Polarization Measurement of the Σ^+ Produced in the Line-Reversed Reactions $\pi^+p \to K^+\Sigma^+$ and $K^-p \to \pi^-\Sigma^+$ at 7 and 11.6 GeV/c

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The polarization of the Σ^+ has been measured for the line-reversed reactions $\pi^+p \to K^+\Sigma^+$ and $K^-p \to \pi^-\Sigma^+$ at 7 and 11.6 GeV/c using the SLAC Hybrid Facility. Since the Σ^+ decay is observed in the bubble chamber, the trigger of the flash lamps on a fast K^+ (π^-) did not bias the polarization measurements. We find that the Σ^+ polarizations from the two reactions have opposite signs but similar magnitudes and are in much better agreement with the predictions of weak exchange degeneracy than previous lower-energy comparisons.

Information on line-reversed pairs of reactions is important for an understanding of the Regge structure of the reaction mechanism. Data on hypercharge exchange reactions have mostly resulted from experiments by different groups using different techniques at different energies.[1,2] The consequent systematic problems have made comparison difficult. As part of a study of line reversal in hypercharge exchange reactions, we present in this Letter measurements of the Σ polarization from the reactions

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

$$K^-p \to \pi^-\Sigma^+, \quad (2)$$

at 7 and 11.6 GeV/c and four-momentum transfer up to $|t|=1$ (GeV/c)^2 from a triggered rapid-cycling bubble-chamber experiment. The Σ decay was observed with 4π geometry and relatively well-understood systematics.

Our experiment was conducted at the Stanford Linear Accelerator Center (SLAC) Hybrid Facility which comprises the SLAC 40-in. rapid-cycling chamber with electronic detectors both upstream and downstream.[3] A sketch of the setup is shown in Fig. 1. The chamber operated at rates up to 12 Hz during the experiment but the camera flash was only triggered when the counters showed evidence that an interaction of interest had occurred.

The triggering signatures for Reactions (1) and (2) are a fast outgoing K^+ and π^-, respectively. With reference to Fig. 1, a fast signal $S1 \cdot C1 \cdot S2 \cdot \overline{C2} \cdot S3$ for Reaction (1) or $S1 \cdot \overline{C1} \cdot S2 \cdot C2$ for Reaction (1) caused readout of the proportional-wire-chamber (PWC) planes into an on-line DGC 840 computer. A software trigger then had the bubble growth time to decide if a picture should be taken. The trigger was rejected if evidence was found for a noninteracting beam downstream, or if no evidence was found that the readout signal was caused by a fast particle originating in the fiducial volume. For the K^- exposure the muon hodoscopes ($S4$ and $S5$) were examined to reject triggers from K^- muon decays. The trigger reduced the typical picture taking rate to one per 250 beam tracks, thus reducing the total number of pictures by an order of magnitude over a conventional bubble-chamber exposure. The events were found by off-line scanning for strange particle topologies and uniquely identified by a multivertex kinematic fit with four constraints at

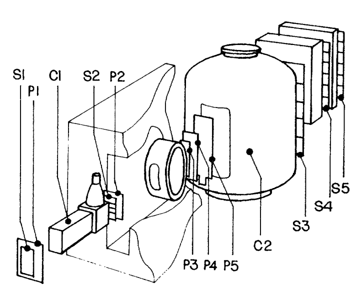

FIG. 1. Perspective drawing of the SLAC Hybrid Facility. The cylindrical bubble chamber is represented in a cut-away drawing of its magnet body. $S1$ is a scintillation counter. $S2$–$S5$ are scintillation hodoscopes. $C1$ and $C2$ are Cherenkov counters. $P1$–$P5$ are proportional chambers. Steel hadron filters are indicated before $S4$ and $S5$.

the primary vertex. Hybridization of the bubble-chamber–track measurement by means of an overall fit to bubbl-chamber and PWC data significantly improved the measurement of the fast outgoing track and this enabled very good discrimination between the 4C $K\Sigma/\pi\Sigma$ and 1C $K\Sigma\pi^0/\pi\Sigma\pi^0$ final states to be achieved. Any $(\Sigma^+ \to p\pi^0)/(\Sigma^+ \to n\pi^+)$ decay ambiguities were resolved by checking the ionization of the decay particle.

Since the fast particle caused the trigger, the acceptance is purely a function of t and is in fact 100% for $0.02 < -t < 0.4$ (1.0) $(\text{GeV}/c)^2$ at 7 (11.6) GeV/c. The lower limit results from the software beam veto while the upper limit is determined by the geometrical acceptance of the downstream system. However, this does not affect the polarization measurements nor do the numerous other corrections which must be made to the data to correct for triggering losses.

Following a successful trigger, events may be missed at the scanning stage because (a) the Σ track is too short to be seen or (b) the decaying track makes too small an angle with the Σ track so that the kink is unobserved. The polarization is determined from the decay asymmetry of the $(p\pi^0)$ Σ decays and so losses of type (a) due to short Σ's do not bias the polarization measurements. Angle losses, which are particularly significant for the proton decays, are symmetric with respect to the production normal and can be corrected for by evaluating the polarization from

$$P_\Sigma = \alpha^{-1}\langle\cos\theta_p\rangle / \langle\cos^2\theta_p\rangle,$$

where α is equal to -0.9794 and is the decay asymmetry parameter and θ_p is the angle between the decay proton in the Σ rest frame and the normal to the production plane (beam times outgoing meson). The $\langle\cos^2\theta_p\rangle$ weighting corrects for such symmetric scanning losses. The effect of this weighting is typically very small and, in general, changes the estimate from that obtained by using $P = 3/\alpha\langle\cos\theta_p\rangle$ by less than 0.1 of a standard deviation. In no case does it make a change greater than 0.5 of a standard deviation.

The results are shown in Figs. 2(a) and 2(b) and tabulated in Table I. The essential features are the same at 7 and 11.6 GeV/c. Between $t_{\min}$ and $-t = 0.2$ $(\text{GeV}/c)^2$ the polarization for the π^+ reaction is small and positive; for the K^- reaction it is very close to zero although slightly different at the two energies. This differs from

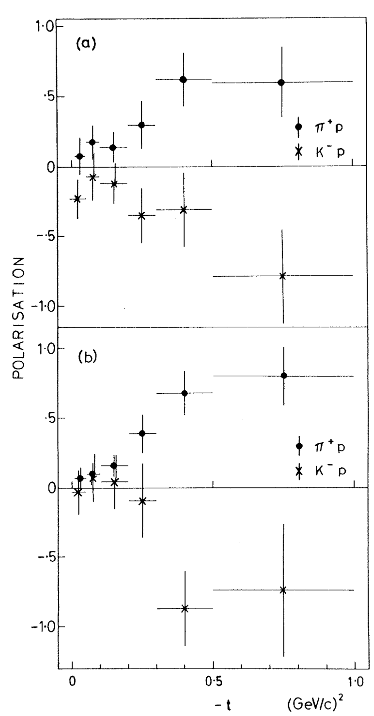

FIG. 2. Momentum-transfer dependence of the Σ polarization at (a) 7 GeV/c and (b) 11.6 GeV/c.

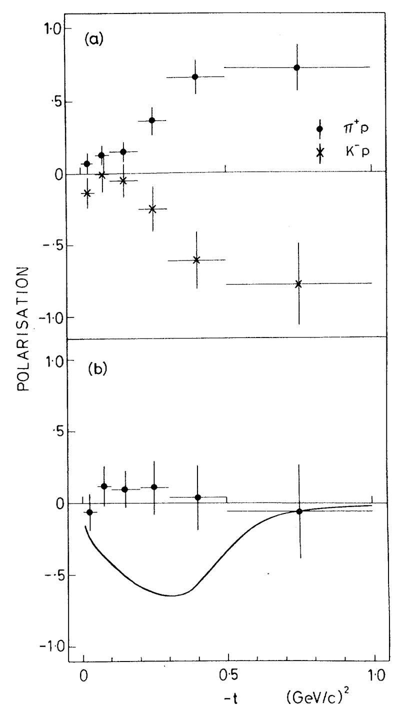

FIG. 3. (a) Σ polarization for the 7- and 11.6-GeV/c data combined. (b) Sum of the polarizations for the π^+ and K^- reactions. Data from 7 and 11.6 GeV/c combined. The curve is the prediction of the model of Navelet and Stevens (Ref. 4) as described in the text.

TABLE I. Polarization measurements of the Σ^+ resulting from Reactions (1) and (2) at 7 and 11.6 GeV/c. The number of events refers to the number of Σ's observed which decay to $p\pi^0$.

$-t$ $(\text{GeV}/c)^2$	Momentum GeV/c	$\pi^+p \to K^+\Sigma^+$ No. events	$\pi^+p \to K^+\Sigma^+$ Polarisation	$K^-p \to \pi^-\Sigma^+$ No. events	$K^-p \to \pi^-\Sigma^+$ Polarisation
$-t_{min}$-0.05	7.0	190	0.08 ± 0.13	151	-0.23 ± 0.14
	11.6	452	0.06 ± 0.07	121	-0.03 ± 0.15
0.05 - 0.10	7.0	218	0.18 ± 0.12	102	-0.07 ± 0.17
	11.6	458	0.10 ± 0.08	93	+0.07 ± 0.17
0.10 - 0.20	7.0	251	0.14 ± 0.11	129	-0.12 ± 0.15
	11.6	432	0.16 ± 0.10	92	+0.05 ± 0.19
0.20 - 0.30	7.0	109	0.30 ± 0.17	71	-0.35 ± 0.20
	11.6	162	0.39 ± 0.14	40	-0.09 ± 0.27
0.30 - 0.50	7.0	77	0.62 ± 0.19	42	-0.31 ± 0.27
	11.6	114	0.68 ± 0.16	27	-0.87 ± 0.27
0.50 - 1.0	7.0	42	0.60 ± 0.25	21	-0.79 ± 0.34
	11.6	61	0.79 ± 0.21	7	-0.74 ± 0.48

earlier low-energy data which showed negative polarization for both reactions at low momentum transfer.[1] As the momentum transfer increases, the polarization from the π^+ reaction becomes strongly positive whereas from the K^- reaction it becomes strongly negative and closely mirros the behavior in the π^+ reaction. This simple reflection symmetry of the Σ polarization for this pair of line-reversed reactions has not been seen before. Since the data at 7 and 11.6 GeV/c are similar we have combined the two energies to reduce the statistical error and the result is shown in Fig. 3(a). With the increased statistical significance the results show even more strongly how well the polarizations reflect. In Fig. 3(b) the polarization from the π^+ and the K^- reactions have been summed. The χ^2 for the hypothesis that all these points lie on the abscissa is 1.9 for 6 degrees of freedom.

It is expected that the dominant t-channel exchange trajectories in Reactions (1) and (2) should be the vector $K^*(890)$ and the tensor $K^{**}(1420)$. For weak exchange degeneracy these will have the same trajectory parameters but different residues. If they are the only contributors we would therefore expect the same differential cross sections, equal and opposite $Pd\sigma/dt$, and hence equal and opposite polarizations for the two reactions. Berglund *et al.*[2] have measured the differential cross sections for these reactions at 10 GeV/c and have fitted them by the form Ae^{bt}. They obtain similar values of A for Reactions (1) and (2) but slightly different slopes. Our preliminary results on the differential cross sections agree with these conclusions. While the difference of the slope parameters implies some additional terms and/or splitting of the trajectories, the symmetry of our polarization coupled with the observed similarity of the cross sections at low momentum transfer suggests that any such violation of the simple weak exchange degeneracy picture must be small at our energies.

The model of Navelet and Stevens[4] uses an effective cut parametrization in addition to the $K^*(890)$ and $K^{**}(1420)$ pole terms to obtain a good description of the lower-energy $d\sigma/dt$ and polarization measurements for both Reactions (1) and (2). Their predictions for the Σ polarizations are very similar at 7 and 11.6 GeV/c. We compare the prediction of this model, appropriately weighted for the combined 7- and 11.6-GeV/c data, with our summed polarization results, Fig. 3(b). It is shown as the solid line on the figure and is in obvious disagreement with the experimental data. We conclude, therefore, that our Σ polarization measurements for the two line-reversed hypercharge reactions (1) and (2) are in much better agreement with the predictions of weak exchange degeneracy than previous lower-energy measurements.

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Line-Reversal Comparison of $\bar{p}p \to \pi^+\pi^-$ and $\pi^-p \to p\pi^-$ at 6 GeV/c

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We present differential cross sections at 6 GeV/c for the baryon-exchange reactions (1) $\bar{p}p \to \pi^+\pi^-$ and (2) $\pi^-p \to p\pi^-$ over the range $-t_{\min} < -t < 1.5$ GeV^2. Unlike previous experiments at similar momenta, our results are consistent with line-reversal symmetry for $-t < 1.0$ GeV^2. We contrast this to our previous results on (3) $\bar{p}p \to \pi^-\pi^+$ and (4) $\pi^+p \to p\pi^+$ for which line-reversal symmetry is not satisfied.

Many Regge models, using either inherent amplitude structure or absorptive corrections, have sought to describe hadronic two-body processes.[1-3] Despite years of theoretical and experimental efforts, the relative importance of these two approaches remains unsettled. Some important tests can be made by comparing reactions involving the same t-channel exchanges, e.g., line-reversed pairs. Simple Regge models predict that their differential cross sections have the same shape, and have magnitudes that are simply related. Data on line-reversed baryon exchange processes have been relatively sparse.

We report here new cross-section results at 6 GeV/c for the pair (1) $\bar{p}p \to \pi^+\pi^-$ and (2) $\pi^-p \to p\pi^-$ over the range $-t_{\min} < -t < 1.5$ GeV^2. Our convention is that the first-named particle goes forward in the center-of-mass system; $-t$ is the square of the momentum transfer to the forward particle. The line-reversal comparison should be particularly interesting since at this momentum s-channel contributions are expected to be insignificant, and since only one amplitude, the t-channel exchange of the Δ^{++}, dominates in these reactions.

Earlier measurements on Reactions (1) and (2) had indicated the failure of line reversal between 3.0 and 5.0 GeV/c, but fair agreement at 6.2 GeV/c.[4-9] The studies at 5 and 6.2 GeV/c, however, used data from different experiments[5] or different geometries and sensitivities[7] in the line-reversal comparison. Our experiment measured $d\sigma/dt$ for (1) and (2) under nearly identical conditions to minimize systematic errors in the comparison.

The experiment was performed at Brookhaven National Laboratory using the multiparticle spectrometer (MPS). The main features of the apparatus, described previously,[10] are as follows. A 6.0-GeV/c separated beam was momentum analyzed in a proportional-wire-chamber spectrometer and steered into a 60-cm-long liquid hydrogen target inside the MPS magnet. Forward-scat-