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Authors
Dahl, Orin
Horwitz, Nahmin
Miller, Donald
et al.

Publication Date
1959-12-03

UCRL 8999

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

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For publication in Phys. Rev. Letters

UCRL-8999

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Lawrence Radiation Laboratory
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Contract No. W-7405-eng-48

PRODUCTION OF Σ^0 AND Λ HYPERONS BY Σ^- CAPTURE IN DEUTERIUM

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Printed for the U. S. Atomic Energy Commission

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Recently, Ross reported a measurement of the branching ratio for the two reactions

$$\Sigma^- + p \rightarrow \Sigma^0 + n \quad (1)$$

$$\rightarrow \Lambda + n \quad (2)$$

induced by the absorption of stopped Σ^- in liquid hydrogen.[1] He found

$$\Gamma(\Sigma^0)/\Gamma(\Sigma^0 + \Lambda) = 0.33 \pm 0.05. \quad (3)$$

Day, Snow, and Sucher have tried to relate the analogous deuterium reactions

$$\Sigma^- + d \rightarrow \Sigma^0 + n + n \quad (4)$$

$$\rightarrow \Lambda + n + n \quad (5)$$

to those in hydrogen by means of an impulse-type calculation.[2] They pointed out that because of the small $\Sigma^- - \Sigma^0$ mass difference it is expected that reaction (4) will be strongly suppressed. However, uncertainties in (a) the details of the two-body Σ^--p absorption process and (b) the strength of final-state interactions prevented a reliable estimate of the effect.

An additional exposure of the 15-in. Alvarez deuterium bubble chamber to the separated K^- beam of the Bevatron has resulted in an improved determination of the branching ratio for reactions (4) and (5).[3] A total of 145 charged Λ decays produced by absorption of Σ^-'s from the reaction

$$K^- + d \rightarrow \Sigma^- + \pi^+ + n \quad (6)$$

have been observed. The presence of the π^+ at the K^- absorption vertex unambiguously indicates the production of a Σ^-, whether or not the range of the Σ^- was great enough to produce a visible track.

In order to determine the Λ momenta, the coordinates of each event were punched onto IBM cards by means of the LRL precision measuring machine (Franckenstein). The events were least-squares fitted by suitable IBM programs which applied the energy-momentum constraints at the decay vertex. The accuracy of the analysis was checked by processing in a similar manner the monochromatic Λ's from reaction (2). In Fig. 1 we have plotted the idiogram calculated from the measured Λ momenta and their uncertainties.

I. Branching Ratio

A recent remeasurement of the $\Sigma^- - \Sigma^0$ mass difference has been reported by Rosenfeld.[4] He found that $M_{\Sigma^-} - M_{\Sigma^0} = 4.45 \pm 0.37$ Mev. Since the Q value for reaction (4) is then only 0.92 ± 0.37 Mev, the Λ's are confined kinematically to the narrow momentum interval from 40 to 109 Mev/c. However, processes other than (4) may contribute to the observation of Λ's in this momentum interval. We have considered the following sources of background:

A. Spectroscopic analysis of the deuterium in the bubble chamber during the course of the exposure indicated that the molar contamination of hydrogen was ~ 2%. Ross found that Λ's resulting from decay of Σ^0's produced in reaction (1) occurred in the momentum interval 0 to 135 Mev/c. Therefore, a Σ^0 production in the residual hydrogen in the present experiment would probably be indistinguishable from reaction (4). If we assume the Σ^- capture occurs in hydrogen in proportion to the amount present, one Σ^0 event and two Λ's (of unique momentum 288 Mev/c) must be subtracted out.

B. From Ross's data it is also estimated that about five of the $\Sigma^- - d$ interactions occurred in flight. Because of the distribution in momentum of the Σ^-'s from reaction (6), the in-flight events cannot be recognized. Since Σ^0 production probably increases rapidly to the hydrogen value with increasing

Σ^- momentum, we take account of the in-flight interactions in the calculation of the branching ratio by an additional subtraction of one Σ^0 and four Λ's.

C. Λ's from reaction (5) may be produced in the expected momentum interval. Calculations were carried out in which the effects of possible final-state interactions were estimated. The results suggest that the contamination of Λ's from reaction (5) is negligible.

We conclude that the branching ratio for reactions (4) and (5) when Σ^- hyperons are captured at rest in deuterium is

$$\frac{\Gamma_D(\Sigma^0)}{\Gamma_D(\Sigma^0 + \Lambda)} = \frac{5 \pm 3}{137} = 0.037 \pm .022. \qquad (7)$$

This ratio is within the limits predicted by Day, Show, and Sucher.[2]

We estimate that the probability is less than 10^{-3} that seven or more events in the expected Σ^0 momentum interval could arise from the sources of contamination listed above. Therefore, the present result may be considered as providing an absolute lower limit to the $\Sigma^- - \Sigma^0$ mass difference:

$$M_{\Sigma^-} - M_{\Sigma^0} > 3.53 \text{ Mev.}$$

II. Λ Spectrum

It is of interest to determine the extent to which an impulse-type calculation is adequate to predict the observed spectrum. We performed the calculation assuming:[5] (a) Σ^- capture at rest proceeds from atomic S orbitals;[6] (b) absorption in the relative S wave of the Σ^--p system dominates; (c) the effects of final-state interactions may be neglected. The Hulthén form was used for the deuteron wave function; the final Λ-2n system was described by a product of plane waves. Since the spin dependence of the two-body absorption operator is unknown, no attempt was made to include the effects of the Pauli principle. The predicted spectrum was found to be insensitive

to the choice of relative $\Sigma - \Lambda$ parity. The result of the calculation is shown in Fig. 1, with the known momentum resolution folded in. (In this comparison it is assumed that the effect of the four Λ's from in-flight Σ^- captures is small.) The agreement is remarkably good.

We conclude that both the branching ratio and the spectrum are qualitatively understandable in terms of a simple impulse model. There is no evidence (within experimental error) for distortions of the spectrum due to the presence of strong final-state interactions.

We wish to thank Professor Luis W. Alvarez for his advice and encouragement, and members of the bubble chamber and scanning staff for their assistance. This work was done under the auspices of the U. S. Atomic Energy Commission.

References

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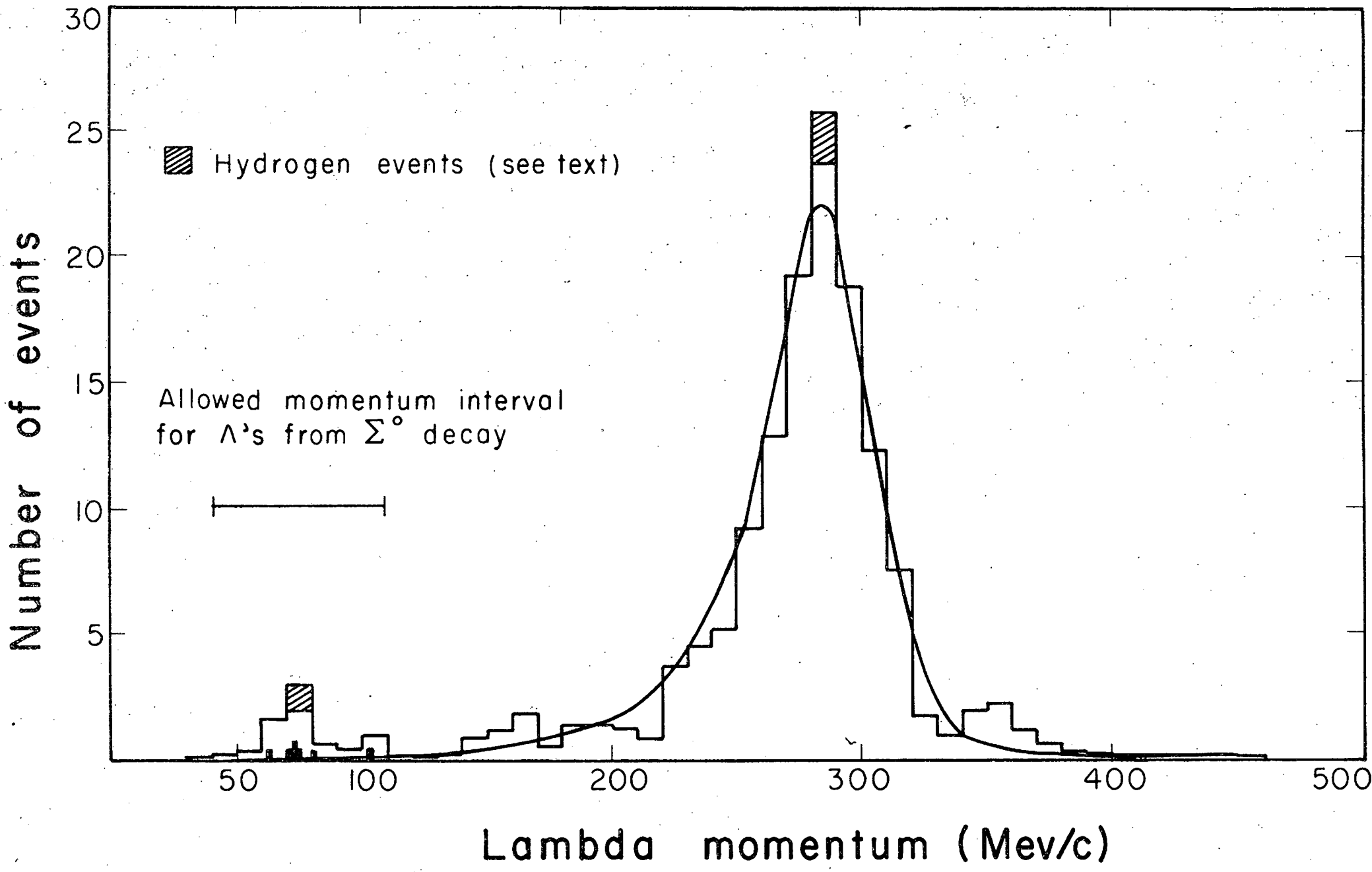
2. Day, Snow, and Sucher, Phys. Rev. Lett. 2, 468 (1959).
3. Arthur H. Rosenfeld, Bull. Am. Phys. Soc., Ser. II, 3, 363 (1958).
4. A preliminary result was reported by Horwitz, Miller, and Murray, Bull. Am. Phys. Soc., Ser II, 4, 289 (1959).
5. The calculations of reference 2 were based upon similar assumptions.
6. Day, Snow, and Sucher, Phys. Rev. Lett. 3, 61 (1959).
   The considerations applied by these authors to the K^--p system are equally applicable to the Σ^- - d system if the interaction proceeds dominantly through the S wave.

Figure Legend

Fig. 1. Comparison of observed spectrum with the prediction of the impulse model.


Hydrogen events (see text)
Allowed momentum interval
for Λ's from Σ° decay
Number of events
Lambda momentum (Mev/c)
30
25
20
15
10
5
50
100
200
300
400
500