Predictions for future electron-hadron colliders using the Balitsky-Kovchegov equation

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Balitsky-Kovchegov equation with b-dependence

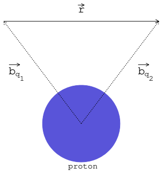
- Evolution of the scattering amplitude N of a $q\bar{q}$ dipole off a hadronic target.
  - Dynamical balance between the gluon emission and recombination.

$$\frac{\partial N(r_{xy}, b_{xy}, Y)}{\partial Y} = \int \mathrm{d}\vec{r}_{xz} K(r_{xy}, r_{xz}, r_{zy}) \Big[N(r_{xz}, b_{xz}, Y) + N(r_{zy}, b_{zy}, Y) - N(r_{xy}, b_{xy}, Y) - N(r_{xz}, b_{xz}, Y) N(r_{zy}, b_{zy}, Y) \Big]$$

- Evolution of the dipole amplitude gives information about target structure.
- The kernel describes the probability of a gluon emission $\rightarrow$ different approximations.
- **Collinearly-improved kernel** (Iancu et al. - PLB 750 (2015) 643; Vera - Nucl.Phys. B722 (2005) 65)
  - Large daughter dipoles suppressed as a result of time-ordering of the emissions.
- **A new initial condition** takes into account the location of the end-points of the dipole

$$N(\vec{r}_{xy}, \vec{b}_{xy}, Y=0) = 1 - \exp\left[-\frac{1}{2}\frac{Q_S^2}{4} r_{xy}^2 T(\vec{b}_{q_1}, \vec{b}_{q_2}) \right]$$

$$T(\vec{b}_{q_1}, \vec{b}_{q_2}) = \exp\left(-\frac{b_{q_1}^2}{2B} \right) + \exp\left(-\frac{b_{q_2}^2}{2B} \right)$$



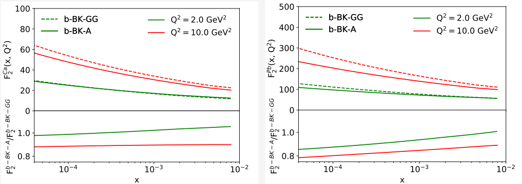
- The r behavior mimics the models for the b-independent dipole amplitude.
- The b behavior contains an exponential fall-off for dipole-ends far away from the target.

- **Modifications to the nuclear case**
  - b-BK-GG: solution to the b-BK for proton target coupled to Glauber–Gribov prescription.
  - b-BK-A: evolution from the initial condition representing a specific nucleus.
  - Nuclear b-dependent profile obtained using the Woods–Saxon distribution.
- Observables in QCD processes can be calculated using $N(x, r, b)$, e.g.

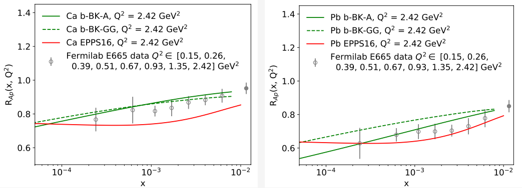
$$\sigma_{T,L}^{\gamma^* p}(x, Q^2) = \sum_f \int \mathrm{d}^2 r \int \mathrm{d}z |\Psi^* \Psi|_{T,L}^f \sigma_{q\bar{q}}(x, \vec{r}); \;\; \sigma_{q\bar{q}}(x, \vec{r}) = 2 \int \mathrm{d}^2 b \, N\left(x, \vec{r}, \vec{b}\right)$$

Inclusive deep-inelastic scattering

- Nuclear F_2
  - A sizeable difference between b-BK-GG and b-BK-A.
  - Clear dependence on x, Q^2, and A.



- Nuclear suppression factors
  - Ca: b-BK-GG and b-BK-A describe data.
  - For Pb, a x-dependent difference is clearly observed between the b-BK-GG and b-BK-A approaches.



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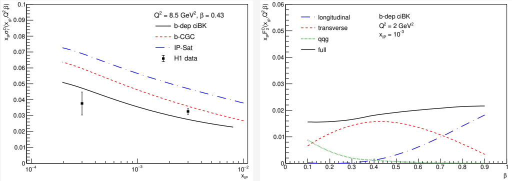
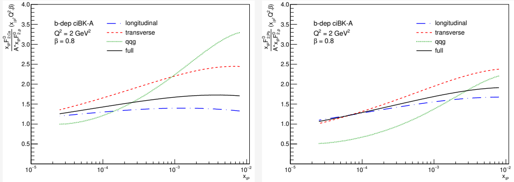
Diffractive-deep inelastic scattering

- b-BK predictions for protons
  - Reasonable agreement with HERA data for σ_r^D.
  - Smaller proton $F_2^{D(3)}$ compared to other models.



- Results for b-BK-A approach at low Q^2 and large β for Ca and Pb
  - F_2^D ratio slightly larger for heavier nuclei.
  - $q\bar{q}g$ component (*green*) suppressed at larger A.



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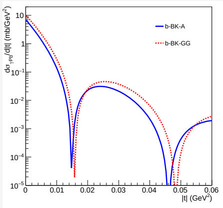
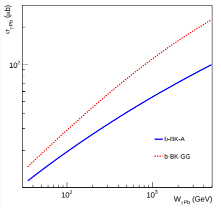
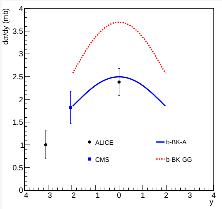
Nuclear J/ψ photoproduction

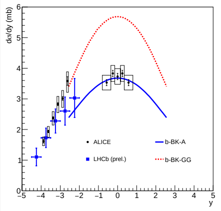
- $|t|$-distribution and energy dependence clearly different for b-BK-GG and b-BK-A.





- Comparison to the LHC data from UPC
  - LHC Run 1 data (left) prefer the b-BK-A.
  - LHC Run 2 data don't provide a clear message.

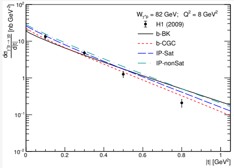


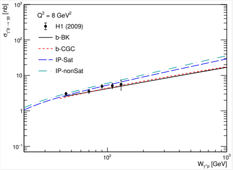


Phys. Lett. B 817 (2021) 136306

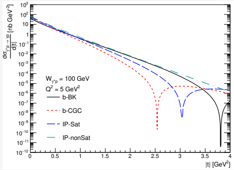
Deeply virtual Compton scattering

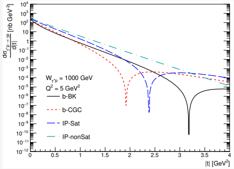
- Comparison to HERA data in a good agreement
  - b-BK model shows a smaller slope in $|t|$ and a milder W-dependence.





- Predictions for EIC and LHeC energies
  - Positions of the diffractive minima for proton clearly displaced among different models.
  - Similar behavior is observed also for nuclear $|t|$-distributions.





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Conclusions

- The collinearly improved kernel and our proposed initial condition suppress the Coulomb tails (prevented direct phenomenological applications without any additional corrections).
- Solutions to the b-BK equation obtained for proton and nuclear targets.
- Successful application of dipole amplitudes obtained from b-BK into several QCD processes.
- Presented results are of an interest for measurements at current and future facilities such as LHC, EIC or LHeC.
- **Proton and nuclear structure functions**
  - Good agreement with proton F_2 data from HERA over wide range of Q^2 and x.
  - Predictions for nuclear F_2 for future EIC measurements.
- **Diffractive DIS with protons and nuclei**
  - Reasonable agreement with HERA data on diffractive reduced cross section.
  - Predictions for future experiments for both proton and nuclear observables together with other CGC-inspired models.
- **Coherent nuclear J/ψ photoproduction in UPC**
  - Predictions for measurement in UPC.
  - A good agreement of b-BK-A approach with LHC Run 1 data (ALICE, CMS).
  - Large uncertainties in experimental data (LHC Run 2) still prevent us from a strong conclusion on b-BK-GG vs b-BK-A approach.
- **Deeply virtual Compton scattering**
  - A reasonable agreement with experimental data from HERA (although b-BK model not favored by the data for this observable).
  - Predictions for future measurements at EIC and LHeC energies.
  - Slope of the $|t|$-distribution and positions of the diffractive minima may enable to distinguish between various models and their approach towards inclusion of saturation effects.