REGGE ANALYSIS OF ASYMPTOTICALLY UNEQUAL $K^{\pm}p$ TOTAL CROSS SECTIONS*

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The possibility of a violation of the Pomeranchuk theorem, as suggested by recent Serpukhov data, is discussed in terms of Regge singularities. At $t=0$, a simple Regge pole of odd charge conjugation is required, but for $t\neq 0$, the singularity structure in the J plane must be more complicated.

Recent results from the Institute for High Energy Physics–CERN collaboration[1] indicate that the K^-p total cross section $\sigma_T(K^-p)$ does not (at least not below 55 GeV/c) fall to the value of about 17.2 mb at which the K^+p total cross section $\sigma_T(K^+p)$ seems[2] to have leveled off below 20 GeV/c. It has been demonstrated by Barger and Phillips[3] that these data are not incompatible with a conventional Regge pole-and-cut model, in which $\sigma_T(K^+p)$ increases above 20 GeV/c, where it has not yet been measured. Nevertheless, it is interesting to contemplate the possibility, suggested by the Serpukhov data, that $\sigma_T(K^-p)$ and $\sigma_T(K^+p)$ approach different constants at infinite energy. In this note we will assume that this is the case, and explore the consequences of this assumption for Regge theory.

Behavior in the forward direction. –We thus assume that $\sigma_T(K^-p)$ and $\sigma_T(K^+p)$ approach different constants at infinite energy. As emphasized by Eden[4] and by Martin,[5] this assumption is consistent with the expected analyticity of the forward-scattering amplitude only if the ratio of the real to the imaginary part of the forward amplitude grows as the log of the energy. Let $A_{K^\pm p}'(s,t)$ be the nonflip amplitude for $K^\pm p$ elastic scattering, normalized so that $\sigma_T=\mathrm{Im}A'(s,0)/s$, and let $A^-(s,t)$ be the corresponding amplitude of odd signature. Then

$$A_{K^+p}'(s,t)-A_{K^-p}'(s,t)=A^-(s,t)-A^-(-s,t), \quad (1)$$

to leading order in s. The assumption of asymptotically unequal total cross sections requires that

$$A^-(s,0)\to s(\ln s), \text{ as } s\to\infty. \quad (2)$$

Now let $b(J,t)$ be the Mellin transform of $A^-(s,t)$, so that

$$A^-(s,t)=\frac{1}{2\pi i}\int_{\lambda-i\infty}^{\lambda+i\infty}dJ\,b(J,t)s^J, \quad (\lambda>1), \quad (3)$$

with the continued partial-wave amplitude $a^-(J,t)$ given in terms of $b(J,t)$ by

$$a^-(J,t)=(\sin\pi J)\,b(J,t) \quad (4)$$

near $J=1$. From (2) and (3), we see that $b(J,0)$ has a double pole at $J=1$; from (4), $a^-(J,0)$ has a simple pole at $J=1$. [There may, of course, be additional singularities which lead to terms in A^- which grow less rapidly than $s(\ln s)$.] This pole represents a (small) odd-signature, odd-charge-conjugation component of the Pomeranchukon. If such a component, with isosopin 0, is not accompanied by any isospin-1 partner, it must violate SU(3) in order to couple to $K\bar{K}$.

Since $J=1$ is a physical value for the odd-signature amplitude, the expectation that the continuation of $a^-(J,t)$ to $J=1$ should agree with the $J=1$ partial wave leads us to insist that $a^-(1,t)$ should not have a pole at $t=0$, in order that there not be a zero-mass particle. As we shall see below, this requirement is not incompatible with the requirement that $a^-(J,0)$ have a pole at $J=1$.

Behavior away from the forward direction. –We have seen that $a^-(J,t)$ is required to have a simple pole at $J=1$ for $t=0$. However, for $t\neq 0$ the structure in the J plane must be more complicated. The reason for this is, as has been stressed by Eden,[4] that since the forward amplitude grows like $s(\ln s)$, the forward peak must decrease like $(\ln s)^{-2}$ in order for the total cross section, and a fortiori the integrated elastic cross section, to remain bounded as the energy increases. It is easy to show that neither a simple Regge pole nor colliding Regge poles nor a Regge dipole can give the necessary decrease.[6] However, the decrease can be obtained from Regge cuts, as is demonstrated by the following construction:

Suppose that $b(J,t)$ be given by

$$b(J,t)=\frac{\beta}{it}\ln\left[1-\frac{\alpha_2^{\,2}t}{(J-1-\alpha_1 t)^2}\right], \quad \alpha_1,\ \alpha_2>0. \quad (5)$$

Then, for $t=0$, b has a double pole at $J=1$, as required; for $t<0$, b has two branch cuts, one running from $J=1+\alpha_1 t$ to $J=1+\alpha_1 t+i\alpha_2(-t)^{1/2}$, and the other from $J=1+\alpha_1 t$ to $J=1+\alpha_1 t-i\alpha_2(-t)^{1/2}$. From (4) and (5), it follows that $a^-(1,t)=0$ for all t, so there is no zero-mass particle.

This choice for b corresponds to

$$A^-(s,t)=(\beta s^{1+\alpha_1 t}/t\ \ln s)[s^{iX}-s^{-iX}]^2$$

[where $X = \frac{1}{2}\alpha_2(-t)^{1/2}$], which, in spite of appearances, is analytic at $t=0$ for all s. It is easy to show that (6) leads to an integrated elastic cross section which is independent of s at large s, and that $A^-(s,0) = \beta\alpha_2^{\,2}s(\ln s)$. Thus this amplitude has the required decrease and the expected analyticity near $t=0$, does not contain any zero-mass particles, and leads to an asymptotically constant nonzero value of $\sigma_T(K^-p) - \sigma_T(K^+p)$, as suggested by the Serpukhov data.

We conclude with three comments:

(i) Independent evidence for large real parts in the forward direction is obtained from comparisons of the K^+p forward elastic differential cross section with the optical value.[7] These comparisons indicate that the real part of the forward amplitude has about 60% of the magnitude of the imaginary part, between 6 and 15 GeV/c. This value is much higher than would be expected in a conventional Regge-pole model,[8] or, presumably, in the model of Ref. 3. Because of the inherent uncertainties in this method of estimating real parts, a direct measurement of the real parts of the $K^\pm p$ forward amplitudes [as well as a determination of $\sigma_T(K^+p)$ above 20 GeV/c] would be of great help in distinguishing between different models.

(ii) It is probably a feature of any model in which the forward amplitude grows like $s(\ln s)$ that the integrated elastic cross section will not go to zero as the energy increases. In the example considered above, this is true even though for $t<0$ all singularities are to the left of the line $\mathrm{Re}J=1$. However, this constant part of the elastic cross section may be quite small; if we let the parameter α_2 in (5) be 1 $(\mathrm{GeV})^{-1}$, and if $\sigma_T(K^-p) - \sigma_T(K^+p) \to 3$ mb, then the integrated elastic cross section at infinite energy (coming from the real part) would be only about 0.3 mb.

(iii) If the normal Pomeranchuk singularity consisted of two complex-conjugate poles [with $\alpha(t) = 1 + 2\alpha_1 t \pm i\,\alpha_2(-t)^{1/2}$], as has occasionally been suggested, then by iteration of these poles one would expect branch points at precisely the positions of the branch points in (5). However, no known model for generating cuts predicts cuts of odd charge conjugation arising from the iteration of poles of even charge conjugation.

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[6]Regge poles that collide at $t=0$, and go into the complex J plane for $t<0$, can give $(\ln s)^{-2}$ decrease in the sense that $(d/dt)\ln A'(s,0)$ grows like $(\ln s)^2$, but the integrated elastic cross section nevertheless grows like $\ln(\ln s)$.
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s-CHANNEL PICTURE FOR REGGEON COUPLINGS TO BARYONS*

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A simple s-channel picture of the dominant non-Pomeranchuk contributions to the A' amplitude in 0^- meson–$\frac{1}{2}^+$-baryon scattering leads to (i) a physical interpretation of the F parameter in Reggeon and tadpole couplings to baryons, and (ii) selection rules for baryon couplings to mesons and baryons.

The view of s-channel resonances and t-channel Regge poles as complementary descriptions of scattering processes has led to many constraints on both descriptions which seem to hold in nature. This principle, first suggested for πN charge exchange,[1] has come to be known as duality.[2]

The constraints implied by duality on Regge models of the A' amplitude in 0^--meson–$\frac{1}{2}^+$-baryon (MB) scattering[3] can be tested quite easily, as A' is related at $t=0$ to total cross sections. These constraints agree with experiment. They