Inclusive Double-Charge-Exchange π^- Production at 100 GeV/c

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Measurements of inclusive cross sections at 100 GeV/c are presented for the double-charge-exchange reactions $a^+p\rightarrow\pi^-X$ with $a=\pi$, K, or p. The measurements covered a kinematic range in the Feynman x variable of $0.3\leq x\leq 0.9$ at transverse momenta of 0.3 and 0.5 GeV/c. A model summing the contributions from resonance production and from inclusive central-region π^- production is used to fit the data and demonstrates the importance of resonance production via one-pion exchange for large values of the Feynman x.

Inclusive reactions in which the incident and observed particles have opposite sign (double-charge-exchange reactions), are expected to be strongly suppressed at large Feynman x in any model based on Regge pole or particle exchanges. However, leading particles of opposite charge may arise from the decay of forward-produced resonances. The strong production of such resonances, e.g., ρ^0, $K^*(890)$, f^0, $K^*(1420)$, would complicate the study of factorization and triple-Regge mechanisms in the leading-particle reactions $ap\rightarrow aX$. Therefore, an understanding of such background processes is essential to any triple-Regge analysis. We present evidence that such resonance production is indeed important.

In particular, we study the reactions

$$(\pi^+,K^+,p)p\rightarrow\pi^-X^{+++}$$

at 100 GeV/c as measured with the Single Arm Spectrometer Facility (SAS) in the $M6E$ beam line at Fermilab. Most of the equipment and data-acquisition procedures have been described in earlier publications.[1] A detailed description of the instrumental changes that have been made will be published later. Briefly, the major alterations are as follows: (1) The liquid H_2 target has been surrounded by detectors to record the charged-particle multiplicity associated with the SAS trigger. These detectors also measure the production angles of the associated charged particles for laboratory angles $\theta\geq 15$ mrad. (2) A different tune of the SAS from that described in Ref. 1 was used in order to obtain a larger solid-angle acceptance. In the present analysis, the whole spectrometer acceptance was taken as a single bin. (3) A steel-scintillator calorimeter was installed at the end of the spectrometer. This addition has improved the accuracy in the measurement of decay corrections, which become important at lower values of x.

With this equipment, the momenta, angles, and masses of the incident beam and of one exiting particle are determined with high precision. In addition, the number and directions of all charged particles emerging from each event are also recorded. The kinematic region in the Feynman x

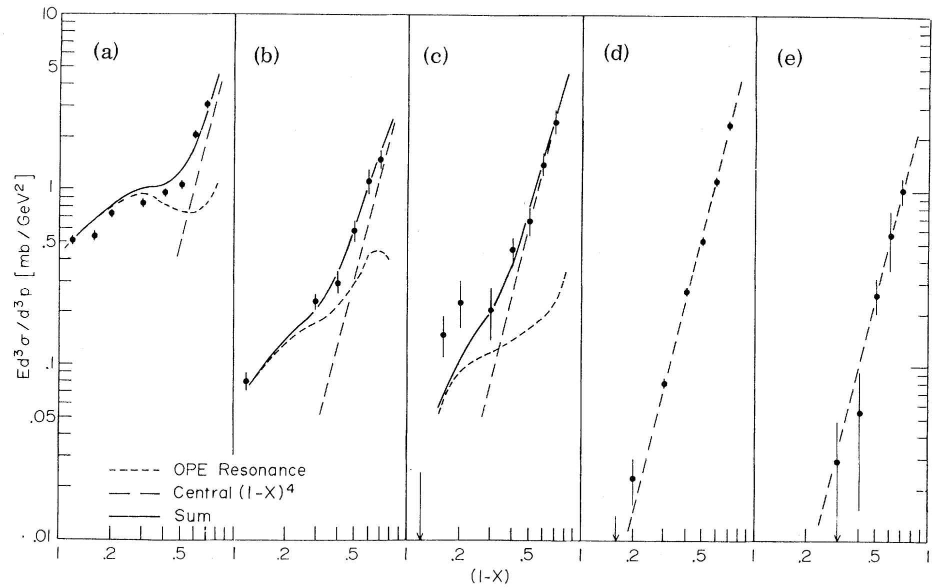

FIG. 1. Inclusive invariant cross sections for the reactions $\pi^+p\to\pi^-X$ at (a) $p_T=0.3$ GeV/c and (b) $p_T=0.5$ GeV/c; (c) $K^+p\to\pi^-X$ at $p_T=0.3$ GeV/c; $pp\to\pi^-X$ at (d) $p_T=0.3$ GeV/c and (e) $p_T=0.5$ GeV/c.

variable of $0.3\le x\le 0.9$ with $P_T=0.3$ and 0.5 GeV/c was covered in a series of spectrometer settings. The data have been corrected for the effects of absorption and multiple-scattering losses in the spectrometer as well as for losses by decay. These corrections range from a factor of 1.36 at $x=0.3$ to a factor of 1.15 at $x=0.88$. The error in these corrections is less than 2% and the relative systematic error between different reaction types is estimated to be less than 5%. In this preliminary analysis, the absolute normalization error for all the reactions is estimated to be less than 15%. The graphs contain statistical errors only.

The invariant cross sections $E\,d^3\sigma/d^3p$ are shown in Fig. 1 as a function of $1-x$ at $p_T=0.3$ GeV/c for all reactions and at $p_T=0.5$ GeV/c for incident π^+ and p only. A power-law behavior $(1-x)^n$, with $n=4$, describes the $p\to\pi^-$ reaction for all x. Such behavior is a characteristic of many fragmentation models.[2] On the other hand, the cross sections for both the π^+- and K^+-induced reactions for high x significantly exceed a simple power-law extrapolation from the region $x<0.5$. This enhancement appears to be consistent with resonance production via one-pion exchange (OPE). Quantitative estimates of the differential cross sections for these reactions have been made by summing the contributions from resonance production and those from inclusive central-region production.

In the case of the π^+-induced reaction, the principal resonance contributions should be due to ρ^0 and f^0 production. The OPE production of these resonances has been parametrized, as illustrated in Fig. 2, assuming constant form factors and a slowly varying π^+p total cross section, $\sigma_{\pi p}\propto s^{-0.1}$. The coupling strengths of the $\rho\pi\pi$ and $f\pi\pi$ vertices have been taken from $\pi\pi$ scattering analyses.[3] This gives an absolute normalization for the model which is estimated to be good to ±20%. Finally, the ρ and f decay angular distributions, obtained from low-energy data,[4] are folded with their production distributions. The sum of the predicted contributions of the ρ^0 and the f^0 to the process $\pi^+p\to\pi^-X$ is shown in Figs. 1(a) and 1(b) as the dotted curves. The parameters of the model are summarized in Table I.

To describe the central-region π^- production the $pp\to\pi^-X$ cross-section dependence, i.e., (1

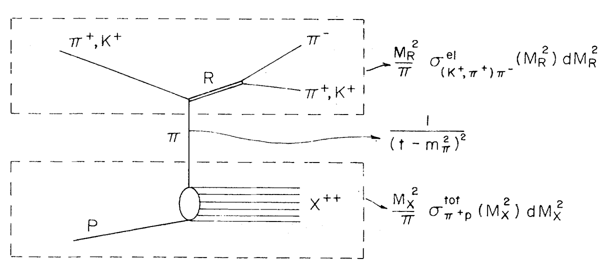

FIG. 2. The exchange diagrams of the OPE resonance production model discussed in the text.

TABLE I. OPE-model parameters.

Reaction	Contributing term	Predicted σ_{tot} (mb)	M_R (MeV)	Γ_{M_R} (MeV)	R
$\pi^+p\rightarrow\pi^-X$	$\pi^+p\rightarrow\rho^0X$, $\rho^0\rightarrow\pi^+\pi^-$	2.0	773	152	$\rho_{00}{}^{ss}=0.2$ $\rho_{00}{}^{pp}=0.8$ $\rho_{00}{}^{sp}=0.2$
	$\pi^+p\rightarrow f^0X$, $f^0\rightarrow\pi^+\pi^-$	0.7	1271	180	$\rho_{00}{}^{ss}=0.4$ $\rho_{00}{}^{dd}=0.6$ $\rho_{00}{}^{sd}=0.4$
$K^+p\rightarrow\pi^-X$	$K^+p\rightarrow K^*(890)X$, $K^*(890)\rightarrow K^+\pi^-$	0.44	892	49	$\rho_{00}{}^{ss}=0.2$ $\rho_{00}{}^{pp}=0.8$ $\rho_{00}{}^{sp}=0.2$
	$K^+p\rightarrow K^*(1420)X$, $K^*(1420)\rightarrow K^+\pi^-$	0.22	1421	108	$\rho_{00}{}^{ss}=0.4$ $\rho_{00}{}^{dd}=0.6$ $\rho_{00}{}^{sd}=0.4$

$-x)^4$, is used and is shown as the dashed curves in Figs. 1(a) and 1(b). In fact, the small-x data are consistent with a power-law exponent between 3.5 and 4.5. The amount of central-region production to be added to the absolute OPE predictions is determined by a fit to the data. The sum of the three components is shown as the solid lines in Figs. 1(a) and 1(b). This simple model clearly provides a quite good description of the data over the entire x region. We also note that the total ρ-production cross section predicted by the model is in good agreement with bubble-chamber measurements[5] at high x.

This model has also been applied to the reaction $K^+p\rightarrow\pi^-X$, making use of $K\pi$ scattering results[6] to describe the meson vertex. It is assumed that $K^*(890)$ and $K^*(1420)$ production dominate the OPE contribution (see Fig. 2 and Table I). We then fold in the corresponding angular distributions for the K^*'s and add the central-region contribution using the scaled $pp\rightarrow\pi^-X$ cross section as in the previous case. Figure 1(c) shows these curves and the sum (solid line) which provides a resonable description of the data but underestimates the enhancement for $x>0.6$. We note in this regard that K^* production, unlike ρ and f production, has a substantial ρ-exchange contribution which has not been included in our model.

Using the multiplicity detector we may further confirm that the excess of events at large x [e.g., Fig. 1(a)] is the result of ρ^0 and f^0 production. Figure 3 shows scatter plots of the pseudorapidity, $\eta=-\ln(\tan\frac{1}{2}\theta)$, versus the azimuth angle φ around the beam for the associated charged particles at two different x settings. The trigger particle is at $\varphi=0^0$ and $\eta=6.4$ (5.6) for $x=0.88$ (0.4). In Fig. 3(a) for $x=0.88$ one sees a clear peak at $\varphi=180^0$ and $\eta\approx4.2$ with about one entry per event. This peak is what one would expect from the two-body decay of a peripherally produced resonance where the other decay product is detected in the spectrometer. At $x=0.4$ the same plot [Fig. 3(b)] shows no evidence for such

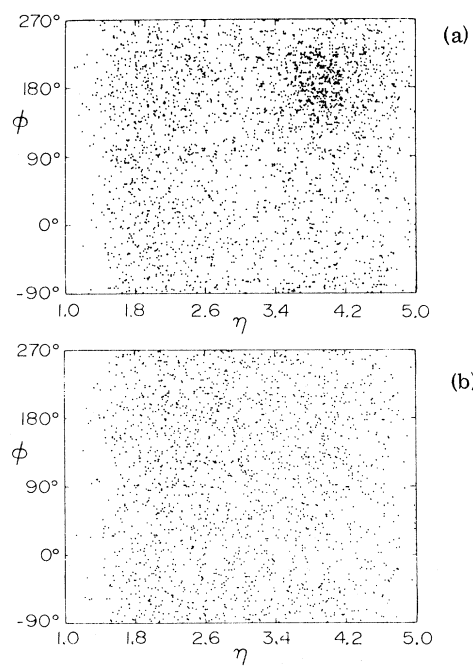

FIG. 3. Scatter plots of azimuthal angle φ vs psuedorapidity η of the associated particles in the system X in the reaction $\pi^+p\rightarrow\pi^-X$. The trigger π^- is at $p_T=0.3$ GeV/c and $x=0.88$ ($\eta=6.5$) in (a) and at $x=0.4$ ($\eta=5.6$) in (b).

a second particle peak, consistent with the onset of the dominance of central-region π^- production.

To conclude, it has been shown that a semiempirical model incorporating a large contribution of resonance production consistently describes double-charge-exchange inclusive π^- production at high values of x. From this model, we estimate that the production of meson resonances could constitute as much as 40% of both leading-particle reactions $\pi^\pm p \to \pi^\pm X$ and $K^\pm p \to K^\pm X$ at $x \approx 0.85$. Furthermore, in these reactions both neutral and charged resonance production will contribute. Therefore, any triple-Regge analysis should correct for meson resonances produced by exchange processes.

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Experimental Limits on Heavy Lepton Production by Neutrinos

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We present upper limits on the production of heavy leptons ($L^\pm$) by neutrinos via the process $\nu_\mu + \text{Ne} \to L^\pm + \cdots$, $L^\pm \to e^\pm + \nu + \bar{\nu}$. These limits imply that the L^- and L^+, if they couple in full strength to ν_μ, are heavier than 7.5 and 9 GeV, respectively. They also imply that the coupling strength ν_μ to the recently discovered 1.9-GeV heavy lepton τ is less than 0.025 of the normal ν_μ-μ coupling.

The possible existence of charged leptons heavier than the electron and the muon has been often discussed in the past. Recently, experimental evidence has been found for the existence of such a particle, called the τ, near 1.9 GeV in mass,[1] and possibly for even more massive ones.[2] The question then naturally arises whether such a lepton has the quantum number of the electron, or the muon, or does it have a new unique lepton number. If its lepton number is the same as that of the muon, then it should be produced in ν_μ interactions, and decay, among other things, into $e^\pm \nu\bar{\nu}$ as shown in the diagram of Fig. 1. For any given mass of the heavy lepton $L^\pm$, both the production cross section and the decay branching ratio into $e^\pm \nu\bar{\nu}$ are calculable. The experimental signal for this process is e^+ or e^- without any other charged leptons in the final state produced in a ν_μ beam.

We have searched for heavy-lepton production

