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-scattered particles traversed a set of plane spark chambers in the magnet, two downstream scintillation counter hodoscopes (H4 and H5), and an atmospheric-pressure Cherenkov counter between H4 and H5 for tagging pions. Large-angle recoil particles were detected in a cylindrical spark-chamber system coaxial with the target.

The event trigger was a single, positive, high-momentum, forward-scattered particle, selected by twofold coincidence logic between appropriate combinations of one counter each from H4 and H5.

Forward and recoil tracks were reconstructed and a vertex was determined. The mass of the recoil particle was computed from the angles, and the four-momentum transfer $-t$ from the forward and beam track angles and momenta. Cuts were imposed on vertex position and coplanarity (±10 mrad); the background remaining under the recoil-particle effective-mass peak was insignificant. The number of events surviving all cuts was 232 for Reaction (1) and 341 for (2).

The geometric acceptance was computed using a Monte Carlo simulation tested on forward elastic cross sections.[10] The other corrections were the same as reported previously[10] except for the following: recoil track reconstruction efficiency for Reaction (1), (2): $92.0^{+8.0}_{-10.0}$, $92.0^{+8.0}_{-10.0}$%; pion decay (1.0 ± 0.5)%, (0.5 ± 0.25)%; and losses due to cuts (3.0 ± 1.0)%, (3.5 ± 1.0)%. We estimate conservatively that the overall normalization uncertainty is ±20% for each reaction.

Our results for Reaction (2) are presented in Fig. 1(a) along with earlier data.[6,7] The differential cross section drops smoothly without apparent structure out to $-t = 1.0$ GeV^2 and can be well fitted by a simple exponential of the form $A\exp(Bt)$ with $A_{(2)} = 4.2 \pm 0.3$ μb/GeV^2 and $B_{(2)} = 2.7 \pm 0.3$ GeV^{-2}.

Figure 1(b) shows our cross sections for Reaction (1) together with earlier results.[5,7] We observe the same smooth exponential drop with $-t$ as in π^-p backward scattering out to $-t = 1.2$ GeV^2 with fit parameters $A_{(1)} = 1.7 \pm 0.2$ μb/GeV^2 and $B_{(1)} = 2.7 \pm 0.3$ GeV^{-2}. There is no indication of a forward flattening or a turnover at small $-t$ as seen in several previous experiments.[4,7] The t slope is fitted remarkably well by the same B used in π^-p backward scattering, $B_{(1)} = B_{(2)} = 2.7 \pm 0.3$ GeV^{-2}. Thus, the simple line-reversal prediction of equal shape of the cross sections for Reactions (1) and (2) holds to within the errors on $B_{(1)}$ and $B_{(2)}$. In making this comparison it is important to note that the apparatus and triggering conditions were identical and that the whole

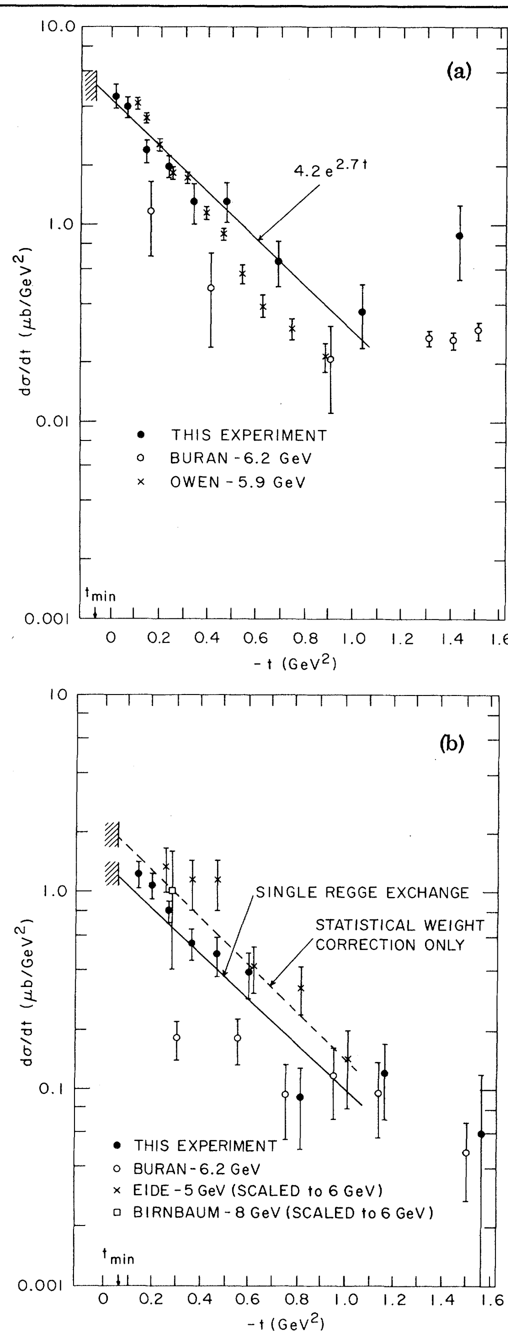

FIG. 1. (a) $d\sigma/dt$ for Reaction (2), $\pi^-p \to p\pi^-$. The solid line is an exponential fit to the data of the form $A\exp(Bt)$ with $A_{(2)} = 4.2$ μb/GeV^2 and $B_{(2)} = 2.7$ GeV^{-2}. All error bars for data from this experiment represent statistical errors only. Data from Refs. 6 and 7 are also shown. (b) $d\sigma/dt$ for Reaction (1), $\bar{p}p \to \pi^+\pi^-$. The best exponential fit (not shown) has $A_{(1)} = 1.7$ μb/GeV^2, $B_{(1)} = 2.7$ GeV^{-2}. The solid line is the fit described in the text using the Regge model prediction of Ref. 11. The dashed line is the fit to Reaction (2) scaled by the line-reversal factor 0.506. Data from Refs. 5, 7, and 8 are also shown, with s^{-2} scaling applied to the 5- and 8-GeV/c data.

t range was covered in one setting, thus mimimizing t-dependent biases in the cross-section ratio.

To compare cross-section magnitudes, we have used two prescriptions. The first is due to Barger and Cline[11] and assumes dominance of a single linear Regge trajectory (Δ_δ) with constant residue at nonasymptotic energy, while the second corrects only for spin-counting and phase-space differences. In both cases, the two cross sections have been scaled to the same s, not the same $p_{1\mathrm{ab}}$. Using s^{-2} scaling, one gets in the second case $d\sigma_{(1)}/dt = \frac{1}{2}(p_{\pi p}^*/p_{\bar{p}p})^2(s_{\pi p}/s_{\bar{p}p})^2\, d\sigma_{(2)}/dt = 0.506\, d\sigma_{(2)}/dt$.

Our data are seen to fall between these predictions, showing that at 6.0-GeV/c line reversal for Reactions (1) and (2) works up to $-t \sim 1.0$ GeV^2, in contrast with the conclusion drawn from earlier data.[5,12] The previous failure of line-reversal predictions for (1) and (2) had been very puzzling theoretically as noted, for instance, by Jackson.[12]

Comparable data on the $\bar{p}$ reaction (1) exist at 5 and 6.2 GeV/c.[5,7] If we use s^{-2} scaling[5] and take into account all normalization errors, the agreement with the 5-GeV/c data is adequate both in t slope and in normalization. Neither our data nor the scaled 5-GeV/c data agree with the t dependence or normalization of the 6.2-GeV/c data for $-t<0.7$ GeV^2. Lower-energy data[4] show a turnover near $t=0$ not seen here.

For Reaction (2), the 5.9-GeV/c data of Ref. 6 agree with ours in normalization, but their slope is steeper: 3.7 vs 2.7 GeV^{-2}. A higher-energy experiment[8] has measured a slope of 3.16 ± 0.24 GeV^{-2}, consistent with ours. Lower-energy experiments[4,9] have found slopes near 3.7 GeV^{-2}. In view of the disagreement with other data samples we note that in this experiment forward-elastic-scattering data were taken simultaneously with the baryon-exchange data, and the forward-elastic angular distributions agree well with the world data.[10] Furthermore, these data were taken in the same run as those of Ref. 10 for which the data-set agreement with other experiments is good.

Comparing our results on (1) and (2) with those from related processes we note the following. Line-reversal predictions are satisfied for the double-charge-exchange reactions (1) and (2) dominated by Δ exchange. In the zero-charge-exchange pair (3) $\bar{p}p \to \pi^-\pi^+$ and (4) $\pi^+p \to p\pi^+$, both N and Δ exchange contribute and, as previously reported by us, line-reversal predictions fail.[10] Backward charge-exchange scattering, (5) $\pi^-p \to n\pi^0$, also involving N and Δ exchange, but in amounts differing from (3) and (4), does not show the same t structure as (4).[13] Rather, it closely resembles the t structure in the annihilation reaction (3). In fact, when one compares Reactions (3) and (5) in $t' = t - t_{\min}$, using the line-reversal factor of Ref. 11, one sees the picture shown in Fig. 2. Note particularly the remarkable agreement with the high-statistics data of DeMarzo *et al.*[13]

It seems difficult for either class of model to account simply for all these results. Models involving amplitudes with intrinsic t structure must explain why the dip in Reaction (4) is unique in position and depth. Absorption models have no difficulty in predicting different t structure for (4) and (5),[14] but must explain the following features: (a) why line-reversal predictions fail for Reactions (3) and (4); (b) why line-reversal predictions work for Reactions (3) and (5) where one would not expect it; and (c) how to accommodate (a) and (b) while maintaining line-reversal symmetry for Reactions (1) and (2). These data, then, constitute a significant challenge to the understanding of baryon exchange scattering.

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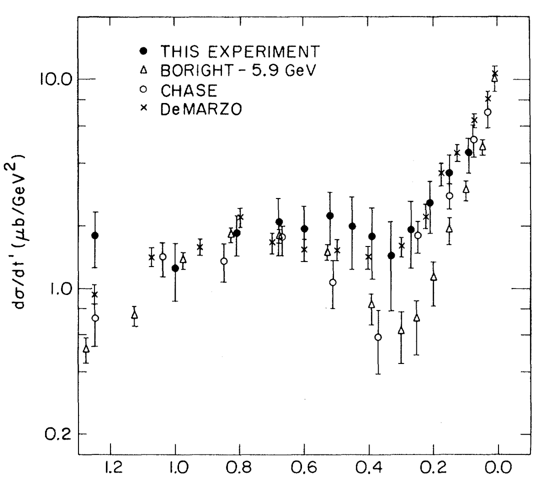

FIG. 2. Line-reversal comparison between Reaction (3), $\bar{p}p \to \pi^-\pi^+$, and Reaction (5), $\pi^-p \to n\pi^0$, plotted in $t' = t - t_{\min}$. The data for Reaction (3) are from this experiment and are scaled up by the line-reversal factor 1/0.38. All the data for Reaction (5) are from Ref. 13.

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Inclusive η Production at Large Transverse Momenta

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We have measured the ratio of inclusive production of η to π^0 at transverse momenta above 1.5 GeV/c. Results are presented for various meson and proton beams with momenta of 100, 200, and 300 GeV/c incident upon a hydrogen target. The η/π^0 production ratio is found to be independent of incident beam momentum and of the transverse and longitudinal momenta of production. The ratio for pion- and proton-induced reactions is 0.44 ± 0.05; for kaons, it is 0.74 ± 0.12.

One reason for the interest in high-transverse-momentum hadron reactions is the theoretical indication that the substructure of hadrons may be studied through these interactions. In recent models,[1-3] high-transverse-momentum (p_T) interactions are broken into three steps: fragmentation of the hadrons into their constituents, scattering of these constituents, and reformation of new hadrons from them. Since each step contains unknown interactions, it is difficult to untangle the first and last parts from the underlying, and potentially most interesting, scattering process. This Letter presents the ratio of η to π^0 production by protons, pions, and kaons at high p_T. The virtue of this ratio is that, in addition to being free of many systematic errors that influence inclusive cross sections, it is predicted to be only a weak function of the dynamical structure of the initial particles and of the shape of the hard scattering distributions. Because of this, the η to π^0 ratio gives one of the first hints about the hadron reformation process.