Quarkonia Production in (Ultra)peripheral PbPb collisions at LHCb

Samuel Belin, on behalf of the LHCb collaboration

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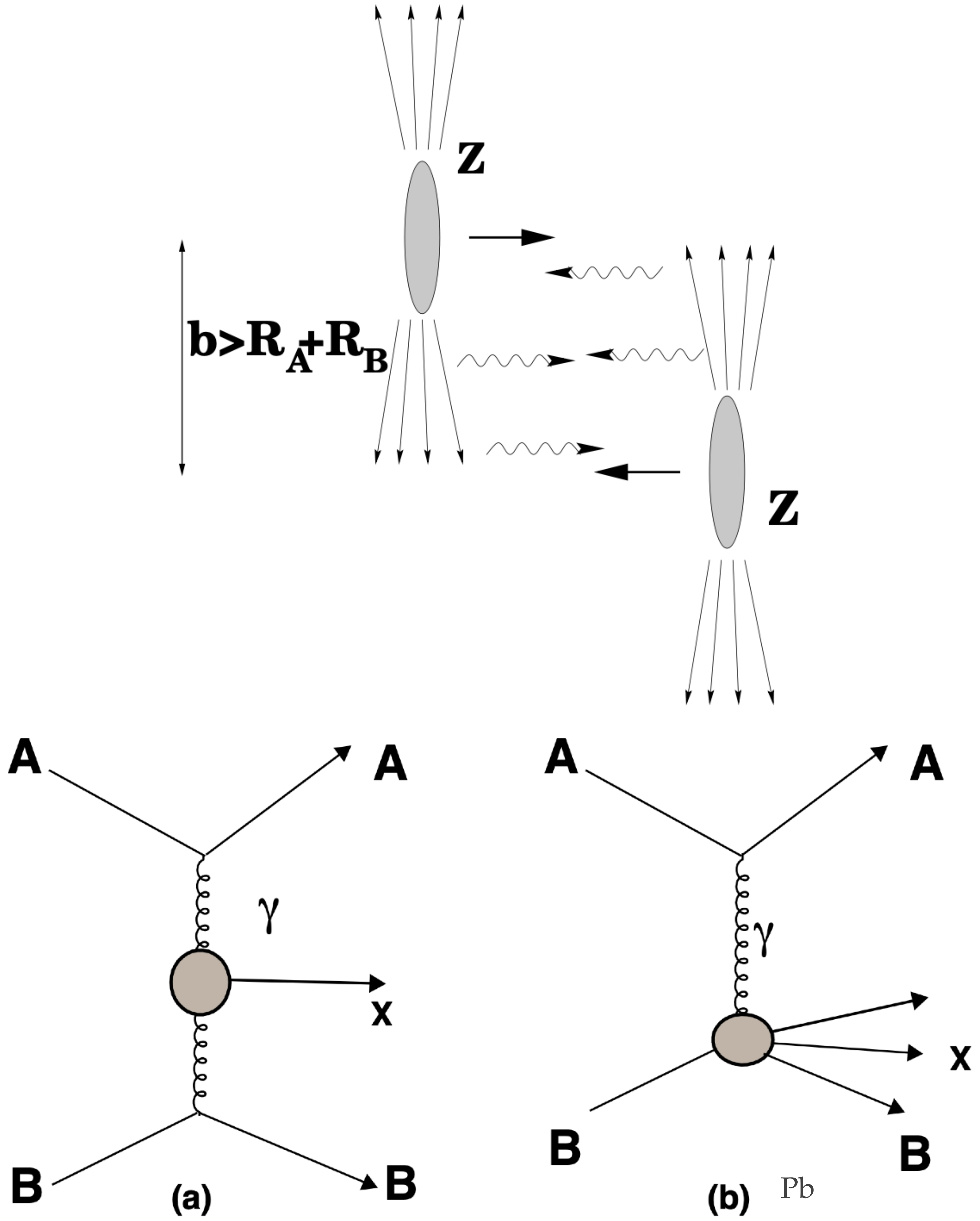
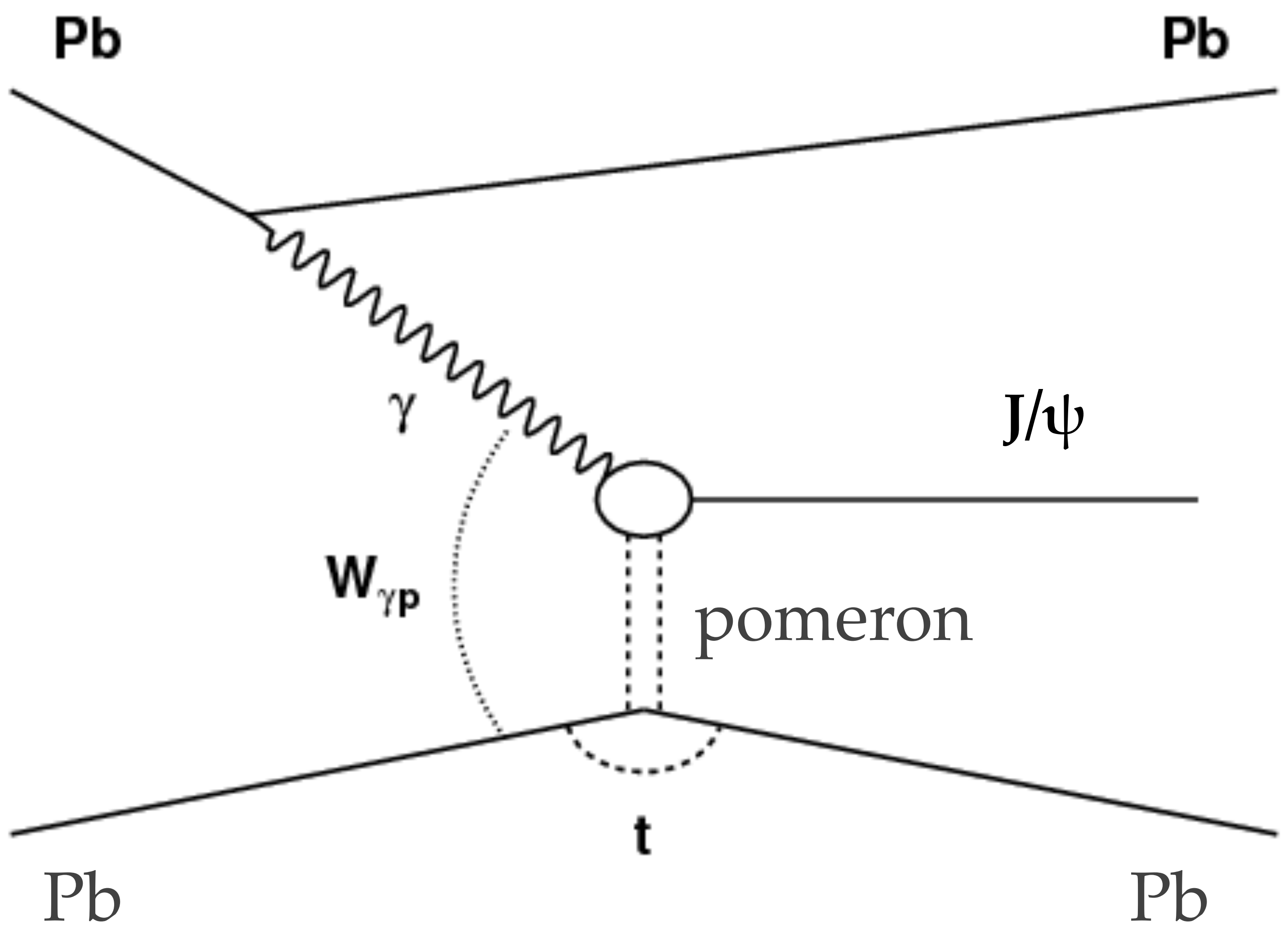
PbPb Ultra-Peripheral Collisions (UPC)

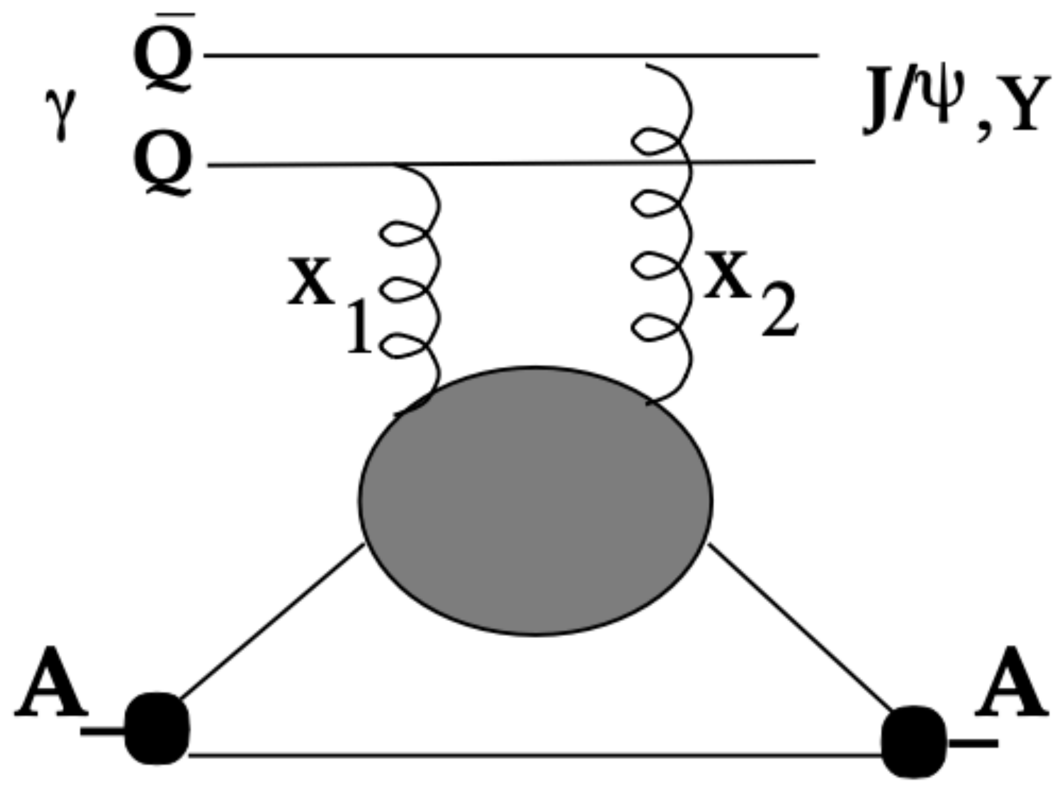


- Impact parameter $b>R_1+R_2$
- Interaction between two nuclei with no actual hadronic collisions
- No destruction of the nuclei A+A->A+A+X
- Interaction through the quasi real-photon cloud from one or both nuclei.
- Large reaction rate as photon flux $\propto Z^2$
- Production of dileptons, vector mesons…

PbPb Ultra-Peripheral Collisions (UPC)

Coherent photo-production





- Production of vector mesons through the interaction of a photon and a pomeron
- Amplitude of quarkonium production proportional to the Generalized Parton Distribution functions (GPDs) of the target nucleus $G_A(x_1, x_2, t, Q^2_{eff})$ at large momentum transfer $Q^2_{eff} \propto m^2_Q/4$ and low x-Bjorken $10^{-5} < x < 10^{-2}$

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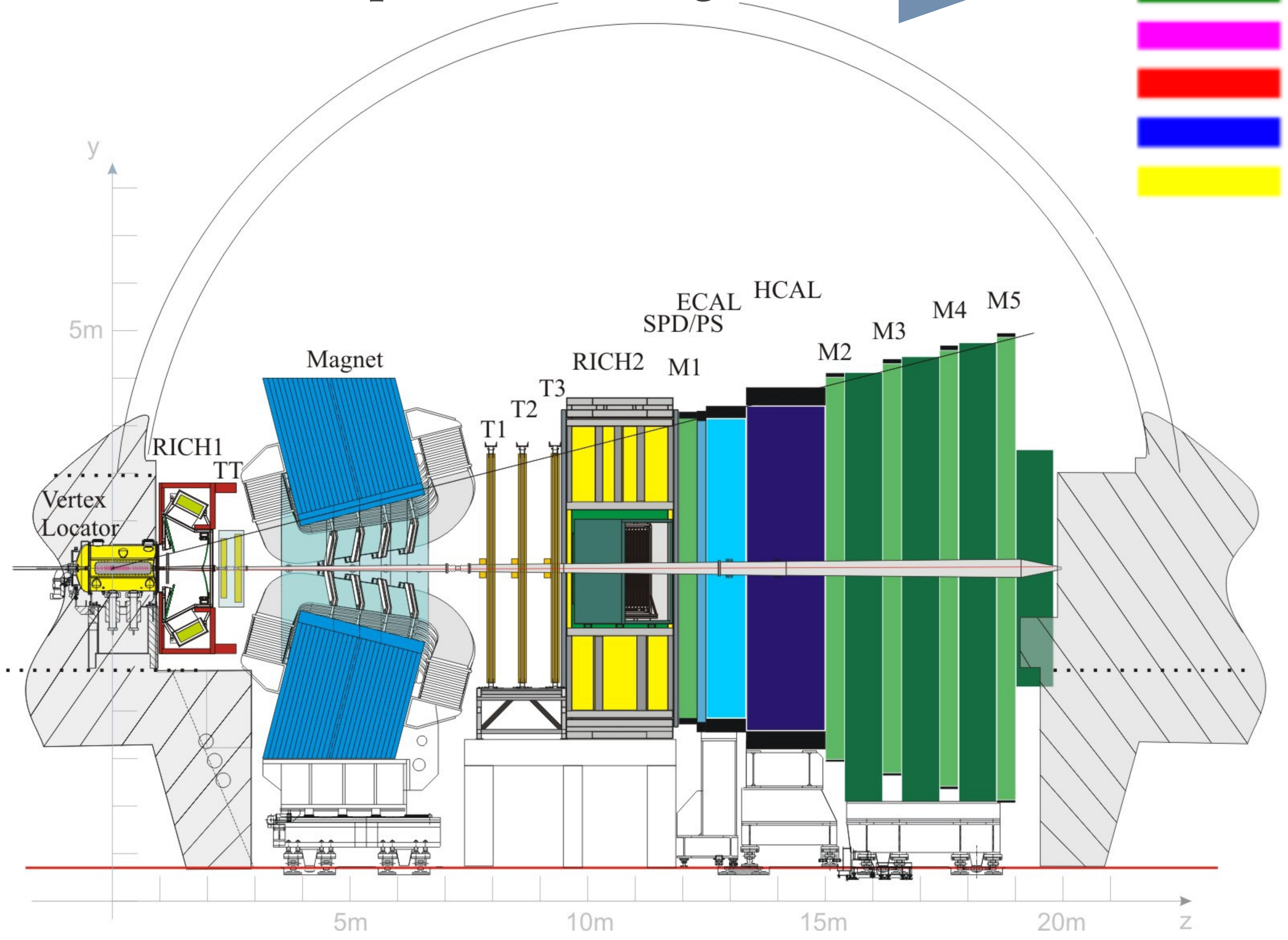
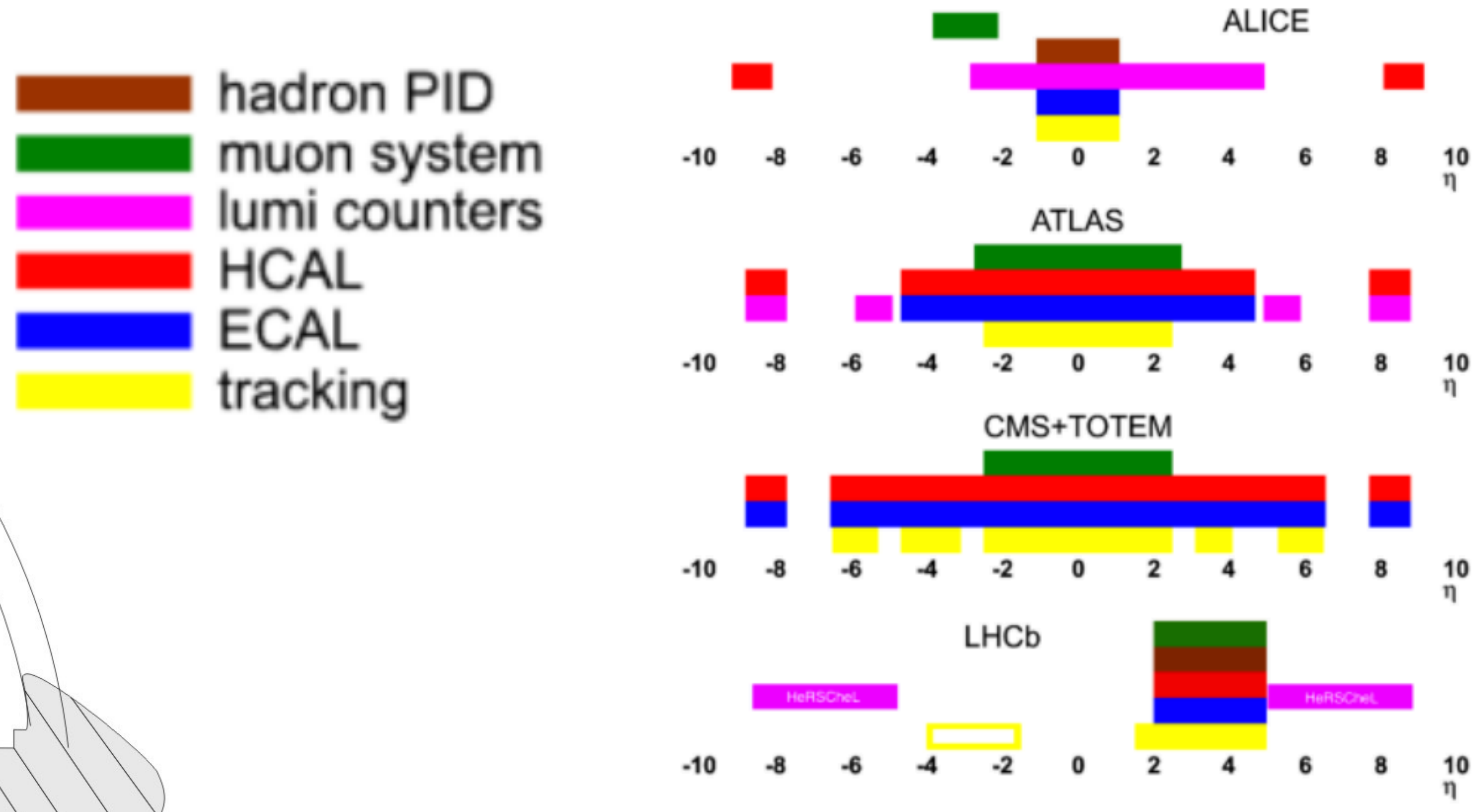
The LHCb detector

Single arm spectrometer fully instrumented in pseudorapidity range $2 < \eta < 5$

Unique in this range





- Excellent tracking down to p_T=0.
- Excellent particle identification.
- Excellent primary vertex determination.

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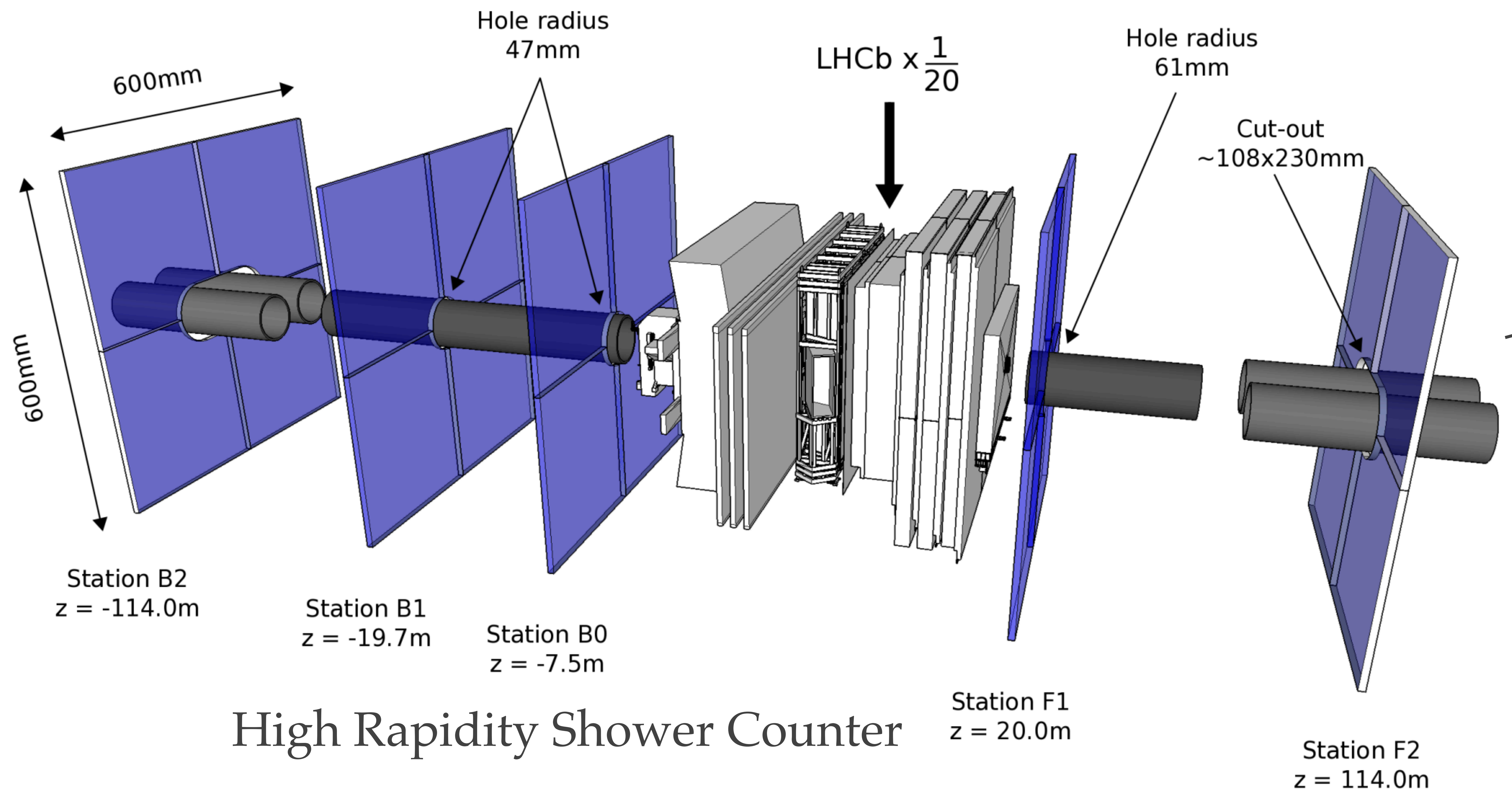
The LHCb detector

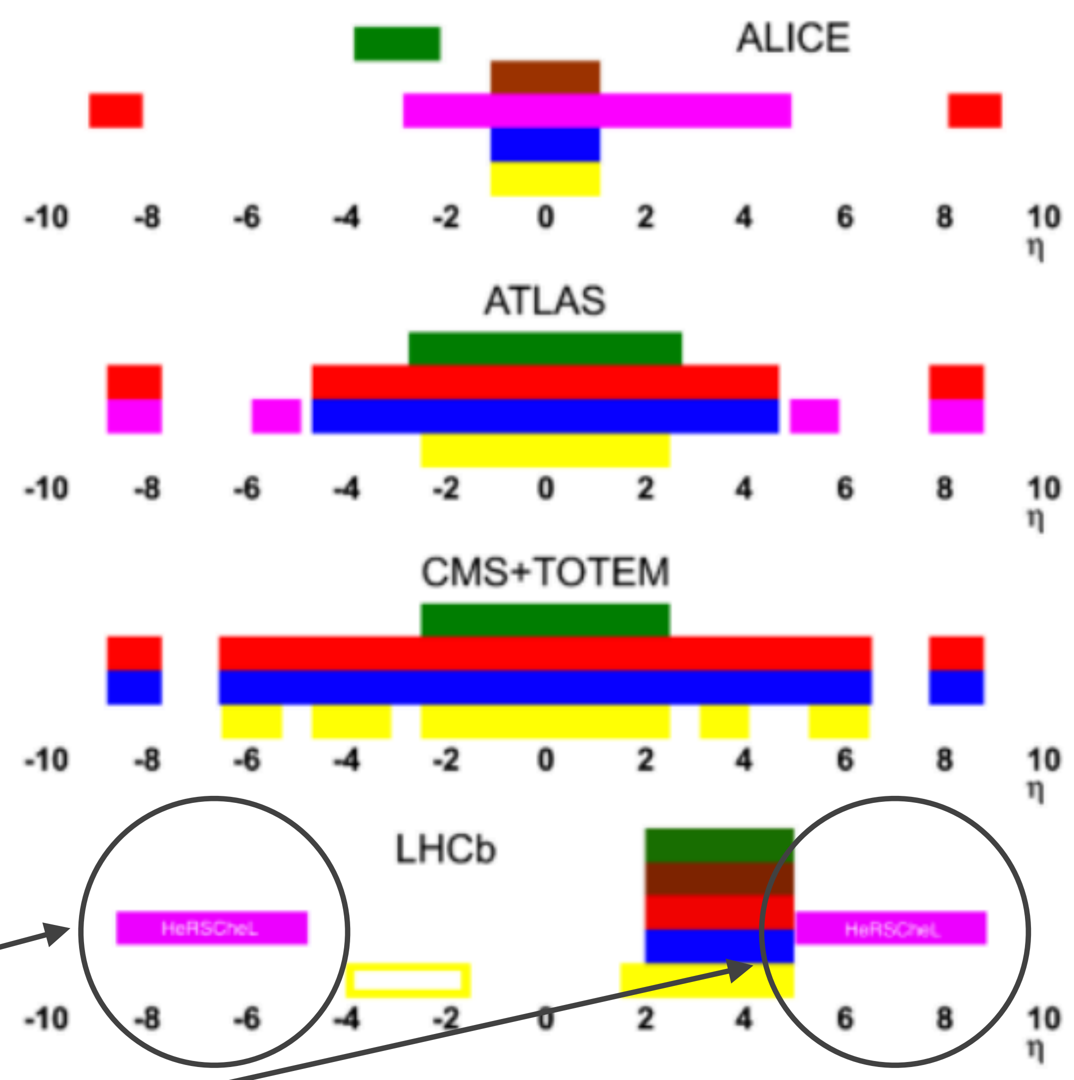
Single arm spectrometer fully instrumented in pseudorapidity range $2 < \eta < 5$

2018 JINST 13 P04017

HeRSCheL detector



High Rapidity Shower Counter



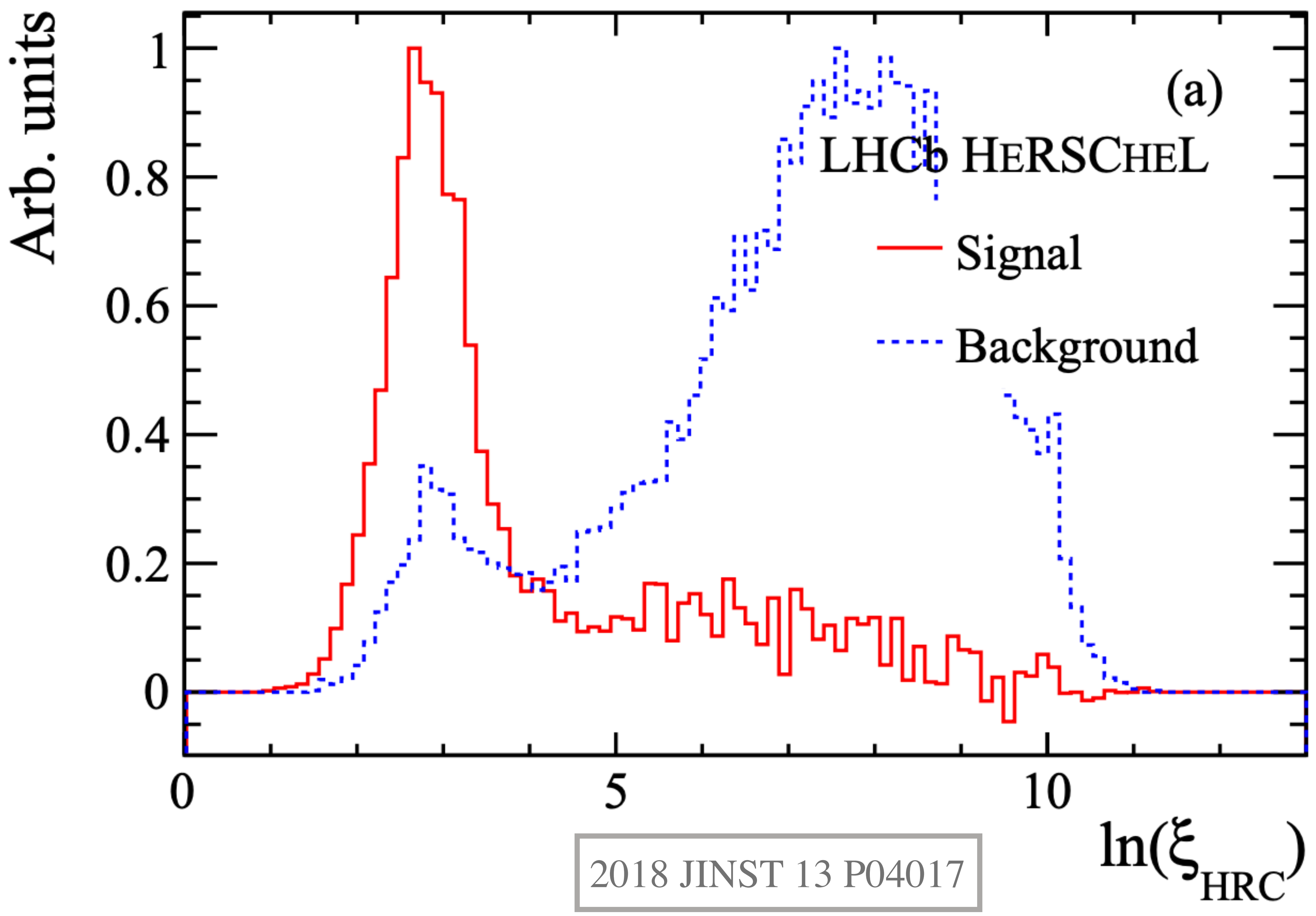
- Excellent tracking down to p_T=0.
- Excellent particle identification.
- Excellent primary vertex determination.

Great detector for UPC!

arXiv:2107.03223

J/ψ PbPb UPC @5TeV

- PbPb data recorded by the LHCb detector in 2015 with in integrated luminosity of about $\mathscr{L}$~10μb
- UPC Event selection:
  - Low activity in the detector
  - Selection thanks to the HeRSCheL detector
- Candidates reconstructed with the dimuon channel
  - Two opposite sign μ with $p_T > 700$ MeV/c
  - $p_T^{\mu\mu} < 1$ GeV/c and $\Delta\varphi^{\mu\mu} > 0.9\pi$

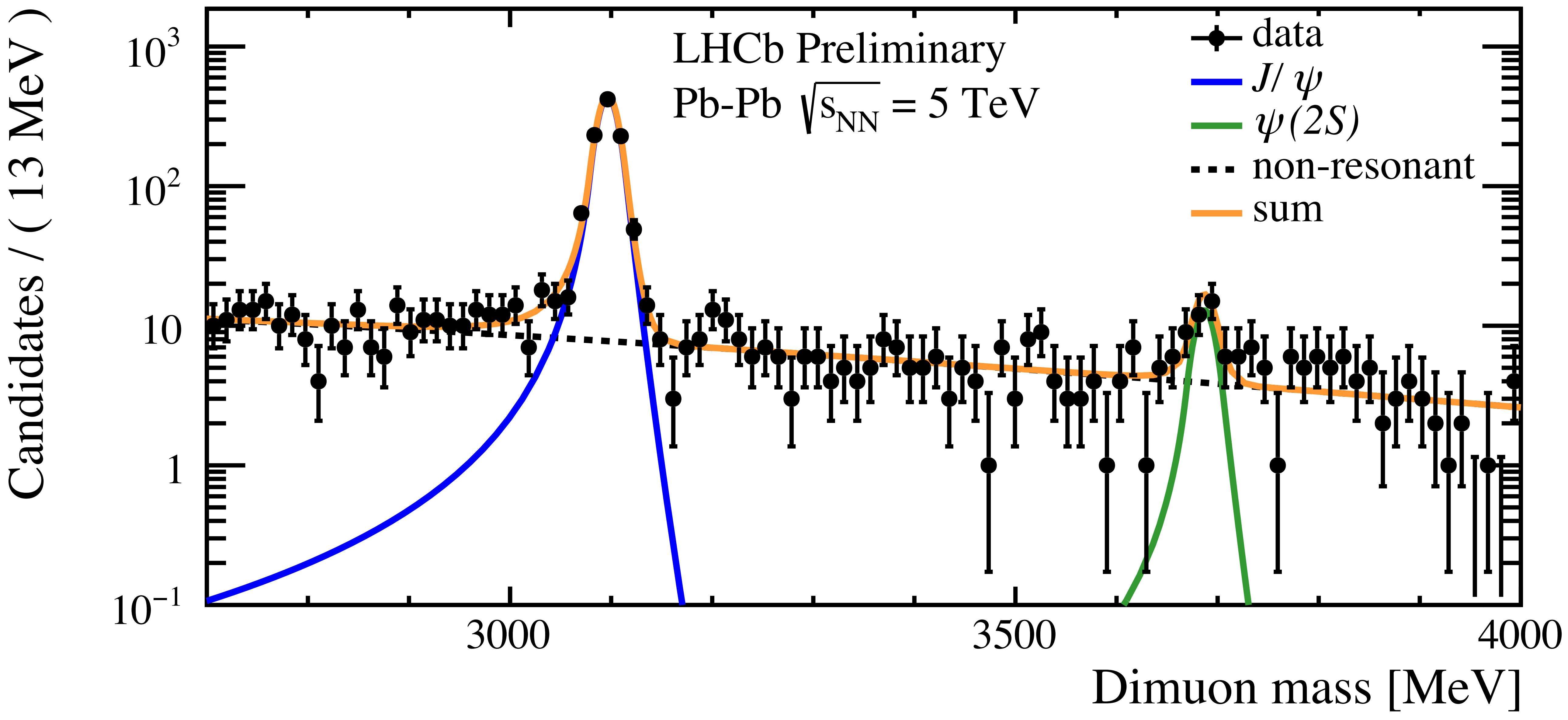


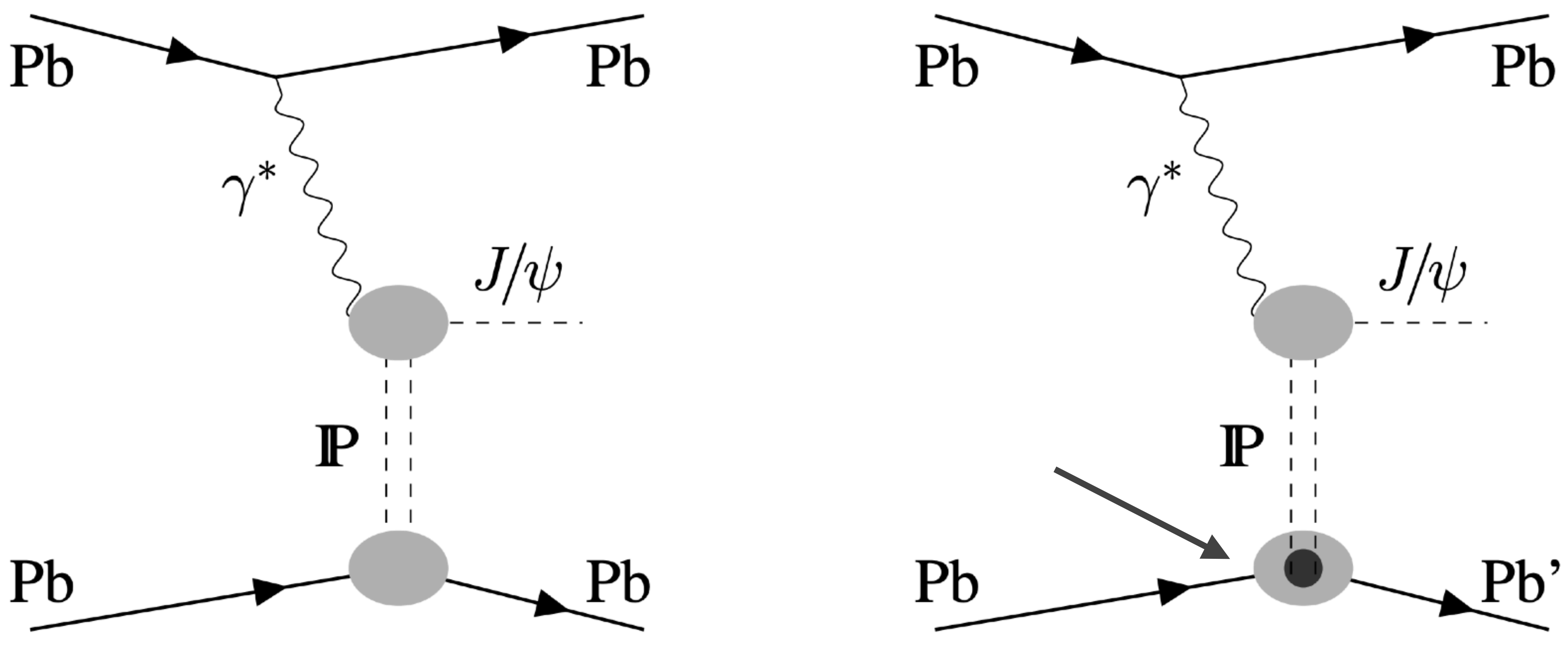
2018 JINST 13 P04017

ξ_{HRC} is a $\chi_2$variable, ξ_{HRC} -> 0 corresponding to zero or little activity in HerRSCheL, compatible with UPC

arXiv:2107.03223

J/ψ PbPb UPC @5TeV





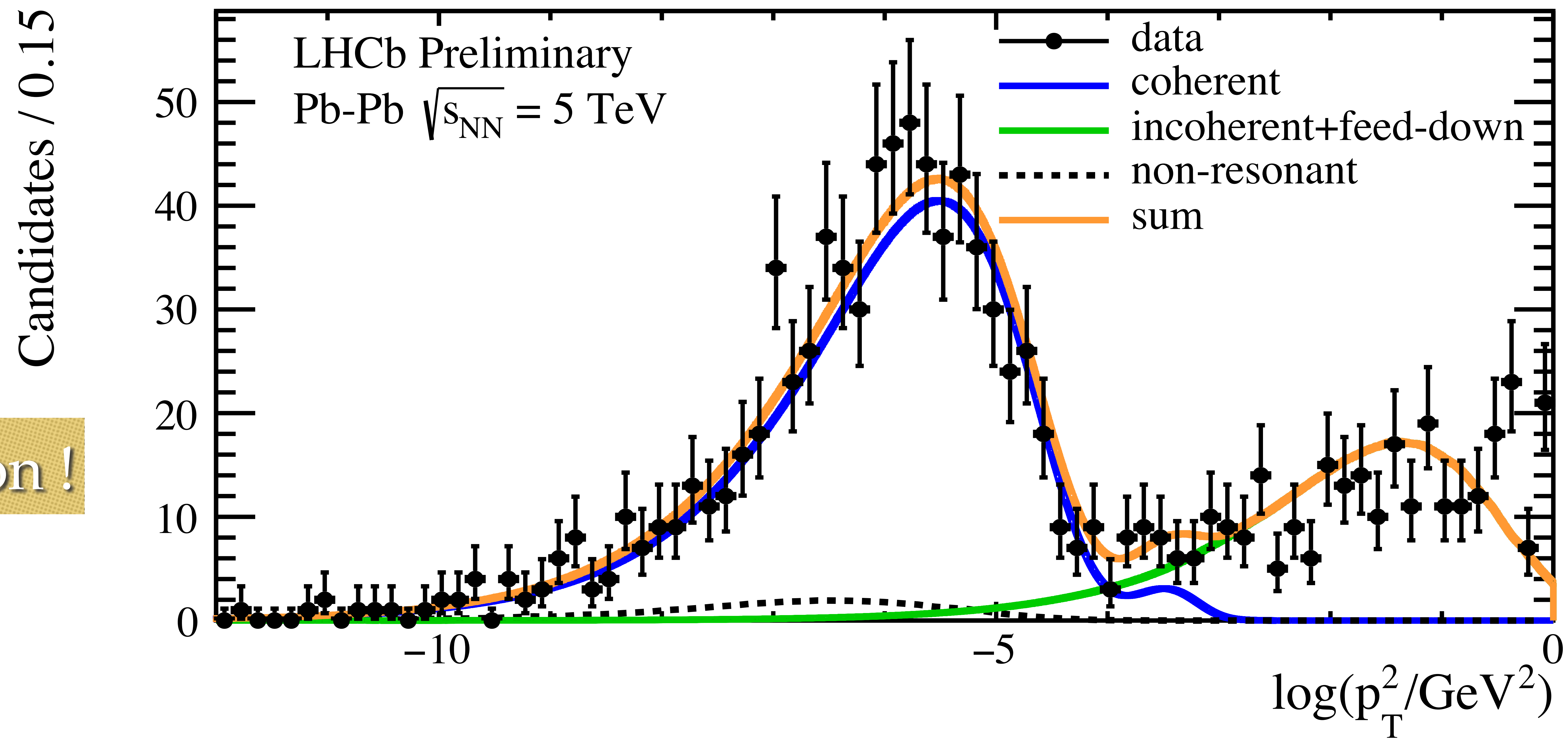
Coherent

Incoherent

- Both signal contain coherent and incoherent produced candidates
- J/ψ from feed-down from ψ(2S)
- Background from $\gamma\gamma \to \mu\mu$ non -resonant

arXiv:2107.03223

J/ψ PbPb UPC @5TeV



Excellent resolution !

STARLight

- Template fit based on the STARLight model
- Shape of the background taken from the side band method

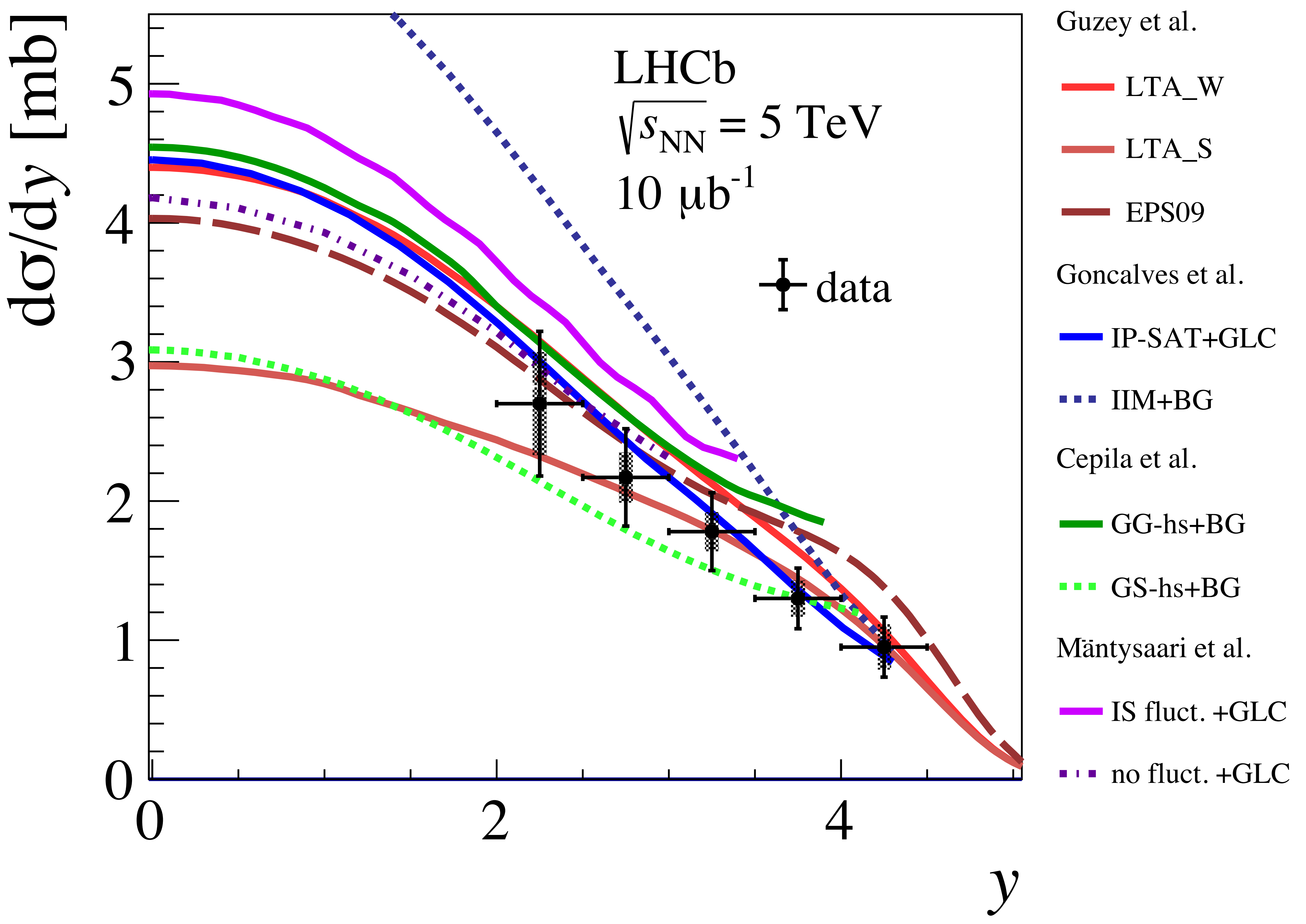
arXiv:2107.03223

J/ψ PbPb UPC @5TeV

Total cross section in 2.0 < y < 4.5:

$$\sigma = 4.45 \pm 0.24\ (\text{stat}) \pm 0.18\ (\text{syst}) \pm 0.58\ (\text{lumi})\ \text{mb}$$

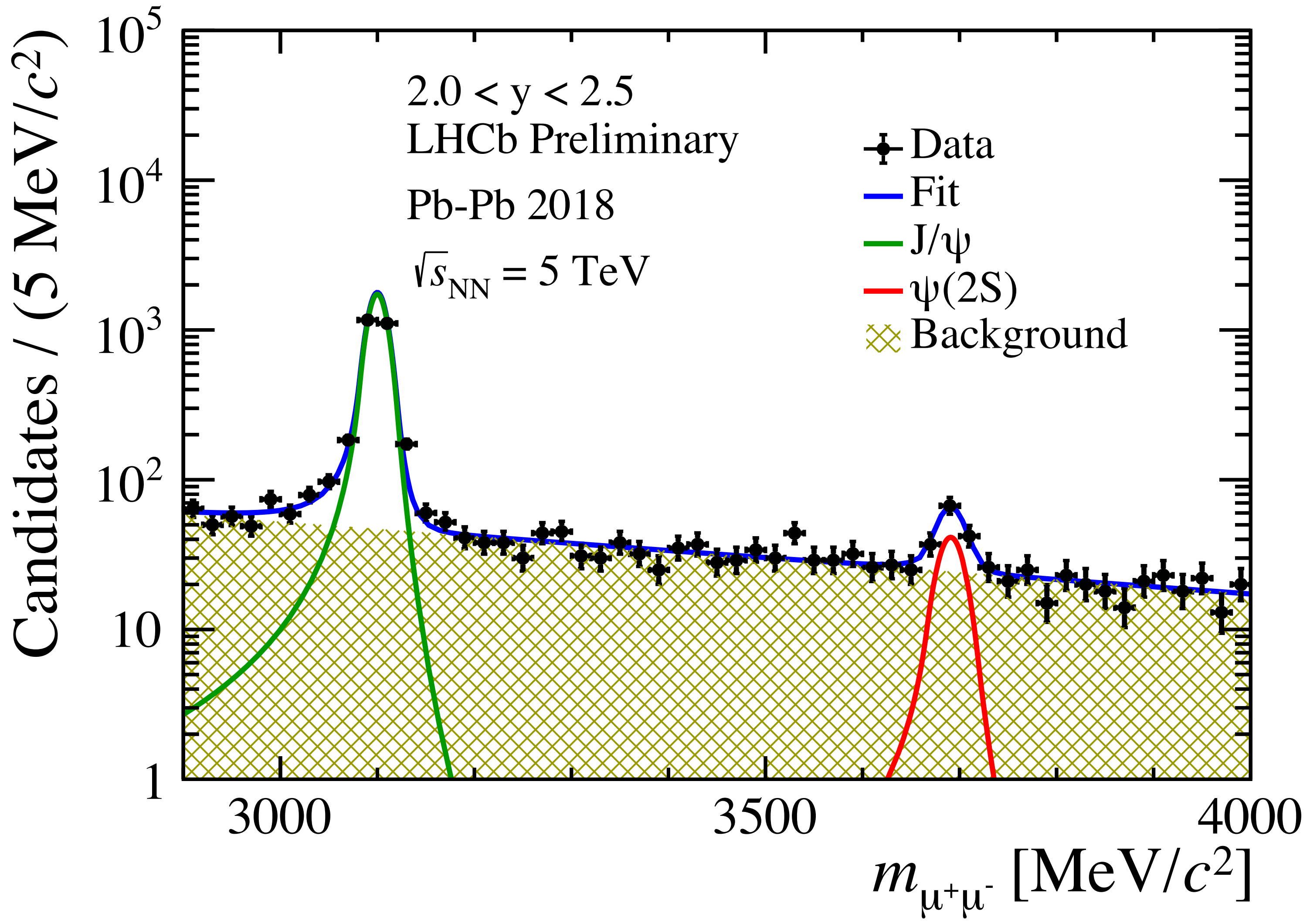
- Largest uncertainty due to the luminosity
- Good description of the data by the different models
- New results with the 2018 dataset, including ψ(2S), will further constrain theory

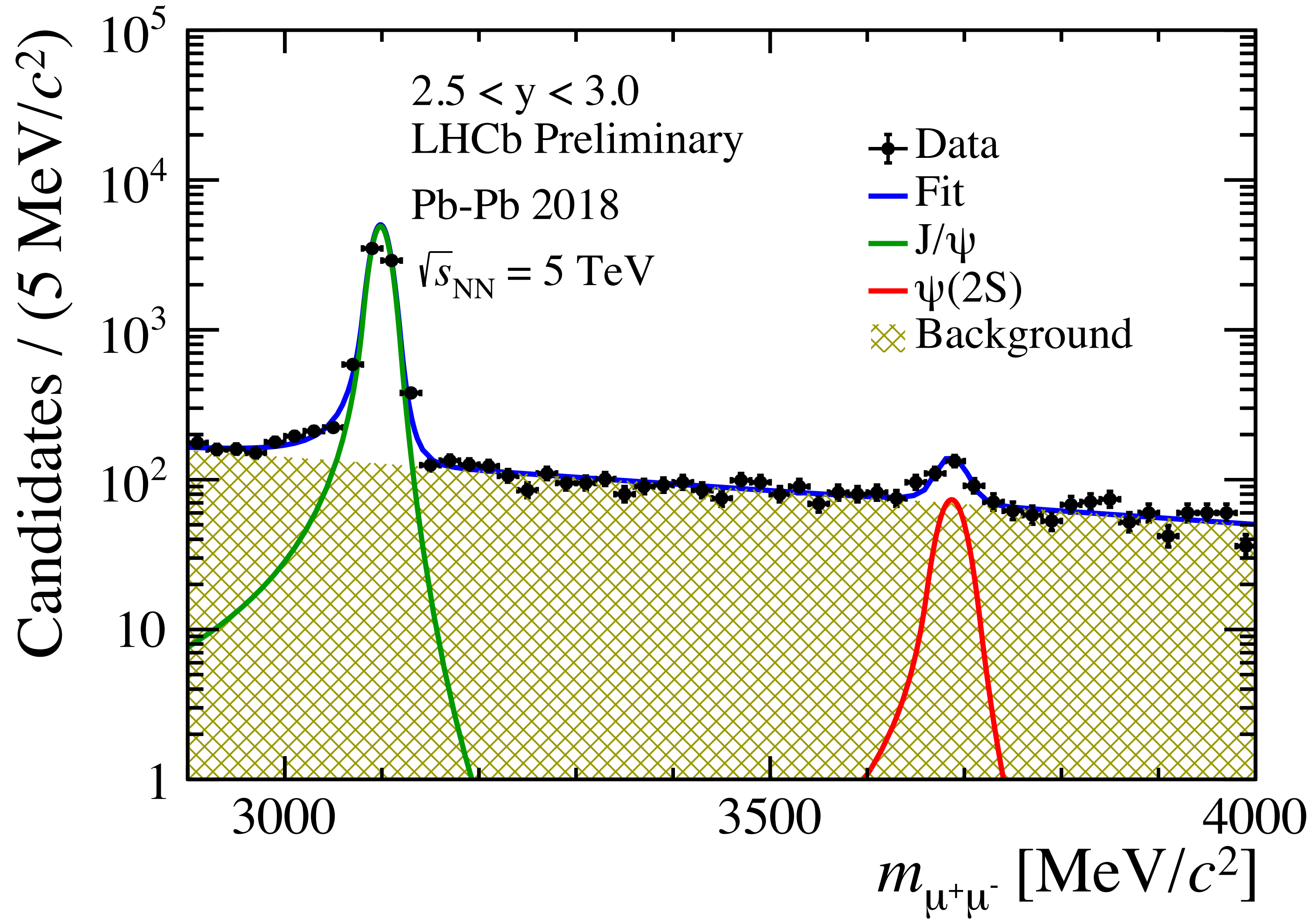


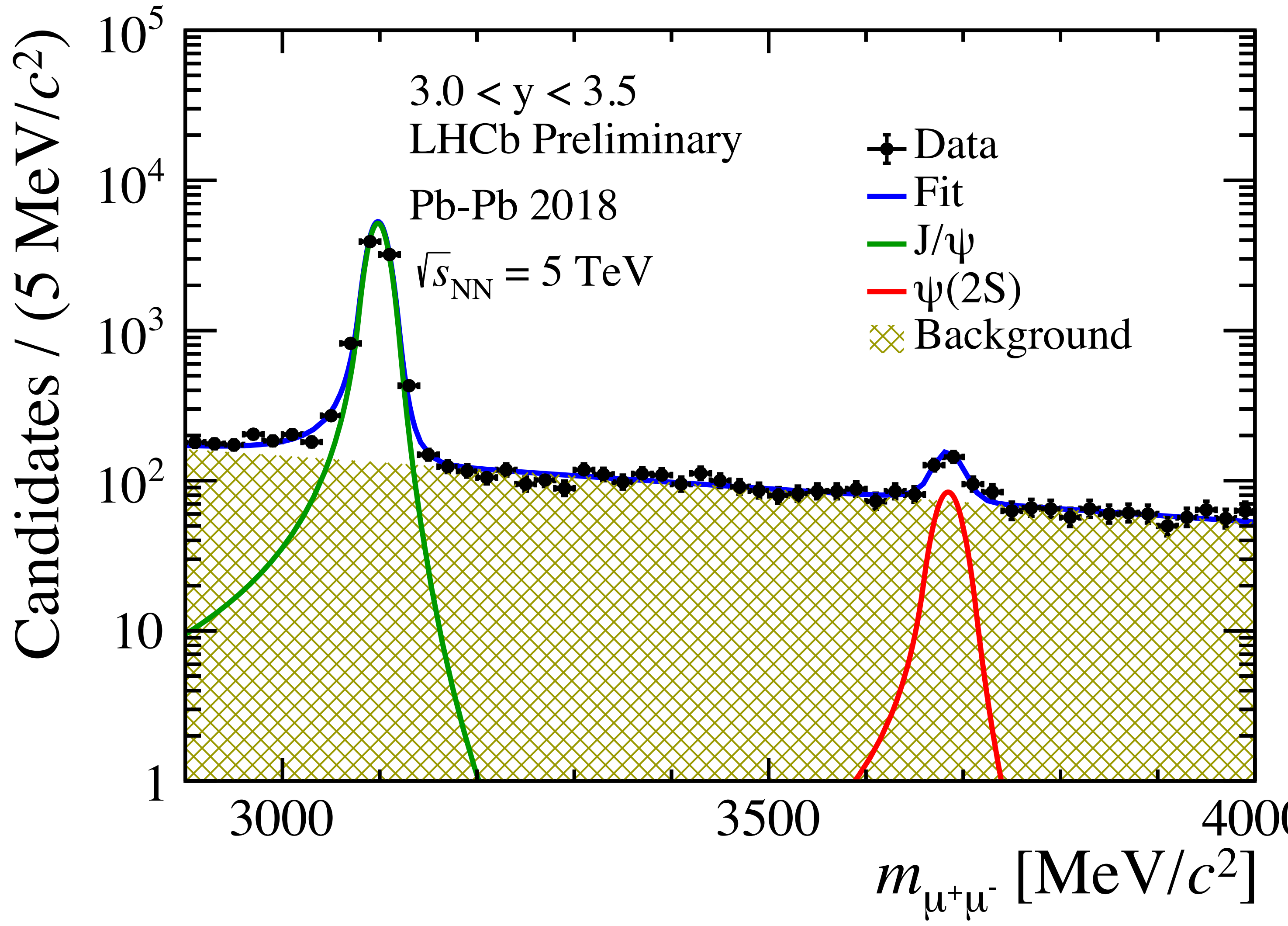
Cepila *et al.* PR C97 024901 (2018)
Gonçalves *et al.* PR D96 094027 (2017)
Guzey *et al.* PR C93 055206 (2016)
Mäntysaari *et al.* PL B772 (2017) 832

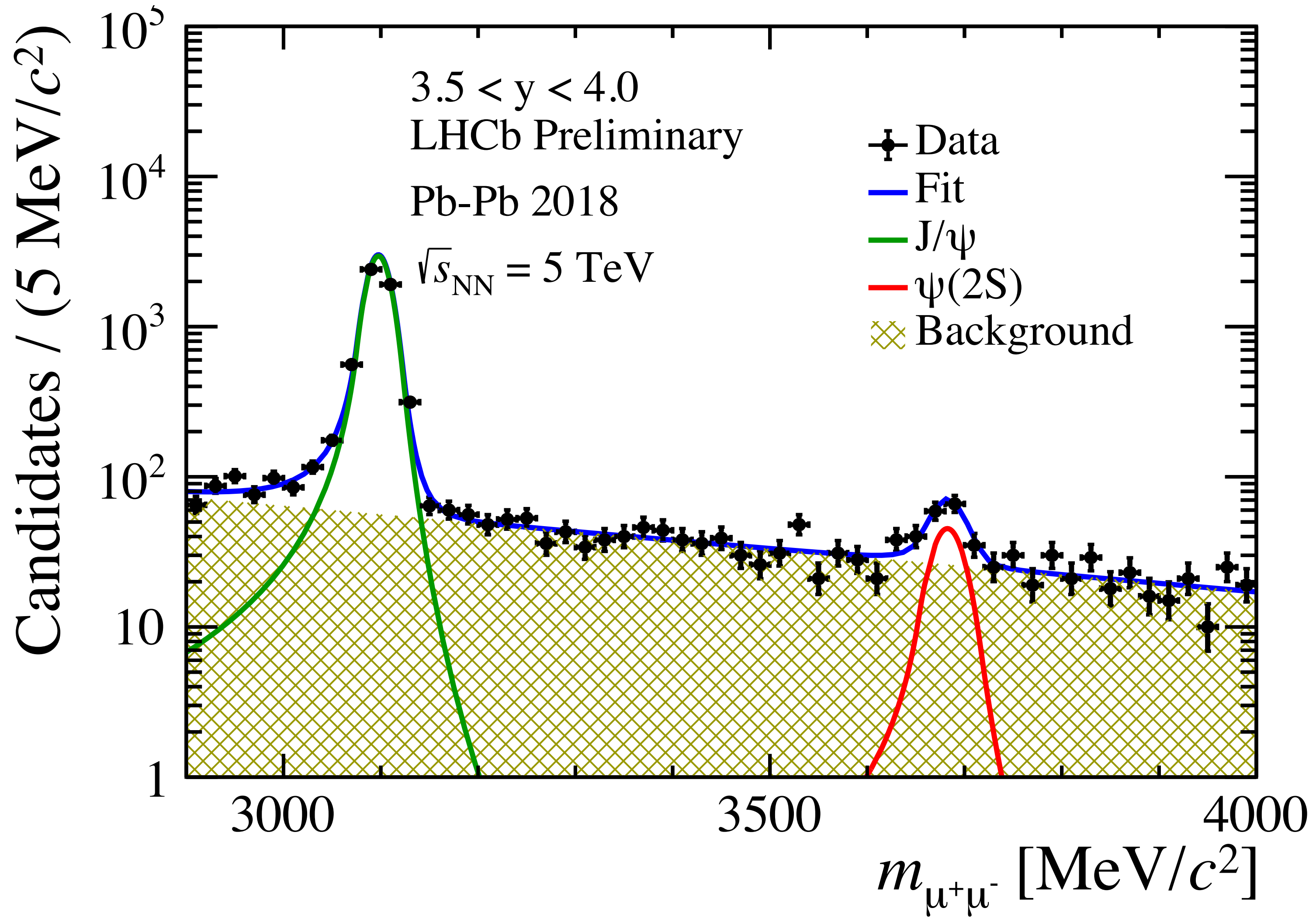
Large statistic, luminosity x20 !

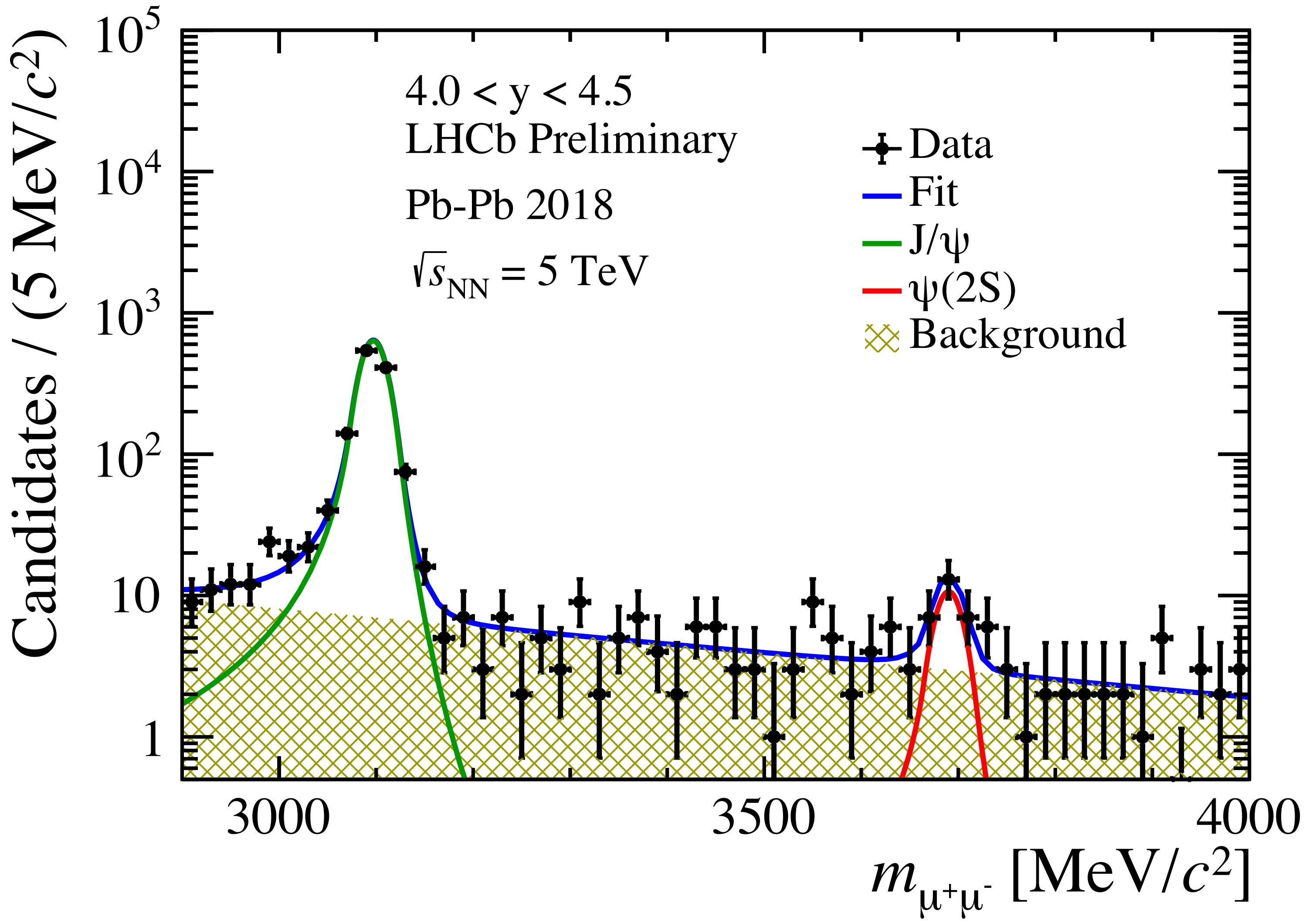
J/ψ, ψ(2S) PbPb UPC @5TeV











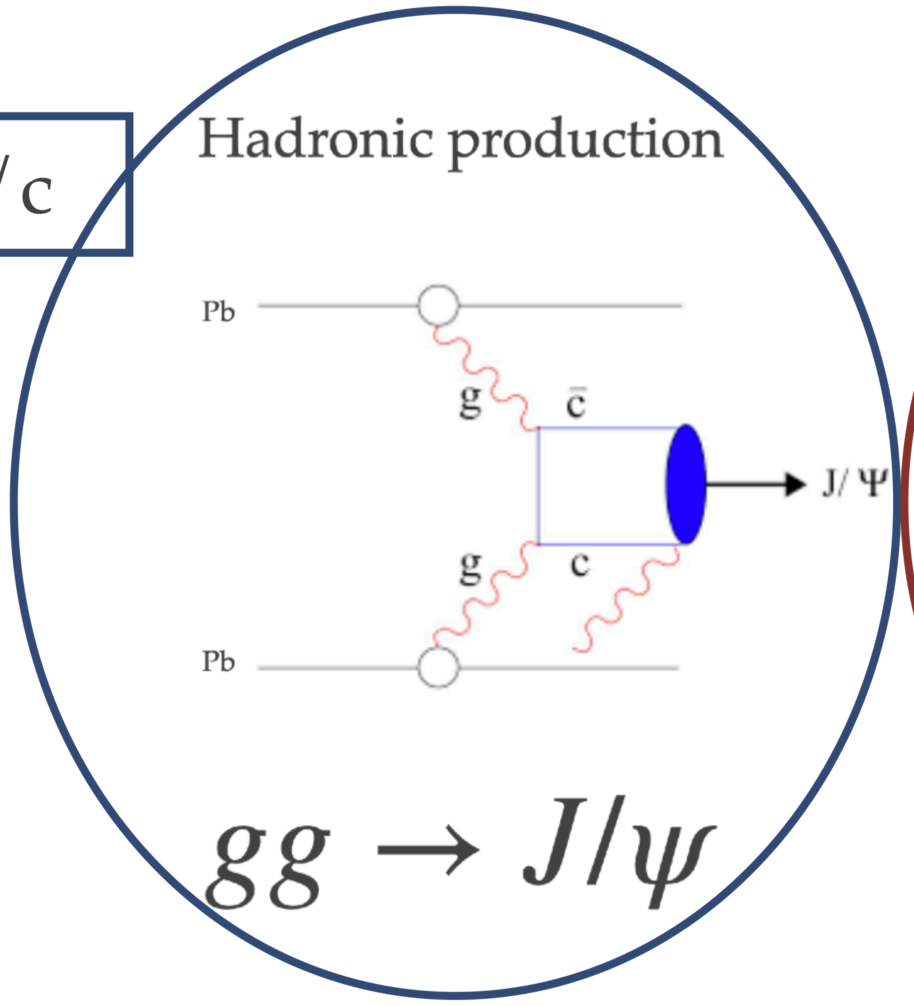
Phys. Rev. C **105**, L032201

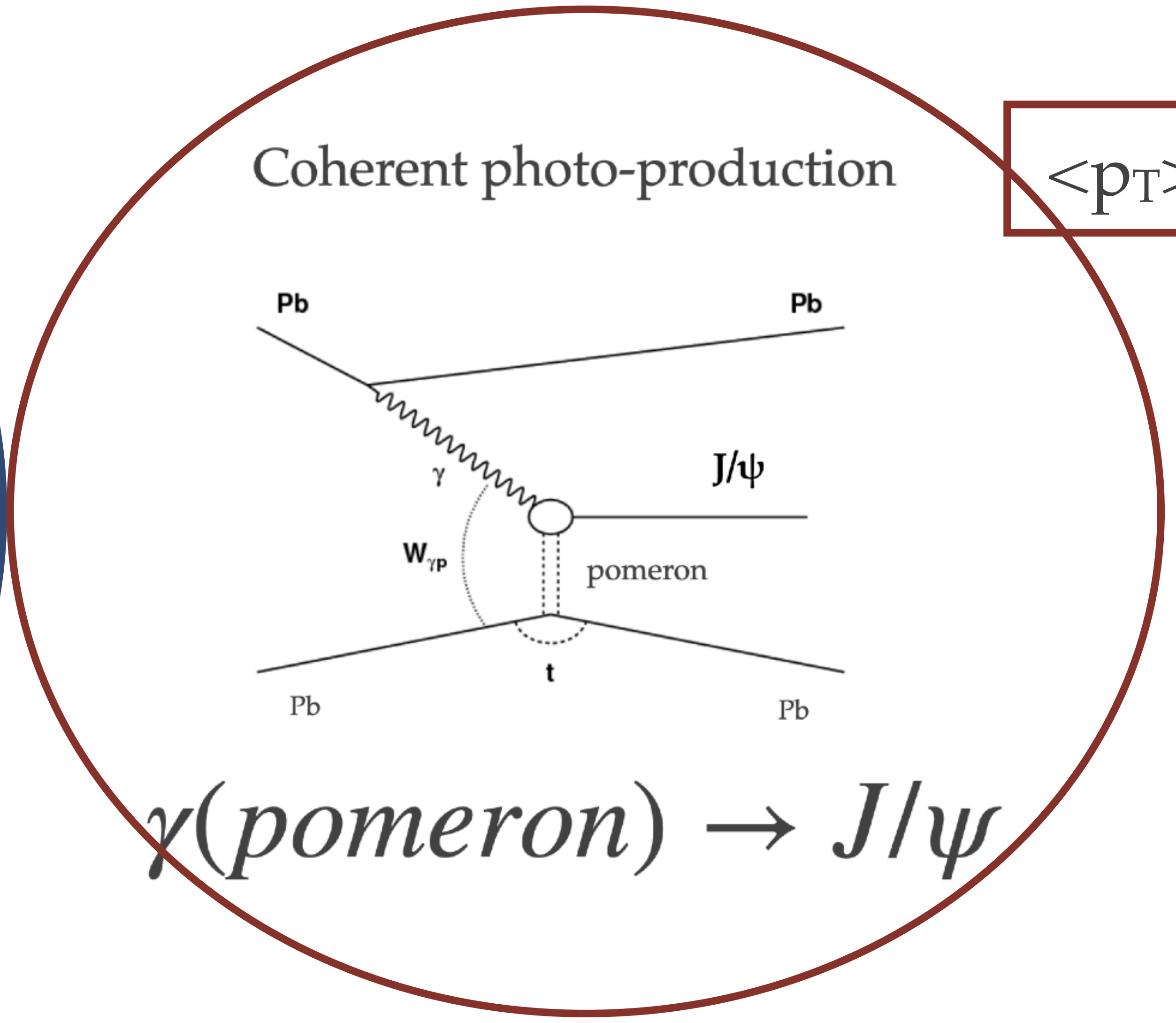
First measurement in PbPb hadronic collisions at LHCb !

Coherent J/ψ in PbPb peripheral collisions

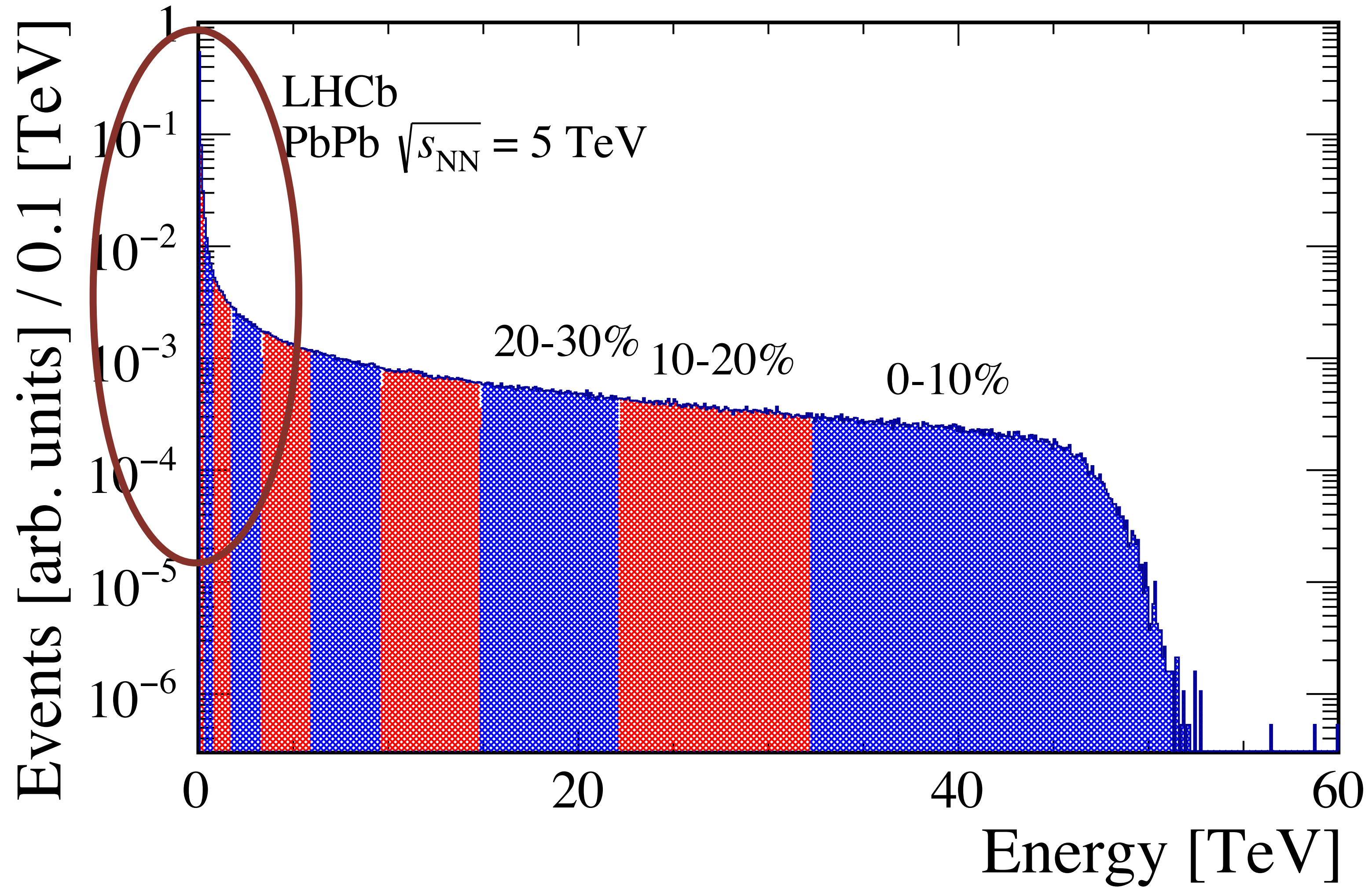
Coherent photo-production in peripheral collisions ? ($b<2R_{Pb}$)

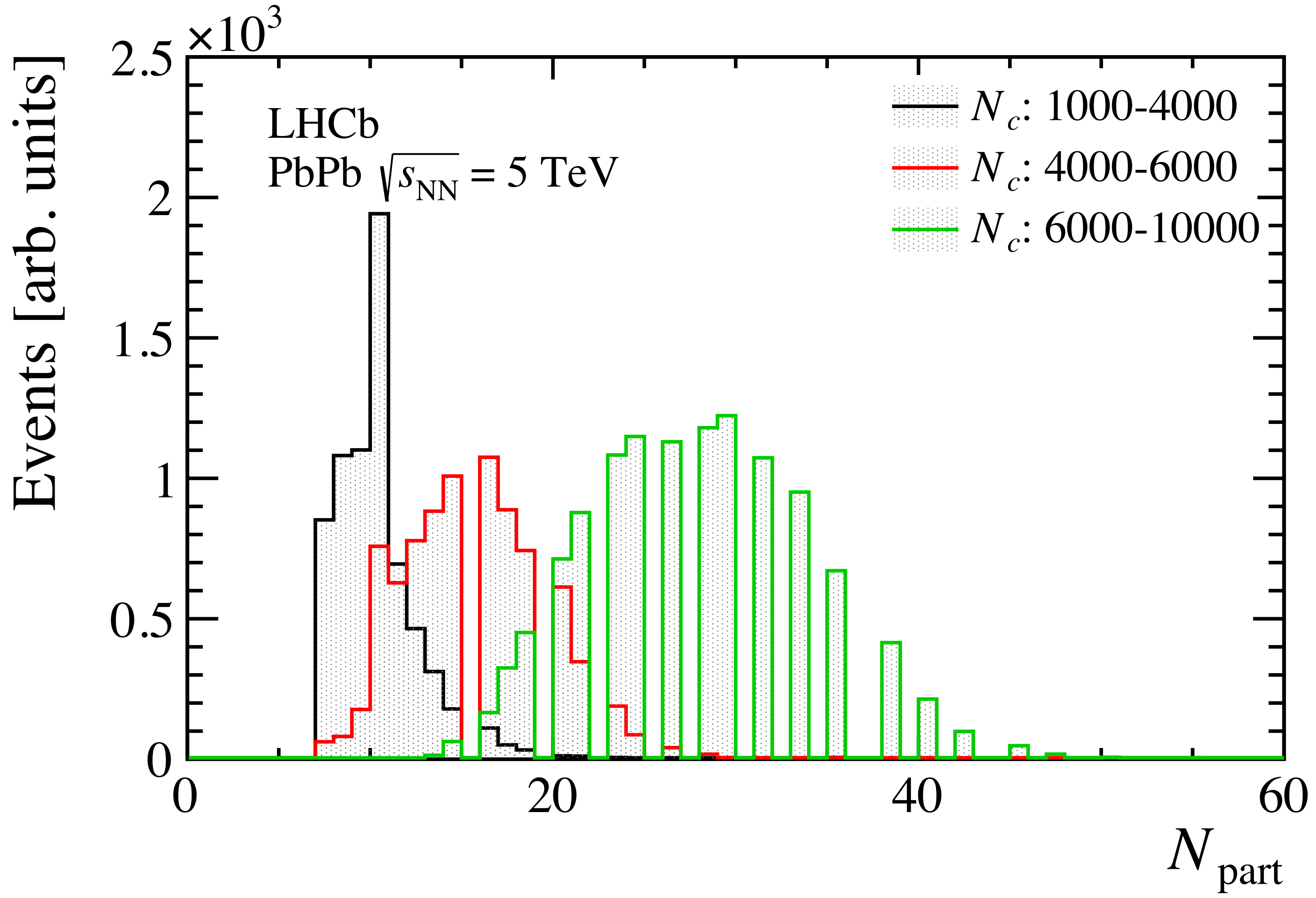
$\langle p_T \rangle$~1-2 GeV/c





$\langle p_T \rangle < 300$ MeV/c





- 2018 PbPb sample at 5.02 TeV, limited to 60-90% centrality
- Candidates reconstructed through the dimuon channel
- Events with minimum energy in the ECal calorimeter to avoid any UPC contamination
- Results display in $\langle N_{part} \rangle$ classes

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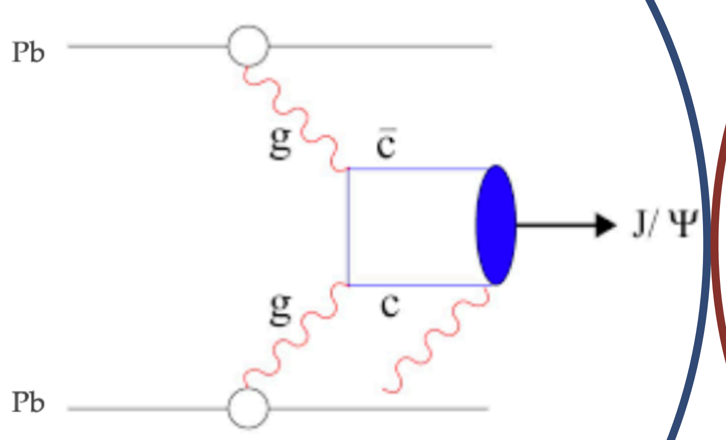
First measurement in PbPb hadronic collisions at LHCb !

Coherent J/ψ in PbPb peripheral collisions

Separate the two contributions through the p_T distribution of the J/ψ

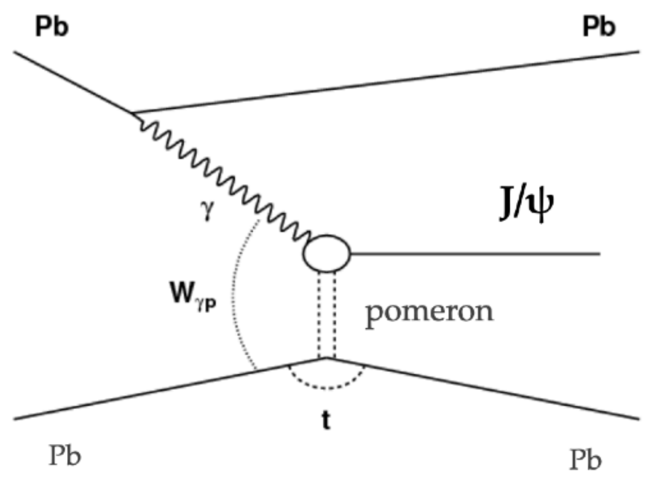
$\langle p_T \rangle \sim$1-2 GeV/c

Hadronic production



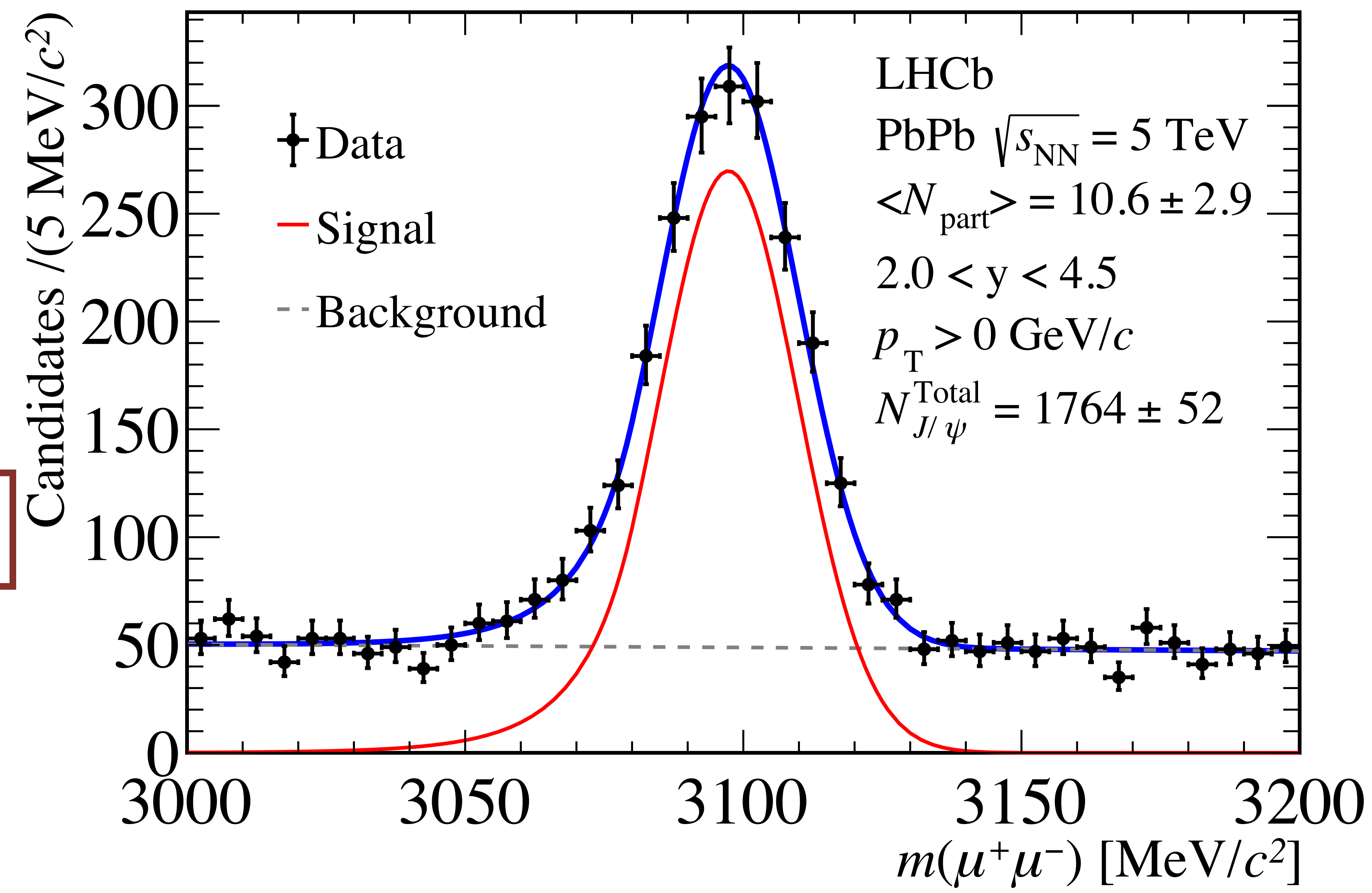
$gg \rightarrow J/\psi$

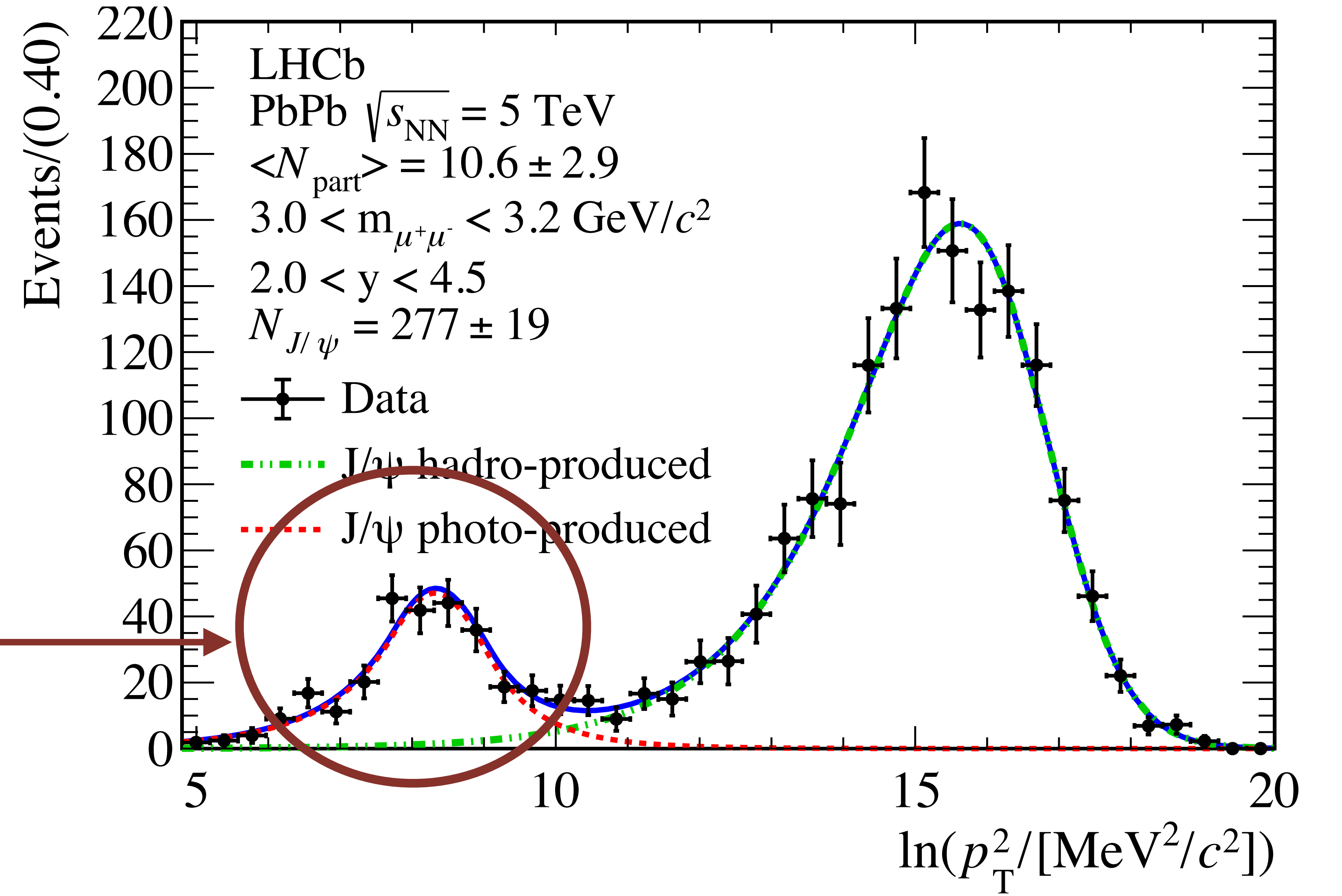
Coherent photo-production



$\gamma(pomeron) \rightarrow J/\psi$

$\langle p_T \rangle$ < 300 MeV/c





« Excess » of J/ψ with mean p_T around ~70 MeV/c
Compatible with coherent photo-production

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

First measurement in PbPb hadronic collisions at LHCb !

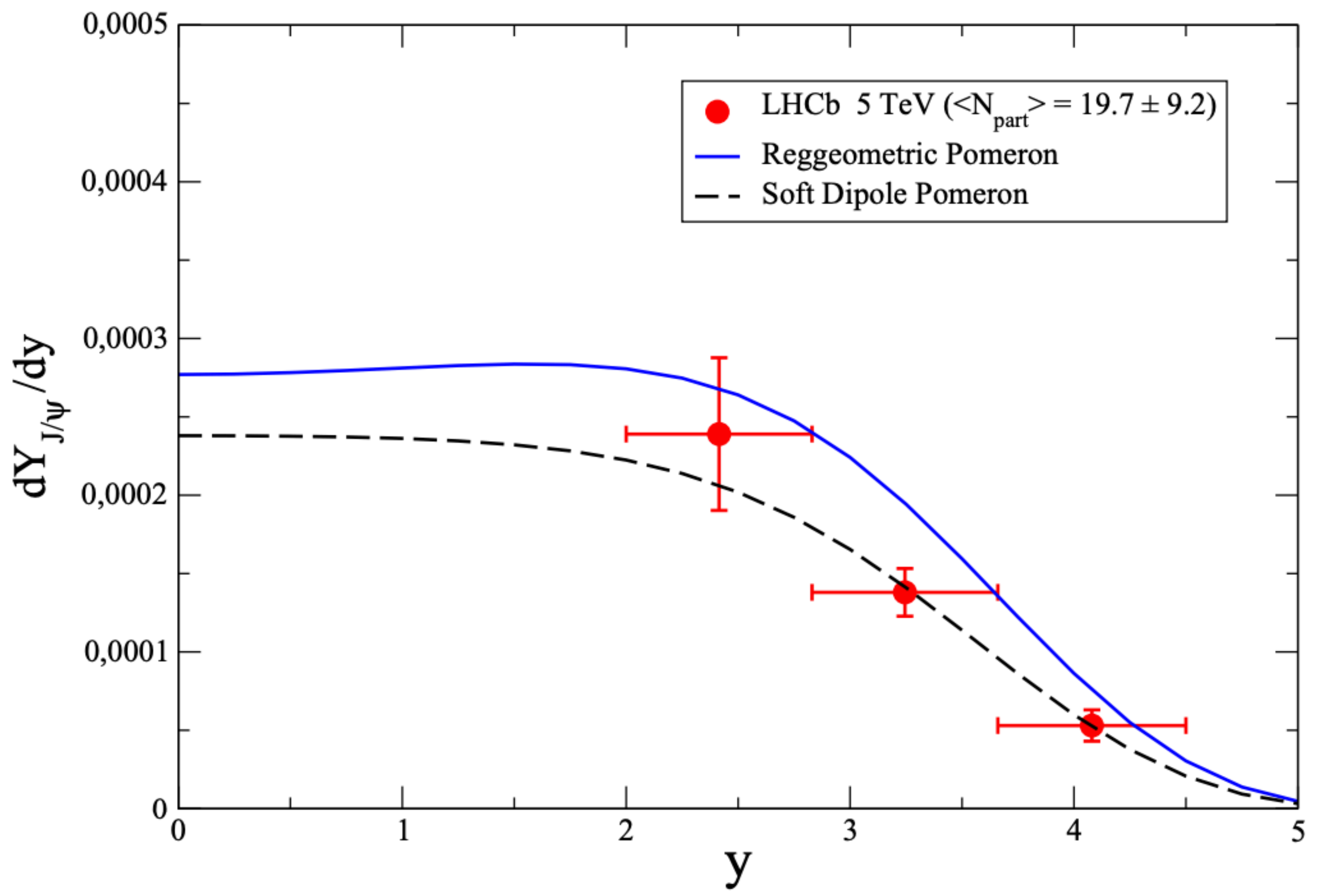
Coherent J/ψ in PbPb peripheral collisions

- Consistent with J/ψ photo-production in PbPb hadronic collisions
- Most precise p_T measurement to date
- Shape compatible with model, two assumptions:
  - No effect of the overlap between the nuclei (UPC-like but small IP)
  - Effect of the overlap

W. Zha et al. Phys. Rev. C97 (2018) 044910 / Phy. Rev. C99, 06901(R)

Coherent J/ψ in PbPb peripheral collisions

Vector Dominance Model + Glauber multiple scattering formalism



- Recent preprint shows good agreement with the soft dipole pomeron model

- J/ψ produced by two colorless object
- Mean p_T much lower than (re)combined J/ψ
- Photo-produced J/ψ melted by QGP not « (re)combined »

➡ Better thermometer for QGP ?

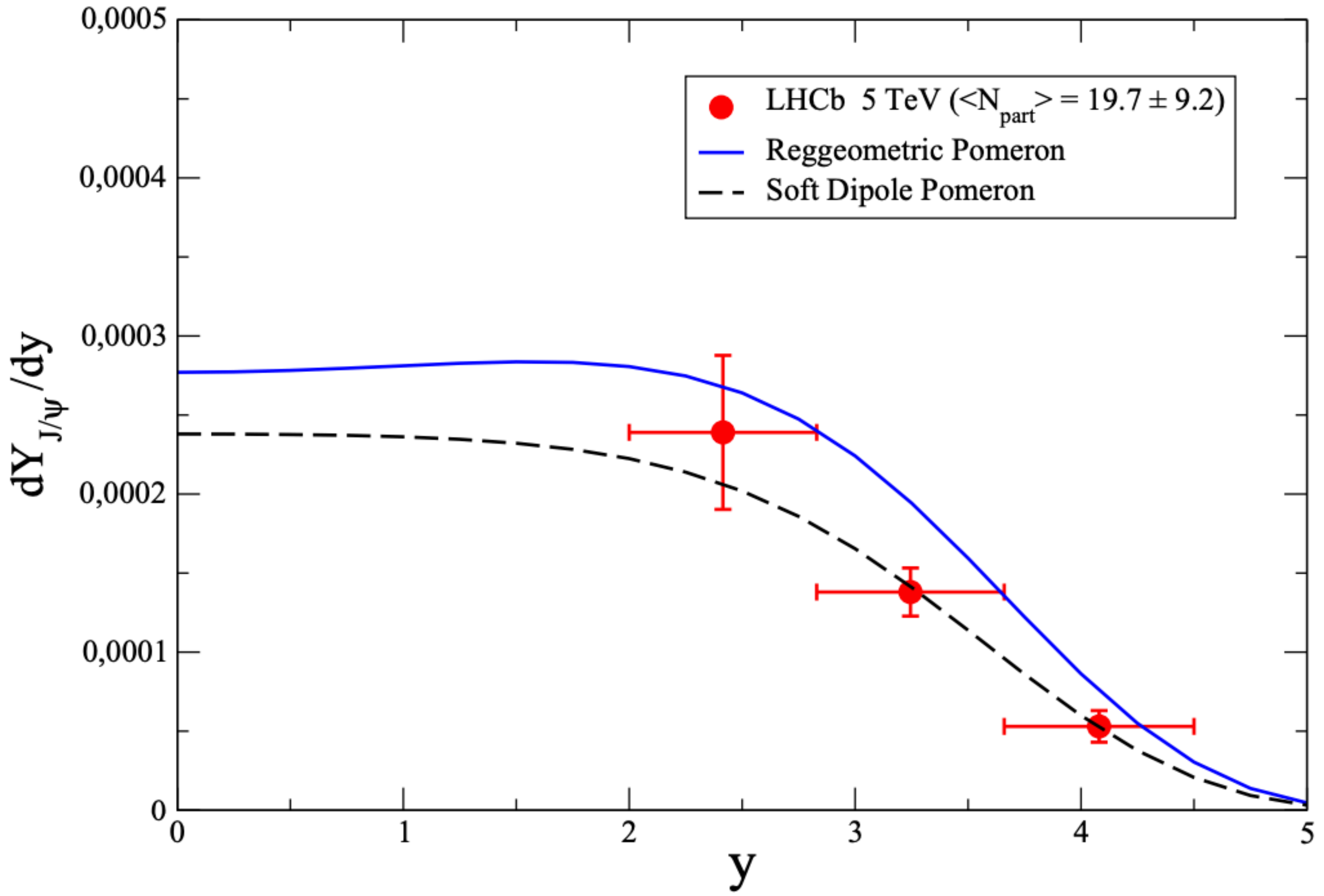
Conclusion

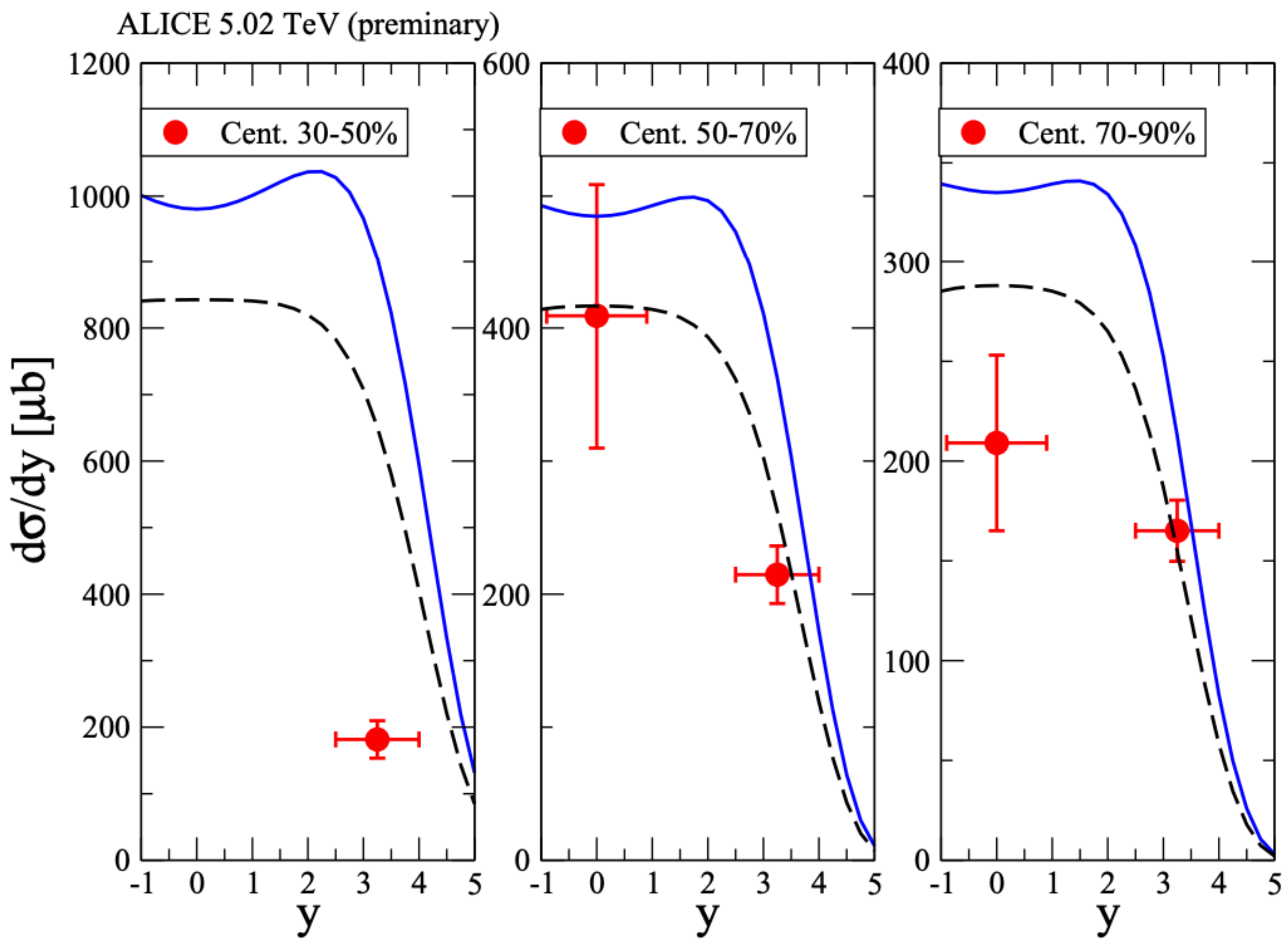
- Precise measurement of coherent J/ψ production in UPC PbPb collisions.
- Coherent J/ψ and $\psi(2S)$ measurement with the large 2018 data coming soon !
- Measurement of photo-produced J/ψ in peripheral PbPb collisions.
  - First result using PbPb hadronic collisions in LHCb.
  - Consistent with photo-production in PbPb peripheral collisions.
  - Agreement with last model
- Many results in the future (CEP J/ψ in *p*Pb, lower mass vector mesons…)

Coherent J/ψ in PbPb peripheral collisions

arXiv:2202.02162v2

Vector Dominance Model + Glauber multiplie scattering formalism



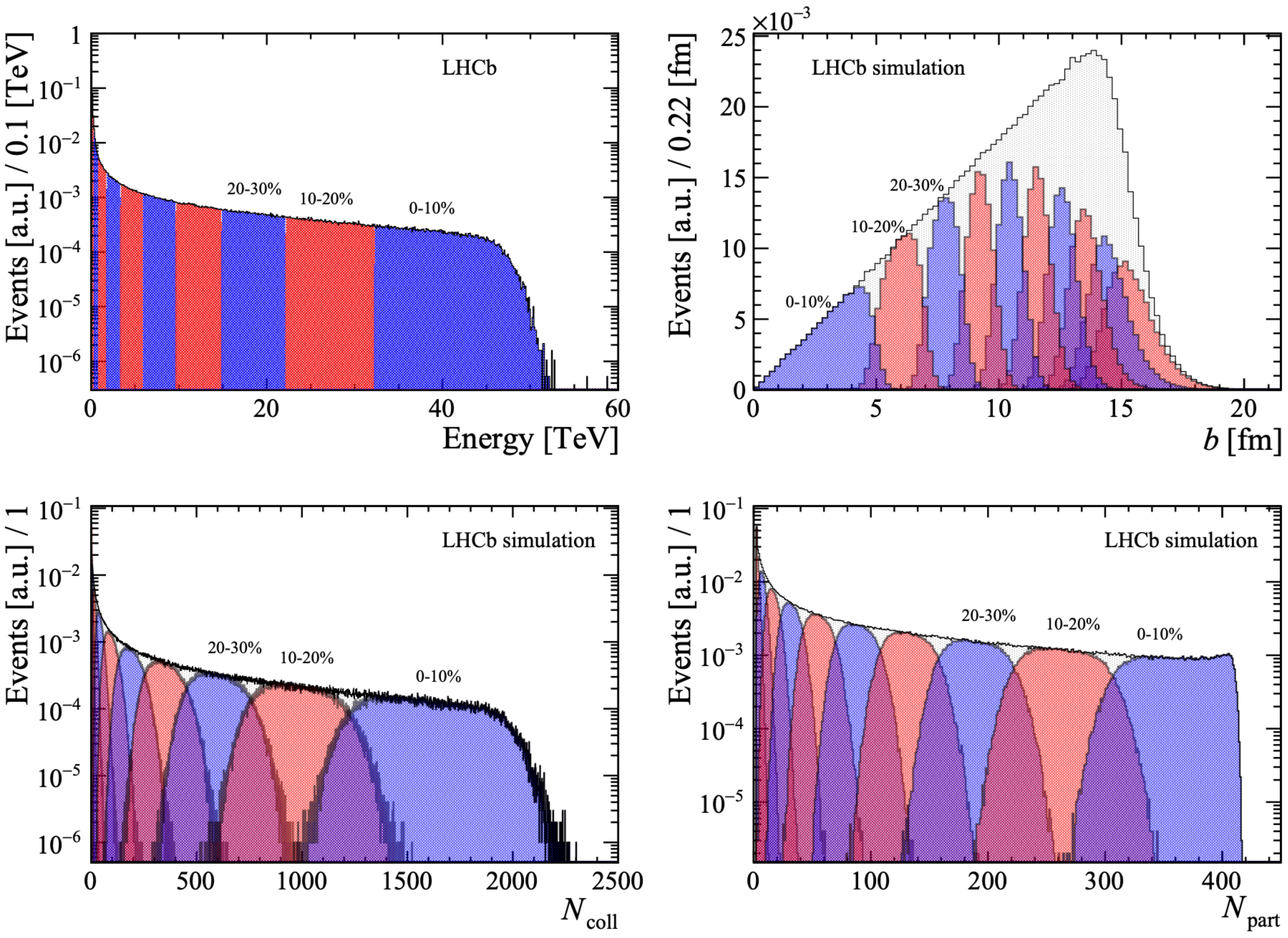


- Recent preprint shows good agreement with the soft dipole pomeron model
- Prediction also in agreement with the ALICE preliminary results

Centrality determination

Centrality determination using MCGlauber model

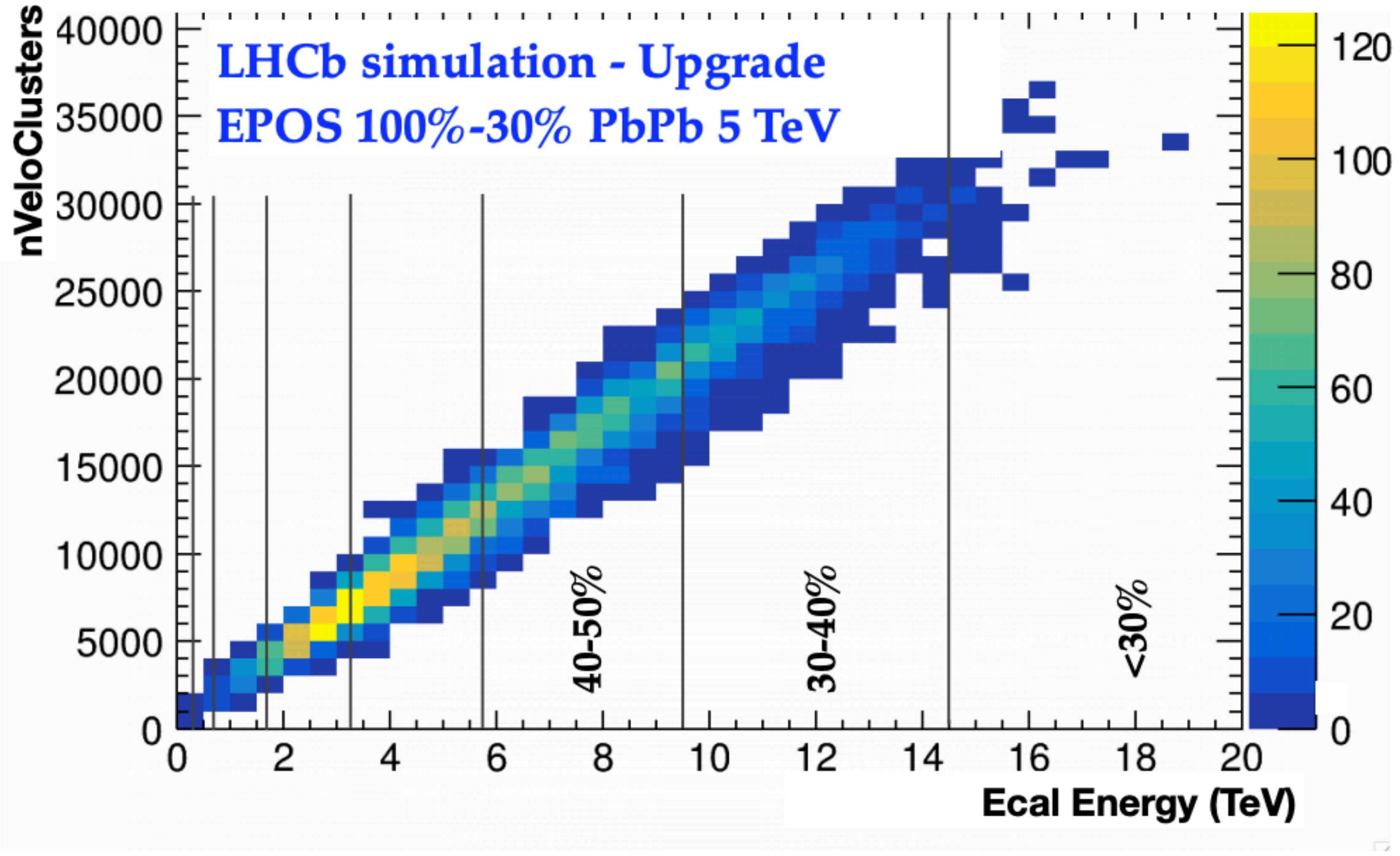
Centrality %	$N_{\text{part}} \pm \sigma$	$N_{\text{coll}} \pm \sigma$	$b \pm \sigma$
$100 - 90$	2.91 ± 0.54	1.83 ± 0.34	15.41 ± 2.96
$90 - 80$	7.03 ± 0.78	5.77 ± 0.64	14.56 ± 1.80
$80 - 70$	15.92 ± 0.64	16.44 ± 0.69	13.59 ± 0.52
$70 - 60$	31.26 ± 0.67	41.28 ± 0.93	12.61 ± 0.28
$60 - 50$	54.65 ± 1.13	92.59 ± 2.01	11.59 ± 0.24
$50 - 40$	87.54 ± 1.01	187.54 ± 2.43	10.47 ± 0.14
$40 - 30$	131.24 ± 1.15	345.53 ± 3.89	9.23 ± 0.08
$30 - 20$	188.02 ± 1.49	593.92 ± 6.62	7.80 ± 0.06
$20 - 10$	261.84 ± 1.83	972.50 ± 10.37	6.02 ± 0.04
$10 - 0$	357.16 ± 1.70	1570.26 ± 15.56	3.31 ± 0.01

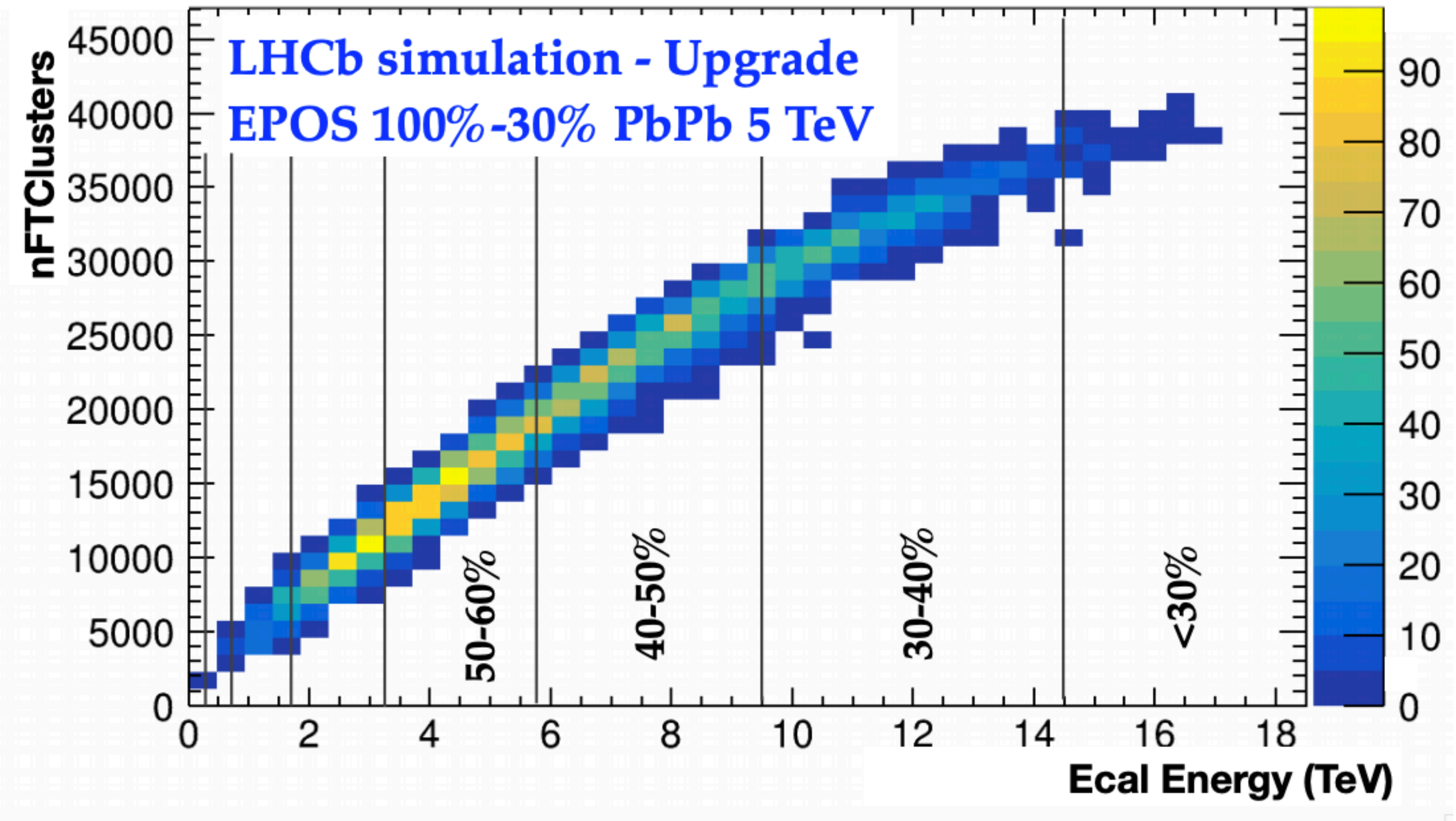


Performances Run 3 PbPb

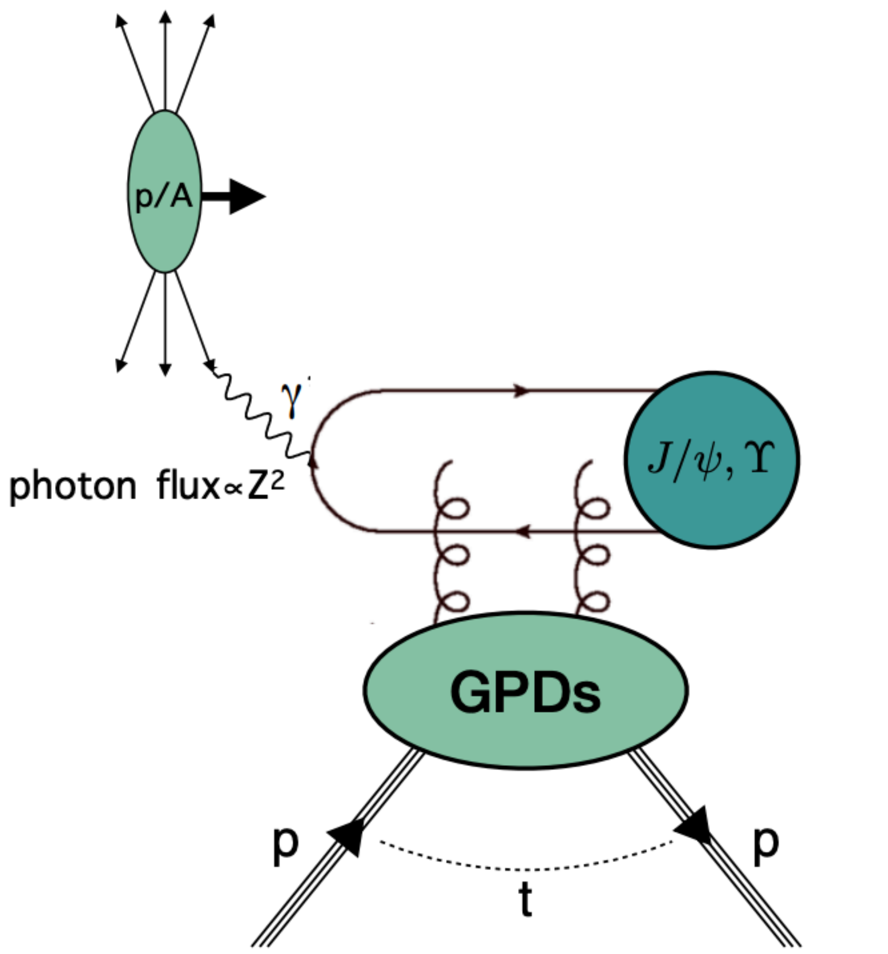
PbPb collisions

LHCB-FIGURE-2019-019





- No significant saturation for 70% most peripheral collisions (simulation for higher centralities are being produced), expect almost no saturation for Run4 (90% most peripheral) and no saturation for Run5.
- Semi-central PbPb collisions soon available : QGP studies for LHCb in run 3 !
- Increased statistics: improvement of UPC studies.



Exclusive meson production