First LHCb results from PbPb collisions at 5.02 TeV

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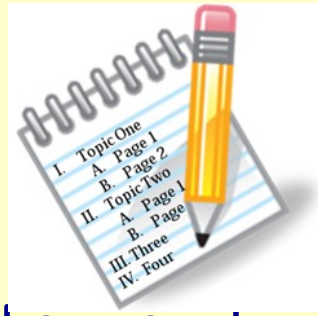
on behalf of the LHCb collaboration

EPS-HEP Conference 2021, Online, 26-30.07.2021

Outline



→ The LHCb detector at the LHC

→ Selected results lead-lead collisions

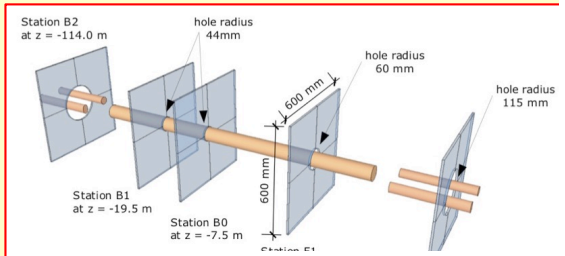
- Study of J/ψ photo-production in peripheral PbPb collisions at 5 TeV
  [LHCb-PAPER-2020-043 (in preparation)]
- The PbPb environment in LHCb: Centrality measurement
  [LHCb-DP-2021-002]
- Study of coherent J/ψ production in PbPb collisions at 5 TeV
  [arXiv:2107.03223, LHCb-PAPER-2021-013, LHCb-CONF-2018-003]

→ Conclusions and outlook

[LHCB-PUB-2018-015 , LHCB-CONF-2018-005 , LHCB-TDR-020]

LHCb Detector at the LHC

- Single arm spectrometer in forward direction
  - Designed for b-physics, becoming a General Purpose Detector
  - Forward and backward coverage for asymmetric beams
  - Precision in the forward region not achievable by others yet



HERSCHEL @± 114 m IP

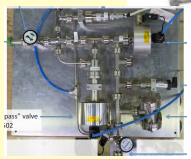
[JINST 3 (2008) S08005]
[IJMPA 30 (2015) 1530022]

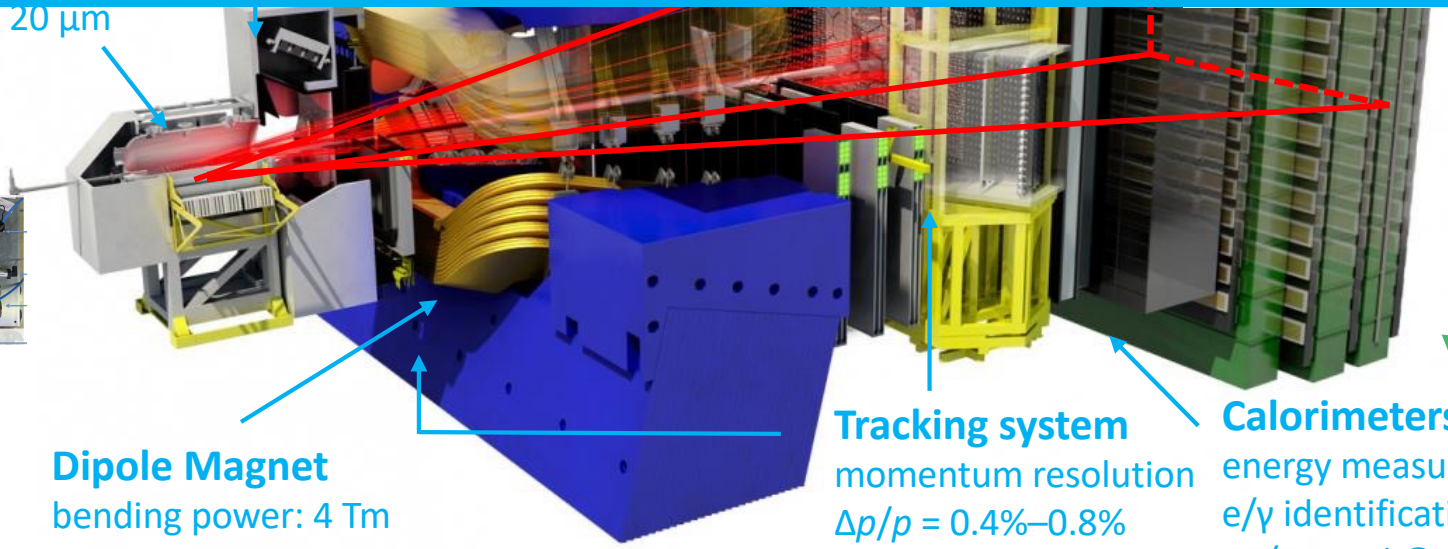
RICH detectors
K/π/p separation
ε(K→K) ~ 95 %

Muon system
μ identification ε(μ→μ) ~ 97 %,
mis-ID ε(π→μ) ~ 1-3 %

Will re-start in 2022 with a brand new detector!

Vertex
reconstr
decay tir
IP resolution: 20 μm


SMOG

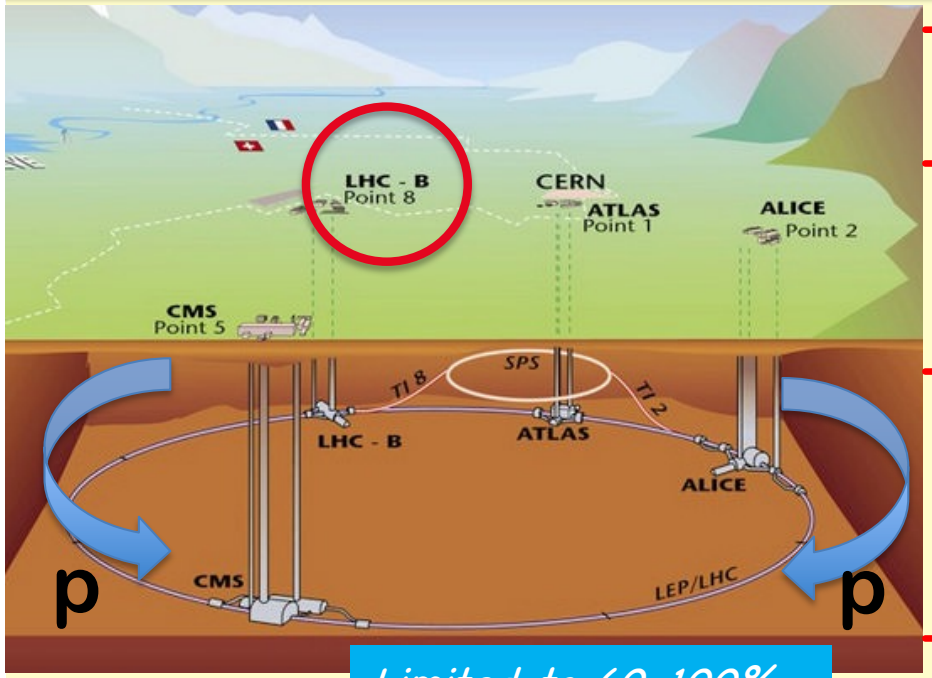

~12 m

Dipole Magnet
bending power: 4 Tm

Tracking system
momentum resolution
$\Delta p/p$ = 0.4%–0.8%
(5 GeV/c – 100 GeV/c)

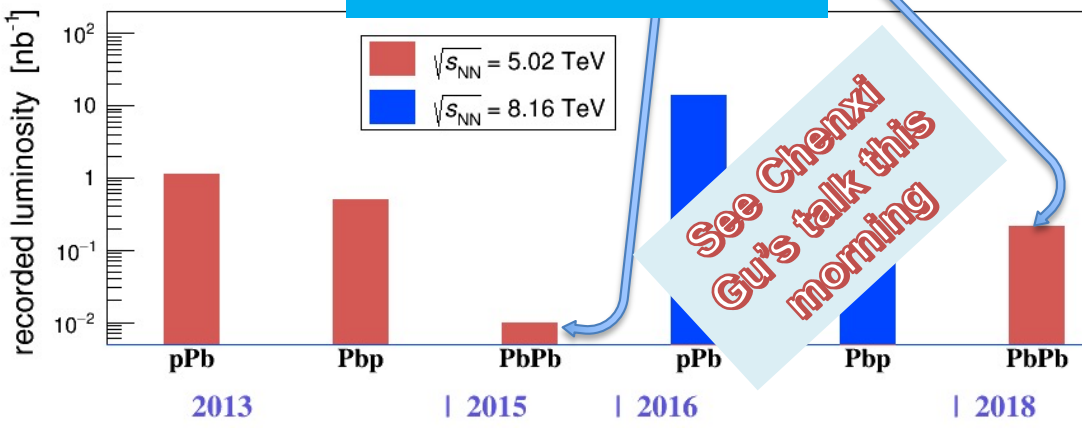
Calorimeters
energy measurement
e/γ identification
$\Delta E/E$ = 1 % ⊕10 %/√E (GeV)

LHC and LHCb

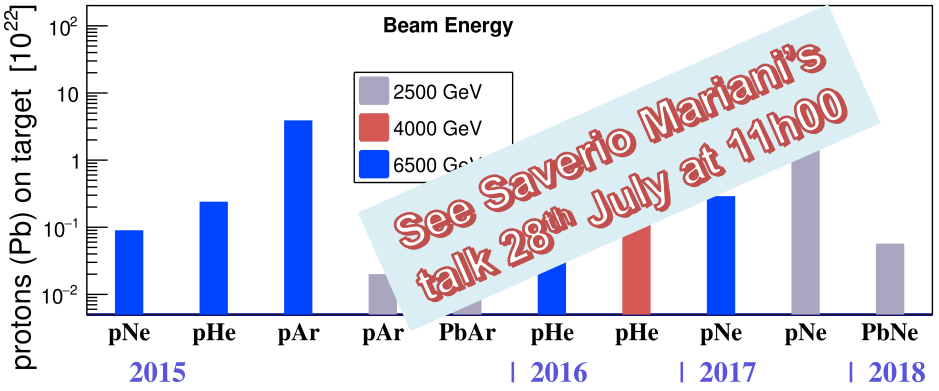


- pp collider 2010-18@$\sqrt{s}$ = 2.76, 5, 7, 8, 13 TeV, L ≈ 9 fb^{-1}
- In 2013 & 2016 collected pPb/Pbp data @ $\sqrt{s_{NN}}$=5 and 8.16 TeV, L=1.6 & 34 nb^{-1}
  - 10^9 minimum bias collisions, ≈1M J/ψ's
- PbPb collisions @ $\sqrt{s}$=5TeV, L ≈ 10 μb^{-1} successfully collected at LHCb for the first time in 2015; already 20x in 2018 (!)
  - XeXe collisions @$\sqrt{s}$=5.4 TeV, L≈0.4 μb^{-1}
- LHCb also able to collect data in "fixed target" mode (SMOG)

Limited to 60-100% in centrality due to detector saturation



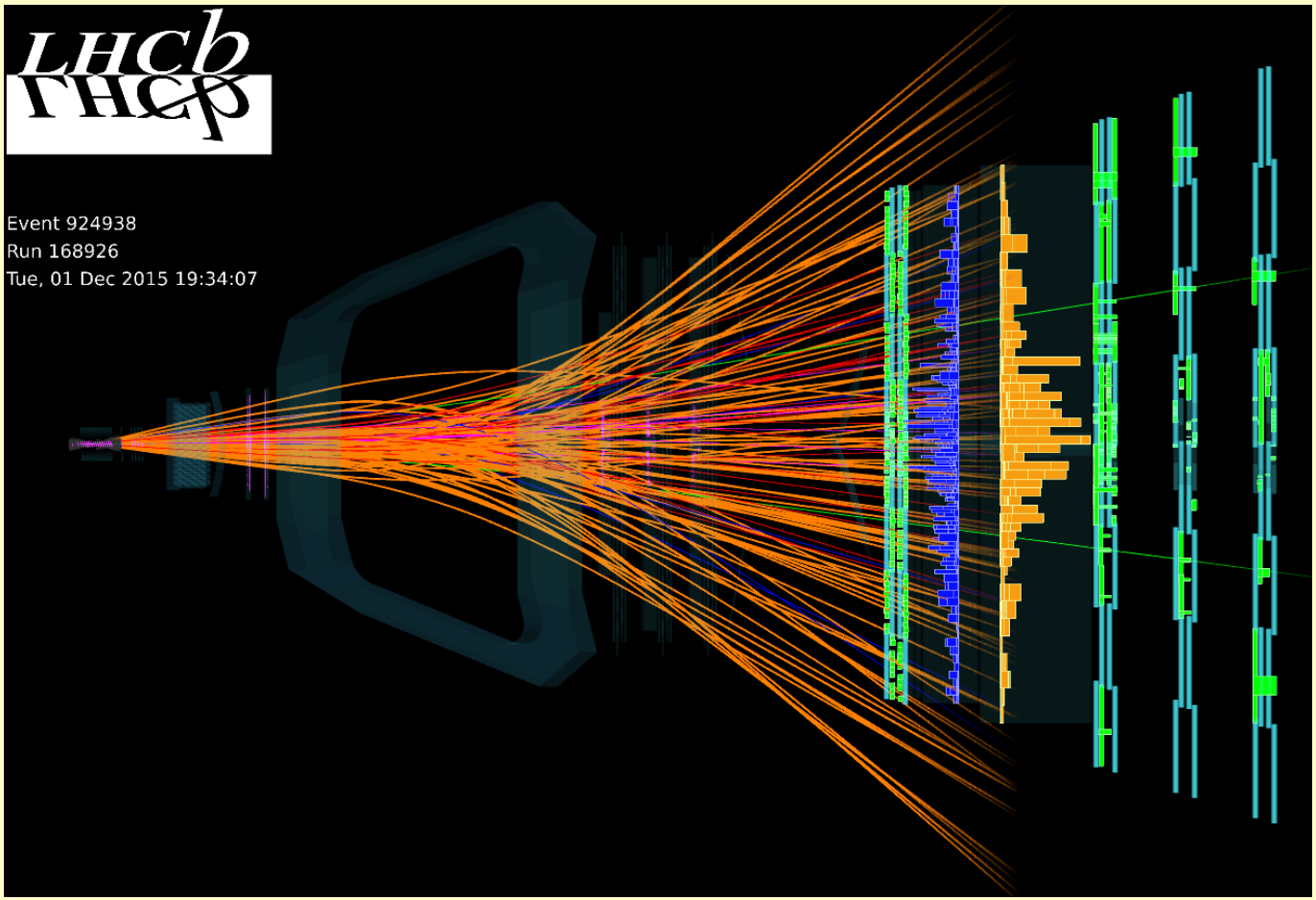
See Chenxi Gu's talk this morning



See Saverio Mariani's talk 28th July at 11h00

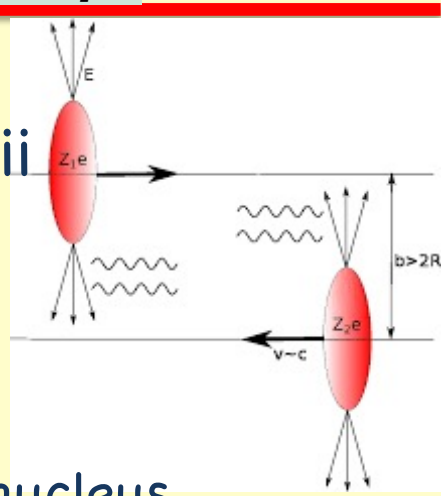
Coherent J/ψ production in ultra-peripheral PbPb collisions

[arXiv:2107.03223, LHCb-PAPER-2021-013, supersedes LHCb-CONF-2018-003]



Ultra-Peripheral PbPb Collisions

[Arxiv:2107.03223]



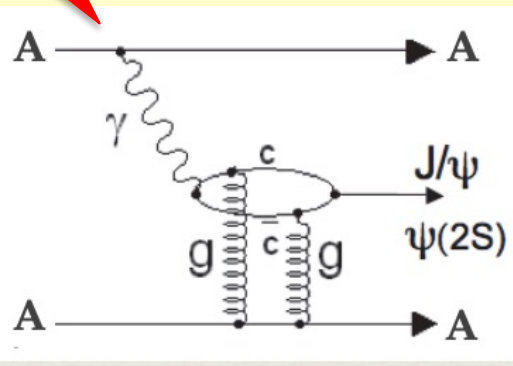
→ UPC: Two nuclei collide with each-other with impact parameter larger than the sum of their radii

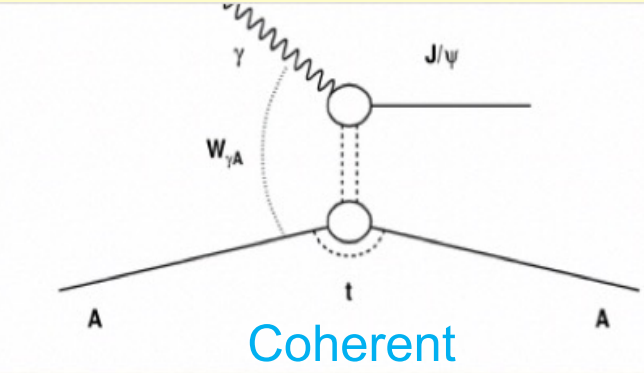
→ Can exchange a photon ! => Photon induced interactions enhanced by strong EM field of nucleus.

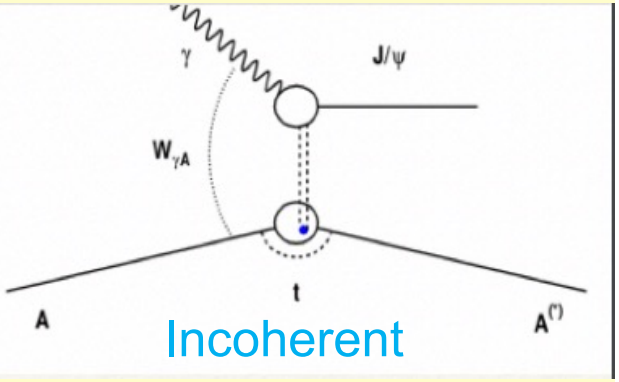
- Coherent: photon interacts with nucleus as a whole
- Incoherent: photon interacts with the nucleons in the nucleus

→ Coherent charmonia production (J/ψ and $\psi(2S)$)

- Constraints on gluon PDFs
- Ratio of the two indicates the correct vector meson wave function in dipole scattering models [PLB 772 (2017) 832, PRC (2011) 011902]







Charmonium production in UPC

[Arxiv:2107.03223]

→ Measurement of coherent cross-section:

$$\frac{d\sigma^{\psi}_{coherent}}{dy} = \frac{N^{\psi}_{coherent}}{\varepsilon_{total} \cdot B(\psi \to \mu^+\mu^-) \cdot \mathcal{L} \cdot \Delta y}, \qquad \psi = J/\psi, \psi(2S)$$

→ Signal: essentially two tracks and nothing else in the detector!

- Herschel used to further reduce the background [JINST 13 (2018) 04 P04017]

→ N signal events extracted from fit on $M_{\mu\mu}$; (coherent+incoherent)

→ Kinematic range of acceptance:

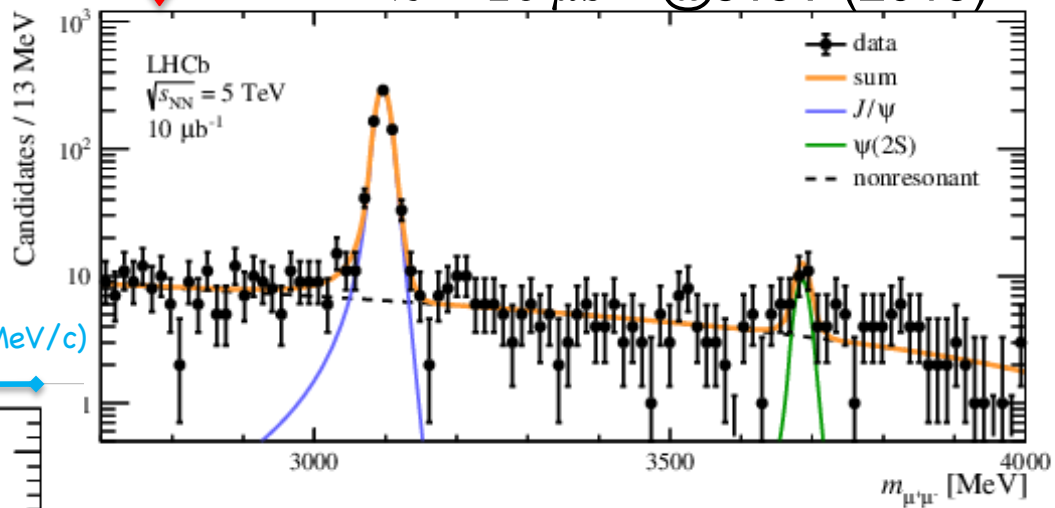
Muons:

- $2.0 < \eta^{\mu} < 4.5$,
- $p_T^{\mu} > 700$ MeV/c

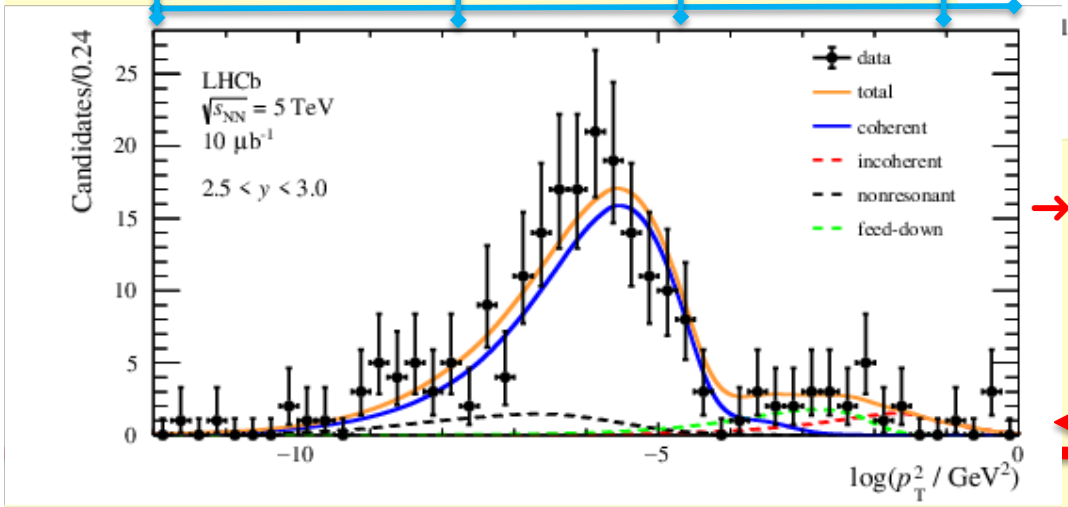
Dimuons:

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

$\mathcal{L} \sim 10\ \mu b^{-1}$@5TeV (2015)



2.5. 18 135. 606. (MeV/c)



→ Coherent component extracted using template fits from STARlight on the natural logarithm of the momentum distribution

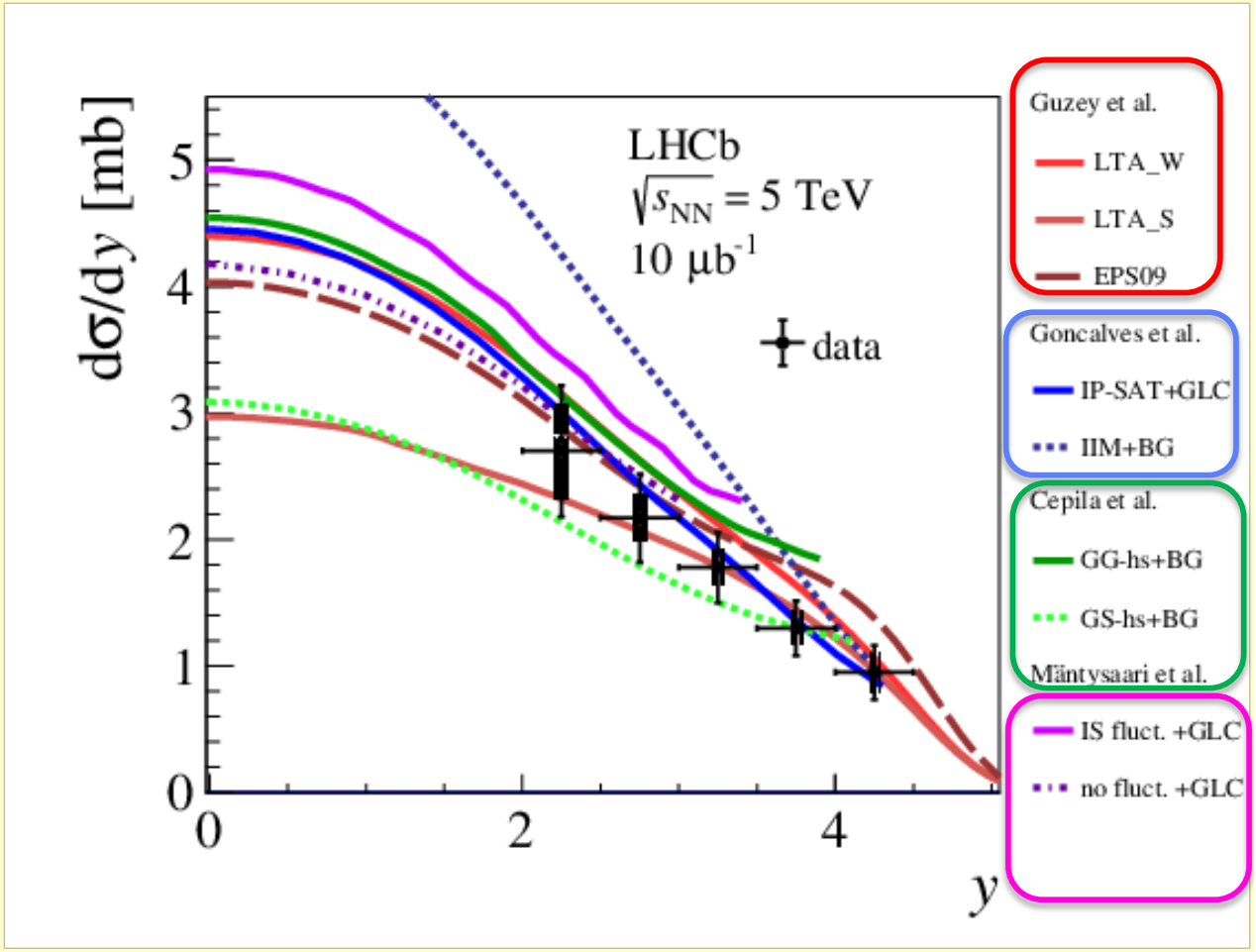
Charmonium production in UPC : Results

[Arxiv:2107.03223]

- Coherent J/ψ cross-section measured as a function of rapidity
- Integrated over y [2.0-4.5]:

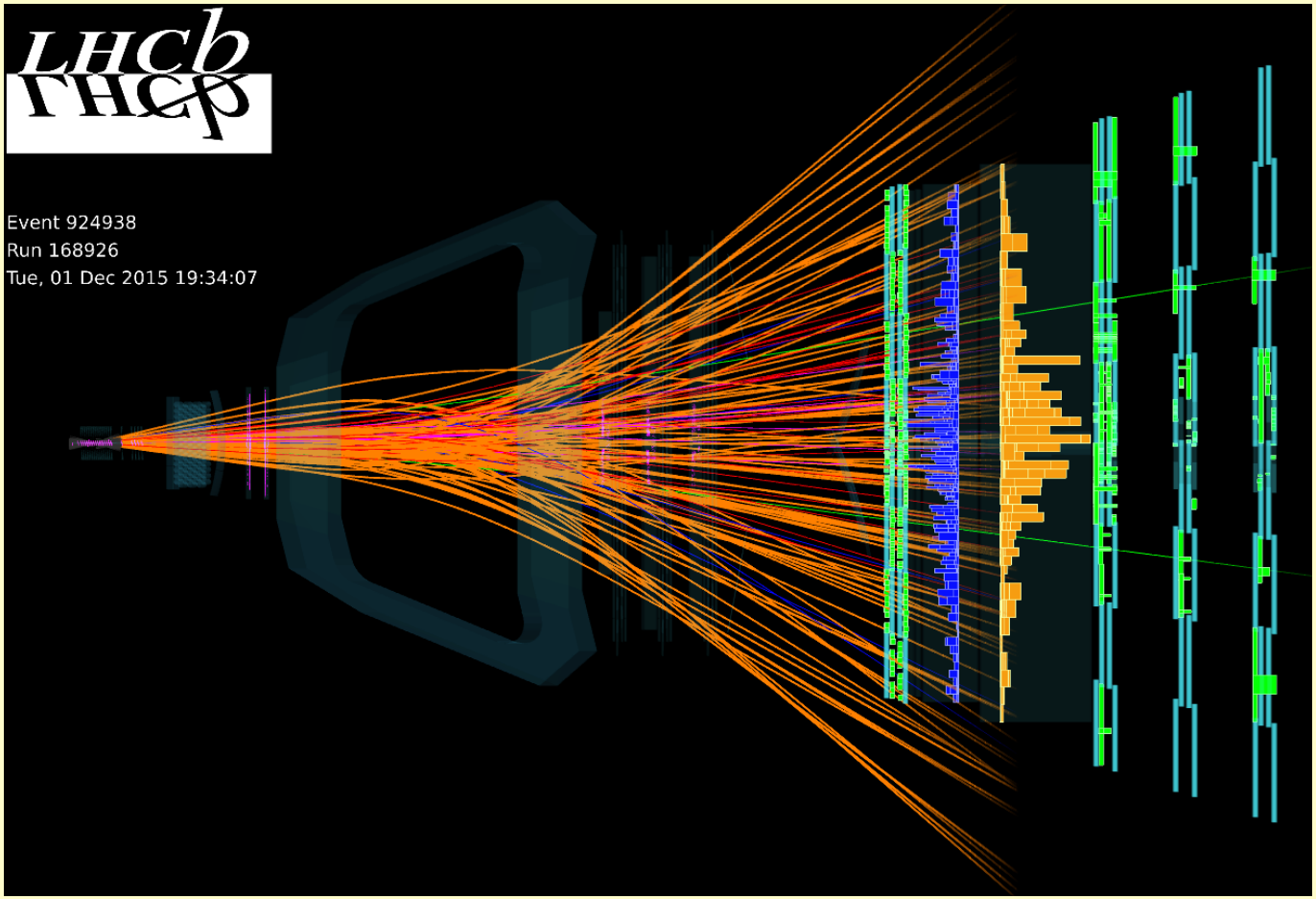
$$\sigma^{\psi}_{coherent} = 4.45 \pm 0.24(stat) \pm 0.18(syst) \pm 0.58(lumi)\ mb$$

- Forward LHCb acceptance allows great discrimination among the theory models
- pQCD calculation
  [PRC 93 (2016) 055206]
- Color dipole models
  [PRD 96 (2017) 094027]
  [PRC 97 (2018) 024901]
  [PLB 772 (2017) 832]
- Analysis update with higher statistics on the way (2018 PbPb data)



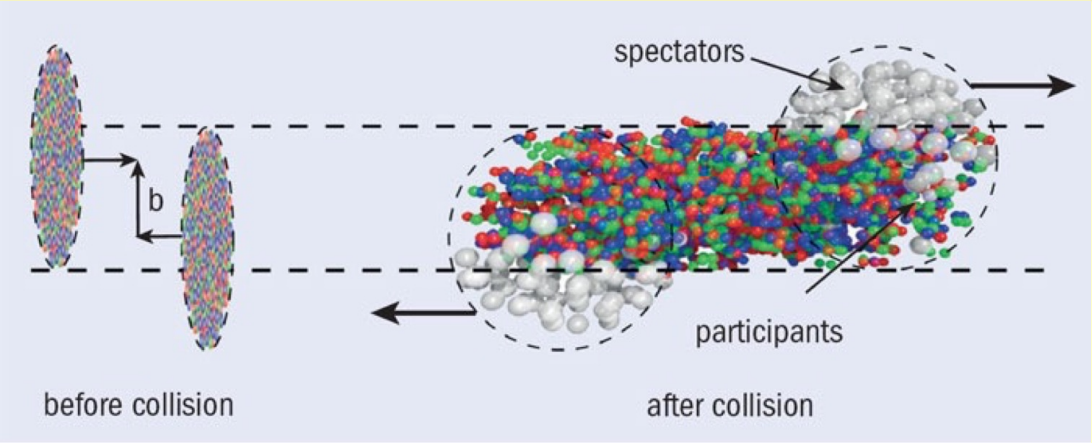
Study of J/ψ production in peripheral PbPb collisions

[arXiv:2107.03223,LHCb-PAPER-2020-043 (in preparation)]

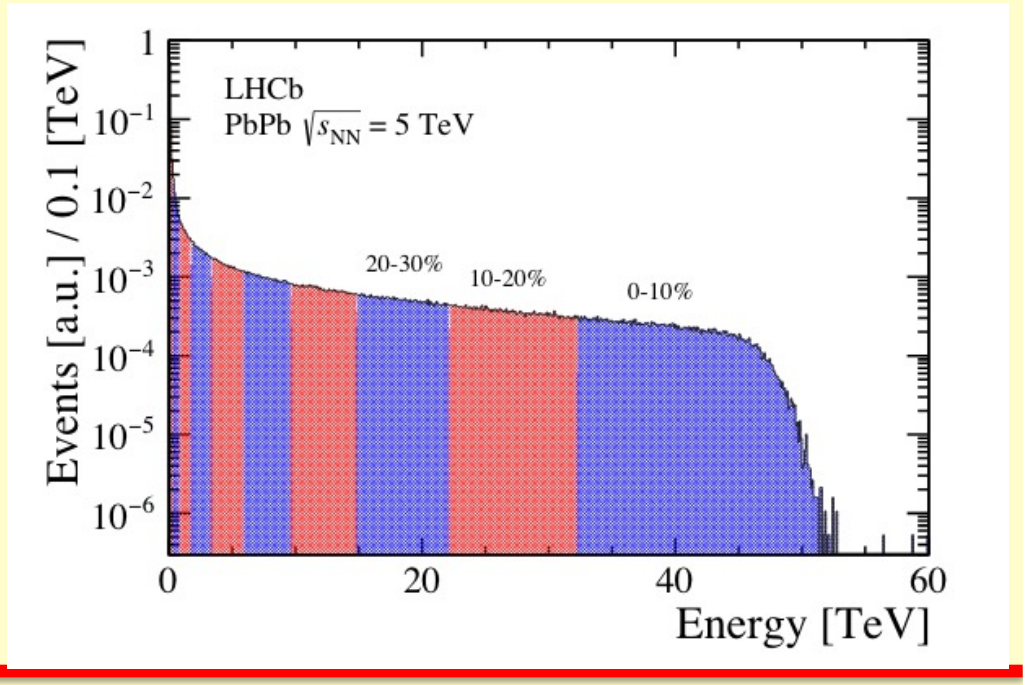


Centrality determination in LHCb

CERN-LHCb-DP-2021-002



- A proxy of the impact parameter b of the collisions can be given by "centrality" classes, defined as percentile of the inelastic PbPb cross section as f($\sqrt{s}$)
- We use the Glauber model to derive Nparticipants (<Npart>), the impact parameter (<b>), etc.
- We use the energy deposit in the Electromagnetic calorimeter to extract the centrality value through the Glauber model

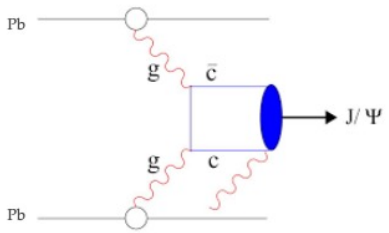


Prompt J/ψ production in peripheral PbPb collisions

→ When b < 2 R Pb the collision is "peripheral"

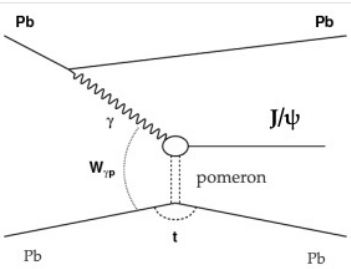
- Possible to identify also hadronic component !

Hadronic production

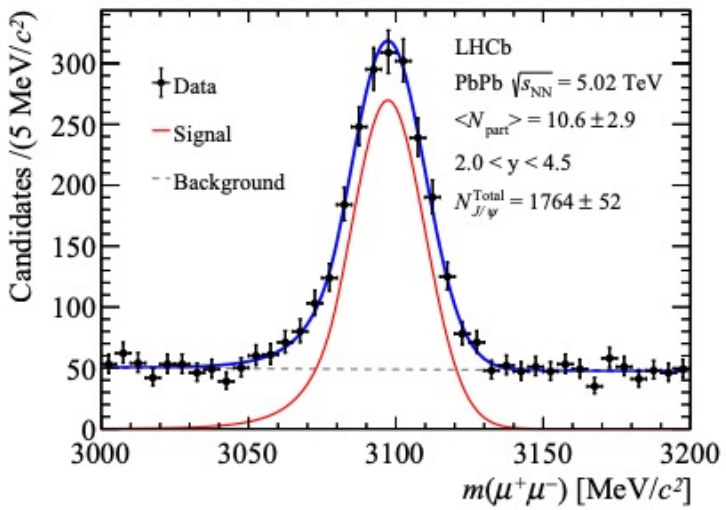


$gg \rightarrow J/\psi$

Coherent photo-production



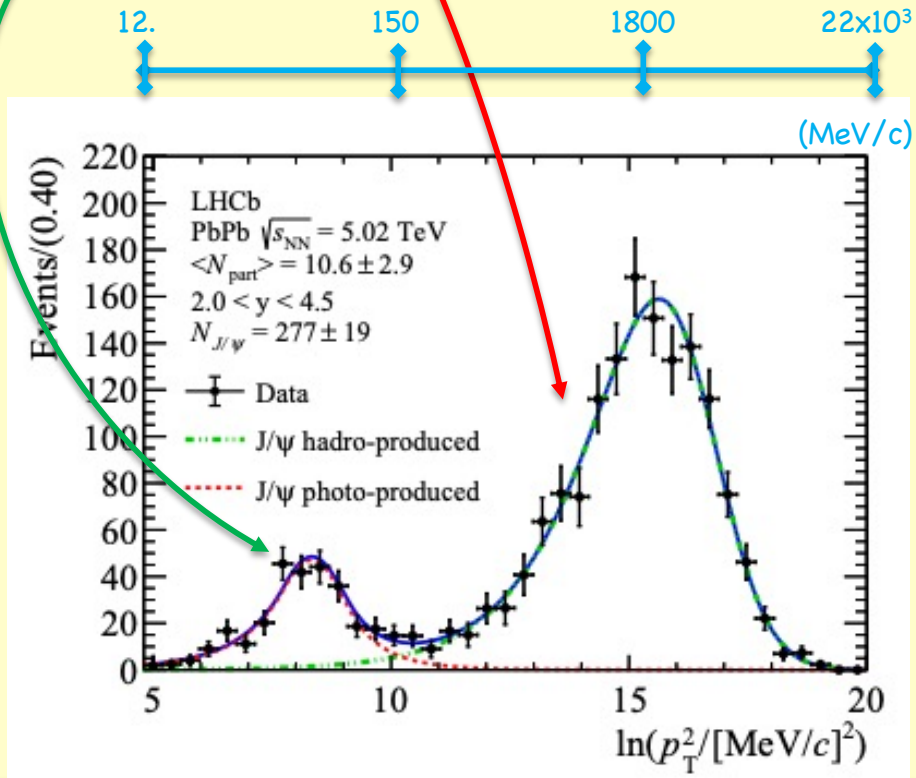
$\gamma(pomeron) \rightarrow J/\psi$



$\mathcal{L} \sim 210\ \mu b^{-1}$@5TeV (2018)

Use p_T distribution of the J/ψ mesons

- Hadronic : mean p_T 1-2 GeV/c,
- Coherent : mean p_T < 300 MeV/c

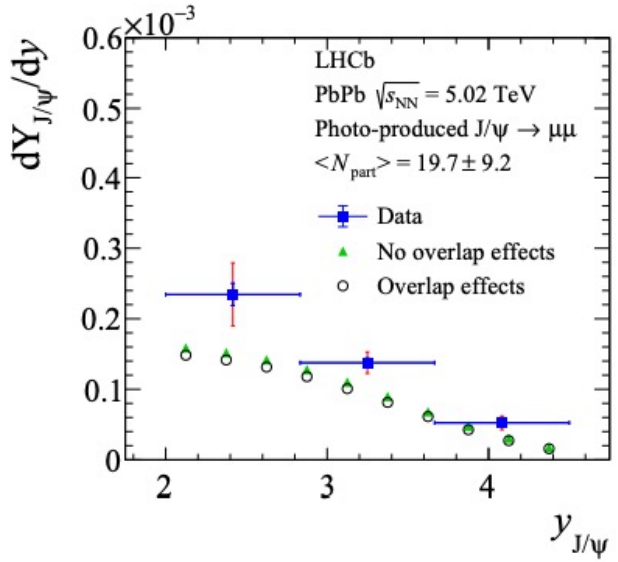


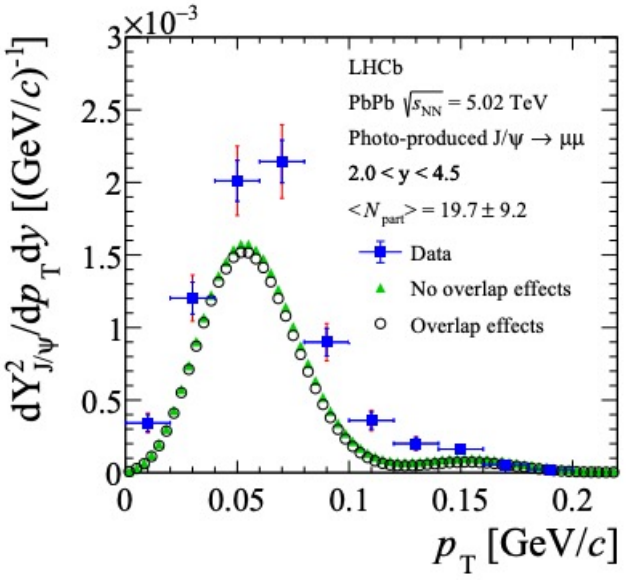
J/ψ production in peripheral PbPb collisions

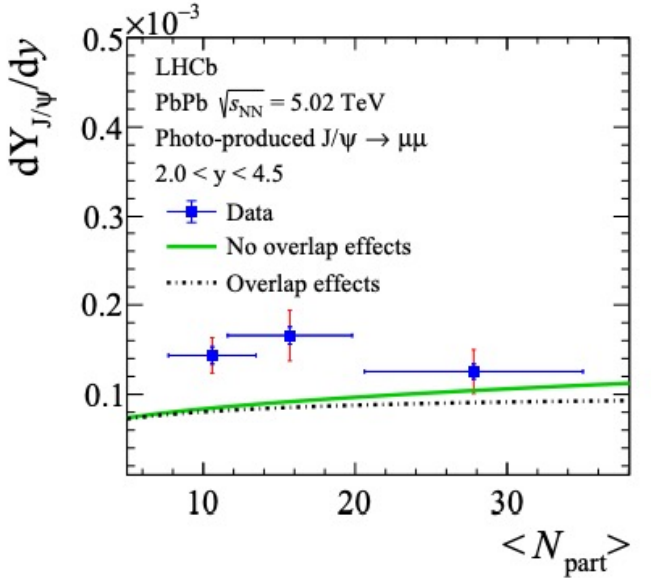
- Consistent measurement J/ψ photo-production in PbPb hadronic collisions
  - Most precise pT measurement to date !
- Shape compatible with theoretical model under two assumptions:
  - "No effect of overlap between the nuclei (UPC interaction at small impact parameter)" or "The overlap has an effect

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

- Yields measured : $\frac{dY_i^{\psi}}{dy\,(dp_T)} = \frac{N_i^{\psi}}{\varepsilon_i^{tot} \cdot N_i^{MB} \mathcal{L} \cdot B(\psi \to \mu^+\mu^-) \cdot \Delta y(\cdot \Delta p_T)}$



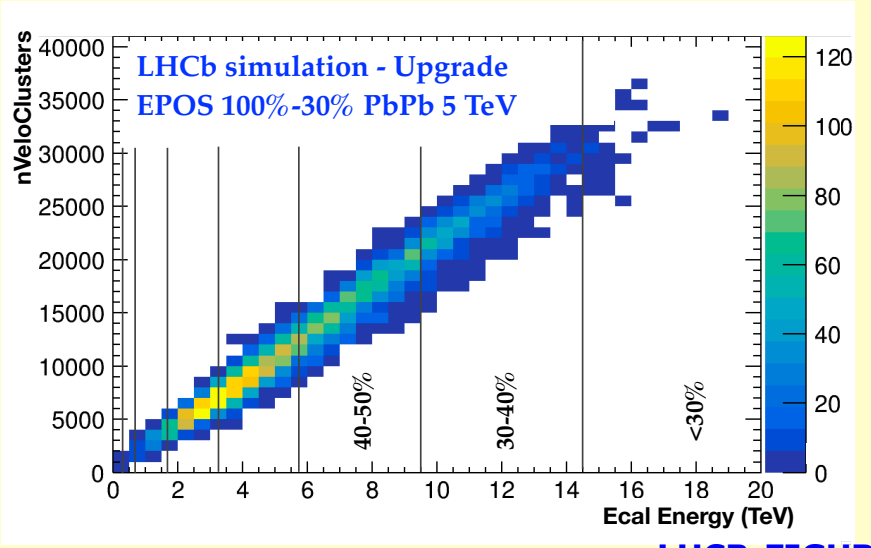


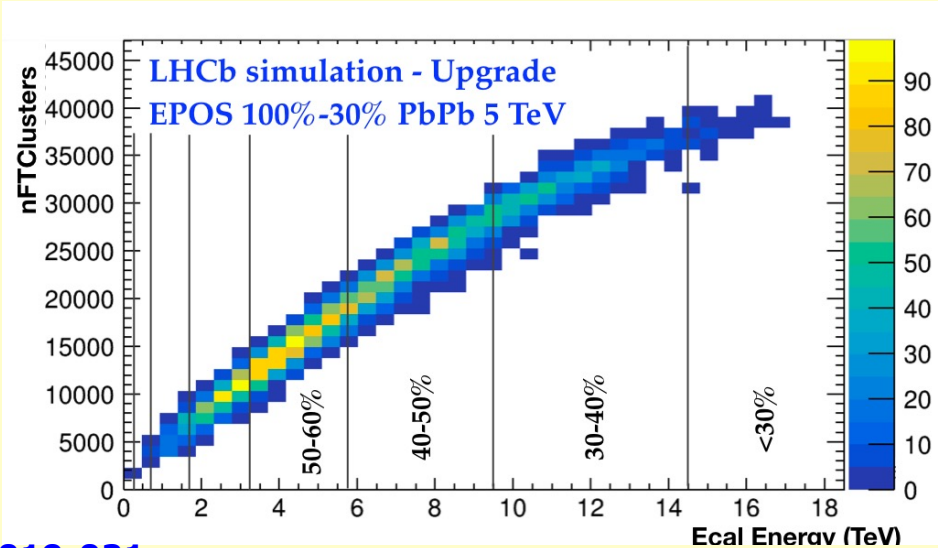


- J/ψ meson <pT> = 64.9 ± 2.4 MeV/c

Summary and Outlook

- LHCb successfully participated in heavy ion data-taking in 2015,2016 & 2018
  - Collected good statistics → could benefit from larger data samples
  - Many measurements performed; first ones with PbPb collisions ever!!
- Charmonium production in PbPb ultra peripheral collisions: refined analysis, good agreement with theory; 2018 results on the way!
- J/ψ studies in PbPb peripheral (hadronic!) collisions using centrality for the first time ! Results with 2018 dataset compared with theoretical predictions, discussion with theorists very lively
- More new results soon with these data
- Many results also studied in view of the new detector in Run3/4
  - Yellow report on the way *LHCB-TDR-12 – 17; CERN-LHCC-2018-026; LHCB-TDR-019*





LHCB-FIGURE-2019-021