Experimental Aspects of Heavy Flavor Physics at EIC: Gluon Dynamics and Hadronization

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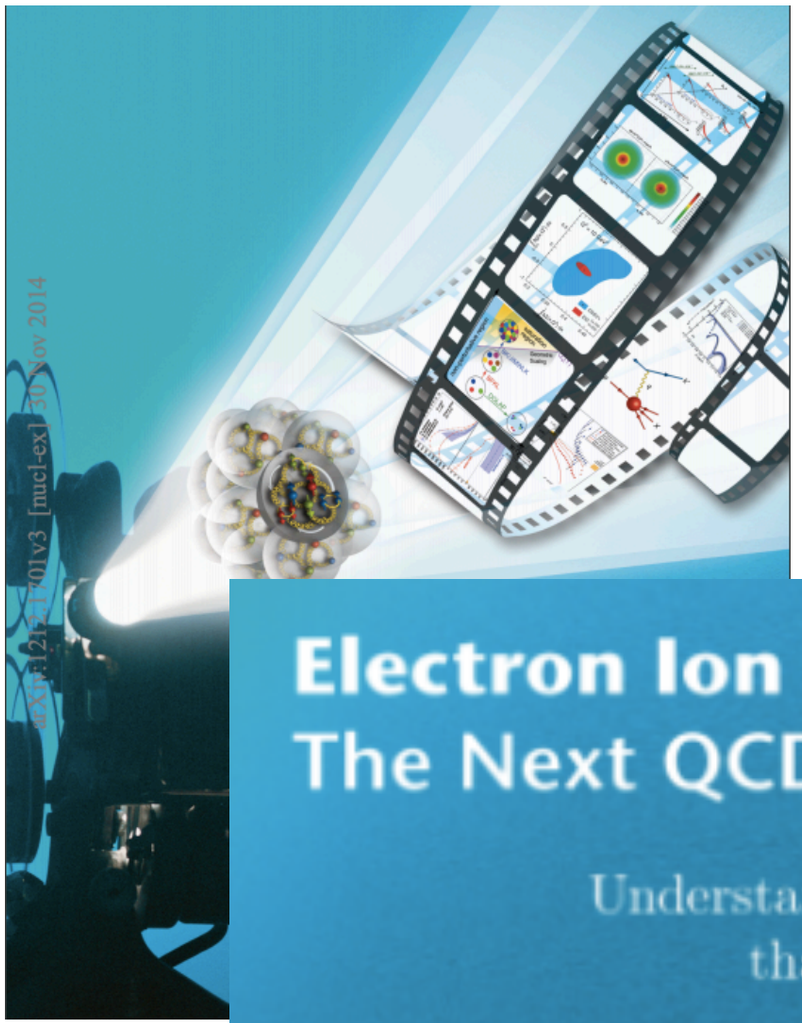
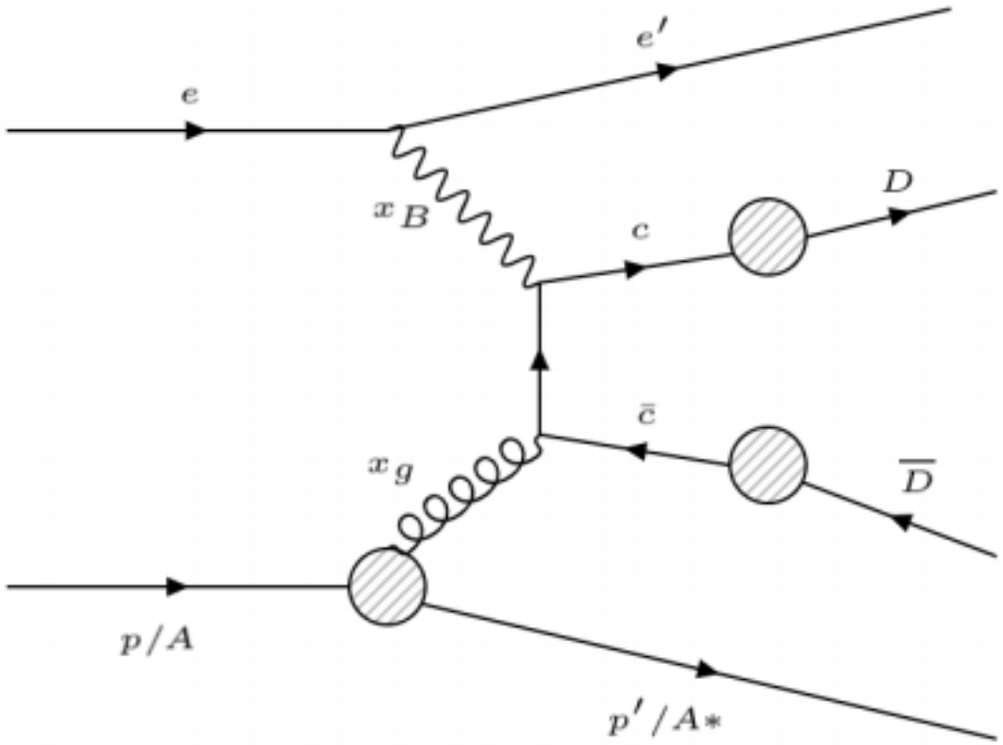
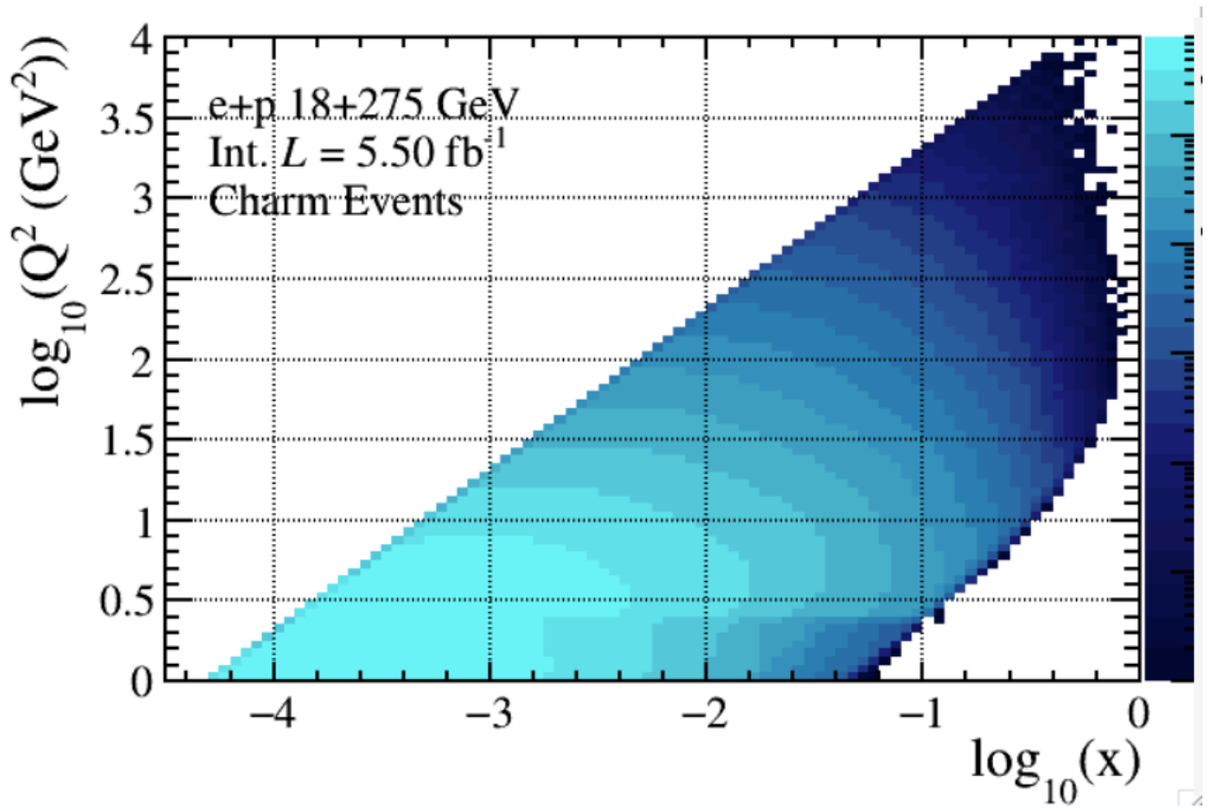


arXiv: 1212.1701

Heavy Flavor to Probe Gluon Dynamics at EIC

- EIC is a machine for precision investigation of gluon dynamics in nucleon/nucleus
- Heavy flavor in NC channel - sensitive probe to initial gluons



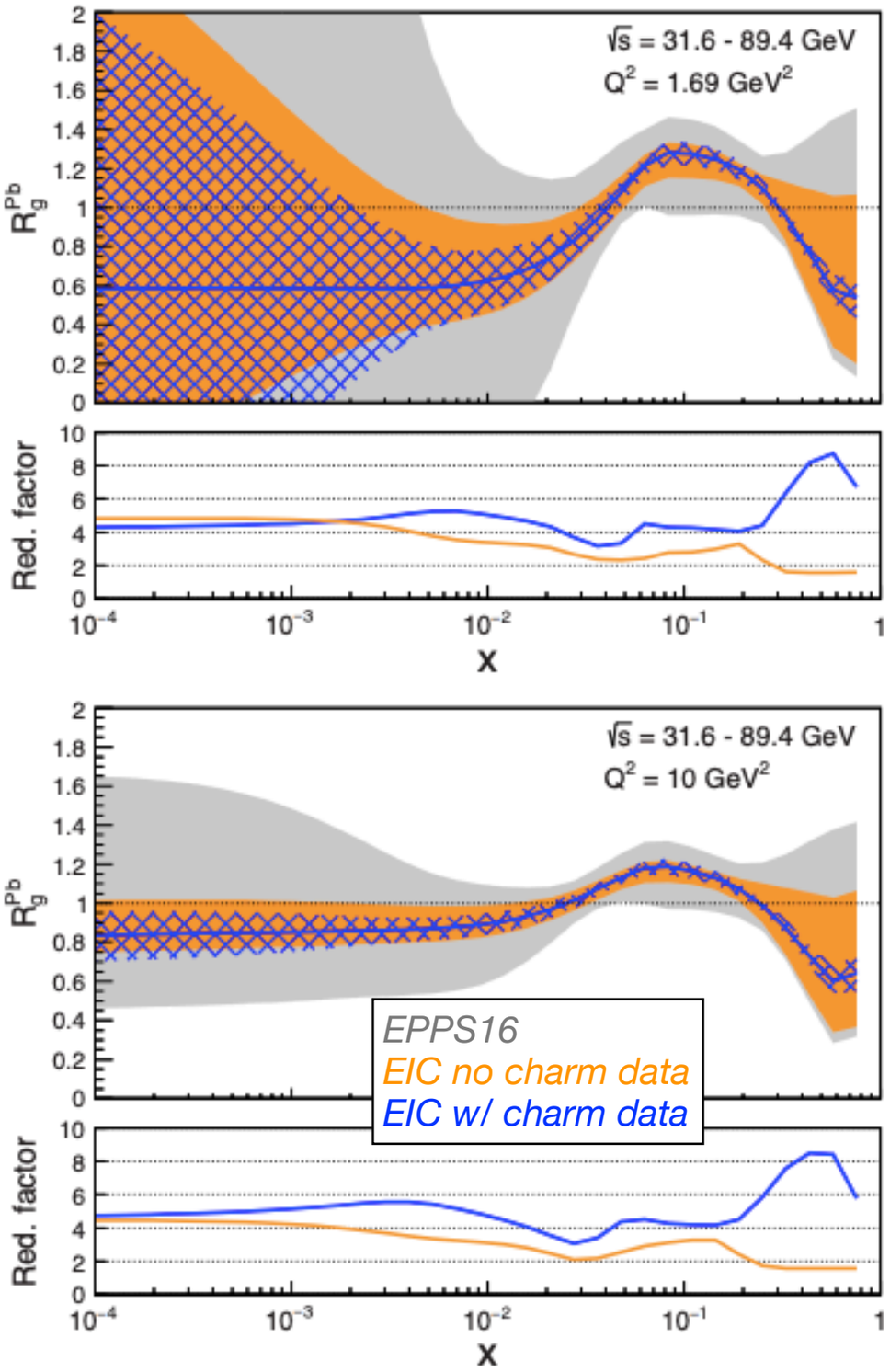


- ***Inclusive*** heavy flavor measurement to constrain *gluon nPDF,* particularly at high x
- Heavy flavor ***double spin asymmetry*** for gluon helicity $\Delta g/g$
- $D\overline{D}$ ***pair*** reconstruction to access *gluon TMD PDFs*
- Heavy flavor hadron (***D***, Λ_c etc.) for *hadronization* and *CNM* effect

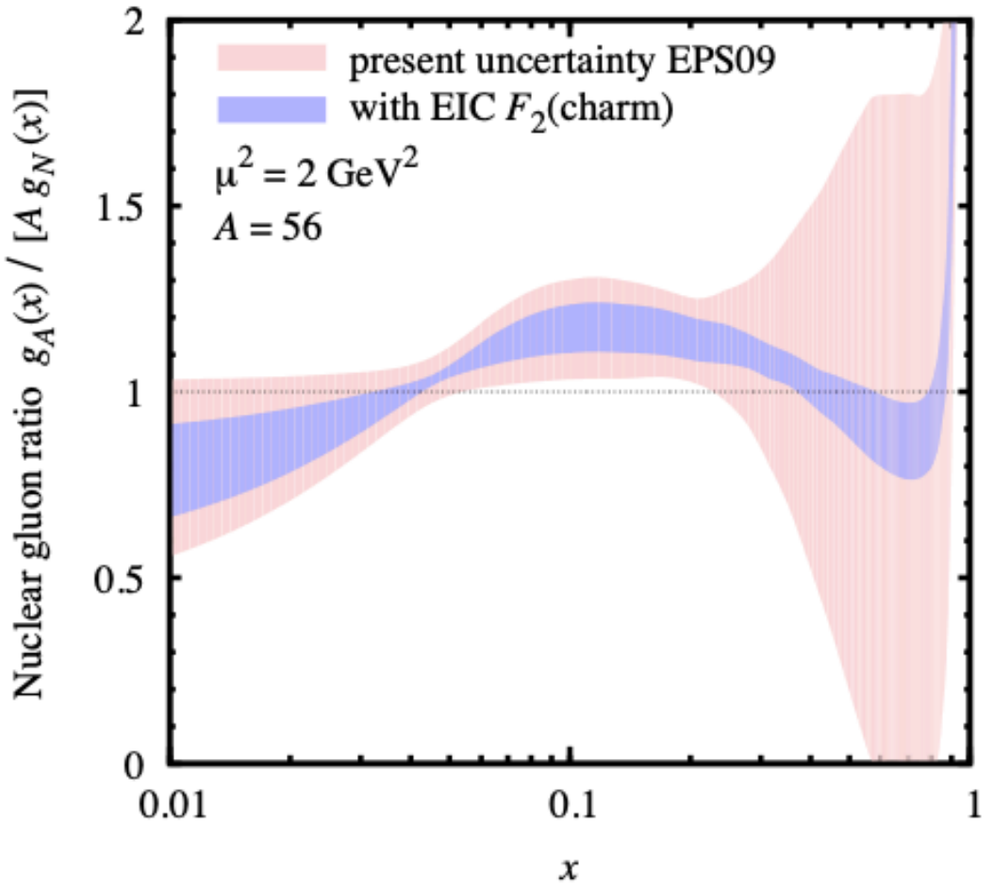
Inclusive Charm -> Gluon nPDF at High x

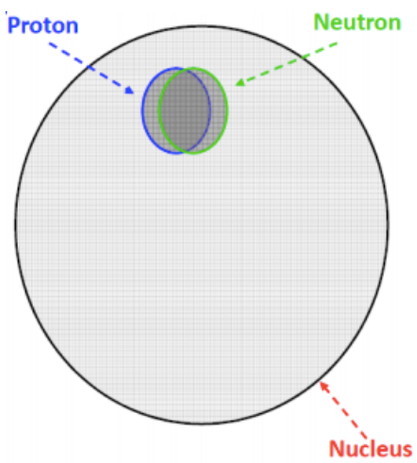
$$R_g^{Pb} = f_g^{Pb}(x,Q^2)/f_g^{p}(x,Q^2)$$

E.C. Aschenauer et al, 1708.01527



E. Chudakov et al, 1610.08536





gluon probe to
short range correlation

More details see S. Sekula's presentation

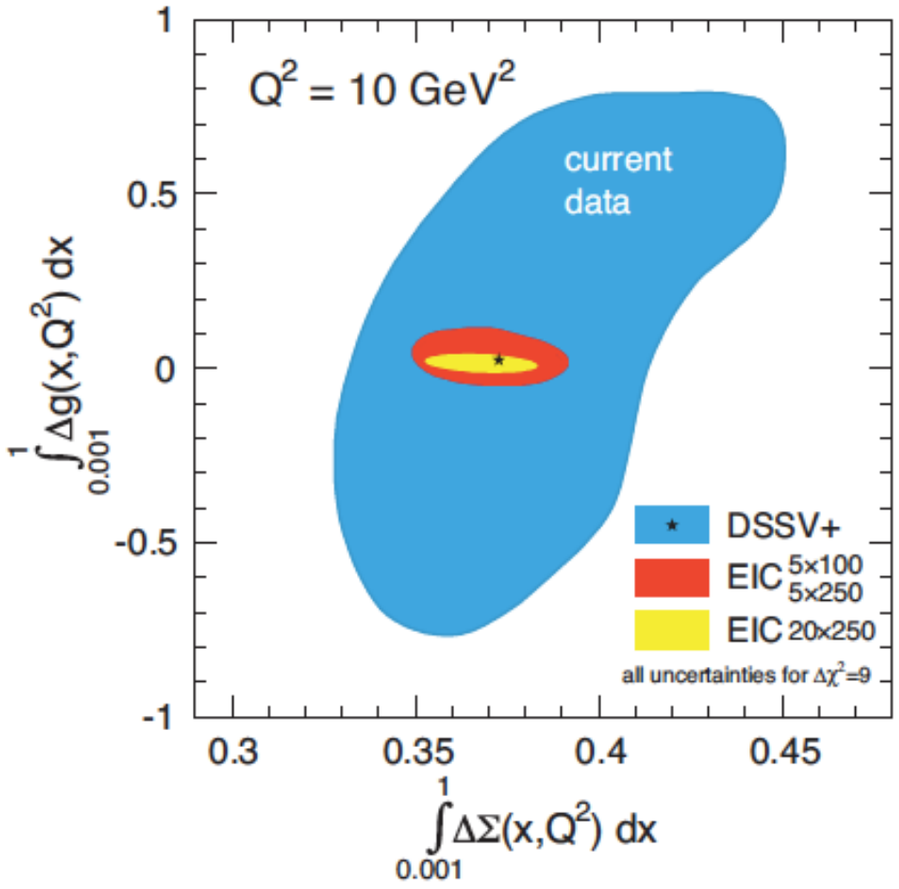
Gluon Helicity $\Delta g/g$

Understanding proton spin is one of the EIC science goals

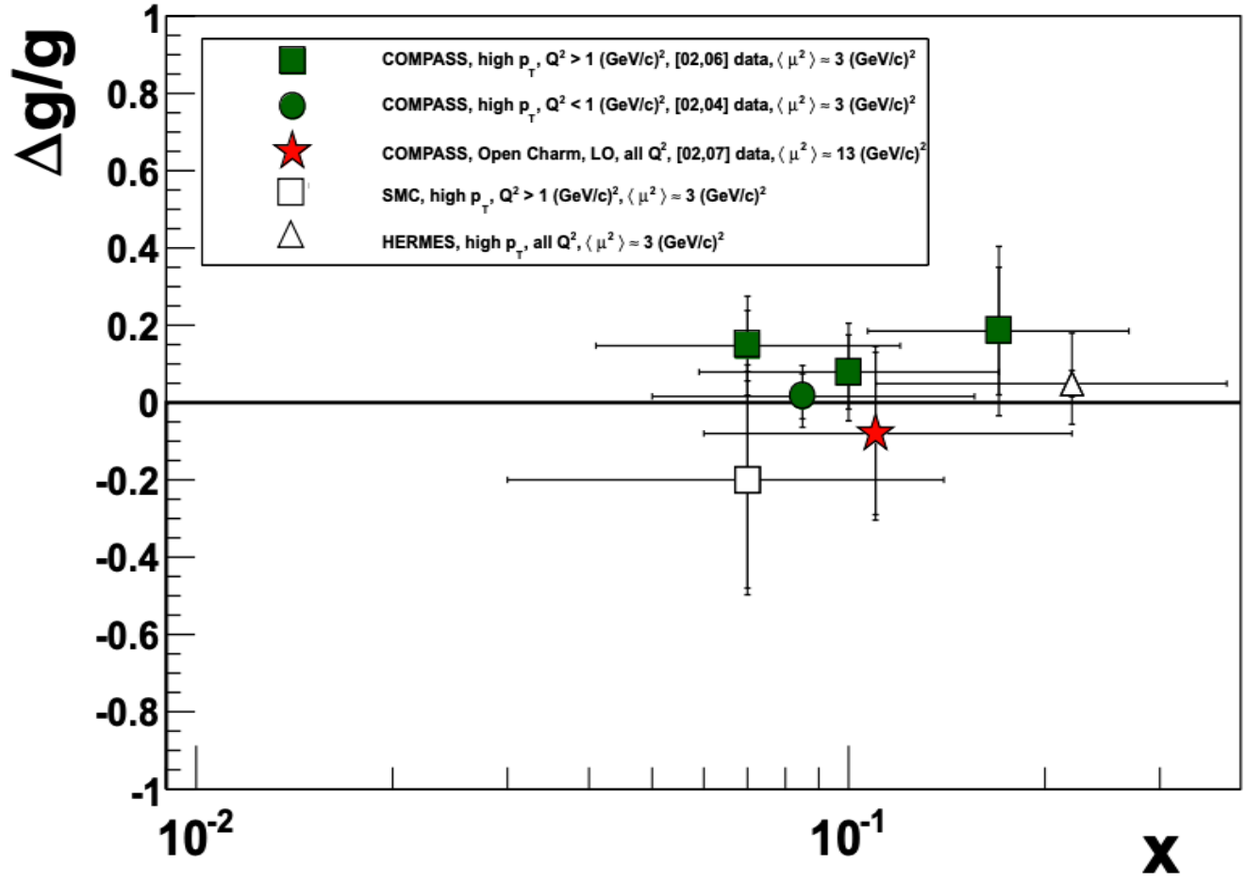
HF - better sensitivity to the gluon dynamics

- complementary to the inclusive measurement
- direct access to $\Delta g/g$ LO $A_{LL} \propto \hat{a}_{LL} \times \Delta g/g$

Inclusive g_1 measurement - EIC white paper



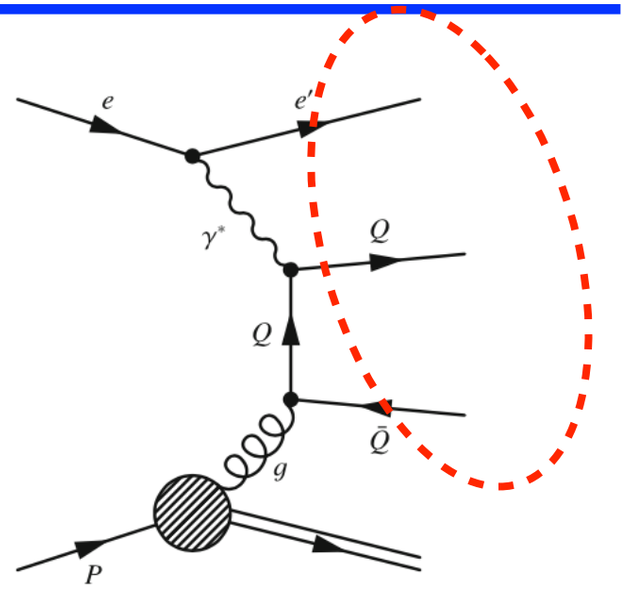
COMPASS data from open charm



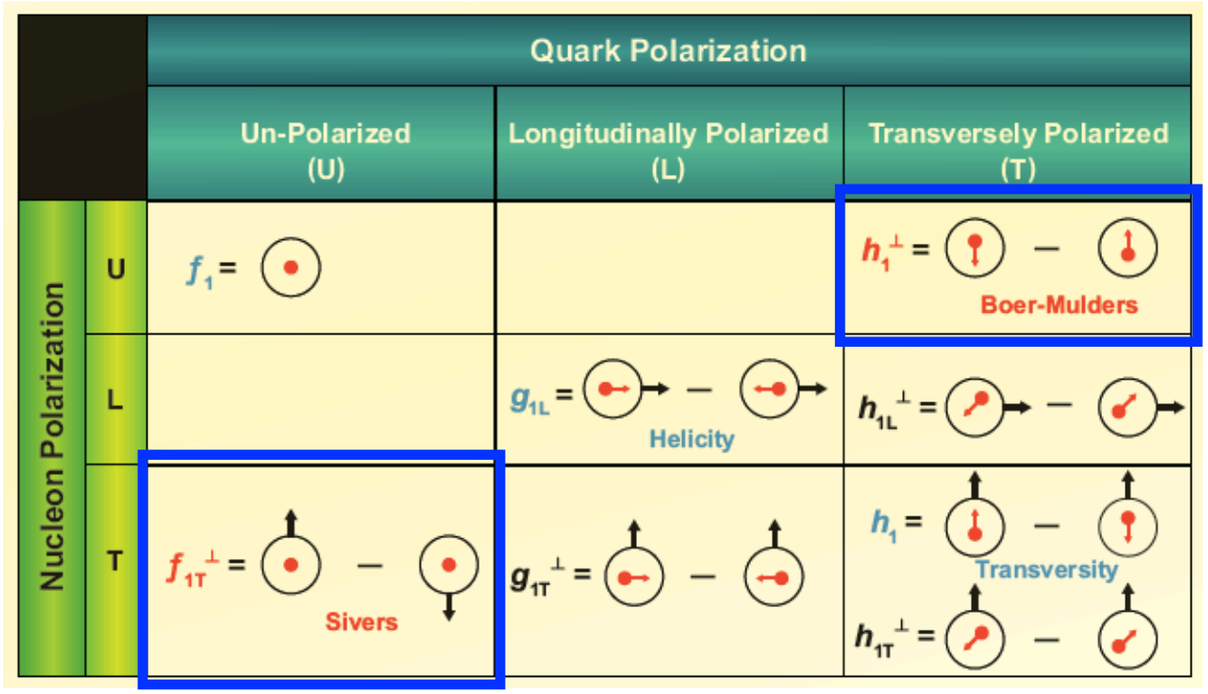
$D\overline{D}$ Pair - Probe Gluon TMDs

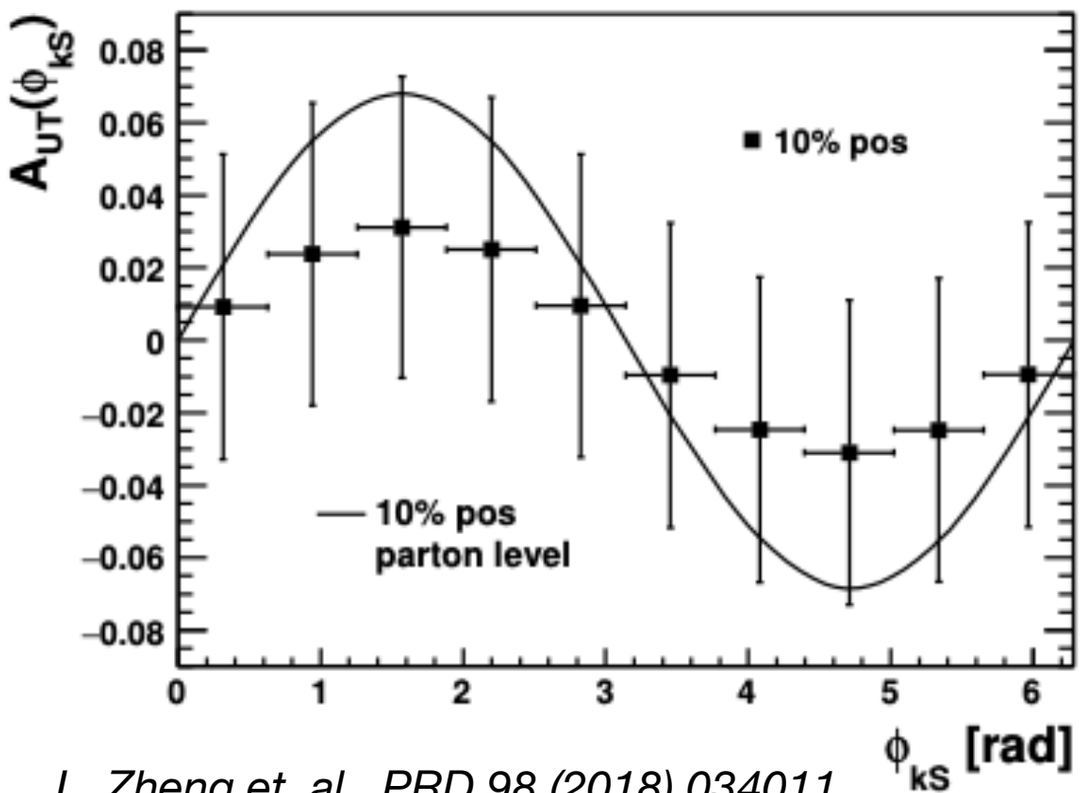
Charm hadron pair in transverse polarized exp.
- gluon Sivers functions

Charm hadron pair in unpolarized exp.
- linearly polarized Boer-Mulders function



$$A_{UT}(\phi_{kS}, k_T) = \frac{d\sigma^{\uparrow}(\phi_{kS}, k_T) - d\sigma^{\downarrow}(\phi_{kS}, k_T)}{d\sigma^{\uparrow}(\phi_{kS}, k_T) + d\sigma^{\downarrow}(\phi_{kS}, k_T)}$$



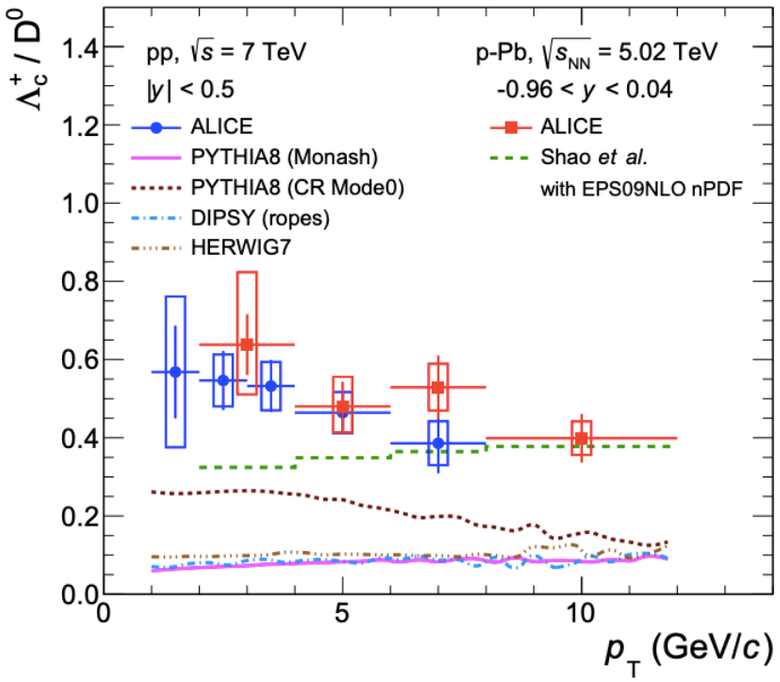


L. Zheng et. al., PRD 98 (2018) 034011

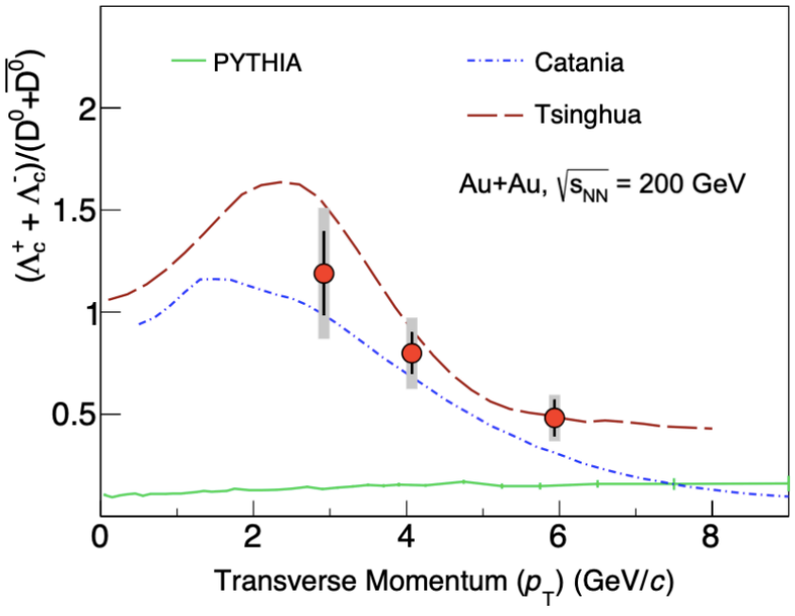
Hadronization and CNM

Charm hadrochemistry

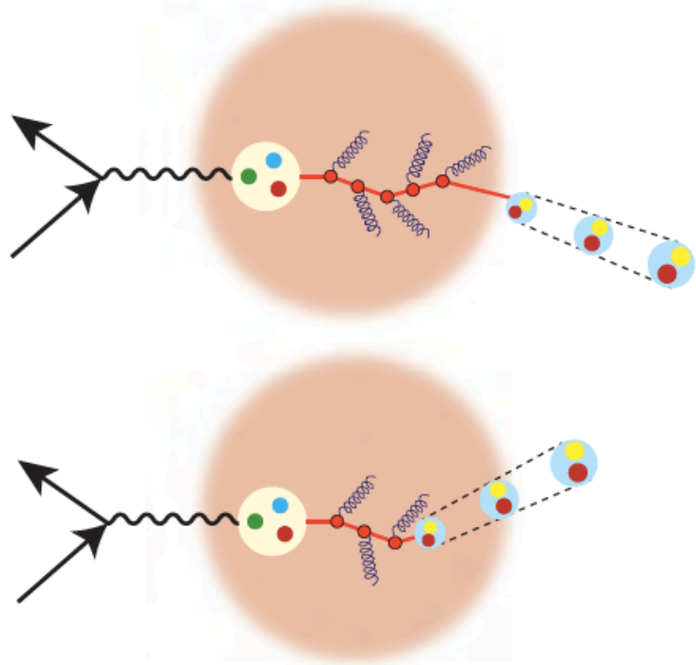
ALICE, JHEP 04 (2018) 108



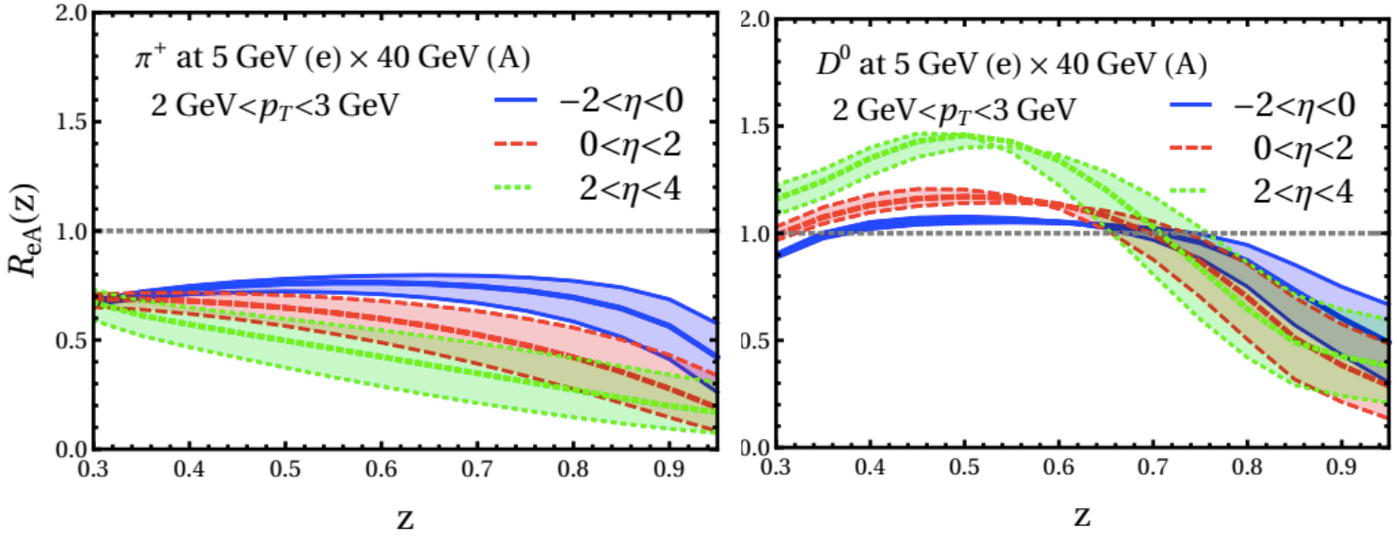
STAR, PRL 124 (2020) 172301



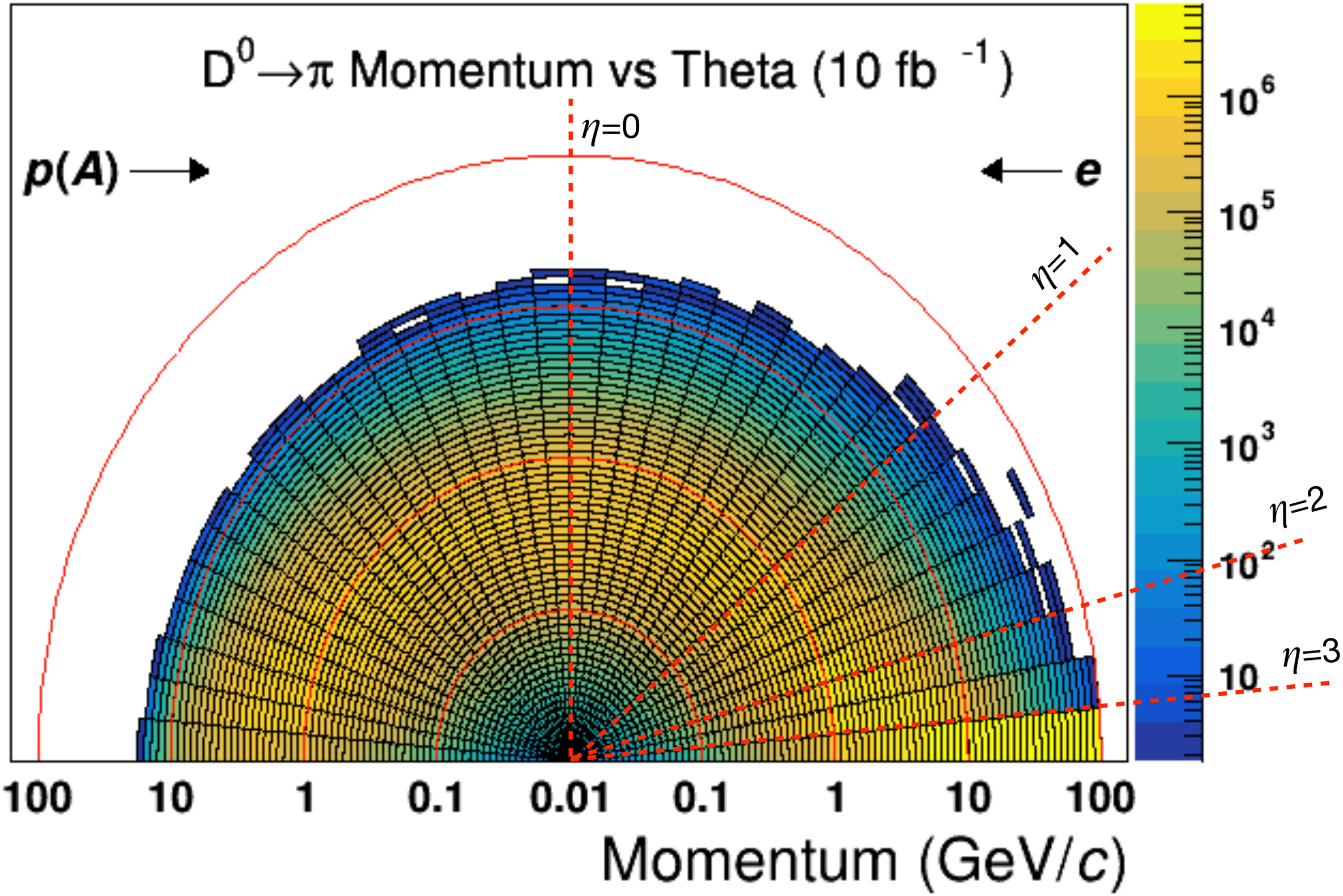
Cold Nuclear Matter Effect on light/heavy hadron production



H. Liu et. al., 2007.10994



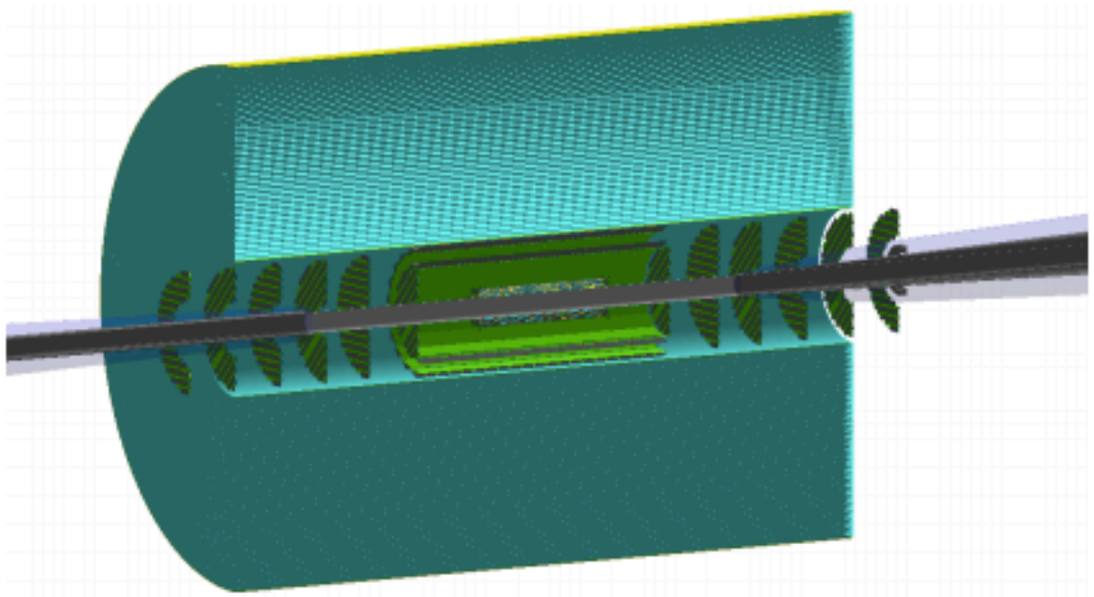
Kinematic Distributions

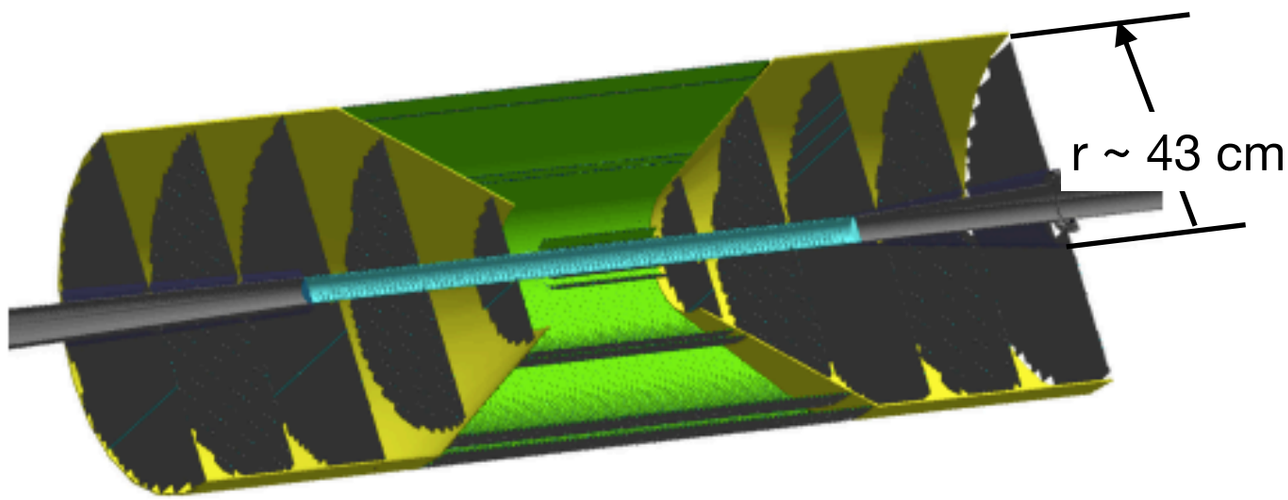


Tracking Detector Concept

Hybrid: gas outer tracker + Si vertex

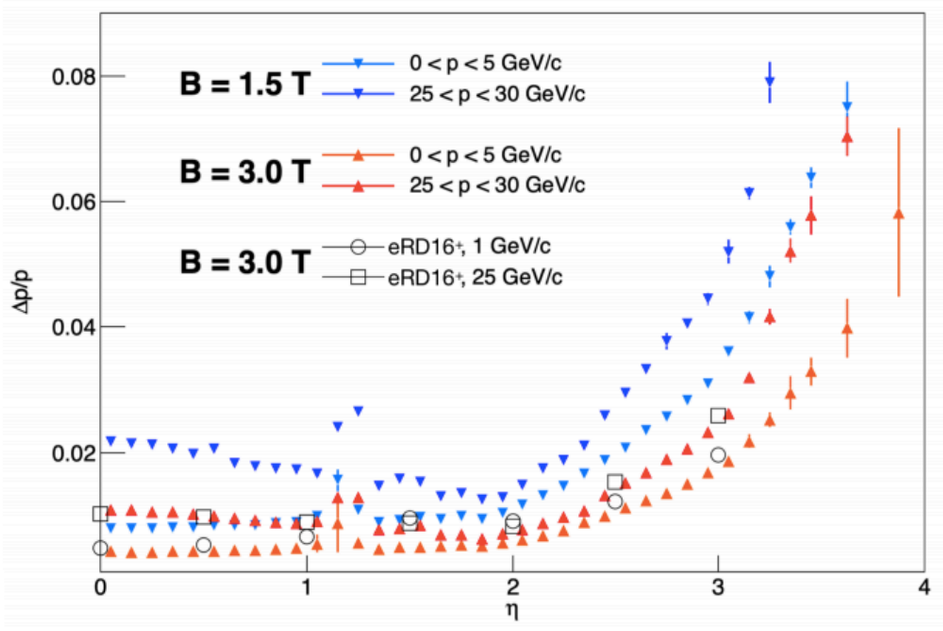
All-Si compact tracker

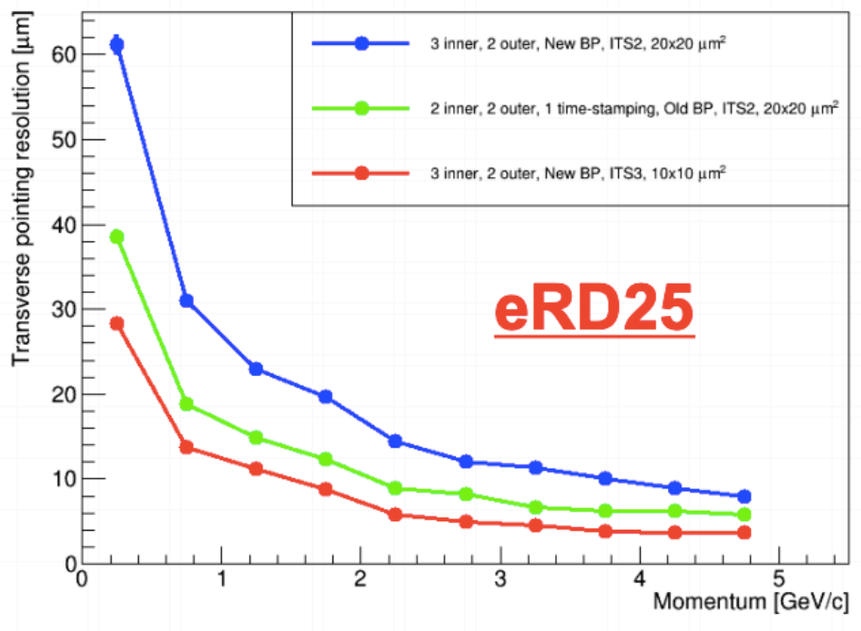




Detector requirements:

- hermetic coverage
- thin detector material
- fine pitch size

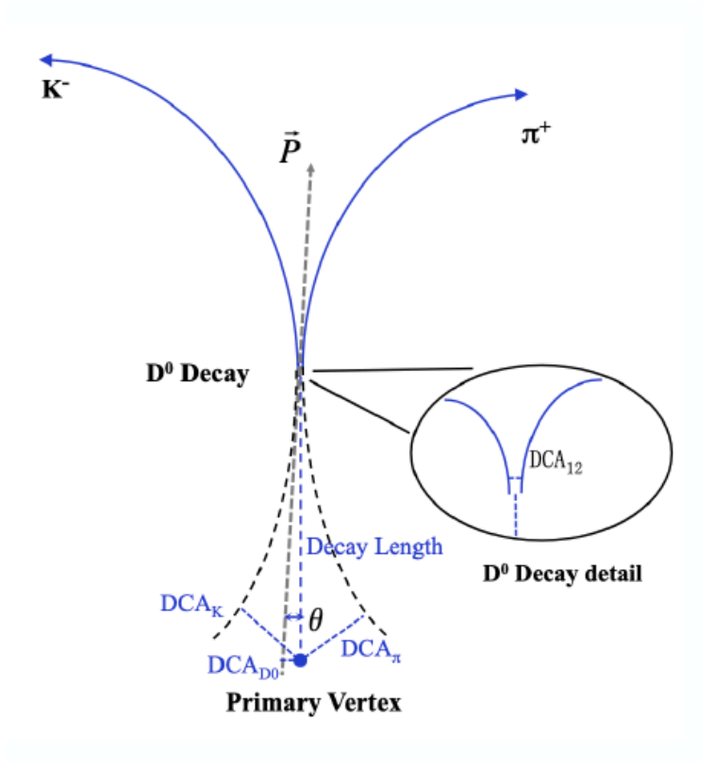


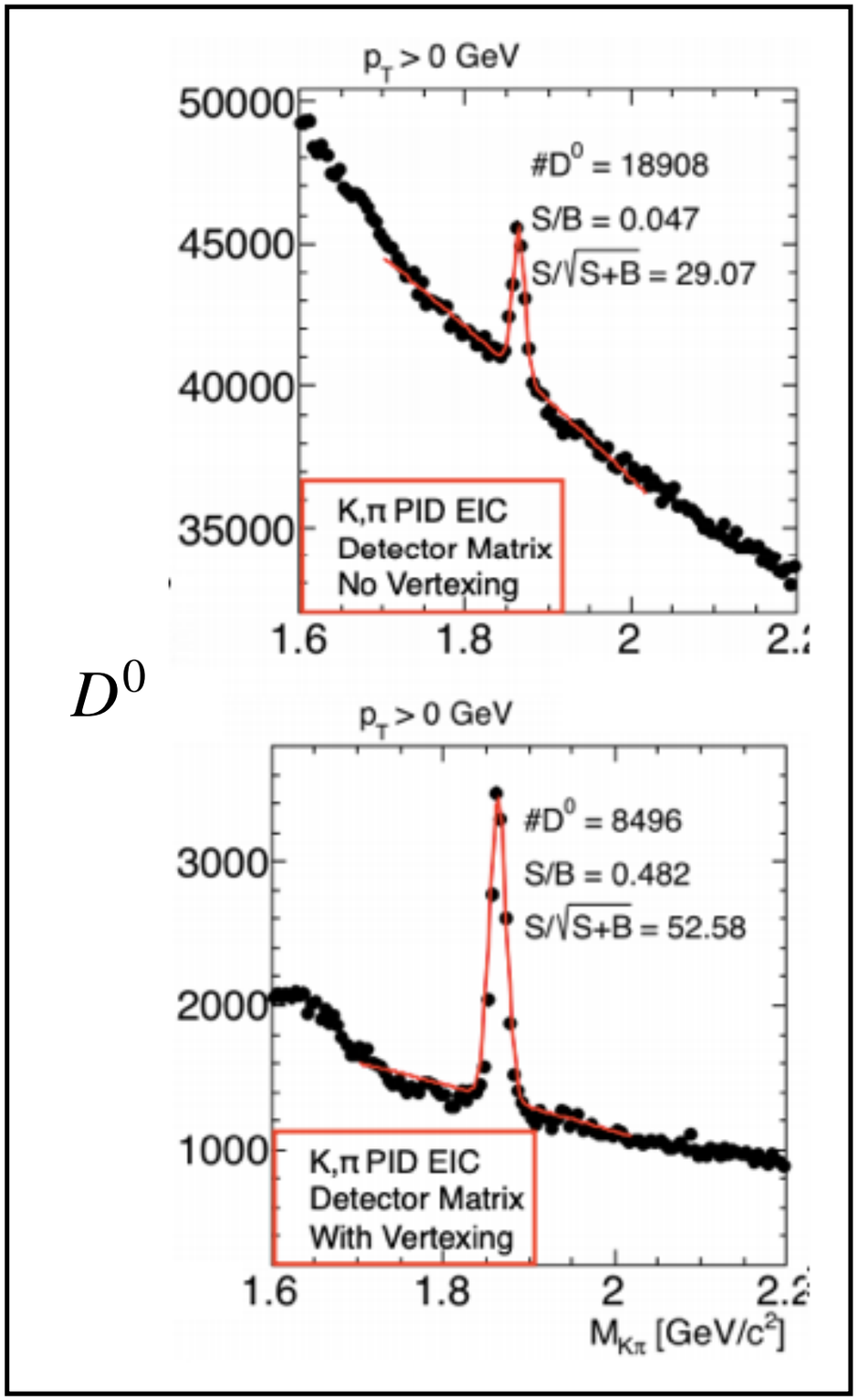


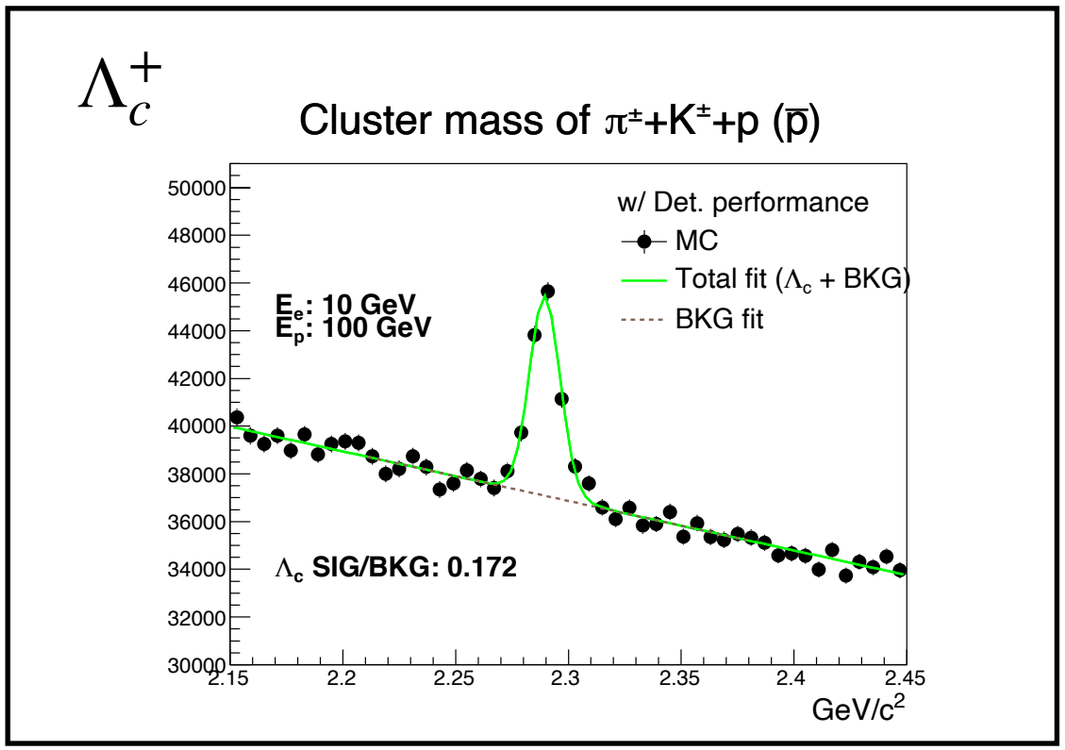
Ultra-thin fine-pitch MAPS: 10x10 um pitch, ~0.05% X_0 vertexing layers

- requirements on PID, calorimeters etc under discussion

Performance

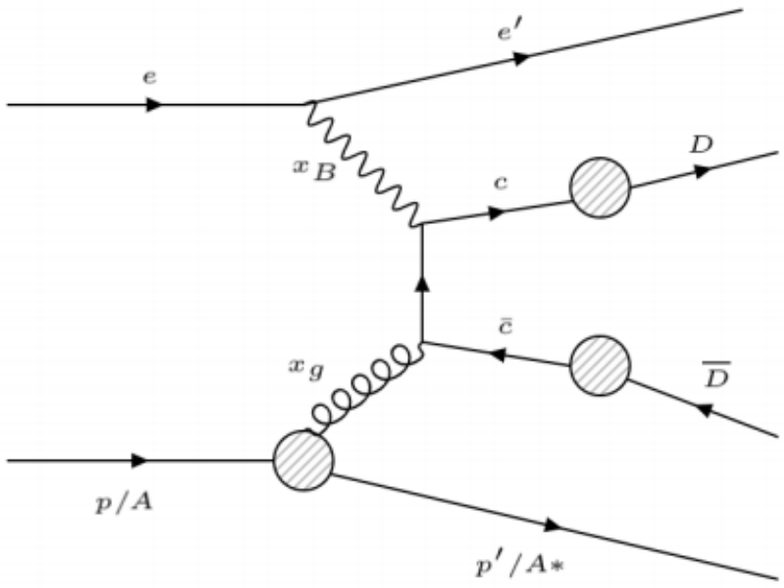






Ongoing efforts in Physics and Detector Working Groups towards EIC Yellow Report

Summary



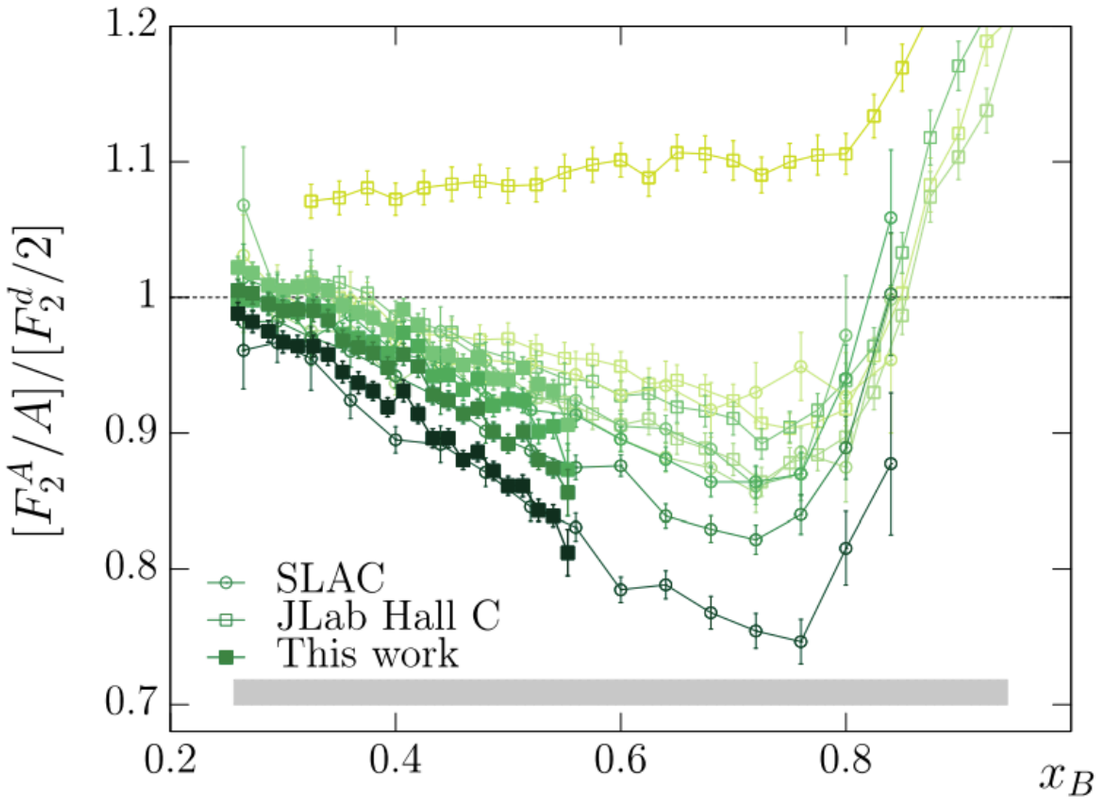
- ***Inclusive*** HF -> *gluon (n)PDF*
- ***HF A_{LL}*** -> *gluon helicity*
- $D\overline{D}$ ***pair*** -> *gluon TMDs*
- ***D***, Λ_c -> *hadronization* and *CNM*

- Heavy quarks offer a unique role in studying gluon dynamics in QCD at EIC.

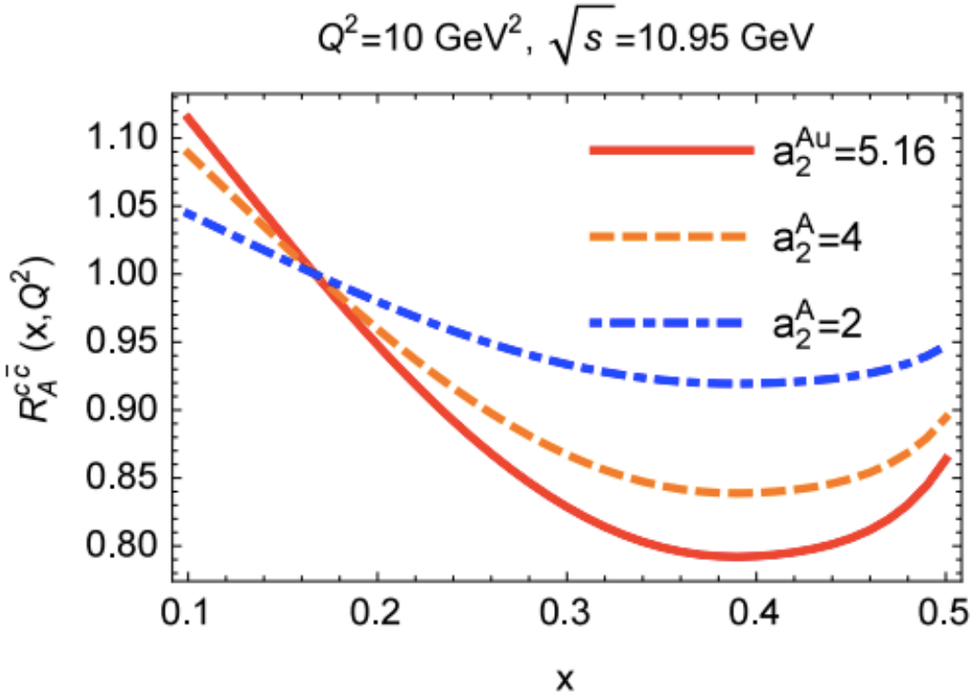
- EIC is a precision QCD machine!
  - Ongoing community efforts aim for optimization of (tracking) detector design.

Backup

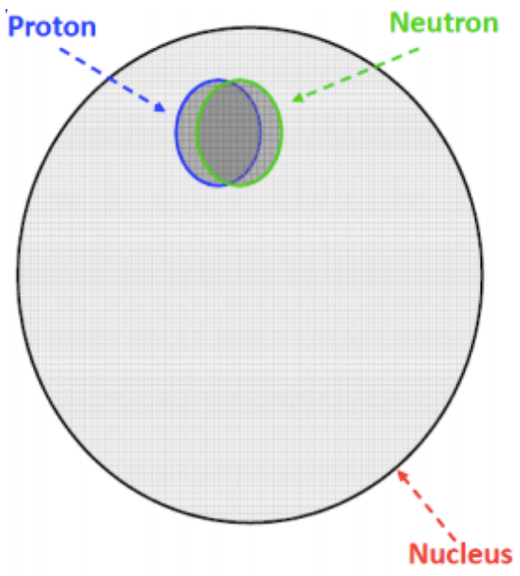
EMC <-> Short-Range Correlation

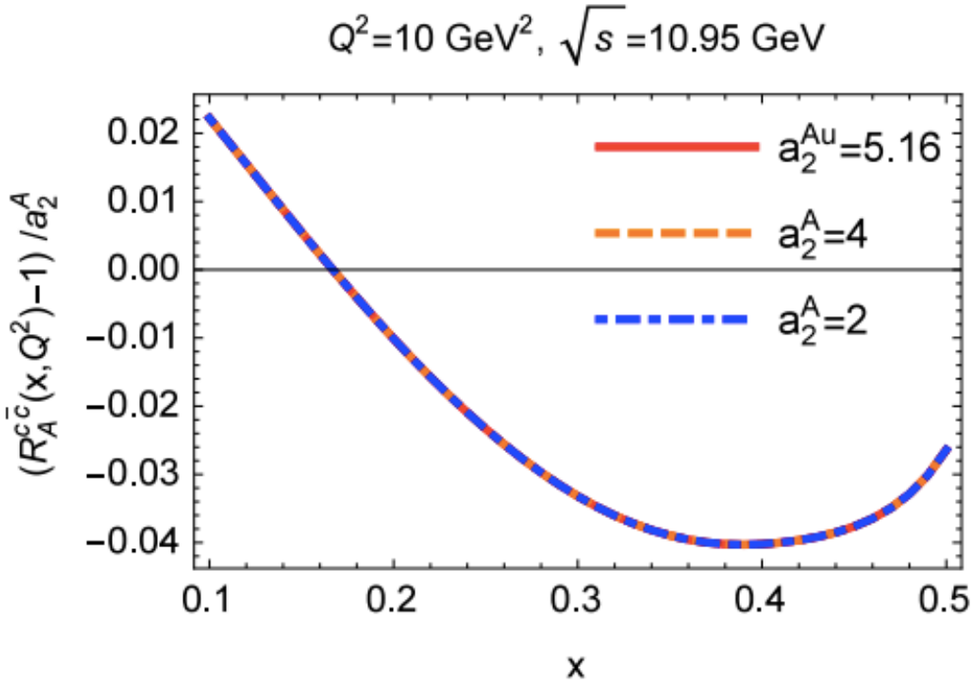


charm -> gluon probe to SRC



EMC effect at large x <-> SRC-np

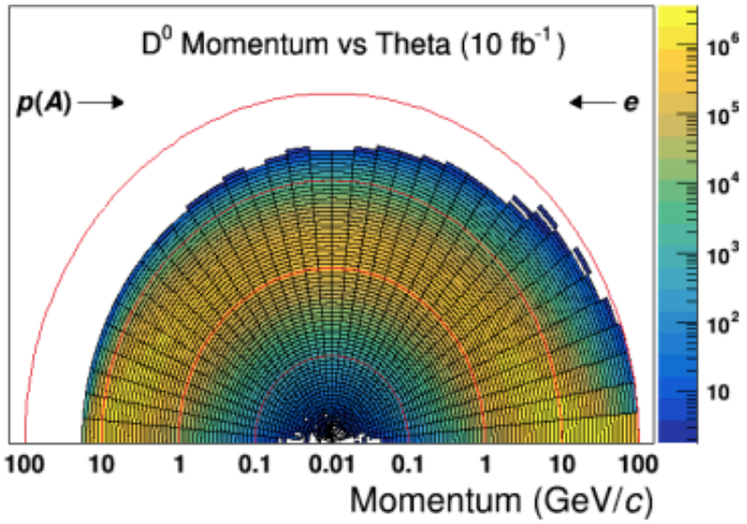


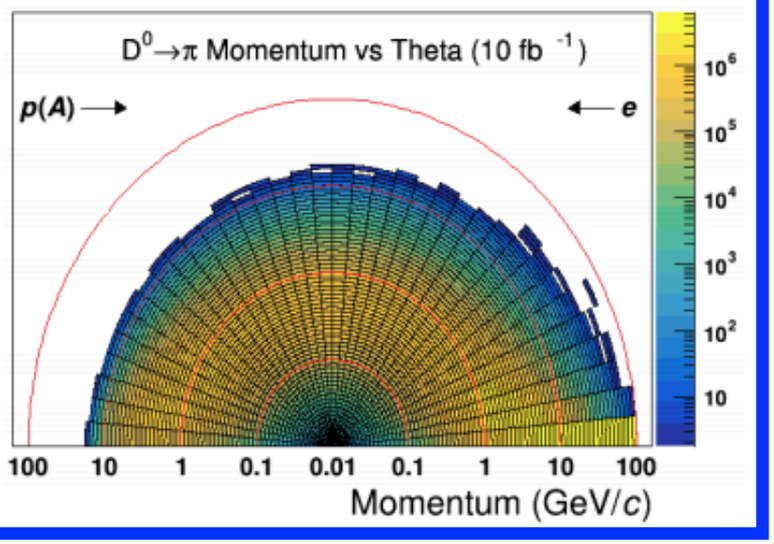


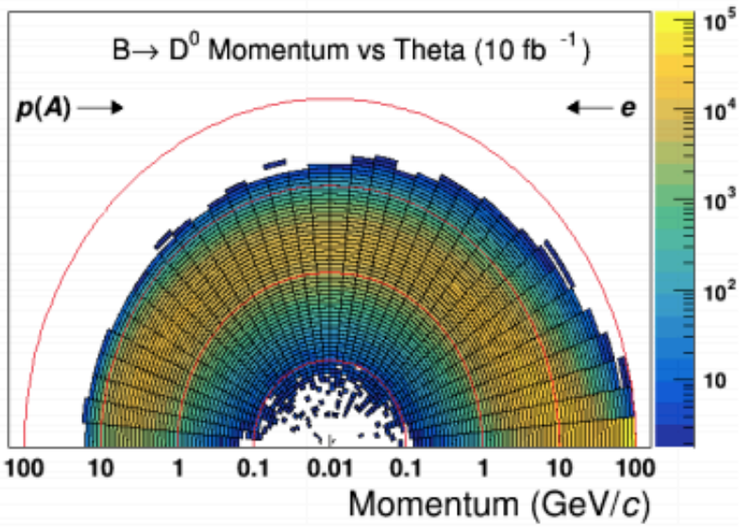
J. Xu and F. Yuan, PLB 801 (2019) 135187

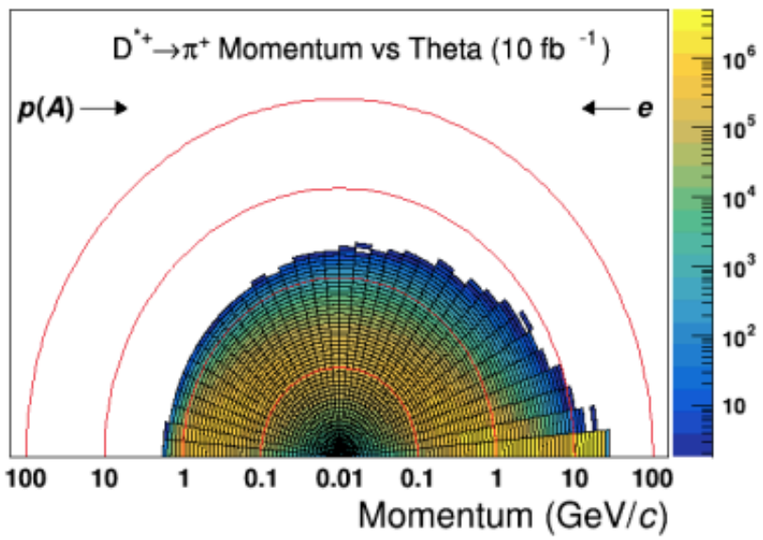
Kinematic Distributions

e + p 18 x 275 PYTHIA 6.4

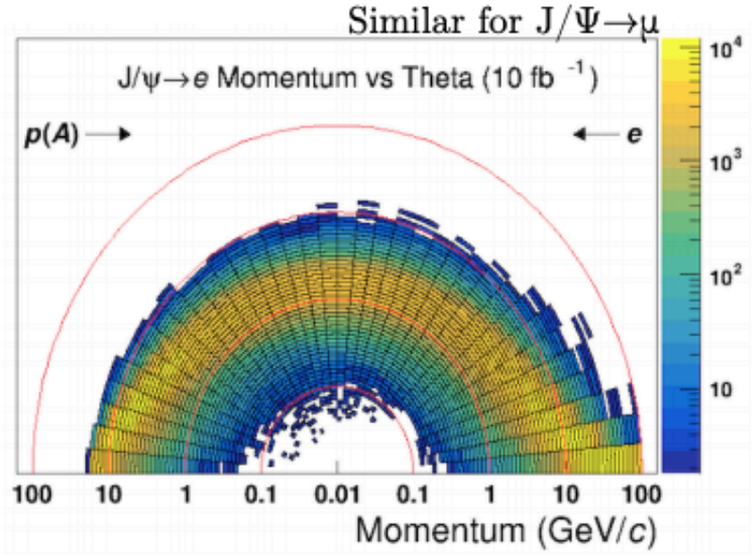


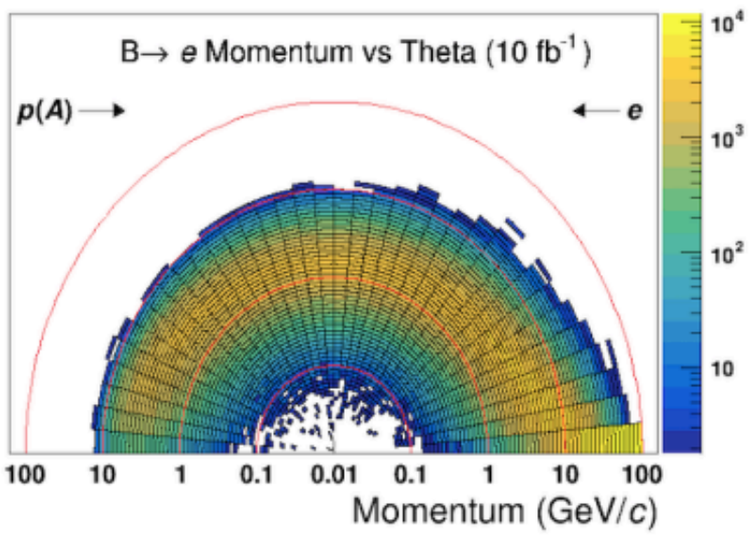






Similar for J/Ψ→μ





Fast Simulation w/ Default Detector Parameters

η	Nomenclature		Tracking			Electrons		π/K/p	
			Resolution	Allowed X/X0	Si-Vertex	Resolution σE/E	PID	p-Range (GeV/c)	Separation
-3.5 to -3.0	Central Detector	Backward Detector	σ_p/p ~ 0.1%⊕0.5%	~5% or less X	TBD	2%/√E	π suppression up to $1{:}10^4$	≤ 7 GeV/c	≥3 σ
-3.0 to -2.5									
-2.5 to -2.0			σ_p/p 0.1%⊕0.5%			2%/√E			
-2.0 to -1.5			σ_p/p 0.05%⊕0.5%			7%/√E			
-1.5 to -1.0						7%/√E			
-1.0 to -0.5		Barrel	σ_p/p ~0.05%×p+0.5%		σ_{xyz} ~ 20 μm, $d_0(z)$ ~$d_0(r\Phi)$ ~ 20/p_TGeV μm + 5 μm	(10-12)%/√E		≤ 5 GeV/c	
-0.5 to 0.0									
0.0 to 0.5									
0.5 to 1.0									
1.0 to 1.5		Forward Detectors	σ_p/p ~0.05%×p+1.0%		TBD			≤ 8 GeV/c	
1.5 to 2.0									
2.0 to 2.5								≤20 GeV/c	
2.5 to 3.0			σ_p/p ~ 0.1%×p+2.0%						
3.0 to 3.5								≤45 GeV/c	

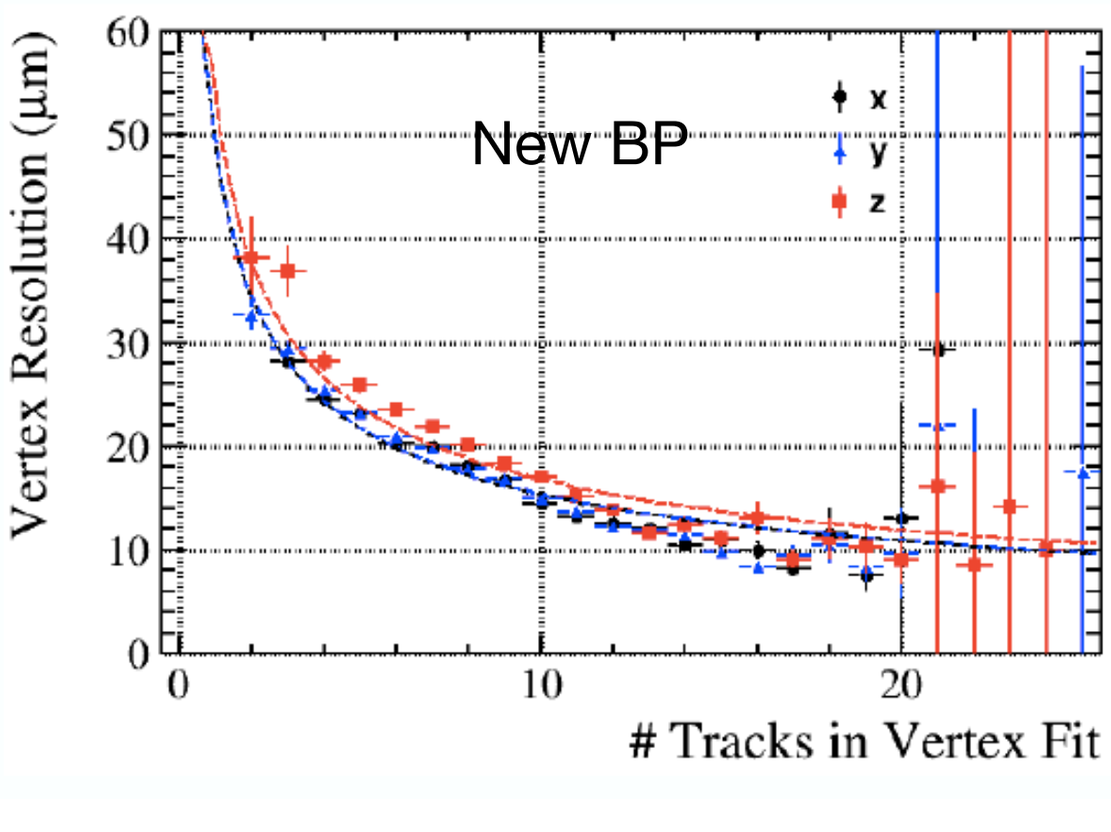
$\sigma_{XYZ} \sim 20\ \mu m$
$d_0(z) \sim d_0(r\phi) = 20/p_T \oplus 5\mu m$

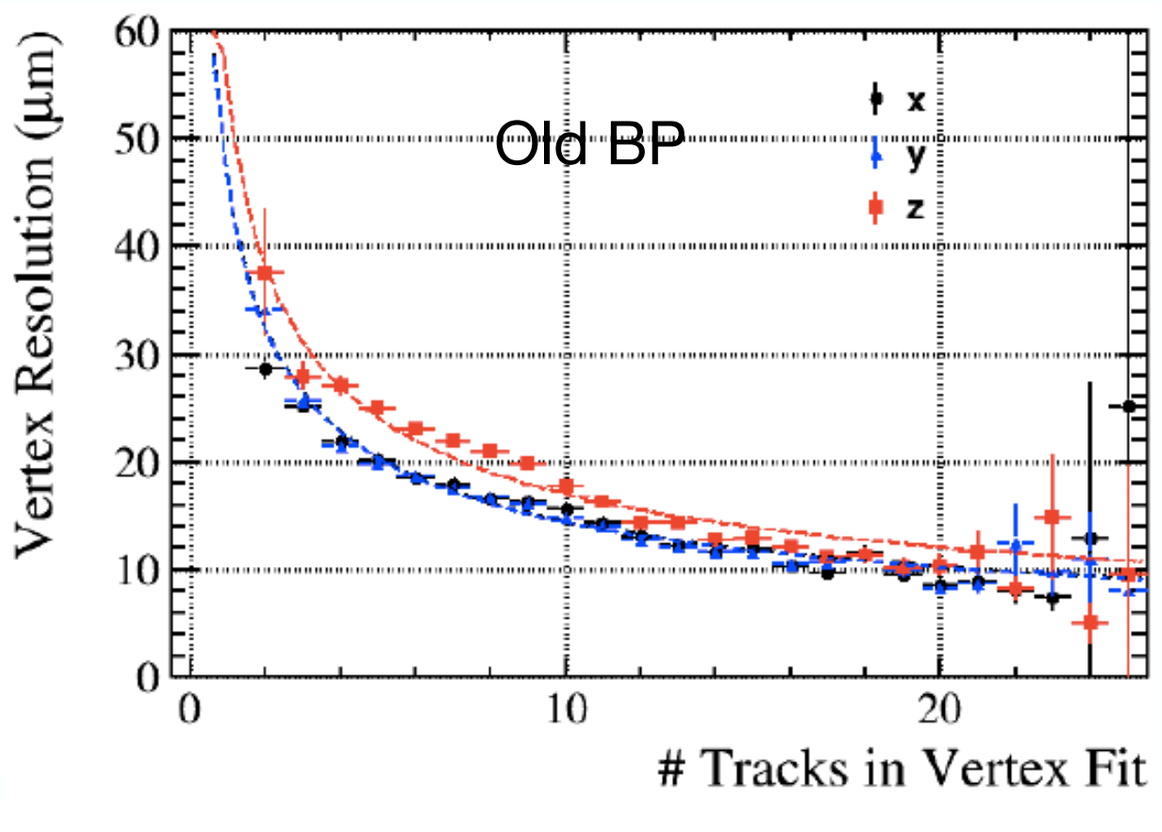
- Charm and bottom reconstruction using fast simulation smearing of PYTHIA 6.4 output
- Momentum and pointing resolutions taken from detector matrix page as baseline
  - central transverse pointing resolution extends to $|\eta|<3$

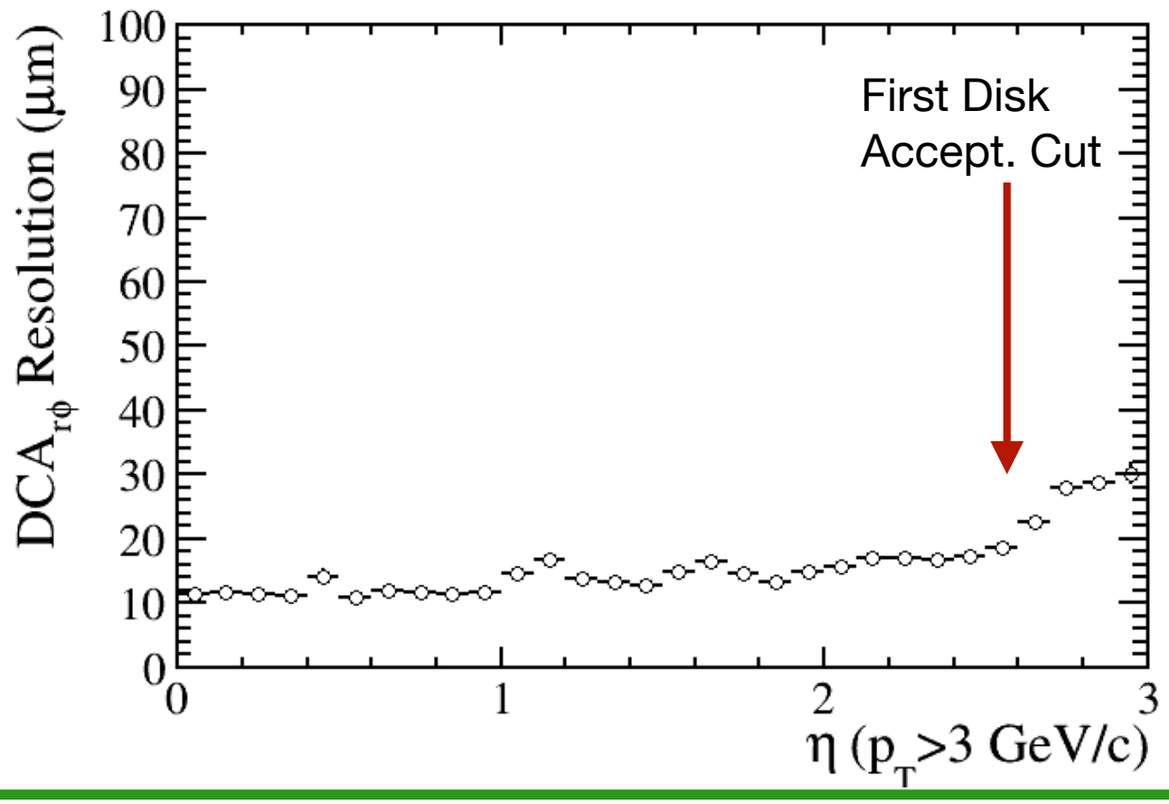
Agreed Requirements within Physics Working Group

Eta Bin	Pointing Resolution
[-2.5, -1.0]	$\sigma_{XY} \sim 30/p_T \oplus 20\mu m$
[-1.0, 1.0]	$\sigma_{XY} \sim \sigma_Z \sim 20/p_T \oplus 5\mu m$
[1.0, 2.5]	$\sigma_{XY} \sim 30/p_T \oplus 20\mu m$
[2.5, 3.0]	$\sigma_{XY} \sim 30/p_T \oplus 40\mu m$
[3.0, 3.5]	$\sigma_{XY} \sim 30/p_T \oplus 60\mu m$

Full Simulation w/ New Beam Pipe

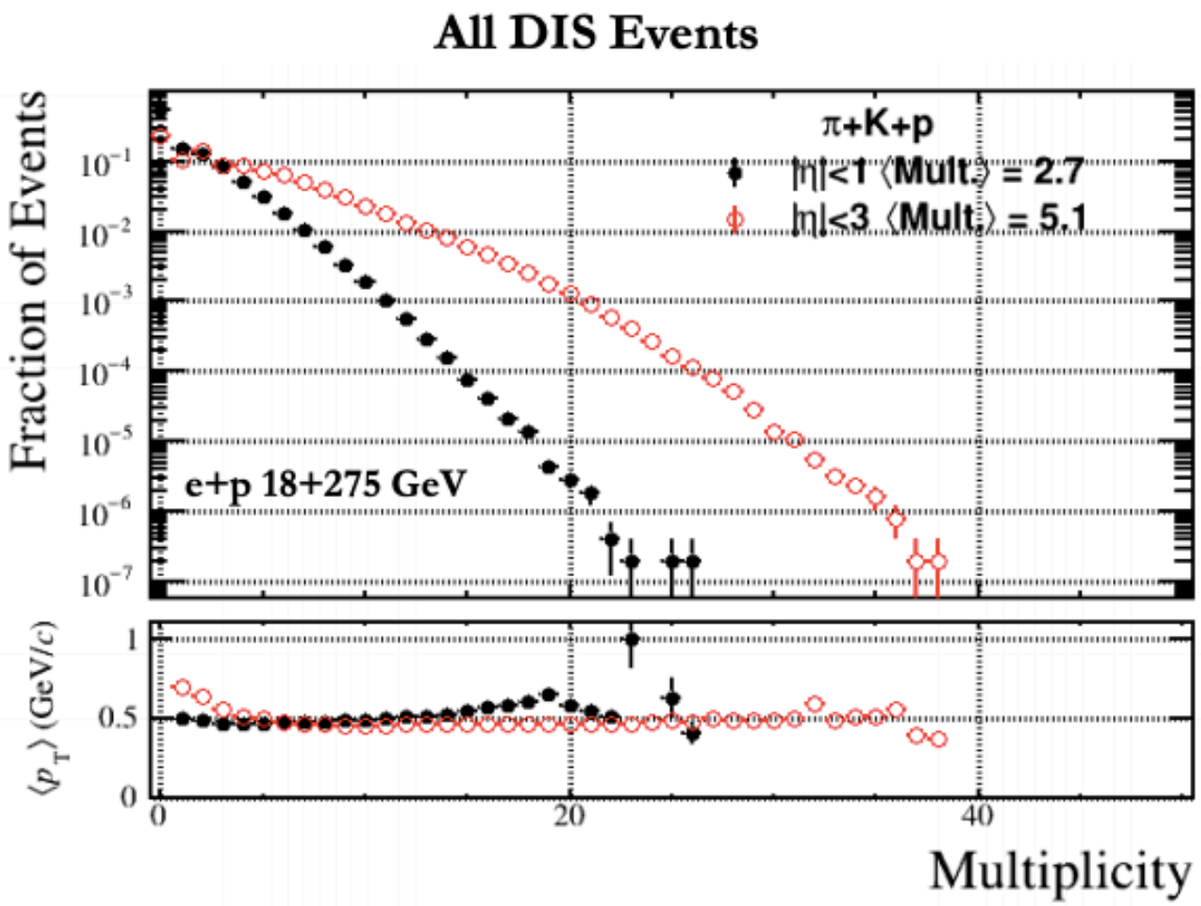


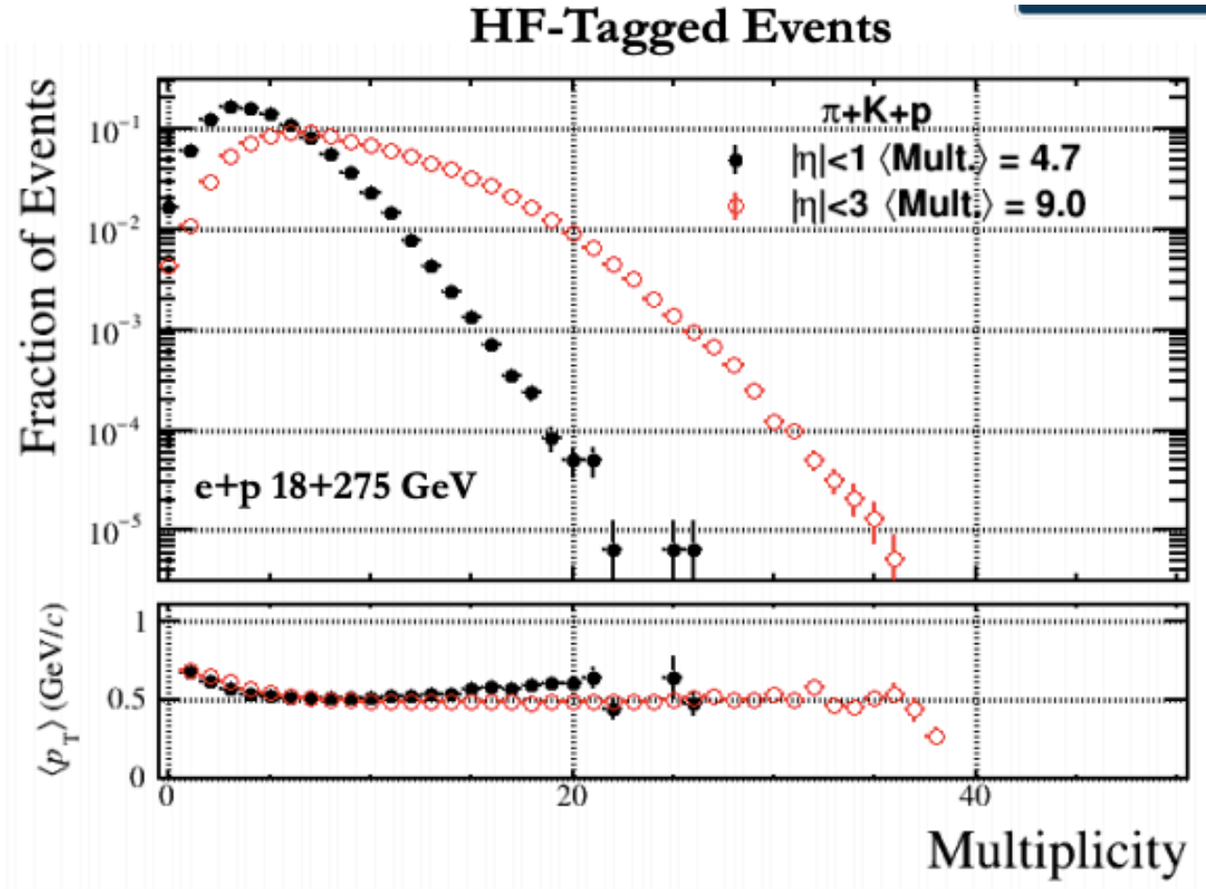


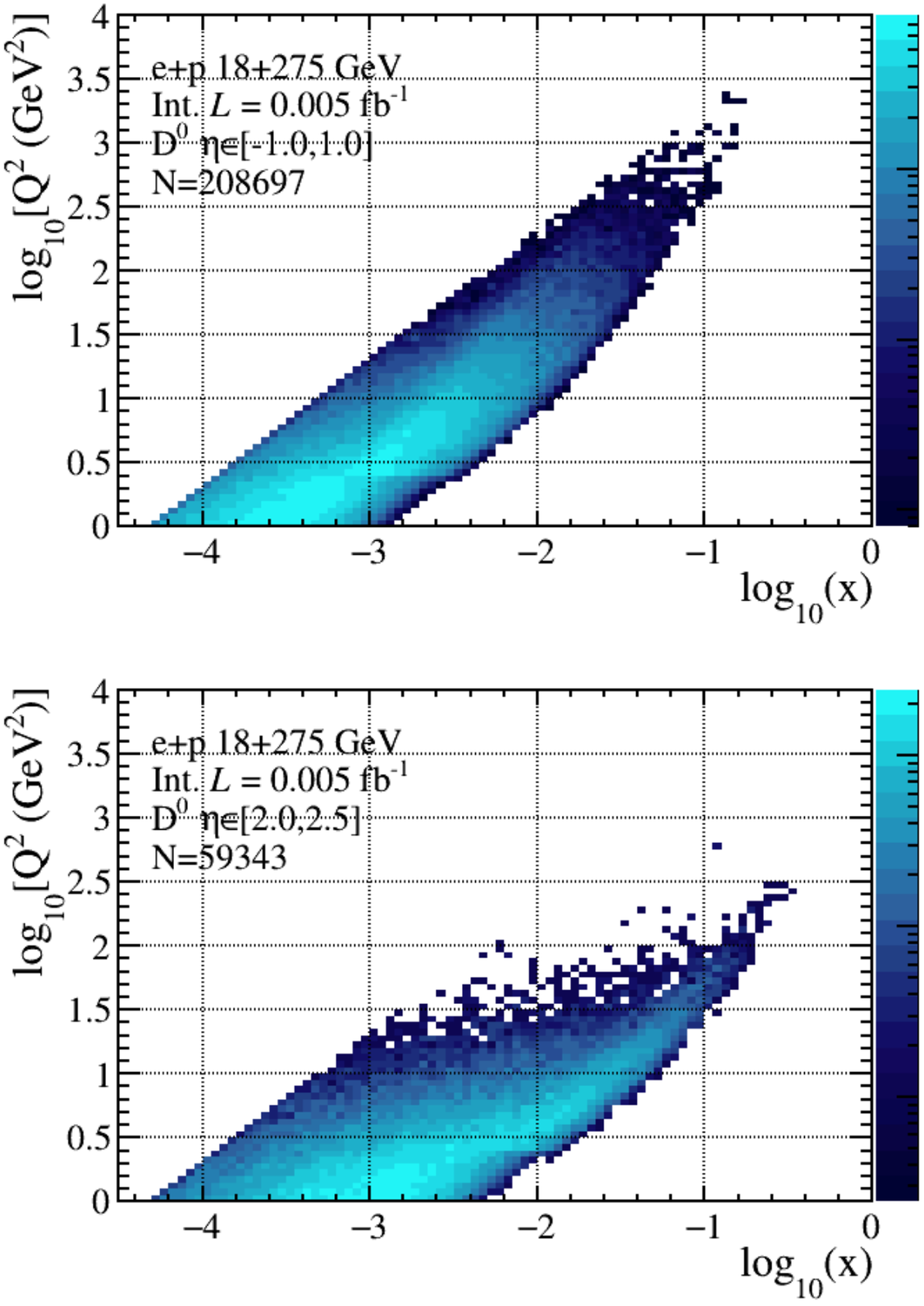


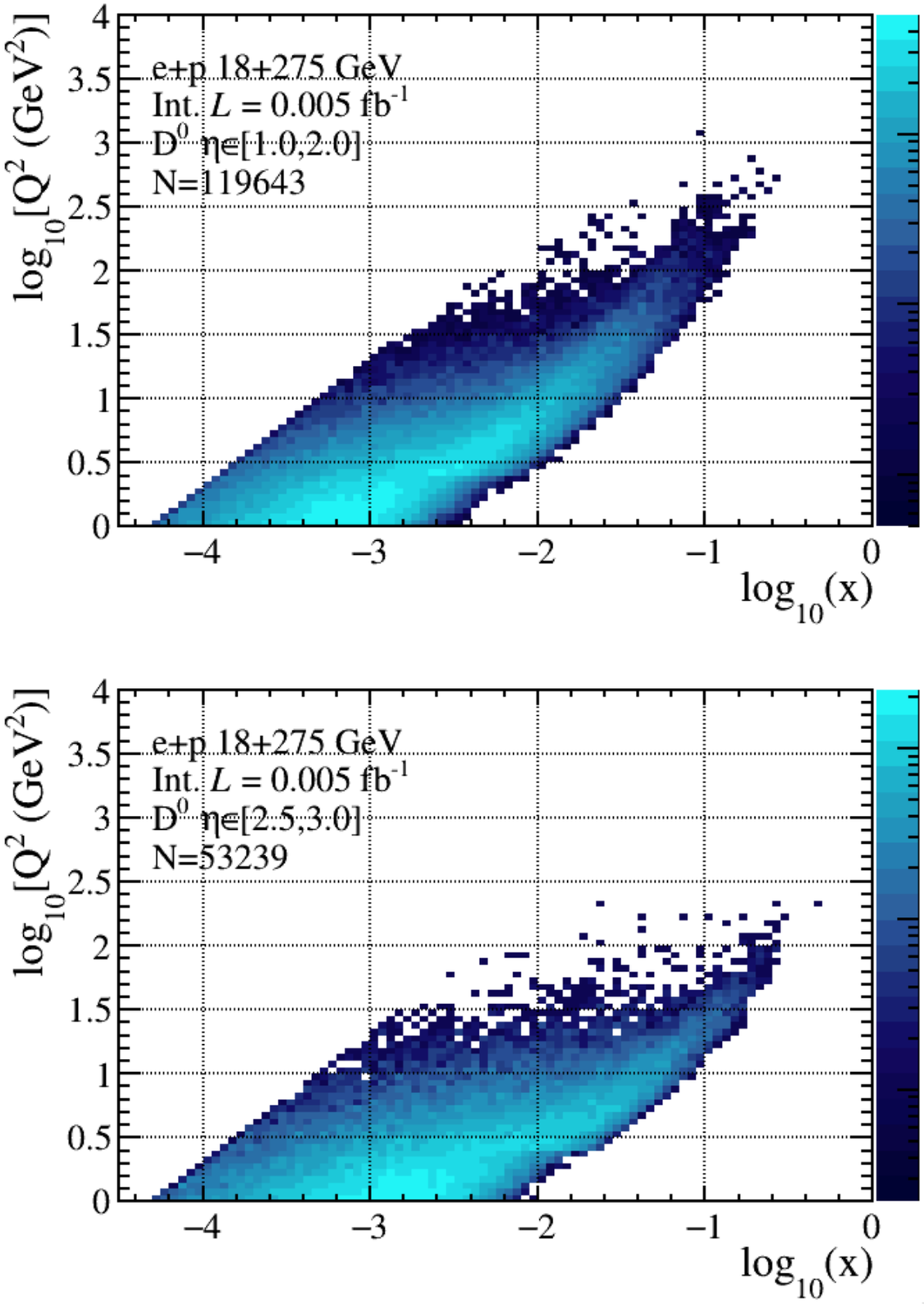
Event Multiplicity Distributions

e + p 18 x 275 PYTHIA 6.4






e+p 18+275 GeV
Int. L = 0.005 fb^{-1}
D^0 η∈[-1.0,1.0]
N=208697
log$_{10}$[Q^2 (GeV^2)]
log$_{10}$(x)


e+p 18+275 GeV
Int. L = 0.005 fb^{-1}
D^0 η∈[1.0,2.0]
N=119643
log$_{10}$[Q^2 (GeV^2)]
log$_{10}$(x)

e+p 18+275 GeV
Int. L = 0.005 fb^{-1}
D^0 η∈[2.0,2.5]
N=59343
log$_{10}$[Q^2 (GeV^2)]
log$_{10}$(x)

e+p 18+275 GeV
Int. L = 0.005 fb^{-1}
D^0 η∈[2.5,3.0]
N=53239
log$_{10}$[Q^2 (GeV^2)]
log$_{10}$(x)