Measurements of charmed mesons and baryons in pp and p-Pb collisions with ALICE at the LHC

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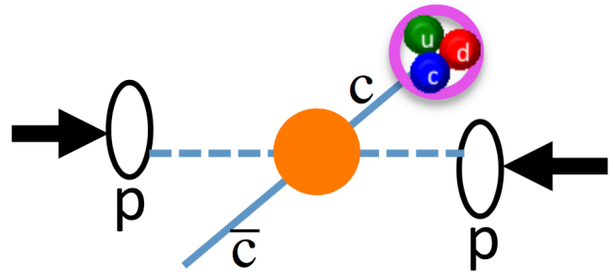
On behalf of the ALICE Collaboration

Heavy quark production at the LHC

- Heavy quarks (charm & beauty) produced in hard parton scattering processes (in the early stage of collision)
- Charmed hadrons (D mesons, Λ_c, Ξ_c baryons), measured in **pp collisions:**
  - useful test of perturbative QCD calculations
  - reference for p-Pb and Pb-Pb measurements
  - baryon production ➔ insight on charm quark hadronisation mechanism



Heavy quark production at the LHC

[1] (Phys.Rev.D36 (1987) 2019; Nucl.Phys.Proc.Suppl.214 (2011) 181–184)

- Heavy quarks (charm & beauty) produced in hard parton scattering processes (in the early stage of collision)
- Charmed hadrons (D mesons, Λ_c, Ξ_c baryons), measured in **pp collisions:**
  - useful test of perturbative QCD calculations
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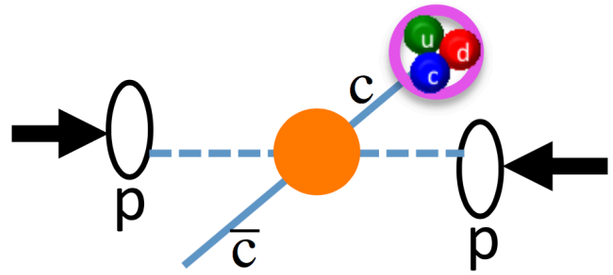
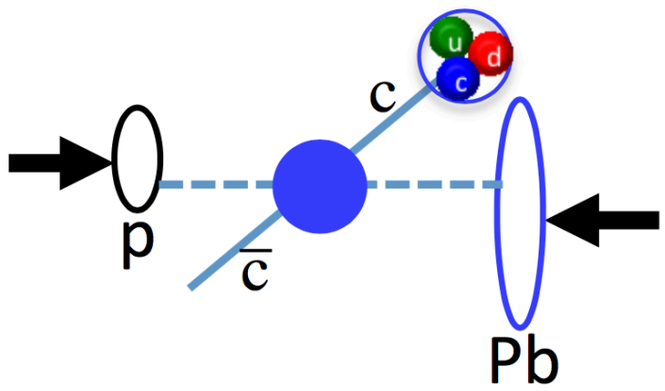
  - baryon production → insight on charm quark hadronisation mechanism



- In **p-Pb collisions:**
  - study the cold nuclear matter effects:
    - energy loss in the initial and final state of the collisions
    - k_T broadening [1]
    - shadowing
  - study possible collective effects in small systems



The ALICE detector

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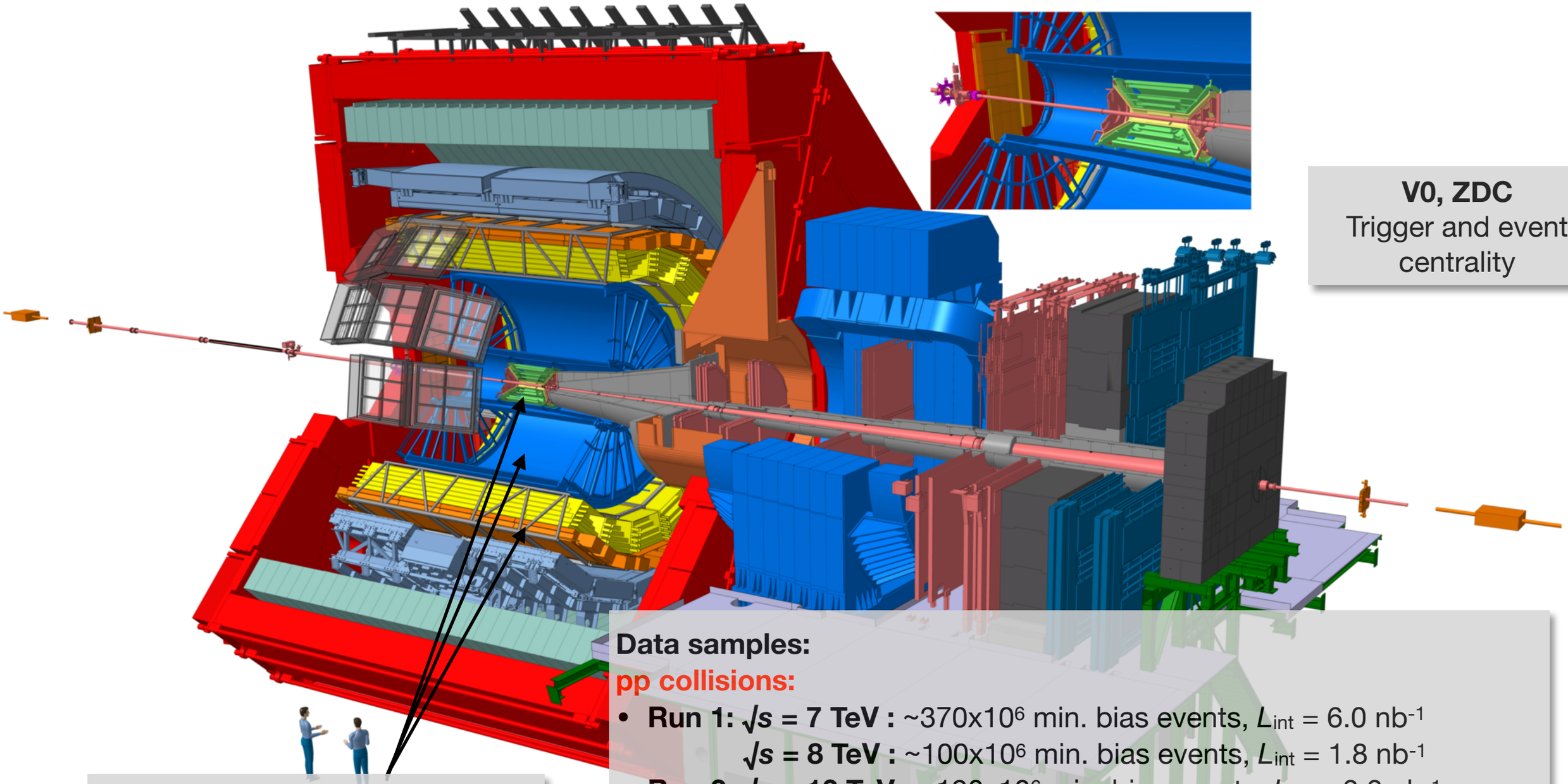


V0, ZDC
Trigger and event centrality

Inner Tracking System (ITS)
Time Projection Chamber (TPC)
Time Of Flight detector (TOF):
Vertexing, tracking and PID
$|\eta| < 0.9$

Data samples:

pp collisions:

- **Run 1:** $\sqrt{s}$ **= 7 TeV :** ~370x10^6 min. bias events, L_{int} = 6.0 nb^{-1}
  $\sqrt{s}$ **= 8 TeV :** ~100x10^6 min. bias events, L_{int} = 1.8 nb^{-1}
- **Run 2:** $\sqrt{s}$ **= 13 TeV :** ~190x10^6 min. bias events, L_{int} = 3.3 nb^{-1}
  $\sqrt{s}$ **= 5.02 TeV (2017):** ~990x10^6 min. bias events, L_{int} = 19 nb^{-1}

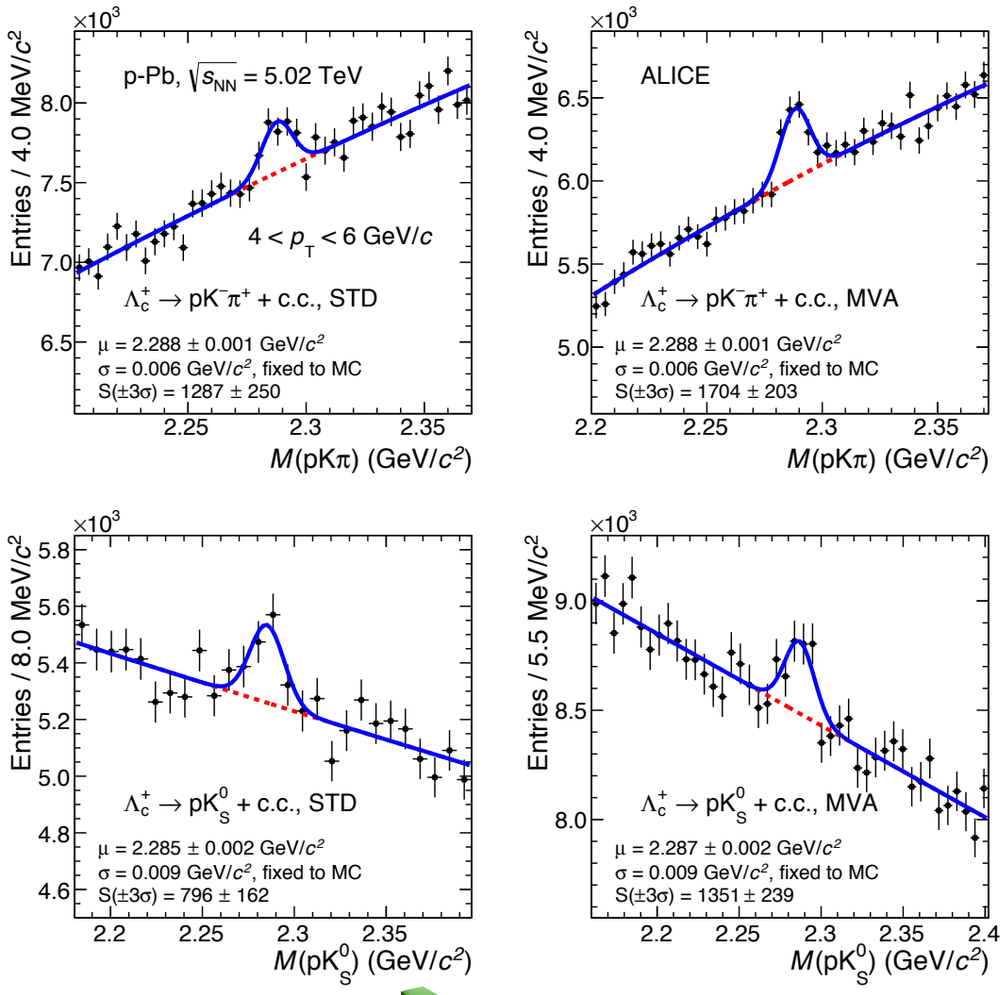
p-Pb collisions $\sqrt{s}$ **= 5.02 TeV:**

- **Run 1:** ~100x10^6 min. bias events, L_{int} = 48.6 μb^{-1}
- **Run 2:** ~600x10^6 min. bias events, L_{int} = 292 μb^{-1}

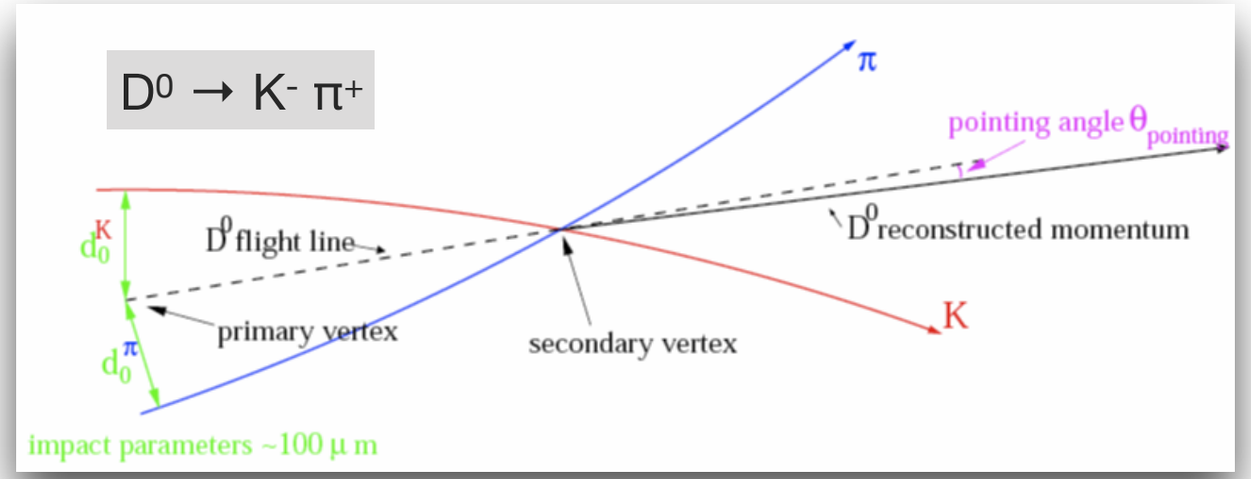
Hadronic decay reconstruction

$D^0 \rightarrow K^- \pi^+$	BR ~ 3.93%	$c\tau$ ~ 123 μm
$D^+ \rightarrow K^- \pi^+ \pi^+$	BR ~ 9.46%	$c\tau$ ~ 312 μm
$D^{*+} \rightarrow D^0 (K^- \pi^+) \pi^+$	BR ~ 2.66%	-
$D_s^+ \rightarrow \phi (K^- K^+) \pi^+$	BR ~ 2.27%	$c\tau$ ~ 150 μm
$\Lambda_c^+ \rightarrow p K^- \pi^+$	BR ~ 6.35%	$c\tau$ ~ 60 μm
$\Lambda_c^+ \rightarrow p K_s^0$	BR ~ 1.58%	"

- Decay topology via secondary vertex reconstruction and PID to reduce combinatorial background
  - Λ_c^+ in p-Pb : apply multivariate approach (BDTs)
- Invariant mass analysis
- Using FONLL-based method to subtract feed-down from b-hadron decays



arXiv:1712.09581



Semileptonic decay reconstruction

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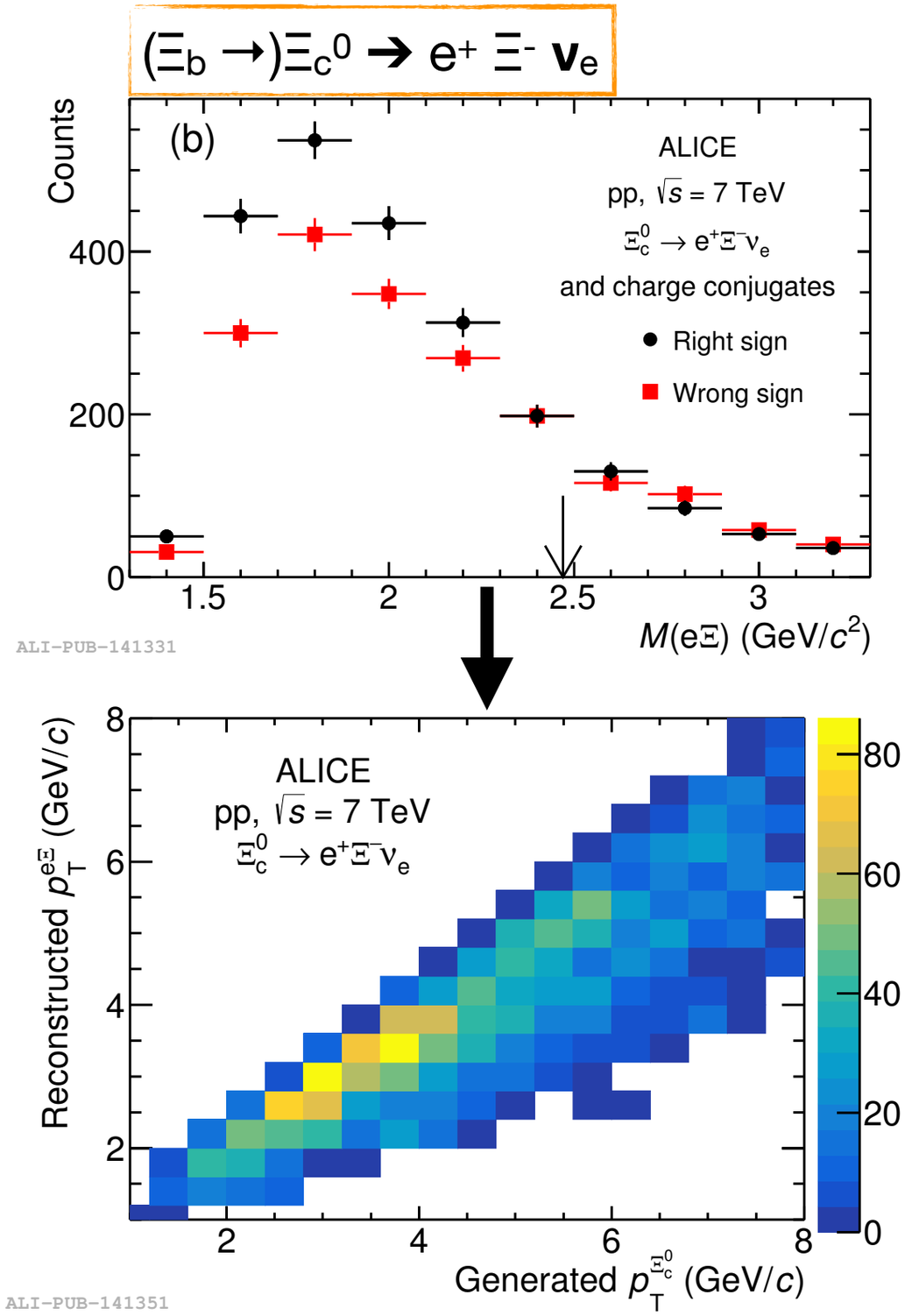
$\Lambda_c^+ \rightarrow e^+ \Lambda \nu_e$ BR ~ 3.6%

$\Xi_c^0 \rightarrow e^+ \Xi^- \nu_e$ BR unkown

- PID is used to reduce combinatorial background
- Wrong-sign $e^-\Lambda$ ($e^- \Xi^-$) pairs subtracted from right-sign spectra $e^+\Lambda$ ($e^+ \Xi^-$)
- Correct for Λ_b^0 and Ξ_b^0 ($\Xi_c^{0,+}$) in wrong-sign (right-sign) spectra
- Unfold $e^+\Lambda$ ($e^+ \Xi^-$) p_T spectra to obtain Λ_c^+ (Ξ_c^0) spectra
- Subtraction of feed-down from Λ_b^0 decay (Λ_c^+ measurement only)



Phys. Lett. B 781 (2018) 8-19

D-meson cross sections

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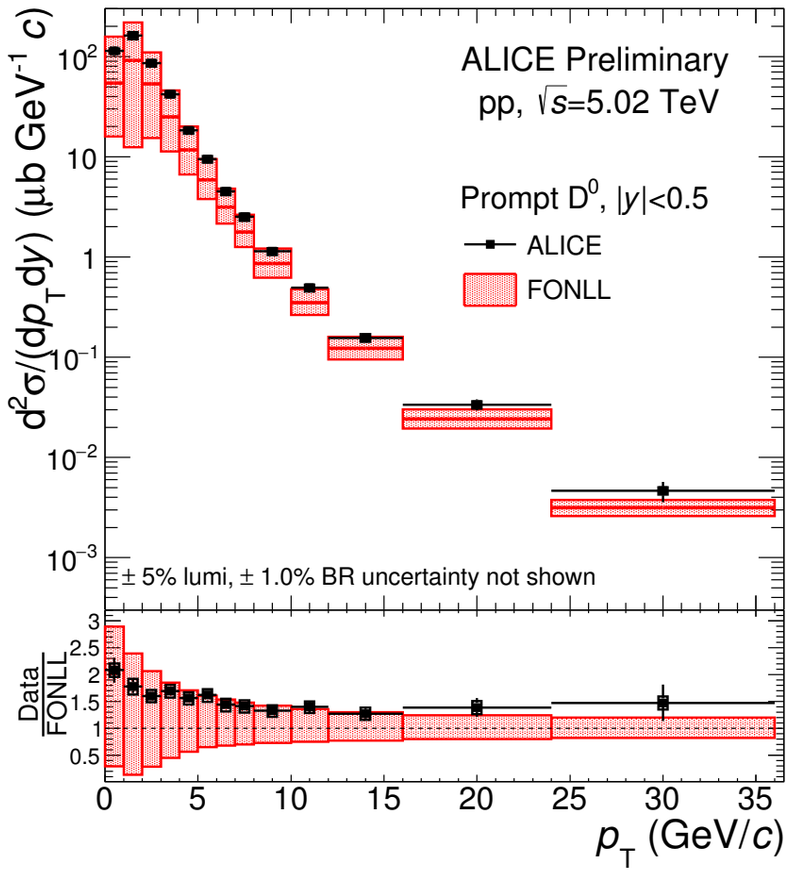
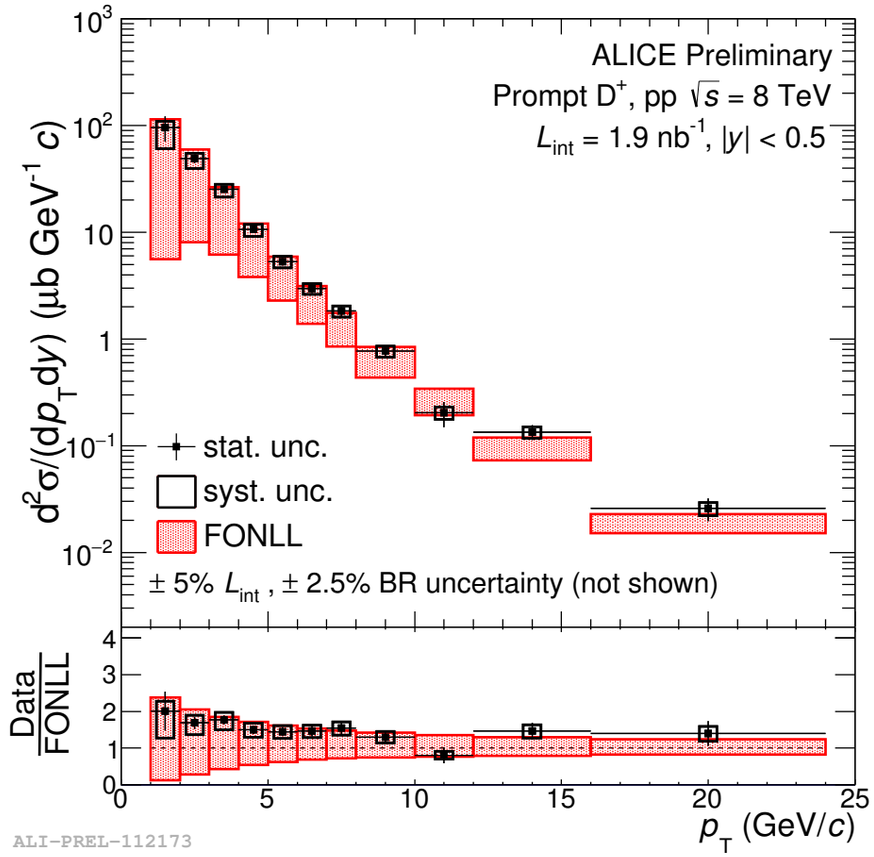
e.g.:

D^0 5 TeV



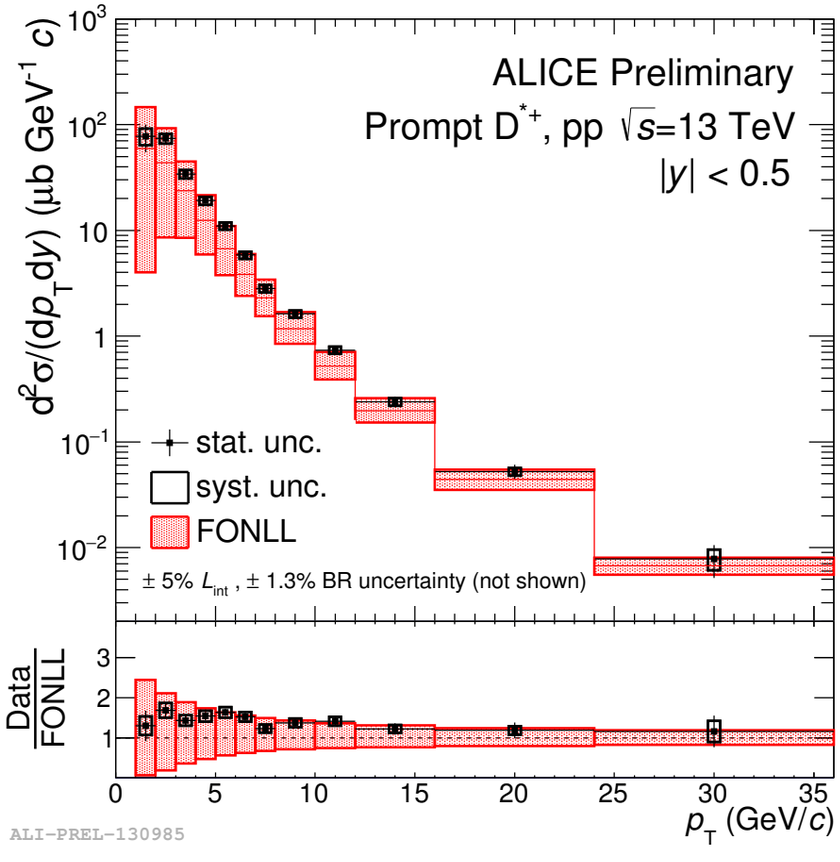
ALI-PREL-151360

D^+ 8 TeV



ALI-PREL-112173

D^{*+} 13 TeV



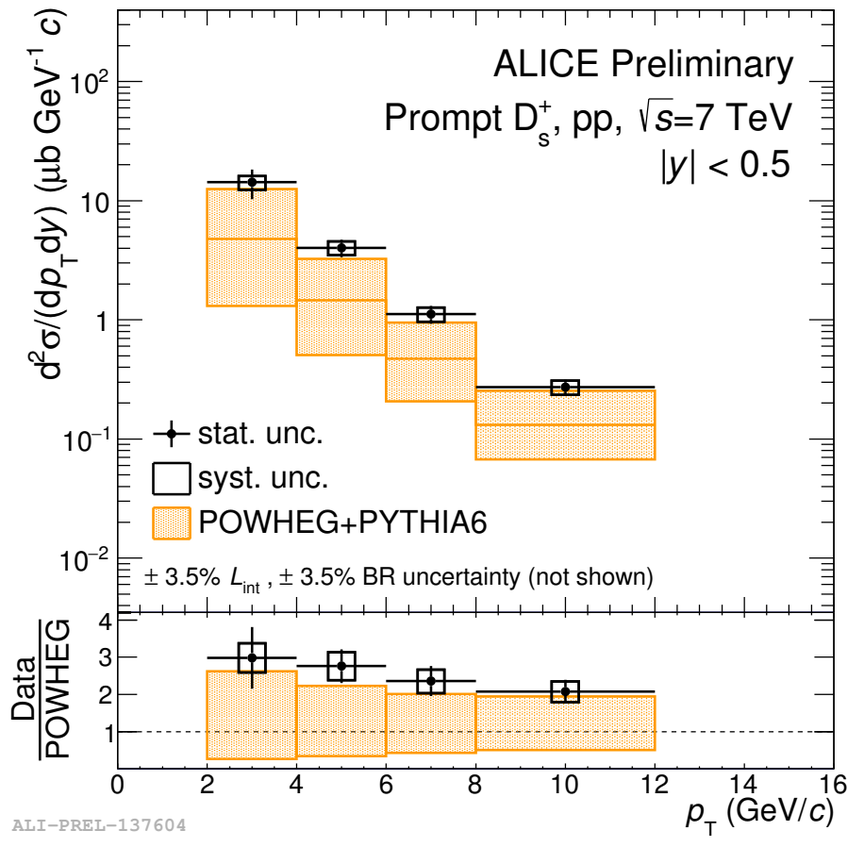
ALI-PREL-130985

- p_T-differential cross section of D mesons described within uncertainties by pQCD calculations (FONLL)

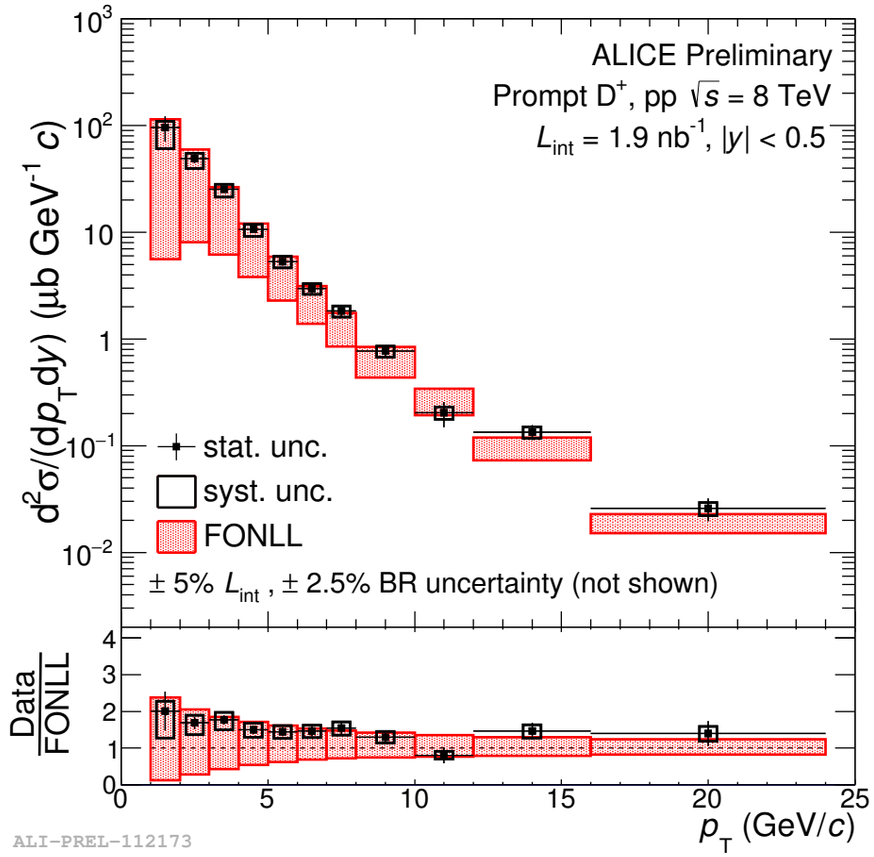
D-meson cross sections

e.g.:

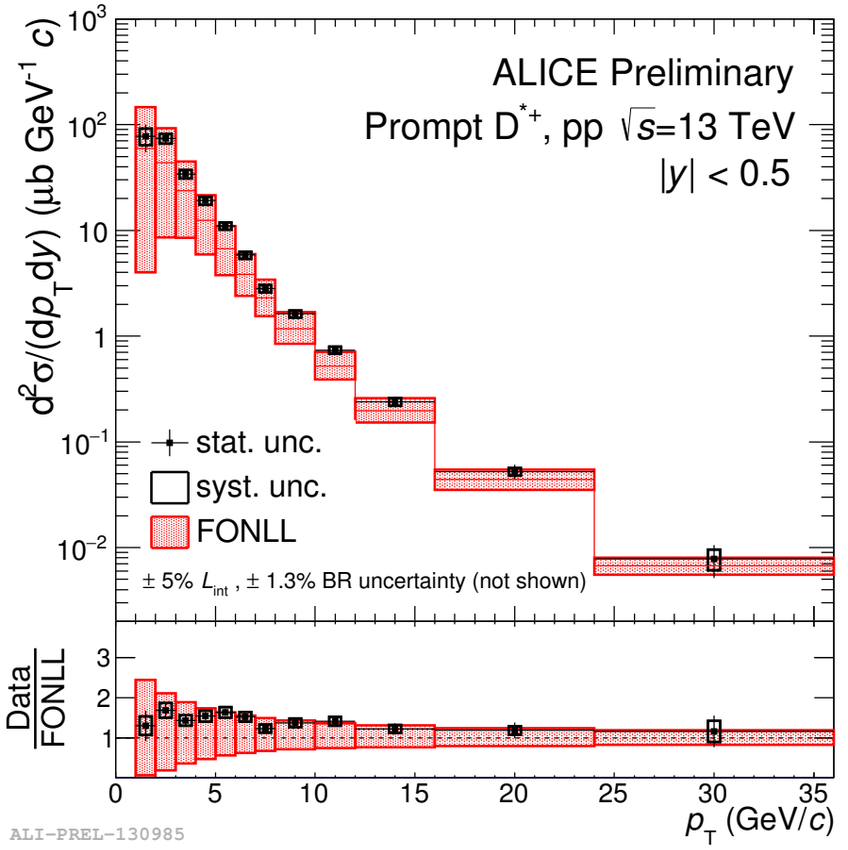
D_s^+ 7 TeV



D^+ 8 TeV



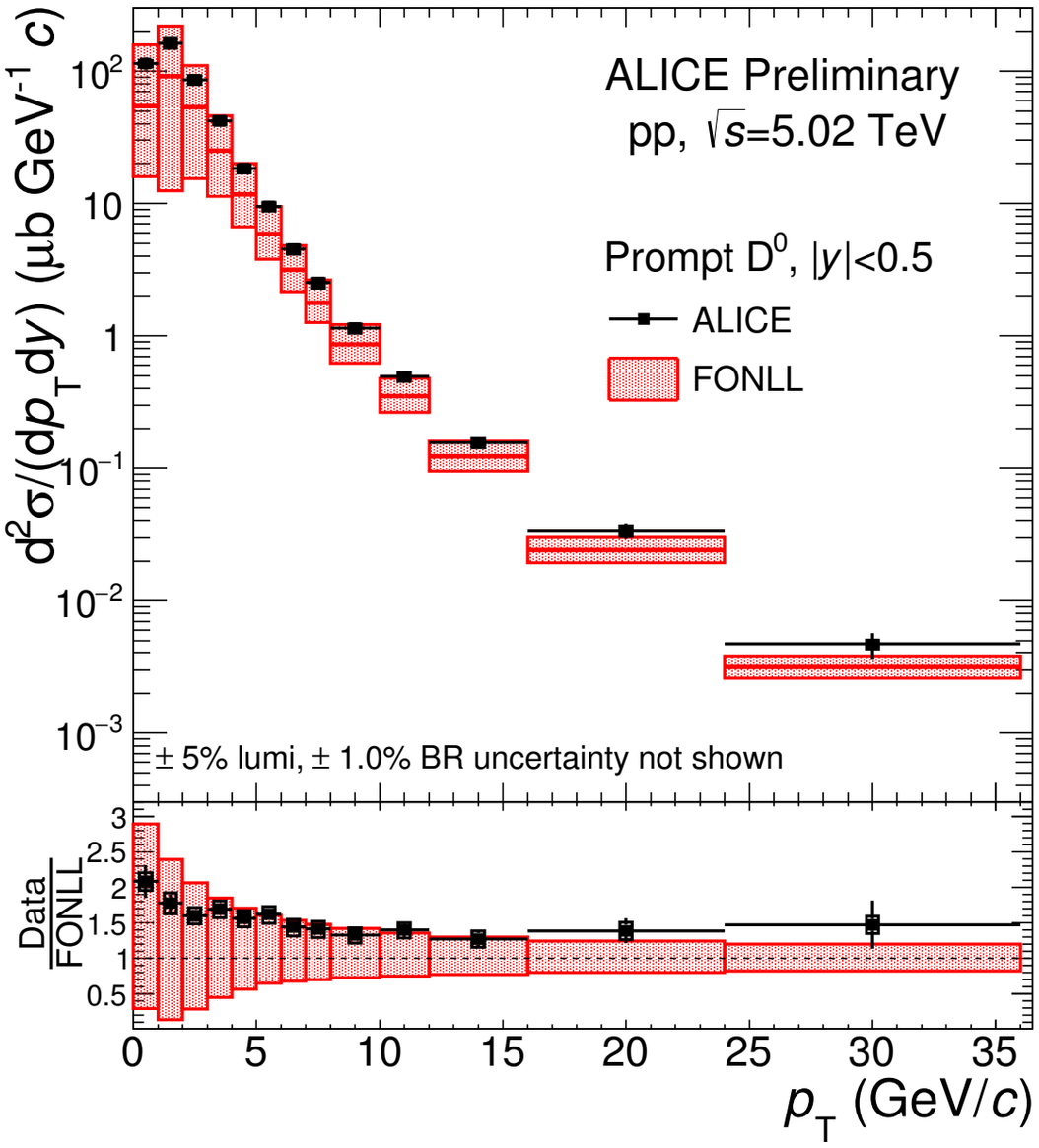
D^{*+} 13 TeV



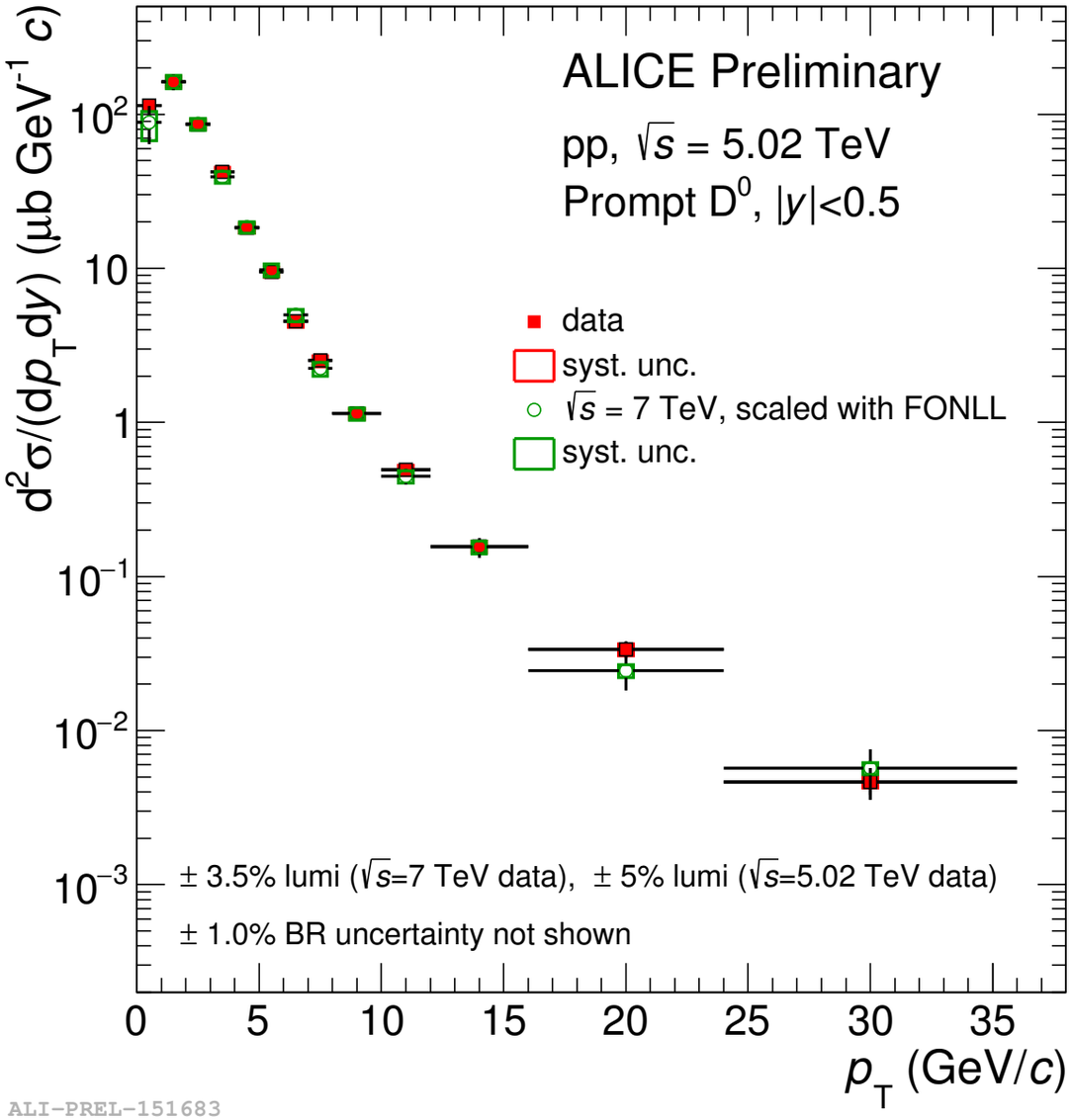
- p_T-differential cross section of D mesons described within uncertainties by pQCD calculations (FONLL)
- D_s^+ cross section reproduced by POWHEG+PYTHIA6 within uncertainties

D-meson cross sections

e.*g.*: **New reference for D mesons in pp collisions at 5 TeV**



ALI-PREL-151360



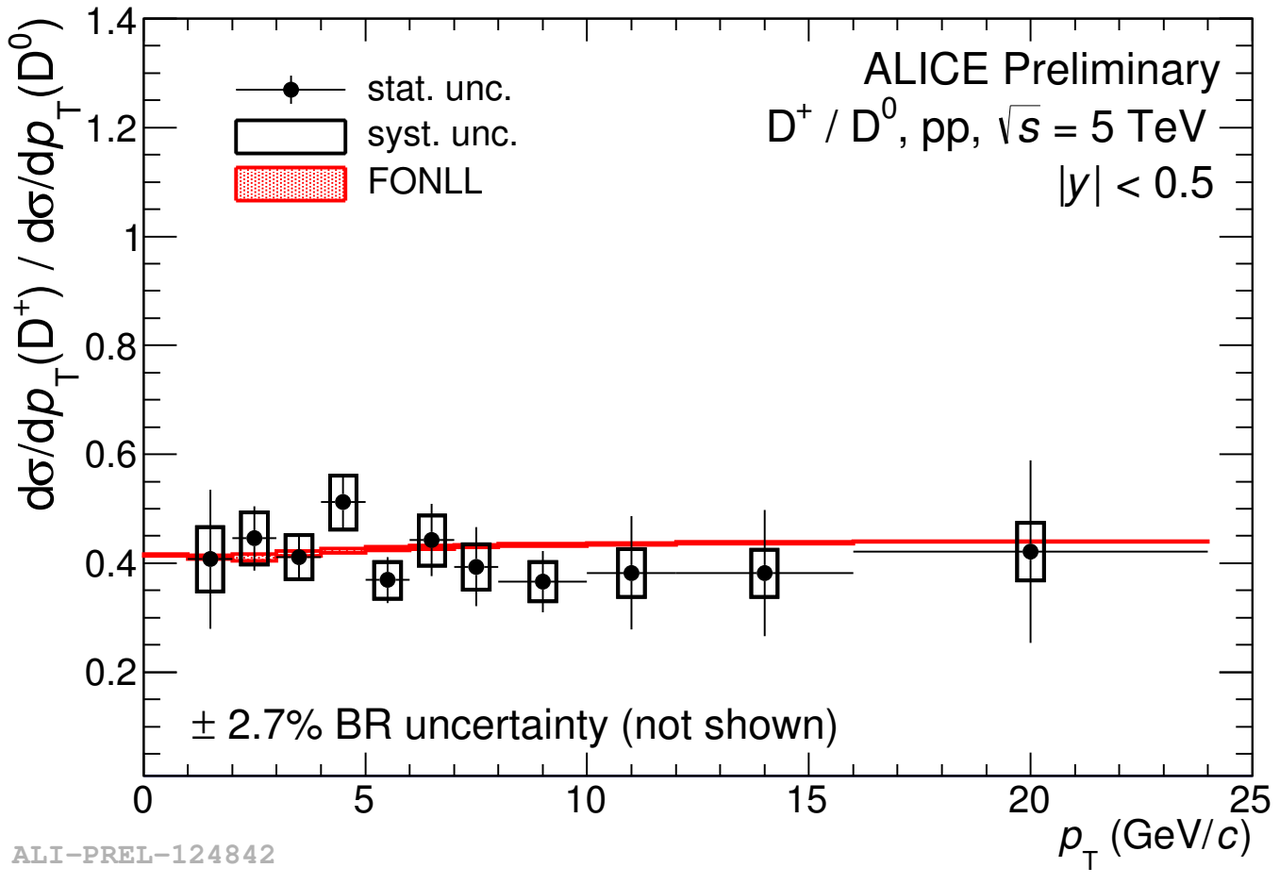
ALI-PREL-151683

- Improved measurement in terms of uncertainties reduction using minimum-bias data sample collected 2017
- New results compatible with scaled reference at 7 TeV

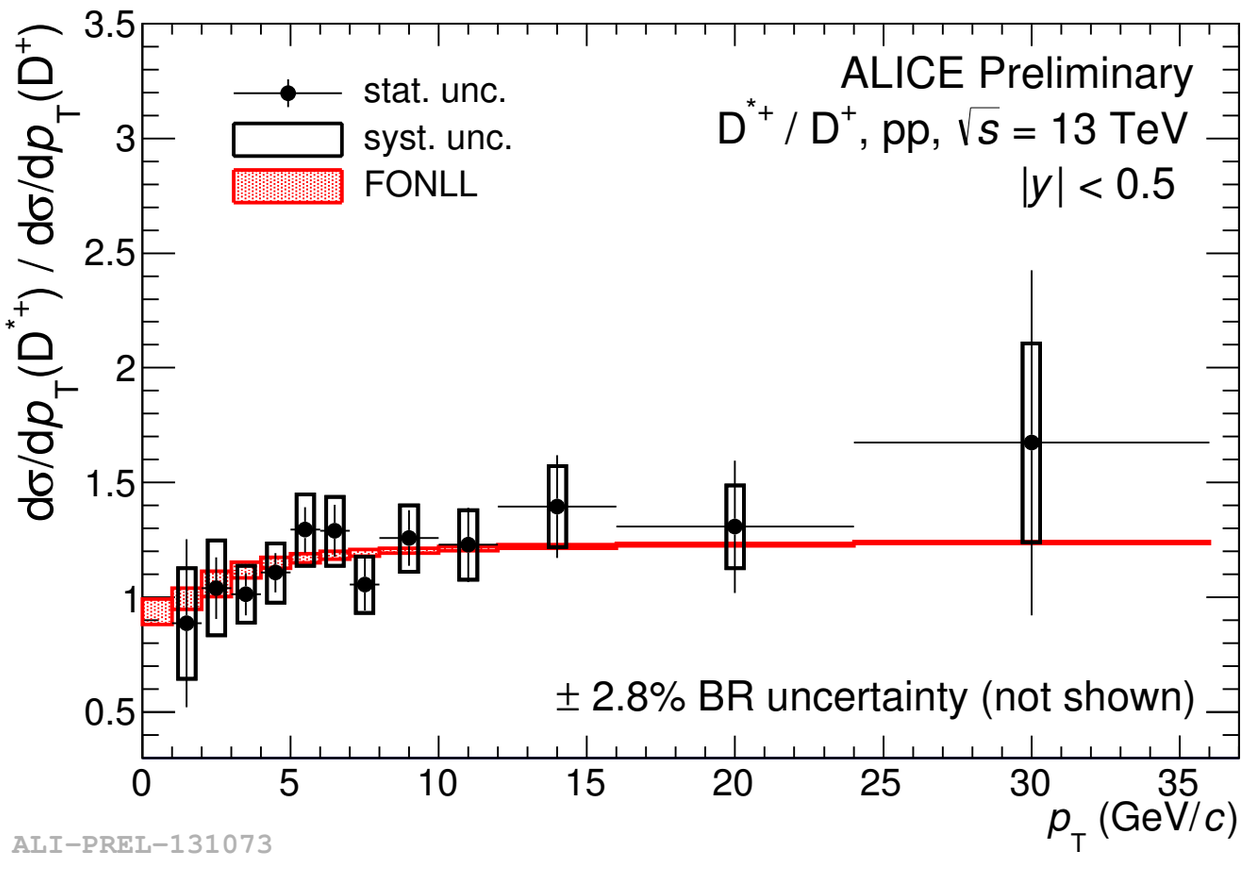
D-meson particle ratios

e.*g.*:

D^+/D^0 cross section at 5 TeV



D^{*+}/D^+ cross section: 13 TeV

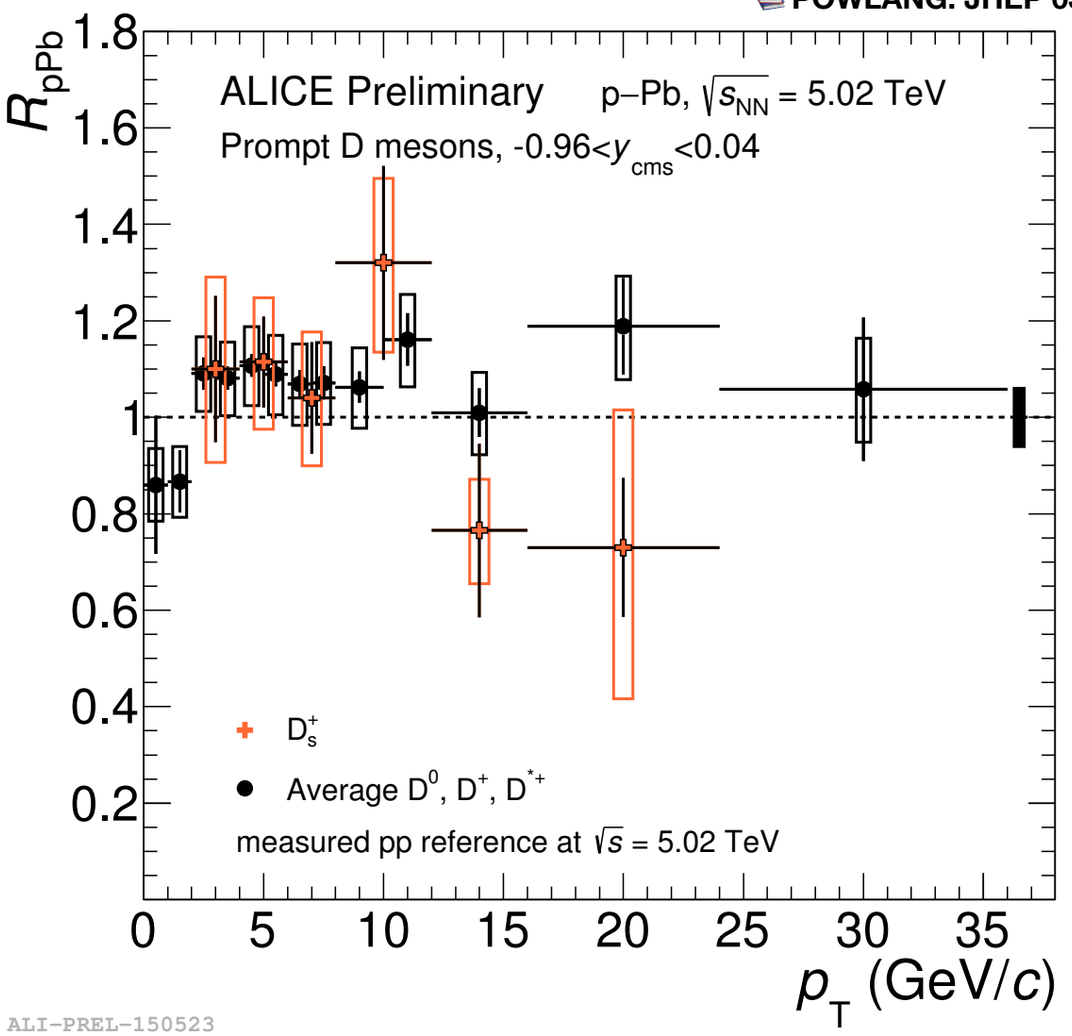


- D-meson species ratios well described by models: sensitive to fragmentation functions
- Results reproduced within uncertainties by FONLL theoretical predictions

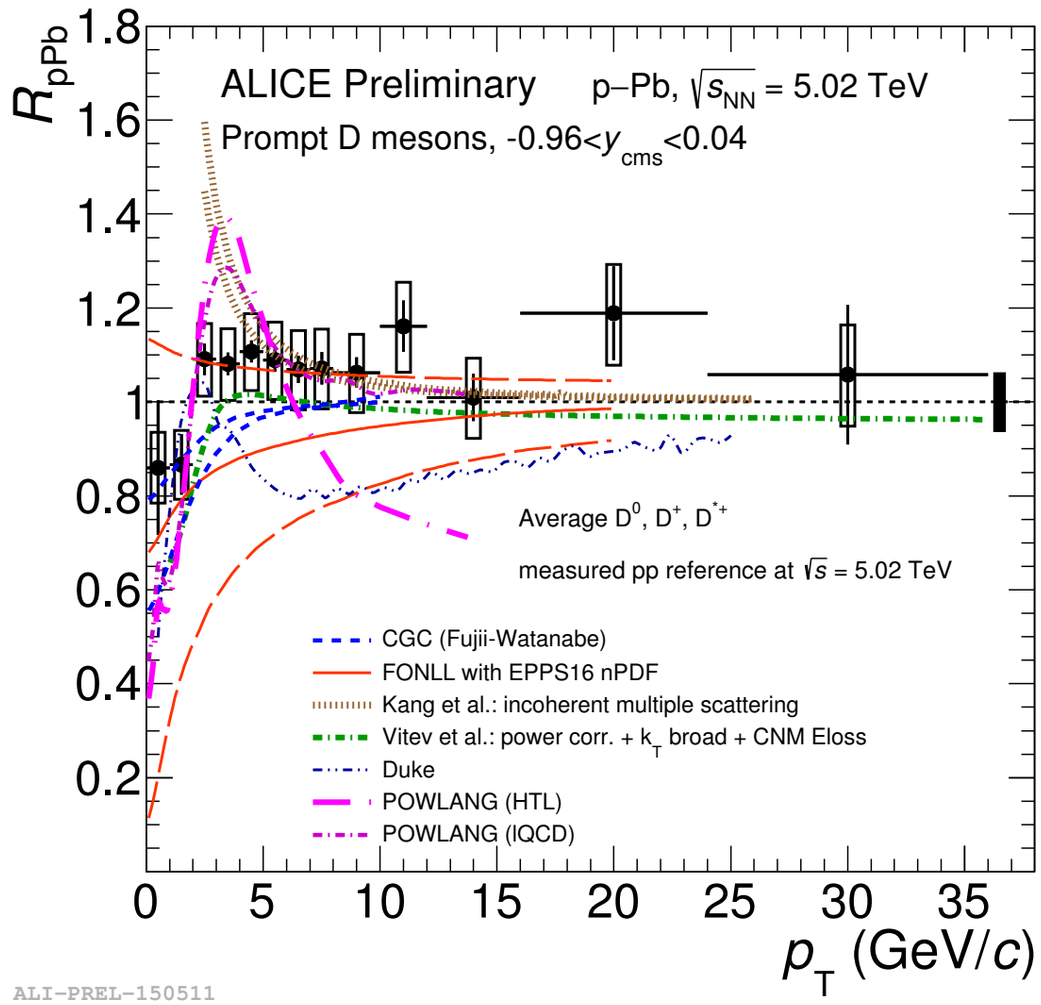
D-meson R_{pPb}

$$R_{\mathrm{pA}} = \frac{1}{A}\frac{\mathrm{d}\sigma_{\mathrm{pA}}/\mathrm{d}p_{\mathrm{T}}}{\mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

- CGC: arXiv:1706.06728
- FONLL (JHEP 1210 (2012) 137, arXiv:1205.6344) with EPPS16 nPDFs (Eur. Phys. J. C77 no. 3, (2017) 163, arXiv:1612.05741)
- Vitev et al: Phys.Rev. C80 (2009) 054902, arXiv:0904.0032.
- Kang et al.: Phys. Lett. B740 (2015) 23–29, arXiv:1409.2494.
- Duke: Nucl. xPart. Phys. Proc. 276-278 (2016) 225–228, arXiv:1510.07520.
- POWLANG: JHEP 03 (2016) 123, arXiv:1512.05186.



ALI-PREL-150523



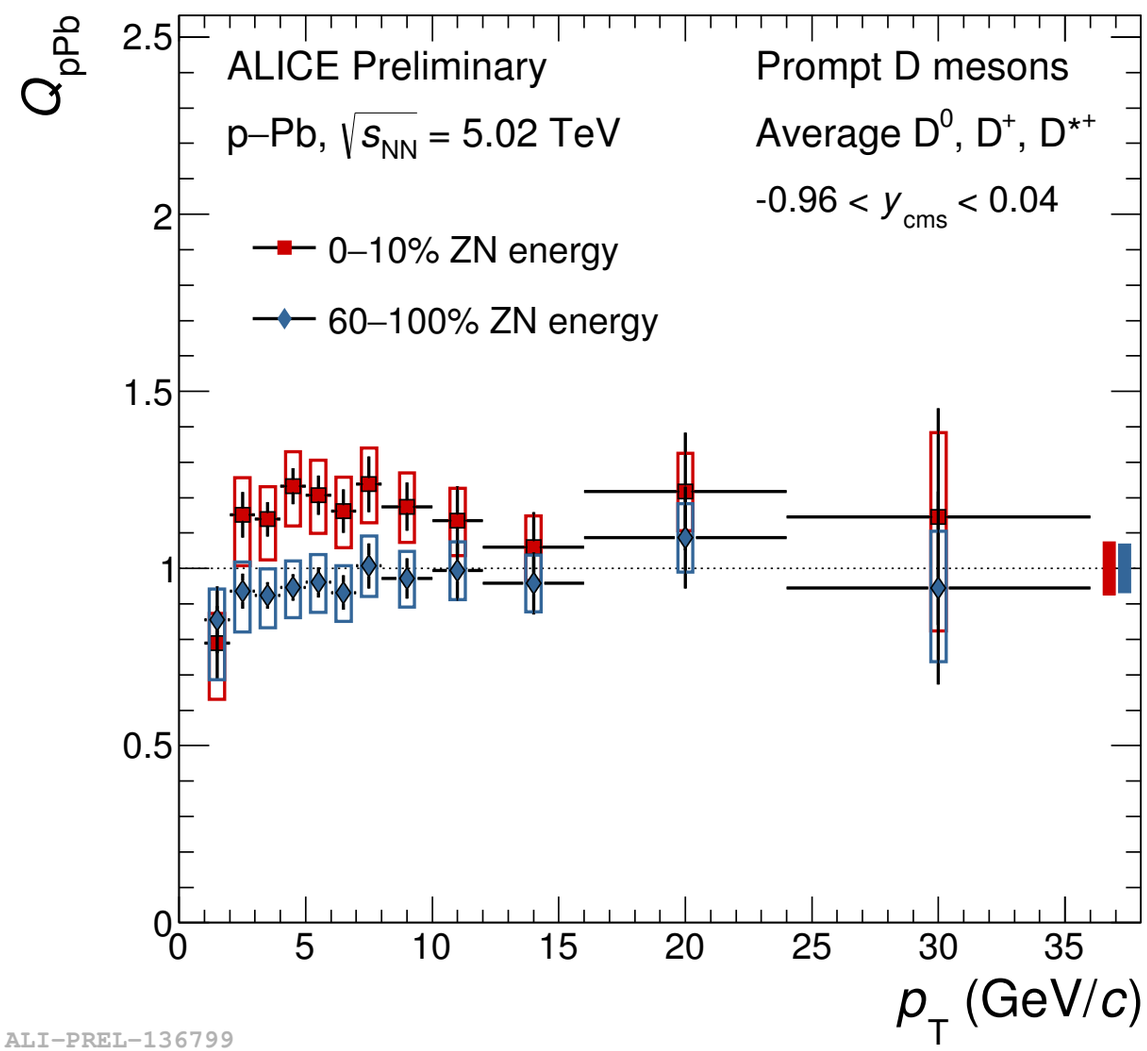
ALI-PREL-150511

- D_s^+-meson R_{pPb} compatible with non-strange D-meson one, both compatible with unity
- Provide stringent constraints to the model predictions

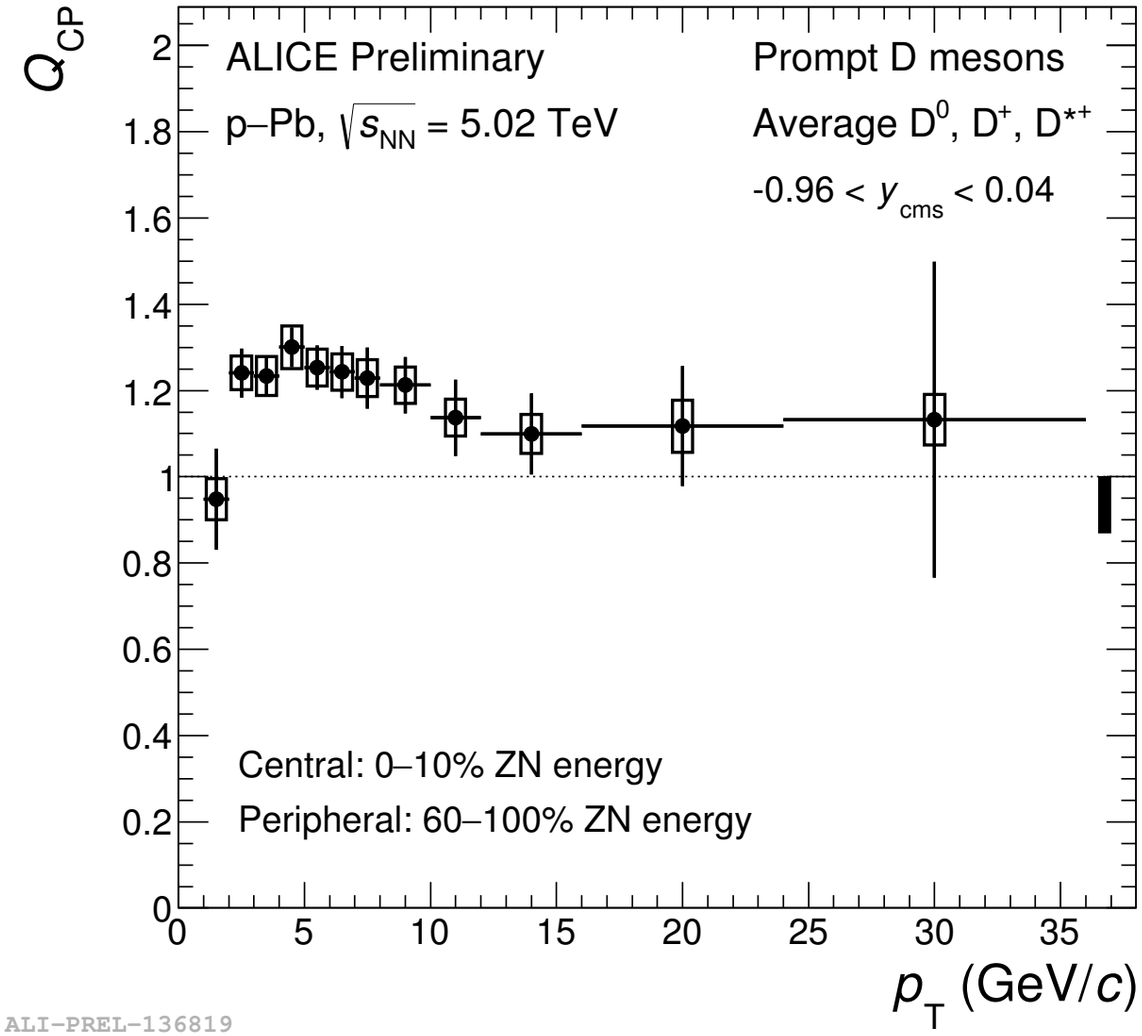
D-meson Q_{pPb}

$$Q_{\mathrm{pPb}}^{mult}(p_{\mathrm{T}}) = \frac{1}{\left\langle T_{\mathrm{pPb}}^{mult} \right\rangle} \frac{\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}}}{\mathrm{d}\sigma_{\mathrm{pp}} / \mathrm{d}p_{\mathrm{T}}}$$

$$Q_{\mathrm{CP}}(p_{\mathrm{T}}) = \frac{\left\langle T_{\mathrm{pPb}}^{60-100} \right\rangle}{\left\langle T_{\mathrm{pPb}}^{0-10} \right\rangle} \frac{(\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}})_{\mathrm{pPb}}^{0-10}}{(\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}})_{\mathrm{pPb}}^{60-100}}$$



ALI-PREL-136799



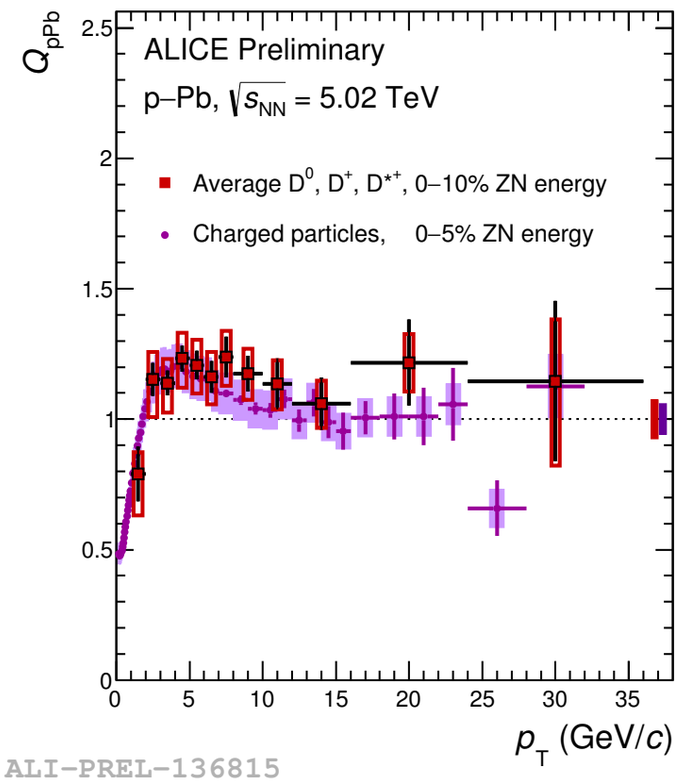
ALI-PREL-136819

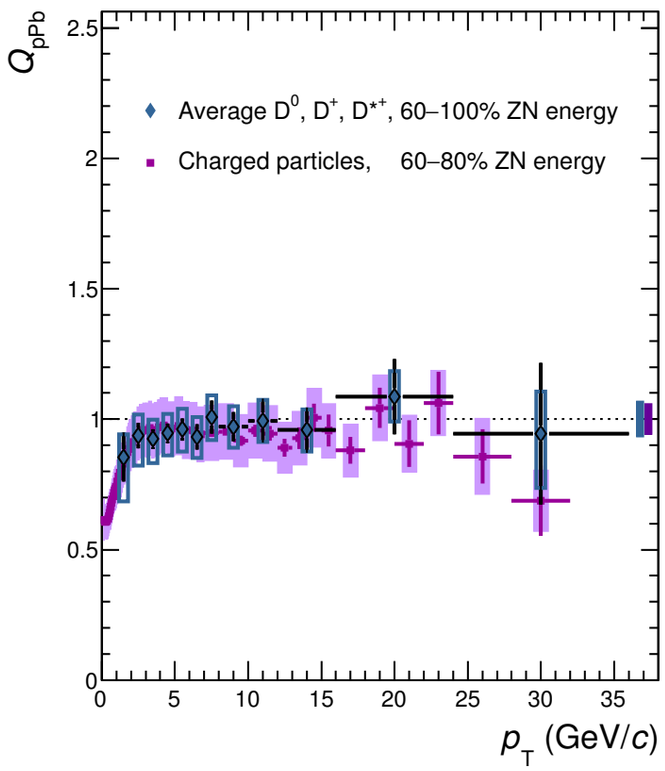
- Q_{pPb} consistent with unity in both centrality ranges
- Hint of $Q_{\mathrm{CP}} > 1$ in $3 < p_{\mathrm{T}} < 8$ GeV/c, 1.5σ effect

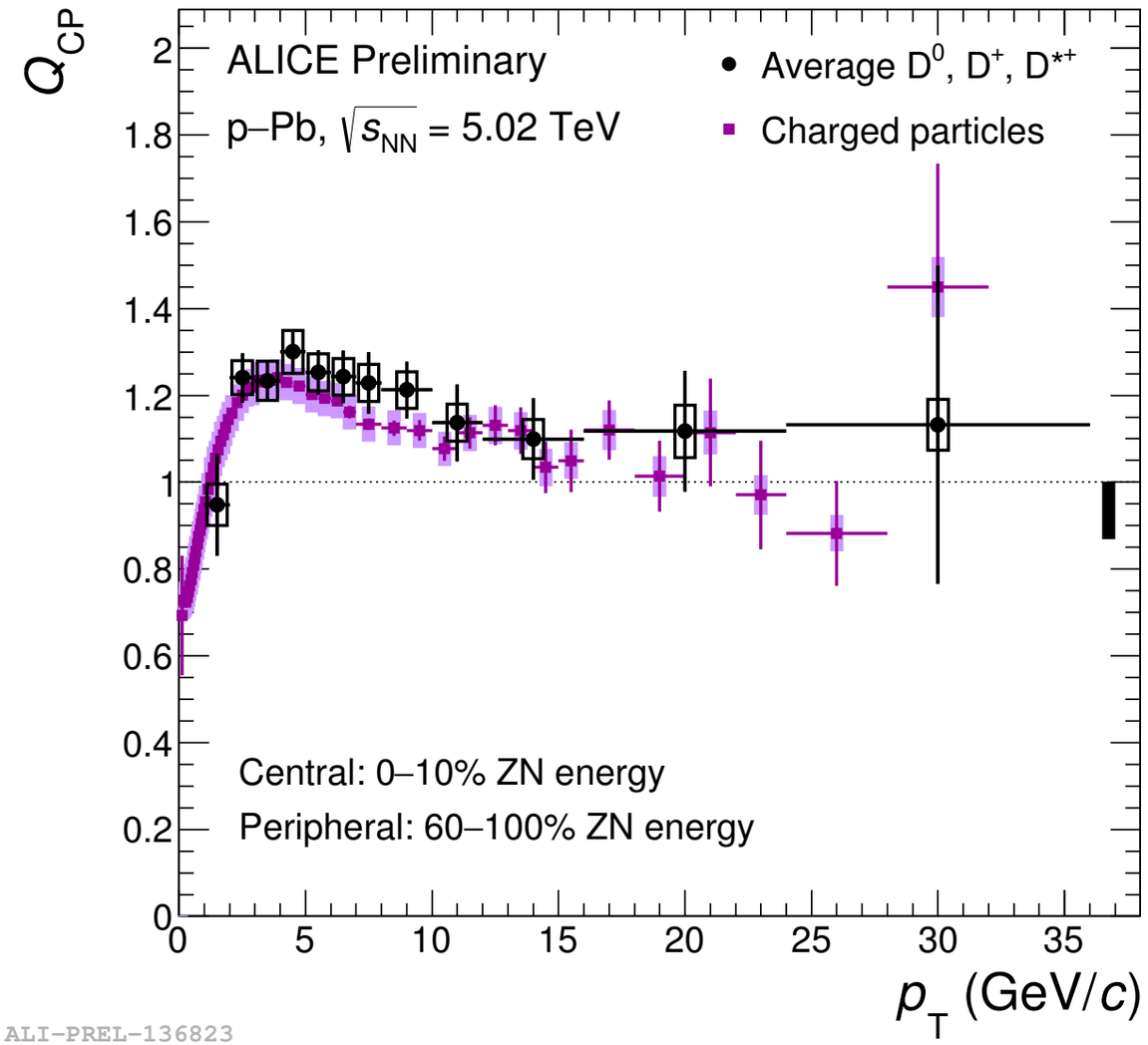
D-meson Q_{pPb}

$$Q_{\mathrm{pPb}}^{mult}(p_{\mathrm{T}}) = \frac{1}{\left\langle T_{\mathrm{pPb}}^{mult} \right\rangle} \frac{\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}}}{\mathrm{d}\sigma_{\mathrm{pp}} / \mathrm{d}p_{\mathrm{T}}}$$

$$Q_{\mathrm{CP}}(p_{\mathrm{T}}) = \frac{\left\langle T_{\mathrm{pPb}}^{60-100} \right\rangle}{\left\langle T_{\mathrm{pPb}}^{0-10} \right\rangle} \frac{(\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}})_{\mathrm{pPb}}^{0-10}}{(\mathrm{d}N_{\mathrm{pPb}} / \mathrm{d}p_{\mathrm{T}})_{\mathrm{pPb}}^{60-100}}$$

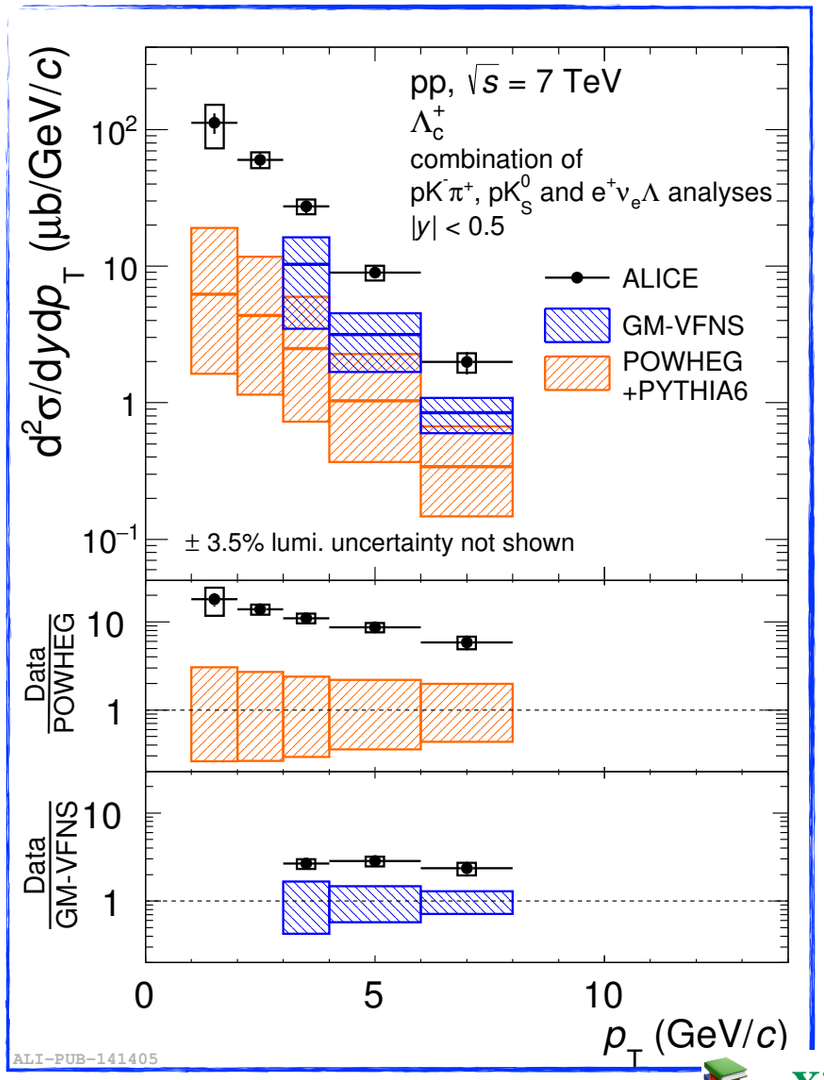


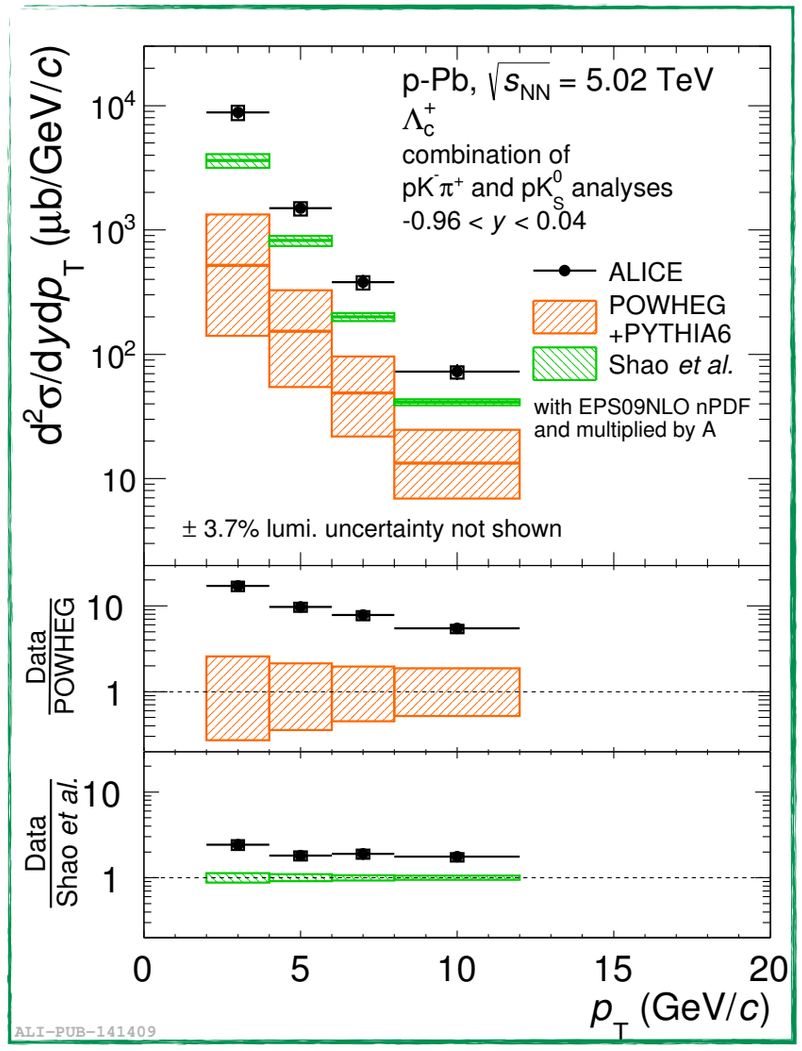


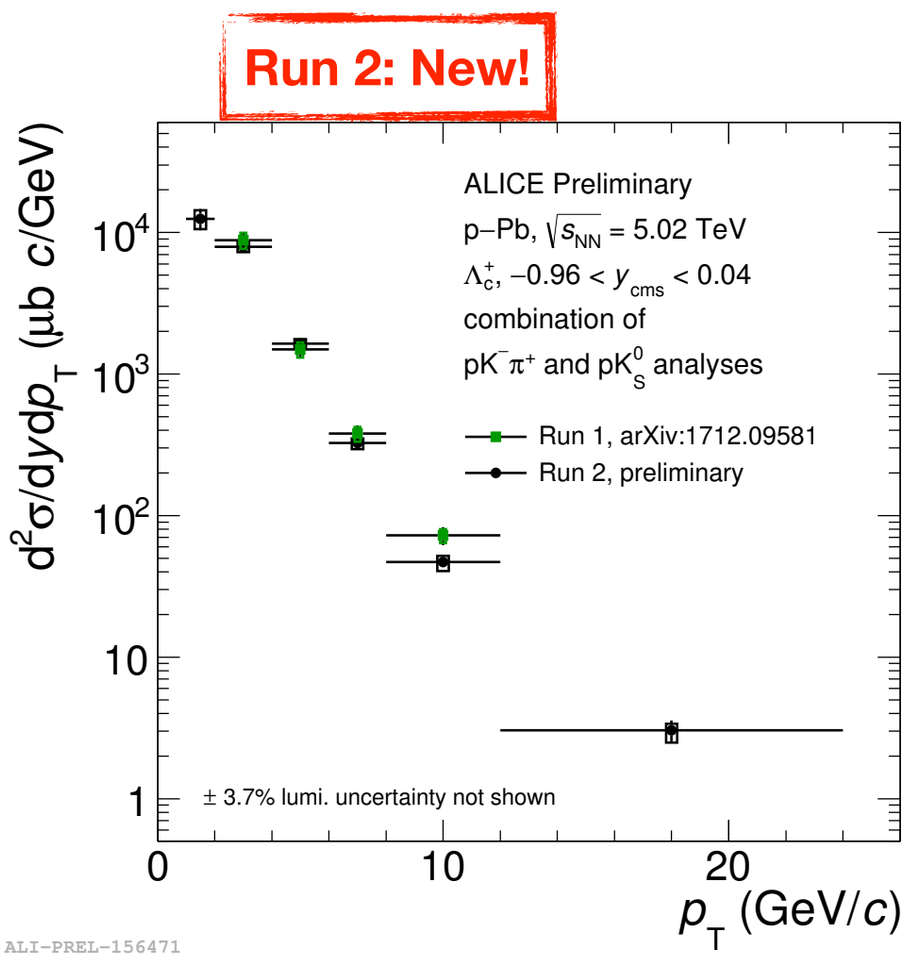


- D-meson Q_{pPb} compatible with that of charged particles within uncertainties both in central and peripheral events
- D-meson Q_{CP} compatible with that of charged particles

Λ_c^+ p_T-differential cross section







arXiv:1712.09581

GM-VFNS: Eur. Phys. J. C72 (2012) 2082
PIWHEG+PYTHIA6: JHEP 09 (2007) 126
Shao et al.: Eur. Phys. J. C77 no. 1, (2017) 1

- Combination of **3 decay channels in pp** (hadronic + semileptonic) and **2 decay channels in p-Pb** (hadronic)
- The theoretical predictions underestimate Λ_c p_T-differential cross section both in pp and p-Pb
- In the models, the fragmentation function is tuned to reproduce the results from lower energy e^+e^- collisions

Λ_c^+/D^0 baryon-to-meson ratio in pp and p-Pb

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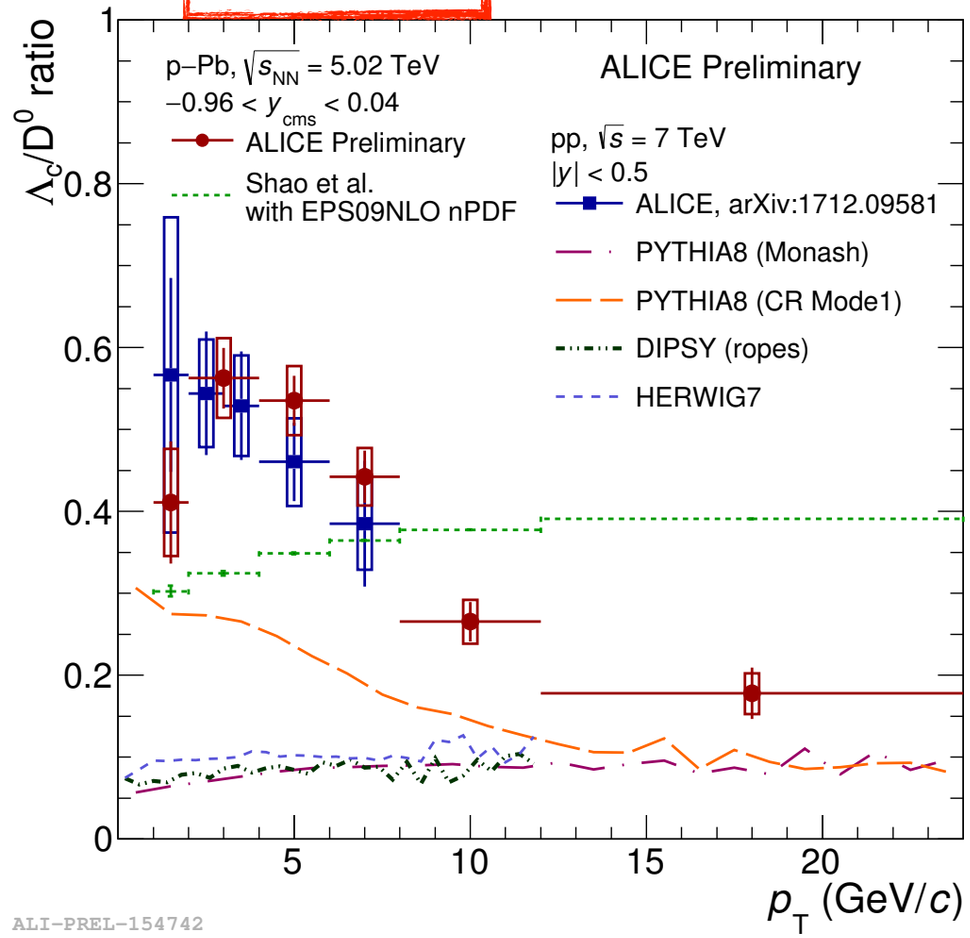
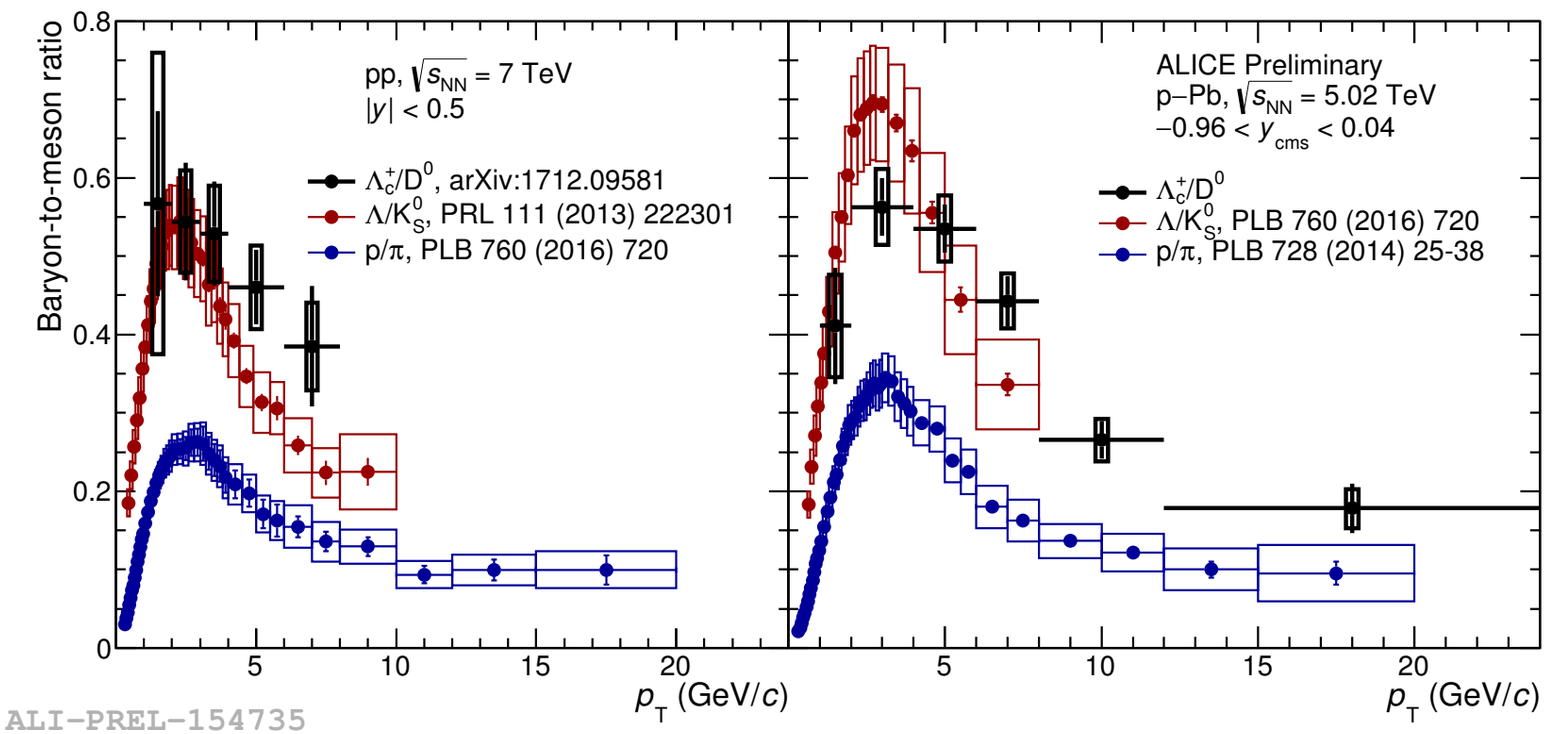
Run 2: New!



Run 2: New!



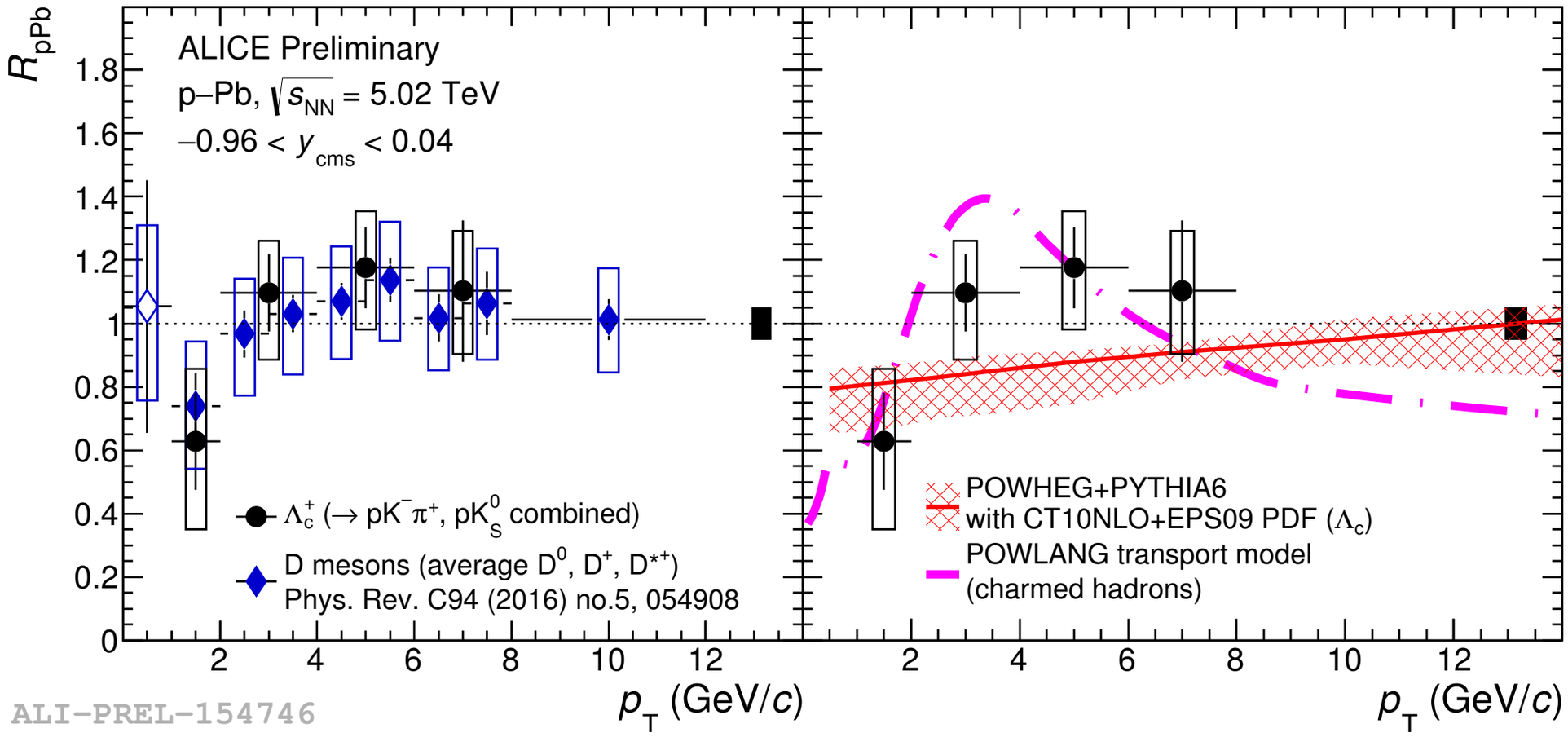
- Λ_c^+/D^0 ratios in pp and p-Pb collisions are compatible within uncertainties
- All theoretical predictions underestimated our measurements:
  - **PYTHIA8 tune with the Monash tune (enhanced color reconnection)**
  - ***Shao et al.*** model (tuned on LHCb pp data)
- New preliminary results in p-Pb collisions at 5.02 TeV (improved measurements in terms of p_T reach and precision): similar trend as baryon-to-meson ratio in the light-flavour sector

Λ_c^+ R_{pPb}

$$R_{pA} = \frac{1}{A}\frac{d\sigma_{pA}/dp_T}{d\sigma_{pp}/dp_T}$$

POWHEG+PYTHIA6 with CT10NLO+EPS09 PDF: JHEP 09 (2007) 126, Phys. Rev. D82 (2010) 074024, JHEP 04 (2009) 065

POWLANG: JHEP 03 (2016) 123

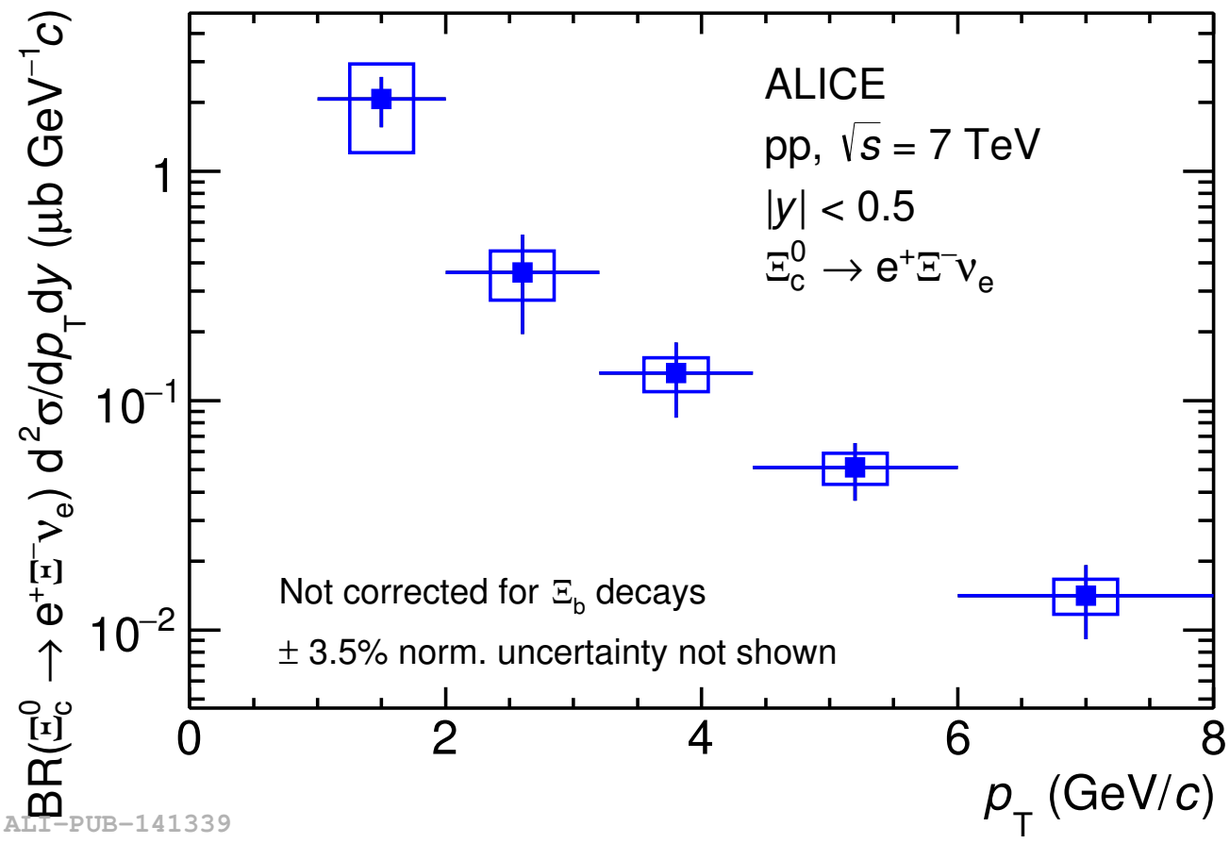


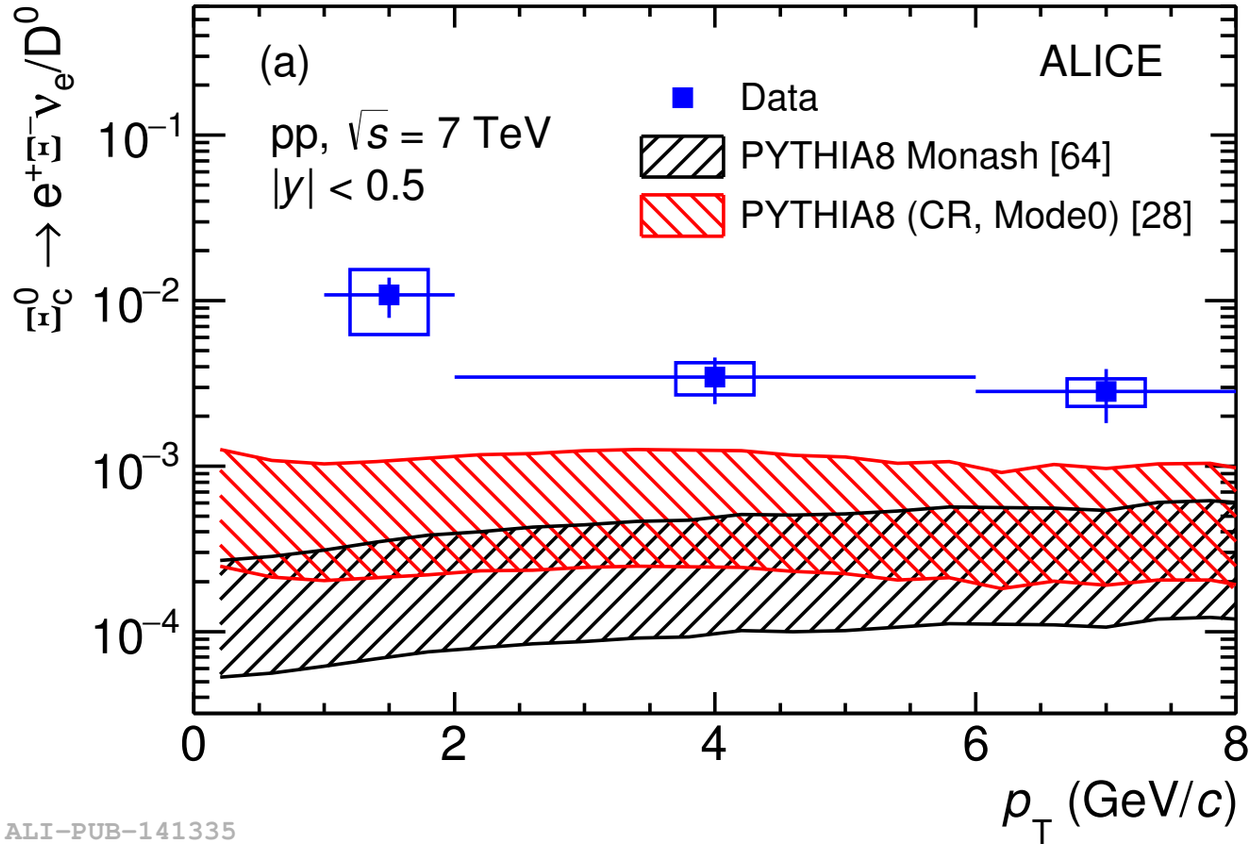
New!

- Λ_c^+ R_{pPb} is consistent with unity as D-meson R_{pPb} and with model predictions within uncertainties:
  - POWHEG+PYTHIA6 with CT10NLO+EPS09 PDF: Cold Nuclear Matter effects
  - POWLANG with "small-size" QGP formation: hot medium effects, collisional energy loss

Ξ_c^0 cross section and Ξ_c^0/D^0

Phys. Lett. B 781 (2018) 8-19





D⁰ from Eur. Phys. J. C77 (2017) 550

PYTHIA 8 Monash: P. Skands, S. Carrazza, and J. Rojo, Eur. Phys. J. C74 (2014) 3024

Colour reconnection: J. R. Christiansen and P. Z. Skands JHEP 08 (2015) 003

- First Ξ_c^0 production measurement at the LHC (BR unknown)
- Baryon-to-meson ratio Ξ_c^0 → $e^+\Xi^-\nu_e/D^0$ larger than model predictions

Summary

- D-meson p_T-differential cross section measured in pp collisions at 2.76, 5.02, 7, 8 and 13 TeV compatible with pQCD predictions
- R_{pPb} of D mesons compatible with unity
- Q_{pPb} consistent with unity and compatible with charged particles in 0-10% and 60-100% centrality classes
- Hint of $Q_{CP} > 1$ in $3 < p_T < 8$ GeV/c, 1.5σ effect
- Λ_c^+ production in pp and p-Pb collisions underestimated by models
- Λ_c^+/D^0 in p-Pb collisions higher than MC predictions: similar trend as the baryon-to-meson ratio in the light-flavour sector
- Ξ_c^0/D^0 production underestimated by the theoretical predictions

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Thank you!

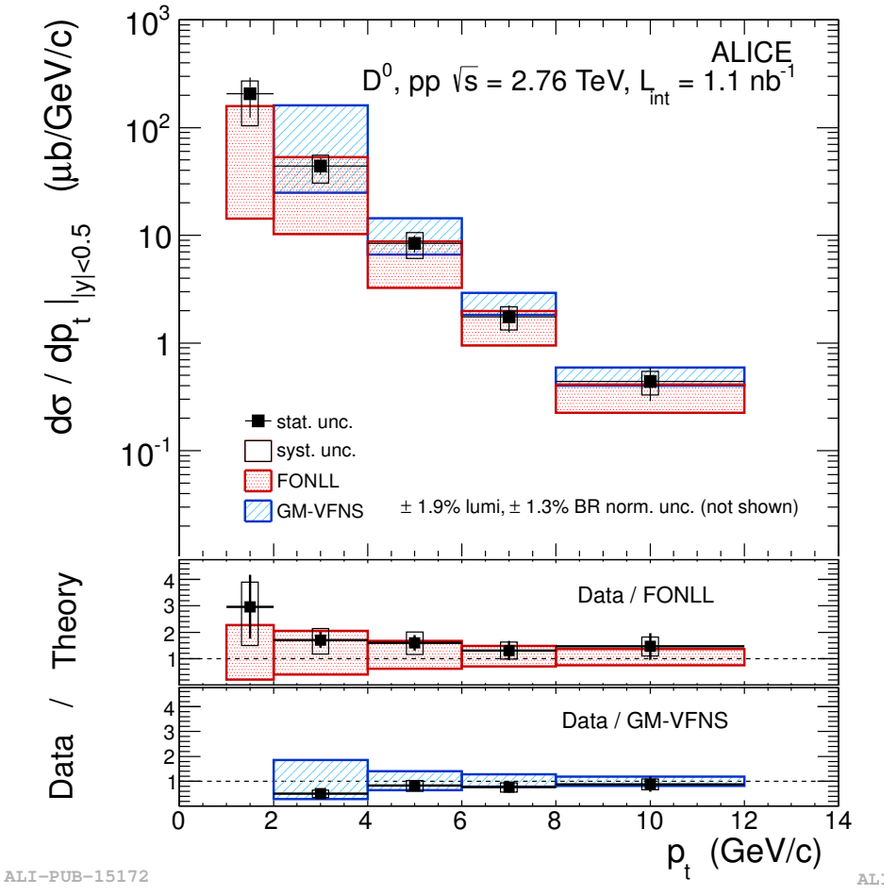
Спасибо!

Netherlands Organisation
for Scientific Research

BACK UP

Published !

D-meson cross sections at 2.76 TeV



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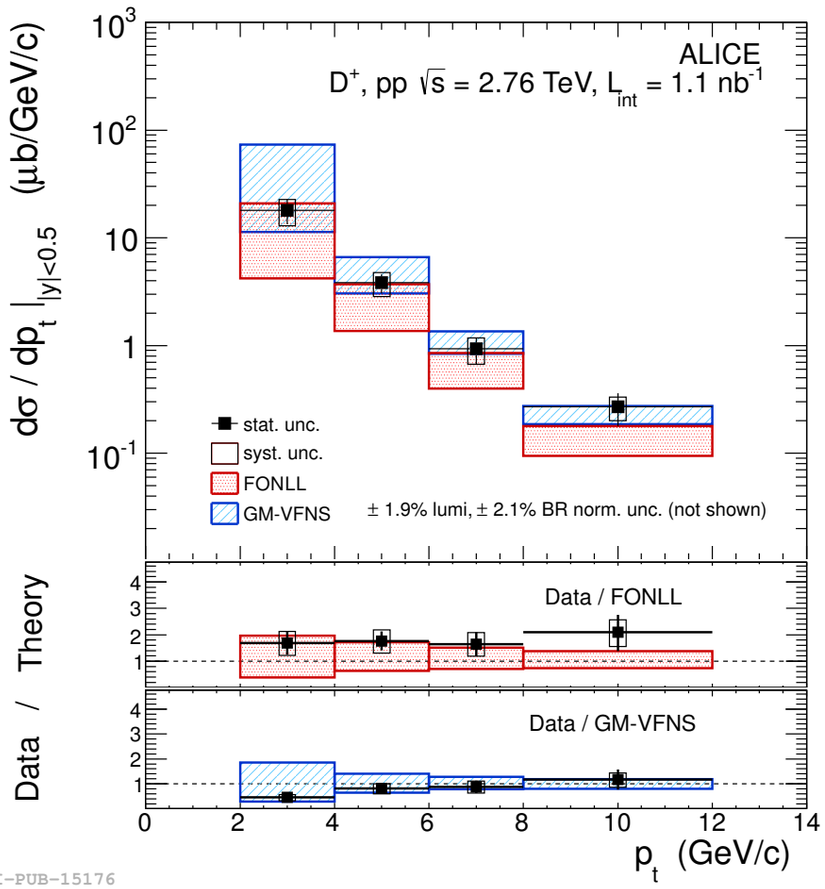

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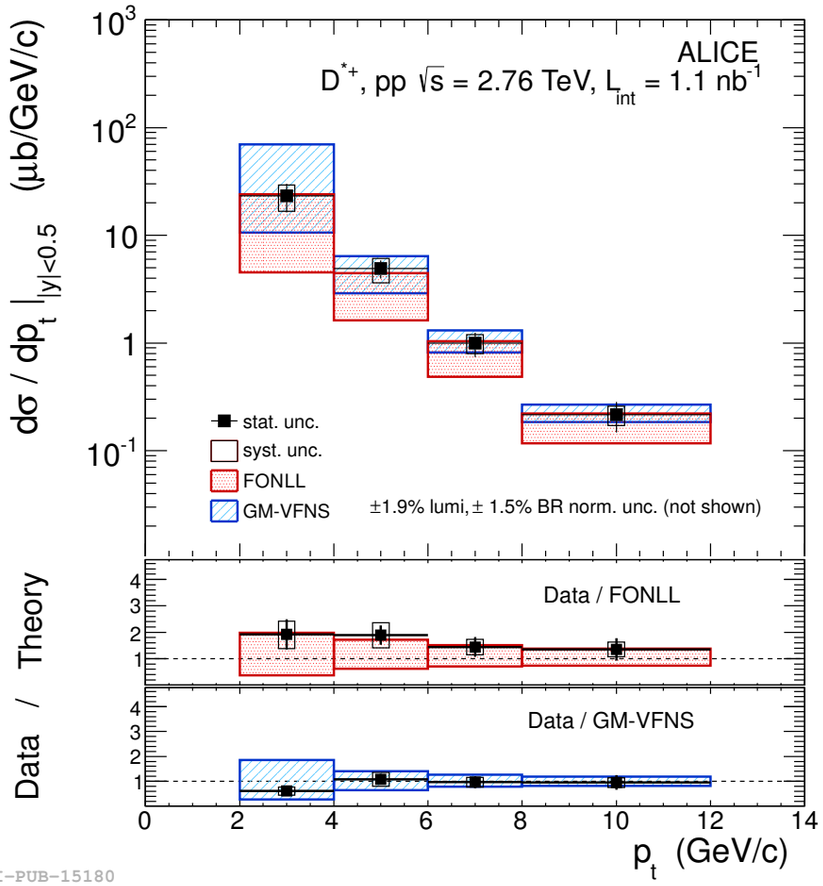
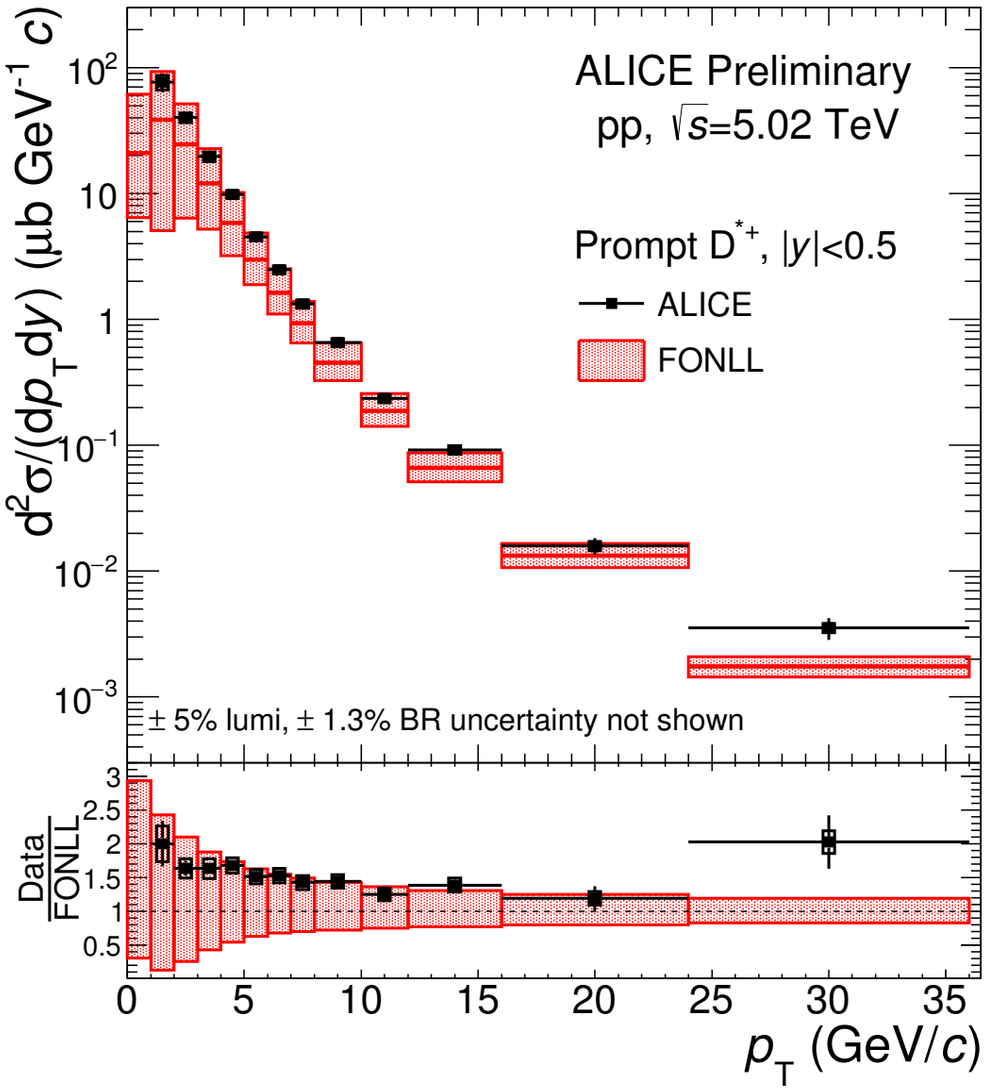


ALI-PUB-15180

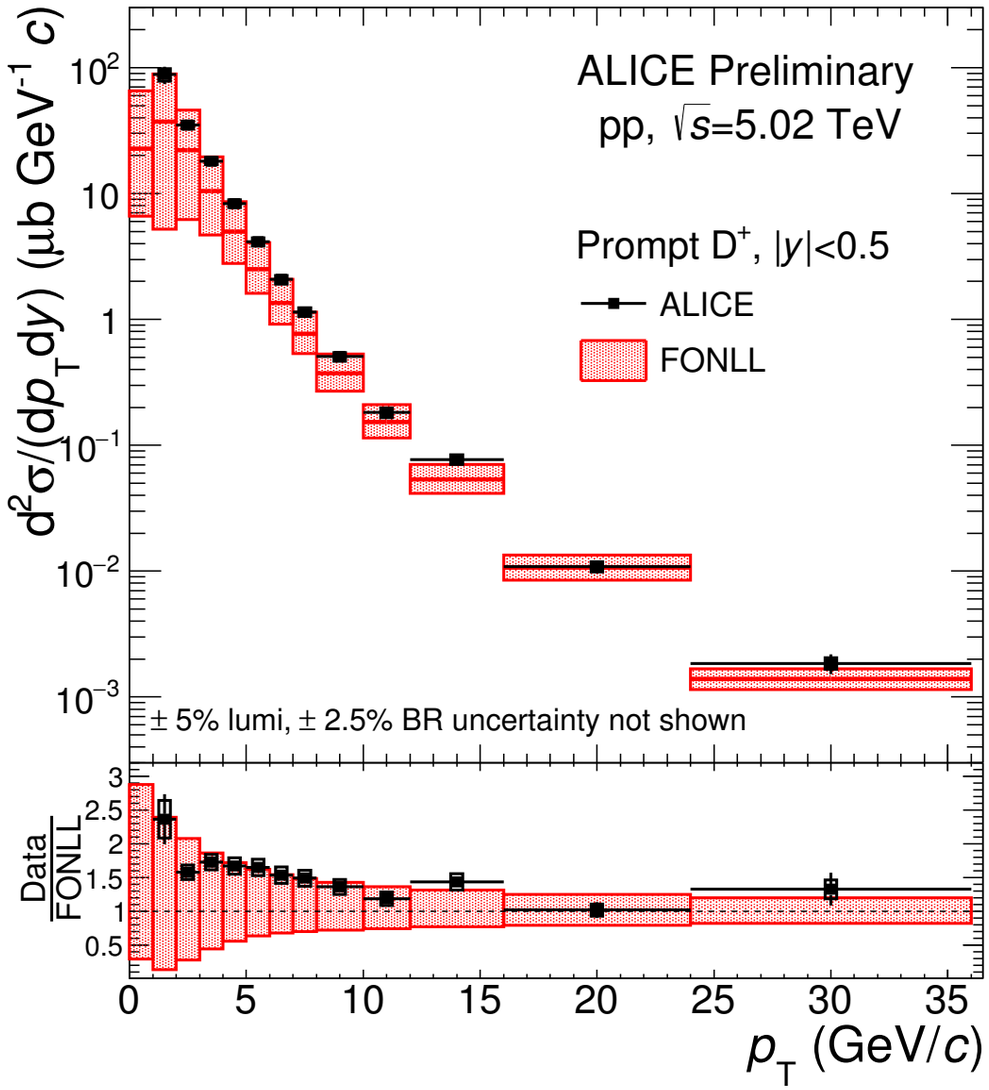
JHEP 1207 (2012) 191

2017 data !

D-meson cross sections at 5 TeV



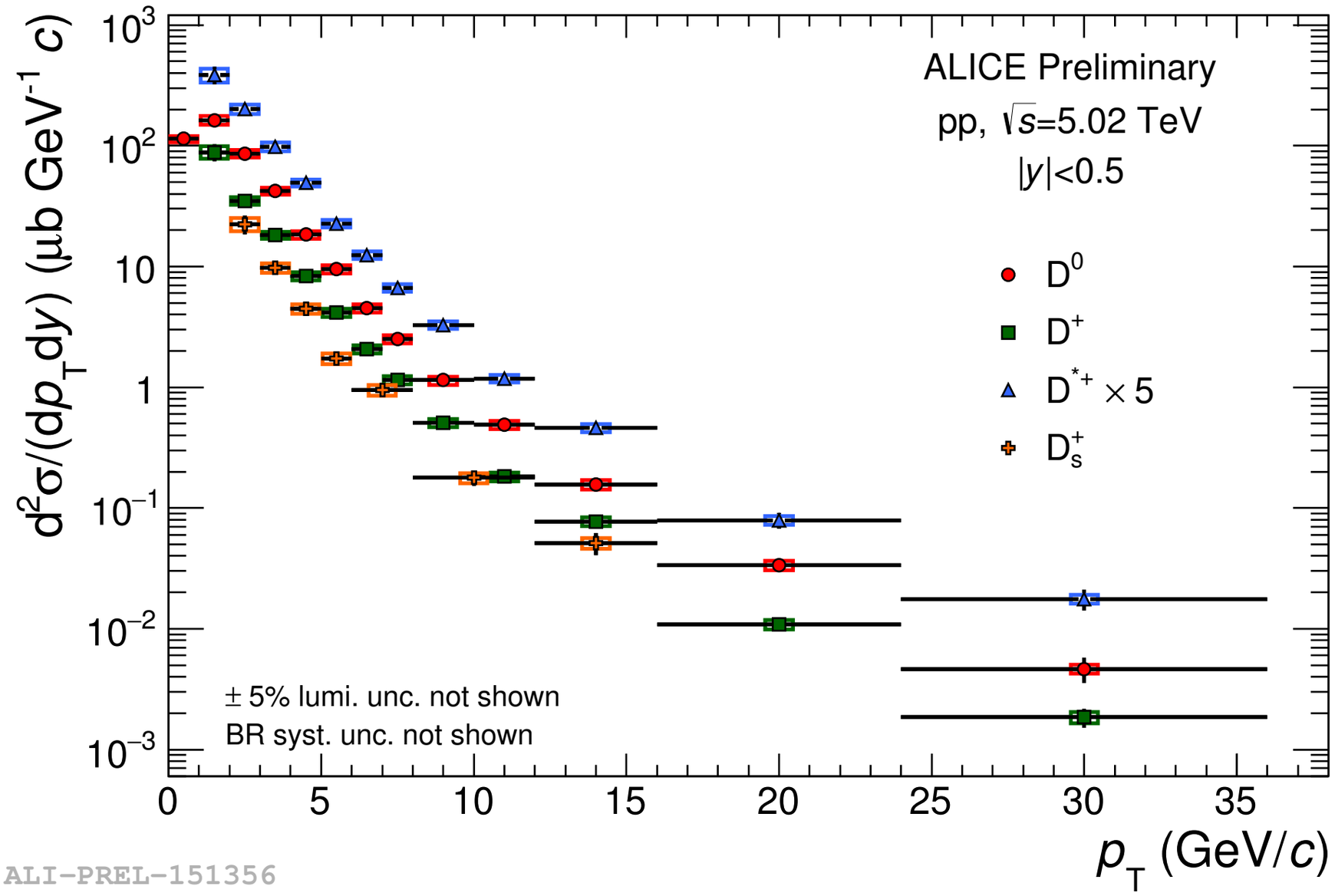
ALI-DER-151376



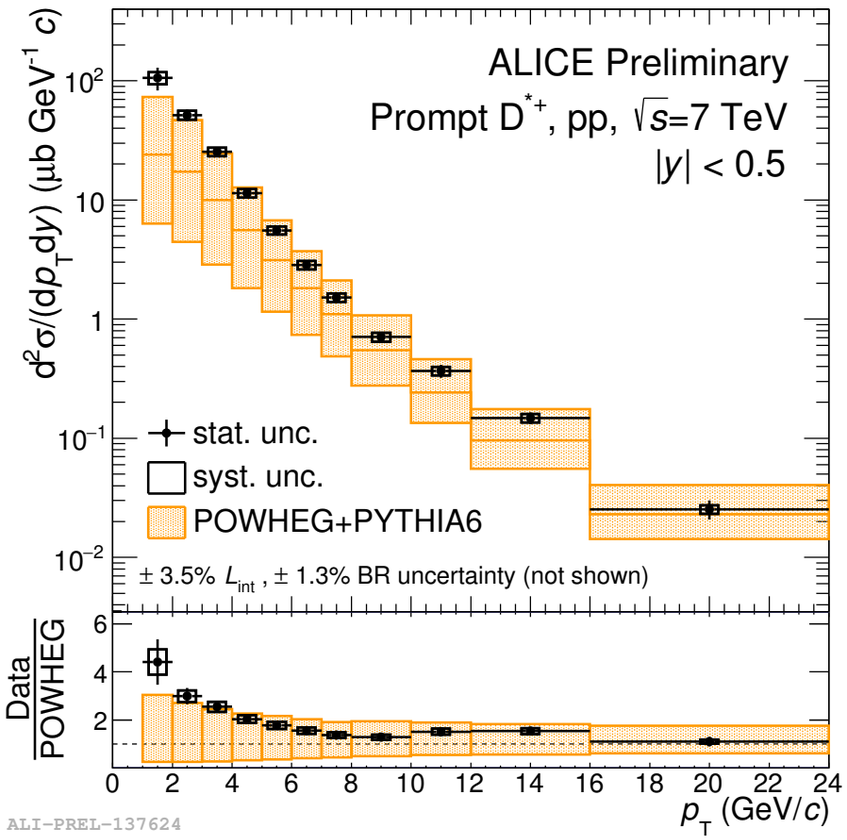
ALI-PREL-151368

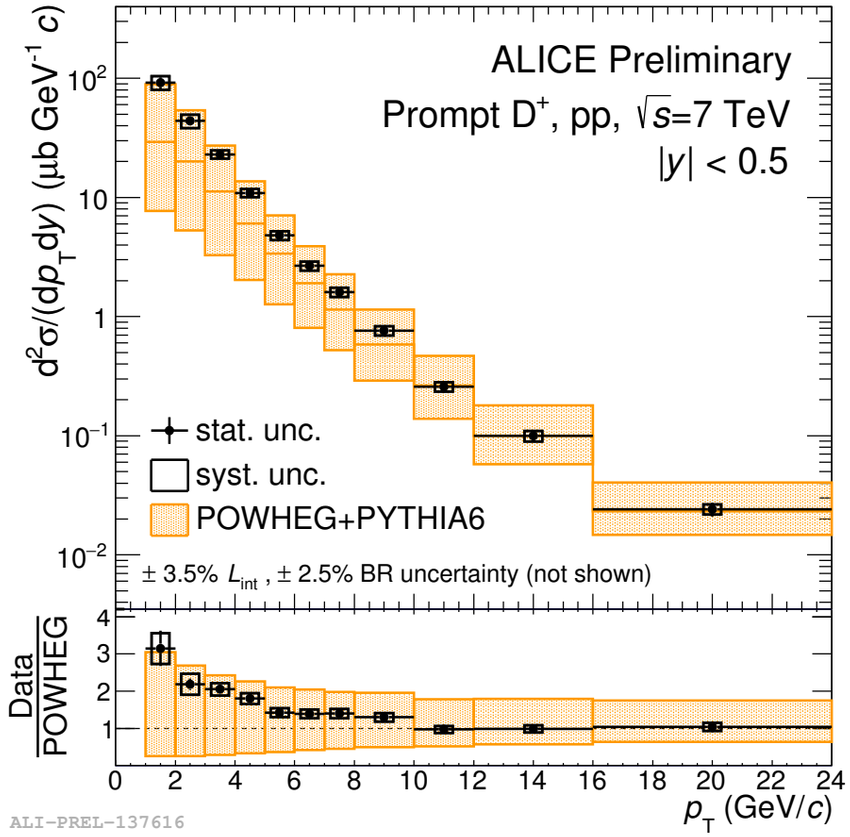
2017 data !

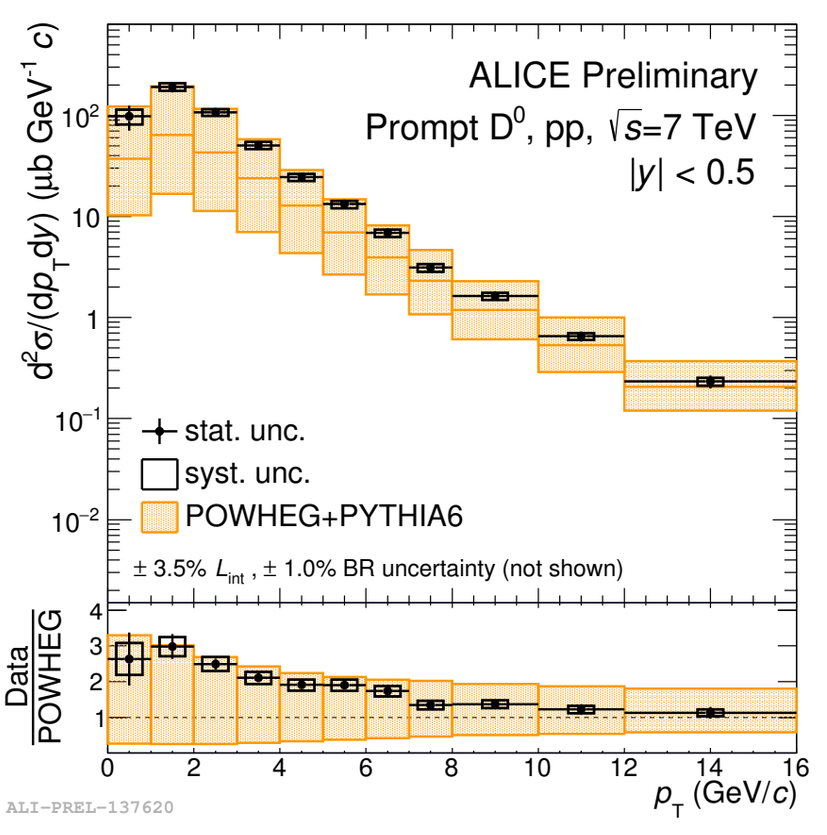
D-meson cross sections at 5 TeV



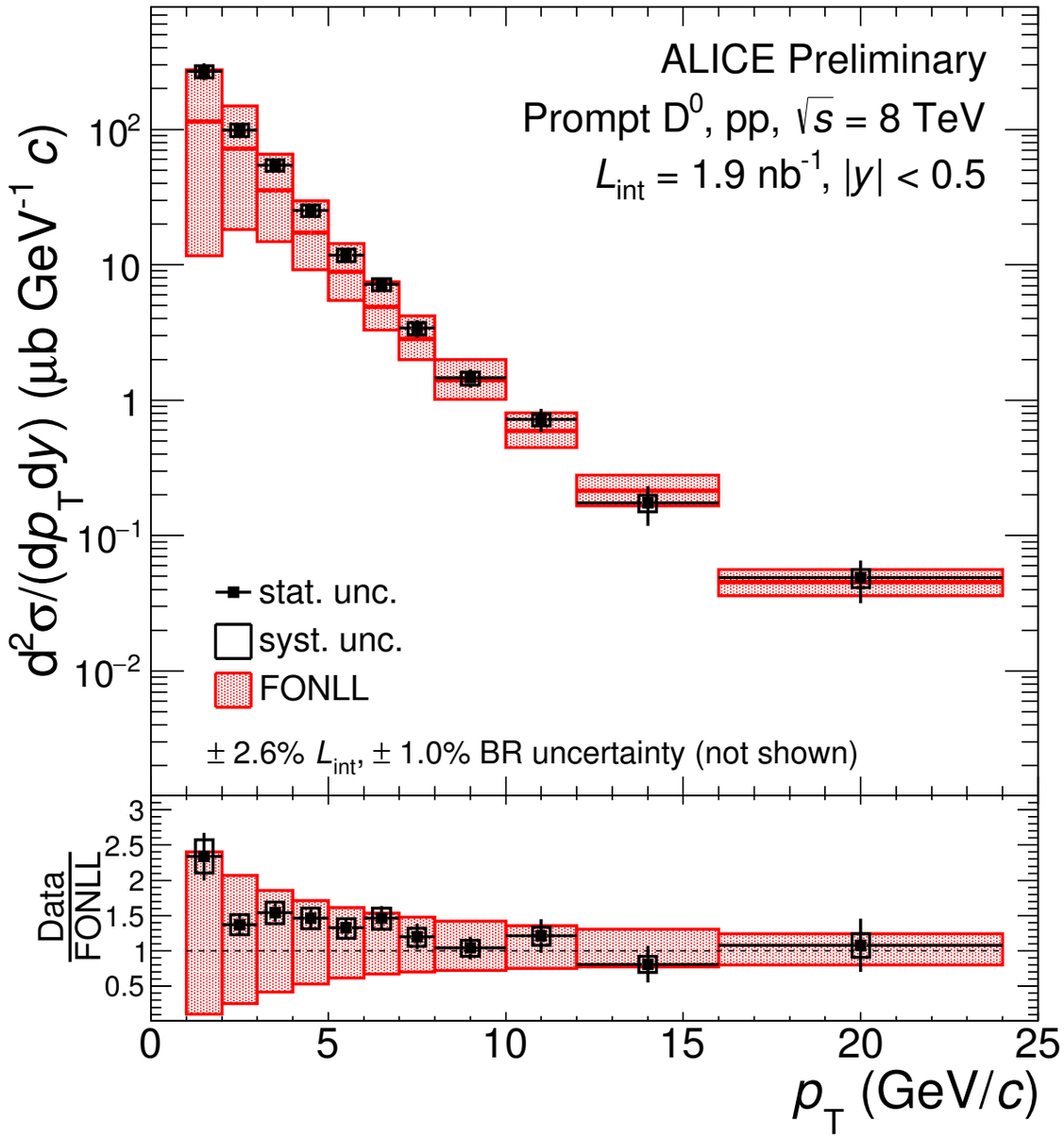
D-meson cross sections at 7 TeV



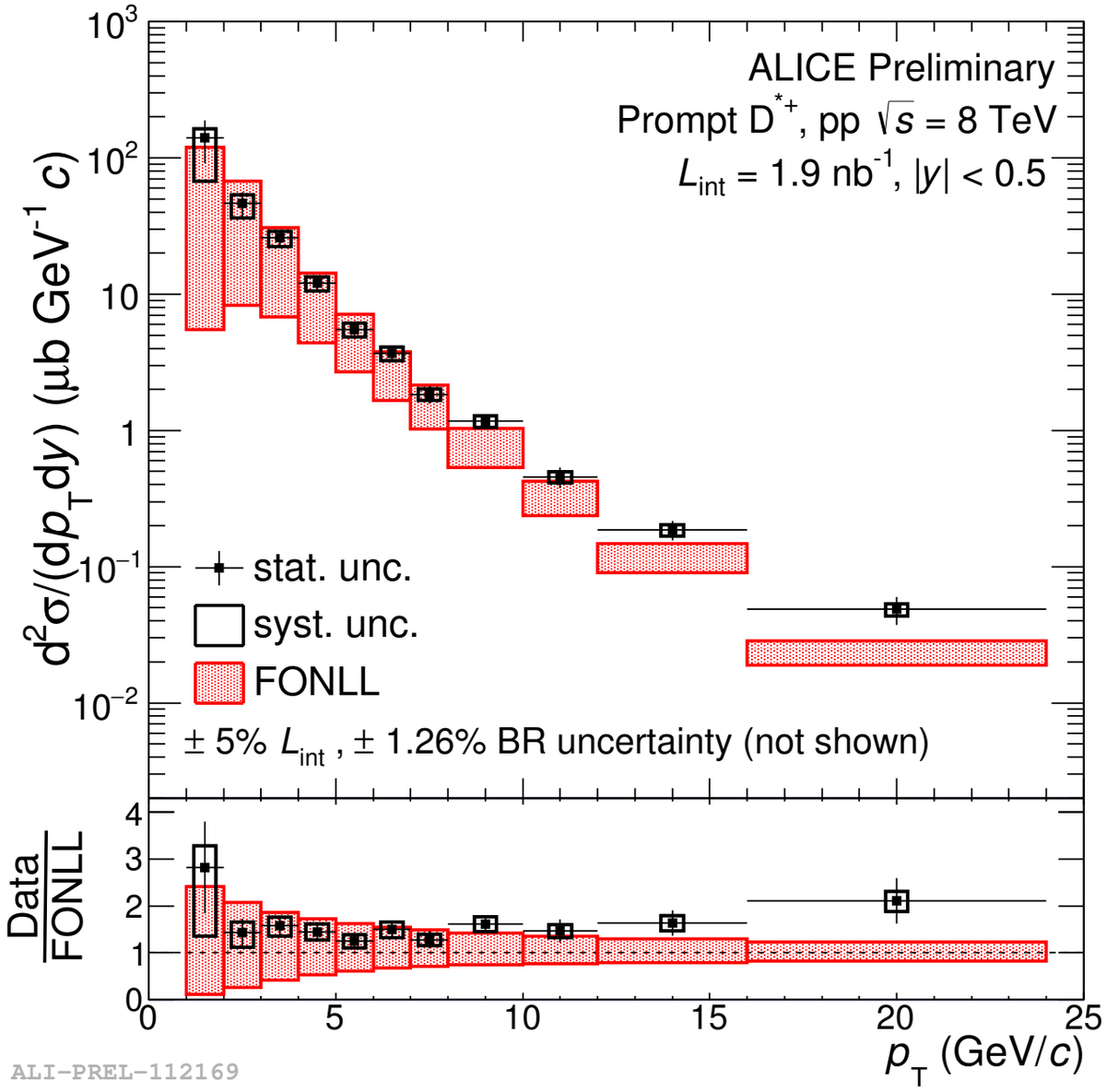




D-meson cross sections at 8 TeV



ALI-PREL-130977



ALI-PREL-112169

D-meson cross sections at 13 TeV