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THE FINE STRUCTURE OF THE POMERON AND THE SLOPE
PARAMETER OF THE DIFFRACTION PEAK

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A B S T R A C T

The j plane structure of the vertex function of the Pomeron suggested by the two-pole multiperipheral model exhibits a fine structure which depends on the triple Pomeron coupling. It is found that this structure alone may explain the energy dependence of the slope parameter of the p-p diffraction peak even with an arbitrarily small slope of the Pomeron trajectory.

Recent studies on the dynamical origin of the Pomeranchuk singularity within the multiperipheral model ¹⁾ have shown that the j plane structure of the propagator and of the vertex function of the Pomeron are modified by logarithmic singularities, the strength of which depends on the triple Pomeron coupling.

A multiperipheral model with two input poles, a Pomeron and a meson pole, leads through the s channel unitarity equation to the following form for the absorptive part of the elastic partial wave amplitude :

$$a(j, t) \equiv \frac{N(j, t)}{D(j, t)} = \frac{\beta(t) - \gamma(t) g_P \ln(j - \alpha_c(t))}{j - \alpha_0(t) + g_P^2 e^{kt} \ln(j - \alpha_c(t))} \quad (1)$$

The above expression is valid near the Pomeranchuk pole $j = \alpha_P$, given by the equation

$$D(j = \alpha_P(t), t) = 0 \quad (2)$$

The D function contains the "unperturbed" leading trajectory $\alpha_0(t)$ which is built up by meson exchange, i.e., by the dominant component for generating the Pomeron in multiperipheral dynamics ¹⁾. The logarithmic term can be attributed to the interference of Pomeron and meson exchange in multiperipheral chains. A typical diagram of this kind is illustrated in Fig. 1a; there, it can be seen that g_P is related to the triple Pomeron coupling ²⁾. Correspondingly, the logarithmic term in the N function, again due to the triple Pomeron coupling, is represented by the diagrams shown in Fig. 1b. Within the multiperipheral model, $\beta(t)$ and $\gamma(t)$ depend on the strength of the Amati-Fubini-Stanghellini (AFS) cuts when the input poles are exchanged, but if one considers that Eq. (1) has a model independent validity, then $\beta(t)$ and $\gamma(t)$ simply represent the structure of the Pomeron residue function. Finally, $\alpha_c(t)$ is the AFS cut corresponding to Pomeron exchange and it is given by the well-known relation : $\alpha_c(t) = 2\alpha_P(t/4) - 1$. Expanding the D function near the point $j = \alpha_P(t)$ and keeping only terms up to first order in g_P , we obtain

$$a(j, t) = \frac{\beta(t) - \gamma(t) g_P \ln(j - \alpha_c(t))}{j - \alpha_P(t)} + O(g_P^2) \quad (3)$$

Due to the logarithmic nature of the branch point of the D function, the first sheet pole $\alpha_P(t)$ stays always to the right of the branch point $\alpha_c(t)$. Then, self-consistency within the multiperipheral bootstrap requires that the intercept of the Pomeron, $\alpha_P(0)$, has to be less than 1 by a small quantity ϵ , $\alpha_P(0) = 1 - \epsilon$, and consequently total cross-sections have to vanish asymptotically. Obviously g_P and ϵ are related and if $\epsilon = 0$ then g_P must be also zero. In addition, if $g_P \neq 0$, the trajectory $\alpha_P(t)$ shows a deviation from linearity for negative t .

The parameters g_P and ϵ describe quantitatively the fine structure of the Pomeron and in the following we discuss their effect in high energy pp scattering. We assume dominance of the imaginary part of the amplitude $T(s, t)$ and we neglect all

low lying singularities, as well as possible additive cuts. We trust Eq. (3) only for small t , consequently we restrict our investigation on the total cross-section and on the slope parameter of the diffraction peak near the forward direction ($|t| < 0.1$ (GeV)²).

The amplitude $a(j, t)$ in Eq. (3) is defined in such a way that $\text{Im } T(s, t)$ is given by the Mellin transform :

$$\text{Im } T(s, t) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} dj s^j a(j, t) \quad (4)$$

and, moreover

$$\sigma_{\text{tot}}(s) = \frac{1}{s} \text{Im } T(s, 0) \quad (5)$$

From the singularity structure of $a(j, t)$, Eq. (4) gives

$$\text{Im } T(s, t) = s^{\alpha_p(t)} \left\{ \beta(t) - \gamma(t) g_p \left[\ln(\alpha_p(t) - \alpha_c(t)) + E_1((\alpha_p(t) - \alpha_c(t)) \ln s) \right] \right\} \quad (6)$$

where

$$E_1(x) = \int_x^\infty \frac{e^{-t}}{t} dt$$

The slope parameter $b(s)$ of the diffraction peak at $t=0$ is given by :

$$b(s) = \frac{\partial}{\partial t} \left(\ln \frac{d\sigma}{dt} \right)_{t=0} \quad (7)$$

Expanding E_1 in Eq. (6) we finally obtain

$$\begin{aligned} \sigma_{\text{tot}} &= s^{-\epsilon} \left[\beta(0) + \gamma(0) g_p f(\epsilon, \ln s) \right] \\ b(s) &= 2 \alpha'_p(0) \ln s + \frac{2\beta'(0) + 2\gamma'(0) g_p f(\epsilon, \ln s) - \alpha'_p(0) \gamma(0) g_p \ln s h(\epsilon, \ln s)}{\beta(0) + \gamma(0) g_p f(\epsilon, \ln s)} \end{aligned} \quad (8)$$

where α'_p , β' , γ' are the corresponding derivatives, and

$$\begin{aligned} f(\epsilon, \ln s) &= \gamma + \ln \ln s + \sum_{n=1}^{\infty} \frac{(-1)^n (\epsilon \ln s)^n}{n n!} \quad (\gamma \text{ is the Euler constant}) \\ h(\epsilon, \ln s) &= \sum_{n=0}^{\infty} \frac{(-1)^n (\epsilon \ln s)^n}{(n+1)!} \end{aligned} \quad (9)$$

We note that the relevant energy dependent quantity $\epsilon \ln s$ may be sufficiently small even at large energies, since ϵ is expected to be very small. Therefore, the energy dependence of the quantities (8) in question is expected to be described by only a few terms in the series (9) and not be the asymptotic behaviour of $f(\epsilon, \ln s)$ and $h(\epsilon, \ln s)$. Using the expressions (8) and (9), we determine the parameters involved in order to get a reasonable χ^2 for the total cross-section up to 60 GeV/c and for the slope parameter, $b(s)$, including the recent ISR data for $|t| < 0.12 (\text{GeV})^2$. Varying α'_p , we found that a better description of the data (smaller χ^2) is achieved if α'_p is arbitrarily small ($\alpha'_p \simeq 0$). This means that the experimentally observed shrinkage can be entirely attributed to the fine structure of the Pomeron, provided that $\gamma(t)$ varies rapidly near $t=0$.

We find $(\gamma'(0)/\gamma(0)) = 52 (\text{GeV})^{-2}$ corresponding to a range of interactions for the triple Pomeron vertex of the order of the pion Compton wavelength. If we restrict the parameter $\gamma(0)$ in the region $\gamma(0) > 0$, as suggested by the multi-peripheral model, then small χ^2 requires $\epsilon \gtrsim 0.02$ and $(\gamma(0)g_p)/(\beta(0)) = 0.054$. This result may be an indirect phenomenological indication for a small triple Pomeron coupling, in agreement with the size of g_p deduced directly from the analysis of inclusive reactions ³⁾. In Figs. 2 and 3, we illustrate the description of the data.

Concluding, we have shown that the fine structure of the Pomeron, suggested by the multiperipheral model, may lead to an energy dependence of the forward amplitude compatible with the data, even with arbitrarily small slope, α'_p , of the Pomeron trajectory and without secondary singularities. In fact, the slope parameter, $b(s)$, of the diffraction peak in p-p scattering, corresponding to a "flat" Pomeron [$\alpha'_p(0)$ being arbitrarily small] increases with energy in agreement with the data of Serpukhov ⁴⁾ and ISR ⁵⁾, and the total cross-section, although it decreases slowly [we expect $\sigma_{\text{tot}} = 36.2 \text{ mb}$ at the ISR energy $s = 2000 (\text{GeV})^2$] it is compatible with the existing data. We note that alternative explanations for the behaviour of $b(s)$, especially in the ISR region, need the effect of secondary singularities ⁶⁾ whereas a fit to the Serpukhov data ⁴⁾ alone needs a slope of the Pomeron trajectory $\alpha'_p = 0.47 (\text{GeV}/c)^{-2}$.

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FIGURE CAPTIONS

Figure 1 Multiperipheral diagrams which contribute to a logarithmic correction term.

a) in the D function, and

b) in the N function.

P and M label the Pomeron and meson trajectory in a two-pole multiperipheral model and g_p is related to the triple Pomeron coupling.

Figure 2 The total cross-section for p-p scattering compared to the experimental data from Refs. 7),9).

Figure 3 The slope parameter, $b(s)$, of the proton-proton diffraction peak for small momentum transfers. The solid line corresponds to the results of our model. The line (----) is a fit to the Serpukhov data ⁴⁾ ($b = b_0 + 2b_1 \ln s$, $b_0 = 6.8 \pm 0.3$, $b_1 = 0.47 \pm 0.09$). The line (-.-.-) is the fit of Ref. 6), with $b = 12.7 - 14.6s^{-\frac{1}{2}}$. The experimental points are from Refs. 4),5),8),9).

FIG. 1a

FIG. 1b

FIG. 2

FIG.3