POMERON CUTS IN INCLUSIVE REACTIONS, GRIBOV VERTICES, AND TOTAL CROSS-SECTION RISE

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It has been found that the Gribov vertices (i. e. the fixed pole residua) which control the strengths of the two Pomeron cut contributions are very sensitive to details of the asymptotic form of the Pomeron-particle amplitude.

Assuming that it is the two Pomeron cut which is responsible for an apparent lack of evidence for an effective triple Pomeron zero, an estimate of the Gribov vertices and their effect on the total pp cross-section has been made.

The contribution of the Regge cut [1] generated by an exchange of the two Regge poles with trajectories $\alpha_1(t)$ and $\alpha_2(t)$ and signatures τ_1 and τ_2 to the forward two body amplitude is given by the following formula [2–4]:

$$A_c(s, t_0 = 0) = \frac{1}{16\pi s}\int V_1(t)V_2(t)R_1(s, t)R_2(s, t)dt, \tag{1}$$

where $R_i(s, t)$ are defined below:

$$R_i(s, t) = \frac{[1+\tau_i e^{-i\pi\alpha_i(t)}]}{\sin \pi\alpha_i(t)} s^{\alpha_i(t)} \tag{2}$$

and the vertex functions $V_i(t)$ being the corresponding fixed pole residua are related in the following way to the absorptive part of the forward Reggeon-particle amplitude A_i:

$$V_i(t) = \int\limits_0^\infty \text{Abs } A_i(M^2, t)dM^2. \tag{3}$$

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Among the two-Reggeon cuts which are of special interest is one generated by an exchange of two Pomeron poles ($\alpha_P(0) = 1$). The contribution of this cut, when added to the Pomeron pole contribution, leads to total cross-sections which *grow* into a finite limit as the energy increases which fits nicely to the experimental data [5]. The detailed structure of the cut contribution depends, however, on the vertex functions V_i (i. e. on their strength, t-dependence, etc.).

The purpose of this note is a discussion of the vertex functions V_i appearing in (1) for the two-Pomeron cut. More precisely, we wish to consider more closely the effect of the asymptotic part of the Pomeron-particle amplitude on the functions V_i and in turn on the forward elastic amplitude through the convolution formula (1).

In what follows, for definiteness, we shall concentrate on the Pomeron-proton forward amplitude $A_{Pp;Pp}(M^2, t)$. The absorptive part of this amplitude is, in principle, measurable in the corresponding single particle inclusive distributions [6–8]. Results of the phenomenological analysis of the latter make it possible to estimate the Gribov vertices V_i and in turn their effect on the forward elastic amplitude [7, 8].

The integral in (3) splits naturally into three parts:

$$V(t) = V^{(el)}(t)+V^{(int)}(t)+V^{(as)}(t), \tag{4}$$

where $V^{(el)}$ corresponds to the proton pole contribution, $V^{(int)}$ to the average over the intermediate missing mass range ($M^2 \lesssim 5$ GeV^2), and $V^{(as)}$ to the asymptotic (i. e. the triple Regge) contribution, respectively.

The integral defining $V^{(as)}(t)$ has to be understood, in general, in the sense of the analytical continuation i. e.:

$$V^{(as)}(t) = f^{(as)}(n = 0; t), \tag{5}$$

where

$$f^{(as)}(n; t) = \int_N^{\infty} \text{Abs } A^{(as)}_{Pp;Pp}(M^2, t)\,(M^2)^{-n} dM^2. \tag{6}$$

The most important contributions to $V(t)$ are: $V^{(el)}(t)$ and the triple Pomeron part of $V^{(as)}(t)$. The triple Pomeron *pole* part $V^{(pole)}_{PP;P}$ of $V^{(as)}$ with the vanishing triple Pomeron coupling for zero mass Pomerons ($t = 0$)

$$b_{PP;P}(t) = -t\bar{b}_{PP;P}(t) \tag{7}$$

is given by the following expression

$$V^{(pole)}_{PP;P}(t) = -\frac{N^{(\alpha_P(0)-2\alpha_P(t)+1)}}{2\alpha'_P(t)}\,\bar{b}_{PP;P}(t).$$

This contribution is evidently negative. The $V^{(el)}$ and $V^{(pole)}_{PP;P}$ enter with the opposite signs in (4) and tend to cancel each other, reducing effectively the absolute value of the vertex function V and correspondingly the strengths of the two-Pomeron cut in the forward amplitude.

The triple Pomeron *pole* zero (for $t = 0$) is required for the Reggeon field theory to be consistent [9]. On the other hand, the phenomenological triple Regge analysis of the reaction pp → pX suggests that the effective triple Pomeron coupling does not vanish for $t = 0$ [8]. If we insist on the traditional Regge *pole* + cuts model for a Pomeron, then the simplest interpretation of this fact is that it is a two-Pomeron cut contribution to the Pomeron-proton amplitude in the triple Pomeron limit which fills the triple Pomeron zero for $t = 0$.

The Pomeron cut contribution in the triple Pomeron limit has been discussed in great detail in Ref. [10]. The following properties of the two-Pomeron cut contributions in this limit are relevant to our purposes:

(a) The crossed-channel unitarity implies that for zero mass Pomerons the discontinuity of the two-Pomeron cut should vanish at the tip of the cut, giving the following contribution to the (forward) Pomeron-particle amplitude:

$$A^{(\mathrm{cut})}_{\mathrm{Pp;Pp}}(M^2, t) = (M^2)^{-1-2t\alpha'_{\mathrm{P}}(t)}\left(\frac{r^{(\mathrm{cut})}}{(\ln M^2)^2} + O\left(\frac{t}{(\ln M^2)}, \frac{1}{(\ln M^2)^3}\right)\right). \tag{9}$$

(b) This cut contribution (at least for $t = 0$) should be *positive* (i. e. $r^{(\mathrm{cut})} > 0$) because, for vanishing triple Pomeron *pole* coupling, this is a leading asymptotic term appearing in the inclusive distributions in the triple regge region. (The positivity of this term is probably achieved as an effect of mutual cancellations between softened negative genuine two-Pomeron cut and positive three-Pomeron cut contributions).

The softening of the Pomeron cut contribution (formula (9)) and its positivity imply that its contribution to $V^{(\mathrm{as})}$ should also be positive, at least for $t = 0$. This should *enhance* the Gribov vertices V, unlike the triple Pomeron *pole* contribution which tends to reduce their value.

In order to get some insight into the possible structure of the vertex functions $V(t)$ with cut contributions taken into account, we estimated them using the following input:

(*i*) For an estimate of $V^{(\mathrm{el})}$ and $V^{(\mathrm{int})}$ we have used the experimental data from Refs [11] and [12].

(*ii*) For an estimate of $V^{(\mathrm{as})}$ we have used the triple Regge parametrization from Ref. [8] for the terms PPR and R ≠ P. The triple Pomeron term in $A_{\mathrm{Pp;Pp}}(M^2, t)$ has been parametrized entirely in the form of the cut contribution (see the formula (9)):

$$A^{(\mathrm{cut})}_{\mathrm{PP;P}}(M^2, t) = \frac{C^2}{(C+\ln M^2)^2} A^{(\mathrm{pole})}_{\mathrm{PP;P}}(M^2, t), \tag{10}$$

where for numerical estimates, we have put for $A^{(\mathrm{pole})}_{\mathrm{PP;P}}(M^2, t)$ the triple Pomeron pole parametrization from Ref. [8] and C has been put (quite arbitrarily) equal to 10.

Our results, concerning the vertex function V, are summarized in Fig. 1.

For comparison we have also drawn the proton-pole contribution to $V(t)$ (i. e. the eikonal model result) and $|V(t)|^2/16\pi$ obtained in Ref. [8], where the asymptotic part of $A_{\mathrm{Pp;Pp}}(M^2, t)$ is described by the triple Pomeron pole term without the forward triple Pomeron zero. It follows from this figure that Pomeron cuts tend indeed to enhance the absolute value of $V(t)$ as compared, for instance, with the eikonal model. Due to the lack of significant cancellations the effective slope of $V(t)$ turns out to be smaller than in the case when the triple Pomeron pole parametrization is used for $A_{Pp;Pp}(M^2, t)$. The corresponding change of the total cross-section for s changing between 200 GeV^2 and 2000 GeV^2

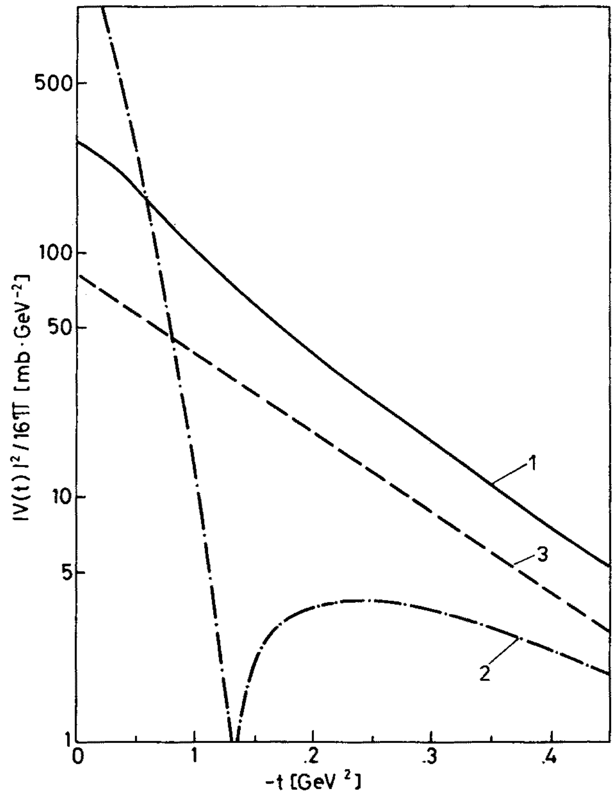

Fig. 1. The function $|V(t)|^2/16\pi$ plotted versus $-t$ for various asymptotic forms of the Pomeron-proton amplitude and compared with the proton pole contribution: *1* — corresponds to the two-Pomeron cut parametrization, *2* — corresponds to the triple Pomeron pole parametrization from Ref. [8], *3* — the proton pole contribution alone

is, however, only 1.7 mb. (It is possible to achieve the total cross-section rise of 4 mb putting $C = 50$ in the formula (10), but the absolute values of the cut contribution are unrealistically large in this case being of the order of 100 mb.)

To sum up we wish to emphasize the following points. The two-Pomeron cut contributions to the Gribov vertices behave very differently from the triple Pomeron pole contribution. The cuts tend to enhance the absolute value of $V(t)$ as compared, for instance, with the eikonal model without changing appreciably the effective slope of $V(t)$. They act in this way, in a right direction for getting the sizeable two-Pomeron cut contributions to the total cross-section. The crude estimate suggests, however, that the obtained change of the total pp cross-section with energy is still not strong enough to produce the observed rise of about 4 mb.

REFERENCES

[1] S. Mandelstam, *Nuovo Cimento* **30**, 1127, 148 (1963).
[2] V. N. Gribov, *Zh. Eksp. Teor. Fiz.* **53**, 654 (1967).
[3] A. B. Kaidalov, B. M. Karnakov, *Phys. Lett.* **29B**, 372, 376 (1969).
[4] A. N. White, *Nucl. Phys.* **B50**, 130 (1972).
[5] U. Amaldi, talk given at the Aix-en-Provence Conference on Elementary Particles, *J. Phys.* (Supplement) **34**, C1–241 (1973) and references cited therein.
[6] R. G. Roberts, *Phenomenology of Inclusive Reactions* (lectures given at the 14th Scottish Universities Summer School in Physics, Edinburgh, August 1973), RHEL *Preprint* RL-73-095 T-68 and references cited therein.
[7] D. P. Roy, R. G. Roberts, *Phys. Lett.* **40B**, 555 (1972).
[8] D. P. Roy, R. G. Roberts, *RHEL Preprint* RL-74-022 T-79.
[9] V. N. Gribov, Ref. [2]; V. N. Gribov, A. A. Migdal, *Yad. Fiz.* **8**, 102 (1968); J. L. Cardy, A. R. White, CERN *Preprint* TH-1740.
[10] J. L. Cardy, *Nucl. Phys.* **B56**, 605 (1973).
[11] R. M. Edelstein, *Phys. Rev.* **D5**, 1073 (1972).
[12] J. V. Allaby et al., *Nucl. Phys.* **B52**, 316 (1972).