

13th International workshop on
Multiple Partonic Interactions at
the LHC



LHCb measurements of Quarkonia Production in Ultraperipheral PbPb collisions

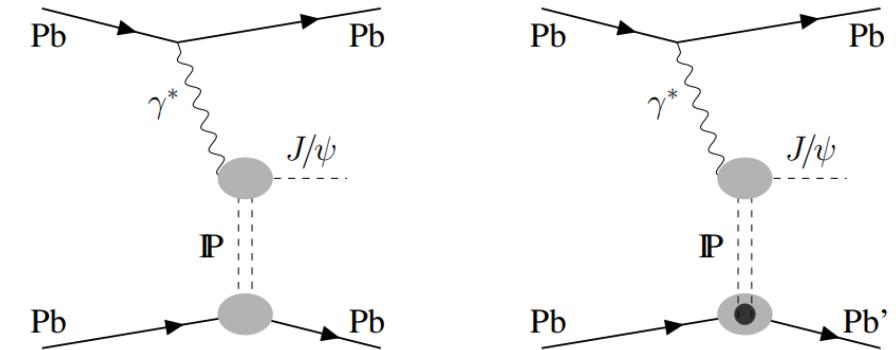
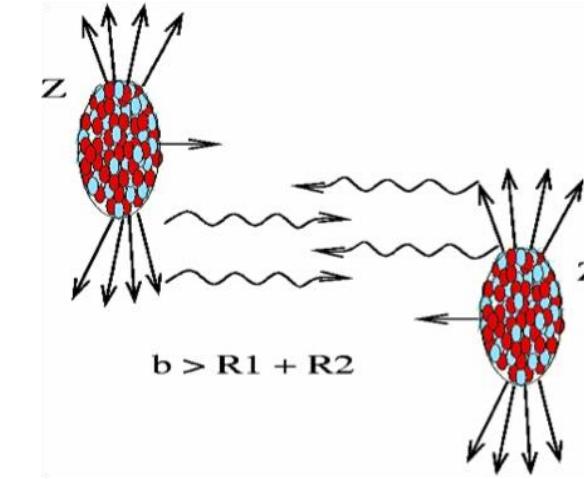
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on behalf of the LHCb collaboration

Ultra-peripheral production of Charmonium

- **Ultra-peripheral collisions (UPC):** Two nuclei bypass each other with an impact parameter greater than the sum of their radii
- **Photon-induced interactions are enhanced by the strong electromagnetic field of the nucleus**
 - Coherent J/ψ and $\psi(2S)$ production gives the most direct constraints on the gluon distribution functions
 - $(J/\psi)/\psi(2S)$ ratio measurement is helpful to constrain the choice of the vector meson wave function in dipole scattering models [e.g. PLB 772 (2017) 832, PRC (2011) 011902]



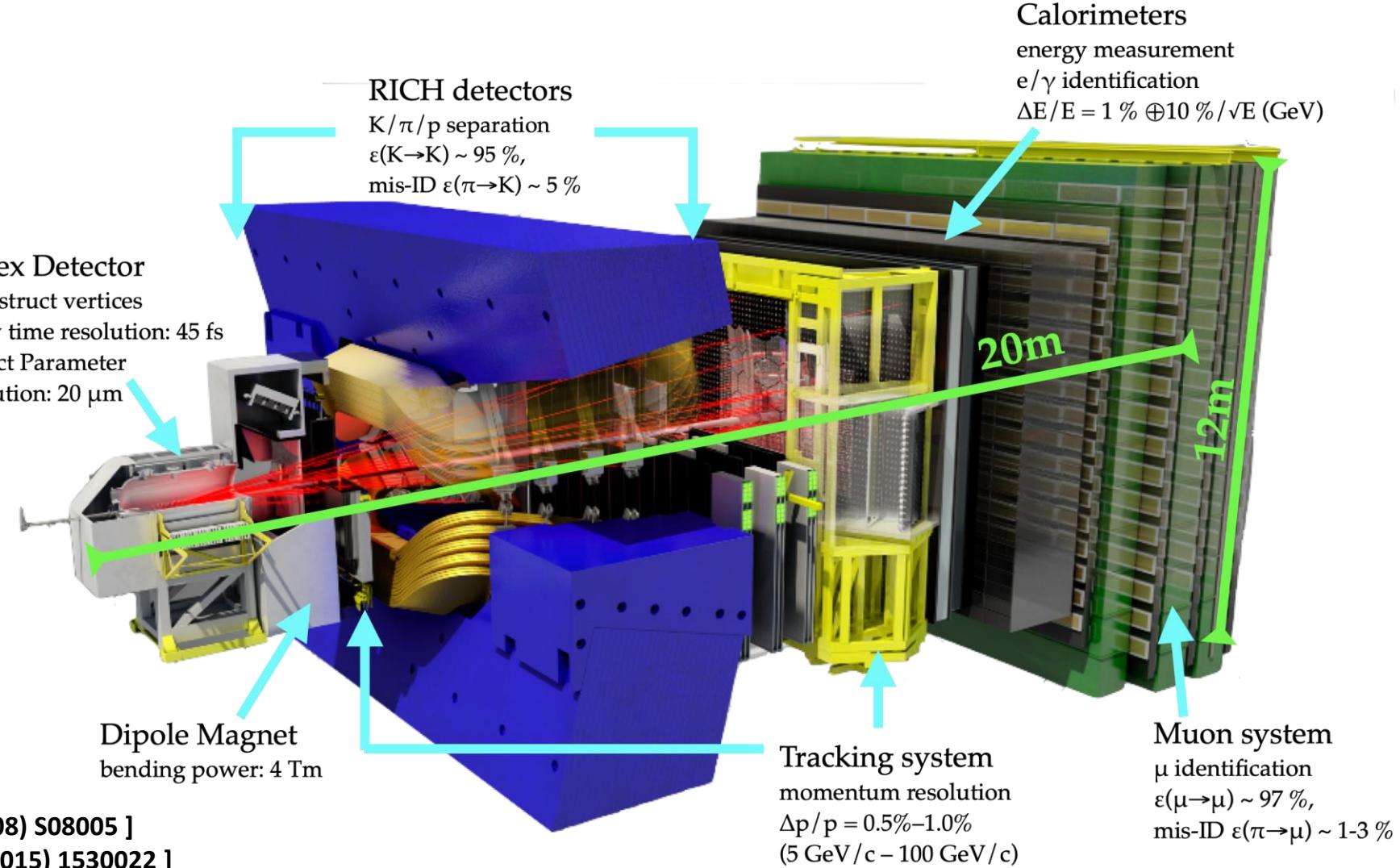
Coherent J/ψ production:
photon interact with the
whole nucleus coherently

Incoherent J/ψ production:
photon interact with
particular nucleons in the
nucleus

The LHCb detector

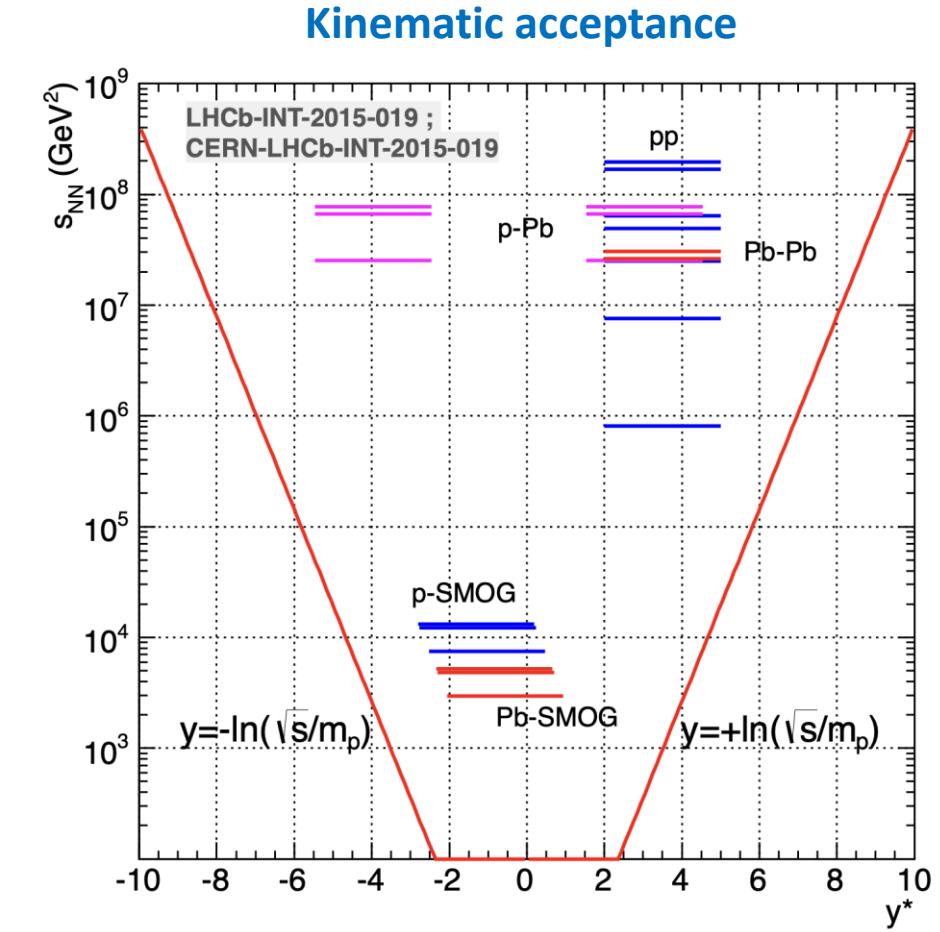
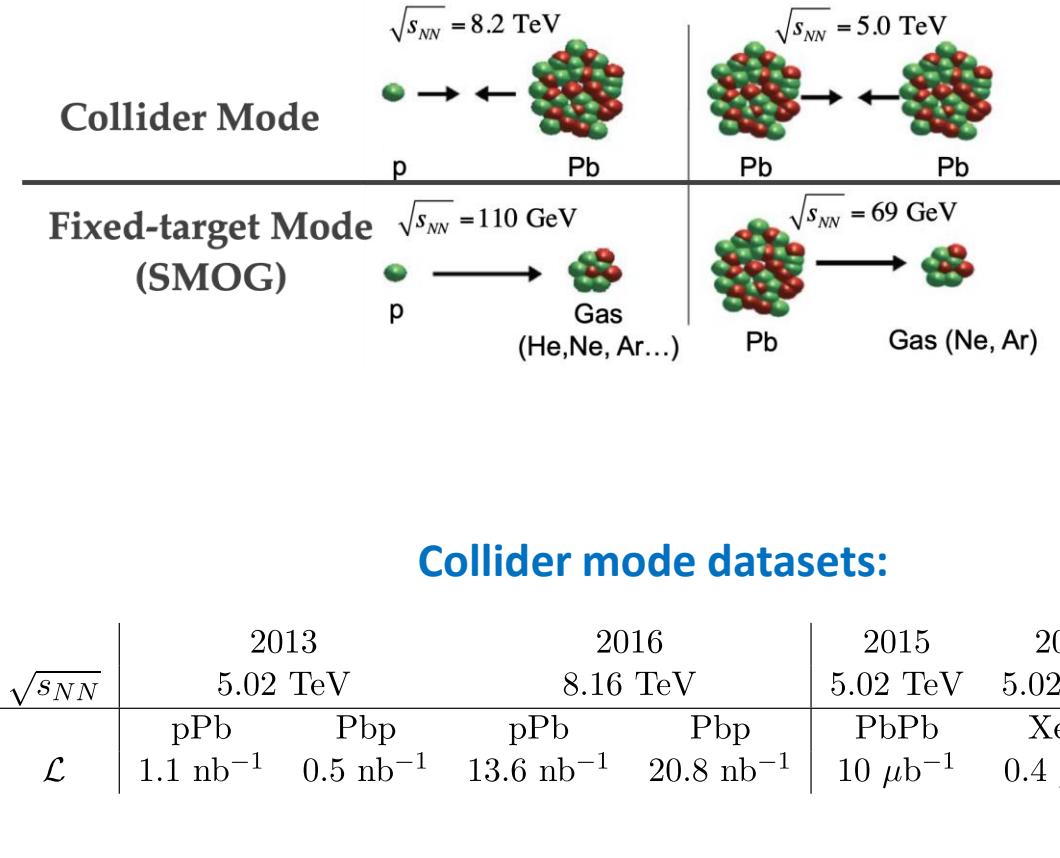
- LHCb is the only dedicated detector (at LHC) fully instrumented in forward region
- Unique kinematic coverage $2 < \eta < 5$
- A high precision device, down to very low- p_T , excellent particle ID, precise vertex and track reconstruction

[JINST 3 (2008) S08005]
[IJMPA 30 (2015) 1530022]



LHCb running modes and kinematic coverage

Both the collider mode and fixed-target mode
running at the same time



Ultra-peripheral production of Charmonium

LHCb-PAPER-2022-012, arXiv:2206.08221

- Dataset: PbPb collisions in 2018 at 5.02 TeV, $228 \pm 10 \mu\text{b}^{-1}$
- Cross-sections of coherent J/ψ and $\psi(2S)$ photon-production are measured as:

$$\frac{d\sigma_{\psi}^{\text{coh}}}{dx} = \frac{N_{\psi}^{\text{coh}}}{\mathcal{L} \times \varepsilon_{\text{tot}} \times \mathcal{B}(\psi \rightarrow \mu^+ \mu^-) \times \Delta x}$$

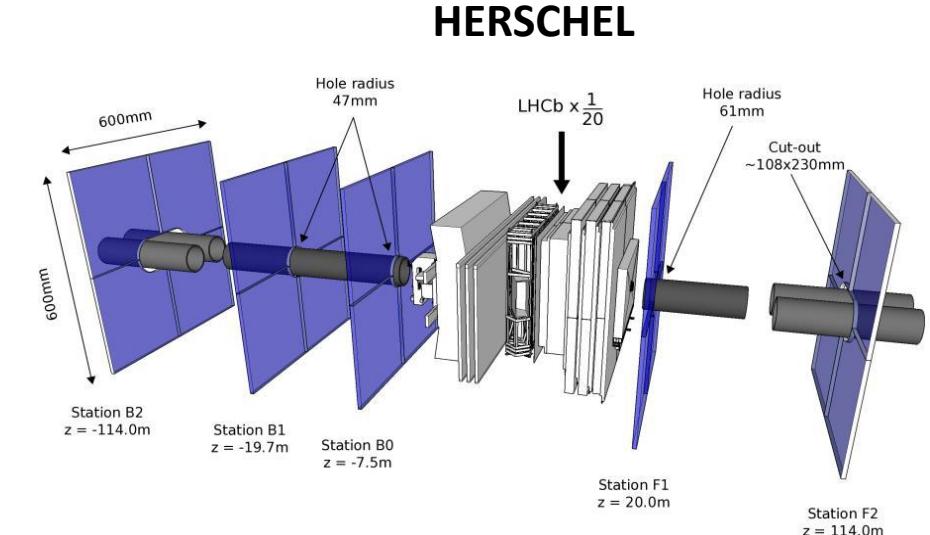
- Event selection:

- require a near empty detector with only two long tracks reconstructed, with acceptance cuts:

$$2.0 < \eta^\mu < 4.5, p_T^\mu > 700\text{MeV},$$

$$p_T^{\mu\mu} < 1\text{GeV}, |\Delta\phi_{\mu\mu}| > 0.9\pi$$

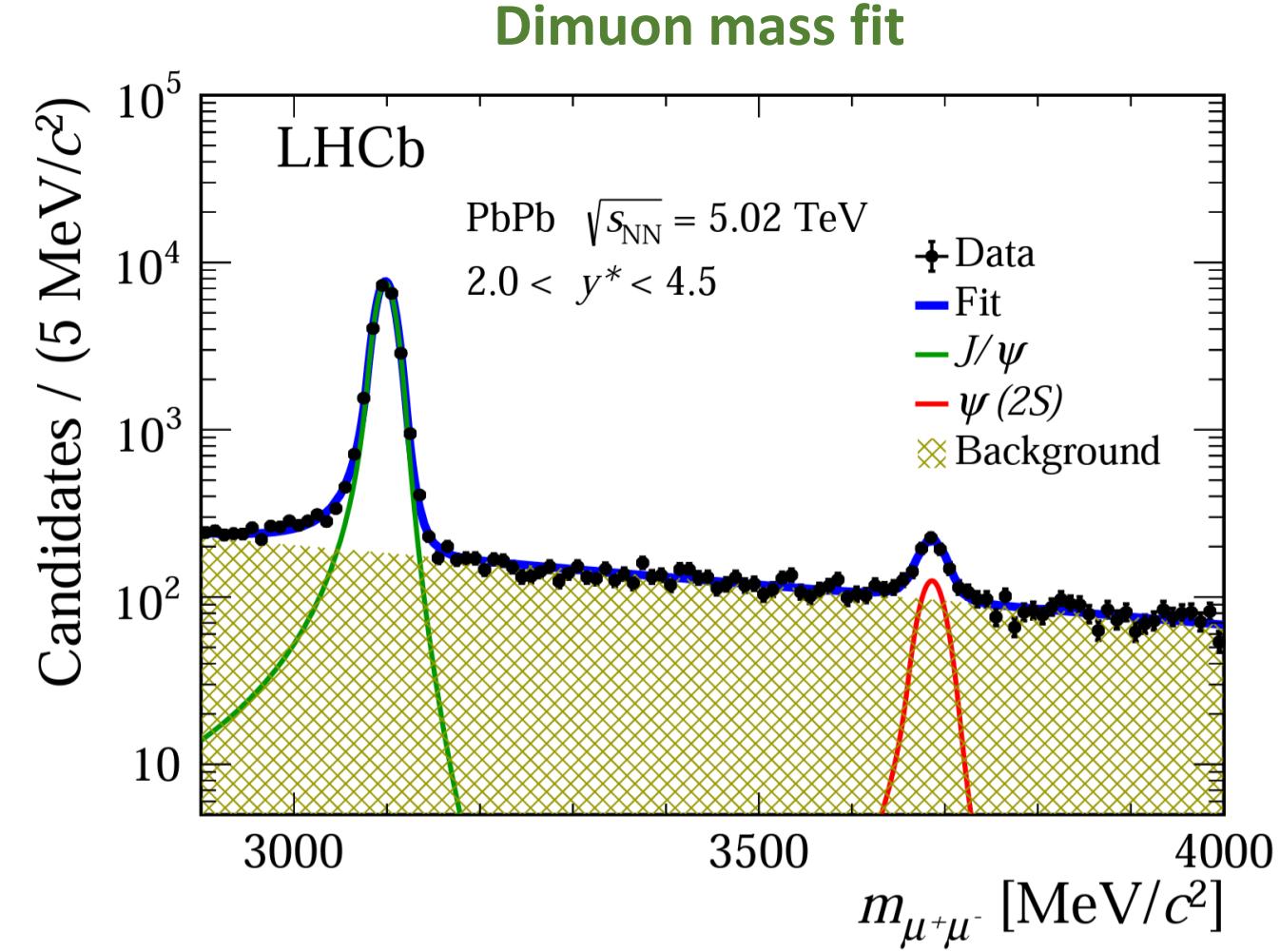
- HERSCHEL detector [JINST 13 (2018) 04 P04017] is used to further purify the selection



Signal extraction (1)

- Charmonia yields are extracted from dimuon mass fit
 - Double sided crystal ball function for the J/ψ and $\psi(2S)$ signals
 - Exponential for the non-resonance background (mainly $\gamma\gamma \rightarrow \mu\mu$ process)

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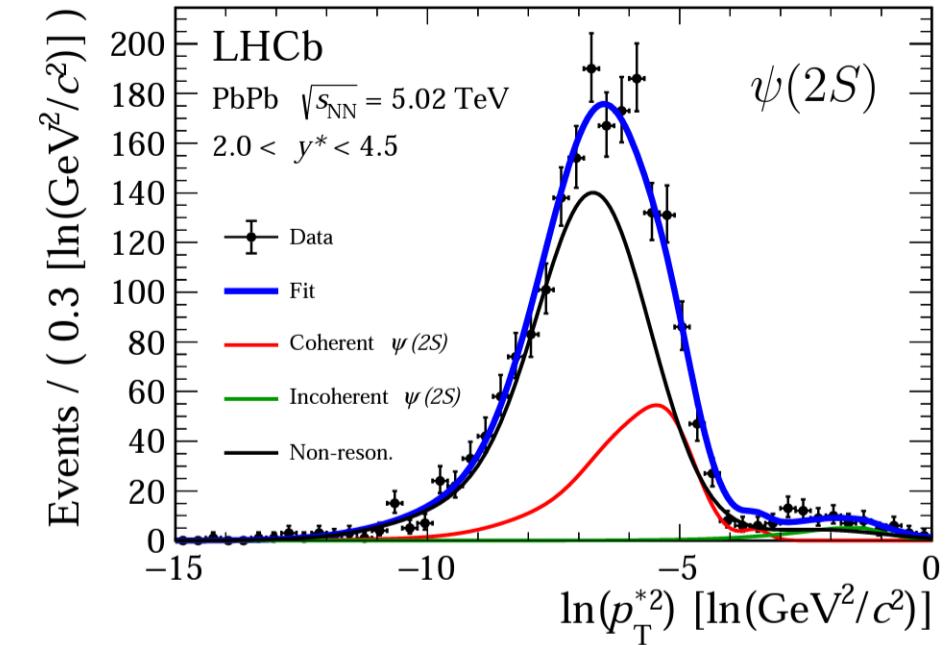
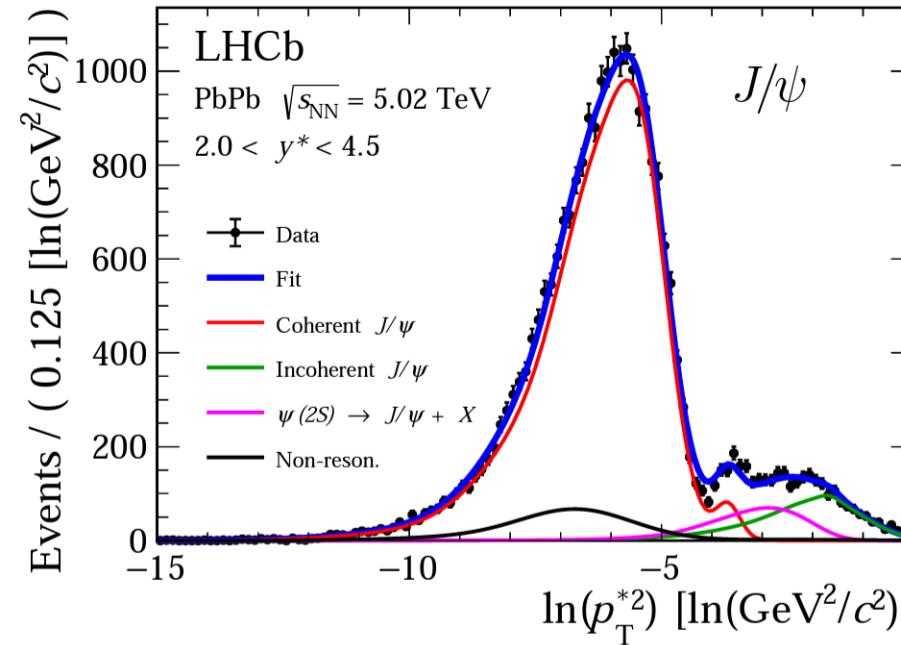


Signal extraction (2)

LHCb-PAPER-2022-012, arXiv:2206.08221

- **Coherent production signal is extracted from a $\ln(p_T^{*2})$ fit**
 - Coherent, incoherent, and feed-down shapes modelled using STARLight + EvtGen + PHOTOS + GEANT4 Simulation
 - Non-resonance shapes determined from data side-band

$\ln(p_T^{*2})$ fit



Integrated cross-section and cross-section ratio

LHCb-PAPER-2022-012, arXiv:2206.08221

- Integrated cross-section and ratio (most precise measurements in the forward region at the moment):

$$\sigma_{J/\psi}^{\text{coh}} = 5.965 \pm 0.059(\text{stat}) \pm 0.232(\text{syst}) \pm 0.262(\text{lumi}) \text{ mb},$$

$$\sigma_{\psi(2S)}^{\text{coh}} = 0.923 \pm 0.086(\text{stat}) \pm 0.028(\text{syst}) \pm 0.040(\text{lumi}) \text{ mb},$$

$$\sigma_{J/\psi}^{\text{coh}} / \sigma_{\psi(2S)}^{\text{coh}} = 0.155 \pm 0.014(\text{stat}) \pm 0.003 (\text{syst}).$$

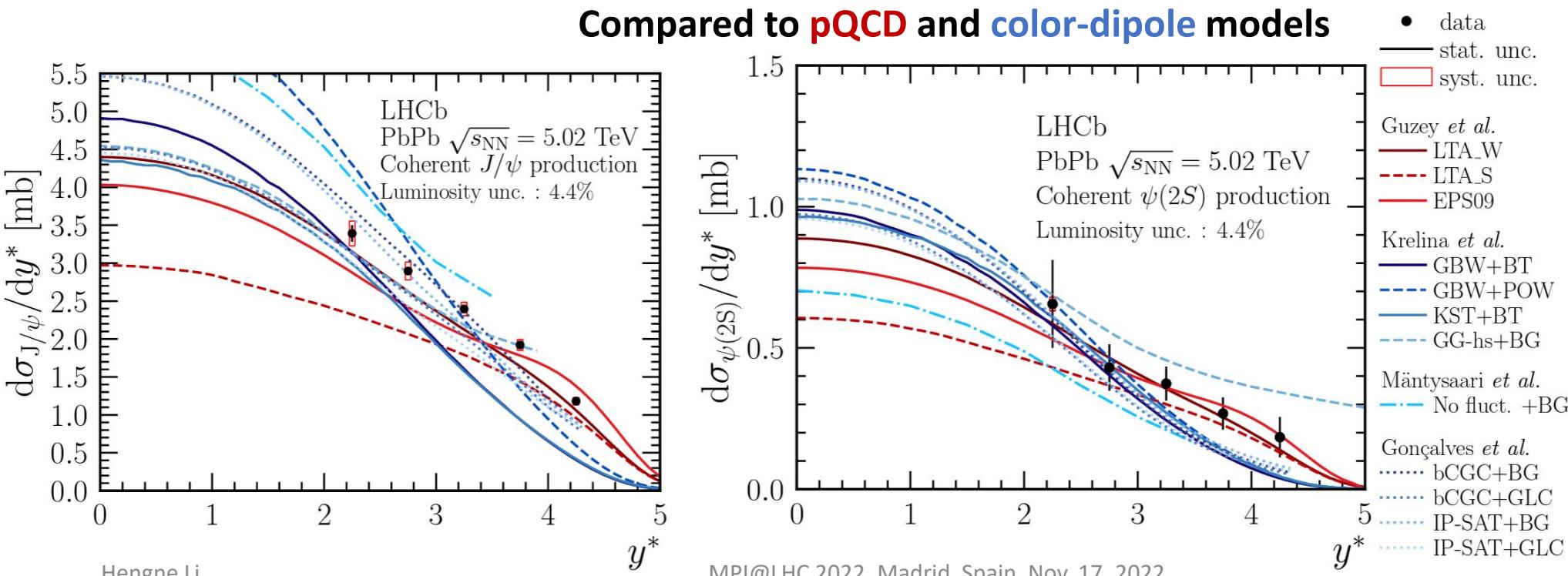
- Systematic uncertainties:

Source	Relative uncertainty [%]	
	$\sigma_{J/\psi}^{\text{coh}}$	$\sigma_{\psi(2S)}^{\text{coh}}$
Tracking efficiency	0.5–2.0	0.5–2.0
PID efficiency	0.9–1.6	0.9–1.6
Trigger efficiency	2.7–3.7	2.1–2.5
HERSCHEL efficiency	1.4	1.4
Background estimation	1.2	1.2
Signal shape	0.04	0.04
Momentum resolution	0.9–34	1.3–27
Branching fraction	0.6	2.1
Luminosity	4.4	4.4

Differential cross-section vs. rapidity

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- The most precise coherent J/ψ production measurement in PbPb UPC in forward rapidity to date
- The first coherent $\psi(2S)$ measurement in forward rapidity at the LHC



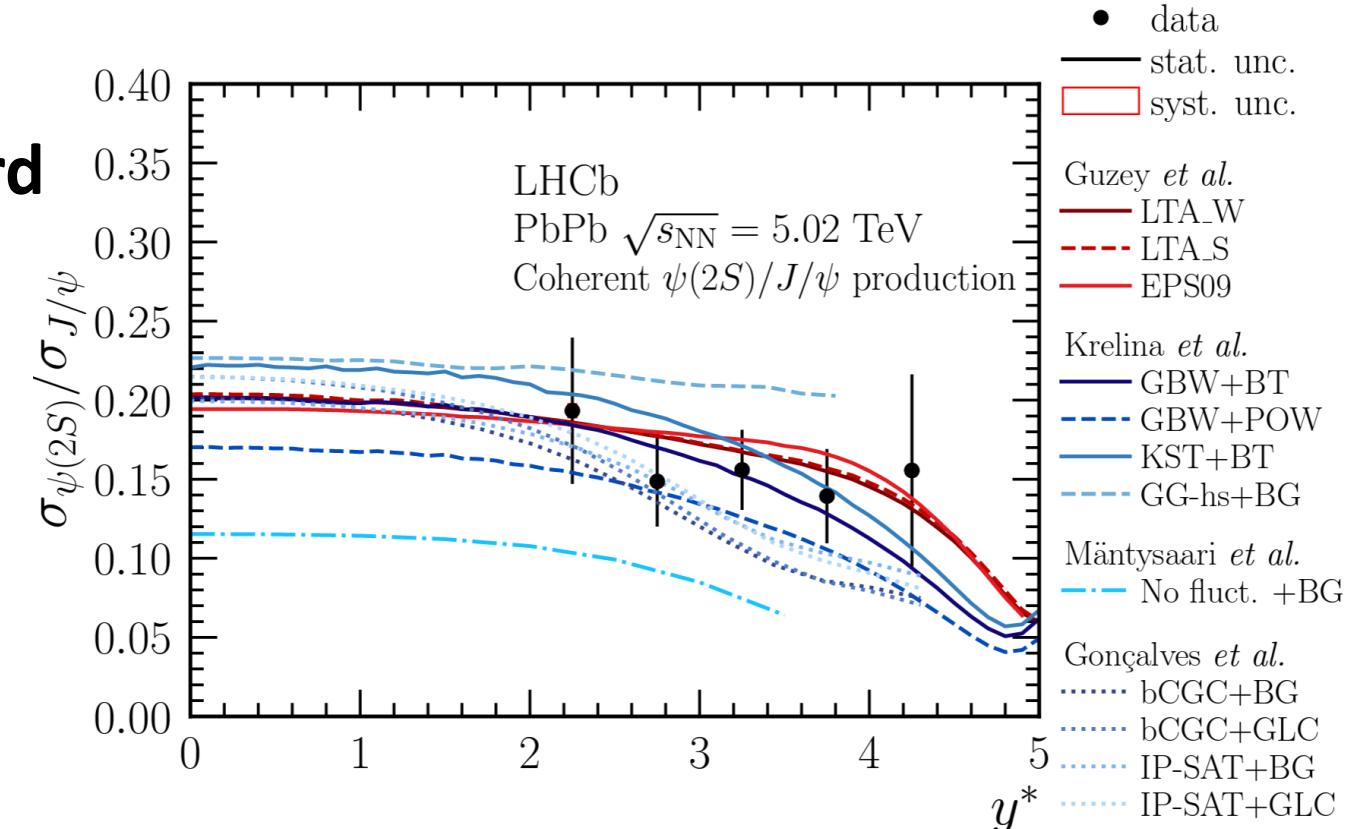
Ultra-peripheral and peripheral photon-production

LHCb-PAPER-2022-012, arXiv:2206.08221

- The first **cross-section ratio**
between J/ψ and $\psi(2S)$ vs.
rapidity measurement in forward
rapidity region at the LHC

Compared to **pQCD** and
color-dipole models

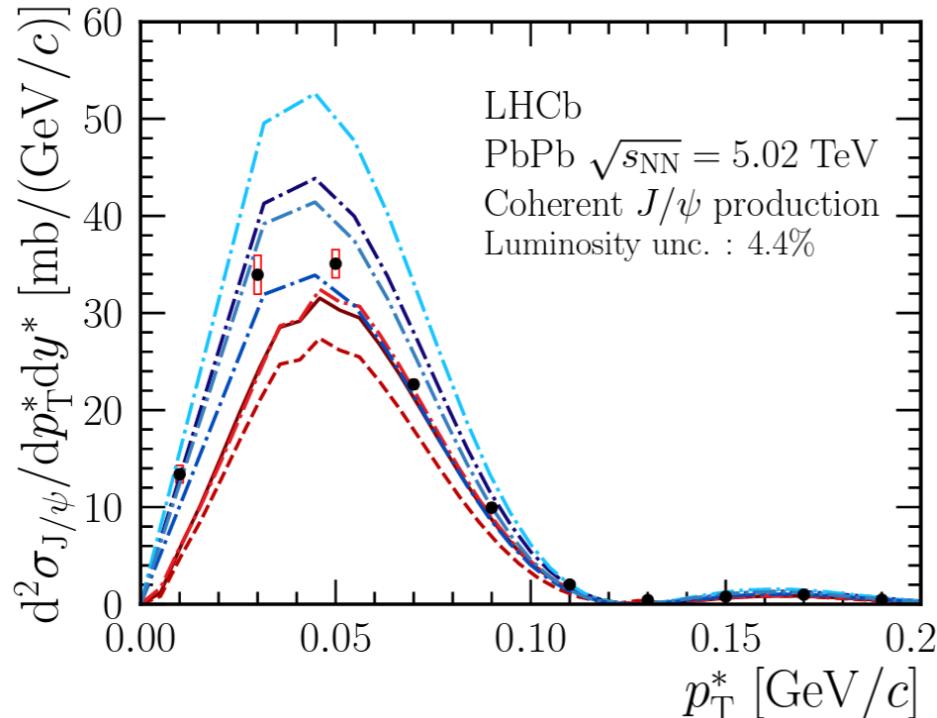
Guzey et al.: PRC 93 (2016) 055206, PRC 95 (2017) 025204,
 Krelina et al.: PRC 97 (2018) 024901, arXiv:2008.05116
 Mäntysaari et al.: PLB 772 (2017) 832, PoS DIS2014 (2014)
 069, PRD 74 (2006) 074016
 Gonçalves et al.: PRD 96 (2017) 094027, EPJC 40 (2005) 519,



Ultra-peripheral and peripheral photon-production

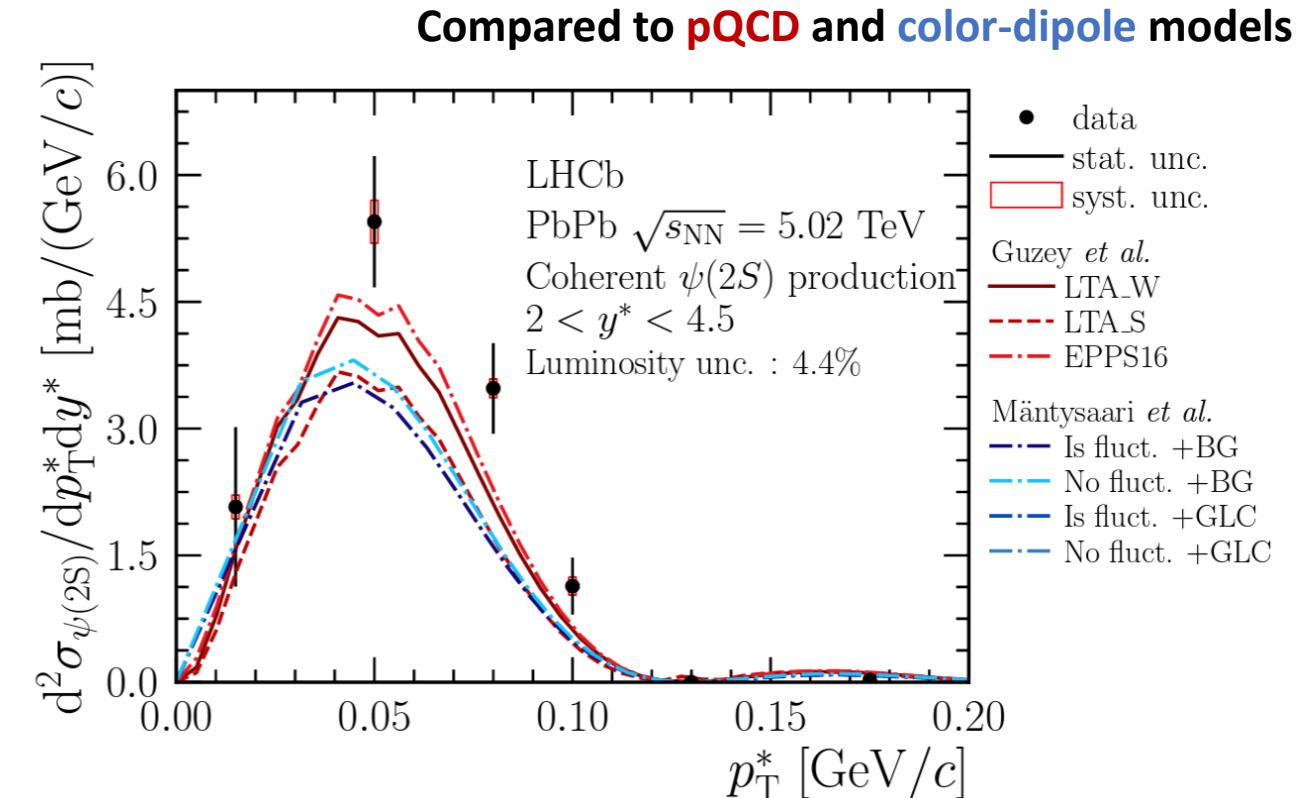
LHCb-PAPER-2022-012, arXiv:2206.08221

- The first measurement of the coherent J/ψ and $\psi(2S)$ production cross-section vs. p_T in PbPb UPC



Guzey et al.: PRC 93 (2016) 055206, PRC 95 (2017) 025204,

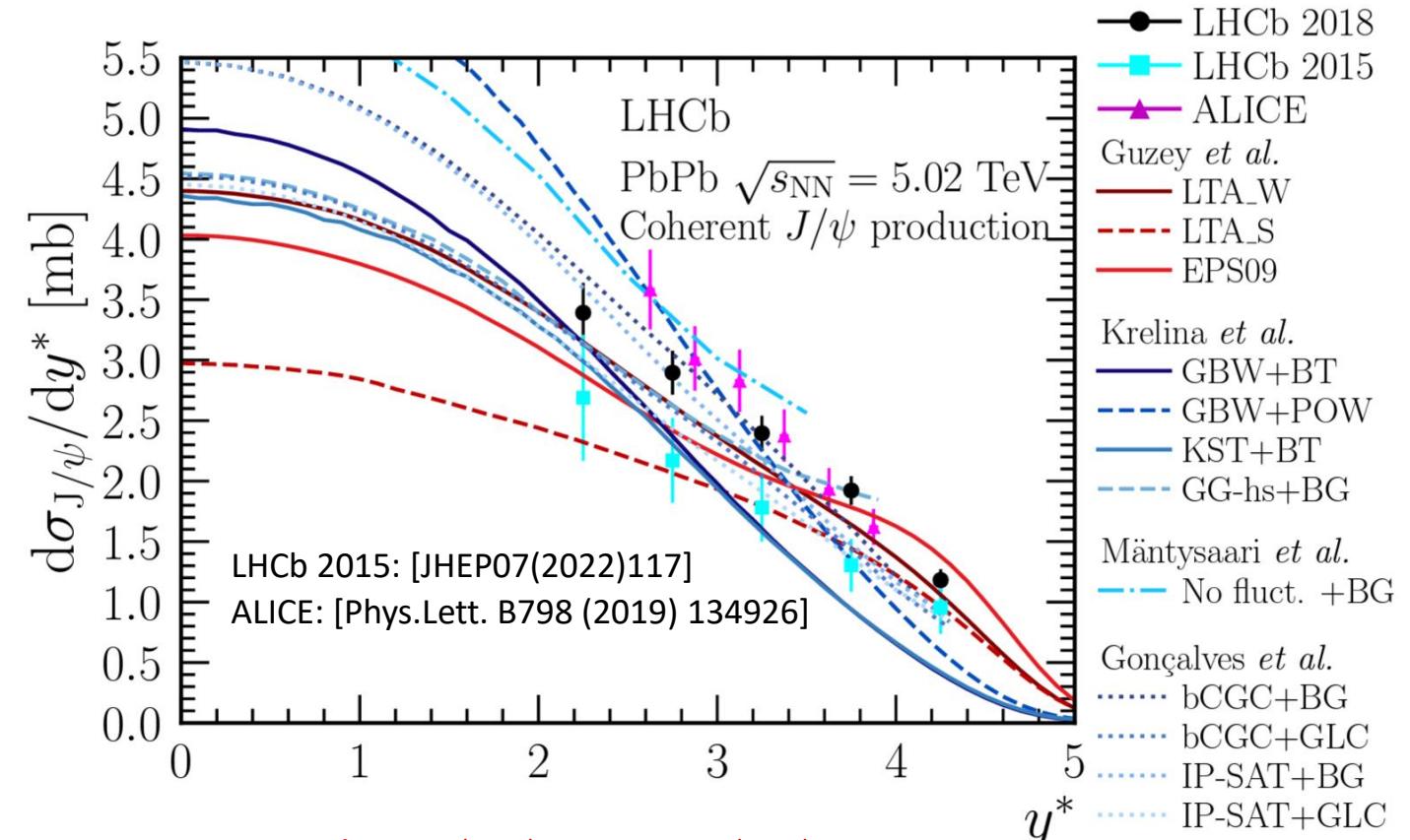
Mantysaari et al.: PLB 772 (2017) 832, PoS DIS2014 (2014) 069, PRD 74 (2006) 074016



Ultra-peripheral and peripheral photon-production

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- The J/ψ measurement is compatible with 2015 and ALICE results
 - The difference between the new results and 2015 measurement is about 2σ

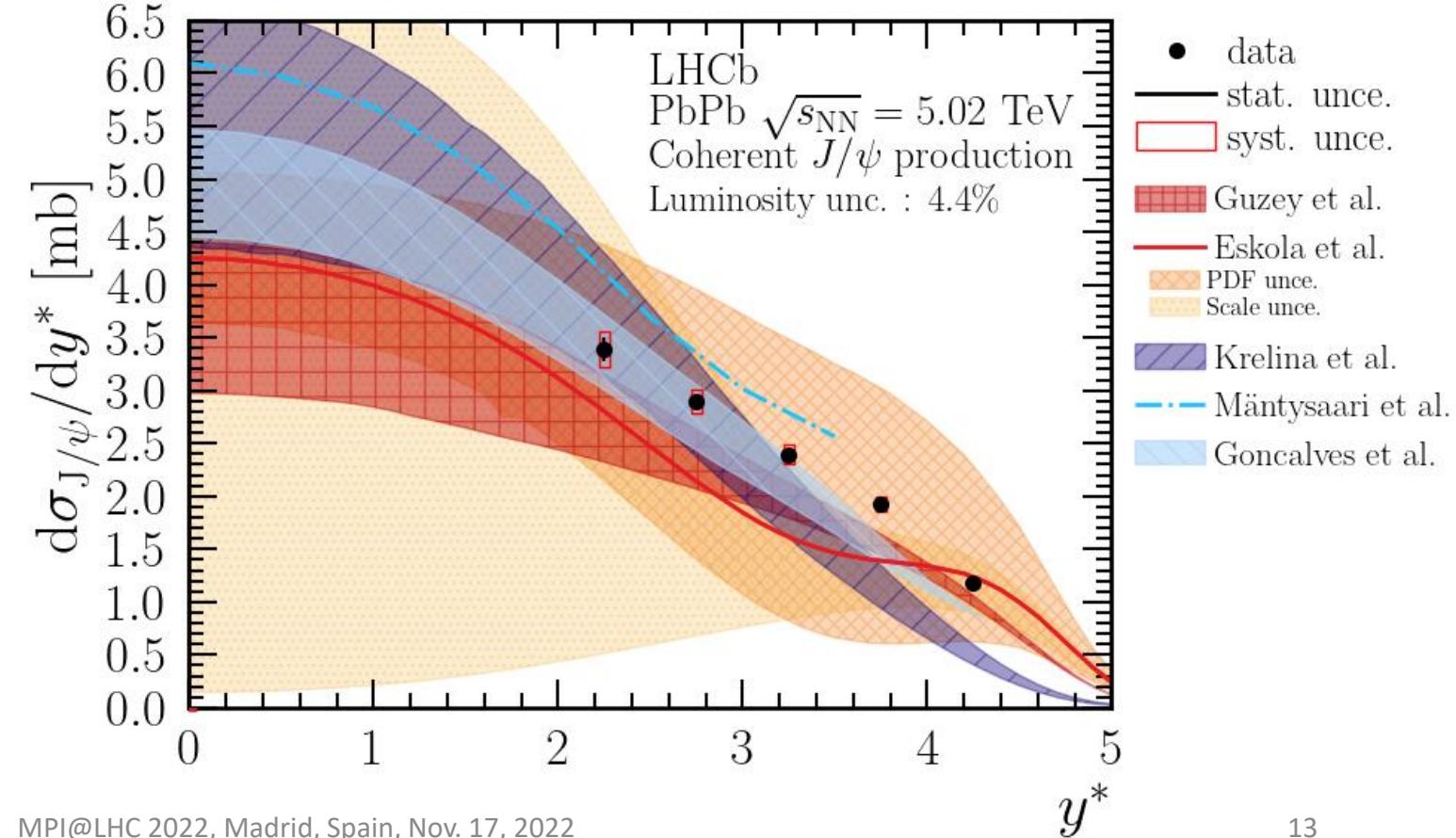


Follow up discussion on the theoretical uncertainties

LHCb-PAPER-2022-012, arXiv:2206.08221

- Update the theoretical calculations on the same plot:
 - p-QCD calculations: include new NLO p-QCD calculation (arXiv:2203.11613), PDF uncert. and factorization / renormalization scale uncert.
 - Color-dipole models: draw different model tuning options as theoretical variations
- The high precision LHCb data are of great value in theoretical model fine-tuning

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Conclusion

- A measurement of exclusive coherent J/ψ and $\psi(2S)$ production and their cross-section ratio in UPC PbPb collisions using 2018 LHCb dataset
 - The **most precise** coherent J/ψ production measurement and **the first** coherent $\psi(2S)$ measurement in forward rapidity for UPC at LHC
 - The **first** measurement of coherent J/ψ and $\psi(2S)$ production cross-section vs. p_T in PbPb UPC
- The results are compatible with current theoretical predictions, providing strong constraints for the fine-tuning of the models
- A rich program in photon-induced production studies is ongoing at LHCb



Backups

