AN UNIFIED DESCRIPTION OF HERA AND RHIC DATA*

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Perturbative Quantum Chromodynamics (pQCD) predicts that the small-x gluons in the hadron wavefunction should form a Color Glass Condensate (CGC), which has universal properties, which are the same for nucleon or nuclei. Making use of the results in V.P. Goncalves, M.S. Kugeratski, M.V.T. Machado, F.S. Navarra, *Phys. Lett.* **B643**, 273 (2006), we study the behavior of the anomalous dimension in the saturation models as a function of the photon virtuality and of the scaling variable $rQ_{\rm s}$, since the main difference among the known parameterizations are characterized by this quantity.

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1. Introduction

Signals of parton saturation have already been observed both in e–p deep inelastic scattering at HERA and in d–Au collisions at RHIC. As the saturation scales in HERA and RHIC are similar, we can check the universality

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property of the saturation physics in the gluon evolution in the target wave-function, as claimed in the Color Glass Condensate formalism [2]. In other words, the gluon evolution in the nucleon or nucleus should be the same. In [1] we have showed that a small modification in the anomalous dimension proposed in [3], is able to describe both sets of data: HERA and RHIC. This can be an important signature of saturation physics.

In the first part of this note we will give some explanation about the differences among saturation models. In the second part we will compare the saturation models in the forward dipole cross-section. Next, we will present how the anomalous dimension evolves with the scaling variable $rQ_{\rm s}$ and with the photon virtuality.

2. Saturation models

Several models for the forward dipole cross-section have been used in the literature in order to fit the HERA and RHIC data. (To see how the observables measured are related with these models, see for example [1].) In particular, the phenomenological models, for example, from Refs. [4, 5] have been proposed in order to describe the HERA data, while those from Refs. [3,6] have been able to describe the d–Au RHIC data. Usually, in these models the function $\mathcal{N}$ has been modeled in terms of a simple Glauber-like formula:

$$\mathcal{N}(x,\boldsymbol{r}) = 1-\exp\left[-\frac{1}{4}\left(\boldsymbol{r}^2 Q_{\rm s}^2(x)\right)^{\gamma(x,\boldsymbol{r}^2)}\right] , \tag{1}$$

where γ is the anomalous dimension of the target gluon distribution. The main difference among these models comes from the predicted behavior for the anomalous dimension (for a detailed comparison among them, see Ref. [7]), where the form of the anomalous dimension is constructed considering known analytical solutions to the BFKL equation. In this letter we only present the form of the anomalous dimension given by the parameterization in Ref. [3] (which we have called by DHJ model):

$$\gamma\left(Y,\boldsymbol{r}^2\right) = \gamma_{\rm s} + \Delta\gamma\left(Y,\boldsymbol{r}^2\right) , \tag{2}$$

where

$$\Delta\gamma\left(Y,\boldsymbol{r}^2\right) = (1-\gamma_{\rm s})\frac{\left|\log\frac{1}{\boldsymbol{r}^2 Q_{\rm T}^2}\right|}{\lambda Y + \left|\log\frac{1}{\boldsymbol{r}^2 Q_{\rm T}^2}\right| + d\sqrt{Y}} , \tag{3}$$

with $Q_{\rm T} = Q_{\rm s}(Y)$ a typical hard scale in the process, $\lambda = 0.3$ and $d = 1.2$. $\gamma_{\rm s} = 0.63$ is the anomalous dimension for BFKL evolution with saturation boundary condition [8].

3. Results and discussion

We start with a comparison between the models: GBW [4], IIM [5], KKT [6], KKTm [9] and DHJ [3] (for a better understanding a check in these references is suggested). In Fig. 1 we compare the behavior for the forward amplitude $\mathcal{N}$ as a function of the squared dipole size. The BK line correspond to a numerical solution of the BK equation with no-dependence in impact parameter [10]. The behavior of the curves IIM, KKT and GBW we have already discussed in [7].

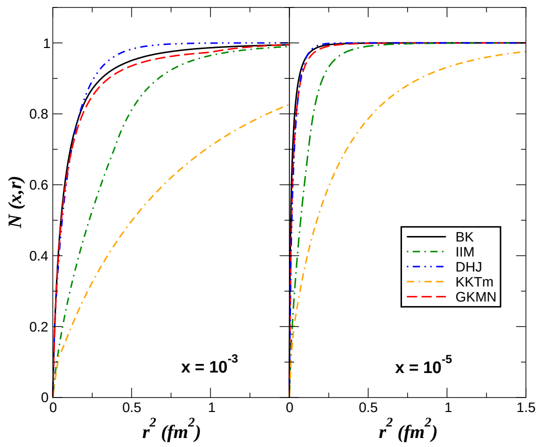

Fig. 1. Forward dipole cross-section, as a function of the size dipole.

As already said before, the main difference between these parameterizations is the anomalous dimension. The difference between them can be demonstrated studying the Q^2 behavior of the effective anomalous dimension, defined by $\gamma_{\rm eff} = d\ln\mathcal{N}(rQ_{\rm s},Y)/d\ln(r^2Q_{\rm s}^2/4)$. In Fig. 2, $\gamma_{\rm eff}$ is shown as a function of the scaling variable $rQ_{\rm s}$ (a) and the virtuality Q^2 (b), using the average dipole size as $r = 2/Q$. We see that, while the GBW model presents a fast convergence to the DGLAP anomalous dimension at large Q^2, the IIM parameterization has a mild growth with virtuality, converging to $\gamma \approx 0.85$ at large Q^2. The KKTm and IIM parameterizations are similar at large Q^2, but differ at small virtualities, with the KKTm one predicting a smaller value. On the other hand, the predictions of the DHJ and GKMN parameterizations are similar at small Q^2 and differ at large virtualities. Here is convenient to remember that the GKMN line represents the modification in the DHJ model. We have assumed that the $Q_{\rm T}$ is a constant factor, like $Q_{\rm T} = Q_0 = 1$ GeV, *i.e.* that the typical scale is energy independent. As seen in Ref. [1], with this modification our prediction agree with experimental data. As a last check, in this reference, we have checked that the RHIC data are still well reproduced after these modifications.

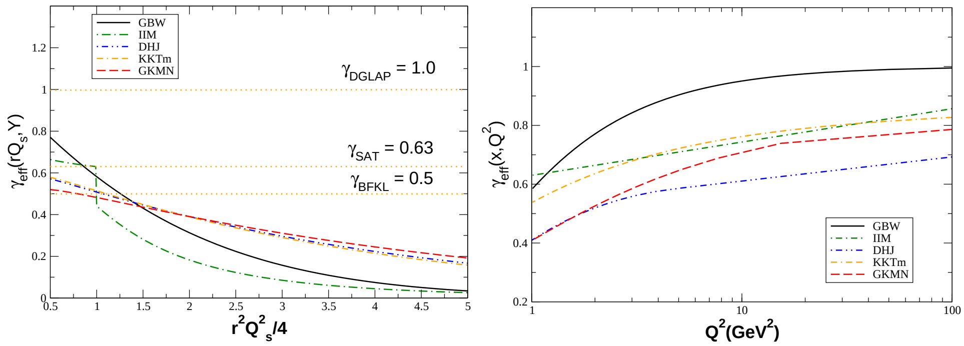

Fig. 2. The effective anomalous dimension as a function of the scaling variable rQ_{s} (left) and the Q^2 behavior, at $x = 3 \times 10^{-4}$ (right).

As a summary, in this letter we have analyzed current parameterizations for the dipole scattering amplitude which are able to describe separately the e–p HERA and d–Au RHIC data as well the parameterization in [1] that is able to describe both sets of data.

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