U.S. DEPARTMENT OF ENERGY

Office of Science

KU

UPC Physics for Snowmass 2021: first discussion/selected topics

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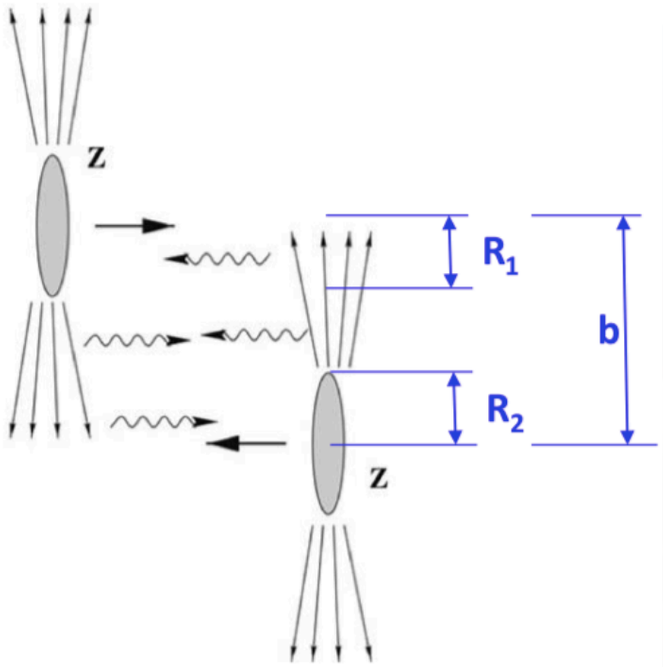
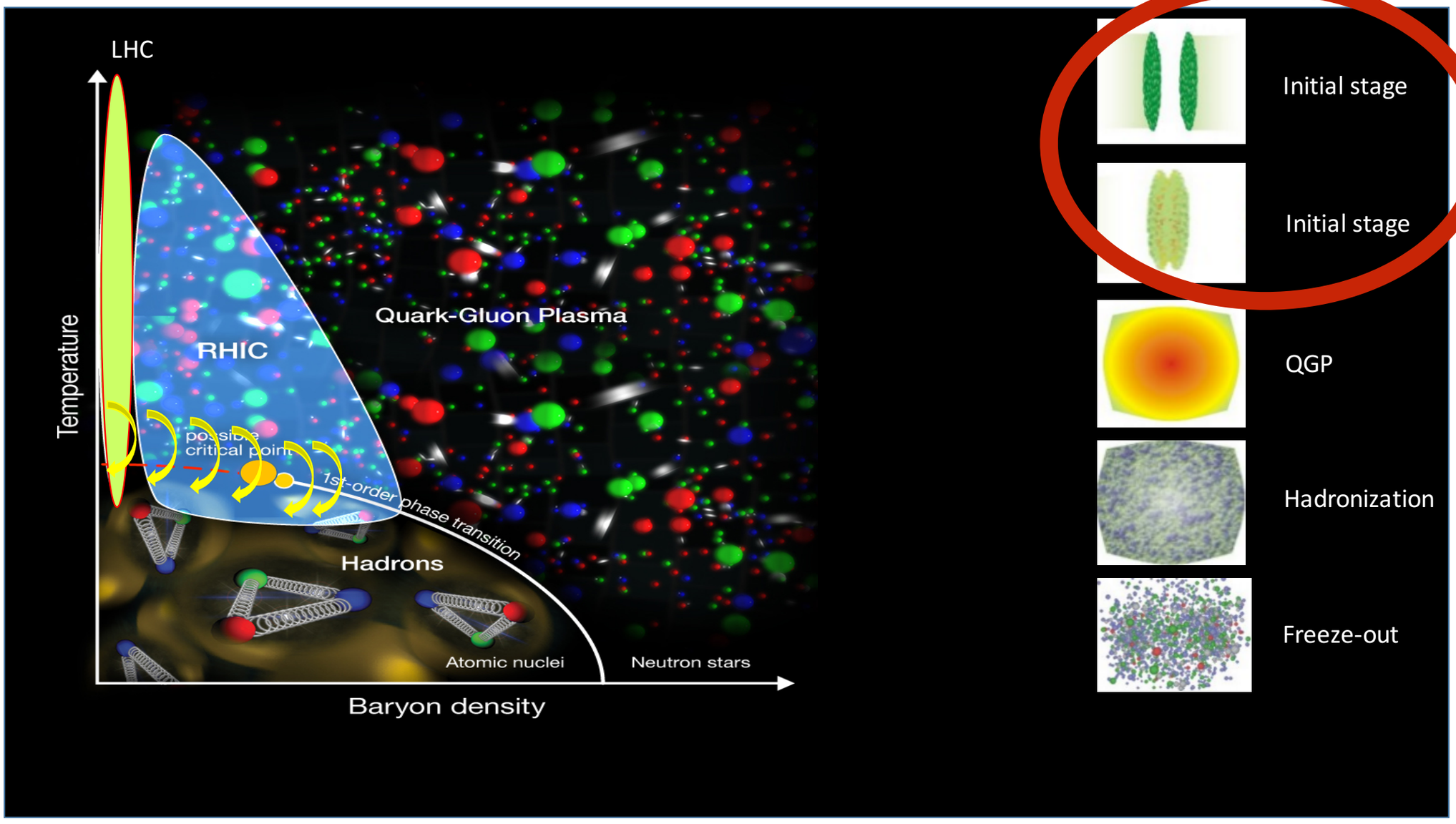
Snowmass 2021 QCD and forward Physics working group

July 15, 2020

Photon-photon, photon-p, photon-A collider



Probing QCD matter with UPCs



Initial state Physics of the proton and nuclei

Nuclear structure at high energies

Gluon saturation phenomena, etc

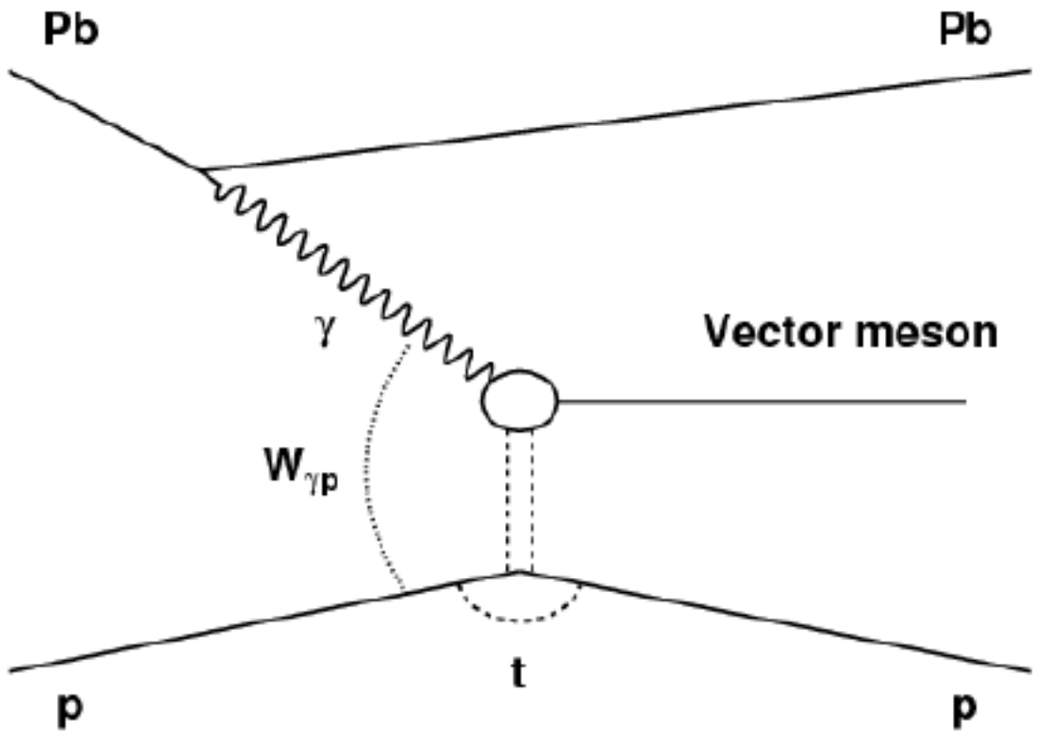
Plan of this talk

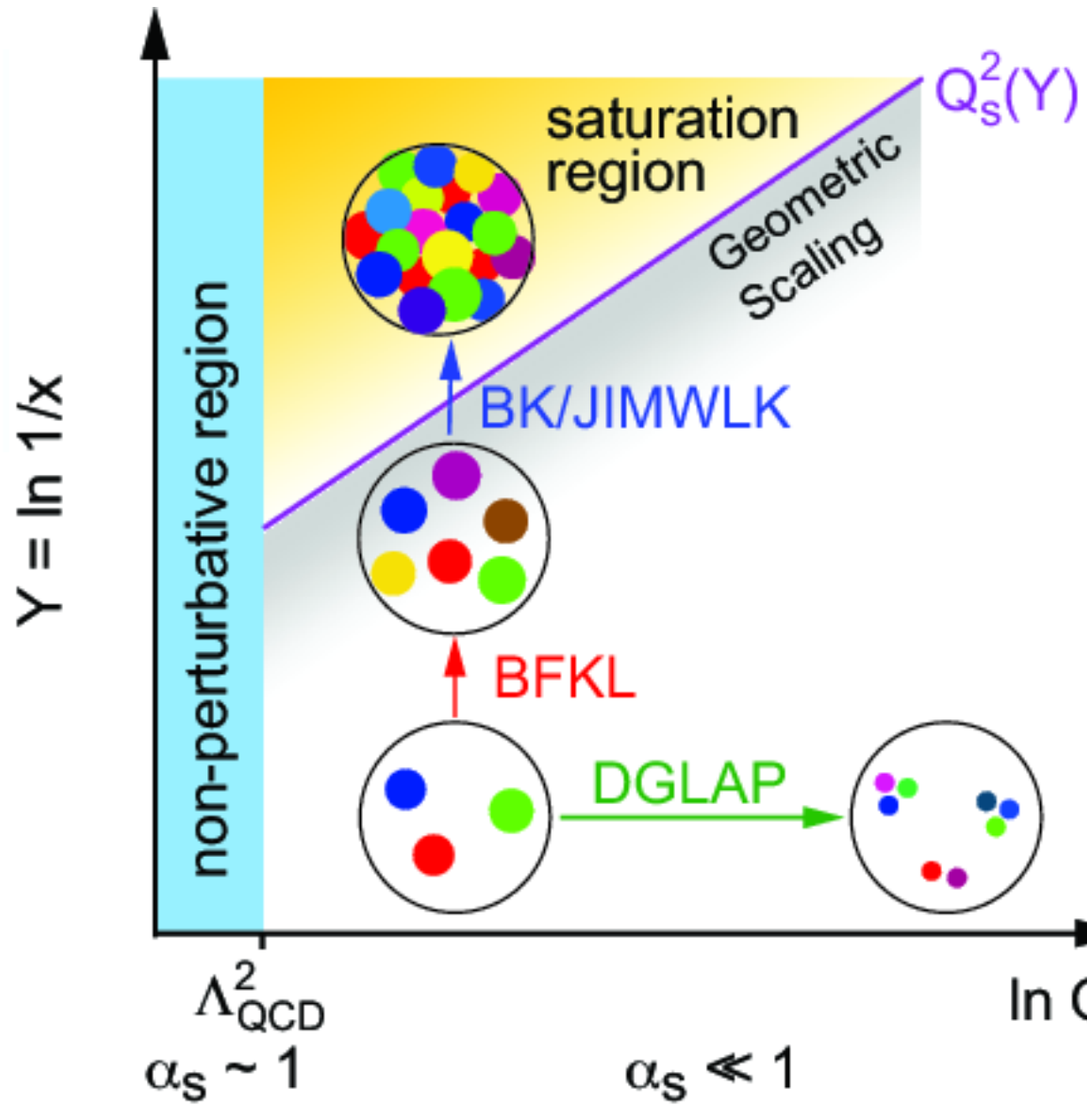
- **First discussion on physics prospects for UPCs for Snowmass 2021**

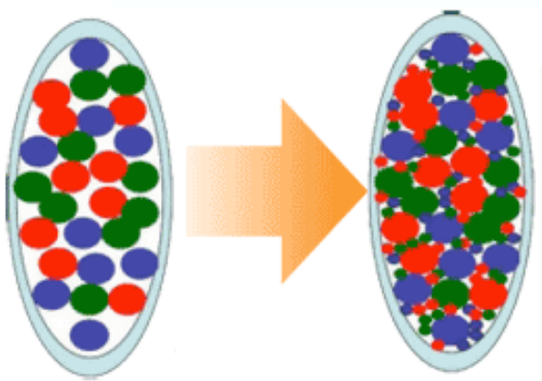
  - Just selected theory/pheno and experimental results for now, to kick off the conversation here - mainly from LHC energies, but results at HERA and RHIC also interesting

- **Together with various theorists and experimentalist, we plan to prepare a paper on UPCs - covering various topics and physics questions and new ideas for Snowmass 20201**

Exclusive VM photoproduction







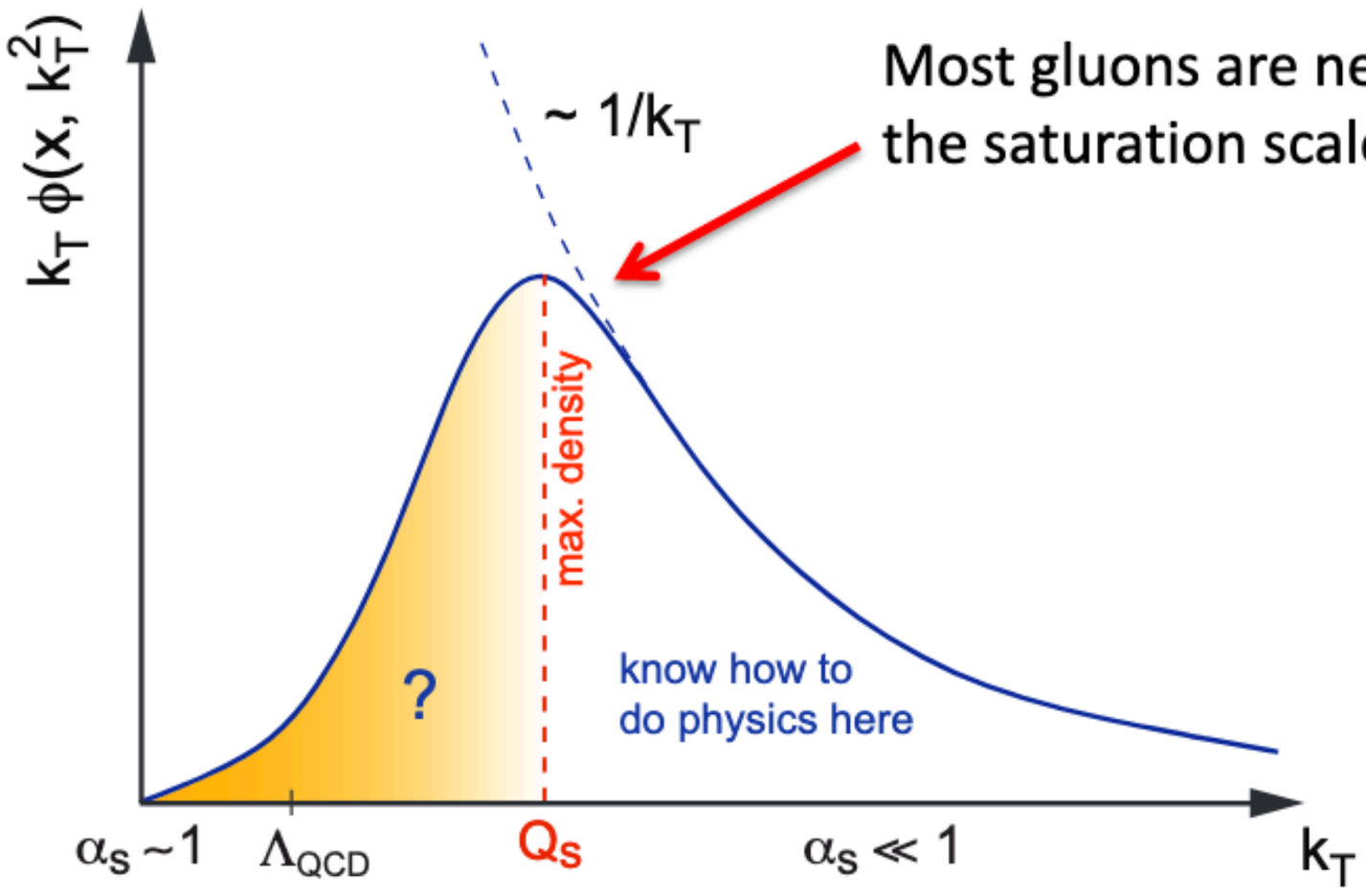
The energy dependance of the cross section

Suggested as a signature of gluon saturation

Typical gluon "size"

From Yuri Kovchegov
Snowmass 2021
July 2020

Number of gluons (gluon TMD) times the phase space



Gluon "size" = 1/transverse momentum
= $1/Q_s$

momentum transverse to the beam

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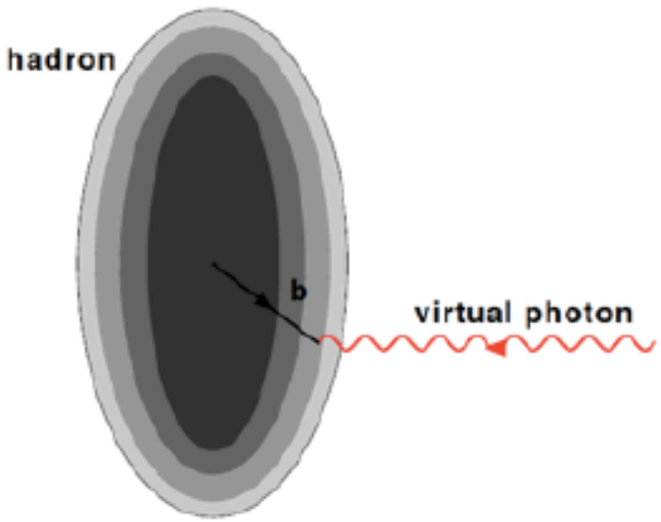
t-distribution

- t-differential measurements give a gluon tranverse mapping of the hadron/ nucleus.

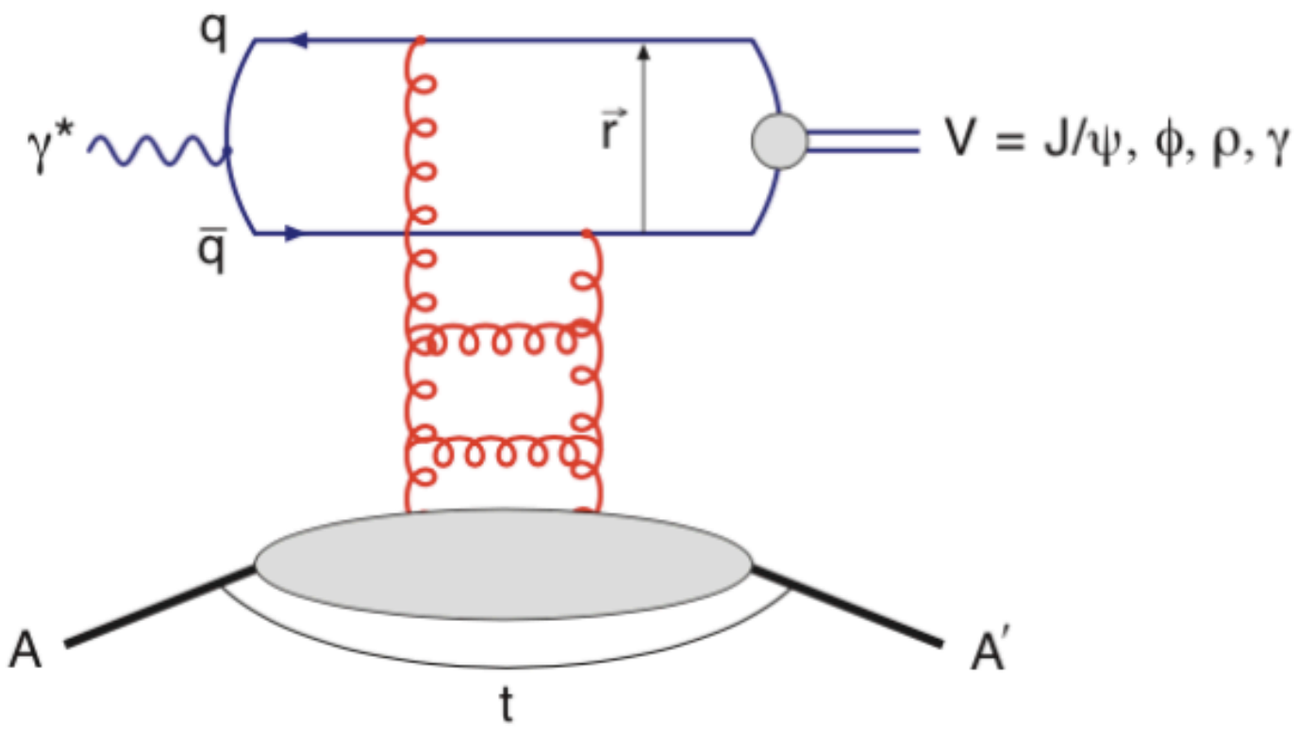


The study of the t-distribution

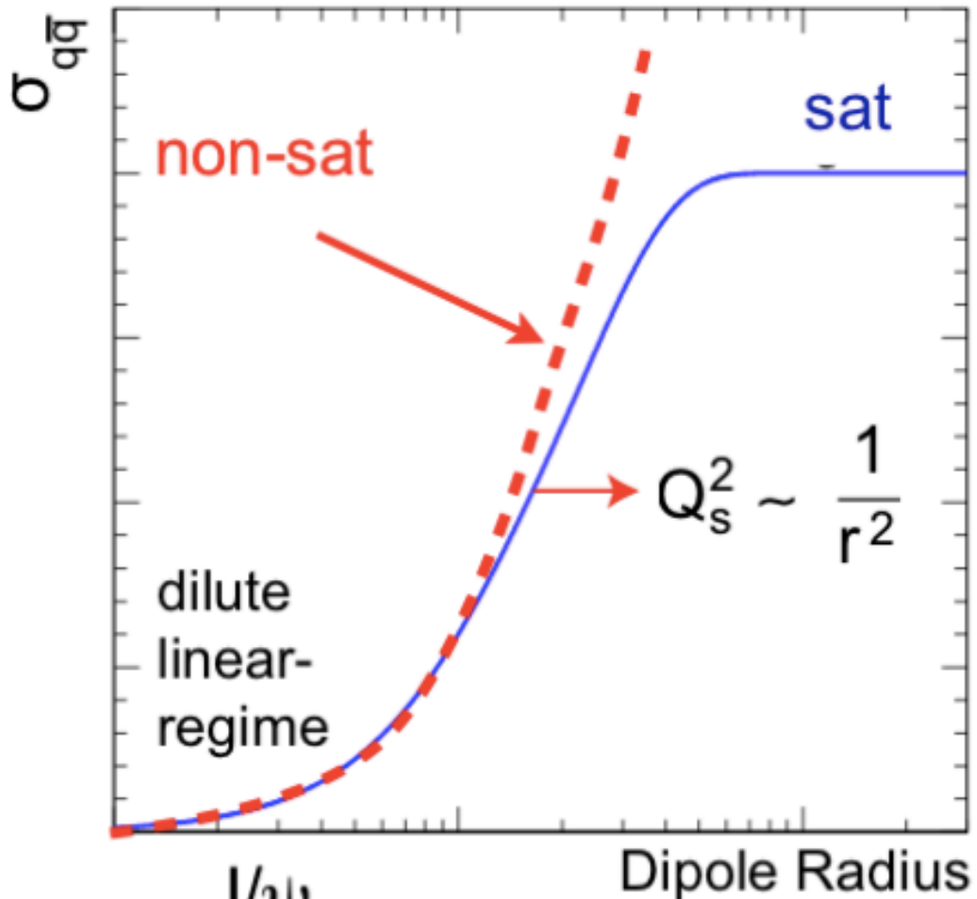
Appearance and location of diffractive dips: signature of gluon saturation

Here:

$$t = (p_A - p_{A'})^2 = (p_{\mathrm{VM}} + p_{e'} - p_e)^2$$



Dipole Cross-Section:



small size (J/Ψ): cuts off saturation region
large size (φ,ρ, ...): "sees more of dipole amplitude"
→ more sensitive to saturation

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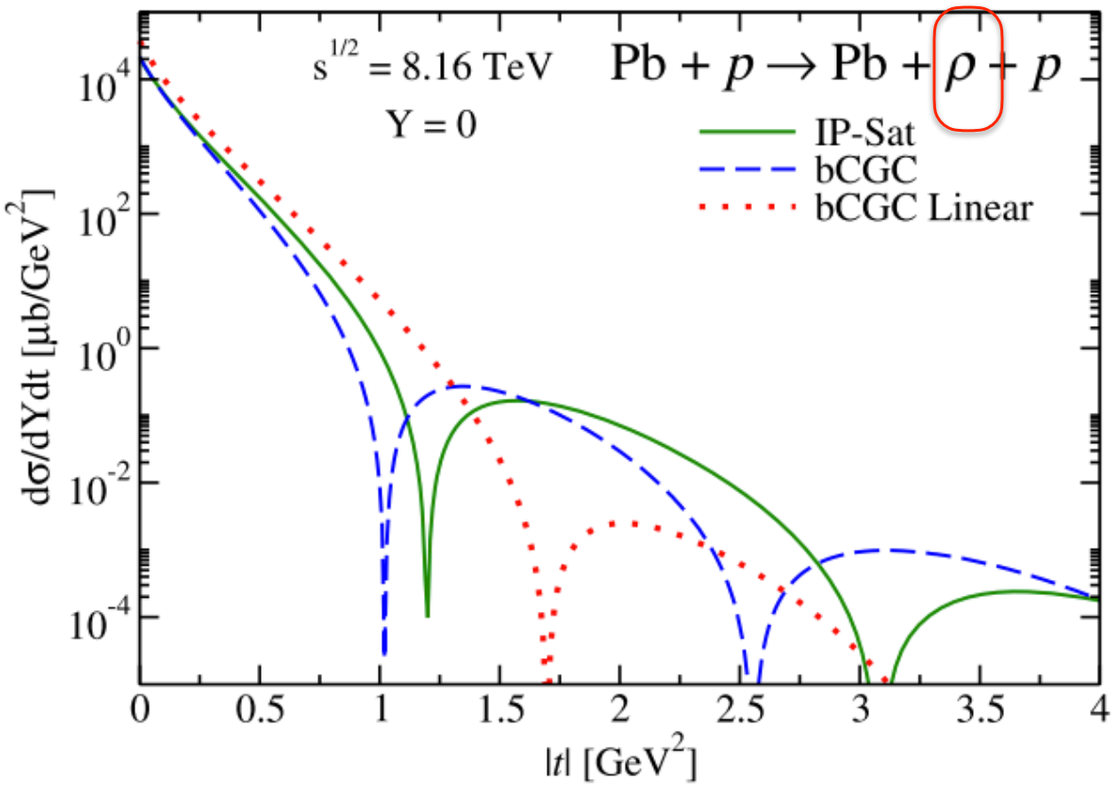
From T. Ullrich, IS 2017

t-distribution
Exclusive VM in γp

V. Goncalves, et al.
Phys. Lett. B791 (2019) 299-304

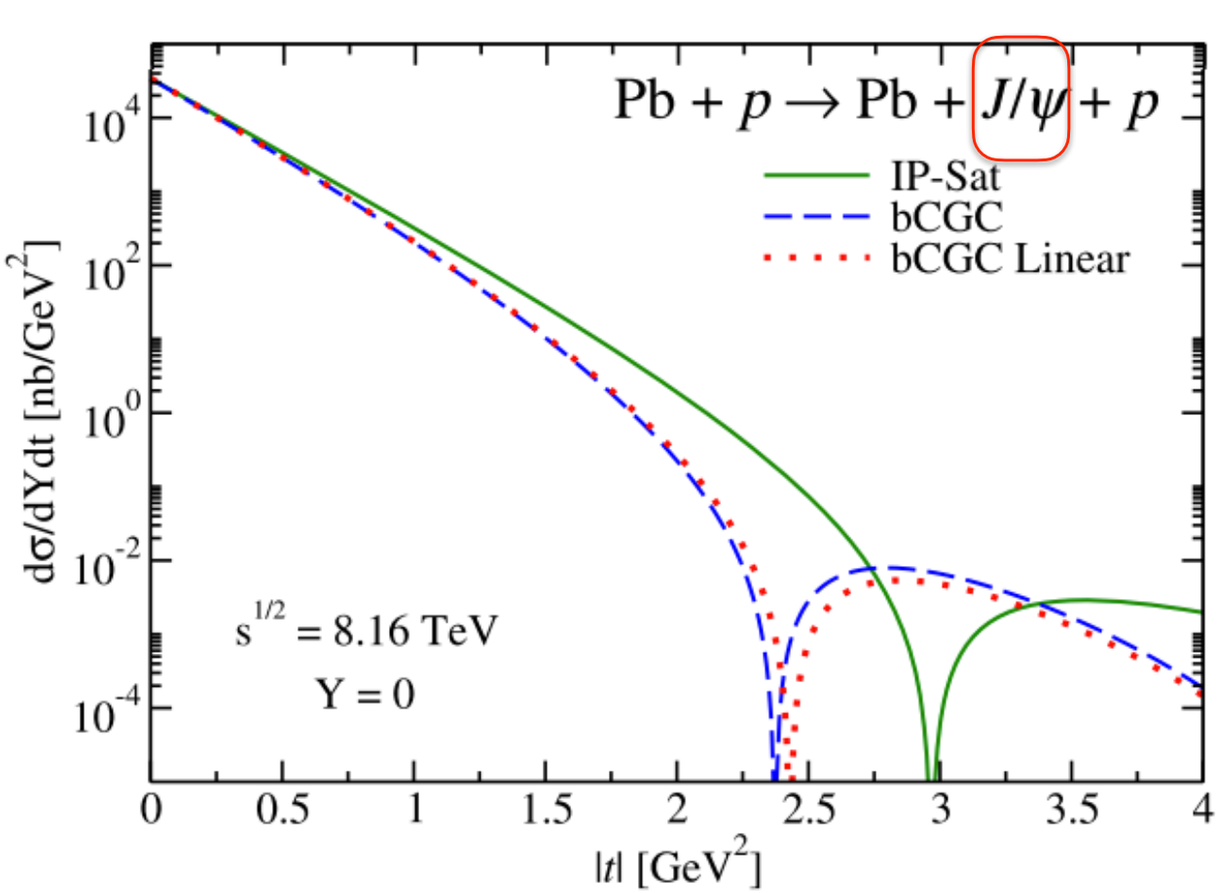


Location of the Diffractive dips: Different for IP-Sat and bCGC

Energy dependence of the t-distribution: onset of gluon saturation

Signature of gluon saturation

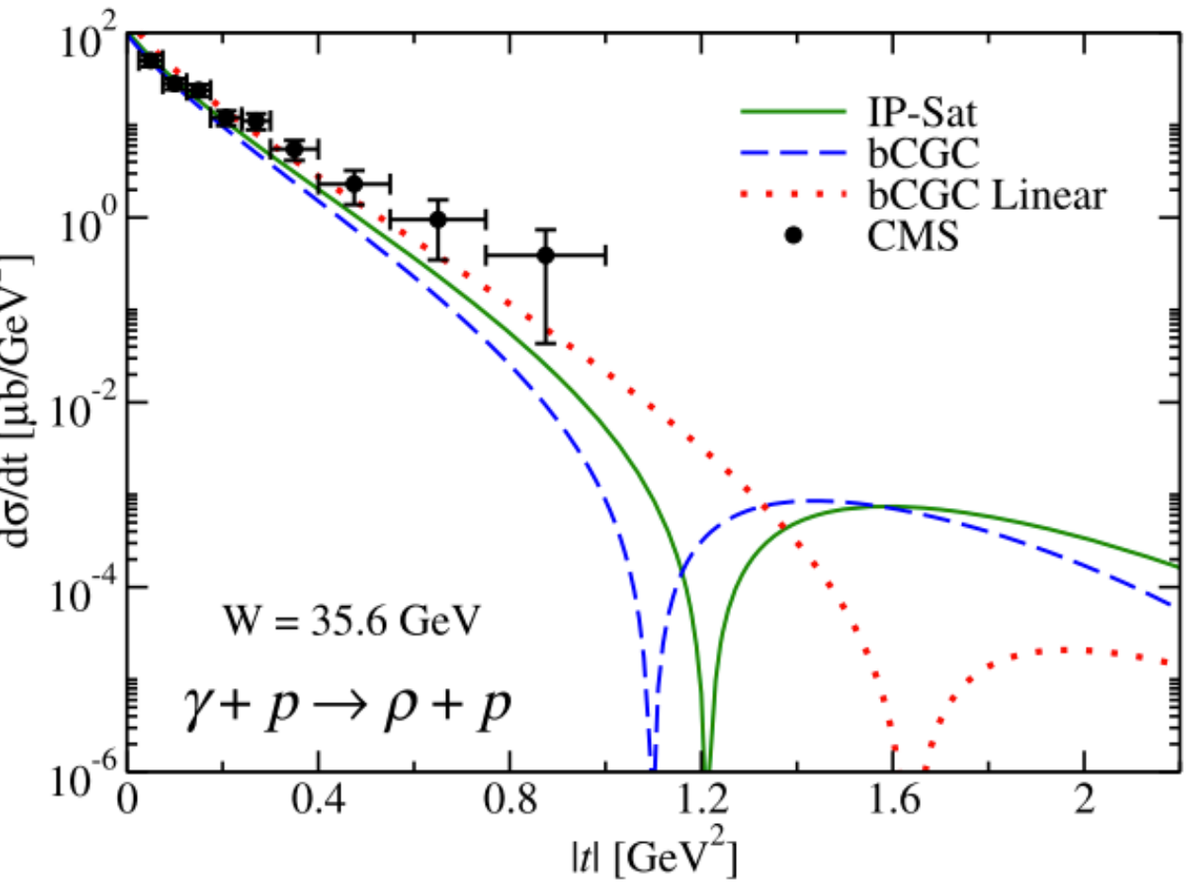
Study of ρ^0 is very promising since diffractive dips expected at lower t values

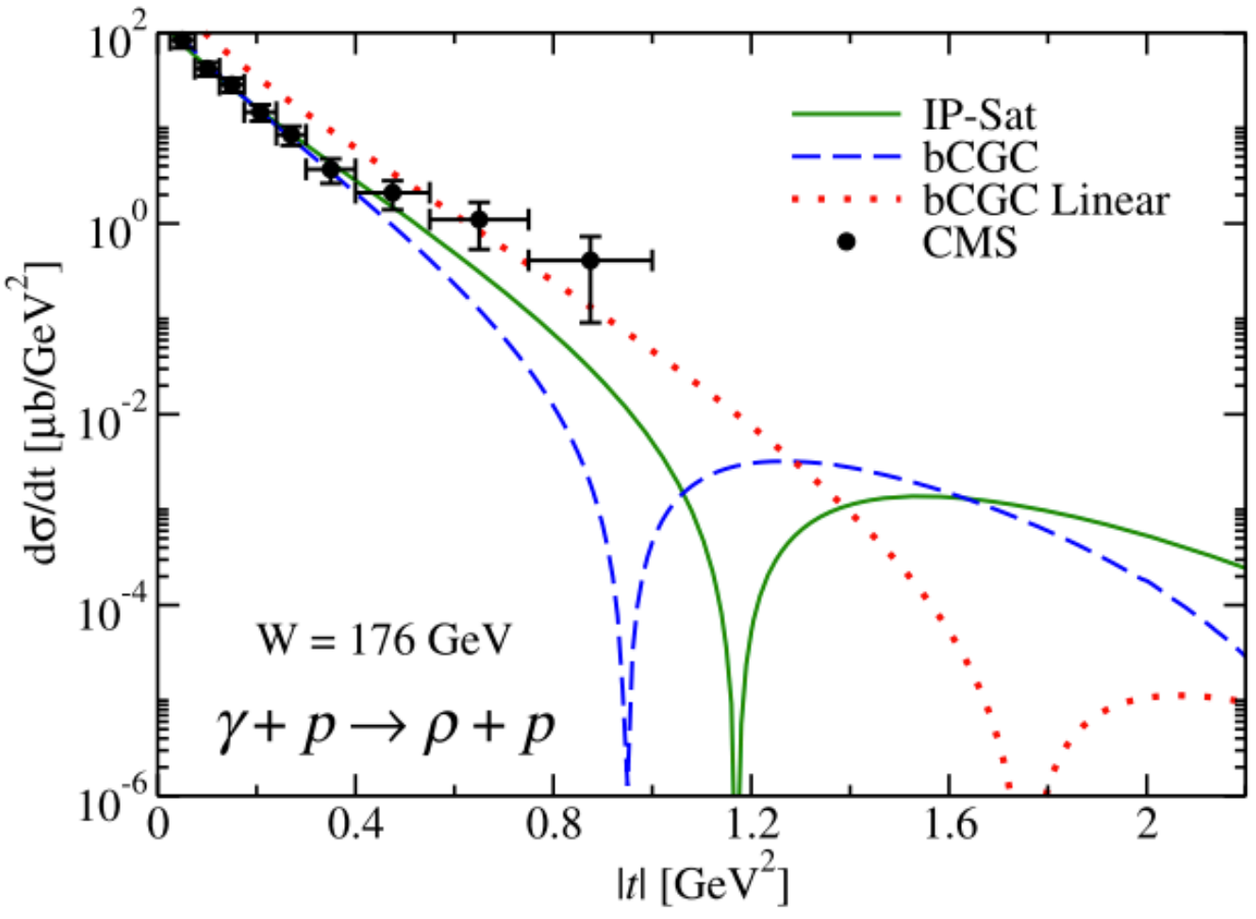


Exclusive ρ^0 in γp

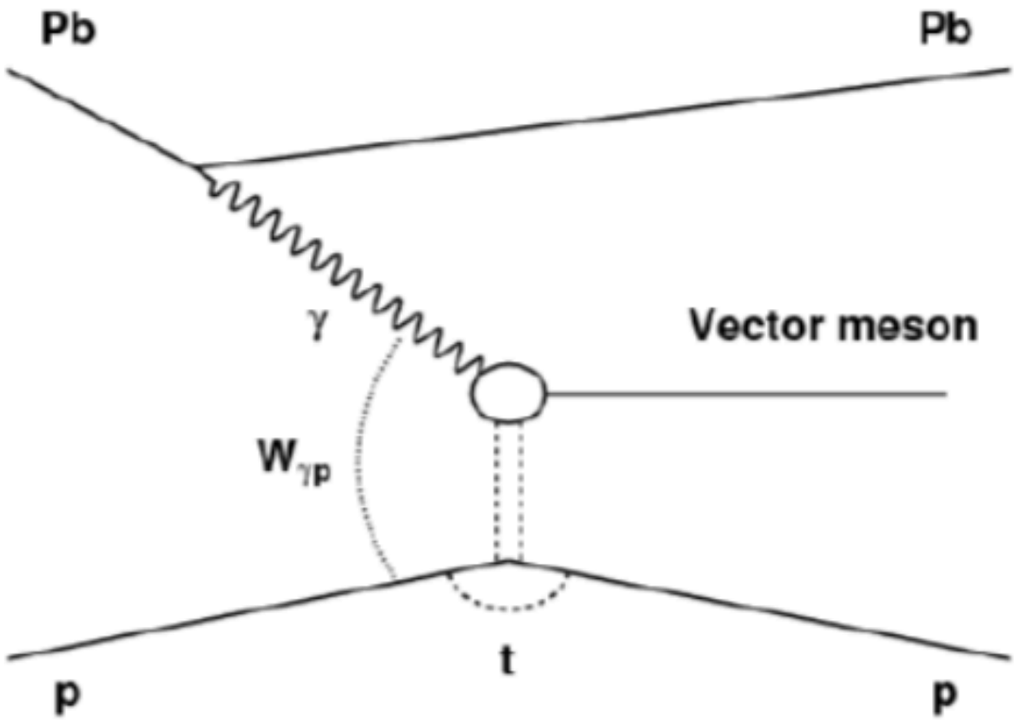
V. Goncalves, et al.
Phys. Lett. B791 (2019) 299-304

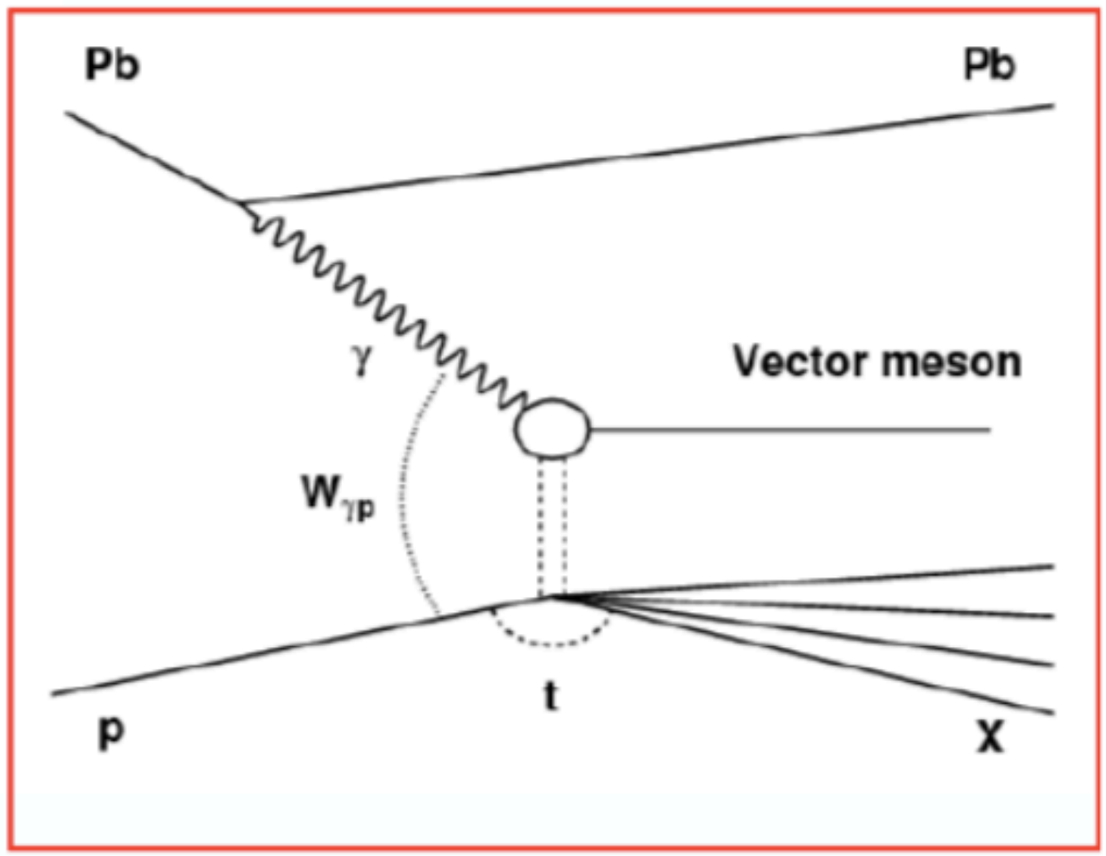
High energy points !





Dissociative/Incoherent production

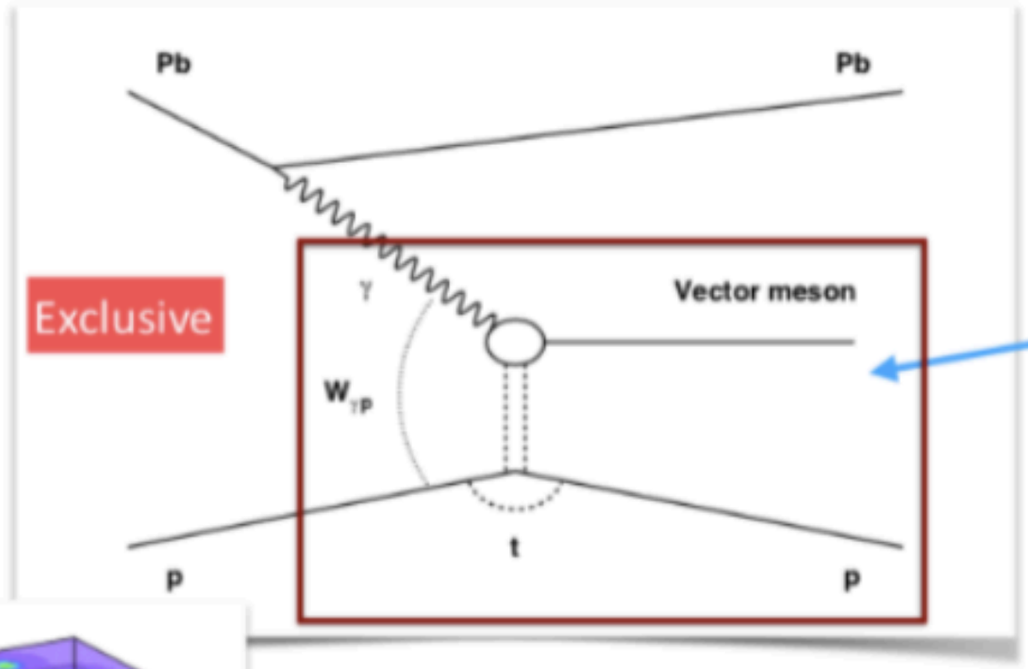


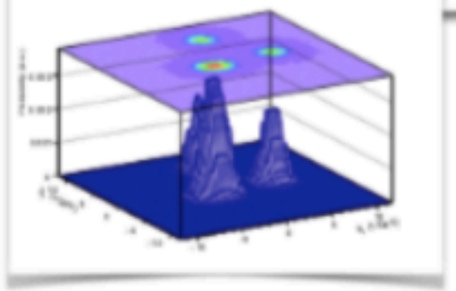


Exclusive and dissociative production

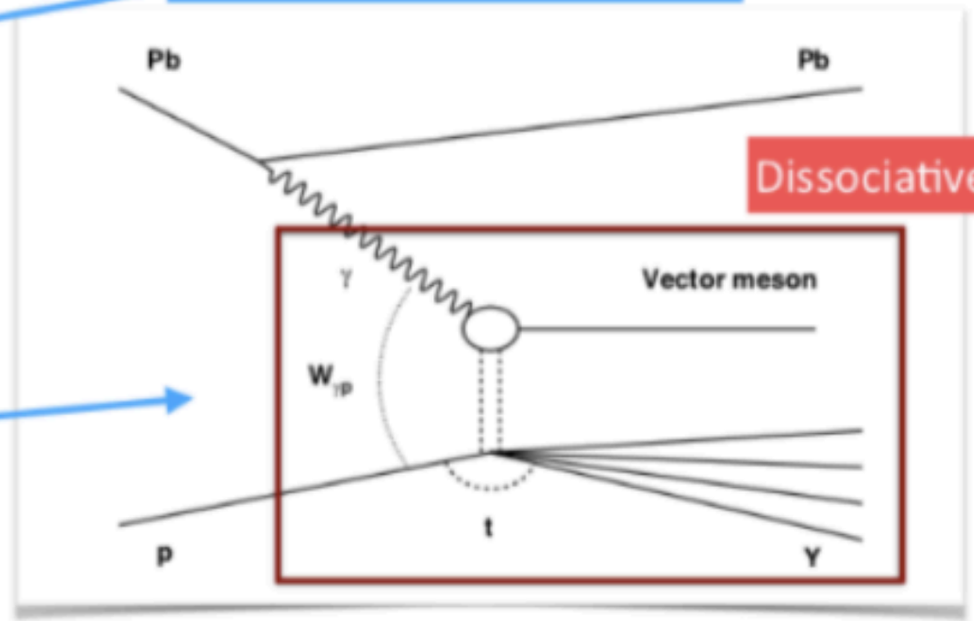
$$\frac{d\sigma(\gamma p \to \mathrm{J}/\psi p)}{dt} = \frac{R_g^2}{16\pi}\left|\left\langle A(x,Q^2,\vec{\Delta})\right\rangle\right|^2$$

Average over configurations





Variance over configurations



$$\frac{d\sigma(\gamma p \to \mathrm{J}/\psi Y)}{dt} = \frac{R_g^2}{16\pi}\left(\left\langle\left|A(x,Q^2,\vec{\Delta})\right|^2\right\rangle - \left|\left\langle A(x,Q^2,\vec{\Delta})\right\rangle\right|^2\right)$$

Good,Walker , PR 120 (1960) 1857

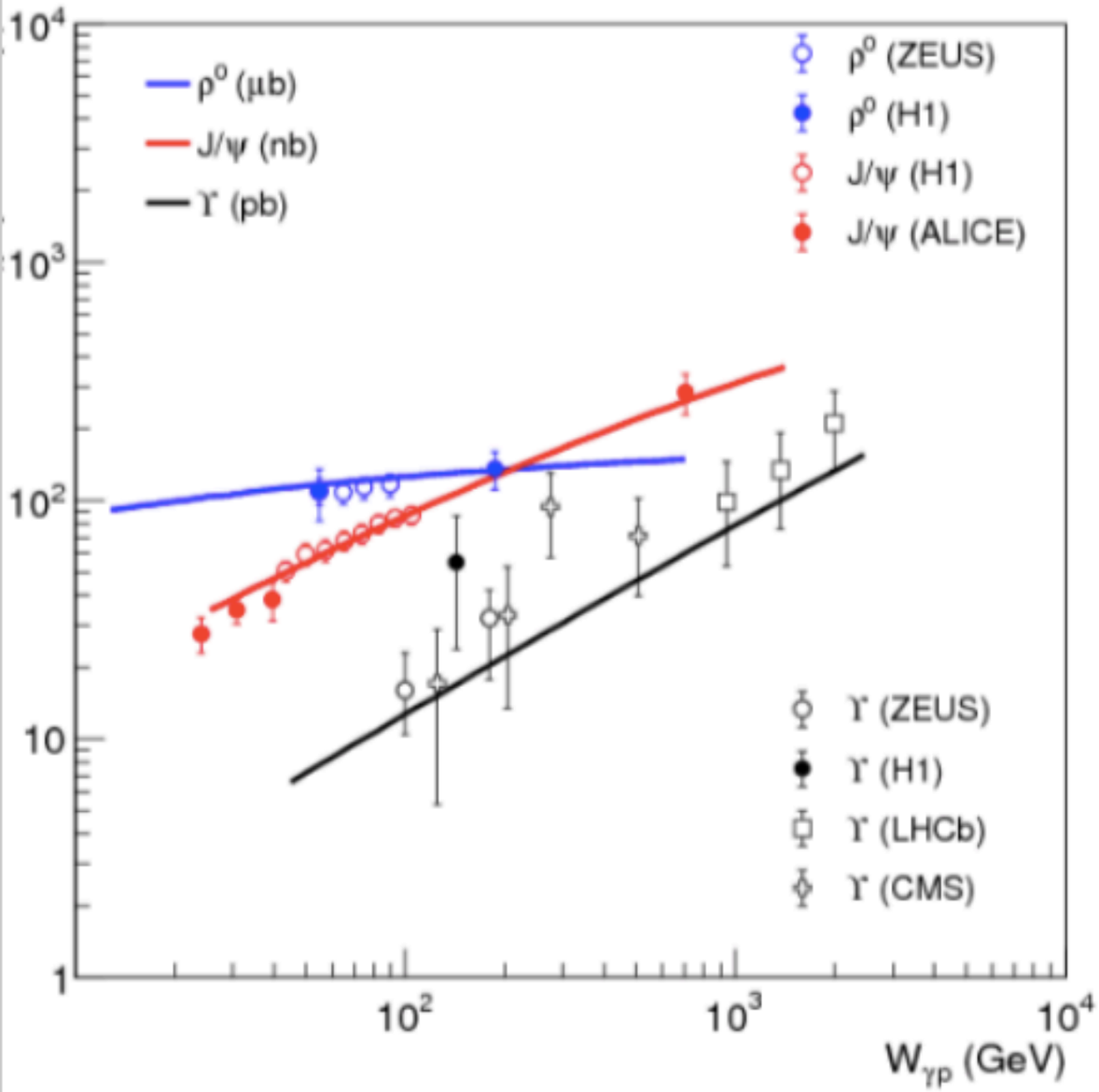
Miettinen, Pumplin, PRD18 (1978) 1696

Mantysaari, Schenke, PRL 117 (2016) 052301

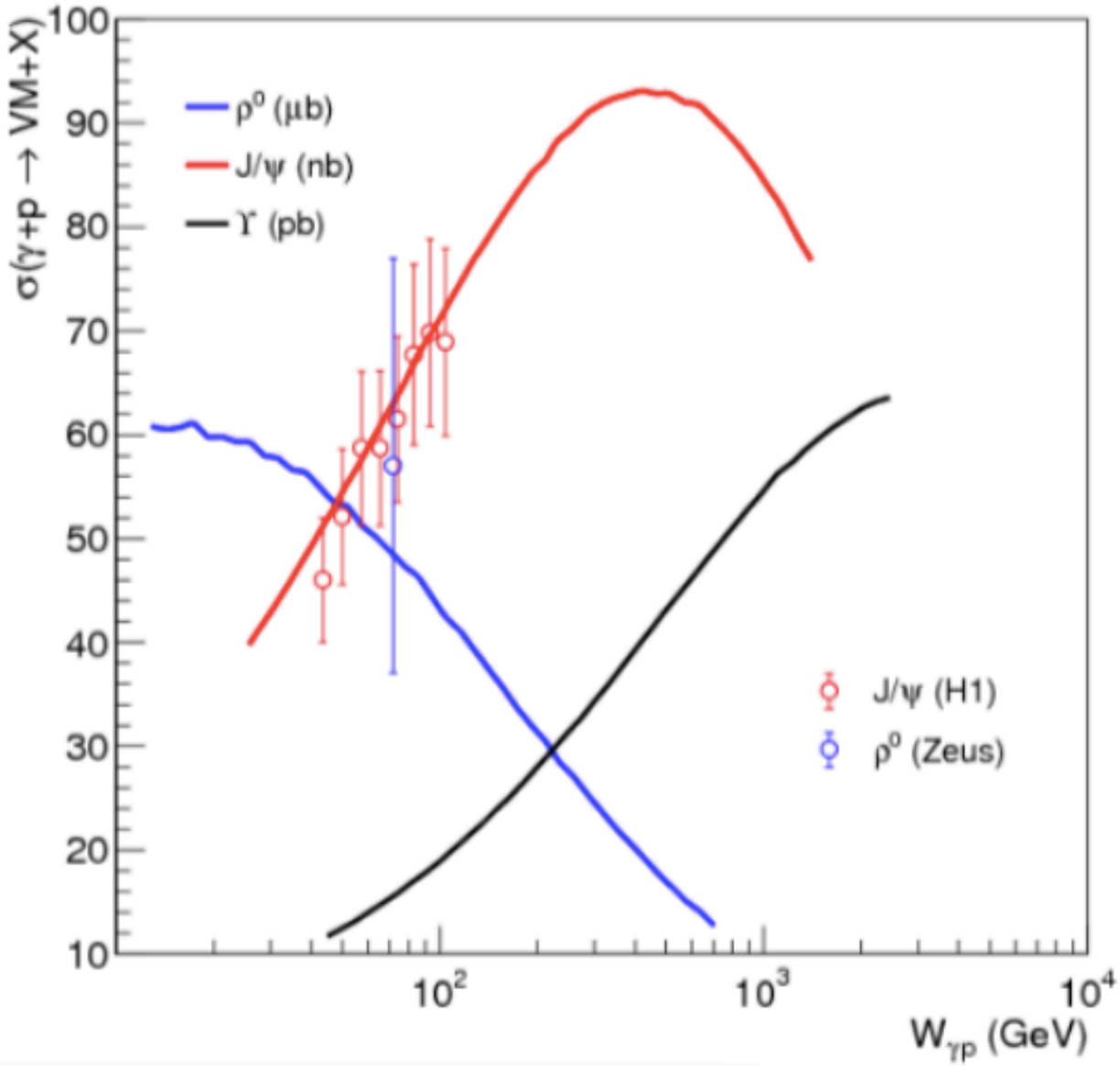
Mass dependance and energy dependance

Nucl. Phys. B934 (2018) 330-340

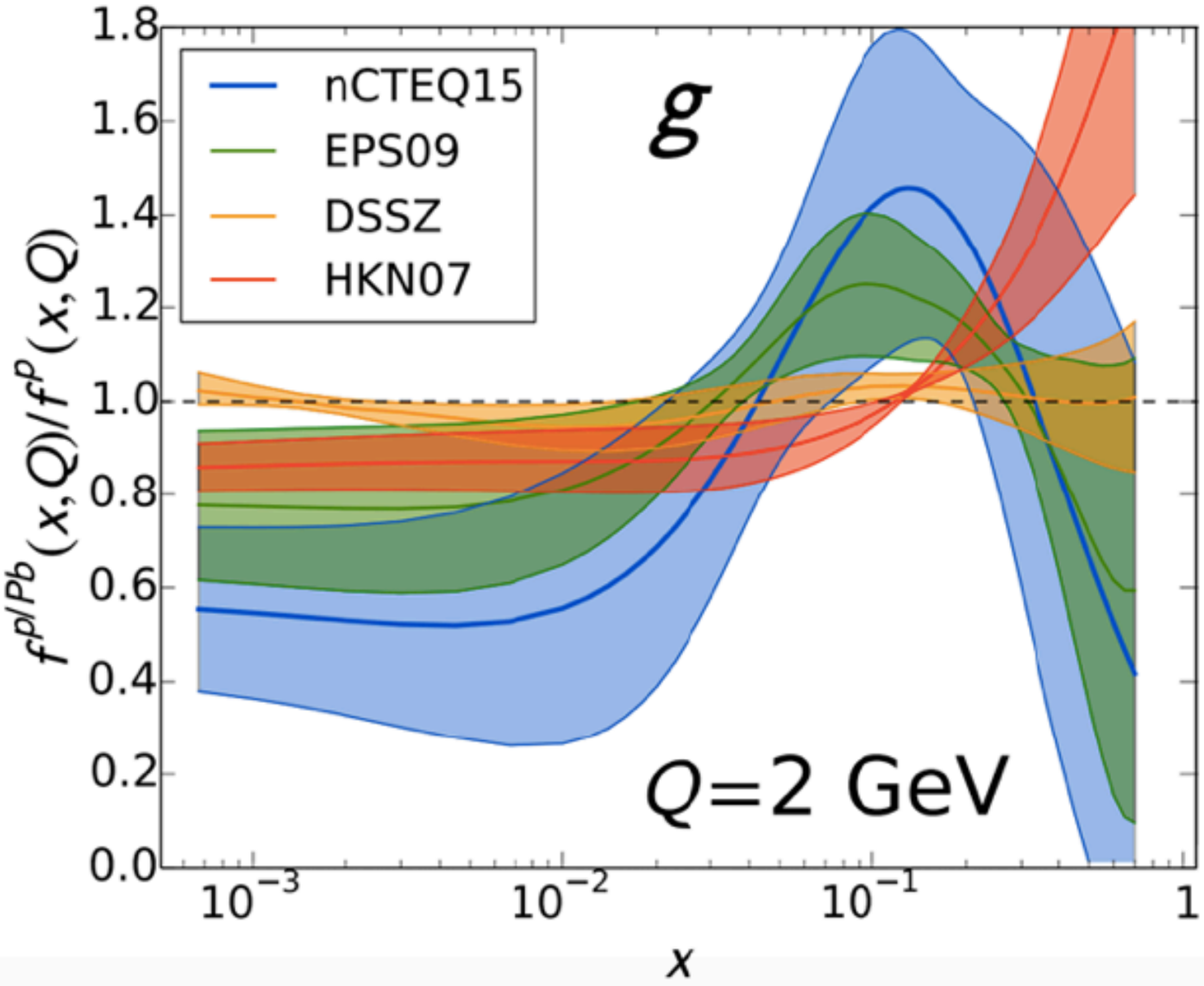
Exclusive



Dissociative

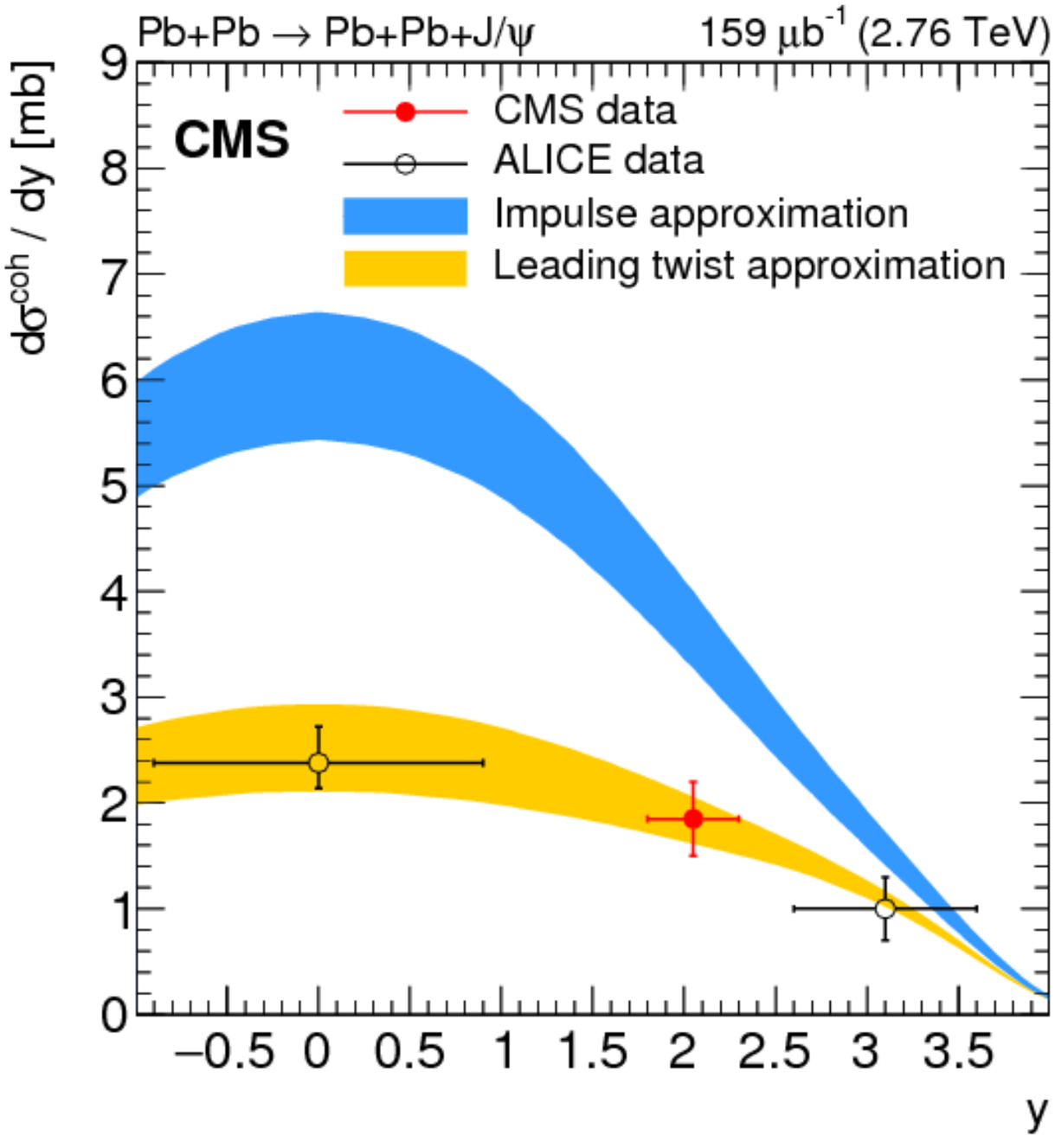


Nuclear gluon density



UPC studies provide the best information the community will get for the next 10 years before, the EIC turns on

Coherent J/ψ



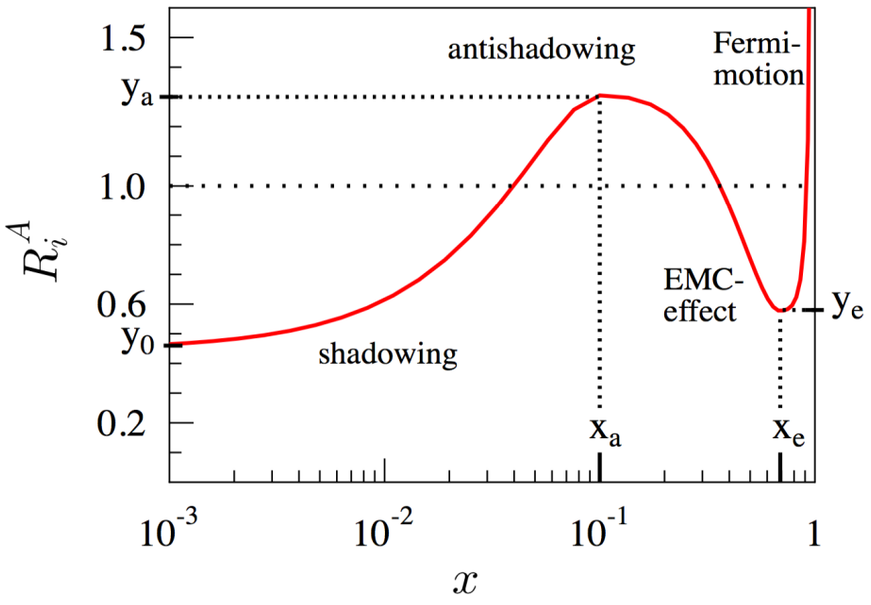
Phys. Lett. B772 (2017) 489-511

Model independent. Parametrization of exclusive J/Ψ data in gamma-proton

i.e. No nuclear effects

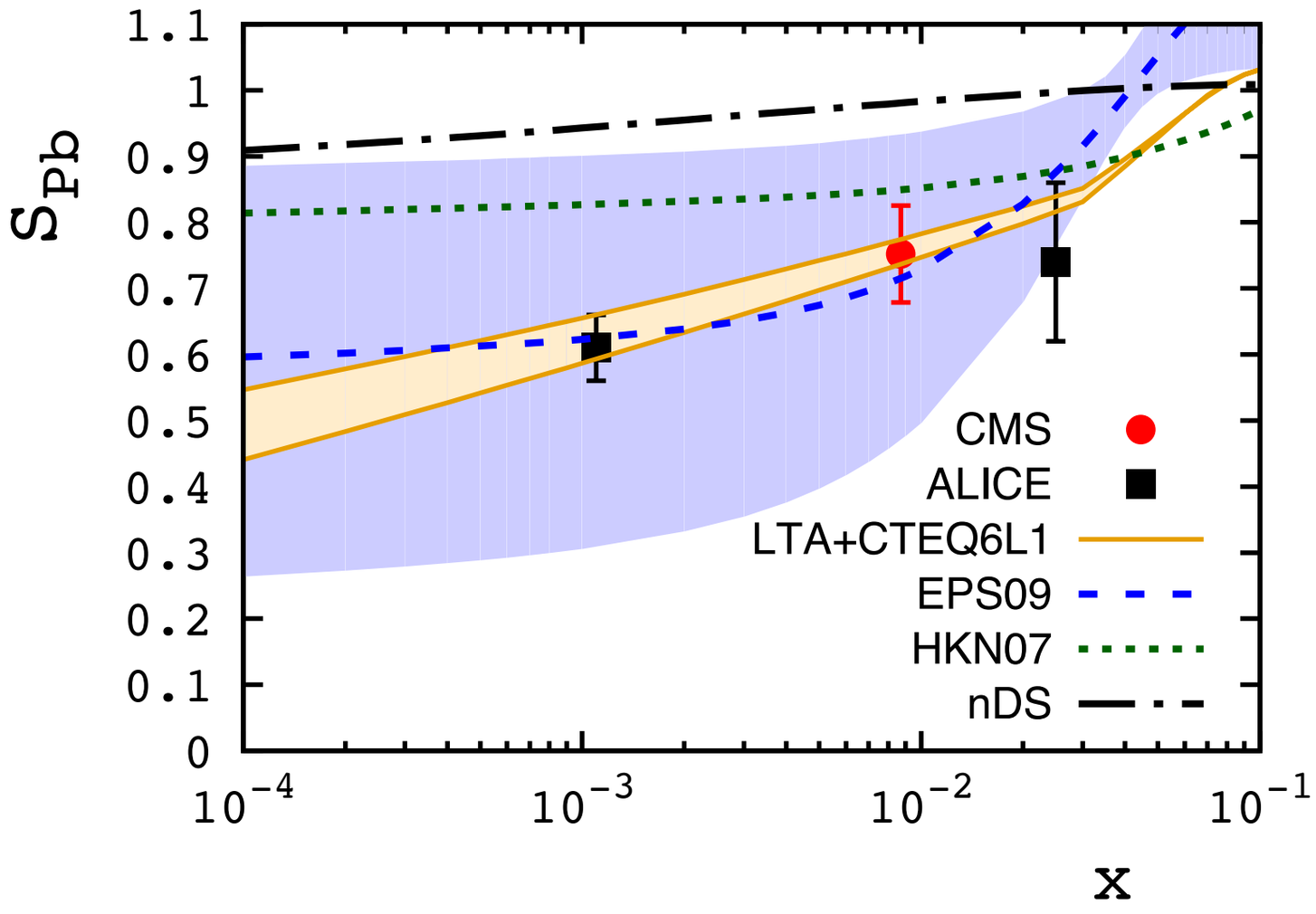
Experimental evidence of nuclear gluon shadowing

Nuclear effects at **Low x**



Coherent J/ψ photoproduction off Pb nuclei

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

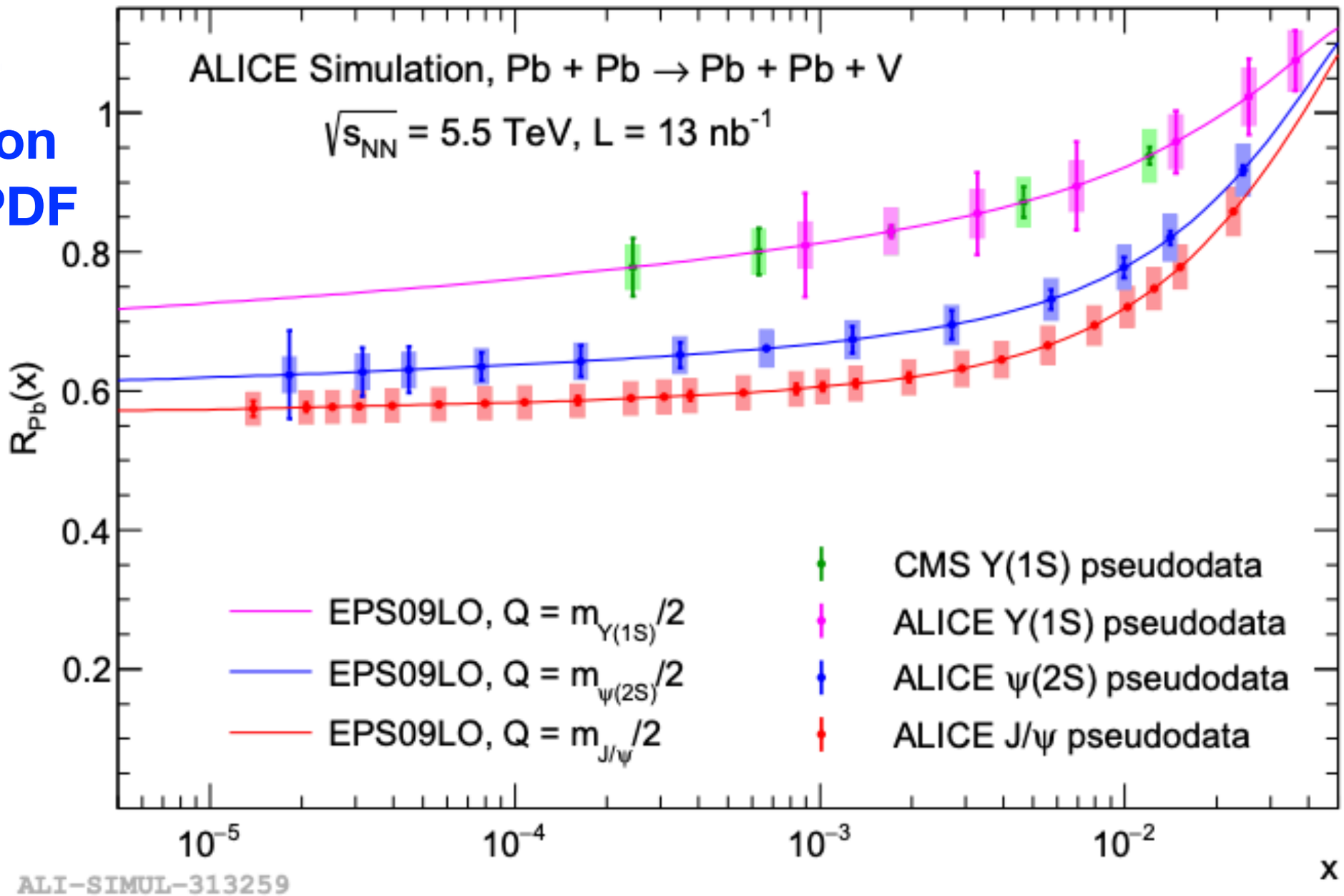


$$R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$

Nuclear gluon density: Future prospects

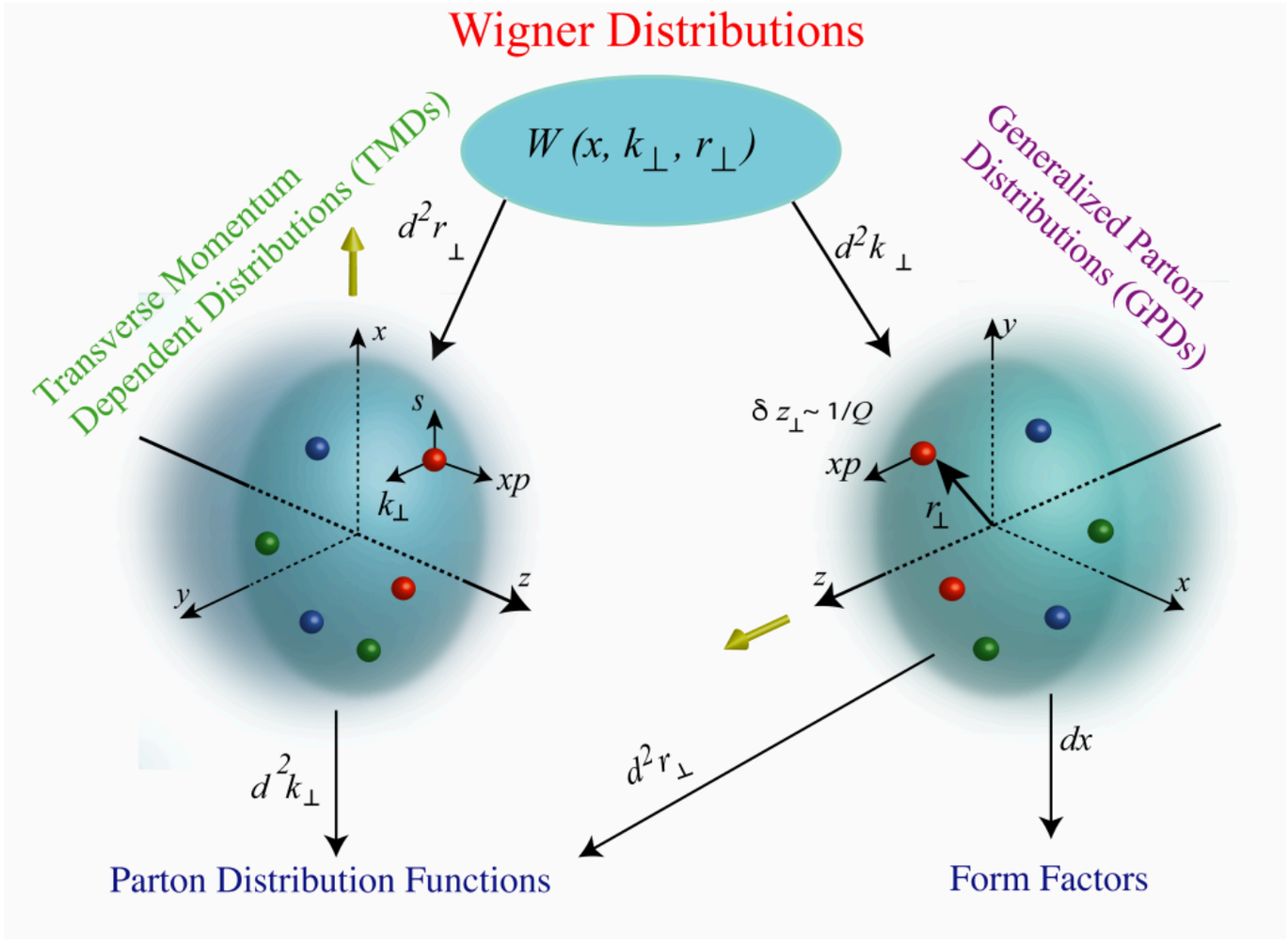
https://arxiv.org/pdf/1812.06772.pdf

Nuclear suppression factor ~ nPDF

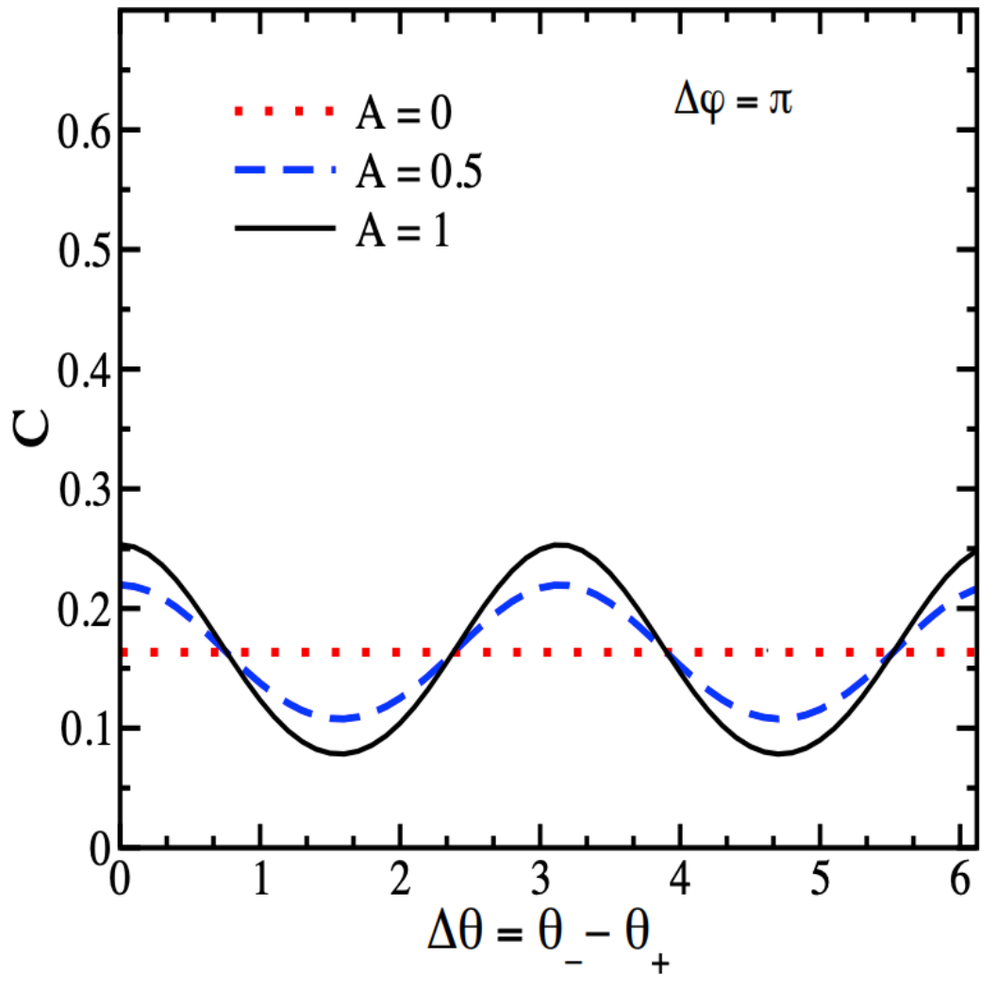


Bjorken-x

Beyond Nuclear PDFs

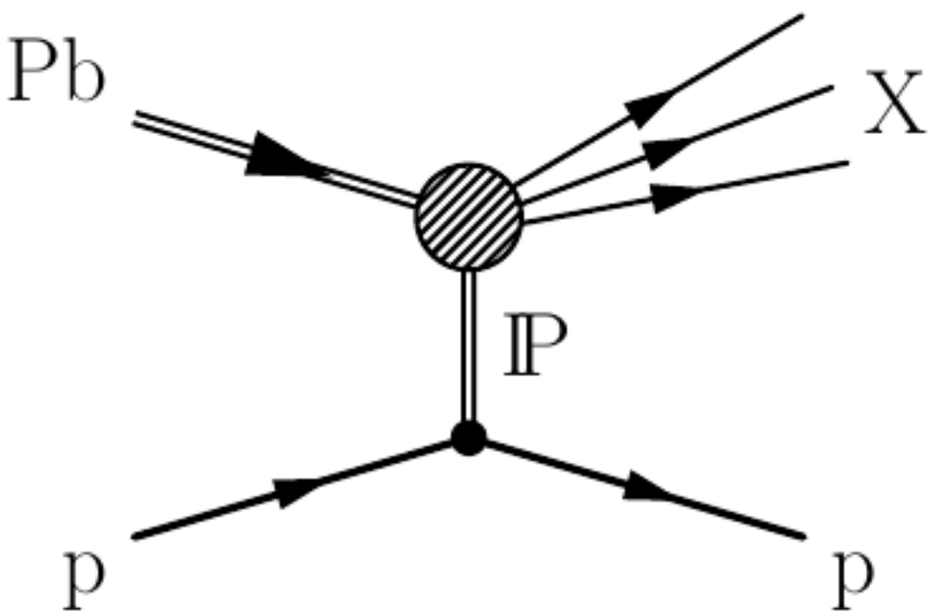


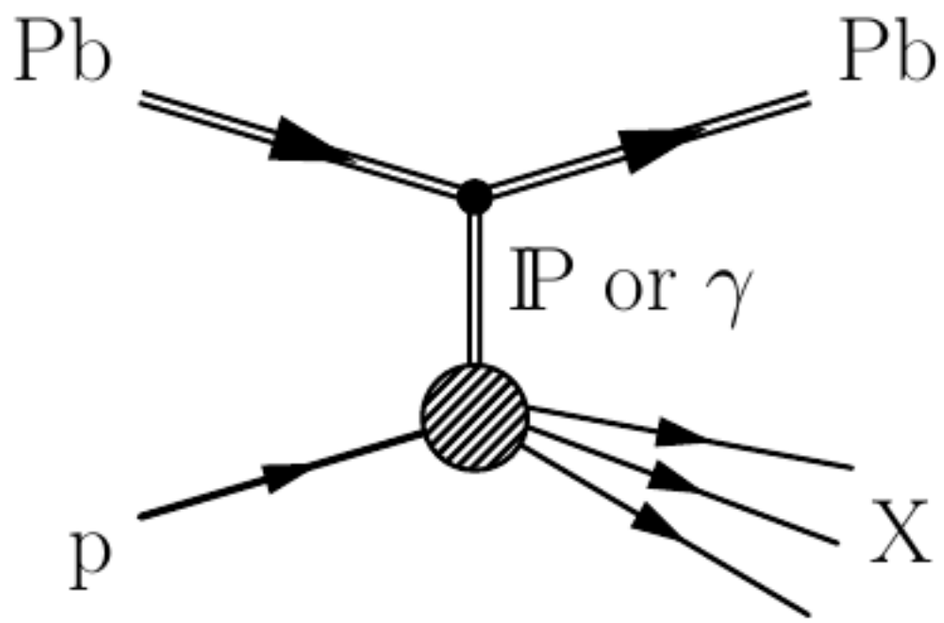
T. Altinoluk, N. Armesto, G. Beuf, and A. H. Rezaeian, Phys. Lett. B758, 373 (2016), arXiv:1511.07452 [hep-ph].



Exclusive dijets: Only process known to be directly sensitive to the gluon Wigner distribution

First diffraction measurement in heavy-ions & prospects for inclusive UPCs



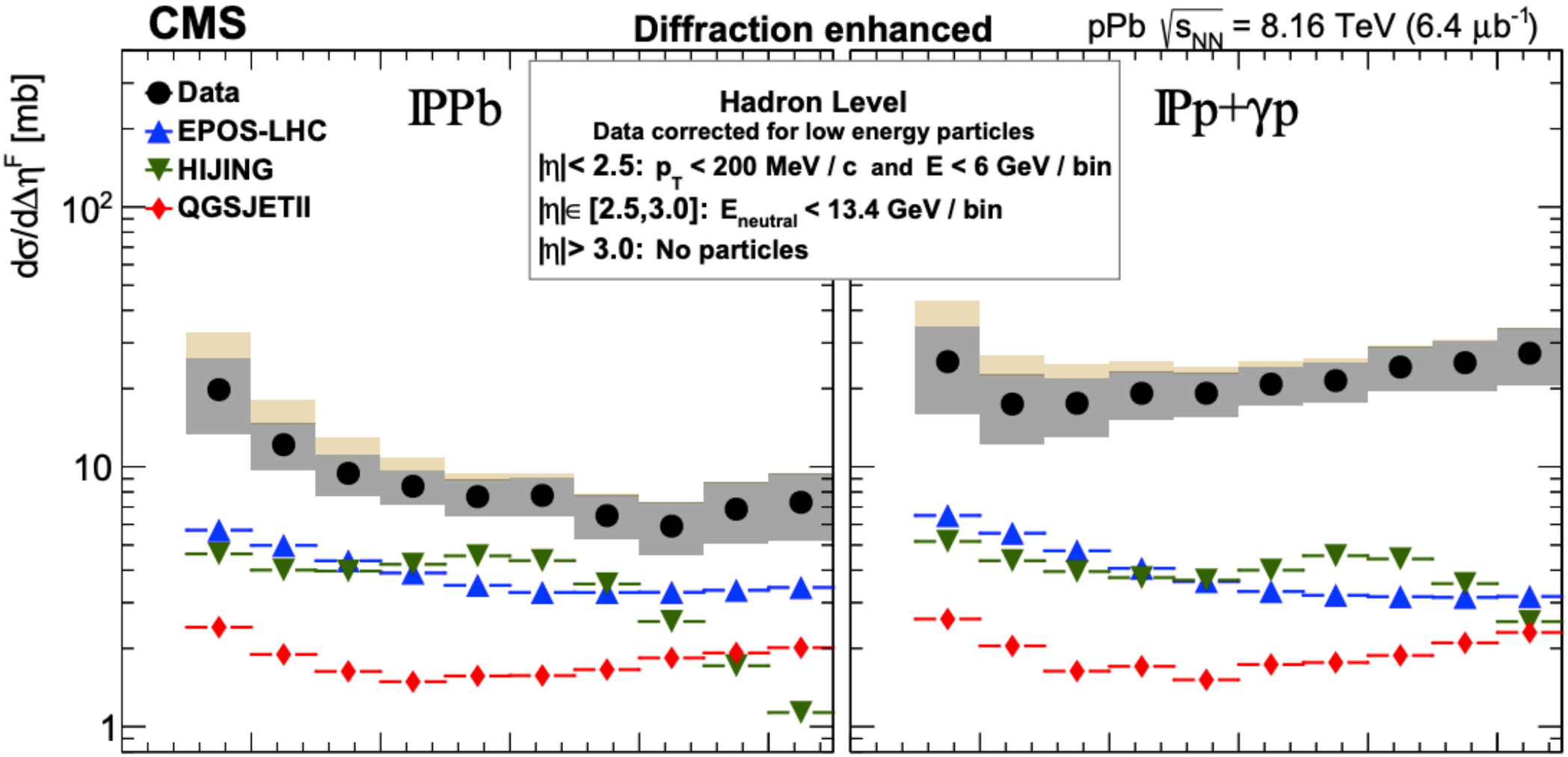


- **Useful for MC tuning of cosmic ray physics**
- **Models of multiplicity studies in pPb**
- **Diffraction is sensitive to gluon saturation**

First diffraction study in pPb

CMS HIN-18-019

Large rapidity gap technique



First Diffraction measurement in pPb
Observation of enhancement of photon-induced component vs. rapidity gap size

Summary

- **Discussed a selection of recent UPC results at LHC. Exploring fundamental questions on QCD and probing QCD matter. Today presented some ideas and selected results**
  - Studying UPC J/ψ in γPb already found evidence of nuclear gluon shadowing at low-x and Q_2
  - Energy dependent studies of the t-distribution of UPC ρ_0 in γp promising for determining the onset of gluon saturation
- **Future projects and new/novel ideas:**
  - **New detectors at LHC and RHIC**
  - **Novel physics analysis methods and techniques**
  - **Ideas future experiments, including at EIC**
- **Together with experimental and theoretical colleagues will start preparing a short paper on UPCs to be submitted to Snowmass 2021**