OBSERVATION OF A DOUBLE HYPERFRAGMENT

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During a systematic scan for interactions of 1.3- and 1.5-GeV/c K^- mesons[1] in emulsions irradiated in the separated K^- meson beam at CERN,[2] an event has been found which is interpreted as the production and subsequent mesonic cascade decay of a double hyperfragment. A photomicrograph and explanatory schematic drawing of the event are given in Fig. 1. A Ξ^- hyperon (track 1) emitted from the interaction of a K^- meson of momentum 1.5 GeV/c (star A) comes to rest and is absorbed at B. A double hyperfragment (track 6) and another charged particle (track 5) are observed to come from star B. The double hyperfragment decays at C into a π^- meson (track 7), a singly charged particle (track 8), and an ordinary hyperfragment (track 9). This hyperfragment decays at D into a π^- meson (track 10) and three other charged particles (tracks 11, 12, and 13). The results of the measurements of the angles of emission and ranges of all the charged particles involved in these processes are summarized in Table I. All reasonable interpretations of this event, other than that of a Ξ^- hyperon capture at B leading to the emission of a double hyperfragment, have been considered and discarded.[3]

The ordinary hyperfragment was analyzed using only the kinematics of its decay, whereas the possible identities and decay schemes of the double hyperfragment were assigned from a study of both the production and decay processes. In particular, the Coulomb barrier argument was used to establish the fact that the Ξ^- hyperon capture occurred on a light nucleus (C, N, O) of the emulsion. The final results of this analysis are summarized in Table II.

From a comparison of the binding energy $B_{\Lambda\Lambda}$ of the two Λ^0 hyperons in double hyperfragments with B_Λ for ordinary hyperfragments, one can expect to obtain information not only on the

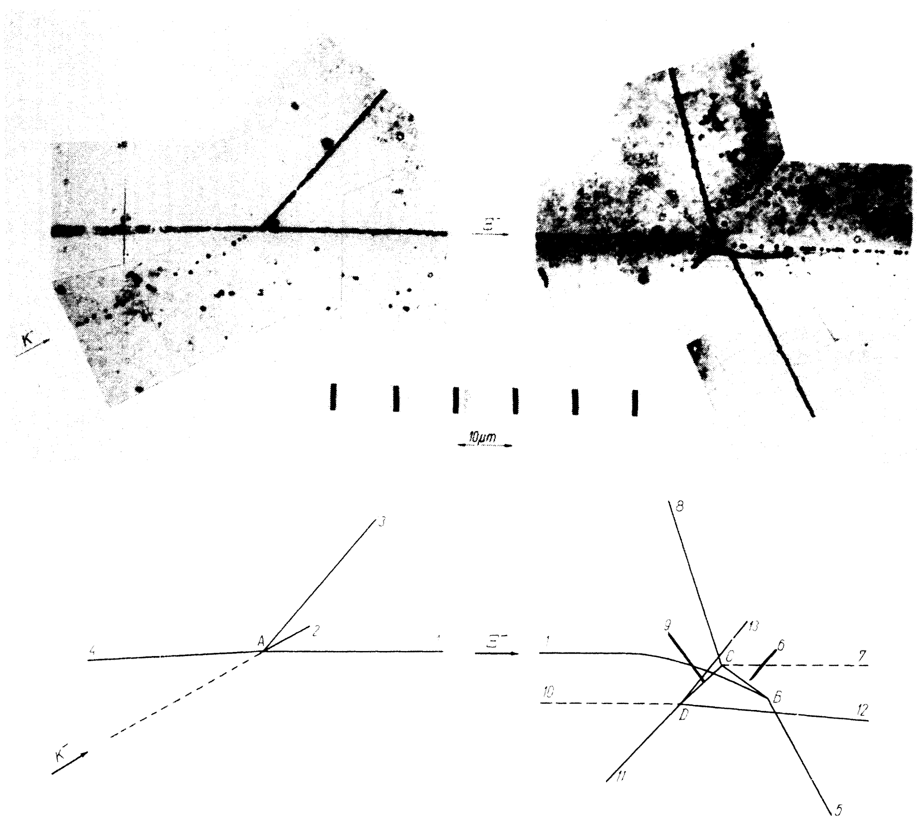

FIG. 1. A photomicrograph and a schematic drawing of the production of a Ξ^- hyperon in a 1.5-GeV/c K^--meson interaction at A followed by capture at rest of the Ξ^- hyperon at B with the emission of a double hyperfragment decaying in cascade at C and D.

Table I. Results of the measurements.[a]

Track No.	Presumed identity	Range (μ)	Dip angle (degrees)	Azimuth angle (degrees)
		Star A		
Primary	K^-	...	0	0
1	Ξ^-	357	- 3	150.2
2	recoiling nucleus	3.7	-27	179
3	H	769	5	200.8
4	H	4616	26.7	332.7
		Star B[b]		
5	H	114 ± 2	-28.7 ± 3.5	0 ± 2
6[c]	$_{\Lambda\Lambda}Be^{10,11}$ or $_{\Lambda\Lambda}Li^{8,9,10}$	3.0 ± 1.0	41 ± 15	206 ± 13
		Star C		
7[d]	π^-	6854 ± 210	5.3 ± 1.0	0 ± 0.8
8	H	318 ± 8	27.5 ± 2.5	107.5 ± 1.5
9[c]	$_{\Lambda}Be^{9,10}$ or $_{\Lambda}Li^{7,8}$	2.5 ± 1.0	-40 ± 20	227 ± 14
		Star D		
10[d]	π^-	13 250 ± 412	63.5 ± 2.5	0 ± 1.0
11	H or He	4.7 ± 0.5	-23 ± 9	42 ± 7
12	H	14.9 ± 0.4	-20 ± 6	175 ± 5
13	He	3.3 ± 0.5	-23 ± 12	226 ± 10

[a] The errors given for the angles include those resulting from measurements. The errors in ranges take into account, apart from measurement errors, also those resulting from straggling.

[b] The interpretation in terms of a $_{\Lambda\Lambda}Li^{8,9,10}$ hyperfragment requires the emission of an additional charged particle from star B which does not give rise to an observable track.

[c] Large errors in the determination of the range and direction of this track results from the observational difficulties and are to be treated as maximum errors.

[d] A capture star is observed at the end of this track.

Table II. Results of the analysis.[a]

Star C: Decay mode of the double HF	Binding energy of a Λ^0 hyperon in the double HF $B_\Lambda({}_{\Lambda\Lambda}Z)$ (MeV)	Star D: Decay mode of the resulting ordinary HF	Binding energy of the Λ^0 hyperon in the ordinary HF $B_\Lambda({}_\Lambda Z)$ (MeV)	Momentum unbalance Δp(MeV/c)	Binding energy of the $2\Lambda^0$ hyperons in the double HF $B_{\Lambda\Lambda}({}_{\Lambda\Lambda}Z^A)$ $=B_\Lambda({}_{\Lambda\Lambda}Z^A)+B_\Lambda({}_\Lambda Z^{A-1})$ (MeV)[b]	$\Delta B_{\Lambda\Lambda}$ $=B_\Lambda({}_{\Lambda\Lambda}Z^A)-B_\Lambda({}_\Lambda Z^{A-1})$ (MeV)[b]
${}_{\Lambda\Lambda}Be^{10} \to {}_\Lambda Be^9 + H^1 + \pi^-$	11.0 ± 0.4	${}_\Lambda Be^9 \to 2He^4 + H^1 + \pi^-$	7.2 ± 0.6	20 ± 12	17.5 ± 0.4	4.5 ± 0.4
${}_{\Lambda\Lambda}Be^{11} \to {}_\Lambda Be^9 + H^1 + n + \pi^-$	$< 7.6 \pm 0.7$	${}_\Lambda Be^9 \to 2He^4 + H^1 + \pi^-$	7.2 ± 0.6	20 ± 12	$<16.0 \pm 0.4$	$<-0.3 \pm 1.0$
${}_{\Lambda\Lambda}Be^{11} \to {}_\Lambda Be^{10} + H^1 + \pi^-$	11.1 ± 0.4	${}_\Lambda Be^{10} \to 2He^4 + H^2 + \pi^-$	7.5 ± 0.6	17 ± 20	19.0 ± 0.6	3.2 ± 0.6
${}_{\Lambda\Lambda}Li^8 \to {}_\Lambda Li^7 + H^1 + \pi^-$	10.8 ± 0.4	${}_\Lambda Li^7 \to He^4 + H^2 + H^1 + \pi^-$	6.5 ± 0.6	40 ± 14	16.3 ± 0.4	5.3 ± 0.4
${}_{\Lambda\Lambda}Li^9 \to {}_\Lambda Li^8 + H^1 + \pi^-$	10.9 ± 0.4	${}_\Lambda Li^8 \to He^4 + H^3 + H^1 + \pi^-$	5.4 ± 0.6	27 ± 15	17.4 ± 0.4	4.4 ± 0.4
${}_{\Lambda\Lambda}Li^{10} \to {}_\Lambda Li^8 + H^1 + n + \pi^-$	$< 7.5 \pm 0.5$	${}_\Lambda Li^8 \to He^4 + H^3 + H^1 + \pi^-$	5.4 ± 0.6	27 ± 15	$<15.5 \pm 0.4$	$<-0.5 \pm 0.6$

[a]The following values were adopted in the calculations: (i) $m_{\Xi^-} = 1321.0 \pm 0.5$ MeV [L. Bertanza, V. Brisson, P. L. Connolly, E. L. Hart, I. S. Mittra, G. C. Monetti, R. R. Rau, N. P. Samios, I. O. Skillicorn, S. S. Yamamoto, M. Goldberg, L. Gray, J. Leitner, S. Lichtman, and J. Westgard, Proceedings of the International Conference on High-Energy Nuclear Physics, Geneva, 1962 (CERN Scientific Information Service, Geneva, Switzerland, 1962), p. 437]; (ii) $Q_{\Lambda^0} = 37.58 \pm 0.15$ MeV [R. G. Ammar, L. Choy, W. Dunn, M. Holland, J. H. Roberts, E. N. Shipley, N. Crayton, D. H. Davis, R. Levi Setti, M. Raymund, O. Skjeggestad, and G. Tomasini, Proceedings of the International Conference on High-Energy Nuclear Physics, Geneva, 1962 (CERN Scientific Information Service, Geneva, Switzerland, 1962), p. 382]; (iii) atomic masses of nuclei [F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. 11, 1 (1959)].

[b]The values taken for $B_\Lambda({}_\Lambda Z^{A-1})$ in computing these two columns are those contained in paragraph (ii) of reference a. An exception has been made in the case of ${}_\Lambda Be^{10}$ where the value given in column 4 in Table II was averaged with that obtained from one event in paragraph (ii) of reference a. It should be emphasized that this procedure is only valid for this particular interpretation, and the event should not be considered as an unambiguous example of ${}_\Lambda Be^{10}$.

strength of the Λ-Λ interaction[4] but also on the spin-dependent part of the binding energy in ordinary hyperfragments.[5] The value of $\Delta B_{\Lambda\Lambda} = B_\Lambda({}_{\Lambda\Lambda}Z^A) - B_\Lambda({}_{\Lambda}Z^{A-1})$ presented in Table II, column 7, is the net contribution of the Λ-Λ interaction and the reduction due to the spin-dependent part of the Λ-core interaction, provided that core distortion effects may be neglected. When the spin of the core is zero (e.g., in ${}_{\Lambda\Lambda}Be^{10}$), $\Delta B_{\Lambda\Lambda}$ gives the contribution of the Λ-Λ interaction only.

Arguments[3] based on consideration of the production and decay of the double hyperfragment (Table II) suggest that the most likely explanation of the whole sequence of events is the production of a ${}_{\Lambda\Lambda}Be^{10-11}$ by a Ξ^- hyperon capture on carbon followed by the decay sequences[6]

$$\begin{aligned} {}_{\Lambda\Lambda}Be^{10} &\rightarrow {}_{\Lambda}Be^{9} + H^1 + \pi^-, \\ {}_{\Lambda}B^{9} &\rightarrow 2He^4 + H^1 + \pi^-, \\ \Delta B_{\Lambda\Lambda} &= +4.5 \pm 0.4 \text{ MeV}, \end{aligned} \quad \text{(i)}$$

$$\begin{aligned} {}_{\Lambda\Lambda}Be^{11} &\rightarrow {}_{\Lambda}Be^{10} + H^1 + \pi^-, \\ {}_{\Lambda}Be^{10} &\rightarrow 2He^4 + H^2 + \pi^-, \\ \Delta B_{\Lambda\Lambda} &= +3.2 \pm 0.6 \text{ MeV}. \end{aligned} \quad \text{(ii)}$$

For both of these processes the value of $\Delta B_{\Lambda\Lambda}$ is well determined and gives the same sign and approximately the same quantitative estimate of the strength of the Λ-Λ interaction, provided that the spin-dependent part of the Λ-core interaction in ${}_{\Lambda\Lambda}Be^{11}$ is taken into account.[7]

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[1]E. R. Fletcher, J. Lemonne, P. Renard, J. Sacton, D. O'Sullivan, T. P. Shah, A. Thompson, P. Allen, Sr., M. Heeran, A. Montwill, J. E. Allen, M. J. Beniston, D. A. Garbutt, R. C. Kumar, P. V. March, T. Pniewski, and J. Zakrzewski, Phys. Letters 3, 280 (1963).

[2]G. Amato, H. Courant, H. Filthuth, E. Malamud, G. Petrucci, A. M. Segar, W. T. Toner, and W. Willis, Nucl. Instr. Methods 20, 47 (1963).

[3]A complete analysis of the event, including a discussion of discarded interpretations, will be presented elsewhere.

[4]R. H. Dalitz and B. W. Downs, Phys. Rev. 111, 967 (1958).

[5]S. Iwao, Nucl. Phys. 26, 1 (1961).

[6]See reference b of Table I.

[7]R. H. Dalitz (private communication) reported by V. Telegdi at the 1963 International Conference on High-Energy Physics and Nuclear Structure, CERN, Geneva, Switzerland (to be published).

PRODUCTION OF HYPERON RESONANCES IN $\Lambda^0 + \bar{\Lambda}^0 + \pi^+ + \pi^-$ FINAL STATES*

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The production of the isospin-1, mass 1385-MeV, hyperon-pion resonance Y_1^* (and its antiparticle $\bar{Y}_1^*$) has been observed in $\bar{p}$-p collisions leading to the reaction

$$\bar{p} + p \rightarrow \Lambda^0 + \bar{\Lambda}^0 + \pi^+ + \pi^-. \quad (1)$$

At least half of the Reactions (1) involve Y_1^* (or $\bar{Y}_1^*$) production. In contrast to the production of nucleon-pion isobars in $\bar{p}$-p collisions,[1] the Y_1^* production does not appear to proceed through a single-particle exchange mechanism. This result is indicated most strongly by the predominance of Y_1^{*-} (and $\bar{Y}_1^{*+}$) which cannot occur via the exchange of any single known particle or resonance.

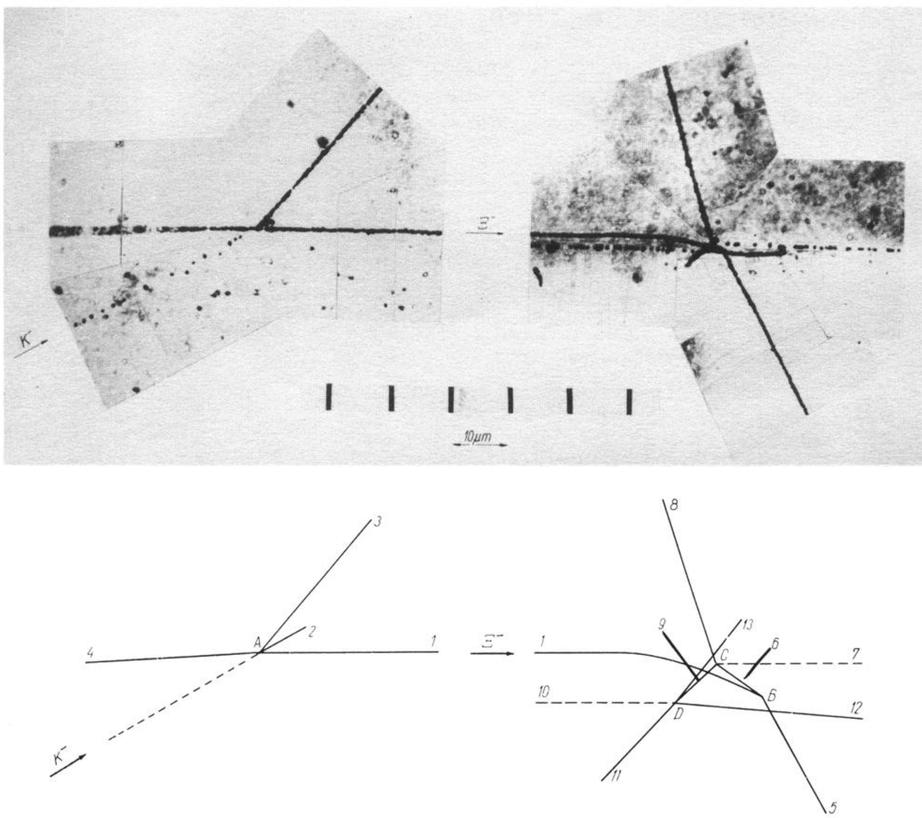

FIG. 1. A photomicrograph and a schematic drawing of the production of a Ξ^- hyperon in a 1.5-GeV/*c* K^--meson interaction at *A* followed by capture at rest of the Ξ^- hyperon at *B* with the emission of a double hyperfragment decaying in cascade at *C* and *D*.