a plausible theoretical estimate of 0.004 mb ($g^2/4\pi\approx 1$) for the antiproton production cross section,[3] we believe that the expected number of 2-Bev pion stars may be as high as 50 times the number of antiproton stars. Thus, combined with the probability factor from blob-density considerations, there may be roughly an equal probability that star *B* arises from the interaction of an antiproton as from a 2-Bev pion. However, since the momentum of a 2-Bev pion is 2140 Mev/*c* and the observed forward momentum of star *B* is visible only 840 Mev/*c*, there is again considerable doubt cast on the possibility that the incident particle could be a high-energy pion.

It should perhaps be pointed out that, since the visible energy evolution in star *B* is only 660 Mev in excess of the incident particle energy, the event is not incompatible with the absorption of a hypothetical boson of approximately protonic mass.

We are deeply indebted to the members of the Radiation Laboratory, University of California, and especially to Dr. E. J. Lofgren and Dr. G. Goldhaber, for the irradiation of the emulsions.

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* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] B. Judek and E. Pickup (private communication); A. Husain and E. Pickup, Phys. Rev. **98**, 136 (1955). Using electrons from $\mu-e$ decays, we have checked the ratio of plateau density to 6.2-Bev proton blob density and find a value of approximately 1.03, which, within experimental error, agrees with value of 1.05 used above. Although there is some disagreement [see Kaplon, Klarmann, and Yekutieli, Phys. Rev. **99**, 1528 (1955)] as to the value of the plateau to minimum blob-density ratio, most observers are in agreement on the form of the blob-density curve above the plateau. Above the plateau, we have used a combination of the curves of Husain and Pickup and of J. R. Fleming and J. J. Lord [Phys. Rev. **92**, 511 (1954)].

[2] The possibility that star *B* is created by an Eisenberg type of particle seems no more likely than in the case of a deuteron; unless perhaps the normally emitted *K* particle decays to pions or is converted directly into kinetic energy.

[3] D. Fox, Phys. Rev. **94**, 499 (1954); R. N. Thorn, Phys. Rev. **94**, 501 (1954); G. Feldman, Phys. Rev. **95**, 1697 (1954).

Antiproton Star Observed in Emulsion*

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In connection with the antiproton investigation at the Bevatron, we planned and carried out a photographic-emulsion exposure in a magnetically selected beam of negative particles. The magnetic system was identical to the first half (one deflecting magnet and one magnetic lens) of the system used in the antiproton experiment of Chamberlain, Segrè, Wiegand, and Ypsilantis.[1] The selected particles left the copper target in the forward direction with momentum 1.09 Bev/*c*.

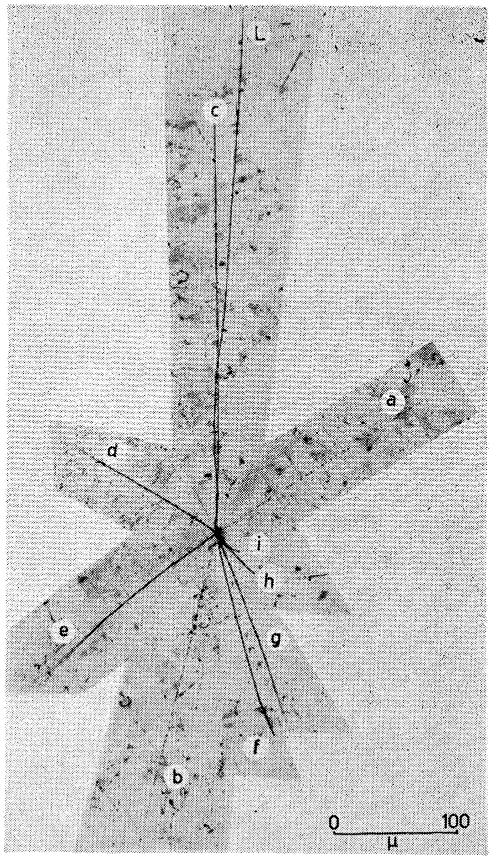

Fig. 1. Reproduction of the star. *L* is the incoming track (9.31 cm of range). For the explanation of the other tracks see Table I.

Cosmic-ray events possibly due to antiprotons had been observed previously by Hayward,[2] Cowan,[3] Bridge, Courant, DeStaebler, and Rossi,[4] and (in nuclear emulsion) by Amaldi, Castagnoli, Cortini, Franzinetti, and Manfredini.[5] We were hopeful of finding events similar to the last one in our experiment as reported here.

When the antiproton concentration in the beam used was measured[1] (one for about 50 000 pions), it became possible to make a rough estimate of the number of antiprotons that should come to rest in the nuclear emulsion stacks. Since the range of antiprotons from the selected beam was considerably greater than the length of the stacks, it was necessary to slow the antiprotons in an absorber (132 g cm^{-2} of copper) before allowing them to enter the stacks in which they were to come to rest. The estimate of the number of antiprotons stopping in the stacks is hence rather drastically affected by the assumption made about their nuclear attenuation cross section in the copper absorber. If the attenuation cross section is assumed equal to that for protons we could expect about 7 antiprotons, while if it were twice that for protons we could expect only about 2.5 anti-

TABLE I. Analysis of the star shown in Fig. 1.[a]

Track	Range (microns)	Ionization (I/I_0)	$p\beta$ (Mev/c)	Identity	E (Mev)
a	23 960 observed	0.90±0.06	430±70	π(?)	332.0
b	19 500 observed	1.29±0.09	98± 9	π	57.5
c	4250 total			p	32.3
d	1100 total			p(?)	15.0
e	340 total			p(?)	7.6
f	202 total			p(?)	5.5
g	4050 total			p(?)	31.4
h	206 total			p(?)	5.5
i	100 total			p(?)	3.6

[a] The particle identity for tracks b and c is certain. That for track a is only slightly uncertain; a very improbable alternative is that it is due to an electron. The others can be protons or alpha particles.

protons, in the scanned part of our stacks. Up to now only one has been found. We think, however, that we should not draw any conclusion about the attenuation cross section from these numbers, since our efficiency of observation is different for different scanning methods and is not easy to estimate.

Intensive scanning in Rome and in Berkeley has produced one star, found in Rome, and shown in Fig. 1. It has outgoing tracks as indicated in Table I. The most reasonable assumption is that track a is a pion. If the black prongs are due to protons, the visible energy release may be computed as follows: kinetic energy of the two pions, 389 Mev; rest energy of the two pions, 280 Mev; kinetic energy of the black tracks, 101 Mev; and binding energy for the black tracks, 56 Mev. The total visible energy is 826 Mev.

The momentum unbalance is 520 Mev/c, and in the most conservative (and very unlikely) assumption that four neutrons escaped, all with the same energy and in the same direction, the minimum invisible energy release would be 65 Mev. A more realistic estimate of the energy represented by neutrons would be 160 Mev. It is possible that a very considerable energy went into neutral pions. Other assumptions on the identity of the heavy tracks give higher total energy releases.

We must conclude that the visible energy release is consistent with that to be expected from the annihilation of an antiproton-proton pair; it would be harder to explain as due to a reaction in which all the energy is supplied by only one particle of protonic mass.

From the magnetic analysis we can say that the particle that generated this star entered the copper absorber preceding the emulsions with a momentum of 1090±20 Mev/c. The observed range is 132 g cm^{-2} of copper plus 9.31 cm of emulsion. From these data we can calculate the ratio M/M_p of the mass of this particle to the proton mass, and we obtain 1.02±0.04, in which the main uncertainty is due to the uncertainty in momentum. We have not considered here the remote possibility of inelastic scattering in the copper absorber, which would lead to a lower mass value. Somewhat less precise values of the mass are obtained from measurements made exclusively in the emulsion. All these mass measurements are reported in Table II.

TABLE II. Mass measurements.

Method	Range interval from the end (mm)	M/m_e	M/M_p
Ionization-scattering	82.0−66.0	1840±250	1.00±0.14
Ionization (mean gap length)-range	74.6−19.0	1810±100	0.99±0.06
Same as above	5−0	1740±130	0.95±0.07
Scattering-range	10−0	1635±280	0.89±0.15
Residual range-momentum (from orbit)	93.14 plus 132 g cm^{-2} copper	1865± 70	1.02±0.04
Weighted average		1824± 51	0.99±0.03

This event is corroborating evidence, but not final proof, for the interpretation given in reference 1 that the new particles observed at the Bevatron are antiprotons. It also gives support to the hypothesis that the star described in reference 5 was indeed due to an antiproton.

A more detailed description of these results is being submitted for publication in *Nuovo Cimento.*

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* This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] Chamberlain, Segrè, Wiegand, and Ypsilantis, Phys. Rev. **100**, 947 (1955).

[2] Evans Hayward, Phys. Rev. **72**, 937 (1947).

[3] E. W. Cowan, Phys. Rev. **94**, 161 (1954).

[4] Bridge, Courant, DeStaebler, and Rossi, Phys. Rev. **95**, 1101 (1954).

[5] Amaldi, Castagnoli, Cortini, Franzinetti, and Manfredini, Nuovo cimento **1**, 492 (1955).

Radiative and Nonradiative Boson Decay into Leptons*

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THE decay $K_{\mu 2}\rightarrow\mu+\nu$, which is the most common K-meson decay, is strikingly similar to $\pi\rightarrow\mu+\nu$. A simple phase-space estimate gives a $K-\mu$ lifetime less than one-tenth the $\pi-\mu$ lifetime, while the observed lifetimes are more nearly equal. In this note, we wish to point out that the long $K_{\mu 2}$ lifetime and the absence of K_{e2} are both understandable in terms of the same interaction (axial vector) as has been invoked[1] to explain the absence of $\pi-e$ decay. Since this interaction is one that suppresses the emission of *fast* electrons, it had been expected[2] that radiative decays like $\pi\rightarrow e+\nu+\gamma$ might be relatively important. That this is not so, however, can be shown in a simple way by a generalized equivalence theorem.

Since γ_5 merely inverts neutrino spins, and in the final state neutrino spins are summed over, the decay of a scalar meson by scalar (vector) coupling is identical with the decay of a pseudoscalar meson by pseudoscalar (pseudovector) coupling. The essential feature of derivative coupling is that the matrix element squared

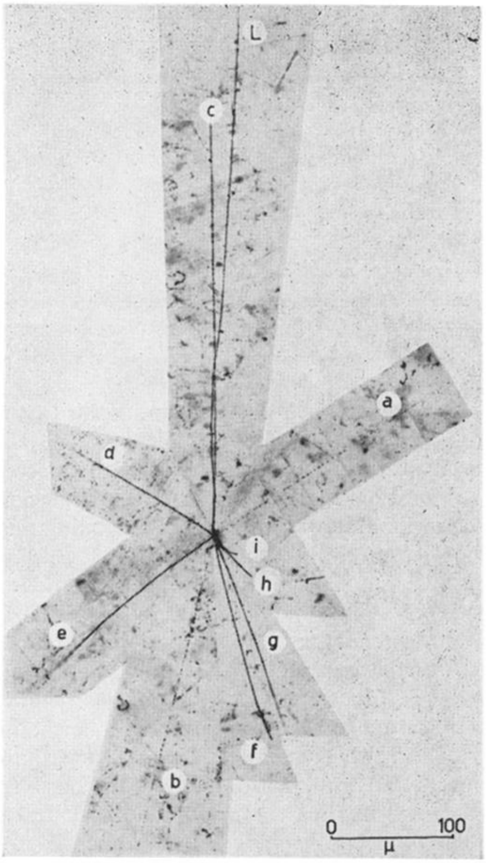

FIG. 1. Reproduction of the star. *L* is the incoming track (9.31 cm of range). For the explanation of the other tracks see Table I.