EXPERIMENTAL RESULTS ON THE ELECTRON SCATTERING FROM NUCLEI WITH THE COINCIDENCE REGISTRATION OF CHARGE SECONDARY PARTICLE

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ABSTRACT

The new generation of experimental results obtained by using continious electron beams and coincidence of the scattered electrons with the secondary particles (SP) are discussed.

The investigation of varius objects by using electron or photon beams was always attractive for experimentalists and theoreticians. The reason is the possibility to use for analysis (i) the well developed theory of the electromagnetic interactions, (ii) the electron "pointlikeness" and (iii) weak interaction of electrons with strongly interacting objects. The interpretation of results obtained by using the electromagnetic probes has no principal theoretical difficulties. However, the small electromagnetic cross section and the necessity to take into account radiation corrections put the high requirements to the electromagnetic experiment luminocity. Here we discuss the nuclear structure investigation by using the electroexcitation of nuclei in the smoll and medium energy region (the excitation energy less than 100 MeV) below the pion production threshold.

In spite of mentioned difficulties the impressive results have been obtained recently in inclusive experiments on electron-nuclei scattering. In particular, that are the elastic scattering experiments for nuclear distribution measurements /1/, the transition dencity measurements by the electroexcitation of isolated levels. I can not stand to mention the example of the 3S-state proton charge density distribution in ^{206}Pb and ^{205}Tl /2/.

In the new generation experiments the reaction product is detected in coincidence with the electron, fixing the momentum transfer and energy of excitation. The additional informational degrees of freedom are the SP type, their energy and the emission direction. Such an experimental performance needs the special technical equipment. The main coincidence experiment demand is to use the continuous electron beam. This is why many projects meeting this demand and high luminocity appear durig last years. The table I shows the list of such facilities.

TABLE 1
THE HIGH DUTY FACTOR FACILITIES

LABORATORY	TYPE OF ACCEL.	ENERGY, MEV	D.F.%	AVERAGE CURR., MKA
		ACTING MACHINES		
1.NOVOSIBIRSK, USSR	Intern.target	100 -500	90	0.5 A
2.STANFORD, USA	Linac	70 -120	75	20
3.ILLINOIS, USA	Racetrac micr.	67	100	2
4.AMSTERDAM, NETH.	Linac	500	2.5	20

5.SACLAY ,FRANCE	Linac	600	1.0	1.0
6.MAINZ ,FRG	R.M.	180	100	10
7.MIT ,USA	Linac	700	1.0	0.5
8.TOCHOKU,JAP.	Stretcher	150	80	0.5
	PROGECTS			
9.DARMSTADT,FRG	Linac	130	100	20
10.NBS ,USA	R.M.	185	100	550
11.LUND ,SVEDEN	Stretcher	100 -550	100	10
12.SASCATOON,CAN.	Linac	300	80	
13.SAO PAULO,BRAS.	LINAC+STR.	17	100	100
14.SACLAY ,FRANCE	Linac+str.	500 -2000	100	100
15.MAINZ ,FRG	R.M.	840	100	100
16.CEBAF ,USA	R.M.	500 -4000	100	200
17.ILLINOIS,USA	R.M.	450	100	20
18.MIT ,USA	R.M.	250 -1000	100	
19.BONN ,FRG	Stretcher	2000	100	
20.MSU ,USSR	R.M.	110	100	100
21.KHARKHOV,USSR	Stretcher	2000	100	
22.NOVOSIBIRSK,USSR	Storage ring	100 -220	90	1.0 A
23.FRASCATI,ITAL.	Stretcher	500	100	100
24.MONTREAL,CAN.	R.M.	200	100	300
25.TSUKUBA ,JAP.	Linac	500	2.0	100

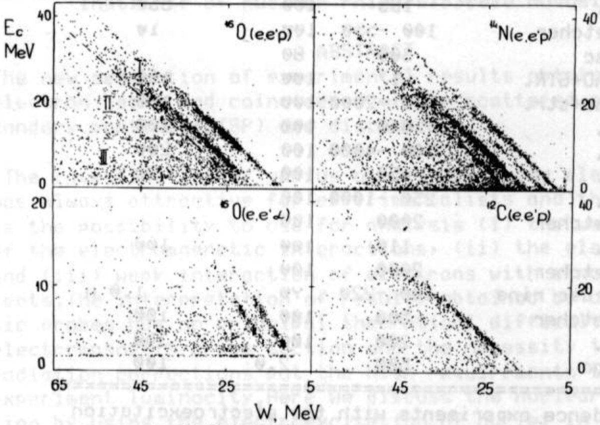
The list of the coincidence experiments with the electroexcitation on nuclei is not complet now,because the new results are appearing from several laboratories.

T A B L E II

THE (e,e'X) TYPE EXPERIMENTS

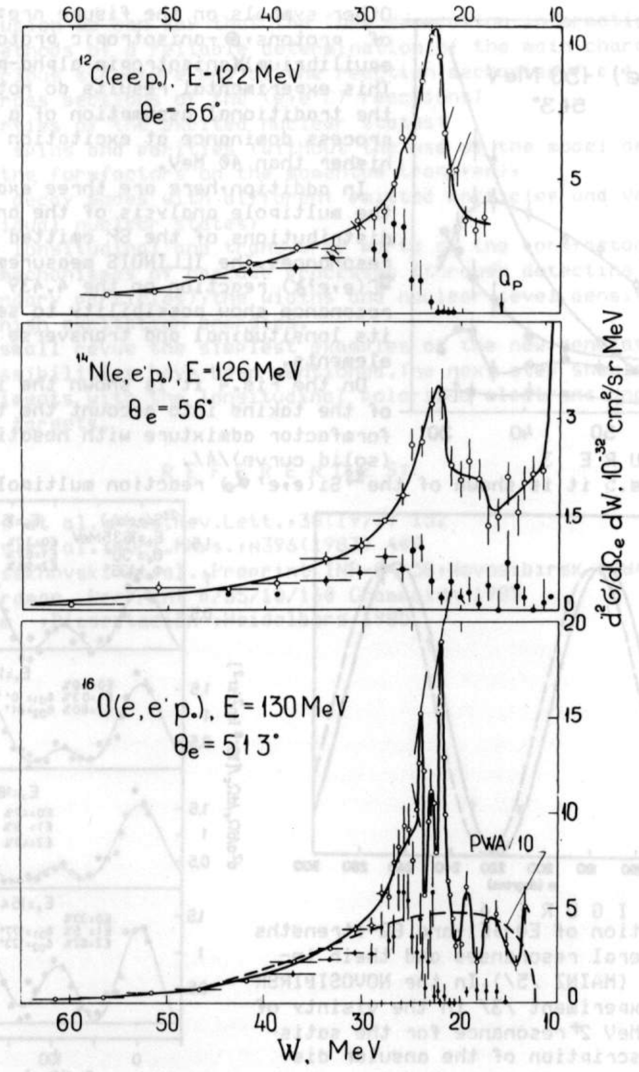
	REACTION	ENERGY (MEV)	EXC.ENERGY (MEV)	LABORATORY
1.	$^{12}C(e,e'p)$	90-126	19-27	STANFORD ,USA
2.	$^{16}O,^{14}N,^{12}C(e,e'C)$	130	0-70	NOVOSIBIRSK,USSR
3.	$^{1}H(e,e'p)$	110	-	"
4.	$^{2}\vec{D}(e,e'd)$	290,400	-	"
5.	$^{2}\vec{D}(e,pn)$	180	20-160	"
6.	$^{12}C,^{51}V,^{90}Zr,^{208}Pb(e,e'p)$	500	0-40	NIKHEF, AMST.
7.	$^{12}C(e,e'\gamma)$	67	4.4	ILLINOIS ,USA
8.	$^{208}Pb(e,e'n)$	80	9-16	"
9.	$^{12}C(e,e'p)$	86		"
10.	$^{28}Si(e,e'p)$	183		"
11.	$^{238}U(e,e'f)$	67	5-11.7	"
12.	$^{238}U(e,e'f)$	170		MIT , USA
13.	$^{238}U(e,e'f)$	180	4-14	MAINZ,GISSEN,FRG
14.	$^{28}Si(e,e'p),(e,e'\alpha)$	180	15-20	MAINZ , FRG
15.	$^{40}Ca(e,e'p),(e,e'\alpha)$	180	10-20	"
16	$^{2}D(e,e'p)n$		1965-2335	BONN , FRG
17.	$^{3}He(e,e'p)$	560		SACLAY, FRANCE
18.	$^{58}Ni(e,e'p)$	129	15-30	SENDAY, JAP.

Before showing typical examples of the experiments I should stress the main(in my opinion) feature of the coincidence information.This conclusion grounds on the Novosibirsk experiments /3/,which were performed by using the storage ring internal target method with the electroexcitation of light nuclei in broad range of excitation energy (0-100 MeV) and at approximately constant momentum transfer.Fig.1 shows the distribution map of events A(e,e'C)(A-nuclei ^{16}O, ^{14}N, ^{12}C;C-charge particles:protons or α) on the plane the of SP energy E (MeV) versus the excitation energy W for the emission direction,which is near to that of the momentum transfer.The analysis of results allows one to separate explicitly three regions,which are connected with various physical processes.The region I contains the "lines" corresponding to the ground and lowlying excited states of a daughter nucleus.In terms of shell structure of the nucleus,the SP appear here as a result of direct knockout from the outer shells.The dense spots on the lines demonstrate the resonance decay channels.The regions II and III have,strictly speaking,a not well defined boundary but also are of a distinguishable phisical nature.Taking into account the angular and energy distributions one can separate the pre-equilibrium (II) and equilibrium events (III).The analysis of the information distributed over regions makes the understanding of nuclear reactions essentially easier.



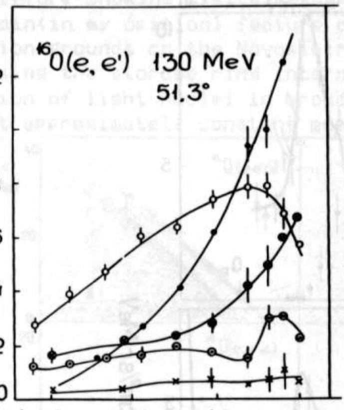
F I G U R E 1

As an example of such simplified examination I show (Fig.2) the analysis of the "line-p$_0$" (the case,when after emission the daughter nucleus remains in its ground state).The information is from the coincidence experiment on ^{12}C, ^{14}N and ^{16}O nuclei(NOVOSIBIRSK /3/).Both the initial and final states are known for this "lines".This is the reason why for this case it is possible to use so-colled multipole analysis of the proton angular distributions at various excitation energies.The presence of the E1 transition and direct processes only in the giant resonance region is assumed.Using an angular distribution,the total cross section (solid line,open circles) and the direct process cross section (closed points)were reconstructed with account of the interference between both processes.The points are:(i)the drastic decreas of the knockout cross section at 22 MeV excitation energy at least for ^{16}O and ^{12}C nuclei; (ii) the account of the interference changes the correlations between the cross sections of both processes.For example,the ^{16}O 21 MeV 1^- resonance cross section changes its value by more then the factor 2 in comparison with the standard procedure.



F I G U R E 2

As other illustration of the coincidence experiment possibilities let us discuss several results of ILLINOIS,MAINZ,NOVOSIBIRSK laboratories. The quantitative information on the ^{16}O(e,e'C) cross sectional structure for the excitation energy range 30-70 MeV is presented in Fig.3 (Novosibirsk). The main contribution comes from the compound nucleus decay with proton (mentioned on the figure o) and alpha- particles



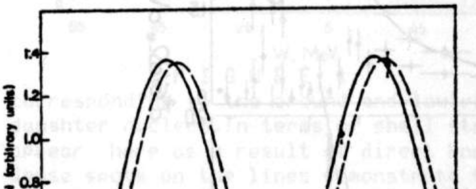
F I G U R E 3

Other symbols on the figure are:• -direct of protons,⊙-anisotropic protons (pre-equilibrium)✗anisotropic alpha-particles. This experimental results do not support the traditional assumption of a direct process dominance at excitation energy higher than 40 MeV.

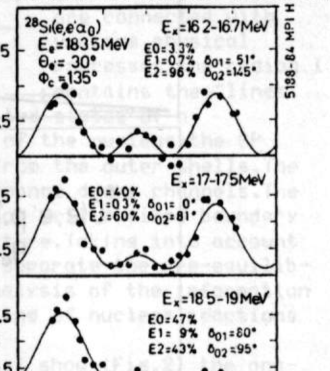
In addition,here are three examples of the multipole analysis of the angular distributions of the SP emitted by the resonances.The ILLINOIS measurements $^{12}C(e,e'\gamma)$ reaction on the 4.439 MeV resonance show possibility to separate its longitudinal and transverse matrix elements.

On the Fig.4 it is shown the influence of the taking into account the transverse formfactor admixture with negative phase (solid curve)/4/.

On the Fig.5 it is shown of the $^{28}Si(e,e'\alpha_0)$ reaction multipole analysis for excitation of E0-,E1-and E2-strengths of the several resonanses and their interference (MAINZ /5/).In the NOVOSIBIRSK $^{16}O(e,e'\alpha)$experiment /3/ in the visinty of the 11.52 MeV 2^+resonance for the satisfactory description of the angular distribution the excitation of this resonance through the transverse multipole operator should be taken into account as well as the presence of the wide 11.26 MeV resonance.By the fitting procedure there were found the longitudinal-transverse ratio -0.087±0.020 and the presence of the 11.26 MeV resonance with the square of the formfactor (80-60)*10^{-3}. The confidence level of the fitting is raised by including this parameters from value less than 10^{-3} to 0.15.



F I G U R E 4



F I G U R E 5

In conclusion we can say that the "new generation information" imply the new methods of a reliable determination of the main characteristics of the nucleus structure and of the reaction mechanism,f.e.:

(i)the cross sections of the (e,e'C) reactions;

(ii)properties of the excited nuclear states:

  (a)the spins and parities (without the use of the model dependences of the formfactors on the momentum transfer),

  (b)the decay modes with different emitted particles and various residual nuclear states,

  (c)the longitudinal and transverse parts of the formfactors;

(iii)the mechanismes of cascade processes (through detecting several secondary particles),the widths and nuclear level densities up to the high excitation energies.

In this small revue the simplest examples of the new generation experiment possibilities have been mentioned.The next step should include the experiments with the longitudinal polarized electrons and the polarized targets.

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