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

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On behalf of the ALICE Collaboration

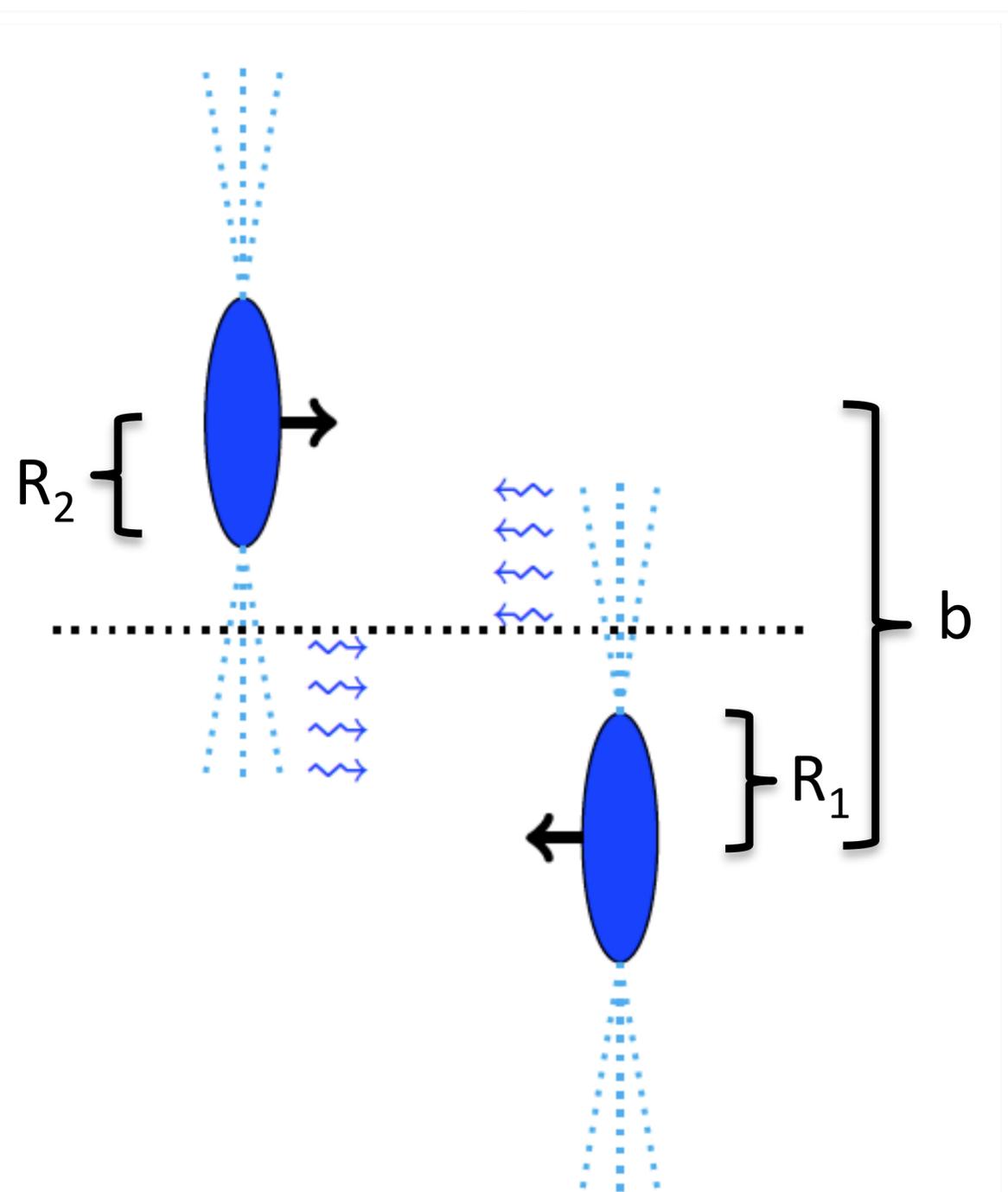
April 4, 2017, Birmingham

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Introduction

The $\text{L}\gamma\text{HC}$ and the $\text{L}\gamma\gamma\text{C}$



- The EM field of protons and ions at the LHC can be viewed as a beam of quasi real photons.

- There are two potential sources, correspondingly two potential targets.

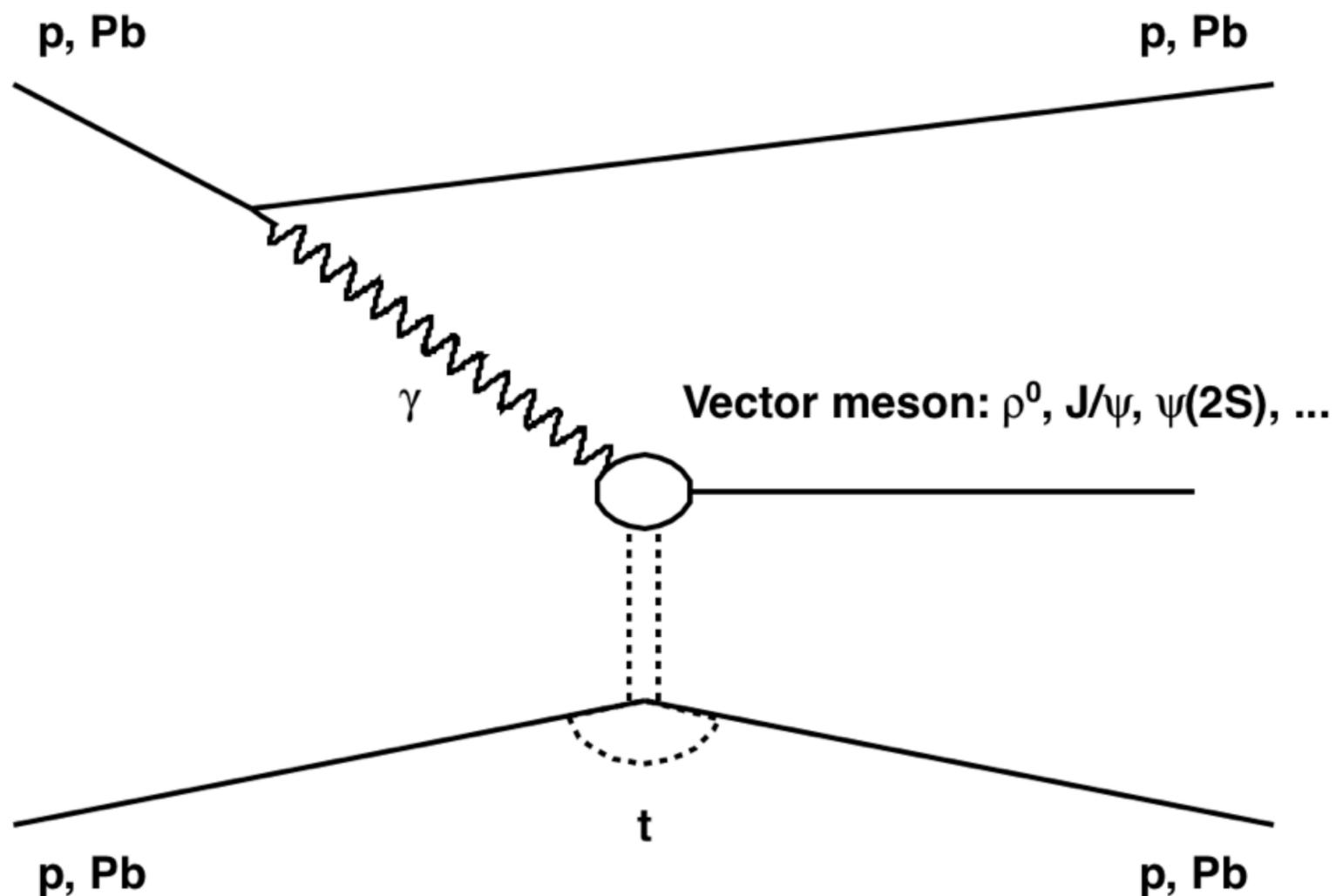
- The photon is coherently emitted by the source and its virtuality is restricted by the radius of the emitting particle: photon from Pb: $Q^2 \approx (30 \text{ MeV})^2$.

- 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: larger energies possible in Run2 w.r.t. Run1.

- The LHC is also a photon-hadron and photon-photon collider **what can we do with it?**

Vector meson photoproduction at the LHC



Photoproduction of vector mesons, among other observables, has been extensively studied at the LHC in pp, p-Pb and Pb-Pb collisions.

Very clean experimental signature:

- Vector mesons with low transverse momentum.
- Either nothing else in the detector or some activity in the very forward direction separated from the vector meson by a large rapidity gap.

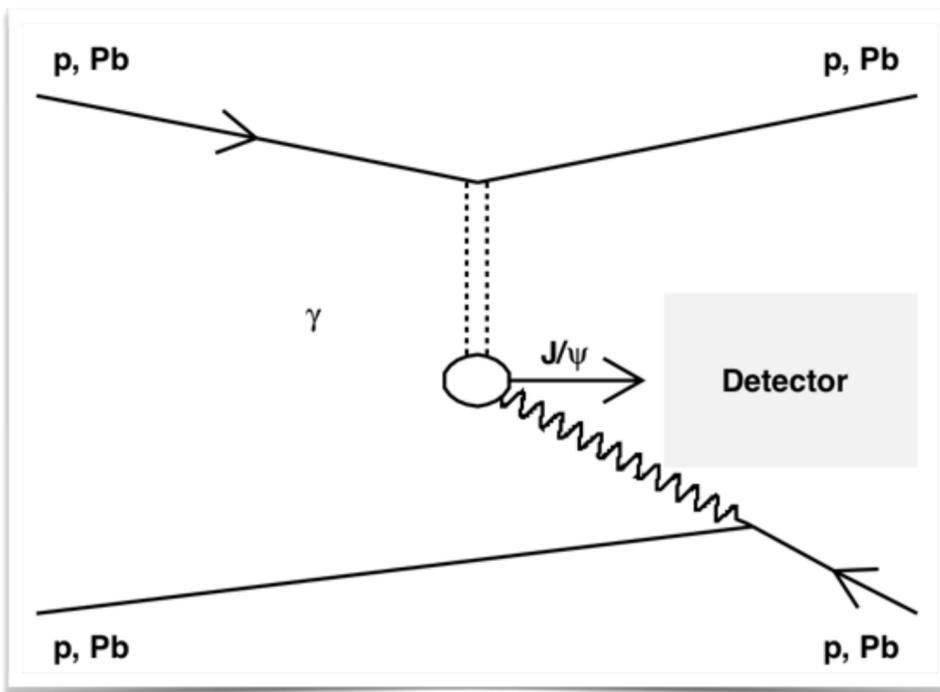
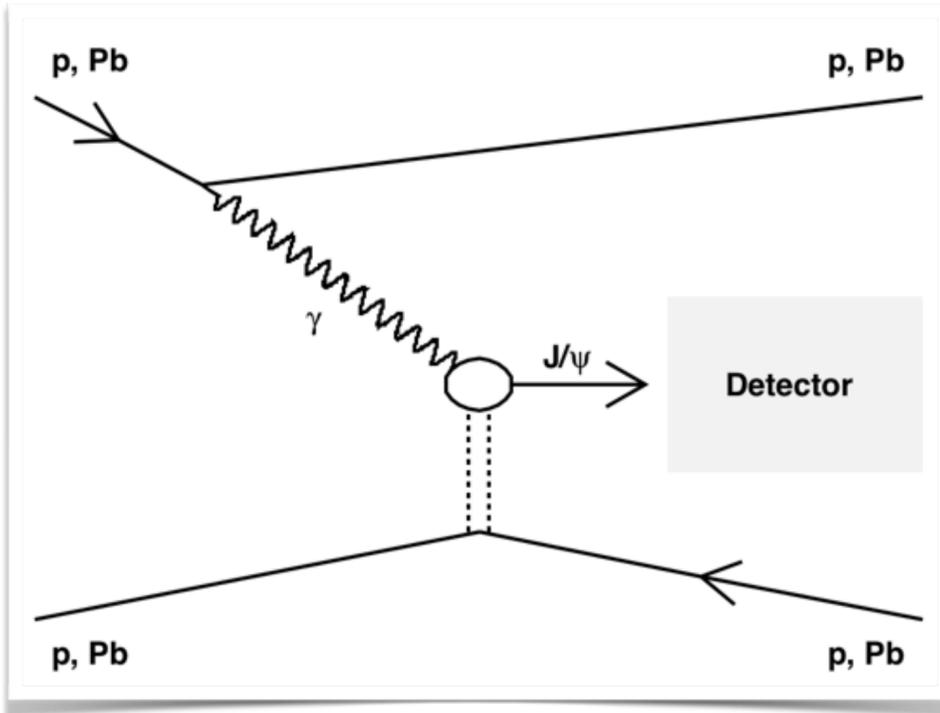
The vector meson determines kinematics of the event.

- Rapidity related to the centre-of-mass energy of the photon-target system.
- Transverse momentum related to the momentum transfer in the target vertex.

New ALICE results from Pb-Pb collisions will be presented later today by

- Valeri Pozdnyakov and
- Kay Graham.

Photoproduction of vector mesons in p-Pb



The cross section can be written as the convolution of

- a photon flux, calculable from standard electromagnetism, and
- the photon-target cross section, which involves QCD.

There are two contributions to this process, as shown in the figures.

- 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.

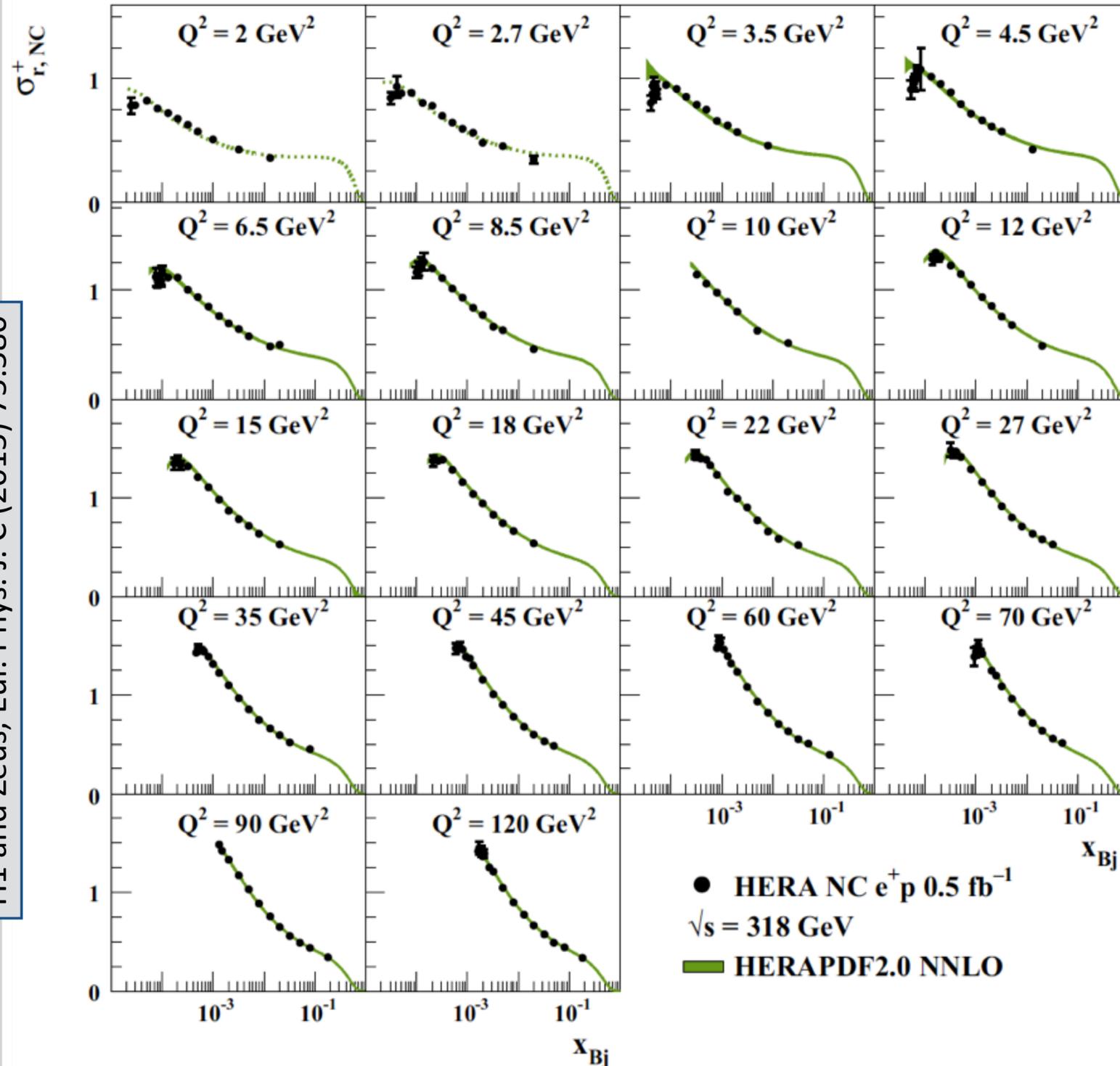
The measured cross sections at the LHC are the sum of both contributions.

- To go from the measured cross sections to the photon-target cross section is not trivial.
- One option is to know which incoming particle acted as a source.

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: only one diagram has to be considered and it is possible to extract the photon-target cross section.

QCD at high energies and gluon saturation

H1 and ZEUS



◉ The inclusive cross section at HERA grows steeply at small x .

◉ Within pQCD the structure of the proton in this kinematic domain 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**.

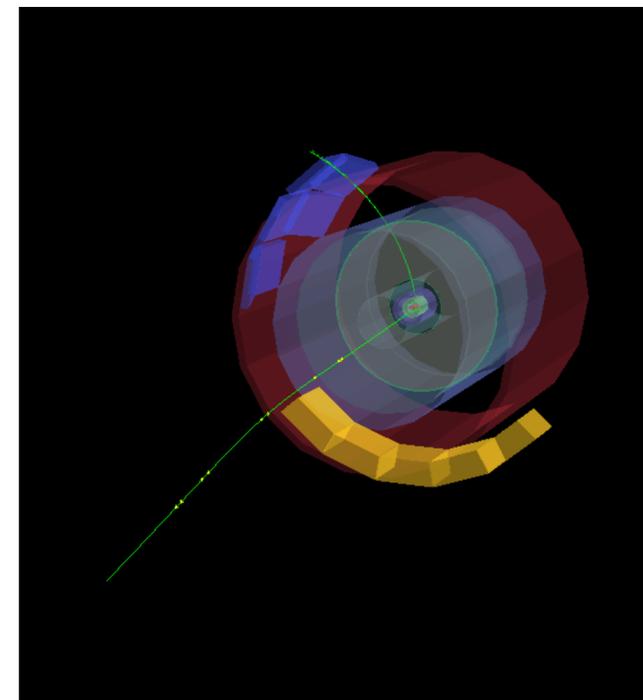
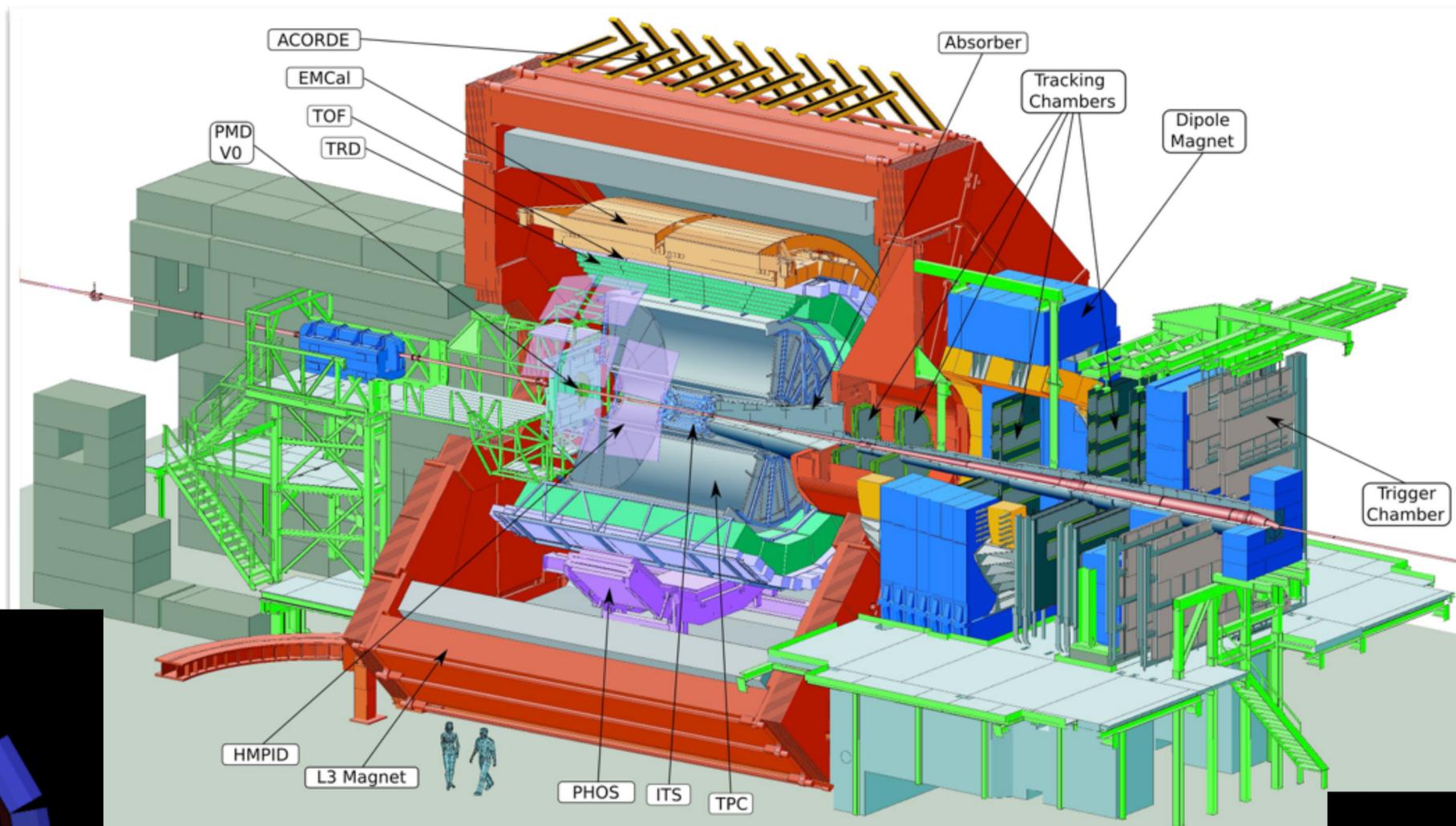
◉ The exclusive photoproduction of a J/ψ involves the exchange of at least two gluons.

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

ALICE

Exclusive J/ψ photoproduction in ALICE: measurement

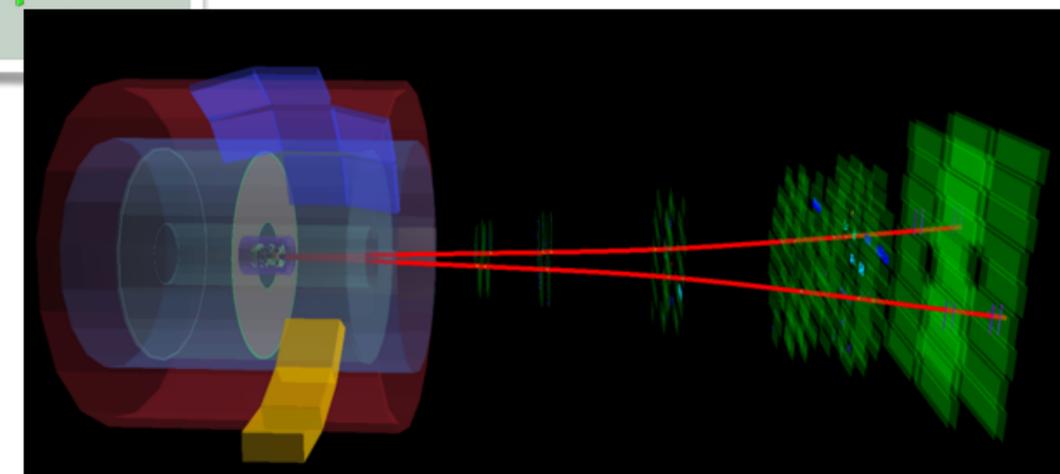
In ALICE the J/ψ is measured using its decay into a lepton pair. We can do this in three configurations:



One muon measured in the muon spectrometer the other in the central barrel.

Both leptons measured in the central barrel.

Both muons measured in the muon spectrometer.

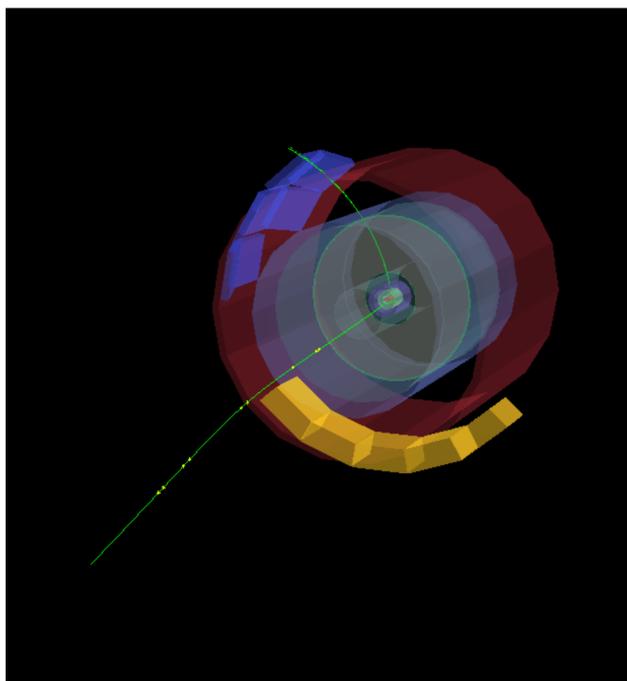


Exclusive J/ψ photoproduction in ALICE: energy ranges

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:

$$W_{\gamma p}^2 = 2E_p M_{J/\psi} \exp(-y).$$

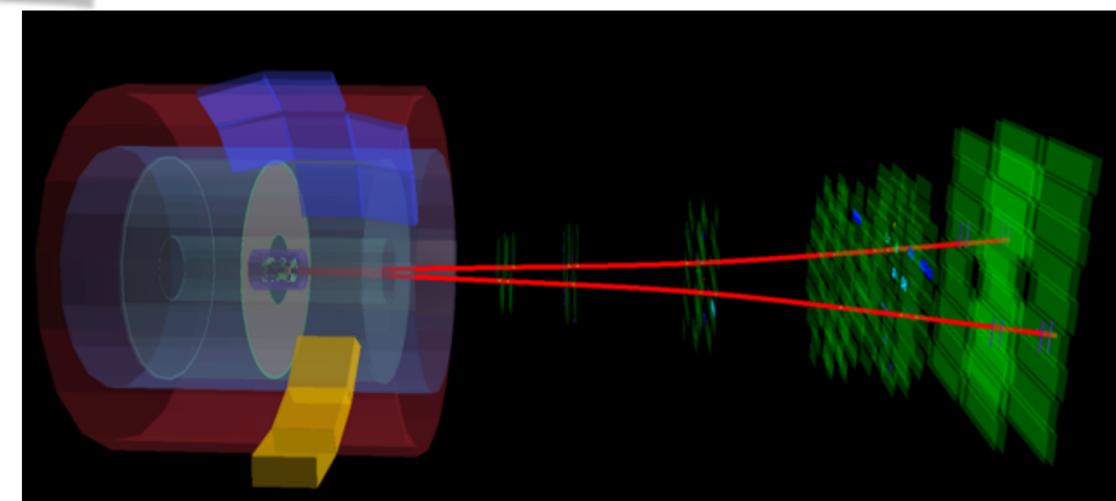
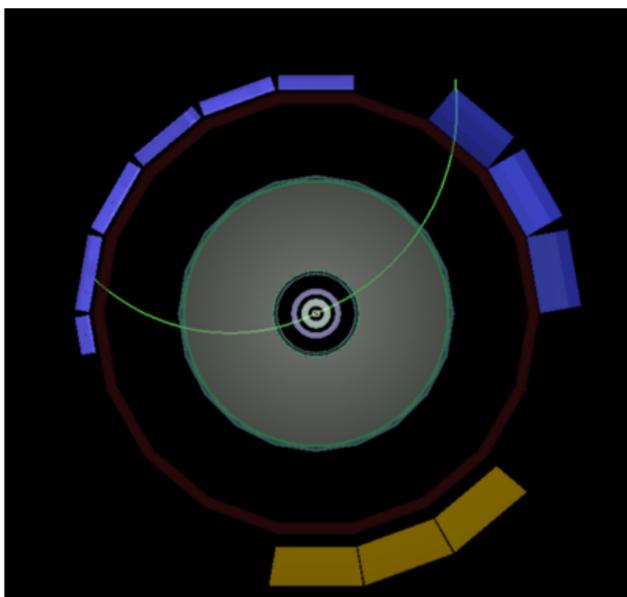


Energy coverage at semi-forward rapidity:

- Run 1:
40 < $W_{\gamma p}$ < 86 GeV (p-Pb)
287 < $W_{\gamma p}$ < 550 GeV (Pb-p)
- Run 2:
60 < $W_{\gamma p}$ < 110 GeV (p-Pb)
365 < $W_{\gamma p}$ < 700 GeV (Pb-p)

Energy coverage at mid rapidity

- Run 1: 106 < $W_{\gamma p}$ < 230 GeV
- Run 2: 135 < $W_{\gamma p}$ < 300 GeV

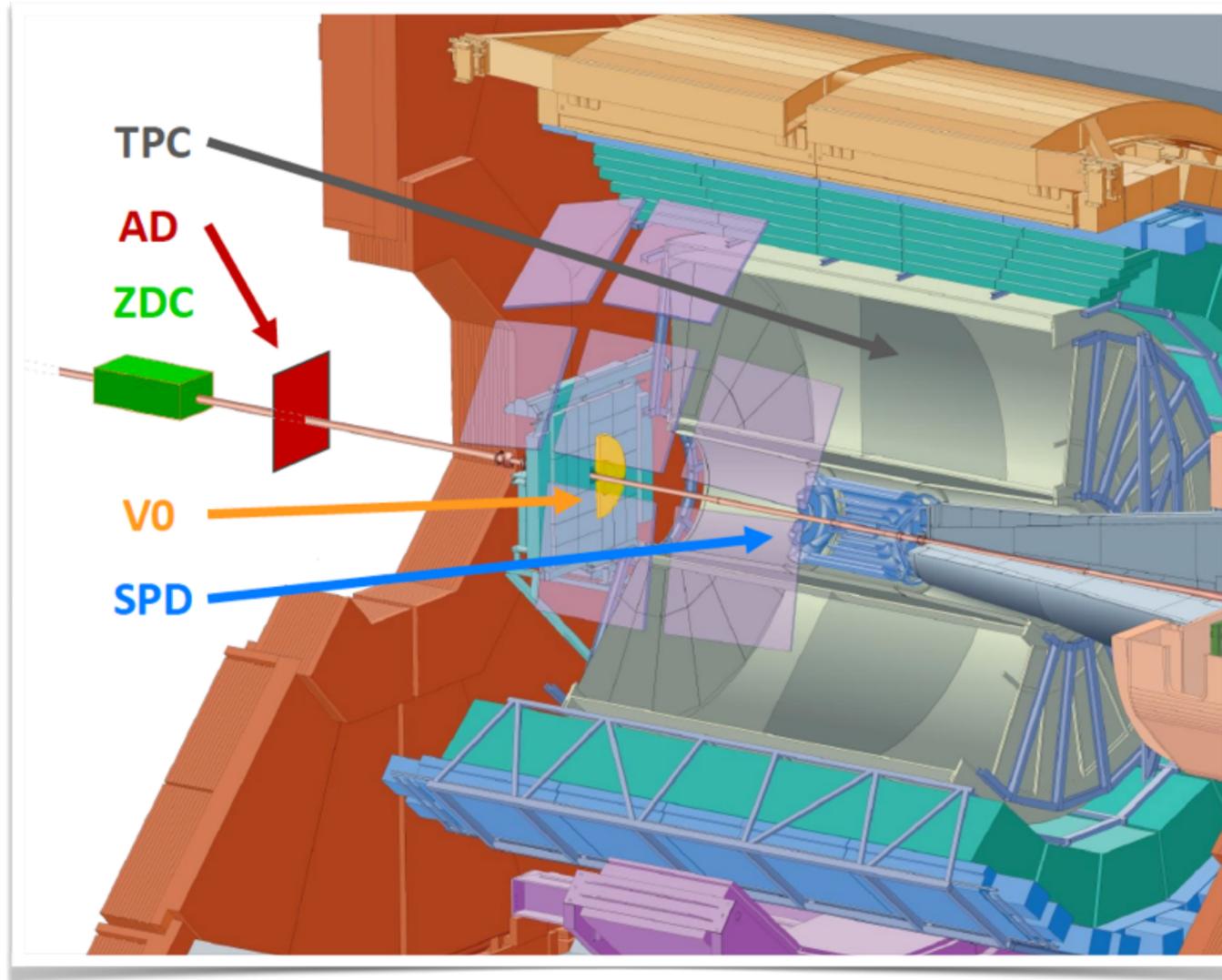


Energy coverage at forward rapidity:

- Run 1:
21 < $W_{\gamma p}$ < 45 GeV (p-Pb)
580 < $W_{\gamma p}$ < 950 GeV (Pb-p)
- Run 2:
27 < $W_{\gamma p}$ < 57 GeV (p-Pb)
700 < $W_{\gamma p}$ < 1480 GeV (Pb-p)

Energy range in ALICE overlaps and extends HERA range!

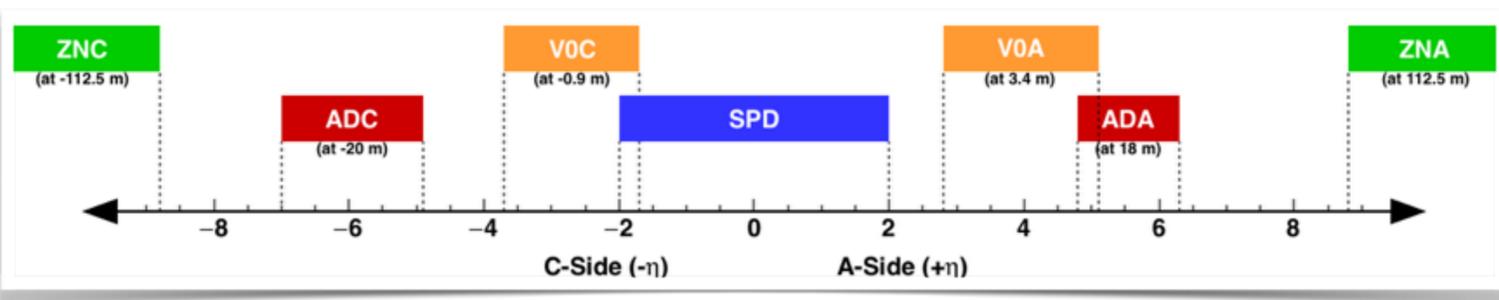
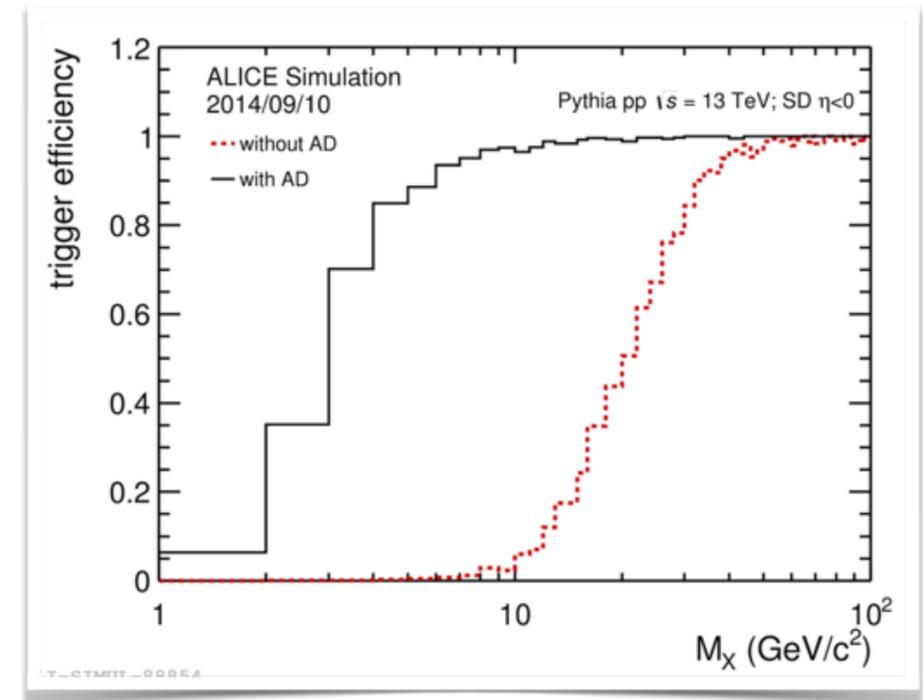
Exclusivity condition in ALICE



One crucial aspect of this kind of measurements is the capacity to veto any other activity in the detector beyond the decay products of the vector meson.

- In ALICE:
 - We have a large rapidity coverage to impose vetoes.
 - We try to set thresholds so that detectors are sensitive to one mip.

In Run2 we added new detectors, the ALICE Diffractive (AD) detectors, which give us enhanced sensitivity to low mass diffractive systems.

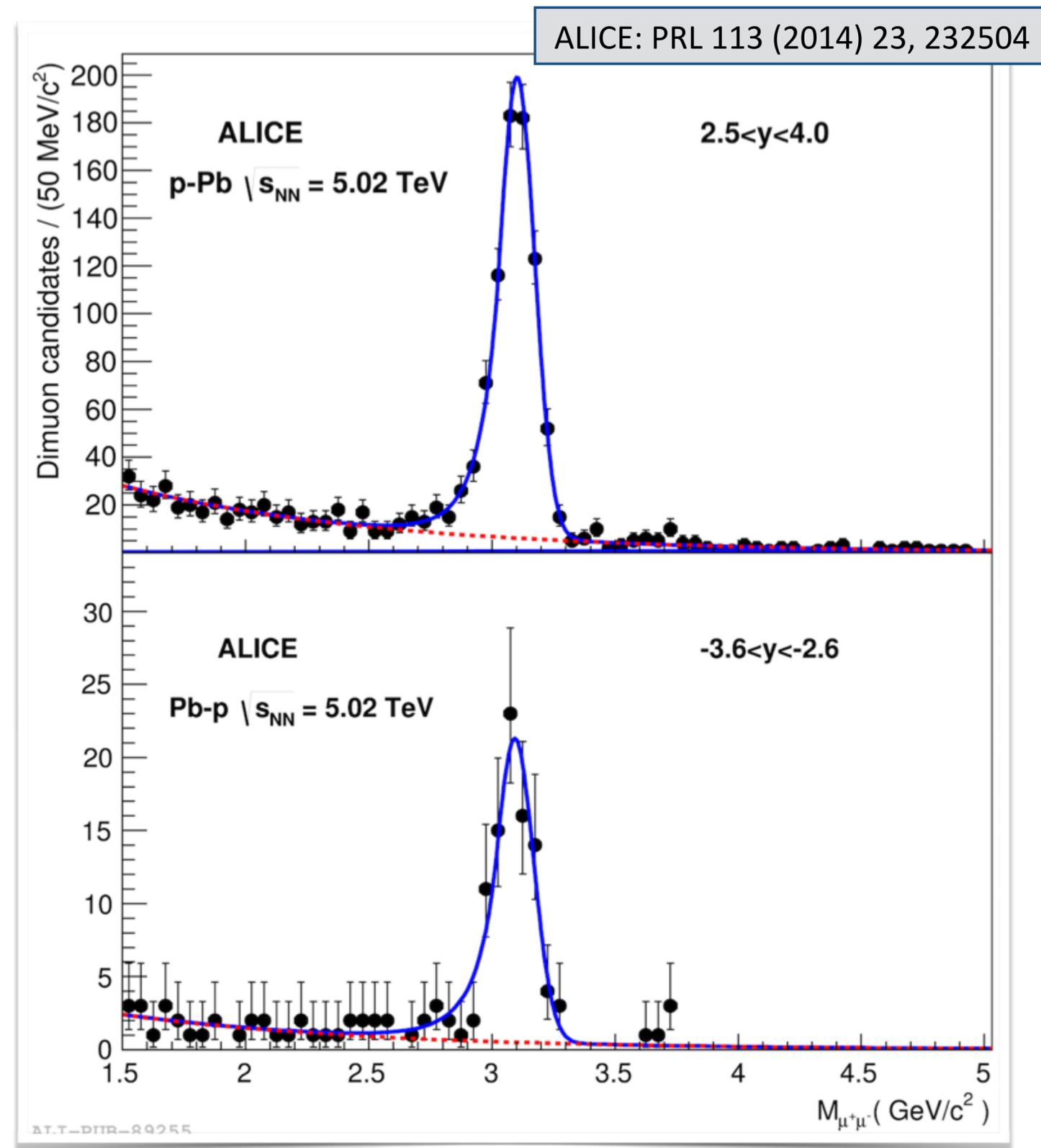


Published cross sections

J/ ψ in the muon spectrometer

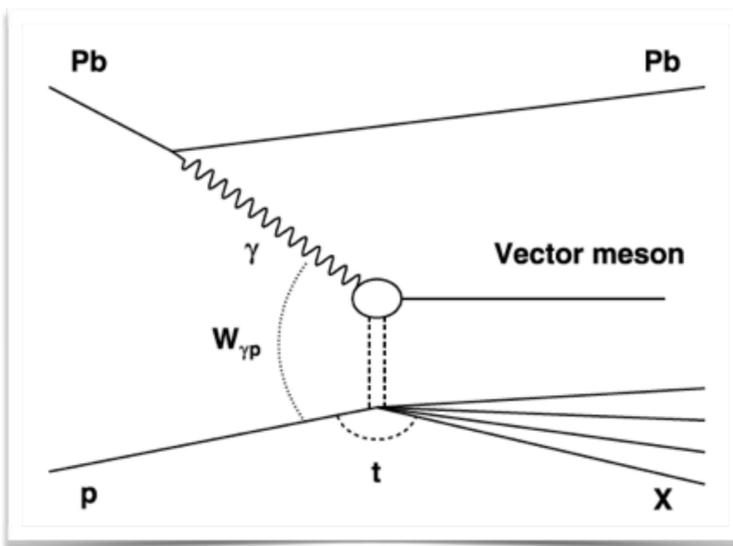
- Data taken during 2013 in two configurations: p-Pb and Pb-p
- Trigger conditions in p-Pb:
 - two oppositely charged tracks,
 - no activity in V0A.
- Trigger conditions in Pb-p:
 - two oppositely charged tracks,
 - no activity in V0A,
 - veto on beam-gas timing in A side,
 - at least one hit in V0C.
- Data selection included in addition:
 - No activity in the central region (SPD).
 - No activity in the very forward region (ZDC).

- Very clear signal seen in the invariant mass distribution over a small background from $\gamma\gamma \rightarrow \mu\mu$ production.



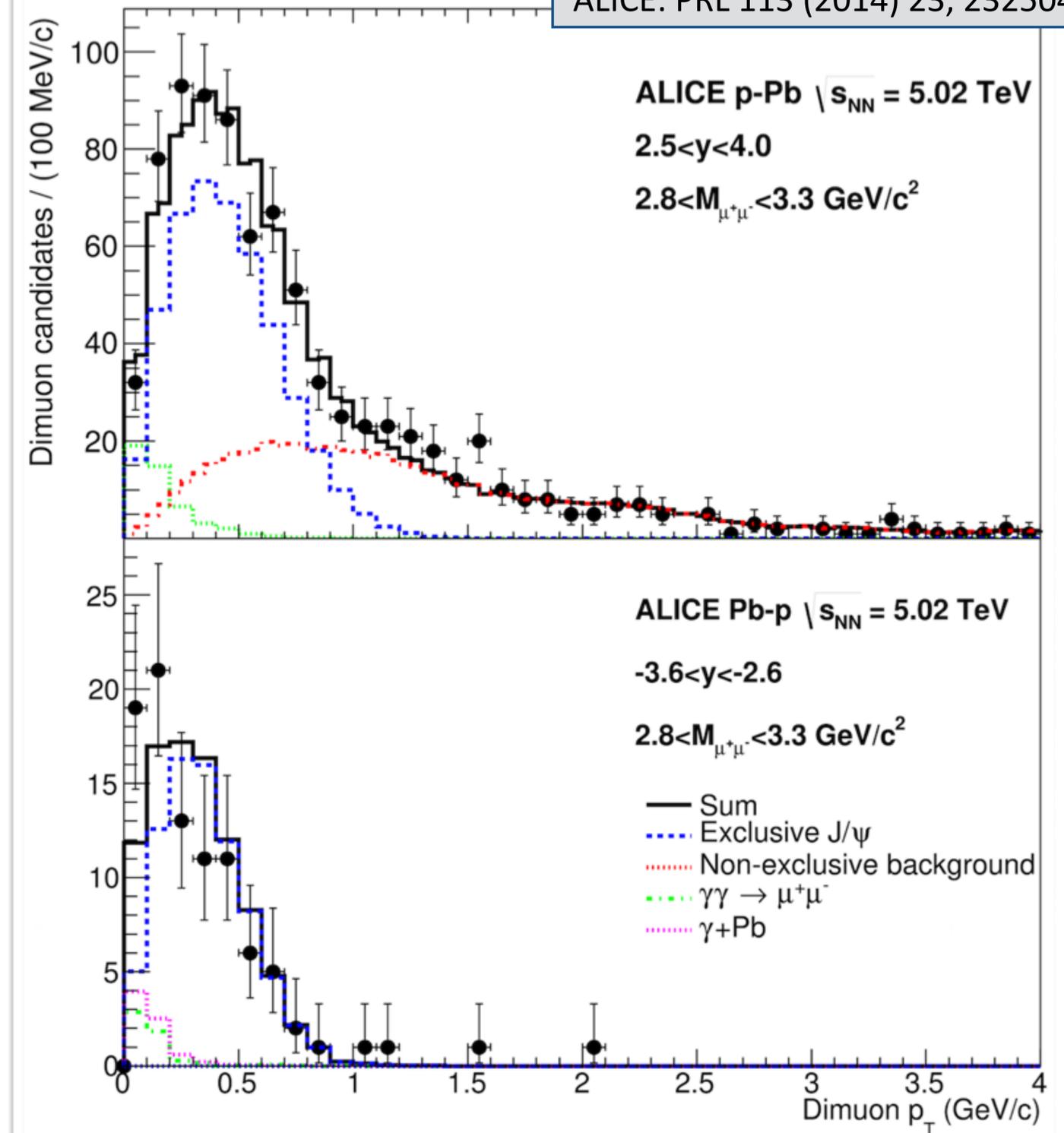
J/ψ in the muon spectrometer: transverse momentum distribution

- Main backgrounds identified using the J/ψ transverse momentum distribution:
 - $\gamma\gamma \rightarrow \mu\mu$ 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 V0.

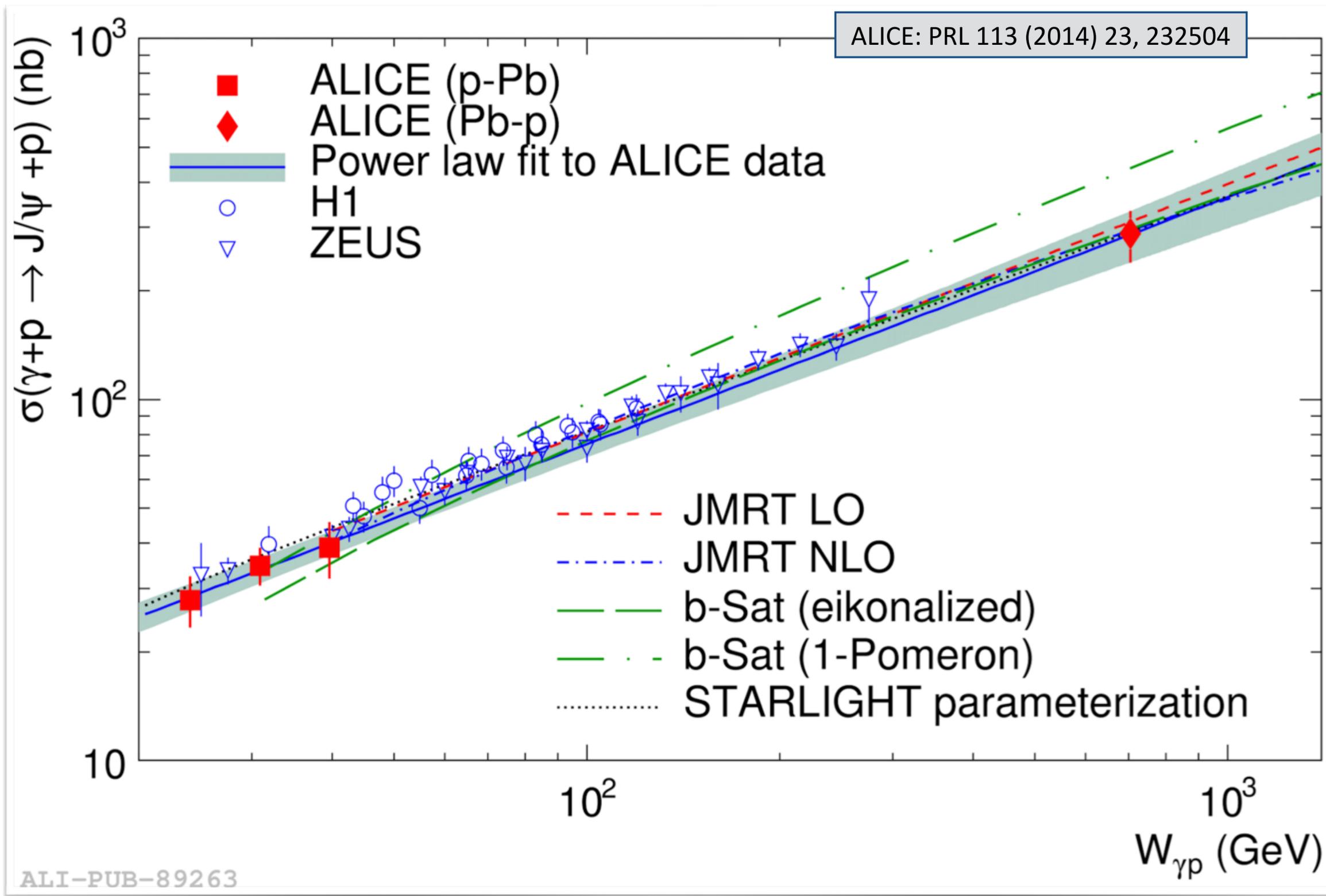


- Main contribution to non-exclusive background from proton-dissociative photoproduction of J/ψ
- Process sensitive to fluctuations of the proton structure!
 - Talks by Jan Čepila and Heikki Mäntysaari later today

ALICE: PRL 113 (2014) 23, 232504

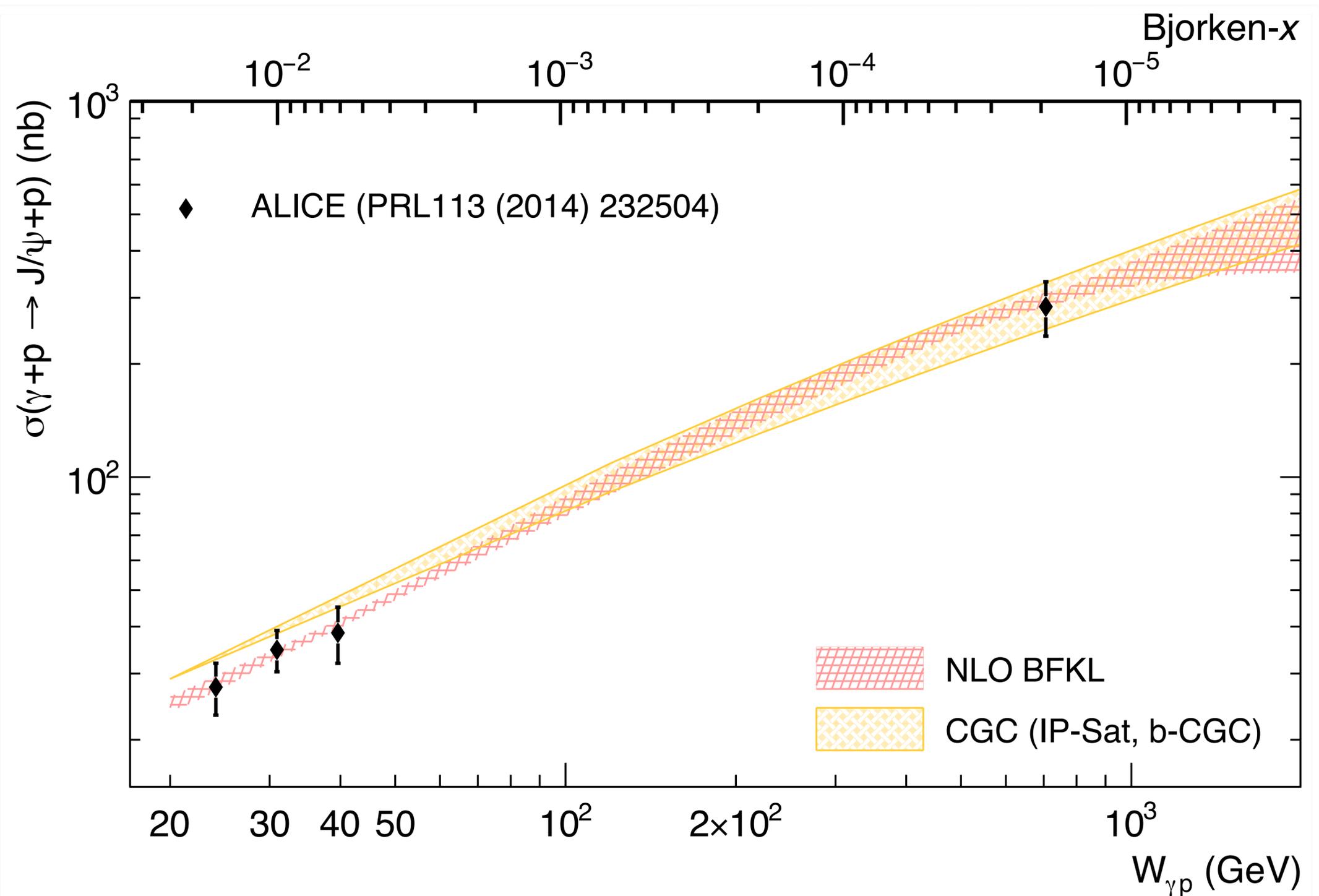


Energy dependence of J/ψ exclusive photoproduction



- Data from 20 to 700 GeV!
- Agreement with HERA data where there is overlap.
- Power law fit of ALICE data yields same parameters as found by H1 and ZEUS.
- All models, except b-Sat 1-pomeron describe correctly the measured data.
- No change in the behaviour of the cross section seen from HERA energies to the highest ALICE measurement (more than twice increase in energy).

Energy dependence of J/ψ exclusive photoproduction



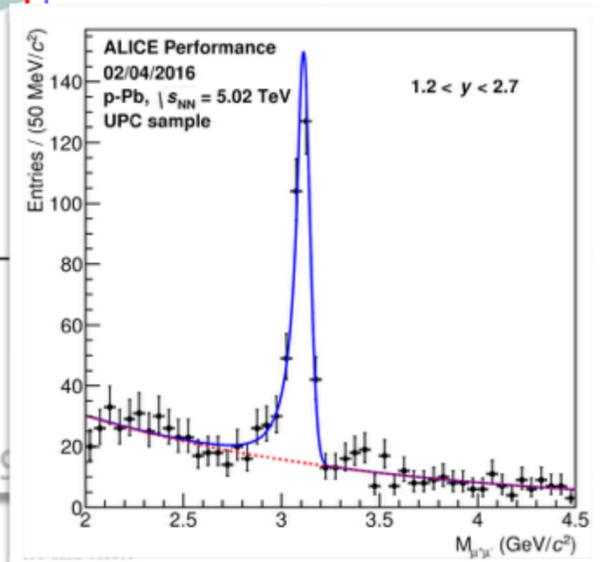
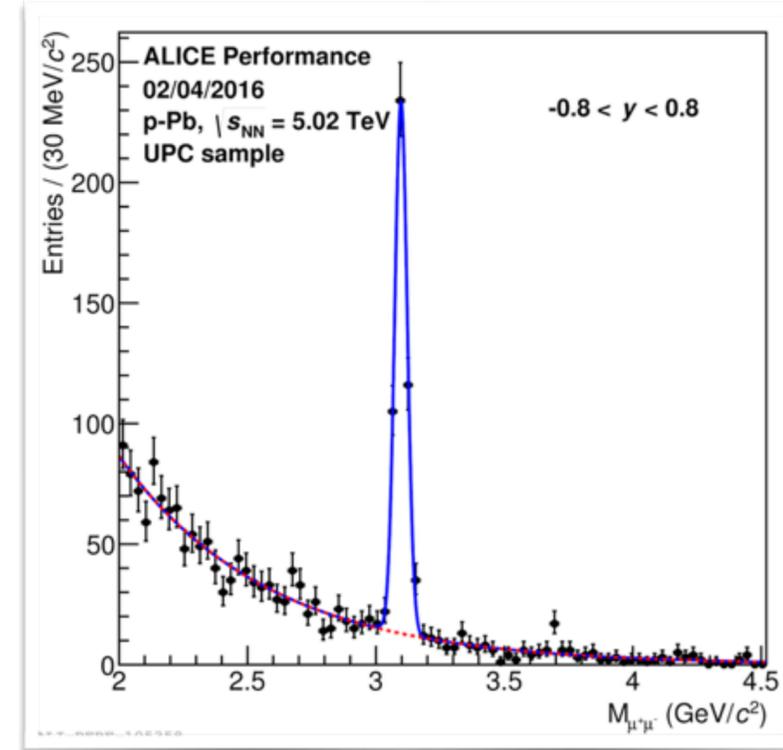
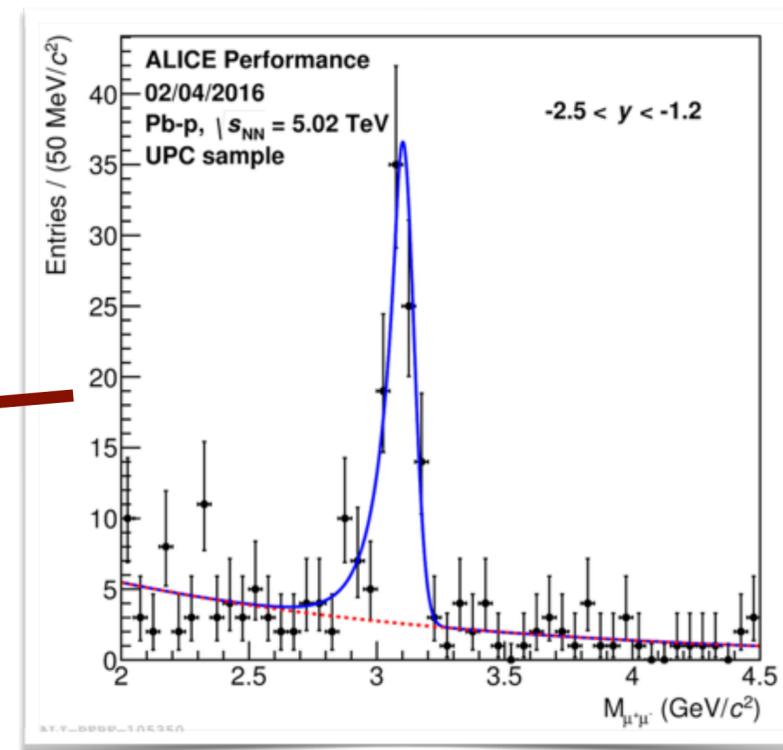
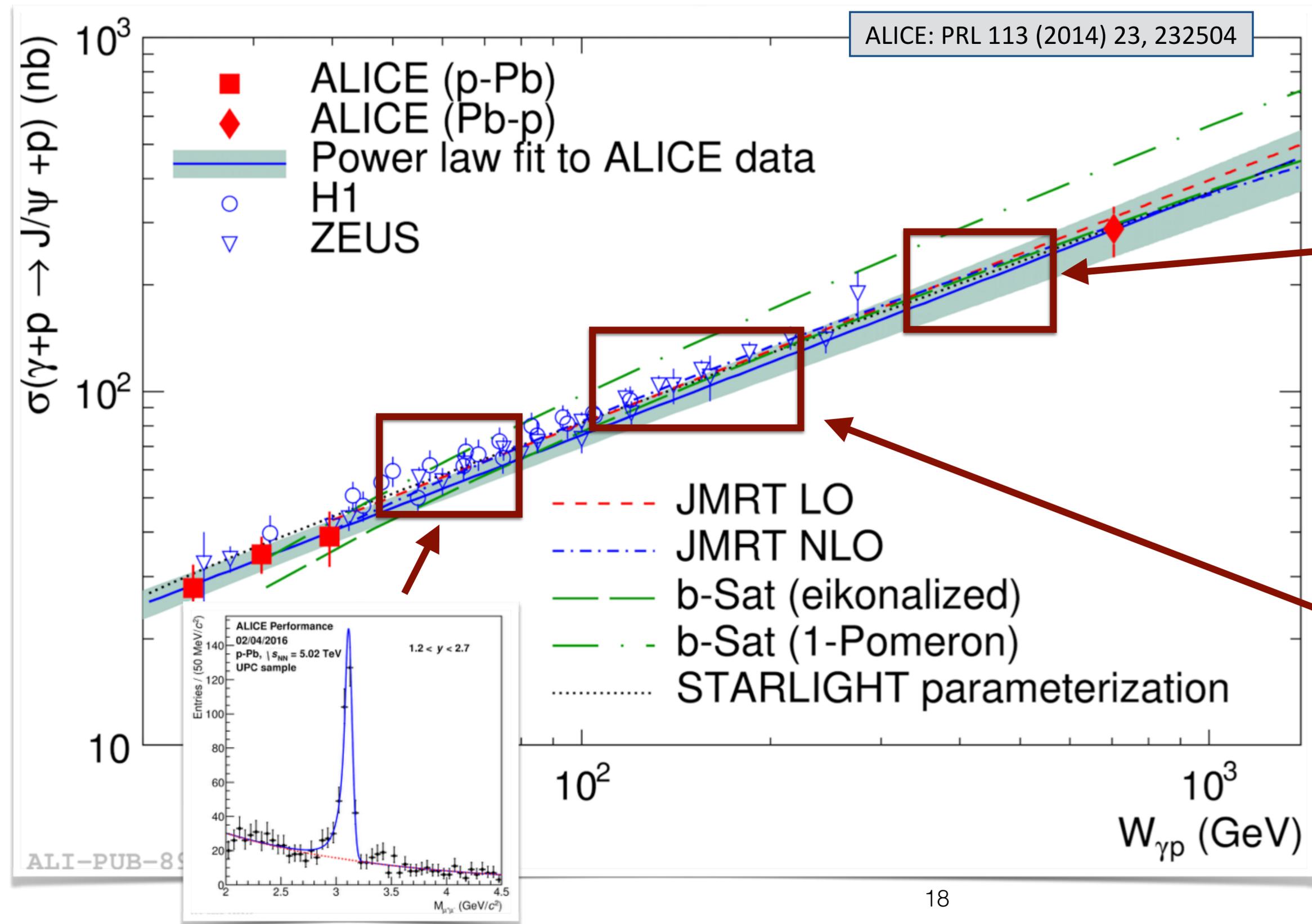
ALICE data also correctly described by recent calculations using:

- CGC by Armesto and Rezaeian
Phys.Rev. D90 (2014) 054003,
- NLO BFKL by Bautista et al
Phys.Rev. D94 (2016) 054002.

See talk by Martin Hentschinski later today!

Sneak peek

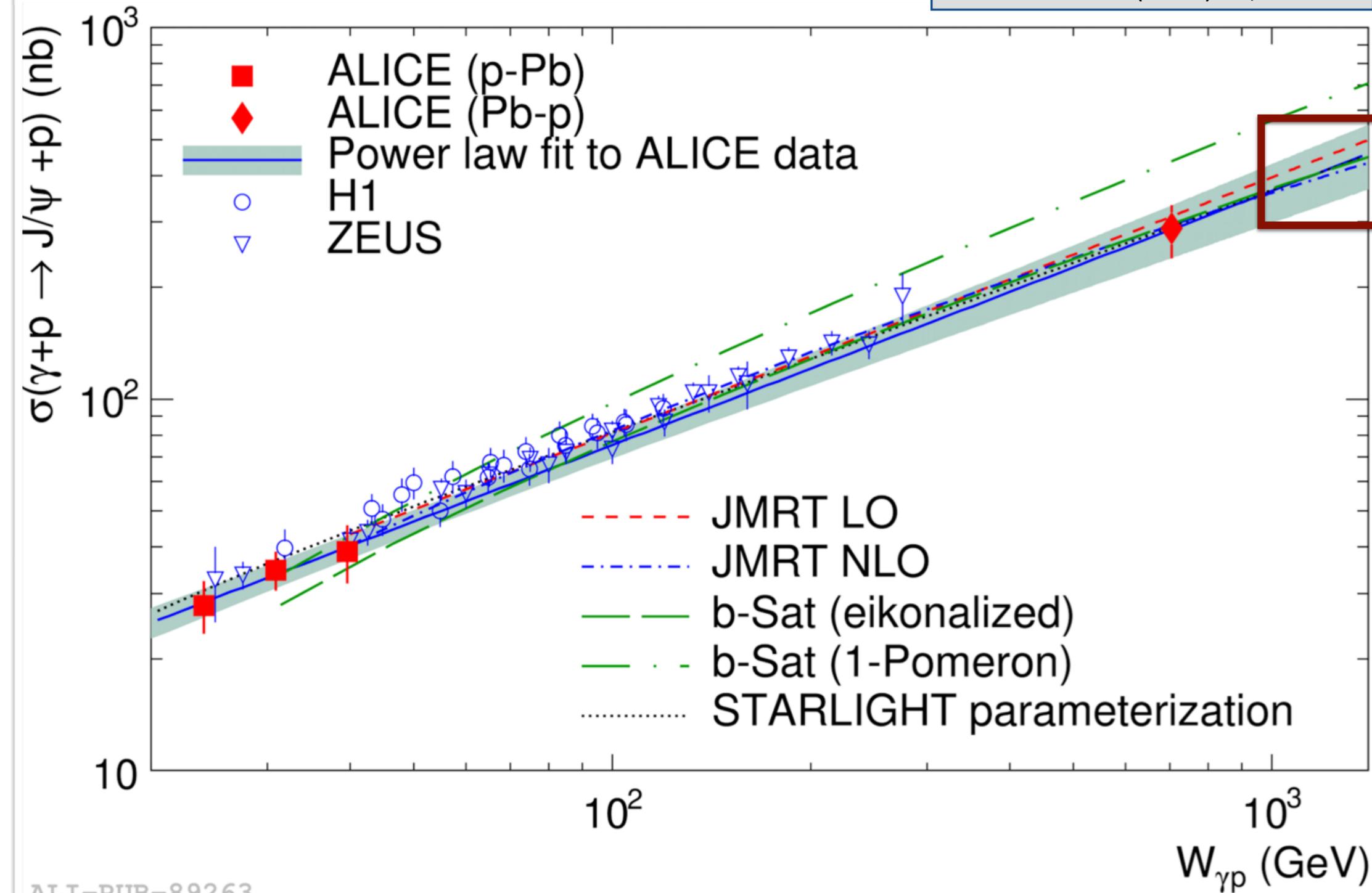
Energy dependence of J/ψ exclusive photoproduction: more 2013 data



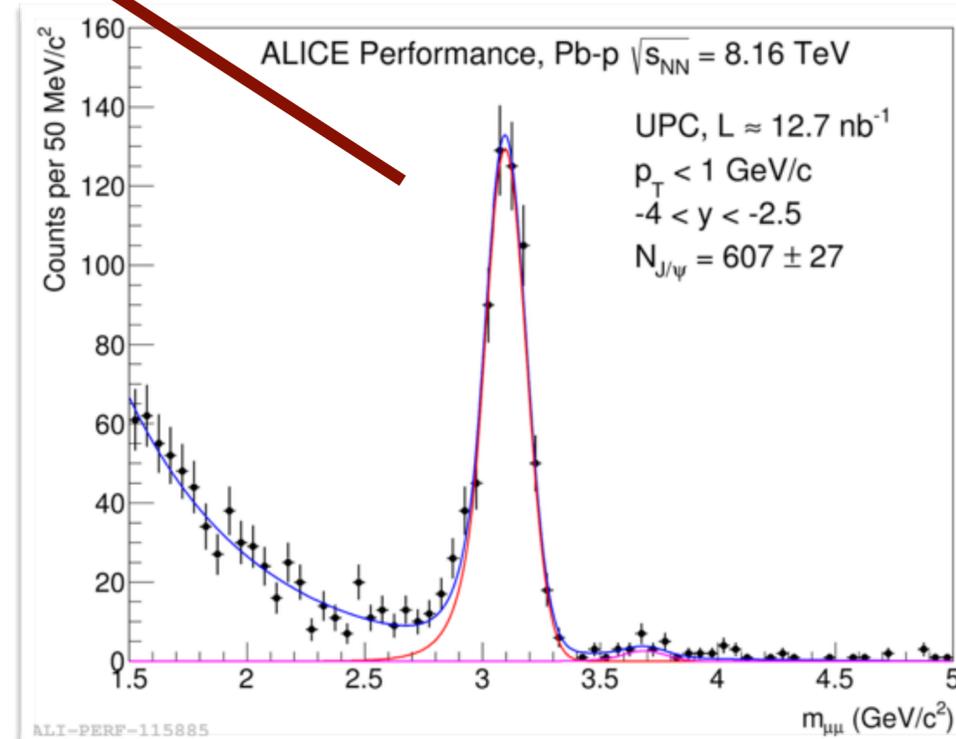
ALI-PUB-89

Energy dependence of J/ψ exclusive photoproduction: 2016 data!

ALICE: PRL 113 (2014) 23, 232504



- At the end of 2016 p-Pb data was recorded by ALICE both, at 5.02 TeV and 8.16 TeV
- Data at 8.16 TeV in Pb-p mode will allow to reach $W_{\gamma p}$ above 1 TeV!



- ALICE also plans to measure for the first time the cross section of proton dissociation!

Summary and outlook

- ALICE has recorded data for the photoproduction of J/ψ in p-Pb and Pb-p modes, which allows to cover a large range of $W_{\gamma p}$ from 20 GeV up to above 1 TeV.
- Cross sections from the 2013 campaign up to energies beyond twice what was measured at HERA have been presented.
- Other measurements from 2013 are very close to completion.
- 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.
- The analyses of photoproduction data taken by ALICE at the end of 2016 has started.
- Interesting times are ahead of us!