Open heavy-flavor production in pA collisions at LHCb

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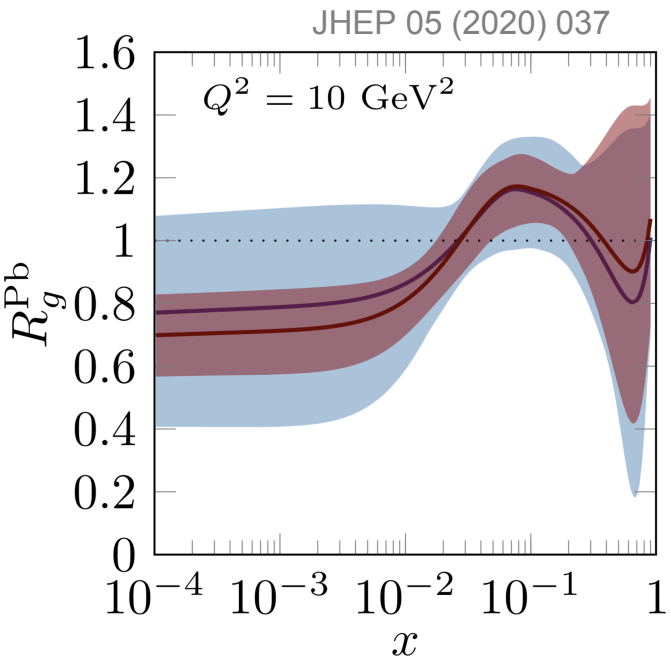
June 1, 2020

1. Introduction
2. LHCb detector and data configuration
3. Results in pPb
   - Prompt open charm production
   - B^+, B^0 and Λ_b^0 production at 8.16 TeV
   - Prompt charm pair production at 8.16 TeV
4. Summary and outlook

Introduction

- Heavy quarks are excellent probes of the cold and hot nuclear matter effects in heavy-ion collisions.
  - Bring information of the early stage.
  - $t_{\text{prod}} \ll t_{\text{QGP}}$: experience whole time evolution of collisions.
  - $m_Q \gg \Lambda_{\text{QCD}}$: allow perturbative calculations.
- Cold nuclear matter effects are assumed to be dominant in pA collisions.
  - Modification of nPDFs.
  - Other initial/final state effects.

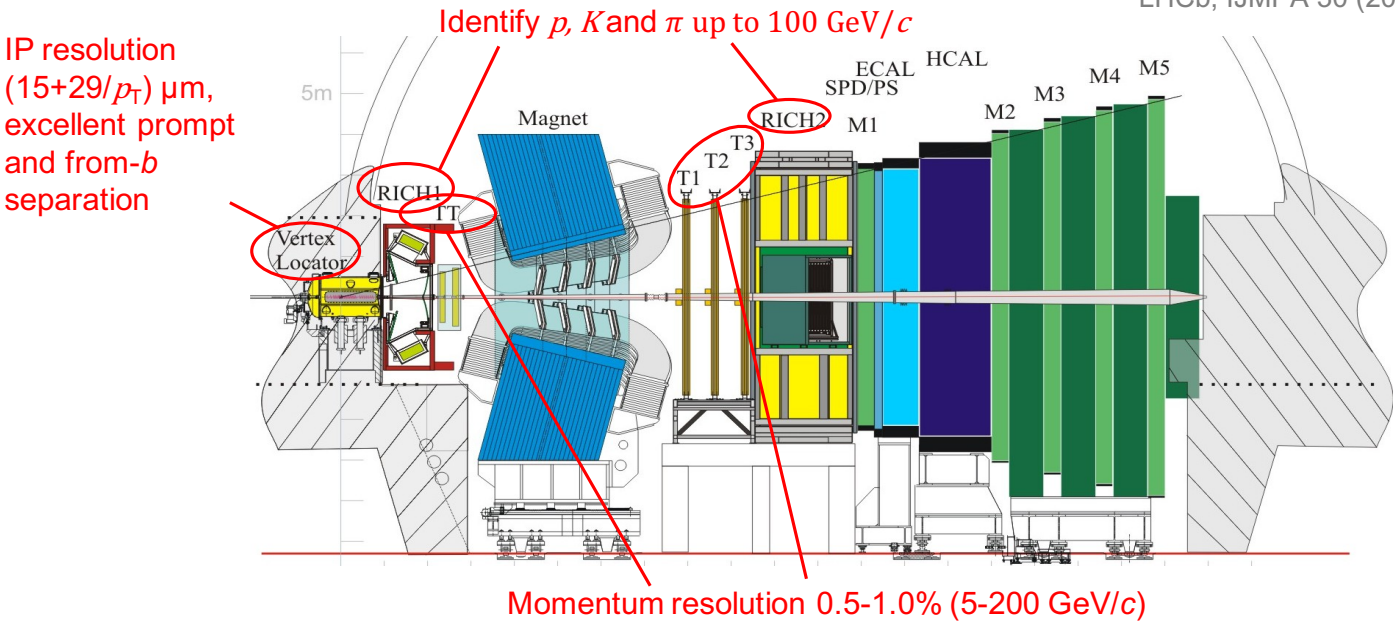


- The baryon-to-meson ratio measurements in heavy-ion collisions help to understand the hadronization of heavy quarks.
  - Comparisons with pp results.

LHCb detector

1. A single-arm forward spectrometer, covering the pseudo-rapidity range of $2 < \eta < 5$.
2. Designed for studying particles containing b or c quarks.

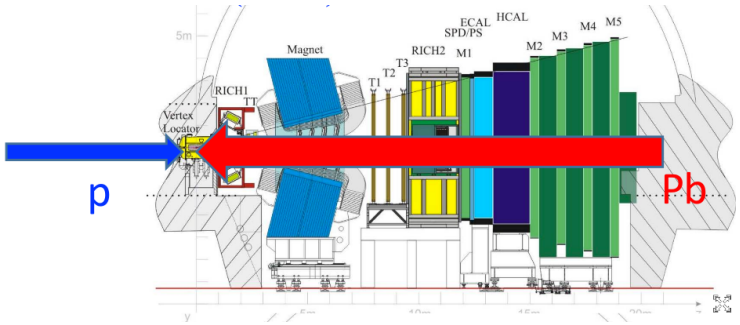
LHCb, JINST 3 (2008) S08005
LHCb, IJMPA 30 (2015) 1530022



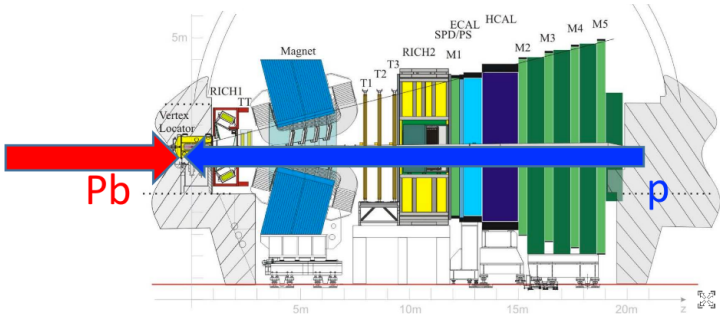
Data configuration

- pPb data taken at 2013 ($\sqrt{s_{\mathrm{NN}}}$ =5.02 TeV) and 2016($\sqrt{s_{\mathrm{NN}}}$ =8.16 TeV), two collision configurations.

pA, forward



Ap, backward



- pPb system boosted in laboratory frame:

  $y^* = y_{\mathrm{lab}} - 0.465$,

- Rapidity acceptance:

  pA: $1.5 < y^* < 4.0$

  Ap: $-5.0 < y^* < -2.5$,

- Transverse momentum acceptance:

  $0 < p_{\mathrm{T}} < 20\,\mathrm{GeV}/c$,

- Luminosity:

  5.02 TeV: 1.06 nb^{-1} (Fwd)

  and 0.52 nb^{-1} (Bwd),

  8.16 TeV: 12.18 nb^{-1} (Fwd)

  and 18.57 nb^{-1} (Bwd).

Open heavy-flavor measurements with pPb collisions

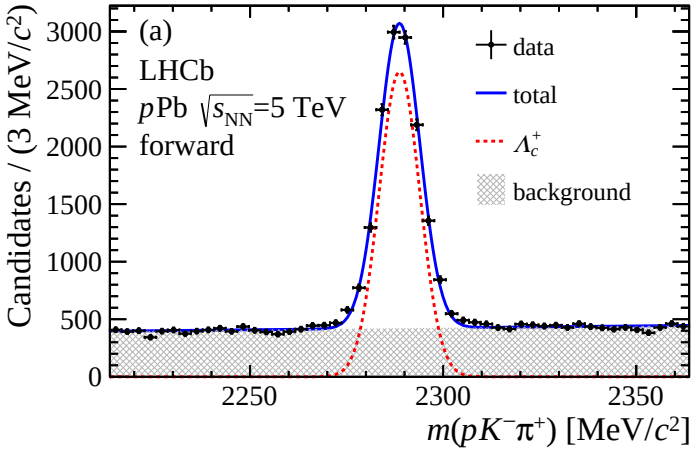
- Prompt D^0 production at 5 TeV [JHEP 10 (2017) 090]
- Prompt Λ_c^+ production at 5 TeV [JHEP 02 (2019) 102]
- Prompt D^0 production at 8.16 TeV [LHCb-CONF-2019-004]
- B^+, B^0 and Λ_b^0 production at 8.16 TeV [PRD 99 052011 (2019)]
- Prompt charm pair production at 8.16 TeV [LHCb-PAPER-2020-010] New!

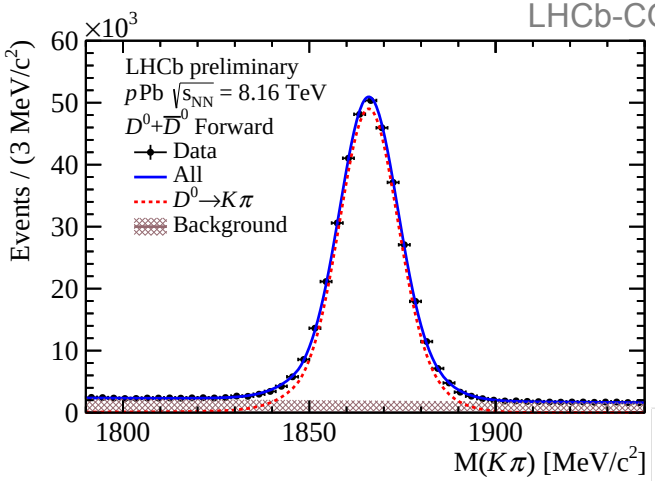
Prompt open charm production

Results on open charm production

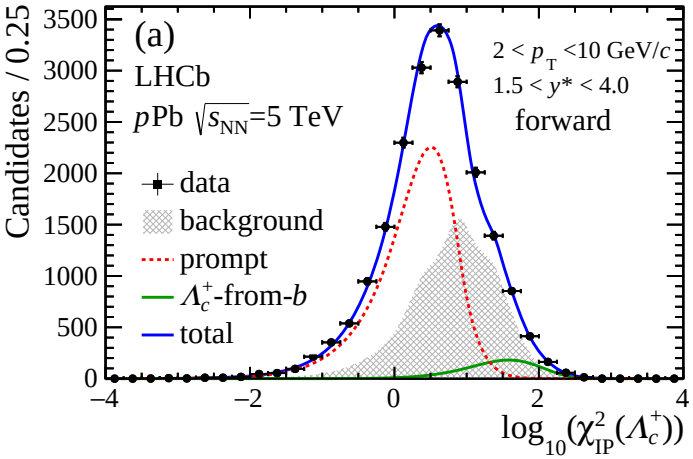
- Charm hadron decay modes: $D^0 \to K^-\pi^+$, $\Lambda_c^+ \to pK^-\pi^+$.

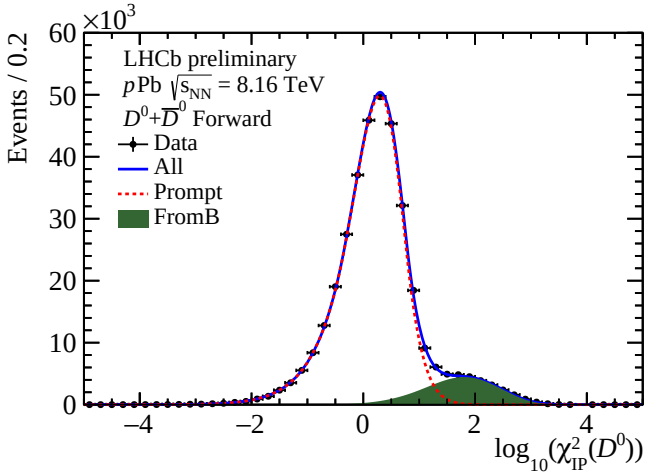
JHEP 02 (2019) 102
LHCb-CONF-2019-004

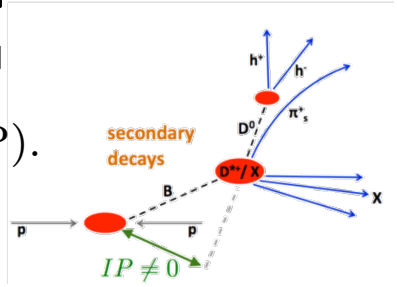




- Prompt and from-b components separated using impact parameter(IP).



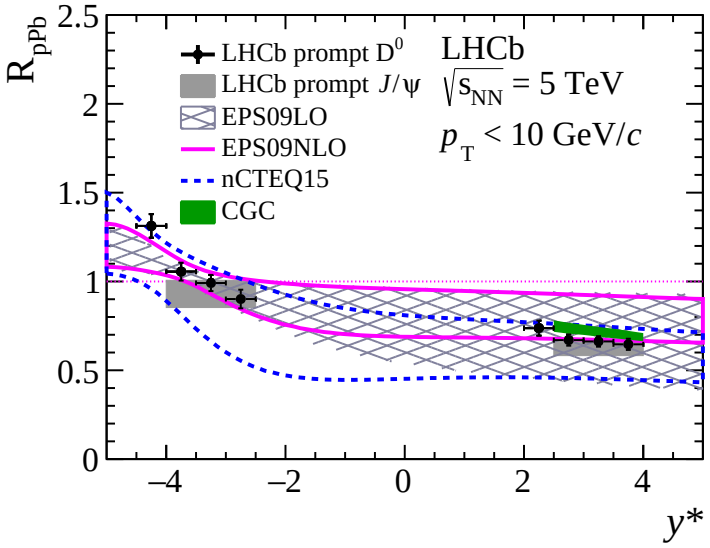


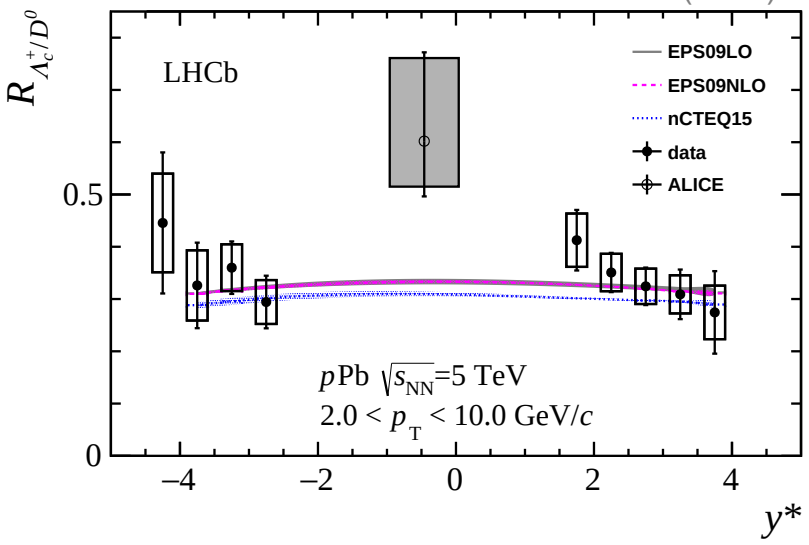


D^0 and Λ_c^+ hadron production at 5 TeV

- D^0 $R_{p\mathrm{Pb}}$ with σ_{pp} from 5 TeV results at LHCb and $R_{\Lambda_c^+/D^0}$.

JHEP 10 (2017) 090
JHEP 02 (2019) 102



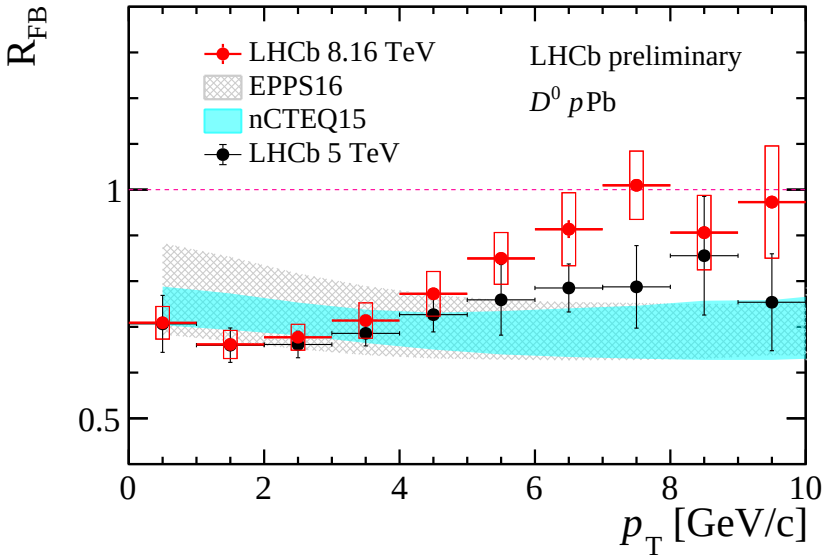


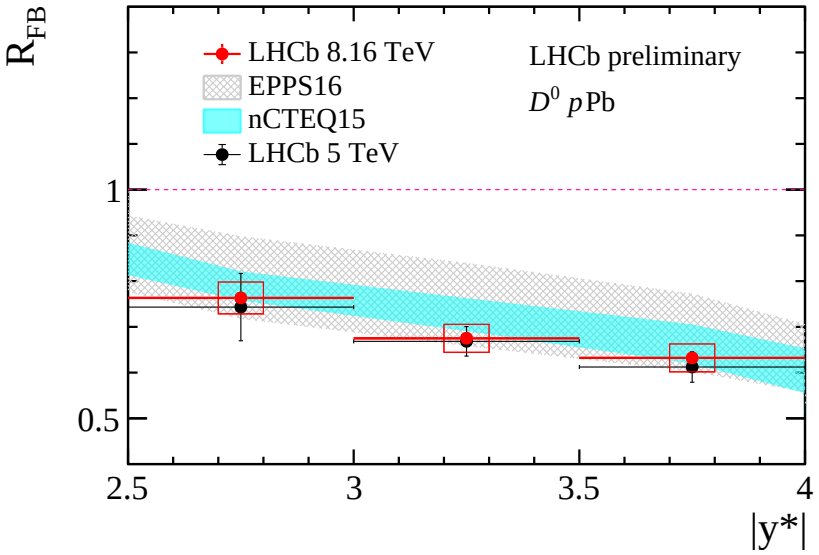
- The D^0 $R_{p\mathrm{Pb}}$ are in agreement with calculations with nPDFs.
- The results of $R_{\Lambda_c^+/D^0}$ are generally in agreement with calculations with nPDFs and LHCb pp results but lower than ALICE results in mid-rapidity region.

JHEP 06 (2017) 147, CPC 198 (2016) 23, PRD 91 (2015) 114005, JHEP 04 (2009) 065
EPJC 77 (2017) 163, arXiv:1706.06728, NPB 871 (2013) 1-20, JHEP 04 (2018) 108

D^0 R_{FB} at 8.16 TeV

LHCb-CONF-2019-004





- The R_{FB} points show a rising trend with p_{T}, which are in agreement with theories in low p_{T} bins while the discrepancy increases in high p_{T} bins.
- The result shows a slight dependence on rapidity, consistent with the measurement at 5 TeV and calculations with nPDFs.

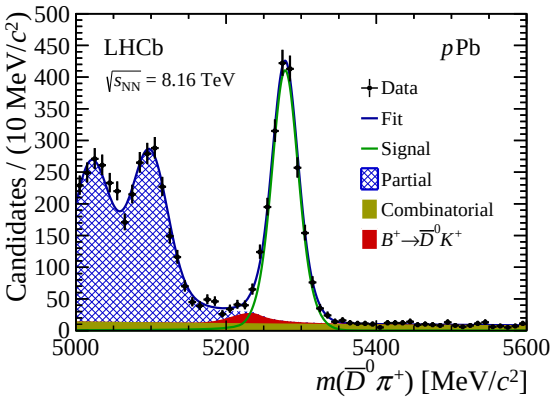
EPJC 77 (2017) 163,EPJC 77 (2017) S10052, PRL 121 (2018) 052004
CPC 184 (2013) 2562-2570, CPC 198 (2016) 238-159

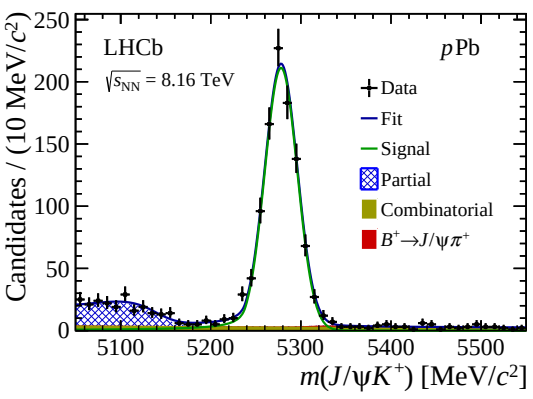
B^+, B^0 and Λ_b^0 production at 8.16 TeV

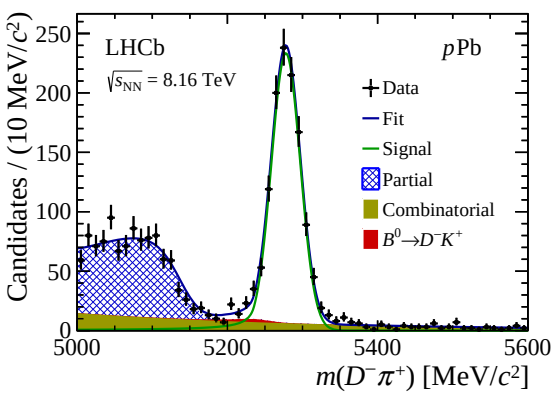
b-hadron mass distributions

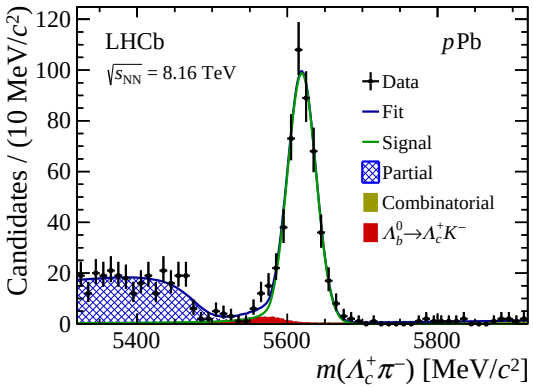
- b-hadron reconstruction using exclusive hadronic modes: $B^+ \to \overline{D}^0\pi^+$, $B^+ \to J/\psi K^+$, $B^0 \to D^-\pi^+$, $\Lambda_b^0 \to \Lambda_c^+\pi^-$.

PRD 99, 052011 (2019)





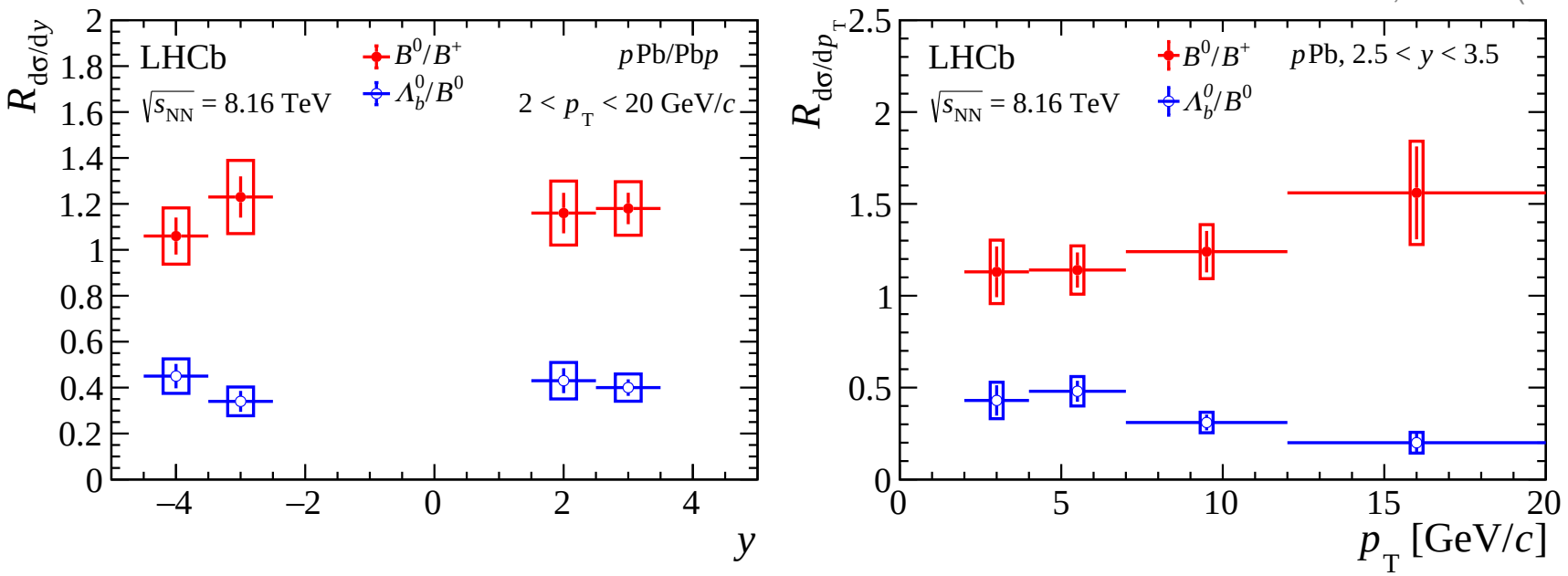




Decay	pPb	Pbp
$B^+ \to \overline{D}^0\pi^+$	1958 ± 54	1806 ± 55
$B^+ \to J/\psi K^+$	883 ± 32	907 ± 33
$B^0 \to D^-\pi^+$	1151 ± 38	889 ± 34
$\Lambda_b^0 \to \Lambda_c^+\pi^-$	484 ± 24	399 ± 23

b-hadron cross-sections ratios

PRD 99, 052011 (2019)

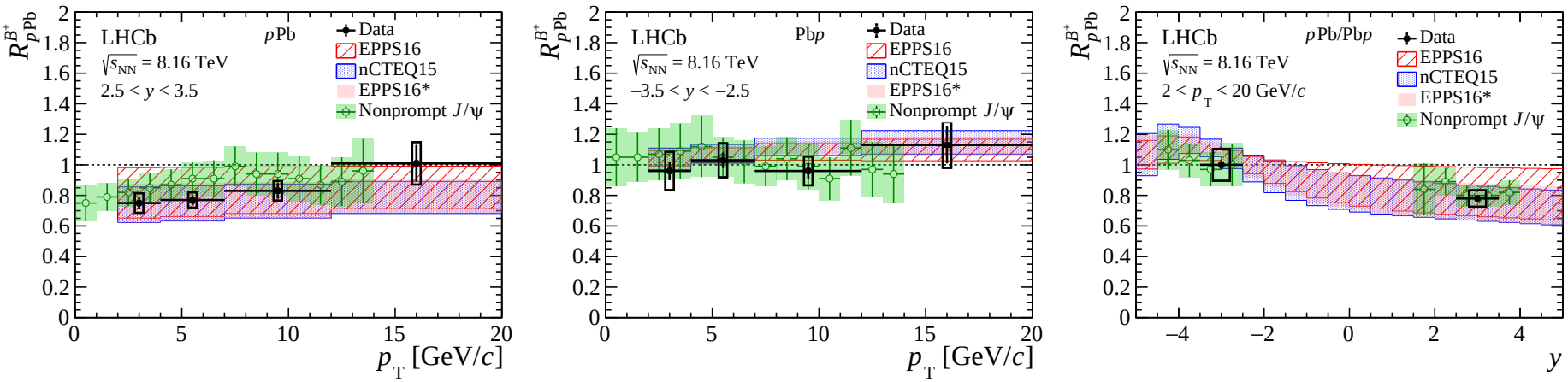


- B^0/B^+ ratio shows no significant p_T and y dependence within experimental uncertainties.
- $\Lambda_b^0/B^0 \approx 0.4$ similar to results in LHCb pp data.
- Λ_b^0/B^0 points show a decreasing trend as a function of p_T.

JHEP 08 (2014) 143

$R_{p\mathrm{Pb}}$ for B^+ meson

PRD 99, 052011 (2019)

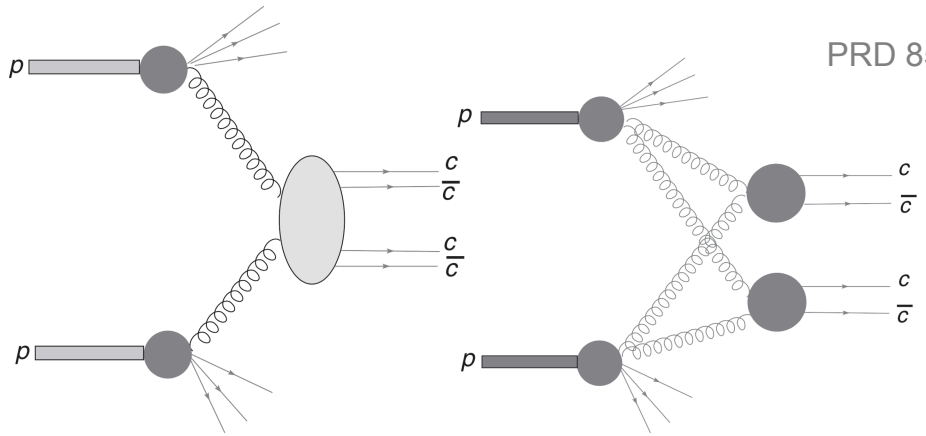


- σ_{pp} obtained from an interpolation of LHCb 7 TeV and 13 TeV results.
- Forward: significant suppression observed and $R_{p\mathrm{Pb}}$ increases with p_{T}.
- Backward : consistent with unity.
- The measurement in good agreement with calculations with nPDFs and J/ψ-from-b results.

JHEP 08 (2013) 117, JHEP 12 (2017) 026
JHEP 04 (2009) 065, EPJC 77 (2017) 163, CPC 198 (2016) 38

Prompt charm pair production at 8.16 TeV

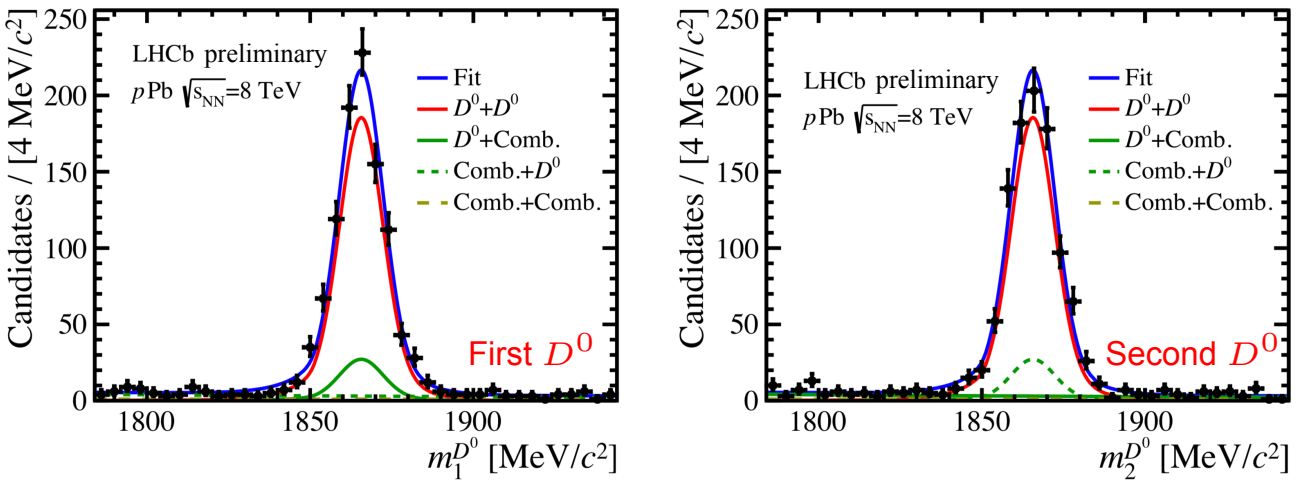
- The first measurement of charm pair production in pPb at 8.16 TeV.
- Simple parton scattering (SPS) vs double parton scattering(DPS)



PRD 85, 094034 (2012)

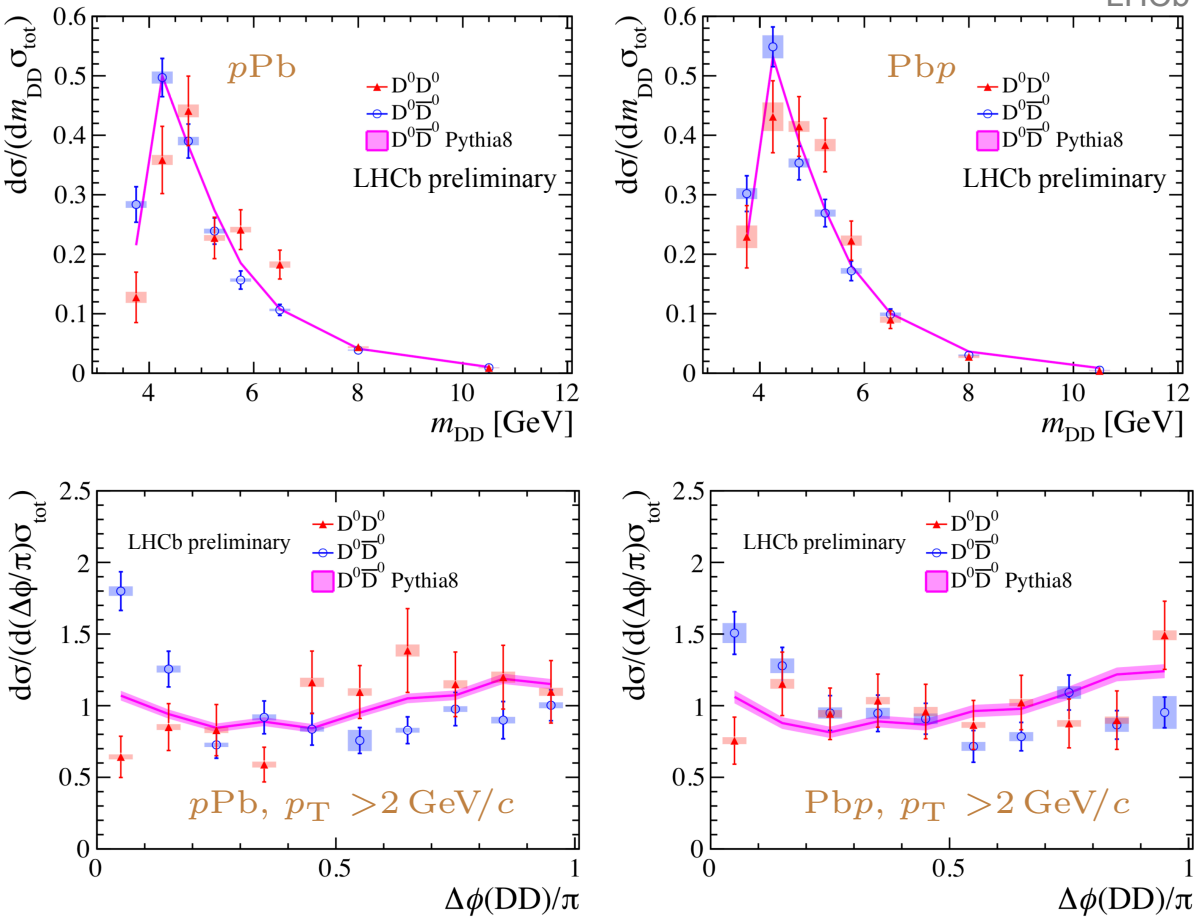
- Mass distributions of D^0-D^0 pair

LHCb-PAPER-2020-010



m_{DD} and $\Delta\phi(DD)$ distributions

LHCb-PAPER-2020-010



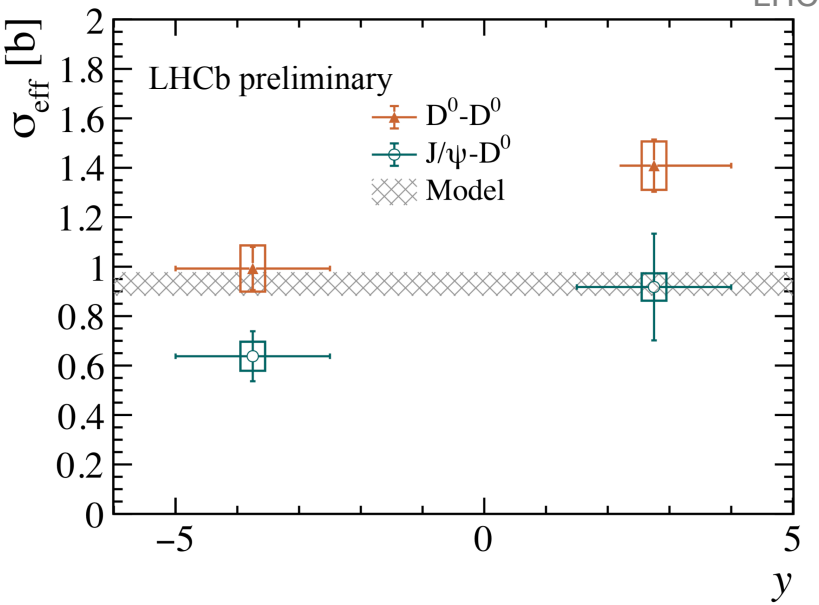
- D^0-D^0 vs D^0-$\overline{D}^0$ data: m_{DD} similar, different at near-side for $\Delta\phi$.
- D^0-$\overline{D}^0$ data vs simulation: in general agreement, a discrepancy at $\Delta\phi \sim 0$.

σ_{eff}

- Obtained using J/ψ-D^0 and like-sign D^0-D^0 results.

$$\sigma_{\text{eff}} = \frac{\sigma^A \sigma^B}{(1+\delta_{AB})\sigma^{AB}_{\text{DPS}}}$$

LHCb-PAPER-2020-010



- In agreement with the expectation of about 0.9b, suggesting DPS/SPS enhanced by a factor 3 in pPb compared to pp.
- σ_{eff} using J/ψ-D^0 smaller than D^0-D^0, similar to the case in pp data, either due to SPS contamination or DPS enhancement in J/ψ-D^0 production.
- σ_{eff} for pPb data higher than Pbp data, suggesting a suppression of DPS signal in pPb data compared to Pbp.

PLB 800 (2020) 135084, JHEP 06 (2017) 147

Summary and outlook

- LHCb has strong capabilities to study heavy flavor in heavy-ion collisions.
- Studied production of D^0, Λ_c^+, b-hadrons and charm pair
  - Prompt D^0 results at 5 TeV down to zero p_{T}:
    constrain nPDF models down to $x \sim 10^{-5}$.
  - Prompt Λ_c^+/D^0 cross-section ratios at 5 TeV:
    consistent with calculations with nPDF models.
  - Preliminary D^0 R_{FB} at 8.16 TeV:
    hint an increasing trend towards high p_{T}.
  - Measurements of b-hadrons using exclusive hadronic modes:
    observe a significant suppression compared to pp in forward region.
  - The first measurement of charm pair production in pPb at 8.16 TeV:
    confirm a DPS/SPS enhancement by 3 in pPb compared to pp and suggest a suppression of DPS in pPb data compared to Pbp.
- More measurements with high statistics in process:
  - D^+, D_s^+, Λ_c^+ (at 8.16 TeV), Ξ_c, correlations, ...

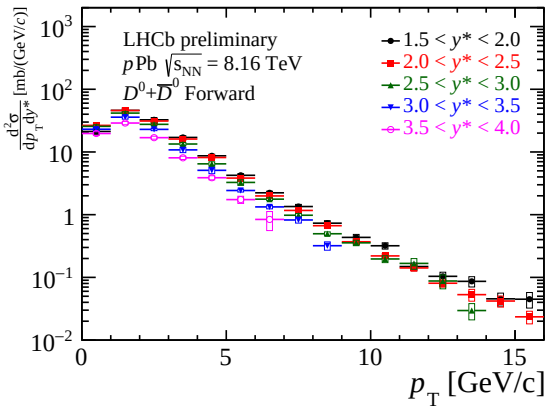
Thanks

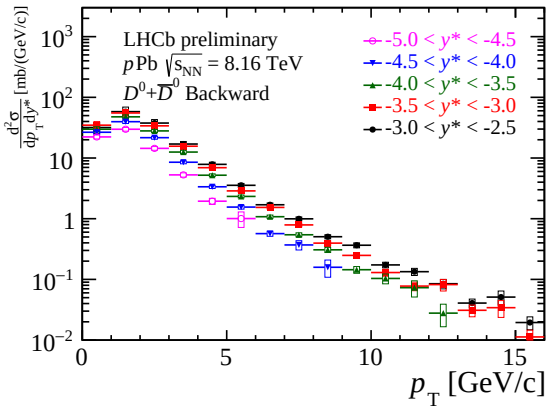
Backups

D^0 cross-sections at 8.16 TeV

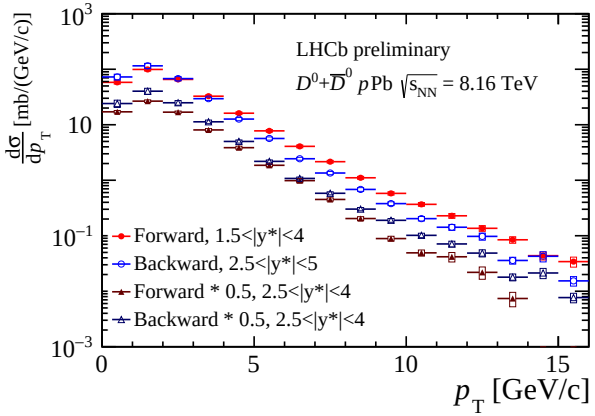
- Double-differential cross-sections:

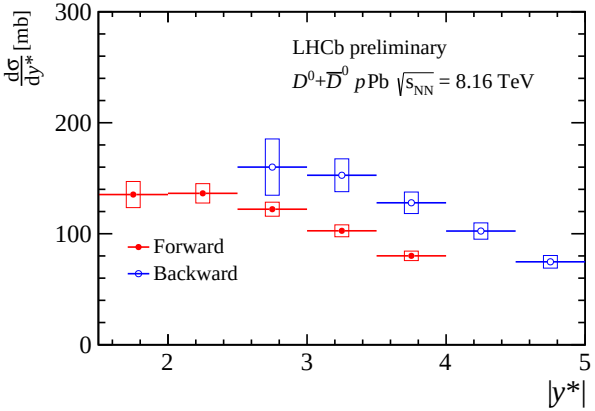
LHCb-CONF-2019-004





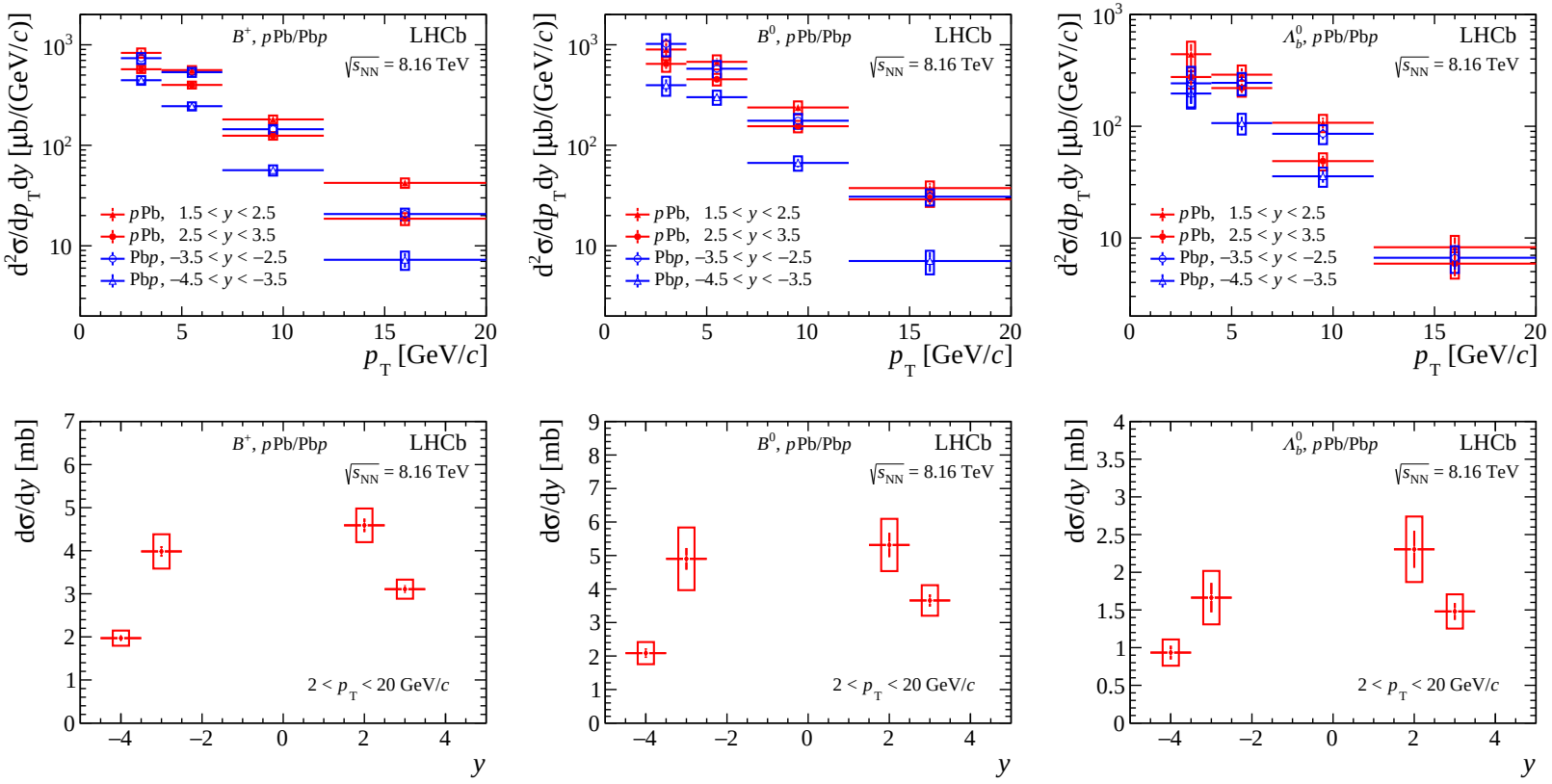
- One-dimensional cross-sections:





b-hadron cross-sections at 8.16 TeV

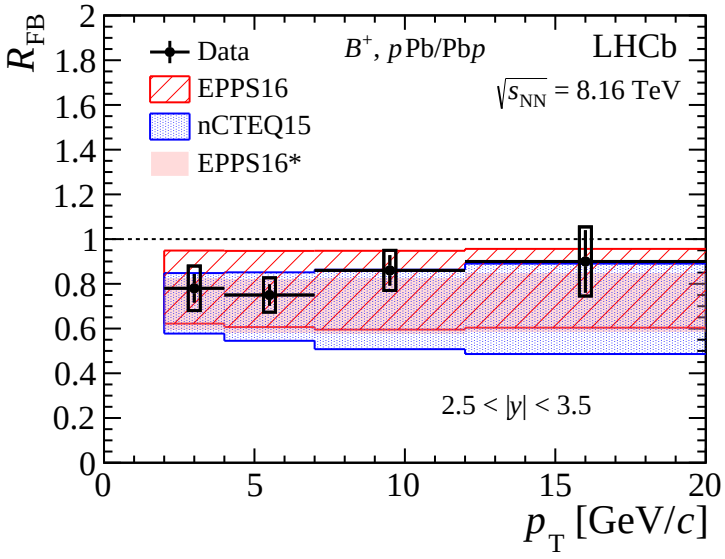
PRD 99, 052011 (2019)

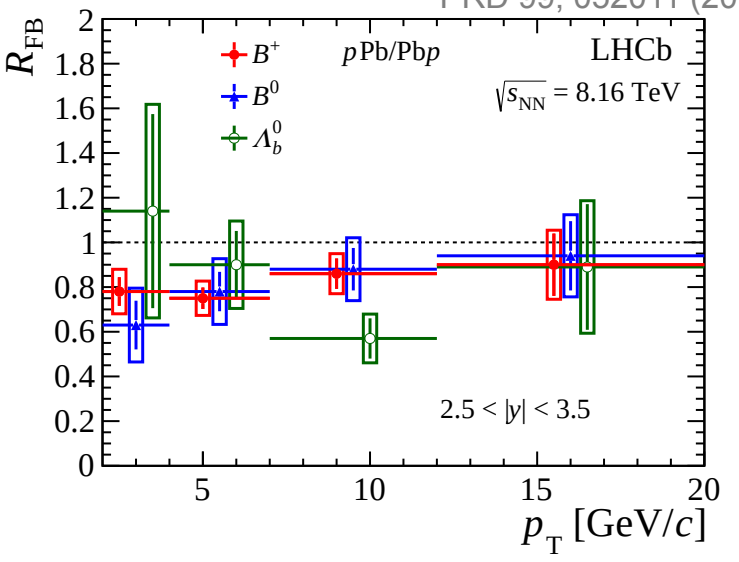


- B^+ cross-sections calculated as average between $J/\psi\, K^+$ and $\overline{D}^0\pi^+$ modes.
- B^+, B^0 and Λ_b^0 cross-sections show similar p_T and y distributions.

b-hadron R_{FB}

PRD 99, 052011 (2019)





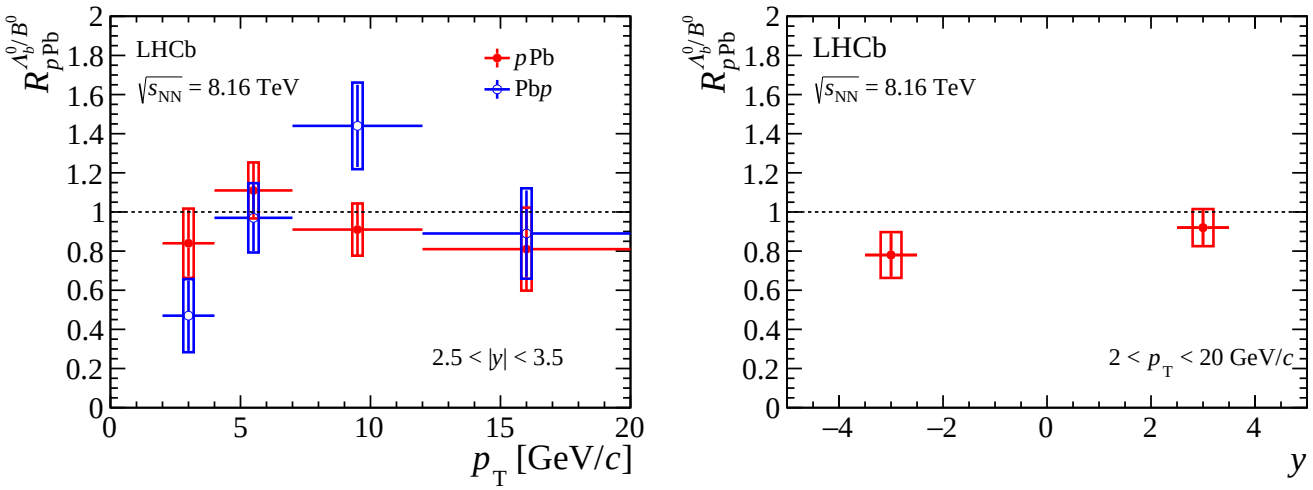
- A suppression of $\sim 25\%$ at positive rapidity is observed, without p_{T} dependence.
- The results are in good agreement with theories.
- The R_{FB} for B^+, B^0 and Λ_b^0 are compatible.

CPC 198 (2016) 23, JHEP 04 (2009) 065, EPJC 77 (2017) 163

Ratio of $R_{p\mathrm{Pb}}$ between Λ_b^0 and B^0

$$R_{p\mathrm{Pb}}^{\Lambda_c^+/D^0} = R_{p\mathrm{Pb}}^{\Lambda_c^+}/R_{p\mathrm{Pb}}^{B^0}$$

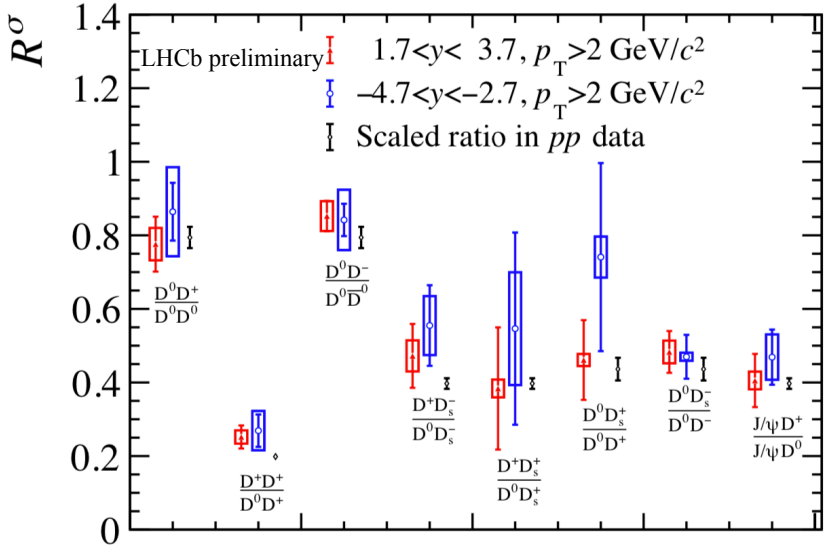
PRD 99, 052011 (2019)

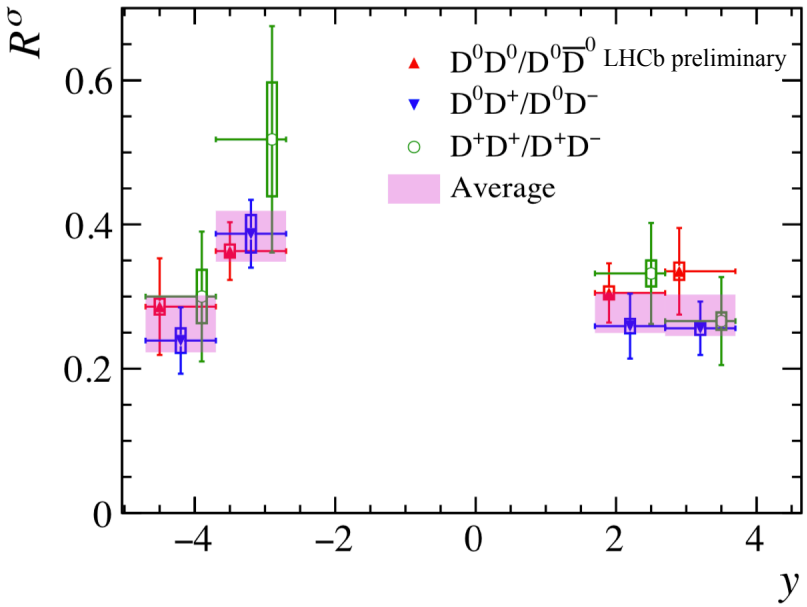


- Positive rapidity: consistent with unity in all kinematic bins $\Rightarrow$ b-quark fragmentation function in pPb similar to pp.
- Negative rapidity: hint of more suppression for Λ_b^0 compare with B^0. More data required to check whether there are different nuclear effects in beauty mesons and baryons.

Charm pair cross-section ratios

LHCb-PAPER-2020-010





- Charm hadronization not strongly modified in pPb compared to pp.
- Like-sign produced enhanced in pPb compared to pp, more enhanced for backward.

JHEP 06 141 (2012)