Charmed-baryon production and hadronization studies with ALICE

C. Hills (University of Liverpool)
for the ALICE Collaboration

Motivation

$$d\sigma^{hard}_{AB\to h} = \boxed{f_{b/B}(x_1, Q^2) \otimes f_{a/A}(x_2, Q^2)} \otimes \boxed{d\sigma^{hard}_{ab\to c}(x_1, x_2, Q^2)} \otimes \boxed{D_{c\to h}(z, Q^2)}$$

Initial state PDF

pQCD partonic cross section

Hadronization

Motivation

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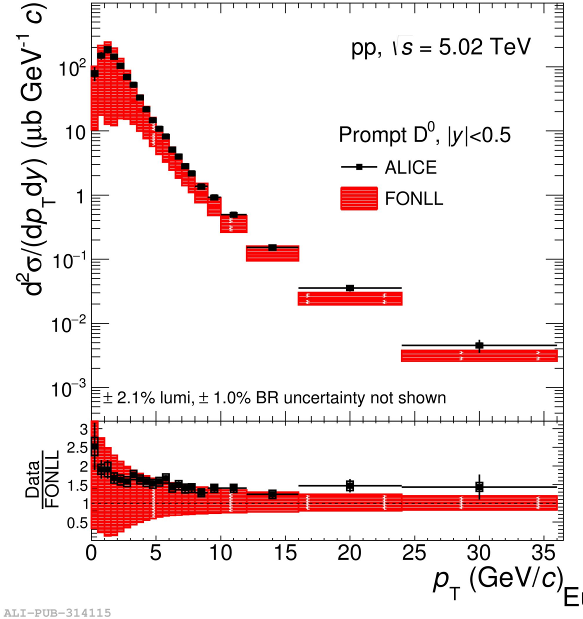
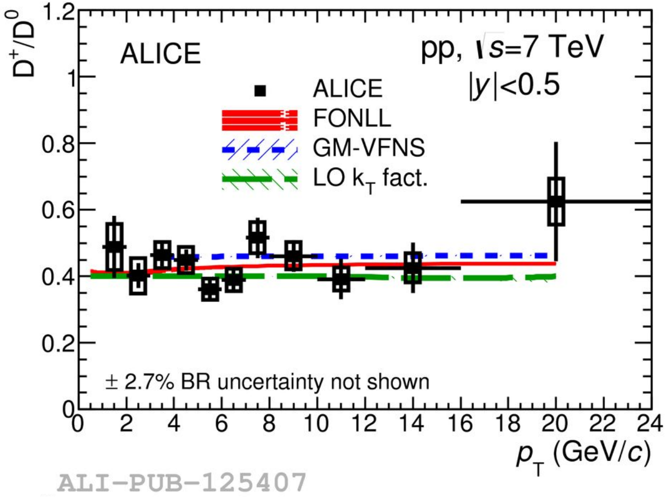
Hadronization



Eur.Phys.J. C79 (2019) 388



Eur. Phys. J. C77 (2017) 550

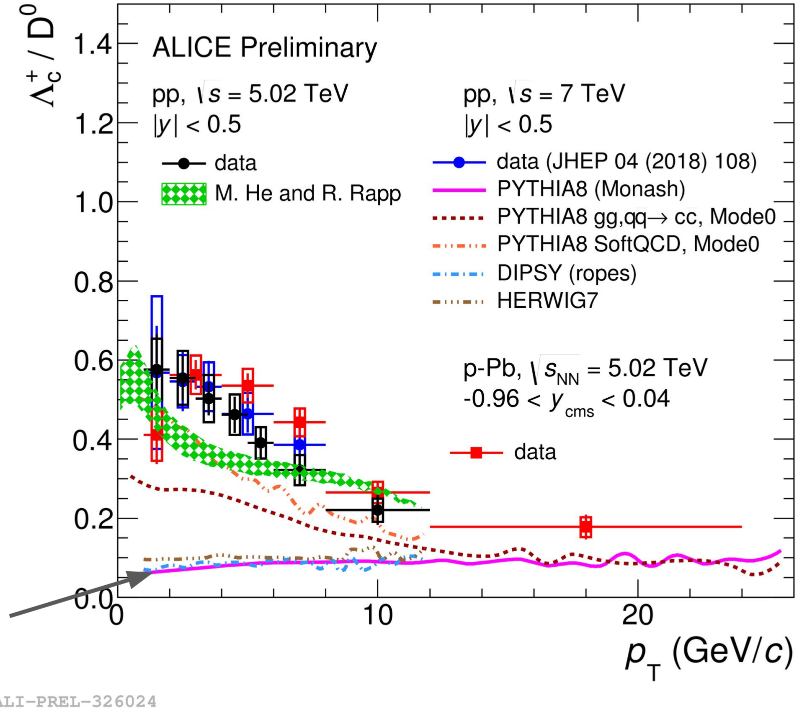
Motivation

- Baryon-to-meson ratios in **pp, p–Pb are enhanced with respect to e^+e^- collisions**
- Is charm **fragmentation the same for all collision systems?**
- Mechanisms that better describe data:
  - **Pythia8 w/Colour reconnection**

    JHEP 1508 (2015) 003
  - **Statistical Hadronization Model w/ augmented set of charm states**

    Phys.Lett. B795 (2019) 117-121

e^+e^-

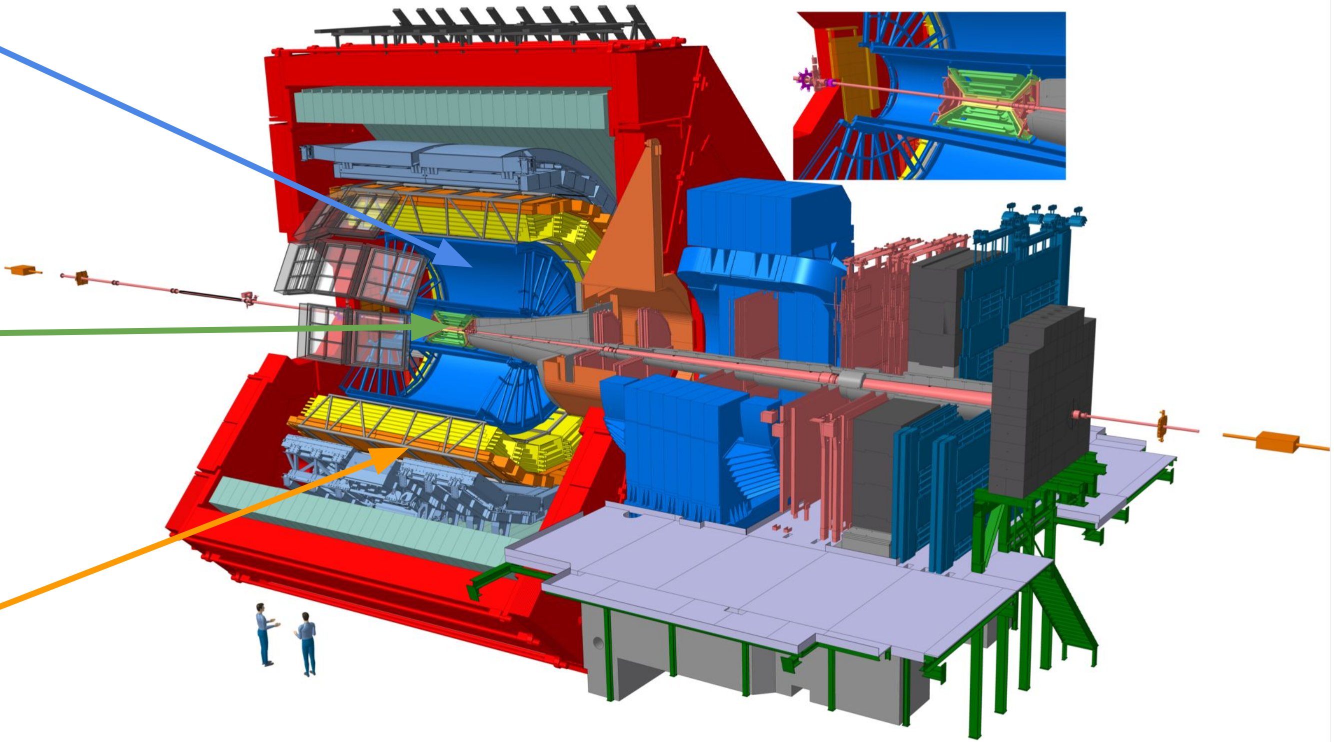


ALICE detector

Time Projection Chamber
($|\eta| < 0.9$)
Track reconstruction
Particle Identification ($\mathrm{d}E/\mathrm{d}x$)

Inner Tracking System
($|\eta| < 0.9$)
Vertex + Track reconstruction

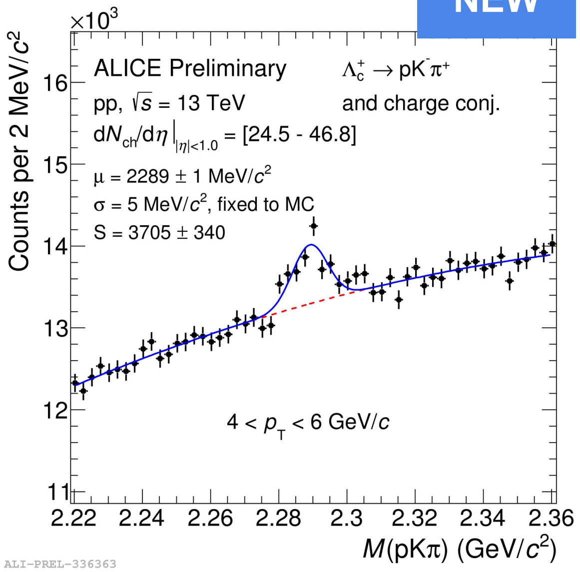
Time Of Flight
($|\eta| < 0.9$)
Particle Identification



Charmed-baryon analyses

NEW

- **PID and Topological selections**
- **Yield extraction** via invariant mass analysis
- **Corrections** to account for detector efficiency and acceptance
- **B Feeddown estimation** subtracted to provide prompt production cross section



Hadronic decays:

Λ_c^+	$\Lambda_c^+ \to pK_s^0$
	$\Lambda_c^+ \to pK^-\pi^+$

$\Sigma_c^{0,++}$	$\Sigma_c^0 \to \Lambda_c^+ \pi^-$
	$\Sigma_c^{++} \to \Lambda_c^+ \pi^+$

$\Xi_c^{0,+}$	$\Xi_c^0 \to \Xi^-\pi^+$
	$\Xi_c^+ \to \Xi^-\pi^+\pi^+$

Charmed-baryon analyses

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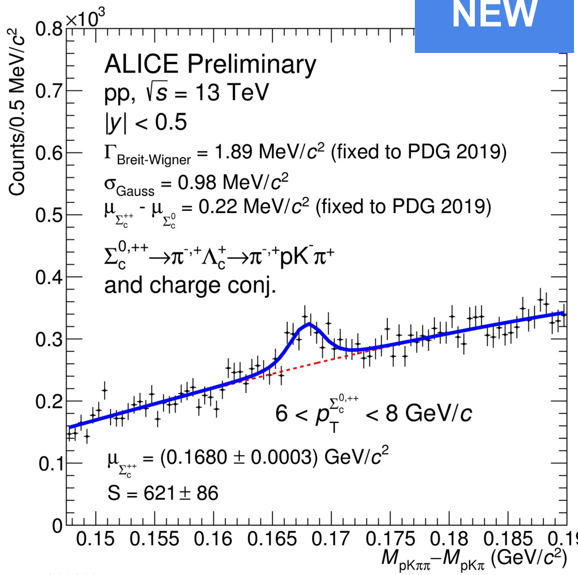

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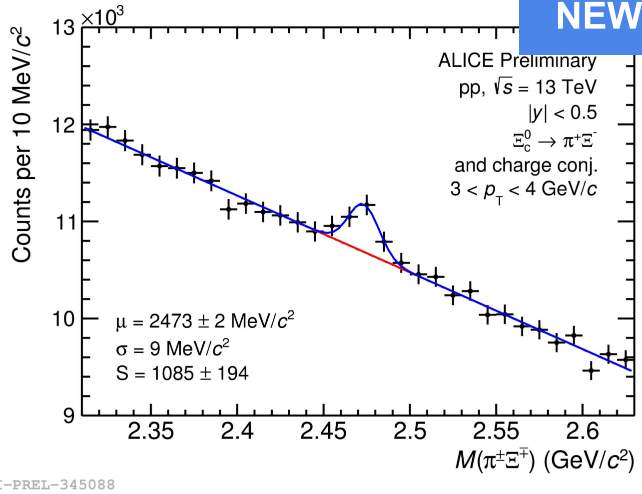

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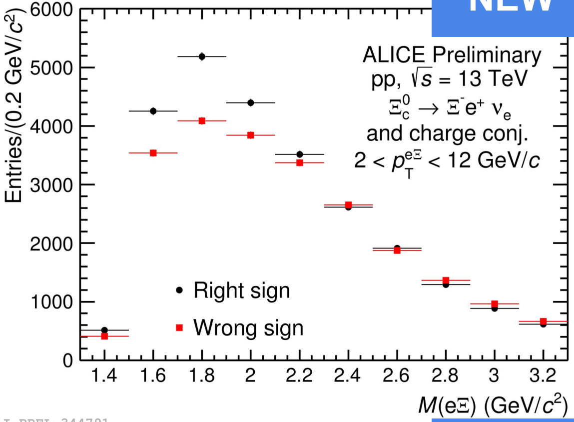
Charmed-baryon analyses

- **PID and Topological selections**
- **Yield Extraction** by subtracting Wrong-Sign pairs from Right-Sign pairs
- **Unfolding** converts eΞ p_T spectra into Ξ_C^0 p_T spectra
- **Corrections** to account for detector efficiency and acceptance

Semileptonic decays:

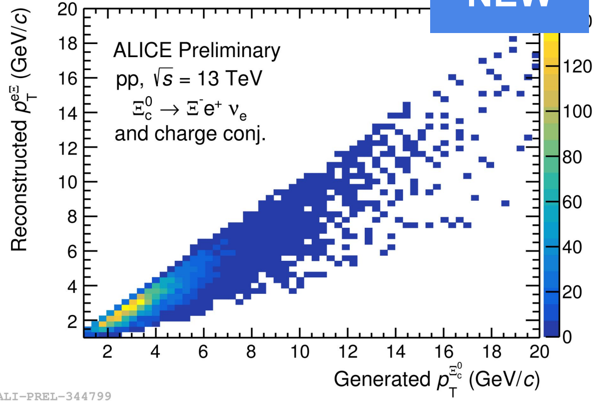
Ξ_C^0	$\Xi_C^0 \rightarrow e^+\Xi^-\nu_e$

NEW



ALI-PREL-344791

NEW

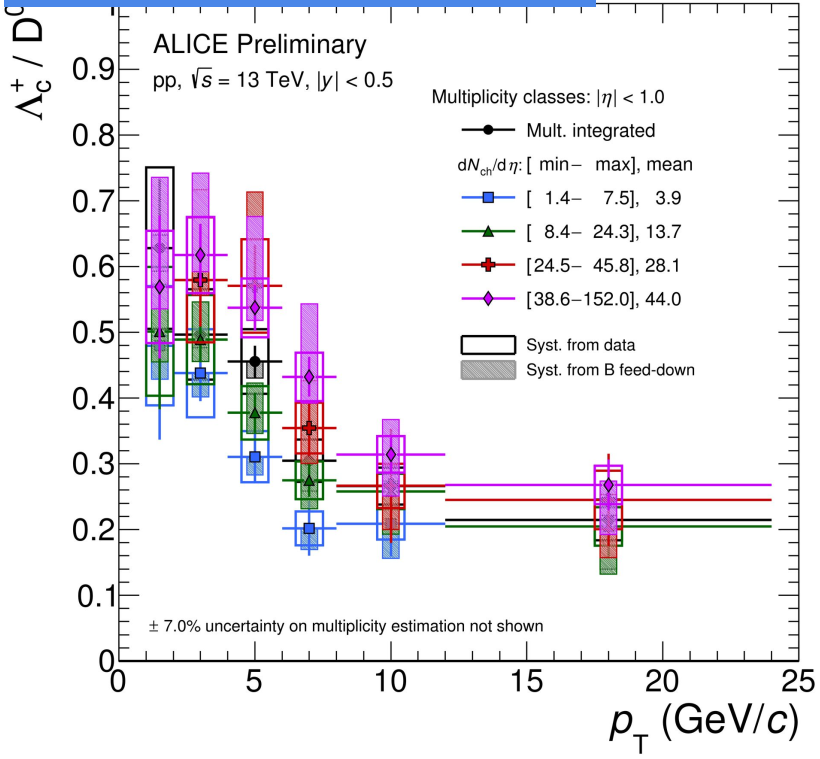


ALI-PREL-344799

Λ_c^+/D^0 baryon-to-meson ratio - pp

Λ_c^+/D^0 vs multiplicity (pp)

NEW



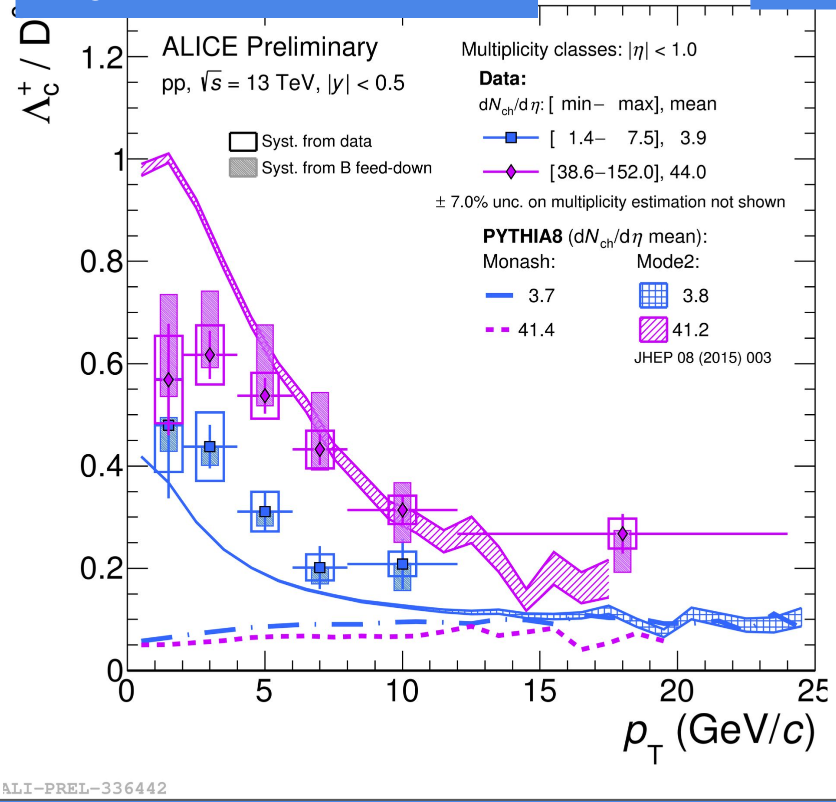
ALI-PREL-336414

- Significant enhancement with multiplicity

Λ_c^+/D^0 baryon-to-meson ratio - pp

Λ_c^+/D^0 vs models (pp)

NEW

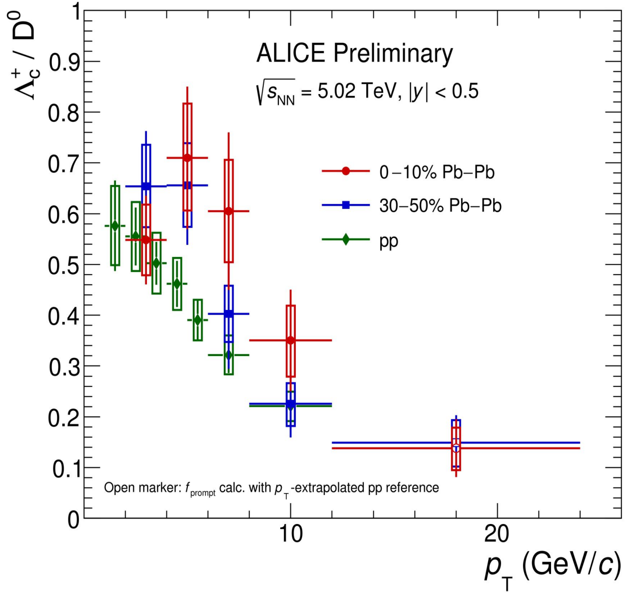


- Significant enhancement with multiplicity
- Described well with Pythia including colour reconnection

Λ_c^+/D^0 baryon-to-meson ratio - Pb–Pb

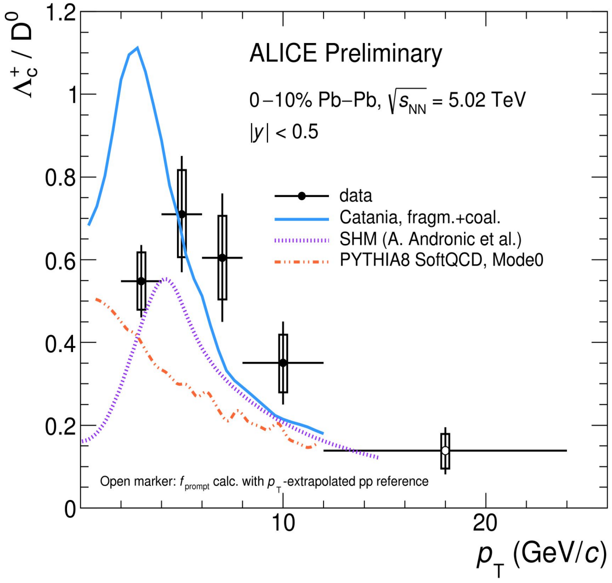
➢ Baryon-to-meson ratios expected to be enhanced in Pb–Pb by recombination

Λ_c^+/D^0 (Pb–Pb and pp)



ALI-PREL-321702

Λ_c^+/D^0 vs models (Pb–Pb)



ALI-PREL-325749

- **hint of enhancement in Pb–Pb**
- **compatible with recombination**

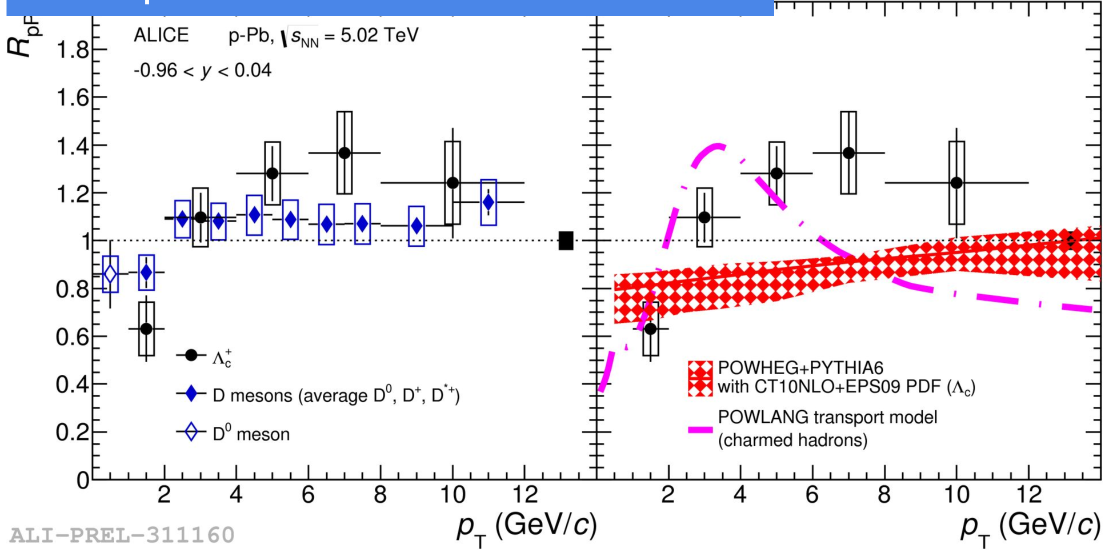
Catania - Eur. Phys. J. C (2018) 78: 348
SHM - Phys. Lett. B 797, 134836 (2019)
Pythia - JHEP 1508 (2015) 003

Λ_C^+ Nuclear modification factor - R_{pPb}

- Λ_C^+ R_{pPb} is compatible with unity
- Compatible with D-meson R_{pPb}

$$R_{\mathrm{pPb}} = \frac{\mathrm{d}N_{\mathrm{pPb}}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle \, \mathrm{d}N_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

Λ_C^+ R_{pPb} (vs D mesons and models)

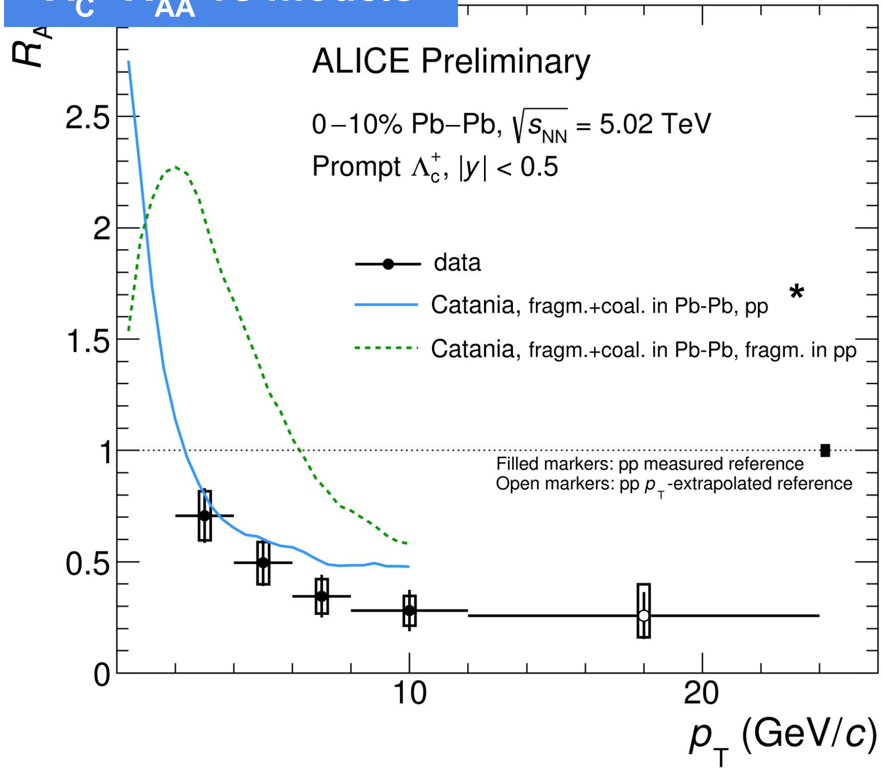


Compatible within uncertainties for models:

- Including only CNM effects JHEP 0709:126,2007
- QGP in small system JHEP 03(2016)123

Λ_c^+ Nuclear modification factor - R_{AA}

Λ_c^+ R_{AA} vs models



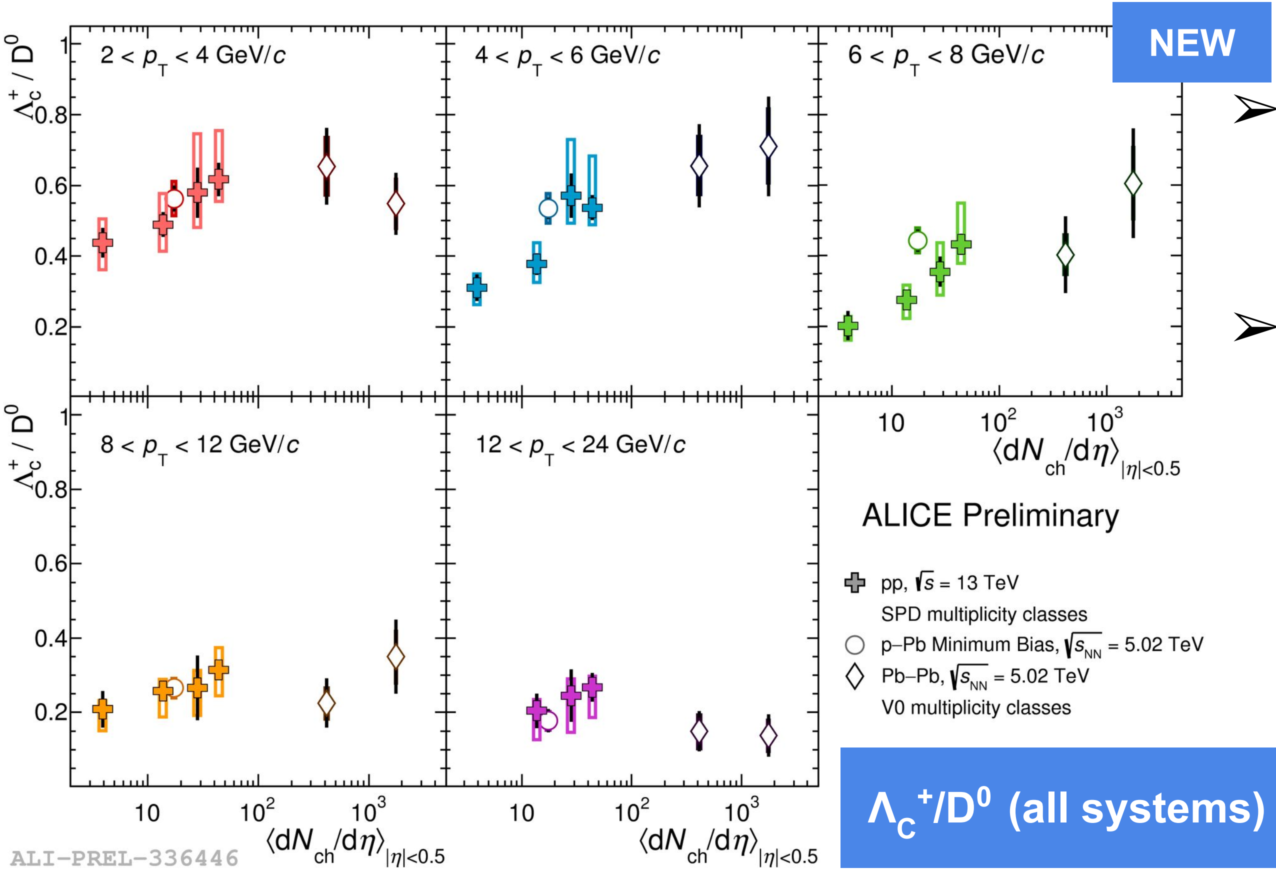
ALI-PREL-321835

- ➢ Λ_c^+ yield is suppressed in Pb–Pb
- ➢ Data favours model where both coalescence and fragmentation are present.

$$R_{AA} = \frac{dN_{AA}/dp_T}{\langle N_{coll} \rangle \, dN_{pp}/dp_T}$$

* Eur. Phys. J. C (2018) 78: 348

Λ_c^+/D^0 in pp, p–Pb and Pb–Pb

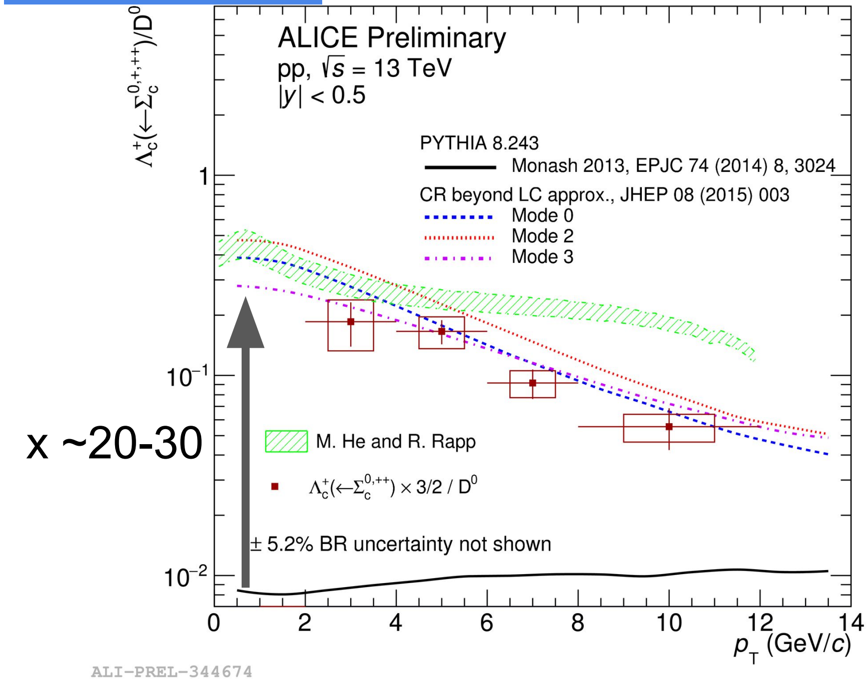


- Smoothly increases from low multiplicity pp to Pb–Pb
- Low multiplicity pp is still enhanced with respect to e^+e^-

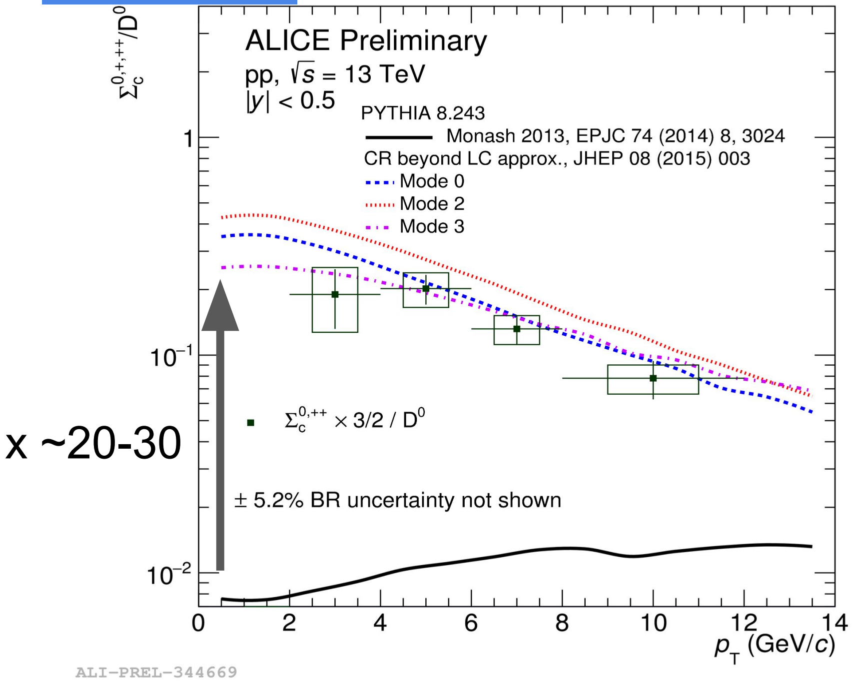
Λ_c^+/D^0 (all systems)

$\Sigma_C^{0,++}/D^0$ baryon-to-meson ratio - pp

$\Lambda_c^+(\leftarrow\Sigma_c^{0,++})/D^0$ **NEW**



$\Sigma_C^{0,++}/D^0$ **NEW**



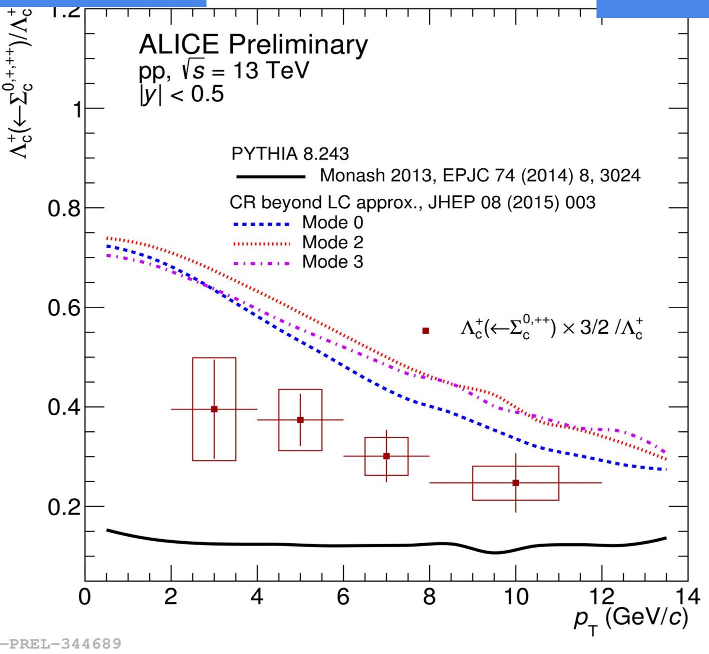
- ➢ Data is in good agreement Pythia with colour reconnection

He and Rapp - Phys.Lett. B795 (2019) 117-121

$\Sigma_c^{0,++}/\Lambda_c^+$ baryon-to-baryon ratio - pp

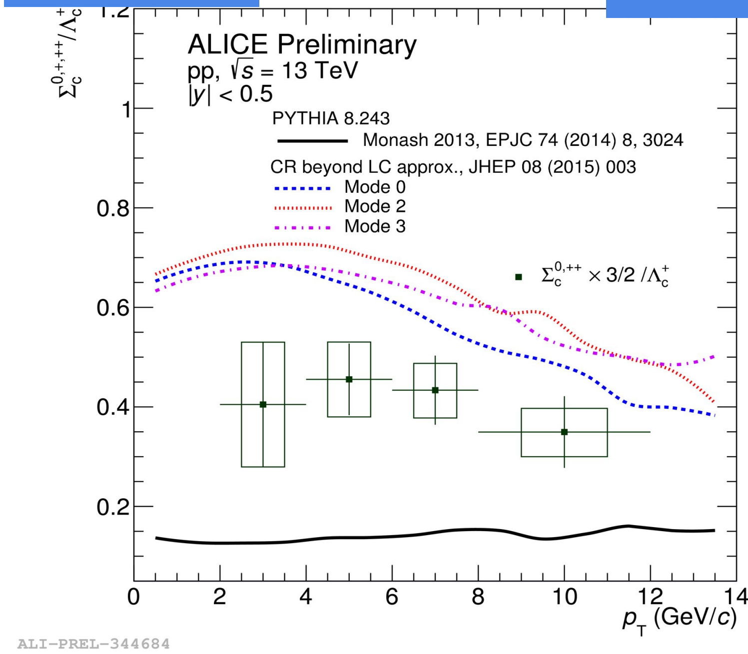
$\Lambda_c^+(\leftarrow\Sigma_c^{0,++})/\Lambda_c^+$

NEW



$\Sigma_c^{0,++}/\Lambda_c^+$

NEW

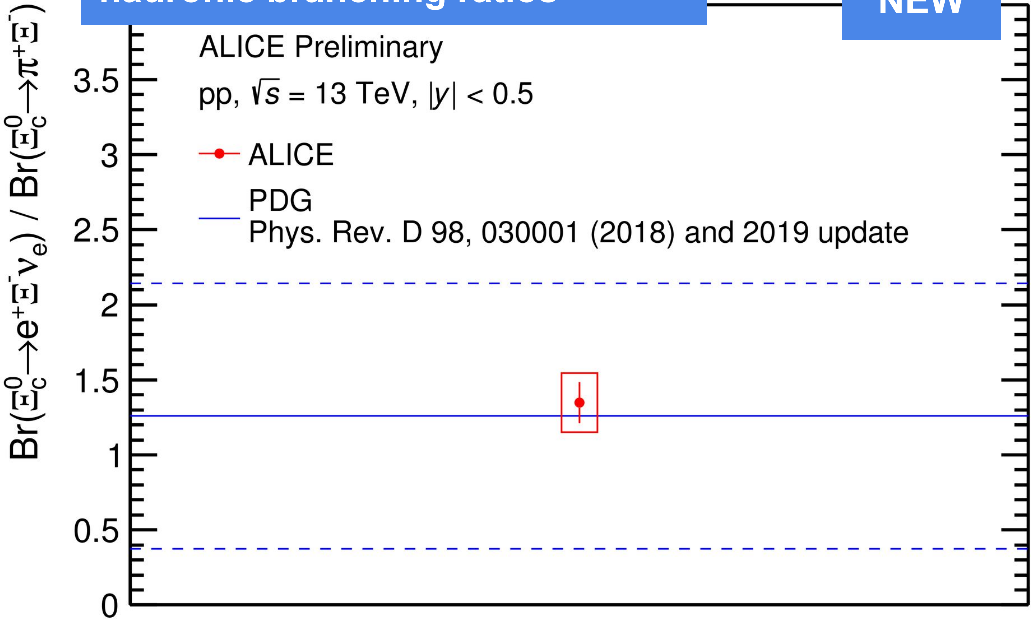


- ➢ Data is not described by Pythia with or without colour reconnection

$Br(\Xi_c^0 \rightarrow e^+\Xi^-\nu_e)/Br(\Xi_c^0 \rightarrow \Xi^-\pi^+)$

Ratio of semileptonic and hadronic branching ratios

NEW



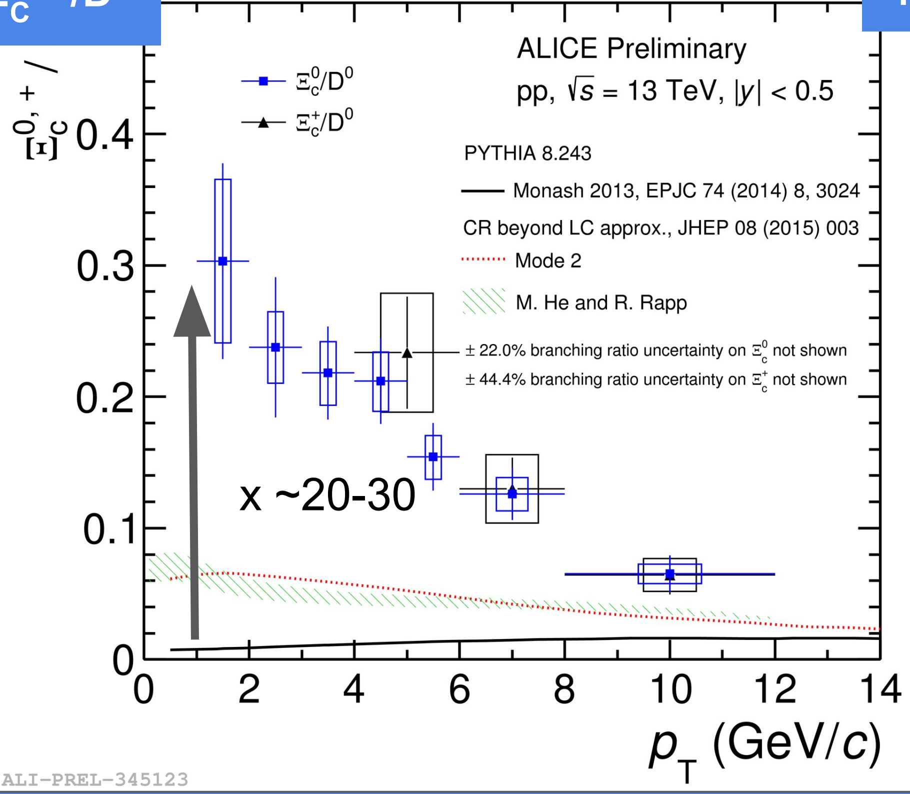
ALI-PREL-345624

- Ratio of semileptonic and hadronic BR measured with small uncertainties compared to PDG value

$\Xi_C^{0,+}/D^0$ baryon-to-meson ratio - pp

$\Xi_C^{0,+}/D^0$

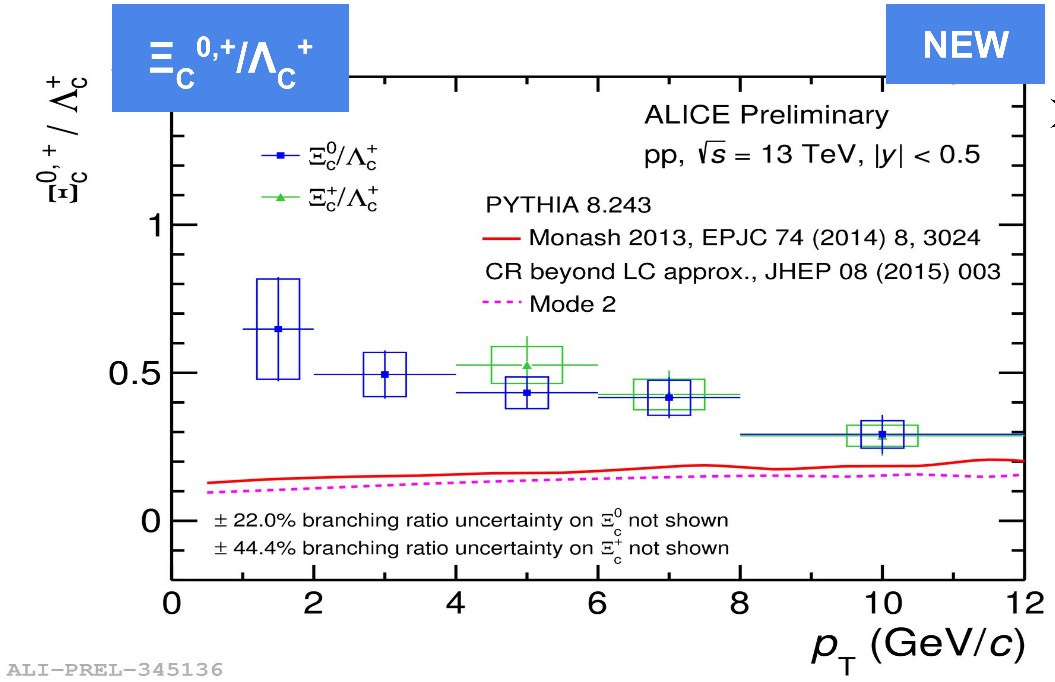
NEW



- Data underestimated by Pythia with and without colour reconnection
- He and Rapp similarly underestimates the data

He and Rapp - Phys.Lett. B795 (2019) 117-121

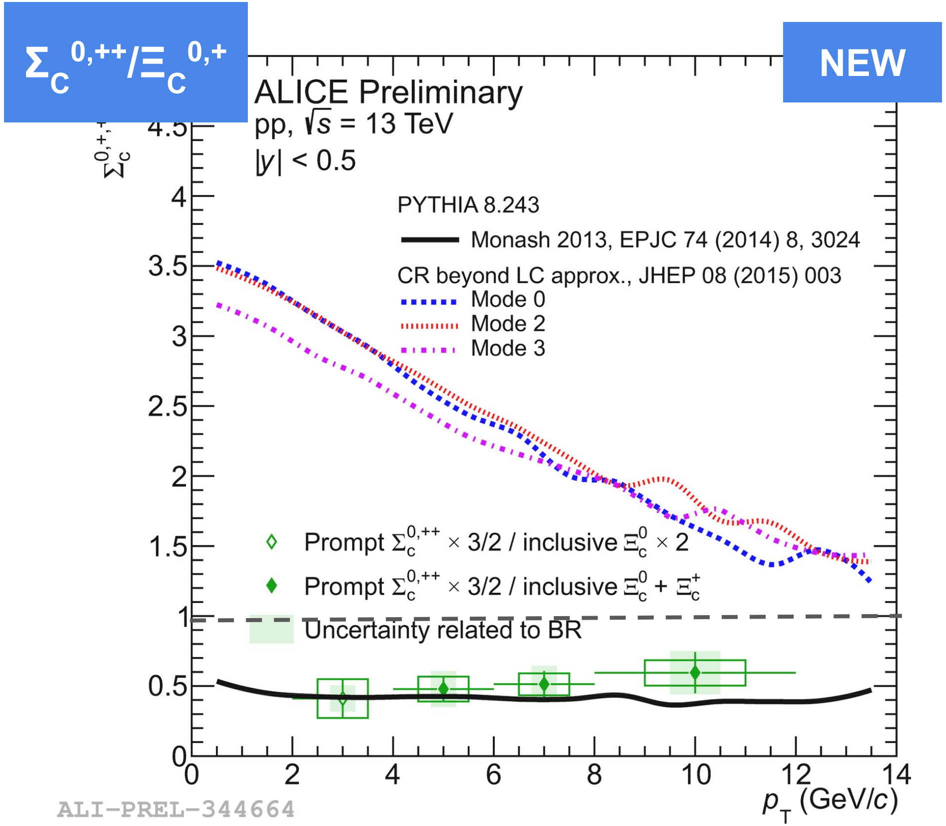
$\Xi_c^{0,+}/\Lambda_c^+$ baryon-to-baryon ratio - pp



➢ Data underestimated by Pythia with and without colour reconnection

$\Sigma_C^{0,++}/\Xi_C^{0,+}$ baryon-to-baryon ratio - pp

- Ratio is described well by Pythia8 without colour reconnection?
- Expectation from SHM is close to unity due to similar masses



Summary

Charmed baryons can act as powerful probe of hadronization:

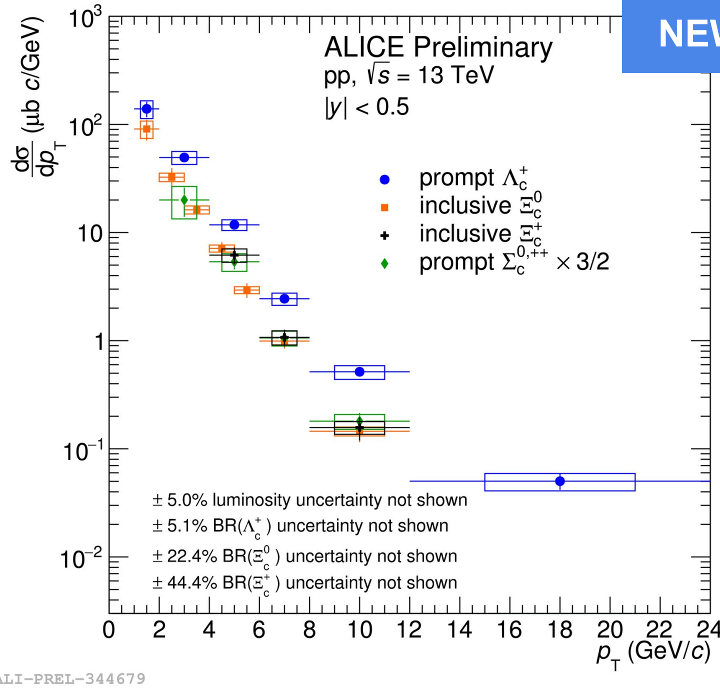
- ➢ enhanced baryon production seen in small systems → *fragmentation non-universal?*
- ➢ enhanced baryon-meson ratio in Pb–Pb → *recombination?*

Measurements of higher mass charmed baryons by ALICE:

- ➢ test theory predictions for Λ_C^+/D^0
- ➢ are needed in computing the total charm cross section

The charmed-baryon family picture...

NEW

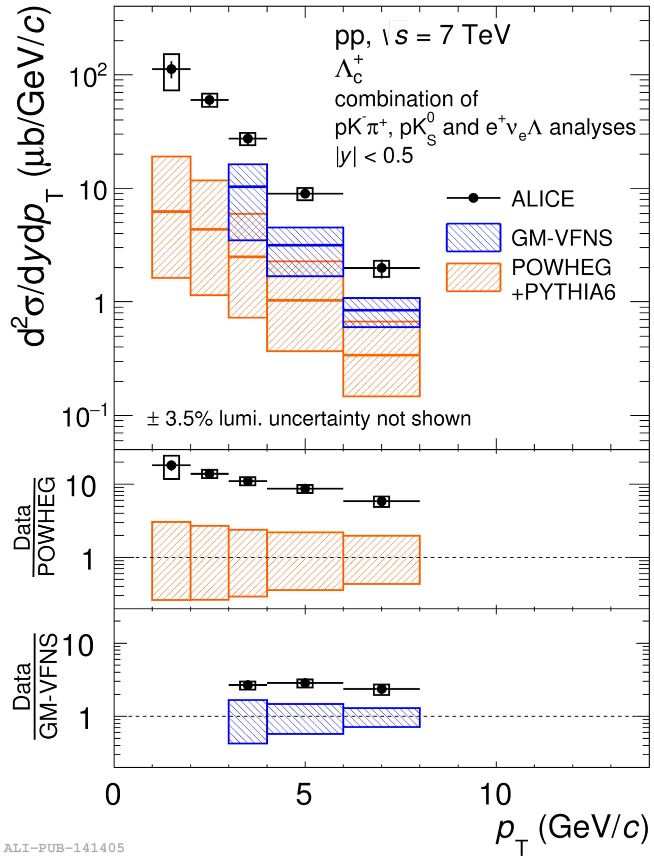


Backup

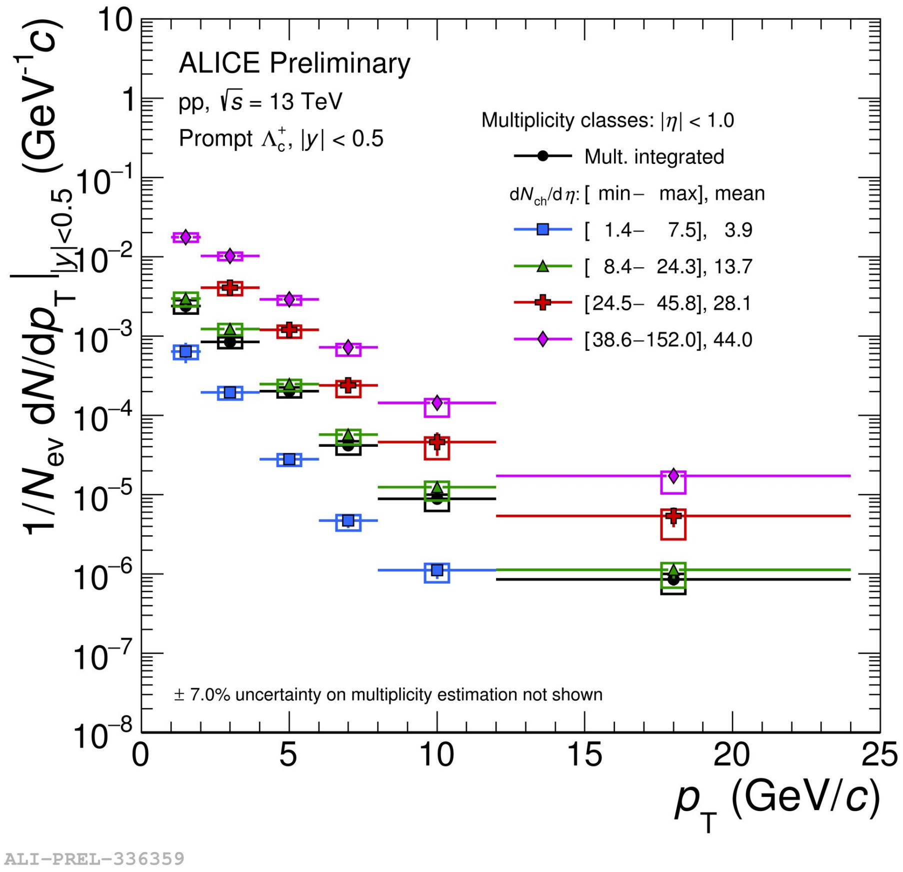
Charmed baryons

Measurements	Mass (MeV/c^2)	Quark content
Λ_c^+	2286	udc
Ξ_c^+	2467	usc
Ξ_c^0	2471	dsc
Σ_c^0, Σ_c^{++}	2455	uuc, ddc

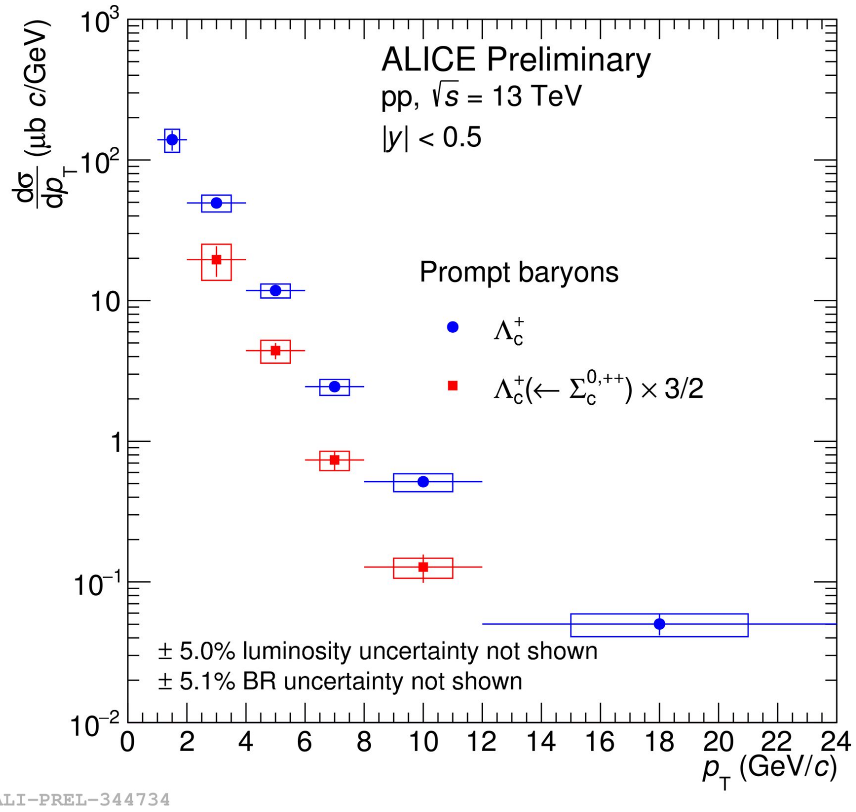
Λ_C^+ production vs models (Run1)



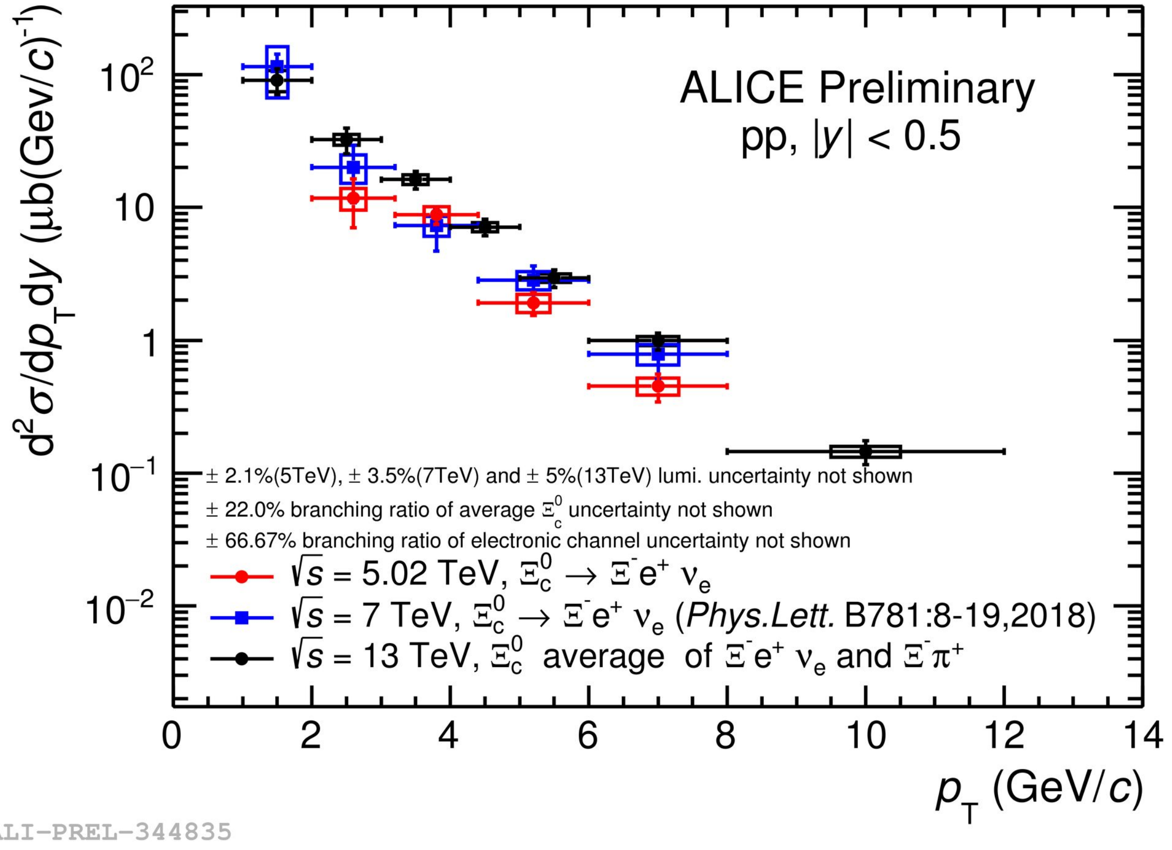
Λ_C^+ production vs multiplicity (13TeV pp)



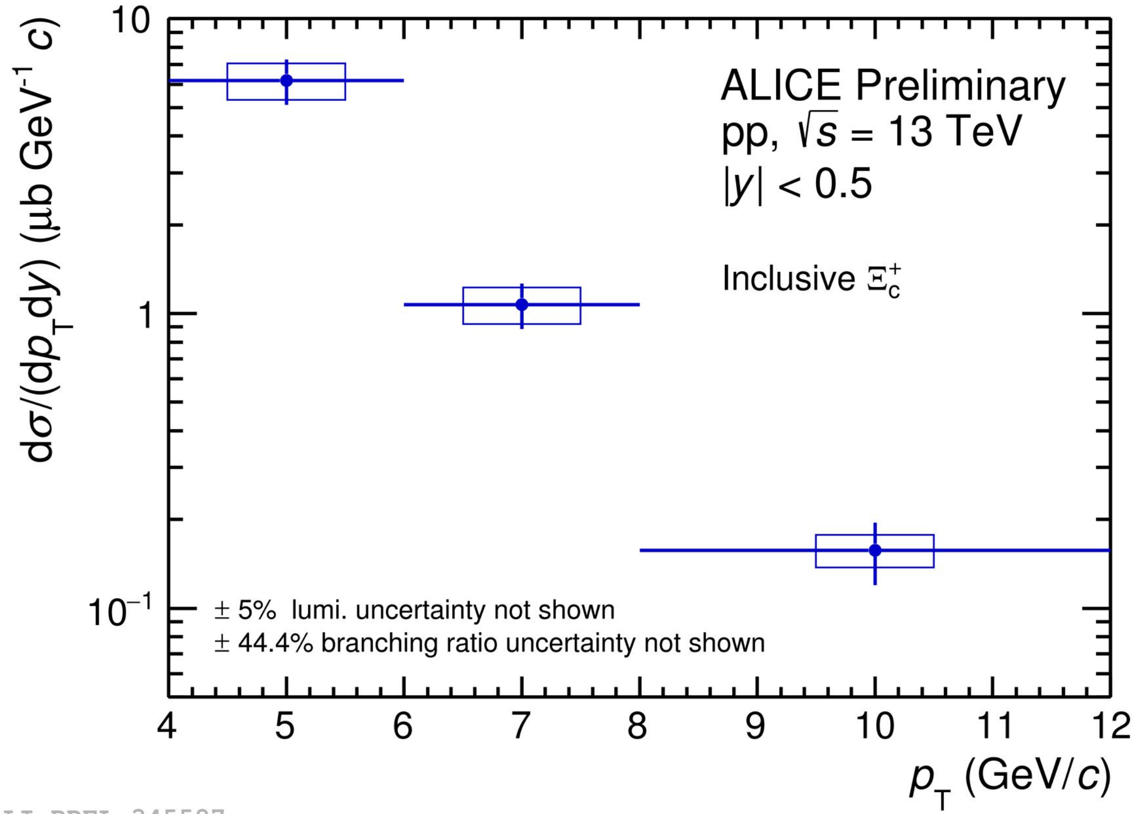
Λ_c^+ vs $\Lambda_c^+(\leftarrow\Sigma_c^{0,++})$ (13TeV pp)



Ξ_C^0 production (5, 7and 13TeV pp)



Ξ_C^+ production (13TeV pp)



ALI-PREL-345587