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Study of the $e^+e^- \to K_S K_L \pi^0$ process up to 2 GeV with the CMD-3 detector at the VEPP-2000 collider

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Abstract. The cross section of the process $e^+ e^- \to K_S K_L \pi^0$ has been studied with the CMD-3 detector at the VEPP-2000 electron-positron collider in the center-of-mass energy range from 1.1 to 2 GeV. Preliminary results on the total cross section of the process are presented.

1 Introduction

At the present time the VEPP-2000 e^+e^--collider is operating at Budker Institute of Nuclear Physics in Novosibirsk. The CMD-3 detector is installed in one of two interaction regions of the collider. The physics program of experiments at VEPP-2000 includes the high-precision measurement of various exclusive cross sections of $e^+e^- \to hadrons$. Values of such cross sections at low energies are necessary for a calculation of the hadronic contribution to the muon anomalous magnetic moment $(g-2)_\mu$, studies of intermediate dynamics of hadron production and verification of theoretical models of light meson production. Final states with two K-mesons and one π^0-meson give a 12% contribution to the total hadronic cross section at the energy 1.7 GeV. In this study we obtain the preliminary results on the process $e^+e^- \to K_S K_L \pi^0$. The current study is based on an integrated luminosity of 81 pb^{-1} obtained in 2011, 2012 and 2017 in the center-of-mass (c.m.) energy range from 1.1 GeV to 2 GeV. The previous measurements of this cross section were performed with the SND [1] and BaBar [2] detectors.

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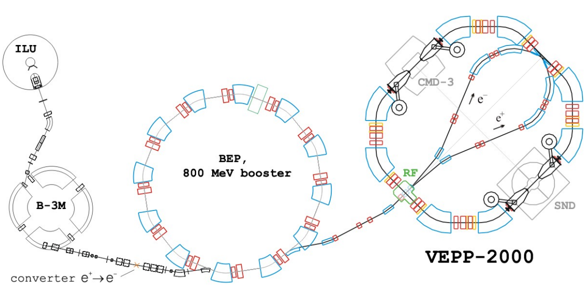

Figure 1. Scheme of the VEPP-2000 collider.

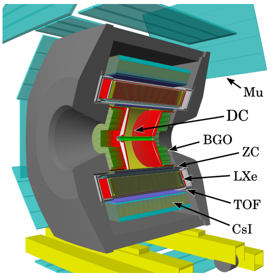

Figure 2. Sketch of the CMD-3 detector.

2 VEPP-2000

The VEPP-2000 is an electron-positron collider at BINP [3]. Its distictive feature is the concept of circular cross sections of the beam, which increases the collider luminosity up to $1 \times 10^{32}/(\text{cm}^2\,\text{s})$ (design value). The measurement of the integrated luminosity is based on the determination of the number of events of the processes $e^+e^- \to e^+e^-$ and $e^+e^- \to \gamma\gamma$.

3 CMD-3

The Cryogenic Magnetic Detector (CMD-3) [4] is a multipurpose detector. Its tracking system consists of the cylindrical drift chamber (DC) and the double-layer cylindrical multiwire proportional Z-chamber installed inside a thin ($0.085X_0$) superconducting solenoid with 1.0 – 1.3 T magnetic field. Both subsystems are also used to provide the trigger signals. The DC is filled with argon-isobutane gas. The electromagnetic calorimeter consists of two subsystems: the endcap and the barrel calorimeter. The calorimeter system covers a solid angle of $0.94 \cdot 4\pi$. BGO crystals of $13.4X_0$ thickness are used in the endcap calorimeter. The barrel electromagnetic calorimeters based on liquid xenon (LXe) ($5.4X_0$) and CsI crystals ($8.1X_0$) are placed outside the solenoid. The total amount of material in front of the barrel calorimeter is $0.13X_0$ that includes the solenoid as well as the radiation shield and vacuum vessel walls. The magnetic flux-return yoke is surrounded by scintillation counters which are used to tag cosmic events.

4 Event selection

The process was studied in the decay modes $K_S \to \pi^+\pi^-$ and $\pi^0 \to \gamma\gamma$. A candidate event should fulfil the following conditions:

- two oppositely charged tracks
- ionization losses correspond to charged pions
- polar angles of tracks are in the range $(0.8; \pi - 0.8)$
- cosine between the sum of track momenta and radius-vector of their common vertex in the XY plate is larger than 0.8
- radial distance from the beam axis to the K_S vertex is larger than 0.2 cm
- at least two photons
- photon candidate should have clusters in LXe-calorimeter or in BGO-calorimeter

- angle between photon candidates is more than 0.2 radians

In addition to the signal, events of the following processes can pass the criteria and form the main background events:

- $e^+e^- \to K_S K_L \gamma$
- $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$
- $e^+e^- \to K_S K_L \pi^0\pi^0$

5 Reconstruction

- reconstruction of the K_S parameters $(E, \vec{P}, M_{inv})$
- correction of photon polar angles to the intersection point with the beam axis and with the K_S momentum
- selection of two photons
  - use of conservation laws to choose two photons which have the closest missing mass to the K_L-meson
- reconstruction of the K_L parameters $(E, \vec{P}, M_{inv})$
- reconstruction of the π^0 parameters $(\epsilon, \vec{p}, m_{inv})$

Therefore, the signal process has a peaking distribution of the invariant masses of the K_S and π^0 mesons. But the process $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ has a uniform distribution of the K_S mass and peaking distribution of the invariant masses of the π^0 mesons. The remaining background processes have a combinatorial distribution of the two-photon invariant mass and peaking distribution of the K_S mass.

6 Number of events

For determination of the number of events we separate the events into two groups: events with invariant mass of two tracks in the signal region (480 MeV/c^2; 520 MeV/c^2) and events with K_S mass in the sideband region (left of 480 MeV/c^2 and right of 520 MeV/c^2), see Fig. 3. We determine the number of events with π^0 by a fit of the invariant mass of two photons in the signal and sideband ranges of a K_S-meson. Then we obtain the signal number of events from the next expression:

$$N_{result} = N_{\pi^0}^{signal} - \alpha N_{\pi^0}^{sideband}$$

,
where $\alpha \approx 0.33$ — the ratio between the number of background events in the sideband and signal ranges which are evaluated by the fitting of the combinatorial background of the invariant mass of two tracks.

7 Total efficiency

The Monte Carlo simulation of the CMD-3 is used to determine the detection efficiency ε_{det} after applying the selection criteria. The Monte Carlo simulation is performed in two models: $e^+e^- \to K^*\bar{K}, \bar{K}^*K$ and $e^+e^- \to \phi\pi^0$ with ISR. In the analysis we used 10^5 events for every energy point taking into account the peculiarities of the season (magnetic field). Because the process reconstruction can miss a signal photon from a neutral pion, we introduce a correction equal to the ratio of the number of events with two signal photons and events

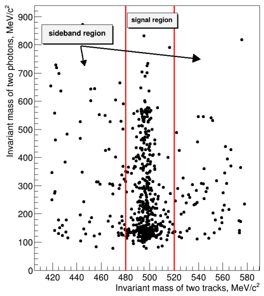

Figure 3. Dependence of π^0 mass on K_S mass.

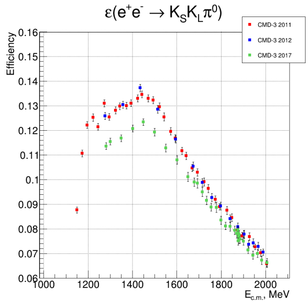

Figure 4. Dependence of the efficiency on c.m. energy

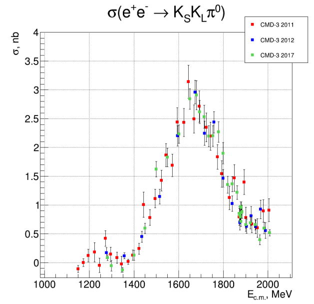

Figure 5. Cross section of the process $e^+e^- \to K_S K_L \pi^0$

which fulfil the selection criteria. After using the sideband method we should obtain the total number of events by introducing the efficiency of the missed candidates. The total efficiency is defined as

$$\varepsilon = \varepsilon_{det} \cdot \varepsilon_{\pi^0} \cdot \varepsilon_{K_S},$$

where $\varepsilon_{det} = \frac{N_{out}}{N_{in}}$ — detection efficiency, $\varepsilon_{\pi^0} = \frac{N_{\pi^0}}{N_{out}}$ — π^0 reconstruction efficiency, $\varepsilon_{K_S} = \frac{N^{signal}}{N_{out}}$ — efficiency of K_S detection, see Fig. 4.

8 Cross section of $e^+e^- \to K_S K_L \pi^0$

The total cross section is determined by the following ratio:

$$\sigma = \frac{N}{\varepsilon \varepsilon_{trigger} L(1 + \delta_{rad})},$$

where N — the number of signal events, ε — detection efficiency, $\varepsilon_{trigger}$ — trigger effeciency, L — integrated luminosity and $(1 + \delta_{rad})$ — initial-state radiative correction. The result is presented in Fig. 5.

9 Conclusions

The preliminary cross section of 2011, 2012 and 2017 seasons of the process $e^+e^- \to K_S K_L \pi^0$ is measured. Now we study of systematic uncertainties.

Acknowledgments

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References

[1] M. Achasov, V. Aulchenko, A. Barnyakov, K. Beloborodov, A. Berdyugin, D. Berkaev, A. Bogdanchikov, A. Botov, T. Dimova, V. Druzhinin et al., Physical Review D **97** (2018)
[2] W. Gradl (2016)
[3] M.N. Achasov et al., JETP **113**, 213 (2011)
[4] B.I. Khazin (CMD-3, SND), Nucl. Instrum. Meth. **A623**, 353 (2010)