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

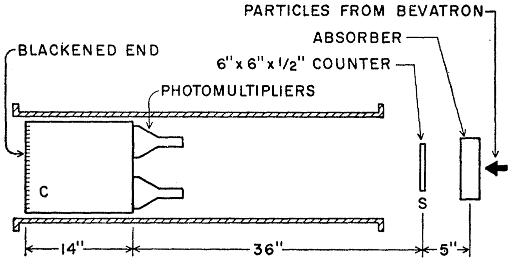

FIG. 1. Schematic diagram of the glass Čerenkov counter with associated scintillation counter and absorber.

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$_2$O, 3% K$_2$O, 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

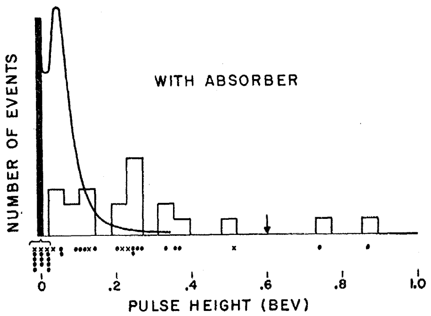

FIG. 2. Pulse-height distribution for YES (>0) events when absorber is in place. (The smooth curve is the pulse spectrum for pions.)

TABLE I. Classification of 92 selected particles.

	Absorber in			Absorber out	
Scintil. pulse	Glass pulse	Number	Scintil. pulse	Glass pulse	Number
YES	=0	11	YES	=0	3
	>0	16		>0	23
NO	=0	21	NO	=0	8
	>0	5		>0	5
		53			39

direct photon products of the annihilation, and the Čerenkov radiation from the showers is measured in terms of pulse height of the photomultiplier response. Consequently, we do not expect the pulses to be representative of the *total* energy release, but rather of that portion of the energy converted into electronic showers, plus a contribution from relativistic charged pions that may be among the products. The radiation length for the glass medium is 2.6 cm, so a large fraction of a shower event can be captured if it is initiated within a favorable region within the glass. Detailed information on construction and characteristics of this Čerenkov counter system, together with its calibration with photons and electrons, is available in preliminary form,[2] and is to be published.[3]

In Fig. 1 the arrow represents the momentum-selected beam of negative particles which emerges from the apparatus of reference 1 and is directed through an absorber, a scintillation counter S, and into the glass C. The glass cylinder was so oriented that the beam in the glass moved away from the photomultiplier face and toward a black end-face which formed a light sink.

The purpose of the black end, and of this orientation, was to minimize the Čerenkov light signal from the 1-Bev negative pions that transverse the defined momentum orbit in great abundance relative to the particles of protonic mass. The latter particles arrive with about 500 Mev of kinetic energy, and should project their secondary (or annihilation) products with rather uniform probability in any direction, particularly if the absorber thickness is so chosen as to cause their ranges to end in the glass, whereas the pions of the beam yield their Čerenkov light primarily into the light sink.

Procedure.—Pulses from the photomultiplier group and from the scintillation counter were presented upon an oscilloscope trace photographically recorded. The sweep of our oscilloscope was triggered by a signal from the system used by Chamberlain, Segrè, Wiegand, and Ypsilantis,[1] so that we generated a trace whenever their oscilloscope was triggered, and a system of accounting was established which allowed the subsequent unique identification of our particular traces that belong to particles judged by them to be of protonic mass by examination of their traces.

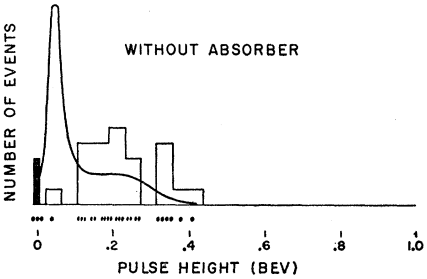

FIG. 3. Pulse-height distribution for YES (>0) events when absorber is removed.

Because of the limited size (6 in. by 6 in.) of our entrance scintillation counter, which was distinctly smaller than the entrance face of the glass (12 inches in diameter), not all the traces so selected displayed a scintillation (S) pulse. In the data that follow, events associated with an S pulse, which implies particle approach toward the central area of the glass face, are termed "YES" events. Selected traces in which the S pulse is absent are "NO" events, and they infer that an approaching particle missed S (because of scatterings) and entered the peripheral area of the glass face or missed the glass entirely in the cases where the glass-counter pulse is also missing.

The observations performed involved counting with absorber and without absorber. The absorber consisted of a 2.5-inch thickness of copper, sufficient to cause the range end of the proton-mass particles to fall somewhat short of the exit (black) face of the glass. When the absorber was removed, these particles, if they did not interact in the glass, could emerge from the exit face with about 250 Mev of kinetic energy remaining.

The purpose of comparing these two absorber conditions was to ascertain the fraction of the proton-mass particles that interact, with yield of considerable energy, in passing through the 14 inches of glass.

Results.—The data that follow are observations on 92 particle passages selected by the Chamberlain-Segrè-Wiegand-Ypsilantis system. Of these, 53 occurred with the absorber in place, and 39 with absorber removed. They are classified as YES or NO events, as mentioned above, and further divided into those which produced Čerenkov pulses in the glass distinctly above noise level and those which did not produce an observable pulse in the glass. Table I is a summary of these 92 cases.

The interpretation of NO pulses with glass pulse=0 is that scattering, either in preceding counters or in the absorber, prevented the particles from registering in either S or C (Fig. 1); and if the selected particle chanced to interact while passing through the absorber, none of the secondary particles registered. NO pulses with glass pulse>0 imply that a selected particle, or a relativistic secondary capable of yielding sufficient Čerenkov light in the glass, missed S but entered C peripherally or by in-scattering from tube base structures between S and C. It is also conceivable that neutral secondary particles could emerge from the absorber and interact in the glass without registering in S.

YES pulses with glass pulse$=0$ can arise from scattered or secondary particles that miss the glass after registering in S, or that are not capable of generating sufficient Čerenkov light in the glass. It is important to note that the proton-mass particles are in this last category if they do not interact in the glass, for the gain of the photomultipliers and electronics was so adjusted that positive protons of 500 Mev entering along the beam direction would not count in the glass.

Finally, the YES pulses with glass pulse>0 imply selected particles that register in S and interact in the glass with yield of considerable Čerenkov light. Also ionizing secondary particles out of the absorber that can meet the Čerenkov requirement will fall in this category, but the number of these is expected to be small since the glass subtends only 0.05 steradian at the absorber.

In Fig. 2 is plotted the pulse-height spectrum of selected-particle events of the YES (>0) type when the absorber is present. The number of cases of glass pulse$=0$ is also indicated but is not plotted as part of the histogram spectrum. The smooth curve represents the spectrum of pulses obtained from the total beam, preponderantly negative pions at about 1 Bev, normalized to the histogram area. This curve was obtained from a few thousand beam particles selected simply by a scintillation counter telescope placed ahead of the glass, and the arrow indicates the largest pulse seen in this manner. The dots along the base line indicate the pulse-height values of the 27 YES events, of which 16 are greater than zero. The ×'s also plotted show eight events recorded before the S-counter had been installed, and these have been included in the histogram.

Figure 3 presents the same kind of display for the data secured with absorber removed. Here, of the 26 YES events, 23 are greater than zero in pulse height.

The energy values assigned to the abscissas of Figs. 2 and 3 mean that the amount of Čerenkov light collected was either appropriate to an electronic shower containing the energy stated or to a total particle energy loss *at minimum ionization* of the value stated for a particle or shower moving axially toward the photomultipliers. This calibration was accomplished by the use of electrons of selected energies up to 1.4 Bev, as described in references 2 and 3, and by analysis of pulses produced by cosmic-ray mesons passing through the glass in trajectories selected by a counter telescope. In this experiment, where one end of the glass is blackened, the influence of track location and direction is much more important than in the preceding calibration experiments, so the energy values assigned to the present pulses are *lower limits*. Considerations of the possibility of escape from the glass of relativistic particles and portions of showers, and of the fact that some of the energy released by events in the glass may be carried off by particles not yielding Čerenkov light, further emphasize that our energy assignments are lower limits upon the energies released in the events.

In discussion of the data of Figs. 2 and 3 the following observations can be made:

1. The negative pions incident at about 1 Bev, which constitute essentially all of the beam, in passing through the glass toward the black face produce a most probable Čerenkov pulse height corresponding to about 50 Mev (smooth curve peak position) on our calibration scale. When the counter direction is reversed, so that the pions approach the photomultipliers, the most probable pulse height is four times as great. The low tail extending to higher energies is considered to be due to interaction of these beam pions in the glass, resulting in the release of larger energies. The "ledge" on the high-energy side of the total beam pulse spectrum in Fig. 3 (without absorber) is not clearly explained; it may involve the simultaneous observation of more than one beam particle, since the S pulses associated with this "ledge" appeared also to be larger than average. However, it is conceivable that it is due to some other component of the beam that is strongly attenuated when the absorber is in place.

2. The histogram spectra of the selected, proton-mass particles are distinctly more rich in large pulses than are the pion-beam spectra; and this provides the answer to the first question with which the experiment is concerned. In Fig. 2, it is apparent that the lower limit assignments on the selected pulses extend higher than the largest pulses observed from several thousand pions of 1 Bev traversing the glass.

3. The presence of the absorber gives rise to many secondary particles that register in S but not in C. This is evident from the large number of YES events with zero glass pulse in Fig. 2.

4. A large fraction of the proton-mass particles interact in flight in the glass. This is apparent from Fig. 3, where these particles in the absence of interaction would have passed through the glass without registering a Čerenkov pulse (at the electronic gains here employed) and emerged with 250-Mev kinetic energy remaining. As a matter of fact, only 3 out of 26 did apparently thus pass through. The behavior of ordinary protons in the glass, with the same kinetic energies as the "antiprotons" possess, was experimentally determined by reversing the magnetic fields of the momentum selector. Their pulses in the glass would fall at "zero" on the energy scales of Figs. 2 and 3.

Conclusions.—The results here reported are not inconsistent with expected behavior of antiprotons. The lower limits observed for the energy release in events associated with the passage of these negative, protonic-mass particles through matter could be appropriate to antiprotons, but the energy values are not so high as to demand this conclusion, since the largest lower limit here recorded is about 0.9 Bev in the form of particles producing Čerenkov light.

If, in the case of no absorber, we assume that the proper interpretation of the YES events with glass pulse=0 (Table I and Fig. 3) is passage through the glass without interaction, we may calculate a cross section for interactions in flight producing large energy loss. The transmission through the 14 inches of glass is $3/26=0.12$; and with consideration of the composition and density of the glass this leads to a value of 1.9 ± 0.6 times the geometric cross section, where the latter is calculated from a radius formula $R=1.25A^{\frac{1}{3}}\times10^{-13}$ cm.

Furthermore, from comparisons of the data with and without absorber, it is possible to compute an attenuation in copper for the proton-mass particles for a geometry in which the detector subtends a solid angle of 0.05 steradian. In each case, the number of incident selected particles is the sum of the YES and NO events. When the absorber is in place, we consider the YES (>0) events to represent the number of these particles surviving passage through the 2.5 inches of copper. When the absorber is removed, *all* the YES events are accepted because a zero glass pulse is now admissible as a pass-through event. We obtain the transmission through the copper by evaluating the ratio: [YES (>0)/(YES+NO)] (with absorber) ÷[YES/(YES+NO)] (without absorber). From the data of Table I, this ratio is $[16/53]\div[26/39]=0.45$. This yields an attenuation cross section 1.7 ± 0.7 times the geometric value for copper. The expressed uncertainty is statistical only.

This preliminary evidence indicates that the cross section for interaction in flight, leading to events releasing considerable energy in the glass, is at least geometric and perhaps larger.

We wish to acknowledge the cooperation of Owen Chamberlain, Emilio Segrè, Clyde Wiegand, and their associates in supplying us with selected particles and oscilloscope trigger signals; and the active support of Edward J. Lofgren and the Bevatron staff is appreciated. Professor Edwin M. McMillan has given the support of his interest and helpful criticism.

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Reduced Widths from Stripping Reactions

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ACCURATE measurements of the cross sections of (d,p) and (d,n) stripping reactions are valuable since they lead to the reduced widths of the levels of the final nuclei so formed. The comparison of corresponding levels in mirror nuclei is particularly interesting. If one assumes charge independence of nuclear forces, these should have approximately equal reduced widths. It has been pointed out by Cooper and Tobocman,[1] however, that the ratios of the reduced widths of mirror levels found from stripping cross sections would depend critically on the relative radii of the boundaries of neutrons and protons in the nucleus; they should, therefore, provide a sensitive test of any inequality in the latter.

A comparison of several corresponding states of Mg^{25} and Al^{25}, using the Butler theory of stripping[2] and published values of the cross sections of the reactions $Mg^{24}(d,p)Mg^{25}$ and $Mg^{24}(d,n)Al^{25}$, has been made by Fujimoto *et al.*[3] who found the surprisingly high value of about 10 for the ratio γ_n^2/γ_p^2. However, corrected values of the (d,p) stripping cross section by Holt and Marsham[4] reduce this by a factor 4 to about 2.5. The accuracy of the above value is limited by that of the ratio of the (d,p) and (d,n) cross sections $\sigma(d,p)/\sigma(d,n)$ which, in this case, was derived from two unrelated experiments and may be subject to unnecessarily large error. It was thought worthwhile, therefore, to measure the quantity $\sigma(d,p)/\sigma(d,n)$ directly in several appropriate cases so as to compare the corresponding reduced widths as accurately as possible.

Targets chosen to yield mirror or, in one case, corresponding levels were bombarded by a beam of 9-Mev deuterons from the Liverpool University 37-in. cyclotron. Resulting proton groups were analyzed by a small NaI crystal, the output of which was recorded on a 100-channel pulse analyzer. Neutron groups were analyzed by means of a fast-neutron spectrometer using scintillation crystals and having a relatively high efficiency. A full description of this spectrometer, previously found reliable in the investigation of (d,n) angular distributions, is at present in press.[5] The proton and neutron spectrometers were placed, when possible, at angles corresponding to the peaks of the stripping distributions on opposite sides of the 0° direction. Protons and neutrons were observed simultaneously. The ratio of the cross sections thus obtained was independent of target thickness (this may not be uniform or may change during bombardment), and it was not necessary to know the total deuteron bombardment employed, so that inaccuracies involved in current integration were eliminated.

The results obtained are shown in Table I; values quoted in column 6 are the experimentally found ratios of the maximum differential cross sections of the (d,p) and (d,n) processes (for unit solid angles in the center-of-mass systems). For C^{12} and Si^{28}, where both spectrometers could not be set on the maxima of the stripping distributions, they were aligned as closely as possible to the maxima and the results normalized according to the experimental angular distributions. The ratios of the reduced widths γ_n^2/γ_p^2 were calculated