DIFFRACTIVE AND ELASTIC SCATTERING IN THE DIPOLE MODEL*

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We present some improvements of our Monte Carlo implementation of Mueller's dipole cascade model and apply it to inclusive, diffractive and elastic scattering in hadron collisions and deeply inelastic *ep* scattering. We obtain a Lorentz-frame invariant description of the total cross-section and, by considering all possible sources of fluctuations, also of diffractive and elastic cross-sections. In all cases we find reasonable agreement with experimental data.

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1. Introduction

We have in a series of papers [1, 2] presented an extention of Mueller's dipole cascade model [3–5] implemented in a Monte Carlo program which includes subleading effects from energy conservation and running coupling, as well as colour suppressed effects from pomeron loops via a *dipole swing* mechanism.

Here we present some recent progress where our model was improved by a consistent treatment of confinement effects, which turned out to be important to obtain a Lorentz-frame invariant description of total cross-sections. With this improvement we then apply the model to diffractive and elastic scattering. Everything in this paper is explained in full detail in [6].

2. A Monte Carlo model of Mueller's dipoles

The advantage of implementing the dipole model by Mueller in a Monte Carlo simulation program is that it facilitates the studying of non-leading effects and the dependence on some implicit model assumptions. The plain dipole model has been implemented before by Salam [7], and in its basic

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form our program is just a reimplementation of this in C++. However, we have developed our program to be able to study a number of sub-leading effects, with the aim that we in the end will be able to also generate exclusive final states. Here is a list of features included.

Energy conservation is included by assigning a transverse momentum to each emitted gluon given by the maximum inverse size of the neighboring dipoles. As a right-moving dipole system is evolved in rapidity, the positive light-cone momentum of the emitted gluons is, hence, monotonically decreasing, while their negative light-cone momentum becomes increasingly negative. A dipole in the right-moving system is then only allowed to interact with one from the left-moving system with large enough negative light-cone momentum to put the corresponding gluons on-shell, and vice versa [1].

Initial wave functions for the a virtual photon is modeled by the standard leading order perturbative longitudinal and transverse form, taking special care to limit the available rapidity range for the evolution by the energy fractions and transverse momenta of the initial quark–anti-quark pair. The proton wavefunction is obtained by a simple non-perturbative model with three dipoles arranged in a triangle with dipole sizes distributed as a Gaussian.

Saturation effects in the evolution of a dipole system is modeled with a dipole-swing mechanism, where two dipoles, $(\boldsymbol{x}_1, \boldsymbol{y}_1), (\boldsymbol{x}_2, \boldsymbol{y}_2)$, with the same colour may recouple into two new dipoles, $(\boldsymbol{x}_1, \boldsymbol{y}_2), (\boldsymbol{x}_2, \boldsymbol{y}_1)$ [2]. Saturations effects in the interaction between two colliding dipole systems is modeled by the standard unitarization of the dipole–dipole scattering amplitude, f_{ij}, giving the total scattering amplitude

$$T(\boldsymbol{b}) = 1 - e^{-\sum_{ij} f_{ij}} \equiv 1 - e^{-F} \,. \tag{1}$$

Confinement effects are treated by replacing the two-dimensional Coulomb potential, both in the dipole–dipole scattering and the dipole emissions, by a screened Yukawa potential with a mass $\propto 1/r_{\max}$, where $r_{\max}$ is taken to be the same size as the one used in the Gaussian in the proton wavefunction.

The running coupling is introduced both in the dipole emissions and in the dipole–dipole interactions, using the leading-order expression for $\alpha_{\rm s}$with the scale taken to be the minimum of the dipole sizes involved.

Taken together, these features allows us to obtain a Lorentz-frame independent description of total cross-sections, both for pp and DIS, in reasonable agreement with data, using basically only two free parameters, $r_{\max}$ and $\Lambda_{\rm QCD}$ [6].

3. Elastic and diffractive scattering

Our treatment of elastic scattering and diffractive excitation is based on the eikonal approximation and the Good and Walker picture [8]. The result is determined by the fluctuations in the collision process originating from the initial wave functions of the proton and the virtual photon, from the dipole cascades and from the dipole–dipole scattering probability. In our formalism all these different components give important contributions.

The distribution in the mass, M_X, of the diffractive state can be obtained by a study of the collision in different Lorentz frames, as discussed by Hatta *et al.* [9]. (It is here essential that we have a frame-independent formalism.) However, in addition to the fluctuations included in this reference and *e.g.* in the GBW approach [10, 11], we also include fluctuations in the evolution of the proton target.

We thus obtain the different contributions to the diffractive cross-section by taking different averages over fluctuations in the left- (L) and right- (R) moving systems, using the notation in Eq. (1)

$$\begin{aligned}
\frac{d\sigma_{\rm el}}{d^2\boldsymbol{b}} &= \langle 1-e^{-F}\rangle^2_{\rm R,L}\,, \qquad (2)\\
\frac{d\sigma^{\rm R}_{\rm SD}}{d^2\boldsymbol{b}} &= \left\langle \langle 1-e^{-F}\rangle^2_{\rm L}\right\rangle_{\rm R} - \langle 1-e^{-F}\rangle^2_{\rm R,L}\,, \qquad (3)\\
\frac{d\sigma^{\rm L}_{\rm SD}}{d^2\boldsymbol{b}} &= \left\langle \langle 1-e^{-F}\rangle^2_{\rm R}\right\rangle_{\rm L} - \langle 1-e^{-F}\rangle^2_{\rm R,L}\,, \qquad (4)\\
\frac{d\sigma_{\rm DD}}{d^2\boldsymbol{b}} &= \left\langle (1-e^{-F})^2\right\rangle_{\rm R,L} - \left\langle \langle 1-e^{-F}\rangle^2_{\rm L}\right\rangle_{\rm R} - \left\langle \langle 1-e^{-F}\rangle^2_{\rm R}\right\rangle_{\rm L}\\
&\quad + \langle 1-e^{-F}\rangle^2_{\rm R,L}\,, \qquad (5)
\end{aligned}$$

where $\sigma^{\rm R}_{\rm SD}$ ($\sigma^{\rm L}_{\rm SD}$) is the cross-section for the diffractive excitation of R (L), and the total diffractive cross-section

$$\frac{d\sigma_{diff}}{d^2\boldsymbol{b}} = \left\langle (1-e^{-F})^2\right\rangle_{\rm R,L}\,. \qquad (6)$$

4. Results

We end this presentation by showing two samples of our results on diffractive scattering in Fig. 1. Clearly, the description of experimental data, both at the Tevatron and at HERA, is quite reasonable. However, it should be noted that to get the elastic cross-section in figure 1a close to the measured value, we had to assume that the fluctuations in the initial proton wavefunction do not contribute, indicating that our model of the proton is too simple and may need to be improved.

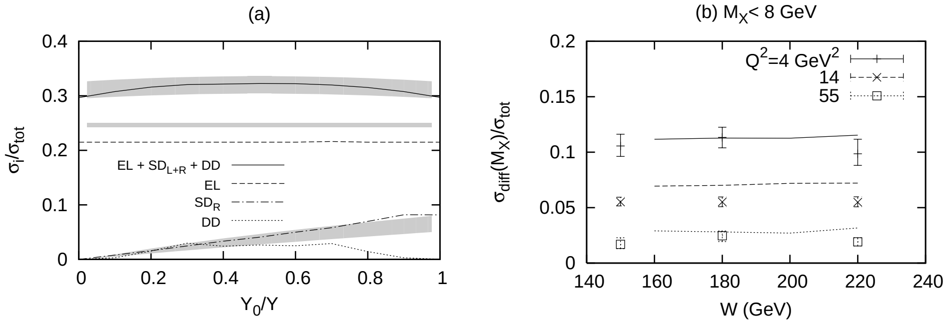

Fig. 1. (a) The ratio between the total diffractive and the total cross-section together with the contribution from elastic (EL), single-right ($\mathrm{SD_R}$) and double diffractive (DD) cross-sections at 1.8 TeV. The lower error band is an estimate from CDF data on single diffraction [12], the middle band is the CDF elastic cross-section [13] and the upper is a sum of the contributions. (b) The ratio of the total diffractive cross-section to the total cross-section as a function of W, for $M_X < 8$ for different values of Q^2 compared to ZEUS data [14].

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