the K^*-π coupling λ, as is indicated by our fits to hyperon decays. We thus believe that a large value of λ is not really unnatural within our framework. It is obvious that if we kept only the K^* contribution to $K_s \to 2\pi$ decay, the amplitude would be 3 times larger than its experimental value. We would like to thank Dr. T. Hagiwara for participation in parts of the calculation reported in this footnote.

Measurement of Asymmetries of Inclusive Pion Production in Proton-Proton Interactions at 6 and 11.8 GeV/c*

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We have used the polarized proton beam at the Argonne zero-gradient synchrotron to measure left-right asymmetries in the processes $p_{\rm pol}+p \to \pi^{\pm}+X$ at $p_0=6$ and 11.8 Gev/c and $x \equiv p_l^*/p_{\rm max}^*=0.1$ to 0.9. For both pion charges, the asymmetries show considerable but different structure in u, the square of the four-momentum transfer between the incident proton and the outgoing pion. The data suggest that pions produced at large x in pp collisions result from a baryon-exchange process.

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 $p_{\rm pol}+p \to p,d,K^{\pm},\pi^{\pm}$ + anything by placing a liquid hydrogen (LH_2) target in the extracted polarized proton beam ($p_{\rm pol}$ denotes polarized proton). The beam polarization is vertical and normal to the plane defined by the incident and scattered momenta. The data reported in this Letter are for the reaction $p_{\rm pol}+p \to \pi^{\pm}+$ anything at incident momenta of 6 and 11.8 GeV/c.

We have used ZGS Beam 5, shown schematically in Fig. 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 Čerenkov counters, each with two optically independent sections, for particle identification. Charged particles produced in a 10-cm-long, 3.8-cm-diam LH_2 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° and 17° 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

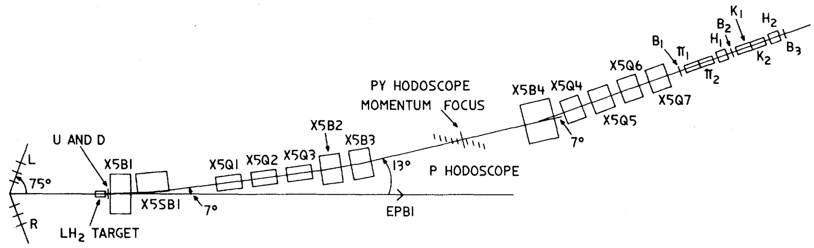

FIG. 1. A schematic layout of the experimental apparatus.

$\times 10^8$ protons per 500-msec pulse) and polarization (typically 70% at 6 GeV/c and 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 0.051 ± 0.002 at $p_0 = 6$ GeV/c and 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 asymmetries are obtained from the equation

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

where $N(\uparrow)$ $[N(\downarrow)]$ are the number of pion coincidences ($B_1B_2B_3\pi_1\pi_2$) recorded for incident beam polarization up (down) normalized to the intensity monitors and P_B is the beam polarization. The asymmetry defined here is positive when more pions 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, and pion 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 $0.07 < t < 0.3$ (GeV/c)^2; the results are consistent with the published data.[2]

Our measurements of the asymmetry for pion production (A_π) for $p_0 = 6$ GeV/c (open circles) and $p_0 = 11.8$ GeV/c (filled circles) are shown in Figs. 2 and 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 πp elastic scattering. The resolution in u is $u \lesssim \pm 0.1$ (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[3] for larger $x \equiv p_l^*/p_{max}^*$, 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.

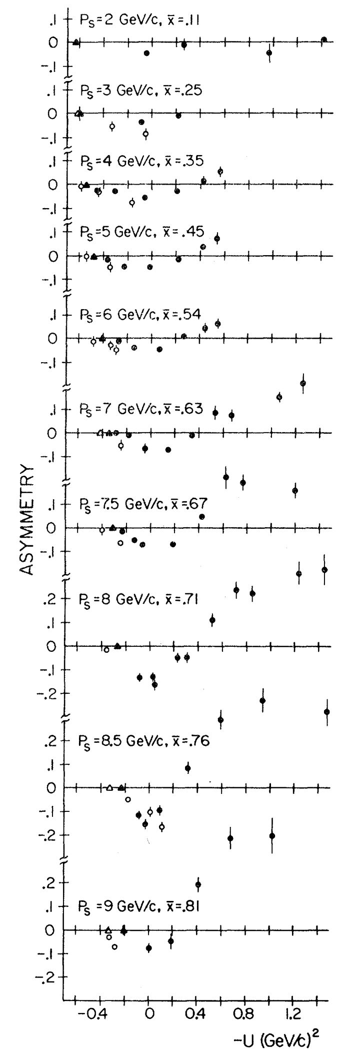

FIG. 2. The asymmetry for inclusive π^+ production in $p_{pol}p$ collisions at 6 GeV/c (open circles) and 11.8 GeV/c (filled circles). Open and filled triangles indicate the 0° point for 6 and 11.8 GeV/c, respectively. Scattered momenta (P_S) values are for 11.8 GeV/c only; $\bar{x}$ values are for both incident momenta. Error bars represent point-to-point statistical errors only; they do not include an overall normalization error of ±6% at 6 GeV/c and ±8% at 11.8 GeV/c.

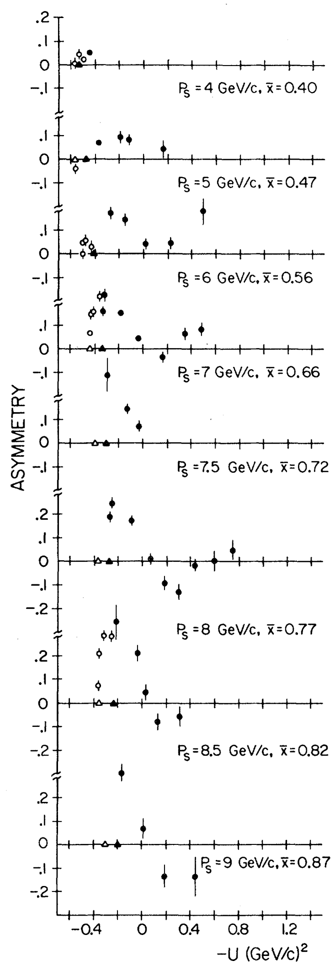

FIG. 3. The asymmetry for inclusive π^- production in $p_{\text{pol}}p$ collisions. The symbols and error bars are the same as in Fig. 2.

Although the production of N^*'s from polarized protons is known to lead to asymmetries which could then cause inclusive pion asymmetries,[4] we believe that direct-channel mechanisms cannot provide a simple explanation for our data. Such mechanisms, presumably, would be different at 6 and 11.8 GeV/c, and only in terms of a dual-resonance model could they account for the fixed-u structure. A simple exchange model, however, is suggested by the remarkable similarity of our data at large x to the πp backward elastic polarization at 6 GeV/c.[5] Except for a minus sign, which results from the polarization of the incident beam rather than the target,[1] the significant features in the overlapping kinematic region are at the same values of u. Since the πp elastic process is usually explained in terms of baryon exchange, we conclude that the asymmetry structure arises most naturally from the properties of the p-π-exchange-baryon vertex. At smaller x, these asymmetries are diluted by other, mostly isotropic processes such as diffractive excitation of the incident proton and fragmentation of the target proton. The inclusive pion cross sections as a function of x at fixed u are consistent with this view of our experiment as backward $p\pi$ scattering from a virtual pion in the target proton.

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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 πp backward scattering from a polarized target, an additional minus sign must be introduced into the asymmetries.

[2]D. R. Rust *et al.*, Phys. Lett. 58B, 114 (1975).

[3]At 6 GeV/c, however, we have data indicating that the asymmetry is small for π^+ production at $x=1$, which proceeds through the exclusive channel $p_{\text{pol}}+p \to \pi^+ + d$.

[4]A. B. Wicklund *et al.*, ANL Report No. HEP-75-02 (unpublished).

[5]L. Dick *et al.*, Nucl. Phys. B43, 522 (1972), and B64, 45 (1973).