THREE EXAMPLES OF $_{\Lambda}Be^7$ HYPERFRAGMENTS

By K. N. Chaudhari, S. N. Ganguli, N. K. Rao and M. S. Swami*

(Tata Institute of Fundamental Research, Bombay-5, India)

Received April 28, 1966

(Communicated by Prof. R. R. Daniel, F.A.SC.)

Abstract

In a systematic study of hyperfragments (HFs), three uniquely identified examples of $_{\Lambda}Be^7$ hyperfragments have been observed; one of them decayed by π^--mesic mode and the other two by non-mesic modes. The data from the present π^-mesic decay of $_{\Lambda}Be^7$ when combined with that from the other two similar events reported in the literature, yielded a mean binding energy of $4 \cdot 99 \pm 0 \cdot 36$ MeV for $_{\Lambda^\circ}$ relative to the lowest level of Be^6.

1. Introduction

The isotopic spin of $_{\Lambda}Be^7$ is one; other members of this triplet are $_{\Lambda}He^7$ and $_{\Lambda}Li^{7*}$. Be^6, the core nucleus of $_{\Lambda}Be^7$, is unstable against break up into $He^4 + 2p$ by $1 \cdot 42$ MeV. Therefore, the minimum binding energy of Λ needed to form $_{\Lambda}Be^7$, such that it remains stable against break up into $_{\Lambda}He^5 + 2p$, is $4 \cdot 52 \pm 0 \cdot 14$ MeV; $0 \cdot 14$ MeV is the uncertainty in the determination of the lowest level of Be^6. The principle of charge symmetry implies the same binding energy for Λ in $_{\Lambda}Be^7$ and in $_{\Lambda}He^7$, but $_{\Lambda}He^7$ is found to have an average binding energy of $3 \cdot 96 \pm 0 \cdot 20$ MeV (Burhop, 1965). This apparent discrepancy between the expected and observed values of binding energy, has been discussed by Danysz and Pniewski (1962) in terms of structural property of core nuclei. It is therefore quite important to know accurately the binding energy of $_{\Lambda}Be^7$.

We have obtained from a systematic study of hyperfragments, three events uniquely identified to be due to decay of $_{\Lambda}Be^7$; one of them decayed by π^--mesic mode and the other two by non-mesic mode. So far in the literature only two π^--mesic decay events of $_{\Lambda}Be^7$ have been reported (St. Lorant and Lokanathan, 1962, and Ammar *et al.*, 1963). In view of the importance of $_{\Lambda}Be^7$ decays, we present the data from the three events here.

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* Now at the Physics Department, Punjab University, Chandigarh, India, on deputation from the Tata Institute of Fundamental Research, Bombay.

2. EXPERIMENTAL DETAILS AND RESULTS

2.1. *Details of the Stack*

The three events were found in a stack of 150 G-5 emulsions each of size 10 cm × 7·5 cm × 600 μm exposed to 17·2 GeV/c π^- beam of the CERN proton synchrotron. The stopping power of the stack was determined by measuring the residual ranges of 50 μ^+ from π^+ decays at rest. The mean value of the muon residual range was found to be 605·0 ± 3·0 μm which is in good agreement with the expected range of 602.2 ± 1·5 μm for a standard emulsion of density 3·815 g./cm.[3] (The thickness of each emulsion pellicle was measured prior to processing.) The three events are described below.

2.2. *Event No.* 455

The primary star in this event is of the type (4 + 2) π^-. The HF emitted from this star was brought to rest after traversing 56·6 μm. It has at its stopping end five associated prongs, four of which are black while the fifth one is grey. All the tracks were followed till they were brought to rest in the stack; the grey track was identified to be due to a π^- from the characteristic four pronged capture star at its stopping end. The details of this event are given in Table I.

TABLE I

Details of Event No. 455—the π^--mesic decay event

Track No.	Range (μm)	Dip angle (degrees)	Azimuthal angle (degrees)	Identity	Energy (MeV)
HF	56·6	51·9	...	$_{\Lambda}Be^7$	28·0
1	9495·0	69·9	0·0	π^-	22·50
2	374·3	8·2	285·0	H^1	7·85
3	14·6	−49·5	49·0	H^1	1·03
4	9·5	0·0	82·0	H^1	0·76
5	7·5	−36·6	141·0	He^4	2·23

The charge of the HF was determined from the mean track-width measurements made at intervals of 1 μm from the stopping end. The mean track width was compared with that of well-identified protons, alpha-particles, Li^8 and B^8 fragments (for details *see* Ganguli *et al.*, 1963 and Chaudhari *et al.*, 1966). From this, it was estimated that the most probable charge of the HF is four or five.

The event was analysed on a CDC 3600 computer for all possible decay schemes. The energies of the particles were determined from the measured ranges and the range-energy relation given by Heckman *et al.* (1960). The mass values were taken from Konig *et al.* (1962) and Rosenfeld *et al.* (1965). The identity of the particle producing the grey track has been established as a negative pion; for the other black prongs, the maximum and minimum charges, *i.e.*, 1 to 6, were assigned and all possible combinations for the decay schemes tried by the computer such that the charge of the HF lay always between 3 and 8. The unbalanced momentum was given to an invisible recoil or a neutron; if the unbalanced momentum was less than 100 MeV/c, the computer also tried schemes without any invisible recoil or neutron. A decay scheme was accepted if the calculated binding energy lay within three standard deviations of the expected binding energy. The only decay scheme that could fit this event is:

$$_{\Lambda}Be^7 \rightarrow \pi^- + H^1 + H^1 + H^1 + He^4.$$

The unbalanced momentum for this scheme is $17 \cdot 9 \pm 26 \cdot 5$ MeV/c. The binding energy* for this decay scheme relative to the lowest level of Be^6 is $4 \cdot 66 \pm 0 \cdot 59$ MeV. The error on binding energy takes into account the measuremental errors on all the prongs and the straggling error on the range of pion; it does not take into account possible errors on the mass values.

The other two published events of St. Lorant and Lokanathan (1962) and Ammar *et al.* (1963) have binding energies of $5 \cdot 64 \pm 0 \cdot 60$ and $4 \cdot 69 \pm 0 \cdot 70$ MeV†, respectively, when referred to the same Q_Λ and mass of Be^6 core used in this work. The mean B_Λ value obtained by combining these two values with the present one is: $4 \cdot 99 \pm 0 \cdot 36$ MeV.

2.3. *Event No.* 162

The HF was emitted from a star of size $(18 + 4)$ π^- and after coming to rest it decayed into four visible charged particles. All the secondary

* The mass values of H^1, He^4 and Be^6 are taken as $938 \cdot 256$, $3727 \cdot 315$ and $5605 \cdot 248 \pm 0 \cdot 14$ MeV respectively. The value of Q_Λ used here is $37 \cdot 60$ MeV.

† The raw data from these two published events have also been analysed with our programme, and the values of B_Λ are found to be $5 \cdot 74$ and $4 \cdot 20$ MeV respectively. The reason for the little discrepancy between these values and those mentioned in the text is not clear.

tracks were followed till they stopped. The charge of the HF was determined in the same way as is described in Section 2.2. The most probable charge of the HF was found to be 4 or 5. The details of this event are presented in Table II.

TABLE II

Details of Event No. 162

Track	Range (μm)	Dip angle (degrees)	Azimuthal angle (degrees)	Identity	Energy (MeV)
HF	41·2	31·9	..	${}_{\Lambda}Be^{7}$	22·7
1	7150·0	66·9	0·0	H^{1}	43·12
2	2225·0	−57·9	159·0	H^{2}	29·69
3	1218·0	−27·2	329·0	$H^{1,2}$	15·70 or 20·83
4	786·0	−15·7	244·0	$H^{2,1}$	16·13 or 12·14

Analysis of this event was made in the same way as is described in Section 2.2. The only acceptable schemes for this event are:

$$ {}_{\Lambda}Be^{7} \rightarrow H^{1} + H^{2} + H^{1} + H^{2} + n \qquad (1\,a)$$

and

$$ {}_{\Lambda}Be^{7} \rightarrow H^{1} + H^{2} + H^{2} + H^{1} + n \qquad (1\,b)$$

The energy of the neutron in schemes (1 *a*) and (1 *b*) are 41·46 and 43·15 MeV respectively and the corresponding B_{Λ} values are $7 \cdot 39 \pm 1 \cdot 49$ and $4 \cdot 54 \pm 1 \cdot 64$ MeV.

2.4. *Event No.* 33

The HF was emitted from a star of size (11 + 2) π^{-} and after coming to rest it decayed into three visible charged particles. As in previous examples the most probable charge of the HF is found to be 4 or 5. The details of this event are described in Table III.

TABLE III

Details of Event No. 33

Track	Range (μm)	Dip angle (degrees)	Azimuthal angle (degrees)	Identity	Energy (MeV)
HF	72·8	30·6	..	$_{\Lambda}Be^7$	32·9
1	43374·0	59·3	0·0	H^1	120·83
2	1551·0	−58·7	144·0	H^1	18·02
3	105·0	−32·8	233·0	He^4	14·43

The only acceptable scheme for this event is:

$$_{\Lambda}Be^7 \rightarrow H^1 + H^1 + He^4 + n.$$

The energy of the neutron is 17·96 MeV and the B_{Λ} value is: $6{\cdot}06 \pm 1{\cdot}36$ MeV.

3. CONCLUSIONS

Three unique $_{\Lambda}Be^7$ events have been observed.

(i) In the first event the HF decayed by π^--mesic mode according to the scheme:

$$_{\Lambda}Be^7 \leftarrow \pi^- + H^1 + H^1 + H^1 + He^4$$

and the binding energy is $4{\cdot}66 \pm 0{\cdot}59$ MeV.

(ii) The second event represents a non-mesic decay according to the two possible schemes:

$$_{\Lambda}Be^7 \rightarrow H^1 + H^2 + H^1 + H^2 + n$$

or

$$_{\Lambda}Be^7 \rightarrow H^1 + H^2 + H^2 + H^1 + n.$$

The binding energy is $7{\cdot}39 \pm 1{\cdot}49$ or $4{\cdot}54 \pm 1{\cdot}64$ MeV respectively.

(iii) The third event also represents a non-mesic decay mode according to the scheme:

$$_{\Lambda}Be^7 \rightarrow H^1 + H^1 + He^4 + n.$$

The binding energy is $6{\cdot}06 \pm 1{\cdot}36$ MeV.

ACKNOWLEDGMENT

We are extremely grateful to Prof. R. R. Daniel for helpful and stimulating discussions.

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361–66. Printed at The Bangalore Press, Mysore Road, Bangalore City, and Published by B. S. Venkatachar, Editor, "Proceedings of the Indian Academy of Sciences," Bangalore