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E+ PRODUCTION BY π^0 HYPERONS

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August 29, 1957

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ABSTRACT

Two Λ^0 hyperons have been observed to interact in flight with protons in a hydrogen bubble chamber. Σ^+ hyperons are produced in the interactions. The experimental data for the events are given and discussed.

Σ^+ PRODUCTION BY Λ^0 HYPERONS

Frank S. Crawford, Jr., Marcello Cresti, Myron L. Good,
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August 29, 1957

Two interesting events have been observed in our 10-inch hydrogen bubble chamber, exposed to a beam of negative pions of 1.1 Bev/c momentum. Photographs of these events are shown in Figs. 1 and 2. Figure 3 is a schematic representation of the event shown in Fig. 1. This event is interpreted below as the associated production of a θ^0 and a Λ^0 where the Λ^0 subsequently undergoes "charge exchange" scattering with a proton. The following relations represent the processes involved:

Event 1:

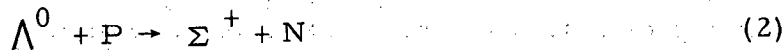
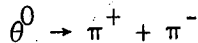
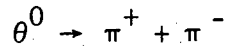


Figure 4 is a schematic representation of the event shown in Fig. 2. This event is interpreted as the associated production of a θ^0 and a Σ^0 . The Σ^0 decays into $\Lambda^0 + \gamma$ and the Λ^0 subsequently undergoes "charge-exchange" scattering as in the previous event. The following relations summarize the processes involved in this case:

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Event 2:

Tables I and II give the experimental details (notation as in Figs. 3 and 4) and reproduce the steps that lead to the above interpretations. The good agreement between the measured and derived values of α_3 and α_4 (Steps c and d) in the case of Event 1, and of α_3 in the case of Event 2, shows rather convincingly that we are indeed dealing with Reaction (1) in Case 1 and with Reaction (4) in Case 2. The decay kinematics of the Σ^+ hyperon produced by the Λ^0 also fit these interpretations.

In Case 1, the momentum p_{Λ^0} of the Λ^0 hyperon is directly obtainable from p_{θ^0} or the production angles α_3 or α_4 , the momentum p_{π^-} of the incoming pion being known (Step e, Table I). If we assume Reaction (2), the momentum p_{Σ^+} of the produced Σ^+ may then be derived (Step f).

It is to be noted that for each given value of p_{Λ^0} there are two solutions for p_{Σ^+} because the direction and momentum of the recoiling neutron are not known. (Under certain conditions these two solutions may coincide.) The agreement between the measured and the calculated momenta for the decay particle (Step g) indicates that the Σ^+ hyperon underwent decay according to mode (3) rather than to the mode $\Sigma^+ \rightarrow P + \pi^0$. The latter can produce a decay angle of $\sim 100^\circ$ only if the Σ^+ momentum is smaller than 220 Mev/c.

In Case 2, p_{Σ^0} and $(\alpha_4 + \alpha_7)$ can be calculated, assuming Reaction (4), from p_{π^-} and α_3 or p_{θ^0} . The angle α_4 being known experimentally, p_{Λ^0} is then derivable from p_{Σ^0} and α_7 . (Table II, Step e). This leads again to two possible values for p_{Σ^+} , assuming Reaction (2), (Step f).

The calculated momenta of the charged decay particle of the Σ^+ are listed in Table II (Step g). The value obtained for $p_{\Sigma^+} = 500$ Mev/c and for the protonic Σ^+ decay mode agrees with the experimental value.

To our knowledge these are the first established cases of nuclear interactions of free Λ^0 particles. We observed these events after having looked at an estimated 221 θ^0 particles produced by negative pions inside the bubble chamber. In estimating this number we used the branching ratio $\frac{2}{3}$ for the charged decay of the Λ^0 , the escape probability from our chamber, and the observed number (120) of events in which both the θ^0 and Λ^0 decays are visible. According to the scheme of Gell-Mann and Nishijima, all of these 221 θ^0 's must have been associated with Λ^0 's. Knowing the average momentum and the mean life of the Λ^0 , we estimate that we have looked at a total Λ^0 path length in liquid hydrogen of ~ 844 cm, in which we observed two Σ^+ productions by Λ^0 . For purposes of orientation, a mean free path of 422 cm corresponds to a cross section of 67 mb.

We are indebted to Dr. Luis W. Alvarez for his interest and encouragement, and to Hugh Bradner, James D. Gow, Ernest M. Lyman, and the bubble-chamber crew for their valuable assistance in running this experiment. Our thanks are also due to our film-scanning group, and in particular to Hugo Bayona who detected the two events here reported.

This work was done under the auspices of the U.S. Atomic Energy Commission.

Table I

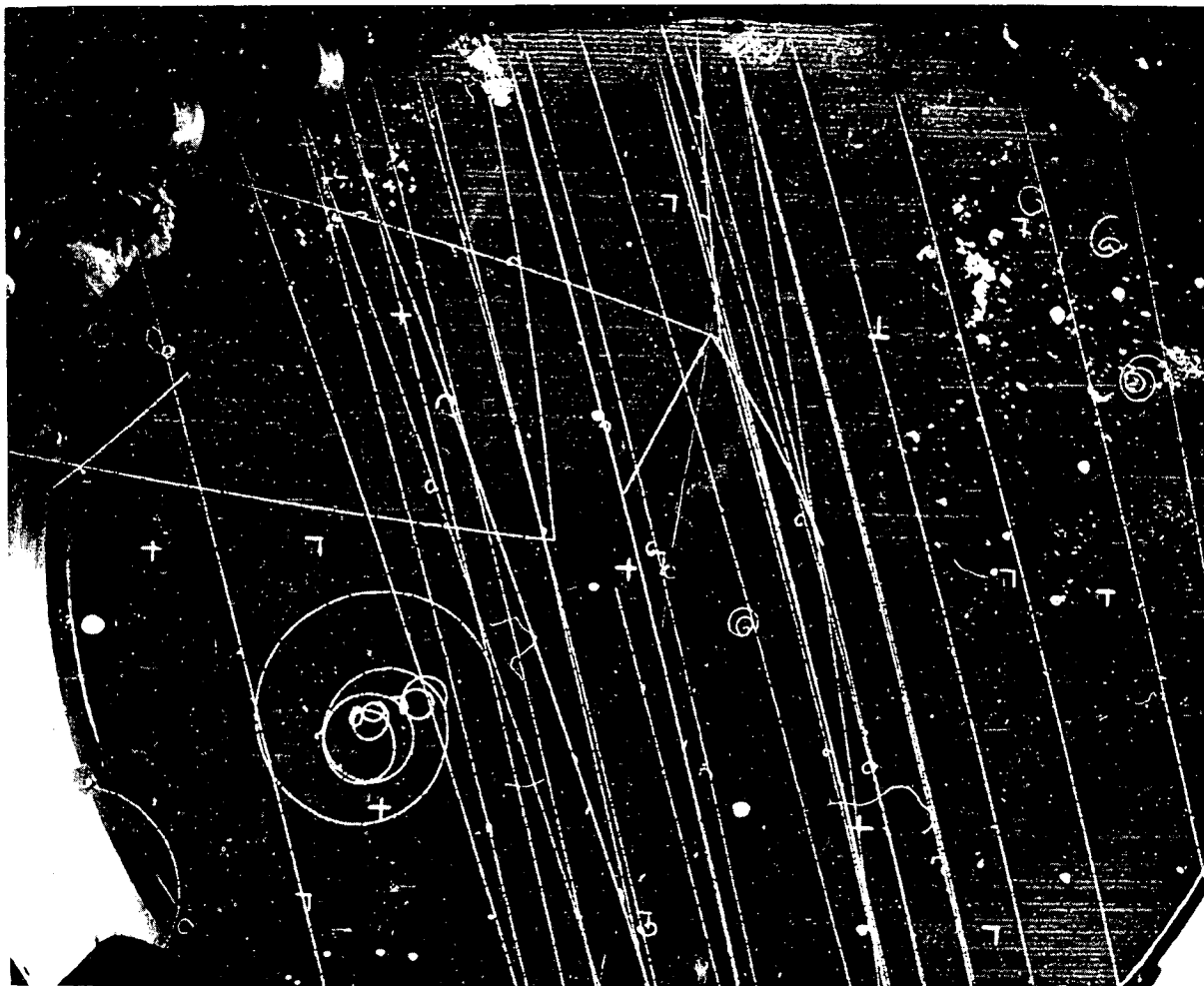
Data of Event I	
a	Measured angle between direction of θ^0 and decay plane of $\theta^0 = 0.1^\circ$
b	p_{θ^0} from a_1 and $a_2 = 475 \text{ Mev/c}$ p_{θ^0} from $a_1 + a_2$ and p_{π^-} (from curvature) = 475 Mev/c p_{θ^0} from $a_1 + a_2$ and p_{π^+} (from curvature) = 467 Mev/c
c	a_3 (measured) = $(41 \pm 2)^\circ$ a_3 (derived from p_{θ^0} (= $(472 \pm 5) \text{ Mev/c}$) and $p_{\pi^- \text{ prim}}$ (1.13 Bev/c) [assuming Reaction (1)] = $(42 \pm 0.5)^\circ$
d	a_4 (measured) = $(20.9 \pm 0.7)^\circ$ a_4 , derived from p_{θ^0} and $p_{\pi^- \text{ prim}}$ = $(22 \pm 0.5)^\circ$
e	p_{Λ^0} from p_{θ^0} and $p_{\pi^- \text{ prim}}$, assuming Reaction (1) = $(840 \pm 5) \text{ Mev/c}$
f	p_{Σ^+} from p_{Λ^0} and a_5 , assuming Reaction (2) = $(560 \pm 20) \text{ Mev/c}$ or $(277 \pm 20) \text{ Mev/c}$ p_{Σ^+} from curvature = $(633 \pm 200) \text{ Mev/c}$
g	p_{π^+} from p_{Σ^+} ($(560 \pm 20) \text{ Mev/c}$) and a_6 , assuming Decay Mode (3) = $(138 \pm 5) \text{ Mev/c}$ p_{π^+} from curvature : $(144 \pm 5) \text{ Mev/c}$ (track length is 9 cm)

Table II

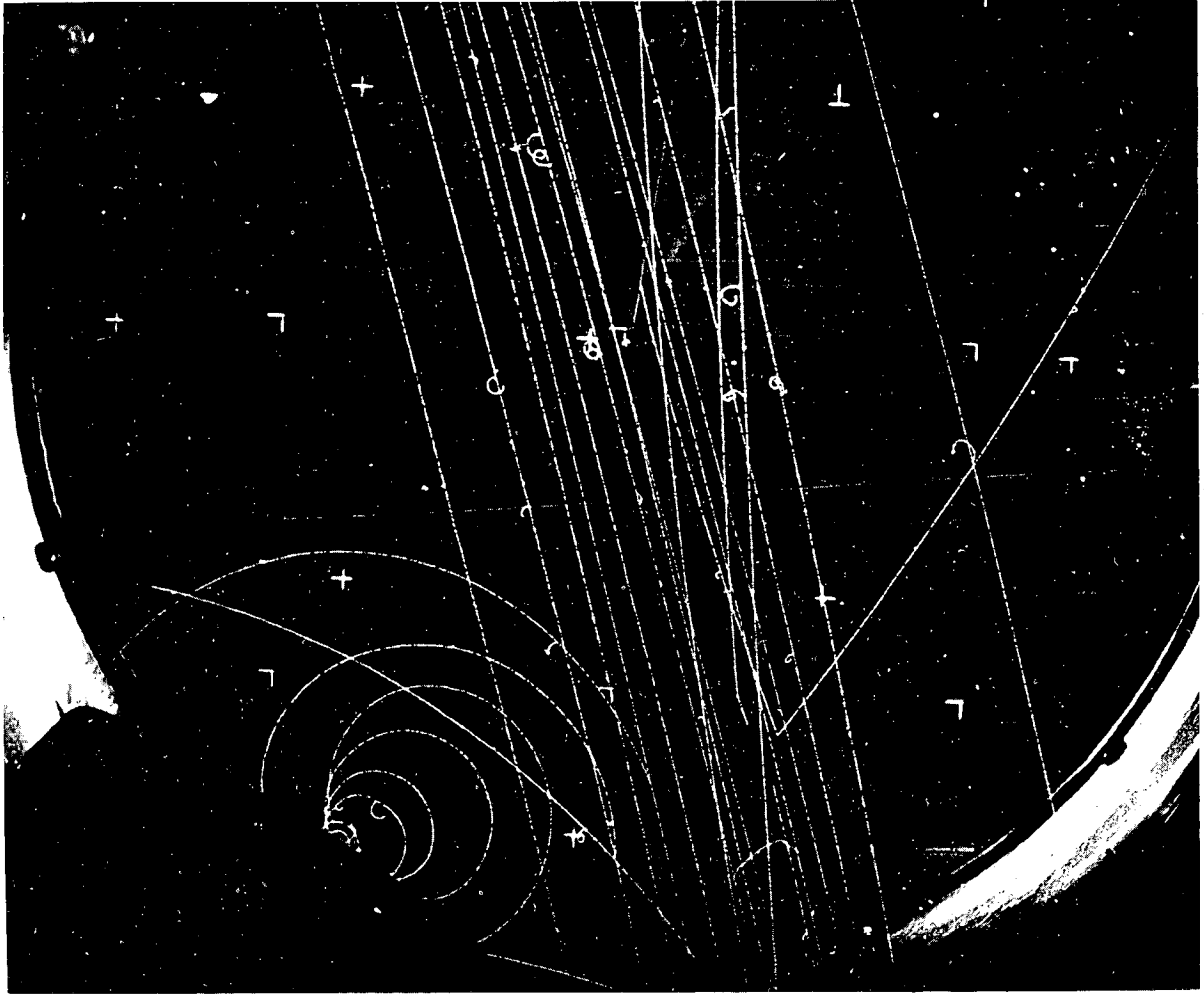
Data of Event 2			
a	Measured angle between direction of θ^0 and decay plane of $\theta^0 = (2 \pm 2)^\circ$		
b	p_{θ^0} from α_1 and $\alpha_2 = 445 \text{ Mev/c}$ p_{θ^0} from $\alpha_1 + \alpha_2$ and p_{π^-} (from curvature) = 445 Mev/c p_{θ^0} from $\alpha_1 + \alpha_2$ and p_{π^+} (from curvature) = 428 Mev/c		
c	α_3 (measured) = $(28 \pm 5)^\circ$ α_3 (derived from $p_{\theta^0} = (445 \pm 20) \text{ Mev/c}$ and $p_{\pi^- \text{ prim}} = (1.13 \text{ Bev/c})$, assuming Reaction (1) = $(44 \pm 2)^\circ$ α_3 (derived as above, but assuming Reaction (4)) = $(25 \pm 2)^\circ$		
d	α_4 (measured) = $(13 \pm 3)^\circ$		
e	p_{Σ^0} from p_{θ^0} (or α_3), $p_{\pi^- \text{ prim}}$, assuming Reaction (4) = $(750 \pm 30) \text{ Mev/c}$ p_{Λ^0} from p_{Σ^0} and $\alpha_7 = (700 \pm 90) \text{ Mev/c}$		
f	p_{Σ^+} from p_{Λ^0} and $\alpha_5 =$ $(275_{-50}^{+75}) \text{ Mev/c}$, or $(500 \pm 150) \text{ Mev/c}$ (The track of Σ^+ is too short for deriving the momentum from its curvature)		
g	$P(\text{decay particle})$ (measured) = $(450 \pm 30) \text{ Mev/c}$ (track length is 15 cm) $P(\text{decay particle})$ from p_{Σ^+} and α_6 , assuming		
	$p_{\Sigma^+} \text{ (Mev/c)}$	$p_{\text{decay particle}} \text{ (Mev/c)}$	$p_{\Sigma^+} \text{ (Mev/c)}$ $p_{\text{decay particle}} \text{ (Mev/c)}$
	275_{-50}^{+75}	243 ± 12	275_{-50}^{+75} 360 ± 30
	500 ± 150	285 ± 15	500 ± 150 400 ± 100

LEGENDS

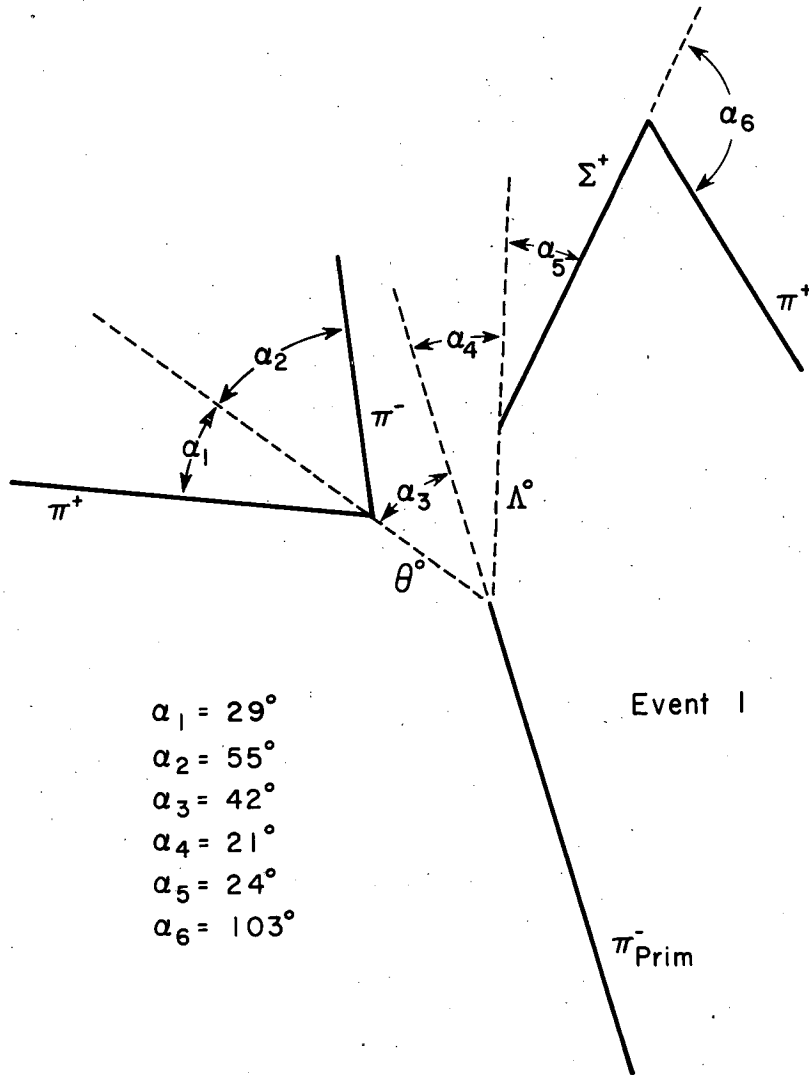
- Fig. 1. Photograph of Event 1.
- Fig. 2. Photograph of Event 2.
- Fig. 3. Schematic diagram of Event 1.
- Fig. 4. Schematic diagram of Event 2.



ZN-1756

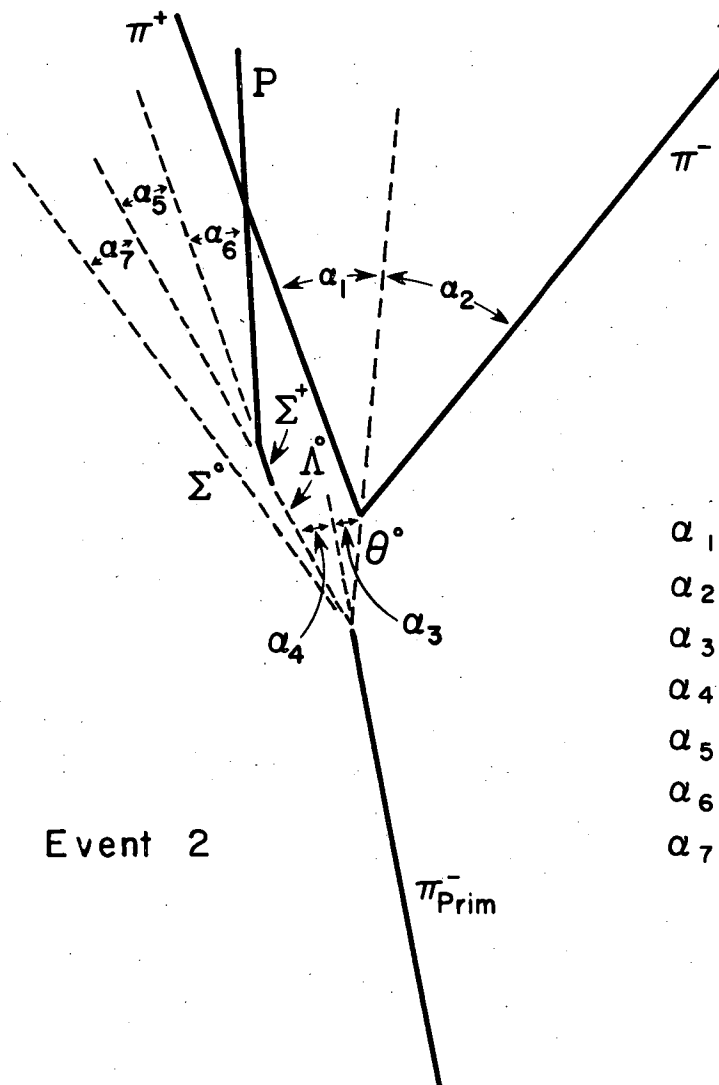


ZN-1757



- $\alpha_1 = 29^\circ$
- $\alpha_2 = 55^\circ$
- $\alpha_3 = 42^\circ$
- $\alpha_4 = 21^\circ$
- $\alpha_5 = 24^\circ$
- $\alpha_6 = 103^\circ$

Event I



- $\alpha_1 = 30^\circ$
- $\alpha_2 = 58^\circ$
- $\alpha_3 = 28^\circ$
- $\alpha_4 = 13^\circ$
- $\alpha_5 = 9^\circ$
- $\alpha_6 = 27^\circ$
- $\alpha_7 = 4^\circ$

Event 2