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INCLUSIVE ASYMMETRIES

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The advent of the polarized proton beam at the Argonne zero-gradient synchrotron (ZGS) has permitted considerable improvement in technique for experiments which study spin dependence in inelastic strong interactions. Although these experiments are possible with a polarized proton target, the backgrounds due to carbon and oxygen in these targets make inclusive measurements difficult. In a recent experiment, we have used the polarized proton beam to measure left-right asymmetries for the reactions $p_{pol} + p \rightarrow p, K^{\pm}, \pi^{\pm}$ + anything by placing a liquid hydrogen (LH_2) target in the extracted polarized proton beam (p_{pol} denotes polarized proton). The beam polarization is vertical and normal to the plane defined by the incident and scattered momenta. A portion of the experiment was run with a target fill of liquid deuterium, so that some information on the reaction $p_{pol} + n \rightarrow p, K^{\pm}$, $\pi^{\pm}$ + anything was obtained. The data reported here are preliminary in nature and were accumulated at an incident proton momentum of 11.8 GeV/c.

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We have used ZGS Beam 5, shown schematically in Figure 1, as a single-arm spectrometer to detect the scattered particle. The spectrometer has an angular acceptance of order 10^{-4} sr, depending somewhat on the kinematic setting, a ± 5% momentum acceptance, and two ethylene-filled, threshold Cerenkov counters, each with two optically independent sections, for particle identification. Charged particles produced in a 10-cm-long, 3.8-cm-diam target are restored to the axis of quadrupoles X5Q1-3 by steering magnets X5B1 and X5SB1. For some points on the edges of the kinematic range, dipole magnets X5B2 and X5B3 are also used in the steering process. The angular range of the spectrometer depends on the momentum and polarity of the scattered pion; the data reported here include laboratory angles between 0^0 and 17^0 and momenta between 2 and 9 GeV/c.

The direction, size, and position of the incident proton beam are determined by two sets of x-y proportional chambers read out in an integrated mode. The relative intensity (typically 5×10^8 protons per 500-msec pulse) and polarization (typically 55% at 11.8 GeV/c) of the incident beam are monitored by four scintillation-counter telescopes (L, R, U, and D). L and R view a thin polyethylene target and act as a polarimeter with an analyzing power of 0.020 ± 0.001 at p_0 = 11.8 GeV/c. This polarimeter has been calibrated at both incident momenta against an absolute elastic-scattering polarimeter located in another experimental area. Telescopes U and D, located in the vertical plane, monitor the proton intensity on the LH_2 target.

The proton target asymmetries are obtained from the equation

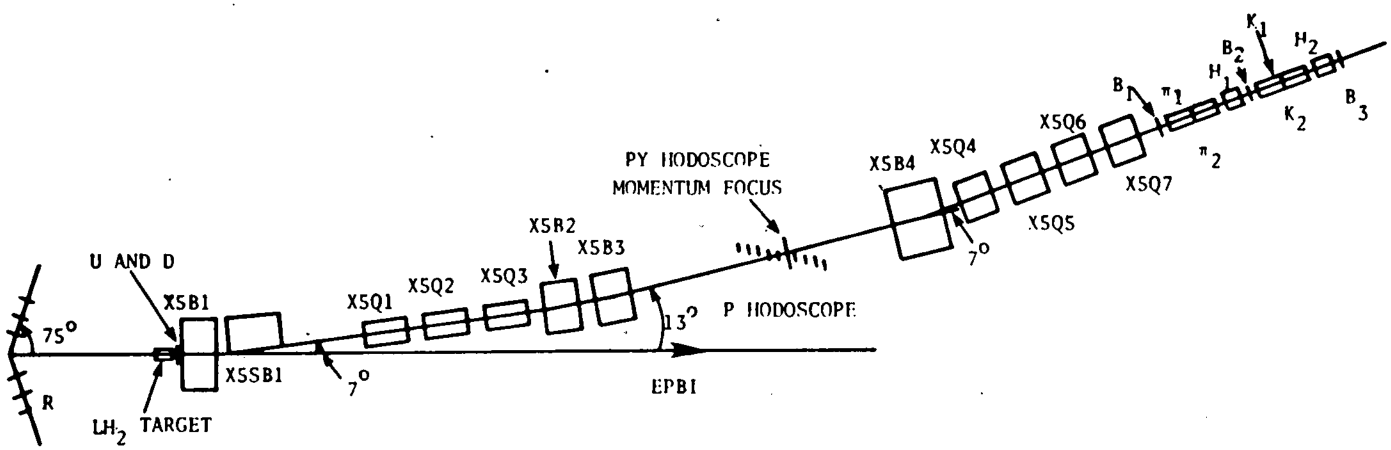


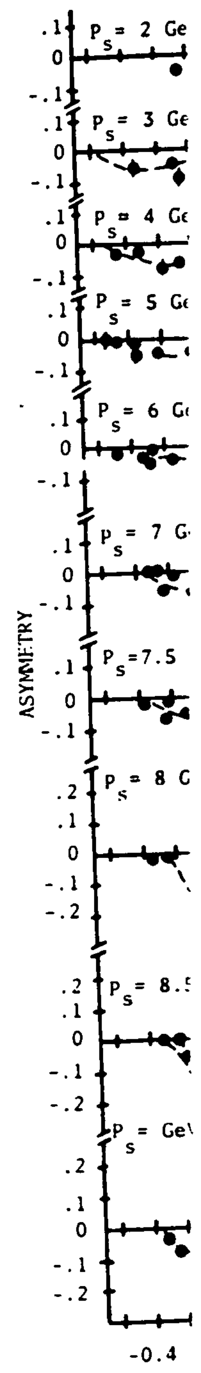
Figure 1. Experimental arrangement

$$A_x = \frac{1}{P_B}\,\frac{N(\uparrow)-N(\downarrow)}{N(\uparrow)+N(\downarrow)}, \qquad (1)$$

where $N(\uparrow)$, $[N(\downarrow)]$ are the number of x-type coincidences ($B_1B_2B_3C_1C_2$) recorded for incident beam polarization up (down) normalized to the intensity monitors and P_B is the beam polarization. The symbols C_1 and C_2 denote the Cerenkov tags appropriate to the detection of particle x in the final state (e.g., both π_1 and π_2 for $\pi^{\pm}$, no signal for p,...). The asymmetry defined here is positive when more particles are produced to the left in the horizontal plane looking in the direction of the incident beam.[1] Corrections due to multiple scattering, nuclear absorption, decays, and uncertainty in the spectrometer acceptance have no effect on the asymmetry. The sign of the beam polarization is reversed on every accelerator pulse to minimize systematic errors. Target-empty background runs have been taken for every data point; the target-empty rate is typically between 10 and 25% of the target-full rate. As an experimental check, we have made single-arm measurements of the pp elastic polarization at p_0 = 6 GeV/c and $0.07<t<0.3$ $(\text{GeV/c})^2$; the results are consistent with the published data.[2]

The neutron target asymmetries are calculated as in equation (1) above, where N now refers to the normalized number of coincidences expected from the neutron content of the deuterium target. The normalization includes a target empty subtraction, equalization of incoming beam polarization and the differing densities of liquid hydrogen and deuterium. No correction has been made for multiple scattering or other nuclear effects, and the data presented here are preliminary in that respect.

Our measurements of the asymmetry for pion production



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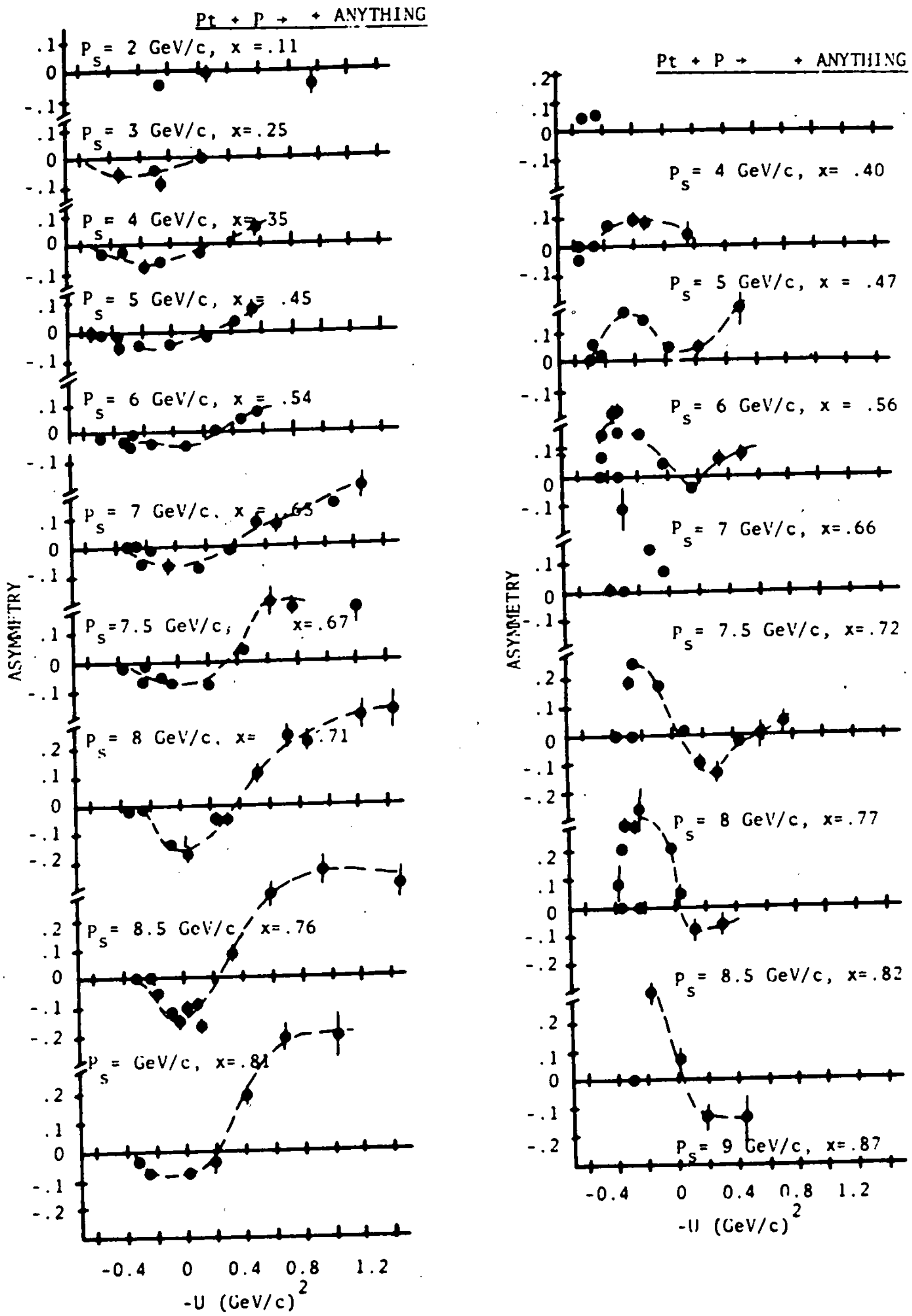

Figure 2. Inclusive pion asymmetries in pp

are shown in Figure 2, which also includes data taken in an earlier run at 6 GeV/c (the few points plotted as open circles at equivalent values of the Feynman x parameter).[3] We have chosen to represent the data as a function of u, the square of the four-momentum transfer from the incident proton to the outgoing pion, in order to emphasize the similarities between these data and the polarization in backward π p elastic scattering. The resolution in u is $\Delta u \lesssim \pm 0.1\ (\mathrm{GeV/c})^2$. The data for the two pion charges are considerably different for any particular kinematic point, but there are some overall similarities. (1) The 6- and 11.8 GeV/c asymmetries are consistent, except where one of the asymmetries is forced to zero by the requirement of no asymmetry for zero production angle (open and filled triangles). (2) The magnitudes of the asymmetries are consistently larger for larger x but the shape of the dependence on u, in particular, the location of the maxima and zeros, is roughly independent of x. (3) The effects of the asymmetry zero for 0° production are of limited extent in u. For example, the π^- asymmetry at large x rises to 20% within 0.6° of the forward direction. We have verified this effect by noting a reversal in the asymmetry for pions from the other side of the proton beam.

The asymmetries for pion production off a neutron target appear to be very similar to the proton target data. These are shown in Figures 3 and 4 for secondary momenta of 8 and 9 GeV/c, respectively. The latter figure includes the existing data on backward π^+p elastic scattering (at 6 GeV/c) as well.[4] Figure 5 presents the data on π^- production off protons and neutrons (at 8.5 GeV/c) as well as the corresponding elastic data.

It is apparent from Figures 4 and 5 that there is

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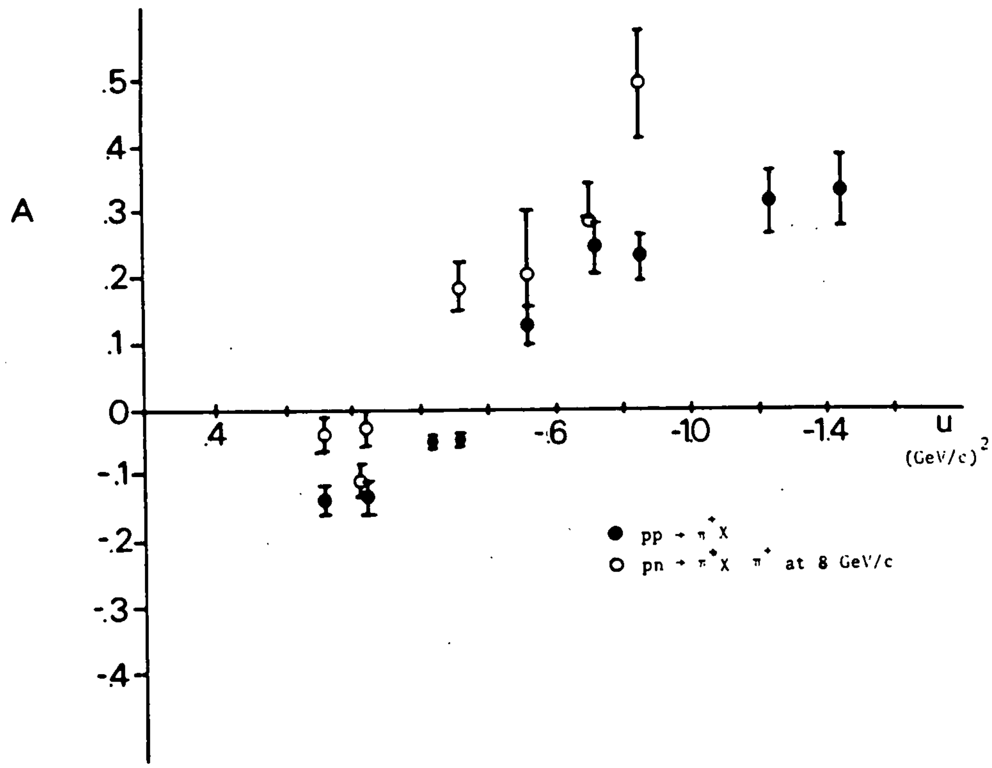

Figure 3. Inclusive π^+ asymmetries

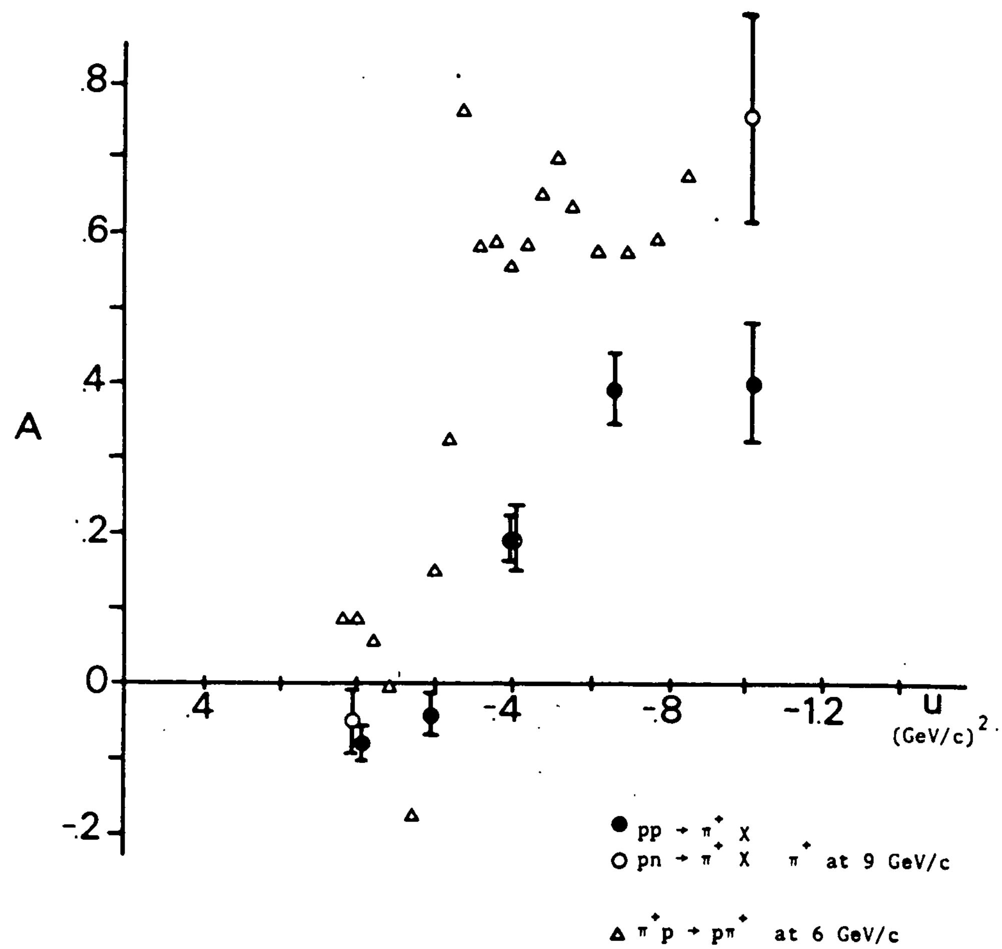

Figure 4. Inclusive π^+ asymmetries

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a strong correlation between the structure in the inclusive and backward pion elastic data, at least in the region (large pion momentum) where the inclusive process is likely to be dominated by baryon exchange. At lower momenta (smaller x), the structure seems to be diluted by other effects, presumably s-channel in nature. A crude model for this correlation may be based on the work of Ader, Meyers and Salin,[3] who showed that for baryon exchange reactions,

$$A\sigma \propto |N|^2 - |U|^2 , \qquad (2)$$

where N and U are the natural and unnatural-parity exchange amplitudes. The diagrams in Figure 6 exhibit the correlation[6]: 6a) is a simple exchange model for backward elastic scattering leading to an asymmetry of the form

$$A\sigma \propto |\beta_N|^2 - |\beta_u|^4 , \qquad (3)$$

where β_N, β_u are the effective natural and unnatural residue functions. These same residues appear in the closure graph, 6b) for the inclusive process, multiplied by an ersatz Reggeon-nucleon total cross section, leading to

$$A\sigma \propto |\beta_N|^2 \, \sigma_T(R_N p) - |\beta_u|^2 \, \sigma_T(R_u p) . \qquad (4)$$

If these total cross sections are approximately equal for both "N" and "U" scattering from protons or neutrons, the similarity of all three sets of data can be naively understood.

If the arguments presented above can be made more

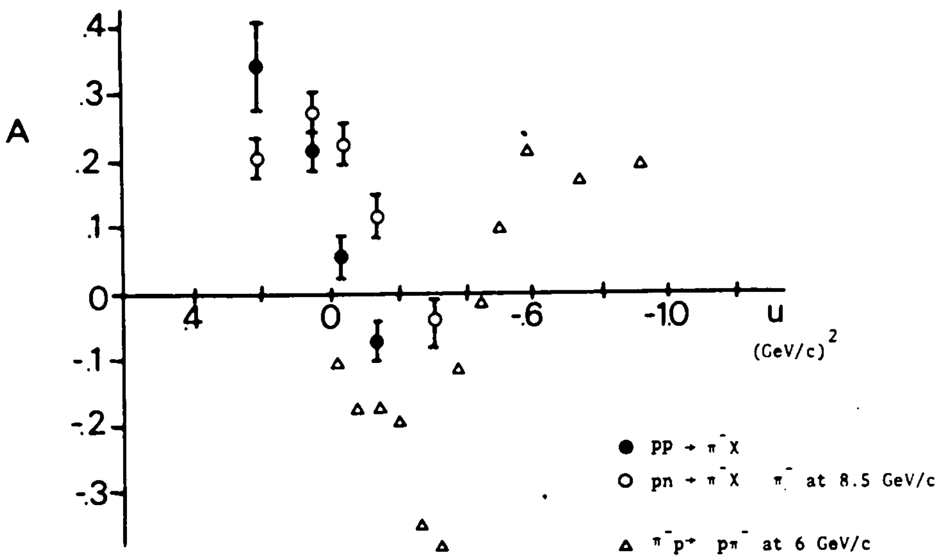

Figure 5. Inclusive π^- asymmetries

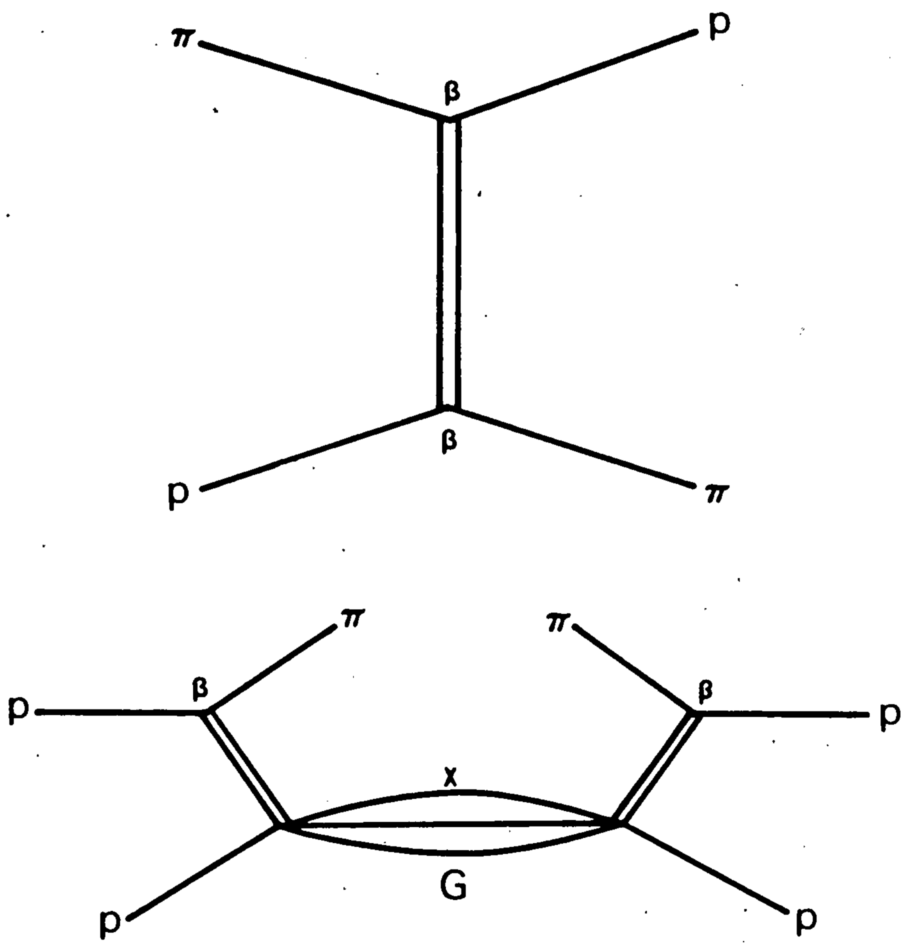

Figure 6. a) Schematic Regge diagram for the backward elastic amplitude. b) Schematic closure diagram for the inclusive cross section.

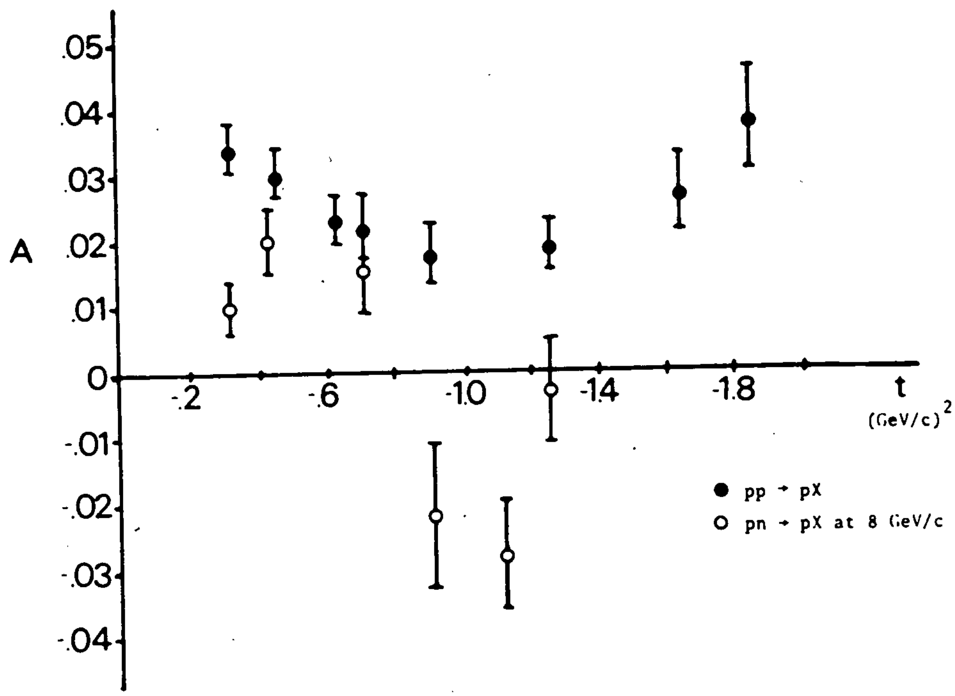

Figure 7. Inclusive proton asymmetries

quantitative, the inelastic data offer one advantage: it is relatively easy to explore the positive-u region with inelastic kinematics. Elastic experiments (from a polarized target) are difficult in this region, where the backward scattered pion has a very low energy.

The inclusive production of baryons shows no such apparent regularity. Figure 7 exhibits the asymmetry for secondary protons at 8 GeV/c from both proton and neutron targets. The asymmetries are small (about half the size of elastic scattering data) and, as in the elastic case,[7] strikingly different for proton and neutron targets. It is apparent that both the $I = 1$ and $I = 0$ amplitudes are significant in these processes.

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1. This convention yields a positive asymmetry for pp elastic scattering which is the same sign as results from the use of the Basel convention for polarized-target scattering. This consistency is the result of the properties of the identical particles in pp scattering. In general, to compare our results with p backward scattering from a polarized target, an additional minus sign must be introduced into the asymmetries.
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