Inclusive Kaon Charge Exchange in the Triple-Regge Region at High Energies

P. M. Yager
University of California, Davis, California 95616

and

H. G. E. Kobrak, R. E. Pitt,[a] and R. A. Swanson
University of California, San Diego, La Jolla, California 92093

and

K. W. Edwards and M. Harrison[b]
Carleton University, Ottawa K1S 5B6, Canada

and

M. A. Abolins, W. R. Francis,[b] and D. P. Owen
Michigan State University, East Lansing, Michigan 48823
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We present cross-section measurements for inclusive kaon charge exchange, $(K^-, p) \to (\bar{K}^0, X)$, at 68, 116, and 176 GeV/c in the kinematic region $x > 0.7$ and $-t < 1.3$ (GeV/c)^2. The results are in excellent agreement with the predictions of triple-Regge theory and for the first time confirm the dominance of the Regge-Regge-Pomeron terms.

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Regge theory[1] describes amplitudes for exclusive scattering processes in terms of their singularities in the complex-angular-momentum plane. When the number of singularities (exchanges) is small, attempts to describe reactions in terms of the simplest singularities (poles) have been very successful. Triple-Regge theory[2] describes inclusive processes in the kinematic region "close" to the conditions of their exclusive counterpart. The two processes

$$\pi^- + p \to \pi^0 + X, \tag{1a}$$

$$\pi^- + p \to \eta + X, \tag{1b}$$

which may be described in terms of a single exchange each, have been extensively studied.[3] (Here X refers to the recoil system in the inclusive process.) The exchanges are the ρ and A_2 trajectories for processes (1a) and (1b), respectively. In this paper we present data on the inclusive process

$$K^- + p \to \bar{K}^0 + X, \tag{2}$$

which may be described by a combination of the above ρ and A_2 exchanges. This process has, in the past, been studied in bubble chambers for incident kaon momenta between 5 and 32 GeV/c.[4] Some of these data have been compared with triple-Regge predictions,[5] but the low acceptance in the kinematic region of interest severely limits the statistical power of these experiments.

The experiment was performed in the tagged-kaon beam in the $M4$ line at Fermilab. The $M4$ spectrometer measures the momentum vectors of the incident K^- and of the charged pions from the $K\pi2$ decay of the neutral kaon. Details of the experiment are given by Pitt.[6] Data were taken for values of s of 128, 218, and 330 GeV^2 (beam momenta of 68, 116, and 176 GeV/c). The measurement resolutions of relevant parameters for each beam momentum are shown in Table I. Of the 110 000 recorded neutral kaons, 21 000 were in the kinematic region appropriate to triple-Regge analysis, namely $0.975 > x > 0.7$ and $t_{min} < |t| < 1.3$ (GeV/c)^2. Here s and t are the squares of the total energy and the four-momentum transfer, respectively, and $x = 1 - m_x^2/s$ ("Feynman x") where m_x is the mass of the recoil system in (2) (to a good approximation, x is the ratio between the $\bar{K}^0$ and K^- momenta).

Triple-Regge theory predicts the cross section

TABLE I. Average relative measurement resolutions in s, x, and t. The average is weighted according to the event distribution in each variable.

Beam momentum (GeV/c)	$\Delta s/s$	$\Delta x/x$	$\Delta t/t$
68	0.005	0.012	0.043
116	0.004	0.016	0.032
176	0.004	0.019	0.028

for process (2) to have the form

$$\frac{d^2\sigma}{dx\,dt} = B_\rho(t)[C_\rho(1-x)^{[1-2\alpha_\rho(t)]} + D_\rho(s,t)] + B_{A_2}(t)[C_{A_2}(1-x)^{[1-2\alpha_{A_2}(t)]} + D_{A_2}(s,t)] + \text{interference term}. \qquad (3)$$

The first bracket contains the dominant ρ-ρ-Pomeron term and the small ρ-ρ-$(\rho+f)$ triple-Regge term; the second, the equivalent terms for A_2 exchange. The (ρ, A_2) interference term is also small. If we neglect the "small" terms, which at our values of s are $<2\%$ of the dominant terms, we have

$$\frac{d^2\sigma}{dx\,dt} = G_\rho(t)(1-x)^{[1-2\alpha_\rho(t)]} + G_{A_2}(t)(1-x)^{[1-2\alpha_{A_2}(t)]}, \qquad (4)$$

where $\alpha_\rho(t)$ and $\alpha_{A_2}(t)$ are the same Regge trajectories which describe reactions (1a) and (1b). SU(3)-symmetry rules[7] relate the residue functions $G_\rho(t)$ and $G_{A_2}(t)$ for kaon charge exchange to those for pion charge exchange as follows:

$$G_\rho^{K,\bar{K}^0}(t) = \tfrac{1}{2}G_\rho^{\pi,\pi^0}(t), \quad G_{A_2}^{K,\bar{K}^0}(t) = \tfrac{3}{2}G_{A_2}^{\pi,\eta}(t). \qquad (5)$$

If we assume the validity of these rules and neglect the above "small" terms, the results of this experiment are completely constrained by triple-Regge theory and the results of the pion charge-exchange experiments, as follows: (i) $d^2\sigma/dx\,dt$ is s independent and its (x, t) dependence is given by (4); (ii) $\alpha_\rho(t)$ and $\alpha_{A_2}(t)$ are the same for kaon and pion charge exchange reactions,

$$d^2\sigma(K^-, \bar{K}^0)/dx\,dt = \tfrac{1}{2}d^2\sigma(\pi^-, \pi^0)/dx\,dt + \tfrac{3}{2}d^2\sigma(\pi^-, \eta)/dx\,dt.$$

As a result of the near equality of $\alpha_\rho(t)$ and $\alpha_{A_2}(t)$, fits of our data to (4) are insensitive to the relative contributions of the ρ and A_2 terms. We therefore fit these data to an x dependence containing an effective trajectory $\alpha_E(t)$,

$$d^2\sigma/dx\,dt = G(t)(1-x)^{[1-2\alpha_E(t)]}. \qquad (6)$$

Figures 1 and 2 show the x dependence of our cross sections for process (2), in two representative t bins, for the three s values of the experiment. The data have been corrected for acceptance, measurement resolution, secondary interactions of the incoming and outgoing particles, and backgrounds due to target nonassociated interactions. Pitt[6] gives a detailed description of these procedures as well as a complete set of measured cross sections. We see that expression (6) represents the x dependence of the data extremely well. The parameters $\alpha_E(t)$ and $G(t)$ obtained from the fits of (6) to our data are shown in Figs. 3 and 4. The prediction that these parameters, and hence the cross sections, be s independent is indeed confirmed. Preliminary and partial comparisons of our data with those from pion charge-exchange reactions (1a) and

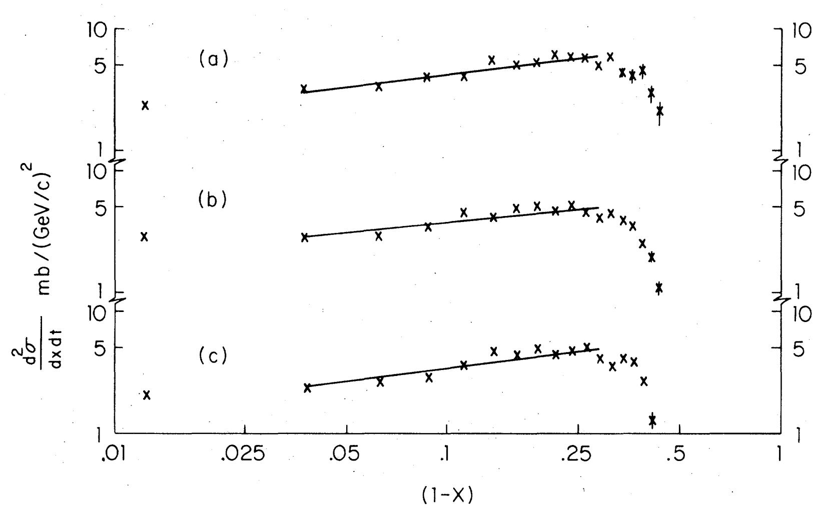

FIG. 1. Measured cross sections for process (2) in the interval $t_{\min} > -0.1$ (GeV/c)^2 at beam momenta of (a) 68 GeV/c, (b) 116 GeV/c, and (c) 176 GeV/c. The line is the best fit of the data to (6).

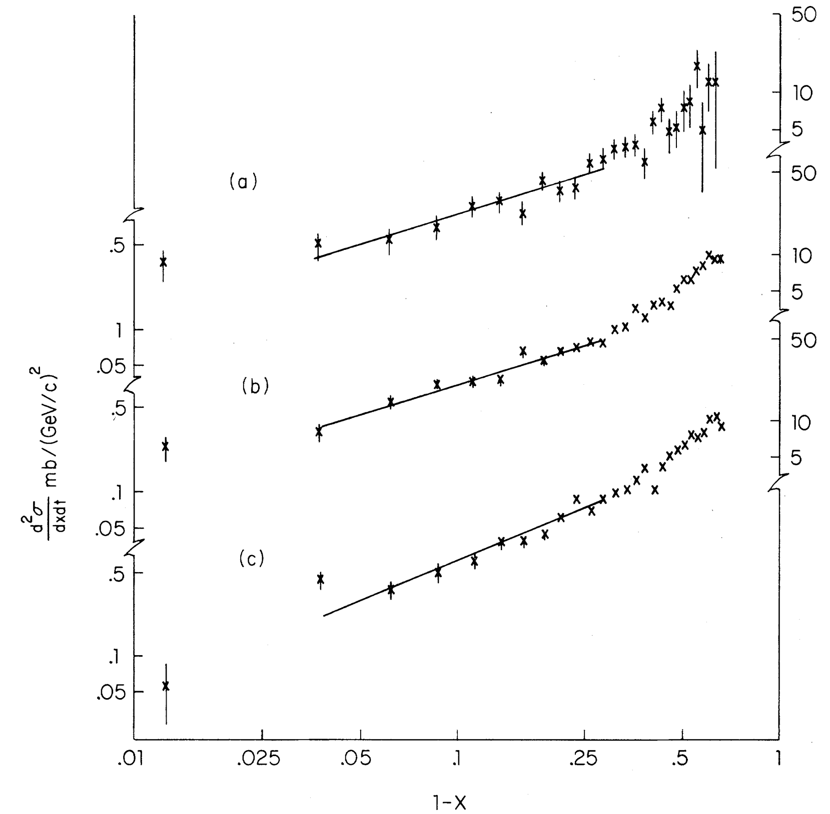

FIG. 2. Measured cross sections for process (2) in the interval $-0.3 > t > -0.4$ (GeV/c)^2 at beam momenta of (a) 68 GeV/c, (b) 116 GeV/c, and (c) 176 GeV/c. The line is the best fit of the data to (6).

(1b) are discussed in Ref. 6. A detailed common analysis of the two experiments will be published shortly.

Our data provide an important test of triple-Regge theory in general and by examining for the first time in detail their s dependence, we show conclusive proof of the dominance of the Regge-

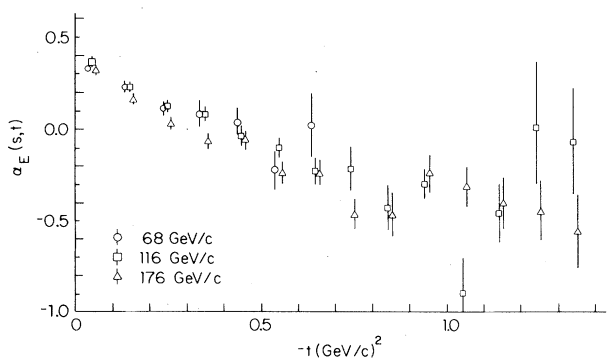

FIG. 3. Value of the effective trajectory $\alpha_E(t)$ from fits of our cross sections to (6).

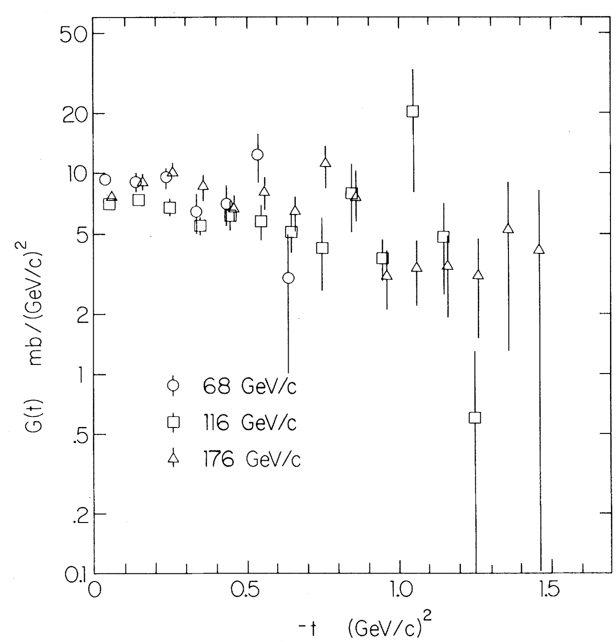

FIG. 4. Value of the residue function $G(t)$ from fits of our cross sections to (6).

Regge-Pomeron terms over the triple-Regge and ρ-A_2 interference terms. As in previous similar experiments,[3] our data are well described by Regge-pole contributions alone. Contributions due to other terms are either small or undistinguishable from those of pole terms.

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[(a)]Present address: Massachusetts Institute of Technology, Cambridge, Mass. 02139.

[(b)]Present address: Fermi National Accelerator Laboratory, Batavia, Ill. 60510.

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Coherent Conversion of Very Light Pseudoscalar Bosons

S. Barshay, H. Faissner, R. Rodenberg, and H. de Witt

III. Physikalisches Institut, Technische Hochschule Aachen, D-5100 Aachen, Federal Republic of Germany

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We discuss coherent conversion of hypothetical very light pseudoscalar bosons into a photon in the Coulomb and vector meson fields of a nucleus. The process provides a way to look for such bosons independently of whether their mass and lifetime allow for detection of the two-photon decay.

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In the context of spontaneously broken symmetries,[1,2] the search for the possible existence of very light pseudoscalar bosons is of continuing interest. The axion[3,4-6] is a particular example. Decay into an electron-positron pair seems to be experimentally excluded[7]; therefore we are considering masses below 1 MeV for which only detection via the decay into two photons remains a possibility. However, if the mass of the hypothetical boson is sufficiently small ($\lesssim 10$ keV), it becomes increasingly difficult to observe the two-photon decay with typical[8] experimental decay paths of a few meters because of the greatly increased lifetime. Fortunately, there is one other process which could allow for the detection of arbitrarily light pseudoscalar bosons and which is a direct consequence of the existence of the two-photon decay. This is the conversion of the boson (denoted by a^0) into a single photon by coherent interaction with a nucleus. The coherent interaction will be with the charge of the nucleus via exchange of a photon (the Primakoff effect[9]) and also with the total nucleon number via exchange of a strongly interacting, isoscalar vector meson, such as the ω^0. In this note, we calculate this process for a current experimental situation. The coherent nuclear process is more important than Compton scattering of a^0 from individual

