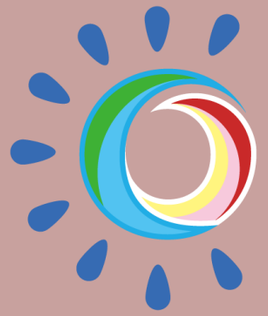


SQM2022

The 20th International Conference on Strangeness in Quark Matter
13-17 June 2022 Busan, Republic of Korea

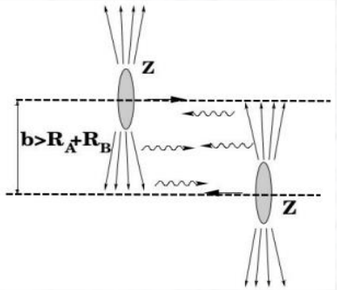
Quarkonia production in Ultraperipheral PbPb collisions at LHCb

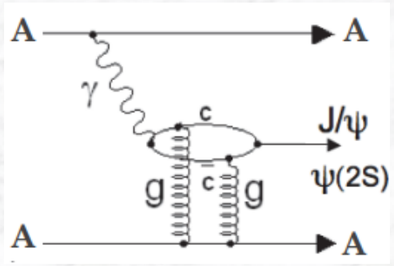
Weisong Duan

On behalf of the LHCb collaboration

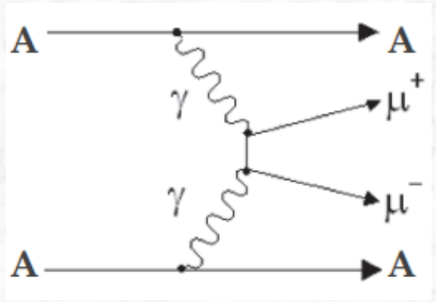
Ultra-peripheral PbPb Collisions

- Ultra-peripheral collisions: Two nuclei bypass each other with an impact parameter larger than the sum of their radii.
- Reactions in which two ions interact via their cloud of semi-real photons, reaction rates $\propto Z^2$.
- Clean background in UPC process.
- Characteristics of coherent J/ψ production has very low transverse momentum.
- Study of coherent charmonium production could constrain the gluon Parton Distribution Functions in nuclear.

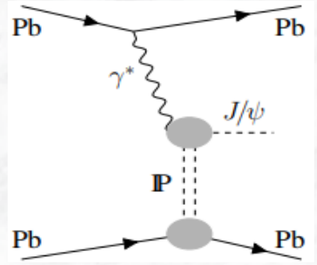




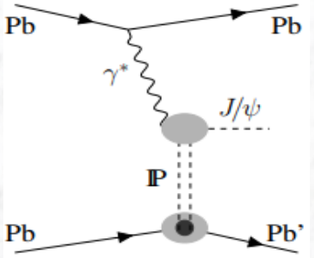
- Photon-induced quarkonium production: A $q\bar{q}$ loop created by the photon interaction with a pair of gluon exchange (pomeron) to produce a quarkonium($c\bar{c}, b\bar{b}$).



- Photon-Photon interactions



Coherent J/ψ production



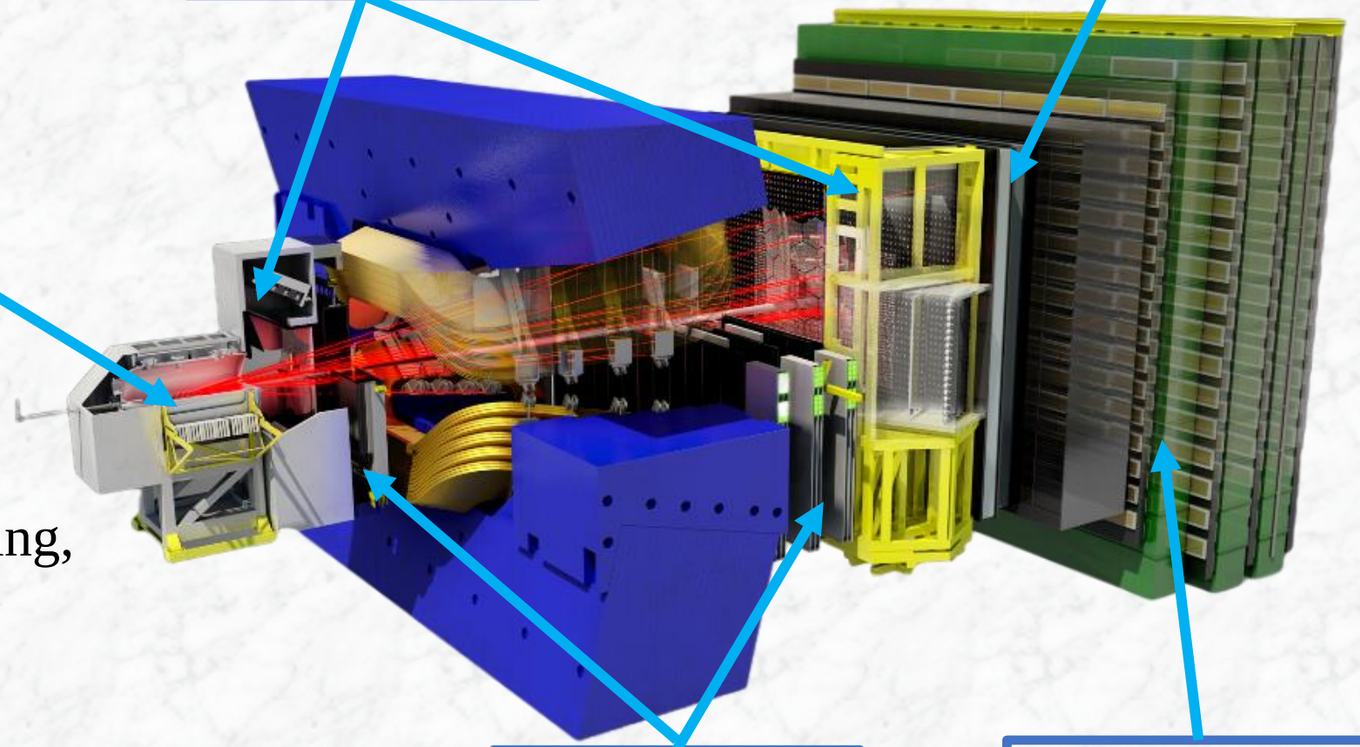
Incoherent J/ψ production

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<η<5**.

- A high precision detector, precise vertex reconstruction and tracking, high momentum resolution, excellent particle identification.



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

Calorimeters
Energy measurement
e/γ identification
$\Delta E/E = 1\% \oplus 10\%/\sqrt{E[GeV]}$

Vertex Detector
Reconstruct vertices
Decay time resolution: 45 fs
Impact parameter resolution: 20 μm

Tracking system
Momentum resolution
$\Delta p/p$ = 0.5%-1.0%
(5 GeV/c-100GeV/c)

Muon system
μ identification
$\epsilon(\mu \rightarrow \mu) \sim 97\%$,
mis-ID $\epsilon(\pi \rightarrow \mu) \sim$ 1-3%

HeRSCheL detector

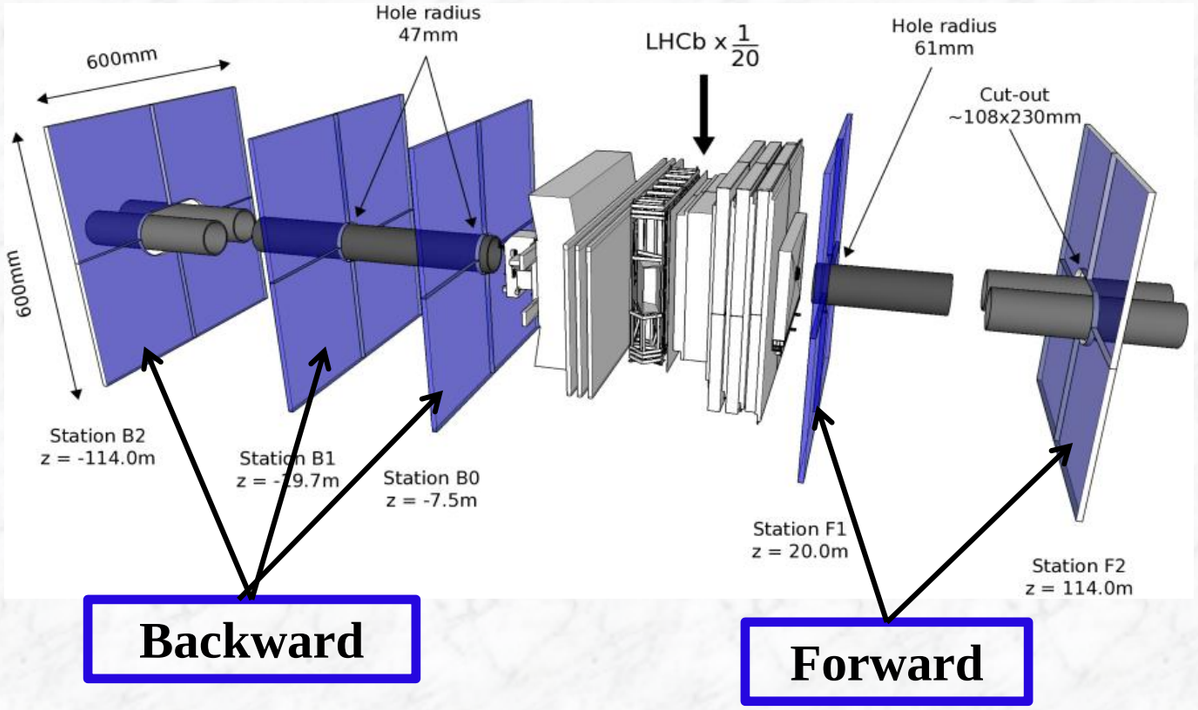
[2018 JINST 13 P04017]

- HeRSCheL(**High Rapidity Shower Counters for LHCb**), is a set of plastic scintillators located in the LHC tunnel on both sides of the LHCb interaction point, used in order to detect any activity in high pseudo-rapidity range.

- Five stations:
  - Three backwards
  - Two forwards

- Pseudo-rapidity coverage:
  - $-8.0 < \eta < -5.0$
  - $5.0 < \eta < 8.0$

- Excellent tracking down to p_T=0, cuts the large momentum components.



LHCb latest results

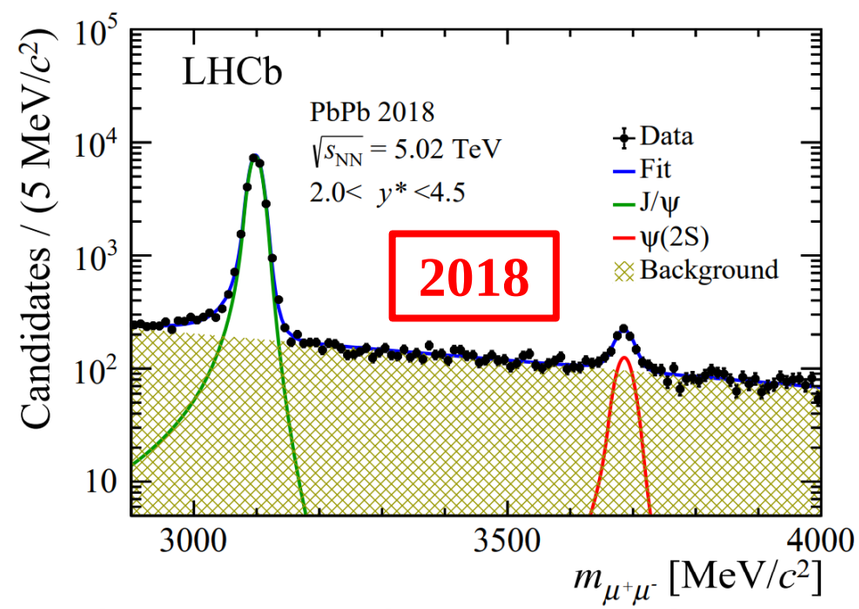
1

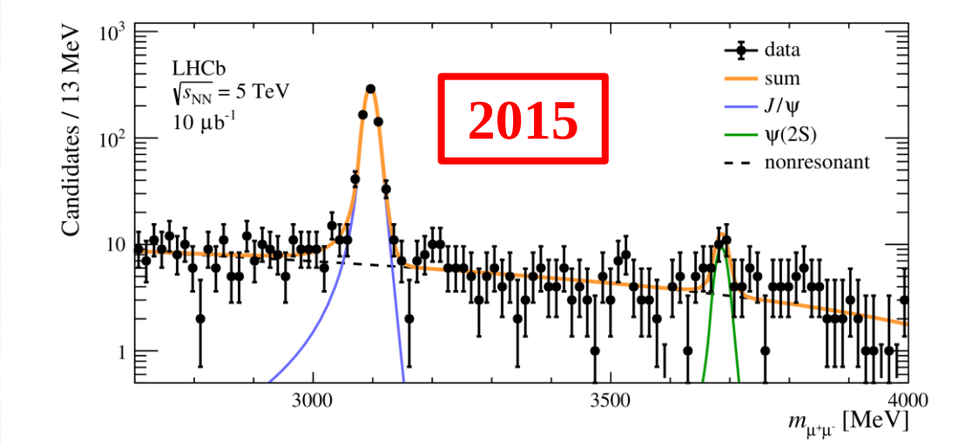
Study of charmonium production in ultra-peripheral lead-lead collisions at LHCb

[LHCb-PAPER-2022-012]
Preliminary result

Signal extraction- Dimuon mass fit

[LHCb-PAPER-2022-012]
preliminary result



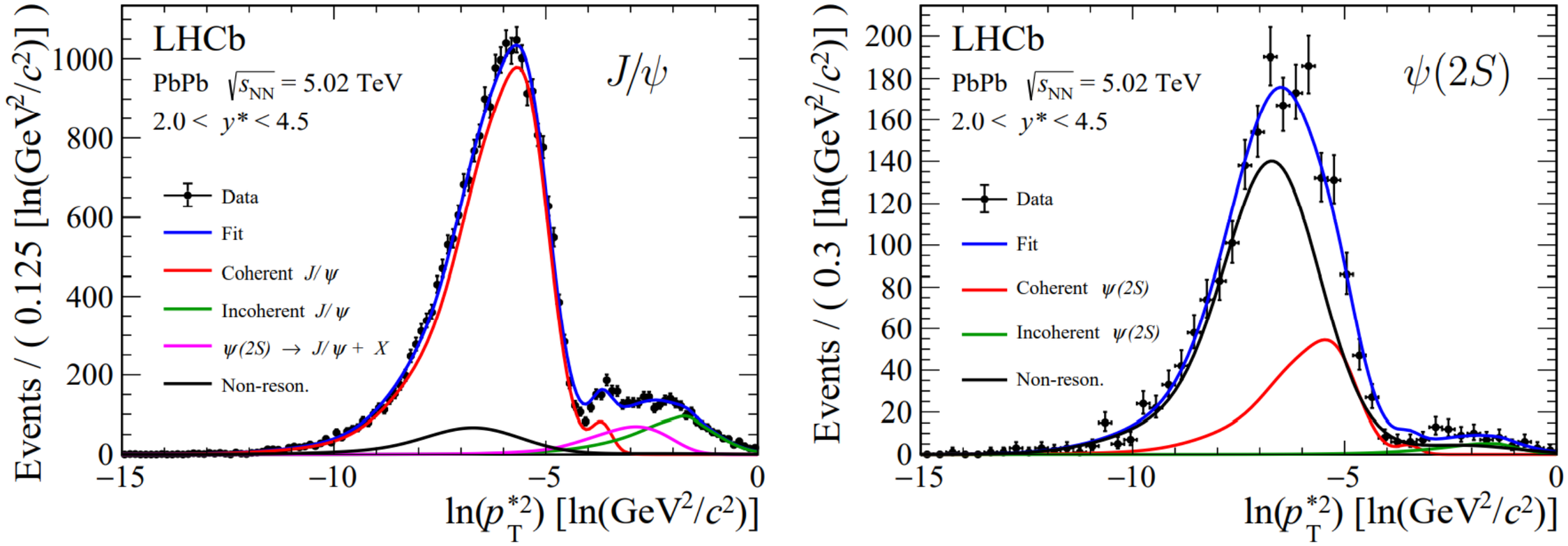


- Data recorded by the LHCb detector in PbPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV taken in 2018 with luminosity 228 $\pm$ 10 μb^{-1}.
- Candidates reconstructed with the dimuon channel:
  - Two opposite muons with $p_{\mathrm{T}} > 700$ MeV/c
  - $p_{\mathrm{T}_{\mu^+\mu^-}} < 1$ GeV/c and $\Delta\varphi^{\mu\mu} > 0.9\,\pi$
- Double-sided Crystal Ball function for the mass peaks:
  - J/$\psi \rightarrow \mu^+\mu^-$ (coherent, incoherent and feed-down components)
  - ψ(2S) $\rightarrow \mu^+\mu^-$(coherent and incoherent components)
- Exponential function for the background:

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

Signal extraction- $\ln p_T^2$ fit

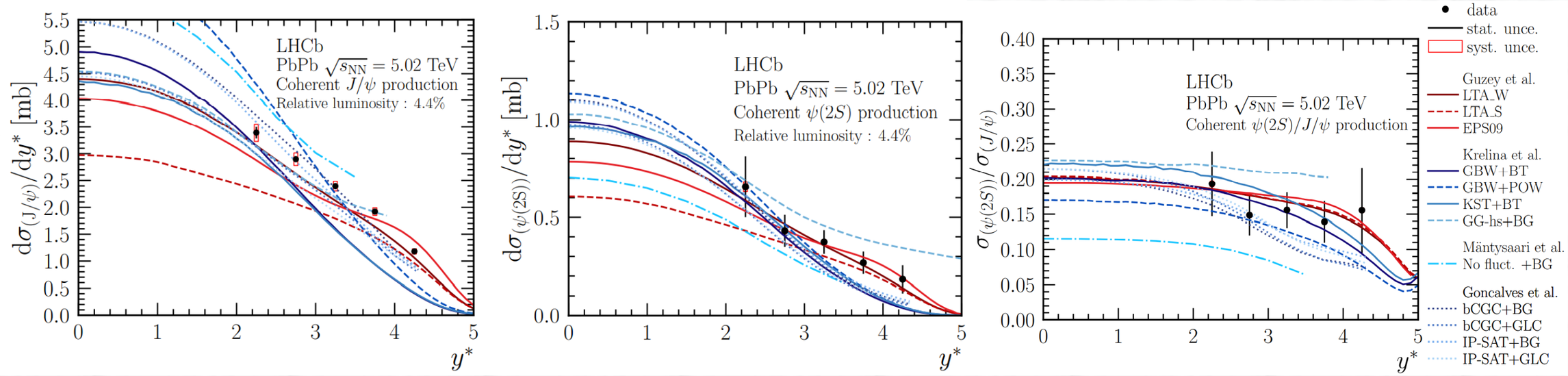
[LHCb-PAPER-2022-012]
preliminary result



- 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

[LHCb-PAPER-2022-012]
preliminary result

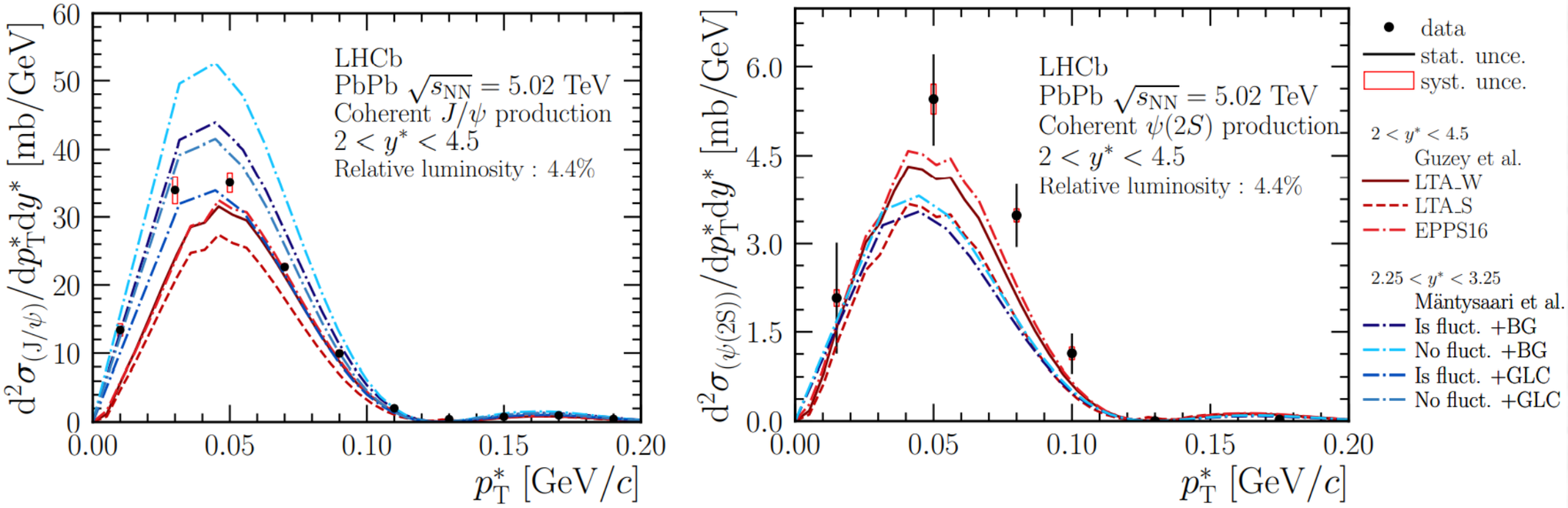


[References of models in backup]

- 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 ψ(2S) measurement in forward rapidity region at the LHC.

Charmonium production cross-section in p_{T}

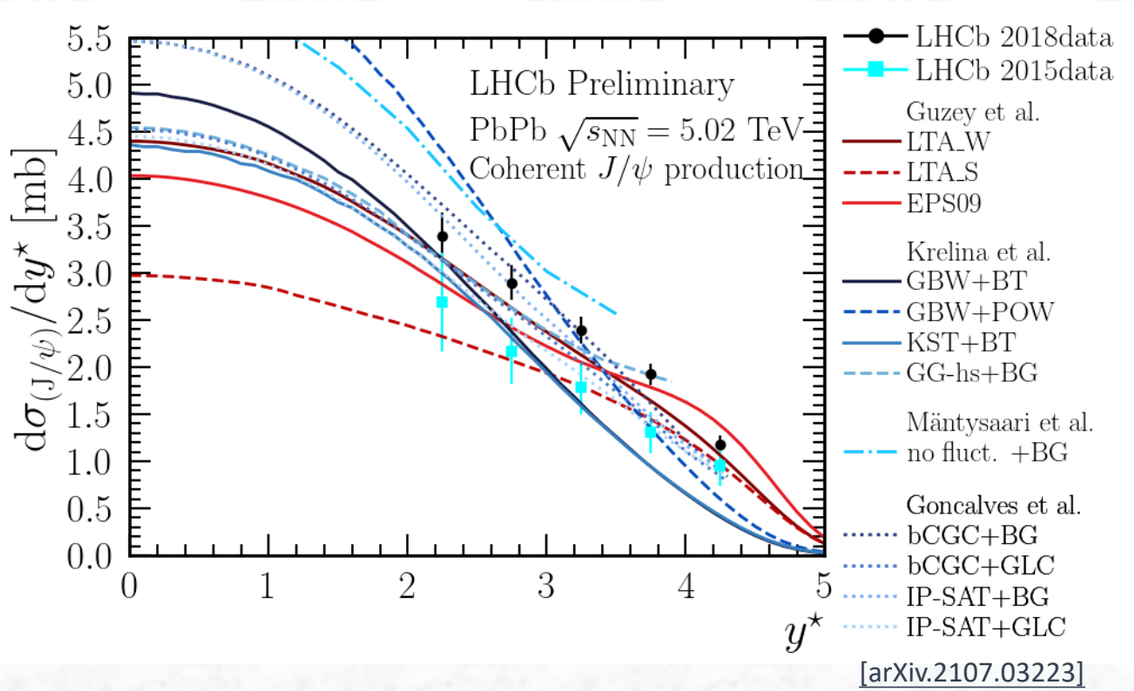
[LHCb-PAPER-2022-012]
preliminary result



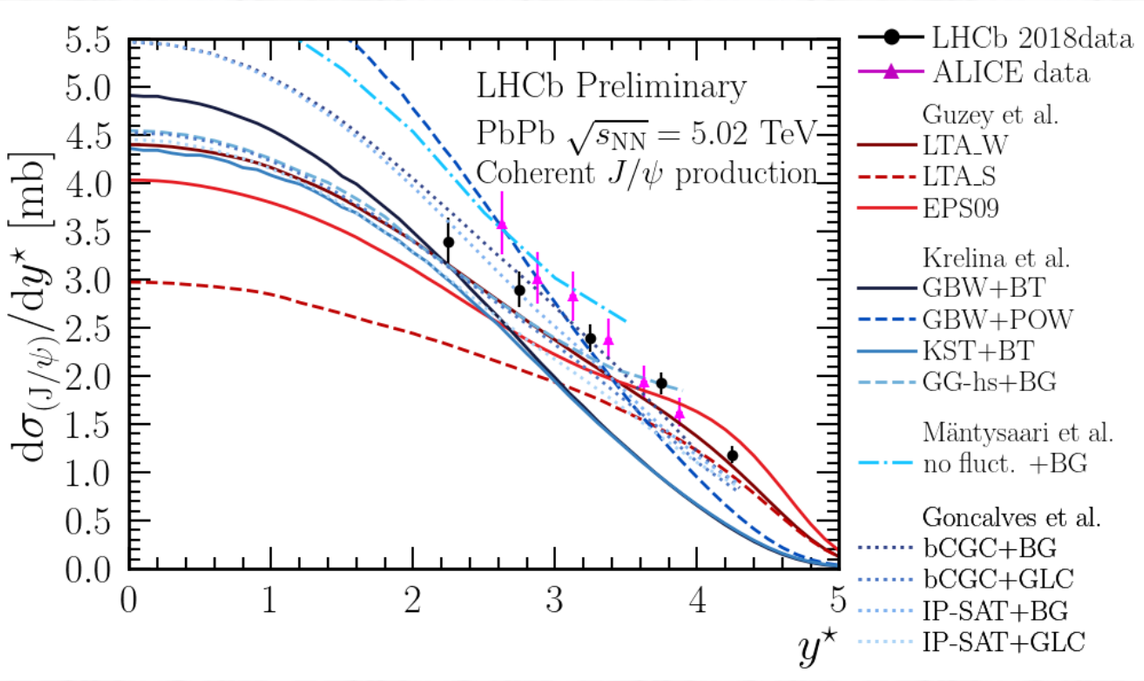
- Data compared with two theoretical predictions.
- A reasonable comparison between measurement and theoretical predictions.
- The first measurement about coherent J/ψ and ψ(2S) production cross-section vs. p_{T} in PbPb UPC.

Compare with previous results

[LHCb-PAPER-2022-012]
preliminary result



[arXiv.2107.03223]



[Phys.Lett. B798 (2019) 134926]

- Comparison with the J/ψ measurement with 2015 and ALICE results.
- The difference between new results and 2015 measurement is about 2.0σ.
- Compatible with ALICE data.

LHCb latest results

2

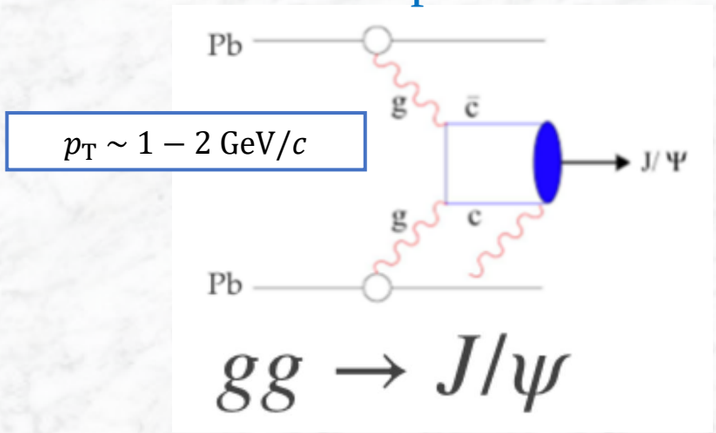
Study of J/ψ photo-production in lead-lead peripheral collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5 TeV

[arXiv:2107.03223]

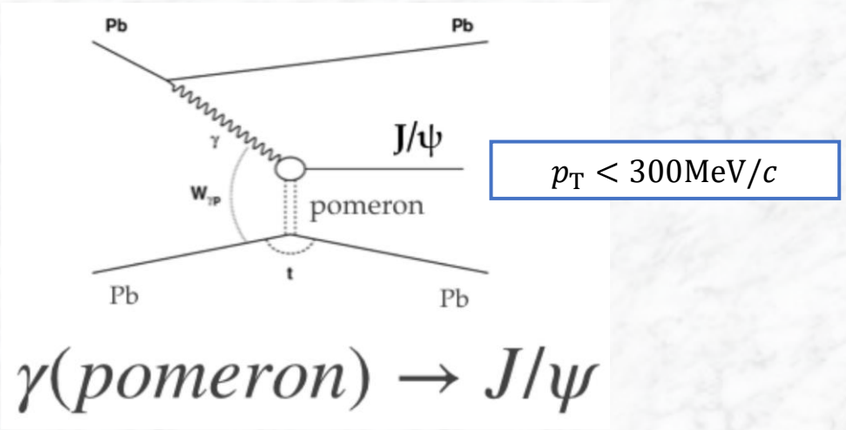
Coherent J/ψ in PbPb peripheral collisions

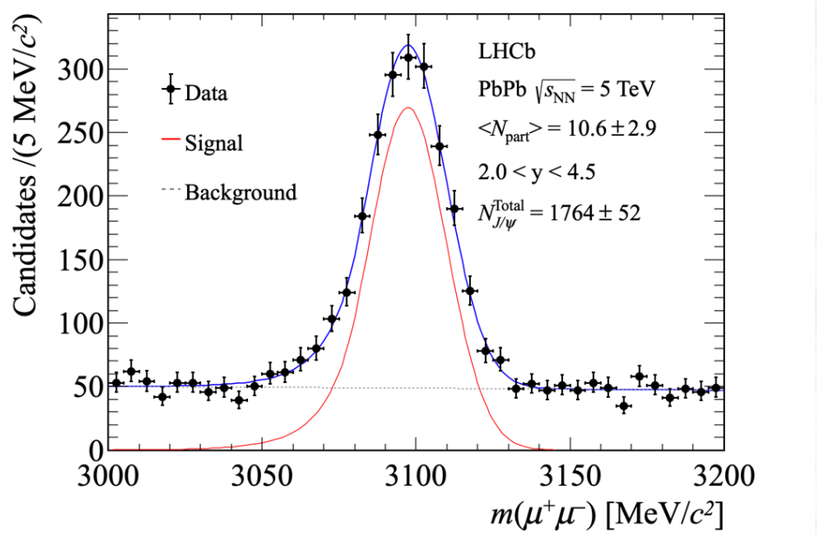
[arXiv:2107.03223]

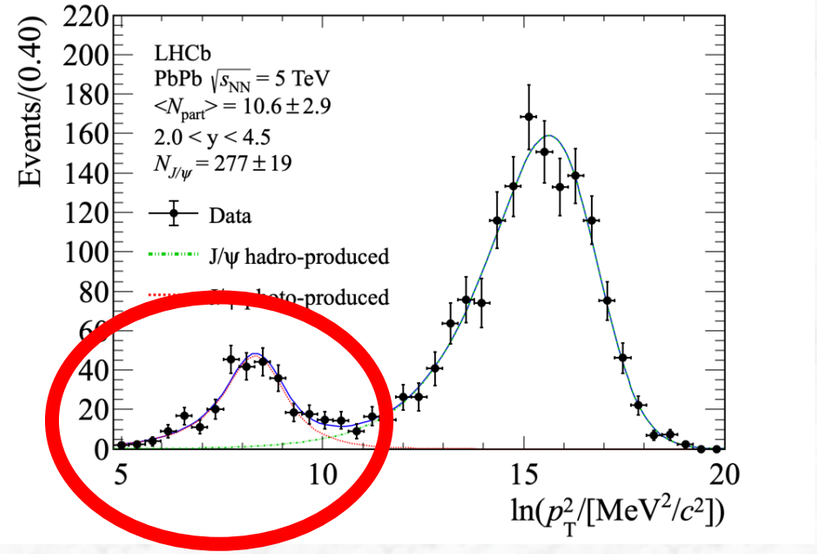
Hadronic production



Coherent photo-production





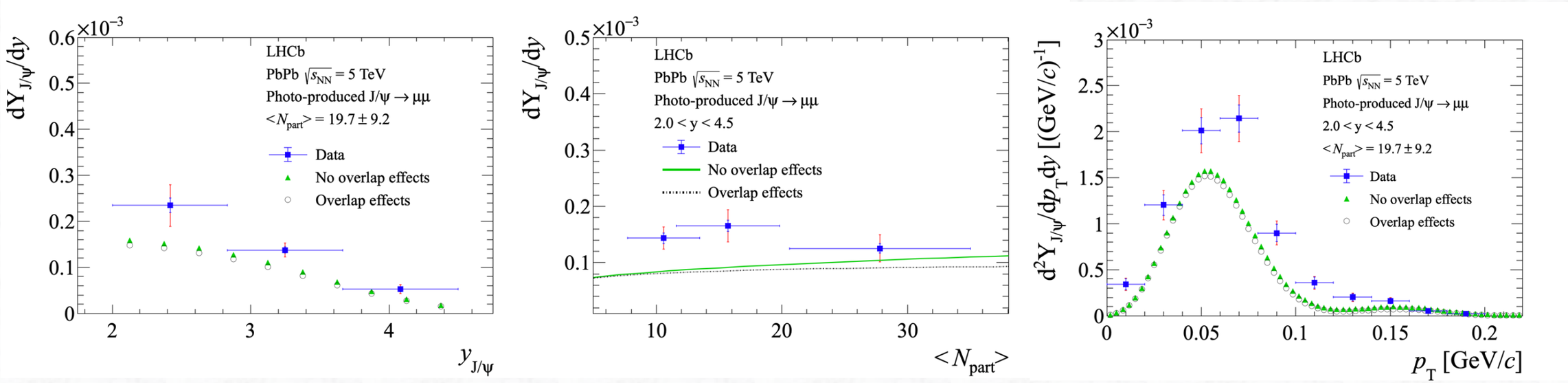


- The photo-production at low transverse momentum of inclusive J/ψ events produced in PbPb peripheral collisions ($b < 2R_{Pb}$) at $\sqrt{s_{NN}}$ = 5TeV taken in 2018 dataset, limited to 60-90% centrality.
- There is not only photo-production but also hadronic production.
- We could separate the two productions from the p_T distribution of J/ψ.

Coherent J/ψ in PbPb peripheral collisions

[arXiv:2107.03223]

- 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 over above the predictions.
- Most precise coherent J/ψ p_{T} measurement to date



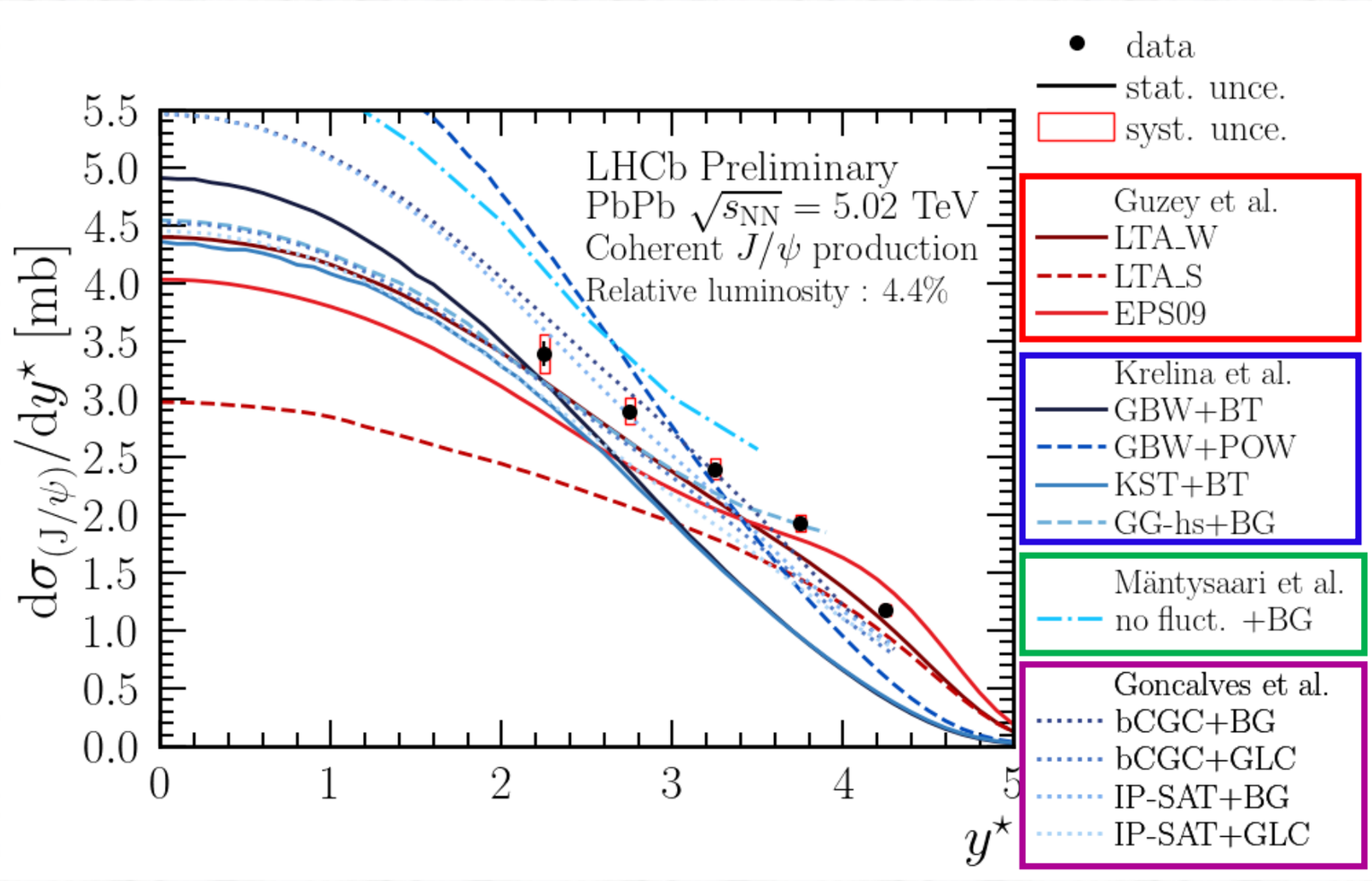
Conclusion

- Measurement of exclusive coherent J/ψ and ψ(2S) production and their cross-section ratio in UPC PbPb collisions using 2018 dataset. **[LHCb-PAPER-2022-012] [preliminary result]**
  - First coherent ψ(2S) measurement in forward rapidity region for UPC at LHC.
  - First measurement about coherent J/ψ and ψ(2S) production cross-section vs. p_T in PbPb UPC.
  - The difference about coherent J/ψ cross-section production between 2018 and 2015 results at LHCb and the ALICE results.
- Measurement of photo-produced J/ψ mesons in peripheral PbPb collisions using 2018 dataset. **[arXiv:2107.03223]**
  - First result using PbPb hadronic collisions in LHCb.
  - Most precise coherent J/ψ p_T measurement to date.

Thanks!

Back up

Charmonium production cross-section in rapidity

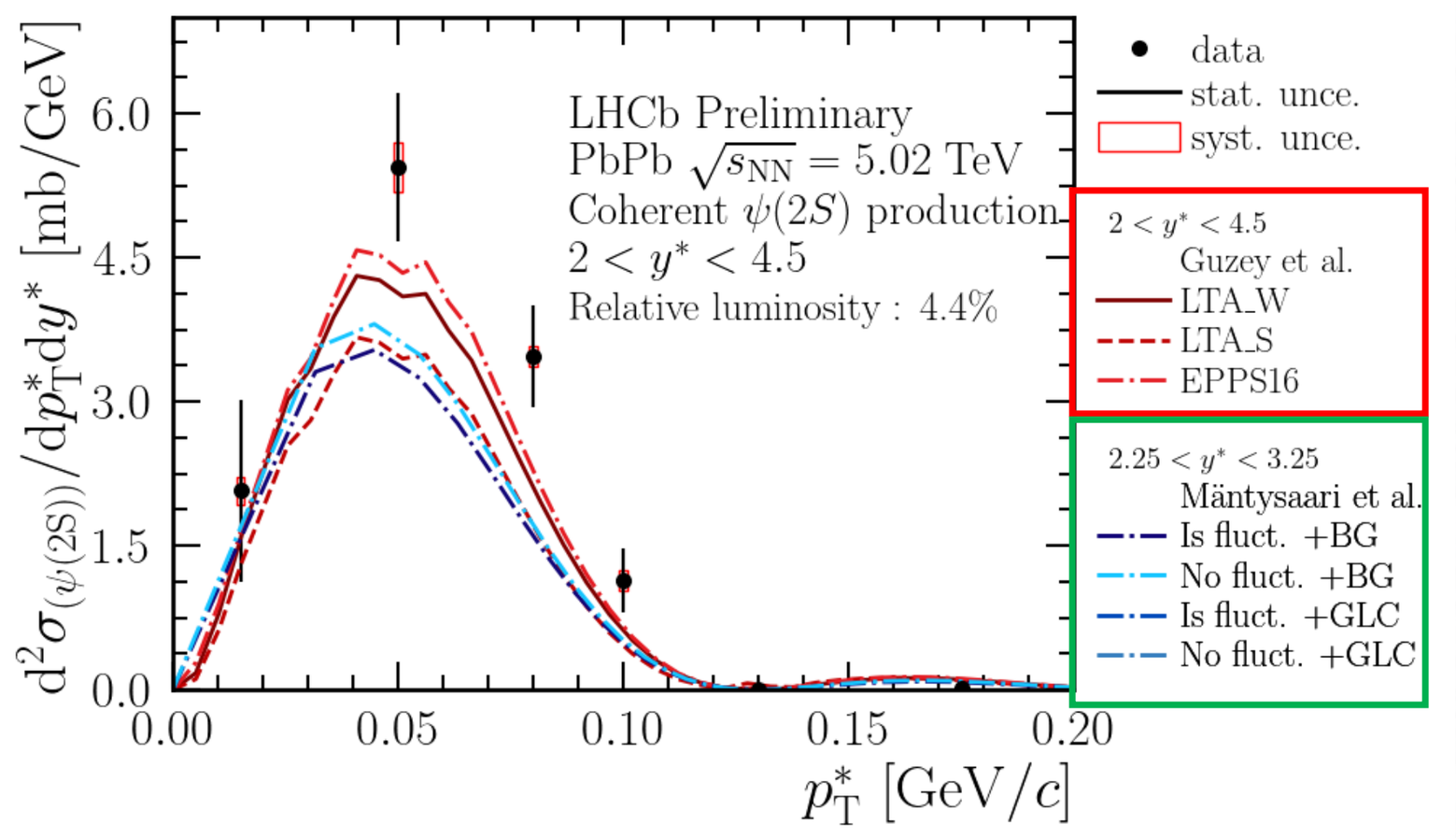


[LHCb-PAPER-2022-012]
preliminary result]

- pQCD calculations:
  - [PRC 93 (2016) 055206]
- Color dipole models:
  - [PRD 97 (2018) 024901]
  - [arxiv:2008.05116]
  - [Physics Letters B 772 (2017) 832–838]
  - [PRD 96 (2017) 094027]
  - [EPJC 40 (2005) 519]

Charmonium production cross-section in p_T

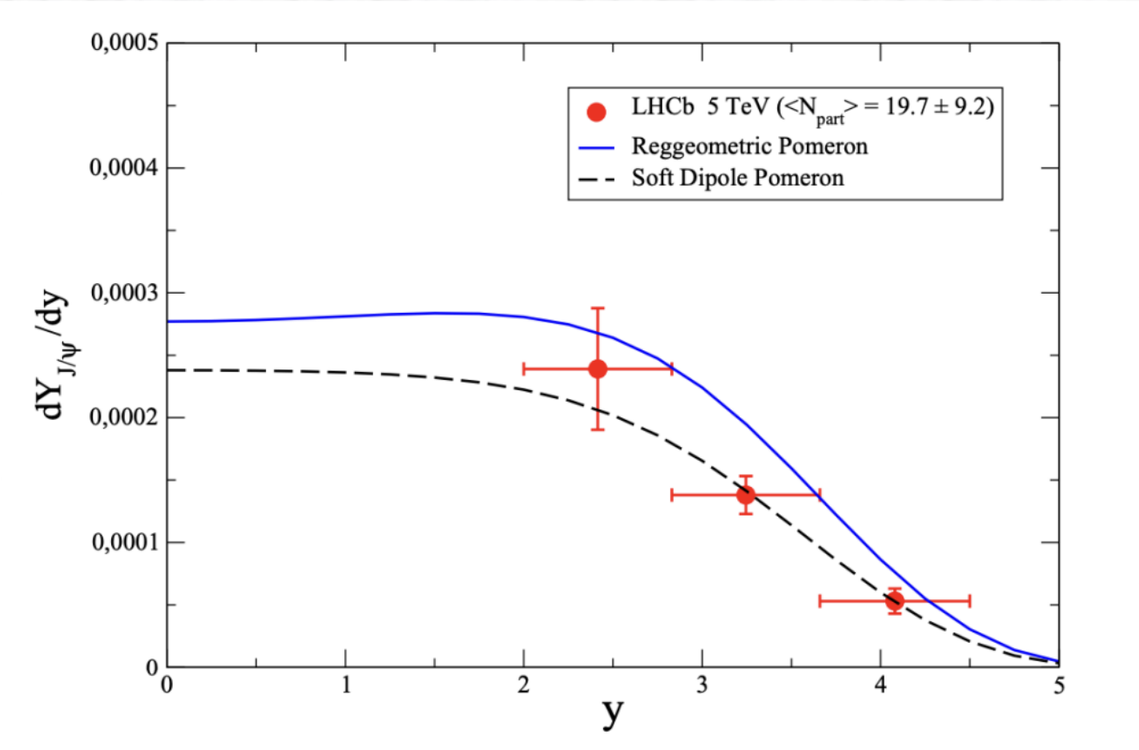
[LHCb-PAPER-2022-012]
preliminary result]



- pQCD calculations:
  - [PRC 95 (2017) 0252064]
- Color dipole models:
  - [arxiv:1406.2877]

Coherent J/ψ 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.