APRIL MEETING 2021

April 17-20

Q2C quarks cosmos

Λ_c production in the future EIC

Yuanjing Ji*

* In collaboration with Xin Dong, Matthew Kelsey, Sooraj Radhakrishnan, Nu Xu

Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Science

BERKELEY LAB

Outline

- Motivation
- Simulation of Λ_c reconstruction in the future EIC
- Summary

Motivation

initial PDF hard process hadronization

$$\sigma = \mathrm{f_i(x)} \otimes \sigma^{ij}_{hard}(x, Q^2) \otimes D^h_j$$

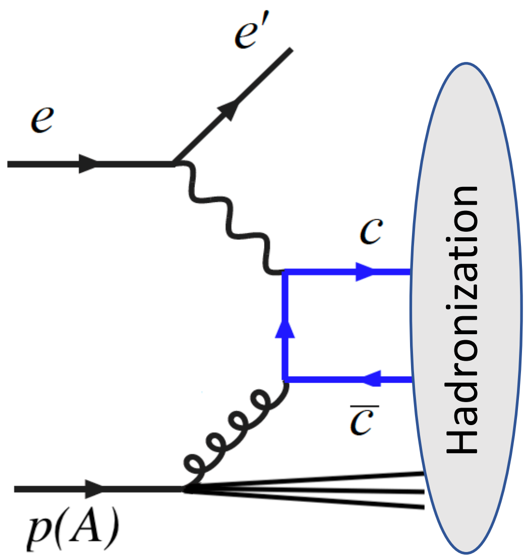
non-perturbative

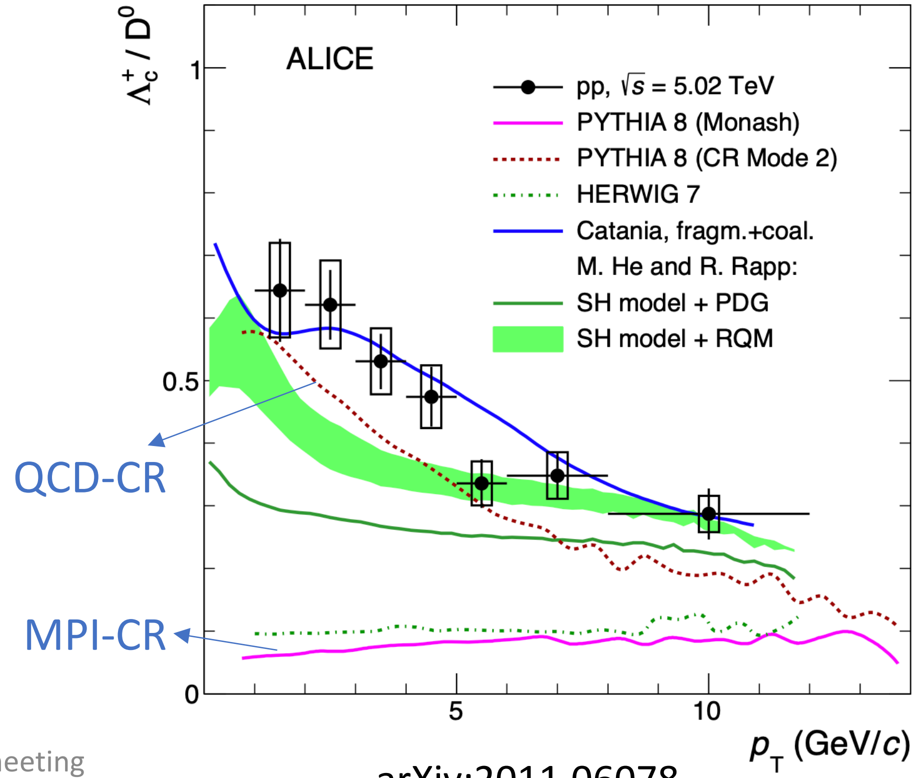
- Hadronization
  - Heavy quarks: $m_c \gg \Lambda_{QCD}$, pQCD calculable
  - p+p collisions: enhanced Λ_c^+/D^0 ratio w.r.t fragmentation baseline in e^+e^-
    - PYTHIA - default: MPI-based color reconnection (MPI-CR)

      \- newer: QCD-based color reconnection (QCD-CR)

  introduction junction formation -> enhance baryon production

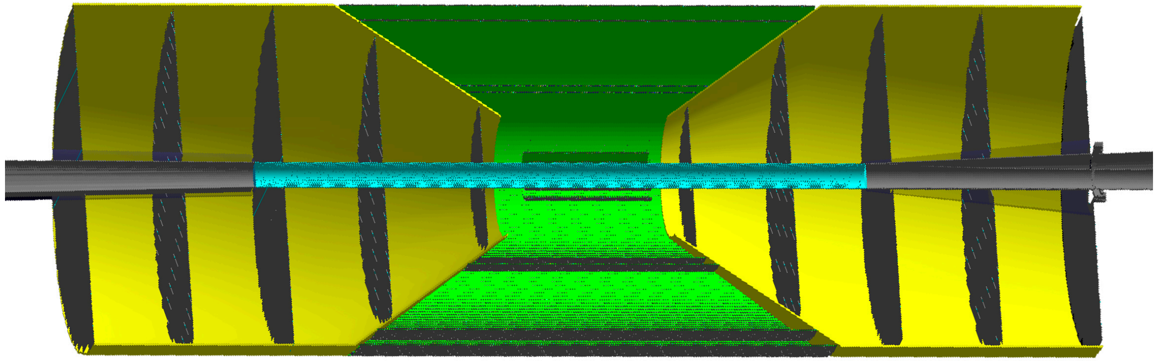
  - ep collision in future EIC
    - CR expected universal, never tested in ep
    - clean initial condition, high statistics





arXiv:2011.06078

All silicon tracking detector for EIC



All-silicon tracker geometry

Details of the detector: arXiv:2102.08337

Detector set up

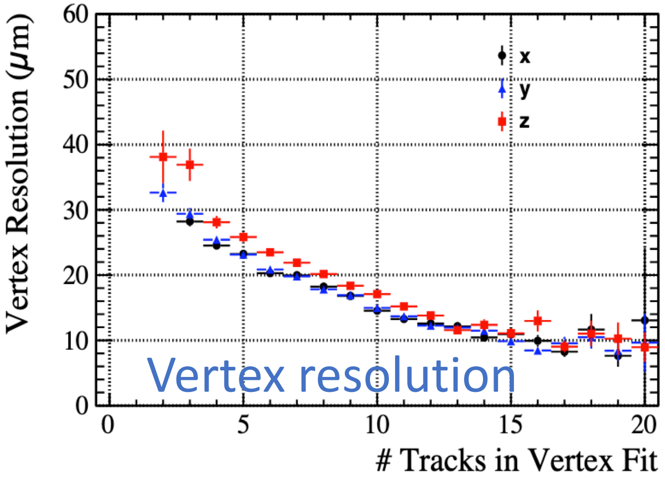
- Pointing resolution
- PID ability
- Momentum resolution with B=3 T
- Primary vertex resolution
- Tracking efficiency

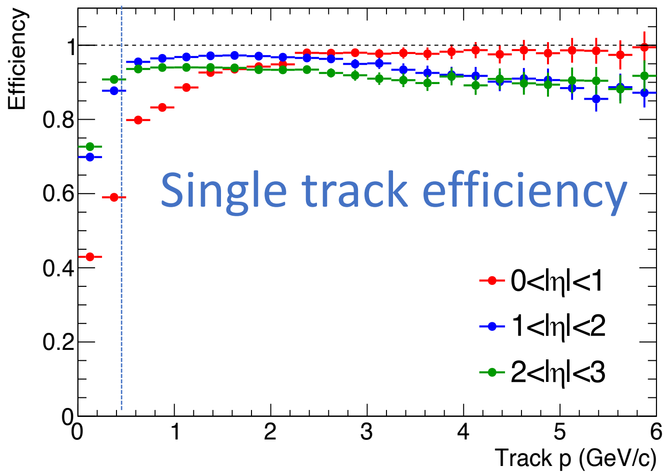
From full Geant4 simulation

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

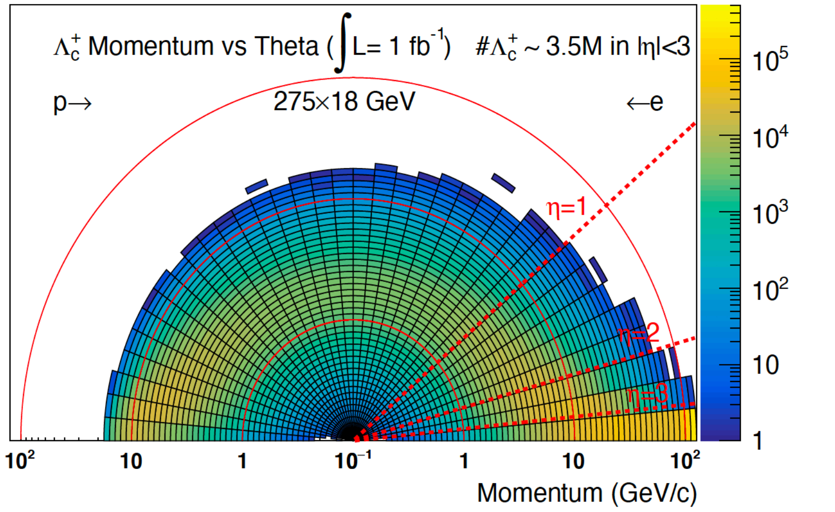
https://physdiv.jlab.org/DetectorMatrix/

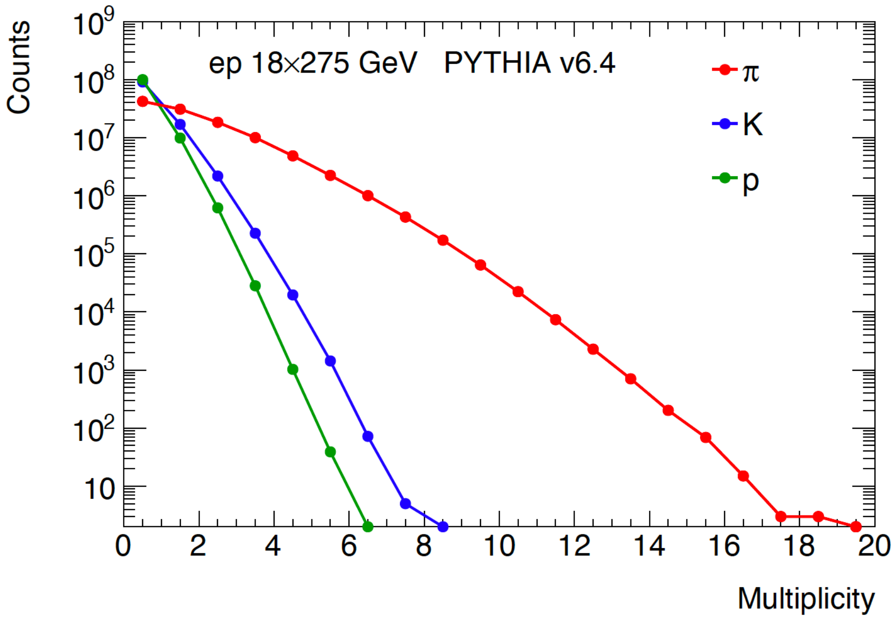


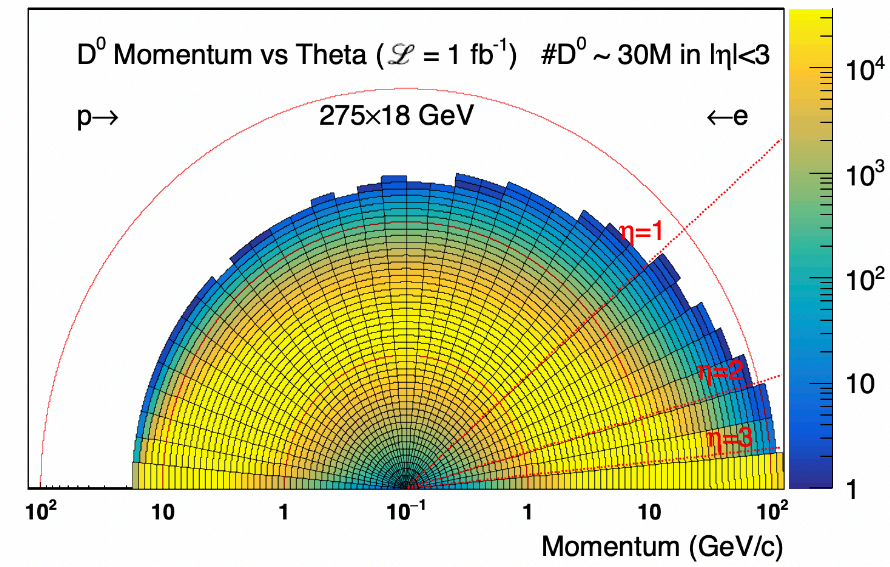


Event simulation and acceptance

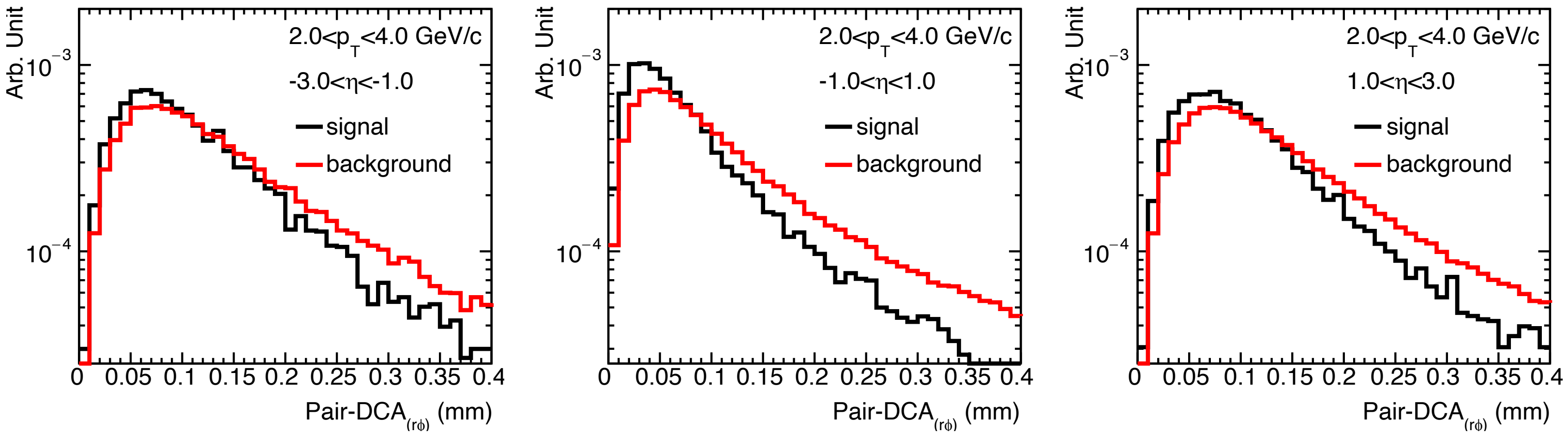
- Events generated by PYTHIA6 with EIC tune;
- Apply detector performance;
- Reconstruction channel:
  $\Lambda_c^+ \rightarrow pK^-\pi^+$ (B.r.=6.28% PDG)
  $D^0 \rightarrow K^-\pi^+$ (B.r.=3.95% PDG)
- Expect much lower combinatorial background w.r.t p+p collisions

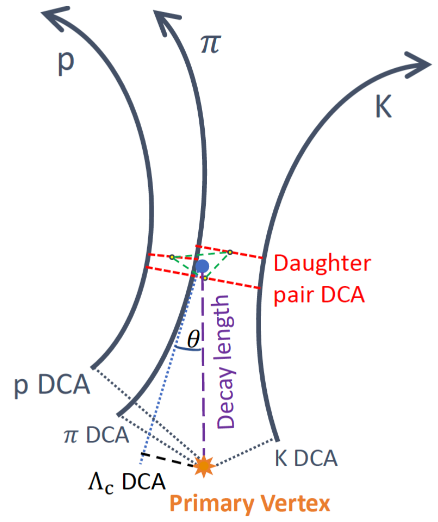


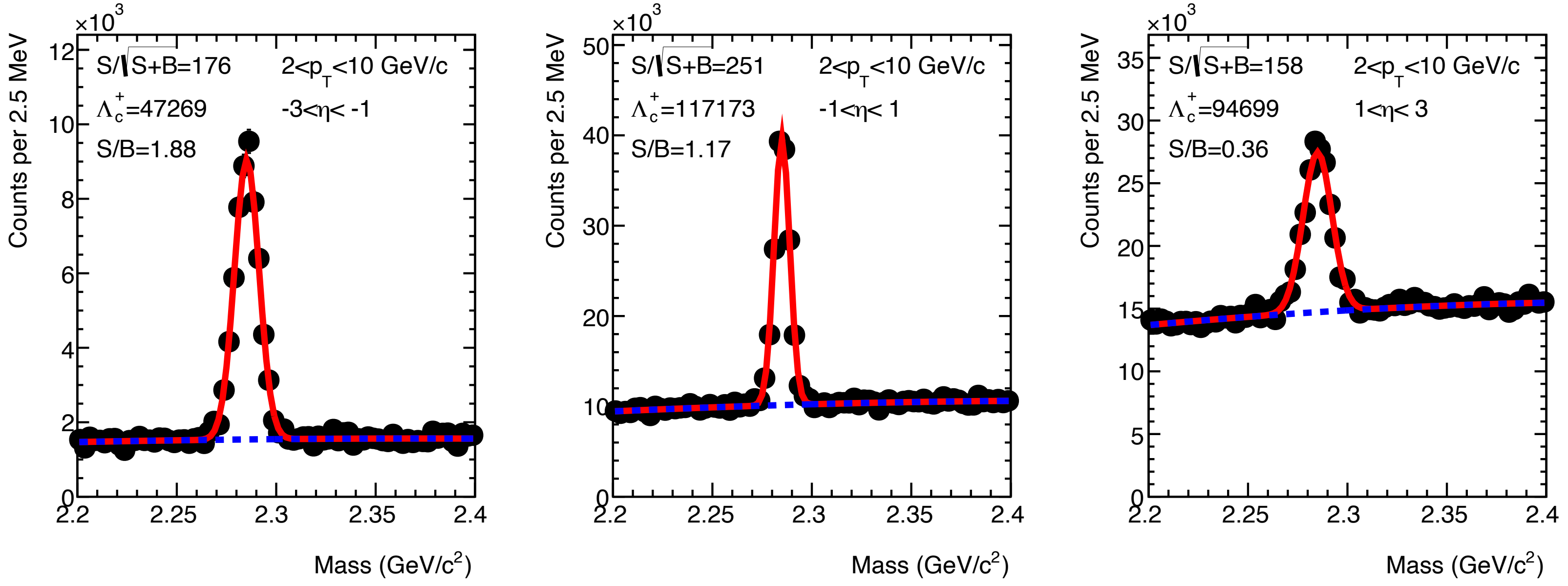




Topology performance and signal projection



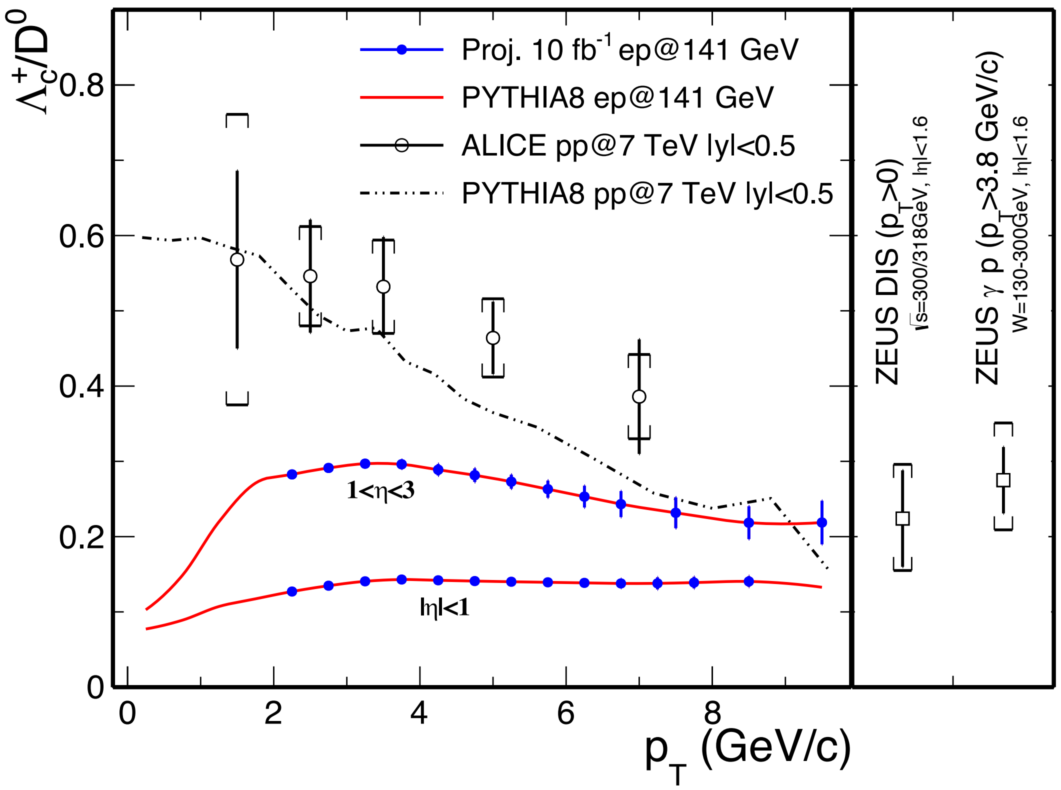


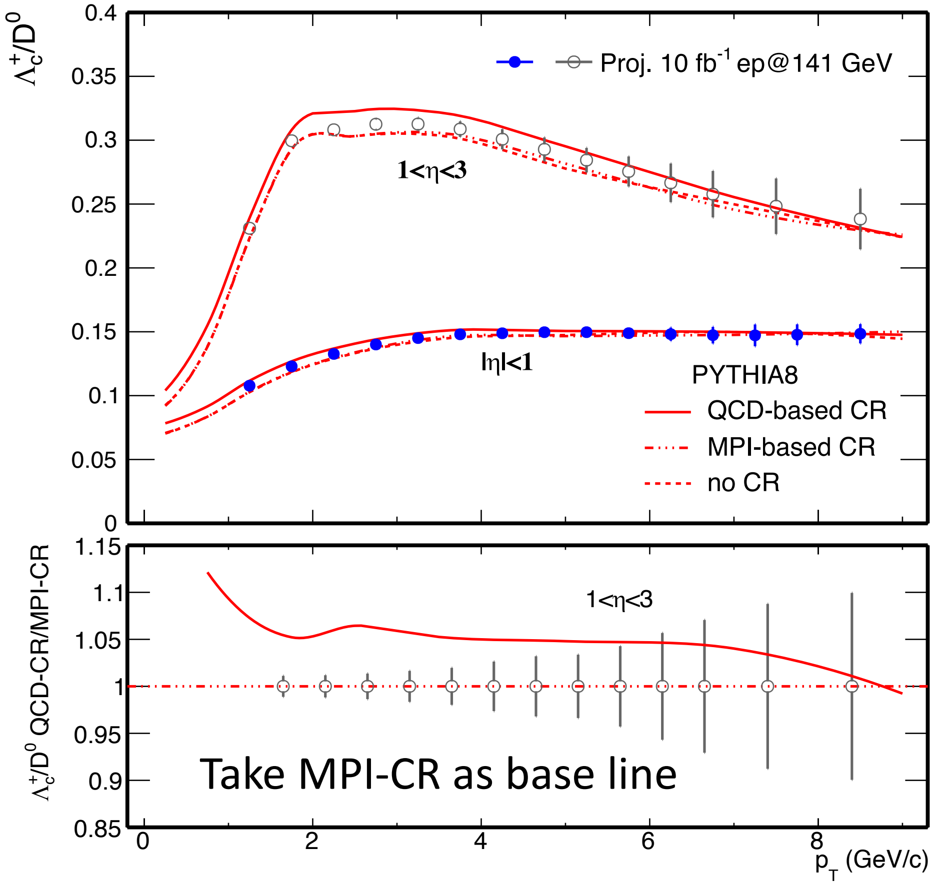


- Improving signals with topology variables;
- Best significance achieved at $|\eta|<1$.

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

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

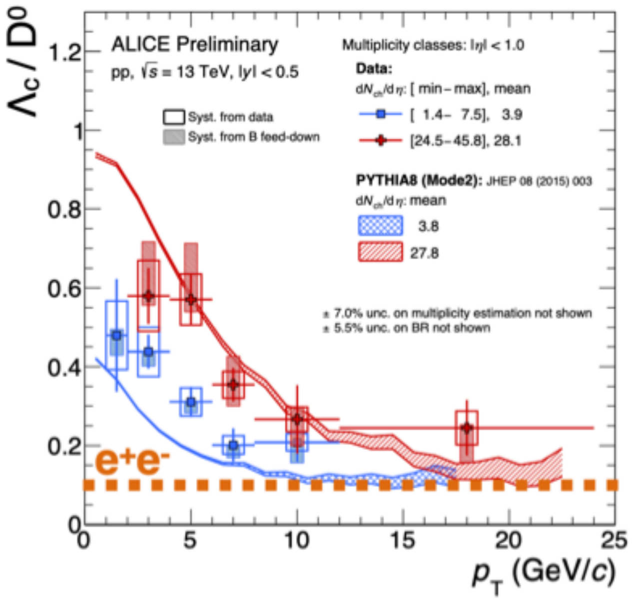


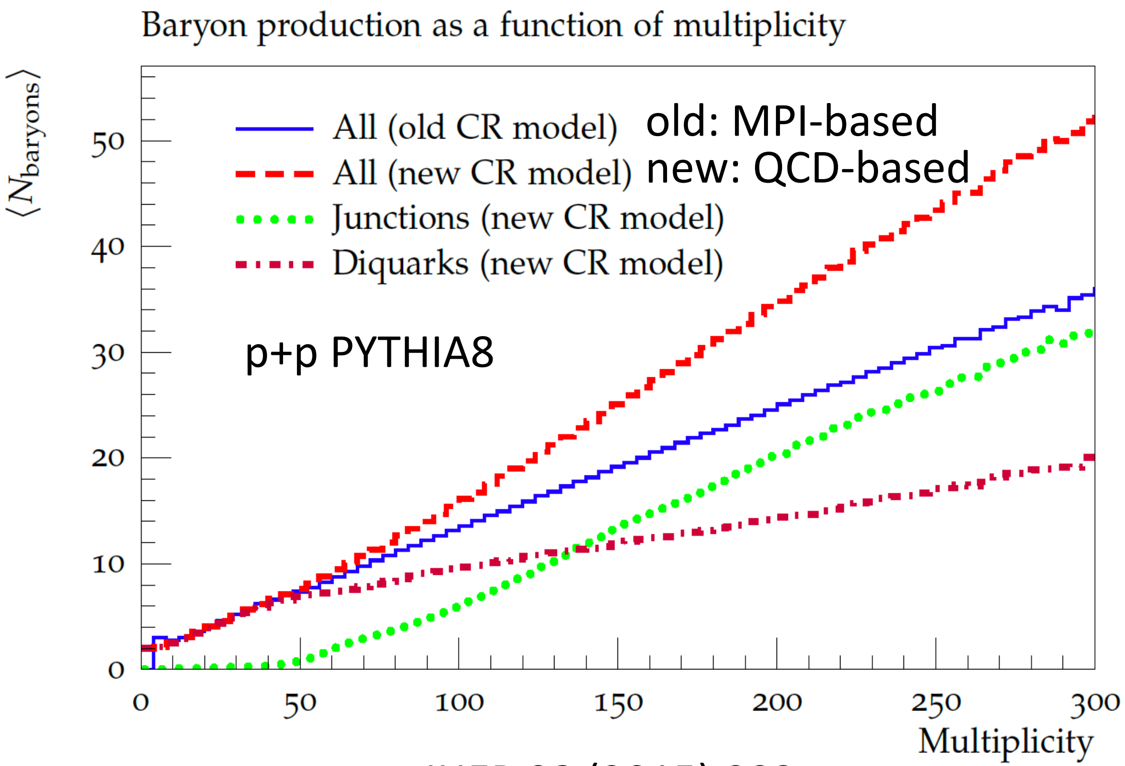


- Precise measurements of charm baryon in future EIC collider;
- Ability to separate two CR frameworks at low p_T with L=10 fb^{-1}.

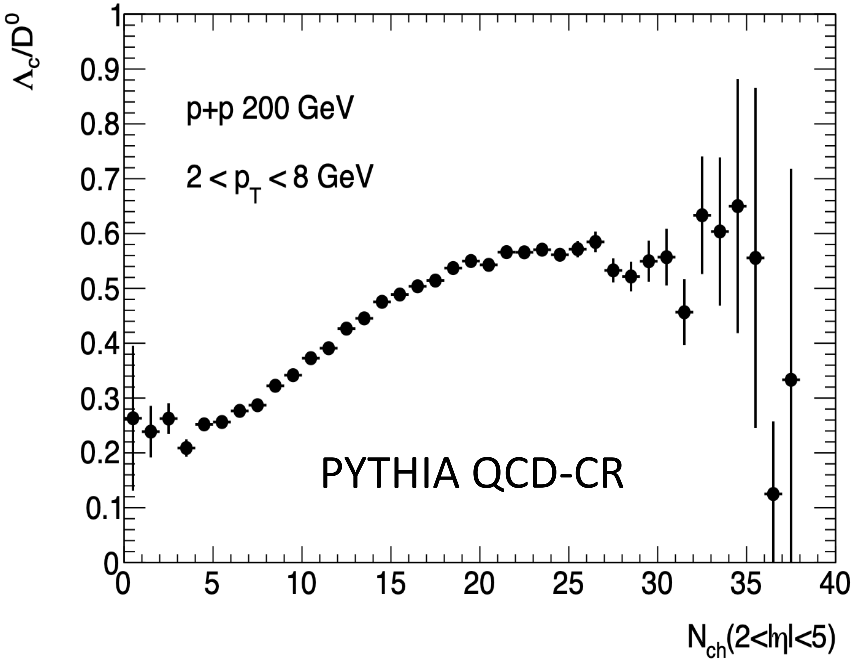
Multiplicity dependence

- 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



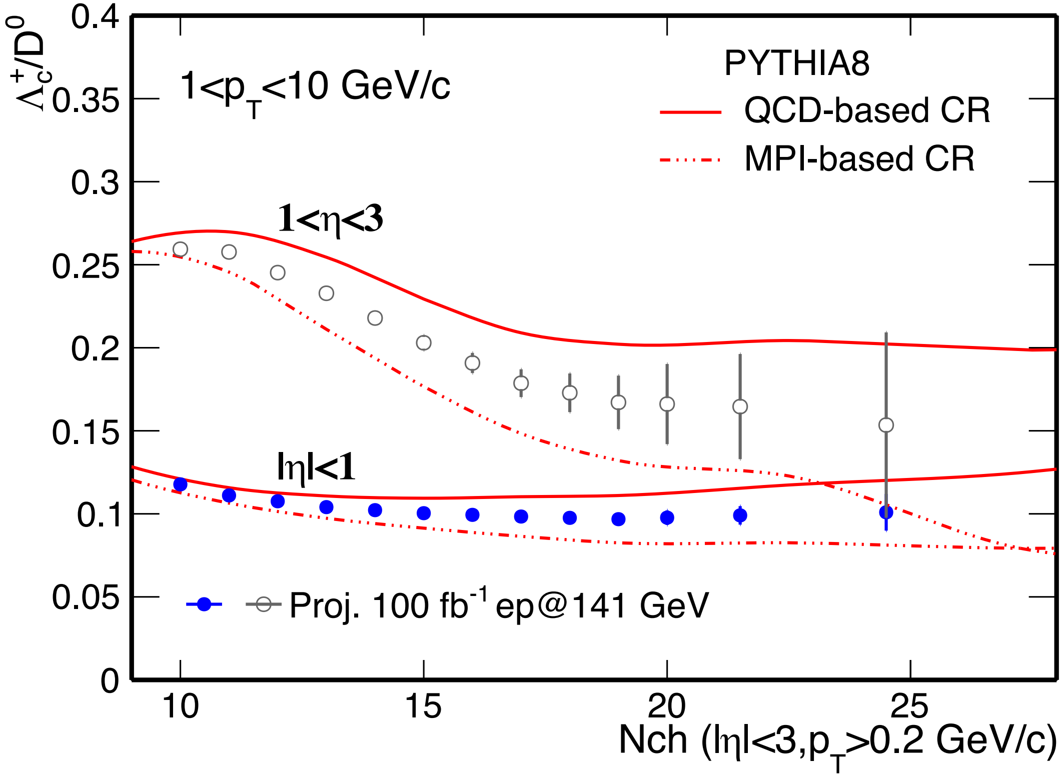


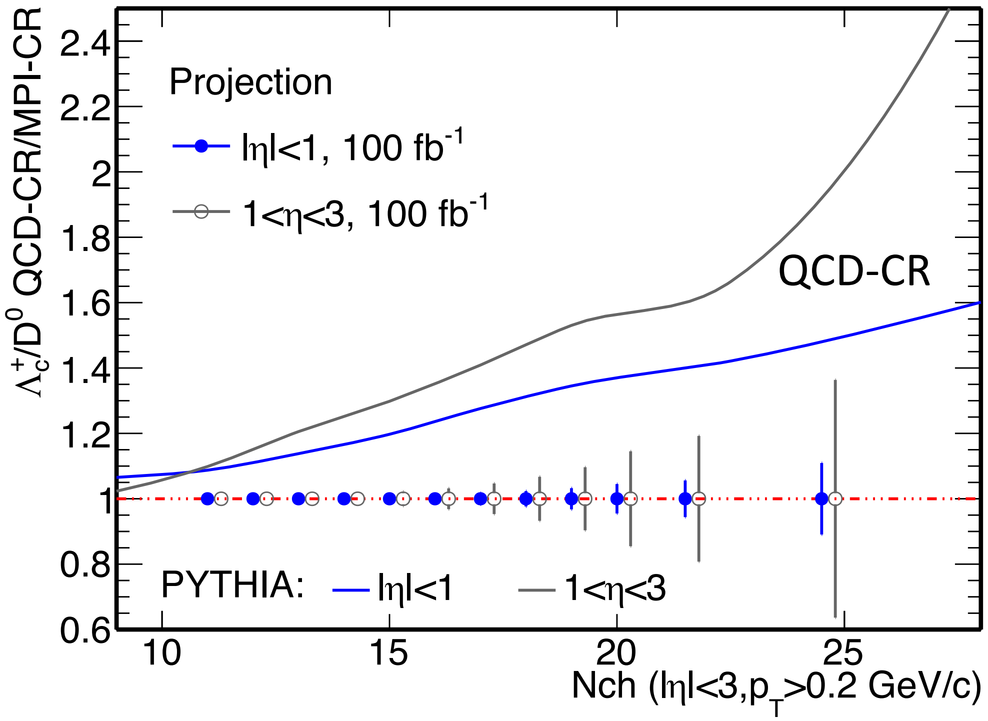
JHEP 08 (2015) 003



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





Take MPI-CR result as base line

Summary

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

  - Λ_c^+/D^0 university of CR framework in different collisions system

    - MPI-CR same as fragmentation baseline, fails in p+p

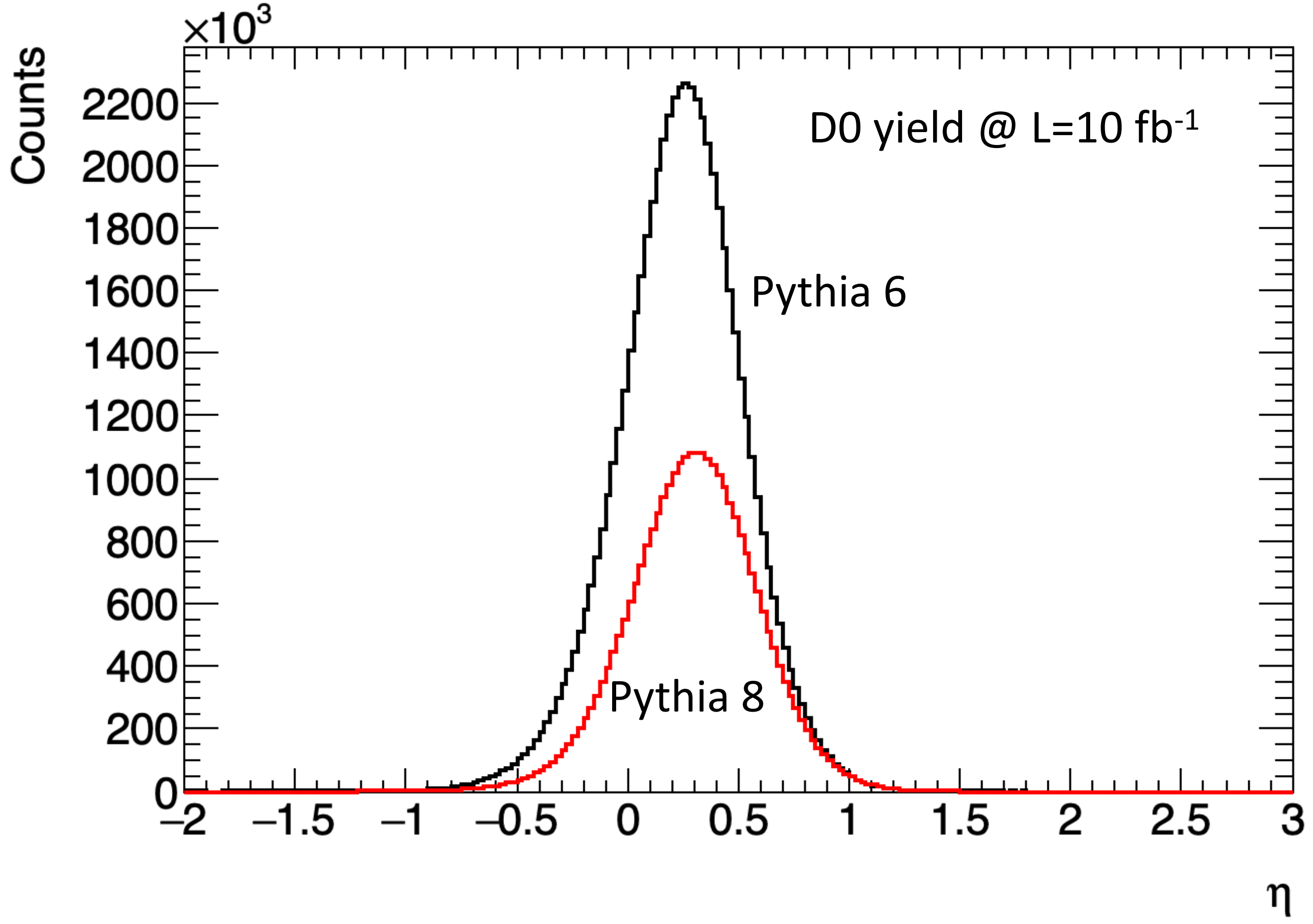
    - QCD-CR enhance baryon production in pp and high multiplicity ep collisions

- Charm baryon measurements in the future EIC

  - high statistics, cleaner background

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

Back ups


×10^3
Counts
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
2.5
3
η
D0 yield @ L=10 fb-1
Pythia 6
Pythia 8

Fast simulation procedure and Λ_c reconstruction

- ep 18x275 GeV events generated by PYTHIA6 with EIC tune
  https://eic.github.io/software/pythia6.html
- Smear primary vertex and single tracks by fast simulation
- Reconstruction channel

Signal:

Λ_c^+ decay in PYTHIA

$\boxed{\Lambda_c^+ \rightarrow pK^-\pi^+ \text{ non-resonant } 3.4\%}$

$\rightarrow p\overline{K^{*0}}$ ~0.5%

$\rightarrow \Delta^{++}K^-$ ~0.65%

$\rightarrow \Lambda\pi^+$ missing $\Lambda \rightarrow pK^-$

Scale to PDG B.R.=6.23%

Combinatorial background

- $pK^-\pi^+$ right-sign
- Reject Λ_c^+ resonance channel signals

Λ_c^+ $c\tau \sim 60\ \mu m$