
# Energy dependence of exclusive J/ψ photoproduction in p-Pb interactions with ALICE

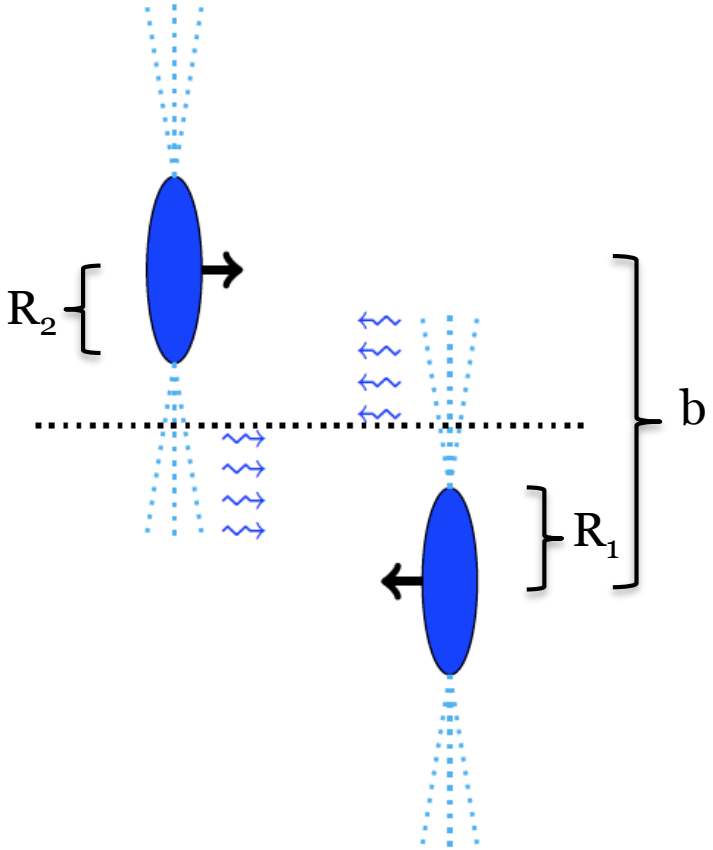
Michal Broz

Czech Technical University in Prague

On behalf of the ALICE Collaboration

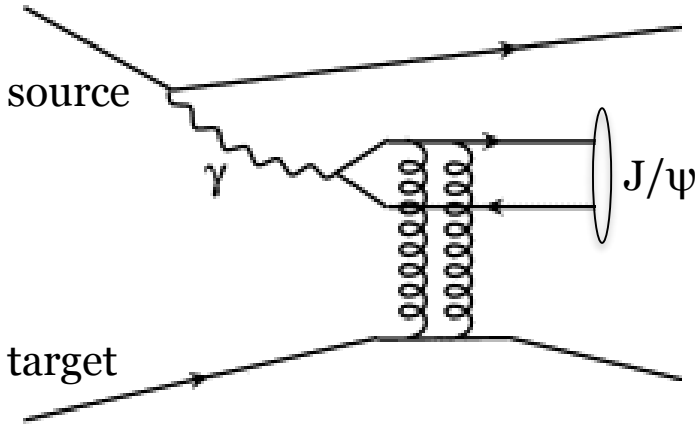
# Ultra-peripheral collisions

- Ultra-peripheral collision = Impact parameter larger than sum of nuclear radii
- The EM field of protons and ions can be viewed as a beam of quasi real photons
- The photon is coherently emitted by the source and its virtuality is restricted by the radius of the emitting particle: photon from Pb: $Q^2 \approx (30\ \mathrm{MeV})^2$.
- The intensity of the photon beam is proportional to $Z^2$
- The max energy of the photons in the lab system is determined by the boost of the emitting particle
- Using p-Pb data at the LHC it is possible to study γp and γγ collisions at higher center of mass energies than ever before



# Ultra-peripheral collisions

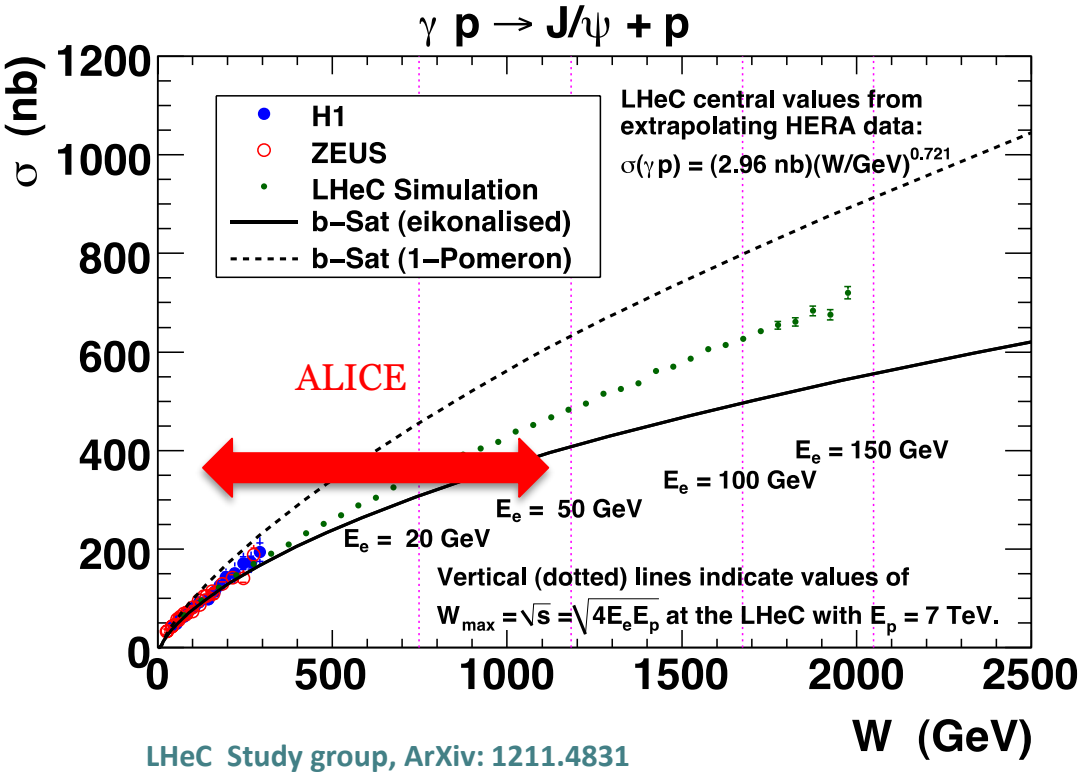
- The cross section can be written as the convolution of
  - a photon flux, calculable from standard electromagnetism
  - the photon-target cross section, which involves QCD
- There are two contributions to this process
  - When the source travels towards the detector where the vector meson is measured, the energy of the photon-target interaction is large.
  - In the opposite case, this energy is small




- In p-Pb collisions, as the probability to emit a photon scales with the square of the electric charge, the lead ion can be considered to be the source of the photon: it is possible to extract the photon-target cross section

# Ultra-peripheral collisions

- Within pQCD the structure of the proton at small $x$ is dominated by gluons
- At some point there will be so many gluons in the proton that they may start to interact among them; this is called saturation
- The exclusive photoproduction of a J/ψ involves the exchange of at least two gluons

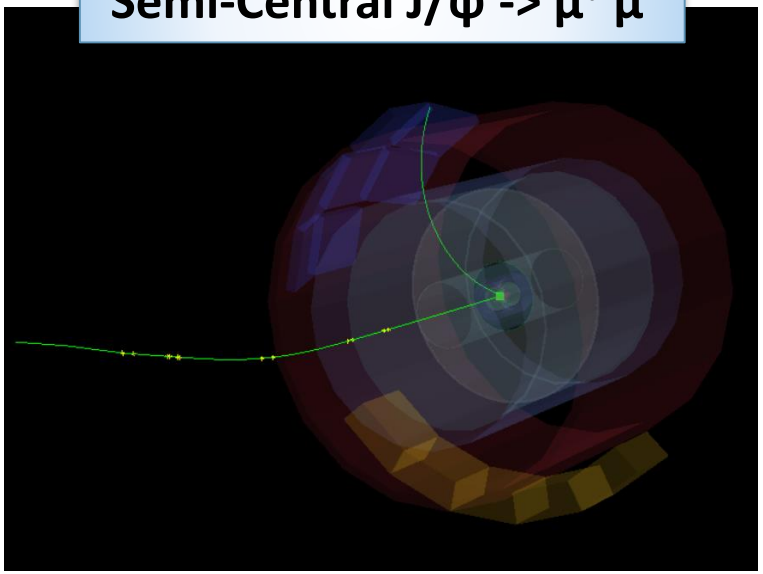


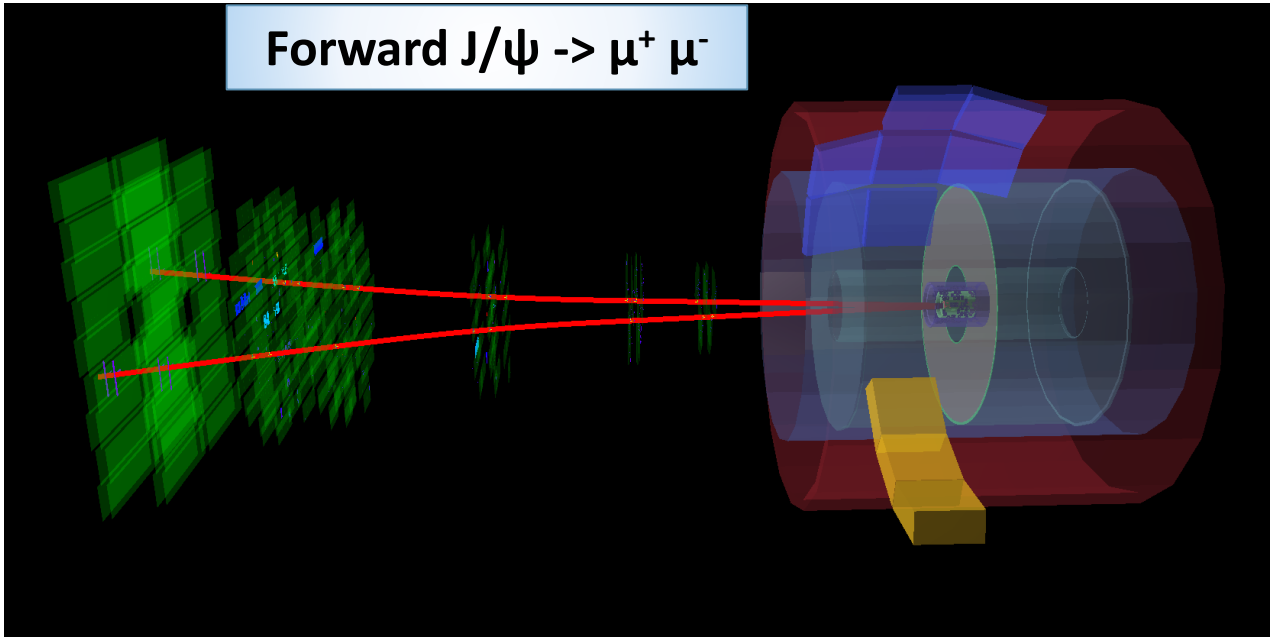

LHeC Study group, ArXiv: 1211.4831

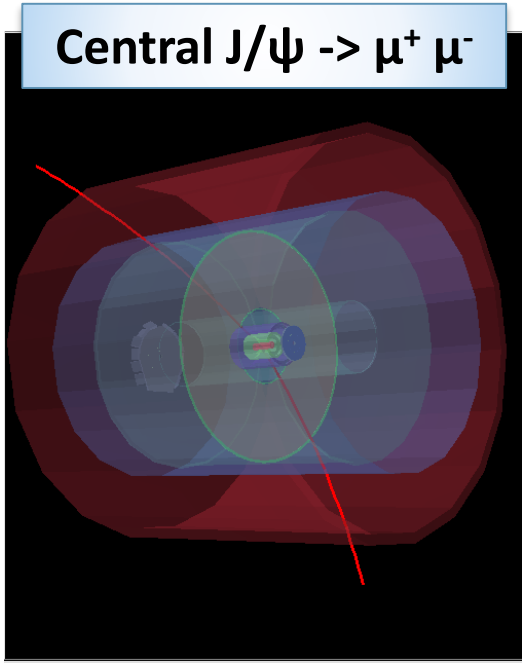
- The energy evolution of this process may provide important insight on the small-$x$ behavior of the gluon distribution of protons.

# Ultra-peripheral collisions

- In ALICE the J/ψ is measured using its decay into a lepton pair. We can do this in three configurations:
  - Both leptons measured in the central barrel
  - One muon measured in the muon spectrometer the other in the central barrel
  - Both muons measured in the muon spectrometer



# Energy ranges

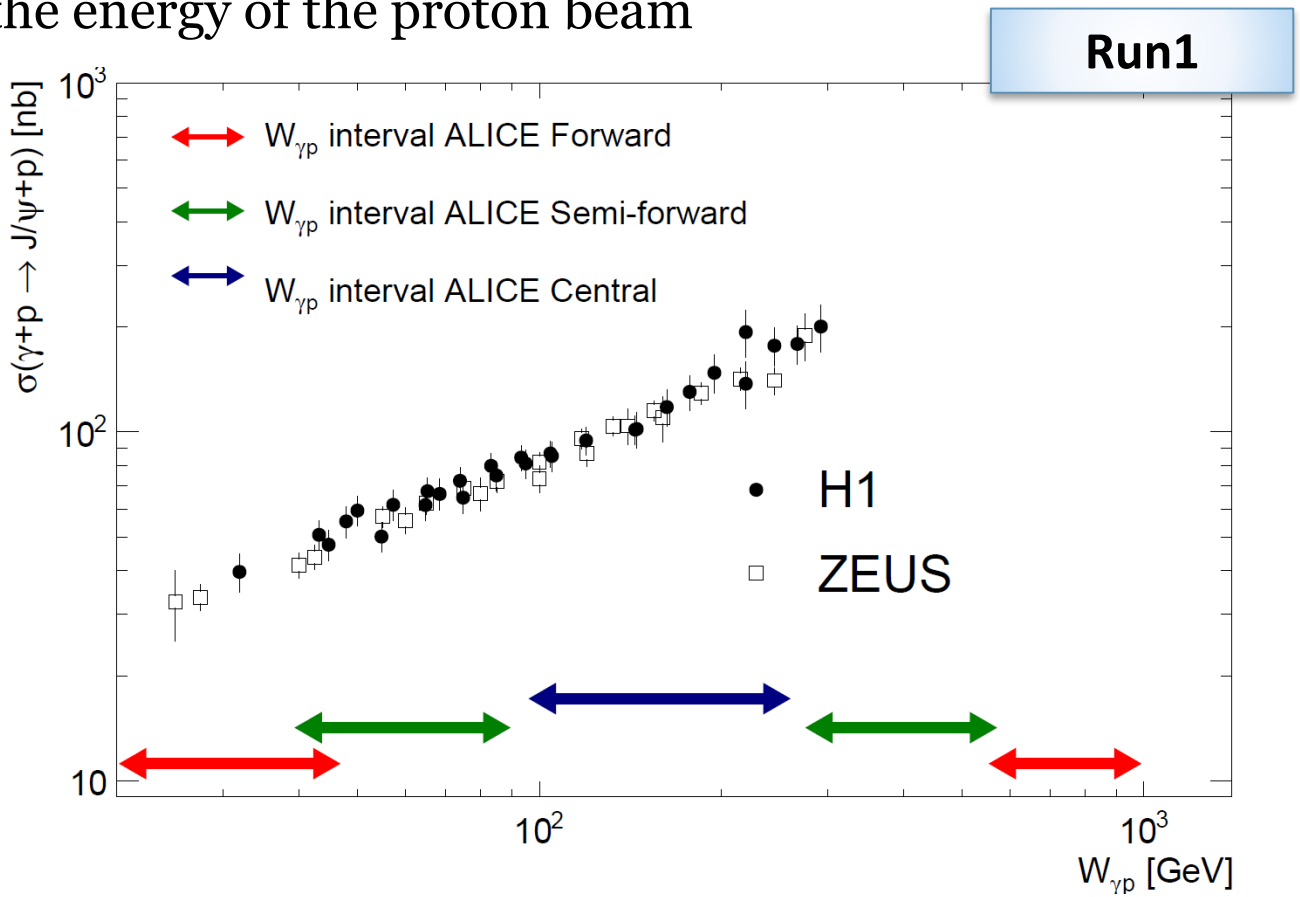
- LHC produced collisions with the proton beam traveling towards (away from) the muon spectrometer: p-Pb (Pb-p)
- The rapidity y of the J/ψ is related to the energy $W_{\gamma p}$ in the γp system by its mass and the energy of the proton beam
- Energy range in ALICE overlaps and extends HERA range!

$$W_{\gamma p}^2 = M_{J/\psi} e^y \sqrt{s_{NN}}$$

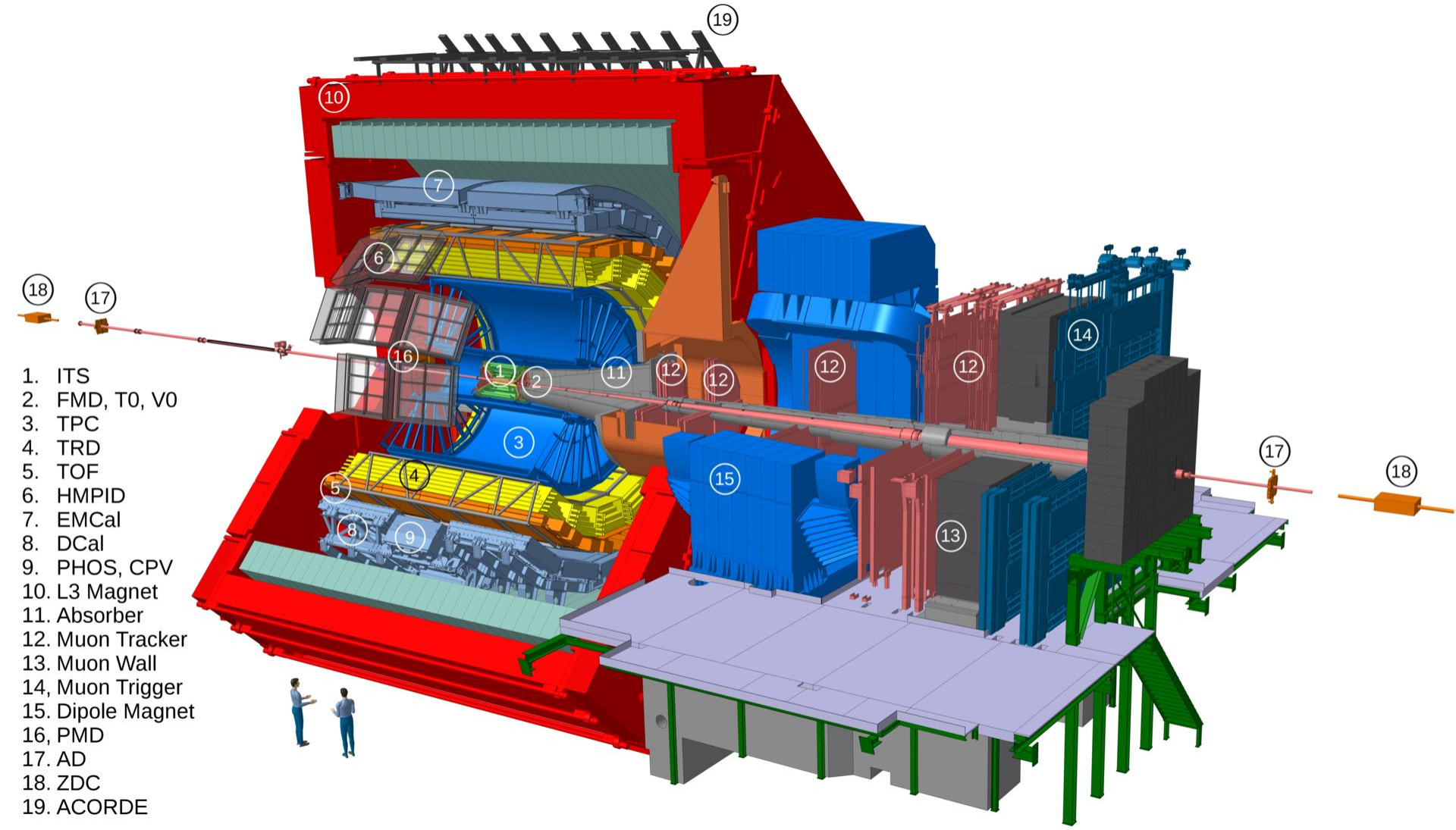
| $W_{\gamma p}$ (GeV) | | Semi-forward | Central | Forward |
|---|---|---|---|---|
| Run1 | p-Pb | 40 – 86 | 106 – 230 | 21 – 45 |
| | Pb-p | 287 – 550 | | 580 – 950 |
| Run2 | p-Pb | 60 – 110 | 135 – 300 | 27 – 57 |
| | Pb-p | 365 – 700 | | 700 – 1480 |

# Energy ranges

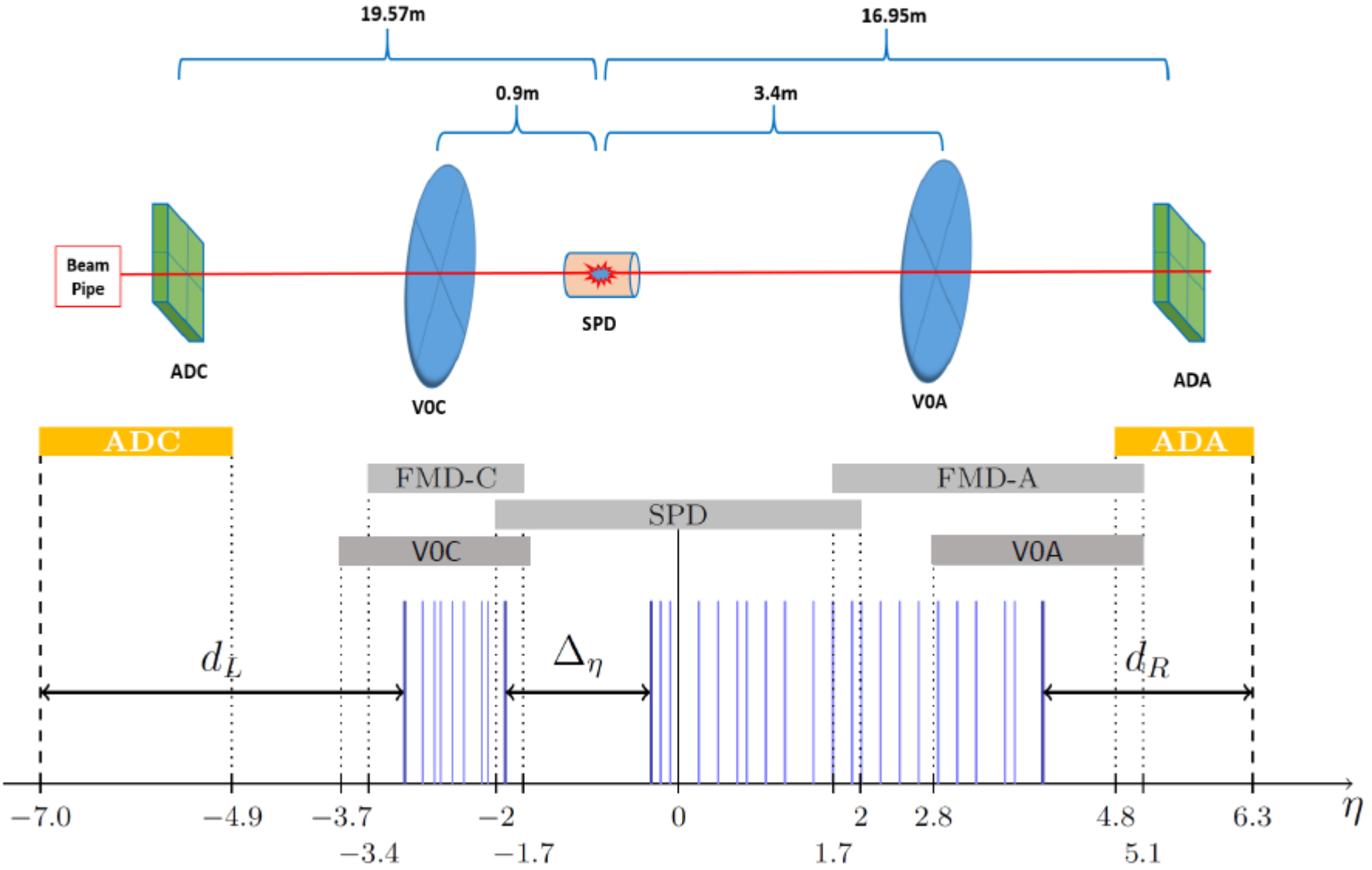
- LHC produced collisions with the proton beam traveling towards (away from) the muon spectrometer: p-Pb (Pb-p)
- The rapidity y of the J/ψ is related to the energy $W_{\gamma p}$ in the γp system by its mass and the energy of the proton beam



# ALICE detector

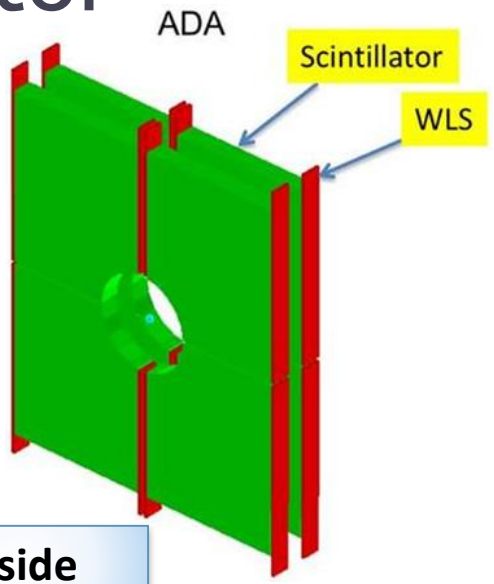


# ALICE Diffractive (AD) detector

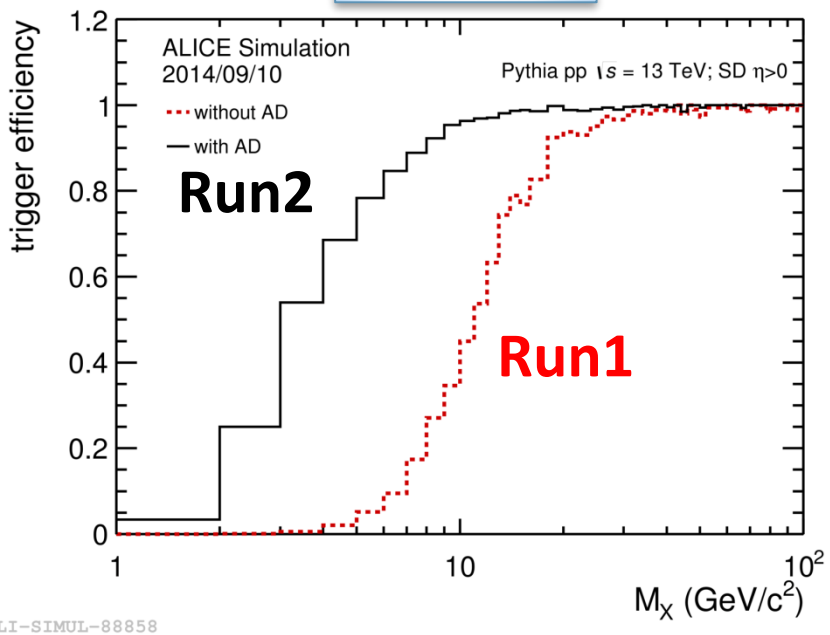


# ALICE Diffractive (AD) detector

- Double layers of scintillator counters
- ADA: z = 17.0 m, 4.8 < η < 6.3
- ADC: z= −19.5 m, −7.0 < η < −4.9
- Increase pseudo-rapidity coverage from 8.8 to 13.2
- Enhanced trigger efficiency at low diffractive masses
- Increased capability to impose veto for exclusive processes in UPC

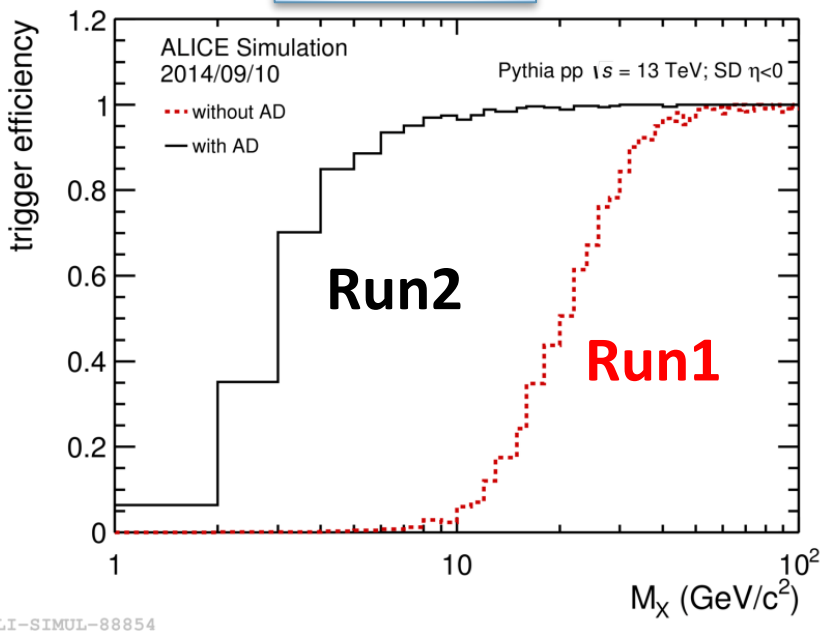



**A-side**




ALI-SIMUL-88858

**C-side**



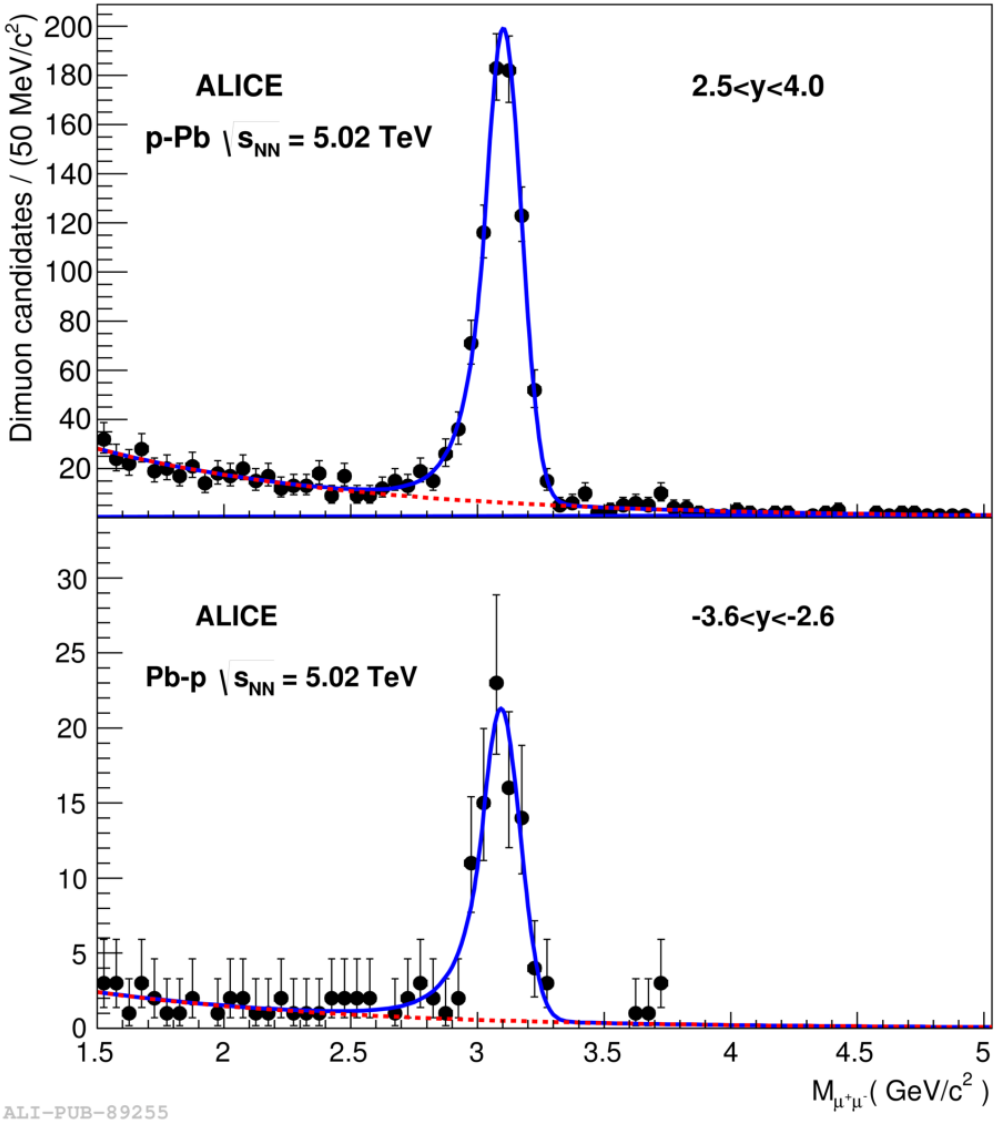

ALI-SIMUL-88854

# J/ψ in p-Pb and Pb-p

**Forward J/ψ -> $\mu^+ \mu^-$**

- 2013 p-Pb data
- Data taken in two configurations: p-Pb and Pb-p
- Very clear signal seen in the invariant mass distribution over a small background from γγ —> μμ production.

ALICE, Phys. Rev. Lett. 113, 232504 (2014)

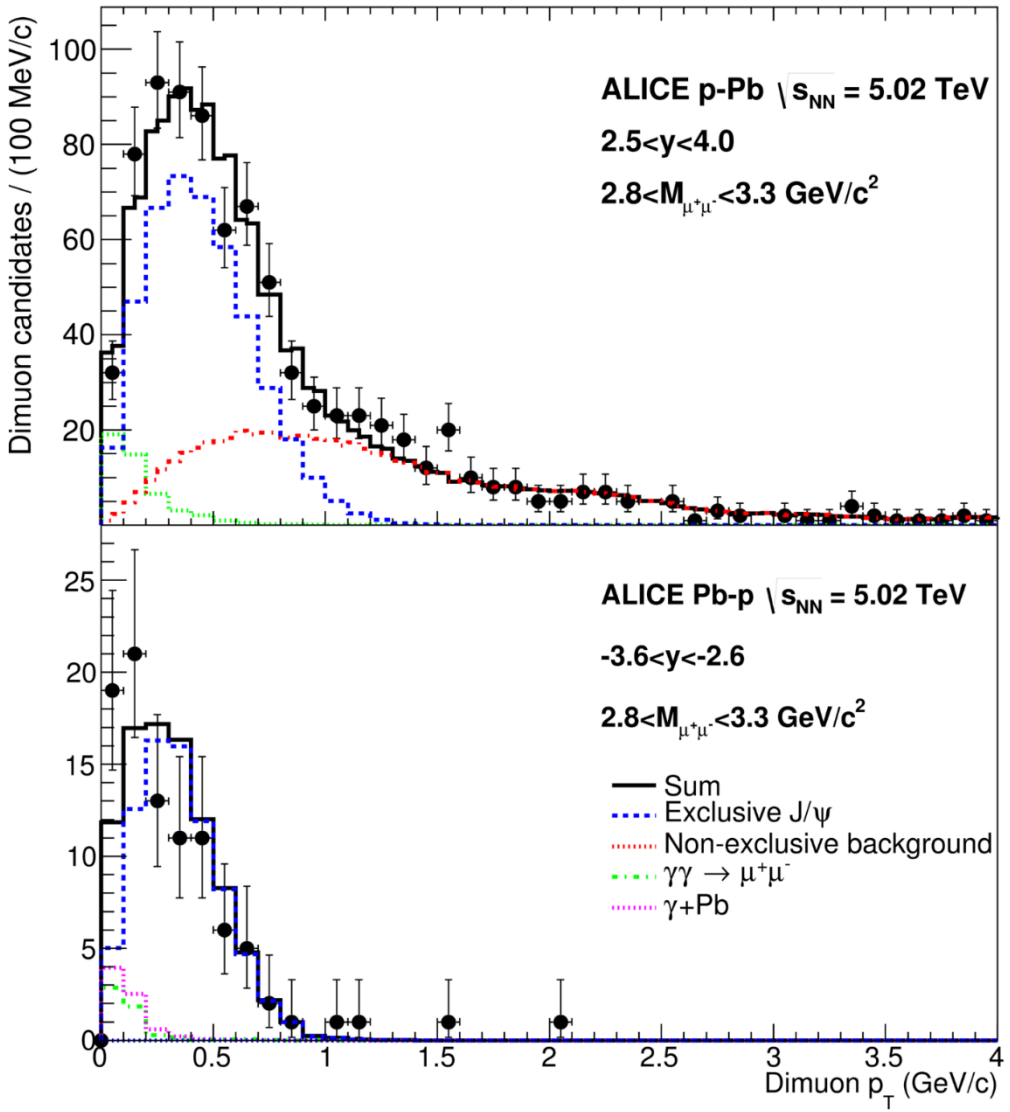


# J/ψ in p-Pb and Pb-p

- 2013 p-Pb data
- Data taken in two configurations: p-Pb and Pb-p
- Main backgrounds identified using the J/ψ transverse momentum distribution:
- γγ —> μμ production constrained using the invariant mass distribution.
- Production in γPb interactions constrained using coherent J/ψ production in Pb-Pb collisions measured by ALICE.
- Shape of non-exclusive background determined from events with extra activity in VZERO
- Main contribution to non-exclusive background from proton dissociative photoproduction of J/ψ

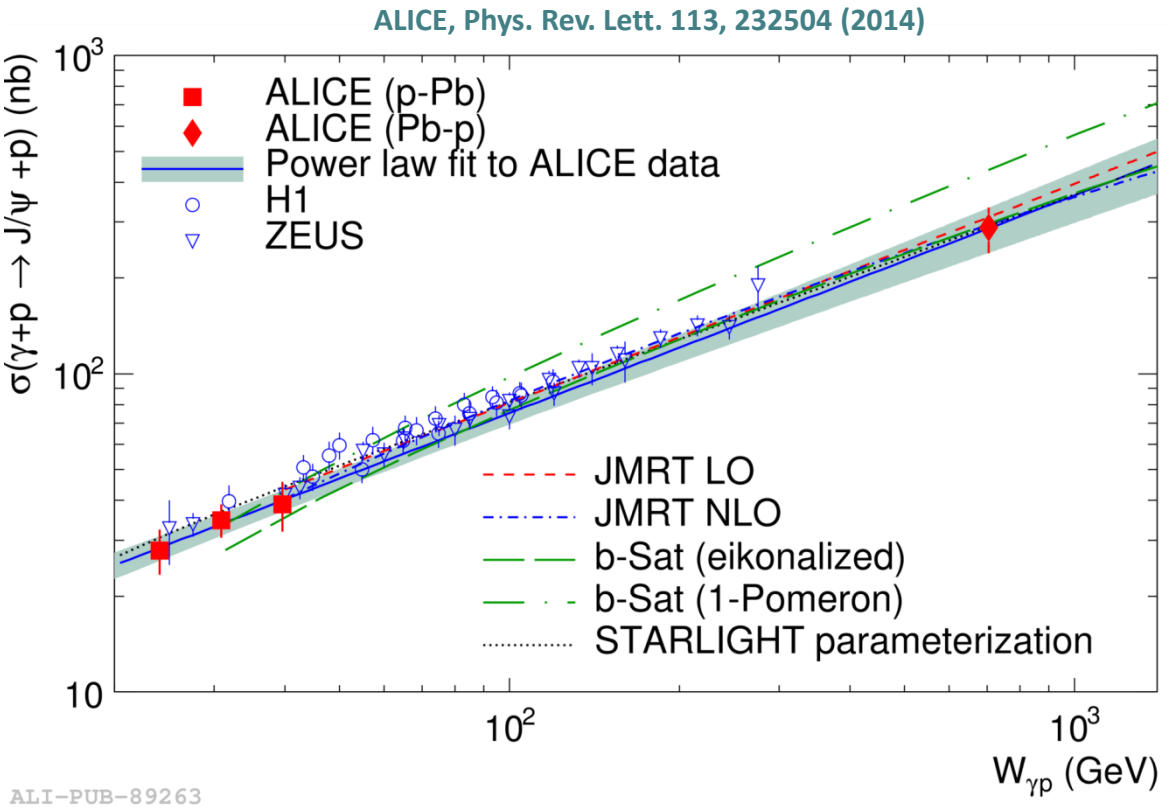
**Forward J/ψ -> $\mu^+ \mu^-$**

ALICE, Phys. Rev. Lett. 113, 232504 (2014)



# Cross section for J/ψ in γp

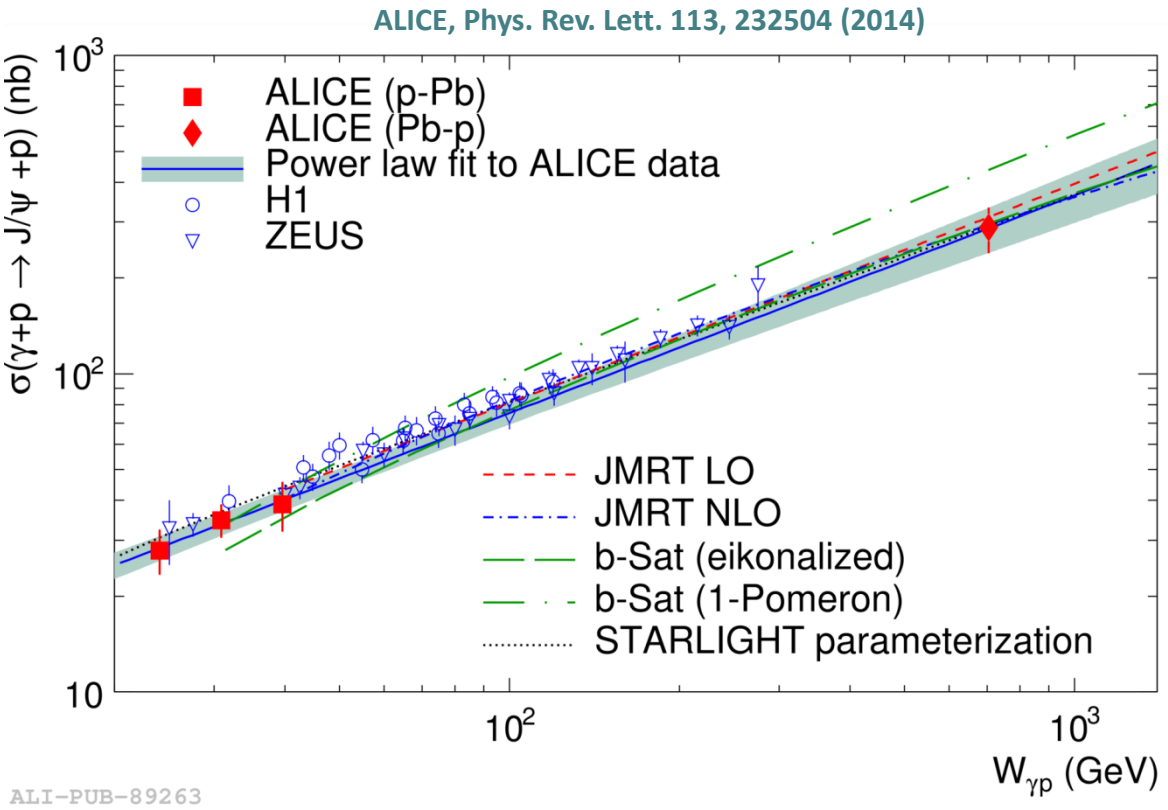
- First direct γp measurement at the LHC
- ALICE data are compatible with a power law with exponent 0.67±0.06
- Exponent is compatible with those from H1 (0.67±0.03) and ZEUS (0.69±0.02±0.03)
- LHCb solutions consistent with the power-law fit obtained from ALICE results




- HERA and ALICE cross section points stay on the same power law
- No change in the behavior of the cross section seen from HERA energies to the highest ALICE measurement

# Cross section for J/ψ in γp

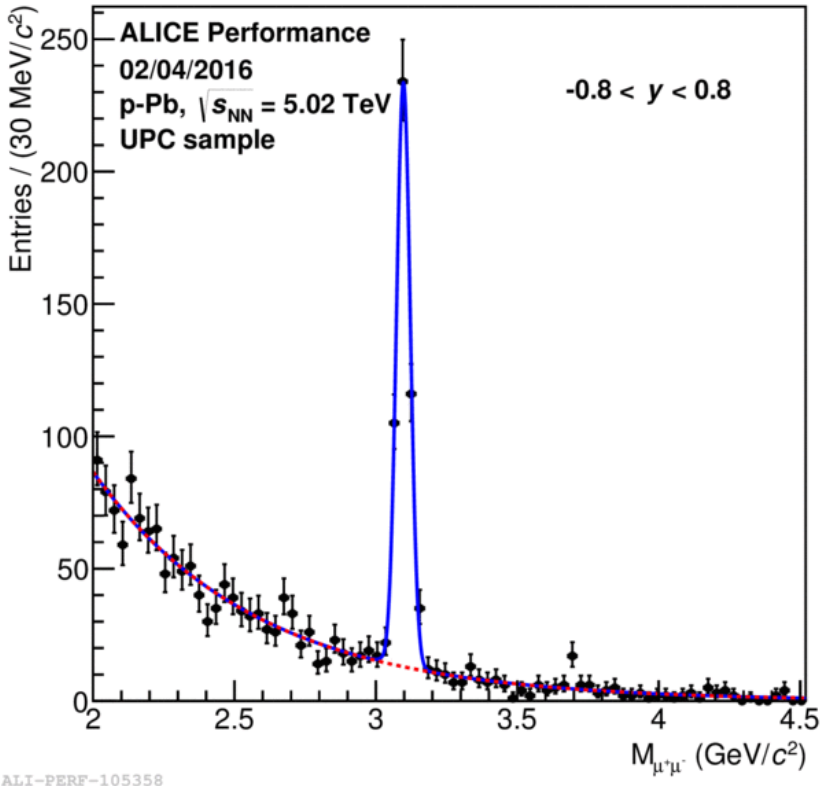
- JMRT: LO model based on a power law. NLO model includes the expected main NLO contributions
- b-Sat (eikonalised) includes b-dependent saturation effects based on a CGC inspired model
- STARLIGHT parameterization is based on a power law fit using only fixed-target and HERA data

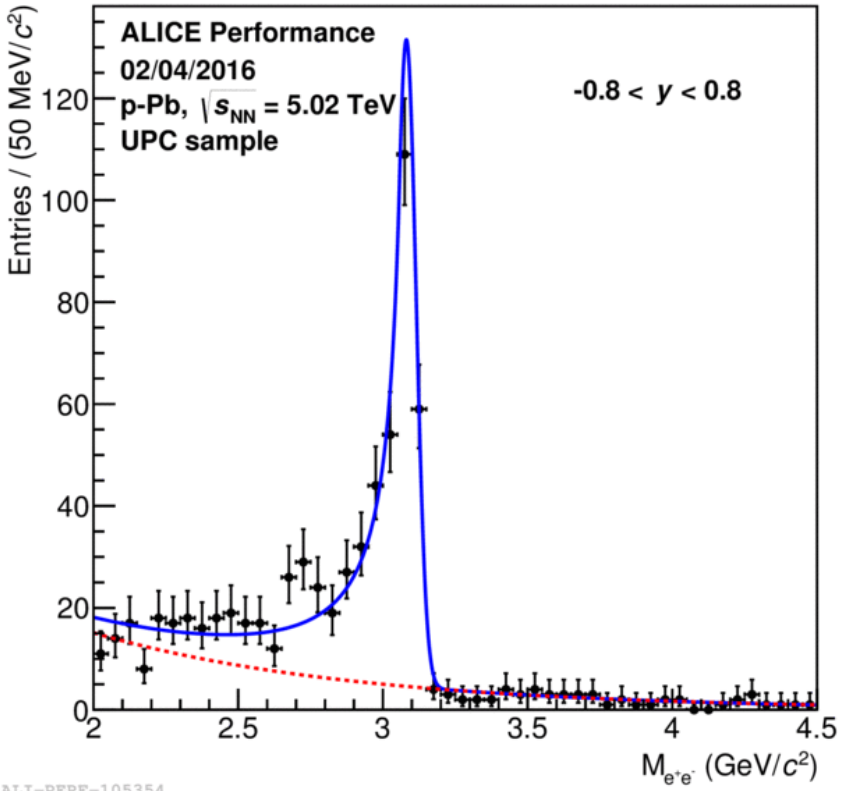



- HERA and ALICE cross section points stay on the same power law
- No change in the behavior of the cross section seen from HERA energies to the highest ALICE measurement

# J/ψ in p-Pb and Pb-p

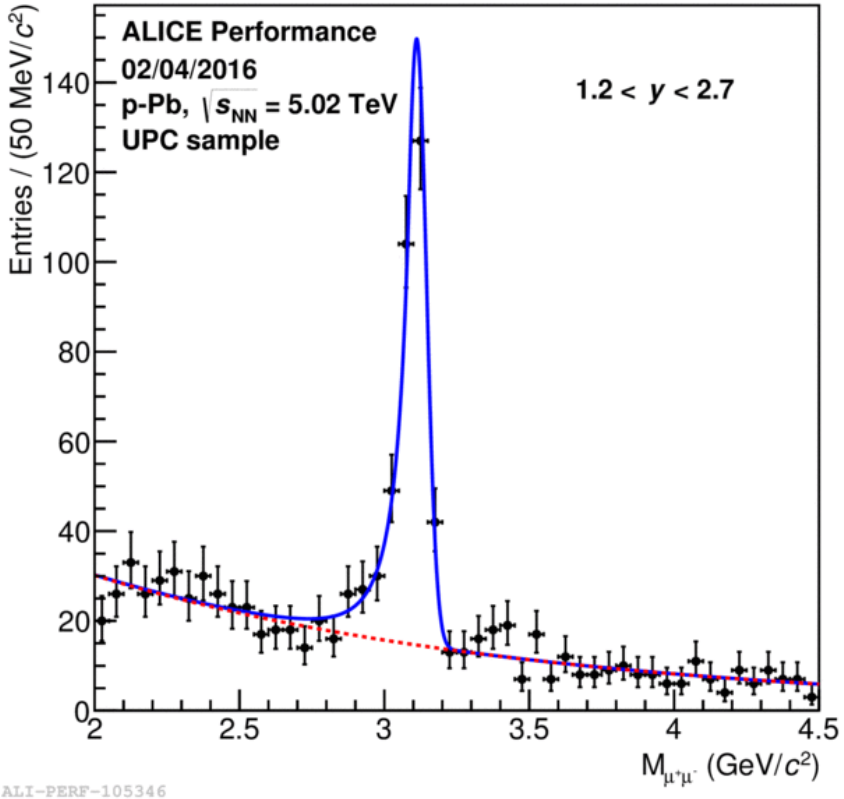
- 2013 p-Pb data
- Central barrel analysis ongoing

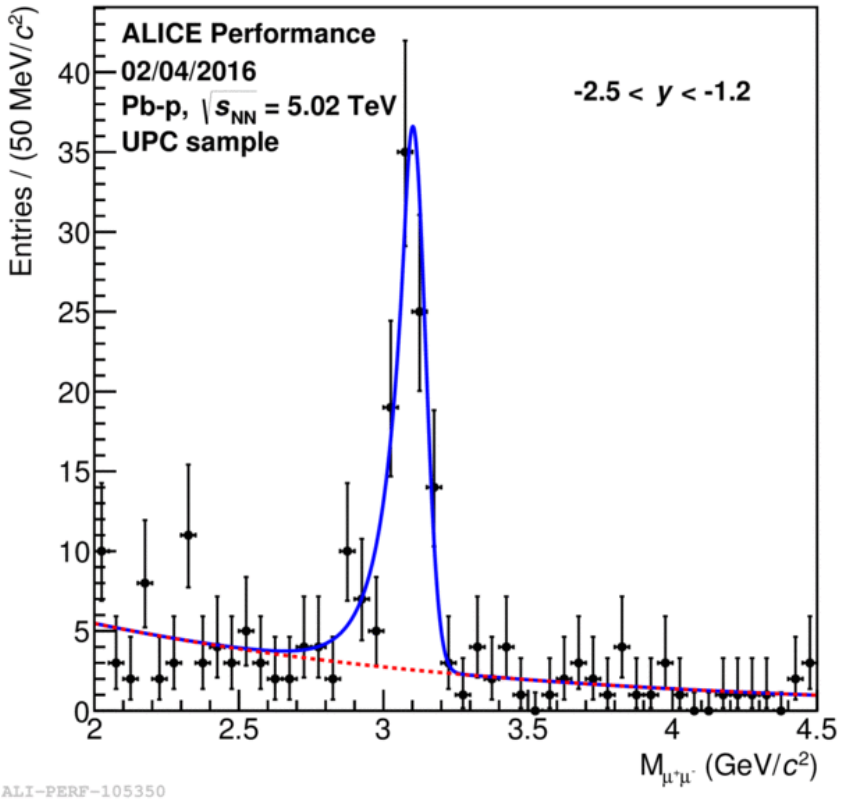


# J/ψ in p-Pb and Pb-p

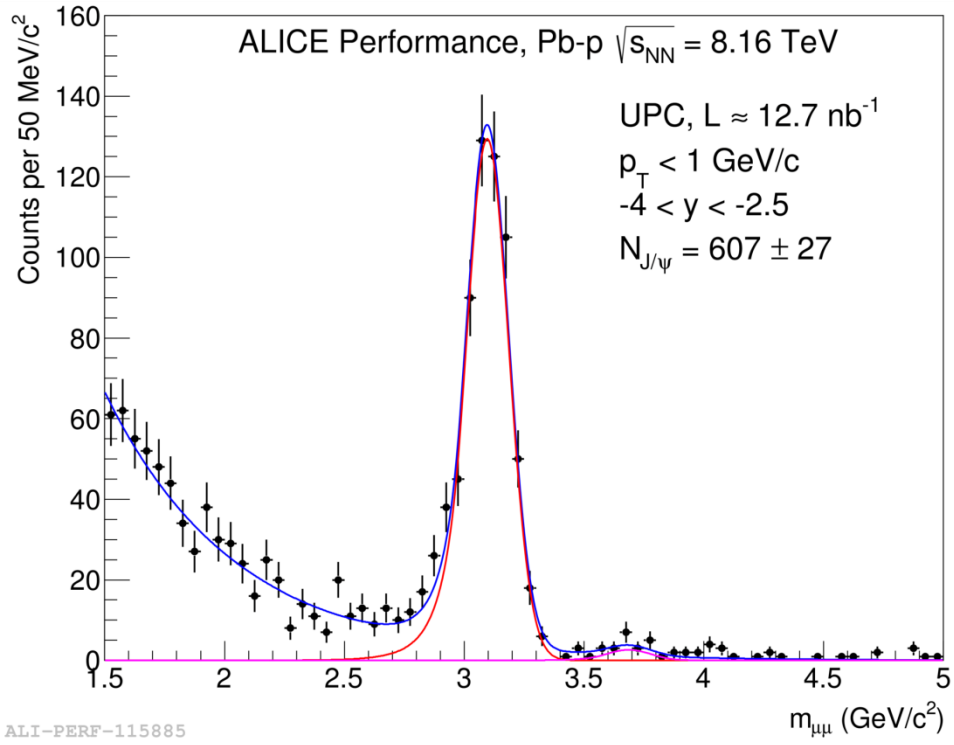
- 2013 p-Pb data
- Semi-Central analysis ongoing

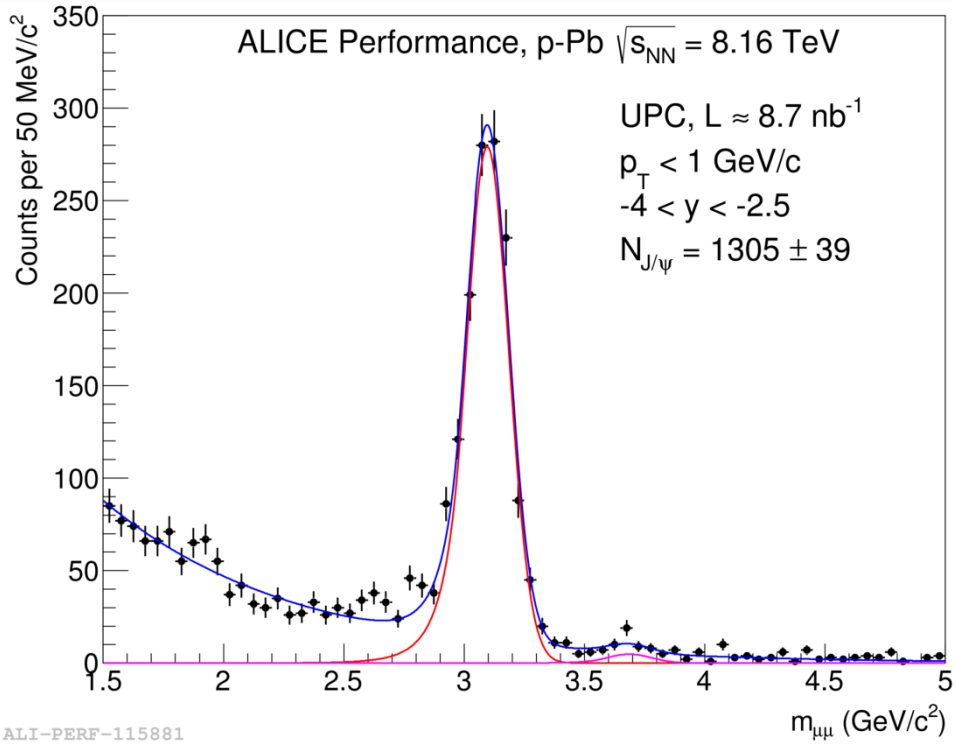


# p-Pb at $\sqrt{s_{NN}}$ = 8 TeV

- Data at 5 TeV and 8 TeV p-Pb and Pb-p were recorded in 2016
- 10x more stats at high $W_{\gamma p}$ ~0.7 - 1.4 TeV
- Search for gluon saturation effects in p at low $x$
- Study proton-dissociative cross section at high $W_{\gamma p}$ using AD and ZDC



# Summary and outlook

- ALICE has recorded data for the photoproduction of J/ψ in p-Pb and Pb-p modes, which covers a large range of $W_{\gamma p}$ from 20 GeV up to above 1 TeV.
- No change in the behavior of the gluon PDF in the proton between HERA and LHC
- During Run2 ALICE added the AD detector which enhances ALICE capabilities to detect low mass diffractive systems:
  - This allows us to have a purer exclusive sample, and
  - to tag efficiently processes where proton dissociation occurs.

- ALICE is analyzing new data from Run2 of the LHC: increase in luminosity and center of mass energy of the photon-target system – **Stay tuned!**