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New Particle Searches and Exotic Phenomena

A Search for Long-Lived Low Mass States Coupling to e^+e^-

S.D. Henderson,[1] P. Asoka Kumar,[2†] J.S. Greenberg,[1] H. Huomo,[2*] K.G. Lynn,[2] S. McCorkle,[2] J. McDonough,[1] B.F. Phlips,[1] A. Vehanen,[2*] and M. Weber[2]

[1]Wright Nuclear Structure Laboratory, Yale University, New Haven, CT 06511
[2]Brookhaven National Laboratory, Upton, NY 11973

Since the observation by the EPOS group at GSI[1] in 1985 of correlated electron-positron pair emission in superheavy ion-atom collision systems there have been many attempts to explain the phenomenon. The EPOS coincidence data[2] show a series of narrow sum-energy lines in the laboratory kinetic energy range 610–820 keV. Recently, similar observations were reported by another group.[3] For lack of conventional explanations for the narrow sum peaks, the production of a previously unobserved neutral system in the heavy ion collision which subsequently decays to e^+e^- was considered as a possibility.[4] If such an object were to exist, then it should be possible to produce it through the s-channel of ordinary electron-positron scattering. We describe the results of a set of experiments to search for such a neutral object directly in e^+e^- collisions.

A lower limit for the lifetime of a light pointlike particle which couples to e^+e^- can be obtained from the discrepency between the theoretical and experimental values of the anomalous magnetic moment of the electron. This comparison provides lower limits between 10^{-14} and 10^{-13} sec, depending on the particular coupling, in the mass range of interest[5]. By considering the acceptance of the EPOS spectrometer, an upper limit on the lifetime of ~1 ns can also be deduced.

The possibility of observing an s-channel resonant enhancement in e^+e^- (Bhabha) scattering is confined to a limited lifetime range due to the large (~200mb) Bhabha (elastic e^+e^- scattering) contribution. As a result, such resonance experiments are sensitive to lifetimes less than a few times 10^{-13} sec. To carry the search to longer lifetimes requires the direct observation of particle production or decay, in the virtual absence of the Bhabha and other backgrounds. We have performed two experiments to search the lifetime range 10^{-14} to 10^{-9} seconds throughout the particle mass range of 1.5 to 1.9 MeV. One experiment is a measurement of the excitation function of e^+e^- elastic scattering, to probe the short lifetime region near the g-2 limit. In another experiment, which is of primary concern herein, the large Bhabha background has been suppressed, and an extended lifetime range is explored.

A 500 to 2500 keV tunable monoenergetic beam of positrons with an intensity of ~400,000 e^+/sec has been constructed at Brookhaven National Laboratory for the purpose of these experiments. A thin low–Z material, typically Lithium or Beryllium, is the source of the target electrons. The detector system, consisting of MWPC's for the charged particle position measurement, and plastic scintillators for the energy measurement, allows for the complete determination of the e^+e^- scattering kinematics, and provides a resolution in polar angle of less than $\frac{1}{2}^\circ$ and less than 1° in azimuthal angle. The coincident e^+e^- scattering events are detected essentially background free.

The target system for the long lifetime experiment consists of a layered arrangement of Beryllium (~50 keV energy loss thickness)–plastic scintillator (300μm)–Platinum (~700μm)–plastic scintillator (300μm). Positrons strike the Be side of the target. The first scintillator provides a signal for any charged particles passing through, or emanating from the Be. The Pt is sufficiently thick to stop the primary beam. This arrangement suppresses the usual Bhabha scattering background produced in the Be target. The last

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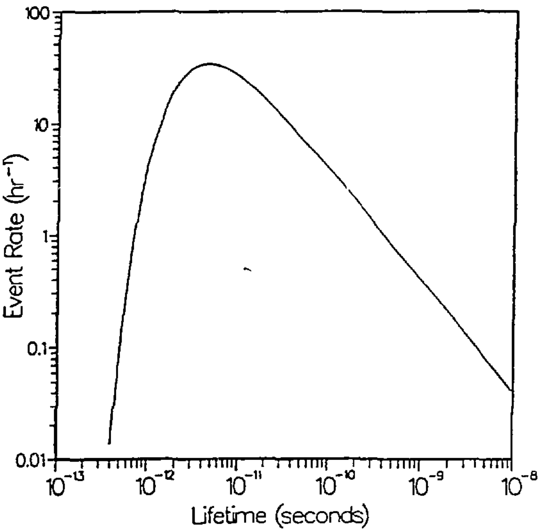
scintillator provides a signal for any secondary charged particles leaving the Pt, as would be produced by γ conversion. This active beam-dump arrangement not only allows for the suppression of all charged particles emanating from the target, but it also provides a method of insuring that any possible particle production occurs in the Be target, so that a typical excitation function can be carried out. A particle signature would therefore appear as the absence of a signal in the active beam-dump (since the neutral, non-interacting particle would escape the beam-dump and subsequently decay), and the presence of a charged particle coincidence in the detectors (a so-called "unvetoed" event). Since the production would take place in the Be target, the kinematics of a candidate unvetoed particle event should be identical to elastic e^+e^- scattering (with the appropriate multiple scattering and energy loss in the Be target).

The accompanying figure shows the expected coincidence count-rate for pseudoscalar coupling with a particle mass of 1.83 MeV as a function of lifetime for our experimental conditions, and assuming that there is no attenuation of the particle yield in the beam-dump. The shape of the curve is due to two contributions: the effect of particles decaying before they escape the beam-dump in the short lifetime region, and the falling production cross-section in the longer lifetime region.



The principal backgrounds in the experiment are coincidences due to cosmic ray showers after the existing cosmic veto counters, and two-photon annihilation in flight of positrons in the Be, followed by conversion of both photons before the wire chambers. The typical counting rate for these backgrounds is $\sim$1 event hr^{-1}, and is further reduced by kinematic cuts. With this low background rate, the active beam-dump method is sensitive to a range of particle lifetimes spanning four orders of magnitude, bounded by the elastic scattering results on the short lifetime side, and the limit due to the fiducial volume of the EPOS spectrometer on the long lifetime side.

Data will be presented from a measurement of the excitation function of unvetoed events which spans the lifetime range of $\sim 4\times 10^{-13}$ to $\sim 10^{-9}$ sec throughout the mass range 1.5 to 1.9 MeV. The available data from a recent measurement of the e^+e^- elastic scattering excitation function will also be presented.

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† Formerly, Department of Physics, City College of CUNY, NY 10031

* Permanent address: Laboratory of Physics, Helsinki University of Technology, SF-02150 Espoo, Finland.

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