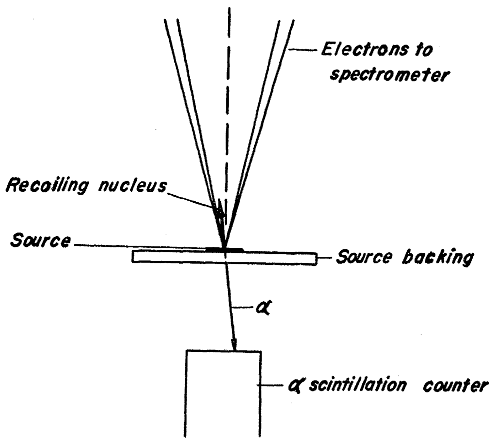

FIG. 2. Schematic diagram of arrangement used for detecting coincidences between conversion electrons and α particles.

In further experiments, the line shape of the "A" line was compared with the line shape obtained in coincidence with the 6.04-Mev α particles, which were selectively detected by a fast scintillation counter, situated behind the source in the lens spectrometer, as shown schematically in Fig. 2. This coincident arrangement selects conversion electrons which are emitted from recoil nuclei moving outwards from the source into vacuum. If the α detector subtends a small solid angle at the source, the resulting coincident peak should show only a small recoil broadening and should have a mean momentum close to the maximum momentum of the recoil distribution which is $p_0[1+(v_\alpha/v_\beta)]$. The results are shown in Fig. 3, where it is seen that the coincidence peak is indeed narrower by about 0.2% and is shifted to higher energies by 0.24%. The measurements were taken at a resolution of 1.2%. Similar behavior has been observed in the low-energy L Auger spectrum (6–12 kev) coincident with the 6.04-Mev α particles.[2] The width of the A line coincident with α particles was found to be about the same as the width of the F line when examined under the same spectrometer resolution. This shows that electron scattering in the source cannot be an important factor contributing to the observed broadening of the lower energy A line.

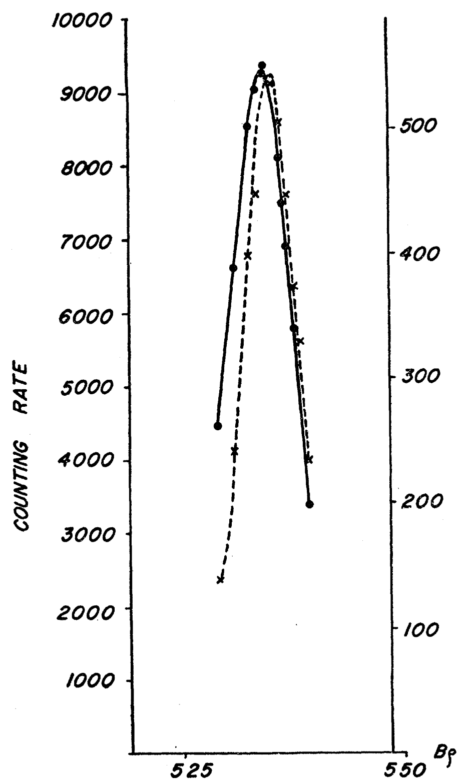

FIG. 3. Comparison of the single and α coincident peaks for the "A" line. In this experiment the α counter subtended an average solid angle of about 1 steradian at the source. The full curve corresponds to the single peak (ordinate scale on left). The broken curve corresponds to the coincident peak (ordinate scale on right).

A detailed analysis of the results has been made, taking into account the finite resolution of the spectrometer, and the possible loss of energy in the source backing suffered by electrons coming from recoil nuclei, which have buried themselves in the source backing. Good agreement with the observed shifts is obtained only if we assume that only the nuclei recoiling into the vacuum give rise to significant shifts. This leads to the conclusion that the nuclei recoiling into the source nuclei lose most of their momentum in the source backing *before* the conversion electrons are emitted. Assuming a linear relation between velocity and residual range for the recoil nuclei[1] and using a value of about 6 $\mu g/cm^2$ for the average range of the recoil nuclei in the aluminum (as measured in this laboratory), we conclude that the recoil nuclei are slowed down in aluminum in about 2×10^{-13} sec. It follows that the lifetime of the 40-kev transition must be greater than 2×10^{-13} sec. An upper limit of 7×10^{-11} sec is given by the experiments of Graham and Bell.[3] An attempt is being made to fix the lifetime between these limits using recoil shifts. The methods may be useful for lifetime measurements in other high-specific-activity α emitters.

[1] Devons, Manning, and Bunbury, Proc. Phys. Soc. (London) **A68**, 18 (1955). This article contains reference to previous work.
[2] J. Burde and S. G. Cohen (to be published).
[3] R. L. Graham and R. E. Bell, Can. J. Phys. **31**, 374 (1953).

Mean Life of K^+ Mesons*†

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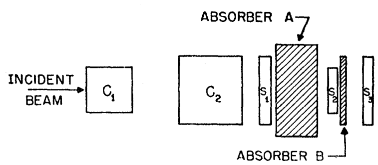
CURRENTLY the best evidence supports the view that there are at least two types of K-mesons in the mass range of 900 to 1000 m_e. The τ meson appears not to have both the spin and parity of the

FIG. 1. Counter arrangement for obtaining differential range curve. The counters are labelled C and S and refer to Čerenkov and scintillation counters, respectively. Absorber B is fixed at $\frac{1}{4}$ in. Cu.



$K_{\pi 2}$ when the experimental data on τ decay are compared with the analysis of Dalitz.[1] On the other hand, there is good evidence from range and momentum measurements on the parent particle and from Q-value measurements that the masses of the $K_{\mu 2}$, the $K_{\pi 2}$, and τ are the same to within one percent.[2] This situation has led us to investigate the lifetime of the K^+-meson as a function of its decay mode. Except in the case of τ decay, previous measurements of the lifetime were made irrespective of the decay mode. These are summarized in the report of the Pisa Conference.[3] This letter reports the results of measurements made on the decay of the $K_{\mu 2}^+ \rightarrow \mu^+ + \nu$ and $K_{\pi 2}^+ \rightarrow \pi^+ + \pi^0$.

The experiment utilizes K^+-mesons produced in the Brookhaven Cosmotron when 3-Bev protons strike a Cu target. The particles emitted at 60° with respect to the circulating proton beam are momentum-analyzed (465 Mev/c) and focused at a point 15 feet from the target.[4] K-particles are distinguished from the much greater number of pions and protons by velocity selection using Čerenkov detectors. Figure 1 shows the counter arrangement used to obtain the differential range curve in Fig. 2. C_1 is a Čerenkov counter sensitive to particles with velocities between threshold and the velocity at which the radiation is totally internally reflected ($0.62 < \beta < 0.78$). C_2 has a threshold above the K-meson velocity and is operated in anticoincidence to eliminate π mesons which have been detected in C_1. Integration of the differential range curve after subtraction of background yields a flux of three K-mesons per 10^{10} protons in the circulating beam of the Cosmotron. This corresponds approximately to one K-meson to every 400 pions traversing the apparatus.

The lifetime of the two decay modes is measured with the counter array shown in Fig. 3. Pulses from counters C_1, S_2, S_3, C_6, C_3, C_4, and C_5 are presented on a fast

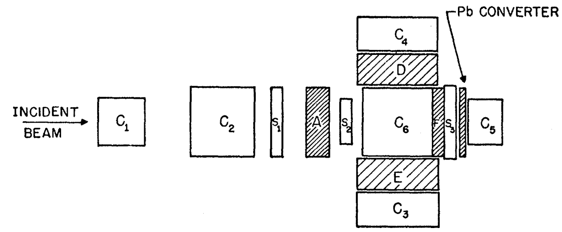
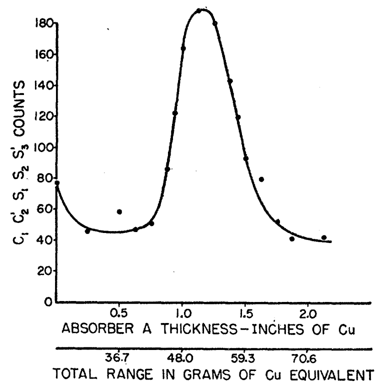


FIG. 3. Counter and absorber arrangement for the measurement of lifetimes.

oscilloscope trace. The sweep is initiated by a $C_1C_2'S_1S_2S_3'C_6$ coincidence (the prime denotes anticoincidence) and the trace is photographed. Counter C_6 is sensitive only to the secondary and the pulse from C_6 is referred to the $t=0$ pulses from C_1 and S_2 to measure the delay. The dispersion in time measurements made from the oscilloscope traces is less than 2 millimicroseconds. The $K_{\mu 2}$ is distinguished by the unique range of the muon secondary. The K-meson is stopped in the middle of C_6 and we require that the secondary cause coincident pulses in C_6 and C_3 or C_4. The absorber interposed between C_6 and C_3 or C_4 is sufficient to stop the pion secondary from the decay of the $K_{\pi 2}$.[3] To identify the $K_{\pi 2}$, the K-meson is stopped in absorber F. We then require a coincidence between C_6 and C_5 with no evidence of an ionizing link in S_3. Approximately 20% of the running time devoted to $K_{\pi 2}$ detection has been with the Pb converter removed. The decrease in rate is consistent with the change in the total amount of converter material present.

We have detected a total of 246 $K_{\pi 2}$ and 393 $K_{\mu 2}$ mesons. Distributions of the times for decay are shown

FIG. 2. Differential range curve of K^+-mesons.



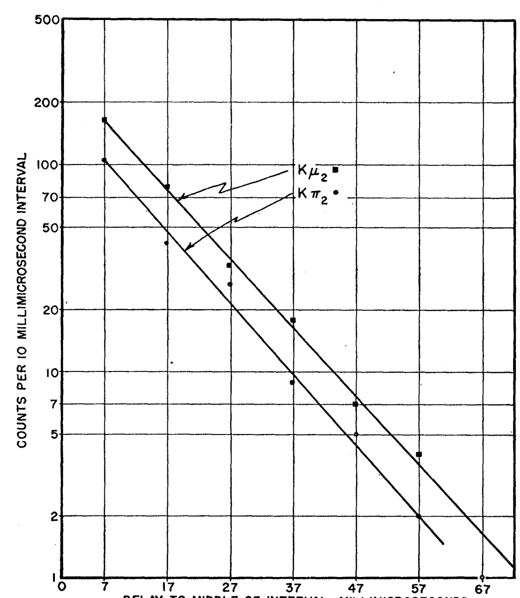


FIG. 4. Time distribution of the K-meson secondaries after separation into the $K_{\pi 2}$ and $K_{\mu 2}$ categories.

in Fig. 4. To avoid difficulties in the $t=0$ region due to the time resolution of the apparatus, we have used only those events with delays greater than 3.5 millimicroseconds to calculate the mean life. On the basis of 164 $K_{\pi 2}$ and 289 $K_{\mu 2}$ events, our results are

$$T(K_{\pi 2}) = (12.1_{-1.0}^{+1.1})\times 10^{-9} \text{ sec.}$$
$$T(K_{\mu 2}) = (11.7_{-0.7}^{+0.8})\times 10^{-9} \text{ sec.}$$

We emphasize that C_6 has a velocity threshold of $\beta=0.7$. The apparatus is thus not sensitive to the τ or τ' particles. The K_{e3} will be detected along with the $K_{\pi 2}$ if the decay process is $K_{e3}\rightarrow e+\pi^0+\nu$ or $K_{e3}\rightarrow e+\gamma+(?)$. From the known frequency of occurrence of the various decay modes[2] we estimate that each of our samples is contaminated less than 20% by all the other modes of decay.

Details of this experiment will be published when current measurements on the τ lifetime are completed.

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† Much of this work was done while the authors were guests of the Brookhaven National Laboratory. It is with pleasure that we acknowledge the assistance and cooperation received from Dr. G. B. Collins and the staff at the Cosmotron.

[1] R. H. Dalitz, Phys. Rev. **94**, 1046 (1954); Proceedings of the Fifth Annual Rochester Conference on High-Energy Physics (Interscience Publishers, Inc., New York, 1955). p. 140.

[2] Ritson, Pevsner, Fung, Widgoff, Zorn, Goldhaber, and Goldhaber, Phys. Rev. (to be published). We thank this group for a preprint of their paper.

[3] Proceedings of the International Conference on Elementary Particles, Pisa, 1955 [Nuovo cimento (to be published)].

[4] We are indebted to Professor J. Rainwater of Columbia University for the use of the focusing magnets, and to Dr. G. Harris of Columbia, Dr. R. Madey, and Dr. W. Moore of the Brookhaven staff for their participation in setting up the magnet system.

Terminal Observations on "Antiprotons"*

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RECENTLY Chamberlain, Segrè, Wiegand, and Ypsilantis[1] have observed negatively charged particles of mass $1840\pm 90m_e$ emerging from a target of the Berkeley Bevatron. In their experiment, protons of 6.2-Bev energy bombarded a Cu target, and secondary particles of unit negative charge emitted near 0° were selected in a momentum orbit of 1.20 ± 0.02 Bev/c by the system of deflecting and focusing magnets described in reference 1. Their additional measurement of flight time over a 40-ft portion of the path allowed the identification of mass within the limits mentioned above, and certain requirements of response in special Čerenkov counters assisted in rejecting background events. The fact that each of these unique particles was

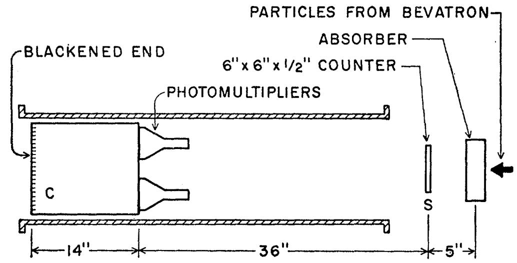

FIG. 1. Schematic diagram of the glass Čerenkov counter with associated scintillation counter and absorber.

accompanied by about 4.4×10^4 negative pions within the defined momentum channel emphasizes the importance of background rejection.

Since it is required of an antiproton that it be capable of annihilation in combination with a nucleon, it is significant to observe the passage through matter of particles purported to be antiprotons, and particularly to examine the region of their range endings for evidences of large energy release. The first aim of the experiment described here was to show that the proton-mass particles produce events different from those associated with passage of the negative pion beam. If such observations can be made on a quantitative basis they can presumably insure the identity of these particles as antiprotons in distinction from combinations of K mesons, hyperons, or unknown objects that could demonstrate the proper charge, mass, and lifetime. Annihilation is expected to occur in several modes, but the immediate products may include pions, photons, and possibly K mesons; and the identities and multiplicities of these product particles may vary.

Apparatus.—In the selected particle beam of reference 1, and following the counters of that experiment, we placed a cylinder (12 inches in diameter and 14 inches long) of dense flint glass (density=3.89 g/cm^3; index of refraction 1.649; 52% PbO, 42% SiO_2, 3% Na_2O, 3% K_2O, by weight), viewed by a group of four photomultiplier tubes 5 inches in diameter mounted on one face and operating in parallel output. Nucleon annihilation within the glass can give rise to electronic showers generated from π^0 decay photons or from

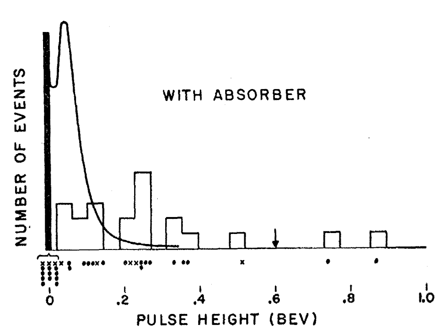

FIG. 2. Pulse-height distribution for YES (>0) events when absorber is in place. (The smooth curve is the pulse spectrum for pions.)