Fermi National Accelerator Laboratory

FERMILAB - CONF -93/ 254 - T
August 1993

LIPATOV-LIKE POMERON AND GEOMETRICAL APPROACHES TO ELASTIC HADRON SCATTERING

E. Gotsman[1], E. Levin[2], U. Maor[3] and M.J. Menon[4]

[1] School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Ramat-Aviv 69978
[2] Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510
[3] Department of Phisics, University of Illinois, Urbana IL 61801
[4] Instituto de Física 'Gleb Wataghin', Universidade Estadual de Campinas, Unicamp, 13083-970, Campinas, São Paulo, Brazil

Talk presented by M.J.Menon at XIV-th Brazilian Meeting on Particles and Fields, Caxambu - MG, Sept. 29 - Oct. 3, 1993.

Abstract. Blackening and expansion in pp and p̄p scattering are discussed in the framework of two different formalisms: (a) pure geometrical (eikonal) model, with energy dependent form factors and suitable parametrization for a non-contact quark-quark scattering amplitude; (b) hybrid eikonal model, which combines the hard Lipatov QCD Pomeron with the soft Pomeron and Regge terms. It is shown that both approaches predict a simultaneous increase in the central opacity and in the radius as function of energy in the ISR-SSC domain. Differences concerning pp and p̄p elastic scattering are also discussed.

1. Introduction

Hadronic diffractive scattering are usually investigated either in the t-channel picture (Regge poles, Pomeron) or in the s-channel picture (optical models). In both cases the connection between model assumptions and physical observables may be estabilished through the impact parameter formalism. With the normalizations,

$$\frac{d\sigma}{dt} = \pi|F(s,t)|^2, \quad \sigma_T = 4\pi Im F(s,0),$$

$$F(s,t) = \frac{1}{2\pi}\int d\mathbf{b} e^{i\mathbf{q}\cdot\mathbf{b}}\Gamma(s,b) \equiv < \Gamma(s,b) >,$$

we have for the integrated cross sections and forward slope parameter

$$\sigma_T = 2\int d\mathbf{b} Im\Gamma(s,b), \quad \sigma_{el} = \int d\mathbf{b}|\Gamma(s,b)|^2,$$

$$B = \frac{\int d\mathbf{b} b^2 \Gamma(s,b)}{2\int d\mathbf{b}\Gamma(s,b)}.$$

Unitarity is automaticaly satisfied by expressing the profile $\Gamma(s,b)$ in terms of the complex eikonal function, $\chi(b,s)$, by

$$\Gamma(s,b) = i[1 - e^{i\chi(b,s)}],$$

with $Im\chi \geq 0$. As long as forward elastic scattering are concerned, $Re\chi$ is very small and assuming $Re\chi \simeq 0$, the eikonal defines the *opaqueness*

$$\Omega(s,b) = Im\chi(s,b).$$

In this paper we are interested to discuss some predictions from two different models (t-channel and s-channel pictures), which were fitted to defferent kinds of data set and energy range, for pp and $\bar{p}p$ scattering. In spite of these differences, we will show that both models predict a simultaneous increase in th e radius and in the central opacity at $\sqrt{s} > 10\ GeV$.

2. Lipatov-Like Pomeron Model

Recently a comparative investigation of various Pomeron models was carried out over the energy range $23 \leq \sqrt{s} \leq 1800\ GeV$. The analysis was based on 74 points on σ_T, B and σ_{el}/σ_T from pp and $\bar{p}p$ scattering.[1] Different forms for the Pomeron were tested with different degrees of complexity in non-unitarized, as well as, unitarized parametrizations. Among the nine models tested an hibrid model presented the best statistical results. In this case the opacity is expressed as a sum of three terms,

$$\Omega(s,b) = A_L(s,b) + A_P(s,b) \pm A_R(s,b),$$

where A_R, A_P, and A_L are associated with Reggeon, soft Pomeron and hard QCD Lipatov Pomeron, respectively. For A_i, $i = P$ or R, the terms are expressed by the Fourier transform

$$A_i(s,b) = < c_i e^{R_{0i}^2 t} s^{\alpha_i(t)-1} sin[\frac{\pi}{2}\alpha_i(t)] >,$$

with $\alpha_i(t) = \alpha_i(0) + \alpha_i^{'}t$. Accordingly $A_i(s,b)$ has four adjustable free parameters: c_i, R_{0i}^2, $\alpha_i(0)$ and $\alpha_i^{'}$. The third term, $A_L(s,b)$, is associated with the Lipatov Pomeron obtained from perturbative QCD. This hard Pomeron comes from a series of poles in the complex j plane above unity and has the form $s^\gamma/(lns)^\delta$, with $\gamma > 1$. Taking account of this dependence and of a non-factorized assumption in energy and impact parameter, the A_L term were set

$$A_L = a_1 \frac{s^{a_2}}{(lns)^{a_3}} exp\{-\frac{b^2}{R_L^2(s)}\},$$

with

$$R_L^2(s) = a_4 + a_5[lns]^{a_6}, \tag{1}$$

and a_i, $i = 1, ..., 6$ are adjustable free parameters. Fitting to the experimental data referred before presented the best result, with $\chi^2/d.f. = 0.96$. Comparison with experimental data, as well as the values of all free parameters may be found in Reference 1. The predictions we are interested will be presented and discussed in Section 4.

3. Geometrical Formalism

The pp and p̄p elastic scattering above 10 GeV have been described from a different point of view. The essential assumption is the expression of the opacity as a triple convolution product, involving form factors and averaged quark-quark amplitudes in the impact parameter space.[2] Parametrizing these quantities by functions with well defined Fourier transform, the opacity has the form of the leading term in the Glauber's Multiple Diffraction Theory,[3]

$$\Omega(b,s) = < G_A G_B f >,$$

where $G_{A,B}$ are the hadronic matter form factors and f, the averaged quark-quark scattering amplitude. With the choices

$$G_j = \left\{ \frac{1}{1+q^2/\alpha_j^2} \cdot \frac{1}{1+q^2/\beta_j^2} \right\}, \quad j = A,\ B, \tag{2}$$

$$f = C\frac{1-q^2/a^2}{1+q^4/a^4},$$

we have four free parameters for pp scattering: α^2, β^2, C and a^2. Making use of σ_T and $d\sigma/dt$ experimental data, fitting was carried out in the range $13.8 \le \sqrt{s} \le 630$ GeV, for both pp and p̄p scattering. In the case of $d\sigma/dt$, Martin's prescription was used as an estimate of the real part of the scattering amplitude in the dip region. As result we obtained $a^2_{pp} = a^2_{\bar{p}p} = 8.20$, $\beta^2_{pp} = 1.80$, $\beta^2_{\bar{p}p} = 1.55$, all in GeV^2, and only two free parameters depending on energy:

$$\alpha(s) = \xi_1[lns]^{\xi_2}, \tag{3}$$

$$C(s) = \xi_3 exp\{\xi_4[lns]^2\}.$$

The values of ξ_j, $j = 1, ..., 6$ for pp and p̄p reactions may be found in References 2 qnd 3. With this, a complete description of all experimental data on σ_T, $d\sigma/dt$, σ_{el}/σ_T and B for both reactions up to 1800 GeV was obtained.[3]

4. Blackening and Expansion

Blackening is characterized by the opacity $\Omega(s,b)$. In the ISR-Tevatron domain the results for the central opacity from the models discussed are as follows.
-Lipatov Pomeron:

$$\frac{\Omega(\sqrt{s} = 1800, b = 0)}{\Omega(\sqrt{s} = 23.5, b = 0)} = 1.50$$

-Geometrical Formalism:

$$\frac{\Omega_{pp}(1800,0)}{\Omega_{pp}(23.5,0)} = 1.49 \qquad \frac{\Omega_{\bar{p}p}(1800,0)}{\Omega_{\bar{p}p}(23.5,0)} = 1.86$$

Expansion are characterized by the radius. In the Lipatov Pomeron model it is directly expressed by equation (1). In the Geometrical model, it may be evaluated from the form factors by $R^2 = -6[dG/dq^2]_{q^2=0}$. Combining equation (2) with the parametrization (3) we obtain the same kind of dependence in lns, as expressed by equation (1), but with different values for the three parameters. Figure 1 shows the predictions for the radius as function of the energy in both models.

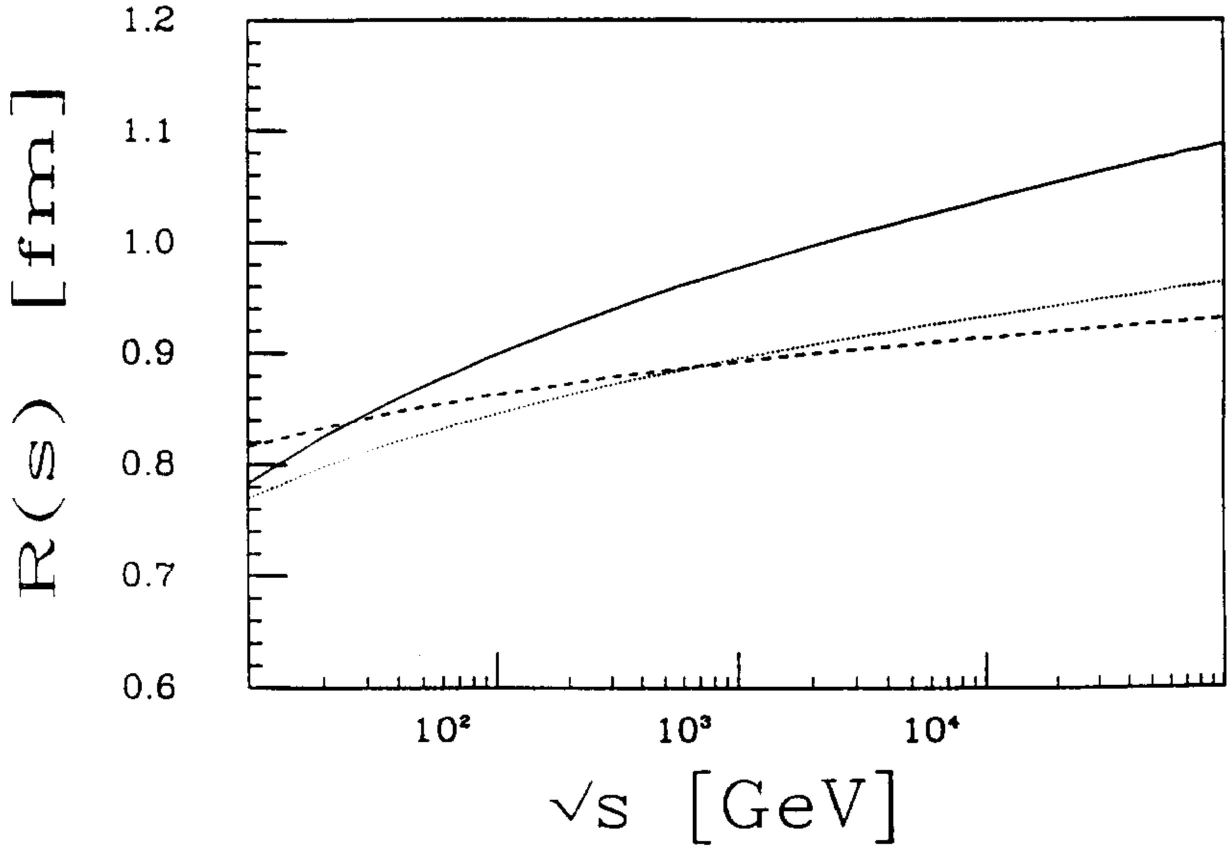

Figure 1. Predicted increases in the radius from the Lipatov-like Pomeron model for pp and p̄p scattering (solid) and from the Geometrical model for pp (dot) and p̄p (dash).

5. Final Remarks

As shown, the two models are based in different assumptions and the data base analized also differs in type, as well as in the energy range. Beside this, a common result is that the σ_T growth is associated with both the expansion and blackening and the predictions are quantitatively similar. However an incongrous feature cencerns the differences between pp and $\bar{p}$p scattering. In the Lipatov Pomeron model the differences come from the Regge term and so becomes negligible in the energy domain investigated. In the geometrical model there was no assumptions concerning the differences and they come from empirical fitting to the experimental data. For example at $\sqrt{s} = 40\ TeV$ (SSC), the predictions for the total cross section are $\sigma_T = 134\ mb$ with the Pomeron model and $\sigma_T(pp) = 110\ mb$ and $\sigma_T(\bar{p}p) = 134\ mb$ with the Geometrical formalism. Global characteristics of diffractive phenomena are being analized along the lines discussed.

References

1. E. Gotsman, E.M. Levin and U. Maor, Zeit. Phys. **C57** (1993) 667; Phys. Lett. **B 309** (1993) 199.
2. M.J. Menon and B.M. Pimentel, *IX Brazilian Meeting on Particles and Fields*, Caxambu (1988), Instituto de Física Teórica - Unesp, São Paulo, preprint P-36/88; Hadronic J. **13** (1990) 315; **15** (1992) 481; Hadronic J. Suppl. **5** (1990) 189.
3. M.J. Menon, Nucl. Phys. B (Proc. Suppl.) **B25** (1992) 94; Phys. Rev. **D48** (1993)...; Hadronic J. **16** (1993)...; Proc. *Vth Int. Conf. Elastic and Diffractive Scatterring*, Providence (1993), in press.