Charm baryon production in the future EIC

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Outline

- Motivation
- Simulation set up and Λ_c^+ reconstruction
- Projections of Λ_c^+/D^0 vs p_T and multipicity
- Summary

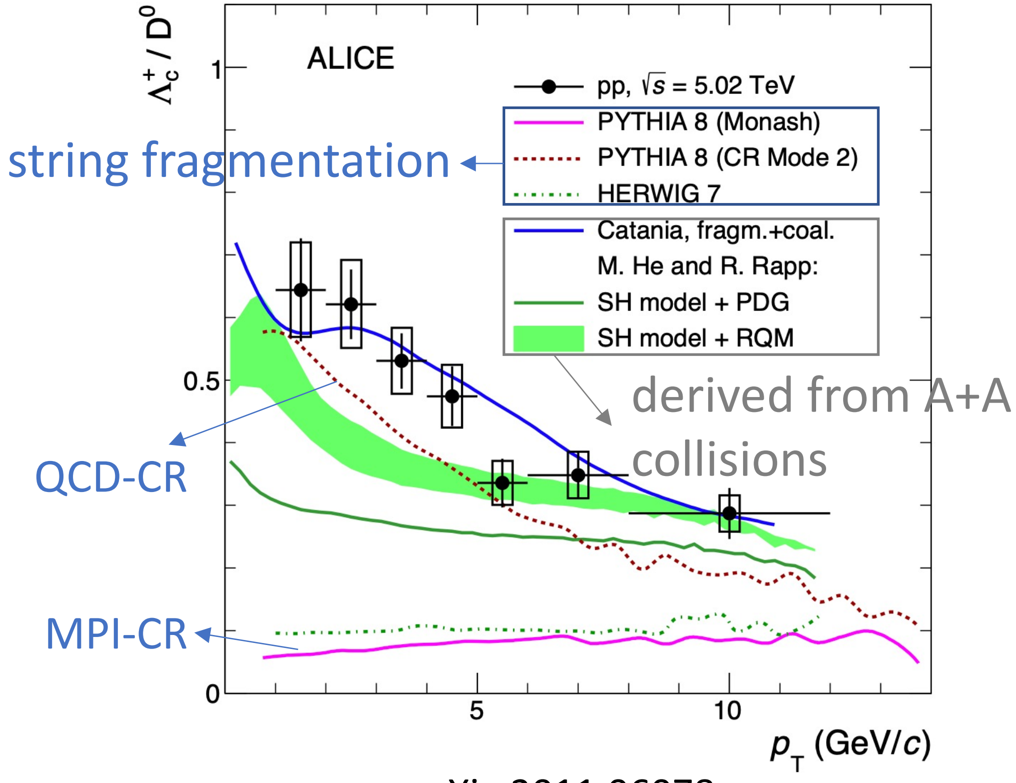
Motivation

initial PDF hard process hadronization

$$\sigma = f_i(x) \otimes \sigma_{hard}^{ij}(x, Q^2) \otimes D_j^h$$

non-perturbative

- Hadronization
  - Heavy quarks: $m_c \gg \Lambda_{QCD}$, pQCD calculable
  - p+p collisions: enhanced Λ_c^+/D^0 ratio w.r.t fragmentation baseline in e^+e^-



arXiv:2011.06078

- Color reconnection (CR):

- between which partons should strings form

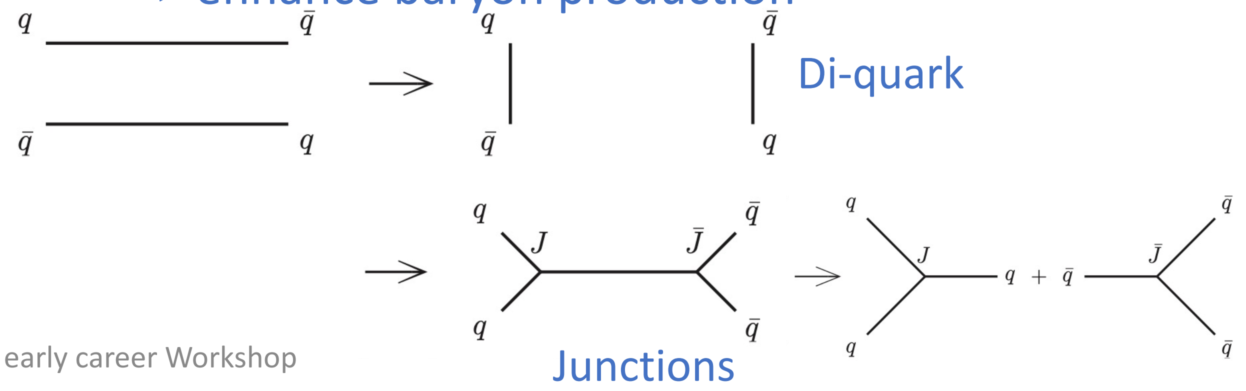
PYTHIA :

- default: MPI-based CR baryon/meson ~ fragmentation
- newer: QCD-based CR JHEP 08:003 (2015)

-> QCD color rule in reconnection possibility

-> introduce junction formation

-> enhance baryon production



Motivation

- $\boldsymbol{\Lambda_c^+}$ measurements in ep collisions in the future EIC
  - limited HF baryon measurements in ep (and pp) currently

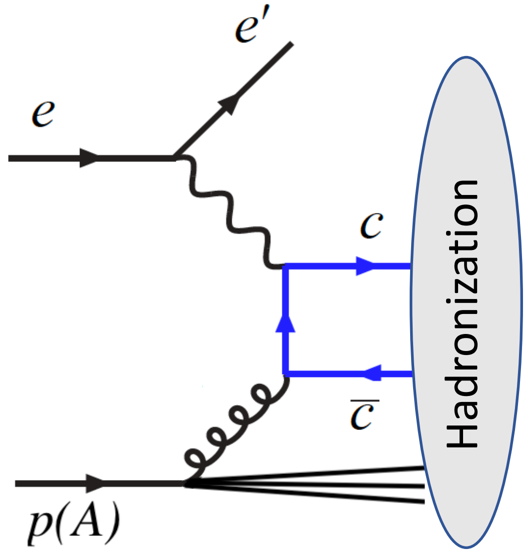
    JHEP 08:003 (2015)

    - probe to relative contribution of diquark- and junction-driven baryon production

      e.g: Σ_c^0 production $\Sigma_c^0 \rightarrow \boldsymbol{\Lambda_c^+}\pi$

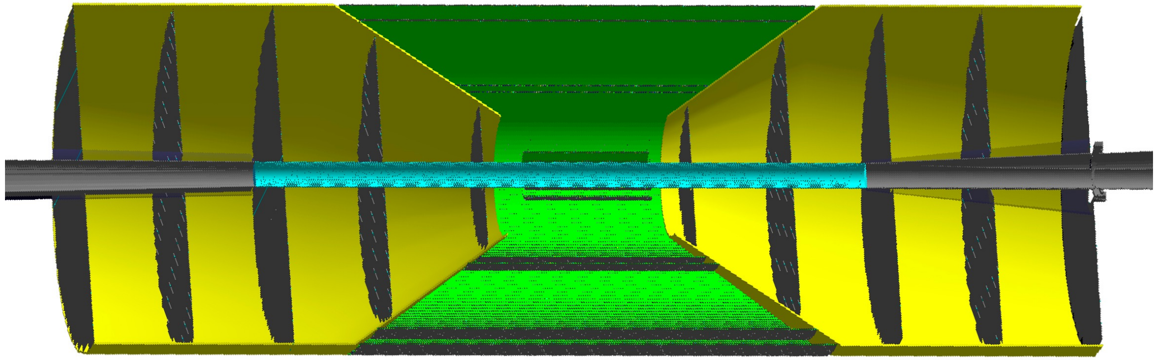
      -> in diquark: dd (spin-1) suppressed relative to ud (spin-0,1) combined with c quark

      -> junction: no special penalty
  - CR expected universal, never tested in ep
  - clean initial condition in ep(A)



All silicon tracking detector for EIC

Details of the detector: arXiv:2102.08337



All-silicon tracker geometry

Detector set up

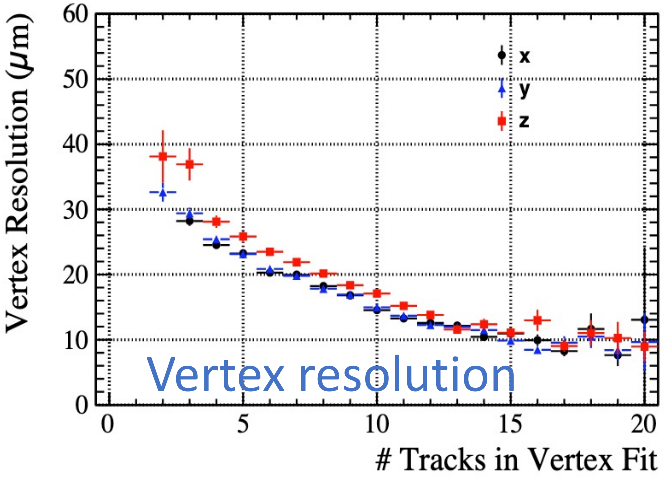
- Pointing resolution
- PID ability
- Momentum resolution with B=3 T
- Primary vertex resolution
- Tracking efficiency

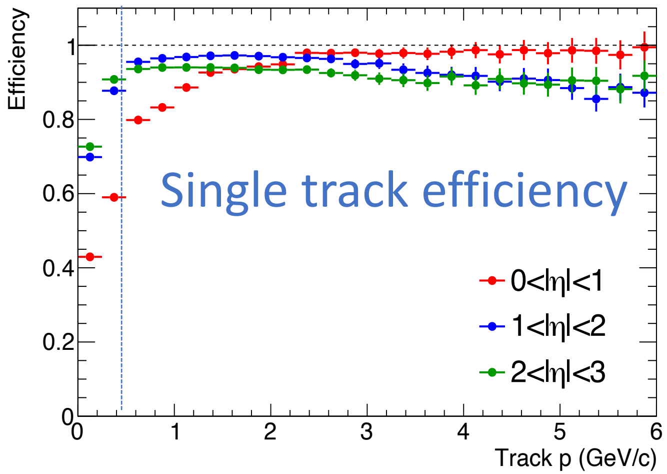
From full Geant4 simulation

Detector performance

η	σ_p/p - 3T (%)	$\sigma(\mathrm{DCA}_{r\phi})$ (μm)	$p_{\mathrm{max}}^{\mathrm{PID}}$ (GeV/c)
(-3.0,-2.5)	$0.1{\cdot}p \oplus 2.0$	$60/p_T \oplus 15$	10
(-2.5,-2.0)	$0.02{\cdot}p \oplus 1.0$	$60/p_T \oplus 15$	10
(-2.0,-1.0)	$0.02{\cdot}p \oplus 1.0$	$40/p_T \oplus 10$	10
(-1.0,1.0)	$0.02{\cdot}p \oplus 0.5$	$30/p_T \oplus 5$	6
(1.0,2.0)	$0.02{\cdot}p \oplus 1.0$	$40/p_T \oplus 10$	50
(2.0,2.5)	$0.02{\cdot}p \oplus 1.0$	$60/p_T \oplus 15$	50
(2.5,3.0)	$0.1{\cdot}p \oplus 2.0$	$60/p_T \oplus 15$	50

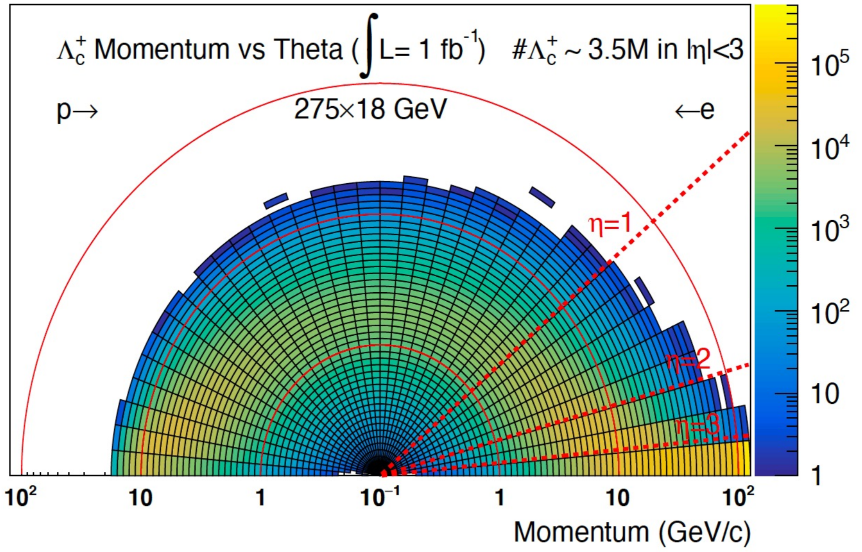
https://physdiv.jlab.org/DetectorMatrix/

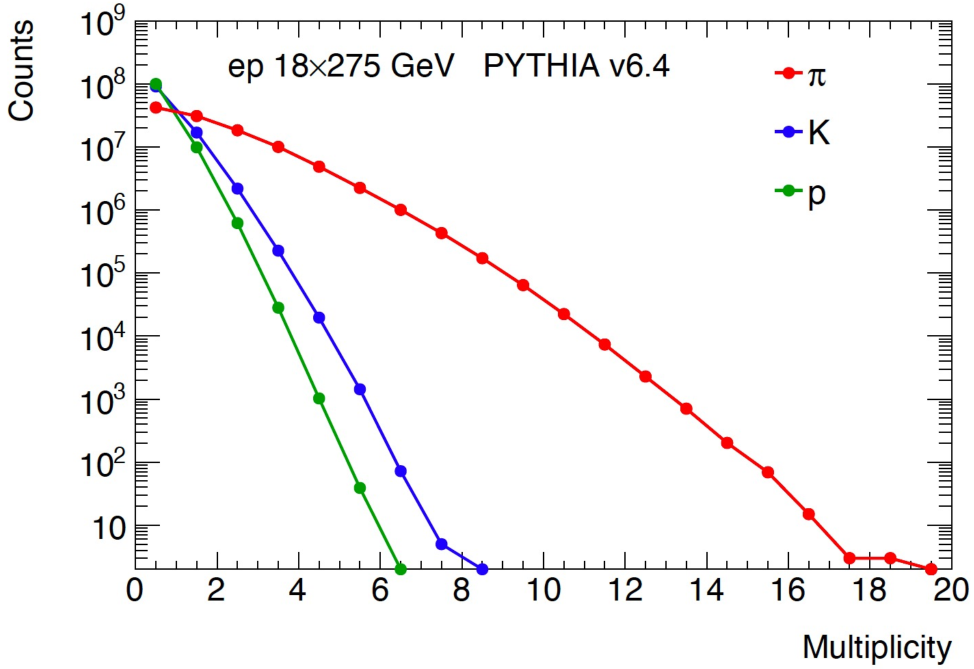


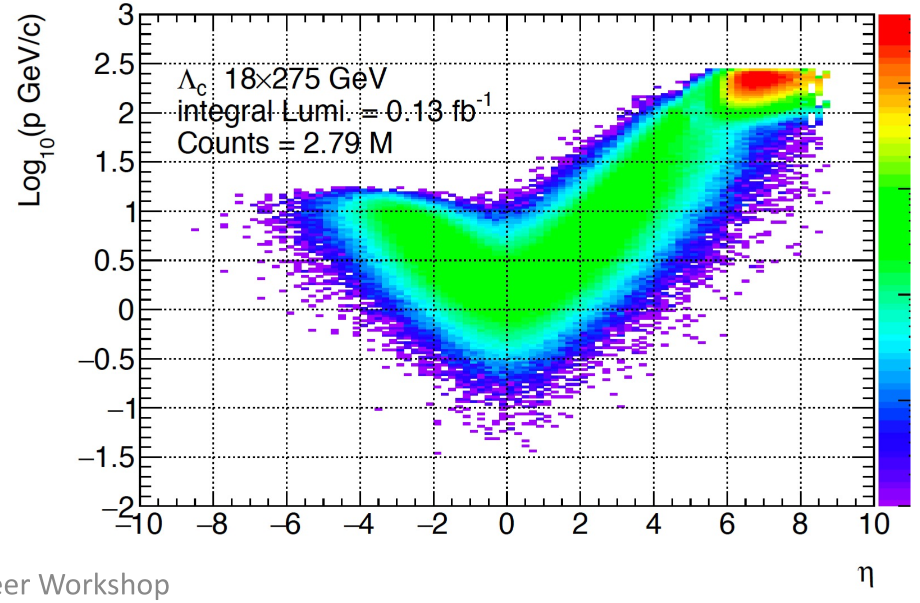


Event simulation and acceptance

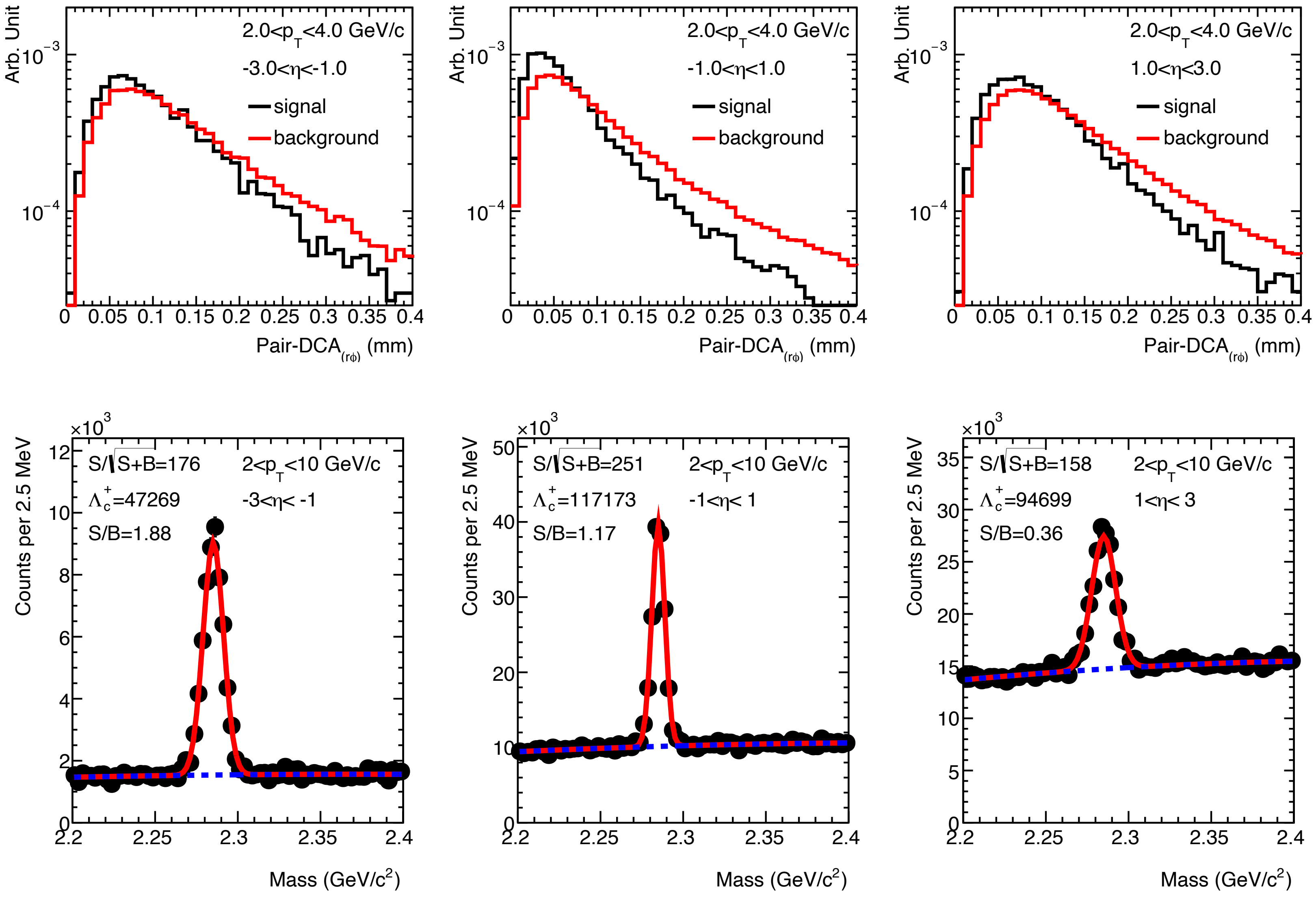
- Events generated by PYTHIA6 with EIC tune;
- Apply detector performance;
- Reconstruction channel:
  $\Lambda_c^+ \to pK^-\pi^+$ (B.r.=6.28% PDG)
  $D^0 \to K^-\pi^+$ (B.r.=3.95% PDG)
- Expect much lower combinatorial background w.r.t p+p collisions

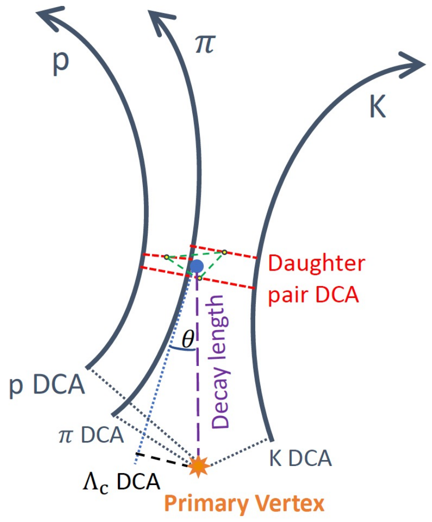






Topology performance and signal projection

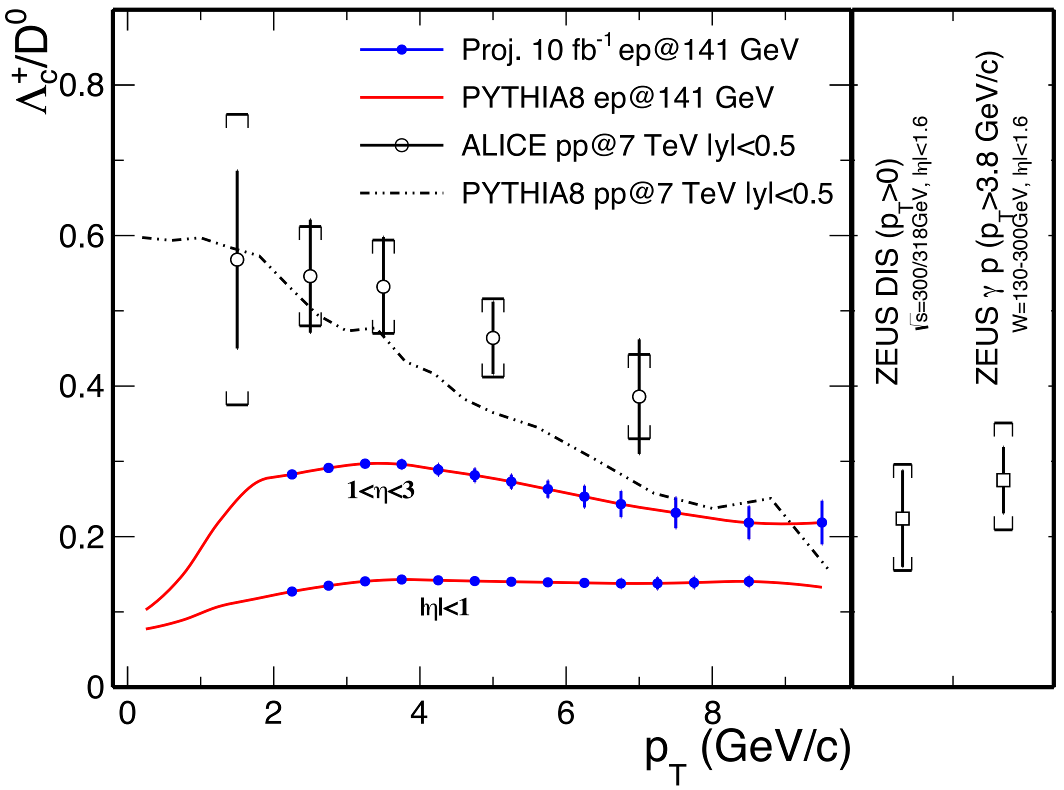


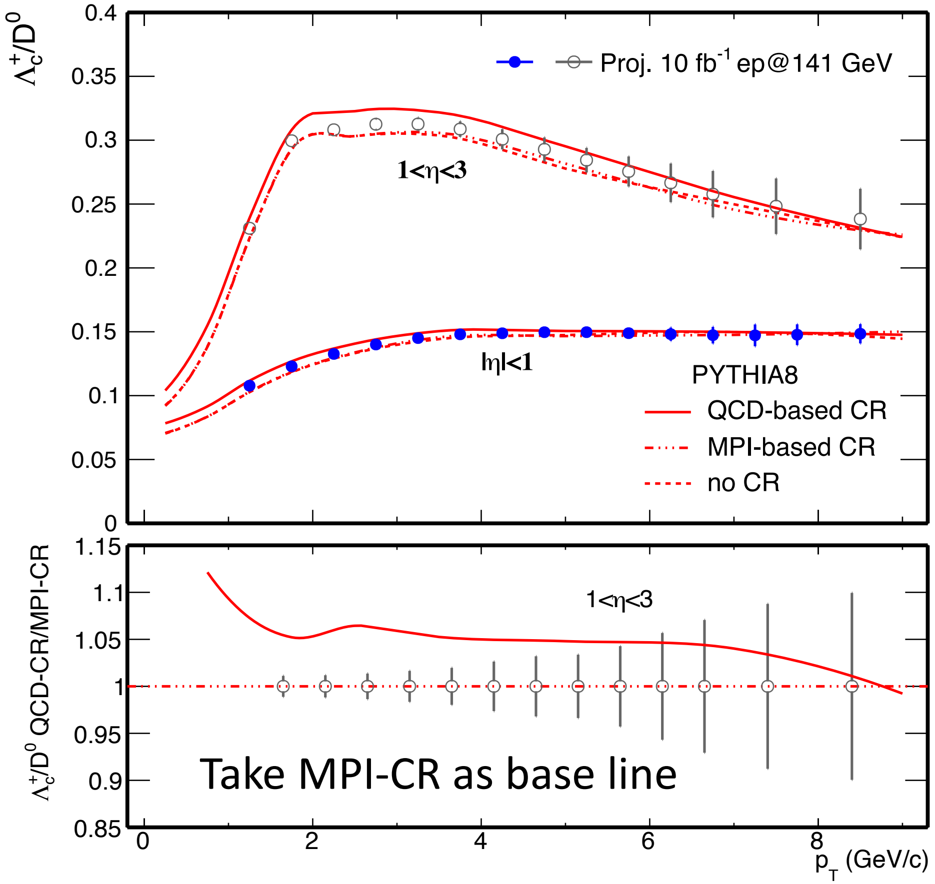


- Improving signals with topology variables;
- Best significance achieved at $|\eta|<1$.

$$\mathcal{L} = 10fb^{-1}$$

Projected uncertainty for Λ_c^+/D^0 vs p_T

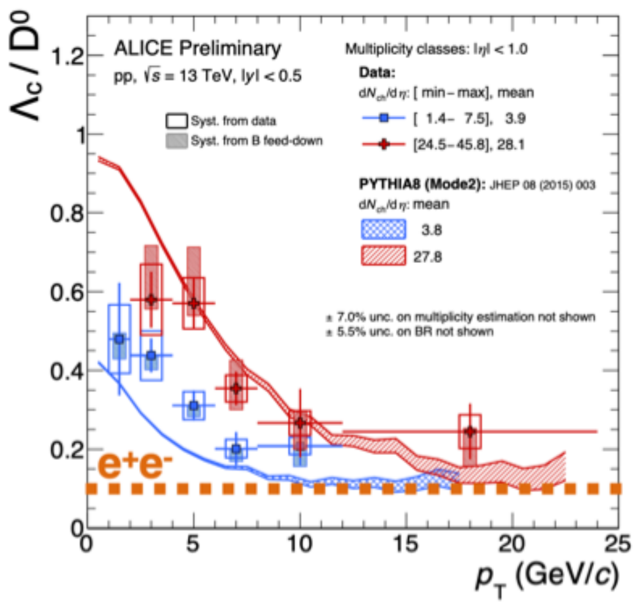


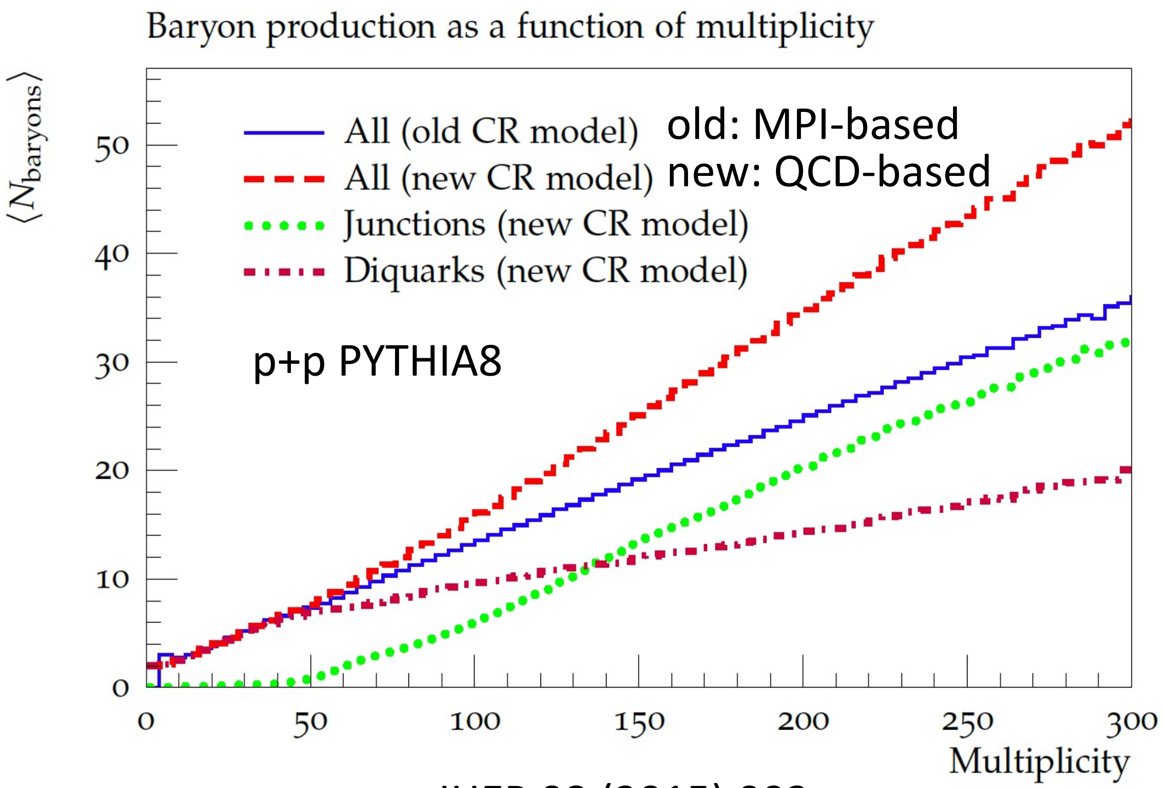


- Precise measurements of charm baryon in future EIC collider;
- Ability to separate two CR frameworks at low p_T with L=10 fb^{-1}.

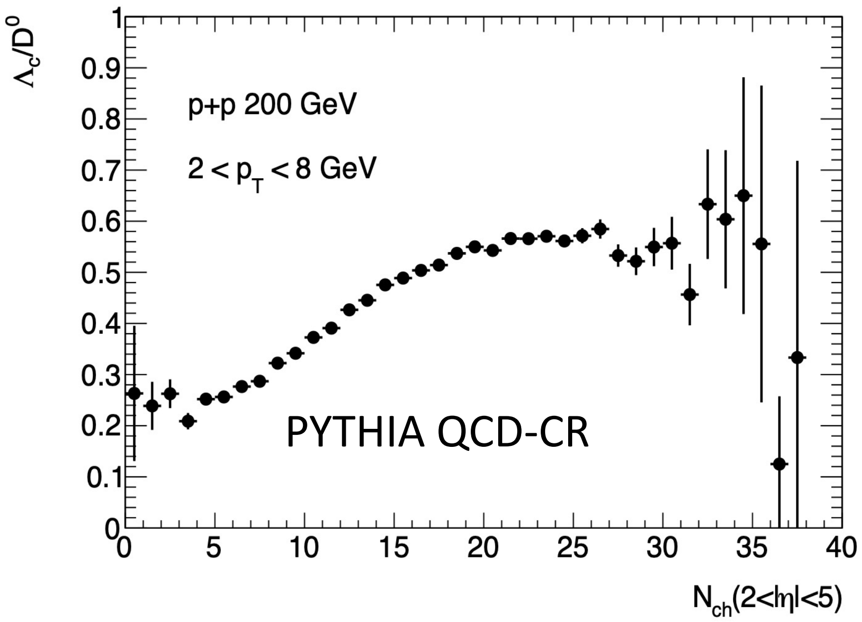
Multiplicity dependence

- Multiplicity
  - correlated with density of quarks and gluons in the final state
- Enhanced Λ_c^+/D^0 ratio at high multiplicity in p+p from ALICE
  - similar structure predicted by QCD-based CR in PYTHIA
- EIC: high tracking efficiency



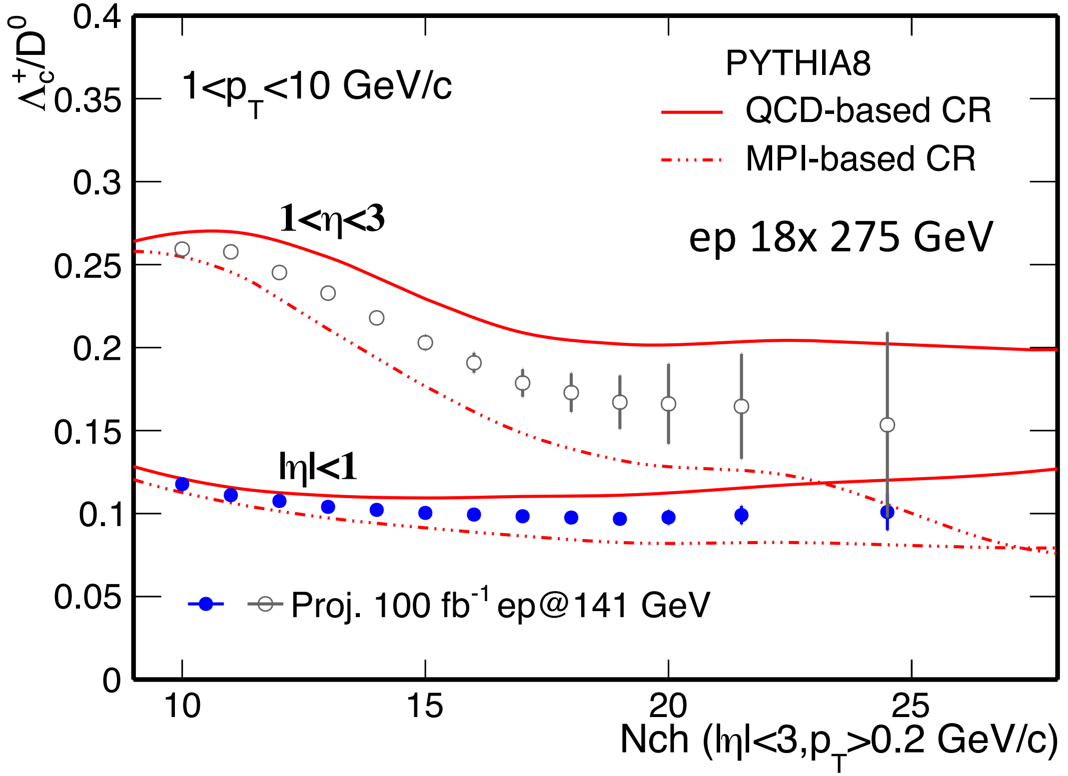


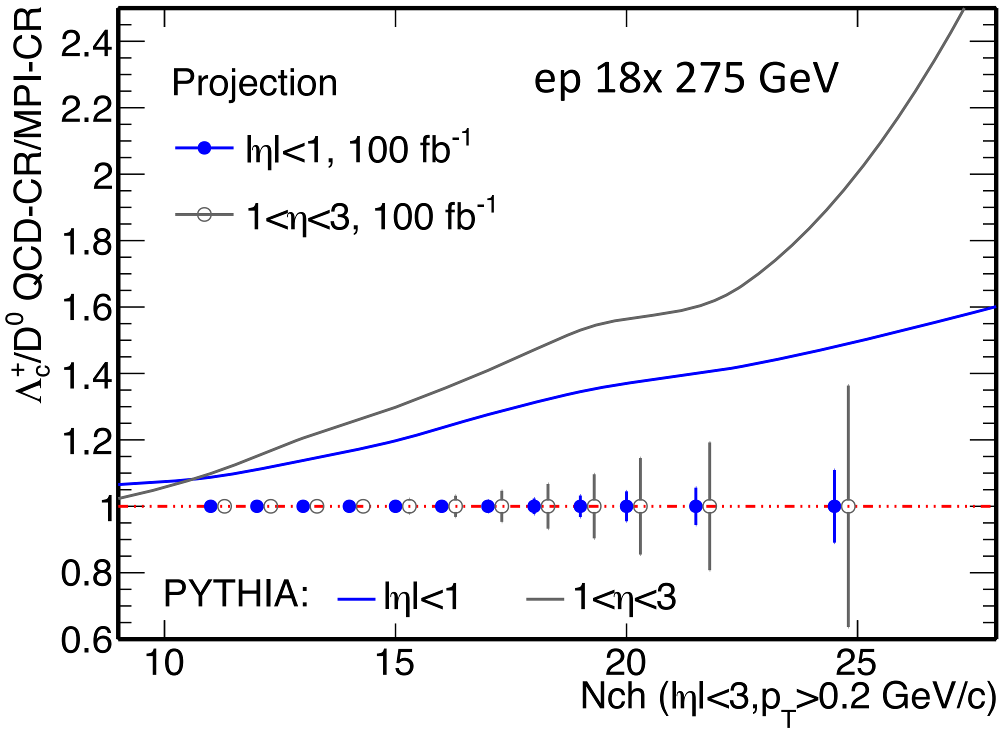
JHEP 08 (2015) 003



Projected uncertainty for Λ_c^+/D^0 vs multiplicity

- Nch: Number of charged particles at p_T>0.2 GeV/c within $|\eta|$<3
- Clear separation at high multiplicity with different CR frameworks
- Larger model difference achieved in 1<η<3 compared to $|\eta|$<1





Take MPI-CR result as base line

Summary

- Charm baryon measurements in the future EIC

  - heavy flavor hadronization in a better-known initial state systems

- Λ_c^+/D^0: test universality of CR framework

  - expect precise measurements in EIC

  - better CR model separation power for Λ_c^+/D^0 vs multiplicity w.r.t p_T in ep collisions

Outlook

- Excited states charm baryons, e.g. $\Sigma_c^{0,+,++}$, Ξ_c

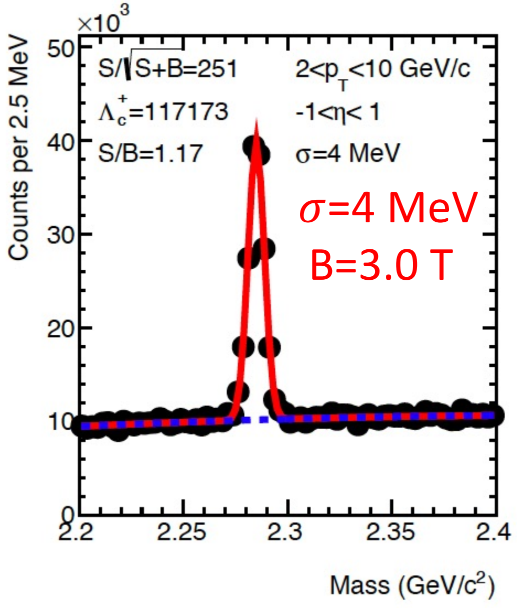
Back ups

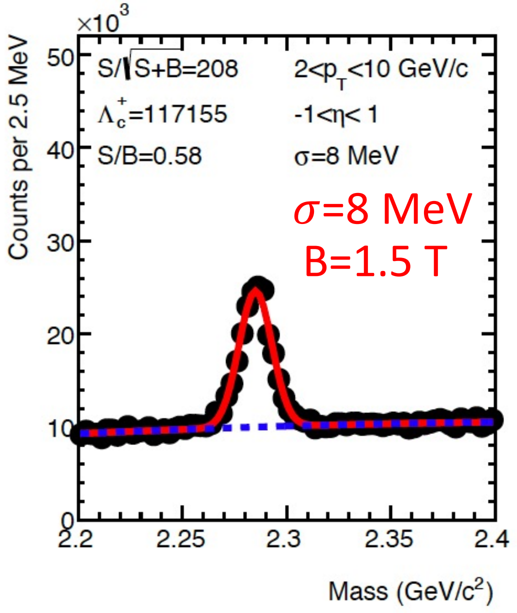
Impact of B=1.5 or 3 T

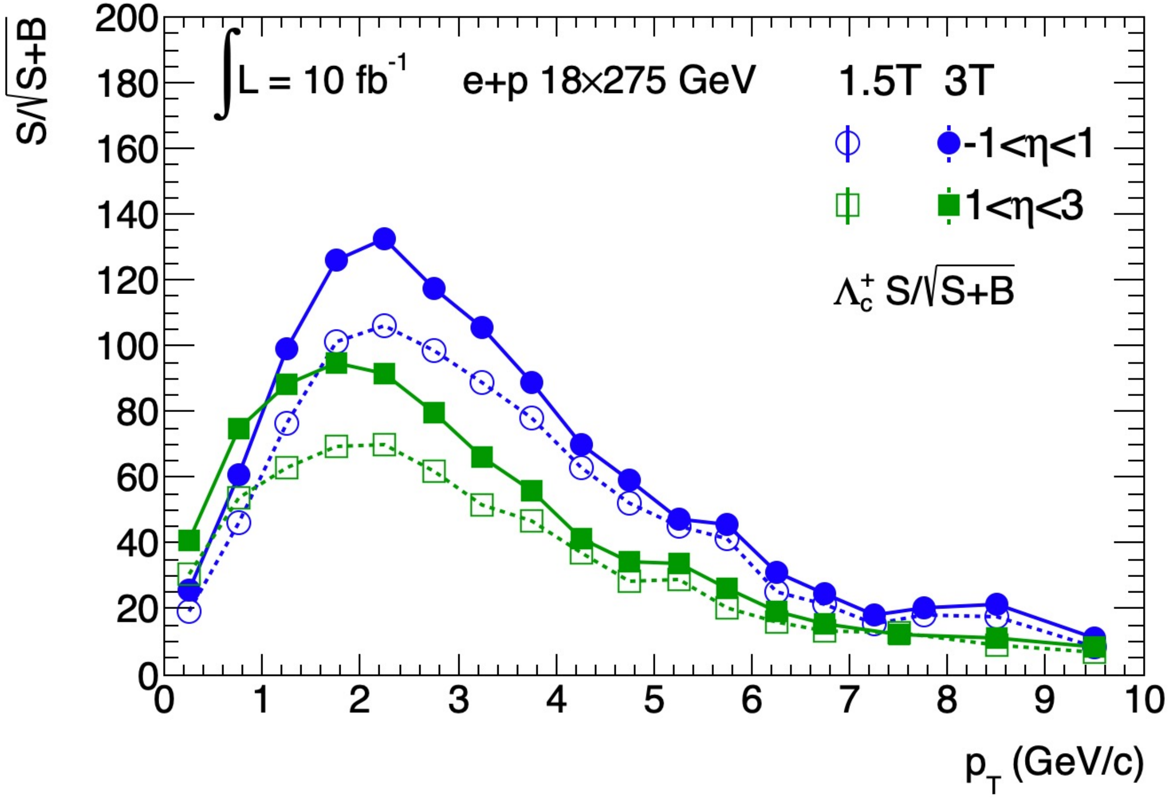
Momentum resolution

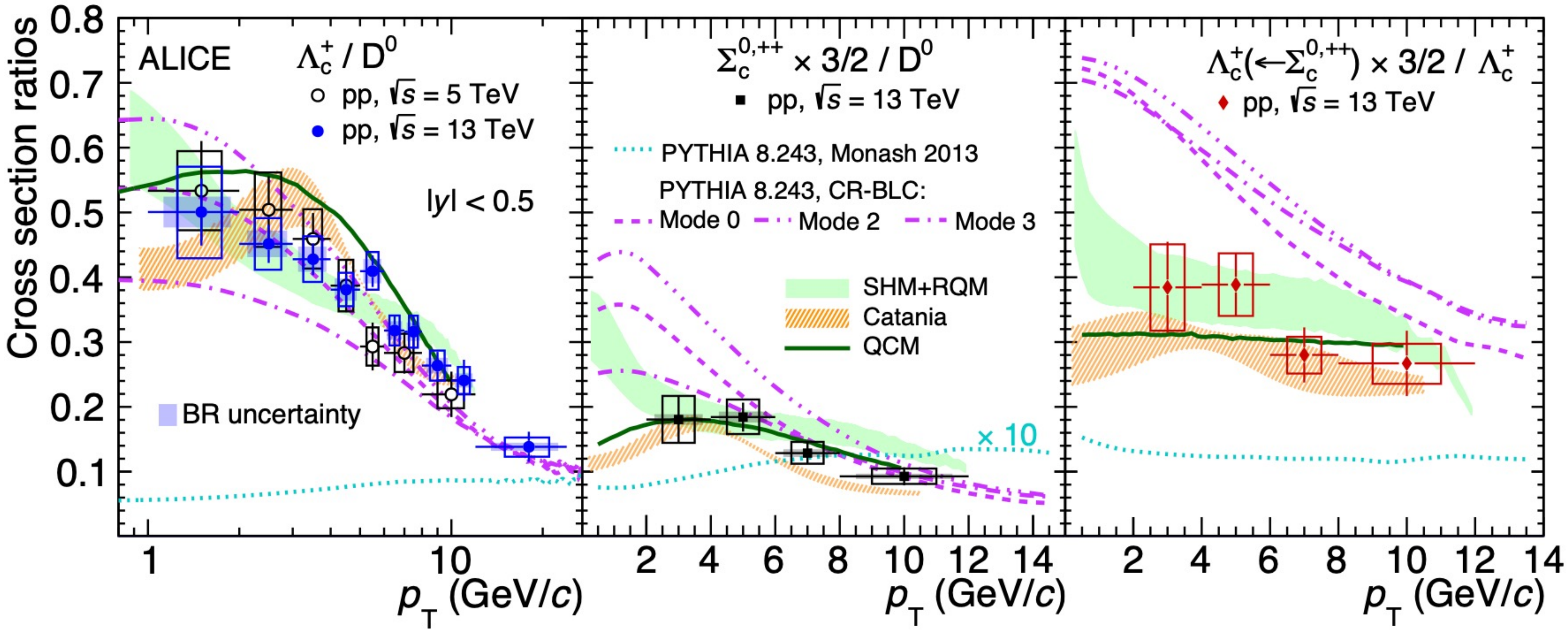
η	σ_p/p - 3T (%)	σ_p/p - 1.5T (%)
(-3.0,-2.5)	$0.1{\cdot}p \oplus 2.0$	$0.2{\cdot}p \oplus 5.0$
(-2.5,-2.0)	$0.02{\cdot}p \oplus 1.0$	$0.04{\cdot}p \oplus 2.0$
(-2.0,-1.0)	$0.02{\cdot}p \oplus 1.0$	$0.04{\cdot}p \oplus 2.0$
(-1.0,1.0)	$0.02{\cdot}p \oplus 0.5$	$0.04{\cdot}p \oplus 1.0$
(1.0,2.0)	$0.02{\cdot}p \oplus 1.0$	$0.04{\cdot}p \oplus 2.0$
(2.0,2.5)	$0.02{\cdot}p \oplus 1.0$	$0.04{\cdot}p \oplus 2.0$
(2.5,3.0)	$0.1{\cdot}p \oplus 2.0$	$0.2{\cdot}p \oplus 5.0$

- Momentum resolution ~ 2 times worse with B=1.5 T compared to B=3 TeV
- Wider signal width -> ~20% decreasing in significance









ALICE
Λ_c^+ / D^0
pp, $\sqrt{s}$ = 5 TeV
pp, $\sqrt{s}$ = 13 TeV
|y| < 0.5
BR uncertainty
Cross section ratios
p_T (GeV/c)
$\Sigma_c^{0,++} \times 3/2 / D^0$
pp, $\sqrt{s}$ = 13 TeV
PYTHIA 8.243, Monash 2013
PYTHIA 8.243, CR-BLC:
Mode 0
Mode 2
Mode 3
SHM+RQM
Catania
QCM
× 10
$\Lambda_c^+(\leftarrow\Sigma_c^{0,++}) \times 3/2 / \Lambda_c^+$
pp, $\sqrt{s}$ = 13 TeV