Study of the $\omega \to \pi^0 e^+ e^-$ conversion decay with the CMD-3 detector at VEPP-2000 collider

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Introduction

- The study of the omega meson conversion decay into $\pi^0 e^+ e^-$ state was performed with the CMD-3 detector at the VEPP-2000 electron-positron collider in Novosibirsk
- Measurement of branching ratios and transition form factors of conversion decays provide an important test of vector dominance model and an accurate background estimation in searches for quark-gluon plasma involving a lepton pair
- Using an integrated luminosity of about 10 pb^{-1} collected at the c.m. energy range from 775 MeV to 800 MeV the visible cross-section of the process under study was measured and the preliminary result for branching ratio $Br(\omega \to \pi^0 e^+ e^-)$ was obtained

Instrumentation

The Cryogenic Magnetic Detector (CMD-3) is a general-purpose detector for the VEPP 2000 electron positron collider, which is located at Budker Institute of Nuclear Physics (BINP, Novosibirsk, Russia). The CMD-3 is designed to study e^+e^- annihilation into hadrons with high precision. The main aspects of physical program of the experiment are precision measurements of hadronic cross sections in the region of center of mass energy range from 0.4 GeV up to 2 GeV

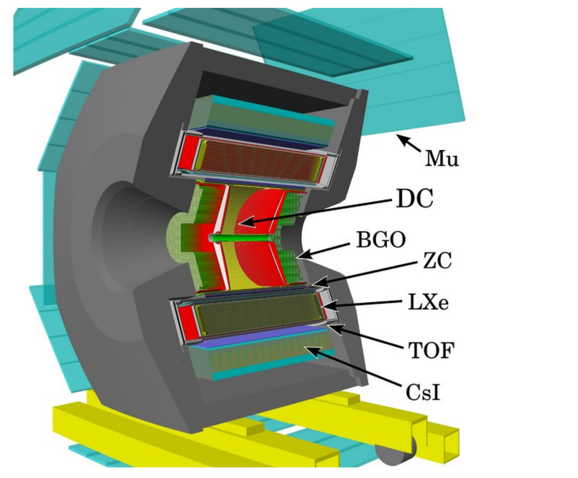

Fig. 1: The CMD-3 detector layout. Mu - muon system; DC - drift chamber; BGO - endcap calorimeter; ZC - Z chamber; LXe - liquid xenon calorimeter; TOF - time-of-flight system; CsI - barrel calorimeter

Selection criteria

- Two reconstructed tracks with polar angles 0.9 < $\theta_{1,2}$ < π-0.9 with a common vertex
- Two or more photons with energy $E_{\gamma 1,2} > 40 MeV$
- The minimal distance between the beam and the tracks $\rho < 1$ cm and the Z-coordinate of the vertex |Zvert| < 8 cm
- The spatial angle between tracks $\Delta\psi <$ 1 rad
- Noncollinear tracks in the $R-\phi$ projection $|\pi - |\phi_1 - \phi_2|| > 0.15$
- The angle between the total momentum of the tracks and each photon is greater than 1.5 rad
- The angle between photons is less than 1.6 rad
- The cut for recoil mass of photon pair, where it is understood that photons are originated from π^0 decay
- The invariant mass of the electron–positron pair and the most energetic photon $M_{inv}(e^+e^-\gamma_0) < 1.9 \cdot E_{beam}$ are followed by the conversion of the γ
- Other selection criteria is shown at Fig. 3 and Fig. 2

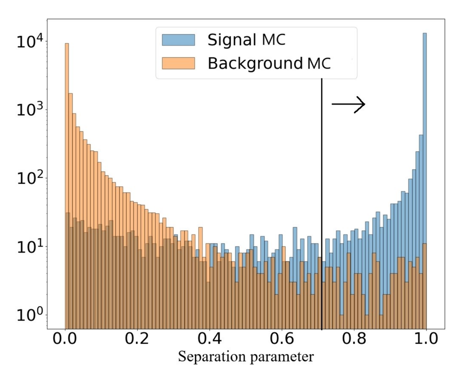

Fig. 2: Separation parameter ξ distribution

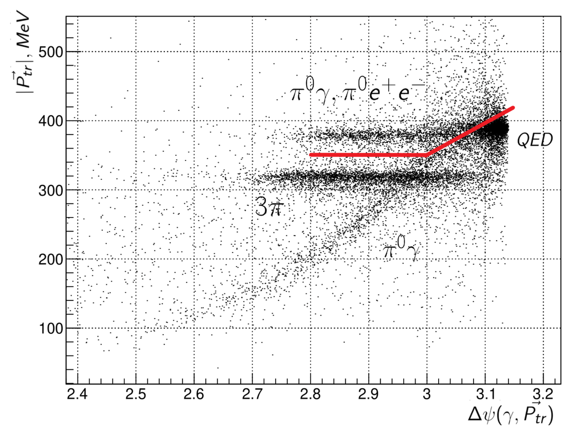

Fig. 3: Dependence of the total momentum of charged particles P_{tr} on the angle between the average momentum of tracks and photon of maximum energy γ_0

Events with π^0

- The number of signal and background events has been obtained from a fit of the invariant mass distribution at each energy point. The shapes of the signal and background curves were fixed from the fit of experimental data in the energy range 775–800MeV (see Fig. 4), so the varying parameters at each energy point were the number of signal and background events. These values were used to determine the visible cross-section of the signal (see Fig. 6), using: $\sigma_{vis} = \frac{N_{sig,i}}{L_i(1+\delta_i)\varepsilon_{det}\varepsilon_{\pi^0}\varepsilon_{\Delta\psi}Br(\pi^0\to\gamma\gamma)}$ and background events, using: $\sigma^{bg}_{vis} = \frac{N^{bg}_i}{L_i\ \varepsilon_{det}}$

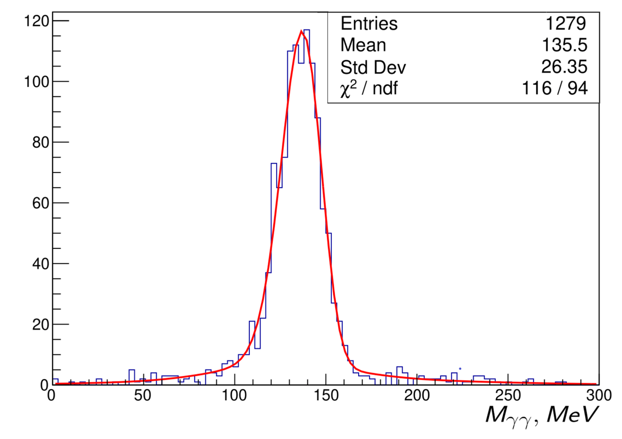

Fig. 4: Invariant mass of $\gamma\gamma$ for experimental data in energy range 775–800 MeV

Photon conversion background

- One of the main physical background to the process under study is radiative decay $\omega \to \pi^0\gamma$, when monochromatic photon converts to e^+e^- pair on the material in front of the detector
- This background process can be suppressed by a separation parameter, derived from machine learning model
- The multilayer perceptron neural network model was trained based on MC signal and background simulation of vertex and tracks parameters. Distribution of separation parameter is shown at Fig. 2. Systematic error evaluated from QED events
- The threshold for class selection was chosen as $\xi_{thresh} = 0.7$, based on statistical error minimization

Efficiencies

- The detection efficiency $\varepsilon^{\pi^0 e^+ e^-}_{det}$ was determined using Monte Carlo simulation based on the GEANT4. It's value varies, depending from the energy, from 20.6% to 22.8%
- Overall trigger efficiency value varies from 0.996 to 1
- The π^0 recovery efficiency in a CMD-3 varies from 0.989 ± 0.006 to 1.007 ± 0.006

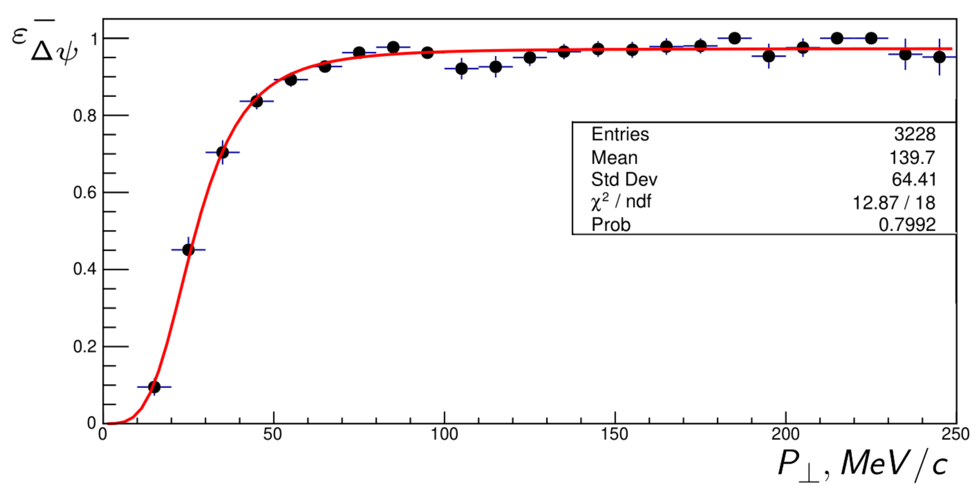

Fig. 5: Efficiency of track reconstruction versus transverse momentum for e^- for experimental data

- Number of 3π events that pass signal selection criteria were calculated and 55 events were found
- Correction $\varepsilon_{\Delta\psi}$ for a difference between the reconstruction efficiencies of close tracks in simulation and experiment was evaluated using events of $\omega \to \pi^0\pi^+\pi^-$ decays followed by the Dalitz decay $\pi^0 \to \gamma e^+ e^-$
- Using the efficiency of tracks reconstruction dependence from the transverse momentum: $\varepsilon^-_{\Delta\psi,exp}$(Fig. 5), $\varepsilon^+_{\Delta\psi,exp}$, $\varepsilon^-_{\Delta\psi,mc}$, $\varepsilon^+_{\Delta\psi,mc}$ correction $\varepsilon_{\Delta\psi}$ was calculated as the average of the following integral:

$$\varepsilon_{\Delta\psi} = \int \frac{\varepsilon^-_{\Delta\psi,exp}(P^-_\perp)}{\varepsilon^-_{\Delta\psi,sim}(P^+_\perp)} \frac{\varepsilon^+_{\Delta\psi,exp}(P^-_\perp)}{\varepsilon^+_{\Delta\psi,sim}(P^+_\perp)} f(P^-_\perp) f(P^+_\perp) dP^-_\perp dP^+_\perp$$

$$\varepsilon_{\Delta\psi} = 0.986 \pm 0.010 \text{ (stat.)} \pm 0.006 \text{ (syst.)}$$

Visible cross-section

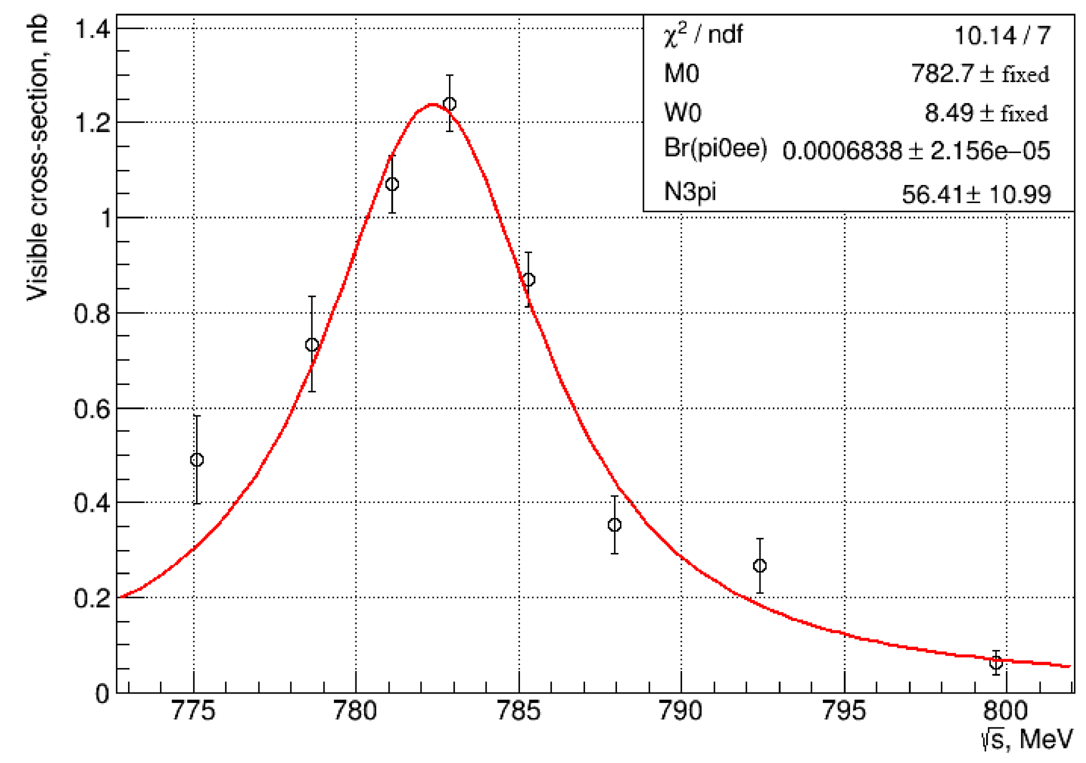

Fig. 6: Preliminary visible cross-section of $e^+e^- \to \omega \to \pi^0 e^+ e^-$, fitted with VMD cross-section parametrization

Table 1: Branching of $\omega \to \pi^0 e^+ e^-$ and statistic in different experiments

	ND	SND	CMD-2	CMD-3 (preliminary)
$Br(\omega \to \pi^0 e^+ e^-), 10^{-4}$	5.9 ± 1.9	$7.61 \pm 0.53 \pm 0.64$	$8.19 \pm 0.53 \pm 0.62$	6.83 ± 0.22
Statistic, pb^{-1}	-	9.8	3.3	10

Table 2: Overall result on investigation of signal events $\omega \to \pi^0 e^+ e^-$ at each energy point

$\sqrt{s}$, MeV	L, nb^{-1}	δ	ε_{det}	ε_{π^0}	$\varepsilon_{\Delta\psi}$	N^{exp}_{sig}	σ_{vis}, pb
775	425.91	-0.212	0.21	0.998	0.986	33	0.4728
779	502.117	-0.218	0.206	1.007	0.986	58	0.7088
781	2019.37	-0.224	0.213	0.999	0.986	347	1.0335
783	2431.22	-0.191	0.212	1.000	0.986	497	1.1983
785	1789.6	-0.138	0.21	0.997	0.986	273	0.8405
788	540.47	-0.035	0.215	0.0.994	0.986	37	0.3413
792	397.1	0.156	0.214	0.986	0.989	27	0.2578
800	350.253	0.427	0.228	0.986	1.005	7	0.0597

Table 3: Several contributions to systematic errors. Analysis in progress.

Luminosity	Resonance parameters of ρ and ω	Selection criteria	Close track efficiency	Suppression of conversion	3π background
0.8%	2.4%	3.2%	0.5%	2%	0.9%

Results and Acknowledgment

- Using integrated luminosity about 10 pb^{-1} collected at the energy range from 775 MeV to 800 MeV, the visible cross-section of the process $\omega \to \pi^0 e^+ e^-$ was measured as it shown at Fig. 6
- The preliminary results for the branching ratio $Br(\omega \to \pi^0 e^+ e^-) = (6.83 \pm 0.22(stat.) \pm 0.32(syst.) \times 10^{-4}$ were obtained

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