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# Polarisation Measurement of the $\Sigma^+$ 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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Abstract

In a triggered bubble chamber experiment we have measured the polarisation of the $\Sigma^+$ produced in the line reversed reactions $\pi^+ p \to K^+ \Sigma^+$ and $K^- p \to \pi^- \Sigma^+$ at 7 and 11.6 GeV/c. The polarisation obtained from the protonic $\Sigma^+$ decays is totally unbiased by the chamber trigger which permits us to achieve sensitivities hitherto unobtainable in bubble chamber work at these energies. The $\Sigma$ polarisations from the two reactions have opposite signs but similar magnitudes and are in much better agreement with 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 polarisation from the reactions :

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

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

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

Our experiment was conducted at the SLAC Hybrid Facility (SHF) which comprises the SLAC 40" rapid cycling chamber with electronic detectors both up and downstream.[3] A sketch of the set-up is shown in Fig. 1. The chamber operated at rates up to 12 Hertz 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 $\pi^-$ respectively. With reference to Fig. 1, a fast signal

$$S1.C1.S2.\overline{C2}.S3 \quad \text{for reaction (1)}$$

or

$$S1.\overline{C1}.S2.C2 \quad \text{for reaction (2)} ,$$

caused read-out of the 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 non-interacting beam downstream, or if no evidence was found that the read-out 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 4-constraint kinematic fit simultaneously at both primary and $\Sigma$ decay vertices. Hybridisation of the bubble chamber track measurement by means of an overall fit to bubble 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 $K\Sigma\pi^o/\pi\Sigma\pi^o$ final states to be achieved. Any $\Sigma^+ \rightarrow p\pi^o/\Sigma^+ \rightarrow n\pi^+$ decay ambiguities were resolved by checking the ionisation of the decay particle.

As the fast particle caused the trigger the acceptance is purely a function of t and is in fact 100% for $0.02 < -t < 0.4\ (1.0)\ (GeV/c)^2$ 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 polarisation 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 $\Sigma$ track is too short to be seen or (b) the decaying track makes too small an angle with the $\Sigma$ track so that the kink is unobserved. The polarisation is determined from the decay asymmetry of the $(p\pi^o)$ $\Sigma$ decays and so losses of the type (a) due to short $\Sigma$ 's do not bias the polarisation 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 polarisation from :

$$P_\Sigma = \frac{1}{\alpha} \frac{< \cos \theta_p >}{< \cos^2 \theta_p >} ,$$

where $\alpha$ is equal to $- 0.9794$ and is the decay asymmetry parameter and $\theta_p$ is the angle between the decay proton in the $\Sigma$ rest frame and the normal to the production plane. (Beam x outgoing meson). The $< \cos^2\theta_p >$ 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 $P = 3/\alpha < \cos\theta_p >$ by less than one tenth of a standard deviation. In no case does it make a change greater than half a standard deviation.

The results are shown in Figs. 2(a) and 2(b) and tabulated in Table 1. The essential features are the same at 7 and 11.6 GeV/c. Between $t_{min}$ and $- t = 0.2$ (GeV/c)$^2$ the polarisation for the $\pi^+$ 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 earlier low energy data which showed negative polarisation for both reactions at low momentum transfer.[1] As the momentum transfer increases the polarisation from the $\pi^+$ reaction becomes strongly positive whereas from the $K^-$ reaction it becomes strongly negative and closely mirrors the behaviour in the $\pi^+$ reaction. This simple reflection symmetry of the $\Sigma$ polarisation for this pair of line reversed reactions has not been seen before. As 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 polarisations reflect. In Fig. 3(b) the polarisation from the $\pi^+$ and the $K^-$ reactions have been summed. The $\chi^2$ for these points all to 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 $K^*$ and the tensor $K^{**}$. 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 $P \frac{d\sigma}{dt}$ and hence equal and opposite polarisations 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 to 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. Whilst the difference of the slope parameters implies some additional terms and/or splitting of the trajectories, the symmetry of our polarisation 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 parameterisation in addition to the $K^*$ and $K^{**}$ pole terms to obtain a good description of the lower energy $\frac{d\sigma}{dt}$ and polarisation measurements for both reactions (1) and (2). Their predictions for the Σ polarisations 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 polarisation 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 polarisation 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.

Acknowledgements

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Table 1.

| $-t$ $(GeV/c)^2$ | Momentum GeV/c | $\pi^+ p \to K^+ \Sigma^+$ | | $K^- p \to \pi^- \Sigma^+$ | |
|---|---|---|---|---|---|
| | | No. events | Polarisation | No. events | 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 |

## Figure Captions

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, C2 are Cerenkov counters. P1-P5 are proportional chambers. Steel hadron filters are indicated before S4 and S5.

2. Momentum transfer dependence of the $\Sigma$ polarisation at (a) 7 GeV/c and (b) 11.6 GeV/c.

3. (a) $\Sigma$ polarisation for the 7 and 11.6 GeV/c data combined.

   (b) Sum of the polarisations for the $\pi^+$ and $K^-$ reactions. Data from 7 and 11.6 GeV/c combined. The curve is the prediction of the model of Navelet and Stevens as described in the text.

## Table Caption

1. Polarisation measurements of the $\Sigma^+$ resulting from reactions (1) and (2) at 7 and 11.6 GeV/c. The number of events refers to the number of $\Sigma$'s observed which decay to $p\pi^o$.

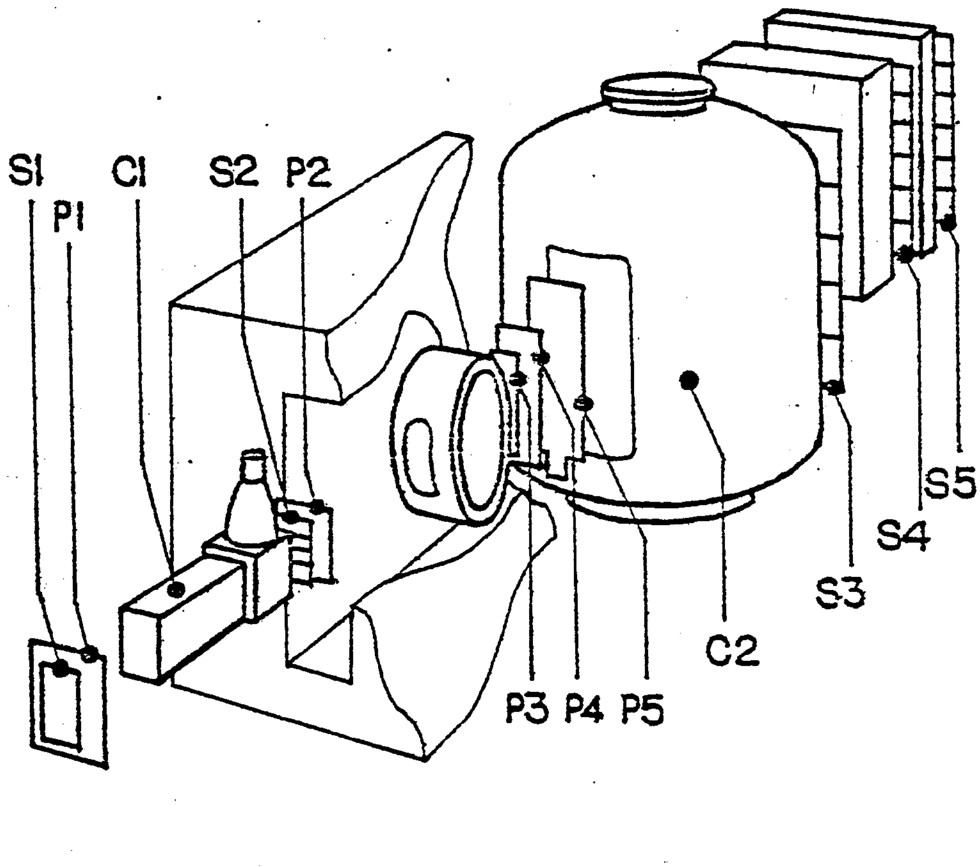


FIG. 1

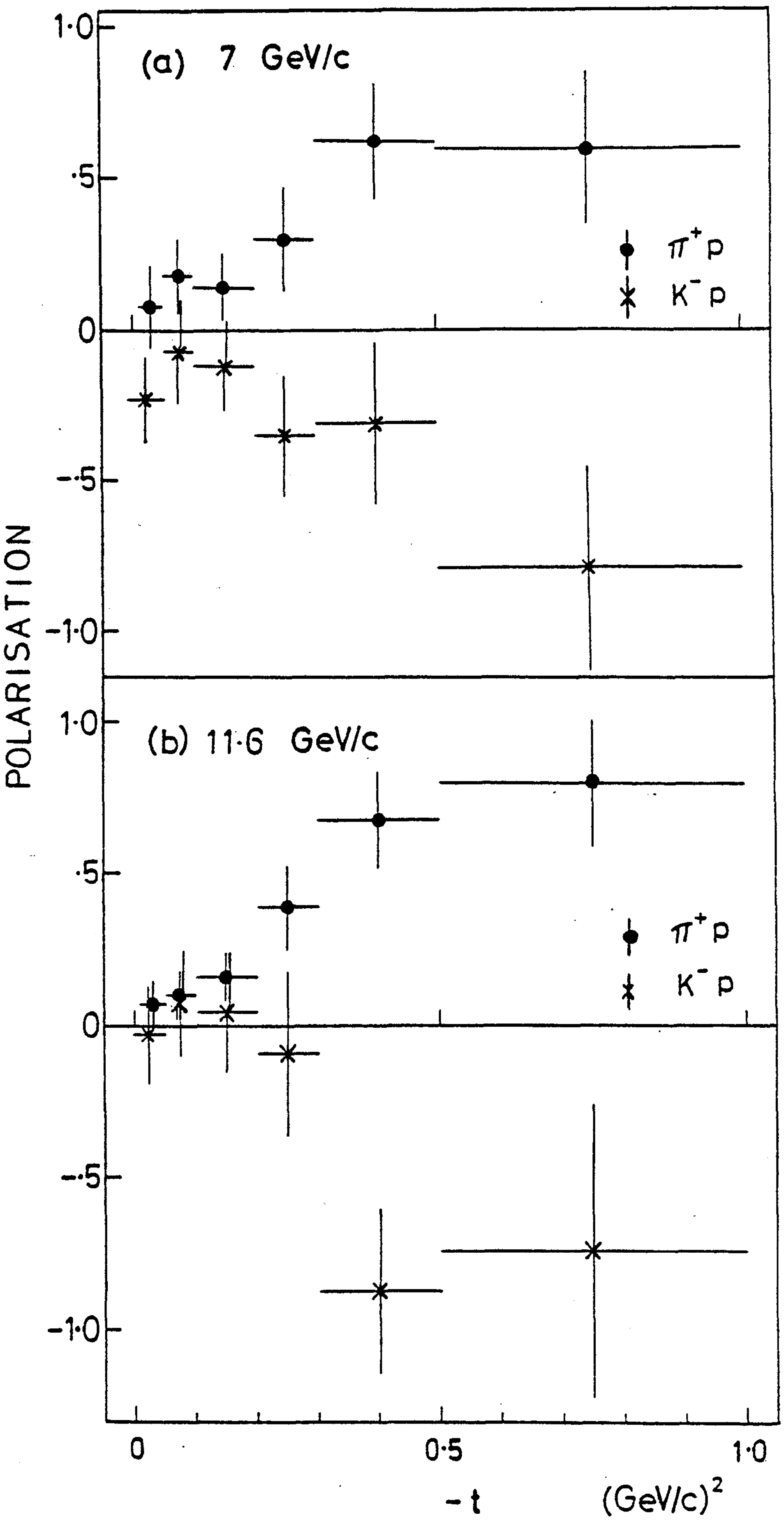


FIG. 2

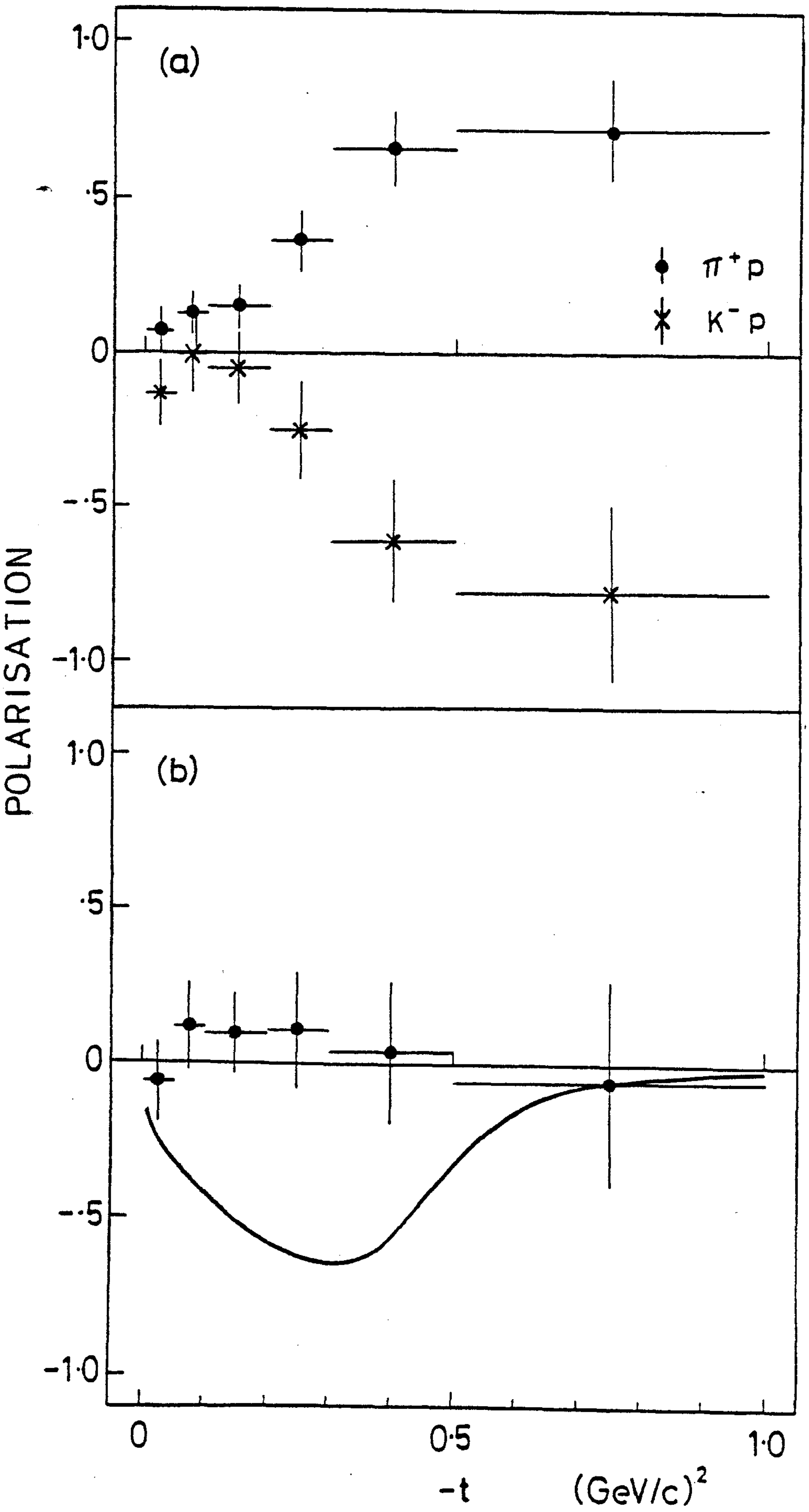


FIG. 3