

David Horák

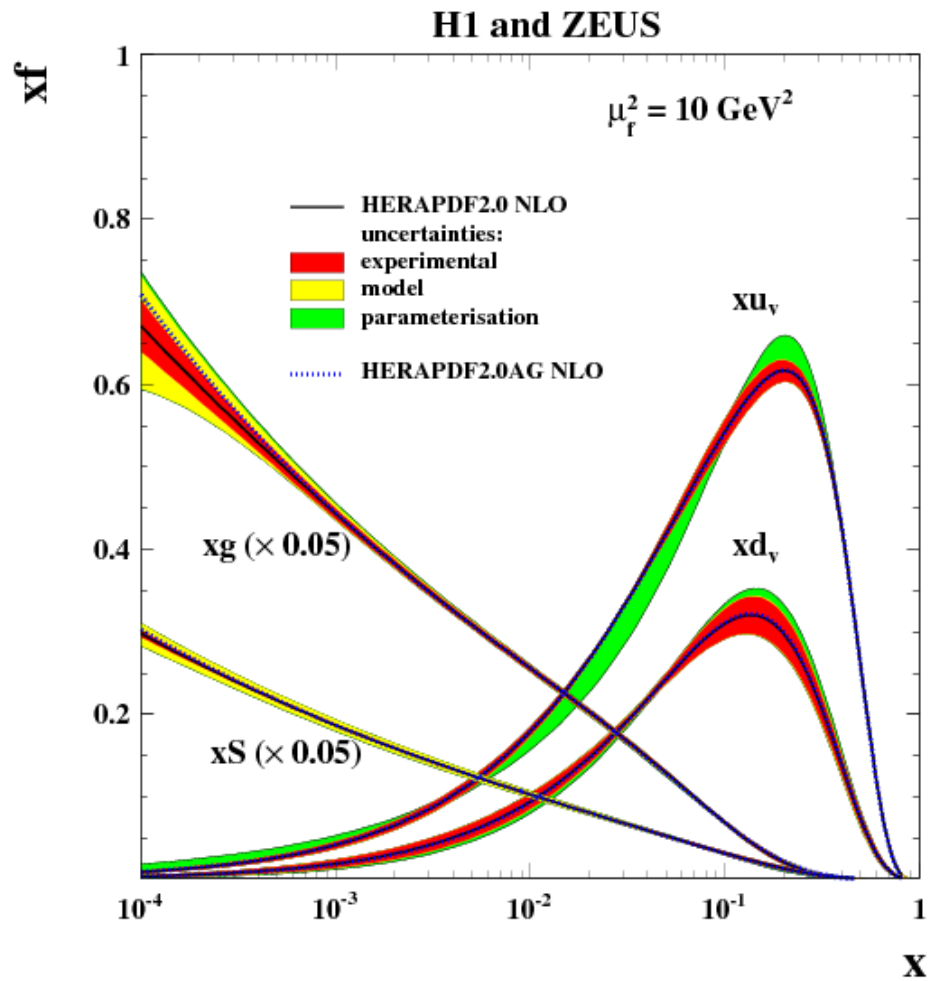
on behalf of the ALICE Colaboration

FNSPE CTU in Prague



Recent ALICE results on ultra-peripheral collisions

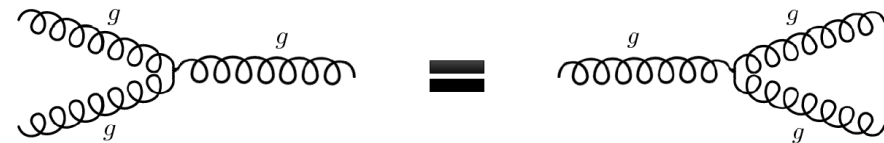
Puebla, Mexico 2019



- The structure of a proton is described by a **parton distribution function**
- At low Bjorken-x the proton structure is dominated by **gluons**

- $$x = \frac{M_V}{\sqrt{s_{NN}}} \exp(-y)$$

- The number of gluons cannot grow indefinitely
 - Recombination will appear and balance it = **saturation**

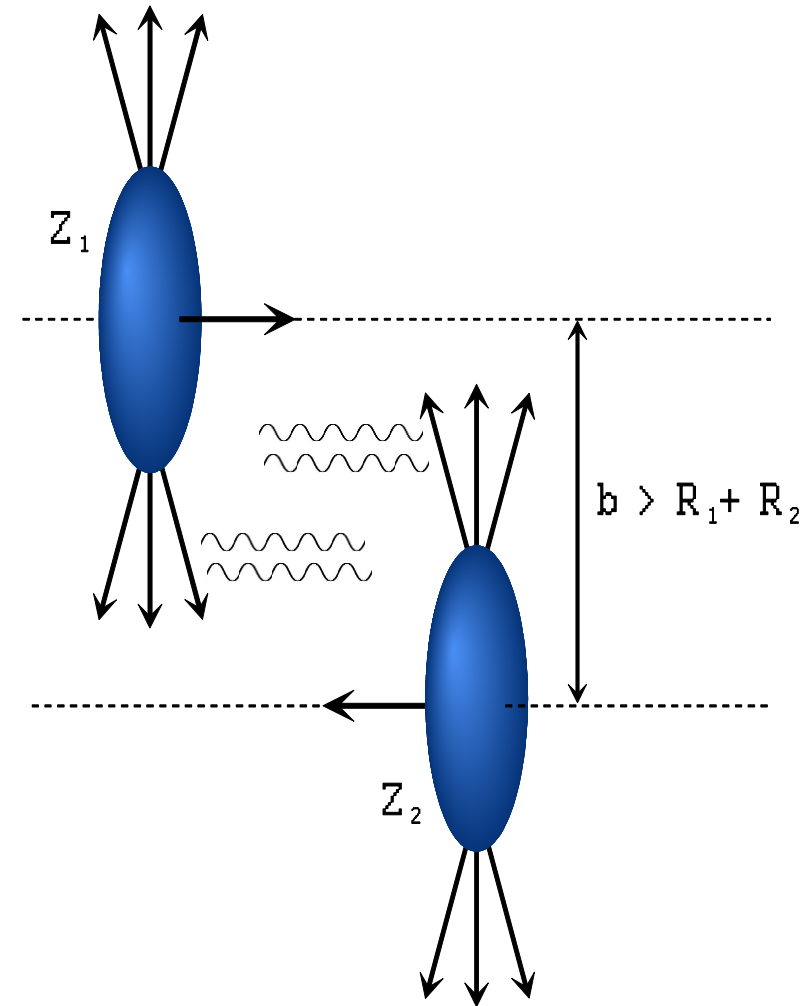


- Nucleus is not a sum of nucleons => **Nuclear shadowing**

Eur.Phys.J. C75 (2015) no.12, 580

What are ultra-peripheral collisions (UPC)?

- EM field of a **relativistic particle** acts as a beam of quasi-real photons
 - Intensity of the EM field proportional to Z_1^2 or Z_2^2
 - Two potential sources and two potential targets
- Impact parameter $b >$ sum of radii
 - **Ultra-peripheral collision**
 - Hadronic interaction suppressed
- Type of interactions (**photoproduction**):
 - photon – photon
 - photon – nucleus (proton)

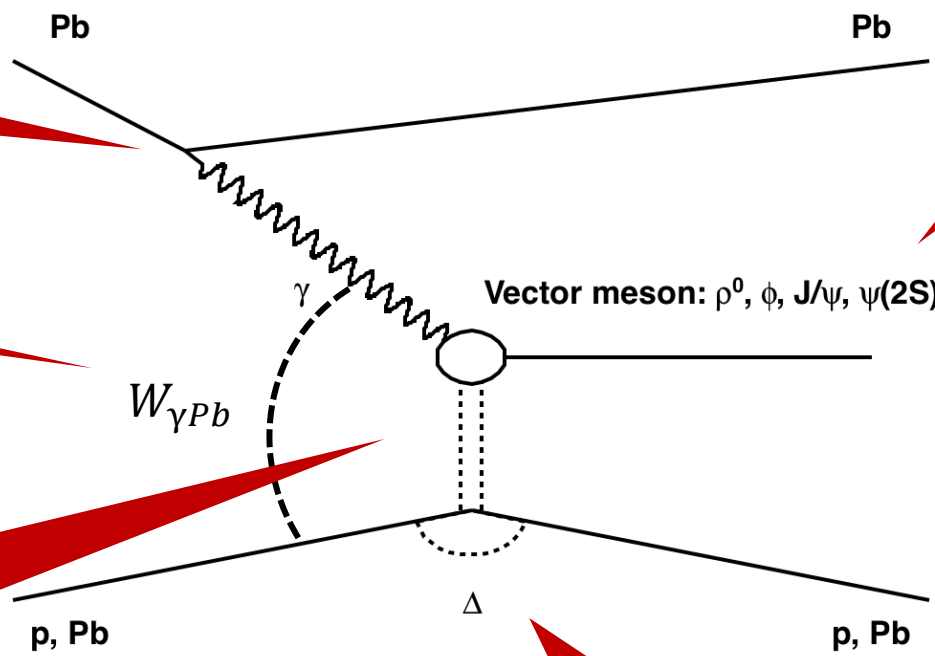


Vector meson photoproduction in UPC

Emission of a photon - flux is given by QED

γ -Pb energy at CMS

In LO pQCD, the cross section is proportional to the gluon density squared



Rapidity is related to the center-of-mass energy of the photon-target system:
 $W_{\gamma Pb}^2 = 2E_{p,Pb} M_{VM} e^{\pm y}$

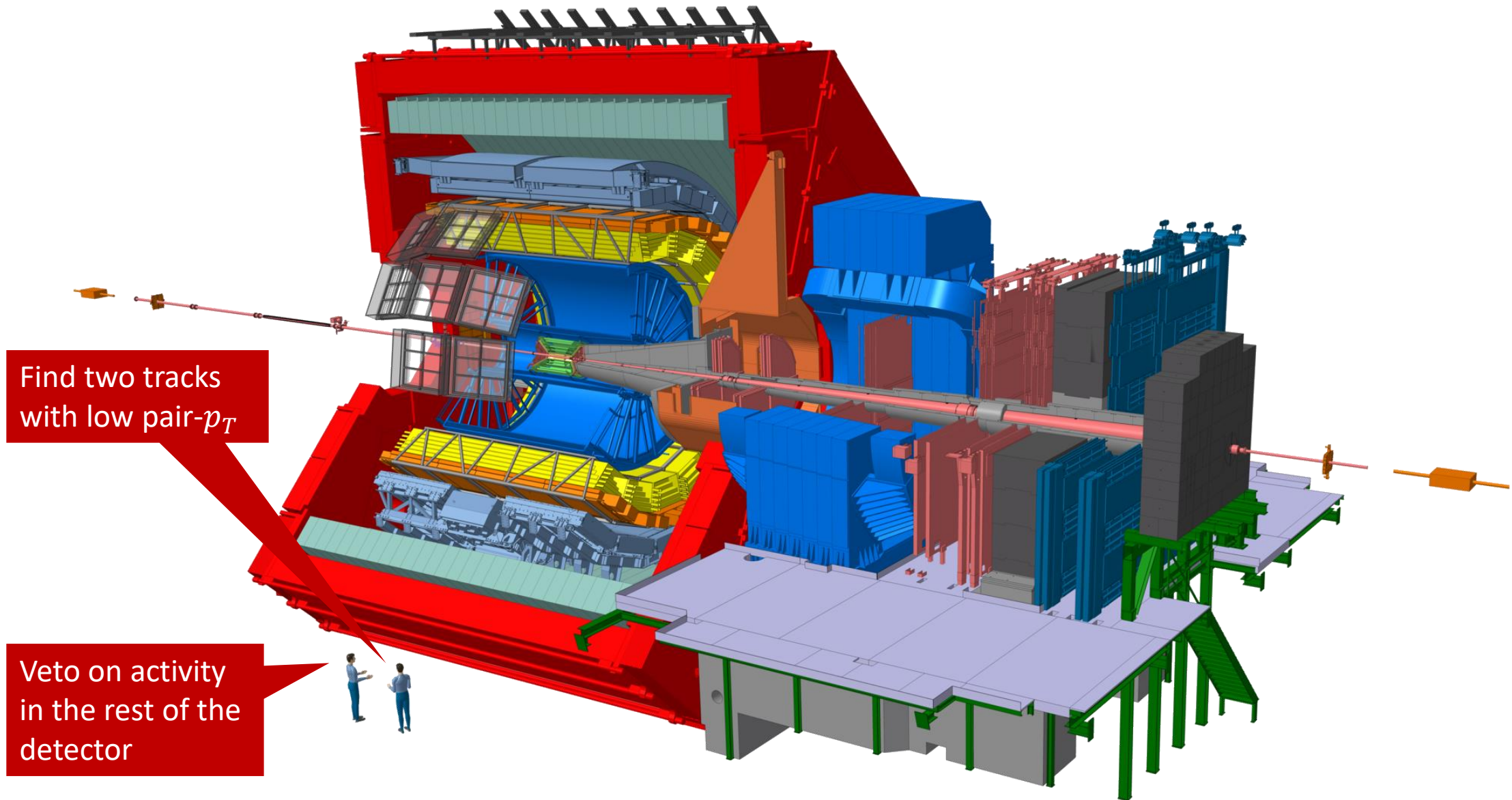
Coherence condition implies low transverse momentum p_T (few tens of MeV)

Nothing else in the detector (except possible few forward neutrons)

Transverse momentum is related to the momentum transfer in the target vertex $\vec{\Delta}^2 = -t$

$$\left. \frac{d\sigma_{\gamma A \rightarrow J/\psi A}}{dt} \right|_{t=0} = \frac{M_{J/\psi}^3 \Gamma_{ee} \pi^3 \alpha_s^2(Q^2)}{48 \alpha_{em} Q^8} [xg_A(x, Q^2)]^2$$

The ALICE Detector



Find two tracks
with low pair- p_T

Veto on activity
in the rest of the
detector

Central Barrel



ALICE

Main solenoid

- 0.5 T

Inner Tracking System (ITS)

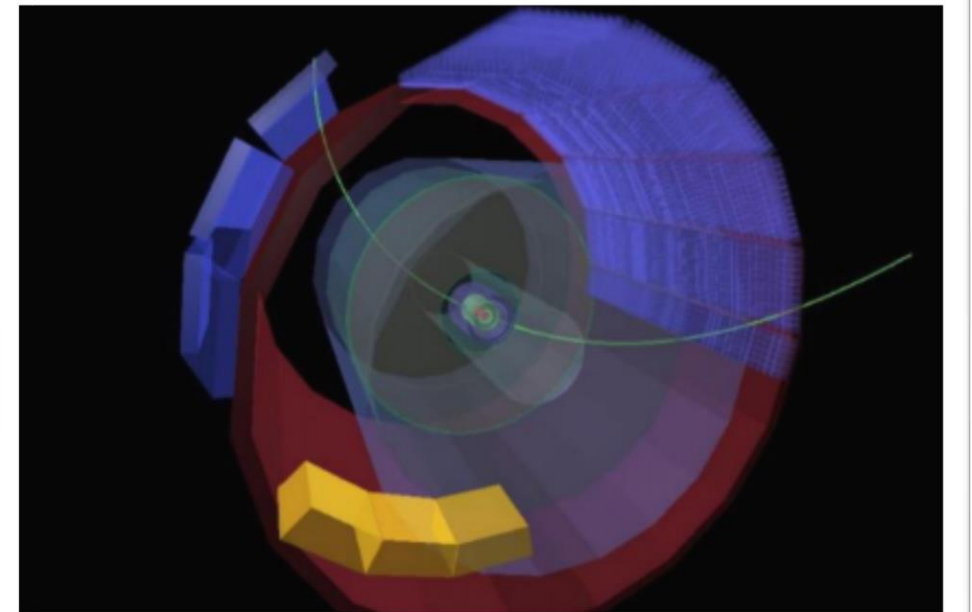
- Vertex position
- Trigger

Time-Of-Flight (TOF)

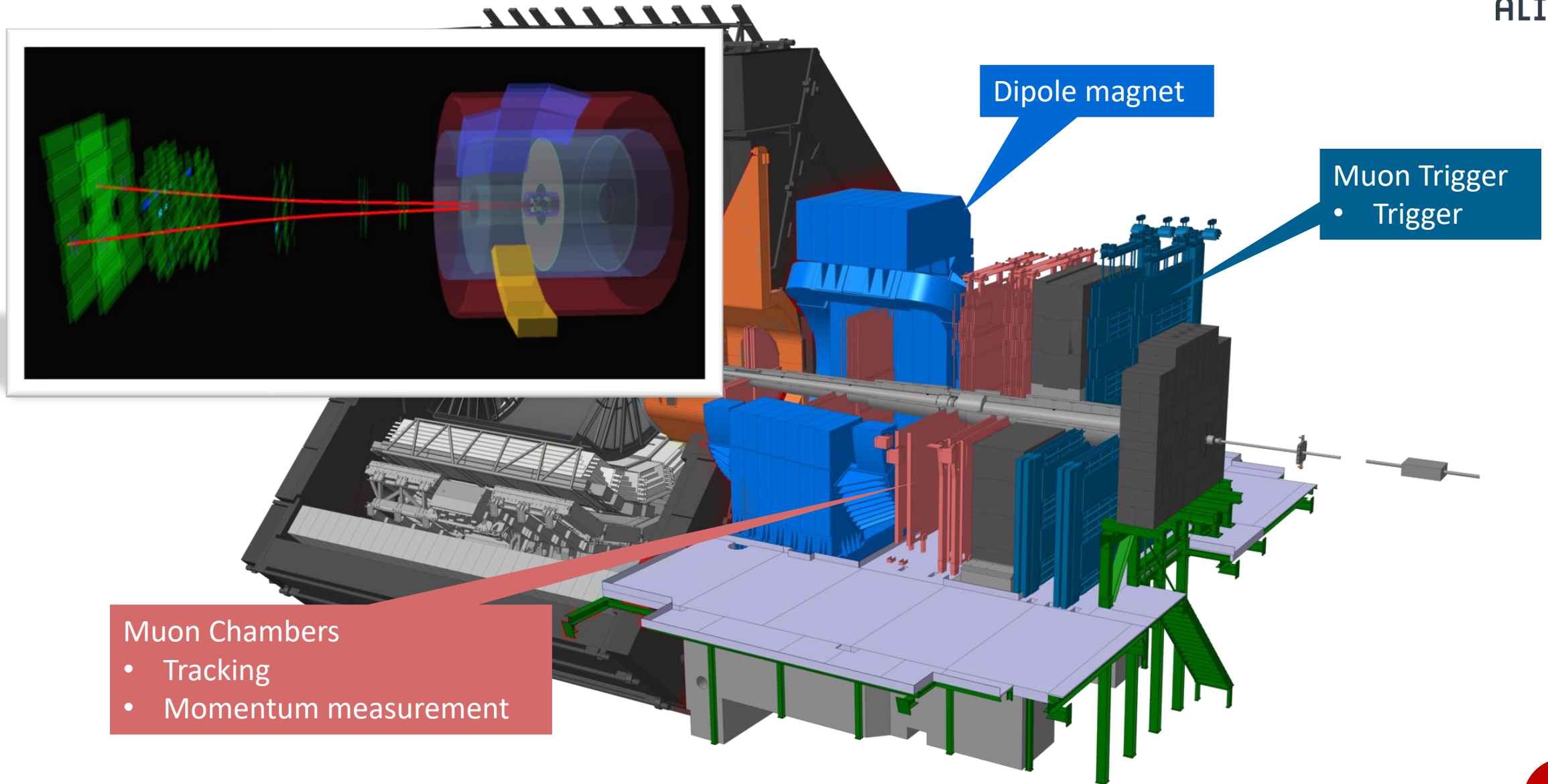
- Particle identification
- Trigger

Time-projection Chamber (TPC)

- Tracking
- Momentum measurement
- Particle identification (PID)



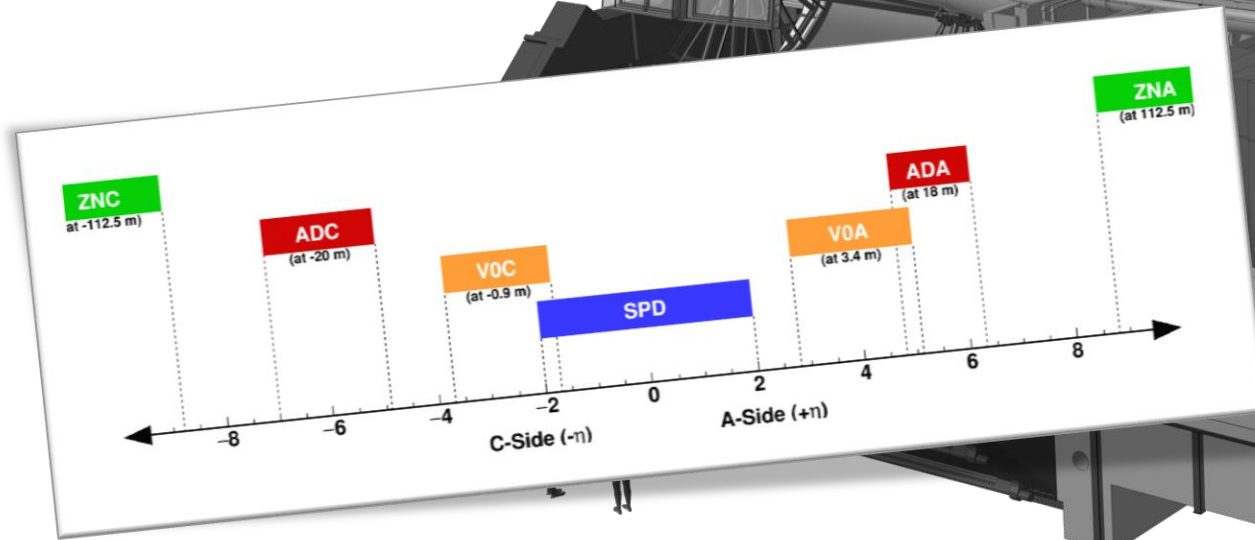
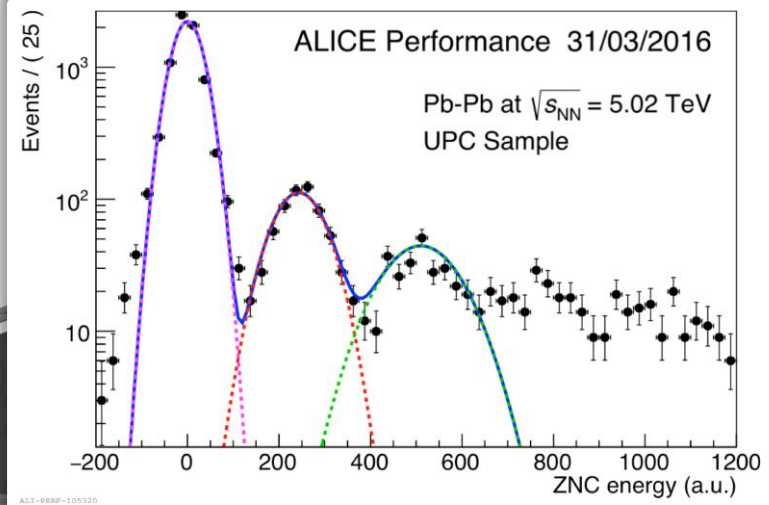
Forward Muon Spectrometer



Veto and neutrons

Veto on different pseudorapidities

- V0
- AD (Run 2)
- SPD



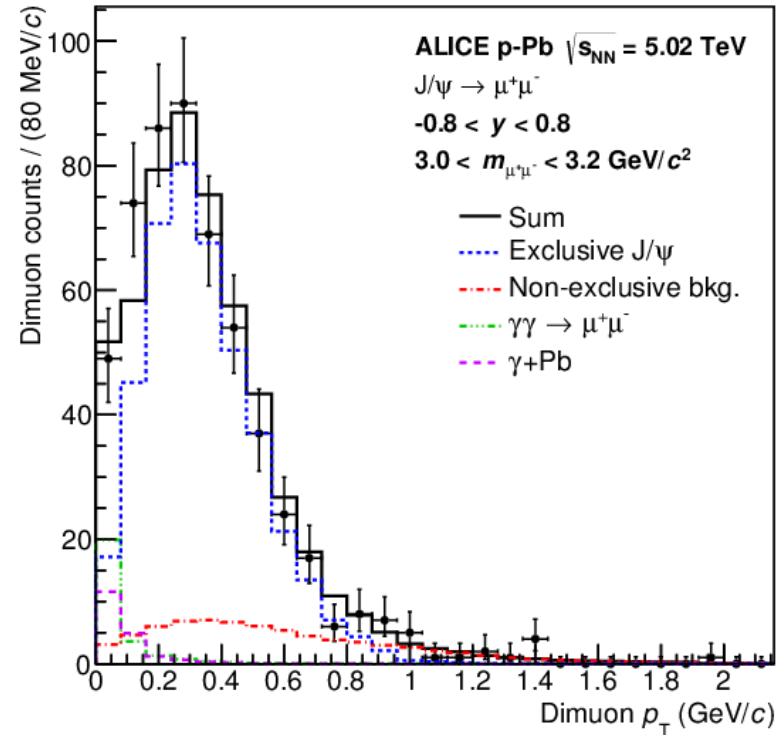
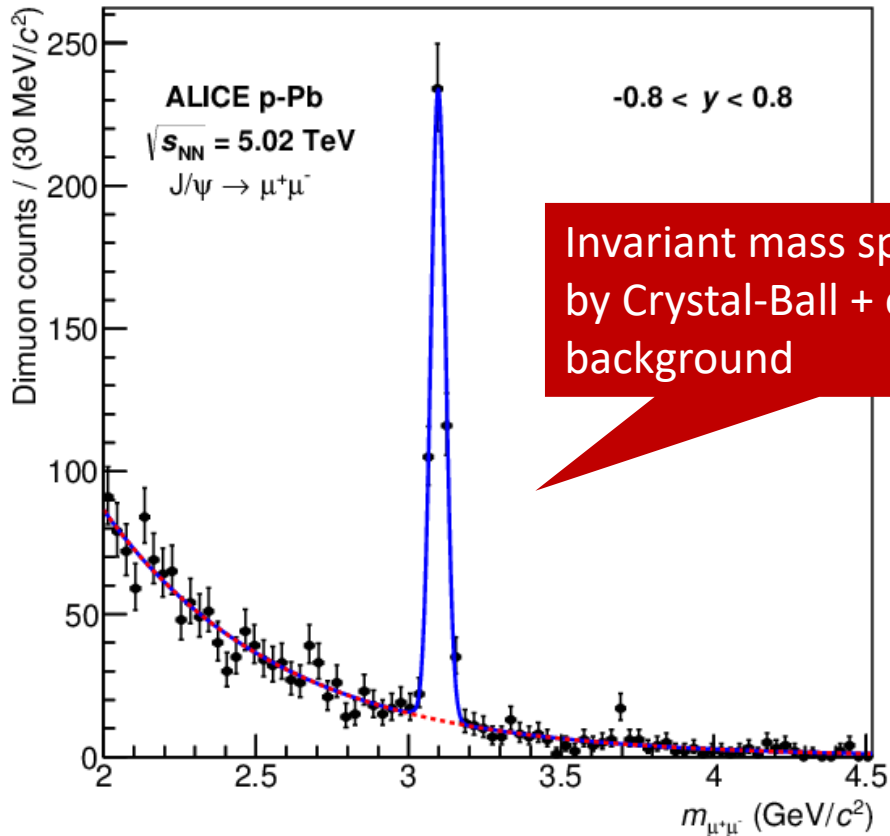
Zero-degree calorimeters

- Forward neutrons

J/ ψ in p-Pb: looking inside the proton...

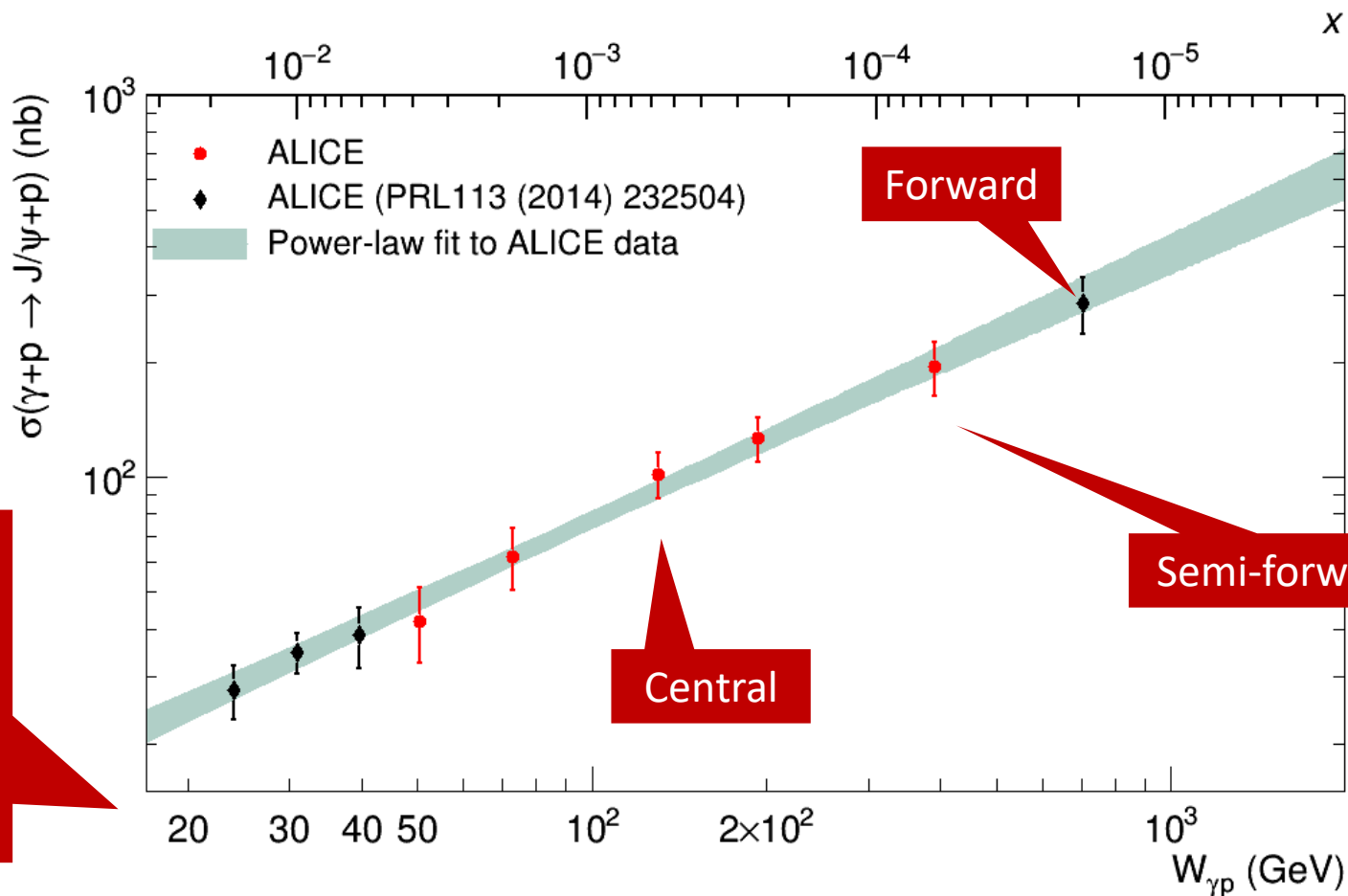


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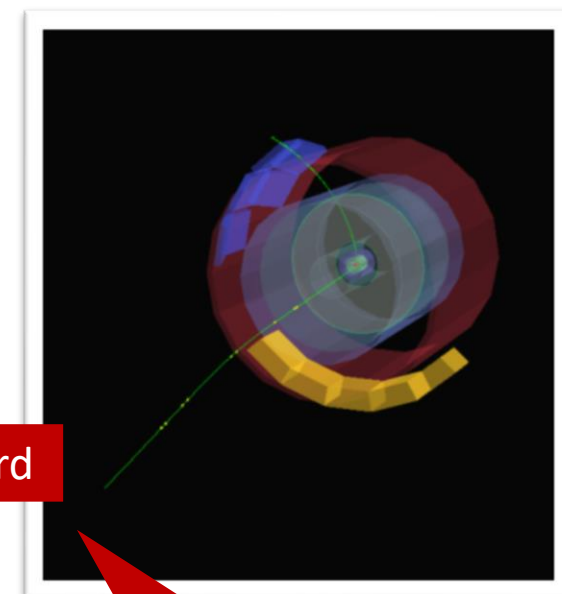


arXiv:1809.03235v1 [nucl-ex] (Accepted for publication in EPJC)

J/ ψ in p-Pb: looking inside the proton...



Energy dependence from 20 GeV to 700 GeV in the photon-proton center-of-mass energy

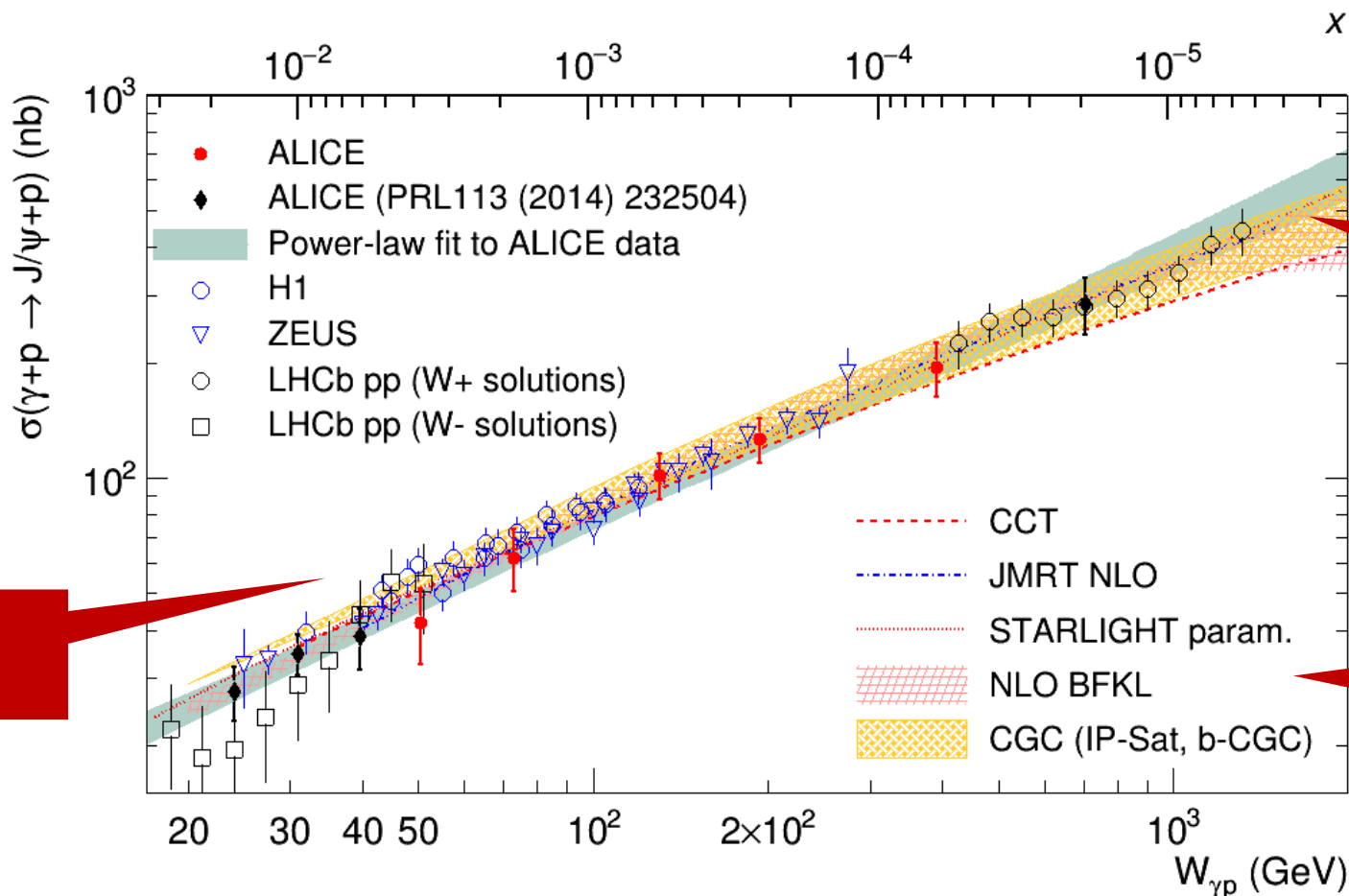


Semi-forward

Rapidity where ALICE has no detectors
This technique is used in ALICE for the first time

arXiv:1809.03235v1 [nucl-ex] (Accepted for publication in EPJC)

J/ ψ in p-Pb: looking inside the proton...



Agreement with
HERA data

ALICE Run 2 data
will reach above
1 TeV! (Work in
progress)

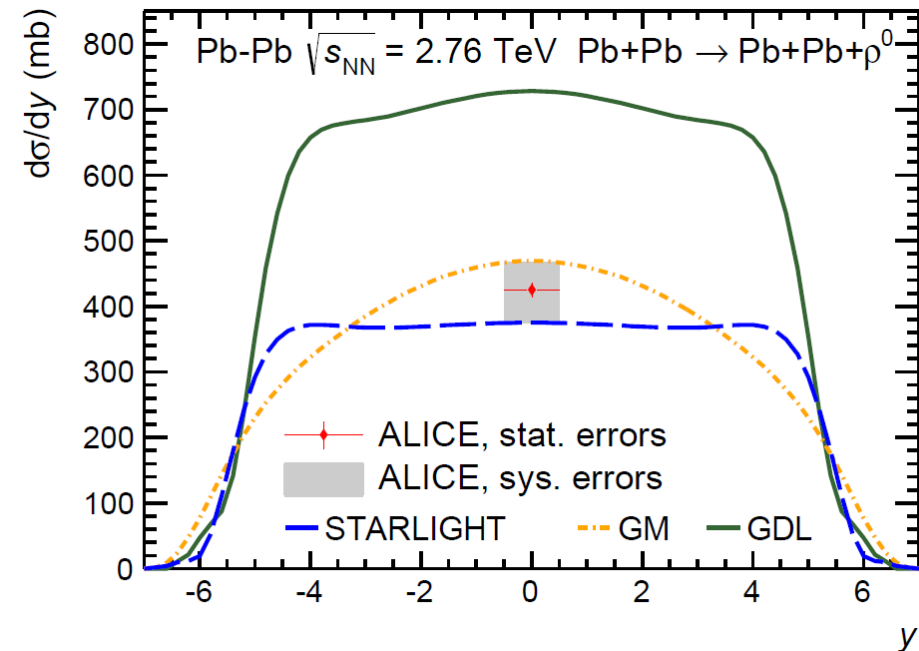
Agreement with various
theoretical predictions
and LHCb solutions

arXiv:1809.03235v1 [nucl-ex] (Accepted for publication in EPJC)

- Physics of coherent photoproduction of ρ^0 :
 - dynamics of QCD at a **semi-hard scale**
 - Large cross section: possibility to study the approach to the **black disk limit of QCD**

- ALICE PbPb measurements at $\sqrt{s_{NN}} = 2.76$ TeV

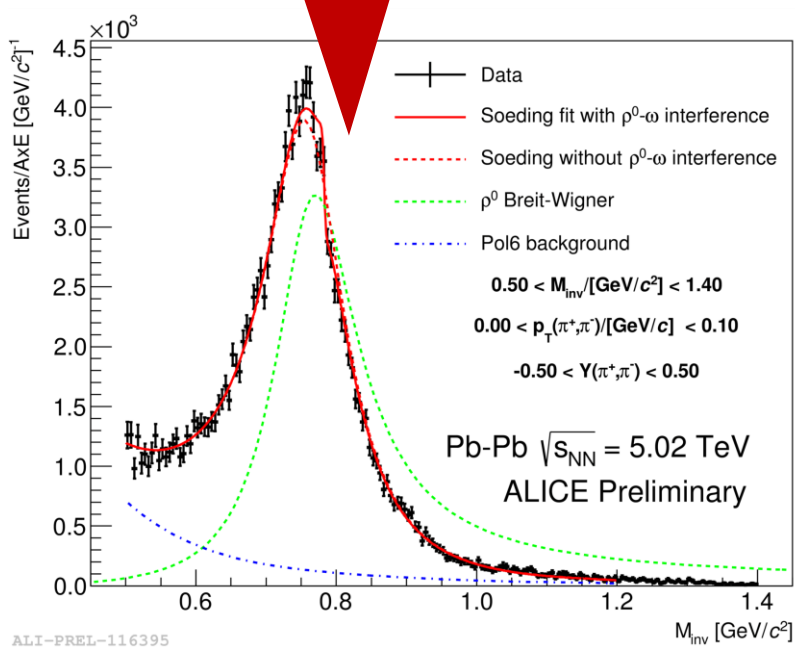
JHEP 1509 (2015) 095



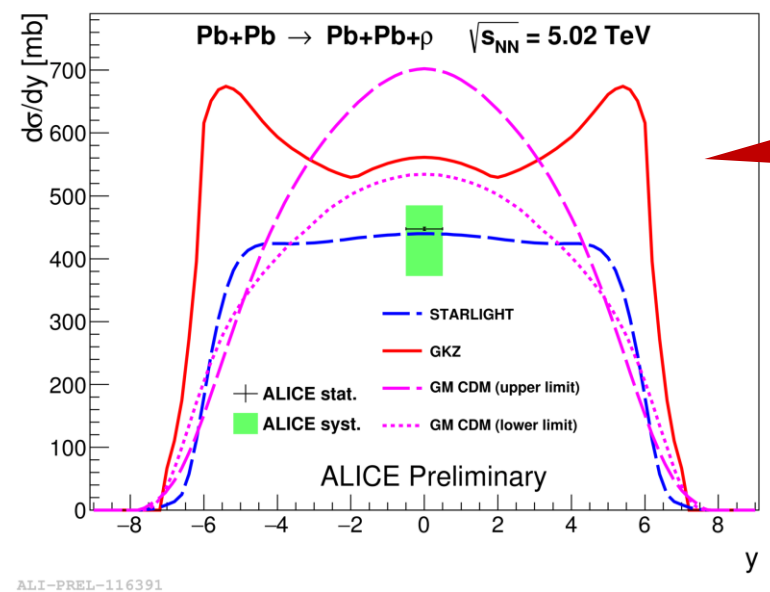
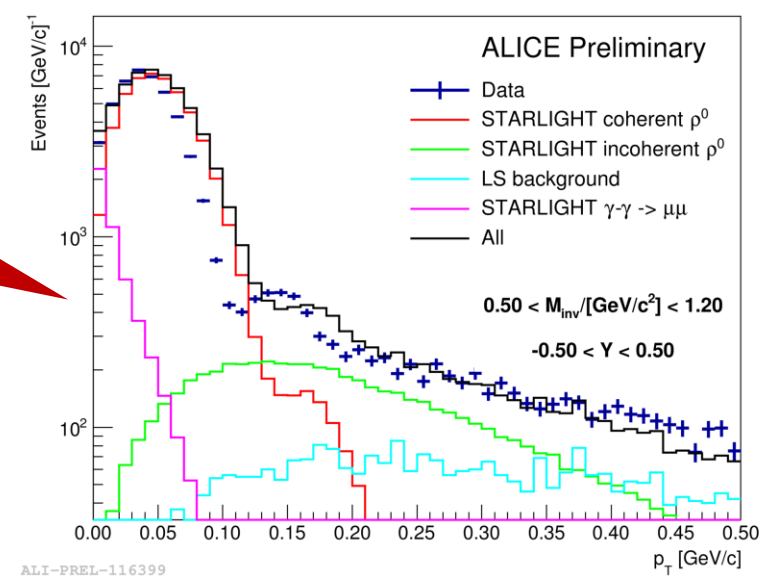
- Highlights of the new measurement (PbPb 2015 at $\sqrt{s_{NN}} = 5.02$ TeV)
 - More data, better precision
 - Possibility to measure ω contribution
 - Rapidity dependence of the cross section
 - Measurement for different classes of forward neutron activity: possibility to extract the energy dependence of the cross section

Coherent ρ^0 production in Pb-Pb (Preliminary Run 2)

ω seen through the interference (kink in the spectrum)



First and second diffractive peaks from ρ^0 clearly visible in the p_T spectrum



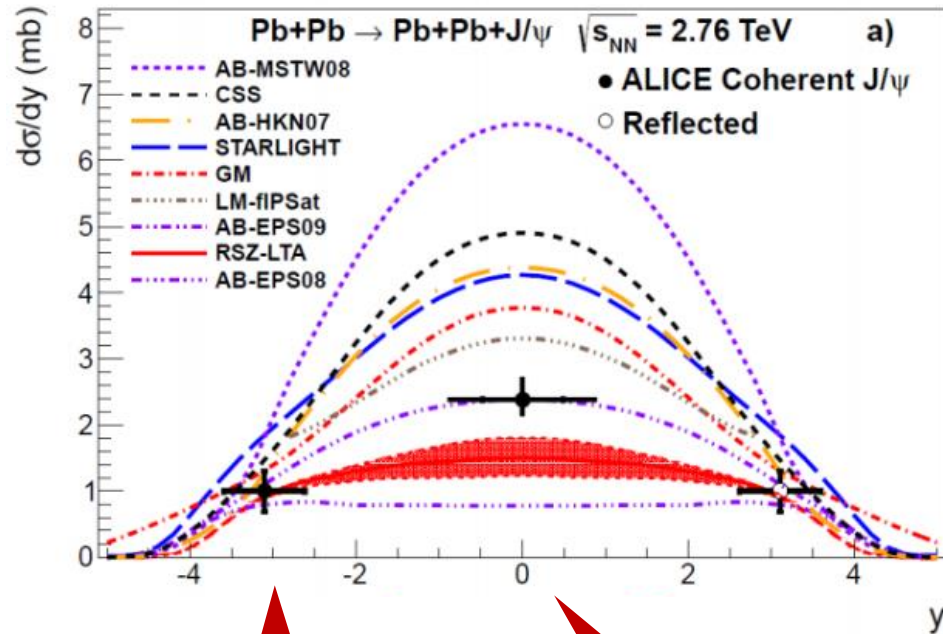
Some models close to the preliminary measurement. Final results coming soon!

Coherent J/ψ in Pb-Pb at midrapidity



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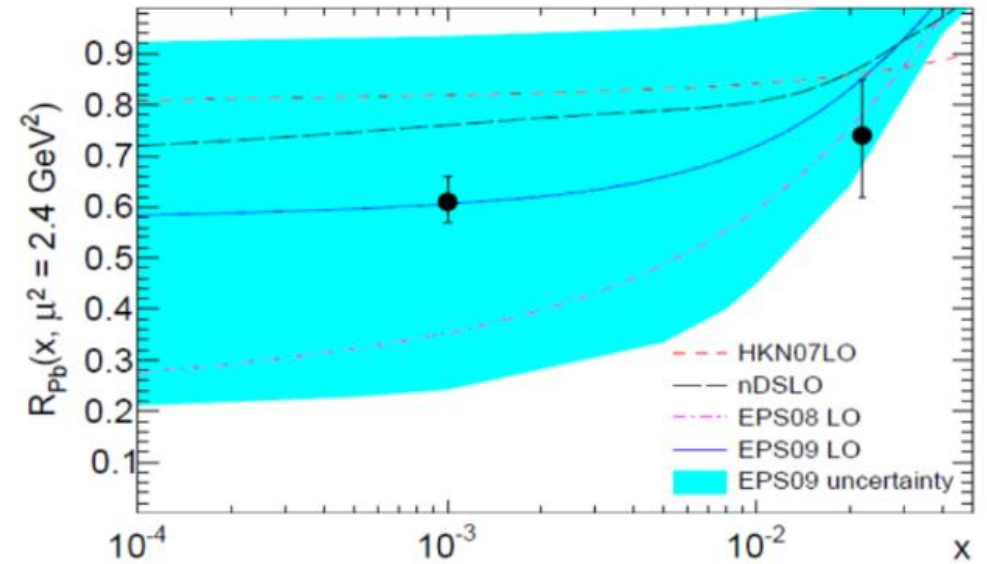
EPJC73 (2013) 2617



Bjorken $x \sim 10^{-2}$

Bjorken $x \sim 10^{-3}$

Best agreement with models based on moderate shadowing

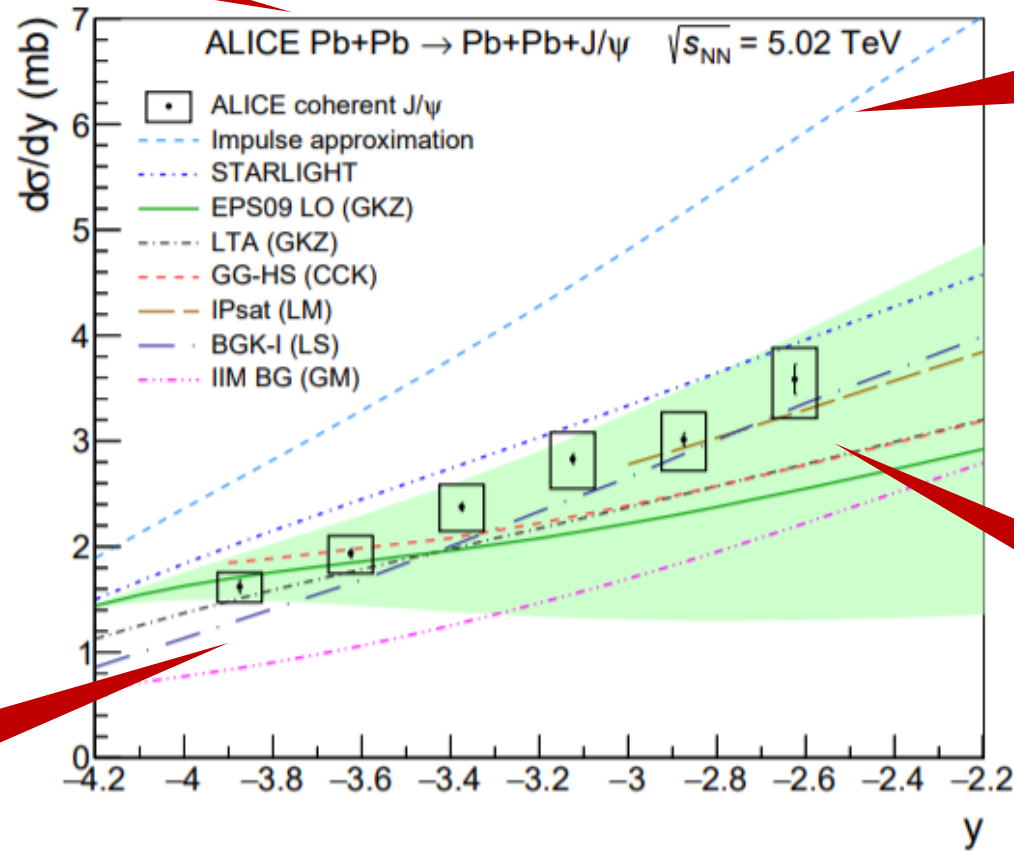


New and more precise data from Run 2 at a higher energy on the way! Stay tuned!

J/ψ forward at large rapidities

x200 increase in statistics wrt Run 1

arXiv:1904.06272v1 [nucl-ex]



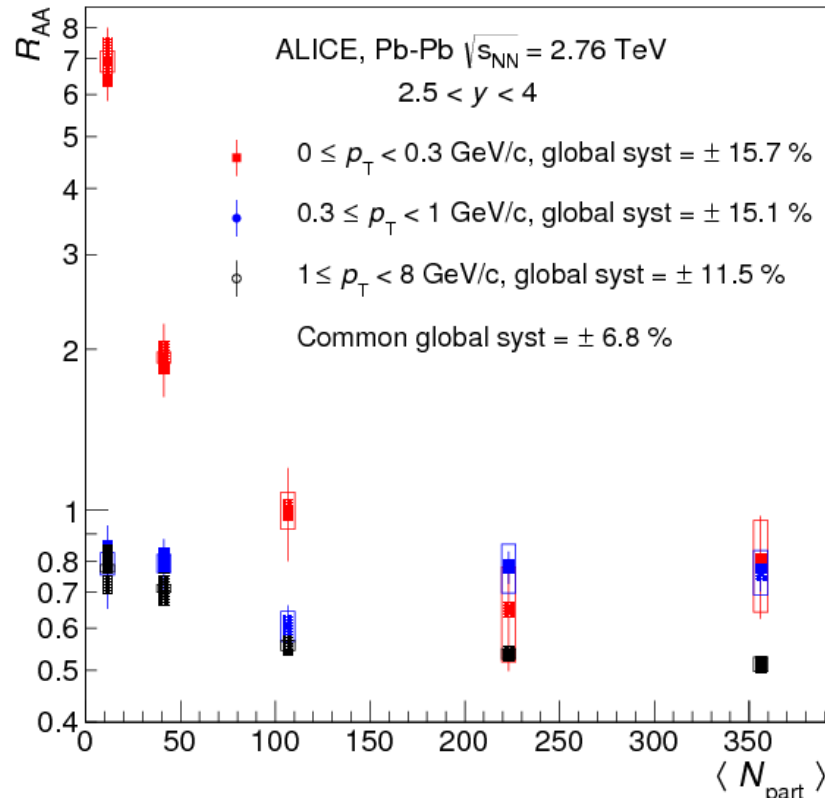
Impulse approximation overpredicts data
• gluon shadowing needed

~ 95%: $x = 0.7 \cdot 10^{-2}$
~ 5%: $x = 5.1 \cdot 10^{-5}$

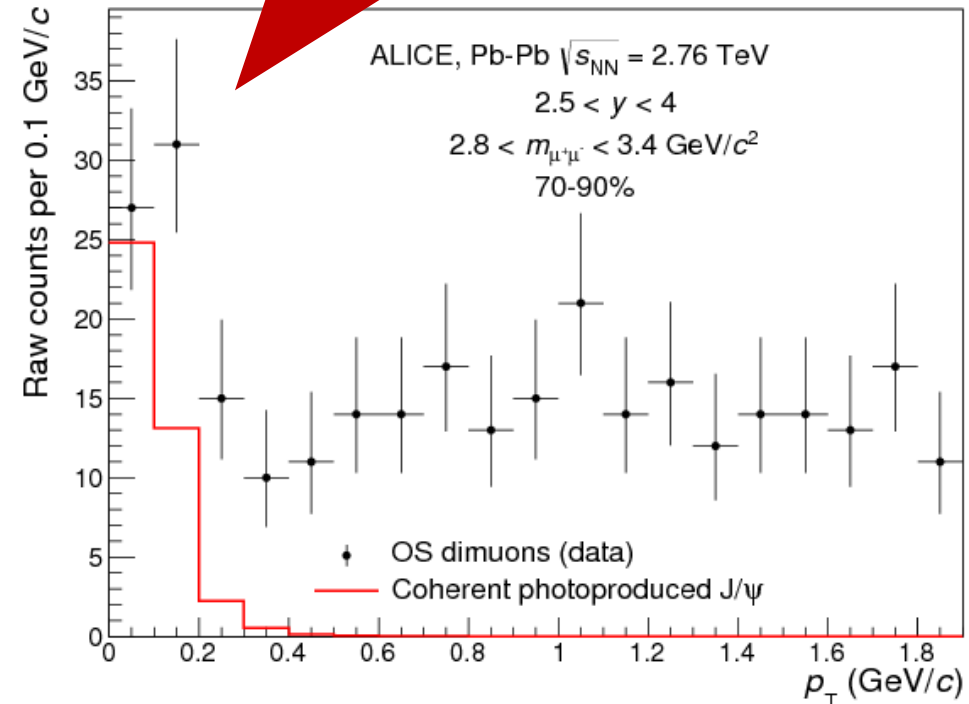
~ 60%: $x = 0.7 \cdot 10^{-2}$
~ 40%: $x = 5.1 \cdot 10^{-5}$

Coherent J/ψ cross section in agreement with moderate nuclear gluon shadowing

Phys.Rev.Lett. 116 (2016) no.22, 222301



J/ψ excess at low p_T in peripheral PbPb collision taken during Run 1



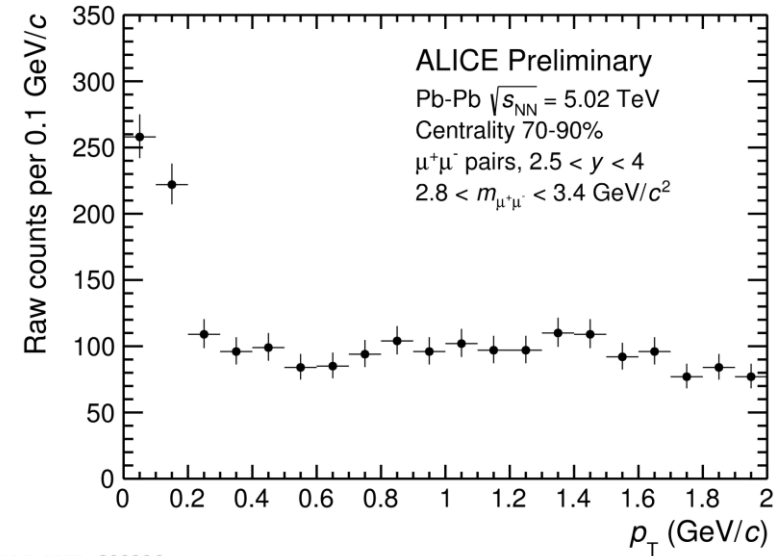
- Interpreted as **coherent J/ψ production**
- How can the coherence condition survive when both nuclei are broken by the hadronic interaction?

J/ψ in peripheral PbPb collisions

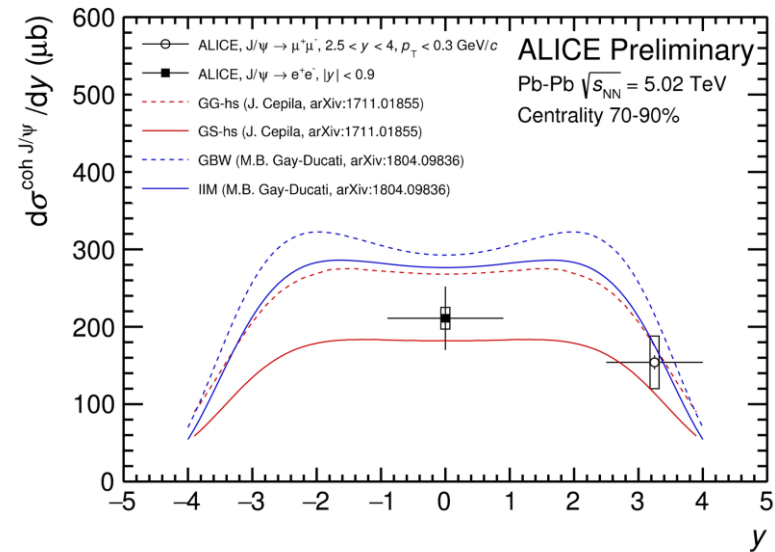


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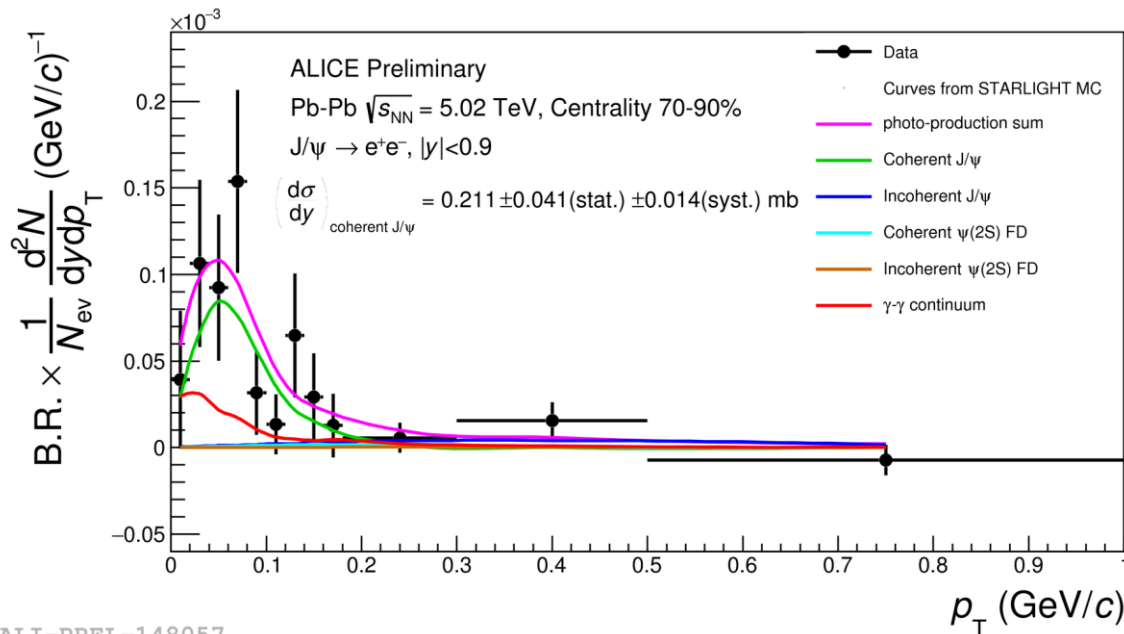
- Increased statistics in Run 2
- Measured **cross section** of the coherent J/ψ
 - Central + forward rapidities



ALI-PREL-309896



ALI-PREL-309948

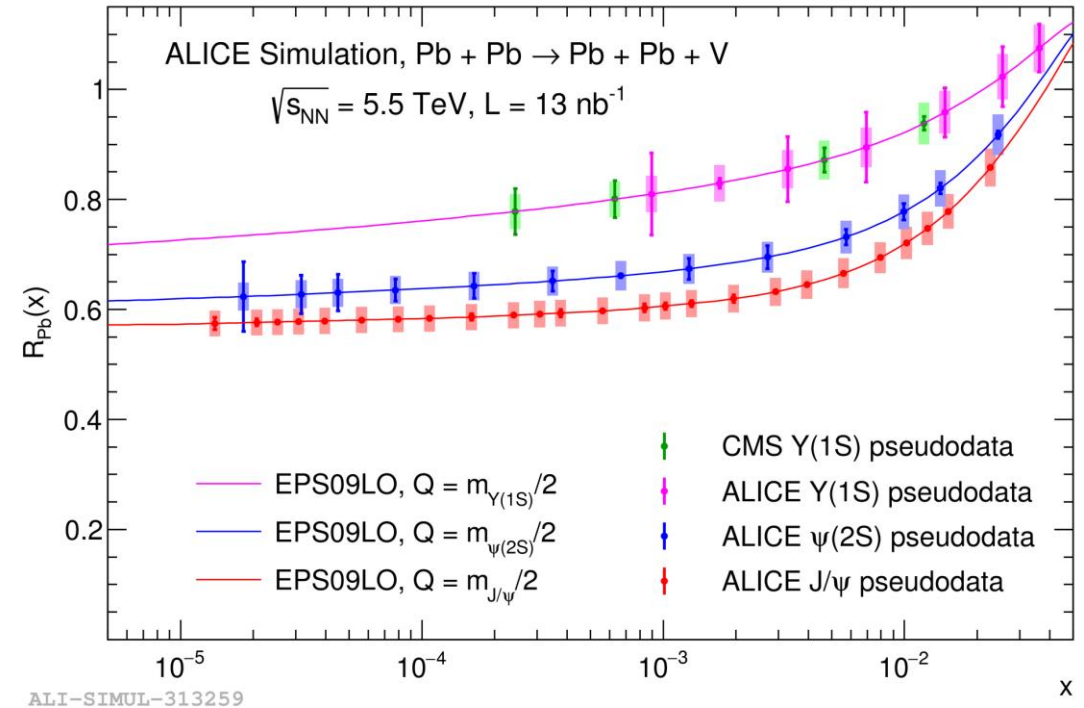


ALI-PREL-148057

arXiv:1812.06772v2 [hep-ph]

Expected 13 nb^{-1} of PbPb collisions compared to 1 nb^{-1} in Run 2

| PbPb, 13 nb^{-1} | | | | |
|--|-------------------|-------|----------------|--------------------|
| Meson | σ | Total | $ \eta < 0.9$ | $-4 < \eta < -2.5$ |
| $\rho \rightarrow \pi^+\pi^-$ | 5.2b | 68 B | 5.5 B | 4.9 B |
| $\rho' \rightarrow \pi^+\pi^-\pi^+\pi^-$ | 730 mb | 9.5 B | 210 M | 190 M |
| $\phi \rightarrow K^+K^-$ | 0.22b | 2.9 B | 82 M | 15 M |
| $J/\psi \rightarrow \mu^+\mu^-$ | 1.0 mb | 14 M | 1.1 M | 600 K |
| $\psi(2S) \rightarrow \mu^+\mu^-$ | 30 μb | 400 K | 35 K | 19 K |
| $\Upsilon(1S) \rightarrow \mu^+\mu^-$ | 2.0 μb | 26 K | 2.8 K | 880 |



Gluon shadowing down to 10^{-5}

- ALICE is an excellent detector to **investigate QCD using UPC**.
 - ALICE has measured exclusive J/ψ production off protons continuously for γ -p energies from 20 to 700 GeV in Run 1. It will reach well above 1 TeV with Run 2 data.
 - ALICE studies the approach to the black-disk limit of QCD with coherent ρ^0 production in Pb-Pb UPC.
- Data are consistent with models containing **moderate shadowing**.
- Data from Run 3+4 will allow us to access the gluon structure functions down to $x \approx 10^{-5}$.
- *Stay tuned for upcoming results!*

Thank you for your attention!

This work has been partially supported by the grant 18-07880S of the Czech Science Foundation (GACR).

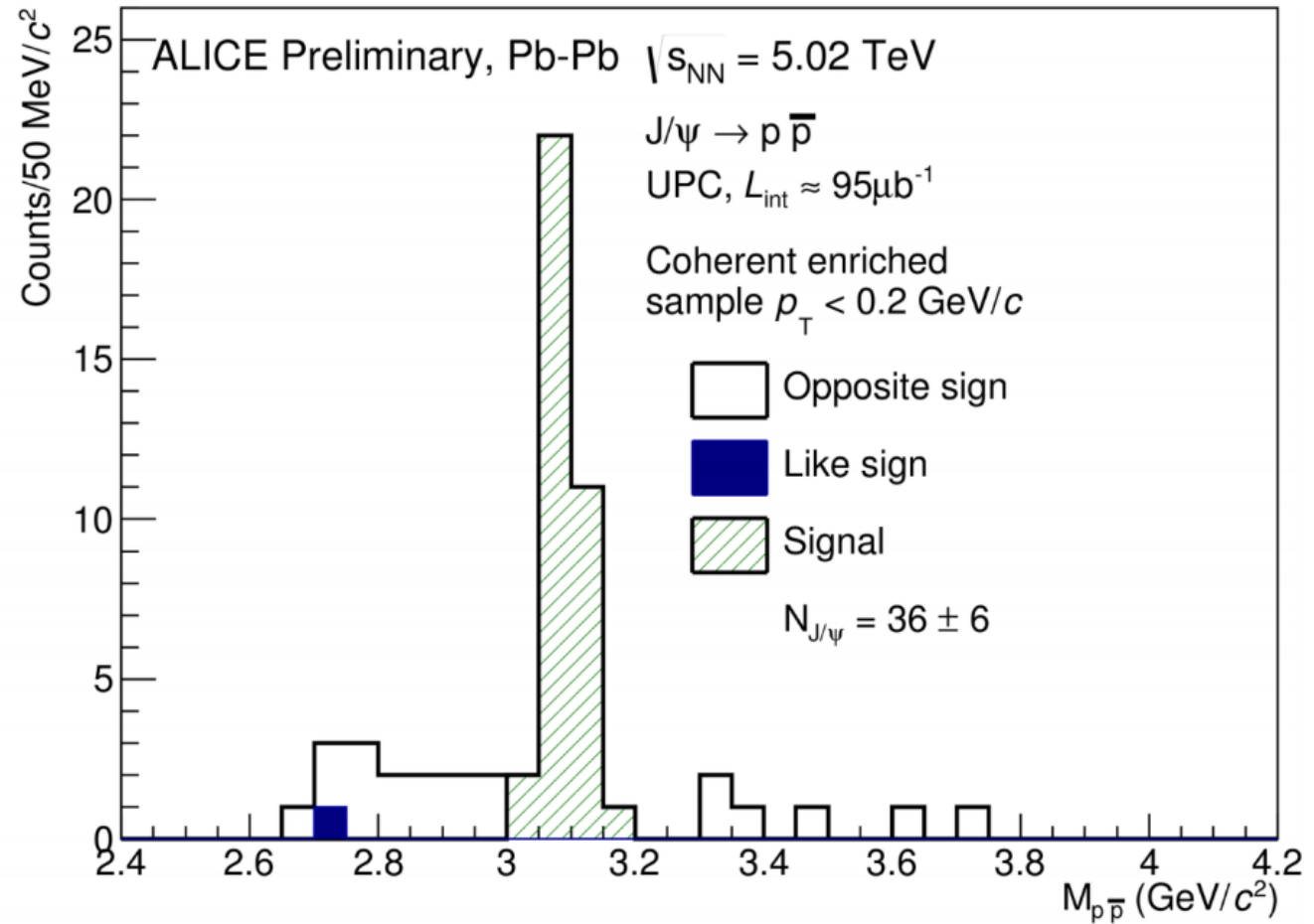


ALICE

Backup Slides

J/ψ to p \bar{p}

- First observation in UPC
- Run 2 data

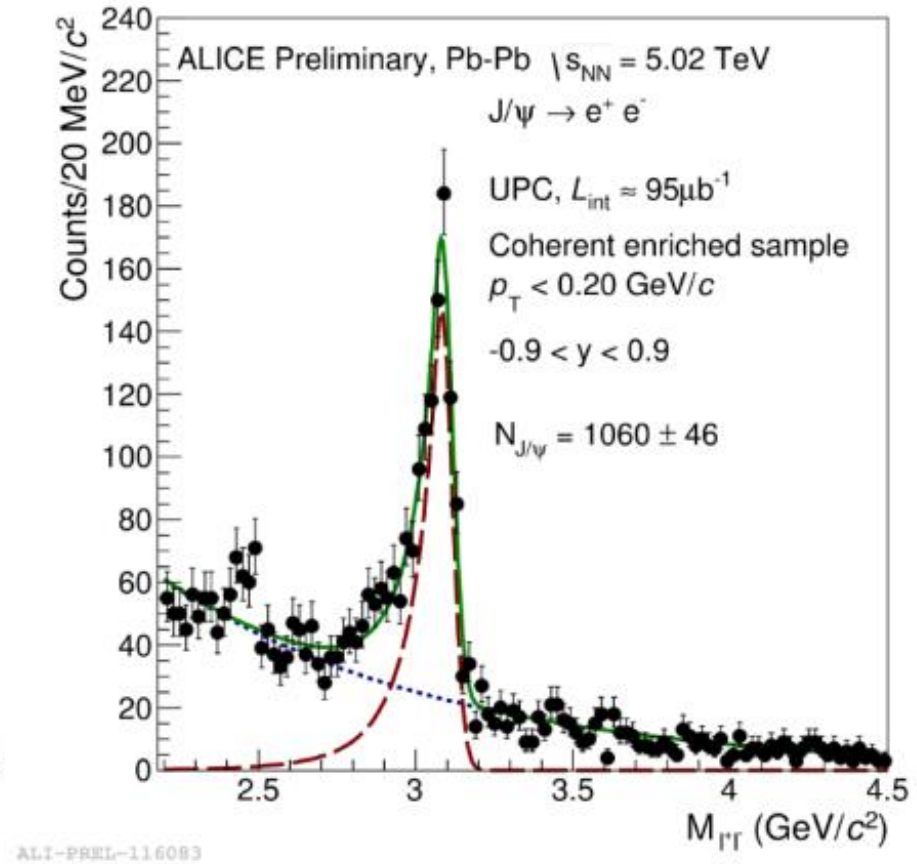
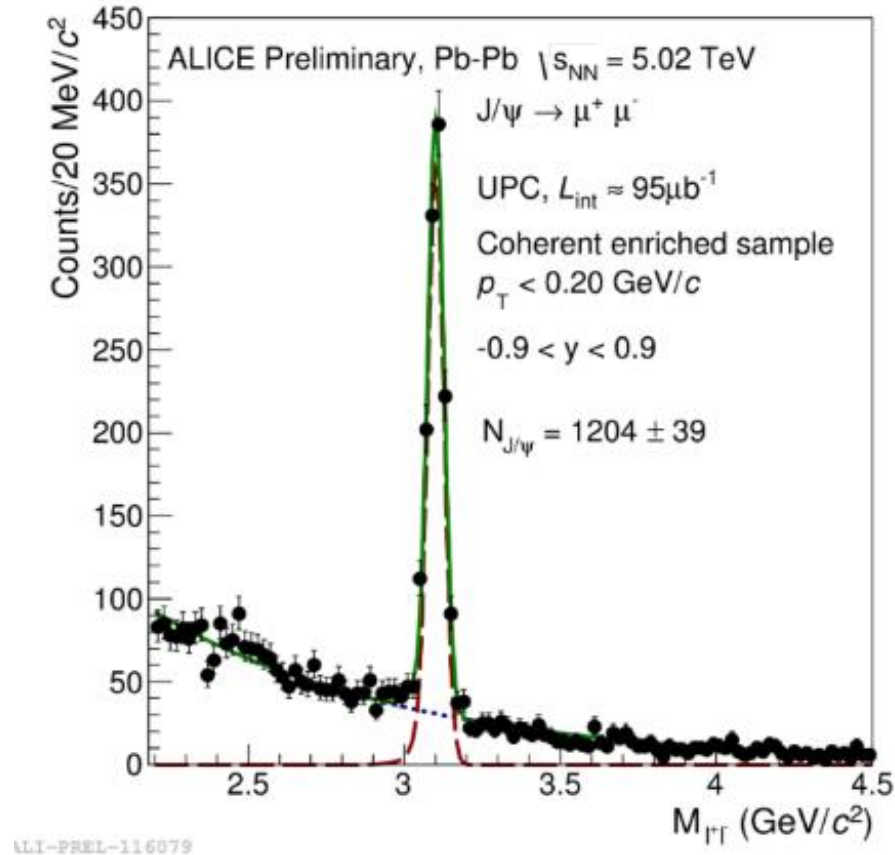


ALI-PREL-117138

Coherent J/ψ in Pb-Pb at midrapidity



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In Run 2 x4 increase in statistics wrt to Run 1