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INELASTIC SCATTERING AMPLITUDES*

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ABSTRACT

New results from inelastic two-body scattering reactions are reviewed. Although predictions of SU(3), factorization and simple Regge theory are found to be qualitatively in agreement with the data, direct channel or absorption effects afford the simplest interpretation of the detailed features of the scattering amplitudes.

INTRODUCTION

As an introduction to the forward scattering data, consider the "parton's eye view" of two body reactions presented in Fig. 1. In this figure an assortment of reactions[1] near 4 GeV/c are shown out to scattering angles exceeding 90° in their center of mass ($|t| \gtrsim 3$ GeV^2). Interestingly all four reactions have approximately equal cross sections for $|t| \gtrsim 2.5$ GeV^2 (to within a factor of 5 or 10), whereas at $t \approx 0$ the cross sections differ by ~3 orders of magnitude! Data at 5 GeV/c reflect this same behavior.

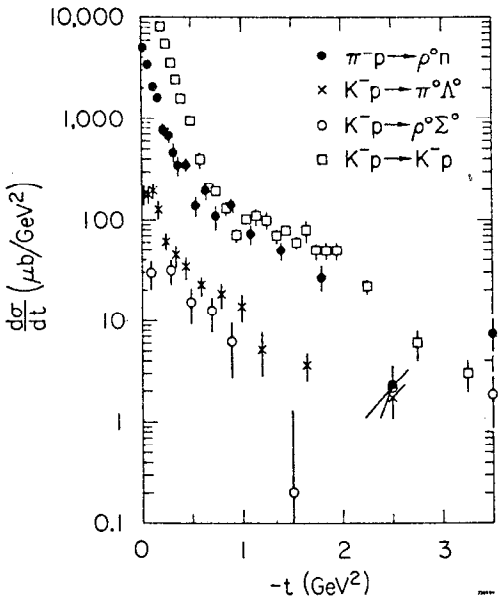

FIG. 1--Assorted large angle differential cross sections at ~4 GeV/c, Ref. 1.

The large $|t|$ data may therefore be intrinsically simpler (cf. parton models)[2] than data at small values of momentum transfer. Nevertheless, we now proceed to the subtleties of the "Regge" scattering region (possibly defined by $0 \lesssim |t| \lesssim 2$ GeV^2 as suggested by Fig. 1) where t channel exchanges are important.

FORWARD SCATTERING DATA

As a framework for discussing the data, we keep in mind the form of typical s channel Regge and absorption[3] model helicity amplitudes:

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$$\text{(Regge)}\quad f_{\Delta\lambda}(s,t) \propto (\sqrt{-t})^{\Delta\lambda/2}\,(s/s_0)^{\alpha(t)}\,(\pm 1 - e^{-i\pi\alpha(t)}) \qquad (1)$$

$$\begin{pmatrix}\text{Absorption}\\ \text{Harari}\end{pmatrix}\quad f_{\Delta\lambda}(s,t) \propto J_{\Delta\lambda}(r\sqrt{-t})\,(s/s_0)^{\tilde{\alpha}(t)}\,(? + i) \qquad (2)$$

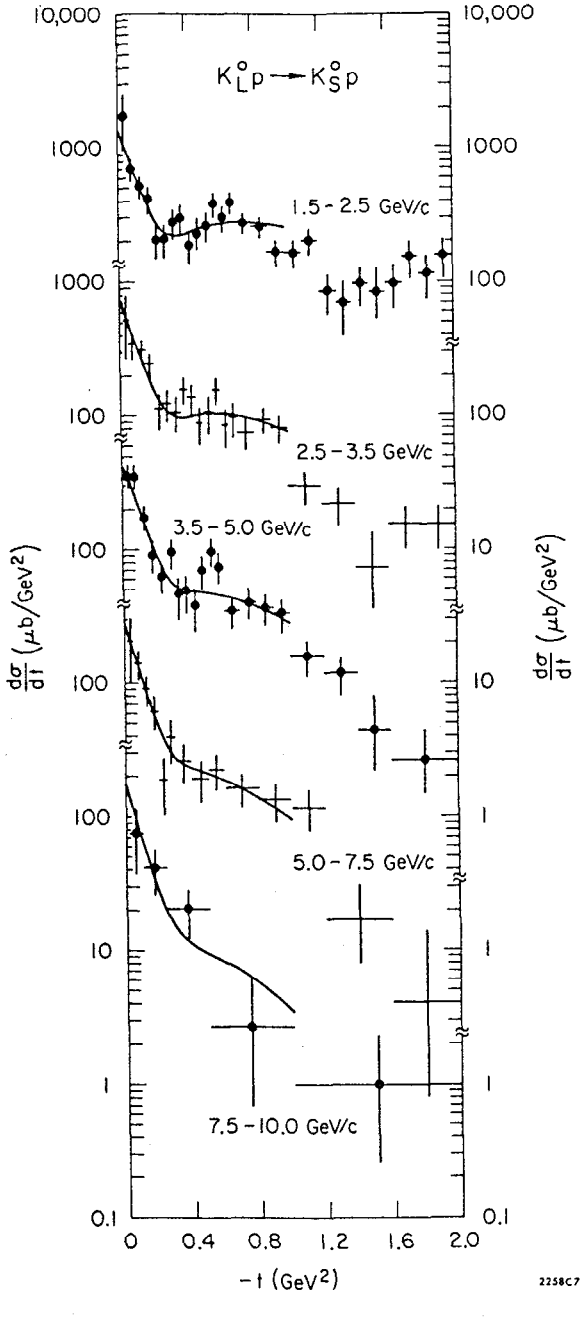

FIG. 2--Forward $K^0_L p \to K^0_S p$ cross sections, Ref. 5.

where $\Delta\lambda$ is the net helicity flip in the reaction. As suggested by Eq. 2, absorption models predict phases and energy dependences of scattering amplitudes that generally differ from simple Regge models. However, this is particularly true of helicity nonflip amplitudes which provide the strongest evidence for absorption in the data.[4]

1. Pseudoscalar-meson baryon scattering

A particularly straightforward study of Regge exchanges and absorption is possible with the new $K^0_L p \to K^0_S p$ scattering data.[5] This reaction is of interest due to its similarity with the well studied reaction $\pi^- p \to \pi^0 n$; in particular simple SU(3) relates the $K^0_L p \to K^0_S p$ and $\pi^- p \to \pi^0 n$ scattering amplitudes:

$$A_{K^0_L p \to K^0_S p} = \frac{1}{2}\left\{(4F-1)\omega^0 - \rho\right\}$$

$$\equiv (2F-1)V$$

$$A_{\pi^- p \to \pi^0 n} = \sqrt{2}\,\rho \equiv \sqrt{2}\,V \qquad (3)$$

with the single constant F.[6]

The forward peaking of the $K^0_L p \to K^0_S p$ differential cross sections,[5] Fig. 2, indicates the importance of the helicity nonflip amplitude in this reaction in agreement with SU(3) predictions.[5,6] However, the absence of a dip in the $K^0_L p \to K^0_S p$ cross section near $|t| \sim 0.6$ GeV^2 is in contrast to $\pi^- p \to \pi^0 n$ differential

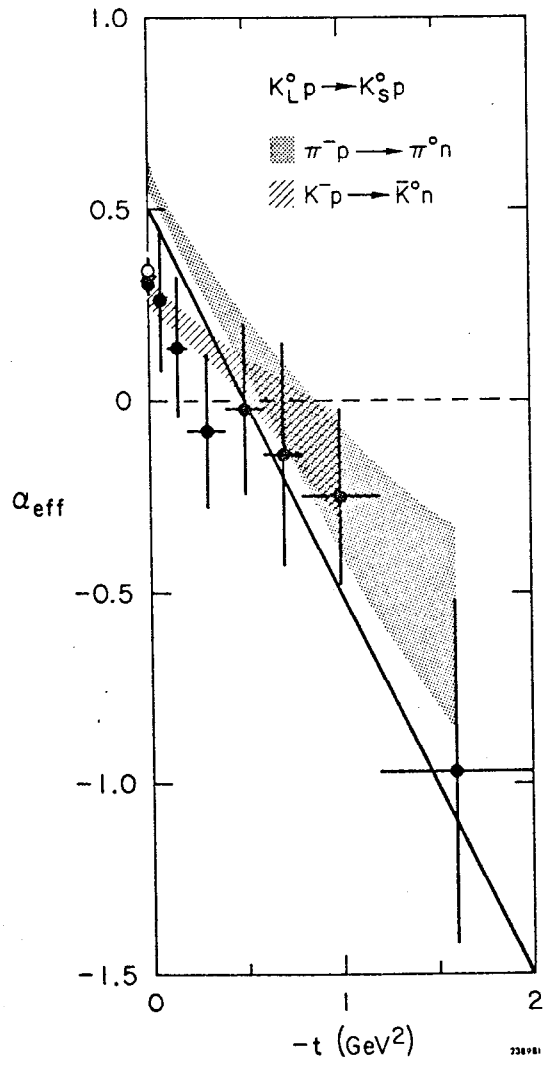

FIG. 3--Effective Regge trajectories for $K_L^o p \to K_S^o p$, $\pi^- p \to \pi^o n$ and $K^- p \to \bar{K}^o n$ reactions.

cross section data, and to the prediction of Eq. (1). A comparison of the energy dependences of these reactions, Fig. 3, reveals a further discrepancy: for $|t| \lesssim 0.4$ GeV^2 the $K_L^o p \to K_S^o p$ data[5] lie systematically below the $\pi^- p \to \pi^o n$ results,[7] in disagreement with the prediction of Eq. (3). Analogous differences in the energy dependence of the total cross section differences,[8] $\sigma^{TOT}_{\pi^- p} - \sigma^{TOT}_{\pi^+ p}$ and $\sigma^{TOT}_{K^- n} - \sigma^{TOT}_{K^+ n}$ are well known. By comparison the energy dependence of KN charge exchange data[9] (ρ and A_2 t channel exchanges), shown cross hatched in Fig. 3, agrees with the $K_L^o p \to K_S^o p$ data! Thus direct channel or absorption effects are suggested as the explanation for the differences in Kp and πp data.[5]

Fresh input to exchange degeneracy comes from new data in the reactions $\pi^- p \to K^o(\Lambda^o, \Sigma^o)$,[10] $\bar{K}^o p \to \pi^+(\Lambda^o, \Sigma^o)$[11] and $K^+ p \to K^o \Delta^{++}$, $K^- n \to \bar{K}^o \Delta^-$.[12] Analyses of the energy dependence of the hypercharge exchange data are consistent with no shrinkage of the $\pi^- p \to K^o(\Lambda^o, \Sigma^o)$ forward slopes, $b_{\pi p}$, whereas the $\bar{K}p \to \pi(\Lambda, \Sigma)$ slopes, $b_{\bar{K}p}$, do exhibit shrinkage. Since $b_{\bar{K}p} < b_{\pi p}$ at lower momenta, this new data suggests that the πp and $\bar{K}$p differential cross sections may become equal for momenta $\gtrsim 10$ GeV/c. By contrast no energy dependence is observed in the $\bar{K}^o p \to \pi^+ \Lambda^o$ polarization data[11] (~3-10 GeV/c), or in the $\pi^- p \to K^o \Lambda^o$ data[13] (5 GeV/c) from lower energy results.

Although $K^- p \to \bar{K}^o n$ and $K^+ n \to K^o p$ differential cross sections are equal by ~5 GeV/c,[14] the new data in the KΔ channel,[12] Fig. 4, are surprisingly unequal at 6 GeV/c. However KΔ data at lower energies[12,15] indicate that the $K^+ p$ and $K^- n$ cross sections are becoming more equal as momentum increases, the data appearing to approach (from either side) the exchange degenerate SU(3) prediction:[16]

$$\left(\frac{d\sigma}{dt}\right)_{K^+p\to K^0\Delta^{++}} = \left(\frac{d\sigma}{dt}\right)_{K^-n\to \bar{K}^0\Delta^-} = \frac{1}{2}\left(\frac{d\sigma}{dt}\right)_{\pi^+p\to\pi^0\Delta^{++}} + \frac{3}{2}\left(\frac{d\sigma}{dt}\right)_{\pi^+p\to\eta^0\Delta^{++}}$$

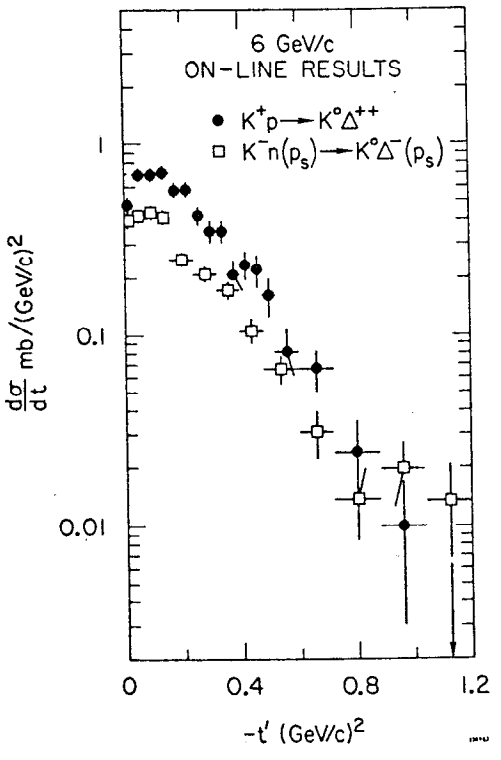

FIG. 4--Forward $K^+p\to K^0\Delta^{++}$ and $K^-n\to\bar{K}^0\Delta^-$ cross sections at 6 GeV/c, Ref. 12.

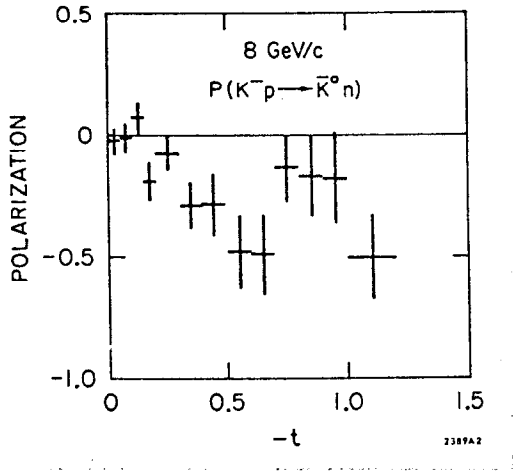

FIG. 5--Polarization in $K^-p\to\bar{K}^0n$ scattering at 8 GeV/c, Ref. 17.

We also note that the long awaited KN charge exchange polarization has been measured. Preliminary results in the reaction $K^-p\to\bar{K}^0n$ at 8 GeV/c[17] are shown in Fig. 5. The data are in agreement with most theoretical predictions: in particular the polarization in $K^-p\to\bar{K}^0n$ is,

$$\mathcal{P}(K^-p\to\bar{K}^0n)\approx\mathcal{P}(\pi^-p\to K^0\Lambda^0)$$
$$\approx -\mathcal{P}(\pi^-p\to K^0\Sigma^0)$$

in agreement with simple SU(3) models.[6] No polarization data in the potentially more interesting channel $K^+n\to K^0p$ exists however.

2. Vector-meson baryon production

Recently there has been increased interest in studying the difficult to analyze B meson data. Preliminary results at 5 GeV/c[18] in the reaction $\pi^+p\to B^+p$ find that the B is produced dominantly with s channel helicity zero, $<\rho^H_{00}> = 0.69\pm0.18$. The background subtracted differential cross section and $\rho^H_{00}\frac{d\sigma}{dt'}$ distribution for this data are shown in Fig. 6. Interestingly the $\rho^H_{00}\frac{d\sigma}{dt'}$ data are suggestive of the absorption prediction of Eq. (2) if the helicity nonflip amplitude dominates (ω^0 exchange rather than A_2 exchange). Detailed questions of the importance of isospin one exchanges,[18,19] reliability of background subtractions, and the relative couplings of ω^0 and A_2 exchanges to helicity zero B mesons are not yet answered however.

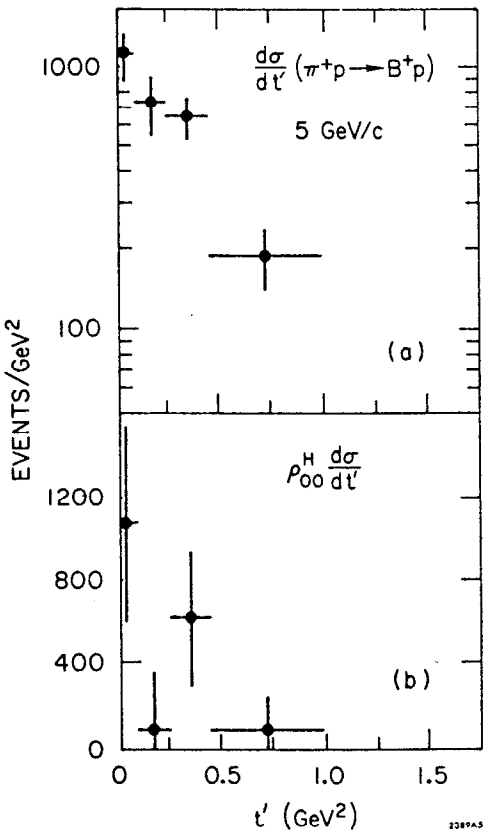

FIG. 6--Background subtracted forward cross sections for $\pi^+p \rightarrow Bp$ at 5 GeV/c, Ref. 18.

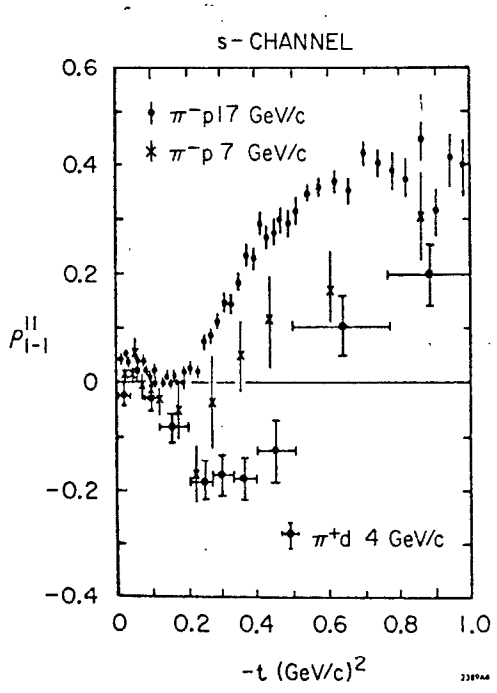

FIG . 7--Energy dependence of ρ^0 density matrix element ρ_{1-1}^H in $\pi N \rightarrow \rho^0 N$ scattering, Ref. 20.

Several recent papers have provided evidence for strong energy dependences in some vector meson density matrix elements in ρ^0 and ω^0 production reactions. These data provide a means of separately studying the amplitudes for (natural/unnatural) parity exchange, $A_\pm$, in these reactions. For example the rapid increase in ρ_{1-1}^H in the $\pi N \rightarrow \rho^0 N$ data[20] shown in Fig. 7, where

$$\rho_{1-1}^H \frac{d\sigma}{dt} = \frac{1}{2}(|A_+|^2 - |A_-|^2),$$

indicates the increased importance of natural parity exchange (A_2 rather than π) as energy increases. A more dramatic comparison of natural (N) and unnatural (U) parity exchanges is obtained from the ratio:

$$\frac{\rho_+}{(1-\rho_+)} = \frac{N}{U}$$

where $\rho_+ = (\rho_{1-1}^H + \rho_{1-1}^H)$ isolates natural parity exchange. Comparison of $\pi^+p \rightarrow \omega^0\Delta^{++}$ data at 2.67 and 7.1 GeV/c,[21] Fig. 8, again indicate the

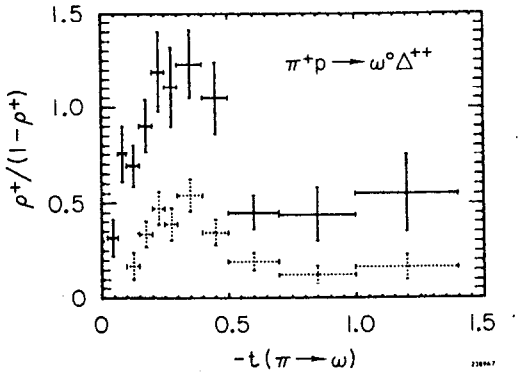

FIG. 8--Energy dependence of ω^o density matrix elements in $\pi^+p \rightarrow \omega^o\Delta^{++}$ scattering, Ref. 21. Dotted (solid) data at 2.67 (7.1) GeV/c.

substantial increase in natural-parity exchange (ρ rather than B) with energy. Extraction of the effective Regge trajectories for unnatural parity exchange amplitudes from the ρ^o and ω^o data find approximate agreement with π-B exchange degeneracy.[21,22]

SUMMARY

The new results presented to this conference confirm the old prejudices that simple Regge theory, SU(3) and factorization provide a qualitative understanding of the data, but emphasize the need to understand direct channel or absorptive effects if real progress is to be made in two body scattering reactions.

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