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Status of the experiments with SND detector at e^+e^- collider VEPP-2M in Novosibirsk

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Аннотация

In 1996 experiments with the new SND detector at e^+e^- collider VEPP-2M were continued. SND is a general purpose nonmagnetic detector with a spherical NaI(Tl) calorimeter. Its parameters, like energy and spatial resolution, background, recording rate etc., obtained during the run in the energy range around $\phi(1020)$, and some preliminary results on $\phi(1020)$ decays, showing detector performance, are presented.

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Introduction

Since 1995 in Novosibirsk experiments have been carried out with the new SND detector at the collider VEPP-2M. At present, before beginning of the DAΦNE era, VEPP-2M is the world only e^+e^- collider, operating in the energy range of ρ, ω and ϕ vector mesons. In 1996 at VEPP-2M, two collider detectors SND and CMD-2 continued data taking in the vicinity of $\phi(1020)$ resonance. In this paper the main SND parameters and preliminary results, obtained from the first run, are presented.

SND detector overview

SND [1] is a general purpose nonmagnetic detector, consisting of the tracking system, three spherical layers of NaI(Tl) crystals, and an outer system of streamer tubes and plastic scintillation counters (Fig. 1). The NaI(Tl) calorimeter consists of 1632 individual crystals of 3.6 tons total weight. The calorimeter thickness in the radial direction is 35 cm $\sim 13.5\ X_0$. The angular size of each crystal is $\Delta\phi = \Delta\theta = 9^o$, the solid angle coverage of the calorimeter is 90% of 4π. Each crystal is viewed by a vacuum phototriode [2] with a charge sensitive preamplifier, located on the crystal. The calorimeter calibration procedure is based on the use of cosmic muons [3].

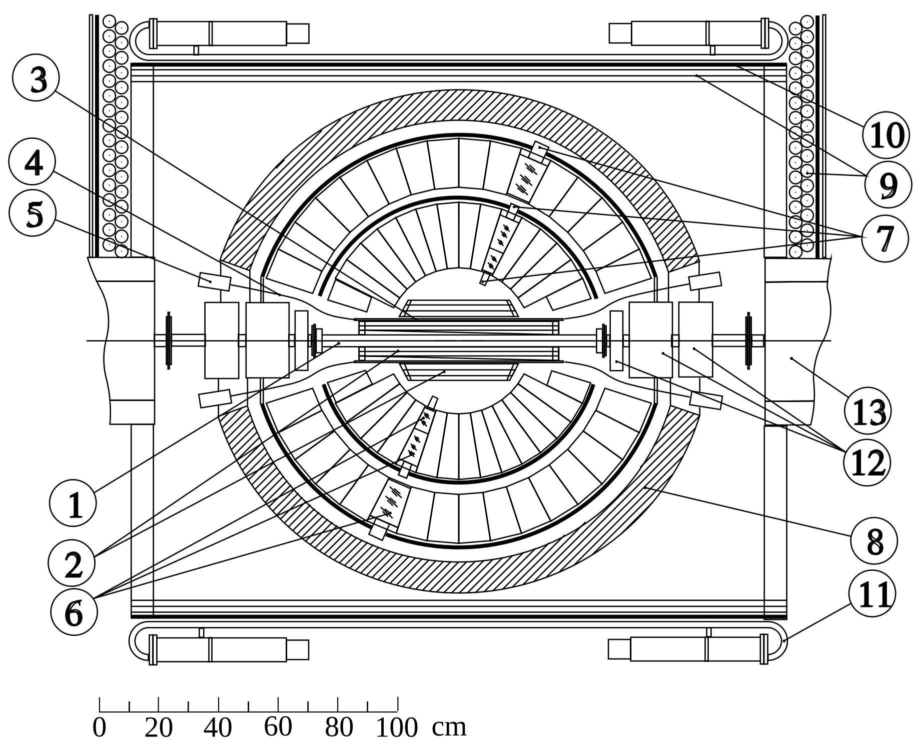

Рис. 1: Detector SND — view transverse to the beam; 1—beam pipe, 2—drift chambers, 3—scintillation counters, 4—fiber lightguides, 5—PMTs, 6—NaI(Tl) counters, 7—vacuum phototriodes, 8—iron absorber, 9—streamer tubes, 10—1 cm iron plates, 11—scintillation counters, 12—magnetic lenses, 13—bending magnets

The tracking system consists of two cylindrical drift chambers. Both chambers are divided into 20 jet-type cells in azimuthal plane. Each cell contains 5 sensitive wires. Longitudinal coordinate is measured by the charge division method with the accuracy of 3 mm. In addition, cathode strip readout for inner and outer layers provides the improvement of the latter value to 0.5 mm.

The muon/veto system consists of plastic scintillator counters and streamer tubes.

1995 test run [4]

The goal of the test run was to minimize background rate, adjust trigger components and calibrate calorimeter and drift chambers. At that time the collider operated in the energy range 660—800 MeV with CMD-2 detector and the average luminosity was about $2 \times 10^{29}\ cm^{-2}sec^{-1}$. We installed lead shields around the beam pipe and found optimum trigger components, which allowed to reduce the trigger rate to the level of $5 \times 10^4\ events \times nb$. The average event length on the tape was about 0.5 kByte. Using events of Bhabha scattering and two photon annihilation we measured the energy resolution of SND calorimeter for 400 MeV electromagnetic showers to be 8% (σ), which should be compared with MC value of 4%. Such a strong disagreement showed, that calorimeter calibration procedure was unsatisfactory at that time. The drift chamber system operated with a gas mixture $Ar + 10\% CO_2$. The spatial resolution measured using Bhabha events was about 0.2 mm in r–ϕ plane, which was close to the expected value.

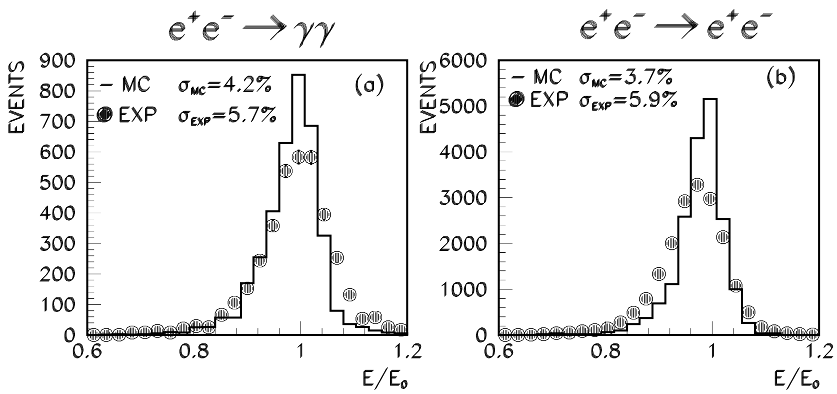

Рис. 2: Energy spectra of electrons and photons for $e^+e^- \to e^+e^-$ and $e^+e^- \to \gamma\gamma$ reactions at $E_{beam} = 517\ MeV$.

1996 $\phi(1020)$ run

The energy range $2E = 984$—1034 MeV around the $\phi(1020)$ maximum was scanned with total integrated luminosity of $4\ pb^{-1}$. The number of produced ϕ's is estimated to be about 5×10^6. The VEPP-2M average luminosity was slightly above $10^{30}\ cm^{-2}sec^{-1}$. The normalized trigger rate was $10^7\ event \times pb$. After improvement of the energy calibration procedure the calorimeter energy resolution reached $\sigma/E = 5.8\%$ for 500 MeV photons (Fig. 2), which is still larger than the expected value of 4.2%. The measured σ of the effective mass spectra of π^0, η and K_s mesons, produced in the ϕ peak and decaying into photon final states, was 13, 18 and the 26 MeV respectively (Figs. 3, 4, 5). Another important feature of SND is reconstruction of events with charged particles and photons together. For example, in the decay $\phi \to \eta\gamma \to \pi^+\pi^-\pi^0\gamma$ the reconstructed mass of η has the width of σ_{M_η}=20 MeV.

Preliminary physical results

In June 1996 about 10% of collected data corresponding to the integrated luminosity of $0.4\ pb^{-1}$ was under processing. We selected the events of main $\phi(1020)$ decays like $\phi \to K^+K^-, K_sK_l, \eta\gamma$, etc. (Fig. 6). After standart routine of fitting the obtained data with Breit-Wigner curve with radiative correction, applying the Table data and MC efficiency for particular channels, we obtained the following preliminary data:

$B(\phi \to \eta\gamma) = (1.26 \pm 0.08)\%$ (from $\eta \to 2\gamma$ mode),

$B(\phi \to \eta\gamma) = (1.15 \pm 0.10)\%$ (From $\eta \to 3\pi^0$ mode),

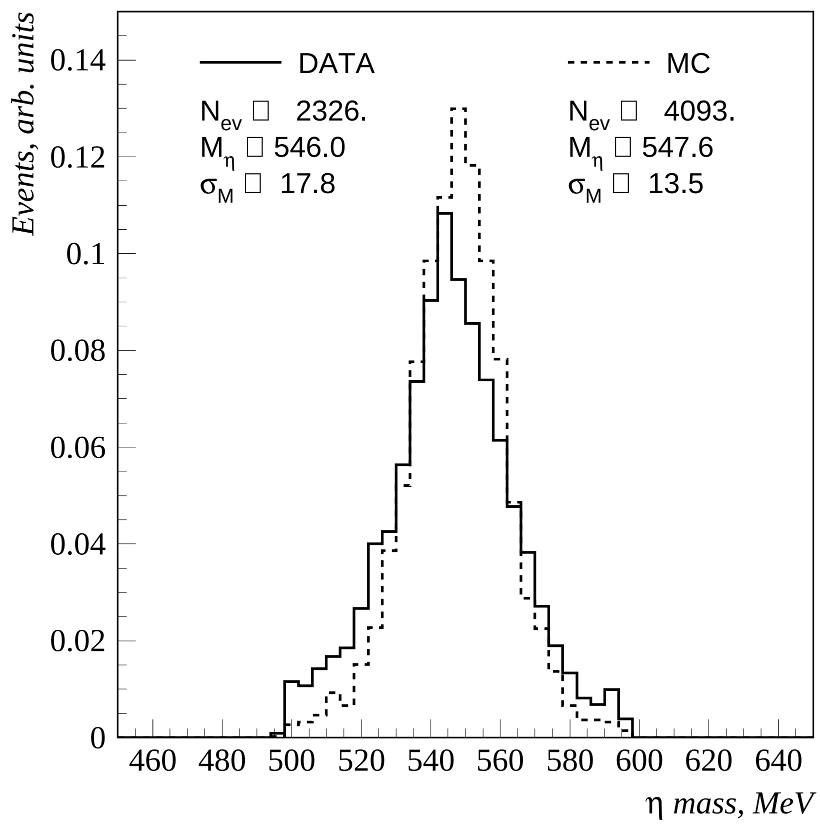

Рис. 3: Effective mass spectrum of two photons for $e^+e^- \to \eta\gamma \to 3\gamma$ reaction.

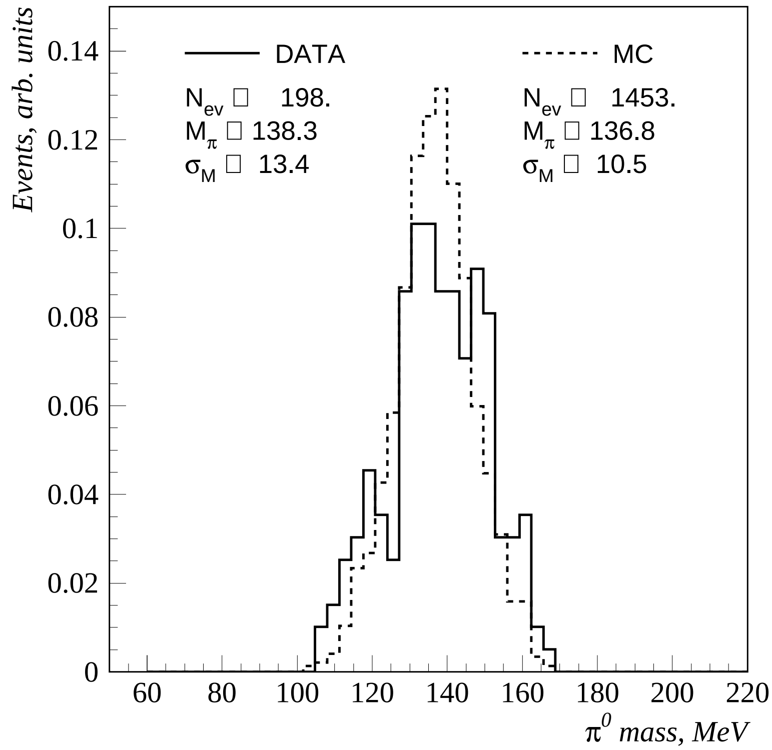

Рис. 4: Effective mass spectrum of two photons for $e^+e^- \to \pi^0\gamma \to 3\gamma$ reaction.

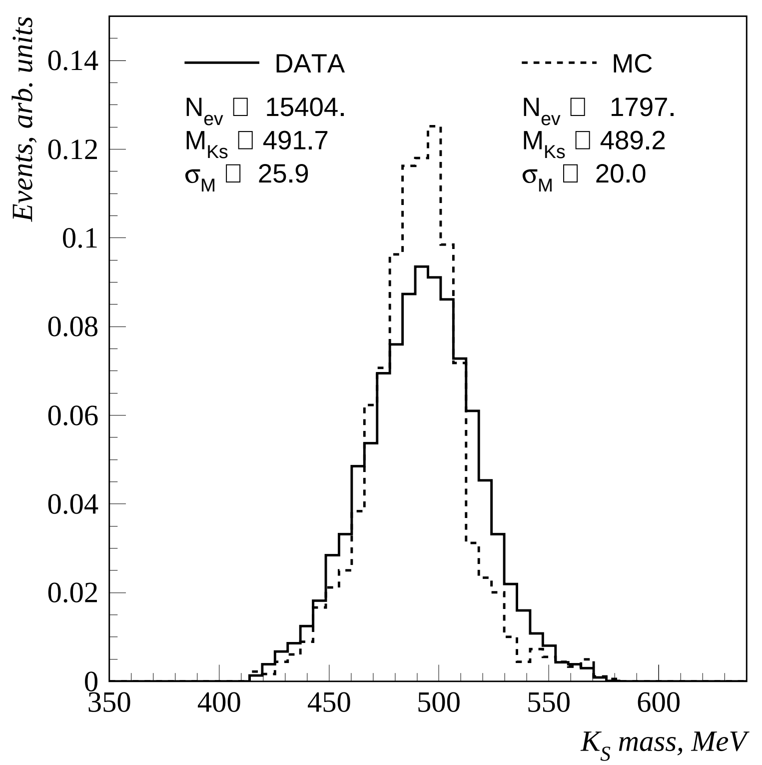

Рис. 5: Effective mass spectrum of four photons for $Ks \to 2\pi^0$ decay.

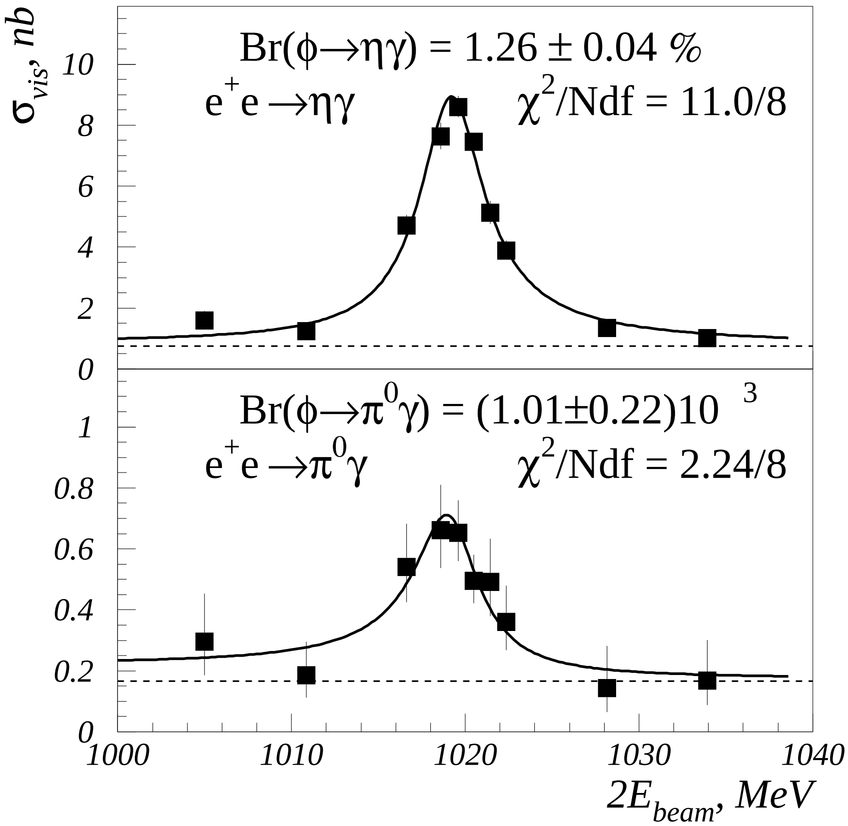

Рис. 6: Visible cross section of $e^+e^- \to \eta\gamma$ and $e^+e^- \to \pi^0\gamma$ reactions.

$B(\phi \to \pi^0\gamma) = (0.10 \pm 0.02)\%$,
$B(\phi \to f_0(975)\gamma) < 9 \times 10^{-4}$ (From $f_0 \to 2\pi^0$ mode), (90% CL),
$B(\phi \to a_0(980)\gamma)B(a_0 \to \pi^0\eta) < 9 \times 10^{-4}$ (From $\eta \to 2\gamma$ mode), (90% CL).

The obtained data still have errors larger than in the Tables and can be considered as a first step, showing the ability of SND to produce new physical results.

The physical program at VEPP-2M

The physical program for SND, includes following processes.

- Radiative decays of $\rho, \omega, \phi \to \pi^0\gamma, \eta\gamma$; $\phi \to \eta'\gamma$; $\phi \to a_0\gamma, f_0\gamma, \pi\pi\gamma, \eta\pi\gamma$; $\rho, \omega \to \pi\pi\gamma$.
- OZI and G-parity suppressed decays $\phi \to \omega\pi, \pi\pi, \eta\pi\pi$; $\rho \to 3\pi$; $\omega \to 2\pi$.
- Electromagnetic decays $\rho, \omega, \phi \to \eta e^+e^-, \pi^0 e^+e^-$
- e^+e^- annihilation into hadrons $e^+e^- \to 2\pi, 3\pi, 4\pi, 5\pi$; $e^+e^- \to \omega\pi, \eta\pi\pi, \phi\pi$; $e^+e^- \to K^+K^-, K_SK_L, KK\pi$;
- Test of QED $e^+e^- \to 3\gamma, e^+e^-\gamma$ $(2 \to 3)$; $e^+e^- \to 4\gamma, e^+e^-\gamma\gamma, 4e$ $(2 \to 4)$; $e^+e^- \to 5\gamma, 3\gamma e^+e^-$, $4e\gamma$ $(2 \to 5)$;
- Search for rare K_S decays $K_S \to 2\gamma, 3\pi^0, 2\pi^0\gamma, \pi^0\gamma\gamma, \pi^0e^+e^-$
- Search for rare η decays
  $\eta \to 3\gamma, e^+e^-, 4e, 2\pi^0$.

- Search for C-even reactions
  $e^+e^- \to \eta', a_0, f_0, a_2, f_2$

The search for electric dipole radiative decays like $\phi \to a_0\gamma$, $f_0\gamma$ can clarify the structure of lightest scalar mesons and help to determine, whether or not are they mixed with 4-quark states.

Accurate measurement of e^+e^- annihilation cross section into hadrons is important for precision theoretical calculations of hadron contribution into muon anomalous magnetic moment (AMM). In the energy range $2E < 1$ GeV, the total hadron production cross section should be measured with the uncertainty of 0.5%. The corresponding error in AMM calculations would be 0.2 ppm.

The hadronic cross-section is also of great importance to solve the problem of existence and location of light vector meson radial excitations ρ, ω, ϕ. This cross section also contributes significantly into some decay spectra and branching ratios of τ-lepton, D- and B-mesons.

Conclusion

In Novosibirsk experiments with the new SND detector at low energy collider VEPP-2M are continued. SND is a general purpose nonmagnetic detector, the main part of which is three layer NaI(Tl) spherical calorimeter with 1632 individual crystals. SND provides good possibility to study processes with multiple photons in final state. In summer 1996 the data taking run in the vicinity of $\phi(1020)$ with the integrated luminosity of about 4 pb^{-1} was done. The measured photon energy resolution and mass resolution for π^0, η, K_s show feasibility of study of e^+e^- processes at VEPP-2M with SND. First preliminary physical results are obtained for $\phi(1020)$ decays.

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