PROCEEDINGS OF SCIENCE

Study of the process $e^+e^- \to K^+K^-\pi^0$ with the CMD-3 detector

Andrei L. Erofeev* **on behalf of the CMD-3 collaboration**
Budker Institute of Nuclear Physics, Novosibirsk
Novosibirsk State University, Novosibirsk
E-mail: andrikola@yandex.ru

The process $e^+e^- \to K^+K^-\pi^0$ has been studied at a center-of-mass energy up to 2 GeV using a 34 pb^{-1} data sample collected with the CMD-3 detector at the electron-positron collider VEPP-2000. The preliminary results of the cross-section measurement are presented.

XVII International Conference on Hadron Spectroscopy and Structure - Hadron2017
25-29 September, 2017
University of Salamanca, Salamanca, Spain

*Speaker.

PoS(Hadron2017)252

1. Introduction

The process $e^+e^- \to K^+K^-\pi^0$ has been studied up to now with low statistical accuracy by the BABAR and DM2 experiments. The data on the total cross section of this process are needed for precise calculation of the hadronic contribution to the muon $g-2$. A detailed study of the production dynamics will improve theoretical models of the light hadron production.

The general-purpose detector CMD-3 has been described in detail elsewhere [1]. The tracking system consists of the cylindrical drift chamber (DC) and double-layer multiwire proportional Z-chamber with both subsystems installed inside a thin superconducting solenoid with 1.0-1.3 T magnetic field. Both subsystems are used to generate a trigger signal. The barrel electromagnetic calorimeters plased outside the solenoid are based on liquid xenon (LXe) and CsI crystals with a thickness of 5.4 X_0 and 8.1 X_0, respectively. The endcap calorimeter is made of BGO scintillation crystals with a thickness of 13.4 X_0.

2. Data analysis

We study the process assuming the $\pi^0 \to \gamma\gamma$ decay mode. Therefore all candidate events are characterized by two tracks with zero total charge and at least two photons.

Let ϕ and θ be the angles of the spherical coordinate system. The following conditions are required: the impact parameter of the tracks $\rho < 0.4$ cm, the z-coordinate of the vertex $|z_{vert}| < 10$ cm. Noncollinearity of the tracks is provided by conditions $||\phi_1 - \phi_2| - \pi| > 0.15$ rad and $|\theta_1 + \theta_2 - \pi| > 0.25$ rad. The purpose of these requirements is mainly to reject cosmic rays and beam background events. We also require the tracks to pass over the central part of the drift chamber for the best agreement of experiment and simulation: $|\theta - \pi/2| < 0.8$ rad. In addition to these limitations, selection also concerned the total energy and momentum: $\Delta E = |\sqrt{s} - \sqrt{\mathbf{p}_1^2 + m_K^2} - \sqrt{\mathbf{p}_2^2 + m_K^2} - |\mathbf{k}_1| - |\mathbf{k}_2|| < 0.2$ GeV, $P = |\mathbf{p}_1 + \mathbf{p}_2 + \mathbf{k}_1 + \mathbf{k}_2| < 0.16$ GeV/c, where $\mathbf{p}$ and $\mathbf{k}$ denote the 3-momenta of the track and the photon, respectively.

We perform a 4C-kinematic fit (KF) for every possible pair of detected photons in an event requiring the energy-momentum conservation without applying a mass constraint. The fit reconstructs the momenta and angles of the selected tracks and photons. The photon pair producing the lowest χ^2 is retained if the reconstructed energies of both quanta $E_\gamma > 40$ MeV.

An essential part of background comes from the processes with charged pions: $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ and $e^+e^- \to \pi^+\pi^-\pi^0$. The tracks of pions and kaons are well separated by ionization losses in the drift chamber unless the momenta of these particles are higher than 500 MeV/c (Figure 1). Additionally, at high $\sqrt{s}$ we have to use kinematics to suppress these parasitic processes.

A significant background contribution, as simulation shows, is also represented by the processes $e^+e^- \to K^+K^-\pi^0\pi^0$ and $e^+e^- \to K^+K^-\gamma$. The events of the former are well separated at high energies by the squared missing mass of the tracks $m^2_{miss} = (\sqrt{s} - |\mathbf{p}_1| - |\mathbf{p}_2|)^2 - (\mathbf{p}_1 + \mathbf{p}_2)^2$, where $\mathbf{p}_1$ and $\mathbf{p}_2$ are track momenta before kinematic reconstruction. The process $e^+e^- \to K^+K^-\gamma$ gives the largest background contribution near the threshold of the signal process. In this case the ISR photon momentum is directed at a small angle to the beam axis.

For further background suppression use was made of the Boosted Decision Tree (BDT) method. In accordance with stated above we accepted as BDT arguments the ionization losses dE/dx of the

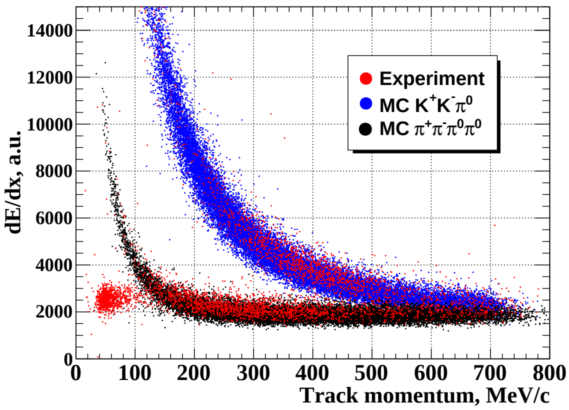

Figure 1: Pion and kaon track separation by ionization losses dE/dx in the DC. Red dots correspond to experimental events. Blue and black dots represent simulated events of signal and $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$, respectively.

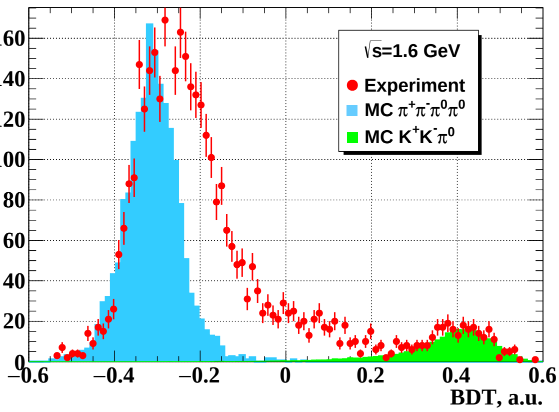

Figure 2: Separation of signal and background events by BDT at $\sqrt{s} = 1.6$ GeV. Red points correspond to the experimental distribution. Green and blue histograms represent the BDT distribution for MC simulation of signal and $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ respectively.

tracks in the DC, the track momenta after kinematic reconstruction, the momenta and angles θ of the photons after KF and the parameter m^2_{miss}. To train and test the classifier we use GEANT4 [2] based Monte Carlo simulation of the signal and all mentioned background processes. Shown in Figure 2 are distributions of the BDT parameter for experimental and simulated data at 1.6 GeV.

The photon pair invariant mass distribution for selected experimental events is shown in Figure 3. The simulated distribution of the photons invariant mass $m_{\gamma\gamma}$ is found to be in good agreement with experimental one. Since the background shape depends significantly on beam energy and the simulation does not completely describe the background, we approximate $m_{\gamma\gamma}$ experimental distribution at every energy point by the sum of the signal function fixed from the simulation and a quadratic polynomial describing the background (Figure 4).

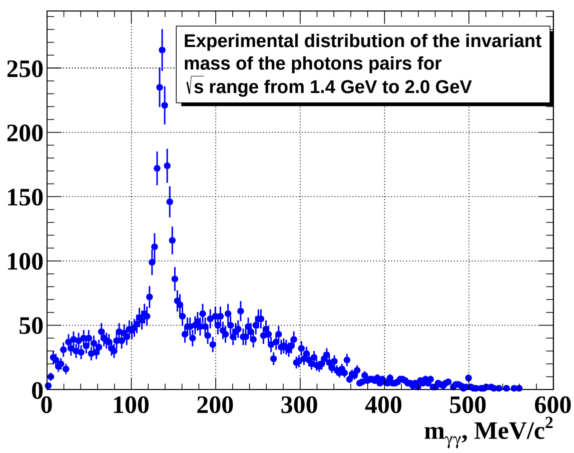

Figure 3: Experimental distribution of the photon pair invariant mass for $\sqrt{s}$ range from 1.4 GeV to 2.0 GeV.

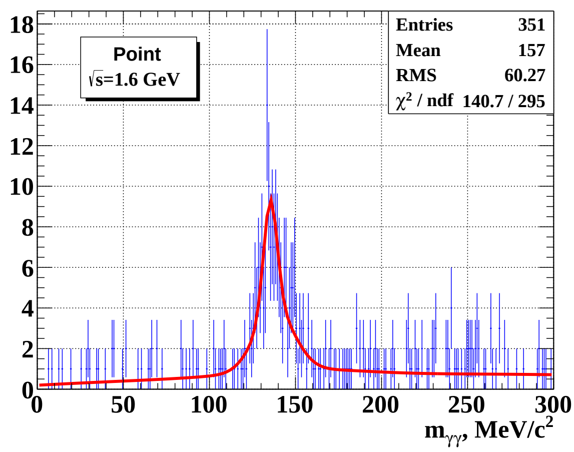

Figure 4: Approximation of the experimental distribution of the photon pair invariant mass for $\sqrt{s} = 1.6$ GeV.

3. Results

Shown in Figure 5 is the Dalitz plot distribution in coordinates of the $K^+\pi^0$ and K^+K^- invariant masses for signal events selected. A small contribution of the $\phi\pi^0$ intermediate state is evident.

The Born cross section at the i-th energy point s_i is determined by the standard formula $\sigma_B(s_i) = N_i/(\varepsilon_i L_i(1+\delta_{rc,i}))$, where N_i, ε_i, L_i and $\delta_{rc,i}$ denote the signal event number, detection efficiency, luminosity and radiation correction, respectively. The detection efficiency was determined from MC simulation of the signal process according to the $e^+e^- \to K^*K$ model as this intermediate mechanism is known to dominate the process. The result is shown in Figure 6 in comparison with the cross section previously measured by BABAR [3] for the K^*K intermediate state.

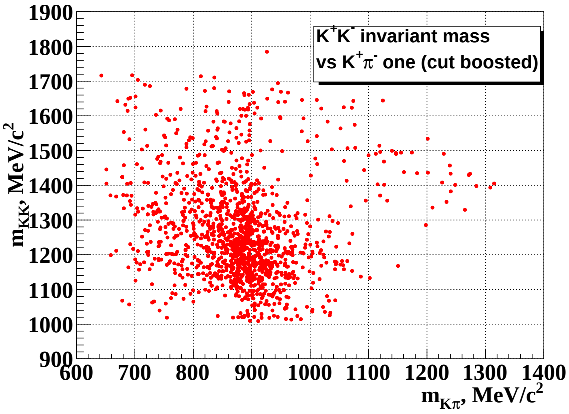

Figure 5: The Dalitz plot distribution for signal events.

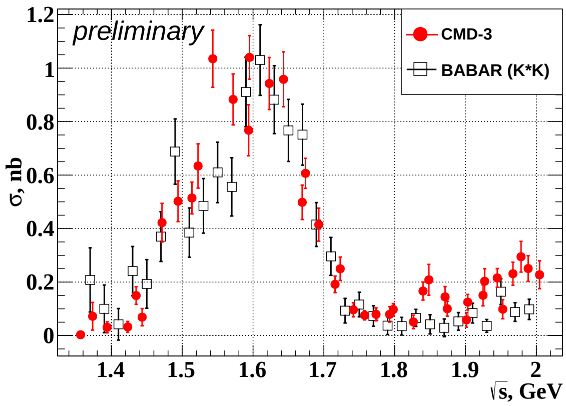

Figure 6: Cross section of $e^+e^- \to K^+K^-\pi^0$ process in comparison with the previous BABAR measurement.

4. Conclusion

The presented results are preliminary. The selection criteria including a cut on BDT are now under optimization. New statistics were collected with the VEPP-2000 collider in 2017 with the instantaneous luminocity increased by a factor 3 – 5. The data are being processed.

This work was supported by the RFBR grant 17-52-50064.

References

[1] B. I. Khazin et al. (CMD-3 collaboration), *Physics and detectors for VEPP-2000*, *Nucl. Phys. B Proc. Suppl.* **181-182** 376 (2008).

[2] S. Agostinelli et al. (GEANT4 Collaboration), *GEANT4—a simulation toolkit*, *Nucl. Instrum. Methods Phys. Res. A* **506** 250 (2003).

[3] B. Aubert et al. (BABAR collaboration). *Measurements of $e^+e^- \to K^+K^-\eta$, $K^+K^-\pi^0$ and $K_s^0K^\pm\pi^\mp$ Cross Sections Using Initial State Radiation Effects*, *Phys. Rev. D* **77** 092002 (2008).