Title

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Publication Date

1955-12-01

UCRL 3224

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UCRL-3224

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Contract No. W-7405-eng-48

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Printed for the U. S. Atomic Energy Commission

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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.

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

[1] O. Chamberlain, E. Segrè, C. Wiegand, and T. 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] E. Amaldi, C. Castagnoli, G. Cortini, C. Franzinetti, and A. Manfredini, Nuovo Cimento 1, 492 (1955).

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 antiprotons, 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 also 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/Mp 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.

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

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

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

Table I

Analysis of the Star Shown in Fig. 1

Track	Range (Microns)	Ionization (I/I_0)	$p\beta$ (Mev/c)	Identity	E (Mev)
a	23960 observed	0.90 ± 0.06	430 ± 70	π(?)	332.0
b	19500 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

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.

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	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

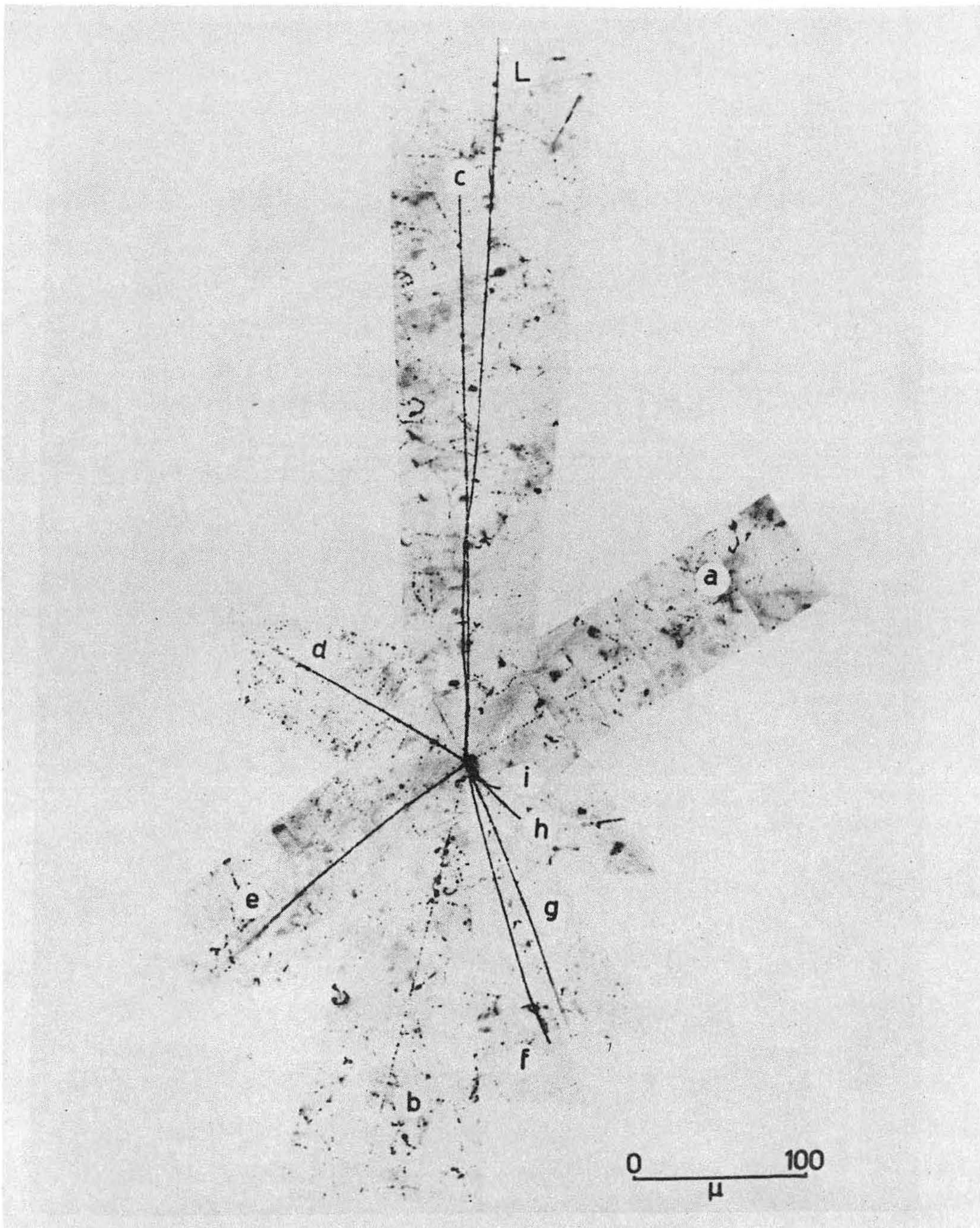

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Fig. 1. Reproduction of the star. L is the incoming track (9.31 cm of range). For the explanation of the other tracks see Table I.