Challenges of the collinearly improved JIMWLK evolution equation

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1. Introduction

One of the four main motivations behind the proposed EIC collider is the search of evidences for the non-linear/gluon high-density phase of matter. There have been multiple attempts to search for signatures of such phase in the data available from HERA, RHIC and LHC [1], unfortunately no clear signal was found. New facilities, the EIC offering DIS experiments on heavy nuclei and new forward physics detectors at the ATLAS and ALICE experiments at LHC, promise to extend the kinematical range of existing data where the "golden channels" are expected to provide decisive evidence. The main objective of the present work is to provide theoretical predictions with an unmatched precision for these "golden" observables

2. JIMWLK evolution equation

The dipole gluon distribution dependence on the transverse momentum at a given rapidity scale s can be evaluated from the Wilson line correlation function $C(\mathbf{x}-\mathbf{y},s)$,

$$C(\mathbf{x}-\mathbf{y},s) = \langle \mathrm{tr}\, U^\dagger(\mathbf{x},s) U(\mathbf{y},s)\rangle, \tag{1}$$

where the average $\langle\cdot\rangle$ is taken over different statistical realizations of Wilson lines. The evolution in rapidity is performed using the Langevin formulation of the JIMWLK equation [2, 3]. The advance in rapidity s by a step δs is given by

$$U(\mathbf{x}, s+\delta s) = \exp\left(-\sqrt{\delta s}\sum_{\mathbf{y}} U(\mathbf{y},s)\left(\mathbf{K}(\mathbf{x}-\mathbf{y})\cdot\boldsymbol{\xi}(\mathbf{y})\right)U^\dagger(\mathbf{y},s)\right)\times$$
$$\times\, U(\mathbf{x},s)\,\exp\left(\sqrt{\delta s}\sum_{\mathbf{y}}\mathbf{K}(\mathbf{x}-\mathbf{y})\cdot\boldsymbol{\xi}(\mathbf{y})\right), \tag{2}$$

where $\mathbf{K}(\mathbf{x})$ is the leading-order JIMWLK kernel function and $\boldsymbol{\xi}(\mathbf{x})$ are random Gaussian vectors intrinsic to the Langevin formulation.

3. Kinematical constraint

The kinematical constraint corresponds to the resummation of subleading corrections enhanced by the kinematics. The full Langevin equation takes the form [4],

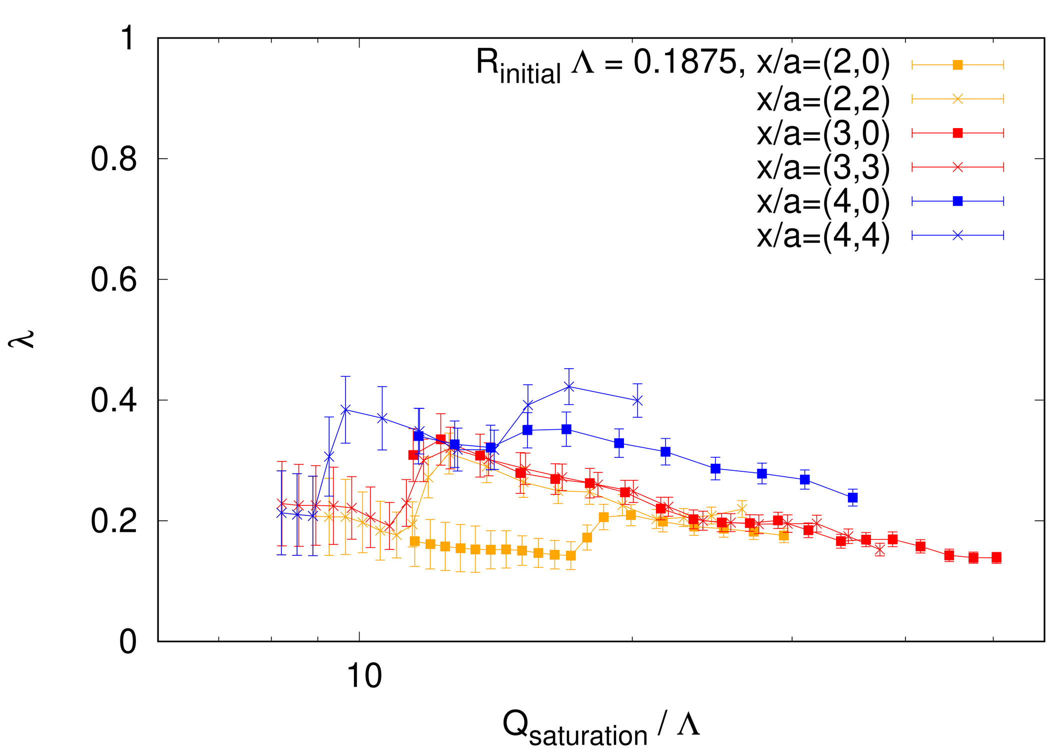
$$U_{(n+1)\epsilon}(\mathbf{x},r) = \exp\left(i\epsilon\alpha^L_{n+1}(\mathbf{x},r)\right)U_{n\epsilon}(\mathbf{x},r)\exp\left(-i\epsilon\alpha^R_{n+1}(\mathbf{x},r)\right) \tag{3}$$

where

$$\alpha^L_{n+1}(\mathbf{x},r) = \frac{1}{\pi}\int_{\mathbf{z}}\sqrt{\alpha_s}\,\theta(n\epsilon - \ln\frac{r^2_{xz}}{r^2})K^i_{xz}\xi^i_{n+1}(\mathbf{z}) \tag{4}$$

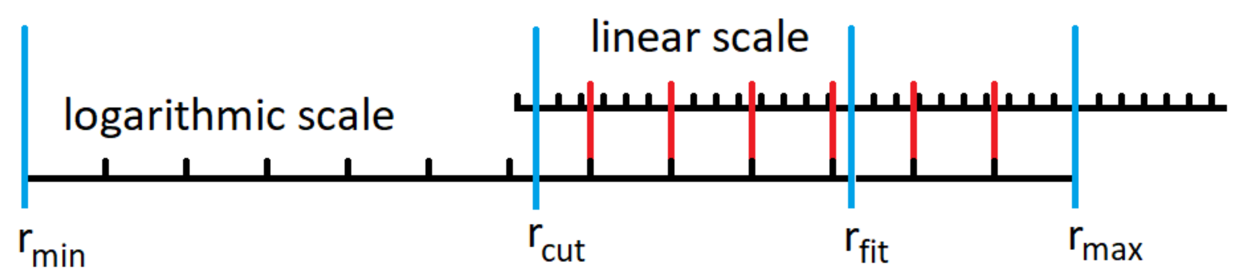
and

$$\alpha^R_{n+1}(\mathbf{x},r) = \frac{1}{\pi}\int_{\mathbf{z}}\sqrt{\alpha_s}\,\theta(n\epsilon - \ln\frac{r^2_{xz}}{r^2})U^\dagger_{n\epsilon-\Delta^r_{xz}}(\mathbf{z},R^r_{xz})K^i_{xz}\xi^i_{n+1}(\mathbf{z})\times$$
$$\times\, U^r_{n\epsilon-\Delta_{xz}}(\mathbf{z},R^r_{xz}) \tag{5}$$



Preliminary results for the saturation scale evolution speed at $R_{\mathrm{initial}}\Lambda = 0.1875$ for different discretizations. Much lower intercept than without the collinear improvement.

4. Sewing together the BK and JIMWLK equations



The basic version of the approach can be summarized by the following steps

1. Once we have the entire gluon dipole amplitude (given by the initial condition at the very beginning) we perform the single step evolution with the BK equation of the short distance part,
2. Knowing $C(r)$ we generate Wilson lines on the linear lattice independently for each distance n_r with the help of the logarithmic Fourier transform,
3. We use JIMWLK evolution equation to compute the single step evolution of the Wilson lines on the linear lattice,
   (a) If a jump to the history is needed, Wilson lines from previous N_{past} are retrieved. This should coincide with a similar jump in the BK equation,
   (b) Repeat for each distance n_r,
4. With the new Wilson lines on the linear lattice we calculate and average the gluon dipole amplitude and update remaining elements. We use these elements to fit the tail,
5. With the completely updated gluon dipole amplitude we return to step 1.

5. Further steps

- calibrate our BK/B-JIMWLK framework with the kinematical constraint by performing a simultaneous fit to three observables, separately for the proton and for the nuclear parton densities, using the available data from HERA, RHIC and LHC. The observables include: All three observables are sensitive to various TMD parton densities and go beyond the simplest gluon dipole amplitude.
- prepare predictions for all 10 TMD parton distributions for the kinematical regimes offered by the new facilities: EIC, HL-LHC (FoCaL forward detector at the ALICE experiment) to focus the searches for gluon saturation signatures.

6. References

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