Heavy flavor results in *p*Pb and PbPb collisions with LHCb

Jiayin Sun (Tsinghua University)
On behalf of the LHCb collaboration

December 23rd, 2017

CLHCP2017

Outline

- Heavy flavor physics in pPb collisions
- LHCb detector
- pPb collisions: recent results
  - Open heavy flavor results
  - Hidden heavy flavor results
- PbPb collisions: work in progress

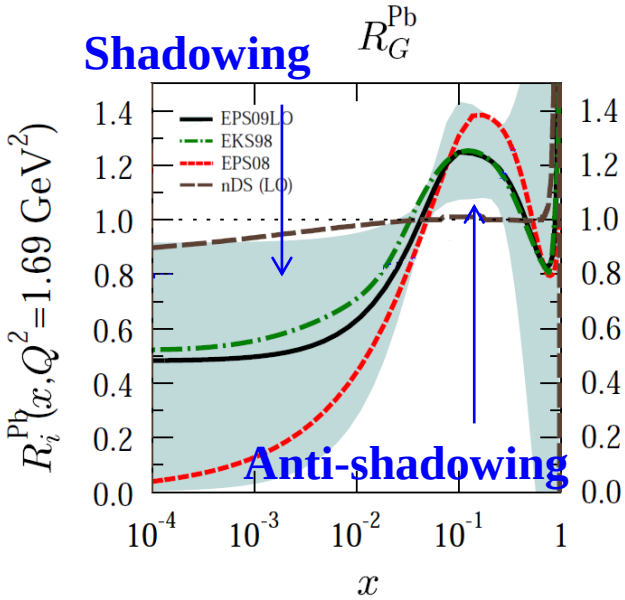
Heavy flavor physics in pPb collisions

- Heavy flavor states are sensitive probes to study the properties of the QGP created in AA collision.
  - Produced in the early stage of the collisions
  - Significant D^0 suppression observed in central PbPb collisions
  - Large Λ_c^+/D^0 ratio measured in mid-central AuAu collisions
  - J/ψ suppression a signature of deconfinement

- Heavy flavor in pA collisions provide baseline measurements to disentangle cold nuclear matter effects from effects of hot and dense medium.

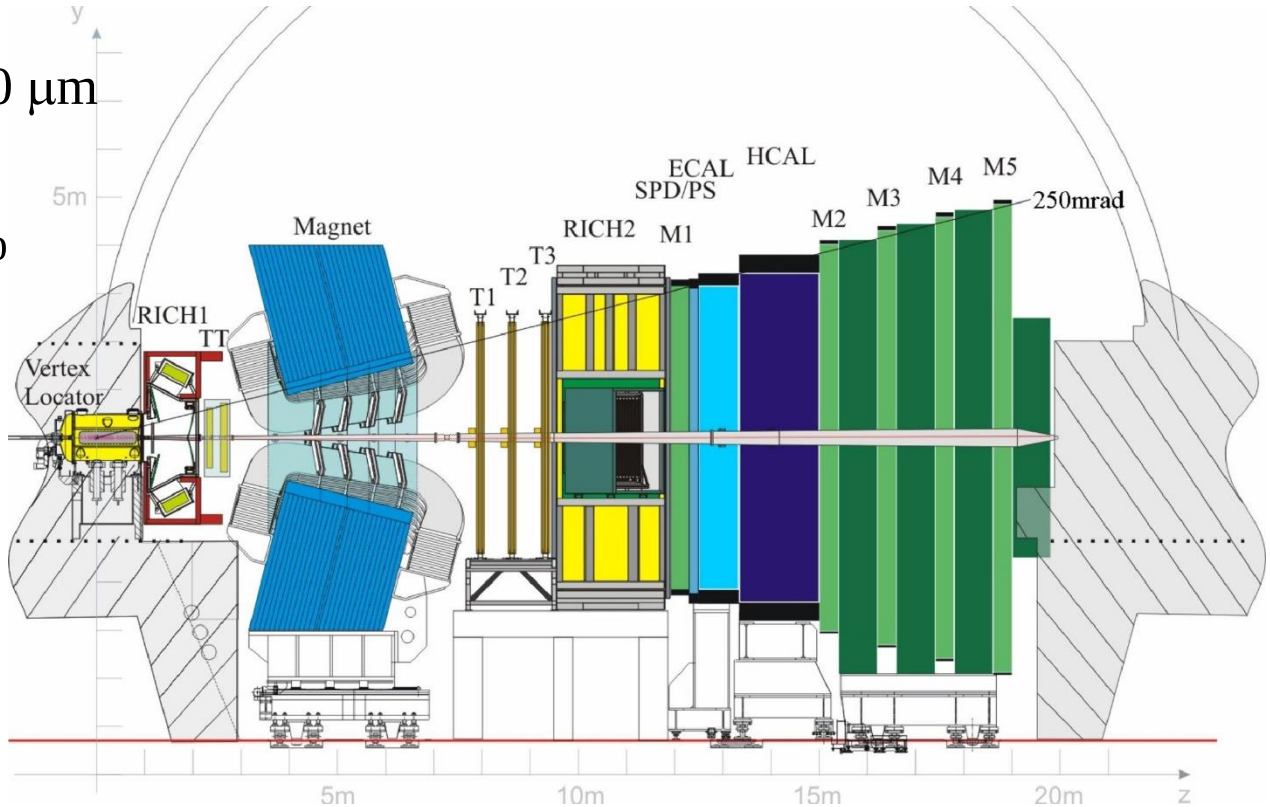
- LHCb well suited for such measurements:
  - Heavy flavor measurement down to p_T close to 0
  - Separation of prompt and b decay components

- Cold Nuclear Matter effects
  - Initial state:
    - Modification of nuclear PDF
    - Gluon saturation
  - Multiple scattering of partons in the nucleus
  - Final state



LHCb detector

- A single arm forward spectrometer designed for the study of particles containing *c* or *b* quark.
- Acceptance: $2 < \eta < 5$
- Vertex detector
  - IP resolution ~ 20 μm
- Tracking system
  - $\frac{\Delta p}{p} = 0.5\% - 1\%$ (5-200 GeV/*c*)
- RICH
  - K/π/p separation
- Electromagnetic + hadronic Calorimeters
- Muon systems

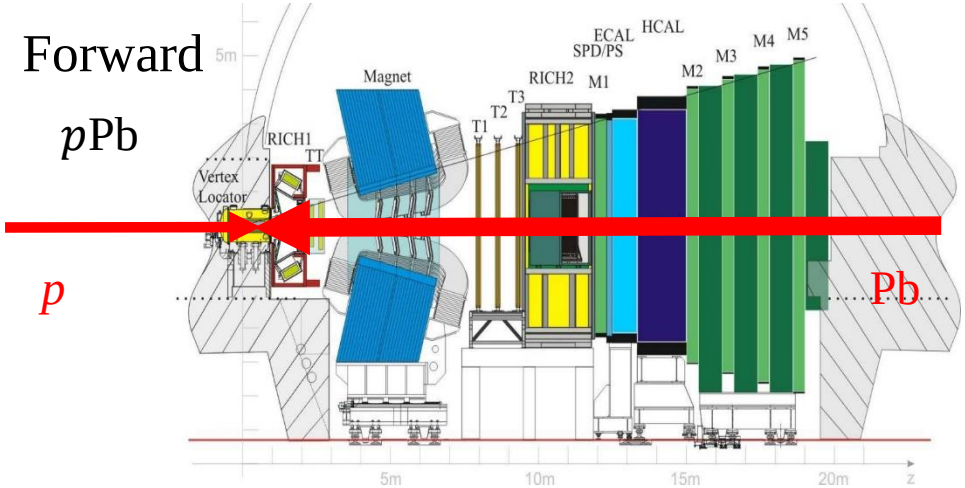


JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

pPb datasets and recent results

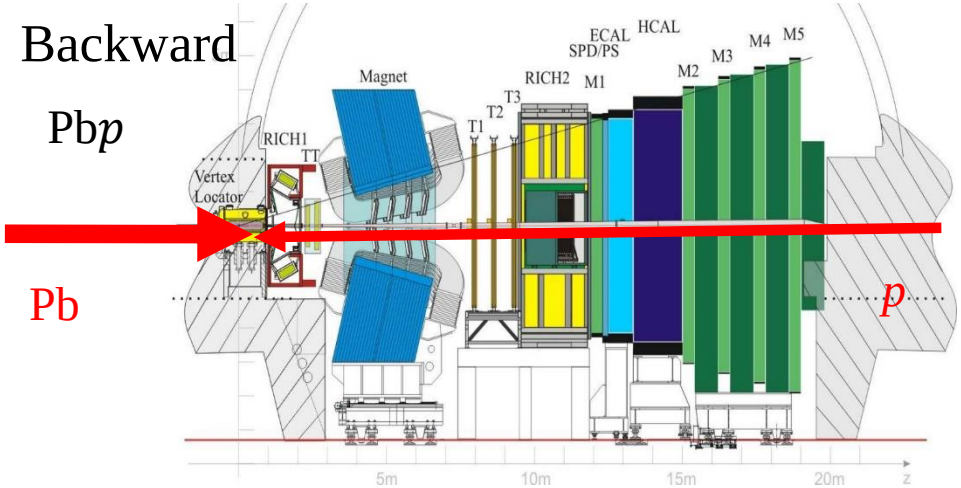
Forward

pPb



Backward

Pbp

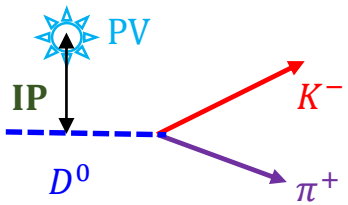


- Rapidity Coverage
  - y^*: rapidity in nucleon-nucleon cms
  - $y_{cms} = \pm 0.465$
  - Forward: $1.5 < y^* < 4.0$
  - Backward: $-5.0 < y^* < -2.5$
  - Common region: $2.5 < |y^*| < 4.0$

- $\sqrt{s_{NN}} = 5$ TeV (2013)
  - pPb (1.06 nb^{-1}) + Pbp (0.52 nb^{-1})
  - Open heavy flavor D^0 and Λ_c^+

- $\sqrt{s_{NN}} = 8$ TeV (2016)
  - pPb (13.6 nb^{-1}) + Pbp (21.8 nb^{-1})
  - Hidden heavy flavor J/ψ

Prompt D^0 measurement in pPb at 5TeV



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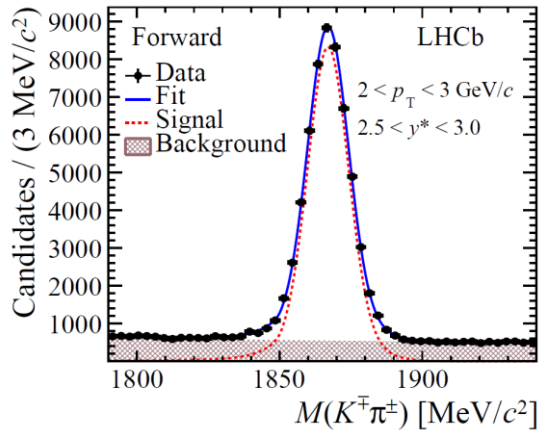

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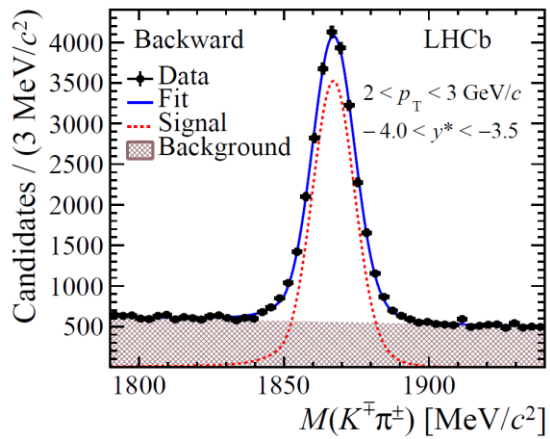
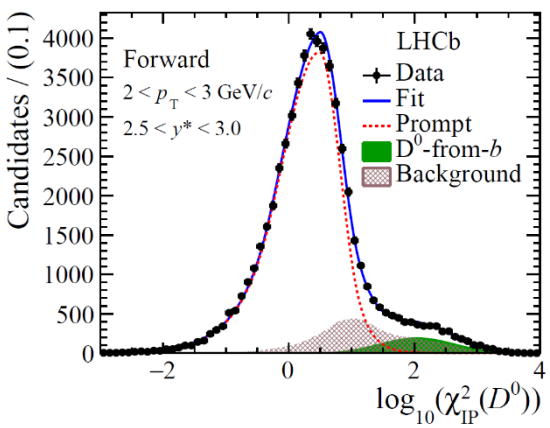
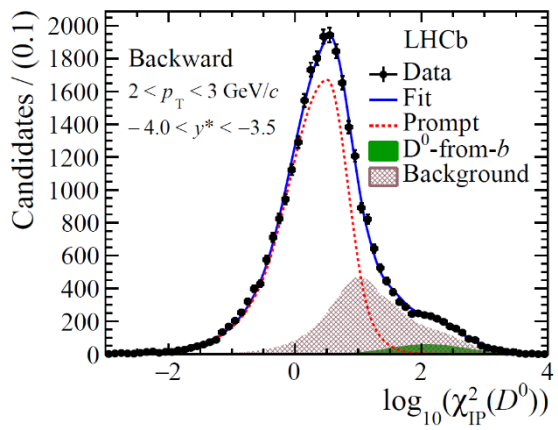


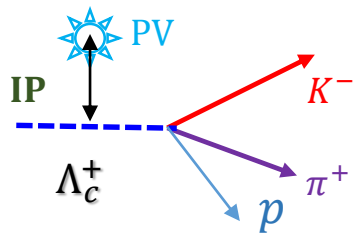




JHEP 1710 (2017) 090

- Reconstructed through decay channel:
  $D^0 \to K^-\pi^+$
- Inclusive D^0 mesons from fitting invariant mass dist.:
  - Signal:
    Crystal Ball+Gaussian
  - Background: linear
- Prompt D^0 fraction extracted from fitting impact parameter dist.:
  - Prompt: simulation
  - D^0-from-b: simulation
  - Background: sideband in data

Prompt Λ_c^+ measurement in pPb at 5TeV



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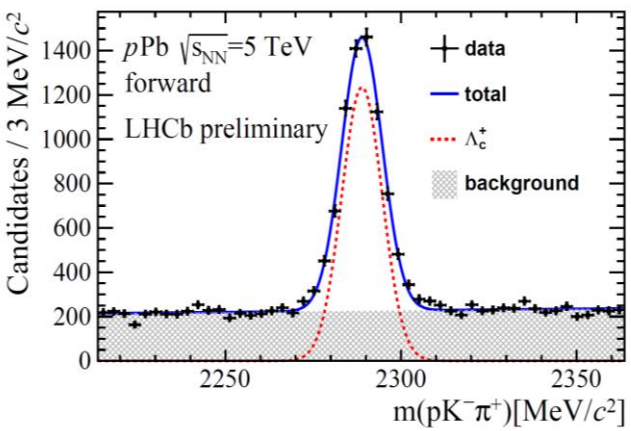

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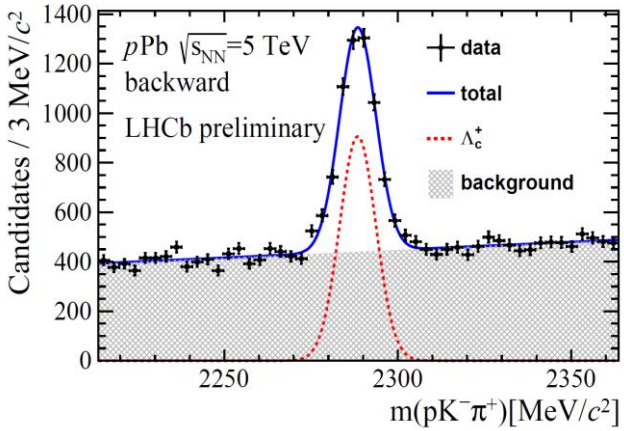
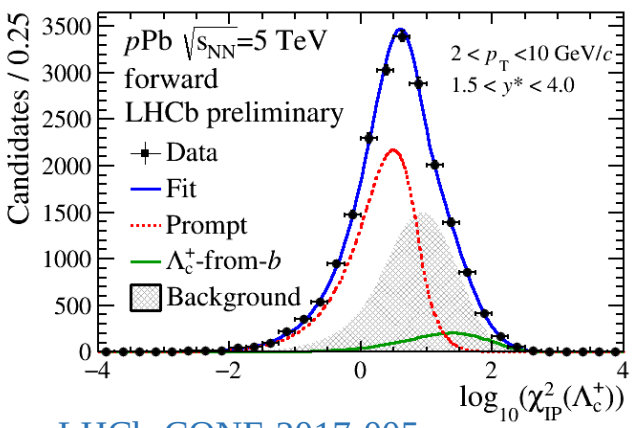
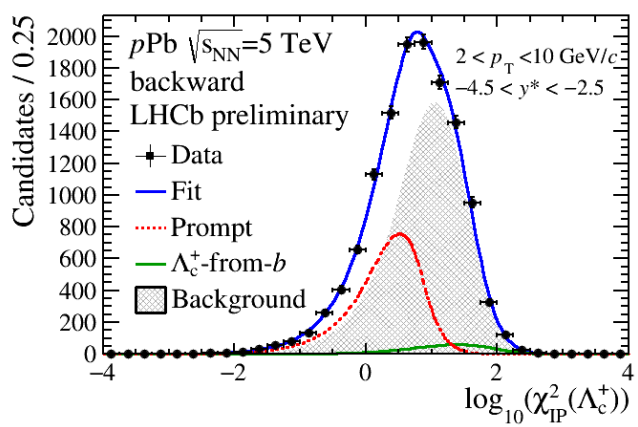


- Reconstructed through decay channel
  $\Lambda_c^+ \to pK^-\pi^+$

- Inclusive Λ_c^+ baryons from fitting invariant mass dist.:
  - Signal: Gaussian
  - Background: linear





Prompt Λ_c^+ fraction extracted from fitting impact parameter dist.:
- Prompt: simulation
- Λ_c^+-from-b: simulation
- Background: sideband in data

LHCb-CONF-2017-005

Prompt D^0 at 5 TeV nuclear modification factor in pPb

JHEP 10 (2003) 046
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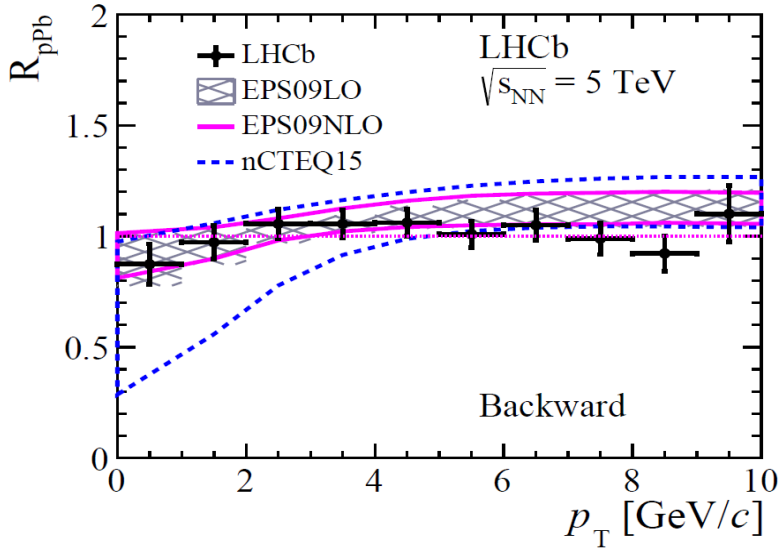
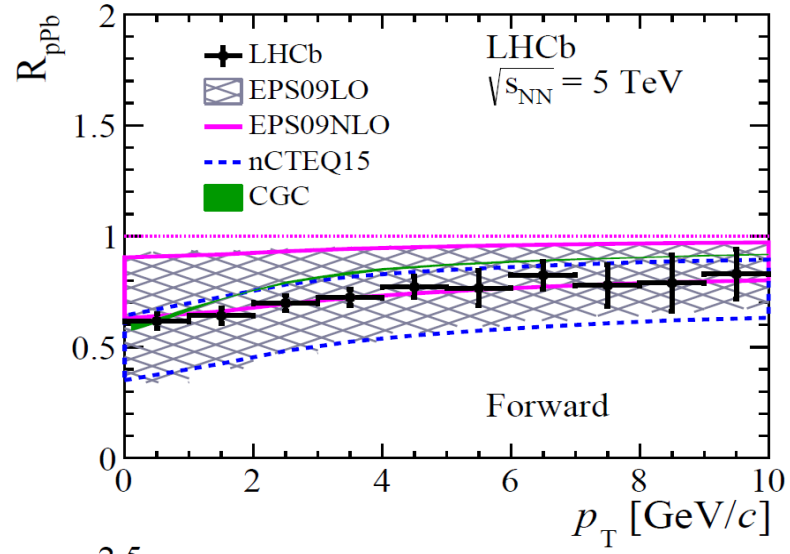
Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238



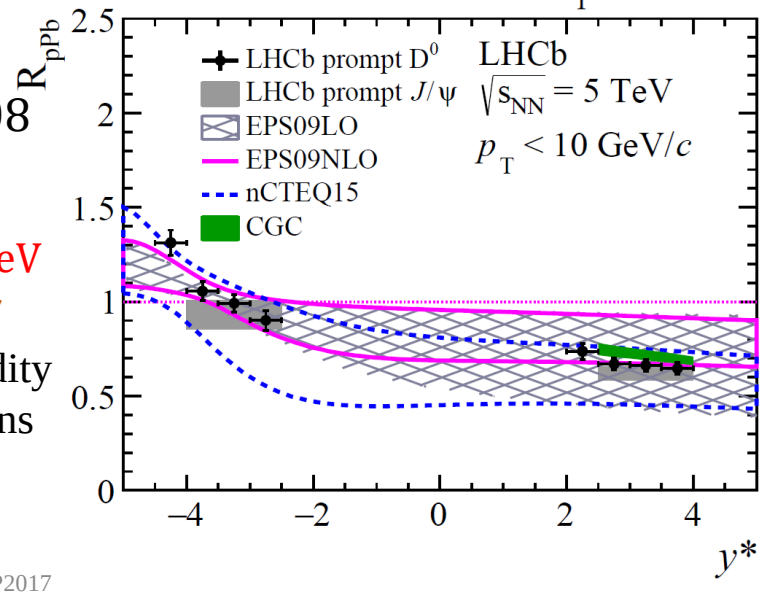


$$R_{pPb}(y^*, p_T) = \frac{1}{A} \times \frac{d\sigma_{pPb}(y^*, p_T, \sqrt{s_{NN}})/dx}{d\sigma_{pp}(y^*, p_T, \sqrt{s_{NN}})/dx}, \quad A=208$$

Updated since preliminary result:
Directly measured with prompt D^0 in pp at $\sqrt{s} = 5$ TeV

JHEP 1706 (2017) 147

- Nuclear modification factor smaller at forward rapidity
- Measurements consistent with theoretical calculations

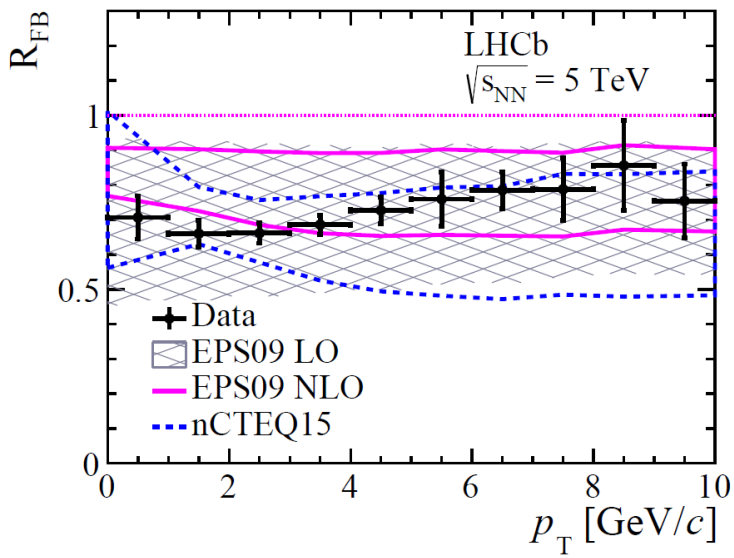


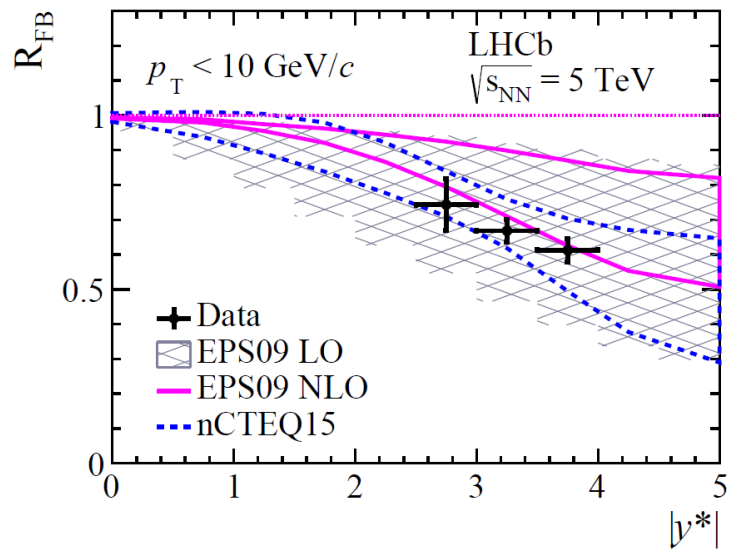
JHEP 1710 (2017) 090

Prompt D^0 at 5 TeV forward-backward production ratio

- $R_{FB} = \frac{d\sigma(+|y^*|,p_T)/dx}{d\sigma(-|y^*|,p_T)/dx}$
- R_{FB} does not need results from pp collisions.
- Compared to next-to-leading order NLO calculations with different nPDFs
- Consistent with theoretical calculations within uncertainty

JHEP 1710 (2017) 090





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Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238

Prompt Λ_c^+ at 5 TeV forward-backward production ratio

LHCb-CONF-2017-005

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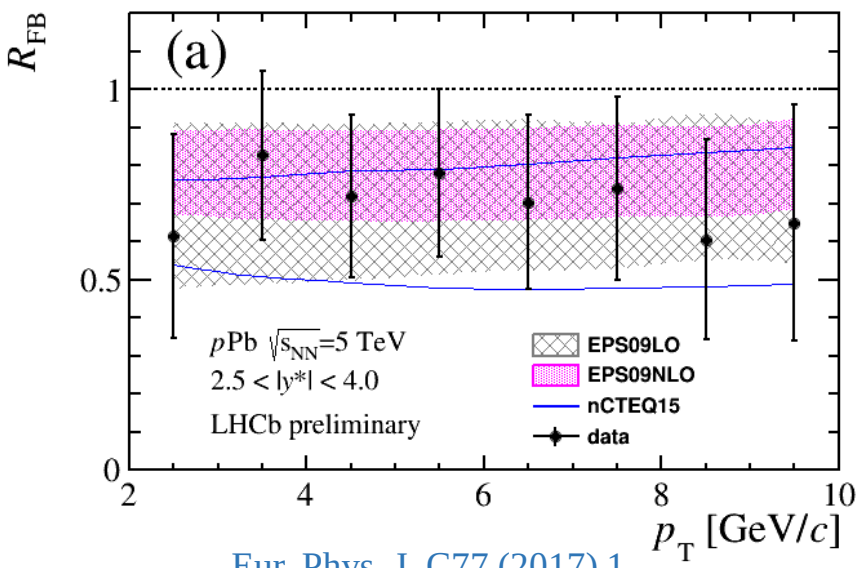

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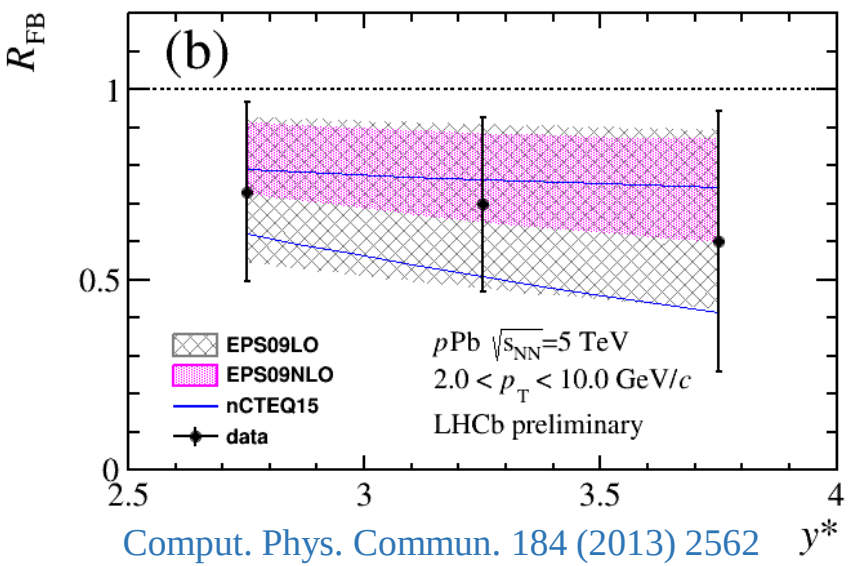

Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238

Charmed baryon/meson production ratio $R_{\Lambda_c^+/D^0}$ at 5 TeV

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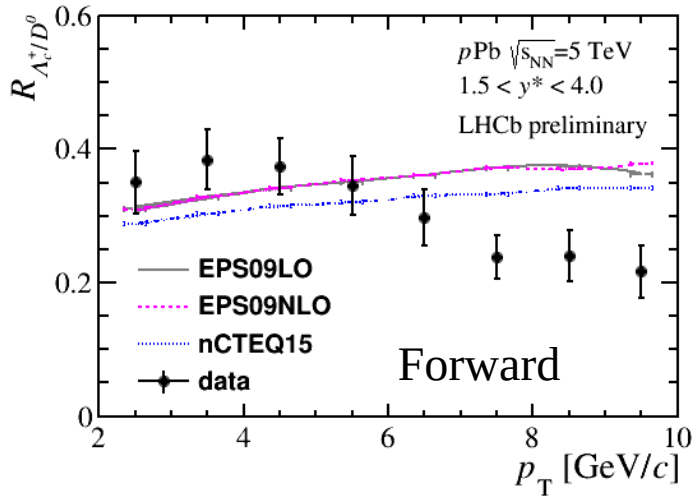
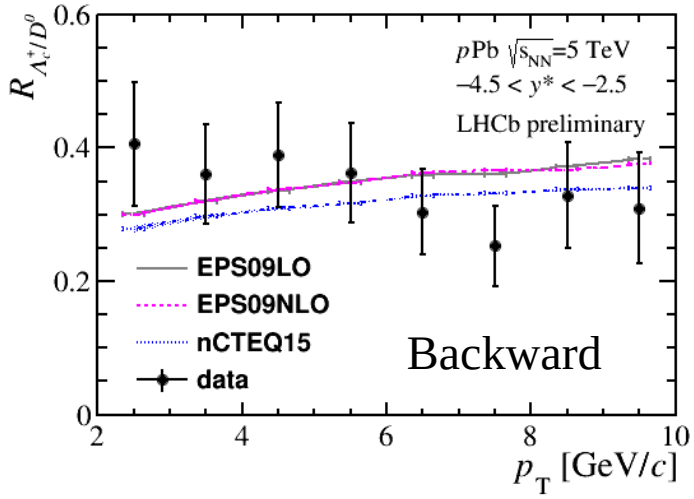
- $R_{\Lambda_c^+/D^0} = \frac{\sigma_{\Lambda_c^+}(y^*, p_T)}{\sigma_{D^0}(y^*, p_T)}$

- EPS09LO & EPS09NLO gives similar predictions.
- nCTEQ15 slightly lower.



- Forward:
  - Consistent at lower p_T
  - Below theory at higher p_T
- Backward:
  - Consistent for all p_T



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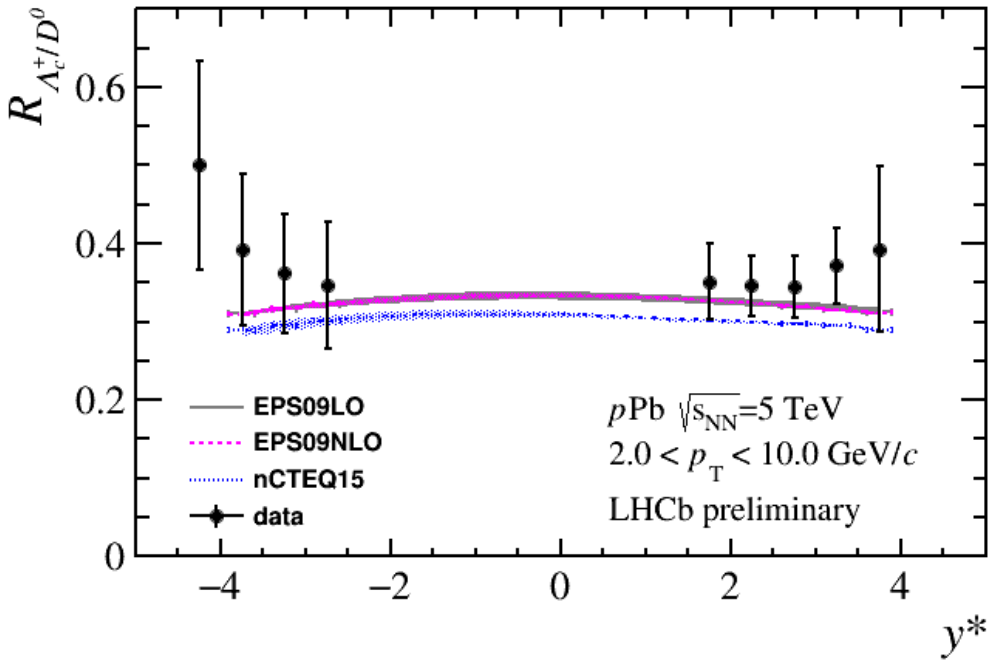
- EPS09LO & EPS09NLO give similar predictions.
- nCTEQ15 slightly lower.

- Forward:
  - Consistent for all $|y^*|$
- Backward:
  - Consistent at lower $|y^*|$
  - Displays a rising trend with increasing $|y^*|$



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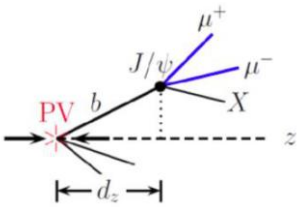
Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238

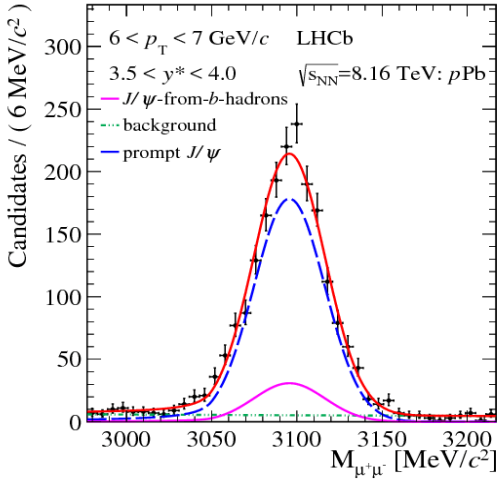
Prompt and nonprompt J/ψ in pPb at 8 TeV

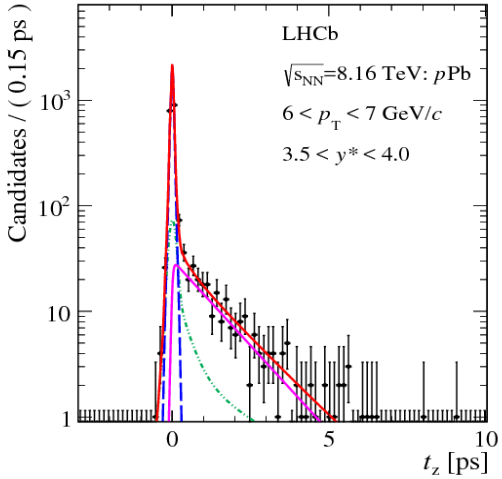


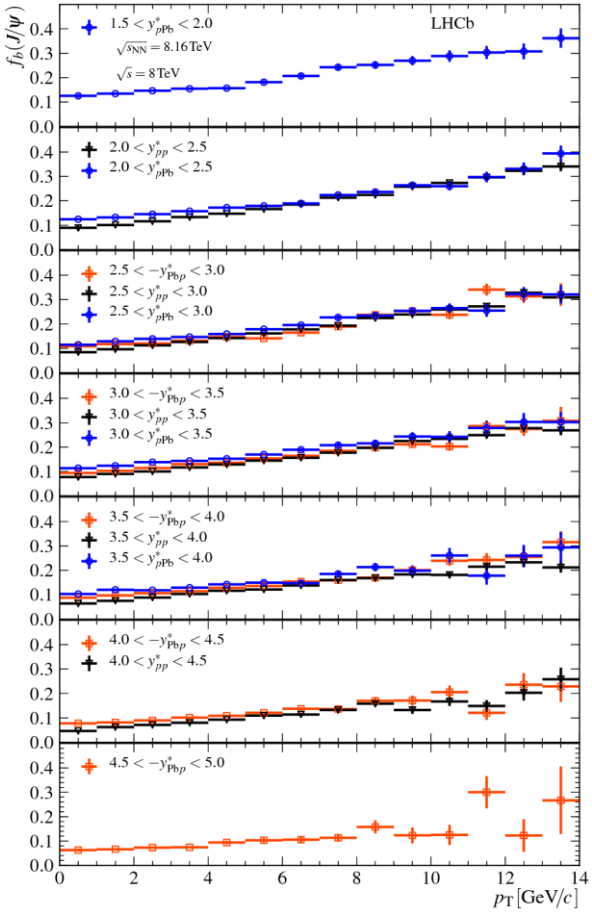
- Reconstructed through $J/\psi \to \mu^+\mu^-$
- Signal extraction with 2D simultaneous fit to mass and the pseudo proper decay time

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

- Prompt and nonprompt (from-b-hadrons) separated
- Fraction from b hadrons:
  - Increasing trend
  - Low p_T : cold nuclear effects different for the prompt and nonprompt







PLB774 (2017) 159

Prompt J/ψ at 8 TeV nuclear modification factor in pPb

$$R_{p\mathrm{Pb}}(y^*, p_T) = \frac{1}{A} \times \frac{\mathrm{d}\sigma_{p\mathrm{Pb}}(y^*, p_\mathrm{T}, \sqrt{s_{NN}})/\mathrm{d}x}{\mathrm{d}\sigma_{pp}(y^*, p_\mathrm{T}, \sqrt{s_{NN}})/\mathrm{d}x}, \; A{=}208$$

- pp reference: interpolation of LHCb measurements at 7, 8 and 13 TeV
- Forward rapidity: suppression up to 50% at low p_T, decreasing with increasing p_T
- Backward rapidity: closer to unity
- Overall agreement with models with large uncertainties on the gluon PDFs at low x
- Compatible with 5 TeV results

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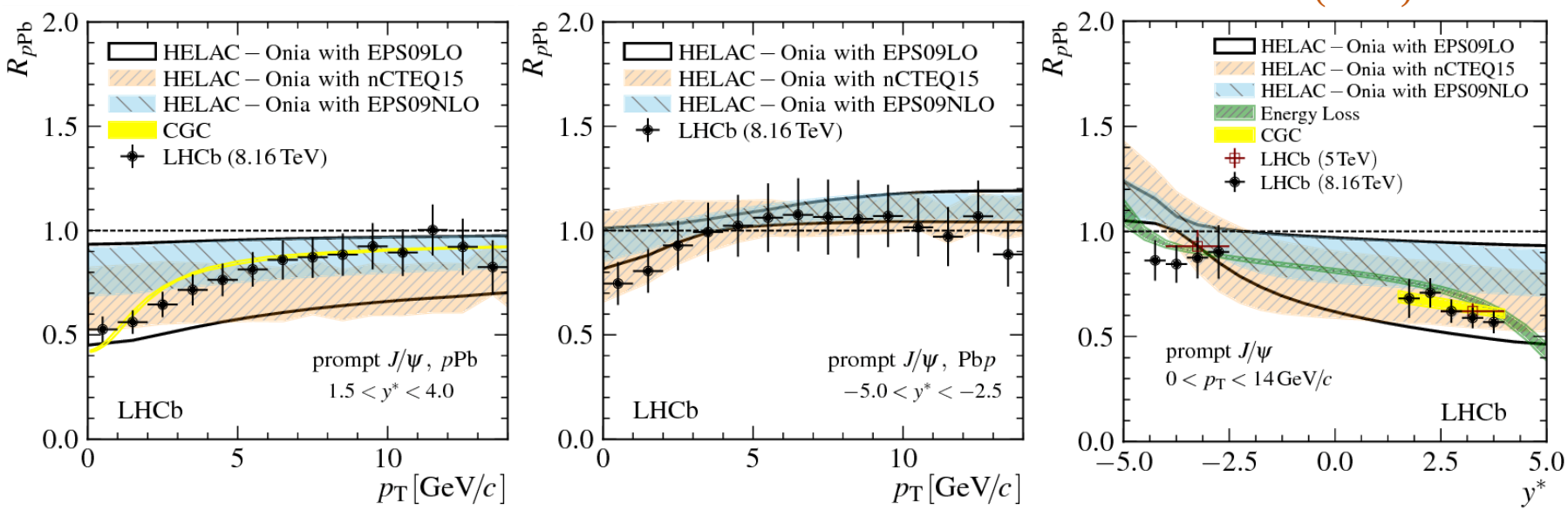

J/ψ-from-b-hadrons at 8 TeV nuclear modification factor in pPb

$$R_{p\mathrm{Pb}}(y^*, p_T) = \frac{1}{A} \times \frac{\mathrm{d}\sigma_{p\mathrm{Pb}}(y^*, p_\mathrm{T}, \sqrt{s_{NN}})/\mathrm{d}x}{\mathrm{d}\sigma_{pp}(y^*, p_\mathrm{T}, \sqrt{s_{NN}})/\mathrm{d}x},\ A{=}208$$

- pp reference: interpolation of LHCb measurements at 7, 8 and 13 TeV
- Forward rapidity: smaller suppression up to 30% at low p_T, reach unity at higher p_T
- Backward: compatible with unity
- FONLL with EPS09NLO consistent with data
- Compatible with 5 TeV results

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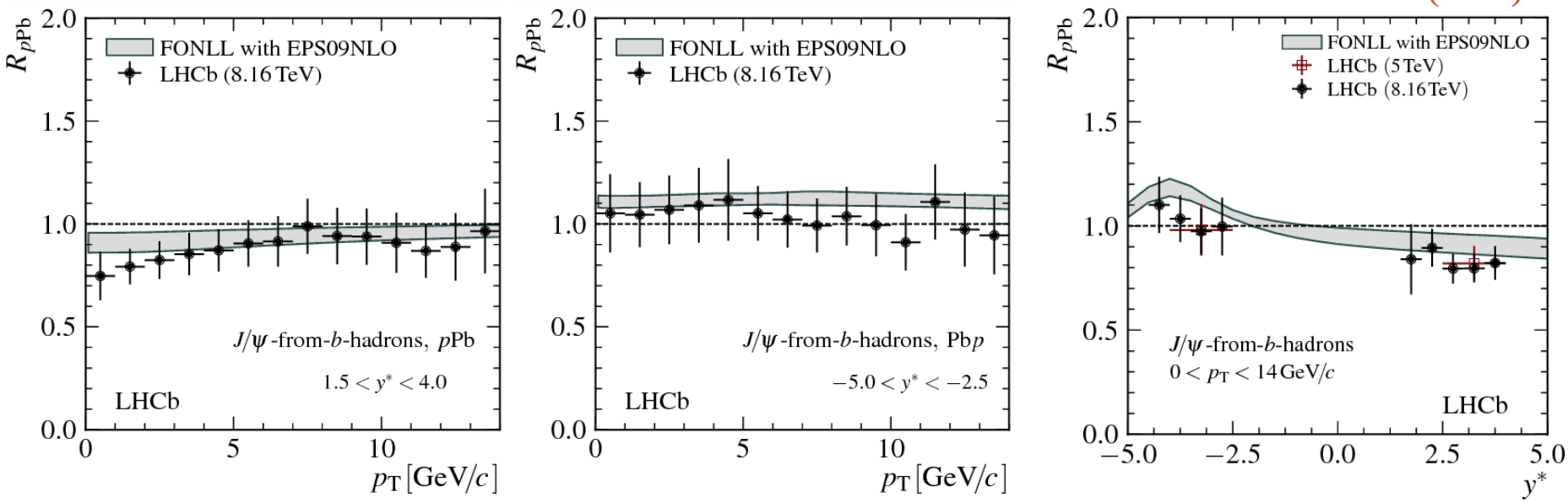
EPS09 JHEP 04 (2009) 065



Prompt J/ψ at 8 TeV forward-backward production ratio

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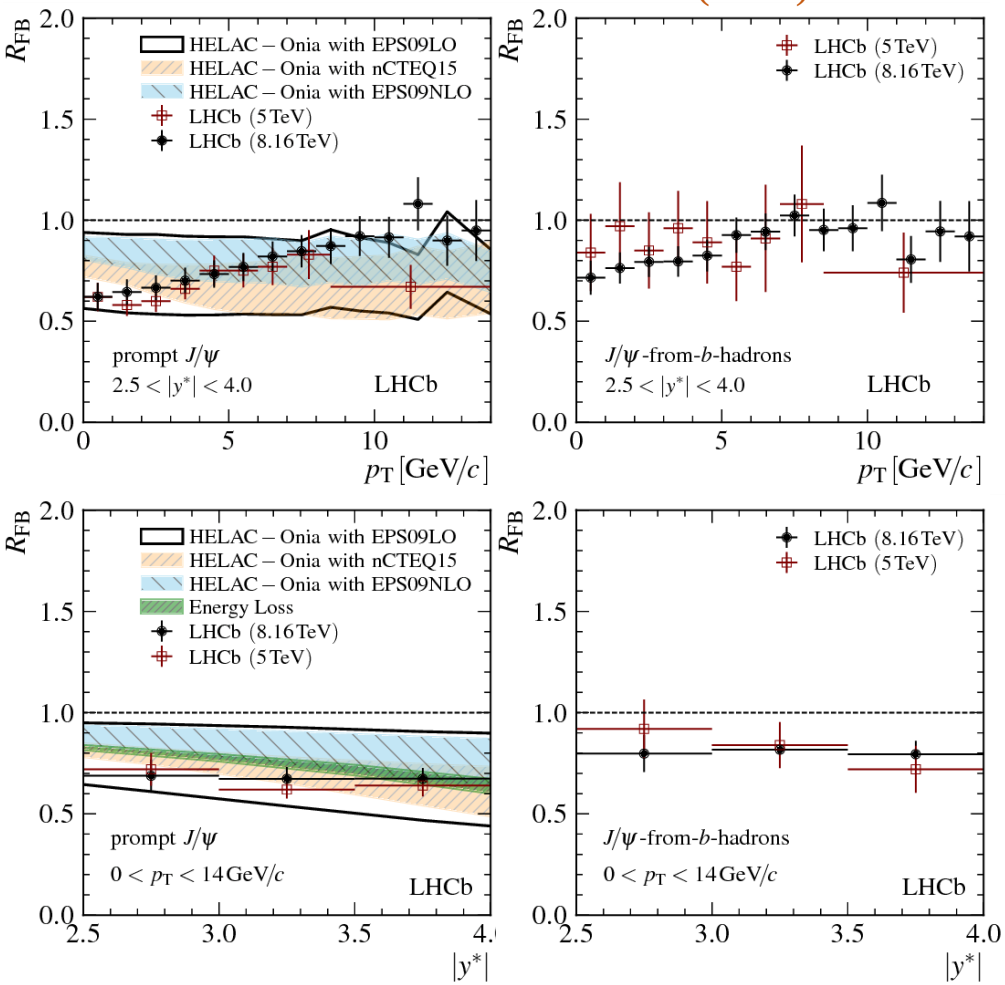
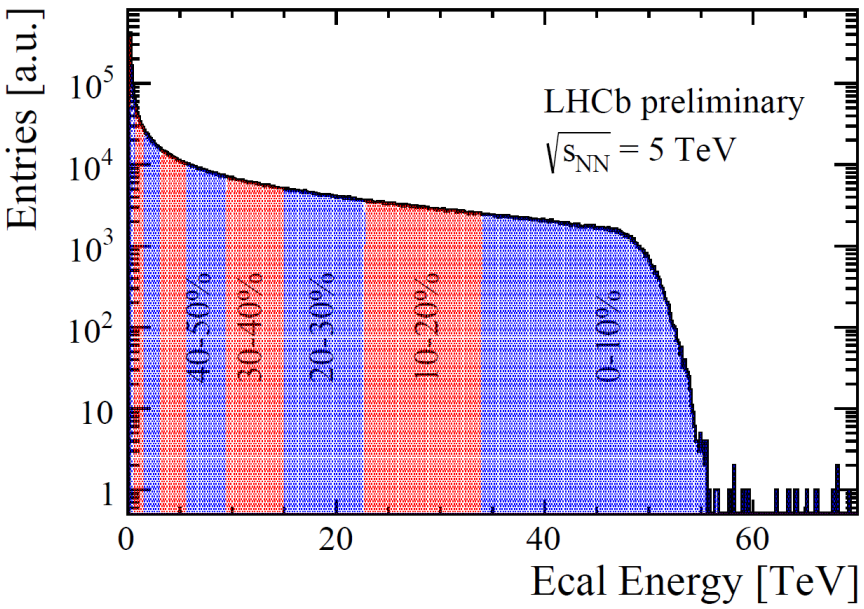
- $R_{\mathrm{FB}} = \dfrac{\mathrm{d}\sigma(+|y^*|,p_{\mathrm{T}})/\mathrm{d}x}{\mathrm{d}\sigma(-|y^*|,p_{\mathrm{T}})/\mathrm{d}x}$
- R_{FB} does not need inputs from pp collisions.
- Prompt J/ψ:
  - Clear forward-backward asymmetry
  - Increasing trend with increasing p_{T}
- Nonprompt J/ψ:
  - Closer to unity
- Models for prompt J/ψ only
- Consistent with 5 TeV results

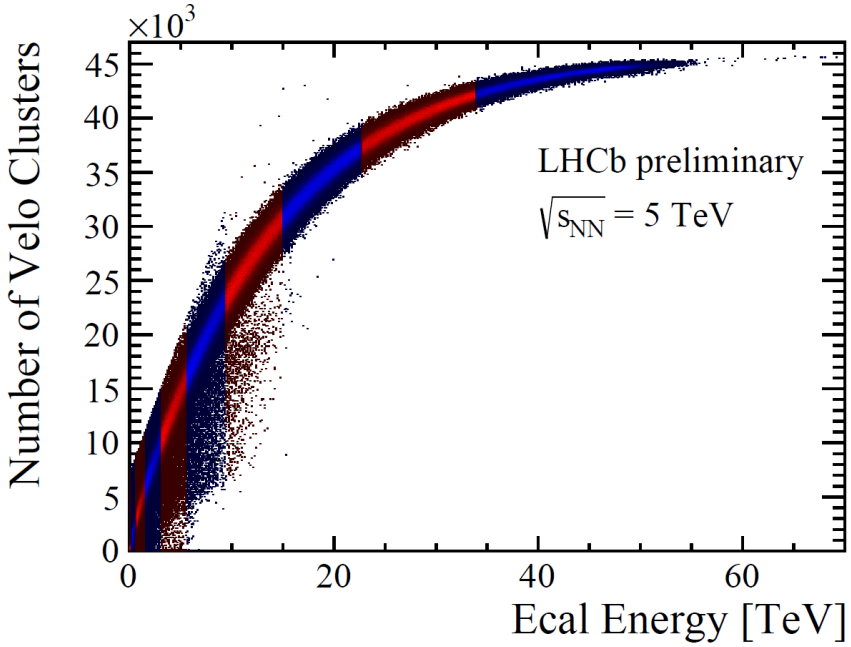


PbPb collisions

https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

- December 2015: first LHCb PbPb data taken
- $\sqrt{s_{NN}} = 5$ TeV (3-5 μb^{-1})
- Event classification: total energy in the calorimeters (Ecal)
- Analyses limited by saturation in Vertex Locator (VELO)
- Track reconstruction: 50-100% event activity (~15k clusters)

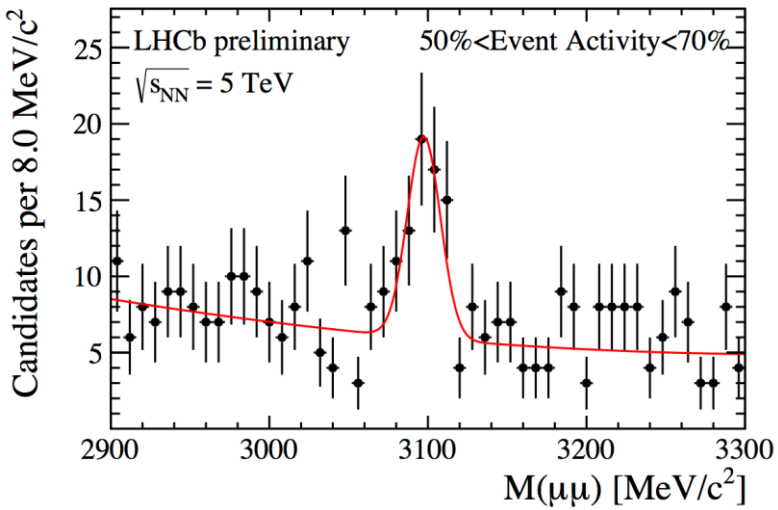




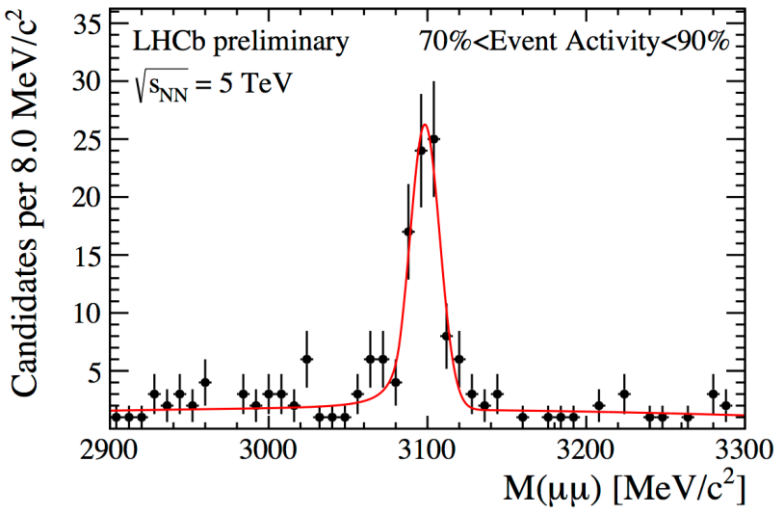
Charm signals in PbPb dataset

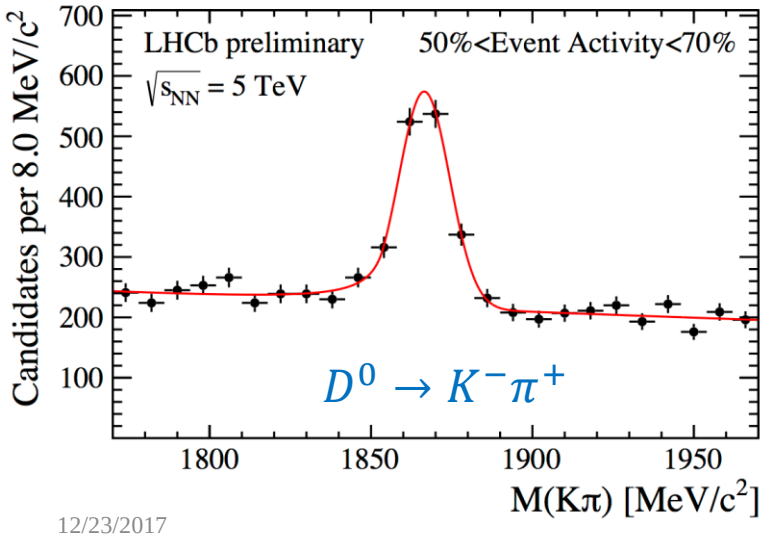
https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

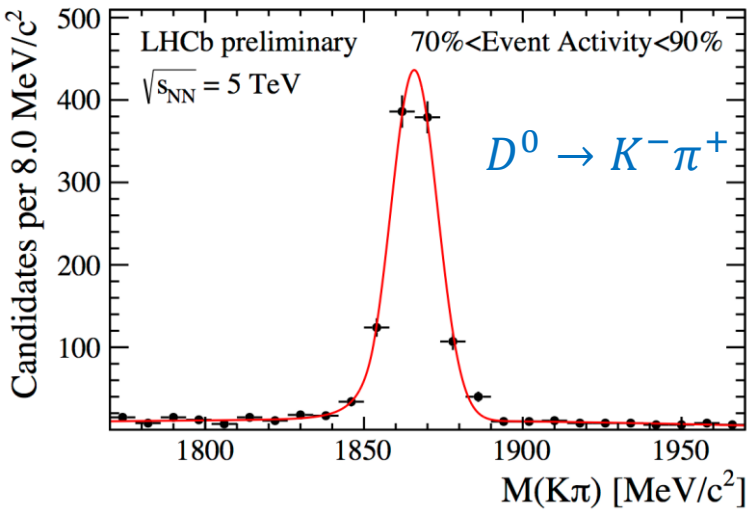
$J/\psi \to \mu^+\mu^-$



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

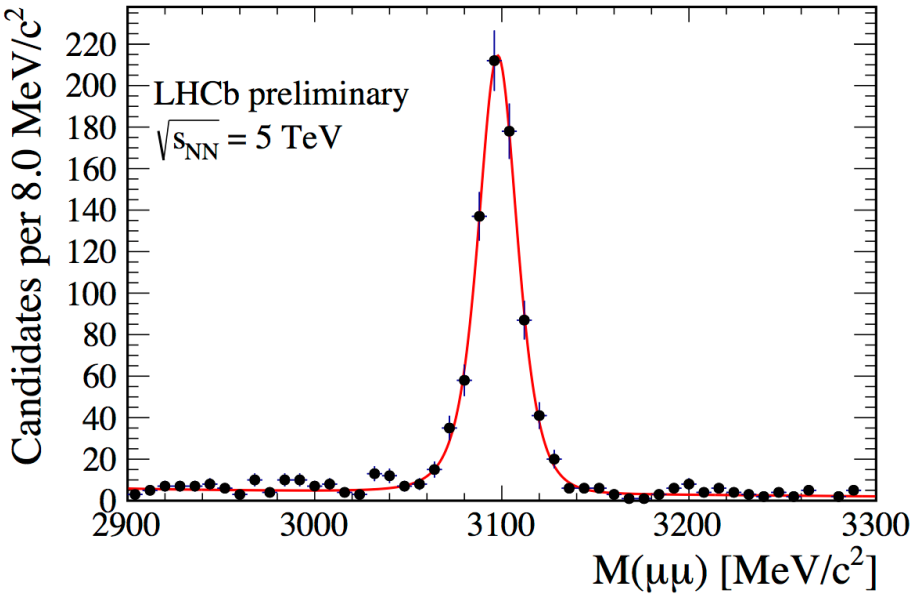


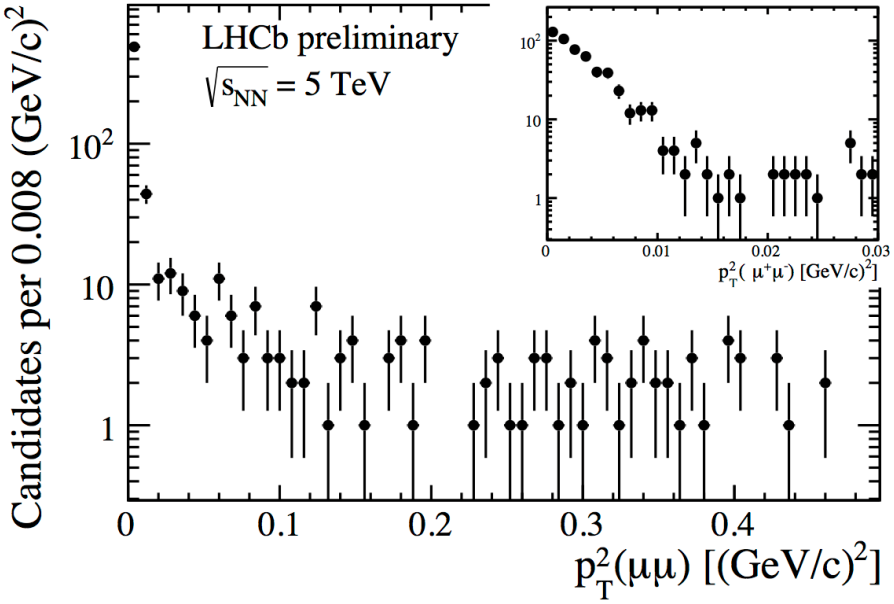




Ultraperipheral J/ψ photo-production

- Selecting events containing only two muon tracks





https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

Conclusion

- Heavy ion collisions
  - pPb collisions at $\sqrt{s_{NN}} = 5$ and 8 TeV in 2013/2016
    - Open heavy flavor analyses: prompt D^0 and Λ_c^+
    - Hidden heavy flavor: prompt and nonprompt J/ψ
  - PbPb collisions at $\sqrt{s_{NN}} = 5$ TeV in 2015
    - Ongoing analyses on semi-central to peripheral collisions