# Feasibility studies of neutrino-jet and hadron-in-jet azimuthal modulations in charged-current DIS at the EIC

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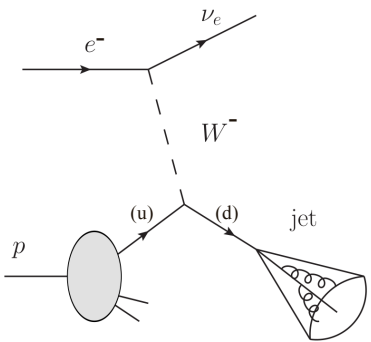
# Introduction

- Charged-current deep inelastic scattering (CC DIS) occurs via exchange of a virtual $W$ boson between an incoming lepton and a bound quark.
- Provides flavour sensitivity with tagging of the electric charge of the struck quark.
- Here we show the feasibility of using jets to study TMD observables in CC DIS reactions at the future Electron-Ion Collider (EIC).



# Electron-Ion Collider conditions in this study

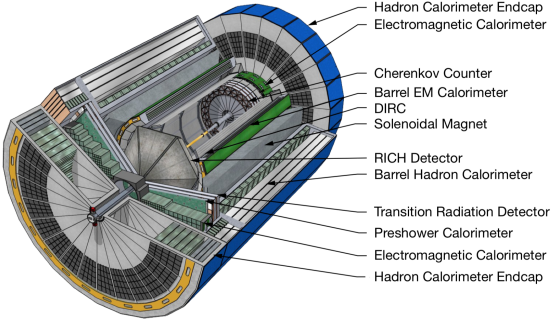
- 10 GeV electrons with 275 GeV protons.
- Projected luminosity: 100 $\text{fb}^{-1}$ (1 year $\times$ $10^{34}\text{cm}^{-2}\text{s}^{-1}$).
- Average proton polarization of 70%

Kinematic range

- $100 < Q^2 < 5000$ $\text{GeV}^2/c^2$
- $0.1 < x_B < 0.8$
- $10 < p_T^{\text{jet}} < 45$ $\text{GeV}/c$

Detector performance:

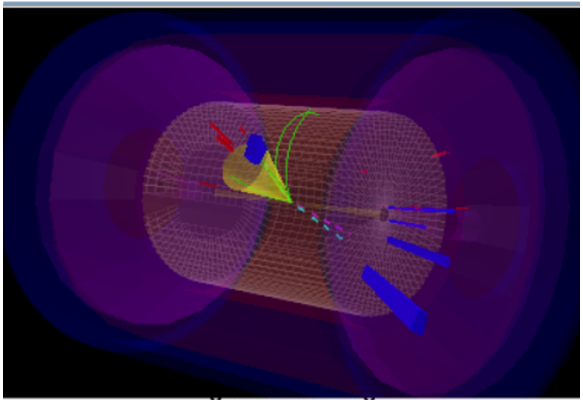
- Based on EIC YR params (3T).
- Tracker performance follows LBNL all-silicon design. [1]



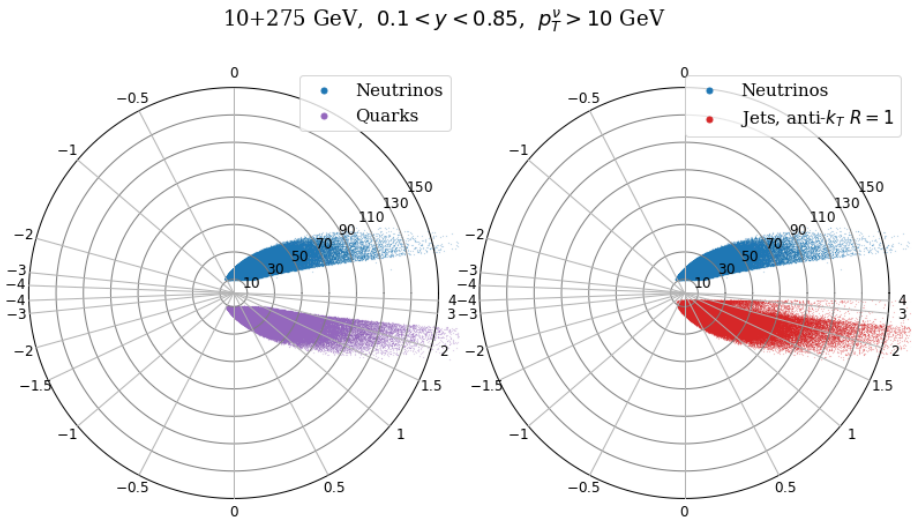

ref. detector, EIC YR

# Simulations

- Pythia for event generation
- Detector readout simulated in Delphes
- Particle-flow algorithm used for reconstructing particles in event.
- Jets reconstructed using anti-$k_T$ algorithm with $R = 1$, separately for particle-flow recon, and generated final-state particles.

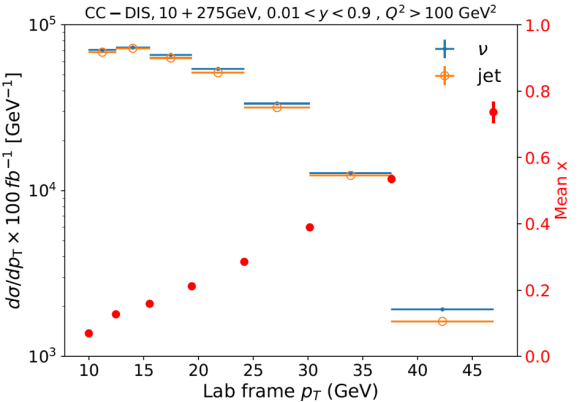


# Jets as a proxy for quarks



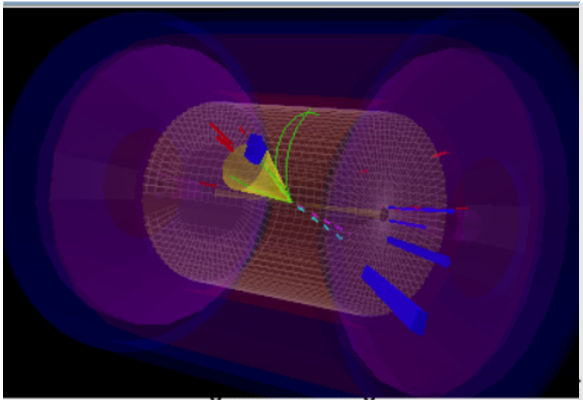
# Expected cross-sections and ability to probe high $x_B$

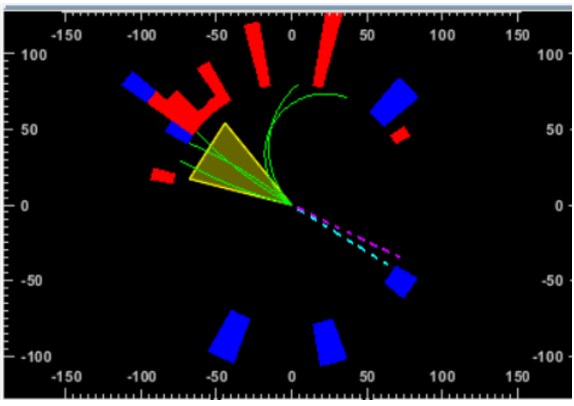
- Jet and $\nu$ cross-sections match as a function of transverse momentum.
- Large Björken $x$ can be probed at large transverse momentum, complementing fixed-target experiments



# Simulated event display

- Neutrino momentum can be inferred from missing momentum in event.

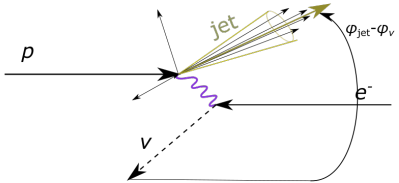


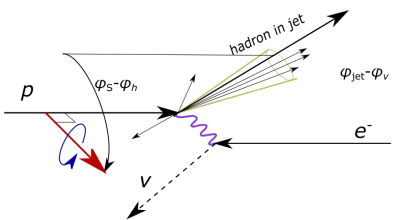


# Observables in this study

Azimuthal asymmetries can be measured with respect to

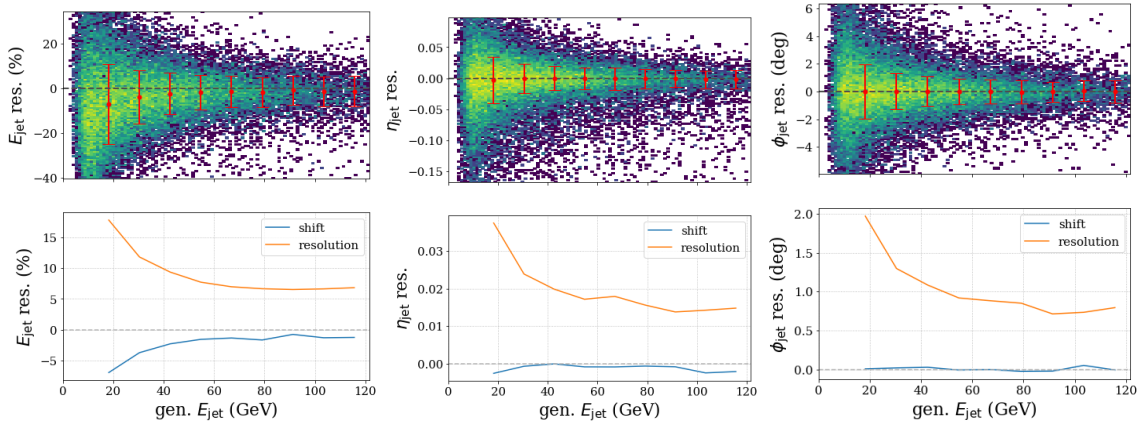
- correlation between proton spin and jet ($\phi_s - \phi_{\text{jet}}$), which can be measured in intervals of $\phi_\nu - \phi_{\text{jet}}$ (lepton-jet Sivers asymmetry)
- transverse $p$ polarization: $\phi_s - \phi_h$ (Collins asymmetry) for hadrons in jet



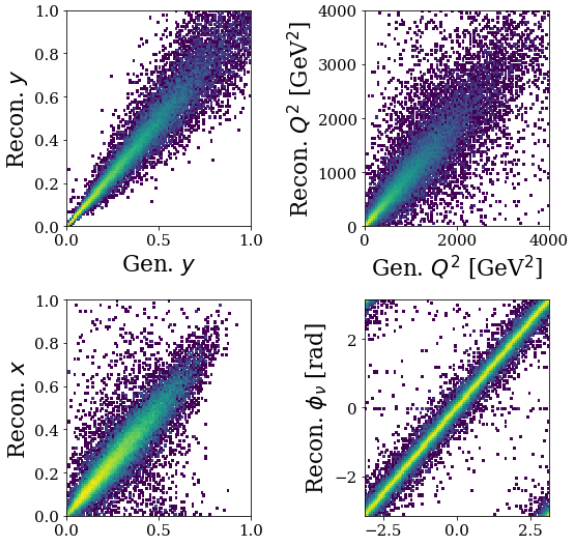



# Jet reconstruction performance: Energy, $\phi$, $\eta$ resolutions

- Jets reconstructed with anti $k_T$ algorithm and $R = 1.0$
- For a 40 GeV jet, $\Delta E_{\text{jet}}/E_{\text{jet}} \approx 10\%$, $\Delta\eta_{\text{jet}} \approx 0.02$ and $\Delta\phi_{\text{jet}} \approx 1.1^\circ$

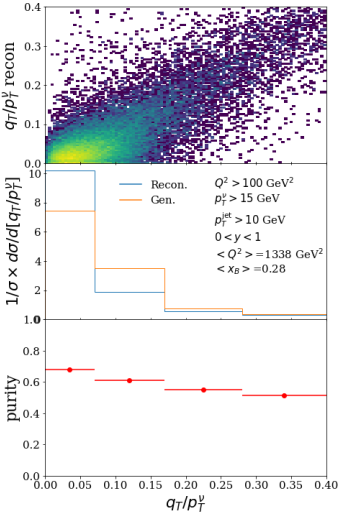


# Lepton kinematics reconstruction




- lepton kinematics estimated using the Jacquet-Blondel method [2].
- Event-inelasticity: $y_{JB} = \sum_{\text{recon}} E_i - p_{z,i}/(2E_e)$
- four momentum transfer: $Q^2_{JB} = (p_T^{\text{miss}})^2/(1 - y_{JB})$
- Björken scaling variable: $x_{JB} = Q^2_{JB}/(s y_{JB})$

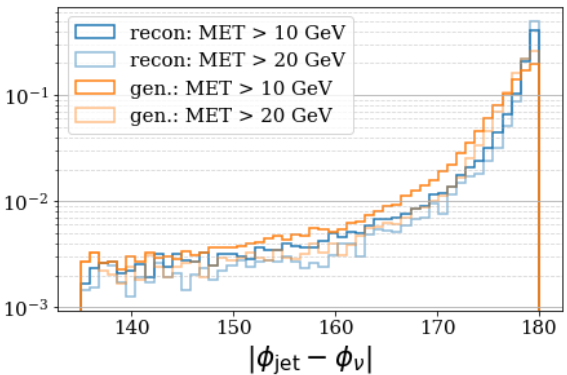
# Resolution: $q_T/p_T^\nu$




- $q_T = |\vec{p}_T^{\,\nu} + \vec{p}_T^{\,\text{jet}}|$ can be used as proxy for the struck quark's initial momentum
- $q_T/p_T^\nu$ is dimensionless; can be used to compare our CC results from EIC with other experiments at other energy scales.
- the resolution on $q_T/p_T^\nu$ is sufficient for binning with over 50% purity in 4 bins.

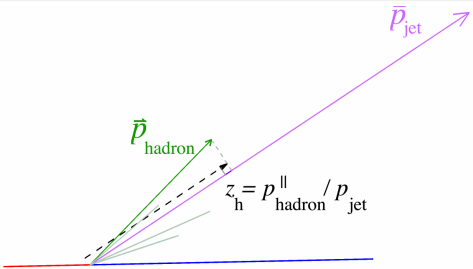
# Lepton-jet asymmetry

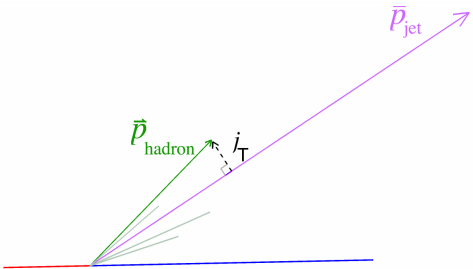
- Jets tend to be produced back-to-back with the $\nu$, as expected from conservation of momentum
- The $|\phi_{\text{jet}} - \phi_\nu|$ spectrum can be measured to probe TMD PDFs.
- Alternatively $|\phi_{\text{jet}} - \phi_\nu|$ can be used as a binning parameter for other measurements. (comparing jets in the peak vs the tail of this spectrum)



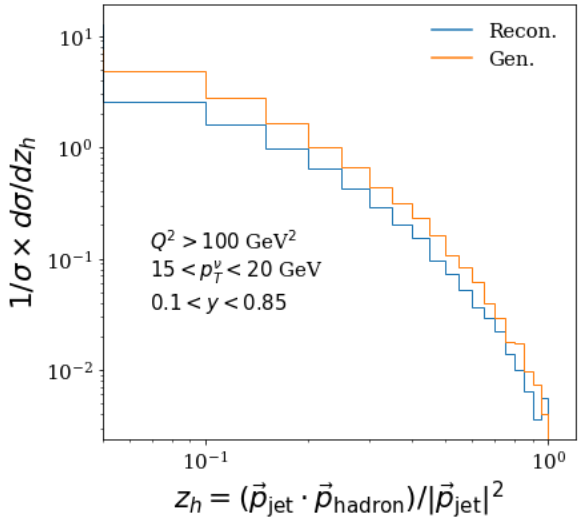
# Hadron-in-jet kinematic variables $z_h$ vs $j_T$

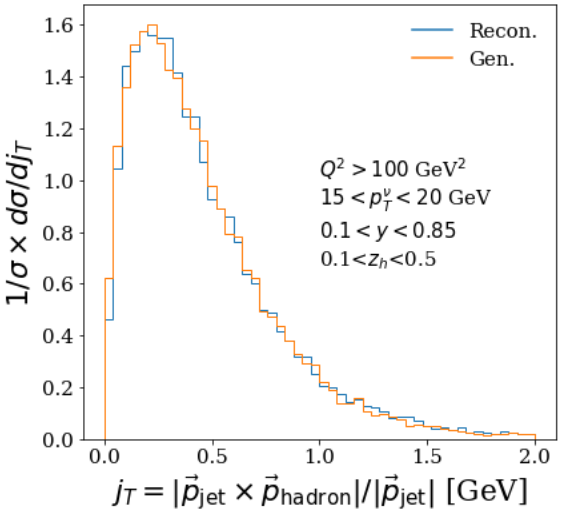
- $z_h$: fraction of momentum carried by hadron along jet axis
- $j_T$: hadron momentum transverse to jet



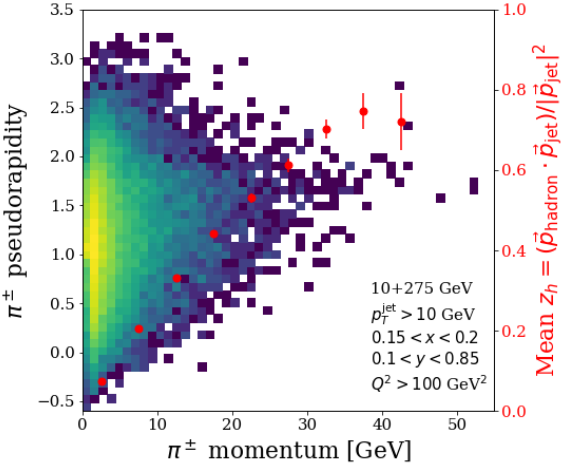
# Hadron-in-jet kinematics: pion $z_h$ vs $j_T$



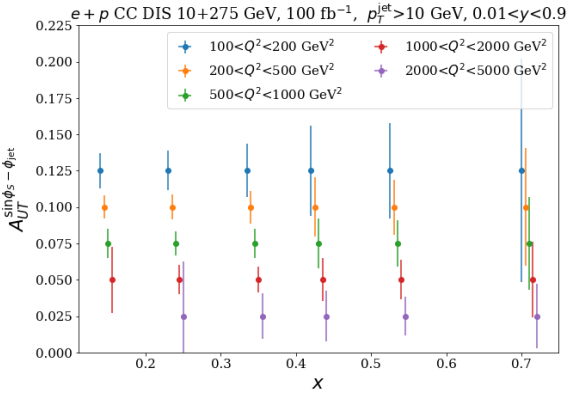
# Hadron-in-jet kinematics: pion $\eta$ vs $p$

- charged pions' momenta can be measured up to $\approx$ 40 GeV.
- not surprisingly, $z_h$ is correlated with hadron momentum.



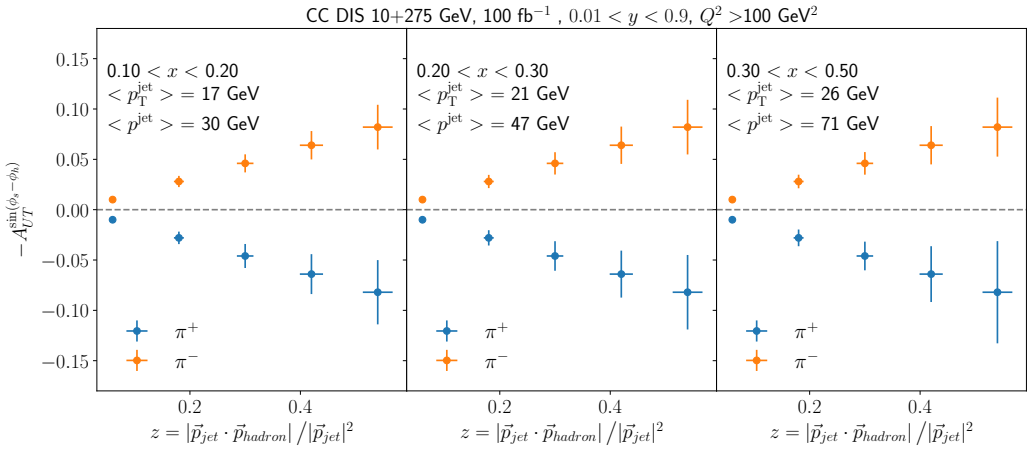
# Expected statistical precision: Transverse polarization asymmetry

- Stat. uncertainties were projected for azimuthal asymmetries between the transverse proton polarization and the jets and/or hadrons in jets.
- $A_{UT} \equiv \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$ is fit to $A_{UT}^{\sin\Delta\phi} \sin\Delta\phi$
- here, $\Delta\phi = \phi_S - \phi_{\rm jet}$




*Central values estimated on NC DIS Liu et al. [3]

# Expected statistical precision: Transverse polarization asymmetry (hadron in jets)




*Central values estimated on NC DIS: Liu et al. [3]

# Conclusions

- Jets are an essential tool to study charged-current DIS.
- Jets can be reconstructed with reasonable resolution and efficiency using the EIC baseline detector.
- Charged-current DIS allows flavor selection of the struck quark, unlike neutral-current DIS.
- Lepton kinematics can be reconstructed with sufficient resolution for binning
- Sufficient statistical precision can be obtained to measure electron-jet and transverse-polarization vs hadron-in-jet asymmmetries.

# BACKUP SLIDES

# References

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