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THE ρ' TRAJECTORY AND ITS CONTRIBUTION TO
NN AND π N CHARGE EXCHANGE SCATTERING

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ABSTRACT

The zero intercept of a ρ' Regge trajectory is determined from experimental data on nucleon-nucleon collisions. A neat explanation of the positive polarization in $\pi^- p \rightarrow \pi^0 n$ is presented.

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As has been noted, the medium energy data on the differences between the proton-proton and proton-neutron total cross-sections and the differential cross-section of proton-neutron charge exchange in the forward direction is inconsistent with φ and R exchange alone. In the Regge pole theory, a consistent fit to these reactions can be obtained only by including a φ' , a R' or both ¹⁾.

In this letter we present results on the intercept of the φ' trajectory at zero momentum transfer. Also we provide an explanation of the observed polarization ²⁾ of the neutron in $\pi^- p \rightarrow \pi^0 n$ which is consistent with the fact that measurements on the differential cross-section for the same reaction are very well described by φ alone ³⁾.

Our determination of the parameters of the φ' is based on a best fit to experimental data on $\sigma_T(pp) - \sigma_T(pn)$, $\sigma_T(\bar{p}p) - \sigma_T(\bar{p}n)$, $d\sigma/dt(pn \rightarrow np)|_{t=0}$ and $d\sigma/dt(\bar{p}\bar{p} \rightarrow n\bar{n})|_{t=0}$. The range of energy used was 3 to 22 GeV/c for total cross-sections ^{4),5)}, and 2 to 8 GeV/c for the differential cross-sections ^{6),7),8),9)}.

Our amplitudes were parametrized and normalized as in Ref. ¹⁾, hereafter referred to as I. The only differences were :

- 1) we used a power expansion E^α instead of an expansion S^α as in I (E is the lab. energy measured in GeV);
- 2) we included a third term in the amplitudes, corresponding to a second φ called φ' .

The amplitudes then have the form

$$A(pn \rightarrow np) = 2\varphi + 2\varphi' + 2R$$

$$A(p\bar{p} \rightarrow n\bar{n}) = -2\varphi - 2\varphi' + 2R$$

where

$$\varphi^{(\prime)} = D_{\varphi^{(\prime)}} \left(i + tg \frac{\pi \alpha_{\varphi^{(\prime)}}}{2} \right) E^{\alpha_{\varphi^{(\prime)}}}$$

$$R = D_R \left(i - \cotg \frac{\pi \alpha_R}{2} \right) E^{\alpha_R}$$

2.

In terms of these amplitudes the differential cross-section and the total cross-section differences have the following form :

$$\left. \frac{d\sigma}{dt} \right|_{t=0} = \frac{1}{16\pi s} \left(\frac{M}{q} \right)^2 |A|^2$$

$$\sigma_T(pp) - \sigma_T(pn) = \frac{M}{q\sqrt{s}} \operatorname{Im} A(pn \rightarrow np)$$

$$\sigma_T(p\bar{p}) - \sigma_T(n\bar{p}) = \frac{M}{q\sqrt{s}} \operatorname{Im} A(p\bar{p} \rightarrow n\bar{n})$$

As in I, $\alpha_{\mathcal{G}}(0)$ and $\alpha_R(0)$ were taken to be fixed with values 0.57 and 0.40, respectively.

The parameters $D_{\mathcal{G}}$, $D_{\mathcal{G}'}$ and D_R which are proportional to the residue functions of the Regge poles and $\alpha_{\mathcal{G}'} = \alpha_{\mathcal{G}'}(0)$ which is the intercept of the $\mathcal{G}'$ trajectory with the angular momentum axes at zero momentum transfer, were taken as free parameters in a least χ^2 fit to the above-mentioned experimental cross-sections.

The values that we got for the best fit were

$$D_{\mathcal{G}} = -3.1, \quad \alpha_{\mathcal{G}'}(0) = -0.60, \quad D_R = -0.25, \quad D_{\mathcal{G}'} = 14.1 \text{ mb}(\text{GeV})^2$$

The fit to the cross-sections with these parameters is shown in Figs. 1 and 2.

We also tried a R' trajectory, instead of the $\mathcal{G}'$, the fit was not so good. Including both $\mathcal{G}'$ and R' changed very little from the inclusion of the $\mathcal{G}'$ alone. A fit to the total cross-section differences without a third trajectory gives values for the differential cross-section which falls outside the scale of Fig. 1. The most exciting aspect of the parameter we got for $\alpha_{\mathcal{G}'}(0)$ is its consequences for a

reaction different from the ones used for its determination. With a ϱ' in addition to a ϱ exchange in $\pi^- p \rightarrow \pi^0 n$, the polarization will be non-zero as observed. We can even from the $\varrho + \varrho'$ model say something about the sign of the polarization.

In the following, we shall use Singh's ¹⁰⁾ notation for the two amplitudes A and B that determine the $\pi N \rightarrow \pi N$ amplitudes. In terms of these, the polarization P is proportional to $\text{Im} A^* B$: $P \sim \text{Im} A^* B$. A is the only of the two amplitudes that is contributing in the forward direction. Now as forward dispersion relations give a phase for A that is consistent with ϱ exchange alone ³⁾, we assume that ϱ' is relatively more weakly coupled to A than to B .

As furthermore $d\sigma/dt$ for $\pi^- p \rightarrow \pi^0 n$ is explained extremely nicely with ϱ alone ³⁾, one is led to give ϱ' the sign that changes the modulus of B as little as possible from the value it would have had if it was given by ϱ alone. It is also believed ¹¹⁾ that A and B lie in the same quadrant in the complex plane, the reason for this assumption is taken from electromagnetic form factors ¹²⁾ and the polarization measurement in $\pi^+ p \rightarrow \pi^+ p$ ¹³⁾.

From these arguments it is then only elementary geometry to convince oneself that the polarization in $\pi^- p \rightarrow \pi^0 n$ should be positive as observed, the phases of ϱ and ϱ' being shown in Fig. 3. If the $\varrho' + \varrho$ model gives the correct explanation for the polarization, it should fall with the lab. energy as $E^{-\alpha_\varrho + \alpha_{\varrho'}} \sim E^{-1,2}$. If furthermore the ϱ' manifests itself as a resonance in the $\pi\pi$ system, its mass can be roughly predicted to be 1.5 GeV by assuming parallel ϱ and ϱ' trajectories. This would correspond to the lowest-lying excited state with $L=2$ in the quark model..

It may be argued that $\alpha_{\varrho'}(0)$ is too low to be a honest Regge pole as it is as low as the background integral. It may therefore be a one pole approximation for this, but we do not believe it. We feel that the phenomenological Regge pole approach may be more general than the

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Regge pole theory. The reason for this is that it is shown that the assumption of a power series expansion of a scattering amplitude through crossing makes the phase linked to the energy dependence ¹⁴⁾ and if one further assumes that the quark model has a connection to reality, the same powers should appear in πN as in NN scattering ¹⁵⁾.

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FIGURE CAPTIONS

Figure 1 : The $R + \mathcal{S} + \mathcal{S}'$ fit to the differential cross-sections of $pn \rightarrow np$ and $p\bar{p} \rightarrow n\bar{n}$ at $t=0$.

Figure 2 : The $R + \mathcal{S} + \mathcal{S}'$ fit to the total cross-section differences $\sigma_T(pp) - \sigma_T(pn)$ and $\sigma_T(p\bar{p}) - \sigma_T(\bar{p}n)$.

Figure 3 : The phases of $\mathcal{S}$ and $\mathcal{S}'$ at small $|t|$. The configuration of $\mathcal{S}$ and $\mathcal{S}'$ giving a value of B corresponding to positive polarization is shown.

FIG. 1

FIG. 2

FIG. 3