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Review of Run1 results from ALICE on p-Pb and Pb-Pb UPC

Guillermo Contreras
(Czech Technical University in Prague)

On behalf of the **ALICE** Collaboration

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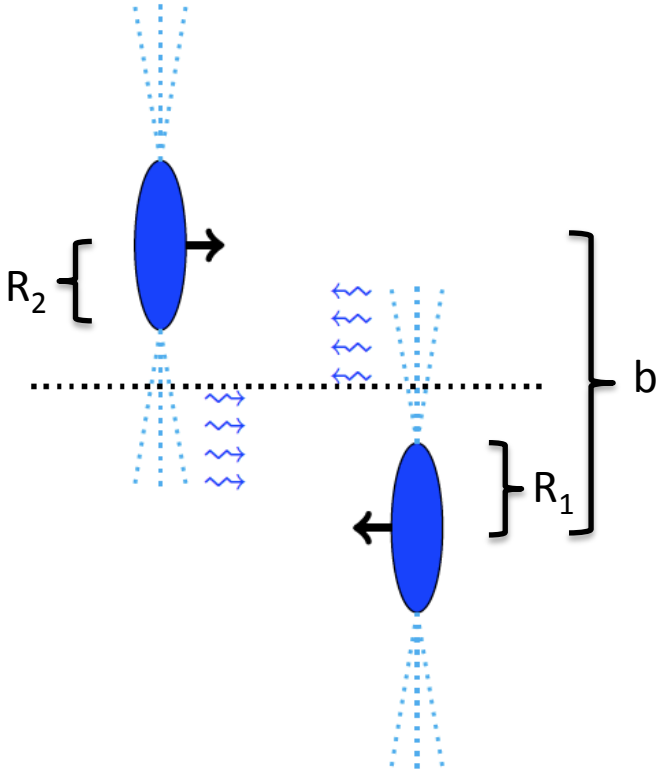
Contents

What are ultra-peripheral collisions (UPC)?

Ultra-peripheral collisions (UPC)

- ✓ The LHC accelerates charged particles: protons or lead ions



$R_1+R_2<b \rightarrow$ UPC

- ✓ The EM field of fast charged particles can be viewed as a beam of quasi real photons

  The virtuality of the emitted photons is restricted by the radius R of the source to be around $(hc/2\pi R)^2$,

  γ from Pb: $Q^2 \approx (30\ MeV)^2$

- ✓ For collisions at impact parameters (b) larger than the sum of the radii of the incoming particles, hadronic interactions are suppressed and EM interactions dominate

  Photoproduction processes can be cleanly studied in hadron colliders using

  Ultra-peripheral collisions (UPC),

UPC processes

- ✓ One possibility to select UPC is to study exclusive processes:
  1. Measure the complete exclusive final state
  2. Make sure there is nothing else in the detector

- ✓ ALICE has measured the following UPC processes with the lead nucleus as the photon source:
  1. Continuum di-lepton production in photon-photon interactions

     This is a standard QED process, but with a strong coupling: $\alpha Z \sim 0.6$
     Interest from theory to know the size of higher order contributions

  2. Exclusive photoproduction of vector mesons off proton or off Pb targets

     This process allows us to study the energy evolution of the cross section at a fixed scale (related to the mass of the vector meson), this give us insight into the QCD structure of the targets

This talk

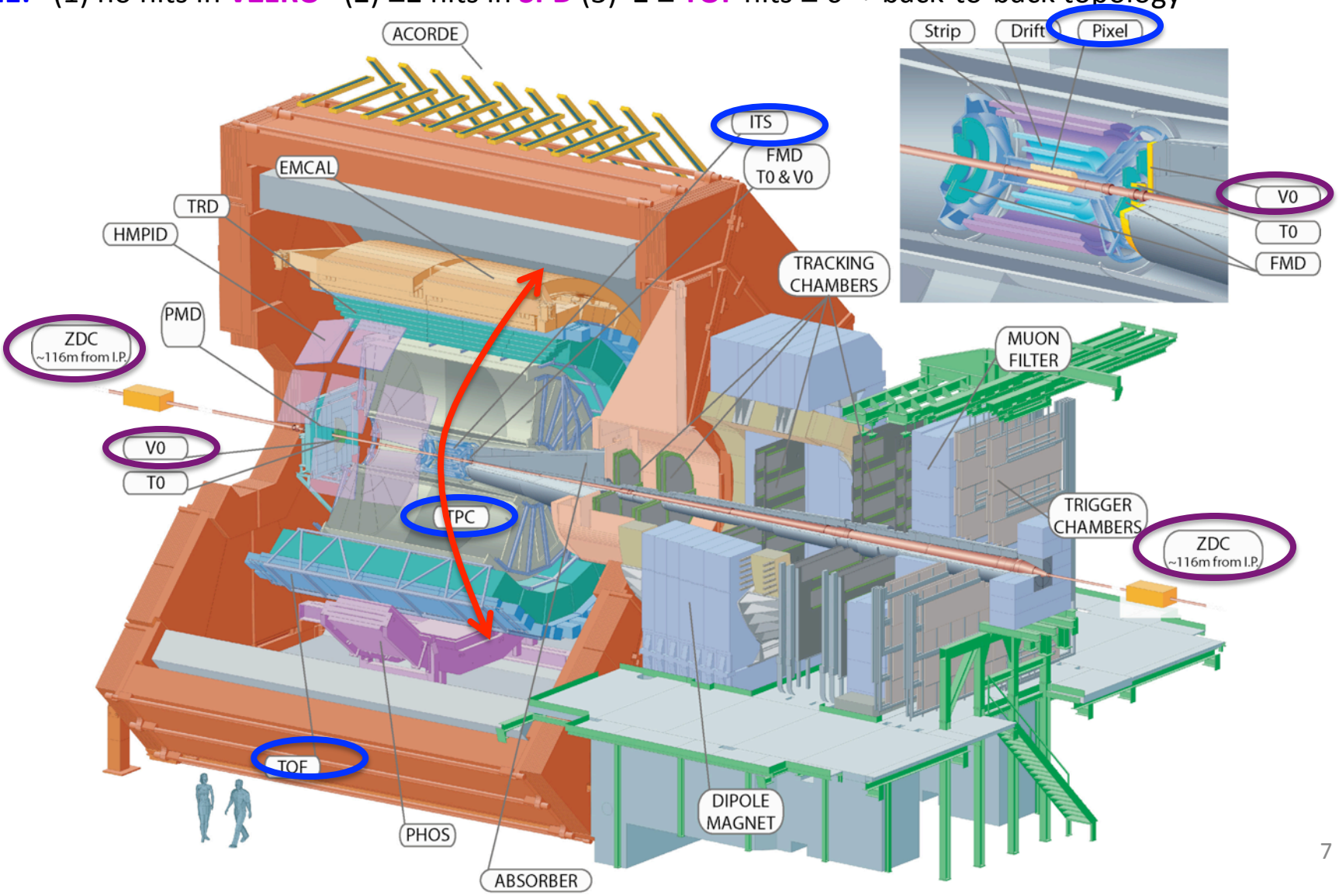
ALICE and UPC

UPC at mid rapidity with ALICE

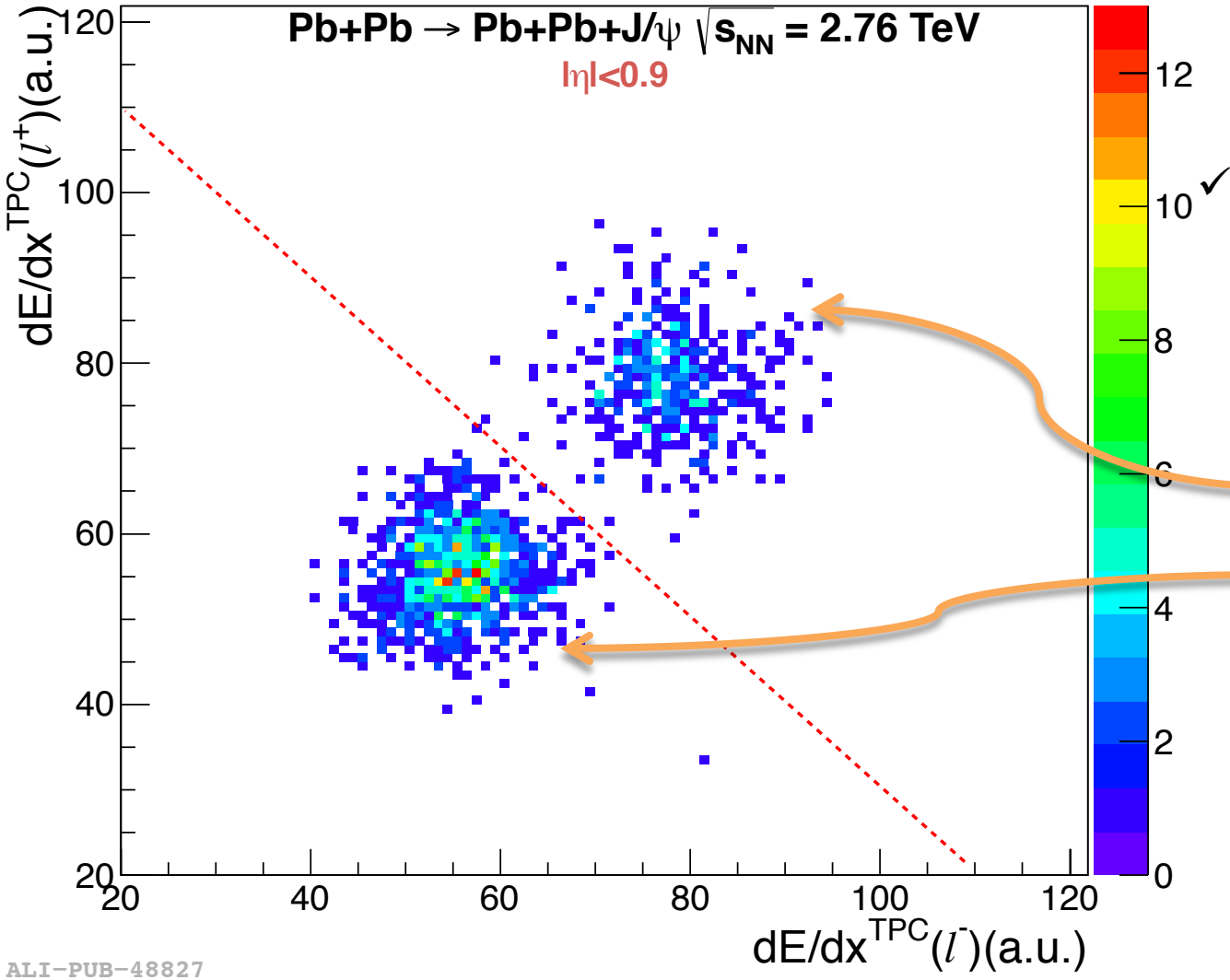
UPC central barrel trigger:

2010: (1) no hits in **VZERO** (2) ≥2 hits in **SPD** (3) 2 ≤ **TOF** hits

2011: (1) no hits in **VZERO** (2) ≥2 hits in **SPD** (3) 2 ≤ **TOF** hits ≤ 6 + back-to-back topology



Particle identification using dE/dx



ALI-PUB-48827

✓ The measurement of dE/dx performed by the TPC allows a clear separation of

electrons

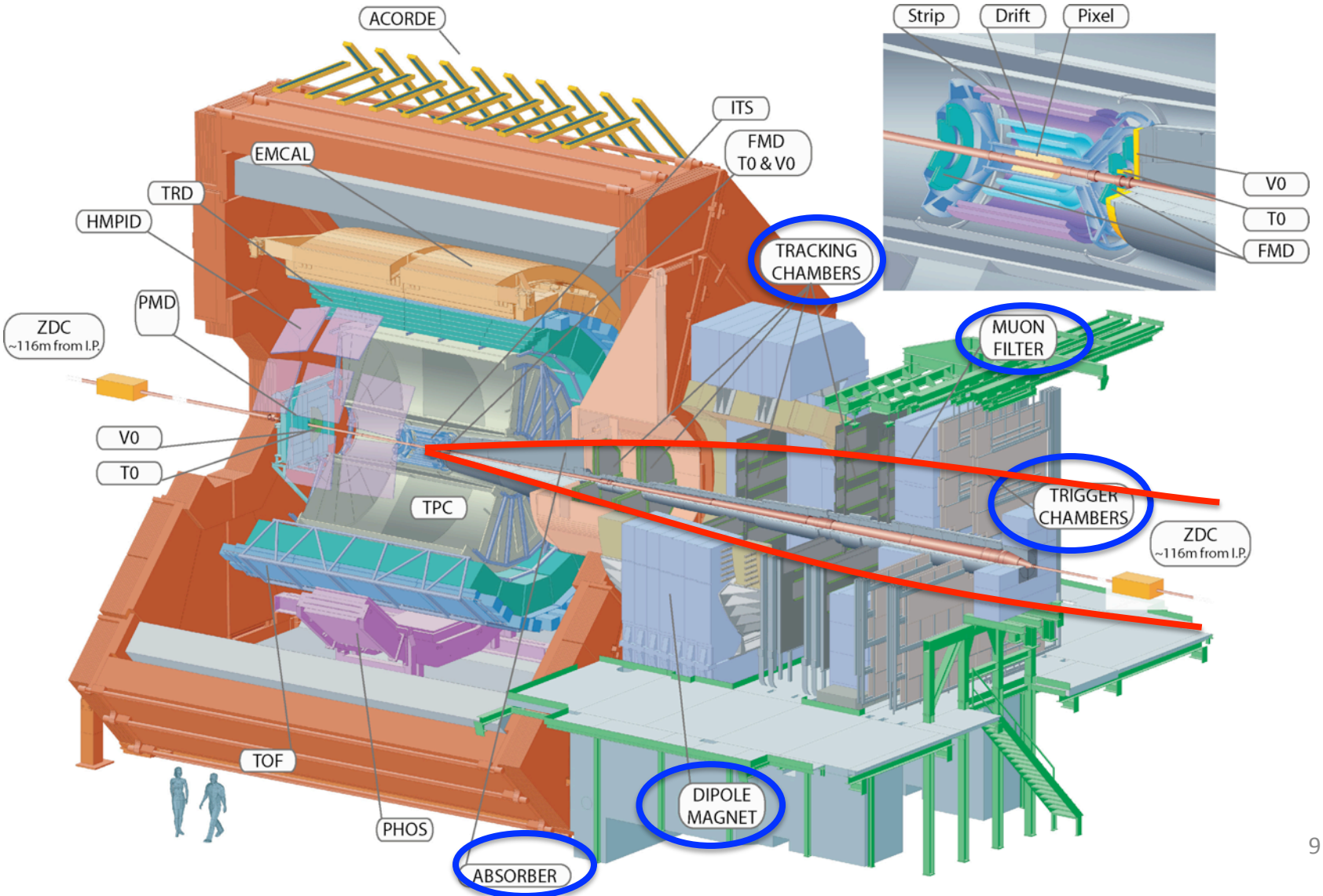
muons/pions

UPC at forward rapidity with ALICE

UPC forward trigger:

2011: (1) no hits in **VZERO-A** (2) hits in **VZERO-C** (3) single **muon** with p_T>1 GeV/c

2013: (1) no hits in **VZERO-A** (2) hits in **VZERO-C** (3) di-**muon** each with p_T>0.5 GeV/c

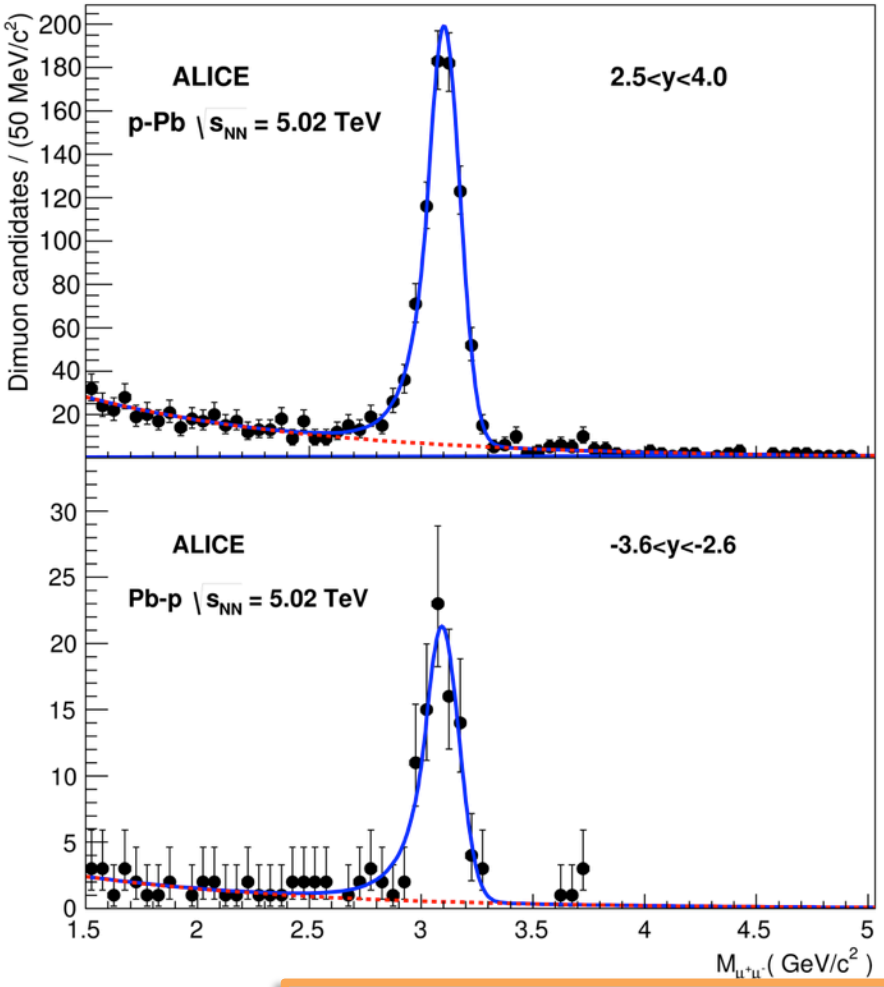


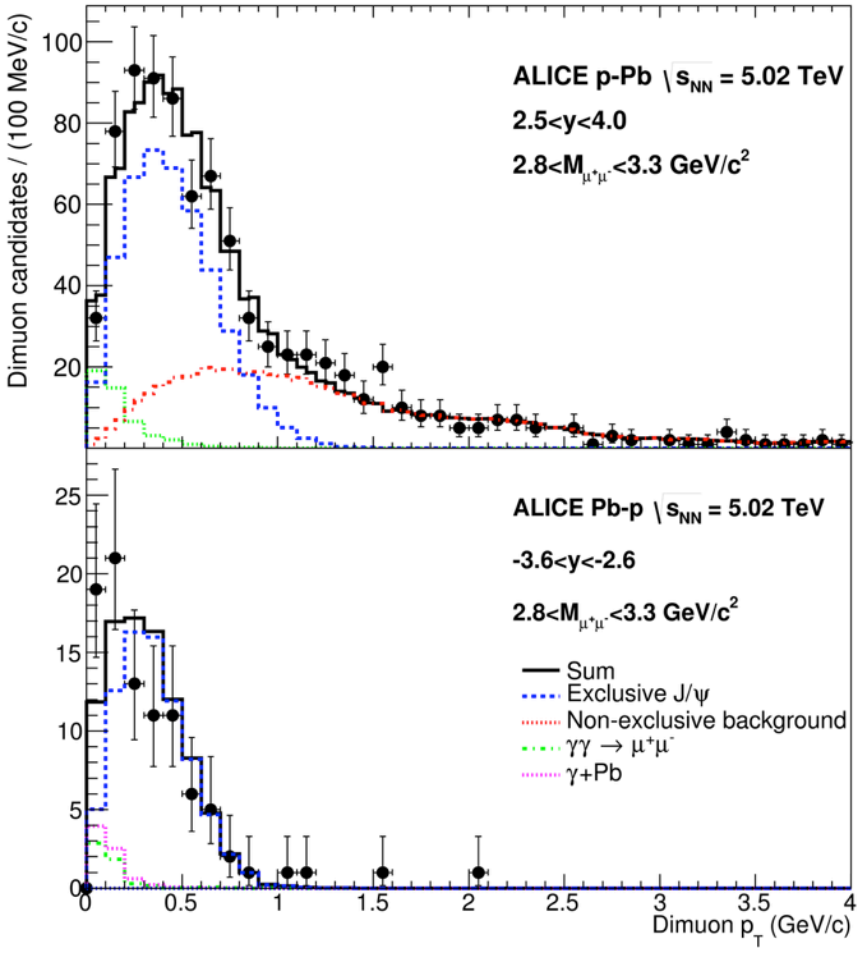
UPC measurements in p-Pb

Exclusive J/ψ production in p-Pb

The photon source is known: it is the lead ion in > 95% of the cases → rapidity of the J/ψ measures $W_{\gamma p}$, the center of mass energy of γp system

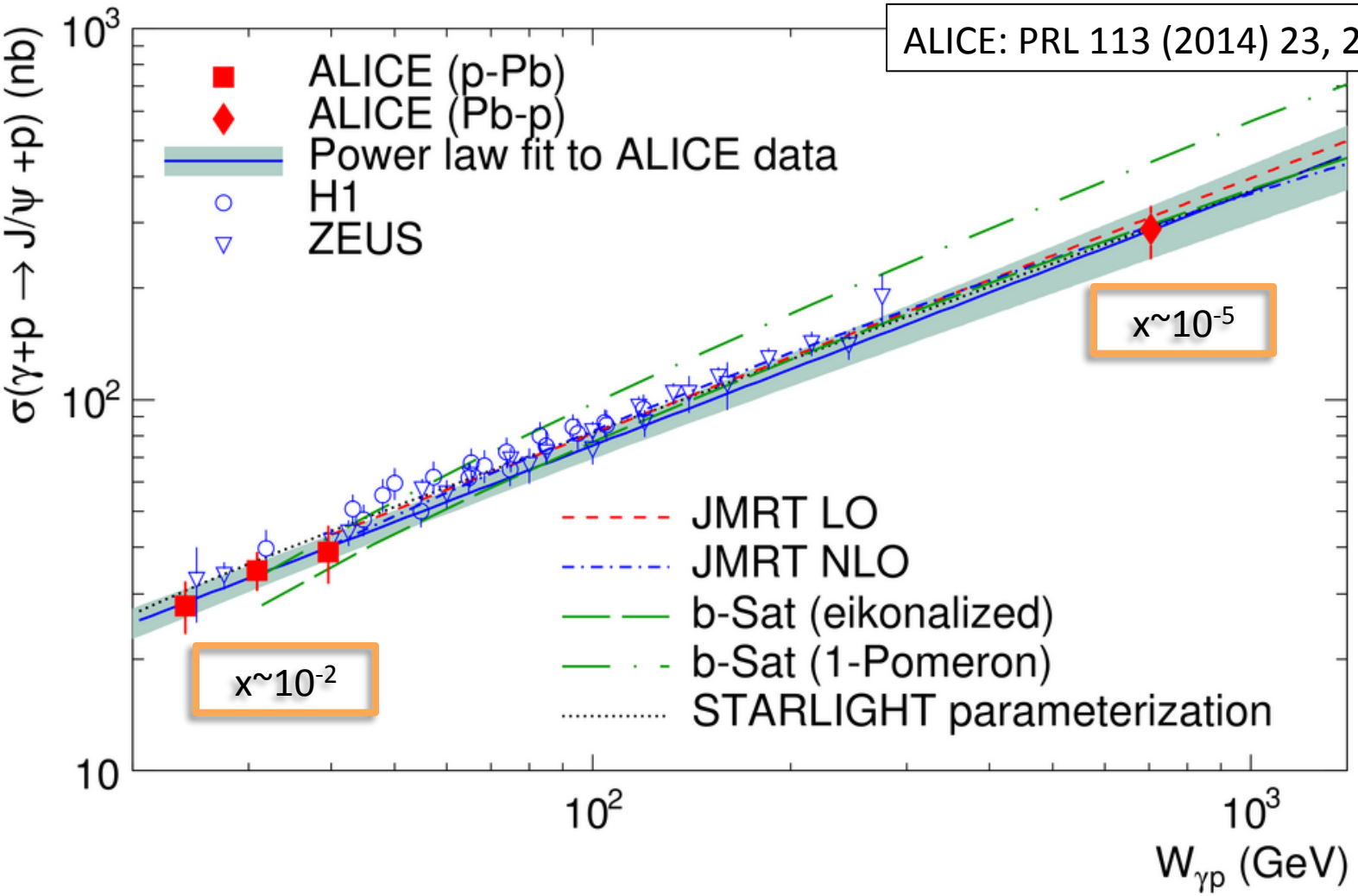
ALICE: PRL 113 (2014) 23, 232504





Clean signals, small background

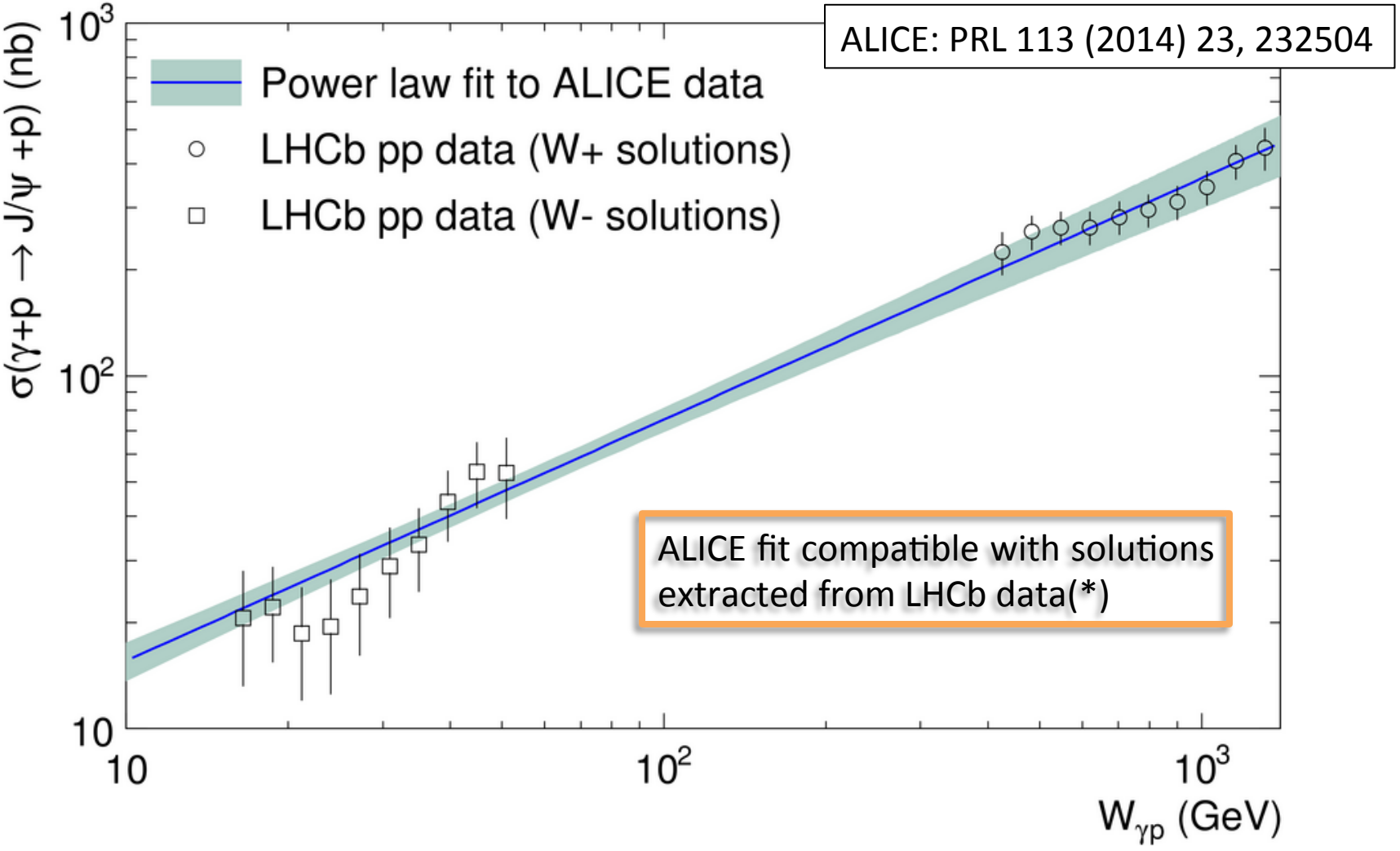
Exclusive J/ψ production in p-Pb: cross sections



- ✓ ALICE data reaches more than twice the largest energy reached at HERA
- ✓ ALICE data alone compatible with a power law with exponent ~0.67±0.06
- ✓ Exponent is compatible with those from H1 (0.67±0.03) and ZEUS (0.69±0.02±0.03)

No change in the behavior of the cross section observed from HERA to LHC

Exclusive J/ψ production in p-Pb: LHCb solutions



(*) LHCb measured exclusive J/ψ production in pp collisions. Extraction of result in γp not trivial and model dependent See discussions in LHCb publications

Measurements in Pb-Pb

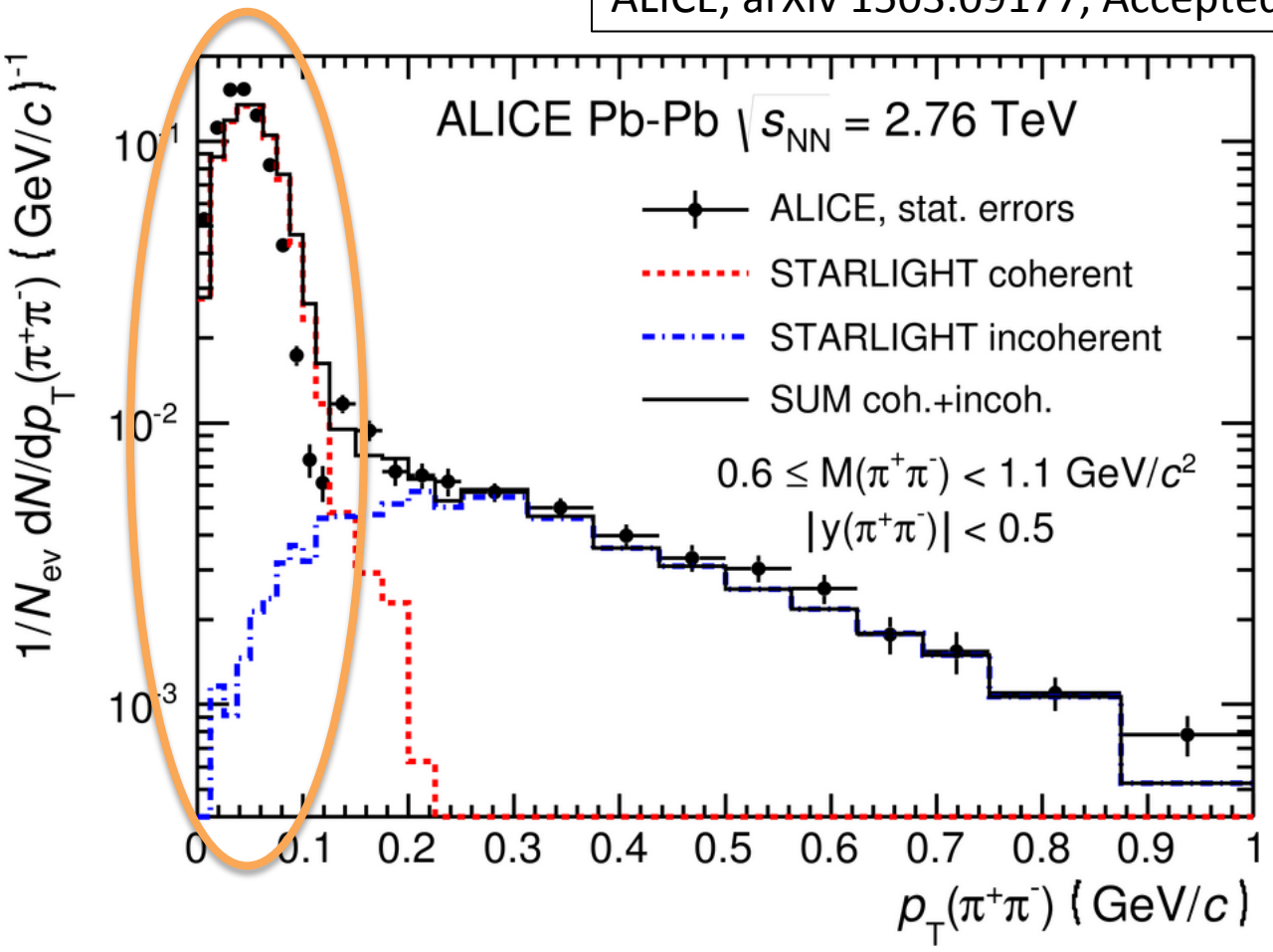
- Coherent ρ production
- Coherent and incoherent J/ψ production
- Coherent ψ(2s) production
- Coherent J/ψ in peripheral events

Coherent ρ production

- ✓ Coherent: photon couples to full nuclei: VM has **very** low transverse momentum
- ✓ Incoherent: photon couples to one nucleon: VM has low transverse momentum

ALICE, arXiv 1503.09177, Accepted by JHEP

- ✓ 2010 data
- ✓ Decay into $\pi^+\pi^-$



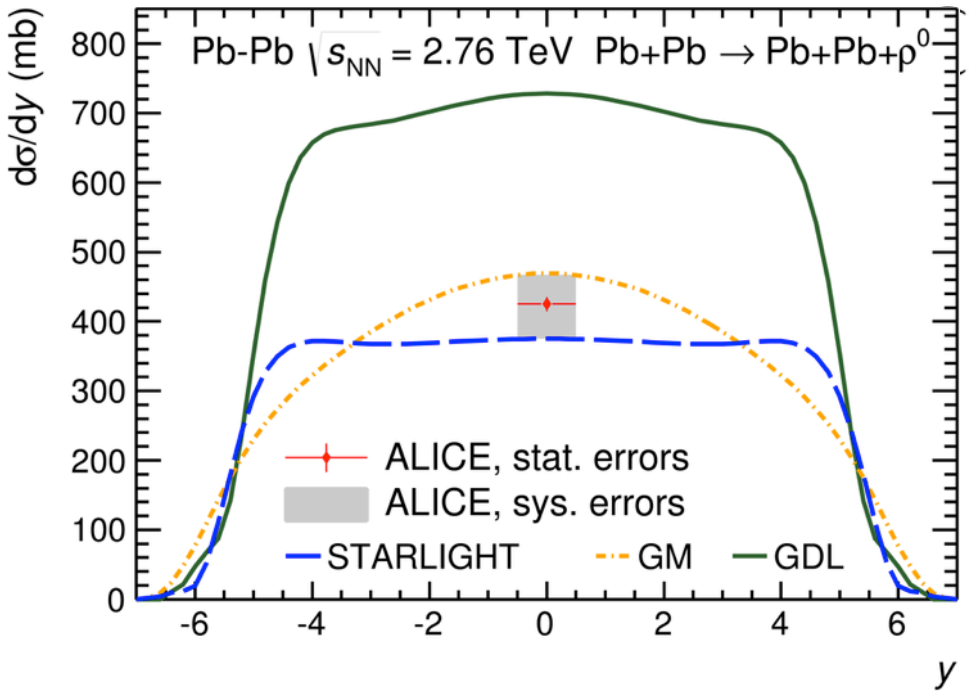
- ✓ Transverse momentum less than 150 MeV/c to reject incoherent contribution

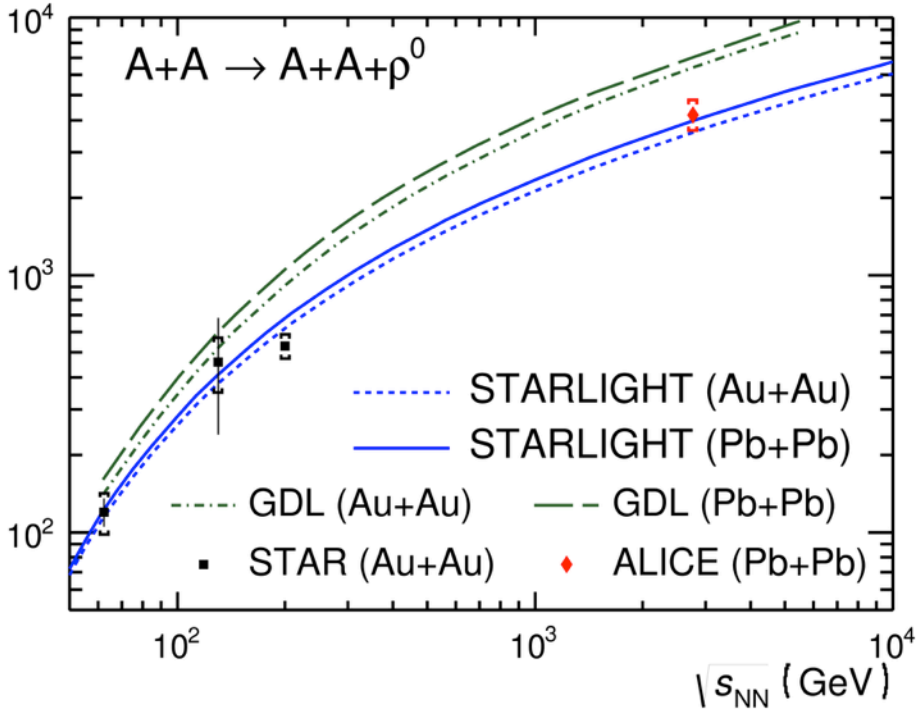
Coherent ρ production: cross section

L. Frankfurt, M. Strikman, M. Zhalov (GDL): QM Glauber + DL fit to HERA data

V.P. Gonçalves, M.V.T. Machado (GM): Color dipole model with CGC-like saturation

S.R. Klein, J. Nystrand (STARLIGHT): Classical Glauber model + fit to HERA data





- ✓ Somehow surprising agreement with Starlight
- ✓ Disagreement with GDL model may be explained by inelastic nuclear shadowing (see arXiv 1506.07150)

ALICE, arXiv 1503.09177, Accepted by JHEP

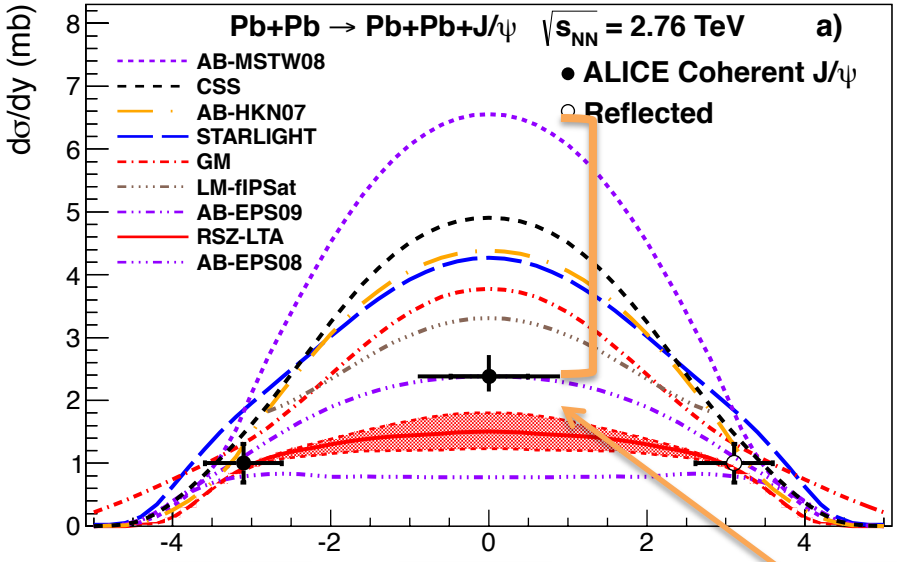
Coherent and incoherent J/ψ production: cross sections

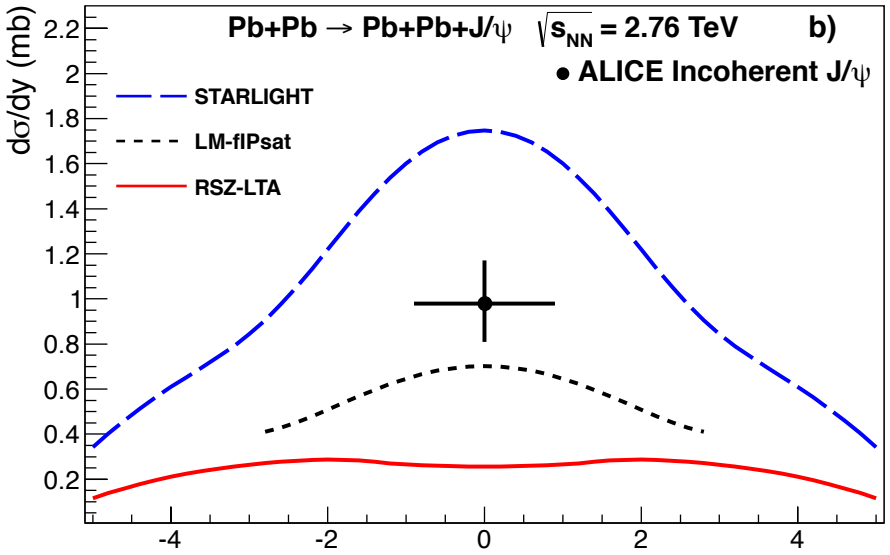
ALICE: Phys.Lett. B718 (2013) 1273-1283 and Eur. Phys. J. C (2013) 73:2617

L. Frankfurt, M. Strikman, M. Zhalov (GDL1): QM Glauber + DL fit to HERA data

T. Lappi, H. Mäntysaari : color dipole model with saturation + Glauber

S.R. Klein, J. Nystrand (STARLIGHT): Classical Glauber model + fit to HERA data





ALI-PUB-66209

$x \sim 10^{-2}$

$x \sim 10^{-3}$

Direct observation of (moderate) gluon shadowing

Cisek, Szczurek, Schäfer (CSS): Color dipole model with unintegrated gluon distribution

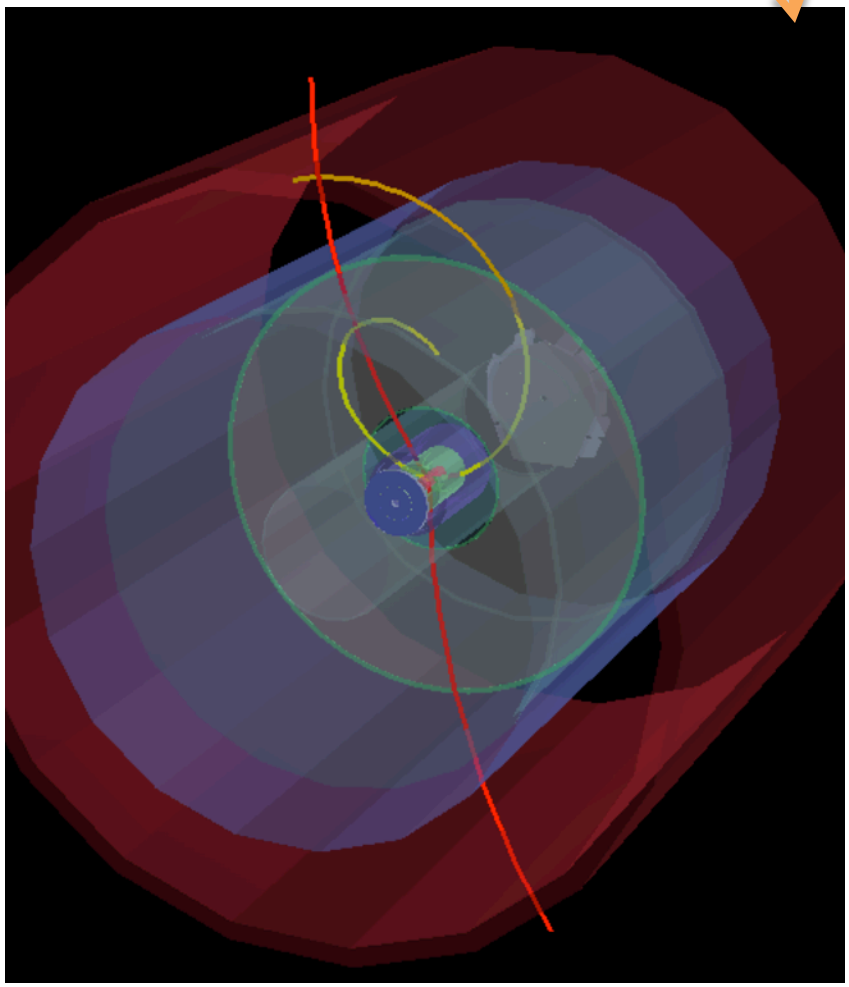
V.P. Gonçalves, M.V.T. Machado (GM): Color dipole model with CGC-like saturation

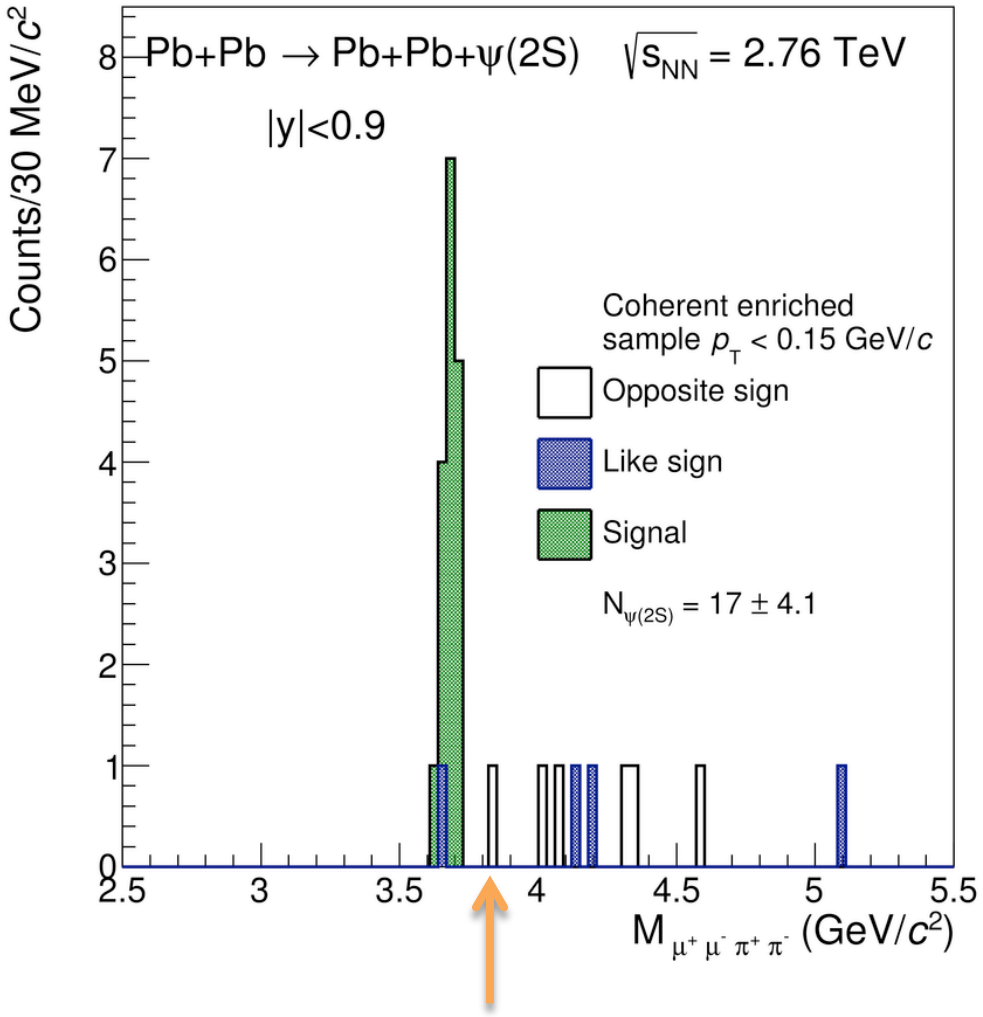
Adeluyi and Bertulani, (AB): LO pQCD + K-factor + nuclear PDFs

Coherent ψ(2s) production

ALICE: arXiv 1508.05076

✓ Measured decay channels:
$\psi(2s) \rightarrow l^+l^-$ and $\psi(2s) \rightarrow J/\psi\pi^+\pi^-$

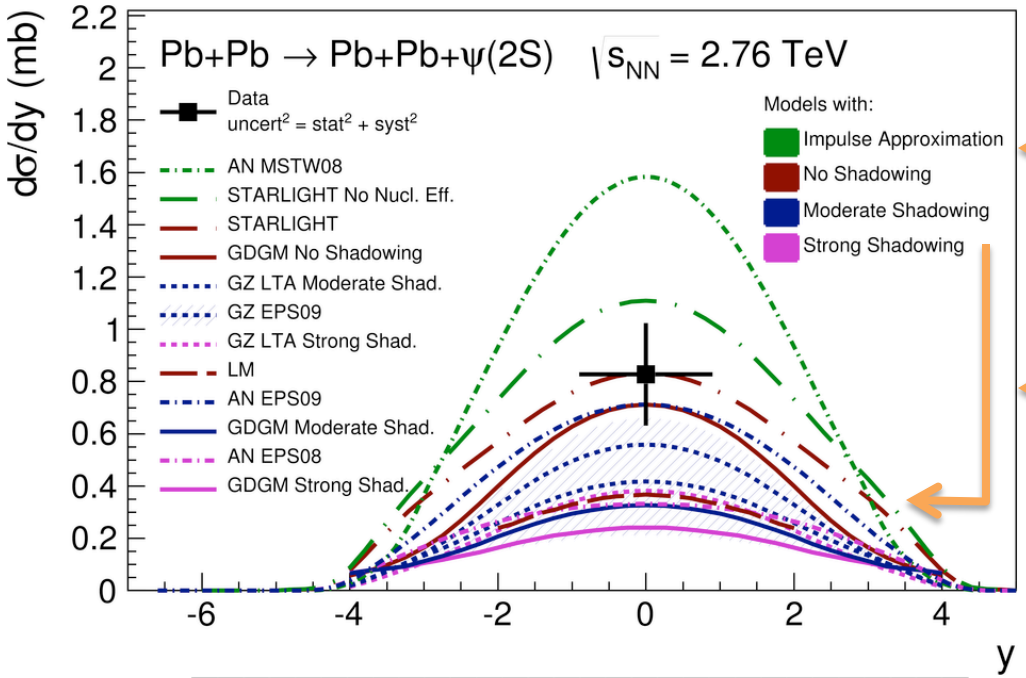


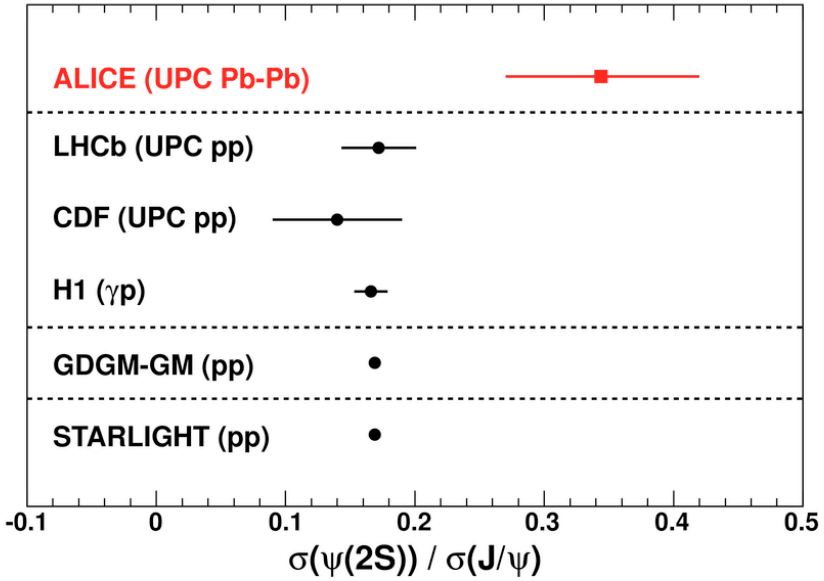


✓ Few signal events with almost no background

Coherent ψ(2s) production: cross section

ALICE: arXiv 1508.05076





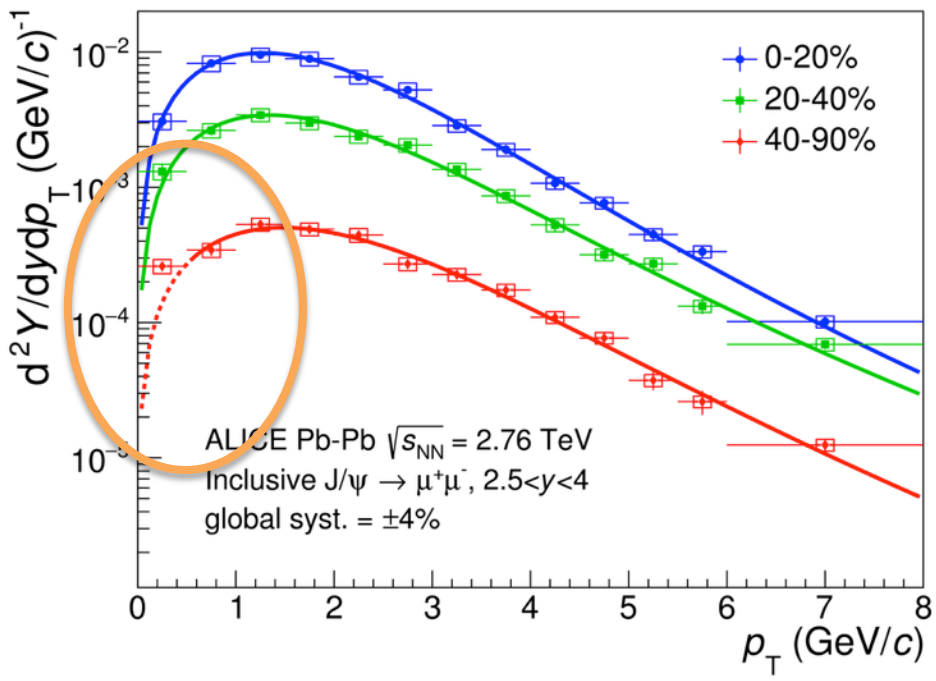
Both impulse approximations should be equal …

Strong shadowing is disfavoured …

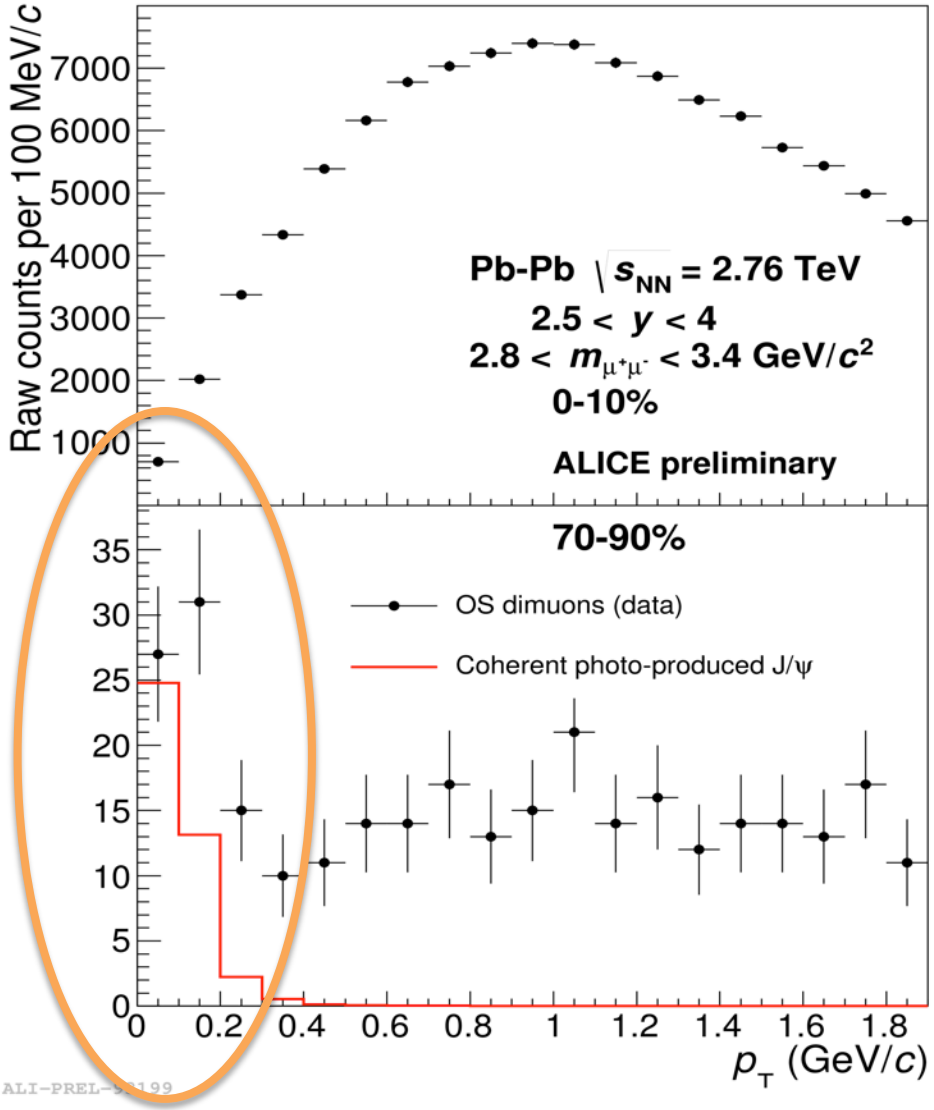
Do nuclear effects affect differently 1S and 2S states?
Need more precise data!

Coherent J/ψ production in peripheral collisions

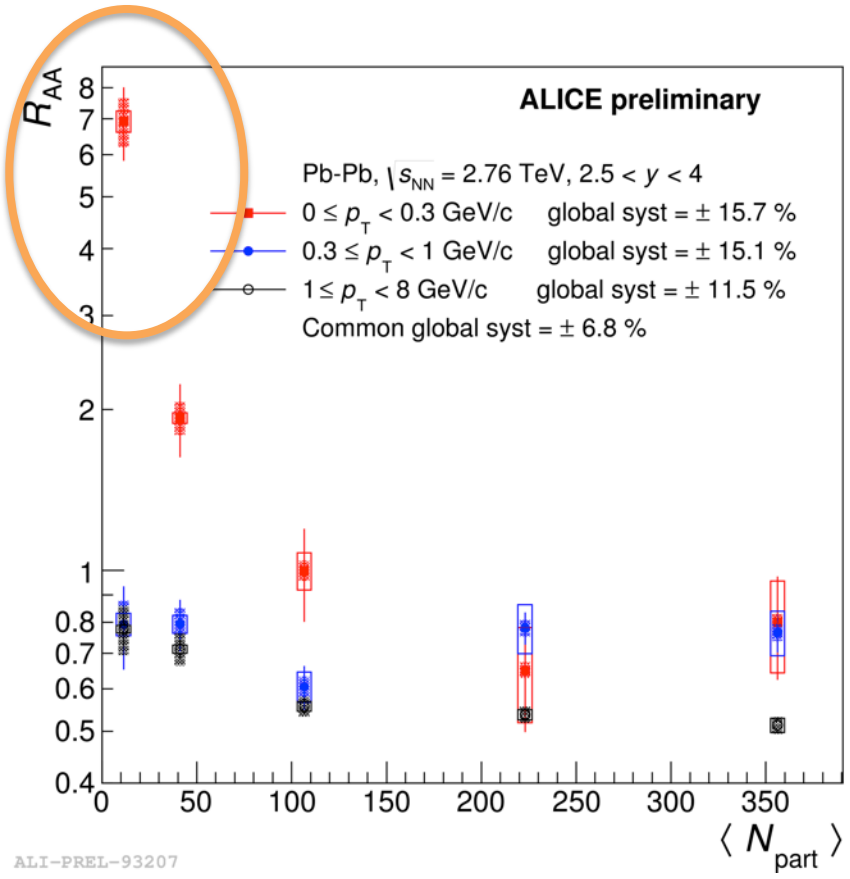
ALICE, arXiv 1506.08805



Clear excess in the yield at low p_T for peripheral collisions



Coherent J/ψ production in peripheral collisions



If excess were from hadronic production, the R_{AA} would reach up to 7!

If photo-production is assumed as the underlying interaction we obtain

Centrality class	Cross section (μb)
0-10 %	<318
10-30%	<290
30-50%	$73 \pm 44_{-27}^{+26}$
50-70%	$58 \pm 16_{-10}^{+8}$
70-90%	$59 \pm 11_{-10}^{+7}$

ALICE preliminary

No theoretical calculations available for coherent photoproduction in peripheral collisions

Summary and Outlook

Photoproduction in ALICE

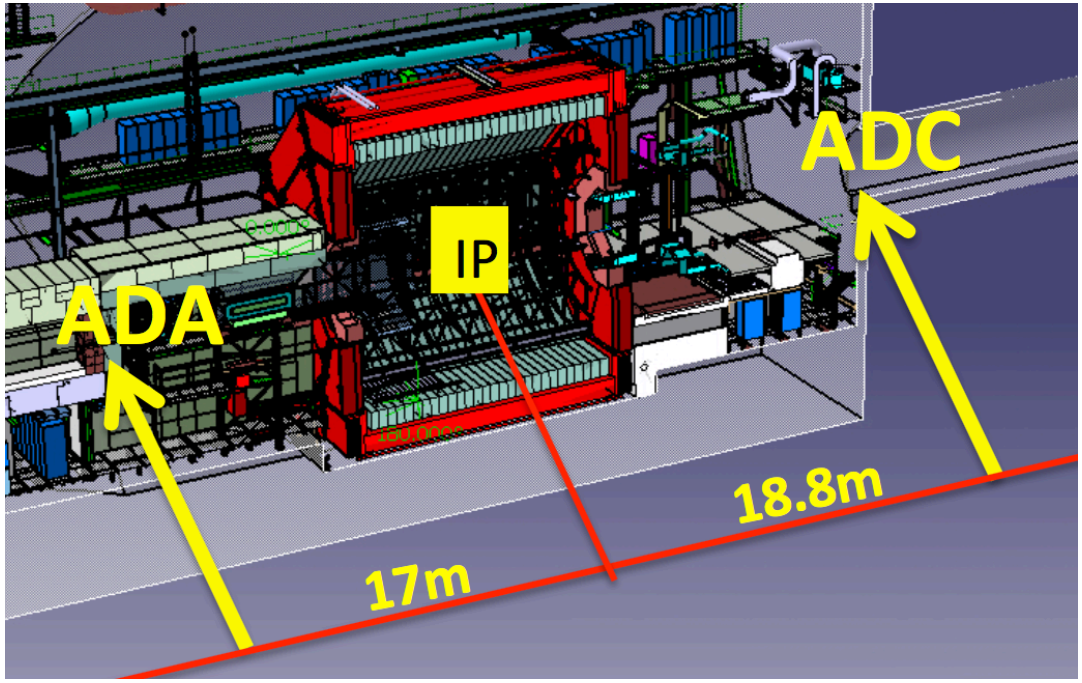
- ✓ LHC Run1
  - ✓ ALICE has measured the exclusive production of vector mesons from the ρ to the $\psi(2S)$; this is covering masses from a non to a perturbative QCD regime.
  - ✓ It has studied photoproduction off protons, reaching more than twice the $W\gamma p$ than HERA, as well as coherent and incoherent production off nuclei, including the direct observation of gluon shadowing and the observation of coherent like production in *peripheral* Pb-Pb collisions.
  - ✓ Still to come with Run 1 data:
    - ✓ Measurements of J/ψ exclusive production at central and semi-forward rapidities with p-Pb (Pb-p) data
    - ✓ Production of other vector mesons both in p-Pb and Pb-Pb UPC

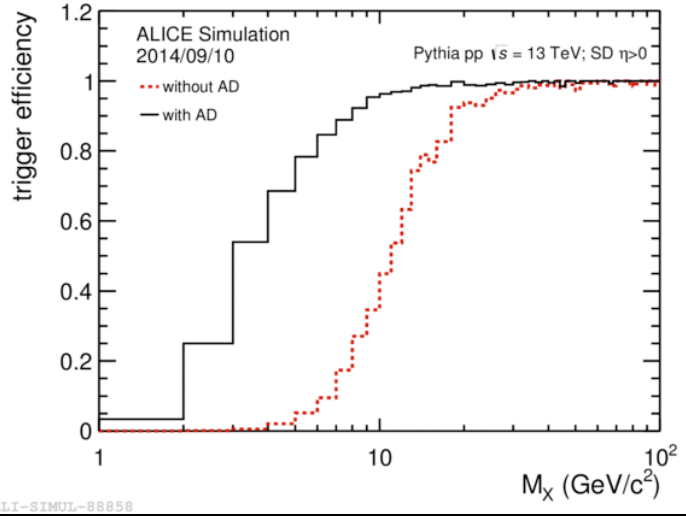
- ✓ LHC Run2
  - ✓ We are ready to collect new data with a substantial increase in luminosity and increase in energy reach
  - ✓ We have installed the new AD detectors to improve the exclusivity condition and the purity of the trigger
  - ✓ We plan to explore new vector mesons and other photo-production processes

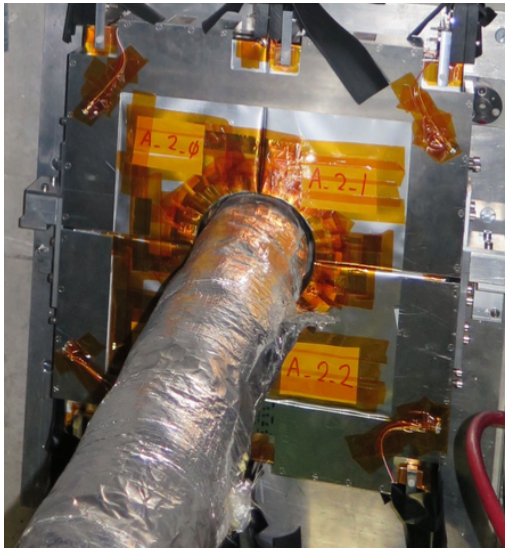
STAY TUNED!

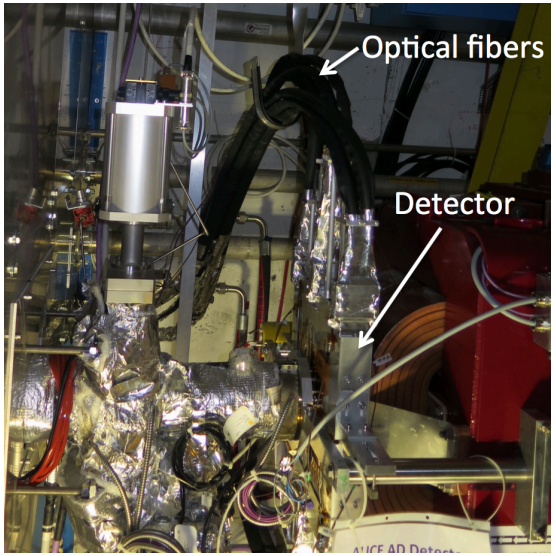
Back up

The AD detector









- ✓ Modules of plastic scintillator read out with PMTs
- ✓ Time resolution below 1 ns allows to reject out of time background
- ✓ Enlarges ALICE geometric rapidity coverage to
  - ✓ $-6.9 < \eta < -4.9$
  - ✓ $4.7 < \eta < 6.3$
- ✓ It increases ALICE reach to tag low mass diffractive events
- ✓ It also Increase ALICE capability to impose veto in extra activity for exclusive processes in UPC