

Λ_c simulation in the future EIC

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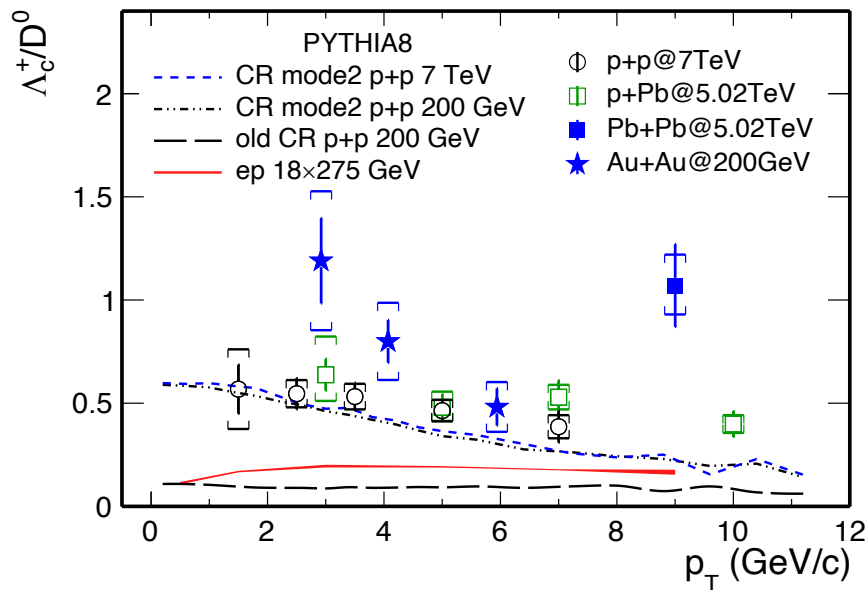
Jets+HF Quarks PWG Meeting

Dec. 14, 2020

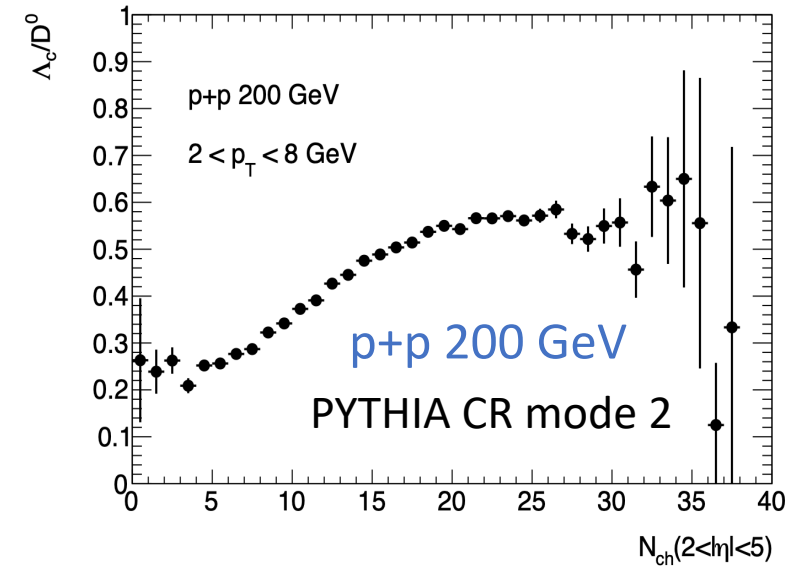
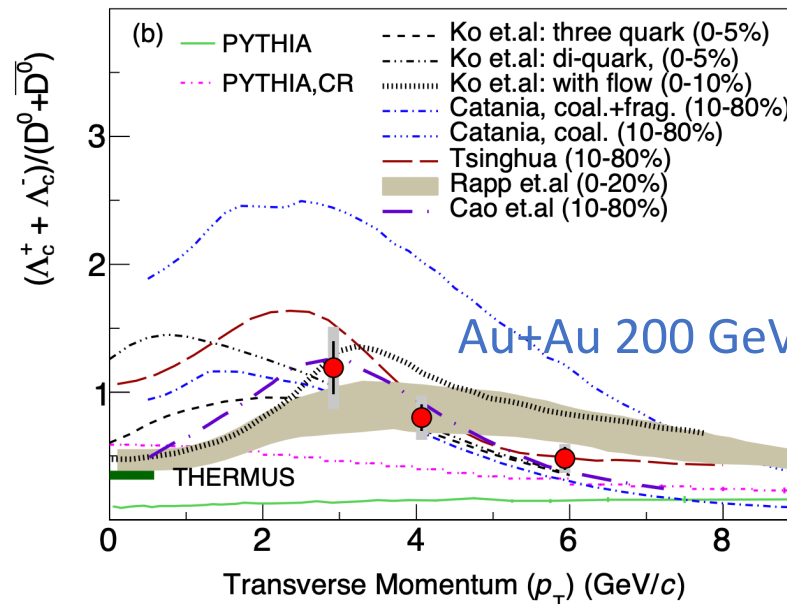


Motivation

- Charm hadronization
 - Fragmentation failed to describe Λ_c^+/D^0 in p+p and A+A collisions
 - A+A collisions - quark coalescence
 - p+p collisions - color reconnection (CR) J. Christiansen JHEP 2015:3 (2015)
 - new CR mode, junction reconnection -> enhance baryon production

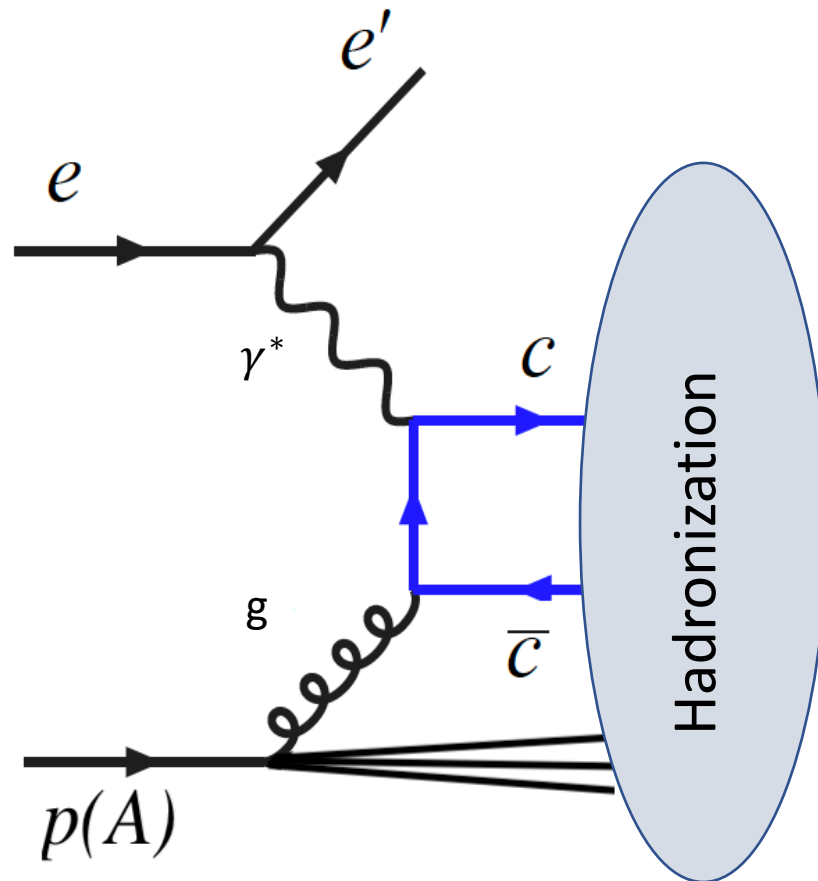


PLB (2019) 793:212
 PRL (2020) 124:172301



Λ_c in $e+p/A$ collisions

- Better understand and controlled initial state condition



Λ_c reconstruction in future EIC

ep 18x275 GeV from
PYTHIA6 with EIC tune

Fast simulation
Detector response on
single tracks

<https://eic.github.io/software/pythia6.html>

Detector set up

- Pointing resolution (DCA resolution)
- Momentum resolution based on $B = 3$ T
- Primary vertex resolution from full Geant4
- Tracking efficiency from full Geant4
- PID scenario

Pointing resolution (Transverse)

	Resolution (XY) (μm)
$ \eta < 1$	$5 \oplus 20/p_T$
$1 < \eta < 2$	$20 \oplus 30/p_T$
$2 < \eta < 3$	$40 \oplus 30/p_T$

Momentum resolution

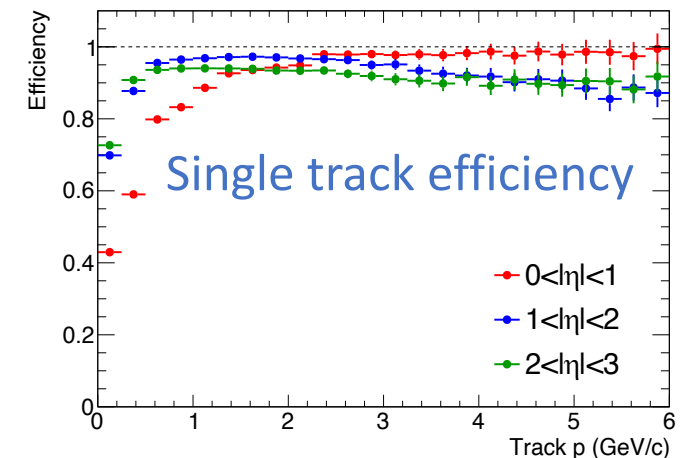
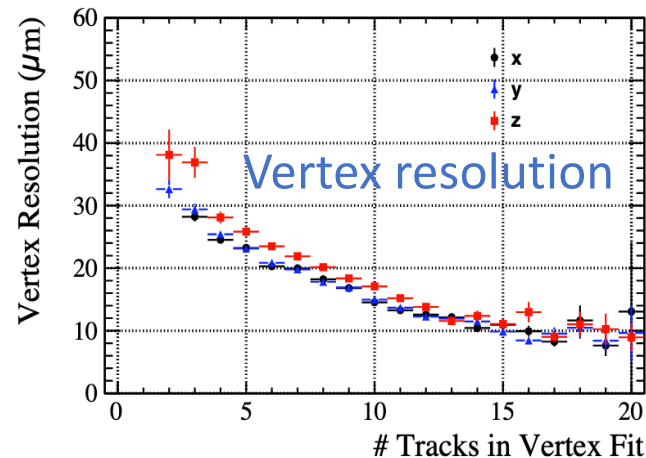
η	Resolution %
$-3.5 < \eta < -2.0$	$0.1 \cdot p \oplus 0.5$
$-2.0 < \eta < 1.0$	$0.05 \cdot p \oplus 0.5$
$1.0 < \eta < 2.5$	$0.05 \cdot p \oplus 1.0$
$2.5 < \eta < 3.5$	$0.1 \cdot p \oplus 2.0$

Assumed 3σ separation between $\pi/K/p$

η	Momentum
$-3 < \eta < -1.0$	$p < 10$ GeV/c
$-1.0 < \eta < 1.0$	$p < 7$ GeV/c
$1.0 < \eta < 2.0$	$p < 10$ GeV/c
$2.0 < \eta < 3.0$	$p < 30$ GeV/c

Full Geant4 simulation from Matthew

https://indico.bnl.gov/event/9398/contributions/41400/attachments/30474/47775/Kelsey_EICJetsHF_21Sep2020.pdf



Λ_c reconstruction in future EIC

ep 18x275 GeV from
PYTHIA6 with EIC tune

Detector response

Reconstruction

- Reconstruction channel

Signal:

Λ_c^+ decay in PYTHIA

Scale to total B.R.=6.28%

$\Lambda_c^+ \rightarrow pK^-\pi^+$ non-resonant 2.96% (PDG 3.4%)

$\rightarrow p\overline{K}^{*0}$ $\sim 0.5\%$ (PDG 1.94%x66.7%)

$\rightarrow \Delta^{++}K^-$ $\sim 0.65\%$ (PDG 1.07%x99.4%)

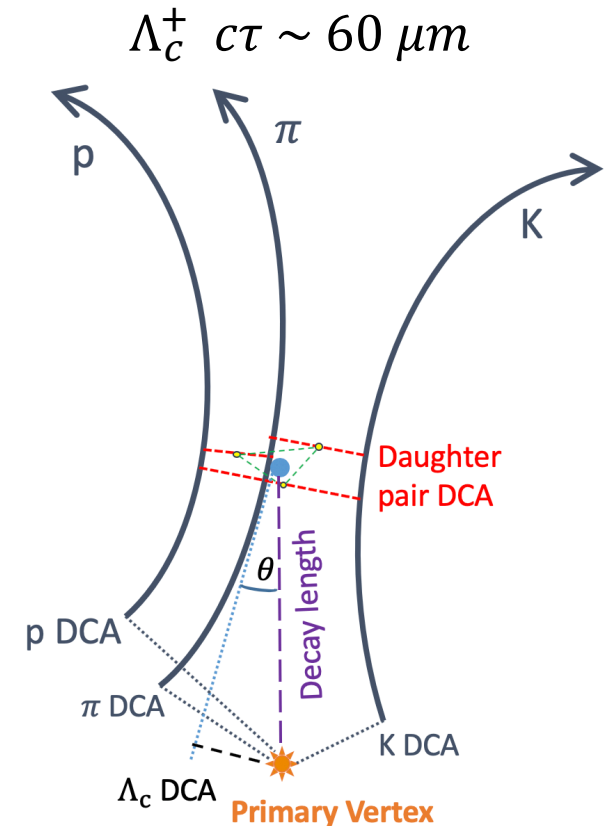
$\rightarrow \Lambda\pi^+$ missing $\Lambda \rightarrow pK^-$ (PDG 2.2%x22.5%)

Other channels:

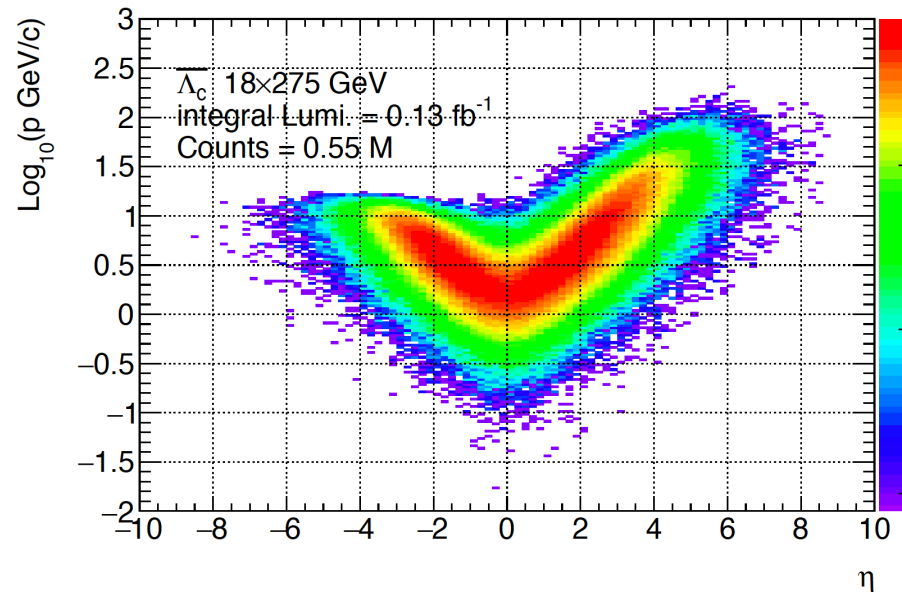
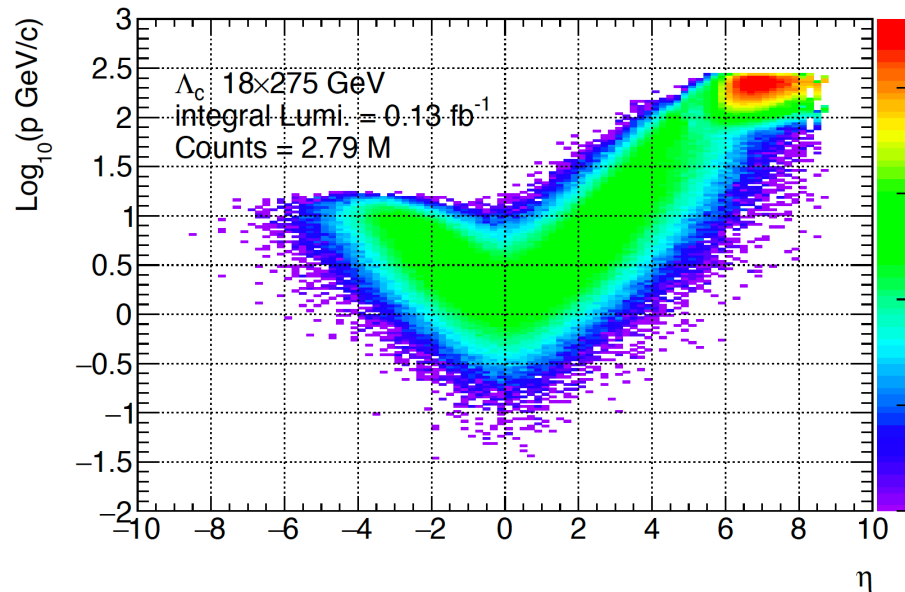
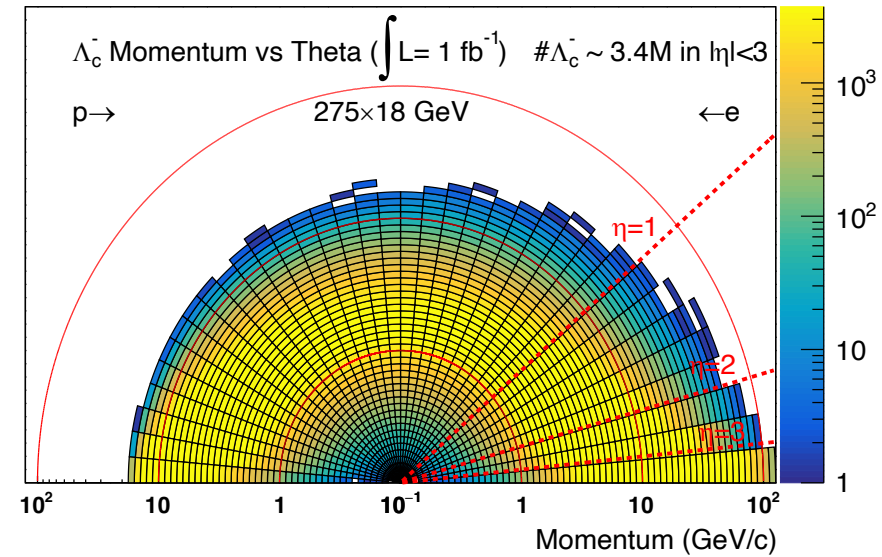
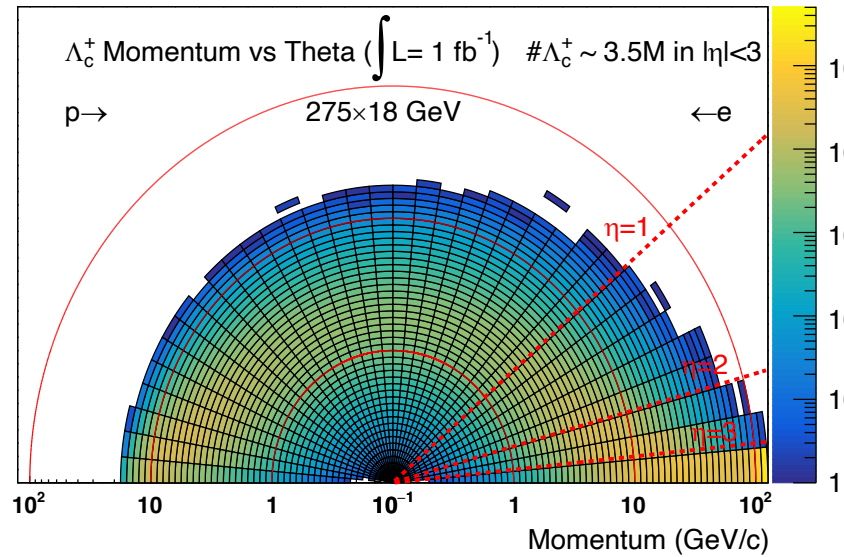
$\Lambda_c^+ \rightarrow pK_s^0$ (1.58%)

Combinatorial background

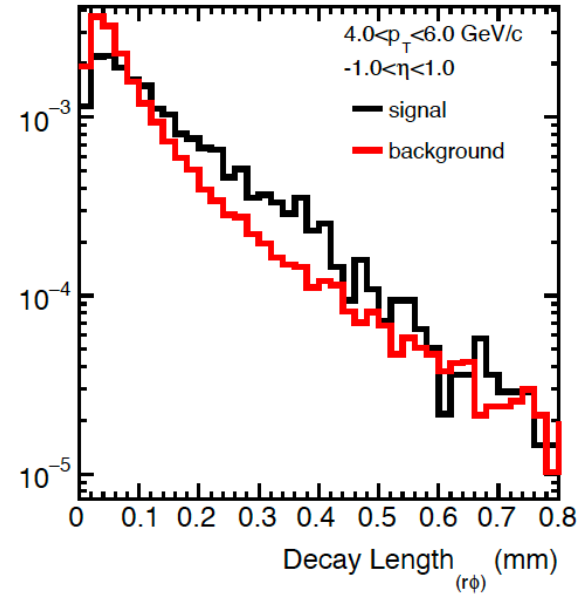
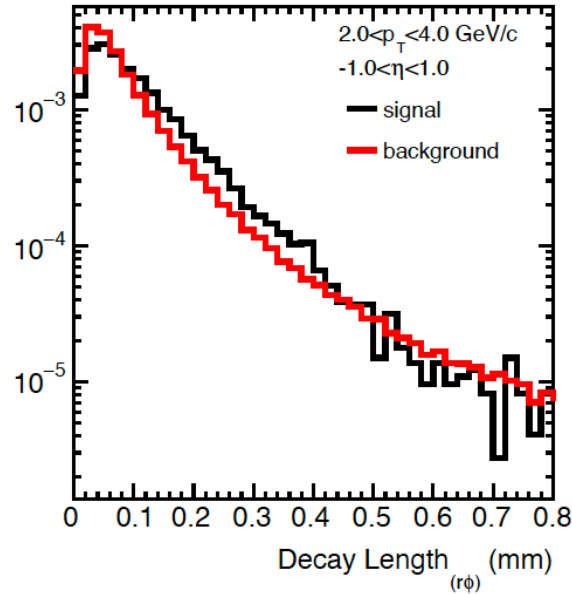
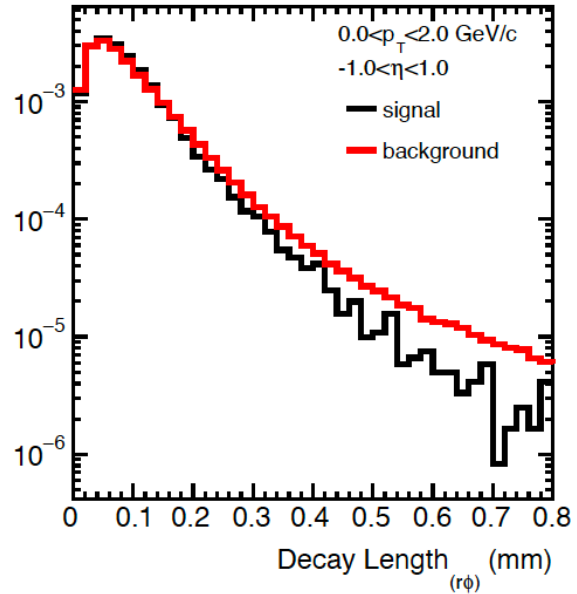
- Combinations of $pK^-\pi^+$ triplets with right-sign (mis-PID if particles cannot be separated)
- Reject Λ_c^+ resonance channel signals



Acceptance for Λ_c in ep 18x275 GeV (PYTHIA v6.4)

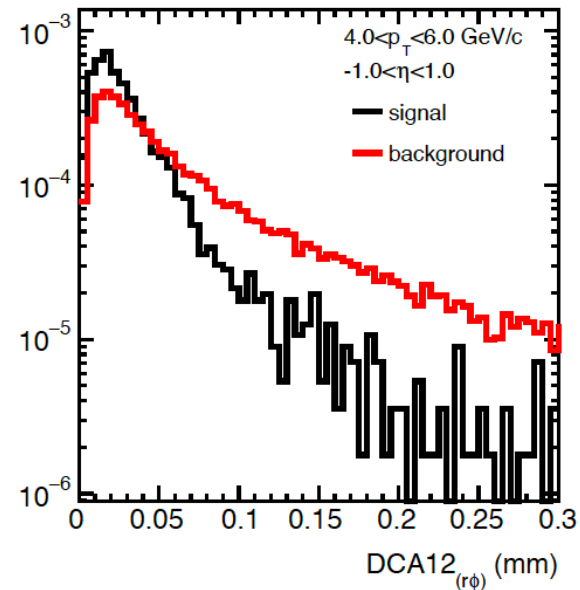
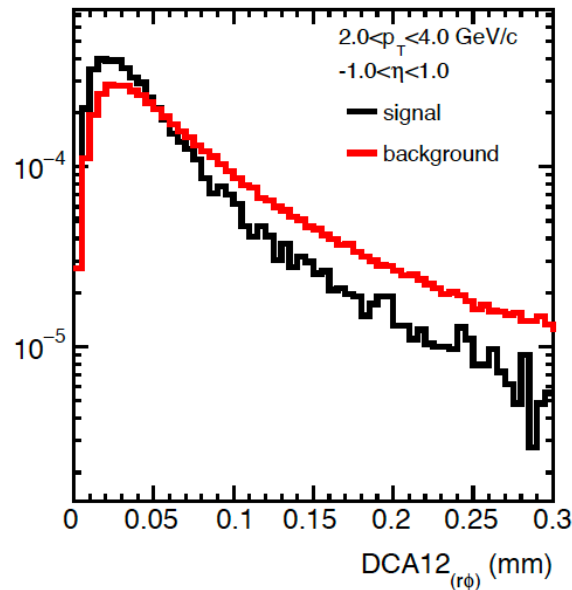
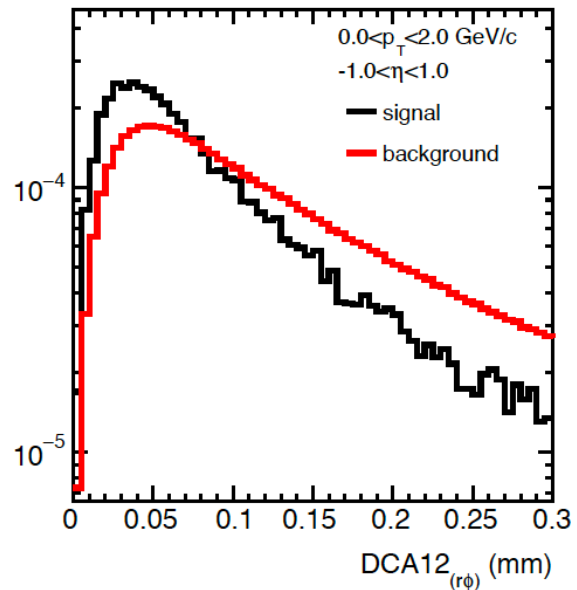


Selected topology parameters – p_T dependence



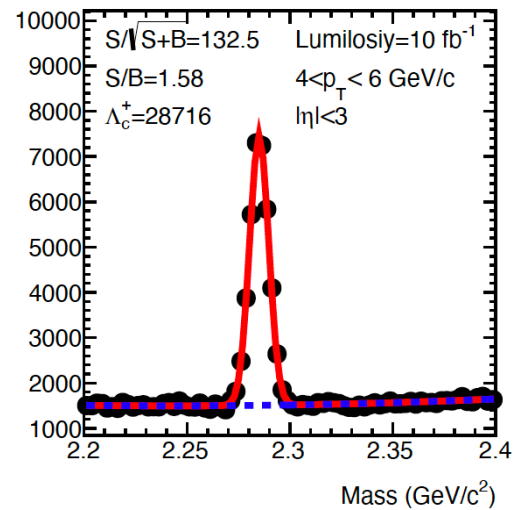
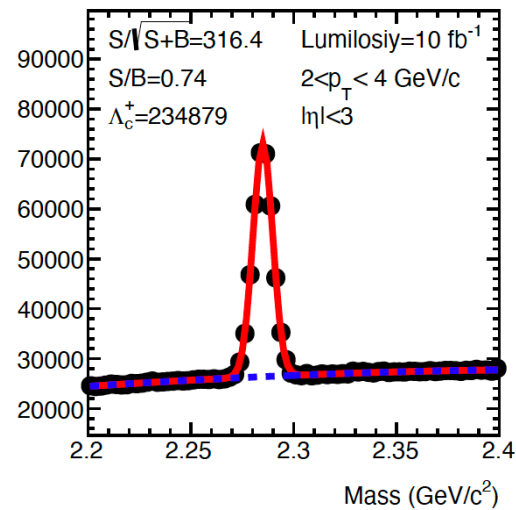
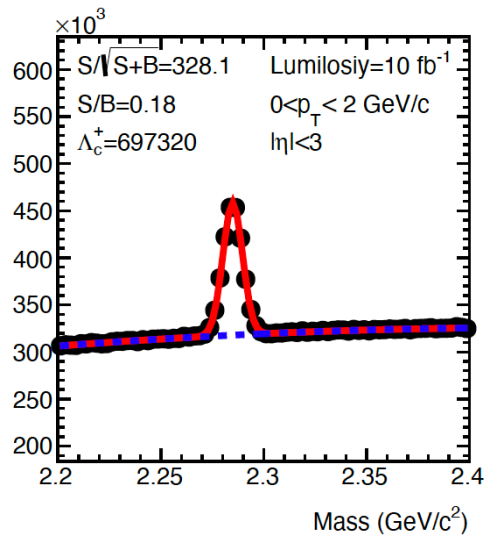
Decay Length

Better separation power at higher p_T



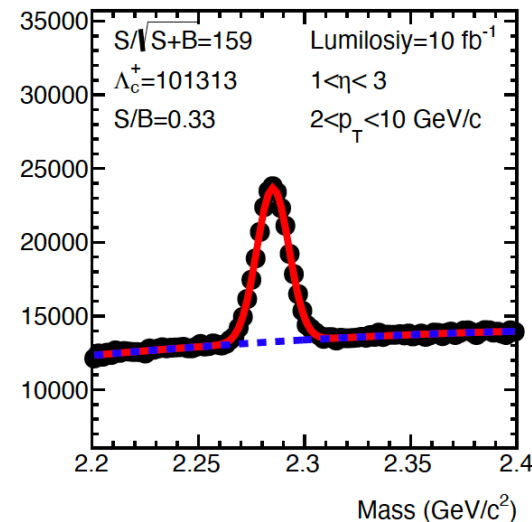
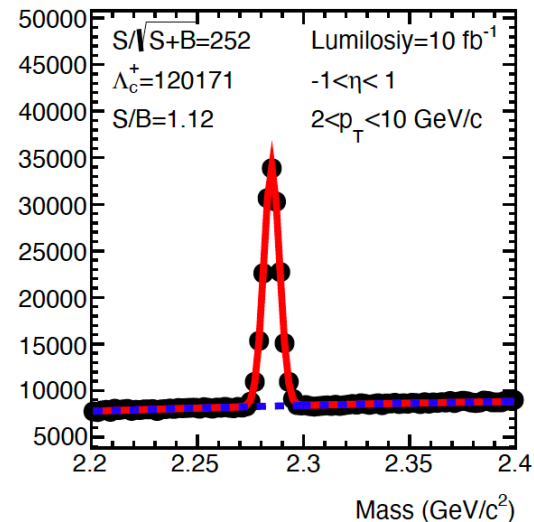
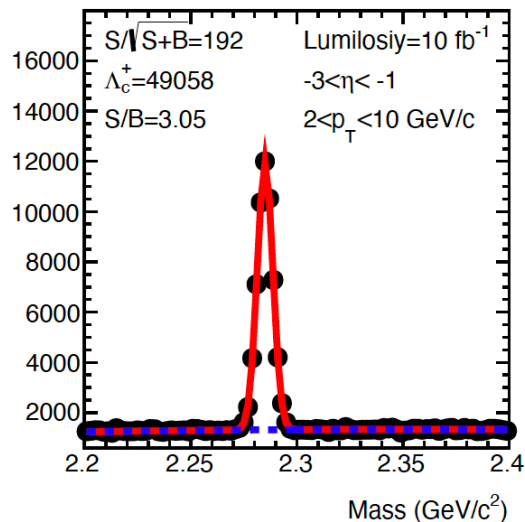
Daughter Pair DCA

Projected Λ_c^+ signal



Signals in p_T bins
 $|\eta| < 3$

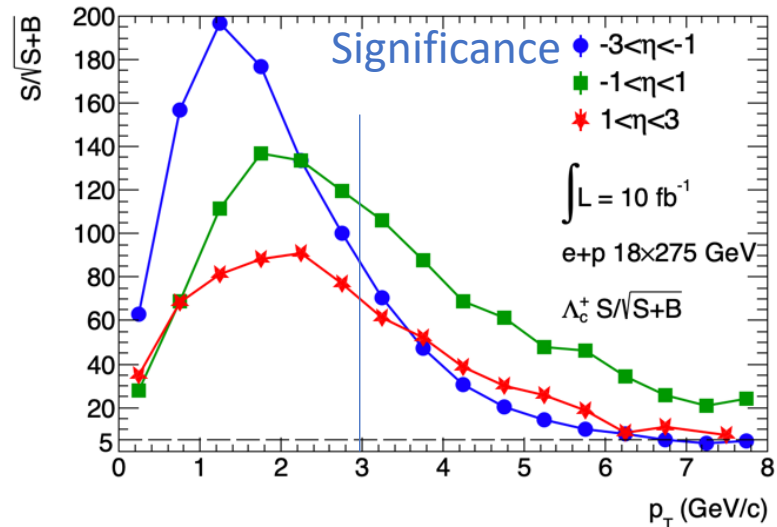
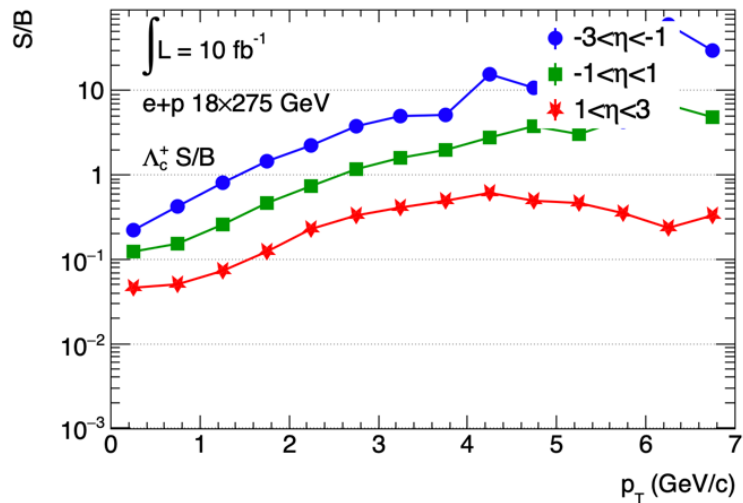
$p_T \uparrow$ $S/B \downarrow$



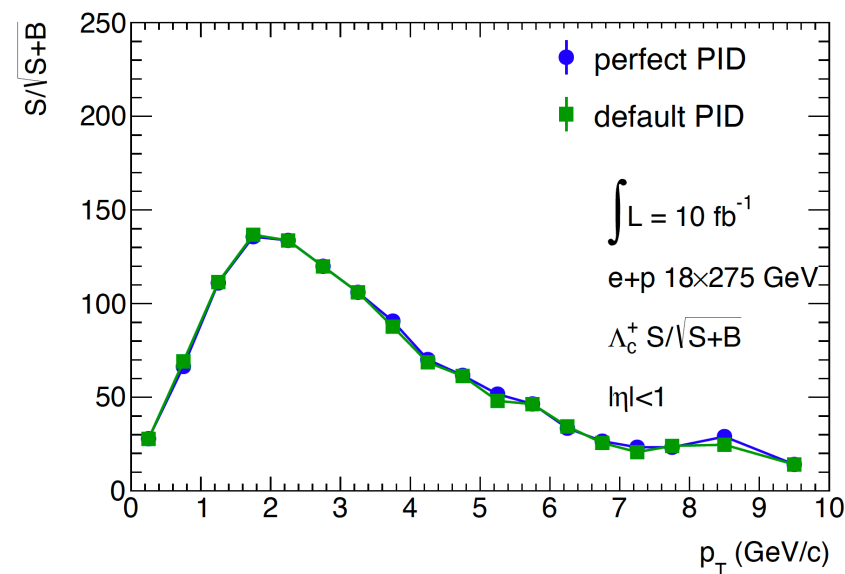
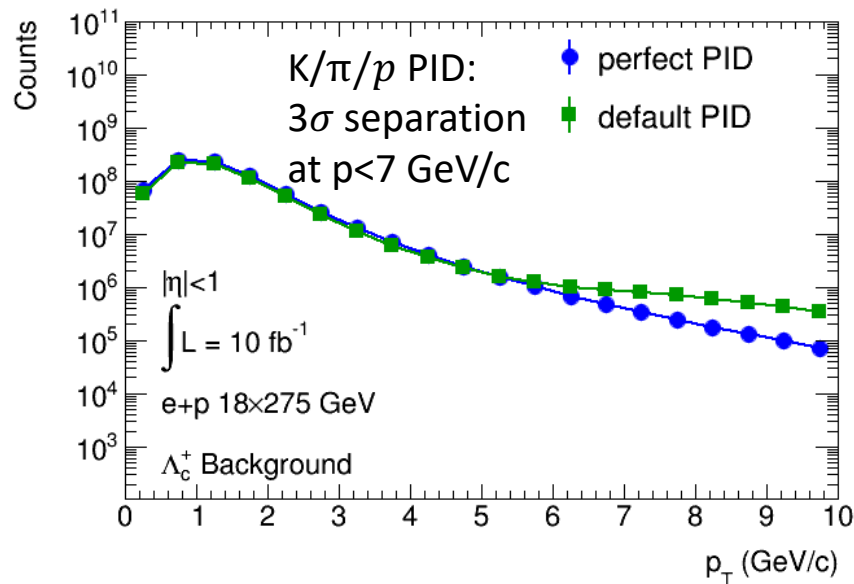
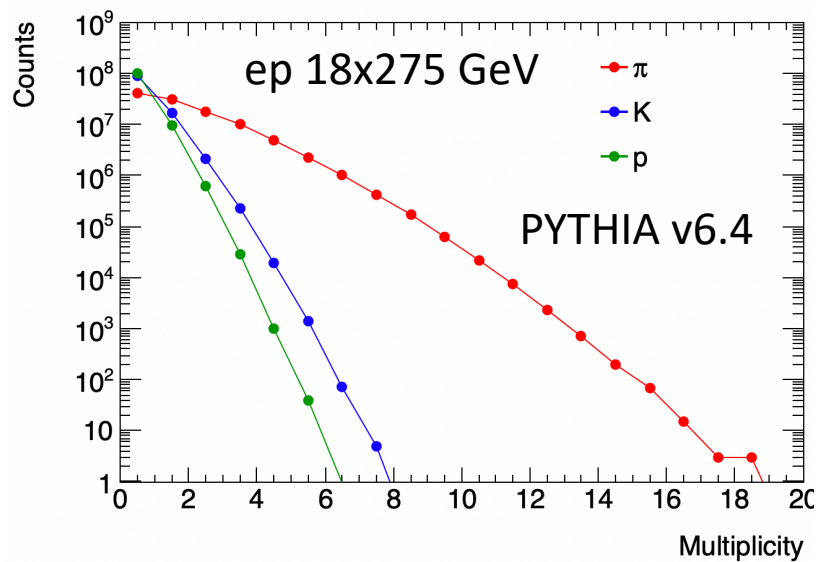
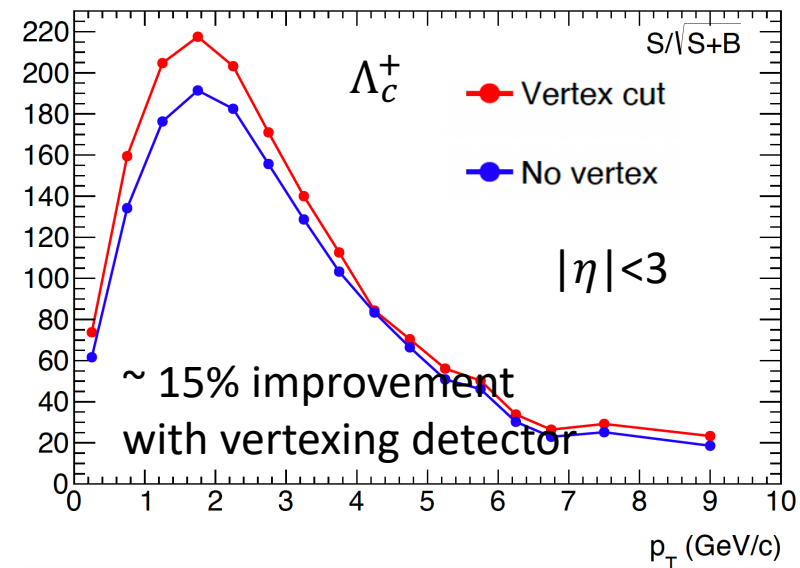
Signals in η bins, $2 < p_T < 10 \text{ GeV}/c$

No p_T cuts;
 Topology cuts:
 $0 < p_T < 4 \text{ GeV}/c$
 Decay length $> 10 \mu\text{m}$, Λ_c DCA $< 150 \mu\text{m}$, Pair DCA $< 300 \mu\text{m}$;
 $4 < p_T < 6 \text{ GeV}/c$
 Decay length $> 20 \mu\text{m}$, Λ_c DCA $< 100 \mu\text{m}$, Pair DCA $< 100 \mu\text{m}$;
 $6 < p_T < 10 \text{ GeV}/c$
 Decay length $> 0 \mu\text{m}$, Λ_c DCA $< 60 \mu\text{m}$, Pair DCA $< 100 \mu\text{m}$.

Significance, S/B vs p_T and η



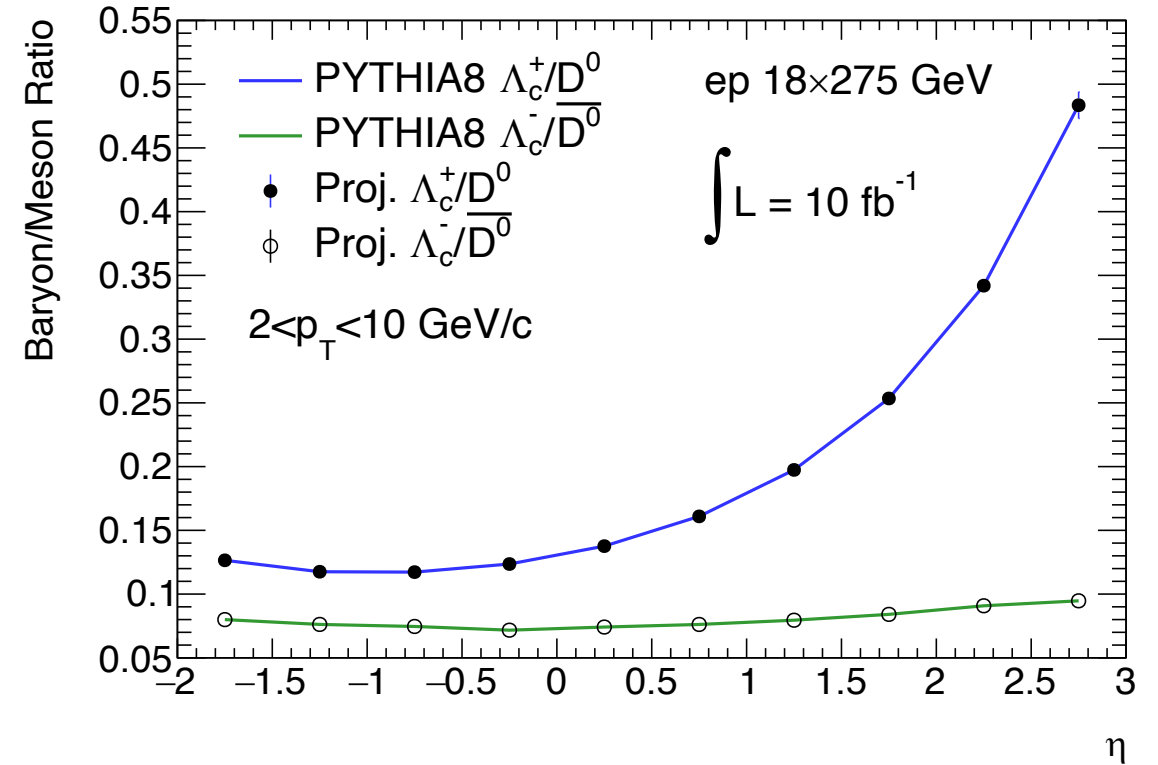
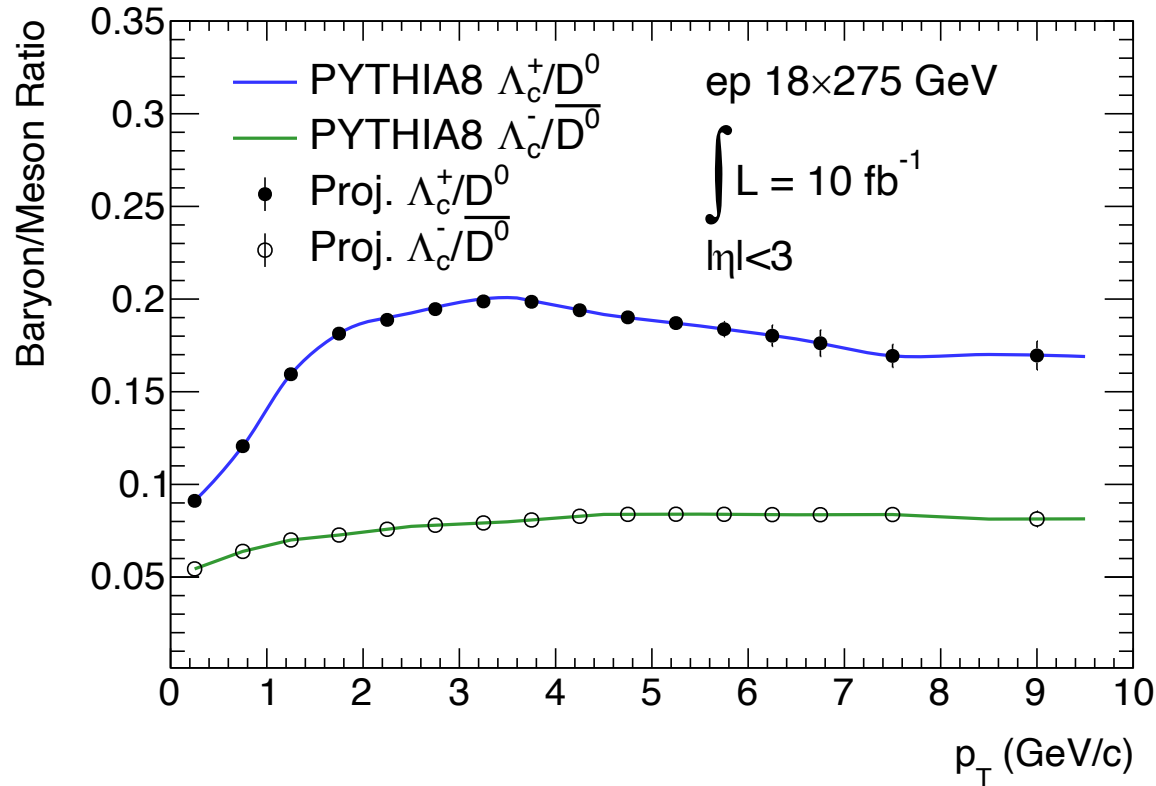
The topological cuts are not optimized.



Projection plots

$$ratio = \Lambda_c/D^0 \quad \frac{\Delta ratio}{ratio} = \sqrt{\left(\frac{\Delta\Lambda_c}{\Lambda_c}\right)^2 + \left(\frac{\Delta D^0}{D^0}\right)^2}$$

$$1/\text{significance} = \sqrt{S + B/S}$$



- Precise Λ_c^\pm measurements over board momentum and η range

Projection plots

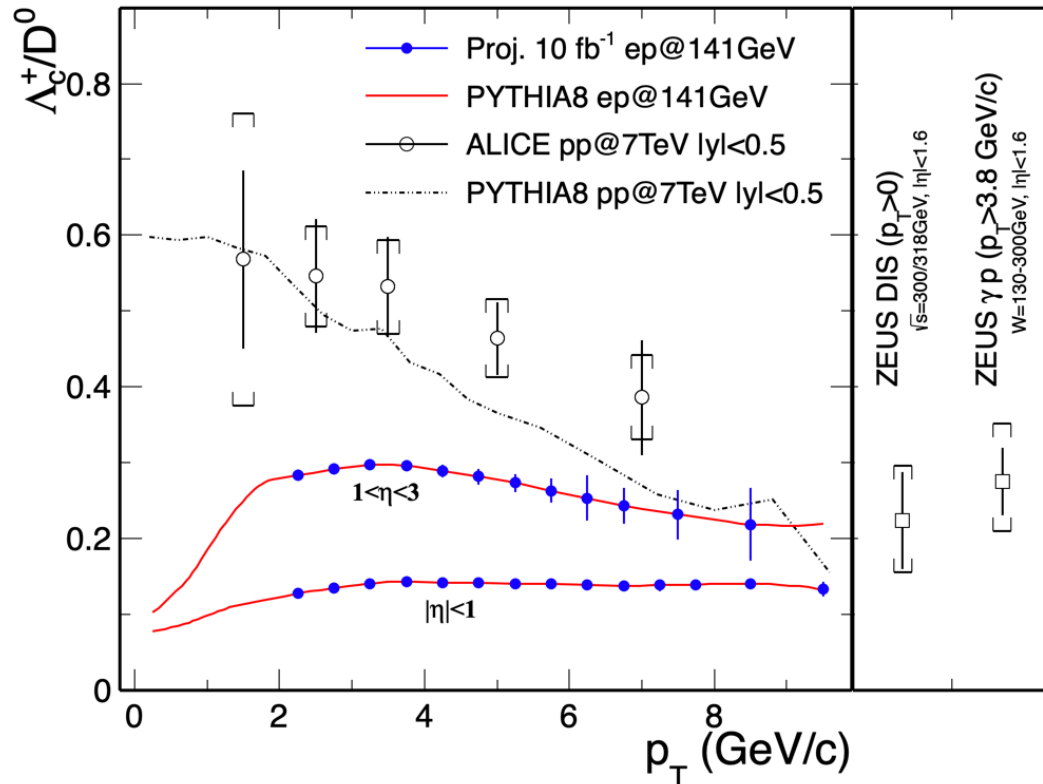
Mom. range for $\pi/K/p$ 3σ separation \rightarrow

Left: default PID

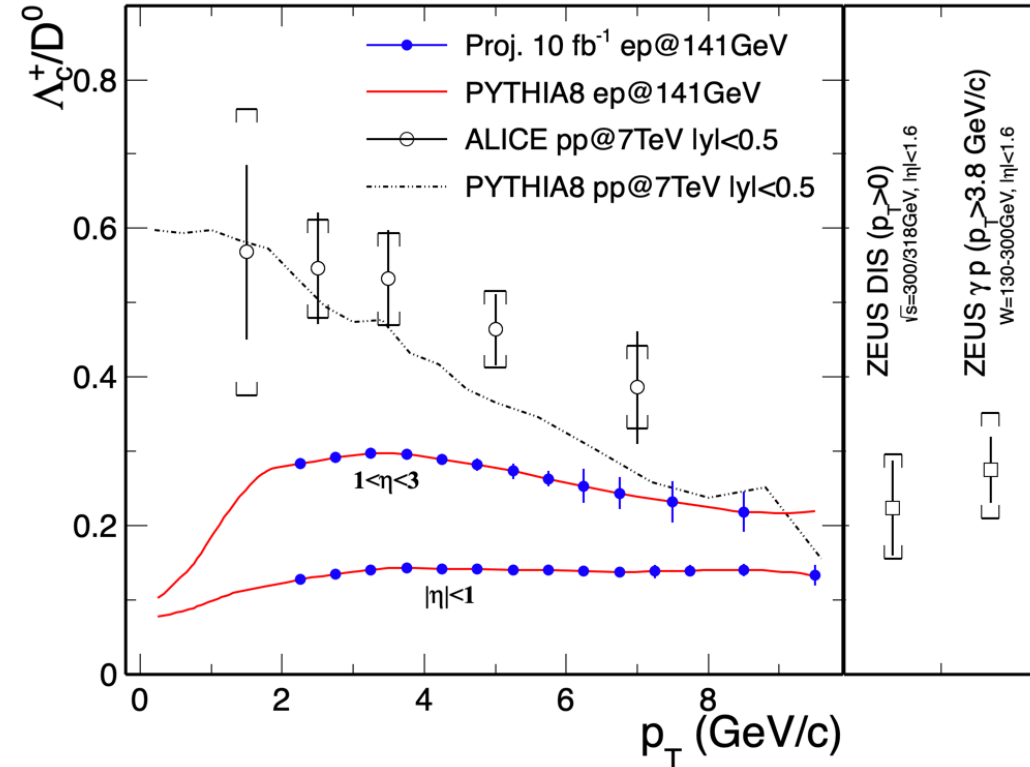
Right: new version in Det. Matrix

η	Momentum	Momentum
$-3 < \eta < -1$	$p < 10$ GeV/c	$p < 10$ GeV/c
$-1 < \eta < 1$	$p < 7$ GeV/c	$p < 6$ GeV/c \downarrow
$1 < \eta < 2$	$p < 10$ GeV/c	$p < 50$ GeV/c \uparrow
$2 < \eta < 3$	$p < 30$ GeV/c	$p < 50$ GeV/c \uparrow

With default PID in this study



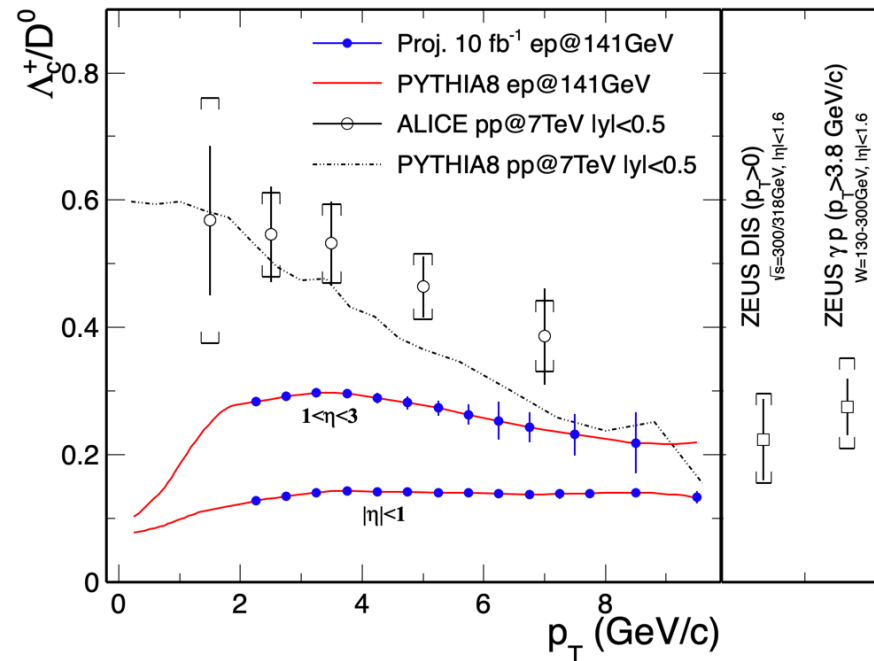
With updated version of detector matrix PID



- Much higher statistics in the future EIC compare to current ZEUS measurements

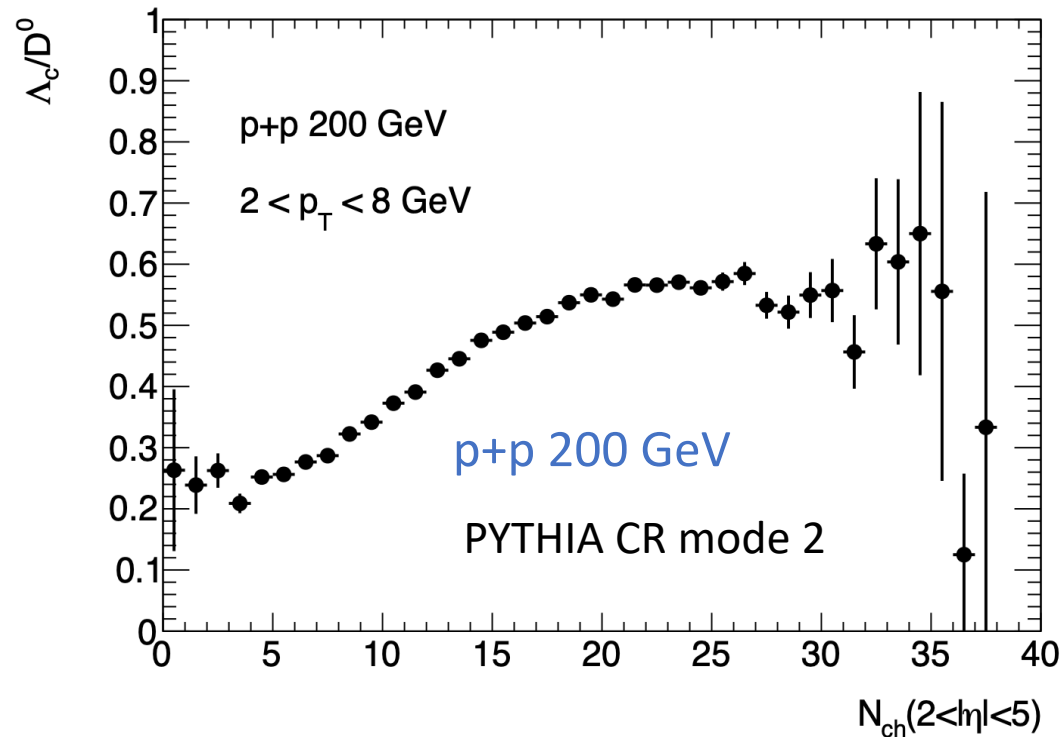
Summary

- Λ_c^+ / D^0 measurements – charm hadronization
 - p+p: current knowledge - color reconnection with baryon junction
 - e+p and e+A ?
- Simulation on Λ_c reconstruction in e+p 18+275 GeV collisions
 - Precise measurements of charm baryon over board momentum and η range in the future EIC

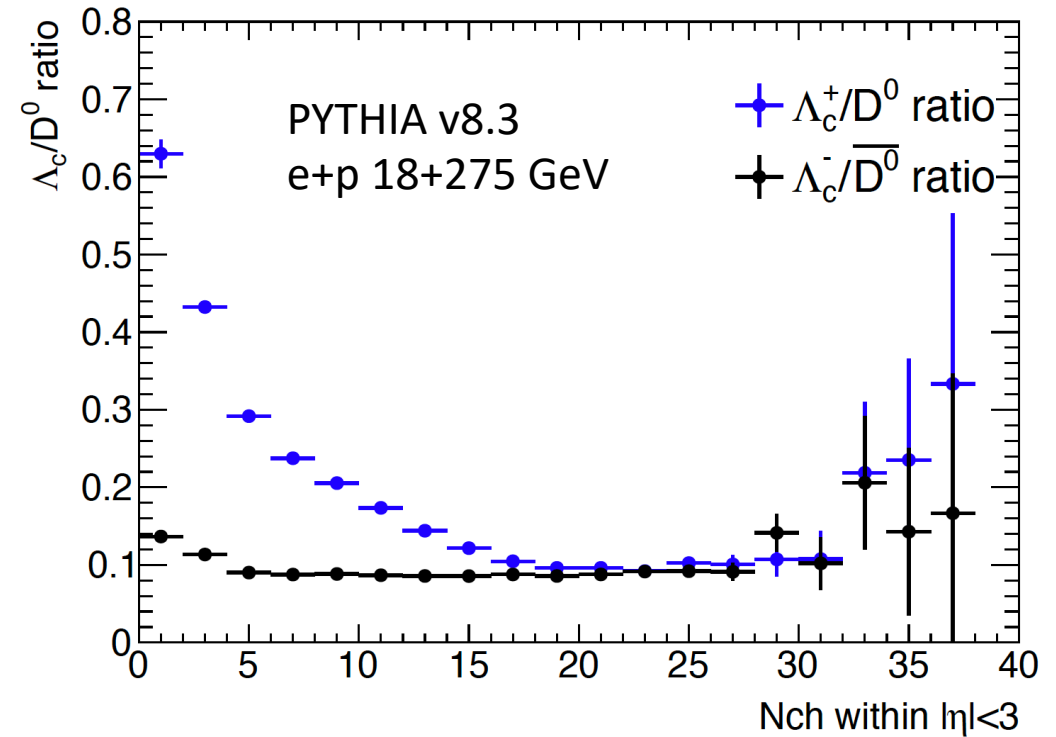


Future perspective – charm hadronization

- Multiplicity dependence of Λ_c^+/D^0
- Nucleus impact on charm baryon production
 - comparing Λ_c^+/D^0 in e+p and e+A



Multiplicity dependence of Λ_c^+/D^0 in p+p



Future perspective

In polarized ep collisions

- Λ_c^+ longitudinal spin transfer D_{LL}
 - gluon polarization in proton
 - spin dependent fragmentation function

$$D_{LL} = \frac{\sigma(++)-\sigma(+-)}{\sigma(++)+\sigma(+-)}$$

Predictions for polarized pp collisions at RHIC:

arXiv:hep-ph/0306285

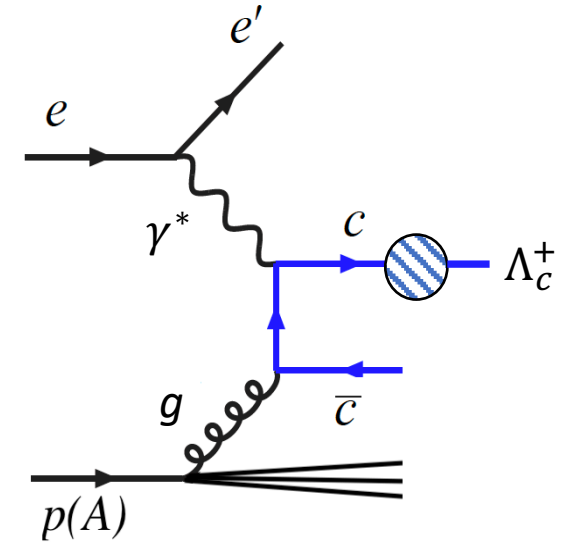
arXiv:hep-ph/0412244

- Λ_c^+ polarization
 - self analyzable in e.g.

$$\Lambda_c^+ \left(J^P = \frac{1}{2}^+ \right) \rightarrow \Lambda \left(J^P = \frac{1}{2}^+ \right) \pi^+ (J^P = 0)$$

$$\frac{d\sigma}{d \cos \theta^*} \propto 1 + P_c \alpha_c \cos \theta^*$$

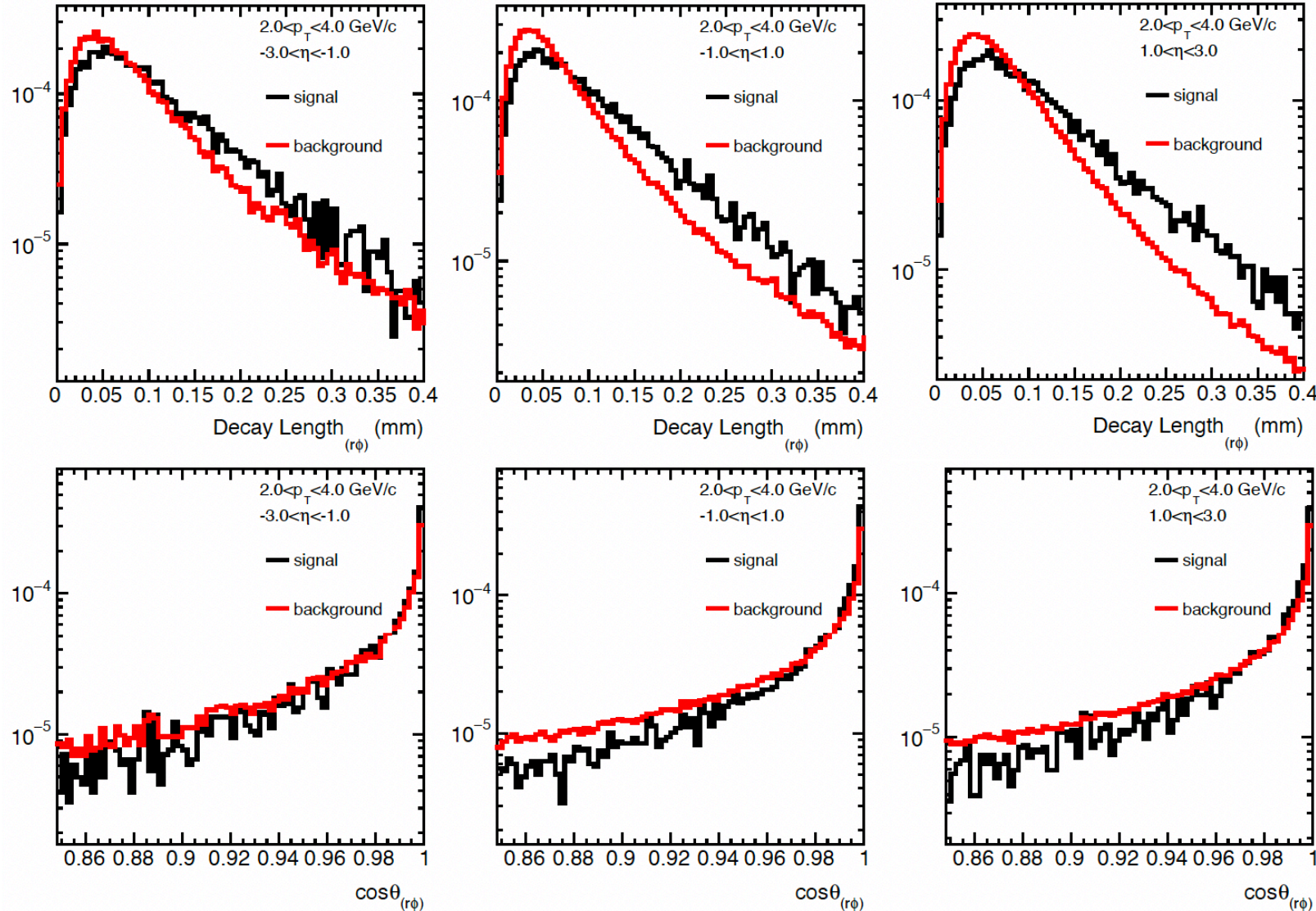
- Similar method as Λ D_{LL} and polarization



- Back ups

Topology parameters - η dependence

Pointing resolution:
 $2 < p_T < 4 \text{ GeV}/c$



	Resolution (σ) (μm)
$ \eta < 1$	$5 \oplus 20/p_T$
$1 < \eta < 2$	$20 \oplus 30/p_T$
$2 < \eta < 3$	$40 \oplus 30/p_T$

Better separation in middle and forward rapidity

- Old pointing resolution

	Resolution (XY) (μm)
$ \eta < 1$	$5 \oplus 20/p_T$
$1 < \eta < 2$	$20 \oplus 30/p_T$
$2 < \eta < 3$	$40 \oplus 30/p_T$

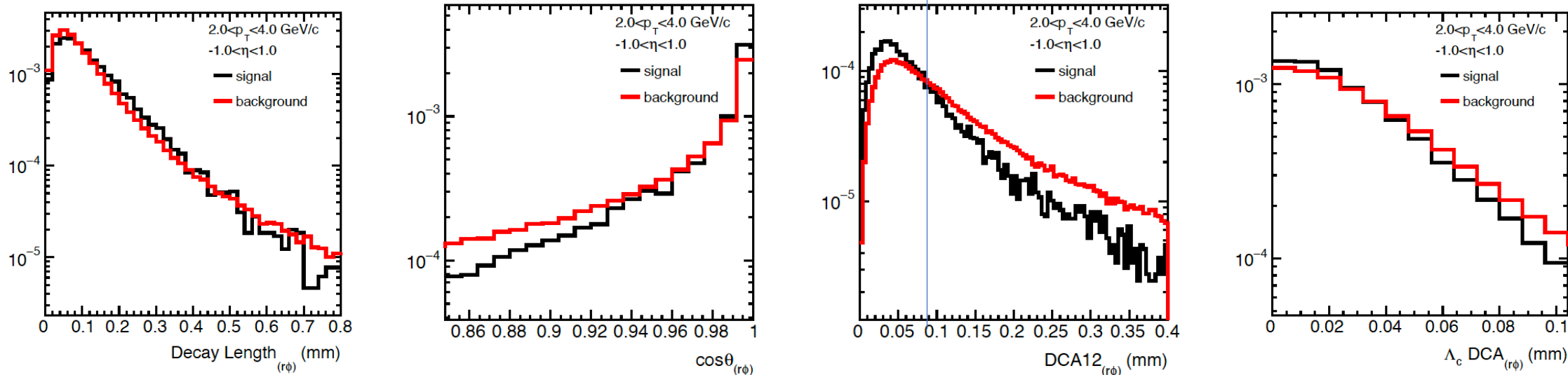
- New pointing resolution

	DCA Resolution in XY (μm)
$ \eta < 1$	$5 \oplus 30/p_T$
$1 < \eta < 2$	$10 \oplus 40/p_T$
$2 < \eta < 3$	$15 \oplus 60/p_T$

Topo. Parameters with new PID

Pre-selection cuts for background:
 $DCA_{12} < 40 \mu\text{m}$, $2.2 < \text{Mass} < 2.4 \text{ GeV}/c^2$

With **new** pointing resolution • No dramatic difference with two set ups for Λ_c



With **old** pointing resolution

