SLAC-PUB-1778 July 1976 (E)

INCLUSIVE HADRON EXCHANGE SCATTERING AT 50 - 175 Gev

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ABSTRACT

Measurements of inclusive hadron processes of the type $a + p \rightarrow b + ...$ have been made at energies of 50 GeV to 175 GeV for Feynman x in the range 0.75 to 0.95 and -t's up to 0.65 GeV². The invariant cross sections are satisfactorily parameterized by a simple form derived

from Regge theory.

We have used the Fermilab Single Arm Spectrometer Facility to measure the inclusive reactions:

π'	$+ p \rightarrow K$	· +	(a)
	P R		(4)

 $\pi^{-} + p \rightarrow K^{-} + \dots$ (b)

$$\pi + p \rightarrow p + \dots$$
 (c)

$$\pi' + p \rightarrow p + \dots \tag{d}$$

$$p + p \rightarrow \pi^{-} + \dots \qquad (e)$$

$$p + p \rightarrow K^{\mathsf{T}} + \dots \tag{f}$$

Work supported in part by the Energy Research and Development Administration, the National Science Foundation, and INFN (Italy).

In the context of Regge theory, inclusive reactions of the type $a + p \rightarrow b + ...$ are of particular interest as they involve quantum-number exchange and cannot proceed via Pomeron exchange. Extensive measurements exist for inclusive reactions of the type $a + p \rightarrow a + ...$, which at large x values are dominated by Pomeron exchange, but relatively few measurements exist for inclusive reactions not involving Pomeron exchange.¹

The experiment was performed with the Fermilab Single Arm Spectrometer Facility.² Particle type was determined in both the beam line and spectrometer allowing all inelastic processes with particles of given charge to be measured at the same time. Incoming beam particles were tagged for particle type by a threshold Cerenkov counter (pions), a DISC counter (kaons or protons), and a differential Cerenkov counter (protons or kaons). A magnetic deflection system varied the angle of the beam at the liquid hydrogen target. Outgoing particles scattered into the spectrometer were identified with a differential counter set for protons (the counter also contained an anti-ring efficient for kaons and pions), a long threshold counter set to count pions and two shorter threshold counters set to count kaons and pions at lower energies.

The experiment was run with beam intensities of 2 to $3 \cdot 10^6$ particles per burst and with ~10% of the R.F. buckets occupied by two particles. To avoid random events, the major source of background, the trigger requirement for reactions of the type $a + p \rightarrow b + ...$ was set to be a present and b <u>not</u> present in the beam and b present in the spectrometer. Therefore the Cerenkov counters in the beam required both high rejections against unwanted particle types and high detection efficiencies. At incident energies above 100 GeV the efficiency of the threshold counter for pions dropped. However, the "anti-ring" of the differential counter counted pions or kaons with 99.8% efficiency and was used

in anticoincidence to ensure protons in the beam line were unaccompanied by pions and kaons. The differential counter retained 99.8% or better efficiency for proton detection up to the highest energies. An additional rejection factor of about ten against the background was obtained by requiring only one particle in the beam line hodoscopes. With these strict Cerenkov and hodoscope requirements, the background from randoms was reduced to less than 5% of the signal for $x \leq 0.95$. The combined rejection ratios were measured by observing the fraction of incorrectly identified events, which satisified the kinematics of elastic scattering.

Inclusive exchange processes have small cross sections and therefore fiducial cuts on the acceptance were kept wide to obtain maximum counting rates. Data³ for the high rate processes $\pi^{\pm} + p \rightarrow \pi^{\pm} + \dots$ were taken in parallel with the inclusive exchange measurements and were used to calibrate the spectrometer acceptance.

The systematic uncertainties introduced by the calibration of acceptances and efficiencies were about 10%. The total number of recorded events was about four thousand events each for $\pi \rightarrow K$ (reactions (a) and (b)), about one thousand events for $\pi \leftrightarrow p$ (reactions (c), (d), and (e)), and about three hundred events for $p \rightarrow K^+$.

Regge theory parameterizes cross sections for inclusive processes^{1,4} of the type $a + p \rightarrow b + MM^2$ (see Fig. 1) with the form:

$$\frac{d^{2}\sigma}{dtdx} = \sum_{i} \frac{|\beta_{abc_{i}}^{(t)}|^{2}}{16\pi s_{0}^{2}} (1-x)^{1-2\alpha_{i}^{c}} \sigma_{tot}^{c_{i}p}(t,MM^{2})$$
(1)

where $\beta_{abc_i}(t)$ is the residue function for an exchanged Reggeon c_i ; α_i^c is the corresponding Regge trajectory; and $\sigma_{tot}^{c_i p}(t, MM^2)$ is the effective total cross section for Reggeon c_i on a proton at a sub-energy corresponding to the missing mass squared (MM²).

To limit the number of parameters, the data were fitted to a semi-emperical form suggested by Eq. (1):

$$\frac{d^2\sigma}{dtdx} = \frac{\left|\beta\right|^2 (1-x)^{(1-2\alpha_{eff})}}{16\pi s_0^2} e^{b_{eff}t} \sigma_{tot}^{cp}(MM^2) , \qquad (2)$$

where the measured total cross sections for πp , Kp, and pp, depending on the strangeness and baryon quantum numbers being exchanged, were used as an approximation for $\sigma_{tot}^{cp}(MM^2)$. The additional approximations involved in this equation are the following: In principle the α_i^c and σ_{tot}^{cp} are t dependent; in practice the measurements did not span a sufficiently large range in t to make this a significant dependence. Experimentally, the x dependence of the data can be parameterized by a single Regge exchange so that the summation sign could be dropped. According to Eq. (1) the cross sections should scale and show no additional s dependence except for the part implicit in σ_{tot}^{cp} . The data were consistent with less than 15% departures from scaling resulting from additional s dependences, except for the " $\pi^+ p \rightarrow p$ " cross section which showed departures from scaling of about 30% from 50 GeV to 175 GeV. In this paper only the data at 140 GeV and 175 GeV are included for this channel.

Table I tabulates the values of the fitted coefficients $|\beta|^2/16\pi s_0^2$, α_{eff} , and b_{eff} determined through a χ^2 minimization procedure. Satisfactory statistical fits were obtained to the form of Eq. (2). The values of α_{eff} are close to those expected by Regge exchange theory. For " $\pi^+ p \rightarrow \kappa^+$ " and " $\pi^- p \rightarrow \kappa^-$ " the observed values of α_{eff} are small and positive, 0.25 and 0.20 respectively,

and for reactions involving nucleon or antinucleon exchange " $\pi^+ p \rightarrow p$," " $\pi^- p \rightarrow \bar{p}$," and " $pp \rightarrow \pi^+$," the α_{eff} were approximately -0.6.

Figure 2 shows plots of fits to log $(d^2\sigma/dtdx)_{eff}$ evaluated at the median t values of the data versus log (1-x) in order to display the expected $(1-x)^{(1-2\alpha}eff)$ dependence. The effective invariant cross section $(d^2\sigma/dtdx)_{eff}$ is defined as:

$$\left(\frac{d^{2}\sigma}{dtdx}\right)_{eff} = \left(\frac{\sigma_{tot}^{cp}(200 \text{ GeV}^{2})}{\sigma_{tot}^{cp}(MM^{2})} \quad \frac{d^{2}\sigma}{dtdx}\right)_{AV}$$
(3)

The factor $\sigma_{tot}^{cp}(MM^2)$ takes out the expected s dependence and the factor $\sigma_{tot}^{cp}(200 \text{ GeV}^2)$ normalizes the cross section to high energies.⁵

Figure 2(a) displays the effective invariant cross sections for the median -t of 0.3 GeV² for " $\pi^- p \rightarrow \bar{p}$ " and " $\pi^+ p \rightarrow p^+$." The " $\pi^+ p \rightarrow p^+$ " is larger by a factor 1.4. In simple Regge theory these two processes should have identical cross sections. The difference in behavior probably arises from u-channel nucleon exchange indicated by the presence of an energy dependent invariant cross section.

Figure 2(b) plots the effective invariant cross sections for " $\pi^- p \rightarrow K^-$ " and for " $\pi^+ p \rightarrow K^+$ " and in accord with Regge theory these cross sections are indeed almost identical. Figure 2(c) plots the effective invariant cross sections for the process "pp $\rightarrow \pi^+$ " and "pp $\rightarrow K^+$."

In conclusion, the Regge expression of Eq. (1), as simplified in Eq. (2), gives a good representation of our high energy inclusive exchange data in the Feynman x range of 0.75 to 0.95.

We would like to thank the many people at Fermilab who have contributed to the successful construction and operation of the Single Arm Spectrometer Facility. We would also like to express appreciation to our technical support personnel for their invaluable assistance in the instrumentation of the facility. We are especially indebted to D. Sivers for clarifying the theory and for many discussions and to H. Abarbanel for careful reading of the paper.

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¹For discussions of experimental results and comparison with theory see: M. Chen, L. Wang, and T. F. Wong, Phys. Rev. <u>D5</u>, 1667 (1972); R. Peccei and A. Pignotti, Phys. Rev. Letters <u>26</u>, 1076 (1971); and D. Sivers, Proc of SLAC Summer Inst., Report No. SLAC-179, Vol. I, p. 327 (1974).

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⁴The normalization is that given in Kaidalov, Khoze, Pirogov, Ter-Isackyan, Phys. Letters 45B, 493 (1973).

⁵A. S. Carroll, et al., Phys. Rev. Letters <u>33</u>, 928,932 (1974).

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Best fit values to the invariant cross section parameterized in the form $\frac{d^2\sigma}{dtdx} = \frac{|\beta|^2}{16\pi s_0} (1-x)^{1-2\alpha} e^{ff} \sigma^{cp}_{tot}(MM^2) e^{b} e^{ff} t.$

Channe 1	Effective -t Range in GeV ²	Laboratory Energy Range in GeV	β ² /16πs ₀ ² (GeV ⁻²) ⁰	^Q eff	(Gevential)
π^+ + p + K ⁺ +	0.1 - 0.65	50 - 140	0.155 ± 0.015	0.20 ± 0.06	3.7 ± 0.3
$\pi^{-} + p + K^{-} + \dots$	0.1 - 0.65	50 - 140	0.135 ± 0.014	0.25 ± 0.06	3.7 ± 0.3
π + p + p +	0.2 - 0.65	50 - 175	0.128 ± 0.012	-0.55 ± 0.15	2.0 ± 0.3
$\pi^+ + p \rightarrow p + \cdots$	0.2 - 0.65	140 - 175	0.240 ± 0.022	-0.50 ± 0.10	3.1 ± 0.5
р + р <u>+</u> п +	-0.2 - 0.20	50 - 175	0.270 ± 0.025	-0.65 ± 0.15	4.4 ± 0.5

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 $+ p \rightarrow K^{+} + \cdots$

-0.2 - 0.20

50 - 175

 0.108 ± 0.015

 -0.65 ± 0.20

 3.0 ± 1.0

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FIGURES

- Fig. 1. Diagrammatic representation of an inclusive process of the type $a + p \rightarrow b + \dots$ via Regge exchange of a particle c.
- Fig. 2. Plots of log $(d^2\sigma/dtdx)_{eff}$, as defined by Eq. (3), against log (1-x) to display the power law dependences of the cross sections. The lines through the data points are the results of fits to Eq. (2) with the parameters given in Table I.



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Fig. 2