Working Group on e-p Physics

A. Bruell, E. Sichtermann, W. Vogelsang, C. Weiss

Antje Bruell, JLab

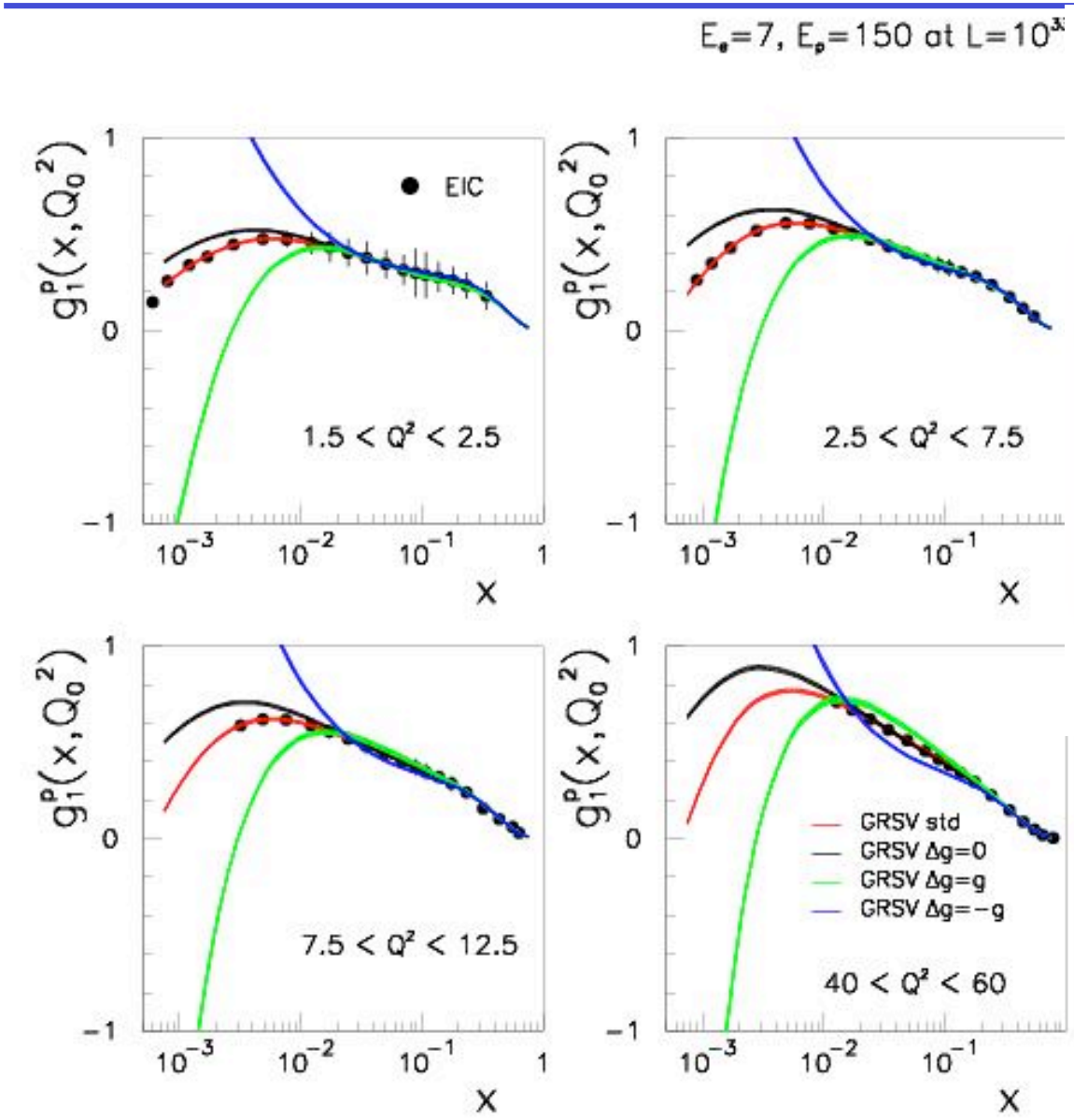
EIC meeting, Hampton, May 23 2008

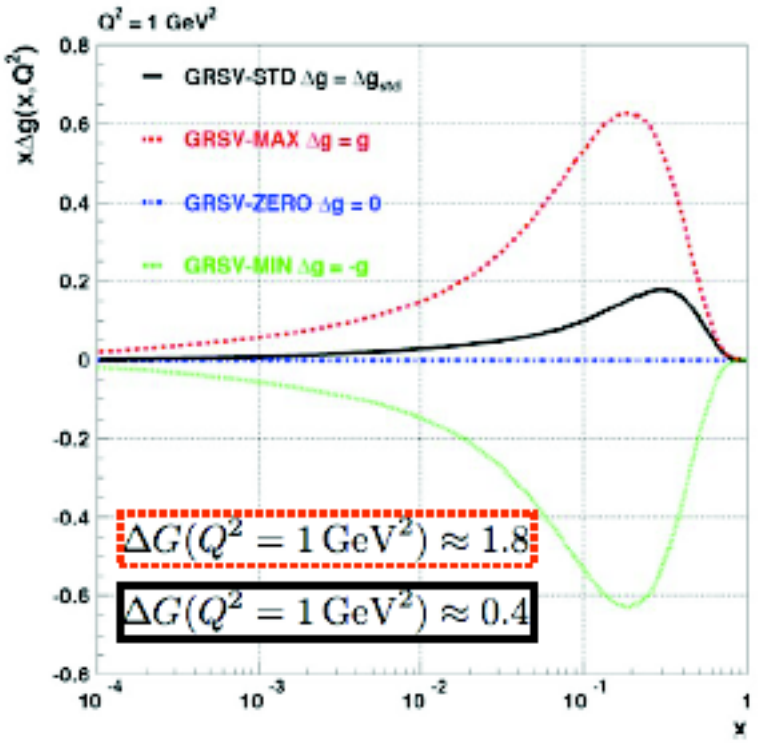
- **Goals of this parallel session/working group**
  - **Recent theoretical developments**
  - **Progress in simulations of Key Processes**
- **Detector consequences & emerging conceptual design**
- **Some remarks**

Physics Topics

- **inclusive physics**
  - unpolarised + polarised structure functions
- **direct measurements of polarised gluon distribution ΔG**
  - charm production+jet rates
- **semi-inclusive physics**
  - current quark fragmentation and flavour separation
  - target fragmentation and correlation between current and target fragmentation
  - transverse Momentum Dependent Parton Distributions
  - Sivers and Collins functions
  - Orbital momentum ?
- **exclusive processes and diffraction**
  - DVCS + meson production (pseudoscalar and vector)
  - 3 dimensional image of the proton & orbital momentum
- **Photoproduction**
- **Jet physics+electroweak physics**

ΔG from scaling violations of g_1

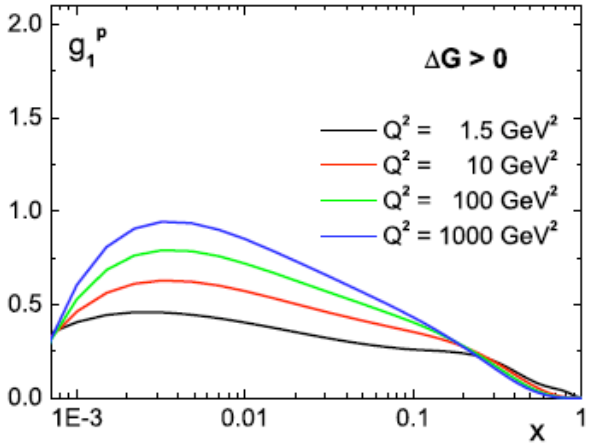


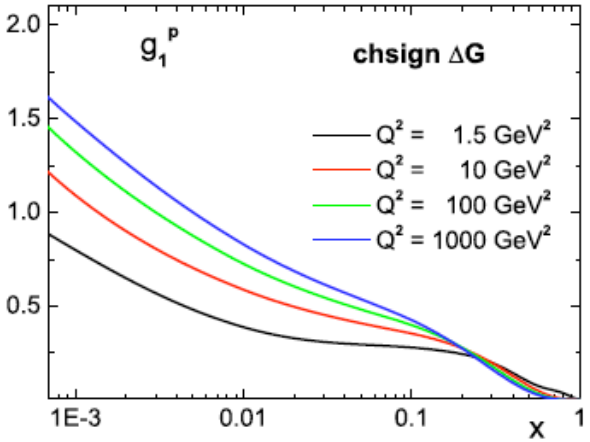


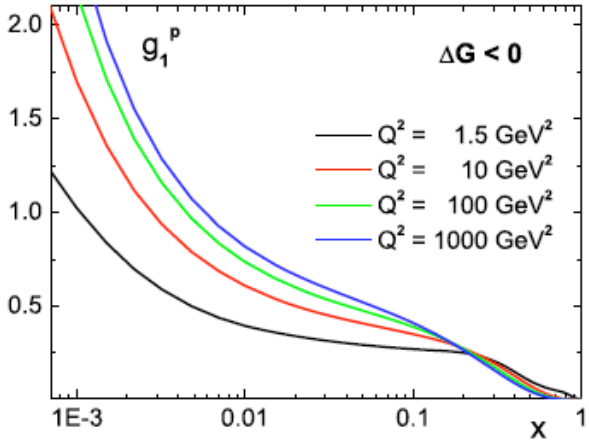
Inclusive scattering

Measurements of $g_1^p(x, Q^2)$ at very small x (EIC) could settle the ΔG problem

The behaviour of $g_1^p(x)$ at small x is quite different in the three cases (LSS'06)

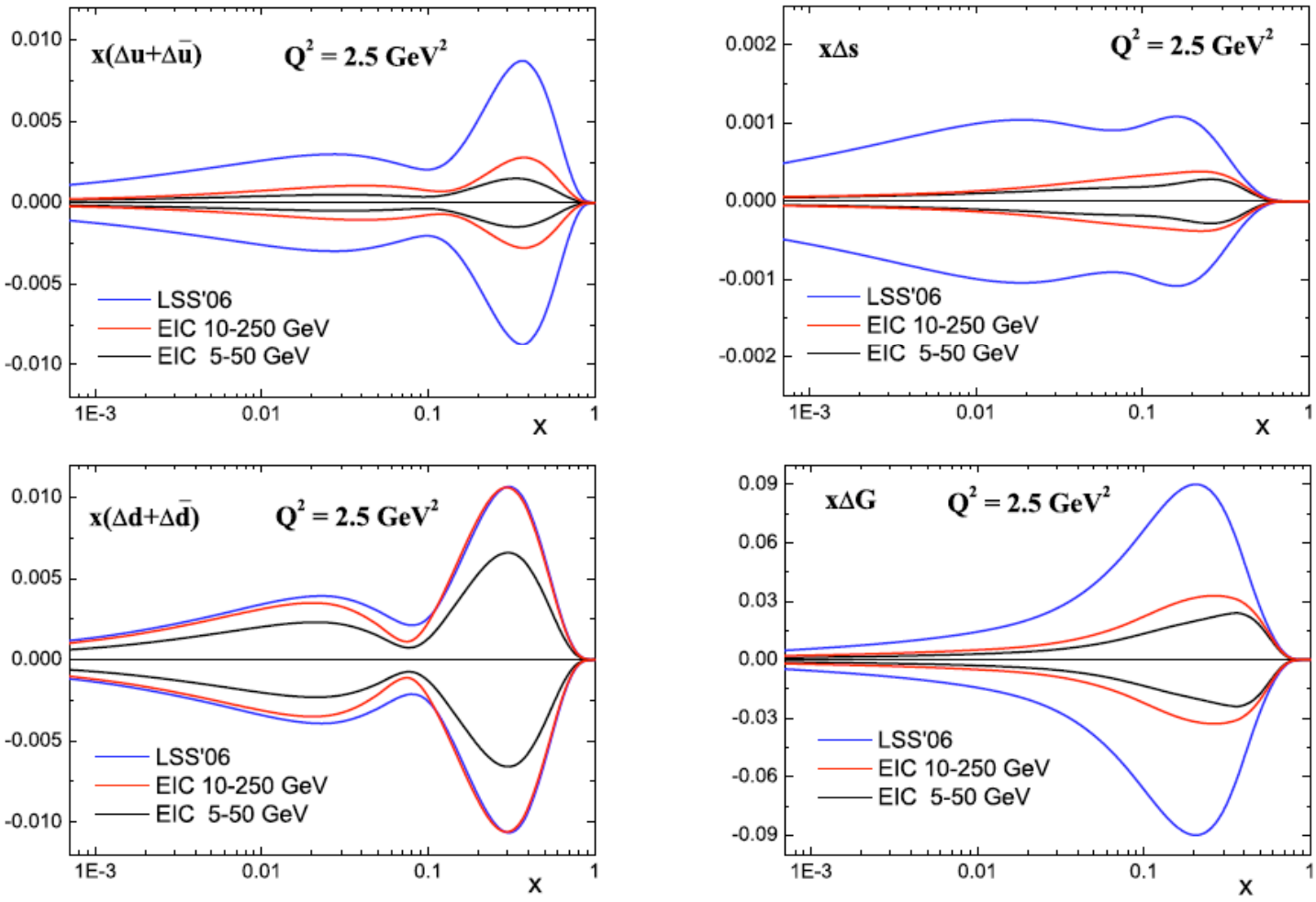






Inclusive scattering

Impact of future EIC data on the uncertainties for NLO polarized PDFs



Global analyses of FFs and pPDFs

"Global": different (independent) processes

$$
\left.\begin{aligned} e^+ e^- &\longrightarrow h^\pm X \\ e^\pm N &\longrightarrow e^\pm h^\pm X \end{aligned}\right\} \text{FFs}
$$

$$
\left.\begin{aligned} p p &\longrightarrow h^\pm X \\ p p &\longrightarrow jets\, X \\ e^\pm N &\longrightarrow e^\pm X \end{aligned}\right\} \text{pPDFs}
$$

"Analyses": consistent PDFs/FFs prescriptions,
consistent pQCD framework,
full NLO

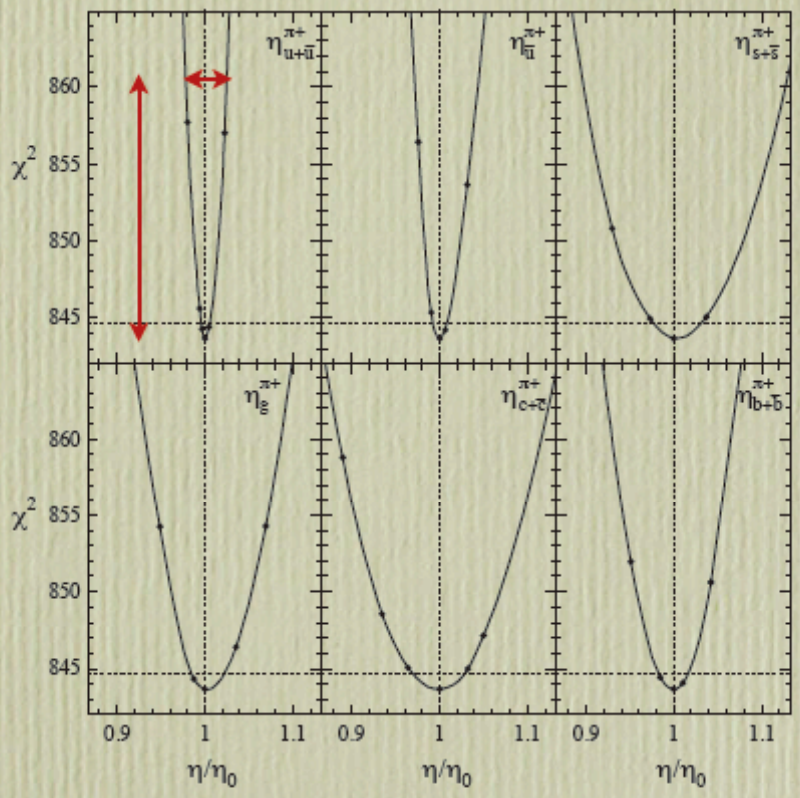
technical challenge!

NLO $\times$ $\mathcal{O}(10^2)$data points $\times$ $\mathcal{O}(10^3)$iterations

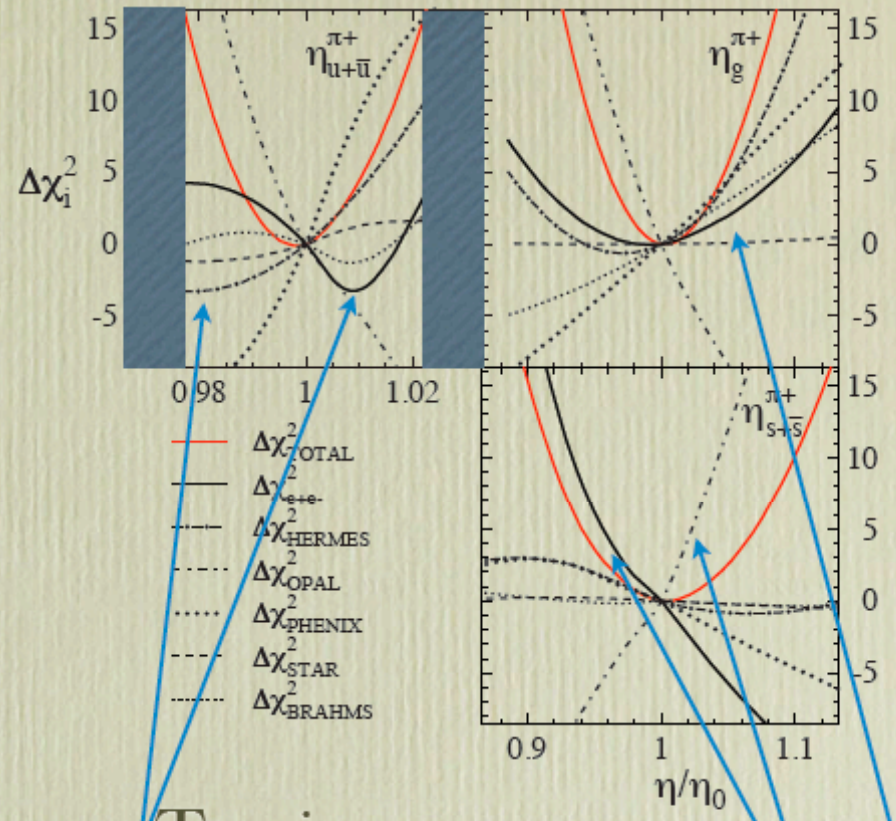
"FFs & pPDFs": FFs: pQCD insight into hadronization,
crucial tools, transcend spin physics
impact on pPDFs analysis as an example

Uncertainties: pions as an example

χ^2 profiles for the different flavors



Individual profiles by experiment



u ~ 2 %

s ~ 10 %

$\Delta\chi^2 = 15 (\simeq 2\%)$

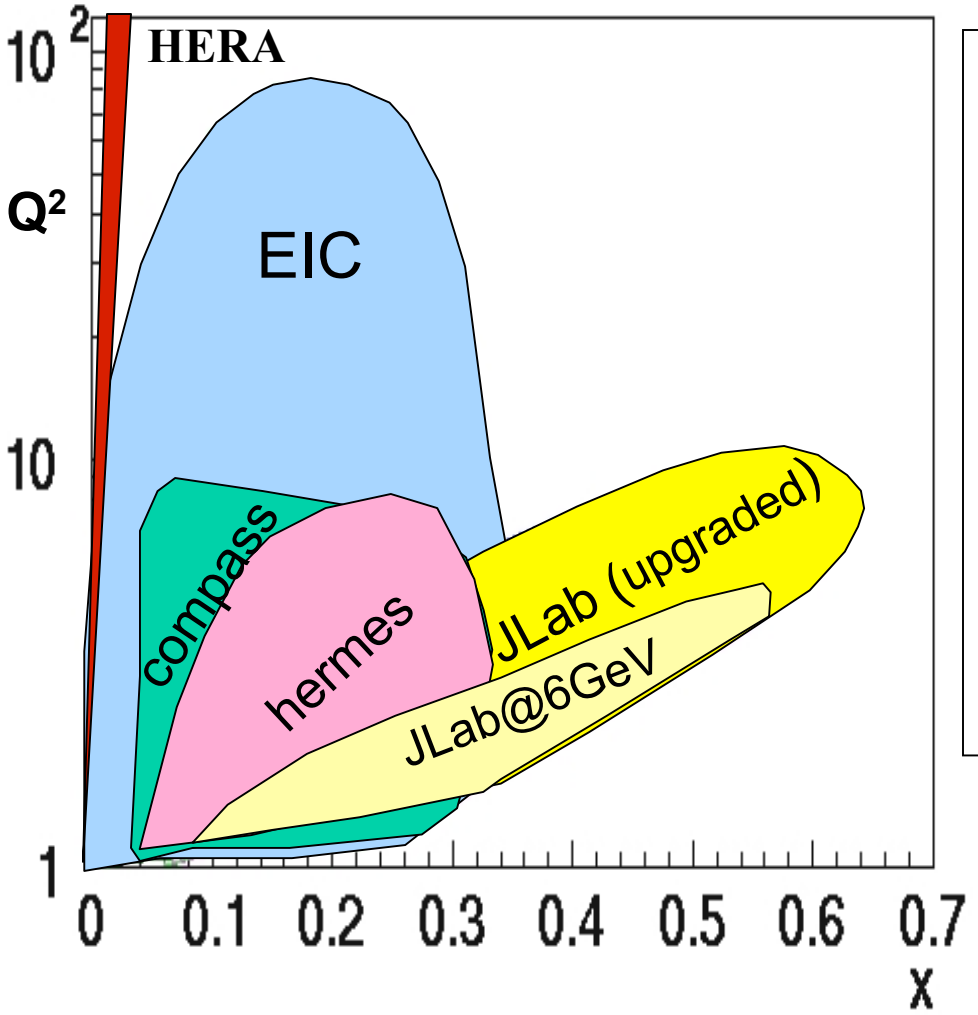
Tension

Complementarity

Precision

Kaon uncertainties: twice larger

Hard Scattering Processes: Kinematics Coverage

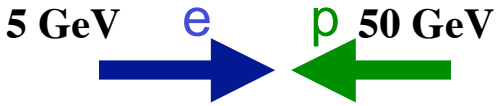


collider experiments
H1, ZEUS (EIC)
$10^{-4}<x_B<0.02$ (0.3): gluons (and quarks) in the proton

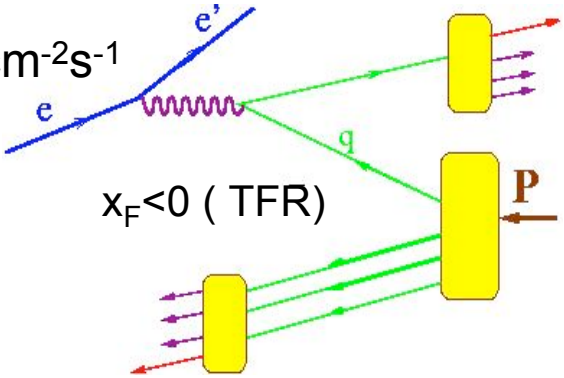
fixed target experiments
COMPASS, HERMES
→ $0.006/0.02<x_B<0.3$: gluons/valence and sea quarks
JLab/JLab@12GeV
→ $0.1<x_B<0.7$: valence quarks

Study of high **x** domain requires high luminosity, low **x** higher energies

EIC: Kinematics Coverage

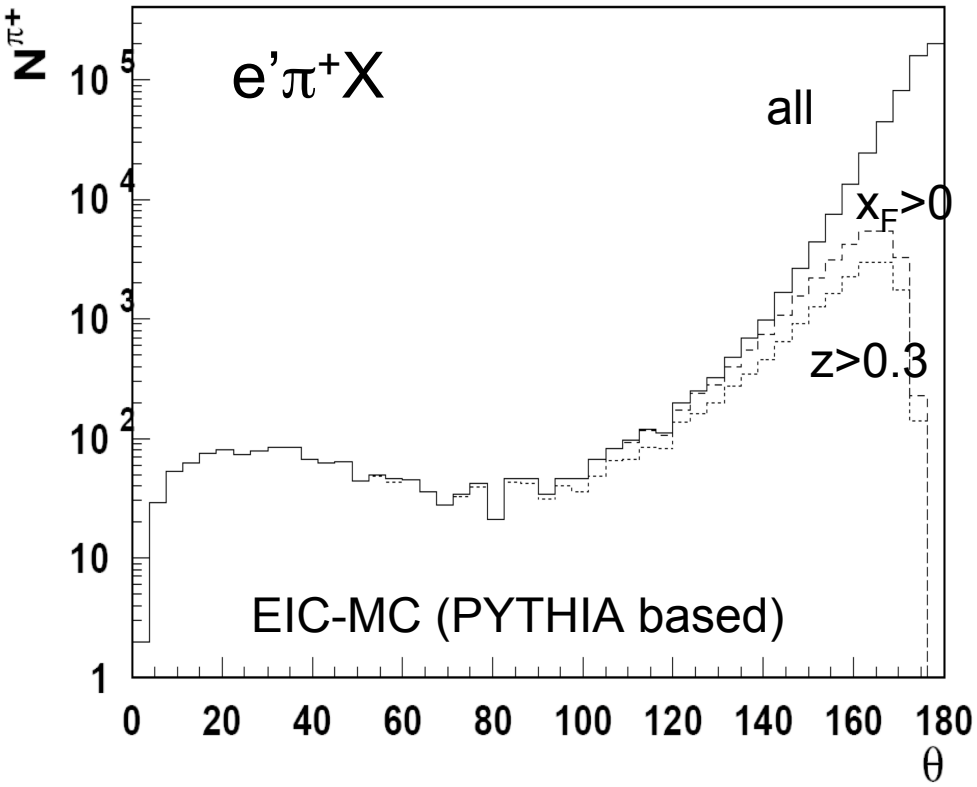


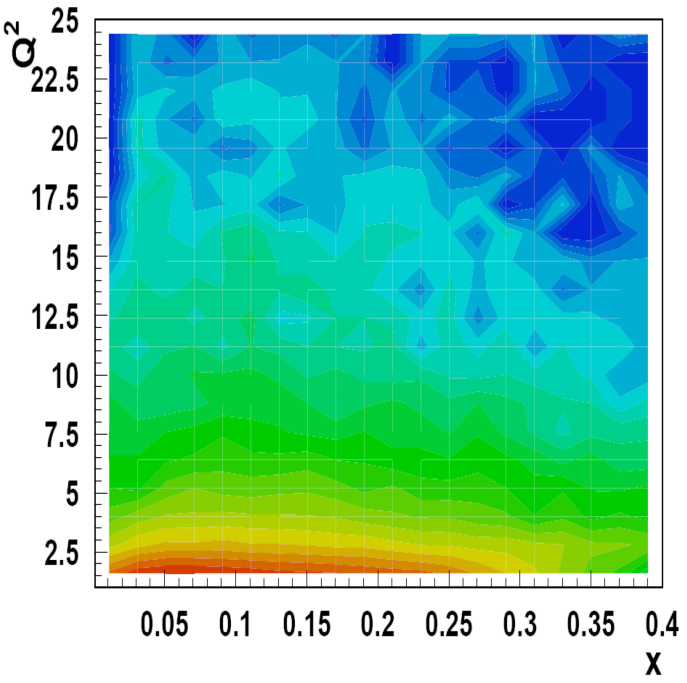
EIC-MC 100 days, $L=10^{33}cm^{-2}s^{-1}$



$x_F>0$ (CFR)

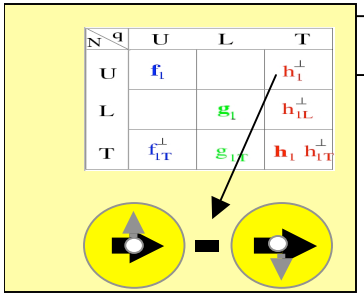
$x_F<0$ (TFR)





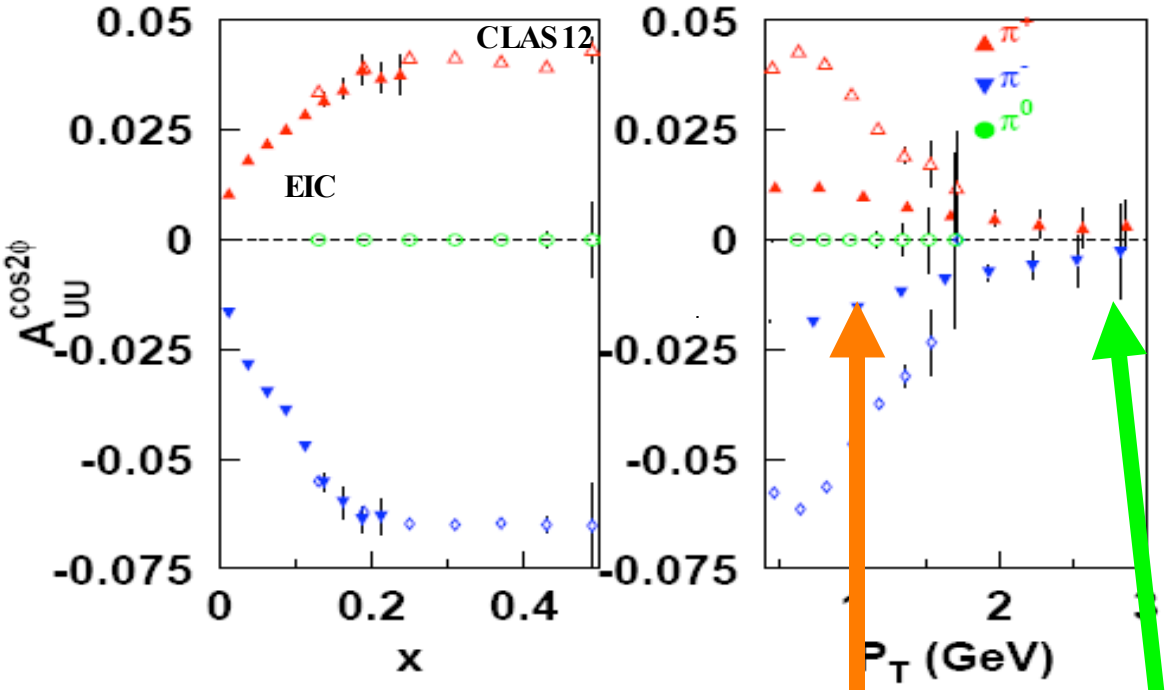
Major part of current particles at large angles in Lab frame (PID at large angles crucial).

Boer-Mulders Asymmetry with CLAS12 & EIC



5-GeV e p 50 GeV

Transversely polarized quarks in the unpolarized nucleon



$\sin(\phi_C) = \cos(2\phi_h)$

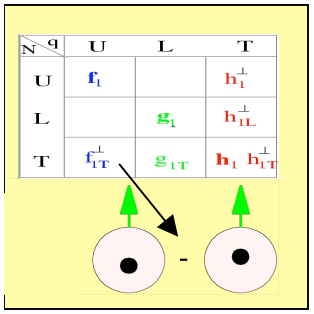
$$A_{UU}^{\cos 2\phi} \propto h_1^{\perp(1)} H_1^\perp$$

$$\langle \cos 2\phi \rangle|_{P_{h\perp} \gg \Lambda_{QCD}} \propto \frac{1}{P_{h\perp}^2}$$

Nonperturbative TMD

Perturbative region

CLAS12 and ELIC **studies of transition from non-perturbative to perturbative regime will provide complementary info on spin-orbit correlations and test unified theory (Ji et al)**

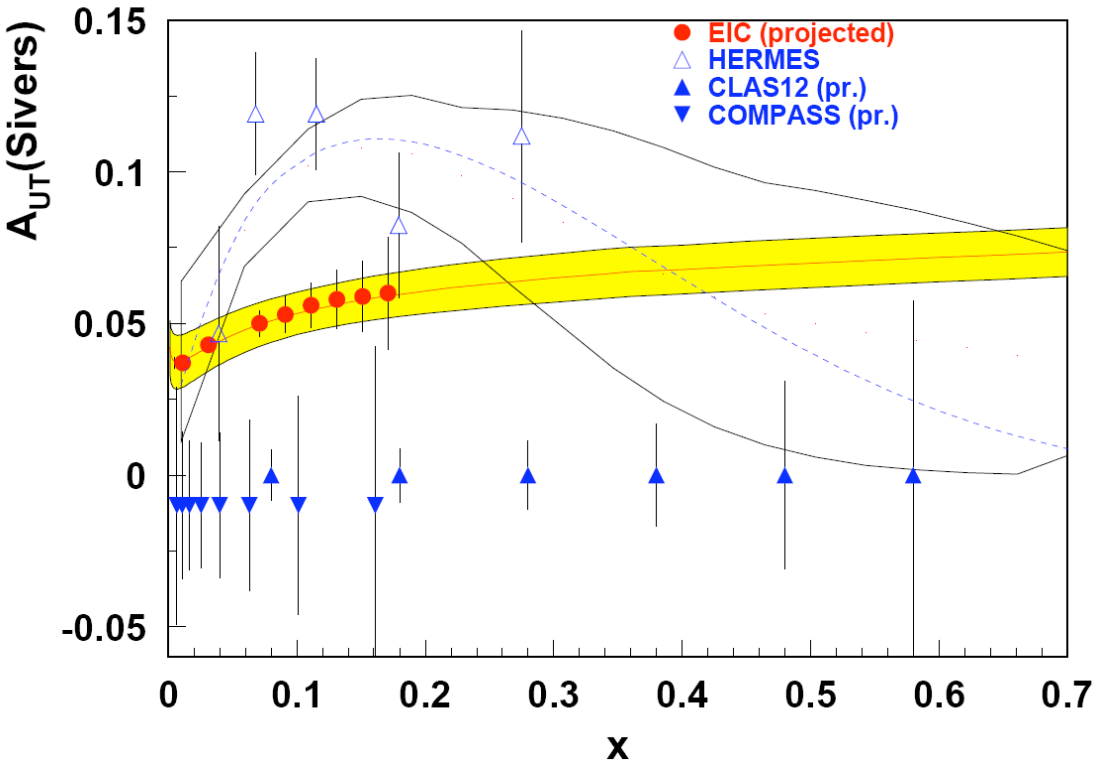


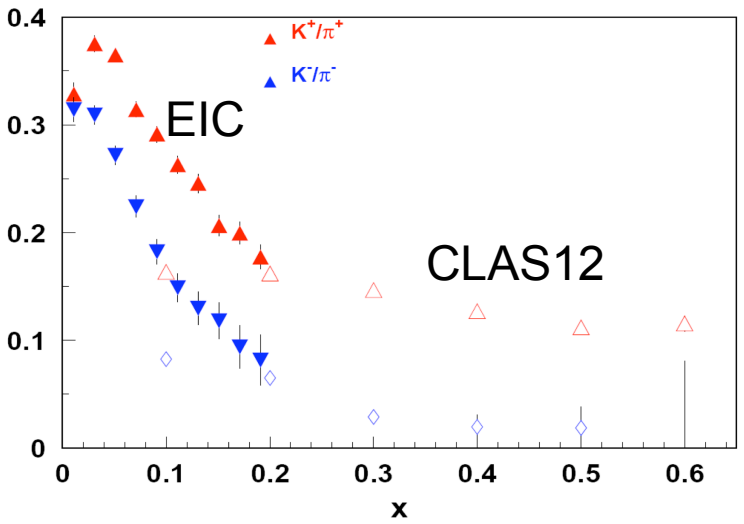
Sivers effect: Kaon electroproduction

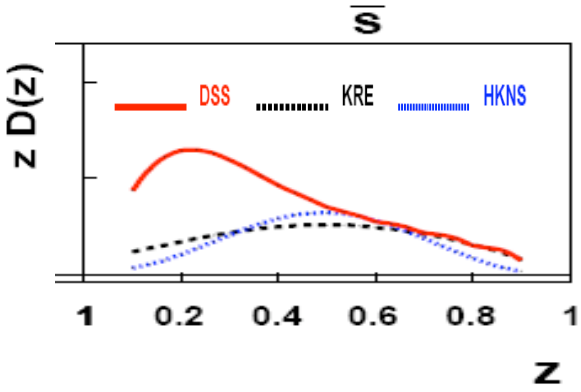
$$A_{UT}^{\sin(\phi-\phi_S)} = \frac{\sum_q e_q^2 f_{1T}^{\perp q} D_1^q}{\sum_q e_q^2 f_1^q D_1^q}$$

$K^+ \sim u\bar{s}$ $K^- \sim s\bar{u}$

ep→e' K$^+$+X



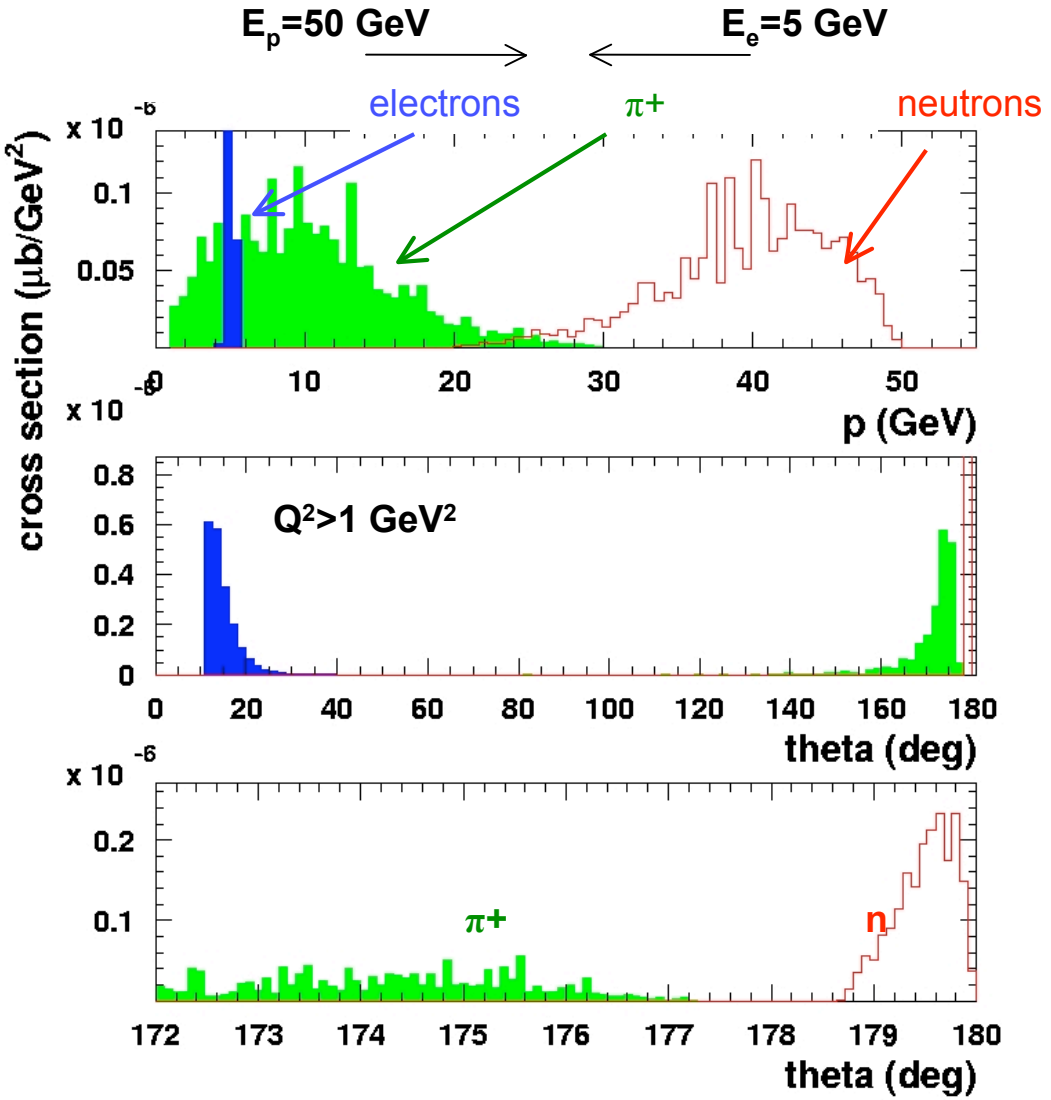




- At small x of EIC Kaon relative rates higher, making it ideal place to study the Sivers asymmetry in Kaon production (in particular K-).
- Combination with CLAS12 data will provide almost complete x-range.

$^1H(e,e'\pi^+)n$ Momentum and Angular Distributions

- Kinematically, electrons and pions are separated
- The neutron is the highest energy particle and is emitted in the direction of the proton beam

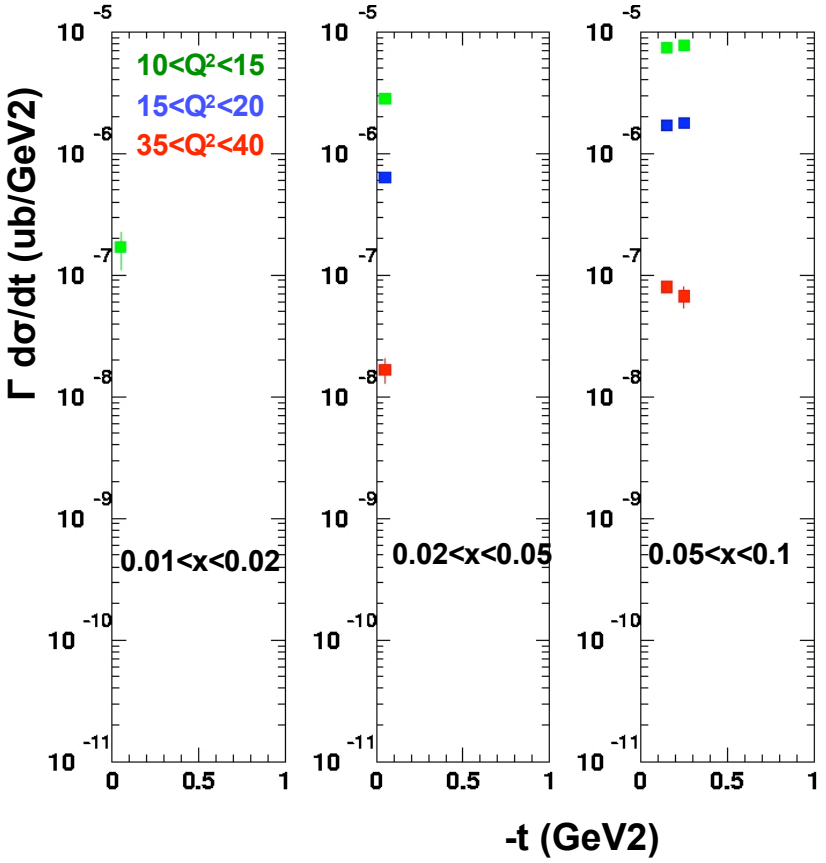


Rates and coverage in different Event Topologies

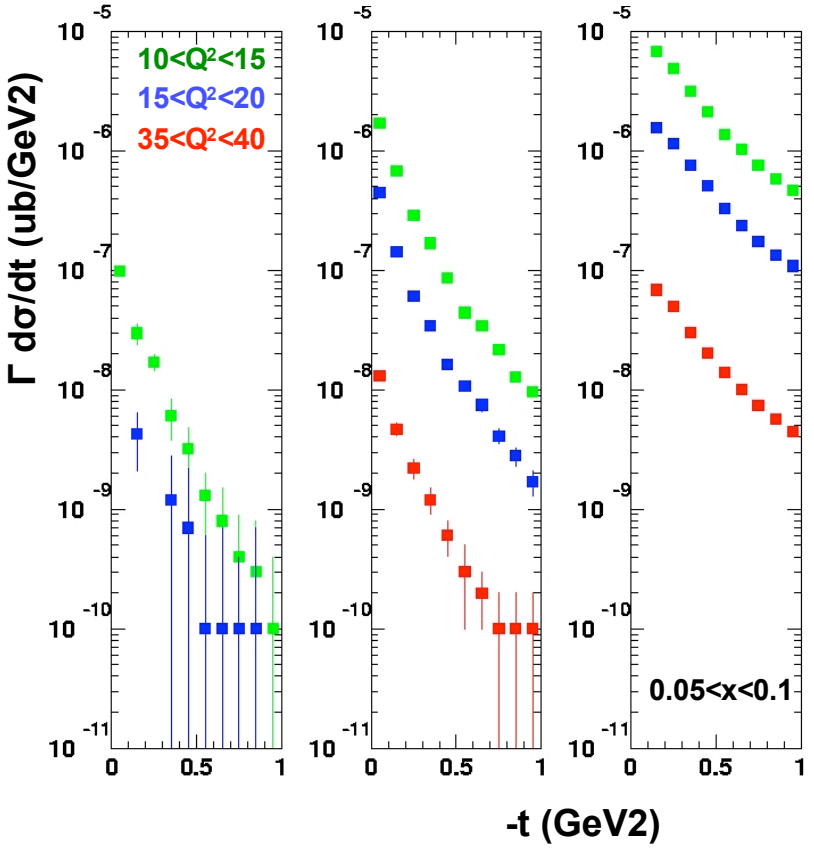
E_p=50 GeV → ← E_e=5 GeV

Assume: 100 days, Luminosity=10E34

Detect the neutron



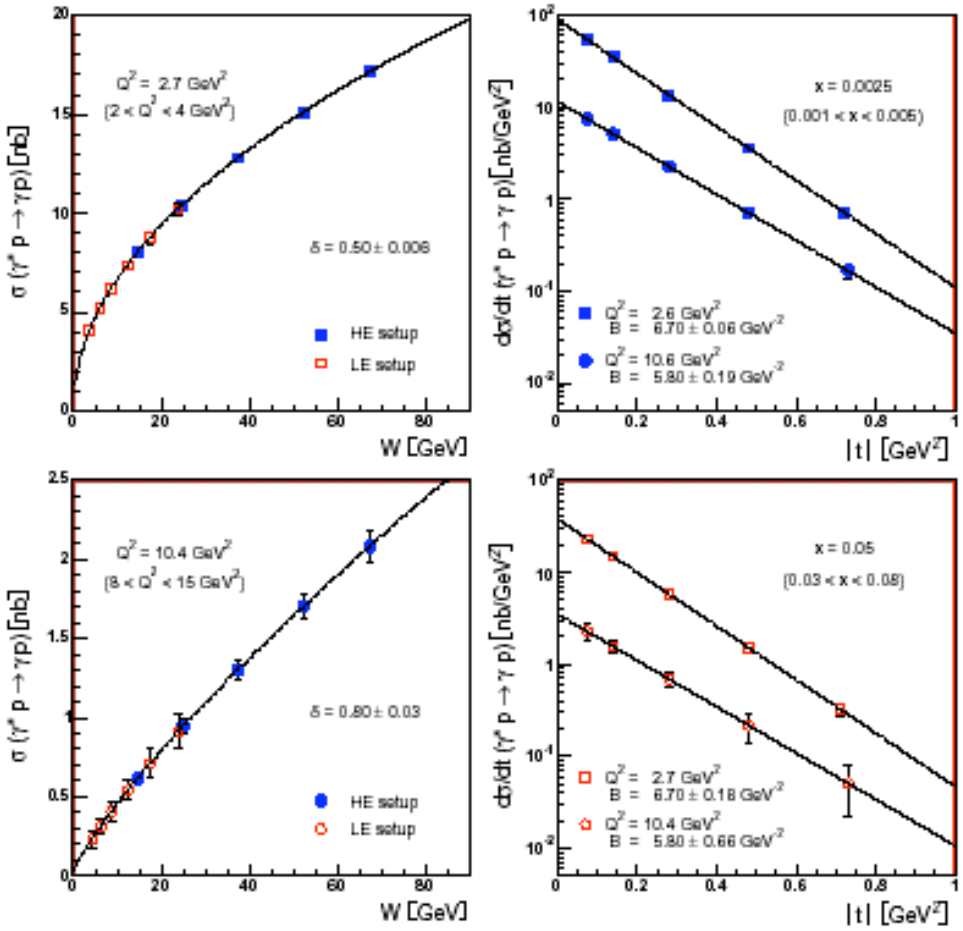
Missing mass reconstruction



- Neutron acceptance limits the t-coverage
- The missing mass method gives full t-coverage for x<0.2

Assume dp/p=1% (p_π<5 GeV)

Diffractive channels: EIC projections



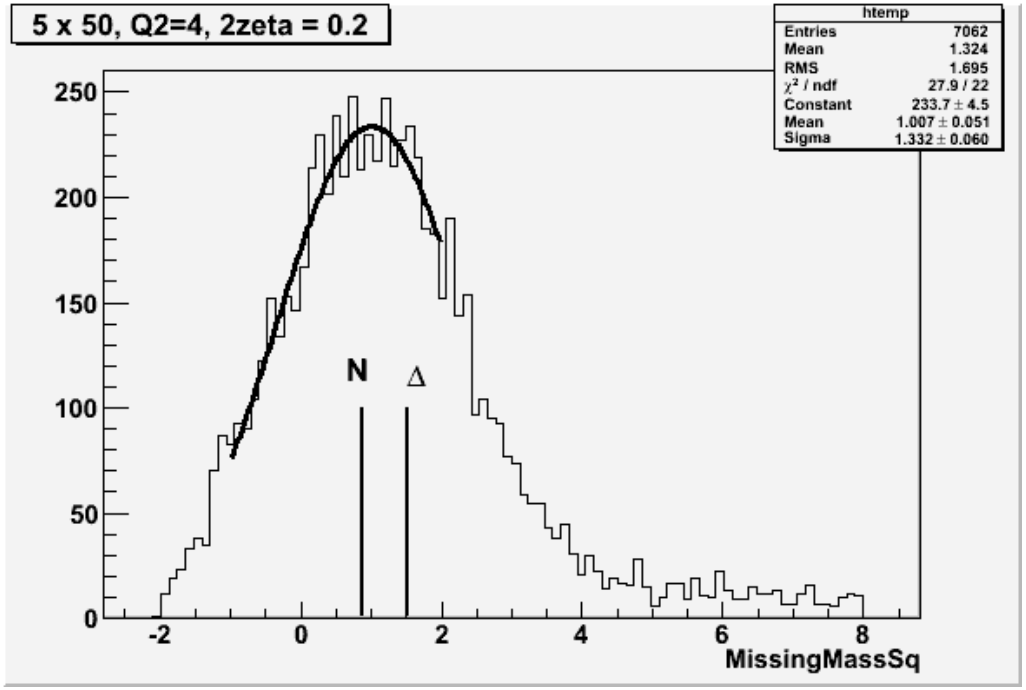
[DVCS with eRHIC HE/LE, $530/180\,\mathrm{pb}^{-1}$
A. Sandacz, GPD White Paper (2007)]

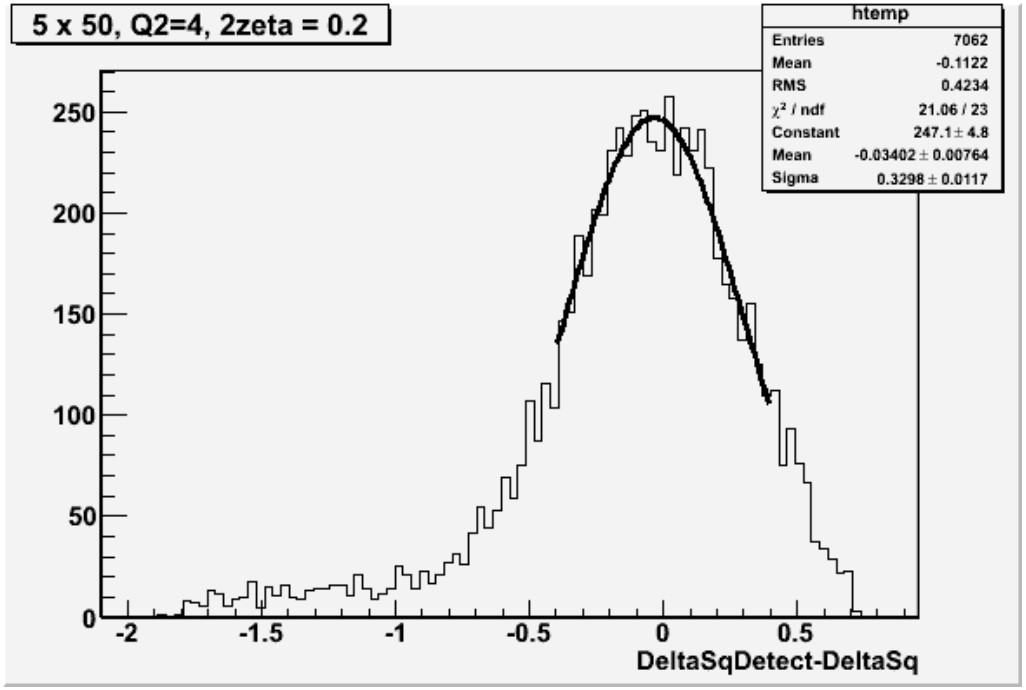
- Aim: Transverse gluon/singlet quark imaging of nucleon over wide range $10^{-3} < x < 10^{-1}$
- Requirements:
  - $Q^2 \sim$ 10–20 GeV^2: Factorization
  - Wide Q^2–range: Leading/higher twist, QCD evolution
  - Wide W–range: x–dependence, overlap with fixed–target
  - Luminosity: Differential measurements in W, Q^2, t

Feasible with high–luminosity EIC; need to work out details

5 GeV ⊗ 50 GeV/c (e^- ⊗ P)

- Q^2=4 GeV^2
- 2ζ= 0.2
- **P' tagging required**
  - Exclusivity
  - Δ^2 Resolution
    - $\sigma(\Delta^2) \approx 0.3 GeV^2$ without tagging
    - Transverse Imaging





Emerging detector concept

- 2 “main” components
  - electron detection in forward direction (theta<40^0)
  - final state detection and hadron identification in proton direction (theta > 140^0 ?)
- some low resolution energy measurement for central angles
- vertex detection (resolution better than 100 μm)
- plus:
  - electron detection at very low angles (how?)
  - detection of “recoiling” neutron and proton (maximum acceptance)
- plus:
  - luminosity measurement with accuracy of ~ 1%
  - polarisation measurements with accuracy of ~ 1% (both electron and ion !)

Emerging detector concept

- Open questions (certainly not complete):
  - what is the optimal magnetic field configurations for such a detector ?
    - simple solenoid most likely NOT sufficient
    - solenoid plus toroid or solenoid plus dipole ?
  - what angular/momentum resolution do we need for the electron ?
  - what angular resolution do we need in the hadron detection ?
- what about jet physics ???
- what about e-A ?
- any other processes not yet considered ?
- how do we get a real handle on backgrounds from beam gas events ?

Some remarks

- e-p working group meeting was useful

- good mixture between theoretical talks and “realistic” estimates for key processes

- some important consequences for detector design could be identified

- emerging detector concept

- **next steps:**

    - test very preliminary detector concept against all processes
    - determine resolution requirements in more detail
    - investigate potential of jet physics at EIC