Jets for 3D imaging

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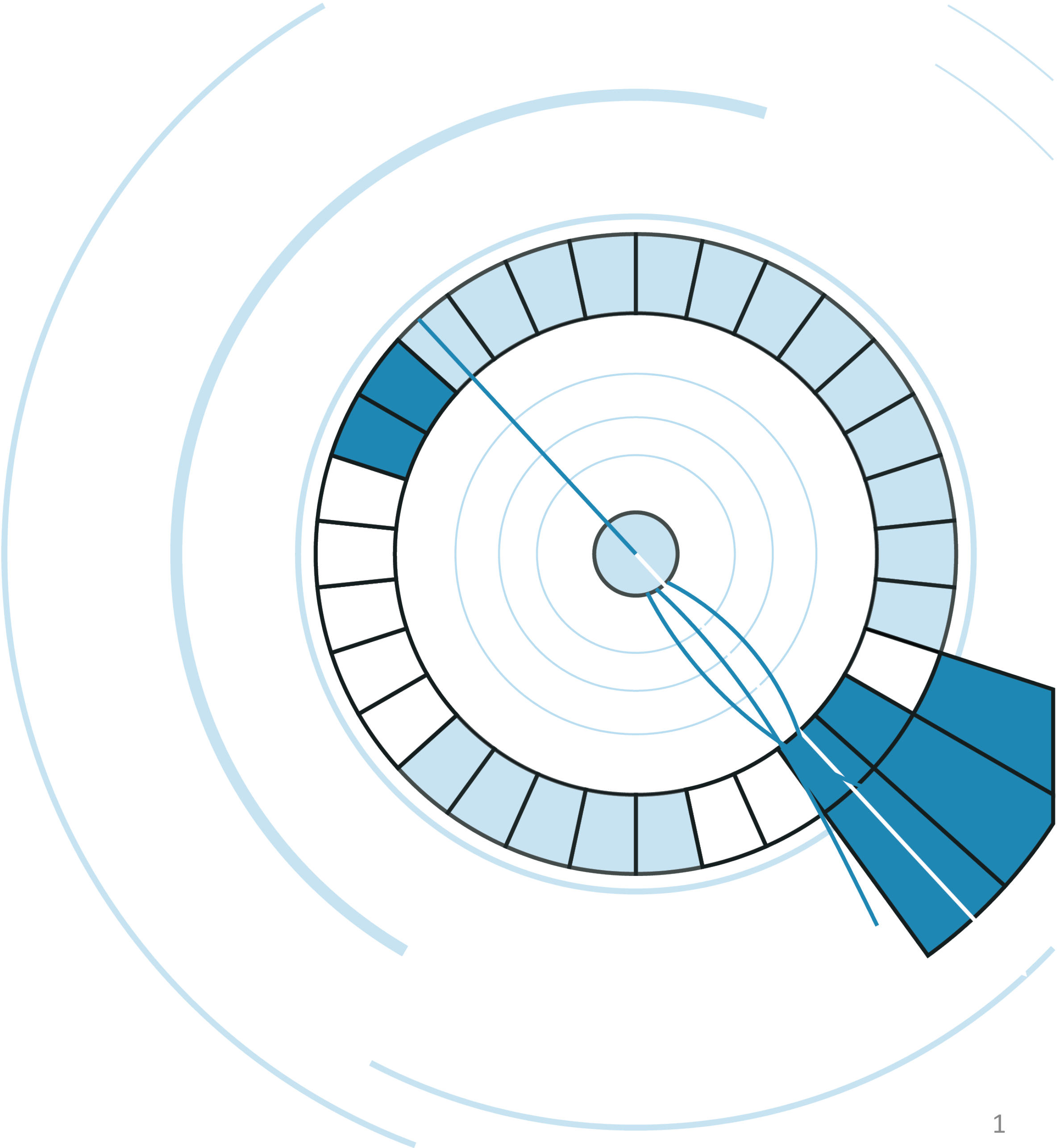
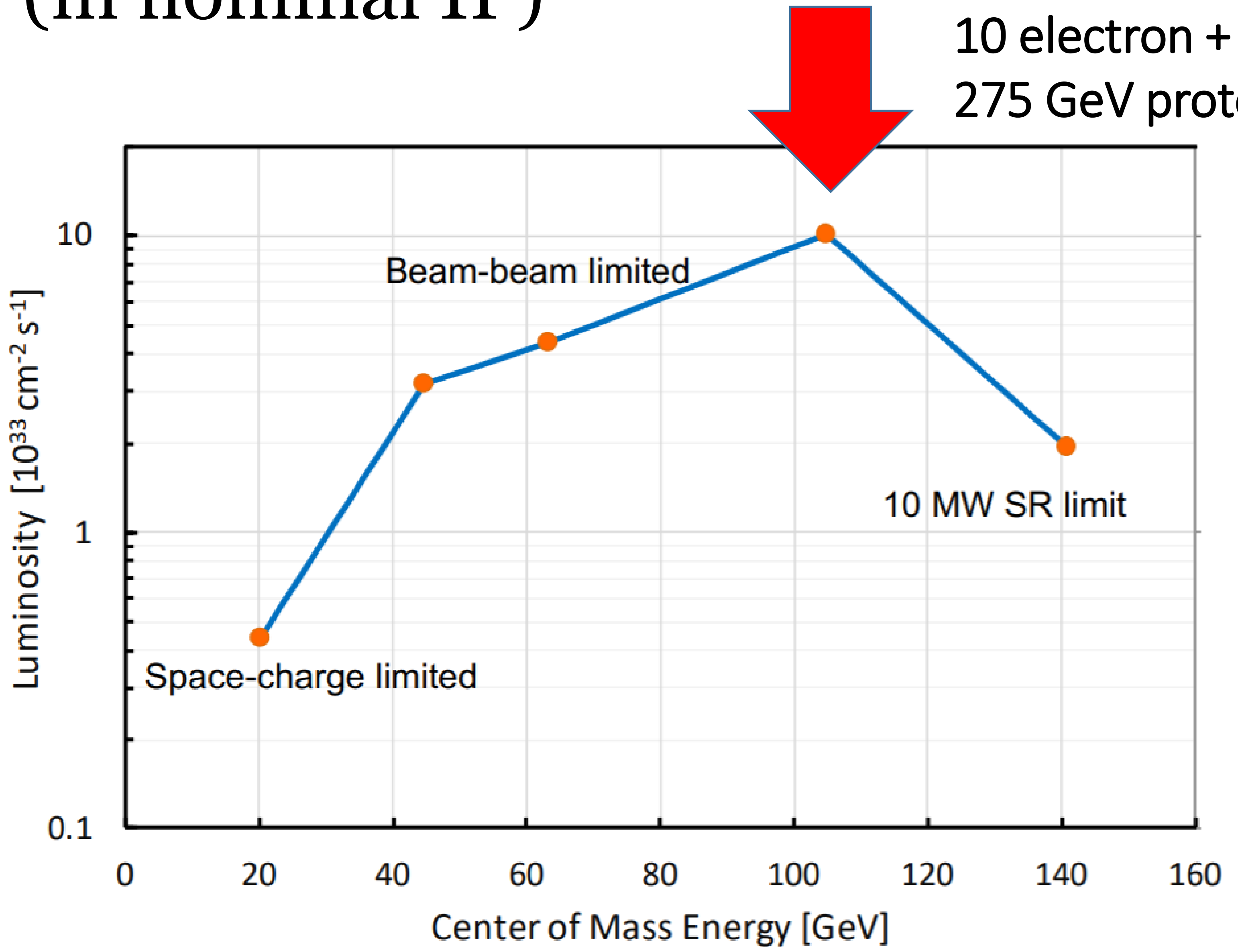


Optimal operating point for 3D-imaging (in nominal IP)

10 electron +
275 GeV proton



Source: eRHIC design study

Simulation parameters

- Pythia8 e-p DIS, DIRE parton shower (angular ordered)
- $E^{proton} = 275$ GeV, $E^{electron} = 10$ GeV
- Event cuts: $0.1 < y < 0.85$, $Q^2 > 25$ GeV^2
- Jets are reconstructed with the anti-k_T algorithm with $R = 1.0$ using FastJet
- Particle cuts: $|\eta^{part}| < 4.5$, $p_T^{part} > 0.25$ GeV
- No radiative corrections yet.
- No detector response yet.

We are using the lab frame, which is trivially related to the lepton-nucleon frame

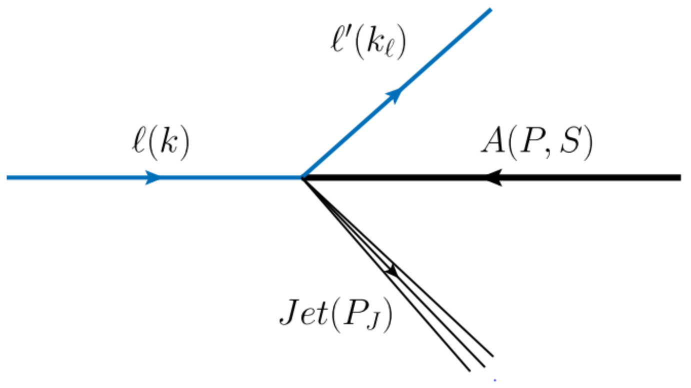
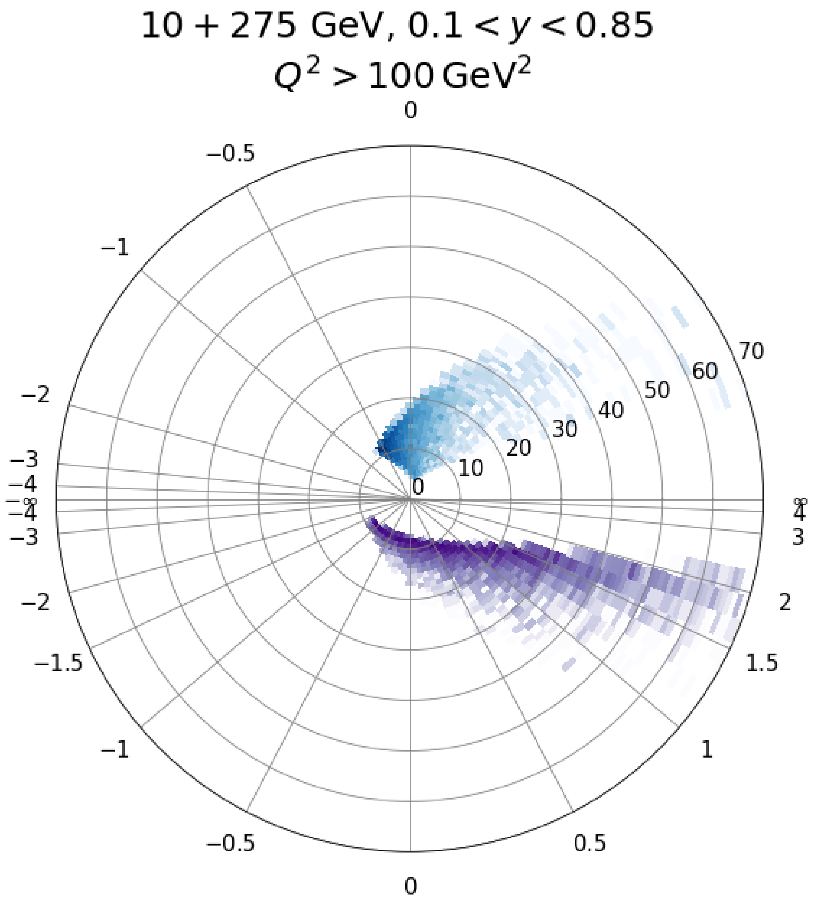


FIG. 1. Lepton-jet correlation for the tomography of the nucleon or nucleus at the EIC. *Liu et al. PRL 122 192003*

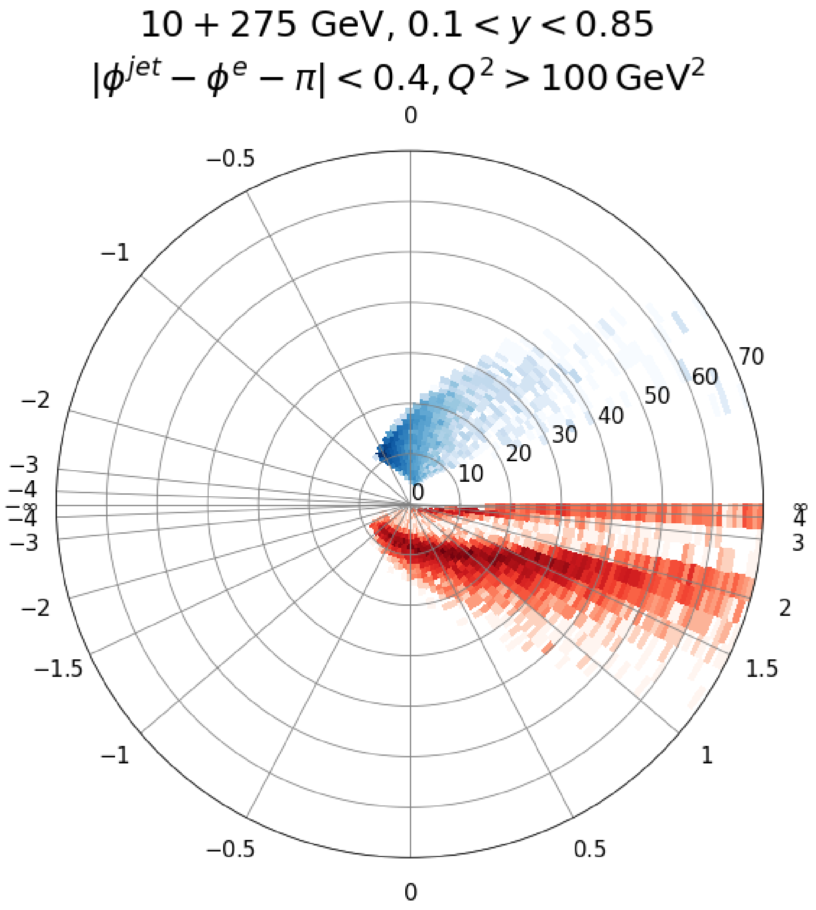
$$Q^2 = -\hat{t} = \sqrt{s}\, p_T^e\, e^{-y_e}$$

$$\hat{u} = \sqrt{s}\, x\, p_T^e\, e^{y_e}$$

Optimal configuration for luminosity (in nominal IP):

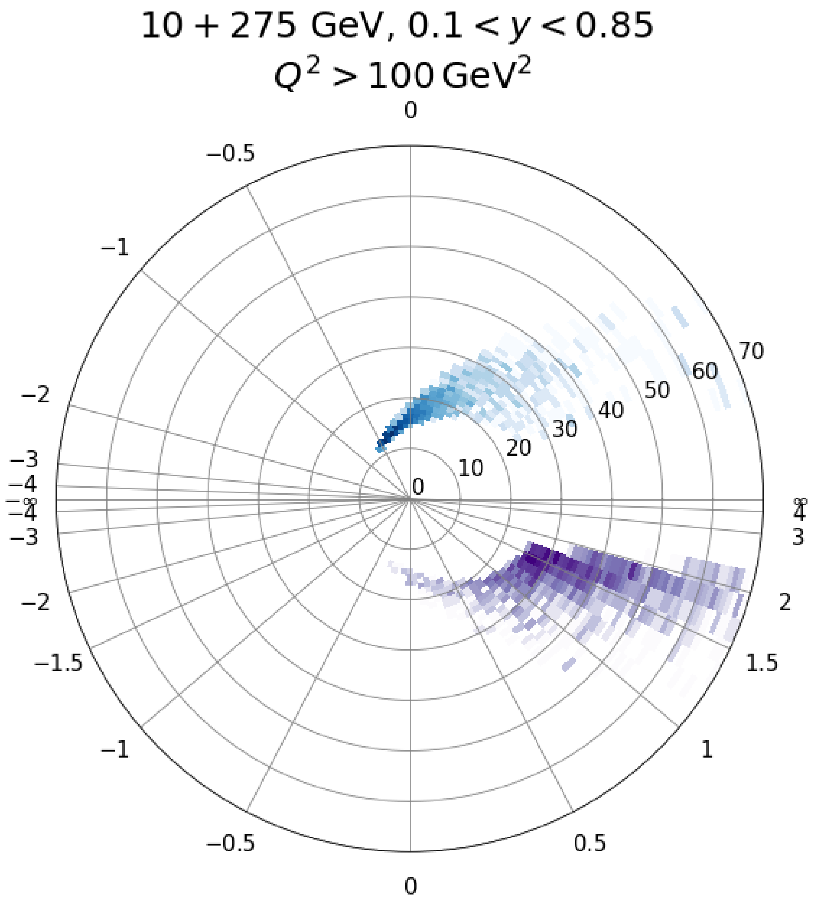


Struck quark

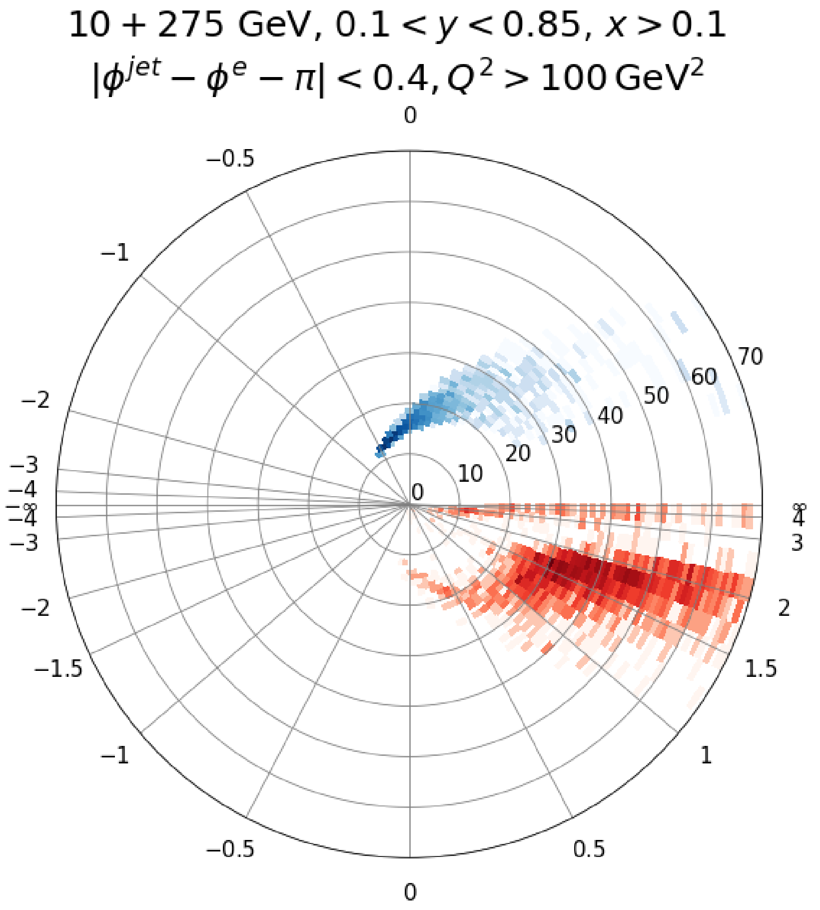


Jets, R=1.0

Focus on the large x

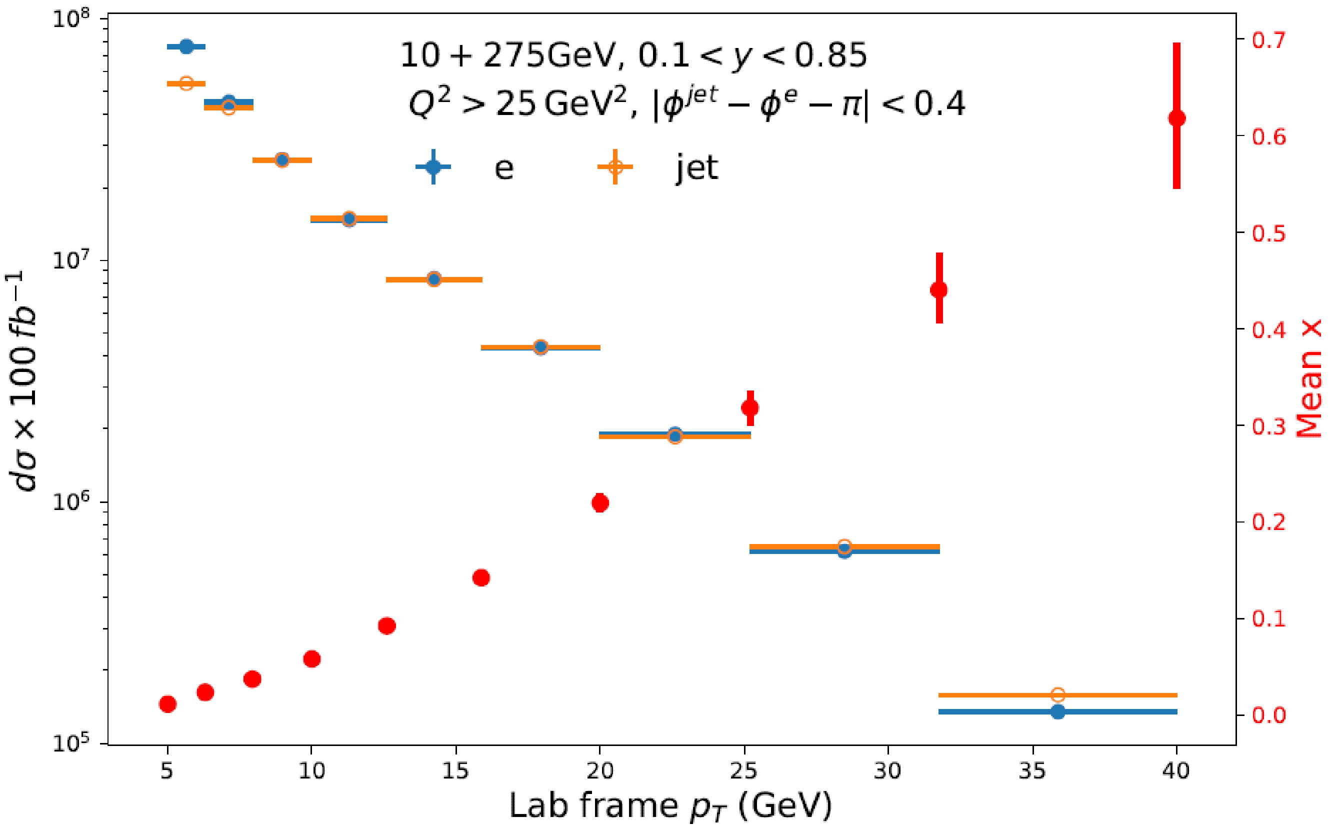


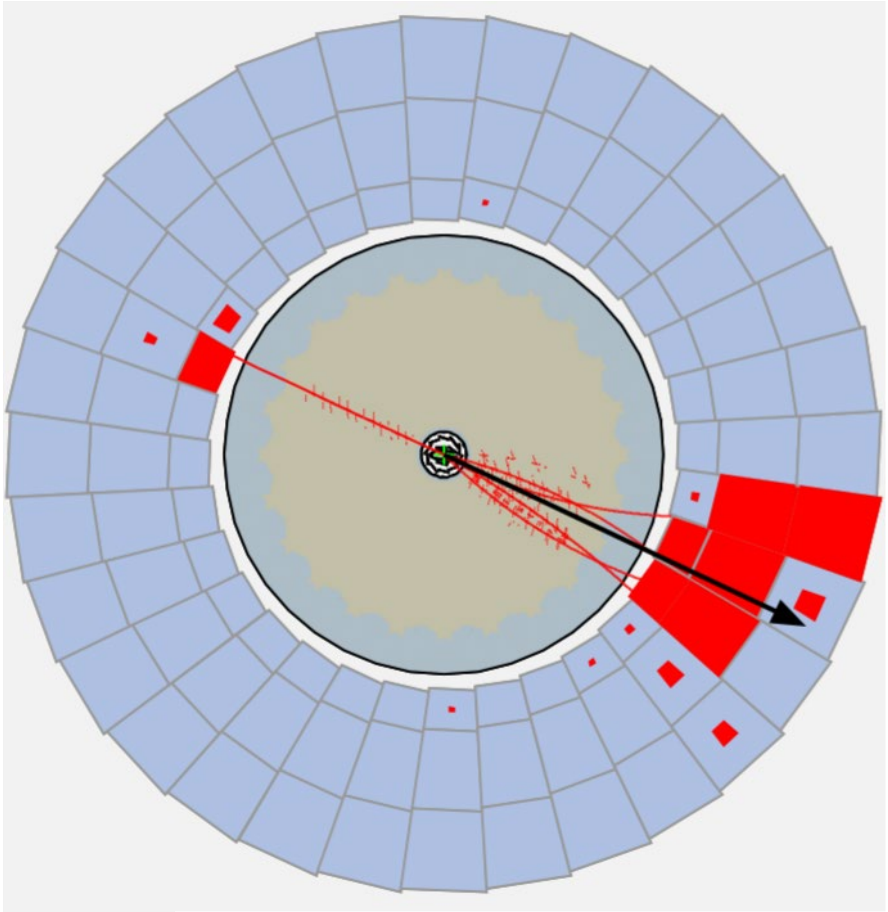
Struck quark



Jets, R=1.0

Kinematics

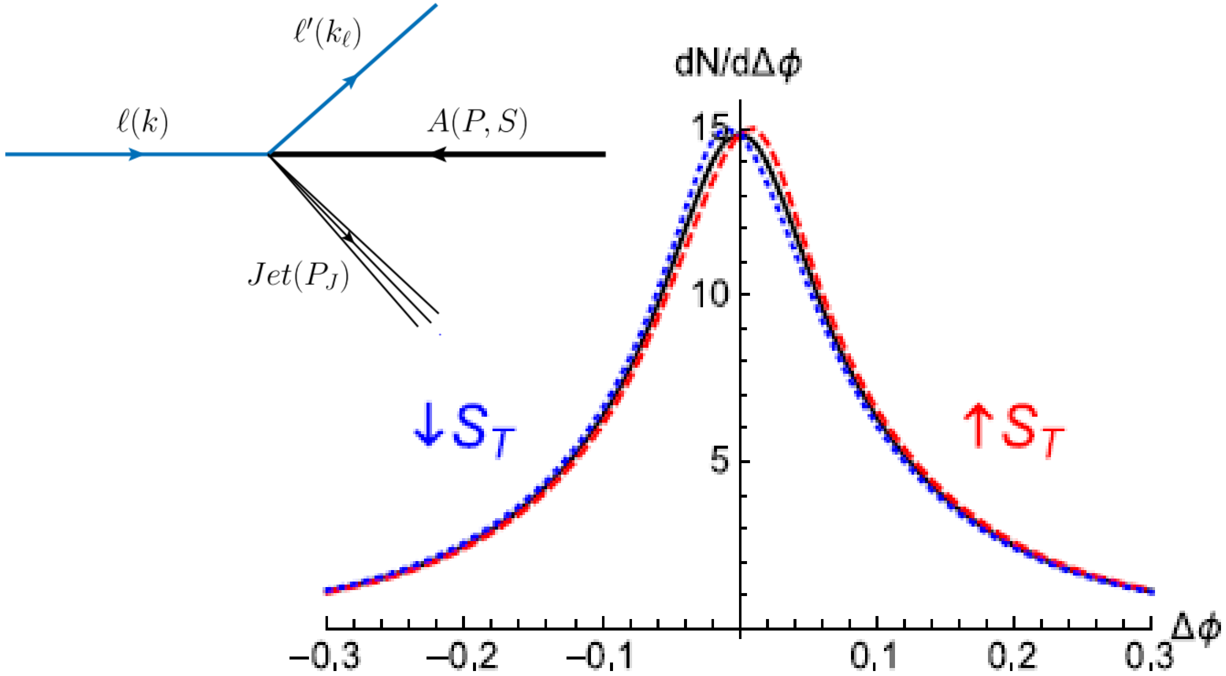




Rev. Mod. Phys. 86, 1037 (2014)

Direct measurement of quark Sivers effect with jets

Liu et al. PRL 122 192003 (2019)



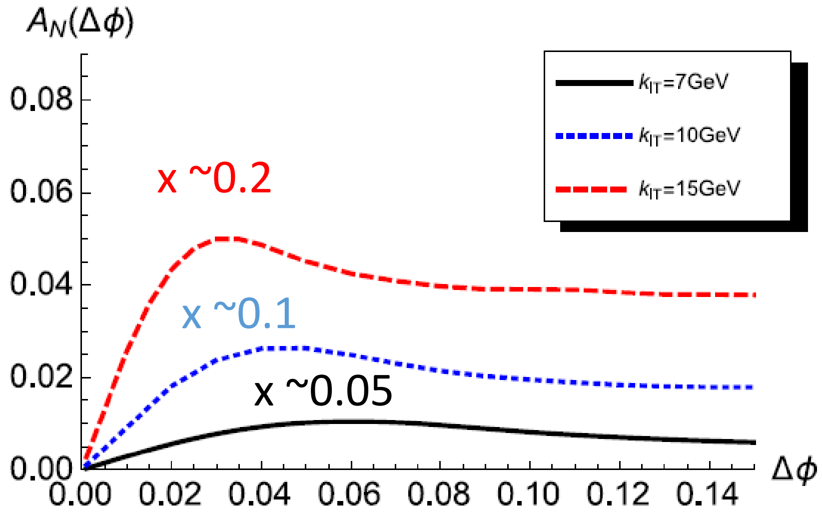
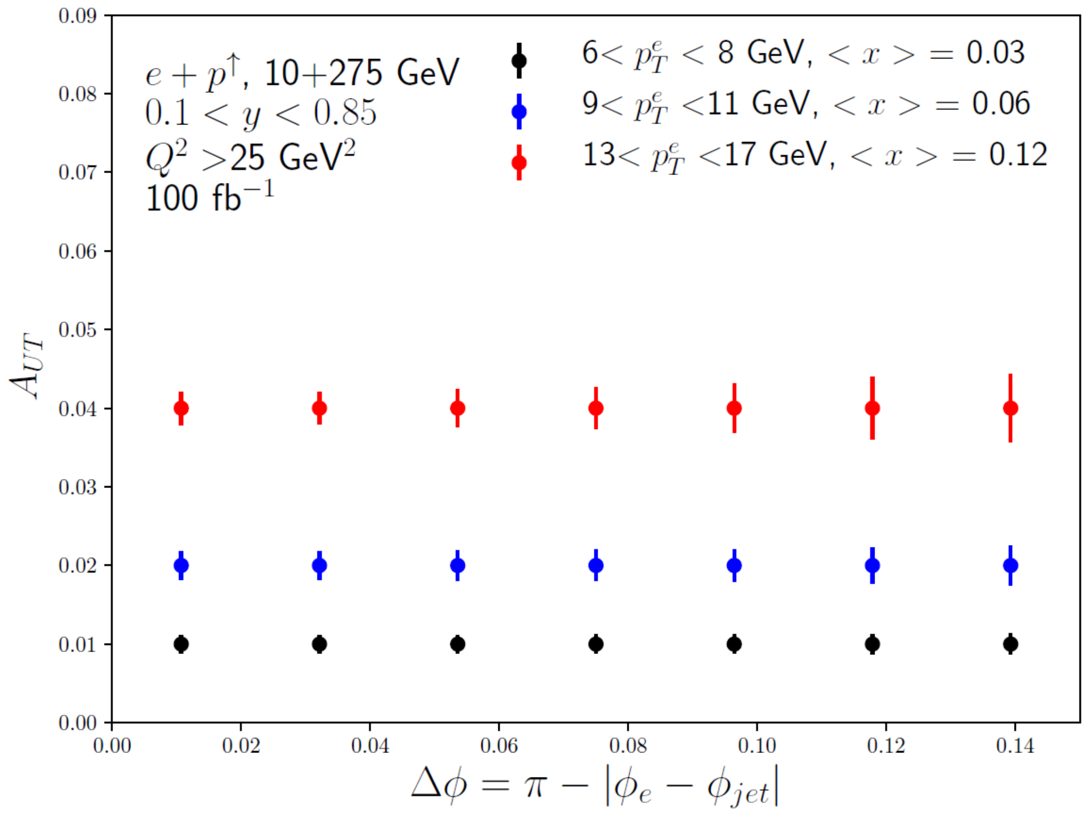
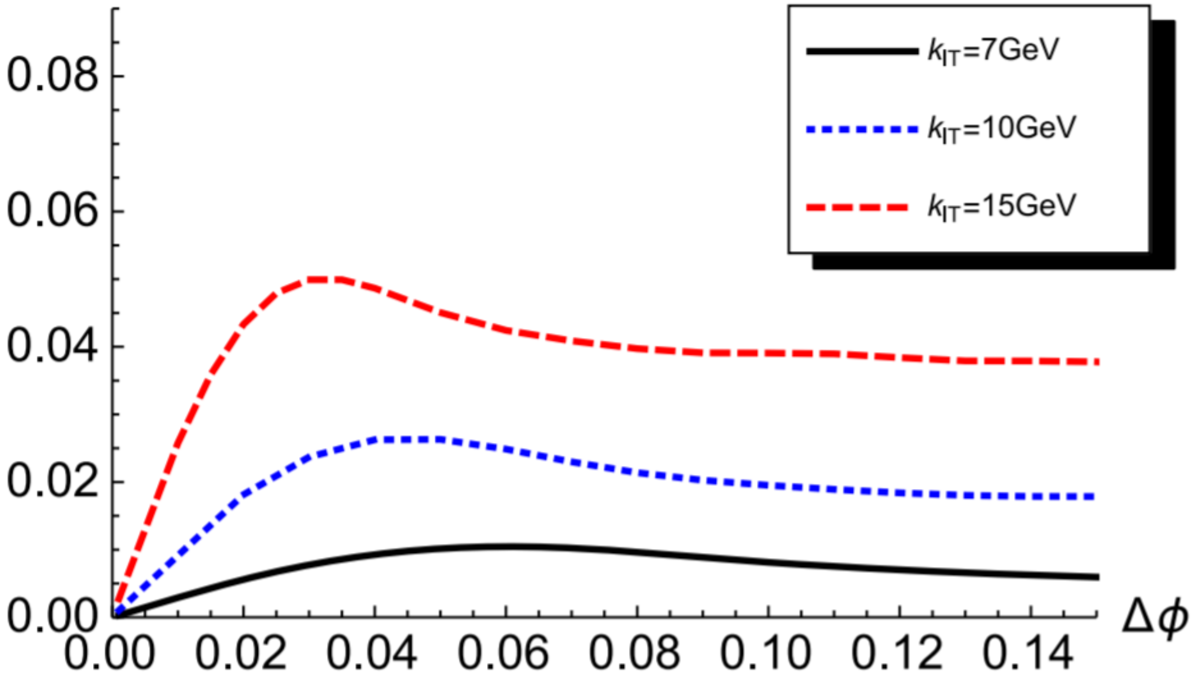


FIG. 3. The single transverse spin asymmetry as a function of $\Delta\phi = \phi_J - \phi_\ell - \pi$ for different lepton transverse momenta $k_{\ell\perp} = 7$, 10, and 15 GeV, respectively, which illustrates the transverse momentum dependence of the quark Sivers function.

"The advantage of the lepton-jet correlation as compared to the standard SIDIS processes is that it does not involve TMD fragmentation functions.".

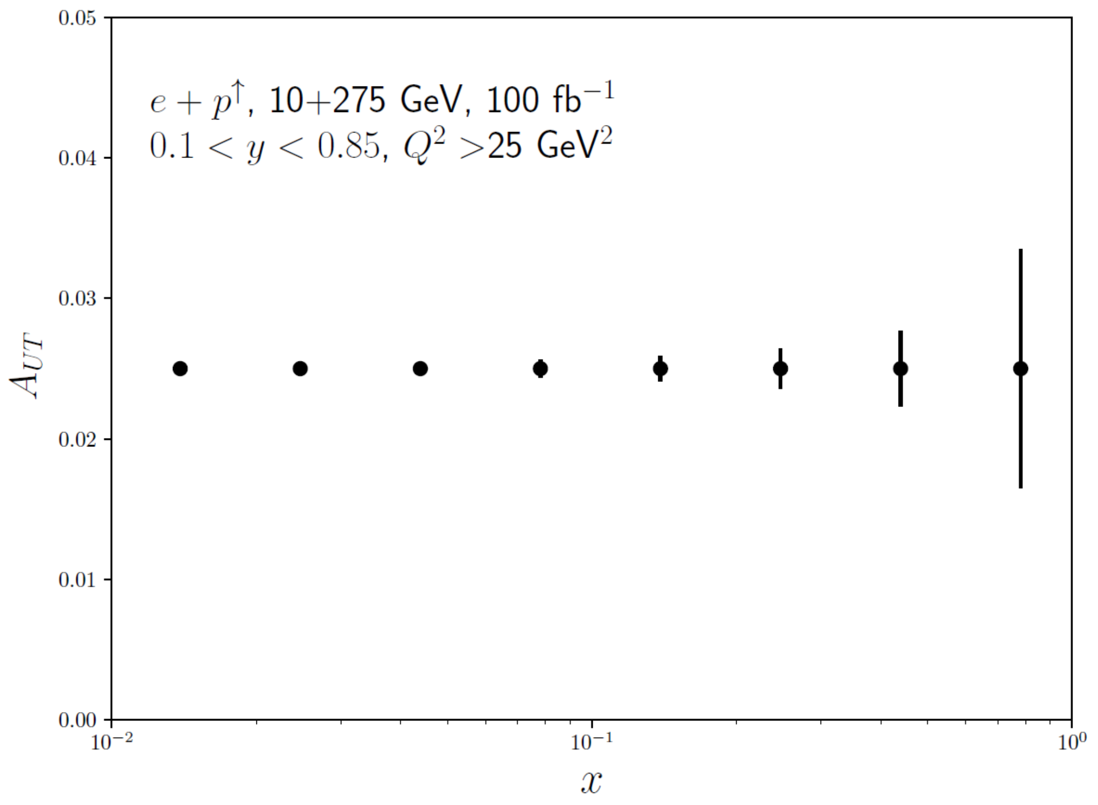
Statistical projection for Sivers effect with electron-jet correlations

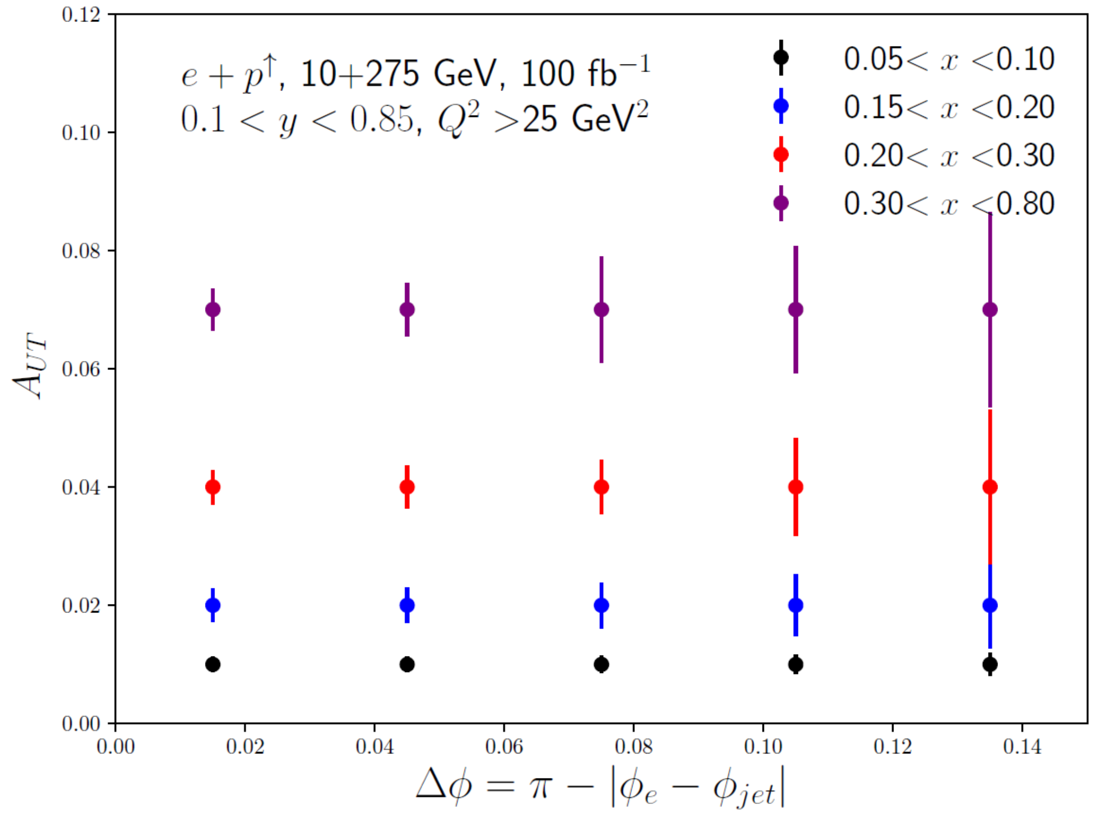




- Projections assume 100 fb-1, 70% polarization, 50% overall efficiency
- Excellent prospects for “direct” measurement of Sivers effect, most systematics cancel completely in the ratio

x-dependence of quark Sivers

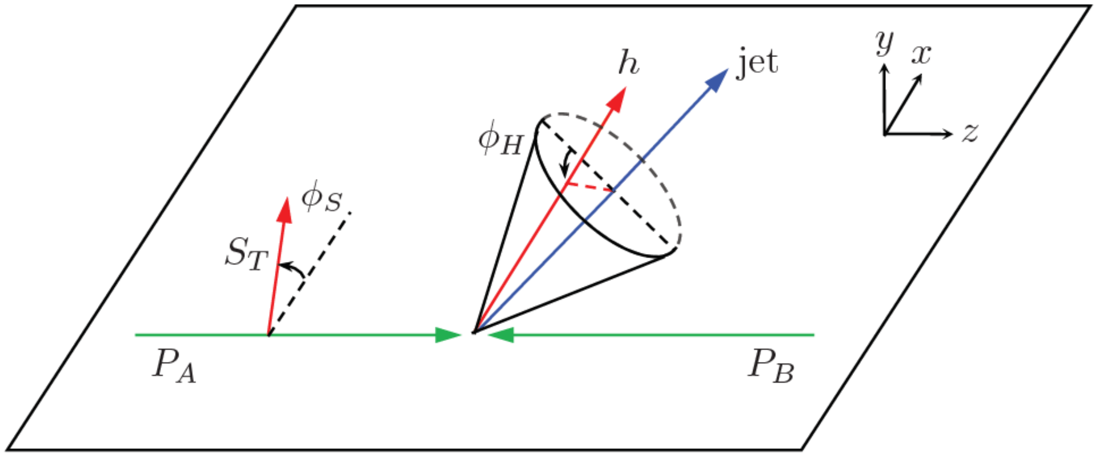




- Excellent kinematic coverage, precise data

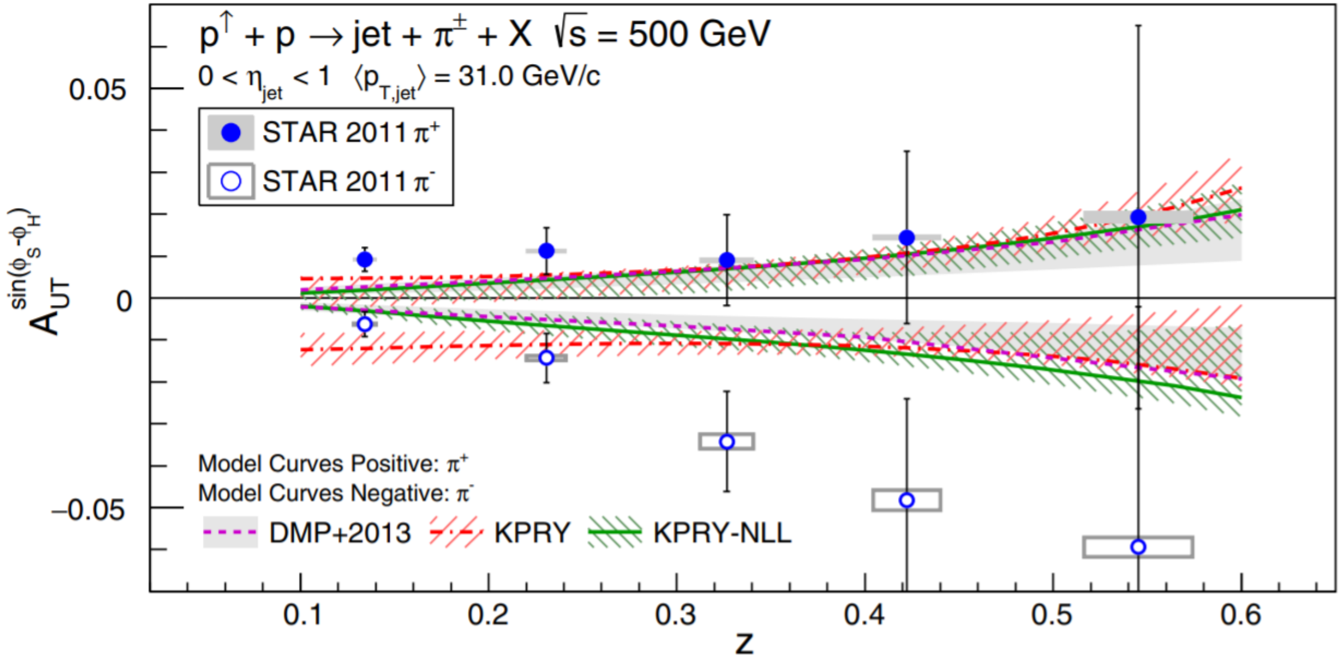
Transversity, h(x), with jets

distribution of transversely polarized quarks inside a transversely polarized nucleon



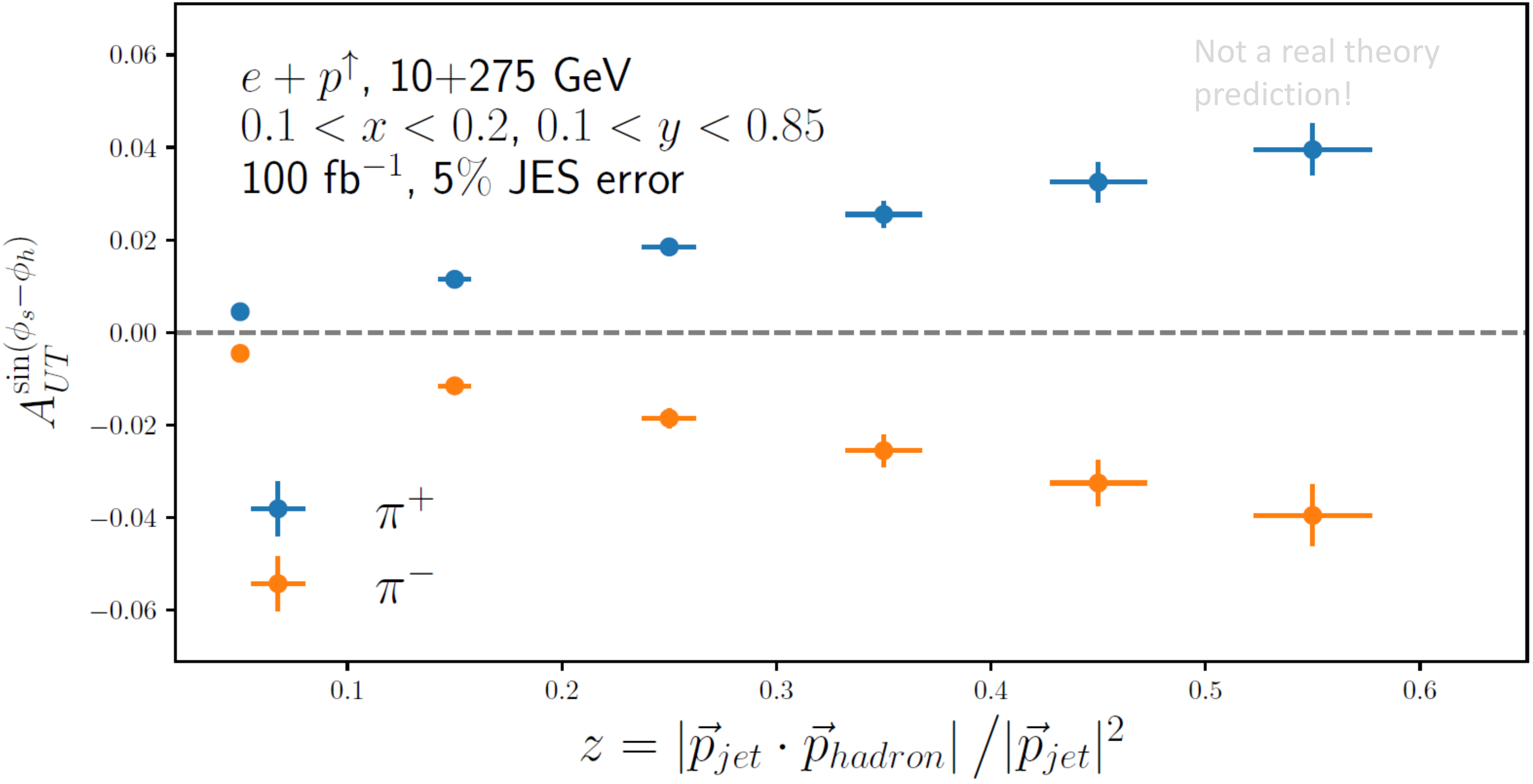
"Collins azimuthal asymmetries of hadron production inside jets
Phys. Lett. B 774, 635 (2017), Kang et al.
"The transverse momentum distribution of hadrons within jets"
JHEP 1711 (2017) 068, Kang et al.

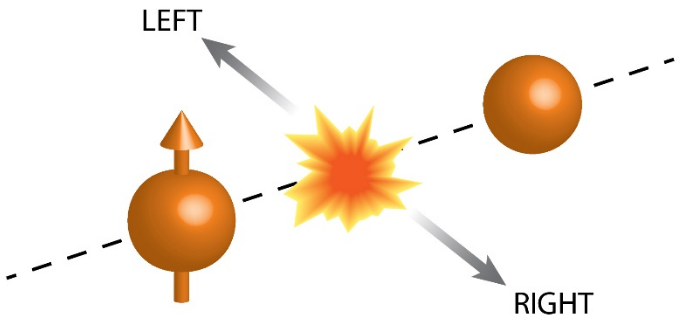
STAR Collaboration, Phys. Rev. D 97, 032004 (2018)



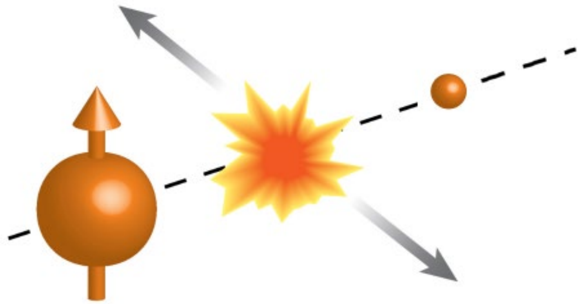
- Jet measurement crucial to factorize initial and final state TMD effects.
- At EIC, we could explore this observable with much higher precision, kinematic control. Tests of TMD evolution & universality; complements di-hadron measurements.

Hadron-in-jet statistical projection

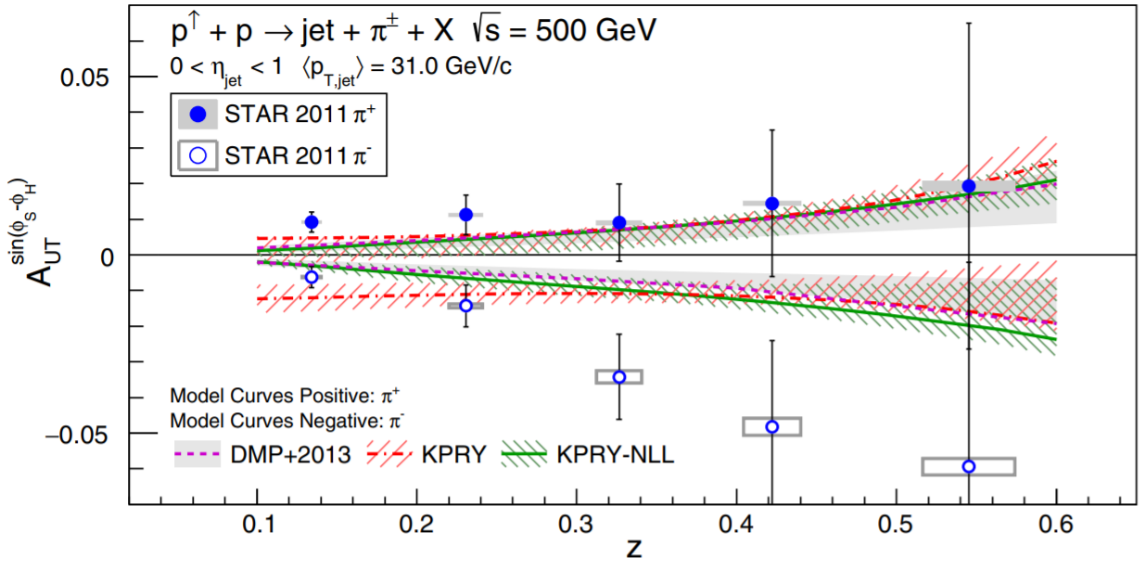




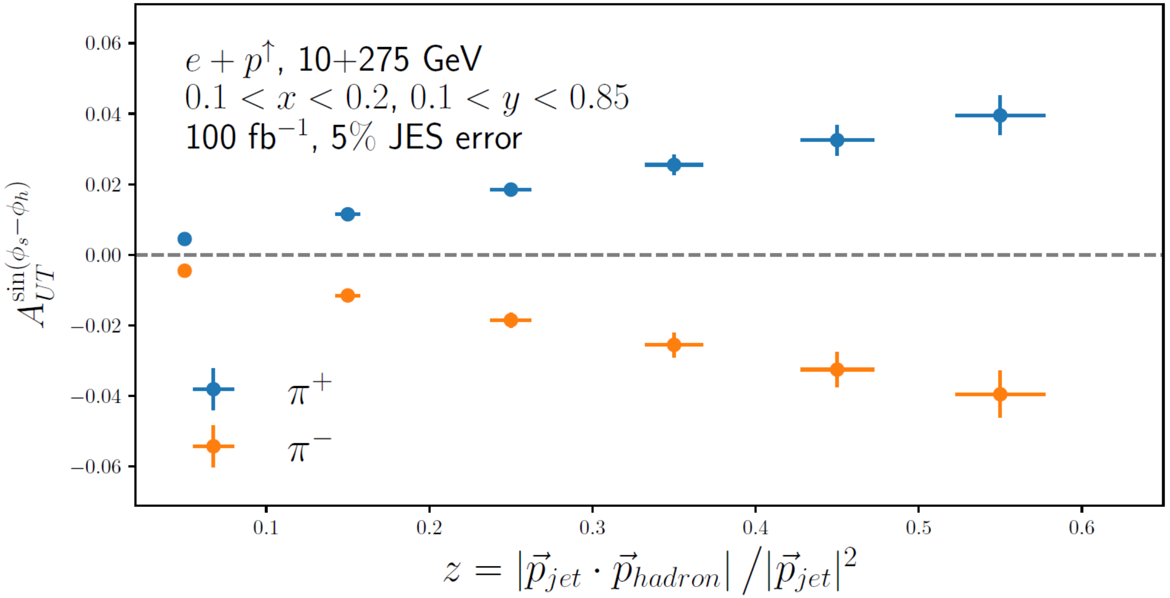
pp at RHIC



ep at EIC

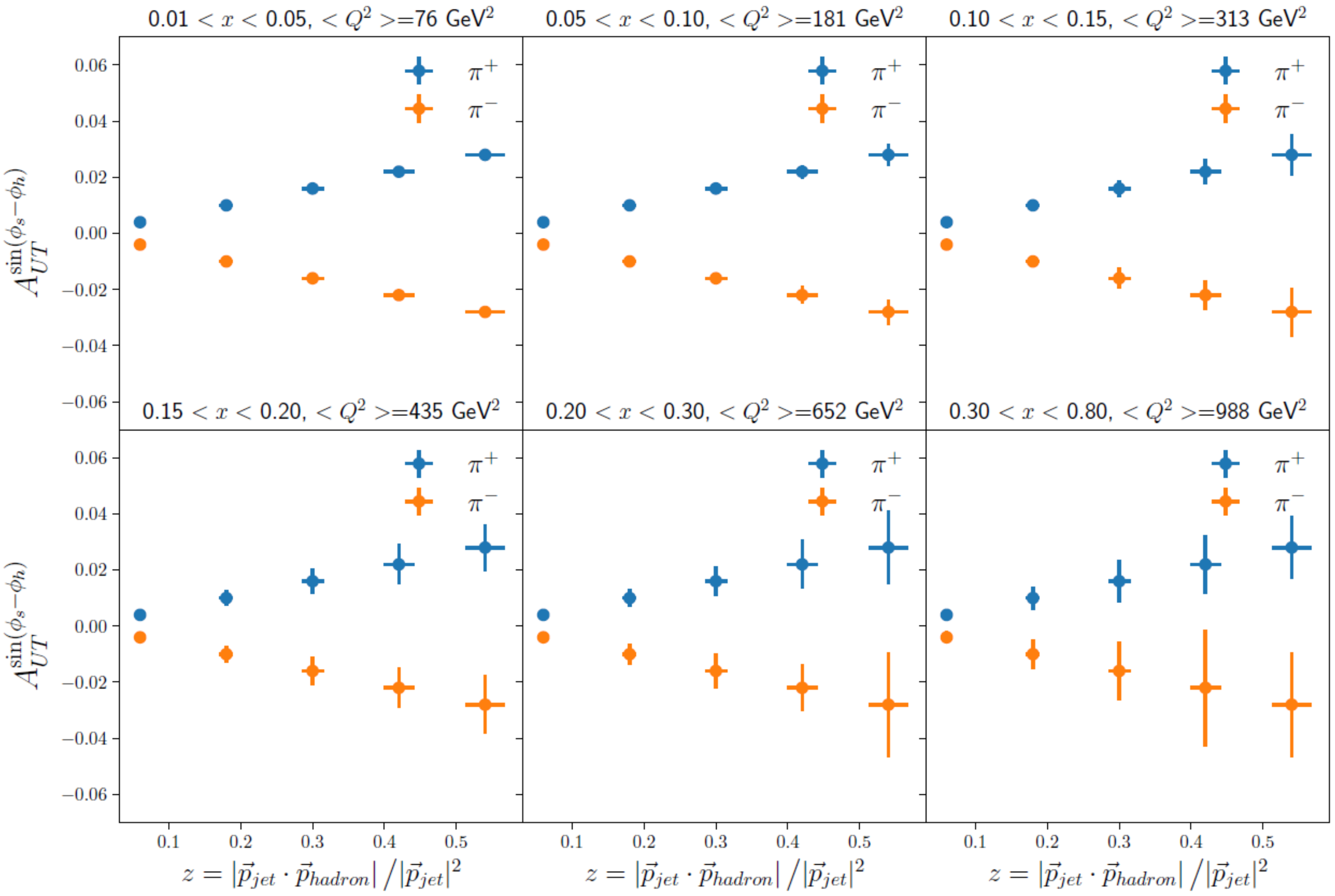


Phys. Lett. B 774, 635 (2017), Kang et al.

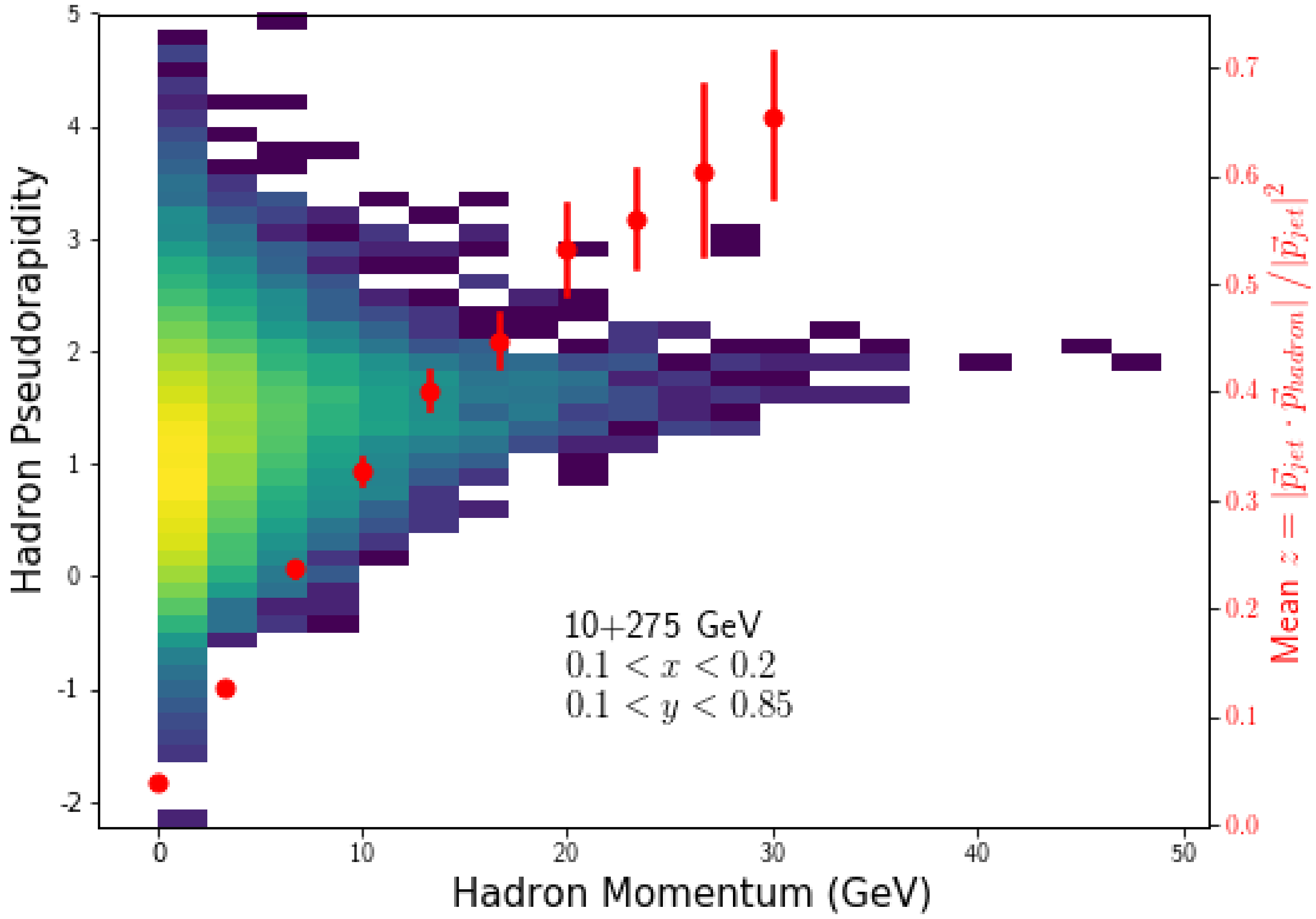


- **Most systematics cancel in the ratio….**
- **We will have sensitivity to TMD evolution effects.**

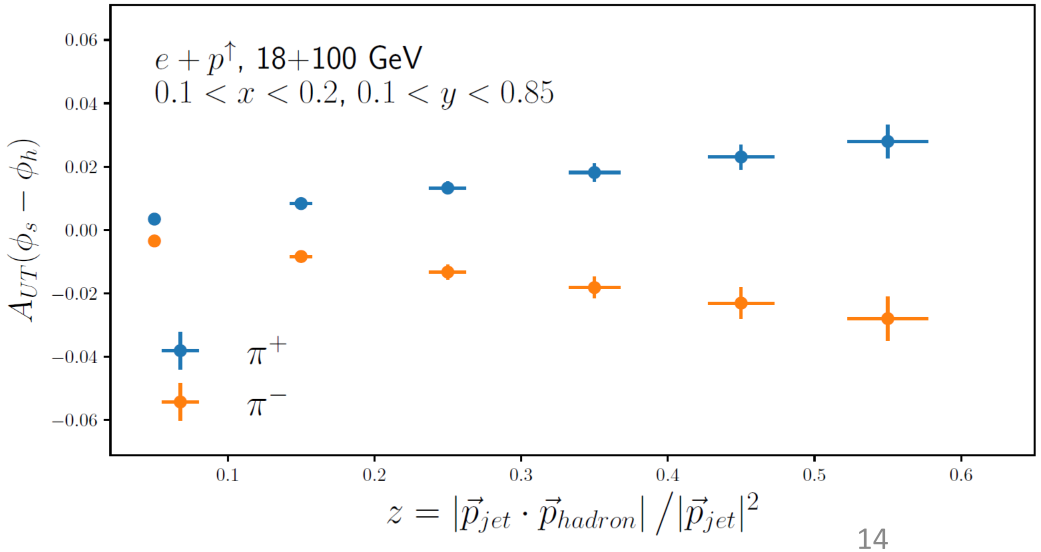
Covering the entire x-range relevant for transversity



PID requirements:

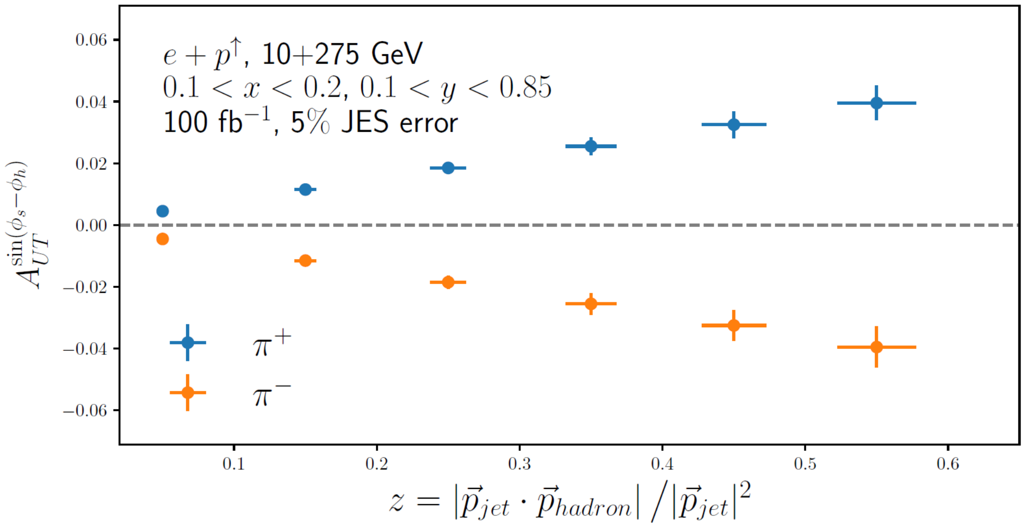


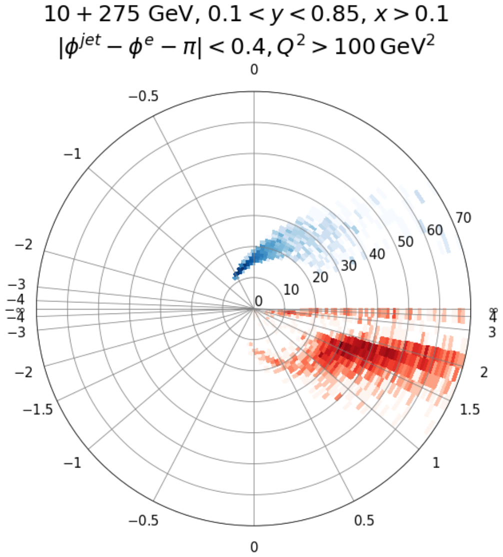
- **Mandatory** for this measurement. "Charged hadron" would not work.
- Charged pions separation from Kaons and protons up to ~30 GeV
- EMCAL granularity for pi0



Jet uncertainties

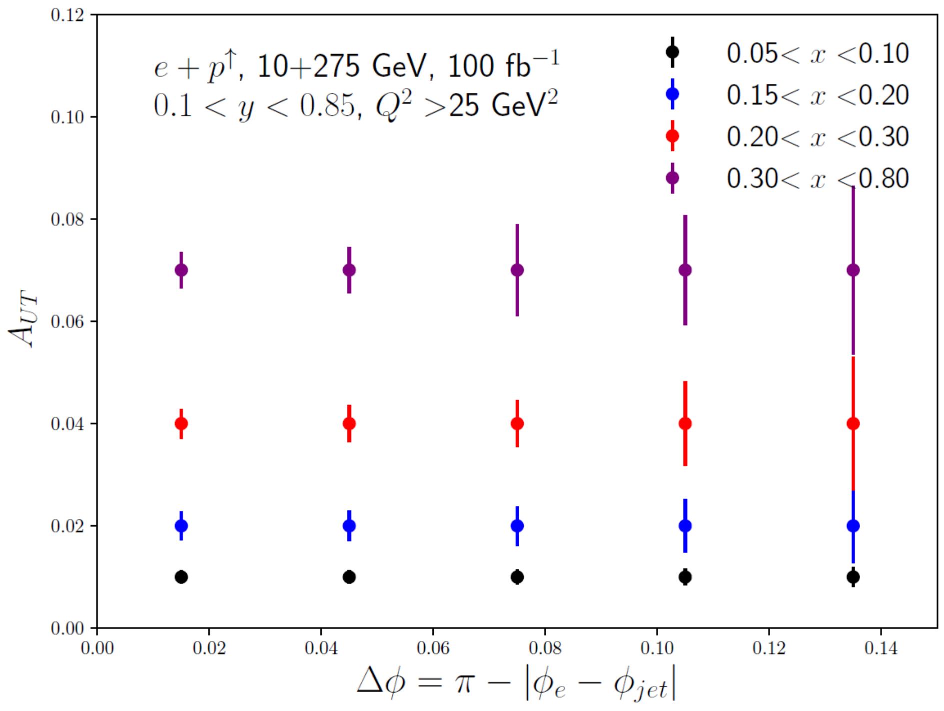
- JES uncertainty cancels completely in ratio, but appears in x-axis.
  JES uncertainty ~5-10% should be OK.
  (~1% was achieved at HERA).
- JER uncertainty cancels in the ratio.
  JER value likely dictated by tracking, which is needed for hadrons in range ~[-1.0, +3.5].
- Note that jet energy is at most ~60 GeV. Forward HCAL with 50%/sqrt(E) + 10% likely enough.
- Hermetic coverage might end up being more important to control systematics for asymmetry measurements.



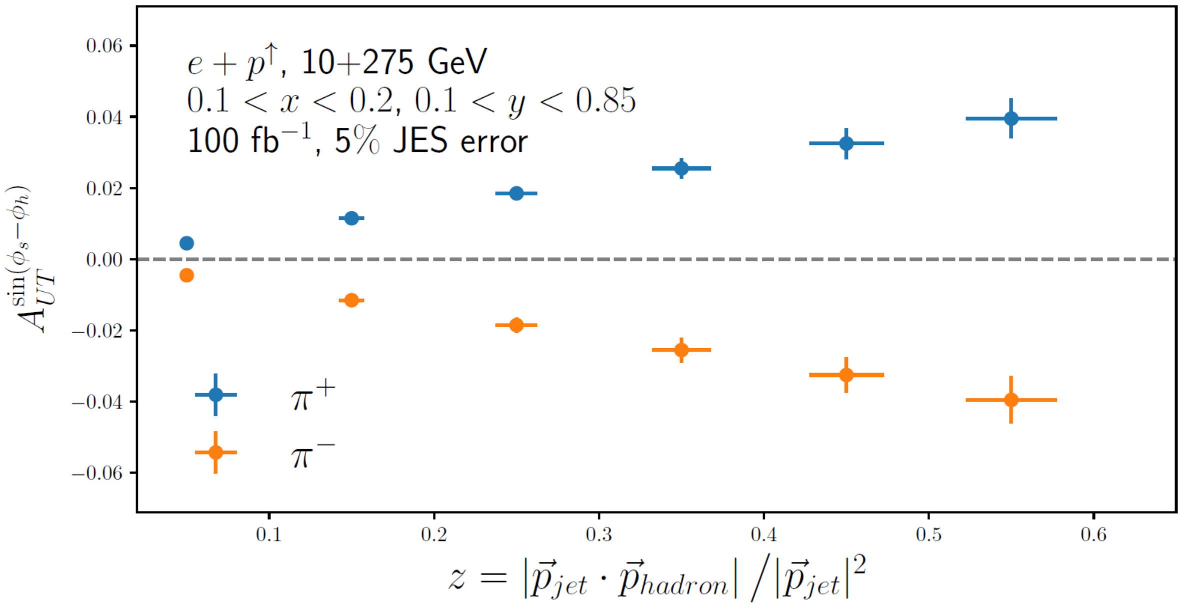


Proposed "money plots"

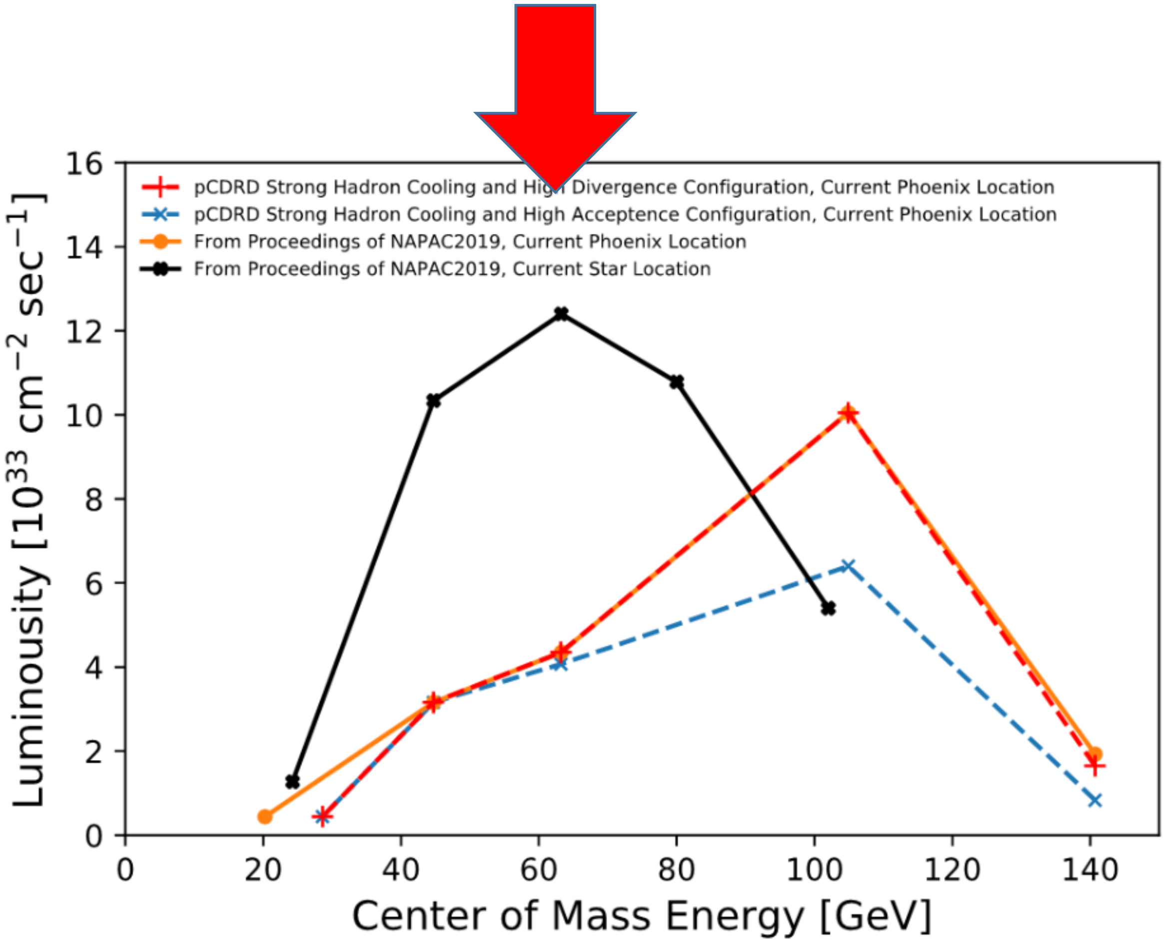
Quark Sivers

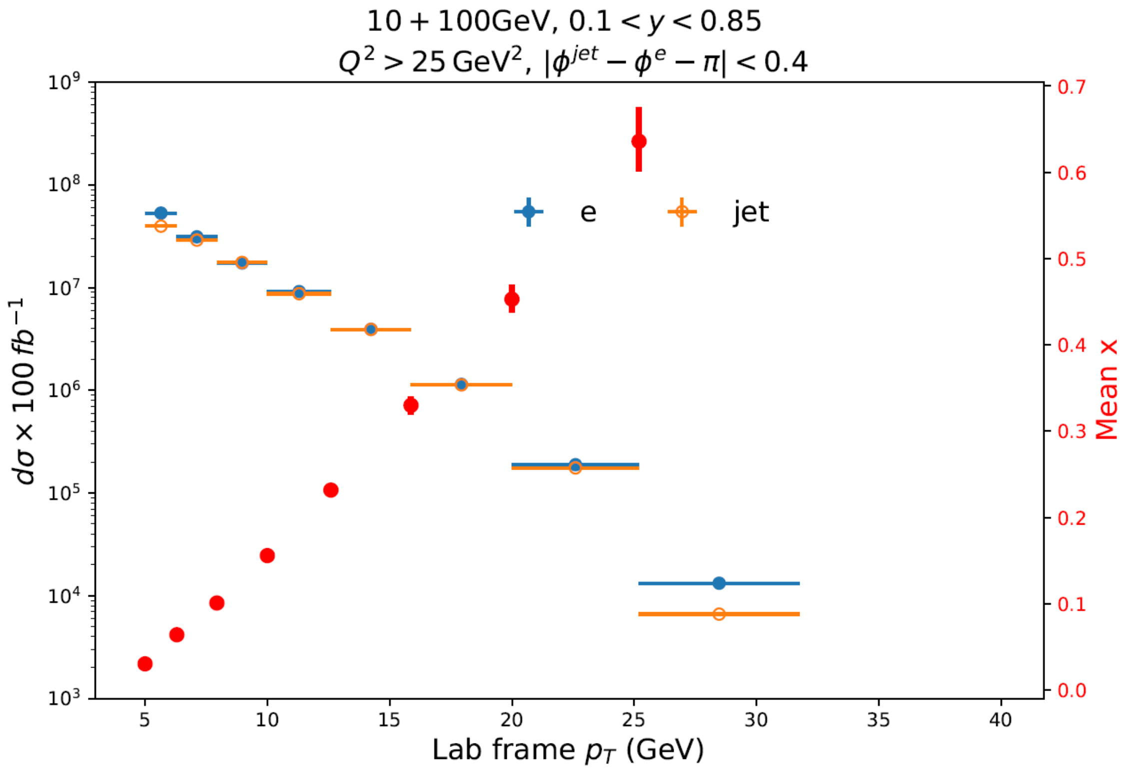


Quark Transversity



On the alternative IP: (more on this next mtg)





Just before the Berkeley YR meeting,

<u>Topics:</u>

- Jet observables, advantages, and opportunities for EIC
- Novel observables via jet substructure
- TMD and SCET formalism for jets and substructure.
- 3D and 5D imaging with exclusive jets (GPDs and Wigner functions)
- Connections to Lattice QCD
- Detector requirements for the EIC

Backup slides

HERA experiments did require high p_T in the Breit Frame We need an orthogonal approach at EIC

~ 0 p_T in Breit frame

Background

High p_T in Breit frame

Signal.

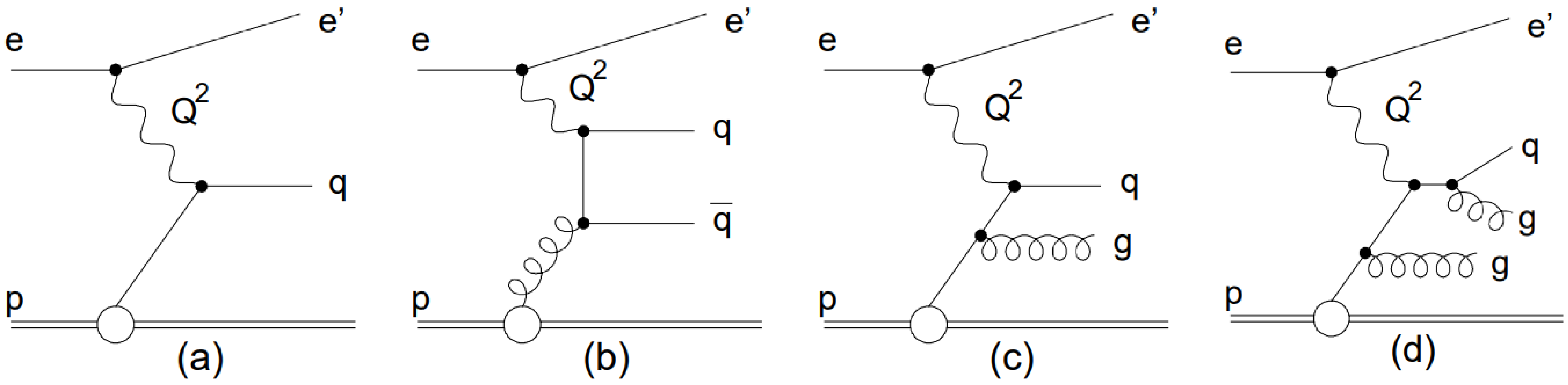


Figure 1: Deep-inelastic *ep* scattering at different orders in α_s: (a) Born contribution to inclusive NC DIS ($\mathcal{O}(\alpha_{\mathrm{em}}^2)$), (b) photon-gluon fusion ($\mathcal{O}(\alpha_{\mathrm{em}}^2\alpha_s)$), (c) QCD Compton scattering ($\mathcal{O}(\alpha_{\mathrm{em}}^2\alpha_s)$) and (d) a trijet process $\mathcal{O}(\alpha_{\mathrm{em}}^2\alpha_s^2)$.

Instead of Breit frame, we'll use lepton frame following:

Lepton-Jet Correlations in Deep Inelastic Scattering at the Electron-Ion Collider

Xiaohui Liu, Felix Ringer, Werner Vogelsang, and Feng Yuan

Phys. Rev. Lett. **122**, 192003 – Published 15 May 2019

We focus on large transverse momentum lepton-jet production in the center of mass (c.m.) frame of the incoming lepton and nucleon, see Fig. 1,

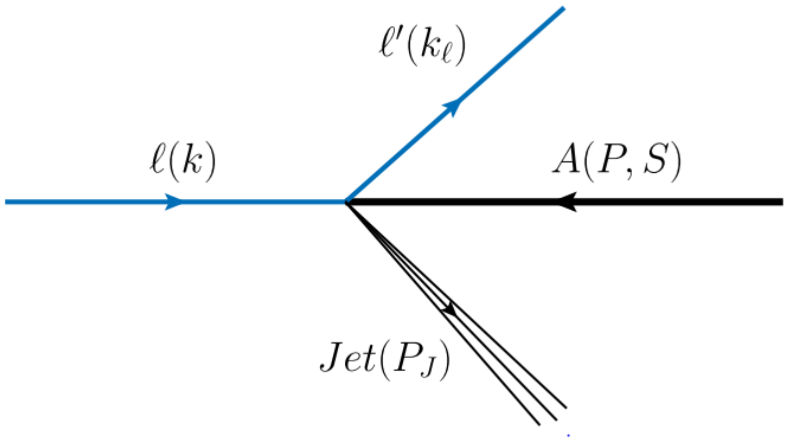


FIG. 1. Lepton-jet correlation for the tomography of the nucleon or nucleus at the EIC.

$$\frac{d^5\sigma(\ell p \to \ell' J)}{dy_\ell d^2k_{\ell\perp} d^2q_\perp} = \sigma_0 \int d^2k_\perp d^2\lambda_\perp x f_q(x, k_\perp, \zeta_c, \mu_F) \times H_{\rm TMD}(Q,\mu_F) S_J(\lambda_\perp, \mu_F)\, \delta^{(2)}(q_\perp - k_\perp - \lambda_\perp) \ .$$