RECENT RESULTS FROM b-BK

Marek Matas
UPC group meeting at Decin 14.9.-16.9.2020

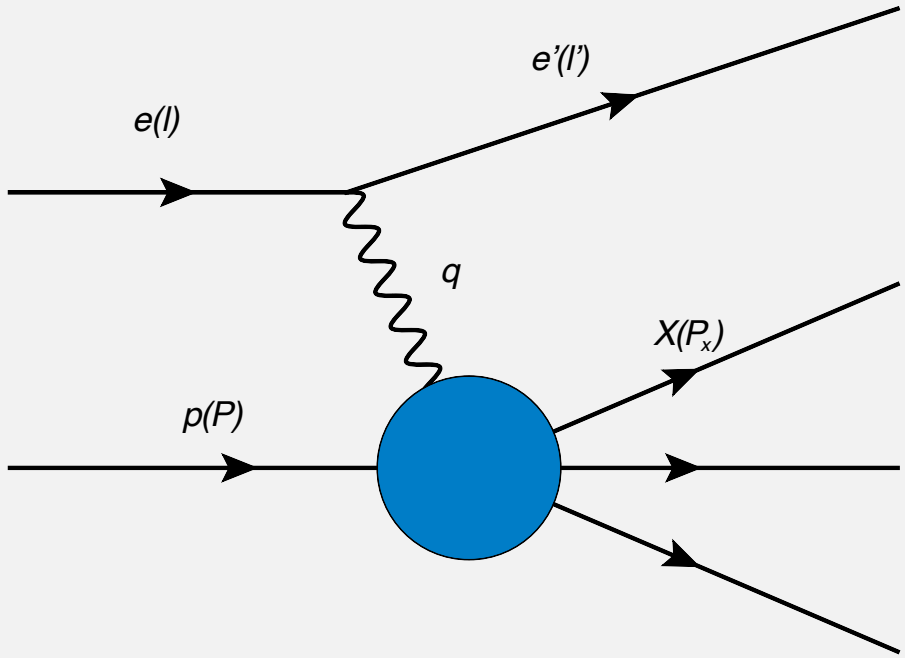
WHAT IS BK EQUATION?

DEEP INELASTIC SCATTERING

DIS is an invaluable probe of protons structure and properties.

The electron-proton collisions are considered to happen as:

1. The incoming electron emits a virtual photon.
2. The virtual photon interacts with the target proton
3. The proton breaks apart.



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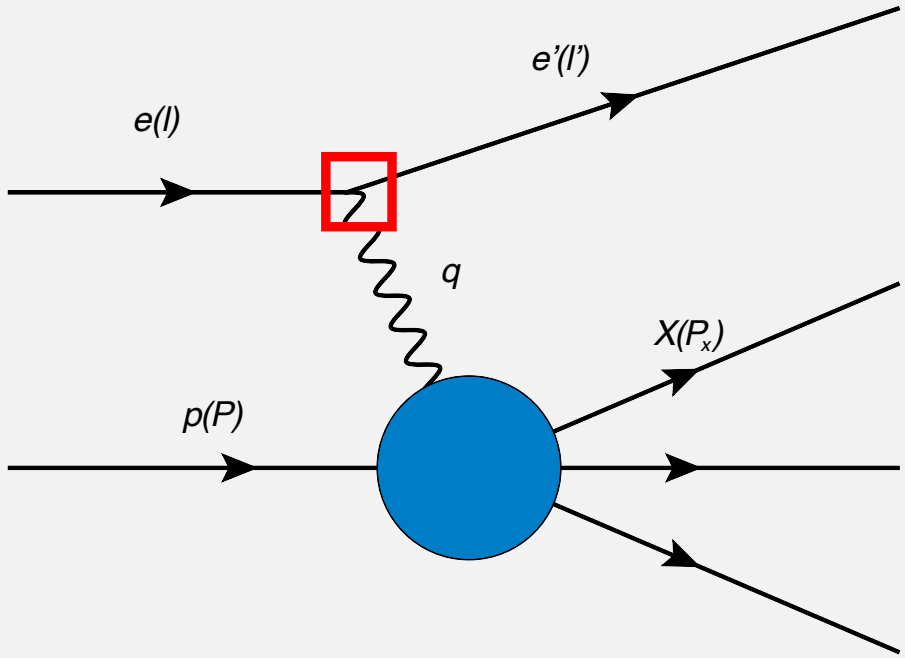

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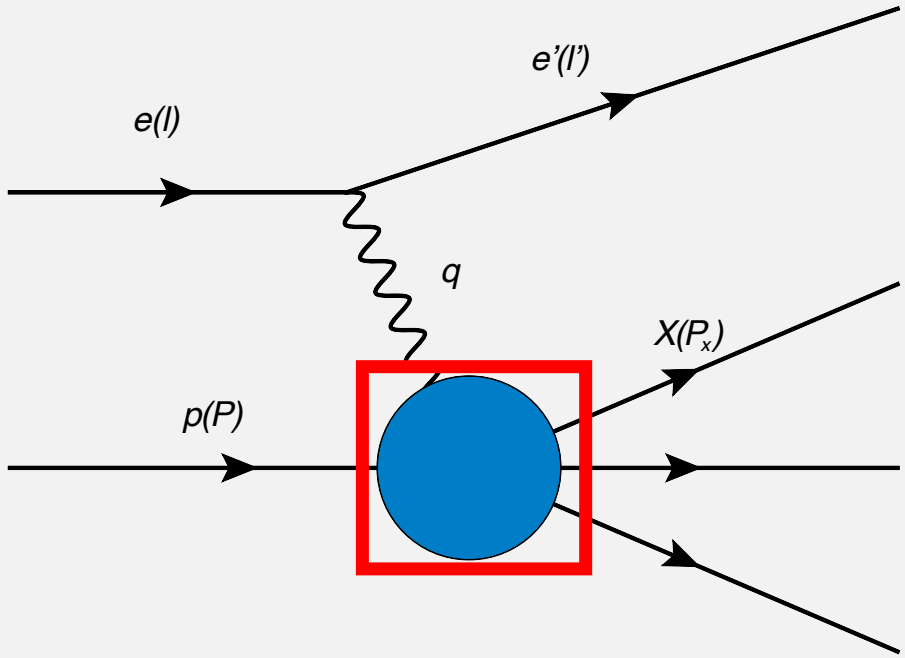

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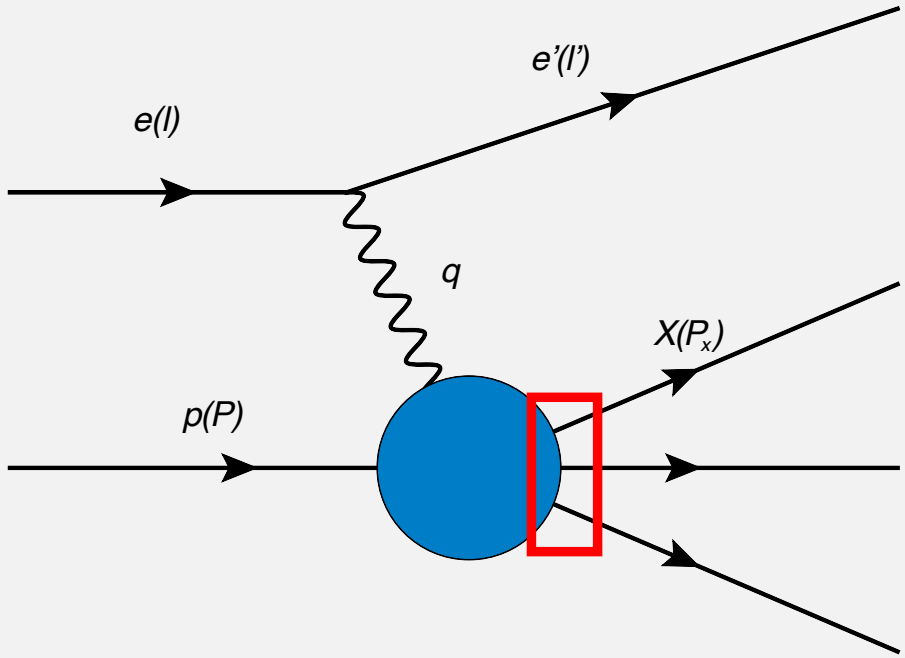
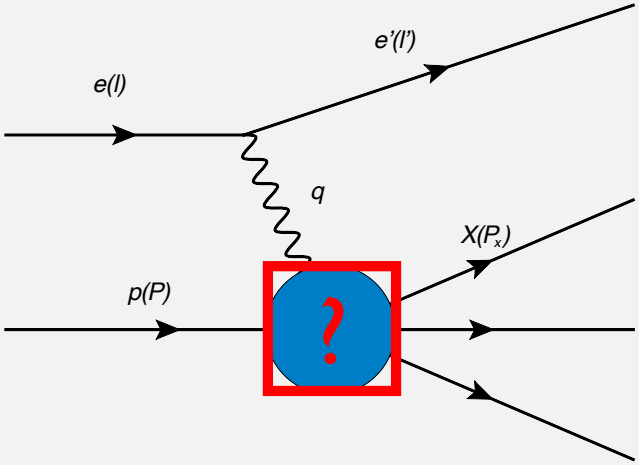
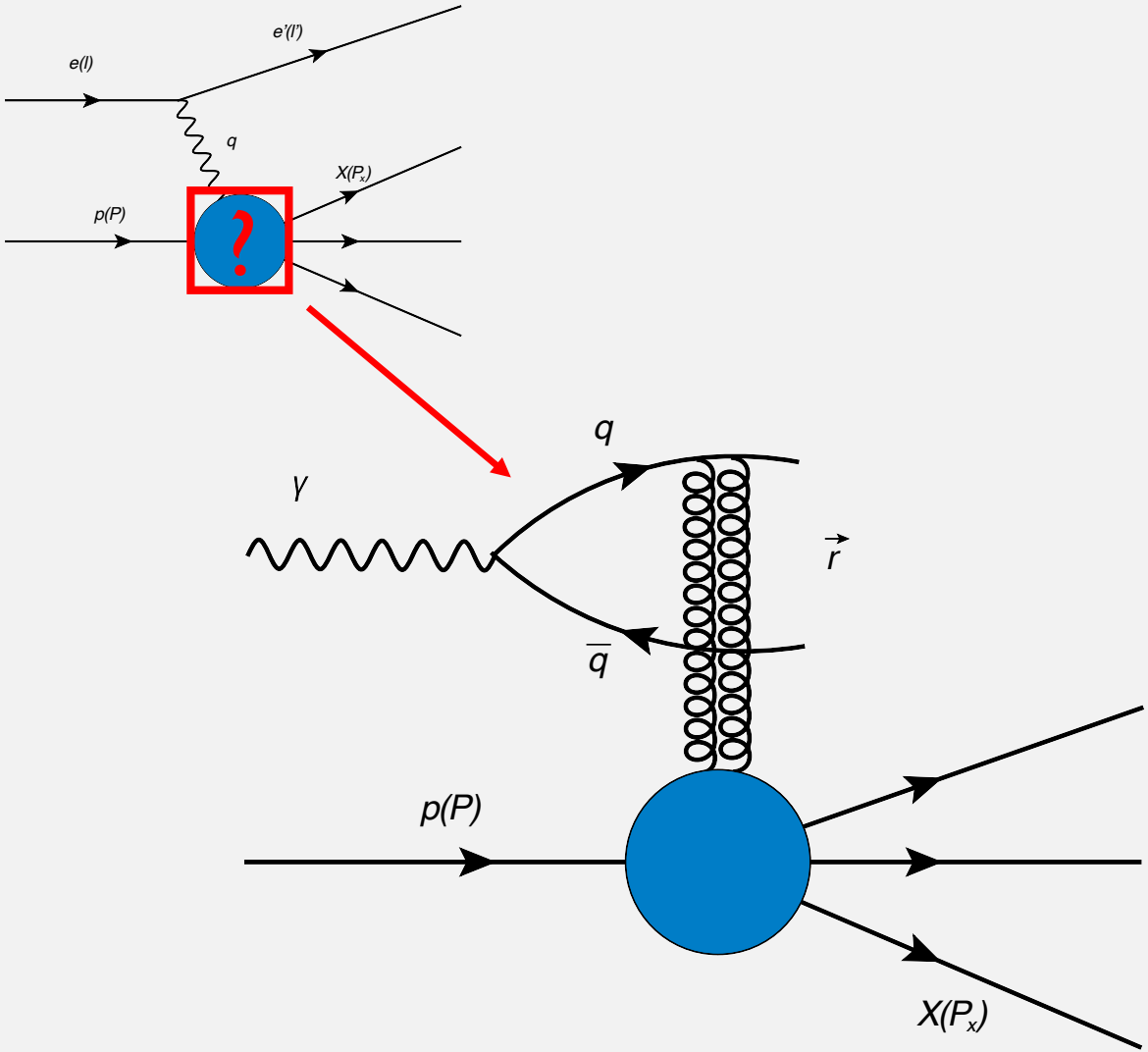


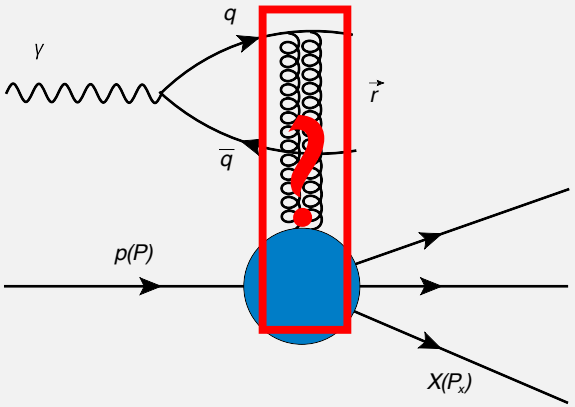
HOW DOES A PHOTON INTERACT STRONGLY WITH A PROTON?



DIPOLE MODEL

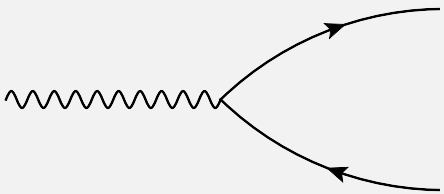


HOW DO WE OBTAIN THE DIPOLE-PROTON CROSS SECTION?



BK EQUATION

Boost to a frame, where dipole is at rest



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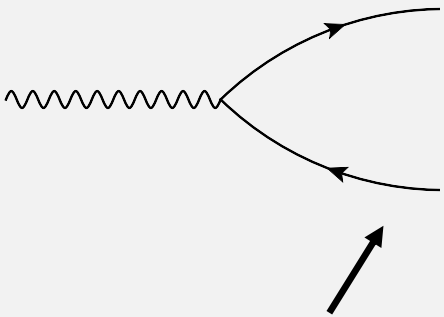

$$N \sim exp\left[-\frac{r_T^2 Q_s^2}{4} log \frac{1}{r_T \Lambda}\right]$$

BK EQUATION

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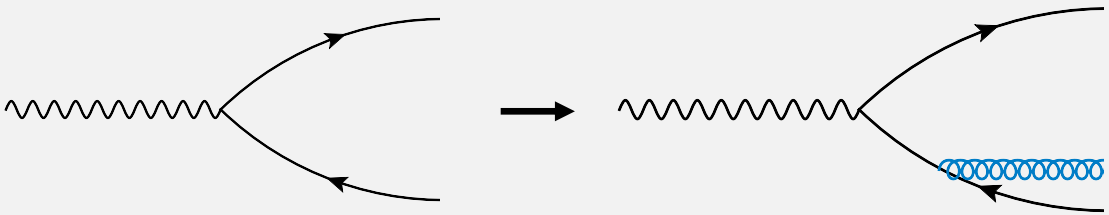

Add a bit of energy

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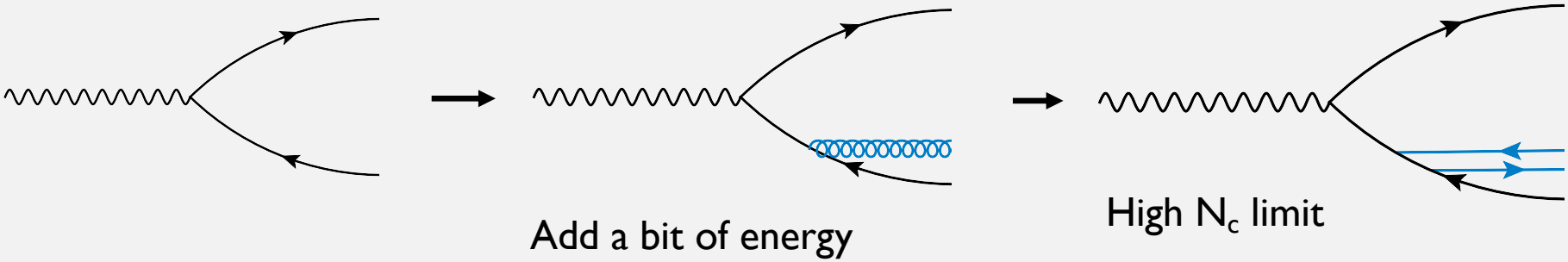

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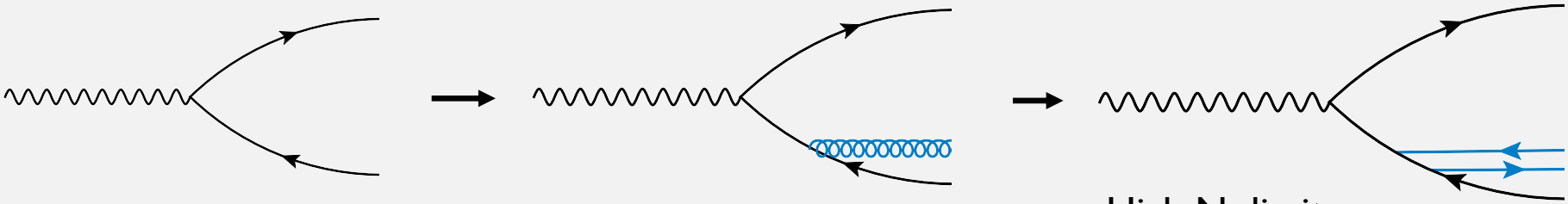
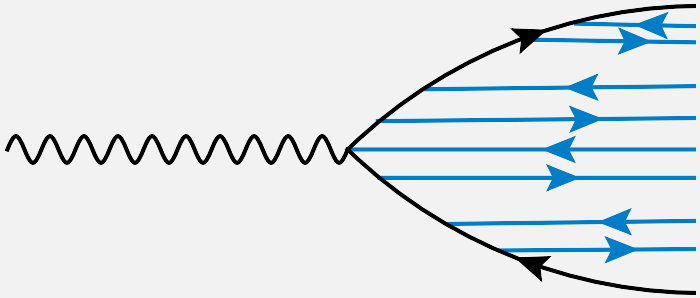


Add a bit of energy

High N_c limit

After some time, the initial dipole becomes dressed.



BK EQUATION

Mathematically, this relates to:

$$\frac{\partial N(\vec{r},\vec{b},Y)}{\partial Y} = \int d\vec{r_1} K(r,r_1,r_2)(N(\vec{r_1},\vec{b_1},Y) + N(\vec{r_2},\vec{b_2},Y) - N(\vec{r},\vec{b},Y) - N(\vec{r_1},\vec{b_1},Y)N(\vec{r_2},\vec{b_2},Y))$$

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This is the change of the scattering amplitude, when we add a bit of energy into the system.

BK EQUATION

Mathematically, this relates to:

$$\frac{\partial N(\vec{r},\vec{b},Y)}{\partial Y} = \int d\vec{r_1} K(r,r_1,r_2)(N(\vec{r_1},\vec{b_1},Y) + N(\vec{r_2},\vec{b_2},Y) - N(\vec{r},\vec{b},Y) - N(\vec{r_1},\vec{b_1},Y)N(\vec{r_2},\vec{b_2},Y))$$

The kernel is computed from QCD to reflect the probability of gluon emission.

BK EQUATION

Mathematically, this relates to:

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Dipole-proton scattering amplitudes for original and emitted dipoles.

BK EQUATION

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$$\frac{\partial N(\vec{r},\vec{b},Y)}{\ldots} \quad \int \ldots \; \vec{b}_2, Y))$$

Because the dipole and the proton distributions are interlinked by a boost of the system, the BK equation gives us direct information about the gluon distribution of the proton.

Dipole-proton scattering amplitudes for original and emitted dipoles.

REMINDER OF WHAT HAVE WE DONE LAST YEAR

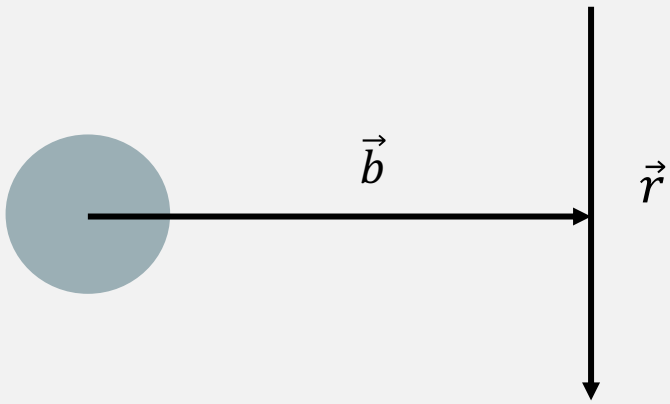
b-BK EQUATION

The Balitsky-Kovchegov equation describes the evolution of a color dipole scattering amplitude $N(\vec{r}, \vec{b}, Y)$ in rapidity

$$\frac{\partial N(\vec{r}, \boxed{\vec{b},} Y)}{\partial Y} = \int d\vec{r_1} K(r, r_1, r_2)(N(\vec{r_1}, \boxed{\vec{b_1},} Y) + N(\vec{r_2}, \boxed{\vec{b_2},} Y) - N(\vec{r}, \boxed{\vec{b},} Y) - N(\vec{r_1}, \boxed{\vec{b_1},} Y) N(\vec{r_2}, \boxed{\vec{b_2},} Y))$$

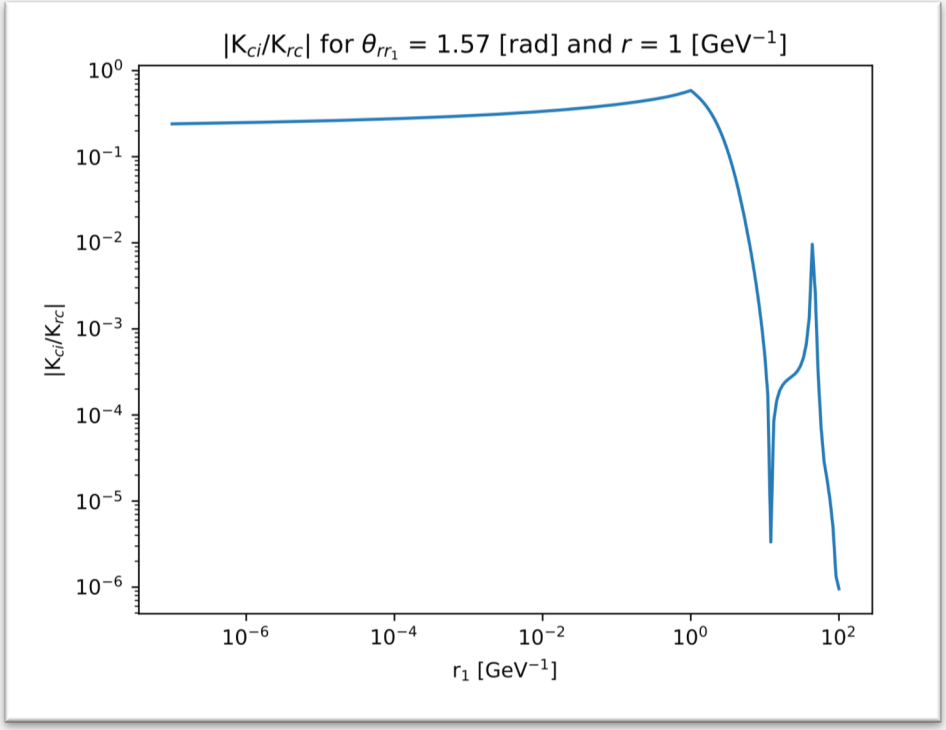
given by $Y = \ln \frac{x_0}{x}$.

Impact parameter dependence enters the equation.



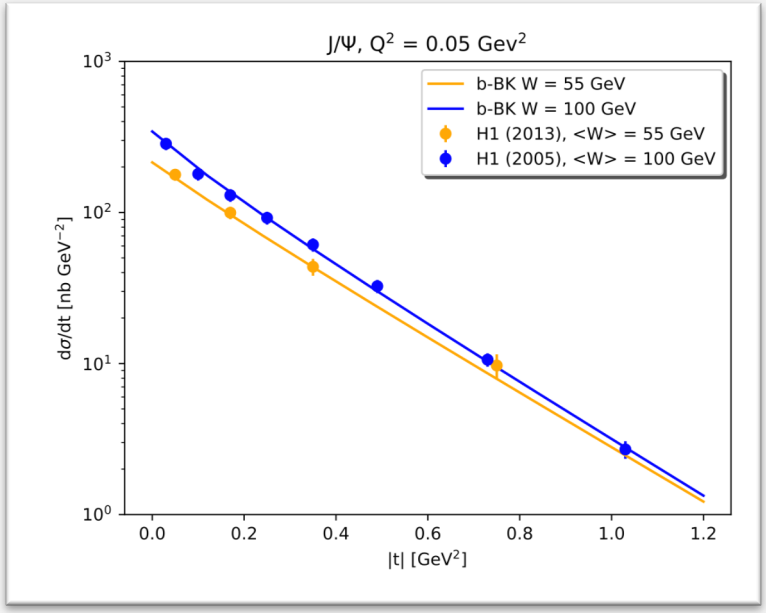
KERNEL CUTOFF

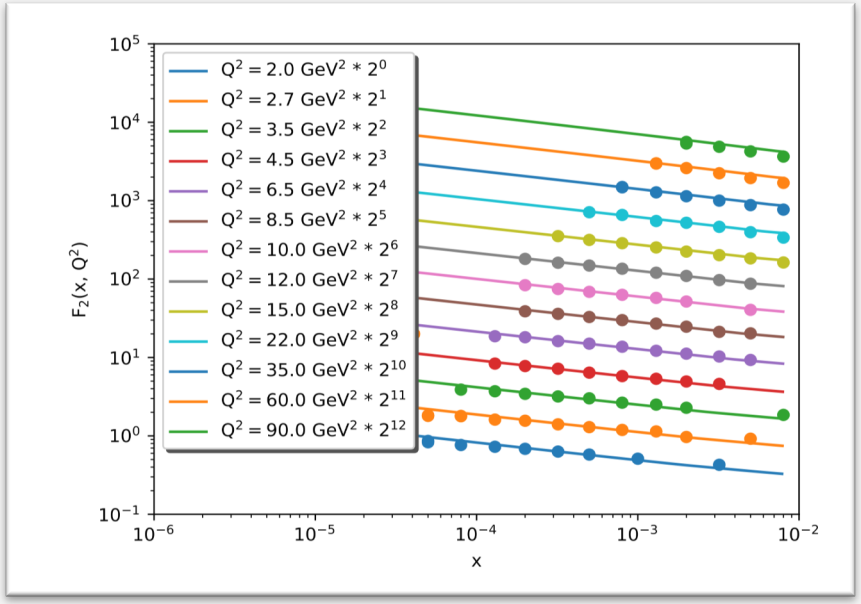
Here we compare the value of the collinearly improved kernel with the running coupling kernel versus r_1.

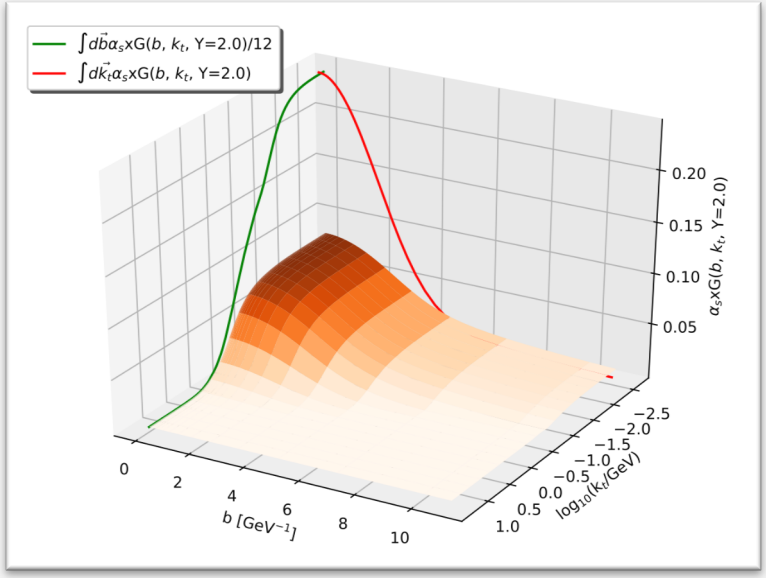


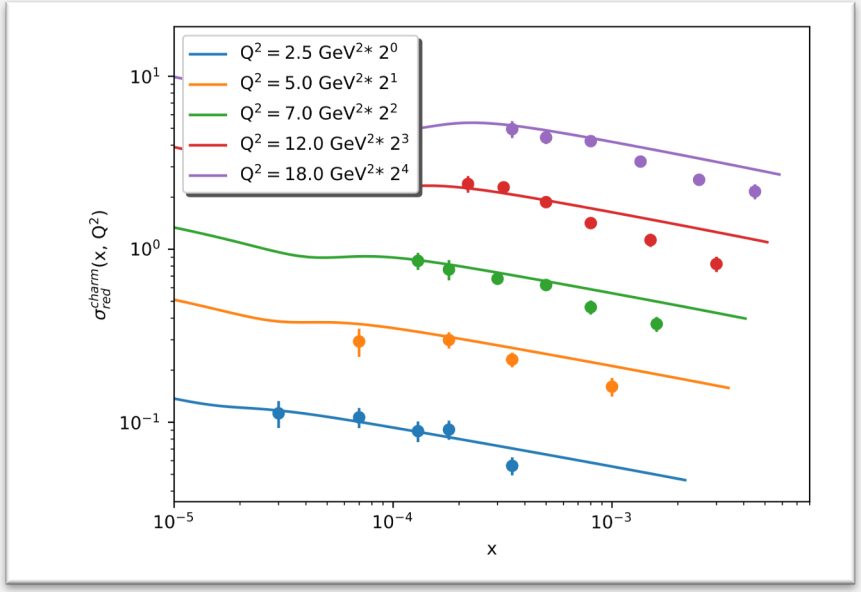
D. Bendova, J. Cepila, J. G. Contreras, M. Matas; Phys. Rev. D 100, 054015

RESULTS









J. Cepila, J. G. Contreras, M. Matas; Phys. Rev. D 99, 051502

WHAT NEW HAVE WE DONE IN 2020

SOLUTIONS FOR NUCLEI AND EIC

To compute the scattering amplitudes for nuclei, we have:

1. Substituted a proton profile with Woods-Saxon distributions.

2. Fitted nuclear saturation scales to EPPS16 at the initial condition.

We have done this for elements Al, Ca, Cu, Fe, W and Pb to study the A dependence of these processes.

Computed structure functions and then nuclear modification factors.

Compared to the Glauber-Gribov model in which only a sum of nucleons is assumed as a nucleus.

These have been confronted with Fermilab E665 data.

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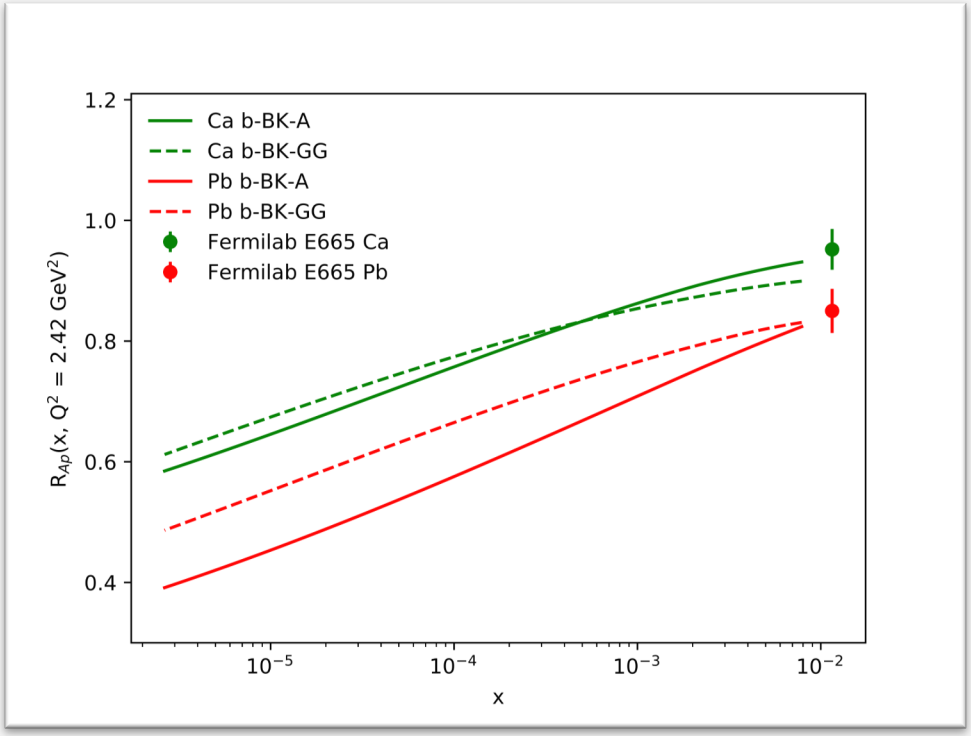

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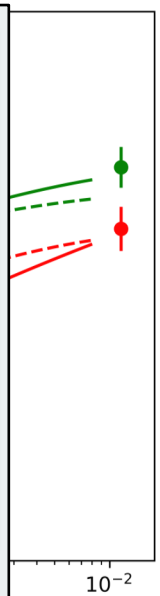
Predictions for nuclear structure functions from the impact-parameter dependent Balitsky-Kovchegov equation

J. Cepila,[1] J. G. Contreras,[1] and M. Matas[1]

[1] *Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Czech Republic*

(Dated: August 21, 2020)

A paper on this topic was submitted to arXiv:2002.11056.



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SATURATION

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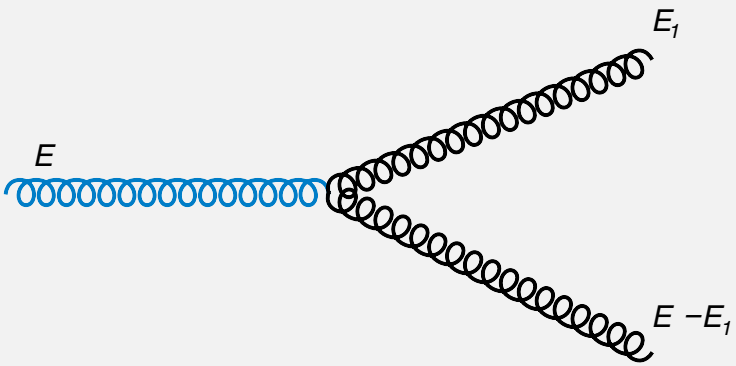

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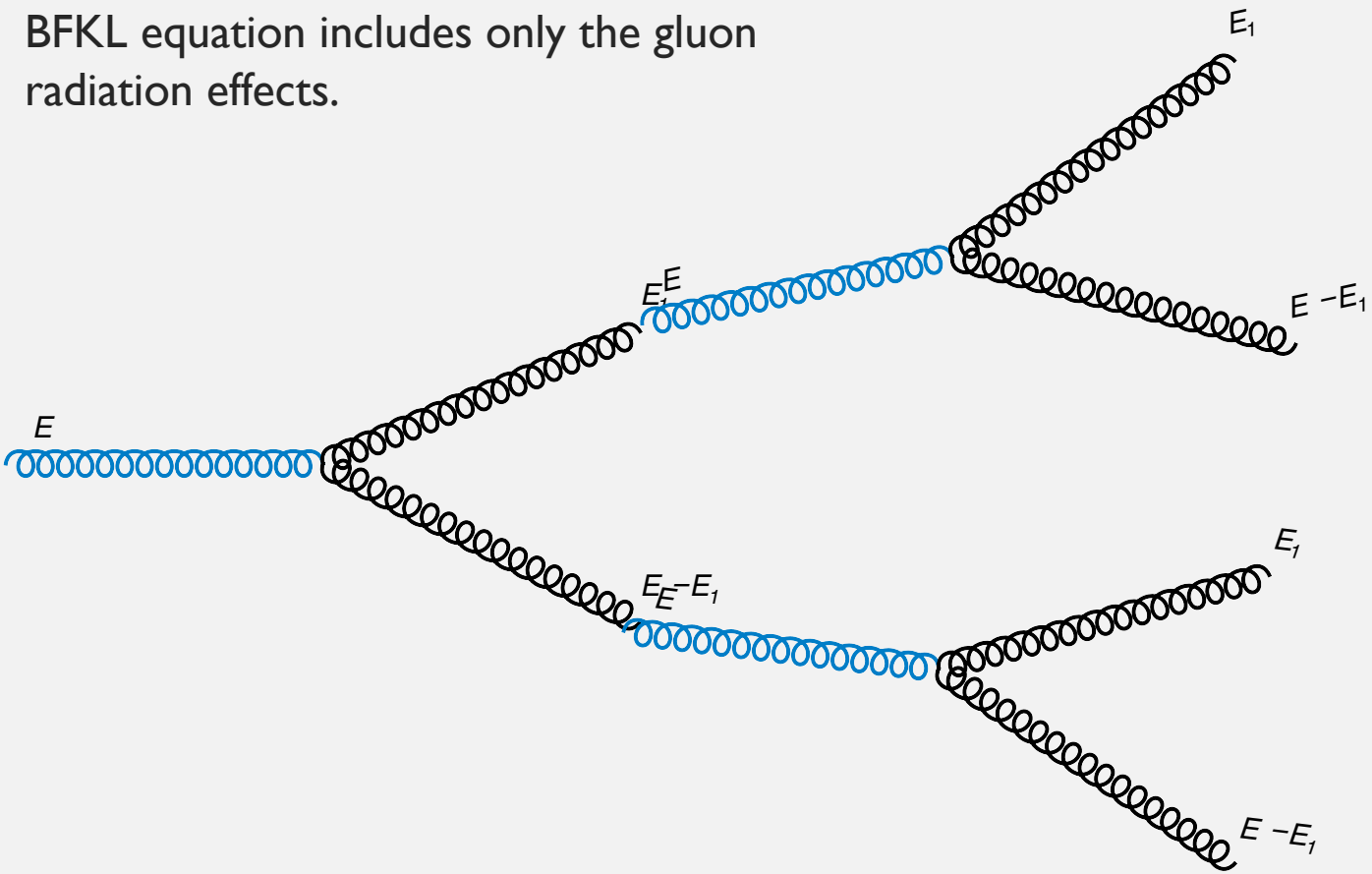

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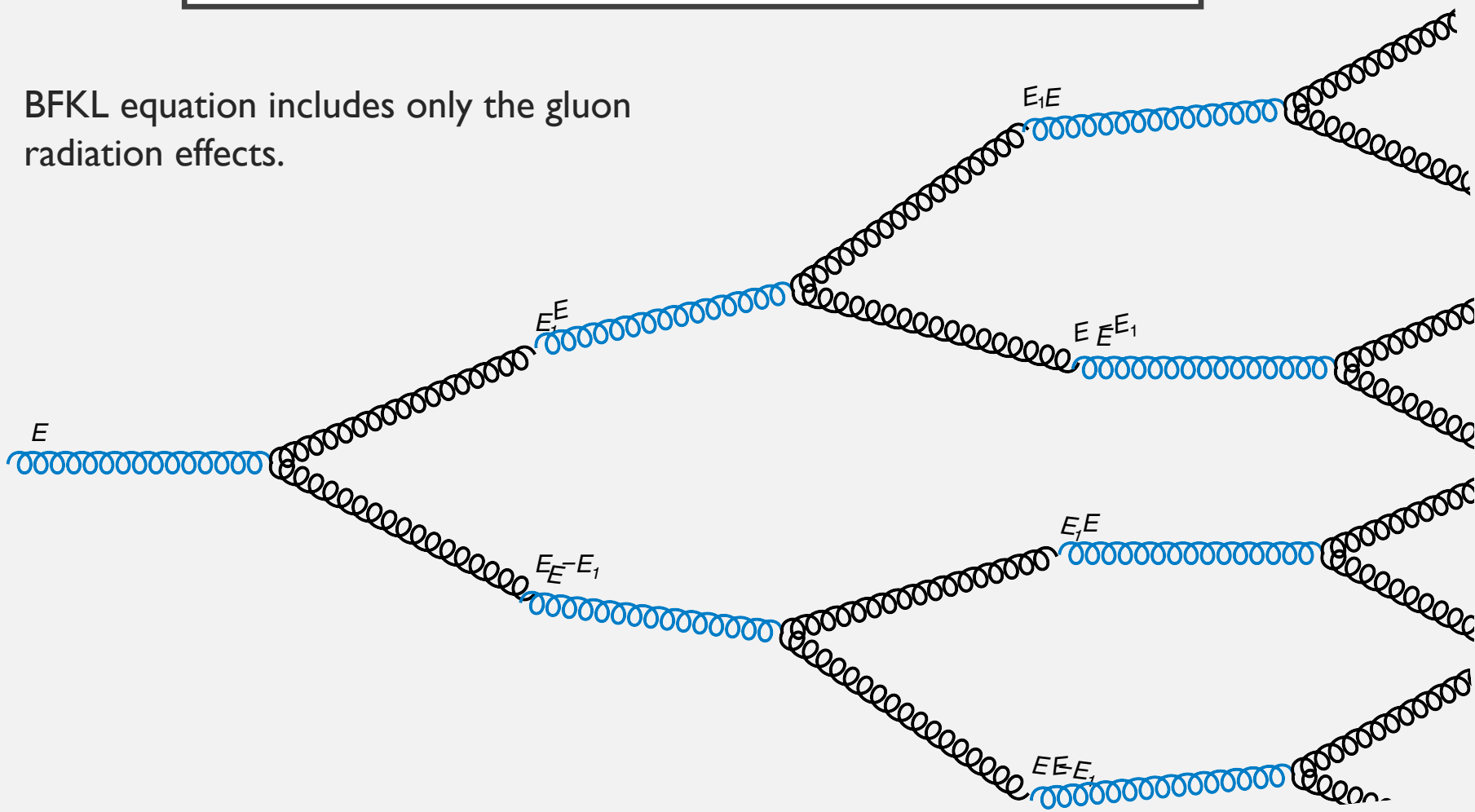

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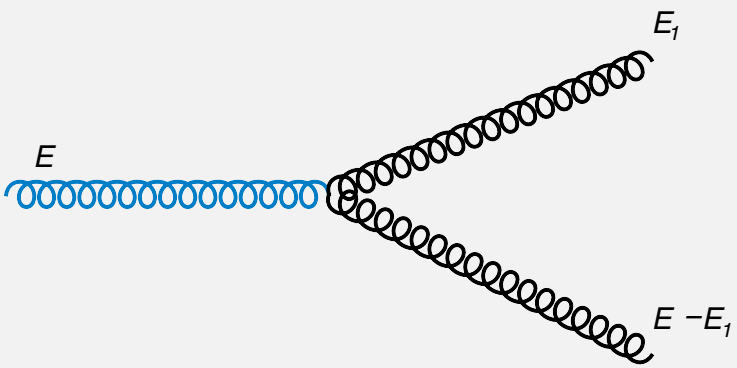
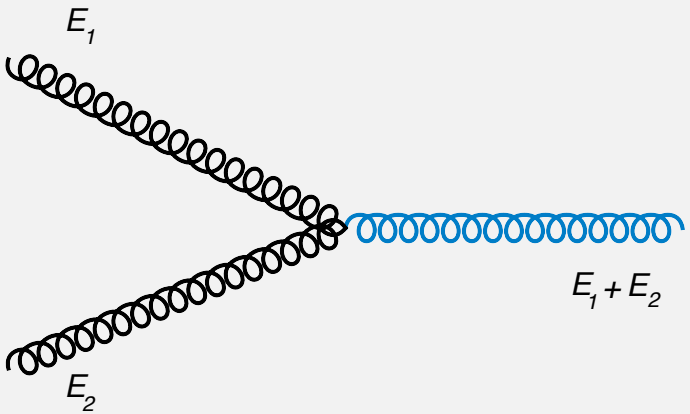
- BFKL equation includes only the gluon radiation effects.
- Other non-linear evolution equation such as the BK equation takes gluon recombination into account.
- This slows down the evolution and tames the unphysical divergences.





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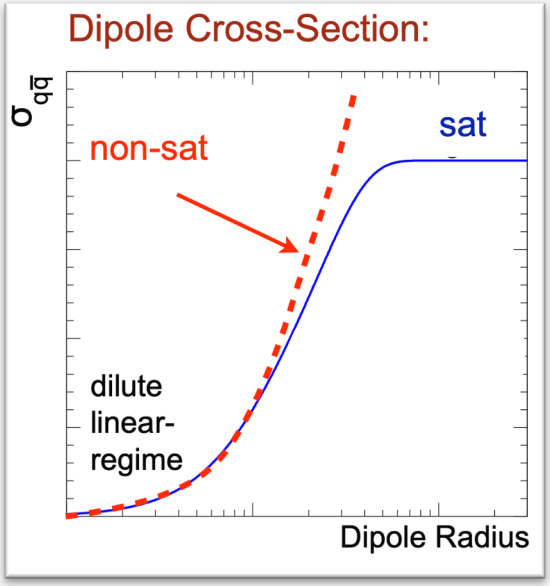

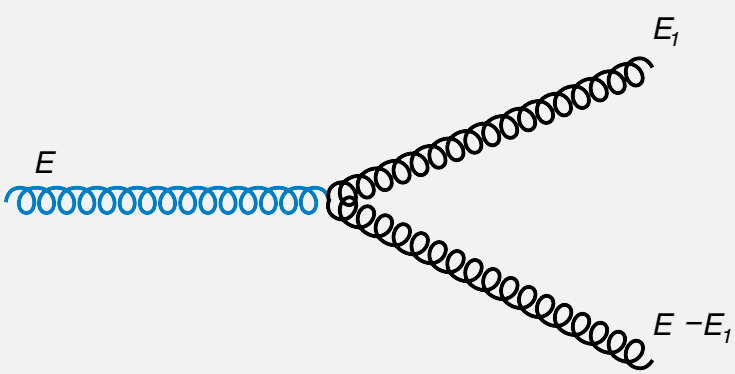

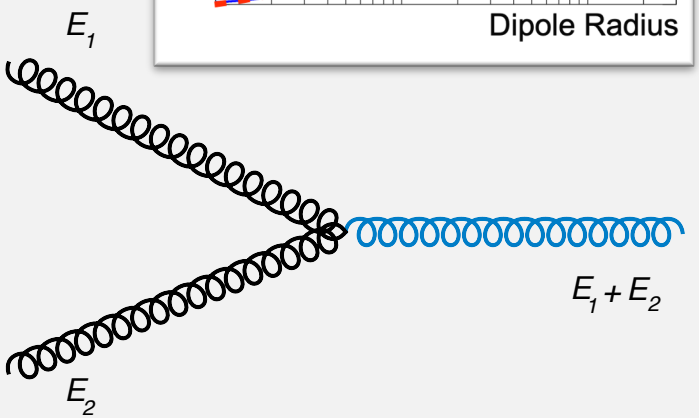

SATURATION

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WIKIPEDIA
The Free Encyclopedia

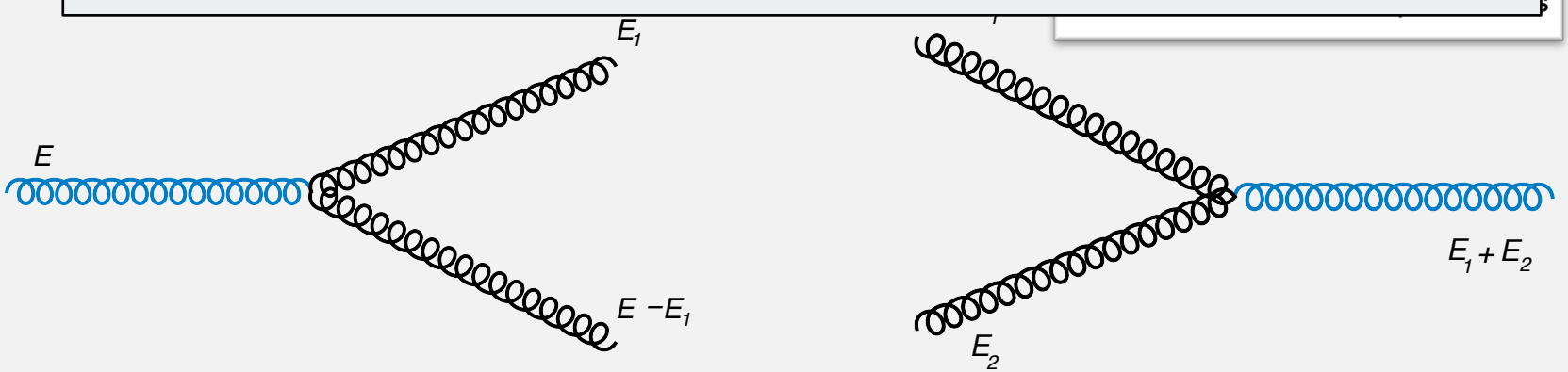
Article Talk

List of unsolved problems in physics

From Wikipedia, the free encyclopedia

Nuclear physics [edit]

- Quantum chromodynamics: What are the phases of strongly interacting matter, and what roles do they play in the evolution of cosmos? What is the detailed partonic structure of the nucleons? What does QCD predict for the properties of strongly interacting matter? What determines the key features of QCD, and what is their relation to the nature
  zero rest mass, within hadrons? Does QCD tr y lack CP violations? Do gluons saturate when their occupation number is large? Do gluons form a dense system called Colour Glass Condensat ? What are the signatures and evidences for the Balitsky–Fadin–Kuarev–Lipatov, Balitsky–Kovchegov, Catani–Ciafaloni–Fiorani–Marchesini evolution equations?



NUCLEAR SATURATION EFFECTS

To determine the contribution of the non-linear saturation effects in nuclear solutions, we have:

1. Solved the BK equation with and without the non-linear term that represents saturation effects.

$$\frac{\partial N(\vec{r},\vec{b},Y)}{\partial Y} = \int d\vec{r_1} K(r,r_1,r_2)$$
$$(N(\vec{r_1},\vec{b_1},Y) + N(\vec{r_2},\vec{b_2},Y) - N(\vec{r},\vec{b},Y) - \cancel{N(\vec{r_1},\vec{b_1},Y)N(\vec{r_2},\vec{b_2},Y)})$$

2. Computed structure functions and then nuclear modification factors for both cases.

We have done this for elements Ca and Pb and compared them.

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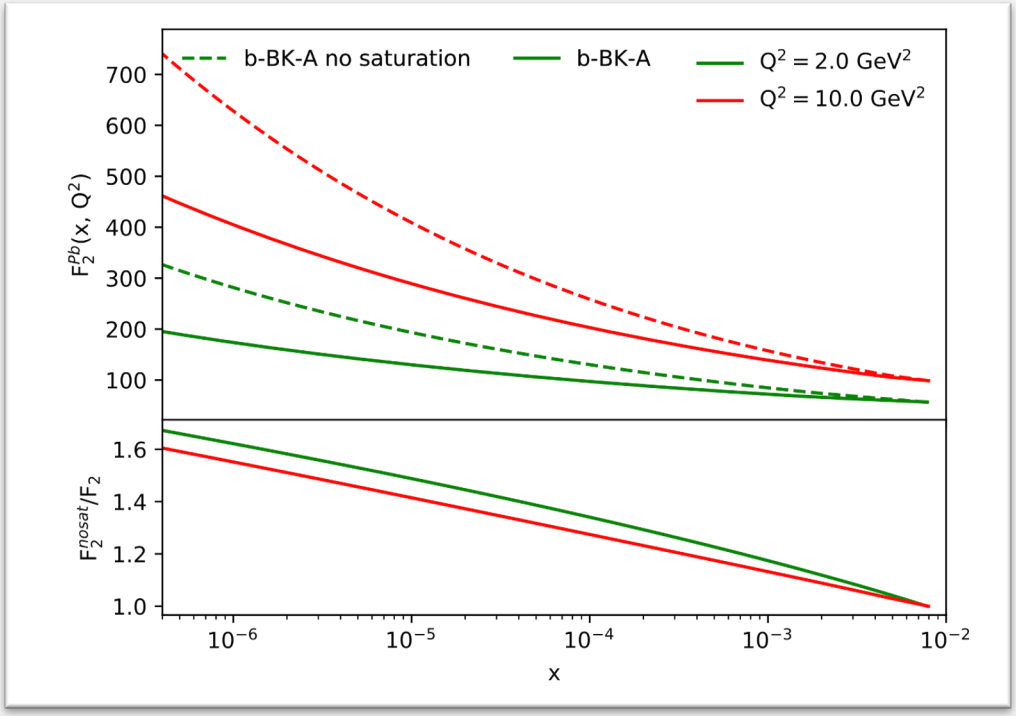

By comparing the computed observables for the two cases for EIC kinematics, we have determined the contribution of saturation effects to the nuclear scattering amplitude.

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$(N(\vec{r_1}, \vec{b_1}, Y) + N(\vec{r}$

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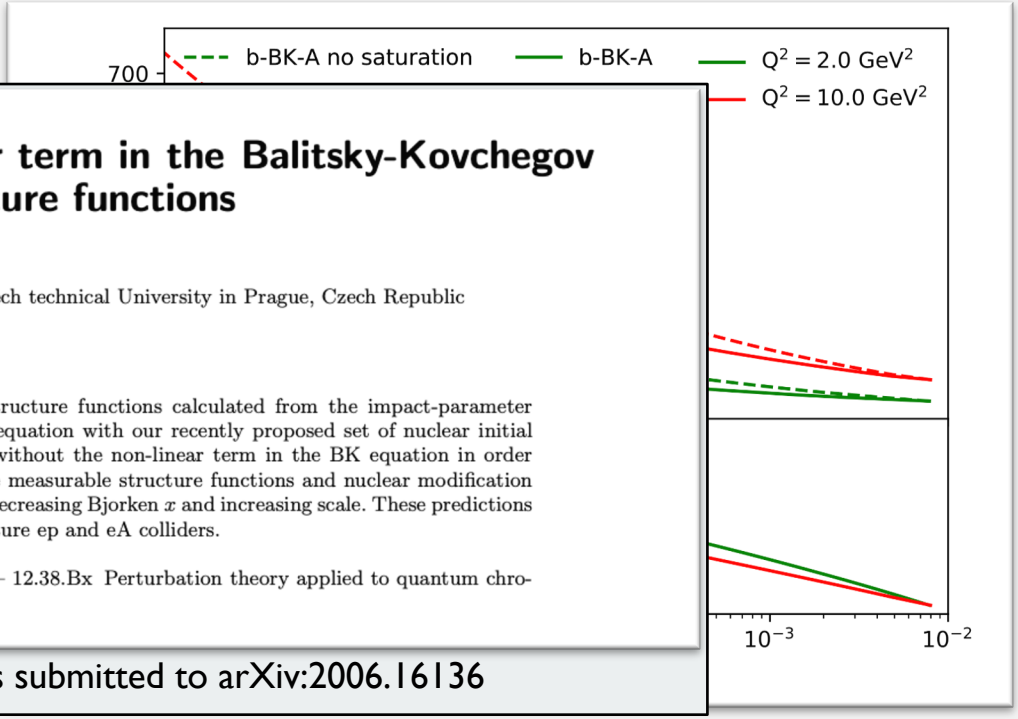

Contribution of the non-linear term in the Balitsky-Kovchegov equation to the nuclear structure functions

Jan Cepila and Marek Matas

Faculty of Nuclear Sciences and Physical Engineering, Czech technical University in Prague, Czech Republic

Abstract. In this paper, we present nuclear structure functions calculated from the impact-parameter dependent solution of the Balitsky-Kovchegov equation with our recently proposed set of nuclear initial conditions. We calculate the results with and without the non-linear term in the BK equation in order to study the impact of saturation effects on the measurable structure functions and nuclear modification factor. The difference of these results rises with decreasing Bjorken x and increasing scale. These predictions are of interest to the physics program at the future ep and eA colliders.

PACS. 12.40.-y Models of Strong Interactions – 12.38.Bx Perturbation theory applied to quantum chromodynamics – 21.60.-n Nuclear models

A paper on this topic was submitted to arXiv:2006.16136

By comparing the computed observables for the two cases for EIC kinematics, we have determined the contribution of saturation effects to the nuclear scattering amplitude.

PHOTONUCLEAR VECTOR MESON PRODUCTION

We have used the obtained scattering amplitude and computed differential J/ψ photonuclear production at the LHC.

1. Used the obtained scattering amplitudes for lead to compute the production of J/ψ vector meson for BK and Glauber approach.

2. Compared with data from ALICE and CMS from run 1, $\sqrt{s_{NN} = 2.76}$ TeV (in the figure) and run 2, $\sqrt{s_{NN} = 5.02}$ TeV.

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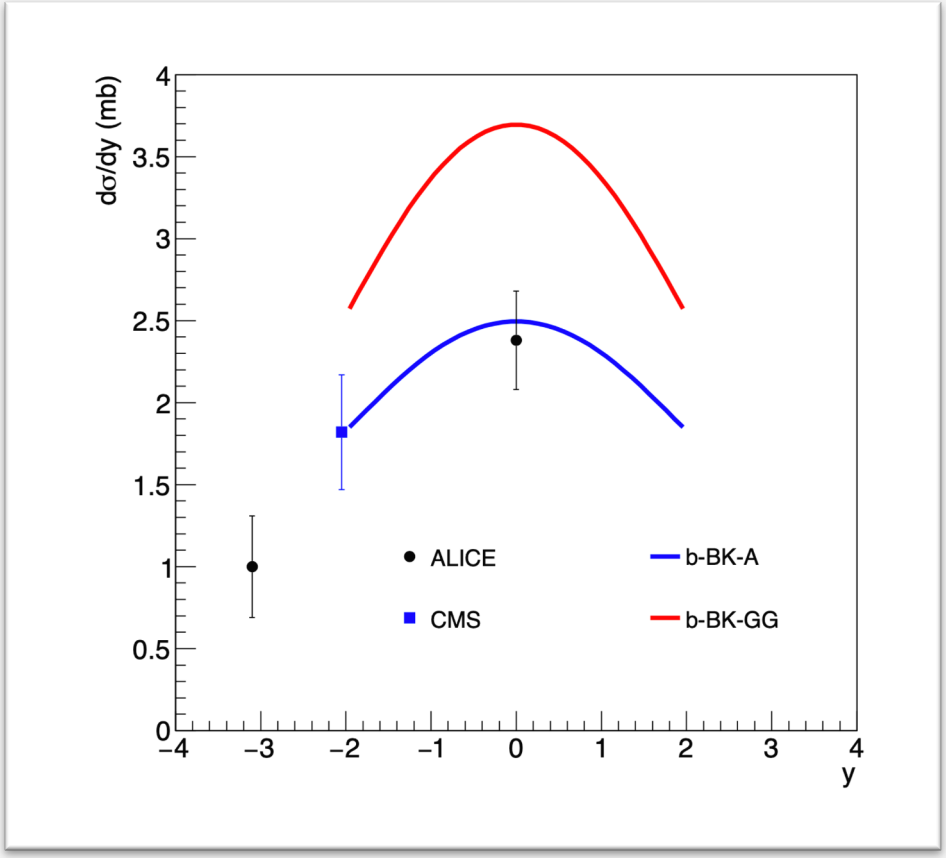

The first run of LHC favors strongly the BK approach whereas the second run is not as decisive since there are yet some discrepancies between ALICE and LHCb data.

PHOTONUCLEAR VECTOR MESON PRODUCTION

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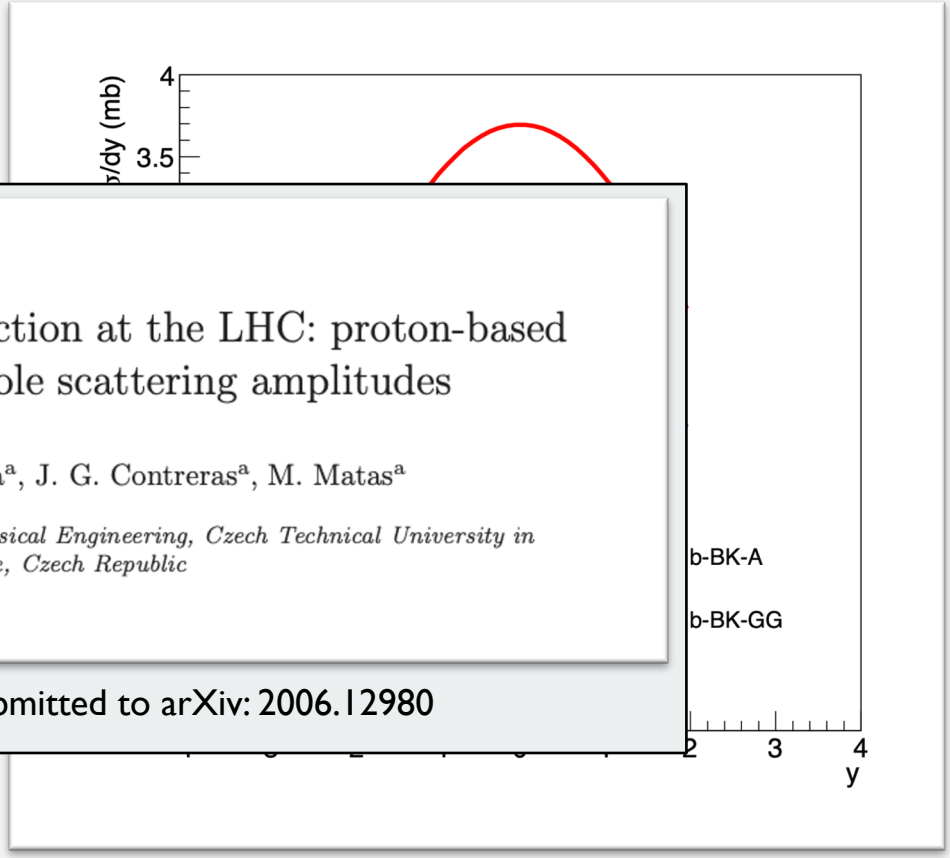

Photonuclear J/ψ production at the LHC: proton-based versus nuclear dipole scattering amplitudes

D. Bendova[a], J. Cepila[a], J. G. Contreras[a], M. Matas[a]

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A paper on this topic was submitted to arXiv: 2006.12980

The first run of LHC favors strongly the BK approach whereas the second run is not as decisive since there are yet some discrepancies between ALICE and LHCb data.

THANK YOU FOR YOUR ATTENTION

No matter what, don't lose hope. We are all bombastic.

- Dan Nekonečný