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Differential and channel cross sections and hyperon polarizations are presented for the reactions $K_L^0 p \rightarrow K_S^0 p$, $\pi^+ \Lambda^0$, and $\pi^+ \Sigma^0$ at an average beam momentum of 550 MeV/c. These data provide constraints on KN and $\bar{K}N$ amplitudes obtained from charged kaon reactions and reject one of the $S=+1$, $I=0$ and one of the $S=-1$, $I=1$ phase shift solutions.

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Partial wave amplitudes in both strangeness -1 and $+1$ states have been studied¹⁻³ using data from low energy K^+p and K^+d experiments. The masses, widths, spin-parity assignments, and branching ratios of $S=-1$ resonances have been extracted from analyses of $\bar{K}N$ data, but detailed behavior of the lower partial waves remains uncertain.⁴ In the $S=+1$ states, evidence for Z^* resonances is inconclusive despite suggestions of resonant-like behavior in some partial waves.⁵ The difficulties encountered in these analyses are due in part to the presence of both $I=0$ and $I=1$ in the K^-p system and to the use of deuterium targets to study the K^+n reactions. In contrast, K_L^0p interactions permit the study of $S=-1$ channels in a pure $I=1$ state and KN channels which are charge-conjugate to those accessible in K^+n reactions but without the complicating deuterium effects.

We present results from a study of the reactions $K_L^0p \rightarrow K_S^0p$ (1), $\pi^+\Lambda^0$ (2), and $\pi^+\Sigma^0$ (3) at a mean center of mass energy of 1588 MeV. The data were obtained in two exposures of the Argonne 12-foot bubble chamber to a K_L^0 beam. The total momentum spread was ± 50 MeV/c about the central value. Scanning for interactions and decays of the K_L^0 beam has been completed on 75% of the film. Single scan efficiencies of $87 \pm 3\%$ for the Vee topology of K_L^0 decays and $80 \pm 5\%$ for the one-prong plus Vee topology of reactions (1)-(3) have been measured from a rescan of 30% of the film.

The K_S^0p channel is uniquely identified by kinematic fitting. Events with short length recoil protons suffer a scan bias but have been recovered by fitting all Vee topologies to reaction (1) with an unmeasured low momentum recoil. The $\pi^+\Lambda^0$ and $\pi^+\Sigma^0$ channels can be separated in 88% of the cases by kinematic fitting, and remaining ambiguities are resolved by

selecting on the mass recoiling against the π^+ . These procedures yield final $\pi^+\Lambda^0$ and $\pi^+\Sigma^0$ samples which contain less than 3% background. We apply standard cuts to minimize biases against short length neutral tracks and low momentum decay products from the Vee. After these cuts, we obtained samples of 2230 $K_S^0 p$, 1619 $\pi^+\Lambda^0$, and 1385 $\pi^+\Sigma^0$ events in the interval $-1.0 \leq \cos\theta^* \leq 0.9$, where θ^* is the scattering angle of the outgoing meson with respect to the incident K_L^0 in the production center-of-mass frame. The rejected forward angular region contains events for reaction (1) with unobserved recoils that are ambiguous with K_L^0 decays and events for reactions (2) and (3) that have large weights.

Absolute cross sections have been determined by normalizing to the three-body charged decay modes of K_L^0 . Table I lists for reactions (1)-(3) the numbers of events, partial cross sections, and the coefficients of the Legendre expansions

$$\frac{d\sigma}{d\Omega} = \pi^2 A_0 \sum_{L=0}^4 \left(\frac{A_L}{A_0} \right) P_L(\cos\theta^*) ,$$

$$P \frac{d\sigma}{d\Omega} = \pi^2 A_0 \sum_{L=0}^4 \left(\frac{B_L}{A_0} \right) P_L^1(\cos\theta^*) .$$

The cross sections have been corrected for the unmeasured interval $0.9 \leq \cos\theta^* \leq 1.0$, and the errors include systematic uncertainties of $\pm 10\%$. Our cross section of 2.65 ± 0.31 mb for $K_L^0 p \rightarrow \pi^+\Lambda^0$ agrees with the result of 2.83 ± 0.16 mb for $K^- p \rightarrow \pi^0 \Lambda^0$.⁶

The differential cross section for the reaction $K_L^0 p \rightarrow K_S^0 p$ is displayed in Fig. 1. The amplitude for this reaction may be expressed as

$$T = 1/4(Z_0 + Z_1) - 1/2 Y_1 ,$$

where Z_0 , Z_1 are the $I=0, 1$ KN amplitudes and Y_1 is the $I=1$ $\bar{K}N$ amplitude. The Z_1 amplitude is well known in the 400-700 MeV/c region from analyses² of K^+p elastic scattering, and we arbitrarily choose the solution of BGT^{2b}. There are four solutions¹ for the Z_0 amplitude, but these reduce to two cases in our energy range. Solutions C and D from the BGRT analysis^{1a} and the single solution from the analysis of Martin^{1b} are similar, while the A solution of BGRT is distinctly different. Accordingly, we have combined the Z_1 amplitudes of BGT and solution D (Fig. 1a) or solution A (Fig. 1b) of the BGRT Z_0 amplitudes with several choices of Y_1 amplitudes and compare the predicted differential cross section to our data in Fig. 1a and 1b. All of these predictions, as well as those discussed below for reactions (2) and (3), have been averaged over our K_L^0 beam momentum spectrum and none has been renormalized. We note that all curves in Fig. 1b fail to reproduce the backward peak that exists in the data, and we therefore conclude that the data reject the A solution for Z_0 .⁷ In Fig. 1a, the LMNO solution^{3c} for Y_1 does not fit our data, but we cannot discriminate among the other Y_1 and Z_0 combinations.⁸ Solution A is also inconsistent with the K^+n charge exchange polarization measurement at 600 MeV/c.⁹ Both solution A and solution C are incompatible with the K^+n $I=0$ total cross section data of Carroll et al.¹⁰ Solution D was favored by London¹¹ in an analysis of a small sample of $K_L^0 p \rightarrow K_S^0 p$ data.

The differential cross section and Λ^0 polarization for reaction (2) are shown in Fig. 2. The curves in this figure are based on partial wave analyses³ of the reaction $K^-p \rightarrow \pi^0 \Lambda^0$. All of the curves adequately describe the differential cross section, but the polarization predictions of LMNO^{3c} appear inconsistent with the data. The data for reaction (3) are displayed

in Fig. 3 where the curves show the predicted behavior based on partial wave analyses^{3c} of $\Sigma\pi$ states in K^-p data. Again, the data are fit reasonably well with the exception of the multichannel analysis of LMMO.^{3c}

We conclude that the Y_1 amplitudes of LMMO and solution A of BGRT for the Z_0 amplitude do not adequately predict the observed data and may thus be rejected.

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Table I

Partial cross sections and Legendre coefficients for the Reaction

$K_L^0 p \rightarrow K_S^0 p, \pi^+ \Lambda^0, \pi^+ \Sigma^0$ at 550 MeV/c.

	$K_S^0 p$	$\pi^+ \Lambda^0$	$\pi^+ \Sigma^0$
Cut Events	2230	1619	1385
Weighted Events	3561	2739	2249
$\sigma(\text{mb})$	3.10 ± 0.36	2.65 ± 0.31	1.93 ± 0.23
A_1/A_0	-0.74 ± 0.05	0.88 ± 0.05	-0.10 ± 0.05
A_2/A_0	0.42 ± 0.07	0.49 ± 0.06	0.11 ± 0.07
A_3/A_0	-0.13 ± 0.08	0.02 ± 0.07	-0.14 ± 0.08
A_4/A_0	-0.06 ± 0.09	-0.30 ± 0.07	0.01 ± 0.09
B_1/A_0	-	0.28 ± 0.08	0.29 ± 0.14
B_2/A_0	-	0.20 ± 0.07	0.11 ± 0.12
B_3/A_0	-	0.03 ± 0.06	0.02 ± 0.10
B_4/A_0	-	0.07 ± 0.06	-0.07 ± 0.09

FIGURE CAPTIONS

Fig. 1. Differential cross section for the reaction $K_L^0 p \rightarrow K_S^0 p$ for $\cos\theta^* < 0.9$. Curves are predictions using $I=1$ $\bar{K}N$ amplitudes from Ref. 3a (CHS), Ref. 3b (LW), Ref. 3c (LMMO), and Ref. 3e (RL-IC) combined with $I=1$ KN amplitudes from Ref. 2d (BGT) and $I=0$ KN amplitudes from Ref. 1a (BGRT). BGRT solution D was used for Fig. 1a and solution A for Fig. 1b. Errors are statistical only.

Fig. 2. Differential cross section and Λ^0 polarization for the reaction $K_L^0 p \rightarrow \pi^+ \Lambda^0$ for $\cos\theta^* < 0.9$. Curves are predictions using partial

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wave amplitudes from Ref. 3b (LW), Ref. 3c (LMMO), Ref. 3e (RL-IC), and Ref. 3f (Litchfield). Errors are statistical only.

Fig. 3. Differential cross section and Σ^0 polarization for the reaction $K_L^0 p \rightarrow \pi^+ \Sigma^0$ for $\cos\theta^* < 0.9$. Curves are predictions using partial wave amplitudes from Ref. 3a(CHS), Ref. 3b (LW), Ref. 3c (LMMO), and Ref. 3e (RL-IC). Errors are statistical only.

— RL-IC - - - - LW
 CHS — LMMO

Fig. 1

Fig. 2

Fig. 3