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Recent results of the study of hadronic production with the CMD-2 and SND detectors at the VEPP-2M collider

M.N. Achasov[1,2], R.R. Akhmetshin[1], V.M. Aulchenko[1,2], V.Sh. Banzarov[1], A. Baratt[3], L.M. Barkov[1,2], S.E. Baru[1], N.S. Bashtovoy[1], K.I. Beloborodov[1], A.V. Berdugin[1,2], A.G. Bogdanchikov[1], A.E. Bondar[1,2], D.V. Bondarev[1], A.V. Bozhenok[1], A.V. Bragin[1], A.D. Bukin[1,2], D.A. Bukin[1], T.V. Dimova[1], V.P. Druzhinin[1,2], S.I. Eidelman[1,2], D.A. Epifanov[1], G.V. Fedotovitch[1,2], N.I. Gabyshev[1], D.A. Gorbachev[1], A.A. Grebeniuk[1], D.N. Grigoriev[1,2], V.W. Hughes[4a], F.V. Ignatov[1], S.V. Karpov[1], V.F. Kazanin[1], B.I. Khazin[1,2], I.A. Koop[1,2], A.A. Korol[1], S.V. Koshuba[1], P.P. Krokovny[1], A.S. Kuzmin[1,2], I.B. Logashenko[1], P.A. Lukin[1], A.P. Lysenko[1], K.Y. Mikhailov[1], A.I. Milstein[1,2], I.N. Nesterenko[1], V.S. Okhapkin[1], A.V. Otboev[1], E.V. Pakhtusova[1], E.A. Perevedentsev[1,2], A.A. Polunin[1], A.S. Popov[1], S.I. Redin[1], N.I. Root[1], A.A. Ruban[1], N.M. Ryskulov[1], S.I. Serednyakov[1,2], A.G. Shamov[1], Y.M. Shatunov[1], B.A. Shwartz[1,2], A.L. Sibidanov[1,2], V.A. Sidorov[1], Z.K. Silagadze[1], A.N. Skrinsky[1], I.G. Snopkov[1], E.P. Solodov[1,2], J.A. Thompson[3], Y.V. Usov[1], A.A. Valishev[1], A.V. Vasiljev[1,2], Y.V. Yudin[1], A.S. Zaitsev[1,2], and S.G. Zverev[1], presented by D.N. Grigoriev

[1] Budker Institute of Nuclear Physics, Novosibirsk, 630090, Russia
[2] Novosibirsk State University Novosibirsk, 630090, Russia
[3] University of Pittsburgh, Pittsburgh, PA 15260, USA
[4] Yale University, New Haven, CT 06511, USA

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Abstract. The Cryogenic Magnetic Detector (CMD-2) and Spherical Neutral Detector (SND) operated at the VEPP-2M electron-positron collider in the c.m. energy range 360-1380 MeV. The total integrated luminosity above 60 pb^{-1} has been collected by both detectors. The cross sections of hadronic production have been measured with high precision. New results for the light vector meson parameters and rare decay mode were obtained.

PACS. 13.66.Bc Hadron production in e^-e^+ interactions – 13.66.Jn Precision measurements in e^-e^+ interactions

1 Introduction

Despite thirty years of experimental studies, e^+e^- annihilation into hadrons at low energies is still rather far from complete understanding. More precise measurements are needed to determine ρ, ω and ϕ meson parameters as well as continuum properties providing the unique information about interactions of the light quarks. Knowledge of $R = \sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$ with high accuracy is required to evaluate the hadronic contribution to the anomalous magnetic moment of the muon $(g-2)_\mu$ and the fine structure constant $\alpha(M_Z^2)$.

The precise measurement of the hadronic cross sections was one the main goals of the experiments running at the VEPP-2M collider [1] in Novosibirsk since 1974 up to 2000 in the c.m. energy range from 0.36 to 1.38 GeV. The latest experiments were carried out with the CMD-2 detector [2] since 1992 and with the SND detector [3] since 1995. A total integrated luminisity > 60 pb^{-1} is collected by both detectors. A short description of the most recent results is presented in this paper.

[a] deceased

2 Study of the $e^+e^- \to K^+K^-$ process

The most precise previous measurement of the cross section of the reaction $e^+e^- \to K^+K^-$ at the energy range 1050-1400 MeV was performed by OLYA detector [4] at the VEPP-2M collider with about 10% error. The new measurements of this cross section at the energy range 1020-1380 MeV with the CMD-2 and SND detector are described in this paper. The integrated luminosity about 9 pb^{-1} collected by each detector is analyzed.

Collinear events were selected to study the process $e^+e^- \to K^+K^-$. Other collinear processes $e^+e^- \to e^+e^-$, $e^+e^- \to \pi^+\pi^-$ and $e^+e^- \to \mu^+\mu^-$ are the main sources of the background. The specific signature of the process $e^+e^- \to K^+K^-$ is the lower momentum of the kaons. The background suppression is based on this property.

The SND detector calorimeter is segmented into three layers. It provides a power tool for the particle identifi-

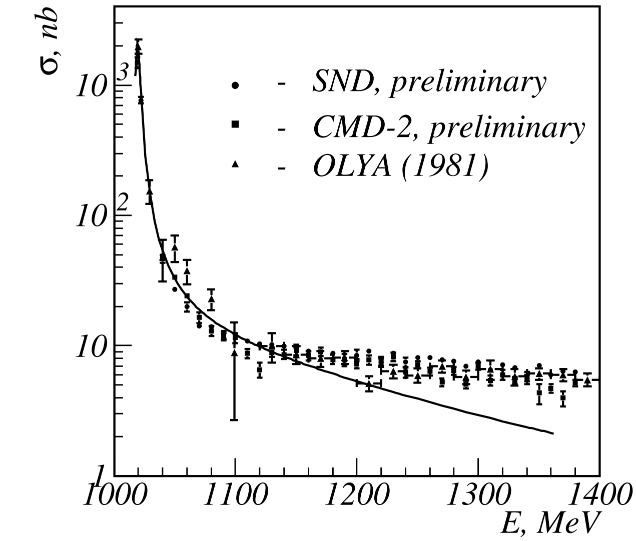

Fig. 1. The cross section of the process $e^+e^- \to K^+K^-$. The *solid curve* - fit with contributions of the $\rho(770)$, $\omega(783)$ and $\phi(1020)$ mesons only

cation. The separation of events of the signal from background events is based on the difference in the energy deposition in calorimeter layers. The initial distribution on the energy depositions in calorimeter layers were obtained from MC simulations. The probability to belong to the specific type of the particle was determined independently for both particles in the events. To decrease the systematic error, the distributions obtained from MC simulation were corrected on the basis of the experimental events. One of the particles in an event was selected to be a kaon, electron, pion or muon and the distributions for the other particle were studied. The detection efficiency and particle identification quality were corrected according to the difference between the experimental and simulated distributions. This analysis was performed for each energy point of the experiment.

Separation of kaons from other collinear events is based on dE/dx measurements in the CMD-2 drift chamber. Ionization losses of kaons are higher compared to other particles due to low velocity. It provides a good possibility to separate kaons from background events. The analysis logics is similar to that described above.

The systematic error of the cross section measurements in both detectors is about 6% and is dominated by the background subtraction procedure. The statistical error in all energy points is smaller than the systematic one.

The measured cross section of the process $e^+e^- \to K^+K^-$ is shown in Fig. 1. The CMD-2 and SND data agree well although different methods of the separation of kaons from background events were used. The cross section measured by the OLYA detector is higher at the energies below 1100 MeV and lower at the energies above 1200 MeV but this experiment has a larger systematic error. The cross section is not described by the contributions of the lightest vector mesons $\rho(770)$, $\omega(783)$ and $\phi(1020)$ only. But the energy range is not sufficient to study a contribution from the excited vector mesons. So new experiments at the energy up to 2000 MeV are needed.

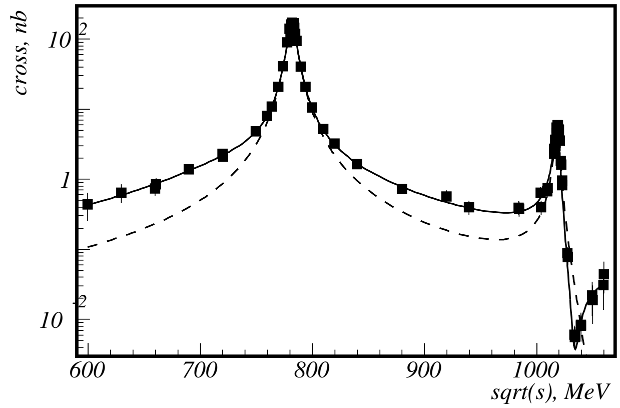

Fig. 2. Cross section of the $e^+e^- \to \pi^0\gamma$ process. *Dots* represent experimental data, the *solid curve* depicts approximated theoretical form with $\rho^0 \to \pi^0\gamma$, *dashed curve* — without ρ^0 contribution

3 Study of the $e^+e^- \to \pi^0\gamma$ process

The presented work is an extension of the studies published in [5] and based on the integrated luminosity of 3.5 pb^{-1} but using additional data at the energy range 600-960 MeV with the integrated luminosity of 5.5 pb^{-1} .

The process $e^+e^- \to \pi^0\gamma$ was studied in the 3γ final state. The main background sources $e^+e^- \to 3\gamma$ and $e^+e^- \to 2\gamma$ misidentified because of additional clusters from machine background have a QED origin. The background events were subtracted by using the distribution in invariant mass of 2γ. A kinematic fit with energy and momentum conservation constraints was applied to selected events to improve π^0 mass resolution. The number of background events agrees with MC simulation of the QED processes.

The cross section of the studied process was parameterized using variable width Breit-Wigner description. The cross sections $\sigma_{V\pi^0\gamma}$ of the $e^+e^- \to V \to \pi^0\gamma$ transitions at resonances mass ($V = \rho^0, \omega, \phi$) and relative phases $\varphi_{\rho\omega}$,$\varphi_{\phi\omega}$ were approximation parameters. The masses and widths of ω, ρ^0, ϕ -mesons and branching ratios of ω and ϕ major decay modes were taken from previous SND measurements [6], other external parameters were taken from the review of particle physics [7]. The approximation was done including the ρ^0 meson contribution and without it. A model without the ρ^0 meson contribution contradicts to experimental data. The obtained cross section is shown in Fig. 2.

The main sources of systematic errors of the cross section are the uncertainty in luminosity determination -2%, in detection efficiency -2.5%, QED background subtraction -0.5-20% depending on the beam energy. The model and external parameters uncertainty also contribute to systematic errors of cross section parameters.

The cross section parameters are found as:

$$\sigma_{\rho^0\pi^0\gamma} = (0.59 \pm 0.07 \pm 0.06)\, nb$$
$$\sigma_{\omega\pi^0\gamma} = (151.9 \pm 1.5 \pm 4.6)\, nb$$
$$\sigma_{\phi\pi^0\gamma} = (5.58 \pm 0.29 \pm 0.29)\, nb$$
$$\varphi_{\rho\omega} = -9.3^\circ \pm 3.3^\circ \pm 2.4^\circ$$
$$\varphi_{\phi\omega} = 151^\circ \pm 9^\circ \pm 11^\circ$$

and branching ratios of $\rho^0, \omega, \phi \to \pi^0\gamma$ decays:

$$B_{\omega\to\pi^0\gamma} = (8.45 \pm 0.09 \pm 0.25)\,\%$$
$$B_{\rho^0\to\pi^0\gamma} = (5.32 \pm 0.63 \pm 0.50) \cdot 10^{-4}$$
$$B_{\phi\to\pi^0\gamma} = (1.34 \pm 0.07 \pm 0.07) \cdot 10^{-3}$$

The results agree with previous experiments but have a 1.5 times smaller error.

4 Study of the decay $\omega \to \pi^0 e^+ e^-$

The branching ratio of this decay was measured in one experiment with the SND detector [8] at the VEPP-2M collider. The new measurement with the CMD-2 detector is described in this paper. The integrated luminosity about 2.5 pb^{-1} collected at the energy range 720-840 MeV is analyzed.

The main background sources are QED processes, $\omega \to 3\pi$ and $\omega \to \pi^0\gamma$ with γ conversion in the detector material. QED events were subtracted by using the distribution on invariant mass of 2γ. To suppress 3π events, cuts were used on the opening angle between tracks $\Delta\psi < 0.5$ and total momentum of tracks $p > p_\gamma - 35$ MeV/c, where p_γ is the momentum in the process $\omega \to \pi^0\gamma$ at a given energy. The residual 3π events were subtracted by using the distribution on $\Delta\psi$. The shape of the distribution was obtained from MC simulation while the normalization was taken from experimental events. Events of the process $\omega \to \pi^0\gamma$ with γ conversion in the detector material have the same as the studied process final state and can't be separated. They were subtracted by MC simulation. To check MC simulation, the QED process $e^+e^- \to 2\gamma$ with γ conversion in the detector material was studied at the energy 720 MeV, where a contribution of the 3π events is negligible. The ratio of the number of the experimental and simulated events is 0.93±0.07. So no correction to MC simulation was needed. The error of comparison of the experiment and simulation is included into the systematic error.

The cross section of the process $e^+e^- \to \pi^0 e^+e^-$ is shown in Fig. 3. It was parameterized with usual variable width Breit-Wigner description. The contribution of the $\rho^0 \to \pi^0 e^+e^-$ decay was fixed from $\rho^0 \to \pi^0\gamma$ decay parameters from Sect. 3. The measured branching ratio $B_{\omega\to\pi^0e^+e^-} = (8.7 \pm 0.9 \pm 0.5) \cdot 10^{-4}$ agrees with the previous experiment result $(5.9 \pm 1.9) \cdot 10^{-4}$ and the theoretical prediction $(7.9 \pm 0.2) \cdot 10^{-4}$ [9]. To study $\rho^0 \to \pi^0 e^+e^-$ decay, the corresponding amplitude was left as a free parametrization parameter. The upper limit on the branching ratio $B_{\rho^0\to\pi^0e^+e^-} < 3 \cdot 10^{-5}$ (90% C.L.) was obtained.

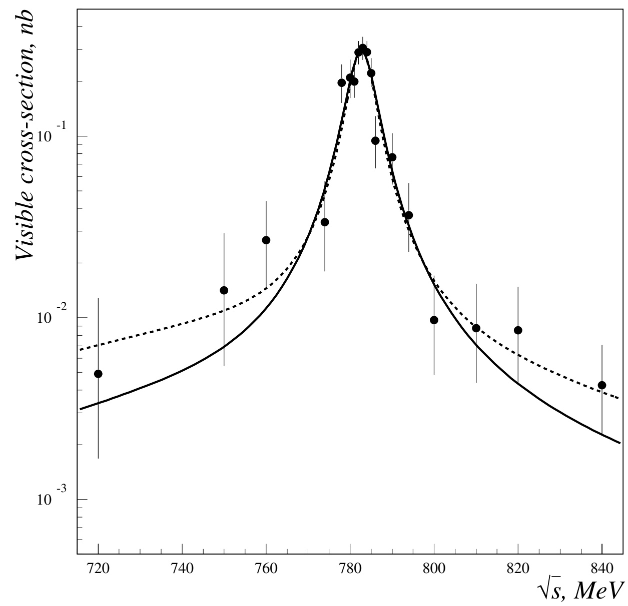

Fig. 3. Cross section of the $e^+e^- \to \pi^0 e^+e^-$ process. *Dots* represent experimental data, the *solid curve* depicts approximated with fixed $\rho^0 \to \pi^0 e^+e^-$, *dashed curve* — with free ρ^0 contribution

5 Conclusion

The hadronic cross sections were measured at the VEPP-2M collider with the CMD-2 and SND detectors with larger statistics and smaller systematic errors compared to previous experiments. The cross sections at the energies above the ϕ meson aren't described by the contributions of the ρ, ω and ϕ mesons only. But the VEPP-2M energy range is not enough to study the excited vector mesons. The new collider VEPP-2000 [10], which is under construction in Novosibirsk now, will provide a nice possibility to study the hadronic production at the energy up to 2000 MeV.

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