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

J. G. Contreras
Czech Technical University

On behalf of the ALICE Collaboration

April 18, 2018, Kobe

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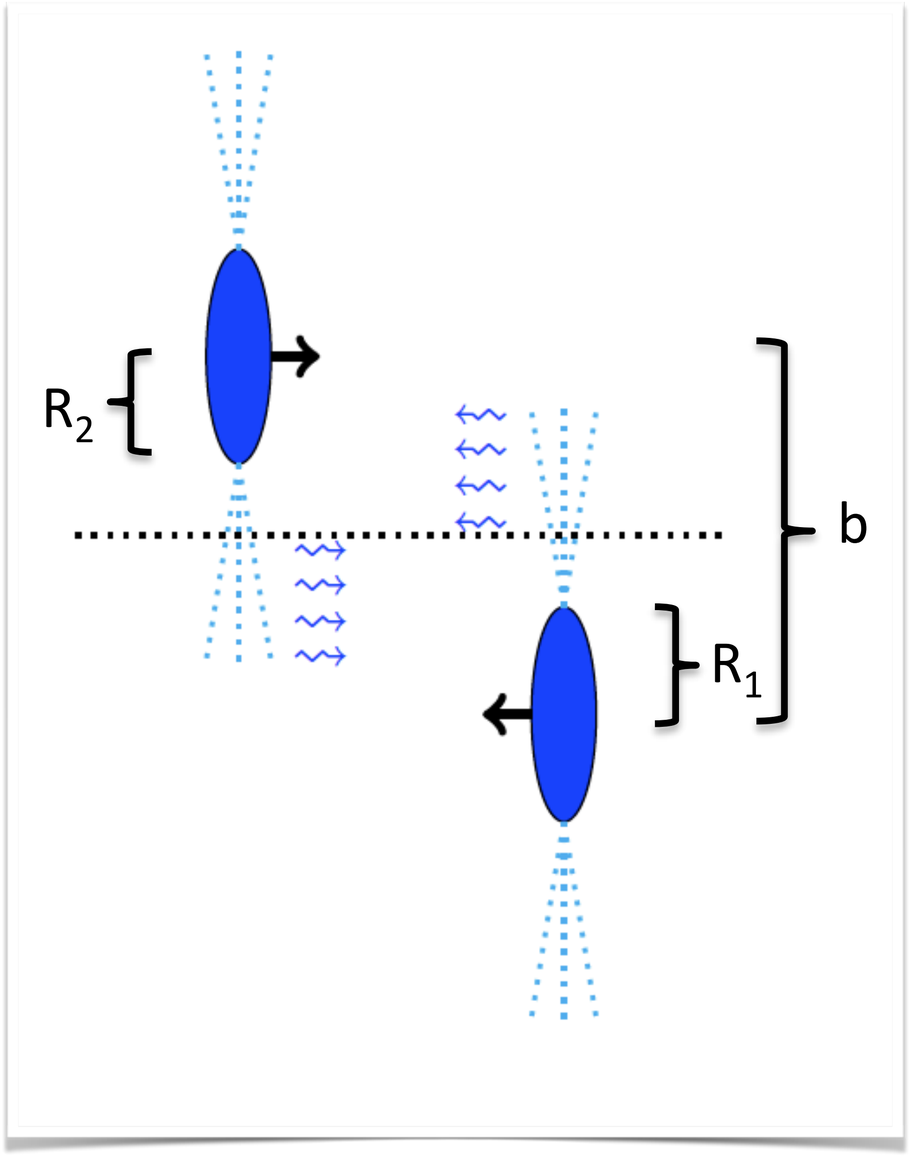
- Introduction: The LγHC and small x physics.
- ALICE and J/ψ photoproduction.
- Energy dependence of the exclusive cross section.
- Sneak peek: what Run 2 will bring.
- Conclusions and outlook.

Introduction

The LγHC and the LγγC



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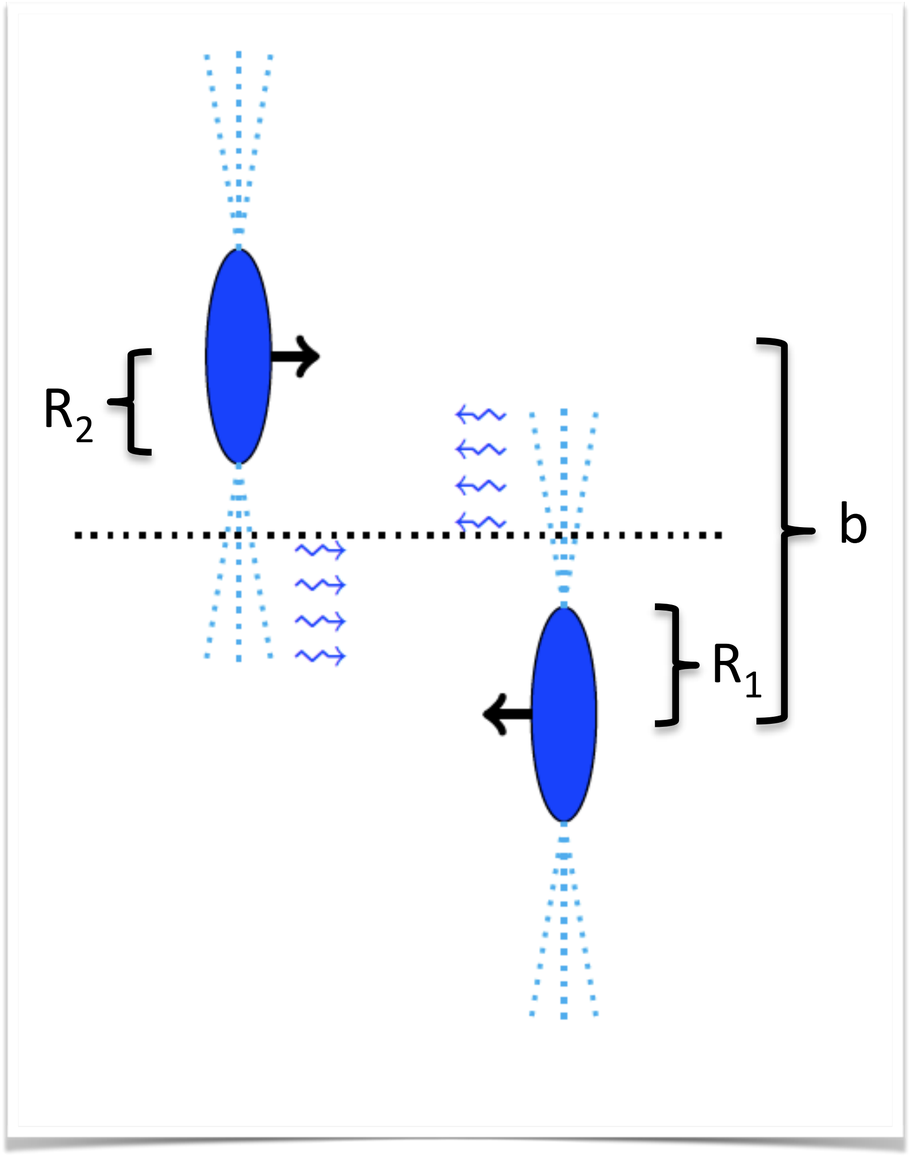

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- The photon is coherently emitted by the source and its virtuality is restricted by the radius of the emitting particle: **Virtuality of photons from Pb: $Q^2 \approx (30\ \text{MeV})^2$.**
- The intensity of the photon beam is proportional to Z^2. **Lead nuclei are intense sources of quasi-real photons!**
- The maximum energy of the photons in the laboratory system is determined by the boost of the emitting particle: **Larger energies possible in the LHC Run2 w.r.t. Run1.**

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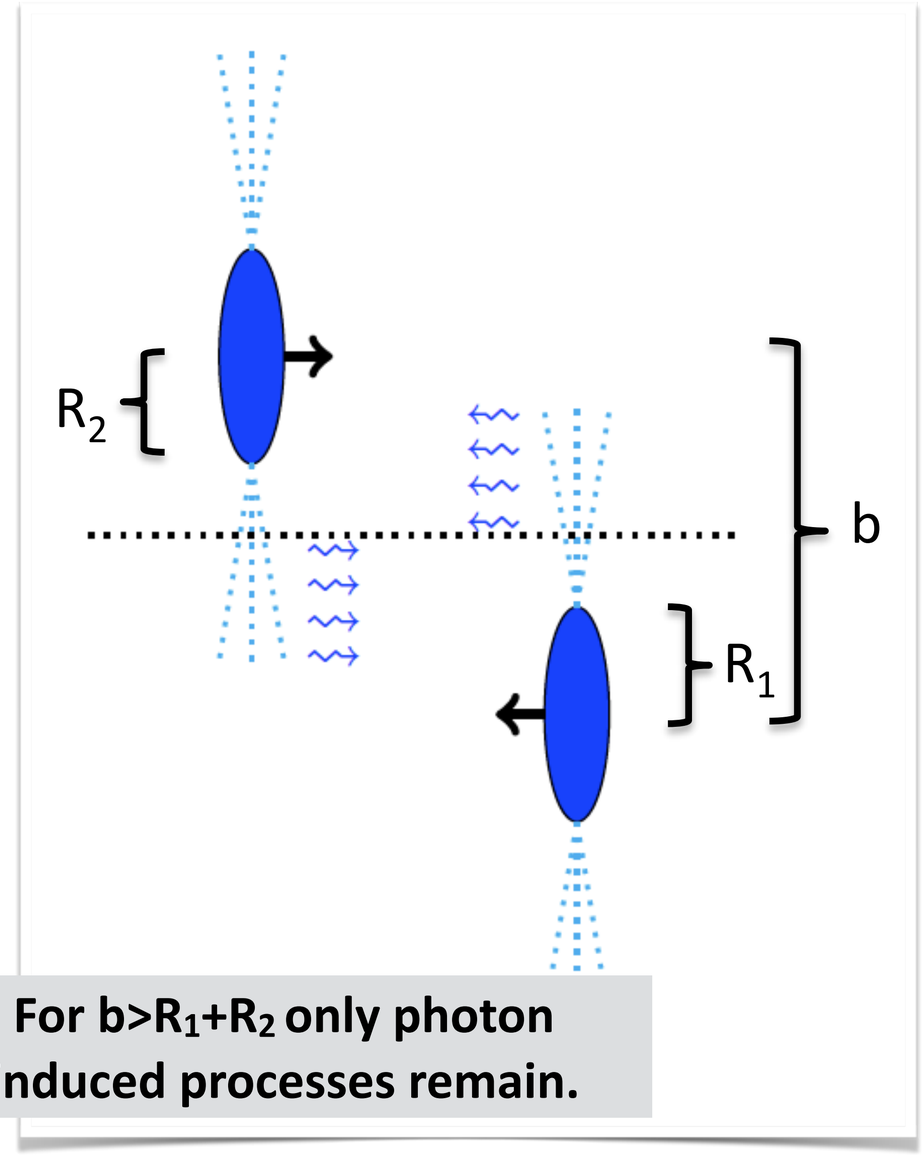

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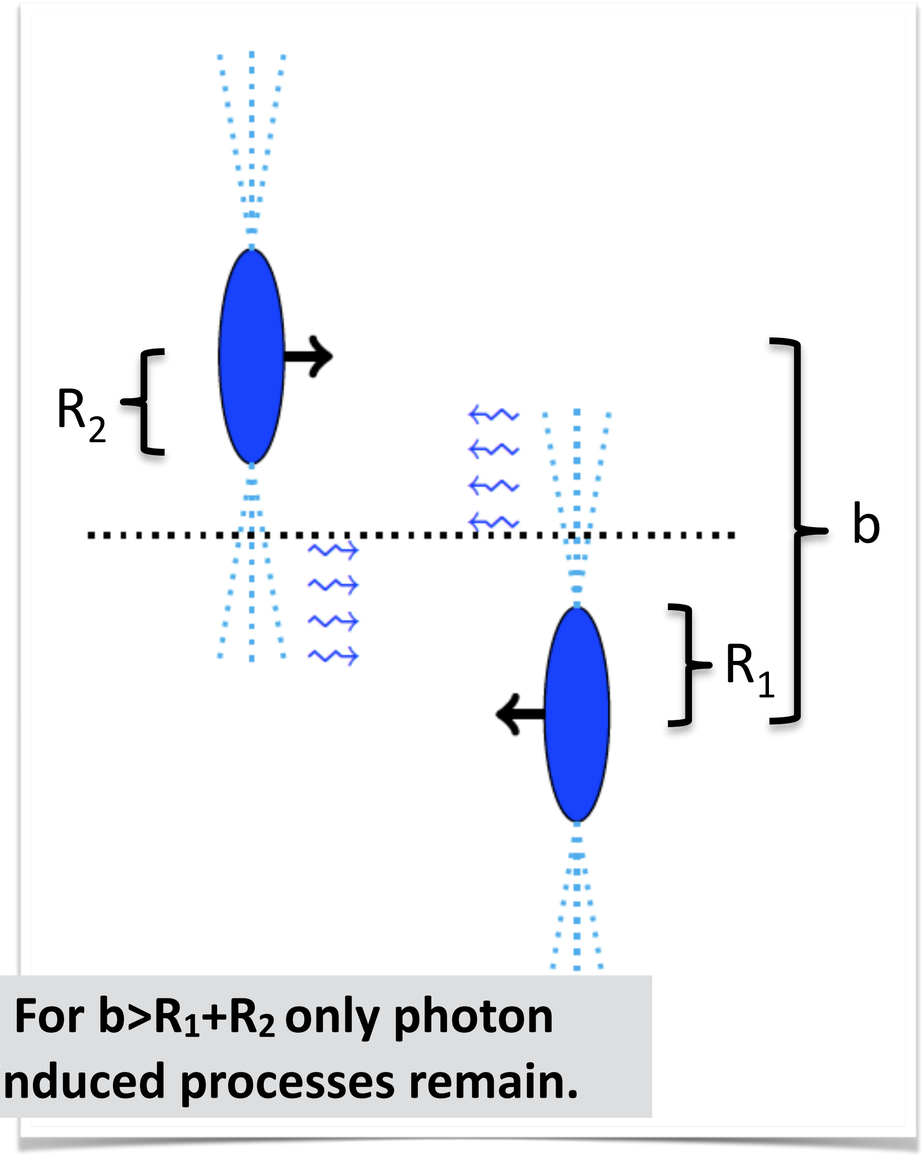

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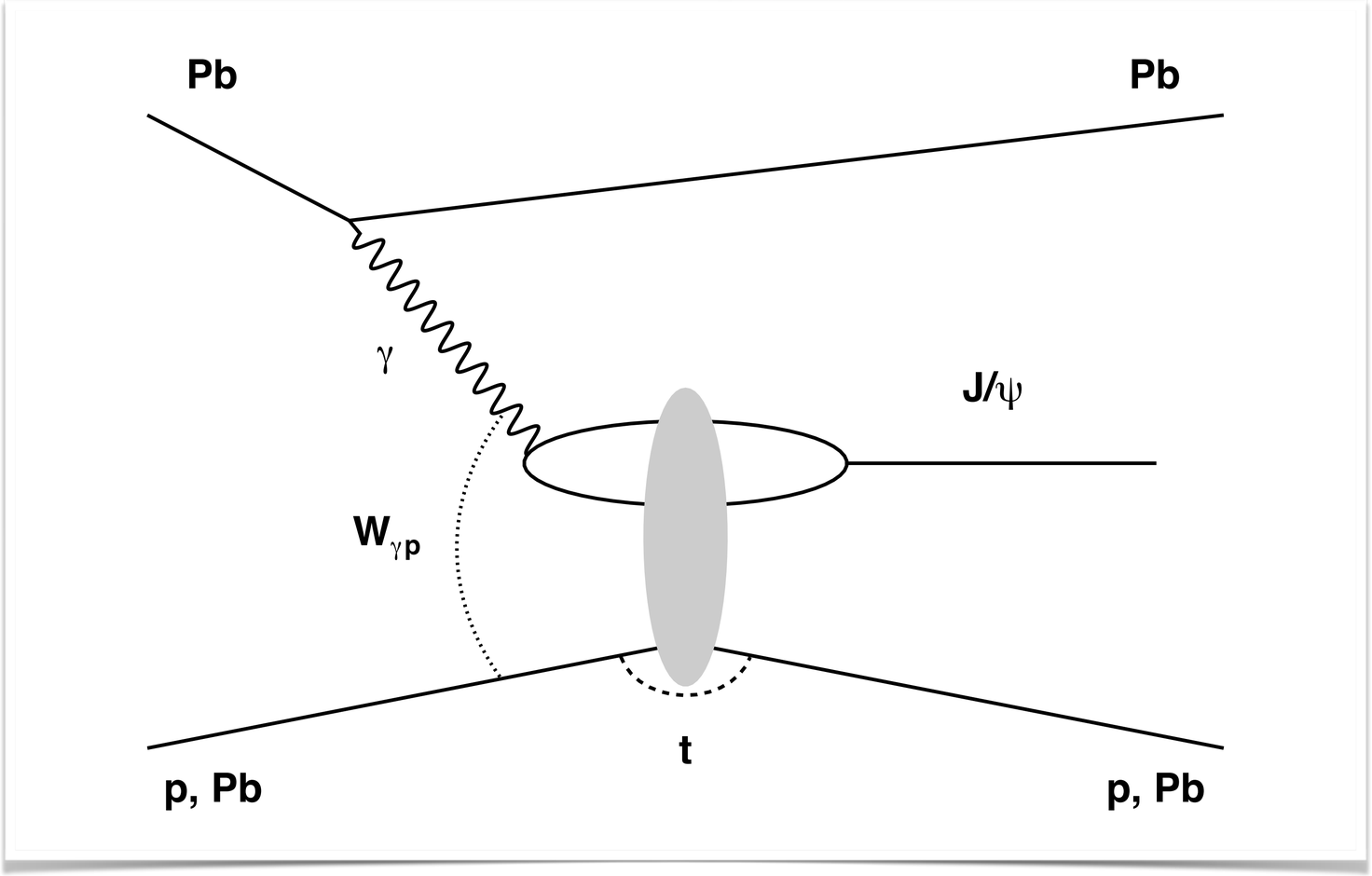
- The LHC is a **photon-hadron and photon-photon collider. what can we do with it?**

The process we are interested in



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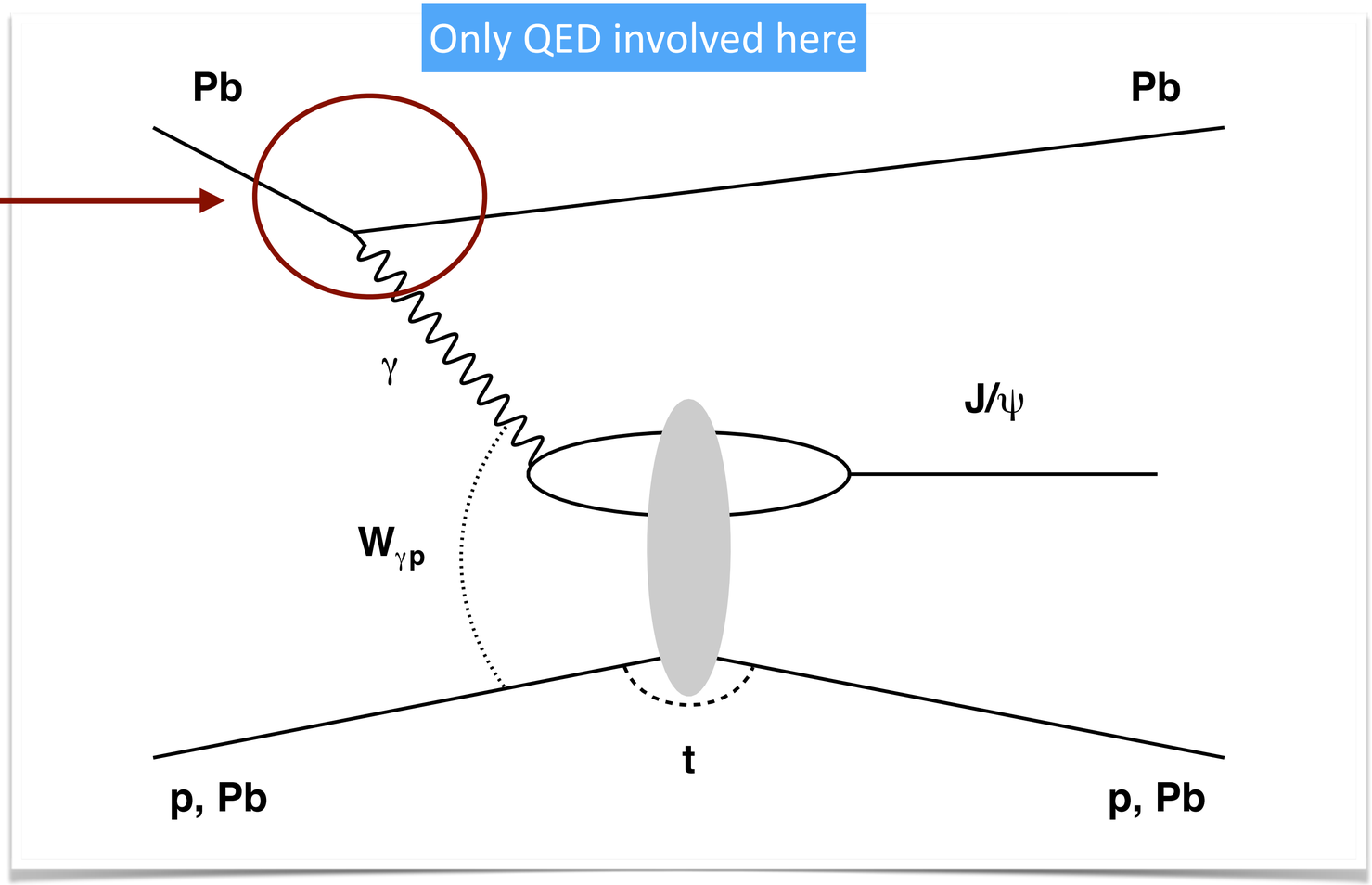

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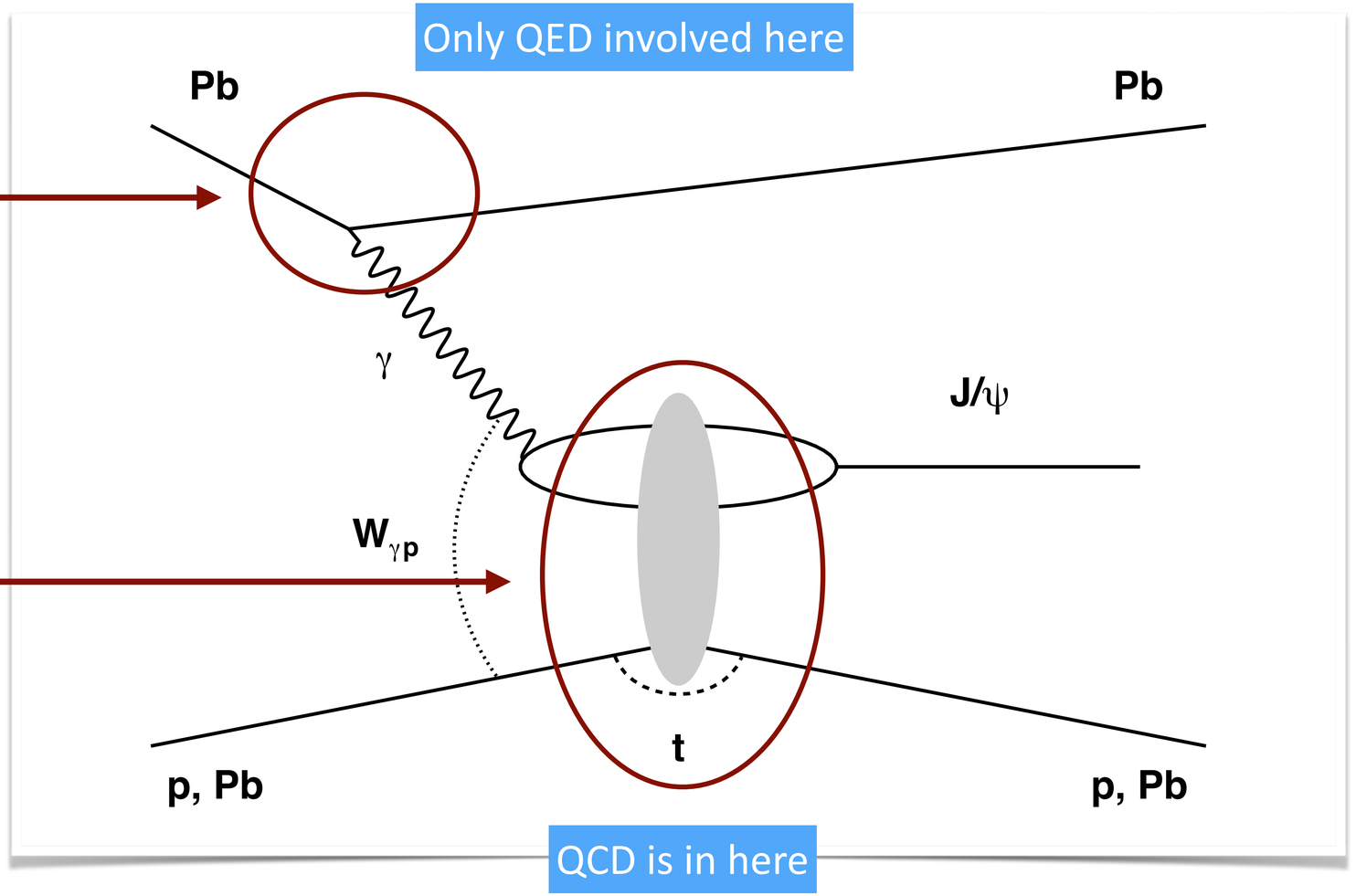
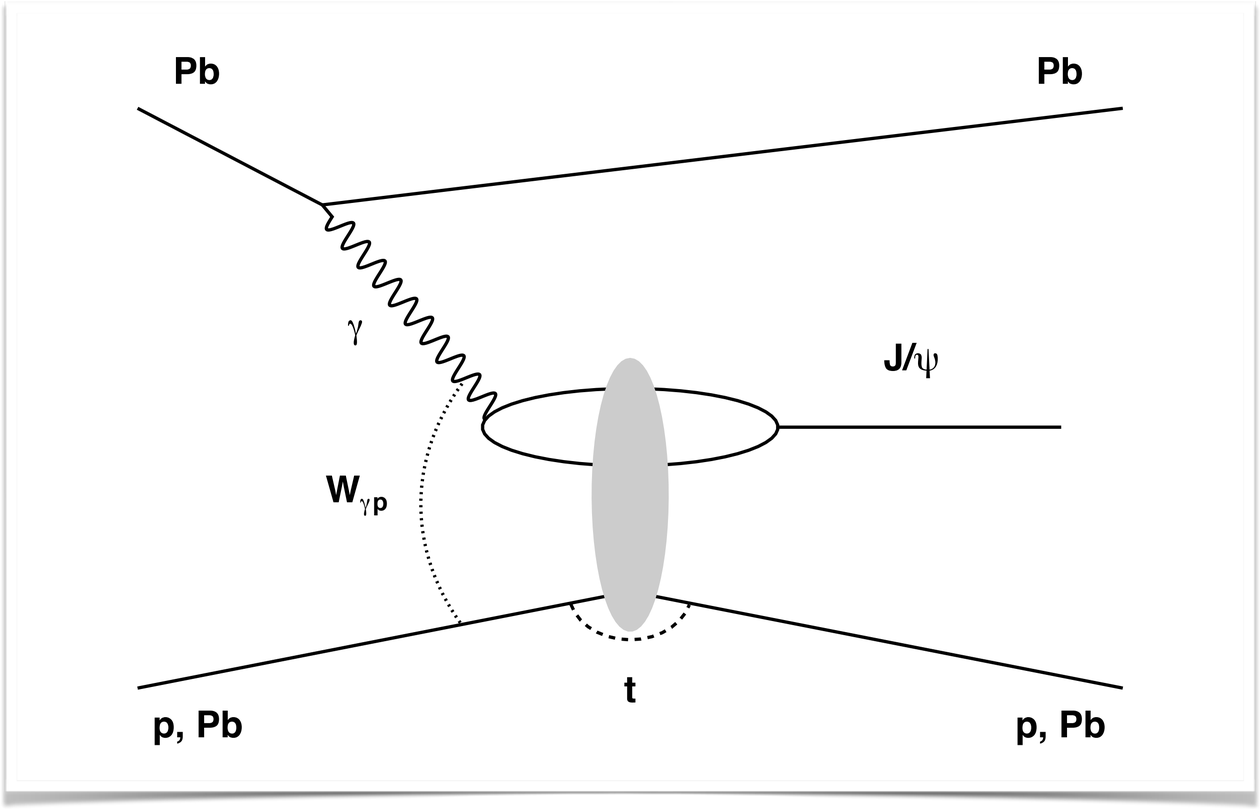
The process can be factorised in two parts:

- Emission of the photon.
- Interaction of the photon with the target.



Vector meson photoproduction at the LHC



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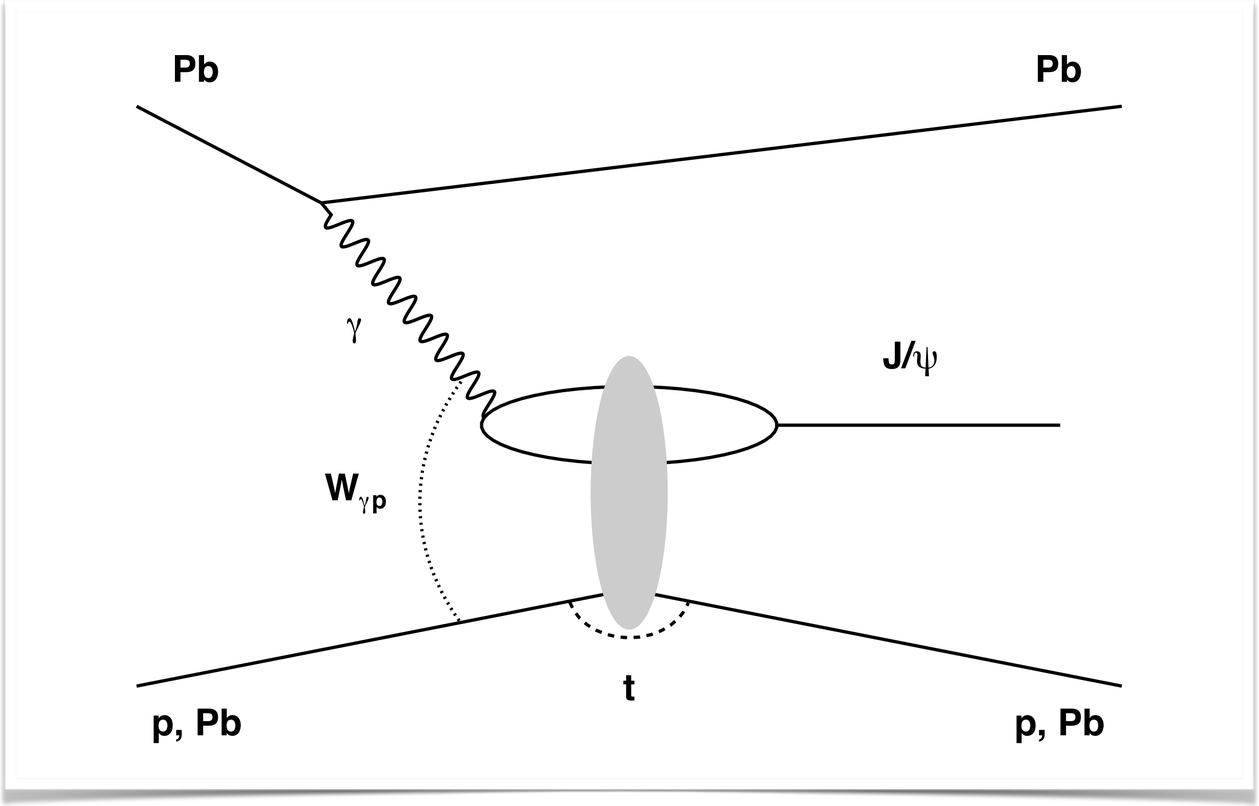

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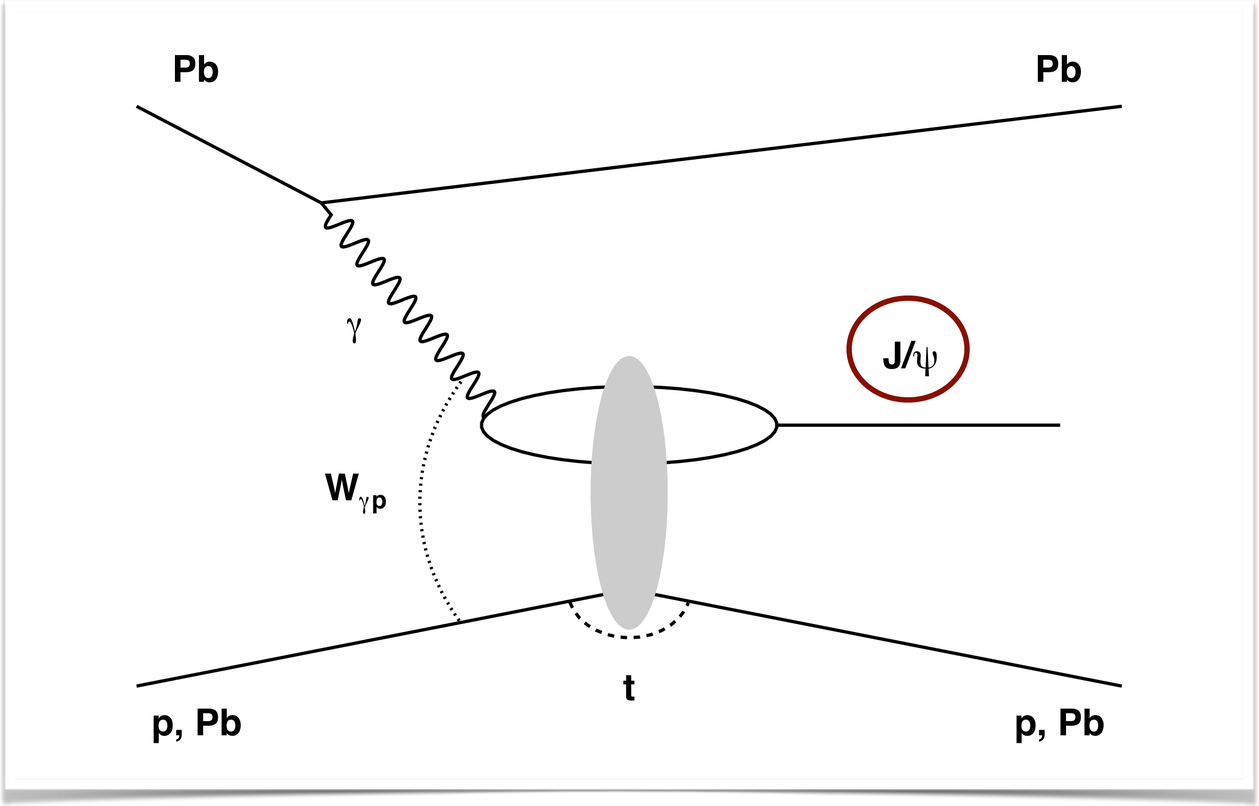

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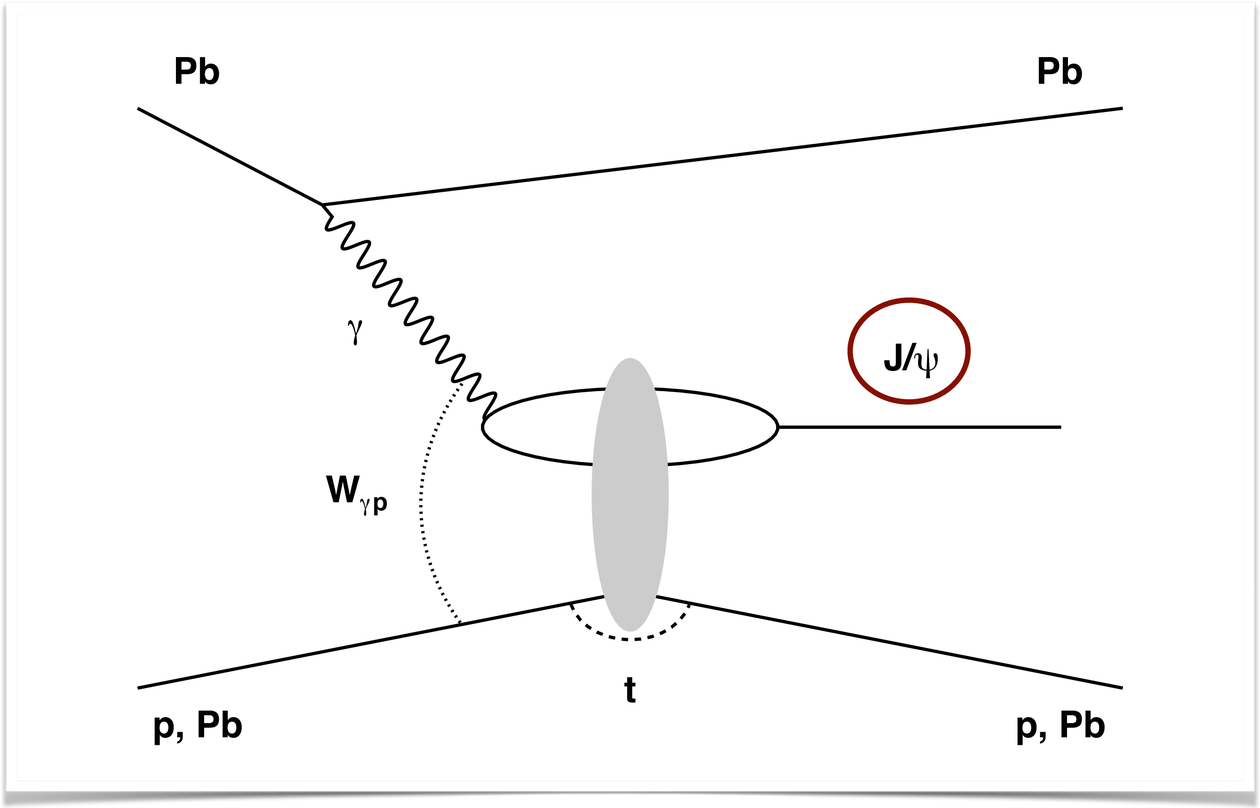

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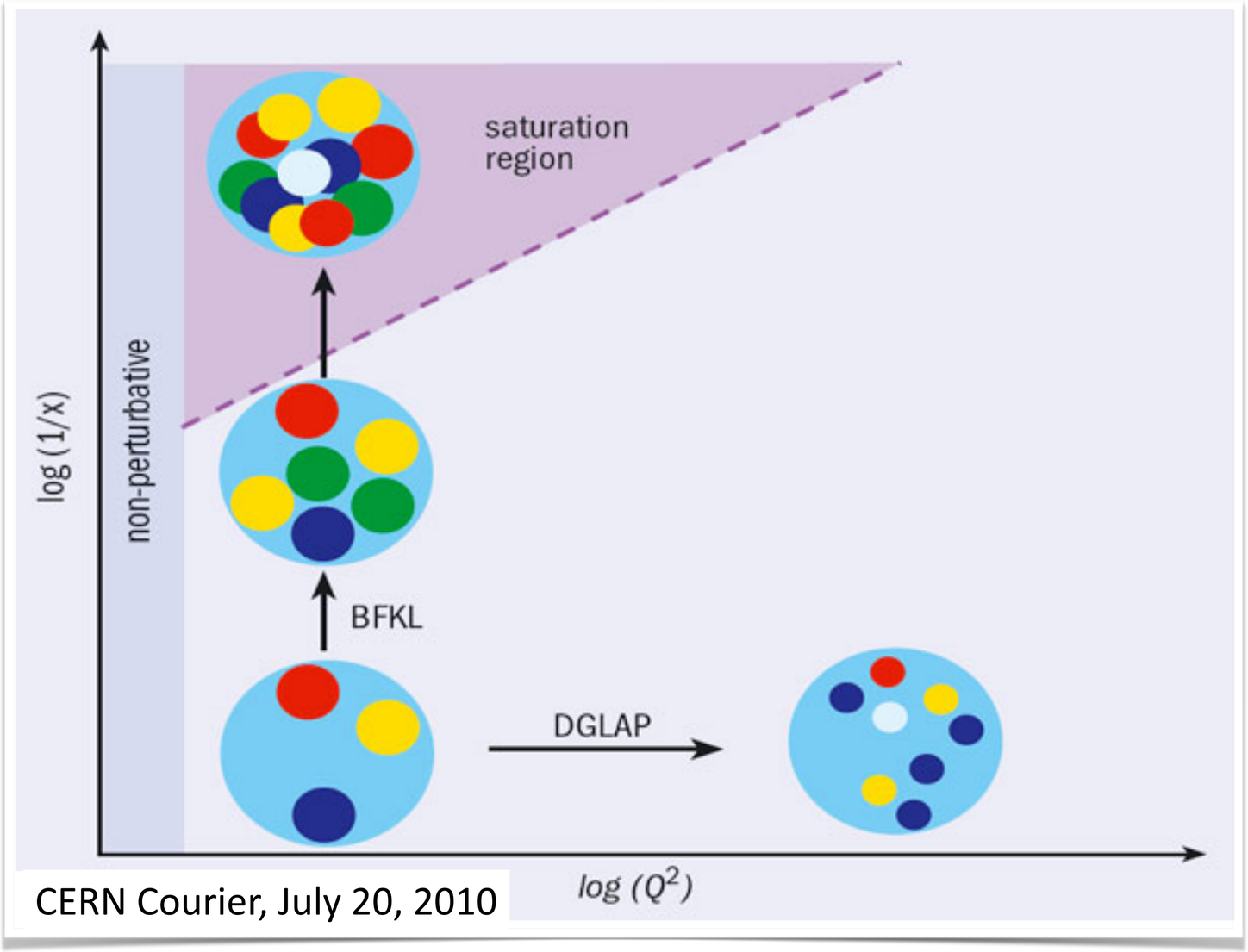
The vector meson determines kinematics of the event.

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

High-energy limit of pQCD



CERN Courier, July 20, 2010

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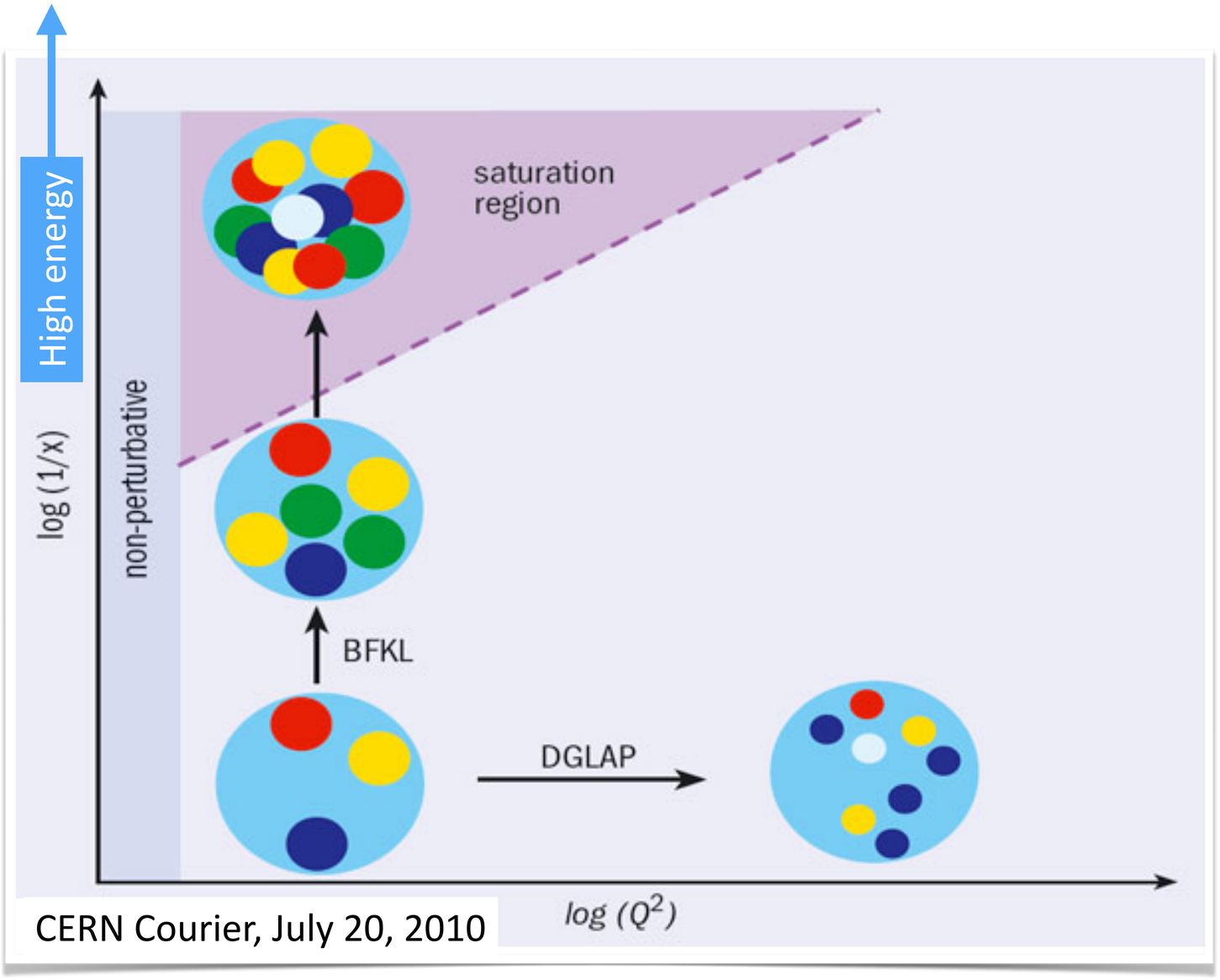

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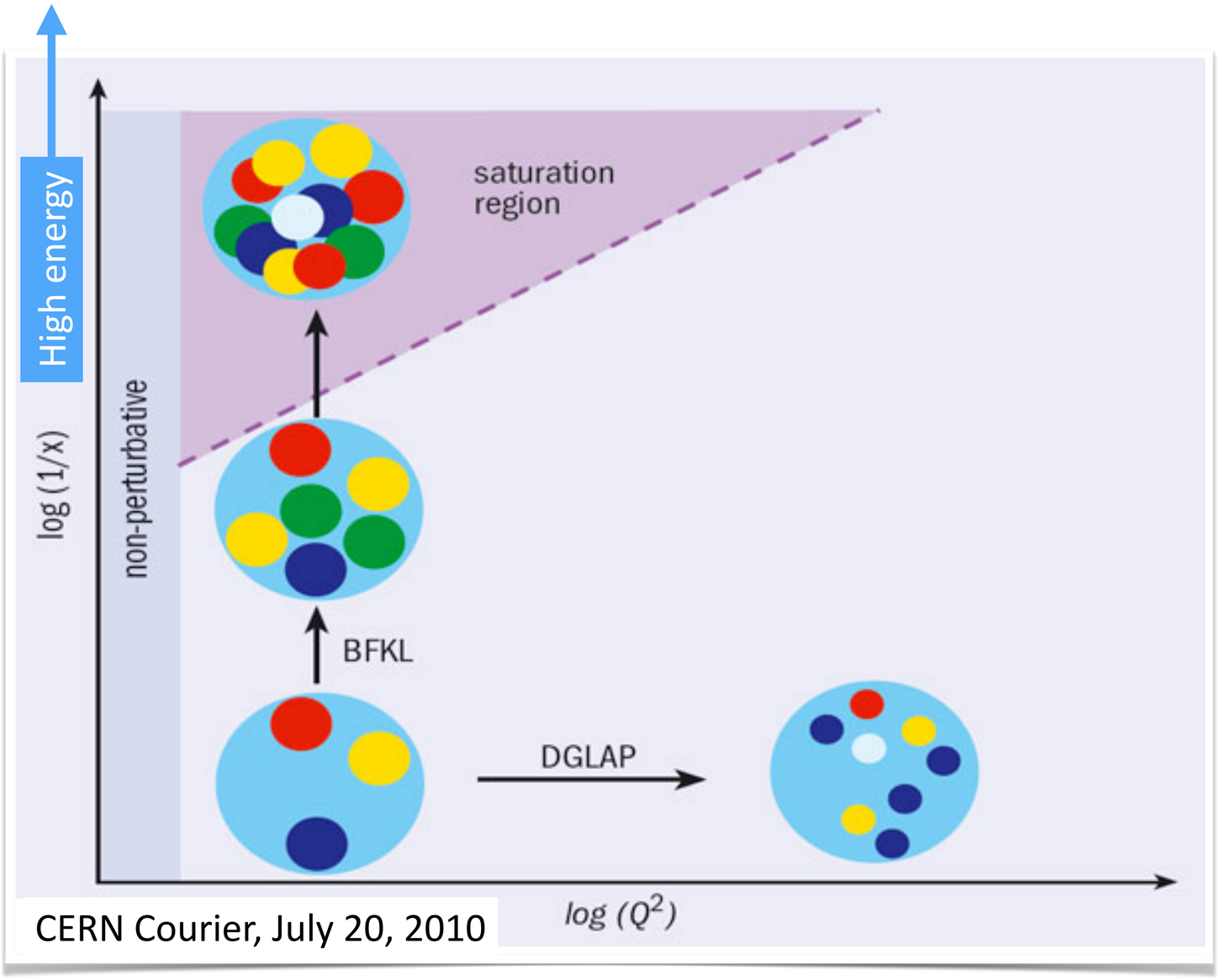

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- there is only **one hard scale**, the mass of the J/ψ, which fixes a point in the $\log(Q^2)$ axis of this diagram;
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$$W^2 = 2E_pM \exp(-y).$$

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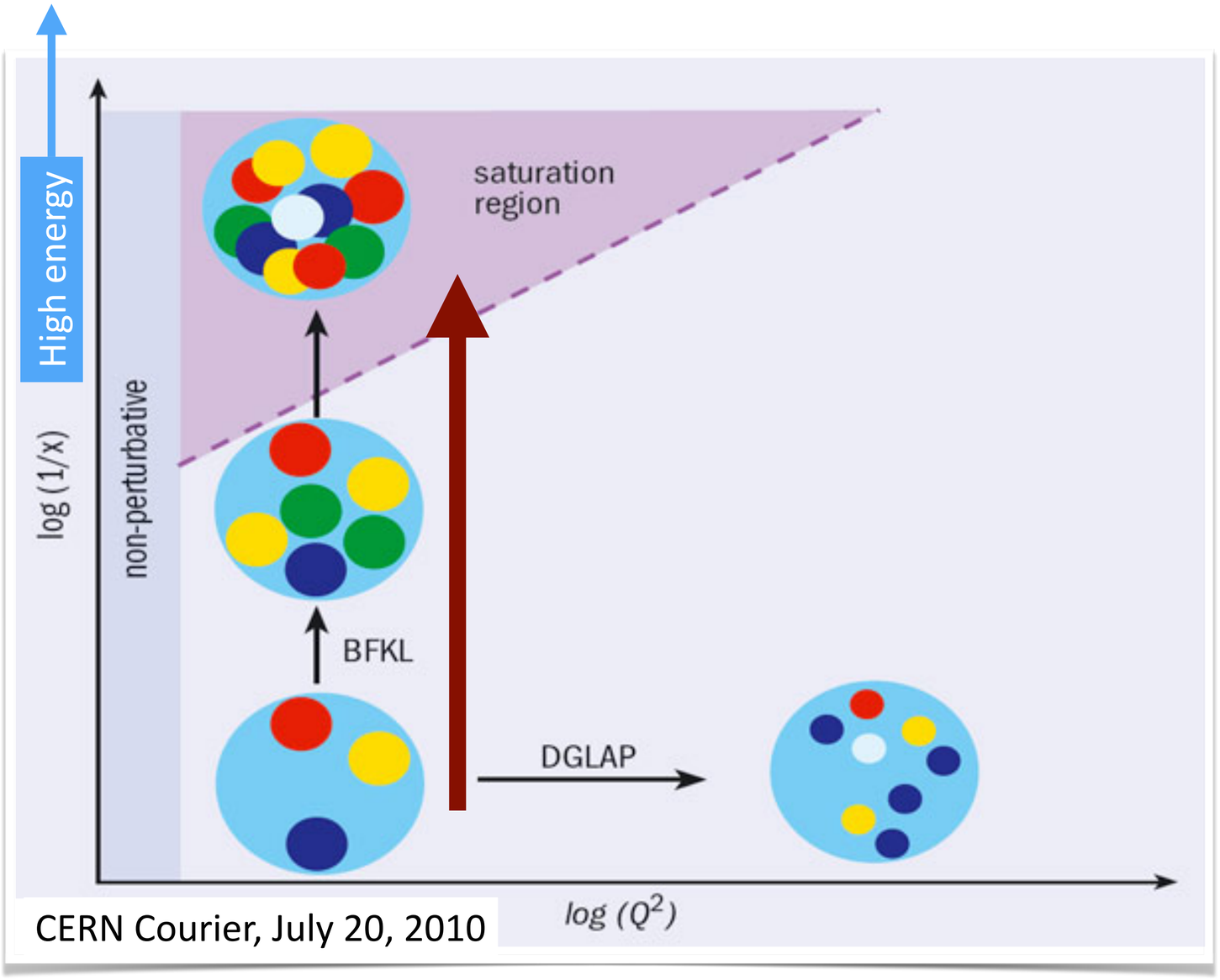

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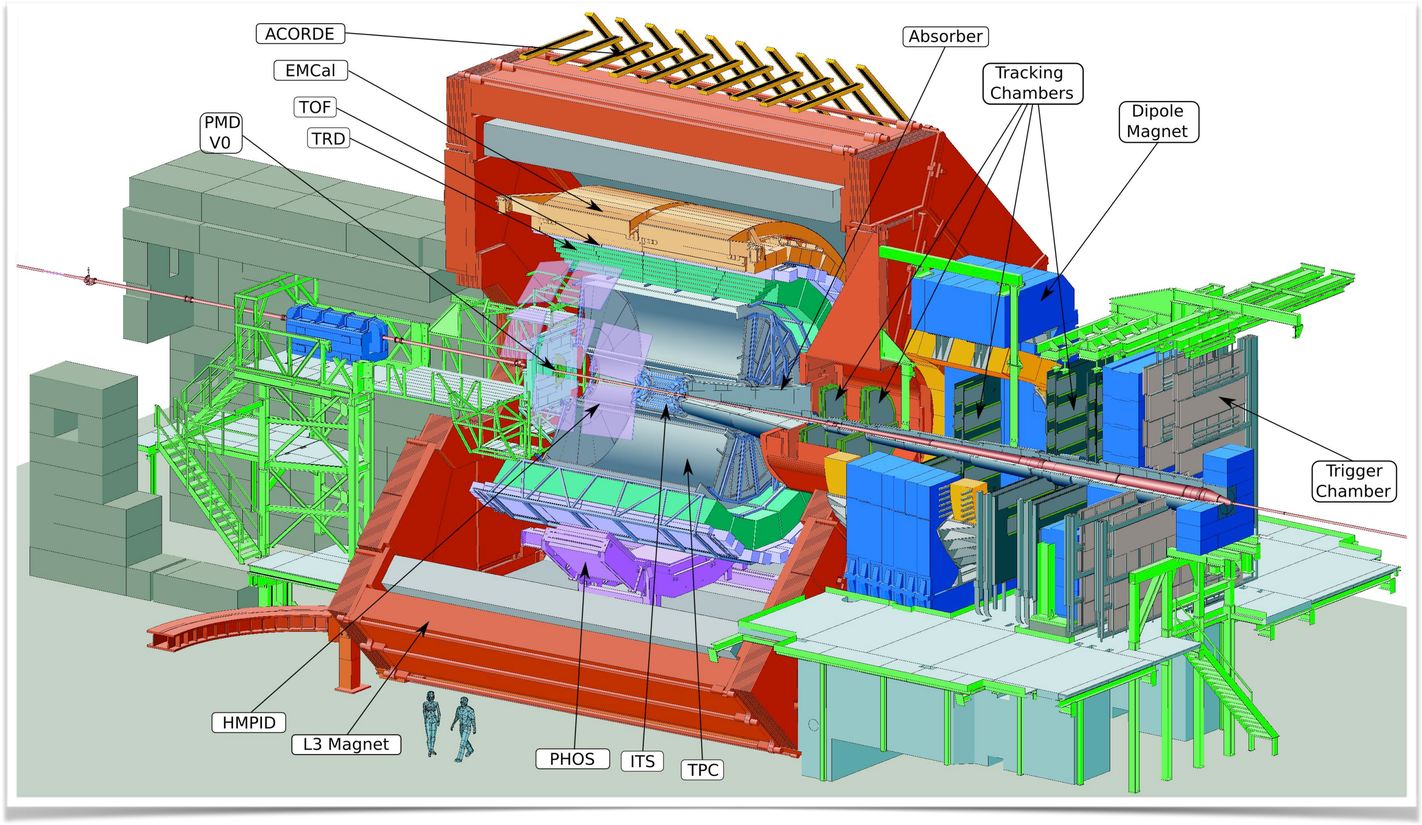
The rapidity dependence of J/ψ photoproduction take us upwards in this diagram and may allow us to search for the region labelled **saturation**.

ALICE

Exclusive J/ψ photoproduction in ALICE: measurement



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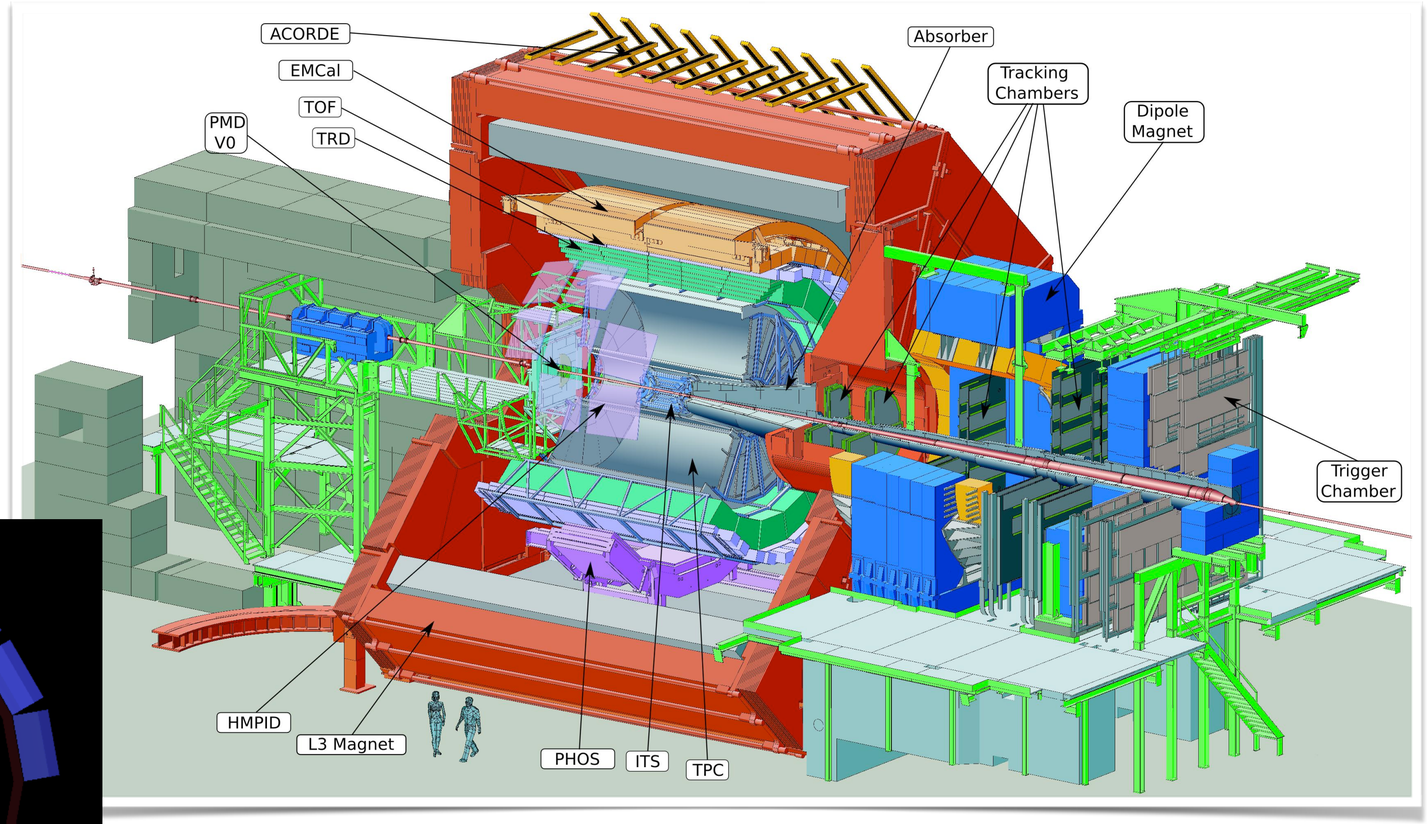

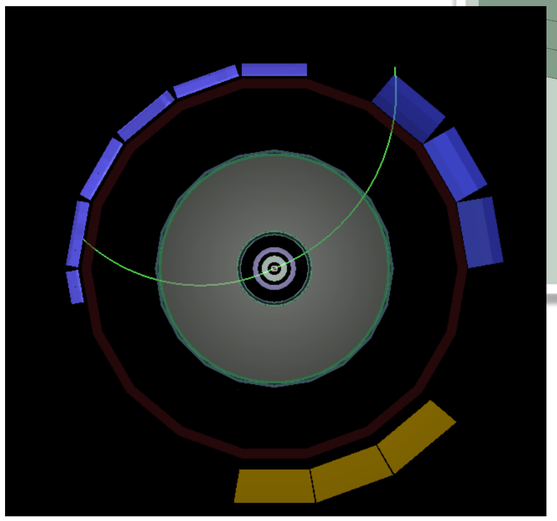

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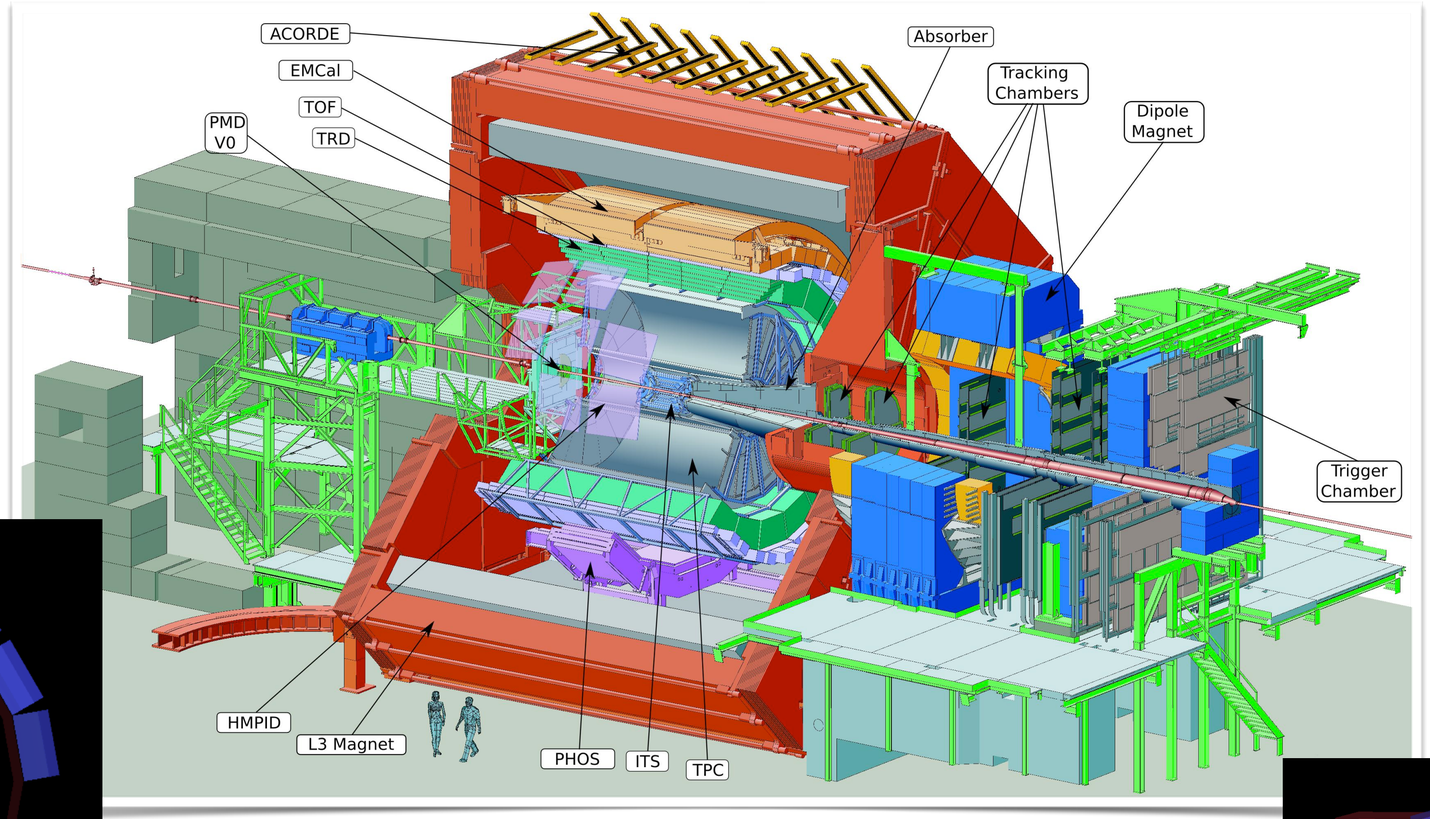

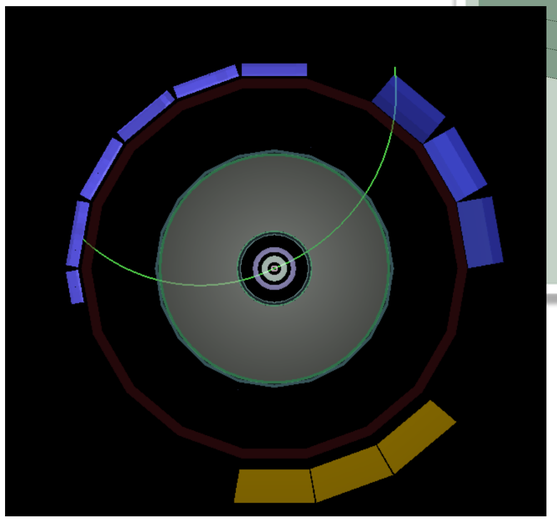

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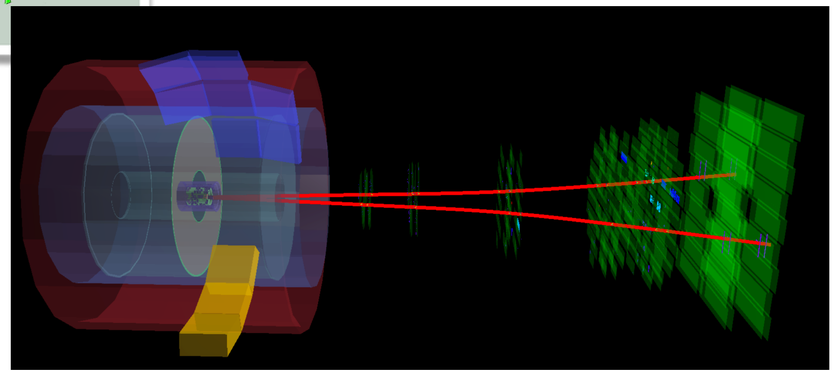

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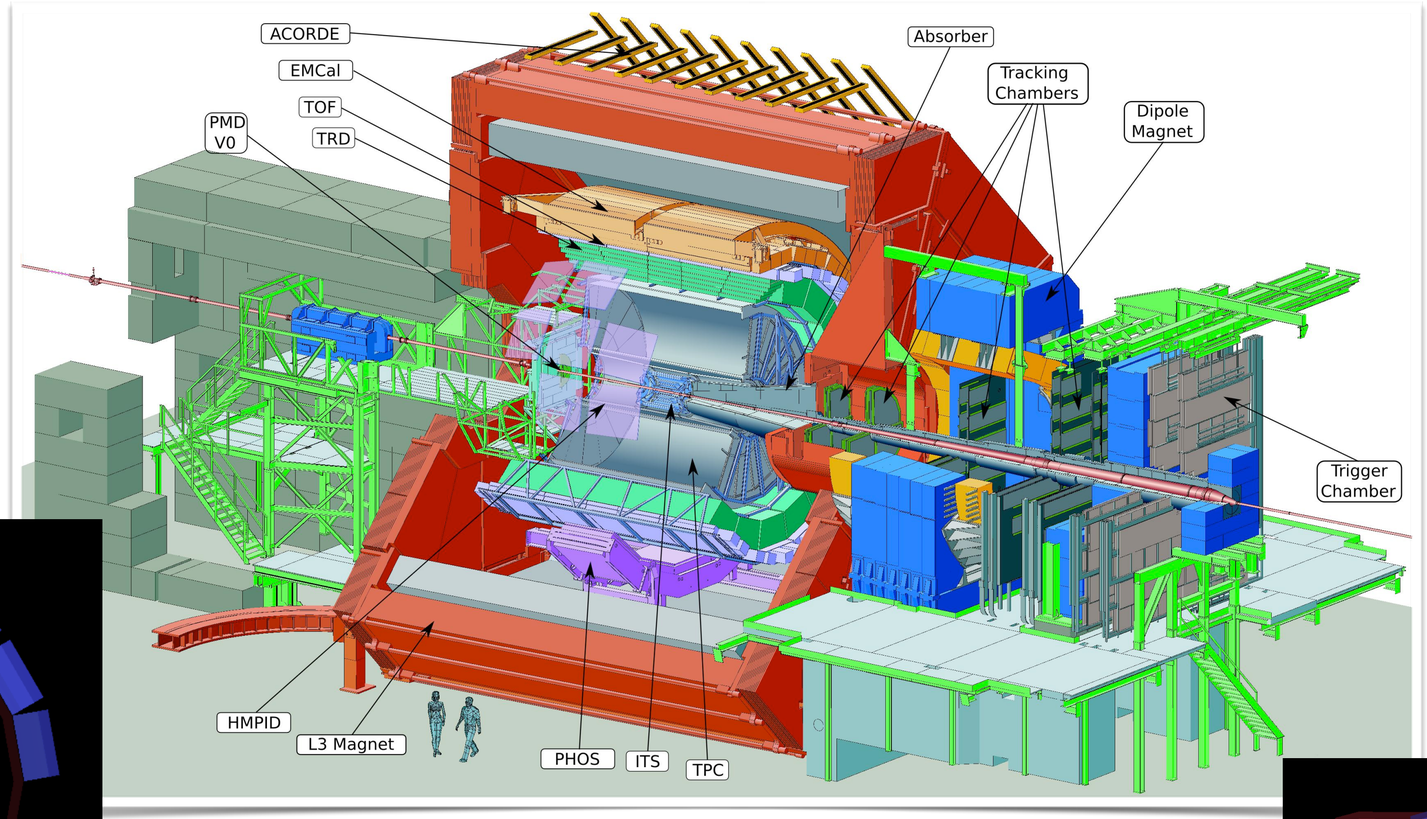
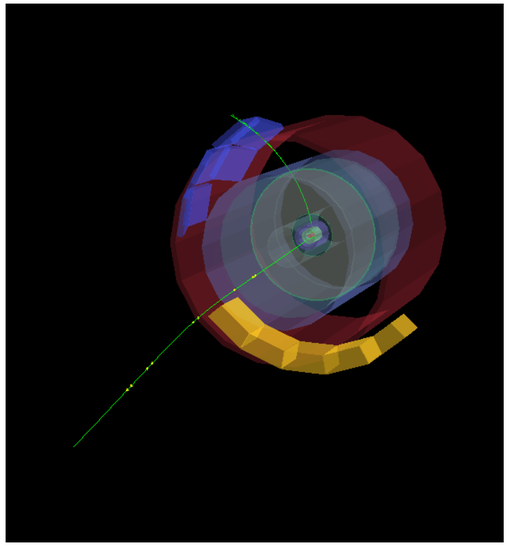
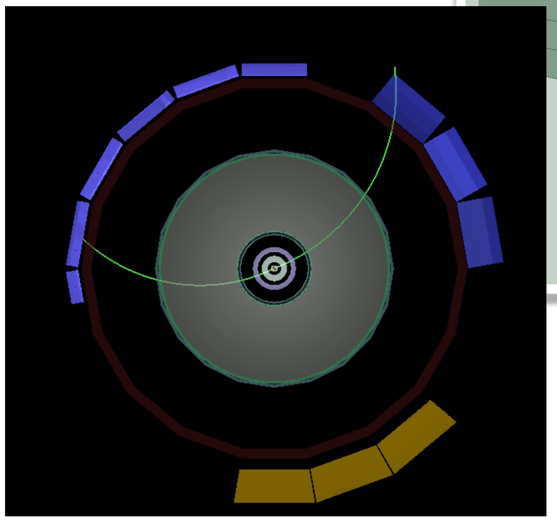




One muon measured in the muon spectrometer the other in the central barrel.



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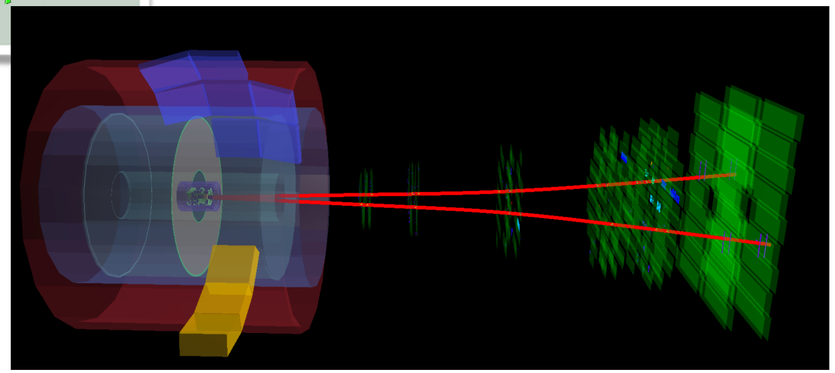

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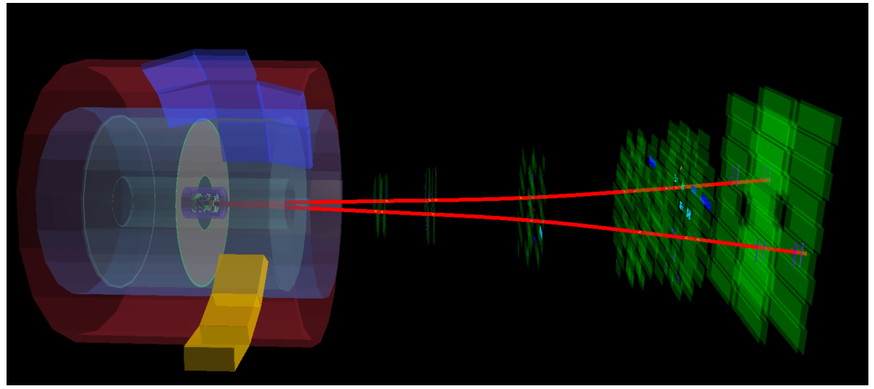

Energy coverage at forward rapidity:

- Run 1:
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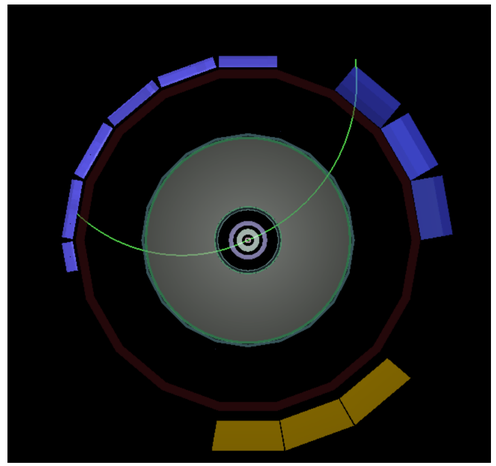

Energy coverage at mid rapidity

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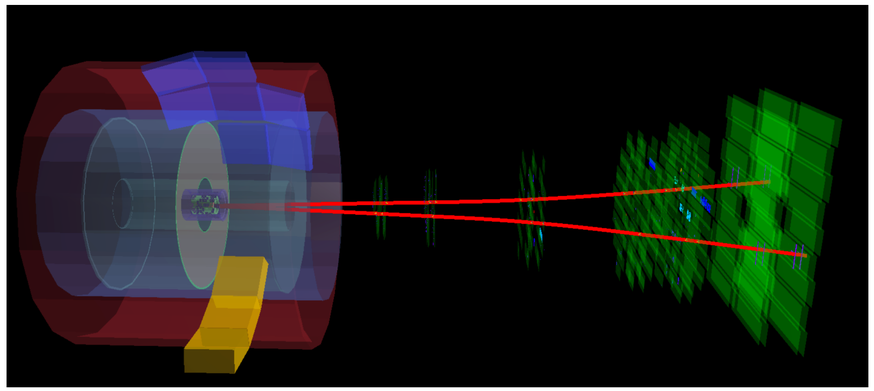

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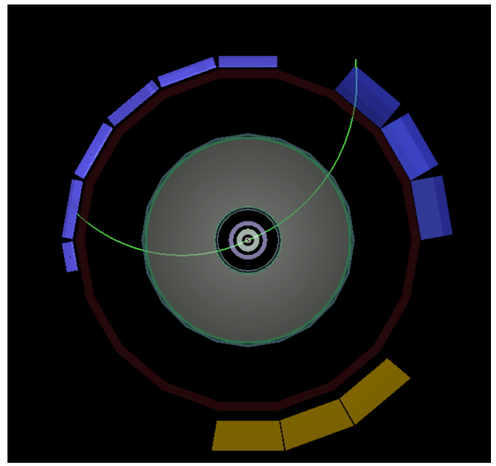

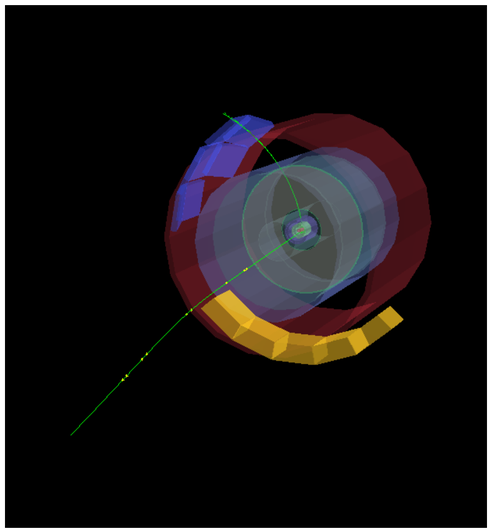

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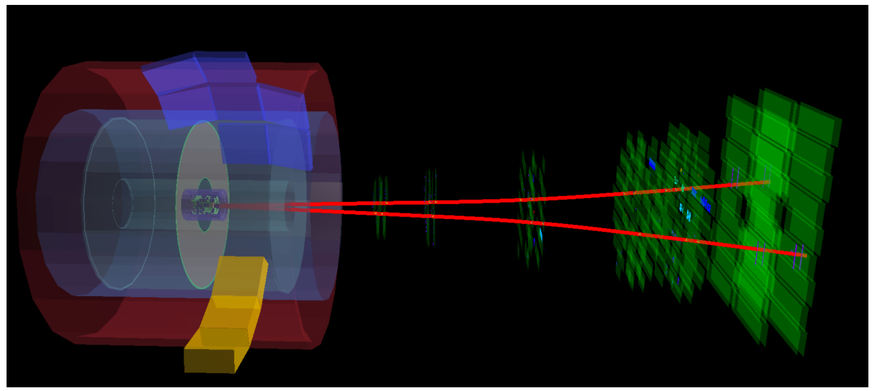

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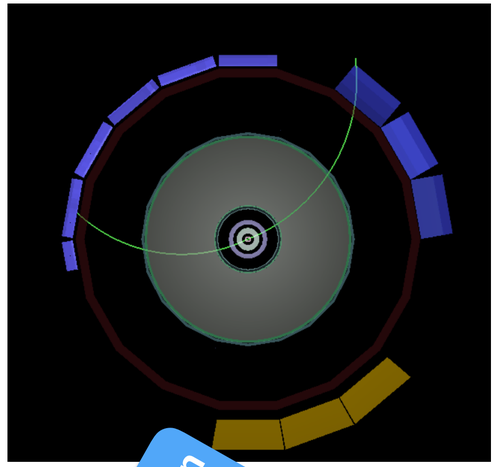

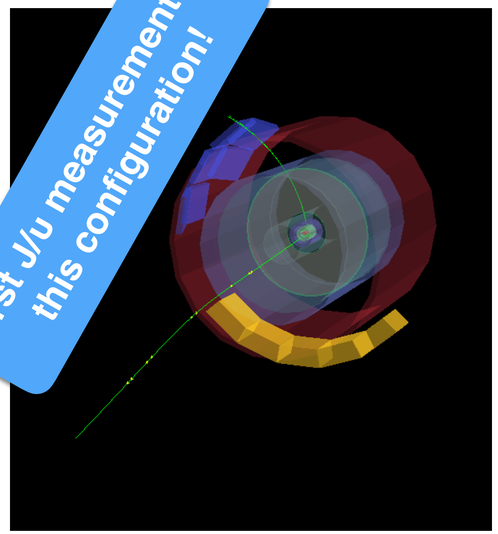

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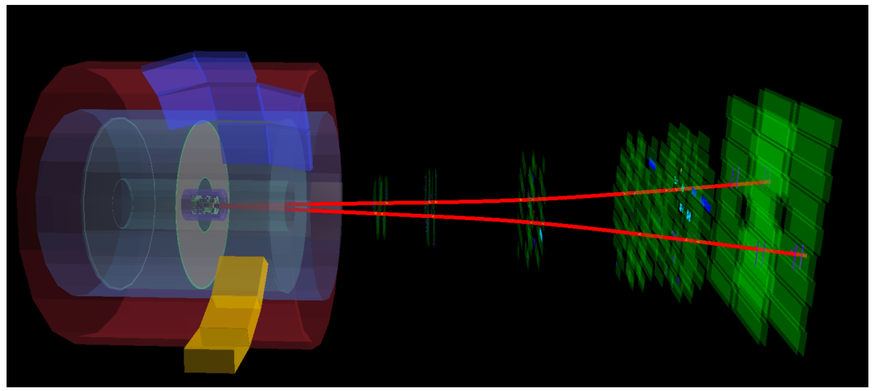

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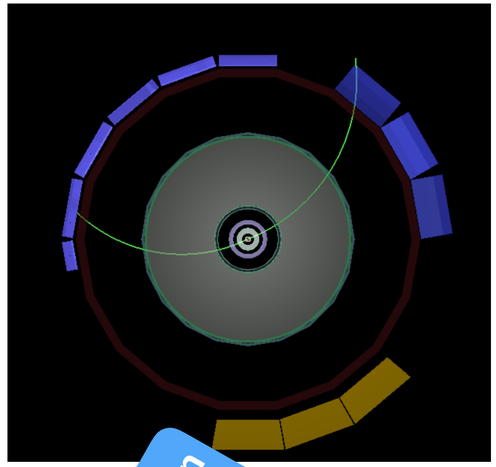

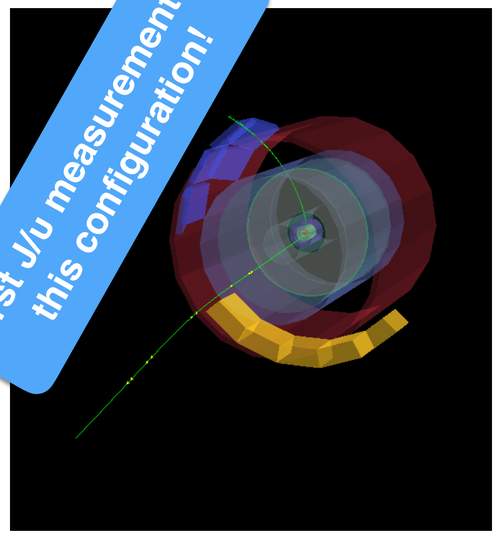

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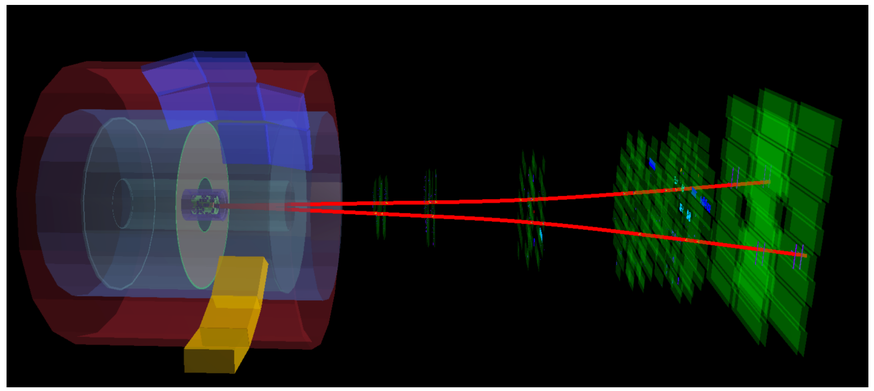

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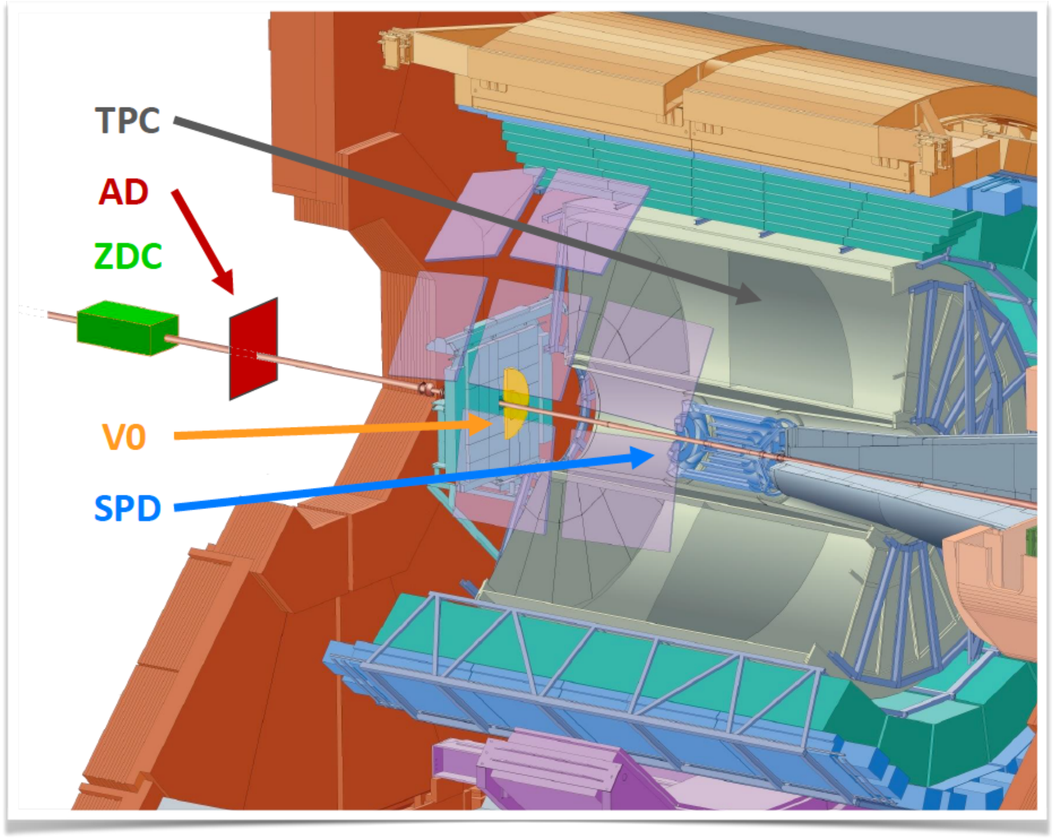
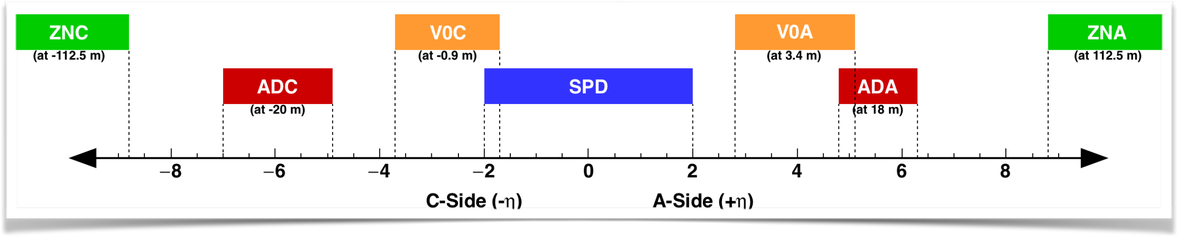
Energy range in ALICE overlaps and extends HERA range!

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.

Exclusivity condition in ALICE





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  - We try to set thresholds so that detectors are sensitive to one mip.

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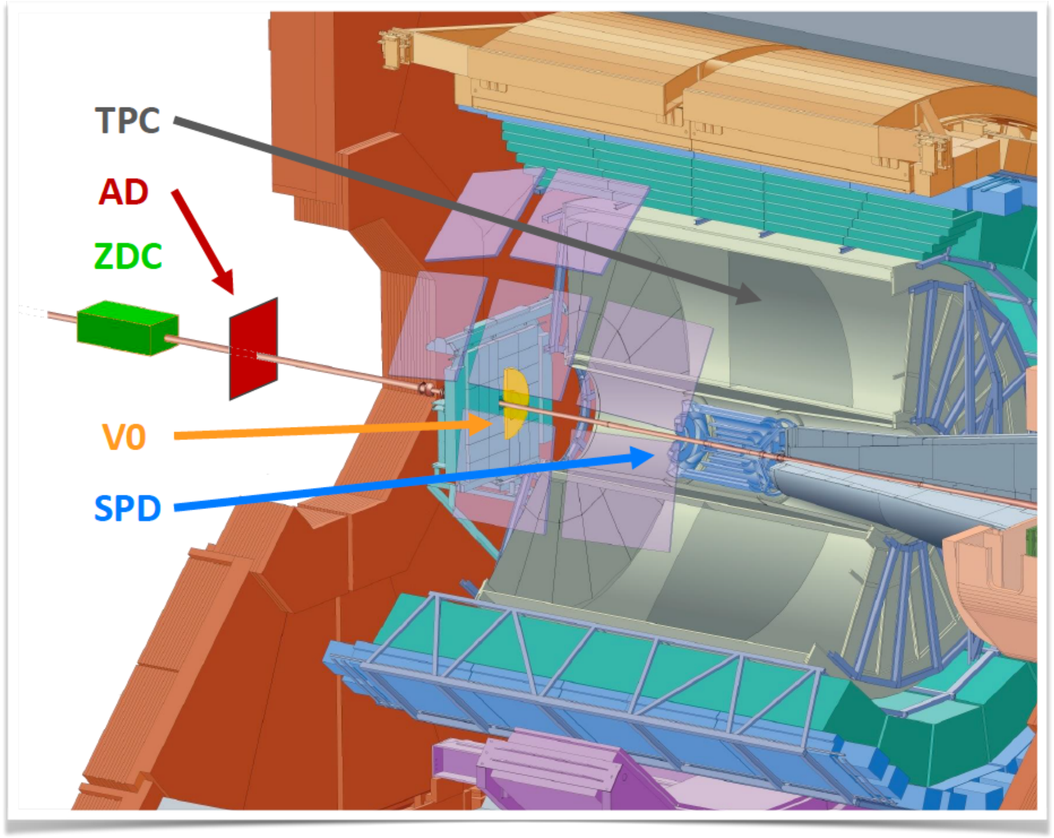

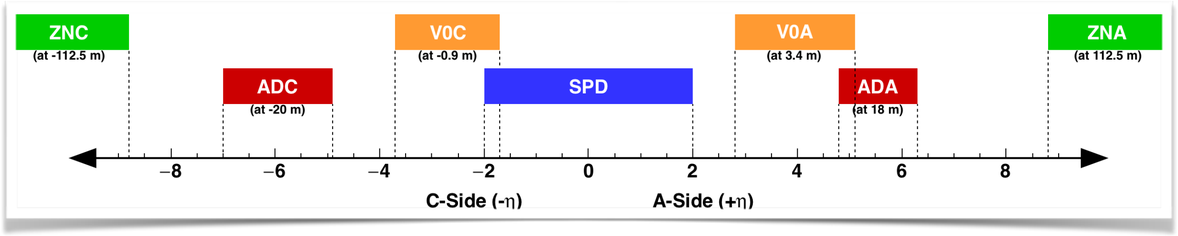

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- In ALICE:
  - We have a large rapidity coverage to impose vetoes.
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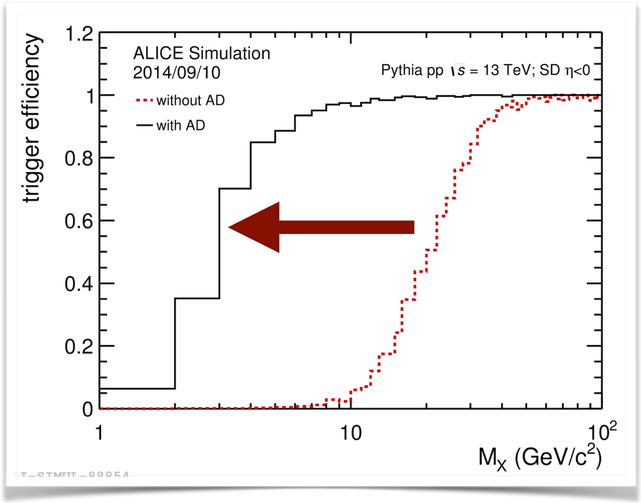
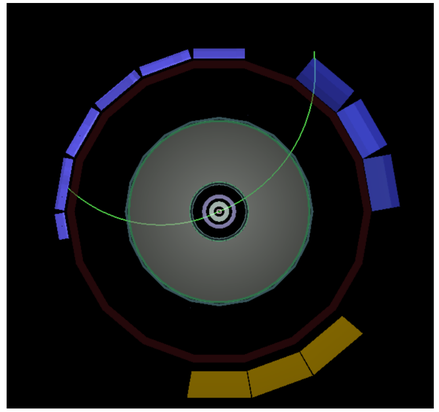
- In Run2 we added new detectors, the ALICE Diffractive (AD) detectors, which give us enhanced sensitivity to low mass diffractive systems.



Energy dependence of exclusive J/ψ photoproduction

Exclusive J/ψ photoproduction in ALICE: triggers



Signal

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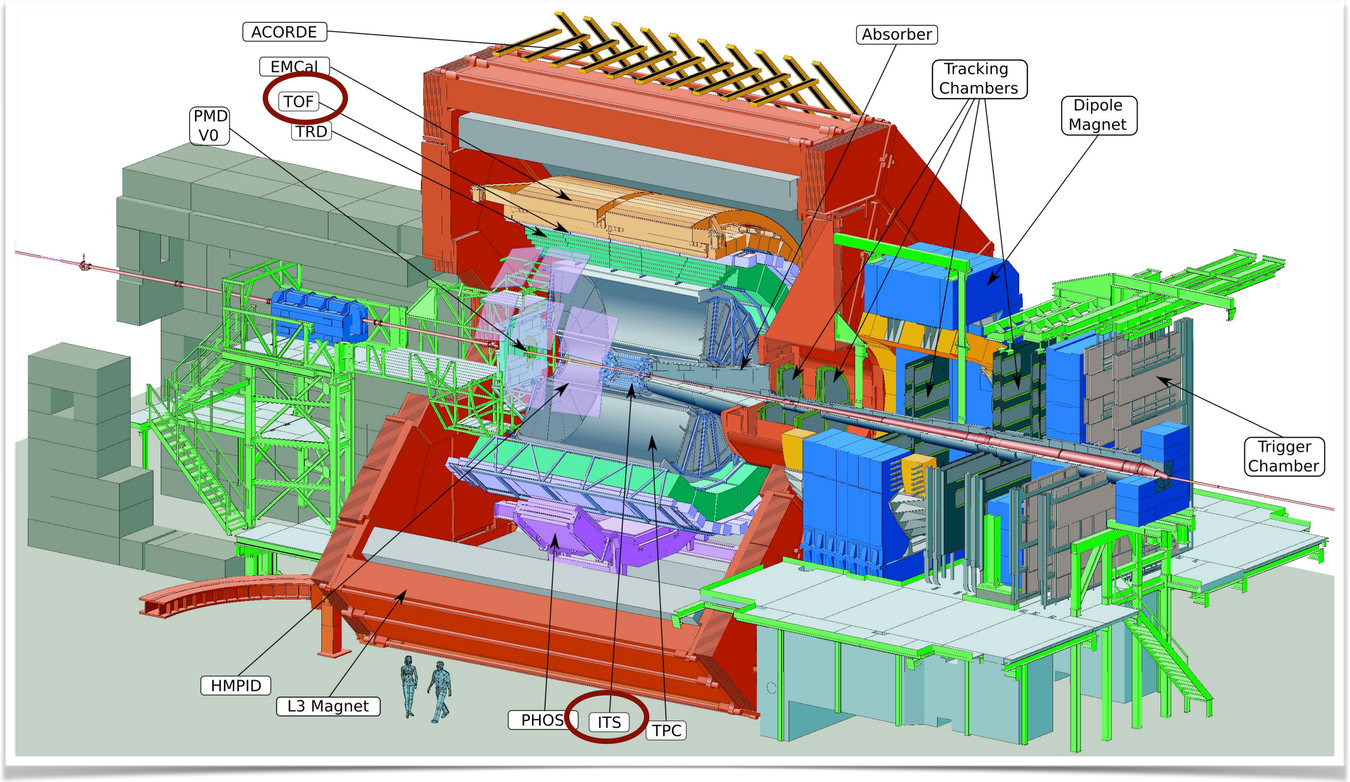
- At least two in a back-to-back configuration.
- 2 **SPD** tracklets in a back-to-back configuration.



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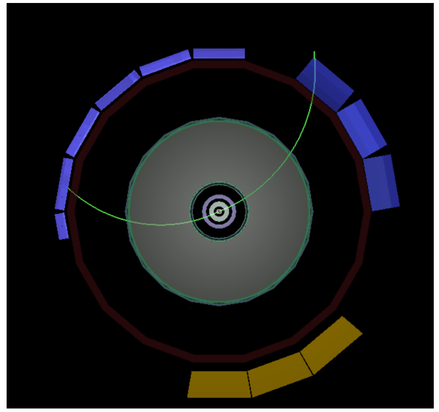

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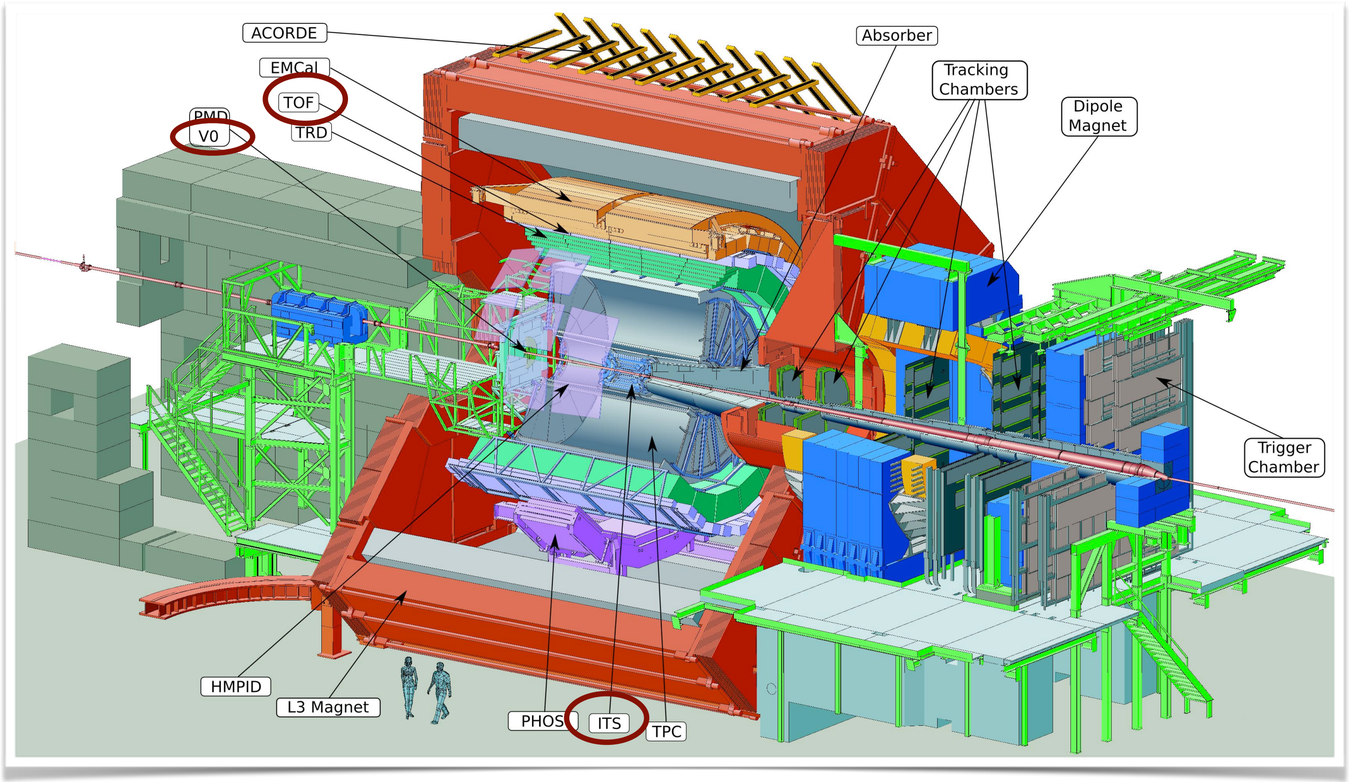
Vetos

- No activity in **V0**.
- Less than 6 hits in the outer **SPD**.



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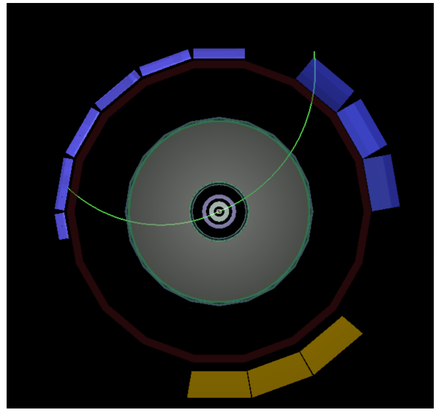

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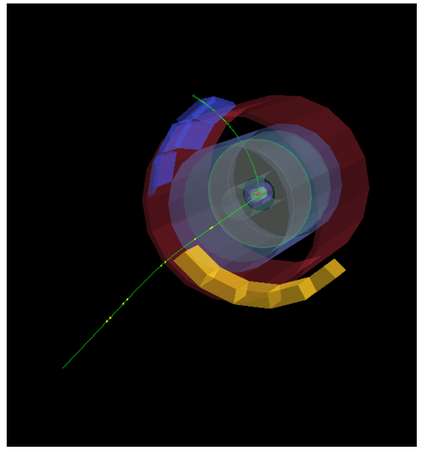

Vetos

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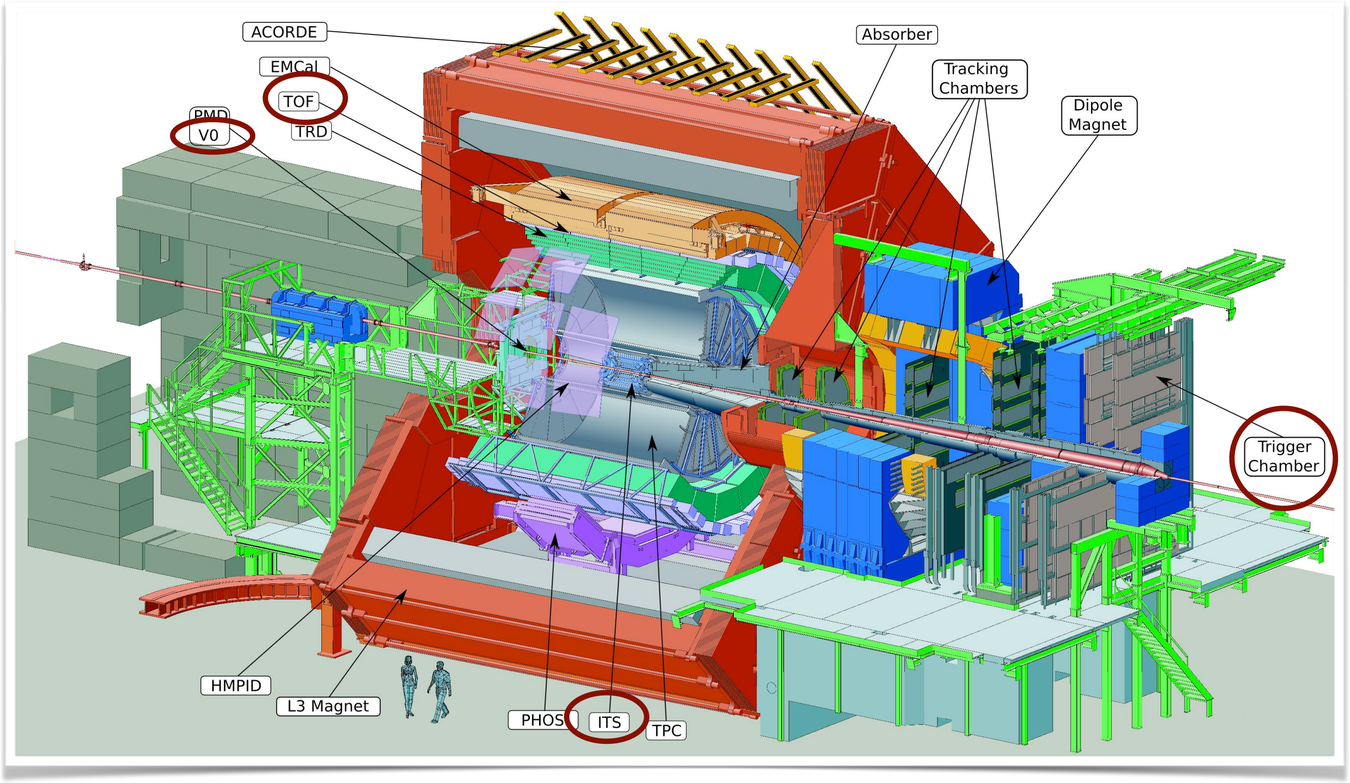
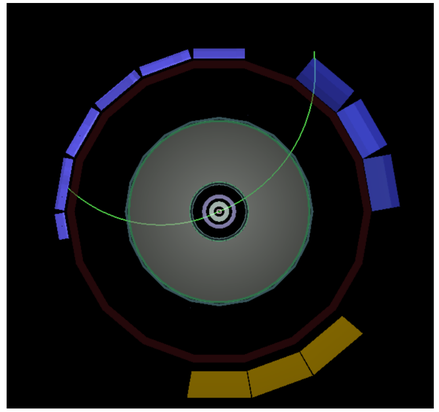


Signal p-Pb

- One low pt muon (above 0.5 GeV) in the **muon spectrometer.**

Exclusive J/ψ photoproduction in ALICE: triggers



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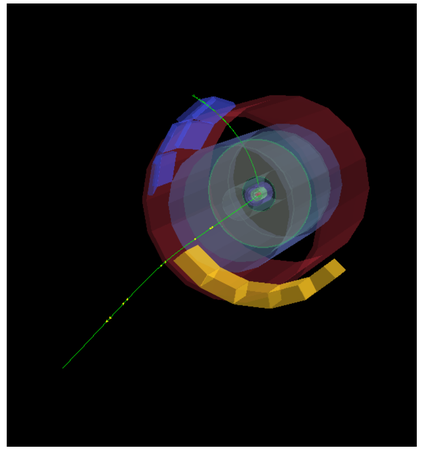

Vetos

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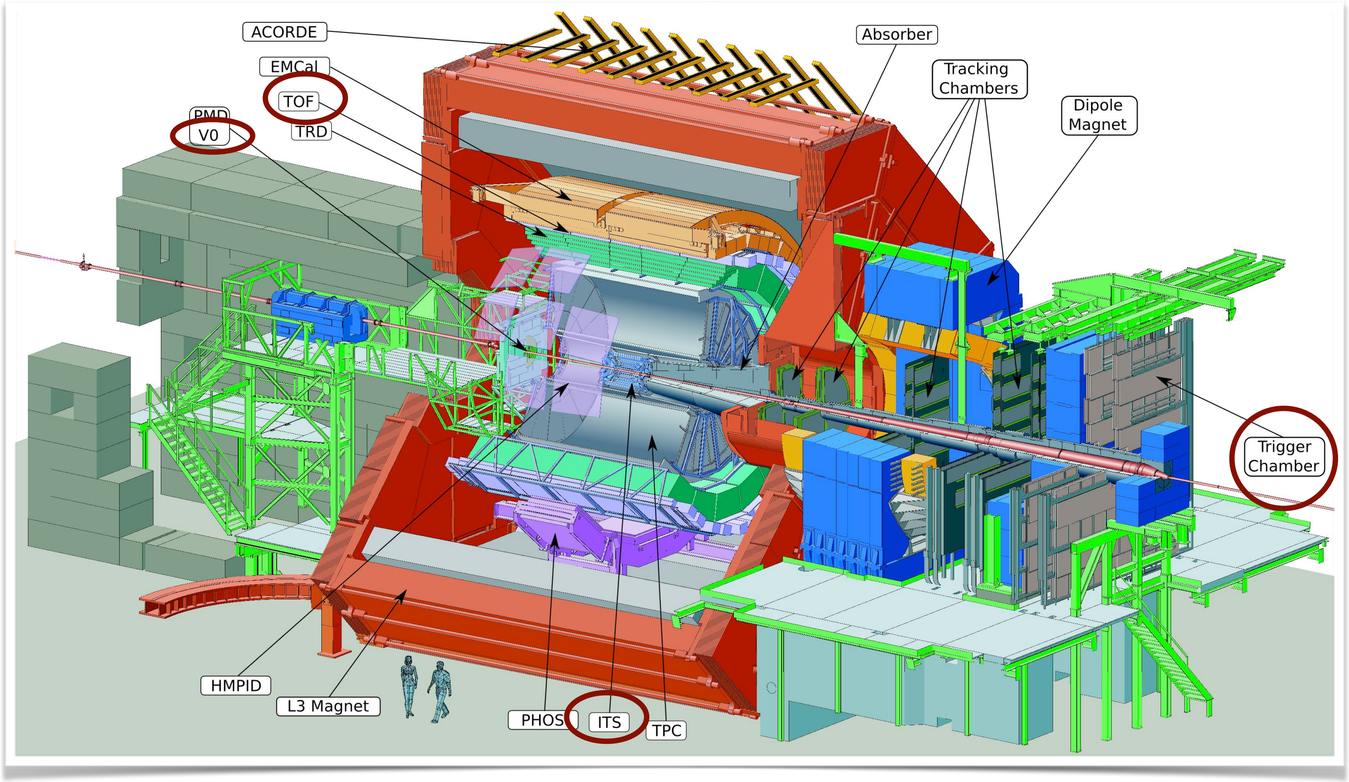


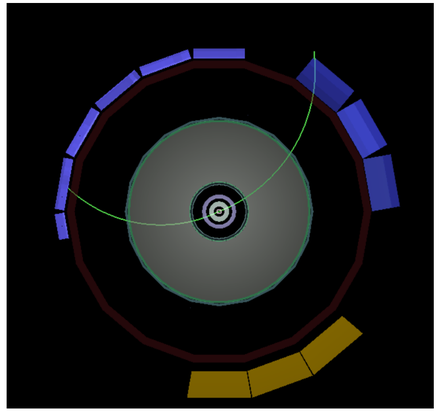
Signal p-Pb

- One low pt muon (above 0.5 GeV) in the **muon spectrometer.**

Vetos p-Pb

- No activity in **V0A**.
- Less than 5 hits in **V0C**.
- Less than 6 hits in the outer **SPD**.

Exclusive J/ψ photoproduction in ALICE: triggers



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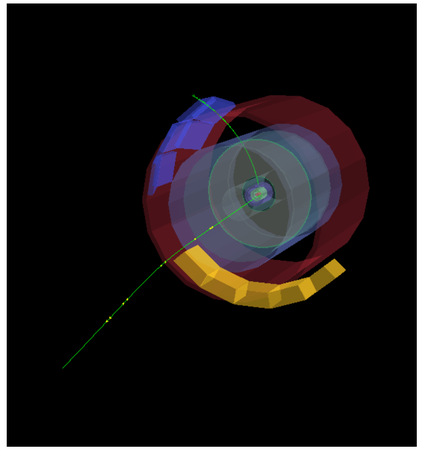
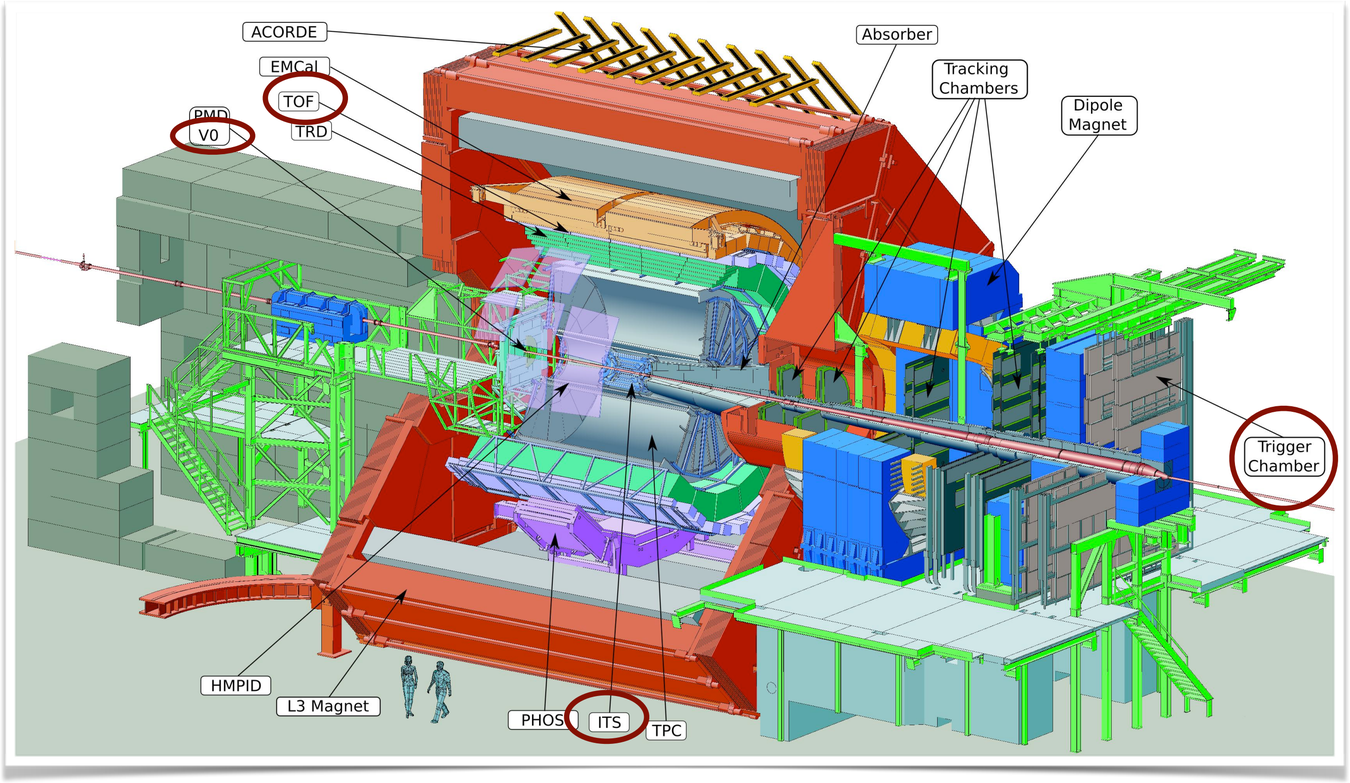


Vetos

- No activity in **V0**.
- Less than 6 hits in the outer **SPD**.



Signal p-Pb

- One low pt muon (above 0.5 GeV) in the **muon spectrometer.**

Additional signal in Pb-p

- **V0C** signal

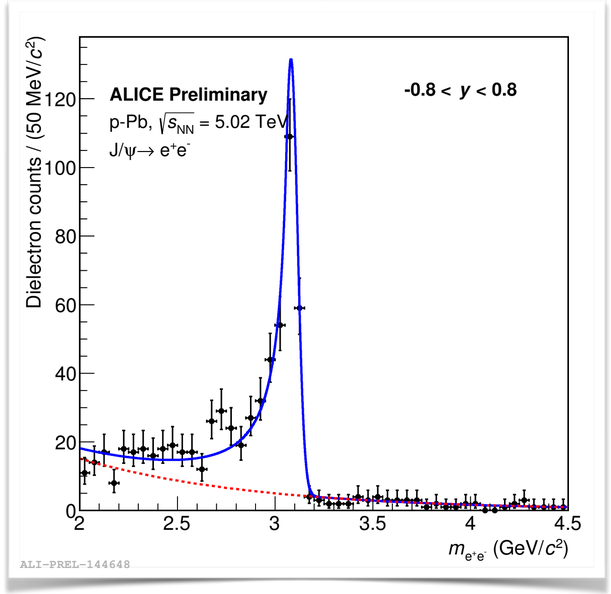
Vetos p-Pb

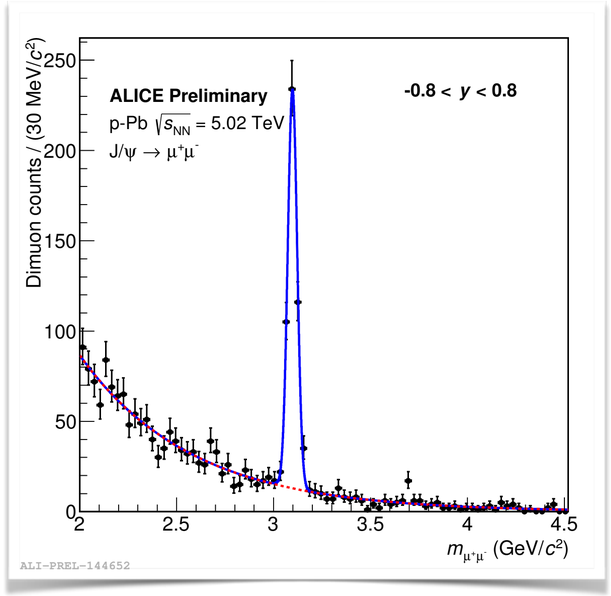
- No activity in **V0A**.
- Less than 5 hits in **V0C**.
- Less than 6 hits in the outer **SPD**.

Additional veto for Pb-p

- No activity in **V0A** beam-gas window.

Mass distributions

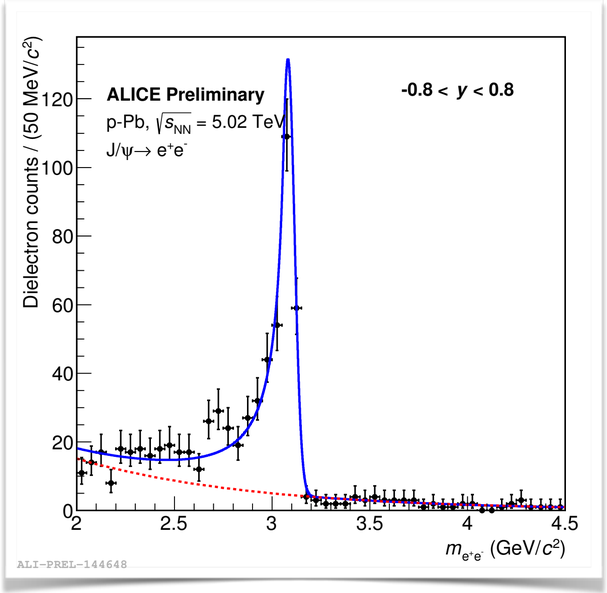


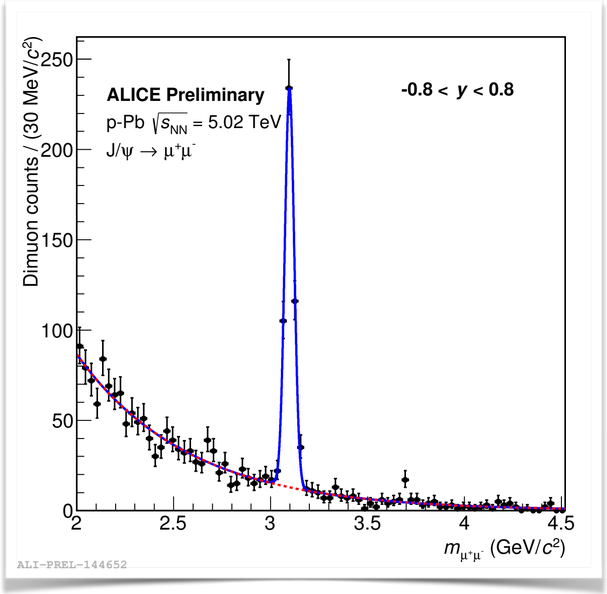


Mid-rapidity:

- Consistent measurement in two channels.
- Consistent measurement in p-Pb and Pb-p.

Mass distributions





Mid-rapidity:

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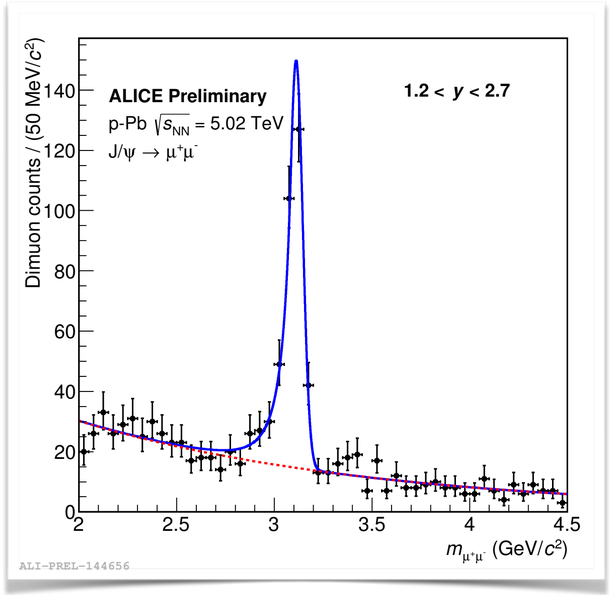
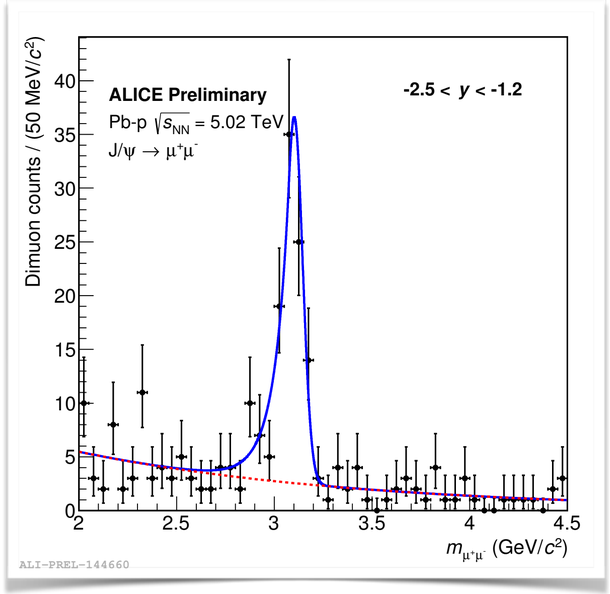
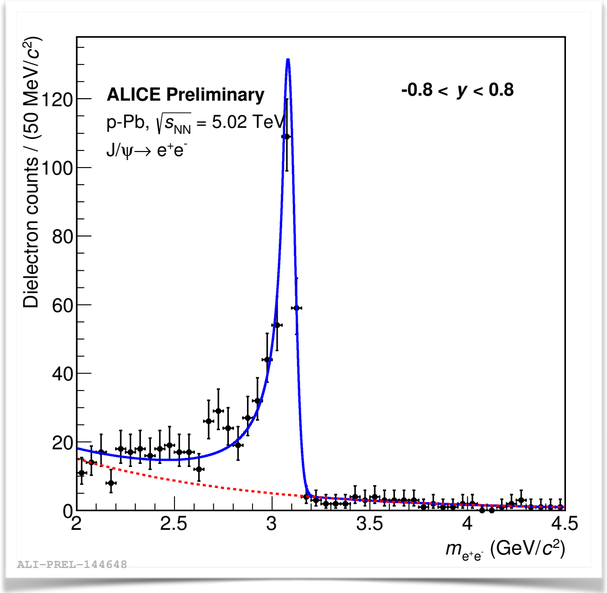
Semi-forward and semi-backward rapidity:

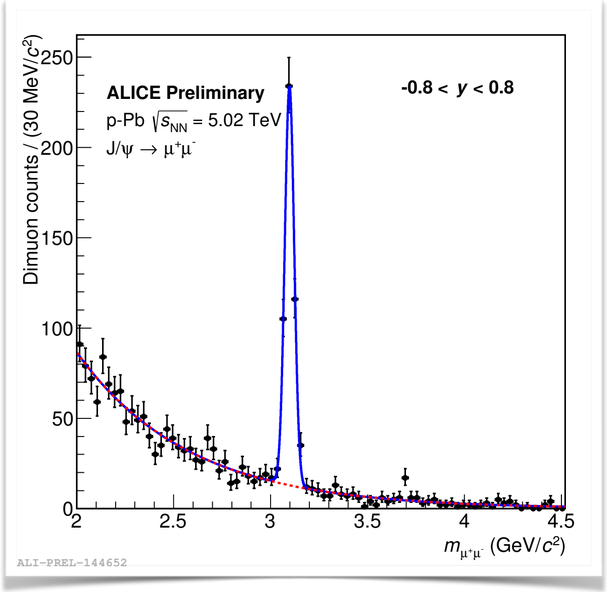
- Measurement of J/ψ at a rapidity where ALICE has no detectors.





Mass distributions





Mid-rapidity:

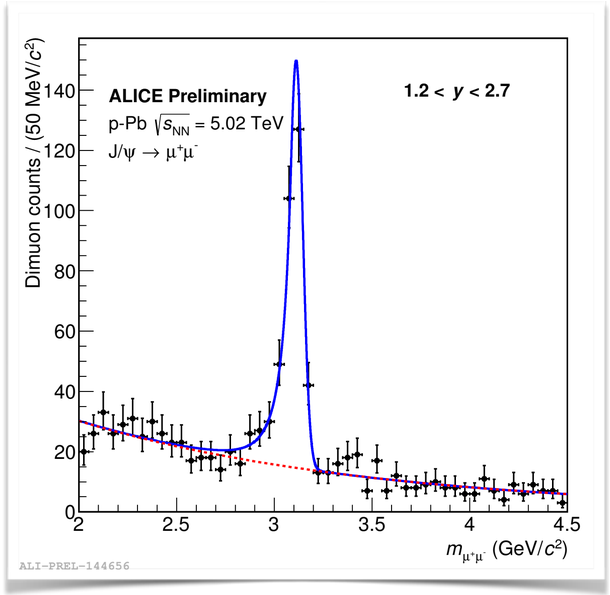
- Consistent measurement in two channels.
- Consistent measurement in p-Pb and Pb-p.

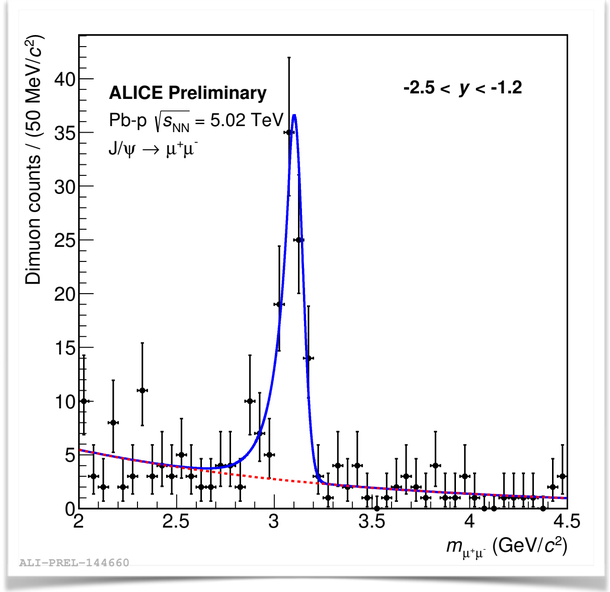
Semi-forward and semi-backward rapidity:

- Measurement of J/ψ at a rapidity where ALICE has no detectors.

All cases:

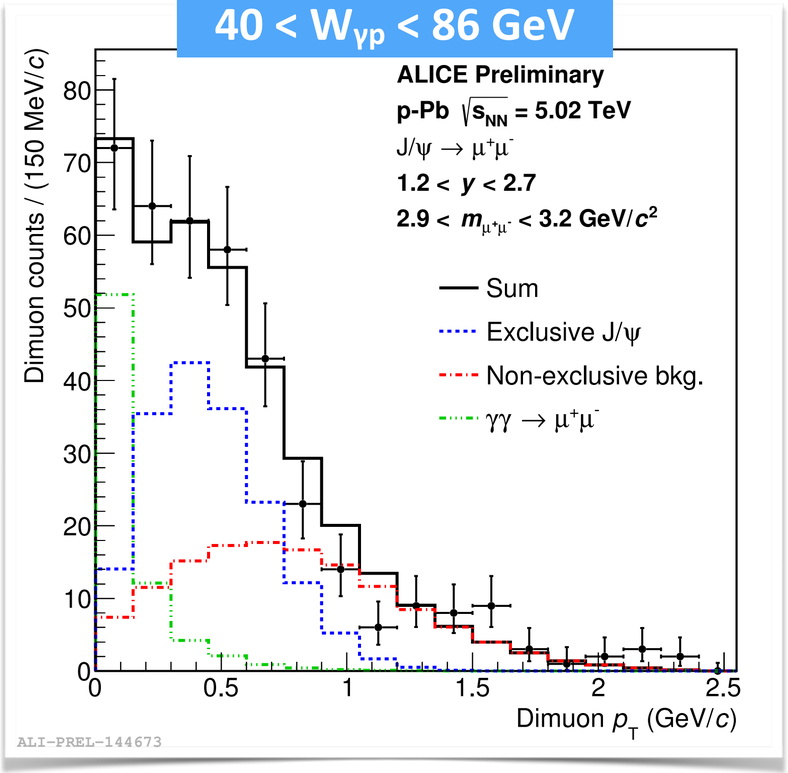
- Clean signal over a small background.



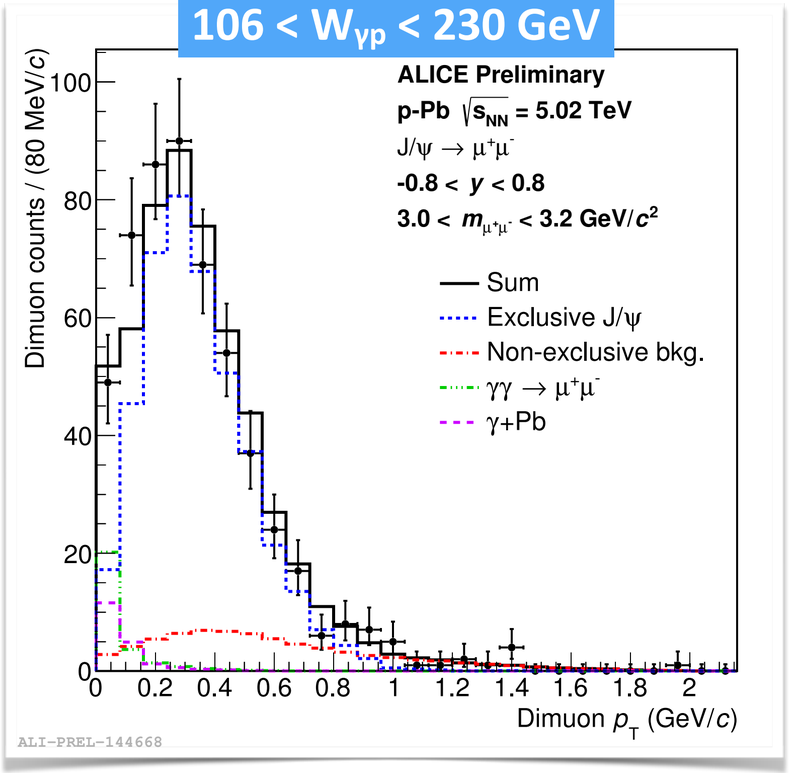


Transverse momentum distributions

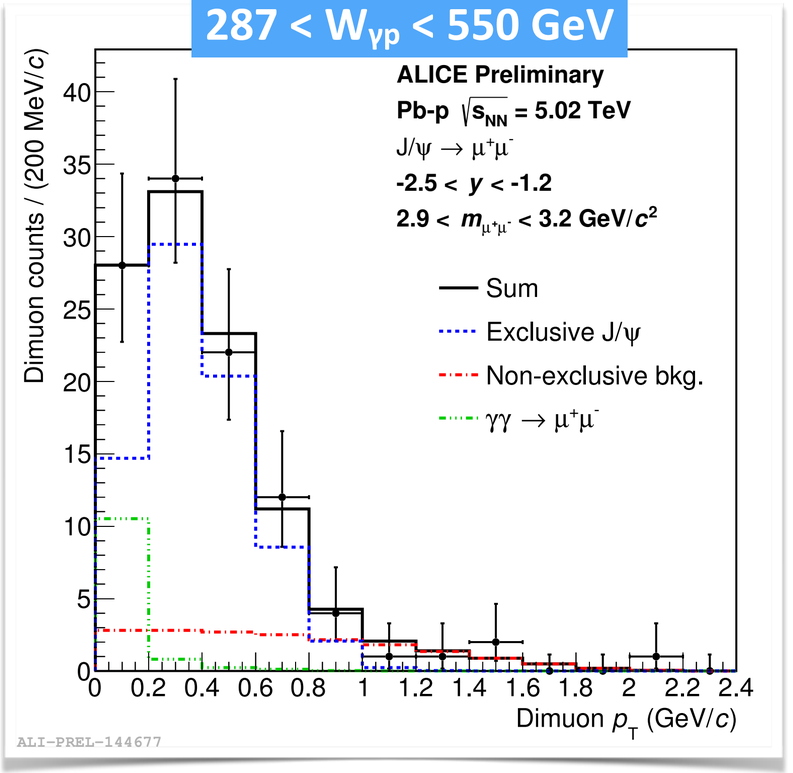
40 < $W_{\gamma p}$ < 86 GeV



106 < $W_{\gamma p}$ < 230 GeV



287 < $W_{\gamma p}$ < 550 GeV



Signal extraction:

- Fit to templates of the different contributions.
- Non-exclusive background distribution obtained from data.
- The width of the distribution decreases with energy, as observed at HERA.

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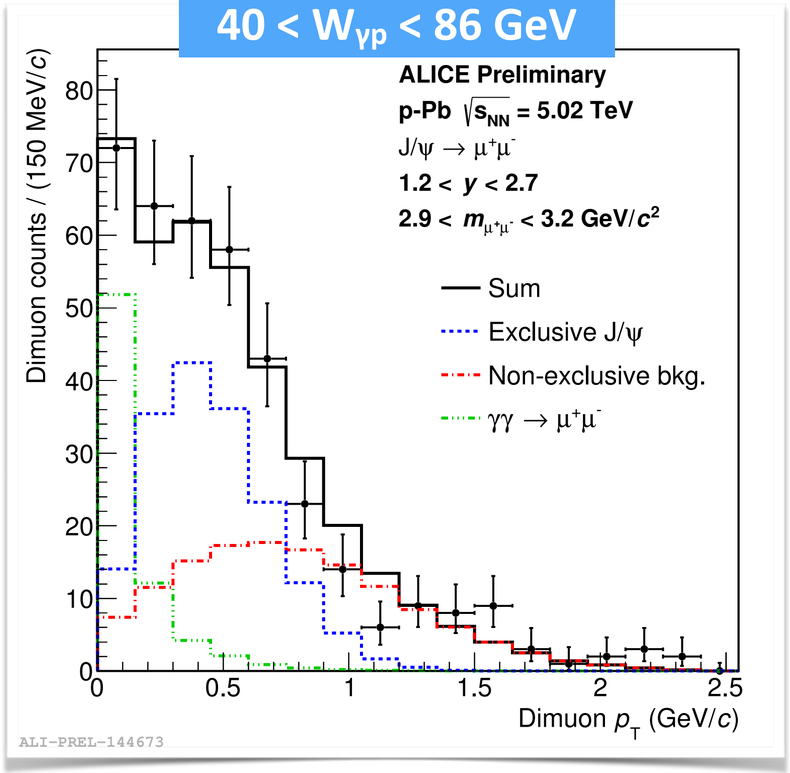

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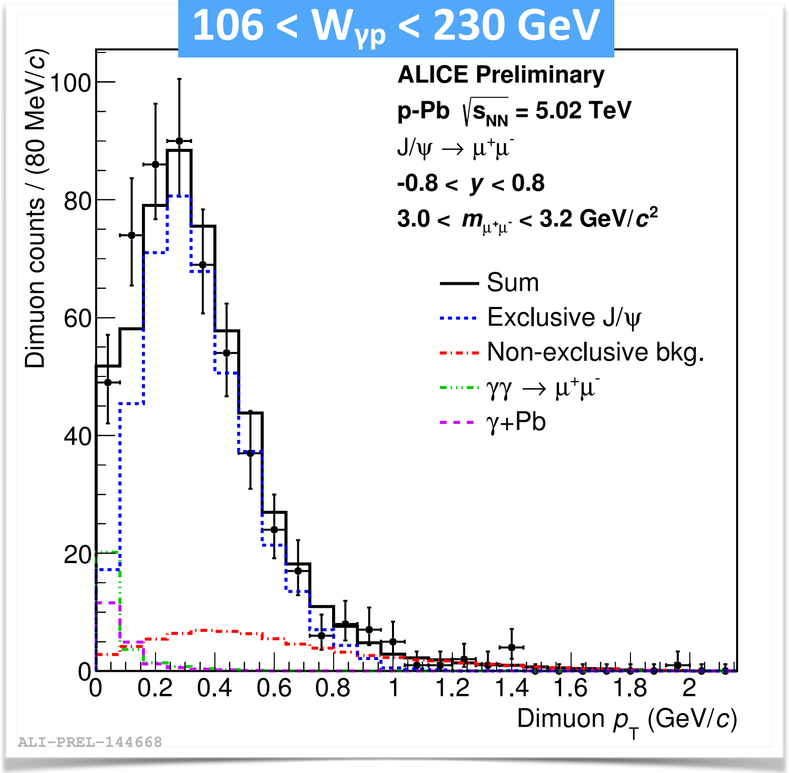

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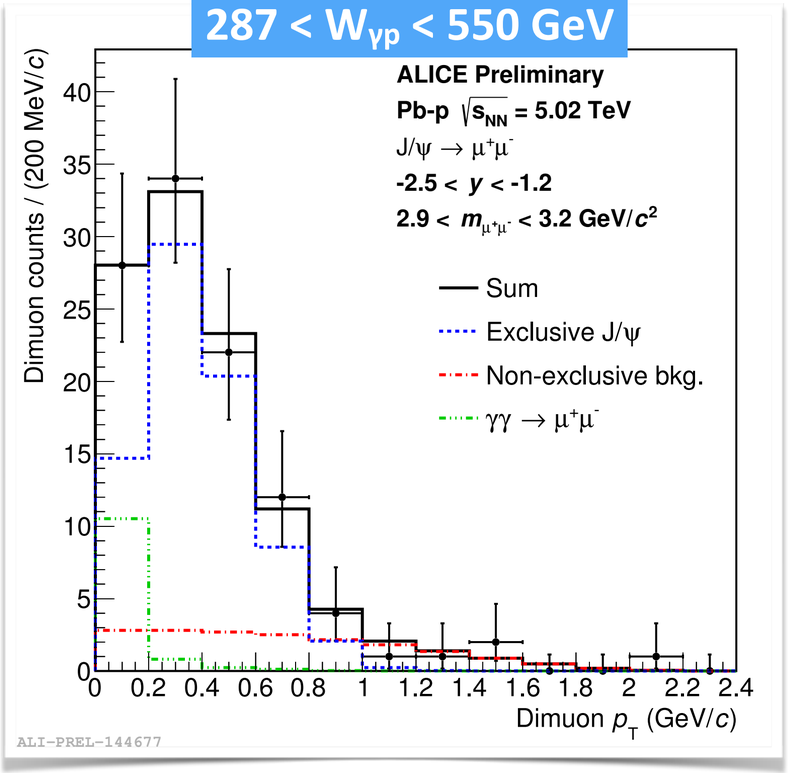

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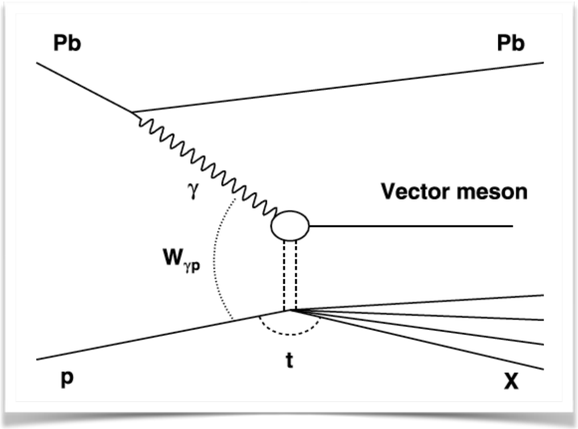
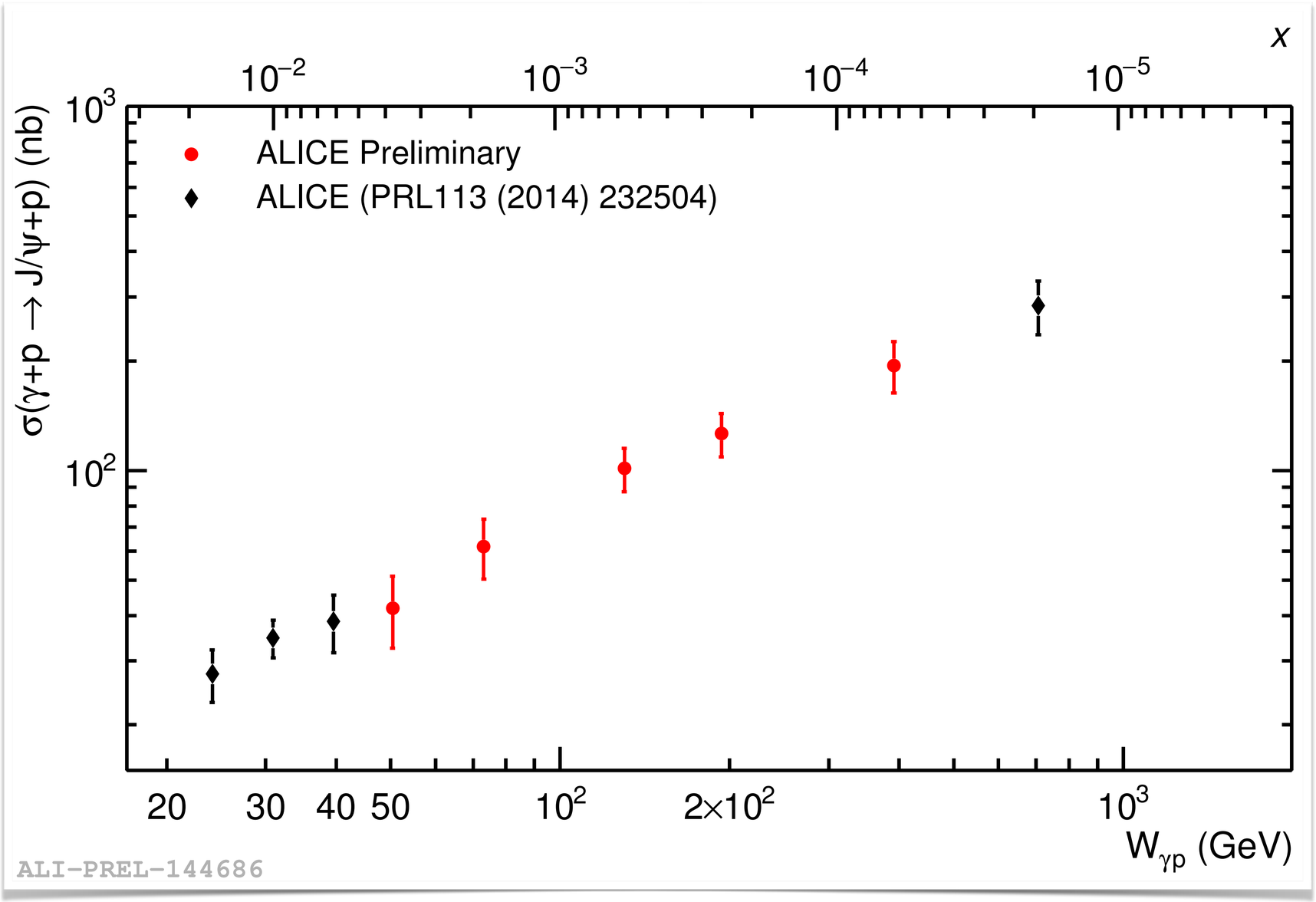
- The width of the distribution decreases with energy, as observed at HERA.

Non-exclusive background:

- Main contribution from proton-dissociative photoproduction of J/ψ.
- Process sensitive to fluctuations of the proton structure!
  (Heikki's talk on Monday, JGC's today).



Energy dependence of exclusive J/ψ photoproduction



ALICE reach:

- Spans energies from 20 GeV to 700 GeV in the photon-proton centre-of-mass system.

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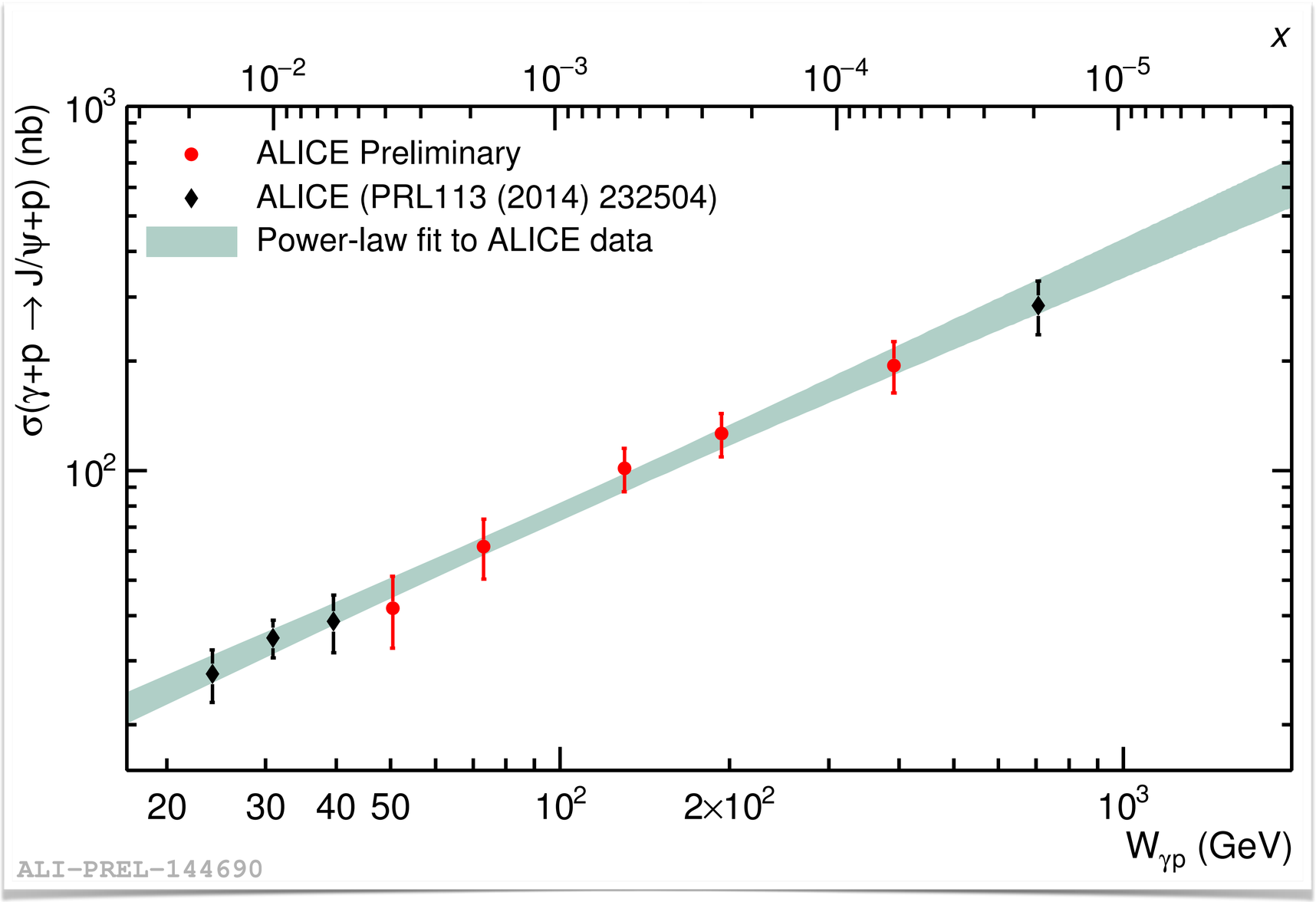

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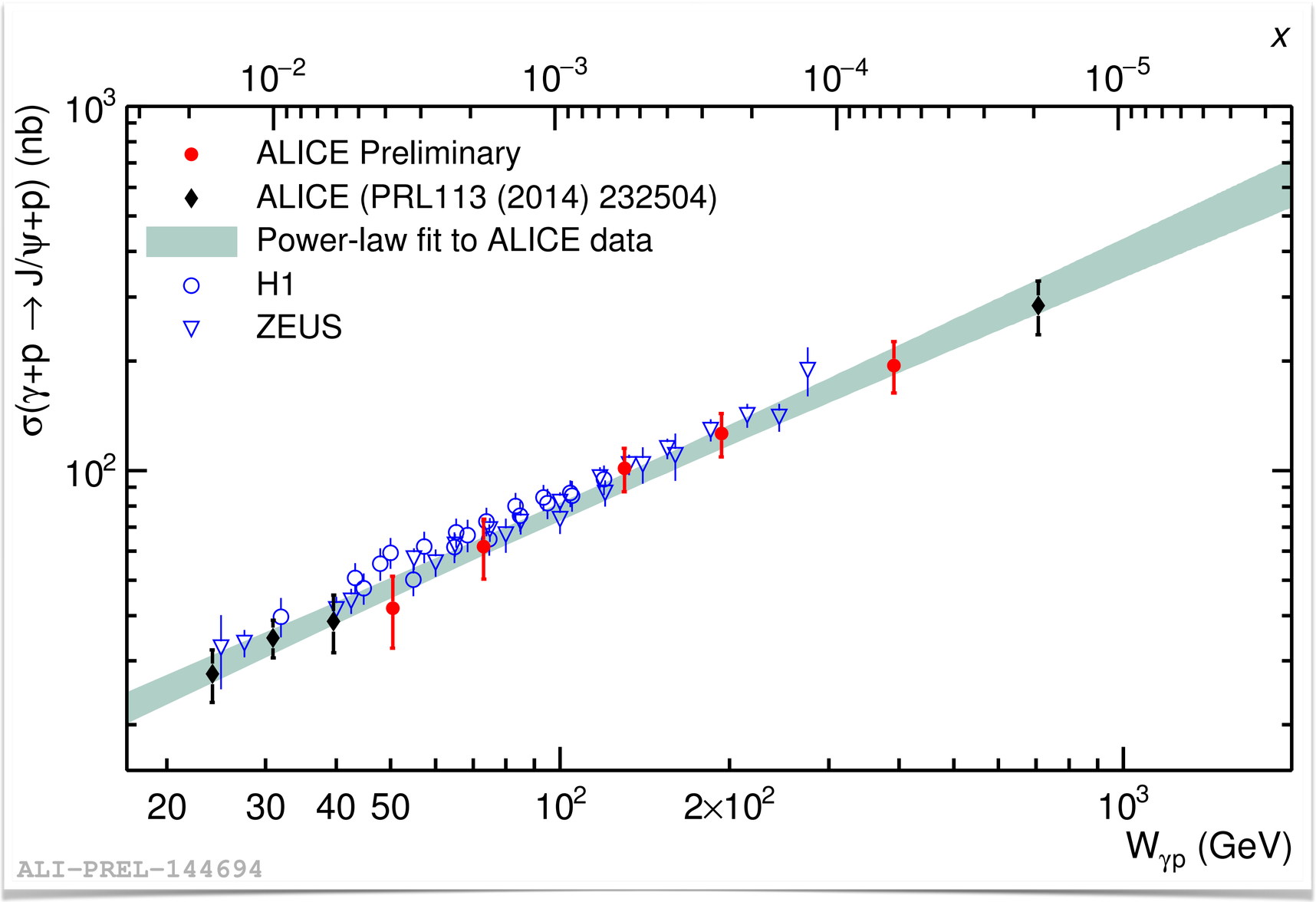

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HERA data::

- Nice agreement between HERA and ALICE data.

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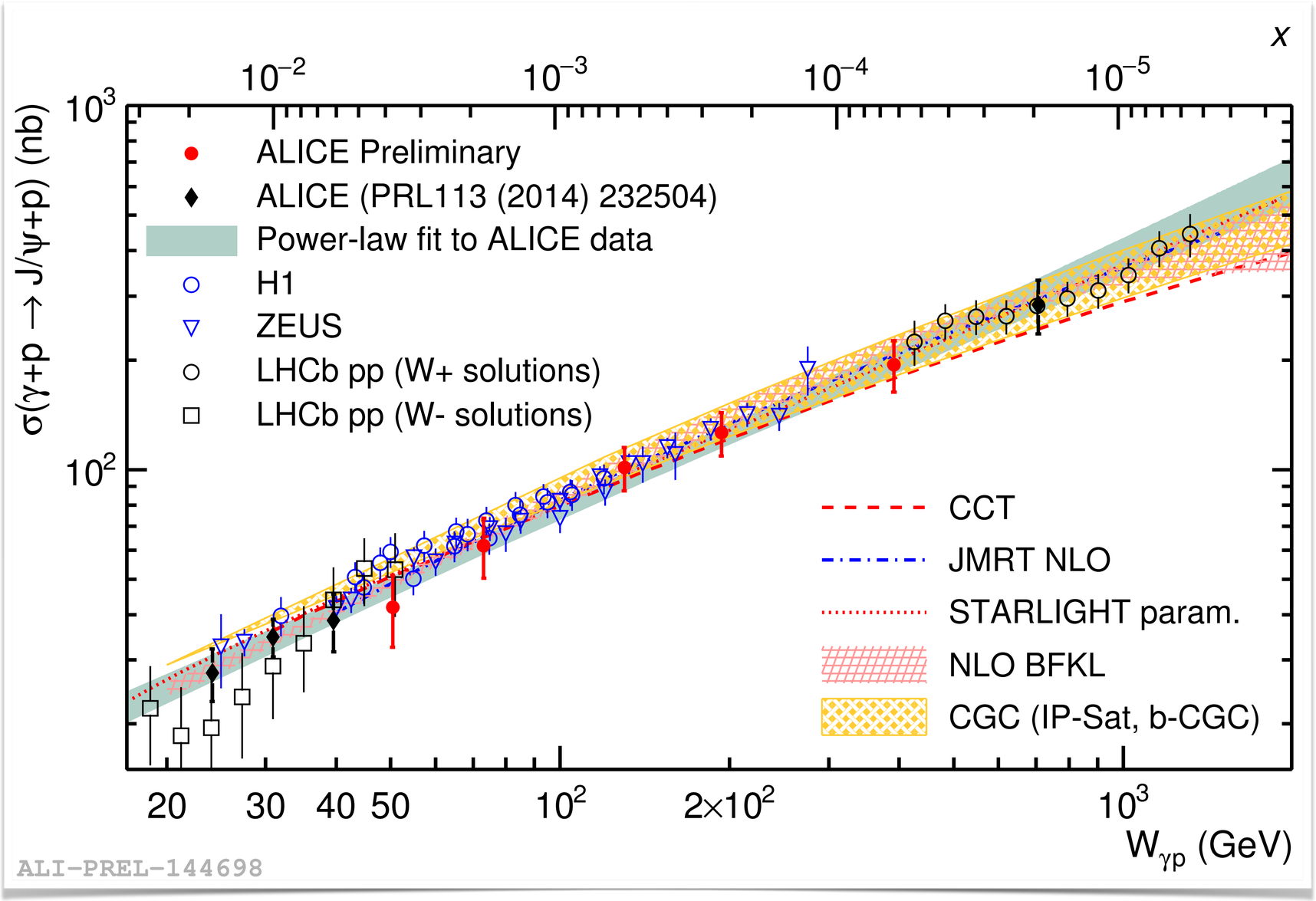

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Comparison to models:

- Agreement with LHCb solutions.
- Good description by all models independently of the inclusion of saturation or subnuclear degrees of freedom.

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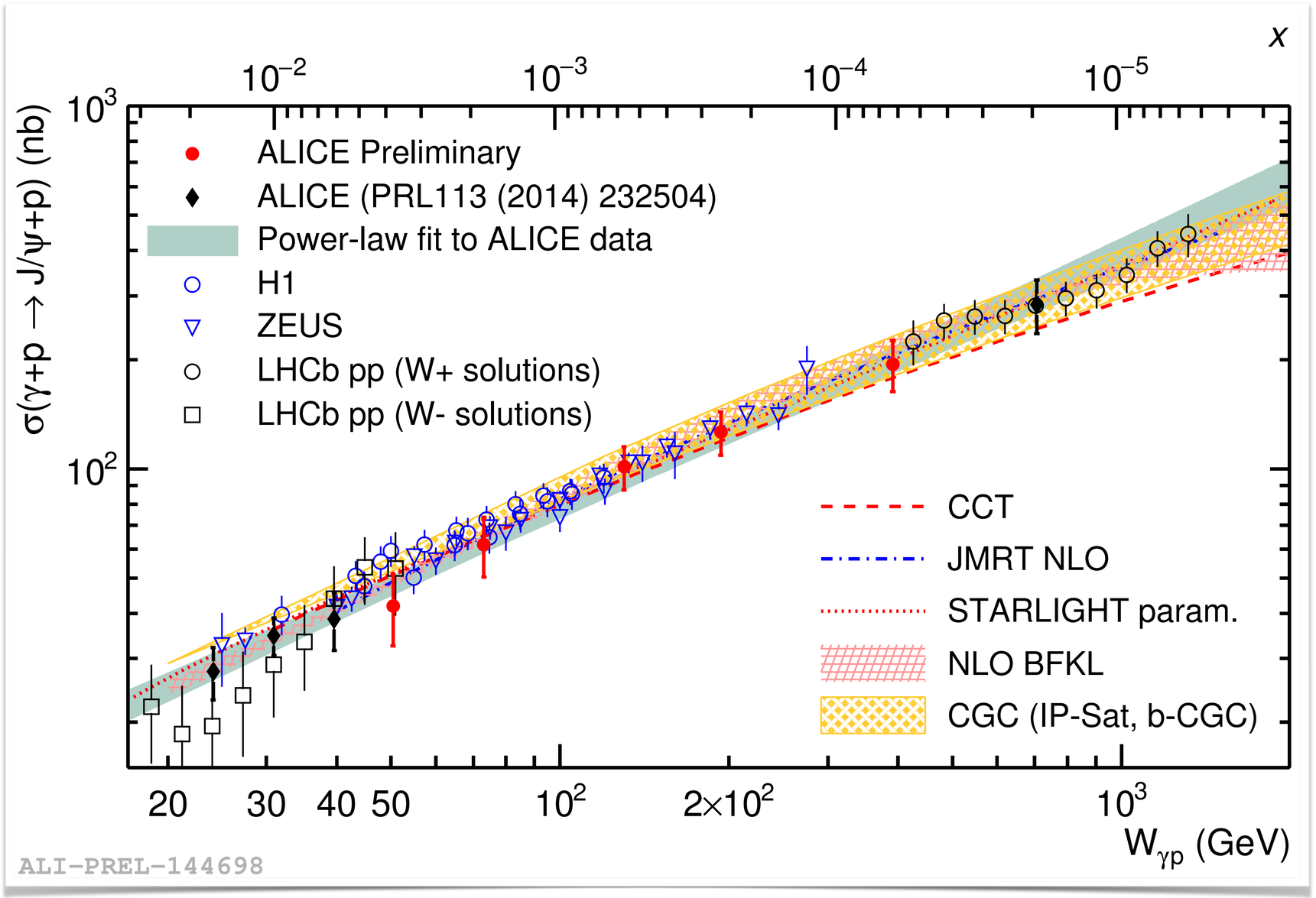

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References to models in the appendix.

Sneak peek

2016 p-Pb collisions @ 8.16 TeV

Run 2 data:

- Towards the end of 2016, the LHC provided the experiments with p-Pb collisions.
- Collisions at 5.02 TeV were taken in the p-Pb configuration.
- There also were collisions at 8.16 TeV for both p-Pb and Pb-p configurations.

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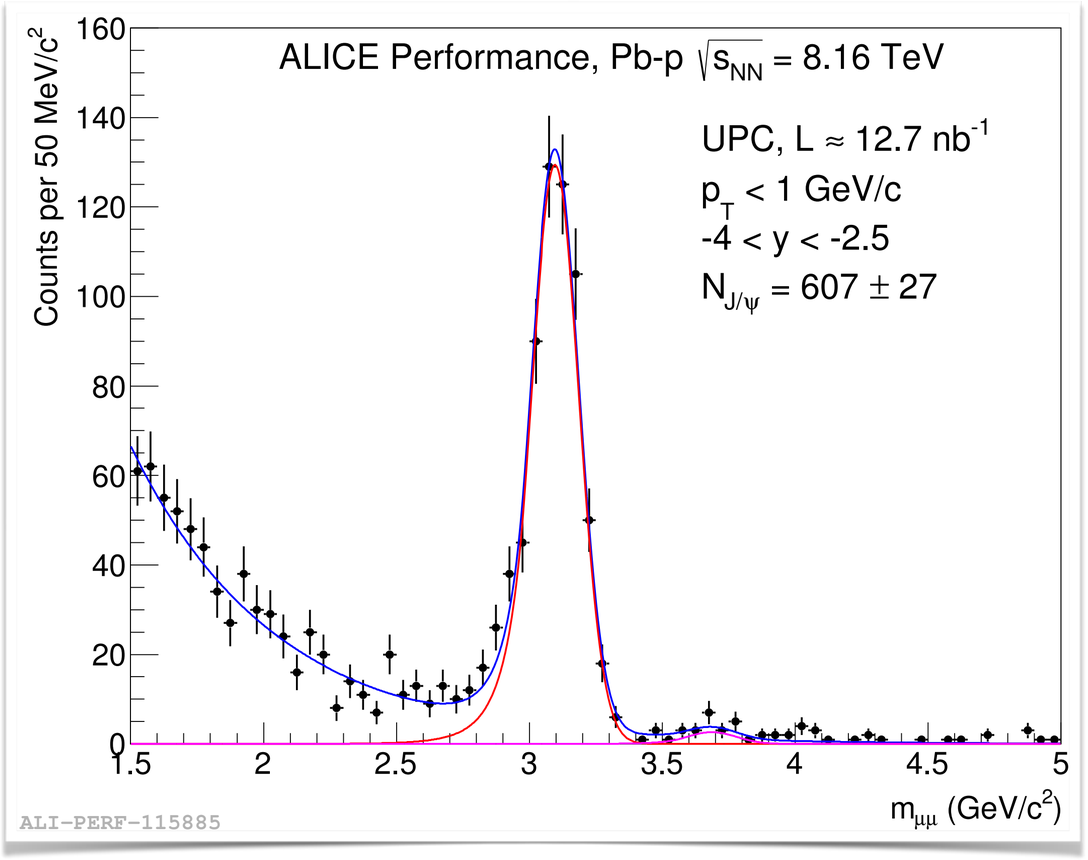

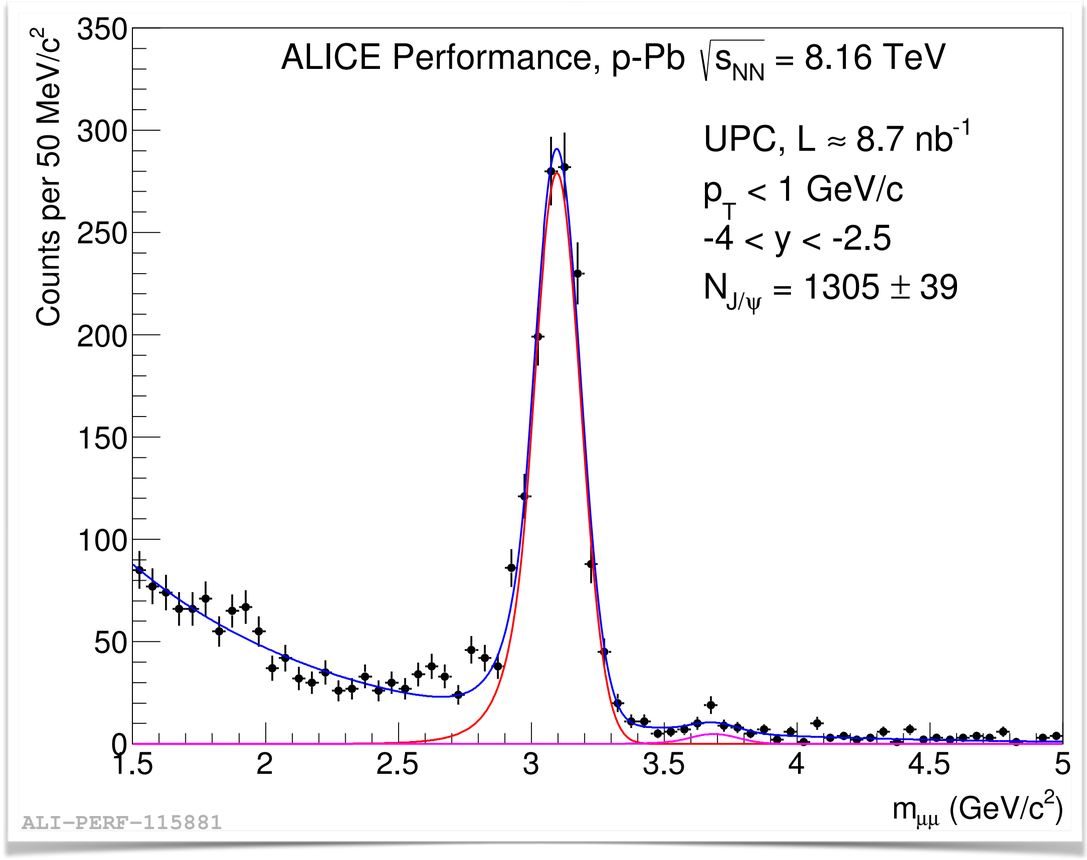

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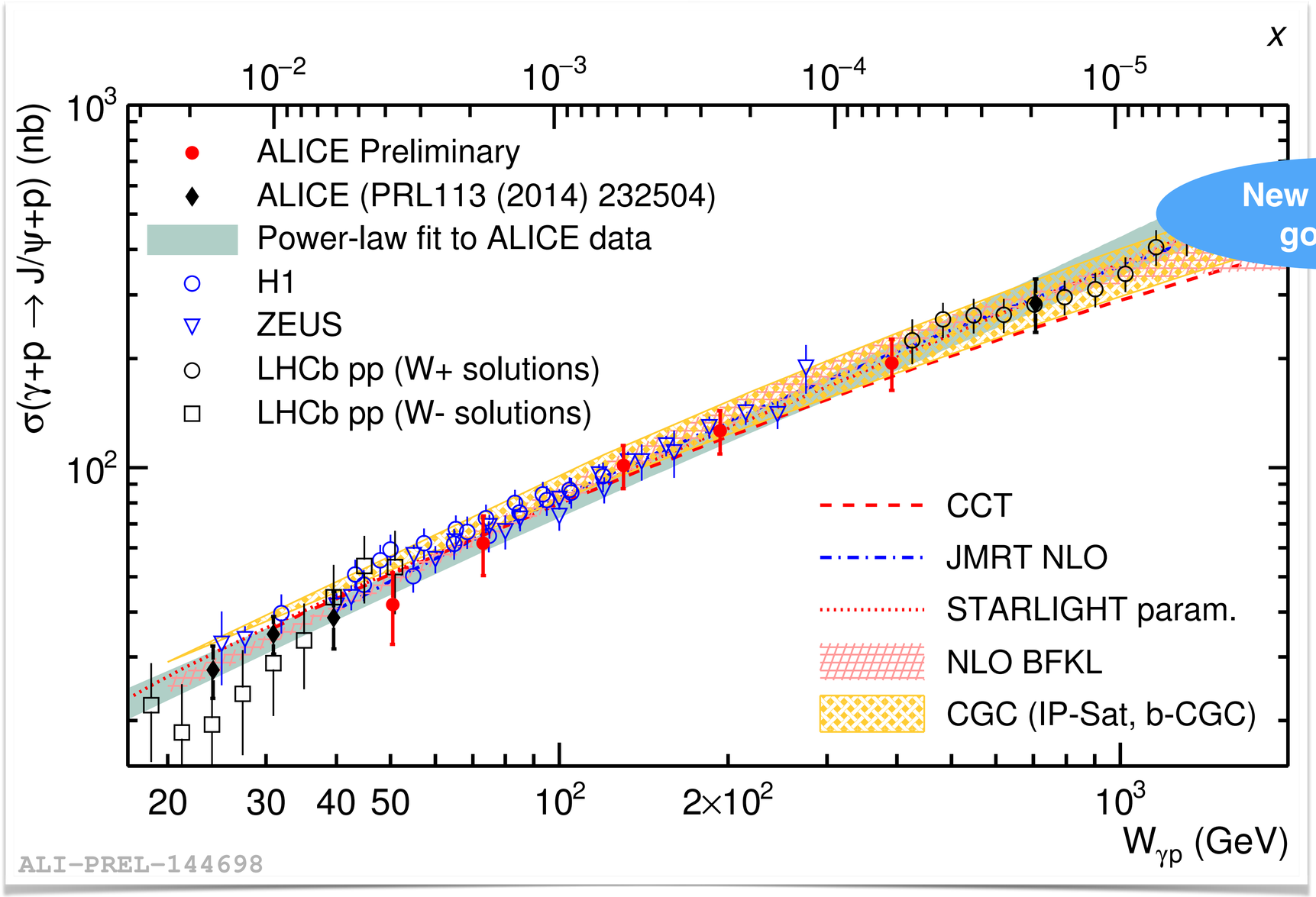


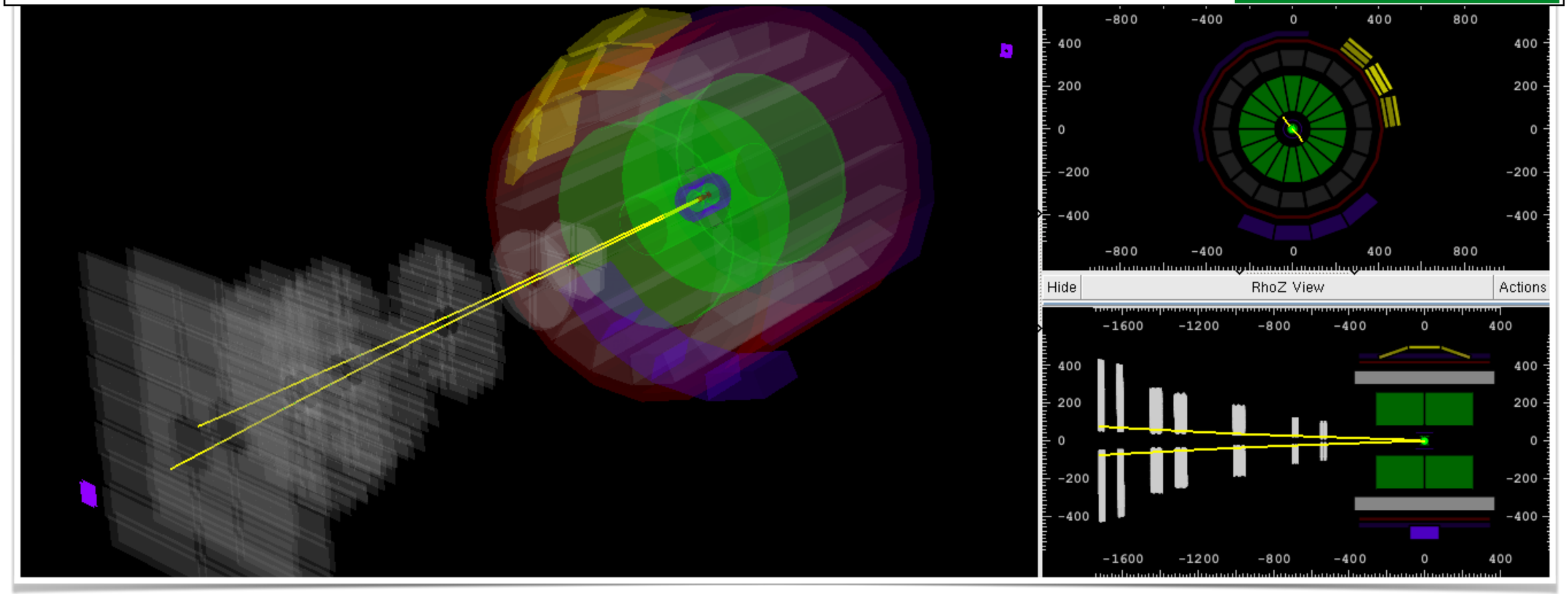
New data will go here!

ALICE reach:

- New Run 2 data in the Pb-p configuration will allow us to reach well above 1 TeV!

2016 p-Pb collisions @ 8.16 TeV

Kinematics: $y = 3.97$, $m = 3.058\ \mathrm{GeV}/c^2$ $p_T = 0.031\ \mathrm{GeV}/c$, $\phi = -1.074$, and **Wγp = 1.463 TeV!**



Higher energy in Run 2 allow us to access energy range well above 1 TeV!

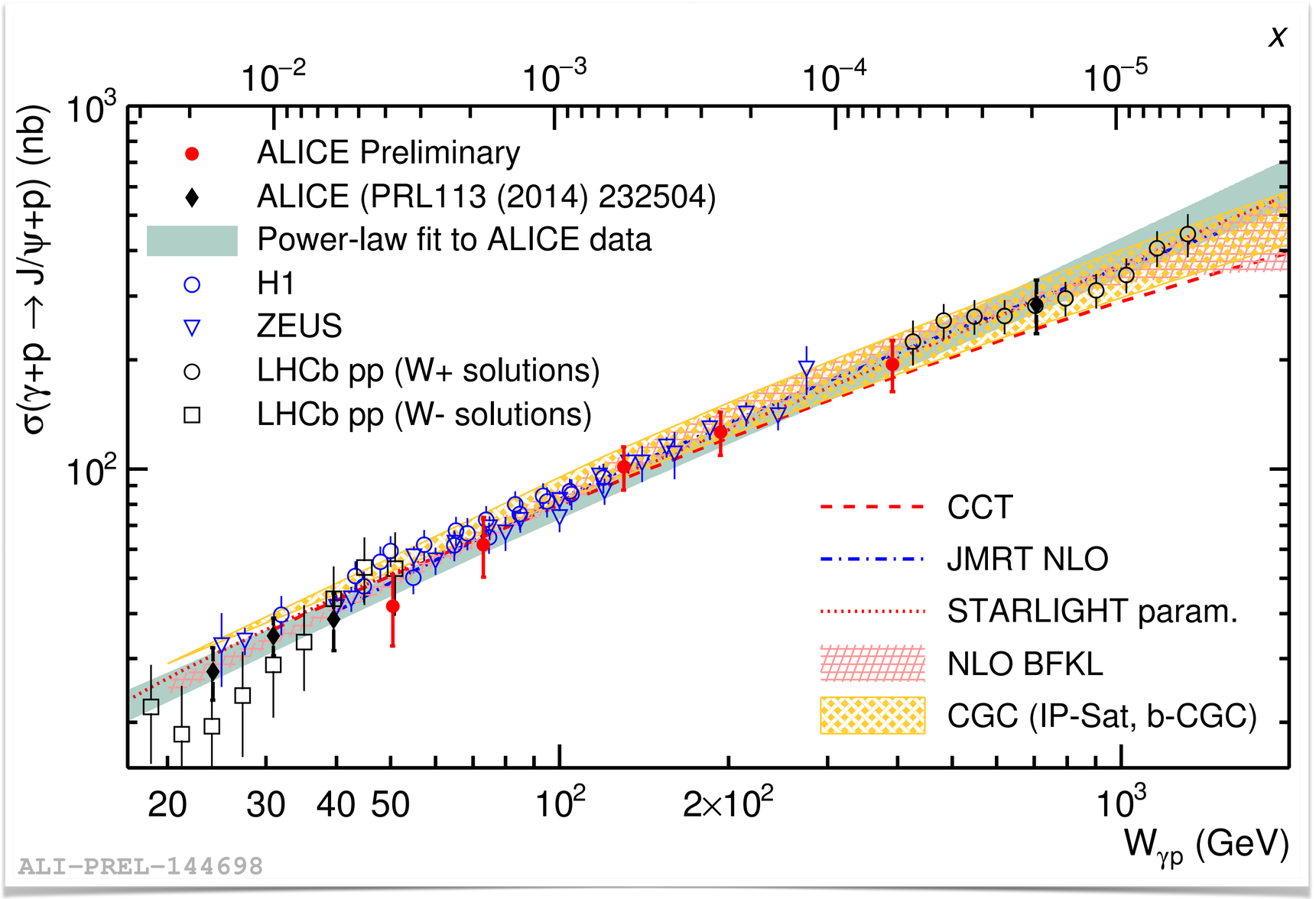
Conclusions and outlook

Summary and outlook

- ALICE has recorded data for the photoproduction of J/ψ in p-Pb and Pb-p modes, which allows us to cover a large range of $W_{\gamma p}$ from 20 GeV up to 700 GeV for Run 1 data, and above 1 TeV for Run 2.
- Cross sections from the 2013 campaign, continuously covering a large energy range going up to energies beyond twice what was measured at HERA, have been presented.
- During Run 2 ALICE added the AD detector which enhances ALICE capabilities to detect low mass diffractive systems:
  - This will 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!

Appendix

Models



CCT:

- Includes saturation in an energy dependent hot spot model.
- PLB766(2017) 186

JMRT NLO

- DGLAP formalism with main NLO contributions included.
- EPJC76 (2016) 633

Starlight:

- Parameterisation of HERA and fixed target data.
- CPhC 212 (2017) 258

NLO BFKL

- Proton impact factor from F2 HERA data.
- PRD94 (2016) 054002

CGC

- CGC models with saturation.
- PRD90 (2014) 054003