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POLARIZATION OF THE RECOIL PROTON IN THE REACTIONS $\pi^{\pm}p \rightarrow pX^{\pm}$ IN THE A_2 REGION*

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ABSTRACT

We present here the results of an experiment to study the polarization of the recoil proton in the reaction $\pi^{\pm}p \rightarrow pX^{\pm}$ at 4 GeV/c incident pion momentum, where M_x varies from 1200 to 1450 MeV and t varies from -.2 to -.8 $(GeV/c)^2$. The polarization of the recoil proton normal to the scattering plane was measured with a wire chamber carbon analyzer. Polarizations are presented as a function of mass M_x for all t, and as a function of t for all masses. The typical error in the polarization is ±.1. A significant difference is observed in the behavior of the polarization associated with the X^+ and X^-. Possible implications of this disparity are explored.

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We discuss here the results of an experiment performed at the Argonne ZGS to measure the recoil proton polarization in the inclusive reaction $\pi^{\pm}p \rightarrow pX^{\pm}$ at 4 GeV/c incident pion momentum. The polarization measurements were made in conjunction with an experiment designed to make a high statistics, high resolution study of the A_2 mass spectrum. The inclusion of a magnetostrictive wire chamber carbon analyzer as the last element in the proton arm allowed the simultaneous recording of missing mass and polarization data. The missing mass results have been reported in Ref. 1. The physics goals of the polarization measurements were: a) to determine if a significant polarization asymmetry might be associated with the two halves of the A_2 meson, and b) to examine the t dependence of the recoil proton polarization for M_x in the region of the A_2, to check the prediction of certain production models.

The experimental layout is shown in Figure 1. A beam of $\sim 10^5$ pions per burst was incident on a 10" long liquid hydrogen target. Beam particles were detected by scintillation counters B1 and B2 and by proportional chambers. The momentum and angle of the recoil proton was determined by a magnetostrictive wire spark chamber spectrometer. The momentum was determined with a resolution of ±1.1 percent, and the recoil scattering angle was measured with a resolution of 1 mr. In addition, the time-of-flight between counters B2 and P was measured for each event to an accuracy of ±.5 ns. This allowed a very clean separation to be made between protons and other particles in the proton arm. The carbon block wire chamber sandwich shown downstream of counter P allowed the polarization of the recoil proton to be determined from the left-right azimuthal asymmetry exhibited by the protons in scattering from carbon nuclei. The carbon analyzing power for protons with energies in the range covered by this experiment is known from previous measurements (Ref. 2).

Numerous tests were made to ensure that no significant experimental biases were present. Use was made of the abundant small angle second scatters to constantly monitor the relative alignment of all elements in the polarimeter. The polarimeter was utilized to measure the known elastic p-p polarization at 1.4 GeV/c as an additional check. The operation of the experiment was monitored with an on-line PDP-15 computer. The efficiencies of the chambers, and the magnet and photomultiplier voltages were continuously checked. Plan and vertical view displays of all proportional chambers and magnetostrictive chambers were available upon request.

In Figure 2 results are presented for the recoil proton polarization normal to the production plane for all t covered by the apparatus (-.2 to -.8 $(GeV/c)^2$) as a function of the missing mass M_x. Three comments can be made concerning these results: a) for both X^- and X^+ production the polarization is symmetric about the A_2 mass, 1.3 GeV; b) the polarization associated with the X^- is consistent with being small and negative for all masses examined; and, c) the polarization associated with the X^+ appears to rise from 0 percent near 1225 MeV to a maximum of $\sim$40 percent near the A_2 mass and then to fall to zero near 1425 MeV.

The t distribution of the polarization data is shown in Figure 3. The data correspond to the missing mass interval of 1200 to 1450 MeV. The results for X^+ production are consistent with a slowly increasing polarization rising from $\sim$20 percent to a value of $\sim$30 percent. On the other hand, the X^- data slowly decreases from about 0 percent at $t = -.25$ to -40 percent at $t = -.73$ $(\text{GeV/c})^2$. Since that part of the experiment associated with the recoil proton spin determination has no direct knowledge of the sign of the incoming pion beam charge, the chance is remote that the above differences are due to systematics.

Since the t-averaged polarization is consistent with being zero in regions outside the A_2 peak and since the polarization is symmetric about the A_2 mass, one might be led to attribute the observed polarization to the A_2 meson and its interference with the background. If one adopts this point of view and further assumes that no significant changes occur in the background amplitudes over the region of the A_2, then the data supports the proposal that the two halves of the A_2 are similar, at least as far as the recoil proton polarization is concerned.

Alternatively, one may take the point of view that since the A_2 events represent a small fraction of the total spectrum, the reactions should be regarded as being inclusives. Here, even though many channels may be contributing, one might nevertheless expect sizeable polarizations.[3] For "polarization out of the blob"[4], the Regge exchanges for $\pi p \to pX$ at small t should be similar to those in πp elastic scattering, the main difference between the two being that the Pomeranchuck contribution is greatly reduced for the inelastic processes. The Pomeranchuck's off-diagonal (inelastic and spin flip) couplings are known to be much smaller than its corresponding elastic couplings. One would therefore expect sizeable polarizations for our inclusive process, and if the ρ exchange again dominates the proton flip amplitude (as it does in the elastic case) one could expect the polarizations for the two reactions $\pi^{\pm} p \to pX^{\pm}$ to be mirror symmetric.

Our results shown in Figure 3 reveal that the inclusive polarizations are indeed comparable to the corresponding elastic polarizations. Moreover, consistent with the above arguments, the $\pi^{+} p \to pX^{+}$ and $\pi^{-} p \to pX^{-}$ polarizations are statistically compatible with approximate mirror symmetry. The shape of the polarization at small t, however, is not similar to that of the corresponding elastic polarization. The possibility of mirror symmetry is emphasized by the mirror symmetric lines drawn in Figure 3. Such symmetry is not suggested by the polarization vs.mass plot in Figure 2, however, since this plot is dominated by the small t data which, as seen in Figure 3, do not alone indicate mirror symmetry.

In summary, we have examined a parameter of the reactions $\pi^{\pm}p \to pX^{\pm}$ which could be relevant both to possible A_2 structure and to our general understanding of inclusive processes. Our results suggest no polarization distinction between the two halves of the A_2. If the observed polarization is due mainly to the A_2, then differences at perhaps the $\sim$25 percent level should have been detected. If the process can indeed be treated as an inclusive process, the Regge predictions may be regarded to be in general agreement with the data. This experiment, to the best of our knowledge, is the first to study the continuous variation of polarization with missing mass. Since the principal interest in the present experiment was the A_2 meson, the missing mass range studied was restricted. To explore inclusive model polarization predictions in depth additional measurements are warranted.

We wish to express our gratitude to the ZGS staff for their help during the installation and execution of the experiment. We wish to acknowledge several useful discussions with R. Arnold, S-Y Chu, A. W. Hendry, and F. Von Hippel regarding the theoretical interest in the experiment. We also gratefully acknowledge the efforts of R. Kammerud, A. Barnes, D. Curtis, J. Krider, S. Levy, and B. Martin in the construction, installation and execution stages of the experiment. In addition, two of us (G.W.A. and H.A.N.) wish to acknowledge the hospitality extended to us by the Aspen Center for Physics during the preparation of a portion of this manuscript.

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FIGURE CAPTIONS

Figure 1. Schematic diagram of the experimental apparatus.

Figure 2. Polarization parameter in $\pi^+ p \rightarrow pX^+$ and $\pi^- p \rightarrow pX^-$ as a function of missing mass.

Figure 3. Polarization parameter in $\pi^+ p \rightarrow pX^+$ and $\pi^- p \rightarrow pX^-$ as a function of the four momentum transfer squared.

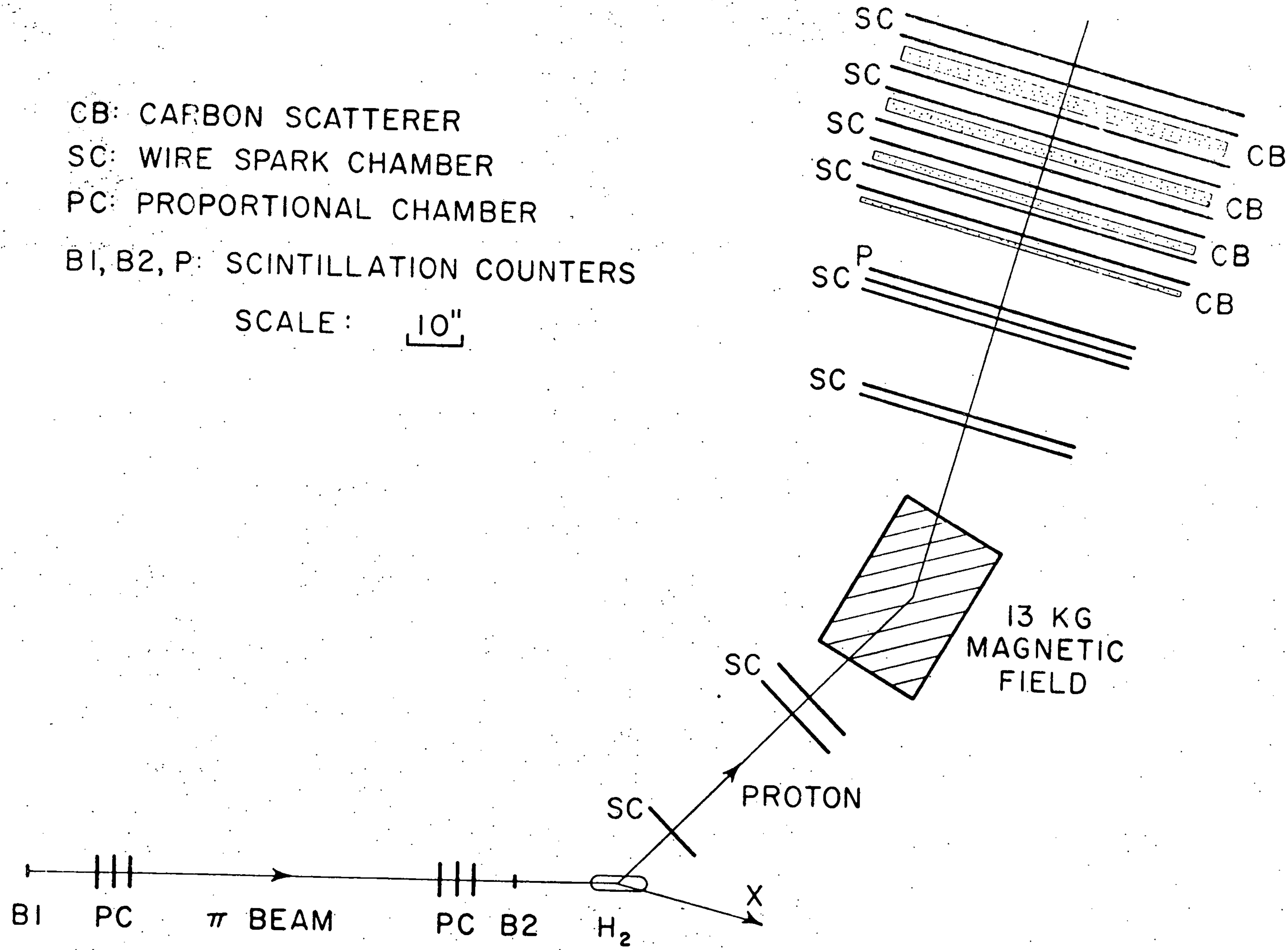

CB: CARBON SCATTERER
SC: WIRE SPARK CHAMBER
PC: PROPORTIONAL CHAMBER
B1, B2, P: SCINTILLATION COUNTERS
SCALE: 10"
SC
SC
SC
SC
CB
CB
CB
CB
P
SC
SC
13 KG
MAGNETIC
FIELD
SC
PROTON
SC
X
B1
PC
π BEAM
PC
B2
H2

Fig. 1

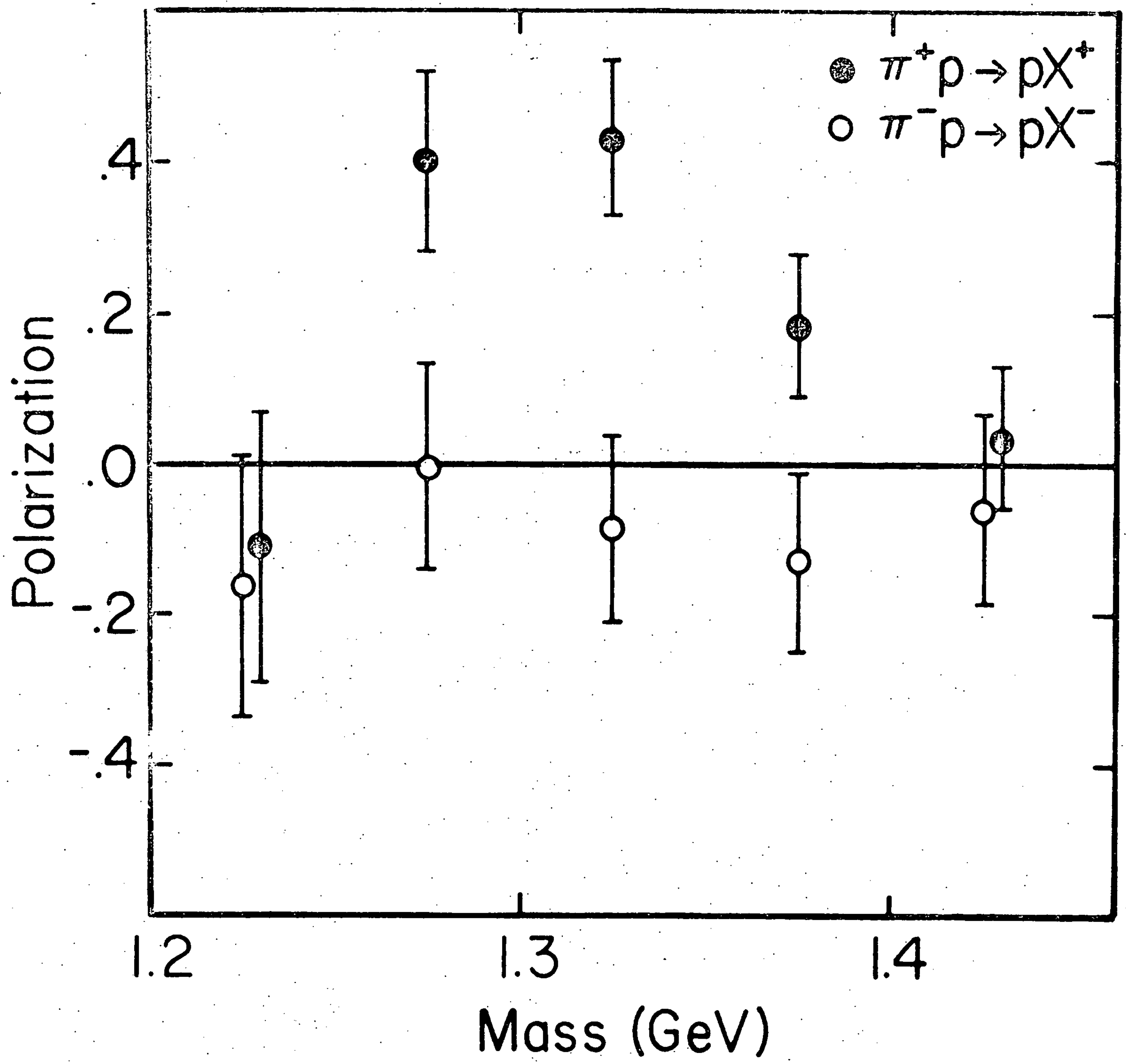
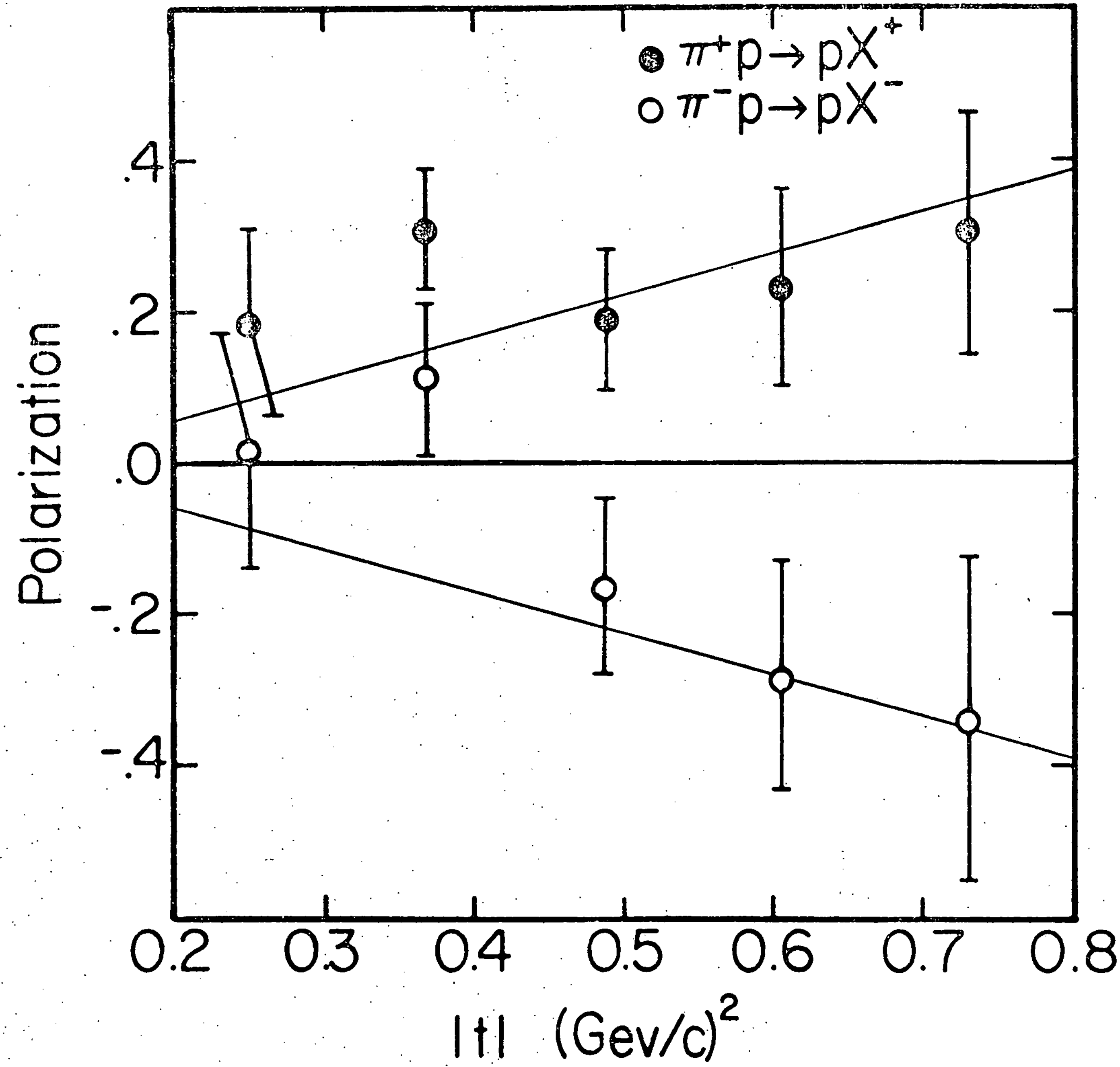

$\pi^+ p \rightarrow pX^+$
$\pi^- p \rightarrow pX^-$
.4
.2
.0
-.2
-.4
Polarization
1.2
1.3
1.4
Mass (GeV)

Fig. 2



$\pi^+ p \to pX^+$
$\pi^- p \to pX^-$
Polarization
.4
.2
.0
-.2
-.4
0.2
0.3
0.4
0.5
0.6
0.7
0.8
|t| (Gev/c)^2

Fig. 3