EIC opportunities for Snowmass

25 Jan 2021, 10:00 → 29 Jan 2021, 16:00 US/Eastern

Probing gluon distributions with heavy flavor hadron pairs at the EIC

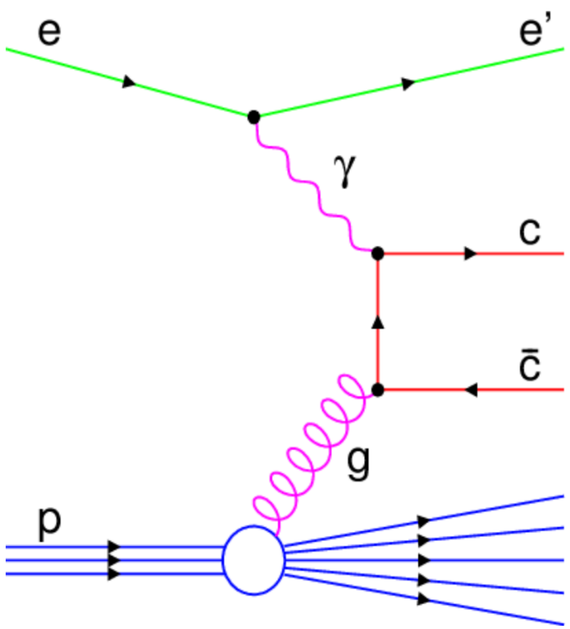
Sooraj Radhakrishnan
Kent State University/ Lawrence Berkeley National Laboratory
(In collaboration with Xin Dong, Yuanjing Ji, Matthew Klesey, Nu Xu)

EIC opportunities for Snowmass: Heavy flavor at EIC

KENT STATE UNIVERSITY

BERKELEY LAB

Heavy Quark Pairs as probes of gluon TMD



- Leading order contribution to heavy quark production in DIS from photon gluon fusion process
- Makes heavy flavor hadron production ideal to probe gluon distributions

- Heavy quark pair production is sensitive to the transverse momentum of the gluons
- Possibility to study gluon Transverse Momentum Dependent distributions of gluons by reconstructing heavy hadron pairs at the EIC

- Study using full detector simulation of future EIC detector

Heavy Quark Pairs as probes of gluon TMD

- Sivers function - correlation between proton spin and transverse momentum of parton
- Can be accessed in transversley polarized e+p (e+A) collisions

- Contributes the measured transverse single spin asymmetry

$$A_{UT}(\phi_{kS}, k_T) = \frac{d\sigma^{\uparrow}(\phi_{kS}, k_T) - d\sigma^{\downarrow}(\phi_{kS}, k_T)}{d\sigma^{\uparrow}(\phi_{kS}, k_T) + d\sigma^{\downarrow}(\phi_{kS}, k_T)} \propto \frac{\Delta^N f_{g/p^{\uparrow}}(x, k_{\perp})}{2 f_{g/p}(x, k_{\perp})},$$

- TMD of linearly polarized gluons - important in determining axial charge distributions in the initial stage and thus to the chiral magnetic effects in heavy-ion collisions

T. Lappi, S. Schlichting Phys Rev D. 97. 034034 (2017)

- Can be accessed in unpolarized e+p (e+A) collisions

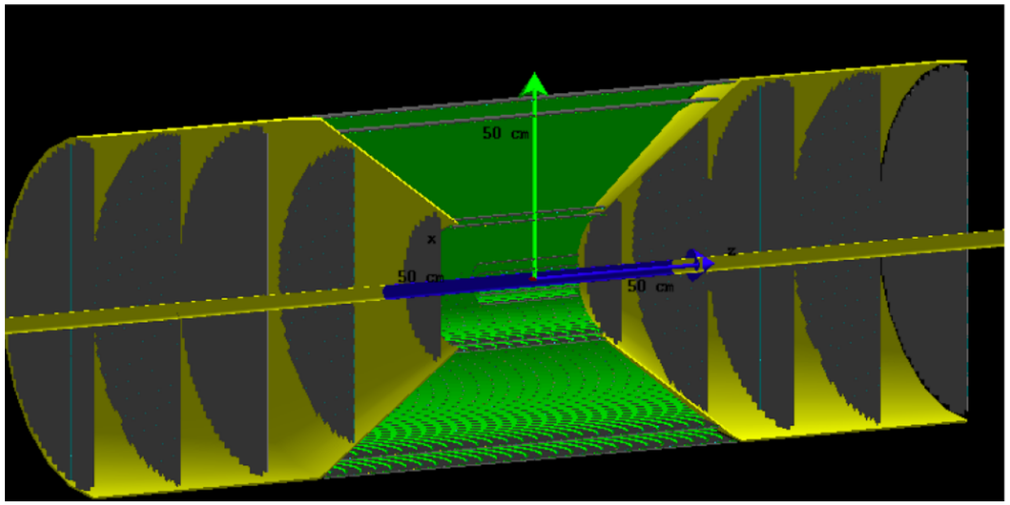
$$|\langle \cos 2\phi_T \rangle| = \frac{\boldsymbol{q}_T^2}{2M^2} \frac{\left| h_1^{\perp g}\left(x, \boldsymbol{p}_T^2\right) \right|}{f_1^g\left(x, \boldsymbol{p}_T^2\right)} \frac{\left| \mathcal{B}_0^{eg \to eQ\overline{Q}} \right|}{\mathcal{A}_0^{eg \to eQ\overline{Q}}}$$

ϕ_T - azimuthal angle of the HQ hadron pair momentum

Sivers previous studies: L.Zheng et.al PhysRevD.98.034011

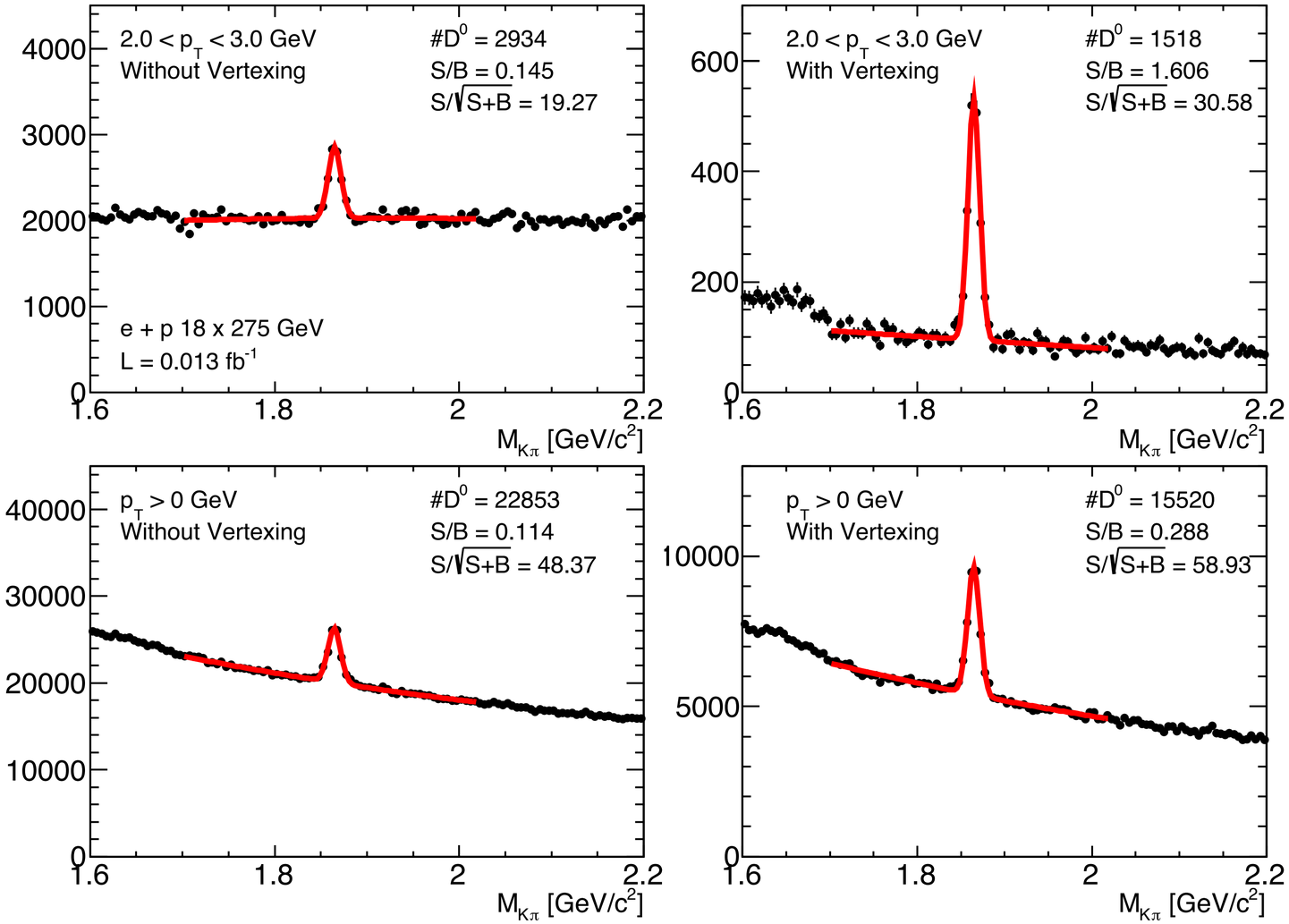
LP TMD Signal projections: Daniël Boer EIC YR WG presentation

PYTHIA and EIC Simulation Setup



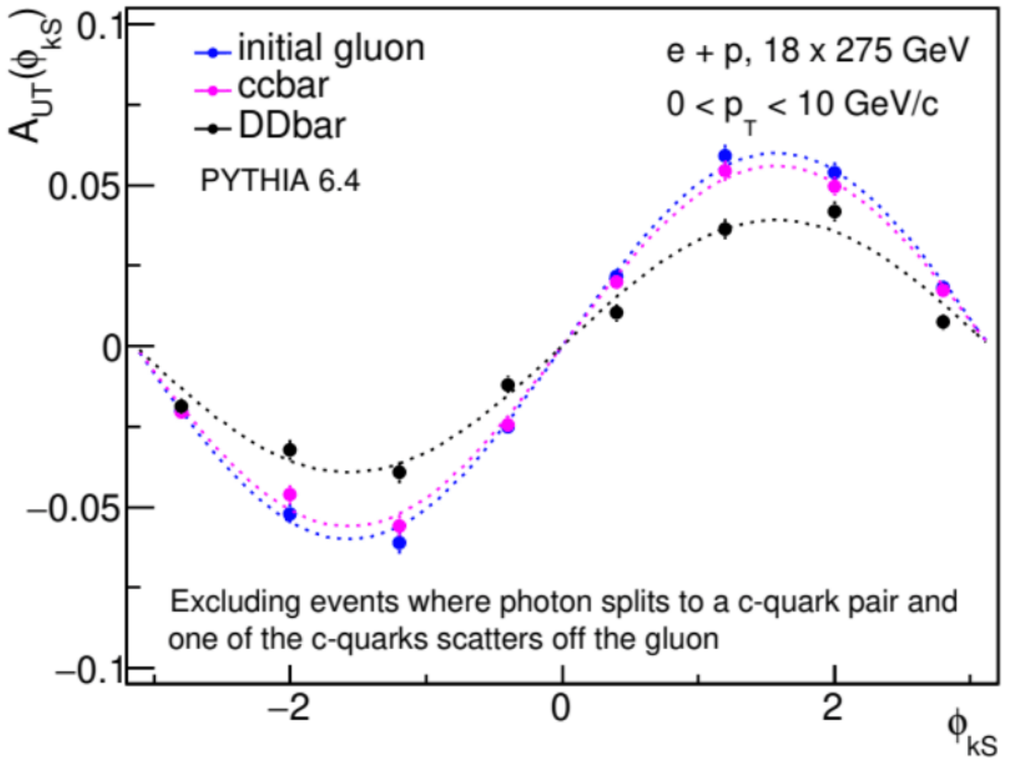
- All-silicon tracker design composed of MAPS sensors
- 3x2 barrel layers with approximately |η| < 1 coverage
- Five disks in forward and backward regions each, with coverage 1 < |η| < 3

Specifications as in EIC Det.Matrix

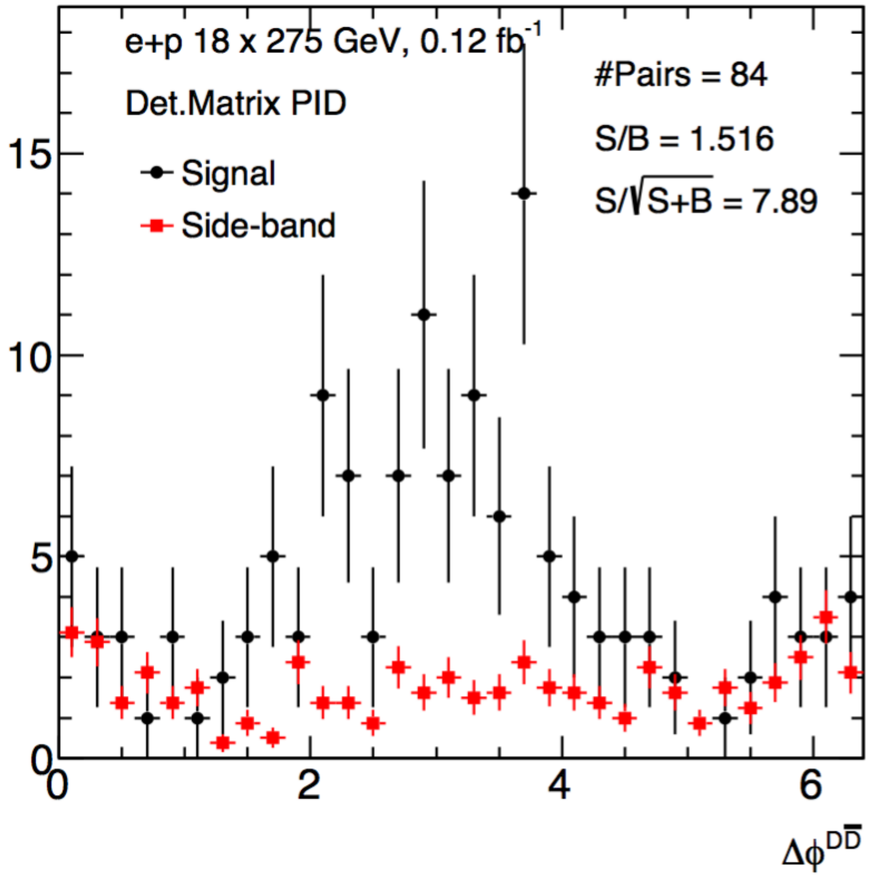


- Signal significance improves greatly with vertexing cuts

D meson pair reconstruction



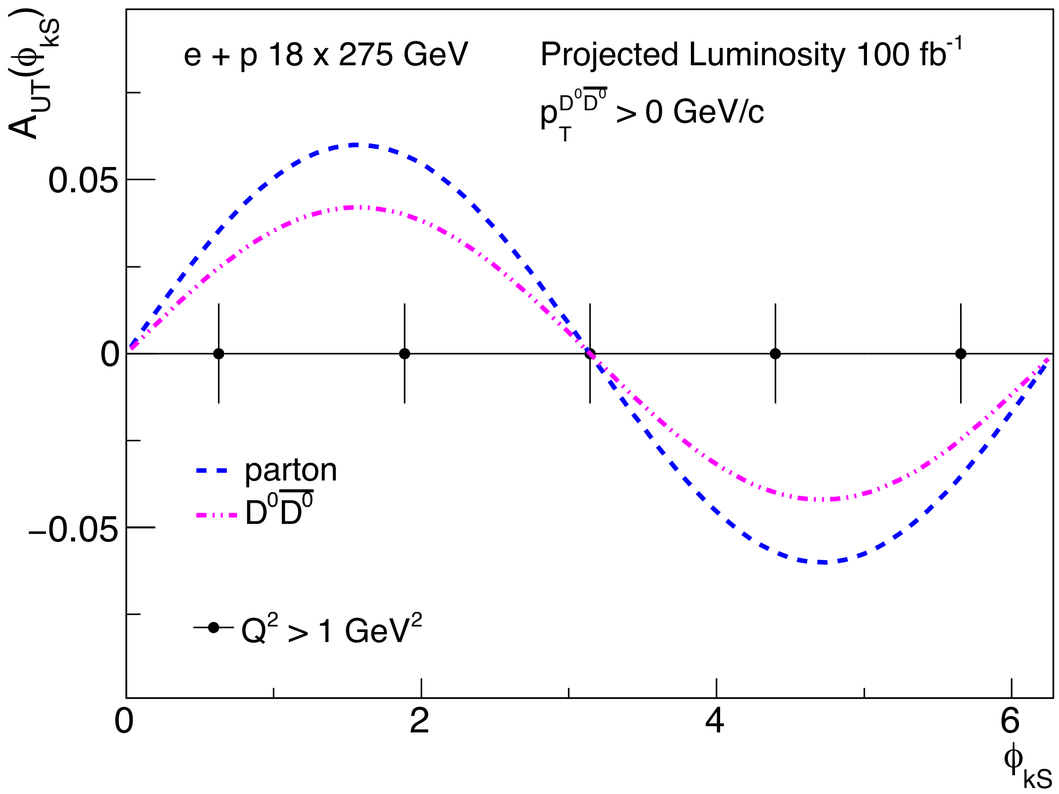
- Initial gluon asymmetry dilutes by ~30% after reconstruction of DDbar

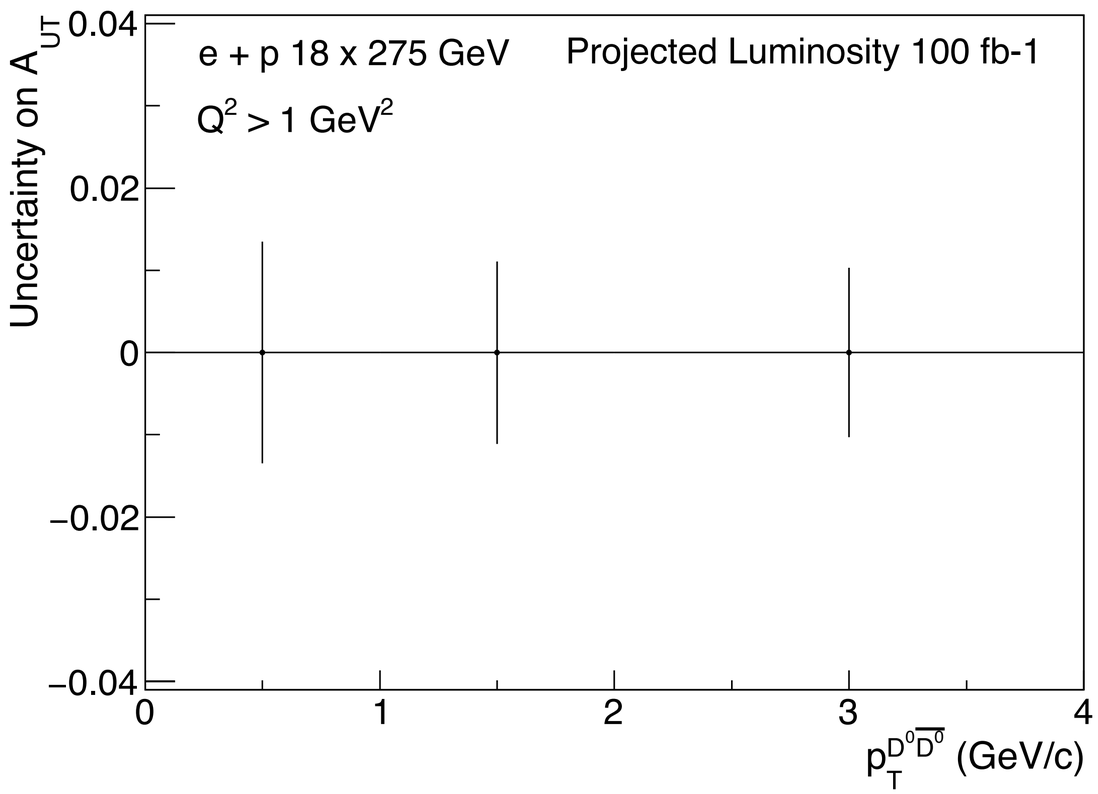


Daughter tracks kinematic cuts:
$p_T > 0.2$ GeV/c
$|\eta| < 3.0$

- Good signal to background ratio
- Expected total signal significance of 230 sigma at 100 fm^{-1} luminosity

Statistical uncertainty projections





Signal projections from:

Sivers:
L.Zheng et.al
PhysRevD.
98.034011

LP TMD:
Daniël Boer
EIC YR WG
presentation

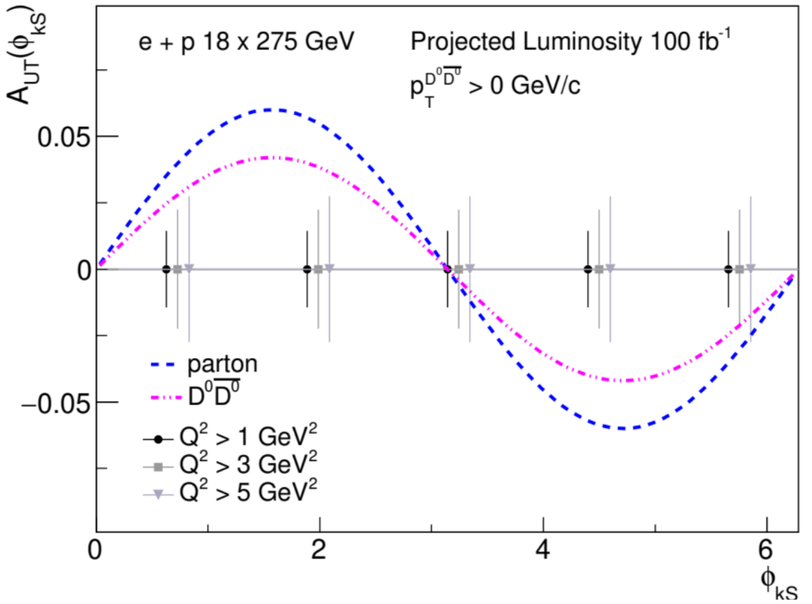
- Projected uncertainty on $\langle A_{UT} \rangle$ is 0.6% (7σ for a signal of 10% positivity bound). Proton beam polarization of 70% is assumed
- Projected uncertainty on $\langle \cos(2\phi) \rangle$ is 0.4% (5σ measurement)

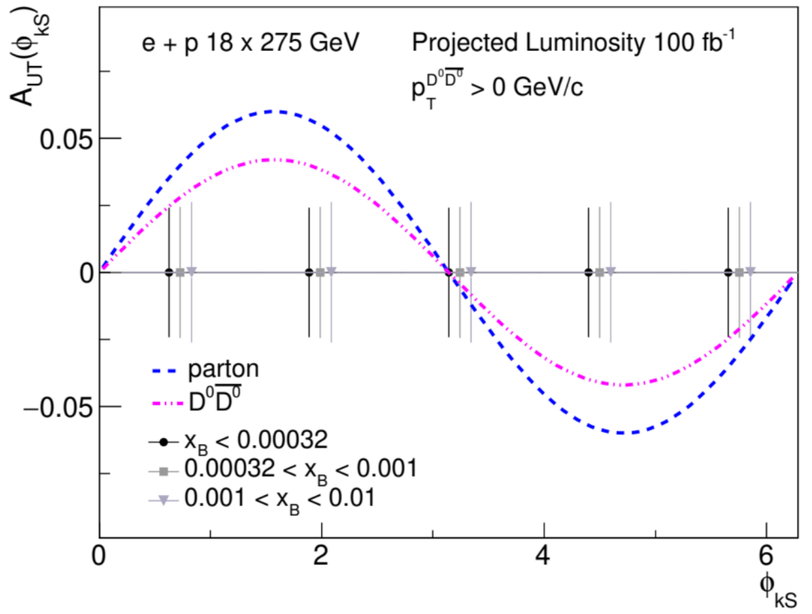
Summary

- Heavy quark pair production offers an unique opportunity to study gluon TMDs at the EIC

- An all-silicon tracking detector design with MAPS allows good secondary vertex resolution - Important for charm hadron reconstruction

- Projected uncertainty on $\langle A_{UT} \rangle \sim 0.6\%$
- Will provide first direct measurements of gluon TMDs





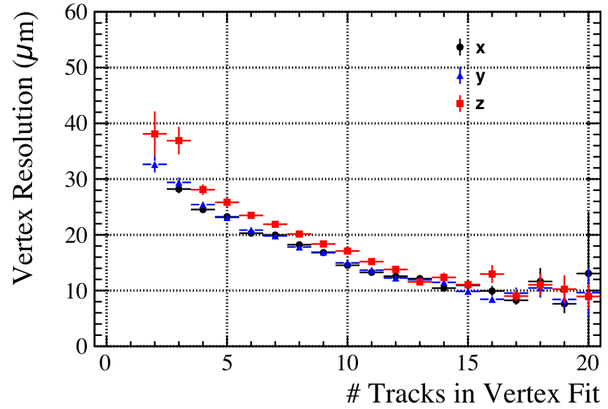
Thank You!!

Back Up

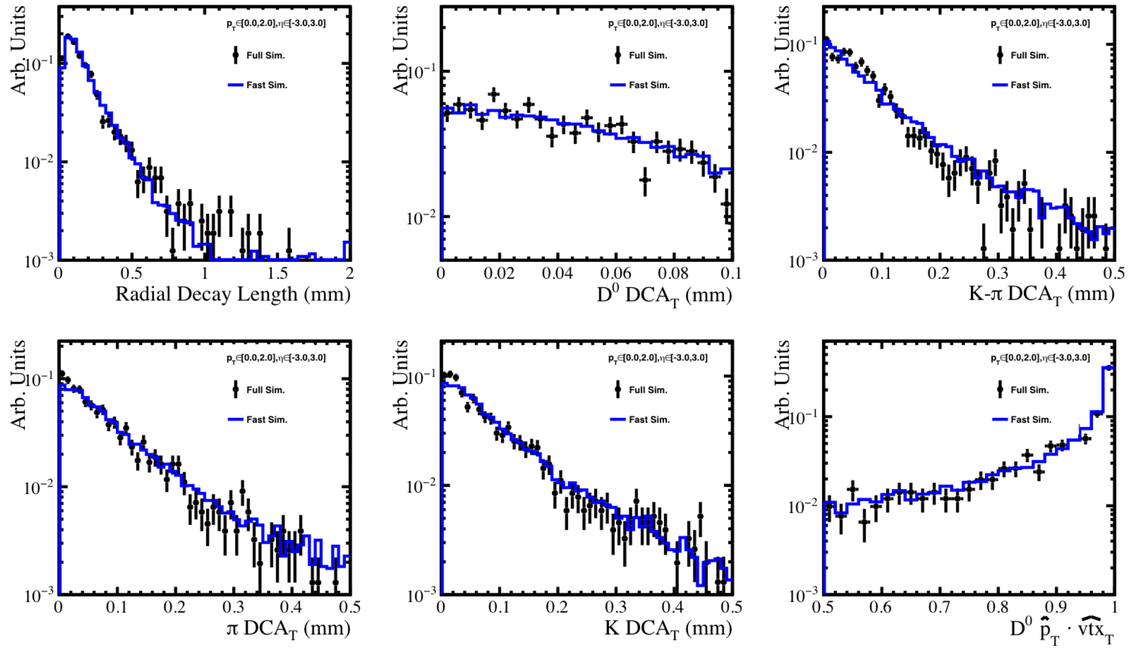
Fast simulation setup

- Detector responses implemented through a fastsimulation with parametrized position and momentum resolutions - for sufficient statistics
- Parametrizations taken from the current EIC detector matrix
- Full simulation studies and fastsim validation: See Rey's and Matt's talks

- Primary vertex resolution taken from full simulation



- Fast simulation performance was validated using full simulation



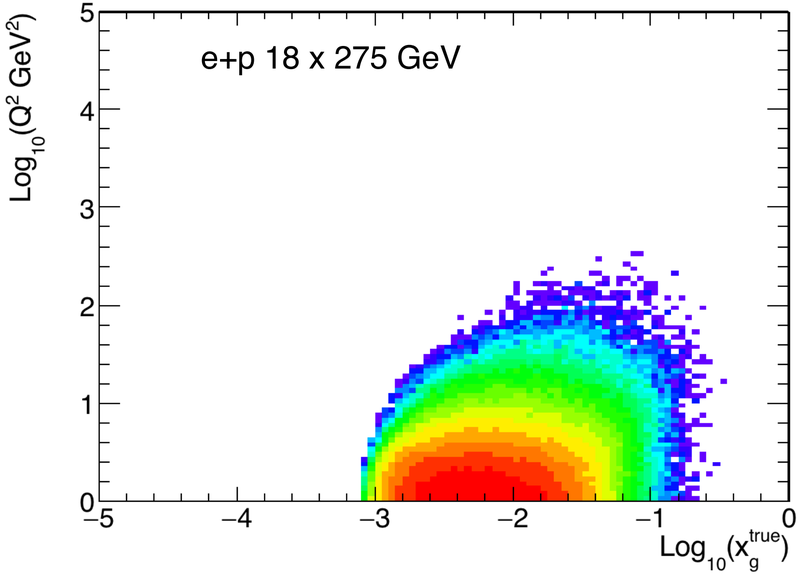
Position resolution

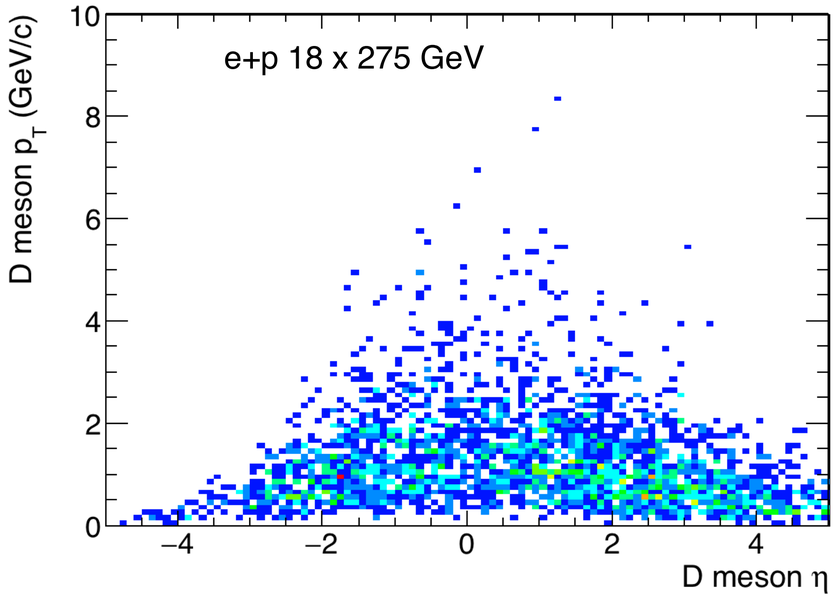
η Region	Detector Matrix (μm)
-3.0< η <-2.5	$30/p_T \oplus 40$
-2.5< η <-2.0	$30/p_T \oplus 20$
-2.0< η <-1.0	$30/p_T \oplus 20$
-1.0< η <1.0	$20/p_T \oplus 5$
1.0< η <2.0	$30/p_T \oplus 20$
2.0< η <2.5	$30/p_T \oplus 20$
2.5< η <3.0	$30/p_T \oplus 40$
3.0< η <3.5	$30/p_T \oplus 60$

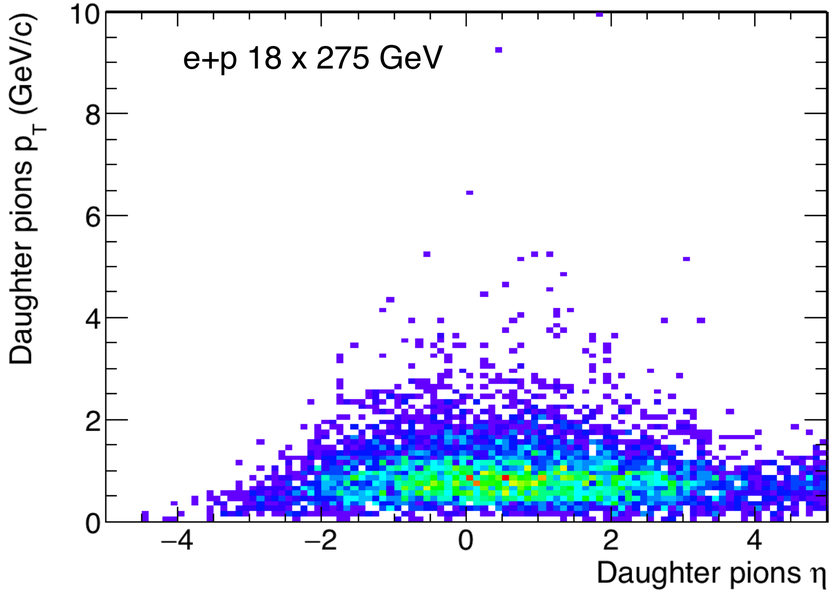
Mom resolution

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

D meson pair kinematics





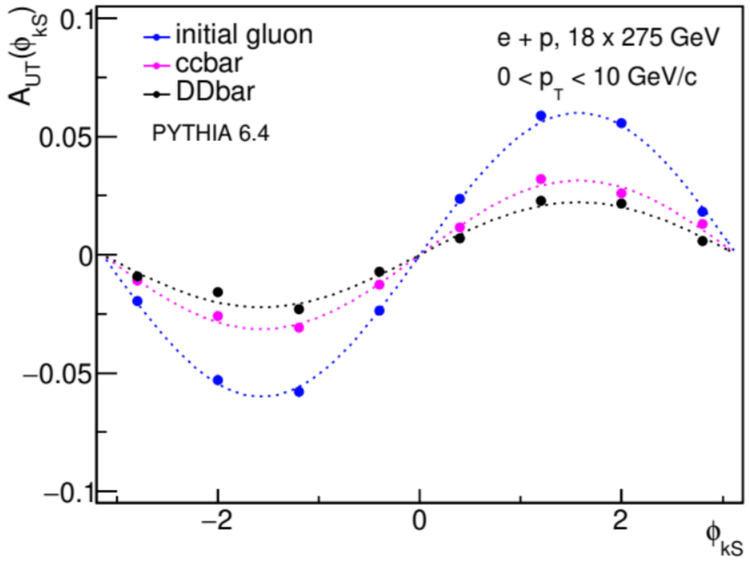


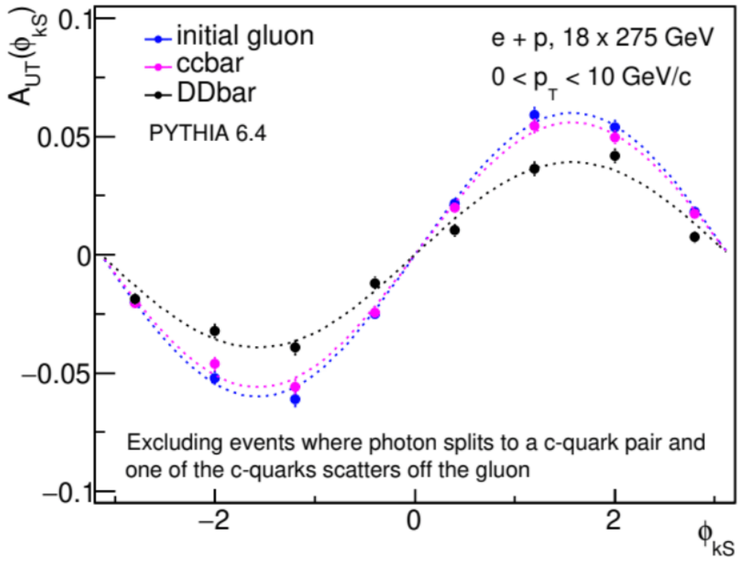
z-axes in log scale

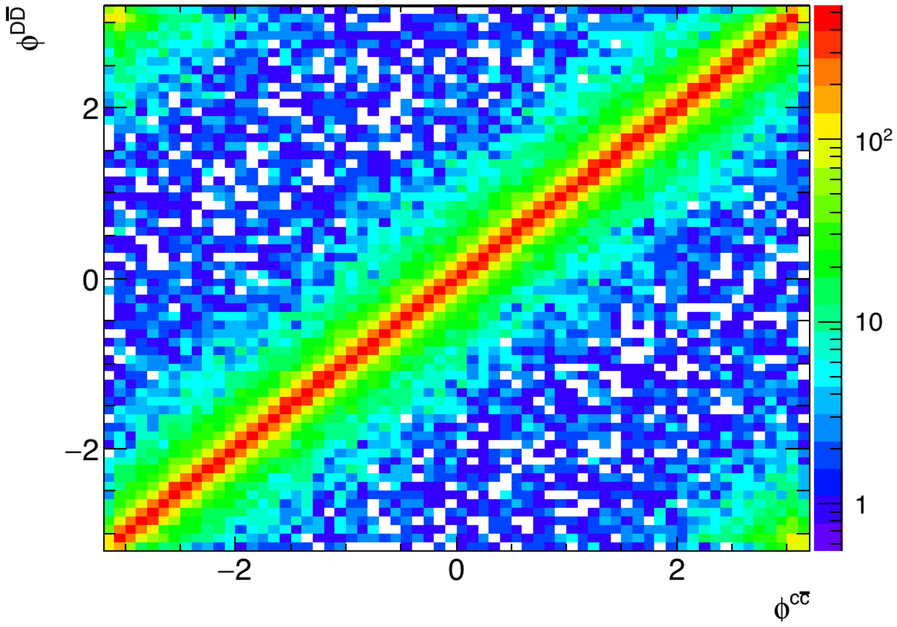
- Parton x reach in the range 0.001 < x 0.1

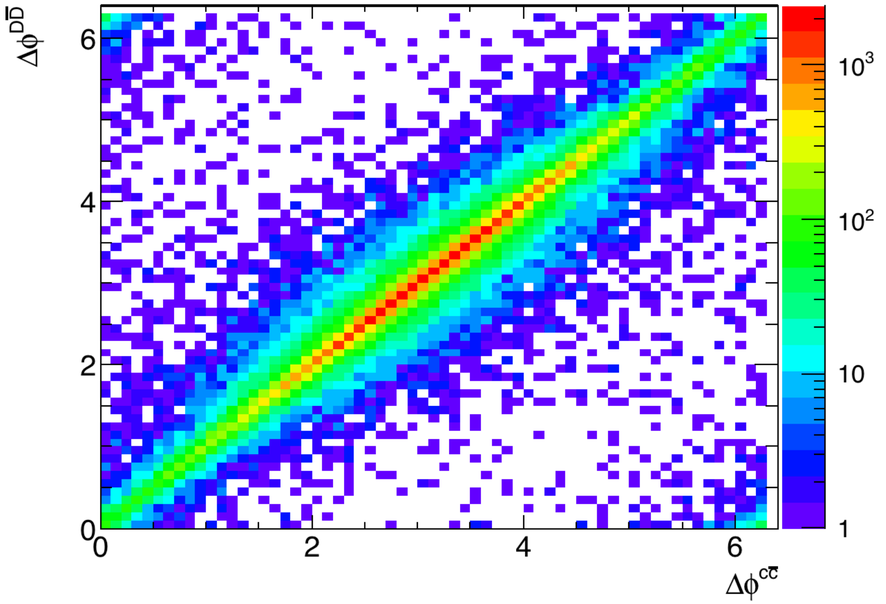
- D mesons and decay daughters in D meson pair events have low p_T (<~ 5 GeV/c)
- Acceptance of daughter tracks mostly within |η| < 3, within detector coverage

Correlations between partonic and hadronic levels









- Hadronization doesn't cause much decorrelation in angular distributions
- Stronger dilution in PYTHIA going from initial gluon to ccbar - but not seen in events where PYTHIA doesn't split photon to