PROCEEDINGS OF SCIENCE

Predictions from the Balitsky-Kovchegov equation including the dipole orientation

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A solution of the target-rapidity Balitsky-Kovchegov (BK) equation is presented considering, for the first time, the complete impact-parameter dependence, i.e. including the orientation of the dipole with respect to the impact-parameter vector. To address the non-local behaviour introduced in the target-rapidity formulation of the BK equation, three different prescriptions are considered to take into account the rapidities preceding the initial condition value. The solutions are used to compute the structure functions of the proton and the diffractive photo- and electro-production of J/ψ. These predictions agree well with HERA data, confirming that the target-rapidity Balitsky-Kovchegov equation with the full impact-parameter dependence is a viable tool to study the small Bjorken-x limit of perturbative QCD at current facilities like RHIC and LHC as well as in future colliders like the EIC, for which we present predictions for DIS and diffractive vector meson production.

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1. Introduction

In the scope of the colour dipole model, the Balitsky-Kovchegov (BK) equation introduces saturation in the evolution of parton densities of hadrons with respect to Bjorken-x. It describes the dipole scattering amplitude, a probability amplitude of an interaction between a quark-antiquark pair (the colour dipole) and a hadronic target in the plane transverse to the beam axis. The geometrical layout of this interaction is shown in Fig. 1. There are four degrees of freedom, which can be expressed in terms of the dipole size r, impact parameter b, the orientation of the dipole with respect to the impact parameter θ and the overall orientation of the reference frame φ.

The initial approximation of the sole dipole-size dependence has been lifted by first taking into account the impact-parameter dependence [1] (2D solution) and subsequently even the dipole orientation (3D solution) as presented in Ref. [6] and summarised here.

The extension to the 3D solution has been shown to reproduce the same quality data description as achieved with the previous 1D and 2D results while opening the possibility of unveiling more complex effects of the hadron structure.

2. The target-rapidity BK equation solution

The target-rapidity formulation [2] of the leading order BK equation [3–5]

$$\frac{\partial N(\eta,\vec{r},\vec{b})}{\partial\eta} = \int \mathrm{d}\vec{r}_1 K(r,r_1,r_2)\Big[N(\eta_1,\vec{r}_1,\vec{b}_1) + N(\eta_2,\vec{r}_2,\vec{b}_2) - N(\eta,\vec{r},\vec{b}) \\ - N(\eta_1,\vec{r}_1,\vec{b}_1)N(\eta_2,\vec{r}_2,\vec{b}_2)\Big] \tag{1}$$

connects the rapidity of the target to the Bjorken-x as $\eta = \log\frac{x_0}{x}$. The value of x_0 defines the evolution starting point.

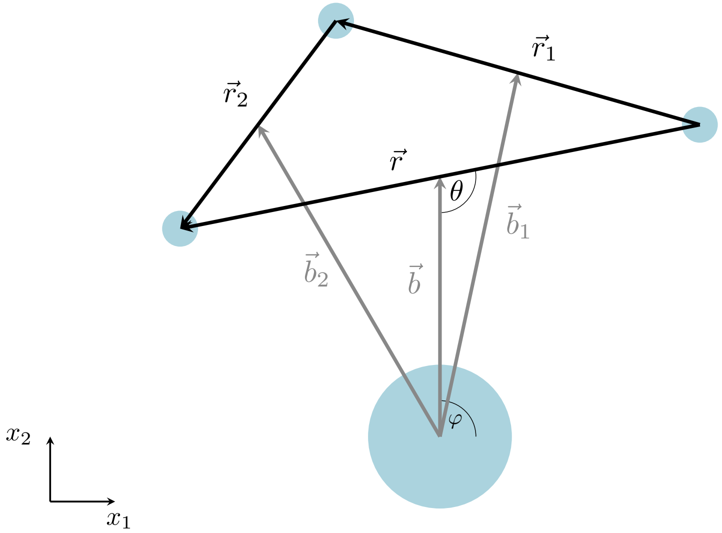

Figure 1: Geometry of the dipole-hadron interaction. The parent dipole (without indices) and two daughter dipoles emerging during the BK-driven evolution.

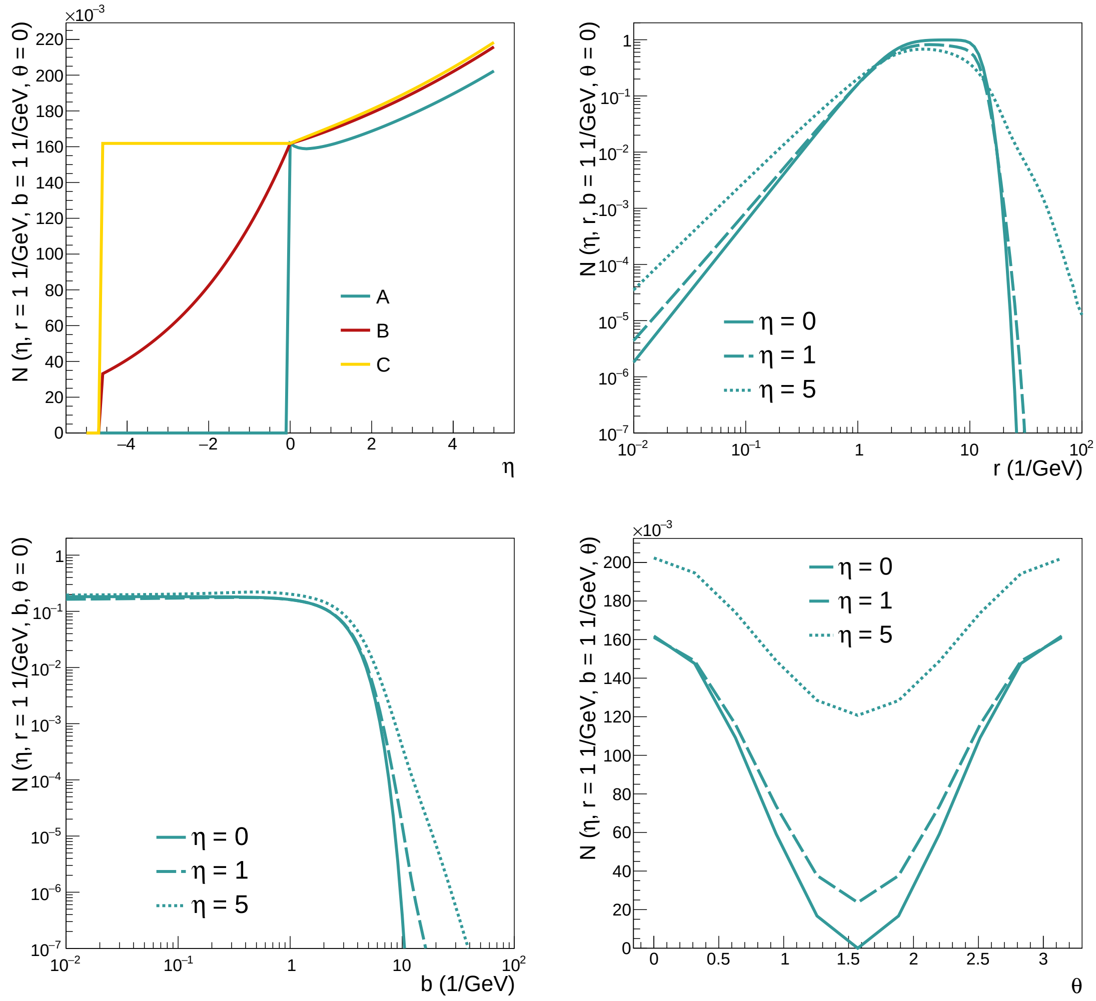

Figure 2: Dependence of the dipole scattering amplitude on rapidity and the three spatial variables at various fixed points.

The presence of the terms η_1, η_2,

$$\eta_j = \eta - \max\{0, \ln \frac{r^2}{r_j^2}\}, \tag{2}$$

on the r.h.s of (1) introduces non-locality in the equation and the behaviour of the dipole amplitude therefore needs to be defined also for rapidities preceding the initial condition. To address this, three schemes have been tested as shown in the top left panel of Fig. 2. Based on comparisons to data and variations in the large-b behaviour, scheme A was chosen here, as discussed in more detail in Ref. [6].

The solution of the 3D BK equation was calculated using

$$N(\eta = 0, r, b, \theta) = 1 - e^{-\frac{1}{4}(Q_s^2 r^2)^{\gamma} e^{-\frac{b^2}{2B} - \frac{r^2}{8B}(1+c\cos(2\theta))}} \tag{3}$$

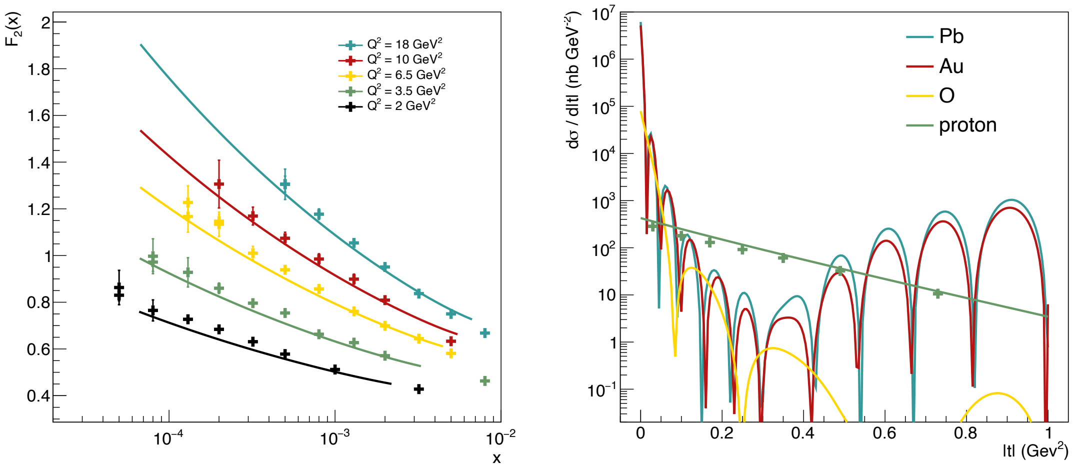

Figure 3: Predictions of observables from the 3D BK equation solutions. The proton structure function F_2 compared to data from HERA [7] (left) and the differential cross section of the coherent J/ψ production off nuclear and proton targets (right). The latter are compared to data from HERA [8].

as the initial condition, for more details see [6]. The resulting dipole scattering amplitudes $N(\eta, r, b, \theta)$ are shown in Fig. 2 at various combinations of fixing all but one variable.

To calculate the amplitude for nuclear targets, the nuclear profile based on a Woods-Saxon distribution was used to model the transverse target shape instead of the Gaussian profile of the proton case.

3. Data comparison

To validate the newly obtained 3D BK solution, the results were successfully used to describe the same data as within the 2D solution in [1]. The results from 3D BK are shown in Fig. 3 with the proton F_2 structure function in the left panel, and the coherent J/ψ production in the right one. The right panel also shows potential predictions for the coherent J/ψ production cross section for scattering off nuclear targets with a clear pattern of the diffractive dips.

4. Summary

The Balitsky-Kovchegov equation was solved taking into account three of the four transverse degrees of freedom for the first time. The resulting dipole scattering amplitude is shown in Fig. 2. The solution was shown to reproduce the data description previously achieved with the 2D BK equation. In particular, the F_2 proton structure function and the coherent J/ψ production cross section for the proton target. The latter was also calculated using initial conditions for various nuclear targets, showing the structure of diffractive dips in the cross section.

Acknowledgements

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