TABLE IV. Adair distributions for spins $\frac{1}{2}$, $\frac{3}{2}$, and $\frac{5}{2}$, for S and P wave production. $I(\theta)$ is the differential cross section for Y_1^* production. D is a P-wave coefficient. $|D|^2 \sin^2\theta \leq I(\theta)$.

Spin	Distribution
$\frac{1}{2}$	1
$\frac{3}{2}$	$(1+3z^2)+\dfrac{2\|D\|^2\sin^2\theta}{I(\theta)}(1-3z^2)$
$\frac{5}{2}$	$(1-2z^2+5z^4)-\dfrac{\|D\|^2\sin^2\theta}{2I(\theta)}(1-18z^2+25z^4)$

are given in Table IV. The measured distributions are consistent with the theoretical for spin $\frac{3}{2}$ since P waves are not excluded in the production process. (For pure S wave, $D=0$, and our results would not be consistent with $\frac{3}{2}$.) For spins higher than $\frac{3}{2}$, the Adair distribution becomes more difficult to wash out with P-wave admixture; for $\frac{5}{2}$, it is quite asymmetric at any production angle, or averaged over any production-angle interval. We have examined the consistency of our data with spin $\frac{5}{2}$ by computing likelihood functions over the range of possible $\frac{5}{2}$ distributions. We find that, for the equatorial range $0.5 > |\cos\theta| \geq 0$, the highest likelihood $\frac{5}{2}$ distribution has $\frac{1}{10}$ the probability of the $\frac{3}{2}$ distribution.

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ΛK^0 and $\Sigma^0 K^0$ Production in 1.5-BeV/c $\pi^- p$ Interactions*

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476 ΛK^0 and 134 $\Sigma^0 K^0$ events have been investigated in the experiment 1.508 BeV/c $\pi^- p \rightarrow \Lambda K^0$ and $\Sigma^0 K^0$. The Λ is produced mostly backward in the center of mass and has an average polarization (-0.76 ± 0.14). The production and polarization angular distributions are well fit with *spd* waves. The total ΛK^0 production cross section is $(214+23)$ μb. The Σ^0 production angular distribution has a small backward peak and an indication of a forward rise; it is consistent with either *sp* or *spd* waves. The statistics are too poor to measure the Σ^0 polarization.

INTRODUCTION

THERE has been a considerable amount of data collected on the associated production reaction[1–9]

$$\pi^- + p \rightarrow K^0 + \Lambda. \tag{1}$$

Most of it has been obtained with pion momenta <1250 MeV/c. The published data on the reaction

$$\pi^- + p \rightarrow K^0 + \Sigma^0, \quad \Sigma^0 \searrow \Lambda + \gamma \tag{2}$$

* Supported by the U. S. Atomic Energy Commission.

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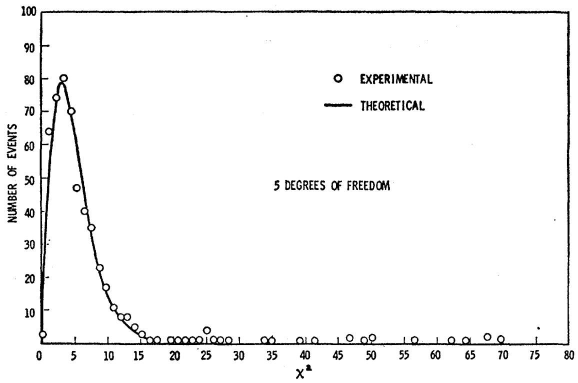

FIG. 1. χ^2 distribution for the ΛK^0 events.

are much more limited.[1,2,4–7,10] This paper describes an investigation of reactions (1) and (2), which were produced in a spark chamber experiment at the Cosmotron. The pion momentum was 1.508 BeV/c. The experiment and the analysis methods have been discussed elsewhere[11] and are just summarized here. Results are presented on the differential cross sections of Λ and Σ^0 and on the polarization of the Λ.

EXPERIMENT AND ANALYSIS

Reactions (1) and (2) were produced by a π^- beam in a liquid-hydrogen target; the Λ and the K^0 from both reactions were observed by their decays in a counter triggered thin foil spark chamber. There was no magnetic field and no attempt to convert gamma rays. The kinematics of the reactions were determined just from the directions of the π^-, Λ, K^0, and the charged secondaries, and the momentum of the π^-, with ionization information from spark densities being used to resolve any ambiguities in Λ and K^0 identification. A spectrum of the missing mass M_{X^0} in the reaction

$$\pi^- + p \rightarrow K^0 + X^0, \qquad (3)$$

showed well resolved Λ, Σ^0, and $(Y_1^*)^0$ peaks. A correction of the incoming pion momentum from the hot wire measurement 1.500 to 1.508 BeV/c put the Λ and Σ^0 peaks at their accepted values. After identification the events were best fit. The ΛK^0 events had five constraints (four kinematic and one spatial reconstruction), the $\Sigma^0 K^0$ had three (two plus one). Due to measurement errors there was no real information on the direction of the decay Λ in the Σ^0 center of mass. A χ^2 distribution plot for the ΛK^0 events is shown in Fig. 1. The cutoff was taken at a χ^2 probability of 1%.

Events in the overlap region between the Λ and Σ^0 on the X^0 mass distribution ($1.150 \leq M_{X^0} \leq 1.170$) were remeasured to see if they fell into either group; if they did not, they were not used. The events also had to be consistent with the ionization measurements to be acceptable. 476 Λ and 134 Σ^0 events survived all the criteria. No events remained from the background run with the liquid hydrogen out; (it was $\frac{1}{5}$ the length of the hydrogen run). However, from the χ^2 distributions we estimate that 1% of the Λ events and 2% of the Σ^0 events were background. From the X^0 mass spectrum the contamination of the Λ events from the Σ^0's (from outside the assumed overlap region) is less than 1% and the contamination of the Σ^0's from the Λ's is less than 4%. For the purpose of correcting the cross sections, the 20 events remaining in the overlap region were presumed divided, 5 as Λ and 15 as Σ^0, using information from the X^0 mass plot and the measured χ^2's. Other corrections, as for the probability of seeing the decays in the chamber, are similar to those discussed in Ref. 11.

RESULTS

ΛK^0 Events

The center-of-mass differential cross section for production of the Λ in reaction (1) is shown in Fig. 2. The usual backward peaking of the Λ is very strongly evident here. (The experimental data are cut off in the forward Λ direction because the K^0 goes at too large an angle in the laboratory and cannot decay in the chamber.) Curves were least-squares fit to the data, assuming sp and spd wave production. In the region $\cos\theta \geq 0.5$ the fitted curve was weakly constrained to be approximately flat. The curve plotted is the spd best fit, because sp waves give poor agreement with the polarization data (see Table III). The parameters of the sp and spd fitted curves are listed in Table I, along with the total cross section from the spd curve. This total cross section is consistent with a smooth extension of the results from other experiments, as indicated in Fig. 3.

The direction of the decay pion in the Λ center of

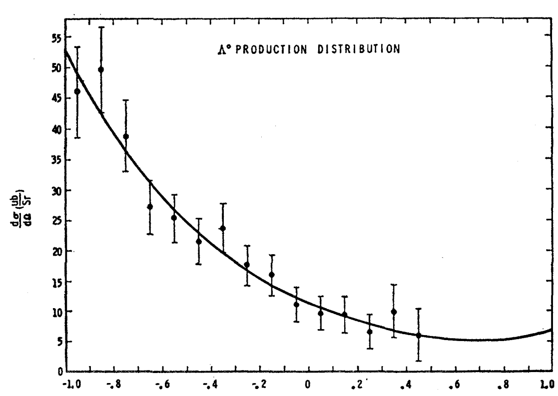

FIG. 2. Differential cross section for ΛK^0 production. Here $\cos\theta = \hat{\Lambda} \cdot \hat{\pi}_{\text{beam}}$. Coefficients for the fitted spd wave curve are given in Table I.

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TABLE I. ΛK^0 production cross section. $d\sigma/d\Omega=\Sigma_n A_n \cos^n\theta(\mu\text{b/sr})$, $\cos\theta=\hat{\Lambda}\cdot\hat{\pi}$.

Partial waves	σ_{tot} (μb)	A_0	A_1	A_2	A_3	A_4	χ^2 Probability
sp		11.2±1.2	−20.0±2.6	17.5± 4.5			97%
spd	214±23[a]	11.4±1.4	−17.7±4.7	14.5±14.9	−5.5±7.9	4.0±17.7	93%

[a] From the extended curve.

mass was obtained by a relativistic transformation from the laboratory to the production center of mass, then to the Λ center of mass. A plot of the distribution, in the Λ center of mass, of the Λ decay pions with respect to the original beam direction is presented in Fig. 4. The cross-hatched region represents the calculated number of events missed due to decay back through the anticoincidence counter. Values of $\alpha\bar{P}_j$ for the three directions are given in Table II. There is no significant fore-aft

TABLE II. $\alpha\bar{P}_j$ for Λ decay. Computed from $\alpha\bar{P}_j=(3/N)\,\Sigma_{i=1}{}^N\,\xi_{ij} \pm(3/N)^{1/2}$, $\xi_{ij}=\hat{\pi}_i\cdot\hat{j}$, $\hat{z}=\hat{\pi}_{\text{beam}}$, $\hat{x}=(\hat{z}\times\hat{\Lambda})/|\hat{z}\times\hat{\Lambda}|$, $\hat{y}=(\hat{z}\times\hat{x})$.

Direction (j)	$\alpha\bar{P}_j$
Up-down (x)	0.47±0.08
Right-left (y)	−0.05±0.08
Fore-aft (z)	−0.01±0.08

or right-left polarization, in agreement with conservation of parity in the production process. There is strong average polarization in the downward direction, $\bar{P}_x=(-0.76\pm0.14)$ [taking $\alpha=(-0.62\pm0.05)$ from the experiment of Cronin and Overseth].[12]

The up-down polarization times the differential cross section is given by the expression

$$P(\theta)d\sigma/d\Omega=2\sin\theta\sum_n S_n\cos^n\theta\,, \tag{4}$$

where the sum goes from 0 to 1 for *sp* waves,[13] and 0 to 3 for *spd* waves. The coefficients in this expansion for *sp* and *spd* waves, obtained by a least squares fit, are given in Table III. The data for the function

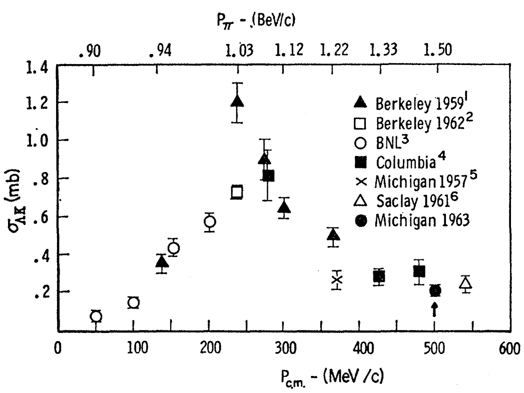

FIG. 3. Compiled experimental results on total cross sections for ΛK^0 production as a function of center-of-mass momentum of the Λ.

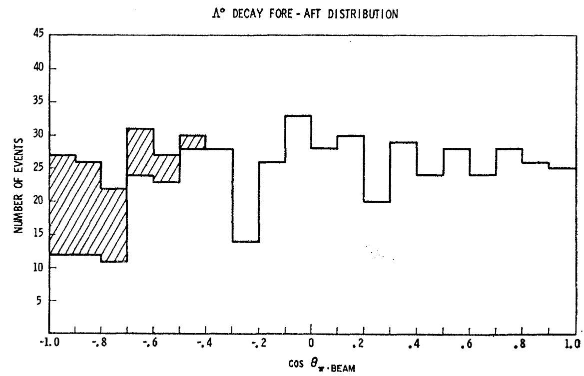

FIG. 4. Distribution of the pions from Λ decay with respect to the beam direction, in the Λ center-of-mass system. The shaded events are the calculated corrections for pions going backward through the anticoincidence counter.

TABLE III. Expansion coefficients for $P(\theta)(d\sigma/d\Omega)(2\sin\theta)^{-1}$. Coefficients defined in Eq. (4).

Partial waves	S_0	S_1	S_2	S_3	χ^2 Probability
sp	0.9±1.7	30.2±5.7			4%
spd	3.1±2.4	10.2±9.0	−31.8±35.7	35.4±51.7	64%

$P(\theta)(d\sigma/d\Omega)(2\sin\theta)^{-1}$ and the fitted curve are shown in Fig. 5. The experimental data for $\alpha P(\theta)$ and its fitted

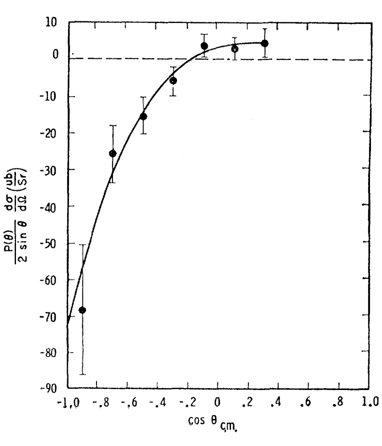

FIG. 5. Plot of $P(\theta)(d\sigma/d\Omega)(2\sin\theta)^{-1}$. Expansion coefficients for the fitted *spd* curve are given in Table III.

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TABLE IV. $\Sigma^0 K^0$ production cross section. Terms as defined in Table I.

Partial waves	$\sigma_{\mu b}$	A_0	A_1	A_2	A_3	A_4	χ^2 Probability
sp		4.0±0.8	14.2±3.3	28.0± 5.0			42%
spd	83±12[a]	4.8±1.0	10.0±5.3	8.5±11.8	8.2±36.1	32.5±33.0	92%

[a] A partial cross section over the region $-1 \leq \cos\theta \leq 0.6$. A crude estimate based on extending the *spd* fitted curve to $\cos\theta = 1.0$ gives $\sigma_{total} = 177\ \mu b$.

curve, obtained from the above *spd* fit and Eq. (4), are presented in Fig. 6. The values of αP for the backward Λ's are large, although still consistent with the α of Cronin and Overseth, indicating a polarization in that angular region of nearly 100%.

$\Sigma^0 K^0$ Events

The differential cross section for production of the Σ^0 in reaction (2) is shown in Fig. 7. There is some backward peaking of the Σ^0, like the Λ, and the apparent beginnings of a strong forward peak, which unfortunately is missed due to the experimental cutoff. The curve is the *spd* fit; the *sp* curve is also consistent. The coefficients for both are listed in Table IV.

The polarization of the Σ^0 can be studied by investigating the polarization of its decay Λ, for[14]

$$\bar{P}_{\Sigma^0} = -3\bar{P}_\Lambda. \tag{5}$$

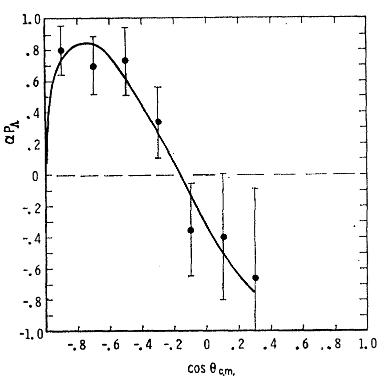

FIG. 6. $\alpha P(\theta)$ for Λ decay. The curve is obtained from the *spd* wave fit of Eq. (4).

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Measured values of $(\alpha\bar{P}_\Lambda)_j$ are given in Table V. The appreciable value of $\alpha\bar{P}_z$ is still consistent with zero, with the large statistical error. Also, the low measured value of $\alpha\bar{P}_x$ does not preclude a large Σ^0 polarization

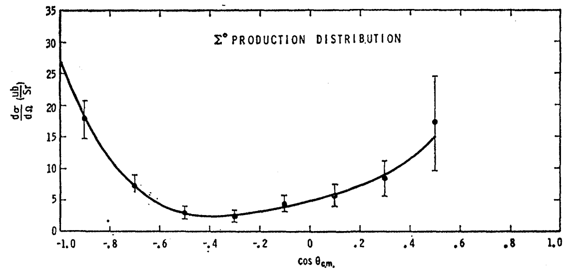

FIG. 7. Differential cross section for $\Sigma^0 K^0$ production. Here $\cos\theta = \hat{\Sigma}^0 \cdot \hat{\pi}_{beam}$. Coefficients for the fitted *spd* curve are given in Table IV.

because of the factor of 3 from Eq. (5) and α; together these give $(\bar{P}_{\Sigma^0})_x = (-0.39 \pm 0.67)$, which says little about the Σ^0 polarization.

TABLE V. $\alpha\bar{P}_j$ of the decay Λ from the Σ^0. Terms as defined in Table II, except $\hat{x} = (\hat{z} \times \hat{\Sigma}) / |\hat{z} \times \hat{\Sigma}|$.

Direction (j)	$\alpha\bar{P}_j$
Up-down (x)	−0.08±0.14
Right-left (y)	0.09±0.14
Fore-aft (z)	0.23±0.14

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