New results on $e^+e^- \to hadrons$ exclusive cross sections from experiments with SND detector at VEPP-2M e^+e^- collider in the energy range $\sqrt{s} = 0.4 \div 1.4$ GeV

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New results of the $e^+e^- \to \pi^+\pi^-$, K^+K^-, $K_S K_L$, $\pi^0\gamma$, $\eta^0\gamma$ processes cross section measurements are presented. The results are based on the 30 pb^{-1} data, accumulated by SND detector at VEPP-2M e^+e^- collider in the energy range $\sqrt{s} = 0.4 \div 1.4$ GeV during 1995-2000 years. The comparison with existing experimental data shows that the measurement accuracy is close to or better than the world average. For the $e^+e^- \to \pi^+\pi^-$ process the accuracy is $\sim 1\%$. This is important for calculation of hadronic contribution into the muon anomalous magnetic moment.

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1. Introduction

Beginning from 1995, experiments have been carried out at VEPP-2M e^+e^- collider [1] with SND detector [2]. The important part of the experimental program was study of the e^+e^- annihilation into hadrons. The latest results of this investigation are presented in this talk [3, 4].

VEPP-2M e^+e^- collider operated during 1974-2000 years in the center-of-mass (C.M.) energy range $E = 0.4 \div 1.4$ GeV. The luminosity depended on the energy, its average value was $L = 2 \times 10^{30}$ $cm^{-2}s^{-1}$ at $E \simeq 1$ GeV. In 2000 the experiments were completed and the collider ring was dismounted. Now the new VEPP-2000 e^+e^- collider [5] with higher maximum energy 2 GeV is under construction at the location of VEPP-2M.

The SND detector is general purpose nonmagnetic detector for low energy e^+e^- colliders. It consists of the drift-chamber tracking system, three layer spherical electromagnetic calorimeter with 1680 NaI(Tl) crystals, and the muon detector with plastic scintillator counters and streamer tubes. The experiments at VEPP-2M were carried out in scanning mode of the collider energy range. The total accumulated luminosity is 30 inverse picobarns.
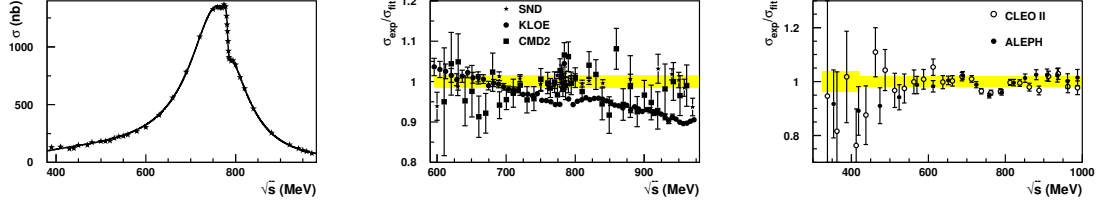
2. The $e^+e^- \to \pi^+\pi^-$ process

The study of the $e^+e^- \to \pi^+\pi^-$ process is important because this process gives the major contribution into the total hadronic cross section at $E < 1$ GeV and hence its contribution into hadronic part of muon anomalous magnetic moment (AMM) a_μ^{hadr} is dominant $\sim 70\%$. In our work [4] the $e^+e^- \to \pi^+\pi^-$ process was measured in the energy range $E = 0.36 \div 0.87$ GeV with integrated luminosity of 10 pb^{-1}. The number of detected $\pi^+\pi^-$ events in the polar angle interval $55^o < \theta < 125^o$ is 4.5×10^6. The detection efficiency depends on energy and varies within the limits $(10 \div 50)\%$. The main background comes from the $e^+e^- \to e^+e^-$, $e^+e^- \to \mu^+\mu^-$, $e^+e^- \to \pi^+\pi^-\pi^0$ processes and from cosmic rays. To select the $\pi^+\pi^-$ events the neural network method was used. The measured cross section is shown in Fig.1a. The systematic error of measurement $(1.3 \div 3.2)\%$ is determined mainly by the polar angle aperture error, uncertainties of the nuclear interactions of pions, pion identification and luminosity errors.
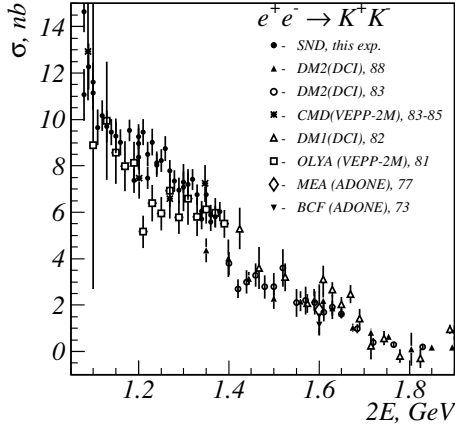
The comparison of the measured cross section with previous measurements is shown in Figs.1b, 1c. The reasonable agreement with τ-lepton data [6], [7] and e^+e^- measurement of CMD-2 [8] is seen. The KLOE data [9] obtained by the radiative return method are in large disagreement with our results. The calculated contribution into the muon AMM from the $e^+e^- \to \pi^+\pi^-$ process is $a_\mu^{hadr}(\pi\pi) = (488.7 \pm 7.1)\ 10^{-10}$ with relative accuracy 1.5%. The ρ and ω mesons parameters were measured in this work also with accuracies better or comparable with the world average (see [4]).

3. The $e^+e^- \to K^+K^-$ and $e^+e^- \to K_S K_L$ processes

These processes are important because they give the considerable contribution into the total hadronic cross section at $E > 1$ GeV and into the muon AMM. Besides this cross sections depend on contributions from all light vector mesons ρ, ω, ϕ, their excitations $\rho\prime$, $\omega\prime$, $\phi\prime$ and possible unknown states. So measurements of the cross section open the possibility to study all these states. Finally, the isovector part of the cross section can be used to test the CVC hypothesis in τ-decays.

Figure 1: a - the measured cross section of the $e^+e^- \to \pi^+\pi^-$ process, the curve is the best fit; b - the ratio of the $e^+e^- \to \pi^+\pi^-$ cross section obtained in CMD-2 [8] and KLOE [9] to the SND fit curve, the shaded area shows SND systematics; c - the ratio of the $e^+e^- \to \pi^+\pi^-$ cross section, calculated from τ-decay spectral function [6, 7] to the isovector part of the SND cross section, the shaded area shows the joint systematic error.

Figure 2: The measured cross section of the $e^+e^- \to K^+K^-$ process
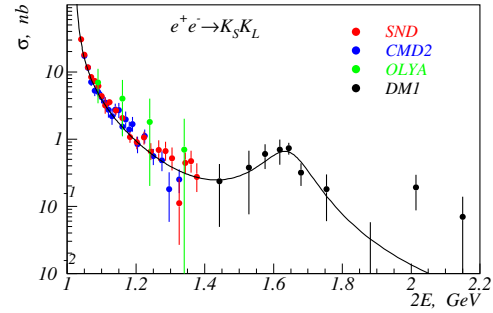
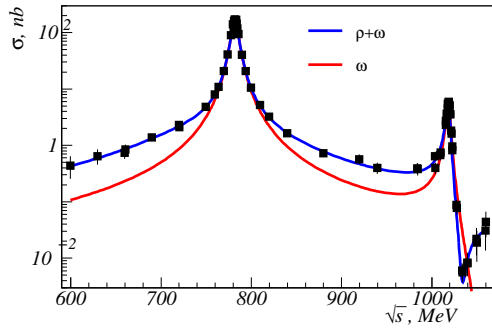**Figure 3:** The measured cross section of the $e^+e^- \to K_S K_L$ process, the curve is the best fit to all data.

The kaon pairs production was studied in numerous experiments, but the accuracy is still not sufficient for full tests of the models mentioned above. In SND experiment we measured the cross section in the energy range $2E = 1.05 \div 1.40$ GeV with integrated luminosity $\Delta L \simeq 6 \ pb^{-1}$. To select K^+K^- events the neural network analysis was used. For $K_S K_L$ channel investigation the neutral mode $K_S \to 2\pi^0$ was used. The measured cross section and results of previous experiments are shown in Figs.2,3. For K^+K^- channel our cross section is the highest in comparison with earlier data and confirms the exhibited linear dependence versus energy. The $\phi\prime(1680)$ resonance is not obviously seen. In $K_S K_L$ channel the SND result agrees with old data. The fit including all data, confirms $\phi\prime(1680)$.

4. The $e^+e^- \to \pi^0\gamma$ and $e^+e^- \to \eta^0\gamma$ processes

Both these reactions have significant cross sections in the vicinity of ρ, ω, ϕ. In SND experiment we measured the cross sections between resonances as well. For the first reaction the 3γ final state was used while for the second one we investigated two modes - with the $\eta \to 3\pi^0$ and

Figure 4: The measured cross section of the $e^+e^- \to \pi^0\gamma$ process, two fitting curves correspond to models with $\rho + \omega$ and ω intermediate states respectively.
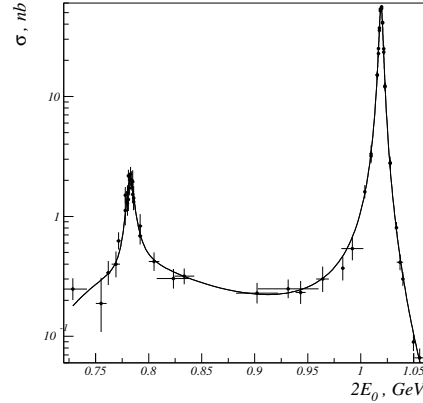
Figure 5: The measured cross section of the $e^+e^- \to \eta^0\gamma$ process, the curve is the best fit.

$\eta \to \pi^+\pi^-\pi^0$ decays. The results are presented in Figs. 4,5, the curves being the vector meson dominance fits. The fitting parameters were vector meson decay parameters, which were measured in our work with accuracy comparable to or better than the world average. Below some prominent parameters measured in this work are listed:

$$Br(\rho \to \pi^0\gamma) = (5.02 \pm 0.73) \cdot 10^{-4}, \ Br(\phi \to \pi^0\gamma) = (1.36 \pm 0.10) \cdot 10^{-3},$$
$$Br(\rho \to \eta^0\gamma) = (2.77 \pm 0.31) \cdot 10^{-4}, \ Br(\omega \to \eta^0\gamma) = (4.22 \pm 0.50) \cdot 10^{-4}.$$

Let us note that the simple vector meson dominance model describes the measured cross section of the $e^+e^- \to \pi^0\gamma$ and $e^+e^- \to \eta^0\gamma$ processes very well.

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