Studies of Open Charm Hadron Reconstruction at the EIC and Implications for Charm Structure Functions

Matthew Kelsey*
Wayne State University

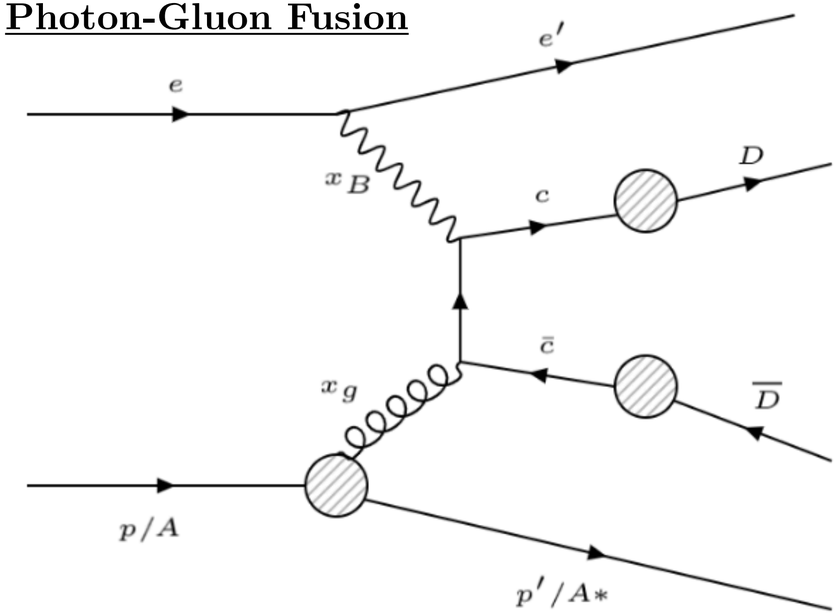
EIC Opportunities for SnowMass
Jan. 25-29 2021

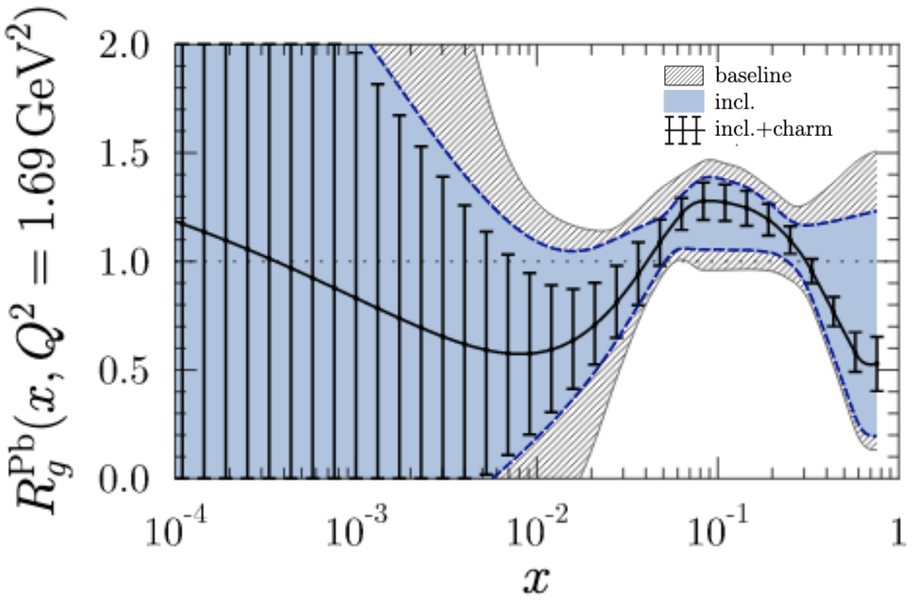
*** In collaboration with Reynier Cruz-Torres, Xin Dong, Yuanjing Ji, Sooraj Radhakrishnan, Feng Yuan, Ernst Sichtermann & Nu Xu**

Introduction

[1] E. Aschenauer et al. Phys. Rev. D96, 114005 (2017)
[2] E. Chudakov et al. Phys. Conf. Ser.770, 012042 (2016)

Photon-Gluon Fusion





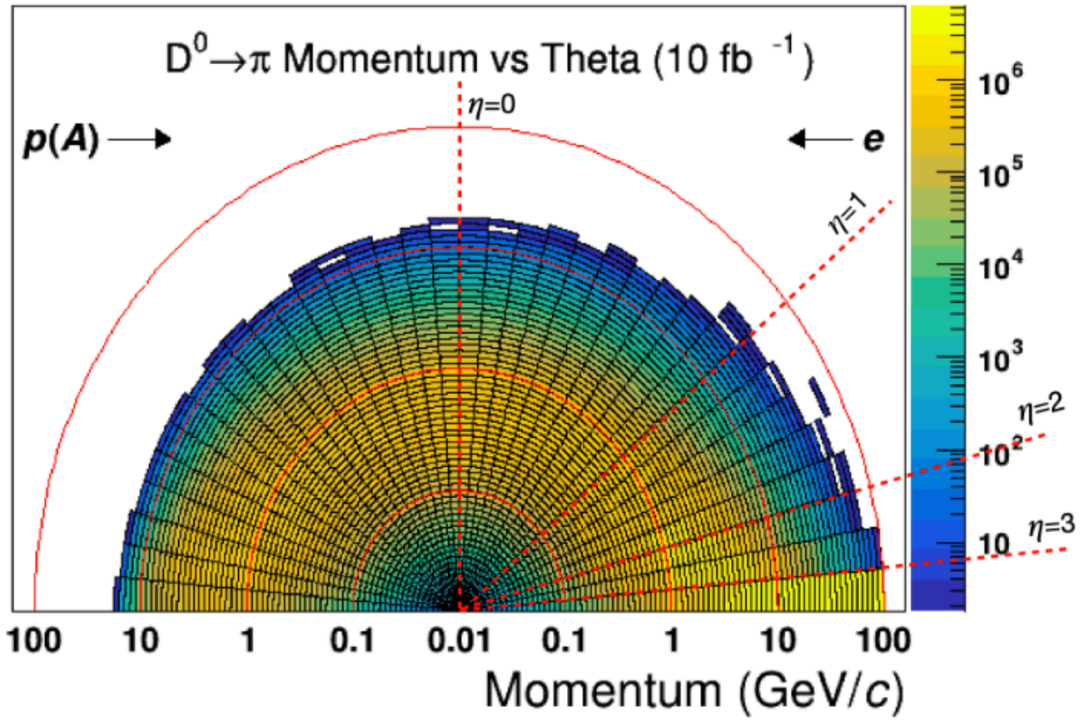
Measurements of heavy-flavor hadrons at EIC span a broad range of physics interests

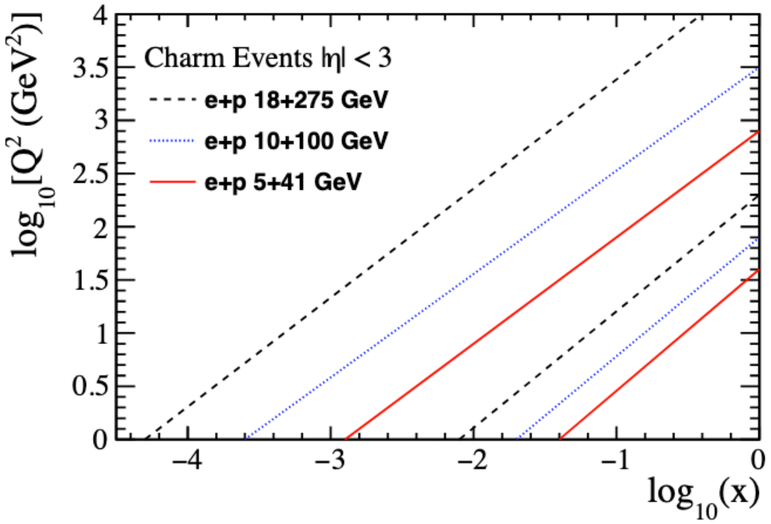
- Gluon density in nucleon/nucleus (previous studies in [1,2])
- Intrinsic charm
- Gluon TMDs
- Hadronization
- Gluon polarization

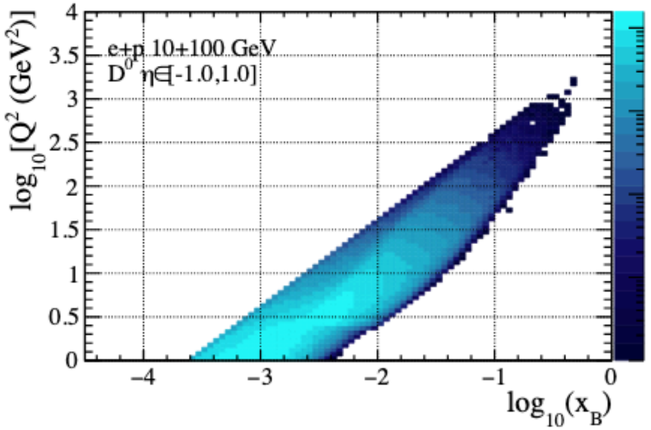
Goal to study charm hadron reconstruction with precision vertex detector and impact on $F_2^{c\bar{c}}$

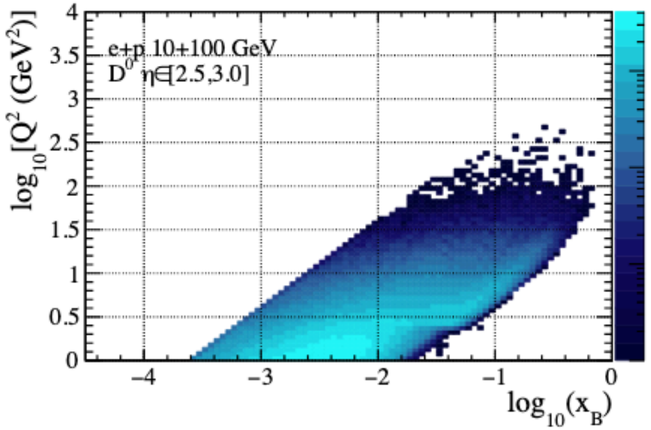
Charm Hadron Distributions in DIS

[1] https://eic.github.io/software/pythia6.html





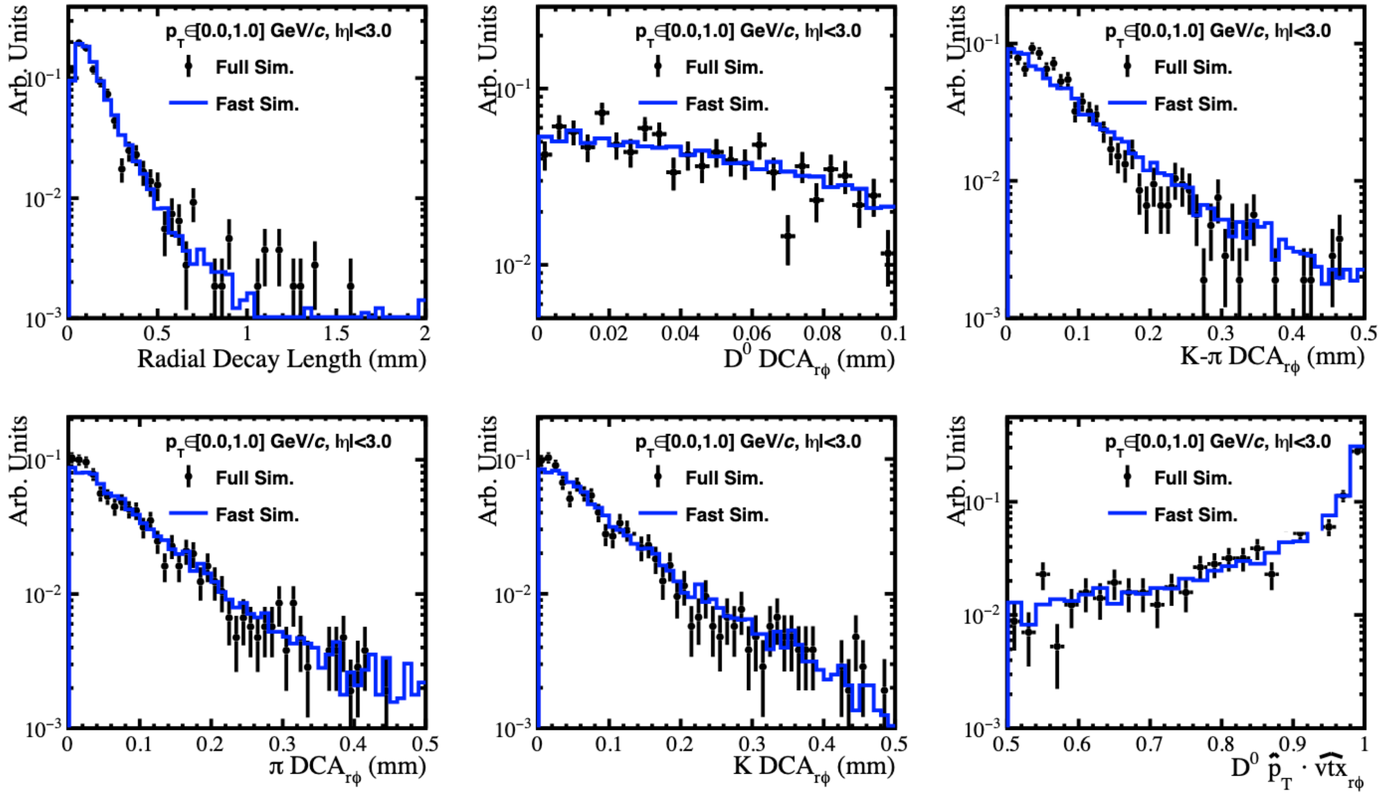




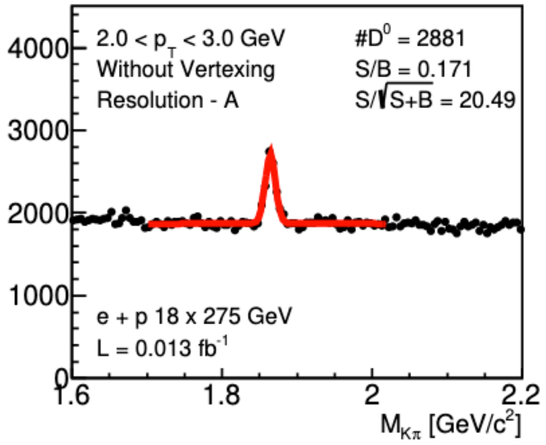
Electron-proton collisions generated with PYTHIA 6 with eRHIC tuning [1]

Charm hadrons (and decay particles) predominately produced within $|\eta|<3$

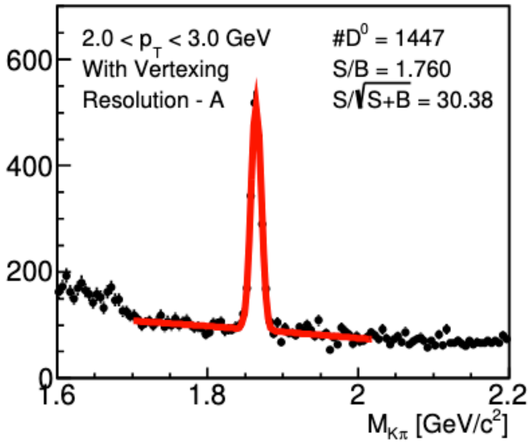
D^0 Reconstruction with Si Vertex Det.

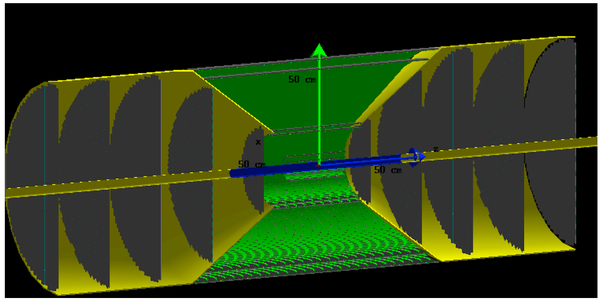


Without decay vertex

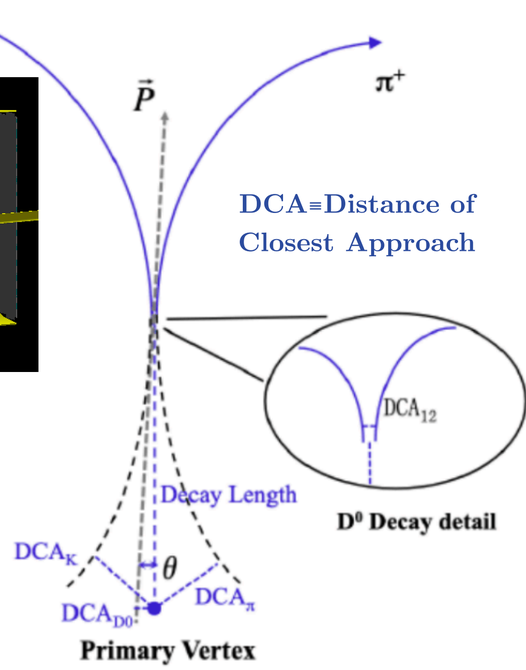


With decay vertex





All-Si EIC Detector Concept



$D^0 \rightarrow K^- \pi^+$ reconstruction with fast simulation setup

- Pointing+vertex+momentum resolution Gaussian smearing
- PID+Tracking
- Validated with GEANT simulation of a compact all-Si detector

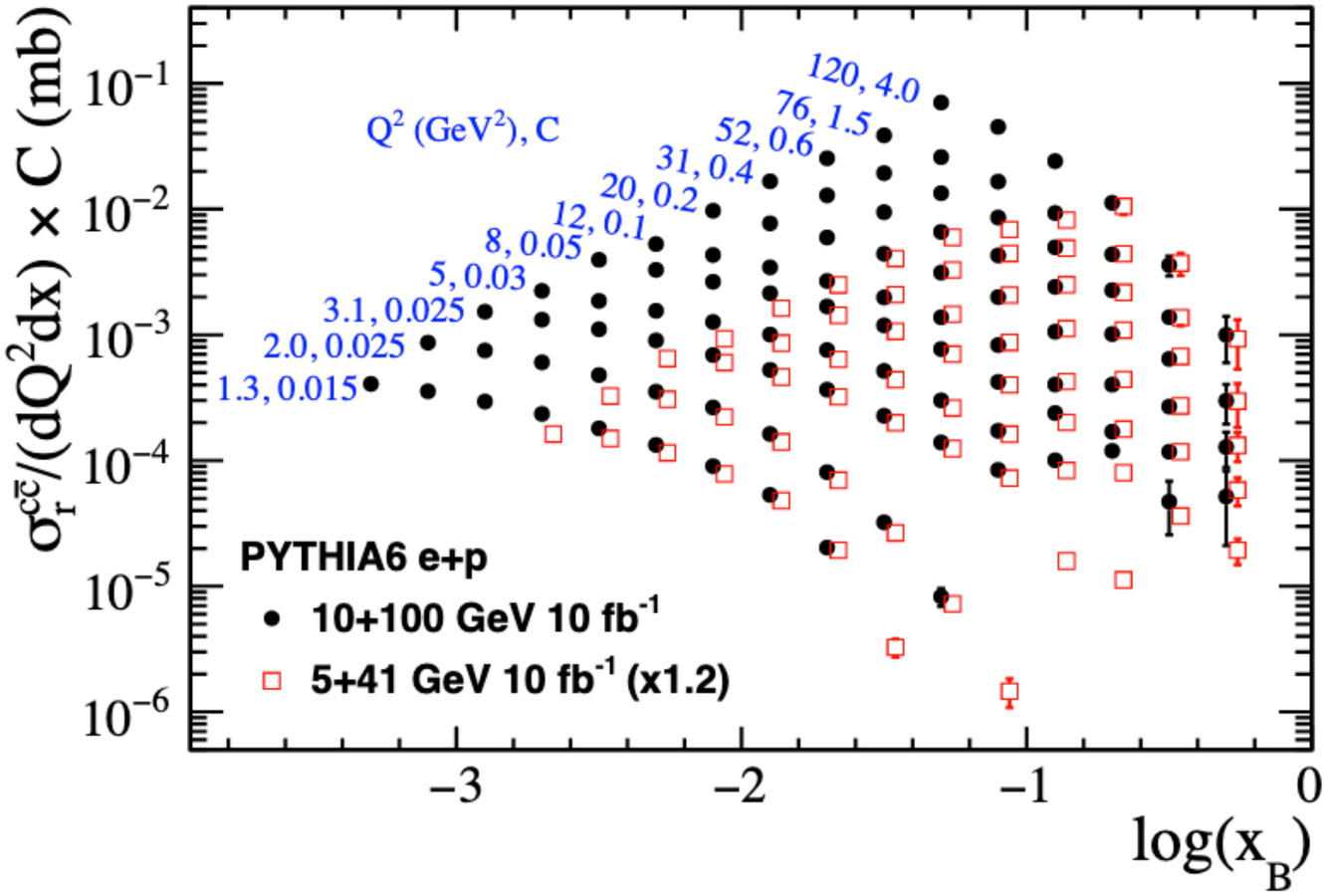
Reduced Cross-Section

$$\sigma_r^{c\bar{c}}(x,Q^2) = \frac{dN(D^0+\bar{D}^0)/2}{\mathcal{L}\cdot\varepsilon\cdot\mathcal{B}(D^0\to K\pi)\cdot f(c\to D^0)\cdot \mathrm{d}x\mathrm{d}Q^2} \times \frac{xQ^4}{2\pi\alpha^2[1+(1-y)^2]}$$

10+100 GeV and 5+41 GeV e+p collisions energies

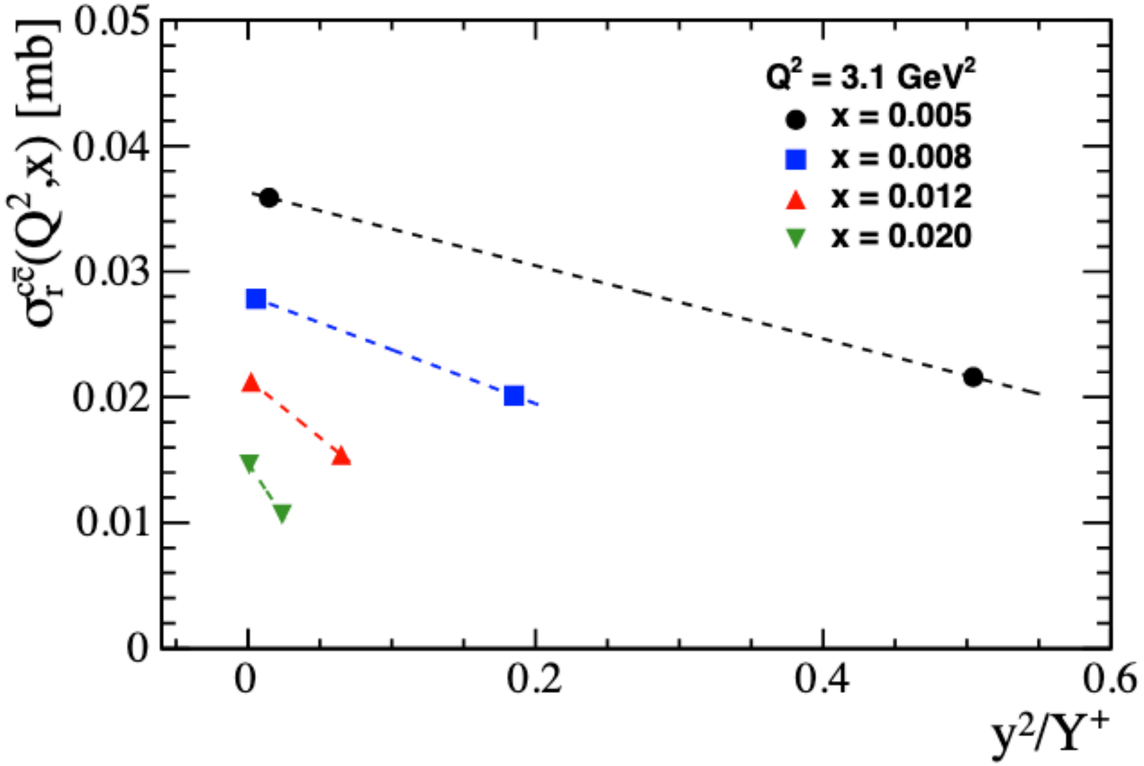
- Scale yield to 10 fb^{-1} per energy as baseline
- $\sqrt{s}$ chosen to maximize high-x_B reach for studies of charm F_2^{cc}

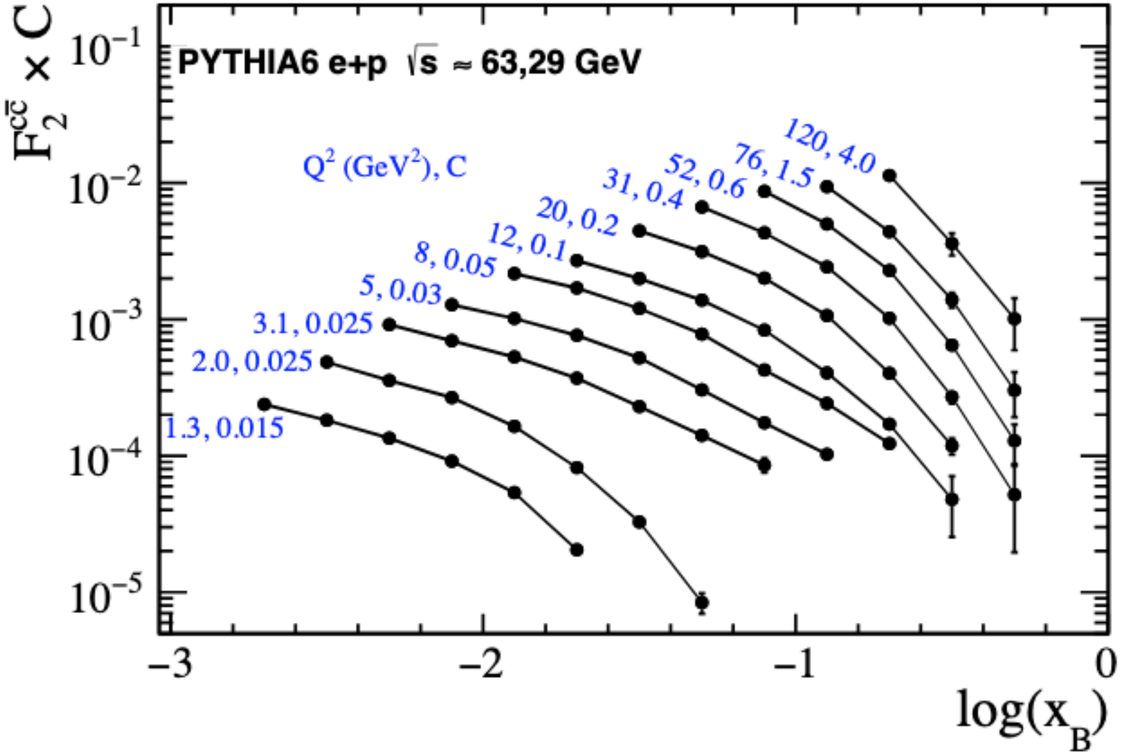
Uncertainties estimated from signal significance with QCD/mis-PID/partially reco. charm backgrounds



Charm Structure Functions

$$\sigma_r^{c\bar{c}}(Q^2,x) = F_2(Q^2,x) - \frac{y^2}{Y^+}F_L(Q^2,x),\ Y^+ = 1+(1-y)^2$$





Broad x-Q² coverage of charm structure functions (HERA x<0.1)

Summary

Studies of D^0 production in PYTHIA e+p collisions with all-Si detector

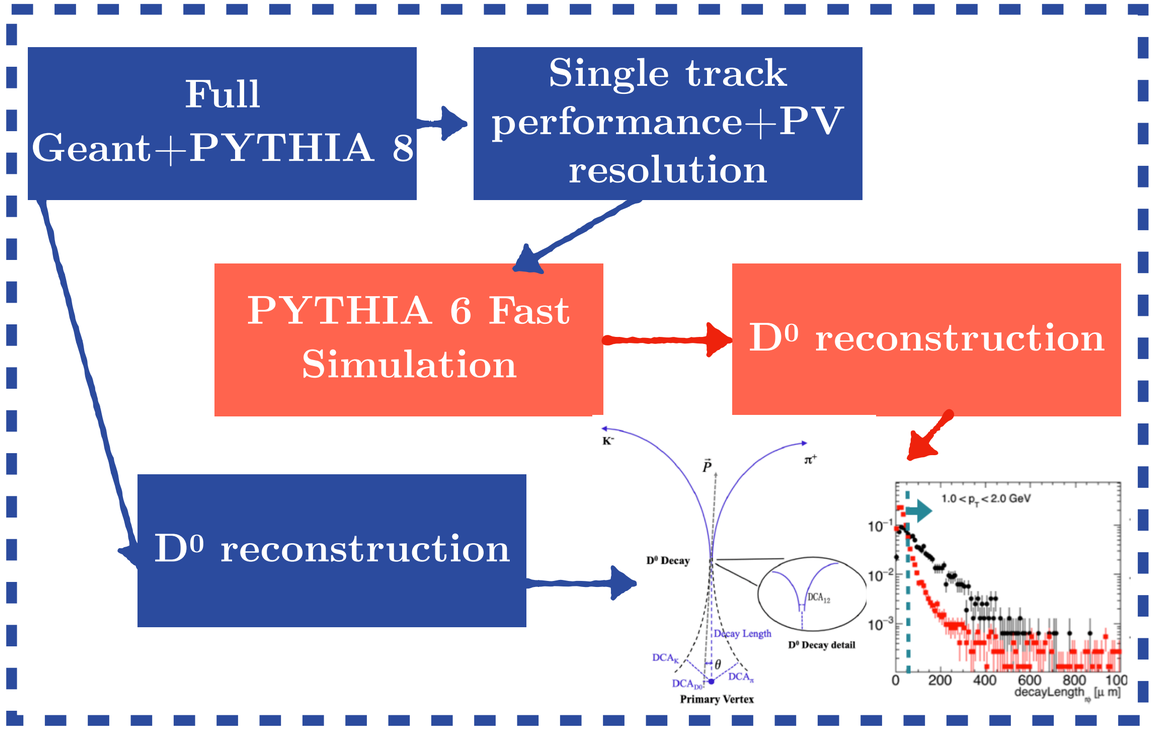
- Fast simulation studies verified with full GEANT simulation of all-Si detector
- Project precise (stat.) and broad coverage of charm structure functions $F_2^{c\bar{c}}$

Studies of nuclear modification and impact on nPDFs in progress

Backup Slides Follow

Fast Simulation Validation

Reliability of fast-sim. D^0 reconstruction evaluated using full GEANT4-based PYTHIA 8 simulation in Fun4All framework [1]



[1] https://wiki.bnl.gov/sPHENIX/index.php/EIC_SPHENIX_FUN4ALL

All-Silicon Detector Concept

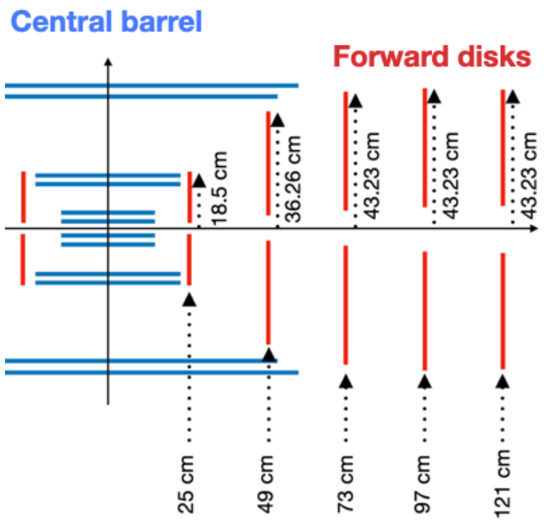
10 μm x 10 μm pixel devices

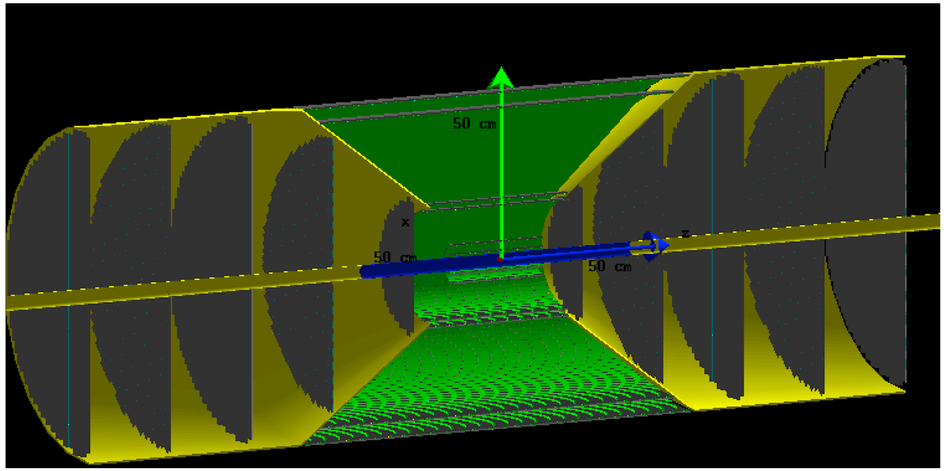
X/X0=0.3% per layer

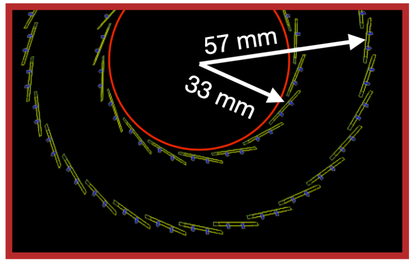
Beampipe r=3.1 cm

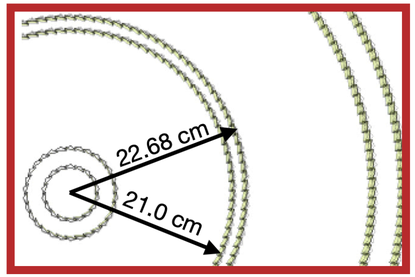
B = 3.0 T

Outer barrel r = 39, 42 cm



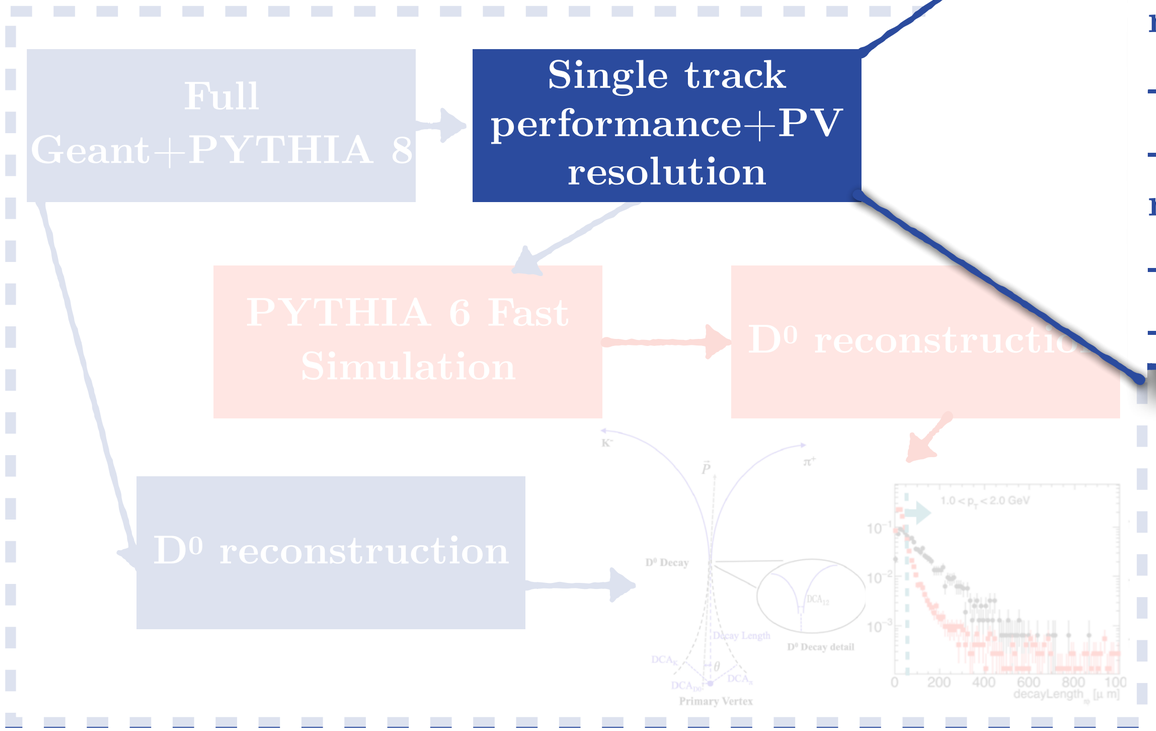






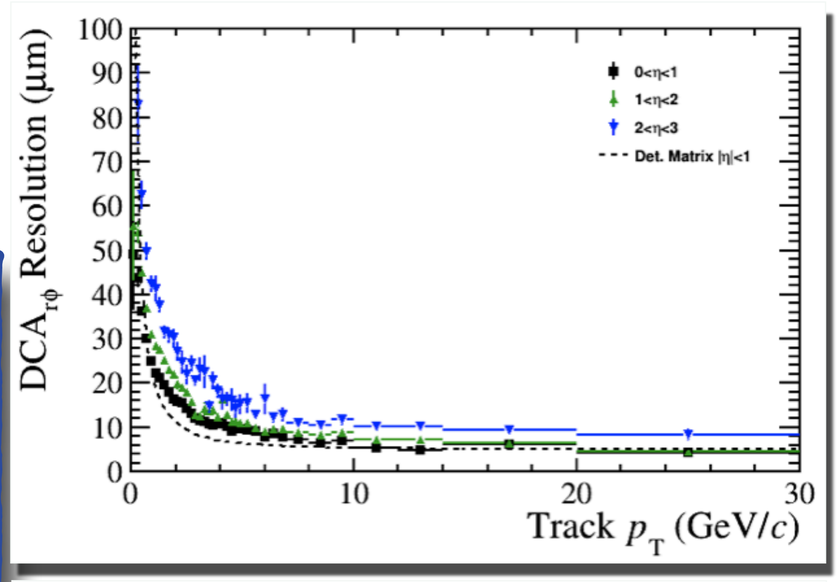
Fast Simulation Validation

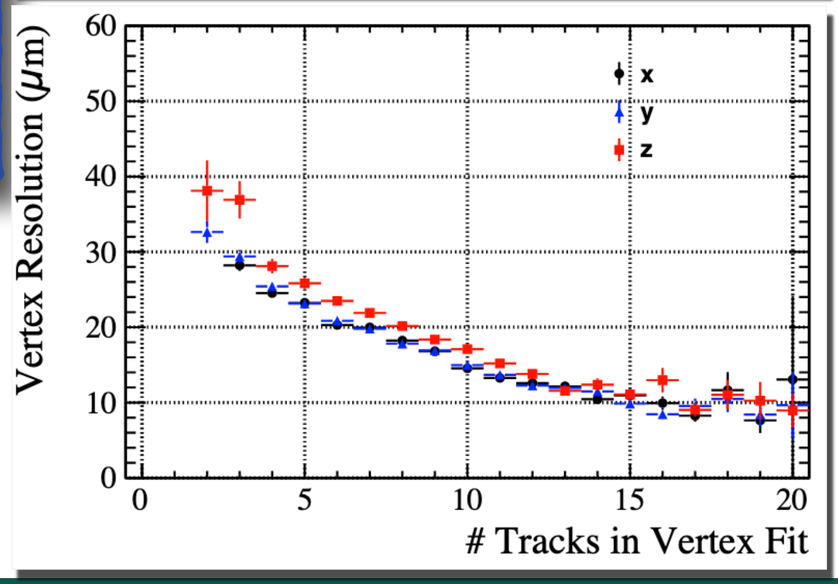
Reliability of fast-sim. D^0 reconstruction evaluated using full GEANT4-based PYTHIA 8 simulation in Fun4All framework b



Full Sim. Highlights

- Comparable pointing resolution to DM
- Ave. PV resolution∼18 μm
- Sub-percent momentum resolution
- Tracking efficiency (>85%)
- Assumption of perfect PID





Fast Simulation Parameters

η	σ_p/p - 3T (%)	σ_p/p - 1.5T (%)	$\sigma(\mathrm{DCA}_{r\phi})$ (μm)	$p_{\mathrm{max}}^{\mathrm{PID}}$ (GeV/c)
(-3.0,-2.5)	$0.1 \cdot p \oplus 2.0$	$0.2 \cdot p \oplus 5.0$	$60/p_T \oplus 15$	10
(-2.5,-2.0)	$0.02 \cdot p \oplus 1.0$	$0.04 \cdot p \oplus 2.0$	$60/p_T \oplus 15$	10
(-2.0,-1.0)	$0.02 \cdot p \oplus 1.0$	$0.04 \cdot p \oplus 2.0$	$40/p_T \oplus 10$	10
(-1.0,1.0)	$0.02 \cdot p \oplus 0.5$	$0.04 \cdot p \oplus 1.0$	$30/p_T \oplus 5$	6
(1.0,2.0)	$0.02 \cdot p \oplus 1.0$	$0.04 \cdot p \oplus 2.0$	$40/p_T \oplus 10$	50
(2.0,2.5)	$0.02 \cdot p \oplus 1.0$	$0.04 \cdot p \oplus 2.0$	$60/p_T \oplus 15$	50
(2.5,3.0)	$0.1 \cdot p \oplus 2.0$	$0.2 \cdot p \oplus 5.0$	$60/p_T \oplus 15$	50

Representative Statistical Uncertainties