Recent Results from the SND Detector\(^1\)

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Abstract—Presented are recent results of experiments on the SND detector. Data were collected on the VEPP-2M and VEPP-2000 colliders (Novosibirsk) in the c.m. energy region 0.3–2.0 GeV. Integrated luminosity used is 70 and 25 pb\(^{-1}\) respectively. Cross section of the processes is measured.

DOI: 10.1134/S1063779618040354

1. INTRODUCTION

We present analysis results of the data collected with SND detector [1–3] at the VEPP-2M [4] and VEPP-2000 [5] colliders in the c.m. energy range 0.3–2.0 GeV.

The SND detector consists of several subsystems (Fig. 1). These are a spherical three-layer electromagnetic calorimeter made of NaI (Tl) crystals, a cylindrical tracking system (a drift and a proportional chambers in the same gas volume), an Aerogel threshold Cerenkov counter, a muon subsystem. The electromagnetic calorimeter covers 95% of the total solid angle, it has an equivalent thickness of \(\delta_{EE} = 0.042\) GeV, the energy resolution depends on the photon energy: \(\delta E/E = 0.042/\sqrt{E}\) (GeV), the angular resolution \(\delta \phi = 1.5^\circ\). The tracking system covers 94% of the total solid angle, the angular resolution in azimuth and polar directions, respectively \(\delta \phi = 45^\circ\) and \(\delta \theta = 0.8^\circ\).

The integrated luminosity collected in experiments with the SND detector on VEPP-2M and VEPP-2000 colliders is summarized in Table 1.

During 2010–2013, luminosity was limited by the lack of positrons. To solve this problem, the acceleration complex undergone an upgrade. After the upgrade electrons and positrons are transferred from the VEPP-5 injection complex. The new data collection run started in December 2016.

| Table 1. Used integrated luminosity |
|-----------------------------------|
| **VEPP-2M**                      |
| **IL**, pb\(^{-1}\) | below \(\phi\) | near \(\phi\) | above \(\phi\) |
| 9.1                              | 13.2                  | 8.8                     |
| \(\sqrt{s}\), GeV                | 0.36–0.97              | 0.98–1.06               | 1.06–1.38       |
| **VEPP-2000**                    |
| **IL**, pb\(^{-1}\) | 15.5                  | 6.9                    | 47.0             |
| \(\sqrt{s}\), GeV                | 0.30–0.97              | 0.96–1.05               | 1.05–2.00       |

\(^1\)The article was translated by the authors.
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(4C): $\chi^{2}_{35} < 30$, $36^\circ < \theta_{\gamma} < 144^\circ$, $80 < M_{\pi^{-}} < 190$ MeV. Here $M_{\pi^{-}}$ is the recoil mass of the most energetic photon. The number of signal events is calculated as the number of $\pi^0$ parameter from the $M_{\pi^{-}}$ spectra fitting.

Our measurement of the $e^+e^- \rightarrow \pi^0\gamma$ process cross section is the most accurate at the present time (Fig. 2). The systematic uncertainty in the vicinity of the $\omega$-meson peak is 1.4%, the main contributions are measuring the luminosity (1.2%) and the efficiency of the selection criteria (0.6%).

Based on the world average values $B(\omega \rightarrow \pi^+\pi^-\pi^0)$ $B(\omega \rightarrow e^+e^-)$ (PDG, [7]), the ratio of the widths

$$\Gamma(\omega \rightarrow \pi^0\gamma)/\Gamma(\omega \rightarrow \pi^+\pi^-\pi^0) = 0.0992 \pm 0.0023,$$

which is significantly larger (by 3.4$\sigma$) than the result of KLOE [8] $0.0897 \pm 0.0016$. The measured value of the relative decay probability

$$B(\rho \rightarrow \pi^0\gamma) = (4.20 \pm 0.47 \pm 0.22) \times 10^{-4}$$
is 1.8σ less than the world average \((6.0 \pm 0.8) \times 10^{-4}\), but agrees well with the value for the charged meson

\[ B(\rho^\pm \rightarrow \pi^\pm \gamma) = (4.5 \pm 0.5) \times 10^{-4}. \]

For the \(\phi\)-meson, we obtained the value

\[ B(\rho \rightarrow \pi^0 \gamma)B(\phi \rightarrow e^+ e^-) = (3.92_{-0.40}^{+0.71} \pm 0.51) \times 10^{-7}. \]

3. PROCESSES NOT STUDIED BEFORE

The total hadronic cross section in the energy region below 2 GeV is calculated as a sum of exclusive hadronic cross sections. At present, its values obtained from inclusive and exclusive measurements is well agree at the boundary [9]. However, in the c.m. energy range 1.5–2.0 GeV, the set of exclusive measurements is incomplete. There is no experimental data on the \(\pi^+ \pi^- \pi^- \eta\), \(\pi^+ \pi^- \pi^0 \eta\), \(\pi^+ \pi^0 \pi^0 \pi^- \eta\), \(\pi^+ \pi^- \pi^0 \pi^- \eta\) final states, and it is very important to carry out these measurements.

The process \(e^+ e^- \rightarrow \pi^+ \pi^- \pi^0 \eta\) [10] is studied for the first time. Its cross section is measured (Fig. 3), intermediate states are studied.

The observed intermediate states are \(\omega \eta\), \(\phi \eta\), structureless \(e^+ e^- \rightarrow \pi^+ \pi^- \pi^0 \eta\), and \(a(980)\rho\). Above 1.8 GeV, the last state is dominant (Fig. 4).

In addition, the cross section of the process \(e^+ e^- \rightarrow \omega \eta\) with the same final state was considered (Fig. 5).

Noticeable is the difference with the previously BABAR result [11].
The process $e^+e^- \rightarrow \omega\pi^0\eta \rightarrow 7\gamma$ [12] is studied for the first time. The events of the $e^+e^- \rightarrow 7\gamma$ final state were selected. In the events, undoubtedly, the intermediate state $\omega\pi^0\eta$ predominates. A possible signal of the $\eta'\gamma$ state is not observed. The invariant mass of the $\pi^0\eta$ combination spectrum for the selected events $\omega\pi^0\eta$ is well described by the intermediate state $a^0(980)\omega$ model (Fig. 6).

The dependence of the cross section on energy is described well with a single resonance model whose mass and width correspond to $\rho(1700)$. The description without resonance is worse than this at the level of $1.2\sigma$ (Fig. 7).
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4. CONCLUSIONS

During the period 2010–2013 the SND detector collected data with an integrated luminosity \( \sim 70 \text{ pb}^{-1} \) at the VEPP-2000 collider in the c.m. energy range 0.3–2.0 GeV. Their analysis is carried out. In combination with the data collected earlier at the VEPP-2M collider, the most accurate results for the process \( \gamma \rightarrow \pi^0 \) are obtained: the cross section, the parameters of the radiative decays of light vector mesons.

The cross sections of the processes \( e^+e^- \rightarrow \pi^0 \) are obtained: the cross section, the parameters of the radiative decays of light vector mesons.

After the upgrade, the VEPP-2000 collider began data collection with an increased luminosity. The goal is to collect the integral luminosity 1 fb\(^{-1}\).

5. ACKNOWLEDGMENTS

The work is supported by RFBR grants 15-02-01037 and 16-02-00327-a. Part of the work related to the reconstruction of photons in the electromagnetic calorimeter is supported by the Russian Science Foundation (grant 14-50-00080).

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