CM-P00057543

Archives

Ref. TH. 742

REGGE POLE AND SINGLE PARTICLE EXCHANGE MECHANISMS

IN HIGH ENERGY COLLISIONS

L. Van Hove

CERN - Geneva

A B S T R A C T

It is shown that if particles and resonances occur in infinite Regge recurrence series, the well-known contradiction between Regge pole and single particle exchange models for high energy two-body collisions can be avoided, and double particle exchange is depressed with respect to single exchange.

67/47/5 - TH. 742

30 January 1967

1. - Recent work on two-body collisions at high energy $s^{\frac{1}{2}}$ and small momentum transfer $(-t)^{\frac{1}{2}}$ has shown that the Regge pole model accounts for many features of the data and that, while the Pomeron pole is almost independent of t , the other most familiar Regge trajectories like ρ and A_2 have a slope of order $1(\text{GeV}/c)^{-2}$. There are in addition indications that the latter as well as the baryonic trajectories are approximately straight lines extending to positive t values of several $(\text{GeV}/c)^2$ and carry several resonances of high mass and spin (Regge recurrences).¹⁾

On the other hand, an alternative and often successful description of inelastic two-body collisions in the intermediate energy range $(2.5 \lesssim s^{\frac{1}{2}} \lesssim 4 \text{ GeV})$ is obtained by assuming a single particle exchange mechanism, with the possibility of absorptive corrections²⁾. The difficulty with the single particle exchange model, however, is that in its usual formulation it generally fails to account for the observed s dependence of the cross-sections at higher energies ($s^{\frac{1}{2}} \gtrsim 4 \text{ GeV}$) where Regge asymptotics agrees well with the facts.

2. - Our purpose is to point out that this contradiction between Regge pole and single particle exchange models for high-energy collisions can be avoided and that the two models can become essentially equivalent if the particles occur in infinite series of Regge recurrences. Taking mesons for simplicity, we consider such an infinite Regge series with mass-spin relation

$$M = M(J), \quad M(J) \rightarrow \infty \quad \text{for } J \rightarrow \infty \quad (1)$$

where J runs over all non-negative even or odd integers. Single exchange of these mesons in the t channel makes the following contribution to the scattering amplitude

$$T(st) = \sum^+ \frac{b(J,t)}{M^2(J)-t} P_J(z) \quad (2)$$

2.

$\Sigma^+(\Sigma^-)$ runs over non-negative even (odd) integers, $b(J,t)$ contains coupling and form factor effects, $[M^2(J)-t]^{-1}$ is the meson propagator except for its spin factor which is given by the Legendre polynomial P_J . The value of z is

$$z = (u-s) (4m^2-t)^{-1} \quad (3)$$

where we have considered the simplest case of a scattering process $A+B \rightarrow C+D$ involving four spinless particles of equal mass m . The asymptotic behaviour of T for $s \rightarrow +\infty$ is then obtained by the methods familiar in the Regge pole model. Assuming the necessary analyticity properties of $b(J,t)$ and $M^2(J)$ in the complex J plane, one carries out the Sommerfeld-Watson transformation in (2) and determines the leading pole (pole with largest $\text{Re } J$) of the expression

$$b(J,t) [M^2(J)-t]^{-1} \quad (4)$$

The mesons of the Regge series are supposed to lie on a trajectory $\alpha(t)$, i.e.,

$$\alpha[M^2(J)] = J, \quad M^2[\alpha(t)] = t \quad (5)$$

The function (4) has therefore a pole at $J = \alpha(t)$, with residue

$$\alpha'(t) b[\alpha(t), t] \quad (6)$$

Assuming this to be the leading pole of (4), we obtain the asymptotic behaviour

$$T(st) \underset{s \rightarrow +\infty}{\sim} \frac{\pi}{2} \frac{1 \pm e^{-i\pi \alpha(t)}}{\sin \pi \alpha(t)} \alpha'(t) b[\alpha(t), t] \left(\frac{s-u}{4m^2-t} \right)^{\alpha(t)} \quad (7)$$

in agreement with the prediction of the Regge pole model for the contribution of the trajectory $\alpha(t)$ to the scattering amplitude. This extremely elementary argument proves our assertion.

3. - The above discussion of single particle exchange can be extended to simultaneous exchange of several particles. Considering double particle exchange and taking for the exchanged particles p_1, p_2 all elements in infinite Regge series defined by the Regge trajectories $\alpha_1(t), \alpha_2(t)$ respectively, we obtain a contribution to the scattering amplitude which behaves at large s in the same way as would result from simultaneous exchange of the two Regge poles $\alpha_1(t), \alpha_2(t)$. As is well known, this simultaneous exchange induces in the J plane a Regge cut $\alpha_c(t)$ given at small $|t|$ by

$$\alpha_c(t) = \alpha_1(0) + \alpha_2(0) - 1 + \frac{\alpha'_1(0) \alpha'_2(0)}{\alpha'_1(0) + \alpha'_2(0)} t + O(t^2) \quad (8)$$

If $\alpha_i(0) < 1$ for both trajectories, $\alpha_c(t)$ is below both $\alpha_1(t)$ and $\alpha_2(t)$ at small $|t|$, so that double particle exchange becomes at high energy negligible compared to single particle exchange.

4. - The Pomeranchuk trajectory $\alpha_p(t)$ deserves some special comments. Firstly, the above considerations are less likely to apply to it than to the other mesonic trajectories or to the baryonic ones. Indeed the slope of $\alpha_p(t)$ is appreciably smaller and is perhaps zero (fixed singularity in J plane), so that it is less likely to carry an infinite Regge recurrence series. This would mean that two-body reactions at high s and small t could be dominated by two complementary mechanisms, diffraction or shadow scattering and single particle exchange, the latter obeying Regge type asymptotics because of occurrence of the particles in infinite Regge recurrence series.

Secondly, our discussion of single particle exchange in Section 2 did not include absorptive corrections. If one chooses to add the latter in Eq. (2), one changes Eq. (7) into a Regge pole formula corrected for absorption in the initial and final states. This modification is essentially equivalent to exchange of one or more trajectories $\alpha_p(t)$ in addition to $\alpha(t)$. The resulting Regge cut $\alpha_c(t)$ verifies $\alpha_c(0) = \alpha(0)$ as can be seen by application of Eq. (8) with $\alpha_1(0) = \alpha(0)$ and $\alpha_2(0) = \alpha_p(0) = 1$. Its slope $\alpha'_c(0)$ is smaller than $\alpha'(0)$.

5. - As a final remark we note that at moderate s the sum in Eq. (2) may be dominated by a small number of terms ; this is the situation supposed to prevail in the usual applications of the single particle exchange model. At higher s , a larger number of terms will contribute appreciably and the infinite character of the Regge series considered above will become relevant, especially to give rise to the $\alpha(t)$ depending phase in Eq. (7).

The author is grateful to Dr. J.J.J. Kokkedee for useful discussions.

R E F E R E N C E S

- 1) For a recent review, see L. Van Hove, Report to the XIIIth International Conference on High Energy Physics, Berkeley, 1966.
- 2) For a recent review, see J.D. Jackson, Report to the XIIIth International Conference on High Energy Physics, Berkeley, 1966.