

Quarkonium measurements in pPb and PbPb collisions at LHCb

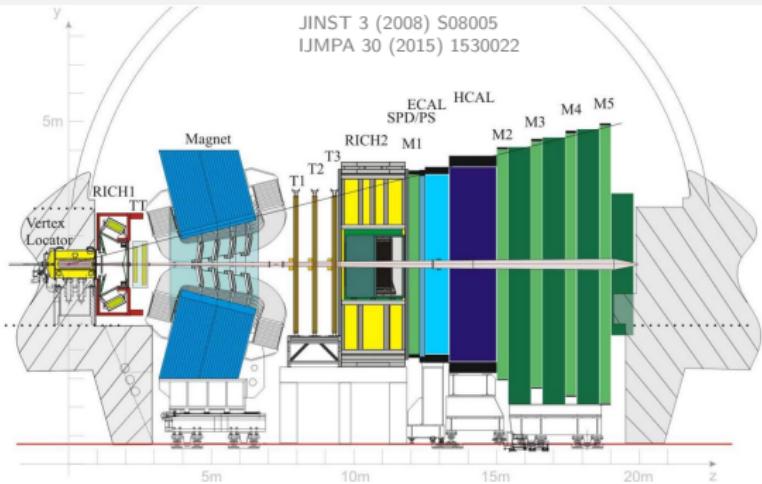
Francesco Bossù
on behalf of the LHCb collaboration

Laboratoire de l'Accélérateur Linéaire, Orsay

EPS HEP2017
VENEZIA, 6 JULY 2017



LHCb detector in heavy-ion collisions



- Single arm spectrometer
- Designed for b-physics
- Fully instrumented in $2 < \eta < 5$
- Complementary to other experiments
- Fixed target capability via gas injection close to the interaction point
- Successful data taking in heavy-ion collisions

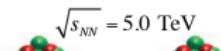
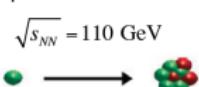
See also: P. Robbe, L. Anderlini,
M. Fontana

Heavy-ion program: novelty for LHCb

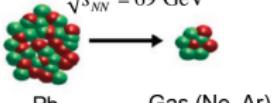
Collider mode



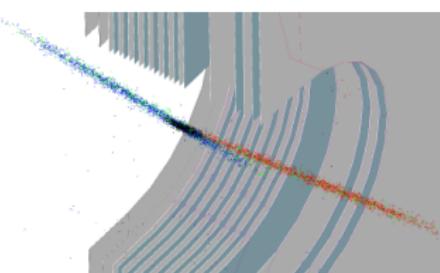
$$\sqrt{s_{NN}} = 110 \text{ GeV}$$



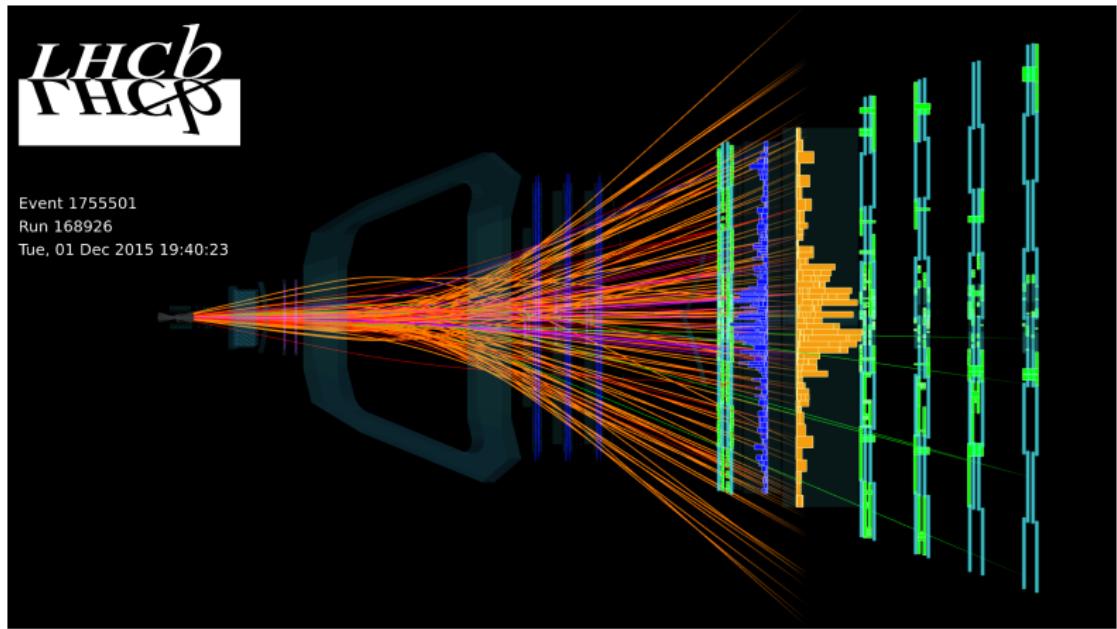
$$\sqrt{s_{NN}} = 69 \text{ GeV}$$



Fixed target mode



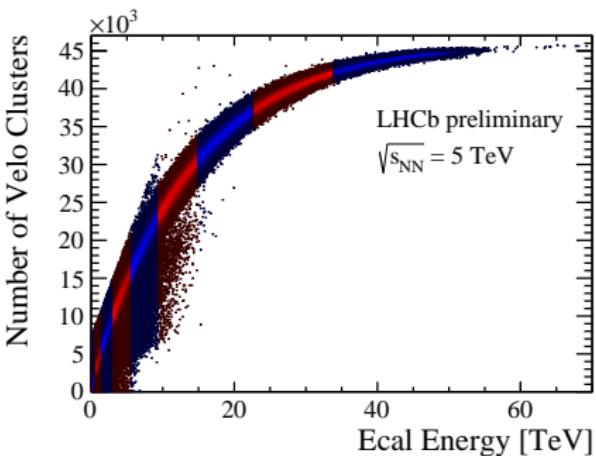
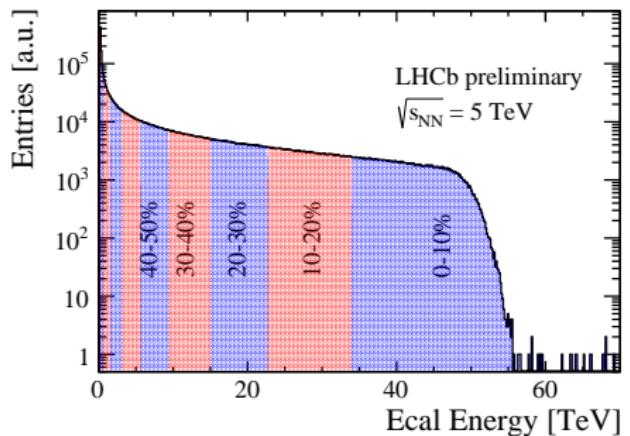
- December 2015. First time of LHCb participation in PbPb data taking
- Only 24 colliding bunches. Luminosity $\approx 3\text{-}5 \mu b^{-1}$
- Minimum bias trigger configuration: all inelastic interactions recorded on tape



Example of one PbPb event with more than 1000 charged tracks and a J/ψ candidate

PbPb - Centrality determination

- Experimental observables: total energy in the calorimeters, EM (Ecal) or hadronic (Hcal)
- No saturation of calorimeter signals for most central collisions

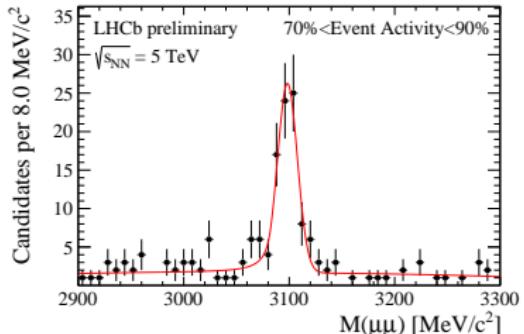


LHCbPlots2015

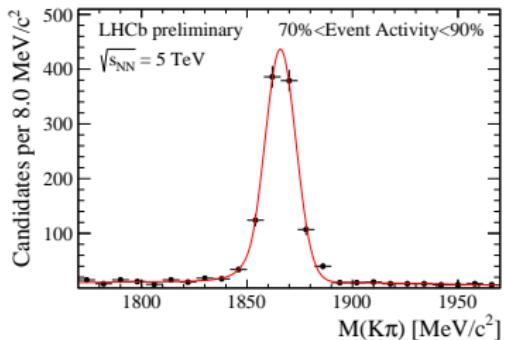
- Event classification in terms of Ecal energy
- Saturation in Vertex Locator (VELO) clearly visible. Track reconstruction was performed up to $\sim 15k$ clusters
- Corresponding range: 50-100% event activity

PbPb - Looking for “heavy” signals...

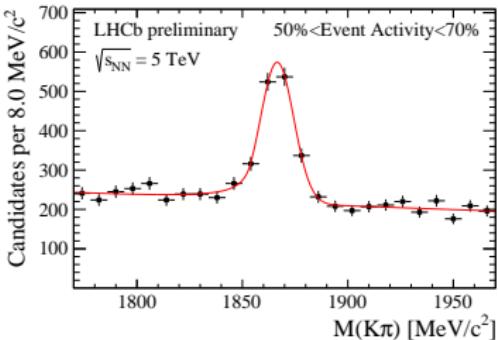
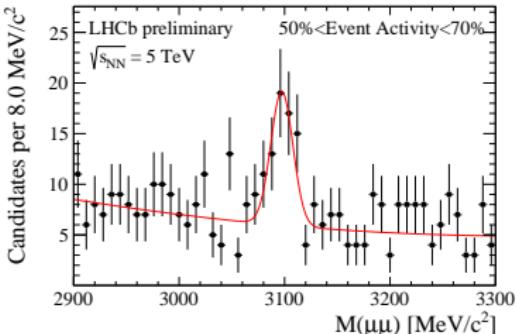
$J/\psi \rightarrow \mu^+ \mu^-$



$D^0 \rightarrow K^- \pi^+$



LHCbPlots2015

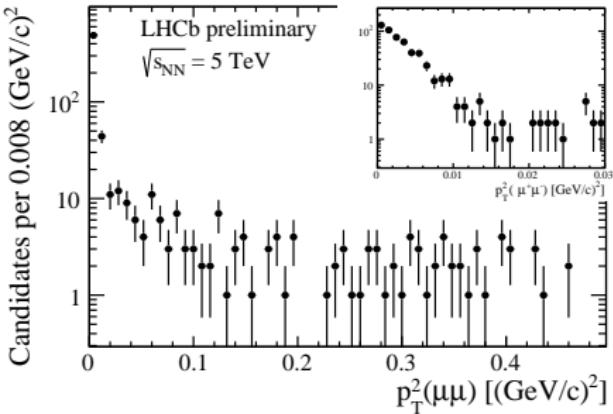
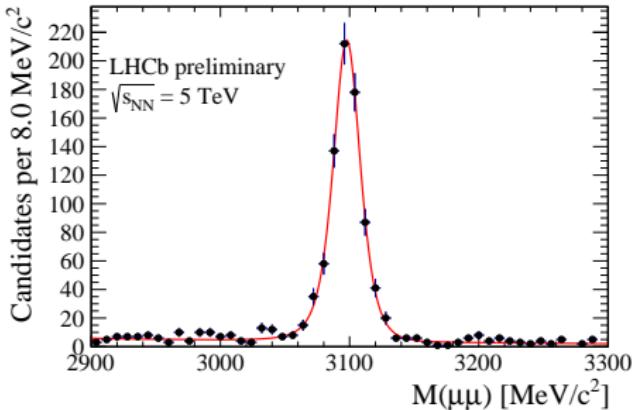


Clear signals also in 50-70% event activity bin

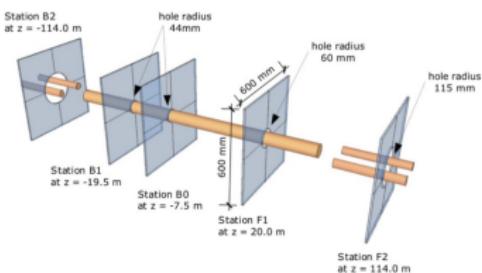
PbPb - J/ψ in ultra-peripheral collisions

Selection: nothing in the detector but two muon tracks

LHCbPlots2015

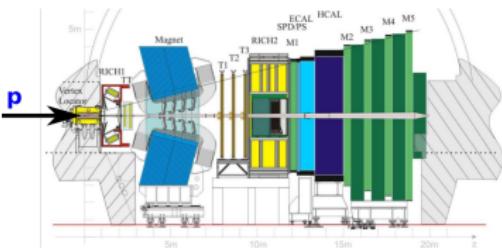
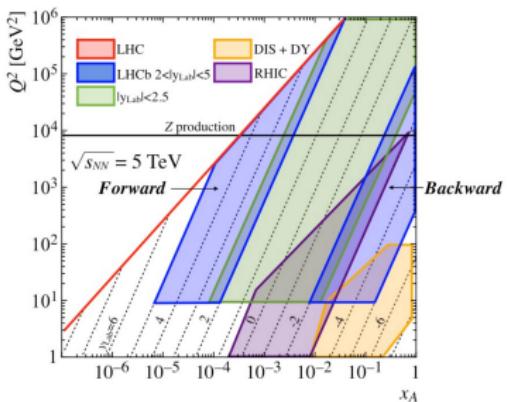


- Candidates of photo-induced J/ψ in PbPb ultra peripheral collisions
- These studies will benefit of the new Herschel detector
 - Possibility to define large rapidity gaps: $5 < |y| < 9$
 - Herschel was taking data in 2015



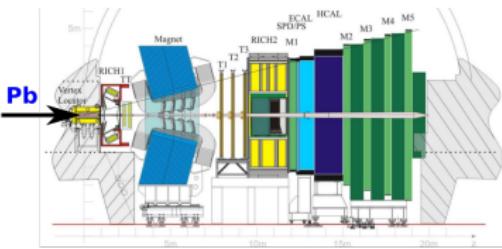
pPb collisions

- Reversal of p and Pb beams allows to study backward and forward rapidity regions
- Asymmetry in beam energies per nucleon: rapidity coverage shifted by $\Delta y \sim 0.47$
- 1.6 nb^{-1} collected in 2013 at $\sqrt{s_{NN}} = 5 \text{ TeV}$
- In 2016, at $\sqrt{s_{NN}} = 8.16 \text{ TeV}$
 - pPb: $13.6 \pm 0.3 \text{ nb}^{-1}$
 - PbP: $20.8 \pm 0.5 \text{ nb}^{-1}$
 - About 10^9 minimum bias events collected per configuration



$$y^* = y_{lab} - 0.47$$

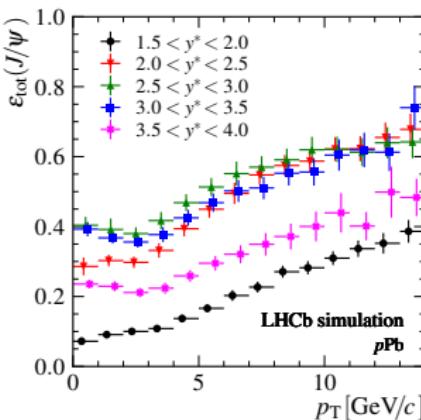
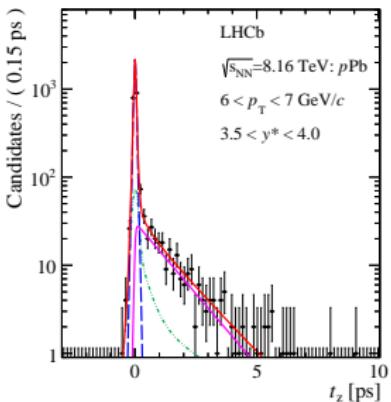
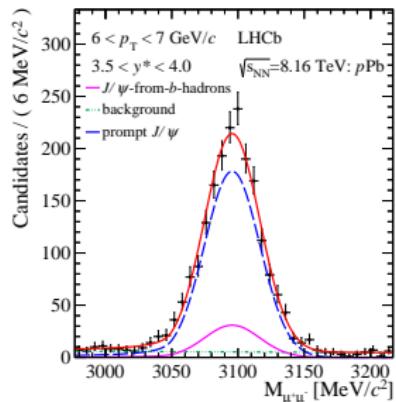
$$1.5 < y^* < 4.5$$



$$y^* = -y_{lab} - 0.47$$

$$-5.5 < y^* < -2.5$$

arXiv:1706.07122

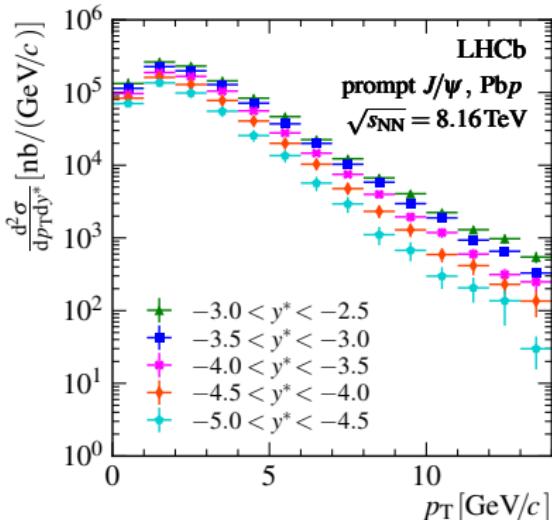
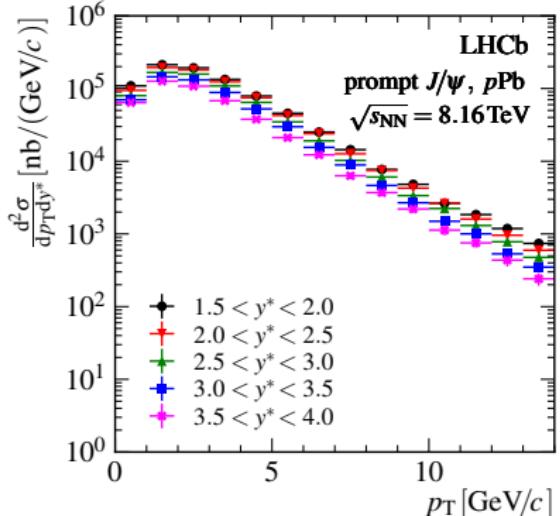


- Candidates: $J/\psi \rightarrow \mu^+ \mu^-$ from the output of the High Level Trigger (Turbo)
- Selection: $p_T^\mu > 750 \text{ MeV}$, good track and vertex qualities
- Signal extraction with 2D simultaneous fit to the mass and the pseudo proper decay time

$$t_z \equiv \frac{(z_{J/\psi} - z_{\text{PV}}) \times M_{J/\psi}}{p_z}$$

- Separation of prompt and nonprompt (from b -hadrons) components
- Acceptance and efficiency: unpolarised production assumed

arXiv:1706.07122

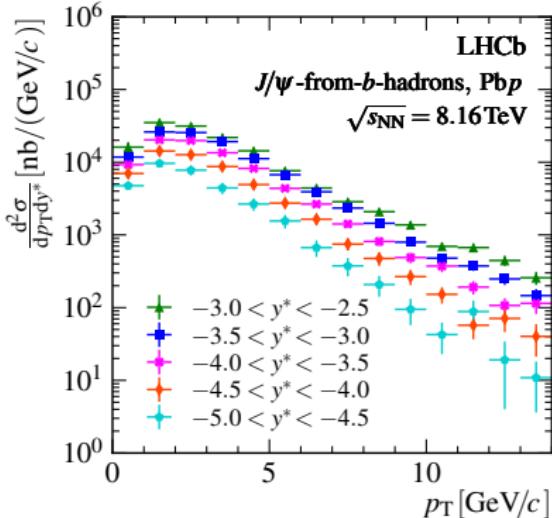
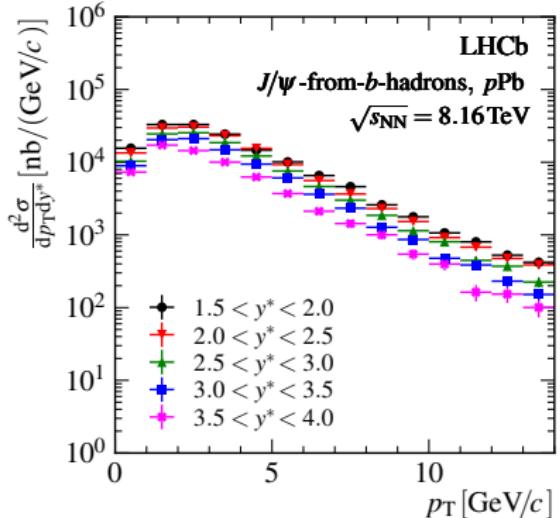


- Prompt J/ψ double differential cross sections
- Total cross sections:

$$\sigma_{\text{prompt } J/\psi} (1.5 < y^* < 4.0, p_T < 14 \text{ GeV}/c) = 1625 \pm 4(\text{stat.}) \pm 117 \mu\text{b}(\text{syst.})$$

$$\sigma_{\text{prompt } J/\psi} (-5.0 < y^* < -2.5, p_T < 14 \text{ GeV}/c) = 1692 \pm 4(\text{stat.}) \pm 182 \mu\text{b}(\text{syst.})$$

arXiv:1706.07122



- Nonprompt J/ψ double differential cross sections
- Total cross sections:

$$\sigma_{J/\psi\text{-from-}b\text{-hadrons}}(1.5 < y^* < 4.0, p_T < 14 \text{ GeV}/c) = 276 \pm 2(\text{stat.}) \pm 20 \mu\text{b}(\text{syst.})$$

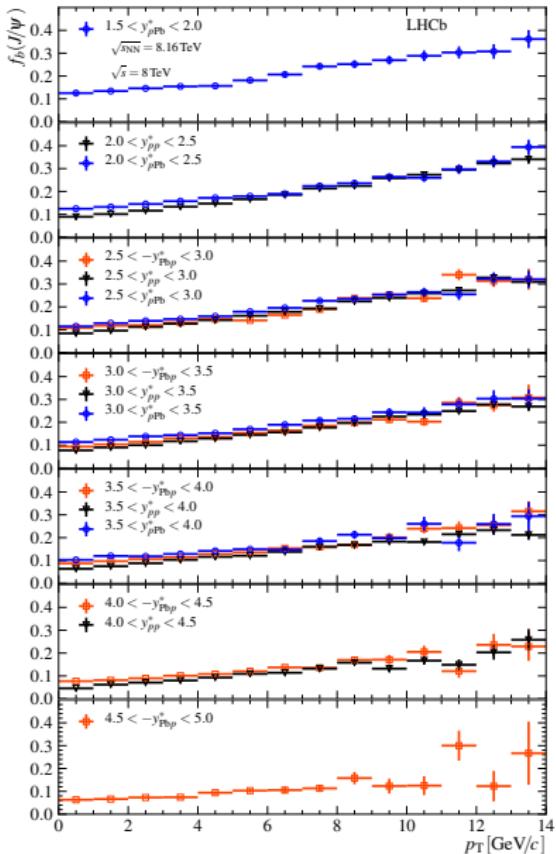
$$\sigma_{J/\psi\text{-from-}b\text{-hadrons}}(-5.0 < y^* < -2.5, p_T < 14 \text{ GeV}/c) = 209 \pm 1(\text{stat.}) \pm 22 \mu\text{b}(\text{syst.})$$

arXiv:1706.07122

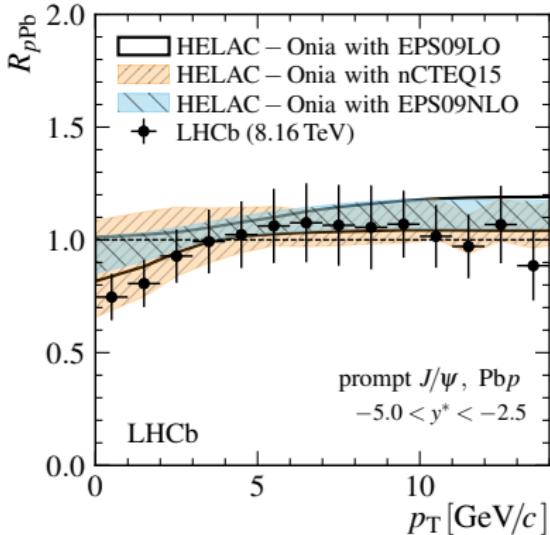
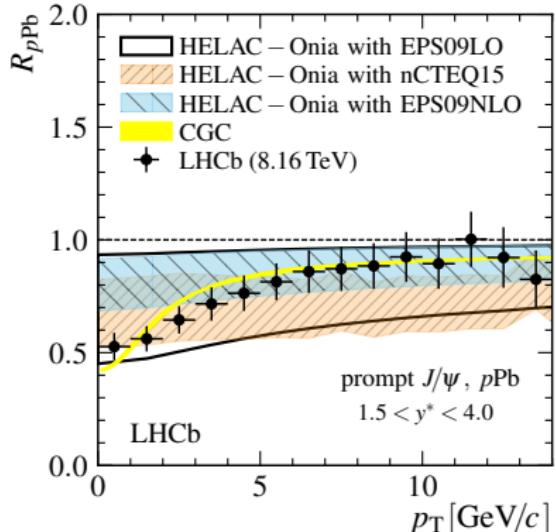
Fraction from b hadrons

$$f_b \equiv \frac{d^2\sigma_{J/\psi \text{-from-} b \text{-hadrons}}/dp_T dy^*}{d^2\sigma_{\text{prompt } J/\psi}/dp_T dy^* + d^2\sigma_{J/\psi \text{-from-} b \text{-hadrons}}/dp_T dy^*}$$

- Comparing pPb and PbPb together with pp@8TeV JHEP 06 (2013) 064
- Similar trends, but at low p_T : cold nuclear matter effects act differently on prompt and nonprompt



arXiv:1706.07122

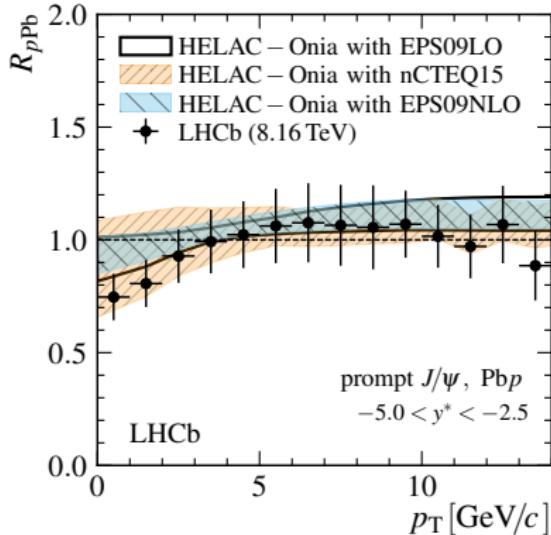
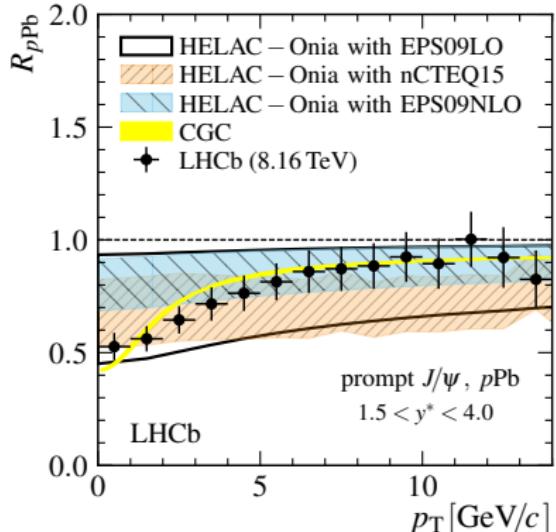


Nuclear modification factor:

$$R_{p\text{Pb}}(p_T, y^*) \equiv \frac{1}{A} \frac{d^2\sigma_{p\text{Pb}}(p_T, y^*)/dp_T dy^*}{d^2\sigma_{pp}(p_T, y^*)/dp_T dy^*}$$

- pp reference at $\sqrt{s} = 8.16$ TeV: interpolation of LHCb measurements at 7, 8 and 13 TeV
- Extrapolation for the rapidity bins not covered by pp data

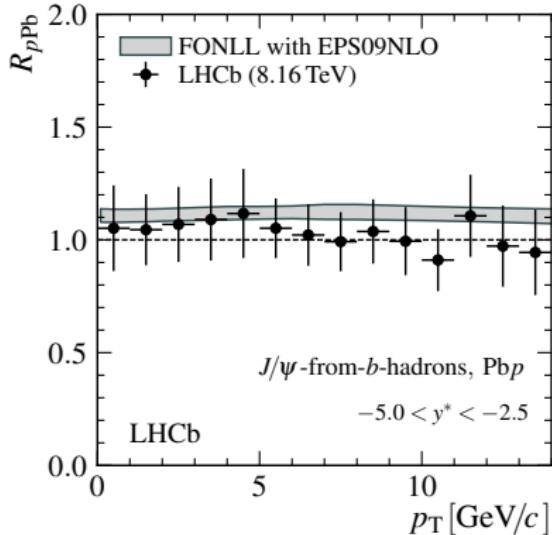
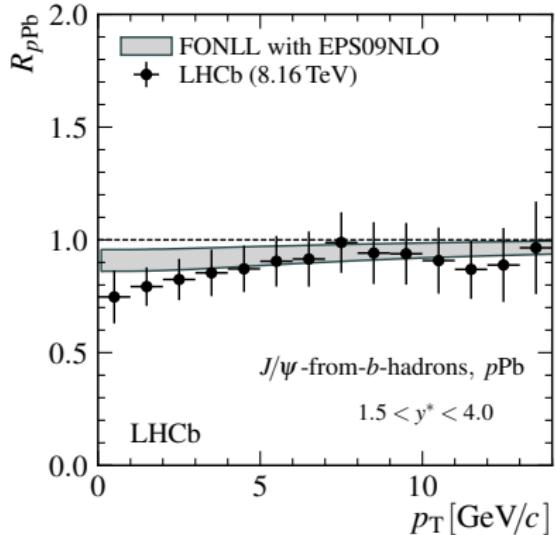
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Prompt J/ψ $R_{p\text{Pb}}$ as a function of p_T :

- Prompt J/ψ shows strong suppression at low p_T , decreasing with increasing p_T
- Collinear factorization including PDF modifications in nuclei is in agreement with data, but large uncertainties from gluon PDFs Comp.Phys.Commun. 198(2016)238-259, JHEP 04(2009)065
- Colour Glass Condensate calculations reproduce the p_T dependence seen in data at forward rapidity Phys. Rev. D94 (2016)074031

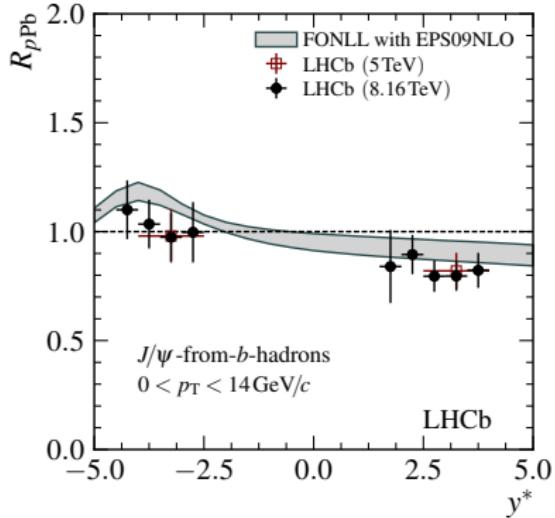
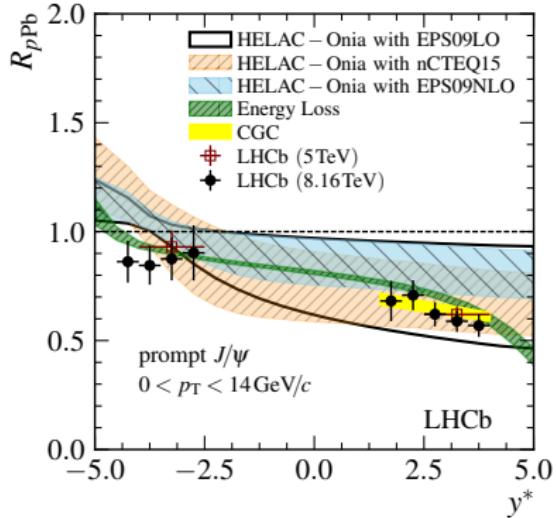
arXiv:1706.07122



Nonprompt J/ψ $R_{p\text{Pb}}$ as a function of p_T :

- Nonprompt J/ψ measurement allows one to access the production of b hadrons
- Small suppression at low p_T at forward rapidity
- Nonprompt J/ψ $R_{p\text{Pb}}$ compatible with unity at backward rapidity
- pQCD calculations with nPDFs are in agreement with data JHEP03(2001)006, JHEP04(2009)065

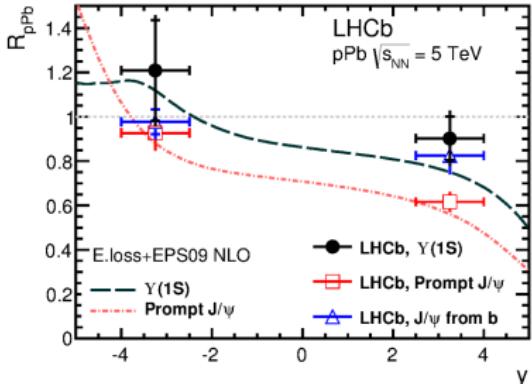
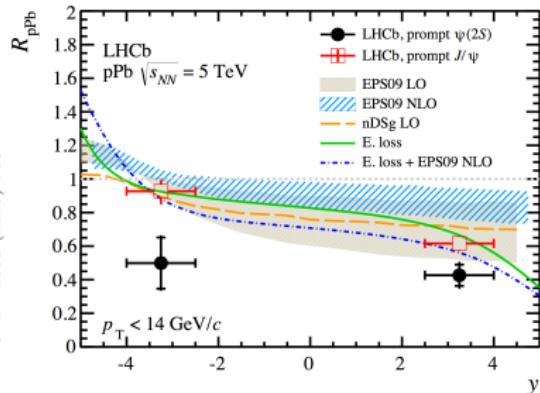
arXiv:1706.07122



J/ψ $R_{p\text{Pb}}$ as a function of y^* :

- At backward rapidity: suppression of prompt J/ψ not well reproduced by models
- At forward rapidity: good agreement of CGC and coherent energy loss calculations with the experimental data PRD94 (2016)074031, JHEP 03(2013)122
- Large uncertainties on the gluon PDFs at low x

- Candidates fully reconstructed from well identified muons



Forward rapidity

- Significant suppression for J/ψ , even larger for $\psi(2S)$
- Moderate suppression for non-prompt J/ψ , similar to $\Upsilon(1S)$

Backward rapidity

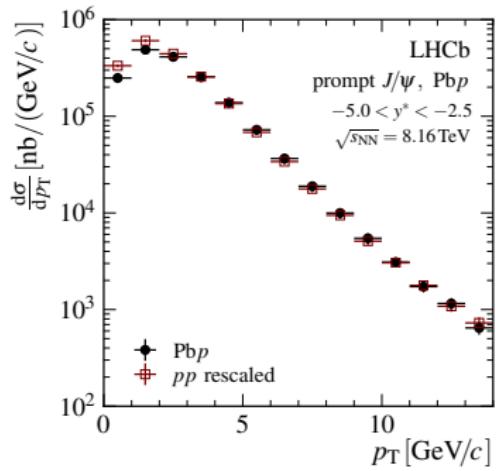
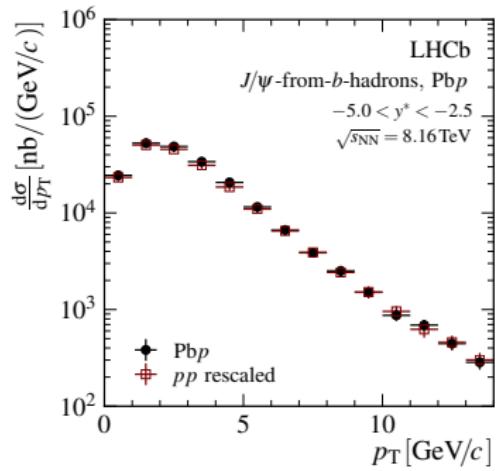
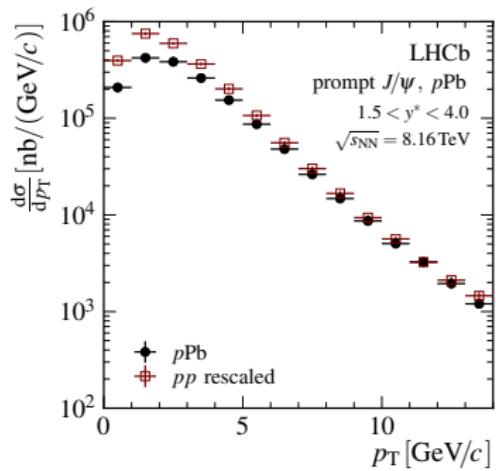
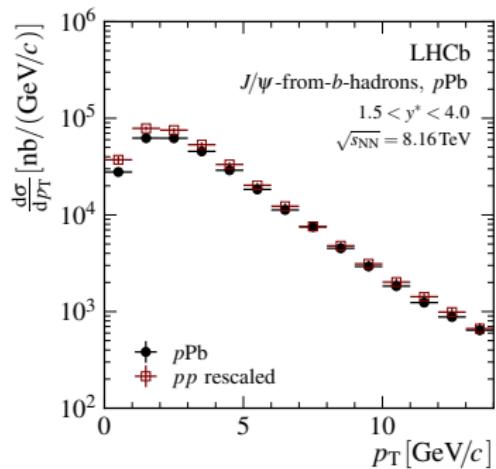
- No suppression for J/ψ and $\Upsilon(1S)$
- Unexpected large suppression for $\psi(2S)$, not described by E.loss and shadowing

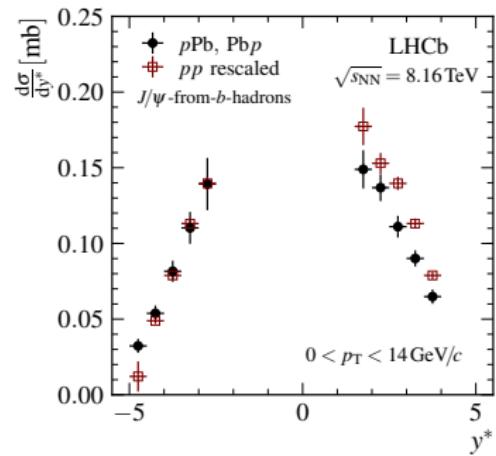
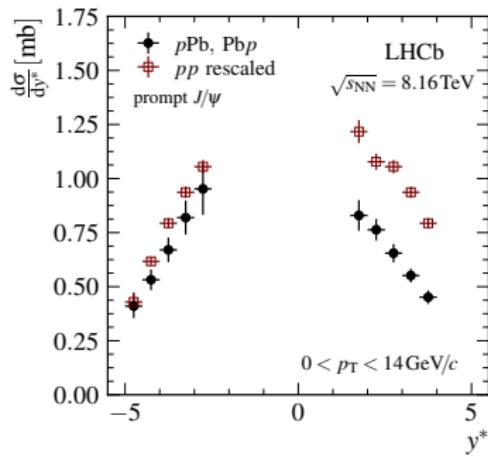
Outlook: similar analyses ongoing with the pPb data at $\sqrt{s_{NN}} = 8.16\text{TeV}$

- LHCb demonstrated that it can play an important role in heavy-ion physics
- PbPb collisions collected in 2015
 - Clear physics signals, challenging detector occupancies, analysis ongoing
- Successful data taking in pPb collisions at $\sqrt{s_{NN}} = 5$ and 8.16 TeV in 2013 and 2016
 - First results at 5TeV have shown LHCb potential in heavy flavour measurements in pA collisions (see P.Robbe's talk)
 - Larger data samples collected at 8.16 TeV
 - Precise measurement of prompt and nonprompt J/ψ production
 - Outlook: analysis ongoing of other charmonium and bottomonium states

Stay tuned!

backups





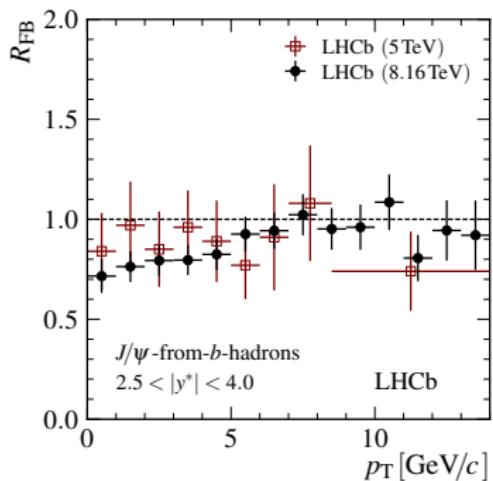
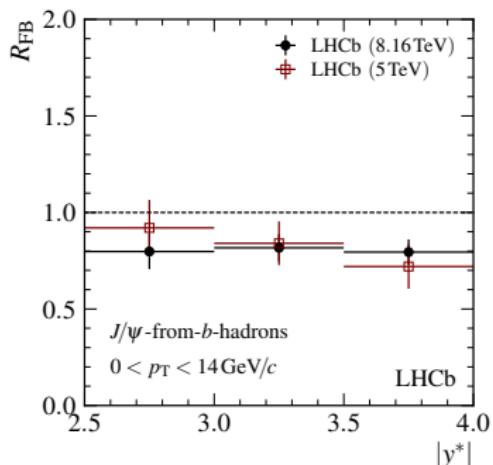
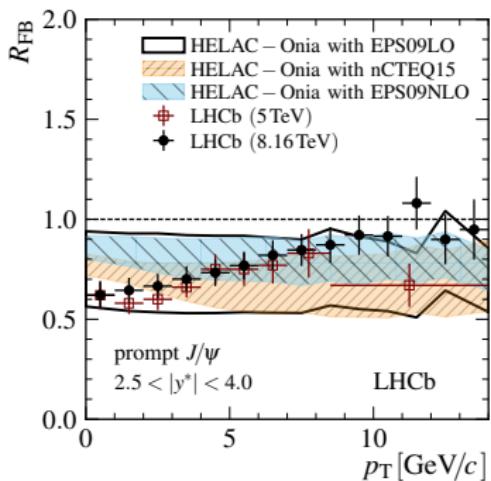
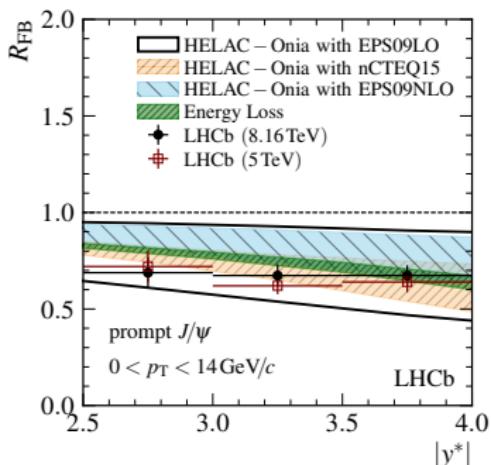


Table 1: Summary of relative systematic uncertainties in $p\text{Pb}$ and Ppb on the cross-section of prompt J/ψ and J/ψ -from- b -hadrons. Uncertainties that are computed bin-by-bin are expressed as ranges giving the minimum to maximum values. The last column indicates the correlation between bins within the same beam configuration.

Source	$p\text{Pb}$	Ppb	Comment
Signal model	1.3%	1.3%	correlated
Muon identification	2.0% – 11.0%	2.1% – 15.3%	correlated
Tracking	3.0% – 8.0%	5.9% – 26.5%	correlated
Hardware trigger	1.0% – 10.9%	1.0% – 7.4%	correlated
Software trigger	2.0%	2.0%	correlated
Simulation statistics	0.4% – 7.0%	0.4% – 26.2%	uncorrelated
$\mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)$	0.05%	0.05%	correlated
Luminosity	2.6%	2.5%	correlated
Polarisation	–	–	not considered