University of Glasgow

Science & Technology Facilities Council

Time-Like Compton Scattering with CLAS12, Run Group C at Jefferson Lab

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Intro

Theory

Internal structure of nucleons

The Timelike Compton Scattering (TCS) process

Generalised Parton Distributions (GPDs)

Observables accessible with TCS

Experimental Setup

Jefferson Lab and the Continuous Electron Beam Facility (CEBAF)

Hall B and The CEBAF Large Acceptance Spectrometer at 12GeV (CLAS12)

Run Group C (RGC) and the polarised target

Experimental Procedure

Preliminary Results

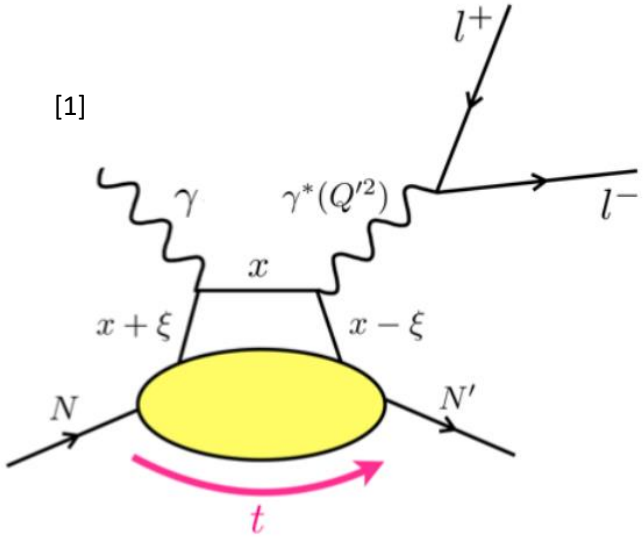
Time-Like Compton Scattering (TCS)

- High energy, exclusive scattering process.
- A real photon interacts with the target nucleon, causing release of virtual photon which decays into a lepton pair.

$$ep \rightarrow e'p'\gamma^*$$
$$\gamma^* \rightarrow \mu^+\mu^- \; or \; e^+e^-$$

- TCS gives access to GPDs via cross section and asymmetry measurements

[1]



$Q^2 = -q^2 = -(k - k')^2$

$t = (p' - p)^2 = (q - q')^2$

$Q'^2 = q'^2 = (l^+ + l^-)^2$

x = longitudinal momentum fraction of struck quark

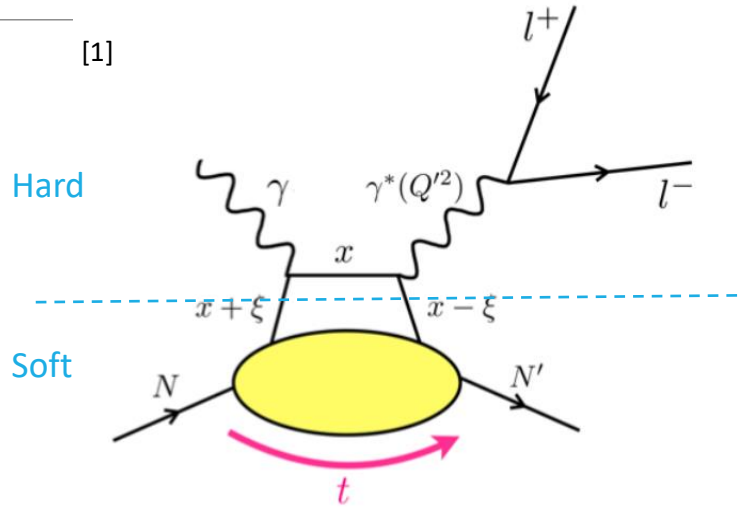
ξ = longitudinal momentum fraction gained/lost by struck quark

Generalised Parton Distributions

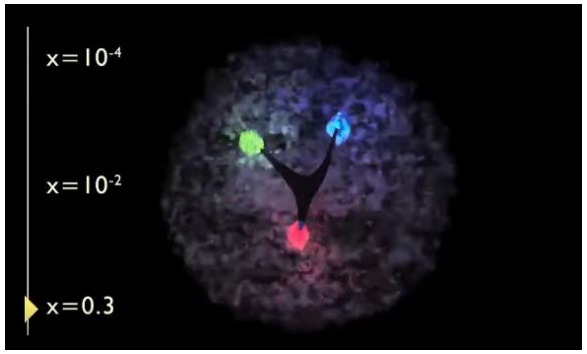
- At high photon virtuality, TCS scattering amplitude can be factorized.

- ‘Hard’ part → QED and perturbative QCD.
- ‘Soft’ part → non-perturbative QCD, described by four Generalized Parton Distributions (GPDs) $H, \widetilde{H}, E, \& \ \widetilde{E}$.
- GPDs relate the transverse positions of quarks and gluons to their longitudinal momentum
- This relation helps to provide a tomographic mapping of nucleon structure.

[1]



[2]

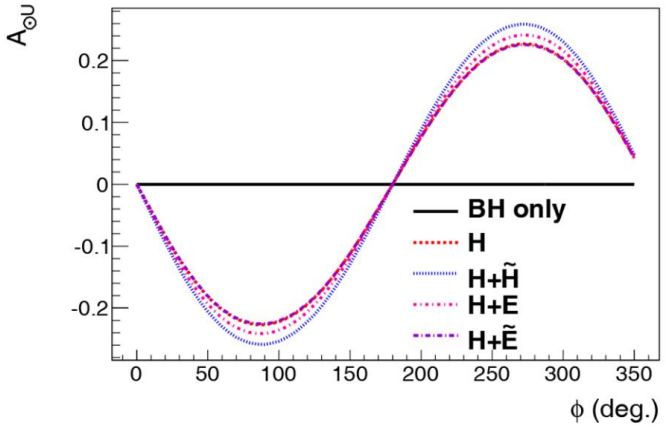


Observables of interest (and theory results)

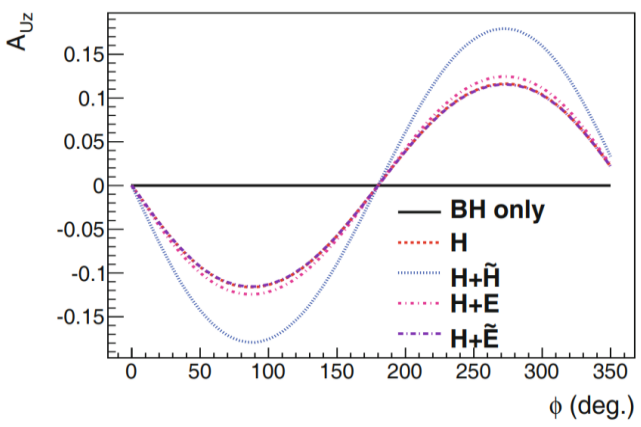
- $\frac{N^+ - N^-}{N^+ + N^-}$
- Beam Spin Asymmetry – H dominates
- Target spin asymmetry – Access to H and $\widetilde{H}$
- Double Spin Asymmetry – Access to H and $\widetilde{H}$, though slightly more complex than TSA

[3]

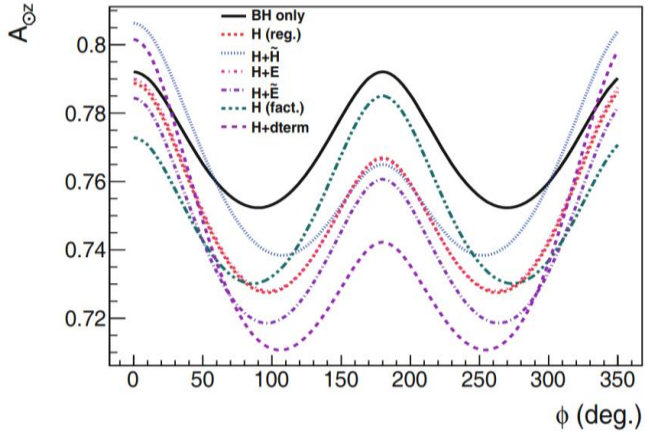
BSA



TSA

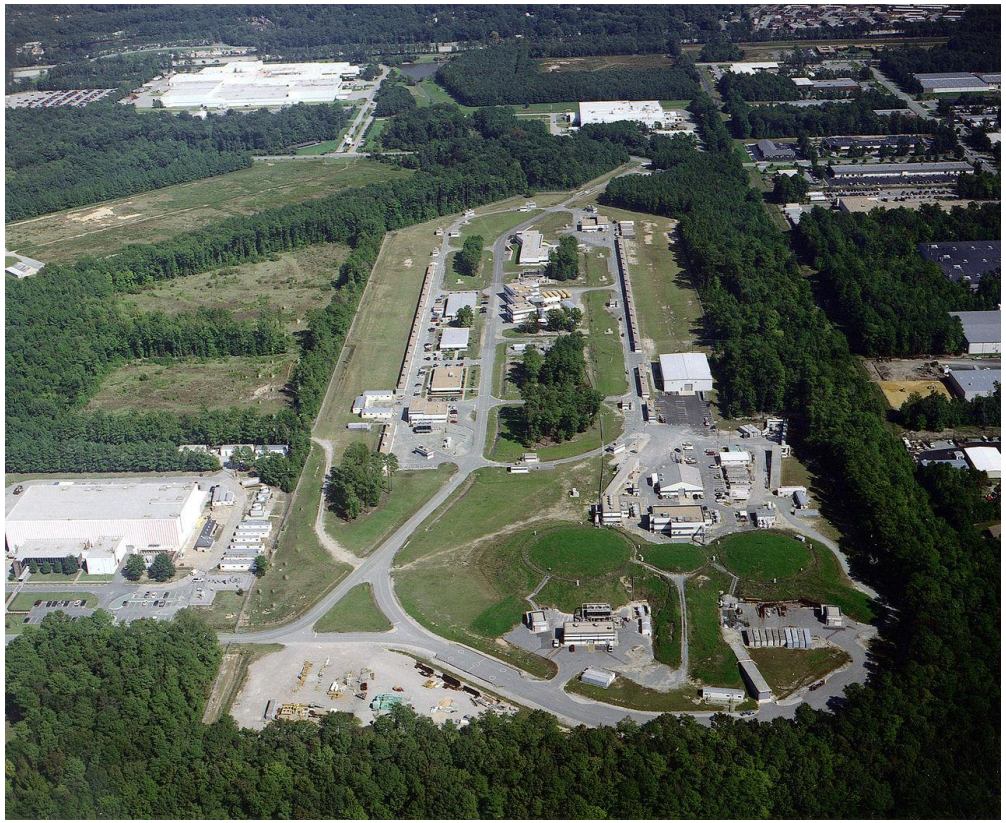


DSA



Jefferson Lab

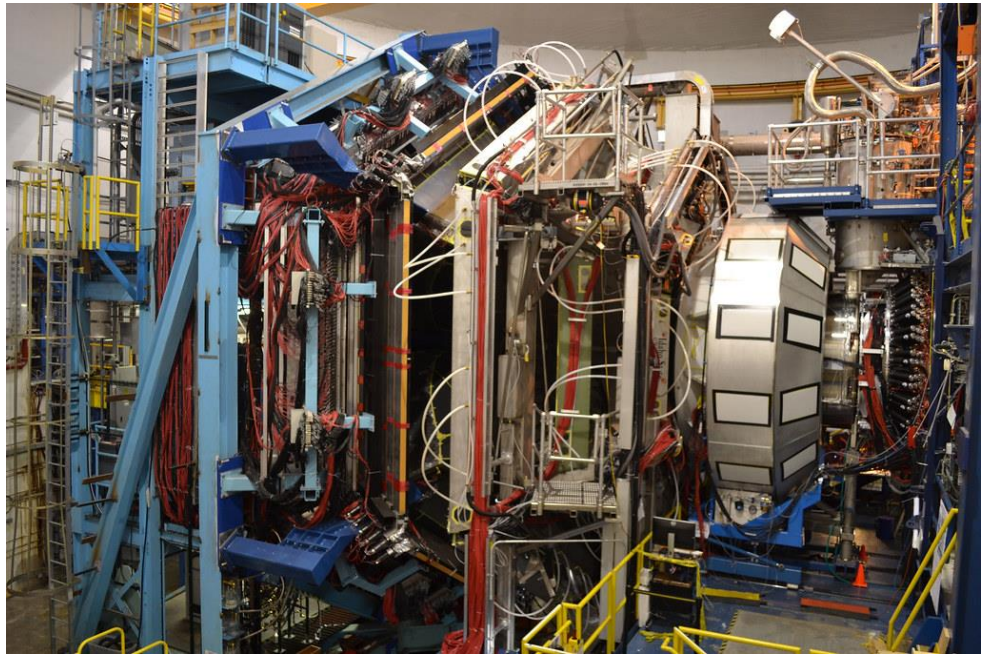
- Continuous Electron Beam Accelerator Facility (CEBAF) provides an electron beam to four experimental halls housing fixed target experiments;
  - Hall A and C - narrow acceptance spectrometers, able to handle large luminosities.
  - Hall B - CLAS12, where Run Group C (RGC) takes its data.
  - Hall D - hadron spectroscopy, has a dedicated photon beamline.



[4]

CLAS12 Detector – Jefferson Lab

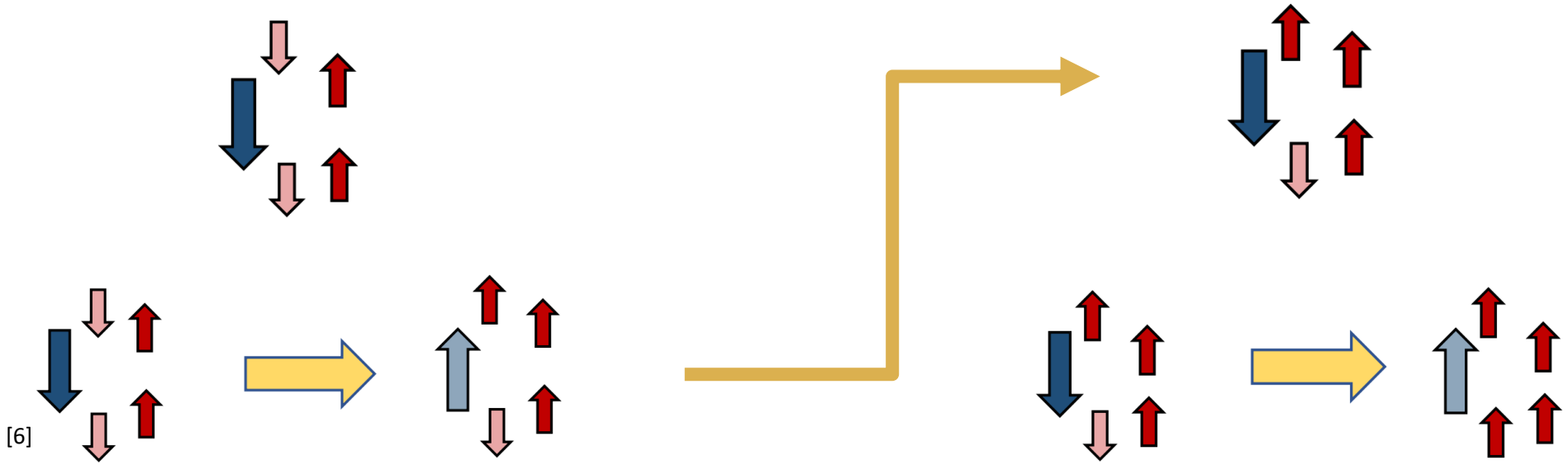
- 2π azimuthal angular coverage
- Polar angle θ coverage 35◦ – 125◦ provided by the central solenoid magnet and detector
- Forward polar angle range < 35◦ provided by forward superconducting torus magnet and forward detector.
- Coverage allows for efficient detection of both charged and neutral particles.



[5]

RGC Polarised target

- Longitudinally polarized NH3 and ND3 targets give access to observables of interest
- Target polarisation;



[6]

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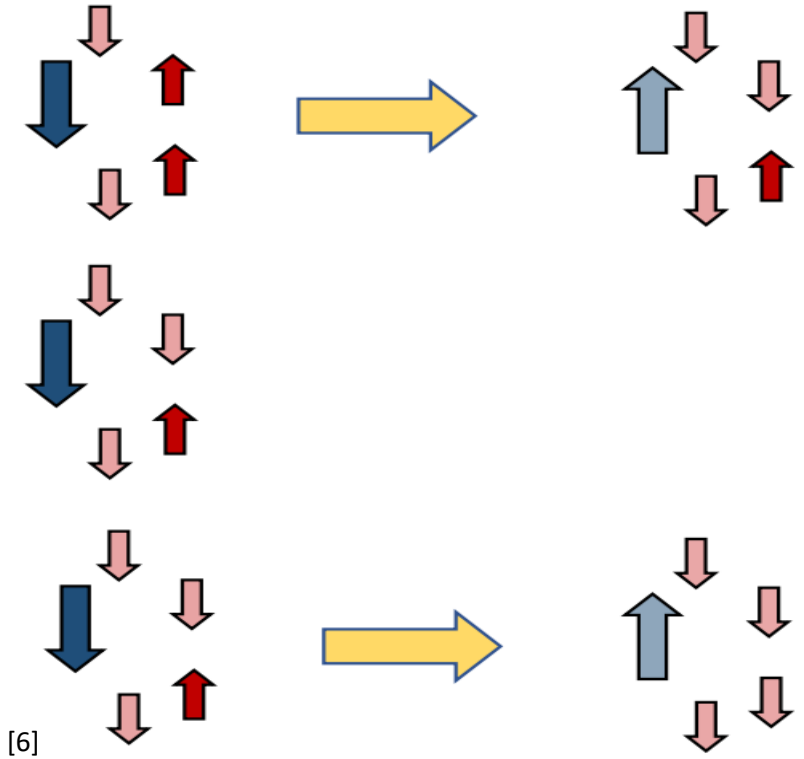


[6]

Experimental Procedure

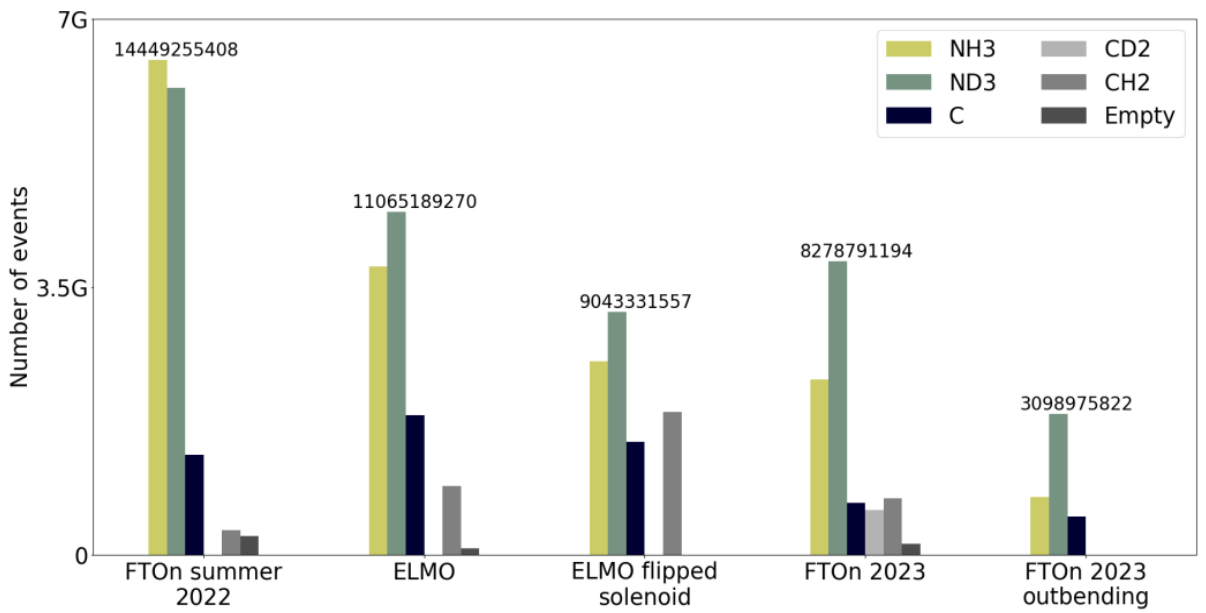
- 12 runs on NH3, 6 T_{pol}^{+} , 6 T_{pol}^{-}
- Require at least one proton, one positron and one electron in final state as well as any other particles
- Phase space cuts (unless otherwise stated);
  - $t > 0.15GeV^2$
  - $11GeV > E_\gamma > 4GeV$
  - $3GeV > Q^{'} > 1.5GeV$
- Data taking for RGC finished on March 23rd

Recall

$$t = (p' - p)^2 = (q - q')^2$$

$$Q'^2 = q'^2 = (l^+ + l^-)^2$$

[7]



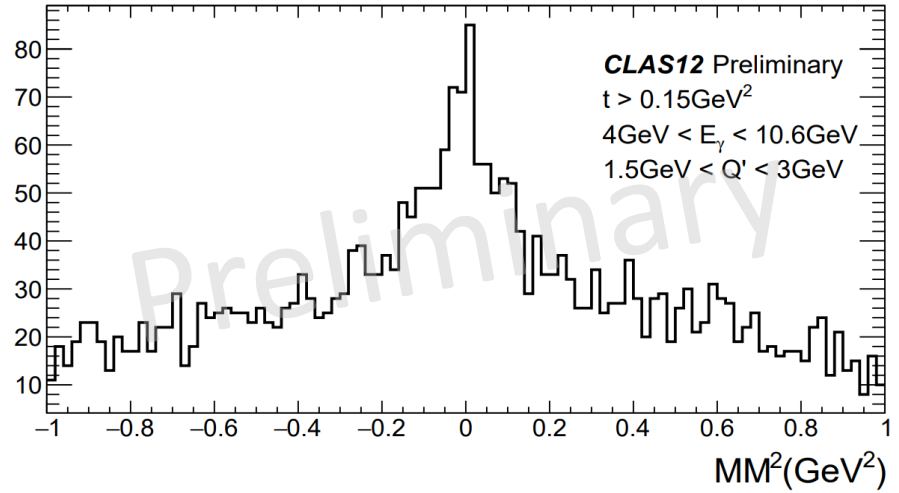
Preliminary results

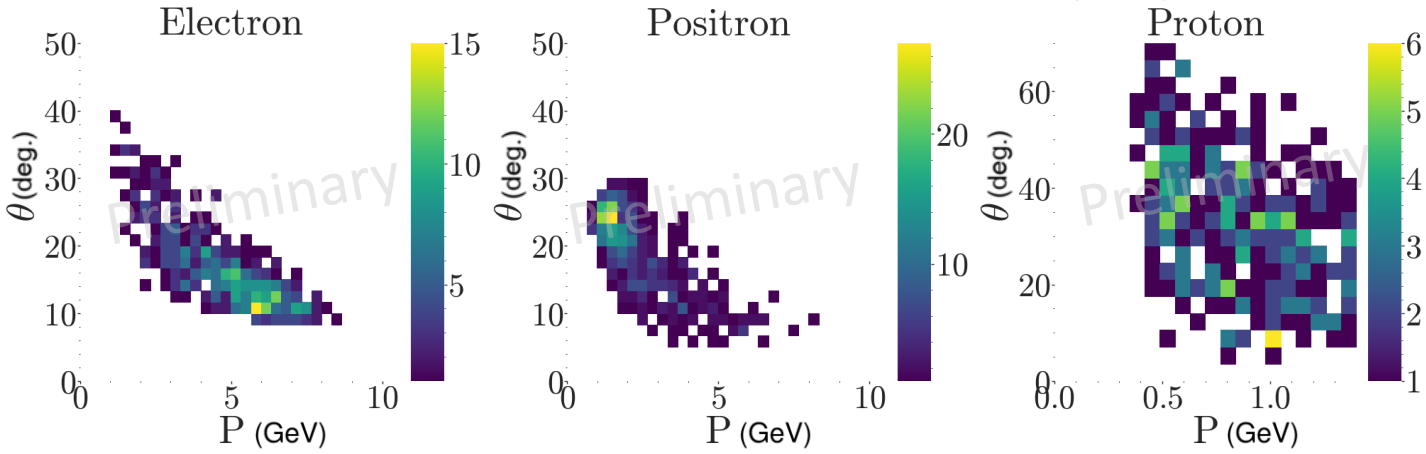
- MM^2 (Top) is of scattered electron;

$$ep \rightarrow e'p'\gamma^*(e^+e^-) = ep \rightarrow Xp'\ (e^+e^-)$$

$$\Rightarrow e + p - p' - e^+ - e^- = X$$

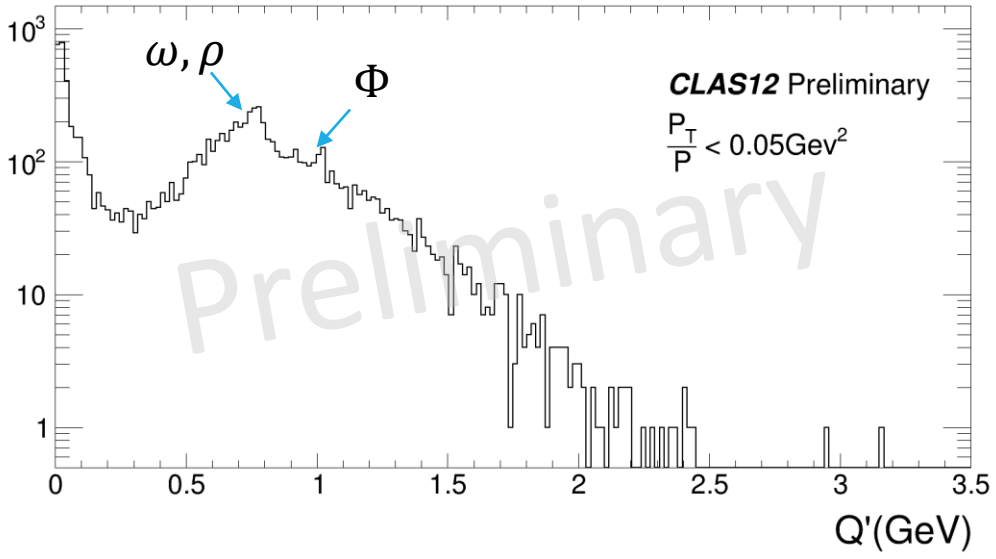
- Final state particle θ vs momenta of the three final state particles (Bottom)
- The shapes follow the expected trend as compared to previous TCS results from CLAS12 using data on an unpolarized H target[8].

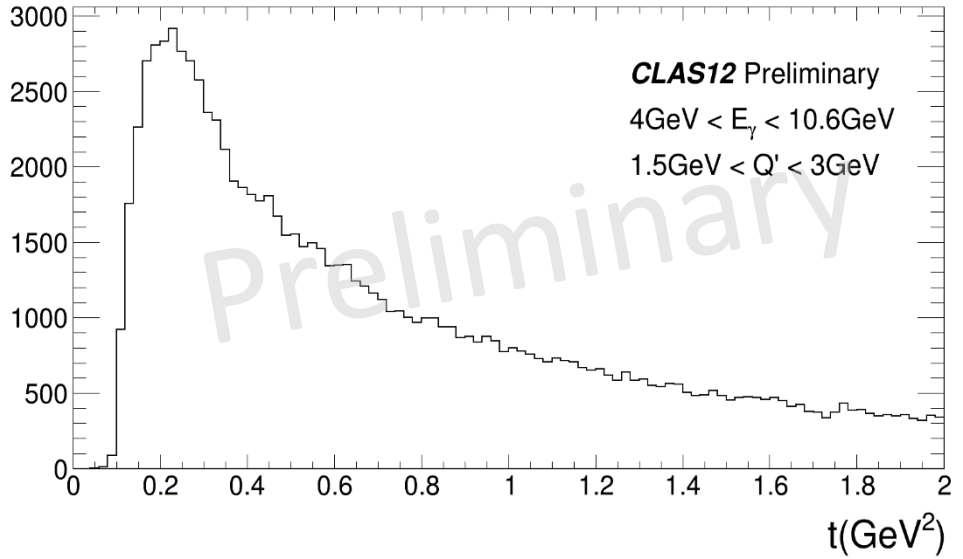




Preliminary Results

- Q’ = Invariant Mass of decay lepton pair ($Q' = e^+ + e^-$)
- $t = (p' - p)^2 = (q - q')^2$ invaluable for accessing GPDs
- Phase space region of interest $0.2\text{GeV}^2 < t < 0.8GeV^2$





Thank you

Questions?

REFERENCES

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[2] R. Milner, R. Ent (Jefferson Lab), C. Boebel, J McMaster (MIT), J. LaPlante: *Visualising the proton.* 2022 https://www.youtube.com/watch?v=e2FrALuacZ4&t=11s

[3] Boër, M., Guidal, M. & Vanderhaeghen, M. Timelike Compton scattering off the proton and generalized parton distributions. *Eur. Phys. J. A* **51**, 103 (2015). https://doi.org/10.1140/epja/i2015-15103-3

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[8] P. Chatagnon, *"Nucleon structure studies with CLAS12 at Jefferson Lab: timelike Compton scattering and the central neutron detector,"* Université Paris-Saclay thesis, 2020.