Open heavy flavor production in *p*Pb collisions with LHCb

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On behalf of the LHCb collaboration

CLHCP2018

Outline

- Open heavy flavor in pPb collisions
- The LHCb detector
- LHCb pPb datasets
- Prompt $D^0$and Λ_c^+ production in pPb collisions at 5 TeV
- B^+, $B^0$and Λ_b^0 production in pPb collisions at 8.16 TeV
- Conclusion

Open heavy flavor in pPb collisions

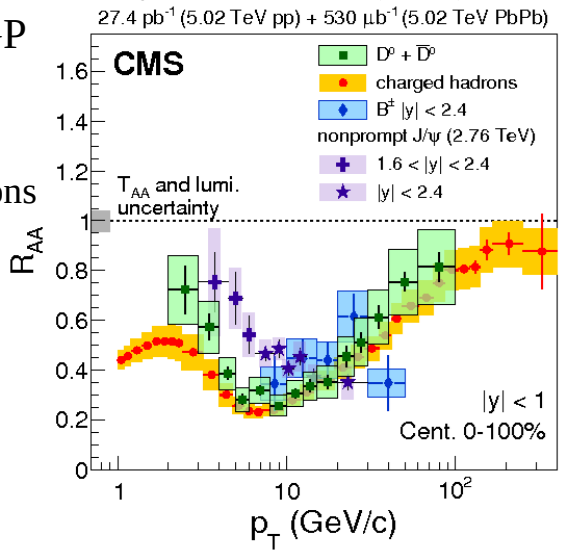
- Heavy flavor states are sensitive probes to study the properties of the QGP created in AA collision.
  - Produced in the early stage of the collisions
  - Significant heavy flavor meson suppression observed in central PbPb collisions
  - Large Λ_c^+/D^0 ratio measured in AuAu collisions

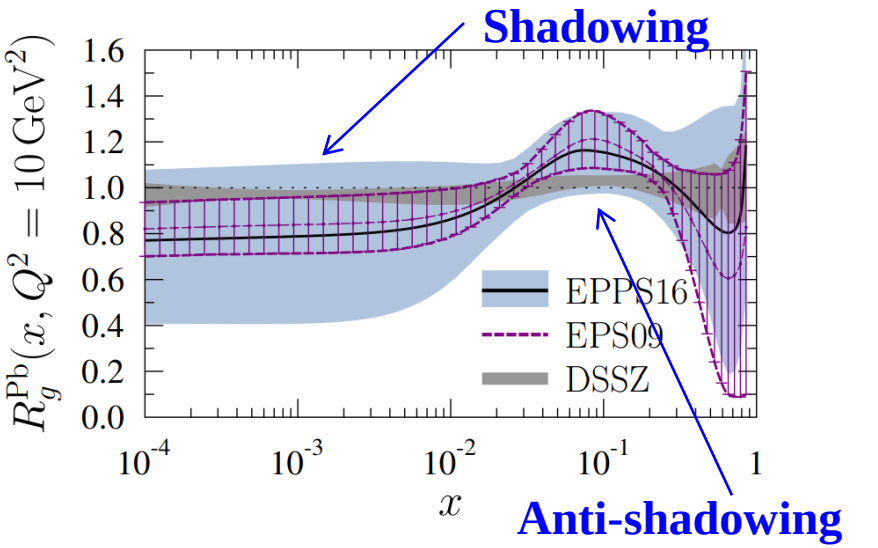
- Heavy flavor in pA collisions provide baseline measurements to disentangle cold nuclear matter effects from effects of hot and dense medium.

- 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

Phys. Lett. B 782 (2018) 474

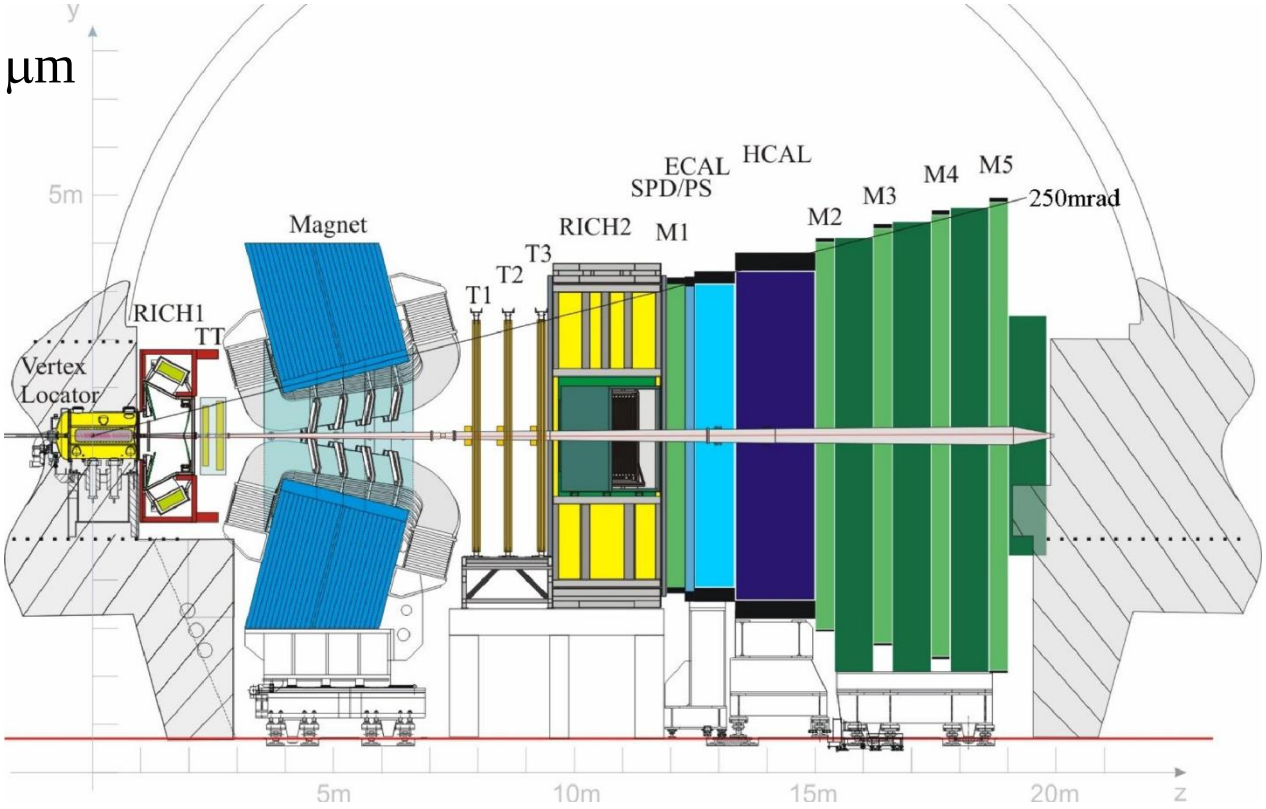




arXiv:1802.05927

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

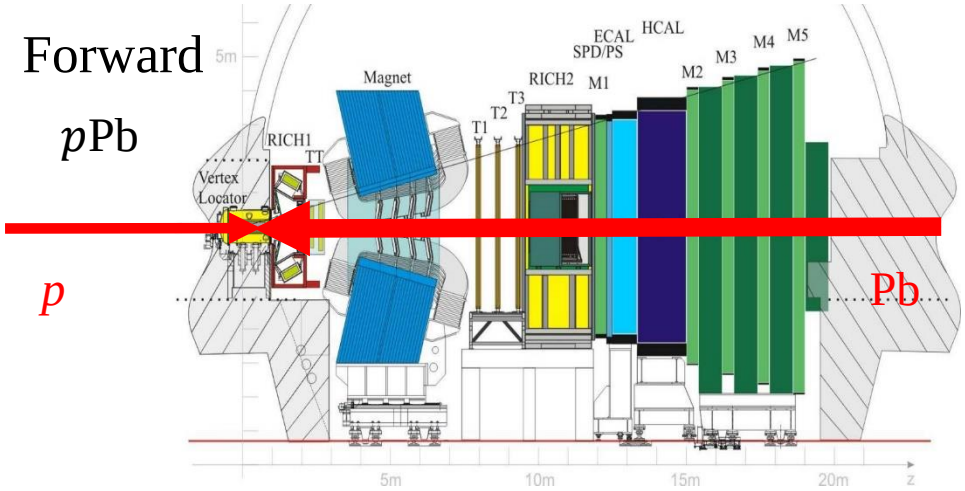


JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

LHCb pPb datasets

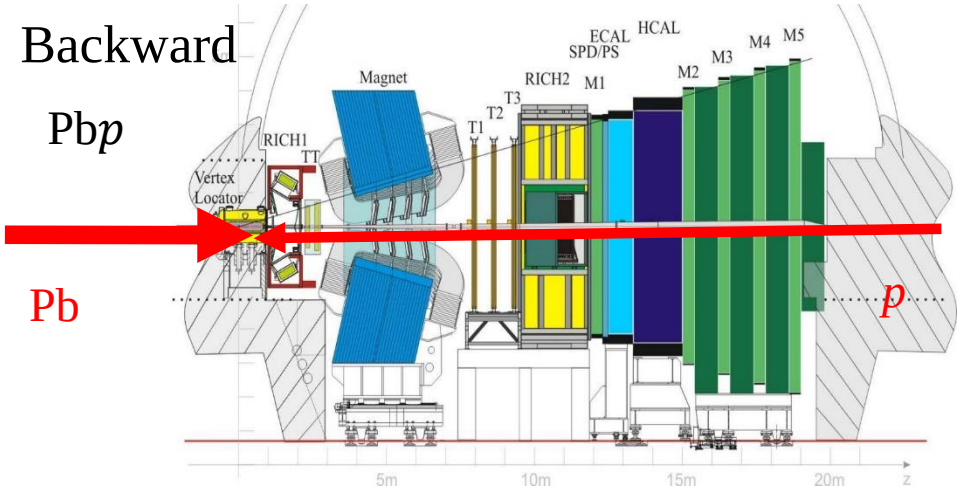
Forward

pPb



Backward

Pbp

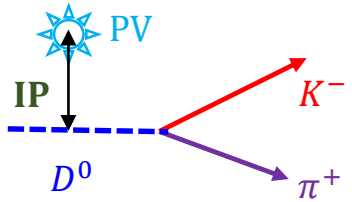


- Rapidity Coverage
  - y^*: rapidity in nucleon-nucleon cms
  - $y_{\mathrm{cms}} = \pm 0.465$
  - Forward: $1.5 < y^* < 4.0$
  - Backward: $-5.0 < y^* < -2.5$
  - Common region: $2.5 < |y^*| < 4.0$

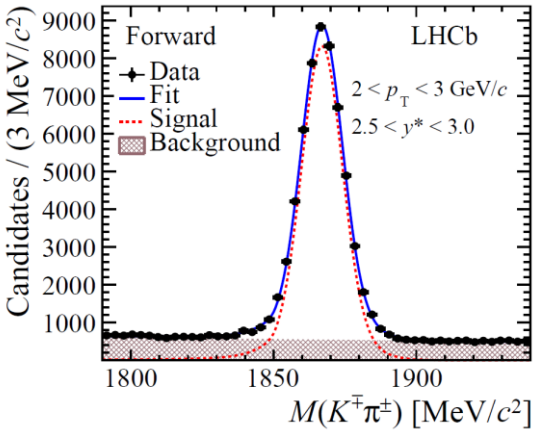
- $\sqrt{s_{NN}} = 5.02$ TeV (2013)
  - pPb (1.06 nb^{-1}) + Pbp (0.52 nb^{-1})

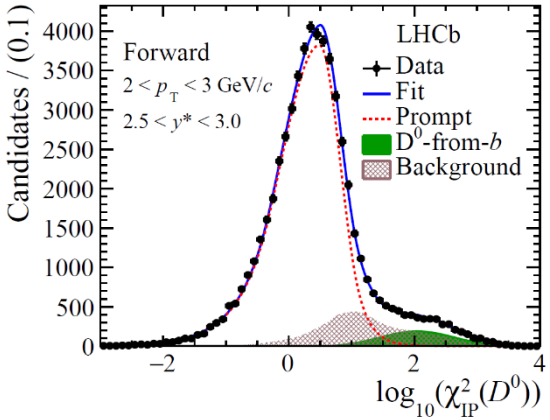
- $\sqrt{s_{NN}} = 8.16$ TeV (2016)
  - pPb (13.6 nb^{-1}) + Pbp (21.8 nb^{-1})

Prompt D^0 and Λ_c^+ measurement in pPb at 5 TeV



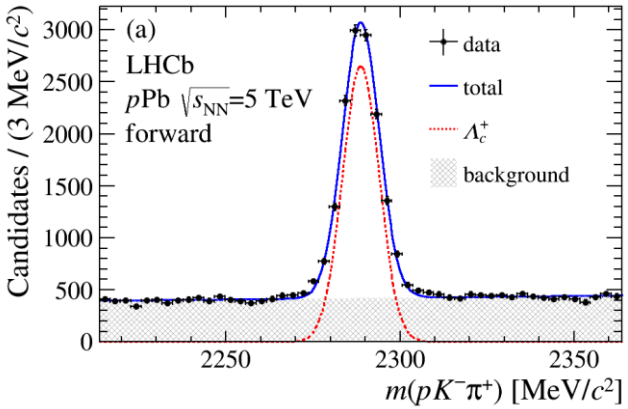
$D^0 \downarrow$

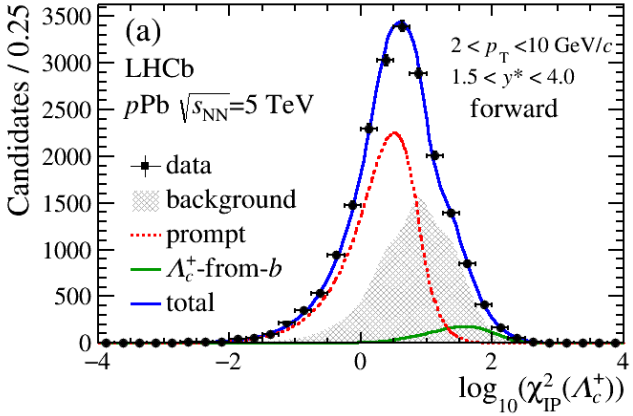




JHEP 10 (2017) 090

$\Lambda_c^+ \downarrow$





arXiv:1809.01404

Reconstructed through decay channel:

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

$\Lambda_c^+ \to pK^-\pi^+$

Inclusive D^0/Λ_c^+ signals from fitting invariant mass dist.:

- Signal:
  Crystal Ball+Gaussian (D^0)
  Gaussin (Λ_c^+)
- Background: linear

Prompt charm fraction extracted from fitting impact parameter dist.:

- Prompt: simulation
- from-b: simulation (D^0)
  sPlot+sim (Λ_c^+)
- Background: sideband in data

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

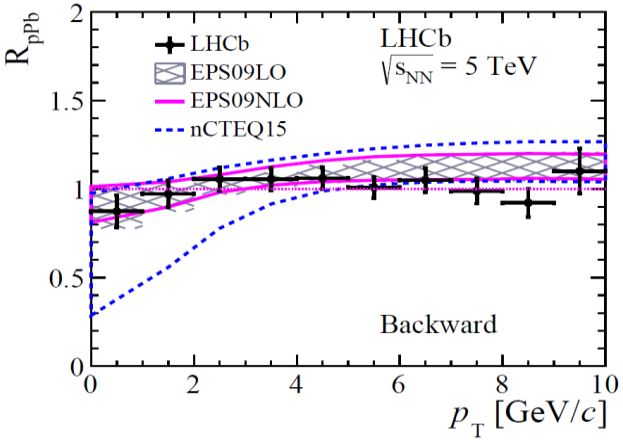
JHEP 10 (2003) 046
Eur. Phys. J. C77 (2017) 1
Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238

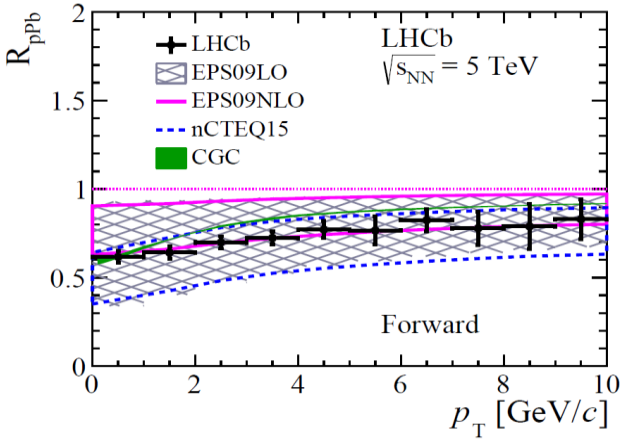
$$R_{p\mathrm{Pb}}(y^*, p_\mathrm{T}) = \frac{1}{A} \times \frac{\mathrm{d}\sigma_{p\mathrm{Pb}}(y^*, p_\mathrm{T}, \sqrt{s_\mathrm{NN}})/\mathrm{d}x}{\mathrm{d}\sigma_{pp}(y^*, p_\mathrm{T}, \sqrt{s_\mathrm{NN}})/\mathrm{d}x}, \quad A{=}208$$

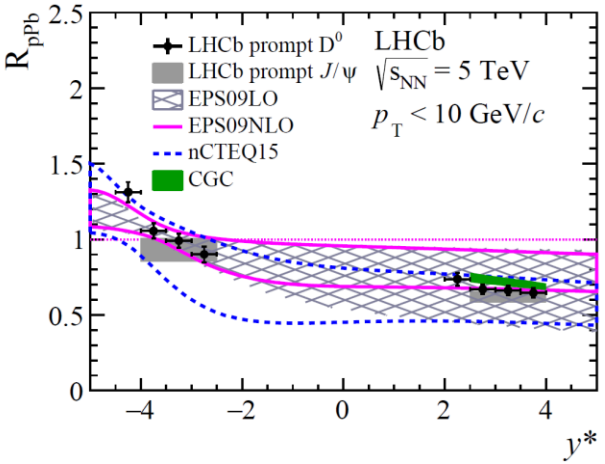
- pp reference directly measured by LHCb
- $R_{p\mathrm{Pb}}$ suppressed at forward rapidity
  - slight increase with increasing p_T
- $R_{p\mathrm{Pb}}$ closer to 1 at backward rapidity
  - hint of enhancement at large rapidity

- Measurements consistent with models with nPDF, CGC
- **Data has smaller uncertainties than theory**

JHEP 10 (2017) 090





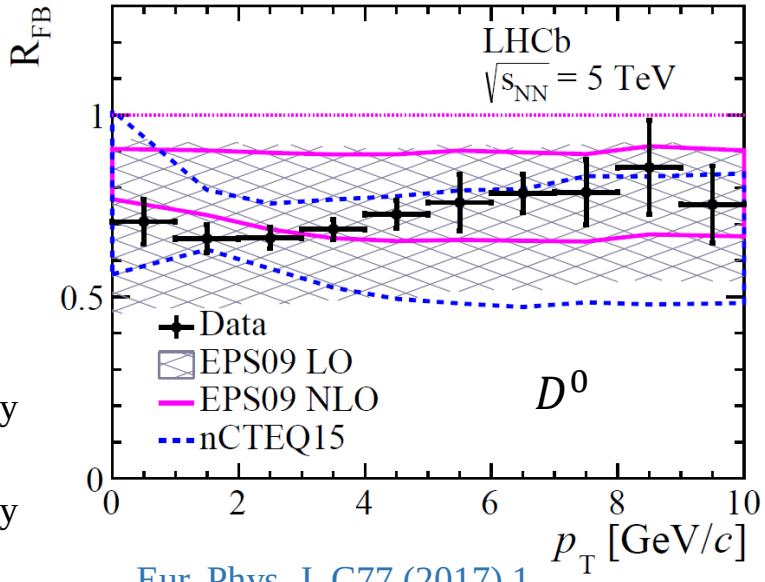


Prompt charm production at 5 TeV forward-backward production ratio

$$R_{\mathrm{FB}} = \frac{\sigma(+|y^*|, p_{\mathrm{T}})}{\sigma(-|y^*|, p_{\mathrm{T}})}$$

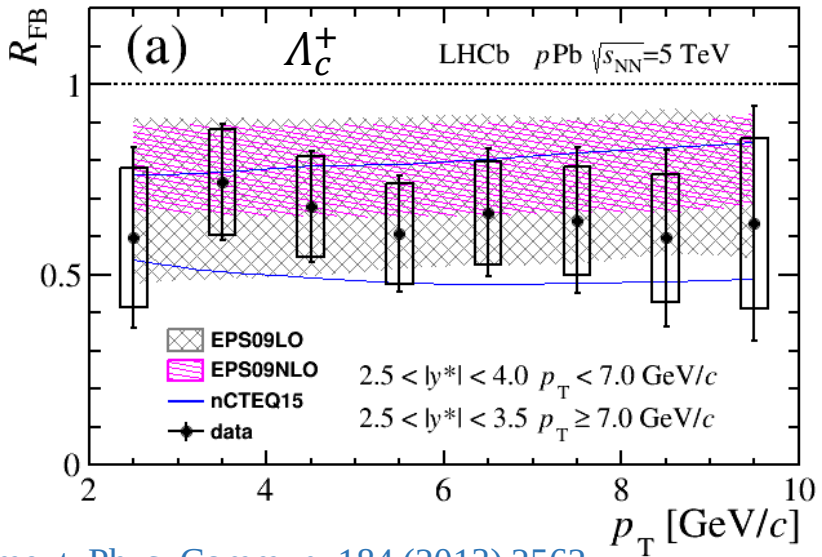
- R_{FB} does not need results from pp collisions.
- Compared to Helac-Onia calculations incorporating different nPDFs
  - Model parameterisation constrained by existing LHC pp cross-section measurements
- Consistent with nPDF predictions within uncertainty
- **D^0 meson show smaller uncertainties than nPDF calculations**

JHEP 10 (2017) 090



Eur. Phys. J. C77 (2017) 1

arXiv:1809.01404



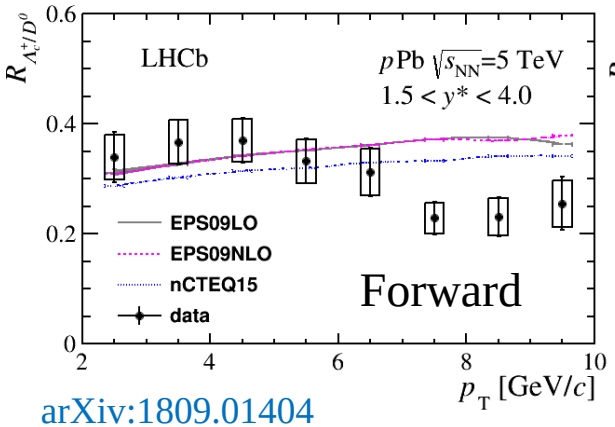
Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238

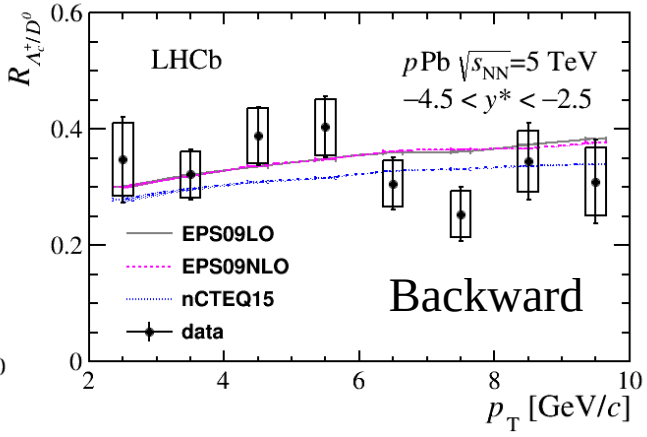
I Total uncertainty
 syst. uncertainty

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

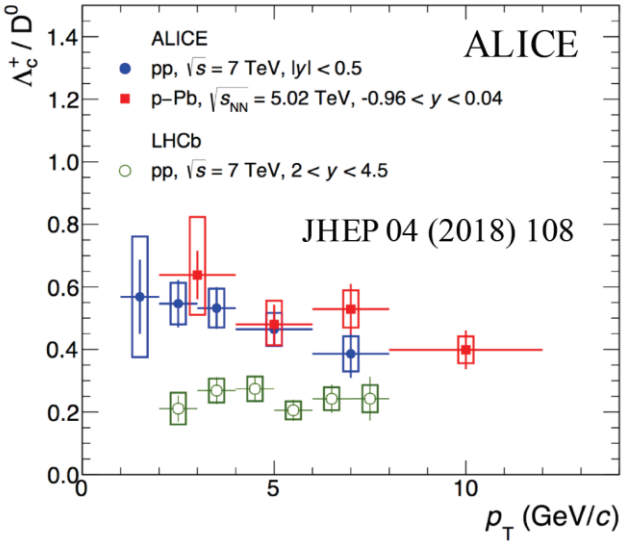
$$R_{\Lambda_c^+/D^0} = \frac{\sigma_{\Lambda_c^+}(y^*, p_T)}{\sigma_{D^0}(y^*, p_T)}$$

Eur. Phys. J. C77 (2017) 1
Comput. Phys. Commun. 184 (2013) 2562
Comput. Phys. Commun. 198 (2016) 238





arXiv:1809.01404



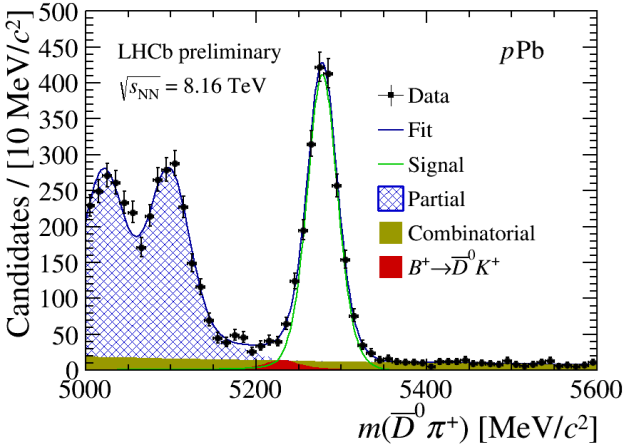
- Sensitive to charm hadronisation mechanisms
- Model based on measured *pp* cross-section
- nPDF effects mostly cancel
  - EPS09LO & EPS09NLO similar
  - nCTEQ15 slightly lower.
- Slight increase with increasing p_T

- Forward:
  - Consistent at lower p_T
  - Below theories at higher p_T
- Backward:
  - Consistent for all p_T
- Consistent with LHCb *pp* results ~0.3
- Lower than ALICE points in midrapidity for both *pp* and *p*Pb

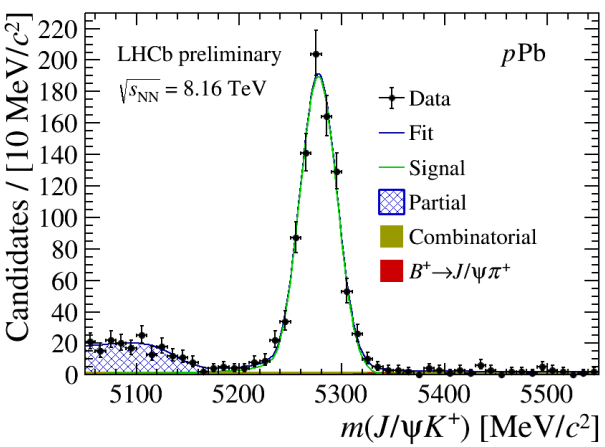
Beauty hadron production in pPb at 8.16 TeV

LHCb-CONF-2018-004

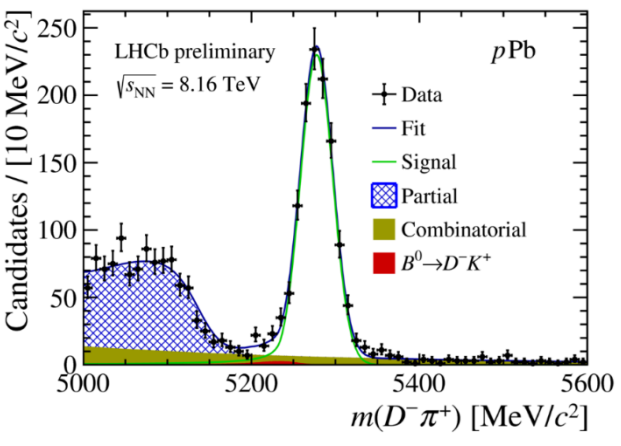
$B^+ \to \overline{D}^0\pi^+$



$B^+ \to J/\psi K^+$



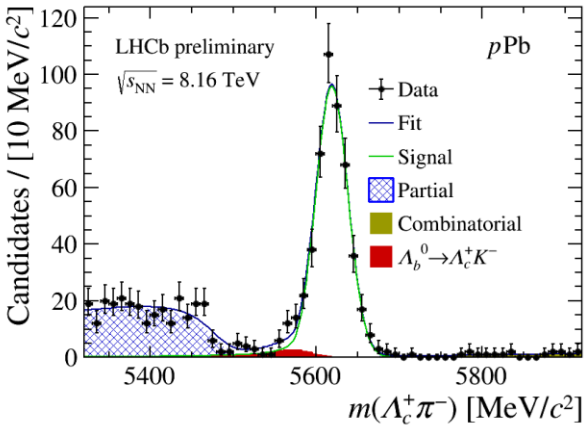
$B^0 \to D^-\pi^+$



Reconstructed through exclusive hadronic decay modes:

Decay	pPb	Pbp
$\mathrm{B}^+ \to \overline{D}^0\pi^+$	1943 ± 58	1824 ± 64
$\mathrm{B}^+ \to J/\psi\, K^+$	883 ± 32	905 ± 33
$\mathrm{B}^0 \to D^-\pi^+$	1155 ± 39	886 ± 34
$\Lambda_b^0 \to \Lambda_c^+\pi^-$	484 ± 24	397 ± 23

$\Lambda_b^0 \to \Lambda_c^+\pi^-$

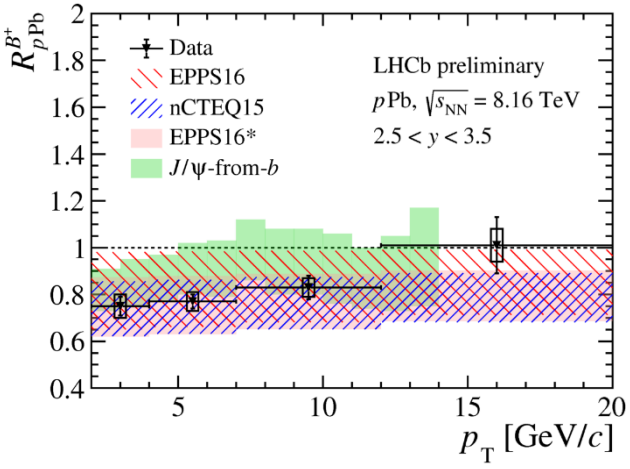


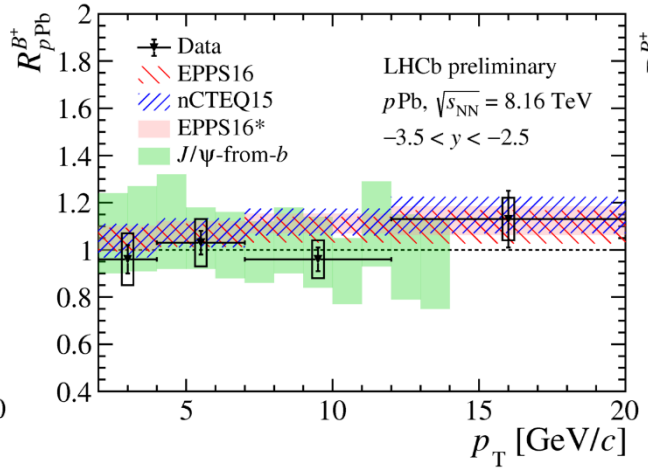
b-hadron production in pPb at 8.16 TeV
B^+ nuclear modification factor

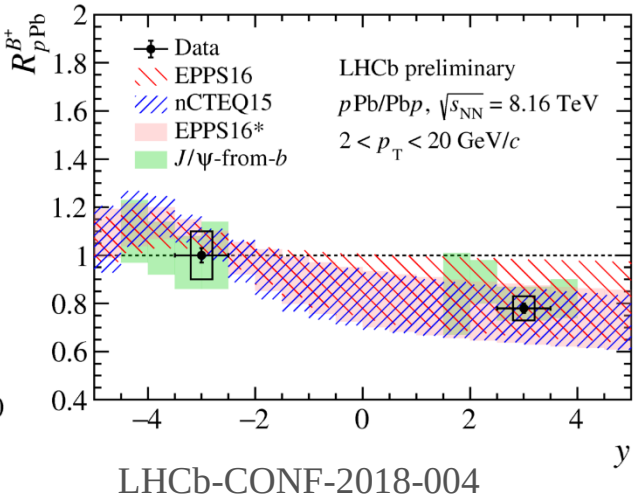
$$R_{p\mathrm{Pb}}(y^*, p_\mathrm{T}) = \frac{1}{A} \times \frac{\mathrm{d}\sigma_{p\mathrm{Pb}}(y^*, p_\mathrm{T}, \sqrt{s_\mathrm{NN}})/\mathrm{d}x}{\mathrm{d}\sigma_{pp}(y^*, p_\mathrm{T}, \sqrt{s_\mathrm{NN}})/\mathrm{d}x}, \; A{=}208$$

- pp reference interpolated between 7 & 13 TeV measurements from LHCb
- $R_{p\mathrm{Pb}}$ suppressed at forward rapidity
  - increase with increasing p_T
- $R_{p\mathrm{Pb}}$ consistent with 1 at backward rapidity

- Measurements consistent with calculations with nPDFs EPPS16 and nCTEQ15
- Consistent with J/ψ-from-b
- Trend similar to D^0 $R_{p\mathrm{Pb}}$





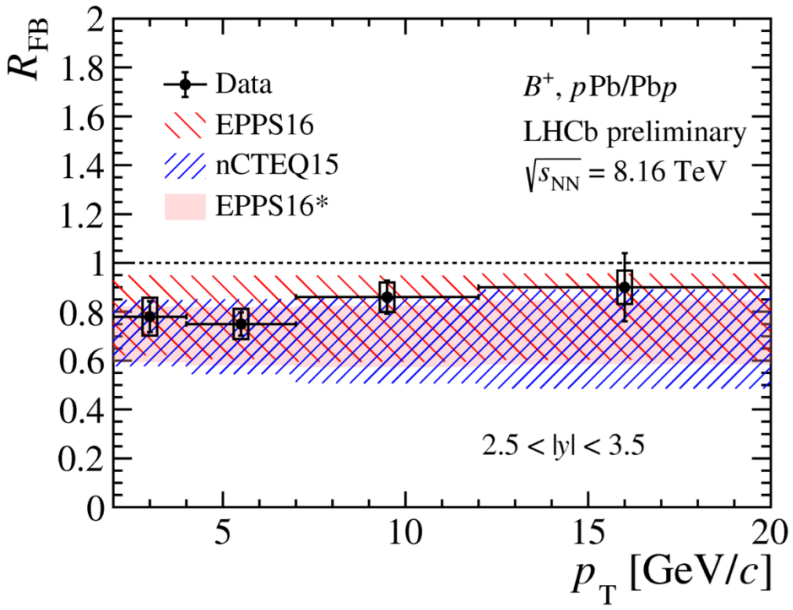


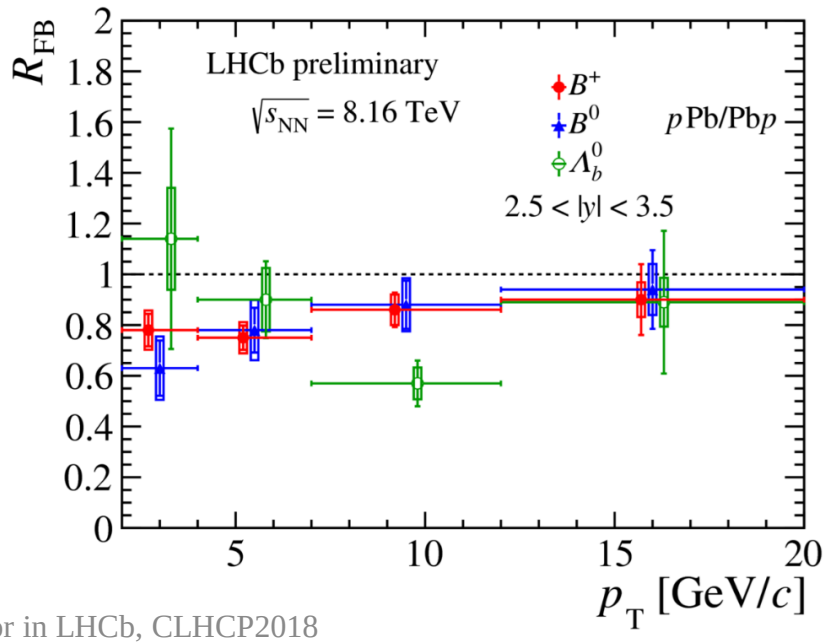
LHCb-CONF-2018-004

b-hadron production in pPb at 8.16 TeV
B^+, B^0 and Λ_b^0 forward-backward production ratio

- B^+ production suppressed in the forward rapidity region compared to the backward.
- Limited statistics to observe clear trend wrt p_{T}
- Consistent with nPDF expectations
- Small uncertainty on B^+ R_{FB}
- Consistent R_{FB} between B^+, B^0 and Λ_b^0

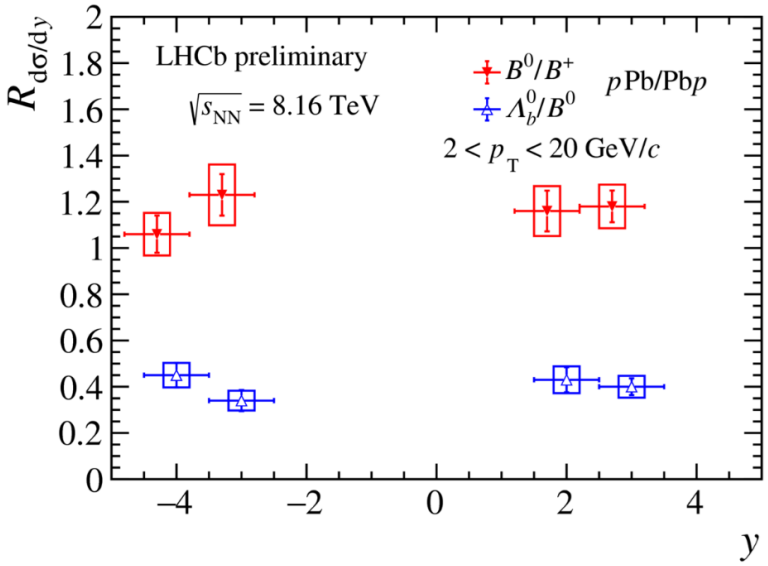
$$R_{\mathrm{FB}} = \frac{\sigma(+|y^*|, p_{\mathrm{T}})}{\sigma(-|y^*|, p_{\mathrm{T}})}$$

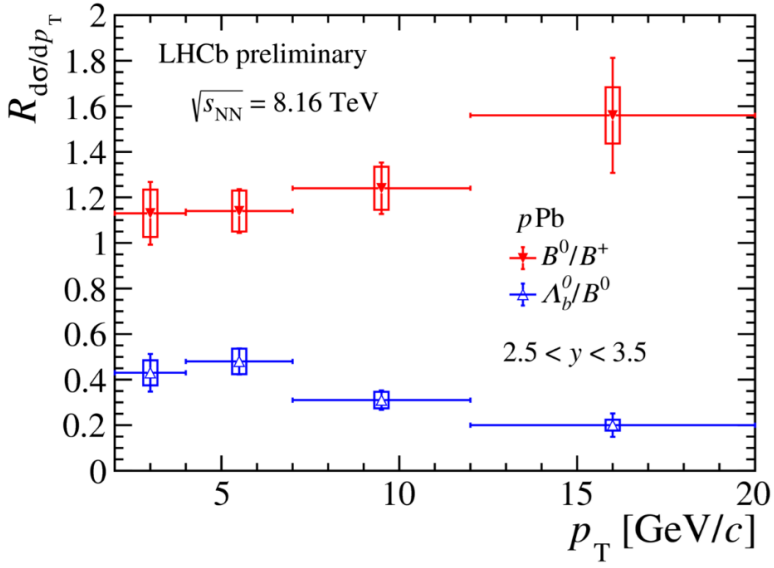




LHCb-CONF-2018-004

b-hadron production in *p*Pb at 8.16 TeV
Production cross-section ratio





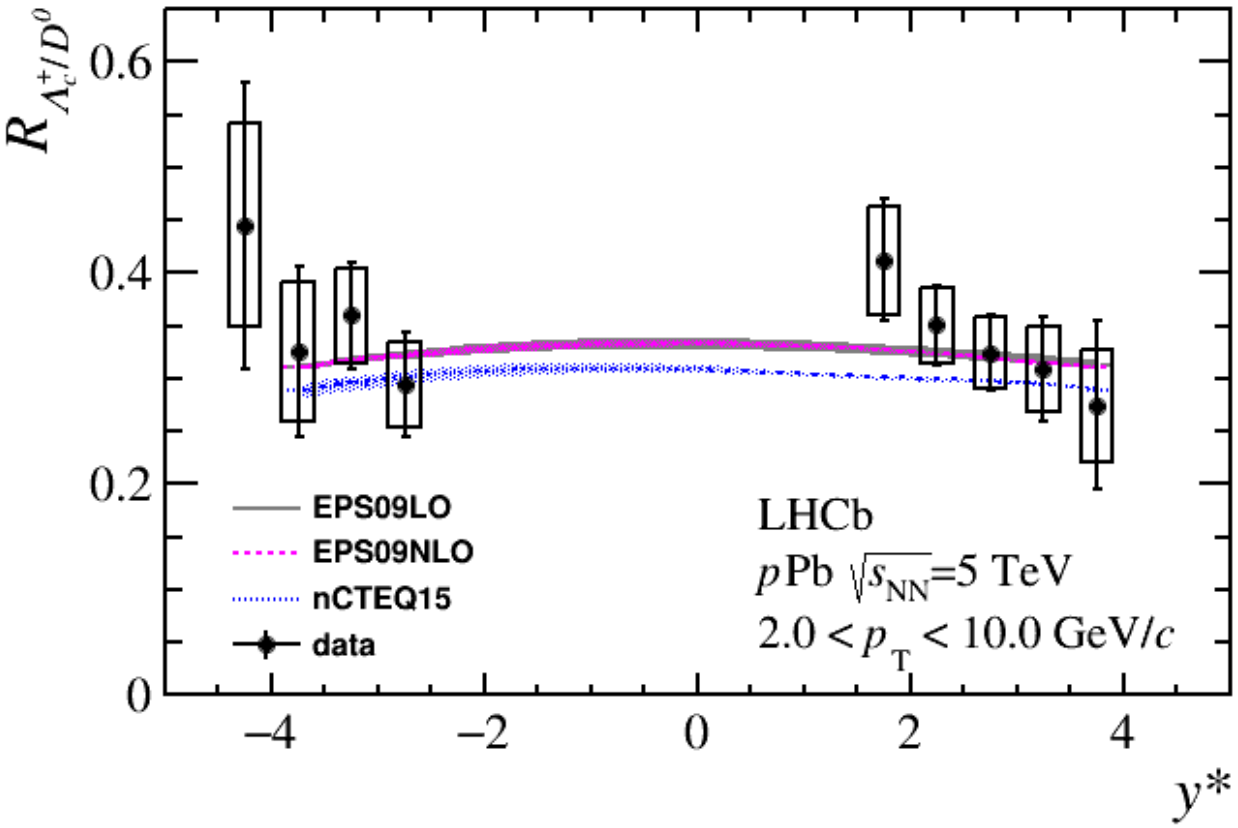
- R_{B^0/B^+}
  - No significant dependence on rapidity and p_T
- $R_{\Lambda_b^0/B^0}$
  - ~0.4, no strong rapidity dependence
  - Similar values observed in LHCb *pp* measurement JHEP 08 (2014) 143
  - Decreases with p_T when $p_T > 5$ GeV/*c*

LHCb-CONF-2018-004

Conclusions

- Production cross-sections of open charm and beauty hadrons in pPb collisions at 5 and 8.16 TeV measured by LHCb
  - Precise prompt D^0 meson measurement down to zero p_{T}. Suppression in the forward rapidity observed.
  - Prompt Λ_c^+/D^0 ratio consistent with theoretical calculations and pp results
  - First measurement of b-hadrons using exclusive hadronic modes. Similar suppression in the forward rapidity as D^0 meson.
  - First direct measurement of Λ_b^0 baryon in heavy ion collisions. Λ_b^0/B^0 ratio ~ 0.4

backup


$R_{\Lambda_c^+/D^0}$
0.6
0.4
0.2
0
−4
−2
0
2
4
y^*
EPS09LO
EPS09NLO
nCTEQ15
data
LHCb
pPb $\sqrt{s_{NN}}$=5 TeV
$2.0 < p_T < 10.0$ GeV/c