CM-P00058935

Ref.TH.1390-CERN

Archives

POMERON f^0 PROPORTIONALITY IN INCLUSIVE REACTIONS

R.C. Brower
CERN - Geneva

A B S T R A C T

The " f^0 dominated" Pomeron, suggested by both multiperipheral and dual models, has strong consequences for inclusive reactions. Combined with exchange degeneracy (for f, ρ, ω, A_2) the $s^{-\frac{1}{2}}$ approach to scaling is controlled by a few constants. As an example, the near constancy of the ratio $d\sigma(K^-p \rightarrow \pi^-X)/d\sigma(K^+p \rightarrow \pi^-X)$ for the proton fragmentation is explained.

Ref.TH.1390-CERN
20 August 1971

The inclusive cross-sections ($a + b \rightarrow c + \text{anything}$, $a + b + c + d + \text{anything}$, etc.) provide an excellent tool for the study of the nature of the Pomeron singularity. Already suggestions have been made to test factorization ¹⁾ and the Toller M number for the Pomeron ²⁾. Here we consider the relationship of the Pomeron singularity ($\alpha_P(0) \simeq 1$) to the lower f^0 singularity and its exchange degenerate partners ρ, ω, A_2 ($\alpha_f(0) \approx \frac{1}{2}$).

Consider the inclusive cross-section for $a(p_1) + b(p_2) \rightarrow c(q) + X$ for the fragmentation of a . For large s , and $q_{||} = x \sqrt{s/2}$, $q_{\perp}$ the centre-of-mass momentum of c , one has the limiting fragmentation formula

$$g \cdot \frac{d\sigma}{ds g} \simeq F^P(x, q_{\perp}) + s^{-\kappa} [F^f(x, q_{\perp}) + F^{\rho, \omega, A_2}(x, q_{\perp})] + O(\frac{1}{s}) \quad (1)$$

neglecting cuts and lower trajectories. Recent multiperipheral and dual models can make strong assertions about the relationship between the inclusive form factors for the Pomeron (F^P) and the f^0 (F^f).

In the multiperipheral model (MPM) of Chew and Snider, the f^0 and P are built up from ordinary exchange plus a (weak) Pomeron exchange ³⁾. Both the output f^0 and P poles couple to the external particles (at the end of the chain) through the same series of ordinary exchanges. Hence by the assumption of no long range correlations the couplings of the f^0 and P Regge poles are proportional. In the dual resonance model (DRM) the groups of produced particles connected by ordinary exchanges are replaced by direct channel resonances and the Pomeron link by a twisted propagator leading to the Freund-Harrari picture of the Pomeron. Again the Pomeron couples through the same mechanism as the f^0 ⁴⁾.

The consequences for the inclusive processes are easily seen by a natural generalization of the analysis of Carlitz, Green and Zee ⁵⁾. We simply replace their vertex $\beta_{aaf}(J, t)$ by the four-particle Reggeon (Fig. 1) vertex $F_{ac}(x, q_{\perp}, J)$ to obtain

$$F_{ac}(x, q_{\perp}, J) \left[\frac{1}{J-\alpha} + \frac{1}{J-\alpha} B(J) \frac{1}{J-\alpha} + \dots \right] \beta_{fb\bar{b}} \simeq F_{ac} \frac{1}{J-\alpha-B} \beta_{fb\bar{b}} \quad (2)$$

Since $t_{b\bar{b}} = 0$ for inclusive cross-sections, we have ignored the $t_{b\bar{b}}$ dependence in F, B, β and α . We are interested here in general consequences, that are independent of the detailed formulation of the problem. So long as the series ^{*)} (in brackets) yields a pole at $J = \alpha_f$ and $J = \alpha_P$ one obtains the form factors ^{**)}

*) For simplicity one may replace the cut in B by a pole, $B = \epsilon (\alpha_P(0) - \alpha(0))^2 / (J - \alpha_P)$ and take only the first two terms (Regge plus Pomeron). The second term has the general features of the dual Pomeron of Lovelace ⁴⁾.

**) A cut with discontinuity concentrated at $J = \alpha_P$ would give similar results, modulus logarithms.

$$F^f(\chi, q_\perp) = F_{ac}(\chi, q_\perp, J) \Big|_{J=\alpha_f} \beta_{fb\bar{b}}$$

$$F^P(\chi, q_\perp) = \epsilon F_{ac}(\chi, q_\perp, J) \Big|_{J=\alpha_P} \beta_{fb\bar{b}} \quad (4)$$

where ϵ is a universal constant independent of abc . In addition to the factorization property, one has the proportionality relation

$$\frac{F^P(\chi, q_\perp)}{F^f(\chi, q_\perp)} = \epsilon \frac{F_{ac}(\chi, q_\perp, J) \Big|_{J=\alpha_P}}{F_{ac}(\chi, q_\perp, J) \Big|_{J=\alpha_f}} \approx \epsilon \quad (5)$$

If one neglects the continuation of $F_{ac}(\chi, q_\perp, J)$ in the J plane, the Pomeron and f^0 inclusive form factors are proportional. In exclusive processes, Carlitz et al. ⁵⁾ introduce the f and the f' with ideal mixing and an SU_3 singlet kernel $B(J, t)$ to explain the SU_3 properties of the Pomeron. The mass terms $1/(J - \alpha_f)$ adequately explain the πN and KN ratio of total cross-sections and the relative slope of the elastic peaks. However, the inclusive process is ideally suited to testing the proportionality relations.

1. - Test of proportionality

The proportionality relations for f^0 (and f'^0), as well as exchange degeneracy for ρ , A_2 and ω give the $1/\sqrt{s}$ departure from scaling in terms of a few constants. Clearly, the energy dependence of inclusive reactions will severely test these ideas.

Even with the present data ⁶⁾ for $K^\pm p \rightarrow \pi^- + X$, one can find some support for f^0 Pomeron proportionality. Neglecting lower singularities,

$$g_0 \frac{d\sigma}{d^3q} (K^\pm p \rightarrow \pi^- X) = F^P + \frac{1}{\sqrt{s}} (F^f + F^\omega + F^{A_2} + F^\rho) \quad (6)$$

Since $ab\bar{c}$ and ab are exotic $K^\pm p \rightarrow \pi^- X$, Ref. 1) and Ref. 7) agree that $F^f = F^\omega$ and $F^{A_2} = F^\rho$. Using exchange degeneracy for ρ , f^0 or the $ab\bar{c}$ exoticity condition of Chan et al. for $\pi^+ p \rightarrow \pi^- X$, one has also $F^\rho/F^f = \text{constant} (\delta)$. Hence with Pomeron f^0 proportionality ($F^P/F^f = \epsilon$), one obtains

$$g_0 \frac{d\sigma}{d^3q} (K^- p \rightarrow \pi^- X) / g_0 \frac{d\sigma}{d^3q} (K^+ p \rightarrow \pi^- X) = 1 + \frac{2(1+\delta)}{\epsilon\sqrt{s}} \quad (7)$$

Figures 2 and 3 give the data ⁶⁾ on logarithmic plots, as a function of x or $q_{\perp}^2$. The near constancy of the difference of the logarithms is (weak) confirmation for this relation. Similar evidence can be sought in other reactions, but the statistics are even less impressive.

2. - J plane continuation

The above discussion can be improved by considering the "kinematical" effect of the J plane continuation for $x \approx 1$. In the triple Regge limit, one has the boundary condition

$$F(x, q_{\perp}, J) \rightarrow \sum_i \gamma_{ii}(t, J) (1-x)^{J-2\alpha_i(t)} \quad (8)$$

so the J dependence cannot be ignored entirely. It is reasonable to pull out the factor $(1-x)^J$ to obtain

$$\frac{F^P(x, q_{\perp})}{F^f(x, q_{\perp})} = \epsilon (1-x)^{1/2} \quad (9)$$

as a better approximation. This corresponds to the plausible criterion that coefficients at constant $M^2 = s/(1-x)$ (or constant phase space for X) are proportional.

$$q_{\perp} \frac{d\sigma}{d^3q} = F^P + (M^2)^{-1/2} \bar{F}^f ; \quad F^P/\bar{F}^f = \epsilon \quad (10)$$

On Fig. 2, the function $\log(1+c/\sqrt{1-x})$ has been fitted to the difference of the logarithms for $c = 2(1+S)/\epsilon\sqrt{s} \approx 2.0$. The logarithmic singularity at $x = 1$ is indicated in the data.

Similarly one may impose the boundary condition of double Regge exchange at $x = 0$, for $x\sqrt{s} \gg 1$.

$$F(x, q_{\perp}, J) \rightarrow \sum_i \beta_{if}(J, q_{\perp}^2) (xs)^J \left(\frac{q_{\perp}^2 + q_{\perp}^2}{x}\right)^{\alpha_i} \quad (11)$$

whence, $F(x, q_{\perp}^2, J) \propto (x)^J$, but there is no indication of the need for this factor at present accelerator energies.

3. - Shrinkage in $q_{\perp}$ distribution

A more general consideration of the J continuation is model dependent. In particular the effect on the $q_{\perp}^2$ distribution in the triple Regge region requires a knowledge of $\gamma_{ii}(t, J)$. For example, in the dual model ⁸⁾,

$$\gamma_{ii}(t, J) = \Gamma^2(-\alpha_i) / \Gamma(J+1-2\alpha_i) \quad (12)$$

resulting in a slightly sharper distribution for the Pomeron component (and therefore $K^+p \rightarrow \pi^- X$), or a shrinkage in the $q_\perp^2$ distribution as limiting fragmentation is approached.

$$\frac{F^P(x, s_\perp)}{F^f(x, s_\perp)} = \epsilon \sqrt{1-x} \frac{\Gamma(1.5 - 2\alpha_\Delta(t))}{\Gamma(2 - 2\alpha_\Delta(t))} \approx \frac{\epsilon}{\sqrt{\pi}} \frac{\sqrt{1-x}}{1.5 - 2\alpha_\Delta(t)} \quad (13)$$

Again the data weakly indicate this effect, but better statistics are needed for a convincing test. Corroboration of this effect is of particular interest, since the (nonsense) factor $J+1-2\alpha_i(t)$ which causes the shrinkage (12), may also be responsible for decoupling the triple Pomeron at $t=0$.

4. - Absolute predictions

In principal, the parameters ϵ, ϵ' are determined in exclusive processes ⁵⁾, so that absolute predictions are possible. But the normalization of the inclusive data is sufficiently uncertain to make these tests rather difficult. It is interesting to note that the general rule (ignoring the J continuation) that a coupling for f^0 and Pomeron obeys the relation

$$g_{pii}/g_{fii} \sim \sqrt{\epsilon} \quad (14)$$

for particles (or Reggeons) i, j has been derived using duality sum rules ⁹⁾. However, the triple Pomeron may well be an exception, since as mentioned above, the J continuation may decouple the triple Pomeron coupling at zero momentum transfer.

While the continuation in J is not without difficulties, the inclusive cross-section should be an ideal way to study Pomeron f^0 proportionality. The simple fixed energy (s) comparison should work for general x away from the kinematical boundaries. At $x \approx 1$, fixed M^2 and at $x \approx 0$ fixed $q \cdot p_b$, extrapolations are called for, if the triple and double Regge effects are clearly visible.

These essentially kinematical effects should not obscure the tremendous simplification that this proportionality implies. In a model with a self-generated Pomreon no such approximate relation would be expected. If this relation can be established for the single particle distributions, it could be used as a constraint for the preliminary two-particle distribution, which should greatly improve our chances of extracting some interesting features from these data.

I wish to thank Chan Hong-Mo, B. Carlitz, P. Goddard and R. Waltz for many helpful discussions, and to acknowledge the hospitality of the CERN Theoretical Study Division.

REFERENCES

- 1) Chan Hong-Mo, C.S. Hsue, C. Quigg and J.M. Wang - Phys.Rev.Letters 26, 672 (1971).
- 2) D.Z. Freedman, C.E. Jones, F.E. Low and J.E. Young - Phys.Rev.Letters 26, 1197 (1971) ;
A. Bassetto and M. Toller - CERN Preprint TH. 1337 (1971).
- 3) G.F. Chew and D.R. Snider - Phys.Rev. D3, 420 (1971).
- 4) C. Lovelace - Phys.Letters 34B, 500 (1971).
- 5) R. Carlitz, M.B. Green and A. Zee - Phys.Rev.Letters 26, 1515 (1971) ;
P.G.O. Freund, H.F. Jones and R.J. Rivers - London ICTP/70/35 (1971).
- 6) M. Foster (Stony Brook Track Chamber Group), from C. Quigg - Invited paper for the
Pasadena Meeting on Hadron Physics at Intermediate Energies (1971) ;
M.S. Chen et al. - Phys.Rev.Letters 26, 1585 (1971).
- 7) J. Ellis, J. Finkelstein, P.H. Frampton and M. Jacob - Phys.Letters 35B, 227 (1971).
- 8) D. Gordon and G. Veneziano - Institute of Advanced Studies Preprint, Princeton (1970) ;
M.A. Virasoro - Phys.Rev., to be published ;
C.E. DeTar, K. Kang, C.I. Tan and J.H. Weis - M.I.T. Preprint, CTP/180 (1971);
R.C. Brower and R.E. Waltz - CERN Preprint TH. 1335 (1971).
- 9) C.L. Jen, K. Kang, P. Shen and C.I. Tan - Brown University Preprint NYO-2262 TA-247

FIGURE CAPTIONS

Figure_1 Pomeron (scaling) contribution for the fragmentation of a in $a + b \rightarrow c + X$.

Figure_2 The $q_{||}$ distribution in the laboratory ($q_{||}^L$)
for $K^-p \rightarrow \pi^- + X$ [●, 9 GeV/c Stony Brook data, Ref. 6],
and for $K^+p \rightarrow \pi^- + X$ [X, 12.7 GeV/c Rochester data, Ref. 6].
The lower curve (●) is the difference of the curves above on a logarithmic scale. The solid line is $\log(1+c/\sqrt{1-x})$, $c = 2.0$.

Figure_3 The $q_{\perp}^2$ distribution for the data of Fig. 2 with $|q_{||}^L| < 1$ GeV/c.
lower curve (●) is the difference of the curves above.

Fig. 1

Fig. 2

FIG.3