

Overview of UPC results from CMS

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On behalf of the CMS Collaboration

**EMMI Workshop: Mining for gluon saturation at the LHC and the
future EIC**

GSI, Darmstadt

6 July, 2026

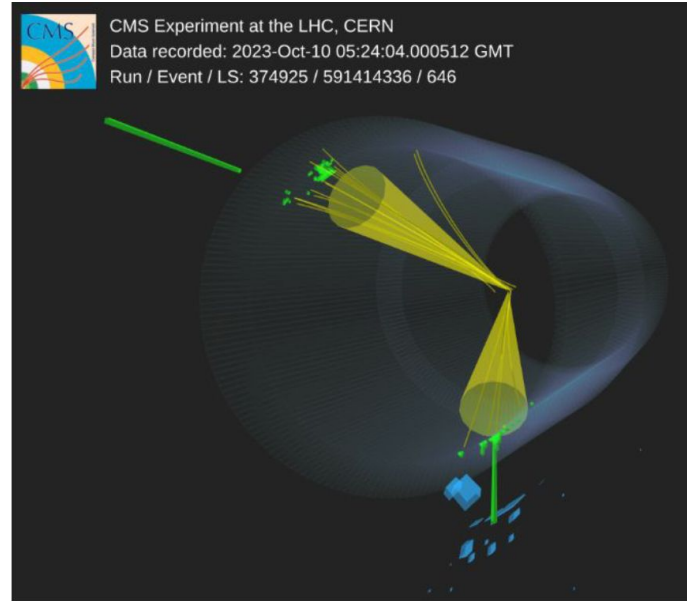
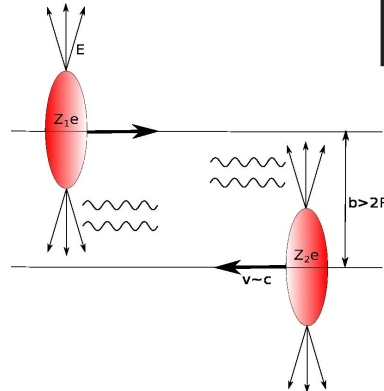
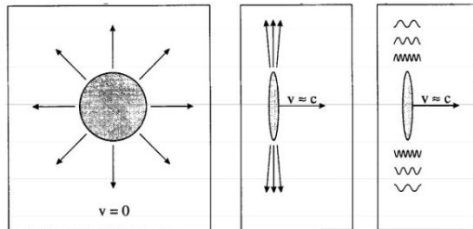


Ultrapерipheral Collisions (UPC)

with $b > R_1 + R_2$.

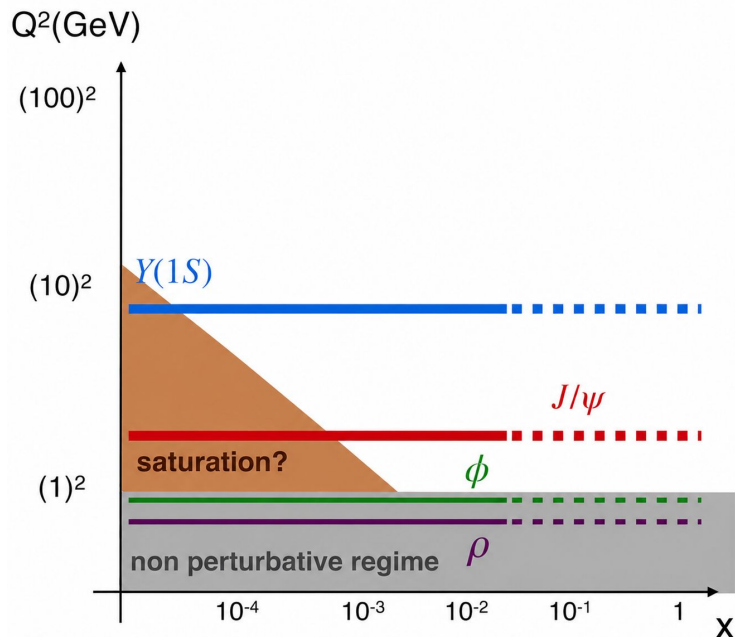
-Very clean environment to study quantum electrodynamics (QED) within the Equivalent Photon Approximation framework and to probe also saturation/CGC since we probe the high gluon density in the heavy object.

- Ultra-relativistic ions are sources of intense EM fields
Photon fluxes enhanced $\sim Z^2$.
- Enhancement of cross sections in Pb+Pb wrt proton-proton (pp) collisions.
- Strong interaction effects are suppressed.



Vector meson photoproduction in UPC

Vector meson photoproduction directly probes gluonic structure of nucleus and nucleon

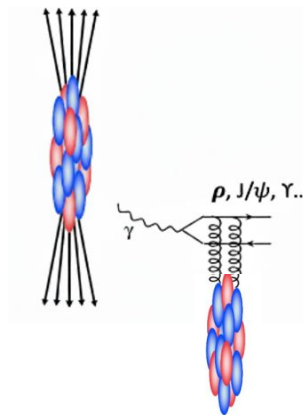
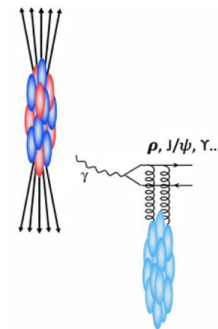


Coherent production:

- Photon interacts coherently to entire nucleus
- Target nucleus remains intact
- VM $\langle p_T \rangle \sim 50$ MeV
- Probing the averaged gluon density

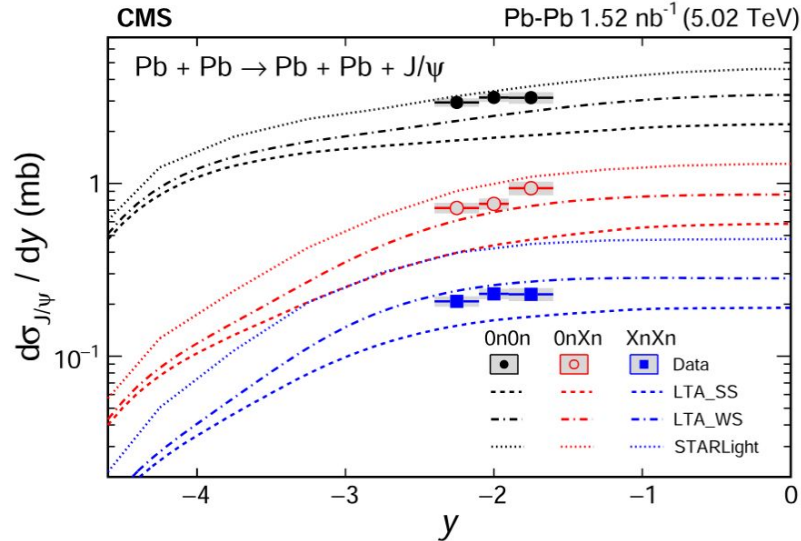
Incoherent production:

- Photon interacts to individual nucleons
- Target nucleus usually breaks
- VM $\langle p_T \rangle \sim 500$ MeV
- Probing the local gluon density fluctuation

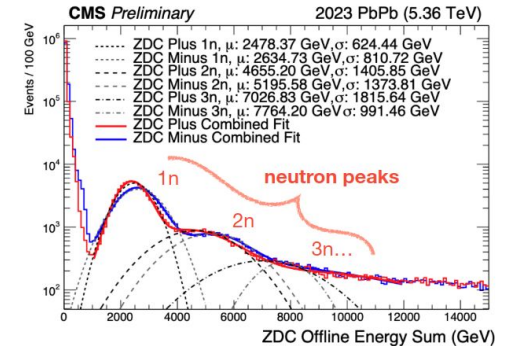
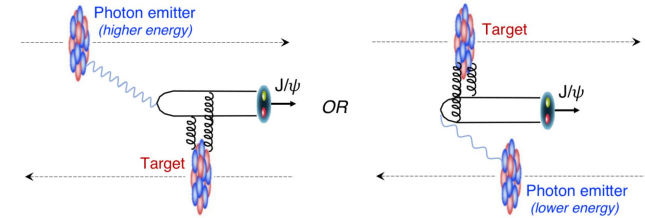
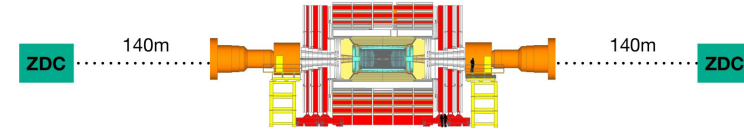


Coherent J/ψ production in PbPb

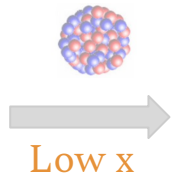
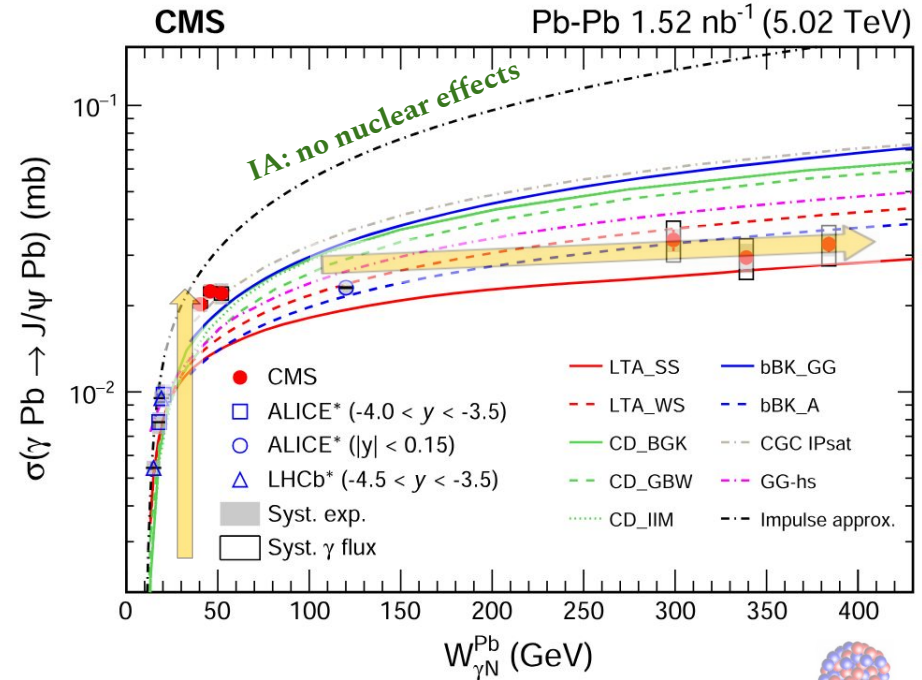
Phys. Rev. Lett. **131**, 262301



- Coherent J/ψ measurement from different neutron classes
- No model can describe the data in different neutron classes
- Allow to disentangle the low- and high- energy photon-nucleus contributions of a single γ +Pb

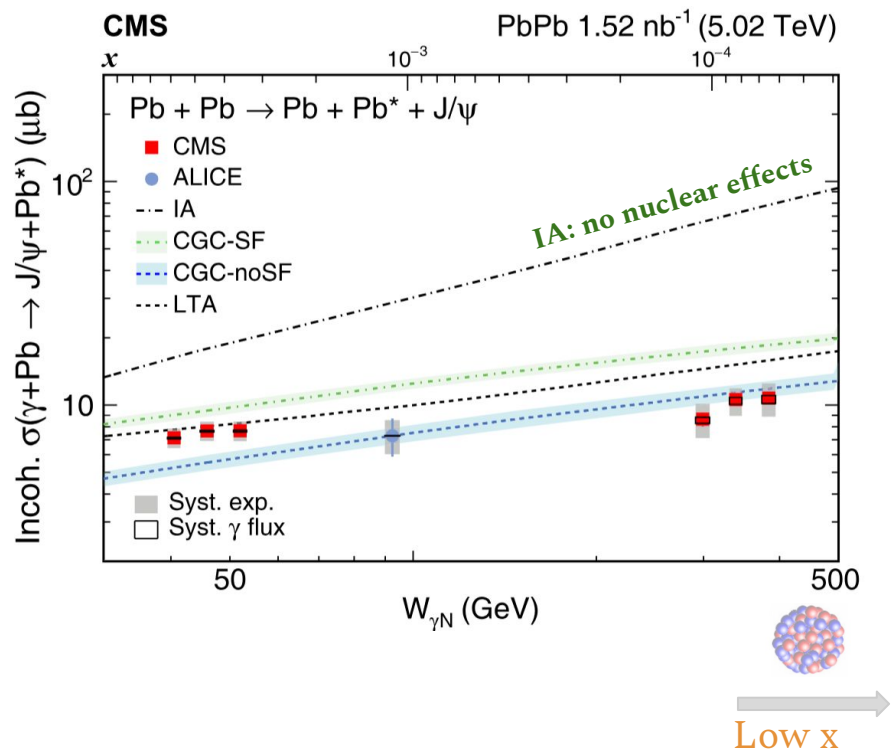


- Suppression at high $W_{\gamma N}$ values compared to no nuclear effects models as the impulse approximation (IA)
- Rapid increase at $W < 40$ GeV.
- Turn into a flat trend for $W > 40$ GeV.
- Both shadowing and saturation models can not fully describe the data distribution.

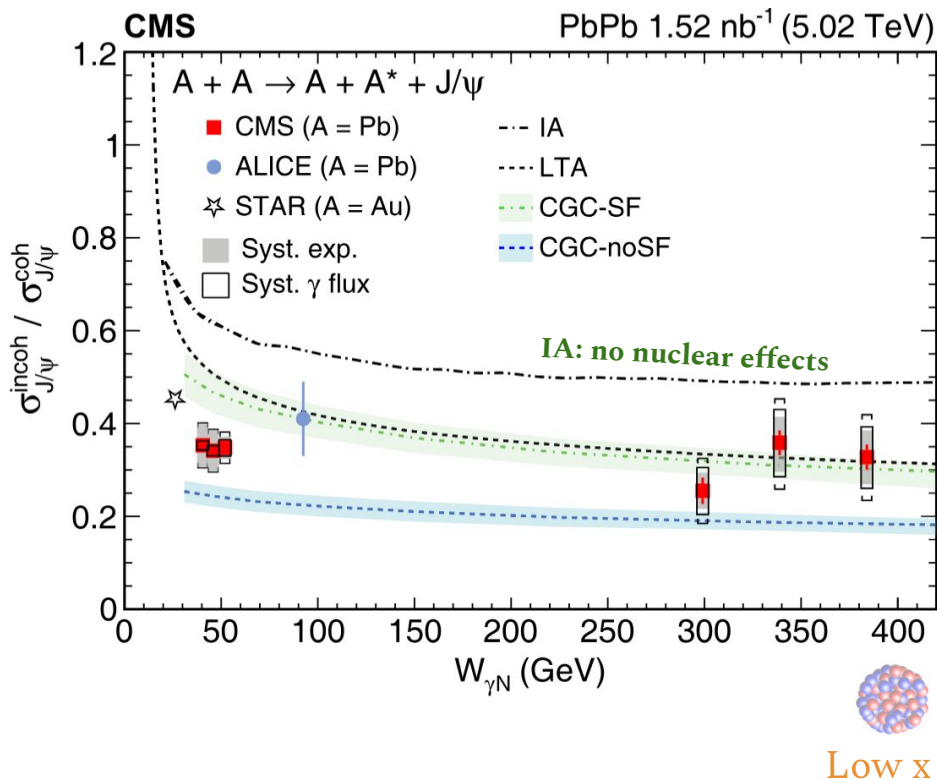


Incoherent J/ψ production in PbPb

[Phys. Rev. Lett. 135 \(2025\) 112301](#)

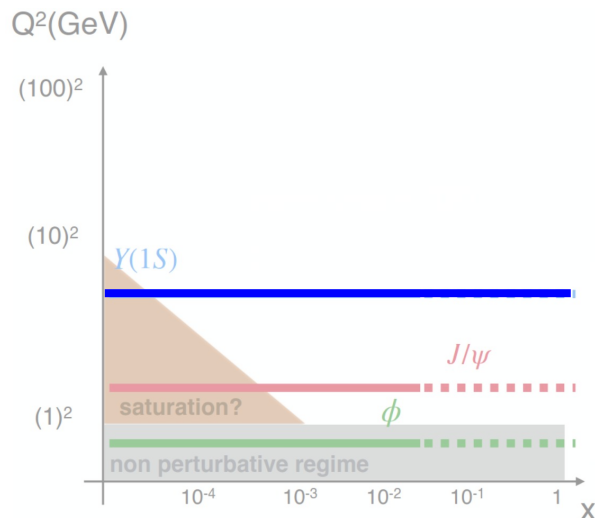


- First measurement of the energy dependence of incoherent J/ψ production
- Data show a strong suppression compared to the impulse approximation.
- The LTA model describes the data well for $W < 60$ GeV, while the CGC model without nucleon substructure fluctuations gives a better description for $W > 90$ GeV.

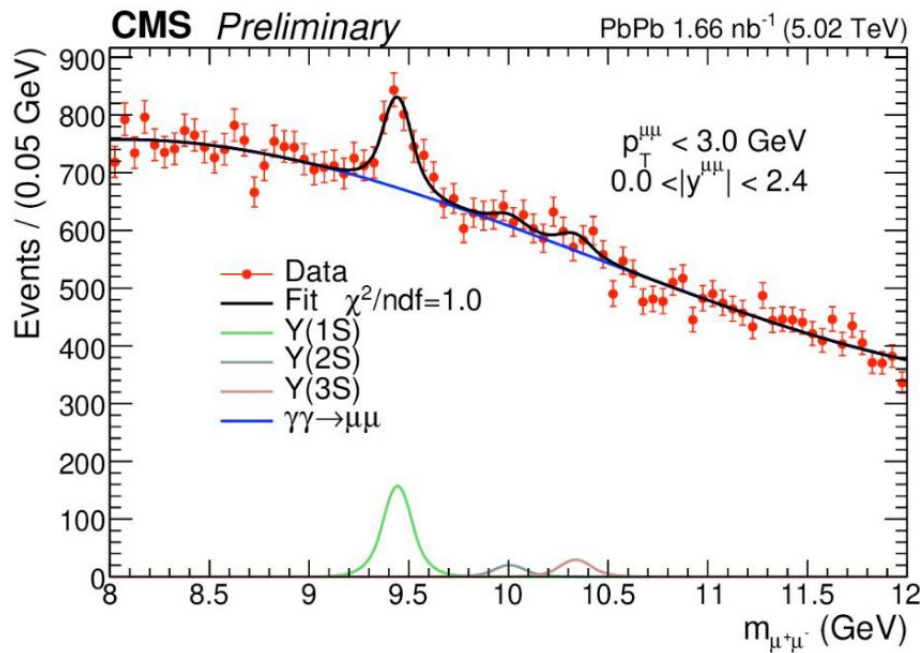


- Incoherent J/ψ production more suppressed than coherent production. underlying effects?
- LTA predicts an increasing trend at low energies not follow by data.
- Ratios stay $\sim$ constant.
- CGC favored by data?

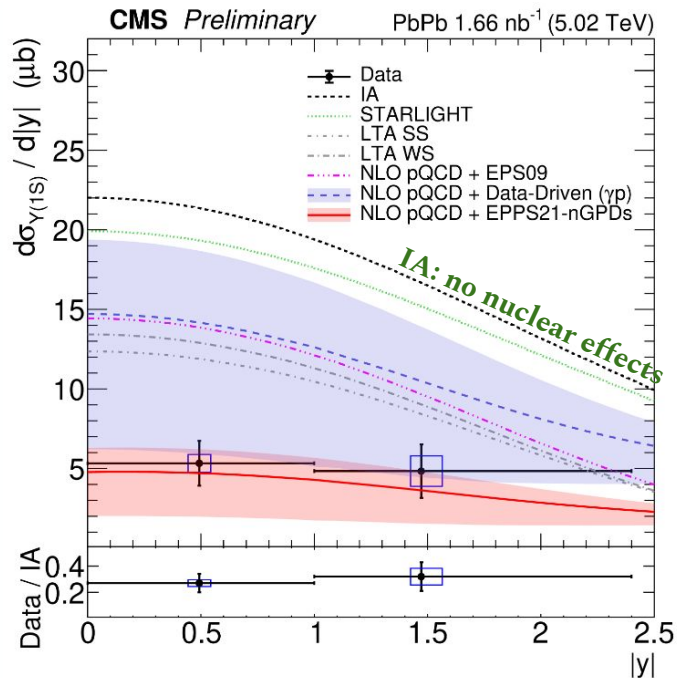
$\Upsilon(1S)$ production in PbPb



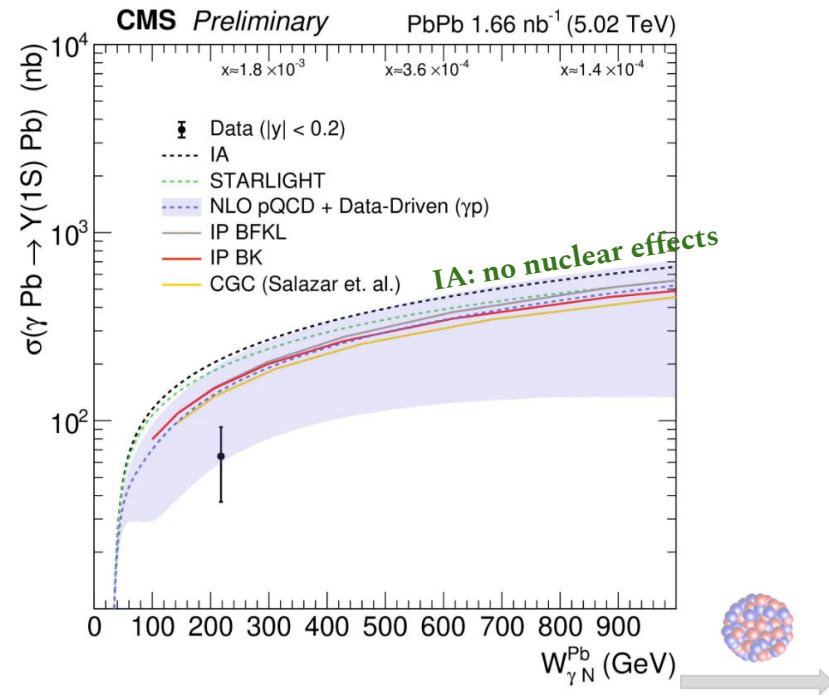
- First observation of $\Upsilon(1S)$ production in UPCs.
- Allowing to explore the gluonic nuclear structure at higher Q^2 region $\sim 10 \times J/\psi$



[arXiv:2604.05814 \(2026\)](https://arxiv.org/abs/2604.05814)



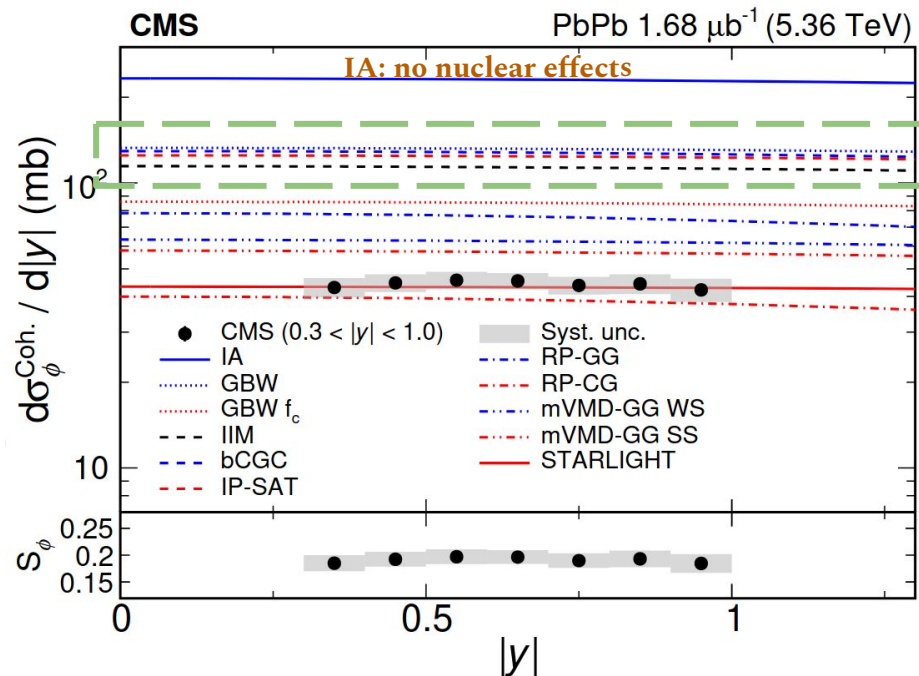
- A suppression of about a factor of four is observed compared to the impulse approximation.
- The measured cross section is lower than predictions from theoretical models incorporating nuclear shadowing



Best agreement is achieved with NLO pQCD calculations using the EPPS21 nuclear PDFs, which model the generalized parton distributions (GPDs) through the Shuvaev transform.

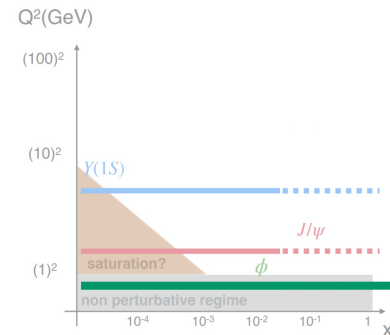
Is suppression encoded in the nPDF parametrization ?

Coherent $\phi(1020)$ production in PbPb



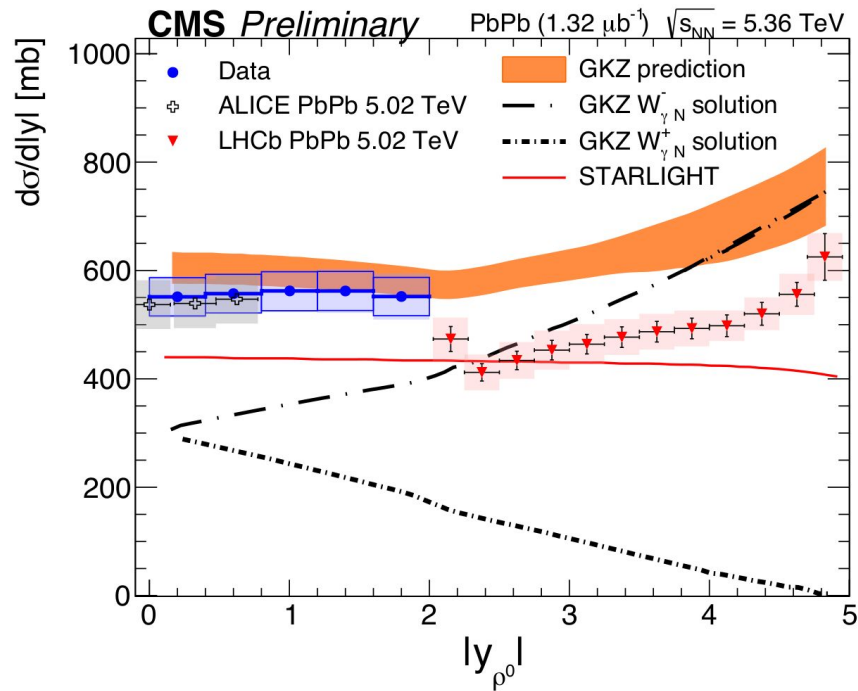
Saturation models

- Coherent production provides sensitivity to low Q^2 .
- small y dependence observed
- Shadowing models offer a better description of the data than saturation models.

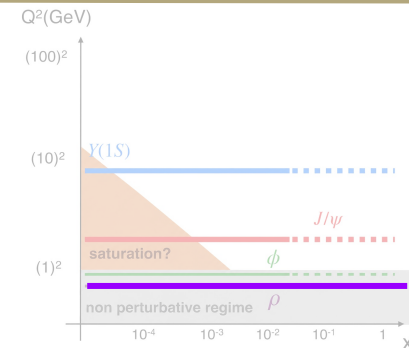


[CMS-HIN-24-009](#)
[arXiv:2504.05193v1](#)

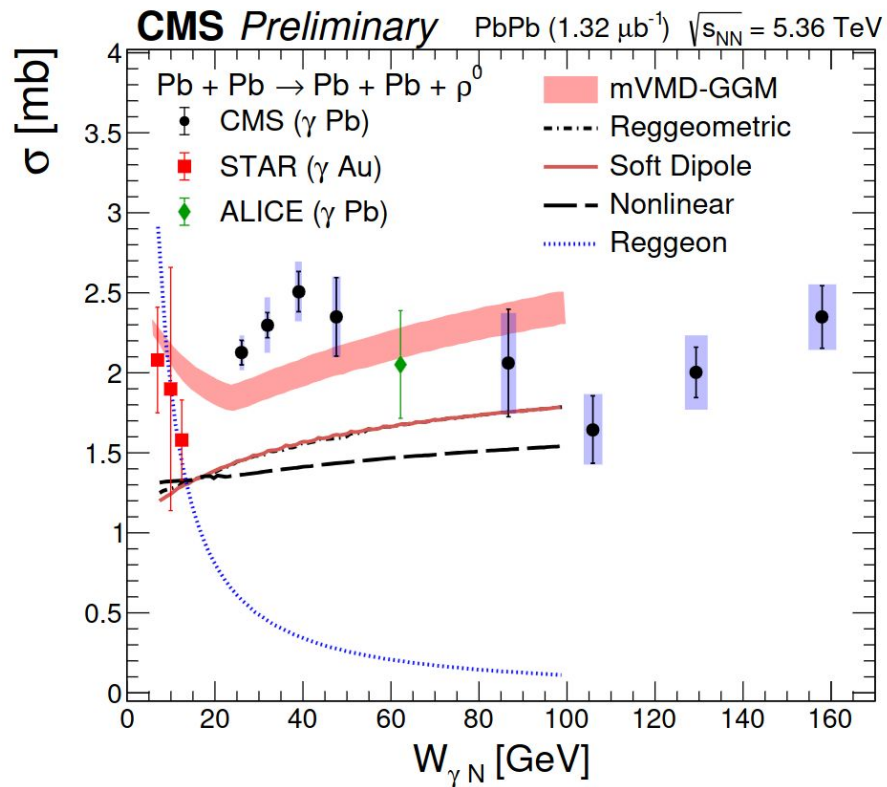
Coherent ρ^0 production in PbPb



- Connecting bridge to the ALICE and LHCb data.
- Flat distribution of cross section is seen in the central rapidity.
- Predictions from STARLIGHT tend to underestimate the data.
- GKZ approach describe the data in the central region, but a higher rapidities a 30 % deviation is observed in the LHCb data



CMS-HIN-24-020

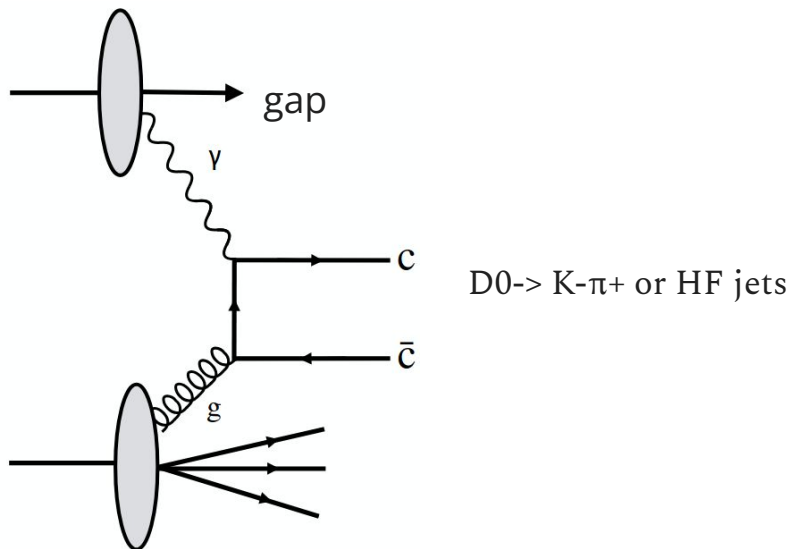


- mVMD-GGM: Model incorporating GG formalism with strong shadowing and weak shadowing scenarios, describes the data better.

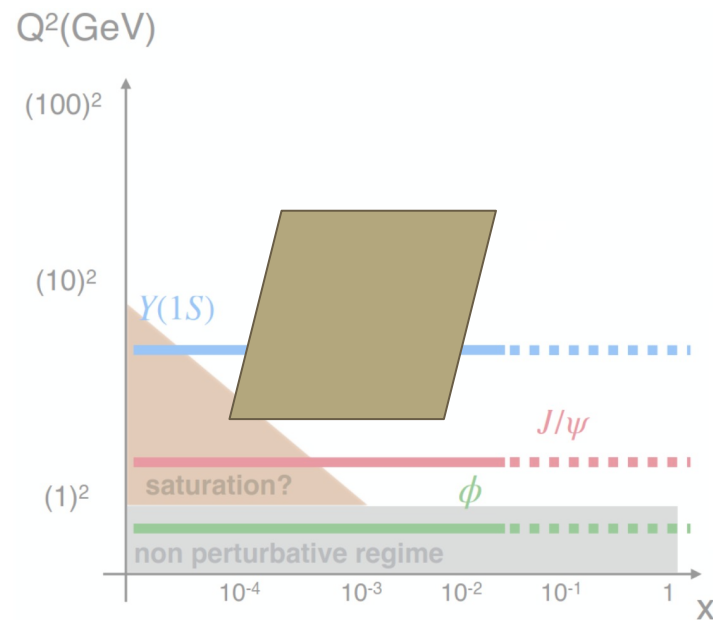
PHOTO-NUCLEAR INTERACTION IN UPCS

D0 meson production in PbPb

[Phys. Rev. Lett. 136 \(2026\) 122303.](#)

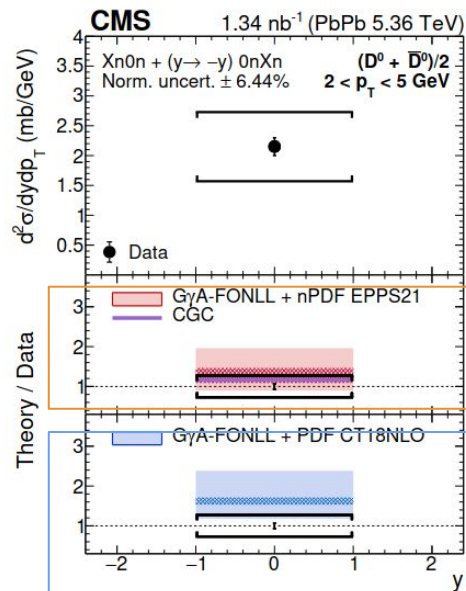


- Complementary to VM measurements. Sensitive to low- x physics
- Offers large coverage in Q^2 and x



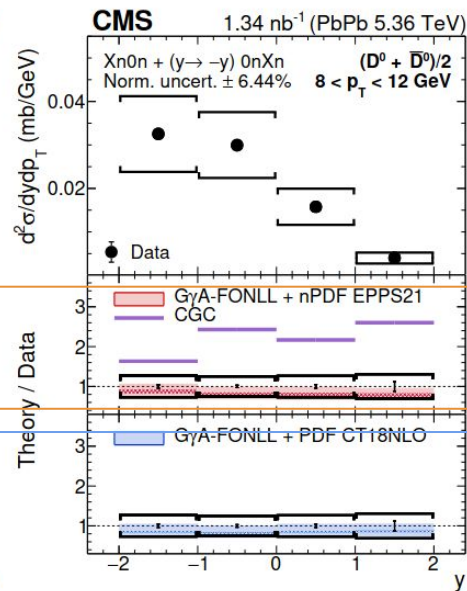
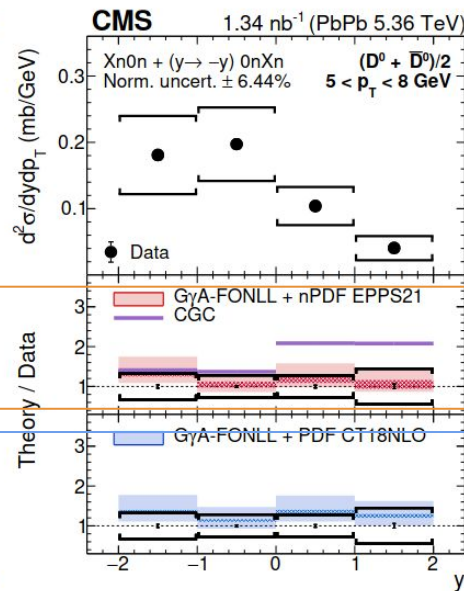
D0 meson production in PbPb

Lowest x/Q^2 probe



FONLL= Fixed Order
Next-to-Leading Logo

Highest x/Q^2 probe

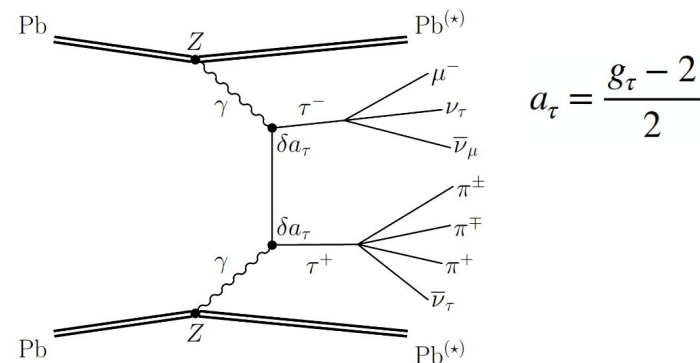
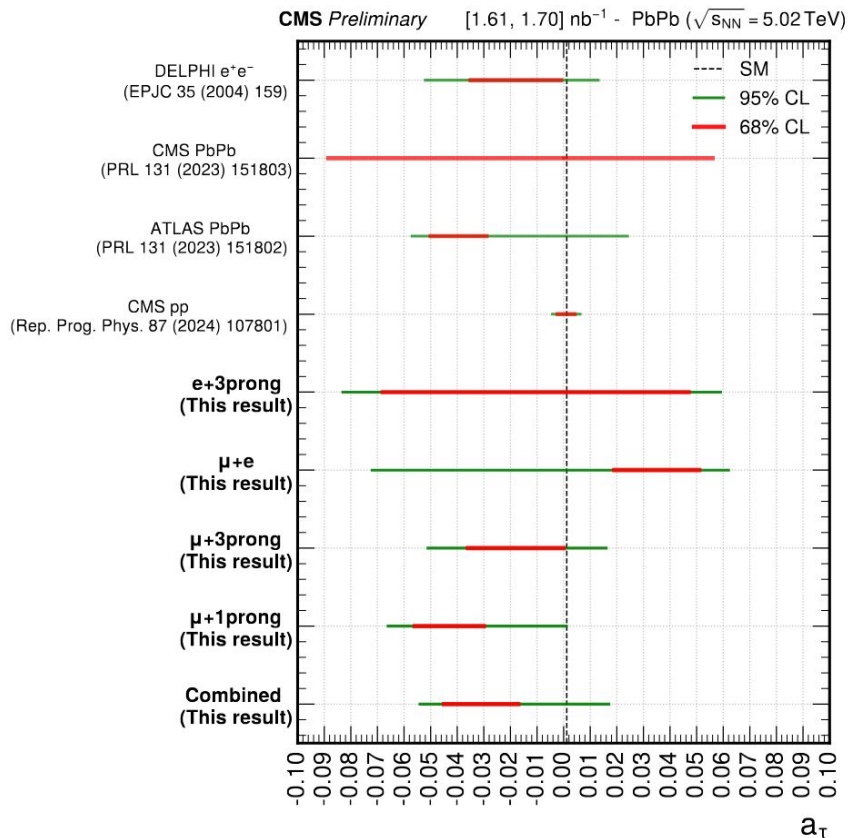


FONNL + nuclear
PDF good
agreement overall.

*FONLL + proton PDF agrees with high pt but overestimates low pt data.

... also for BSM physics and precision measurements

Anomalous magnetic moment of τ in PbPb

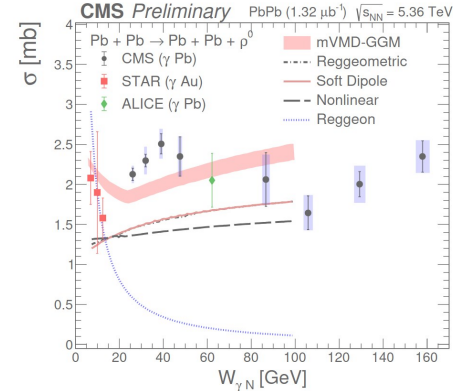
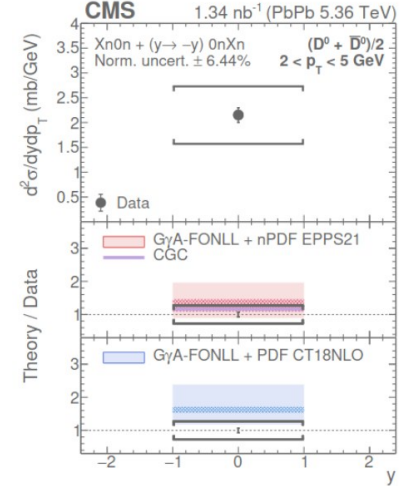
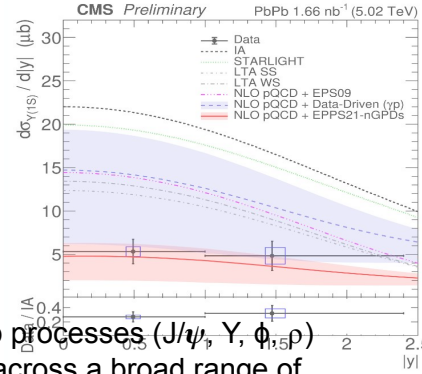
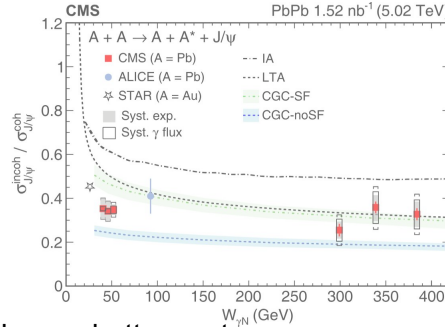


- CMS measurements in pp and PbPb collisions are consistent with Standard Model predictions.
- Improved last CMS result. ~ 4 times decreased uncertainties

[CMS-PAS-HIN-24-011](#)

Summary

- Vector-meson photoproduction in UPCs provides a clean and sensitive probe of the nuclear gluon structure.
- CMS measurements involving charm, bottom, strange processes, up processes (J/ψ , Υ , ϕ , ρ) challenge current models of gluon saturation and nuclear shadowing across a broad range of Bjorken- x .
 - The first energy dependence measurement of incoherent J/ψ shows strong suppression relative to the impulse approximation, with distinct model sensitivities at different W ranges.
 - Coherent production measurements at low Q^2 favor shadowing models over saturation-based approaches.
 - From Upsilon results; is suppression encoded in the nPDF parametrization?
 - From, Rho results; shadowing describe the data better.
 - Open heavy-flavor results offer new constraints on the nuclear parton structure through p and rapidity dependence.
- Upcoming Run 3 and HL-LHC data will provide improved precision and expand UPC studies.



Thank you for you attention