AN ANTIPROTON EVENT

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Plate

ABSTRACT. During the systematic scanning for double stars in nuclear emulsions exposed to 3 Gev. pion beam an event was recorded and from analysis it can be interpreted as due to the annihilation of an antiproton produced in the emulsion. The details of the event along with a microphotograph are given below.

INTRODUCTION

A G–5 emulsion stack was exposed to 3 Gev negative pion beam at the Berkeley Bevatron and it was developed at the T.I.F.R., Bombay. During the area scanning for hyperfragments a double star was observed; the parent star of size (7+0).0 has all its tracks produced by slow particles and the total kinetie energy associated with the star is quite low. There is no minimum ionising track in the known direction of the primary pion beam. No energetic charged particle is associated with it except the suspected antiproton which after travelling a distance of 1057μ in the same emulsion plate apparently stops and gives rise to a second big star of size $(9+1)\bar{p}$. The inter-connecting track emitted from the parent star is quite flat and it is not difficult to know its direction of motion from the change of ionisation. The mass measurement by constant sagitta method is also possible. The second star is also carefully examined for any minimum ionising track in the known primary direction; but, there is no such track. All the particles except three coming out from the star stop in the same emulsion plate. The light track which goes out of the plate and is followed for a distance of 1.8 c.m. is indentified as due to a pion, the direction of its motion can also be determined.

The mass from the constant sagitta measurements on the inter connecting track—

$$\bar{D} = 0.8 \pm .2\mu, \text{ —using the scheme } p(1, 0)$$

The Mass—value obtained is

$$= 1566 \pm \frac{1212}{628} \text{ Mev}$$

The error shown is purely statistical.

TABLE I

Details of the Second Star

Track No.	Identity of the partiels	Ranges	Energy Mev.
1	α	200μ	21.5
2	α	277.3	26.5
3	p	86.6	3.2
4	p	182.5	5.1
5	α	203	21.6
6	π	18000	34.0
7	p	400	8.2
8	p	150	4.5
9	p	487	9.2

The following equation is used by several workers to estimate the total energy involved in the annihilation process,

$$E_H(\text{Mev}) = 2.2\bar{T}_g N_g + \bar{T}_b(N_b + 4\times 3N_b) + 8(N_b + N_g)$$

where,

E_H(Mev) = Total energy released among the charged heavy particles.

T_g = Average K.E. of the grey tracks where $E > 35$ Mev.

T_b = — — black tracks where $E < 35$ Mev.

N_b = No. of black tracks.

N_g = — grey —

$8(N_b + N_g)$ = B.E. of the nucleons.

In this problem,

$$N_g = 0 \qquad N_b = 8$$

$$\bar{T}_g = 0, \qquad \bar{T}_b = 99.8/8 \text{ Mev},$$

$$E_H(\text{Mev}) = \bar{T}_b(N_b + 4\times 3N_b) + 8\times N_b$$

$$= \frac{99.8}{8}\ (8+12\times 8)+8\times 8$$

$$= 99.8\times 13+64$$

$$= 1361.4 \text{ Mev for heavy particles.}$$

For the pion the total energy is

$$E_\pi = (34+139.6)$$

$$= 173.6 \text{ Mev.}$$

Hence the total energy involved in the disintegration is = 1535 Mev.

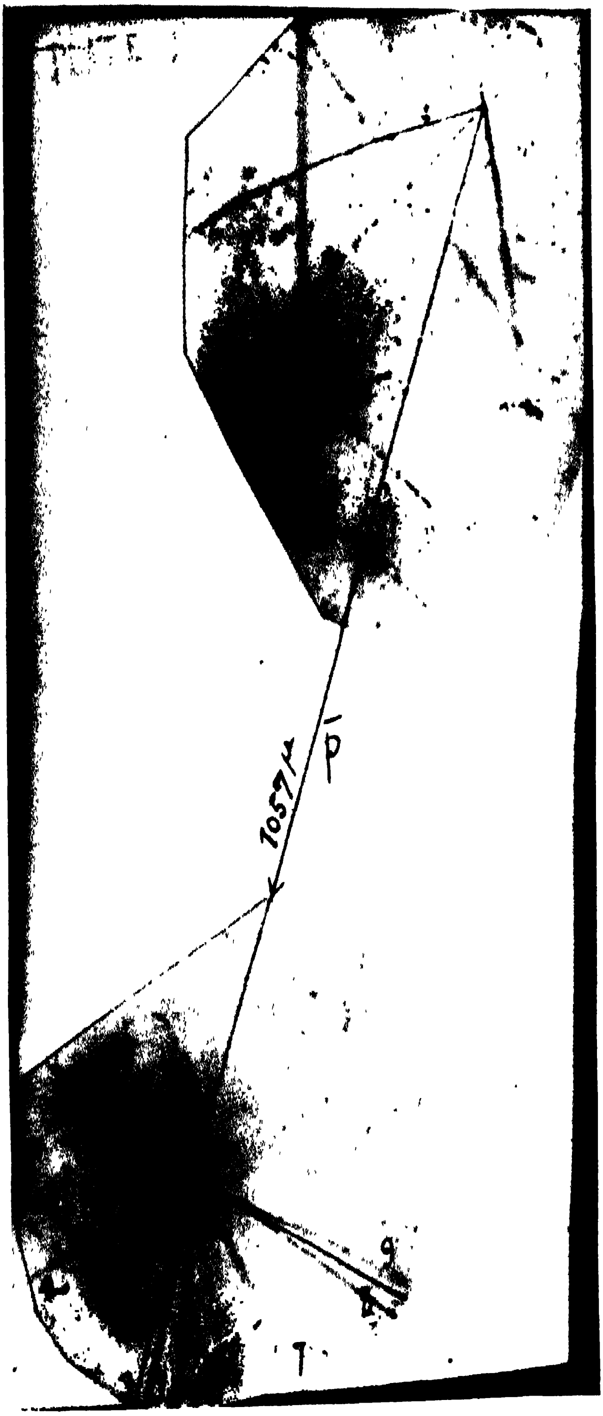
DISCUSSIONS

Possibility of the event being due to

(i) Π^-K^- and Σ^--capture in the emulsion,

(ii) chance coincidence,

(iii) 2 G.e.v. pion interaction,


1057μ
p̄

could be eliminated from the following considerations :

The interconnecting track which is a flat and long one does not show the characteristic coulomb scatterings of a pion track. The larger kinetic energy released in the second star eliminates the possibility of a Σ^--capture in which the energy-release does not exceed 100 Mev. The mass measurement on the track is more in favour of a proton rather than a k-meson, also the total K.E. involved is much higher than what we expect from K^--capture star i.e. 475 Mev.

As both the stars are situated in a clean part of the emulsion, the details of the event can be examined quite closely and one can eliminate the possibility of chance coincidence from such observations. Further, the stars were examined in the similar way under high magnification for any minimum ionising tracks, but there was none. Such tracks in other directions were followed through to know the direction of motion thinking that the first star might be produced by some of them. From these observations we are led to a tentative conclusion as follows : the interconnecting track is due to an antiproton produced in the first star which is perhaps initiated by either an anti neutron or a very high energetic neutron; the antiproton so produced is then annihilated at rest by an amulsion nucleus which as a result is disintegrated.

Possible sources of production of the antiproton

As the parent star which is a small one has not any visible primary track, so it must be produced by some electrically neutral particle. The incident pion of the kinetic energy 3 G.e.v. can by no means produce an antiproton because it requires K.E. in the laboratory system at least 7 Bev. one is then inclined to think of the event to be due to a cosmic ray neutron or antineutron. The results of the previous balloon flight experiments indicate that the existence of antiproton and antineutron in cosmic rays is very rare and the production cross-section of antiproton in such reactions is also believed to be extremely low.

Now one has to think of the neutron and antineutron directly coming from the target, such particles being least affected by the bending magnetic field of the accelerating machine. These neutrons could be produced by the 10 Bev proton beam of the Bevatron hitting the target, and then these can travel in any direction without losing any appreciable amount of energy; the magnetic field however can produce some spinning effect on these particle because of their magnetic moment.

Hence the following reactions are considered—

$$N+P \rightarrow P+\bar{P}+N+P \qquad \ldots (1)$$

$$\bar{N}+N \rightarrow P+\bar{P}+\pi^{+}+\pi^{-} \qquad \ldots (2)$$

For these reactions we have to consider the following points,—similar to the case of electron—pair production by photon, an antinucleon is produced when a nucleon in a Dirac's negative energy state is raised to a positive energy state leaving a hole i.e. an antinucleon. This means that the production of an antinucleon will simultaneously lead to the production of its counter part i.e. a proton and an antiproton, a neutron and an anti-nutron. The most promising mechanism for production of nucleon-antinucleon pair is the nucleon-nucleon collision, when such a pair is produced the final state consists of four particles each possessing the mass of the nucleon (M). At the threshold the incident nucleon must possess a K.E. of at least 6M $= 938 \times 6 = 5.628$ Bev. in order to produce a nucleon-antinucleon pair with a target nucleus at rest. Again using the Fermi energy of 22 Mev for a nucleon and assuming the most favourable circumstances i.e. the nucleon moving in an equal and opposite direction to the incident nucleon, the threshold is reduced to 4.6 Bev. This means that the incident nucleon must possess K.E. at least 4.6 Bev.

So far the properties of anti-proton production have been studied by several workers, all reasonable estimate indicate extremely small cross-sections for nucleon-antinucleon pair production except at very high energy of the order of 10^{13}ev. Antiproton production is therefore rather rare, although their detection is not so difficult.

Now assuming the second star to be an annihilation of the antiproton, we consider various possibilities. The annihilation of an antinucleon by a nucleon has some features in common with position-electron annihilation, but there are some differences too. The nucleons have strong interactions with the pi-meson field much stronger than the electro-magnetic field and consequently the annihilation process should give rise to a pair of gamma-rays. Hence any of the following annihilation reactions may take place.

$$P+P^- \rightarrow \pi^+ + \pi^- \quad \ldots (1)$$

$$\rightarrow 2\pi^0 \quad \ldots (2)$$

$$N+P^- \rightarrow \pi^- + \pi^0 \quad \ldots (3)$$

As our star possesses only one pion track any of these reactions are quite likely.

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