

Initial State and Ultra-Peripheral Collisions

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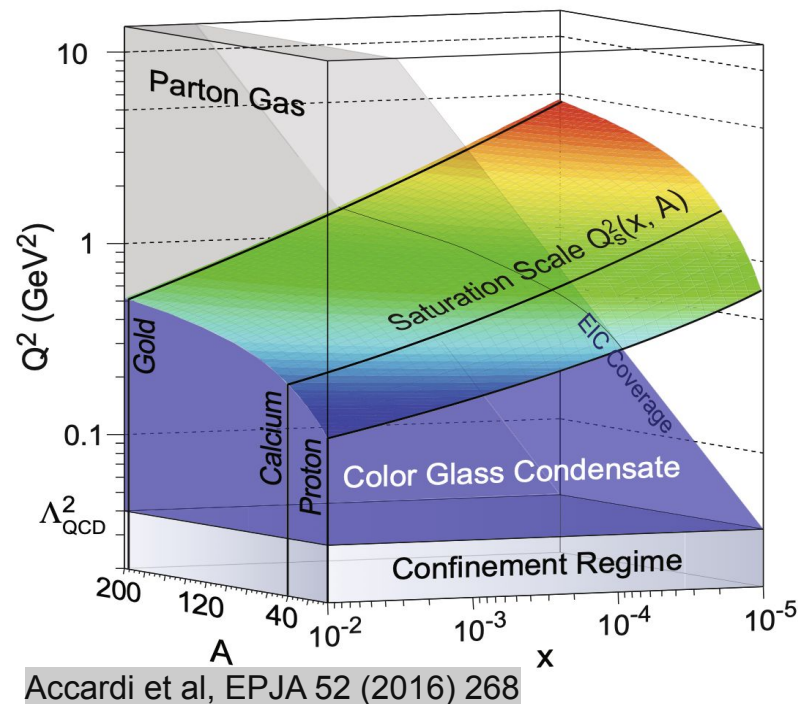
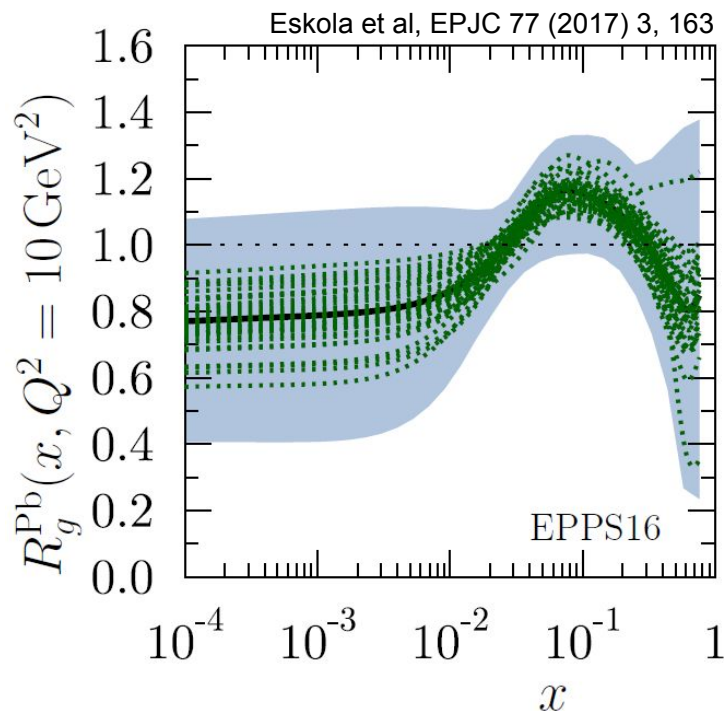
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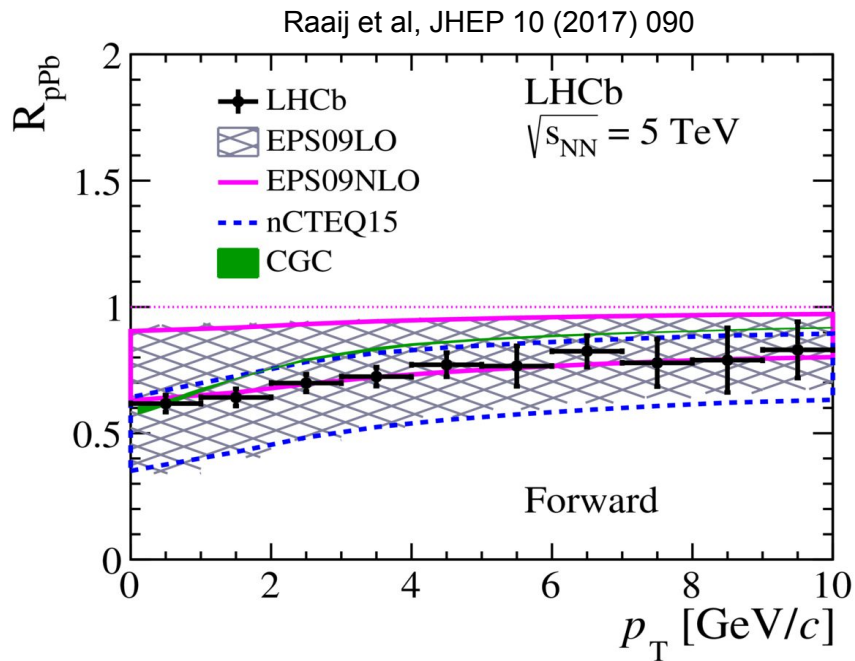
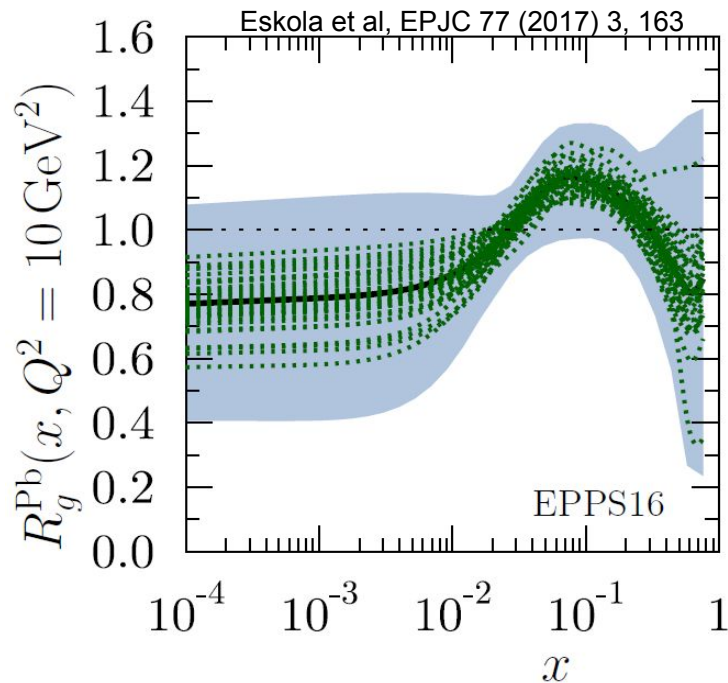
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The goals of low-x physics



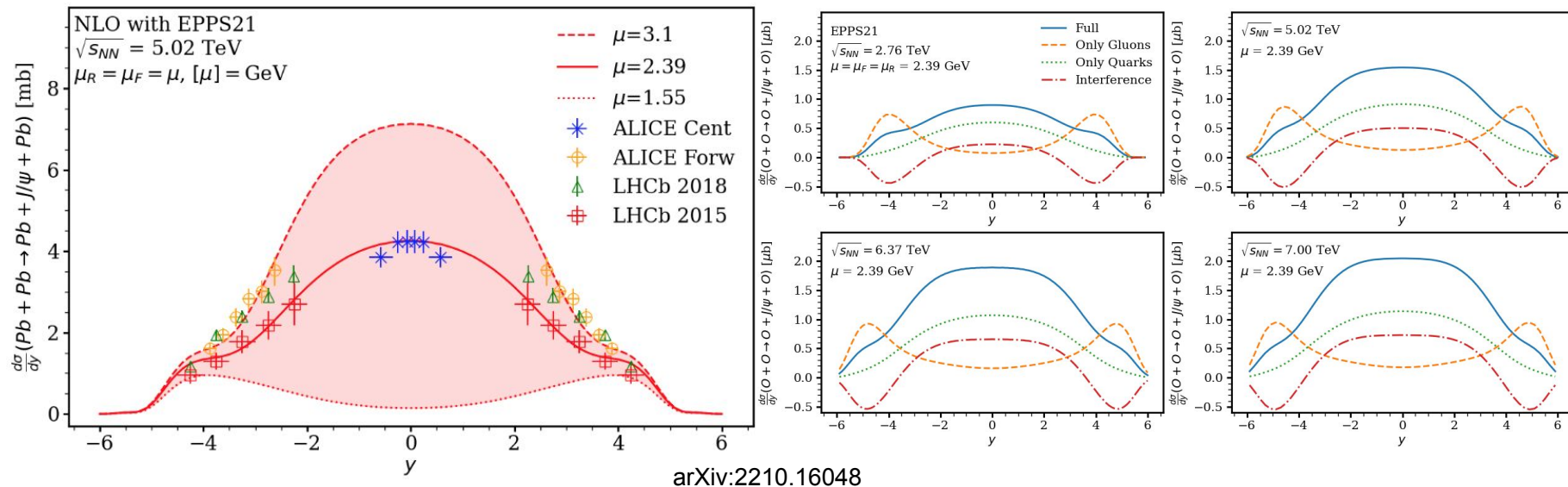
Describe the partonic structure of nuclei at low-x (nPDFs) and **understand** QCD at high parton densities.

The recent past



Until recently, nPDFs were poorly constrained at low x , and we hoped that LHC data could provide a clear signature of parton saturation.

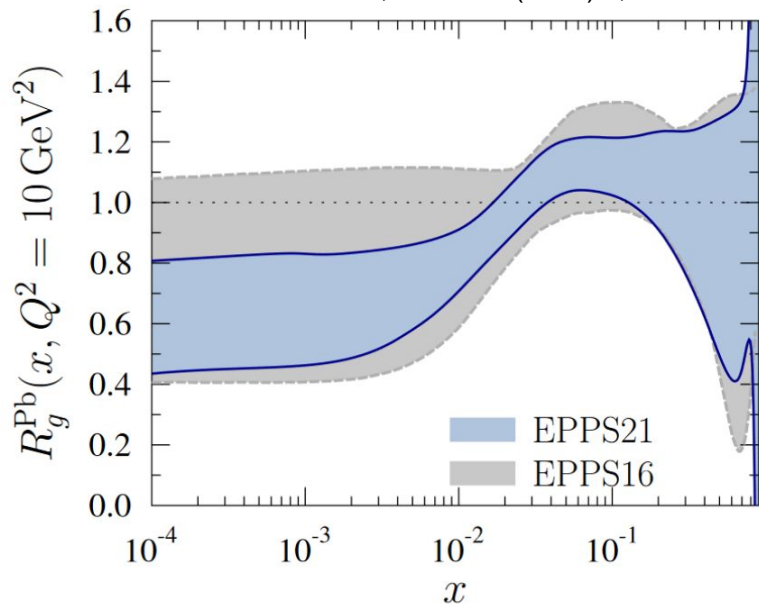
The recent past: UPCs



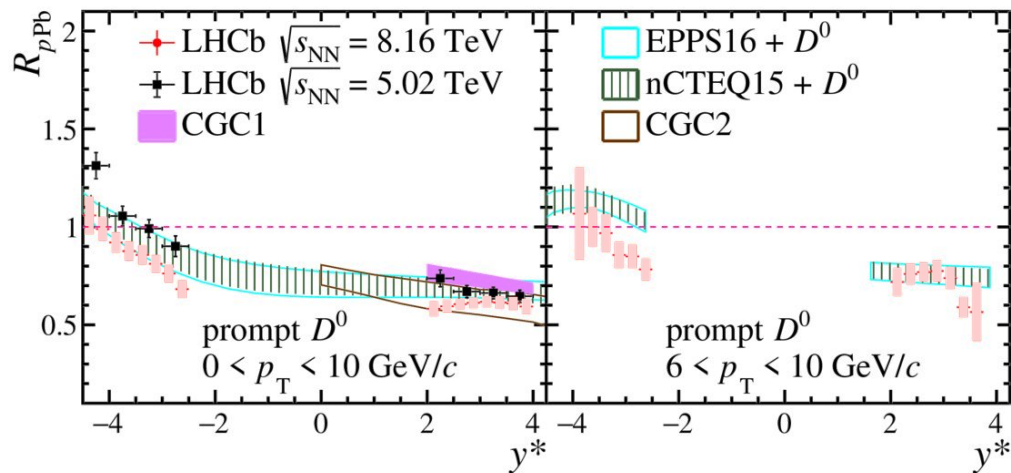
Vector meson production in UPCs is sensitive to low Q^2 and low x , but large scale uncertainties make interpretation difficult. Recent NLO calculations also reveal surprising contributions from quarks!

Recent progress: nPDFs and saturation

Eskola et al, EPJC 82 (2022) 5, 413

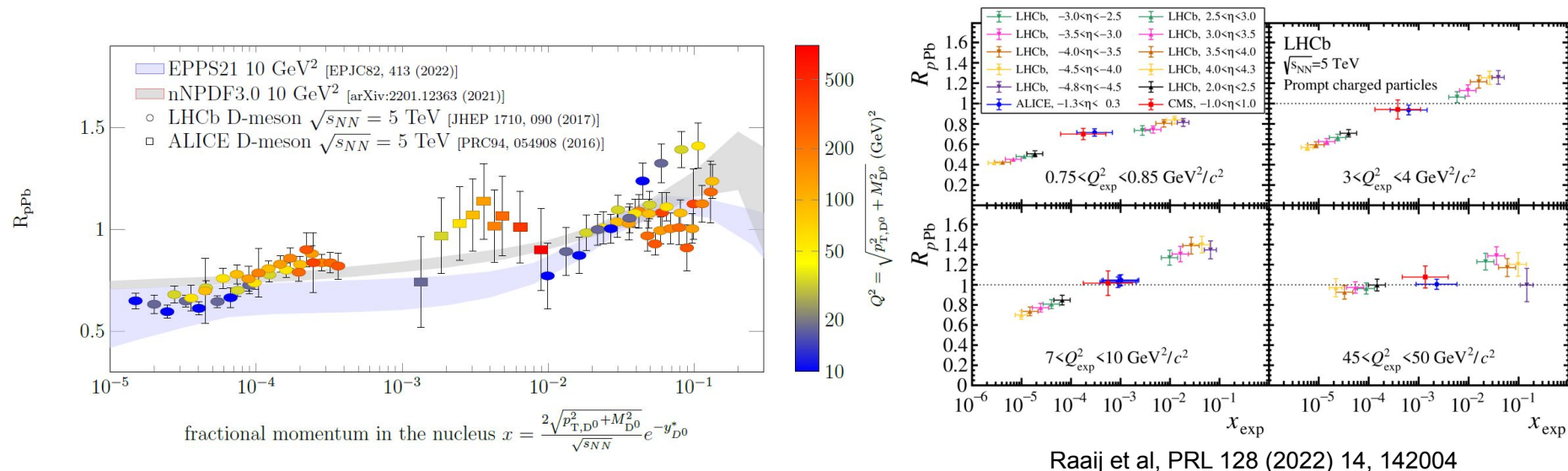


arXiv:2205.03936



New data have improved nPDF constraints, but saturation models still agree with nPDF predictions. Uncertainties at low Q^2 are still large.

This week: Progress in forward physics



Probing nPDFs over a wide range of x and Q^2 will overconstrain nPDFs and could reveal nonlinear parton density evolution. Observables like particle correlations can provide additional handles.

This week: Experimental progress in UPCs

CMS: PAS HIN-22-002 (2022)

Solving ambiguity problem with
electromagnetic dissociation
(EMD) classes

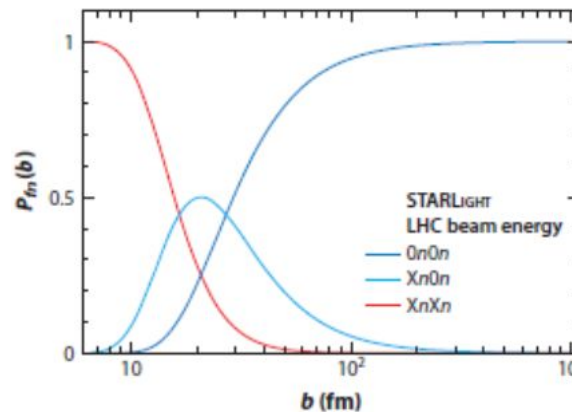
No breakup (0n0n)



Single breakup (Xn0n + 0nXn)



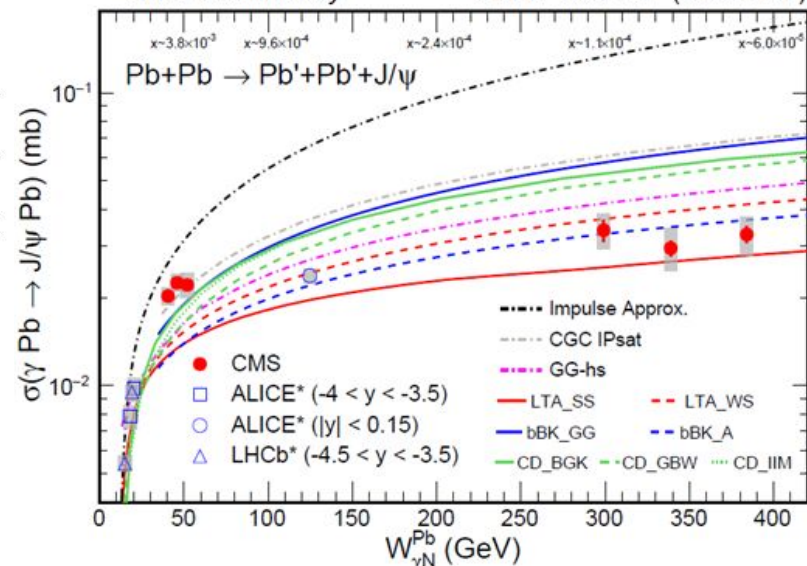
Double breakup (XnXn)



S. Klein, P. Steinberg,
Annu. Rev. Nucl. Part. Sci. 70(1), 323 (2020)

CMS Preliminary

PbPb 1.52 nb⁻¹ (5.02 TeV)

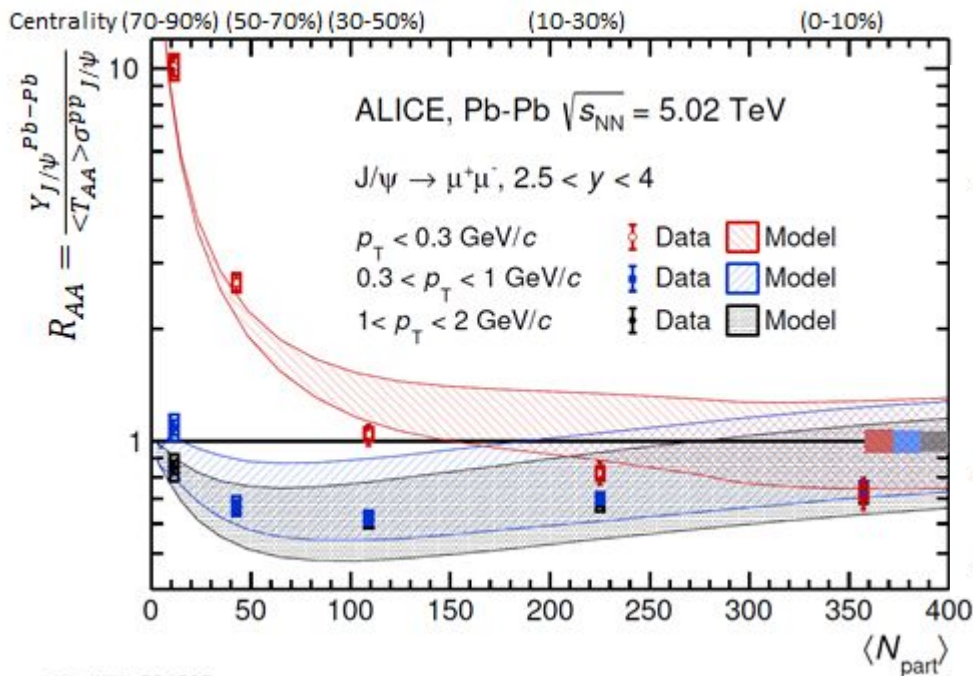


$$\frac{d\sigma^{0n0n}}{dy} \frac{AA \rightarrow AA' J/\psi}{AA \rightarrow AA' J/\psi} = N^{0n0n}(\omega_{\gamma 1}) \cdot \sigma_{\gamma A}(\omega_{\gamma 1}) + N^{0n0n}(\omega_{\gamma 2}) \cdot \sigma_{\gamma A}(\omega_{\gamma 2})$$

$$\frac{d\sigma^{XnXn}}{dy} \frac{AA \rightarrow AA' J/\psi}{AA \rightarrow AA' J/\psi} = N^{XnXn}(\omega_{\gamma 1}) \cdot \sigma_{\gamma A}(\omega_{\gamma 1}) + N^{XnXn}(\omega_{\gamma 2}) \cdot \sigma_{\gamma A}(\omega_{\gamma 2})$$

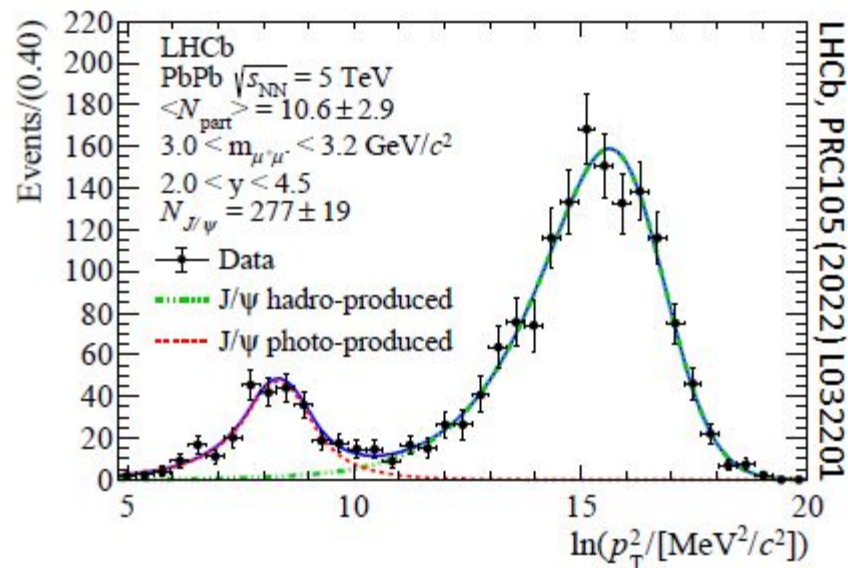
This week: Experimental progress in UPCs

Photoproduction from peripheral towards central collisions



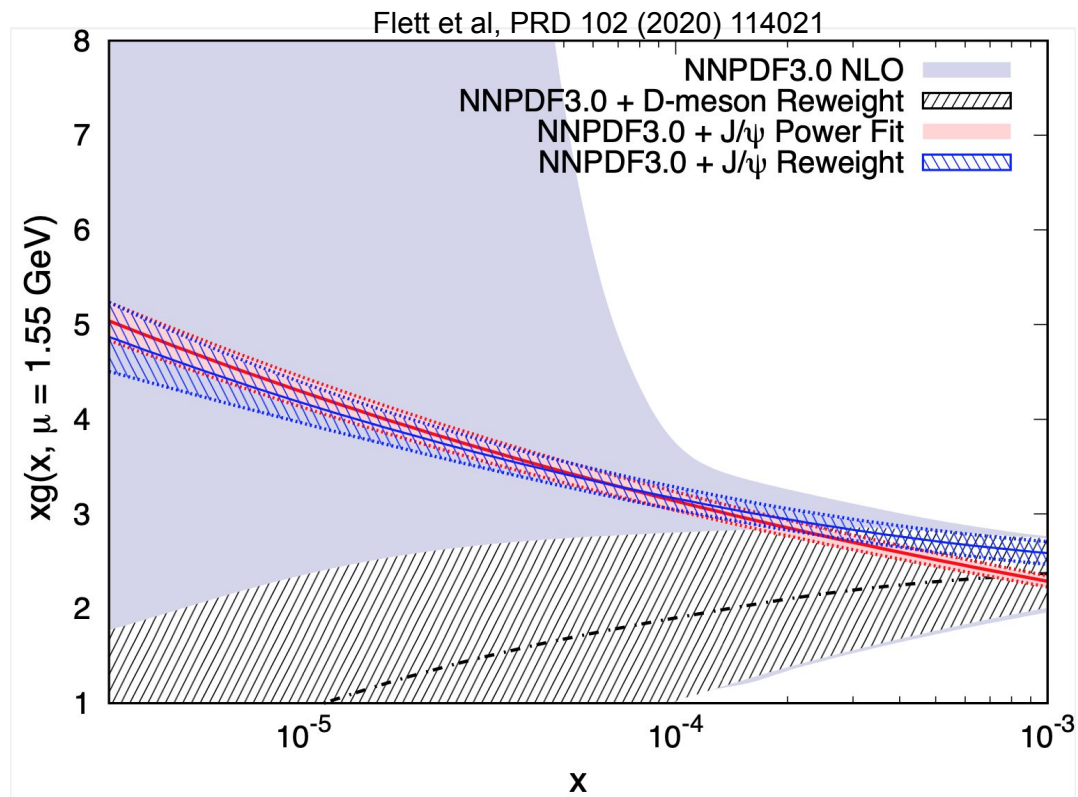
ALI-PUB-521507

ALICE, arXiv:2204.10684 (2022)



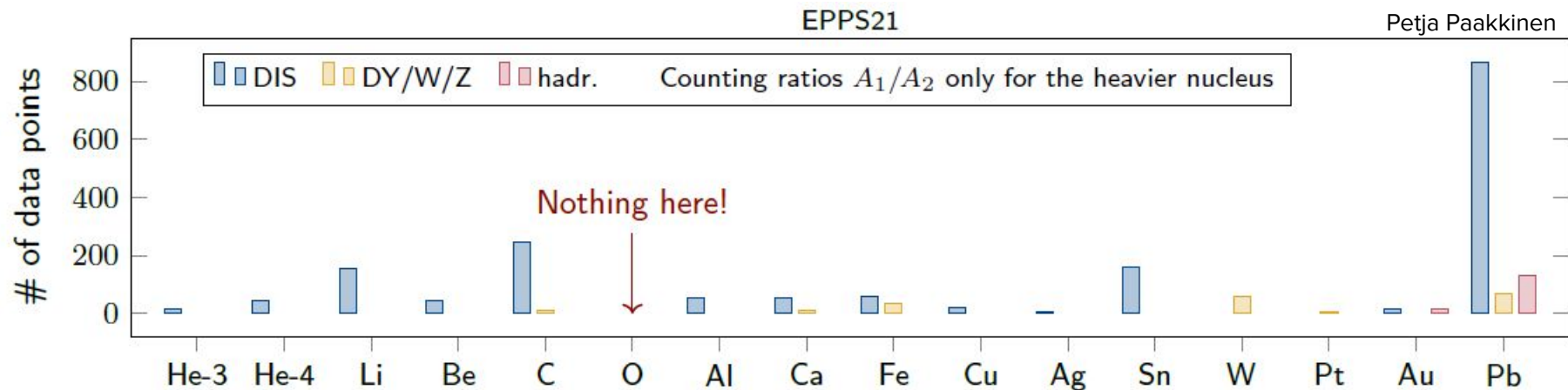
This week: Theoretical progress in UPCs

- Include exclusive J/ψ and inclusive D^0 data in PDF determination using Bayesian reweighting
- First extraction of a PDF using exclusive production data from pp collisions
- Requires NLO calculations and taming large scale uncertainties
- Work in progress to perform a full PDF fit using this data



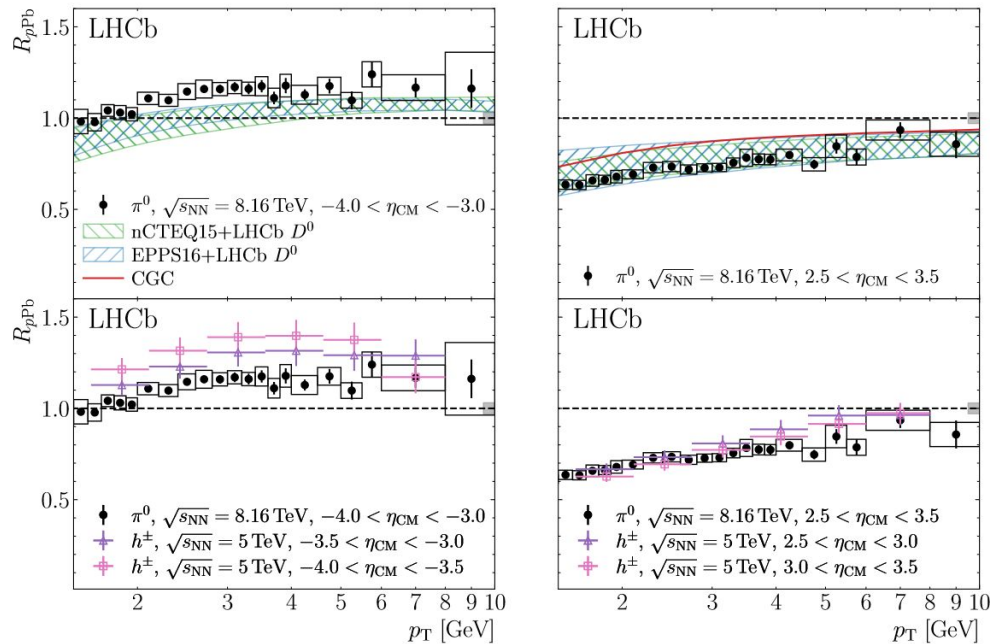
The future: p-O and O-O at the LHC in 2024

- About 0.5 nb^{-1} OO for ATLAS, CMS, ALICE
- About 2 nb^{-1} , pO in one direction for LHCb
- **Initial state:** Understand the evolution of low-x suppression with A
- **Jet quenching and hydrodynamics:** Study the onset of jet quenching and collective effects in small systems (need nPDFs)
- **Astro QCD:** Input for understanding cosmic ray air showers

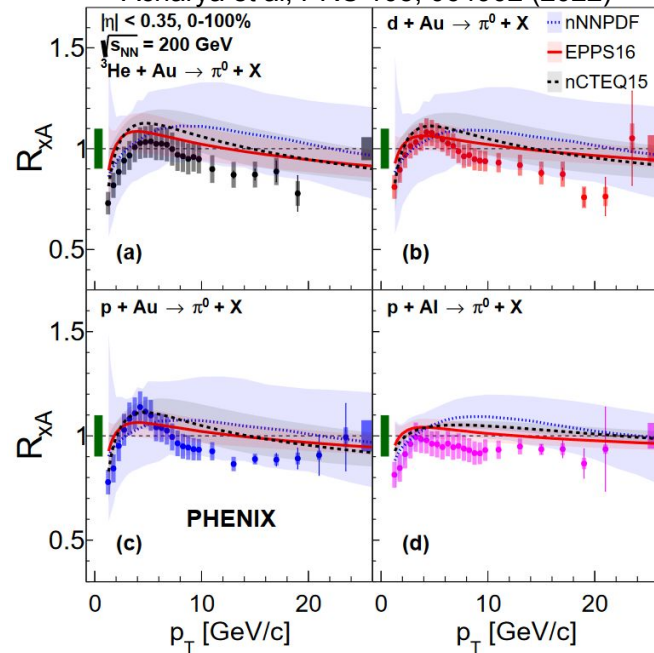


The future: Disentangling collective and initial state effects

arXiv:2204.10608

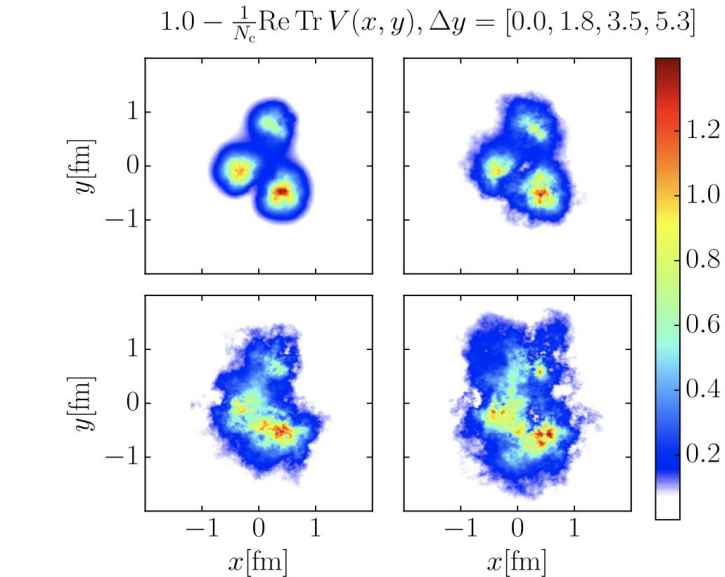


Acharya et al, PRC 105, 064902 (2022)

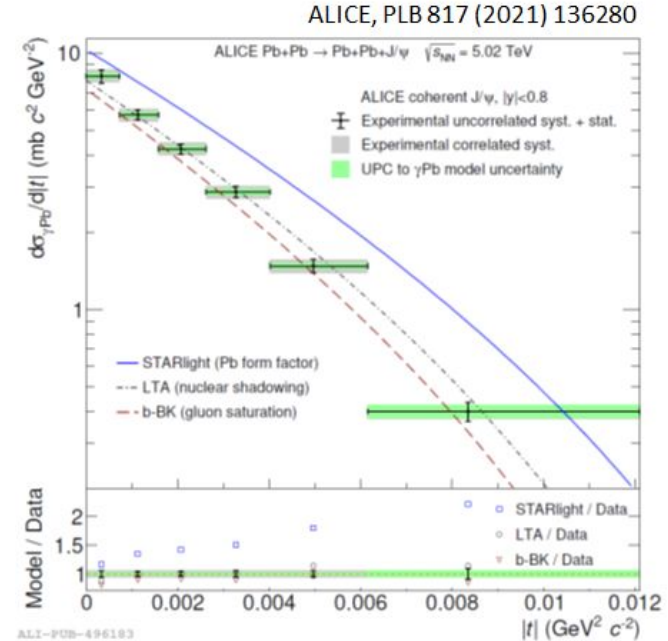


pO data can help explain unexpected “Cronin” enhancements in π^0 production at PHENIX and LHCb.
Would benefit from collecting data in pO and Op configurations!

The future: Initial conditions for small systems



Mäntysaari, Schenke PRD98, 034013 (2018)



Can use UPCs to study the size of the proton/nucleus. Incoherent production probes fluctuations in the parton densities. Measurements in pO can provide further input for small-system hydro calculations.

Conclusions

- **Low-x physics is transforming into a high-precision field.**
- nPDFs at low-x have gone from unconstrained to well-known. Overconstraining nPDFs could provide evidence for nonlinear QCD evolution.
- Theoretical advances are improving our understanding of precise UPC data.
- Experimental advances are letting us extract additional information from UPCs.
- We're on our way to having the data and theoretical tools to create a consistent picture of QCD at high parton densities.