NONMESONIC DECAY OF HYPERNUCLEI

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A nucleus containing among its nucleons also a λ^0-hyperon is called a hypernucleus. The characteristics of the λ^0-hyperon are the following:

$$m_\lambda=1115.60 \text{ MeV}, \quad I(J^P)=0(\tfrac{1}{2})^+, \quad S_z=-1, \quad T=2.578\times10^{-10}\text{s} \qquad (1)$$

where m is the mass, I, J, P and S are the isospin, parity and strangeness quantum numbers respectively, and T is the mean life of the particle. A free λ-hyperon decays according to the scheme

$$\begin{aligned}\lambda \rightarrow\ &\pi^- + p\\ &\pi^0 + n\end{aligned} \qquad (2)$$

A λ-hyperon in a nucleus may decay not only according to scheme (2) but also by a stimulated process[1] on one of the nucleoms, i.e.

$$\begin{aligned}\lambda^0 + p &\rightarrow n + p\\ \lambda^0 + n &\rightarrow n + n\end{aligned} \qquad (3)$$

In the first case a π-meson arises and the decay of the hypernucleus is called mesonic (MHN), while in the second case it is said to be nonmesonic (NMHN).

According to the present state of knowledge, stimulated decay is the only strangeness non-conserving weak interaction involving 4 fermions-baryons[2,3].

Data are sought concerning the relative frequency of processes (2) and (3) in each type of hypernucleus, as well as those concerning the dependence of the processes on the characteristics of the nucleus to which the λ-hyperon is bound[4,5].

The study of nonmesonic decays of hypernuclei is a source of information on stimulated interaction.

Because of the decay of the λ^0-hyperon in a HN the nucleus itself is unstable and decays into fragments. In very light hypernuclei the mesonic decay is predominant, whereas already in HN with A>4 the nonmesonic decay is prevailing. The study of stimulated decay enables the following experimental data to be obtained6,7):

a) The ratio of nonmesonic to mesonic decays for a definite hypernucleus:

$$Q^{-} = \frac{NMHN}{MHN}$$

b) The ratio of neutron to proton stimulated decays for a definite hypernucleus:

$$C = \frac{\lambda_n}{\lambda_p}$$

c) The characteristics of the NM N decay fragments, in particular those of emitted high-energy particles.

Since identification of HN is not simple, most data on Q^{-} are given not for one species, but for a group of hypernuclei.

TABLE I

No	Hypernucleus	Q^{-}	References	Technique
1	${}^{4}_{\lambda}H$	0.26 ± 0.13	Block et al.(1963)6)	Bubble chamber
2	${}^{4}_{\lambda}He$	0.52 ± 0.10	Block et al.(1963)6)	" "
3		0.70 ± 0.19	McKenzie(1969)7)	" "
4	${}^{5}_{\lambda}He$	1.20 ± 0.10	Coremans et al(1970) ref. 8	Nuclear emulsions
5		1.21 ± 0.19	Miller et al. (1968) ref. 12	" "
6	${}^{4,5}_{\lambda}He$	1.01 ± 0.12	Chaudhari et al. (1969), ref. 13	" "
7	${}_{\lambda}Li$	2.55 ± 0.66	Chaudhari et al. (1969), ref. 13	" "
8	${}_{\lambda}Li$, Be	2.4 ± 0.7	Holland(1964)14)	" "
9	Be	4.3 ± 1.1	Montwill et al. (1974), ref. 9	" "
10	${}_{\lambda}Be$	6.6 ± 1.4	Chaudhari et al. (1969), ref. 13	" "
11	${}^{11}_{\lambda}B$	4.8 ± 1.1	Montwill et al. (1974), ref. 9	" "
12	${}_{\lambda}B$	5.3 ± 1.3	Holland (1964)14)	" "
13	${}_{\lambda}B$, ${}_{\lambda}C$, ${}_{\lambda}N$	5.9 ± 1.2	Coremans et al. (1971), ref. 10	" "

14	$_{\lambda}B, _{\lambda}C, _{\lambda}N$	5.5 ± 0.5	Montwill et al. (1974), ref.9	Nuclear emulsions
15	$40 \leq A \leq 100$	∿ 180	Lagnaux (1964)$^{15)}$	" "

TABLE II

No	Hypernucleus	Total number of NM decays	λ_n/λ_p	Reference
1	$^{4}_{\lambda}He$	48	0.43	Block et al. (1963)$^{6)}$
2		163	0.66	Rao et al. (1970)$^{16)}$
3	"Light" HN	453	2.3	Chaudhari et al. (1967), ref. 13
4	$_{\lambda}B, _{\lambda}C, _{\lambda}N$	739	0.53	Montwill et al. (1974), ref. 9
5	A>10	240	2.1	Mangotra et al. (1973), ref. 17
6	"Heavy" HN	483	5.65	Ganguli et al. (1967), ref. 18
7	A=40-100	1374	1.5-9	Lagnaux et al. (1964), ref. 15
8	"	1182	9	Cuevas et al. (1967), ref. 19

Corrected experimental data on the ratio C are given in Table II. The correction is necessary because the emitted high-energy may also from a secondary interaction of the stimulation products (3) with nucleons or with fragments of the HN parents.

Among the characteristics of a HN decay, it is, first of all, the energy and identity of the fast particles produced in the HN decay that should be determined.

The European K$^-$ Collaboration, whose primary aim has been to investigate the binding energy of λ-hyperon in HN$^{20)}$, has found in a nuclear emulsion stack exposed to K$^-$ mesons 2786 events may be attributed to the process

$$K^- + \begin{array}{c} C \\ N \\ O \end{array} \rightarrow \pi^- + (p,d,t) + \begin{array}{c} _{\lambda}B \\ _{\lambda}C \\ _{\lambda}N \end{array} \qquad (4a)$$

$$K^- + \begin{array}{c} C \\ N \\ O \end{array} \rightarrow \pi^- + (He^3, He^4) + \begin{array}{c} {}_\lambda Be \\ {}_\lambda B \\ {}_\lambda C \end{array} \qquad (4b)$$

By a kinematic analysis it has been established that 1601 events pertain to process (4). All the cases could not be identified as attributable to only one of the processes (4a) and (4b). Analyzing the process

$$\begin{array}{l} K^- + {}^{12}C \rightarrow \pi^- + {}^{12}_{\lambda}C \\ \qquad\qquad\qquad\qquad\;\; \downarrow \\ \qquad\qquad\qquad\qquad\;\; p + {}^{11}_{\lambda}B \end{array} \qquad (5)$$

data were obtained on the Q^- value for ${}^{11}_{\lambda}B$ and ${}_\lambda Be$. It was found that $Q^- = 5.5 \pm 0.5$ and 4.3 ± 1.1 for ${}_\lambda B^{11}$ and ${}_\lambda Be$ respectively[9,11]. For the ${}_\lambda B$, ${}_\lambda C$, ${}_\lambda N$ group the Q^- and C values were determined to be 5.9 and 0.53 respectively[9,10] (see Tables I and II).

An analysis of fast charged particles[21,22] produced in the NMHN decay shows that not all the fast particles are protons. Our analysis of 223 events shows that about 20% of the fast particles are deuterons or tritons. They may be the products of interaction of stimulated nucleons arising from process (2) with the nucleons of the parent nuclei, but also they indicate that stimulated process may take place not only on one, but also on many nucleons.

REFERENCES

1) W.B. Cheston: H. Primacoff, (1953), *Phys. Rev.* 92., 1537.

2) R.H. Dalitz: The strong and weak interactions of bound λ particles. *Proc. 1963. Easter Scool for Physicists, St Cergue, CERN Report 64-6*

3) R.H. Dalitz: The present problem and future outlook in λ-hypernucleon physics. *Proc. Int. Conf. on Hypernucleon Physics (Argonne 1969), Vol. II. 708.*

4) D.H. Davis, J. Sacton: Hypernuclear Physics, High Energy Physics, *Vol. II. Edited by Burhop, Acad. press 1967.*

5) D.H. Davis, J. Sacton: Hypernuclear Physics using Photographic emulsion. *Proc. Int. Conf. on Hypernuclear Physics, (Argonne, 1969.), Vol. I. 159.*

6) M.M. Block et al.: *Proc. Int. Conf. on Hyperfragments (St Cergue 1963.) CERN report 64-1, p. 63.*

7) J. McKenzie: *Proc. Int. Conf. on Hypernucleon Phys. (Argonne 1969)p. 403.*

8) G. Coremans et al., *Nuclear Physics,* B16 (1970) 209

9) A. Montwill et al. *to be published in Nuclear Physics*

10) G. Coremans-Bertrand et al.: *Bulletin de l' Institut de Physique de l'Université Libre de Bruxelles No. 46, (1971)*

11) G. Bohm et al.: *Nuclear Physics,* B12 (1969) 1

12) H.G. Miller et al.: *Phys. Rev.* 167 (1968) 922

13) K.N. Chaudhari et al.: *Proc. Ind. Acad. Sc. ,* 69 (1969) 78

14) N.W. Holland: *Nuovo Cimento,* 34 (1964) 48

15) J.P. Lagnaux, *Bulltin de l'Institut de Physique de l'Université Libre de Bruxelles No. 12 (1964)*

16) N.M. Rao et al.: *Proc. Ind. Acad. Sc.,* 71A (1970) 100

17) L.K. Mangotra et al.: *Nuovo Cimento,* 13A (1973) 826

18) S.N. Ganguli and M.S. Swami, *Proc. Ind. Acad. Sci.,* 66A (1967) 77

19) J. Cuevas et al.: *Nuclear Physics,* 1B (1967) 411

20) M. Jurić et al.: *Nuclear Physics,* B47 (1972) 36

21) O. Adamović et al.: *Comp. Ren Congres Inter. Phys. Nucle,* 2 - 8. VII 1964.

22) K.N. Chaudhari et al.: *TIFR NE 66-12.*