Study of the $\omega \rightarrow \pi^0 e^+ e^-$ 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 $Br(\omega \rightarrow \pi^0 e^+ e^-)$ was obtained.

Events with $\pi^0$

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 775–800 MeV (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: $\epsilon_{\text{vis}} = \frac{N_{\text{exp}} - N_{\text{bkg}}}{N_{\text{sim}}}$ and background events, using: $\epsilon_{\text{bkg}} = \frac{N_{\text{bkg}}}{N_{\text{bkg}}}$.

Photon conversion background

One of the main physical background to the process under study is radiative decay $\omega \rightarrow \pi^0 \gamma$, 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 $\epsilon_{\text{thresh}} = 0.7$, based on statistical error minimization.

Efficiencies

The detection efficiency $\epsilon_{\gamma}$ 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 $e^+ e^-$ recovery efficiency in a CMD-3 varies from 0.989 ± 0.006 to 1.007 ± 0.006.

Number of $3\gamma$ events that pass signal selection criteria were calculated and 55 events were found.

Correction $\epsilon_{\text{corr}}$ for a difference between the reconstruction efficiencies of close tracks in simulation and experimental was evaluated using events of the process $\omega \rightarrow \pi^0 \gamma$.

Using the efficiency of tracks reconstruction dependence from the transverse momentum $\epsilon_{\text{cor}}, \epsilon_{\text{vis}}$, the correction $\epsilon_{\text{corr}}$ was calculated as the average of the following integral:

$\epsilon_{\text{corr}} = \frac{1}{2\pi} \int_0^{\sqrt{\Delta E}} \epsilon_{\text{vis}} \epsilon_{\text{cor}}(\sqrt{\Delta E}) d\sqrt{\Delta E}$

Visible cross-section

The preliminary results for the branching ratio $Br(\omega \rightarrow \pi^0 e^+ e^-)$ was measured as shown at Fig. 6.

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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 $\omega \rightarrow \pi^0 e^+ e^-$ was measured as it shown at Fig. 6.

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

Fig. 2: Separation parameter $\xi$ distribution

Fig. 3: Dependence of the total momentum of charged particles $P_{\text{vis}}$ on the angle between the average momentum of tracks and photon of mass energy $\gamma_0$

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

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

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

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

<table>
<thead>
<tr>
<th>$\gamma\delta$</th>
<th>ND</th>
<th>SND</th>
<th>CMD-2</th>
<th>CMD-3</th>
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<tbody>
<tr>
<td>$\omega$</td>
<td>9.1</td>
<td>7.6</td>
<td>0.5</td>
<td>0.2</td>
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<tr>
<td>$\omega \pm 0.53$</td>
<td>8.1</td>
<td>0.5</td>
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<td>0.2</td>
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<tr>
<td>$\omega \pm 0.62$</td>
<td>6.5</td>
<td>0.6</td>
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<tr>
<td>$\omega \pm 0.64$</td>
<td>3.3</td>
<td>0.6</td>
<td>0.2</td>
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Table 2: Overall result on investigation of signal events $\omega \rightarrow \pi^0 e^+ e^-$ at each energy point

<table>
<thead>
<tr>
<th>$\sqrt{s}$, MeV</th>
<th>$\Delta\gamma$</th>
<th>$\Delta\delta$</th>
<th>$\delta$</th>
<th>$\gamma$</th>
<th>$\epsilon\Delta\gamma\Delta\delta$</th>
<th>$\epsilon\Delta\gamma\Delta\delta$</th>
<th>$\epsilon\Delta\gamma\Delta\delta$</th>
<th>$\epsilon\Delta\gamma\Delta\delta$</th>
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<tbody>
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<td>800</td>
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Table 3: Several contributions to systematic errors. Analysis in progress.

<table>
<thead>
<tr>
<th>Systematic</th>
<th>Uncertainty</th>
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<tr>
<td>Luminosity</td>
<td>0.8%</td>
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<tr>
<td>$\rho_{\omega}$</td>
<td>2.4%</td>
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<tr>
<td>Selection</td>
<td>3.2%</td>
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<tr>
<td>Close track efficiency</td>
<td>0.5%</td>
</tr>
<tr>
<td>Suppression</td>
<td>2%</td>
</tr>
<tr>
<td>Conversion</td>
<td>0%</td>
</tr>
<tr>
<td>3$\gamma$</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Results and Acknowledgment

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