Discussion for the UPC contribution paper for Snowmass 2021 – EF06

Spencer Klein and Daniel Tapia Takaki

October 13, 2020

Plan of this talk

- Report on the submitted Letter of Interest by the community
  - Review recent results and discussion of prospects for future measurements
- Discussion for the outline of the contributed paper

arXiv:2009.03838 [hep-ph], September 8, 2020

Snowmass2021 - Letter of Interest

New opportunities at the photon energy frontier

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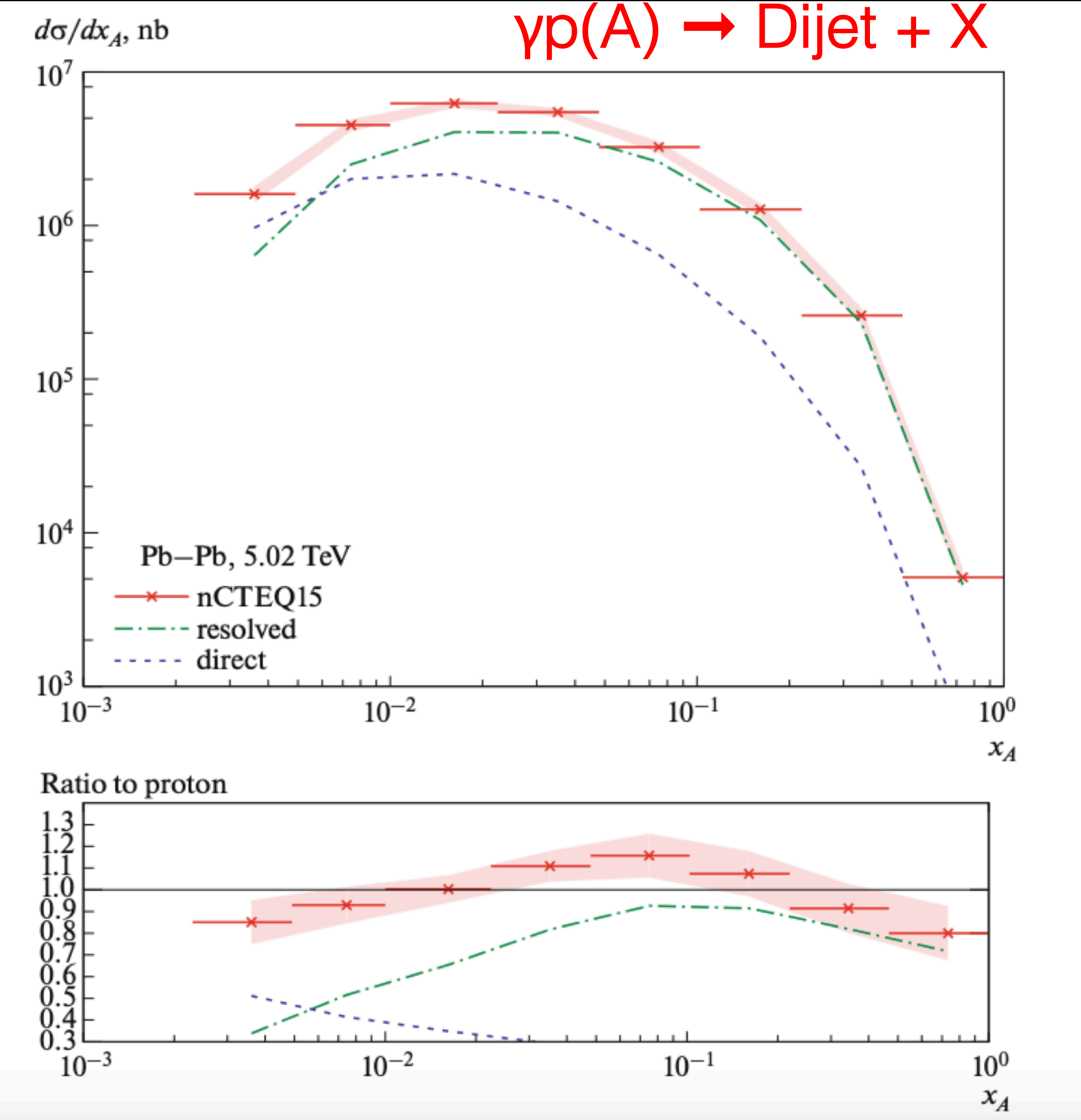
Structure of the LoI

Many of these topics discussed in
Z. Citron *et al.*
[Report from Working Group 5 : Future physics opportunities for high-density QCD at the LHC with heavy-ion and proton beams]

- UPCs as the energy frontier
- Photoproduction and parton distributions
- Light-by-light scattering, W pair and dilepton production
- Strong fields, quantum correlations and quantum tomography
- UPCs at the FCC and synergies with future colliders

Inclusive dijet photoproduction



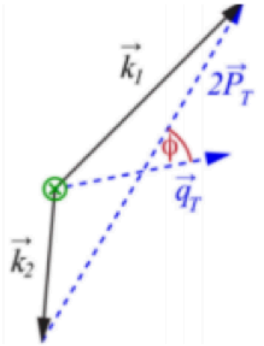
Fairly direct probe of the gluon distribution

NLO pQCD cross section of dijet photoproduction in PbPb UPCs & preliminary ATLAS data

V. Guzey Phys.Part.Nucl.Lett. 16 (2019) 5, 498-502

Exclusive dijets in UPC PbPb @5 TeV

(CMS-PAS-HIN-18-011)



Vector sum of 2 jets:

$$\vec{Q}_T = \vec{k_1} + \vec{k_2}$$

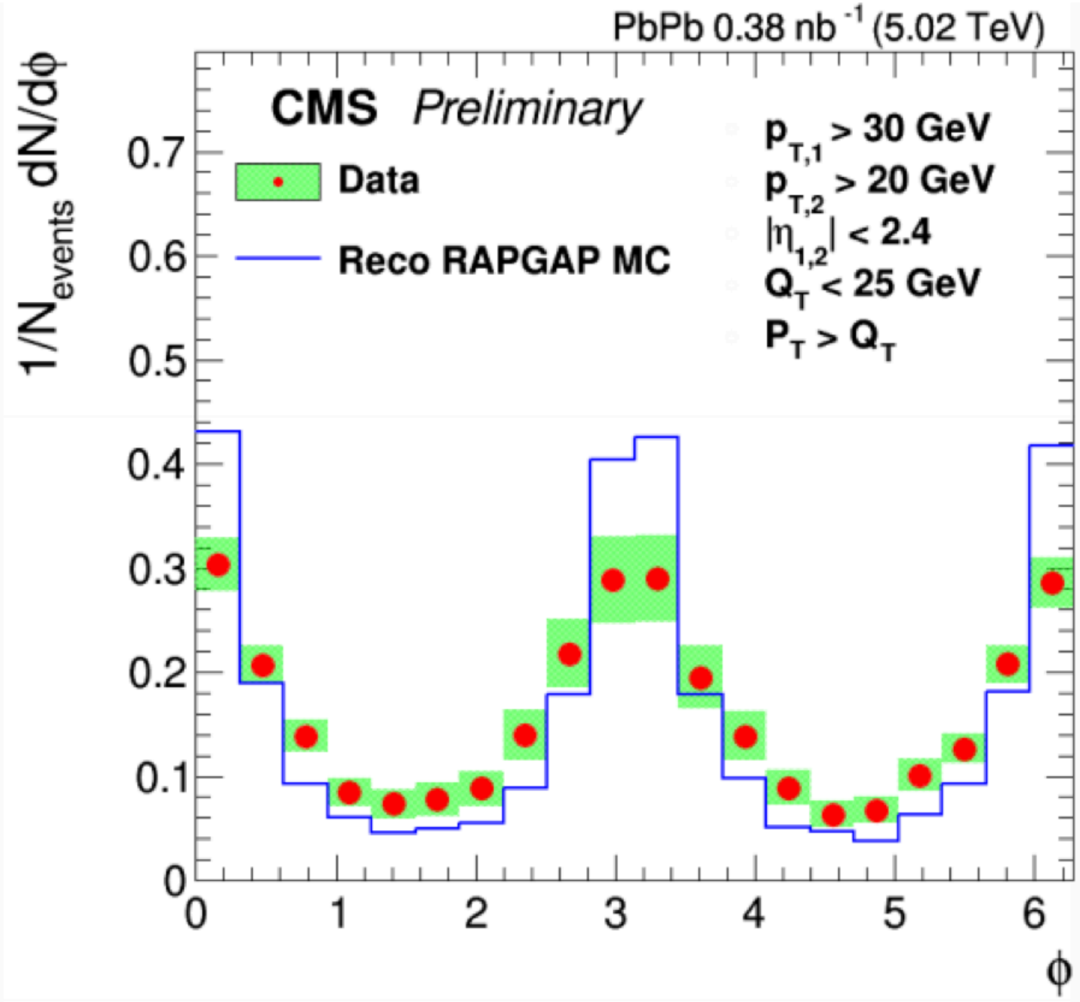
Vector difference of 2 jets

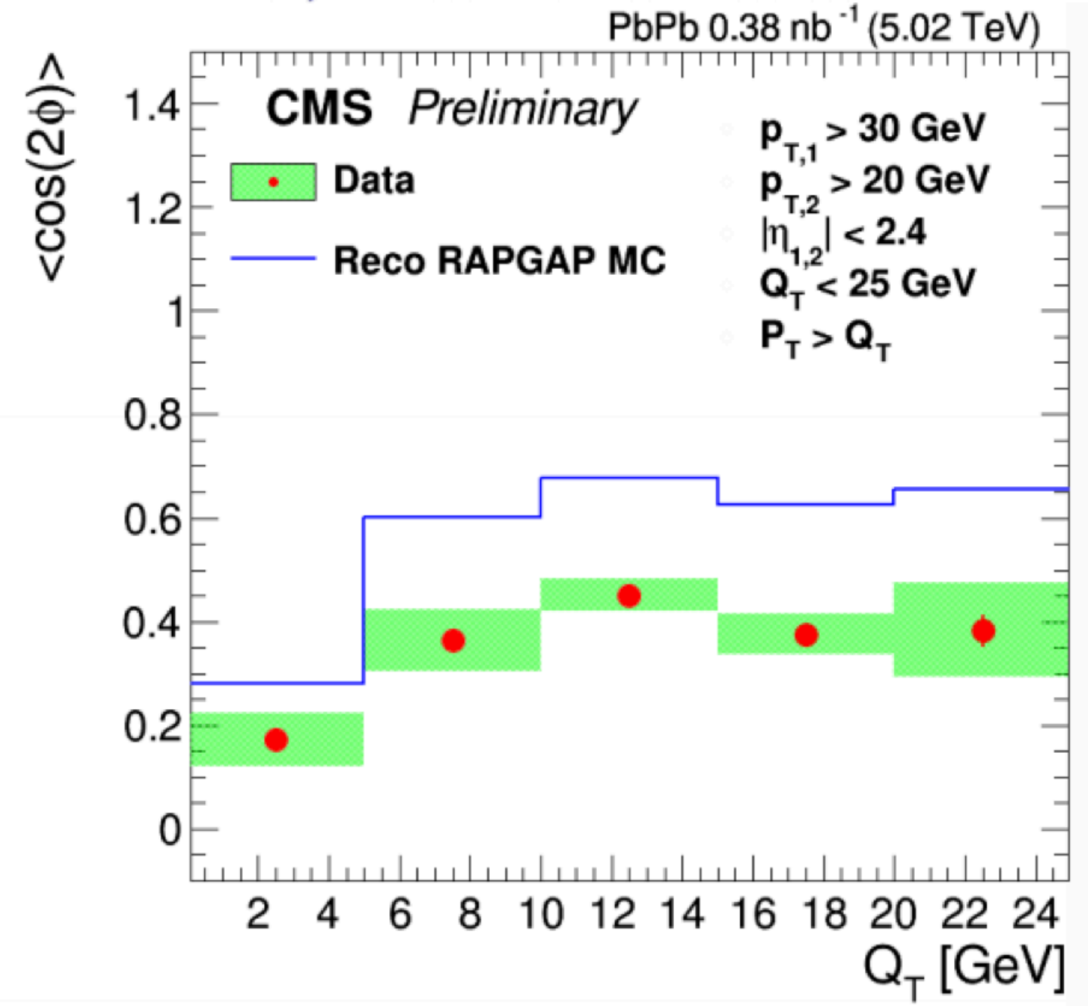
$$\vec{P}_T = \frac{1}{2}(\vec{k_1} - \vec{k_2})$$

NEW!

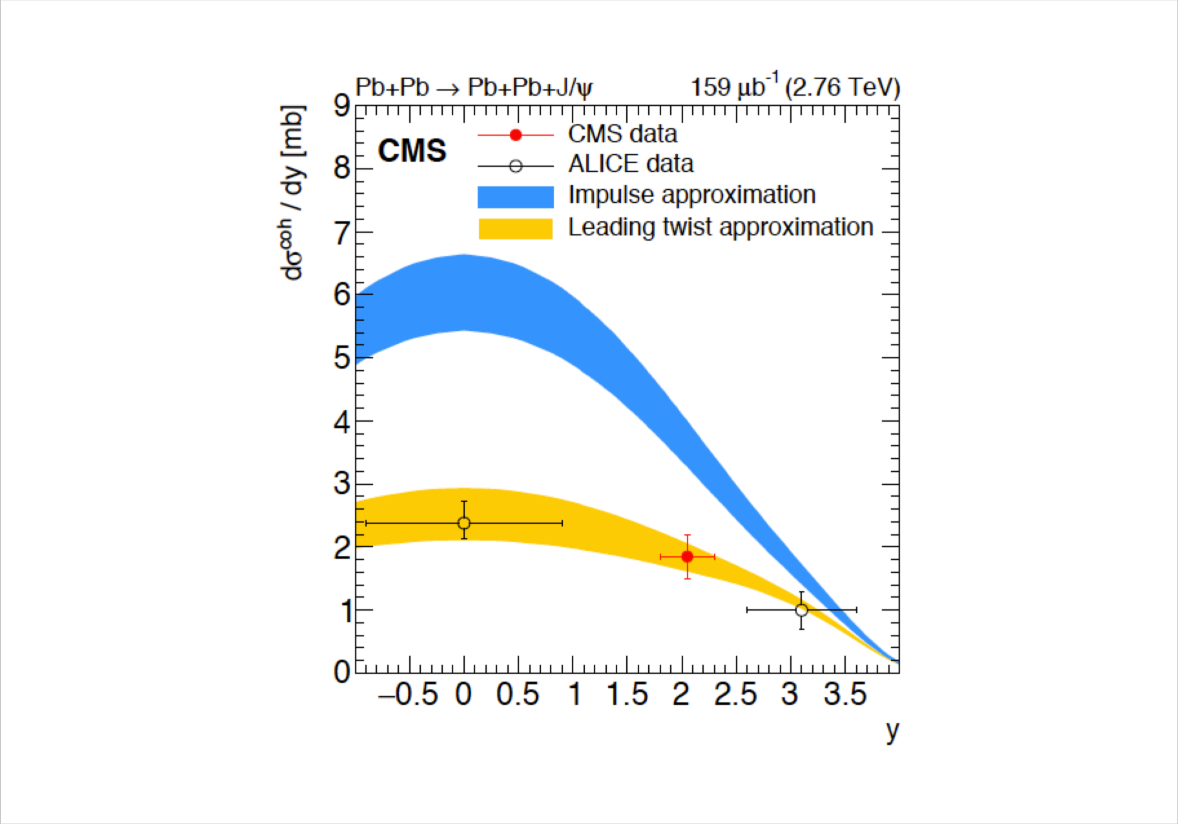
“Elliptic gluon” dynamics

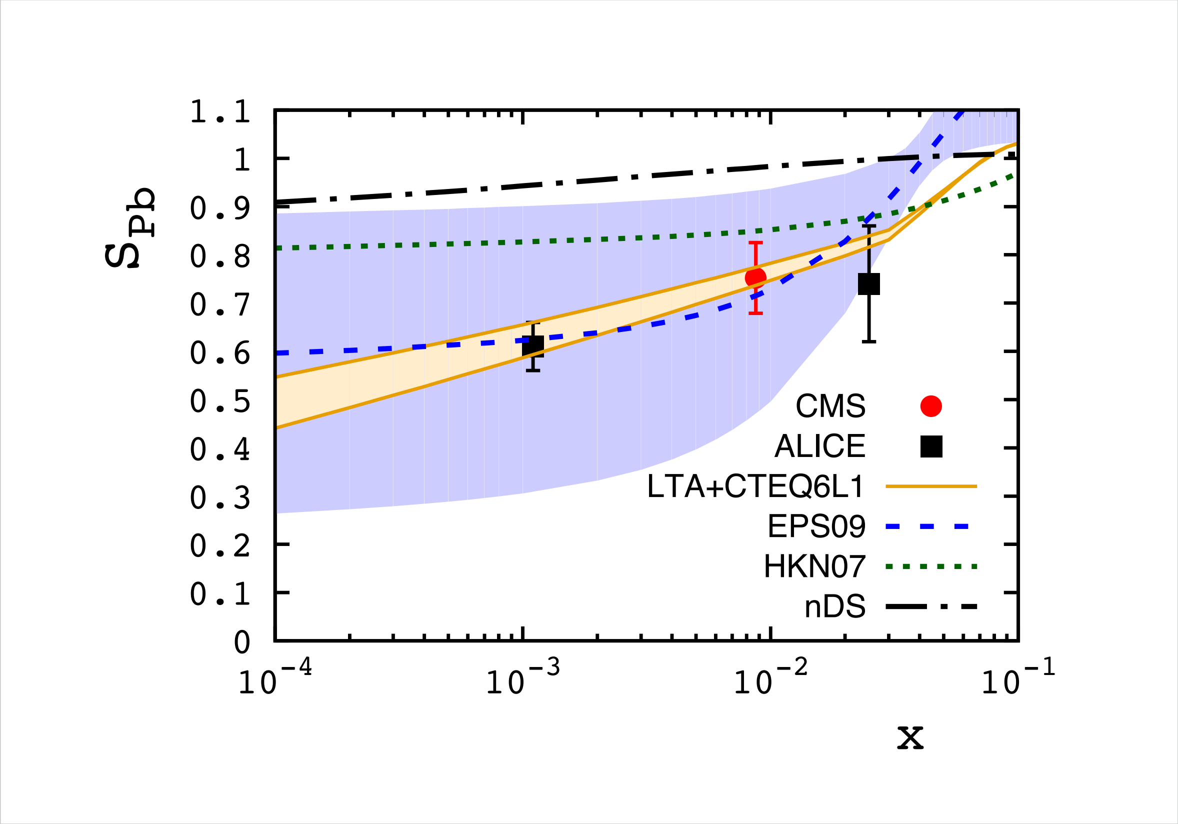
A. Bylinkin
ICHEP 2020



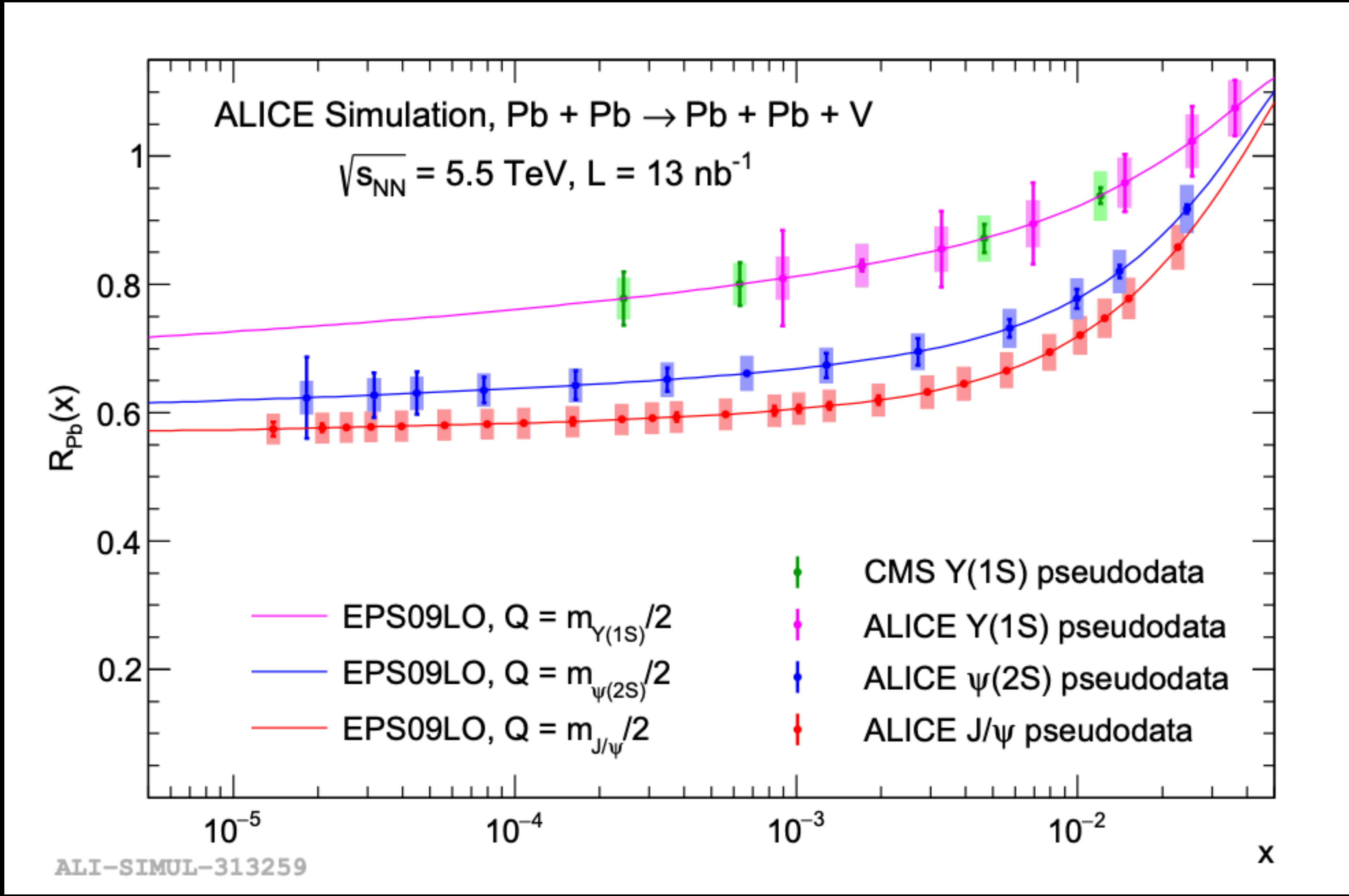


Experimental evidence of nuclear effects in the Pb at high energies, low Bjorken-x



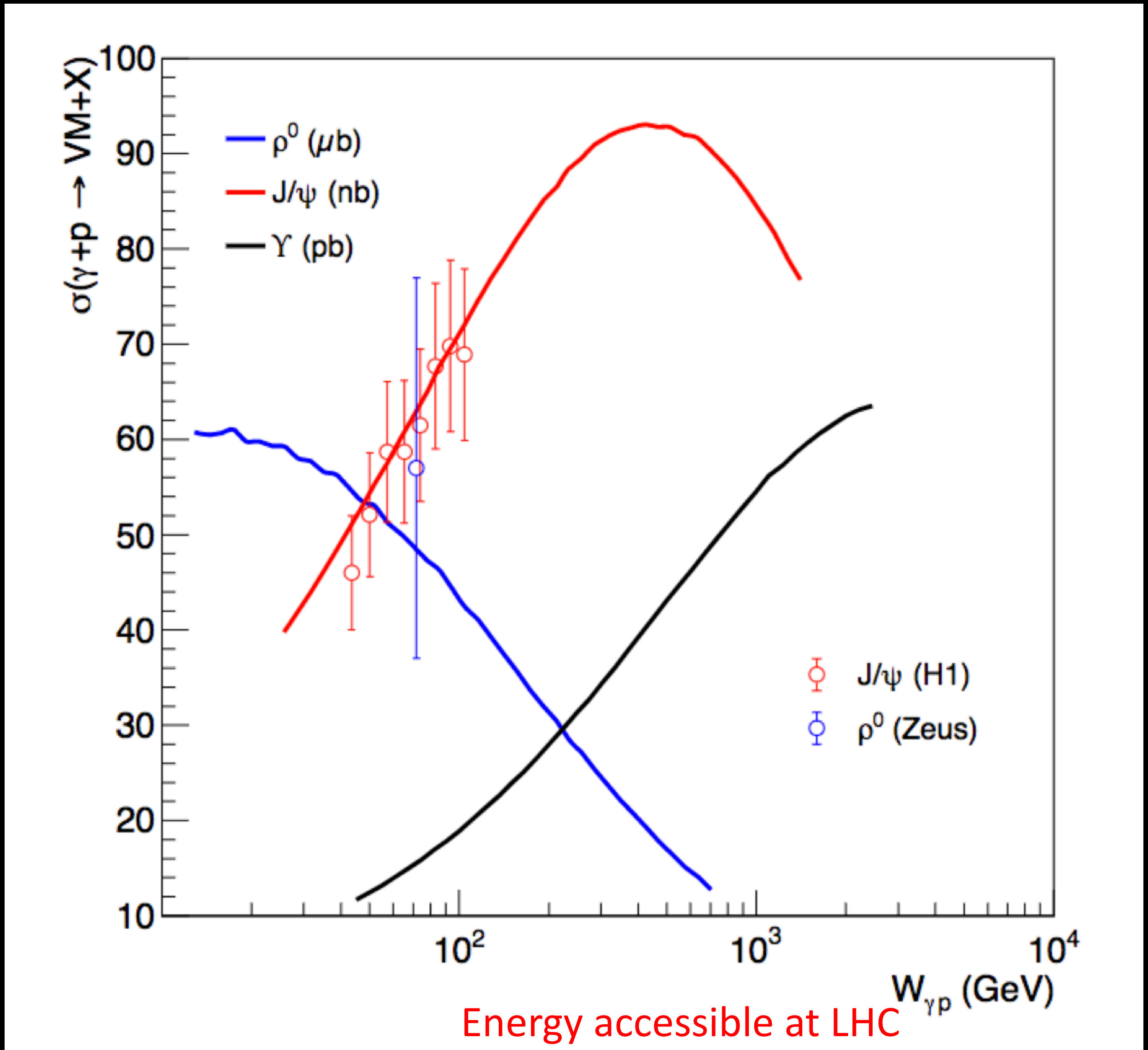


Projections for nuclear suppression factor Vector meson photoproduction

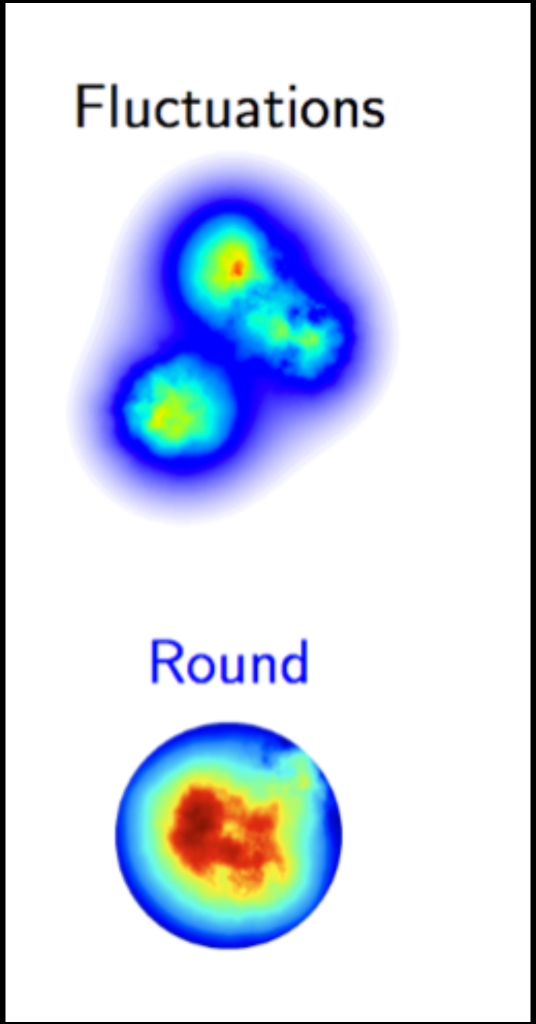


Pseudodata points are derived from EPS09-based photoproduction

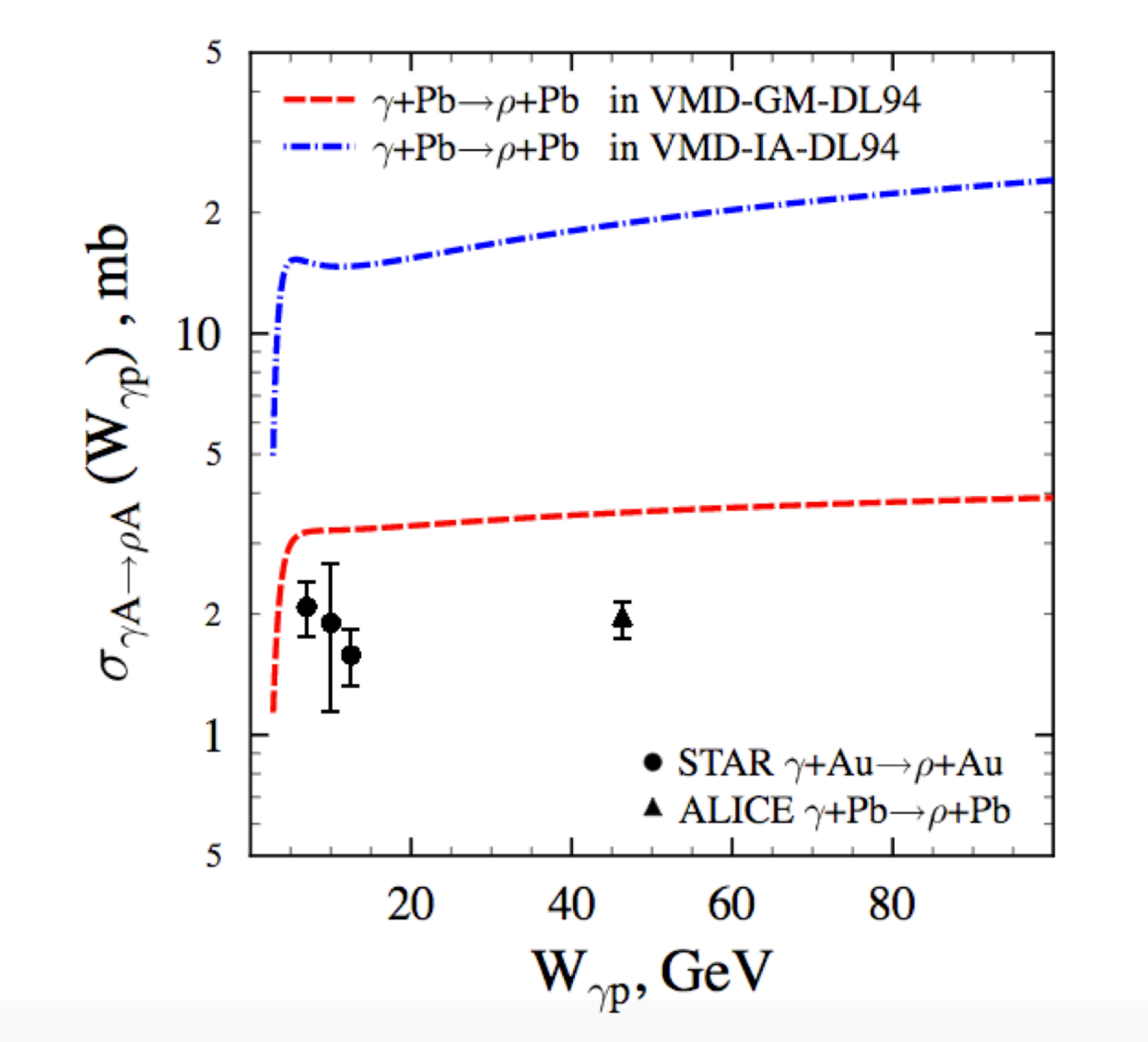
Incoherent production & fluctuations



Energy accessible at LHC



ALICE JHEP 1509 (2015) 095

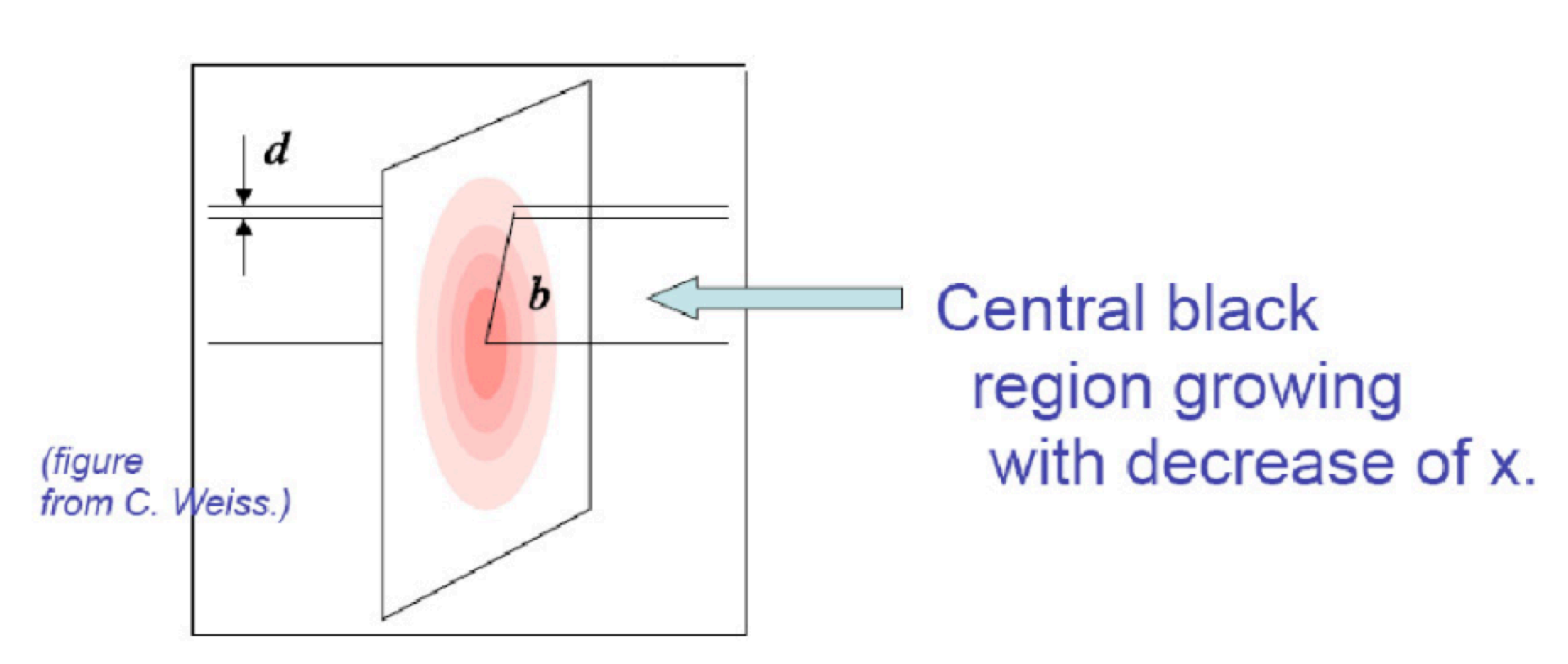


L. Frankfurt et al.
Phys.Lett. B752 (2016) 51-58

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

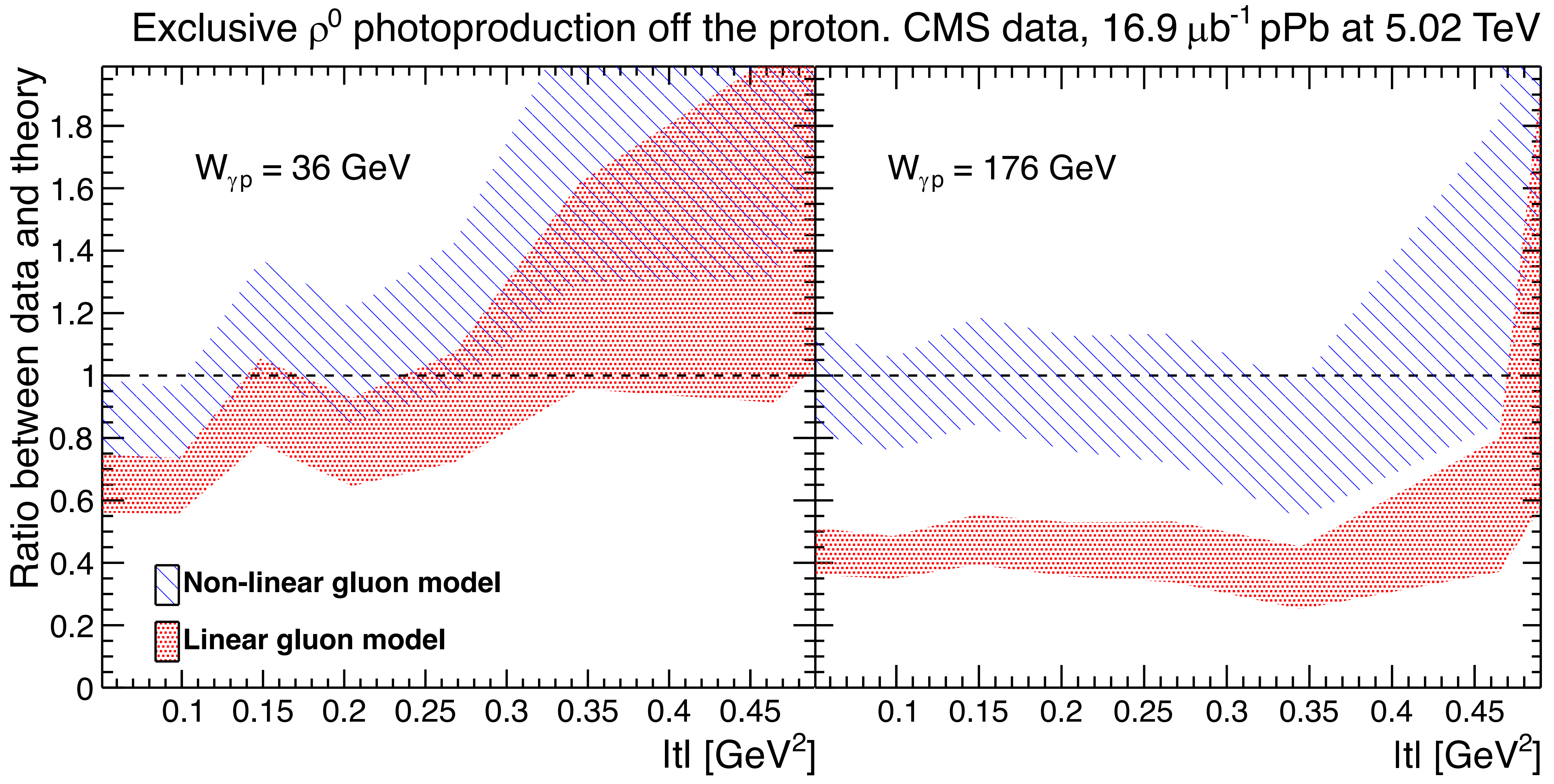
Nuclei does not behave like individual nucleons

t-dependence gives access to the transverse profile of the target



In UPC can study spatial distribution of target scatters in nucleus

Onset of gluon saturation effect



Energy and t dependence of UPC Rho0

New measurements with UPCs at the LHC

- Charm photoproduction
- Event-by-event fluctuations in the nuclear configuration using incoherent photoproduction
- Spatial distribution of target scatters in nucleus
- Perturbative Pomeron dynamics
- Color fluctuations in the photon
- Gluonic Sivers function
- Search for the Odderon

From theory

- Next-to-leading (NLO) order calculations for UPC processes: one of the future directions of the theoretical program

- Sub-Eikonal Frontier

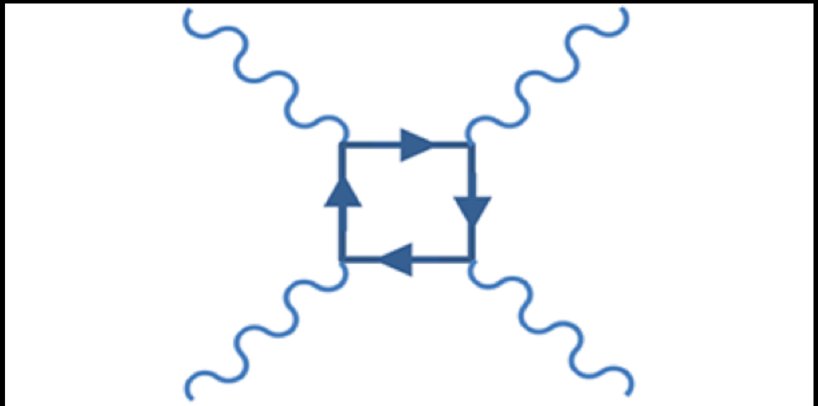
- Connecting small and large x

Nice summary of recent theory prospects in M. Sievert talk

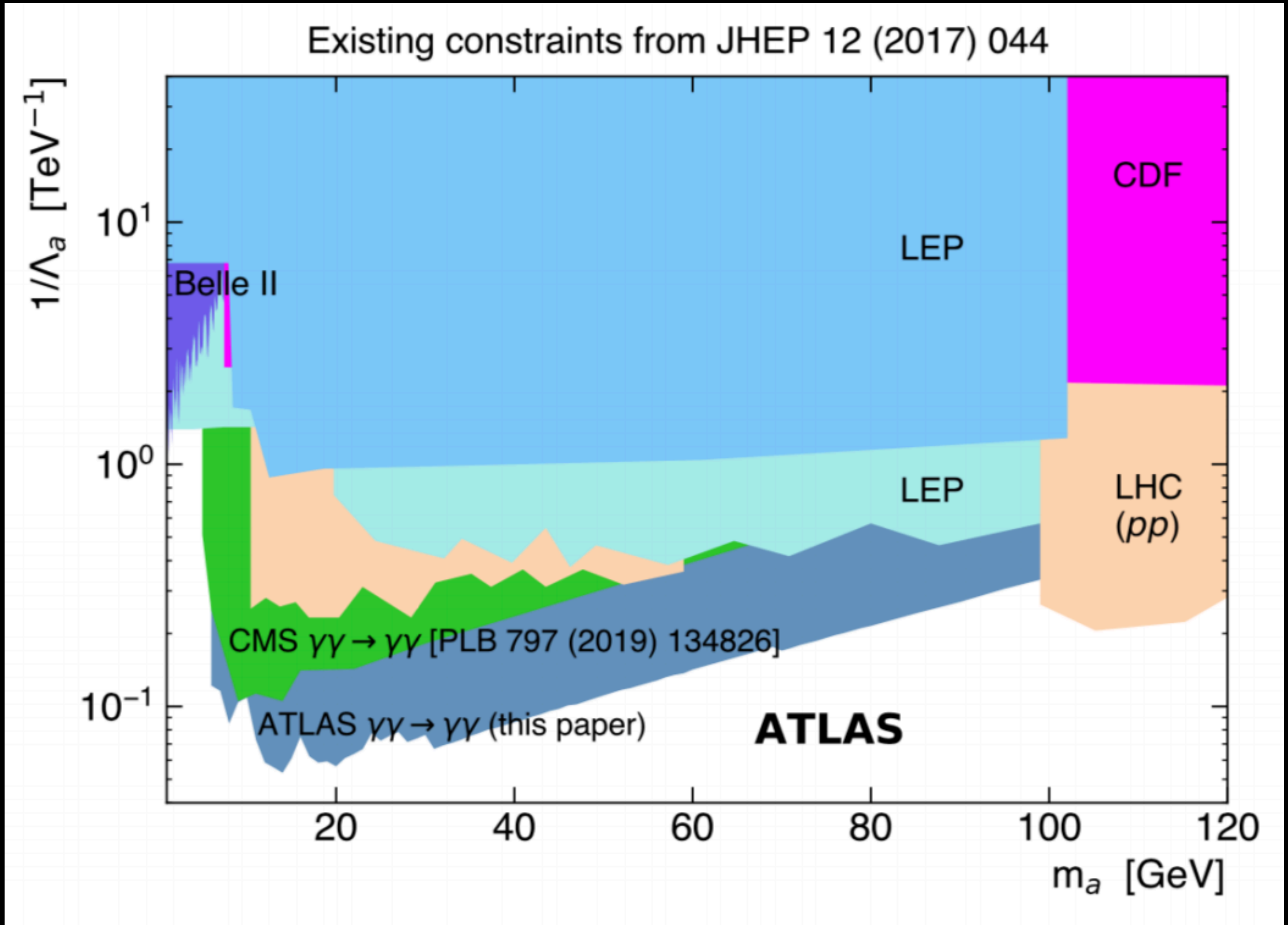
https://indico.cern.ch/event/751767/contributions/3840641/attachments/2048640/3433170/Sievert_Plenary.pdf

Two-photo physics, LbyL scattering

- Two-photon reactions are sensitive to many beyond-standard-model processes
- The subprocess $\gamma\gamma \rightarrow \gamma\gamma$ proceeds only via a charged-particle box diagram. The cross section is sensitive to all charged particles, including BSM particles such as vector fermions, GeV- mass axion-like particles (ALPs) and magnetic monopoles. The reaction also probes non-linear (BSM) corrections to electromagnetism.
  - ATLAS and CMS have recently observed this process
- Limits on anomalous quartic gauge couplings



Light-by-light scattering



Exclusion limits on ALP-photon coupling (1/Λa) vs. ALP mass, from light-by-light scattering and other processes

New measurements on two-photon physics

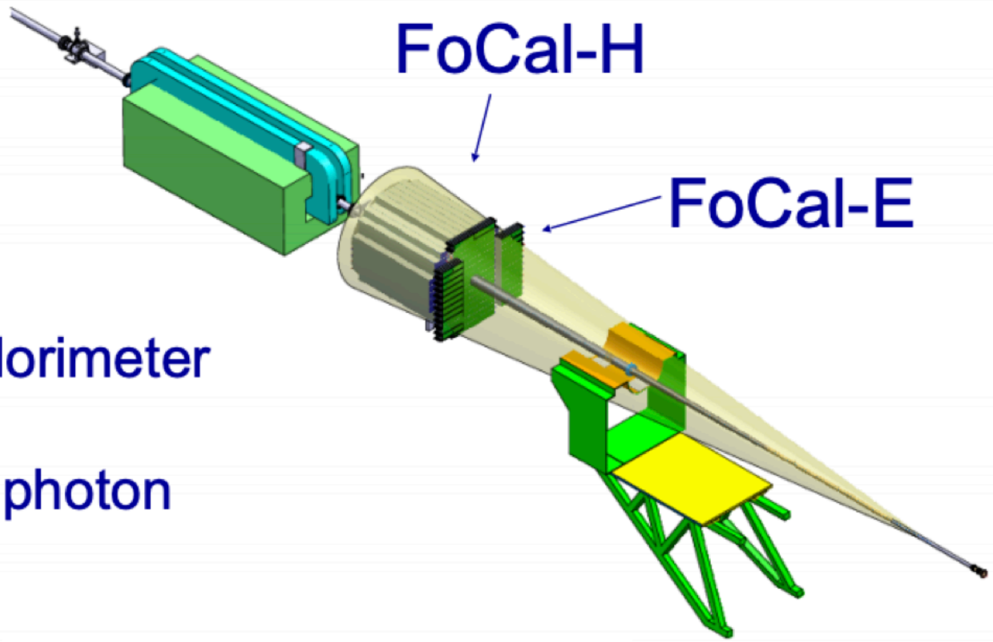
- Extend results
- Probe low-mass light-by-light scattering using ALICE and LHCb (m <5 Gev)
- $\gamma\gamma \rightarrow \tau\tau$
- Two-photoproduction of heavy flavors
- Search for pentaquarks, tretaquarks and other exotica

Strong fields, Quantum correlations and quantum tomography

- Very strong fields to explore reactions involving multiple photon exchange
- EPR (Einstein-Podolsky-Rosen)-type experiments
- Quantum tomography techniques can probe quantum correlations and entanglement

New detectors. For example, ALICE FoCal for Run 4 (2026)

$3.2 < \eta < 5.8$



FoCal-E: high-granularity Si-W calorimeter for photons and π^0
FoCal-H: hadronic calorimeter for photon isolation and jets

Observables:

- π^0
- Direct (isolated) photons
- Jets

Advantage in ALICE:
forward region not instrumented;
'unobstructed' view of interaction point

https://cds.cern.ch/record/2696471

UPCs at the FCC and synergies with future colliders

- FCC and proposed LHeC probing higher energies than LHC:
  - Extensive BSM physics
  - Top photoproduction
  - Two-photon production of the Higgs

Outline of contributed paper on UPC

- Introduction
- Strategies for observing nonlinear and gluon saturation effects in photon – nucleus scattering
- QCD dynamics using photonuclear processes
- Quantum mechanics effects and UPCs
- Two-photon physics at the LHC
- Electromagnetic effects in peripheral events
- Synergies between UPCs at RHIC and LHC and EIC and beyond

Will work with collaborators and authors of LoI to complete these sections