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Author
Clark, Alan R.

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DISCLAIMER

A SEARCH FOR LONG-LIVED NEUTRAL PARTICLES WHICH DECAY INTO ELECTRON PAIRS[+]

Alan R. Clark, T. Elioff*, R. C. Field, H. J. Frisch[‡], Rolland P. Johnson, Leroy T. Kerth, R. C. Sah, G. Shen and W. A. Wenzel

Lawrence Berkeley Laboratory
University of California
Berkeley, California

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ABSTRACT

A search was conducted at the Bevatron for long-lived neutral particles, of mass less than the K^o mass, which decay into e^+e^- pairs. The neutral beam was produced by proton interactions in a copper target. No evidence for particles with proper lifetimes between 10^{-10} and 10^{-6} seconds was observed.

Anomalies in electron bremsstrahlung and in pair production were reported from a recent bubble chamber experiment.[1] These could be interpreted as evidence for one or more new particles, possibly produced through strong interactions. It was suggested that one of these particles might be a light, long-lived neutral particle (mass $\lesssim 30$ MeV/c^2) which decayed into an electron pair.

Using equipment constructed to search for the decays $K_L^0 \to \mu^+\mu^-$, e^+e^-, and $e^\pm \mu^\mp$ [2], we have examined the neutral particle mass spectrum between 28 MeV/c^2 and 488 MeV/c^2 for e^+e^- decays. The neutral beam was produced by 5.8 GeV/c protons from a copper target in the Bevatron external proton beam. The channel subtended a solid angle of 0.87 msr at an angle of 3.7° from the proton beam axis. The 6 meter long decay volume began 7.6 meters from the target.

The momenta of the decay secondaries were measured in symmetric spectrometers, each with a bending magnet and magnetostrictive wire spark chambers (Fig. 1). To search for neutral particles of mass m, the magnets were set to produce a deflection equivalent to a transverse momentum of $p^* = c\sqrt{m^2/4 - m_e^2} \approx \frac{mc}{2}$.

Therefore, independent of the neutral particle momentum, electrons from transverse two-body decays of particles of mass m emerged from the magnets parallel to the incident neutral particle direction. Downstream of the last spark chamber, two hodoscopes selected trajectories with maximum horizontal divergences of ± 45 mrad from the beam direction. By varying the bending magnet currents, this apparatus was tuned to search for neutrals of different mass. For a given mass, only neutrals produced within the momentum range $1.7\ mc < p < 10mc$ could be detected.

Electrons were identified in 2.3 meter long Freon Cherenkov counters, which were found to be more than 99.6% efficient during preliminary tests. Muons were identified by range measurements. For mass settings below about 300 MeV/c^2, the signals from the Cherenkov and range counters were not used in the trigger but were recorded for use later in the analysis. For mass settings higher than about 300 MeV/c^2, a "di-lepton" requirement was added to suppress unwanted triggers from $K_L^o \to \pi \ell \nu$ and $K_L^o \to \pi^+ \pi^- \pi^o$ decays. That is, a count from the Cherenkov counter or from either the second or third range counter was required from each arm of the spectrometer. Less than two per cent of the pions gave counts in the Cherenkov counters; and about 30% of the pions penetrated into the range box, mainly by decay in flight.

Data taken at 23 magnetic field settings were analyzed with a CDC 6600 computer. Candidates for decays into an e^+e^- final state were selected by rejecting events without Cherenkov counts in both spectrometer arms. Surviving events were considered candidates for two-body decays if the two reconstructed trajectories approached each other within 10 cm in the decay volume, and if the reconstructed trajectory of the parent particle passed within 10 cm of the production target. In order to obtain good efficiency two-body decays, these data cuts were chosen to be wider than the measured resolutions of the detection apparatus.

Calculations of the acceptance indicated that the detection efficiency was approximately constant (i.e., less than ± 12% variation) for a mass interval of 25% at each magnet setting. All events outside this band at each mass setting were rejected. Most of the surviving events were background K_{e3} decays in which the pion was counted by a Cherenkov counter. These events were indistinguishable from two-body decays, and were included in the differential production cross-sections calculated for each mass bin. The data were binned into 4 MeV/c^2 intervals, the measured width (FWHM) of the $K_L^0 \to \pi^+\pi^-$ mass spectrum. A long-lived particle decaying into an electron pair would be seen as a narrow peak above background.

In order to derive production cross-sections, a definite probability of decay within the decay volume must be assumed; these calculations were carried out for three assumed parent neutral particle proper lifetimes, 10^{-6} seconds, 10^{-8} seconds, and 10^{-10} seconds. The choice of 10^{-8} seconds resulted in the cross-sections shown in Fig. 2. The expression $d^2\sigma/d\omega dp$ is the laboratory differential cross-section for a 5.8 GeV/c proton striking a copper nucleus in the production target to produce a two-body decay candidate within a solid angle $d\omega$ and within a momentum range dp.

The indicated errors are statistical only. We estimate that uncertainties in the proton flux (as measured by a secondary emission monitor), targetting efficiency, and detection efficiency introduce systematic errors of less than ± 25%.

We interpret the absence of sharp peaks in the cross-sections as a failure to observe evidence for a long-lived neutral which decays into electron-positron pairs. However, these results are not in direct conflict with the bubble chamber data,[1] because of the very different method used to search for long-lived neutral particles.

Table 1 gives upper limits on the production cross-sections for such long-lived neutral particles. These limits represent three times the statistical error in measuring the cross-sections. Nearly equal numbers of incident protons were used at each mass setting. The larger limits for low mass values result from the smaller momentum acceptance in that region.

The data were also analyzed for long-lived neutrals which decay into other final states. An analysis of the $e^{\pm}\mu^{\mp}$, $e^{\pm}\pi^{\mp}$, $\mu^{+}\mu^{-}$, and $\mu^{\pm}\pi^{\mp}$ decay modes revealed no evidence for neutral particles. The limits on the production cross-sections are approximately five times higher for these decay modes, because of background from $K\ell 3$ decays.

We wish to thank the Bevatron operating crew and engineering staff, our secretaries, and our technicians for their interest and efforts which made the experiment possible. We also thank Professor J. D. Jackson for bringing the bubble chamber results to our attention.

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* On leave from Lawrence Berkeley Laboratory to the U. S. Atomic Energy Commission, Washington, D. C.

‡ Present address: Enrico Fermi Institute of Physics, University of Chicago, Chicago, Illionis.

1 "Anomalies in Electromagnetic Processes", R. E. Ansorge, A. R. Atherton, W. W. Neale, J. G. Rushbrooke and G. S. B. Street, Cavendish Laboratory, Cambridge, England; January, 1970 (unpublished).

2 Alan R. Clark, T. Elioff, R. C. Field, H. J. Frisch, Rolland P. Johnson, Leroy T. Kerth, and W. A. Wenzel, Phys. Rev. Letter, 26, 1667 (1971).

A complete description of the apparatus can be found in R. P. Johnson, thesis, UCRL Report No. UCRL-19709, 1970 (unpublished); H. J. Frisch, thesis, UCRL Report No. UCRL-20264, 1971 (unpublished).

TABLE 1.

Upper limits on $\frac{d^2\sigma}{d\,\omega\,d\,p}$ $\left(\frac{cm^2}{sr \quad MeV/c}\right)$

Assumed Proper Lifetime (sec)	Mass Range (MeV/c^2) 28 – 100	100 – 300	300 – 488
10^{-6}	1.2×10^{-34}	1.1×10^{-35}	1.2×10^{-35}
10^{-8}	1.8×10^{-36}	2.5×10^{-37}	2.9×10^{-37}
10^{-10}	9.4×10^{-23}	3.8×10^{-23}	4.4×10^{-23}

FIGURE CAPTIONS:

Figure 1 — Plan view of experimental apparatus. H, F, R, and T are banks of scintillation counters.

Figure 2 — Differential cross-section for the production of neutral particles ($\tau = 10^{-8}$ sec.) which decay into electron pairs. The non-zero cross-sections are due mainly to Ke3 decays in which the pion counts in a Cherenkov counter. A long-lived neutral would appear as a sharp peak above this background.

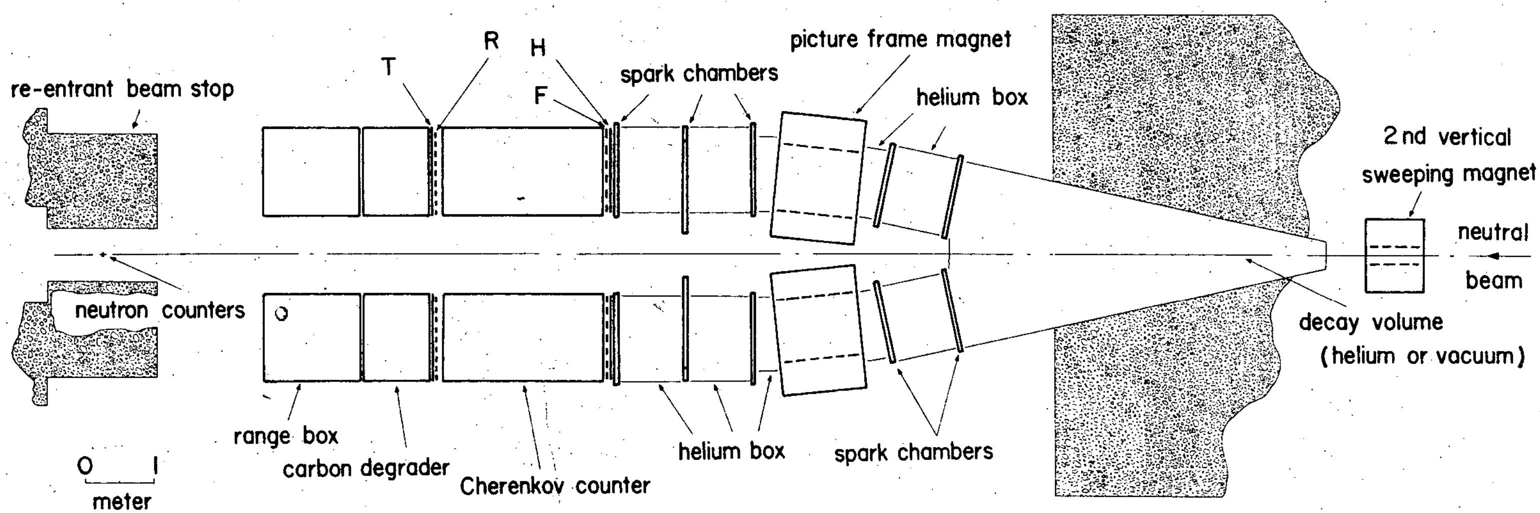

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Figure 1

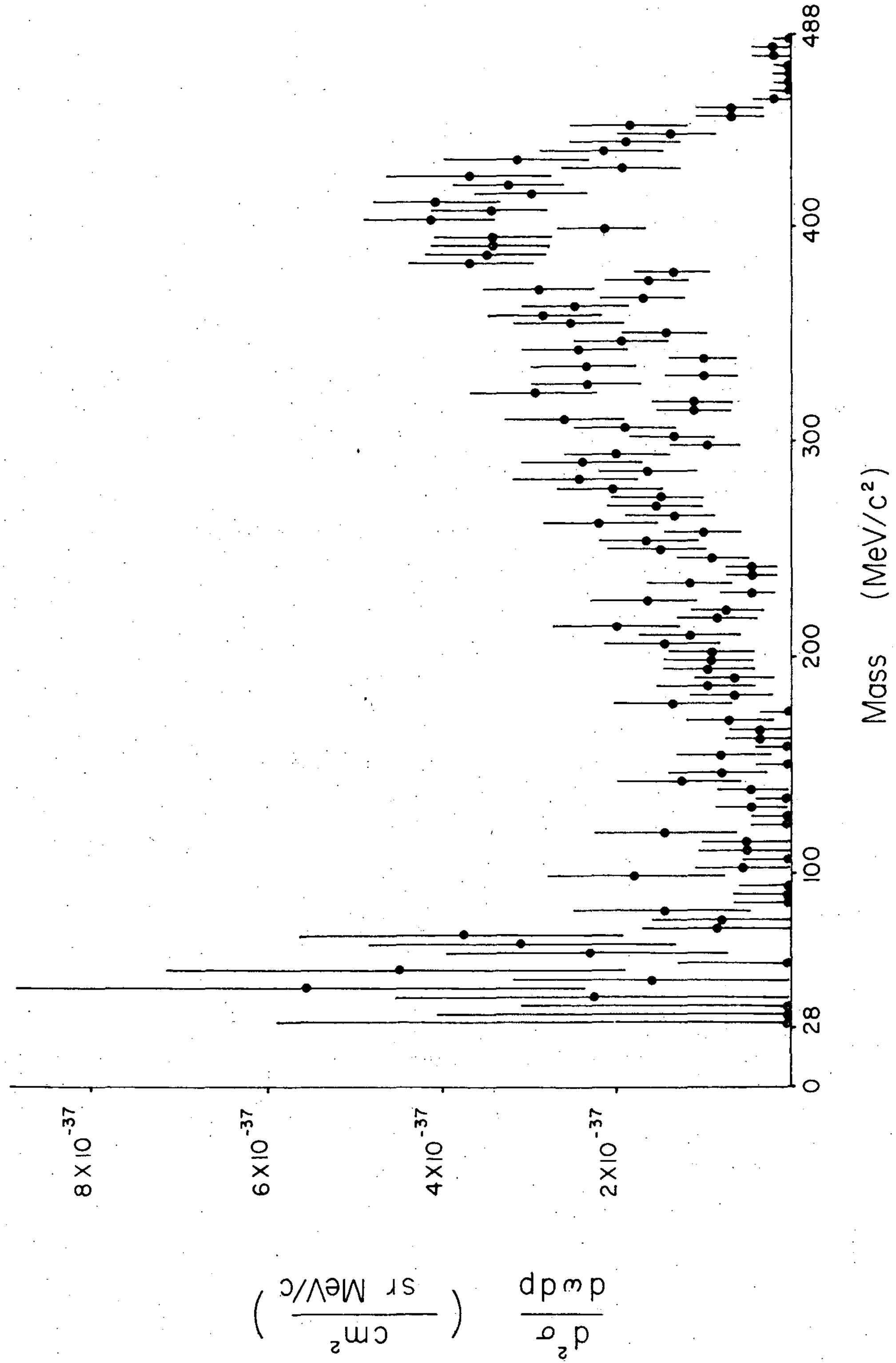

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Figure 2

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720