Measurement of the properties of the ω meson with a cryogenic magnetic detector

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The following values have been found for the properties of the ω resonance in the channel $e^+e^- \to \pi^+\pi^-\pi^0$ with the help of a cryogenic magnetic detector at the VÉPP-2M storage ring: $M_\omega = 781.78 \pm 0.10$ MeV, $\Gamma_\omega = 8.30 \pm 0.40$ MeV, $\sigma_{\text{peak}} = 1549 \pm 57$ nb, and $B_{\omega \to e^+e^-} = (7.2 \pm 0.3) \times 10^{-5}$.

An experiment has been carried out with a cryogenic magnetic detector[2] at the VÉPP-2M storage rings[1] to measure the properties of the ω meson. The charged-particle tracks in the detector are detected by means of an optical spark chamber with cylindrical electrodes inside a superconducting solenoid with a magnetic field up to 32 kG. The high spatial resolution, 50 μm in the plane perpendicular to the axis of the beams and 1.5 mm in the longitudinal direction, provides a momentum resolution of 2.5% at 400 MeV and makes possible a good identification of the charged products of the e^+e^- collisions, on the basis of the kinematic characteristics of the particles.

The trigger system for the cryogenic magnetic detector includes two cylindrical multiwire proportional chambers, inside and outside the spark chamber. These proportional chambers trigger the detector highly efficiently.

To determine the average energy of the particles in the storage rings within 15 keV, we used a method of resonant depolarization,[3] for the first time in research on the ω meson, along with a system which automatically regulated the magnetic field in the storage rings to compensate for thermal fluctuations in the ring dimensions. Because of the long beam polarization time at an energy $E \approx 390$ MeV in the region of the ω meson, the polarization was carried out at an energy of 600 MeV. The polarization was preserved, during the subsequent reduction of the beam energy, by a method of adiabatic crossing of the entire spin resonance at $E \approx 440.65$ MeV, as proposed in Ref. 4.

To measure the properties of the ω meson, we scanned the energy of the beams in the storage rings over the range from 2×380 MeV to 2×405 MeV and measured the cross section for the reaction $e^+e^- \to \pi^+\pi^-\pi^0$. The total luminosity integral achieved was about 50 nb^{-1}; 310 000 photographs were taken. On these photographs, 130 000 events were found and digitized; the only frames rejected were those that contained no tracks at all.

To suppress the background processes $e^+e^- \to e^+e^-\gamma, \pi^+\pi^-\gamma, \mu^+\mu^-\gamma$ and also the cosmic-ray background, we used the selection conditions

$$\Delta\varphi > 15^0, \quad 0.45 \leqslant p/E < 0.725, \quad L < 1 \text{ mm},$$

where $\Delta\varphi$ is the angular deviation from collinear directions in the plane perpendicular to the axis of the beams, $p/E = (|p_1| + |p_2|)/2E$ is half the sum of the momenta of the charged particles, divided by the beam energy, and L is the minimum distance from the two tracks to the beam axis. We selected 3805 candidates for $e^+e^- \to \pi^+\pi^-\pi^0$

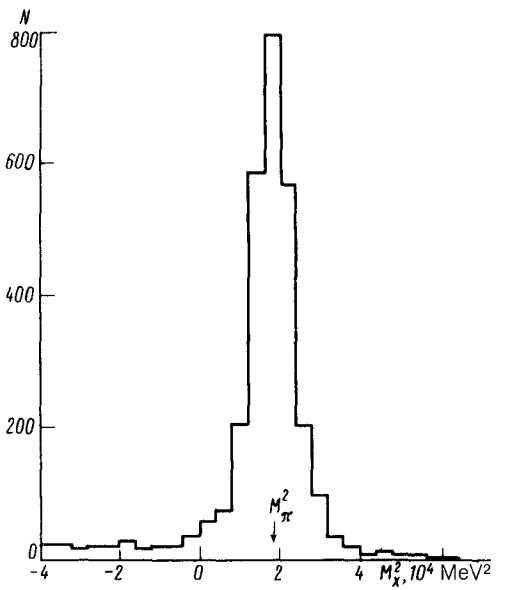

FIG. 1.

events. Figure 1 shows the distribution of these events in the square of the missing mass. We see a peak near the square of the mass of the π^0 meson.

From the number of 3π events detected at each energy point and from the luminosity integral we determined the cross section for the process under study:

$$\sigma_{e^+e^-\to\pi^+\pi^-\pi^0} = \frac{N_{\pi^+\pi^-\pi^0}}{L\epsilon_{\pi^+\pi^-\pi^0}(1+\delta_{\pi^+\pi^-\pi^0})},$$

where L is the luminosity integral, $\epsilon_{\pi^+\pi^-\pi^0}$ is the efficiency at which 3π events were detected, and $\delta_{\pi^+\pi^-\pi^0}$ is a radiation correction. The luminosity integral was determined experimentally from the number of elastic-scattering events; the procedure for identifying the latter events was described in Ref. 5. The detection efficiency was found by simulating the passage of particles through the detector; the result was $12.9 \pm 0.1\%$. The radiation corrections were calculated from the formulas given in Ref. 6, whose error is on the order of 0.1%.

Figure 2 shows values found for the cross section for the decay $e^+e\to\pi^+\pi^-\pi^0$. To determine the properties of the resonance, we used the expression which was used in Ref. 7 for the energy dependence of the cross section. As adjustable parameters we adopted the properties of the resonance and the magnitude of the nonresonant background. The curve in Fig. 2 corresponds to the optimum values of the properties of the ω meson: $M_\omega = 781.78 \pm 0.10$ MeV, $\Gamma_\omega = 8.30 \pm 0.40$ MeV, $\sigma_{\text{peak}} = 1549 \pm 57$ nb, and a background of 69 ± 9 nb. Here we have $\chi^2 = 27.3$ with 24 degrees of freedom; this figure corresponds to a 30% agreement of theory with experiment. The value of σ_{peak} has been corrected (3.5%) for the nuclear interaction of π mesons with the wall material of the outer proportional chamber (3 mm of copper) and also (1.2%) for the reaction

$$e^+e^-\to\pi^+\pi^-\pi^0, \quad \pi^0\to e^+e^-\gamma,$$

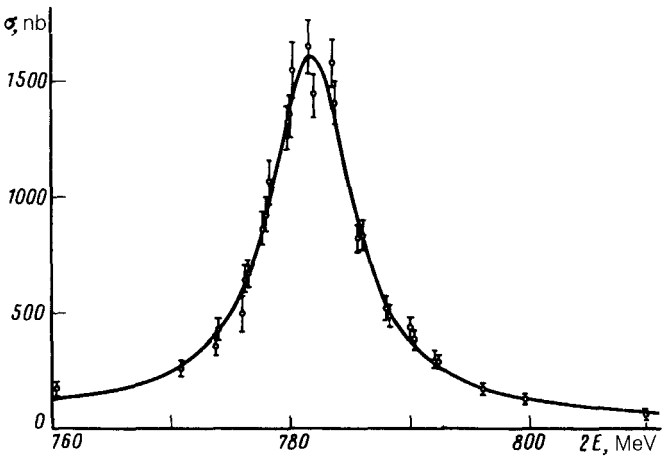

FIG. 2.

whose events were discarded during the selection of events. Using the relation $\sigma_{\text{peak}} = (12\pi/M_\omega^2) \times B_{\omega \to \pi^+\pi^-\pi^0} \times B_{\omega \to e^+e^-}$ and the tabulated value $B_{\omega \to \pi^+\pi^-\pi^0} = 0.896 \pm 0.005$ we find the branching ratio $B_{\omega \to e^+e^-} = (7.2 \pm 0.3) \times 10^{-5}$. During the experiment, we carried out two independent scans of the ω region, finding the results to be in agreement with each other. Analysis of the systematic errors shows that they are substantially smaller than the statistical errors and do not exceed 30 keV in terms of the mass of the ω meson.

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