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NEAR FORWARD PEAKS IN THE K^-p AND π^-p CHARGE-EXCHANGE SCATTERING*

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The peak observed for very small t (square of the momentum transfer in the center-of-mass frame) in the π^-p[1] and K^-p[2] charge-exchange scatterings has been explained recently on the basis of the contribution of the spin-flip amplitude.[2-4] In the first analysis,[3] for K^-p, the ratio of the spin-flip to spin-nonflip contribution necessary to explain the data comes out to be large (about 1.8 at $t=0.4$) and cannot be accounted for by the mechanism of ρ exchange, not even with absorptive corrections. In the second analysis,[4] for π^-p, the spin-flip amplitude is again assumed to be larger than the spin-nonflip amplitude and to have essentially a diffraction-type behavior with a maximum at small t. Also in π^-p, a ρ-exchange model with absorptive corrections fails completely to explain the behavior of the charge-exchange scattering.[5]

Such a large spin-flip contribution at these very small t values and the shape of the spin-flip amplitude would be quite startling. For one thing, the spin-flip amplitude is expected to become appreciable only around $\sin\theta \approx 1$ or $t=-2q^2$ (-9.85 at 10 BeV/c) and is likely to cause the secondary diffraction peak, also observed in charge-exchange scattering.[6] Furthermore, the spin-flip amplitude g involves the difference of the partial-wave amplitudes $\alpha_{l,+}$ and $\alpha_{l,-}$, whereas the spin-nonflip amplitude f is the sum of these partial-wave amplitudes:

$$f=\sum_l\{la_{l,+}+(l+1)a_{l,-}\}P_l,$$

$$g=\sum_l\{a_{l,-}-a_{l,+}\}P_l^{\,1}(z).$$

Therefore, we expect only a few low partial waves to contribute to the spin-flip amplitude, whereas all partial waves together make up the diffraction peak of the spin-nonflip part of the scattering. In fact, the elastic scattering on the whole range of momentum transfer and the secondary diffraction peak near $\sin\theta=1$ can be well explained by a single, constant and small, p-wave spin-flip amplitude in the case of K^-p and by a few partial waves in the case of π^-p scattering.[7] Thus, the spin-flip amplitude alone is not expected to show a diffraction behavior.

We want to point out that the charge-exchange scattering, being the difference of two isospin amplitudes, is very sensitive to the changes in the relative phase, as a function of t, of the two isospin amplitudes and accounts in a simple way for the behavior of the charge-exchange scattering. The elastic scatterings are not sensitive to this relative phase. Thus, it would be important to measure the relative phase in the charge-exchange scattering. A small spin-flip contribution may be introduced which accounts for the secondary peaks, as in the case of elastic scattering. Furthermore, the parameters of the charge-exchange scattering can be related to those of the elastic scattering.

K^-p scattering.—We assume that each of the $I=0$ and $I=1$ amplitudes has a diffraction-peak behavior, for small t, of the form

$$A^0=ae^{\frac{1}{2}\alpha t},\quad A^1=\eta ae^{\frac{1}{2}\alpha t}, \tag{1}$$

where η contains a relative phase $\varphi(t)$ between the two amplitudes $[\eta=|\eta|e^{i\varphi(t)}]$. For simplicity we have assumed the same exponent α in

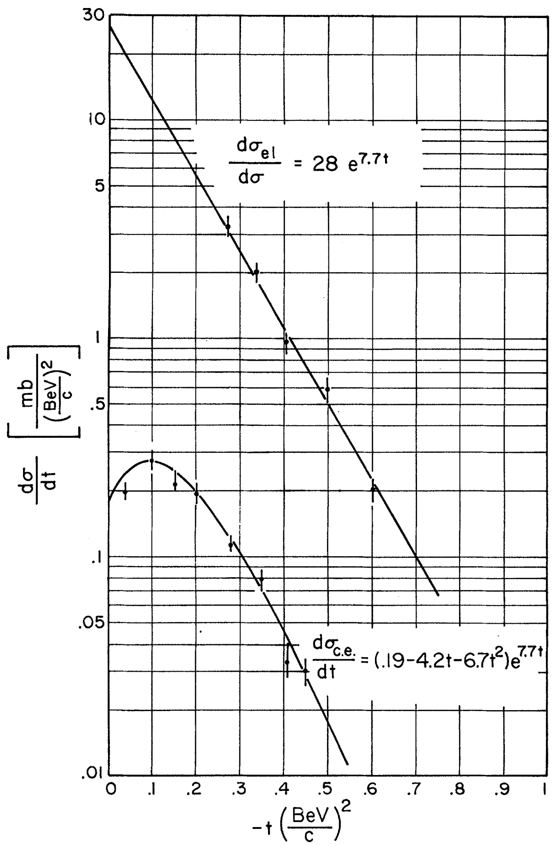

FIG. 1. K^-p elastic and charge-exchange differential cross sections; experimental data from Ref. 2 and from K. J. Foley et al., Phys. Rev. Letters 11, 503 (1963).

both A^0 and A^1. Then the elastic and charge-exchange differential cross sections are given by

$$(d\sigma/dt)|_{K^-p\,\mathrm{el}} = |a|^2 |1+\eta|^2 e^{\alpha t}, \tag{2a}$$

$$(d\sigma/dt)|_{K^-n\,\mathrm{el}} = 2|a|^2 e^{\alpha t}, \tag{2b}$$

$$(d\sigma/dt)|_{\mathrm{ce}} = |a|^2 |1-\eta|^2 e^{\alpha t}. \tag{2c}$$

The ratio of elastic to charge-exchange forward cross section is very large. Thus η must be close to 1, making the A^0 and A^1 amplitudes nearly equal. Consequently, the factor $|1-\eta|^2$ is very sensitive to small phase changes in $\varphi(t)$: A small t dependence of $\varphi(t)$ can cause large deviation of $(d\sigma/dt)|_{\mathrm{ce}}$ from the diffraction-peak shape. In contrast to this, $|1+\eta|^2$ is not sensitive to such small changes.

Let us now expand the phase $\varphi(t)$ for small t:

$$\varphi(t) = \gamma_0 + \gamma_2 t + \gamma_2 t^2.$$

Then, if $\gamma_1 t + \gamma_2 t^2$ is small,

$$(d\sigma/dt)|_{\mathrm{el}} = |a|^2 e^{\alpha t}\{1 + 2|\eta|\cos\gamma_0 + |\eta|^2\} \tag{3}$$

and

$$(d\sigma/dt)|_{\mathrm{ce}} = |a|^2 e^{\alpha t}\{1 - 2|\eta|\cos\gamma_0 + |\eta^2| + 2|\eta|\sin\gamma_0(\gamma_1 t + \gamma_2 t^2)\}$$
$$\equiv \{C_0 - C_1 t - C_2 t^2\} e^{\alpha t}. \tag{4}$$

Equations (3) and (4) fit the data very well (Fig. 1) if we take

$$\alpha \cong 7.4, \quad |a|^2 \cong 7, \quad |\eta| \approx 1, \quad \gamma_0 < 20°;$$
$$C_0 = 0.19, \quad C_1 = 4.2, \quad C_3 = 6.7.$$

If γ_0 were known, we could predict $\varphi(t)$:

$$\varphi(t) \approx \gamma_0 + (2\sin\gamma_0)^{-1}(-C_1 t - C_2 t^2). \tag{5}$$

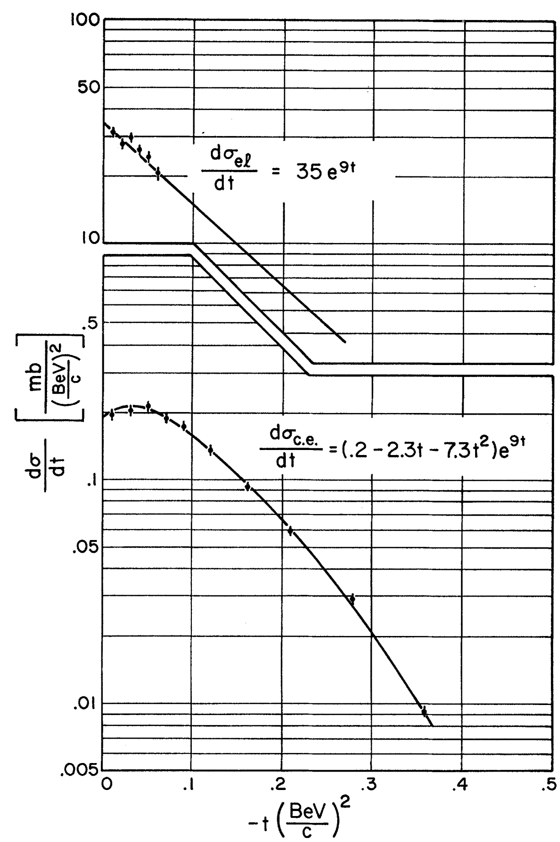

FIG. 2. π^-p elastic and charge-exchange differential cross sections; experimental data from Ref. 1 and from K. J. Foley et al., Phys. Rev. Letters 14, 862 (1965).

$\pi^- p$ scattering.—The same type of analysis starting with the $I=\frac{3}{2}$ and $I=\frac{1}{2}$ amplitudes leads to the differential cross sections

$$(d\sigma/dt)|_{\pi^+ p\,\mathrm{el}} \cong |a|^2 e^{\alpha t}, \tag{6a}$$

$$(d\sigma/dt)|_{\pi^- p\,\mathrm{el}} \cong (|a|^2/9)e^{\alpha t}\{1+4|\eta\cos\gamma_0+4|\eta|^2\}, \tag{6b}$$

$$(d\sigma/dt)|_{\mathrm{ce}} \cong (2|a|^2/9)e^{\alpha t}[1-2|\eta|\cos\gamma_0+|\eta^2| +2|\eta|\sin\gamma_0(\gamma_1 t+\gamma_2 t^2)] \equiv (C_0-C_1 t-C_2 t^2)e^{\alpha t}. \tag{6c}$$

Again one can fit the data extremely well (Fig. 2) by the following choice of the parameters:

$$\alpha \cong 9, \quad |a|^2=30, \quad |\eta|\approx 1;$$

$$C_0=0.2, \quad C_1=2.3, \quad C_2=7.3.$$

The phase measurements of elastic and charge-exchange amplitudes given by Foley et al.[8] are not accurate enough to fix γ_0. If γ_0 is known, one can again predict $\varphi(t)$, as in Eq. (5).

Thus we see that diffraction peaks in each isospin channel provide a natural explanation of the observed "anomaly" in the charge-exchange scattering. No spin-flip amplitude has been needed to fit the data up to $t=-0.4$. The spin-flip amplitude may play a role for larger values of t and cause the secondary peaks, as in the case of elastic scattering.[7] The measurements of relative phases and polarization will decide whether the present mechanism or the spin-flip hypothesis causes the near-forward peaks in charge-exchange scattering.

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EXCHANGE-DEGENERACY CLASSIFICATION OF REGGE TRAJECTORIES AND THE TOTAL CROSS SECTIONS*

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In this Letter we present an analysis of the meson-nucleon, nucleon-nucleon, and nucleon-antinucleon total cross sections. The analysis is based on Regge trajectories whose factorized reduced residues are related by SU(3) symmetry. Thus, in this respect our treatment is basically the same as that of Barger and Olsson[1] but with some minor differences. Furthermore, we make the additional assumption of exchange degeneracy with respect to the signature as hypothesized by Arnold.[2] The trajectories to which we apply this hypothesis are, however, not exactly the same as those chosen by Arnold, and we assume that the residues, as well as the trajectory functions, exhibit this degeneracy. Our aim is to show that the experimental data on total cross sections are in agreement with this hypothesis, thereby raising the possibility of reducing the number of parameters in Regge-pole phenomenology.

It can be shown,[3] under rather general assumptions, that the nucleon-nucleon and nucleon-antinucleon total cross sections depend only on the exchange of four sets of quantum numbers specified by vacuum, ρ, ω, and R. This is also the case for kaon-nucleon cross sections. For the pion-nucleon case, the exchange of the quantum numbers of ω and R does not contribute due to the G-parity conservation. In the Regge-pole model these four types of exchanges are in the form of Regge trajectories. Note that there may be more than one trajectory for a given set of quantum numbers.

Now it is well known that the vector mesons