Search for sharp lines in e^+-e^- coincidences from positrons on Th

T. F. Wang, I. Ahmad, S. J. Freedman, R. V. F. Janssens, and J. P. Schiffer
Physics Division, Argonne National Laboratory, Argonne, Illinois 60439
(Received 8 July 1987)

Two mini-orange spectrometers were used to view e^+-e^- pairs from a positron source and a Th scatterer from opposite directions, 180° apart. No statistically significant evidence for peaks previously reported was found in the coincidence spectra.

Recent experiments at the GSI (Darmstadt) on e^+-e^- coincidences from heavy ion collisions[1] have reported the observation of sharp lines seen previously[2] in singles experiments. Indeed, more than a single positron line seems to have been observed. The origin of these lines is not yet understood. One possible explanation is that they arise from the decay of some unknown neutral resonance with rest mass around 1.8 MeV nearly at rest, although it should be noted that the angle between the coincident e^+-e^- pairs is not directly determined in the GSI experiments. Recently, Erb, Lee, and Milner[3] searched for e^+-e^- coincidences produced by bombarding a thorium scatterer with positrons from a ^{68}Ge-^{68}Ga positron source. Their experiment employed two mini-orange spectrometers facing the source at 90° to each other to filter electrons and positrons. Surprisingly, a sharp line of energy around 340 keV appeared in both the coincident positron and electron spectra. This energy is similar to the energies of peaks seen in the GSI experiments. Since the positron endpoint energy of the source is only 1.9 MeV, a resonance with a rest mass of 1.8 MeV cannot be produced with free electrons; however, it is kinematically possible that the bound electrons in the Th atom could participate. This leaves a substantial kinematic puzzle: the fact that the electron and positron peak energies are the same would require a resonant state that is nearly at rest in the laboratory. Except for multiple scattering, the decay of such an object would not allow the electron-positron pair to be emitted at 90°.

We have therefore performed measurements similar to those of Erb *et al.*[3] but with the mini-orange spectrometers viewing the source from opposite directions, 180° apart. Bhabha scattering from free electrons cannot be observed in this geometry, but the decay of neutral particles that have low kinetic energies in the laboratory frame should produce a clear signature.

The detectors for the electrons and positrons were both 2 mm thick 50 mm^2 Si surface barrier detectors with energy resolution of $\sim$20 keV. The two mini-orange spectrometers,[4] with magnet configurations of $(3A)$ and $(2A+2B)$ (see Ref. 4), were optimized with a ^{137}Cs electron source. The measured transmissions for 300-keV electrons were 7.2×10^{-3} and 4.2×10^{-3} for the $(3A)$ positron and $(2A+2B)$ electron spectrometers, respectively. A 4 cm Pb absorber on the axis of each spectrometer blocked direct radiation. A 7.6 cm$\times$7.6 cm NaI detector 2.5 cm behind the positron detector helped identify positrons by detecting annihilation radiation. A 100 μCi ^{68}Ga-^{68}Ge source with a 50 mg/cm^2 Th foil similar to those used in Ref. 3 was placed between the electron and positron spectrometers.

Coincidences were collected for a month. The trigger was a positron-electron coincidence within a 1 μs time window. Signals from two time-to-amplitude converters (TAC's—between the electron and the positron detectors, and between the positron and the NaI detectors) as well as the energy signals from electron, positron, and the NaI detector were recorded on magnetic tape. In the present analysis we consider the electron and positron energy spectrum with software conditions imposed

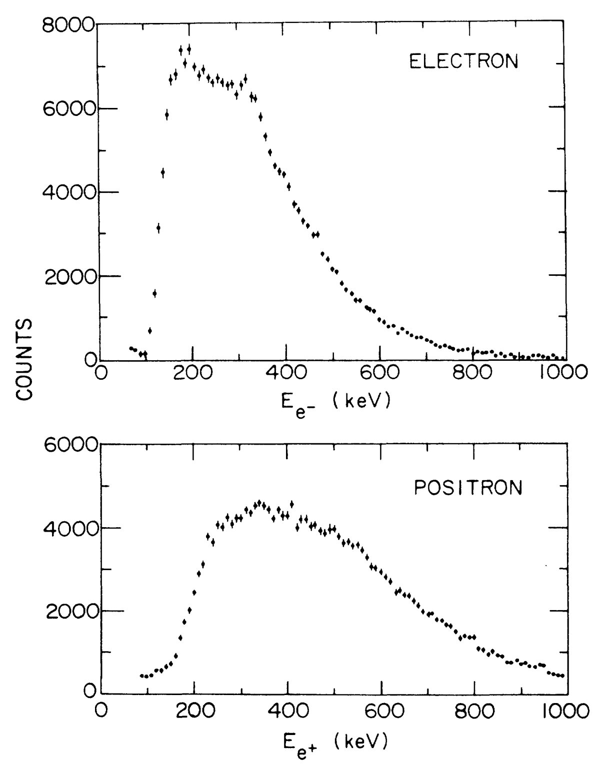

FIG. 1. Coincident spectra of positrons and electrons (after random subtraction) from a ^{68}Ga(Ge) source and a thorium foil. The data are plotted with a bin width of 10 keV.

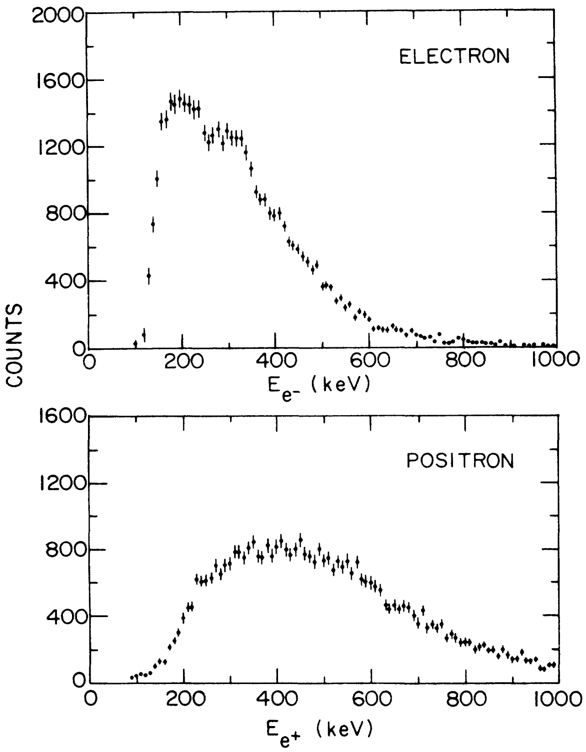

FIG. 2. Same as Fig. 1, but with additional coincidence requirement for annihilation radiation in the NaI detector (see the text).

the following. (1) a coincidence requirement on the TAC spectrum between the electron-positron detectors with a 35 ns window; the time resolution was 15 ns. Coincidence events were collected with a real-to-random ratio of 0.61. The random spectrum was determined with a broader time gate away from the prompt peak and subtracted with appropriate normalization. (2) A similar condition was also placed on the TAC spectrum between the NaI-positron detectors, where the prompt peak of 20 ns FWHM was contained in a 40 ns window and the real-to-random ratio was 40. In addition to the TAC condition, a window was placed on the 511-keV photopeak and its Compton edge in the NaI energy spectrum.

Coincident electron-positron spectra with condition (1) after random subtractions are shown in Fig. 1; the corresponding spectra constructed under conditions (1) and (2) are shown in Fig. 2. Neither the electron nor the positron spectra show any significant peaks at the expected energies. A peak that seems to correspond to the Compton edge of the 511-keV gamma ray is present in the electron spectra and much weaker in the positron spectra. The peak in the electron spectrum may be due to Compton electrons produced by annihilation quanta from positrons stopping near the surface of the positron detector. This electron can then be focused onto the

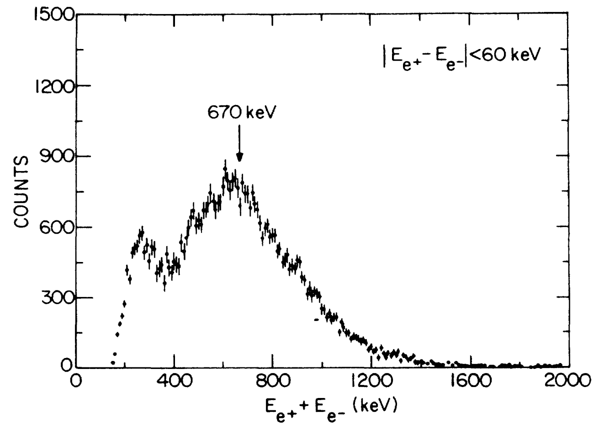

FIG. 3. Summed energy spectra for equal-energy electrons and positrons. The number events per unit energy is about 80% of that in the comparable plot of Ref. 3. The arrow denotes the position of the peak seen in that work.

electron detector because of our special geometry, thus enhancing the counts in the region below 320 keV. The numbers of coincidence events in the electron and positron spectra with condition (1) in the region of interest ($\sim$330 keV) are approximately 6500 and 4500 counts per 10 keV bin, respectively. These numbers are approximately 0.3 and 0.8 of the comparable rates in Ref. 3. Following Ref. 3, the coincidence data may also be plotted as the summed energies of positrons and electrons versus the difference. A special sum energy spectrum [with condition (1)] subject to the restriction $|E_{e^+} - E_{e^-}| < 60$ keV of Ref. 3 is shown in Fig. 3. An arrow indicates the position of the peak, which has a total area of 500$\pm$150 events above a background of 5000 counts, reported by Erb *et al.* Since we have only 80% of the coincidence events compared to those in Ref. 3, we expect to observe a peak with an area of at least 400$\pm$120 events above a background of 4000 events. This is a conservative estimate since a major source of the background in Ref. 3, from Bhabha scattering, is absent in our geometry. In fact, we see no peak and would estimate 78$\pm$147 events above a linear background of 3850 events in our data for a peak centered at 670 keV with a width of 30 keV (our folded resolution).

In summary,we have not seen a statistically significant peak, such as seen by Erb *et al.*, in our back-to-back geometry which should be more sensitive to the decay of a neutral resonance.

We would like to thank Dr. J. Napolitano and Mr. J. Nelson for their help, and are grateful to Dr. K. Wisshak for the loan of the mini-orange spectrometer. This research was supported by the U.S. Department of Energy, Nuclear Physics Division, under Contract W-31-109-Eng-38.

[1]T. Cowan *et al.*, Phys. Rev. Lett. **56**, 444 (1986); Yale Report No. 3074-927, 1987.
[2]J. Schweppe *et al.*, Phys. Rev. Lett. **51**, 2261 (1983).
[3]K. A. Erb, I. Y. Lee, and W. T. Milner, Phys. Lett. B **181**, 52 (1986).
[4]J. van Klinken, S. J. Feenstra, and G. Dumont, Nucl. Instrum. Methods **151**, 433 (1978).