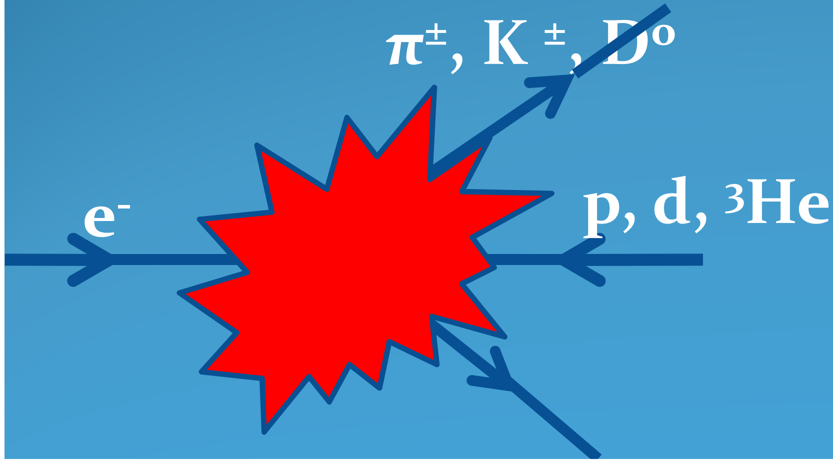
TSSA Measurements from SIDIS at EIC

M. Anselmino et al.
Eur. Phys. J., A47:35, 2011

Hadron 2012
KITPC, Beijing

Min Huang
Duke University



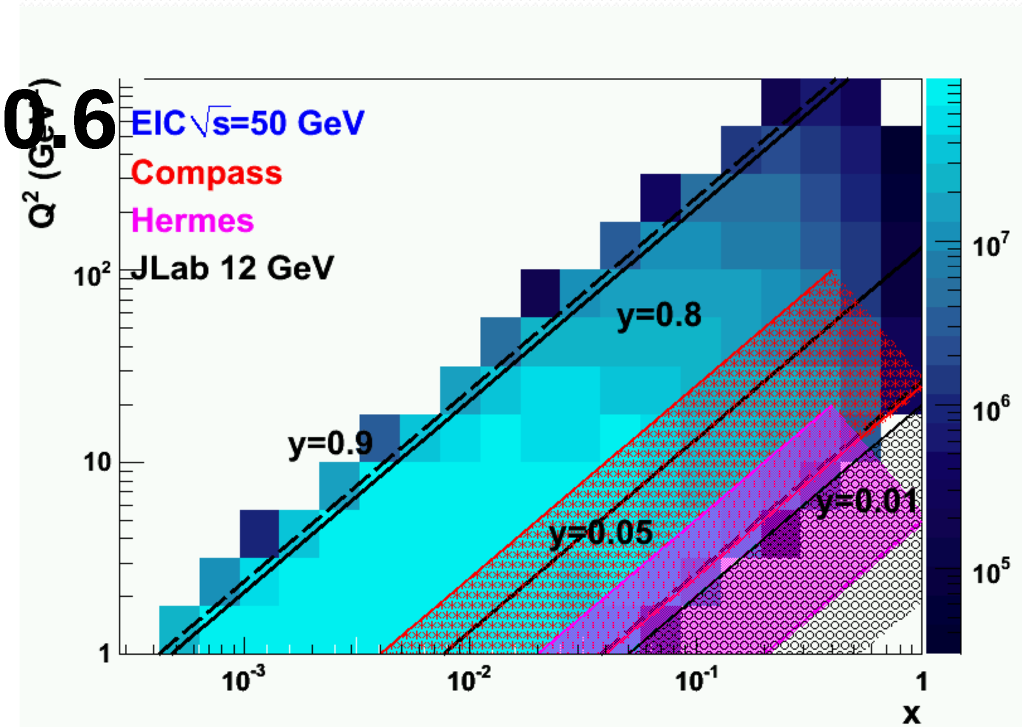
nT < 0.4

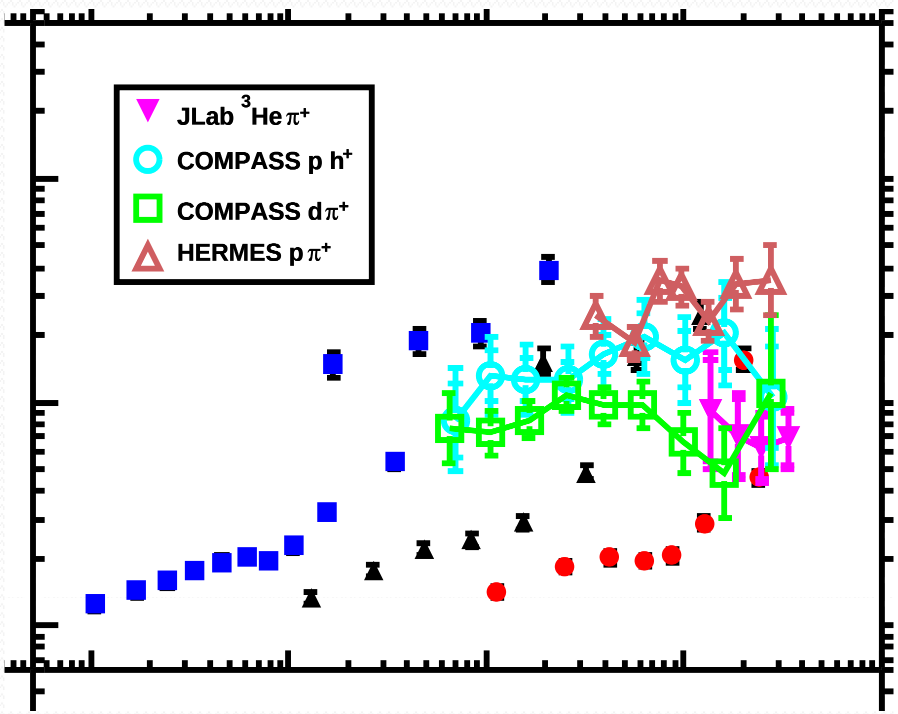
TSSA Measurements

- Pioneer: HERMES (p), COMPASS (p,d), Hall A (n)
- By the time of EIC running, what will we learn in addition?
  - JLab 12 GeV , Compass-II

Talks by R. McKeown, H. Gao, J.-P. Chen

nT < 0.6





nT < 0.8

TSSA Measurements

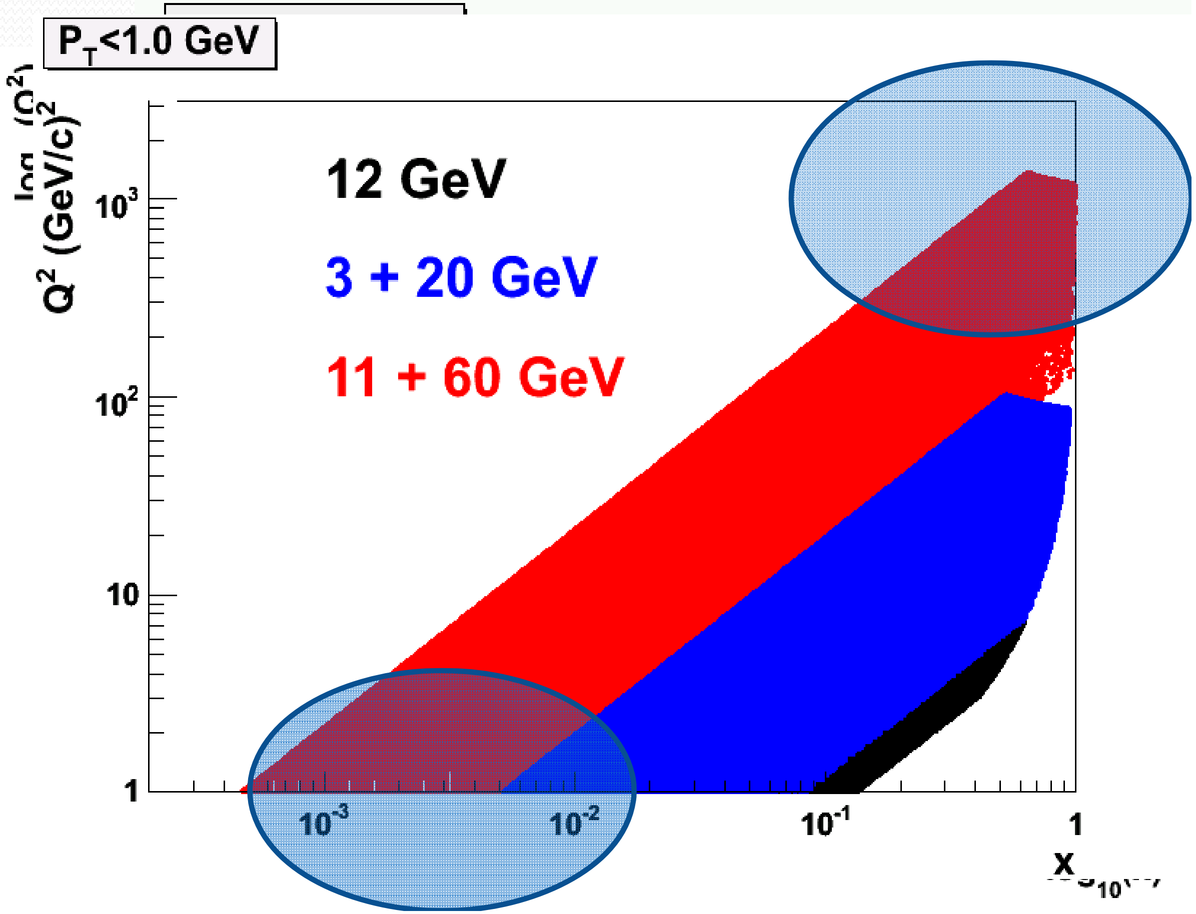
- Pioneer: HERMES (p), COMPASS (p,d), Hall A (n)
- By the time of EIC running, what will we learn in addition?
  - Potential of JLab 12 GeV, Compass-II

Talks by R. McKeown, H. Gao, J.-P. Chen

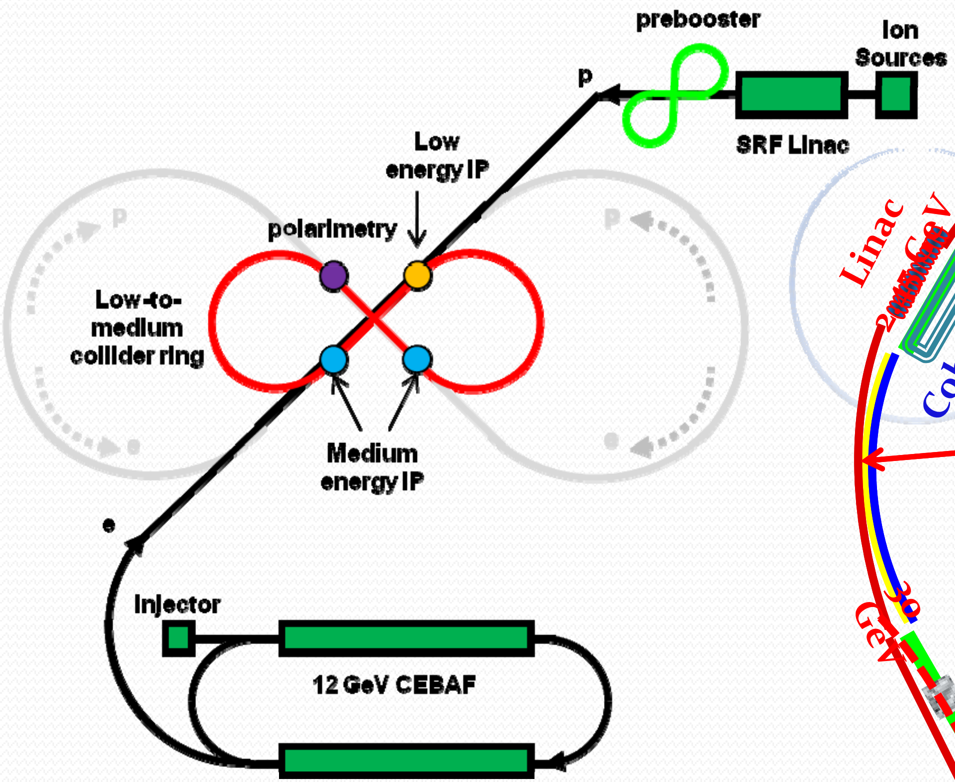
SoLID projection in R. McKeown's talk

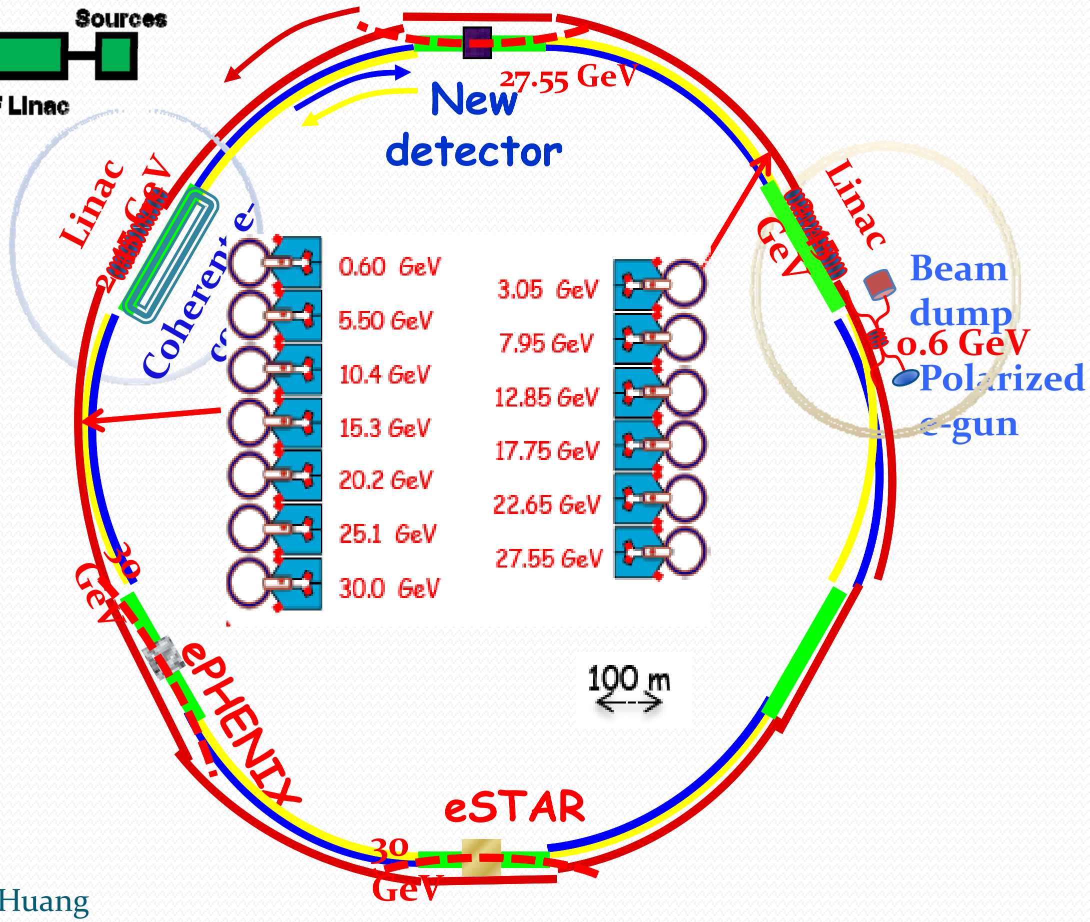
- low x → Study sea & gluon
- High Q^2 + High Luminosity -> Study Evolution & clean measurements of valence region

Electron-Ion Collider!



EIC: The Next-Generation QCD Machine

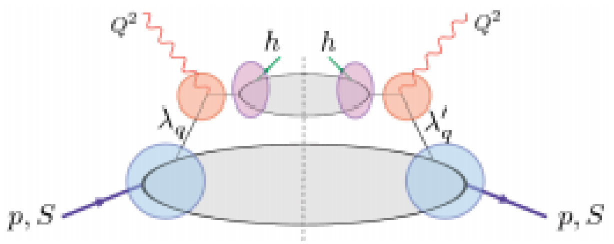




J. Qiu's talk

EIC is ideal for probing TMDs

❑ Two scales – SIDIS has the natural kinematics:

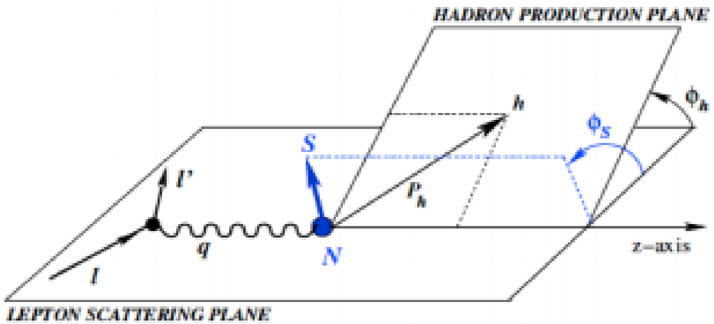


$$\ell(s_e) + p(s_p) \to \ell + h(s_h) + X$$

Natural event structure:

- high Q - localized probe
- Low p_T - sensitive to confining scale

❑ Two scattering plans – Separation of various TMDs:



Two scattering plans:

leptonic, and hadronic

Angular modulation to separate Collins effect from Sivers effect

$$A_{UT}(\varphi_h^l, \varphi_S^l) = \frac{1}{P} \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

$$= A_{UT}^{Collins} \sin(\phi_h + \phi_S) + A_{UT}^{Sivers} \sin(\phi_h - \phi_S)$$

$$+ A_{UT}^{Pretzelosity} \sin(3\phi_h - \phi_S)$$

$$A_{UT}^{Collins} \propto \langle \sin(\phi_h + \phi_S) \rangle_{UT} \propto h_1 \otimes H_1^{\perp}$$

$$A_{UT}^{Sivers} \propto \langle \sin(\phi_h - \phi_S) \rangle_{UT} \propto f_{1T}^{\perp} \otimes D_1$$

$$A_{UT}^{Pretzelosity} \propto \langle \sin(3\phi_h - \phi_S) \rangle_{UT} \propto h_{1T}^{\perp} \otimes H_1^{\perp}$$

J. Qiu's talk

SIDIS Events Distributions

-- in Current Fragmentation Region

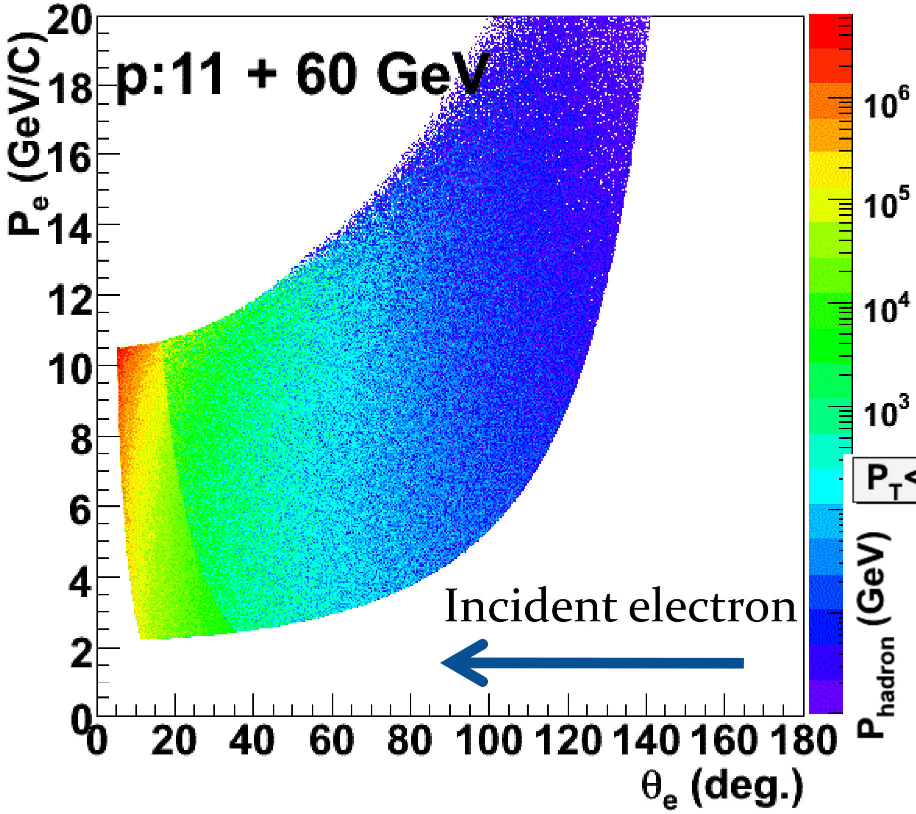
DIS cut: $Q^2 > 1$ GeV^2

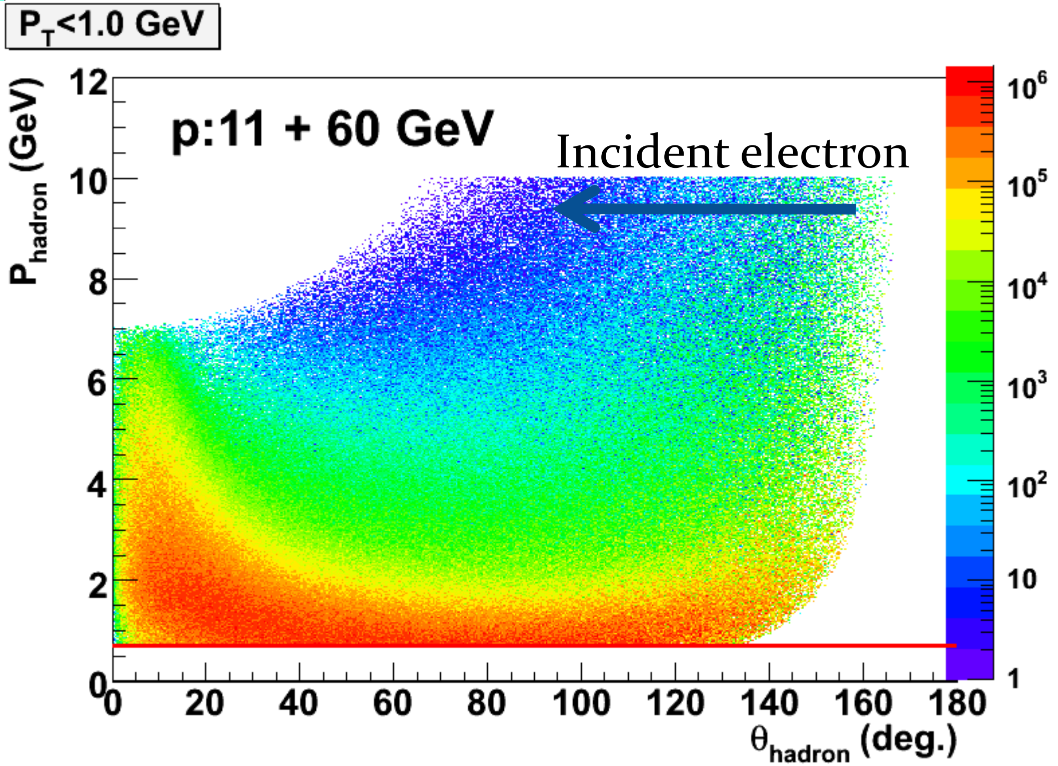
$W > 2.3$ GeV

$0.9 > y > 0.05$

SIDIS cut: $W' > 1.6$ GeV

$0.8 > z > 0.2$





$Q^2 > 1$ GeV^2 ➡ $\theta_e > 5^\circ$

No need to cover extreme forward angle for electron and extreme backward angle for hadrons

Projections with Proton on π^+

$\sqrt{s}$ 140 GeV (20x250)
50 GeV (11x60)
15 GeV (3x20)

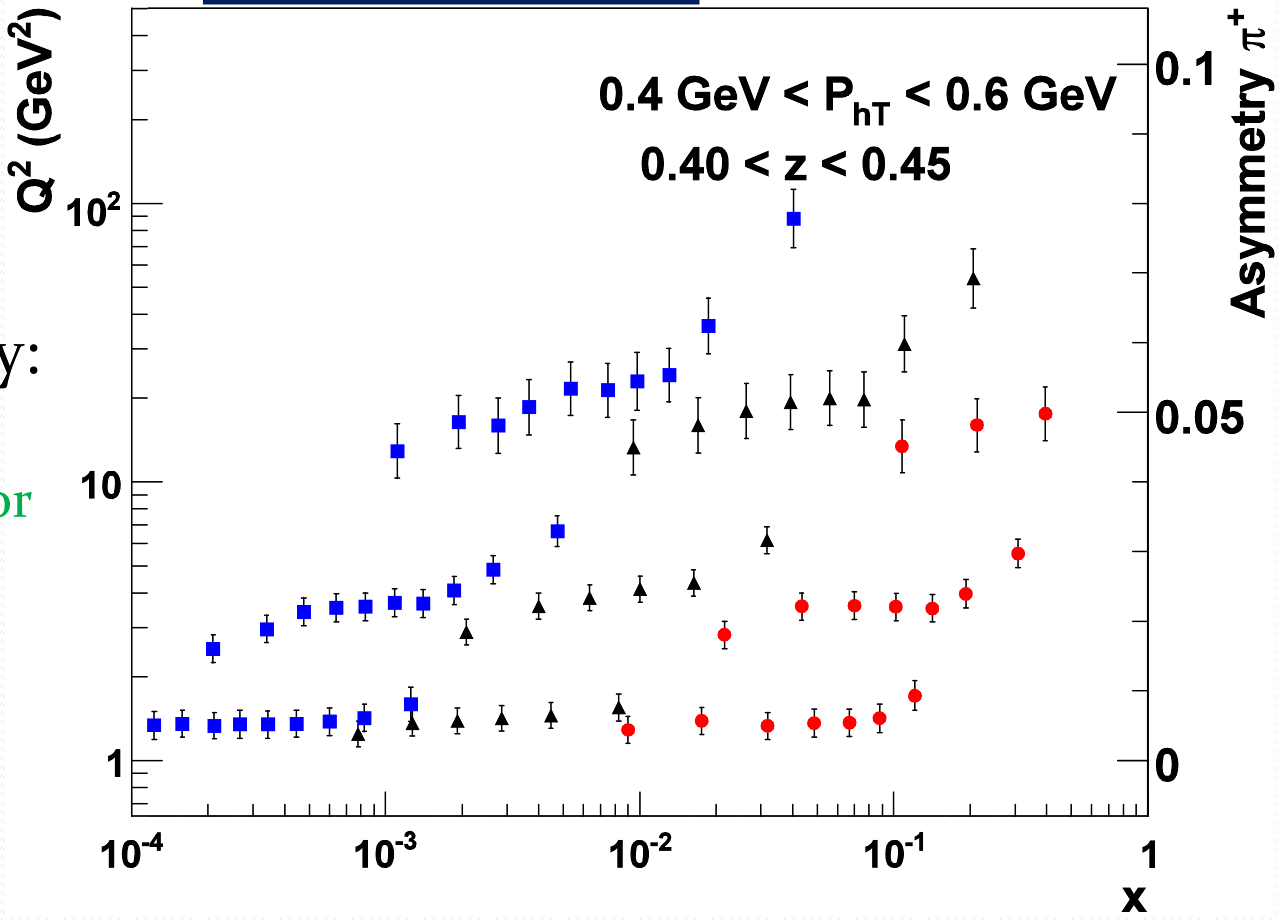
Integrated Luminosity:
30 fb^{-1}
(about 1 month running for $10^{34}/cm^2/s$)

0.8>y>0.05

Polarization 70%
Overall efficiency 50%

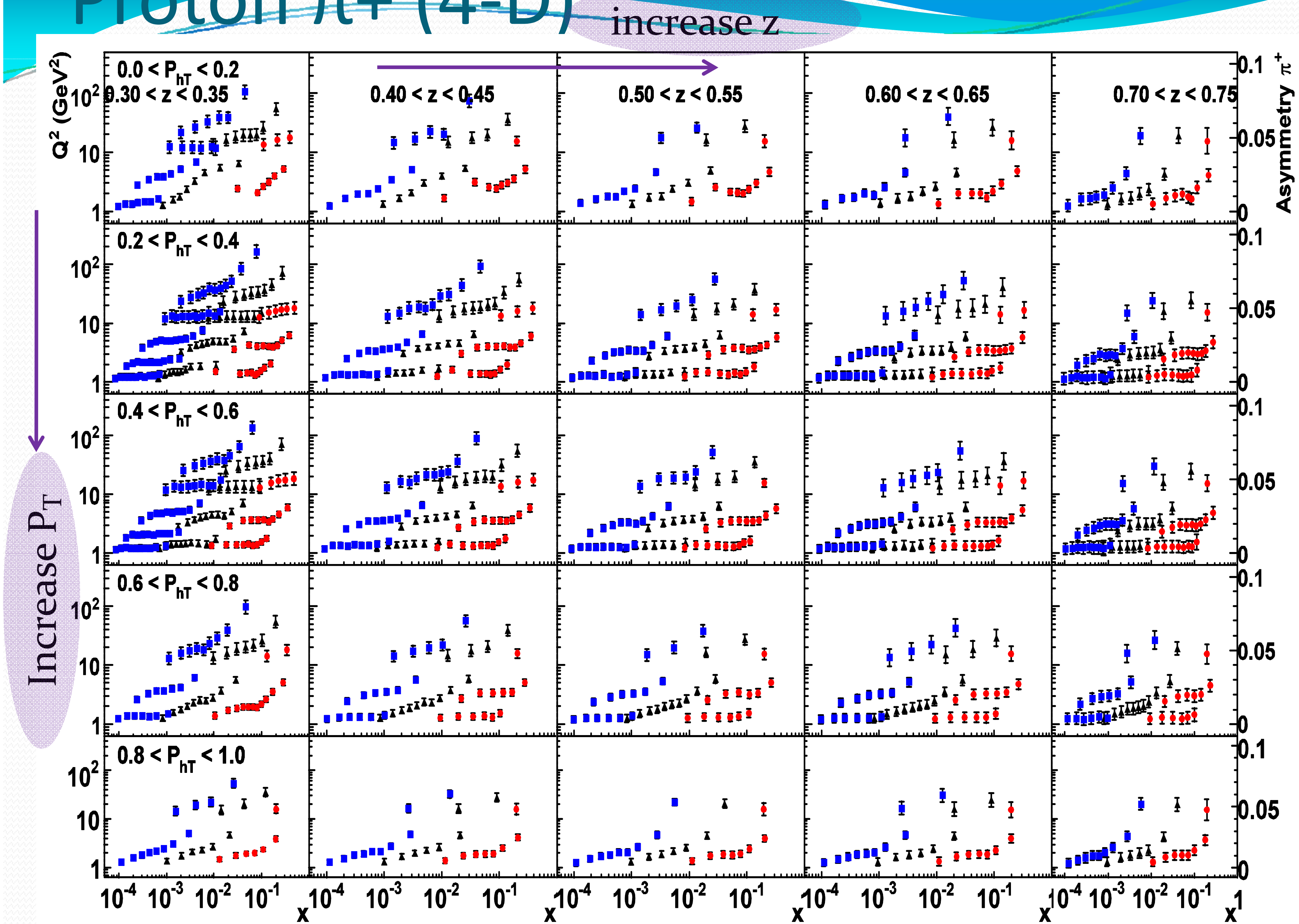
z: 12 bins 0.2 - 0.8
P_T: 5 bins 0-1 GeV

1/60 bins on (P_T, z)



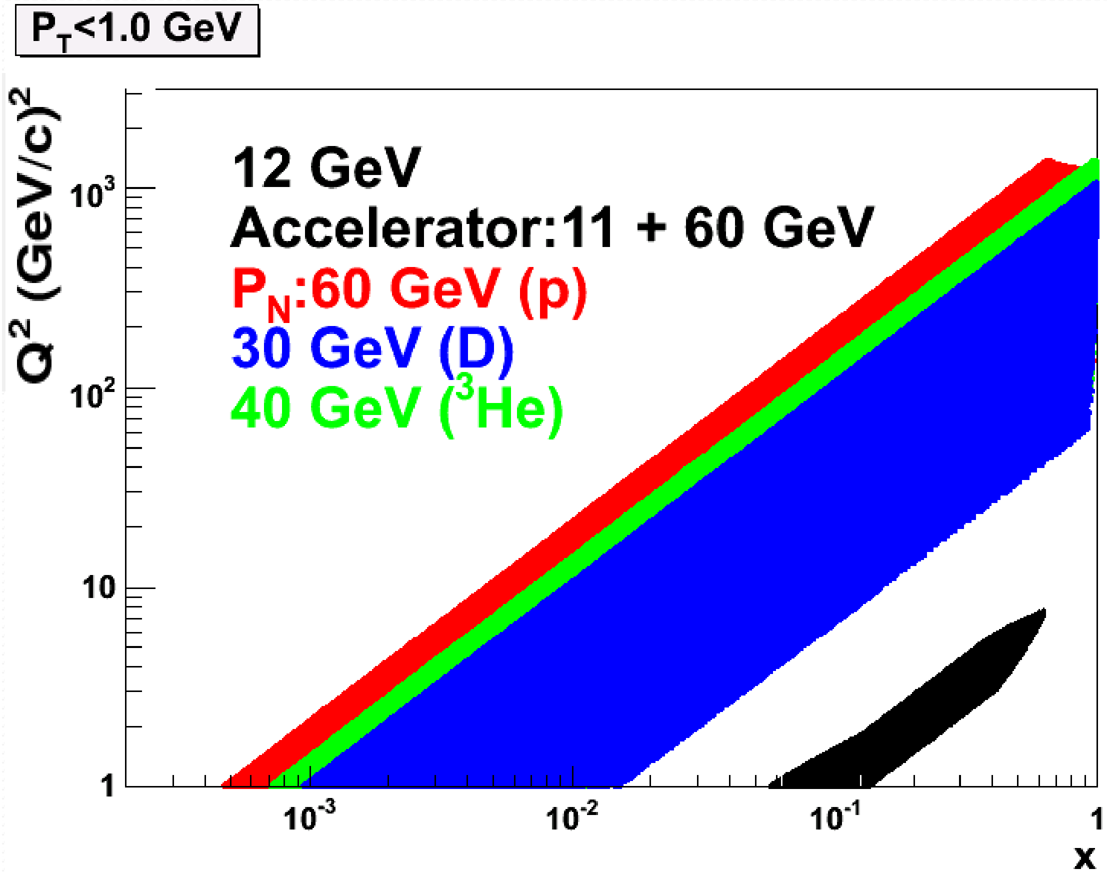
Also π-, K+, K-

Proton π+ (4-D)



increase z
Increase P_T
$0.0 < P_{hT} < 0.2$
$0.2 < P_{hT} < 0.4$
$0.4 < P_{hT} < 0.6$
$0.6 < P_{hT} < 0.8$
$0.8 < P_{hT} < 1.0$
$0.30 < z < 0.35$
$0.40 < z < 0.45$
$0.50 < z < 0.55$
$0.60 < z < 0.65$
$0.70 < z < 0.75$
Q^2 (GeV^2)
Asymmetry π^+
x

Study both Proton and Neutron



Neutron as important as proton in nucleon structure study

Flavor separation

ion momentum $\propto$ Z

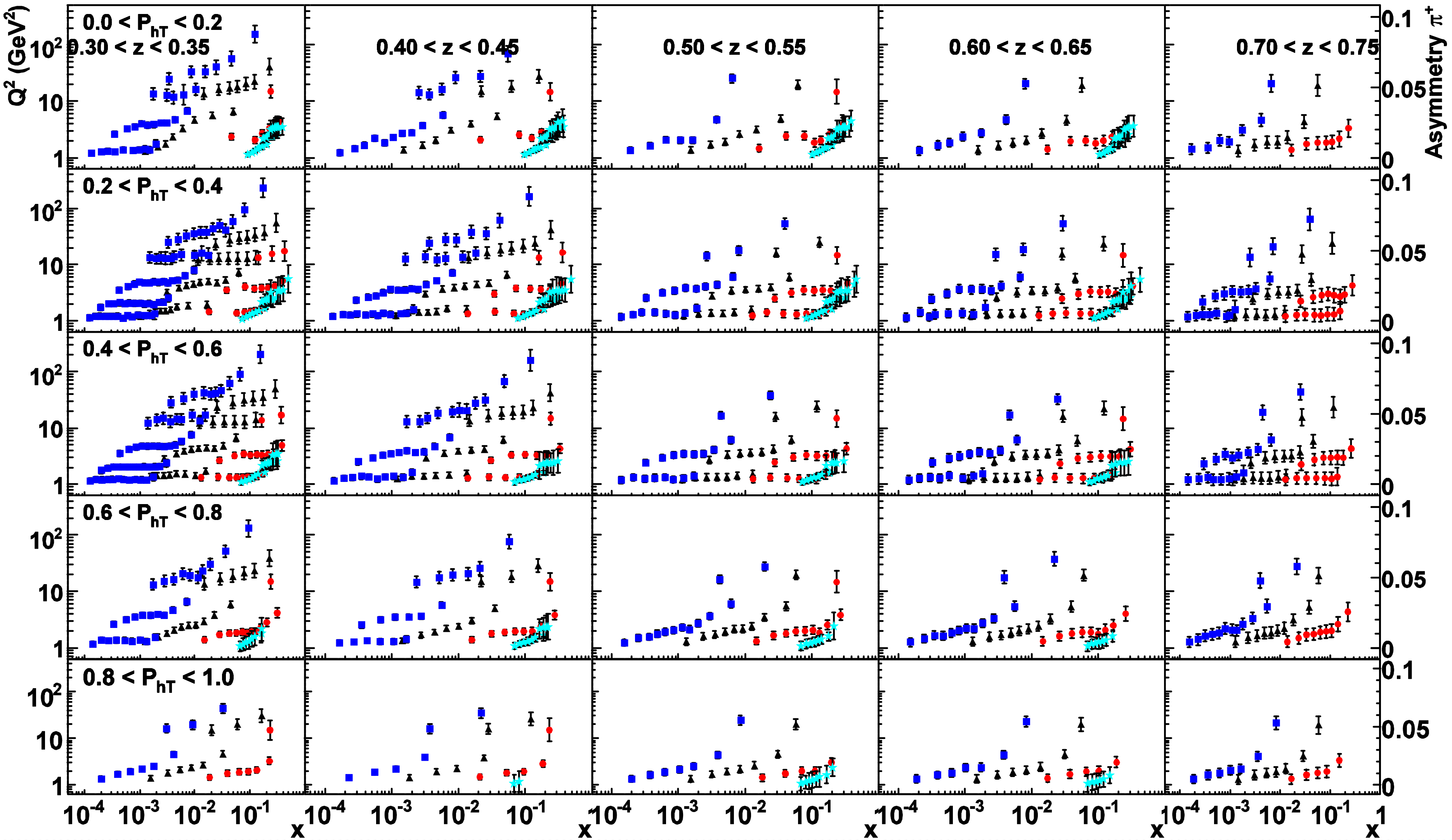
$P_N \propto Z/A$

Combine the data, the lowest achievable x limited by the effective neutron beam

^{3}He π^+ (4-D)

combine ^{3}He and D 120 fb^{-1}

12 GeV Jlab

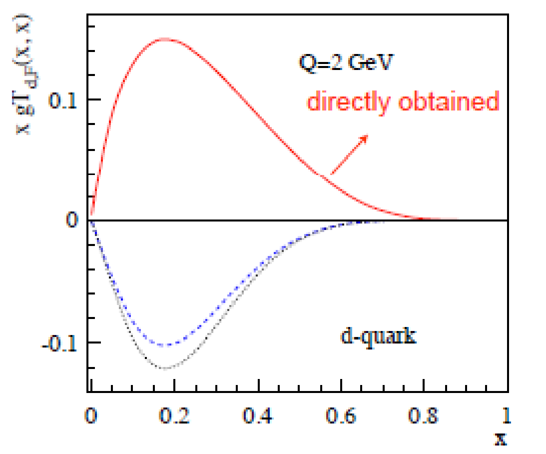


High P_T Physics

- TMD: $P_T \ll Q$

Talks by F. Yuan, J.P. Ma

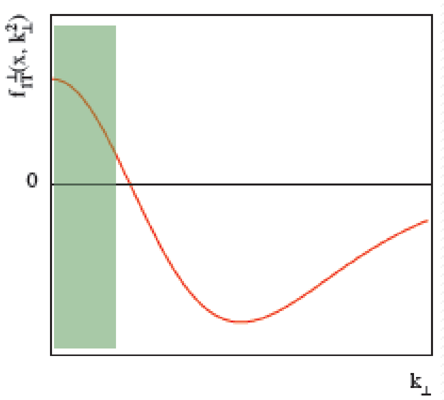
- Twist-3 formulism: $\Lambda_{QCD} \ll P_T$
- Unified picture in $\Lambda_{QCD} \ll P_T \ll Q$
  - Ji et al. PRL 97 082002 (2006)



- Sign 'mismatch' of ETQS function

$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)|_{\text{SIDIS}}$$

vs. global fitting from pp collision



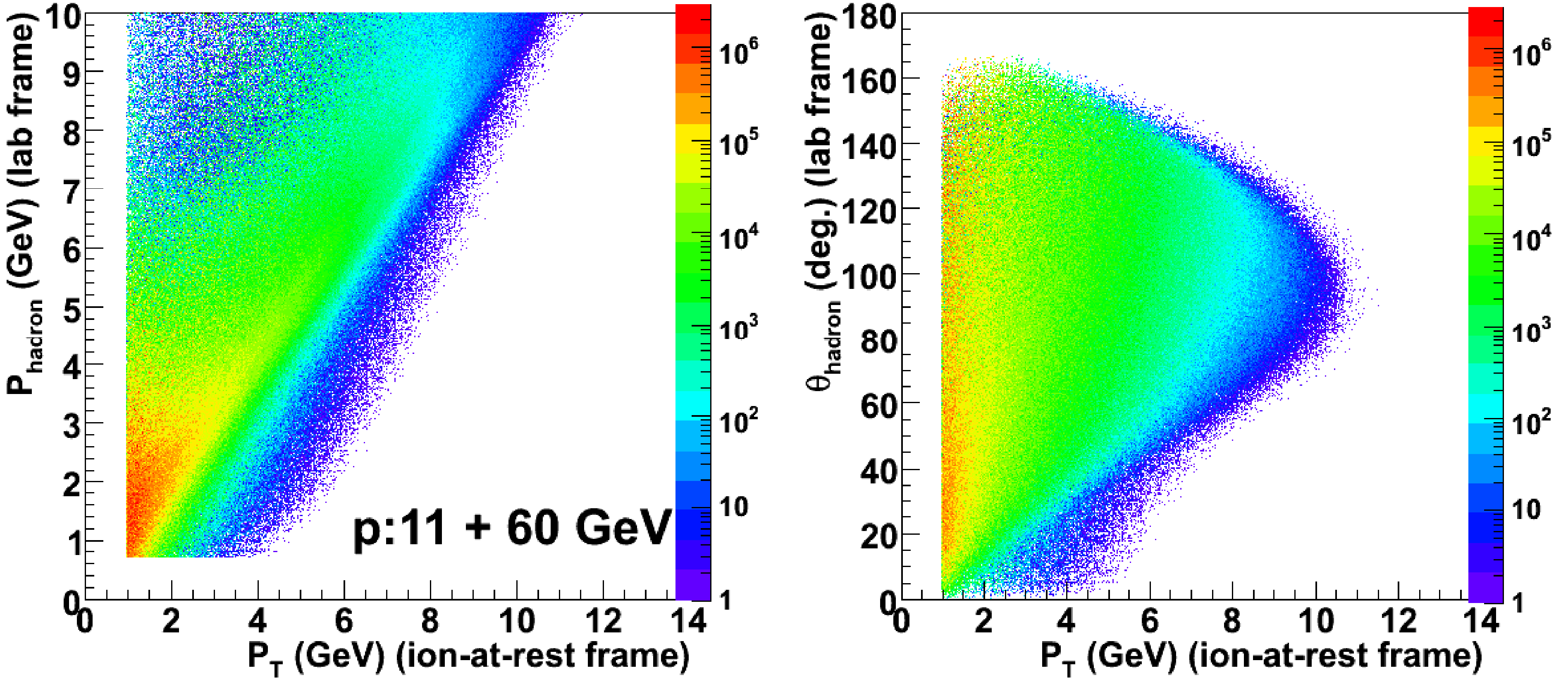
- P_T weighted integral Asymmetries

$$A_{UT}^{J\sin(\phi_h-\phi_S)} = \frac{\int dP_T J(P_T) A_{UT}^{\sin(\phi_h-\phi_S)} \cdot \sigma_{UU}}{\int dP_T \sigma_{UU}}$$

Kang, Qiu, Vogelsang and Yuan, Phys. Rev. D83:094001,2011

Kang, Prokudin, Phys. Rev. D85 (2012) 074008

High P_T kinematics

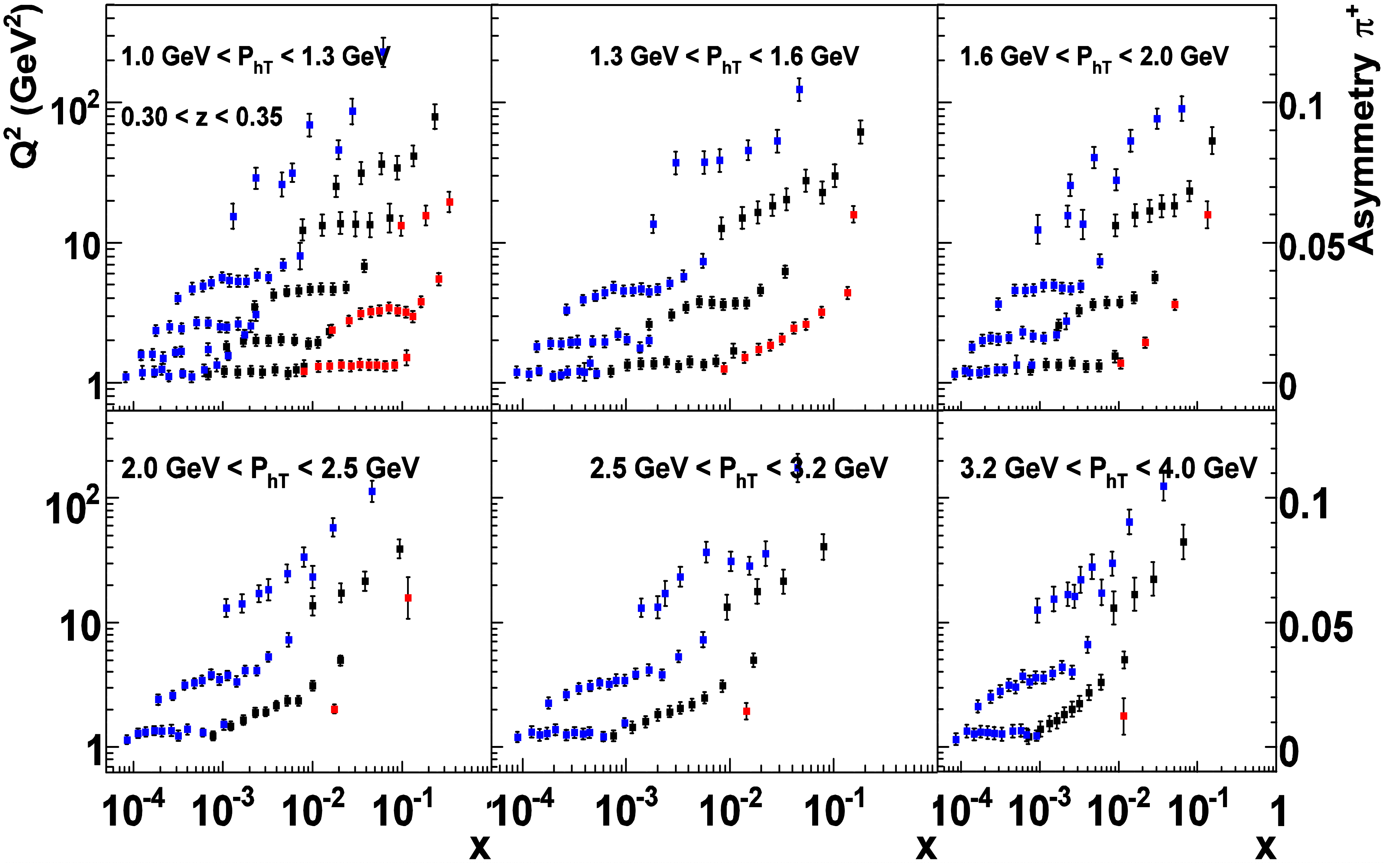


High P_T : hadron momenta dramatically increase

require high momentum PID, large polar angular coverage

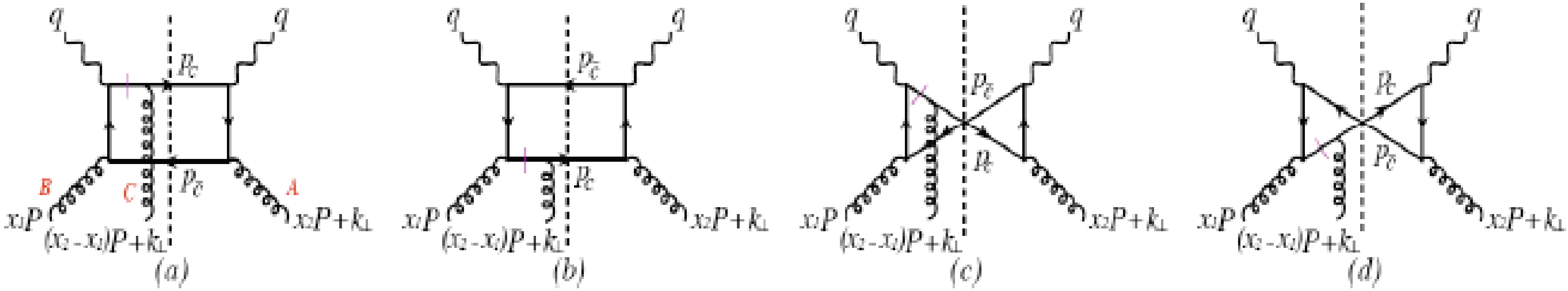
P_T dependence (High P_T) on p of π^+

120 fb^{-1}



D-meson Production

- Dominated by tri-gluon subprocesses (Kang, Qiu PRD 2008)



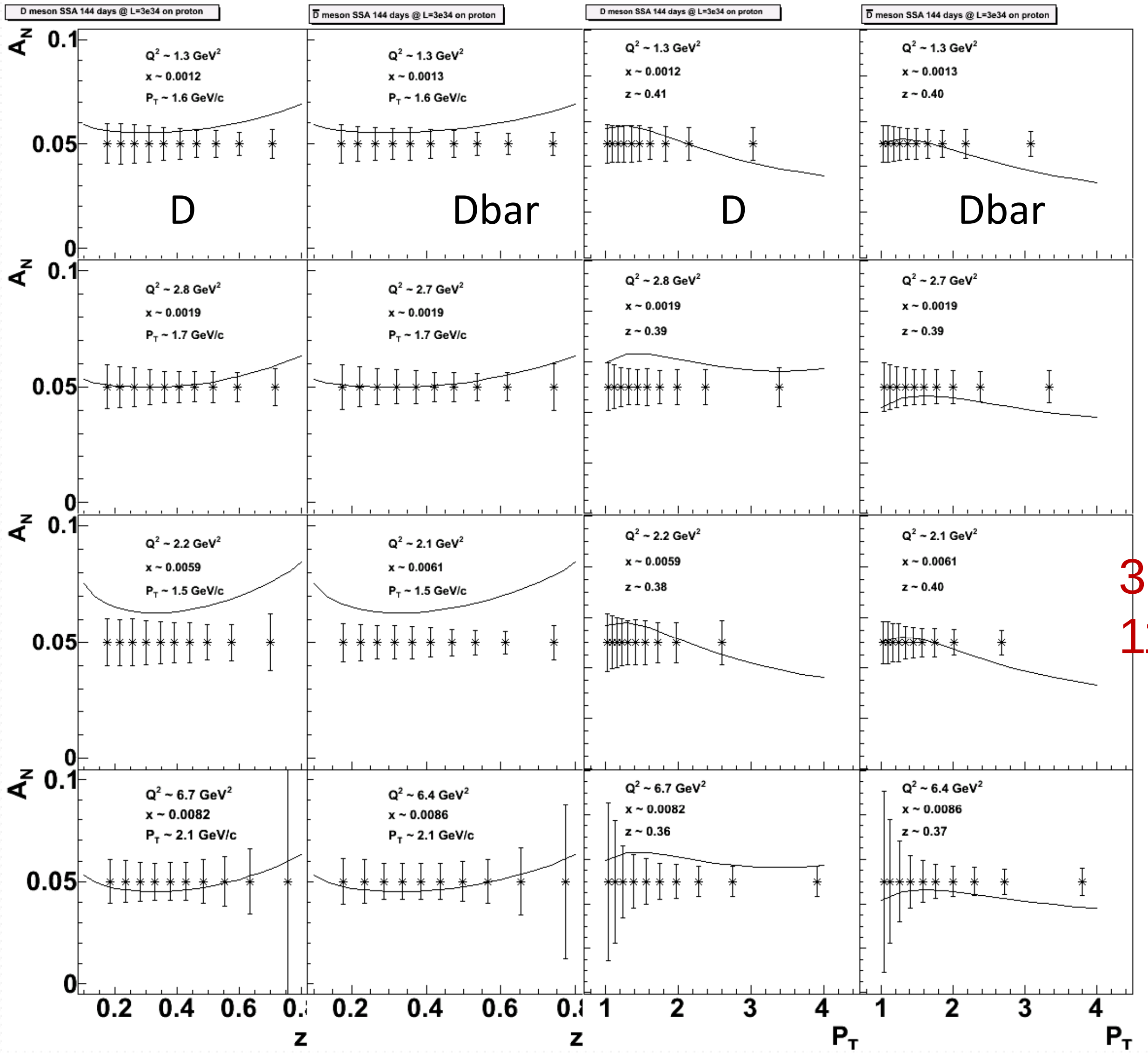
  - Four tri-gluon distributions (Kang, Koike, Tanaka)
  - Closely related to gluon Sivers function
- Transverse Single Spin Asymmetries
  - Proportional to tri-gluon functions

$$D^0(c\bar{u}) \rightarrow \pi^+(u\bar{d})K^-(s\bar{u})$$
$$\overline{D^0}(\bar{c}u) \rightarrow \pi^-(\bar{u}d)K^+(u\bar{s})$$

Branching ratio: 3.8+-0.07%

D-meson Projection

X. Qian



360 fb^{-1} on Proton
11x60 GeV

Calculations from Z. B. Kang

Gluon Sivers Distribution

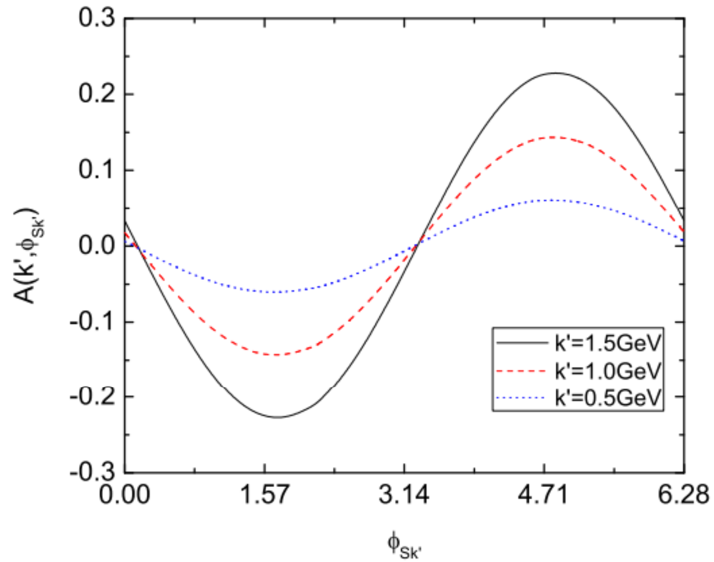
BNL/INT/Jlab EIC whitepaper, arxiv: 1108.1713

- Focus on charm production back-to-back D Dbar

$$\gamma^* g \rightarrow q\bar{q}$$

- Approximate a factor of 50 suppression compare to the single D meson production at 11x60 GeV
  - Higher C.M. energy -> Larger Xs
  - Explore other decay channels -> Larger branching ratio
  - Higher luminosity

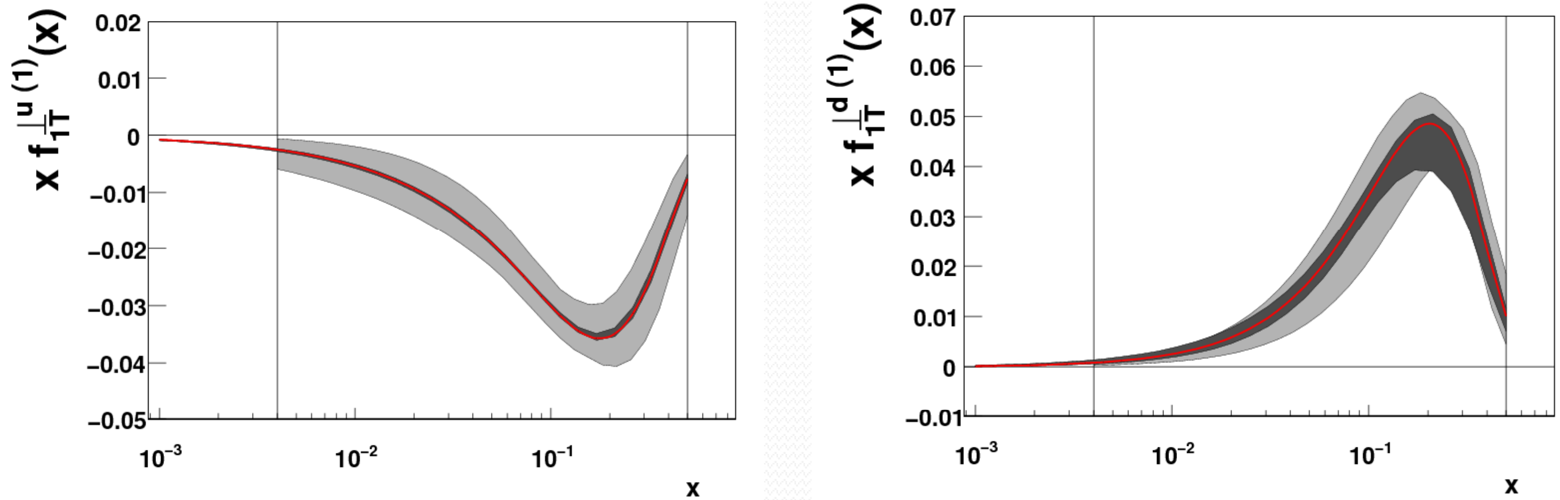
$$\gamma^* p \rightarrow D^0 \bar{D}^0 + X$$



Impact of the EIC

- Eg: precision to extract Sivers function
- Sivers function parameterization
  - M. Anselmino et al., J. Phys. Conf. Ser. 295, 012062 (2011)

A. Prokudin
F. Yuan's talk



- Grey band: existing data;
- Dark grey band around red line: pseudo EIC data
  - $4fb^{-1}$ luminosity (brief period of operation for an EIC)
  - Energy $\sqrt{s} = 45GeV$

Summary of Luminosity

Typically for 11 + 60 Gev, s = 50 GeV

ion	Detected hadron	P_T region (divide @ 1GeV)	Luminosity (fb^{-1})
p	π	Low	30
n(^{3}He + D)	π	low	120
p	K	low	>3 x 30 (match with pion)
p	π	high	120
p	D	high	360 (multi-D binning, much fewer bins)
p	$D+\overline{D}$	high	Tens of 360 or high s?

Summary

- EIC is an ideal machine to study 3D structure in transverse momentum space
  - One of the golden channels: Sivers Effect
- High luminosity, ability to cover large Q^2 : clean quantitative measurements of TMDs in the valence region, study of evolution
- High luminosity, wide kinematic coverage: essential for 4-D mapping of TSSA for π, K, D, and high P_T physics
  - Sea Quark Sivers
- Unique access to TMDs for gluons
  - back-to-back D meson production
- Detector Requirement (SIDIS)