Mesonic Decay of a Lithium Hyperfragment

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The mesonic decay of a nuclear fragment in a photographic emulsion is described. The event is most simply interpreted as the disintegration of a Li^{7*} hyperfragment according to the scheme $Li^{7*} \rightarrow He^4 + H^2 + H^1 + \pi^-$. The binding energy of the Λ^0 particle in the fragment is 4.4 ± 1.0 Mev.

DURING the last few years a number of hyperfragments of hydrogen and helium have been observed for which the binding energy of the Λ^0 particle could be established. The study of heavier hyperfragments is complicated by the fact that the decay of nuclei with charge $Z>2$ is predominantly nonmesonic, and this leads to high nuclear excitation. The emission of more than one neutron from such a disintegration is highly probable, and therefore most of the events are not analyzable. Occasionally, however, examples are observed in which no neutrons are involved. An event which possibly represents the mesonic decay of an unstable Li^{7*} nucleus with no free neutrons emitted has been observed in our laboratory. It was recorded in a stack of stripped Ilford G5 emulsions, each 600 μ thick, exposed at high altitudes by means of free balloons. A projection drawing of the event is shown in Fig. 1.

From a nuclear disintegration of type $23+8p$ is emitted a slow unstable particle P which comes to rest after 22 μ and gives rise to a four-prong star A, B, C, D. An estimate of the charge of the particles by pure inspection cannot be made because of the shortness of the tracks. The prong C shows the characteristic multiple scattering and change in grain density of a π meson. It stops after traversing 10 955 μ of emulsion, and low energy electron tracks are associated with its ending, indicating that the particle was a negative π meson. The track of the π meson is very flat, and in estimating its energy corrections have been made for the 3588 μ which the particle traverses in the tissue paper spacers between the strips of emulsion. In calculating these corrections we have estimated the stopping power of photographic emulsion to be $\sim$12 times that of the tissue paper, for π mesons in the energy region considered. Using the range-energy relations of Baroni *et al.*,[1] we calculate the kinetic energy and momentum of the π meson to be 25.0 Mev and 87.1 Mev/c, respectively. The characteristics of the other prongs are given in Table I.

TABLE I. Relevant data for the tracks A, B, C, and D.

Track	A	B	C	D
Range in microns	16.8	7.5	10 955	44.0
Angle with the direction of C, projected on the plane of the emulsion	$171.8 \pm 2°$	$139.1 \pm 2°$	0	$57.3 \pm 2°$
Angle of dip with the plane of the emulsion	$11.6 \pm 3°$ up	$13.1 \pm 3°$ up	$0 \pm 3°$	$23.6 \pm 3°$ down

Since the track P is short, it is not possible to exclude the possibility that the event is the nuclear capture of a slow negative hyperon or K meson. In the following, however, we will investigate the possibility of the event being a hyperfragment decay. As a starting point in the analysis we assume, tentatively, that no neutral particles were emitted in the disintegration. Then one can infer the indentities of the particles A, B, and D by the requirement of momentum balance. Further, because of the small dip angles of the prongs we assume as a first approximation that all the tracks lie in the plane of the emulsion. It can be shown that this simplification does not change the calculations significantly. At the end of the analysis, the results will be recalculated taking into account the dip of the tracks.

Knowing the identity of C, and assuming various combinations for the identities of A and B, we calculate the momentum M_D and the angle θ_D which the particle D must make with the direction of C in order to give momentum balance between all four tracks. The result is represented in Fig. 2. In these calculations we have used the range energy relations for light nuclei given by

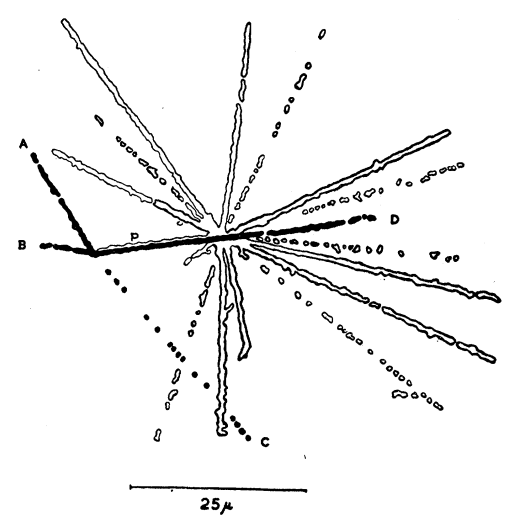

FIG. 1. Projection drawing of a star emitting an unstable particle P producing a four-prong secondary star A, B, C, D. The track C is a negative π meson. The prongs of the secondary star are drawn in black lines.

[1] Baroni, Castagnoli, Cortini, Franzinetti, and Manfredini, Bureau of Standards CERN Bulletin No. 9 (unpublished).

Allred and Armstrong.[2] The only two combinations of nuclei A and B consistent with the observed value $57.3 \pm 2°$ are

(a) $A = H^1$, $B = He^3$, giving $\theta_D = 58.2°$ and $M_D = 81.0$ Mev/c,

(b) $A = H^1$, $B = He^4$, giving $\theta_D = 54.9°$ and $M_D = 101.5$ Mev/c.

The corresponding ranges of the particle D, assuming different light nuclei, are represented in Table II.

As seen from the table, assumption (b), with D being a deuteron, is in very good agreement with the observed range 44.0 μ of D. Therefore, the above data strongly indicate that the event is the mesonic decay of a Li^{7*} hyperfragment according to the mode

$$Li^{7*} \rightarrow He^4 + H^2 + H^1 + \pi^-. \quad (1)$$

TABLE II. Calculated ranges of the particle D under the assumptions (a) and (b).

D	Assumption (a) Range in microns	Assumption (b) Range in microns
H^1	95.0	200.0
H^2	23.5	44.5
H^3	12.2	21.9
He^3	3.9	6.0

On the basis of this decay scheme, the expected values of θ_D, M_D, and the dip of the track D were recalculated, taking into account the dip of the tracks A and B. The angle and the dip of D were calculated to be 55.3° and 24.4° (down), which are in good agreement with the observed values in Table I. The recalculation of the momentum of the particle D gives 98.7 Mev/c corresponding to a deuteron of range 41.4 μ, which still is in very good agreement with the observed value.

The binding energy of the Λ^0 particle in the Li^{7*} hyperfragment is found to be B.E.$(\Lambda^0) = 4.4 \pm 1.0$ Mev. This value may be compared with the energy 7.3 Mev required to remove a neutron from a normal Li^7 nucleus.

The above analysis was based on the assumption that no neutral particles were emitted in the disintegration. If we consider the emission of one or more neutrons, a large variety of different decay schemes has to be investigated. In that case it can be shown, however, that the only hyperfragment decay giving a positive binding energy for the Λ^0 particle is

$$Li^{7*} \rightarrow He^4 + H^1 + H^1 + n^1 + \pi^-, \quad (2)$$

with the track B being the alpha article. The corresponding binding energy is B.E. $(\Lambda^0) \sim 2.4 \pm 1.0$ Mev. However, in view of the increase in the binding energy of the Λ^0 particle with mass number, as reported by different observers,[3] we regard the decay scheme (2) as much less probable than (1).

In the calculation of the binding energies we have used the mass values for elementary particles and light nuclei given by Barkas and Hahn,[4] and 36.9 Mev for the Q value in the decay of a free Λ^0 particle.[5]

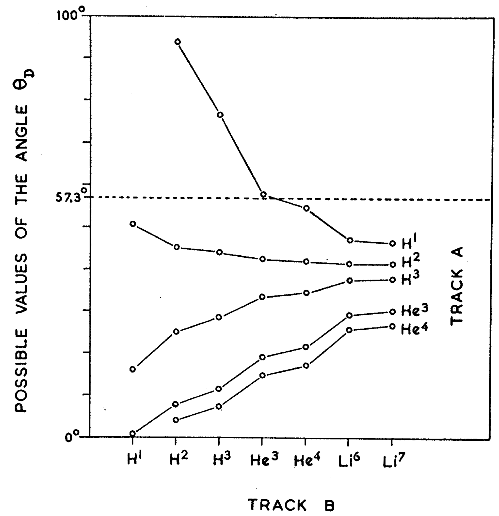

FIG. 2. Calculations of the angle θ_D which the particle D must make with the direction of C in order to give momentum balance between all four tracks A, B, C, and D. The full-drawn curves represent various combinations for the identities of the nuclei A and B. The dashed curve represents the observed value $57.3 \pm 2°$.

ACKNOWLEDGMENTS

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[2] J. C. Allred and A. H. Armstrong, Los Alamos Scientific Latoratory Report LA—1510, 1953 (unpublished).

[3] Fry, Schneps, and Swami, Phys. Rev. **101**, 1526 (1956).

[4] W. Barkas and G. Hahn, Emulsion Tables, University of California Radiation Laboratory Report UCRL-2579, 1954 (unpublished).

[5] Friedlander, Keefe, Menon, and Merlin, Phil. Mag. **45**, 533 (1954).