U.S. DEPARTMENT OF ENERGY

Office of Science

KU

Vector meson photoproduction: recent results and discussion

Daniel Tapia Takaki

University of Kansas

Workshop on forward physics and QCD with LHC, EIC, and Cosmic Rays

January 20, 2021

Plan of this talk

- **Review of some of the physics questions**
- **Discussion of recent results**
- **Points for discussion:**
  - Future planned Measurements
  - Impact of detector upgrades
  - Special runs

Physics questions (II)

- Initial stage of the proton and nuclei: space, momentum and polarization features
- Extract info on parton distribution functions (GPDs, PDFs)
- Determine the onset of gluon saturation in protons
- Study nuclear effects such as shadowing present in nuclei and not in protons
- Role of high-mass energy stages in hadron-nucleus interactions

Physics questions (II)

- Test different mechanics. e.g. DGLAP vs perturbative Pomeron dynamics
- Role of the dipole size in photon-hadron interactions
- Color fluctuations of the photon
- Hadronic and Odderon searchers
- Role of Quantum correlations, entanglement

Vector meson photoproduction at LHC

- ALICE measurements:
  - Coherent J/ψ in PbPb: *Phys.Lett.B* 718 (2013) 1273-1283 e-Print: 1209.3715 [nucl-ex]
  - Coherent Charmonium and two-photon process in UPC PbPb *Eur.Phys.J.C* 73 (2013) 11, 2617 e-Print: 1305.1467 [nucl-ex]
  - Exclusive J/ψ in UPC pPb *Phys.Rev.Lett.* 113 (2014) 23, 232504 e-Print: 1406.7819 [nucl-ex]
  - Coherent ρ^0 in PbPb *JHEP* 09 (2015) 095 e-Print: 1503.09177 [nucl-ex]
  - Coherent ψ(2S) *Phys.Lett.B* 751 (2015) 358-370 e-Print: 1508.05076 [nucl-ex]
  - Energy dependence of UPC pPb *Eur.Phys.J.C* 79 (2019) 5, 402 e-Print: 1809.03235 [nucl-ex]
  - Coherent J/ψ in PbPb *Phys.Lett.B* 798 (2019) 134926 e-Print: 1904.06272 [nucl-ex]
  - Coherent ρ^0 in PbPb *JHEP* 06 (2020) 035, JHEP06 (2020) 35 e-Print: 2002.10897 [nucl-ex]
  - Coherent J/ψ and ψ(2S) in UPC PbPb e-Print: 2101.04577 [nucl-ex]
  - t-dependence of coherent J/ψ in UPC PbPb 2101.04623 [nucl-ex]
  - Coherent ρ^0 in UPC XeXe 2101.02581 [nucl-ex]

Vector meson photoproduction at LHC

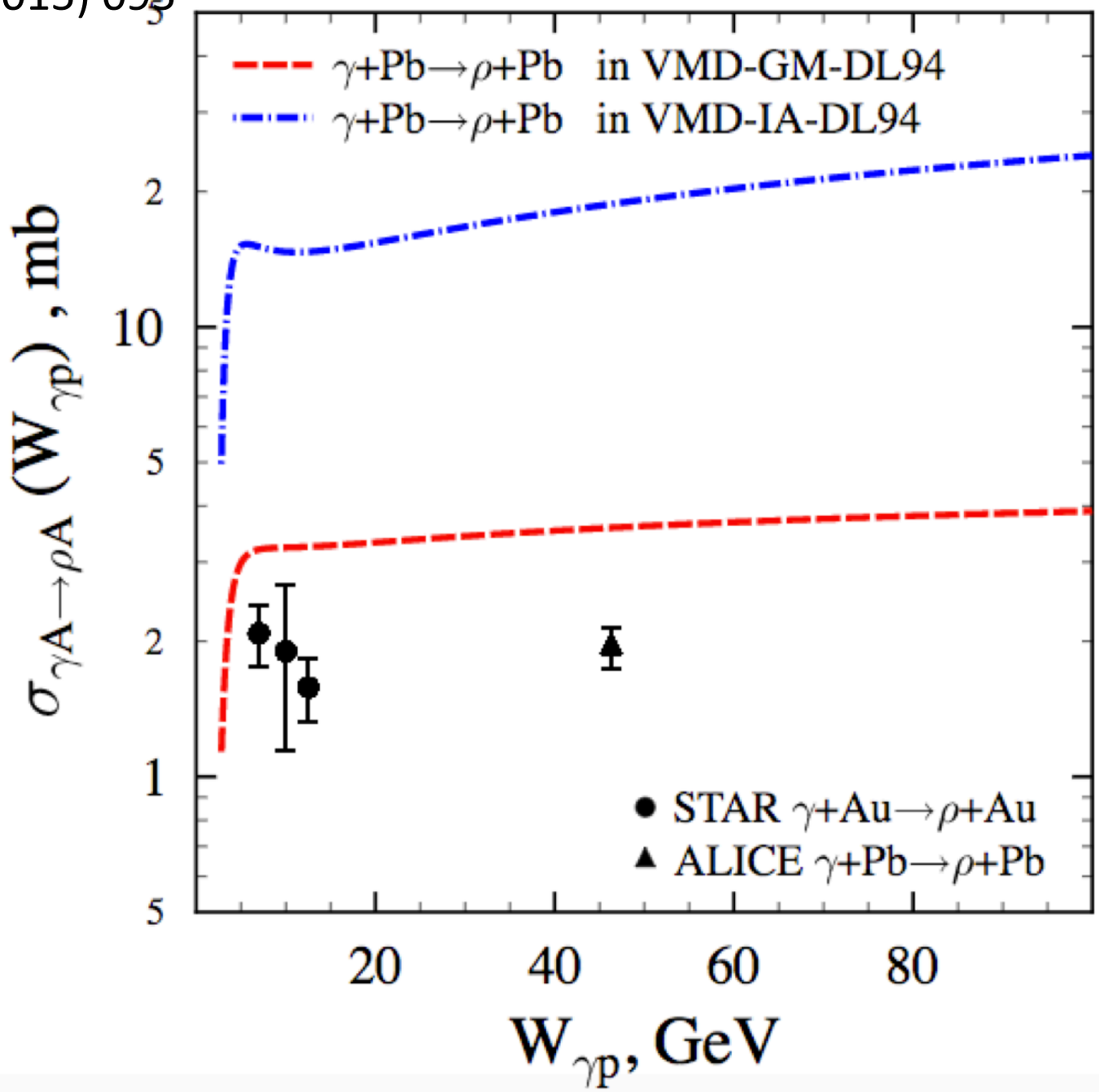
- CMS measurements:
  - Coherent J/ψ in PbPb: *Phys.Lett.B* 772 (2017) 489-511e-Print: 1605.06966 [nucl-ex]
  - Exclusive Upsilon in UPC pPb: *Eur.Phys.J.C* 79 (2019) 3, 277 e-Print: 1809.11080 [hep-ex]
  - Exclusive ρ^0 in UPC pPb *Eur.Phys.J.C* 79 (2019) 8, 702e-Print: 1902.01339 [hep-ex]

Vector meson photoproduction at LHC

- LHCb measurements:
  - Exclusive J/ψ and Psi(2S) in UPC pp *J.Phys.G* 40 (2013) 045001 e-Print: 1301.7084 [hep-ex]
  - Update on exclusive J/ψ and Psi(2S) in UPC pp at 7 TeV *J.Phys.G* 41 (2014) 055002 e-Print: 1401.3288 [hep-ex]
  - Exclusive Upsilon in UPC pp at 7 and 8 TeV *JHEP* 09 (2015) 084 e-Print: 1505.08139 [hep-ex]
  - Exclusive J/ψ and Psi(2S) in UPC pp at 13 TeV *JHEP* 10 (2018) 167 e-Print: 1806.04079 [hep-ex]
  - Preliminary results on coherent J/ψ in UPC PbPb presented at QM 2018

Coherent ρ^0 in UPC PbPb

ALICE
JHEP 1509 (2015) 095

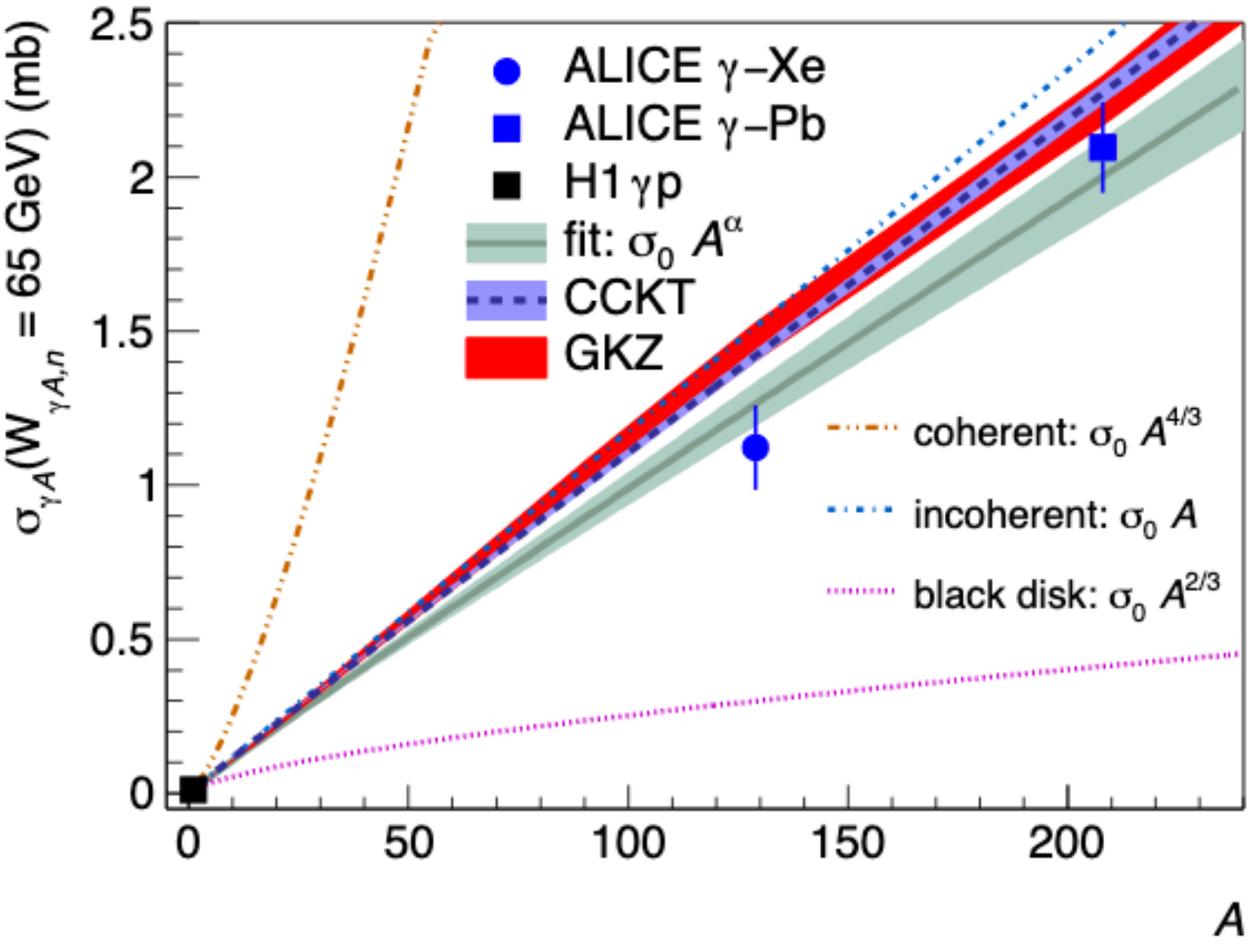


L. Frankfurt et al.
Phys. Lett. B 752 (2016) 51-58

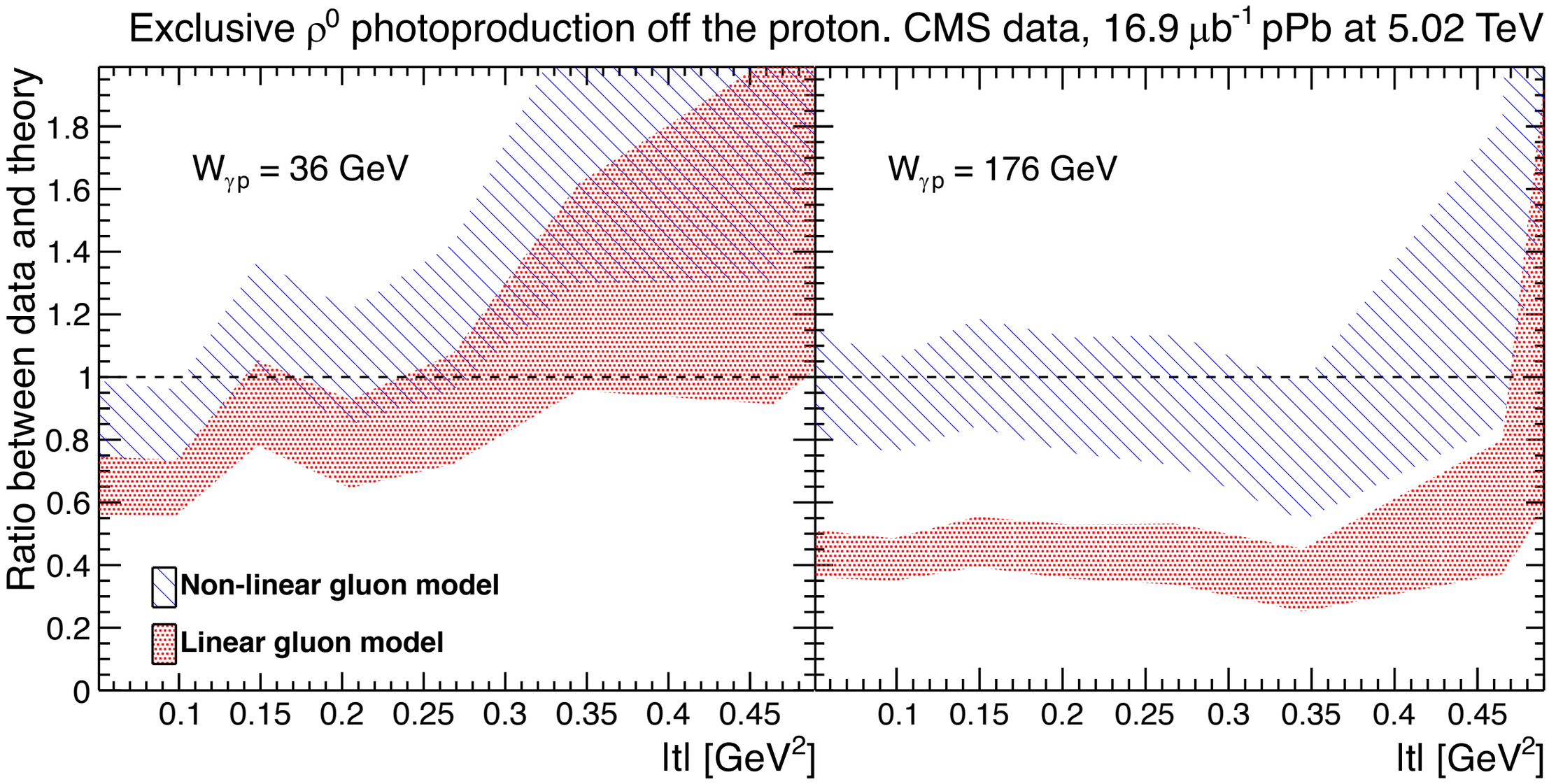
Both ALICE and STAR find measured cross section ~40% lower than predicted by Glauber, ….although works fine at fixed-target experiments

Nuclei does not behave like individual nucleons

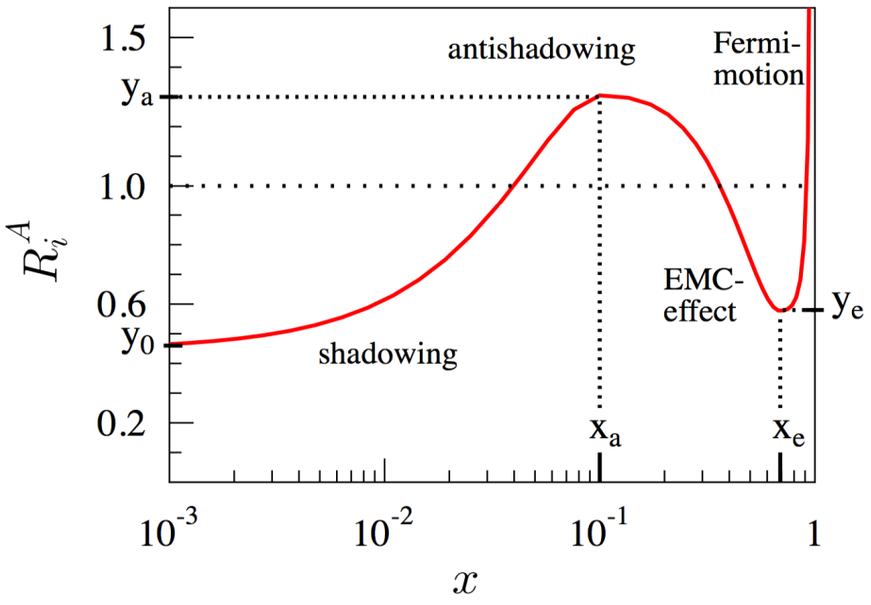
Coherent ρ^0 in UPC PbPb



Coherent ρ^0 in UPC **pPb**



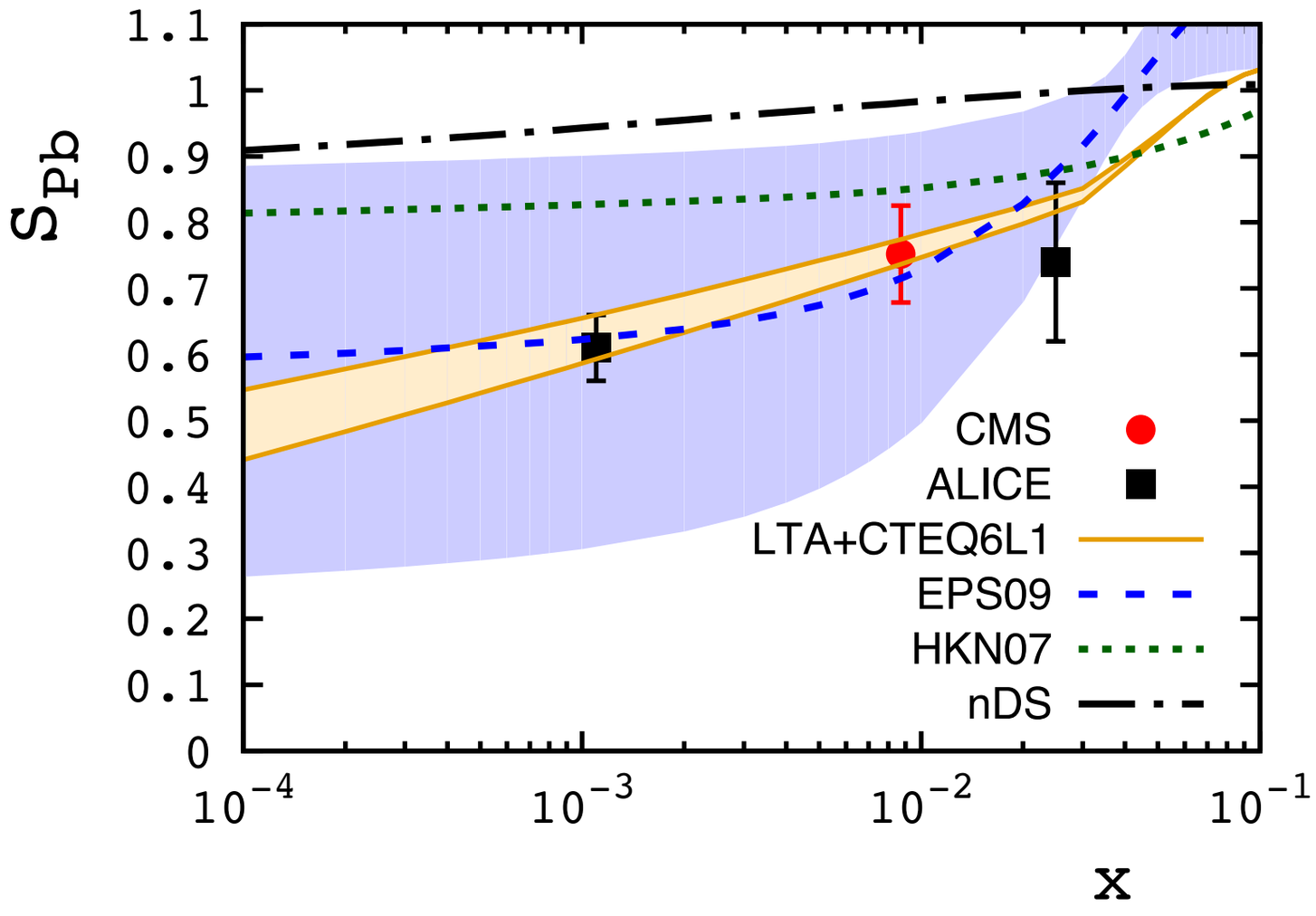
Nuclear effects at **Low x**



See talk by Vadim Guzey

Coherent J/ψ photoproduction off Pb nuclei

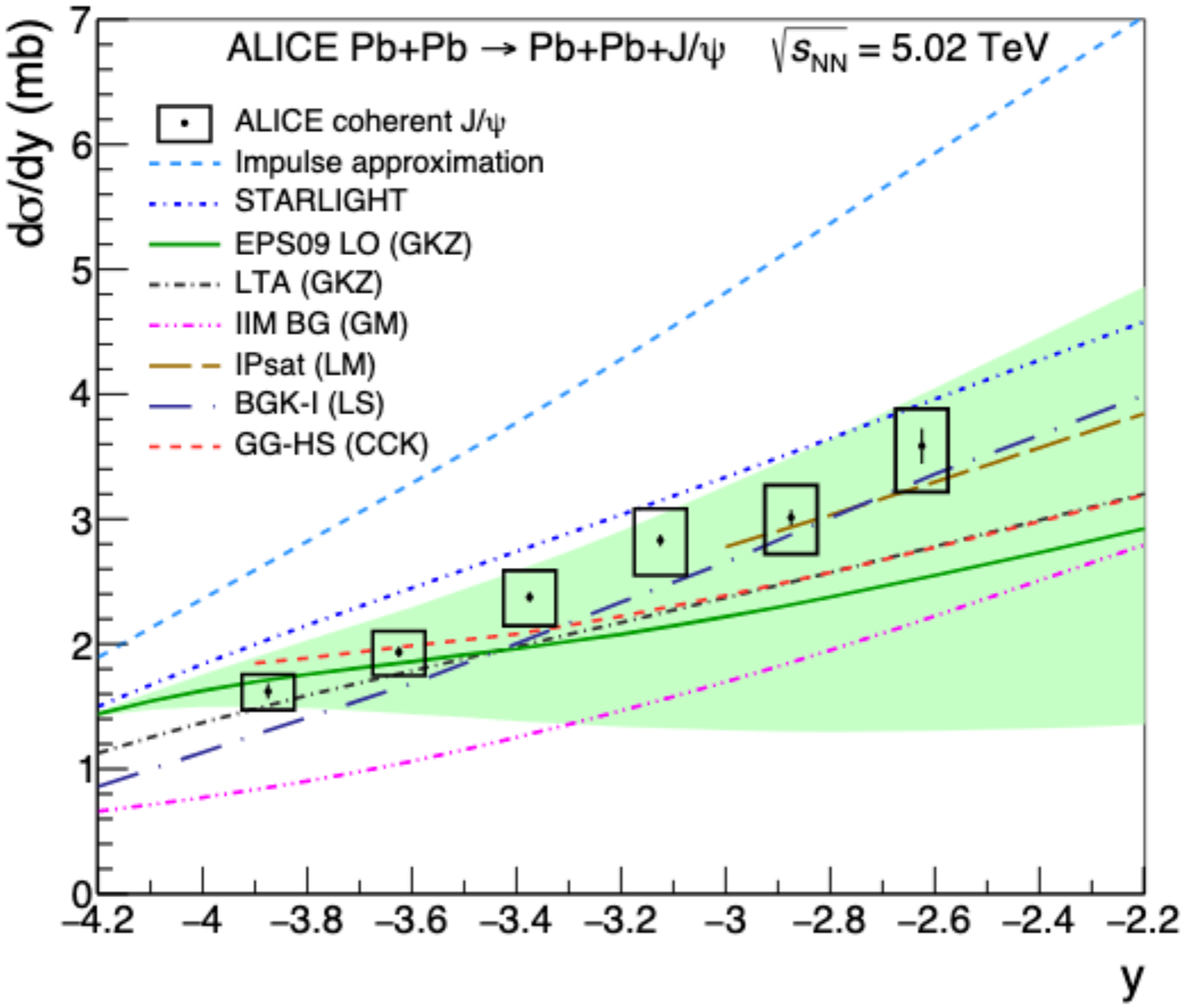
By V. Guzey, et. al using Phys. Lett. B726 (2013) 290–295
and ALICE and CMS results from Run 1



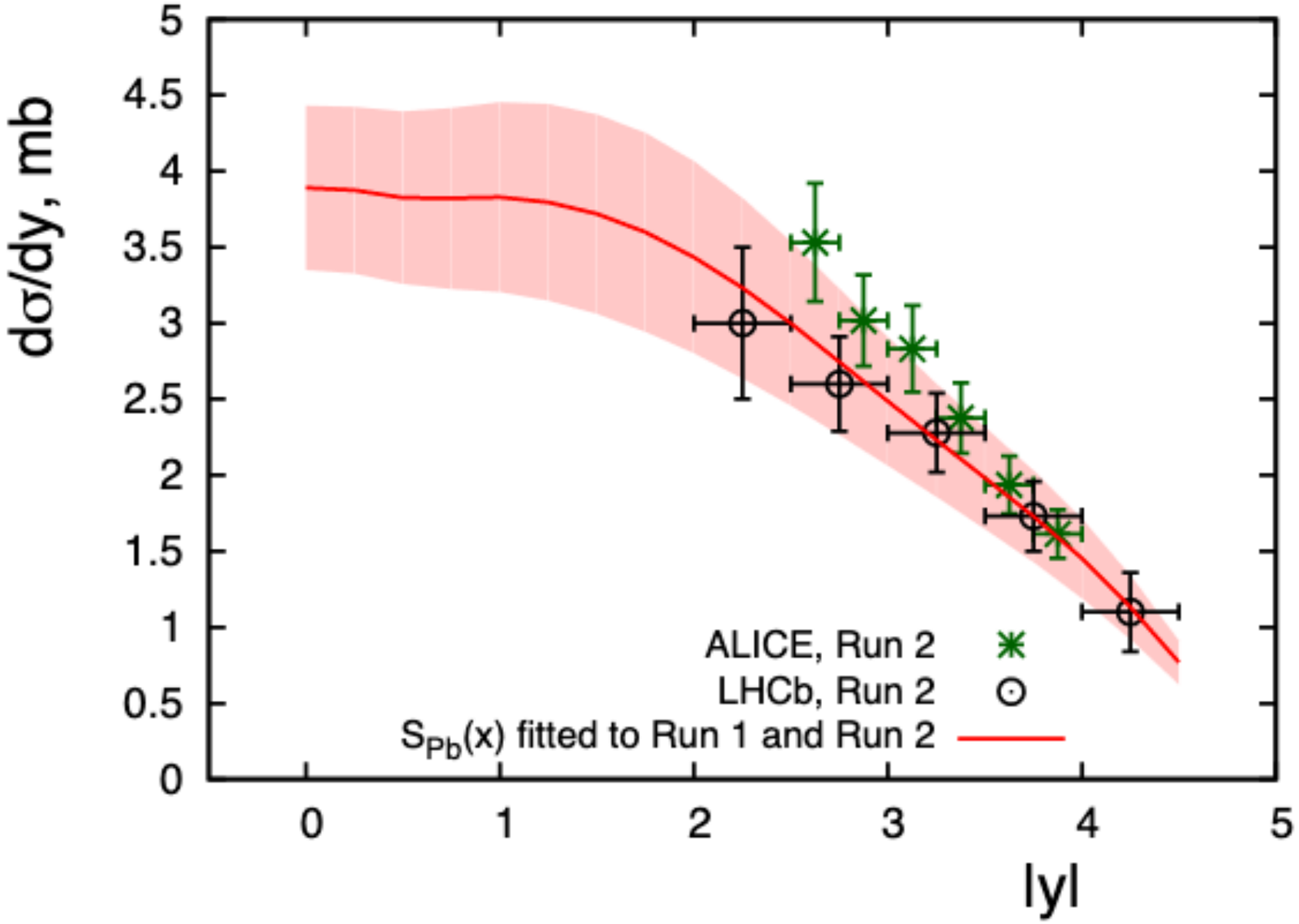
$$R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$

Coherent J/ψ in UPC PbPb - Forward data

Phys. Lett. B 798 (2019) 134926

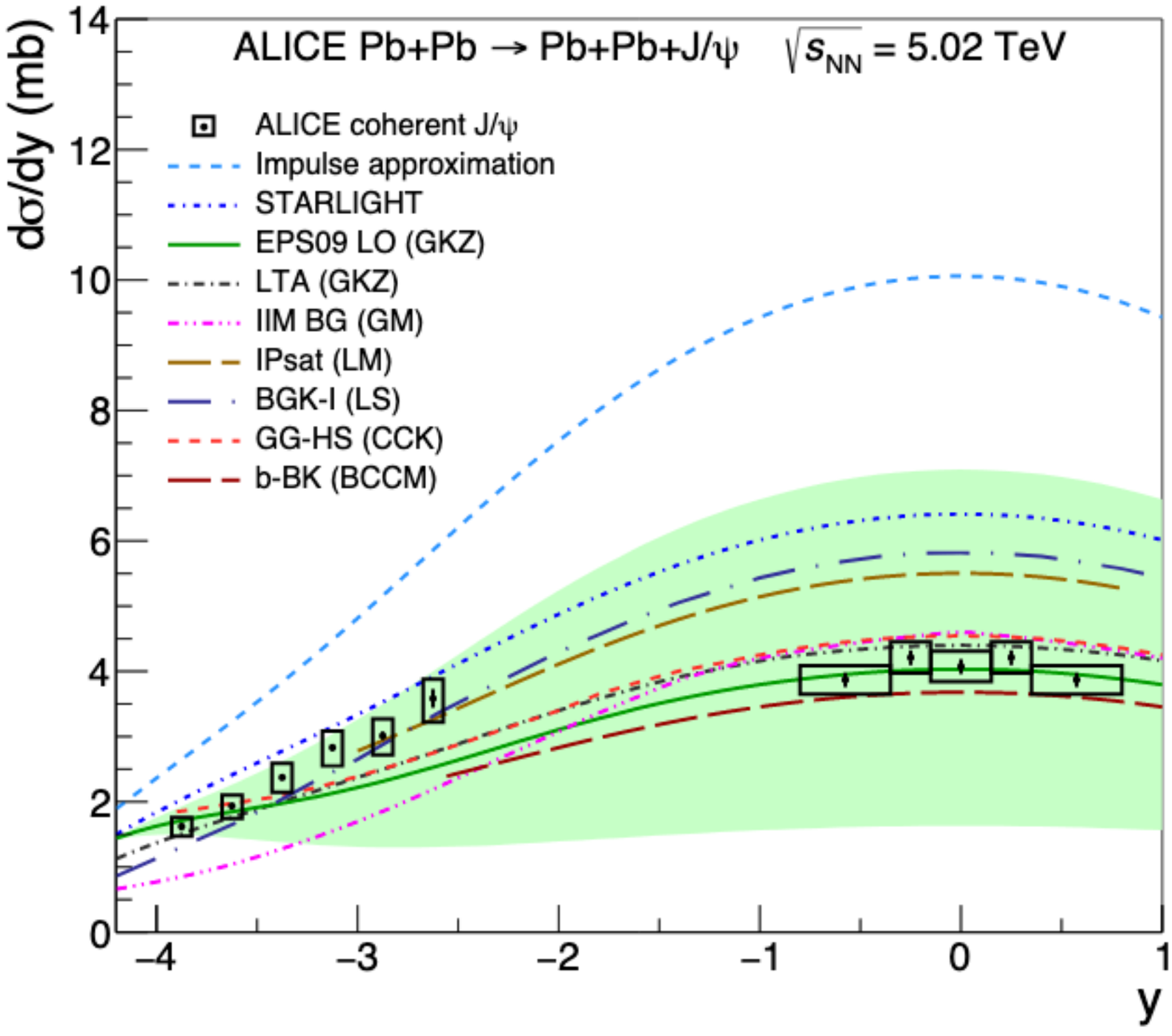


Coherent J/ψ data in UPC Forward ALICE and LHC



V. Guzey et al. e-Print: 2008.10891 [hep-ph]

Coherent J/ψ in UPC PbPb

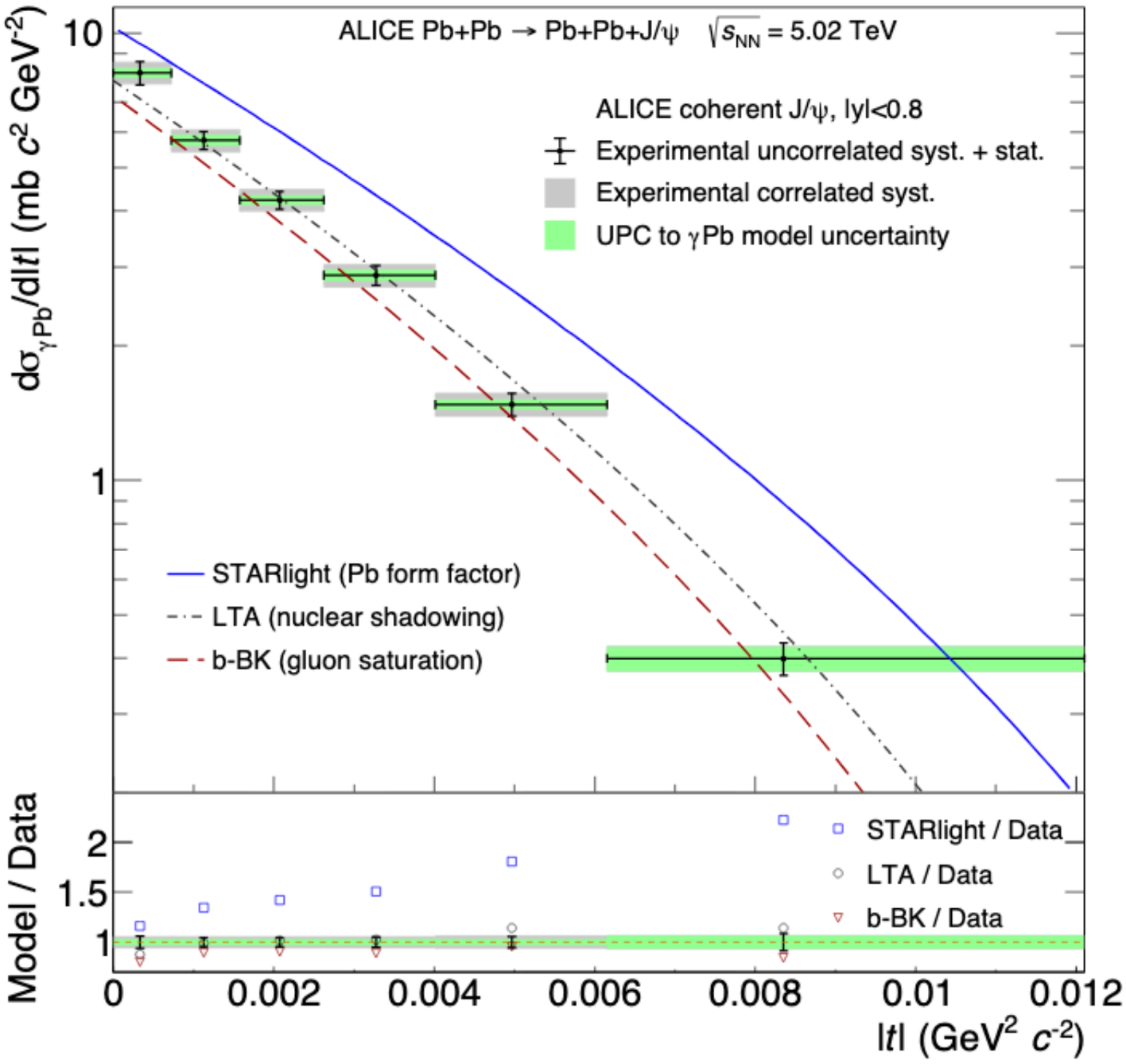


Non of the models can fully describe the y-dependence

Different high-x and low-x contributions at intermediate y?

e-Print: 2101.04577 [nucl-ex]

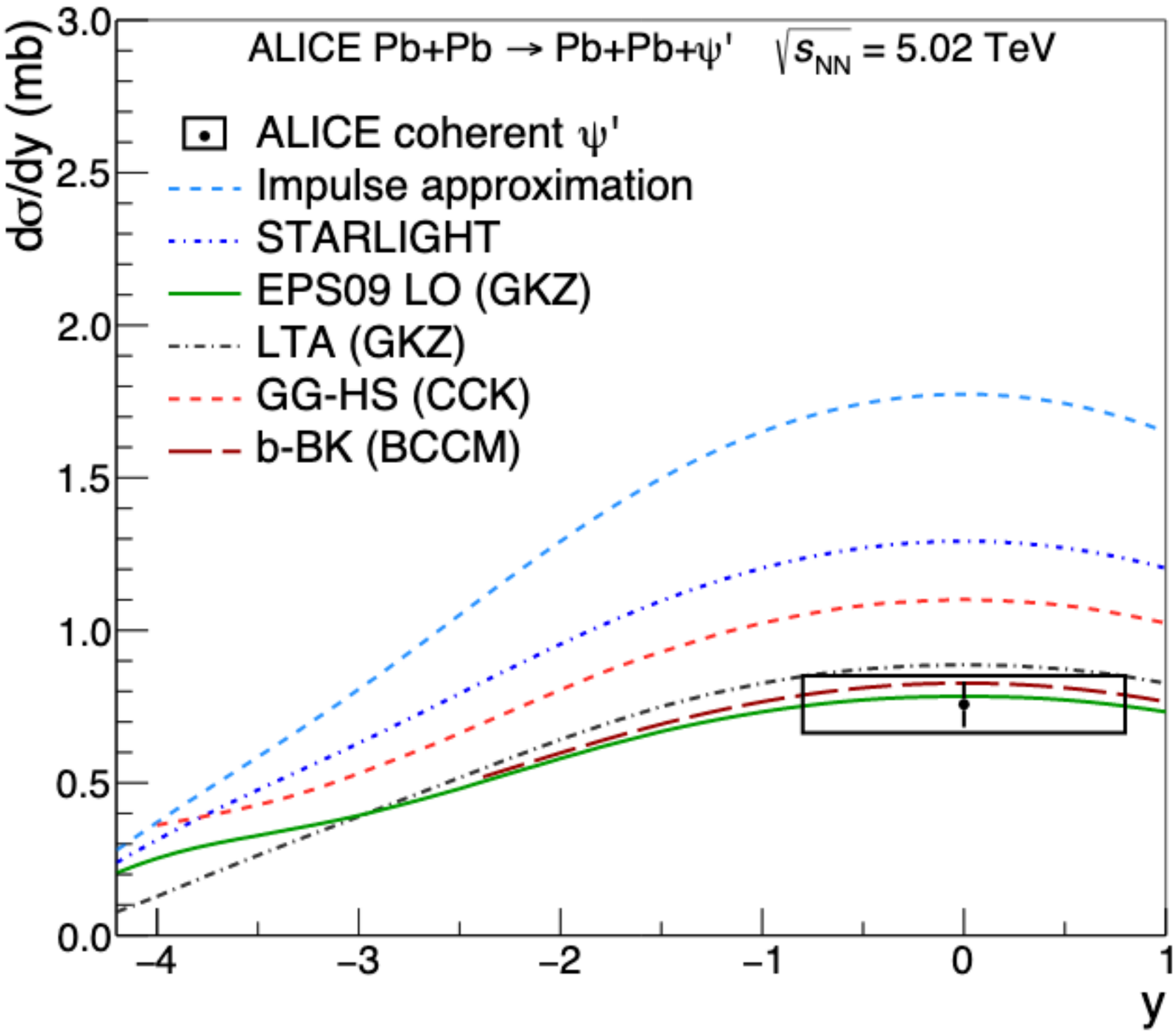
t-dependence of UPC J/ψ in PbPb



Nuclear shadowing (LTA) or gluon saturation (b-BK) describe the data

2101.04623 [nucl-ex]

Recent results: Coherent ψ(2S)



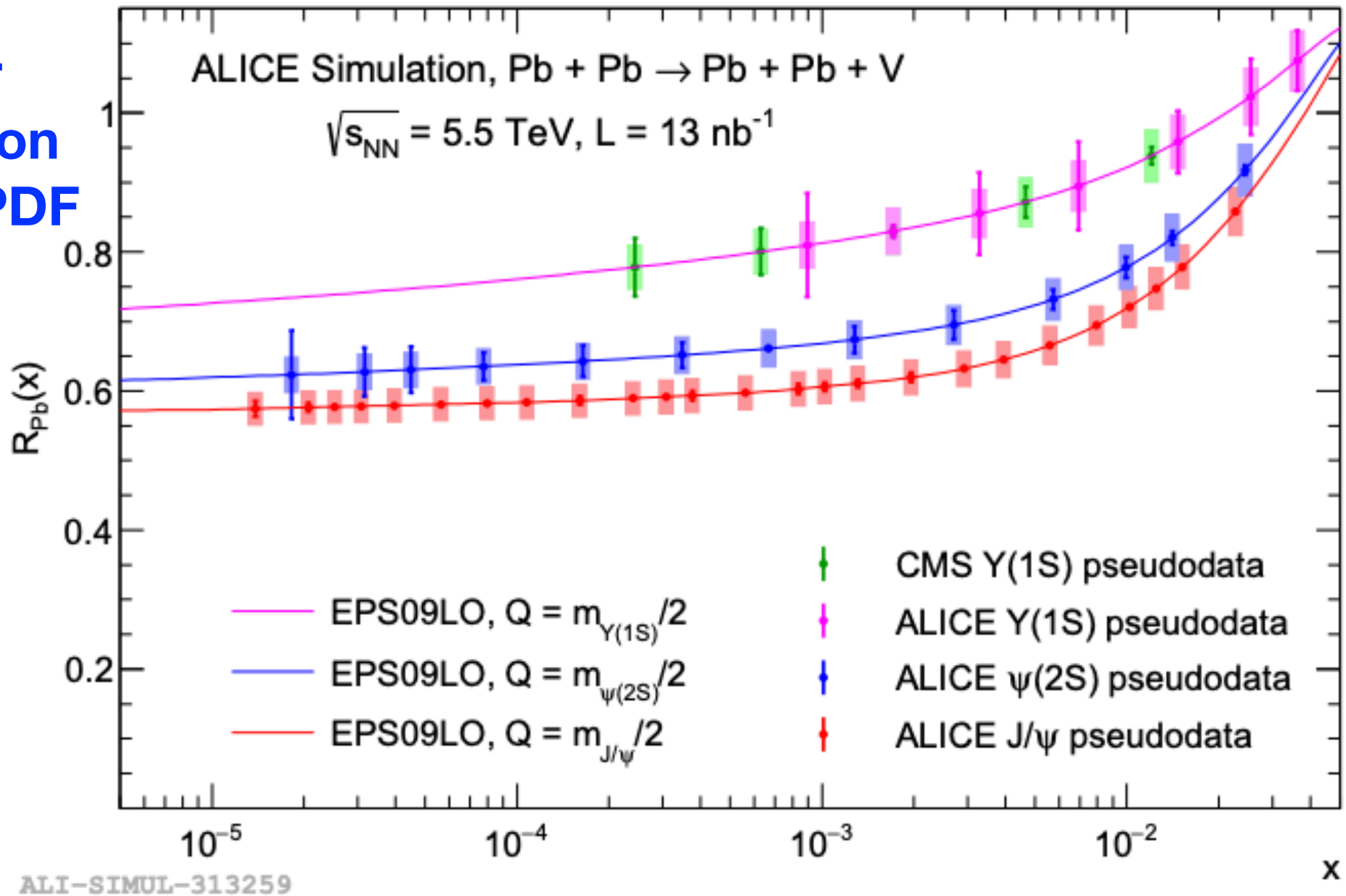
e-Print: 2101.04577 [nucl-ex]

ψ(2s) to J/ψ ratio agrees with world data

Future prospects

https://arxiv.org/pdf/1812.06772.pdf

Nuclear suppression factor ~ nPDF



Bjorken-x

Discussion points - Future measurements (I)

- **Incoherent photoproduction**
- **Coherent Upsilon in UPC PbPb**
- **Neutron dependence cross section of all UPC VMs**
- **More “semi-forward” measurements**

Discussion points - Future measurements (II)

- **Polarization of VMs**
  - **Are there any models predicting any observables beyond s-channel helicity conservation?**
- **More A-dependence studies**
- **Role of dipole size on exclusive VM photoproduction at the same photon-proton energy**

Discussion points - Detector upgrades at LHC

- **In ALICE**
  - Run 3: continuous readout, access to all luminosity
  - Potential for FoCal detectors: $3.2 < n < 5.8$
  - Use of MUON/MFT + FoCal for very large rapidity selections
- **LHCb:**
  - Run 4 looks very promising for UPC studies, but new forward detectors like HERSCHEl will be needed. Plans for ZDCs?
- **Fixed-target mode:**
  Plans/discussions at ALICE and LHCb sounds very promising

Discussion points - Special runs

- **Special runs in Run 3 and Run 4 for UPC VMs?**
- **A-dependence of VM photoproduction of Rho0 and J/ψ?**
- **Higher statistics in pPb for t-dependence studies of light vector mesons**
  - Extracting transverse profile of the target from t-dependence

Discussion points - Challenges

- **Separating coherent and incoherent production**
- **Separating exclusive and dissociative production (more challenging!)**
- **Experimental strategies for inclusive photoproduction**
- **Use of TOTEM in pPb runs in CMS?**

Discussion points - Theory

- **What is compatible across all models describing UPC VMs? What models or what parts can be “discarded”?**

- **What are the challenges from the theory side?**

- **New NLO calculations**

- **How this knowledge serve the community preparing for future facilities like the EIC?**

Summary

- **Tremendous progress on UPC VMs results at LHC. Several studies indicating nuclear effects beyond those in photon-hadron**

- **Lots of new experimental studies foreseen**

- **Run 3 and Run 4 prospects very promising to do systematic studies of UPC VMs thanks to high statistics and new detector capabilities**