of delayed neutrons with T1/2 ~ 1 ms.

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CHARGED PARTICLES EMISSION IN FAST NEUTRONS PROCESSES ON MO ISOTOPES

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The Molybdenum nucleus, (protons numbers Z=42 and mass A= 83-115) has 33 isotopes of which 7 are natural (A=92, 94, 95, 96, 98, 100) and four isomers. The first 6 natural isotopes are stable but the nucleus with A=100 is unstable with the time of life of 7.8 ⊠ 1018 y. The isotopes with A=100 is a fission product and it is used in medicine.
Nuclear reactions induced by fast neutrons are of great interest for fundamental and applicative researches. For fundamental investigations fast neutrons reactions are a source of new data on nuclear reactions mechanism and structure of nuclei. For applications these reactions provide precise nuclear data for reactors technology (fission and fussion), processing of long live nuclear waste, reprocessing of U and Th for transmutation and energy projects, accelerated driven systems (ADS) etc. Fast neutrons cross sections data for charged particles emission are of interest also because, the accumulation of Hydrogen and Helium in the walls and vessels of nuclear facilities lead to the modification of their physical properties.
Neutrons are neutral elementary particles and therefore they have high penetrability power in the matter. This property is very useful in neutrons activation analysis because it is possible to analyze large solid samples. Furthermore, the emitted gamma quanta resulted in the neutron capture process emerging from the samples can be also registered. Instrumental Neutron Activation Analysis (INAA) performed with slow neutrons is a powerful tool for elemental analysis. Complemantary to INAA is Fast Neutrons Activation Analysis (FNAA) method which allows to obtain better gamma emitters.
The following reactions 94Mo(n,p)94Nb and 95Mo(n,np)94Nb induced by fast neutrons were analyzed. Cross sections, isomers ratios, parameters of nuclear optical potentials were also evaluated. The 94Nb isotope can be found in the radioactive wastes. This nucleus is unstable, has a very large time of life (T1/2 = 20300 y) and contributes to the low level geological activity of the environment due the buried wastes.

ASTROPHYSICAL PRODUCTION OF P NUCLIDES IN THE FAST PROTON INDUCED P - PROCESSES

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The fast proton induced p – processes reactions play a key role in the astrochemical elements yields of the big bang nucleosynthesis for standard cosmology. Astrophysical concurrence of several p - process mechanisms in the production of p – nuclei was analyzed for proton energy up to 25 MeV. Cross sections of proton induced reactions and contribution of each nuclear reaction mechanism for each process are evaluated theoretically and measured experimentally at Electrostatic Generator EG-5 from FLNP for incident protons up to 5 - 10 MeV. For protons up to 4-8 MeV compound processes are dominant and they are described applying Hauser – Feshbach statistical approach. At higher energies direct and pre-equilibrium mechanisms cannot be neglected. Contribution to the cross section of direct mechanism was determined using DWBA approach and pre-equilibrium processes by exciton model. Parameters of optical potential and levels density for incident and emergent channels were also extracted. Cross sections, parameters of potentials and levels density are of a great importance for astrophysical reactions rates estimation and for estimation of the astrochemical elements abundance.

The statistical uncertainties reduction was done by Talys using a Bayesian Monte Carlo procedure based on the EXFOR database and they were in fair agreement with the standards. The uncertainties in the nuclear element abundances originating from the combined effect of experimental and theoretical errors leading to total uncertainties in the final abundances were determined.
Present results are obtained in the frame of the bilateral scientific JINR - Romania projects dedicated to nuclear reactions for astrophysics developed at JINR Dubna basic facilities.

EFFECT OF NONLOCALITY OF THE IMAGINARY PART OF THE DISPERSIVE OPTICAL MODEL POTENTIAL ON CROSS SECTION OF THE (d,p) REACTION

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The dispersive optical model potential (DOMP) for stable Ca and Zr isotopes was found fitting to the experimental data on the nucleon scattering, single-particle properties, charge density distributions, charge root-mean square radii and neutron skin thickness for $^{40-48}$Ca and $^{90-96}$Zr isotopes. In the present study, the distorted wave Born approximation (DWBA) and the adiabatic-wave approximation (ADWA) with DOMP were used to calculate the cross sections of the (d,p) reaction on stable isotopes of the above mentioned nuclei and a good agreement with the experimental data was achieved. It was shown that taking into account of nonlocallity of the imaginary part of DOMP sufficiently affects spectroscopic factors of (d, p) reaction. Also, the dispersive optical model [1] is expected to be very useful for study of reactions with rare isotopes.

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THEORETICAL PREDICTIONS OF THE FRAGMENT AND PROMPT NEUTRON CHARACTERISTICS IN THE SPONTANEOUS FISSION OF SUPERHEAVY NUCLEI

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The consistent theoretical model for the calculations of the mass, charge and energy of fission fragment and the prompt fission neutron energy and multiplicity distributions [1, 2] is applied for the description of the spontaneous fission of the superheavy nuclei. The prompt fission neutron characteristics are formed during emission at descent from the fission barrier to the scission point and the evaporation from the fully accelerated heated fragment after neck rupture. The neutron emission during the saddle-to-scission descent time is important in the spontaneous fission of the heavy elements with Z > 96. For accurate calculations of nucleon composition and excitation energy of the fissioning nucleus at the scission point, the time-dependent statistical model with inclusion nuclear friction effects was used. Monte Carlo simulation method is used to describe the neutron emission at the limited descent time.

For each member of the compound nucleus ensemble at the scission point, the primary fission fragment characteristics: kinetic and excitation energies and their yields are calculated using the scission-point fission model with deformed nuclear shell and pairing effects. Isovector quantal excitations during the collective motion from saddle to scission point influence on the charge polarization and charge splitting between fission fragments. The charge distribution of the primary fragment isobaric chain was considered as result of the frozen quantal fluctuations of the isovector nuclear matter density at the finite scission neck radius in the harmonic approximation [3]. The collective isovector potential was calculated for the di-nuclear system of deformed fragment at the minimum of potential energy at scission point. The deformation energy at scission point is calculated using the macroscopic-microscopic approach. The average charge asymmetry and the stiffness parameter of the collective potential were obtained by the parabolic approximation of the calculated potential energy at the fixed mass asymmetry. The charge width of the fission fragment isobaric chain are determined mainly by the of collective ground-state wave function. Results of calculations of the spontaneous fission characteristics of the superheavy nuclei of element chains with $104 \leq Z \leq 118$ will be presented.

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RECENT STUDIES ON PRE-COMPOUND EMISSION IN LIGHT AND HEAVY ION REACTIONS AT LOW ENERGIES

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The pre-compound (PCN) emission has been one of the important mechanisms both in light and heavy ion reactions at relatively high energies above 10 MeV/A. Recent observations of PCN emission even at low incident energies below 10 MeV/A, where evaporation process dominates, have renewed interest to carry out further research in the aforesaid reaction mechanism[1-2]. Plenty of experimental data on PCN processes is available but no systematics has been developed with mass number of target nuclei and excitation energy. In order to develop a systematics for PCN process, the excitation functions of the reaction residues produced in the interaction of alpha beam with target nuclei 51V, 55Mn, 93Nb, 121Sb, and 123Sb, 159Tb, 169Tm, 181Ta and 197Au have been studies. However, to see some systematics in heavy ion reactions, the reaction residues produced in the interaction of ^{12}C and ^{16}O projectiles with target nuclei 159Tb, 169Tm and 181Ta have been investigated at varying energies from near the Coulomb barrier to below 8 MeV/nucleon.
The experiments for alpha induced reactions have been performed at the Variable Energy Cyclotron Centre (VECC), Kolkata and the Inter University Accelerator (IUAC), New Delhi has been used to investigate ^{12}C and ^{16}O beam reactions with heavy target nuclei. A systematics of the pre-compound process has been developed both for alpha and heavy projectiles at low energies. Further details

will be presented.

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TEST OF THE ^{16}O(^{10}B,^{9}Be)^{17}F REACTION FOR ANC ^{17}F→^{16}O+p OBTAINING

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In this work the measurements of the differential cross sections (DCS) of the reaction ^{16}O(^{10}B,^{9}Be)^{17}F have been carried out at ^{10}B ions beam of the C-200P cyclotron of the Heavy Ion Laboratory (University of Warsaw) with the energy $E_{^{10}B}$=41.3 MeV. The purpose of the experiment is to find out the suitability of this reaction near the Coulomb barrier to extract the ANC values to use in the calculations of astrophysical S- factors of proton radiative capture.
Thin Al2O3 self-supporting film with the thickness of ~0.15 mg/cm2 was used as a target. The charged particles were detected and identified by four ΔE-E counter telescopes which were installed in the ICARE experimental chamber [1]. The spectra were analyzed with the use of ROOT [2] software. A typical two–dimensional spectrum (ΔE, E) is shown in Fig. 1.

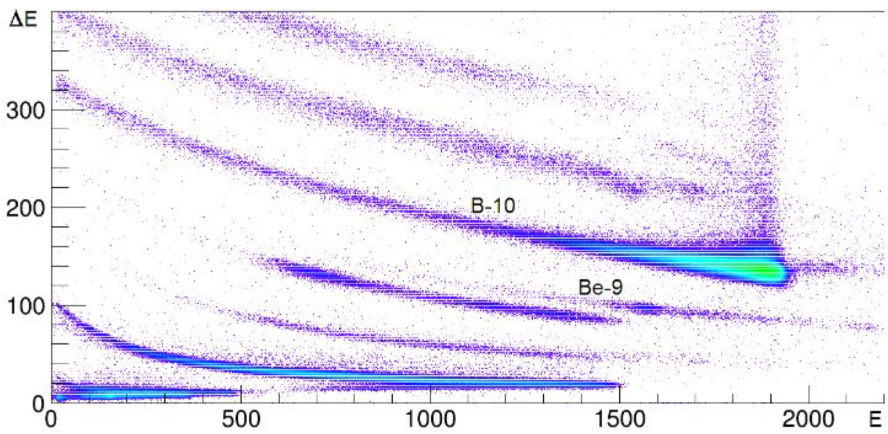

Figure 1: Two-dimensional $(\Delta E, E)$ spectrum at irradiation of Al_2O_3 target by ^{10}B ions

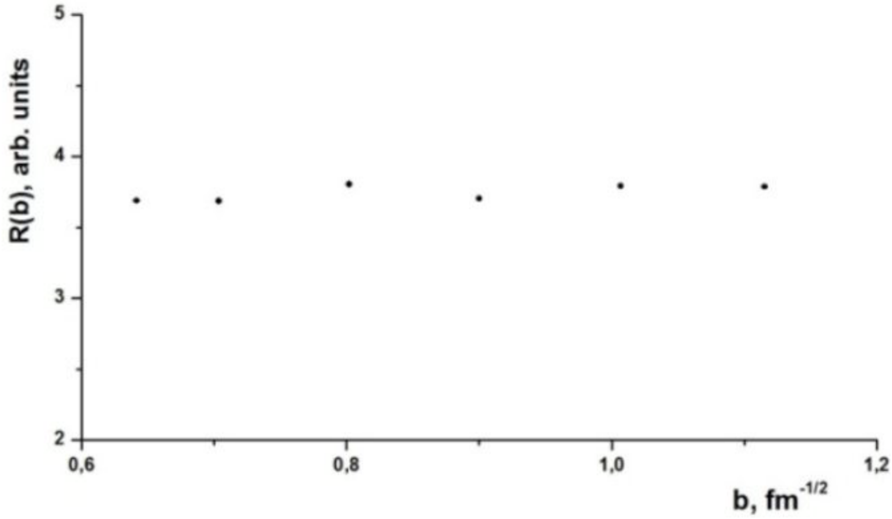

Figure 2: Testing function $R(b)$ for the $^{16}\mathrm{O}\left(^{10}\mathrm{B},{}^{9}\mathrm{Be}_{\mathrm{gs.}}\right)^{17}\mathrm{F}_{\mathrm{g.s.}}\mathrm{DCS}$ at $\theta_{\mathrm{c.,m.}}=11^{\circ}$

The analysis of the ^{16}O(^{10}B,^{9}Beg.s.)^{17}Fg.s. reaction by testing function R(b) of MDWBA approach [3] shows that the proton transfer has peripheral character at the forward hemisphere of the ^{9}Be escape as the function R(b) is practically constant at varying the values of geometry parameters of the Woods-Saxon potential within the physically reasonable range (see Fig. 2). So the DCS of the reaction should be calibrated by the product of the ANCs squares (C^{10}B⟶^{9}Be+p)2×(C^{17}F⟶^{16}O+p)2 in accordance with MDWBA. As the ANC value C^{10}B⟶^{9}Be+p is rather well known from [4,5], one can obtain the ANC for the ^{17}F⟶^{16}O+p.

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EXPERIMENTAL STUDY OF HALO IN ISOBAR-ANALOG STATES

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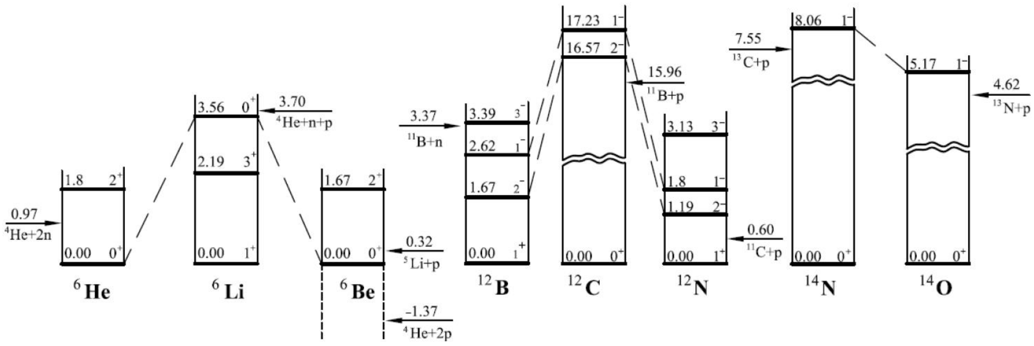
One of the most striking discoveries in nuclear physics made at the end of the last century was the discovery of the neutron halo in the ground states of some light nuclei located near the neutron stability boundary.

The discovery of the halo led to a revision of many existing ideas in nuclear physics. The purpose of this research is to search and study halo in isobar - analog states of light nuclei. The study of states with a halo in isobar analogs allows one to investigate the manifestation of isotopic invariance at new objects and to relate the properties of the neutron and proton halo. The question of the existence of halo in isobar - analog states has so far not been practically raised in the experimental plan.

The proposed approach is based on measuring the radii of states in which the halo exists or can exist. Its first application made it possible to determine the proton halo in an unbound state of ^{13}N.

Isobaric invariance leads to the fact that the states of two neighboring nuclei obtained by replacing a neutron with a proton are analogous, i.e. have in the first approximation the same structure. In the case of isobar analogs having a halo, the situation is more complicated, since such a change leads to a change in the thresholds that determine the very fact of the appearance of the halo. The data on the radii can give new information for solving the long-standing problem of a single description of the halo in both parts of the spectrum - discrete and continuous. It is proposed to solve problem: Experimentally determine the radii of a number of states in which there can be a halo in nuclei from ^{6}Li to ^{14}O, forming isobar - analog doublets and triplets. The figure shows the studied isobar-analog states of ^{6}Li, ^{6}Be, ^{12}B, ^{12}C, ^{12}N, ^{14}N and ^{14}O. Arrows indicate decay thresholds.



DETERMINATION OF PHOTONEUTRON PRODUCTION FROM DIFFERENT TARGETS IRRADIATED BY ELECTRON BEAM

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This research focused on photoneutron production determination using three different photoneutron converters BeO, LiCl, D2O. Experiment was carried out on a linear electron accelerator [1] in A. Alikhanyan National Laboratory in Yerevan, Armenia. A set of targets was irradiated by 70 MeV electron beam. Reaction rates were determined as a result of investigations. Besides experimental results, a number of simulations were also conducted using MCNP software [2] to determine reaction rates and they were compared with ones obtained from the experiment.

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DYNAMICS OF THREE-NUCLEON SYSTEMS AT 100 MEV

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The dynamics of the three-nucleon system can be very extensively tested by means of the deuteron-proton breakup reaction. Experimental studies of the dp system expose various dynamical ingredients, like three-nucleon force (3NF) and Coulomb force, which play an important role in correct description of observables (e.g. cross section). It is worth to underline that experiments with polarized beams (or targets) give opportunity to study a large number of observables sensitive to various dynamical components, which are hidden in the unpolarized case. All studied observables (e.g. vector and tensor analyzing powers [1]) are interesting for testing theoretical calculations based on various approaches [2 - 5] to model the interaction in three-nucleon systems. Moreover, studies of the dp breakup reaction at low energy are very crucial for testing The Chiral Perturbation Theory [6] (calculations for the nucleon-deuteron breakup reaction at low energies will be available soon).
The presentation will concentrate on testing the 3NF and the Coulomb force effects for the differential cross section of the 1H(d, pp)n reaction at beam energy of 100 MeV. The experiment was performed at KVI in Groningen, with the use of the BINA detector [1,7].

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ASTROPHYSICAL S-FACTOR OF THE DIRECT ^{3}He(α,γ)^{7}Be CAPTURE REACTION IN CLUSTER MODELS

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The direct ^{3}He(α,γ)^{7}Be radiative capture reaction is studied in the framework of two- and three-body potential cluster models [1,2]. E1 and E2 transitions are described at the long-wavelength approximation. The two-body model is based on a simple Gaussian form α^3He-potential of Dubovichenko V_D^a from [1], with a modification in d waves. The new potential parameters are

V_0=-180 MeV, α=0.4173 fm^{-2} and V_0=-190 MeV, α=0.4017 fm^{-2} in the $d_{3/2}$ and $d_{5/2}$ partial waves, respectively. The potential describes correctly the phase shifts in the s, p, d and f waves and binding energies of the ground $p_{3/2}$ and the first excited $p_{1/2}$ bound states. As can be seen in Fig.1, the modification of the potential in d waves allows to improve the description of the astrophysical S factor for the direct ^{3}He(α,γ)^{7}Be radiative capture reaction at intermediate energies E>0.5 MeV in comparison with the results of [1]. In the three-body model the ^{7}Be nucleus is described as a bound state of α+p+d in the Hyperspherical Lagrange mesh method. The initial state is factorized into the p+d bound state and the α+^{3}He scattering state. The αd-potential is from [2], while αN-potential was taken from Ref.[3]. The pd-potential of the Gaussian form [4] with parameters V_0=-34.92 MeV, α=0.15 fm^{-2} and V_0=2.4 MeV, α=0.01 fm^{-2} are used in the even and odd partial waves, respectively. The α^3He-potential is the same as in the two-body model. The three body bound state wave functions of ^{7}Be was corrected at R=6 fm with the help of the Whittaker asymptotics.

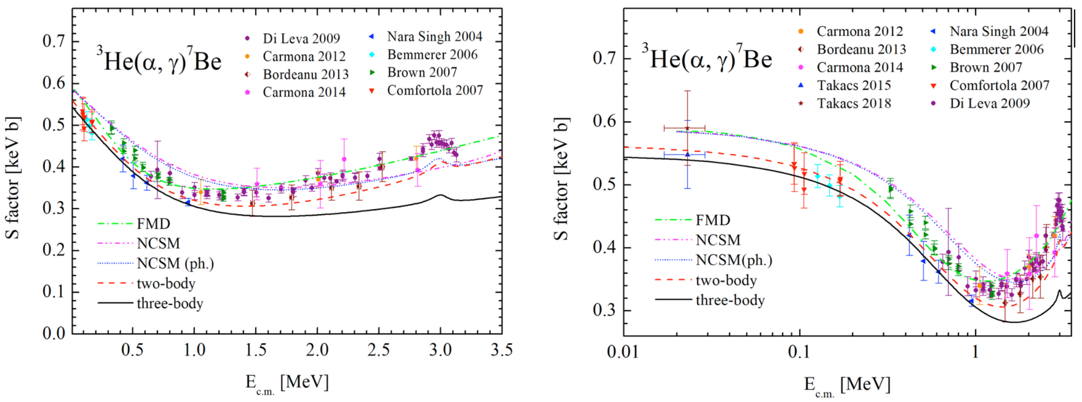

Figure 1: (a) Astrophysical S factor within the two- and three-body models in comparison with the available experimental data. Panel (b) highlights the low energy region.

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SPONTANEOUS FISSION of ^{252,254}No ISOTOPES

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Several experiments aimed to investigate properties of short-lived SF nobelium isotopes we carried out in FLNR. The neutron-deficient isotopes of nobelium were produced in fusion-evaporation reactions using ^{206,208}Pb target and an intensive beam of ^{48}Ca. Fusion-evaporation residues were separated by the SHELS separator and implanted into a large-area double-sided 48x48 strip silicon detector surrounded by 54 ^{3}He-counters of neutrons. The half-life and decay branching ratio for ^{252,254}No is measured. The average number of neutrons per spontaneous fission of ^{254}No is determined for the first time.

EXPERIMENTAL INVESTIGATION OF (N,α) REACTION CROSS SECTION FOR ZINC ISOTOPES

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The paper presents the (n,α) reaction cross section data for zinc isotopes (^{64}Zn and ^{66}Zn). The work was performed at the tandem accelerator IPPE.
In the work, special attention was paid to background neutrons arising from the solid deuterium target. The background component was investigated in detail using a digital neutron spectrometer based on the organic scintillator. The thickness of the targets was measured by Rutherford backscattering method. To register the products of the studied reaction, a new digital spectrometer was used, which made it possible to significantly reduce the contribution from background events. Measurements were carried out in the energy range from 3.5 to 7.5 MeV. The data obtained for the isotopes of zinc-64, 66 are compared with the available experimental data of other authors and the estimated data of different libraries.

Section 3. Modern nuclear physics methods and technologies

PRODUCTION OF IONIZING RADIATION SOURCE OF IRIDIUM-192 FOR NDT

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Studies have been carried out to determine the optimal modes of neutron activation of metal disks of natural iridium in reactor WWR-SM, and the radionuclide Iridium-192 with a specific activity of ~ 250 Ci /g Ir (up to 8 Ci per 1 disk of iridium) was obtained. Manufacture of ionizing radiation source Ir-192 by nuclear reaction Ir-191 (n,ϒ) Ir-192 began with the fact that 20÷30 pieces of natural iridium disks (∅=2.7mm, h=0.2mm, m=31.7mg) were placed in aluminum foil package using a special technology and package with iridium disks was placed in container (EK-10), which was placed in the central hollow part of the fuel assembly IRT-4M in the vertical channel of the WWR-SM reactor and was irradiated by neutrons in the following mode: the reactor nominal power is 10 MW; optimal place for target irradiation in the reactor core is 30–45 cm below the upper point of the IRT-4M ; reactor operating mode with periodic shutdowns; thermal neutron flux density is $\geq 0{,}7\cdot 10^{14}$ n/cm^2·sec; irradiation time is ≥550 hours. In the "hot cells", the irradiated target was placed in special installation, where radiochemical treatment was carried out of irradiated iridium disks, which were then placed in magnetic stainless steel capsule (∅= 4.5 mm, h = 8.0 mm) and after closing the lid the capsule was welded spot argon-arc welding. Leak test of the Iridium-192 source was made by the immersion method. Source specifications: activity of source is 50÷100 Ci, active part of Ir-192 source has dimensions ∅=3.0 mm, h=4.0 mm, the level of radioactive contamination on surface of source is <185 Bk (sealed source). Ir-192 source with Gammaride 192/120M was equipped in a protective chamber using special equipment: Ir-192 source was placed in a holder, which was rolled up, then connected to a flexible shaft and charged into radiation head of the Gammaride 192/120M. Ir-192 sources, complete with gamma flow detector, were used to conduct gamma-radiographic non-destructive testing (NDT) of welds of various structures and pipelines at the construction of thermal power plants and gas processing plants. X-ray images were obtained (see Fig. 1), which in terms of sensitivity and quality correspond to the requirements of Russian standards (GOST-7512-82. "Non-destructive testing. Welded connections. Radiographic method") and USA standards (ASME).

Figure 1: X-ray picture of welded seam sample (∅=50.8 mm) received by ionizing radiation source of Ir-192.

EFFICIENCY AND ENERGY RESOLUTION CALCULATION UNDER DEVELOPING OF FAST NEUTRON DETECTOR WITH BORON-10 CONVERTER

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Under developing new position-sensitive ionization detector of fast neutrons with energies above 1 MeV events of ^{7}Li and ^{4}He nucleus emission from ^{10}B layer is simulated. Detector gives possibility to determine direction of nucleus emission due to signals from anode and pairs of cathodes and grids. Ionization signals from detector gas gaps is proportional to the partial and total ionization losses of the nucleus. Nucleus is identified and its energy is determined by above magnitudes. Energy of incident neutron is calculated from reaction kinematics. Expected relative resolution of neutron energy is $\sim 6\%$. Choice of high signal threshold suppresses registration of ^{4}He nucleus and other types of radiation and provides monotonic dependence of loss on ^{7}Li nucleus energy. Detector efficiency in the energy range from 1 to 7 MeV varies slightly and is estimated as ~ 10^{-7} [1, 2]. Thus, it becomes possible to determine energy and coordinates of neutron without measuring the time of flight.

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CLAS PHYSICS DATA BASE FOR THE PHYSICS ANALYSIS OF THE EXPERIMENTS WITH ELECTROMAGNETIC PROBES

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CLAS Physics Data Base (CLAS DB) has been developed in collaboration between the SINP at MSU and the Hall B at Jefferson Lab [1,2]. CLAS DB contains most experimental results on inclusive semi-inclusive and exclusive reaction off proton and nuclei obtained with the CLAS detector. The substantial part of these experimental results represent the only available in the world data sets. The results stored in the CLAS DB are of particular importance for exploration of the structure of the ground and excited hadron states offering the insight into strong QCD dynamics which underlie their generation from quarks and gluons [3,4]. The status of CLAS DB and the opportunities to use the available information for the research in hadron physics will be presented in the talk. In particular, the web-interface and the build-in tools for the customer data search and for extraction of semi-inclusive and exclusive structure functions in electron scattering will be presented. The work in progress on the development of the web resources for interpolation and extrapolation of inclusive/exclusive electron scattering observables [5] will be discussed.

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SILICON PIXEL DETECTORS FOR THE INNER TRACKING SYSTEM OF MPD EXPERIMENT AT THE NICA COLLIDER

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Today the studies of the hadron yields containing heavy quarks are of particular interest for high-energy physics. These yields are characterized by small cross-sections for interaction with the nuclear medium. As a result, for the processes of relativistic nuclear collisions the information about the states of nuclear matter (arising in such processes) could be obtained. In this case, the efficient identification of strange and charmed particles registered by the experimental setup plays an important role in the analysis of possible phase transitions. In addition, at the energies of the colliding nuclei which are accelerated in Nuclotron-based Ion Collider fAcility (NICA) [1], it is possible to study clusters of dense nuclear matter arising inside the nuclei. Therefore, for precise registration of short-lived particles produced in nucleus-nucleus collisions the Vertex detector based on silicon monolithic active pixel detectors (as a part of the Multi-Purpose Detector (MPD) experiment) was proposed.
In present overview the properties of silicon monolithic active pixel detectors (developed for the upgraded Inner Tracing System of ALICE experiment in CERN [2]) together with new ultralight, radiation-transparent carbon fiber support structures as basic elements for Vertex detector of MPD experiment will be discussed. To investigate the tracking efficiency and main characteristics of the silicon pixel detectors, the comprehensive studies with a variety of gamma, beta sources and also with cosmic rays were carried out.
Acknowledgments: the reported study was supported by RFBR, research project No. 18-02-40075.

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TAGS SPECTRA ANALYSIS AND BETA DECAY STRENGTH FUNCTION STRUCTURE

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Successful applications of the total absorption γ-spectroscopy ($TAGS$) for the β-decay strength function $S_\beta(E)$ resonance structure study, methods of $TAGS$ spectra interpretation, and results

of analysis of $S_\beta(E)$ structure for the Gamow-Teller (GT) β^+/EC and β^- -decays were summarized in [1,2]. Development of experimental technique allows application of methods of nuclear spectroscopy with high energy resolution for $S_\beta(E)$ fine structure measurement [2-4]. First results of the $S_\beta(E)$ fine structure study were summarized in [2,3].The combination of the $TAGS$ with high resolution nuclear spectroscopy may be applied for detailed decay schemes construction [2]. It was shown [2-4] that the high-resolution nuclear spectroscopy methods give conclusive evidence of the resonance structure of $S_\beta(E)$ for GT and first-forbidden (FF) β-transitions in spherical, deformed, and transition nuclei. High-resolution nuclear spectroscopy methods [2-5] made it possible to demonstrate experimentally the reveal splitting of the peak in the $S_\beta(E)$ for the (GT) β^+/EC-decay of the deformed nuclei into two components.
The operating principle of a total-absorption γ-spectrometer is based on summation of the energies of the cascade γ-rays produced after β-decay to excited levels of the daughter nucleus in 4π-geometry. There are two methods of the $TAGS$ spectra analysis [1]. In the first one it is necessary to identify the total absorption peaks in $TAGS$ spectra and have 4π-spectrometer with exponential energy dependence of the photoefficiency (i.e., the ratio of the number of pulses in the total absorption peak to the number of γ-ray incident on the detector) for γ-ray registration. Only in this case the efficiency of $TAGS$ peak registration does not depend on the details of decay scheme [1,3]. This method gives good results, but can be applied for nuclei with total β-decay energy Q_β less than $5-6MeV$. Quantitative characteristics may be obtain as a rule only for one (β^--decay) peak and for two peaks (β^+/EC-decay) in $S_\beta(E)$ [1-3].
The second method is based on so called response function application, but a lot of assumption must be done for extraction the $S_\beta(E)$ shape from the $TAGS$ spectrum shape. Analysis depends on the assumptions [1] about the decay scheme which as a rule is not known. It is very difficult to estimate the associated systematic errors of such analysis [1] and only qualitative information about $S_\beta(E)$ may be obtained.
$TAGS$ can't distinguish the GT and FF transitions and don't take into account the conversion electron emission, which give the systematic uncertainties, especially for high Z.
In this report some results of $TAGS$ spectra analysis are considered. It is shown that only combination of $TAGS$ with high resolution nuclear spectroscopy methods may give the quantitative information about $S_\beta(E)$.

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COOLING SYSTEMS FOR THE NOVEL PIXEL DETECTORS

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Today the silicon-based detector systems are playing a key role in experimental studies of the nuclear matter properties. Using thin silicon pixel detectors for the precise identification of charged particles opens completely new opportunities to investigate the states of nuclear matter arising in processes of relativistic nuclear collisions. For stable operational conditions of such detectors, the efficient mechanic and cooling systems at minimum material budget should be used.
In present work, the ideas and developments for mechanic and cooling systems for novel vertex detectors based on silicon pixel sensors have been presented.
The reported study was supported by RFBR, research project No. 18-02-40075.

FEATURES OF NICKEL-63 LARGESCALE PRODUCTION WITH NUCLEAR POWER PLANT

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Nickel-63 is perspective isotope to produce microsized radioisotope power source [1]. Advantage of nickel-63 is combination of long half-life (T1/2 = 100 y), low beta-particle energies and absence of accompanying gamma-emissions. In industry nickel-63 is produced by nuclear reactor irradiation of nickel-62 [2].
Nickel-63 has been produced with nuclear power plant irradiation of nickel-62. Initial nickel abundance was 99.36% of nickel-62 and chemical purity - 99.9%. After nickel-62 irradiation for 300 days in a power nuclear reactor a product with abundance about 1.5% has been obtained. Production of nickel-63 was accompanying by accumulation of lateral gamma-radioactive isotopes (^{60}Co, 46Sc, 59Fe, 65Zn, 51Cr, 117Sn, 54Mn, 124Sb) with activation of admixtures and via parallel nuclear reactions. The main doze-generating admixture was ^{60}Co with specific activity 1 mCi/g of product.
In order to use nickel-63 as a power source it has to contain minimal amount of such radioactive admixtures. Radiochemical purification of nickel-63 from radioactive admixtures was based on the principle of volatile tetratrifluorophosphine of nickel [3]. This allowed to obtain product with contamination of lateral gamma-radioactive isotopes lower than 1 μCi/g.
Measured activity values of nickel-63 and its accompanied admixtures has been compared with calculated ones to verify a computer code to predict a future nickel 63 production with use of other nuclear reactors.

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TUNING THE NEET PROBABILITY

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Of great interest are nuclides, in which there are excited state with extremely low energies, within the scale of e few eV or keV: ^{201}Hg, ^{189}Os, ^{237}Np, ^{235}U, ^{229}Th and other nuclides. Such levels are isomeric owing to small their energies. They effectively mix up with close atomic levels, forming resonances in the optical domain [1]. This gives the chance to operate with the lifetimes of these isomers in a resonant field of laser radiation. One can exploit various proper schemes of NEET – Nuclear excitation by Electron Transition for the purpose of producing the isomers through optical pumping, and measuring their precise energy [2]. Unlike the atomic spectra, the nuclear lines are stable against influence of external fields and environment. They possess rather narrow widths. These advantages do their use attractive in many aspects, including creation of reference points of frequency in the optical range. This gives basis for development new nuclear technologies, founded

on application of lasers for mastering nuclear processes. From such standpoint, one of the most perspective looks ^{229}Th, in which nucleus the splitting of the basic and excited levels is minimum and makes less than 10 eV. There are projects of creation of an atomic clock on this transition with an uncertainty within 10-21.
However, there is a problem induced by extremely small probability of NEET. In all the considered cases, it is ~10-8 and smaller. This makes extremely difficult the optical pumping of the isomer. We offer the way of enhancing this probability radically, up to values of the order of unity, by scanning the resonance defect with a laser, as proposed in Ref. [3] for inducing the isomer depletion.

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ABOUT THE RECOIL NUCLEI METHOD OF THE FAST NEUTRON SPECTRA MEASUREMENT WITH TELESCOPE OF SEMICONDUCTOR SI DETECTORS

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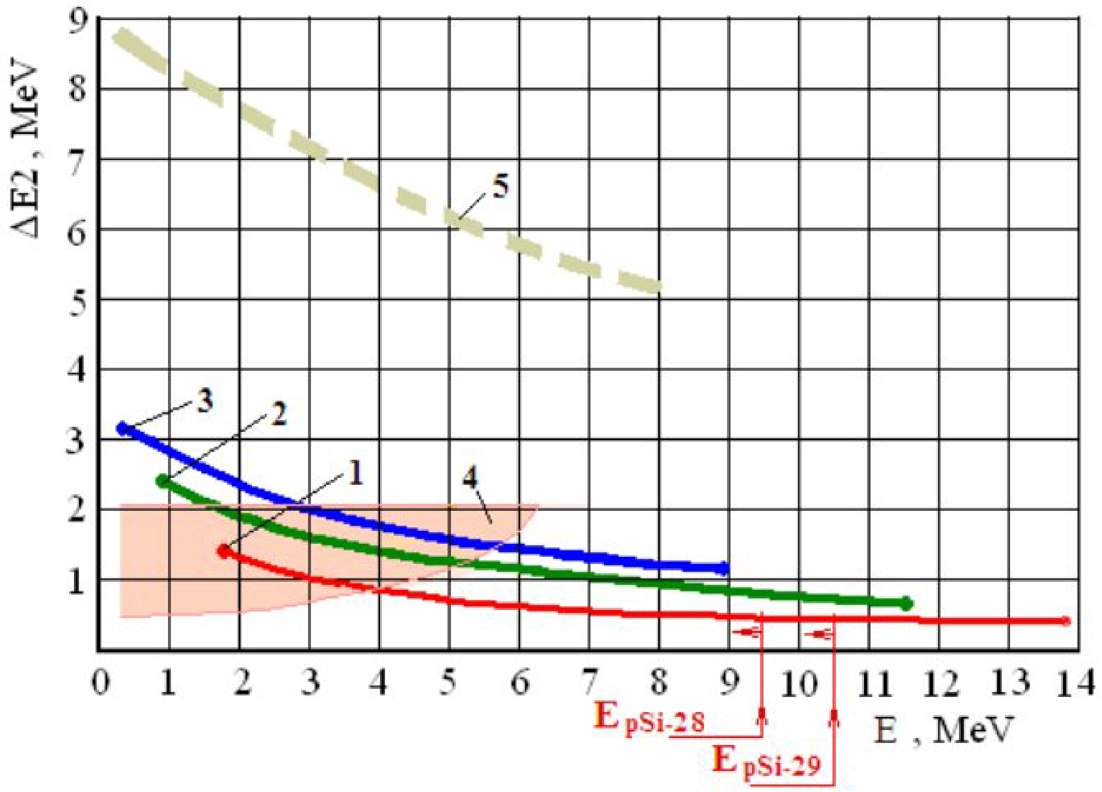
The method of measurements of fast neutron spectra by the hydrogen recoil nuclei is well known. However, when it is used, the problem of background reactions initiated by neutrons in the detector material arises almost always.
To specify these effects we performed a simulation of two-dimensional ΔE2 − E spectra formed when neutrons with energies <14 MeV are detected by a telescope of semiconductor silicon detectors, consisting of 2 passing detectors, ΔE1 and ΔE2, and a detector of E-losses. For generating the recoil nuclei a thin converter is proposed, containing three types of hydrogen isotopes (see loci 1-3 in Fig.). A charged particle arising from the interaction of neutrons with the material of converter or detectors is registered only when passing through all 3 detectors. It is shown that the telescope arrangement is optimal when deuteron-polyethylene film serves as a converter and the thicknesses of the telescope detectors are ΔE1 ~ 20 μm, ΔE2 ~ 60 μm, and E ~ 700 μm. One can see, that the reactions 28,29Si(n,p)28,29Al in the detector ΔE1 leave for the recoil protons detection without background only the region of the proton locus (1) above 10.5 MeV. The region of the deuteron locus that is suitable for the background-free detection of deuterons is much larger (Ed ~ 5.5 MeV ÷ 9.0 MeV which corresponds to En ~ 7.8 MeV ÷ 14.0 MeV). At that the main background reaction is the proton emission in the opposite direction from the ^{28}Si(n,p)^{28}Al reaction in the material of E detector (region (4) in Fig.). The reaction ^{28}Si(n,d)^{27}Al which occurs in the material of ΔE1-detector produces deuterons with energies lower than the above mentioned protons. For illustration, the triton locus (3) is also given at using tritium as a converter. It should be noted that tritons, ^{3}He ions, alpha particles which arise in the background reactions can't be detected by such telescope as their ranges are less than the summed thickness of the ΔE detectors (see hypothetic locus (5) of alpha-particles). In principle, the contribution of the above-mentioned background sources due to elements of the telescope itself can be estimated and subtracted under similar experimental conditions when irradiated with neutrons without a converter.
Such detecting system was made and tested at the 14 MeV neutron flux of the neutron generator NG-150 of the INP AS (Uzbekistan).



NUCLEI PRODUCED FROM ^{238}U IRRADIATED BY SECONDARY GAMMA INITIATED BY ELECTRON BEAM (E = 140 MEV)

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The experiment was carried out at the electron accelerator (JINR, Dubna).
We studied the reaction products inside thin ^{238}U sample irradiated by secondary gamma created from lead target by electron beam [1,2].
The mass distribution of uranium fission products on electron beam at energy of 140 MeV is shown in Fig. 1.

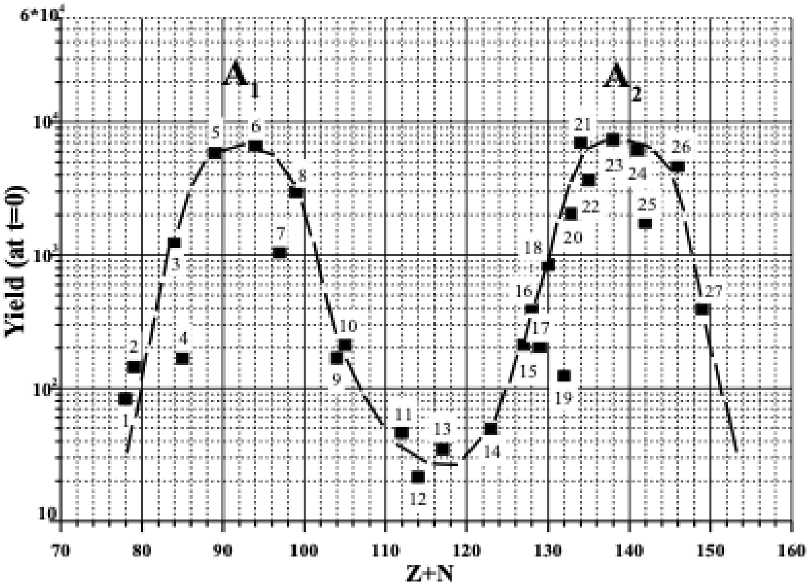

Figure 1: Fission product yield of ^{238}U electron beam E_{e-}= 140 MeV: 1- ^{78}Ge, 2- ^{79}Kr, 3- ^{84}Br, 4- ^{85}Kr, 5- ^{89}Rb, 6- ^{94}Y,^{94m}Tc, 7- ^{97}Zr,^{97}Nb, 8- ^{99}Pd, 9- ^{104}Cd, 10- ^{105}Rh, 11- ^{112}Ag, 12- ^{114m}In, 13- ^{117}Sb, 14- ^{123}I, 15- ^{127}Sn, 16-^{128}Sn, ^{128}Sb, 17- ^{129}Sb, 18- ^{130}Sb, 19- ^{132}I, 20- ^{133}I, ^{133}Te, 21- ^{134}I, ^{134}Te, 22- ^{135}I, ^{135m}Xe, 23- ^{138}Cs, 24- ^{141}Ce, ^{141}Ba, 25- ^{142}La, 26- ^{146}Pr, 27- ^{149}Nd.

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STANDARD THEORY OF SCINTILLATION SPECTROMETERS WITH ONE PHOTODETECTOR

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The current theory of scintillation spectrometers with one photodetector, the quintessence of which is generalized in the book [1], has a number of fundamental drawbacks. The correct mathematical description of the process of converting the energy of a primary particle into the signal at the output of a scintillation spectrometer allows overcoming these drawbacks. In this work, the mathematical model that serves as the basis of the standard theory of scintillation spectrometers with one photodetector was formulated. This theory allows obtaining the formulae for arbitrary moments of the distribution function of the signal at the output of the scintillation spectrometer with one photodetector. In particular, the formulae for the average value of the amplitude and the variance of the signal at the output of the photodetector are obtained. The structure of the formula for the energy resolution of a scintillation spectrometer with one photodetector reveals the contributions of the processes that take place at converting the energy of a primary particle into the output signal, particularly the contribution associated with the nonlinearity of the scintillator light output. It was shown that in the developed standard theory of scintillation spectrometers with one photodetector there are no drawbacks of the current theory of scintillation spectrometers.

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THE DEPENDENCE OF SPATIAL LOCATION AND SIZE OF NEUTRON FLUX ON THE MAXIMUM NEUTRON ENERGY

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The spatial distribution of neutrons with the maximum energies from 3.3 to 5.3 MeV was investigated using a two-coordinate ^{10}B detector. The detector was located at the 119 cm distance from the 1000 cm3 beryllium target at the output of on electron accelerator based photoneutron source. Between the ^{10}B detector and the target the collimator of 3 cm diameter was located. The contribution of slow neutrons was suppressed by 0.5 cm thickness cadmium filter. The ^{3}He counter behind the ^{10}B detector was used to take into account the contribution of the background of slow neutrons. From the kinematics of the ^{9}Be $(\gamma$, n)^{8}Be reaction it follows that an increase in gamma-ray energy by 1 MeV entails an increase in neutron energy by 0.9 MeV.
The maximum intensity of the neutron flux measured along the horizontal axis shifts back relative to the direction of the primary electron beam with increasing electron energy and, accordingly, with the maximum neutron energy, as shown in Fig. 1. The position of the maximum intensity of neutrons distribution is associated with a maximum of neutron energy in the flux. In addition, one may note that the width of the neutron intensity distribution in the flux increases with increasing maximum neutron energy. It is possible that these effects can be used to control the maximum neutron energy in the stream at the output of the source collimator.

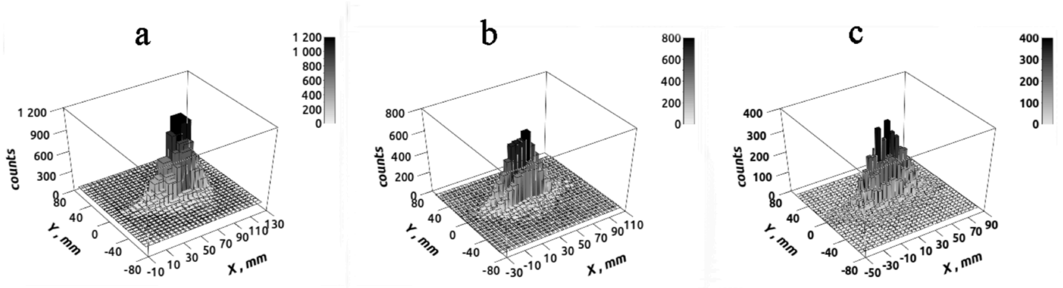

Figure 1: Distribution of neutrons in the flux with the maximum energy: a) 3.3 MeV; b) 4.3 MeV and c) 5.3 MeV.

ON THE POSSIBILITY OF CONTROL THE MAXIMUM ENERGY OF FAST NEUTRONS BY THE PULSE HEIGHT SPECTRA OF THE ^{10}B-DETECTOR

Author: Stanislav Potashev[1]; Yuri Burmistrov [1]; Aleksey Afonin [1]; Alexandr Drachev [1]; Evgene Konobeevski [1]; Victor Marin [1]; Igor Meshkov [2]; Sergey Karaevsky [1]; Alexander Kasparov [1]; Vasily Ponomarev [1]; Gennady Solodukhov [1]; Sergei Zuyev [1]

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The possibility of control the maximum energy in the neutron flux by analyzing the pulse height spectra of the ^{10} B-detector [1] was investigated. Two possible nuclear reactions were considered: direct reaction and reaction throuh the exited ^{11}B* nucleus with the production of ^{4}He and ^{7}Li. The ionization losses of nuclei in two detector gaps were calculated. A change in the ionization loss spectrum of the ^{4}He, ^{7}Li nuclei and their sum, depending on the neutron energy and the detection threshold in the second sensitive ionization gap of the ^{10}B detector was found.
The measurements were performed at the output of the collimated channel of a compact neutron source based on the electron accelerator at several energies from 5 to 9 MeV. By increasing the detection threshold in the second gap of the detector, the signal of which served as the trigger, the contribution of events with the registration of the ^{4}He nuclei can be suppressed in comparison with the contribution of the ^{7}Li. The position of the maximum in the pulse height spectrum from the first gap of the detector and in the calculated spectra of ionization losses shifts with increasing of electron energy, the boundary energy of γ-quanta, and the maximum neutron energy. It is possible that this fact can be used to control the maximum neutron energy in the flux.

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APPLICATION OF BM@N SI-MICROSTRIP DETECTORS AT MUON STAND FOR TESTING STRAW DETECTORS

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After BM@N technical run in spring 2018, the first physical stage of the experiment will begin in 2021. For stop time Silicon tracking modules of BM@N Forward Silicon Detector are applied at muon stand to test and measure R-t characteristics of straw detectors (6 mm diameter, produced by JINR, Dubna) by reconstructing cosmic rays tracks (based on bmnroot software). Muon stand consists of Triggering scintillators, Silicon tracking planes, Straw detectors and Data Acquisition System. Si modules based on Double-sided Silicon Strip Detectors (DSSDs, pitch 95 μm p+ side and 103 μm n+ side, stereo angle between strips is 2.5o) are used as external tracking system in muon stand. General view of stand, Si-modules description and first measurement results are presented.

THE DEVELOPMENT OF SILICON BEAM TRACKER AND BEAM PROFILOMETER AT THE BM@N EXPERIMENT

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The BM@N is a fixed target experiment for studies of baryonic matter at the Nuclotron (JINR, Dubna). According to upgrade plans for BM@N, vacuum beam pipe will be added into experimental setup. To determine the coordinates of incident "trigger ion" and to tune the beam, it is necessary to develop three coordinate stations of beam tracker and two coordinate stations of beam profilometer respectively. Each station of beam tracker or beam profilometer will be based on Double-sided Silicon Strip Detector (DSSD) with 175 μm thickness and following number of strips: 128x128 is for tracker and 32x32 – profilometer. Front-end electronics for these Silicon Detectors are based on the multichannel IDEAS (Integrated Detector Electronics AS, Norway) ASICs. Overview of developing system is presented.

SEGMENTED SEMI-CONDUCTOR SPECTROMETER FOR STUDYING OF α-β-γ ANGULAR CORRELATIONS IN 4π-GEOMETRY

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New semi-conductor spectrometer dedicated to study of α-β-γ angular correlations in 4π-geometry was created in close cooperation between JINR and Baltic Scientific Instruments. The main part of the spectrometer is an HPGe detector that has a segmented N-area with six segments. Each of the segments has an energy resolution (FWHM) better than 1 keV for the energy 122 keV ($\gamma-$ line of Co-57) and better than 2 keV for the energy 1332 keV ($\gamma-$ line of Co-60). The HPGe crystal has cylindrical coaxially drilled hole in the middle. Diameter of the through hole is 23 mm. The through hole and the crystal segmentation allow investigate γ γ-coincidences in near 4π-geometry. Sensitive volume of the HPGe detector is 70 cm^3, diameter and height of the crystal are 50 mm. Second part of the spectrometer is segmented Si-detecstrong texttor placed in the through hole. It is gives an opportunity to study coincidences of $\gamma-$ quanta with $\alpha-$ and $\beta-$ particles.
This work was supported by the grant AYSS 20-203-04.
The work was partly supported by RFBR grant N 18-02-00159 A.

STUDYING A POSSIBILITY OF NEUTRON-ACTIVATION DETERMINATION OF RHENIUM CONTENT IN RADIOACTIVE ROCKS

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Existing chemical procedures are characterized by ambiguity in determining the content of rhenium due to competing manifestations of other elements. There is a need to develop independent methods for the analysis of rhenium-containing rocks. The complexity of this analysis also lies in the presence of naturally radioactive elements in the samples.
The composition and content of non-radioactive elements in ore samples of the Briketno-Zheltukhinskoe U-Mo-Re deposit [1] were determined using neutron activation analysis. Rock samples were irradiated by neutron flux of the IN-LUE photoneutron source of INR RAS [2].
Measurements of the samples activity were carried out using a low-background gamma-ray spectrometer [3], which included a high purity germanium (HPGe) detector placed in a low-background chamber with "passive" protection. The use of such spectrometer allows comparative measurements of both gamma spectra of natural radioactivity of samples and their activation spectra.
A comparative analysis of these spectra showed that in the range up to 200 keV they have a simple form. In the activation spectra, there are several noticeable peaks corresponding to short-lived (^{188m}Re, 18.6 min) and long-lived (^{186}Re, 89 h; ^{188}Re, 17 h) rhenium isotopes that do not overlap with background peaks and peaks from other elements. The peak corresponding to the 155 keV state of ^{188}Re with a half-life of 17 hours should be considered as the most convenient for analytical purposes.
An analysis of activation gamma spectra indicates the possibility of an unambiguous determination of rhenium against the background of accompanying elements, which makes the neutron activation analysis acceptable for determining the rhenium content.
The reported study was funded by RFBR, project number 19-35-90095.

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CARBON NANOMATERIALS APPLICATION FOR ISOL-METHOD OF HEAVY ION FUSION REACTION PRODUCTS

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The experiment directed to the study of a new carbon nanomaterials application was performed on the U-400M heavy ion beam at MASHA facility, FLNR, JINR. In the present speech a new technical improvements will be discussed such as usage of thin carbon nanotubes paper (thickness 6.4 mg/cm2) and graphene (thickness 1.1 mg/cm2) in reaction products catcher block unit. The main goal of the experiment was to determine radiation resistance of these materials for ISOL method. Previous experimental researches performed with thermally expanded graphite hot catcher showed an incompatibility with high intensity beams [1]. Measurements via new carbon nanomaterials showed also decreasing of the separation time for mercury in reaction ^{144}Sm(^{40}Ar, xn)184-xHg. Thus, it became possible to gain statistics and to analyze 6n-evaporation channel decays (^{178}Hg) with the $T1/2$=0.266 s at the focal plane data acquisition system. Early separation time measurements performed by beam interruption method [2] showed average separation time for mercury 1.8±0.3 s. The improvements of ISOL method application allow synthesizing new products at the beam intensities up to 0.5 pmkA and even more for the SHE factory perspective. Consequently, the experiment with carbon nanotubes paper demonstrated perspectives for the fusion reaction products separation at MASHA facility due to its radiation resistance and response time.

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POSSIBILITIES OF USING CDZNTE AND CEBR3 CRYSTALS FOR MEASURING PHOTON RADIATION IN A WIDE RANGE OF ENERGY

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The new semiconductor detectors, which, based on CdZnTe crystals and CeBr3 scintillator, are presented in this work. The spectroscopic setup for testing measurements was created, which consists of CdZnTe, CeBr3, and Si (measuring α and γ) detectors. The main characteristics of these detectors including enegy resolution FWHM/Eγ (keV) and ef˜ciency ε(%) were investigated and determined. Moreover, we have checked the possibility of registration in a wide range of energy. The α–γ and γ–γ coincidence measurements were carried out using these detectors. The results could be used to study the mechanisms of nuclear reactions and the properties of reaction products.

STATUS OF THE PITRAP PROJECT – THE PENNING TRAP AT THE REACTOR PIK

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It is expected that PIK reactor, being a powerful source of neutrons, will be able to produce exotic neutron-rich nuclides in quantities greater than ever achievable or expected at other planned facilities. If one use extremely sensitive equipment, synergy can be achieved in the study of the properties of nuclides, including as yet unknown ones. Such extraordinary sensitivity on the level of single nuclide can be received by the Penning traps [1]. The PITRAP project proposes to install such a trap on-line with a beam of nuclides formed during the fission of uranium target by neutrons. The system should be dedicated to measure the masses (total binding energies of nuclides) in order to reproduce the experimental mass landscape which will give an information concerning the real pathways of astrophysical s- and r-processes.
Fission products are formed in the uranium target located near the reactor core. The hot target connected with the ion source of the mass separator IRINA is under consideration. The separated ion beam is directed to the ion trap system which includes the RFQ cooler/buncher and a multiple reflection TOF unit, which can be considered as an additional mass separator that allows determining masses with an accuracy of 10−7 in an independent mode.
It is expected to obtain a high flux of the resulting fission nuclides, which will far exceed the yields of nuclides in the planned projects based on particle accelerators (FRIB, FAIR, SPIRAL, RIKEN etc.). The PITRAP-system with including the Penning traps is designed to measure the masses of nuclides with a relative precision of 10−9. An important point is the development of a new method of trapping an individual ion (see details in [2]). The status of the project and developments achieved after the previous review publication [3] are discussed.

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A COMPARATIVE STUDY ON THE GAS-JET TRANSPORTATION METHOD FOR NUCLEAR SPECTROSCOPY MEASUREMENTS

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One of the numerous perspective experimental implementations of the high-flux PIK- research reactor in Gatchina (Russian Federation) is connected with high-precision mass spectroscopy measurements, at the future planned facility PITRAP [1], of beta-unstable short-lived exotic nuclides. The study and measurement of the basic physical properties of exotic nuclides far from the line of stability in the chart of nuclides plays a crucial role in solving the astrophysical puzzle regarding the nucleosynthesis paths of the elements heavier than iron [2].

The successful study and detection of such short-lived nuclei is dependent upon their high rates of production and, rapid and highly effective transportation from the production chamber to the spectroscopy measurement setup. As the high-flux PIK-reactor is intended to fulfill the first condition by promising neutron fluxes reaching 1015 n/s/cm2, the rapid gas-jet transportation method is meant to fulfill the last two requirements.
In this work a comparative study of the gas-jet transportation method is presented based upon its successful implementation at the TRIGA-SPEC facility[3] in Mainz (Germany) and IGISOL facility[4] in Jyväskylä (Finland). Based on previous experimental measurements, simulations and mathematical modeling have been done for the purpose of the estimation and comparison of the most important transport parameters studied in both cases: evacuation time, transport time and efficiency of transport. As an addition, ionization and recombination processes of ionized exotic nuclides in gas-cells has been studied, which is important for determining the degree of consideration of plasma effects in the gas flow. A special consideration and suggestions will be presented for the future successful implementation of the gas-jet transportation method in the special case of the PIK-reactor, based on the previously derived conclusions and mathematical apparatus.

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GLOBAL TRACKING IN THE BM@N EXPERIMENT

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BM@N (Baryonic Matter at Nuclotron) is the first experiment to be realized at the accelerator complex of NICA-Nuclotron at JINR (Dubna). The aim of the experiment is to study interactions of relativistic heavy ion beams with a kinetic energy from 1 to 4.5A GeV with fixed targets.
In the report an algorithm for global tracks reconstruction in the BM@N experiment are described. The core of the global track is the track inside the magnet, to which are added upstream and downstream tracks.
The results of the proposed algorithm working for both the BM@N experiment and its extension SRC program are presented. Matching efficiency and residuals are shown. Influence of global matching procedure on quality of momentum reconstruction and other parameters of a track are presented.

HYBRID ION TRAP: FIRST APPROACH

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Penning trap is a powerful device for measuring properties of ions and
subatomic particles. Presently it can reach the highest accuracy in a determination of the mass of a nuclide. The typical Penning-trap system for on-line mass measurements requires two dedicated traps. The first trap – preparation trap (PT) – serves for the purification and cooling of the captured

ions via the conventional mass selective
buffer-gas cooling technique. The second trap – measurement trap (MT) – which is in combination with the downstream MCP detector serves for the determination of the ion's cyclotron frequency and, therefore, its mass. Such a typical system gives rise to mass measurements with uncertainties of a few keV on medium-heavy nuclides with half-lives down to about a few hundred milliseconds. However, when captured, the ions are no longer well centered acquiring coherent axial and magnetron motions, what in turn introduces additional systematic shifts in the measurement of eigenfrequencies and, thus, the systematic error of the measured mass. This effect is one of the limitations in the final precision for the PI-ICR detection technique [1]. For the sake of mass measurements of short-lived nuclides the issue can be circumvented by combining the features of both the PT and MT in a single 'hybrid' trap. In the hybrid trap the buffer gas can be injected in the trap region in a pulsed manner using a fast piezo valve. In this way the pressure in the trap volume is built up only for the cooling phase, then the valve is closed letting the buffer gas to be pumped out, and when the pressure drop is sufficient, finally the frequency measurement takes place. Besides the reduction of the systematic effects, such the hybrid system would lower the overall cost of the apparatus because it would require only one standard superconducting magnet instead of two, or instead of a special single magnet with two regions of highly homogeneous magnetic fields. This work presents the design of the proposed 'hybrid' Penning trap system, estimation of its capabilities, and its relevance to the future PITRAP project – the Penning-trap mass spectrometer at the PIK reactor in Gatchina [2].

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HIGH-PERFORMANCE OPTIMIZATION OF EVENT SIMULATION AND TRACK RECONSTRUCTION SOFTWARE IN THE BM@N NICA EXPERIMENT

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BM@N experiment of the NICA accelerator complex at the Joint Institute for Nuclear Research, Dubna is aimed at studying heavy ion collisions with fixed targets. The BmnRoot software package [1, 2] is used in the BM@N experiment and it plays a crucial role both in event simulations and in track and event reconstruction [3]. Event reconstruction may take significant time per event. Time of reconstruction depends on the kind of the colliding particles, the beam energy, the collision centrality and other parameters. Event simulations with realistic Monte-Carlo generators are also time-consuming. Processing of big amount of data which is produced in physical runs of the accelerator takes significant time, so the software performance should be optimized to make the data processing efficient [4].

We have performed high-performance optimization of the simulation and reconstruction modules of the BmnRoot software package. The optimization is based on the performance analysis [5] of the BmnRoot package on representative test cases and on localization of the performance bottlenecks in the software source code. Several approaches have been tested and the most suitable approaches to the BmnRoot optimization are chosen. Parallelization of some modules has been performed. Numerical estimates of the scalability and speedup of the parallelized modules for event simulation and reconstruction demonstrate good efficiency of parallelization.

Other approaches to high-performance optimization such as adaptation of the BmnRoot software package for hybrid computing systems, its vectorization and algorithmic optimization are also

considered.
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ПРАКТИЧЕСКИЕ МЕТОДЫ ГЛОБАЛЬНОЙ ОПТИМИЗАЦИИ МНОГОПАРАМЕТРИЧЕСКИХ СИСТЕМ УПРАВЛЕНИЯ ПУЧКАМИ ЧАСТИЦ

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Известно, что в современных ускорительных системах (от небольших систем до циклических ускорителей) необходимо использовать достаточно сложные системы управления, которые предназначены для реализации необходимых характеристик пучка частиц. В данной статье обсуждаются методы формирования оптимальных структур пучка частиц в каналах ускорителей. Заметим, что необходимые требования к пучку могут быть сформулированы в виде некоторого набора функциональных критериев, что позволяет использовать современные методы вычислительной математики. Отметим, что подобные проблемы относятся к так называемым NP-полным задачам и требуют поиска допустимых (при заданных условиях) решений в многопараметрических пространствах используемых параметров. В данной статье рассматриваются методы поиска классов оптимальных решений (с учетом задаваемыми условиями) на примере различных задач физики пучков частиц: от класса ионно-оптических систем (таких как микро- и нано-зондовые системы, согласующие каналы и т. п.) и до циклических ускорительных систем. Для решения этих проблем в работе рассмотрены как теоретические, так и вычислительные методы задач глобальной оптимизации. Использование генетических алгоритмов и методов нейронных сетей позволяет учитывать особенности сложных систем с целью обучения управляющей системы с использованием информационных технологий методов обучения.
Заметим также, что в современных ускорительных системах (от небольших систем до циклических ускорителей) необходимо использовать достаточно сложные системы управления, которые предназначены для реализации необходимых характеристик пучка частиц. В данной статье обсуждаются проблемы формирования оптимальных структур пучка частиц в каналах ускорителей. Необходимые требования к пучку могут быть сформулированы в виде некоторого набора функциональных критериев. Известно, что подобные проблемы относятся к так называемым NP-полным задачам и требуют поиска возможных решений в многопараметрических пространствах используемых параметров. В данной статье рассматриваются методы поиска классов оптимальных траекторий на примере различных задач физики пучков частиц: от класса ионно-оптических систем (таких как микро- и нано-зондовые системы, согласующие каналы и т. п.) и до циклических ускорительных систем. Для решения этих проблем в работе рассмотрены как теоретические, так и вычислительные методы задач глобальной оптимизации. Использование генетических алгоритмов и методов нейронных сетей позволяет учитывать особенности сложных систем с целью обучения управляющей системы с использованием, в том числе, информационных технологий методов обучения.
Приведены примеры реализации предлагаемых методов для тестовых задач физики пучков.

CHARACTERISTICS OF SMALL-SIZED SPECTROMETERS BASED ON CDZNTE FOR NUCLEAR PHYSICS RESEARCH

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The article describes the main characteristics of small-sized semiconductor spectrometers for performing real-time measurements directly in the channels of nuclear physics facilities and the results of their application.
Variants of using such spectrometers in experiments on an electron accelerator are considered.

HIGH-PRECISION PENNING-TRAP MASS SPECTROMETER PENTATRAP FOR FUNDAMENTAL PHYSICS

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The Penning-trap mass spectrometer Pentatrap [1] located at the Max Planck Institute for Nuclear Physics in Heidelberg recently proved its capabilities performing first mass-ratio measurements with a relative uncertainty in the 10^{-11} regime using highly charged ions of ^{187}Re [2] and different xenon isotopes [3]. Pentatrap will continue with mass measurements of dedicated nuclides which will allow, among others, to contribute to tests of special relativity, bound-state QED, neutrino-physics research, and to a search for suitable transitions in highly charged ions for a new generation of clocks. Achieving this level of precision requires using a cryogenic detection system with single ion sensitivity and phase sensitive Fourier Transform Ion Cyclotron Resonance (FT-ICR) image-current detection methods in combination with highly charged ions provided by external ion sources. A unique feature of Pentatrap is the suppression of systematic uncertainties by performing simultaneous measurements in multiple traps. The overview of the Pentatrap setup, its current performance and the latest results will be presented.

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COMBINED SPECTROMETER FOR MEASURING THE SPECTRA OF PROMPT FISSION NEUTRONS IN A WIDE ENERGY RANGE

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There are serious contradictions in the theoretical and experimental data on the prompt fission neutron spectra for a number of fissile isotopes. Particularly large discrepancies are observed in the experimental data for the region of low (<0.5 MeV) and high (> 6 MeV) neutron energies. This is due to the large influence of systematic errors on the results of the neutron spectra measurements for these energy ranges, among which the main ones are the influence of the scattered neutrons and gamma-rays on the shape of the measured spectrum, the quality of n/γ separation, and the influence of the uncertainty in determining the time mark when the time-of-flight method used. The aim of this work was to create a universal digital spectrometer of the prompt fission neutrons. The spectrometer includes: the organic scintillator based on p-terphenyl for the fast neutron detection; slow neutron detector based on the inorganic scintillator Cs2YLiCl6:Ce, fission chamber. Using a digital approach to processing signals from different elements of the detector, it is possible to solve problems related to the suppression of background events and systematic errors in determining the occurrence time of the signals at a new qualitative level. The paper presents the results of test measurements in which a number of important characteristics of the spectrometer were determined - its detection efficiency, light output, quality of gamma-background suppression, time characteristics.

STATUS OF THE BM@N STS MODULE ASSEMBLY

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BM@N experiment at Nuclotron in Dubna is currently being upgraded for the study of dense nuclear matter in heavy-ion collisions. One of the major upgrades is a new hybrid tracking system consisting of large-area Silicon Tracking System (STS) with fast data-driven readout to be installed in-front of seven GEM planes currently partially installed. The STS contains of four position-sensitive stations built of modules with double-sided microstrip silicon sensors which have been developed for the CBM experiment at FAIR. STS consumes 292 silicon modules the assembly of which is making a challenge. For this task a working group in VB LHEP JINR developed customized methods to be briefly reported along with the workflow description and first results.

ION-GUIDE SYSTEM FOR THE GALS SET-UP

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The GALS set-up [1] uses a high-pressure gas cell for stopping heavy ion reaction products. In the dense ionized medium initially high-charged reaction products thermalize and neutralize. By the gas flow they move to the electrically isolated ion-free region, where part of them selec-tively reionize using three step laser resonant ionization process.
To perform an effective mass separation of the reionized ions, one need to separate them from buffer gas and to produce a well formed ion beam with low energy spread. We use the radiofrequency quadrupole (RFQ) ion-guide system for transport the nuclear reaction products from the high-pressure gas cell throw the differential pumping chambers into the high-vacuum region and to form low-energy radioactive ion beam.
Ion-guide system consist of three different part: S-shaped RFQ, located into the first differ-ential pumping chamber; wedged-type microRFQ, passed through the wall between the first and second chambers; and linear RFQ, passed through the wall between the second and third chambers.
The design and construction of all parts of the ion-guide system are discussed.

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SILICON TRACKING SYSTEM AS A PART OF HYBRID TRACKER OF BM@N EXPERIMENT

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In order to study the high-density nuclear equation-of-state in collisions between gold nuclei at Nuclotron beam energies (2− 4.5A GeV), the existing BM@N experiment at JINR in Dubna has to be substantially upgraded. The measurement of high-multiplicity events at interaction rates up to 5 MHz requires the installation of four new tracking stations equipped with double-sided micro-strip silicon sensors, which have been developed for the CBM experiment at FAIR. It has been demonstrated by simulations that the hybrid tracking system comprising four silicon stations and seven (already partly existing) GEM tracking detectors will be able to reconstruct charged particles including hyperons emitted in Au+Au collisions with good efficiency and high signal-to-background ratio. The results of the simulations and the status of the detector development are presented.
Work is supported by RFBR 18-02-40047 grant.

THE FAST INTERACTION TRIGGER FOR ALICE LHC RUN 3 AND 4

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As part of the preparations for the LHC Run 3 and 4, the ALICE experiment at CERN is undertaking a thorough upgrade of the setup. In particular, all ALICE subsystems have to cope with the increased interaction rate of 50 kHz in Pb-Pb and up to 1 MHz in pp collisions. Compared to Run 2, this is up to two orders of magnitude more collisions. Although the solution for the majority of ALICE detectors is to switch to a continuous readout, several of the older systems (TRD, CPV, HMPID, EMCAL, DCAL and PHOS) would still need an external trigger or a wakeup signal.
The Fast Interaction Trigger (FIT) will generate a minimum-bias and a multiplicity trigger with the maximum latency below 425 ns. It will also measure the collision time with a resolution of < 40 ps and serve as the main ALICE luminometer, providing direct, real-time feedback to the LHC for the beam tuning. In the offline analysis FIT will aid in the reconstruction of the vertex position, assess forward particle multiplicity, centrality and event plane, and will be used for the study of diffractive physics at forward rapidity.
FIT consists of three sub-systems: a fast Cherenkov detector array using MCP-PMTs as photosensors, a large scintillator ring employing a novel light collection system, and a scintillator-based Forward Diffractive Detector. After a short description of the detector components, functionalities and a brief summary of the physics objectives, the key test results of the assembled detector will be presented and discussed.

METHOD OF ANALYSIS OF LARGE ARRAYS OF DISCRETE EMPIRICAL DISTRIBUTIONS OF COUNTS WITH A SMALL SAMPLE NUMBER

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During the radiometry of emission fluxes by recording the sequence of counts $K(\Delta t)$ in time intervals Δt the procedure of forming the sequence of random vectors $(n_0...n_i...n_l)_j$ is performed, where n_i $(k_i = i)$ is a random number of equal values of k_i in one random sample of the size $n = n_0 + ...n_i + ...n_l$. With a small sample size $n \leq 10$, a large number of $M > 10^5$ and the number of different types of j vectors $Q > 10^4$ statistical analysis of their frequency characteristics is a difficult problem. A particular implementation of type j of the combination of values n_i occurs in a vector with a random frequency M_j, the binomial estimation of which is MP_j, where P_j is a polynomial probability of the vector appearance. To each type of vector j, the discrete functionality $ID(-)_j = (a_0n_0 + ... + a_ln_l)$ corresponds unambiguously, where $(a_0, ..., a_l)$ is a specified non-random vector $1 \leq a_0 \leq ... \leq a_l$ with integer components a_i.
Multimodal empirical distributions $M_j(ID_j)$ depending on the values of a_j make it possible to unite homogeneous vectors of the corresponding types into peaks without complicated testing of hypotheses about the type of distribution in small samples.

REGISTRATION EFFICIENCY OF A STILBENE BASED NEUTRON DETECTOR

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Detection efficiency of a stilbene based neutron detector at neutron energy at 14 MeV for different amplitude thresholds is presented. Experiment was performed in Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research, Dubna, Russia using the VNIIA ING-27 generator of 14 MeV neutrons. Comparisons of the calculated neutron energy spectra with experimental data induced by 6.29, 7.07 and 14 MeV neutrons are presented. Neutron interactions with the detector were simulated in Geant4 toolkit and energy spectra obtained with the use of Birk's Law.

LOW-ENERGY ELECTRON LINACS FOR PHYTOSANITARY PROCESSING OF AGRICULTURAL PRODUCTS

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Ionizing radiation is commonly used to suppress the activity of phytopathogens in foodstuffs [1-3]. According to international standards, electron linear accelerators (linacs) with the energy up to 10 MeV are recommended as a safe and reliable technic for irradiation treatment of a wide range of agricultural products [4-6].
It is known that 10 MeV electrons have the penetration depth up to 10 cm, which allows to treat products with the thickness not exceeding 10 cm [5]. While some foodstuffs, such as meat and fish, require deep penetration of the beams, treatment of vegetables contaminated by pathogenic fungi on the surface level is performed with lower energy electrons as they are sufficient for inhibition of the pathogens.
Agricultural products, such as potato, are often infected by a variety of bacterial, viral and fungal diseases, including black scurf caused by Rhizoctonia Solani which can be found in at least 20 % of tubers grown in Russia.
This paper studies the effect of low-energy electron radiation in different doses on the development of R. Solani species grown from sclerotia irradiated using continuous electron accelerator UELR-1-25-T-001 with beam energy of 1 MeV and average beam power of 25 kW. The samples were placed on a duralumin plate. During processing, the value of the charge absorbed by the plate was monitored to determine the dose absorbed by the samples using GEANT 4 source code.
After irradiation, the growth rate of R. Solani fungus was studied. Sclerotia was placed in Petri dishes filled with potato-dextrose agar. The samples were cultured in a thermostat at the temperature of 24℃. The intensity of fungi growth was studied 24, 48, 72, and 96 hours after seeding.
As a result, the dose 1,8 kGy significantly decreases the growth of the fungus during the first two days after seeding. The dose 4,5 kGy completely inhibits the germination of the fungus. In this case, the electron penetration depth is about 3 mm, which allows further irradiation of pathogens directly on the surface of potato tubers and similar crops. Thus, the use of low-energy electron linacs for phytosanitary processing of foodstuffs is an effective method.

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EFFECTS OF ELECTRON BEAM APPLICATION ON MICROBIOLOGICAL AND ORGANOLEPTIC PARAMETERS OF CHILLED TURKEY

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The radiation processing of food products is one of the most effective and universal technologies for extending the shelf life of meat and meat products during storage [1-4]. More than 1.3 million tons of various agricultural and food products, including meat, are irradiated annually in the world [5,6]. Currently, it has become a priority to optimize the exposure parameters, such as radiation source, energy of ionizing particles, and irradiation technique for treatment of meat and poultry.
The aim of this study was to investigate the impact of various irradiation parameters on microbiological and organoleptic properties of chilled turkey.
The experiment used three types of chilled turkey samples. The first type was 0.5 ml minced turkey homogenate in 2 ml Eppendorf tubes which were used to estimate microbiological parameters of minced turkey. The second type was thin slices of turkey (weight (40 ± 5) g, width (2.8 ± 0.2) cm, length (12 ± 0.5) cm and thickness (6 ± 1) mm) in vacuum bags which were used to estimate organoleptic parameters, such as the changes in taste, odor, and texture of chilled turkey after irradiation. The third type was turkey cubes (weight (0.3 ± 0.05) g, size (6 ± 0.3) mm) in 2 ml Eppendorf tubes used to estimate the dose rate influence on microbiological parameters of minced turkey.
Samples were treated by 1 MeV electrons using the industrial electron accelerator UELR-1-25-T-001. The samples were irradiated in the range of doses from 0.25 kGy to 10 kGy. The dose rate was varied by modifying beam current from 60 nA to 6 μA. Computer simulation using GEANT4 code was performed to estimate the dose absorbed in samples of turkey, taking into account the technical properties of the accelerator. Each time during irradiation the total charge absorbed by the plate was monitored to determine the required dose of irradiation. The dose is proportional to the charge absorbed by the plate.
It was found that 1 MeV accelerated electron irradiation with the doses over 1 kGy reduced bacterial content in minced turkey 100 times compared with non-irradiated samples. At the dose of 6 kGy complete sterilization of the product was observed. However, doses exceeding 2 kGy had a significant impact on organoleptic properties of treated turkey meat. Therefore, a dose range of 1 kGy to 2 kGy is found to be most efficient for treatment of this type of product.
The study of the dose rate showed the nonlinear dependence of the number of viable cells in chilled turkey irradiated with low-energy accelerated electrons in the range from 0.25 kGy to 3 kGy on the dose rate. Irradiation with the doses up to 1 kGy ensured a more significant reduction in bacterial content in turkey meat treated with the dose rate 1 Gy/sec and 10 Gy/sec. In contrast, irradiation with the dose range of 2 kGy to 3 kGy enabled a more considerable decrease in the amount of pathogens at the dose rate of 100 Gy/sec.
As a result of this study, 1 kGy to 2 kGy at the dose rate from 1 Gy/sec to 10 Gy/ were selected for eliminatihg of pathogens and preserving organoleptic properties of chilled turkey.

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PRODUCTION OF THE ^{178m2}Hf ISOMER IN NUCLEAR REACTOR

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The reactor production of the nuclear high-spin isomer ^{178m2}Hf ($T_{1/2}$ = 31 years) was considered. According to [1], in the inelastic scattering of neutrons by ^{178}Hf and in the (n, 2n) reaction by ^{179}Hf, the ^{178m2}Hf isomer is not formed, because this requires the transfer of too large angular momentum to the nucleus. For the formation of the ^{178m2}Hf in the radiative capture of neutrons by ^{177}Hf nuclei, two different cross section values were obtained earlier. In [2] σ = 0.2 ± 0.1 μbarn when the ^{177}Hf isotope was irradiated with thermal neutrons with fluence up to 10^{22} cm^{-2}. In [3] σ = 2.6 ± 0.7 μbarn when neutron irradiating natural hafnium at the IBR-2 reactor of the Joint Institute for Nuclear Research (Dubna) with a relatively small fluence of ~10^{18} cm^{-2} (the errors are at the level of one standard deviation).

We studied the formation of the ^{178m2}Hf isomer in the material of the regulatory body of the RBT-6 reactor (SSC RIAR), made of 6 mm thick plate of metallic natural hafnium [4], after it's irradiation with neutron flux of ~ 10^{14} cm^{-2}·s^{-1} with fluence up to 10^{22} cm^{-2}. Samples were taken at several points of the plate from the upper layer with a depth of 0.5 mm and from a depth of 2 to 4 mm. The neutron fluence at the sampling points with an accuracy of 20% was determined using a numerical model based on the MCU code (version MCU-RR). For one of the typical sampling points, the fluence of neutrons of energy less than 0.625 eV was 7.5×10^{21} cm^{-2}, the specific activities of the surface and deep samples were 1547 ± 92 Bq×g^{-1} and 1368 ± 82 Bq×g^{-1}, respectively. If we assume that the whole ^{178m2}Hf isomer was formed by the capture of thermal neutrons by ^{177}Hf nuclei, then taking into account the burn-up of ^{177}Hf and ^{178m2}Hf, the isomer cross section σ = 3.6 ± 0.5 μbarn is obtained, which coincides with the result of [3]. Thus, we did not see the contribution of any other reactions to the formation of the ^{178m2}Hf isomer other than radiative capture of neutrons by ^{177}Hf nuclei.

In principle, the ^{178m2}Hf isomers can be produced by the two-stage reaction ^{179}Hf (n, n ')^{179m2}Hf + ^{179m2}Hf (n, 2n)^{178m2}Hf, which was already discussed in [5] for the interaction of 14 MeV neutrons with ^{179}Hf nuclei. According to our estimates, in the irradiated hafnium studied by us, the specific activity of the ^{178m2}Hf isomer obtained by this reaction is ~ 0.1 Bq×g^{-1}.

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PRODUCTION OF THE ^{186m}Re ISOMER IN NUCLEAR REACTOR

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The nuclear isomeric state ^{186m}Re with an energy of 149 keV and a half-life of 2×10^5 years is of great interest for experiments on the stimulation of de-excitation of nuclear isomers in plasma [1, 2]. In this work, the possibility of reactor production of a substance with a high concentration of ^{186m}Re isomer is considered. A cross section of about 0.3 barn of excitation of the ^{186m}Re isomer by the thermal neutrons capture by ^{185}Re nuclei was obtained in [3]. Compared to this reaction, the excitation of the ^{186m}Re isomer in inelastic neutron scattering by ^{186}Re nuclei in the ground state, decaying with a period of 90 hours, or in (n, 2n) reactions on the ^{187}Re isotope is not significant.
This conclusion corresponds to the production of the ^{186m}Re isomer in 2006 at the WWR-M reactor at the Petersburg Nuclear Physics Institute, when the metal powder of natural rhenium was simultaneously irradiated in the B-8 channel (thermal neutrons) and in the reactor core, where the neutrons were more high-energy. Within the measurement error of the neutron fluence for both samples, the isomer production was proportional to the fluence of thermal neutrons with an isomer cross section of 0.29 ± 0.06 barn (error at the level of one standard deviation), which coincides with the result of [3].
Thus, to produce the isomer, the ^{185}Re isotope should be placed in the thermal neutron flux. The exposure is limited to the burn-up of the ^{185}Re isotope and the produced ^{186m}Re isomer. The production of the ^{186m}Re isomer is maximum at a neutron fluence of Φmax ≈ 2×10^{22} cm^{-2}, while the number of ^{186m}Re nuclei is 0.2% of the starting number of ^{185}Re nuclei. To obtain material of the pure ^{186m}Re isomer, it is first possible to clean the irradiated rhenium from chemical impurities on an ion-exchange column and then isolate an isotope with a mass number of 186. This will be the practically pure ^{186m}Re isomer, since ^{186}Re nuclei in the ground state decay quickly. For this operation, gas-centrifuge separation of rhenium isotopes in the form of hexafluoride, the boiling point of which is only 33.7℃, is promising.
Interestingly, a pure ^{186m}Re metal will essentially be a new state of matter.

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MODERN METHODS FOR STUDYING "HOT" PARTICLES OF VARIOUS ORIGIN

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"Hot" particles have formed as a result of nuclear weapon testing, accidental releases at nuclear facilities, etc. In studying them much attention is paid to the analysis of transuranic elements (TUE) because they are long-lived alpha-emitting radionuclides, especially ^{238,239,240}Pu and ^{241}Am. The current accumulation and increase of the TUE content in the environment require to develop prompt methods for reliable monitoring of these isotopes in environmental objects, biological materials, and other samples.

We have developed a method for determining the activity of α-emitting plutonium isotopes using x-ray and γ-spectra spectroscopy. It allows you to quickly, reliably and with sufficiently high accuracy to carry out mass studies of samples without radiochemical separation of elements. This method is reducing the cost of analysis of one sample by almost two hundred times.
The essence of the method is as follows. As a result of alpha decay of plutonium isotopes, a series of low-energy states of the corresponding uranium isotopes with an energy lower than the K-electron binding energy are excited with a probability of about 25%. The decay of these states occurs through the internal conversion of gamma rays, followed by the emission of characteristic x-ray radiation with a 13-23 keV range energy. Thus, we obtain data about the plutonium content in the sample by measuring the intensity of x-ray radiation using semiconductor spectrometers. The accuracy of the proposed method in environmental samples is 10-15% for activities over 100 Bq and 20-30% for activities less than 100 Bq.
The developed method has been used to study the isotopic composition of "hot" particles of various origins: from an atomic and thermonuclear explosion, accidental origin from the 4^{th} Chernobyl nuclear power unit.
The results of spectrometric studies are confirmed by the data of traditional, radiochemical studies. To isolate actinides from the particles, the Eirchrom ACW03-21 extraction chromatographic method was used with UTEVA + TRU resins (TrisKem Int). Radiography with Imaging Plates, alpha-track radiography, SEM-EDX, micro-XRF, and XAFS have used to search, isolate and non-destructive analysis of "hot" particles. The obtained results are discussed. The reported study was funded by RFBR, project number 19-05-50095.

INVESTIGATION OF THE DEPENDENCE OF THE TIME RESOLUTION OF SI DETECTORS ON THE BIAS VOLTAGE

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The aim of this work was to measure the parameters of Si detectors and study their dependences on the bias voltage. It was measured the amplitude and time resolution, signal-to-noise ratio in the fast and slow channels, the value of the signal front and surface temperature for each detector.
When studying reactions on light nuclei at the SINP accelerator we use a two-arm spectrometer [1]. It consists of an *ΔE− E* telescope of silicon surface-barrier detectors for charged particles and scintillation detectors in the other arm. The telescope determines the energy and type of charged particles, scintillation detectors separate neutron events from gamma by the pulse shape and determine the neutron energy by time of flight. In [1] a method for time calibration and measuring the time resolution of the detectors by using an accelerator is described. However, for the preliminary selection of detectors for experiment such a method is too expensive.
To accomplish this task, we used the standard α- source RSAS Ra-226. We record simultaneous emitted alpha and gamma rays from the decays. The source was located near the detectors. The measurements were carried out using the same equipment used in the experiments [1]. Alpha particles were detected by a Si detector, gamma quanta were detected by scintillation detectors based on a Hamamatsu-2083 PMT and an EJ301 or EJ315 type liquid scintillator having pre-measured characteristics, in particular the time resolution, is obviously better than that of the our Si detectors. The measurements were carried out on a large number of detectors (mainly PIPS) with an area of 20 to 100 mm^2 and a working layer thickness of 23 to 1000 microns, made mainly 35-40 years ago in the USSR. CANBERRA 2003BT and ORTEC142 preamplifiers were used in the measurements.
As a result of the measurements sets of dependences of the time and amplitude characteristics on the bias voltage were obtained and recommendations were developed on its choice to achieve the best resolutions.
The reported study was funded by RFBR according to the research project N 18-32-00944.

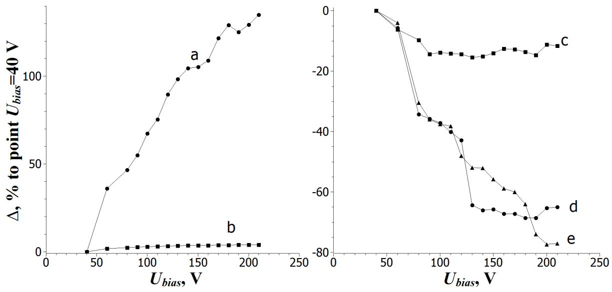

Figure 1: The y axis - the change in the value of the Si detector parameters (500 μm, S - 90 mm^2) as a percentage of the point with a bias voltage of 40 V. a- the signal amplitude in the slow channel, b- the amplitude in the fast channel, c- is the amplitude resolution, d- time resolution, e- the fast signal front at the level of 0.1-0.9.

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Section 4. Relativistic nuclear physics, elementary particle physics and high-energy physics

DEEP SUBTHRESHOLD PRODUCTION PROCESSES OF J/PSI AND MUON PAIRS AND COLD DENSE BARYONIC MATTER

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Deep subthreshold production processes of J/Psi and muon pairs and cold dense baryonic matter are proposed to study at a NICA fixed target experiment FITNEX. Such studies should be very sensitive to cold dense baryonic matter and can be complimentary to upcoming MPD, SPB and BM@N experiments at NICA.

ОБРАЗОВАНИЕ Δ^0-ИЗОБАР В NC-СОУДАРЕНИЯХ ПРИ 4.2 ГэВ/с

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Изучение образования протонов в адрон- и ядро-ядерных соударениях при высоких энергиях позволяет получить ценную информацию о вкладах различных механизмов их происхождения. Особый интерес представляет сравнительный анализ различных характеристик протонов в изотопически сопряженных реакциях – в pC- и nC-соударениях при одинаковых энергиях. Такое сравнение позволяет, в частности, изучить кинематические особенности зарядообменных процессов при образовании протонов. В настоящее время имеется достаточно много экспериментальных данных по взаимодействиям протонов с нуклонами и ядрами в широком диапазоне первичных энергий. Экспериментальная же информация по соударениям нейтронов с ядрами (nA) чрезвычайно скудна [1–3] из-за трудности получения монохроматических пучков нейтронов, особенно, полученных в условиях полной геометрии. В связи с этим получение новых экспериментальных данных по nA-соударениям и сопоставление их с таковыми для pA-взаимодействий при одной и той же энергии и для одного и того же ядра-мишени представляет определенный интерес. Результаты этих работ показали, что ширина и масса Δ резонанса, образованного в столкновениях тяжелых ионов значительно отличаются от таковых для резонанса, рожденного в столкновениях свободных нуклонов. Таким образом, свойства адронов модифицируются в плотной ядерной среде в ядро-ядерных соударениях, что ведет к значительному уменьшению массы Δ. Это явление объяснялось в рамках термальной и изобарной моделей [4].
Данная работа посвящена исследованию множественности импульсных и угловых

характеристик протонов, образованных в nC-соударениях при импульсе 4.2 ГэВ/с. Впервые представлены экспериментальные результаты по изучению образования Δ^0-изобар в nC-соударениях при 4.2 ГэВ/с. Были получены экспериментальные и нормированные к ним фоновые распределения эффективных масс протонов и π^--мезонов. Экспериментальный материал получен с помощью 2м пропановой пузырьковой камеры ЛВЭ ОИЯИ, облученной пучками дейтронов и α-частиц с импульсами 4.2 ГэВ/с.

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PRODUCTION OF THE HEAVY FLAVOURS (D AND B MESONS) IN THE MONTE CARLO MODEL WITH STRING FUSION

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The production of heavy flavor mesons in pp and p-Pb collisions at LHC energy is considered in the Monte Carlo model [1,2] with the string fusion. In the model, the elementary partonic collisions are implemented as interactions of color string, and the particle production is implemented using a string mechanism. The particle differentiation is implemented according to the Schwinger mechanism [3,4].
In order to ensure the correct description of p_t-spectra of produced hadrons as well as the $\langle p_t \rangle_{N_{\rm ch}} - N_{\rm ch}$ correlations [5], the hardness of the collision is defined by the size of colliding dipoles [6].
Transverse and rapidity spectra of heavy flavors, as well as nuclear modification factors, are calculated at LHC energy and obtained in a reasonable agreement with the experimental data [7].
New observables are proposed for the ALICE measurements in the LHC Run 3 with new upgraded ITS.
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ANISOTROPIC FLOW MEASUREMENTS FROM THE NA61/SHINE AND NA49 BEAM MOMENTUM SCAN PROGRAMS AT THE CERN SPS

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The NA61/SHINE experiment at the CERN SPS has recently extended its program for the energy scan with Pb ions. In the past, the NA49 experiment, which preceded NA61/SHINE, also recorded data for Pb-Pb collisions at different energies. Together, the two experiments cover a wide range of beam energies provided by the CERN SPS in the range 13 - 150A GeV/c. Analysis of the new NA61/SHINE data and reanalysis of the existing NA49 data using modern measurement techniques allow for a new comprehensive systematic study of collective flow relative to the spectator plane. The measurements at the lowest energy available at the SPS are also relevant for the preparation of the Compressed Baryonic Matter (CBM) heavy-ion experiment at the future FAIR facility in Darmstadt.
We will present new NA61/SHINE results on directed and elliptic flow measurement in Pb-Pb collisions at 13 and 30A GeV/c relative to the spectator plane determined with the Projectile Spectator Detector. Also a new analysis of 40A GeV data collected by the NA49 experiment using forward spectator calorimeters (VETO and RCAL) will be shown. The flow coefficients are reported as a function of rapidity and transverse momentum in different classes of collision centrality. The new results are compared with existing results from the previous NA49 analysis and the STAR experiment at RHIC.

SCALING PROPERTIES OF AZIMUTHAL ANISOTROPY FROM RHIC TO NICA

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A central goal of current relativistic heavy-ion experiments is to study the properties of the hot and dense QCD matter. Such studies can give provide on the QCD phase diagram, as well as the transport coefficients of the strongly-coupled Quark Gluon Plasma (sQGP). Anisotropic flow measurements of identified particles play an essential role in such studies.
We report on the results of the recent measurements of elliptic and triangular flow and discuss them using different scaling relations for azimuthal anisotropy.
The reported study was funded by RFBR according to the research project No 18-02-40086.

METHODS FOR CENTRALITY DETERMINATION IN HEAVY-ION COLLISIONS WITH THE CBM EXPERIMENT

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Centrality is an important concept in a study of strongly interacting matter created in a heavy-ion collision which evolution depends on its initial geometry. Experimentally collisions can be characterized by the measured multiplicities or energy of produced particles at midrapidity or spectator fragments emitted in the forward rapidity region. Relation between collision geometry and experimentally measured multiplicities is commonly evaluated within the Monte-Carlo Glauber approach.
We will present methods for centrality determination in heavy-ion collisions with the Compressed Baryonic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR). The multiplicity of charged hadrons is provided by the CBM silicon tracking system (STS) and connected to collision geometry parameters using the Monte-Carlo Glauber model. The energy of spectator fragments is estimated with the CBM projectile spectator detector (PSD). We will discuss possibilities to determine centrality using the PSD and Monte-Carlo Glauber model.
This study was partially supported by RFBR, research project No. 18-02-40086.

POSSIBILITY OF EXISTENCE OF NEW DIBARYONS BELOW PION PRODUCTION THRESHOLD

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Search for new dibaryons was carried out in [1, 2]. It was found that the data of two independent experiments [3, 4] might give an affirmative answer to this question. Furthermore, the data from [1] and [2] are in a so striking agreement that their incidental coincidence should be considered as a marvel. On this basis, it is reasonable to assume existence in an excited neutron-proton system a large group of narrow dibaryon resonances located below the pion production threshold. In this report, two possible theoretical justifications for the existence of such dibaryons are proposed. One of them is based on the Brodsky-de Teramond explanation of the color transparecy violation. The second ground appeals to a chance of the existence inside the deuteron of a strongly coupled system of two Δ-resonances, which is excited in deuteron–deuteron collisions. It is shown that verification of the both hypotheses is feasible at the future NICA SPD facility.

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METHODS FOR EVENT PLANE DETERMINATION IN FLOW MEASUREMENTS WITH HADES

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Anisotropic transverse flow is one of the main observables in the study of strongly interacting matter created in nucleus-nucleus collisions. Spatial asymmetry of overlapping region of two ions transforms due to particles interaction into momentum anisotropy of produced hadrons. Comparison of measured azimuthal anisotropy with theoretical calculations allows to extract properties of the created matter such as its equation of state.
The results of flow analysis in Au-Au collisions relative to the spectator symmetry plane at the beam energy of $1.23A$ GeV recorded with the HADES experiment are presented. The spectator symmetry plane is estimated with subevents from the HADES Forward Wall hodoscope. Three-subevent technique is used for differential measurements of the directed and elliptic flow of protons and to extract systematic uncertainties in the event plane determination. Corrections for the detector azimuthal non-uniformity are applied using an extension of the Qn-Corrections Framework developed originally for the ALICE experiment at the LHC.
The study was partially supported by RFBR, research project No. 18-02-40086.

PERFORMANCE FOR CHARGED HADRONS ANISOTROPIC FLOW MEASUREMENTS OF THE CBM EXPERIMENT AT FAIR

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The Compressed Baryonic Matter experiment (CBM) at FAIR aims to study the area of the QCD phase diagram at high net baryon densities and moderate temperatures using collisions of heavy ions at center-of-mass energies of a few GeV per nucleon. Anisotropic transverse flow is among the key observables to study the properties of matter created in such collisions. The CBM performance for charged hadron's anisotropic flow measurements is studied with Monte-Carlo simulations using gold ions at SIS-100 energies with lab momentum up to $12A$ GeV/c employing different heavy-ion event generators. Various combinations of CBM detector subsystems are used to investigate the possible systematic biases in flow measurement and to study the effects of detector azimuthal non-uniformity. The resulting performance of CBM for flow measurements is demonstrated for different harmonics of identified charged hadron anisotropic flow as a function of rapidity and transverse momentum in different centrality classes.
The study was partially supported by RFBR, research project No. 18-02-40086.

SEARCHES FOR THE SMALLEST DROPLET OF QGP MATTER AT THE LHC

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The primary goal of the ultra-relativistic heavy-ion collision program at the Large Hadron Collider (LHC) is to study the properties of the Quark-Gluon Plasma (QGP), a novel state of strongly interacting matter which exists in the early universe. Anisotropic flow, which quantifies the anisotropy of the momentum distribution of final state particles, is sensitive to the fluctuating initial conditions and the transport properties of the created QGP. The successful description of the measured anisotropic flow coefficients by hydrodynamic calculations suggests that the created medium behaves like a nearly perfect fluid. However, the observation of collective flow phenomena in high energy proton-lead and proton-proton collision triggers intense discussions. Whether the smallest droplet of QGP has been produced in these collisions or other physics mechanisms will be attributed to this phenomenon, is under debate.
In this talk, I will present the latest developments of flow studies at the LHC, including both recent theoretical model calculations and experimental measurements in proton-lead collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV and proton-proton collisions at $\sqrt{s} = 13$ TeV. I will especially highlight the current challenge of the hydrodynamic description on multi-particle cumulants measurements, and try to answer whether we have the evidence of the creation of a small droplet of QGP in these small collision systems.

THE QUALITY ASSESSMENT OF THE MPD TRACKING SYSTEM FOR THE DETECTION OF CHARMED PARTICLES IN Au-Au COLLISIONS AT THE NICA COLLIDER

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The Multi-Purpose Detector (MPD) is being constructed to study the properties of extremely dense nuclear matter formed in relativistic nucleus-nucleus collisions at the NICA collider energies.The yields of strange and charmed particles are the important observables sensitive to critical phenomena in phase transitions of the QGP-matter at high net-baryon density. Highly efficient registration of such short-lived products of nuclear interactions using a vertex silicon detectors will play a key role in the analysis of the possible onset of deconfinement in nuclear matter.
The Time Projection Chamber (TPC) is considered as a main detector of the MPD tracking system. Its performance will be further enhanced with a vertex inner tracking system (ITS) based on the Monolithic Active Pixel Sensors (MAPS) to provide reliable identification of short-lived hadrons. The identification ability of the ITS+TPC tracking system, when reconstructing the decays of D^0 and D^+ produced in central Au+Au collisions at $\sqrt{s_{NN}}$ = 9 GeV has been studied in the course of computer simulation in the object-oriented software framework MpdRoot. The selection of D-meson signals in the invariant mass spectrum of their decay products was performed by using a toolkit for multivariate data analysis.
Two variants of the ITS layout of the MAPS layers were considered: 5-layer configurations adopted for a beam pipe diameter of 40 and 64 mm respectively. The results of simulation show that the study of the heavy-flavour physics in the MPD experiment is promising if the diameter of the MPD beam pipe is reduced to an optimum value of 40mm.
The reported study was supported by RFBR, research project No. 18-02-40075 and No. 18-02-40119.

OBSERVATION OF ATMOSPHERIC TEMPERATURE AND PRESSURE EFFECTS IN COSMIC MUONS FLUX WITH THE DANSS DETECTOR

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The DANSS detector is located under a commercial reactor core at the Kalinin Nuclear Power Plant. DANSS position below industrial reactor core provides overburden about 50 m. w. e. in vertical direction. So in terms of cosmic rays it occupies an intermediate position between surface and underground detectors. The core of the detector is a cubic meter of plastic scintillator with fine segmentation and combined PMT and SiPM readout, surrounded by multilayer passive and active shielding. Detector can reconstruct muon tracks passing its sensitive volume. The detector is placed on a lifting platform and the data is taken in three positions - 10.9, 11.9 and 12.9 meters from the core. The overburden parameter <Ethrcosθ>, the averaged multiple of the zenith angle cosine and of the corresponding threshold energy, is evaluated for up, middle and down positions of the detector. Muon data were collected for more than two years. Correlation coefficients α and β between the relative variation of the muon rate and the relative variations of the effective atmospheric temperature and of the surface pressure, are calculated for each detector position.
The work is supported by RSF grant 17-12-01145П.

ADVANCES IN N* PHYSICS WITH CLAS/CLAS12

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Dressed quarks with dynamically generated masses shape the structure of the ground and excited nucleon states (N) as their active constituents. The generation of >98% of hadron mass and the emergence of quark-gluon confinement are encoded in the momentum dependence of dressed quark mass. Experimental studies of electroexcitation amplitudes of prominent nucleon resonances in a broad range of photon virtuality Q^2 offer an effective tool for insight into the dynamics of hadron mass generation [1]. The analyses of the experimental data on the exclusive $p\pi^0$, $n\pi^+$ and $\pi^+\pi^-p$ electroproduction channels measured with CLAS already provided information on electroexcitation amplitudes of most N in the mass range <1.8 GeV and at photon at Q^2 up to 5.0 GeV^2 [2].
Consistent results on dressed quark mass function obtained from independent studies of nucleon elastic form factor and electroexcitation amplitudes of $\Delta(1232)3/2^+$ and $N(1440)1/2^+$ resonances demonstrated the capability to map out momentum dependence of dressed quark mass getting insight into the hadron mass generation in the regime of large QCD running coupling, the so-called strong QCD regime. The current status of the N electroexcitation studies in connection
with the insight into strong QCD regime, as well as their future extension from the data on exclusive electroproduction experiments with the new CLAS12 detector in Hall B at Jefferson Lab [3], will be presented in the talk.
The CLAS12 [2] detector is the only facility in the world capable to explore N electroexcitation

amplitudes at Q^2 >5.0 GeV^2 where the transition from the strong to the perturbative QCD regimes is expected and where the dominant part of hadron mass is generated. These studies will address key open problems of the Standard Model on the nature of hadron mass, quark-gluon confinement, and their emergence from QCD [4].

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NEW APPROACH FOR CENTRALITY DETERMINATION WITH FORWARD HADRON CALORIMETERS IN HEAVY ION REACTIONS

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To measure the centrality in heavy ion reactions in the future experiments CBM@FAIR, BM@N, NA61/SHINE@SPS and MPD@NICA the forward hadron calorimeters with transverse and longitudinal segmentations will be used. All these calorimeters have the beam hole in the center. This feature leads to uncertainty in determining the centrality, since in this case the total energy deposition in the calorimeter depends non-monotonically on the impact parameter. New approach using machine learning methods was developed to solve the problem of centrality determination by the calorimeters with the beam hole. This approach uses information about the spatial energy distribution of spectators in calorimeter. Details of this new approach for centrality determination and first results of applying the approach to the simulation data will be shown. This work was supported by the Russian Foundation of Basic Research (RFBR) Grants №18-02-40081 and №18-02-40065.

LOW AND HIGH ENERGY CONSTRAINTS IN AdS/QCD MODELS

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The AdS/QCD models are believed to interpolate between low and high energy sectors of QCD. This claim is usually based on observations that many phenomenologically reasonable predictions follow from bounds imposed at high energies although the hypothetical range of applicability of semiclassical bottom-up holographic models is restricted by the gauge/gravity duality to low energies where QCD is strongly coupled. To test the feasibility of high energy constraints it is interesting to calculate holographically several observable constants at low and high momenta independently and compare. We will discuss an AdS/QCD model which describes the Regge-like linear spectrum of spin-1 mesons in a general form and demonstrate that under certain physical

assumptions the low-energy constraints on 2-point correlation functions lead to nearly the same numerical values for the parameters of linear radial spectrum as the high energy ones. This coincidence looks surprising in view of the fact that such a property for observables is natural for conformal theories while real strong interactions are not conformal.
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SPIN OBSERVABLES OF pd ELASTIC SCATTERING AT 20 – 50 GeV/c WITHIN THE GLAUBER MODEL AND pN AMPLITUDES

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Spin amplitudes of pp- and pn elastic scattering contain important information on the dynamics of the NN interaction. Systematic information on these amplitudes is accumulated in the SAID data base [1] and available up to kinetic energy 3 GeV for pp and 1.2 GeV for pn scattering. At higher energies there are only non-complete data on pp scattering, whereas information about the pn amplitudes is very poor. In the literature there are some parametrizations for pN amplitudes obtained in the eikonal model [2] and within the Regge phenomenology for 3 - 50 GeV/c [3]. A possible way to check the existing parametrizations is to study spin effects in proton-deuteron (pd) and neutron-deuteron (nd) elastic and quasi-elastic scattering. At high energies and small four-momentum transfer t pd scattering can be described by the Glauber diffraction theory of multistep scattering, which involves as input on-shell pN elastic scattering amplitudes. Application of this theory with spin-dependent effects included [4] demonstrates a good agreement with the pd scattering data at energies about 1 GeV if the SAID data on pN scattering amplitudes are involved into calculations [4,5].
Here we apply the spin-dependent Glauber theory [4] to calculate spin observables of pd elastic scattering at 20 - 50 GeV/c using available pp elastic scattering amplitudes f_{pp} parametrized in Ref. [3] within the Regge formalism. As a first approximation, for pn elastic scattering we use pp amplitudes from [3]. We should note that the Regge formalism allows one to construct pn- (and antiproton N) amplitudes together with the pp amplitudes. However, in view of scare experimental information about the spin dependent pn amplitudes, and taking into account that the spin-independent parts of the pp- and pn amplitude at high energies are approximately the same, we put here $f_{pn} = f_{pp}$. The calculated vector (A_y^p, A_y^d) and tensor (A_{xx}, A_{yy}, A_{xz}) analysing powers and the spin-correlation coefficients like $C_{y,y}$, $C_{y,yy}$, $C_{x,x}$ can be measured at SPD NICA [6] that will provide a serious test of the used pN amplitudes.

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DIS ON NUCLEI AT THE LHeC AND FCC-eh

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The Large Hadron-electron Collider is the proposal of an upgrade of the HL-LHC. An energy recovery linac will provide 50 GeV electrons to collide with the HL-LHC hadrons beams or, later, with the hadron beams at the Future Circular Collider. When combined with the available HL-LHC Pb beams, it will deliver e-Pb collisions with nucleon-nucleon centre-of-mass energies around 0.8 TeV, and per nucleon instantaneous luminosities around 10^{33} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Such collisions will explore a completely uncharted region of the $x - Q^2$ plane that extends the region presently covered by nuclear DIS experiments by three to four orders of magnitude in x and Q^2. In this talk we present the physics opportunities with such machine: a determination of nuclear parton densities with complete flavour unfolding, studies of 3D structure using diffractive observables, and the opportunities to search a new non-linear regime of QCD - parton saturation - through combined studies of e-p and e-A collisions. Besides, studies of QCD radiation and hadronisation in the nuclear environment. All these aspects have strong implications of our understanding of heavy ion collisions at high energies and of the quark-gluon plasma.

FIRST OBSERVATION OF DIFFRACTION IN PROTON-LEAD COLLISIONS WITH THE CMS DETECTOR

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We present the first measurements of diffraction in $\sqrt{s_{NN}} = 8.16$ TeV proton-lead collisions with CMS. The very large angular coverage of CMS is used to tag rapidity gaps on both the proton-going and lead-going sides and to identify both pomeron-lead and pomeron-proton topologies. Since the previous highest energy measurement of these processes was at $\sqrt{s_{NN}} = 30$ GeV, the current data provides essentially unique information. The rapidity gap distributions are sensitive to the gluon distribution within nuclei but also provide important information for modeling cosmic ray collisions. The results are compared to predictions from the EPOS, QGSJET and HIJING event generators.

PRODUCTION OF K*(892) MESONS IN Cu+Au AND U+U COLLISIONS

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One of the first proposed signatures of quark-gluon plasma (QGP) formation in heavy ion collisions was strangeness enhancement [1]. Due to its strange quark content, the K^* meson is a good probe

for the study of the QGP formed in heavy-ion collisions. K^*-meson production was previously measured by PHENIX [2] in symmetric Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV [3]. To continue the study of the QGP properties, we have performed analyses of K^*-meson production in asymmetric Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as well as collisions of highly deformed uranium nuclei at $\sqrt{s_{NN}}$ = 192 GeV. In this talk, we present invariant transverse momentum spectra and nuclear modification factors of K^*-mesons measured in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and U+U collisions at $\sqrt{s_{NN}}$ = 192 GeV. In central Cu+Au and U+U collisions in the intermediate transverse momentum range, K^*-meson yields are less suppressed than the yields of non-strange mesons such as π^0, η, and ω, which might indicate that additional particle production mechanisms are involved in K^*-meson production. Production of K^*-mesons in Cu+Cu, Cu+Au, and U+U collisions scales with number of participants and seems to depend on nuclear overlap size, but not on its geometry [4]. Implications for hadronization and strangeness production will be discussed.

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YIELD OF PARTICLES IN THE CUMULATIVE REGION AT CENTRAL RAPIDITIES AND LARGE TRANSVERSE MOMENTA AT THE NICA COLLIDER

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We estimate the yields of particles at central rapidities and large transverse momenta in the region outside NN-kinematics (the so-called cumulative region) in AuAu collisions, which in principle may be observed by MPD and SPD detectors at the NICA collider facility. We suppose that particles is this kinematical region are produced due to scattering from the clusters of cold dense quark-gluon matter presented inside nuclei - the nuclear "fluctons".
To obtain the input information for the calculations of these processes we use the results of the well-known cumulative experiments investigating the fragmentation of the various nuclear targets in the backward hemisphere under the influence of a proton beam. Basing on the flucton mechanism of particle production we choose as basic variables the so-called cumulative number and the transverse momentum of the particle. The parameterization of the dependence of cumulative particle yields on the transverse momentum at fixed value of cumulative number is not yet well established, so along with the one commonly used in works we perform the new parameterization of this dependence to trace it influence on the obtained results.
As expected, the existing experimental uncertainties in the type of the dependence of the particle yields on the transverse momentum at a fixed cumulative number result in our predictions obtained for the cross sections of particle yields in the new cumulative region of central rapidities and large transverse momenta in AuAu collisions due to the nucleon-flucton interaction production mechanism. Nevertheless, even despite these uncertainties, an interesting result was obtained. It is found that the relation between the yield of protons and pions in a new cumulative region of mid rapidities and large transverse momenta is completely different, compared to the previously studies in nucleus fragmentation region. If in the region of nucleus fragmentation the experiment the yield of cumulative protons is considerable dominate over pions, then, according to the estimates obtained, the situation radically changes in this new cumulative region where the yield of cumulative pions starts to dominate over protons.
This effect is caused by a stronger dependence of the cumulative proton yield on the transverse momentum compared to pions. Theoretically, it can be explained by different mechanisms of the formation of these cumulative particles - the coherent coalescence (recombination) of three flucton

quarks for a proton and the fragmentation of one flucton quark for a pion. Observation of this effect in the production of cumulative particles with large transverse momenta at mid rapidities with the MPD and SPD detectors at NICA would allow to verify these theoretical ideas about the mechanisms of particle formation in the cumulative region.
The research was supported by the Russian Foundation for Basic Research grant (No. 18-02-40075) and the St. Petersburg State University grant for outgoing academic activity (Id: 41159705).

CHARGED HADRON PRODUCTION IN Cu+Au COLLISIONS

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The PHENIX experiment aims to study the hot and dense state of strongly interacting matter produced in high energy heavy ion collisions, the quark-gluon plasma (QGP). Measurements of proton production, when contrasted with light meson production, provide excellent opportunities to study the constituent quark number dependence of certain observables. In this talk, we present a systematic study of proton production in heavy ion collisions using the PHENIX experiment, specifically the invariant yield and nuclear modification factors (R_{AB}) as a function of transverse momentum in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Comparison with previously obtained results in symmetric collisions like Au+Au enables the study of the influence of collision geometry on proton production. At same number of participants (N_{part}) proton R_{AB} in Cu+Au and Au+Au seems to be in agreement. This suggests that proton production scales with the average size of the nuclear overlap region and not depend on the details of its shape. The proton R_{AB} shows less suppression than π^0 and φ - mesons R_{AB} in Cu+Au for most central collisions. This difference between gradually disappears with decreasing centrality. Implications for hadronization will be discussed.

HE STRATOSPHERE EVENT OF 1975 REVISITED: NEW PHYSYCS IN ASTROPARTICLE COLLISION VS. LHC NUCLEUS-NUCLEUS DATA

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The event of astroparticle collision at high energy was detected in 1975 during the balloon flight in the stratosphere. The hundred particle tracks in x-ray films have been re-analyzed in the style of LHC experiments: rapidity distributions of charged particles and transverse mass spectra of multiparticle production have been built. The comparison of rapidity-and-transverse-mass histograms with the knowledge accumulated in the Quark-Gluon String Model gives us the conclusion that it was the carbon nucleus collision with the matter of atmosphere at the c.m.s. equivalent energy $\sqrt{s}$ = 5 TeV. After QGSM analysis of scarce data, we know the following: 1) the value of maximal rapidity of one projectile proton and 2) the density of particle multiplicity in the central rapidity region. In such a way, we can practically distinguish how the astroparticle interaction is similar to or differs from the average A-A collision event at LHC. The data include some features of new physics, as an example, it may be baryonic DM particle collision. Previously, the suggestion was

done that baryonic Dark Matter cannot be reproduced in accelerators. It appears in the space at a huge mass densities near the giant objects like Black Holes. Finally, we conclude that the cosmic ray experiments on the high altitude in the atmosphere are, on one hand, good supplements to the LHC measurements. On the other hand, they are able to observe events of new astroparticle collisions in the full kinematical region.

OVERVIEW OF HADRON AND JET PRODUCTION RESULTS FROM ALICE

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The ALICE experiment is designed to study the hot and dense medium, the quark-gluon plasma, produced in ultra-relativistic heavy-ion collisions at the LHC. Measuring the production of hadrons with large Q^2 transfer in these collisions provides the possibility to explore one of the most spectacular effects – parton energy loss in hot QCD matter. By varying the observables among light- and heavy-flavor hadrons and fully reconstructed jets and by changing the colliding systems from pp to p-Pb to Pb-Pb, one can explore the transport properties of hot QCD matter in great detail.
In this talk we present an overview of recent ALICE results on high-pT hadron and jet production in pp, pA and AA collisions at LHC energies.

QCD PHASE DIAGRAM: BARYON DENSITY, ISOSPIN AND CHIRAL IMBALANCE

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The talk is devoted to QCD phase diagram studies, including the region of large baryon density that will be probed at NICA.
Recently It has been shown that in the large-Nc limit (Nc is the number of colors of quarks) there exist duality correspondences (symmetries) in the phase portrait, which are the symmetries of the thermodynamic potential and the phase structure itself. The first one is a duality between the chiral symmetry breaking and the charged pion condensation phenomena. And there are two other dualities that hold only for chiral symmetry breaking and charged pion condensation phenomena separately. For example, we have shown that charged pion condensation does not feel the difference between chiral and isospin imbalances of the medium. They were shown to exist in the matter with chiral imbalance that can be produced in compact stars or heavy ion collisions. One of the key conclusions of these studies is the fact that chiral imbalance generates charged pion condensation in dense baryonic/quark matter. It was shown that our results in particular cases are consistent with the simulation of lattice QCD, which is possible in these cases.
Duality was used to show that there takes place catalysis of chiral symmetry breaking by chiral imbalance.
It was also shown that chiral imbalance generates the phenomenon of charged pion condensation in dense baryonic/quark matter even in the case of charge neutral matter, which is interesting in the context of the astrophysics of neutron stars.

It is known that chiral imbalance can occur in high energy experiments of the collision of heavy ions, due to temperature and sphaleron transitions. Our studies show that different types of chiral imbalance can occur in the cores of neutron stars or in heavy ion experiments, where large baryon densities can be reached, due to another phenomena - the so-called chiral separation and chiral vortical effects.
Duality was shown to exist even in case of inhomogeneous condensates. This example shows that the duality is not just entertaining mathematical property but an instrument with very high predictivity power.
The unified picture and full phase diagram of isospin imbalanced dense quark matter have been assembled. Acting on this diagram by a dual transformation, we obtained, in the framework of an approach with spatially inhomogeneous condensates and without any calculations, a full phase diagram of chirally asymmetric dense medium.
Continuing our studies of dualitiesl, we noted that there are dualities in 2-color QCD that are connected with adiitional symmetry of QCD with two colors namely Pauli-Gursey symmetry.
It has been also shown that found duality is a more fundamental and can be shown at the level of Lagrangian. It has been shown that duality is a property of real QCD. It is not bounded by large Nc approximation and exists in the cases of 2 and 3 and infinite number of colours.

ONE-DIMENSIONAL PION FEMTOSCOPY IN d+Au COLLISIONS AT $\sqrt{s}_{NN}$=200 GeV FROM STAR

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Femtoscopy is an important tool to measure spatial and temporal characteristics of the collision system. In this talk, the results of one-dimensional pion femtscopic analysis performed for d+Au collisions at $\sqrt{s}_{NN}$ =200 GeV will be shown. We will present various dependences of the invariant radii on pair transverse momentum and particle multiplicity per event. The physics implications of the resulting radius from the 1D pion femtoscopic analysis in this small system will be discussed.

ROLE OF MAGNETIC FIELD ON THE SIGNATURE OF QUARK GLUON PLASMA

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We study the important role of magnetic field on one of the indirect signature of quark gluon plasma as equation of state. The magnetic field plays an important role in producing the equation of state of QGP using simple phenomenological model. The results are significant at RHIC and LHC.

THE COMPARISON OF METHODS FOR ANISOTROPIC FLOW MEASUREMENTS WITH THE MPD EXPERIMENT AT NICA

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The main goal of study the relativistic heavy-ion collisions at energies of accelerator facility NICA (4–11 GeV) is to explore the QCD phase diagram in the region of high net baryon chemical potential and moderate temperatures. The anisotropic collective flow is one of the important observables sensitive to transport properties of strongly interacting matter created in such collisions. The MPD performance for anisotropic flow measurements is studied with Monte-Carlo simulations using collisions of Au+Au and Bi+Bi ions employing several state of the art event generators. Different methods for flow measurements: event plane, scalar product and direct cumulants are used to investigate the contribution of non-flow correlations and flow fluctuations.
The reported study was funded by RFBR according to the research project No 18-02-40086.

THE STUDY OF CHARGED HADRONS AND NUCLEAR FRAGMENTS FORWARD PRODUCTION IN CC COLLISIONS AT BEAM ENERGY 20.5 GEV/NUCLEON

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Inclusive differential cross sections for the forward production of charged hadrons and nuclei are measured in CC-interactions depending on their momentum at beam energy 20.5 GeV/nucleon ($\sqrt{S_{NN}}$ =6.3 GeV). The measurements have been performed at the U-70 Accelerator Complex (Protvino) using a combined spectrometer on base of beamline 22. Particle selection was carried out by measuring of ionization in scintillation counters taking into account the data from threshold Cherenkov counters and hadron calorimeter and mass was determined through Cherenkov light emission angle measured in the spectrometer of ring imaging Cherenkov radiation. For hadrons the available data are for momenta from 8 to 51 GeV/c. For fragments the data are given for charge $1 \leq Z \leq 6$, atomic number $1 \leq A \leq 10$ and $A/Z<3.4$ with momenta in range 20 – 210 GeV/c. The measurements are compared with Fritiof model, statistical models and theoretical parameterizations on the base of scaling invariance for nuclear processes. The hadrons data show essential yield of particles in the kinematical forbidden region in free NN collisions. The maxima of distributions for fragments are shifted towards large momenta proportionally to the fragment atomic number A and they also substantially produced in the kinematical forbidden region above this peak. The comparison of these data with analogous results at lower energy 1.05 GeV/nucleon shows that the general dependence of cross sections on the variable $x=P_{lab}/p_0$ is similar, but they are noticeably lower at larger energy 20.5 GeV/nucleon. The mentioned difference varied from a factor of 5 times near the fragmentation peak to several orders of magnitude beyond this peak.
This work was supported by the grant from the Russian Foundation for Basic Research No 19-02-00278.

HIGH PT ANTI-PROTON AND MESON PRODUCTION IN CUMULATIVE pA REACTION AT 50 GeV/c

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First data on the high pt cumulative K+/- and anti-proton particles produced at angle of 40 deg. (lab.syst.) in proton-nucleus interaction are presented. The anti-proton, pion and K-meson inclusive cross-sections in proton interactions with C, Al, Cu and W targets at 50 GeV/c were investigated. The available pt range 0.6 < pt <2.7 GeV/c exceeds free proton – nucleon kinematic limit (2.3 GeV/c for pions). It was found that within the experimental error the anti-p /pi- ratio is the same for all targets at all values of the particle momentum. Although the K+ /K- ratio is the same for all used nuclei, however it was turned out that anti-p/K depends on target. The data indicate substantial contribution of the multiparton processes in the cumulative meson and anti-p production. K/pi and anti-p/pi ratios behavior is qualitatively similar to the data from very high energy experiments like ALICE, STAR etc. The experimental data were obtained at the IHEP U-70 accelerator at SPIN setup.

FIT PERFORMANCE IN Pb-Pb COLLISIONS DURING RUN 3

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The Fast Interaction Trigger (FIT) [1] is one of the new detectors being constructed for the upgrade of the ALICE experiment at CERN. FIT is a thoroughly modernized design, combining the functionality of four detectors used by ALICE during LHC Run 2: the T0, V0, AD and FMD. During the upcoming LHC Run 3 and 4, in addition to the multiple triggering tasks, FIT will monitor luminosity, measure precisely the collision time, and determine centrality and event plane for heavy-ion collisions.

In non-central collisions, the geometry of the colliding nuclei can be described by the reaction plane that is determined by the beam axis and impact parameter. Since the impact parameter cannot be measured, one cannot determine the reaction plane precisely. An approximation for the reaction-plane angle Ψ_{RP} is the second-order event plane ψ_2, often simply referred to as event plane ψ, that is given by the flow vector determined from the measured final hadrons. The difference between Ψ_{RP} and ψ is measured with event-plane resolution, that is evaluated using the sub-event method [2].

In this presentation, I will summarise the FIT performance in Pb-Pb collisions during Run 3 based on simulations using realistic detector- and beam pipe geometry. The focus will be on the influence of sub-event selection on event plane determination and resolution. These results will be compared to the performance of the ALICE setup during LHC Run 2.

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THE MEANING BEHIND OBSERVED P_T REGIONS AT THE LHC ENERGIES

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We argue that p_T distribution data from the LHC on the invariant differential yield of the charged primary particles in Pb–Pb collisions at 2.76 TeV with six centrality bins contains several p_T regions with special properties. These distributions were analyzed by fitting the data with exponential functions. We conclude that the regions reflect features of fragmentation and hadronization of partons through the string dynamics. The nuclear transparency results in negligible influence of the medium in the III region (p_T > 17–20 GeV/c), which has highest p_T values. The effects and changes by the medium start to appear weakly in the II region (4–6 GeV/c < p_T < 17–20 GeV/c) and become stronger in the I region (p_T < 4–6 GeV/c). It seems that the II region has highest number of strings. The increase in string density in this region could lead to fusion of strings, appearance of a new string and collective behavior of the partons in the most central collisions. These phenomena can explain anomalous behavior of the Nuclear Modification Factor in the II region. We propose the II region as a possible area of Quark Gluon Plasma formation through string fusion. The first p_T regions are the ones with the maximum number of hadrons and minimum number of strings due to direct hadronization of the low energy strings into two quark systems–mesons.

PROBING PROPERTIES OF PION- AND KAON-EMITTING SOURCES AT NICA ENERGIES

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Relativistic heavy-ion collision experiments are aimed to study the properties of nuclear matter under extreme conditions, i.e. high baryon density and/or temperature, and to understand the underline mechanism of transition from quark-gluon to hadron matter. The phase transition may leave imprints on space and time characteristics of particle-emitting source that can be measured using femtoscopy technique.
In this talk, we will report the results of two-pion and two-kaon femtoscopic expectations for NICA energies. We explore the possible effects on the femtoscopic radii for different description of collision evolution scenarios from the UrQMD (microscopic transport theory based on h-h collisions) and vHLLE+UrQMD (relativistic hydrodynamics + cascade) models. The physics implications will be discussed.

NOTES ON POSSIBLE PHYSICAL EXPERIMENTS ON SPD AND BM@N DETECTORS OF THE NUCLOTRON-NICA ACCELERATOR COMPLEX

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The SPD and BM@N detectors of the Nuclotron-NICA accelerator complex at JINR are designed to operate at relatively high luminosities, which potentially significantly expands their physical program. The presented report is intended to stimulate the development of models and the development of experiments that are adequate to these capabilities. The report discusses the influence of polarization on the properties of nuclear matter at high baryon density and moderate temperature. In particular, we discuss the relationship between the role of diquarks in cold and dense matter and possible polarization effects in hyperon cross-section ratios, as well as the manifestation of spin effects in kinematically cooled nuclear matter.

OVERVIEW OF HERMES RESULTS ON LONGITUDINAL SPIN ASYMMETRIES

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The HERMES experiment has collected a wealth of data using the 27.6 GeV polarized HERA lepton beam and various polarized and unpolarized gaseous targets. This allows for a series of unique measurements of observables sensitive to the multidimensional (spin) structure of the nucleon, in particular semi-inclusive deep-inelastic scattering (SIDIS) measurements, for which the HERMES dual-radiator ring-imaging Cherenkov counter provided final-hadron identification between 2 GeV to 15 GeV for pions, kaons, and (anti)protons.
In this contribution, longitudinal single- and double-spin asymmetries in SIDIS will be presented. The azimuthally uniform double-spin asymmetries using longitudinally polarised nucleons constrain the flavour dependence of the quark-spin contribution to the nucleon spin. For a first time, such asymmetries are explored differential in three dimensions in Bjorken-x and the in the hadron kinematics z and $P_h\ \perp$ (which respectively represent the energy fraction and transverse momentum of the final-state hadron) simultaneously. This approach increases the quark-flavour sensitivity and allows to probe the transverse-momentum dependence of the helicity distribution. The measurement of hadron charge-difference asymmetries allows, under certain simplifying assumptions, the direct extraction of valence-quark polarisations. The azimuthal modulation of this double-spin as well as of the single-(beam)spin asymmetry probe novel quark-gluon-quark correlations through twist-3 distribution and fragmentation unctions. Also here asymmetries are explored in several dimensions. Furthermore, in case of the beam-spin asymmetry, results for electro-produced protons and antiprotons have become available. The beam-spin asymmetries for pions are compared to similar measurements for pions at CLAS and unidentified hadrons at COMPASS. Last but not least, the potential of using Λ hyperon leptoproduction for further insights in the nucleon structure will be discussed.

HADRON PRODUCTION IN HIGH-ENERGY PARTICLE COLLISIONS

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Based on the quark-hadron duality concept the hadronization of the deconfined matter arising in high-energy particle collisions is considered. The number of generated hadrons is shown to be entirely determined by the exact non-equilibrium Green's functions of partons in the deconfined matter and the vertex function governed by the probability of the confinement-deconfinement phase transition.
Compactifying the standard (3+1) chromodynamics into $QCD_{xy} + QCD_{zt}$, the rate of hadrons produced in particle collisions with respect to both the rapidity and p_T distributions is derived in the flux tube approach. Provided that the hadronization is the first order phase transition, the hadron rate is derived in the explicit form. The obtained rate is found to depend strongly on the energy of the colliding particles, number of tubes, hadron mass as well as on the temperature of the confinement-deconfinement phase transition. In the case of the pion production in pp collisions we obtain a good agreement to the experimental results on the pion yield with respect to both the rapidity and p_T distributions.

DESCRIPTION RELATIVISTIC NUCLEAR INTERACTION IN FOUR VELOCITY SPACE

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The description of relativistic nuclear interactions in the four velocity space allows to enter the self-similarity parameter. This parameter allows us to describe rather well the ratio of the proton to anti-proton yields in A-A collisions as a function of the energy in a wide range from 10-20 GeV to a few TeV. It is shown that the inclusive spectra of the produced hadrons in hadron-hadron and nuclear-nuclear collisions can be presented as the universal function dependent of the self-similarity parameter in analytical form. The experimental data are in good agreement with results our calculations in a wide energy range from a few GeV to a few TeV in central rapidity region.

BOTTOM-UP HOLOGRAPHIC APPROACH TO MESON SPECTROSCOPY

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The holographic methods inspired by the gauge/gravity correspondence from string theory have been actively applied to the hadron spectroscopy in the last fifteen years. Within the phenomenological bottom–up approach, the linear Regge-like trajectories for light mesons are naturally reproduced in the so-called "soft-wall" holographic models. I will give a very short review of the underlying ideas and technical aspects related to the meson spectroscopy.

PHOTOPRODUCTION OF RHO-MESONS ON NUCLEI IN ULTRAPERIPHERAL NUCLEAR COLLISIONS AT THE LHC

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Using the Gribov–Glauber model for photon–nucleus scattering and a generalization of the vector meson dominance (VMD) model for the hadronic structure of the photon, we make predictions for the cross sections of coherent and incoherent photoproduction of rho-mesons in Pb-Pb ultraperipheral collisions (UPCs) at the LHC. We find that the effect of inelastic nuclear shadowing is significant and leads to an additional 40% (25%) suppression of the coherent (incoherent) cross section. Our approach provides a very good description of the ALICE data on coherent rho photoproduction in Pb-Pb UPCs at 2.76 and 5.02 TeV. Comparing our predictions to those of the STARlight Monte-Carlo framework, we observe very significant differences.

WHAT CAN WE LEARN FROM REMNANTS OF SPECTATOR MATTER IN CENTRAL NUCLEUS-NUCLEUS COLLISIONS?

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Participating nucleons in collisions of relativistic nuclei are well separated kinematically from spectator nucleons, which propagate forward with the initial beam energy. In central ^{208}Pb–^{208}Pb collisions (0-5% centrality) the nuclear centres are typically separated by less than 3.5 fm [1]. This suggests that only few nucleons in far nuclear periphery escape collisions and move forward as spectators. Indeed, as found by measurements with fixed targets at the CERN SPS [2], 9 neutrons, 7 protons and 0.5 deuterons are produced on average in central ^{208}Pb–^{208}Pb collisions. The most central collisions can be unambiguously selected in experiments in colliders by requiring the highest multiplicity of secondary particles in the central barrel [3]. With our recently developed Abrasion-Ablation Monte Carlo for Colliders model (AAMCC) we calculate the yields of spectator neutrons and protons in central ^{197}Au–^{197}Au and ^{208}Pb–^{208}Pb collisions, respectively, at NICA and at the LHC. We demonstrate the sensitivity of the calculated yields to the presence of the neutron-skin [4] in initial nuclei and also evaluate the content of bound spectator nucleons in such collisions, which is extremely sensitive to the excitation energy of spectator matter. We argue that the measurements of central events with unequal numbers of spectator neutrons and protons (e.g., with a single proton accompanied by several neutrons and vice versa) can reveal these effects.
This work has been carried out with financial support of RFBR within the project 18-02-40035-mega.

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NEW APPROACHES TO MEASURE CENTRALITY IN THE HADES HEAVY ION EXPERIMENTS

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The experimental determination of event centrality classes is one of the important tasks in studying the properties of strongly interacting matter.
New approaches for event centrality selection in nucleus-nucleus collisions based on the particles charge distributions measured with Forward Wall hodoscope at the HADES experiments will be discussed.
The comparison of experimental charge distribution in Ag+Ag collisions at an energy of $1.58A$ GeV and in Au+Au at $1.23A$ GeV with corresponding charge distributions from the DCM-QGSM-SMM event generator will be presented.

EXPLORING NUCLEAR FRAGMENTATION AT HEAVY-ION COLLIDERS

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As the kinetic energy of nuclei grows, studying their fragmentation in collisions with fixed targets becomes an increasingly complicated task. Secondary spectator fragments emitted at small angles close to the beam do not allow the placement of advanced detectors for their registration. This explains the use of nuclear photoemulsion or track detectors at ~$1-100A$ GeV beam energies [1-3], where the universality of spectator fragmentation has been demonstrated [3]. It is impossible to detect spectator fragments in nucleus-nucleus collisions at RHIC and at the LHC. However, as shown in the present work, some features of the fragmentation at highest collision energies still can be deduced from forward neutrons and protons detected by Zero Degree Calorimeters [4]. We employ our Abrasion-Ablation Monte Carlo for Colliders model (AAMCC) to predict various correlations between the total charge of undetected nuclear spectator fragments Z_{bound}, their total mass Abound and the numbers of free forward neutrons and protons and describe measured dependencies [1-3]. AAMCC is based on the well-known Glauber Monte Carlo model [5] to calculate the numbers of participant and spectator nucleons and on the nuclear evaporation, Fermi Break-up and SMM models from Geant4 library [6] to simulate decays of exited spectator matter. The calculated correlations between the numbers of free spectator neutrons and Z_{bound} are shown in Fig.1 for two collision energies. While the general shape of the correlation is preserved at the LHC, a higher yield of central events with small Z_{bound} is predicted due to a larger σ_{NN} in the calculations at the LHC.

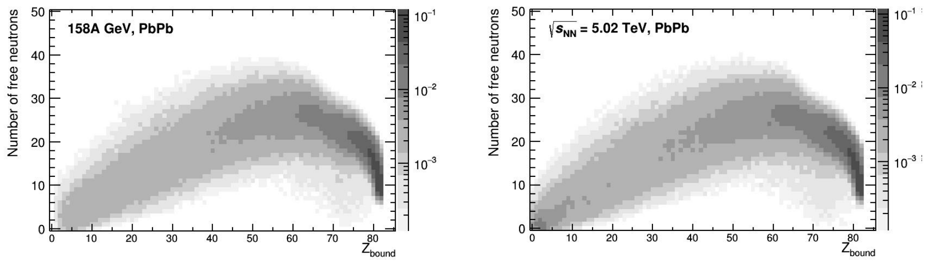

Figure 1: Correlations between the numbers of free spectator neutrons and Z_{bound} calculated with AAMCC model for ^{208}Pb-^{208}Pb collisions at the CERN SPS (left) and the LHC (right).

In future LHC experiments Z_{bound}, A_{bound} and the numbers of spectator neutrons and protons can be related to collision impact parameter which, in its turn, can be independently evaluated from the numbers of produced particles detected in the central barrel. We propose to evaluate Z_{bound} along with A_{bound} in each event by subtracting the measured numbers of free protons and neutrons from Z and A of initial nuclei corrected for estimated numbers of participants. In this way the studies of nuclear fragmentation can be extended to LHC energies in order to confirm or refute the universality of spectator fragmentation.

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CHARGED PARTICLE IDENTIFICATION BY THE TIME–OF–FLIGHT METHOD IN THE BM@N EXPERIMENT

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Baryonic Matter at Nuclotron (BM@N) is a fixed target experiment at the NICA - Nuclotron accelerator complex (JINR). It is aimed at studies of nuclear – nuclear (up to gold-gold) collisions at high densities. The Nuclotron provides heavy ion beams with energies from 2.3 to 3.5 GeV, which is suitable for studies of strange mesons and multi–strange hyperons produced in nucleus-nucleus collisions close to the kinematic threshold.

The contribution is devoted to the identification of light particles (pi, K, p) and fragments (He3, d/He4, t) in the BM@N experiment using the Time–of– Fight method. Three detector subsystems are involved: it is a central tracker, Cathode Strip Chamber (CSC) and Time–of–Flight detector (TOF). The main purpose of the central tracker is to reconstruct the charged particles tracks and momenta. We use CSC to filter out the bad tracks. And we obtain the time information from the TOF. For now the method allows us to separate the light particles up to 2 GeV/c and the light fragments up to 4 GeV/c by the full momentum.

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SHORT-RANGE NN CORRELATIONS AND QUASI-DEUTERON CLUSTERS IN THE REACTION ^{12}C+p→^{10}A+pp+N

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Short range correlated (SRC) NN pairs play an important role in structure of atomic nuclei and are studied in many nuclear centers using electron beams [1]. A new step was done at BM@N in JINR [2] where the reaction ^{12}C+p→^{10}A+pp+N is studied using the ^{12}C beam at energy of 4 GeV/nucleon at kinematics providing interaction of the hydrogen target with the SRC pair in the ^{12}C. For theoretical analysis of the SRC effects in the reaction ^{12}C+p→^{10}A+pp+N it seems natural to use a properly modified approach [3] developed earlier (see Ref. [4] and references therein) to describe the quasi-elastic knock-out of fast deuterons from the light nuclei ^{12}C and ^{7,6}Li by protons in the reactions (p,pd) and (p,nd) [5]. An elementary sub-process in the (p,Nd) was the backward elastic scattering of the proton on the two-nucleon clusters p$\{pn\}$→pd and p$\{nn\}$→nd at the proton beam energy 670 MeV. Spectroscopic amplitudes for NN-pairs in the ground state of the ^{12}C nucleus are calculated here within the translation-invariant shell model (TISM) with mixing configurations. The factorization of the two-nucleon momentum distribution over the internal $n_{rel}(q_{rel})$ and the c.m.s. $n_{cm}(k_{c.m.})$ momenta is assumed and at large q_{rel} the squared deuteron (or singlet deuteron) wave function is used for $n_{rel}(q_{rel})$. Relativistic effects in the sub-process p+$\{NN\}$p+N+N are taken into account in the light-front dynamics [3]. We found [6] that the c.m. distribution of the deuteron clusters obtained within the TISM and used in [3], [4] to describe the (p,Nd) data [4] has to be modified considerably to describe the $k_{c.m.}$ distribution of the SCR NN pairs measured in the electron data [1].The ratio of the spin-singlet to spin-triplet $\{NN\}_s$ pairs is calculated.

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NEW EXPERIMENTAL METHODS AND OBSERVABLES FOR ANISOTROPIC FLOW ANALYSES IN HIGH-ENERGY PHYSICS

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The properties of an extreme state of nuclear matter, the Quark-Gluon Plasma (QGP), are studied in experiments at RHIC and LHC with heavy-ion datasets collected at ultrarelativistic energies. The

QGP consists of asymptotically free quarks and gluons which move freely over distances large in comparison to the typical size of a hadron. If the nuclear matter produced in heavy-ion collisions reaches thermalization, its behavior will be dominantly governed by non-trivial collective effects, like anisotropic flow. In non-central heavy-ion collisions, the initial ellipsoidal volume containing the interacting nuclear matter is anisotropic in the coordinate space, due to the geometry of non-central collisions. Multiple interactions within this anisotropic volume cause the anisotropy to be transferred from coordinate space into momentum space. This transfer is the anisotropic flow phenomenon. Flow measurements have provided the key constraints on transport properties of QGP (e.g. on its shear viscosity), and these results helped a great deal in establishing the perfect fluid paradigm about QGP.
In this contribution, we introduce new experimental methods and observables for anisotropic flow analyses in high-energy physics, which can provide further and independent constraints on QGP properties. The cornerstone of this approach are multiparticle azimuthal correlations, from which the new observables, dubbed higher-order Symmetric Cumulants, have been recently derived in [1], as well as new estimators for symmetry-plane correlations in [2]. Both theoretical predictions and first experimental results from ALICE Collaboration are presented and discussed.

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PERSPECTIVES OF STRANGENESS STUDY AT NICA/MPD FROM REALISTIC MONTE CARLO SIMULATION

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Relativistic heavy-ion collisions provide a unique opportunity to study nuclear matter under extreme density and temperature. The study of the strangeness production is of particular interest. Since strange hadrons are initially not present but created during the heavy-ion collision, the strangeness is one among the most sensitive probes for the deconfinement phase transition as well as for the in-medium effects in dense nuclear matter.
The Nuclotron-based Ion Collider fAcility (NICA) is a new flagship project aimed in the construction at JINR (Dubna) a modern machine providing beams of heavy ions with the highest intensity ever achieved in the energy range from 4 to 11 GeV per nucleon [1]. The main scientific goal of the NICA project is the experimental exploration of a yet poorly known region of the QCD phase diagram of the highest net-baryon density with an emphasis on the nature of the deconfinement phase transition, study of hadron properties in dense baryon matter, and search for the critical end point (CEP).
Hyperon identification and reconstruction should be one of the most important tasks of experiments at NICA. The MPD/NICA start version's characteristics for measuring hyperons (Λ, $\bar{\Lambda}$, $\Xi^{\mp}$, $\Omega^{\mp}$,) obtained on Monte Carlo simulated event samples of gold-gold collisions at NICA energies will be presented.
For the present study the Parton-Hadron-String Dynamics (PHSD) model was used, based on a microscopic off-shell dynamical transport approach incorporating the partonic degrees-of-freedom in terms of strongly interacting quasi-particles, their hadronization and further of-shell dynamics for the hadronic stage [2]. The deconfinement phase is realized to reproduce the lattice QCD Equation-of-State with a crossover phase transition at high temperature and small chemical potential. The PHSD has been successfully applied to describe many observables measured from low to very high energies [3].

Particles produced by the event generators were transported through the detector using the GEANT3 transport package. Track and vertex reconstruction methods [4] were based on the Kalman filtering technique. (Multi)strange hyperons were reconstructed by combining charged tracks found in the TPC, first to select a V0-candidate (a characteristic topology of two oppositely charged daughter tracks) and then to match it with one of the secondary pion candidate.
It will be shown that the MPD start version will provide a good opportunity to perform such measurements and the current status of the event reconstruction algorithms and software is adequate for a study of the strangeness production at NICA (achieved mass resolution 2-3 MeV/c^2 with high enough yields). The reliability of the conclusions is assured by the realistic simulation of the detector response as will be described for the MPD TPC (Time Projection Chamber).

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MEASUREMENTS OF HEAVY-FLAVOUR HADRON PRODUCTION WITH ALICE AT THE LHC

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Since the production and hadronisation of heavy-flavour quarks is well-separated within the evolution of a high-energy particle collision, the resulting yields and kinematics of heavy-flavoured hadrons are valuable signals to gain insight in the underlying processes and dynamics of a hadronic collision.
In this contribution, an overview of recent results on heavy-flavour hadron production measured by the ALICE experiment at the CERN LHC is presented. Results from proton-proton, p-Pb, and Pb-Pb collisions are discussed, where the focus is placed on collisions involving heavy ions. Data are compared with available theoretical or phenomenological calculations.

CENTRALITY DETERMINATION IN CARBON BEAM DATA FOR BM@N EXPERIMENT WITH ZERO DEGREE CALORIMETER (ZDC)

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The Baryonic Matter at Nuclotron (BM@N) is the fixed target experiment on NICA-Nuclotron acceleration complex in Dubna (JINR). The main goals of experimental data taking in 2016-2018 at the BM@N were measurements of strange and multistrange hyperon productions and searching for the hyper-nuclei in nucleus nucleus collisions. First data with carbon, argon and krypton beams have been taken at the BM@N with different targets. The BM@N experimental set-up

consists of several beam detectors, analyzing magnet with precise tracking system and time-offlight detectors. In order to have possibility to measure reaction centrality the forward hadron Zero Degree Calorimeter (ZDC) has been installed downstream. Methods to determine nucleus-nucleus collision centrality with ZDC will be presented. The experimental data analysis for C+C reactions and event selection for different centrality classes will be discussed.
This work was supported by the Russian Foundation of Basic Research (RFBR) Grant No. 18-02-40081.

STUDY OF THE SPECTATOR MATTER IN HEAVY ION COLLISIONS AT THE BM@N EXPERIMENT

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The BM@N (Baryonic Matter at Nuclotron) is fixed target experiment to study nucleus-nucleus reactions with the ion beams energies up to 4.5A GeV. It is supposed to perform differential measurements of the energy, charge composition, transverse momentum and other characteristics of the projectile spectators at the BM@N. These observables would be sensitive to the processes in the dense interaction region because the transit time of an incident nucleus through a target nucleus is comparable to the lifetime of the dense nuclear matter created at these energies. The measurements of spectators would allow to determine the geometry of nuclear collisions (centrality and reaction plane) as well as to understand the mechanisms of fragmentation and the equation of state of nuclear matter.
The BM@N is the most suitable experiment for such a study because it has a powerful analyzing dipole magnet which deflects the charged components of the spectators and partially separates them from the neutron spectators. The measurements of the neutron spectators are proposed to do with new forward hadron calorimeter (FHCal), which is already installed at the BM@N. To measure the heavy charged fragments and proton spectators the quartz and scintillator hodoscopes are under development. The performance of this new forward detector system at the BM@N will be shown.

φ-MESON PRODUCTION IN SMALL SYSTEMS COLLISIONS

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The meson has a small inelastic cross section for interaction with nonstrange hadrons, therefore it is less affected by late hadronic rescattering and better reflects the initial evolution of heavy ion collisions. Small systems, such as p+Al, p+Au, and ^{3}He+Au, can help us understand whether the suppression of hadron yields in the region of intermediate to large transverse momenta is associated with hot (QGP) or cold nuclear matter effects. In this talk we will present a study devoted to the phi meson production in small collisions systems at $\sqrt{s_{NN}} = 200$ GeV as measured by the PHENIX experiment at RHIC. The -meson production shows a small system size dependence in the most central p+Al, p+Au, ^{3}He+Au collisions, and the nuclear modification factors are consistent with those of the ^{0} within uncertainties for all three collision systems. Implications for hadronization and strangeness production will be discussed.

THERMAL PHOTON MEASUREMENTS WITH THE FUTURE MPD EXPERIMENT AT NICA

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The future MPD experiment at the NICA collider is going to explore the dense hadronic matter produced in heavy-ion collisions in the energy range 4-11 GeV and search for signs of the phase transition to the deconfined quark-gluon plasma state. Measurements of soft thermal photon spectra via photon conversions can significantly extend the physics program of the MPD experiment, allowing one to probe the temperature of the medium created in heavy-ion collisions at NICA energies. In this contribution, feasibility studies on the thermal photon measurements with the conversion method in the projected MPD setup will be presented.
This work was funded by RFBR according to the research project No.18-02-40045 and partially supported by the National Research Nuclear University MEPhI in the framework of the Russian Academic Excellence Project (contract No.02.a03.21.0005, 27.08.2013).

SHORT-LIVED RESONANCES IN THE PHYSICAL PROGRAM OF THE MPD EXPERIMENT AT NICA

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The short-lived resonances have always played an important role in the physical programs of heavy-ion experiments. The resonances measured in the hadronic decay channels probe the strangeness production, the hadronization mechanisms at intermediate and high transverse momenta, rescattering and regeneration effects in the hadronic phase of nucleus-nucleus collisions at various energies. Properties of resonances have never been studied in detail in heavy-ion collisions at NICA energies. In this presentation, we review the expected properties of the resonances and their sensitivity to different stages of Au+Au collisions at NICA energies. Results of feasibility studies for reconstruction of resonances in the MPD experimental setup will also be presented and discussed.
This work was funded by RFBR according to the research project No.18-02-40038 and partially supported by the National Research Nuclear University MEPhI in the framework of the Russian Academic Excellence Project (contract No.02.a03.21.0005, 27.08.2013).

TRACK RECONSTRUCTION IN THE UPGRADED TRACKING SYSTEM OF MPD/NICA.

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Although the start-up of the MPD experiment is still ahead, the work on the preparation and physics validation of the future detector upgrade program has already been initiated.

As one of the possible MPD upgrade steps, an Inner Tracking System (ITS) based on the next generation silicon pixel detectors is being considered to be installed between the beam pipe and the Time Projection Chamber (TPC). It is expected that such a detector will increase the research potential of the experiment for both the proton-proton (high luminosity) and nucleus-nucleus (high particle multiplicity) interactions. According to the proposed design, the MPD ITS will consist of five layers of silicon pixel detectors. The main purpose of the ITS is to provide a better precision of the primary and secondary vertex reconstruction and improve track reconstruction in the MPD in the region close to the interaction point.
The existing in the MPD track reconstruction method is based on the Kalman filter in the TPC. Its simple extension to the ITS is not considered as the most efficient approach. Therefore, another method, based on the "vector finder" approach, was developed. The talk will describe the proposed algorithm and present its performance results for primary and secondary track reconstruction in the MPD ITS obtained on Monte-Carlo generated data of nucleus-nucleus collisions.

ON THE TRANSVERSE MOMENTUM DISTRIBUTIONS OF SECONDARY PARTICLES IN PROTON-PROTON COLLISIONS IN A THERMODYNAMIC APPROACH AT HIGH ENERGIES

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The transverse momentum distributions for lambda-hyperons are found in the thermodynamic model, which are in agreement with experimental data for proton-proton collisions with energies of $\sqrt{s}$ = 53, 200, 900, and 7000 GeV. The calculated spectra are consistent with the results of the quark-gluon string model [1].
The spectra of soft photons in proton-proton collisions were also considered in the thermodynamic approach at a proton momentum of 450 GeV /c on a fixed target [2], and the possibility of an exess in this experiment for a new particle, X17 boson with a mass of 17 MeV [3,4], was analyzed.

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STUDY OF STRONGLY INTENSE QUANTITIES AND ROBUST VARIANCES IN MULTI-PARTICLE PRODUCTION AT LHC ENERGIES

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The strongly intense quantities and robust variances in processes of multi-particle production in pp and AA interactions at LHC energies was studied. The Monte Carlo and analytic modelling of these quantities in the framework of a quark-gluon string model were implies. The string fusion effects were also taken into account by implementing of a lattice (grid) in the impact parameter plane. Strongly internsive variable $\Sigma(n_F,\ n_B)$ was calculated for different energies for two values of the width of the observation rapidity windows as a function of the distance between the centers

of this windows.
Scaled variance ω_n and robust variance R_n for different energies and for different width of the observation rapidity window was calculated by MC simulations. Strongly internsive variable $\Sigma(n_F,\ n_B)$ calculated from MC simulation results was also compared with preliminary ALICE experimental data.
This talk is based on CERN Summer Student Project [1].

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STUDY OF QCD AT BESIII

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The BESIII experiment, installed at the BEPCII electron positron collider in Beijing, has acquired large data sets at center-of mass energies between 2.0 GeV and 4.6 GeV. One of the main aspects of the BESIII physics program is to test the understanding of QCD at intermediate energies. Applying different experimental techniques, form factors of hadrons are measured. An overview of the recent results at BESIII will be reported.

EMBEDDING PROCEDURE AS AN INSTRUMENT TO BE USED FOR OPTIMAL RECONSTRUCTION OF PARTICLE TRAJECTORIES FROM Λ^0 DECAY

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BM@N is a really working fixed target experiment considered as a first step towards a fulfil realization of physics program at the NICA accelerator complex (Dubna, Russia). It has an extensive physics program to be investigated. Estimation of yields of strange particles in the BM@N energy range ($E_{lab} = 2 - 6\ A$ GeV) is considered as a point of utmost importance due to lack of measurements. The enhanced yield of strange particles in this energy range could be attributed to onset of deconfinement. To cover this aspect of the BM@N physics program, one requires to have an appropriate tracking procedure and robust algorithms of reconstruction of secondary particles produced by strange particles decays. The current work is dedicated to a corresponding adjustment of the BM@N tracking procedure aimed at a better reconstruction of tracks from the $\Lambda^0 \to \pi^- p$ decay. It is done by embedding the Monte Carlo information from the Λ^0 decay products produced in the conditions very close to those ones one had in the course of experiment, so taking into account a set of realistic effects when doing detector simulations, in existing experimental data obtained in the recent experimental run of BM@N (March, 2018). Some issues concerning

a developed algorithm of the embedding procedure, data separation, efficiency and so on are discussed in the work. Preliminary setups for the BM@N tracking procedure to be used for optimal reconstruction of Λ^0 decay products are also planned to be presented.

DETERMINING THE INITIAL CONDITIONS AND TRANSPORT PROPERTIES OF QUARK-GLUON PLASMA BY FLOW MEASUREMENTS AT THE LHC

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The collective expansion of the color-deconfined fireball created in relativistic heavy-ion collisions maps the initial state of the quark-gluon plasma (QGP) to the final-state particle spectrum.
The LHC experiments are completing the flow harmonic measurements at the highest energies to date as well as improving flow harmonic correlation techniques to understand the properties of the QGP and the full evolution of the heavy-ion collisions.
In this talk, a brief summary of the flow measurements developed in recent years and their implications to constrain the initial conditions and transport properties of heavy-ion collisions will be discussed.

CUMULATIVE PIONS IN ^{12}C FRAGMENTATION AT 3.2 GEV/NUCLEON

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Charged pion momentum spectra in ^{12}C fragmentation at a laboratory angle of 3.5o on Be target were measured in the FRAGM experiment at ITEP TWA heavy ion facility. Carbon beam energy was 3.2 GeV/nucleon. Positive pions were identified on severe proton background by TOF and Cherenkov counters. Yields of positive and negative pions have been measured up to 5.2 GeV/c momentum, which is approximately two times larger than maximal pion momentum in interaction of free nucleons. A kinetic energy spectra in a rest frame of projectile carbon ion are well described by an exponent. The slope parameter was compared with other measurements in ion-ion collisions as well as in proton-nucleus interactions in cumulative region..These data are also compared with predictions of four ion-ion interaction models: Binary Cascade, Quantum Molecular Dynamics, Los-Alamos Quark Gluon String Model and Liege Intranuclear Cascade. Negative to positive pion ratio is the most sensitive to differences between the models. Momentum spectra of protons, deuterons and ^{3}He are also presented and compared with the model predictions. The work was supported by RFBR grant № 18-02-0844.

PERFORMANCE OF THE MPD DETECTOR IN THE STUDY OF STRANGENESS PRODUCTION AND EVENT-BY-EVENT FLUCTUATIONS IN Au+Au COLLISIONS AT NICA

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The future heavy-ion collider NICA (JINR, Dubna) will provide a variety of beam species in the energy range of 4 – 11 GeV. New experimental data on strangeness production and event-by-event fluctuations from NICA allow addressing important QCD properties such as the nature of the deconfinement phase transition and existence of the Critial End Point (CEP). Heavy-ion collisions at NICA will be measured with a multi-purpose detector – MPD, which provides precise reconstruction of multiple physics channels.
NICA physics goals and MPD concept will be presented with an emphasis to detector performance in strange mesons reconstruction as well as in the measure of high order moments of the net-proton and net-kaon event-by-event multiplicity distributions.
This work was supported by the Russian Foundation for Basic Research grant 18-02-40037.

PHYSICS WITH SPECTATORS IN MPD/NICA EXPERIMENT

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At present the heavy ion accelerator complex NICA is under construction in Dubna, Russia. The Multi-Purpose Detectors (MPD) will operate at NICA to study the properties and phase diagram of strongly interacting matter. The Forward Hadron Calorimeter (FHCal) is one of the basic sub-detectors of MPD and is intended for the detection of the particles in very forward rapidity region, mainly, non-interacting projectile fragments (spectators). Since the FHCal has a beam hole, most of the bound spectators escape in this hole, while the free spectators (protons and neutrons) deposit their energy in calorimeter. Experimental study of energy and space distributions of the spectators could provide an important information about the geometry of the heavy-ion collisions, namely, the centrality and the reaction plane orientation. Also, the angular distributions of the spectators can carry the information about the transverse momentum obtained from the collision region.
In this report the simulation results of the energy and space distributions of spectators in FHCal are presented. The approaches for the measurements of the collision centrality and the reaction plane orientation are discussed. It would be shown that the measurement of the spectators with forward calorimeter has a spectrum of the important physical tasks.
This work was supported by the Russian Foundation of Basic Research (RFBR) Grant No. 18-02-40065.

C, P, T SYMMETRIES AND LORENTZ TRANSFORMATIONS IN THE THEORY OF SUPERALGEBRAIC SPINORS

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The study of continuous (Lorentz transformations) and discrete symmetries of P, T, C, CP, and CPT and their disturbances is one of the important directions in modern quantum field physics. However, the derivation of formulas defining these transformations for spinors still relies heavily on physical considerations, rather than on the algebraic properties of spinors. Initially, in quantum field theory, spinors were considered using the Dirac matrix formalism. The modern theory of spinors is formulated in the framework of the formalism of Clifford algebras, such spinors are called algebraic [1]. However, algebraic spinors are rarely used in quantum field theory, since difficulties arise in constructing the vacuum state vector, second quantization theory, and spinor bundles. The theory of superalgebraic spinors [2-4], which is an extension of the theory of algebraic spinors, solves these problems. In it, spinors, basis Clifford vectors (analogues of Dirac gamma-matrices) and the state vector of vacuum are constructed from Grassmann variables and derivatives with respect to them. In this case, the expansion of the second quantization for the operator of the spinor field is obtained from purely algebraic relations, and the spinor momentum, electromagnetic and other gauge fields are of the same nature - they arise as affine connections in a superalgebra bundle. In the case of four independent Grassmann variables and derivatives with respect to them, not five Dirac matrices arise, but seven gamma operators - superalgebraic analogues of such matrices. Of these, one corresponds to the fifth Dirac matrix, multiplied by an imaginary unit, and is a pseudovector.

We have shown that in a matrix formalism there are two outwardly indistinguishable, but fundamentally different types of matrix operators acting on spinors. Operators of the first type are associated with spinor transformations. The operators of the second type are associated with the replacement of the spinor basis, and in the superalgebraic formalism, the spinor itself does not change from such a replacement.

We have constructed in an explicit form the state vector of the vacuum and its change during symmetry transformations. It is invariant with respect to Lorentz transformations and spatial reflections. There are two unitary transformations of the reflection of the time axis, which act equally on Clifford vectors, but act differently on spinors. For one of them, the vacuum is not T-invariant. When the time axis is reflected, it passes into an alternative vacuum, for which the spinor creation operators turn into annihilation operators, and the annihilation operators turn into birth operators. For the second operator, the vacuum is T-invariant, and the corresponding CPT transformation is an anti-unitary symmetry transformation.

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HIGGS AND COSMOLOGY

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I review the role of the Higgs boson as a unique probe of the hidden sector, which has direct implications for dark matter physics and inflation. This framework leads to specific signatures at the LHC.

TIME SCALE OF THE THERMAL MULTIFRAGMENTATION IN C(22 GeV) + Au COLLISIONS

Authors:

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The relative angle correlation of intermediate mass fragments has been studied for C(22 GeV) + Au collisions at the Dubna Nuclotron with the FASA [1] 4pi detector array. Strong suppression at small angles is observed caused by IMF-IMF Coulomb repulsion. Experimental correlation function is compared to that obtained by the multibody Coulomb trajectory calculations with the various decay time of fragmenting system. The analysis has been done on an event by event basis. The multibody Coulomb trajectory calculations of all charged particles have been performed starting with the initial breakup conditions given by the combined model INC [2] + SMM [3]. The correlation function was calculated (using HybriLIT platform of LIT, JINR) for prompt breakup and for mean life time of the system 200 fm/c at freeze-out volume Vf = 3V0.
It was found a good agreement of measured and calculated correlation function for prompt breakup which is in accordance with the scenario of a simultaneous multibody decay of a hot and expanded nuclear system.
The research was supported by Grant No. 19-02-00499A from Russian Foundation for Basic

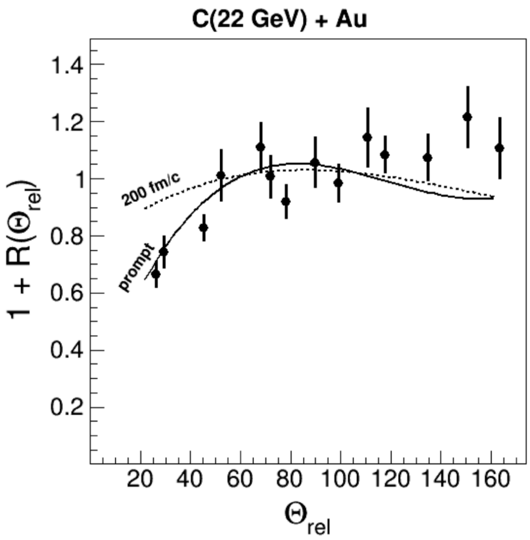

Figure 1: Relative angle correlation function for IMF produced in C + Au collisions at 22 GeV. Points – experimental data. Solid line – INC+SMM calculations with prompt secondary disintegration. Doted line correspond to INC+SMM calculations with mean time of secondary disintegration 200 fm/c.

Research.

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MEASUREMENT OF THE NEUTRON TIMELIKE ELECTROMAGNETIC FORM FACTOR AT THE VEPP-2000 E+E- COLLIDER WITH THE SND DETECTOR

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The e+e- -> n+anti-n cross section has been measured in the experiment at the VEPP-2000 e+e- collider with the SND detector. The technique of the time measurements in the multichannel NaI(Tl) electromagnetic calorimeter is used to select n+anti-n events. The measured value of the cross section in the energy range from the threshold up to 2 GeV is of order of 0.5 nanobarn, what corresponds to the neutron timelike formfactor ~0.3. The presented work is supported by the RFBR grant No. 18-02-00147a.

P,T-ODD FARADAY EFFECT: A NEW APPROACH TO THE SEARCH FOR THE P,T-ODD INTERACTIONS IN NATURE

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A search for the time-noninvariant (T-odd) interactions is one of the most fundamental not yet resolved problems in physics and, more generally, in nature. In 1950, Purcell and Ramsey [1] suggested that it is equivalent to the search for the electric dipole moment(EDM) of any elementary particle. The existence of EDM violates both P- and T-invariance (P is the space parity). The search for the EDMs continues already for 50 years without any success. In [2-3] it was predicted that in heavy diatomic molecules, the electron EDM (eEDM,d_e) can be greatly (up to 10^9 times) enhanced. The other possible P,T-odd effect in atomic systems - scalar-pseudoscalar interaction of an electron with atomic nucleus in an external electric field can be always presented as an existence of ''equivalent" eEDM $d_e^{\rm eqv}$ [3]. The most advanced recent experiment on the observation of eEDM in the ThO molecule (ACME collaboration, USA) sets the upper bound for eEDM $d_e < 1.1 \times 10^{-29}$ e cm (e is the electron charge) [4]. The accurate evaluation of eEDM within the standard model (SM) is still absent, the maximum estimated value is $d_e \sim 10^{-38}$ e cm [5]. No signs of "new physics" inside this gap of 9 orders of magnitude between the theory and experiment are not yet found. This encourages to suggest the new, more sensitive methods for observation of eEDM in atomic physics. Such a suggestion was made in [6-7] where the P,T-odd Faraday effect (rotation of the polarization plane for the light propagating through a medium in presence of an external electric field) was considered. The experiment was assumed to be performed with the modern ICAS (intra-cavity absorption spectroscopy) techniques which made important successes during the last decades [8]. Theoretical simulations of such experiments together with accurate calculations of the molecular structure showed that the sensitivity of the P,T-odd Faraday experiment on the PbF molecule can exceed the sensitivity of ACME experiment by 6-7 orders of magnitude. An advantage of the P,T-odd Faraday experiment is that the P,T-odd effect is cumulated on the light, while in ACME experiment (electron spin precession in an external electric field) it is cumulated on molecules. To surpass the shot-noise limit (which is the main condition to reach the higher sensitivity) it is much easier

to have larger number of photons than the larger number of molecules. Then, using the nonlinear optical effects one may hope to close fully the gap between experiment and SM theory for eEDM.

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A POSSIBILITY OF CPT VIOLATION IN THE STANDARD MODEL

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It is shown that there is a possibility of violation of CPT symmetry in the Standard Model which does not contradict to the famous CPT theorem. To check this possibility experimentally it is necessary to increase the precision of measurements of the proton and antiproton mass difference by an order of magnitude.

АВТОМОДЕЛЬНОСТЬ В РЕЛЯТИВИСТСКИХ ЯДЕРНЫХ СТОЛКНОВЕНИЯХ

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Рассматривается автомодельное описание релятивистских ядерных столкновений. Автомодельный подход иллюстрируются широким набором экспериментальных данных по кумулятивным, подпороговым процессам, а также реакциям с рождением частиц с большими поперечными импульсами. Рассматриваются критерии применимости понятия «элементарная частица». Обсуждается принцип редукционизма и соотношения между стандартной теоретико-полевой моделью и феноменологическими методами описания релятивистских ядерных взаимодействий.

РЕЛЯТИВИСТСКИЕ ЯДЕРНЫЕ СТОЛКНОВЕНИЯ И НАПРАВЛЕННОЕ ЯДЕРНОЕ ИЗЛУЧЕНИЕ

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Исследование и применение свойств геометрии Лобачевского для описания релятивистских ядерных реакций. Рассматриваются свойства инклюзивного и множественного рождения частиц, полученных при помощи пузырьковых камер и современных экспериментов в условиях геометрии, близкой к 4π. Рассматривается фундаментальная связь между свойствами пространства Лобачевского и релятивистскими явлениями. Обсуждается новое явление – Черенковскоподобное направленное ядерное излучение.

EXCLUSIVE π^0p ELECTROPRODUCTION IN THE RESONANCE REGION WITH CLAS12

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The excitation of nucleon resonances (N*) by real and virtual photons is an important source of information on the structure of excited nucleon states and dynamics of the nonperturbative strong interaction underlying the resonance generation from quarks and gluons [1, 2]. This information has already become available from the nucleon resonance electroexcitation amplitudes ($\gamma_v pN^*$ electrocouplings). Exclusive $p\pi^0$ electroproduction channel is the important source of information on $\gamma_v pN^*$ electrocouplings [3]. The CLAS12 detector [4] is the only facility in the world capable to provide information on $\gamma_v pN^*$ electrocouplings from the data of $\pi^0 p$ channel at still almost unexplored range of photon virtualities $Q^2 > 5.0$ GeV^2 and to extend the studies of N^* in the mass range > 2.0 GeV.
The preliminary results from analysis $\pi^0 p$ electroproduction data measured with CLAS12 will be presented in the talk. Application of the exclusive event selection procedure, developed based on MC simulation, to the CLAS12 $\pi^0 p$ data analysis provided high purity sample of $\pi^0 p$ events in the kinematic range covered by the measurements in RG-K run. The results obtained are paving a way for extraction of beam asymmetry and eventually cross sections for exclusive $\pi^0 p$ electroproduction measured with the CLAS12.

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SINGULAR BACKGROUND IN A MODEL OF MATERIAL PLANE INTERACTING WITH DIRAC PARTICLES

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A method is proposed [1] for constructing a model for the interaction of fields of quantum electrodynamics (QED) with two-dimensional materials in the framework of the Symanzik approach [2]. It is based on the modification of the QED Lagrangian by adding to it an additional contribution (the Lagrangian of the defect) concentrated in a two-dimensional region of space. The requirement to comply with the basic principles of QED (renormalization, locality, gauge invariance) makes significant restrictions on the type of defect Lagrangian. As a result of the modification of QED, a small number of new dimensionless parameters appear in the model which describe the material properties of defect. The Dirac spinor fields in this approach can be used to describe the processes of interaction of spin ½ particles (electrons, protons, neutrons) with two-dimensional objects. The talk presents the results of the study of the scattering of Dirac particles on a homogeneous isotropic plane, as well as properties of bound states arising from the interaction of the spinor field with the plane [3-8]. It is shown that the choice of specific values of the seven dimensionless parameters in the model can achieve significant differences in the quantitative characteristics of the studied physical effects. Theoretical investigations within the framework of the proposed approach may be useful both for improving the methodology of experiments with two-dimensional materials, and for analyzing the possibilities of technical devices created on their basis.

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HADRONIC INTERACTIONS OF THE Y-MESON

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We calculate the cross sections for reactions of the Y-meson with light mesons. We use effective Lagrangians to calculate the production cross section and also the absorption cross section in the corresponding inverse processes. We considered a mesonic formfactor scheme for the introduction of formfactors for the SU(5) chiral meson Lagrangian approach to the Y breakup cross sections by pion and rho meson impact. The obtained cross sections are used as input to solve the rate equation which allows us to follow the time evolution of the multiplicity. The relevance of our study to heavy ion collisions is discussed.

CHIRAL IMBALANCE MEDIUM IN LINEAR SIGMA MODEL AND CHIRAL PERTURBATION THEORY

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In a chirally-imbalanced medium we compare some constraints on parameters both in the linear sigma model (LSM) and in the chiral perturbation theory (ChPT) as realizations of low energy quantum chromodynamics (QCD) for light mesons. The relations between the low-energy constants of the chiral Lagrangian and the corresponding constants of the linear sigma model are established as well as the expressions for the decay constant of the pion and the mass of the a_0 mesons in chiral medium are found. A possible experimental detection of chiral- imbalance medium (and therefore a phase with Local Parity Breaking) potentially can be found in the charged pion decays inside the fireball.

ANGULAR CORRELATIONS IN dA COLLISIONS AT RHIC AND LHC IN THE FUSING COLOR STRING MODEL

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In the color string picture with fusion and percolation the elliptic and triangular flows are studied for p-Au and d-Au collisions at 200 GeV and 5.02 TeV. The ordering $v_n(d-Au) > v_n(p-Au)$ observed experimentally for central collisions is reproduced.The calculated elliptic flow v_2 at central collisions agrees satisfactorily with the data. The triangular flow v_3 is found to be greater than the experimental values, similar to the results obtained in the approach based on the Color Glass Condensate initial conditions with subsequenthydrodynamical evolution.

GEOMETRODYNAMICS A CONSTRUCTIVE APPROACH TO THE LOCAL, CANONICAL BASE OF GRAVITY

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The local canonical growth of gravitational 3 dimensional commuting space dependent gauge fields is shown to be constructable in a canonical way which can well be chosen to include all gauge field pertaining to gravity in a unique way compatible with renormalizable structure, which

however necessarily contain nonperturbative regions, not easily displaying exclusively perturbative approximation.

PROBING OF MULTIQUARKS STRUCTURE IN PP AND PA COLLISIONS

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The spectroscopy of charmonium-like mesons with masses above the $2m_D$ open charm threshold has been full of surprises and remains poorly understood [1]. The currently most compelling theoretical descriptions of the mysterious XYZ mesons attribute them to hybrid structure with a tightly bound $c\bar{c}$ diquark [2] or $cq\bar{c}\bar{q}$ tetraquark core [3-5] that strongly couples to S-wave $D\bar{D}$ molecular like structures. In this picture, the production of a XYZ states in high energy hadron collisions and its decays into light hadron plus charmonum final states proceed via the core component of the meson, while decays to pairs of open-charmed mesons proceed via the $D\bar{D}$ component.

These ideas have been applied with some success to the XYZ states [2], where a detailed calculation finds a $c\bar{c}$ core component that is only above 5% of the time with the $D\bar{D}$ component (mostly $D_0\bar{D}_0$) accounting for the rest. In this picture these states are compose of three rather disparate components: a small charmonium-like $c\bar{c}$ core with $r_{rms} < 1$ fm, a larger D+D- component with r_{rms} = ħ/(2μ+B+)^1/2 ≈ 1.5 fm and a dominant component D0D0 with a huge, r_{rms} = ħ/(2μ0B0)^1/2 > 9 fm spatial extent. Here μ+(μ0) and B+(B0) denote the reduced mass for the D+D- ($D_0\bar{D}_0$) system and the relevant binding energy $|2m_D + 2m_D - M_{X(3872)}|$ (B+ = 8.2 MeV, B0 < 0.3 MeV). The different amplitudes and spatial distributions of the D+D- and D0D0 components ensure that the X(3872) is not an isospin eigenstate. Instead it is mostly I = 0, but has a significant (~ 25 %) I = 1 component.

In the hybrid scheme, XYZ mesons are produced in high energy proton-nuclei collisions via its compact ($r_{rms} < 1$ fm) charmonium-like structure and this rapidity mixes in a time (t ~ ħ/δM) into a huge and fragile, mostly D0D0, molecular-like structure. δM is the difference between the XYZ meson mass and that of the nearest $c\bar{c}$r mass pole core state, which we take to be that of the χc1(2P) pure charmonium state which is expected to lie about 20 ~ 30 MeV above M_X(3872) [6, 7]. In this case, the mixing time, cτ_mix 5 ~ 10 fm, is much shorter than the lifetime of X(3872) which is cτ_X(3872) > 150 fm [8].

The experiments with proton-proton and proton-nuclei collisions with √S_pN up to 26 Gev and luminosity up to $10^{32} cm^{-2}s^{-1}$ planned at NICA may be well suited to test this picture for the X(3872) and other XYZ mesons. In near threshold production experiments in the √S_pN ≈ 8 GeV energy range, XYZ mesons can be produced with typical kinetic energies of a few hundred MeV (i.e. with $\gamma\ \beta$ ≈ 0.3). In the case of X(3872), its decay length will be greater than 50 fm while the distance scale for the $c\bar{c}$r ⟶ D0D*0 transition would be 2 ~ 3 fm. Since the survival probability of an r_rms ~ 9 fm "molecular" inside nuclear matter should be very small, XYZ meson production on a nuclear target with r_rms ~ 5 fm or more (A ~ 60 or larger) should be strongly quenched. Thus, if the hybrid picture is correct, the atomic number de-pendence of XYZ production at fixed √S_pN should have a dramatically different behavior than that of the Ψ', which is long lived compact charmonium state.

The current experimental status of XYZ mesons together with hidden charm tetraquark can-didates and present simulations what we might expect from A-dependence of XYZ mesons in proton-proton and proton-nuclei collisions are summarized.

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Section 5. Neutrino physics and astrophysics

COMPREHENSIVE GEONEUTRINO ANALYSIS WITH BOREXINO DETECTOR DATA AND EARTH RADIOGENIC HEAT

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The results of new comprehensive data analyses of geoneutrino measurements in Borexino experiment at underground Gran Sasso national laboratory (LNGS) are presented. The analysis is the result of 3262.74 days of data between December 2007 and April 2019 with improved analysis techniques and optimized data selection, which includes enlarged fiducial volume and sophisticated cosmogenic veto. Geo-neutrino fluxes generated in the processes of radioactive decay of elements in the depths of the Earth carry information about the radioactive elements inside our planet and its geological structure. The measured geoneutrino signal at LNGS is compared to the expectations of different geological models. The extraction of the mantle signal using knowledge of the signal from the bulk lithosphere and the consequences of the new geoneutrino measurement with respect to the Earth's radiogenic heat are discussed.

SEARCH FOR LOW-ENERGY BOREXINO'S SIGNALS CORRELATED WITH GAMMA-RAY BURSTS, SOLAR FLARES AND GRAVITATIONAL WAVE EVENTS

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The results of a low-energy neutrino search with the Borexino detector in coincidence with gamma-ray bursts (GRB), solar flares (SF) and gravitational wave (GW) events are presented. The correlated events with energies greater than 0.25 (1.0) MeV, positioned inside the detector fiducial volume and not identified as alpha-particles or fast cosmogenic decays (neutrino-like events) were searched within various time windows centered around the GRB or GW detection time. The events correlated with SF were searched in the time window corresponding to SF duration. All count rates obtained are in good statistical agreement with the expected count rate of natural, cosmogenic and neutrino backgrounds in the detector. As a result, we have obtained the best current upper limits on all flavor neutrino fluences associated with these astrophysical sources for neutrino energy below 5-7 MeV. The obtained limits allow to exclude the solar neutrino explanation of the anomaly of the run 117 in the Homestake River neutrino experiment.

^{127}I(ν,e)^{127}Xe REACTION FOR SOLAR NEUTRINO SPECTRUM CLARIFICATION

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Solar neutrino spectrum measurement plays a crucial role for solar metallicity determination. ^{127}I(ν,e)^{127}Xe reaction is sensitive to CNO and boron components of the solar neutrino spectrum due to the relatively high threshold (662 KeV).
For neutrinos with energies upper S_n = 7.246 MeV ^{127}I(ν,e) capture produces ^{126}Xe + n. The concentration ratio of ^{127}Xe and ^{126}Xe could clarify parameters of high energy solar neutrino spectrum and neutrino oscillations. We present production rate estimation for of ^{127}Xe and ^{126}Xe based on experimental strength function from ^{127}I(p,n)Xe reaction.

ON POSSIBILITY TO DETECT LIGHT STERILE NEUTRINO IN BETA- AND NEUTRINOLESS DOUBLE BETA-DECAYS OF NUCLEI

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A (3+3)-neutrino model is used to describe the effects of sterile neutrinos in beta-decay and neutrinoless double beta-decay of nuclei. This model was detailed in [1] and includes three active neutrinos ν_α (α = e, ν τ) and three new sterile neutrinos: a sterile neutrino ν_s, a hidden neutrino ν_h and a dark neutrino ν_d. The 6×6 mixing matrix Umix is used in the model. The values of mixing angles and masses of active neutrinos are taken with allowance made for available experimental data [2]. For additional parameters concerning sterile neutrinos the test values are used, including appropriate values in the light sterile neutrinos mass range [3]. This choice is due to the fact that we have to deal with Majorana neutrinos, for which $0\nu2\beta$-decay is possible, so existing restriction on the effective Majorana neutrino mass $m_{\beta\beta}$ is taken into account, as well as restriction on the effective neutrino mass m_β in the β-decay [4,5]. Estimates of the effective masses m_β and $m_{\beta\beta}$ of the electron neutrino are obtained, which can be tested in experiments on β-decay and $0\nu2\beta$-decay, in particular, in the KATRIN, SuperNEMO and CUPID experiments.

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EXPERIMENTAL SEARCHES FOR SOLAR AXIONS

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Intensive experimental searches for axions and axion-like particles are currently supported by two main reasons: firstly, axions solve the CP problem of strong interactions and, secondly, axions are well-motivated candidates for the role of dark matter particles. If axions exist, the Sun should be a powerful source of such particles. The expected energy spectrum of solar axions, like the spectrum of solar neutrinos, contains both continuous spectra and monochromatic lines. Moreover, the fluxes of solar axions should be directly proportional to the fluxes of neutrinos; only the proportionality coefficients remain unknown, which are determined by the effective coupling constants of the axion with photons, electrons, and nucleons. The report discusses some past, present and future experiments aimed at detecting solar axions and axion-like particles. This work was supported by the Russian Foundation for Basic Research (project nos. 16-29-13014, 17-02-00305 and 19-02-00097).

NEUTRINO ASTROPHYSICS WITH BOREXINO: COMPREHENSIVE STUDY OF SOLAR NEUTRINOS

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Recent achievements in experimental neutrino physics allow studying the Sun's deep interior through the high precision spectroscopic measurements of the solar neutrinos. Currently the most sensitive solar neutrino detector Borexino, which takes data in Gran Sasso national laboratories in Italy, is able to separately measure neutrinos produced in various nuclear reactions of the solar proton-proton fusion chain. Recent Borexino results indicate the preference of high over low metallicity solar models - the step forward of extreme importance for solar physics. Borexino's measurements contribute to neutrino physics as well: for the first time single neutrino detector examines simultaneously the MSW-LMA neutrino oscillation paradigm both in the vacuum and the matter dominated regimes. In this talk I overview the major Borexino accomplishments.

THE DANSS NEUTRINO SPECTROMETER: THE RESULTS OF REACTOR ANTINEUTRINO STUDIES

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The DANSS detector is a movable neutrino spectrometer currently operating under one of industrial reactors of the Kalinin Nuclear Power Plant. Its plastic scintillator composition with no flammable or otherwise dangerous materials allows placing it close to the reactor core thus benefiting

from ample antineutrino flux. Complex multilayers of the active and passive shielding and high segmentation of the sensitive volume makes it possible to reconstruct up to 5000 IBD events per day with residual cosmic background on the level of few percent. The data are recorded in three different positions from the center of the reactor core, which gives a great opportunity to search for short-range neutrino oscillations to a hypothetical sterile state in a wide range of mixing parameters.
In this talk the DANSS collaboration reports the results on short-range oscillations, which are obtained from the 2016-2019 data set comprising about three million IBD events. The dependence of the measured antineutrino spectrum on the nuclear fuel composition is also presented. Finally, the long-term measurements of the reactor power are discussed, illustrating the excellent DANSS capacity for independent high-precision monitoring of nuclear reactor.

DARK MATTER SEARCH IN DEAP-3600 EXPERIMENT

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DEAP-3600 is a low-background liquid argon detector for a direct WIMP (Weakly Interacting Massive Particles) dark matter search. The detector consists of 3279 kg of LAr contained in a spherical acrylic vessel. Liquid argon is an excellent scintillator, transparent to its own scintillation light. Scintillation is detected by photomultiplier tubes, and pulse shape discrimination is used to differentiate between nuclear recoils, which may result from WIMP-nucleus scattering or some rarer backgrounds, and electronic recoils, the most abundant backgrounds which predominantly come from the beta-decay of Ar39. Ar39 is an inevitable component of background created by interaction of Ar40 with cosmic rays. Here we report the results of an analysis of a 231 live-days data set taken during the first year of operation. We also describe a detailed background model, WIMP selection criteria and future plans including blinding scheme for analysis and machine learning techniques for discrimination against alpha-decays in the neck of the detector.

HADRON PRODUCTION MEASUREMENTS AT NA61/SHINE FOR PRECISE DETERMINATION OF ACCELERATOR NEUTRINO FLUXES

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The total systematic uncertainty of the neutrino flux in accelerator-based neutrino experiments is dominated by the Monte Carlo modeling of hadronic interactions. Direct hadron production measurements for T2K and Fermilab neutrino experiments, MINERνA, NOνA and DUNE, are being performed at the NA61/SHINE spectrometer at CERN's Super Proton Synchrotron. Crucial for improving neutrino flux predictions, hadron yields, inelastic and production cross sections are obtained at NA61/SHINE where interactions of various hadron beams with thin and thick (replica) targets are reproduced. Recently obtained results will be reported. An extension of NA61/SHINE's programme of hadron production measurements for neutrino experiments is planned beyond 2020.

THERMODYNAMICALLY CONSISTENT EQUATION OF STATE FOR AN ACCRETED NEUTRON STAR CRUST

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We study equation of state (EOS) of an accreting neutron star crust. Usually, such EOS is obtained assuming (implicitly) that the free (unbound) neutrons and nuclei in the inner crust move together. We argue, that this assumption violates the condition $\mu_n^\infty = \mathrm{const}$, required for hydrostatic (and diffusion) equilibrium of unbound neutrons (μ_n^∞ is the redshifted neutron chemical potential). We construct a new EOS respecting this condition, working in the compressible liquid-drop approximation. We demonstrate that it is close to the catalyzed EOS in most part of the inner crust, being very different from EOSs of accreted crust discussed in the literature. In particular, the pressure at the outer-inner crust interface does not coincide with the neutron drip pressure, usually calculated in the literature, and is determined by hydrostatic (and diffusion) equilibrium conditions within the star. We also find an instability at the bottom of fully accreted crust that transforms nuclei into homogeneous nuclear matter. It guarantees that the structure of fully accreted crust remains self-similar during accretion.

SYNTHESIS OF P-NUCLEAR IN KILONOVA

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In kilonova, two neutron stars merge or a black hole absorbs neutron star. In this case, extreme physical conditions arise: in a kilonova substance it can be extremely high temperatures (up to 10^{10} K) and high densities (up to 10^{10} $g \cdot cm^{-3}$). The consequence of such an extreme state of matter may be the intensification of nuclear fusion processes. This also applies to the synthesis of p-nuclei (otherwise, bypassed nuclei). To date, the problem of their synthesis in stars has not found a generally accepted solution. This applies to the quasiequilibrium stages of the evolution of massive stars (s-processes), and to the explosive stages during the transition of a massive star to a supernova (r-processes, collision processes involving protons, α-particles, etc.). The individual successes of the private order do not give significant progress in solving the problem of all 33 p-nuclei [1].
In this work, we simulate the reactions of the synthesis of chemical elements during the absorption of a neutron star by a black hole, including p-nuclei. We took collisional beta decay (CBD) as the basis for the synthesis of the latter. This process was first proposed in [2], and was used in [3] to solve the problem of the origin of p-nuclei. The reaction cross sections were calculated using data from the REACLIB open library. The basis of the calculations is the procedure for approximating the temperature dependence of the cross sections by a special function, including seven parameters unique to each reaction [4]. For a number of isotopes, we calculated the cross sections of the CBD induced by collisions of nuclei with protons. The parameters of their temperature approximation were determined in the format of the REACLIB library. The CBD process with the obtained cross sections was included in the set of reactions that can take place when a neutron star is absorbed by a black hole. We examined the application of CBD to the synthesis of some p-nuclei. This was done on the basis of kinetic theory. We used a computational experiment method using the open SkyNet library [5]. We have shown that for the synthesis of p-nuclei the contribution of CBD induced by collisions with protons is significant.

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SELF-CONSISTENT APPROACH TO NEUTRINO CAPTURE BY HEAVY NUCLEI

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A self-consistent approach to the cross-sections of neutrino capture by heavy nuclei due to charged currents is presented. Non-magic nuclei with pairing in the neutron and proton sectors are considered in the framework of the energy density functional (EDF) theory. Various versions of the EDFs proposed by Fayans *et al.* are used (DF3 [1], DF3-a [2]). In order, to calculate the strength functions of the Fermi, Gamow-Teller and spin-dipole excitations we use the quasiparticle random-phase approximation with the particle-hole continuum taken into account [1, 2, 3]. Particular attention is paid to the neutrino capture by ^{72,74}Ge nuclei. This is the background process in the measurements of double beta decay. The work is supported by the Russian Foundation for Basic Research (Grant no.18-02-00670_a) and the grant by the Department of Neutrino Studies of the NRC KI.

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SURFACE ENERGY OF THE NUCLEAR MATTER AT ALL POSSIBLE CONDITIONS OF TWO-PHASE BOUNDARY COEXISTENCE

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We calculate the surface energy, the surface tension and the neutron skin thickness of the nuclear matter at all possible conditions of two-phase boundary coexistence [nuclear matter-vacuum, nuclear matter-neutron matter (after neutron drip), and nuclear matter-nuclear matter (after proton

drip)]. Following [1,2], calculations are based on extended Tomas-Fermi approach. We apply a set of Skyrme-type forces [3], which agrees with nuclear physical and astrophysical constraints. The results for surface energy, surface tension and neutron skin thickness are approximated by simply analytical expression, which explicitly agree with thermodynamic consistency conditions [4]. This approximations are especially useful for modeling the inner crust of neutron stars, where atomic nuclei (nuclear clusters) are immersed into background of unbound neutrons. In particular, they can be applied to model nonspecial nuclear shapes, which can exist at the deepest regions of the inner crust (so-called pasta phases, because cluster shape can be of spaghetti or lasagna type).

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SHAKE AS THE DETERMINING MECHANISM OF THE NEUTRINOLESS DOUBLE ELECTRONIC CAPTURE

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The process of double neutrinoless e-capture is of great interest as a test of the Majorana nature of neutrino. This process is traditionally considered as as a resonance one, since not a single particle is emitted as a result of the nuclear transformation [1]. For this reason, it cannot occur in bare nuclei, even if the energy release Q > 0. In contrast, we performed calculations of the probability of shake off and up, with the ionization or excitation of the electron shell during the the nuclear transformation. ^{152}Gd nuclei have the lowest resonance defect among all known nuclei. It is considered as one of the main candidates for discovering the neutrinoless mode of the process [2]. As a result, the contribution of the new mechanism turns out to be smaller than that of the traditional resonance mechanism, thus representing a correction to the decay probability. However, the value of this amendment is high enough, attaining twenty-three percent [3].
It rapidly increases with increasing resonance defect, so that for other nuclei it exceeds the contribution of the resonance mechanism and becomes the main mechanism of the double neutrinoless electron capture. Thus, in the case of ^{164}Er its contribution is already 4.5 times as high as from the traditional resonance mechanism. Therefore, account of the shake mechanism increases the decay rate by an order of magnitude. One can conclude that the double neutrinoless e-capture appears not to be a resonance process at all.

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NUCLEAR INELASTIC SCATTERING EFFECT IN SUPERNOVA NEUTRINO SPECTRA

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The neutrino scattering on nuclei in hot and dense matter relevant for core collapse supernovae, neutron star mergers, and proto-neutron stars is considered accounting for magnetization. At finite temperature neutrinos undergo exo- and endo-energetic scattering [1] on nuclei due to the neutral current Gamow-Teller component. The energy transfer cross section in neutrino-nucleon scattering is shown to change from positive to negative values at neutrino energies four times the matter temperature. Effects in neutrino transport and spectra are discussed.

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DIFFERENTIAL INTENSITIES OF TWO NEUTRINO DOUBLE BETA-DECAY OF SELENIUM-82

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Stable isotope selenium-82 is a perspective object for double beta decay investigations and searches for neutrinoless transition. It is used as a 2β-source in large-scale projects - NEMO-3, SuperNEMO, CUPID-0. In the recent experimental works [1,2] two-neutrino channel for ^{82}Se was examined in order to determine nuclear mechanism of $2\nu2\beta$-decay. The question is whether contribution of the single lowest 1+ level dominates in the total transition amplitude, and SSD –mechanism takes place, or otherwise higher state dominates, that corresponds to HSD-mechanism. The effective method to distinguish these possibilities is to measure energy distribution of emitted electrons, which has different form for SSD and HSD mechanisms [3,4]. It should be noted that for 82Se the quantum numbers of intermediate nucleus ^{82}Br ground state is 5-, so the first excited 1+ - state of ^{82}Br should be taken into account. The energy spectra of electrons produced in $2\nu2\beta$-decay are calculated. For SSD mechanism the ^{82}Se $2\nu2\beta$ amplitude is determined by the product of two nuclear matrix elements, where first excited low-lying 1+ state of ^{82}Br is involved. Assumption has made, that the measurement of total intensity of two-neutrino process can give information on the value of these matrix elements, additional to the results, based on charge-exchange reactions study.

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NUCLEOSYNTHESIS RATE AND ABUNDANCE OF HEAVY NUCLEI

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Nucleosynthesis process, supported by multiple neutron captures (r-process) is responsible for the formation in nature more than the half of all the nuclei heavier iron, and the region of its propagation on the map of nuclei lies very close to neutron drip-line [1, 2, 3]. Nucleosynthesis rate of heavy nuclei formation in reactions with neutrons depends on astrophysical scenario and beta-decay rates of nuclei involved into the r-process. When r-process nucleosynthsis wave changes its speed on the way to heaviest nuclei region, the r-process path dependence on time is changing and the position and structure of the third peak on abundance curve of heavy elements is shifted also.
In a result the r-process modeling and calculations of heavy nuclei abundances, the dependence of the chemical elements abundances on nuclear input was evaluated. The influence of beta-decay rates, calculated in the framework of different theoretical approaches on the abundances of heavy nuclei was analyzed.
The calculations of the r-process have shown that predictions of beta-decay half-lives $T_{1/2}$ can significantly influence on the physical processes leading to the formation of third peak on the abundance curve and forms its position and structure. This influence can be even significantly stronger than fission neutrons impact [4]. And the results of nucleosynthsis modeling show either the nonsystematic overabundance of beta-decay half-lives, predicted by some theoretical models [5, 6] for the nuclei from the r-process region. And it is clear that further work on development of microscopic models [7, 8] for global predictions of $T_{1/2}$ is very important for the deep understanding of physical details of the r-process nucleosynthsis.
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BETA DECAY OF NEUTRON IN HEAT FIELD AND NEUTRON ANOMALY

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We investigated the effect of two processes on the natural beta decay of a neutron: photobeta decay and inverse internal bremsstrahlung. The diagram of the latter process is topologically equivalent

to that of internal bremsstrahlung in beta decay, but only with absorption of a photon by the beta electron. Both processes make it possible to take into account the effect of the thermal field of the medium on beta decay and complement the process of natural beta decay, in which two leptons (an electron and an antineutrino) are emitted. We calculated the neutron beta-decay rate in the temperature range from 300 K to $(0.5 \div 1.0) \times 10^{10}$ K.
We found that the thermal effect on the neutron beta decay at room temperature is negligible. Such a result is obtained only after eliminating the infrared divergence. This was done when calculating the total rate of the decay process (compare with the results of [1]). We can say that the processes of photo-beta decay and inverse internal bremsstrahlung do not contribute to the theoretical lifetime of the neutron. Therefore, they are not related to the problem of neutron anomaly (see [2]).
In strongly heated matter of massive stars, neutron decay can occur at an increased rate [3]. This can affect the rate of reactions involving neutrons in the synthesis of chemical elements in stellar matter. In particular, in a medium heated to temperatures of $(3 \div 5) \times 10^9$ K, the neutron lifetime can be reduced by up to 3%. Such temperatures are characteristic of the stages of combustion of the oxygen layer and silicon core in massive stars at the quasiequilibrium stages of their evolution. A large decrease in the lifetime to 32% occurs at temperatures of about 10^{10} K. Such extremely high effective temperatures can be reached in kilonova when a black hole absorbs a neutron star or two neutron stars are combined into one. A decrease in the neutron lifetime during thermal exposure to the medium can affect the physical processes in kilonova matter.
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THE IMPURITY COMPONENTS IN THE ^{7}BE SOLAR NEUTRINO FLUX

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In the present work, a development [1], the flavor structure of the ^{7}Be solar neutrino (SN) flux is investigated. The electron spectrum of the (v_e)‾e-scattering differs from the fairly flat spectra of all neutrinos. Such difference will open the way for the Borexino Collaboration to search for an antineutrino admixture in the SN flux [2]. If the part of this flux transforms into neutrinos of the second and third generations and related antiparticles v‾e, the total electroweak spectrum of recoil electrons can be written in the form:

$$\left(\frac{d\sigma}{dT}\right)_{tot} = P(\nu_e)\left(\frac{d\sigma(\nu_e e)}{dT}\right) + P(\nu_{\mu,\tau})\left(\frac{d\sigma(\nu_{\mu,\tau} e)}{dT}\right) + P(\nu_e^-)\left(\frac{d\sigma(\nu_e^- e)}{dT}\right)$$

where T is the kinetic energy of the final electron.
The table shows the results of calculations based on the Borexino data: a limit of the conversion probability $P(\nu_e \to \nu-_e) < 0.35$ (90% C.L.) for 862 keV ^{7}Be neutrinos [2], under the assumption of ν_e transition to other active neutrino flavors, the SN survival probability $P(\nu_e) = 0.51 \pm 0.07$ [3]. Each spectrum is presented by ten values of the differential cross sections, corresponding to the recoil electron kinetic energy for the kinematically allowed escape angles, determined by the segment [0°; 90°].
The graphical image of these spectra is presented in the form of figures.

$P(\nu_e^-)$	$(\frac{d\sigma}{dT})_{tot}$
0	[0.28; 0.36]
0.05	[0.27; 0.39]
0.1	[0.27; 0.41]
0.2	[0.26; 0.46]
0.3	[0.25; 0.51]

Figure 1: Table.

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ATMOSPHERIC NEUTRINO PHYSICS WITH JUNO

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The atmospheric neutrino flux represents a continuous source that can be exploited to infer properties about Cosmic Rays and neutrino oscillation physics. The JUNO observatory, a 20 kt liquid scintillator currently under construction in China, will be able to detect the atmospheric flux, given the large fiducial volume and the excellent energy resolution. The light produced in neutrino interactions will be collected by a double-system of photosensors: $18.000 \times 20''$ PMTs and $25.000 \times 3''$ PMTs. The rock overburden above the experimental hall is around 700m and the experiment is expected to complete construction in 2021 In this work, potential JUNO measurements in the field of atmospheric neutrinos are evaluated. A sample of Monte Carlo events has been generated from theoretical models of the atmospheric neutrino flux, through the *Genie* software. To evaluate the JUNO performances, the events have been processed by a full *Geant4* - based simulation, which propagates all the particles and the light inside the detector. The different time evolution of light on the PMTs allows to discriminate the flavor of the primary neutrinos. To reconstruct the time pattern of events, the signals from $3''$ PMTs only have been used, because of the small time resolution. A probabilistic unfolding method has been used, in order to infer the primary neutrino energy spectrum by looking at the detector output. JUNO will be particularly sensitive in the energy range $(100 - 1000)\mathrm{MeV}$, where neutrino-induced events can be fully contained within the instrumented volume. The energy region is particularly interesting, for several reasons: first, the flavor oscillation effects due to the large neutrino mass-splitting are maximized; then, the region covers an area of interest for other studies too, like the search for nucleon decay and relic supernovae neutrinos.

PROSPECTS OF THE NEUTRINO-4 EXPERIMENT ON THE SEARCH FOR STERILE NEUTRINO

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The Neutrino-4 collaboration plans to modernize the existing installation and create a second neutrino laboratory at reactor CM-3 and a second neutrino detector with increased sensitivity. To improve the result, in addition to continuing the current experiment, a new study with an improved neutrino detector is also necessary. The project of the new neutrino laboratory at the CM-3 reactor is being prepared for implementation. Using a scintillator

with a high concentration of gadolinium (5 g/l) and with the ability to separate signals in shape will suppress the background of random matches by 3 times, and the correlated background by half. Thus, a new detector of an even larger volume will improve the accuracy of measuring the flow of reactor antineutrinos by 3.1 times. After starting the PIC reactor at full power, the experiment will continue in Gatchina. For this, a preliminary design of another detector and a project for its placement on the PIK reactor are already being developed.

Section 6. Plasma physics and thermonuclear fusion

PROSPECTS FOR PLASMA EXCITATION OF 186MRE NUCLEAR ISOMER

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In [1], a laser plasma with electron temperature Θ_e ~ 1 keV and the lifetime of $\tau \approx$ 0.5 ns was formed from rhenium metal containing ^{186m}Re isomer nuclei ($T_{1/2}$ = 2×10^5 years) with an isomer concentration of ~ 10^{-3} %. In this plasma the stimulated de-excitation of ~ 10^{-5} % isomeric nuclei was observed. The experimental results made it possible to assume in the ^{186}Re nucleus at an energy of a slightly higher isomer energy the existence of a previously unknown level to which a trigger transition occurs upon stimulation of de-excitation of the ^{186m}Re isomer. Later this assumption was supported by the study of the decay curve of ^{186}Re nuclei produced in the (p, n) reaction on ^{186}W nuclei [2].
Only a weak effect was observed in [1], and for its amplification, a technique was proposed for the reactor production of the ^{186m}Re isomer to a concentration of ~ 0.1 % and a technique for isolating the pure ^{186m}Re isomer as a separate phase. Also instead of a laser plasma it was proposed to use a high-current electric discharge plasma, the lifetime of which increases to ~ 50 ns while maintaining the plasma temperature Θ_e ~ 1 keV [3].
To further enhance the stimulation effect, the irradiation of plasma, containing isomeric nuclei, by the photons resonant to the trigger transition was proposed [4], however, for this, it is first necessary to determine the energy of the trigger transition. In this work, the plasma itself is considered as a source of resonant irradiation when atoms with resonant characteristic X-ray radiation are introduced into it. With an increase in the lifetime of the discharge plasma and with resonant photon irradiation of ^{186m}Re atoms, the probability of de-excitation of the ^{186m}Re isomer in the plasma can be increased by four orders of magnitude compared to [1].
The results already give grounds for the development of a power unit based on the stimulated de-excitation of the ^{186m}Re isomer with the following parameters: specific energy capacity ~ 10^8 J/g, specific operating power ~ 1 kW/g, specific storage power ~ 70 μW/g.

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Section 7. Synchrotron and neutron studies and infrastructure for their implementation

STUDYING NEUTRON SPECTRUM OF PHOTONEUTRON SOURCE OF INR RAS

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A W-Be-photoneutron neutron source IN-LUE based on a linear electron accelerator was created and installed at the Institute for Nuclear Research of RAS [1]. The shape of the neutron spectrum and flux estimation was obtained earlier as a result of simulation [2]. Due to the impossibility of measuring the neutron spectrum in a wide range of energies within the source, various methods of spectrum unfolding based on the solution of the inverse problem are usually used.
In this work, the results of unfolding the neutron spectrum of the source are presented. As experimental data for unfolding, we used the data of neutron activation analysis of samples irradiated in the source (Ag, Mg, Mn, Sb, Ti, etc.).
To unfold the spectrum, a number of well-known Nuclear Energy Agency (NEA) programs were used [3], which implement various algorithms for solving the inverse problem. Algorithms and results of using the author's method of spectrum unfolding are also presented. The results of unfolding both test and real spectra are considered.

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Section 8. Nuclear medicine

TIMEPIX DETECTOR WITH A CODED APERTURE FOR SMALL ANIMAL SPECT

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Single-photon emission computed tomography (SPECT) is a well known imaging method of nuclear medicine, which allows obtaining tomographic images of the biodistribution of radiolabeled compounds, both throughout the patient's body and in separate organs. At the same time, a small animal SPECT is currently a key tool in the development of new radiopharmaceuticals and to seek for methods for their targeted delivery. However, in studies of small animals, the region of interest typically has a small size and a high spatial resolution is necessary to get a good image. A system based on the coded aperture and the hybrid pixel Timepix detector with the CdTe sensor is developed as a possible imaging solution for the small animal SPECT. Characterization of the system using an X-ray source and various radioactive gamma emitters, including Tc-99m and I-125, is made. The spatial resolution is shown to be of 0.8-0.9 mm at the field of view of 3 cm x 3 cm for the energy range typical for SPECT. The experimental data, supported by the simulation, confirm that a 1 mm thick tungsten coded aperture is sufficient to obtain an image of the distributed radioactive sources with the energy of gamma rays at least up to 180 keV without significant reconstruction artifacts. The reconstructed tomographic images of a SPECT phantom are presented.

RADIOSENSITIZATION OF CANCER CELLS USING NANOPARTICLES IN X-RAY AND ION BEAM THERAPY

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Many different tumor-targeted strategies have been developed worldwide to limit the side effects and improve the effectiveness of cancer therapies, such as chemotherapy, intensity modulated radiation therapy, biology-driven personalized radiotherapy, ion beam radiotherapy, target-alpha-therapy, high intensity focused ultrasound therapy, etc. Recent advances in nanotechnology have also given rise to trials with various types of metal nanoparticles (NPs). Different metal-based NPs, e.g. gold, gadolinium, titanium, silver, hafnium and bismuth have been evaluated to enhance the radiosensitization of the cancer cells while reducing or maintaining the normal tissue complication probability during radiation therapy. When X-rays or a charged particle hit a metal, there are multiple possibilities of eventual outcome. Among the several emissions that occur, the most relevant to cancer radiotherapy are scattered X-rays/photons, photoelectrons, Compton electrons, Auger electrons and fluorescence photons. The energy of the X-rays is important, since the photoelectric effect is decided by $(Z/E)^3$, where E is the energy of the incoming photon and Z is the atomic number of the molecule being targeted. The photoelectric effect is therefore dominant at lower energies and is prevailing until the photon energy reaches a medium energy (e.g. around 500 keV for gold (Z = 79)) with a cross section varying with Z^4 or Z^5, depending on the material. When using X-rays, mainly the inner electron shells are ionized, which creates cascades of both low and high energy Auger electrons. Increasing the Z of the NPs is enhancing the photoelectric and Compton effects when they

are exposed to X-rays. High Z NPs are therefore more radio-sensitizing when using X-rays than low Z NPs. Gold is a promising radio-sensitizer in this regard due to its high atomic number and mass energy coefficient relative to soft tissue. In addition to that it, it is very inert and it is highly biocompatible. When using high LET particles, e.g. carbon ions for therapy, mainly the outer shells are ionized, which give electrons with lower energies than when using X-rays. However, the density of the produced low energy electrons is higher when exposing NPs to ions then when exposing them to X-rays. Since ions traverse the material along tracks, and therefor give rise to a much more inhomogeneous dose distributions than X-rays, there might be a need to introduce a higher density of NPs when using ions compared to when using X-rays to create enough primary and secondary electrons to get the desired dose escalations. This raises the questions of toxicity. Though, even below the ionization threshold, electrons can induce molecular damage via Dissociative Electron Attachment (DEA) and production of highly reactive oxygen species, such as $OH\bullet$, $H\bullet$, O_2^-, H_2O^+ from the surrounding water molecules via radiolysis or DEA. The created Auger and photo electrons will of course have the same effect. This paper will discuss the need for systematic studies of the behavior of NPs, when exposed to different kinds of ionizing radiation, depending of the Z, surface treatment, sizes, ionizing radiation, etc.

THE NEUTRON ACTIVATION ANALYSIS IN INVESTIGATION OF THE MICROELEMENT CONTENT OF INTERVERTEBRAL DISC

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Purpose: Evaluation The progressive prevalence, significant economic losses, the cost of compulsory health insurance and high-tech medical care have turned the problem of lumbar osteochondrosis into a socially significant issue. The relevance of this problem is dictated by the need to study the etiopathogenesis of the course of degenerative changes for an integrated approach when choosing an adequate treatment.
The progression of the pathological process in the spine significantly contributes to changes in the metabolism of connective tissue, which is closely associated with the violation of microelements.
of changes in the homeostasis of the intervertebral disc, in particular the study of the microelement composition of the intervertebral disc at various stages of development of hernias of the lumbar spine using instrumental neutron activation analysis.
Material and methods: The studied biomaterial was obtained intraoperatively, with traditional microdiscectomy in herniations of the spine at the level of VL3-4, VL4-5, VL5-S1. By the method of instrumental neutron activation analysis, a study of biomaterials, represented by tissue fragments of the remote part of the hernia of the intervertebral disc, located at different stages of the degenerative process, was carried out.
Results: The quantitative content of 22 macro- and microelements in the removed fragments was determined. As a result of the data obtained, it was found that in the tissues of the intervertebral discs, a gradual change in the content of a number of essential elements occurs, depending on the stage of development of the degeneration process.
Conclusion: Changes in the microelement composition indicate metabolic processes occurring in the intervertebral discs, and the relationship of the microelement composition of the disc tissue and the course of the degenerative process can be used to predict the condition of the patient and choose an adequate treatment.

SECONDARY PARTICLES EMITTED FROM HUMAN-LIKE TISSUE DURING CHARGED PARTICLE THERAPY

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Charged particle therapy is a rapidly developing way for tumor treatment. During irradiation, the primary beam interacts with tissues nuclei results in the production of radioactive isotopes and secondary particles emission, e.g. electrons, gammas and neutrons. Estimation of the treatment effect of secondary radiation using only Monte Carlo is not precise and, depends on the type of radiation, the direct measurement of it is difficult. During presentation the experimental results of induced radioactivity will be discussed. Such experiments have been done at the Institute of Nuclear Physics PAS. Moreover method of neutron energy spectrum measurement will be presented. Measured spectra and geometry of experimental set-ups allow appraising the cross-section of reactions that occurs in the target and then calculate the dose that is deposited in human tissues as a result of therapy aside from the primary beam.

REACTOR PRODUCTION OF NUCLEAR MEDICINE ALPHA-EMITTERS WITH RADIUM-226

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Radioisotopes of ^{227}Ac and ^{227,228,229}Th are basis of the radiochemical generators for production of alpha-emitters radium-223, radium-224, actinium-225 and bismuth-213. These generator radionuclides are used to produce radiopharmaceuticals and therefore their radiochemical purity has to be maintained high demands. For example, actinium-225 generator has to contain less than 1·10-3 % of each Ra and Th isotopes (standard of ORNL), radium-223 generator – less than 0.5% of thorium-227 and 0.04% of actinium-227.

Irradiated radium-226 used in the presented work is contained mixture of all abovementioned isotopes with their daughter radionuclides. In frame of the presented work methods of chromatographic extraction [1] of thorium-229 and actinium-227 from irradiated radium-226 have been developed and tested with technological reprocessing procedures [2]. Activities of ^{226}Ra, ^{227}Ac, ^{227,229}Th and their daughter nuclides for chemical procedures and final batches have been measured with gamma- and alpha-spectrometry. Measured activities of ^{227}Ac and ^{227,229}Th were compared with values calculated by a computer code.

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LOW THRESHOLD-ENERGY ION-CHAMBER SYSTEM FOR PROTON THERAPY MONITORING

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A system of three low threshold-energy ion-chambers, giving new possibilities
in proton beam monitoring and analyzing, is considered. The system includes a new double-gap chamber with the total gap of 1mm, with polyimid films of 3μm thickness and with the sensitive area 113cm^2 and two double-gap ion-chambers, each with the total gap of 2 mm. Ionization losses in each of six sensitive air gaps, as well as the total loss, are measured in coincidence for every accelerator spill. Total amount of material crossed by the beam is only 1.7 g/cm^2. Being almost transparent for protons at Bragg-peak energy and below, the anode separates two neighbour gaps and peculiar behavior of loss correlations can be observed. This behavior can be explained by alternative trend of energy-loss dependence below and above Bragg peak. Recombination contribution is estimated as only few percents at 1 nA/cm^2. An essential contribution to the dose from protons at about 1 MeV and below was demonstrated both by calculations and experimental data. Selected contributions of fast and slow protons and δ electrons to the energy loss can be extracted from data. The system demonstrated a stable operation after a proton irradiation of 5 Mrad.

INVESTIGATION OF EXPOSURE OF EPITHERMAL NEUTRONS RADIATION ON THE SAMPLES OF TUMOR TISSUES AT Gd-NCT

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The purpose of the study was to assess the impact of radiation exposure of epithermal neutron and epithermal neutrons with gadolinium neutron capture reaction on the samples of brain tumor tissues.
For the experiments were carried out calculations for neutron capture reaction of gadolinium. Natural gadolinium is composed of seven isotopes, of which ^{155}Gd and ^{157}Gd have very large (n,γ) cross-section, are respectively 255,000 and 60,000 barns Therefore, these isotopes, which are> 30% ^{nat}Gd, are the most effective isotope for neutron capture. For ^{nat}Gd thermal neutron capture cross section is equal to 49,000 barns, whereby ^{nat}Gd is one of the widely used elements in neutron capture therapy.
To create the required absorbed dose in tumor tissue sample the different concentrations of gadolinium are used, which can be adjusted by diluting the starting preparation of Magnevist. The concentration of gadolinium in Magnevist is 65.916 mg/g (65.916 ppm).
In the reaction of epithermal neutron beam with biological tissue elements the release of energy takes place as a result of nuclear reactions and absorption of the secondary gamma-ray quanta. The nuclear reactions produce the charged particles and recoil nuclei having a short run, and their energy is absorbed in the layers with several tens of microns thick. Secondary gamma rays quanta have energies up to ~ 10 MeV, and their run is a few tens of centimeters. Therefore, calculation the dose in biological tissue requires knowledge of the full spectrum of gamma rays and the partial

kerma dependence on neutron energy and the gamma rays quanta for all elements of the biological tissue. Kerma, a close analogue of the absorbed dose, at known neutron spectrum was determined by the method published earlier [1]. The database EPAPS [2] was used for calculation for partial neutron kerma depending on energy of elements, composing of biological tissue.
Investigations were carried out on the samples of human glioma tumor tissues extracted during standard surgical operation. From tumor tissue samples the living slices were prepared and placed in culture medium. Prepared living slices were used for epithermal neutron beam irradiation with different absorbed doses in the presence of gadolinium-containing preparation Magnevist (gadopentetata dimeglyumin) or without it. After irradiation, the slices of samples were incubated saline with 5% glucose for 24 hours at 4°C. After incubation, slices were fixed in 10% formalin and histological analysis was performed for estimation of degree of tumor tissue necrosis. The findings allow to obtain accurate estimate the degree of necrosis of the tumor tissue after irradiation with different absorbed dose and at irradiation by epithermal neutrons and irradiation by epithermal neutrons with particles produced during the gadolinium-neutron capture reaction.

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POST-EFFECTS OF RADIOACTIVE DECAY IN DOTA CHELATOR AND MAGNETITE NANOPARTICLES LABELLED WITH AUGER- AND INTERNAL CONVERSION ELECTRON-EMITTERS, ALPHA- AND BETA DECAY RADIONUCLIDES

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As it has been demonstrated by the conducted experiments, the production of targeted radioactive pharmaceutical preparations (RPHs) that are based on alpha-emitters using the traditional approach (biologically active molecular constructs with a chelate, DOTA, that carries a radioactive tracer) is just a sort of scientific mystification: the recoil nuclei formed after such decay will destroy the carrier molecules thus completely excluding a targeted transport of the preparation.
A success in the production of such pharmaceutical formulations that are based on the use of alpha-emitters is possible only in the case when there is some way of "levelling" the harmful effect of recoiling nuclei, for example, by means of using inorganic compounds ("nano-containers") of a high radiation resistance.
As such a model matrix material, magnetite, Fe_3O_4, has been used whose main transport characteristic that accounts for the transportation accuracy of magnetite-based RPHs is the value of the internal magnetic field on the iron nuclei. The magnetite nano-crystallites have been prepared labelled with Auger- and internal conversion electrons, beta- and alpha-emitters (^{57}Co, ^{60}Co and ^{241}Am radionuclides).
A comparative analysis has been conducted of radiation-induced damage patterns in nano-crystallites in the dependence of nuclear- and physical characteristics of the radioactive tracer and total fluence. It has been established that under irradiation there is a comminution of crystallites taking place, the effective magnetic fields on the iron atoms in the labelled nano-crystallites remaining unchanged irrespective of the "dose load".
Taking into consideration the typical recoil energies (90 keV to 150 keV) of the daughter atoms that are produced as a result of alpha-decay, the chemical composition and density of possible "carriers" needed for an efficient "conservation" of traditional therapeutic radionuclides (in particular, ^{211}At, ^{212}Bi, ^{213}Bi, and ^{223}Ra), "nano-containers" should be used with the particle size of not less than 80 nm.
The work was supported by a grant from the Russian Foundation for Basic Research (18-03-00832).

Gd SELF-SHIELDING EFFECT IN NCT EXPERIMENTS WITH MAGNEVIST

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Taking into account the effect of Gd self-shielding in experiments with Magnevist on Gd NCT significantly improves the accuracy of determining the absorbed dose. As is known, collimated neutron beams are mainly used in NCT, therefore, the bulk of thermal neutrons fall from the front side and, at a high concentration of gadolinium, are absorbed by the front layers of gadolinium. In work [1], the effect of self-shielding was confirmed by calculations using MSNP for modeling and when measuring the dose of gadolinium using chemical Frice dosimeters. The effect of self-shielding when using a drugs based on ^{10}B and B_4C was also investigated in works [2,3]. It is especially important to consider this effect when conducting radiobiological experiments, since excess concentration of gadolinium can lead to an underestimation of the expected dose in the tumor or to the irregularity of its exposure. In this paper, we present the results of calculations of the MCNP simulation of experiments on epithermal neutron irradiation of biopsy samples of human brain glioma tumors. Using these calculations, we performed experiments on tissue samples of human glioma tumors extracted during surgery. From tissue samples of tumors, live sections were prepared and placed in a nutrient medium. Prepared live sections were used to irradiate a beam of epithermal neutrons in the presence of the Magnevist preparation. The dependence of the percentage of necrosis in the samples on the concentration of Gd in human brain glioma tumors was studied experimentally The results showed that the percentage of necrosis in the tissues of human brain tumors linearly depends on the concentration of Gd to 1000 ppm, and with a further increase in the concentration, the percentage of necrosis does not change. This indicates that, due to the above factors, there is a certain optimal concentration of Gd for irradiating human brain glioma tumors, and a further increase in the concentration of Gd can adversely affect, i.e. reduces the absorbed dose. This fact must be taken into account when using various drugs to increase the effectiveness of GdNCT.

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THE FRAGMENTATION OF TARGET (FOOT) EXPERIMENT

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The main goal of the FOOT experiment is to provide nuclear cross section measurements necessary in two different fields: hadrontherapy and radioprotection in space.
In the last decade, a continuous increase in the number of cancer patients treated with Particle Therapy (PT) has been registered, due to its effectiveness in the treatment of deep-seated solid

tumors [1]. When the charged particles travel through the patient, nuclear interactions occur producing nuclear fragments that can cause side effects in regions outside the tumor volume. Nuclear fragmentation produces both light and heavy fragments: the first are produced within a wide opening angle, while the second close to the beam direction. To detect both types of fragments, the FOOT detector consists of two different configurations: an electronic setup [2] and an emulsion chamber [3].
Target (^{16}O,^{12}C) fragmentation induced by 150-250 MeV proton beam will be studied via inverse kinematic approach, where ^{16}O and ^{12}C beams, in the 150-200 MeV energy range, collide on graphite and hydrocarbons target to allow the extraction of the cross section on Hydrogen. This configuration explores also the projectile fragmentation of these beams. The electronic setup includes a pre-target region (a plastic scintillator and a drift chamber), a magnetic spectrometer based on silicon pixel and strip detectors, a scintillating crystal calorimeter able to stop the heavier fragments produced and to achieve the needed energy resolution, and finally a TOF and ΔE scintillating detector for particle identification. The emulsion chamber setup includes the same pre-target region as the electronic setup and a set of three different emulsion chambers for different purposes.
Regarding to the second FOOT mission, the XXI century will be characterized by a deeper exploration of the Solar System that will involve long term missions as the expedition to Mars. Health risks are associated to exposure to Galactic Cosmic Radiation (GCR), that is very energetic (on average around 700-1000 MeV/u) and produces showers of light fragments and neutrons by nuclear fragmentation when hitting the spaceship shields. Considering that the GCR are composed of 90% of protons, 9% of helium and the rest of heavy nuclei, the overlap with the measurements for hadrontherapy purposes is large, the main difference being the energy range.
The experiment is being planned as a 'table-top' experiment in order to cope with the small dimensions of the experimental halls of the CNAO, LNS, GSI and HIT treatment centers, where the data taking is foreseen in the near future (2020). The detector, the performances, the physical program and the timetable of the experiment will be presented.

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OBTAINING OF THE ^{89}Zr MEDICAL ISOTOPE IN THE (γ, αn)-REACTION

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The modern medical method of nuclear visualization based on monoclonal antibodies, the new carriers of the radioactive label, is Immuno-PET. For its realization, it is necessary that the biological half-life of the molecule, the label carrier, coincides with the half-life of the radioactive isotope. The ^{89}Zr isotope has optimal physical characteristics for Immuno-PET: it decays with a half-life of 78.41 hours by positron emission and electron capture to the intermediate state ^{89m}Y, which decays to stable ^{89}Y with half-life 15.7 s.
Traditionally, ^{89}Zr is produced with cyclotrons in the (p, n)- and (d, $2n$)-reactions. However, in both methods, the exclusion of ^{88}Zr isotope impurities with a half-life of 83.4 days and its daughter ^{88}Y isotope with a half-life of 106 days resulting from (p, $2n$)- or (d, $3n$)-reactions presents a significant problem.
Therefore, an urgent task is to study the ^{89}Zr yield in various photonuclear reactions.
We irradiated a ^{94}Mo enriched molybdenum target and a tantalum monitor target using an electron

accelerator with a 20 MeV maximum electron energy.
The spectra of irradiated targets were measured by Canberra and Ortec gamma spectrometers with ultra-pure semiconductor detectors with a (15–40)% detection efficiency compared to a 3′×3″ NaI(Tl) detector. The energy resolution of the spectrometers was 1.8–2.0 keV on the 1332 keV ^{60}Co γ-line. In the studied spectrum, γ-transitions from ^{89}Zr decay are reliably identified. The bremsstrahlung spectrum was simulated using the Geant4 software code.
As a result, we obtained the integral cross-section for the ^{94}Mo(γ, n)^{89}Zr reaction equal 4.5 mbn×MeV. The ^{89}Zr yield is 5×10^4 Bq×μA×hour. Obtained data are discussed.

A STUDY OF NEUTRON FLUX FROM 20 MeV MEDICAL LINEAR ACCELERATORS

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Currently, photon beams obtained from linear electron accelerators are used for radiation therapy. The most widely used bremsstrahlung is ones with a maximum energy of 6, 10, 15, 18, and 20 MeV. The main advantages of radiation therapy with high-energy photons (15, 18 and 20 MeV) are high penetrating ability, the ability to create a maximum dose at almost any depth of the tumor in the patient's body, a reduced dose for the skin and a reduced peripheral dose due to lower angular dispersion. However, the interaction of photons with an energy of more than 8 MeV with the structural elements of the accelerator made of materials with a high atomic number is accompanied by the formation of secondary neutron radiation through (γ, Xn) reactions, subsequent neutron capture is a source of induced gamma radioactivity, which does not generate a dose taken into account in radiotherapeutic treatment.
The neutron flux intensity of the Varian Trilogy linear medical accelerator with a maximum electron energy of 20 MeV was estimated by the activation method by irradiating tantalum targets with brake beams under conditions close to clinical. Because fast neutrons make the main contribution to the patient's dose, the targets were irradiated as part of the tantalum – cadmium – tantalum – cadmium foil assembly to cut off thermal neutrons.
The spectra of irradiated targets were measured by Canberra and Ortec gamma spectrometers with ultra-pure semiconductor detectors with a (15–40)% detection efficiency compared to a 3′×3″ NaI(Tl) detector. The energy resolution of the spectrometers was 1.8–2.0 keV on the 1332 keV ^{60}Co γ-line. The gamma transitions from the ^{180}Ta formed in the ^{180}Ta(γ, n)^{181}Ta reaction and ^{182}Ta formed in the ^{181}Ta(n, γ)^{182}Ta reaction were reliably distinguished in the studied spectra.
The average fast neutron energy was calculated from the reconstructed spectrum obtained by a modified Bonner activation spectrometer. The energy distribution of the secondary neutron flux density in the neutron energy range 0.1–15 MeV were obtained by the SDMF-1608PRO spectrometer-dosimeter. After analyzing the spectra, it was found that the average fast neutron energy of the Varian Trilogy linear medical accelerator is 0.89$\pm$0.02 MeV. Experimental data of neutron energy and activation of tantalum monitor targets were used to estimate the fast neutron flux. It was found that the flux of fast neutrons on the tantalum monitor target is from 5 to 10% during the accelerator operates with a 20 MeV bremsstrahlung maximum energy.
Taking into account the coefficient of relative biological efficiency of neutron radiation for neutrons with energies from 100 keV to 2 MeV, equal to 20, compared with the coefficient for gamma rays (equal to 1), even in preliminary studies, there is a significant underestimation of the contribution radiation of secondary neutrons in the total dose received by the patient during radiation therapy with 20 MeV bremsstrahlung maximum energy.
A discussion of the findings is ongoing. The reported study was funded by RFBR according to the research project №18-00-00745.

METHOD OF CORRECTION BEAM HARDENING ARTIFACTS IN CT

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The beam hardening effect can induce strong artifacts in CT images, which leads to severe deterioration in image quality. This work develops an effective beam hardening correction algorithm using filtered back-projection based maximum *a posteriori*.
An x-ray tube emits a continuous spectrum, which gives rise to energy-dependent attenuation of different tissues. The spectrum is not known with sufficient accuracy as a rule/ Low-energy photons are preferentially absorbed compared to photons with higher energy along the integral path of a polychromatic x-ray beam, such that the beam gradually becomes harder, i.e. its mean energy increases. Neglecting this beam hardening effect in reconstruction leads to artifacts.
The iterative approaches that suppress beam hardening induced artifacts by directly incorporating the beam hardening effect into the projection matrix in an iterative reconstruction model were proposed earlier in [1]. The proposed method can be considered as an iterative maximum a posteriori reconstruction with the beam hardening effect incorporated in the forward-projection.
The algorithm has important properties. Most other iterative approaches require prior knowledge of the energy spectrum or the material composition, which is difficult to obtain in some clinical practice cases. The proposed method does not suffer from this obstacle, and can be used when no information about the beam spectrum or the material properties is available. It based on a fact that attenuation in every voxel can be decomposed into a photoelectric component and Compton scatter component. Besides, the photoelectric component depends on atomic number very strong: total cross section is proportional to $Z^{4.5}$ and its maximum value is shifting to the more energies when Z increase. In our method, we use the database for energy dependence of the photoelectric cross section for the different materials that might induce "hardening" artifacts, such as bone, aluminum and titanium implants etc.
This method has a high computation efficiency and needs small amount of iterations to obtain a satisfying reconstruction result. With usage of high voltage or bow-tie wedges to reduce the amount of low energy photons, the iteration number can be further reduced. In addition, the proposed method performs well in terms of both the overall reconstruction quality and suppression of beam hardening induced artifacts.

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COMBINED RADIATION DEVELOPMENT STRATEGY FOR BONE IMPLANT STERILIZATION METHODS

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The authors proposed a development strategy for combined radiation methods for sterilization of bone implants in order to increase their effectiveness in clinical use [1]. The relevance of this work

is determined by the ever-increasing need for plastic material during reconstructive operations in bioimplantology [2]. Recent works have confirmed the promise of combined sterilization methods [3], which are based on the use of the advantages of radiation exposure on bone implants in combination with preliminary ozone treatment, which reduces the radioresistance of pathogenicity. The synergistic effect achieved in this case provides effective sterilization with a significant reduction in the absorbed dose and side effects of each of the acting factors separately [4].
Particular attention is paid to the development of objective methods for assessing the quality of implants, indirect control of the initial osteoinductive and osteoconductive properties, the structural and functional state of the surface layer with the determination of its elemental composition. The condition and surface characteristics of the bone implant largely determine its osteinductive and osteoconductive properties, regenerative potential and, thus, the effectiveness of application in bioimplantology [5].

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DIGITAL IMAGE PROCESSING IN NUCLEAR MEDICINE

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The nuclear physics methods are increasingly important in medicine for the early diagnosis of diseases. Nuclear medicine is of the most modern methods of non-invasive functional diagnostics, providing information that cannot be acquired with other imaging technologies. Its methods require advanced mathematics for data processing and analysis [1]. Development of mathematical methods and data processing software for single photon emission computed tomography (SPECT) and positron emission tomography (PET) remains challenging problem.
The report discusses the methods for radionuclide image processing for dynamic and gated SPECT data [2]. There is a trend toward complete automation of processing and interpretation of radionuclide studies. The report presents the developed data processing software suite for nuclear medicine imaging. In conclusion, the main directions and prospects for the development of nuclear medicine data processing tools are considered.

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Section 9. Nuclear-physical methods in the study of cultural heritage objects

CUTTING METAL INTO PERFECT 100-300 NM STRIPS IN THE 16-17TH CENTURIES

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Metal threads are strips of metal used either as an independent thread, or twisted around a silk core. They have been used to decorate textiles since ancient times. Typical sizes of threads of 16-17th centuries were 130-420 um width and 3-15 um thickness. A base metal was copper or silver. Some of threads were gilded on two or only one side.
All known publications [1, 2, 3, etc.] agree that before the invention of the wire drawing the threads were simply cut off from the foil sheet (with scissors or something else) and they became a product of rolling the wire after the invention. There is only one point of view about the method of gilding: it was diffusion gilding. About 40 samples of threads (5 mm each) were examined in a scanning electron microscope with an EDS detector. The specific defects of the gold layer, as well as the absence of Hg, confirmed diffusion gilding. But our measurements (plus some calculations and a search in the history of technology) disprove the version about the wire and rollers. It is impossible to explain perfectly parallel edges and a rectangular thread cross-section (Fig. 1) and gilding on only one side of some threads as well.

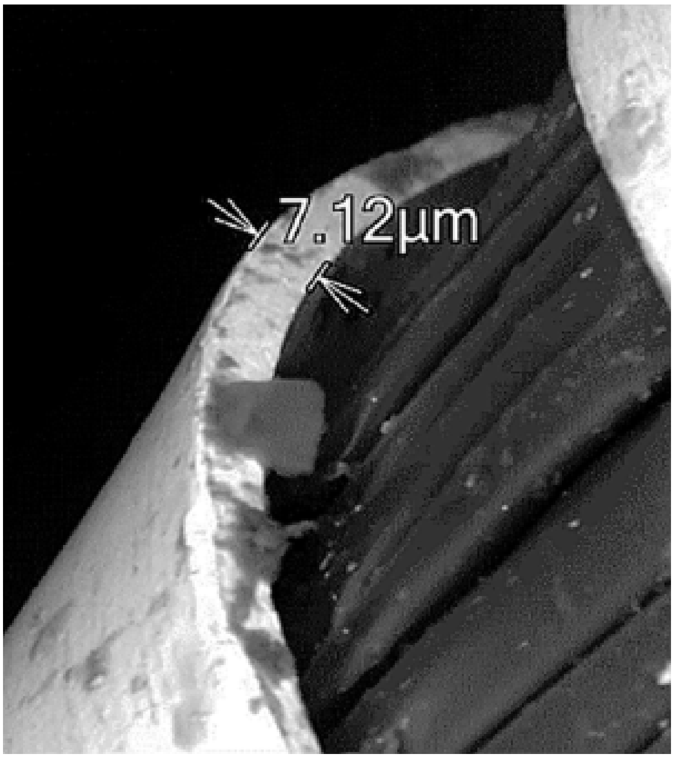

Figure 1: SEM photo of a metal thread.

We suggested that the threads were made by cutting from a sheet of foil as before (i.e. without a wire drawing), but not with a hand tool. The fact is that rollers were already known to jewelers in the 14th century, two centuries before first roller mill [4]. A pair of precisely arranged rollers can move the foil sheet in a straight line. If you add a blade, you can make a straight cut. But since there are no tool marks or deformation marks on the edges of the thread, the blade had to be placed almost parallel to the sheet and be very sharp, about 1 μm at the tip [5]. The sheet (unlike the rod) can be gilded only on one side by heating to 600-900 ℃ and pressing [6].
Of the 40 threads studied, even from one textile, there were not two of the same width. According to our assumption, this can be explained as follows: the thread each time was simply cut into two, equal or not. It would be interesting to study a long thread (» 5 mm) to find the point (and method) of joining together. If two threads of different widths are joined, our assumption can be considered proven. And therefore, the main invention that changed the technology of manufacturing metal threads was not wire drawing , but rollers and a method of parallel and non-deformation cutting into strips.

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INVESTIGATION OF THE CULTURAL HERITAGE ITEMS BY NEUTRON RESONANCE CAPTURE ANALYSIS

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In the framework of collaboration with the Institute of Archeology of the Russian Academy of Sciences and FLNP, JINR experiments to study the materials found during archaeological excavations were conducted. The measurements were carried out at the IREN facility in FLNP. The method of neutron resonance capture analysis was used to determine the elemental composition of the samples. The elements and isotopes are identified by measuring neutron resonance energies in the radiative capture reaction, and their concentration in the sample is determined by measuring the output of γ-quanta in the observed resonances. In the analysis, comparative measurements with the test and standard samples are used.
The area method is used for processing the resonances on the time-of-flight spectra.
The output of γ-quanta in the resonance is: $\Sigma N = \Pi(E)\epsilon_\gamma(\Gamma_\gamma/\Gamma)A$, where ΣN - the number of counts in the resonance, $\Pi(E)$ – the neutron flux in the resonance region, ϵ_γ - the detection efficiency of the γ- ray detector, Γ_γ, Γ - the radiative and the full width of the resonance, respectively, A - the area of the resonance.
The mass of the isotope is deduced from the value of A - the area of the resonance - which depends on the parameters of the resonance and the concentration of the isotope.
The non-destructive nature of the method and practical absence of induced activity makes it possible to study samples of any shape and size, which makes such analysis an effective tool for studying archaeological artifacts and cultural heritage samples.

PROVENANCE OF THE LEAD DETECTED IN THE ANTIQUE CERAMIC SCULPTURE FROM THE KERCH BAY

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The large ceramic antique sculpture from the Kerch Bay was studied in detail by the use of modern minimally invasive techniques. Radiocarbon calibrated date of the resin sample selected from the surface of the sculpture was established within V^{th} century BC. The study of provenance of the lead taken from the terracotta cavity was carried out using different modern techniques such as trace element analysis and lead stable isotope analysis. Isotope ratios of the lead were determined by ICP-MS. Trace elements composition was studied by ICP-AES and ICP-MS. Main elements of the alloy were analyzed by energy dispersive X-ray microanalysis. All the samples preliminary were examined by optical microscopy. The advantage of the isotopic composition study in comparison with the detailed element composition of trace elements is the stability of isotopic composition of a heavy elements like lead regardless to the processes involved in the treatment of ores such as roasting or smelting, cupellation or melting, dissolution or corrosion. The isotopic composition remains constant. Nevertheless, trace element pattern indicates the type of an ore.
The results of lead stable isotope analysis demonstrate that non recycled lead was used in the case. It was shown that the lead is originally proceeds from a single source such as Laurion ore deposit (Attica, Greece). The results of trace element analysis of lead support this conclusion. This is the earliest recorded case of the appearance of the Athenian ”non-coin” lead on the antique Bosporus.
This research was financially supported by the Russian Foundation for Basic Research (grant No 18-00-01094).

TOWARDS A MULTI-PROXY BIOAVAILABLE STRONTIUM ISOTOPE BASELINE FOR THE ORENBURG REGION, RUSSIA

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Strontium isotopes are used in archaeology, ecology, forensics, and other disciplines to study the origin of artefacts, humans, animals and food items. Strontium in animal and human tissues such as bone and teeth originates from food and drink consumed during life, leaving an isotopic signal corresponding to their geographical origin (i.e. where the plants grew, the animals grazed and the drinking water passed through) [1].
To assess the mobility and provenance of ancient populations, it is necessary to compare their $^{87}Sr/^{86}Sr$ isotope ratios with the local bio-available strontium baseline (background), characteristic of each specific location or potential provenance region of an individual or artefact. Its definition requires a comprehensive approach to the analysis of different samples ("proxies") characterizing the ecosystem of the archaeological site under study, the identification of the most suitable proxies,

as well as the unification and standardization of the sampling and analytic protocols [2]. Common proxies when producing strontium isotope baselines are surface/ground water, plants, soil leachates, and faunal remains, and the choice largely depends on the nature of material under investigation, and of the availability of sampling material [3].
In order to construct multi-proxy strontium isotope baselines for the Orenburg region, where unique and significant archeological monuments of the Mesolithic era to the Middle Ages are situated, a one-month long fieldwork was implemented. Samples characterizing bioavailable strontium (vegetation, soil, rocks, surface and ground water, as well as bone and dental remains of modern fauna, the shells of bivalve and gastropod mollusks) were collected on the territory of about 124 thousand km2. Due to its location, the territory of the Orenburg region has a complex geological structure, which is reflected in highly variable environmental Sr isotopic signatures.
A methodology of 87Sr/86Sr isotope analysis of collected proxies of different types by Neptune Plus MC-ICP mass-spectrometer after Sr chromatographic separation will be applied in the Zavaritsky Institute of Geology and Geochemistry, UB RAS, and strontium isoscapes (iso - isotope, scape - landscape), representing lines/areas with certain $^{87}Sr/^{86}Sr$ isotopic ratios of bioavailable strontium will be constructed. Obtained strontium isoscapes will be used for unveiling the regions potentially connected with the provenance (birth) of human and animal individuals and their mobility as well as to discuss the origins of archaeological textiles. These data will greatly expand the possibilities of historical interpretations and will allow the traditional archaeological cultural and geographical models to be verified.
The work was carried out at the "Geoanalitik" Center for Collective Use and supported by RFBR grant No. 20-09-00194.

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MINERALOGICAL AND CHEMICAL COMPOSITION OF PREHISTORIC CAVE PAINTINGS AND PICTOGRAPHS (SOUTHERN URALS, RUSSIA) BY ENERGY DISPERSIVE X-RAY MICROANALYSIS

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Scanning electron microscopy has been extensively used for the material characterization of objects of artistic and archaeological importance, especially in combination with energy dispersive X-ray microanalysis (SEM-EDX) [1, 2], and become an indispensable tool in delineating the degradation processes of ancient as well as modern materials in art and archaeology [1].
Rock art is found on every continent and comprises one of the most abundant and informative of archaeological artefacts [3]. In general, paintings are made by mixing dry pigments with a liquid binder either of animal or plant origin [1, 3]. After drying the paint layer, a new layer can be applied [1]. Three main problems arising when studying the composition of ancient paintings are the determination of the paint production technology and raw material sources, as well as the way of how the paint is applied [2].
Present study is devoted to the elemental and mineral composition of pigments from the cave paintings of the Ignatievskaya cave [4] and pictographs of the Idrisovskaya cave [5] (Southern Urals, Russia) using SEM-EDS. SEM images and elemental mapping of carbon sputtered samples were performed using JEOL JSM-6390LV with INCA Energy 450 EDS spectrometer with accelerating

voltage of 20 kV at the IGG UB RAS.
It has been shown that the main inorganic components of the pigments are goethite and hematite-containing ochres and carbon, most likely derived from burnt bone; organic binder is likely of animal origin. The technology of dye manufacture could include the stage of thorough grinding of inorganic raw materials with a binder, and the application of paint could occur in layers.
For the images of open-air pictographs, the presence of calcium oxalates, formed as a result of the interaction of organic components with rock matter, is characteristic, which can perform a stabilizing function and protect pigments from weathering and reliably fix the dye to the substrate as it was pointed out by [6].
The work was carried out at the UB RAS "Geoanalytic" Center for Collective Use within IGG UB RAS state assignment № AAAA-A18-118053090045-8.

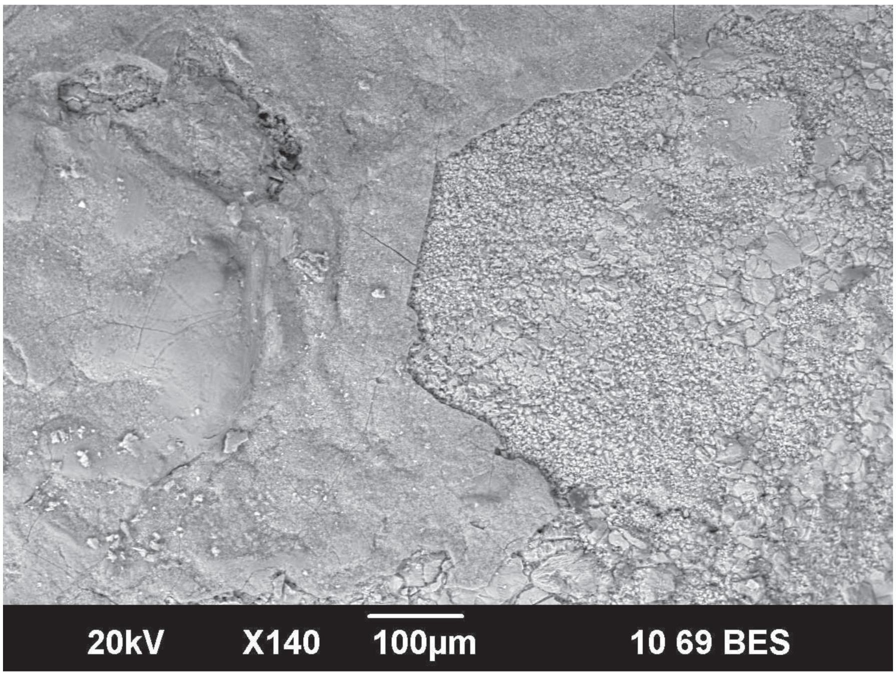

Figure 1: BSE image of red pigment from the Idrisovskaya cave. Fine-grained calcite crystals of the wall and paint layers.

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X-RAY, SYNCHROTRON AND NEUTRON IMAGING OF METAL ARTIFACTS FROM THE BLACK GRAVE MOUND

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Synchrotron and neutron imaging are the unique tools that allow non-destructive studies of the internal structure of bulk metal objects. It's very significant for the assessing artifacts preservation, clarifying the manufacturing technology and localization of possible decorative ornaments.
A complex of imaging techniques including X-ray computed tomography, synchrotron radiography and tomography at the KISI ”Kurchatov” synchrotron radiation source and neutron tomography at the neutron source Research reactor IR-8 are used at the Kurchatov Institute. These methods are complementary, since the different nature of radiation interaction with matter.
We have studied some artifacts from the most famous mound of Medieval Rus' – Chernaya Mogila (Black Grave mound, X century, Chernigov) from the collection of State Historical Museum in Moscow. The presented results of X-ray, synchrotron and neutron studies of metal artifacts showed rich ornamentation of weapons and allowed us to study on the hidden features. In particular:
- the silver decoration of Scandinavian style was detected on the object with unknown function, later it was supposed that this object was 'barbarian scepter' [1];
- a part of a mark on a blade fragments was recognized [2];
- details of a manufacturing technology were clarifying for composite construction of the helmet [2];
- some items (stirrup, spear-heads etc.) were recognized inside the sintered bulk of weapon [2].

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STUDY OF THE ELEMENTAL COMPOSITION BRONZE STATUES FROM THE COLLECTION OF THE STATE MUSEUM OF FINE ARTS A.S. PUSHKIN

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The results of research on 17 bronze statues from a collection of the State Museum of Fine Arts A.S. Pushkin are presented.

The analyses of the metal elemental composition in sculptures and objects of decorative and applied art is a relatively young and rapidly developing area of scientific knowledge. This method is effective for identifying the "non-standard" alloy compositions [1]. Analysis of the alloy composition by inductively coupled plasma mass spectrometry (ICP-MS) allows determine the basic elements as well as micro- and trace impurities excluding carbon, nitrogen, oxygen, fluorine, chlorine and noble gases. The sample preparation corresponded to protocol reported in [2].
The variability of the metal compositions was assessed by the statistical analysis of the obtained ICP-MS data, performed in the program "StatSoft STATISTICA 10.0.1011.0" by the K-means method using several variations in the number of clusters. In order to involve into cluster analysis of all micro- and trace impurities in addition to base elements, all ICP-MS data on elements content were standardized. It made possible to identify several groups of alloys among the samples studied.
Comparison of data on statues alloys with metal compositions of exhibits of known attribution and with published data of Renaissance metal sites and later ones, made it possible to clarify the time periods for making the statues.

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RED WAX SEALS: RECONSTRUCTION OF HISTORICAL TECHNOLOGY

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The results of a comprehensive study of red wax pendant seals attached to the Russian documents of the late 15th - early 18th centuries are presented. Seals of adjacent territories were used for comparison of dyeing technologies for Western European and Russian wax seals.
Since the seals included a variety of organic and inorganic materials according to historical recipes, the set of methods included: X-ray diffraction phase analysis, scanning electron microscopy with energy-dispersive X-ray microanalysis, inductively coupled plasma mass-spectrometry, gas chromatography, IR-spectroscopy. Experimental techniques were testing out on model samples of red seals made from modern beeswax with the use of various pigments: red lead, cinnabar and white lead.
A study of historical seals showed that beeswax, resin and cinnabar were used in the manufacture of European seals in full accordance with historical recipes. The composition of Russian seals of the 15th-17th centuries differs from the list of materials purchased for the needs of the *Posolsky Prikaz* (Ambassadorial Prikaz) responsible for the manufacturing of state charters. The composition for the seal of Peter the Great (a mixture of beeswax, resin, cinnabar and red lead) is consistent with the recipes for Russian seals of the early and mid-17th century. It was found that the presence of lead in the samples is not always associated with coloring pigments.
Thus, an evolution in the Russian practice of making red wax seals with some difference from

synchronous European recipes was traced.

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^{87}Sr/^{86}Sr ISOTOPE RATIO DETERMINATION IN BIOAPATITE BY MC-ICP-MS USING THE SSB TECHNIQUE FOR ARCHAEOMETRIC PROVENANCE STUDIES

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Measuring the natural abundance of isotopes and the variations in their ratios in the archaeological hard tissues (such as bones and teeth) can provide important information about the evolution and migration of humans and animals and their origin. Strontium isotopes are among the most effective for characterizing the prehistoric mobility of humans and animals [1]. ^{87}Sr/^{86}Sr isotope ratio incorporates into the surrounding biosphere from underlying bedrocks and is practically not fractionated by biological organisms. Since Sr can replace Ca in the hydroxyapatite crystal lattice of bones and teeth, ^{87}Sr/^{86}Sr ratio can be directly attributed to the isotopic ratio of the geochemical province where humans and animals reside [1].

The work presents the method of ^{87}Sr/^{86}Sr isotope ratio analysis in biogenic apatite by multi-collector (MC) ICP-MS using the standard-sample bracketing (SSB) technique with preliminary chromatographic separation of Sr.

All works were performed in cleanrooms (ISO 6, 7) of the Zavaritsky Institute of Geology and Geochemistry, UB RAS. Single-step chromatography technique modified from [2] and described in detail in [3] was applied for strontium isolation using SR resin (100–200 mesh, Triskem®). Sr isotope measurements were carried out using a MC ICP-MS Neptune Plus (Thermo Fisher Scientific, Germany) equipped by the ASX 110 FR sample introduction system (Teledyne CETAC, USA) fitted by PFA micro-flow nebulizer (50μL min^{-1}) connected to a quartz spray chamber.

Mass bias was corrected by the combination of exponential law normalization and standard-sample bracketing (SSB), the ^{87}Sr/^{86}Sr ratio was normalized by the value of 88/86=8.375209 [4]. In addition, interference correction was provided by accounting of ^{86}Kr and ^{87}Rb by ^{83}Kr/^{86}Kr=0.664162, ^{83}Kr/^{84}Kr=0.201579 and ^{87}Rb/^{85}Rb=0.386 ratios (also normalized). Subsequently, the normalized values were additionally corrected by the mean value variation of SRM-987 "bracketed" each two samples from the reference value of 0.710245 (GeoReM database, http://georem.mpch-mainz.gwdg.de/).

The analysis of Bone Meal SRM 1486 and Bone Ash SRM 1400 standard reference materials was carried out, and the expanded uncertainty was calculated. For NIST Bone Ash 1400, ^{87}Sr/^{86}Sr = 0.71318 $\pm$ 0.00026, and for NIST Bone Meal 1486 ^{87}Sr/^{86}Sr = 0.70933 $\pm$ 0.00022, which is in an excellent agreement with the GeoReM Database data (0.7131-0.7134) and (0.709269-0.70964), respectively. The method precision was estimated as the within-laboratory standard uncertainty (2σ) obtained for SRM-987 and was $\pm$ 0.003 %.

The developed method was applied to the strontium isotope analysis of animal and human teeth and bones from a number of archaeological sites in Russia.

The work was carried out at the "Geoanalitik" Center for Collective Use and supported by RFBR grant No. 20-09-00194.

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THE ELEMENTAL COMPOSITION AND CHRONOLOGY OF THE SICKLES FROM THE SOSNOVAYA MAZA HOARD OF THE LATE BRONZE AGE

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The hoard near the village of Sosnovaya Maza in the Saratov region in the Lower Volga was found in 1901. The Sosnovaya Maza hoard mostly contains sickles (44 in total) but also celts, daggers and fragments. Practically all artifacts of this assemblage are kept in the State Historical Museum in Moscow, several items from the assemblage are now in the Saratov local lore museum and the Khvalynsk local lore museum.
The technological and chemical analyses of the sickles from the Sosnovaya Maza hoard which is one of the largest hoards found in eastern Europe of the final stage of the Bronze Age, application of the ICP-MS method to study metal elemental composition, the examination of artifacts referred to the block of cultures dating to the final stage of the Late Bronze Age that share typological similarities with the hoard artifacts, research experiments to melt copper-iron alloys similar to those of the Sosnovaya Maza helped connect the sickles from the Sosnovaya Maza hoard discovered by chance in the Lower Volga region early in the 20th century without any archaeological context with the sickle from a closed cultural assemblage, which is pit-house 4 at the Alekseyevka settlement attributed to the Alekseyevka-Sargary culture of northern Kazakhstan. In contrast to the sickles from the hoard, the Alekseyevka sickle was found inside pit-house 4, which is a closed archaeological context, among other things, including carbon-containing animal bones. The 14C date of the cattle bone retrieved from pit-house 4 can be regarded to be a chronological benchmark for the Sosnovaya Maza type sickles and the entire Sosnovaya Maza hoard enabling us to narrow down the time interval during which such sickles made from iron-containing copper were used and date the hoard to 1400-1300 calBC.
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PROVENANCE OF METAL ARTEFACTS OF THE LATE BRONZE AGE FROM THE SOSNOVAYA MAZA HOARD BY MC-ICP-MS LEAD ISOTOPE ANALYSIS

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Lead isotope analysis (LIA) is widely applied by archaeologists as a method for provenance studies of metal artifacts [1, 2]. Nevertheless, there are several issues complicating LIA interpretation of

archaeological artefacts, including following [2]: 1) ore deposits can have identical or overlapping isotope compositions, even when they are geographically far apart; 2) the recycling of scrap metal has also to be taken into account, and the isotope pattern resulting from such processes cannot be compared with the original ore source; 3) the assignment of metal artefacts to a raw material source could be hindered further if ores from different sources had been smelted together [2].
The hoard found near the village of Sosnovaya Maza (Saratov region, Russia) in 1901 is the second largest hoard of the Bronze Age in Eastern Europe with its total weight of 22.5 kg. It is composed of sickles and their fragments, daggers and their fragments, and some other metal artefacts [3].
The aim of the work is to assess the homogeneity/heterogeneity of the ore base used when smelting the sickles of the Sosnovo-Mazinsky hoard and to determine the probable ore resource base or several sources of ore used for metal smelting.
The lead isotope composition of copper alloys of items from the Sosnovaya Maza hoard and bronze items of a comparative samples from the archaeological sites of the Urals and Kazakhstan was studied.
A Perkin Elmer ELAN DRC-e quadrupole ICP mass-spectrometer was used to obtain lead isotope ratios according to the methodology proposed by [4]. For Pb isolation, an extraction chromatographic column containing Pb-selective PBA052316 100-150 mm resin was used.
The comparative analysis of obtained data with the lead isotopic analysis of copper ores from ancient and modern mines of the Cis- and Trans-Urals regions allowed an assumption to be made about the probable use of several types of deposits – copper-pyrite of the Southern Urals; Late Permian oxidized ores of the Urals from the Sakmara-Samara mining and metallurgical region; the ore of the third type, characterized by highly radiogenic $^{208}Pb/^{204}Pb$, probably comes from the deposits of northern Kazakhstan. The variability of the lead isotopic composition of the hoard items confirms the use of several ore deposits and the re-melting of bronze scrap.
The work was supported by RFBR grant No. OFI-M 17-29-04176.

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LEAD ISOTOPE ANALYSIS OF THE BRONZE AGE METAL FROM THE STEPPE CIS- AND TRANS-URALS

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Lead isotope analysis (LIA) has been rapidly approved by archaeologists as a method for provenance studies of metal artefacts as well as glass, pottery, pigments, etc. [1, 2]. The major advantage of LIA application for provenance studies is that lead isotope ratios do not change during metallurgical processes, which means that the isotope pattern remains constant independent on the temperature of ore roasting or Red-Ox conditions of metal smelting. The pattern is therefore characteristic of a particular deposit and allows a secure assignment of the finished product to the initial raw material [1]. The modern instrumental methods of isotope analysis, in particular, mass-spectrometry, are characterized by high sensitivity and precision. Lead mass of 10^{-9} - 10^{-7} g is sufficient for a routine isotope measurement resulting in the sample mass of only tens of mg, which can be very important

when working with unique and valuable archaeological artefacts.
Lead isotope measurements of a number of bronze and copper artefacts and ingots of the Bronze Age steppe Cis- and Trans-Urals of were carried out on a Neptune Plus multicollector ICP-mass spectrometer (Thermo Fisher Scientific, Germany) using Tl-normalization technique [3] after the chromatographic lead isolation. A conventional ion-exchange chromatography technique using Bio-Rad AG 1x8 resin (100–200 mesh) proposed by [4] was applied for lead isolation [5]. The calculated U(k=2) method expanded uncertainty was U(^{208}Pb/^{204}Pb)=0.3%, U(^{207}Pb/^{204}Pb)=0.1% and U(^{206}Pb/^{204}Pb)=0.1%. All works were performed in cleanrooms (ISO 6, 7) of the Zavaritsky Institute of Geology and Geochemistry, UB RAS.
The obtained data for bronze and copper artefacts and ingots of the steppe Cis- and Trans-Urals of the Bronze Age indicate their fairly clear assignment to the ores of the Trans-Urals and Ural-Mugodzharsky or Cis-Urals ancient mining and metallurgical centers. For a number of samples studied, the interpretation is complicated. More correct comparisons will become possible only after the implementation of a large-scale program of isotopic analyzes of ore deposits and occurrences of all mining and metallurgical centers of the Bronze Age of the Southern Urals.
The work was carried out at the "Geoanalitik" Center for Collective Use and supported by RFBR grants № 18-00-00036 К (18-00-00030, 18-00-00031).

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COMPREHENSIVE RESEARCH OF HISTORICAL INK: THE CONCEPT OF LARGE MANUSCRIPTS ARRAYS STUDYING

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The existing coverage of the material in the study of ink of Old Russian manuscripts was extremely insufficient to reveal their real information potential [1], in particular, in the identification of different levels of relationships between the dye and the executed text, characteristic for the manuscript culture of Old Rus'.
We propose a comprehensive approach to the laboratory studies of manuscripts, which makes it possible to study large arrays with varying degrees of detail and includes: spectro-zonal visualization of text, express XRF analysis of the ink basic elemental composition, detailed analysis of the elemental composition and structure of ink by transmission electron microscopy with EDX,

Raman and IR spectroscopy for organic compounds identification.
An approvement of the developed approach was made by using experimental inks replicated from some historical receipts as well as actual historical documents. In order to IR-spectra processing verification we used high-effective liquid chromatography with mass-spectrometry as a method for identification of organic compounds in general.
We hope that the proposed approach to large-scale historical ink analysis will improve traditional paleographic methods in manuscript studies.
Research is supported by Russian Foundation for Basic Research (Project № 18-00-00429 (K) «Development of nondestructive analysis of manuscripts and parchments and advancing of new materials and methods for their conservation» including projects № 18-00-00311 and № 18-00-00407).

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Poster session

SPECTROMETRIC DETECTION UNIT BASED ON SCINTILLATION SrI2(Eu) DETECTOR

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Energy resolution of spectrometric instruments for radiation control systems today should be below 4.5% as required by international standards. Example, the American national standard ANSI N42.34-2015 introduces a requirement for the resolution of RID spectrometer channel to be not above 4%.
Developed a spectrometric detection unit based on scintillation SrI2(Eu) detector. According to the results of spectrometric test the typical resolution for the 662 keV line of the ^{137}Cs radionuclide was 3.3% at maximum count rate 150 000 cps [1].
Based on the SrI2 (Eu) scintillation crystal also a detection unit with a nonlinear channel - energy conversion scale from 15 keV to 8 MeV was developed. The capabilities of this measuring instrument were tested in the field of capture gamma radiation from targets at the AT140 Neutron Calibration Facility [2].
The developed spectrometric detection unit can be widely used both in installed radiation control systems and in mobile devices with a function of radionuclide identification.

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FIELD OF CAPTURE GAMMA RADIATION WITH AN ENERGY OF UP TO 10 MeV

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The use of dosimeters calibrated in reference fields with corresponding energies for correct estimation of dose loads for personnel working in high-energy gamma-radiation fields with energies above 3 MeV is required. The creation of reference fields with gamma-radiation energies up to 7 MeV is essential for photon radiation dosimetry at nuclear power plants, where a significant gross dose rate component is stipulated by the radiation with an energy of 6.13 MeV associated with the ^{16}O(n, p)^{16}N reaction in the water cooling loop. Apart from nuclear power plants, such tasks occur on electron accelerators, widely used for therapeutic, industrial and other purposes.
The state verification schedule (Republic of Belarus and Russian Federation) stipulates the use of ^{241}Am (0.06 MeV), ^{137}Cs (0.662 MeV) and ^{60}Co (1.250 MeV) radionuclides for reference dosimetry measurements of gamma radiation in the range from 0.06 to 3 MeV. No standard calibration and verification is performed for nuclear physics equipment in bremsstrahlung with an energy above 3

MeV generated by accelerators. Dosimeters calibrated in the radionuclide sources fields may not measure the dose rate from high-energy gamma radiation correctly. At the same time, there is a nomenclature list of instruments with various detector types, where the energy range has to be expanded to 7 MeV or 10 MeV following the relevant research is carried out.
High-energy capture gamma-radiation fields with energies up to 7 MeV (titanium target) and up to 10 MeV (nickel target) to calibrate the energy scale and verify the energy dependence of developed spectrometric and dosimetric measuring instruments were generated by AT140 Neutron calibration facility for radiation monitoring instruments according to the requirements of international standard ISO-4037:2019 [1, 2].
The report presents the results of experimental studies. The standard dosimeter AT5350/1 with a highly sensitive ionization chamber TM32002 was used to determine the air kerma rate and ambient dose equivalent rate of gamma radiation [3].

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MACHINE LEARNING APPROACH TO NECK ALPHA EVENTS DISCRIMINATION IN DEAP-3600 EXPERIMENT

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Machine Learning (ML) have been widely applied in the High Energy Physics (HEP) to help physical community to solve complex problem in classification and analysis. Here we describe application of ML to solve the problem of classification background and signal events in DEAP-3600 experiment (SNOLAB, Canada) that constructed to search WIMP particles. We apply Boosted Decision Trees (BDT) method of ML, which upgraded by using Extra Trees and eXtra Gradient boosting method (XGBoost).

PRECISION BETA-SPECTRUM MEASUREMENT OF RaE WITH SEMICONDUCTROR SPECTROMETERS

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Precise knowledge of forbidden transition beta-spectra plays a significant role in both nuclear and particle physics.
In this work we present a precision measurement of the beta-spectrum shape for ^{210}Bi (historically RaE) performed with spectrometers based on semiconductor Si(Li) detectors. This first forbidden non-unique transition has the transition form-factor strongly deviated from unity and knowledge

of its spectrum would play an important role in low-background physics in presence of ^{210}Pb background. The studies were performed with spectrometers in target-detector and 4-π geometries. The measured transition form-factor could be approximated as $H(W) = 1 + (-0.433 \pm 0.002)W + (0.0510 \pm 0.0004)W^2$ and $H(W) = 1 + (-0.433 \pm 0.002)W + (0.0510 \pm 0.0004)W^2$ for the target-detector and 4-π spectrometer respectively that is in good agreement between the two experiments as well as with the previous studies. The form-factor parameter precision has been substantially increased with respect to the previous experimental results. This work was supported by the Russian Foundation for Basic Research (project nos. 16-29-13014 and 19-02-00097).

INTERACTION OF ANTIPROTONIC HELIUM WITH MEDIUM ATOMS AND COLLISIONAL TRANSITIONS BETWEEN HFS $(\bar{p}\mathrm{He}^{+})$ STATES

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Collisions of metastable antiprotonic helium atoms with the medium atoms induce, inter alia, transitions between hyperfine structure (HFS) states, as well as shifts and broadening of microwave M1 spectral lines. These effects were studied in the experiments with the low-temperature ^{4}He [1,2] and ^{3}He [3] targets, and were considered in the framework of the model interaction between (pHe^{+}) and He [4,5]. In this work, interaction between thermalized antiprotonic $(\mathrm{p}^4\mathrm{He}^{+})$ atom and ordinary ^{4}He atom is described by an ab initio potential energy surface (PES) calculated in the framework of unrestricted Hartree-Fock method with account for electron correlations in the second-order perturbation theory (MP2). With this PES, the system of close-coupling equations for HFS channels is solved numerically. Cross sections and transition rates, shifts and broadening of M1 spectral lines are calculated. They are used to obtain a numerical solution of the master equation that determines the time evolution of the HFS-states density matrix. The results are compared with the experimental data and with the model calculation.

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THE CORRELATION CHARACTERISTICS OF ^{14}C(3⁻; 6.73 MeV) NUCLEUS IN THE ^{13}C(d, p γ)^{14}C REACTION

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In [1] we have investigated the cross sections of the ^{13}C(d, p γ)^{14}C(3^-; 6.73 MeV) reaction at E_d = 15.3 MeV. In this article the double-differential cross sections of the same reaction were measured for six proton emission angles on the SINP MSU 120-cm cyclotron. The angular correlation functions

$W(\theta_\gamma, \varphi_\gamma; \theta_p)$ were measured at four φ planes of γ-rays registration. It allowed to restore sixteen even $A_{k\kappa}(\theta_p)$ components of density matrix spin-tensor of the final nucleus ^{14}C(3⁻). The obtained $A_{k\kappa}(\theta_p)$ were used to determine other ^{14}C(3⁻) orientation characteristics: the populations $P_{\pm M}(\theta_p)$ of sublevels with the M projection of the 3^- spin, orientation tensors $t_{k\kappa}(\theta_p)$ and polarization tensors $T_{k\kappa}(2 \leq k \leq 6)$.
Experimental data were compared with theoretical ones, obtained within the neutron stripping mechanism by the coupled-channel method (code FRESCO [2], dotted curves in Fig. 1*a*, *b*, *c*) and for the compound nucleus statistical mechanism (code CNCOR [3], dash-dot curves).
Our model analysis of ^{14}C(3⁻) orientation characteristics has revealed that neutron stripping mechanism are dominant mechanisms of ^{13}C(d, p)^{14}C(3⁻) reaction.

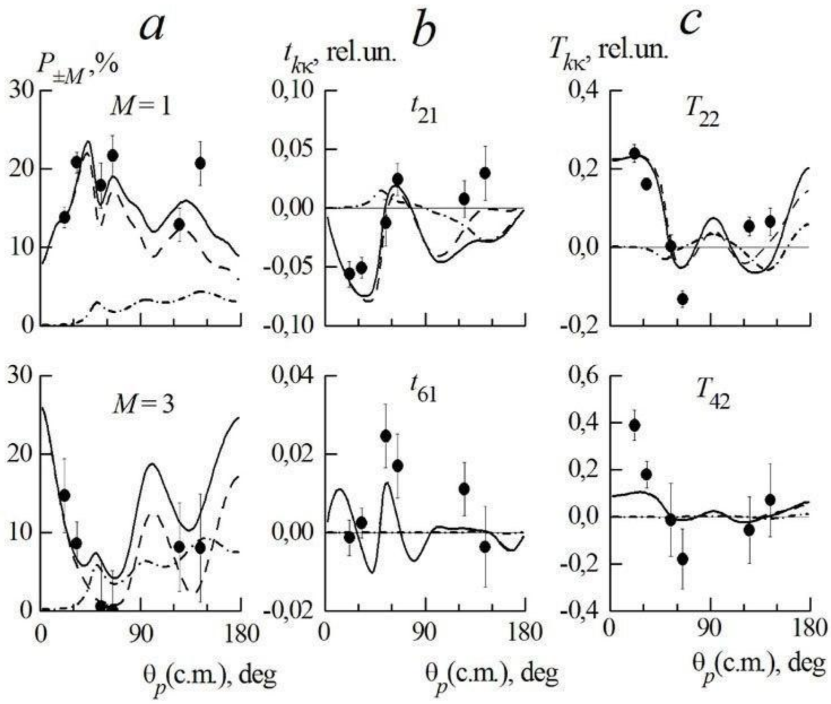

Figure 1: a – The populations $P_{\pm M}(\theta_p)$ of sublevels ^{14}C(3⁻) nucleus, b – orientation tensors $t_{k\kappa}(\theta_p)$, c - polarization tensor $T_{k\kappa}$. Solid curve – the sum of the mechanisms examined.

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SiC NUCLEAR RADIATION DETECTORS BASED ON 4H-SiC EPITAXIAL LAYER

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Very perspective material for fabrication radiation-tolerant electronics, high-temperature electronics as well as for nuclear radiation detectors of ionizing radiation for working in harsh environments

is silicon carbide (SiC). Mainly, 4H-SiC polytype is mostly investigated for its physical properties, e.g.: the band gap energy is 3.26 eV, the mean energy of electron-hole pair creation is 7.78 eV, the electron saturation drift velocity is 2x10^7 cm/s and the breakdown voltage is 2x10^6 V/cm at room temperature. Detectors based on high quality epitaxial layer of 4H-SiC show a high radiation hardness [1] and good spectroscopic resolution at room and also at elevated temperatures (>300℃) [2].
Our detector structures [3] were prepared on a 25 μm or 50 μm thick nitrogen-doped 4H-SiC layer (donor doping ~ 1 x 10^{14} cm^{-3}) grown by the liquid phase epitaxy on a 4" SiC wafer (donor doping ~ 2 x 10^{18} cm^{-3}, thickness 350 μm). Circular Schottky contact (diameter 3.0 mm) to 4H-SiC layer (Ni/Au with thicknesses 10/30 nm) was formed through a contact metal mask, while full area contact (Ti/Pt/Au with thicknesses 10/30/90 nm) was evaporated on the other side (substrate).
Electrical characteristic of prepared SiC detectors were measured using Keithley measuring complex, which consisted of 4200A-SCS Parameter Analyzer, 2657A High Power System and CVIV Multi-Switch. Current-voltage (I-V) and capacity-voltage (C-V) measurements were performed up to 300 V. The reverse breakdown voltage exceeded 300 V and the reverse current was below 10 pA. The forward parts of the I-V curves were analysed on the basis of the thermionic emission theory. The barrier height, the ideality factor and the series resistance of 4H-SiC Schottky detector diodes were determined. From C-V measurements the depletion thickness and doping concentration profile were calculated. Spectroscopic parameters were measured with alpha sources ^{226}Ra and ^{238}Pu and FWHM of SiC detectors varied round of 20 keV for 5.5 MeV α-particles energy.
SiC detectors were used in experiments at the IC-100 cyclotron of the Joint Institute for Nuclear Research in Dubna. We studied the degradation of our detectors under impact of the high-energetic beam of heavy ions of Xenon, as well as the effect, which is known in the literature as Pulse Height Defect [4]. High radiation resistance and their good energy resolution allow to use these SiC detectors for long-term monitoring of heavy ion beams.

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STATUS OF SOME PARTS OF THE TPC FOR THE MPD AT THE NICA PROJECT

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The Time-Projection Chamber (TPC) is the main tracking detector and charged particles identification of the MPD central barrel. The TPC-MPD will provide:
- The overall acceptance of $|\eta| < 1.2$;
- The momentum resolution for charge particles under 3% in the transverse momentum range $0.1 < p_t < 1$GeV/c;
- Two-track resolution of about 1 cm;
- Hadron and lepton identification by dE/dx measurements with a resolution higher than 8%.
These requirements must be satisfied at the NICA design luminosity, charged particle multiplicity ~ 1000 in central collisions and the event rate about 7 kHz.
The TPC design and structure are similar to those of the TPCs used in the STAR, ALICE and NA49 experiments.
The TPC being a large but conceptually simple detector must be constructed with very high precision to reduce nonlinear systematic effects. High stability of the mechanical structure and uniformity of the drift field, the temperature, the drift gas purity and the gas gain have to be provided to get precise

track reconstruction and energy-loss measurements.
The structure of the TPC, the basic design parameters of the TPC and the basic TPC configuration are presented. Developed design tools for the TPC assembling, laser calibration system and parts of the TPC cooling system are provided.

PSEUDORAPIDITY FLUCTUATIONS IN RELATIVISTIC NUCLEAR INTERACTIONS

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Results on the Event-by-event pseudorapidity fluctuations of the relativistic charged particles produced in O-AgBr interactions at 60 and $200A$ GeV/c will be presented. To compare the experimental results, analysis of AMPT simulated data will also be presented. Results are suggestive of the presence of pseudorapidity fluctuation and strong correlation.

DOSE ADJUSTMENT FOR IRRADIATION OF FOODSTUFFS OF NON-RECTANGULAR GEOMETRY

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These days radiation technologies are widely used in food industry to prolong the shelf life of foodstuffs by inhibiting pathogens [1-2]. With the increase in types of food processed using irradiation, researchers have faced the problem of determining the required dose distribution in foodstuffs of complex geometry as well as heterogeneous chemical composition and structure [3-5].
The purpose of the study performed by Physics Department of MSU in collaboration with Scientific Research Institute of Nuclear Physics is to develop the dose distribution methodology for more uniform irradiation of cylindrical foodstuff.
The experiment involved simulation of water cylindrical object 7 cm in diameter irradiated from the opposite sides by 9.5 MeV electron beam using source code GEANT 4. It was found that the difference between the dose absorbed by the phantom at the perimeter and the dose in the center was up to 80 %.
It is highly important to achieve a more uniform distribution of radiation in prepackaged products, such as ham, sausage and salami, in order to avoid excessive irradiation which can cause detrimental change of organoleptic properties. Thus, it is necessary to modify the dose distribution to make it more uniform throughout the product.
Simulation showed that putting an aluminum plate of different thickness between the irradiated object and the output electron beam can ensure a more uniform irradiation, minimizing the discrepancy between absorbed doses up to 20 %.
This theoretical method requires further experiments to confirm the estimated irradiation parameters and become applicable for a wide variety of foodstuffs.

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DECONFINEMENT TEMPERATURE FROM HOLOGRAPHIC MESON SPECTRUM

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The interrelation between the deconfinement temperature of hadron medium and parameters of radial Regge trajectories within the bottom-up holographic models for QCD is scrutinized. We show that the lattice data on the deconfinement temperature can yield a powerful restriction on the spectrum of excited mesons and glueballs within the framework of holographic approach.

PREPARATION OF THE SOLDER ON THE BASIS OF ARCHAEOLOGICAL LEAD FOR LOW BACKGROUND EXPERIMENTS

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Modern experiments with aim of investigation or search of ultra-rare events, for example neutrino or dark matter interaction within a low background detector, place high demands for the radiation purity of the materials used, even for those used in small quantities. These include materials used for soldering elements in detector systems, i.e. a solder and flux. Radioactive purity of the materials is crucially important since their location in a close proximity to the detector's body inside of the shields. Radionuclide purity of commercial solders does not meet the requirements because they are made of natural lead which contains the radioisotope ^{210}Pb ($T_{1/2}$ = 22.3 y.) on a level of 1÷100 Bq/kg.
In this paper we report on the preparation of solder with the composition: 60% Sn and 40% Pb, made from marketable tin with a chemical purity of 99.9999% [1] and raw archaeological Roman lead [2]. The investigation of the chemical purity of archaeological lead was performed in [3]. Two ingot tin-lead solders with a mass of 100 grams each were produced. In addition, for comparison of measurements, a sample of the same weight was made from commercial lead with a chemical purity

of 99.9999% and high-purity tin. The solder fabrication work was carried out in a specially equipped clean room in JINR (Dubna), and measurements of the solder radioactivity levels were carried out in the Modane underground laboratory using a low-background HPGe detector Obelix.

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CHARACTERISTICS OF X-RAY BEAM USED IN COMPUTED TOMOGRAPHY

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Patient exposure from Computed Tomography (CT) was simulated using Monte Carlo method. The model of rotating source was implemented previously.
Conversion coefficients from measured dose indexes to doses in organs and tissues of patient were determined. Each coefficient is a quotient of calculated organ dose divided by a weighted calculated computed tomography dose index ($CTDI_w$). Simulation using Monte Carlo method requires the energy spectrum of incident radiation. The anode angle and total beam filtration determine the energy spectrum. When these quantities are unknown, measurements of attenuation in cylinder dosimetric phantom can be used to characterize the spectrum.
A comparison of radiation doses to patients during CT examinations was performed in [1] and showed that the $CTDI_w$ measured in CT scanners from various manufacturers have large discrepancies while input settings are the same. Organ doses differed by a factor of two and the similar image quality. Hence, the scanner-specific doses should be calculated. However, when a conversion coefficients are studied, their variation is much smaller (several percent). This suggests using of a limited set of conversion coefficients, calculated for a number of combinations of filters and anode angles. These values can be matched to calculated coefficients based on $CTDI_W$ measurements.
Energy spectrum can be characterized using the quotient of $CTDI_w$ measured in cylinder dosimetric phantom to $CTDI_{air}$ measured free-in-air. This relation lies in the range of 0.27 to 0.77 for different CT scanners [2]. Based on this relation appropriate set of conversion coefficients can be chosen to estimate organ doses. Current quality assurance protocols requires only phantom measurements of $CTDI_w$. This approach can provide doses to adults only [3].
Apart from the energy spectrum beam profile also impacts the dose. Simulation needs the shape of bow-tie filter that determines the beam profile. The beam profile can be measured using ionization chamber while the X-ray tube position is fixed. Several beam profiles were published [4] and can be used in simulation of specific scanners.

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LASER-PLASMA GENERATION OF ULTRA-SHORT INTENSE NEUTRON PULSE

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Acceleration of Deytron nuclear in thin (micron size) laser targets (polyethylene C_2D_4) to a MэB energy and the subsequent interaction with the secondary targets from D_2O, LiF, Be of 1 mm thickness was considered. It is shown, that at the energy of laser pulse of 250 J, duration 10 ps, diameter of the laser spot 5 microns and intensity 1.3x10^{20} W/cm^2 in a secondary target there is the generation of ultrashort (<30 ps) neutron pulse containing from 4x10^9 (for LiF secondary target) to 10^{10} neutrons (Be target) with characteristic energy about 10 MeV. Pulse intensity of a neutron flux from a surface of a secondary target reaches 10^{20} neutrons/cm^{2}s, that exceeds the intensity of neutron flux of the reactors making in a continuous regime ~10^{15} neutrons/cm^{2}s. Angular distribution of neutrons has a maximum in laser pulse direction and semi-width about ±60^o from this direction is calculated. At 10 Hz repetition rate of a laser pulse, the realization quasi-stationary neutrons source with average intensity about 10^{12} neutrons/cm^{2}s is possible. In laser-plasma neutron source a laser pulse with less (~ 100 fs) duration and upper (up 1 kHz) repetition frequency may be used. Peak intensity of a neutron flux thus will decrease on 2 order, however average intensity will remain constant. Despite of smaller average intensity and essentially smaller total number of neutrons, some potential application of laser-plasma super-short neutron pulses can be interesting for neutron spectroscopy of ultrafast (tens ps) physical, chemical and biological processes, which cannot be realized by means of traditional neutron sources.

ESTIMATION OF MASSES OF RADIOACTIVE ELEMENTS IN GEOLOGICAL SAMPLES USING R PROGRAMMING LANGUAGE AND ROOT LIBRARIES

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In nuclear and high energy physics many processes have statistical nature. In current paper statistical data analysis is considered in a nuclear spectrometry problem of radioactive element masses estimation.
The problem was solved independently by means of R programming language and using ROOT package libraries. Based on the lines of calibration Eu-152 and Am-241 sample, several variants of spectrometers absolute efficiency curve were built. Masses of elements Ac-228, Tl-208, Bi-21 and K-40, contained in geological samples, were estimated by means of this curve and spectral lines approximation.
Estimations of statistical errors were also retrieved.
An assumption was made that the method of approximation may influence the final result and increase errors. This statement is especially true for low signal-noise ratio.
To prove this assumption, the problem was solved twice: using TH1F::Fit() method for Gauss function from ROOT, and using nls() function for identical model in R.
The result differences, caused by different methods, prove to be of the same order as statistical errors. However, for certain spectral lines differences can be huge due to incorrect execution of one of the methods for low signal-noise ratio data. Overall the ROOT algorithm can solve harder cases.

These findings concerning influence of approximation method in case of low signal-noise ratio may prove useful in other problems of nuclear or high energy physics.
Also execution time of identical programs of R and ROOT was compared. The ROOT program runs at least 25% faster. However, the computations took seconds, and part of the time was spent on running the program and displaying graphs. Therefore, this difference is not significant.

THE YIELDS OF THE NUCLEI FORMED IN THE ^{237}Np AND ^{241}Am SAMPLES IRRADIATED BY THE NEUTRON FIELD

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The studies were carried out on proton beam with energy of 660 MeV, which generates a neutron field from "QUINTA"-setup [1,2].
The (n, γ) and fission reactions in the targets of ^{237}Np and ^{241}Am irradiated by neutron field were studied.
The obtained results were compared with the EXFOR experimental base and interpreted using the GEANT4 and FLUKA programs [3].

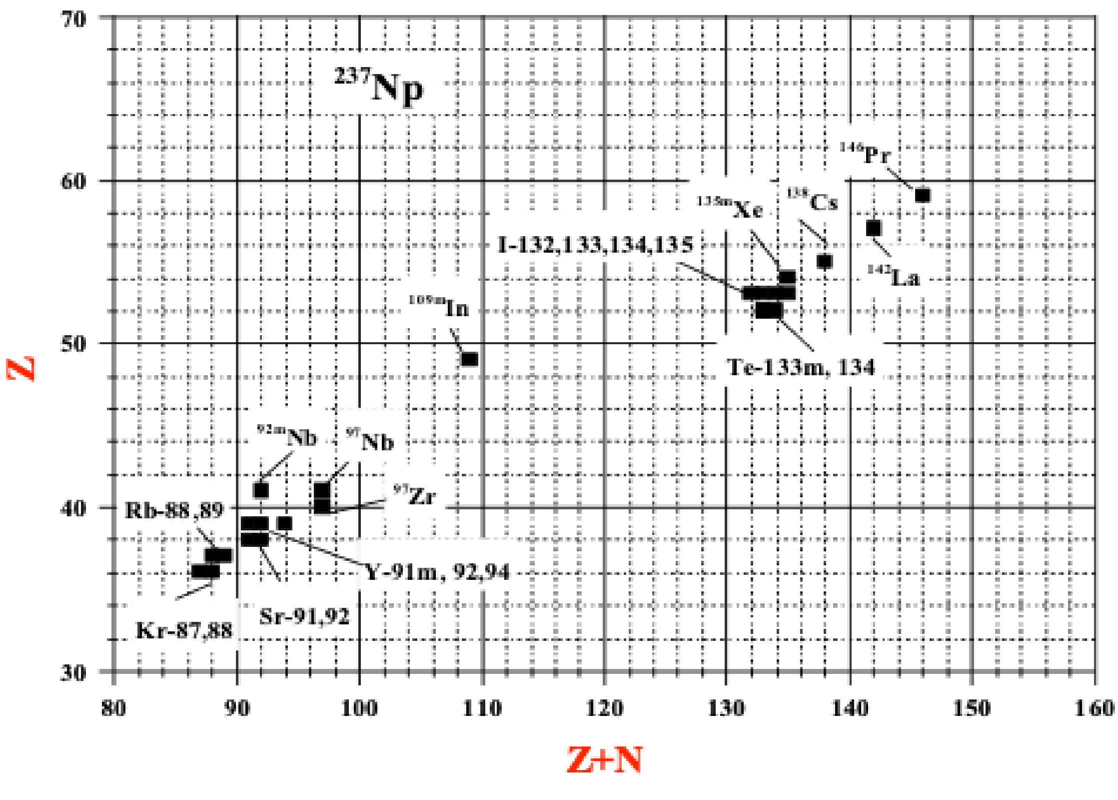

Figure 1: Fission products from ^{237}Np irradiated by neutron field of "QUINTA"-setup from proton beam with E= 660 MeV.

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MODEL OF NUCLEUS-NUCLEUS INTERACTION ON THE BASIS OF PRODUCTION OF QUARK-GLUON MATTER BLOBS WITH A LARGE ORBITAL MOMENTUM

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In many cases, interactions of nuclei are considered as collisions of A1 and A2 nucleons if it is possible to neglect the binding energy of the nucleus. However for very high kinetic energy of colliding nuclei there is a possibility of collective interaction of nucleons with production of quark-gluon matter blobs. As it was shown earlier, in this case a large orbital momentum appears. In that paper, calculations were made for equal nuclei. Here we generalize this approach and calculate orbital momentum for various ratios of radii of interacting nuclei.

ON THE COVARIANT DESCRIPTION OF THE ELASTIC SCATTERING OF LONGITUDINALLY POLARIZED LEPTONS BY HALF-INTEGER SPIN NUCLEI

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In [1], in the framework of a general approach to the covariant description of the structure of half-integer spin nuclei, analytical expressions were found for the multipole expansion of the structure functions, entering into the differential cross section for elastic scattering of longitudinally polarized leptons

$$\frac{d\sigma}{d\Omega} = \sigma_{Mott}\left\{W_1 + 2tg^2\frac{\theta}{2}W_2 - \zeta\tau\left[\frac{M}{E} + \left(1+\frac{M}{E}\right)tg^2\frac{\theta}{2}\right]W_4\right\}.$$

In the effective current approximation, valid for high energies $E >> m_l$ of the scattered lepton, structure functions W_k depend upon $\tau = -q^2/4M^2$, lepton helicity ζ, and electromagnetic and weak nucleus form factors, and lepton electroweak constants.

In this work using Rarita-Schwinger formalism to describe [2] nuclei with half-integer spin $J \leq 7/2$, we construct explicit expressions for covariant electromagnetic and weak vertex functions $\Gamma^{\mu(\alpha)_j(\beta)_j}_{em,\, weak}$ $(j = J - 1/2)$,
as well as for the density matrix $\Lambda_{(\alpha)_j(\beta)_j}$ of an unpolarized nucleus state. Then, using multipole expansion technique in the Breit zero energy transfer system, we consider traditional multipole form factors – vector $F_{Cl}(\tau)$ $(l = 0, 2, \ldots 2J-1)$ and $F_{Ml}(\tau)$ $(l = 1, 3, \ldots 2J)$, as well as axial $F_{5El}(\tau)$ and $F_{5Ll}(\tau)$ $(l = 1, 3, \ldots 2J)$ - and get expressions for them through the covariant form factors of the vertex functions $F_E^{(n)}(\tau),\ F_M^{(n)}(\tau),\ G_1^{(n)}(\tau)$ and $g_E^{(n)}(\tau),\ g_M^{(n)}(\tau),\ g_A^{(n)}(\tau)$.

Then we obtain and discuss expressions for the right-left asymmetry A_{RL}, as well as the spin correlations of transversely polarized incident and scattered leptons. We show, that elastic scattering is helicity conserving due to smallness of the lepton mass, and right-left asymmetry contains contribution from anapole moment of the target, whereas transverse correlations arise only with simultaneous polarization of incident and scattered leptons.

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INVESTIGATION CLUSTERIZATION EFFECTS OF ^{9}Be FROM ^{2}H AND ^{3,4}He SCATTERING

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Angular distributions of protons, deuterons, tritons and alpha particles emitted in the reaction d+^{9}Be at E_{lab}=19.5 and 35 MeV were measured with an aim to shed light on the internal cluster structure of ^{9}Be and to study possible cluster transfer of ^{5}He. The experimental angular distributions for ^{9}Be(d, d)^{9}Be, ^{9}Be(d, ^{4}He)^{8}Be, ^{9}Be(d, ^{7}Be)^{5}He, ^{9}Be(3 d, ^{6}Li)^{6}Li and ^{9}Be(d, ^{7}Li)^{5}Li reaction channels were measured on the extracted beams of the cyclotronsK-120 of the University of Jyvaskula (Jyvaskula, Finland) and U-120 of the Institute of Nuclear Physics (Rez, Czech Republic)[1, 2].
Experimental angular distributions for the corresponding ground states (g.s.) were analyzed. The calculated double-folding potential within the framework of the optical model, the coupled-channel approach and the distorted-wave Born approximation has been applied successfully in describing the cross sections of elastic and inelastic scatterings, one-nucleon transfer and cluster-transfer reactions. The strong coupling effects have been shown for the (d,p) and (d,t) one nucleon transfer nuclear reactions. Furthermore, it was found that in the ^{9}Be (d ,α)^{7}Li nuclear reaction the ^{5}He heavy cluster is transferred mainly simultaneously, and the contribution of its sequential transfer is an order of magnitude lower. The importance of taking into account the mechanism of sequential transfer of the n-p system has been revealed. Based on these observations from studying the interaction of the deuteron with ^{9}Be, it can be concluded that the ^{9}Be nucleus has cluster structure.
The analyze confirms a significant contribution of simultaneous five-nucleon transfer in the reaction channel ^{9}Be(d,^{4}He)^{7}Li with an agreement with the conclusion [3].

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STATUS ON THE PROTON-CAPTURE CAMPAIGN AT GSI

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Highly-charged stable or radioactive ions can be stored and cooled in a heavy-ion storage ring offering unrivaled capabilities for precision studies for the atomic, nuclear structure, and astrophysics [1]. We have employed the unique feature of the Experimental Storage Ring (ESR) facility at GSI to address astrophysically relevant reactions. In 2009, as a proof-of-concept experiment, the cross section of ^{96}Ru(p,γ) has been successfully investigated [2]. Later, in 2016 the study of the ^{124}Xe(p,γ) reaction has been performed with decelerated fully-ionized $^{124}Xe^{54+}$ ions [3]. Using a Double Sided Silicon Strip Detector (DSSSD), introduced directly into the Ultra High Vacuum environment of the storage ring, the ^{125}Cs proton-capture reaction products have been successfully detected on the high energy tail of the Gamow-window for hot, explosive scenarios. Early this year, in March 2020, as the next step in our experiment campaign the first attempt was carried out to measure the proton-capture using a radioactive ion beam.

In this contribution, our precision (p,γ) reaction studies will be introduced highlighting the developments on the used measurement techniques. In addition, a novel approach will be expounded to increase the sensitivity of the identification for (p,γ) products by combining active ion scraping with offline energy selection on the detected ions.

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EXCITATION OF ISOMERIC STATES IN REACTIONS (γ,n) AND (n,2n) ON ^{81}Br AND ^{86}Sr

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Nuclear reactions with various bombarding particles serve as an important source of information both on the mechanisms of nuclear reactions and on the properties of the excited states of atomic nuclei.

This work presents work results of investigation of the isomeric yield ratios $Y_{\mathrm{m}}/Y_{\mathrm{g}}$ of the $^{86}\mathrm{S}(\gamma,\mathrm{n})^{85\mathrm{m,g}}\mathrm{Sr}$, $^{86}\mathrm{Sr}(\mathrm{n},2\mathrm{n})^{85\mathrm{m,g}}\mathrm{Sr}$, $^{81}\mathrm{Br}(\gamma,\mathrm{n})^{80\mathrm{m,g}}\mathrm{Br}$ and $^{81}\mathrm{Br}(\mathrm{n},2\mathrm{n})^{80\mathrm{m,g}}\mathrm{Br}$ reactions. The isomeric yield ratios were measured by the induced radioactivity method. Samples of natural Sr and

Br have been irradiated in the bremsstrahlung beam of the betatron SB-50 in the energy range of $10 \div 35\text{MeV}$ with energy step of 1 MeV. For 14 MeV neutron irradiation, we used the NG-150 neutron generator.
The gamma spectra reactions products were measured with a spectroscopic system consisting of HPGe detector CANBERRA with energy resolution of 1.8 keV at 1332 keV gamma ray of ^{60}Co, amplifier 2022 and multichannel analyzer 8192 connected to computer for data processing. The filling of the isomeric and ground levels was identified according to their γ lines. Values Y_m/Y_g at $E_{\gamma,\text{max}} = 30\text{MeV}$ for the reaction (γ, n) on nuclei ^{81}Br and ^{86}Sr are respectively: 0.46 ± 0.02 and $0,56 \pm 0.04$. In the range $26 \div 35$ MeV the isomeric yield ratios Y_m/Y_g of the reaction (γ, n) on ^{81}Br and ^{86}Sr, are obtained at first. Using the isomer yield ratio and the total cross section of the (γ, n) reaction on ^{81}Br and ^{86}Sr [1] received the cross sections of $(\gamma, n)^m$ and $(\gamma, n)^g$ reactions. The cross section isomeric ratios at $E_\gamma = E_\text{m}$ are estimated.
The experimental results have been discussed, compared with those of other authors as well as considered by the statistical model [2]. Theoretical values of the isomeric yield ratios have been calculated by using code TALYS-1.6.

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INVESTIGATION OF ENERGY DEPENDENCE OF LIGHT CHARGED PARTICLES EMISSION FROM (p,x) REACTION WITH ^{120}Sn NUCLEUS

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The double-differential and integral cross sections of the reactions initiated by nucleons play a key role in development of the theory of nuclear reactions, verification of computer codes based on them. From another hand such data are necessary for the design of safety systems for power reactors, development of advanced nuclear technologies, in particular, hybrid nuclear energy systems (ADS-Accelerator Driven System) [1,2]. The experiment with protons accelerated to energy of 30 MeV was performed on an isochronous cyclotron U-150M of the Institute of Nuclear Physics. The double-differential cross sections of the reactions with light particles in exit channels were measured in the angular range 30-135o with angle increments of 15°. Theoretical analysis of the obtained experimental results was performed within the framework of the TALYS and PRECO calculation code, which is widely used in interpreting many experimental results. To describe the complete inclusive spectra of scattered particles, all possible mechanisms of nuclear reactions were taken into account. A satisfactory agreement between experimental and calculated values has been achieved. A distinction between direct nuclear reactions, pre-equilibrium decay and equilibrium emission at different incident protons energy for ^{120}Sn(p,x) reaction was established.

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DEVELOPMENT OF HARDWARE-SOFTWARE COMPLEX FOR CARRYING OUT OF NUCLEAR REACTION EXPERIMENTS ON THE VNIIEF ELECTROSTATIC TANDEM ACCELERATOR

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Hardware-software complex was used at electrostatic tandem accelerator EGP-10 (RFNC-VNIIEF) [1] for measuring the energy and angular distributions of charged particles produced in nuclear reactions [2]. Renewal of ΔE–E telescopes and modernization of signal registration spectrometer channels were performed.
The new ΔE–E telescope developed at Ioffe Institute RAS, St.-Petersburg includes charge-sensitive amplifiers which are situated in the telescope body near to the silicon detectors. This telescope scheme results to noise decreasing and increasing of spectrometer channel energetic resolution.
Modernization of spectrometer measuring line consisted in renewal of amplifiers and measuring devices. The used amplifiers were replaced by special 8-channel "8-Chann SA-MUX" type amplifiers produced in "Tekhinvest" Ltd., Dubna. The used analog-to-digital converter was replaced by "PA27n" type 2-channel analog-to-digital converter produced in "Tekhinvest" Ltd., Dubna. Spectrometric measuring channels based on these devices are more high-speed. It helps to increase the speed of spectrometric information collection.

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STUDY OF THE MULTIWIRE PROPORTIONAL CHAMBER CATHODE SAMPLES OF THE LHC EXPERIMENTAL FACILITIES

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The motivation of the present studies is creation of the spontaneous self-supporting currents commonly denoted as Malter effect (ME) in multiwire proportional chambers used at Large Hadron Collider (LHC) beam experiments in European Organization for Nuclear Research (CERN).
Search for reasons of the origin and analysis of the nature of this effect are necessary for development of procedures meant to decrease ME-current which is 100 times higher than ionization current at detector during collider processing. The importance of these studies is growing while collecting the charge running through the proportional chambers during processing at LHC. Another reason is planning increase of LHC luminosity by about 10 times, from $L = 7 \cdot 10^{33} sec^{-1} \cdot cm^{-2}$ (2012) to $L = 5 \cdot 10^{34} sec^{-1} \cdot cm^{-2}$.
For the study of detector degradation processes under its irradiation life tests of two proportional chamber prototype detectors of the muon CSC (Cathode Strip Chamber) system were carried out. After ^{90}Sr β-source irradiation the first prototype collected 1.39 Coulomb/cm charge, the second one collected 0.39 Coulomb/cm charge. The next studies of prototype detector cathode samples

have shown that the reason of creation of ME spontaneous currents is plasmochemical influence of gaseous charge products at cathode copper surface and radiation damage [1].
In the present work the results of complex structure-element analysis of cathode samples derived from multiwire proportional chamber are shown. This chamber had been working in LHC physical experiment for about 10 years and was influenced by repeated origins of spontaneous ME-current. Comparative analysis of obtained results and data from life tests of radiation resistance of prototype detectors is made, possible reasons for ME creation are discussed.

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SIMULATION OF 14 MeV NEUTRON SCATTERING ON TITANIUM, CHROMIUM AND IRON NUCLEI

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In connection with the modern development of technologies in nuclear energy, the important task is to substantially refine the experimental data on fast neutron scattering. The high cost of nuclear facilities leads to the need for an accurate model description of the processes of neutrons interaction with atomic nuclei. As important components of structural materials, titanium, chromium and iron isotopes have priority in the list of studied nuclei [1,2,3].
The TANGRA collaboration is studying inelastic scattering reactions of 14 MeV neutrons [4]. Our previous work was devoted to studying the reaction ^{52}Cr(n, n') [5]. New data are obtained on the cross sections of γ-quanta emission in reactions $(n, X\gamma)$, where $X = n, 2n, \alpha$, on ^{48}Ti and ^{56}Fe. We present the results of modeling neutron scattering using the program code TALYS 1.9 and compare new experimental data and simulations with the results of other experiments.

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PARAMETRIZATION OF ELEMENTARY πN- AND $K + N$-AMPLITUDES AT INTERMEDIATE ENERGIES

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When studying elastic and inelastic scattering of mesons on light nuclei at intermediate energies based on the Glauber diffraction theory, it becomes necessary to know the scattering amplitudes of these mesons on individual nucleons of the nucleus. The elementary amplitudes of the πN and $K + N$ interactions are input parameters of the Glauber theory. They are usually determined from independent experiments and parameterized in the form of gaussoids.
The differential reaction cross section calculated on the basis of Glauber's theory strongly depends on the value of these parameters. Therefore, the correct determination of their value, depending on the energy of the mesons, is an important task. In the scientific literature there is a wide range of their meaning. However, they are not systematized and in some cases contradict each other. In addition, the main experimental data relate to scattering of pions from nucleons, while there is not much data for scattering of kaons.
In this work, the values of these parameters were found for meson energies from several hundred MeV to 2 GeV, from the best agreement with experiment at a scattering angle of 0 to 50 degrees. The corresponding experimental data were taken from the electronic database SAID [1]. The found parameters are given in the form of tables.
The scientific literature knows the problem associated with the description of the scattering of kaons from nuclei, where there is an indication that the interaction of a kaon with a nucleon in a nucleus differs significantly from its interaction with a free nucleon. For a correct assessment of this difference, it is also important to have an accurate knowledge of the parameters of the amplitude of the free kaon – nucleon interaction in the corresponding kinematic region.

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DETERMINATION OF THE OPTIMAL INTERACTION PARAMETERS OF ^{14}N IONS WITH ^{10}B NUCLEI AT ENERGIES 21 - 93.6 MeV

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The experiments at the DC-60 heavy ion accelerator in nuclear physics are focused, on obtaining the missing information on the internuclear interaction potentials, with the contribution of the elastic transfer process in the region of the rear angles. In this work, we measured the angular distributions

of elastic scattering of ^{10}B(^{14}N,^{14}N)^{10}B at energies E_{lab} = 21 and 24.5 MeV in the range of angles 30^0-165^0 in the center of mass system. In the experiment, self-sustaining ^{10}B films with a thickness of 30-40 μg/cm^2 were used as target [1]. The measurements were carried out using the ΔE-E method of registration and identification of nuclear reaction products.
The analysis of angular distributions together with literature data [2, 3] was carried out in the framework of the optical model and folding model using the FRESCO program. The optimal values of potential parameters are found. It should also be noted that we introduced two additional potentials in a phenomenological way, exploring the sensitivity of scattering to the optical potential.

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STUDY OF THE ELASTIC SCATTERING PROCESS OF ^{14}N IONS WITH ^{16}O NUCLEI IN A WIDE INTERVAL ENERGY

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The mechanisms for the formation of cross sections for elastic scattering of heavy ions on light nuclei remain controversial and require more detailed studies. In the differential cross sections of earlier papers [1], weak oscillations are observed in the region of small and medium angles, while in the backscattering angles they manifest themselves quite sharply, and with increasing energy of the incident ion, the oscillations increase. A noticeable increase in cross sections in the region of large angles is also observed. Such a behavior of the angular distributions of elastic scattering of heavy ions is difficult to theoretical description within the framework of the standard optical model. It follows from this that, in addition to the purely potential interaction, other mechanisms that must be taken into account in theoretical analysis contribute to the formation of elastic scattering cross sections in these processes. In particular, it is necessary to take into account the cluster structure of the studied nuclei and the mechanisms of cluster transfer.
At the DC-60 accelerator of the Institute of Nuclear Physics (Nur-Sultan, Kazakhstan), differential cross sections of elastic scattering of ^{14}N ions on ^{16}O nuclei were measured at energies of 1.5 and 1.75 MeV/nucleon in the range of angles 30^0–165^0 in the center of mass system [1].
The analysis of angular distributions at energies of 21–76.2 MeV was carried out in the framework of the optical model and the distorted wave Born approximation (DWBA) methods using the FRESCO program. It should also be noted that we introduced two additional potentials in a phenomenological way, exploring the sensitivity of scattering to the optical potential. In the framework of the DWBA, elastic scattering was analyzed taking into account the contribution of the cluster transfer mechanism, which showed that for ^{16}O(^{14}N,^{16}O)^{14}N processes in the region of large angles, the influence of this mechanism on the formation of scattering cross sections is significant.

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UNIQUE CORRELATION OF QUADRUPOLE DEFORMATION OF NUCLEI WITH THEIR HALF-LIVES

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The problem of halo nuclei [1] in a detailed analysis of sizes and deformations in isotopic series reveals not abrupt behavior in the topology of nuclei, but a sequential continuous change in the structural nuclear parameters as they move away from the axis of the "Line of stability". This suggests the inevitable correlation of structural isotopic parameters with electromagnetic and purely nuclear [2].
In the this work, this phenomenon is traced by the example of isotopic series of Barium and Xenon, in which, as in the previous study [2], it was possible to find a correlation between the parameter $\beta 2$ and half-life T1/2 for oblate nuclei with signβ2<0 and anti-correlation for elongated nuclei signβ2>0. Using the found analytical expressions for the function β2(T1/2) in these isotopic series, it is possible to semi-empirically approach the boundary of the bound states of nucleon systems both from the side of neutron-deficient nuclei and from the side of neutron-rich ones, which is an independent fundamental problem. These relations make it possible to calculate quadrupole deformation parameters β2 from the usually measured half-lives T1/2 with high accuracy (from 5 to 10%), and through them the average radii of exotic nuclei $< R >$. Of particular interest is the possibility of extending this pattern to the region of superheavy nuclei. This method is a new way of assessing the Z-region, in which, probably, the maximum of the "Island of stability" is located.
In addition, when considering isotopic changes in the radii of nuclei in the present work, it can be seen that if the law of growth of radii, based on the growth of their masses $< R >= r_0 A^{1/3}$ (or for isotopic series $< R >= r_0 N^{1/3}$) is well observed in the direction of neutron excess, then this law is broken in the direction of neutron deficiency due to Coulomb repulsion of protons. And, as the mass number A decreases, it does not lead to a decrease in their radii, but, on the contrary, to their growth. This effect apparently allows for the first time to ascertain the experimental detection of void nuclei.

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FORMATION OF INCLUSIVE REACTION SPECTRA (p, xd) ON MIDDLE CORES

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The development of the concept of the mechanism of pre-equilibrium decay in nuclear reactions, reflecting the dynamics of the formation and evolution of an excited system to an equilibrium

state, remains an urgent task of the theory of nuclear reactions [1] To a large extent, its solution is connected with the need to obtain precision experimental data that are currently missing for double differential cross sections in reactions with charged particles.
The experimental measurements of the double-differential reaction cross sections (p, xd) were carried out on a beam of accelerated protons with an energy of 30 MeV of the isochronous cyclotron U-150 M INP using self-sustaining targets. The measurements were performed in the angular range of 30-135° in the laboratory coordinate system with a step of 15°.
The systematic errors in the cross sections were mainly caused by errors in the determination of the target thickness (<5%), calibration of the current integrator (1%), and solid angle of the spectrometer (1.3%). The energy of a beam of accelerated particles was measured with an accuracy of 1.2%. The total systematic error did not exceed 10%. The statistical error varied for deuterons from 5% in the low-energy to 20% in the high-energy energy regions. After integration over the angle of the double-differential cross sections, integral cross sections of these reactions were obtained.
The analysis of the experimental results was carried out in the framework of the Griffin exciton model [2] of pre-equilibrium nuclear decay according to the PRECO-2006 program [3], which describes the emission of particles with mass numbers from 1 to 4. Satisfactory agreement was obtained between the experimental and calculated values in the energy region corresponding to the pre-equilibrium mechanism.

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STUDY OF GROUND STATES OF ^{10,11}B, ^{10,11}C NUCLEI BY FEYNMAN'S CONTINUAL INTEGRALS METHOD

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The wave functions of the ground states of few-body nuclei ^{10,11}B, ^{10,11}C were calculated by Feynman's continual integrals method in Euclidean time [1–3]. The algorithm of parallel calculations was implemented in C++ programming language using NVIDIA CUDA technology [4]. Calculations were performed on the NVIDIA Tesla K40 accelerator installed within the heterogeneous cluster of the Laboratory of Information Technologies, Joint Institute for Nuclear Research, Dubna.
The studied isotopes are considered as cluster nuclei with the following configurations: ^{10}B (2α + n + p), ^{11}B (2α + n + n + p), ^{10}C (2α + p + p) and ^{11}C (2α + n + p + p). Results of the cluster model were compared with results of the shell model of deformed nuclei [5, 6].

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INVESTIGATION OF INCLUSIVE SPECTRA OF LIGHT CHARGED PARTICLES EMITTED FROM (p,x) REACTION WITH ^{27}Al NUCLEUS

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The role of new nuclear-physics experiments in the creation of nuclear databases and development of theoretical models in accordance with modern approaches is key in both fundamental and applied researches related in particular to the development of electro-nuclear plants (Accelerator Driven System, ADS) for the nuclear transmutation of long-lived radioactive nuclear waste and energy production [1,2].
The experiments with protons accelerated to energy of 7 and 30 MeV were performed on an isochronous cyclotron U-150M of the Institute of Nuclear Physics. A self-supporting ^{27}Al foil have been chosen as the objects of our investigation since it is the construction elements of a hybrid nuclear energy plant and experimental data on which are necessary for the development of ADS systems The double-differential cross sections of the reactions with light particles in exit channels were measured in the angular range 30-135° with angle increments of 15°.
Theoretical analysis of the obtained experimental results was performed within the framework of the TALYS calculation code. To describe the complete inclusive spectra of scattered particles, all possible mechanisms of nuclear reactions were taken into account. A satisfactory agreement between experimental and calculated values has been achieved. A distinction between direct nuclear reactions, pre-equilibrium decay and equilibrium emission at different incident protons energy for ^{27}Al(p,x) reactions were established.
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AVERAGE CROSS-SECTIONS AND ISOMERIC RATIOS OF THE ^{93}Nb(γ,4n)^{89m,g}Nb AND ^{93}Nb(γ,5n)^{88m,g}Nb REACTIONS UP TO $E_{\gamma max}$ = 91 MeV

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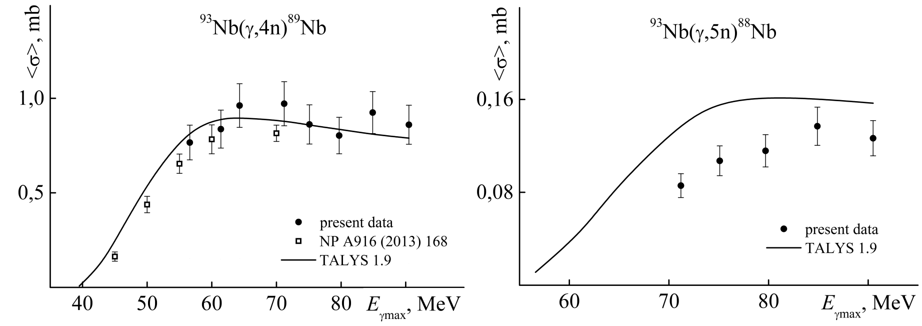
The flux-weighted average cross-sections <σ(E)> and the isomeric yield ratios IR for the ^{93}Nb(γ,4n)^{89m,g}Nb and ^{93}Nb(γ,5n)^{88m,g}Nb reactions were studied. The ^{93}Nb targets were irradiated with the bremsstrahlung beam for the end-point bremsstrahlung energies $E_{\gamma max}$ = 36-91 MeV using the electron linac LUE-40 RDC "Accelerator" NSC KIPT. The induced γ-activities of the samples were measured using a semiconductor HPGe detector with the 20% absolute efficiency and the

1.8 keV energy resolution at the 1332 keV ^{60}Co γ-line.
The obtained experimental values of <σ(E)> were compared with the data from [1] and the theoretical values calculated using computer code TALYS1.9 (presented in figures). For the case of the ^{93}Nb(γ,4n)^{89t}Nb reaction the theoretical results from TALYS 1.9 and found <σ(E)> are in good agreement. The comparison of the ob-tained <σ(E)> values for m- , g-states of the ^{93}Nb(γ,5n)^{88m,g}Nb reaction and isomeric yield ratios IR with the calculations performed in TALYS 1.9 shows satisfactory agreement.



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THE ^{100}Mo(γ,n)^{99}Mo REACTION CROSS-SECTIONS AT $E_{\gamma max}$ = 30-100 MeV

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The flux-weighted average cross-sections <σ(E)> of the photonuclear reaction ^{100}Mo(γ,n)^{99}Mo were determined for the end-point bremsstrahlung energies $E_{\gamma max}$ = 30-100 MeV using the γ-activation method. Targets from natural molybdenum were irradiated by the bremsstrahlung beam with a step ΔE_e = 4 MeV using the linear electron accelerator LUE-40 RDC "Accelerator" NSC KIPT. To determine the values of <σ(E)>, we used γ-lines with energies E_γ = 739.5 and 140.5 keV. The cross-section values obtained for these γ-lines coincide within the experimental errors. The found values <σ(E)> gradually decrease from 36 mb to 28 mb with increasing energy from 36 to 91 MeV.
The theoretical values <σ(E)> were obtained as a convolution of the cross-section σ(E) reaction, calculated using computer code TALYS1.9, and the bremsstrahlung spectra of electrons from GEANT4, calculated using of real energy profiles of electron beam. The comparison of theoretical average cross sections with experimental ones showed a difference of 8-18%, which is mainly determined by the deviation of the real flux of bremsstrahlung quanta from the calculated one. The obtained cross-sections <σ(E)> for the ^{100}Mo(γ,n)^{99}Mo reaction at $E_{\gamma max}$ = 30-100 MeV were used as the monitor for measuring of the cross sections for the photo-nuclear reactions on other nuclei.

THE GAUGE-INVARIANT DESCRIPTION OF THE ALPHA-ALPHA BREMSSTRAHLUNG WITH INITIAL AND FINAL STATE INTERACTIONS INCLUDED

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One of motivations in studying the $\alpha+\alpha\to\alpha+\alpha+\gamma$ bremsstrahlung is to get a supplementary information on a strong part of the alpha-alpha interaction. Our departure point in describing this reaction is to use the Fock-Weyl criterion and a generalization of the Siegert theorem [1,2]. Along the guideline we obtain the gauge-independent bremsstrahlung amplitude in a nonrelativistic cluster picture. This amplitude can be expressed through the alpha particle form factor $F_{CH}(q)$ and the three dimensional overlap integral $I(\mathbf{k}',\mathbf{k};\mathbf{q})=\langle\chi^{(-)}_{\mathbf{k}'}|e^{-i\frac{1}{2}\mathbf{qr}}|\chi^{(+)}_{\mathbf{k}}\rangle$, where the "distorted" wave $\chi^{(-)}_{\mathbf{k}'}$ ($\chi^{(+)}_{\mathbf{k}}$) describes the α-α scattering in the final (entrance) channel. The corresponding interaction operator $V=V_S+V_C$ consists of the strong nuclear interaction between alpha particles V_S, while V_C describes the Coulomb repulsion between them. Such a consideration leads to the division $I=I_C+I_{CS}$ with the Coulomb integral I_C responsible for the Coulomb bremsstrahlung and the mixed Coulomb-strong one $I_{CS}=I-I_C$ (cf. [3]). In its turn, the Coulomb integral is given by the analytical expression [4], while the integral I_{CS} can be reduced to the summation of its partial wave expansion with the simple radial integrals. A distinctive feature of our approach is to provide the convergence of the expansion. The numerical calculations of the radial integrals are performed with help of the contour integration method [5]. In order to demonstrate to which extent the obtained results depend on the choice of the model interaction V_S we show in Fig.1 the cross section $d\sigma=d^5\sigma/dE_\gamma d\Omega_{1i}d\Omega_{1f}$ for the coplanar kinematics in which one of the outgoing alphas is detected in coincidence with the emitted photon. In such a kinematics all momenta have a coplanar disposal, where the photon momentum is directed along the Z-axis and the rest lie in the XZ-plane, viz.,$\hat{\mathbf{k}}_{1i}=(\theta_{1i},0),\hat{\mathbf{k}}_{1f}=(\theta_{1f},\pi)$. We see, first, that the strong interaction effects can be dominant to compared the pure Coulomb interaction and, second, measurements of such a correlation function can bring a supplementary information on the strong part of the interaction between alpha particles.

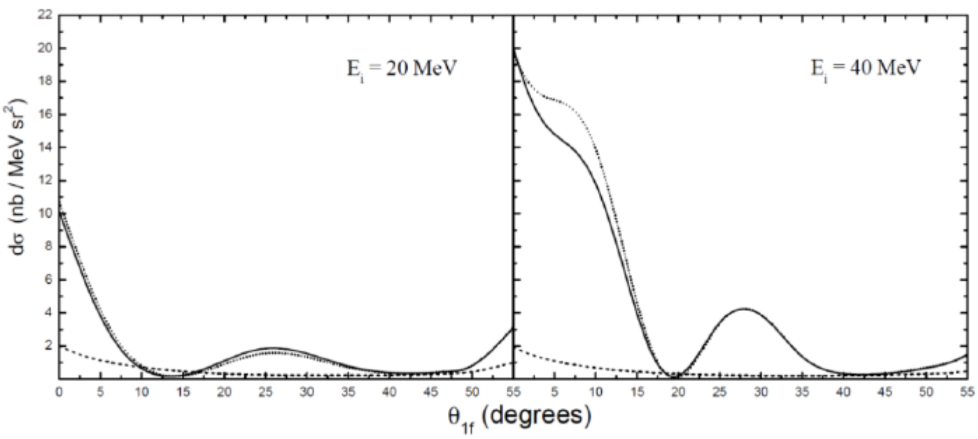

Figure 1: The α-α bremsstrahlung cross section versus the angle $\hat{\mathbf{k}}_{1f}$ and $\hat{\mathbf{k}}_\gamma$ at the different values of the incident energies E_i calculated for potential form [6] (solid curves), potential form [7](dotted) and Coulomb one (dashed).

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METHOD OF THE UNITARY CLOTHING TRANSFORMATIONS IN QUANTUM FIELD THEORY: CALCULATION OF THE DEUTERON MAGNETIC AND QUADRUPOLE MOMENTS

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We continue our explorations [1] of the electromagnetic properties of the deuteron with help of the method of unitary clothed transformations (UCTs) [2,3]. It is the case, where one has to deal with the matrix elements $\langle \mathbf{P}', M'|J^\mu(0)|\mathbf{P}=\mathbf{0}, M\rangle$. Here the operator $J^\mu(0)$ is the Nöther current density $J^\mu(x)$ at the point $x=0$, sandwiched between the eigenstates of a "strong" field Hamiltonian H, viz., the deuteron states $|\mathbf{P}=\mathbf{0}, M\rangle$. These states meet the eigenstate equation $P^\mu|\mathbf{P}, M\rangle = P_d^\mu|\mathbf{P}, M\rangle$ with $P_d^\mu = (E_d, \mathbf{P}), E_d = \sqrt{\mathbf{P}^2 + m_d^2}, m_d = m_p + m_n - \varepsilon_d$, the deuteron binding energy $\varepsilon_d > 0$ and eigenvalues $M = (\pm 1, 0)$ of the third component of the total (field) angular-momentum operator in the deuteron center-of-mass (details in [3]). In the subspace of the two-clothed-nucleon states with the Hamiltonian $H = P^0 = K_F + K_I$ and the boost operator $\mathbf{B} = \mathbf{B}_F + \mathbf{B}_I$, where free parts K_F and $\mathbf{B}_F$ are $\sim b_c^\dagger b_c$ and interactions K_I and $\mathbf{B}_I$ are $\sim b_c^\dagger b_c^\dagger b_c b_c$, the deuteron eigenstate gets the form $|\mathbf{P}, M\rangle = \int d\mathbf{p}_1 \int d\mathbf{p}_2 C_M([\mathbf{P}]; \mathbf{p}_1\mu_1; \mathbf{p}_2\mu_2) b_c^\dagger(\mathbf{p}_1\mu_1) b_c^\dagger(\mathbf{p}_2\mu_2)|\Omega\rangle$ and we will show how one can find the C-coefficients within the clothed particle representation (CPR). Further, we use the expansion in the R-commutators

$J^\mu(0) = W J_c^\mu(0) W^\dagger = J_c^\mu(0) + [R, J_c^\mu(0)] + \frac{1}{2}[R, [R, J_c^\mu(0)]] + ..., (*)$

where $J_c^\mu(0)$ is the primary current in which the bare operators $\{\alpha\}$ are replaced by the clothed ones $\{\alpha_c\}$ and $W = \exp R$ the corresponding UCT. In its turn, the operator being between the two-clothed-nucleon states contributes as $J^\mu(0) = J^\mu_{one-body} + J^\mu_{two-body}$, where the operator

$J^\mu_{one-body} = \int d\mathbf{p}' d\mathbf{p} F^\mu_{p,n}(\mathbf{p}', \mathbf{p}) b_c^\dagger(\mathbf{p}') b_c(\mathbf{p})$

with $F^\mu_{p,n}(\mathbf{p}', \mathbf{p}) = e\bar{u}(\mathbf{p}') F_1^{p,n}[(p'-p)^2]\gamma^\mu + i\sigma^{\mu\nu}(p'-p)_\nu F_2^{p,n}[(p'-p)^2] u(\mathbf{p})$ that describes the virtual photon interaction with the clothed proton (neutron). By keeping only the one-body contribution we arrive to certain off-energy-shell extrapolation of the so-called relativistic impulse approximation (RIA) in the theory of e.m. interactions with nuclei (bound systems). Of course, the RIA results [1] should be corrected including more complex mechanisms of e-d scattering (see other our contribution). Since, as before in [1], we start with the following formula

$\mu_d = \frac{1}{m_d}\langle \mathbf{0}; M'=1|\frac{1}{2}\left[\mathbf{B} \times \mathbf{J}(0)\right]^z|\mathbf{0}; M=1\rangle$

for the magnetic moment of the deuteron, special attention has been paid to finding a relativistic correction due to the interaction part $\mathbf{B}_I$ of the RIA results obtained in [1].

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CHARACTERISTICS OF DETECTORS OF GAMMA RAYS AND NEUTRONS

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At Joint Institute for Nuclear Research (JINR, Dubna, Russia), in the framework of the project TANGRA (TAgged Neutrons and Gamma RAys) [1], we continued the experiments for studying the inelastic scattering of fast neutrons on some important for nuclear science and technology isotopes [2]. We are using several different types of gamma-detectors, such as: NaI(Tl), BGO, Stilbene, HPGe, Plastic scintillators and $LaBr_3$ [3-5]. The design of the experimental setup that includes a ring of gamma-detectors and a neutron generator, allows us to measure the angular distribution of gamma quanta with a good accuracy. A single HPGe gamma-detector and an ING-27 neutron generator we are using to determinate the cross-section of the inelastic neutron scattering reactions. The information about the gamma-ray energy and angular distributions, and cross-sections, makes it possible to test different models, describing neutron-nuclear reactions, and to improve the accuracy of the fast neutron elemental analysis.

The aim of this work is to determine the main characteristics of the experimental setups, such as: gamma and neutron efficiencies, energy and time resolutions, at different source-detector geometries and PMT's high-voltages, for which point-type standar ^{137}Cs and ^{60}Co gamma-ray sources and 14.1 MeV neutrons were used.

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SEARCH FOR NEW INTERNUCLEON SHORT-RANGE INTERACTION IN NEUTRON SCATTERING

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There are 4 known types of interaction in nature, but nowadays the existence of a new force mediated by new unknown bosons is widely discussed in the literature [1,2]. This work deals with the application of a neutron scattering technique for the search for a new short-range interaction and for setting constraints on the coupling constant of such interaction.

The main idea is to perform an experiment of neutron scattering on the powder of silicon (powder diffraction) and to get the information on scattering amplitude dependence on scattering angle. Within this work the calculations showing the possibility of the idea were made. The coupling constant constraints were obtained using the calibration data of powder diffractometer SPODI from the FRM II reactor, Munich, Germany. It is shown that the new constraints are competitive with the existing ones. Performing a new full-time experiment is expected to provide an improvement of the constraints for about 2 orders for the interaction range $\lambda < 10^{-11}$ m.

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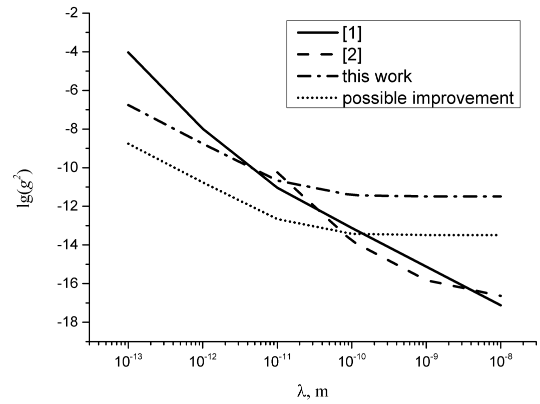

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ФОРМИРОВАНИЯ ЭЛЕКТРОМАГНИТНЫХ ПОЛЕЙ В ОПТИЧЕСКОМ ДИАПАЗОНЕ, ВОЗНИКАЮЩИХ В РЕЗУЛЬТАТЕ ВЗАИМОДЕЙСТВИЯ ПОЗИТРОНОВ СО СРЕДОЙ.

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В работах [1, 2, 3] применен полуклассический подход и модель линейного тока [4] для расчета изменений электромагнитных полей в оптическом диапазоне, формируемых при взаимодействии электронов, гамма квантов с жидкой, твердой и газовой средой. В подходе, применённом при решении конкретных задач, использовался пособытийный анализ формирования электромагнитных полей с применением пакета GEANT [5].

В данной работе метод применен к задаче прохождения высокоэнергичных позитронов с воздухом. Приведены результаты расчетов изменений электромагнитных полей в оптическом диапазоне для воздуха при прохождении через него высокоэнергичных позитронов.

Рассчитанные угловые распределения изменений энергии согласуется с экспериментальными результатами работы [6].

Результаты расчетов, проводимых по данной методике, могут быть использованы при моделировании и конструировании детекторов для экспериментов в физике высоких энергий. Работа выполнена с использованием оборудования ресурсного центра “Вычислительный центр СПбГУ”

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CROSS-SECTIONS FOR PHOTONUCLEAR REACTIONS ^{93}Nb(γ,n)^{92m}Nb AND ^{93}Nb(γ,3n)^{90}Nb IN THE RANGE $E_{\gamma max}$ = 36-91 MeV

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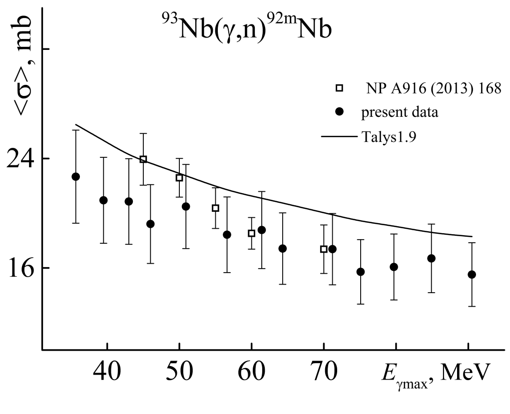
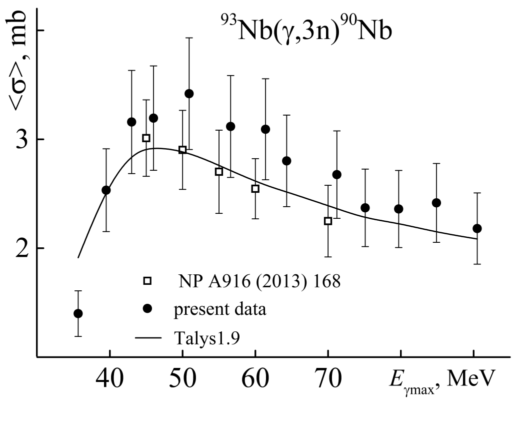
The photonuclear reactions ^{93}Nb(γ,n)^{92m}Nb and ^{93}Nb(γ,3n)^{90t}Nb were investigated by the γ-activation method using a bremsstrahlung beam generated from an electron linac LUE-40 RDC “Accelerator” NSC KIPT. The flux of bremsstrahlung γ-quanta was controlled using a monitor target from natural molybdenum and the ^{100}Mo(γ,n)^{99}Mo reaction cross-section values.
The experimental cross-sections <σ(E)>, averaged over the bremsstrahlung spectrum in the energy interval from the reaction threshold to the end-point bremsstrahlung energies $E_{\gamma max}$ = (36-91) MeV, were determined for the reactions ^{93}Nb(γ,n)^{92m}Nb and ^{93}Nb(γ,3n)^{90t}Nb. The obtained values of <σ(E)> (presented in Figures) are in reasonable agreement with the estimates calculated using computer code TALYS 1.9 and with experimental data from [1].





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ISOTOPIC SPIN IN LIGHT NUCLEI

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The isotopic spin in light and medium nuclei is a quantum number that serves to identify the ground and excited states and it is conserved in various nuclear processes. To verify this statement, we considered nucleon decays in the odd nuclei of the $1p$-shell with isospin $T = 3/2$. By the magnitude of the widths Γ of the decaying states, they can be classified into 2 groups. In ^{7}Li, ^{11}B, ^{15}N nuclei, as a result of the decay of levels with $T = 3/2$, the direct transitions to daughter nuclei levels with $T = 1$ are possible. These are "allowed" transitions. In ^{9}Be and ^{13}C (^{13}N) nuclei, direct nucleon decay into levels with $T = 1$ of the formed even-even ^{8}Be and ^{12}C nuclei is not possible by energy. Decays to levels with $T = 0$ are possible only due to Coulomb mixing of the levels $T = 3/2$ and $T = 1/2$. These are "forbidden" transitions. Within the multi-particle shell model, we calculated the nucleon widths Γ for ^{7}Li, ^{11}B, and ^{13}C nuclei, as well as for nuclei mirror to them. The Coulomb mixing of the $T = 3/2$ and $1/2$ levels in ^{9}Be and ^{13}C (^{13}N) nuclei was calculated using perturbation theory. A similar situation arises for the ^{12}C nucleus level with (J^π, T) = (1^+, 1) at 15.11 MeV. Alpha decay of this level into ^{8}Be nucleus levels is possible only due to Coulomb mixing of the $T = 1$ and $T = 0$ levels in initial nucleus.
The calculation results show that the Γ-widths for all "forbidden" transitions are several orders of magnitude smaller than the widths of "allowed" transitions, which indicates a high isospin level of light nuclei.

STRUCTURE OF LOW-LYING STATES OF ^{9}Be NUCLEUS

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An application of Glauber theory of multiple scattering to calculation of differential cross sections and polarizing characteristics of particles scattering on light nuclei took an important place in research activity of E.T.Ibraeva. All calculations were carried out in the framework of reliable spectroscopic approach to nuclear reactions. Its essence is in use of nuclear models reproducing practically all spectroscopic characteristics of the nuclei under consideration. Three-particle models of ^{6}Li and ^{9}Be nuclei developed in MSU are related to that; as well as a multiparticle shell model for nuclei with $A = 6 - 14$ and particle-hole shell model with $A = 15$; a three-particle model of ^{8}Li and ^{9}Li nuclei and two-particle αt-model for ^{7}Li nucleus suggested in KazNU and etc. As our experience shows when realizing the spectroscopic approach, if the dominating mechanism of process is known, one can obtain not only a description of the main characteristics of the process but can also rely on the predictive character of the theory.
The particular role is for direct evidence of the halo-structure of the low-lying excited states of ^{9}Be nucleus with quantum numbers $1/2^+$ and $3/2^+$ obtained by the authors lately [1]. In the framework of $\alpha\alpha n$-model of ^{9}Be nucleus it was shown that the valence neutron is located with a large probability at a distance of 11 fm from the center of mass of two α-particles, at the same time this distance is several times smaller in the ground $3/2^-$ state.
In the present work the results obtained are supported by calculations of the structure of low-lying $5/2^+$ and $5/2^-$ levels. This allows concluding generally: levels of negative parity in ^{9}Be nucleus, in which the valence neutron is in p-state, do not have a halo-structure; at the same time the low-lying

levels of positive parity do have it.
Conclusions about structure of the low-lying levels of ^{9}Be nucleus, obtained on the base of $\alpha\alpha n$-model, are supported with calculations of p^9Be-scattering: an account of halo-structure only allows reproducing experimental data on inelastic scattering on levels of positive parity [2].

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ALPHA PARTICLE ENERGY LOSS IN THIN LAYERS OF AN INHOMOGENEOUS ABSORBER

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The energy loss of alpha particles in thin layers of various absorbers, including those composed of various materials was investigated.As absorbers, aluminum films with a thickness of 1–10 microns and lavsan films with a thickness of 5–20 microns were used.The radiation sources were standard alpha sources ^{238}Pu and ^{239}Pu.
A Gaussian distribution in the calculations approximated the distribution of energy losses near mean energy in the absorbers. The mean energy loss of alpha particle was estimated by Bethe Bloch formulae. The dependence of energy losses on the order of successive layers of aluminum and lavsan in the absorber is obtained if the residual energy of the particles is close to the Bragg peak. This is due to the strong non-linearity of losses near the end of the path of alpha particles and to the different positions of the Bragg peak for various substances. When the sequence of films in the absorber changes, the energy loss changes up to 0.5%. This effect can contribute to the expansion of a single Bragg peak in alpha spectrometry.

CENTRAL DIFFRACTION AND ULTRA-PERIPHERAL COLLISIONS IN ALICE IN RUN 3 AND 4

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The ALICE experiment at the LHC is undergoing a major upgrade during Long Shutdown 2 (2019-2020). In particular, the Time Projection Chamber (TPC) is being equipped with new GEM-based readout chambers and the readout electronics of several detectors is being replaced with faster and more flexible technology. This will allow ALICE to read out most of the detectors in the continuous mode and record minimum bias Pb-Pb events at rates of about 50 kHz in Run 3 (2021-2024) and Run 4 (2027-2030). The ALICE collaboration is also considering the possibility to collect a large sample of proton-proton collisions at interaction rates of about 1 MHz using online and offline preselection of rare events. These goals require a completely new online computing system that will be used to perform fast reconstruction and compression of the data stream. The event selection strategy becomes especially challenging for the case of rare central diffractive events and ultra-peripheral Pb-Pb collisions characterized by rapidity gaps at forward and backward directions with only few tracks at central rapidity. In this contribution, the motivation for studying central diffractive and ultra-peripheral events is presented, and feasibility studies for their selection in runs 3 and 4 will be given.

ELECTRON PARAMAGNETIC DATING OF FOSSIL TOOTH FOUND AT THE AGHSTAFA DISTRICT IN AZERBAIJAN

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At present, the study of an archaeological site without the associated radioisotope research methods is an anachronism. As many geoarchaeologists rightly point out, the cultural layer cannot be fully studied only by excavating and collecting artifacts; this requires the application of methods of natural sciences.
Electron paramagnetic resonance (EPR) analysis is one of the alternative methods on dating of ancient artifacts and based on the fact that natural ionizing irradiation produces paramagnetic centers in tooth enamel with the long mean life. Those centers are stable at the temperatures below 100 °C and might be considered as a measure of the total irradiation dose to which a particular sample has been exposed. In this work the EPR method has been applied to determine the age of animal tooth enamel found in Aghstafa archeological site in Azerbaijan. Method based on the fact that the intensity of the EPR signal increases linearly with the additional laboratory irradiation. The enamel was initially removed from teeth using a dental drill and water cooling. The 2 mm mean thickness enamel was then placed in a 30% NaOH solution for one day to disinfect it and separate any remaining dentine. A dental drill was used to strip around 50±5 μm from inside and outside of the enamel surface to ensure that alpha radiation had no effect. In total 0.6 g enamel was collected and it was air-dried at room temperature for three days. ESR signal for the sample was measured with a Bruker EMXplus (X-band) spectrometer. Fig. 1 shows the dose dependence spectra for the enamel sample from the tooth found Aghstafa district of Azerbaijan. The archaeological dose obtained by the extrapolation back to zero ordinate was 9.73±0.47 Gy. In order to estimate the natural dose rate soil samples were collected from the site and U, Th, and K content analysis by gamma spectrometry Canberra GR4520. ROSY program was employed to calculate the age of tooth enamel. The age of the tooth found in Aghstafa archeological site was estimated as 8432+/-416 BP.

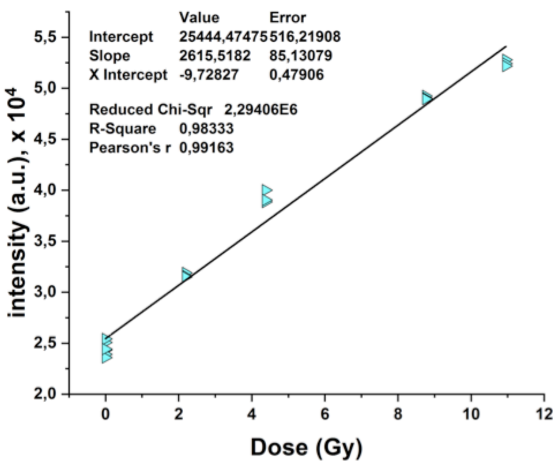

Figure 1: Dose dependence of EPR signal intensity of tooth enamel.

INFLUENCE OF γ-RADIATION ON STRUCTURE OF HIGH DENSITY POLYETHYLENE COMPOSITES WITH GaAs AND GaAs <Te> FILLERS

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This paper presents the results of Fourier-IR spectroscopic studies of γ-radiation effect on the structure of composite films of high density polyethylene (HDPE) with semiconductor fillers of gallium arsenide (GaAs) and gallium arsenide doped with tellurium (GaAs <Te>) at room temperature. IR spectroscopy allows one to follow structural changes due to the influence of gamma radiation and identify patterns associated with these changes.
A homogeneous mixture was prepared from HDPE and GaAs and GaAs <Te> semiconductors powders (with particle size $\approx$50 micron) through mechanical mixing. Then samples were exposed to hot pressing at T = 413 K temperature within 15 minutes and cooled to room temperature within 30 min. The samples were irradiated with γ-rays from a ^{60}Co source at room temperature with a dose rate of 1.05 Gy / s. The absorbed dose was Φ_γ = 5-150 kGy.
The Fourier-IR absorption spectra of the initial and γ-irradiated composite samples were recorded on a Varian 640 FT-IR spectrometer at room temperature in the frequency range 4000–400 cm−1. Structural changes associated with the influence of γ radiation were observed in the frequency range 750–700 cm^{-1}, corresponding to the pendulum vibration of the CH2 group of HDPE. The band at 730 cm^{-1} characterizes crystalline regions, and the band at 720 cm^{-1} characterizes crystallites + amorphous layers.
The crystallinity degree of the samples was calculated based on the optical densities by the following formula:

$$K = \frac{1.4 \cdot (D_{730}/D_{720})}{1 + 0.4 \cdot (D_{730}/D_{720})},$$

where D_{730} and D_{720} are optical density of 730 and 720 cm^{-1} bands in the IR spectra of HDPE + GaAs and HDPE + GaAs <Te> films respectively.
The degree of crystallinity and their correlation along the absorption bands with maximum at 720 and 730 cm^{-1} were determined. By the dose dependence of the relative degree of crystallinity, it was found that in the absorbed dose range Φ_γ = 5-150 kGy, the HDPE / GaAs <Te> composites are the most radiation-resistant in comparison with the HDPE / GaAs composites.

THE ROLE OF NUCLEUS REACTIONS IN PETROLEUM METAMORPHISM

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Many published scales reflect the irreversible effects of organic metamorphism. A.Hood, C.C.M.Gutjahr and R.L.Heacock refer to the process of thermal metamorphism of organic matter as "organic metamorphism'. It also has been called "transformation" (Dobryansky, 1963), metamorphism (Landes, 1966-67), "thermal alteration" (Henderson *et al.*, 1968, Staplin, 1969) and subsequently many others described the process as a series of thermocatalytic reactions leading to products of lower free energy by degradation, leading to smaller molecules of increasing volatility, mobility and hydrogen content and condensation. For application to petroleum exploration problems, however, there has been a need for a single numerical scale that is applicable over the

entire thermal range of interest in the generation and destruction petroleum [1, 2].
It was studied the hydrocarbon transformation by Yu.V. Larichev and O.N. Martyanov[3]. They presented the results of the in situ SAXS study of the asphaltene aggregate transformations due to dilution of several heavy crude oils by heptane within the time range from 5 min to 3 days. The main growth of the asphaltene aggregates was usually observed within the first minutes. The analysis of the SAXS data obtained in situ for the oils having significantly different relative content of resins showed their great influence on the dynamics of aggregates formation on a nanometer scale. In particular, it has been shown that the resins can prevent the asphaltene aggregation via a certain mechanism which usually leads to the high anisotropy of the aggregates. Therefore the relative content of resin and asphaltenes as well, as aromatics and aliphatic, lead to the asphaltene aggregates with different shapes and different density of deposits. It has been found that asphaltene could form secondary aggregates with different shapes (worm –like and micelle-like shapes) and the Shape of asphaltene aggregate and their evolution during the time are dependent on the resin content in the heavy crude oils.
The presented research work has been devoted the key role of nucleus reactions in petroleum metamorphism, that is transformation of hydrocarbons. As crude oil was used Gunasli oil from Azerbaijan. Investigations were carried out under the influence of gamma rays at room temperature. The samples were irradiated with gamma radiation from the ^{60}Co isotope under static conditions, within vacuumed and then sealed quartz tubes at room temperature. The dose rate was 10.5 Rad/sec. It was studied that petroleum's metamorphism process is a series of radio-catalytic reactions.

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INVESTIGATION OF THE RADIATION-CATALYTIC PROPERTIES OF nano-ZrO_2 + nano-SiO_2 SYSTEMS IN THE PROCESS OF PRODUCING HYDROGEN FROM WATER BY IR SPECTROSCOPY

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This paper presents the results of Fourier-IR spectroscopic studies of the radiation decomposition of water in a heterogeneous system of nano-ZrO_2 + nano-SiO_2 + H_2O at room temperature (T = 300 K) and exposure to γ-quanta in order to establish the role of intermediate-active particles (ion-radical groups) in these processes. The ratio of nano-ZrO_2 and nano-SiO_2 nanopowders varied as follows: 50% nano-ZrO_2 + 50% nano-SiO_2, 16.7% nano-ZrO_2 + 83.3% nano-SiO_2, and 83.3% nano-ZrO_2 + 16.7% nano SiO_2.
The Fourier IR absorption spectra were recorded on a Varian 640IR FT-IR spectrometer in the frequency range ν = 4000–400 cm^{-1} at room temperature. An analysis of the decomposition spectra of water in the γ-irradiated system of 50% nano-ZrO_2 + 50% nano-SiO_2 shows that new absorption bands (AB) are observed in the spectra at frequencies of 1570, 3142, and 3968 cm^{-1}. Perhaps the bands at 1570 and 3142 cm^{-1} relate to adsorbed [O_2] molecules in an uncharged form. The nanostructure of ZrO_2 and SiO_2 powders allows one to detect, along with the main absorption band ($\nu 1$ = 1570 cm^{-1}), surface-adsorbed molecular oxygen and its AB in the overtone region ($\nu = 2\nu 1$ = 3142 cm^{-1}). The absorption band at ν = 3968 cm^{-1} refers to surface adsorbed molecular hydrogen [H_2]. A change in the weight content of ZrO_2 and SiO_2 nanopowders results in a redistribution of AB intensities, which is due to a change in the surface states of the powders and their defects.
In the spectra, in the region of lattice vibrations of nano-SiO2 (ν = 1400–400 cm^{-1}), AB with maxima

of 472, 798, and 1095 cm^{-1} are detected. The observed bands are related to symmetric and asymmetric stretching vibrations of Si-O and Si-O_2 – Si. A change in the weight ratios of ZrO_2 and SiO_2 nanopowders is accompanied by a redistribution of the intensities of the AB vibrations of Zr-O and Si-O.
In an unirradiated heterosystem, after water adsorption on the surface of zirconia and silicon dioxide in the region of stretching vibrations of hydroxyl (OH) groups, AB appear, which indicate the occurrence of molecular and dissociative forms of adsorption: the molecular form of adsorption (intense broad bands with maxima of 3240 and 3280 cm^{-1} in the region of 3500–3000 cm^{-1}) and dissociative chemisorption (relatively narrow bands with maxima of 3450, 3475, 3520, 3580 cm^{-1}). The occurrence of two types of adsorption is also confirmed by the formation of AB in the region of deformation vibrations of OH with maxima at 1610, 1630, 1640, and 1680 cm^{-1}.
Irradiation of a 50% nano-ZrO_2 + 50% nano-SiO_2 + H_2O heterosystem with γ-quanta at room temperature (T = 300 K) leads to radiation decomposition of water and the formation of intermediate-active decomposition products. Among these products, the most interesting are the surface hydrides of zirconium and silicon. Thus, in the spectrum in the frequency range 2000–1700 cm^{-1}, AB appear with maxima of 2100, 2000, 1995, and 1880 cm^{-1}. These absorption bands belong to the stretching vibrations of Zr-H (1995, 1880 cm^{-1}) and Si-H (2100, 2000 cm^{-1}) and indicate the formation of surface zirconium and silicon hydrides of Zr-H, Zr-H_2, Si-H, Si-H_2 [6], among which the most stable forms are Zr-H_2 and Si-H_2. Unfortunately, we were not able to register AB oxygen containing intermediate-active surface particles of water decomposition. Since, these PPs overlap with the absorption bands of Si–O stretching vibrations (ν = 1200–900 cm^{-1}).
In the Fourier IR absorption spectra of nano-ZrO_2 + nano-SiO_2 + H_2O samples with adsorbed water, in the region of stretching vibrations of OH groups and water (ν = 4000–3000 cm^{-1}), bands of hydrogen-bonded groups with maxima of 3580 are observed, 3520, 3475, 3450 cm^{-1}, as well as adsorbed water molecules at 3280 and 3240 cm^{-1}.
The radiation decomposition of water at room temperature is accompanied by a decrease in the intensity of the molecular water band, the formation of a number of AB hydrogen-bonded hydroxyl groups at 3350, 3500 cm^{-1}, as well as new absorption bands at 3630 and 3690 cm^{-1}. The last bands refer to isolated OH groups.

CHARGE DIPOLE POLARIZATION IN ULTRAMAGNETIZED NUCLEI

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Properties of ultramagnetized atomic nuclei relevant for supernovae, neutron star mergers, magnetar crusts and heavy-ion collisions are analyzed. Nuclear magnetic reactivity of Zeeman type is shown to dominate for field strengths below ten teratesla. Respective linear magnetic response is given as a combined reactivity of valent (outer shell) nucleons and can be described in terms of nuclear magnetic susceptibility. Valent protons and neutrons occupy [1] orbitals with minimum and maximum spin projection on a field axis, respectively. Consequently, charged (protons) and neutral (neutrons) nucleons are spatially separated. Effects of such charge dipole polarization in nuclear reactions are discussed.

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INTRANUCLEAR CASCADES EFFECTS ON THE COMPOSITION AND ENERGY OF (p,x)-NUCLEAR REACTION PRODUCTS

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The relaxation of the nucleus in the pre-equilibrium phase, excited in reaction with protons of high energy, proceeds predominantly via an emission of several nucleons and α-particles. In addition to light nuclei with Z ≤ 2 and neutrons at the proton energies E0 > 140 MeV, γ quanta, leptons, and mesons there can also be emitted. The charge, mass, and energy distributions of heavy fragments formed in the collisions of protons with silicon and iron nucleus are studied using TALYS-1.9 [1], GEANT4 [2] and FLUKA [3] programs. The divergence between TALYS and GEANT4, FLUKA results above 300 MeV is analyzed and ascribed to the contribution of intranuclear cascades developed in the p+Si and p+Fe nuclear systems which is taken into account in GEANT4 and FLUKA, but not in TALYS. From the comparison, we deduce the essential role of intranuclear cascades in the compound p+Si and p+Fe nuclear systems at the pre-equilibrium phase of reaction at high colliding energies.

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ELECTROMAGNETIC INTERACTIONS IN THE VOLUME OF NUCLEI

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Structuring the volumes of nuclei and the complex topology of their surfaces, along with attractive nuclear forces, in certain conditions, electromagnetic forces manifest themselves more significantly. At the line of the stability path of exotic nuclides, these forces begin to prevail.
In this paper, we describe the mechanism of interaction of nucleons in the nucleus volume as the interaction of dipole-dipole intranuclear clusters. Such an interaction and its sign, first of all, will depend on the spatial orientation of nucleons or clusters in the nucleus and, therefore, the interaction potential of electromagnetic forces should include not only the Coulomb repulsion of charged nucleons (clusters) but also the magnetic component, which includes the spin-orbit the interaction of nuclear clusters $V = V_c + V_m(sl)$, where V_c is the Coulomb potential; $V_m(sl)$ is the potential of the dipole-dipole interaction. The magnetic component of the electromagnetic potential depends both on the total spin of the nuclear clusters and on their spatial position (orbital). This paper considers nucleons and nuclear clusters that form in dipoles. Based on experimental data on the elastic scattering of alpha particles by ^{24}Mg from the found cluster widths for mass numbers from 1 to 4 [2], it was possible to construct the corresponding dipole – dipole interaction in s, p, and d states. In the field of heavy nuclei, neutron-deficient and neutron-rich isotopes, the density of nuclear matter fluctuates with respect to the constant 0.15 fm^{-3} [1]. This fluctuation is associated not only with the deformation of nuclei, but also with the spatial distribution of nucleons within the volume of the nucleus. With an increase in the mass number, the Coulomb repulsive forces cause protons and isolated nuclear clusters to move to the periphery of the nucleus, thereby abnormally increasing the average radius of the nucleus and its deformation, which should affect the density of nuclear

matter. From the constructed isotonic dependences of the binding energy of nucleons in the nucleus on the proton excess and deficit, it can be seen that the binding energy per one nucleon decreases quadratically with a decrease and addition of each subsequent proton, which leads to inflation of the nucleus volume and, possibly, the formation of "bubble" nuclei that were still unsuccessfully tried to find in the experiment. Such an idea about inflating the volumes of nuclei was expressed to the authors by Oganessian Yu.T., who drew attention to a particularly significant effect in the field of "Island of stability".

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EXPLOSION OF LOW-MASS NEUTRON STAR IN CLOSE BINARY SYSTEM AND NUCLEOSYNTHESIS OF HEAVY ELEMENTS

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First observation of neutron star merger and registration of heavy elements presence in this process [1] confirmed our understanding that main scenario for the r-process is connected with the ejecta during neutron star merger (NSM) at the end of close binary system evolution rather than with the supernova explosion [2].
A number of NSM model were created [3] since 1999 year and with their help the main conditions of the r-process in jets were researched. Neutron stars in close binaries is approaching each other because the system lost angular momentum due to gravitation wave emission. Further evolution of their mutual approaching and merger depend on masses of binary components. In case when masses are close to each other and when the mass of every component is close to solar mass (it usually is called as "standard" neutron star mass), then scenario of neutron stars merger is realized.
In present report we will discuss the binary of neutron stars when neutron stars have significantly different masses, m_1 > m_2 [4]. In such a binaries the matter of the component with smaller mass starts to flow from low-mass companion to higher-mass one m_1. When the mass of low-mass neutron star have reached the minimum mass value ~0.1M, the low-mass companion lost its hydrodynamical stability and blows up [5].
On the results of first calculations of low-mass companion of close neutron stars system, for the ejecta with different chemical composition the nucleosynthesis calculations of heavy elements were done and theoretical abundances of heavy elements are in a good agreement with our knowledge of solar system matter.
The work was under under financial support of Russian Fond of Basic Research (project №. 18-29-21019 мк).

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CSC FOR BM@N EXPERIMENT

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The coordinate detector "Cathodic Strip Chamber" (CSC) is designed to refine the parameters of the track obtained by multilayer GEM detectors inside the analyzing magnet. In addition to improving impulse resolution, an updated track is needed to find the corresponding hit in the ToF400 flight system. The first prototype CSC was tested on the BM@N technical wound in the 55th session of the Nuclotron in 2018. Charge distributions are obtained, coordinate resolution and detector efficiency are estimated. The design of CSC detectors used in the BM@N experiment is described and the results of studies of their characteristics are presented.

PARTICLE SETS IN $NN\bar{K}$ QUASI-BOUND STATE

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The theoretical consideration of the $NN\bar{K}$ quasi-bound system is based on the isotopic-spin formalism in which mesons $\bar{K}^0$ and K^- are two isospin states of the $\bar{K}$ particle with the isospin of $\frac{1}{2}$. Nucleon is also considered as isospin $\frac{1}{2}$ particle having two states (proton and neutron) with the different projections of the isospin. According to the isospin formalism, the isospins in the $NN\bar{K}$ system are summed as isospins of three identical particles. And along with this, in the $NN\bar{K}(s_{NN} = 0)$ system, the particle channels ppK^- and $pn\bar{K}^0$ are defined in literature due to the possible particle transition $n\bar{K}^0 \to pK^-$. Taking into account this assumption, the system can be found as ppK^- or $pn\bar{K}^0$ at the same time. The question is how these particle channels can be described within the isospin formalism.

In the presented work, the kaonic system $NN\bar{K}(s_{NN} = 0)$ is studied based on the configuration space Faddeev equations. We considered two models associated with isospin "natural" basis and isospin "charge" basis. We show that the "particle representation" [1-3] for $NN\bar{K}(s_{NN} = 0)$ system motivated by the "charge" basis does not describe the system in terms of coupled particle channels $ppK^-/pn\bar{K}^0$ [4]. The particle configurations of the $NN\bar{K}(s_{NN} = 0)$ system may be classified by the masses and pair potentials (in particular, presence or absence of the Coulomb interaction). The $NN\bar{K}(s_{NN} = 0)$ system is represented by four configurations: ppK^-, npK^-, $np\bar{K}^0$, $nn\bar{K}^0$. The results of the calculations including the kaon mass difference, the charge dependence of nucleon-nucleon interaction [5] and the Coulomb force for these particle configurations will be presented.

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RECOIL NUCLEI OF ^{186}Re FOR USE IN THE MEDICAL PURPOSES

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The isotope of ^{186}Re is widely used (glass-based TheraSphere, Nordion, Canada and resin-based SIR-Spheres, Australia) for transarterial radioembolism in hepatocellular carcinoma (second in the world in total mortality).
The average β-radiation energy of ^{186}Re 1.07 MeV is one of the highest among the radionuclides used in palliative therapy.
The powder of rhenium activated by bremsstrahlung at the Linac of the NSC KIPT. The photonuclear reaction ^{187}Re(γ,n)^{186}Re was used. After activation, the powder was dissolved in HCl and, according to one of the methods, was homogenized with clinoptilolite particles (≈20-40 μm), which were previously treated with hexadecyltrimethylammonium chloride to more efficiently sorption rhenium. The resulting mixture modified thermally. According to the second method, after the activated powder was dissolved in the HCl solution, electrolysis was carried out at pH=1.5, followed by isolation of 186ReO2 at the cathode in the form of clinoptilolite particles [1].
The proposed methods for obtaining the isotope ^{186}Re can significantly reduce the cost of the procedure of radionuclide therapy in comparison with the used commercial agents.

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PHOTONUCLEAR PRODUCTION OF ^{18}F, ^{99}Mo, ^{149}Pm, ^{153}Sm and ^{175}Yb BY USE OF NANOPARTICLES

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Photonuclear technologies for the production of ^{18}F, ^{99}Mo, ^{149}Pm, ^{153}Sm and ^{175}Yb with high specific activity were developed at the linear electron accelerator NSC KIPT. The method of recoil nuclei using oxides of nanoparticles of these elements to obtain isotopes of the lanthanide group and ^{99}Mo was applied. Nanoparticles of CaF_2 were used for obtaining ^{18}F.
The proposed photonuclear technologies for the production of isotopes are alternative to the technologies widely used in the world at reactors and cyclotrons. The advantages of these technologies there are high specific activity, high isotopic purity (absence of other isotopes in the form of impurities), and no need to immobilize the resulting radioactive waste. Therefore these photonuclear technologies have no alternative.
Samples in the form of nanoparticles were activated by bremsstrahlung radiation on a linear accelerator with an electron energy of 13 MeV. Activated nanoparticles were used as donors in the reaction of recoil nuclei, and nanoparticles of biocompatible aluminosilicate - as an acceptor. The activity

of the isotopes was measured by the Ge(Li)-detector. The ratio of recoil nuclei in aluminosilicate nanoparticles for ^{99}Mo, ^{149}Pm, ^{153}Sm and ^{175}Yb and sodium chloride for ^{18}F ranged from 12.3% to 1.7%.
Also, preclinical studies have been conducted on the accumulation of the ^{99m}Tc isotope in blood plasma, isolated tumor cells, and also with the help of various carriers, the functional ability of individual organs of animals on a gamma camera has been registered.
The isotope production with use MoO^3 nanoparticles with size 15 nm and of bremsstrahlung with $E_{max} = 25$ MeV on 10 kW electron accelerator will allow producing 22 mCi/g per day of ^{99}Mo with a high specific activity, which is necessary for manufacturing generators ^{99m}Tc-^{99}Mo. For the production of ^{149}Pm, ^{153}Sm and ^{175}Yb with $E = 25$ MeV and a current 260 μA it is possible to produce 0.5 Ci during the day by using of targets (30 g) of natural isotope composition. The estimation of the ^{18}F production on an electron accelerator with a power of 10 kW and an energy of 25 MeV can be up to 1 Ci for 4 hours.

LITHIUM-LOADED PLASTIC SCINTILLATORS FOR THERMAL NEUTRON DETECTION

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This work presents the results of the optimization of the composition of lithium-loaded plastic scintillators (Li-PS) based on a copolymer of styrene and methacrylic acid. The light output, transparency and luminescence spectra were measured.
The composition of the Li-PS was optimized by measuring the light yield dependence on the concentrations of the primary (PPO) and secondary (POPOP) scintillation additives, as well as the secondary solvent (naphthalene). Lithium acetate was used as a lithium-containing additive.
As a result, the samples of lithium-loaded plastic scintillators with optimal concentrations were obtained: PPO – 4%, POPOP – 0.02%, naphthalene – 15%. The maximum concentration of lithium in the obtained samples was 0.3%.

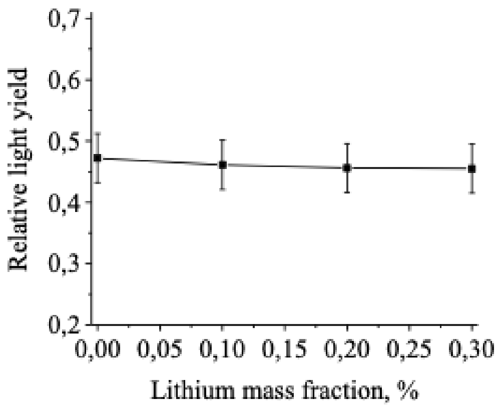

Figure 1: The dependence of the light yield of scintillators based on a copolymer of styrene and methacrylic acid containing 4% PPO, 0.02% POPOP and 15% naphthalene on the concentration of lithium (relatively to the light yield of unloaded polystyrene based plastic scintillator).

The light yield of designed Li-PS practically does not depend on the metal fraction and is close to the half of the light yield of unloaded polystyrene based plastic scintillator.

MONITOR SYSTEM FOR STOPPED PION SELECTION

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Description of a semiconductor system for selection of events in the reactions of stopped pion absorption by nuclei [1, 2] is presented. The system consists of two thin silicon detectors. The regions of energy release in the detectors corresponding to pion stops in the targets are determined using a "live" target - a silicon detector of a certain thickness. The thicknesses of other targets used in the experiment must be equivalent to the pion range in the "live" target.
The monitor system makes it possible to achieve ~ 90% efficiency of pion selection in a target. The total number of pion stops in various targets was obtained in an experiment performed at the PNPI accelerator. It is shown that the accuracy of absolute calibration is 7% for the "live" target and 8% for other targets.

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CHARGE MEASUREMENTS OF EvRs IN EXPERIMENTS ON THE SYNTHESIS OF Ra AND Th ON A NEW GAS-FILLED SEPARATOR DGFRS-II

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Since 1998, experiments on the synthesis of superheavy elements (SHE) have been carried out at the Flerov Laboratory of Nuclear Reactions (FLNR) of the Joint Institute for Nuclear Research (JINR) on a gas-filled recoil separator (DGFRS). The heaviest element ^{294}Og with Z = 118 was registered in 2002, 2005, 2012 and 2015. In all these experiments, ^{48}Ca heavy ion beams accelerated at the *U-400* cyclotron were used. Further use of calcium ions as an incident projectile does not allow the synthesis of elements heavier than ^{294}Og, since there is no sufficiently stable target material. To conduct further studies of SHEs at the JINR FLNR, the SHE Factory based on the new *DC-280* cyclotron was created. Achieved beam intensity is 10 times higher than *U-400*. The first experimental setup of the SHE Factory is the new DGFRS-II which have configuration of QDQQD magnets (Q – quadrupole, D – dipole). The main feature of this setup is the high collection efficiency of synthesized superheavy nuclei, exceeds 60% for targets up to 0.5 mg/cm^2 thick, which is 2 times higher than DGFRS-I. In 2019, test experiments on the new separator were conducted. The main goal of this experiments was to determine the optimal parameters of the DGFRS-II separator: $^{170}Er +^{48} Ca—>^{214,215} Ra,^{nat}Yb,^{174}Yb +^{48} Ca—>^{216,217} Th$.
In this talk, results of this experiments are shown. For each experimental reaction charge of the synthetized nuclei were calculated together with dispersion on two main dipoles. Energy losses during evaporation residues transport were calculated as well.

MODELING OF THE DISTRIBUTION OF RADIONUCLIDE CONCENTRATIONS IN ORGANS AND TISSUES OF THE HUMAN BODY

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Monitoring the accumulated dose in the population from natural terrestrial radionuclides and timely assessment of the maximum dose to prevent potential risks of radiogenic oncological diseases is an important and one of the priority tasks. The main source of the accumulated dose by the population is the natural terrestrial radionuclides that enter the body through human life, and this problem is international in nature [1].

The concentration of chemical elements in the organs and tissues of the human body pretty much depends not only on the use of certain products, but also on geographical residence with a different geological landscape [2]. Different concentrations of chemical elements accumulated in various organs or tissues entail the accumulation and corresponding distribution of natural radionuclides. In this work, the authors developed a software-mathematical complex [3], which allows you to simulate the distribution of natural nuclides and radionuclides in the organs and tissues of the human body. Unlike existing software systems that simulate the interaction of radiation with biological objects, such as Geant4-DNA, etc. [4], the developed program simulates the spread of radionuclides throughout the body, taking into account the conversion factors from one organ to another. Thus, a mathematical calculation based on experimental accumulation coefficients and methods for calculating the doses of ICRP makes it possible to calculate the internal radiation doses of the corresponding organs and tissues. Such modeling allows us to calculate the risks of cancer due to internal exposure to incoming natural terrestrial radionuclides. The distribution of the studied radionuclides is visualized, which allows you to visually study the potential areas of internal sources of radioactive radiation.

The result of the development of this software was the collective work of a team of authors, which was carried out in an open-type nano-technological laboratory at KazNU al-Farabi from 2018 to 2020. with the support of state grant funding for basic research (project: "Fundamental research on the mechanisms of formation of nanoscale oncradiogenic structures in the body and the development of anti-cancer rapid devices for their detection", No. IRN AP05131884).

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STUDY OF THE INTERACTION TRIGGER AND BEAM ION FRAGMENTATION FOR Au + Au COLLISIONS IN BM@N EXPERIMENT

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The Monte-Carlo simulation of the trigger detector performance and interaction trigger efficiency for Au + Au collisions in BM@N[1-2] experiment at energy of $4A$ GeV was performed with a code DCM-QGSM[3] + GEANT4[4]. The Au ion fragmentation and detection of spectator neutrons by a neutron zero-degree calorimeter and charged nuclear fragments by a forward Cherenkov counter were studied with the aim to include this information to the fast interaction trigger providing more reliable selection of events by centrality.

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NEWBY SHIFTS IN ODD-ODD TRANSITIONAL NUCLEI AT A∼190

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Correct accounting for residual NN-interaction between valence particles is of utmost importance for structure interpretation of deformed odd-odd nuclei. This interaction manifests itself in such effects as the Gallagher-Moszkowski (GM) splitting of two-quasiparticle doublets, the Newby shift of odd-even spin value levels in K=0 rotational bands, as well as the ΔK=0 mixing of rotational bands due to non-diagonal matrix elements when wave function components of both valence particles exchange. In two-particle plus rotor model calculations, one usually uses NN-interaction potential parameters obtained via a fit to empirical matrix element values derived from a wide range of well-deformed odd-odd nuclei (see, e.g., [1]). However, it is hard to perform similar studies for transitional nuclei due to a lack of confident experimental data about complete doublets.

Detailed experimental structure studies performed recently for ^{186,188}Re and ^{192}Ir [2-4] allowed to obtain empirical values for a number of residual NN-matrix elements responsible for GM-splittings and Newby shifts in transitional deformation region at A∼190. Especially unique are data obtained for ^{192}Ir where one has three confidently established K=0^- rotational bands.

The residual proton-neutron interaction matrix elements have been evaluated using expressions of [1]. The finite-range V_{np} potential with Gauss radial dependence included both the short, and the long range central forces with spin polarization, as well as the tensor interaction terms. The set of fitted empirical matrix elements included Newby shift values for nine K=0 rotational bands of ^{186,188}Re, and ^{190,192,194}Ir. For comparison of NN-interaction potential parameters, values of GM-splittings have been evaluated as well.

It has been found that the long-range NN-interaction can be compensated by variation of the short-range space-exchange Heizenberg interaction strength V_H. The latter parameter is most essential

in order to reproduce both GM-splittings and Newby shifts. However, while GM-splittings show strong dependence also from spin-exchange Bartlett interaction strength V_B and core polarization, the Newby shifts practically do not depend on values of these parameters, but display dependence on tensor interaction, though weaker than that from V_H.

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STRUCTURE FUNCTIONS GENERATED BY ZERO SOUND EXCITATIONS

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We study the form of the structure functions connected to the zero sound excitations in the symmetric and asymmetric nuclear matter (ANM). The density response $\Pi(\omega,k)$ (the retarded polarization operator) of ANM to the small external field $V_0(\omega,k)=\tau_z e^{i\vec{q}\vec{r}-i(\omega+i\eta)t}$ is considered. The structure function $S(\omega,k)$ is defined as $S(\omega,k)=-\frac{1}{\pi}\mathrm{Im}\,\Pi(\omega,k)$ [1].
In [2] the three complex branches of the zero sound excitations in ANM were obtained: $\omega_{si}(k)$, $i=n,p,np$. We calculate these branches as solutions of the dispersion equation $E(\omega,k)=0$. Calculations were made in the framework of RPA with the Landau-Migdal quasiparticle-quasihole isovector interaction $F'(\vec{\tau},\vec{\tau}')$ with $F'=1.0$.
It was shown that in the external field $V_0(\omega,k)$ the total polarization operator is the sum [3]: $\Pi=\Pi^{pp}+\Pi^{nn}-\Pi^{pn}-\Pi^{np}$. Expressions for $\Pi^{\tau,\tau'}$ are obtained from the system of equations M of the type similar to the system for the effective fields in [4]: $\Pi^{pp}=\Pi_0^p(1-\Pi_0^n\,F^{nn})/\det M(\omega,k)\equiv D^{pp}/\det M(\omega,k)$, $\Pi^{np}=\Pi_0^p\,\Pi_0^n\,F^{np}/\det M(\omega,k)\equiv D^{np}/\det M(\omega,k)$. Changing $p\leftrightarrow n$ we obtain Π^{nn}, Π^{pn}. Dispersion equation for the frequencies of zero sound excitations is $E(\omega,k)\equiv\det M(\omega,k)=0$. So, the branches $\omega_{si}(k)$ are the zeros of $\det M$ and the poles of $\Pi^{\tau,\tau'}$ by construction.
In our approach $S(\omega,k)$ must be considered as a sum over three independent processes: the widths of the different $\omega_{si}(k)$ correspond to the different decays of excitations. The imaginary part of $\omega_{sn}(k)$ describes in nuclei the semidirect decay due to emission of a neutron, reaction (γ,n). Decay of $\omega_{sp}(k)$ accompanied by emission of proton. About of $\omega_{snp}(k)$ we can say that one nucleon is emitted and its isospin is not fixed [2]. We rewrite $S(\omega,k)=\Sigma_i S_i(\omega,k)$.
Near the pole at $\omega\approx\mathrm{Re}(\omega_{si})$ we approximate $(\det M(\omega,k))^{-1}=R^i(\omega_{si},k)/(\omega-\omega_{si})+Reg(\omega,k)$. Here $Reg(\omega,k)$ is a smooth function near the pole. This permits us to write
$S(\omega,k)_i=-\frac{1}{\pi}\mathrm{Im}[\Sigma_{\tau,\tau'}(D^{\tau\tau'}(\omega,k))\,R^i(\omega_{si},k)/(\omega-\omega_{si})+Reg]$. Then, let define the envelope curve of the pole terms $S^e(\omega,k)=-\frac{1}{\pi}\Sigma_{\tau,\tau'}\mathrm{Im}[D^{\tau,\tau'}(\omega,k)\Sigma_i\,R^i(\omega_{si},k)/(\omega-\omega_{si})]$.
We demonstrate results for ANM with asymmetry parameter $\beta=0.2$ (see Fig. 1). In the left figure the branches $\omega_{sn}(k)$, $i=n,p,np$ are shown [2]. In the right figure $S^e(\omega,k)$ are presented for $k/p_0=0.6$ and $k/p_0=0.2$ ($p_0=0.268$ GeV). For $k/p_0=0.6$ the structure functions for the different processes $S_i(\omega,k)$, $i=n,p,np$ are presented (the numbers $1,2,3$, correspondingly). As it was expected the form of the structure function is decomposed over the contributions of the definite processes, corresponding to $\omega_{si}(k)$. The widths of maxima ($right$) are determined by the imaginary parts of ω_{si} ($left$).

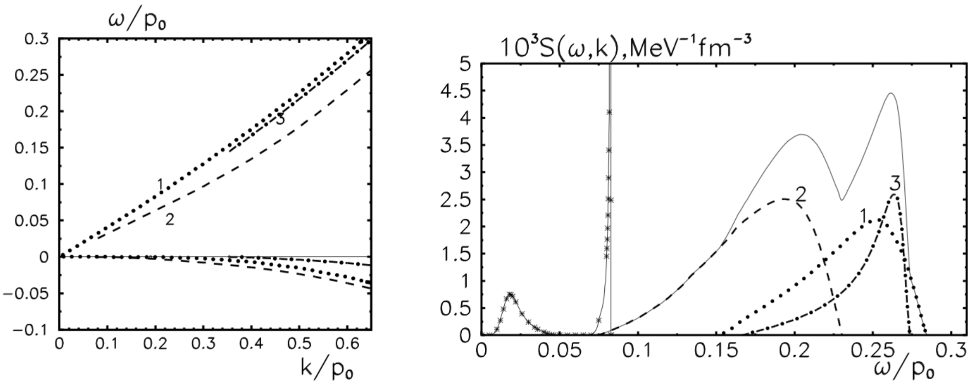

Figure 1: *left*: $\omega_{sn}(k)$ (dotted curve, 1), $\omega_{sp}(k)$ (dashed curve, 2), $\omega_{snp}(k)$ (dash-dotted, 3). At $\omega > 0$ ($\omega < 0$) the real (imaginary) parts of $\omega_{si}(k)$ are demonstrated; *right*: the pole terms of $S(\omega, k)_i$, $i = n, p, np$ (numbers 1, 2, 3) are shown. The envelope curve $S_e(\omega, k)$ is marked by the solid curve for $k/p_0 = 0.6$ and by the solid with stars for $k/p_0 = 0.2$.

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LINEAR TRANSVERSE, ANGULAR, AND TIME CHARACTERISTICS OF ELECTRON-TO-POSITRON CONVERSION AT E^{-}(55; 220; 1000) MEV

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Beams of ultrarelativistic positrons are an essential tool for experimental studies in physics of atomic nuclei and elementary particles. Usually positrons for these beams are produced by conversion of ultrarelativistic electrons to positrons in thick targets-converters. In one variant some magnetic system separates from all positrons from converter those which have necessary energy without their additional acceleration (see, e.g., [1, 2]). In another variant initial positrons, emitted from converters with rather low energies, undergo acceleration up to necessary energies (see, e.g., [3, 4]).
The most important characteristic of positron generation in converters is a coefficient of conversion $K(E^{-}, E^{+}, T, Z) = N^{+}/(N^{-}\Delta\Omega^{+}\Delta E^{+})$ for a "instantaneous and needle-like" beam of electrons, normally incident on a converter, and a positron emission angle $\Theta^{+} \approx 0$, where E^{-} and E^{+} – kinetic energies of electrons and positrons; T - a converter thickness; Z - an atomic number of a converter material; N^{-} and N^{+} – numbers of incident electrons and emitted positrons; $\Delta\Omega^{+}$ and ΔE^{+} small considered values of a solid angle and an energy spread for emitted positrons. In the previous our work [5] the calculations were made using GEANT-4 [6] for the pointed out conversion coefficients K for E^{-} from 10 MeV and up to 1000 MeV for converters from Cu, Ta, and Pb and close to optimal values of T in comparison with available experimental data.

To understand the possibilities of further handling positron beams from converters, one need to know also linear transverse, angular, and time characteristics of electron-to-positron conversion which we obtained in the present work from full array of data, calculated in [5] and compared them with some known data from [7–9].
The obtained new data together with $K(E^-, E^+, T, Z)$ data from [5] may be useful in modeling and designing equipment for matching emittances of positron beams and acceptances of further magnet systems and/or additional positron accelerators.

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ON THE NEUTRON DRIP-LINE OF Ca ISOTOPES

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On the basis of the Hartree-Fock-Bogolyubov (HFB) method with various versions of Skyrme forces we investigated the position of the neutron drip-line (NDL) of Ca isotopes with allowance for axial deformation of nuclei. For calculations of the properties of the ground state of even-even isotopes of Ca, we used computer code HFBTHO v2.00d [1] and our software package as in [2]. Our calculations and those of various authors [3] have shown that the position of the NDL for different types of Skyrme forces differs significantly in the boundary value of the number of neutrons $N_{drip-line}$. We have shown that for the same type of Skyrme forces, the determination of the $N_{drip-line}$ is also ambiguous. We performed constrained HFB calculations of the total energy of Ca isotopes in the vicinity of the NDL depending on the quadrupole deformation parameter β_2 in the range of $-0.5 \leq \beta_2 \leq 0.5$. It is shown that for the isotopes ^{68}Ca (forces UNEDF1) and ^{66}Ca (forces SLy4) over the entire range of considered β_2, in the vicinity of the min curve E(β_2), the chemical potential of the nuclei is $\lambda_n < 0$. These isotopes can be considered as neutron-stable. For the isotopes ^{70}Ca (forces UNEDF1) and ^{68}Ca (forces SLy4) in the vicinity of the min curve E(β_2), the chemical potential of the nuclei is $\lambda_n > 0$. If we consider the condition $\lambda_n < 0$ as a condition for the stability of the nucleus with respect to the emission of one neutron, then the nucleus ^{70}Ca (for forces UNEDF1) and ^{68}Ca (for SLy4 forces) cannot be considered as neutron-stable. In [3], these nuclei are given as neutron-stable for which the separation energies of one neutron have positive values.

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METHODS FOR MEASURING DAUGHTER PRODUCTS OF RADON DECAY IN THE SURFACE ATMOSPHERIC LAYER OF THE EARTH

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Despite numerous studies of radon emanation [1-3], the problem of studying the distribution of radon concentrations in the surface atmospheric layer of the Earth is relevant. The contribution of radon and its daughter decay products to the general background radiation is large and amounts to more than 50%. Time of variations of radon emanation, studied by the authors of [4], showed its strong concentration dynamics not only from daily and seasonal variations, but also from other external factors. In addition to time of distributions, we and other authors have shown that radon and its daughter decay products are distributed in the surface atmospheric layer of the Earth both in a complex manner depending on the height inside the buildings and on the geological landscape [5]. We performed measurements with a spectrometric setup of beta spectra for the period from October 2018 to February 2020, from which it is clear that the integral values of the spectra of beta particles during the day strongly fluctuate relative to the average daily value. The mechanism of such fluctuations may be the soft electron-photon component of the secondary cosmic radiation.
To measure the low-background beta radiation of various samples for the content of natural beta-radionuclides in the present work, the authors proposed a technique that will allow for taking into account events arising from other sources. Based on this technique, a spectrometric "telescope" was developed [6], in which, as protection against cosmic radiation, active protection was applied in the form of a second detector that detects external radiation, which is included in the anticoincidence scheme with the main detector. The opposite arrangement of the detectors on the vertical axis and in the lead glass of the main detector allows one to register events that occur in the local area of the space to which the telescope is oriented.
The work was supported by the state grant financing of basic research (project No. IRN AP05131884)

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INFLUENCE OF RELATIVISTIC NUCLEON DYNAMICS ON THE SCALAR QUARK CONDENSATE IN NUCLEAR MATTER

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The scalar quark condensate $\kappa(\rho) = \langle M|\sum_i \bar{q}_i q_i|M\rangle$ in nuclear matter can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N\rho + S(\rho)$ with $\langle M|$ the ground state of the matter while q are the operators

of the light quarks u and d. Here ρ is the density of the matters, $\kappa(0)$ is the vacuum value of the condensate. In the second term on the right hand side the matrix element κ_N is $\kappa_N = \langle N|\sum_i \bar{q}_i q_i|N\rangle$ with $\langle N|$ standing for the free nucleon at rest. This matrix element can be expressed in terms of the nucleon sigma term σ_N related to observables. The various experiments provide the values between 40 MeV and 65 MeV for σ_N. The first two terms in definition of $\kappa(\rho)$ compose the gas approximation.

The contribution $S(\rho)$ describes the change of $\kappa(\rho)$ caused by the nucleon interactions. It was demonstrated that $S(\rho)$ is due mostly to the pion cloud created by interacting nucleons (see [1] for references). In the latter calculations $S(\rho)$ was obtained employing the nonrelativistic approximation for nucleons of the matter (curve 1 in Fig. 1). The latest results obtained in framework of chiral perturbation theory [2] are shown by the curve 2.

In the present report the matter is viewed as a relativistic system of nucleons. In the first step we neglect their interactions. We find that the quark condensate can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N \rho F(\rho, m^*(\rho))$ with $F(\rho, m^*(\rho)) = 2/(\pi^2\rho)\int_0^{p_F} dp\, p^2\, m^*/\sqrt{m^{*2}+p^2}$. Here p_F is the Fermi momentum, m^* is the nucleon Dirac effective mass. Note that the same function $F(\rho, m^*(\rho))$ connects the vector and scalar densities in the Walecka model.

The effective mass m^* can be calculated in a hadron model. In the version of QCD sum rules presented in [3] the right hand side of the scalar channel equation contains the effective mass $m^*(\rho)$ while the left hand side contains the scalar condensate $\kappa(\rho, m^*(\rho))$. Thus we come to self-consistent equation for $m^*(\rho)$ which was solved in [3]. Here we employ these results for calculation of $\kappa(\rho)$ (curve 3 in Fig. 1). One can see that inclusion of the relativistic dynamics of nucleons is as important as that of nucleon interactions.

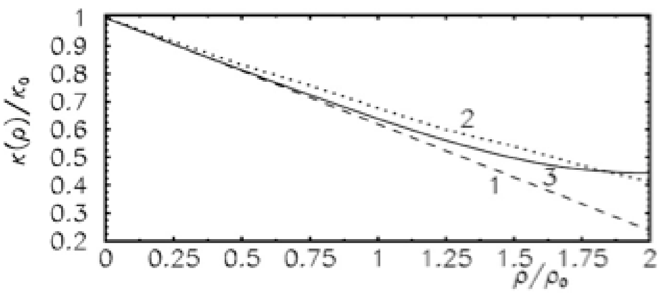

Figure 1: $\kappa(\rho)$ as a function of ρ.

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THE ELECTRONS AND GAMMA QUANTA SOURCE AT THE LUE-8-5 ACCELERATOR OF INR RAS FOR CALIBRATION OF NUCLEAR DETECTORS

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A source of electrons and gamma quanta for nuclear detectors calibration is described. The source was developed on the basis of the LUE-8-5 electron accelerator of the INR RAS. The electrons energy

is variable within 4 – 10 MeV. The energy resolution (FWHM) is better than 1%, the counting rate is of order of one particle per acceleration cycle. Repetition rate is up to 300 s-1. beam pulse duration of 3 μs, the duty cycle equals to 0.1%. The source consists of a stretching magneto-optical system and beam correction, collimation and cleaning systems. The source is provided by information storage and processing system.

STUDY OF DECAY PROPERTIES OF ^{260}Sg* NUCLEUS FORMED VIA DIFFERENT INCOMING CHANNELS BY USING GSKI SKYRME FORCE

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The method being successfully used for the synthesis of superheavy elements is that of complete fusion reactions, which are classified as cold fusion and hot fusion reactions. In the present work, we have studied the excitation functions (EFs) of ^{260}Sg*, formed in fusion reaction ^{52}Cr + ^{208}Pb [4], based on Dynamical Cluster decay Model (DCM) [1]. For the nuclear interaction potentials, we use the Skyrme energy density functional (SEDF) based on semiclassical extended Thomas Fermi (ETF) approach under frozen density approximation. The Skyrme force used is the new GSkI force [3] for our calculation for cross section and comparison with the experimental data taken from [4]. Here, only the EFs for the production of ^{260}Sg* isotope via 2n decay channel from the ^{260}Sg* compound nucleus are studied at E*= 13 to 19 MeV for incoming channel, including quadrupole deformations β_{2i} and cold-optimum" orientations θ_i.The calculations are made within the DCM where the neck-length ΔR is the only parameter representing the relative separation distance between two fragments and/or clusters A_i (i=1,2) which assimilates the neck formation effects. Our calculations are shown in table.

Table:1 The "cold fusion" excitation function of 2n evaporation channels from ^{260}Sg* due to entrance channels ^{52}Cr + ^{208}Pb, calculated on the basis of DCM for a best fit of ΔR, at different E*= 13 to 19 MeV energies for GSkI Skyrme.

CN	E (MeV)	T (MeV)	xn	Deltar (ΔR)	Cross Section (σ^{Theo}_{2n})(pb)	Exp. (σ^{Exp}_{2n}) (pb)
^{260}Sg*	13.3	0.74	2n	2.4408	55	55
	15.9	0.8	2n	2.1182	62.8	63
	18.6	0.87	2n	1.859	34	34

The calculations are made for best fit to each and every data point and clearly, irrespective of excitation energy, Skyrme Force GSKI included DCM reproduces data nicely.

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PRODUCTION OF HIGH PURIFIED AMMONIUM SALTS FOR NUCLEAR MEDICINE AND LOW BACKGROUND APPLICATIONS

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Ammonium salts are at the basis for the synthesis of a number of substances, which are used in different medical applications. Ammonium media has no adverse effects on the body. It is chemically and biologically sufficiently stable. These salts often used as a buffer for binding the radionuclide to a chelator, which in turn promotes the binding of the radionuclide to the active part (peptide, antibody, etc.) of radiopharmaceuticals. It is very important to obtain radiopharmaceuticals with the highest specific activity. For this reasons, substances with a minimum content of two-, three-, and tetravalent elements are required for nuclear medicine applications.
In addition, ammonium salts are used as a fluxing agent in soldering for electronic devices that work in the area of low-background experiments (for example, neutrino physics). The solder and flux must meet the requirements of radioactive purity.
The chemical properties of impurities are usually similar to the basic substance, otherwise they would have easily separated in its synthesis. Therefore, developing combined methods of purification is very important.
In this work, we report the production process of a high purified ammonium salt. The initial components for the synthesis of salt was undergo an additional purification by sub-distillation. The synthesis of ammonium salt was achieved with transfer of gas phase ammonia to the acid. The final product obtained is a dry salt of ammonium chloride and ammonium acetate in form of white granules.
To achieve high purity of the final product all the processes were performed in a clean room (JINR, Dubna) with the use of chemically resistant equipment made from pre-purified materials.
A γ-ray screening with ultra-low background spectrometer, an instrumental neutron activation analysis and ICP-MS elemental analysis have been performed to estimate the radioactivity level and composition of the final product. Will be presented comparison results for commercial and custom-made ammonium salts.

NEUTRONIC PARAMETERS AND CPS (CONTROL AND PROTECTION SYSTEM) WORTH CALCULATION OF THERMAL RESEARCH REACTOR USING MCNPX CODE

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One of the main attributes of reactor core design is finding the best distribution of the core controls and protection systems. Nuclear reactors have several distinctive types of control and protection elements, such as control rods, shimming rods and emergency rods. Each of these elements performs a separate task in a control procedure. The distribution of these elements in the core contributes to their worth and expense, therefore finding the best location and distribution of the control protection

system (CPS) elements is very important from the viewpoint of nuclear reactor design and safety. The scope of this paper is to present the neutronic parameters such as effective multiplication factor (Keff), Neutron Spectrum and CPS worth calculation of research heavy water reactor using MCNPX code. In order to reduce the possible systematic errors due to inexact geometry, a very exact three-dimensional model of Reactor was developed. The MCNPX2.6 input file was prepared in such a way that a very quick setup of any desired core configuration with an adequate position of all Control and Protection Systems (CPS) is possible. Utilizing the appropriate material cross-sections in an MCNP calculation is essential to obtain reliable results. The MCNP neutron interaction tables used in this study are processed from ENDF/B-VII evaluated data file at room temperature. The thermal scattering treatment was used for light and heavy water, and polyethylene.
The obtained computational data showed that when all the emergency rods are fully inserted in the core, or when all the emergency channels are filled by light water, the negative imposed reactivity is more than the clean core excess reactivity (5% ΔK/K) plus 1%. Therefore, the emergency system satisfies the nuclear safety regulations.

NON-ZERO θ_{13} AND LEPTOGENESIS IN TYPE-I SEESAW WITH $\Delta(27)$ DISCRETE SYMMETRY

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In this work, we consider a beyond the Standard Model (SM) framework, based on the non-abelian discrete group $\Delta(27)$ to explain the observed non-zero reactor mixing angle θ_{13}. The deviation from the tri-bimaximal (TBM) neutrino mixing pattern, in the context of the type-I seesaw is realized by including new particles to the SM particle content, which thus provides non-zero θ_{13}, consistent with the recent experimental results. The non-zero neutrino masses can be understood via type-I seesaw mechanism by introducing three right-handed neutrinos, which transform as triplets and a $SU(2)_L$ scalar singlet under $\Delta(27)$ symmetry. Similarly, to accommodate the charged lepton mass, $SU(2)_L$ scalar doublets transforming as singlets under $\Delta(27)$ symmetry are also included. We demonstrate that, the model successfully explains all the neutrino oscillation parameters such as the atmospheric and solar mass squared differences, all the mixing angles and the CP-violating phase δ_{CP}, as well as the cosmological bound on the sum of active neutrino masses ($\sum_i m_i$). In addition, it also explains the baryon asymmetry of the Universe through Leptogenesis. The non-zero lepton asymmetry is generated through the decay of the right handed neutrinos, involving the neutrino Yukuwa couplings.

MEASUREMENT OF THE Λ_C^+ FRAGMENTATION FUNCTION IN PP COLLISIONS AT $\sqrt{S} = 13$ TEV WITH THE ALICE EXPERIMENT

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Charm quark production occurs via hard scattering processes in relativistic hadron-hadron collisions and is well described by perturbative QCD down to low transverse momenta. These highly virtual

quarks subsequently fragment and hadronise. Measurements of charm baryon-to-meson ratio show significant modifications in pp collisions compared to e^+e^- [1], prompting further studies into the role of hadronisation mechanisms.
The initial kinematics of the scattered charm quarks could be reconstructed by means of studies of the final state hadrons clustered into jets. This provides us with a new tool to study hadronisation effects. We report the first measurement of the fragmentation function of Λ_c^+-tagged jets at the LHC, obtained in pp collisions at $\sqrt{s} = 13$ TeV with the ALICE experiment. Jets are here tagged by the presence of Λ_c^+ baryon amongst their constituents and are reconstructed using the anti-k_t algorithm [2] with a resolution parameter of R=0.4. The results are fully corrected to particle level and are compared to a variety of theoretical models, which will be presented together with future prospects for heavy flavour jet studies in upcoming LHC runs.

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MODELING OF A POSITION-SENSITIVE RESONANT SCHOTTKY CAVITY PROTOTYPE FOR THE RARE-RI RING AT RIBF/RIKEN

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Schottky cavity pick-ups have proven to be fast and sensitive detectors for use in storage ring experiments with radioactive ion beams (RIB) relevant for nuclear astrophysics [1]. Cavity pick-ups with longitudinal sensitivity have been successfully used in the storage ring ESR in GSI facility [2-4], CSRe in Lanzhou [5] and in R3 ring in RIKEN [6]. Some initial studies were carried out in order to extend the concept to sensitivity in transverse direction for use in different storage rings [8-10]. In the current work we report on the progress of the modelling of a prototype of a position-sensitive resonant Schottky cavity for the R3 storage ring in the RIKEN facility.

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LOCAL PERTURBATION OF DENSITY DISTRIBUTIONS IN BORN APPROXIMATION FOR ANALYSIS OF ELECTRON SCATTERING DATA ON LIGHT NUCLEI

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The investigation of distribution of charge density of nuclei by means of electronic scattering have begun from Hofstadter work series [1–2]. Further many important works were made in this field [3–5]. Here I present specific models of charge distribution with symmetrized Fermi distribution in the center of nuclei and small perturbation on periphery used for fitting electron scattering data by Born approximation method. I have chosen the local functions as perturbations (will be discussed in the report). In this work I consider only light even-even nuclei with N=Z, so called alpha-particle nuclei.
In my opinion the most interesting result of the paper is decreased level of significance for applied in this work hypotheses for nuclei lighter then O-16. It seems very realistic to use such charge distributions for Mg-24, Si-28, S-32.
Also in my report, I am going to consider reliability of applications of various charge distributions for analysis of electronic scattering data that exist today.

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EQUATION OF STATE OF PNJL MODEL IN MAGNETIC FIELD AND NON ZERO CHEMICAL POTENTIAL

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We extended our calculations of the recent research work for two flavor magnetized PNJL model cooperating non zero chemical potential and thermal mass in the potential as in the Lagrangian. We calculate the equation of state of PNJL model and its thermodynamic properties. We Show the results of the phase transition temperature obtain to a lower value in comparison to earlier value of phase transition, the result is much conformation with the lattice data. The result shows that the thermodynamic behavior of lattice data are well agreed with the prediction of the model field theories.

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INVESTIGATIONS OF ELECTROWEAK SYMMETRY BREAKING MECHANISM FOR HIGGS BOSON DECAYS INTO FOUR FERMIONS

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Models with extended Higgs boson sectors are of prime importance for investigating the mechanism of electroweak symmetry breaking for Higgs decays into four fermions and for Higgs-production in association with a vector bosons [1]. In the framework of the Two-Higgs-Doublet Model [2] using two scenarios obtained from the experimental measurements we presented next-to-leading-order results on the four-fermion decays of light CP-even Higgs boson, $h \rightarrow 4f$ [3]. With the help of Monte Carlo program Prophecy 4f 3.0 [4], we calculated the values $\Gamma = \Gamma_{EW}/\left(\Gamma_{EW} + \Gamma_{SM}\right)$ and $\Gamma = \Gamma_{EW+QCD}/\left(\Gamma_{EW+QCD} + \Gamma_{SM}\right)$ for Higgs boson decay channels $H \rightarrow \nu_\mu \overline{\mu} e \overline{\nu_e}$, $\mu\overline{\mu}e\overline{e}$, $e\overline{e}e\overline{e}$. We didn't find significant difference when accounting QCD corrections to EW processes in the decay modes of Higgs boson.
Using computer programs Pythia 8.2 [5] and FeynHiggs [6] we calculated the following values: $\sigma(VBH)BR(H \rightarrow ZZ)$ and $\sigma(VBF)BR(H \rightarrow WW)$ for VBF production processes, $\sigma(ggH)BR(H \rightarrow WW)$ and $\sigma(ggH)BR(H \rightarrow ZZ)$ for gluon fusion production process at 13 and 14 TeV and found good agreement with experimental data [7].

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APPLICATION OF THE LIQUID SCINTILLATION ALPHA AND BETA SPECTROMETER QUANTULUS 1220 FOR DATING OF NATURAL OBJECTS

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The Quantulus 1220 is a liquid scintillation counting (LSC) system for the quantitative measurement of extremely low levels of alpha and beta activity. With both passive and active shielding, the Quantulus 1220 employs a universal background reduction system which is optimized according to type of analysis.
In the Centre of Isotopic Research (CIR) of FGBU «VSEGEI» Quantulus 1220 is used for radiocarbon dating of various organic objects (wood, peat, soil, bottom sediments, bones), dating young bottom sediments using ^{210}Pb as well as determination the tritium content in water.
For radiocarbon dating the organic matter of a sample is chemically converted to benzene. The ^{14}C activity is measured relative to the modern standard. Also it is necessary to measure the activity of the background sample (benzene without ^{14}C).
When dating young bottom sediments by ^{210}Pb, all the lead (99%) in the sample is chemically extracted. Then Optiphase HiSafe 3 liquid scintillator is added to the slightly acidic solution containing

the lead.
When measuring the tritium content in water, a water sample is directly mixed with the Optiphase TriSafe 3 liquid scintillator. The minimum detectable concentration of tritium in water is approximately 1 Bq/L.
The obtained results are presented as the decay spectra of radioactive isotopes with age calculations.

GLAUBER MONTE-CARLO MODEL AT PARTONIC LEVER FOR PP-COLLISIONS IN A WIDE ENERGY RANGE

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At present, experiments devoted to studying collisions of hadrons and nuclei at high energy are being performed at various facilities, including the LHC and SPS (CERN) and RHIC (BNL). Due to the peculiarities of the strong interaction, constructing a collision model from the first principles of the QCD theory is a rather difficult task. Therefore, various empirical models are developed based on the available experimental data. The basic model for describing interactions involving hadrons and nuclei is the Glauber model [1-2]. For the more detailed description of nuclear interaction features, this model is increasingly being used at the parton level [3-5], however, usually, pp-interaction is given insufficient attention. Before the transition to the nucleus-nucleus collisions, one should ensure that the major features of the pp interaction are adequately described.
In this regard, the work is devoted to a systematic study of pp collisions in a wide energy range at the parton level.
The Glauber Monte Carlo model was developed and implemented for a detailed description of pp collisions at the parton level. Various types of spatial parton distributions in the proton are considered. It is shown that, within the framework of this model, such quantities as the total, elastic, and inelastic cross sections, the slope of the diffraction cone in the energy range from SPS to LHC are satisfactorily described, while the best agreement with experiment is obtained for the exponential form of the spatial parton distribution.
The self-consistency of the model is checked regarding the transition to a moving reference frame. An explicit form of the dependence of the number of initial partons on the beam energy is obtained, which ensures the exact Lorentz invariance of the cross sections and the slope of the diffraction cone, and the values of its parameters are determined. The behavior of proton-proton cross sections in the high-energy limit is analyzed. The developed approach can be applied not only to pp interaction but also can serve as the basis for more advanced models of both pp and AA collisions.

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REACTIONS $PN \rightarrow D\pi^0\pi^0$ AND $PD \rightarrow PD\pi\pi$ WITHIN THE $D_{03}(2380)$ RESONANCE EXCITATION MECHANISM

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Search for dibaryon resonances in two-nucleon systems has a long history (for review see [1]). At present as one of the most realistic candidate to the dibaryon resonance is considered the $D_{IJ} = D_{03}$ peak observed by WASA@COSY [2] in the total cross section of the reaction of two-pion production $pn \rightarrow d\pi^0\pi^0$, here I is the isospin and J is the total angular momentum of this resonance. The mass of the resonance is 2.380 GeV is close to the $\Delta\Delta$-threshold, but its width $\Gamma = 70$ MeV is twice lower as compared to the width of the free Δ-isobar. This narrow width is considered as the most serious indication to a non-hadronic, but most likely, quark content of the observed resonance state. The spin-parity of this resonance $J^P = 3^+$ were established by polarized measurements. One possible mechanism of the reaction $pn \rightarrow d\pi^0\pi^0$ suggested in paper [3] involves sequential excitation and decay of two dibaryon resonances, $D_{03}(2380)$ and $D_{12}(2150)$.
Rather similar resonance structure was observed by ANKE@COSY in the differential cross section of the two-pion production reaction $pd \rightarrow pd\pi\pi$ at beam energies 0.8-2.0 GeV with high transferred momentum to the deuteron [4]. This kinematic conditions strongly differ from the quasi-free reaction studied in [2]. In distribution over the invariant mass $M_{d\pi\pi}$ of the final $d\pi\pi$ system the resonance peaks were observed at $M_{d\pi\pi} \approx 2.380$ GeV [4] that is the mass of the isoscalar two-baryon resonance $D_{IJ} = D_{03}$. The widths of these peaks are by factor of ~ 1.5 larger than for the D_{03} that can be caused by the isovector component of the final $\pi\pi$ system. In order to explain the observed resonance behavior of the reaction $pd \rightarrow pd\pi\pi$ we apply [5] the modified two-resonance model [3] with inclusion of the σ-meson exchange between the proton and deuteron. Two variants of the σ-meson interaction are considered and one of them with assumption on the partial restoration of the chiral symmetry [3] and another one without it. Neglecting the contribution of the isovector state of the final $\pi\pi$ pair, we show that it is possible to explain simultaneously the shape and absolute value of the measured in [2] the $M_{d\pi}$ distribution in the cross section of the reaction $pn \rightarrow d\pi^0\pi^0$ and some properties of the reaction $pd \rightarrow pd\pi\pi$, namely, position of the resonance peak in the cross section and roughly its absolute value at $T_p = 1.1 - 1.4$ GeV. The shape of the distribution over the invariant mass of the final $\pi\pi$ system in the reaction $pd \rightarrow pd\pi\pi$ is reproduced only qualitatively.

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STUDY OF DIFFERENT INTERACTION MODELS OF DOUBLE FOLDING POTENTIAL FOR ^{6}He+^{12}C NUCLEAR SYSTEM

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Our investigation aims to study different interaction models of double folding potential for ^{6}He+^{12}C nuclear system. We analyzed the available experimental elastic scattering angular distributions data for $^{6}He+^{12}C$ nuclear system at energies 5.9, 9.9, 18, 30, 229.8, 249.6 and 493.8 MeV. Data analysis performed within the framework of optical model (OM) potential using the phenomenological Woods–Saxon (WS). We created the real part of the nuclear potential using the double folding approach based upon different interaction models such as: DDM3Y1 Paris, CDM3Y6 Paris, BDM3Y1 Paris and BDM3Y1 Reid. Among these models, the shallowest depth Potential generated by BDM3Y1 Reid interaction model, which reflects the necessity to use higher renormalization factor. The calculated angular distributions are in a good agreement with the experimental data in the whole angular range. The calculations have been performed using SFRESCO computational code.

NEW CALORIMETRY BASED ON SILICON PIXEL DETECTORS

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Today calorimetry plays an important role both in experimental studies in high energy physics and in applied research. For determination of incident particles energy with higher energy resolution the digital calorimetry can be used [1]. The digital electromagnetic calorimeter includes the segmented layers and counts the total number of particles passing through the detector volume as opposed to an analogue calorimeter, which counts the total deposited energy in a given volume. In this work the new type of digital electromagnetic calorimeter, based on silicon pixel sensors has been proposed for the identification of electron beam parameters. The conception of such calorimeter was provided together with the experimental results from beam tests and GEANT Monte Carlo simulations.
The reported study was supported by RFBR, research project No. 18-02-40075.

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FORWARD-BACKWARD MULTIPLICITY CORRELATIONS WITH STRONGLY INTENSIVE OBSERVABLES IN PP COLLISIONS SIMULATED IN PYTHIA

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Strongly intensive observables can be used to measure forward-backward (FB) correlations between charged particles in two separate pseudorapidity intervals. We will present calculations of observables in pp collisions simulated in PYTHIA at the LHC energies, and examine the azimuthal dependence of such correlations.
Within the model of independent statistically identical particle sources, these observables do not depend on the mean value and fluctuations in the number of the sources, and therefore may provide a signature of collective behavior in the system. The magnitude of the FB correlation strength is obtained for different gaps between pseudorapidity intervals and for different combinations of azimuthal windows, selected within the pseudorapidity intervals. The collision energy and multiplicity class dependence of the FB correlations is studied.

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COMPARATIVE STUDY OF NEUTRON-DEFICIENT ^{178}Pt, ^{180}Hg, ^{182}Hg NUCLEI EXHIBITING ASYMMETRIC FISSION

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A new region of asymmetric nuclear fission zone of extremely neutron deficient sub-lead island has been emerged out in recent years from the discovery of unusual mass-asymmetry in ^{180}Hg [1-4]. These extremely neutron-deficient exotic nuclei play an important role to understand the influence of microscopic effects near saddle point on the fission process [1]. The asymmetric nature of fission fragments of ^{180}Hg examined in β -delayed fission of ^{180}Tl at the excitation energy of < 10.4MeV is found to persist towards high excitation energies up to 85MeV formed in the ^{36}Ar + ^{144}Sm[3]. To test the relative presence of asymmetric distributions nearby fissioning nuclei ^{180}Hg, ^{182}Hg, and ^{178}Pt formed via ^{36}Ar + ^{144}Sm, ^{40}Ca + ^{142}Nd, and ^{36}Ar + ^{142}Nd, respectively [3, 4], a comparative study has been carried out at similar excitation energies and angular momenta. The mass and total kinetic energy distribution of fission fragments of ^{180,182}Hg was determined from the measured velocity and position information of coincident fission fragments using the double-arm time-of-flight spectrometer CORSET utilizing the U400 cyclotron at FLNR, JINR, Dubna. Fission fragment mass distributions of ^{182}Hg, ^{180}Hg, and ^{178}Pt is shown in the figure at similar excitation energies and angular momenta. It is clearly evident from the figure that there are variations in the width of mass distributions at lower excitation energy that vanishes at higher excitation energy. However, significant variations at the central part of mass distributions indicate that the contribution of asymmetric distribution in ^{180}Hg is relatively large in comparison to its nearby fissioning nuclei ^{182}Hg/^{178}Pt differing by only two neutrons/protons, respectively.

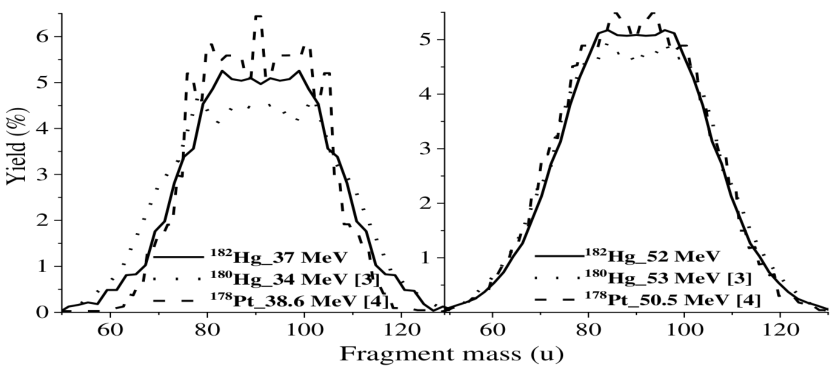

Figure 1: Mass distributions of ^{180,182}Hg, ^{178} Pt at similar excitation energies and angular momenta

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NUCLEI PRODUCED FROM ^{238}U IRRADIATED BY SECONDARY NEUTRON FIELD INITIATED BY PROTON BEAM (E = 660 MEV)

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The experiment was carried out at the proton accelerator (JINR, Dubna).
We studied the reaction products inside thin ^{238}U sample irradiated by secondary neutron field created from lead target by proton beam (E = 660 MeV) [1-3].
The distribution of uranium fission products on proton beam at energy of 660 MeV is shown in Fig.1.

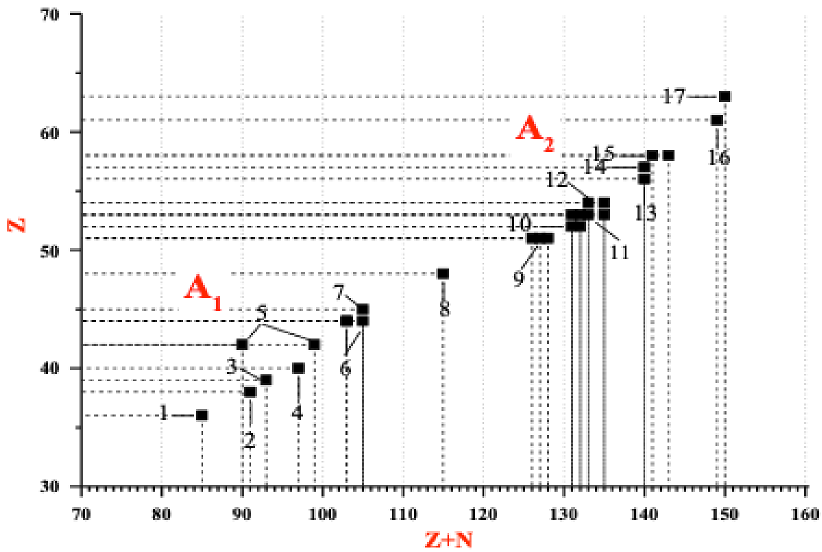

Figure 1: Fission products from ^{238}U on proton beam E= 660 MeV: 1- ^{85m}Kr, 2- ^{91}Sr, 3- ^{93}Y, 4- ^{97}Zr, 5- from ^{90}Mo to ^{99}Mo, 6- ^{103}Ru, ^{105}Ru, 7- ^{105}Rh, 8- ^{115}Cd, 9- ^{126}Sb, ^{127}Sb, ^{128}Sb, 10- ^{131m}Te, ^{133}Te, 11- ^{131}I, ^{132}I, ^{133}I, ^{135}I, 12- ^{133}Xe, ^{135}Xe, 13- ^{140}Ba, 14- ^{140}La, 15- ^{141}Ce, ^{143}Ce, 16- ^{149}Pm, 17- ^{150m}Eu.

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PROTON STOPPING IN A HYDRODYNAMIC MODEL OF PA COLLISIONS AT SPS AND NICA ENERGIES

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We study the phenomenon of high energy proton stopping in the nuclear matter and suggest the effective model that describes this effect. To compare our model with the data of relatively low energy experiment [1] we use the correlation between mean multiplicity and number of so-called grey nucleons - particles, which are knocked out of the nucleus by the incoming proton.

Proton decelerates in the nuclear matter transferring its energy to the production of new particles in inelastic interactions. We introduce the stopping force from hydrodynamics to explain this deceleration in an effective way. The idea is to treat target nuclei as a liquid drop with given internal energy density and volume. As soon as the projectile-proton gets into the target-nuclei the stopping force begins to act on it. With this force we obtain a differential equation that describes relativistic motion of a proton in a nucleus. Setting the final speed - the speed after which binary collisions do not contribute to multiplicity - we calculate the length of the proton's path in the nucleus. This path length cuts out a region, in the nucleus to which we apply the Glauber-like approach to obtain number of binary collisions. (Note that in a pure Glauber approach, the integration extends to the entire space.) The method of calculating dependency of mean multiplicity on impact parameter is also suggested. As an input in this model we use empirical dependency of mean multiplicity on energy in pp-collisions [2] and values of σ_{inel}^{NN} [3].
Results on the correlation between mean multiplicity and a number of grey nucleons are compared in this work to the available experimental data on centrality dependence of stopping and π^- production in p-Au collisions at a beam momentum of 18 GeV/c [1]. The linear dependence of the correlation between mean multiplicity and grey nucleons predicted by the model is well in line with the experimental data obtained at low numbers of grey nucleons. At the same time, it is shown that the limited acceptance of pion registration can produce a strong deviation from the linearity as observed in the experiment with slow protons at large values of pion multiplicity and number of grey nucleons.
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MC SIMULATIONS OF BEAM-BEAM COLLISIONS MONITOR FOR EVENT-BY-EVENT STUDIES AT NICA

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The colliding beams of heavy ions (Au+Au, Pb+Pb or Bi+Bi), currently planned for NICA at JINR with the average luminosity at the level of 10^{27}cm^2/s, will provide the vast amounts of precise data at the center-of-mass energies up to 11 GeV per pair of nucleons. This will give the possibilities for

the detailed, event-by-event studies of properties of high-density baryonic matter in the region of the expected onset of deconfinement, as well as for the search of the critical first-order end-point of the phase diagram of strongly interacting matter and of some signals of chiral symmetry restoration. With the aim of selection the events of interest, it was proposed in [1] to create a fast beam-beam collisions monitor, which would determine the time and space of each ion-ion collision, providing also the event-by-event information on the relevant multiplicity of charged particles. Circular (segmented ring-shaped) detectors on the microchannel plates (MCP) with high timing characteristics (signal duration below 1 ns) were suggested to be placed in vacuum of the beam-pipe at some distance from the interaction of the ion beams. The multipad readout system has to ensure the time-of-flight measurements with the accuracy below 50 ps, and multiplicity and azimuthal distributions of particles produced in collision.
In this report, we present our results of MC simulations of the beam-beam collisions monitoring system at NICA based on the MCP detectors. Different generators SMASH 1.8 [2], UrQMD [3], DQGSM [4] were used with the purpose to estimate the accuracy in determination of the position of the interaction point and multiplicity in the event. The assessments take into account the arrival times of particles to the detector, the rising edge of the current pulse in the MCP channels, the influence of communication lines, electronic equipment, and information retrieval technology.
The performed calculations show that it is the signal formation time in the microchannel plates that brings the main contribution to the error in determination of the interaction point. Calculations confirmed also the possibility of determining by this compact detector system the event multiplicity by using MCP detectors in the counting mode. The possibilities of event-by-event measurements of arrival times for different types of charged particles coming from the interaction point are also discussed.
Acknowledgments: the study was supported by RFBR, research project No. 18-02-40097.

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CORRELATIONS BETWEEN PROPERTIES OF NUCLEAR MATTER AND NEUTRON STARS

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Over the last decades, our knowledge on Neutron Stars (NS) has been greatly advanced: NS with large masses were discovered, radii of a number of NS were measured, and a gravitational signal from the merger of two NS was observed. These data establish significant restrictions on the equation of state of the NS matter and pose new problems for the theory of nuclear matter [1,2].
Many authors have been suggested the interplay between the properties of effective nucleon interactions used to calculate the equation of state and characteristics of NS. In this work, an attempt is made to put the study of such interplay on a quantitative footing. We analyze a large number of sets of parameters of the Skyrme nucleon-nucleon potential [3] and of the Lagrangian of the relativistic mean field theory [4] and calculate the coefficients of correlation between the saturation quantities of the nuclear matter and the NS properties.
The calculation indicates a strong correlation between the derivative of the symmetry energy and other quantities, which describe the nuclear matter energy dependence on the isospin asymmetry, on the one hand, and the radius and central density of NS with a mass of 1.4MSun, on the other hand.

The significance of nuclear symmetry effects for NS structure is obvious and has been numerously discussed. However, we did not find a meaningful correlation between the symmetry properties and the maximum NS mass. There is also almost no correlation between the characteristics of NS and the incompressibility of the infinite symmetric nuclear matter. This shows that the stiffness of the equation of state of the NS matter is not directly related to the incompressibility. The correlations in the non-relativistic the Skyrme approach and the relativistic mean field theory are similar, therefore, we observe real (non-model) relationships between physical quantities.

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ANALYSIS OF VELOCITY AND ISOTOPE DISTRIBUTIONS IN PROJECTILE FRAGMENTATION REACTIONS OF ^{18}O AT 35 MeV/NUCLEON ON ^{9}Be AND ^{181}Ta TARGETS

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Up to date analysis of velocity and isotope distributions of light fragments obtained in the projectile fragmentation reactions of ^{18}O at 35 MeV/nucleon on ^{9}Be and ^{181}Ta targets measured at COMBAS fragment separator at the U400M Research Facility in JINR [1] are presented. The results of velocity spectra analytical parametrization and isotopic ratios are compared with the ones obtained in the experiments presented in the literature [2,3]. The discussion of the different mechanisms involved in these types of the reactions is given.

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TRANSVERSE MOMENTUM AND MULTIPLICITY CORRELATIONS IN NICA AND SPS ENERGY RANGE

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Correlations between multiplicity of charge particles and mean transverse momentum was observed experimentally in pp collisions from top SPS energy to LHC energy. The change of the correlation

function's shape with collision energy was successfully described by the multi-pomeron exchange model [1,2] as an interplay of string fusion and energy-momentum conservation. The situation at lower collision energies where role of resonance decays would increase can be studied by the NA61/SHINE experiment at SPS and by the forthcoming MPD experiment at NICA. In prior to the experimental analysis the phenomenon was studied using Monte Carlo event generators.
In this contribution Monte-Carlo simulations results will be presented for the pt-n correlation function and correlation coefficient calculated for different electric charge combinations. The role of limited experimental acceptances of NA61/SHINE and MPD facilities will be discussed. Moreover, he dependency of the correlation coefficient on the width of considered rapidity interval is studied.
This study was funded by RFBR according to the research project No 18-02-40097.

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HADRONIZATION OF DECONFINEMENT MATTER AND QUARK-HADRON DUALITY

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The hadronization of the deconfinement matter is considered based on the concept the quark-hadron duality. Under such an approach the hadron rate is shown to be the convolutions of the multiple particle Green's function of quarks in the Kadanoff-Baym-Keldysh formalism with the probability to create the quasi-hadron bound quark-antiquarks states in the deconfinement matter. This probability depends strongly on the color correlation in the deconfinement matter. When the probability is governed by the first order phase transition, the rapidity distribution of two- and tetra-quark hadrons is explicitly calculated in the longitudinal dominance approximation. The derived rapidity distribution is compared with experimental data.

PHENOMENOLOGICAL APPROACH TO EXTRAPOLATION OF NUCLEAR BINDING ENERGIES IN THE TRANSFERMIUM REGION

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Nowadays all the elements up to 118^{th} are known due to success of experimental nuclear physics in new heavy element synthesis [1], however, not all the masses of new nuclides have been measured. In our work, the phenomenological approach based on local mass relations is implemented to predict masses of unknown isotopes. This approach is characterized by mathematical simplicity and accuracy [2], especially when it is concerned with mass relations for residual proton-neutron interaction [3, 4]. In the region of heavy and superheavy elements the behavior of various mass relations associated with nucleon correlations is considered. Estimations of nuclides' masses and

α-decay energy values for elements with Z=107-110 are gained by approximation of these mass relations. The results are compared with calculations using other approaches [5-7] and also with the machine-learning based calculations.

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SYNTHESIS OF MAGNETIZED HEAVY NUCLEI

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The properties and mass distribution of the ultramagnetized atomic nuclei which arise in heavy-ion collisions and magnetar crusts, during Type II supernova explosions and neutron star mergers are analyzed. For the magnetic field strength range of 0.1−10 teratesla, the Zeeman effect leads to a linear nuclear magnetic response that can be described in terms of magnetic susceptibility [1]. Binding energies increase for open shell and decrease for closed shell nuclei. A noticeable enhancement in the yield of corresponding explosive nucleosynthesis products with antimagic numbers is predicted for iron group and r-process nuclei. Magnetic enrichment in a sampleof 44Ti corroborate theobservational results and imply a significant increase in the quantity of the main titanium isotope, 48Ti, in the chemical composition of galaxies. The enhancement of small mass number nuclides in the r-process peak may be due to magnetic effects.

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USING OF BURNABLE POISON IN THE PIK REACTOR

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In the work is investigated the effect of a burnable poison on the rate of reactivity drop in the PIK reactor. The core consists of six 6-sided fuel assemblies in the inner perimeter, six 4-sided fuel assemblies and six 6-sided fuel assemblies in the outer perimeter. The hexagonal fuel assembly contains 241 fuel elements, and the tetrahedral fuel assembly - 161. The fuel elements of the PIK reactor have a cruciform cross-section. The used fuel is UO_2 with the addition of Cu and 0.6% of Be. The mass of ^{235}U in one fuel element is 8.57 grams. There are 6 displacers or rods of a burnable poison in a hexagonal fuel assembly, and 14 or 2 rods of a displacer and 12 rods of a burnable poison in a tetrahedral one. Rods of a burnable poison have a form of half-cylinders in the clad of steel

alloy EI-847. The material of the burnable poison is a powder of oxides ZrO_2 + 20%Y_2O_3 + 5.2% Gd_2O_3 mixture [1]. The main absorbing element are gadolinium isotopes ^{155}Gd (14.73%) and ^{157}Gd (15.68%), with cross sections equal to 60,900 × 10^{28} m^2 and 254,000 × 10^{28} m^2, respectively. The total gadolinium content in one rod is 0.7 grams. The fuel assembly cladding is made of zirconium alloy.

The time variation of the multiplication factor was calculated for two core design options. In the first case, only displacer rods made of E-125 zirconium alloy are used and in the second case, the rods of a burnable poison and two steel displacer rods made of 12Kh18N10T steel are used. The calculations were performed using the MCNP Version 6.1 program [2]. The calculation of the multiplication factor showed that the using of burnable poison reduces the multiplication factor at the beginning of operation cycle, but the initial reactivity is still too high to be compensated with the reactor control rods, as shown in the Figure 1. To reduce the initial reactivity it was decided to use additional boric burnable absorber in zirconium alloy.

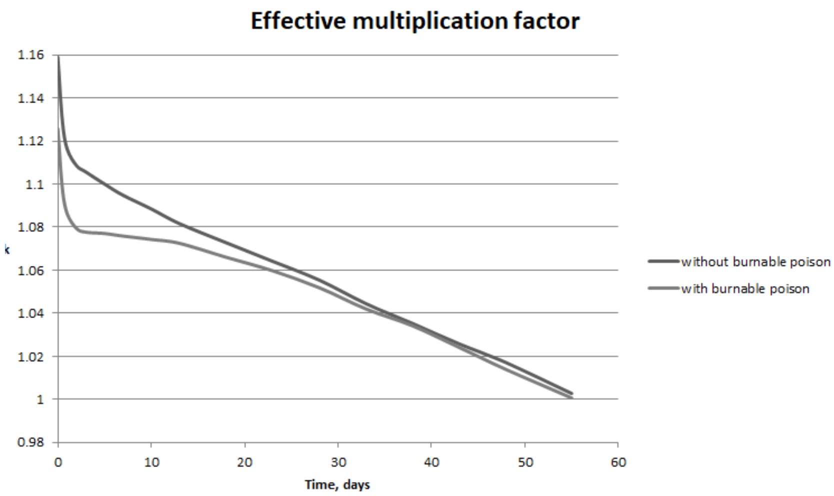

Figure 1: Effective multiplication factor as a function of time.

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DOUBLE CORE HOLE PRODUCTION IN ELECTRON K-CAPTURE AND ATOMIC PHOTOIONIZATION

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Double core hole (DCH) states enclose two vacancies in the electronic K-shell of atoms and molecules. This object currently attracts close attention and DCHs might become a new tool for chemical analysis [1] and plasma diagnostics [2]. DCHs are efficiently created by high-brilliance

X-ray free-electron lasers in double ionization by two sequentially absorbed γ-quanta [3]. On another side, the DCHs were first detected many years ago in the process of K-electron capture by an atomic nucleus [4], when the nuclear charge is reduced by unity, and the second electron is shaken-up from the K-shell mostly due to the sudden change of the atomic potential. Using bright synchrotron radiation sources, the DCHs are observed in photoabsorption of the X-ray photon by the K-shell electron, with simultaneous shake of the second K-electron [5], similar, in a sense, to the case of the K-electron capture, but with the nuclear charge remaining the same.
In this theoretical contribution we compare the two mechanisms of producing the DCH: K-electron capture and K-shell photoionization. General theoretical approaches to both problems are known, but we are not aware of such a comparison, based on up-to-date models for many-electron atoms. We also believe that theoretical predictions for the shake process in the K-capture, made decades ago, may be improved by using these models. Here we focus on the DCH states in ^{7}Be and ^{37}Ar isotopes with natural electron capture radioactivity and determine the relative DCH production probability P_{KK}. Furthermore, we analyze the relative probability of shake-up and shake-off, when the second K-electron is excited to a discrete state or is ionized, respectively. The shake-off electron spectra in the K-capture are obtained and compared with the results of different theoretical approaches and experiment. The photoionization calculations were performed by the R-matrix method with B-splines, as realized in the BSR package [6]. The non-orthogonality between electron wave functions in the initial and final states, which is crucial in treating ionization from the inner shell, was fully taken into account. The electron wave functions for the bound states were obtained in the multi-configuration Hartree-Fock approximation. The model for the K-capture is based on conventional sudden approximation and is utilizing codes from the same BSR package. Detailed results will be presented at the conference.

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TIME-DEPENDENT ANALYSIS OF NEUTRONS TRANSFER REACTIONS ^{181}TA(^{18}O,^{19}O) AT NEAR-BARRIER ENERGIES

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Numerical solution of the time-dependent Schrodinger equation (TDSE) [1] is used for studying neutron transfer processes at near-barrier energies. The evolution of the wave functions for outer neutron is determined for reactions ^{181}Ta(^{18}O,^{19}O). TDSE allows us to visualize the dynamics of taking place processes [1-3]. The transfer probabilities are calculated for outer neutron shells of the colliding nuclei. The results of calculations of transfer cross sections are in satisfactory agreement with experimental data [4] for reaction ^{181}Ta(^{18}O,^{19}O). High probability of neutron transfer from the ^{181}Ta nucleus to the $2s$ orbital of ^{18}O nucleus at near-barrier energies has been yielded (see Figure 1). In previous our work [4], differential cross sections for the formation of oxygen isotopes in the reaction ^{18}O + ^{181}Ta have been measured at projectile nucleus energy $10A$ MeV on the high-resolution magnetic spectrometer MAVR. Theoretical analysis has been performed in the DWBA formalism using the FRESCO code under the assumption of sequential neutron transfer mechanism.

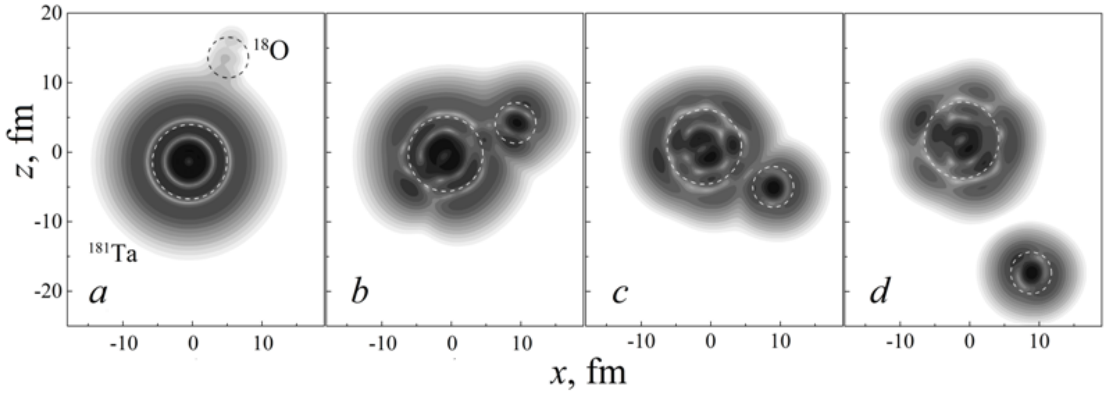

Figure 1: Evolution of probability density of outer neutron of ^{181}Ta nucleus (a, b, c, d) in ^{18}O+^{181}Ta reaction at $E_{\text{c.m.}}$ = 81.86 MeV and the impact parameter b = 4.76 fm (V_{B} = 68.94 MeV). The radii of the circles are equal to the root-mean-square charge radii of the nuclei.

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CONTRIBUTION OF TENSOR FORCES TO FORMATION OF GAMOW-TELLER RESONANCE AND ITS OVERTONE IN CLOSED-SHELL PARENT NUCLEI

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A mean-field and interaction in the particle-hole (p-h) channel are the input quantities for any RPA-based approach to describing Gamow-Teller Resonance and its overtone – Isovector Giant Spin-Monopole Resonance in the $\beta^{(-)}$ -channel (GTR and IVGSMR$^{(-)}$) , respectively). The recent example of such an approach is given in Ref.[1], where main properties of mentioned resonances in ^{208}Bi are described within the continuum-RPA-based semimicroscopic p-h dispersive optical model. A realistic partially self-consistent phenomenological mean field and Landau-Migdal p-h interaction have been used in this study. Provided that dimensionless strength g' of the spin-isospin part of the mentioned interaction is adjusted to reproduce in calculations of the GT strength function the observable GTR energy, the calculated IVGSMR$^{(-)}$) energy is found to be less (on about 3 MeV) than respective experimental value. In the present study, we attempt to resolve this puzzle by taking into account tensor forces, which lead to mixing 1^+ spin-monopole and spin-quadrupole excitations. In applying to describing GT strength distribution, tensor forces have been considered in Ref.[2]. Mentioned mixing takes place due to both the spin-orbit term in a mean field (so-called nonsymmetric or non-diagonal approximation in RPA-based approaches employing central forces [3]) and non-central (tensor) forces. Using the mentioned continuum-RPA-based analysis of Ref.[1] as a starting point, we resolved the above-described puzzle related to evaluation of the IVGSMR$^{(-)}$) energy by

taking tensor forces into account. As expected, the strength parameter of the spin-isospin part of non-central forces g'_T is found to be less than the Landau-Migdal parameter g'.
This work was partially supported by the Russian Foundation of Basic Research (grant No. 19-02-00660).

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DEVELOPMENT OF A FACILITY FOR FAST NEUTRON SPECTROMETRY USING A PLASTIC SCINTILLATOR EJ-276 WITH PSD CAPABILITY

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The paper presents the development stage of an installation for fast neutron spectrometry using an EJ-276 plastic organic scintillator including the results and processing of measurements of mixed gamma-neutron spectra of an ING-07T pulsed neutron generator, calibration of the spectrometer, and unfolding of neutron spectra. Separation of signals from gamma and neutron radiation was carried out on a CAEN-DT5730 digitizer using the pulse shape discrimination (PSD) method. The obtained experimental results are compared with the results of mathematical modeling in the GEANT4.
The PSD spectra of the ING-07T pulsed neutron generator with and without a neutron moderator were measured, as well as the spectra of the spontaneous fission source Cf-252. As a result it was possible to successfully separate the mixed signal of the neutron generator into signals generated by gamma and neutron radiation with acceptable quality (parameter Figure of Merit (FoM) ~ 1.5 at a radiation detection threshold of 200 keV). At the same time, PSD separation with FoM> 1 is considered to be of high quality.
The spectrometer based on an organic scintillator was calibrated. Calibration in this case is an independent task due to the absence of full absorption peaks in the energy spectrum and is carried out along the Compton edges by using simulated spectra. In addition, it was shown that, due to the different light outputs from neutron and gamma radiation, calibration should be carried out separately for each type of radiation (in this case, according to the electrons and protons of the recoil). At the same time, neutron calibration was carried out based on our own experiment and published data on measuring the light output in an EJ-299 plastic scintillator (analogous to EJ-276) [1-3].
Moreover, the neutron energy spectra of a pulsed neutron generator and a spontaneous fission source Cf-252 were unfolded using least squares method and maximum entropy method (MAXED program). It is shown that results of unfolding are correct and, therefore, this technique will allow us to restore spectra from other types of neutron sources.

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STUDY OF ELEMENT CONTENT OF ARCHAEOLOGICAL SAMPLES AND METEORITES BY X-RAY FLUORESCENCE AND NEUTRON ACTIVATION ANALYSIS

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In recent years, studies based on the application of the natural sciences methods on archaeological research have become increasingly important. The number of research programs on studying the cultural heritage of various eras is increasing. Still continues the development of different modern techniques for non-destructive analysis of the elemental and structural composition of ancient materials, their age and origin.

Neutron activation and XRF analysis are promising methods for analyzing of element content of archaeological materials. In present work the results of studies on development of instrumental neutron activation and X-ray fluorescence analysis of archaeological materials and fragments of meteorites are presented. Also the results of analysis of archaeological finds and fragments of the meteorite using the developed techniques are presented.

The quantitative composition of the meteoritic matter, which can be attributed to carbonaceous chondrites, is determined. Analysis of archaeological finds: according to the quantitative content of certain elements, all archaeological finds (ring, coin, bell, deer-form candlestick) can be attributed to the Bronze Age.

NEUTRON SPECTRA UNFOLDING IN NEUTRON ENERGY RANGE FROM 0.1 TO 15 MEV FROM DIAMOND RADIATION DETECTOR RESPONSE

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Diamond radiation detectors became more popular in the neutron radiation measurements at these days. It's happen due to the such detectors advantages as small sensitive volume (which lead to less distortion from detector housing in the detected neutron spectra), high radiation, temperature and chemical resistance, low energy consumption, ability to work in high magnetic fields and low sensitivity to the background gamma- or x-ray radiation. Besides this, there is decreasing in cost of such detectors due to the development of artificial diamond growth.

In this paper, we present the results of the development and creation of two algorithms for neutron spectrum unfolding with a diamond detector responses. One of the algorithms is based on the detector response decomposing procedure into the sum of basic components, which are the product of the responses matrix. To implement the decomposition procedure, a modified nonlinear least squares method is used in which the main modification is a condition for mandatory non-negativity of the problem possible solutions. The second algorithm is a variation of the Tikhonov regularization method for solving the unfolding spectra problem. For the second algorithm there also performed searching the optimal value of the regularization parameter value.

Verification of the created algorithms was carried out using model spectra and detector responses obtained using Geant4 tools. In this case, the detector model developed in Geant4 [2] was verified by comparing the simulation and experiment results for detecting neutron and alpha radiation. The model spectra and responses of radioisotope neutron sources (252Cf, PuBe), as well as the spectra

of neutrons formed during the DT reaction, are considered.
Also, in this work, the quality criteria for the unfolding of neutron spectra [3] are considered. The studies showed that the use of the response matrix obtained using Geant4 allows the unfolding of neutron spectra in the energy range from 0.1 to 15 MeV from diamond detector responses a with a difference in the unfolded and the real one spectrum less than 1%. In this case, the solution of unfolding problem remains stable in the presence of uncertainty in the input data, which is determined by the inaccuracy of the simulation or modeling results.

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EVALUATION OF THE π^+n AND π^0p ELECTROPRODUCTION CROSS SECTION FROM THE DATA MEASURED WITH THE CLAS DETECTOR

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The measurements of exclusive π^+n and π^0p electroproduction with the CLAS detector in Hall B at Jlab provided the dominant part of the world data on observables of these channels [1] stored in the CLAS Physics Data Base [2]. The data on exclusive $N\pi$ and $\pi^+\pi^-p$ electroproduction are the major source of the information on nucleon resonance (N^*) electroexcitation amplitudes. They offer insight into the N^* structure and strong QCD dynamics which underlie the nucleon resonance generation from quarks and gluons [1,3,4]. The approach for evaluation of the four-fold $N\pi$ differential cross sections and unpolarized, transverse-transverse, longitudinal-transverse exclusive structure functions will be presented in the talk. The estimates of $N\pi$ electroproduction observables have become available from the measured with the CLAS detector differential cross sections for the first time. They cover a broad kinematics area of the invariant masses of the final hadron system of $W < 1.7$ GeV and the photon virtuality range $Q^2 < 5.0$ GeV^2. The estimated $N\pi$ cross sections and exclusive structure functions are of particular importance both in the studies of the N^* structure in 1-dimension and in exploration of the ground nucleon structure in 3-dimesions from the results on the chiral-odd generalized parton distributions constrained by the data of deeply virtual $N\pi$ electroproduction.

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SUPERCONDUCTING TUNNEL JUNCTIONS AS NUCLEAR PARTICLE DETECTORS

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Josephson current between two one-dimensional nanowires with proximity induced either s-wave or p-wave pairing and separated by a narrow dielectric barrier in the presence of Rashba spin-orbit interaction (RSOI), in-plane and normal Zeeman magnetic fields (ZMF). A topological superconducting phase in a Josephson junction of s-wave superconductors (s-JJ) is realized under the condition $|\Delta|^2 > B^2 + h^2$, where Δ, B, and h are correspondingly the gap, Zeeman energy of in-plane and normal magnetic fields. Instead, the condition $\Delta_k = \frac{\vec{k}}{|k|}\Delta_0$ guarantees an existence of a conducting state in the gap and realization of a generic topological phase of the p-wave superconductor (p-JJ). Andreev retro-reflection is shown to be realized through two different channels. A scattering in a conventional particle-hole channel, when an electron-like quasi-particle reflects to a hole-like quasi-particle with opposite spins, provides the current which depends only on the order parameters' phase differences ϕ, and oscillates fractionally with 4π period. Second anomalous particle-hole channel, corresponding to the Andreev reflection of an incident electron-like quasiparticle to hole-like quasi-particle with the same spin orientation, survives only in the presence of the in-plane magnetic field. The contribution of this channel to the Josephson current oscillates with 4π period not only with ϕ but also with orientational angle of the in-plane magnetic field θ resulting in a magneto-Josephson effect. Evident expressions for the effects of RSOI and ZMF on Andreev bound state energy are found in several asymptotic cases for both s-JJ and p-JJ. RSOI and ZMF are shown to split the quasi-electron and quasi-hole excitation states in the superconducting gap, and two quasi-particle and quasi-hole pairs instead of one pair appear in the gap, which are localized symmetrically around Fermi level. ZMF is shown to destroy this symmetry. Even in the absence of the magnetic fields in s-JJ the energy gap between the Andreev bound states decreases with increasing RSOI. Investigation of ac-Josephson current in s-JJ shows that the width of the resulting Shapiro steps in such a system can be tuned by varying the RSOI constant. In the presence of RSOC and normal-to-plane magnetic field h in p-JJ, a forbidden gap is shown to open in the dependence of Andreev bound state energies on the phases ϕ and θ at several values of RSOC strength and ZMF, where Josephson current seems to vanish.The formalism that we develop here may be extended to regime of strong α and B where the presence of Majorana bound states shapes the characteristics of the Josephson current.

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SOME CORRELATIONS OF SECONDARY CHARGED PIONS PRODUCED IN ULTRA-RELATIVISTIC NUCLEAR COLLISIONS

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In the present articles an attempt has been made for the determination of multiplicity distributions of the secondary charged particles produced in the central region of relativistic heavy ion collisions.

Due to sophisticated measurement of energy in the nuclear emulsion experiment only some particles having special criteria could be selected to measure their energy with consenting accuracy. A hypothetical model is proposed to correlate the energy of the produced particles to their emission angles so that it becomes easy to estimate the energy distribution in terms of measured emission angle. The proposed model is constructed upon statistical thermodynamic assumptions. Moreover, two additional base functions are originated that play the role of the statistical angular weight factor and the nuclear density of the compressed nuclear matter at the moment of particle emission. The prediction of the model are compared with complete set of measured data of the reactions of proton, helium, carbon and neon nuclei with the composite emulsion nuclei as target at an energy of 14.6A GeV.

PHOTONUCLEAR REACTIONS ON ^{102,104}PD

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Experimental studies and theoretical calculations of photoneutron reactions on light palladium isotopes ^{102}Pd and ^{104}Pd were performed. The target from a natural mixture of palladium isotopes was irradiated with brake γ-quanta on the RM-55 electron accelerator at an electron energy of 55 MeV. Absolute yields of photonuclear reactions on ^{102}Pd and ^{104}Pd isotopes with up to three neutrons are determined. Comparison with the results of calculations using the TALYS [1] and the estimated cross sections from the KAERI library [2] showed that in all cases, the theoretical cross sections of photoneutron reactions are overestimated. This is due to the fact that the theoretical calculations of partial cross sections did not take into account the isospin splitting of GDR, which should lead to a significant increase in the share of photoproton reactions and a decrease in the share of photoneutron reactions in the full cross section of photoabsorption on the ^{102}Pd and ^{104}Pd isotopes.

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HIGH-PRECISION LIMITS ON W-W′ AND Z-Z′ MIXING FROM DIBOSON PRODUCTION USING THE FULL LHC RUN 2 ATLAS DATA SET

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The full ATLAS Run 2 data set with time-integrated luminosity of 139 fb^{-1} in the diboson channels in hadronic final states is used to probe a simple model with an extended gauge sector (EGM), proposed by Altarelli *et al.*, and often taken as a convenient benchmark by experimentalists. This model predicts new charged W' and neutral Z' vector bosons with modified trilinear Standard Model gauge

couplings, decaying into electroweak gauge boson pairs WZ or WW, where W/Z decay hadronically. Exclusion limits at the 95\% C.L. on the Z' and W' resonance production cross section times branching ratio to electroweak gauge boson pairs in the mass range of $\sim 1 - 5$ TeV are here converted to constraints on W-W' and Z-Z' mixing parameters and masses for the EGM. We present exclusion regions on the parameter space of the the W' and Z' by using the full Run 2 data set comprised of pp collisions at $\sqrt{s} = 13$ TeV and recorded by the ATLAS detector at the CERN LHC. The obtained exclusion regions are significantly extended compared to those obtained from the previous analysis performed with Tevatron data as well as with LHC data collected at 7 and 8 TeV in Run~1 and are the most stringent bounds to date.

DEVELOPMENT OF THE NEUTRINO CONTROL METHOD FOR NUCLEAR REACTORS WITHIN THE iDREAM PROJECT

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The aim of the iDream project is a development of an industrial detector of the reactor antineutrinos for the reactor active zone monitoring. There is a description of the control methodology, a prototype design and a status of the project up to date.

AVERAGE CROSS SECTIONS OF PHOTONUCLEAR REACTIONS ON ^{89}Y

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In this work, an experimental study of ^{89}Y the photodisintegration is performed. Absolute yields and average cross sections weighted by the bremsstrahlung were measured for photoneutron reactions on ^{89}Y at the upper limit of 55 MeV brake photons. The measured yields and average cross sections weighted by the bremsstrahlung are compared with the yields of reactions calculated from theoretical cross sections of photoneutron reactions based on the TALYS and with the results of experiments performed on beams of quasimonochromatic [1,2,4] and brake photons [5-8] and the estimated cross sections. The average cross section calculated in this work, weighted by the bremsstrahlung for the photoneutron reaction (γ, 1n) is consistent with the results of the calculation according to the TALYS and the cross sections from [1, 4].

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^{166}Ho FORMATION IN PHOTONUCLEAR REACTIONS ON A NATURAL MIXTURE OF ERBIUM ISOTOPES

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The method of induced activity was used to study photonuclear reactions on a natural mixture of erbium isotopes. The experiment was performed on a bremsstrahlung of an RM55 electron accelerator at an electron energy of 55 MeV. The study examined the possibility of producing carrier-free ^{166}Ho isotope in photonuclear reactions on a natural mixture of erbium isotopes. Experimental data on the cross-sections of photoproton reactions on Er isotopes are not available in the literature. The yields of the formation of ^{161,165}Er isotopes as a result of ^{nat}Er(γ, in) reactions, the target nuclide ^{166}Ho and the side nuclide ^{165}Ho as a result of ^{nat}Er(γ, in1p) reactions were measured. The yield of ^{166}Ho formation under the experimental conditions was approximately $4 \cdot 10^4 Bq/(\mu A \cdot h \cdot g/cm^2)$. The experimentally obtained yields of photonuclear reactions are compared with the yields calculated using theoretical cross-sections of photonuclear reactions from the combined model of photonuclear reactions (CMFR) and the TALYS program. There is a good agreement between the experimental data and the results of the calculation by CMFR for both photoneutron and photoproton reactions.

NEW "DRY" PLASMA TECHNOLOGY FOR NUCLEAR MATERIALS PROCESSING

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New approach to solve a wide range of problems in various nuclear materials processing is discussed. One of them – irradiated reactor graphite decontamination with inert gas (argon) plasma sputtering and thermo-treatment with interdisciplinary synthesis of plasma physics, materials science and reactor physics. At present time wide search of effective technology to deactivate reactor graphite is very acute due to the large volumes of accumulated irradiated
graphite in the world (about 100 thousand tons) and the challenging problem of uranium-graphite reactors decommissioning period. Proposed high pressure short discharge technology has advantage compared with traditional radiochemistry in versatility (work with any kind of radionuclides, since ion etching process allows ones to sputter any atoms) and in the absence of the additional secondary radioactive wastes (as a buffer media is inert gas forming no chemical
compounds with radionuclides). It is known [1] that one of the possible contamination mechanisms of graphite masonry surfaces is the neutron activation of nitrogen atoms from the cooling gas mixture, as well as the process of intercalation of nitrogen migrating inside graphene-graphene layers of graphite.
This leads to the fact that the RBMK graphite masonry acquires significant activity due to the 14C isotope localized on and inside of the surface layers of micron depth. We experimentally studied sorption capacity of the surface for some fresh (before irradiation) reactor graphite samples and

obtained that the 14C isotopes arising from nitrogen neutron activation may be localized under the graphite surface of the 30 nm thickness. It is very suitable for plasma etching and provides problems for the other competitive technologies creating large volume of secondary radioactive wastes. Our estimates of operating parameters for the irradiated reactor graphite deactivation in an inert gas plasma were made for discharge current (0.001 - 1 A / cm2), voltage (300-1000V), inert gas pressure (0.01-1 atm.), gap between the treated graphite surface and the anode collector
(1-5mm). The reactor graphite temperature under treatment was in the range of 600-1800K [2], integrity of the treated graphite blocks remains and they are ready for a final burial, in comparison with competitive approaches.
Also proposed plasma technology is applicable for a fast deactivation of the internal of the nuclear power plants constructions during reload or repair periods, instead of radiochemical methods. Described plasma treatment provides removal and transfer of the surface contaminating radionuclides in highly concentrated form with the opportunity to extract selectively useful radioisotopes via proposed spatial differentiation of the sputtered atoms
condensation according to their individual evaporation temperatures.
Additionally, some modification of our technology can be used for a new scheme of spent nuclear fuel reprocessing with uranium deoxidation-oxidation reactions and fission fragments removal in plasma gas mixture with the following fuel sedimentation, adapted for the perspective new nuclear energetics and closed circulating fuel cycle. Technology is patented in collaboration of Intro-Micro LLC, Concern Rosenergoatom JSC and Rosatom [3] and is suitable for Fukushima NPPs accident dismantling efforts.

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A SEARCH FOR RESONANT ABSORPTION OF SOLAR AXIONS VIA THE TM-CONTAINING BOLOMETER

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The existence of an axion (a hypothetical pseudoscalar boson) was originally considered as a consequence of sponatneous breaking of newly introduced chiral symmetry, which was suggested in 1977 by R. Peccei and H. Quinn in attempt to solve the strong CP problem. The interactions of axion with ordinary matter are described via the effective coupling constants that are inversely proportional to the symmetry breaking scale f_A. The experimental searches for axion have been attempted ever since its original introduction, although none had yielded positive results so far.
After exclusion of "standard" axion (that assumed $f_A \approx 250$ GeV, comparable to the electro-weak scale), the theoretical model were modified so that f_A value was allowed to become arbitrary large, therefore supressing the axion couplings and reducing its mass. This led to the appearance of light and weakly interacting "invisible" axion, which naturally became the viable dark matter candidate, further stimulating the motivation for its experimental discovery.
Axions should be intensely produced inside stellar cores and significant portion of axion experiments is targeted towards the detection of solar axions. Due to the axion-nucleon coupling axions can undergo resonant absorption in nuclear transitions of M1-type. A series of experiments were performed at Petersburg Nuclear Physics Institute searching for the resonant absorption of solar axions by several target nuclei (^{7}Li [1], ^{57}Fe [2], ^{169}Tm [3], ^{83}Kr [4]).

A new technique, developed in collaboration with Max Planck Institute for Physics (Munich) and Kurchatov Institute (Moscow), allows for a significant increase in experiment sensitivity by employing the cryogenic bolometer detector based on the Tm-containing crystal [5]. This new approach scalable and can be potentially used for installation with a kg scale target.

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ON THE INFLUENCE OF CHEMOTHERAPY ON THE BRAGG PEAK PARAMETERS IN THE WATER CUBE MODEL

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Both radiation therapy and chemotherapy are efficient methods of cancer treatment [1]. Efficiency of the hadron therapy is based on the phenomenon of the Bragg peak. Parameters of the Bragg peak such as its distance from the entrance pointe and maximum magnitude depend on kind of particles in the therapeutic beam and it energy, physical properties of target medium and its chemical composition [2]. During chemotherapy and some time after it chemical composition of tissues may be changed so it may leads to changes of the Bragg peak parameters in the case of combined treatment. Influence of the chemotherapy on the dose-depth distribution is studied. The computational models are proposed and different schemes of chemotherapy have been considered for the proton and carbon ion beams. The study is based on the numerical simulations with the software package Geant4.

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ПРИМЕНЕНИЕ ГАММА-СПЕКТРОМЕТРИИ С ГЕРМАНИЕВЫМ ДЕТЕКТОРОМ ДЛЯ ЦЕЛЕЙ ПОИСКОВОЙ ГЕОЛОГИИ

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Радиогеохимические методы входят в состав поисково-оценочных и разведочных работ на углеводороды, рудные тела и алмазы. Вместе с тем существуют ограничения для их более широкого применения, связанные как с особенностями геохимии урана (образование

органометаллических соединений, переменная валентность и др.), так и с большими трудозатратами при исследовании изотопов радиоактивных элементов.
Для повышения эффективности результатов исследований геологических объектов предложено применение неразрушающего прецизионного гамма-спектрометрического метода. Применение метода основано на анализе значений такого показателя как отношение активностей урана и тория (AU/ATh). Этот показатель определяется по отношению интенсивностей гамма-линий 351,9 кэВ и 238,6 кэВ в распаде дочерних нуклидов ^{214}Pb и ^{212}Pb. По образцам керна скважин нефтегазоносных регионов России были получены данные по активности урана, тория и калия. Измерения образцов пород (50 г) и пластовых вод из скважин (100 мл) проводились на гамма-спектрометре с полупроводниковым HPGe-детектором с чувствительным объемом 51 см3.
Предложенный показатель AU/ATh, отличается от широко применяемого в геохимии ториево-уранового отношения значительно большим диапазоном изменения значений, что более обоснованно позволяет выявить те или иные процессы в земной коре. Например, наиболее высокие величины отношения активности урана к активности тория, свидетельствующие о накоплении урана в органическом веществе, достигают нескольких десятков, а величины геохимических значений ториево-уранового отношения для этих же образцов оказываются на порядок меньше. В работе на основе предложенного критерия и данных других методов [1] показано, что по значениям отношения активности урана и тория (AU/ATh) возможен контроль за рядом геологических процессов: от этапов осадконакопления и влияния разломной тектоники, зон распространения трещиноватых пород до процессов накопления в отложениях нерастворимого органического вещества, урана и углеводородов. Данный способ может быть предложен при проведениии исследований на поисково-оценочном этапе геологоразведочных работ.

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INVESTIGATION OF THE ELECTRIC FIELD UNIFORMITY IN THE RED DETECTOR

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Dark matter remains one of the few fundamental problems of particle physics and cosmology that is not explained in the Standard Model (SM). Today, the direct search for dark matter results in a limitation on parameter space of mass and the spin-independent cross section of WIMP interaction. For low mass WIMPs, the best results are shown by the noble liquid time projection chambers (TPCs). The signal in the LAr TPC is observed both from excitation, which results in a direct scintillation, and from ionization of argon. Part of the electron-ion pairs recombines, and the remaining free electrons are drifted towards the liquid surface, by an applying electric field, and are extracted into the gas phase. In the so-called gas pocket, electrons, further accelerated by a stronger electric field, excite the gas atoms producing a secondary scintillation via electroluminescence. The light components emitted in liquid argon and in gas are called *S1* and *S2*, respectively. To accurately reconstruct the position of recoil events, it is necessary to know the exact parameters of the electric field in the TPK.
This work presents the results of modeling the drift field in TPC for the ReD experiment, aimed at nuclear recoil studies in a neutron beam at the INFN Laboratori Nazionali del Sud in Catania. To verify the accuracy of the simulation of the electric field in the chamber, a comparison of

2-dimensional modeling, made by the Comsol multiphysics package, with the semi-empirical formula [1] was conducted, the result of this study will be presented in this talk.

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DEGRADATION OF SI-BASED DETECTORS PARAMETERS UNDER THE ALPHA-PARTICLE IRRADIATION

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The response function of the recoil nuclei in the detectors designed to detect neutrinos or dark matter particles can be determined only by using a neutron source with known energy spectrum. Therefore, the development and creation of a calibration neutron source is an important task for a number of current and future nuclear and astrophysical experiments [1, 2]. The neutron source has to be combined with a semiconductor detector that detects the moment of neutron appearance.
Silicon semiconductor detectors are widely used in various nuclear physics experiments and possess perfect operating parameters, such as thin window layer, sufficient temporal and good energy resolutions. However, their performance could be considerably limited by the radiation defects formed during the operation process. Since in the suggested experiments [1, 2] semiconductor detectors should operate under intense level of α-particles and fission fragments irradiation, which inevitably accompany the process of spontaneous fission of the nucleus, studies of the radiation hardness of Si detectors are of a significant importance for the successful implementations of the suggested nuclear physics experiments.
This work is devoted to the investigations of Si detectors parameters degradation during long-termed irradiation by α-particles. For these investigations an experimental setup for simultaneous measurement of α-particles spectrum and determination of the operational indications of the detector degradation (decrease of energy resolution and signal-to-noise ratio, growth of the reverse current, etc.) was developed by our group. Two types of Si detectors were under investigations - silicon-lithium Si (Li) p-i-n detectors and silicon surface barrier detectors. As a result of the measurements, the maximal permissible radiation doses for the correct operation of the detectors of both types and the correlation between the received radiation dose and the spectroscopic characteristics of the detectors were determined. Additional set of experiments was aimed to study the type and concentration of the radiation defects formed under irradiation. Detailed discussion of the obtained experimental results will be presented at the Conference.
The reported study was funded by RFBR, project number 20-02-00571.

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CALIBRATION OF GAMMA RADIATION DETECTION UNIT BASED ON LABR3 (CE) CRYSTAL IN THE ENERGY RANGE FROM 30 keV TO 10 MeV

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Gamma radiation spectrometric detection units based on lanthanum bromide LaBr3 (Ce) have significantly better energy resolution in comparison with detection units based on common NaI (Tl) crystals. To provide measurements in fields of high-energy gamma radiation in energy range from 30 keV to 10 MeV an experimental detection unit based on a LaBr3 (Ce) detector with dimensions of Ø38x38 mm was developed by SPE «ATOMTEX».
During the energy scale calibrating of the detection unit the energy range was divided into 2 sub-ranges: from 30 keV to 3 MeV and from 3 MeV to 10 MeV. The energy scale of the detection unit in sub-range from 30 keV to 3 MeV was calibrated using OSGI type point sources of gamma radiation. Calibration in energy sub-range from 3 MeV to 10 MeV of the detection unit was carried out according to the spectra obtained in the field of capture gamma radiation at the neutron radiation calibration facility AT140 using titanium and nickel targets. The thermal neutron flux was formed by the container collimator of the facility with a Pu-Be source in the geometry of thermal neutrons. Obtained during the measurements the instrumental spectrum is complex due to neutron irradiation of the target, the detection unit and surrounding materials of constructions.
The scintillation detection unit with a NaI (Tl) crystal Ø63x160 mm was calibrated under similar conditions. The detection efficiency for both detection units in the entire energy range under consideration was estimated. An analysis of the acquired instrumental spectra in the field of capture gamma radiation from nickel and titanium targets showed that due to the better energy resolution the detection unit with a LaBr3 (Ce) crystal at smaller detector sizes can be calibrated more accurately in energy range from 5 MeV to10 MeV.
Results of the investigation were used to develop detection units with a LaBr3 (Ce) -based scintillation detector designed to measure the energy distribution of gamma radiation and for radiation control purposes such as identification of the radionuclide composition of a controlled object and measurement of the ambient dose rate equivalent of gamma radiation in mixed gamma-neutron fields in the range from 30 keV to 10 MeV.

DETERMINATION OF ISOBAR YIELDS FROM MASS DISTRIBUTION OF HEAVY FISSION PRODUCTS IN ^{239}PU(NTH,F) REACTION

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Sets of fission yields have an impact on different fields of interest. From a theoretical standpoint they are interesting for the understanding of matter, because they allow the description of the phenomena occurring in a nucleus undergoing large collective motion at low excitation energy and, hence, are influenced by nuclear shells that disappear at higher excitation energies. From a practical standpoint fission yields are of importance for the design of nuclear reactors and for waste management.
The purpose of work was definition of independent yields - number of atoms of a specific nuclide produced directly (not via radioactive decay of precursors) in fission reactions. Measured heavy fission products distributions on ionic charges for ^{239}Pu(nth,f) reaction are used for estimation of isobar composition [1]. The basic difficulty consisted in correct transition from measured ionic charges to charges of heavy fragments at the moment of nuclear fission. For this transition we used the

modified expression from [2]. Isobar yields for the measured heavy fission products of ^{239}Pu(nth, f) reactions are defined and compared with theoretical data [3].

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PERFORMANCE OF THE MPD DETECTOR FOR THE STUDY OF STRONGLY-INTENSIVE MULTIPLICITY AND TRANSVERSE MOMENTUM FLUCTUATIONS IN HEAVY-ION COLLISIONS

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The Multi-Purpose Detector, to be operating at NICA, aims to study the phase diagram of strongly interacting matter at high baryonic densities. One of the sensitive tools to probe the critical behaviour is the analysis of event-by-event fluctuations. Strongly intensive observables are considered to be especially sensitive to the phase transitions as they suppress trivial volume fluctuations. In this contribution, we present the performance of the MPD detector in measurements of fluctuations via strongly intensive quantities between multiplicities and transverse momenta in different kinematic acceptances. The results from the full MPD simulation and reconstruction chains are demonstrated. The dependence of the considered fluctuation observables on the centrality estimation method is discussed as well.
This study was funded by RFBR according to the research project No 18-02-40097.

USING OF FILM SCINTILLATION DETECTORS FOR MONITORING THE OPERATING CONDITIONS OF A PHYSICAL SETUP

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Film scintillation detectors 0.3-0.5 mm thick and their corresponding optical fiber are used to detect α-radiation and various nuclear reaction products.
These detectors and the used spectrometric electronics make it possible to register radiation and transmit information with a frequency of more than 10^5 pulses per second and pulse duration ≤ 5 *ns*.
In combination with film-based detectors, XP2020 photomultiplier tubes were used.
The film scintillation detectors were made according to Russian Technology.

EXPERIMENTAL DATA OF ^{58}NI(N, α)^{55}FE REACTION CROSS-SECTION FOR 3.5 - 7.5 MEV NEUTRONS

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Nickel is a part of most stainless steels, therefore, the cross section for the helium production on the nuclei of the nickel isotopes is significant for evaluation of radiation damages in structural materials of reactors. 58Ni is the main isotope in the natural mixture (^{58}Ni 68.27%, ^{60}Ni 26.10%, ^{61}Ni 1.13%, ^{62}Ni 3.59%, ^{64}Ni 0.91%); therefore, its contribution is one of the determining ones.
The cross-section of the ^{58}Ni(n, α)^{55}Fe reaction was obtained on a solid target using new low-background digital spectrometer, based on an ionisation chamber with Frisch grid. The neutron flux was monitored using the ^{238}U fission reaction. Monoenergetic neutrons for the experiment were obtained at the accelerator complex of JSC "SSC RF-IPPE"" in the reaction D(d,n)^{3}He. The neutron spectrum was monitored during the experiment. The measurements were carried out for neutrons with energies from 3.5 to 7.5 MeV. The obtained data are in satisfactory agreement with the data of other authors and the available theoretical estimation, presented in the main libraries of evaluated data.

THE SYSTEMATIC SHIFT OF THE TIMING MARK FOR AN ORGANIC SCINTILLATOR AND ITS EFFECT TO THE PROMPT FISSION NEUTRON SPECTRUM

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An analysis of the experimental and theoretical works devoted to the spectra of prompt fission neutrons (PFN) showed serious contradictions in the obtained results. Most authors attribute the discrepancy in the measurement results to the influence of a number of systematic errors, the contribution of which is most pronounced at neutron energies below 1 MeV and above 6 MeV.
The vast majority of experiments on measuring the PFN spectra are carried out by the time-of-flight method. One of the possible sources of systematic error for this measurement method is associated with uncertainty in determining the timing mark from detector.
In the time-of-flight method any (even small) shift in the determination of the timing mark can lead to a significant change in the measured spectrum shape and, as a consequence, a change in the average energy of PFN. This work presents the results of a detailed study of the dependence of the systematic shift of the timing mark on the energy of the registered protons.
It is shown that a timing mark shift takes place, and its value is essential for the correct determination of the spectrum of PFN, especially for small path length.

ПЕРВЫЕ РЕЗУЛЬТАТЫ ПО ИЗУЧЕНИЮ ПИГМИ РЕЗОНАНСА МЕТОДОМ ФОТОПОГЛОЩЕНИЯ НА ЛУЭ-8-5 ИЯИ РАН

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Приведены первые результаты новых экспериментов по исследованию полных ядерных сечений фотопоглощения в области пигми резонанса (от 5 до 10 МэВ), выполненных на ЛУЭ-8-5 ИЯИ РАН. Начало экспериментов стало возможным после выполнения методических работ по модернизации ускорителя и системы формирования гамма пучка. Описан метод полного фотопоглощения, который ранее использовался в области гигантского дипольного резонанса (10–30 МэВ) и теперь адаптируется к области низких энергий. Этот метод позволяет получить данные о статической и динамической деформации и квадрупольных моментах исследуемых ядер.

MEASUREMENT OF THE TIME-OF-FLIGHT SPECTRA OF THE NEUTRONS BY THE INTEGRATED METHOD ON PULSED NEUTRON SOURCES

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An increase in the intensity of pulsed neutron sources leads to an unprecedentedly large pulsed neutron flux density up to $10^{11}\mathrm{n/s/cm^2}$ and, as a result, to the impossibility of using data acquisition systems operating in counting mode. On the other hand, in the study of small P-odd effects in stationary reactors, the integral method is often used. This article presents the results of measuring TOF spectra by the integral method.

PRECISION MEASUREMENT OF β-SPECTRA OF $^{144}\mathrm{Ce} -^{144}\mathrm{Pr}$ NUCLEI

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Precision measurements of β-spectra have always been and are still playing an important role in several fundamental physical problems, predominantly in neutrino physics. In Petersburg Nuclear Physics Inst. NRC KI, the β-spectra of $^{144}\mathrm{Ce} -^{144}\mathrm{Pr}$ nuclei were measured with aim to determine the spectrum of electron antineutrinos. The artificial source of antineutrinos $^{144}\mathrm{Ce} -^{144}\mathrm{Pr}$ is one of

the most promising for the experiments on the search for neutrino oscillations to the sterile state [1]. Several β-spectrometers based on silicon detectors have been developed. The first β-spectrometer, based on full absorption Si(Li) detector and thin transmission detector, allows to perform efficient separation β-radiation and accompanying X-rays and γ-radiation [2,3].
A new β-spectrometer was created from two Si(Li) detectors with a sensitive region thickness of more than 8 mm [4]. The response function of such a spectrometer for electrons with an energy of less than 3 MeV is almost Gaussian. The setup includes a 3" BGO detector for detecting gamma rays in order to select the decays of $^{144}\mathrm{Ce}-^{144}\mathrm{Pr}$ nuclei into excited levels of daughter nuclei. As a result, the beta spectra of $^{144}\mathrm{Ce}-^{144}\mathrm{Pr}$ nuclei were measured and the spectra of electron antineutrinos corresponding to β-transitions to the main and excited states. The measured form of the allowed β-transition is completely consistent with theoretical calculations. The created spectrometer with a response function close to Gaussian practically solves the problem of determining the spectrum of electronic antineutrino arising in the β-decay of ^{144}Pr nuclei. The spectrometer can also be used in precision measurements of the spectrum shape of various radioactive nuclei.
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T-ODD EFFECTS IN THE BINARY FISSION OF URANIUM INDUCED BY POLARIZED NEUTRONS

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T-odd effects in fission of heavy nuclei have been extensively studied during more than a decade in order to study the dynamics of the process. A collaboration of Russian and European institutes discovered the effects in the ternary fission in a series of experiments performed at the ILL reactor (Grenoble) [1-3] and the effects were carefully measured for a number of fissioning nuclei. The analogous effects for gammas and neutrons in fission of ^{235}U and ^{233}U were also measured [3-6] after the observation of T-odd effects for ternary particles accompanying the reaction ^{235}U(n,f) induced by cold polarized neutrons. All experiments up to now were performed with cold polarized neutrons, which suggests a mixture of several spin states of the compound nucleus, the relative contributions of which are not well known. The measurements of gamma and neutron asymmetries in an isolated resonance of uranium are important in order to get "clean" data. Therefore, our team continues to carry out a series of experiments by polarized neutrons with different energies. The present work describes a number of our team's measurements that include the results of T-odd effects in the

fission of uranium isotopes by polarized neutrons with different energies at the POLI facility and the MEPHISTO beamline of the FRM2 reactor in Garching.

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MEASUREMENT OF THE TIME DEPENDENCE OF THE BACKGROUND OF DELAYED NEUTRONS ON THE 1-ST CHANNEL OF IBR-2

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A new time-of-flight method for measuring the neutron lifetime τ_n was proposed in [1]. The time-of-flight method for measuring the neutron lifetime τ_n is very sensitive to the background. It was found that the background should be less than 10^{-6}. According to [2], between the power pulses of the IBR-2 reactor, about 7% of the reactor power is allocated. Since the number of neutrons is proportional to the power of the reactor, the background from the delayed neutrons will also be 7% in 200 milliseconds. Measurements of the background of delayed neutrons were made and a complex dependence of the background on time was established. The influence of the background of the delayed neutron on the accuracy of measuring the neutron lifetime by the time-of-flight method is estimated.

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IN SITU GAMMA SPECTROSCOPY DETERMINATION OF RADIOACTIVE CONCENTRATION IN SOILS

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The results of development of new method for *in situ* gamma spectroscopy determination of radioactive soil contamination are presented. The novelty of the method developed is that no priori assumptions about the distribution of nuclides in the soil and no soil sampling are needed. Only *in situ* spectra measured over the territory of interest are used.

The method is based on attenuation factor value determination from shielded gamma source spectrum directly. The only one peak in the spectrum is enough to calculate the shield attenuation value. No priori information about the shield or shield material sampling is used. The gamma spectrum of the unshielded source is not used too.
The results of *in situ* determination of artificial and natural radionuclides concentrations in different soils, including the soils with Chernobyl contamination, are presented.

OPTIMIZATION OF DIGITAL SIGNAL PROCESSING ALGORITHMS FOR NEUTRON DETECTOR BASED ON CS26LIYCL6:CE SCINTILLATOR

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One of the promising type of scintillation detector for neutron registration and spectroscopy is Cs26LiYCl6:Ce. The work presents study of characteristics of this detector. Optimization of digital algorithms for neutron/gamma-separation was performed. Pulse shape discrimination quality of charge integration and correlation analysis was investigated. Also tuning of pulse start time measuring was carried out. Time resolution for signals obtained from registration neutrons and gamma-rays was compared.

NUMERICAL STUDY OF THE MAGNETIC FIELD EFFECT ON COMPRESSED PLASMA

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The problem statement and a mathematical model of the interaction of a cryogenic and then a plasma target with powerful jets (plasma and laser beams) are presented taking into account the external and spontaneous magnetic field. The authors developed a numerical technique and a method for calculating the characteristics of a target and the parameters of compressing beams and jets in a strong magnetic field.
The processes in the target are simulated and the results of the calculation of the plasmodynamic parameters inherent in similar magnetic inertial fusion facilities are presented. The calculation results are presented in the form of graphical dependences of the main parameters of the plasma target (temperature, pressure, density) and magnetic field on the energy characteristics of the powerful radiation and compression system (laser radiation intensity, plasma jet velocity) over the radius of the target at different times.
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