



Diffraction  
and LOW-x



# Quarkonia production in Ultra-peripheral PbPb collisions at LHCb

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On behalf of the LHCb collaboration

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1

# LHCb Detector

[Int. J. Mod. Phys. A 30, 1530022 (2015)]

- LHCb detector is a **single-arm forward spectrometer** fully instrumented in unique kinematic coverage:  $2 < \eta < 5$ .

- A high precision detector with excellent particle identification, precise vertex and track reconstruction.

**Vertex Detector**  
Reconstruct vertices  
Decay time resolution: 45 fs  
Impact parameter resolution: 20  $\mu\text{m}$

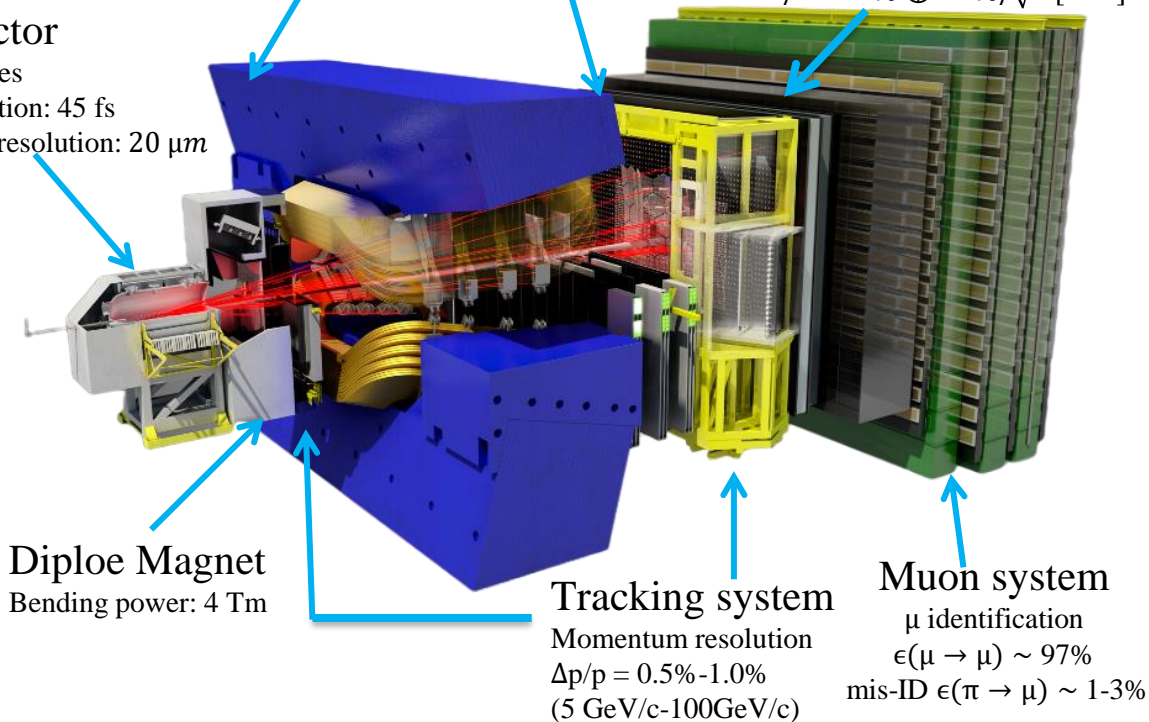
**RICH detectors**

$K, \pi, p$  separation  
 $\epsilon(K \rightarrow K) \sim 95\%$   
mis-ID  $\epsilon(\pi \rightarrow K) \sim 5\%$

**Calorimeters**

Energy measurement  
 $e/\gamma$  identification

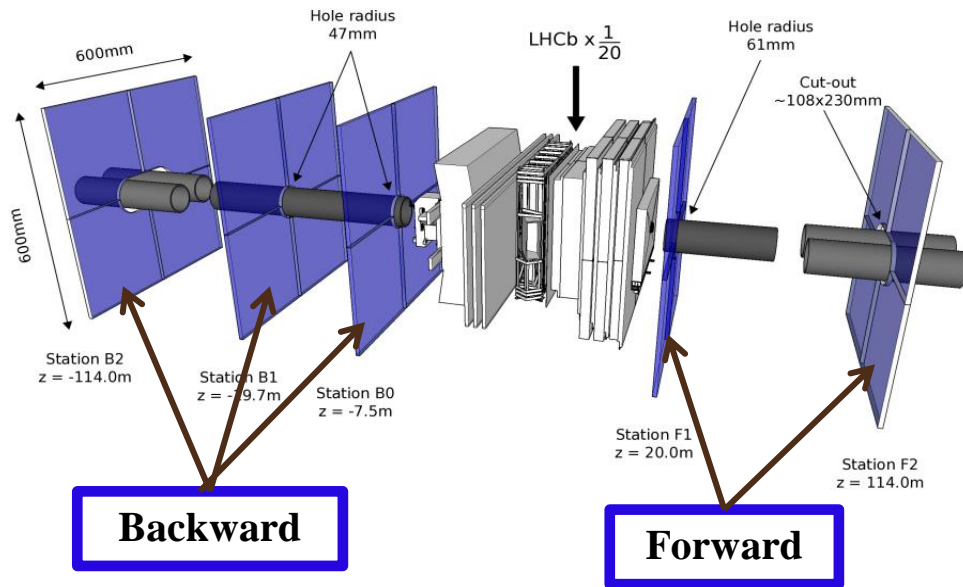
$\Delta E/E = 1\% \oplus 10\%/\sqrt{E[\text{GeV}]}$



# HeRSChel detector

[2018 JINST 13 P04017]

- HeRSChel (**H**igh **R**apidity **S**hower **C**ounters for **LHCb**), is a set of plastic scintillators located in the LHC tunnel on both sides of the LHCb interaction point, in order to extend the pseudo-rapidity coverage of the LHCb in the high-rapidity regions either side of the interaction point.
- HeRSChel detector extends the LHCb forward coverage up to a pseudo-rapidity of around 10.
- HeRSChel detector is used to cut the component with large momentum, for example, the incoherent component.

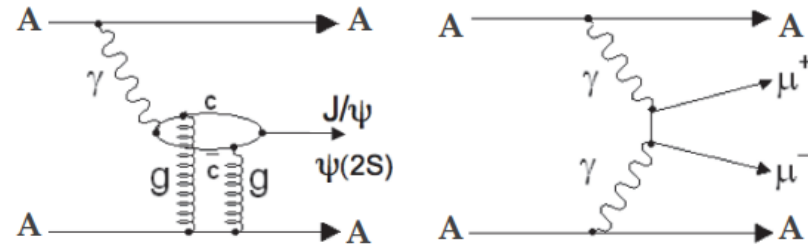
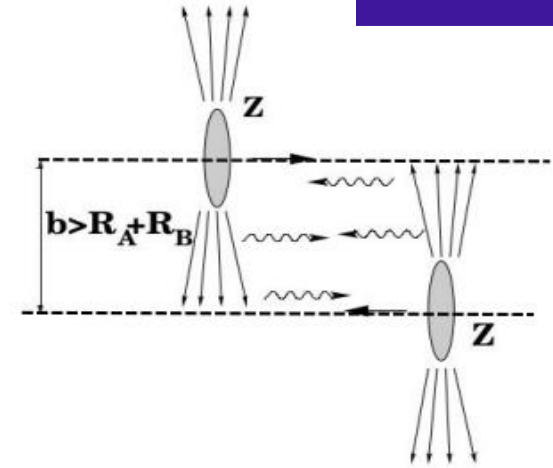


# Ultra-peripheral PbPb Collisions



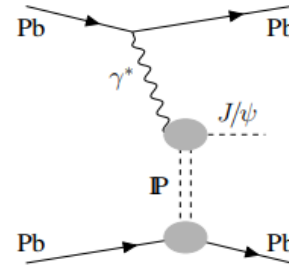
## ➤ Ultra-Peripheral Collisions(UPCs):

- Two incoming nuclei bypass each other with an impact parameter greater than the sum of their radii.
- Reactions in which two ions interact via their cloud of semi-real photons.
- The number of photons  $\propto Z^2$ .
- Photon-induced quarkonium production:  
A  $q\bar{q}$  loop created by the photon interaction with a pair of gluon exchange (pomeron) to produce a quarkonium( $c\bar{c}, b\bar{b}$ ).
- Non-resonant background:  $\gamma\gamma \rightarrow \mu^+\mu^-$ .

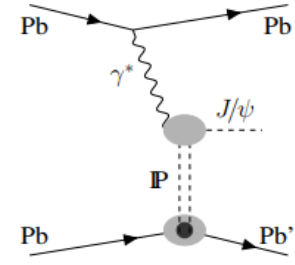


# J/ψ production in UPC

- **Coherent J/ψ production**, the photon interacts with a pomeron emitted by the entire nucleus.
- **Incoherent J/ψ production**, the photon interacts with a pomeron emitted from a single nucleon within the target nucleus.
- J/ψ from the feed-down of coherent and incoherent  $\psi(2S)$  production.
- **Characteristics of coherent J/ψ production:**
  - No additional particle production ( $Pb + Pb \rightarrow Pb + Pb + J/\psi$ ).
  - low J/ψ mesons transverse momentum.
- Study of coherent charmonium production could constrain the gluon Parton Distribution Functions in nuclear.



Coherent J/ψ production



Incoherent J/ψ production

# LHCb latest results

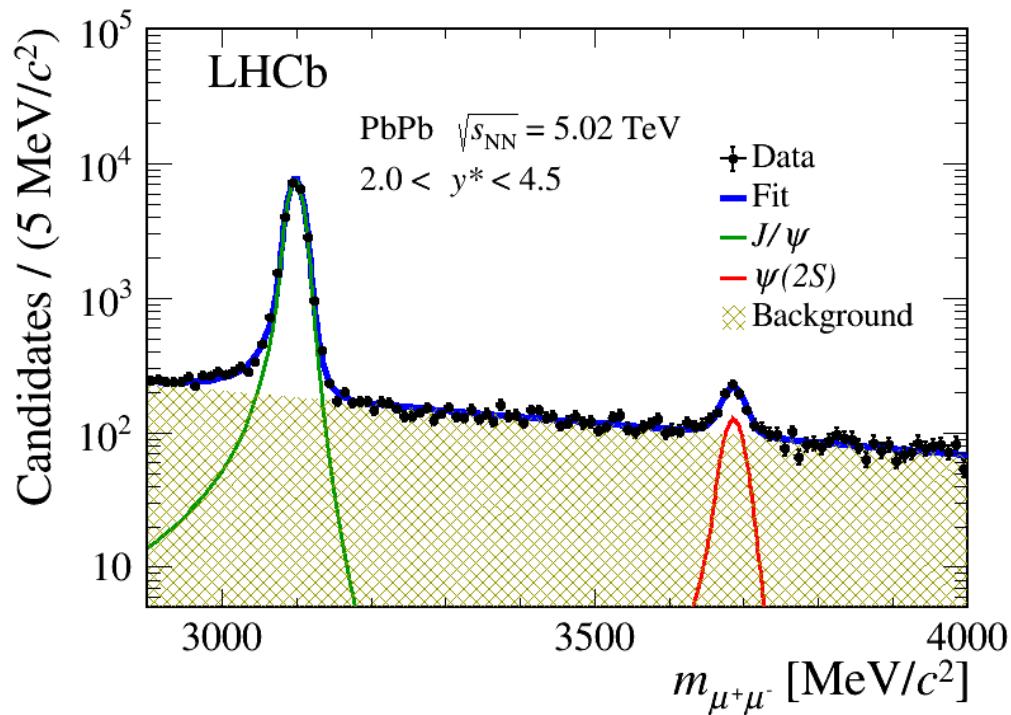
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Study of charmonium production in ultra-peripheral  
lead-lead collisions at LHCb

[arXiv:2206.08221](https://arxiv.org/abs/2206.08221)

# Signal extraction

[arXiv:2206.08221](https://arxiv.org/abs/2206.08221)



➤  $J/\psi \rightarrow \mu^+\mu^-$  and  $\psi(2S) \rightarrow \mu^+\mu^-$  events from PbPb collisions at  $\sqrt{s} = 5$  TeV taken in 2018 with luminosity  $228 \pm 10 \mu b^{-1}$ .

➤ Double-side Crystal Ball function for the mass peaks:

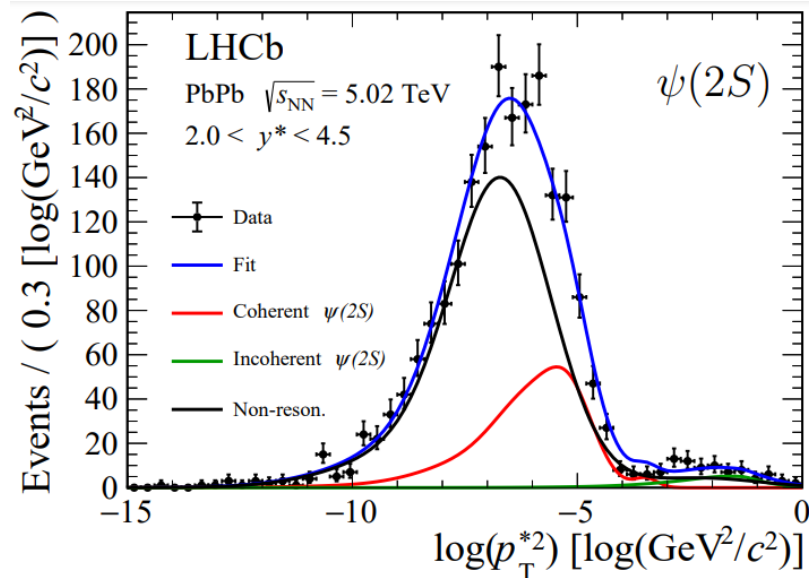
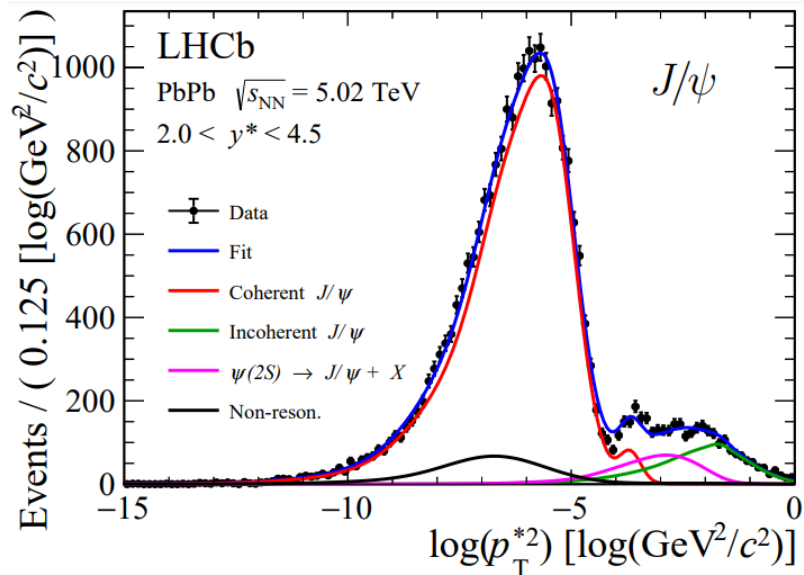
- $J/\psi \rightarrow \mu^+\mu^-$  (coherent, incoherent and feed-down components)
- $\psi(2S) \rightarrow \mu^+\mu^-$  (coherent and incoherent components)

➤ Exponential function for the background:

- $\gamma\gamma \rightarrow \mu^+\mu^-$

# Signal extraction

arXiv:2206.08221

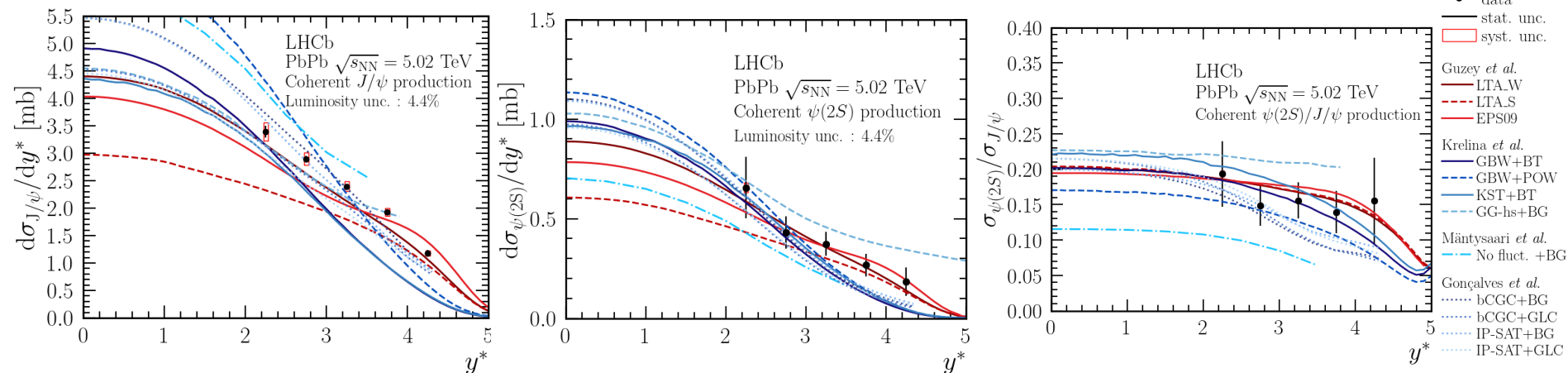


- All signal pdfs are estimated using the STARLight generator and the LHCb detector simulation.
- The shape of background taken from the side-band method, then the normalization is fixed from mass fit.



# Charmonium production cross-section in rapidity

arXiv:2206.08221

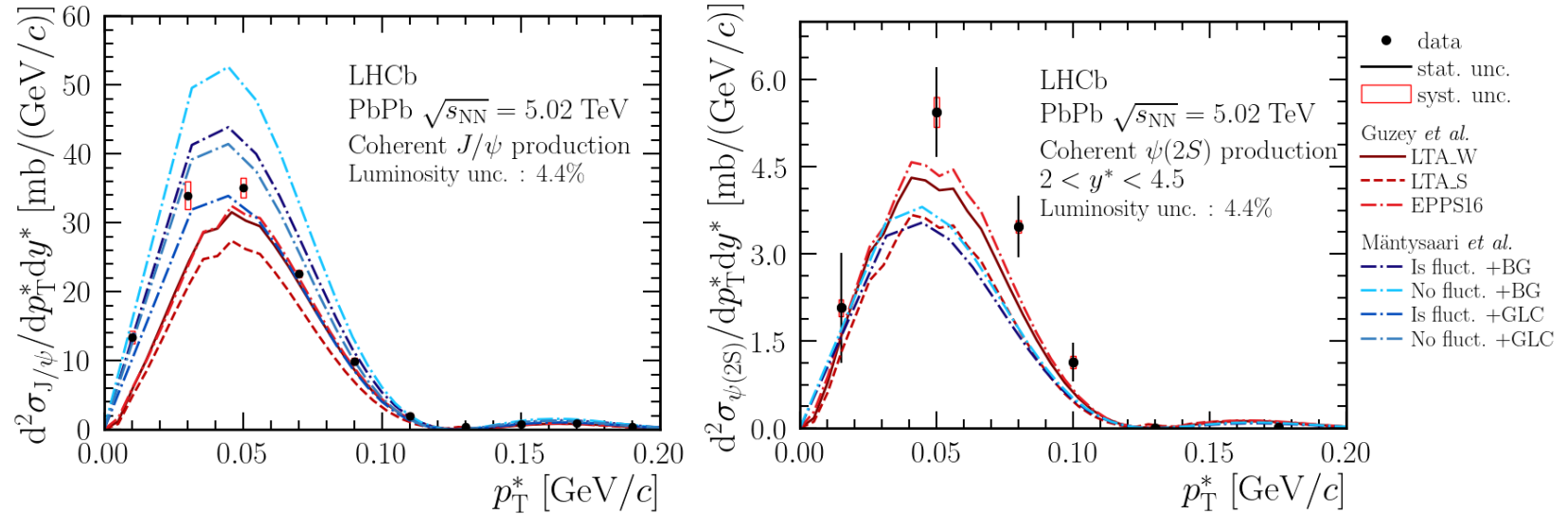


[References of models in backup]

- Differential cross-section as a function of rapidity results compared with color-dipole model (blue lines) and pQCD model (red lines) theory predictions.
- The first coherent  $\psi(2S)$  measurement in forward rapidity region at the LHC.

# Charmonium production cross-section in $p_T$

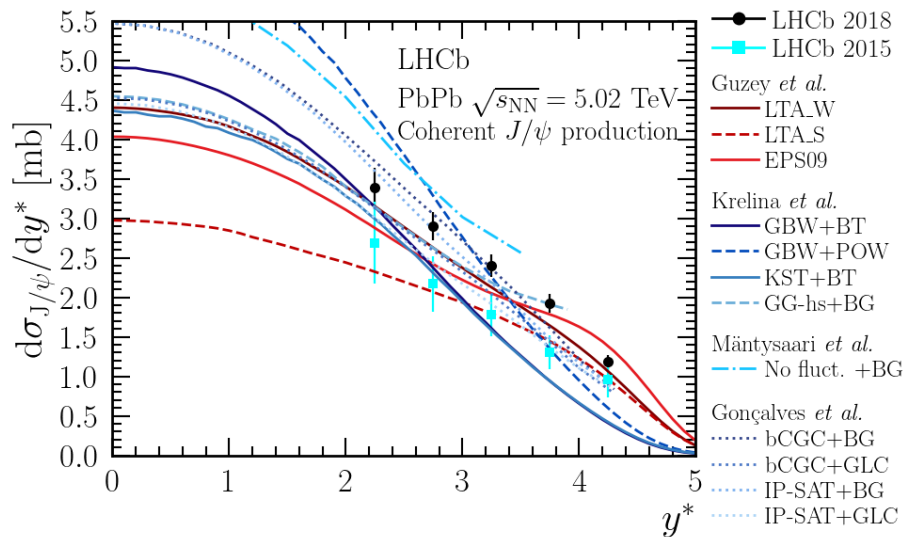
arXiv:2206.08221



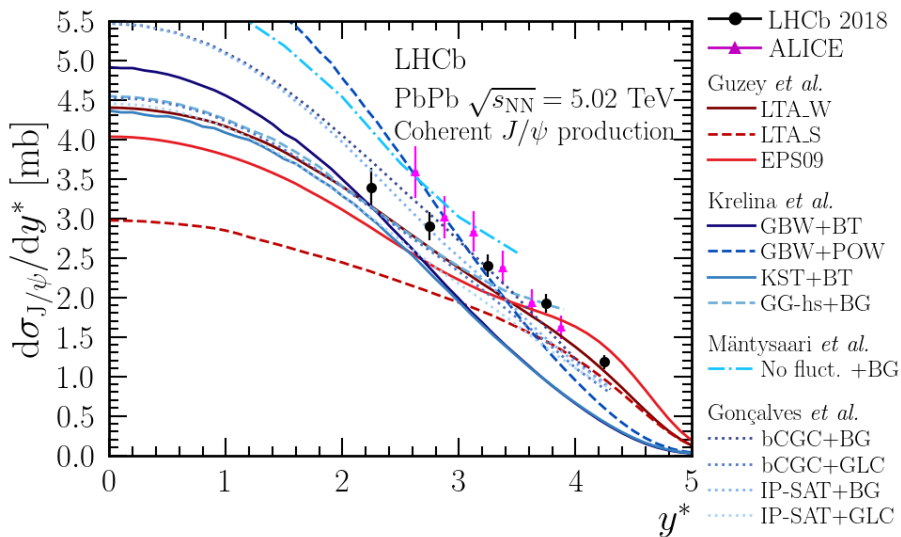
- Data compared with color-dipole model(blue lines) and pQCD model(red lines) theory predictions.
- A reasonable comparison between measurement and theoretical predictions.
- The first measurement about coherent  $J/\psi$  and  $\psi(2S)$  production cross-section vs.  $p_T$  in PbPb UPC.

# Compare with previous results

arXiv:2206.08221



[JHEP 07 (2022) 117 ]



[Phys.Lett. B798 (2019) 134926]

- Comparison with the  $J/\psi$  measurement with 2015 and ALICE results.
- The difference between new results and 2015 measurement is about  $2.0\sigma$ .
- Compatible with ALICE data.

# LHCb latest results

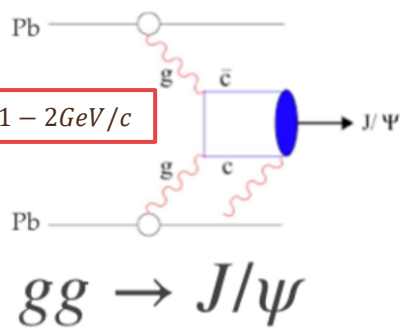
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Study of  $J/\psi$  photo-production in lead-lead peripheral collisions at  $\sqrt{s} = 5$  TeV

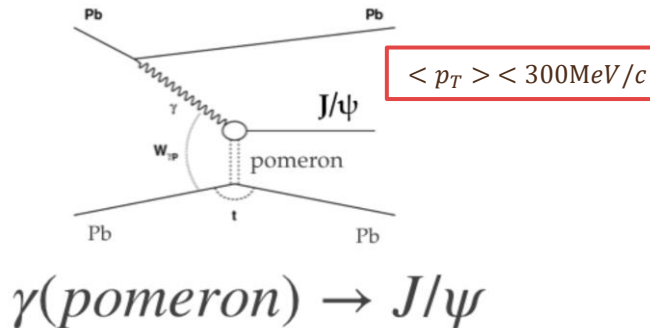
Phys. Rev. C **105**, L032201

# Coherent J/ $\psi$ in PbPb peripheral collisions

## Hadronic production



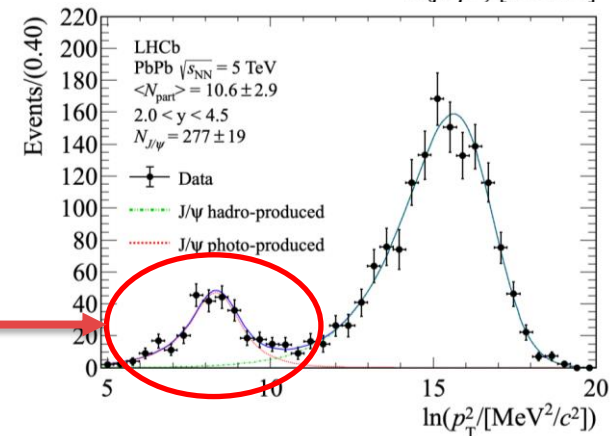
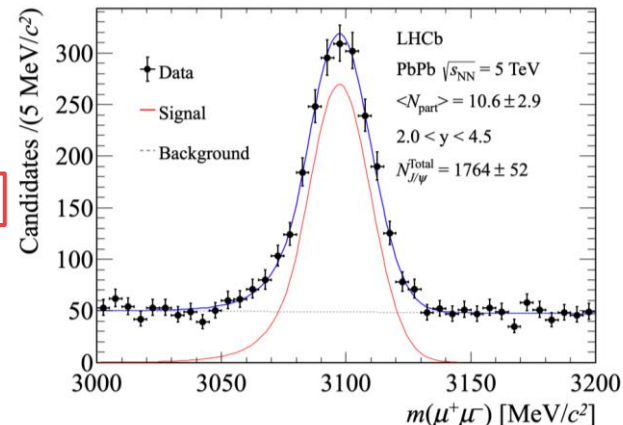
## Coherent photo-production



➤ The photo-production at low transverse momentum of inclusive J/ $\psi$  events produced in PbPb peripheral collisions ( $b < 2R_{Pb}$ ) at  $\sqrt{s_{NN}} = 5 \text{ TeV}$  taken in 2018 dataset, limited to 60-90% centrality.

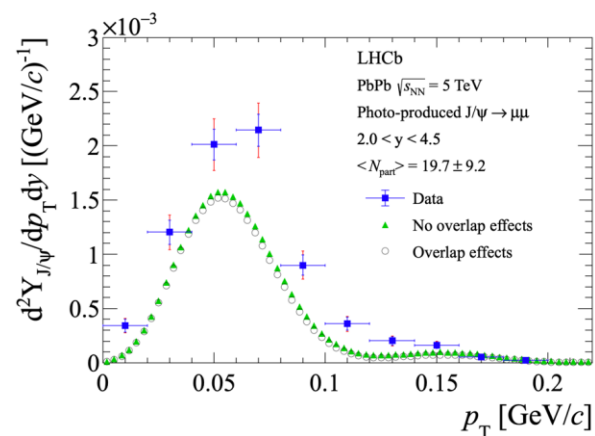
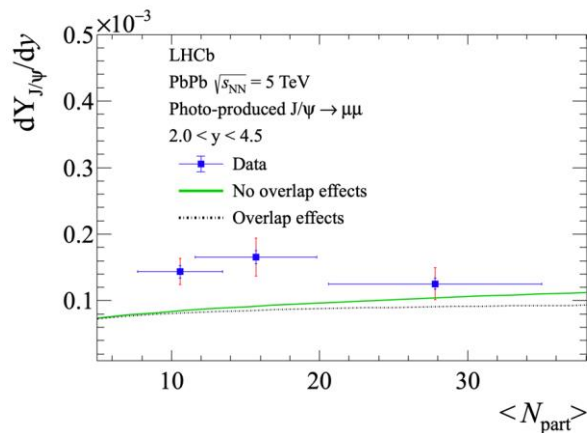
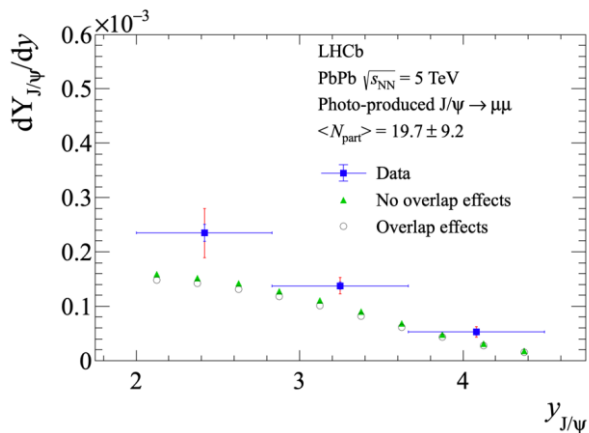
➤ There is not only photo-production but also hadronic production.

➤ We could separate the two productions from the  $p_T$  distribution of J/ $\psi$ .



# Coherent $J/\psi$ in PbPb peripheral collisions

- Results compare with one model with two assumptions:
  - No effect of the overlap between the two nuclei (UPC-like but smaller  $b$ )
  - Effect of the overlap [W. Zha et al. Phys. Rev. C97 \(2018\) 044910 / Phy. Rev. C99, 06901\(R\)](#)
- The trend is consistent, but the data is above the predictions.
- Most precise coherent  $J/\psi$   $p_T$  measurement in PbPb peripheral collisions to date.



# Conclusion



- Measurement of exclusive coherent  $J/\psi$  and  $\psi(2S)$  production and their cross-section ratio in UPC PbPb collisions using 2018 dataset. [arXiv:2206.08221](https://arxiv.org/abs/2206.08221)
  - First coherent  $\psi(2S)$  measurement in forward rapidity region for UPC at LHC.
  - First measurement about coherent  $J/\psi$  and  $\psi(2S)$  production cross-section vs.  $p_T$  in PbPb UPC.
- Measurement of photo-produced  $J/\psi$  mesons in peripheral PbPb collisions using 2018 dataset. [Phys. Rev. C \*\*105\*\*, L032201](https://arxiv.org/abs/2206.08221)
  - First result using PbPb hadronic collisions in LHCb.
  - Most precise coherent  $J/\psi$   $p_T$  measurement in PbPb peripheral collisions to date.
- Many more results in the near future (CEP  $Y(nS)$  in pp collision, incoherent production in PbPb UPC collision, CEP  $J/\psi$  in pPb collision...)



# Thanks!

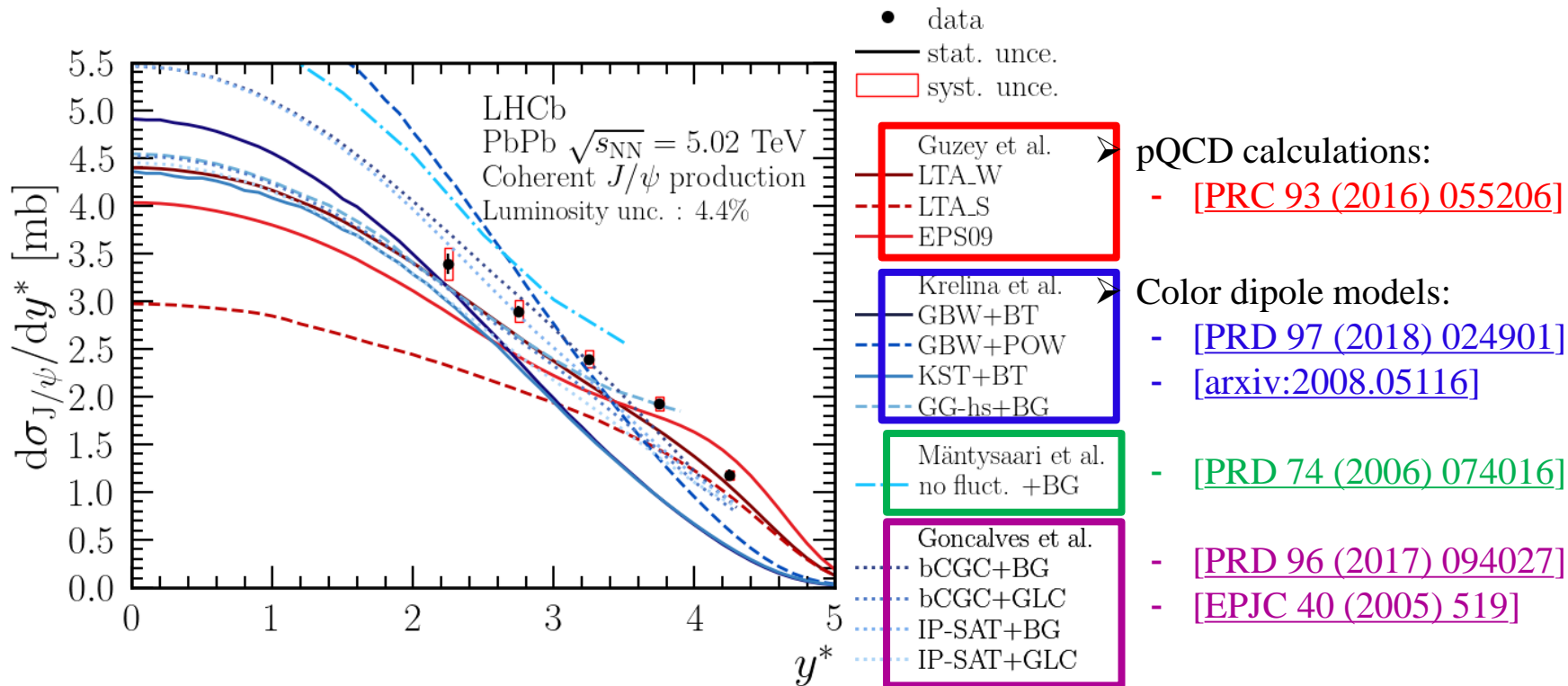


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# Back up

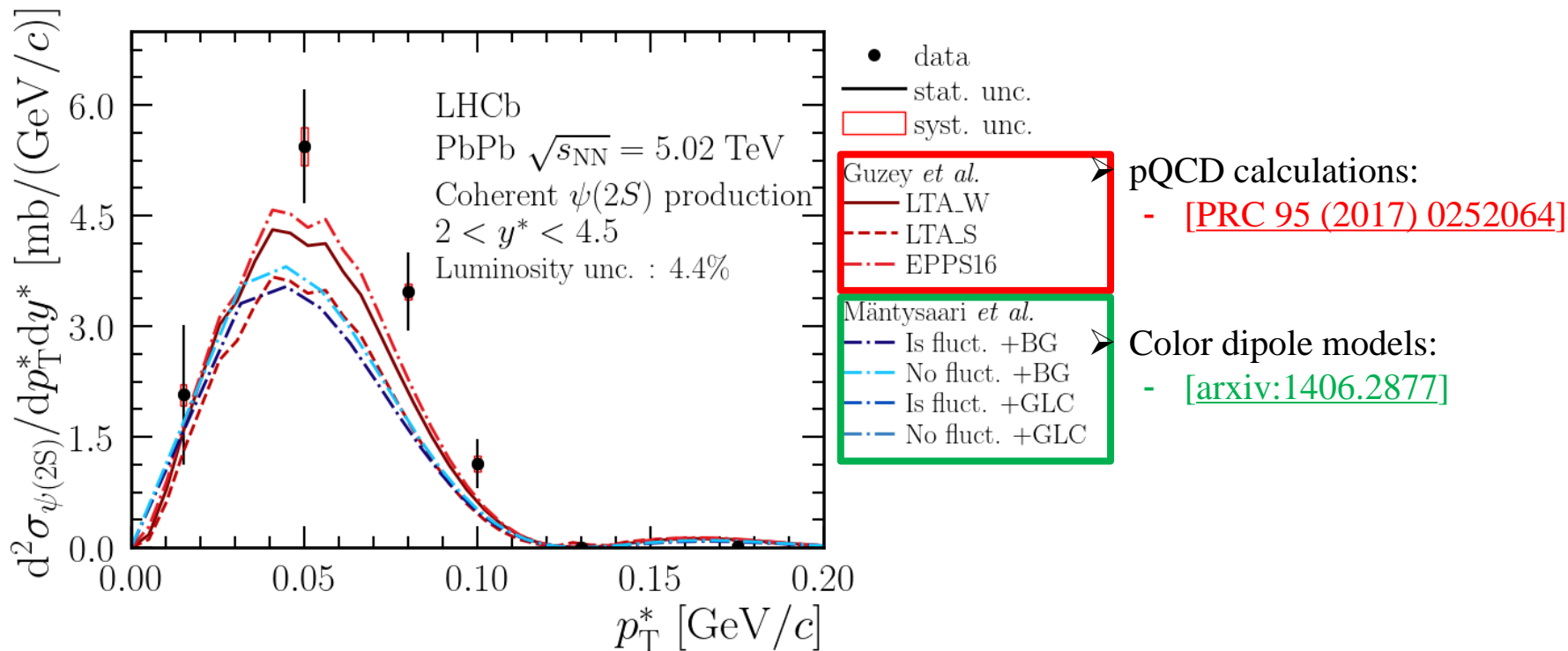
# Charmonium production cross-section in rapidity

arXiv:2206.08221

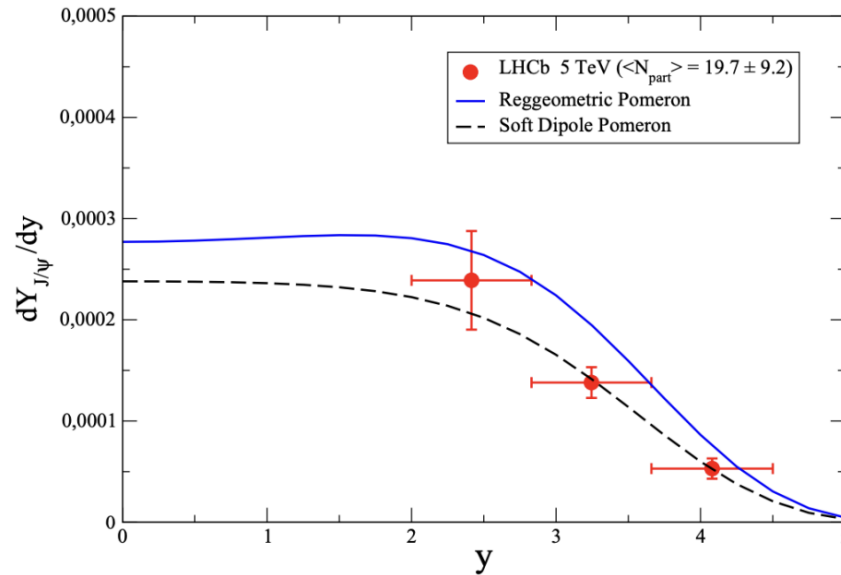


# Charmonium production cross-section in $p_T$

arXiv:2206.08221



# Coherent $J/\psi$ in PbPb peripheral collisions



[arXiv:2202.02162v2]

- Model based on Vector Dominance Model + Glauber multiple scattering formalism
- Recent preprint shows good agreement with the soft dipole pomeron model.