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MEASUREMENT OF $e^+e^- \to \phi \to K^+K^-$ CROSS SECTION WITH CMD-2 DETECTOR AT VEPP-2M COLLIDER

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ABSTRACT

About 363 000 $e^+e^- \to \phi \to K^+K^-$ events in the center-of-mass energy range from 1010 to 1034 MeV were used for the measurement of the ϕ meson parameters. The following results have been obtained: $\sigma_0 = (2044 \pm 10 \pm 57)$ nb, $m_\phi = (1019.448 \pm 0.010 \pm 0.080)$ MeV/c^2, $\Gamma_\phi = (4.25 \pm 0.03 \pm 0.03)$ MeV, $B_{ee} \cdot B_{K^+K^-} = (14.46 \pm 0.07 \pm 0.40) \cdot 10^{-5}$.

1 Introduction

$\phi \to K^+K^-$ decay is the main ϕ meson decay mode (its branching ratio is about 50%), but until recently it was measured with relatively poor accuracy [1, 2]. A study of the K^+K^- production in the center-of-mass (CM) energy range around 1020 MeV also allows a determination of the ϕ meson parameters.

* On behalf of the CMD-2 Collaboration

In this paper we present the preliminary result of a study of the process $e^+e^- \to K^+K^-$ in the CM energy range 2E = 1010 – 1034 MeV, performed with the CMD-2 detector [3] at the VEPP-2M collider [4]. The analysis is based on 0.74 pb^{-1} of integrated luminosity collected in one scan of the ϕ meson region, corresponding to 6% of data taken at the ϕ resonance.

2 The CMD-2 Detector

The CMD-2 detector is described in more detail elsewhere [3]. Its tracking system consists of the cylindrical drift chamber (DC) surrounding the interaction point and providing precise particle momentum and dE/dx measurement, and proportional Z-chamber (ZC) for precise polar angle measurement, both also used for trigger. Both chambers are inside a thin (0.38 X_0) superconducting solenoid with a field of 1 T. The barrel electromagnetic calorimeter placed outside the solenoid consists of 892 CsI crystals of $6\times6\times15$ cm^3 size. The muon-range system of the detector, also located outside the solenoid, is based on streamer tubes. The endcap electromagnetic calorimeter based on BGO crystals makes the detector almost hermetic for photons.

3 Selection Criteria

A candidate to a $e^+e^- \to K^+K^-$ event is an event with two low momentum tracks and high ionizing losses, originating from the interaction region. There is a number of effects, which lead to the loss of a charged kaon track: decays in flight, nuclear interactions, track reconstruction inefficiency etc. If one track is not reconstructed, the event can still be identified using second detected track. In our analysis we selected events with one or two "good kaons" found, where a "good kaon" is defined according to the following criteria:

- Track total momentum is $P_{tot} < 200$ MeV/c.
- Track ionization losses is $dE/dx > 4000.0$ (while minimal ionizing particle has $dE/dx_{MIP} = 2000.0$).
- Track impact parameter in $R-\phi$ plane is $\rho < 0.4$ cm.
- Polar angle of the track is $1.0 < \theta_K < \pi$ - 1.0.

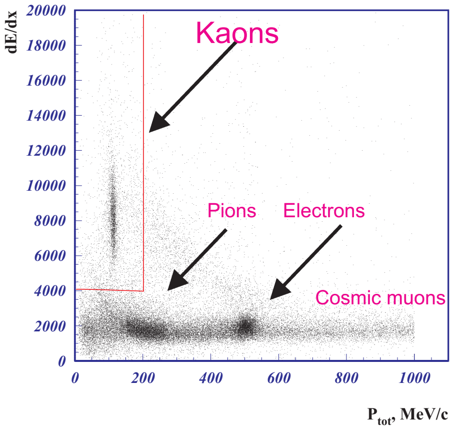


Figure 1: *Track ionization losses versus track momentum.*

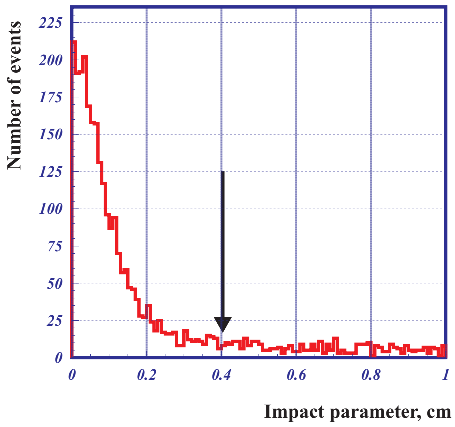
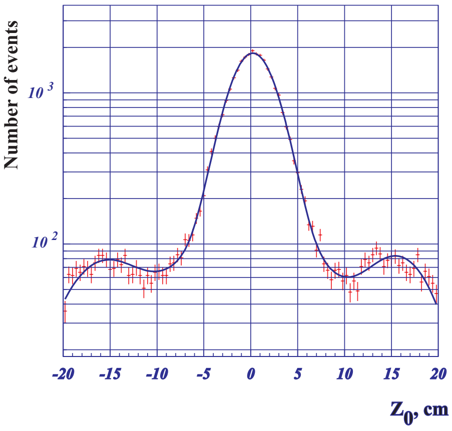


Figure 2: *Distribution of track impact parameter in the $R-\varphi$ plane.*

The selection criteria on the track total momentum and track ionization losses are shown (by lines) in Fig. 1. They allow to easily separate events with charged kaons from events with other particle types. Figure 2 demonstrates the event distribution over a track impact parameter in the $R-\phi$ plane. Our cut on this parameter is plotted by a vertical arrow.

The number of events with one or two "good" kaons found is determined from the distribution over a Z-coordinate of the point, closest to the interaction region along the beam axis. Figure 3 demonstrates the Z-distribution of events with one "good kaon" found. To determine the number of events, the distribution is fitted with the sum of a Gaussian, describing the effect, and smooth function, describing background. The shape of background was derived from the analysis of events, collected at the energy point below the thershold of charged kaon pair production. The background distribution is shown in Fig. 4. It was fitted with the sum of three Gaussians and all values of fitting parameters, but the number of background events, were then used for background description at each energy point.

After background subtraction we select about 1.21×10^5 events with one "good kaon" and about 2.42×10^5 events with two "good kaons".



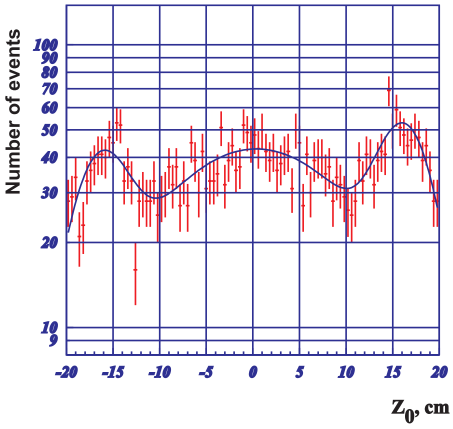


Figure 3: *Distribution over Z-coordinate of point closest to the interaction region for events with one "good" kaon found as well as the fitting function.*

Figure 4: *Background events distribution over Z-coordinate of point closest to the interaction region as well as the fitting function.*

4 Analysis

At each energy point the $e^+e^- \to K^+K^-$ cross section is calculated according to formula:

$$\sigma = \frac{N_1 + N_2}{\varepsilon \mathcal{L} \cdot (1 + \delta_{rad})} \cdot \frac{1 + \Delta_{EXP}}{1 + \Delta_{SIM}}, \tag{1}$$

where N_1 – number of events with one "good" kaon, N_2 – number of events with two "good" kaons, ε – detection efficiency, $\mathcal{L}$ – the integrated luminosity, calculated using large angle scattering events according to procedure, described in [5], $(1 + \delta_{rad})$ – initial state radiative correction, determined according to Ref. [6]. Δ_{EXP} – probability to loose both charged kaons in an experimental event. Δ_{SIM} – probability to loose both charged kaon in a MC event.

Detection efficiency is determined using MC simulation events (50000 events of the process $e^+e^- \to K^+K^-(\gamma)$ at each energy point). It is a product of acceptance and trigger:

$$\varepsilon = \varepsilon_{geom} \cdot \varepsilon_{trig} \tag{2}$$

The typical values of the acceptance and trigger efficiency are the following: $\varepsilon_{geom} = 0.64$ and $\varepsilon_{trig} = 0.89$.

The probabality to loose both kaons in the event is determined for both experimental and MC events at each energy point, assuming that kaons are lost independently. For $E_{beam} = 510.0$ MeV this probability is $\Delta_{EXP} = 0.039$, $\Delta_{SIM} = 0.043$. These values are close to each other and the corrections are almost cancelled in the ratio.

The systematic error in the cross section value is estimated to be equal to 2.8% and its sources are listed in a Table 1.

Table 1: *Contributions to the systematic error of* $e^+e^- \to K^+K^-$ *cross section.*

Source	Contribution, %
Trigger efficiency	2
Selection criteria	1.4
Luminosity	1
Acceptance	0.7
Radiative correction	0.5
$\oplus$ Total	2.8

The experimental points were fit with a Breit-Wigner function [2], which includes the contributions of the ρ, ω and ϕ mesons. The following ϕ meson parameters were obtained from the fit:

$$\sigma_0(\phi \to K^+K^-) = 2043 \pm 10 \pm 56 \text{ nb} ,$$

$$m_\phi = 1019.448 \pm 0.010 \pm 0.080 \text{ MeV/c}^2,$$

$$\Gamma_\phi = 4.25 \pm 0.03 \pm 0.03 \text{ MeV},$$

$$B_{ee} \cdot B_{K^+K^-} = (14.46 \pm 0.07 \pm 0.40) \cdot 10^{-5},$$

where the first error is statistical and the second is systematic. Systematic error on ϕ-meson mass and total width is due to accuracy of beam energy determination. The parameters are in good agreemenet with their world average values from PDG [7] and are the most precise.

The experimental data together with the fitting curve are presented in Fig. 5 together with the results of the previous most precise experiments. The results of all experiments are in good agreement.

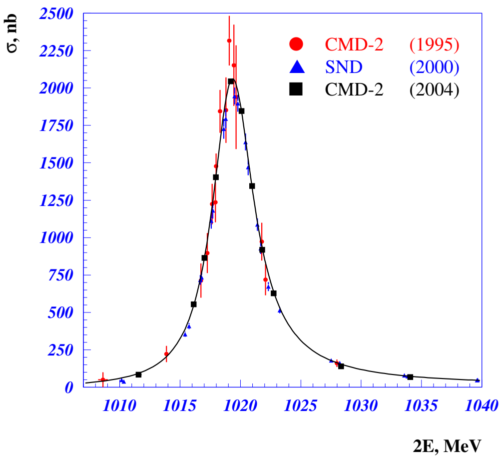


Figure 5: *Experimental cross section and ϕ meson excitation curve in the channel $e^+e^- \to \phi \to K^+K^-$, obtained in this analysis as well as in experiments* [1, 2].

5 Conclusion

Using the CMD-2 data sample of 3.63×10^5 $\phi \to K^+K^-$ events with one or two reconstructed charged kaons, the following preliminary ϕ-meson parameters have been obtained:

$$\sigma_0(\phi \to K^+K^-) = 2043 \pm 10 \pm 56 \text{ nb} ,$$

$$m_\phi = 1019.448 \pm 0.010 \pm 0.080 \text{ MeV/c}^2,$$

$$\Gamma_\phi = 4.25 \pm 0.03 \pm 0.03 \text{ MeV},$$

$$B_{ee} \cdot B_{K^+K^-} = (14.46 \pm 0.07 \pm 0.40) \cdot 10^{-5}.$$

These results are in agreement with the results of other experiments and are more precise than the corresponding measurements from any other e^+e^- experiment.

6 Acknowledgements

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