indications have been found in both reactions at 1100 Mev.[2]

The spectra show marked evidence for the presence of the $\frac{3}{2}$, $\frac{3}{2}$ resonance.[2–7] Peierls has shown how a mixture of nucleon-isobar and pion-pion states might account for the branching ratio at 960 Mev.[13] Carruthers has made an extensive analysis of the relations between pion-pion interactions and nucleon isobars, in which the $T=\frac{3}{2}$ state as well as the $T=\frac{1}{2}$ state is included, but up to the present date these relations have not yielded calculable branching ratios.[14]

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[13] R. F. Peierls, Phys. Rev. Letters **5**, 166 (1960).

[14] P. Carruthers (private communication).

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Progress Report on an Experiment to Study Lambda^0-K^0 Production at Sigma-K Threshold*

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I. INTRODUCTION

Baz and Okun[1] and, independently, Adair[2] have pointed out that a cusp phenomena, the nature of which was first investigated by Wigner,[3] should occur in the amplitude for the process $\pi^-+p\rightarrow\Lambda^0+K^0$ at the threshold for the threshold for the process $\pi^-+p\rightarrow\Sigma+K$.

If one assumes that $\Sigma-K$ production starts out in the s wave, then one can write the S matrix, above $\Sigma-K$ threshold, connecting states with $J=\frac{1}{2}$, $I=\frac{1}{2}$, and parity$=P(\Sigma K)$ as (in the notation of Baz and Okun)

$$S=\begin{array}{c|cccc} & \pi^--p & \Lambda^0-K^0 & \cdots & \Sigma-K \\ \hline \pi^--p & S_{11} & S_{12} & \cdots & m_1k^{\frac{1}{2}} \\ \Lambda^0-K^0 & S_{21} & S_{22} & \cdots & m_2k^{\frac{1}{2}} \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \Sigma-K & m_1k^{\frac{1}{2}} & m_2k^{\frac{1}{2}} & \cdots & x \end{array},$$

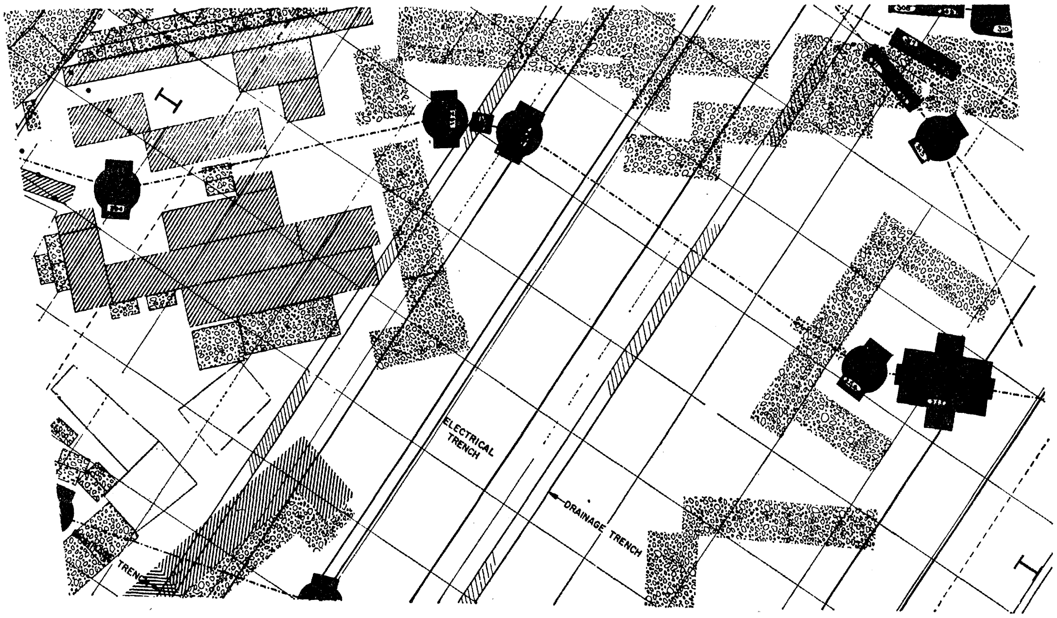

Fig. 1. Beam setup for experiment.

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* Presented by M. Schwartz.

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[1] A. N. Baz and L. B. Okun, Soviet Phys.—JETP **8**, 526 (1959).

[2] R. K. Adair, Phys. Rev. **111**, 632 (1958).

[3] E. P. Wigner, Phys. Rev. **73**, 1002 (1948).

where $S_{ij}=S_{ji}$, $k=(E-E_0)^{\frac{1}{2}}$, and E_0 is the threshold energy.

The requirement of unitarity implies that the elements S_{ij} must have a behavior $S_{ij}=S_{ij}^0+a_{ij}k$ just above the threshold. In order that the amplitude be analytic, we see that S_{ij} below threshold must be of the form $S_{ij}=S_{ij}^0\pm ia_{ij}K$, where $K=(E_0-E)^{\frac{1}{2}}$. The choice of sign comes from the requirement that the outgoing $\Sigma-K$ wave above threshold must become an exponentially damped wave below threshold. In other words,

$$e^{ikr}/r\longrightarrow e^{-Kr}/r$$

implies that S_{ij} below threshold $=S_{ij}^0+ia_{ij}K$.

Hence, the effect of the new threshold is to make all connected amplitudes undergo a 90° left turn at that point. The applicability of this is clear. Inasmuch as only states of the same parity are connected, a knowledge of which Λ^0-K^0 amplitude has this left turn immediately gives us the relative parity of Λ^0 and Σ. For example, if a cusp is observed in the outgoing $S_{\frac{1}{2}}$ Λ^0-K state, the relative $\Lambda-\Sigma$ parity is even. If the cusp is observed in the $p_{\frac{1}{2}}$ $\Lambda-K$ state, then the relative $\Sigma-\Lambda$ parity is odd.

II. PROCEDURE IN THE EXPERIMENT

The procedure is as follows:

(1) Study $\Sigma-K$ production at threshold to ensure that the s wave predominates. This has already been done by the Berkeley group[4] and it seems safe to say that this condition is fulfilled.

(2) Study $\Lambda-K$ production over a region spanning the cusp and isolate the various angular momentum states involved by measuring the angular distribution and polarization of the process.

(3) Plot the $s_{\frac{1}{2}}$ and $p_{\frac{1}{2}}$ amplitudes and observe which has a discontinuous behavior.

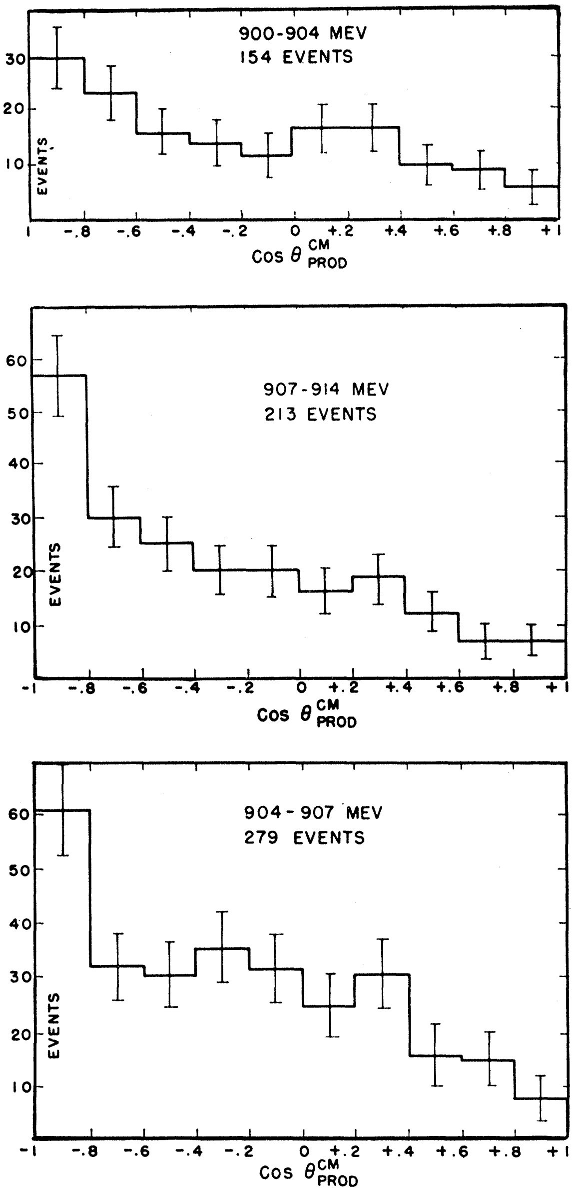
III. MINAMI AMBIGUITY

The foregoing prescription would be straightforward were it not for the Minami ambiguity. As it turns out, one can get an equally valid set of solutions by reversing the parity of each amplitude. Hence, without additional dynamical assumptions, it is impossible to demonstrate rigorously which state has the cusplike behavior.

Normally one might avoid this difficulty by cutting off at some highest orbital angular momentum. However, in this case as we soon see, this becomes somewhat more tenuous because of the seemingly resonant behavior of the total $\Lambda-K$ cross section in the vicinity of the cusp.

IV. EXPERIMENTAL DETAILS

1. Beam setup. Technically, the heart of the experiment is the beam setup. It is essential to have a resolution of the order of ±0.1%. The setup used is shown in Fig. 1. Wire measurements made of various magnet orbits after shimming indicate that the magnets are at least that good. Vacuum pipe was used for all but the last 8 ft of beam. Most of the energy spread is then given by the target width and would seem to be ~±1 Mev.



ENERGY	NO. OF EVENTS	BACKWARD / FORWARD	$\alpha\bar{P}$
900-904	154	1.61 ± .22	.44 ± .16
904-907	279	2.10 ± .18	.47 ± .13
907-914	213	2.51 ± .25	.61 ± .14

Fig. 2. Summary of results.

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[4] M. H. Alston, J. A. Anderson, P. G. Burke, D. D. Carmony, F. S. Crawford, Jr., N. Schmitz, and S. E. Wolf, Proc. Ann. Rochester Conf. High Energy Phys. 10, (1960).

2. Fiducial region in the chamber. In analyzing the pictures, events occurring in the last 5 cm of the chamber were excluded to avoid having to make large efficiency corrections.

3. Energy calibration. Two groups of data were taken, differing by 5 Mev. Calibration was made by wire measurement, by observing the rise of the $\Sigma-K$ cross section, and from accurate measurement on the events themselves. Each event was assigned an energy according to its position in the chamber.

V. RESULTS

Approximately 100 000 pictures were taken, yielding events. These events were analyzed to determine center of mass, production angle, and Λ^0 decay asymmetry angle. The results are summarized in Fig. 2.

For simplicity, the data was broken into three energy groups. For reference, the threshold occurs at about 902 Mev. Unfortunately, we have data only above 900 Mev to report at the present moment.

The first point is that the angular distributions are not easily fit by just s and p waves. The difficulty for the most part lies in the disproportionately large number of events in the backward 10% of solid angle. In fact, if the two groups of higher energy data are combined, then the best fit to $A+B\cos\theta+C\cos^2\theta$ is about three standard deviations from the observed distribution.

The total $\Lambda-K$ cross section at this point is quite high—in fact, 50% higher than it is at 960 Mev. Also, there is a resonance in the total $\pi^- - p$ cross section at 900 Mev which is known to have total angular momentum $\frac{5}{2}$. If the magnitude of the $\Lambda-K$ cross section is substantially influenced by this resonance, then one might expect appreciable $\cos^3\theta$ and $\cos^4\theta$ contribution. We return to the implications of this conjecture shortly.

TABLE I. Summary of possible deductions from experiment [assume $P(K)=+$].

$P(\Lambda)$	Resonant $\Lambda-K$ state	State having cusp	$P(\Sigma)$
	Case 1. Resonant $\pi-p$ state is $d_{\frac{5}{2}}$		
$+$	$f_{\frac{5}{2}}$	$s_{\frac{1}{2}}$	$+$
$-$	$d_{\frac{5}{2}}$	$p_{\frac{1}{2}}$	$+$
	Case 2. Resonant $\pi-p$ state is $f_{\frac{5}{2}}$		
$+$	$d_{\frac{5}{2}}$	$p_{\frac{1}{2}}$	$-$
$-$	$f_{\frac{5}{2}}$	$s_{\frac{1}{2}}$	$-$

There is a considerable flattening out of the angular distribution in the immediate vicinity of the threshold. This is best illustrated by noting the change in the backward-forward ratio as a function of energy. The difference between the highest energy group and the threshold group is ~ two standard deviations.

Finally, there seems to be some sign of decreasing polarization in the neighborhood of the threshold.

VI. HOPES FOR THE FUTURE

At present the foregoing data are being quadrupled, so it is hoped that much of it will become statistically more reliable. However, it is not useless to speculate on the path the experiment seems to be taking.

If we assume that the appreciable $\cos^3\theta$ contribution is really there then one can ask two questions.

(1) Is there a cusp in the $\cos^3\theta$ term?

(2) Are the $\cos^3\theta$ and $\cos^4\theta$ terms contributed for the most part by one $\Lambda-K$ state with the same quantum numbers as the resonant $\pi-p$ state at 900 Mev?

If the answer to both questions is affirmative, then we can summarize the possible deductions from the experiment (see Table I).

DISCUSSION

G. F. Chew, *University of California, Berkeley, California:* Yesterday we heard evidence that perhaps this πp resonance is a mixture and not a pure state. Have you worried about that sort of thing?

M. Schwartz: If it is a mixture of two states both of which have isotopic spin $\frac{1}{2}$, then it fouls up the experiment. If you ask me which I would prefer, I would prefer that this be a $D_{\frac{5}{2}}$ state instead of an $F_{\frac{5}{2}}$ state only because it is somewhat more difficult to overcome the angular momentum barrier in an $F_{\frac{5}{2}}$ state. If I believe that, then I have an odd parity. All this is extremely tentative.

B. J. Moyer, *University of California, Berkeley, California:* I want to reaffirm what I said yesterday about the mixture. Our data calls for D and F. But the D which is present may be a $T=\frac{3}{2}$ state at about 800 Mev. The F is in $T=\frac{1}{2}$, so that you may still be saved with a pure state so far as the $T=\frac{1}{2}$ is concerned.

R. K. Adair, *Brookhaven National Laboratory, Upton, New York:* With respect to the idea of assigning this to an F state, rather elementary calculations concerning the angular momentum barrier suggests that the particle width for production would not be much greater than 1 Mev.

A 1-Mev partial width would not allow more than about 1% of the interaction to go into this state and this would not seem to be in agreement with the results. Now, any penetration barrier argument depends on where you assign the radius, and if you assign quite a large radius this difficulty somewhat dissolves, but I think it is in general still quite difficult to think that this is primarily an F state.