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ρ-MESON REGGE TRAJECTORY AND HIGH-ENERGY CHARGE-EXCHANGE SCATTERING

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(Received 27 May 1963)

The n-p charge-exchange differential and total cross sections were recently measured at 2.04 and 2.85 BeV.[1] A very sharp forward peak was reported in the differential cross section. A possible explanation of this sharp peak was proposed by Phillips[2] in terms of an interference between the single pion contribution and the background part of the NN amplitude. The purpose of this communication is to propose an alternative explanation in terms of the ρ meson treated as a Regge pole. If this explanation is indeed correct, the high-energy π^--p and K^--p charge-exchange reactions should also show a similar sharp peak for small momentum transfers.

It is well known that only the exchange of particles and resonances of isospin 1 or greater are possible for charge exchange. Of the known particles and resonances, the ρ and π mesons should be important for n-p charge exchange and the ρ meson only for π^--p and K^--p charge exchange. In the n-p case if the π and ρ mesons are treated as poles in lowest order perturbation theory with currently expected coupling constants[3] $g_{\rho-N\bar{N}}^2/4\pi \approx 2$ and $g_{\pi-N\bar{N}}^2/4\pi = 15$, one finds total disagreement with the experimental results in reference 1. This is not surprising since the ρ contribution, due to the large ρ mass, gives rise to a broad peak, and the π contribution which is 0 in the forward direction is too large at the larger angles. Because of the spin structure of the NN amplitude and the quantum numbers of the π and ρ mesons, an interference between the π and ρ contributions is impossible and any one-pion contribution is additive.

In this communication the ρ-meson Regge trajectory is assumed to be the dominant mechanism in high-energy charge exchange, and it is shown that the slope of the ρ trajectory $\alpha'(t)$, $t \leq 0$, can be adjusted to give rough agreement with the n-p experimental data[1] for small momentum transfers. The ρ meson treated as a Regge pole gives a different angular distribution than the broad angular distribution from that due to the ρ treated as a perturbation-theory pole.

A detailed treatment of the NN problem in terms of Regge poles is given.[4] The contribution of the ρ trajectory to the NN helicity-nonflip amplitude is

$$\phi^T(s,t) = -\frac{\pi}{2(s)^{1/2}}\frac{\beta(t)}{\sin\pi\alpha(t)}[2\alpha(t)+1] \times[\mathcal{P}_\alpha(-z_t) - \mathcal{P}_\alpha(z_t)]\tfrac{1}{2}[1+2(-1)^T], \quad (1)$$

where $\beta(t)$ and $\alpha(t)$ are the residue and position of the ρ trajectory. The quantities s and t are the usual Mandelstam variables. The ρ is exchanged in the t $N\bar{N}$ channel. The quantity T is the total isospin for the NN channel. The function $\mathcal{P}_\alpha(z_t)$ is related to the hypergeometric function[5] by

$$\mathcal{P}_\alpha(z_t) = \frac{(2z_t)^\alpha\,\Gamma(\alpha+\frac{1}{2})}{\Gamma(\alpha+1)(\pi)^{1/2}} F\left(\tfrac{1}{2}(1-\alpha), -\tfrac{1}{2}\alpha, \tfrac{1}{2}-\alpha, \frac{1}{z_t^{\,2}}\right), \quad (2)$$

where z_t, the c.m. scattering angle for the t $N\bar{N}$ channel, is defined by

$$s=-2p_t^2(1+z_t),$$
$$t=4(p_t^2+m^2), \tag{3}$$

and m is the nucleon mass.

The contribution of the helicity-flip amplitudes and the magnetic coupling of the ρ to nucleons are neglected at small momentum transfers which is the region of interest here.

The single-pion contribution is contained in the helicity-flip amplitudes[4] in such a manner that there is no interference between the ρ and π contributions to the differential cross section after summing over all helicities.

Retaining the first term in the expansion of the hypergeometric function in $1/z_t^2$ [Eq. (2)], the contribution of the ρ to the charge-exchange n-p amplitude is

$$\phi_{\text{c.e.}}\approx\frac{1}{2}\left(\frac{\pi}{s}\right)^{1/2}\frac{(2\alpha+1)\beta(t)\Gamma(\alpha+\frac{1}{2})}{\Gamma(\alpha+1)}2^{\alpha}\left(\frac{s+2p_t^2}{2p_t^2}\right)^{\alpha}\times\left[\frac{1-\exp(-i\pi\alpha)}{\sin\pi\alpha}\right]. \tag{4}$$

The quantity s is related to the laboratory kinetic energy T_L by

$$s=2m(T_L+2m), \tag{5}$$

and $p_t^2\approx -m^2$ for t near the forward direction. The threshold behavior[6] of $\beta(t)$ is removed in the following manner:

$$\beta(t)=(2p_t^2/t_0)^{\alpha}b(t). \tag{6}$$

The function $b(t)$ is real for $t\leq 0$. The scale factor t_0 is assumed to be the square of the mass of the ρ ($t_0\approx 28\,m_\pi^2$). The function $b(t)$ is also assumed to be constant in the momentum transfer region $0\leq|t|<10\,m_\pi^2$. All other t dependence is contained in $\alpha(t)$ in Eq. (4). The position of the ρ trajectory $\alpha(t)$ is approximated by

$$\alpha(t)\approx\alpha(0)+t\alpha'(0)\ \text{for}\ t\leq 0. \tag{7}$$

The contribution of the ρ trajectory to the laboratory differential cross section is

$$\frac{d\sigma_{\text{c.e.}}}{d\Omega}\approx\frac{\pi\cos\theta_L}{(2m+T_L\sin^2\theta_L)^2}b^2\left[\frac{\Gamma(\alpha+\frac{1}{2})(2\alpha+1)}{\Gamma(\alpha+1)\cos\frac{1}{2}\pi\alpha}\right]^2\times\exp\{2[\alpha(0)+t\alpha'(0)]K\}, \tag{8}$$

where $K=\ln[4m(T_L+m)/t_0]\approx 3.24$ for $T_L=2.85$ BeV and θ_L is the laboratory scattering angle. The 2.85-BeV data are fitted with Eq. (8) in Fig. 1 by varying $\alpha(0)$ and $\alpha'(0)$; b is determined from the experimental cross section at 0°. The most sensitive parameter in the fit is the slope of the trajectory $\alpha'(0)$. The t dependence contained in the square bracket in Eq. (8) plays an important role and makes the choice of scale factor in Eq. (6) less critical. The larger value of $\alpha(0)\approx 0.7$ and the slope $\alpha'(0)\approx 1/35\,m_\pi^2$ is more favorable since the ρ was assumed to be the dominant mechanism at this energy. This assumption is clearly the weakest point; charge-exchange n-p scattering might be a great deal more complicated and a subtle cancellation of amplitudes could give rise to the peak. Also the fit to the 6° point is the poorest, indicating that other mechanisms such as the single-π exchange are more important for the larger angles.[7] However, the n-p charge-exchange peak can be understood in terms of the simple mechanism of a dominant ρ if one constructs a suitable trajectory to fit the experimental data of reference 1. If the estimate of the slope used in fitting this data is taken seriously,

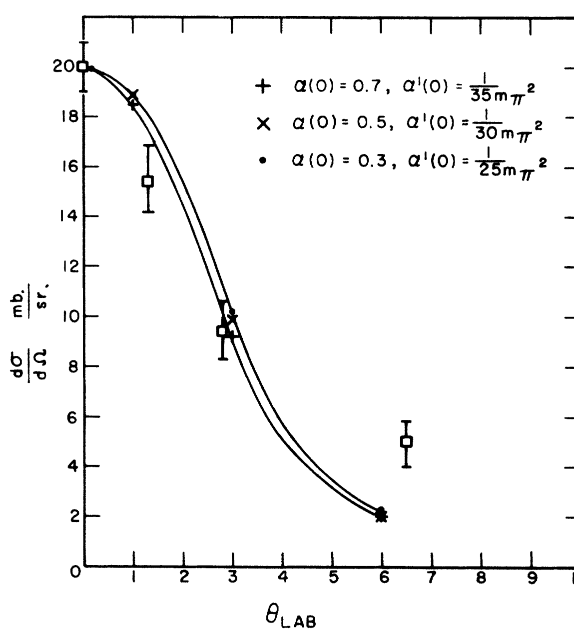

FIG. 1. The differential cross section for the elastic charge-exchange reaction at 2.85 BeV. The open squares are the experimental points of Palevsky et al.[1] Three different sets of $\alpha(0)$ and $\alpha'(0)$ are plotted. All three sets give approximately the same fit to the data since the α dependence in Eq. (8) is more rapidly varying for the larger α requiring a smaller slope to fit the data.

the π^--p and K^--p charge-exchange reactions will also show a similar sharp peak at small momentum transfers. Of the known particles and resonances, the ρ alone is exchanged in π^--p and K^--p charge exchange.

In conclusion, the following differences of total cross sections $\sigma(\pi^+-p)-\sigma(\pi^--p)$ and $\sigma(p-p)-\sigma(n-p)$ can also be related to the ρ-meson trajectory at $t=0$.[8] At high energies the above differences should approach 0 with the energy dependence $s^{\alpha(0)-1}$. The experimental information indicates[9] that $\sigma(p-p)-\sigma(n-p)<2$ mb in the momentum range 5-25 GeV/c and $\sigma(\pi^--p)-\sigma(\pi^+-p)\approx 2$ mb in the momentum range 10-20 GeV/c. However, the experimental information on the n-p total cross section is scanty, and it is difficult to obtain $\alpha(0)$ from $\sigma(p-p)-\sigma(n-p)$. von Dardel et al.[9] obtained a value of $\alpha(0)\approx 0.3$ by fitting all of the π^+-p and π^--p data between 4.5 and 20 GeV/c with a Regge pole formula. However, the data are not inconsistent with a value of $\alpha(0)\approx 0.5$ or greater, and more experimental data are needed to determine $\alpha(0)$ accurately.[10]

I would like to thank Professor E. M. Henley for a critical reading of the manuscript. I would also like to thank Professor G. F. Chew for stimulating correspondence concerning this problem and Professor S. Drell and Mr. A. Pignotti for interesting discussions.

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VECTOR MESON EXCHANGE MODEL FOR ISOBAR PRODUCTION*

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The one-pion-exchange model for inelastic processes has achieved some success in describing reactions like $p+p\rightarrow N_{3/2}^{*++}+n$ and $\pi^-+p\rightarrow\rho^-+p$.[1] There are, however, processes such as

$$\pi^++p\rightarrow N_{3/2}^{*++}+\pi^0, \quad (1a)$$

$$K^++p\rightarrow N_{3/2}^{*++}+K^0, \quad (1b)$$

$$\pi^++p\rightarrow Y_1^{*+}+K^+, \quad (1c)$$

$$K^-+p\rightarrow Y_1^{*+}+\pi^-, \quad (1d)$$

where one-π exchange or one-K exchange is forbidden but one-ρ or one-K^* exchange is allowed.[2] In this note we would like to present some specific predictions of immediate experimental interest based on the vector meson exchange model for isobar production.[3] The results we report here depend only on angular momentum and parity considerations; more detailed calculations including estimates of cross sections based on the "ρ-photon analogy" and the "broken eightfold way" will appear in a separate communication.

When a spin-one particle is exchanged in Reactions (1a)-(1d), we have a situation analogous