SEARCH FOR NARROW RESONANCES IN THE REACTION $\gamma + \mathrm{Be} \to e^+e^- + X$ AT $1.8 \leqslant M_{e^+e^-} \leqslant 2.6$ GeV

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The reaction $\gamma + \mathrm{Be} \to e^+e^- + X$ was studied with a bremsstrahlung beam of 7.2 GeV maximum energy. For invariant pair masses $1.8 \leqslant M_{e^+e^-} \leqslant 2.6$ GeV, no evidence for narrow resonances of width smaller than 40 MeV was found. For the mass interval $2.1 \leqslant M_{e^+e^-} \leqslant 2.6$ GeV, we obtained an upper limit of $\sigma \cdot B_{e^+e^-} < 2 \times 10^{-35}\ \mathrm{cm^2}$/nucleon (90% confidence level), assuming a production mechanism similar to the $\phi(1019)$ meson.

The results of a search for narrow resonances in the e^+e^- invariant mass spectrum of the reaction $\gamma + \mathrm{Be} \to e^+e^- + X$ are presented. This investigation was stimulated by the discovery of the narrow resonances at 3.1 GeV [1, 2] and 3.7 GeV [3] and by the observation that $3.7^2 - 3.1^2 \approx 3.1^2 - 2.4^2$.

In the experiment a 7.2 GeV electron beam hits a 0.04 radiation length thick copper radiator placed 2m upstream from the 15mm thick beryllium target. After passing through the target and a secondary emission chamber located 12m behind the target, the beam is focused onto a Faraday-cup which acts as the primary intensity monitor and beam stop. Electrons and positrons produced in the target are detected by two almost identical magnetic spectrometers, designed for electroproduction experiments. One of the spectrometers is shown in fig. 1. It consists of three quadrupole magnets followed by a dipole magnet which bends the central trajectory vertically by 10°. Four multiwire proportional chambers, each having two planes of orthogonal readout wires, are located in front (1) and behind (3) the bending magnet. The chambers are followed by two scintillation-counter hodoscopes, a threshold Čerenkov counter, two further scintillation-counter hodoscopes, and a shower counter, which is seven radiation lengths thick, consisting of layers of lead and scintillator. One of the scintillation-counter hodoscopes is also used for time-of-flight information.

The momentum of a particle was measured by reconstructing its trajectory through the bending magnet, and the production angles were determined by tracing the trajectory back through the quadrupole magnets to the target position. The momentum resolution achieved was 1.2% (FWHM), and the accepted momentum band amounted to 45% (FWHM). The an-

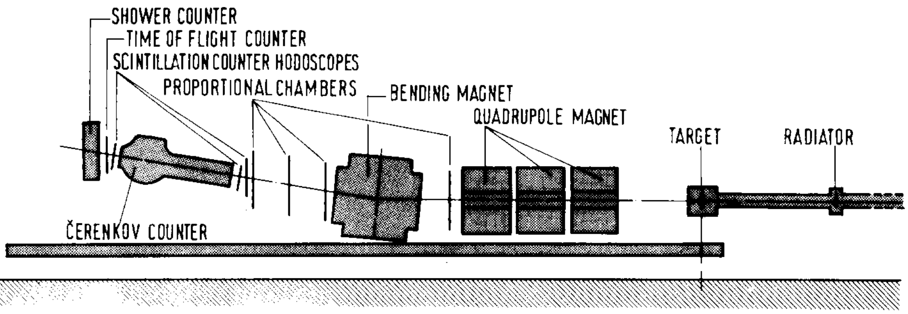

Fig. 1. Side view of one spectrometer.

gular acceptance was 16mrad in the horizontal direction and ± 100mrad in the vertical.

For a trigger an eightfold coincidence between the scintillation-counter hodoscopes of the two spectrometers was required. The information about an event satisfying this trigger requirement was collected by a small on-line computer and sent to a central computer for on-line anaysis and for recording on magnetic tape. Electrons and positrons were identified by means of the threshold Čerenkov counters and shower counters. The Čerenkov counters were filled with ethylene at 0.7 atm. The cuts applied in the pulse height spectra of these counters yielded a single arm detection efficiency ⩾ 96% for electrons in the accepted momentum band. This efficiency was determined by the detection of scattered electrons at small angles. These cuts implied a hadron detection efficiency of 0.1% for each spectrometer.

Electrons and positrons were detected at angles of 24.2° and of 19.5° (the maximum possible angle of one spectrometer) with respect to the incident beam and with central spectrometer momenta of 2.92 GeV and of 3.55 GeV respectively, yielding the maximum acceptance at $M_{e^+e^-} \approx 2.4$ GeV. Part of the data were taken with interchanged magnet polarities. In total 25 e^+e^- pair candidates were detected, collecting a flux of 1.5×10^{16} equivalent photons, of which 24% were very low q^2 virtual photons, 58% came from electron bremsstrahlung in the copper radiator, and 18% from bremsstrahlung in the beryllium target. The time-of-flight differences between the two detected particles are plotted in fig. 2. The measured time resolution was 1.2 nsec (FWHM). We conclude from fig. 2

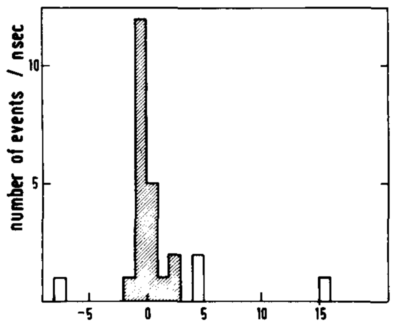

Fig. 2. Time-of-flight difference of the e^+e^- pair candidates. The events between −1 and +3 nsec were accepted for further analysis.

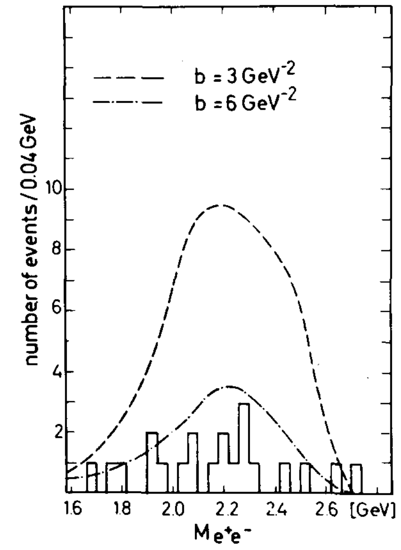

Fig. 3. The mass distribution of the 21 observed e^+e^- pairs. The curves shown indicate the number of events expected from a narrow resonance produced and decaying according to $B_{e^+e^-} \cdot \mathrm{d}\sigma/\mathrm{d}t = 2.5 \times 10^{-34}\ \mathrm{cm}^2/\mathrm{GeV}^2 \cdot \exp(bt)$ with b = 3 GeV^{-2} and b = 6 GeV^{-2}, respectively.

that 21 ± 2 candidates are real coincidences. The invariant mass distribution of these events is shown in fig. 3. The mass resolution was $\Delta M/M \approx 1.5\%$ (FWHM). There is no evidence for a resonance structure. We expect 3 pairs to be due to the Bethe-Heitler-process [4], and we estimate that 8 ± 3 events are due to π^+-electroproduction with the π^+ misidentified as a positron.

In order to obtain an upper limit for the production cross section of a narrow resonance, we assumed it to be diffractively produced, but we only took the production off the individual target nucleons into account, i.e.

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} = \left.\frac{\mathrm{d}\sigma}{\mathrm{d}t}\right|_{t=0} \cdot \exp(bt). \qquad (1)$$

Due to the large value of $t_{\min}$ the coherent production is estimated to contribute less than 10% for $M_{e^+e^-} >$ 2.0 GeV. Using eq. (1) we calculated the expected number of events for each 40 MeV mass bin with the help of a Monte-Carlo simulation of the experiment. This calculation took into account the bremsstrahlung spectrum of the incident beam, the Fermi motion of the nucleons, an isotropic decay in the restframe with

Table 1
90% confidence upper limits for the product of the production cross section per nucleon and the e^+e^- decay branching ratio of a resonance of a width < 40 MeV obtained from the data assuming eq. (1).

b	$\sigma \cdot B_{e^+e^-}$	$d\sigma/dt\|_{t=0} \cdot B_{e^+e^-}$
3 GeV^{-2}	2.5×10^{-35} cm^2	2.5×10^{-34} cm^2/GeV^2
6 GeV^{-2}	2.0×10^{-35} cm^2	9.0×10^{-34} cm^2/GeV^2

branching ratio $B_{e^+e^-}$, and the acceptance of the spectrometers. Corrections for losses due to reconstruction inefficiency (~ 30%) and due to radiative effects (~ 25%) were applied. The results are shown in fig. 3. The 90% confidence upper limits obtained for $d\sigma/dt|_{t=0} \cdot B_{e^+e^-}$ and $\sigma \cdot B_{e^+e^-}$ are listed in table 1 for two values of b.

An experimental check of the calculations was performed by reducing the central momenta of the two spectrometers by a factor of 2.4, to look for e^+e^- pairs in the mass region of the $\phi(1019)$ meson. The number of events observed for $1.000 \leqslant M_{e^+e^-} \leqslant 1.030$ was consistent with the number calculated from the known production and decay cross sections of the ϕ meson.

Summarizing the results we conclude: no evidence for a resonance of a width < 40 MeV was found in the mass range $1.8 \leqslant M_{e^+e^-} \leqslant 2.6$ GeV. A 90% confidence upper limit of $\sigma \cdot B_{e^+e^-} < 2.5 \times 10^{-35}$ cm^2/nucleon was obtained for $2.1 \leqslant M_{e^+e^-} \leqslant 2.6$ GeV. A similar search has been performed by Dakin et al. [5], who obtained an upper limit of $\sigma \cdot B_{\mu^+\mu^-} < 1.6 \times 10^{-34}$ cm^2/nucleon for $1.0 \leqslant M_{\mu^+\mu^-} \leqslant 2.7$ GeV and a maximum photonenergy of 20.5 GeV. It might be instructive to compare our upper limits with the following resonance values: $d\sigma/dt|_{t=0} \cdot B_{e^+e^-} \approx 7 \times 10^{-34}$ cm^2/GeV^2/nucleon, $b \approx 4$ GeV^{-2} for $\phi(1019)$ photoproduction [6] (which is roughly independent of the photonenergy) and $d\sigma/dt|_{t=0} \cdot B_{e^+e^-} = 7 \times 10^{-35}$ cm^2/GeV^2/nucleon, $b = 1.25$ GeV^{-2} at $E_\gamma = 11$ GeV and $d\sigma/dt|_{t=0} \cdot B_{e^+e^-} = 1.2 \times 10^{-33}$ cm^2/GeV^2/nucleon $b = 2.9$ GeV^{-2} at $E_\gamma = 21$ GeV for J(3100) photoproduction [7, 8].

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