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DECAY OF A NEGATIVE HYPERON INTO $\Lambda^0 + e^- + \bar{\nu}$ *

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The search for leptonic decay modes of hyperons has been carried out by many groups.[1] Clear examples of the following modes have thus far been observed:

$$\Lambda^0 \to p + e^- + \bar{\nu}, \quad (1)$$

$$\Lambda^0 \to p + \mu^- + \bar{\nu}, \quad (2)$$

$$\Sigma^- \to n + e^- + \bar{\nu}. \quad (3)$$

We wish to report here an example of a hyperon β decay of the following type:

$$Y^- \to \Lambda^0 + e^- + \bar{\nu}, \quad (4)$$

in which the hyperon can be either a Ξ^- or Σ^-. We believe this event is of interest in either case. Firstly, if the Y^- is a Ξ^-, the event is the first observed case of a leptonic cascade decay. Alternately, if the Y^- is a Σ^-, the event is the first clear example of a Σ^- β decay with $\Delta s = 0$.

The event shown in Fig. 1 was found in pictures obtained from an exposure of the 20-in. BNL hydrogen bubble chamber to a 2.24-BeV/c K^- beam at Brookhaven's AGS.[2] The kinematic variables of each track are given in Table I. Also included are the ionization densities of each track obtained by means of a gap count measurement. From these ionization and momentum measurements it is clear that the (decay) track 4 is an electron, and track 2 is a π^+. On the other hand, the Y^- (track 3) can be either a Ξ^- or a Σ^-.

The event was kinematically analyzed using the BNL TRED-KICK[3] system. Considering the decay process first, the results show that the V (tracks 5 and 6) can only be a Λ^0, and, furthermore, that it must come from the decay vertex. The χ^2 probabilities for the only two possible decay modes are given in Table II. It is clear that the event cannot be identified on this basis alone.

Next we consider the production process. The two possible production modes are[4]:

$$\Xi^- + \pi^+ + (A), \quad m_A \neq 0, \quad (5)$$

$$\Sigma^- + \pi^+ + (B), \quad m_B \neq 0, \quad (6)$$

where A and B can be any number of neutral particles. The measured masses for A and B are listed in Table II. In order to determine the probability that this event comes from either reaction (5) or (6) we have investigated the neutral mass distribution for events in which only two charged particles are visible and where these are positively identified as either $(\Sigma^-\pi^+)$ or $(\Xi^-\pi^+)$ pairs. Both of these missing mass distributions are shown in Fig. 2 where we have omitted events which fit $(\Sigma^-\pi^+)$ without any neutral. From the overlap of areas of the measured mass values to the total available area, we find that the relative probability of obtaining an event whose missing mass is 563 ± 27 MeV from (5) and 764 ± 25 MeV from (6)

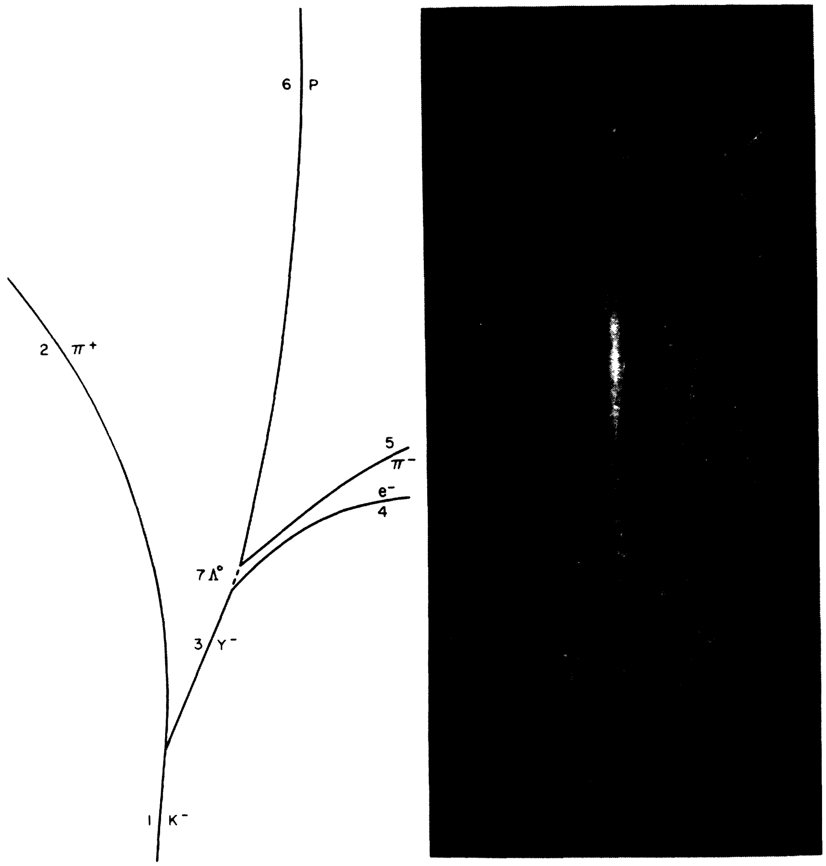

FIG. 1. Photograph of decay of a negative hyperon into $\Lambda^0 e^- \bar{\nu}$.

are 0.15 and 0.02, respectively. The relative cross sections for reactions (5) and (6) as determined from this experiment are in the ratio $\sigma(5)/\sigma(6) = 1/2$. Therefore, we estimate that this relative probability that this event is an example of Ξ^- versus Σ^- leptonic decay, $R^E(\Xi^-/\Sigma^-)$, is

$$R^E = \frac{P(\Xi^- \to \Lambda e^- \bar{\nu})}{P(\Sigma^- \to \Lambda e^- \bar{\nu})} \times \frac{\sigma(5)}{\sigma(6)} \times \frac{P(\Xi^- \pi^+ \mathrm{MM} = 563 \pm 27)}{P(\Sigma^- \pi^+ \mathrm{MM} = 764 \pm 25)},$$

$$R^E = \frac{0.94}{0.57} \times \frac{1}{2} \times \frac{0.15}{0.02} \approx \frac{7}{1}.$$

In the absence of a reasonably certain kinematic identification of the event, one can make an a priori estimate of the relative likelihood that the event is a β decay of a Ξ^- or Σ^-. Of course, the relative decay probability is not known. Thus the best one can do is to use theory as a guide; that is, to make

Table I. Tabulation of measured and fitted angles, momenta, and bubble density.

Track No.	Assigned particle	Measured angles, momenta, and bubble density: ϕ(Azimuth)	θ(Dip)	p(MeV/c)	Bubble density	Ξ^- fit: p	Ξ^- fit: Expected bubble density	Σ^- fit: p	Σ^- fit: Expected bubble density
1	K^-	354.9 ±0.5	−0.5 ±0.5	2240 ± 45[a]					
2	π^+	354.5 ±0.2	+0.1 ±1.2	168 ± 4	1.9 ±0.2		1.7		1.7
3	Ξ^-, Σ^-	340.5 ±0.2	19.3 ±1.0	940 ±141	2.7 ±0.3	935 ±17	3.1	1023 ±21	2.4
4	e^-	325.8 ±0.4	45.0 ±2.0	83 ± 3	1.5 ±0.2	84 ± 4	1.4	84 ± 4	1.4
5	π^-	313.8 ±0.2	6.9 ±1.1	200 ± 8	1.5 ±0.2	204 ± 2	1.5	204 ± 2	1.5
6	p	347.7 ±0.1	19.0 ±0.5	765 ± 15	2.8 ±0.2	759 ±15	2.7	759 ±15	2.7
7	Λ^0	340.5 ±0.8	16.1 ±4.0			933 ±16		932 ±15	

[a]Mean momentum of K^- beam.

Table II. List of production and decay hypothesis.

Hypothesis	χ^2 probability	MM
Decay		
$\Xi^- \to \Lambda e^- \bar{\nu}$	0.94	
$\Sigma^- \to \Lambda e^- \bar{\nu}$	0.57	
Production		
$K^- + p \to \Xi^- + \pi^+ + \mathrm{MM}$		563 ± 27
$K^- + p \to \Sigma^- + \pi^+ + \mathrm{MM}$		764 ± 25

use of the Universal Fermi Interaction (UFI). Such a calculation using the weak interaction coupling constant found from nucleon β decay yields a decay probability, P_D^{th},

$$P_D^{\mathrm{th}} = \frac{\Xi^- \to \Lambda e \bar{\nu}}{\Sigma^- \to \Lambda e \bar{\nu}} \approx \frac{100}{1}.$$

This large ratio is mainly due to the greater phase space available in the cascade decay. However, present experimental evidence[1] indicates that the rate of hyperon β decay involving $\Delta s = 1$ currents is a factor of ~10 lower than that predicted by UFI. Since the $\Xi^- \to \Lambda e \bar{\nu}$ decay involves $\Delta s = 1$ currents, while the $\Sigma^- \to \Lambda e \bar{\nu}$ decay involves only $\Delta s = 0$ currents, it seems reasonable to reduce the Ξ^--decay rate[5] P_D to ≈10/1. If we combine this a priori probability with the probability based on the measured values, R^E, we find that the Ξ^- interpretation is favored by ~70/1. However, the above estimate is uncertain by an order of magnitude.

In summary, although it is not possible to clearly establish the identity of the hyperon, its decay into ($\Lambda e^- \bar{\nu}$) is definite.

We would like to acknowledge the cooperation of the AGS staff and 20-in. hydrogen chamber crew for aid in obtaining the film.

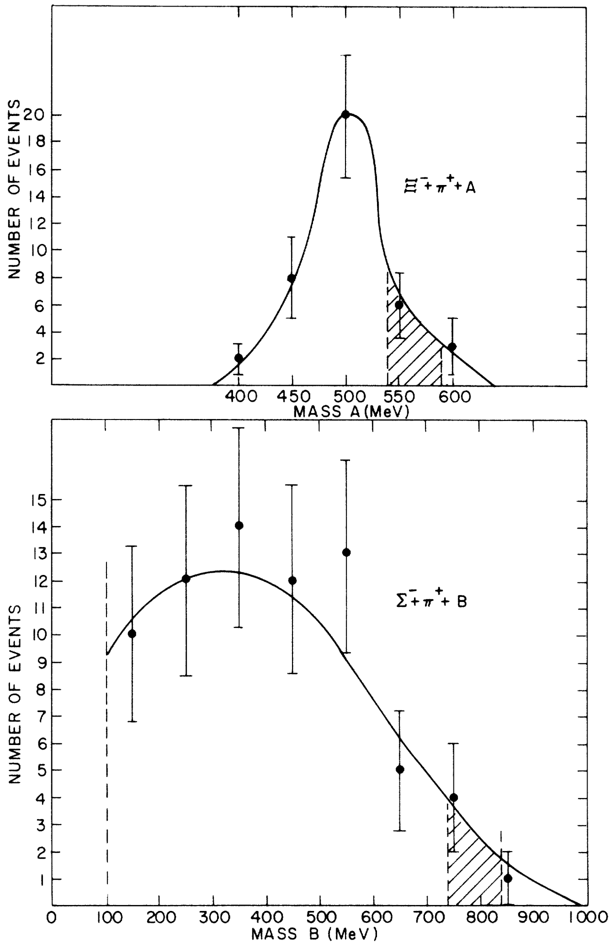

FIG. 2. Experimental distributions for particles A, B in the reactions: $K^- + p \to \Xi^- + \pi^+ + A$; $\Sigma^- + \pi^+ + B$. Also shown are the values measured for this event.

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[5] Recently, J. Bernstein and R. Oehme [Phys. Rev. Letters 6, 639 (1961)] have shown that this factor may be as large as 30.

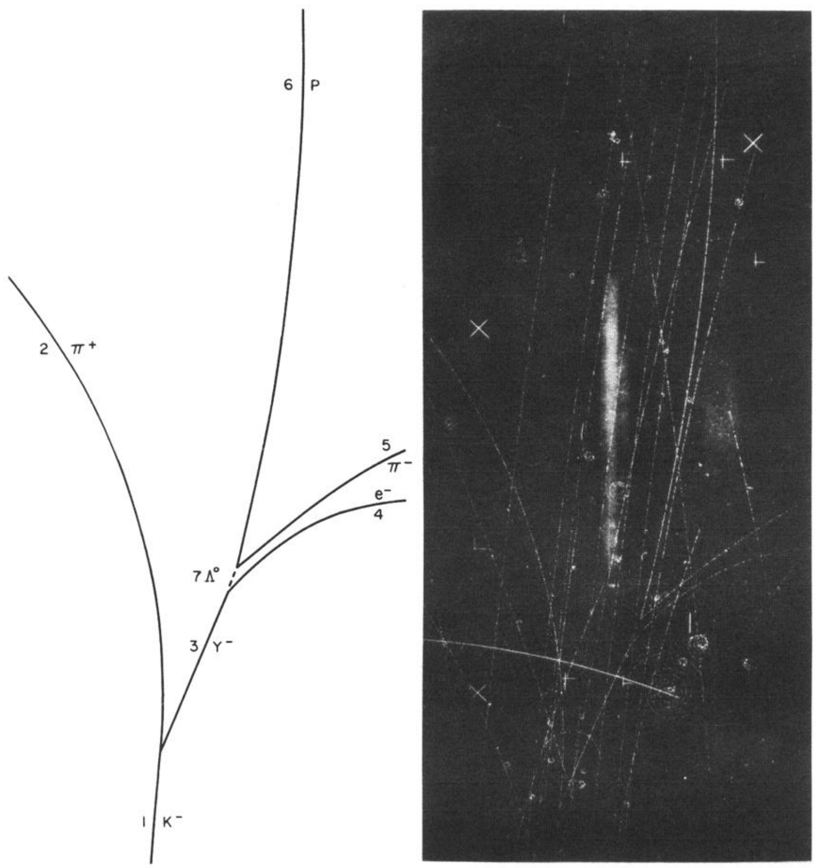

FIG. 1. Photograph of decay of a negative hyperon into $\Lambda^0 e^- \bar{\nu}$.