$_\Lambda H^4$ HYPERFRAGMENT EMITTED FROM AN ANTIPROTON CAPTURE STAR*

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The observation of a definite case of Λ^0 hyperon emission from an antiproton annihilation in a medium heavy nucleus is reported. The lambda hyperon is emitted bound in a $_\Lambda H^4$ hyperfragment.

It is known[1-7] that antiproton annihilations, in general, produce a number of pions and that strange particles occur only rarely. From emulsion experiments, Chamberlain et al.[5] estimate that about 3.5 % of all antiproton stars contain $K\bar{K}$ meson pairs. A similar result has been obtained in our study. When the annihilation takes place in a nucleus, one may expect some cases where hyperons are produced, either by a secondary process involving the reabsorption of a $\bar{K}$ meson or by a primary process involving two nucleons and the antiproton. Observations of two possible Σ hyperons emitted from antiproton capture stars have been published.[1,5] In view of the uncertainties attached to these earlier observations, we regard our observation to be of some general interest.

The event occurred in an emulsion stack exposed to a beam of 740-Mev/c antiprotons at the Bevatron in Berkeley. The number of antiprotons observed in this experiment is 374. Details on the scanning technique and the identification of the antiprotons have been published elsewhere.[8]

A microphotograph of the antiproton star with the hyperfragment is shown in Fig. 1. The particle which is assigned to be the antiproton was found to be moving towards the star and to have protonic mass. As the kinetic energy of this particle at the star is only 96 ± 6 Mev and the energy release is at least 979 Mev, it is clear that the star represents the annihilation of an antiproton. All the tracks connected with this event are completely contained in the stack. Each of the eleven outgoing tracks are numbered as seen in the figure. Number 7, which according to our measurements most probably is a proton of 150-Mev energy, interacts in flight. All other particles come to rest.

Number 2 is the hyperfragment. This track is very suitably located for accurate measurements. It is 3630 microns long and passes through 3 plates before decaying at rest (at point B in the figure). The charge of the fragment was measured by counting the number of δ rays along the entire track length. The result $Z = 1$ is certain. The mass was determined by the constant sagitta scattering method to be 4.0 ± 1.1 proton masses. Calibration results from measurements on protons were utilized for both the charge and the mass determination. These results indicate that the particle is probably a H^3 or H^4 hyperfragment.

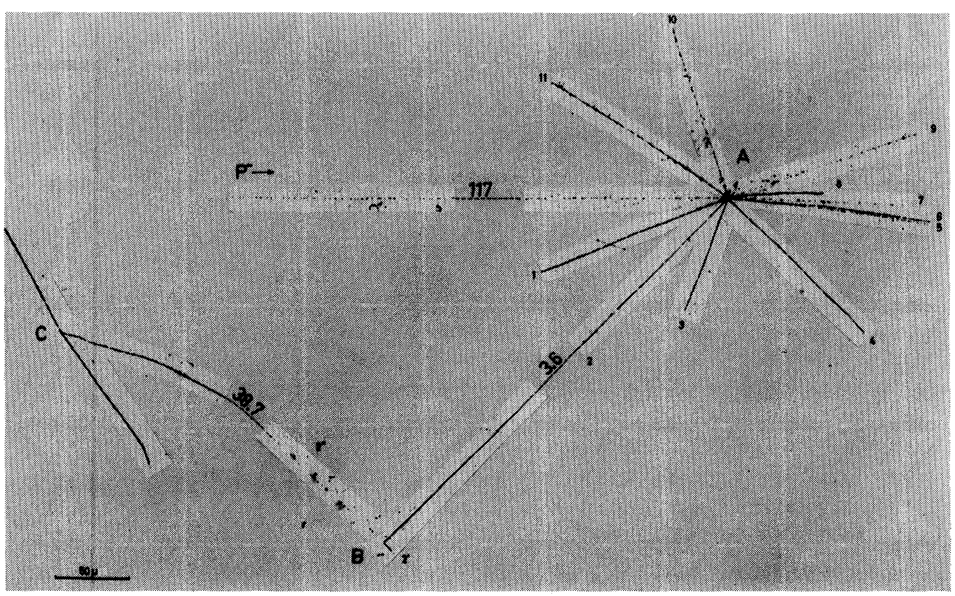

FIG. 1. Microphotograph of the antiproton annihilation at A and the mesonic decay of the $_\Lambda H^4$ fragment at B. The kinetic energy of the hyperfragment is 54 Mev. Path lengths are in millimeters. Track 10 is due to an 18-Mev negative π meson, track 11 to an 89-Mev He nucleus. All other prongs in star A represent protons.

The two secondary tracks, one of which is a negative pion, are collinear within experimental errors. They are emitted at an angle of 22.5° with the emulsion plane (in unprocessed emulsion). The range of the secondary π^- meson is 38.7 mm and it gives an absorption star at rest (at point C in the figure). The kinetic energy of the pion is then 52.3 ± 1.0 Mev, where the standard error is computed from straggling error, observational error, uncertainty of emulsion density, and uncertainty of shrinkage factor. The other secondary has a range of $(8.0 \pm 0.4)\ \mu$. The approximate collinearity of the two secondary prongs suggests that the event represents a two-body decay. We assume that this is the correct interpretation and will later return to a discussion of this assumption. The nature of the recoil particle is deduced from its observed range and its momentum, which is equal to the observed π-meson momentum on the above-mentioned assumption of a two-body decay. On the basis of momentum, we expect the range to be $8.0 \pm 0.4\ \mu$ if the recoil particle is He^4, and $11.5 \pm 0.5\ \mu$ if He^3. The measured range of $8.0 \pm 0.4\ \mu$ is consistent with a He^4 recoil. This leads to the following interpretation of the event:

$$_{\Lambda}H^4 \rightarrow He^4 + \pi^- + Q,$$

where $Q = 54.6 \pm 1.0$ Mev.

Other interpretations of this event were considered. In addition to the above elimination of a He^3 recoil because of range, it is further ruled out in a two-body decay, $_{\Lambda}H^3 \rightarrow He^3 + \pi^- + Q$, because it leads to a negative binding energy of -12.5 Mev for the Λ hyperon. Although the observed collinearity indicates a two-body decay, we have also considered the only possible three-body decay, namely $_{\Lambda}H^4 \rightarrow He^3 + n + \pi^- + Q$. This, too, is ruled out because it leads to a negative binding energy of the Λ hyperon (in this case $B_{\Lambda} < -15.7$ Mev).

The result is that the event is consistent only with a $_{\Lambda}H^4$ fragment undergoing mesonic two-body decay. The binding energy of the Λ in $_{\Lambda}H^4$ is then $B_{\Lambda} = 2.6 \pm 1.0$ Mev, which is consistent also with other measurements of this quantity.[9] In our calculation of the Λ-binding energy, we used the following input data: $Q_{\Lambda} = 37.36$ Mev, and proton separation energy in $He^4 = 19.80$ Mev.

A limited search for a neutral K meson in association with the event was undertaken. None was found in a volume such that the probability to find the decay of θ_1 meson was about 5%.

We conclude that the observation establishes the emission of a Λ hyperon bound in a $_{\Lambda}H^4$ fragment from an antiproton annihilation in a medium heavy nucleus. The binding energy of the hyperon in $_{\Lambda}H^4$ is 2.6 ± 1.0 Mev.

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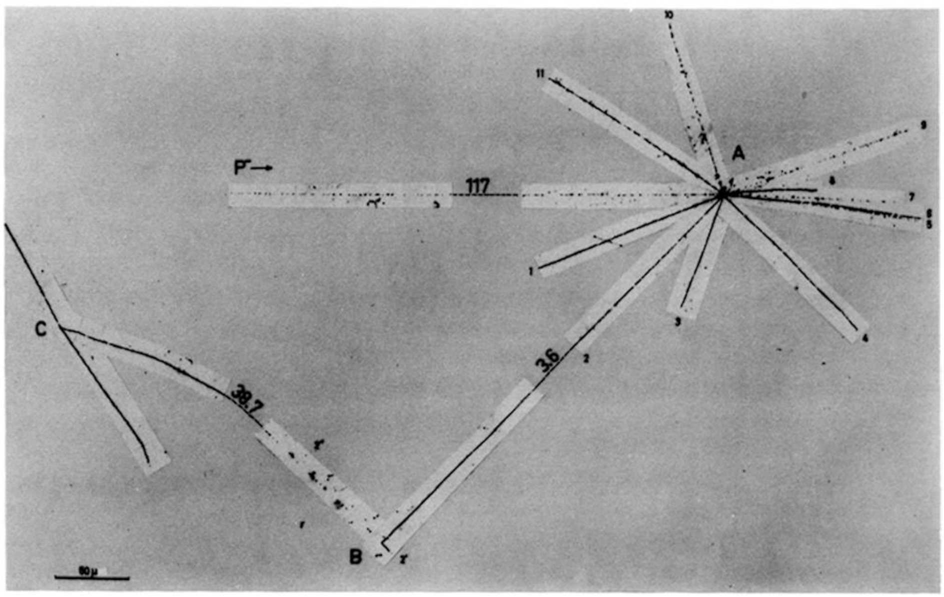

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