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Λ INTERACTIONS IN HYDROGEN

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Frank T. Solmitz, M. Lynn Stevenson, and Harold K. Ticho

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While studying the associated production processes, we have encountered six cases in which the Λ subsequently interacts with a proton in the liquid hydrogen bubble chamber.[1]

The classes of Λ interactions we have seen are

$$\Lambda + p \rightarrow \Lambda + p \text{ (4 events)}, \quad \text{and} \tag{1}$$

$$\Lambda + p \rightarrow \Sigma^{+} + n \text{ (2 events)}. \tag{2}$$

We have not yet seen any examples of the reaction

$$\Lambda + p \rightarrow \Sigma^{0} + p . \tag{3}$$

(Charge independence predicts that Reaction (3) should be half as frequent as Reaction (2)).

The momentum spectrum of the Λ produced in our associated production experiment is shown in Fig. 1. The letters "Λ" and "Σ^{+}" in this figure indicate the Λ momentum that produced the above reactions. The threshold for the endothermic reaction (2) is 635 Mev/c. Table I contains the pertinent information concerning the reaction dynamics for each event.

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[1]The two $\Lambda + p \rightarrow \Sigma^{+} + n$ reactions have been discussed previously by Crawford, Cresti, Good, Gottstein, Solmitz, Stevenson, and Ticho, Σ^{+} Production by Λ^{0} Hyperons, UCRL-3924, Aug. 1957.

Figure 2 shows one of the Λ elastic scatters. The original Λ was produced in the direction indicated by arrow No. 2. (The associated K^0 did not decay in the chamber.) At Point A, the Λ scatters in the direction indicated by arrow No. 3. At point B, the Λ decays into a pion (Track 4) and a proton (Track 5). Track 6 is the recoil proton.

Figure 3 shows one of the $\Lambda + p \rightarrow \Sigma^+ + n$ interactions. Tracks 3 and 4 are the negative and positive decay pions of the K^0 (arrow No. 2) that was produced in the primary reaction $\pi^- + p \rightarrow K^0 + \Lambda$. The Λ (arrow No. 5) interacts at point A to produce a Σ^+ (Track 6) and a neutron. The Σ^+ then decays at point B into a π^+ (Track 7) and a neutron.

The 655 Λ's that we have observed to decay in the chamber have traversed a total path length in liquid hydrogen of 2200 cm.

In addition to the observed Λ decays there were 195 cases in which only the K^0 decays. From the observed K^0 we can predict the direction in which the unseen Λ traverses the chamber. We then search along this direction for a recoil proton or a "recoil" Σ^+. We estimate that Λ's of this category traversed 700 cm of liquid hydrogen. From the combined path length in liquid hydrogen of 2900 cm we obtain an elastic scattering cross section[2]

$$\sigma_{\Lambda\Lambda} = 40 \pm 20 \text{ mb} .$$

If the cross section is assumed to have the energy dependence of $\sigma = \epsilon \pi \lambda^2(\text{c.m.})$, with ϵ constant, then by averaging over the Λ momentum spectrum we obtain

$$\epsilon_{\Lambda\Lambda} = \sigma_{\Lambda\Lambda}/\pi \left\langle \lambda^2(\text{c.m.}) \right\rangle = 2.4 \pm 1.2 .$$

Here λ(c.m.) is the de Broglie wave length of the Λ in the c.m. system.

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[2] A Λ that scatters less than 10 degrees produces a recoil proton that would escape detection. Our elastic scattering cross section therefore corresponds to scatterings greater than 10 degrees.

Of the total path length of 2900 cm, 2000 cm was traversed by Λ's of momentum higher than the threshold for the $\Lambda + p \rightarrow \Sigma^+ + n$ reaction. From the two observed reaction of type (2) we obtain

$$\sigma_{\Lambda\Sigma^+} = 30 \pm 20 \text{ mb} .$$

By averaging over Λ momenta above threshold, we find the corresponding value

$$\epsilon_{\Lambda\Sigma^+} = 3 \pm 2 .$$

Furthermore, by detailed balancing we can predict the cross section for the inverse reaction,[3] $\Sigma^+ + n \rightarrow \Lambda + p$,

$$\text{i.e.,} \qquad \sigma_{\Sigma^+ n} = (p/p')^2 \, \sigma_{\Lambda\Sigma^+} = 120 \pm 80 \text{ mb} .$$

The two events had momenta of 120 and 220 Mev/c in the $\Sigma^+ + n$ c.m. system. If charge independence holds we expect the $\Sigma^0 + p \rightarrow \Lambda + p$ cross section to be 60±40 mb. (We mention this because of the evidence for such an interaction in the $K^- + d$ experiment of Horwitz et al.[4])

We are grateful to Professor Luis Alvarez for his stimulation and guidance during this experiment. We are indebted to Don Gow and the bubble chamber crew, and to Hugh Bradner and the scanners for their help. We thank George Kalbfleisch and Roger Douglass for their assistance with the data analysis.

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[3] We assume that both the Λ and the Σ have the same spin.

[4] Horwitz, Miller, Murray, Schwartz, and Taft, Bull. Am. Phys. Soc. 3, No. 7, 363 (1958).

Table I. Reaction dynamics

Event frame number	Initial momentum (lab) (Mev/c)	Hyperon angle (c.m.) (degrees)	Momentum in center of mass of "scattering" Incoming	Outgoing
A. $\Lambda + p \rightarrow \Lambda + p$				
318425	1000	65	420	420
321560	1000	120	430	430
389195	500	80	220	220
439748	880	170	380	380
B. $\Lambda + p \rightarrow \Sigma^+ + n$				
232018	700	40	310	120
309771	840	90	360	220

FIGURE CAPTIONS

Fig. 1. This figure shows the Λ path length, L_Λ, as a function of the momentum of the Λ's prior to the interactions. The momenta of the Λ elastic scatterings are indicated by the "Λ" symbols, and the two $\Lambda + p \rightarrow \Sigma^+ + n$ reactions by the "Σ^+" symbols.

Fig. 2. The primary reaction is π^- (Track 1) + p $\rightarrow \Lambda$ (arrow No. 2) + K^0 (not seen). The Λ travels 3.7 cm and scatters elastically at point A in the direction indicated by arrow No. 3. Track 6 is the recoil proton. At point B the scattered Λ decays into a π^- (Track 4) and a proton (Track 5).

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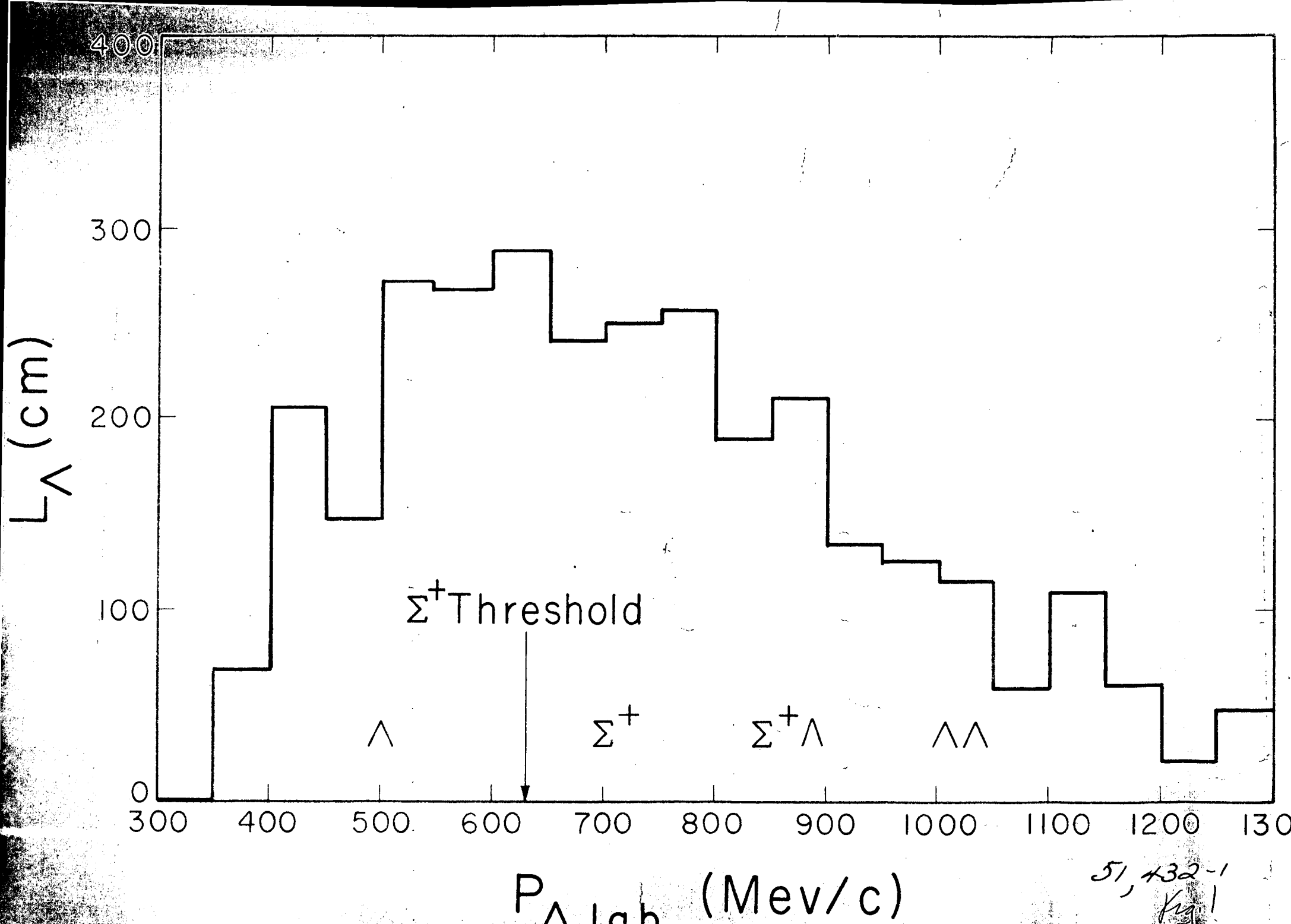
400
300
200
100
0
L_Λ (cm)
Σ^+ Threshold
Λ
Σ^+
$\Sigma^+\Lambda$
$\Lambda\Lambda$
300
400
500
600
700
800
900
1000
1100
1200
130
$P_{\Lambda\,lab}$ (Mev/c)

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Fig. 1

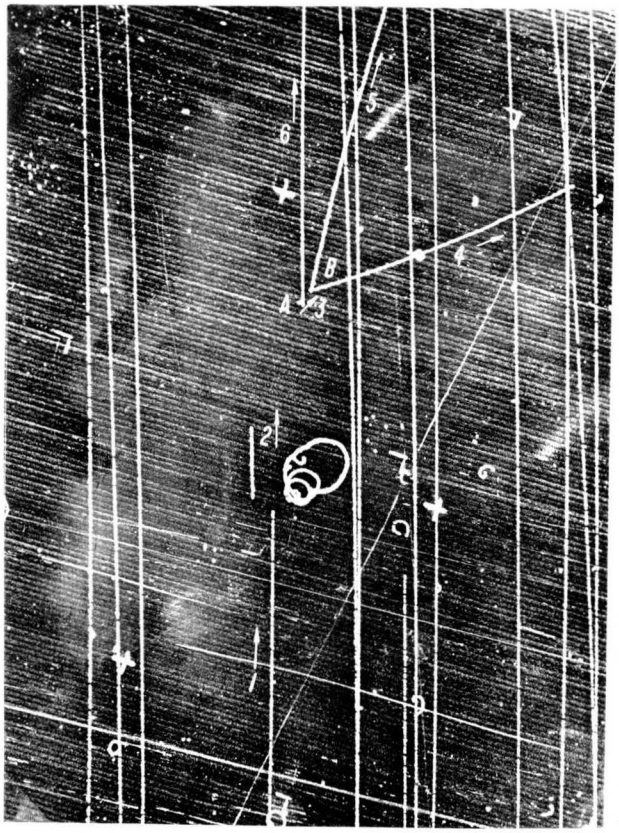

Fig. 2

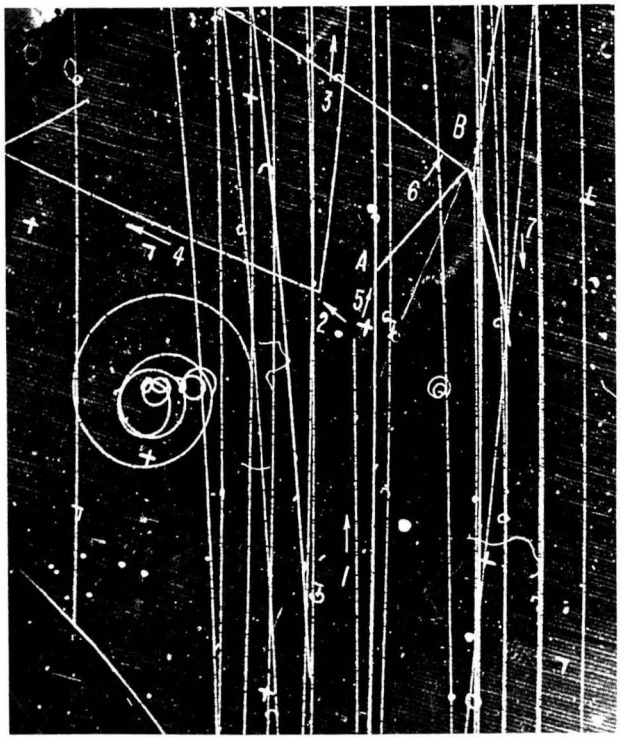

Fig. 3