THE $Q+R$ MODEL AND $p n$ CHARGE EXCHANGE SCATTERING

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ABSTRACT

From medium energy nucleon-nucleon data it is concluded that a consistent description in terms of Regge poles is possible only if the polarization is non-zero in $\Lambda^- p \rightarrow \Lambda^0 n$ or $\Sigma^- p \rightarrow \Sigma^- n$ at medium energies.
It is commonly believed that pn charge exchange is one of the triumphs of the Regge pole theory \(^1\),\(^2\). We want in this letter to report on a part of a study we made in parametrizing total cross-sections by means of a Regge-like power expansion in \(s\), the c.m. energy squared. What we want to stress is that just \( \gamma \) and \( R \) together cannot simultaneously explain \( \sigma_{\pi^0}(pn) - \sigma_{ar{p}p}(pp) \) and \( (d\sigma/dt)(pn-np)\big|_{t=0} \) down to \( P = 2.83 \) GeV/c. In this we disagree with an earlier result \(^3\).

We parametrized our amplitudes in the forward direction in the following manner:

\[
A(pn \rightarrow np) = \mathcal{S} + \mathcal{R}
\]

\[
A(p\bar{p} \rightarrow n\bar{n}) = -\mathcal{S} + \mathcal{R}
\]

where

\[
\mathcal{S} = D_\gamma \left( \frac{s}{s_0} \right)^{\delta_\gamma} \left( 1 + \frac{t}{t_\gamma} \frac{u_{\gamma}}{z_{\gamma}} \right)
\]

\[
\mathcal{R} = D_R \left( \frac{s}{s_0} \right)^{\delta_R} \left( 1 - \omega R \frac{t_{\gamma}}{z_R} \right)
\]

The relation between energy dependence and phase follows from the Regge pole model and the normalization is such that

\[
\sigma_{\pi^0}(pn) - \sigma_{ar{p}p}(pp) = \frac{m}{q^2 s} \left( J_m A(p\bar{p}) - J_m A(pn) \right)
\]

\[
= \frac{m}{q^2 s} J_m A(pn \rightarrow np)
\]

and

\[
\frac{d\sigma}{dt}(pn \rightarrow np) \big|_{t=0} = \frac{1}{K_{\pi^0}} \left( \frac{m}{s} \right)^2 \left| A(pn \rightarrow np) \right|^2
\]
In formulae (3)-(6), $\alpha_3$ and $\alpha_R$ are the intercepts of the $\rho$ and the $R$ trajectories at zero momentum transfer, $D_\rho$ and $D_R$ are proportional to the residues of the Regge poles, $M$ is the nucleon mass and $q$ the centre-of-mass three-momentum. $A(pp)$ is the amplitude for elastic $pp$ scattering, $A(pn)$ for $pn$ elastic scattering and $A(pn\rightarrow mp)$ and $A(\bar{p}p\rightarrow \bar{m}n)$ the amplitudes for the charge exchange reactions. $\Gamma_T(pp)$ and $\Gamma_T(pn)$ denote the total cross-sections for $pp$ and $pn$ scattering.

It is an experimental fact that the difference $\Gamma_T(pp) - \Gamma_T(pn)$ changes sign at $P \approx 3.7$ GeV/c and becomes negative at higher energy. This is easily explained from Eqs. (1), (3), (4) and (5) by giving $D_\rho$ and $D_R$ opposite signs.

From an analysis of the energy dependence of the process $\pi^- p \rightarrow \eta^0 n$, $\alpha_3$ is very well determined to be 0.57, while $\alpha_R$ is determined from the process $\pi^- p \rightarrow \gamma n$ to be 0.4. As the values of $\alpha_3$ and $\alpha_R$ are known, the zero of $\Gamma_T(pn) - \Gamma_T(pp)$ fixes the ratio $D_\rho / D_R$ and only one parameter remains to be fixed.

Assuming $D_\rho$ and $D_R$ to have opposite signs, makes the imaginary parts to cancel in (1) and the real parts to add in (2) and the amplitude $A(pn\rightarrow mp)$ is almost completely real for a wide energy range. As a consequence, one sees from Eqs. (3), (4) and (6):

$$\frac{d\sigma}{dt}(pn\rightarrow mp) \sim \left[ C_1 S^{0.57} + C_2 S^{0.40} \right]^2,$$

$C_1$ and $C_2$ are positive constants.

The experimental data show, however, that from $P = 2.83$ to $P = 8$ GeV/c, $d\sigma/dt$ is roughly proportional to $1/s^2$. How bad is the situation - can best be seen from some numbers. Choosing $s_0 = 1(\text{GeV})^2$ and making a least square fit to measured total cross-sections in $pp$, $\bar{p}p$, $\bar{p}n$, and $pn$ scattering above $P = 3$ GeV/c in terms of the Regge poles $P, P', \rho, \omega$ and $R$ we find
\[ D_\Sigma = -4\eta_{1,0} + \eta_{1,1} \quad \text{mb} \quad \sigma_{\pi}^\Sigma \]

\[ j = 4\eta_{1,1} + 0,6 \quad \text{mb} \quad \sigma_{\pi}^\eta \]

These values give at \( P = 8 \text{ GeV/c} \) a value of \( (d\sigma/dt)(\pi n - \pi p) \) which is a factor 60 too big. If, on the other hand, we restrict ourselves to fit data above 6 GeV/c, we find \( D_\Sigma = 0.23 \pm 0.77, \ D_\eta = -1.96 \pm 1.25 \text{ mb GeV/c} \), which give a value for the charge exchange cross-section at \( t = 0 \) that is compatible with experiment, but only for \( P > 6 \text{ GeV/c} \). This set of values does not, however, give the change in sign of \( \sigma_T(\pi n) - \sigma_T(\pi p) \).

If one wants to fit nucleon-nucleon data at medium energies down to 3 GeV/c, one would need at least a new \( \Sigma \) trajectory : \( \Sigma' \) or a new \( \eta' \). The \( \Sigma' \) would then contribute to \( \pi^- p \rightarrow \pi^0 n \), the \( \eta' \) to \( \pi^- p \rightarrow \eta n \) and one would then, at medium energies, get a non-vanishing polarization in one of these processes. The success in explaining them by only one trajectory in the medium energy range would then be just good luck.

The conclusion we have reached is: if the Regge pole approach is going to work for medium energy \( N-N \) interactions, one expects - at least in this energy region - a non-vanishing polarization effect either in \( \pi^- p \rightarrow \pi^0 n \) or in \( \pi^- p \rightarrow \eta n \).
REFERENCES


