Detector SND for VEPP-2M

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The Spherical Neutral Detector (SND) operates at VEPP-2M collider in Novosibirsk studying e^+e^- annihilation in the energy range up to 1.4 GeV. Detector consists of a fine granulated spherical scintillation calorimeter with 1632 NaI(Tl) crystals, two cylindrical drift chambers with 10 layers of sense wires, and a muon system made of streamer tubes and scintillation counters. The detector design and performance are described.

1. Introduction

For more than 25 years the VEPP-2M e^+e^- collider has been operating in BINP, Novosibirsk, in the center-of-mass energy range $2E_0 = 0.36 \div 1.4$ GeV [1]. During this period several generations of detectors carried out experiments at VEPP-2M. Much of the current data on particles properties [2] at low energy region were obtained in these experiments.

The SND detector [3] operates at VEPP-2M since 1995 [4–7]. Its main part is a three-layer spherical calorimeter consisting of 1632 crystals of NaI(Tl). Although the SND is a general purpose detector, it is optimized for studying of the processes with multi-photon final states.

2. General description

The layout of the apparatus is shown in Fig. 1. Electron and positron beams collide inside the beryllium beam pipe with a diameter of 2 cm and thickness of 1 mm. The beam pipe is surrounded by tracking system consisting of two drift chambers with a cylindrical scintillation counter [8] between them. Both chambers consist of 20 jet-type drift cells. Each cell has 5 sense wires.The solid angle coverage of the tracking system is about 98% of 4π.

The three-layer spherical electromagnetic calorimeter based on NaI(TI) crystals with vacuum phototriode [9] readout surrounds the tracking system. Spherical shape of calorimeter provides good uniformity of response over the whole solid angle. Pairs of counters of the two inner layers with thickness of 2.9 and 4.8 X_0 ($X_0 = 2.6$ cm) are sealed in thin (0.1 mm) aluminum containers, fixed to aluminum supporting hemispheres. Behind it, the third layer of NaI(Tl) crystals, 5.7 X_0 thick, is placed. The number of crystals per layer varies from 520 to 560. The total mass of the calorimeter is 3.5 t. The total calorimeter thickness for particles originating from the center of the detector is 34.7 cm (13.4 X_0) of NaI(Tl) and the total solid angle is 90% of 4π.

Outside the calorimeter a 12 cm thick iron absorber of the residuals of electromagnetic showers is placed. It is surrounded by segmented muon system. Each segment consists of two layers of streamer tubes and a plastic scintillation counter separated from the tubes by 1 cm iron plate. The iron layer between the tubes and the counter reduces the probability of their simultaneous firing by photons produced in e^+e^- collisions to less than 1% for 700 MeV photons.

3. SND performance

A good energy and angular resolution for photons in the energy range from 30 to 700 MeV is essential for suppression of background in the reconstruction of π^0 and η mesons and detection of photons emitted in radiative transitions between quarkonium states. To achieve highest possible energy resolution, the calorimeter is calibrated using cosmic muons [10] and $e^+e^- \to e^+e^-$ process events [11]. The dependence of the calorimeter energy resolution on photon energy (Fig. 2) was fitted as:

$$\sigma_E/E(\%) = \frac{4.2\%}{\sqrt[4]{E(\mathrm{GeV})}}. \quad (1)$$

To estimate the photon angles the method introduced in [12] is used. The dependence of the angular resolution on the photon energy is shown in Fig. 3 and can be approximated as:

$$\sigma_{\phi,\theta} = \frac{0.82^\circ}{\sqrt{E(\mathrm{GeV})}} \oplus 0.63^\circ. \quad (2)$$

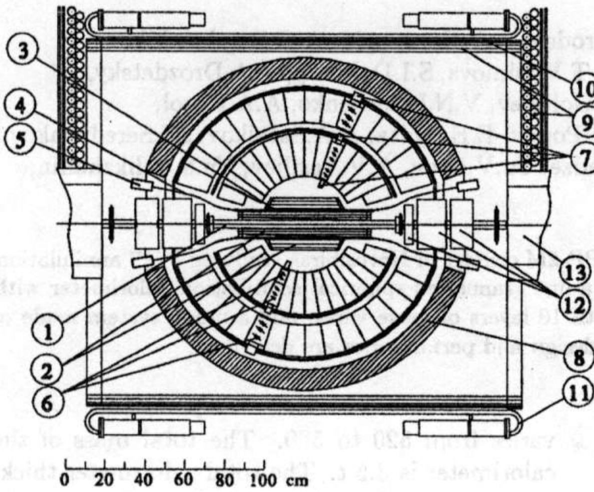

Figure 1. SND detector, section along the beams: (1) beam pipe, (2) drift chambers, (3) scintillation counter, (4) light guides, (5) PMTs, (6) NaI(Tl) crystals, (7) vacuum phototriodes, (8) iron absorber, (9) streamer tubes, (10) 1 cm iron plates, (11) scintillation counters, (12) and (13) elements of collider magnetic system.

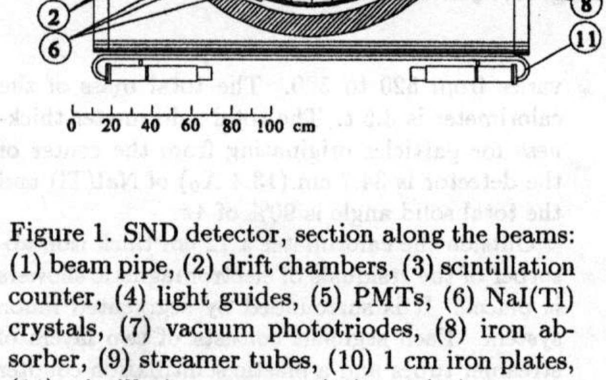

Figure 2. Dependence of the calorimeter energy resolution on the photon energy, $\sigma_E/E(\%) = 4.2\%/\sqrt[4]{E(\text{ GeV})}$. σ_E/E – energy resolution obtained using $e^+e^- \to \gamma\gamma$ (dots) and $e^+e^- \to e^+e^-\gamma$ (circles) reactions.

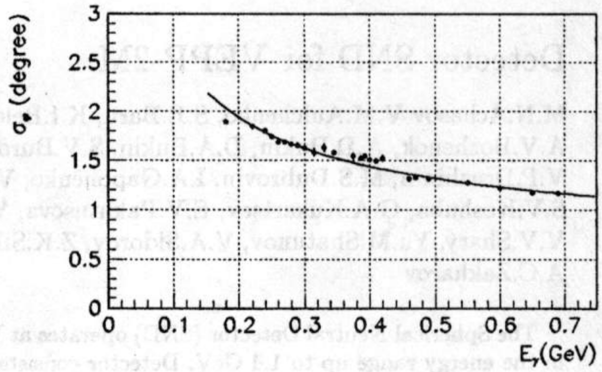

Figure 3. Dependence of the angular resolution on the photon energy, $\sigma_\phi = 0.82°/\sqrt{E(\text{ GeV})} \oplus 0.63°$.

The tracking system polar angle resolution $\sigma_\theta = 1.7°$ for electrons and $\sigma_\theta = 1.9°$ for pions. The azimuth angle resolution $\sigma_\phi = 0.51°$ for electrons and $\sigma_\phi = 0.54°$ for pions. The impact parameter in $r-\phi$ plane resolution $\sigma_R = 0.5$ mm. Small differences in angular resolutions for electrons and pions can be attributed to the different average ionization losses and θ distributions for these particles. dE/dx resolution is about 30% and it is enough to provide $\pi^\pm/K^\pm$ separation in the energy region of ϕ-meson production. Muon system provides muon identification and suppression of cosmic background. The time resolution of the system is about 1 ns (Fig. 4). The Monte-Carlo simulation of SND carried out in the framework provided by the UNIMOD [13] code, show a good agreement of experimental and simulated distributions (Figs.5, 6).

4. Conclusions

SND detector operates at VEPP-2M since 1995. The total integrated luminosity $\sim$ 25 pb^{-1} at the center-of-mass energy range $2E_0 = 0.4 \div 1.4$ GeV was collected. Electric dipole radiative decays $\phi \to \pi^0\pi^0\gamma$ [14], $\eta\pi^0\gamma$ [15] and OZI and G-parity suppressed decay $\phi \to \omega\pi^0$ [16] were observed for the first time. The $\phi \to \eta'\gamma$ [17] decay existence was confirmed. Other interesting physical results were also obtained. The methods realized at SND experiments at VEPP-2M have proved their adequacy, so we expect new physical results.

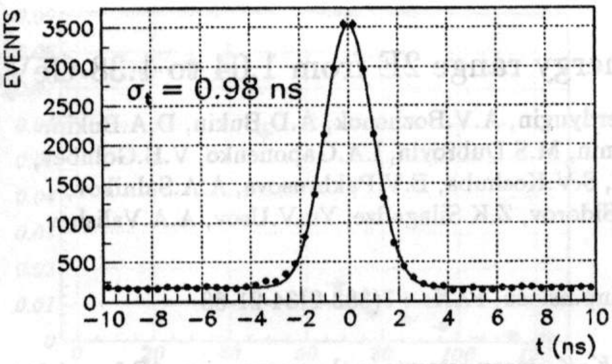

Figure 4. Time of scintillation counters signals with respect to the beams collision time for events of the $e^+e^- \to \mu^+\mu^-$ reaction at the center-of-mass energy range $2E_0 \sim 1$ GeV. The cosmic muons background is also seen as an uniform distribution.

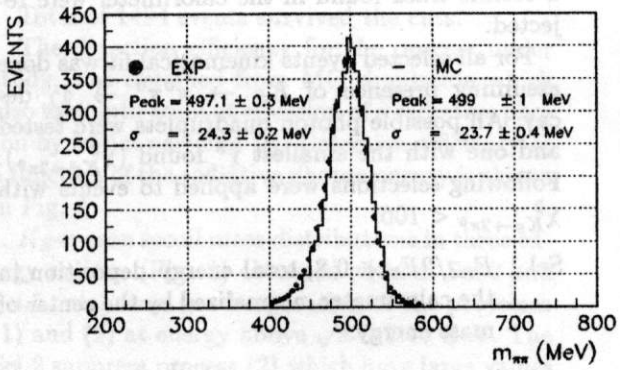

Figure 5. Invariant mass distribution of π^0-mesons pairs from the $K_S \to \pi^0\pi^0$ decay.

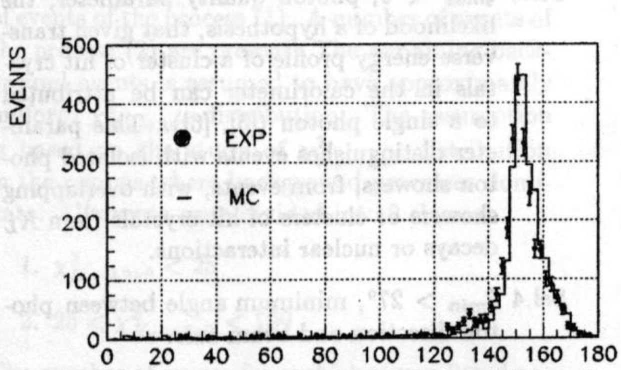

Figure 6. Angle ψ between pion pairs from the $K_S \to \pi^+\pi^-$ decay

5. Acknowlegement

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