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MOMENTUM DEPENDENCE OF CROSS-SECTION AND ANGULAR DISTRIBUTIONS OF REACTIONS $K^-p \rightarrow \Lambda\pi^0$, $K_2^0p \rightarrow \Lambda\pi^+$ NEAR THRESHOLD*

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The suggestion of possible I = 1 resonances just above the $\overline{K}N$ threshold has recurred several times in the past few years, in a variety of different reactions.[1-2] In our analysis of the K_2^0p interactions at low momenta,[3] we also found anomalies in mass plots and production angular distributions which could be ascribed to resonance behavior in this region, i.e., 1450 to 1550 MeV, approximately.

We have now extended our investigation of this region to cover the reaction $K^-p \rightarrow \Lambda^0\pi^0$, from an experiment performed about a year ago at the Bevatron, using the LRL 25-inch hydrogen bubble chamber. In addition, the complete set of data has now been collected from the K_2^0 experiment, also using the 25-inch chamber, which has added about 60% more data to those already published. Direct comparison of the results from these independent experiments, each having good statistics, should permit a strong test for possible resonances.

The low-momentum K_2^0 experiment has been adequately described;[3] the technique employed in the K^- experiment deserves some mention here. A significant advantage over previous low-energy K^- experiments results from an improved knowledge of the incident K^- momentum; this results in a better resolution of the missing mass, and a cleaner separation of the I = 1 and I = 0 reactions

$$K^- p \rightarrow \Lambda^0 \pi^0, \qquad (1)$$

$$K^- p \rightarrow \Sigma^0 \pi^0, \ \Sigma^0 \rightarrow \Lambda^0 \gamma. \qquad (2)$$

This separation heretofore has been usually a difficult problem. In this experiment, the K^- are separated (with about 20% contamination) at 400 MeV/c by means of Murray's septum separator,[4] with a momentum bandwidth of ±1%, and after being degraded with beryllium, enter the chamber at (a) 310±8 MeV/c for the higher-momentum run, or (b) 245±14 MeV/c for the lower. There is no trouble distinguishing the heavily ionizing K^- from the 20% minimum-ionizing background. Less than 10% mixing occurs between reactions (1) and (2) in the higher-momentum data (310 to 230 MeV/c).

To properly correct for the mixing between reactions (1) and (2) that does occur, a set of Monte Carlo events has been generated for these reactions by using the new program PHONY,[5] and these events have been analyzed by use of the same program (SIOUX) as the real events. Resolutions have been checked for agreement between the real and Monte Carlo events, and the agreement is found to be satisfactory. Reactions (1) and (2) were separated by dividing events on the missing-mass plot at $(\text{missing mass})^2 = 30\,000$, and correcting for the mixing. About 20% of the film was rescanned, and the scanning efficiencies were found to be ≥90% on both experiments. Corrections taking account of these efficiencies were included.

Several independent distributions have been studied in the search for anomalous behavior in this energy region. The quantities (a) cross section, (b) production angular distribution, and (c) decay asymmetry of the Λ^0 have been determined, as functions of the total c.m. energy, for reaction (1) and the corresponding K_2^0 reaction

$$K_2^0 p \to \Lambda^0 \pi^+. \qquad (3)$$

A discussion of these distributions follows.

1. Partial Cross Section for Λ^0 Production

The cross sections have been determined for reactions (1) and (3), as a function of the c.m. energy, $M(\overline{K}p)$, in 5-MeV intervals. In order to make these determinations, the incident-beam path length was derived by observing decays of beam particles, $\tau^- \to \pi^-\pi^-\pi^+$, for reaction (1) and K_{e3}^0 decays[6] for reaction (3). These results are shown in Fig. 1. The K_2^0 spectrum covers a broader region than that of the K^-, but the results are in reasonable agreement in the overlap region. The problem of the twofold ambiguity for the K_2^0 momentum was treated by using an unfolding technique based upon Monte-Carlo-generated events. Tests indicate that the spectrum is reliably determined in this way. As can be seen, there is no evidence from this plot for any deviation from a smooth behavior dominated by the 1/(K velocity) behavior close to threshold. From these cross sections, one can make a fit for the imaginary part of scattering length $A = a + ib$; the result is quite insensitive to the real part, which is much smaller in magnitude. Fitting to data corresponding to $P_{lab}(\overline{K}) < 300$ MeV/c, we obtain $b = 0.56 \pm 0.12$. Limits of error include the uncertainty in ϵ as directly determined from the K_2^0 data.

2. Production Angular Distributions

In Fig. 2 are shown the angular distributions for Λ^0 production corresponding to reactions (1) and (3). These are given in five energy intervals, with K^- data denoted by solid lines and circled points, and K_2^0 data by dashed lines and small triangles. The agreement between the two experiments is good, in general, and within uncertainty from statistics. No K^- data are available in the highest energy interval shown. One sees indications of events lost from the bin corresponding to the most backward Λ^0 direction, or displaced in the fitting process because they are too near the limit. For this reason, the K_2^0 data were fitted omitting this bin. The K^- data were fitted to all 10 bins, however. The results of fitting these distributions to second-order Legendre polynomials is given in Table I and in Fig. 3, where the coefficients are plotted vs $M(\bar{K}p)$. Again, there are no abrupt changes in these coefficients in this energy region. In all fits, the first Legendre coefficient, A_0, is set equal to unity. The fits to these distributions are good, in general, the average confidence level being 64%. The need for P wave as well as S wave is quite evident, and is believed to arise from the nearby $\Sigma(1385)$ resonance. No significant asymmetry is present in Σ production, and these data are omitted. Coefficients for K_1^0p production are shown in Table I.

3. Λ^0 Decay Asymmetry

There is almost no asymmetry observed in the Λ^0 decay from the K_2^0 reaction, and no significant evidence from the K^- data. For this reason the distributions themselves are not shown in Fig. 2 but only the linear coefficient, A_1, of the first-order Legendre expansion (Fig. 3). Again, there is no significant evidence of an abrupt change vs energy. We have also looked for an asymmetry term that changes sign with $\cos\theta(\Lambda)$, and find none.

4. Discussion and Conclusions

From the enlarged amount of K_2^0 data and the new K^- data, a more detailed investigation has been made of possible resonances in the I = 1, Y = 0 channel. No significant evidence has been found for such behavior. The difficulty experienced in fitting the K_2^0 interaction data previously in one mass region seems to be due partly to a "loss" of events in the backward bin for $\cos\theta(\Lambda)$; by eliminating this bin satisfactory fits are obtained. The angular distributions and cross sections all seem to have smooth behavior vs energy, and are reasonably consistent between the K^- and K_2^0 data. A small excursion in the A_2 coefficient for K_1^0 production (Fig. 3) is found, but is not judged to be compelling evidence for deviation from nonresonant S and P waves.

In Fig. 3 are shown the predicted values of A_1 and A_2 for Λ^0 production based upon the hypothesis that the P-wave contribution arises from the presence of the $\Sigma(1385)$. The strength of the S-wave contribution was based upon our own determination of the cross section (b = 0.56 F), while the $\Sigma(1385)$ is based purely on the Breit-Wigner distribution for P-wave resonance, using the barrier-penetration factor to give the correct widths. A phase difference between S and P waves of about 150 deg was taken to give a good fit to the Λ^0 decay asymmetry, but no other adjustment or normalization was made to obtain the curves shown in Fig. 3 for A_1 and A_2: they are predicted independently of any experimental data on A_1 and A_2. The data agree reasonably well with the predictions, giving support to the hypothesis that the reactions in this energy region can be explained by a nonresonant S wave, plus a P wave arising mainly from the

$\Sigma(1385)$ resonance tail.

The cross section for Λ^0 production has been determined, and has been used to determine the imaginary part of the scattering length for this channel. For completeness, the parameters

$$R = \frac{(K_1^0 p)}{\text{all hyperons}} , \qquad \epsilon = \frac{(\Lambda^0 \pi^+)}{\text{all hyperons}}$$

defined for K_2^0 interactions in previous papers have also been included in Table I.

FOOTNOTES AND REFERENCES

*Work supported by the U. S. Atomic Energy Commission.

1. Phys. Letters 16, 336 (1965).
2. David Cline (University of Wisconsin), private communication, 1968.
3. Phys. Rev. Letters 17, 599 (1966); Proceedings of the XIIIth International Conference on High-Energy Physics, Berkeley, 1966, pp. 202-203.
4. Roger Bangerter, K-65 Beam Optics, Alvarez Group Memo No. 574, Oct. 14, 1965.
5. E. Burns, D. Drijard, G. Lynch, and Y. Oren, PHONY (preliminary writeup), Trilling-Goldhaber Technical Note No. 143, April 1968. PHONY generates events using FAKE (G. Lynch, LRL Report UCRL-10335 March 1963), and projects the resulting tracks onto a simulated film strip, including all the real effects normally encountered, such as multiple scattering and all magnetic field components. The output is a set of points along each track simulating the output of a measuring machine.
6. Phys. Rev. Letters 19, 597 (1967). For cross-section determination of reaction (3), the K^0_{e3} partial rate was taken from UCRL-8030, Jan. 1968.

Table I. R, ϵ, and coefficients in Legendre-polynomial expansion to fit production and decay angular distributions.[a]

Mass ($\overline{K}p$), MeV		1450-1460	1460-1470	1470-1480	1480-1490	1490-1506
No. K_2^0 events		486	890	310	376	422
$R = \dfrac{N(K_1^0 p)}{N(\text{All hyperons})}$		0.24 ± .04	0.31 ± .03	0.36 ± .06	0.26 ± .03	0.44 ± .07
$\epsilon = \dfrac{N(\Lambda^0\pi^+)}{N(\text{All hyperons})}$		0.38 ± .04	0.37 ± .03	0.32 ± .05	0.28 ± .04	0.37 ± .04
Fit to $K_2^0 p \to \Lambda^0\pi^+$ production	A_1	-0.53 ± .14	-0.93 ± .10	-0.99 ± .17	-1.17 ± .15	-1.16 ± .14
	A_2	0.09 ± .18	0.35 ± .12	0.61 ± .25	0.45 ± .20	0.70 ± .20
	Confidence level	91%	62%	90%	15%	96%
Fit to $K^-p \to \Lambda^0\pi^0$ production	A_1	-0.74 ± .20	-0.77 ± .12	-0.86 ± .07	-0.90 ± .08	No
	A_2	0.75 ± .25	-0.01 ± .16	0.29 ± .09	0.31 ± .11	data
	Confidence level	58%	13%	48%	98%	--
Fit to $K_2^0 p \to K_1^0 p$ production	A_1	-0.11 ± .26	-0.30 ± .21	-0.26 ± .17	-0.37 ± .19	-0.49 ± .16
	A_2	0.06 ± .30	0.02 ± .25	-0.54 ± .26	-0.41 ± .26	-0.05 ± .24
	Confidence level	40%	51%	66%	1.3%	92%
Fit to Λ^0 decay asymmetry $K_2^0 p \to \Lambda^0\pi^+$ $\Lambda^0 \to \pi^- p$	A_1	0.13 ± .10	0.14 ± .08	0.42 ± .19	0.013 ± .14	0.19 ± .14
	A_2	---	---	---	---	---
	Confidence level	47%	67%	71%	6.1%	86%

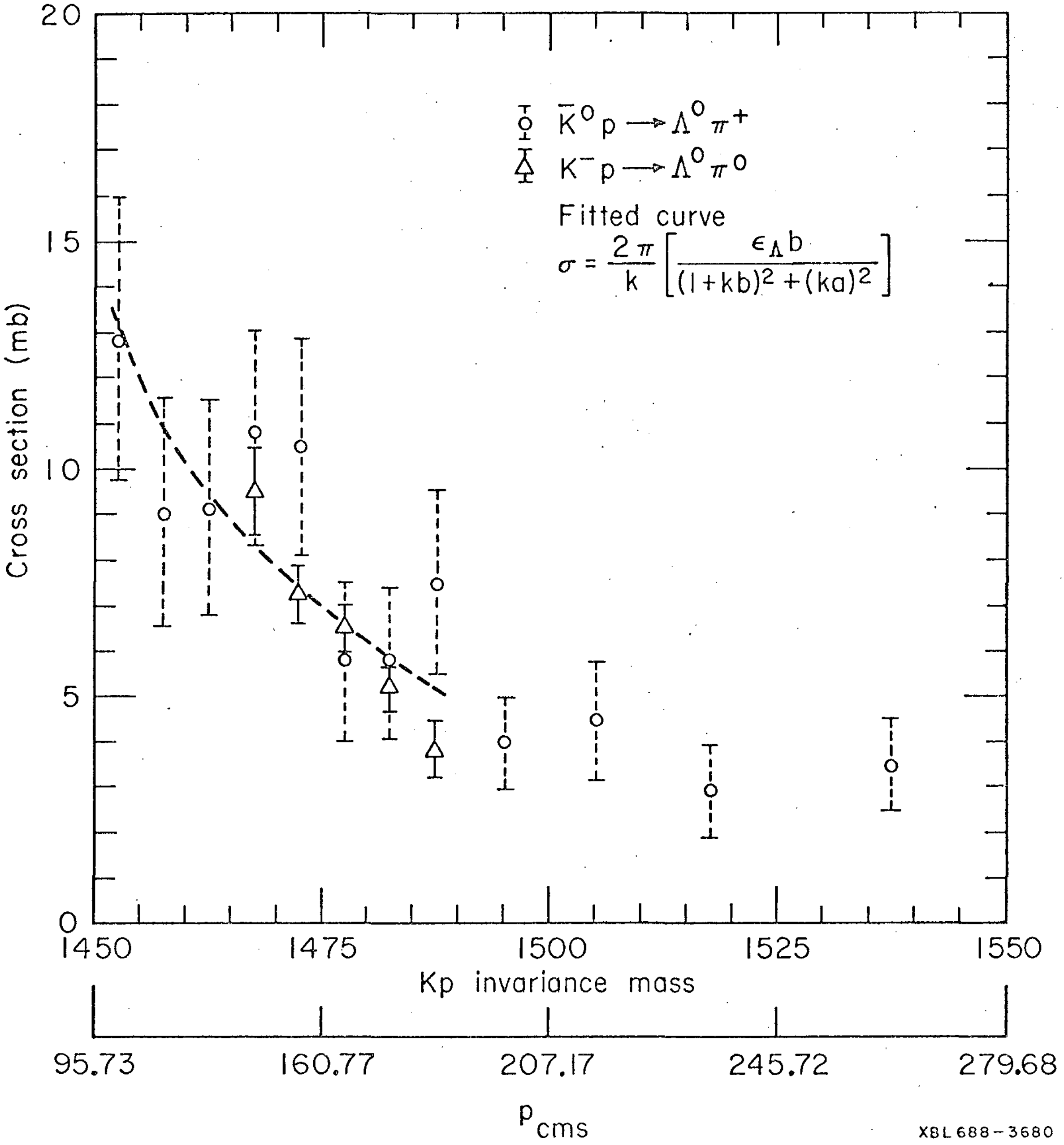
[a] Compiled Aug. 20, 1968; 2nd Revision of Table I in Phys. Rev. Letters 17, 599 (1968).

FIGURE CAPTIONS

Fig. 1. Cross section for Λ^0 production from the K^- and K_2^0 data. Statistical errors are indicated. The curve indicates the best fit for b, the imaginary part of the $I = 1$, $Y = 0$ scattering length. The K^- data are represented by the solid lines, and K_2^0 data by dashed lines.

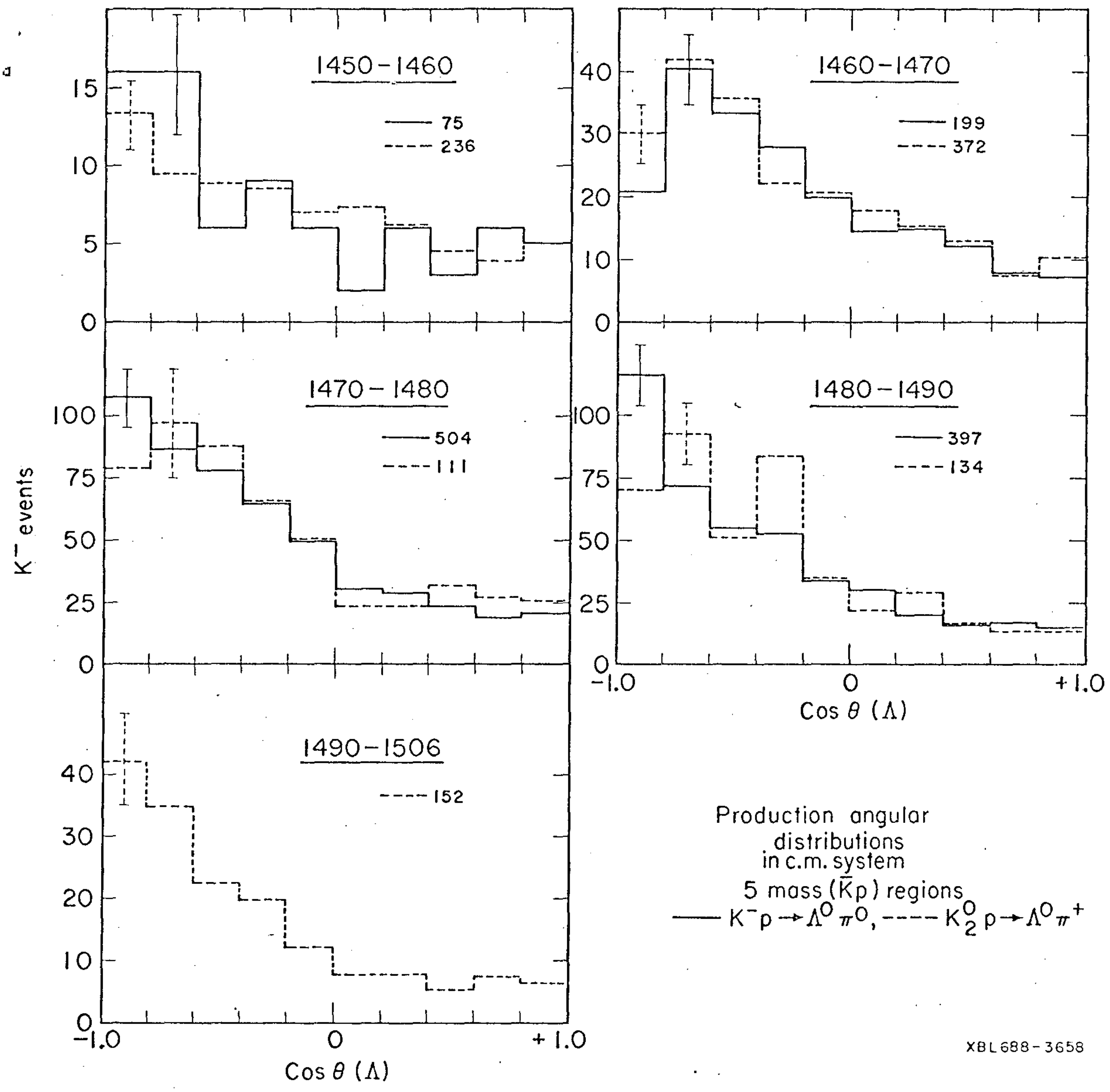
Fig. 2. Center-of-mass angular distributions for Λ^0 production. K^- and K_2^0 data are signified as in Fig. 1. The number of events of each experiment is indicated on the graphs in each energy interval. The direction of the Λ^0 is taken relative to incident K^- direction.

Fig. 3. Coefficients in Legendre polynomial, $\Sigma A_i P_i (\cos \theta)$ expansion for c.m. production angle of Λ^0 and K_1^0, and for Λ^0 decay. K^- and K_2^0 data are signified as in Fig. 1. The direction of Λ^0 or K_1^0 is taken relative to the incident $\overline{K}$ production for production, while for Λ^0 decay the π^- direction is taken relative to the direction of $\underset{\sim}{K} \times \underset{\sim}{\pi}^0$, where $\underset{\sim}{K}$ and $\underset{\sim}{\pi}^0$ are the $\overline{K}$ and π^0 directions. The curves indicated for Λ production are predictions based on the assumption that P wave arises solely from the presence of $\Sigma(1385)$.



20
15
10
5
0
Cross section (mb)
$\bar{K}^0 p \rightarrow \Lambda^0 \pi^+$
$K^- p \rightarrow \Lambda^0 \pi^0$
Fitted curve
$\sigma = \frac{2\pi}{k}\left[\frac{\epsilon_\Lambda b}{(1+kb)^2+(ka)^2}\right]$
1450
1475
1500
1525
1550
Kp invariance mass
95.73
160.77
207.17
245.72
279.68
p_{cms}

XBL 688-3680



Production angular distributions in c.m. system 5 mass ($\bar{K}p$) regions

—— $K^- p \rightarrow \Lambda^0 \pi^0$, ---- $K_2^0 p \rightarrow \Lambda^0 \pi^+$

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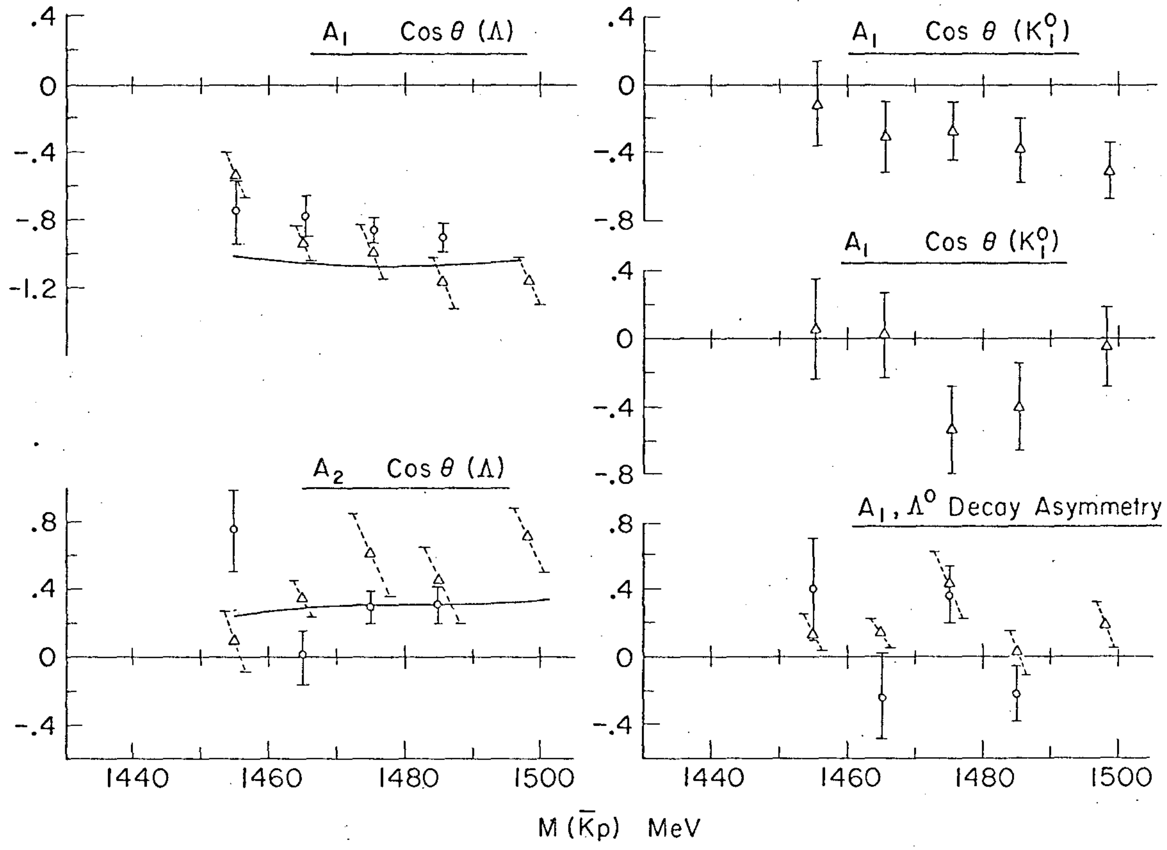
A_1 Cos θ (Λ)
A_1 Cos θ (K_1^0)
A_1 Cos θ (K_1^0)
A_2 Cos θ (Λ)
A_1, Λ^0 Decay Asymmetry
.4
0
-.4
-.8
-1.2
.8
1440
1460
1480
1500
M ($\overline{K}$p) MeV

XBL 688-3657