Title

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ADDITIONAL DATA IN THE REACTION $\pi^+ p \to \Sigma^+ K^+$ AT 1.28 AND 1.41 GeV/c AND A TEST OF CHARGE INDEPENDENCE IN THE c.m. ENERGY RANGE 1.820 TO 2.090 GeV*

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ABSTRACT

Data at two additional π^+ momenta (1.28 and 1.41 GeV/c) in the reaction $\pi^+ p \to \Sigma^+ K^+$ are presented. Charge independence is tested over the c.m. energy range 1.820 to 2.090 GeV; we used our data for the $\Sigma^+ K^+$ channel and published data for the $\pi^- p \to \Sigma^0 K^0$ and $\Sigma^- K^+$ channels.

I. DATA AND RESULTS

All the experimental details were the same for these data as those described in our previous paper.[1] Table I shows the microbarn equivalent at each energy, and the cross section, Table II the Legendre polynomial coefficients A_i/A_0. Figure 1 shows the angular distributions and Fig. 2 the plot of αP_Σ versus $\cos\theta$. In each case the curves are partial-wave solutions with essentially the same parameters as solution 192A in Ref. 1.

These new data were combined with our previous data and, using the partial-wave-analysis fits obtained in Ref. 1 as starting values, new sets of partial waves were obtained that fit the data. It was found that these were very close (all within their errors) of the previous values, and that the probabilities were also essentially

unchanged. Thus all conclusions reached in Ref. 1 are still valid.

II. TEST OF CHARGE INDEPENDENCE IN Σ PRODUCTION

Charge independence in strong interactions predicts definite relationship between the amplitudes of the reactions

$$\pi^+ p \to \Sigma^+ K^+, \qquad (1)$$

$$\pi^- p \to \Sigma^0 K^0, \qquad (2)$$

and

$$\pi^- p \to \Sigma^- K^+. \qquad (3)$$

If the amplitudes of these reactions are $f^+(\theta)$, $f^0(\theta)$, and $f^-(\theta)$, respectively, then for each spin state the following relationship holds:

$$f^+(\theta) = \sqrt{2}\, f^0(\theta) + f^-(\theta). \qquad (4)$$

This corresponds to a triangle in the complex plane.

Since the differential cross sections are the squares of the amplitudes, the following "triangle inequalities" between the cross sections (for each spin state) hold:

$$\left(2\frac{d\sigma}{d\Omega}\Big|_{\Sigma^0}\right)^{1/2} \leq \left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^+}\right)^{1/2} + \left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^-}\right)^{1/2}, \qquad (5)$$

$$\left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^+}\right)^{1/2} \leq \left(2\frac{d\sigma}{d\Omega}\Big|_{\Sigma^0}\right)^{1/2} + \left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^-}\right)^{1/2}, \qquad (6)$$

$$\left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^-}\right)^{1/2} \leq \left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^0}\right)^{1/2} + \left(\frac{d\sigma}{d\Omega}\Big|_{\Sigma^+}\right)^{1/2}. \qquad (7)$$

In fact, it can be shown that the relationships (5)-(7) also hold after summing over spins.

The purpose of this section of the paper is to examine these inequalities, using our data and published data at 1.277, 1.325, 1.50, 1.60, 1.70, and 1.86 GeV/c in the reactions $\pi^- p \to \Sigma^0 K^0$ and $\pi^- p \to \Sigma^- K^+$.[2-4]

For the purpose of this paper we have used the fitted A_n coefficients [where $d\sigma/d\Omega = \lambda^2 \Sigma_n A_n P_n(\cos\theta)$ has been used] to represent the data. We have also interpolated between our data points to obtain values of A_n for 1.5, 1.6, and 1.7 GeV/c in order to perform the tests at momenta for which data in the other channels are available. The A_n coefficients for $\pi^- p \to \Sigma^0 K^0$ and $\pi^- p \to \Sigma^- K^+$ were taken from Refs. 2-4. We have plotted only the inequality at each momentum which is closest to being violated.

Figures 3a-f show the tests of the triangle inequalities at 1.28, 1.43, 1.50, 1.60, 1.70, and 1.76 GeV/c. The broken lines represent the (rhs) of expression (6) [expression (5) at 1.28 GeV/c]. The dotted lines represent the lhs. Thus the inequality is satisfied if the dotted line remains below the broken line. In the case where there is no "violation" at any angle, we have not indicated errors. Where there is a crossing of the curves we have drawn two regions--corresponding to ± 1 standard deviation for the lhs and rhs. Charge independence, therefore, requires that the lower dotted line not be significantly higher than the upper broken line.

By examining Fig. 3 we note the following:

(a) There is no clear evidence for a violation of charge independence although at the upper four momenta the <u>mean</u> value of the lhs of (6) is greater than the <u>mean</u> value of the rhs in the forward direction. At the two momenta closest to the $\Delta^{++}(1950)$ the extent of this effect is greatest, extending from $\cos\theta = 0.75$ to 1.0 at 1.5 GeV/c and from $\cos\theta = 0.1$ to 1.0 at 1.6 GeV/c.

(b) As the momentum increases the triangle becomes flatter, and relation (6) becomes an equality--first in the forward direction at 1.5 GeV/c and then extending over the whole range in $\cos\theta$.

(c) At the lowest momentum (1.28 GeV/c), relation (5) becomes an equality in the forward direction.

III. DISCUSSION

1. Our results are perfectly consistent with those of Binford et al.[5] at the lowest momentum and with Pan and Forman[6] at 1.7 GeV/c. This is not surprising, since in each case the same $\pi^- p \to \Sigma^0 K^0$ and $\Sigma^- K^+$ data were used and the only difference was in the $\Sigma^+ K^+$ data.

2. Since there appears to be a persistent, but statistically not very significant, violation of condition (6), we have examined the data in the region close to $\cos\theta = 1.0$ carefully and, in particular, the data of Dahl et al.,[4] which were used at 1.5 GeV/c and above for both $\Sigma^0 K^0$ and $\Sigma^- K^+$. We found that at 1.5, 1.7, and 1.86 GeV/c the actual angular distribution was considerably higher than the fit obtained by Dahl et al. using the Legendre polynomials, in the forward bin $(0.9 < \cos\theta < 1.0)$ for the $\Sigma^0 K^0$ channel. The effect of this is to increase the value of the rhs of condition (6) in the region above $\cos\theta = 0.9$, which therefore tends to reduce any violation of condition (6).

3. At 1.6 and 1.7 GeV/c the angular distribution of $\Sigma^0 K^0$ is forward peaked with no events in the backward direction, whereas the angular distribution of $\Sigma^- K^+$ is backward peaked with no events in the forward direction. Assuming no violation of charge independence, the triangle has to be flat with $(d\sigma/d\Omega|_{\Sigma^+}) = (2 d\sigma/d\Omega|_{\Sigma^0})$ in the for-

ward direction and $(d\sigma/d\Omega|_{\Sigma^+}) = (d\sigma/d\Omega|_{\Sigma^-})$ in the backward direction. In both these directions the two isospin amplitudes have to be relatively real. In the backward direction they are in phase, whereas in the forward direction they are 180 deg out of phase.

The relative realness of these amplitudes would result if the reactions proceeded via a particle-exchange mechanism. Thus K^* exchange in the forward direction and Λ exchange in the backward direction could be used as an explanation for the flatness of the triangle. However, at energies close to or below the $\Delta(1950)$ this interpretation is clearly not valid. Binford et al.[5] have also pointed out this curious behavior.

Finally, a higher-precision test of the triangle inequalities at about 1.6 GeV/c would be extremely interesting.

FOOTNOTE AND REFERENCES

*Work done under the auspices of the U. S. Atomic Energy Commission.

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See also Lawrence Radiation Laboratory Report UCRL-19777 for a fuller account of the work at 1.28 and 1.41 GeV/c.

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5. T. O. Binford, M. L. Good, and R. R. Kofler, Phys. Rev. 183, 1148 (1969).

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Table I. Microbarn equivalents and cross-sections.

Momentum (GeV/c)	Microbarn equivalent	Cross section (μb)
1.28	0.6	340 ± 35
1.41	0.6	490 ± 45

Table II. Legendre polynomial coefficients for angular distributions and polarizations.

Momentum (GeV/c)	A_1/A_0	A_2/A_0	A_3/A_0	A_4/A_0	B_1/A_0	B_2/A_0	B_3/A_0
1.28	-0.46	0.02	1.12	0.13	-0.35	0.40	0.08
	(±0.14)	(±0.19)	(±0.24)	(±0.37)	(±0.23)	(±0.17)	(±0.15)
1.41	-0.26	0.31	0.93	0.42	-0.30	0.38	-0.28
	(±0.12)	(±0.17)	(±0.22)	(±0.27)	(±0.18)	(±0.18)	(±0.14)

FIGURE LEGENDS

Fig. 1. Production angular distribution of $\pi^+p \to \Sigma^+K^+$ (with $\Sigma^+ \to \pi^+n$) at 1.28 and 1.41 GeV/c. Cosθ is defined as the cosine of the angle in the c.m. between the incident π^+ and the outgoing K^+. The curves are described in the text.

Fig. 2. $\alpha\overline{P}_\Sigma$ (for $\Sigma^+ \to p\pi^0$) as a function of cosθ at 1.28 and 1.41 GeV/c. The curves are described in the text.

Fig. 3(a). Test of triangle inequality (5). Broken line, rhs; dotted line, lhs. (b-f). Test of triangle inequality (6). Broken line, rhs; dotted line, lhs.

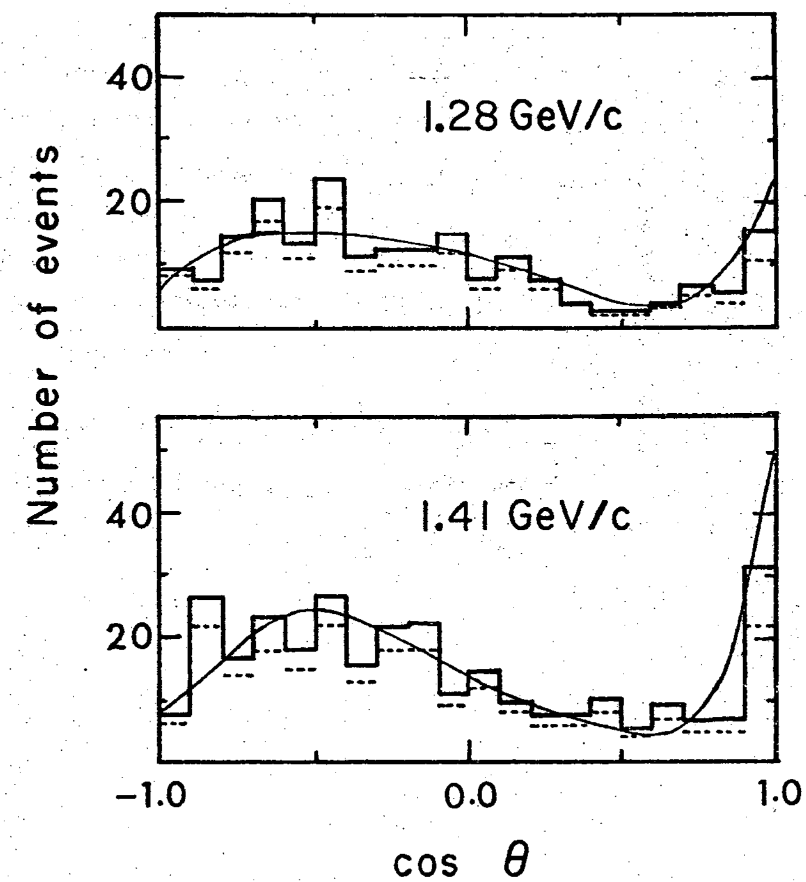

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Fig. 1

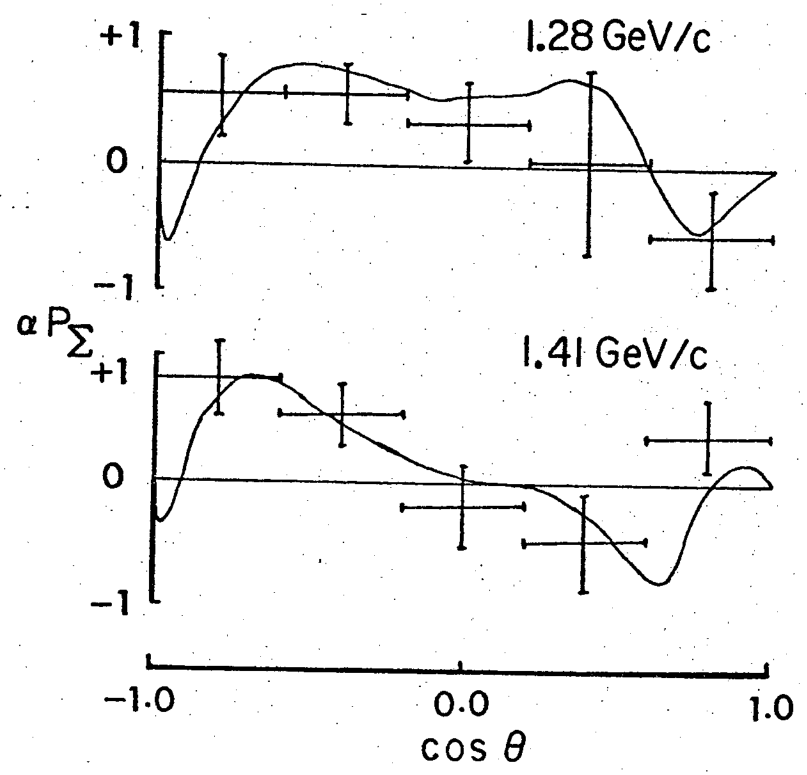

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Fig. 2

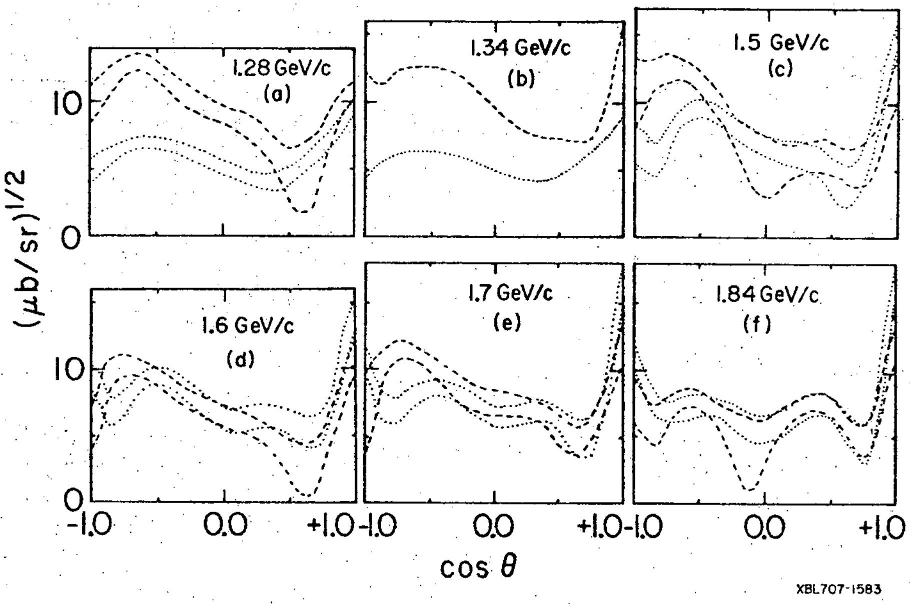

Fig. 3

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