

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 multiplicity
- Summary

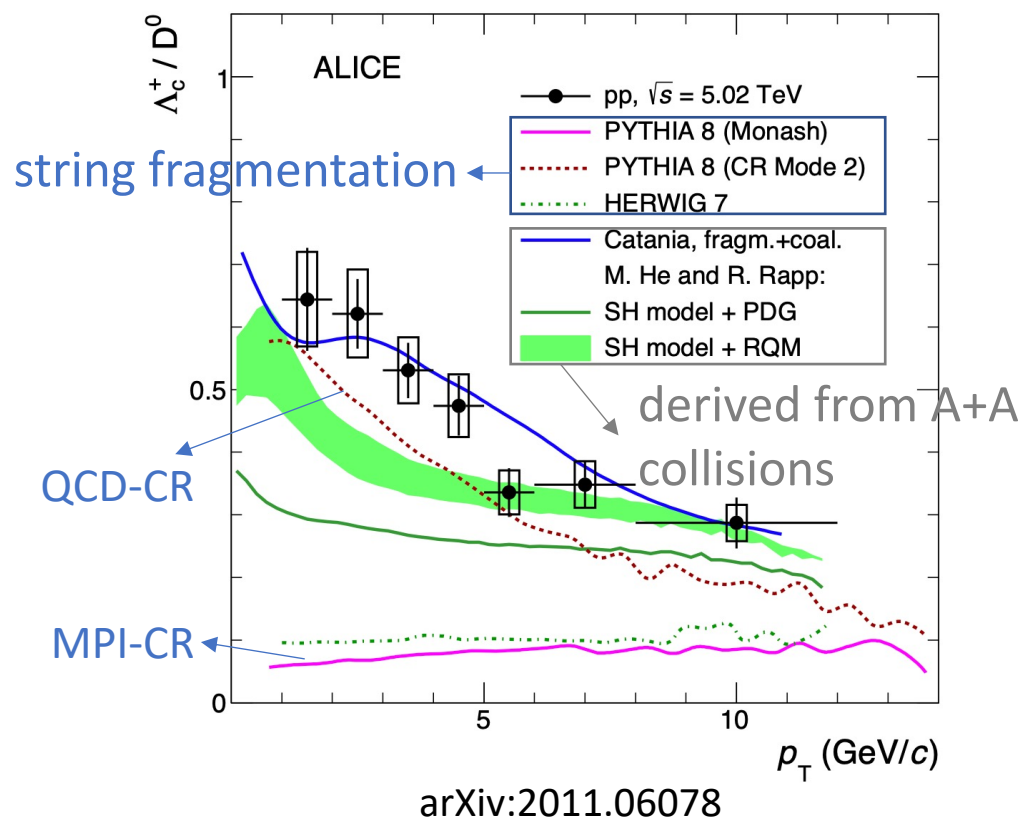
Motivation

- 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^-

$$\sigma = f_i(x) \otimes \sigma_{hard}^{ij}(x, Q^2) \otimes \underbrace{(D_j^h)}_{\text{non-perturbative}}$$

initial PDF hard process hadronization



- Color reconnection (CR):

- between which partons should strings form

PYTHIA :

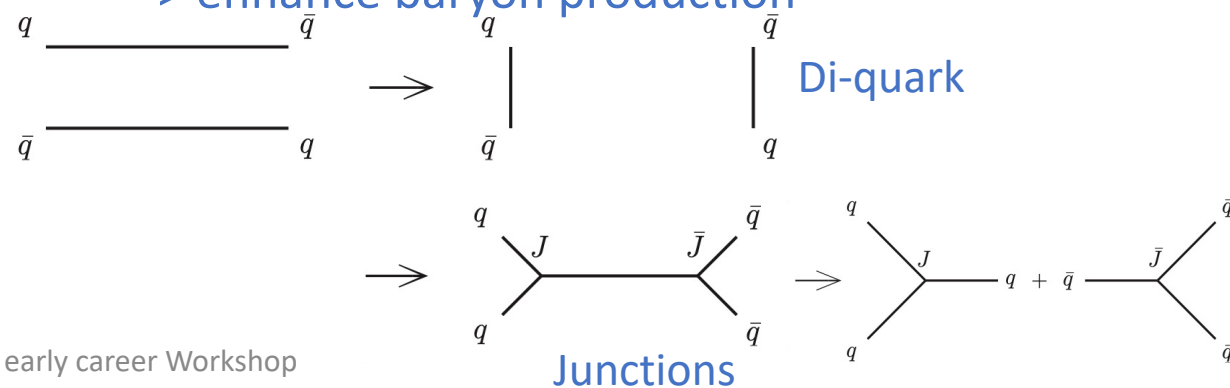
- default: MPI-based CR baryon/meson $\sim$ fragmentation

- newer: QCD-based CR JHEP 08:003 (2015)

-> QCD color rule in reconnection possibility

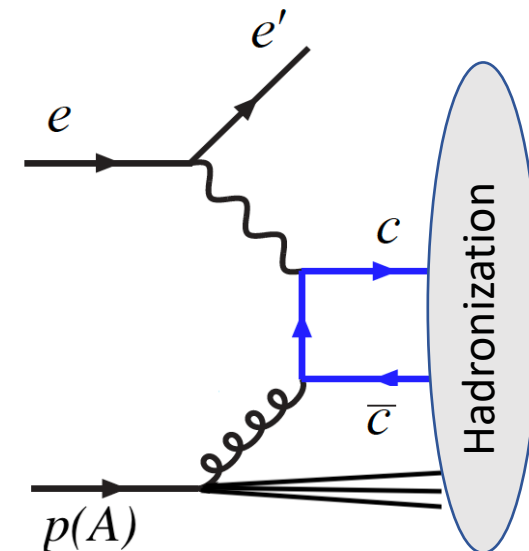
-> introduce junction formation

-> enhance baryon production



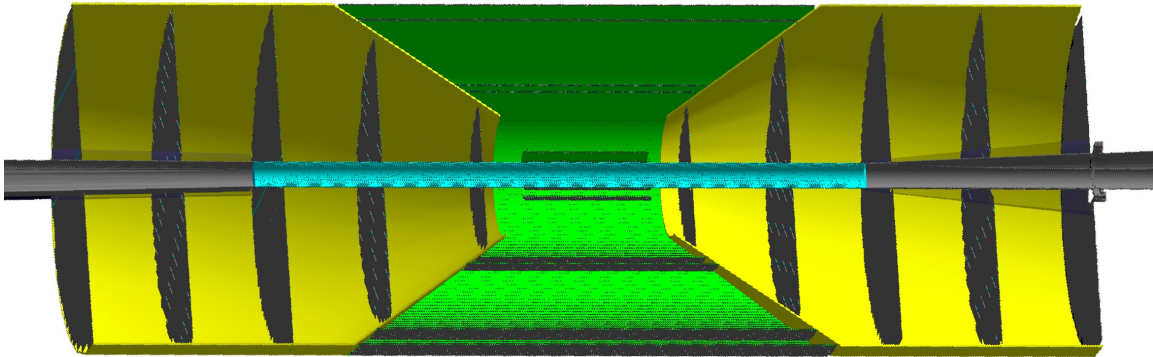
Motivation

- Λ_c^+ measurements in ep collisions in the future EIC
 - limited HF baryon measurements in ep (and pp) currently
 - help constrain parameters e.g. StringFlav:probQQ1toQQ0join JHEP 08:003 (2015)
 - probe to relative contribution of diquark- and junction-driven baryon production
 - e.g: Σ_c^0 production $\Sigma_c^0 \rightarrow \Lambda_c^+ \pi$
 - > in diquark: dd (suppressed relative to ud) 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](https://arxiv.org/abs/2102.08337)



All-silicon tracker geometry

Detector set up

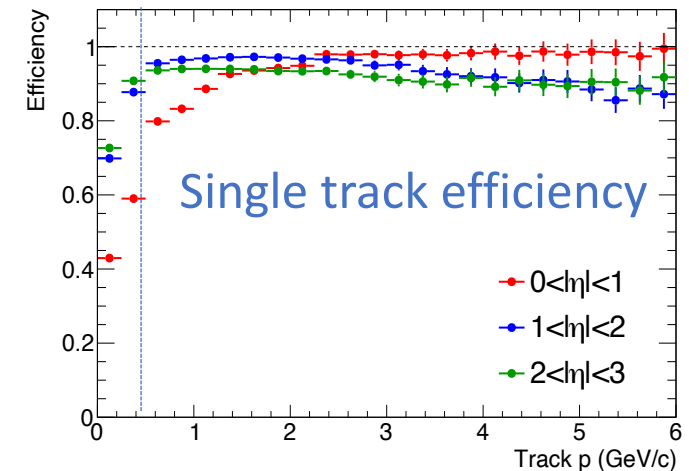
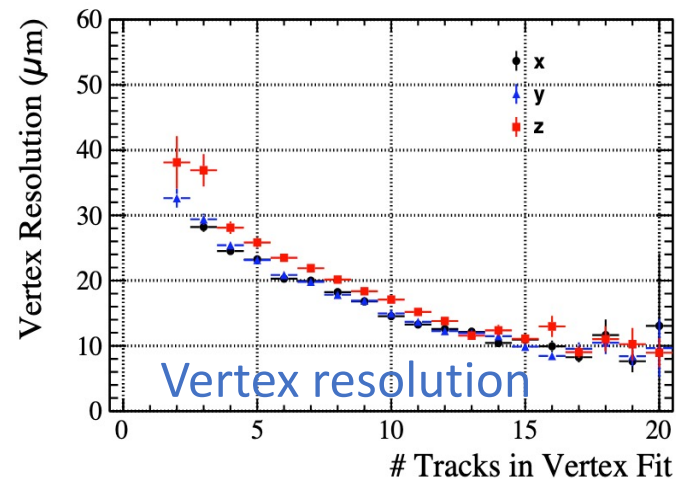
- Pointing resolution
- PID ability
- Momentum resolution with $B=3$ T
- Primary vertex resolution
- Tracking efficiency

From full Geant4 simulation

Detector performance

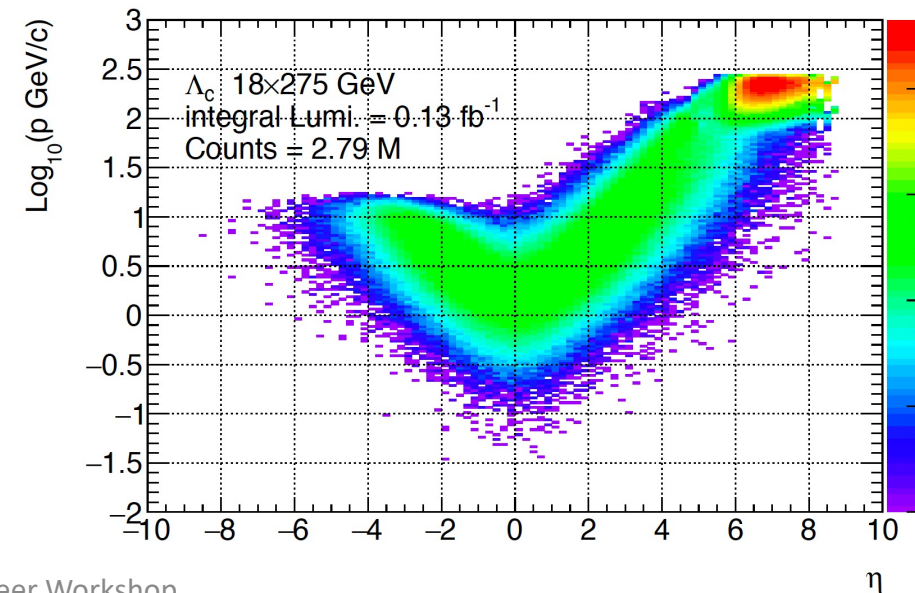
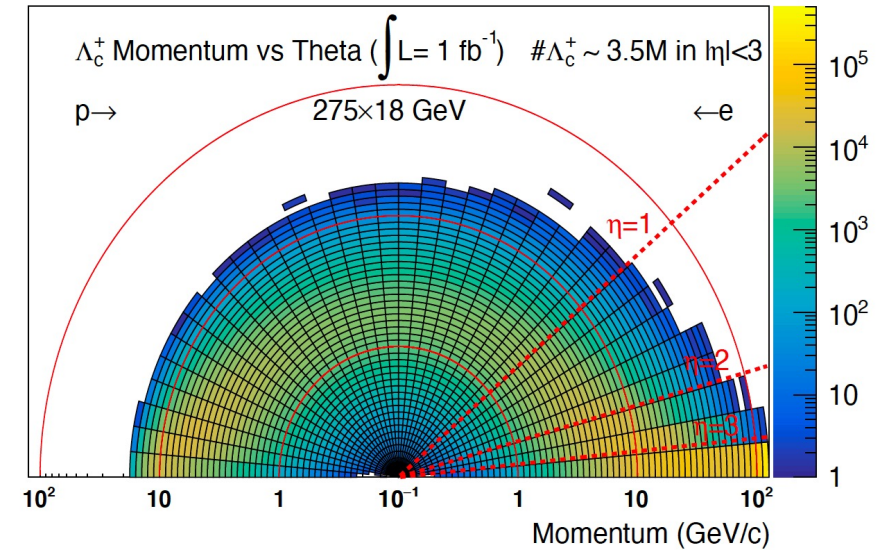
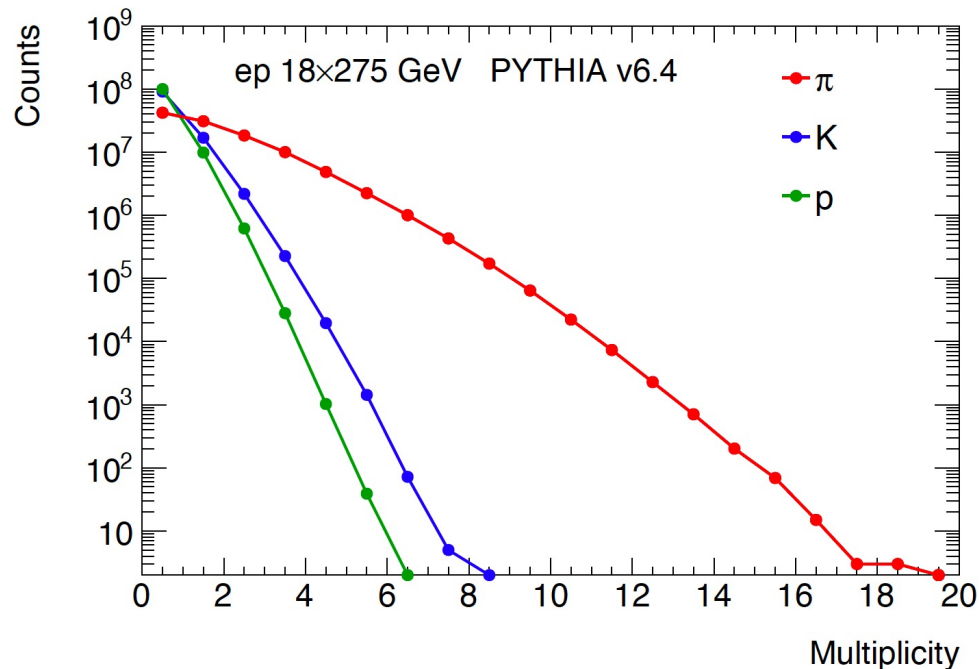
η	$\sigma_p/p - 3T$ (%)	$\sigma(\text{DCA}_{r\phi})$ (μm)	$p_{\text{max}}^{\text{PID}}$ (GeV/c)
$(-3.0, -2.5)$	$0.1 \cdot p \oplus 2.0$	$60/p_T \oplus 15$	10
$(-2.5, -2.0)$	$0.02 \cdot p \oplus 1.0$	$60/p_T \oplus 15$	10
$(-2.0, -1.0)$	$0.02 \cdot p \oplus 1.0$	$40/p_T \oplus 10$	10
$(-1.0, 1.0)$	$0.02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

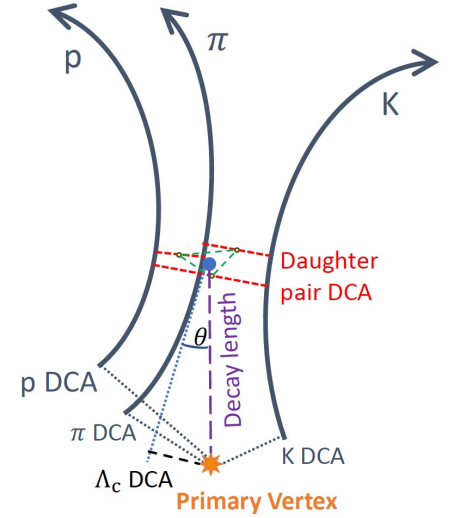
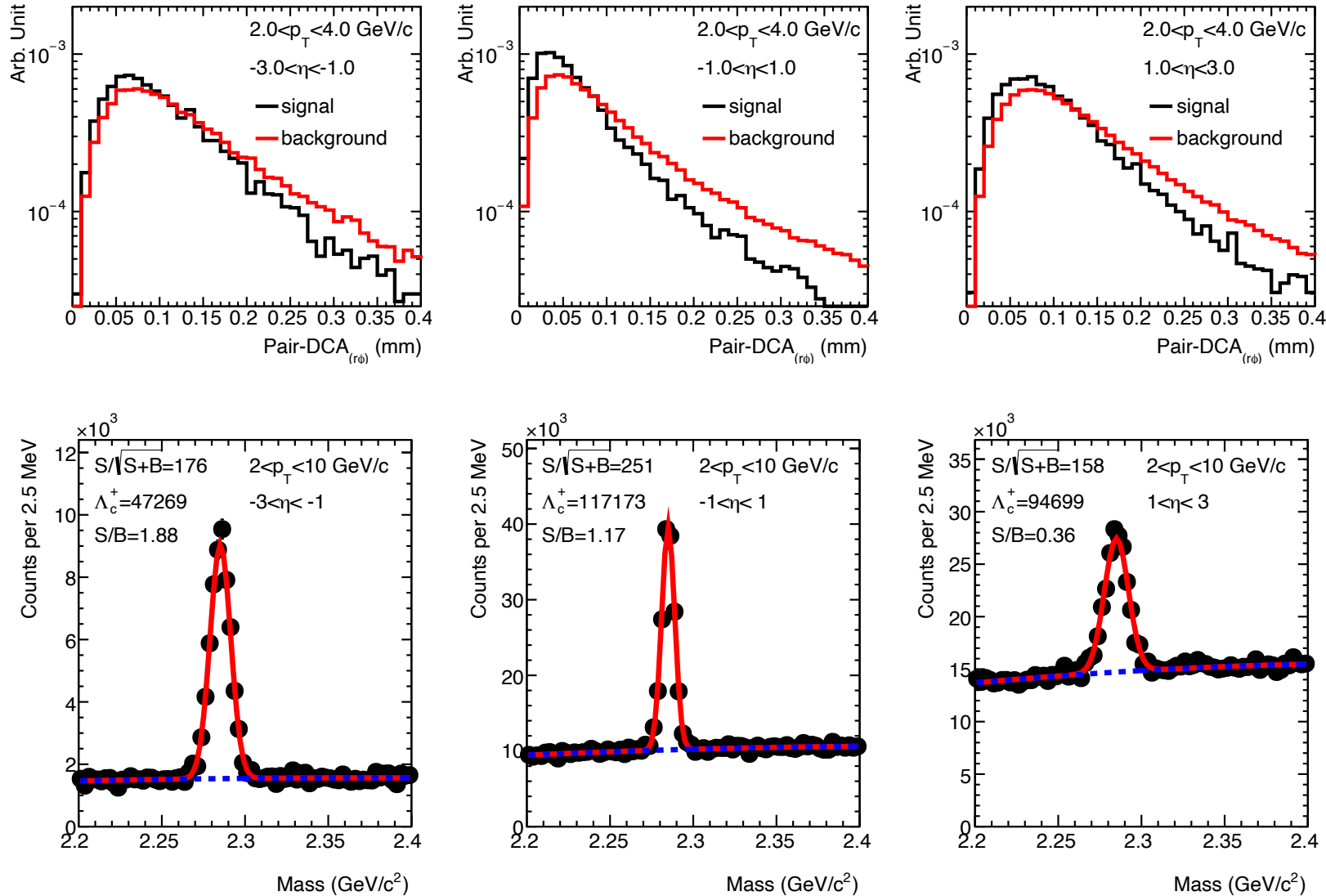


Event simulation and acceptance

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



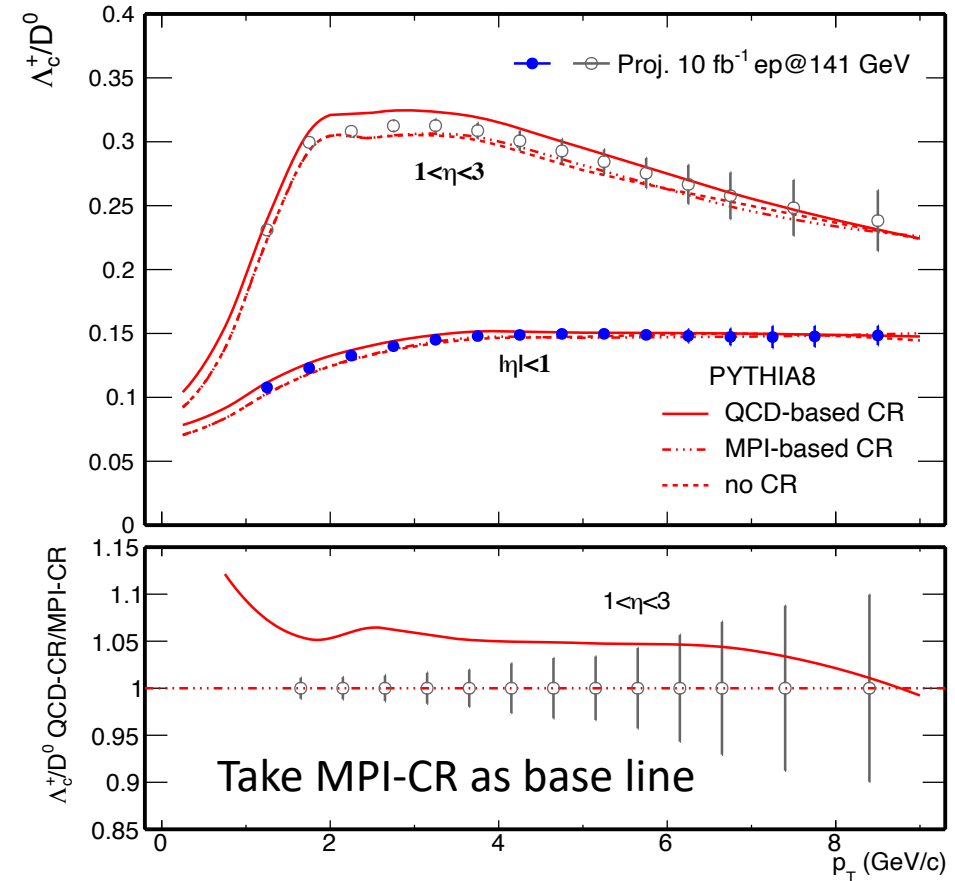
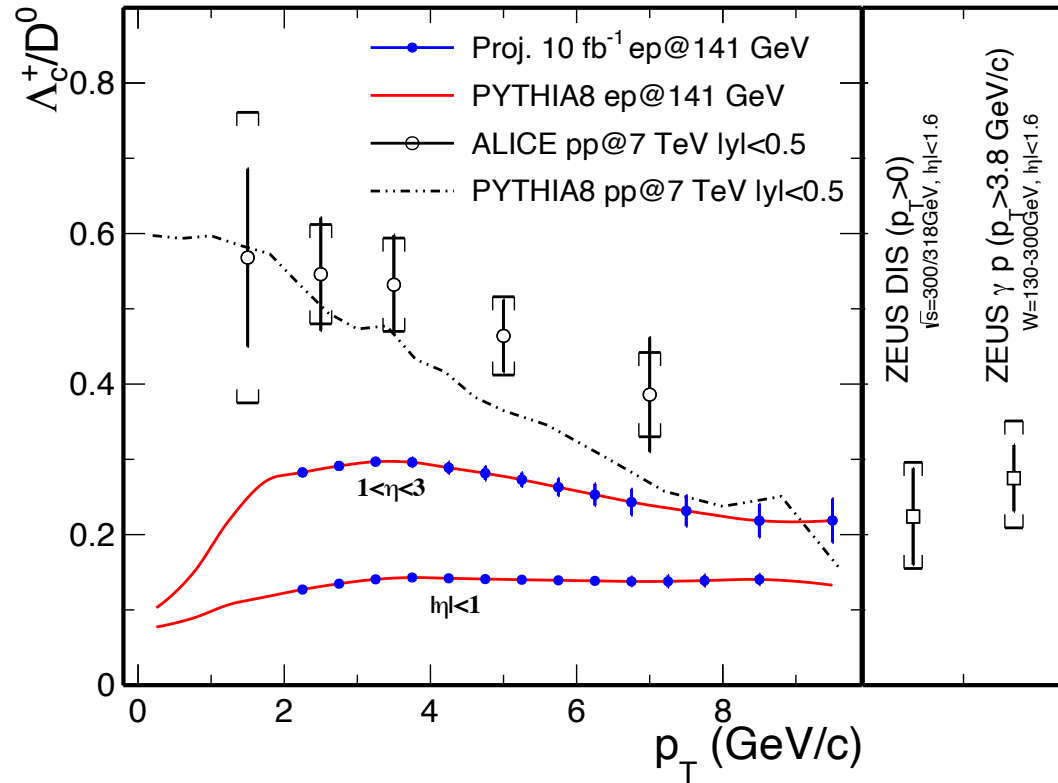
Topology performance and signal projection



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

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

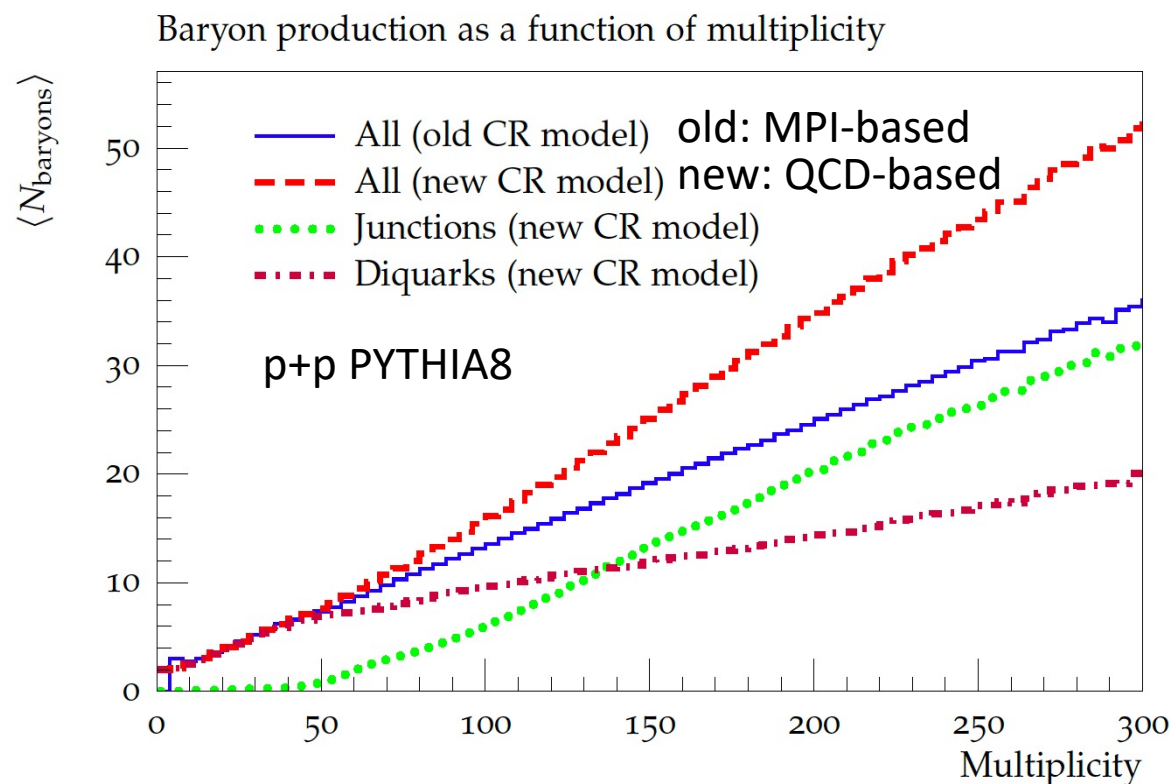
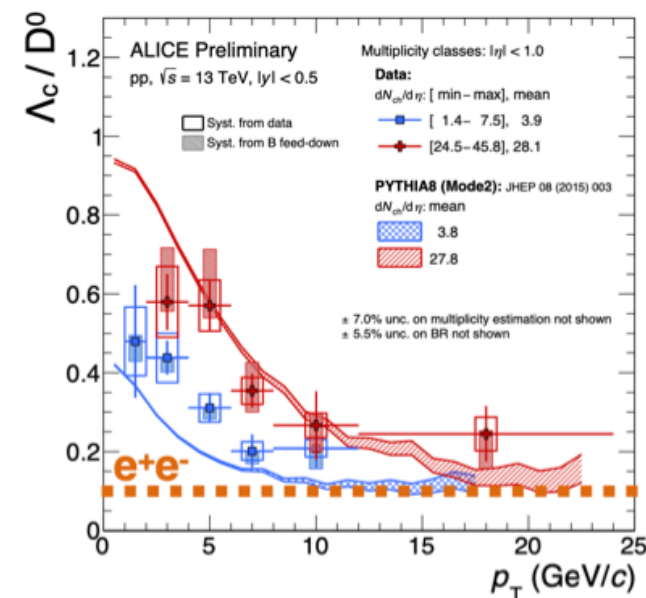
Projected uncertainty for Λ_c^+/D^0 vs p_T



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

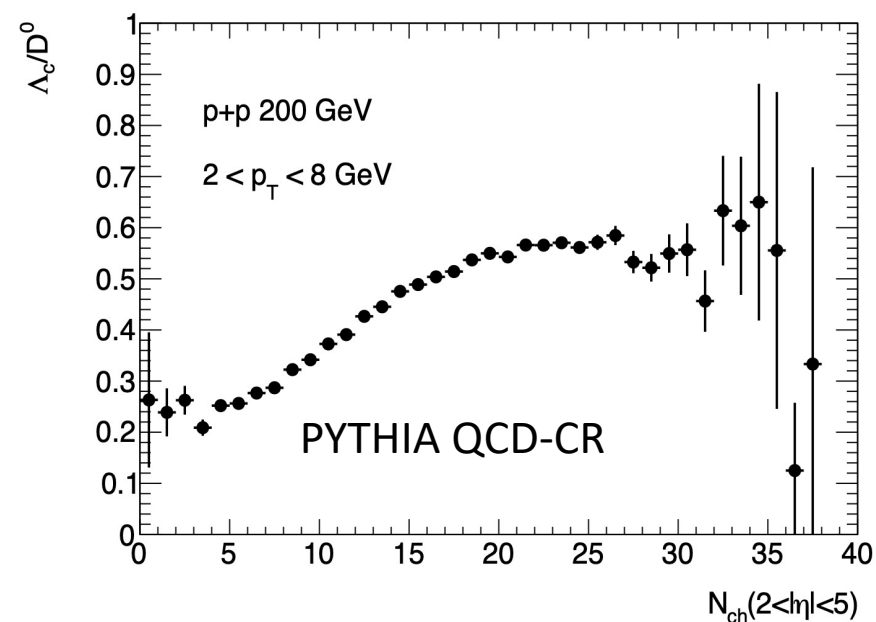
Multiplicity dependence

- 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



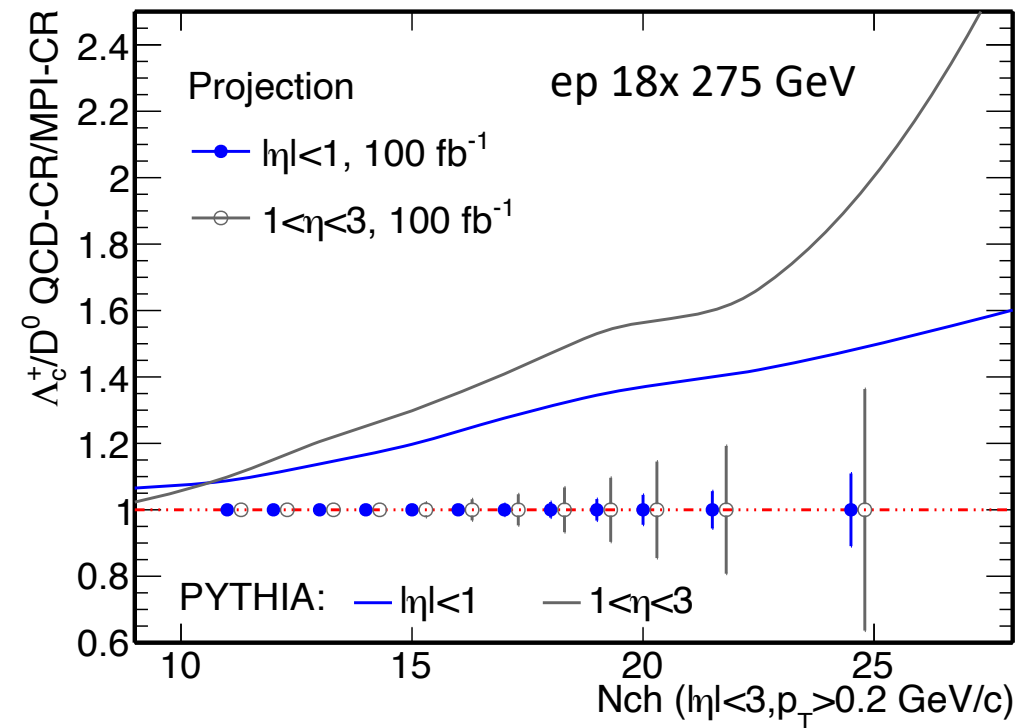
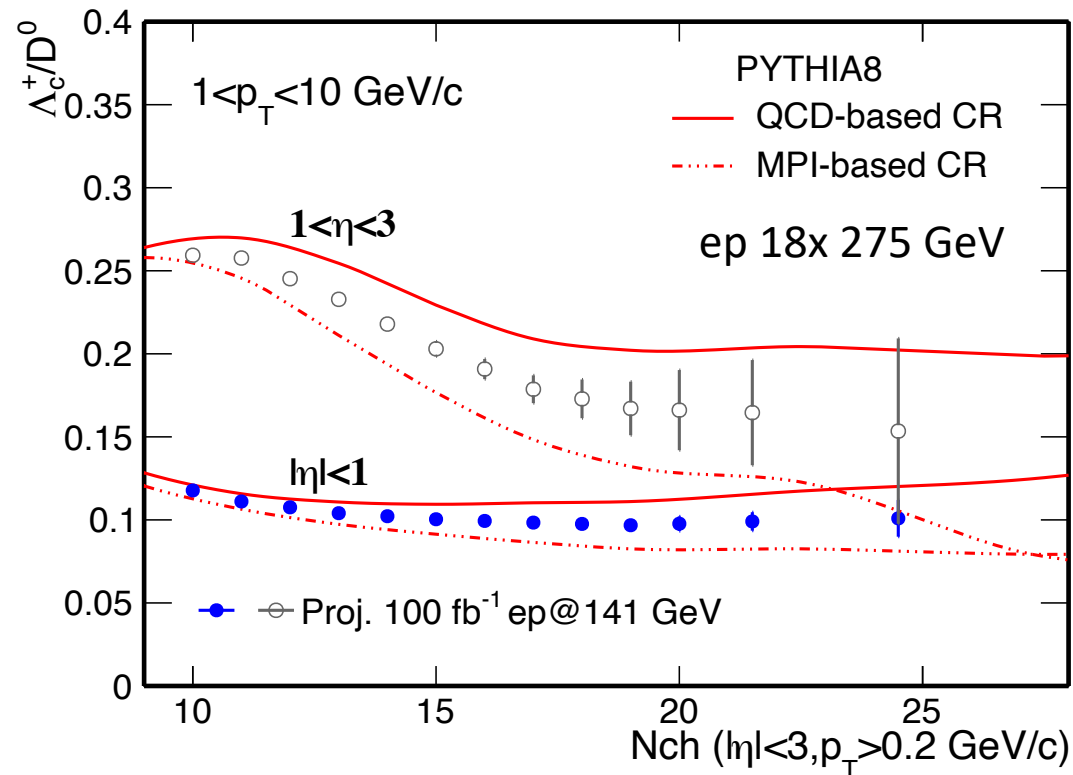
JHEP 08 (2015) 003

Yuanjing Ji, EIC early career Workshop



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 $1 < \eta < 3$ 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

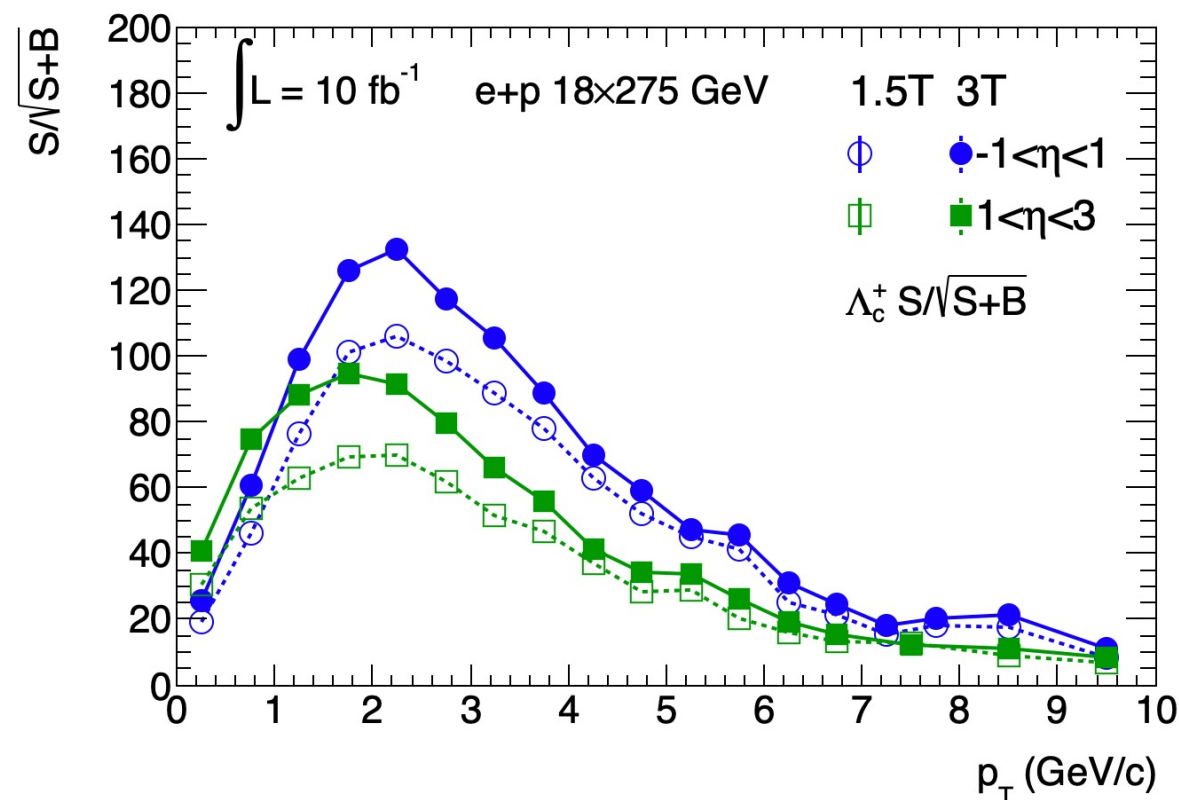
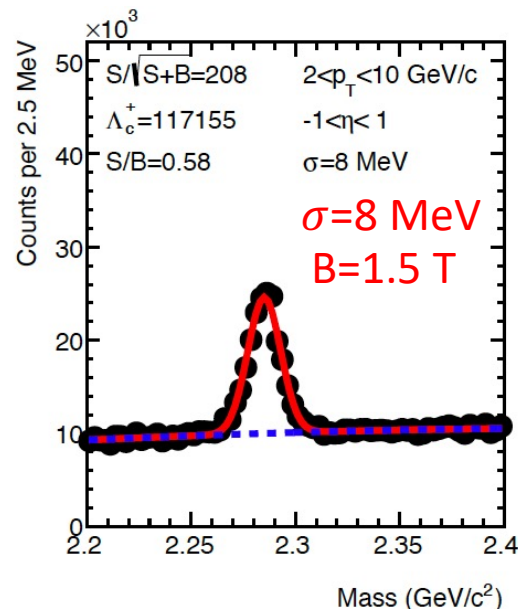
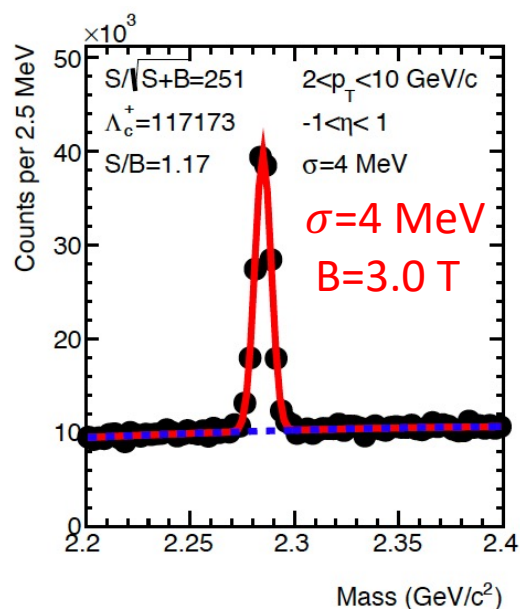
Back ups

Impact of B=1.5 or 3 T

Momentum resolution

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

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



Λ_c^+ / D^0 in PYTHIA8 e+p(Au)

Higher multiplicity in eA collisions

- Hadronization in nuclear environment
 - initial condition: nuclear modification on PDF
 - nuclear medium effects

$$R_{eAu} = \frac{(\Lambda_c^+ / D^0)_{eAu}}{(\Lambda_c^+ / D^0)_{ep}}$$

- Switch proton PDF
 - > Nuclear PDF in PYTHIA8
 - Only impact from initial PDF
 - a baseline for nuclear medium effects study

nPDF: an average nucleon within given nucleus

