Hadron production at LHC in dipole momentum space

E. A. F. Basso[*], M. B. Gay Ducati[*] and E. G. de Oliveira[†]

[*]Instituto de Física, Universidade Federal do Rio Grande do Sul, Caixa Postal 15051, 91501-970 — Porto Alegre, RS, Brazil
[†]Instituto de Física, Universidade de São Paulo, Caixa Postal 66318, 05314-970 São Paulo, SP, Brazil

Abstract.
The dipole color approach is the framework that considers the quark-antiquark pair scattering off the target. The rapidity evolution of color dipoles is given by the nonlinear Balitsky-Kovchegov (BK) equation, for which analytical solutions are not yet known. A good way to explore the asymptotic BK solutions is through the traveling wave method of QCD, that uses a correspondence between the BK evolution equation in momentum space and reaction-diffusion physics. Using the traveling wave based AGBS model for the dipole amplitude in momentum space, and within the k_t-factorization formalism, we describe the LHC data on single inclusive hadron yield for $p - p$ collisions.

PACS: 12.38.Bx, 13.60.Hb, 13.85.Ni

AGBS PARAMETRIZATION

A parametrization of dipole-proton scattering amplitude in momentum space has been proposed by de Santana Amaral, Gay Ducati, Betemps, and Soyez (AGBS) [1]. The F_2 structure function takes the form:

$$F_2(x, Q^2) = \frac{Q^2 R_p^2 N_c}{4\pi^2} \int_0^\infty \frac{dk}{k} \int_0^1 dz \, |\tilde{\Psi}(k^2, z; Q^2)|^2 \tilde{T}(k, Y) \tag{1}$$

where now the photon wavefunction is expressed in momentum space and $\tilde{T}(k, Y)$ is the scattering amplitude in momentum space. The AGBS model analytically interpolates between the behavior of the BK scattering amplitude in the dilute regime and the saturation one, in which it behaves like

$$N(k, Y) \stackrel{k \ll Q_s}{=} c - \log\left(\frac{k}{Q_s(Y)}\right). \tag{2}$$

The expression for the tail of the scattering amplitude reads

$$N(k, Y) \stackrel{k \gg Q_s}{\approx} \left(\frac{k^2}{Q_s^2(Y)}\right)^{-\gamma_c} \log\left(\frac{k^2}{Q_s^2(Y)}\right) \exp\left[-\frac{\log^2\left(k^2/Q_s^2(Y)\right)}{2\bar{\alpha}\chi''(\gamma_c)Y}\right], \tag{3}$$

where $\lambda = \min \bar{\alpha}\frac{\chi(\gamma)}{\gamma} = \bar{\alpha}\frac{\chi(\gamma_c)}{\gamma_c} = \bar{\alpha}\chi'(\gamma_c)$

Interpolation in the AGBS model is done through the following expression for the scattering amplitude ($\rho \equiv \ln(k^2/k_0^2)$)

$$\tilde{T}^{\text{AGBS}}(\rho,Y) = L_F\left(1 - e^{-T_{\text{dil}}}\right),\tag{4}$$

where

$$T_{\text{dil}} = \exp\left[-\gamma_c\left(\rho - \rho_s\right) - \frac{\mathscr{L}^2 - \log^2(2)}{2\bar{\alpha}\chi''(\gamma_c)Y}\right],\tag{5}$$

$$\mathscr{L} = \ln\left[1 + e^{(\rho-\rho_s)}\right] \qquad \text{with} \quad Q_s^2(Y) = k_0^2\,e^{\lambda Y},\tag{6}$$

and

$$L_F = 1 + \ln\left[e^{\frac{1}{2}(\rho-\rho_s)} + e^{-\frac{1}{2}(\rho-\rho_s)}\right].\tag{7}$$

Such model was already used to investigate the possibility of gluon number fluctuations on the high energy evolution at HERA energies [2]. Recently it has been shown that the AGBS model describes equally well the DIS and inclusive hadron production in $p+A$ and $p+p$ collisions [3], defining the model parameters used in the present work. This was made in a new simultaneous fit to HERA data on the proton structure function [4] and RHIC data on the p_t distribution of the produced hadrons and pions from BRAHMS and STAR collaborations [5]. This fit will be used here within the k_t-factorization formalism to describe the hadron production at LHC.

HADRON PRODUCTION FROM k_t-FACTORIZATION

To describe the single inclusive hadron production we use the k_t-factorization formalism [6], which states that the cross section for gluon production is given by

$$\frac{d\sigma^{A+B\to g}}{dy\,d^2p_t\,d^2R} = K\frac{2}{C_F p_t^2}\int^{p_t}\frac{d^2k_t}{4}$$
$$\times \int d^2b\,\alpha_s(Q)\varphi\left(\frac{|p_t+k_t|}{2},x_1;b\right)\varphi\left(\frac{|p_t-k_t|}{2},x_2;R-b\right),\tag{8}$$

where $x_{1,2} = (p_t/\sqrt{s})e^{\pm y}$ are momentum fractions of the incoming gluons and $C_F = (N_c^2-)/2N_c$ is the Casimir for the fundamental representation. Within this formalism we have used $K = 2$.

In the large N_c limit, the unintegrated gluon distribution in either of the two colliding hadrons can be related to the dipole scattering amplitude through

$$\varphi(k,x;b) = \frac{N_c}{2\pi^2\alpha_s(k)}k^2\nabla_k^2 N_G(k,x;b).\tag{9}$$

The charged hadron yield, given in terms of (8), reads

$$\frac{dN_{ch}}{d\eta\,d^2p_t} = \frac{h[\eta]}{\sigma_{nsd}}\int d^2R\int\frac{dz}{z^2}D_h(z=p_t/k_t,\mu)\frac{d\sigma^{A+B\to g}}{dy\,d^2p_t\,d^2R},\tag{10}$$
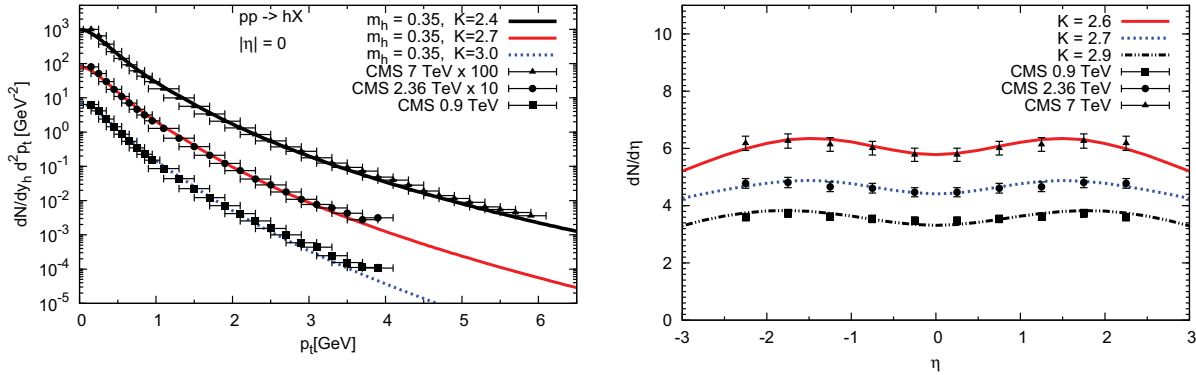
FIGURE 1. Predictions of the AGBS model to the LHC CMS charged hadron yield for $p + p$ collisions at $\sqrt{s} = 0.9,\, 2.36$ and $7\,\mathrm{TeV}$ [9].

where $D_h(z = p_t/k_t, \mu)$ stands for the fragmentation function of the produced gluon into hadrons, for which we used the LO KKP model [7] with the scale $\mu = p_t$ of the hadron, and σ_{nsd} is the non-single-diffractive cross section taken from the KMR model [8]. The model describe quite well the LHC data [9] on both the high and small p_t regions, as seen in Figure 1. Thus, it appears as a good tool to investigate saturation physics on the $p + Pb$ LHC running, where one can really consider a dilute proton interacting with the dense gluonic field of the nucleus. This will allow us to confirm whether such saturation effects are really worth to describe the small-x data.

ACKNOWLEDGMENTS

REFERENCES

1. J. T. de Santana Amaral, M. B. Gay Ducati, M. A. Betemps and G. Soyez, Phys. Rev. D **76**, 094018 (2007)
2. E. Basso, M. B. Gay Ducati, E. G. de Oliviera, and J. T. de Santana Amaral, Eur. Phys. J. C **58**, 9 (2008); E. Basso, M. B. Gay Ducati, E. G. de Oliviera, and J. T. de Santana Amaral, Braz. J. Phys. v. **38**, 483 (2008).
3. E. A. F. Basso, M. B. Gay Ducati and E. G. de Oliveira, Phys. Rev. D **84**, 034024 (2011).
4. F. D. Aaron *et al.* (H1 and ZEUS Collaborations), JHEP **0110** 109 (2010).
5. I. Arsene *et al.* (BRAHMS Collaboration), Phys. Rev. Lett. **93**, 242303 (2004); J. Adams *et al.* (STAR collaboration), Phys. Rev. Lett. **97**, 152302 (2006).
6. M. Braun, Phys. Lett. B **483**, 105 (2000); Y. V. Kovchegov and K. Tuchin, Phys. Rev. D **65**, 074026 (2002).
7. B. A. Kniehl, G. Krammer and B. Pötter, Nucl. Phys. **B582**, 514 (2000).
8. M. G. Ryskin, A. D. Martin and V. A. Khoze, Eur. Phys. J. C **71** (2011) 1617.
9. V. Khachatryan *et al.* (CMS Collaboration), JHEP **0210**, 041 (2010) [arXiv:hep-ex/1002.0621]; Phys. Rev. Lett. **105**, 022002 (2010).