Heavy Flavour in LHCb - results and prospects

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Second LHCb Heavy Ion Workshop
5th September 2019

LHCb heavy-ion recent results

- **Antiproton production in fixed-target configuration**
  - **LHCb-PAPER-2018-031, PRL 121 (2018) 222001**
- **Charm production in fixed-target configuration**
  - **LHCb-PAPER-2018-023, PRL 122 (2019) 132002**
- **Heavy flavour production in *p*Pb collisions**
  - ***D^0*@5.02TeV: LHCb-PAPER-2017-015, JHEP (2017) 090**
  - ***Λ_c^+*@5.02TeV: LHCb-PAPER-2018-021, JHEP 02 (2019) 102**
  - ***B^+*, *B^0*, *Λ_b^0*@8.16TeV: LHCb-PAPER-2018-048, PRD99 052011 (2019)**
  - ***J/ψ*@8.16TeV: LHCb-PAPER-2017-014, PLB774 (2017) 159**
  - ***$\Upsilon(nS)$*@8.16TeV: LHCb-PAPER-2018-035, JHEP 11 (2018) 194**
- **Exclusive photonuclear *J/ψ* production in ultra-peripheral PbPb collisions @5TeV**
  - **LHCb-CONF-2018-003**

LHCb heavy-ion recent results

- Antiproton production in fixed-target configuration
  - LHCb-PAPER-2018-031, PRL 121 (2018) 222001 → Saverio Mariani
- Charm production in fixed-target configuration
  - LHCb-PAPER-2018-023, PRL 122 (2019) 132002 → Saverio Mariani
- Heavy flavour production in *p*Pb collisions
  - D^0@5.02TeV: LHCb-PAPER-2017-015, JHEP (2017) 090 → This talk
  - Λ_c^+@5.02TeV: LHCb-PAPER-2018-021, JHEP 02 (2019) 102 → This talk
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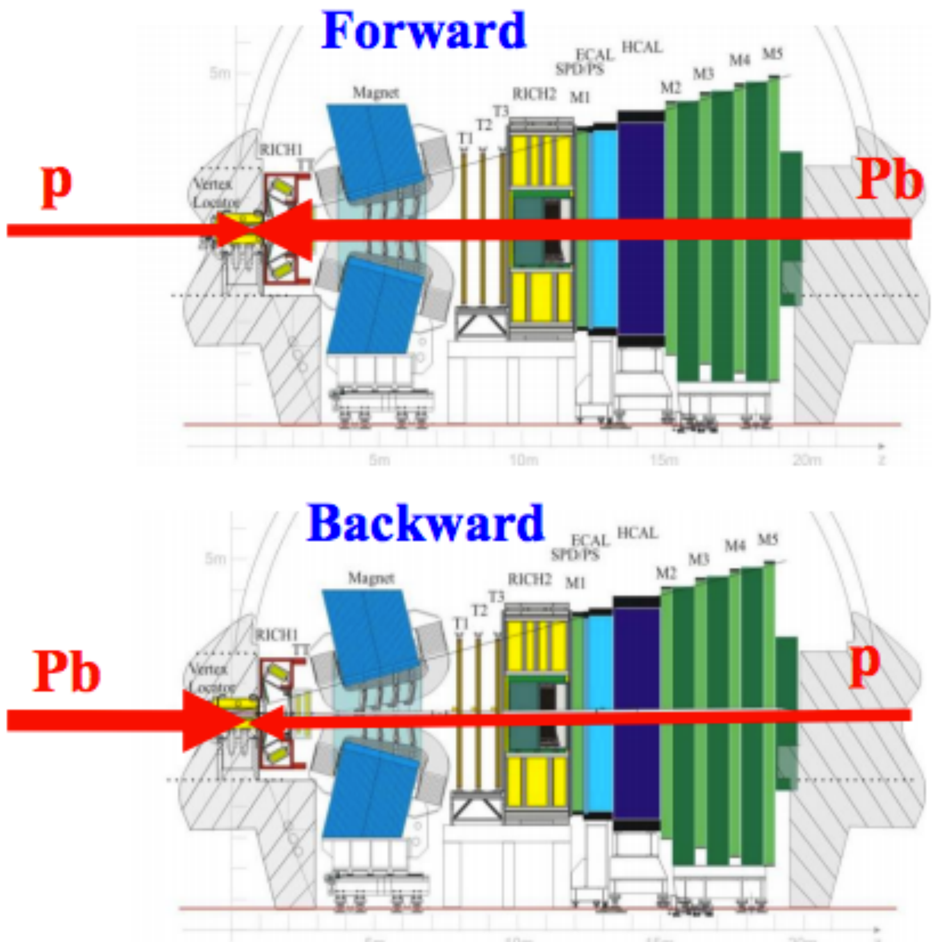
  - J/ψ@8.16TeV: LHCb-PAPER-2017-014, PLB774 (2017) 159 → Jana Crkovska
  - $\Upsilon(nS)$@8.16TeV: LHCb-PAPER-2018-035, JHEP 11 (2018) 194 → Jana Crkovska
- Exclusive photonuclear J/ψ production in ultra-peripheral PbPb collisions @5TeV
  - LHCb-CONF-2018-003 → Albert Bursche

Proton-lead modes setups at LHCb



Ion = $^{208}_{82}$Pb

Forward region:

- $y^* = y_{lab} - 0.465$
- pPb: $1.5 < y^* < 4.0$

Backward region:

- $y^* = -(y_{lab} + 0.465)$
- Pbp : $-5.0 < y^* < -2.5$

2013 data taking: $\sqrt{s_{NN}} = 5.02$ TeV

- 1.1 nb^{-1} (Fwd), 0.5 nb^{-1} (Bwd)

2016 data taking: $\sqrt{s_{NN}} = 8.16$ TeV

- 13.6 nb^{-1} (Fwd), 20.8 nb^{-1} (Bwd)

Proton-lead collisions

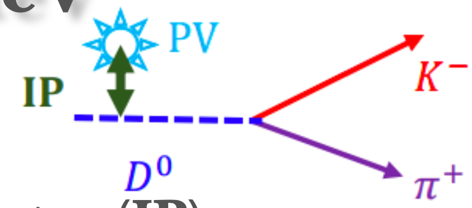
- **Study of cold nuclear matter effects**
- **(Hot nuclear matter effects contributing?)**
- **Nuclear effects quantified by nuclear modification factor:**

$$R_{p\mathrm{Pb}}(p_{\mathrm{T}}, y^*) \equiv \frac{1}{A} \frac{\mathrm{d}^2\sigma_{p\mathrm{Pb}}(p_{\mathrm{T}}, y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}{\mathrm{d}^2\sigma_{pp}(p_{\mathrm{T}}, y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}, A = 208$$

where reference σ_{pp} at 5.02 TeV are from *pp* 5 TeV measurements, and reference σ_{pp} at 8.16 TeV are from interpolations with *pp* 2.76, 5, 7, 8, 13 TeV data

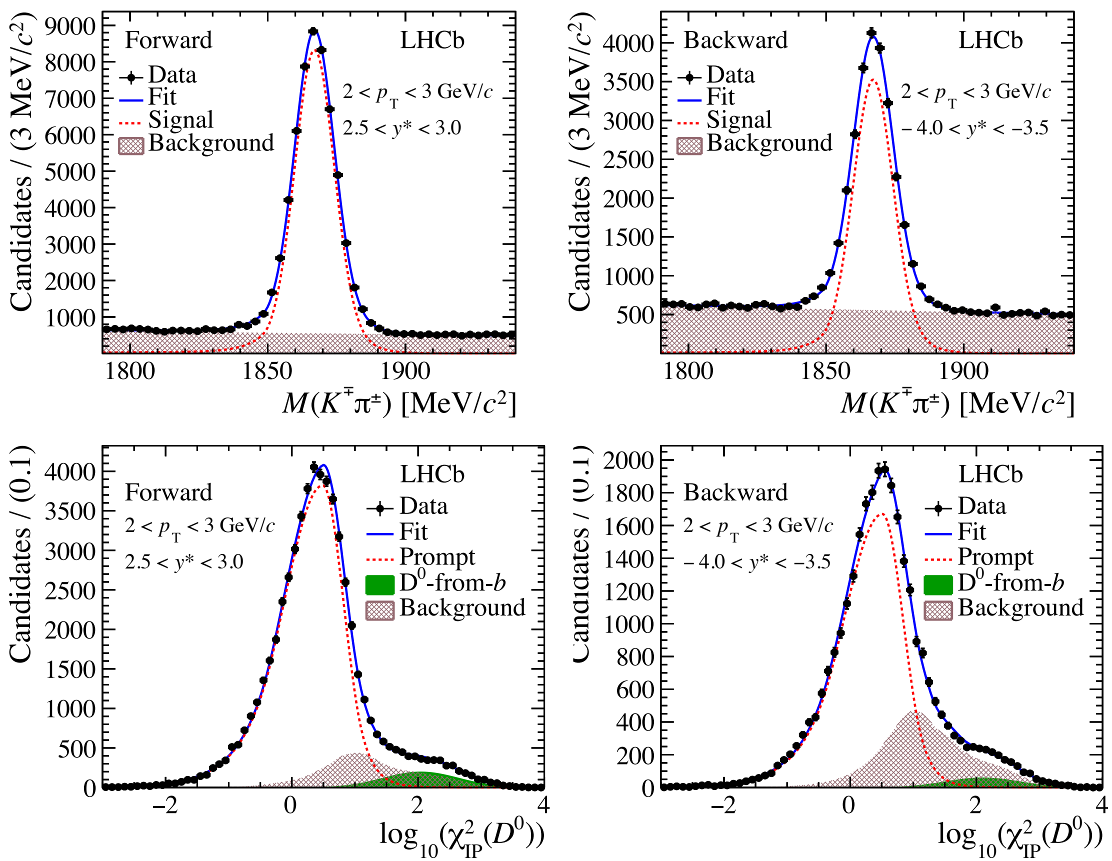
JHEP (2017) 090

Prompt D^0 production in pPb at 5.02 TeV



- **Reconstructed through $D^0 \to K^- \pi^+$ decays**
- **Simultaneous 2D fit to D^0 mass and impact parameter (IP)**

Forward backward

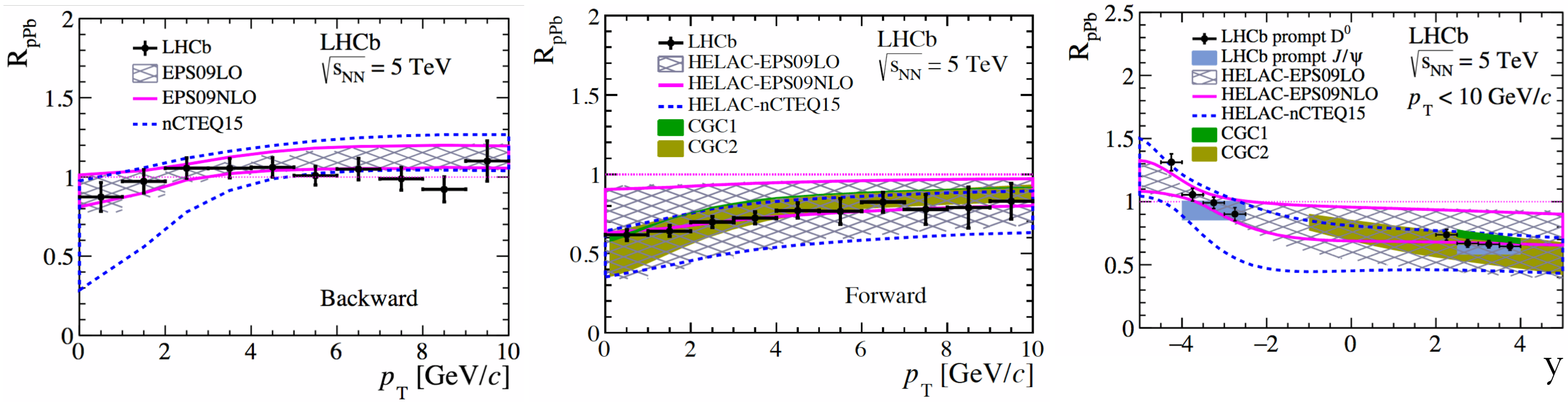


Mass distribution:
Signal: Crystal Ball
Background:Linear

IP distribution:
Prompt signal: from simulation
D0 from b: from simulation
Background: shape from sidebands

JHEP (2017) 090

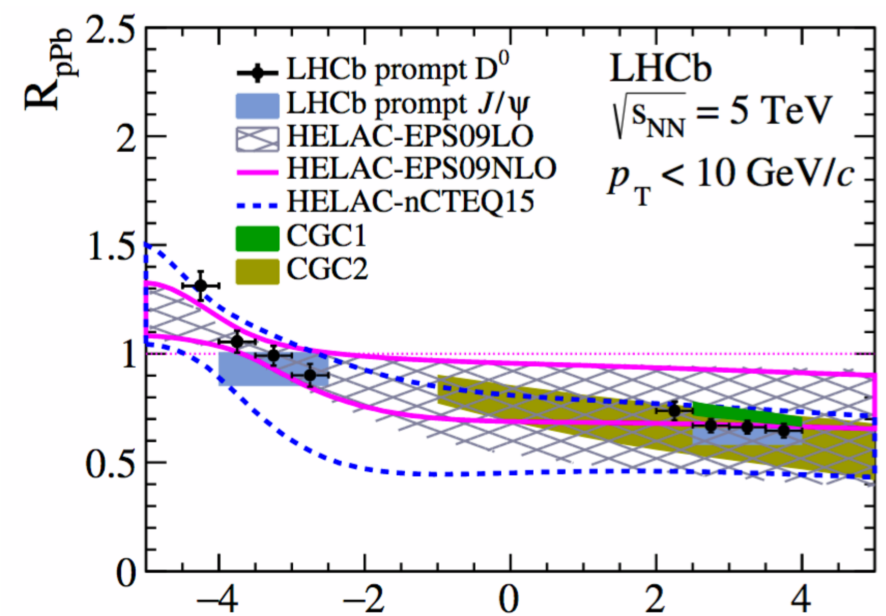
Prompt D^0 nuclear modification factor

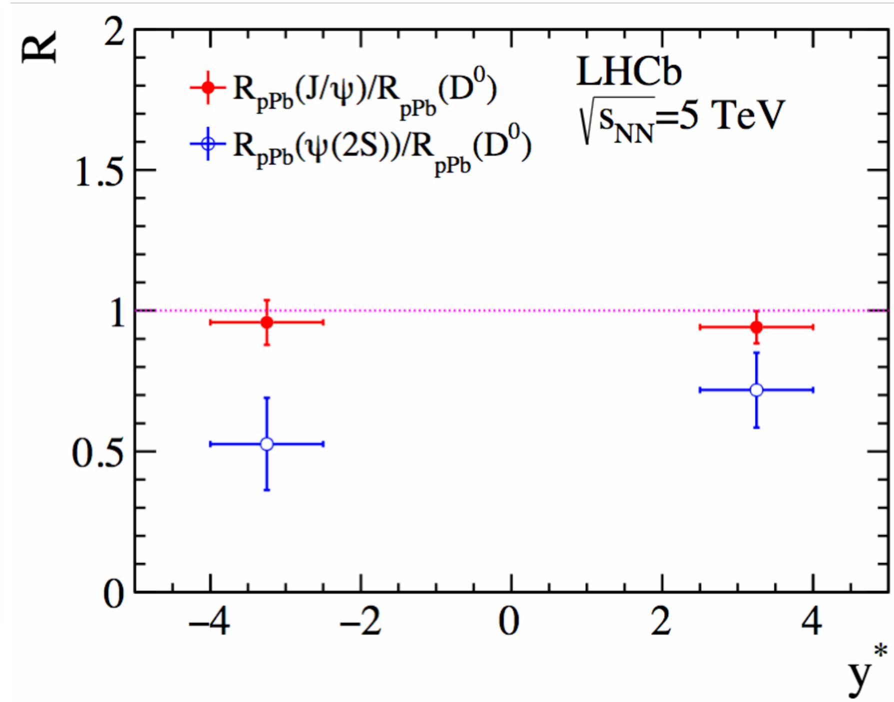


- Strong suppression at forward rapidity (~30%),
- Backward rapidity: compatible with no suppression and hint of enhancement —> different nuclear effect in forward and backward regions
- Suppression-enhancement pattern predicted by nPDFs [Eur. Phys. J. C77 (2017) 1, Comput. Phys. Commun. 184 (2013) 2562, Comput. Phys. Commun. 198 (2016) 238]
- At forward rapidity region also consistent with Colour Glass Condensate (CGC) models [Phys. Rev. D91 (2015) 114005, arXiv:1706.06728], with a proper saturation scale

JHEP (2017) 090

Prompt D^0 nuclear modification factor



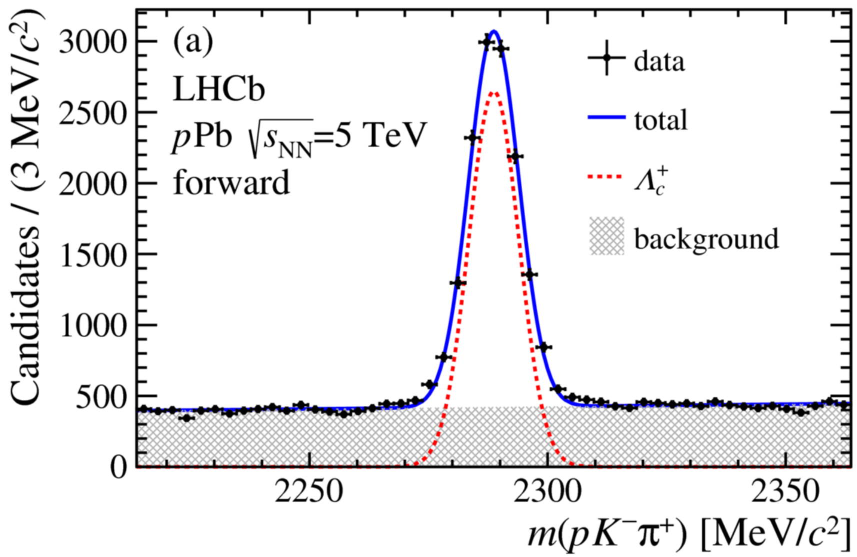


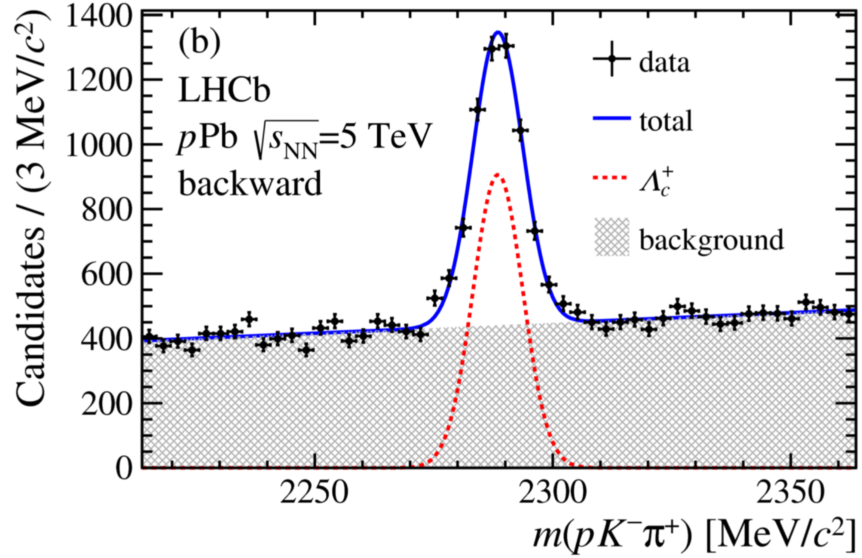
- **Compare with** ***J/ψ*** **and** ***ψ(2S)*** **results at 5 TeV**
- **Similar nuclear modification factor for** ***J/ψ*** **to** D^0**,** $\frac{R_{pPb}(J/\psi)}{R_{pPb}(D^0)} \sim 1$
- **More suppressed for** ***ψ(2S)*** **to** D^0

JHEP 02 (2019) 102

Prompt Λ_c^+ production in *p*Pb at 5.02 TeV

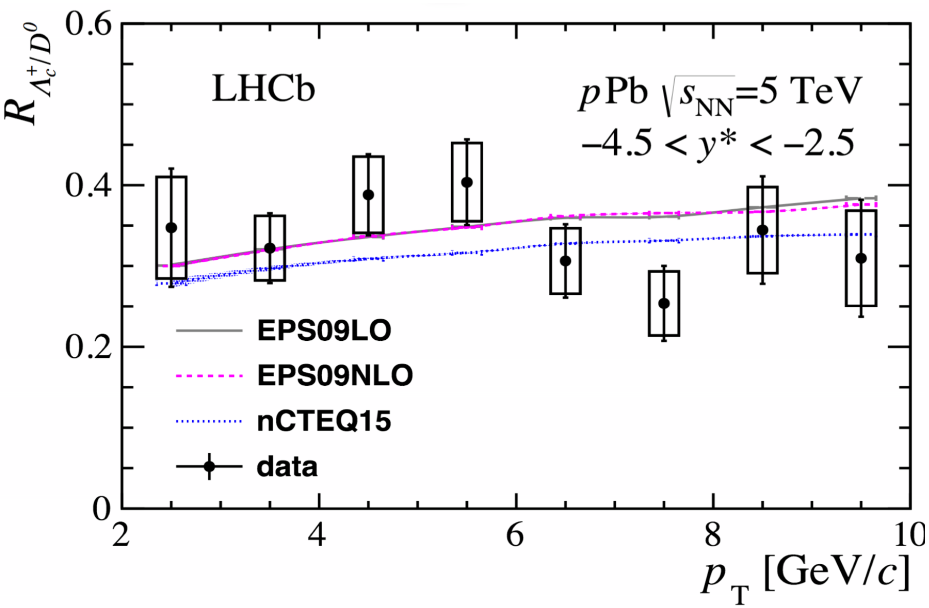
- **Reconstructed through $\Lambda_c^+ \to pK^-\pi^+$ decays**

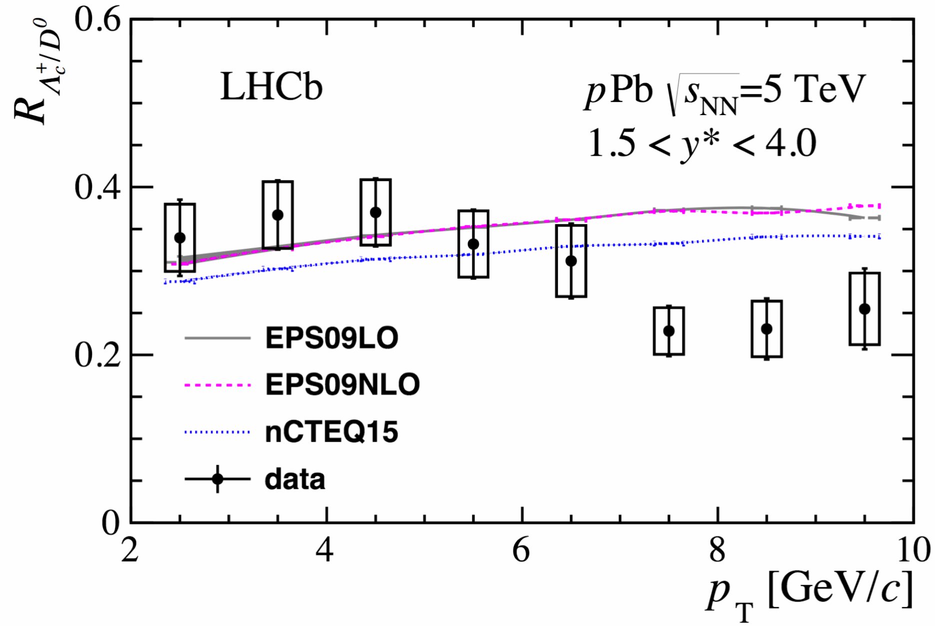




- **Similar analysis strategy as D^0**

Prompt Λ_c^+ production in pPb at 5.02 TeV

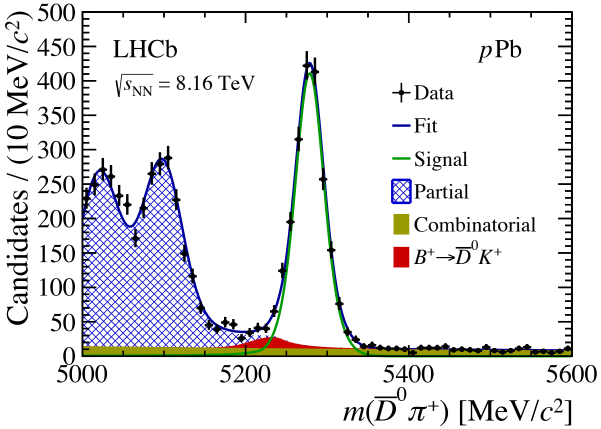


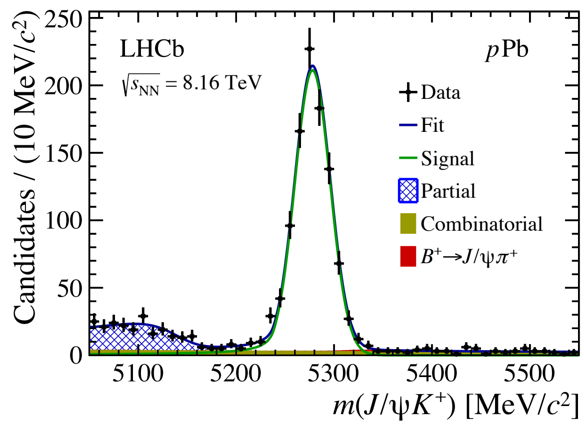


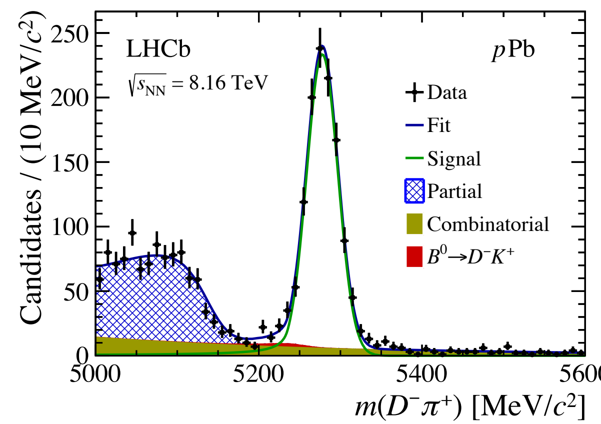
- Λ_c^+/D^0 similar in forward and backward directions
- Generally consistent with expectations from pp data $\Lambda_c^+/D^0 \sim 0.3$,
- Compared with nPDFs [JHEP 04 (2009) 065, EPJ C77 (2017) 1, Comput. Phys. Commun. 198 (2016) 238], hint of discrepancy at high p_T in forward direction

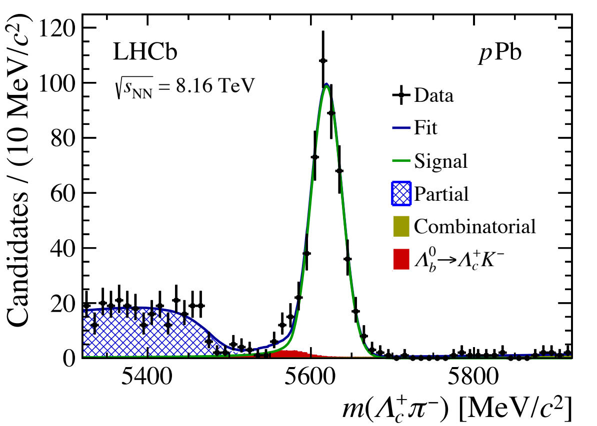
b-hadron production in pPb at 8.16 TeV

- **Exclusive decay modes: $B^+\to J/\psi K^+$, $B^+\to D^0\pi^+$, $B^0\to D^-\pi^+$, $\Lambda_b^0\to\Lambda_c^+\pi^-$**





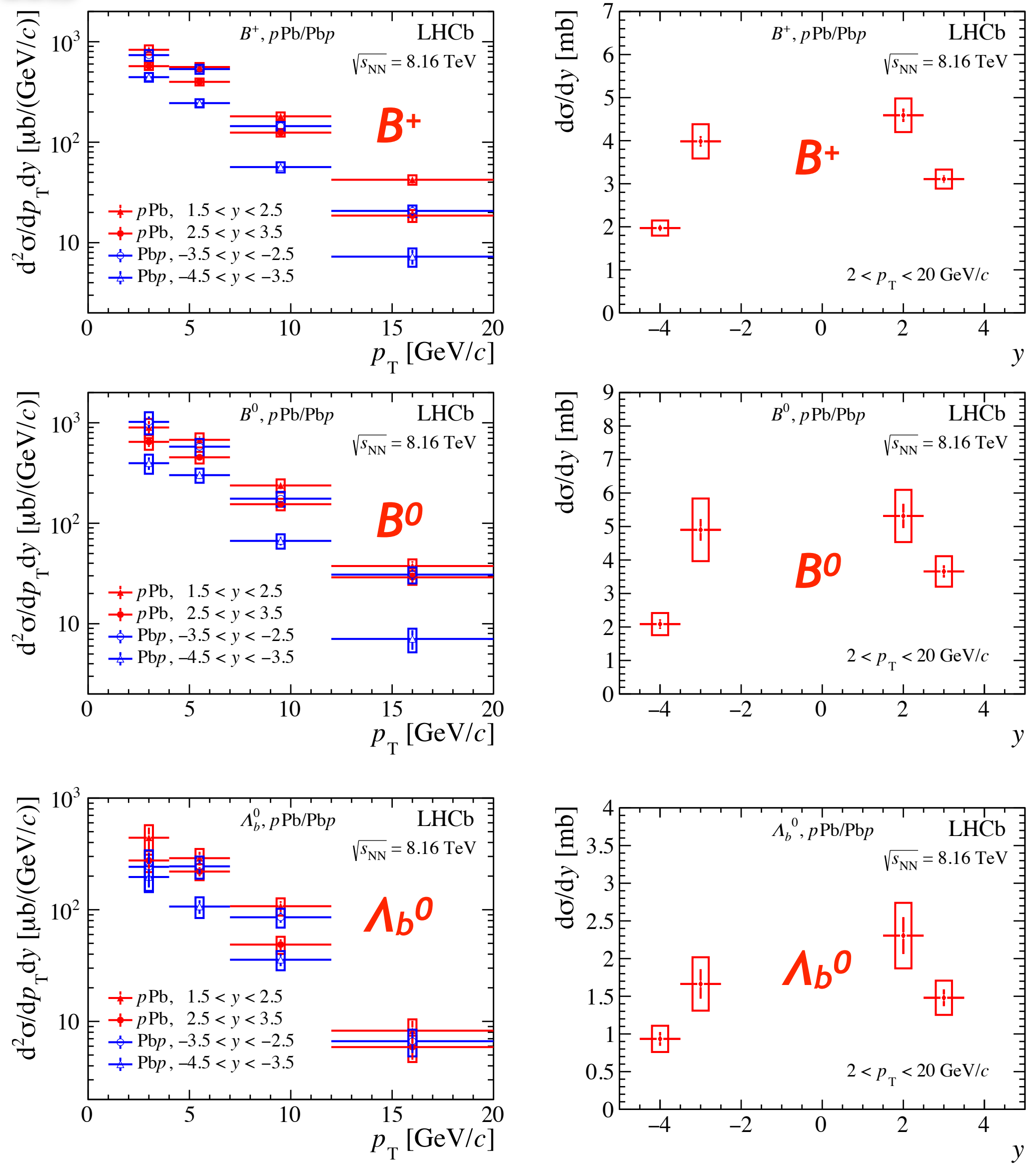




Decay	pPb	Pbp
$B^+\to\overline{D}^0\pi^+$	1943 ± 58	1824 ± 64
$B^+\to J/\psi K^+$	883 ± 32	905 ± 33
$B^0\to D^-\pi^+$	1155 ± 39	886 ± 34
$\Lambda_b^0\to\Lambda_c^+\pi^-$	484 ± 24	397 ± 23

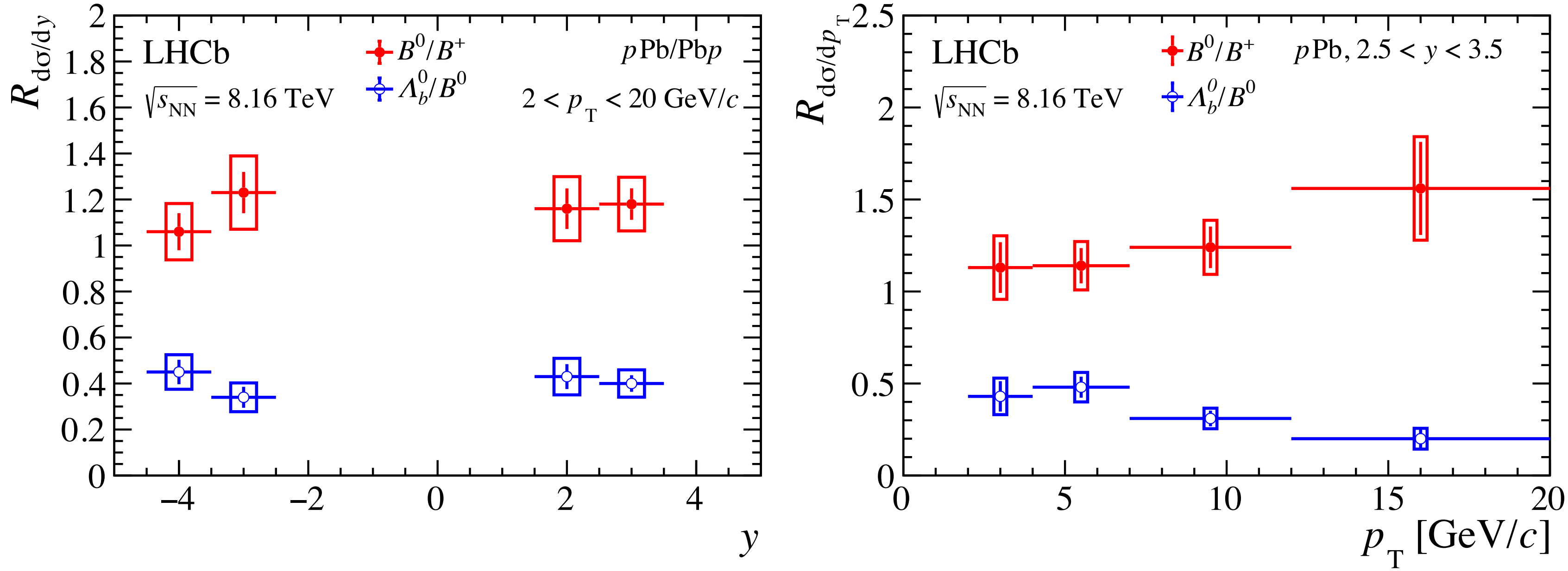
b-hadron cross-sections

- B^+ cross-section studied in $J/\psi K^+$ and $D^0\pi^+$ modes. Both modes consistent. Weighted average shown here
- Similar p_T and y distributions for B^+, B^0 and Λ_b^0 hadrons



b-hadron cross-section ratios

- **Probing relative *b*-quark fragmentation into different *b*-hadrons**

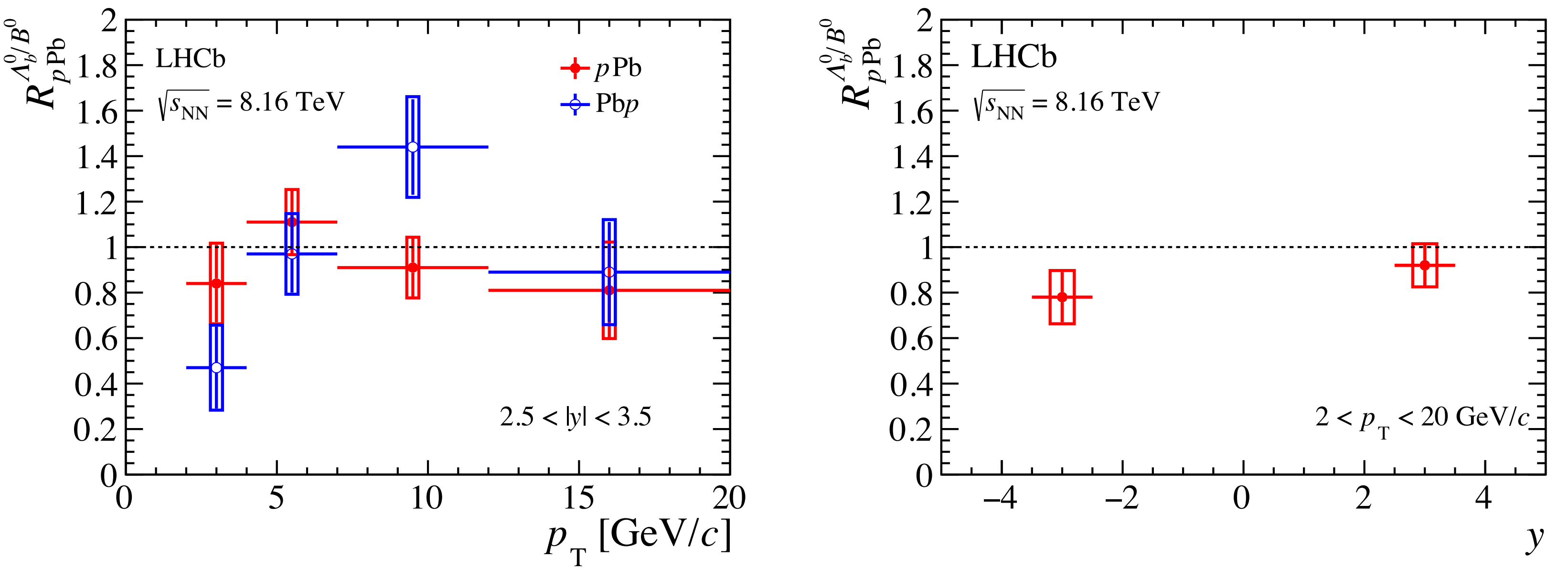


- **B^0/B^+ ratio independent of y and p_T , slightly above unity (isospin symmetry)**
- **Λ_b^0/B^0 ≈40%, decreasing with p_T, no hint of strong rapidity dependence. similar to results in LHCb *pp* data [JHEP 08 (2014) 143]**
- **Λ_b^0/B^0 ratio reaches LEP data at high p_T, 0.20 ± 0.02 [arXiv:1612.07233]**

PRD99 052011 (2019)

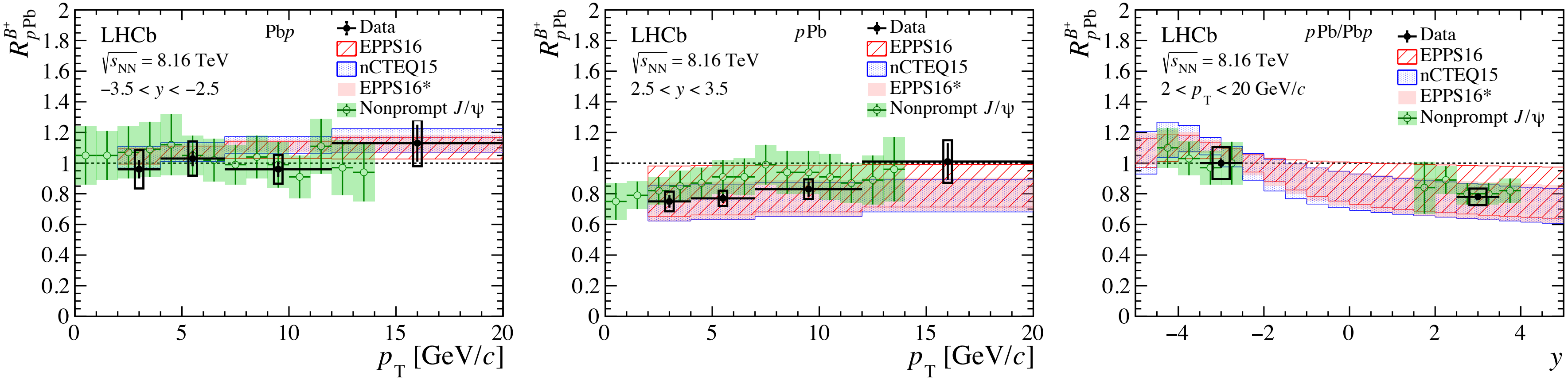
Λ_b^0 and B^0 relative modification

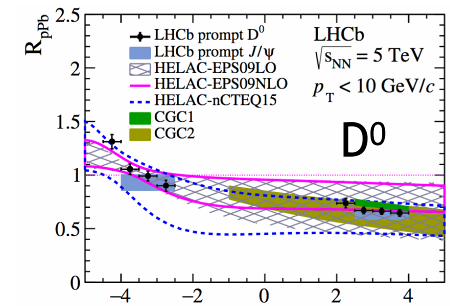
- Ratio of R_{pA} between Λ_b^0 and B^0 hadrons



- Forward rapidity: consistent with unity in all kinematic bins —> b-quark fragmentation function at forward rapidity similar to pp
- Backward rapidity: hint of stronger suppression for Λ_b^0 compared with B^0. Demanding more statistics for a firm conclusion.

B^+ nuclear modification factors





- **Pattern consistent with R_{pA} of D^0 hadron**
- **Significant suppression (≈ 25%) in forward rapidity, suppression decreased at large p_T**
- **Consistent with unity at backward rapidity**
- **Measurements in good agreement with J/ψ-from-b decay data and calculations using nPDF sets [JHEP 04 (2009) 065, EPJ C77 (2017) 1, Comput. Phys. Commun. 198 (2016) 238]**

Conclusions

- **Heavy flavour production in *p*Pb collisions**
  - **Tested heavy-flavour bound state hadronisation & fragmentation down to low-p_T**
  - **Nuclear suppressions in *p*Pb forward: up to 20-30%**
  - **Analyses on open charm production at 8.16 TeV in progress, targeting QuarkMatter2019**
  - **Stay tuned!**

Backups