A MEASUREMENT OF LARGE ANGLE e^+e^- SCATTERING AT THE 3100 MeV RESONANCE

DASP – Collaboration

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Elastic e^+e^- scattering has been measured at total energies covering the newly found resonance at 3100 MeV. The angular distribution is consistent with spin-parity 1^-, and the cross section integrated over energy yields $\Gamma_{ee}^2/\Gamma_{tot}$ = 0.23 ± 0.05 keV for the resonance.

The new 3100 MeV resonances [1] has been studied in the reaction $e^+e^- \to e^+e^-$ at the DESY colliding beam facility DORIS using a non-magnetic spectrometer. The rings were normally filled every 6 hours, and the luminosity averaged over one fill was about $2 \times 10^{29} \text{cm}^{-2}$. The luminosity was monitored by observing the rate of small angle Bhabha scattering using a set of four counter telescopes located in the horizontal plane symmetrically with respect to the interaction point. Each telescope consists of three scintillation counters and one shower counter. The scintillation counters define the direction of the scattered electron or positron, a the shower counter measures its energy. A Bhabha event is defined as a coincidence between two such telescopes located on opposite sides of the beam pipe at a mean scattering angle of 8°. With the threshold of the shower counter set at 500 MeV the accidental rate is negligible. For this experiment the luminosity monitor was used as a relative monitor only.

The apparatus shown in fig. 1 is a part of the Double Arm Spectrometer (DASP) and consists of two identical detectors mounted above and below the beams. Events were accepted for θ between 40° and 140° in a total solid angle of 1.2 sterad. The basic unit of this detector is made of a scintillation counter hodoscope, a sheet of lead 5 mm thick, and a proportional tube chamber [2]. Each chamber (see insert of fig. 1) has three layers of brass tubes, 10 mm in diameter and with 0.25 mm wall thickness, oriented at 0° and ±30° with respect to the beam axis. The efficiency for detecting one charged particle is 95% per plane, a value consistent with the geometric efficiency. Each of the scattered particles passes through a layer of scintillation counters surrounding the beam pipe, then through four of the units just described, and finally

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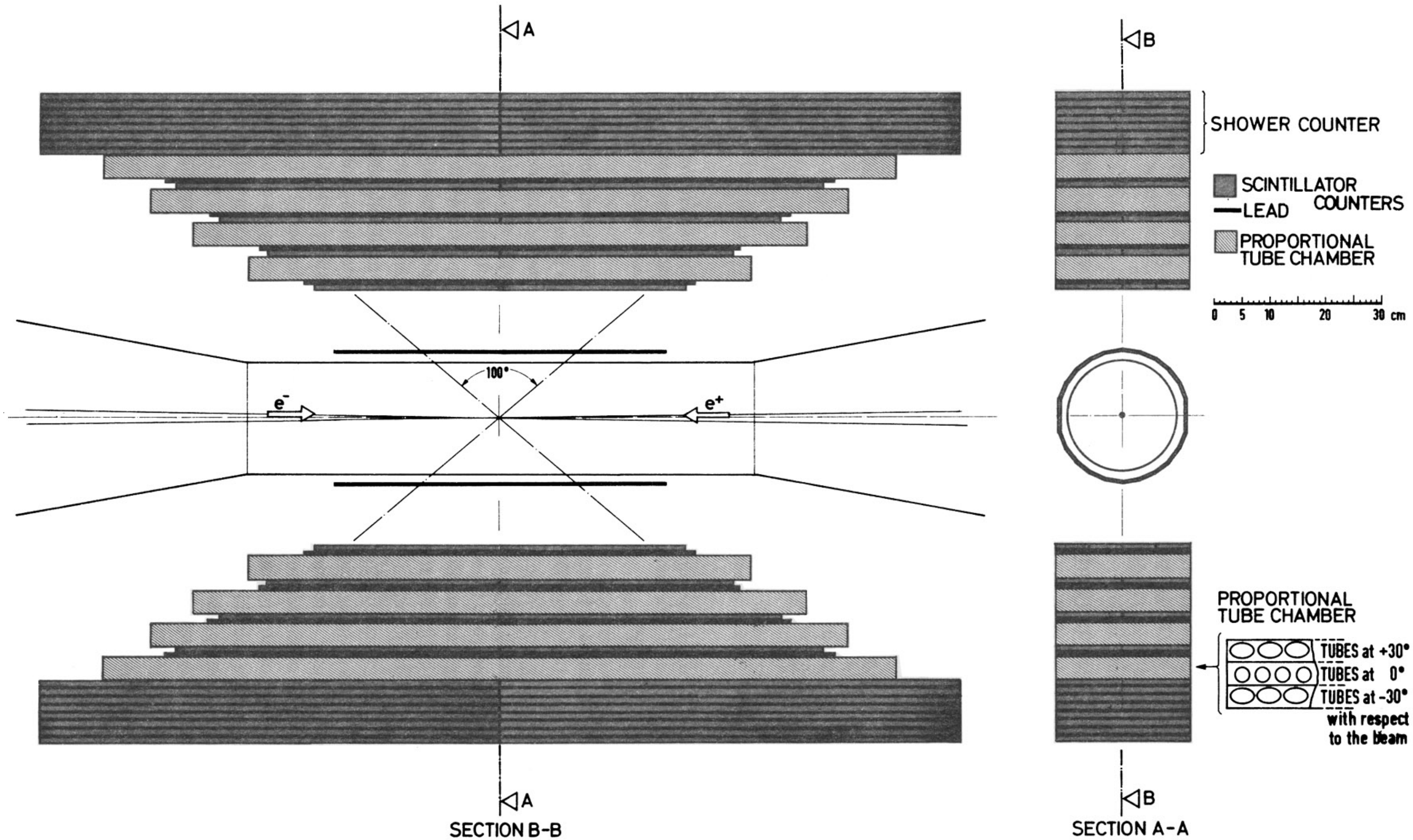

Fig. 1. Sketch of the detection apparatus.

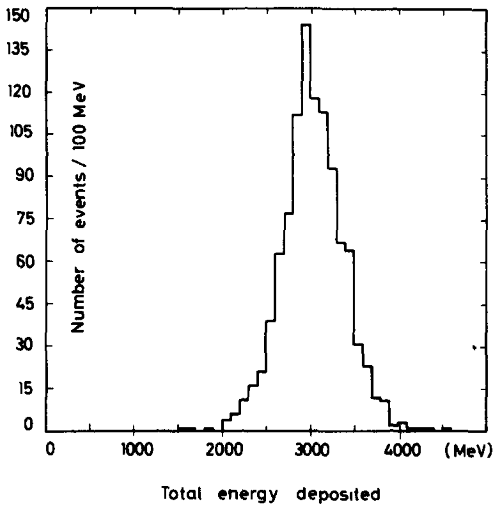

Fig. 2. Spectrum of total shower pulse height for accepted events. The minimum pulse height required was 1400 MeV.

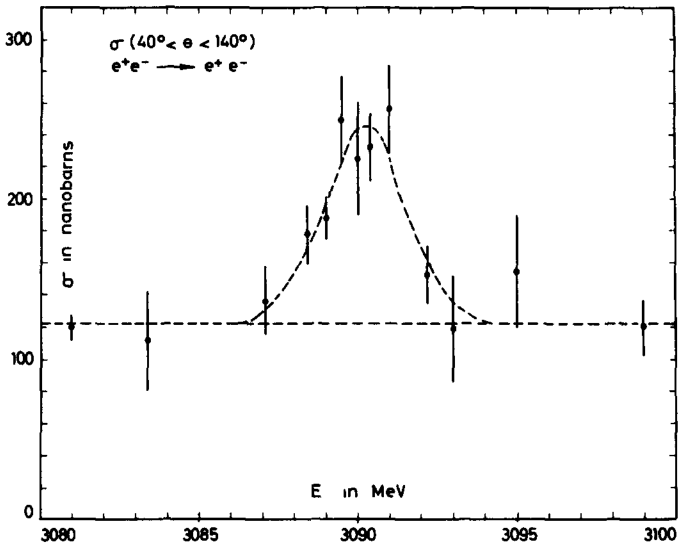

Fig. 3. The observed e^+e^- scattering cross section for $40° < \theta < 140°$ plotted against the total energy. The dashed lines show the best fit Gaussian plus nonresonant background.

through a lead-scintillator shower counter 8 radiation lengths thick. Both detectors were calibrated for incident energies between 50 MeV and 3 GeV using a well defined monochromatic electron and photon beam at the DESY synchrotron. The angular resolution of each detector is about ±1 degree.

In this experiment the trigger in each detector required a coincidence between the shower counter and one of the two preceding scintillation counters. The energy loss required was well below the measured energy loss of a 1.5 GeV electron traversing the detector. The event trigger was defined by demanding a coincidence between the two detectors.

Data were collected at closely spaced total energies between 3081 and 3099 MeV. The total luminosity integrated over the duration of the experiment was $5 \times 10^{34} cm^{-2}$. To separate the Bhabha events from the background due to cosmic rays and beam-gas interactions the following criteria were used in the analysis:

1) The energy deposited in each detector should be at least 100 MeV, and the total should be more than 1400 MeV for both detectors.

2) At least 35 proportional tubes should be set (at 3 GeV 90 ± 18 tubes are set on the average).

3) The time difference between pulses from the two detectors should be less than 3.5 nsec.

4) The final particles should be collinear within 6°.

Relaxing these conditions did not significantly change the results. The limits on the scattering angles θ and ϕ, defined in the upper detector, were chosen to be 40° to 140° and ±12°, respectively. The corresponding member of the pair was then well within the detection aperture of the lower detector. We find that 1037 events satisfy all the selection criteria. Fig. 2 shows the distribution in the sum of pulse heights from the two shower counters for these events.

Fig. 3 shows the dependence on total energy E of the yield of e^+e^- scatters between 40° and 140°. The shape of the peak is well fit by a Gaussian with a root-mean-square width of 1.3 MeV. Since the energy of the rings was not exactly reproduceable, this width is larger than the 0.9 MeV expected from the spread in energy of the beams. The value of the peak energy, 3090 MeV, observed here is in reasonable agreement with values reported for other storage rings [1].

The angular distributions (summed for θ and $\pi - \theta$, since we do not distinguish e^+ and e^- in the final state) are plotted separately in fig. 4a and b for energies outside the peak and inside the peak. The absolute cross sections in figs. 3 and 4 have been determined by fitting the distribution outside the peak to the nonresonant Bhabha scattering differential cross section,

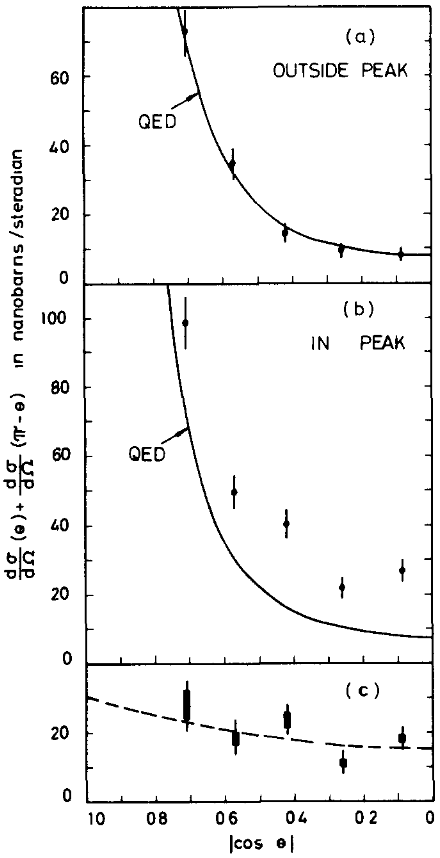

Fig. 4. Measured differential cross sections for $e^+e^- \rightarrow e^+e^-$ at (a) energies outside the peak (E = 3081 and 3099 MeV) and (b) energies in the peak (3089 $\leqslant E \leqslant$ 3091 MeV). The solid curve is the theoretical nonresonant Bhabha scattering cross section. The data in (a) are normalized by best fit to the theoretical curve; the same normalization is used in (b) and (c). In (c) is plotted the contribution of the 3100 MeV particle, the difference between the data and the curve in (b). The broad error bars indicate the correlated error due to normalization uncertainty: the narrow bars include the independent statistical errors. The dashed line shows the best fit to the form $1 + \cos^2\theta$.

corrected for bremsstrahlung and higher order radiative effects [3]‡. If we assume that the energy spread of the beams is much greater than the natural width of the resonance the interference with the nonresonant scattering will be effectively averaged out for energies close to the peak. The angular distribution for the e^+e^- decay of the 3100 MeV particle (fig. 4c) is then obtained by subtracting the theoretical Bhabha scattering cross section from the angular distribution measured in the peak. Although in fitting and subtracting the nonresonant background we have used the radiative correction for Bhabha scattering [3], we have not taken into account radiative effects in the cross section for production and decay of the 3100 MeV particle.

The data of fig. 4c are well fit by the form $1 + \cos^2\theta$, as expected for the lepton pair decay of a spin-one particle. A fit to $1 + b \cos^2\theta$ with b as a free variable yields $b = 1.4 \pm 1.1$. Assuming the $1 + \cos^2\theta$ distribution, integrating over θ, and taking into account the observed energy resolution function (fig. 3), we derive the energy integral of the cross section $\sigma(E)$ for the production and e^+e^- decay of the 3100 MeV particle:

$$\int \sigma(E)\mathrm{d}E = 560 \pm 120\,\text{nb} - \text{MeV}\,.$$

The quoted error includes an estimate of the systematic uncertainties from the luminosity monitor and the machine energy settings. The cross section integral can be related to the mass and decay widths:

$$\int \sigma(E)\mathrm{d}E = \frac{6\pi^2}{m^2}\frac{\Gamma_{ee}^2}{\Gamma_{tot}}\,.$$

Therefore, $\Gamma_{ee}^2/\Gamma = 0.23 \pm 0.05$ keV.

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