THE PRECISE MEASUREMENT OF THE ω-MESON PARAMETERS WITH THE CMD-2 DETECTOR *

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Abstract

The integrated luminosity of $\sim 100\ nb^{-1}$ has been collected in the ω-meson energy region. The acquired statistics allows to improve the accuracy of ω leptonic width by a factor of two. Preliminary results on the ω parameters are presented.

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1 Introduction

The VEPP-2M collider at the Budker Institute of Nuclear Physics in Novosibirsk covers a center of mass energy range from 0.4 upto 1.4 GeV[1]. One of the two detectors on this machine is the general purpose detector CMD-2[2, 3] with a 1 T axial magnetic field, tracking system and CsI(barrel) and BGO(endcap) calorimeters.

During 1994–1995 the c.m. energy region from 2x380 to 2x405 MeV has been scanned at 13 energy points with a total luminosity integral of 122 nb^{-1}. The beam energy in each point has been measured by the resonant depolarization technique and is known to an accuracy better than 10^{-4}[4].

All data were collected using two independent triggers — the Charged Trigger[5] and the Neutral Trigger[6]. That allowed to estimate systematic errors of the results originating from the uncertainty of the trigger efficiency.

2 Data Analysis

In the ω energy region any event with two non-collinear tracks is a good candidate for a $\omega \to \pi^+\pi^-\pi^0$ decay. Therefore all events with two tracks originating from the same vertex each having a polar angle $.85 < \theta < \pi - .85$, to be within the fiducial volume of the detector, were selected for further analysis.

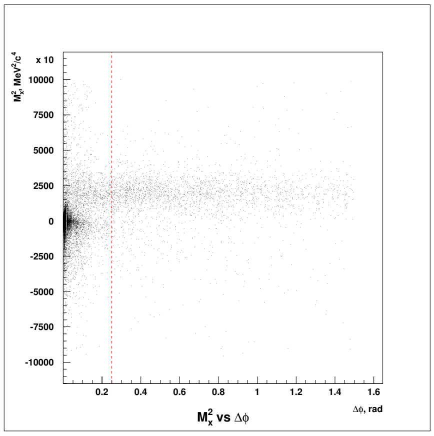
Since only the Drift Chamber[7] information has been used for the 3π events selection, most of the background comes from the processes with a hard radiative photon emission:

$$e^+e^- \to e^+e^-\gamma, \pi^+\pi^-\gamma, \mu^+\mu^-\gamma.$$

These processes have the same signature as $\pi^+\pi^-\pi^0$, except that they have a different acollinearity angle ($\Delta\phi$) distribution which has a strong peak near $\Delta\phi = 0$. Thus the rejection of events with a small $\Delta\phi$ drastically reduces the background but also decreases the number of 3π events. A value of $\Delta\phi = .25$ was used as a reasonable compromise(see Figure 1).

Additional background suppression can be achieved using the "missing mass" parameter, assuming all charged particles to be pions and taking into account momentum and energy conservation. For real $\pi^+\pi^-\pi^0$ events the distribution over the missing mass squared has a peak in the region of $M^2_{\pi^0}$ contrary to the background processes which have a peak around $M^2_{\pi^0} = 0$ for $e^+e^- \to \pi^+\pi^-\gamma, \mu^+\mu^-\gamma$ or peak in the negative region for $e^+e^- \to e^+e^-\gamma$. Figure 2 shows the squared missing mass of two charged particles versus maximum energy deposition in the calorimeter produced by these two particles. The lines show the cut applied for the separation of $\pi^+\pi^-\pi^0$ events from the background. The effect of this cut is illustrated in Figure 3

The resulting numbers of $\pi^+\pi^-\pi^0$ events were obtained by fitting the histograms similar to the one shown in Figure 3 with the sum of Gaussian functions



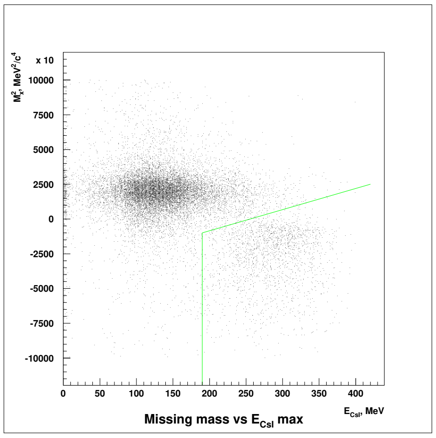
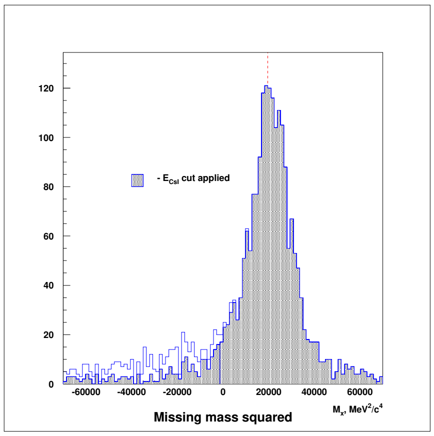


Figure 1: The squared missing mass vs acollinearity angle.

Figure 2: The squared missing mass vs CsI energy(see text).



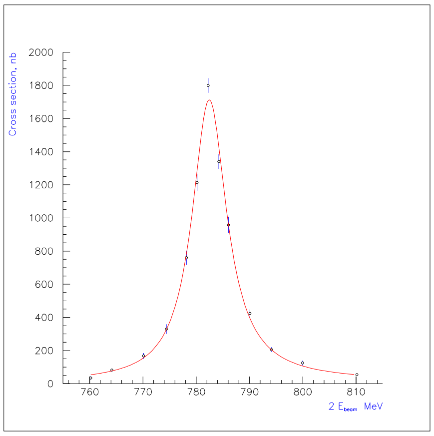


Figure 3: The squared missing mass of two charged particles(taken as pions). Shaded histogram corresponds to cut shown in Figure 2 applied. Vertical dashed line points to the $M_{\pi^0}^2$ value.

Figure 4: ω-meson excitation curve.

describing 3π and background events.

The cross section at each energy point was calculated as follows:

$$\sigma = \frac{N}{L \cdot \epsilon \cdot (1 + \delta_{rad})},$$

where N is the number of 3π events, L — the luminosity, ϵ — the total registration efficiency for $e^+e^- \to \pi^+\pi^-\pi^0$ events and δ_{rad} — the radiative correction.

Luminosity was determined by the number of the Bhabha events, selected by the presence of two collinear tracks in the Drift Chamber and high energy deposition in the CsI barrel calorimeter[8] with the statistical error in each energy point on the level of 1–2 %.

Radiative corrections were calculated according to [9] with an accuracy better than 1%.

The geometric efficiency was taken from Monte-Carlo simulations while trigger and reconstruction efficiencies were determined with the help of special "test" events, known to be $\pi^+\pi^-\pi^0$ events with a sufficient level of reliability. Such events were obtained as a result of the constraint fits based on the information from Z-chamber[7] and CsI calorimeter only.

The combined trigger and reconstruction efficiency was found to be approximately the same within the errors for all energy points with a mean value of .91 ± .01

3 Fit to data and ω-meson parameters

Experimental data were fitted with a resonant curve corresponding to the interference of two relativistic Breit-Wigner cross sections with energy-dependent widths for the ω and ϕ mesons. It can be written as:

$$\sigma_{e^+e^-\to\pi^+\pi^-\pi^0}(s) = \left| \sqrt{\frac{\sigma_0(\omega\to\pi^+\pi^-\pi^0)}{F(M_\omega^2)}} \cdot \frac{M_\omega\Gamma_\omega}{M_\omega^2 - s - i\sqrt{s}\Gamma_\omega(s)} + e^{i\alpha}\sqrt{\frac{\sigma_0(\phi\to\pi^+\pi^-\pi^0)}{F(M_\phi^2)}} \cdot \frac{M_\phi\Gamma_\phi}{M_\phi^2 - s - i\sqrt{s}\Gamma_\phi(s)} \right|^2 \cdot F(s),$$

where $F(s)$ is a three pion phase space. Its value was calculated on the basis of the $\omega \to \rho\pi \to 3\pi$ decay model.

The relative phase of $\omega - \phi$ mixing α was taken to be 155° according to [10].

The leptonic width can be calculated with the help of the formula:

$$\Gamma_{\omega\to e^+e^-} = \Gamma_\omega \cdot \frac{\sigma_0(\omega\to\pi^+\pi^-\pi^0)}{B(\omega\to\pi^+\pi^-\pi^0)} \cdot \frac{M_\omega^2}{12\pi}.$$

Here $B(\omega \to \pi^+\pi^-\pi^0) = .888 \pm .006$ was taken from [11] and all other parameters were defined from the fit.

Currently the main systematic error in the ω leptonic width comes from the uncertainty in the luminosity determination and is about 3%. The improvement of the Bhabha event selection procedure will reduce this error to the value of $\sim 1\%$.

Another possible source of significant systematic error is the efficiency determination which depends on the "purity" of the test event sample. This error presumably do not exceed $2-3\%$ and is subject of further investigations.

Several other error sources are the accuracies of the radiative corrections, detector fiducial volume determination, pion decays in flight and nuclear interaction processes inside the tracking system. All of them are on the order of .5% or less and at present do not contribute significantly to the total systematic error of the ω leptonic width.

The systematic error of the total ω width originates mainly from the background uncertainty and is estimated to be on the level of the statistical error, i.e. $\sim 2.5\%$. It could be reduced by a better background suppression with the help of the barrel calorimeter.

Experimental points together with the fitted excitation curve are shown in Figure 4. The following ω-meson parameters were obtained from the fit:

$$\Gamma_{e^+e^-} = .62 \pm .01 \pm .02 \ \text{keV},$$
$$\Gamma_{tot} = 8.23 \pm .20 \pm .30 \ \text{MeV},$$

This should be compared to the current PDG values[11]:

$$\Gamma_{e^+e^-} = .60 \pm .02 \ \text{keV},$$
$$\Gamma_{tot} = 8.43 \pm .10 \ \text{MeV},$$

We do not present here the value of the ω-meson mass, because its systematic error is not sufficiently studied yet.

4 Conclusions

The acquired integrated luminosity of $\sim 120\ nb^{-1}$ allows us to determine the ω-meson leptonic width with the accuracy of about 1.5–2%. Current systematic errors are of the order of 3% but can be lowered below 1% with a more accurate investigation, thus reducing the error of the ω leptonic width by a factor of 2.

Careful investigation of different factors contributed to the beam energy systematic error will set the error on ω-meson mass to the value of $\sim$0.1 MeV.

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