Deeply Virtual Compton Scattering with CLAS12 at Multi-Energy Polarized Electron Beam

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Outline

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II. Experiment

III. Analysis

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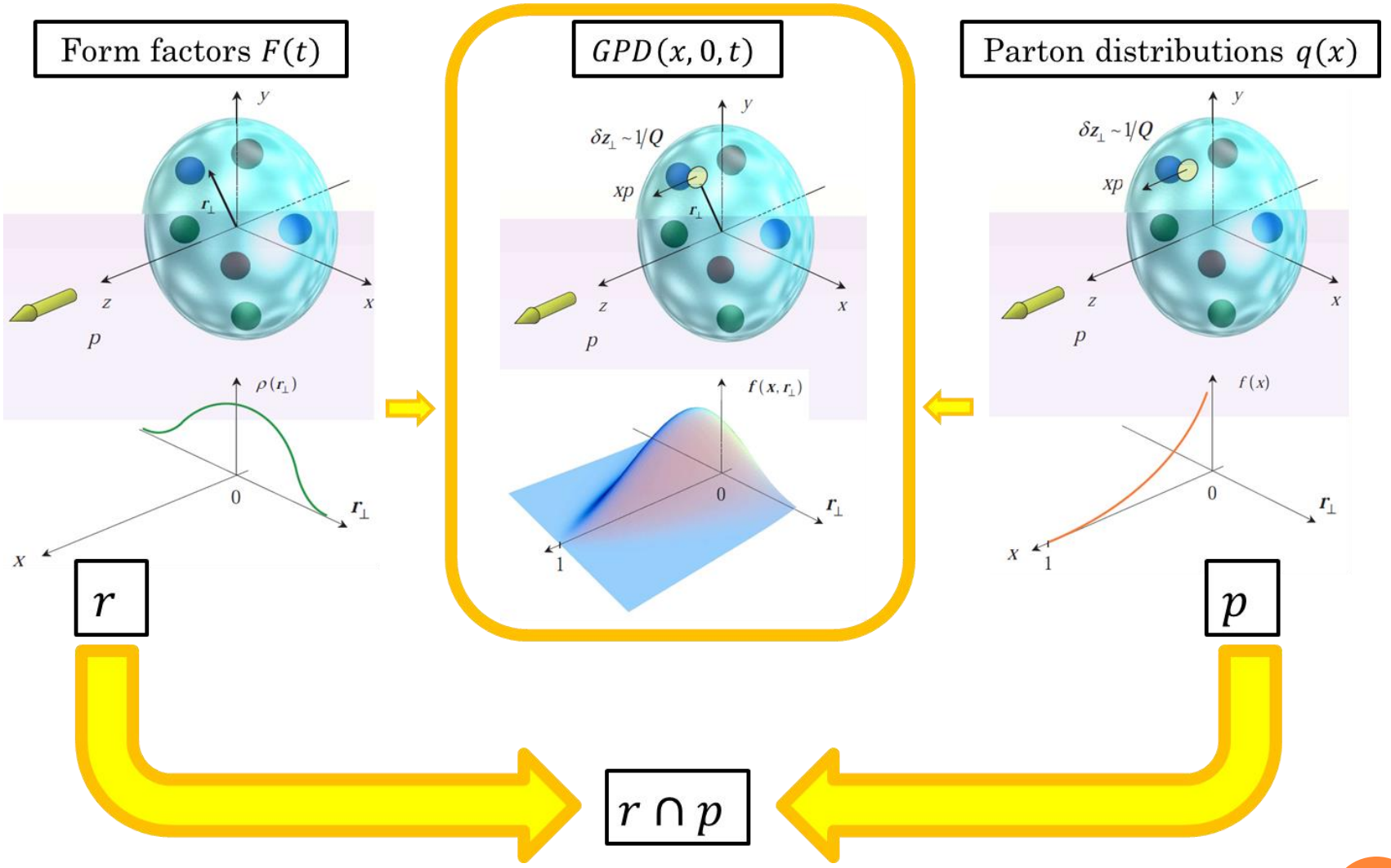
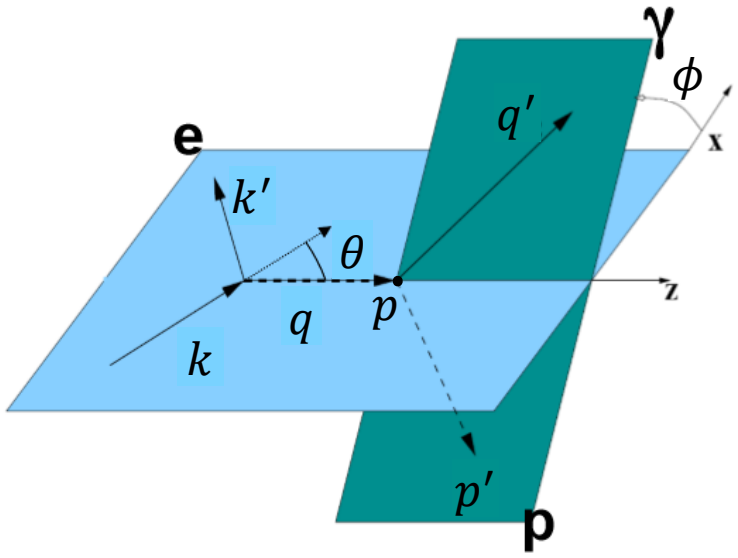
I. Introduction

Generalized Parton Distributions

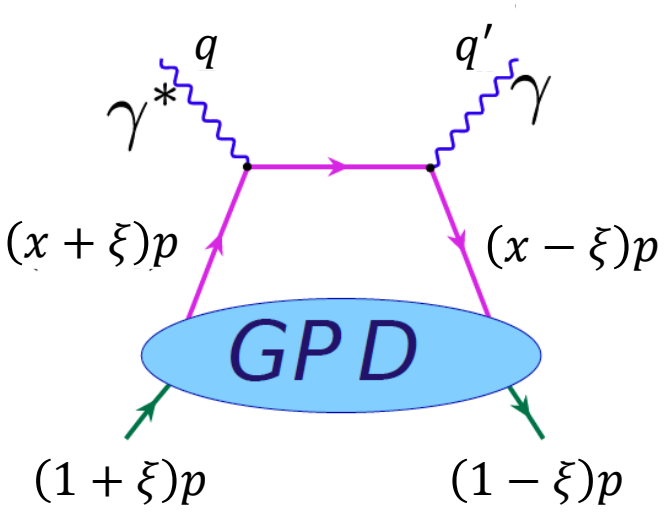


GPDs describe correlation between quark longitudinal momentum and transverse spatial distributions.

Deeply Virtual Compton Scattering



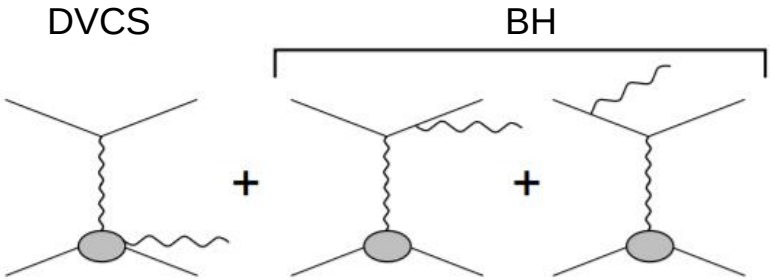
DVCS kinematics:
scattering plane (light blue)
and reaction plane (cyan)



DVCS accessing GPDs

Deeply virtual Compton scattering (DVCS) provides the cleanest access to chiral-even GPDs: H^q, $\widetilde{H}^q$, E^q, and $\tilde{E}^q$.

DVCS and Bethe-Heitler



Amplitude of photon production:

$$\mathcal{T}^2 = |\mathcal{T}_{\mathrm{DVCS}} + \mathcal{T}_{BH}|^2 = |\mathcal{T}_{\mathrm{DVCS}}|^2 + |\mathcal{T}_{BH}|^2 + \mathcal{I}$$

Beam spin asymmetry for unpolarized target:

$$A_{\mathrm{LU}}(\phi) \propto s^{\mathcal{I}}_{1,\mathrm{unp}} \sin(\phi)$$

$$A_{\mathrm{LU}}(\phi) = \frac{d\sigma^{\uparrow}(\phi) - d\sigma^{\downarrow}(\phi)}{d\sigma^{\uparrow}(\phi) + d\sigma^{\downarrow}(\phi)} = \frac{1}{\varepsilon}\frac{N^{\uparrow}(\phi) - N^{\downarrow}(\phi)}{N^{\uparrow}(\phi) + N^{\downarrow}(\phi)}$$

$$A_{\mathrm{LU}}(\phi) \propto \Im\mathrm{m}\left\{F_1\mathcal{H} + \frac{x_B}{2 - x_B}(F_1 + F_2)\widetilde{\mathcal{H}} + \frac{t}{4M^2}F_2\mathcal{E}\right\}$$

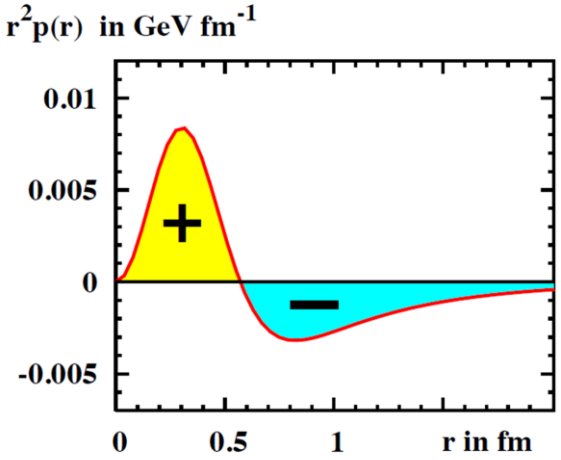
Compton form factors $\mathcal{H}$, $\widetilde{\mathcal{H}}$ and $\mathcal{E}$:

$$\{\mathcal{H}, \mathcal{E}\}(\xi, t, Q^2) = \sum_q \int_{-1}^{1} dx C_q^{(-)}(\xi, x)\{H^q, E^q\}(x, \xi, t, Q^2)$$

$$\widetilde{\mathcal{H}}(\xi, t, Q^2) = \sum_q \int_{-1}^{1} dx C_q^{(+)}(\xi, x)\widetilde{H}^q(x, \xi, t, Q^2)$$

DVCS at Multiple Beam Energies

Nucleon Pressure Distribution



P. Schweitzer et al., Nucleon form-factors of the energy momentum tensor in the chiral quark-soliton model Phys. Rev. **D75** : 094021 , 2007

DVCS measured at different beam energies allows the extraction of $|\mathcal{T}_{\mathrm{DVCS}}|^2$ for which GPD enters through the Compton form factor $\mathcal{H}(\xi,t)$.

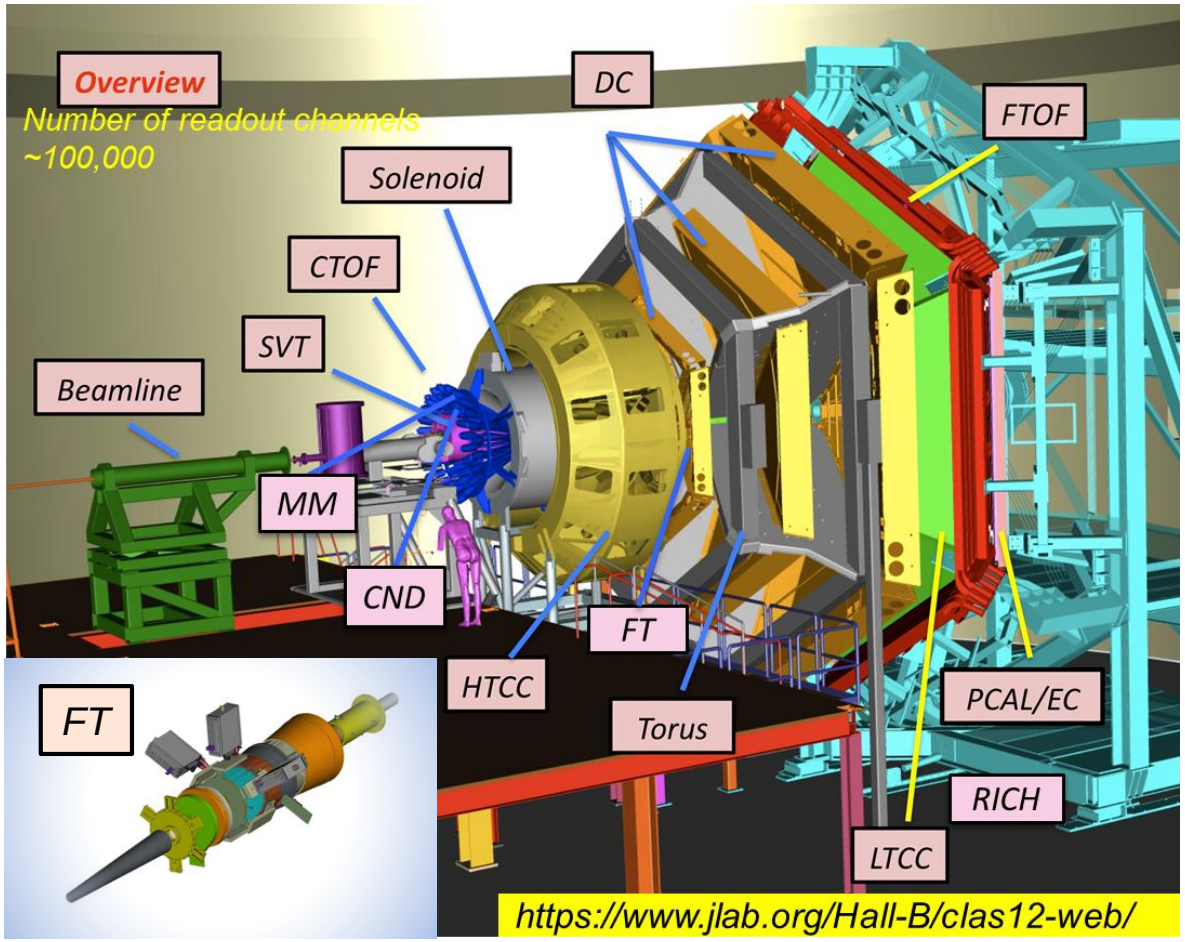
With $H(x,\xi,t)$, the Dispersion Relations allow access to $D(t)$ term and eventually to the form factor d_1:

$$d_1(t) = 15M_N \int d^3r \frac{j_0\left(r\sqrt{-t}\right)}{2t} p(r) = 5M_N \int d^3r \frac{j_2\left(r\sqrt{-t}\right)}{t} s(r)$$

Pressure $p(r)$ and shear force $s(r)$ distributions inside the nucleon may shed light on confinement mechanism.

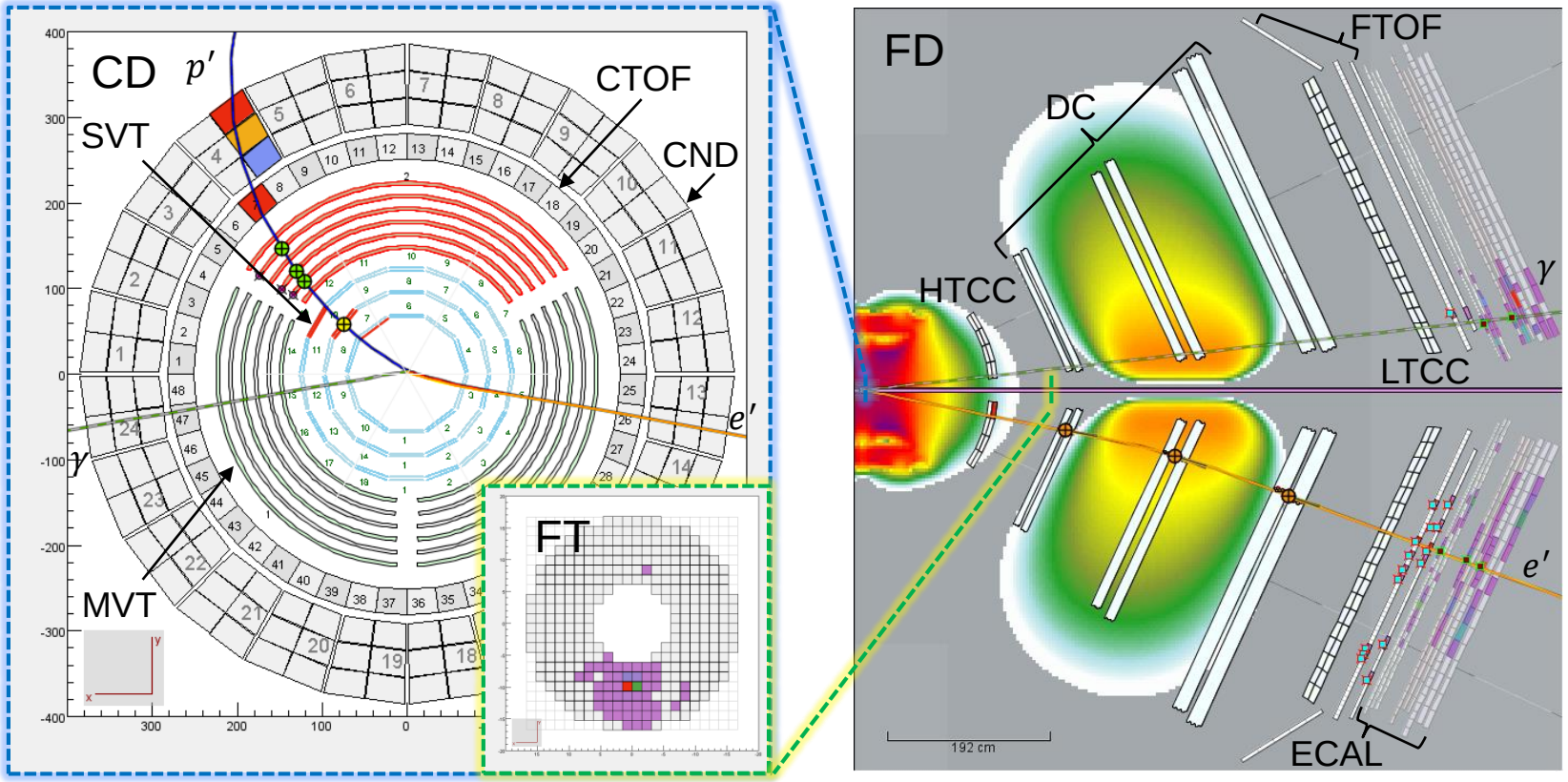
II. Experiment

CEBAF AT 12 GEV AND CLAS12



First DVCS experiment with CLAS12 was performed in of 2018 at 6.4 GeV, 7.5 GeV, and 10.6 GeV polarized beam energies with ~85% average polarization, employing liquid hydrogen as production target.

Detector-based $e'p'\gamma$ Selection



p' in CD Subsystem and γ Hit in FT $e'\gamma$ in FD Subsystem

CLAS event display for a simulated DVCS event

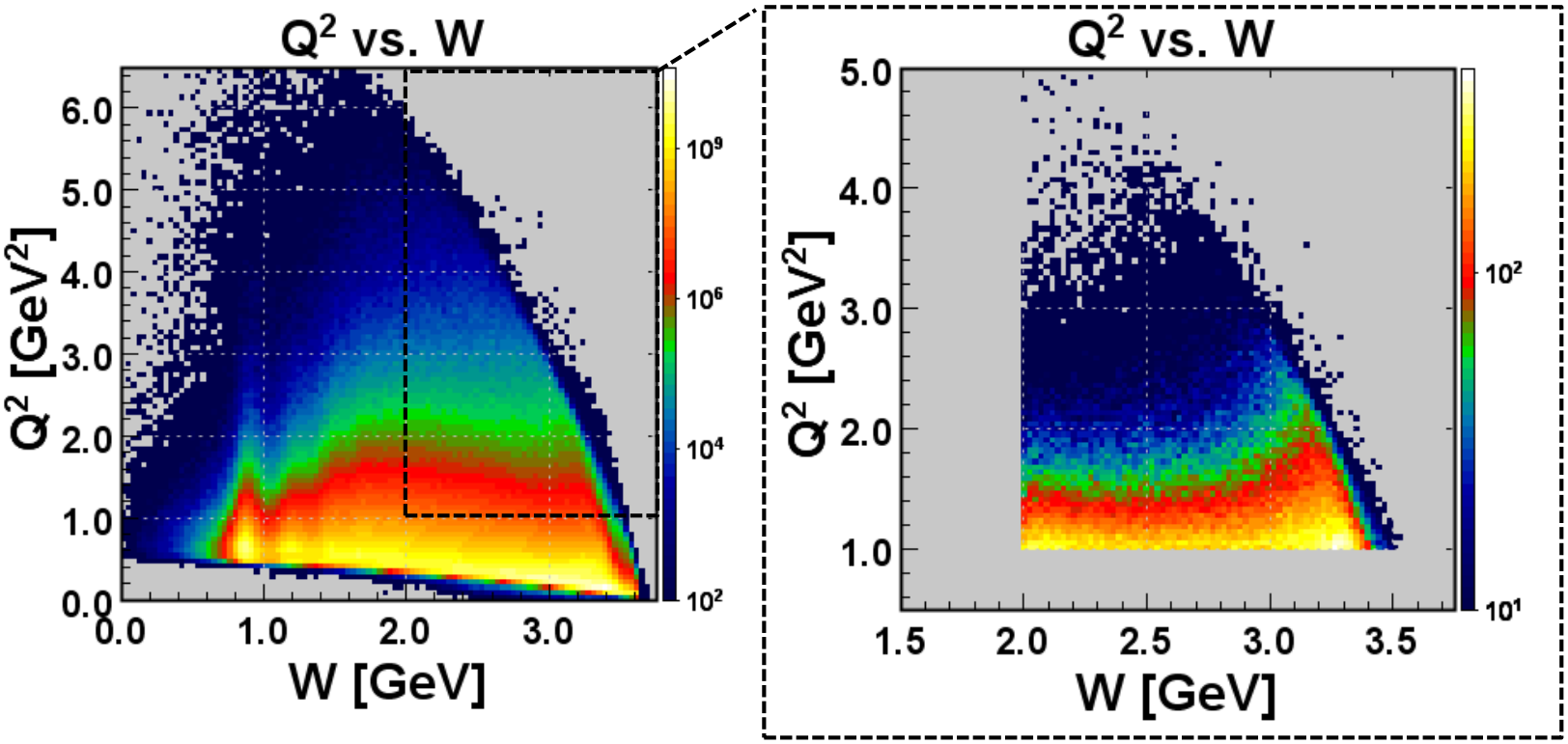
Sample selection requires 1 electron from the forward detector (FD) subsystem, 1 proton from the central detector (CD) subsystem, 1 photon (no detector subsystem requirement), and nothing else.

III. Analysis

Deep Inelastic Scattering Region

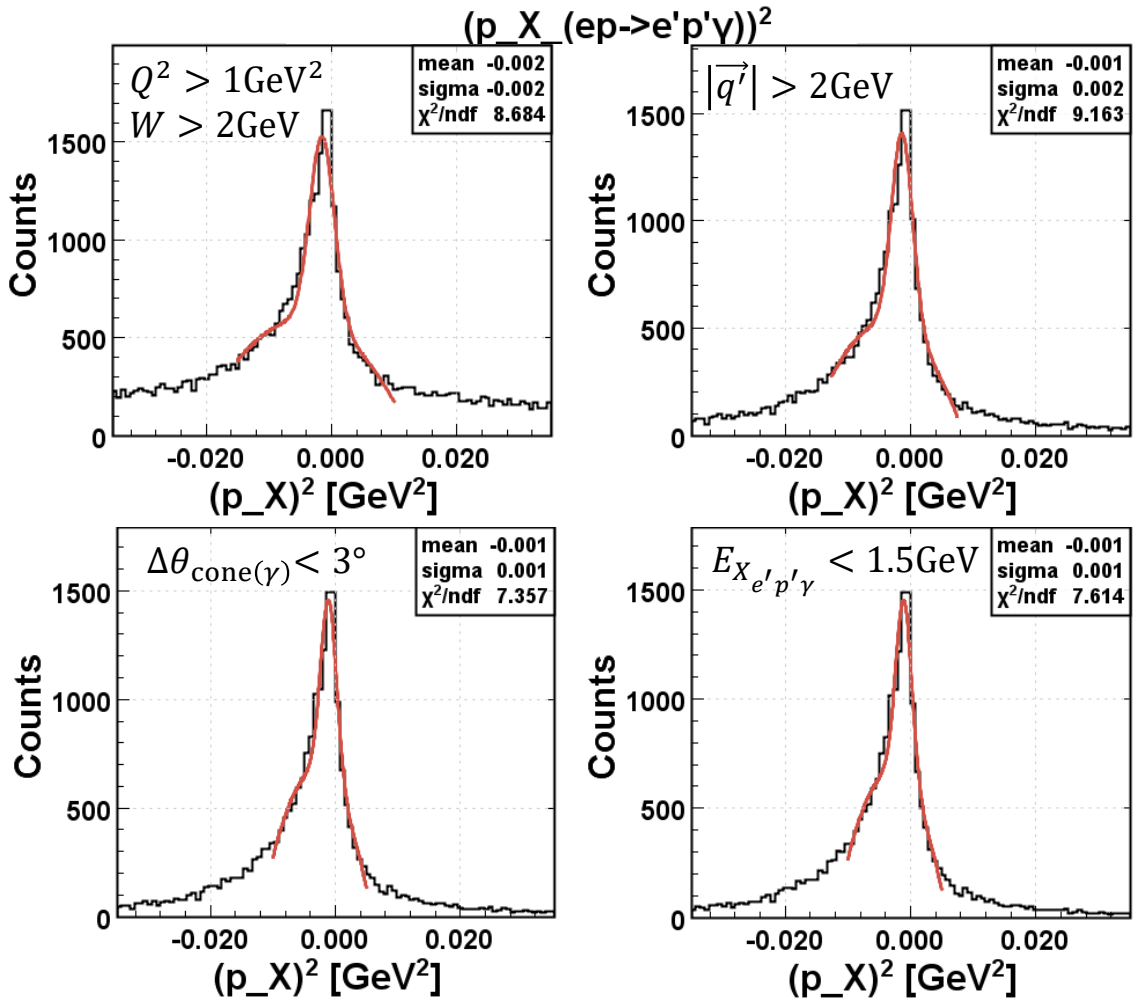
$$Q^2 = -q^2$$

$$W = \sqrt{(q+p)^2}$$



Exclusive $e'p'\gamma$ events are selected from the deep inelastic scattering (DIS) region of the inclusive e' spectrum (left): $Q^2 > 1$ GeV^2 and $W > 2$ GeV (right).

$ep \rightarrow e'p'\gamma$ Exclusivity Cuts

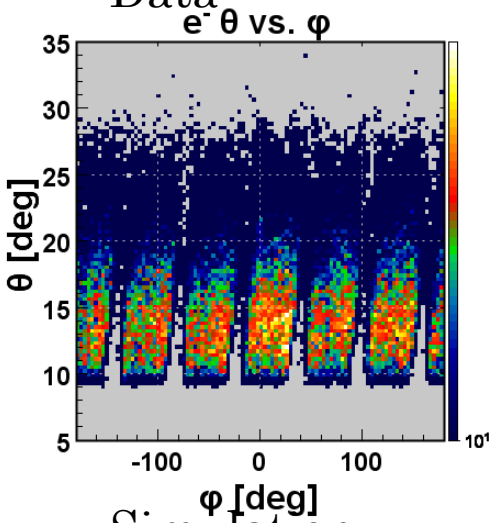


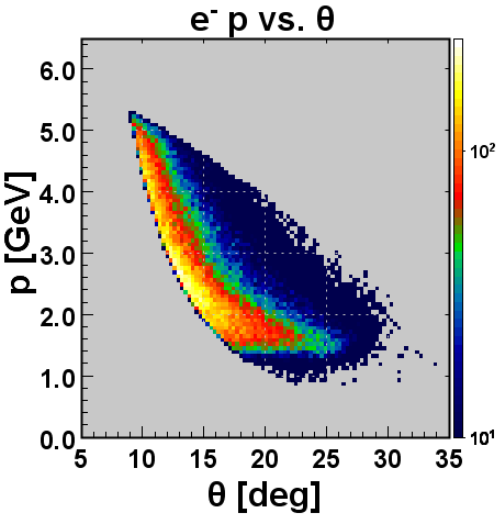
$$\Delta\theta_{\text{cone}(\gamma)} = \cos^{-1}\left(\vec{q'} \cdot \vec{X_\gamma} / |\vec{q'}||\vec{X_\gamma}|\right)$$

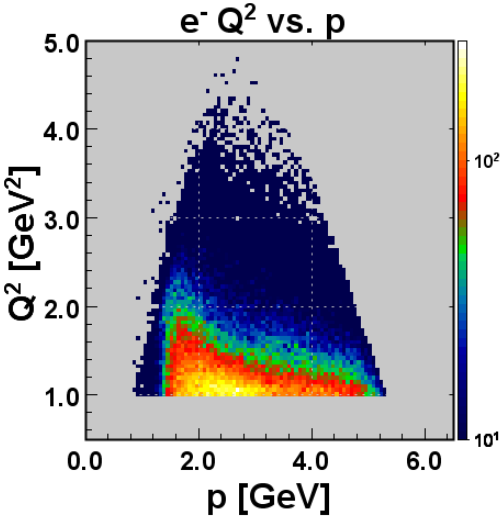
$|\vec{q'}|$ cut suppresses the background of the $e'p'\gamma$ missing mass distribution. $\Delta\theta_{\text{cone}(\gamma)}$ and $E_{X_{e'p'\gamma}}$ cuts further clean the sample.

e' Kinematics

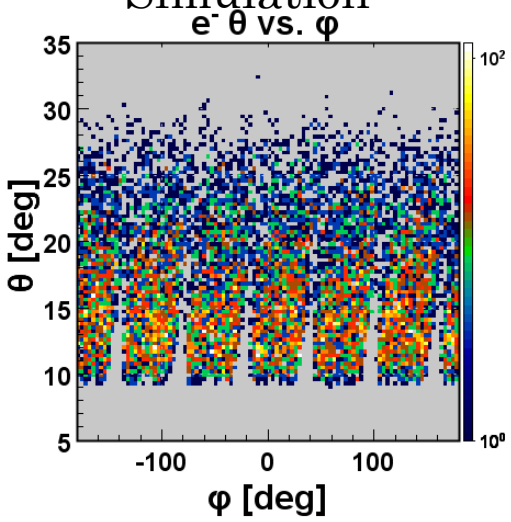
Data

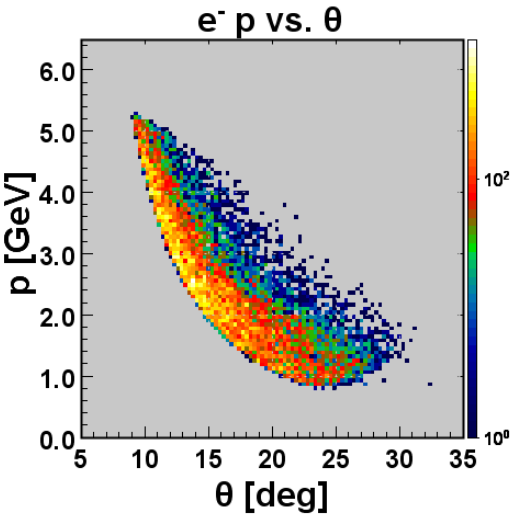


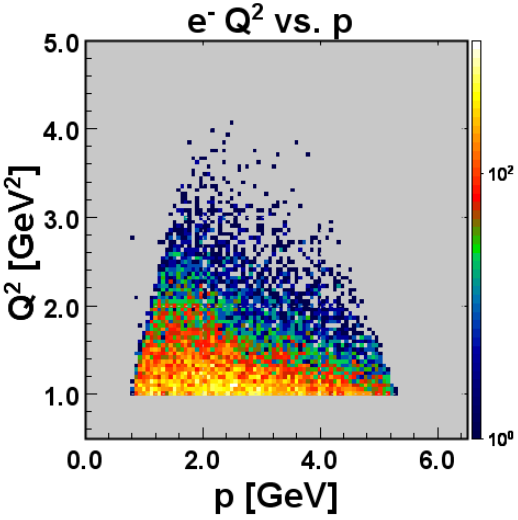




Simulation



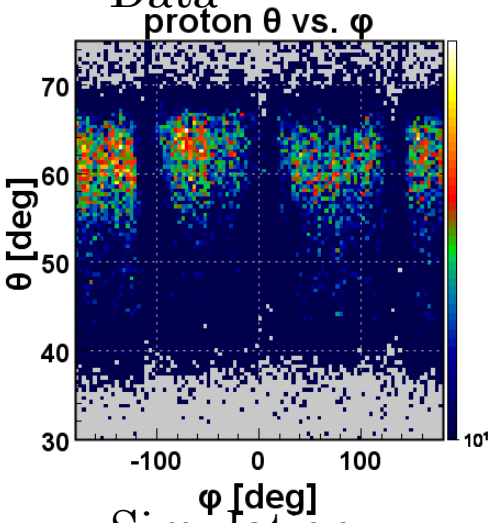


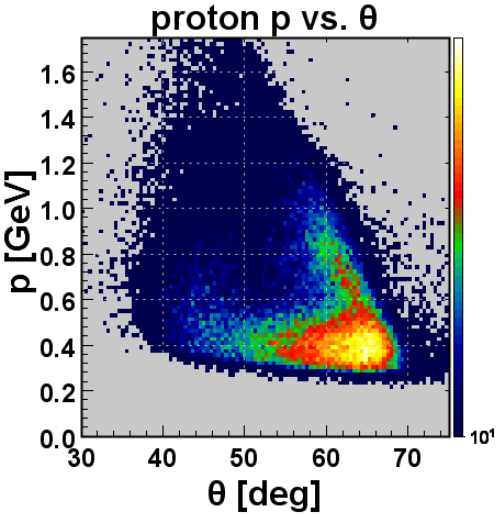


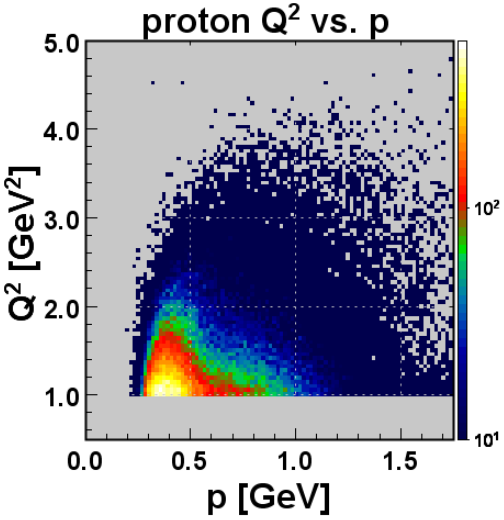
Electron kinematic distributions from the data (top) agree well with the simulation (bottom).

p' KINEMATICS

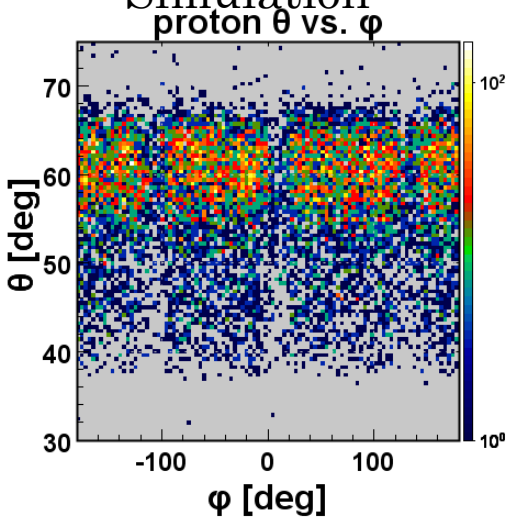
Data

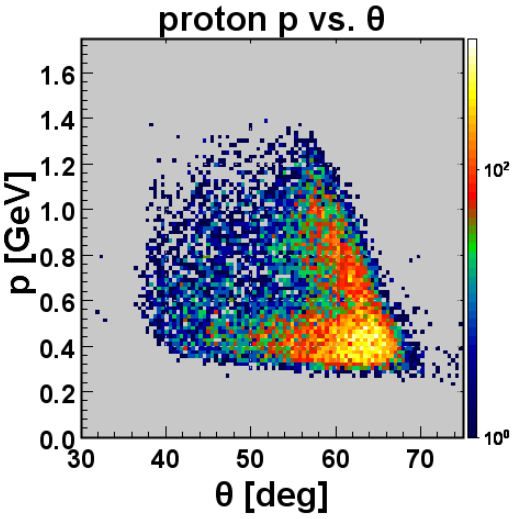


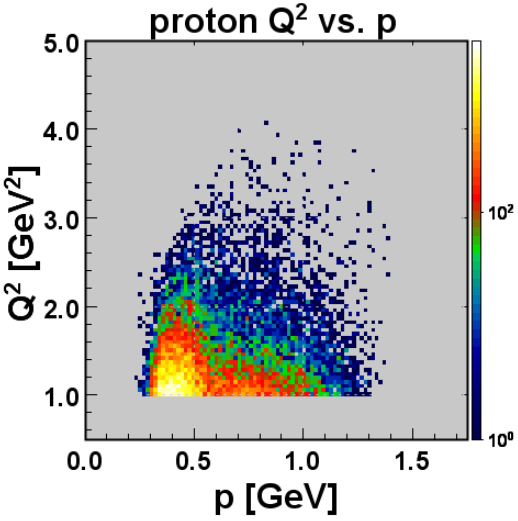




Simulation



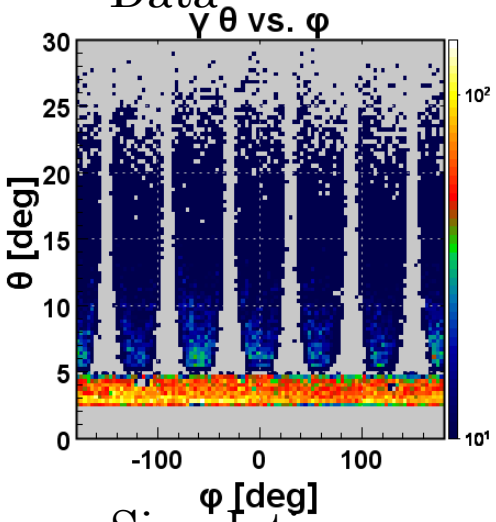


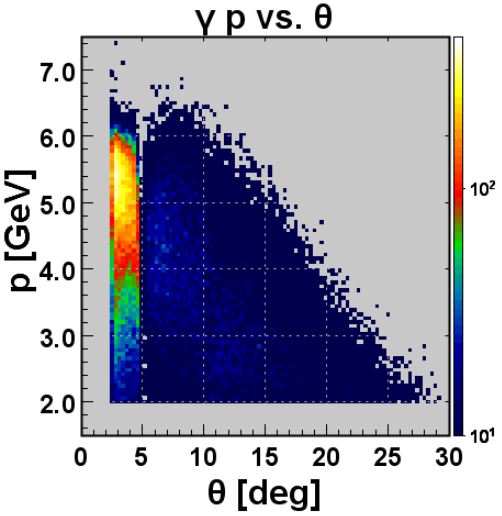


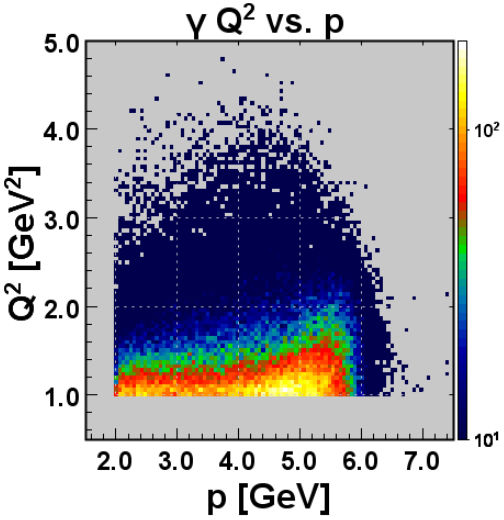
Proton kinematic distributions from the data (top) agree well with the simulation (bottom).

γ Kinematics

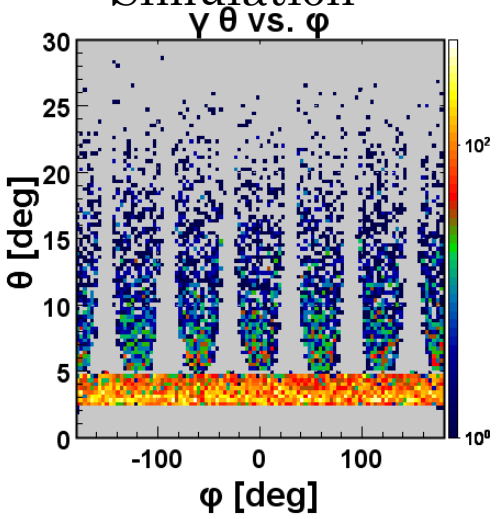
Data

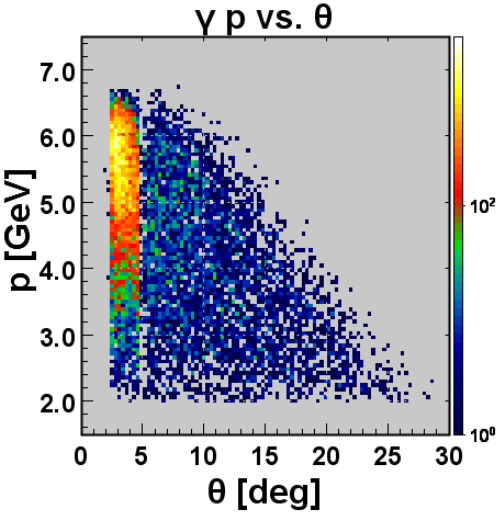


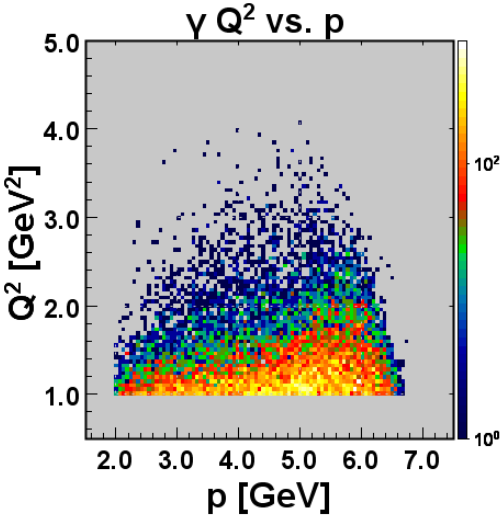




Simulation



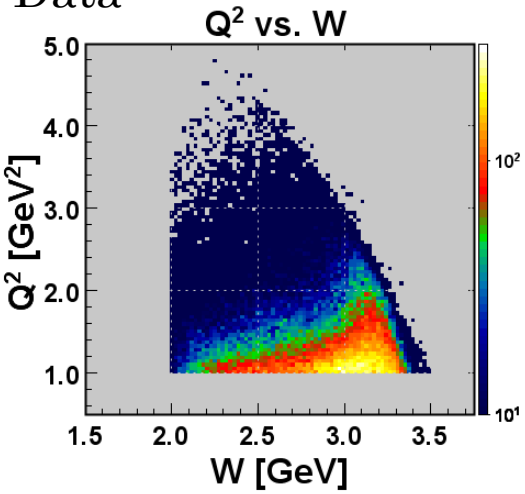


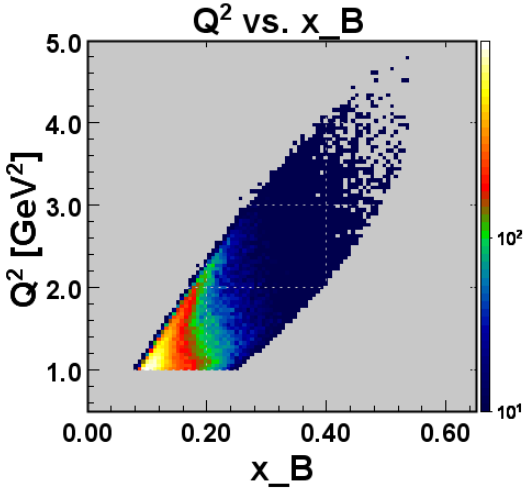


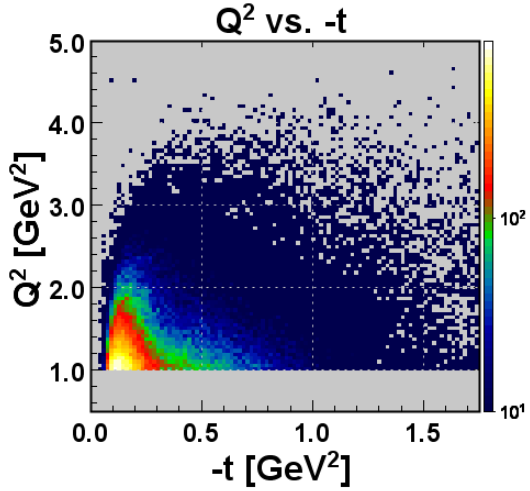
Proton kinematic distributions from the data (top) agree well with the simulation (bottom).

Kinematic Variables

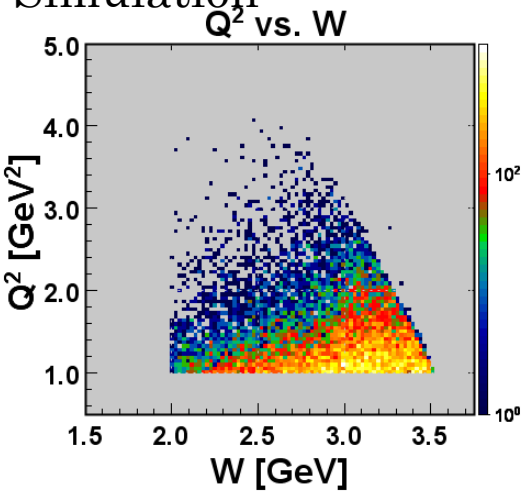
Data

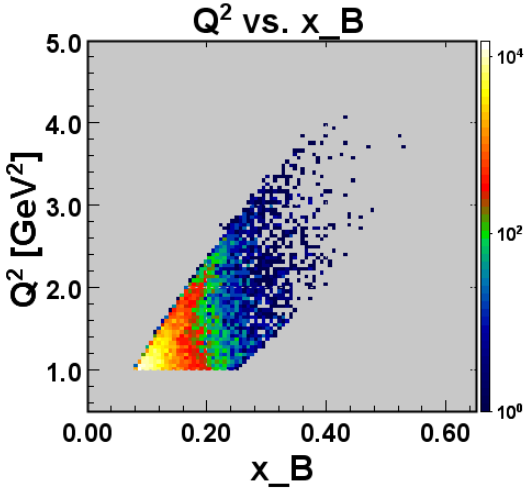


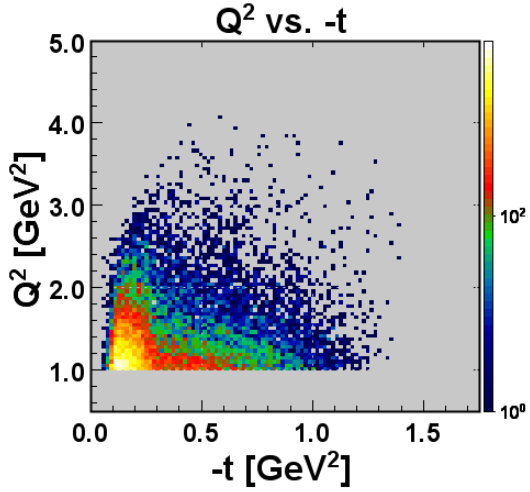




Simulation



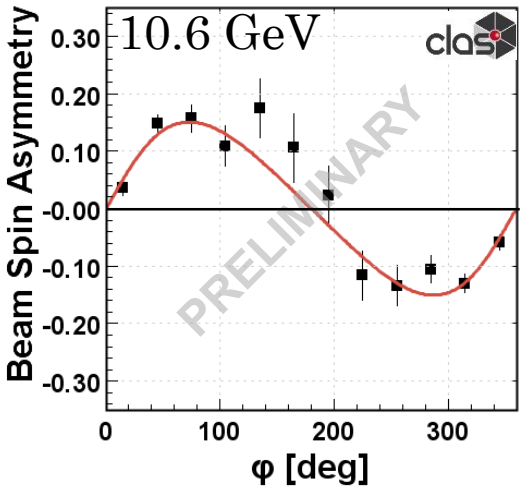


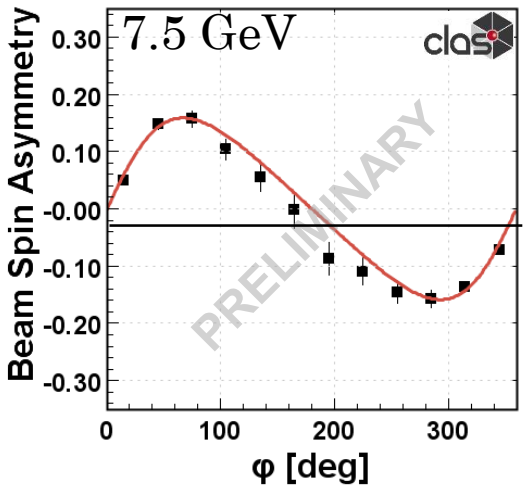


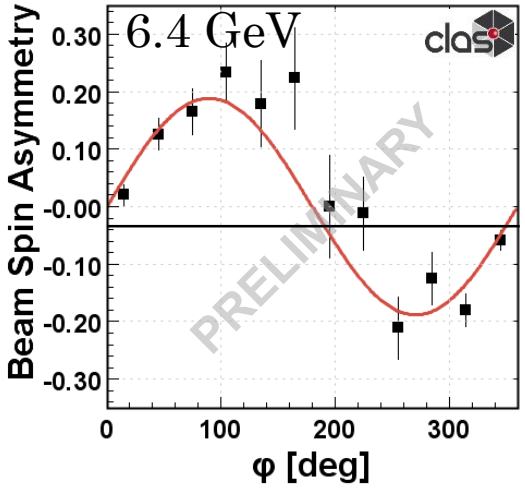
Distributions of kinematic variables from the data (top) agree well with the simulation (bottom). Here, $x_B = \frac{Q^2}{2p \cdot q}$ and $-t = (p' - p)^2$.

IV. First Look

Beam Spin Asymmetry $A_{LU}^{\sin\phi}$







Statistics:
- Integrated over all bins

Error:
- Statistical only

Fitting Function:
- $BSA = \frac{A_{LU}^{\sin\phi}\sin\phi}{1+A_{LU}^{\cos\phi}\cos\phi}$

Beam spin asymmetry fits with $Q^2 > 1$ GeV^2, $W > 2$ GeV, $|\vec{q'}| > 2$ GeV, $\Delta\theta_{\mathrm{cone}(\gamma)}$ cut, and $E_{X_{e'p'\gamma}}$ cut is qualitatively in agreement with the previous CLAS DVCS results.

V. Summary and Future Plans

Summary and Future Plans

Summary:

- DVCS beam spin asymmetry access to the GPDs H^q.
- DVCS experiment with CLAS12 performed at 6.4 GeV, 7.5 GeV, and 10.6 GeV in 2018.
- Extracted DVCS beam spin asymmetry in qualitative agreement with published CLAS DVCS results.

Next steps and Future Plans:

- Detailed systematic studies:
  - π^0 background subtraction
  - Kinematical corrections
  - Fiducial cut
- Extraction of DVCS beam spin asymmetry for various kinematic bins.

Thank You!!!