Gluon Saturation at the Electron Ion Collider

CFNS “EIC opportunities for Snowmass” Workshop

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Writing process

Goal: Summarize and document Electron Ion Collider (EIC) related science that has been discussed within the SnowMass2021 process

An updated and expand version of this document based on future discussion will become the EIC Proceedings as part of the SnowMass2021 document

We will contribute the gluon saturation section to EIC Proceedings

Proposal:

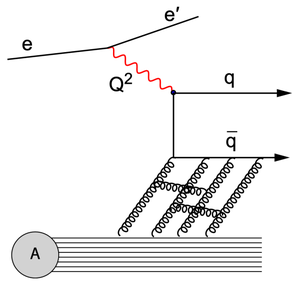
- Every speaker today contributes **~250 words** on their topic
- **by Feb. 12 2021**
- Send your contribution **tex file** to bschenke@bnl.gov
- Please use bibtex directly from inspirehep.net website

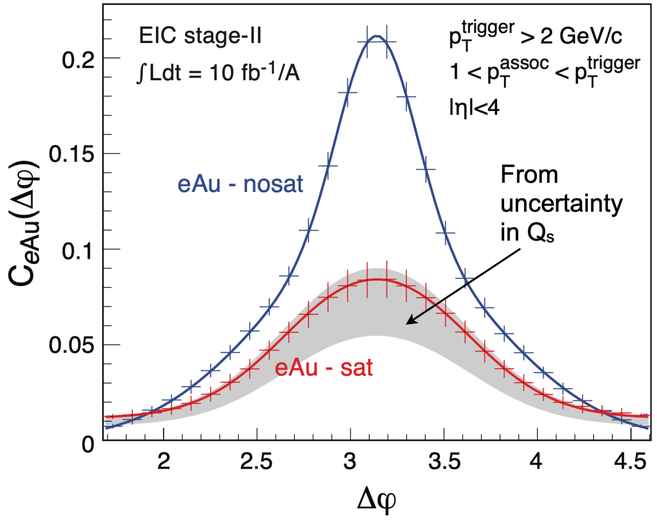
We will compile, add missing topics, and generate a preliminary writeup

Other topics to cover

- **Semi-inclusive DIS: Clear key measurement**
  - Significant difference between sat and non-sat case
  - Has equivalent to pA (e.g. RHIC forward measurements)

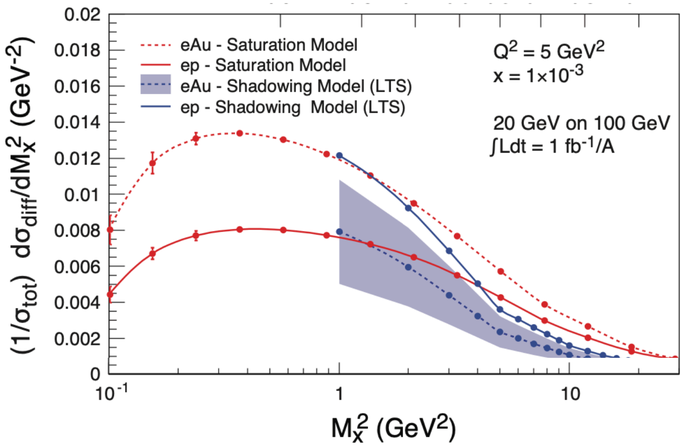
C. Marquet, B. -W. Xiao and F. Yuan, Phys. Lett. B 682 (2009) 207
L. Zheng, E.C. Aschenauer, J.H. Lee, Bo-Wen Xiao, Phys. Rev. D 89, 074037 (2014)

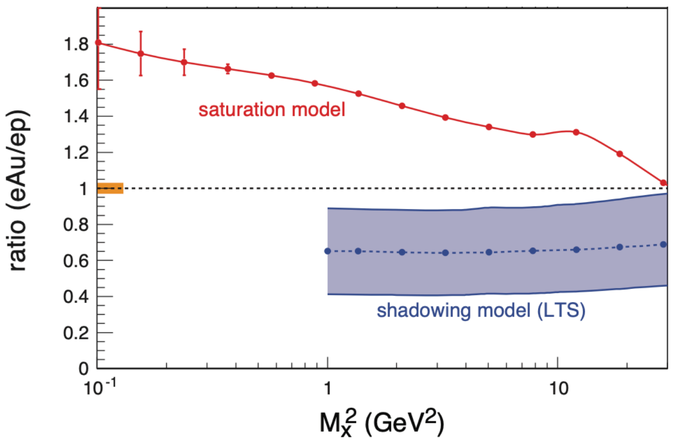




- **Diffractive processes:** Dipole amplitude enters quadratically
  - Ratio of diffractive and total cross-section in ep and eAu collisions
  - Clear difference between saturation models and leading twist shadowing (LTS)

A. Accardi et al., EIC White Paper, Eur.Phys.J.A 52 (2016) 9, 268

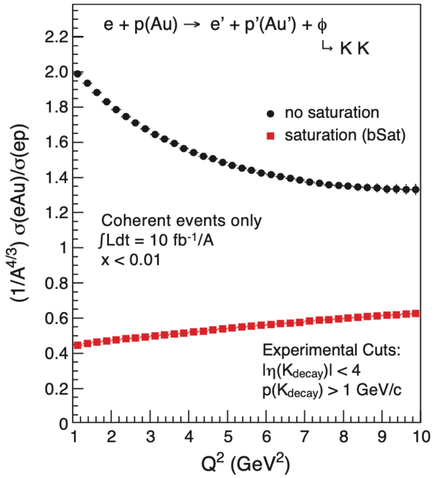


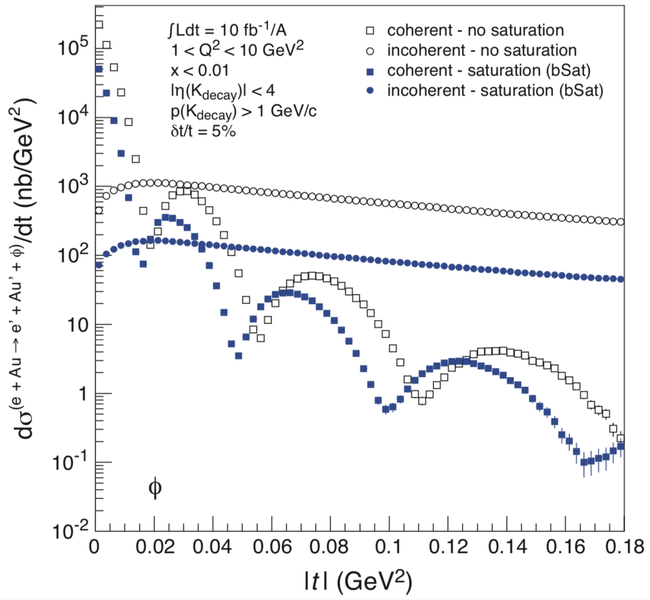


Other topics to cover

- **Diffractive vector meson production** (specifically):
  - Clear saturation effects for lighter vector mesons
  - |t|-spectrum: coherent case: sensitive to target shape incoherent case sensitive to fluctuations

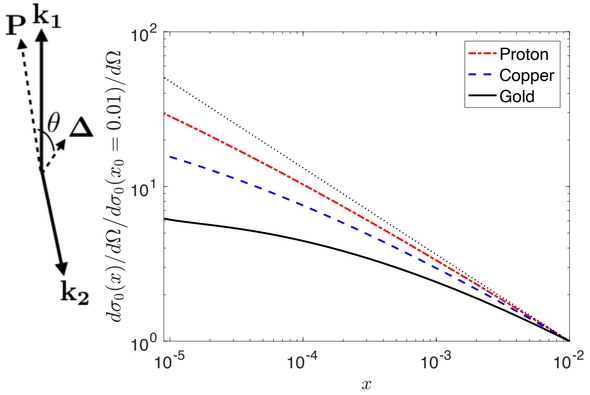
T. Toll, T. Ullrich, Phys.Rev.C 87 (2013) 2, 024913
A. Accardi et al., EIC White Paper, Eur.Phys.J.A 52 (2016) 9, 268
H. Mäntysaari, B. Schenke, Phys. Rev. Lett. 117 (2016) 052301; Phys.Rev. D94 (2016) 034042

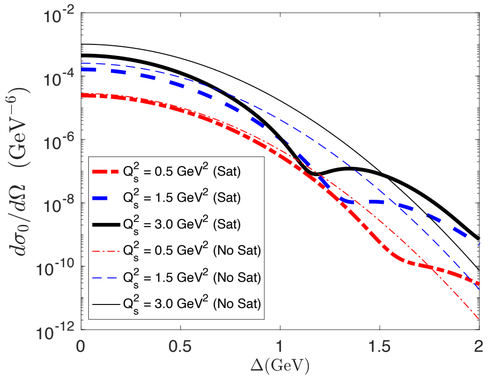




- **Diffractive dijet production:**
  - Slow down of cross section growth for heavier nuclei
  - Saturation leads to diffractive dip even for a Gaussian proton

F. Salazar, B. Schenke, Phys.Rev. D100 (2019) 034007





- **Connection to cosmic ray physics**
  Neutrino-nucleon cross section depends on saturation effects

A. Accardi et al., EIC White Paper, Eur.Phys.J.A 52 (2016) 9, 268

P. Abreu et al., arXiv:1107.4804

Theory developments

Calculations within the color glass condensate are moving to NLO:

NLO Impact factors for

- Fully inclusive DIS **Balitsky, Chirilli; Beuf; Hänninen, Lappi, Paatelainen**
- Semi inclusive single particle production in p+A
  Chirilli, Xiao, Yuan; Altinoluk, Armesto, Beuf, Kovner, Lublinsky; Hänninen, Lappi, Paatelainen
- Photon+dijet prodution in e+A **Roy, Venugopalan**
- Exclusive light vector meson and dijet production
  Boussarie, Grabovsky, Ivanov, Szymanowski, Wallon

NLO evolution equations

- NLL Wilson line evolution **Balitsky, Chirilli**
- NLL dipole evolution **Balitsky, Chirilli**
- NLL 3-point operator evolution **Balitsky, Grabovsky**
- NLL 4-point operator evolution **Grabovsky**
- NLL JIMWLK Hamiltonian (from 4 above results) **Kovner, Lublinsky, Mulian**

Phenomenology at NLO **G. Beuf, H. Hänninen, T. Lappi, H. Mäntysaari, arXiv:2007.01645**

Summary

- The EIC is expected to start operation in 2030 and the experimental identification and study of gluon saturation is one of its major science goals
- Gluon saturation becomes increasingly important also for particle production in hadronic collisions as the collision energy increases
- Theory is advancing significantly, moving on to NLO calculations
- A series of observables has been identified and predictions are improving
- Detailed studies for detector requirements in the ongoing EIC Yellow Report (see update from Tuomas)
- A very active and exciting field