NONMESONIC DECAYS OF HYPERFRAGMENTS

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In a systematic scanning of 47 cm^3 of emulsion irradiated by 4.5-Bev π mesons, 8 double stars were found which were attributed to nonmesonic decays of hyperfragments with $Z = 2$ to 6. In these stars, the connecting track thinned down and one of the secondary tracks had a range $> 5000\,\mu$. The hyperfragments, together with their secondary products, have been identified. Possible decay schemes are proposed for the hyperfragments, assuming one neutron to be emitted.

As is well known, at the present time there is considerable interest in nonmesonic decays of hyperfragments. The number of reliably identified cases is still small, although heavy hyperfragments decay in this way a significant fraction of the time. The difficulty in the analysis lies in the occurrence of neutral particles, and of heavy, short-range fragments among the decay products of the hypernucleus.

In the work reported here, we tried to identify several hyperfragments found in a G-5 emulsion exposed to 4.5 Bev π mesons. That these cases do indeed involve hyperfragments is shown by the facts that the track thinned down toward the end of its range and that the range of one of the secondary particles was more than $5000\,\mu$. The presence of a fast proton is a sufficient but not necessary criterion for the recognition of a hyperfragment. The probability of accidental superpositions in the entire volume scanned is about 10^{-4}, which practically eliminates the possibility of coincidences in the cases we examined. However, in doubtful cases the emulsion was soaked and examined from the opposite side with a long focus objective. Conclusions about the nature of the hyperfragments were based on as exact as possible identifications of the hyperfragment itself and its decay products. The charge of the hypernucleus was determined by measuring the width of the track as a function of the residual range. As a preliminary step, we constructed integral curves for p, α, Li, Be and B to be used for calibration.

In several cases, the charge was found from the thin-down length. The secondary particles were identified by measuring intervals G (R) and scattering $\overline{\alpha}$ (R). In the following we describe the cases considered in detail:

Case No. 264 (Fig. 1). This case was very favorably located in the emulsion. All tracks end in one layer and lie in the same plane. The hypernucleus had charge 3, as found by measurements

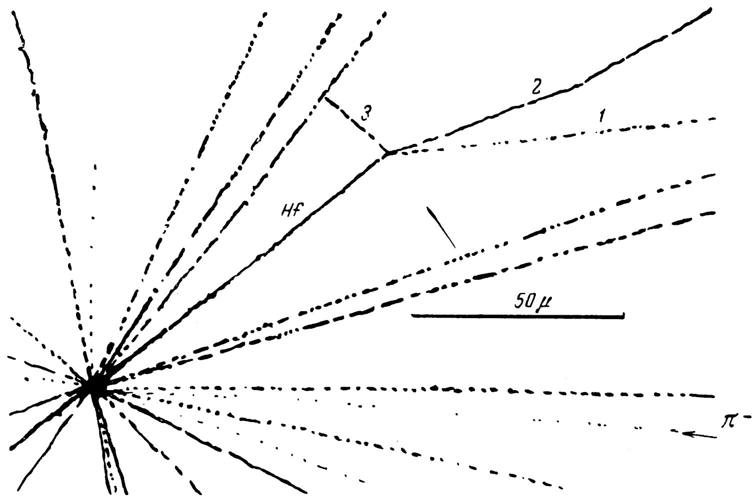


FIG. 1

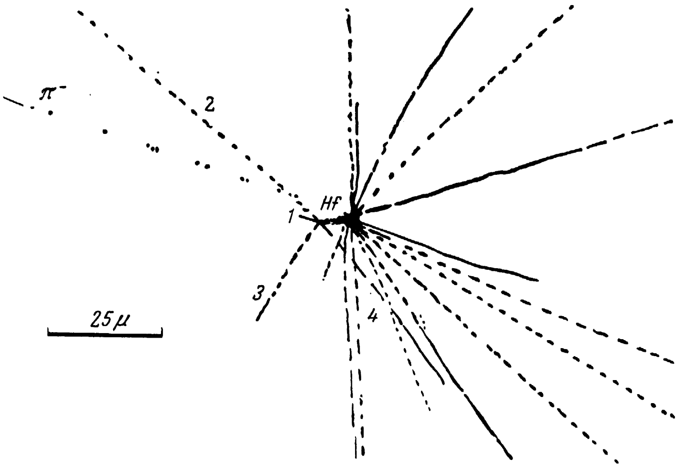


FIG. 2

of the track width and thin-down length. We calculated decay schemes containing one neutron among the products:

1. ${}_\lambda Li^6 \rightarrow H^1 + H^1 + H^3 + n;$
2. ${}_\lambda Li^6 \rightarrow H^1 + H^2 + H^2 + n;$
3. ${}_\lambda Li^6 \rightarrow H^1 + H^3 + H^1 + n.$

The binding energy B_λ corresponding to these possibilities is > 20 Mev.

4. ${}_\lambda Li^7 \rightarrow H^1 + H^3 + H^2 + n;$
5. ${}_\lambda Li^7 \rightarrow H^1 + H^2 + H^3 + n.$

For these decay schemes, B_λ > 15 Mev.

6. ${}_\lambda Li^8 \rightarrow H^1 + H^3 + H^3 + n, B_\lambda = 5$ Mev.

Comparing this value for B_λ with values obtained by other authors, we concluded that the most probable decay scheme is

$$ {}_{\lambda_0}Li^8 \rightarrow H^1 + H^3 + H^3 + n. $$

Case No. 3013 (Fig. 2). The tracks of all the secondary particles except 2 and 4 are short and inclined, which makes identification difficult. Track 2 is a proton, while tracks 3 and 4 correspond to charge 1. Track 1 was made by a particle having charge not less than 2. Hence, the hypernucleus has a charge of at least 6. Assuming $Z_{Hf} = 6$, calculations on decay schemes give a binding energy $B_\lambda = 70$ Mev. A reasonable value for the binding energy of the λ_0 particle is obtained, together with conservation of energy and momentum, if we assume the decaying nucleus is B^{10} and one neutron is emitted. The most probable decay scheme is the following:

$$ {}_\lambda B^{10} \rightarrow He^4 + H^1 + 2H^2 + n. $$

Case No. 3021 (Fig. 3). The charge of the hypernucleus is 6, as determined by measurements of the track width and the thin-down length. The en-

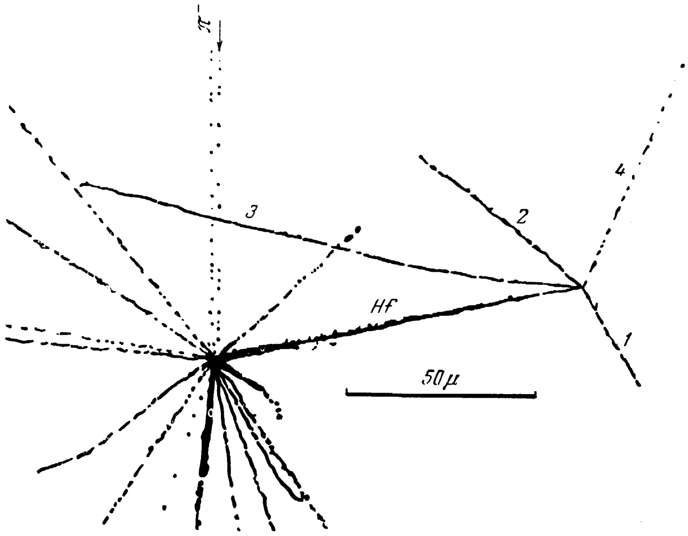


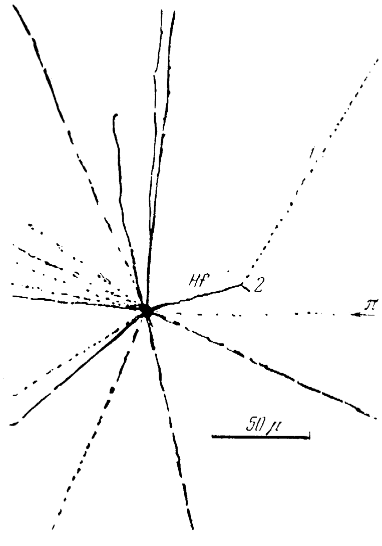
FIG. 3

ergy associated with track 4 was found from changes in the ionization under the assumption that the track is that of a proton. Tracks 1 and 2 have charge 2, as found from measurements of the width, while track 3 has charge 1. We calculated all possible decay schemes of ${}_\lambda C^{12}$, ${}_\lambda C^{11}$, and ${}_\lambda C^{10}$, assuming that one neutron was emitted. The most probable decay scheme is

$$ {}_\lambda C^{12} \rightarrow 2He^4 + H^1 + H^2 + n. $$

The binding energy in this case is $B_\lambda \approx 8$ Mev.

FIG. 4



Case No. 312 (Fig. 4). In this case the hypernucleus has charge 2, as found by measuring the track width. Both the secondary tracks end in the same layer. Track 1 was identified by measuring intervals G(R) and the scattering $\overline{\alpha}$(R). It turned out that track 1 is a deuteron. Assuming that one neutron was emitted, the following three

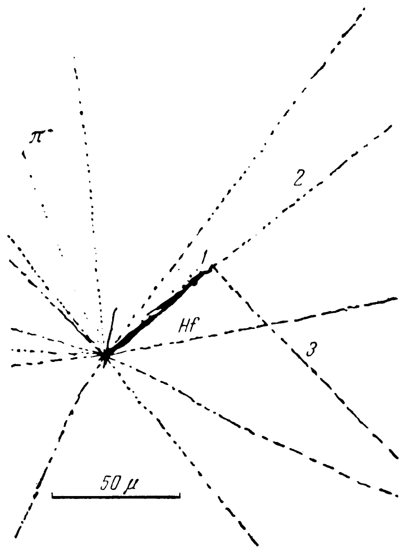


FIG. 5

possibilities were calculated:

1. $_{\lambda_0}He^6 \rightarrow H^2 + H^3 + n, \quad B_\lambda > 10$ MeV;
2. $_{\lambda_0}He^4 \rightarrow H^2 + H^1 + n, \quad B_\lambda > 15$ MeV;
3. $_{\lambda_0}He^5 \rightarrow H^2 + H^2 + n, \quad B_\lambda \approx 1$ MeV.

Comparing these values of B_λ with those given by other authors, we consider that this case corresponds to the decay scheme

$$_{\lambda_0}He^5 \rightarrow H^2 + H^2 + n.$$

Case No. 338 (Fig. 5). One of the decay products of the hypernucleus is a heavy fragment. The tracks of the hypernucleus and of the heavy fragment are inclined at the same angle to the plane of the emulsion. The points corresponding to the track widths of the hyperfragment are beyond the range of the calibration curve for boron. The points corresponding to the widths of the heavy

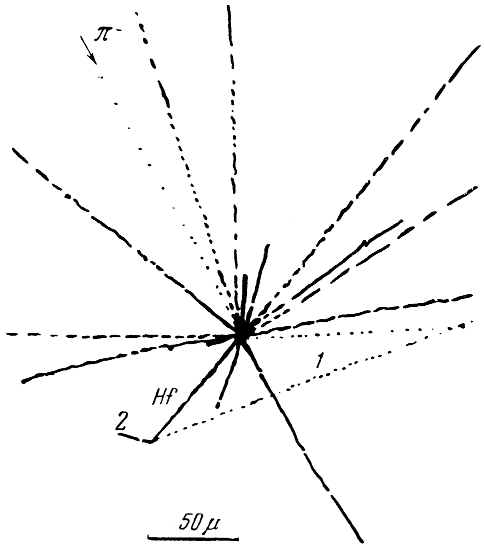


FIG. 7

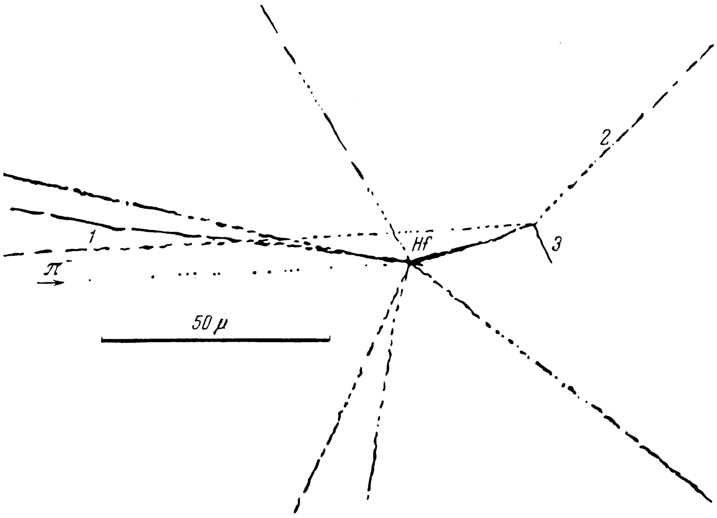


FIG. 6

fragment correspond to beryllium. The charges of the other tracks were found by ionization measurements and are $Z_1 = 4$, $Z_2 = 1$, and $Z_3 = 1$. The hyperfragment could be either λ_0C^{12} or λ_0C^{13}, since analysis of the decay schemes for λ_0C^{12} and λ_0C^{13} both lead to the reasonable value $B_\lambda = 9 - 10$ Mev. The decay schemes are

$$_{\lambda_0}C^{12} \rightarrow Be^9 + 2H^1 + n,$$

$$_{\lambda_0}C^{13} \rightarrow Be^{10} + 2H^1 + n.$$

Case No. 284 (Fig. 6). The track of the hypernucleus is short ($28\,\mu$) but its inclination is also small; comparison of its mean width with the calibrating curves indicate a charge $Z = 4$ for the hypernucleus. This method does not work for track 3. The charge associated with this track was obtained by comparing the charge of the hypernucleus with the charges associated with the other two tracks, the latter charges being obtained from ionization measurements. Analysis of the decay schemes for λ_0Be shows that more than one neu-

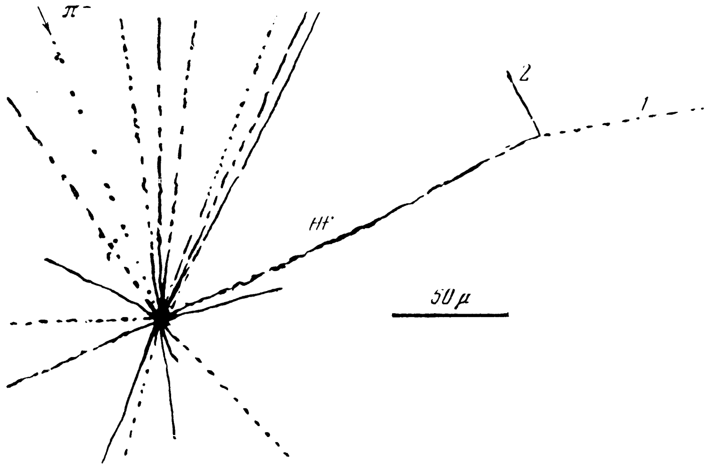


FIG. 8

tron must have been emitted. It is presumed that the decay scheme is either

$$_{\lambda_0}Be^9 \rightarrow H^1 + H^2 + He^4 + 2n,$$

or

$$_{\lambda_0}Be^{10} \rightarrow H^1 + H^2 + He^5 + 2n.$$

Case No. 2711 (Fig. 7). The charge of the hypernucleus is taken to be 2, since along the whole range the track widths lie below the calibrating curve for the α particle. Particle 1 was identified from ionization measurements. The charge of particle 2 cannot be found from width measurements; Z_2 was taken to be 1 on the basis of a comparison between the charges of the hypernucleus and particle 1. Of the three possible decay schemes for λ_0He, we adopt

$$_{\lambda_0}He^5 \rightarrow H^1 + H^3 + n.$$

The value of the binding energy B_{λ_0} found for this decay scheme is the one that lies closest to values quoted in the literature.

Case No. 275 (Fig. 8). The length of the hypernucleus track in this case is $181\,\mu$, and it is but little inclined. Measurements of the track width give the charge with good resolution in Z. The points corresponding to the track widths lie on the calibrating graph near Li. The charge of track 1 is 1, as determined from measurements of the ionization. The charge of the second nucleus is $3 - 1 = 2$. Of all the decay schemes calculated, the most probable one is

$$_{\lambda_0}Li^6 \rightarrow H^1 + He^4 + n$$

This decay scheme gives a binding energy < 8 Mev.

The table below summarizes the cases considered. A characteristic feature of most of these is

Case no.	Primary star	Tracks: symbol	Tracks: particle	Range, μ	Neutron energy, Mev	B_λ Mev
	$11+3\pi$	*Hf*	$_\lambda He^5$	50		
312 (fig. 4)	•	1	H^2	5900		
		2	H^2	3.5*		~1
		3	*n*		99	
	$15+0\pi$	*Hf*	$_\lambda He^5$	77.7		
2711 (fig. 7)		1	H^1	<15 000		
		2	H^3	16*		>1
		3	*n*	—	89	
	$17+0\pi$	*Hf*	$_\lambda Li^6$	181		
275 (fig. 8)		1	H^1	>23 000		
		2	He^4	43		<8
		3	*n*	—	77	
	$18+3\pi$	*Hf*	$_\lambda Li^8$	87		
		1	H^1	9900		
264 (fig. 1)		2	H^3	88		
		3	H^3	22*		~5
		4	*n*	—	90	
	$7+0\pi$	*Hf*	$_\lambda Be^9$	28.5		
		1	H^1	3746		
284 (fig. 6)		2	H^2	2983		
		3	He^4	16*		—
		4	2*n*	—	72	
	$14+0\pi$	*Hf*	$_\lambda B^{10}$	16*		
		1	He^4	10*		
		2	H^1	16 500		
3013 (fig. 2)		3	H^2	26*		~3
		4	H^2	47.5		
		5	*n*	—	72	
	$12+2\pi$	*Hf*	$_\lambda C^{12}$	94.5		
		1	He^4	47		
		2	He^4	48.5		
3021 (fig. 3)		3	H^2	135		>8
		4	H^1	<25 000		
		5	*n*	—	42	
	$13+0\pi$	*Hf*	$_\lambda C^{12}$	55		
		1	Be^9	34		
338 (fig. 5)		2	H^1	821		~10
		3	H^1	609		
		4	*n*	—	108	

*The indicated mass numbers were assigned on the basis of the adopted decay scheme.

that two nucleons are emitted which carry off most of the energy. This supports the idea that nonmesonic decays of hyperfragments go according to the decay scheme[1]

$$\lambda + N \rightarrow n + N.$$

The fact that in most of the cases one fast proton is emitted gives grounds for supposing that there is a fast neutron among the decay products of the hypernucleus.[2] Hence, most of the nonmesonic decays of hyperfragments which have been described here go according to $\lambda^0 + p \rightarrow n + p$.

H^2, H^3, and He^4 occur among the secondary products of the decay. It is possible that the existence of these particles at the instant of decay is due to an unstable substructure in light nuclei.[3]

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[2] M. Baldo-Ceolin et al., Nuovo cimento **7**, 328 (1958).

[3] J. Combe, Nuovo cimento Suppl. **3**, 182 (1956).

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