

DETECTION OF A CUSP IN $\Lambda^0 K^0$ PRODUCTION AT $\Sigma^- K^+$ THRESHOLD

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(presented by F. Solmitz)

Preliminary results from a 72-inch hydrogen chamber experiment now in progress suggest a cusp behavior for the reaction $\pi^- + p \rightarrow K^0 + \Lambda^0$ at 1034 MeV/c, the threshold for production of $\Sigma^- K^+$. Since our observed effect has a sharp momentum dependence, we will first discuss our momentum resolution.

The pion beam incident on the chamber has a momentum spread calculated from the geometry to be ± 1.5 MeV/c (rms). In passing through the chamber windows and hydrogen to the center of the chamber an additional momentum spread of about ± 3 MeV/c is introduced through delta-ray production (Landau effect). In order to check the initial ± 1.5 MeV/c we reversed our magnetic fields so as to accept positive particles and tuned our parallel-plate mass spectrometer so as to accept protons of the same momentum as the pions. Enough copper absorber (about 6.5 inches) was then placed in front of the chamber so that protons stopped in the middle of the chamber. (The Landau straggling is negligible for protons.) The proton range distribution, based on 570 stopping protons, fits a gaussian with rms half width of 0.57 ± 0.02 gm/cm² of hydrogen. (The total proton range corresponds to 55 gm/cm² of hydrogen.) If there were no range straggling this would correspond to ± 4.7 MeV/c beam spread. However the calculated straggling is ± 0.56 gm/cm². Our proton range curve is thus consistent with a monoenergetic beam, and also with ± 1.5 MeV/c, within the errors.

We next consider the Landau straggling of energy loss of the pions. The pions can produce delta rays

of up to 60 MeV. The average number of delta rays of more than 1 MeV kinetic energy is 1.5, in passing through 1 inch of plastic scintillator, $1/4$ inch of stainless steel windows, and 100 cm of hydrogen. The energy loss due to delta rays in the visible part of the hydrogen can be eliminated, by measuring the delta rays. (A 1 MeV delta ray makes 4 turns, independent of dip.) This has not yet been done. The distribution of pion energy loss was calculated in two ways. First by a Monte Carlo method, using the known δ -ray production cross sections; second, through curves contained in K. Symon's thesis¹⁾. The two methods agree. Fig. 1 shows the result from Symon's thesis. If half a Gaussian were fit to the leading edge, the rms half width would be about 1.9 MeV/c.

The position of $\Sigma^- K^+$ threshold in the chamber was determined to within ± 2 cm by fitting an $E^{\frac{1}{2}}$ threshold S-wave dependence (folded with a Gaussian corresponding to the beam width) to the $\Sigma^- K^+$ production. (One centimeter corresponds to 0.23 MeV/c momentum loss for the incident pions.) We have not as yet tried similarly to locate the $\Sigma^0 K^0$ threshold in the chamber. According to current mass values, the threshold momentum for $\Sigma^0 K^0$ production is lower than that for $\Sigma^- K^+$ by 1.0 ± 1.4 MeV/c, corresponding to 4.4 ± 6 cm of hydrogen.

Fig. 2 shows the $\Lambda^0 K^0$ production angular distribution in three regions of the chamber: a 10 cm region just above threshold, a 5 cm region including threshold, and a 10 cm region just below threshold. Fig. 3 shows the corresponding backward to forward production. The large backwards peaking of Λ^0 's evident

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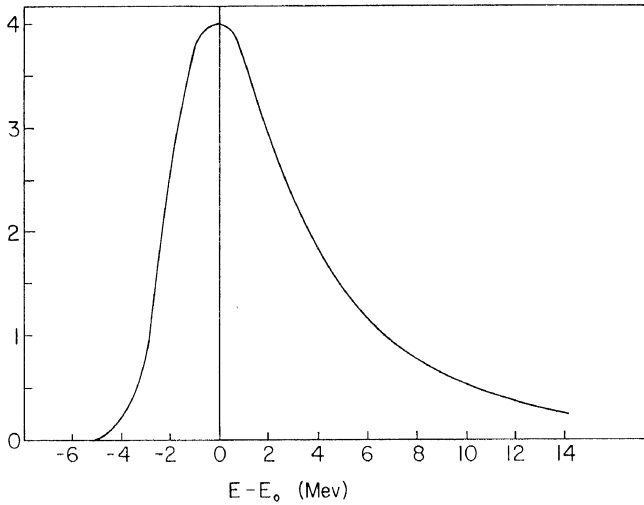


Fig. 1 Landau straggling, theoretical probability distribution for $(E-E_0)$. (E = energy loss, E_0 = most probable energy loss.)

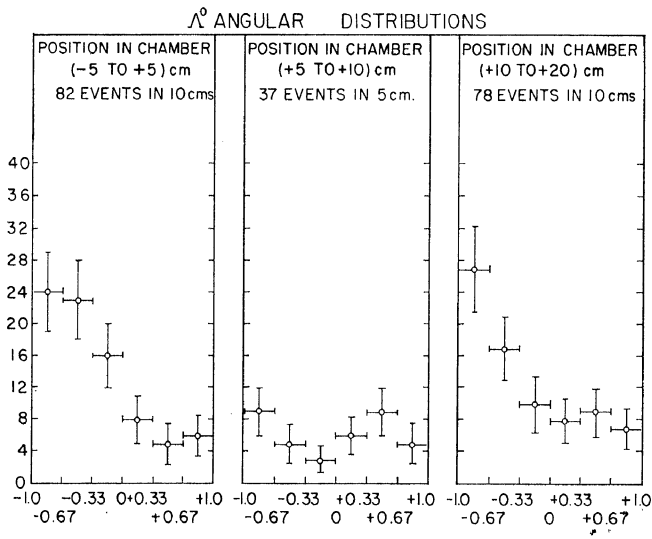


Fig. 2 Center of mass angular distributions of Λ^0 for three momentum intervals of the incident π^- around Σ^- threshold.

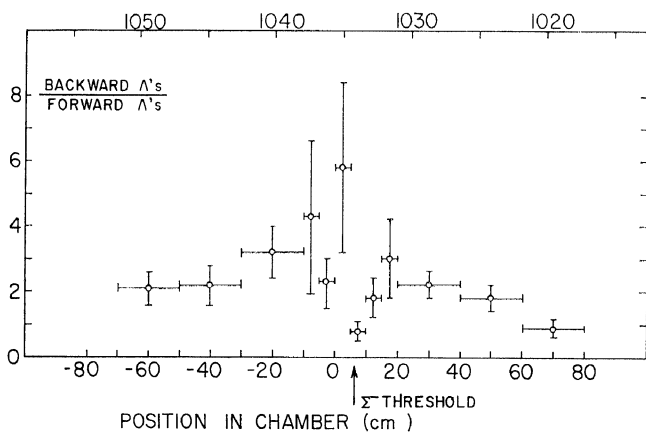


Fig. 3 Ratio of backward to forward produced Λ^0 's (in center of mass system) as a function of the incident pion momentum (finer intervals).

above and below threshold (and also, as is well known, at all other energies that have been observed for this process) is not present at threshold. Since our calculated momentum resolution does not seem to warrant 5 cm (1.2 MeV/c) intervals, we repeat these curves, and give the remaining curves, for 10 cm intervals. Fig. 4 shows the $\frac{\text{backward } \Lambda^0}{\text{forward } \Lambda^0}$ ratio.

Fig. 5 shows $\alpha\bar{P}$, the Λ^0 decay asymmetry with respect to the production plane, versus position in the chamber. Both the production and the decay asymmetry show rapid variation at threshold, outside of statistics.

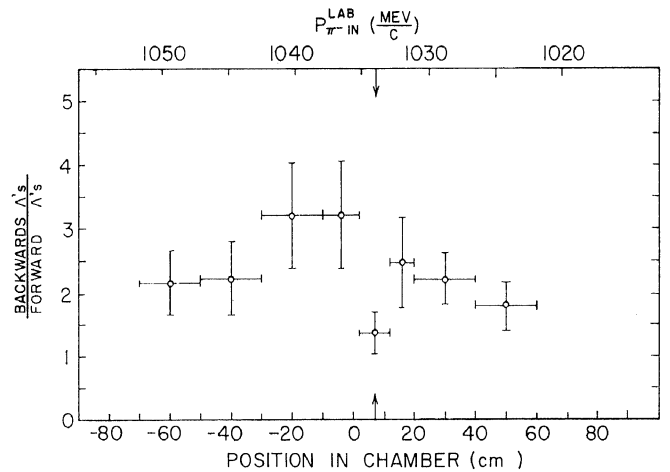


Fig. 4 Ratio of backward to forward produced Λ^0 's (in center of mass system) as a function of the incident pion momentum (broader intervals).

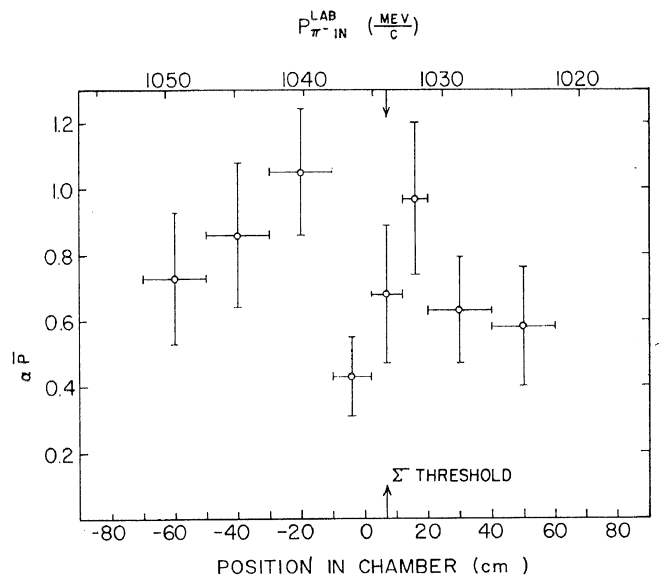


Fig. 5 $\alpha\bar{P}$ as a function of the incident pion momentum.

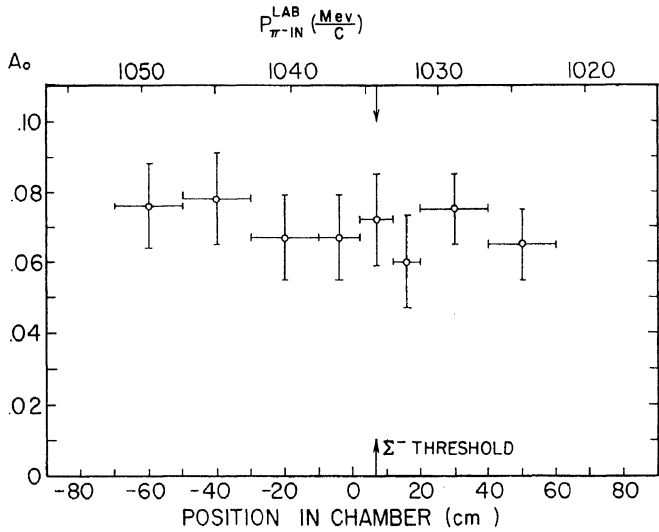


Fig. 6 A_0 as a function of the incident pion momentum.

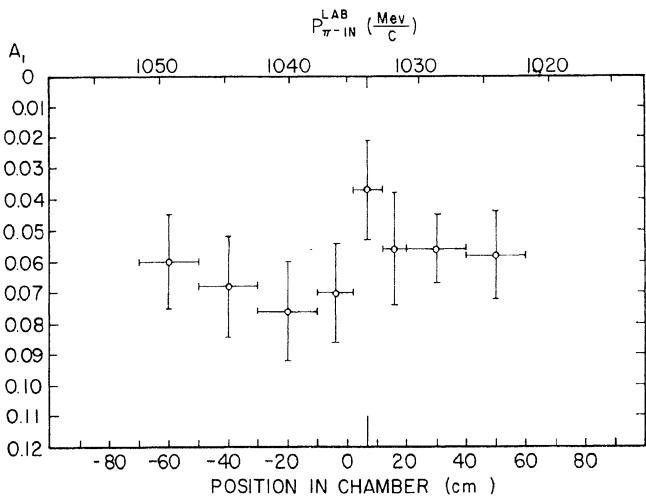


Fig. 7 A_1 as a function of the incident pion momentum.

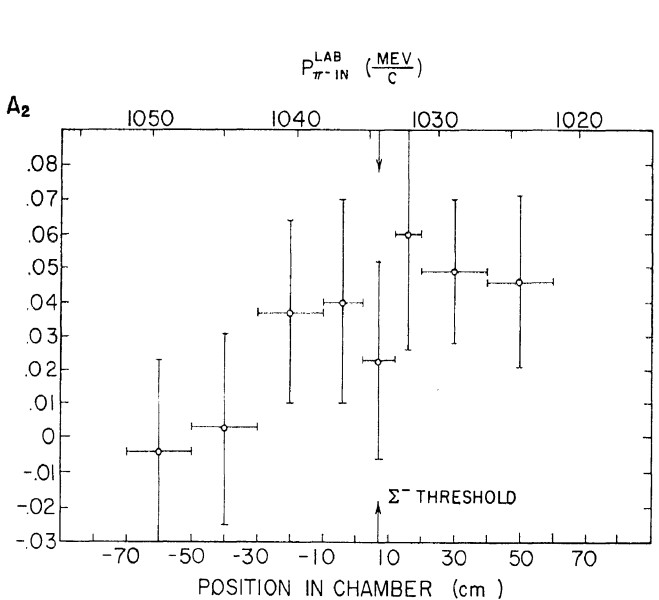


Fig. 8 A_2 as a function of the incident pion momentum.

The angular distribution for production and decay has been fit by the maximum likelihood method to the expression :

$$d^2N = \frac{d\mu}{2} \frac{d\xi}{2} [A_0 + A_1\mu + A_2\mu^2 + \alpha\xi(1-\mu^2)^{\frac{1}{2}}(A_3 + A_4\mu)].$$

Here μ is the cosine of the c.m. production angle and ξ is the cosine of the decay pion with respect to the direction $\mathbf{P}_{\pi_{inc}} \times \mathbf{P}_A$. The coefficients A_0 through A_4 are plotted versus position in the chamber in Figs. 6, 7, 8, 9, 10. The $\Sigma^- K^+$ threshold is at $y = \pm 7$ cm.

Baz and Okun²⁾ show that one can determine the relative $\Lambda^0 \Sigma$ parity if one can measure the "cusp"

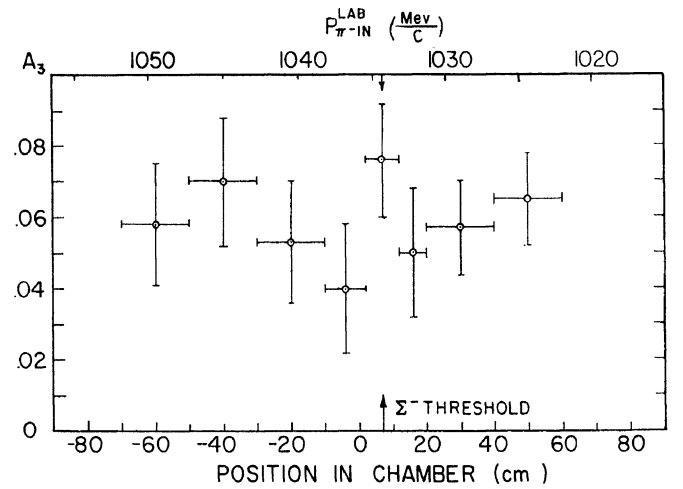


Fig. 9 A_3 as a function of the incident pion momentum.

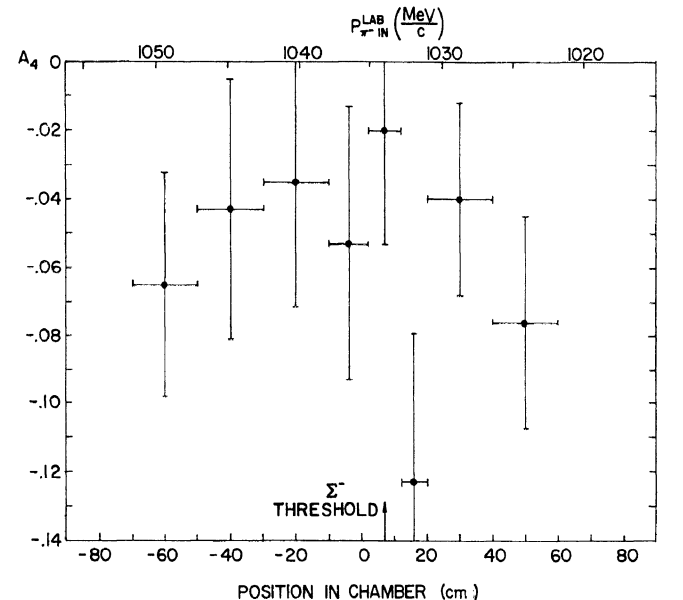


Fig. 10 A_4 as a function of the incident pion momentum.

contributions: terms linear in the c.m. momentum difference from threshold. It is necessary to assume that the Σ 's are produced in S -states. Our results for $\Sigma^- K^+$ production indicate that this condition is satisfied, at least for real production. The results of Baz and Okun are that for either sign of the relative parity, A_0, A_1 in the production angular distribution, and A_3 in the polarization angular distribution should show anomalous behavior at Σ threshold. The $\cos^2\theta$ term A_2 , in the angular distribution, and the $(\sin\theta)(\cos\theta)\xi$ term, A_4 , in the polarization, will have an anomalous behavior only if the relative parities are odd. Our results indicate anomalous behavior in A_1 and A_3 , and perhaps also in A_2 and A_4 . However, even aside from statistical uncertainties in A_2 and A_4 , we are not prepared to claim that this shows that the relative parity is odd. First, only terms linear in k , the momentum difference from threshold, should be used in determining the parities. (For instance terms in k^2 could arise from P -wave Σ 's). With our present statistics we cannot separate out the linear

terms. Second, in the immediate vicinity of threshold we may be seeing a very complicated superposition of the separate cusps from the $\Sigma^0 K^0$ and $\Sigma^- K^+$ thresholds, if these are in fact separated by 1 or 2 MeV/c. At distances far enough on either side of threshold we can consider the average contribution from both thresholds, and can then hope to determine the relative parities.

At the time of writing we have not yet analyzed the angular distributions for production and decay into partial waves.

The total cross section shows no anomalous behavior, within statistics, at Σ threshold.

The production angular distribution and decay asymmetry angular distribution, averaged over the entire chamber, are shown in Figs. 11 and 12.

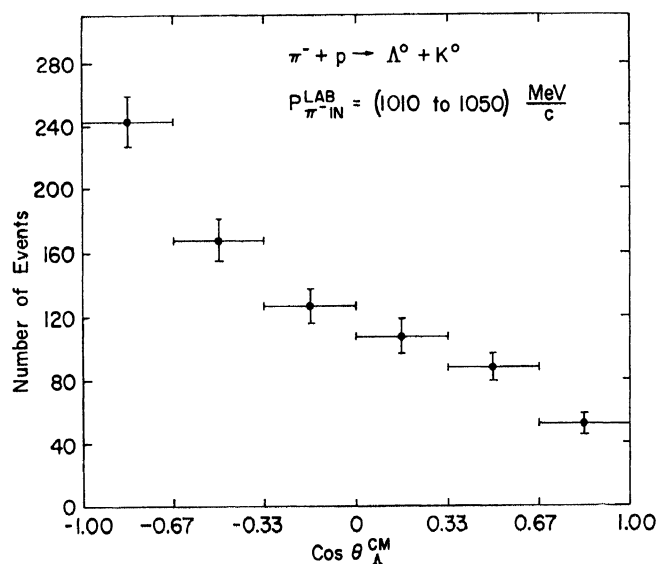


Fig. 11 Average center of mass angular distribution of Λ^0 .

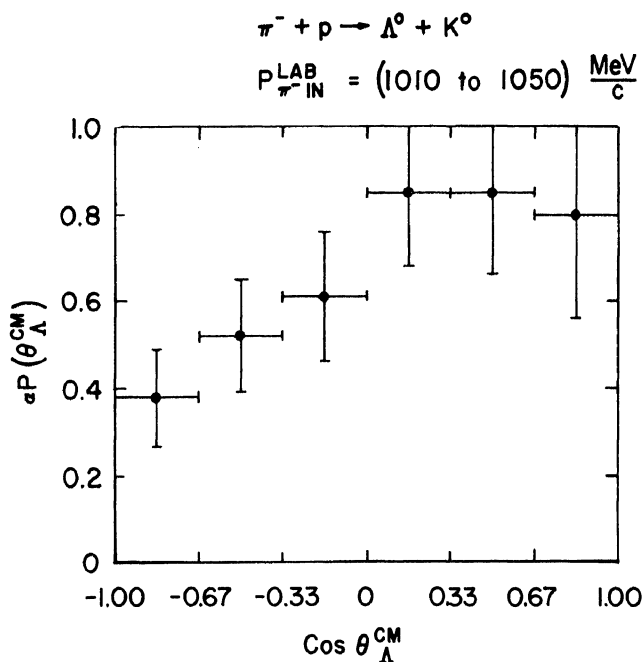


Fig. 12 $aP(\theta)$ as a function of the center of mass angle of Λ^0 .
 Note added in proof: In fig. 12 the point at $\cos\theta = +0.17$ now has the value $aP = 1.13$.

LIST OF REFERENCES

1. Symon, K. R. Thesis, Harvard University, January (1948).
2. Baz, A. N. and Okun, L. B. Soviet Phys. JETP 8, p. 526 (1959).