The 6th China LHC Physics Workshop (CLHCP2020)

Ξ_c^0 and Ξ_c^+ baryon production in pp collisions with ALICE

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Motivation

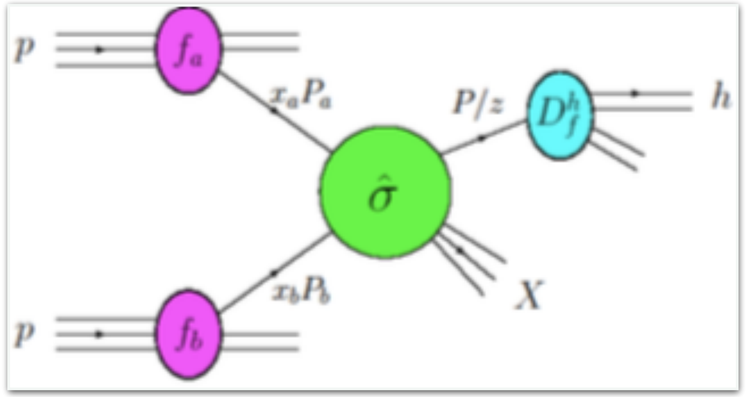
- **Charmed& beauty meson production can be described by factorization:**

$$\frac{d\sigma^{\mathrm{D}}}{dP_{\mathrm{T}}^{\mathrm{D}}}(p_{\mathrm{T}};\mu_{\mathrm{F}};\mu_{\mathrm{R}}) = PDF(x_1,\mu_{\mathrm{F}})PDF(x_2,\mu_{\mathrm{F}}) \otimes \frac{d\sigma^{\mathrm{c}}}{dp_{\mathrm{T}}^{\mathrm{c}}}(x_1,x_2,\mu_{\mathrm{R}},\mu_{\mathrm{F}}) \otimes D_{\mathrm{c}\to\mathrm{D}}(z=p_{\mathrm{D}}/p_{\mathrm{c}},\mu_{\mathrm{F}})$$

initial state parton distribution function

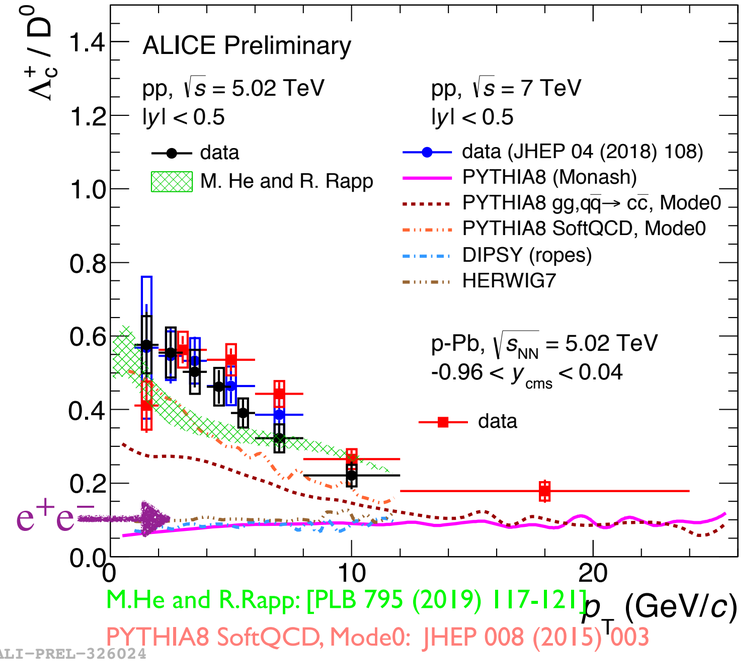
pQCD parsonic cross section

hadronization by fragmentation



- **The importance of studying charm hadrons in all collision systems**
  - pp: test ground for perturbative QCD calculations
  - p-Pb: cold nuclear matter effects
  - Pb-Pb: modification of hadronization mechanism in the medium
- **Heavier charmed-baryon measurement**
  - Possible enhancement due to strange component
  - Needed for total charm cross section
- **Charmed baryon-to-meson ratio sensitive to hadronization mechanism**

Motivation



M.He and R.Rapp: [PLB 795 (2019) 117-121]

PYTHIA8 SoftQCD, Mode0: JHEP 008 (2015) 003

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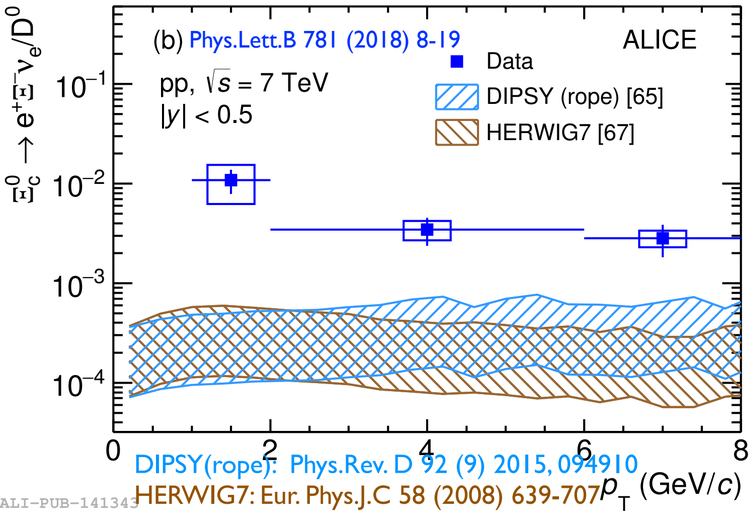


DIPSY(rope): Phys.Rev. D 92 (9) 2015, 094910

HERWIG7: Eur. Phys.J.C 58 (2008) 639-707

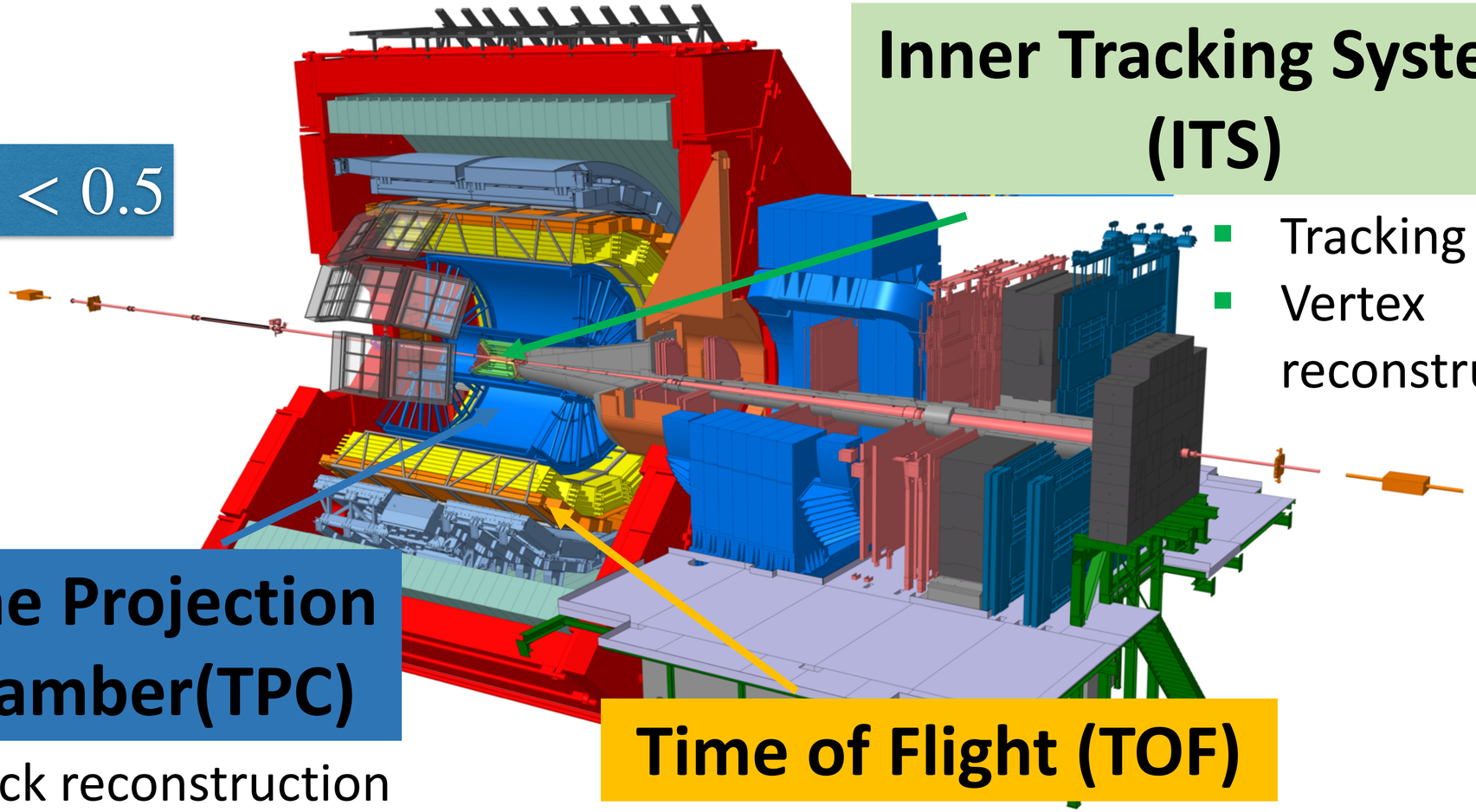
ALI-PUB-141343

- Charmed baryon-to-meson ratio in pp and p-Pb collisions at LHC **higher** than the predictions from MC generators tuned to e^+e^- measurement
- Two models close to data in Λ_c^+/D^0
  - M.He and R.Rapp: feed-down from augmented set of charm-baryon states
  - PYTHIA8 SoftQCD, Mode0: PYTHIA8 with string formation beyond leading color approximation
- Calculations from QCD-inspired models like PYTHIA8 with Monash tune, DIPSY(rope), and HERWIG7 **underestimate** both Λ_c^+/D^0 and Ξ_c^0/D^0

ALICE detector

Ξ_c^0, Ξ_c^+

mid-rapidity $|y| < 0.5$



Inner Tracking System (ITS)

- Tracking
- Vertex reconstruction

Time Projection Chamber(TPC)

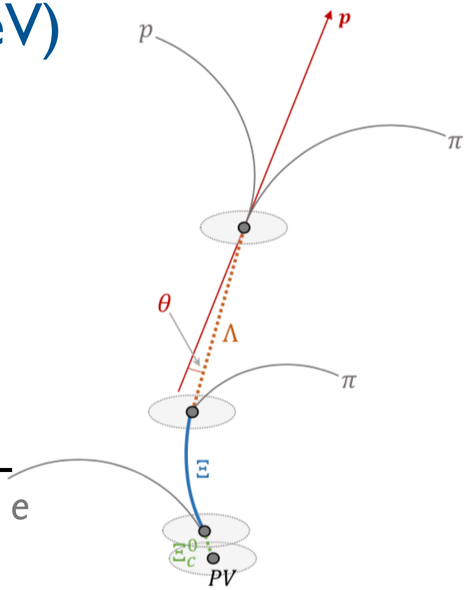
- Track reconstruction
- PID ($\mathrm{d}E/\mathrm{d}x$)

Time of Flight (TOF)

- PID (time-of-flight)

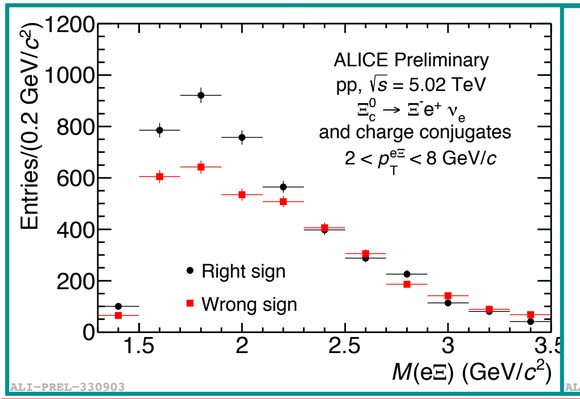
Charm-baryon analysis

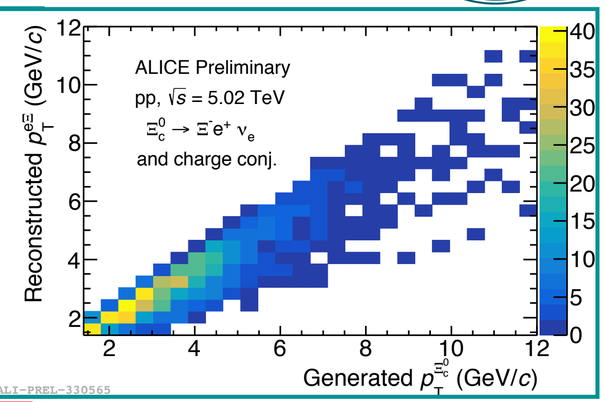
- **Semi-leptonic decays:**
  - $\Xi_c^0 \rightarrow e^+\Xi^-\nu_e$ (5 & 7 &13 TeV)

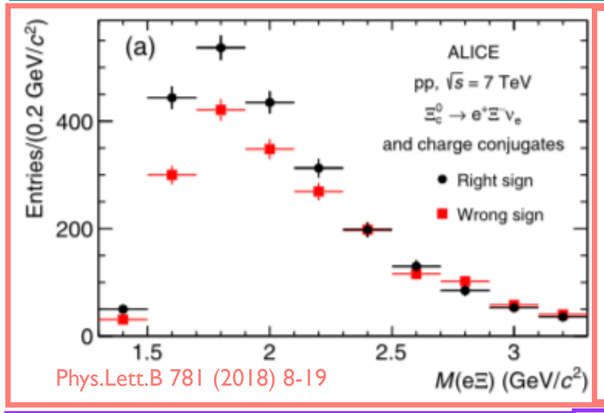


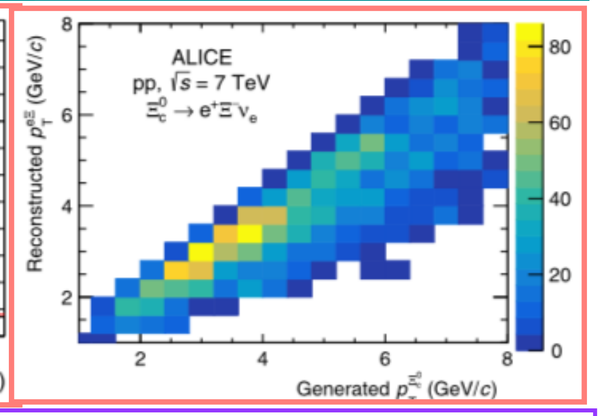
Analysis strategy:

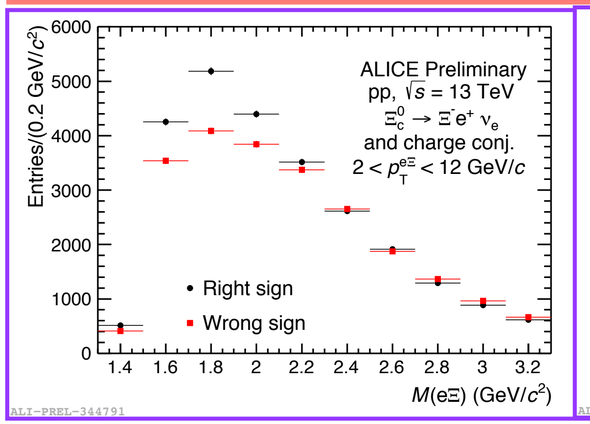
- PID and topological selections
- Signal extraction via (Right-Sign – Wrong-Sign)
- Unfolding method (convert $p_{\mathrm{T}}^{e\Xi}$ into $p_{\mathrm{T}}^{\Xi_c^0}$)
- Acceptance x efficiency correction

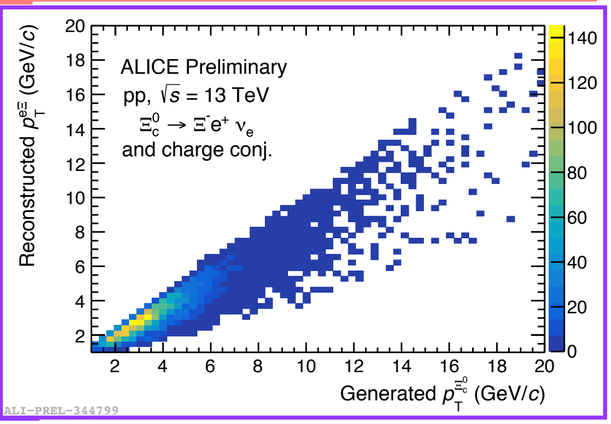






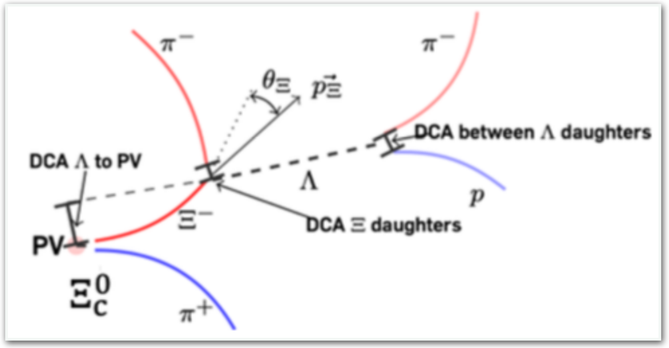






Charm-baryon analysis

- **Hadronic decays:**
  - $\Xi_c^0 \rightarrow \Xi^-\pi^+$ (13 TeV)

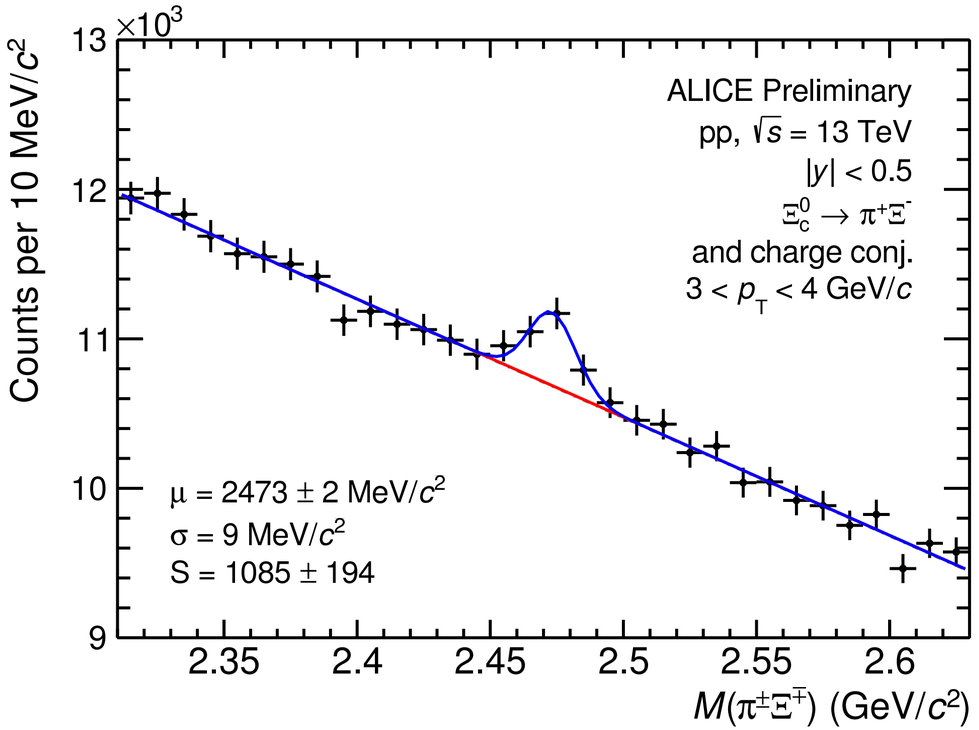


- Short-lived particle:
  - Topological cuts are not available
  - KF particle is used for reconstruction

(KFParticle Vertexing Package more details in backup)

Analysis strategy:

- Select $\pi^{\pm}$ and $\Xi^{\mp}$ (pre-selections)
- $\Xi^{\mp}$ reconstruction with KF
- Signal extraction via invariant mass analysis
- Selection optimized with ML (Boosted Decision Tree (BDT) algorithm)
- Acceptance x efficiency correction



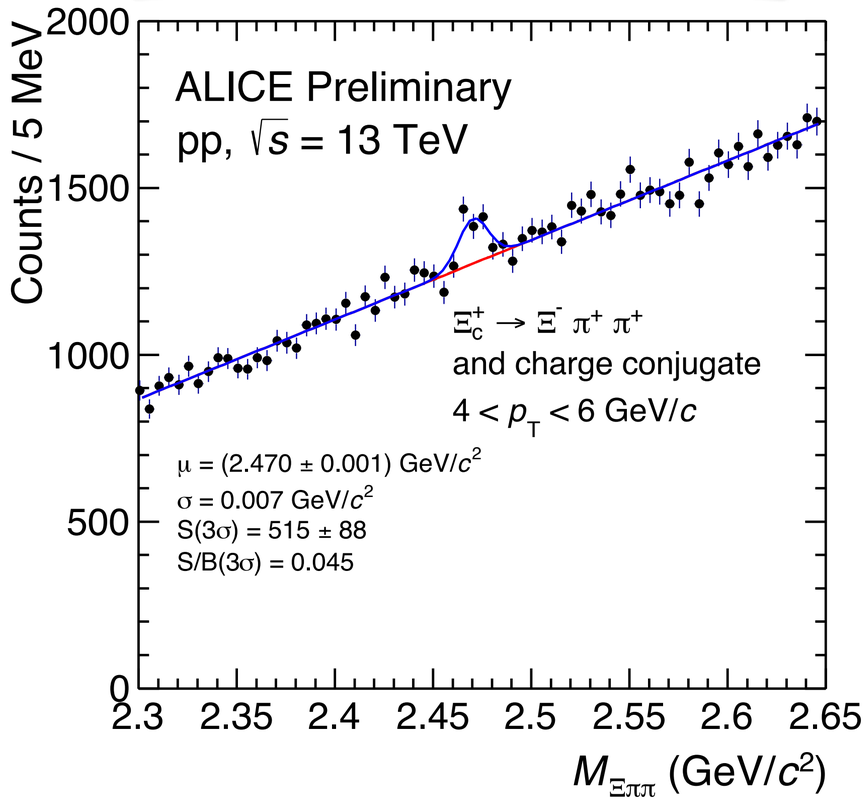
Charm-baryon analysis

- **Hadronic decays:**
  - $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ (13 TeV)

	Ξ_c^+ (usc)
Mass (MeV/c^2)	2467.93±0.18
Life time (μm)	132
Decay channel	$\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ [BR=(2.86±1.21±0.38)%]* *[Phys. Rev. D 100, 031101

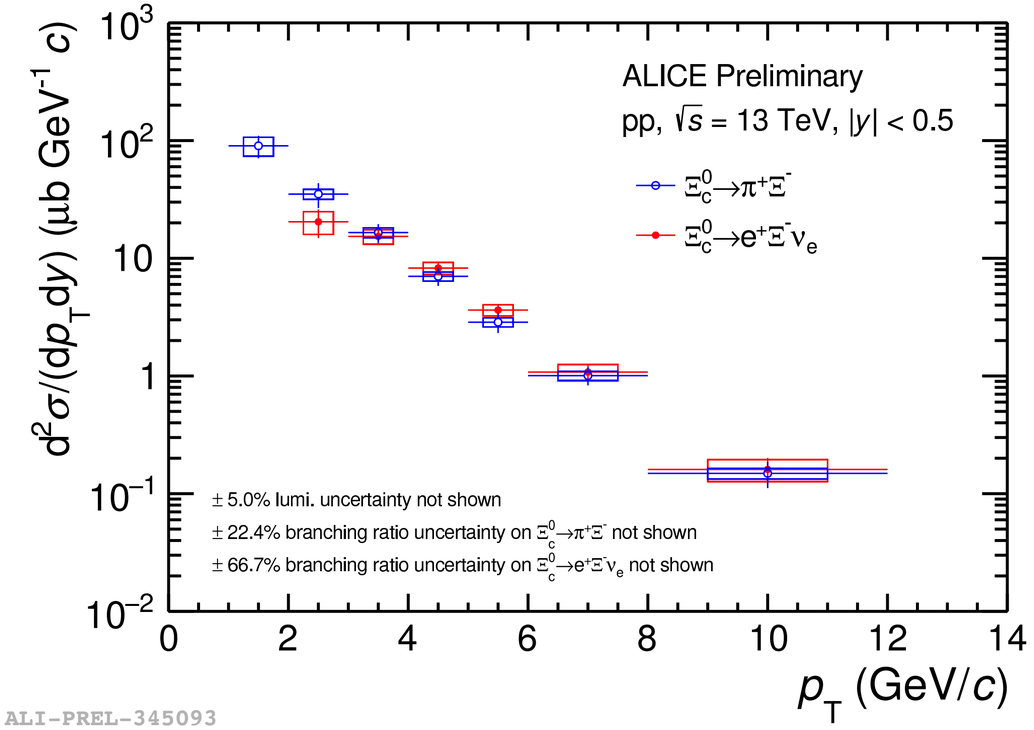
Analysis strategy:

- Select $\pi^{\pm}$ and $\Xi^{\mp}$ (pre-selection)
- Combine the Cascade with the charged tracks
- Reconstruct secondary vertex of two selected π
- Signal extraction via invariant mass analysis
- Acceptance x efficiency correction



$\mathrm{BR}(\Xi_c^0 \to e^+\Xi^-\nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^-\pi^+)$

Average of e/h ratio vs p_T used to estimate BR ratio



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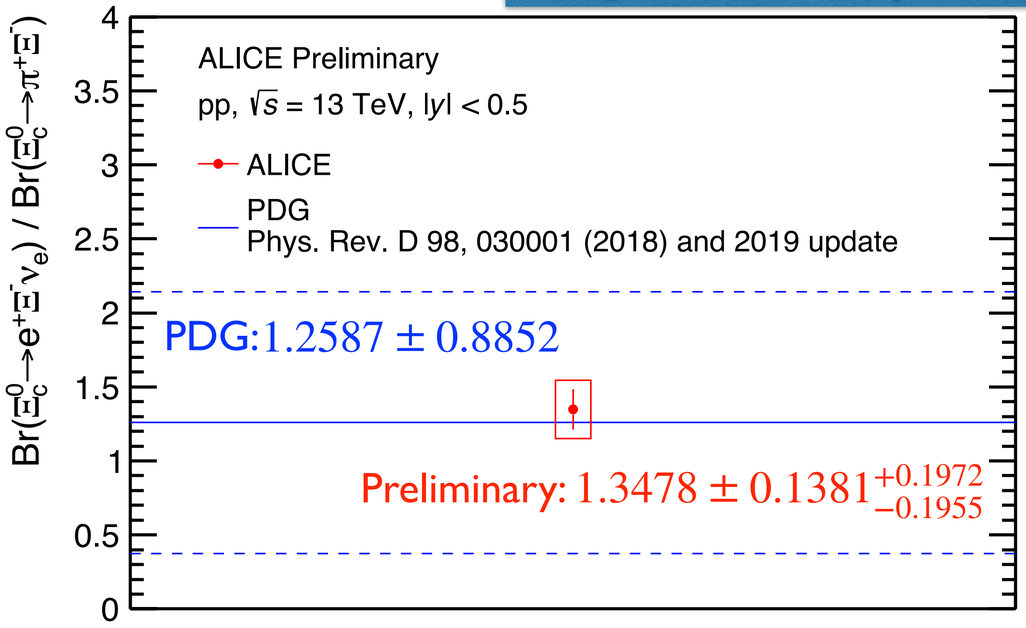


ALI-PREL-345624

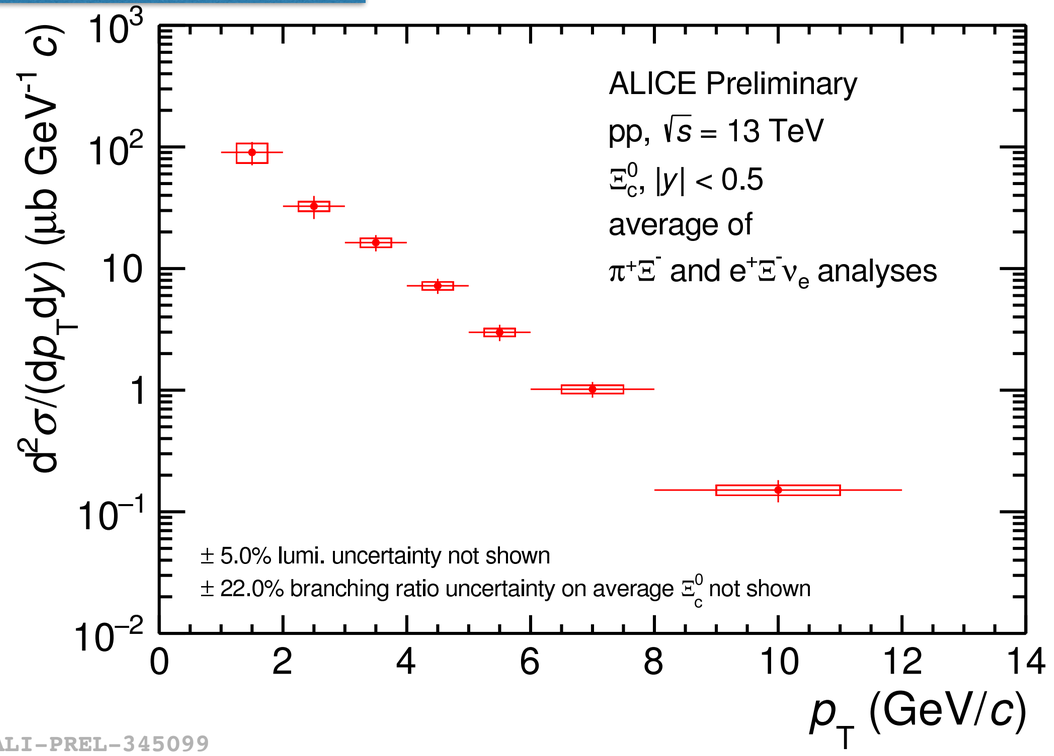
- First measurement of ratio of semi-leptonic and hadronic decay with ALICE
- The final syst. value on the ratio:
  - Summing in quadrature of relative statistic and relative p_T uncorrelated systematic uncertainties
- $\mathrm{Br}(\Xi_c^0 \to e^+\Xi^-\nu_e)/\mathrm{Br}(\Xi_c^0 \to \Xi^-\pi^+)$:
  - ~4 times smaller uncertainty w.r.t. PDG value

$\mathrm{Br}(\Xi_c^0 \to e^+\Xi^-\nu_e, \mathrm{PDG}) = (1.8 \pm 1.2)\,\%$

$\mathrm{Br}(\Xi_c^0 \to \Xi^-\pi^+, \mathrm{PDG}) = (1.43 \pm 0.32)\,\%$

Ξ_c^0 cross section production

Weighted average cross section



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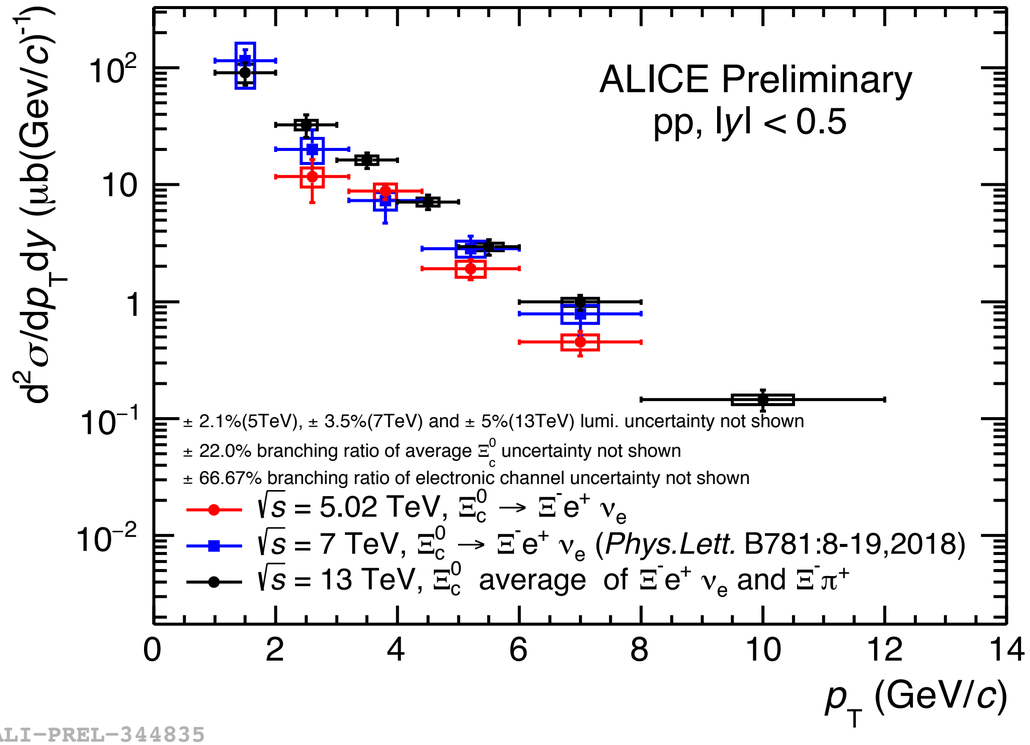
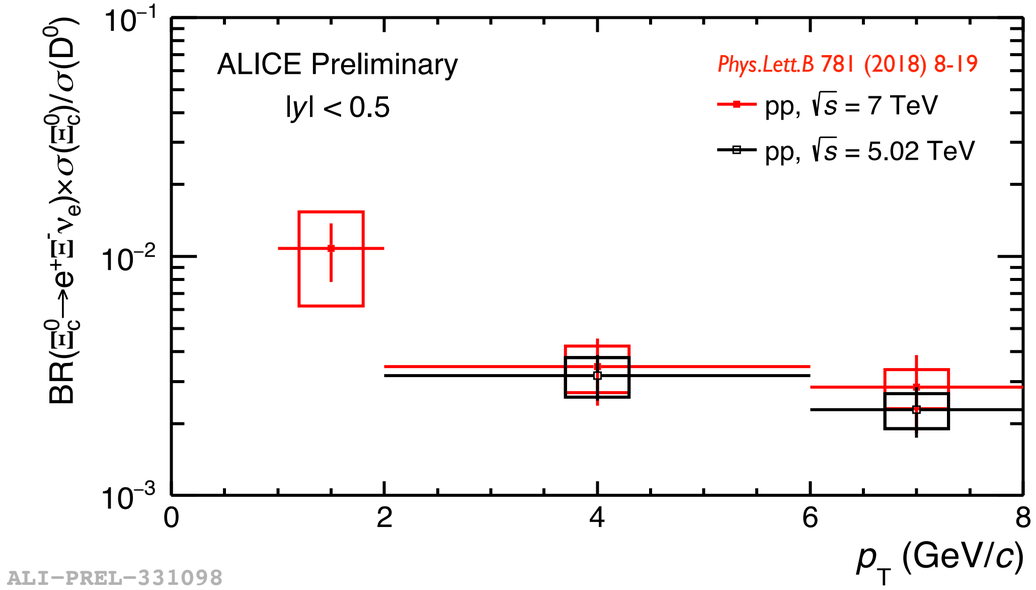


ALI-PREL-344835

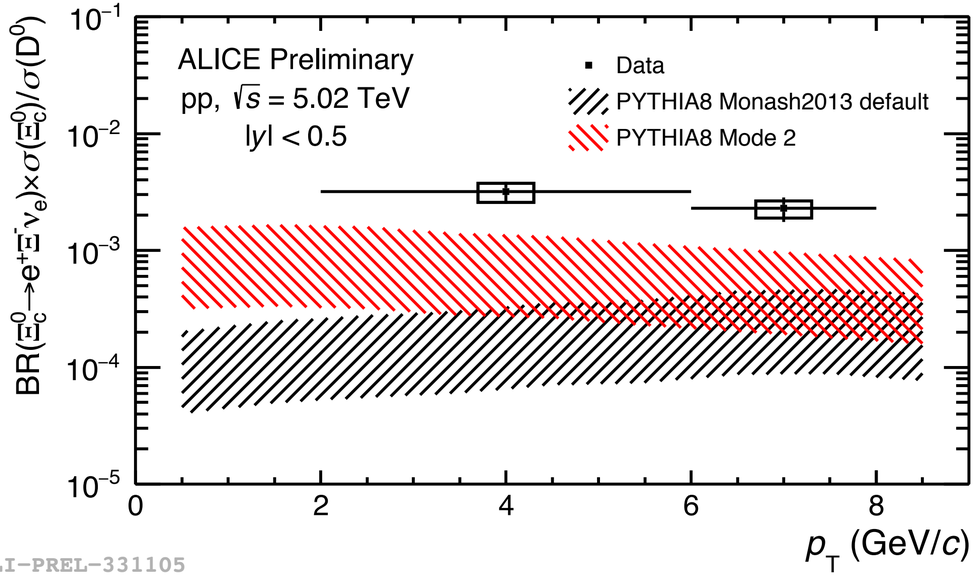
- More precise measurement of Ξ_c^0 is obtained by combining the two decay channels
- Weights:

  the inverse of the quadratic sum of the relative statistical and uncorrelated systematic uncertainties
- More differential measurements are shown

Ξ_c^0/D^0 in pp collisions at 5&7 TeV

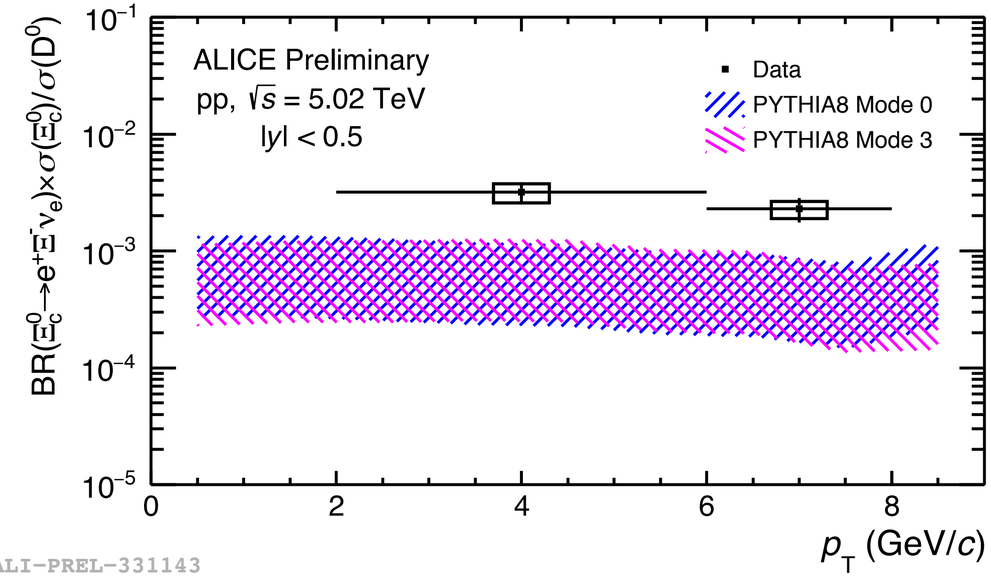


ALI-PREL-331098



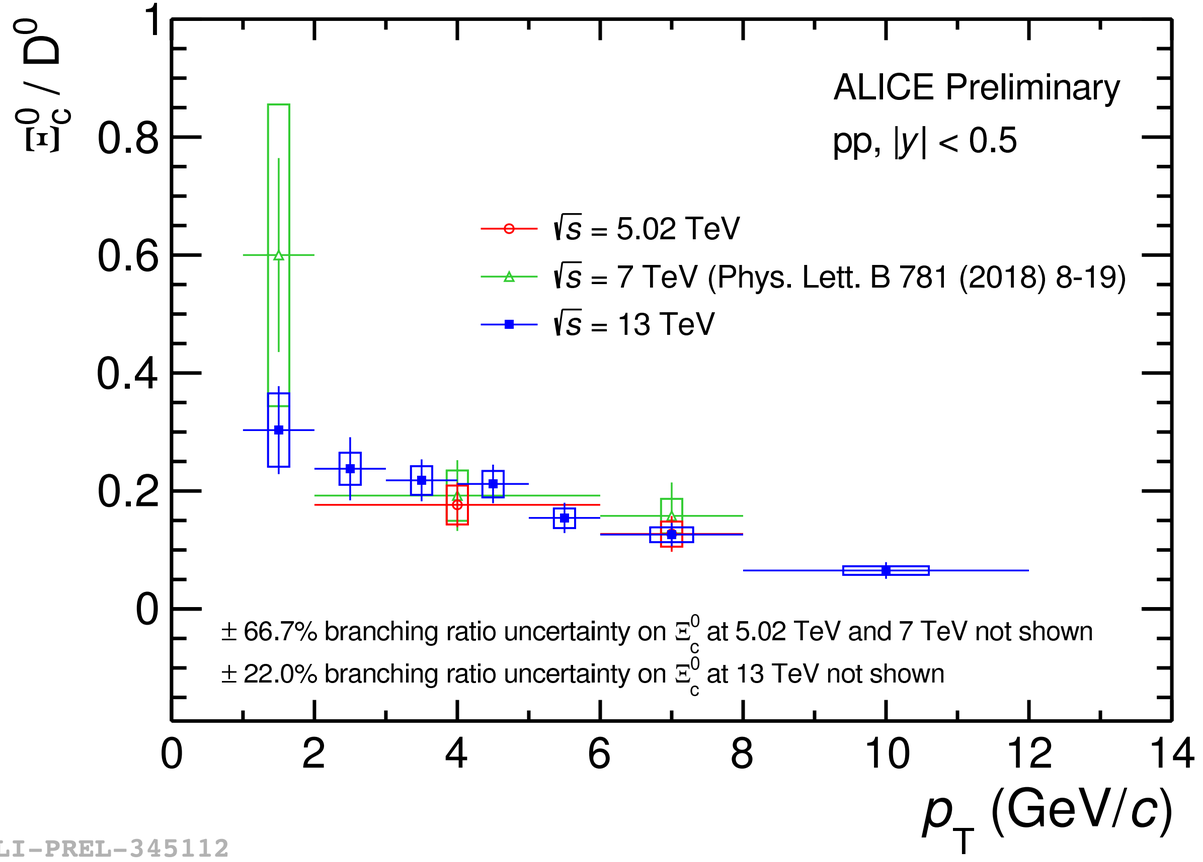
ALI-PREL-331105

- The ratio at 5 and 7 TeV are fully compatible
- PYTHIA8 with various tunes also underestimated the measured ratio at 5 TeV



ALI-PREL-331143

Ξ_c^0/D^0 in pp collisions at 5&7&13 TeV

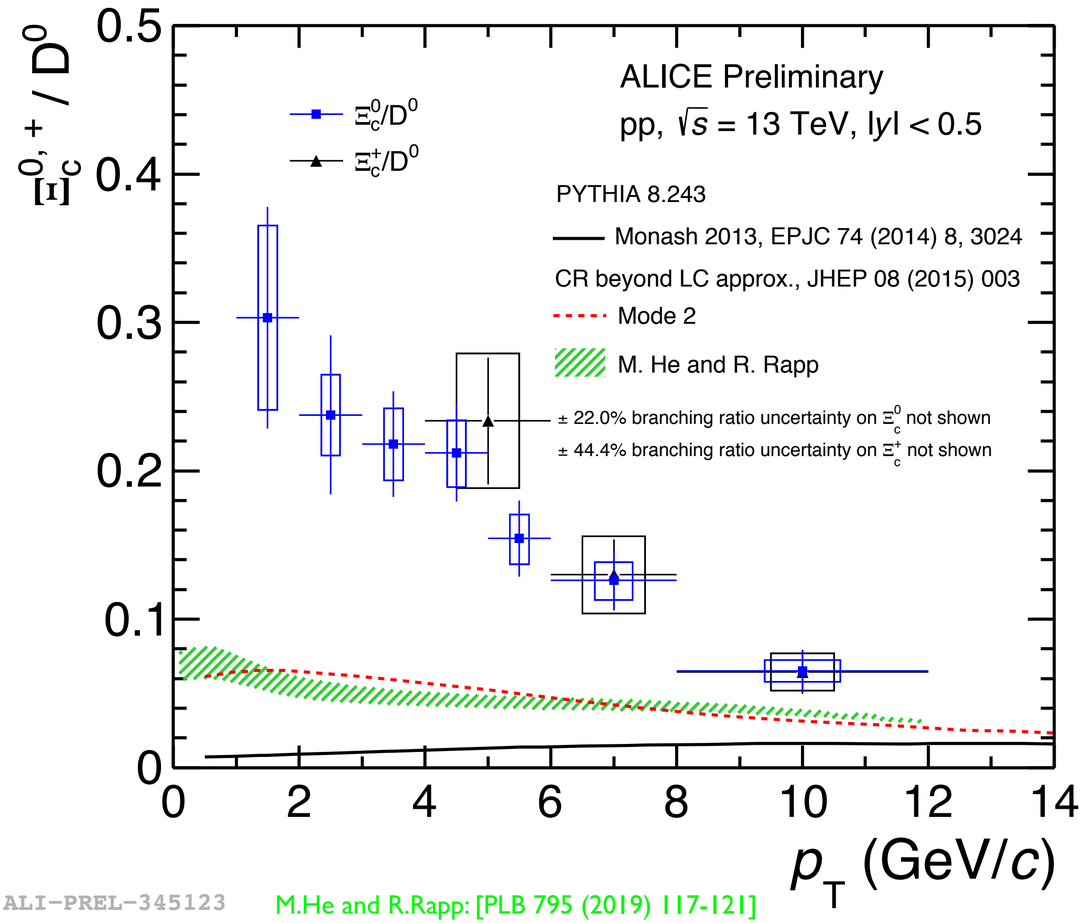


LI-PREL-345112

Ξ_c^0/D^0 :

- Consistent ratios are obtained with different decay channel in different collision energy
  - At low p_T, the ratio value is about 0.2
  - At high p_T, the ratio value is about 0.1

$\Xi_c^{0,+}/D^0$ in pp collisions at 13 TeV



ALI-PREL-345123

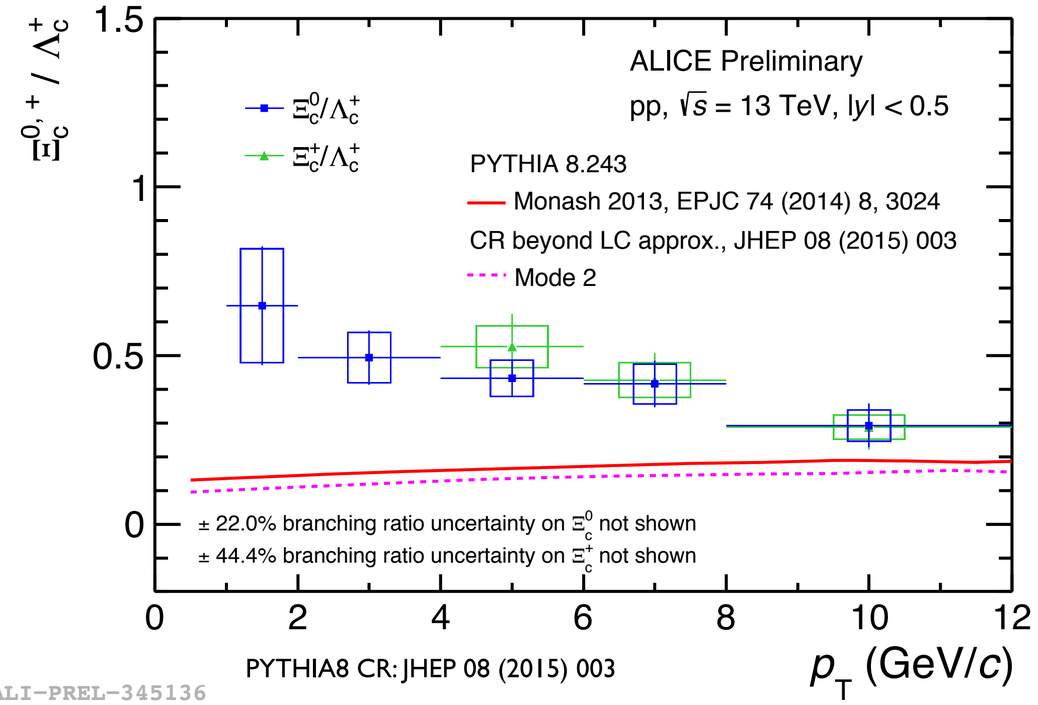
M.He and R.Rapp: [PLB 795 (2019) 117-121]

PYTHIA8 CR: JHEP 08 (2015) 003

$\Xi_c^{0,+}/D^0$:

- First measurement of Ξ_c^0 and Ξ_c^+ production via hadronic decay channel at LHC
- Observed enhanced $\Xi_c^{0,+}$ production in pp collisions
- Underestimated by PYTHIA8 with CR& M.He and R.Rapp
- More constraints on the microscopic description of the enhancement

$\Xi_c^{0,+}/\Lambda_c^+, \Sigma_c^{0,+,++}/\Xi_c^{0,+}$ in pp collisions

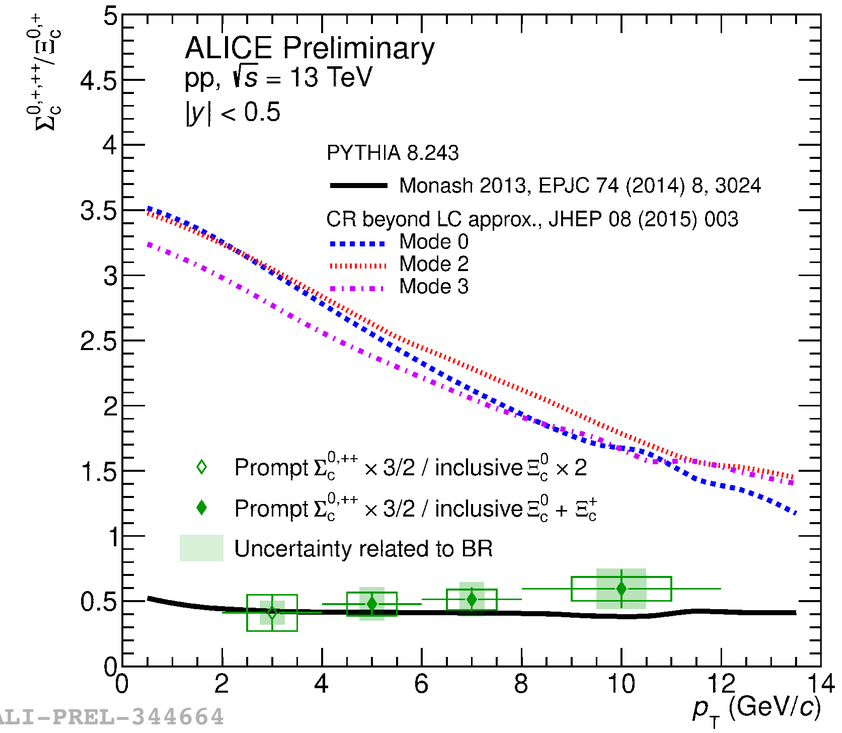


$\Xi_c^{0,+}/\Lambda_c^+$:

- The ratio is about 0.5 with a mild p_T dependence
- None of the modes reported are able to describe the ratio

$\Sigma_c^{0,+,++}/\Xi_c^{0,+}$:

- Overestimated by PYTHIA8 with CR
- Described by PYTHIA8 Monash (why?)



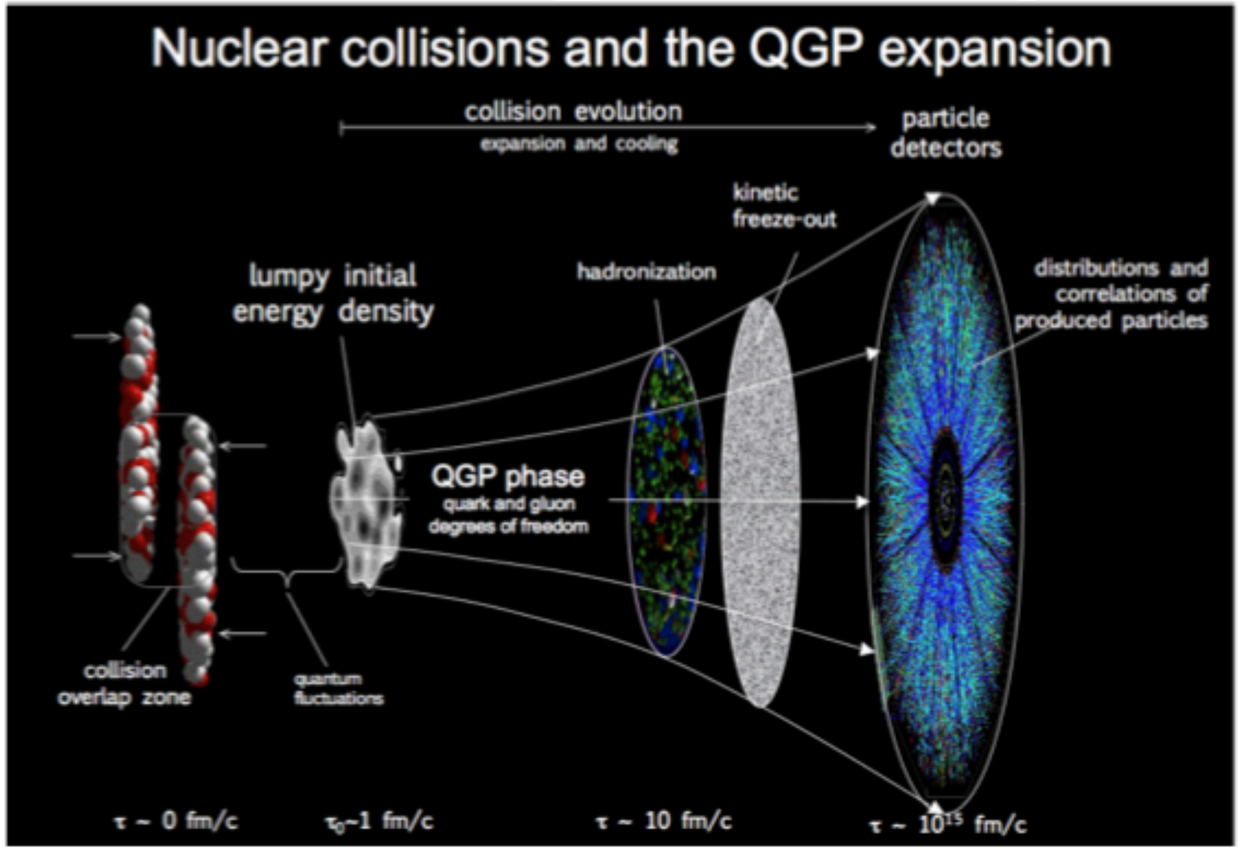
Summary

- The measurement of $\Xi_c^{0,+}$
  - Check universality of charm fragmentation in hadronic collision at LHC
  - Stringent constraints on models of charm quark hadronic hadronisation in pp collisions
- PYTHIA8 with CR beyond LC and SHM with augmented set of charm-baryon states does not describe $\Xi^{0,+}/D^0$ well
- **First measurement** of ratio of semi-leptonic and hadronic decay with ALICE and smaller uncertainty w.r.t. PDG value

THANK YOU!

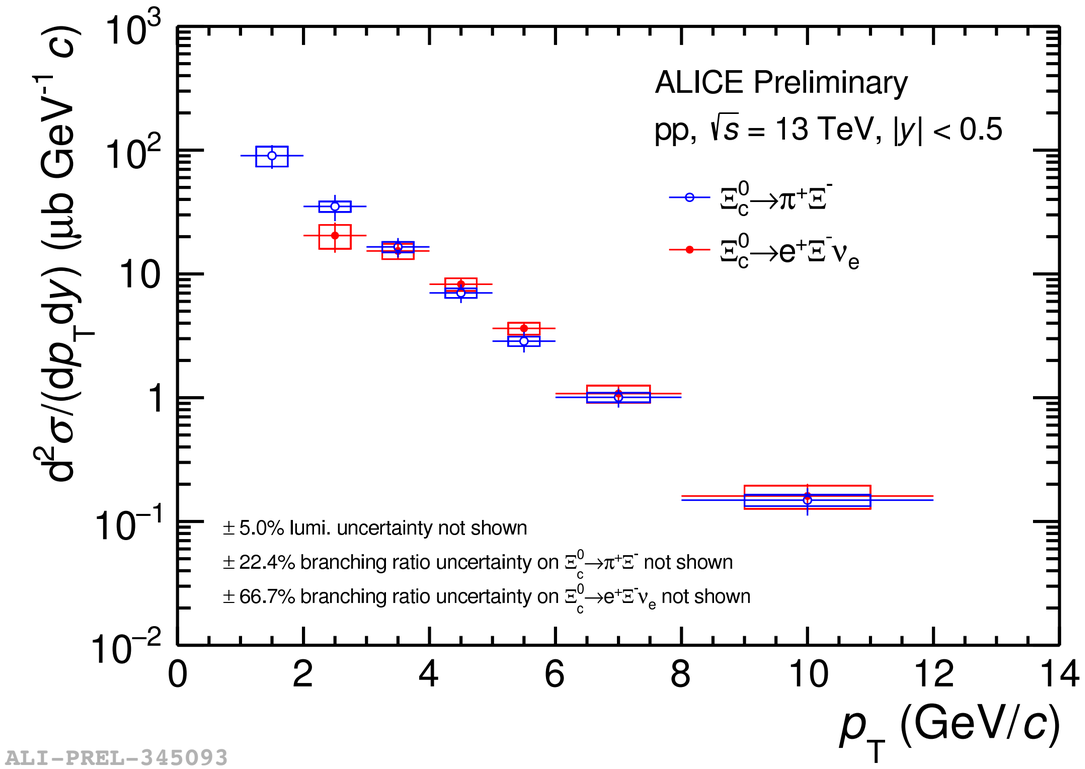
BACKUP SLIDES

Heavy quarks through a heavy-ion collision



- **Initial hard scatterings**
  - nPDFs
  - Cold nuclear effects
- **Pre-euqilibrium**
  - Time to equilibration
  - Pre-equilibrium energy loss
  - Magnetic field
- **QGP evolution**
  - Hydro model
  - Transport coefficients
- **Freeze-out**
  - Fragmentation
  - Coalescence effects
  - Hadrochemistry
- **Hadronic phase**
  - Diffusion through hadronic phase

Ξ_c^0 cross section production



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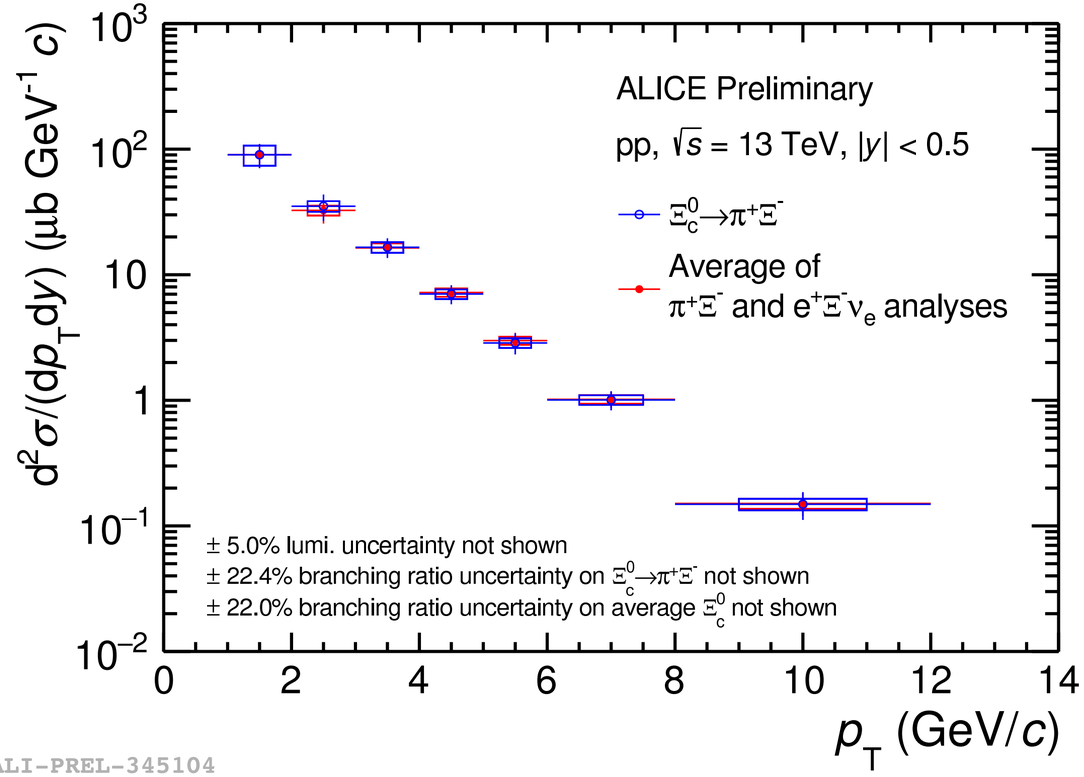

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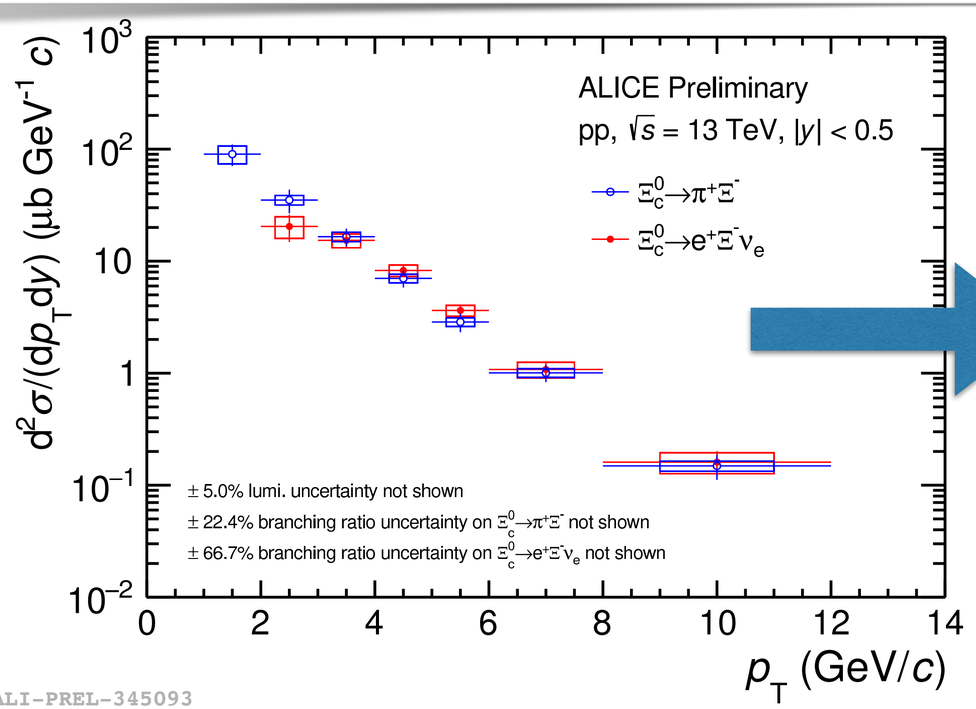
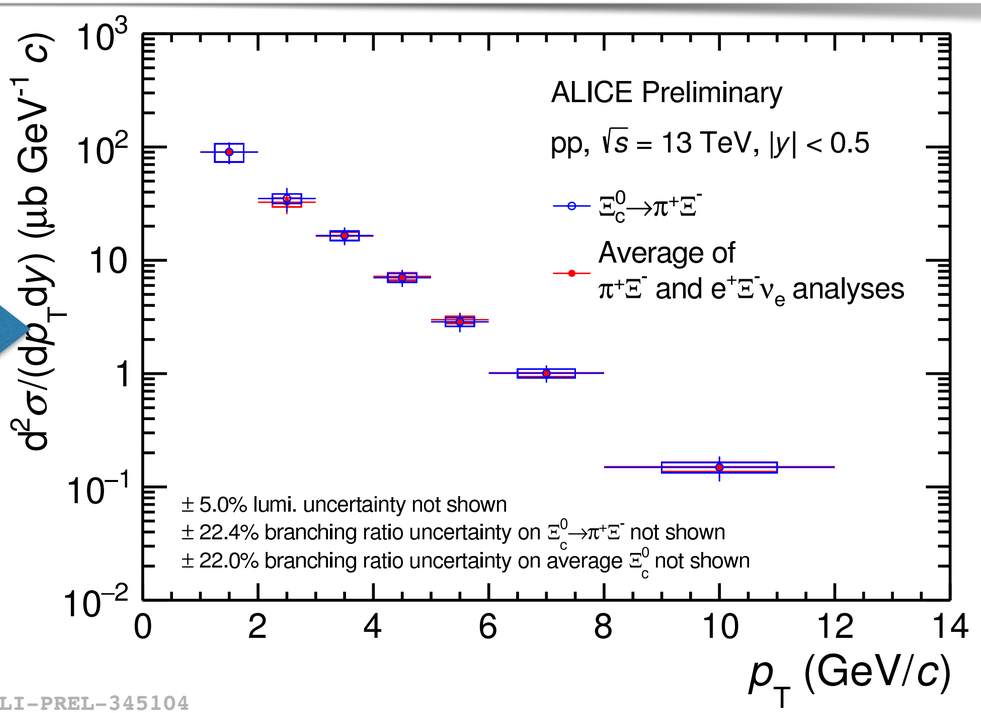
Merged cross section(hadronic and electronic)

- Merged measurement by hadronic decay and electronic decay
  - Include systematic of BR only in the weight

$$w_i^{uncorr} = \sqrt{(\frac{\sigma_i^{stat}}{N_i})^2 + (\frac{\sigma_i^{uncorr.\ syst}}{N_i})^2} \qquad < N > = \frac{N_h * \frac{1}{w_h^2} + N_e * \frac{1}{w_e^2}}{\frac{1}{w_h^2} + \frac{1}{w_e^2}} \qquad < \sigma_{stat} > = \frac{\sqrt{(\sigma_h^{stat} * \frac{1}{w_h^2})^2 + (\sigma_e^{stat} * \frac{1}{w_e^2})^2}}{\frac{1}{w_h^2} + \frac{1}{w_e^2}} \qquad < \sigma_{syst} > = \frac{\sqrt{(\sigma_h^{syst} * \frac{1}{w_h^2})^2 + (\sigma_e^{syst} * \frac{1}{w_e^2})^2}}{\frac{1}{w_h^2} + \frac{1}{w_e^2}}$$





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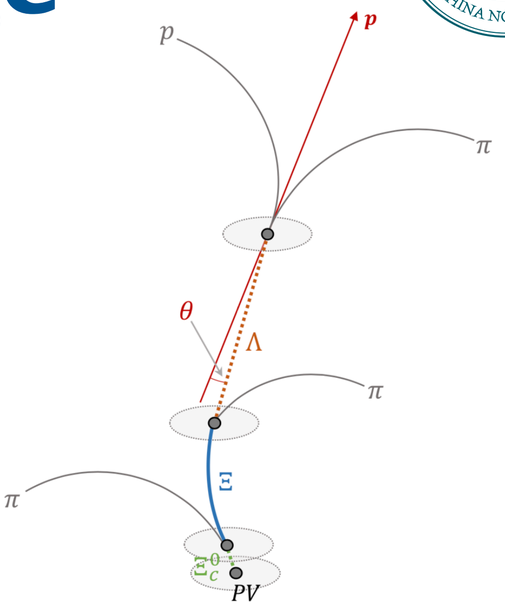
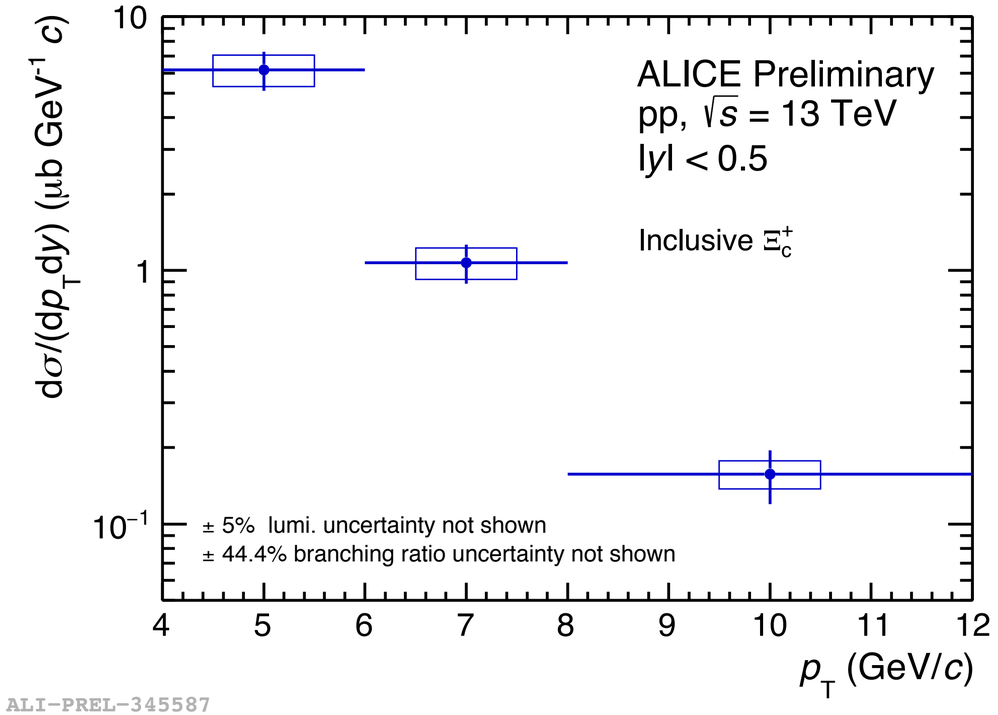
KFParticle Vertexing Package

- **Kalman Filter**
  - State Vector $\mathbf{r}^{\mathrm{T}} = (\mathbf{x}, \mathbf{y}, \mathbf{z}, \mathbf{p_x}, \mathbf{p_y}, \mathbf{p_z}, \mathbf{E}, \mathbf{s})$
  - Covariance Matrix $\mathbf{C} = \mathbf{Cov}(\mathbf{r})$
- **KFParticle**
  - Mother and daughter particle have same state vector
  - Take into account track uncertainties
  - Allows to move tracks to make them converge to certain vertex
  - Easy reconstruction of decay trees



- **Variables**
  - χ^2_{geo}: Fit on daughter tracks
  - χ^2_{topo}: Fit on production vertex
  - $l/\Delta l$: Distance between PV and decay vertex in terms of localization error of vertices
  - θ: Pointing Angle

Ξ_c^+ cross section in pp collisions 13 TeV



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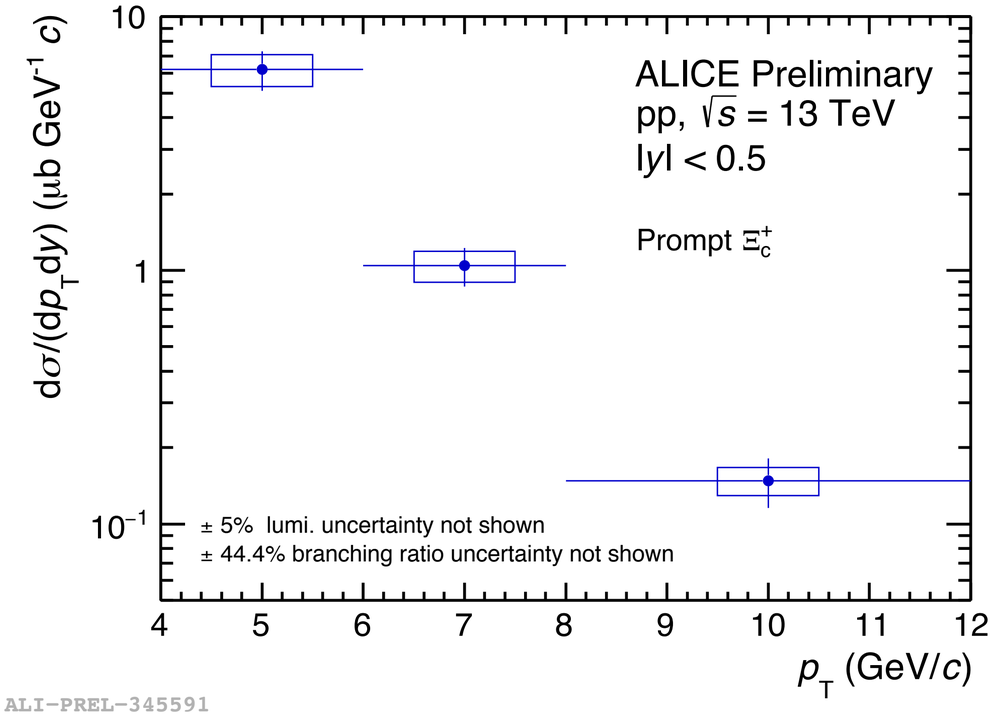

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