Hall C TCS Project

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NPS Collaboration Meeting, 02/16/2022

Outline

Physics case and motivation

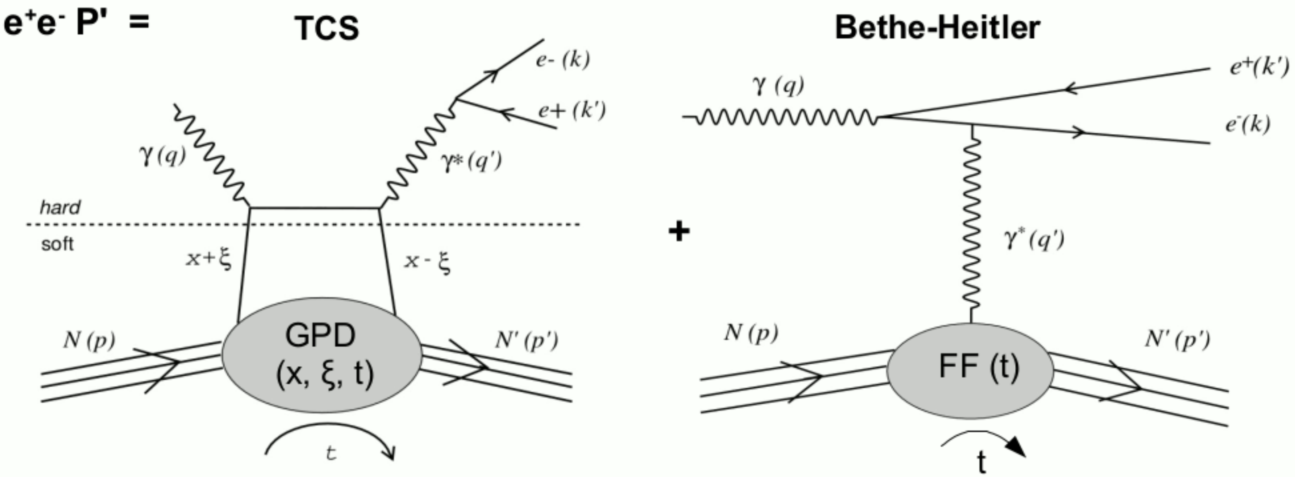
Experimental setup

Simulation results

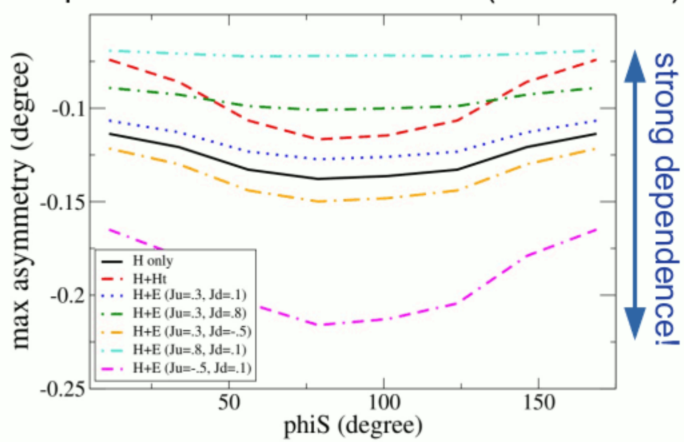
Summary and Outlooks

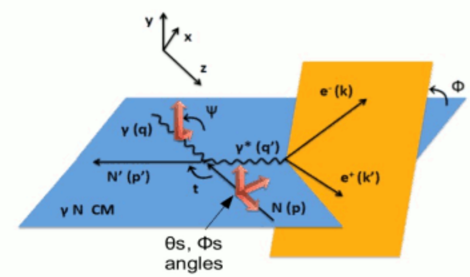
Physics goals

$\gamma P \rightarrow e^+e^- P'$ =



Sin(φ) moment of transverse spin asymmetry vs φ_S,
Dependence in GPD E and $J^{u,d}$ (VGG model)





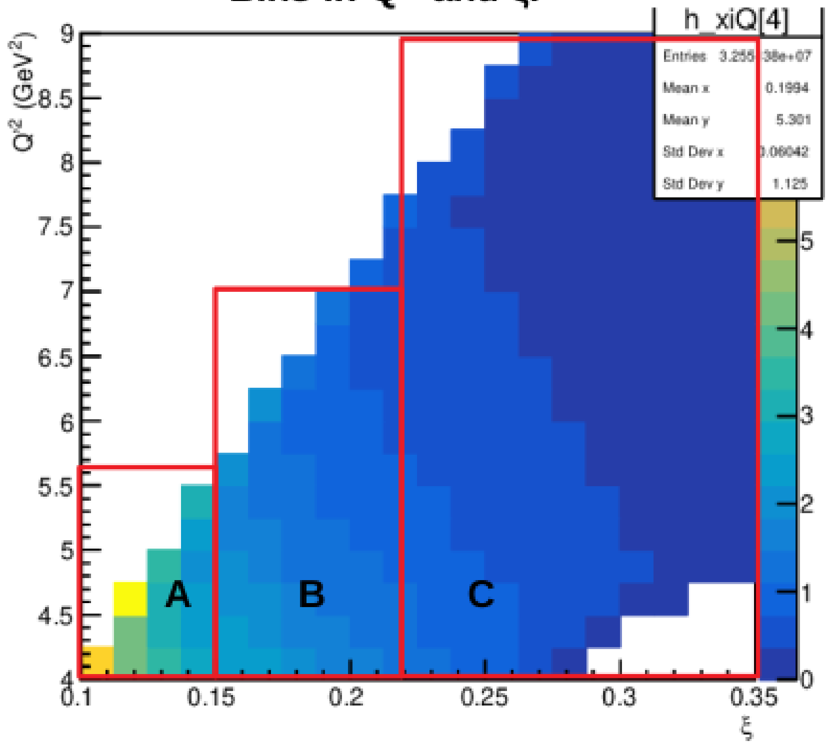
TSA as a function of φ and φ_S

- Sensitive to Im(interference), BH cancels
- Strong dependence in angular momenta,

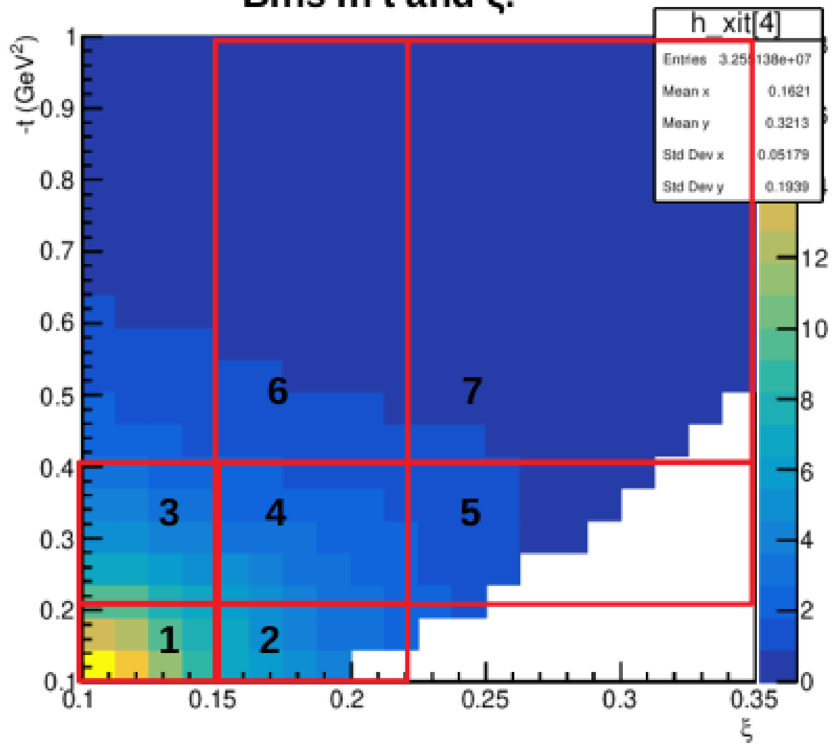
Sensitivity to GPD E (also to H, Ht)

Courtesy M.Boer

Bins in Q'² and ξ:

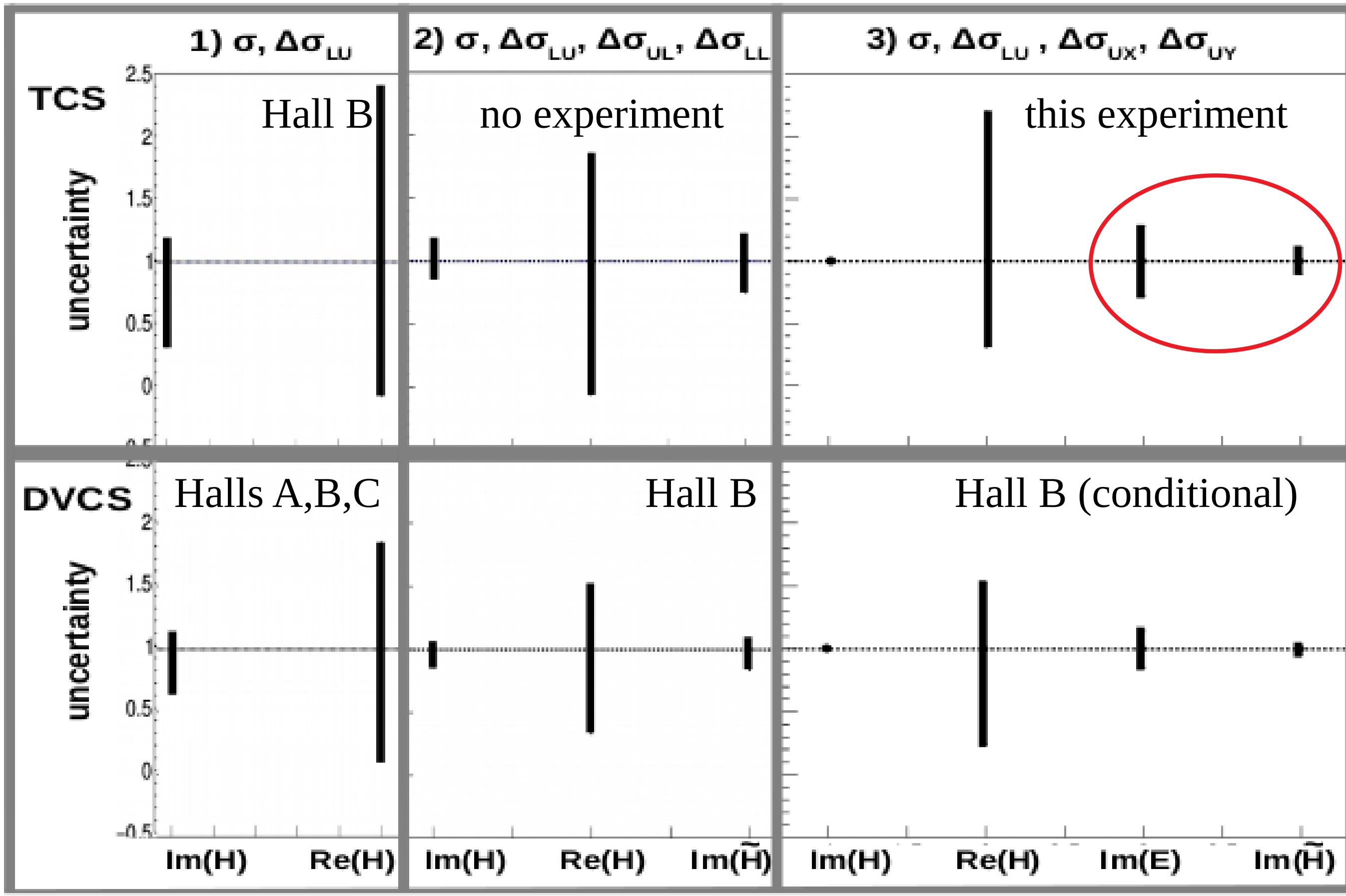


Bins in t and ξ:



A: .10 < ξ < .15 ; 4 < Q'² < 5.5 GeV²
B: .15 < ξ < .22 ; 4 < Q'² < 7 GeV²
C: .22 < ξ < .35 ; 4 < Q'² < 9 GeV²

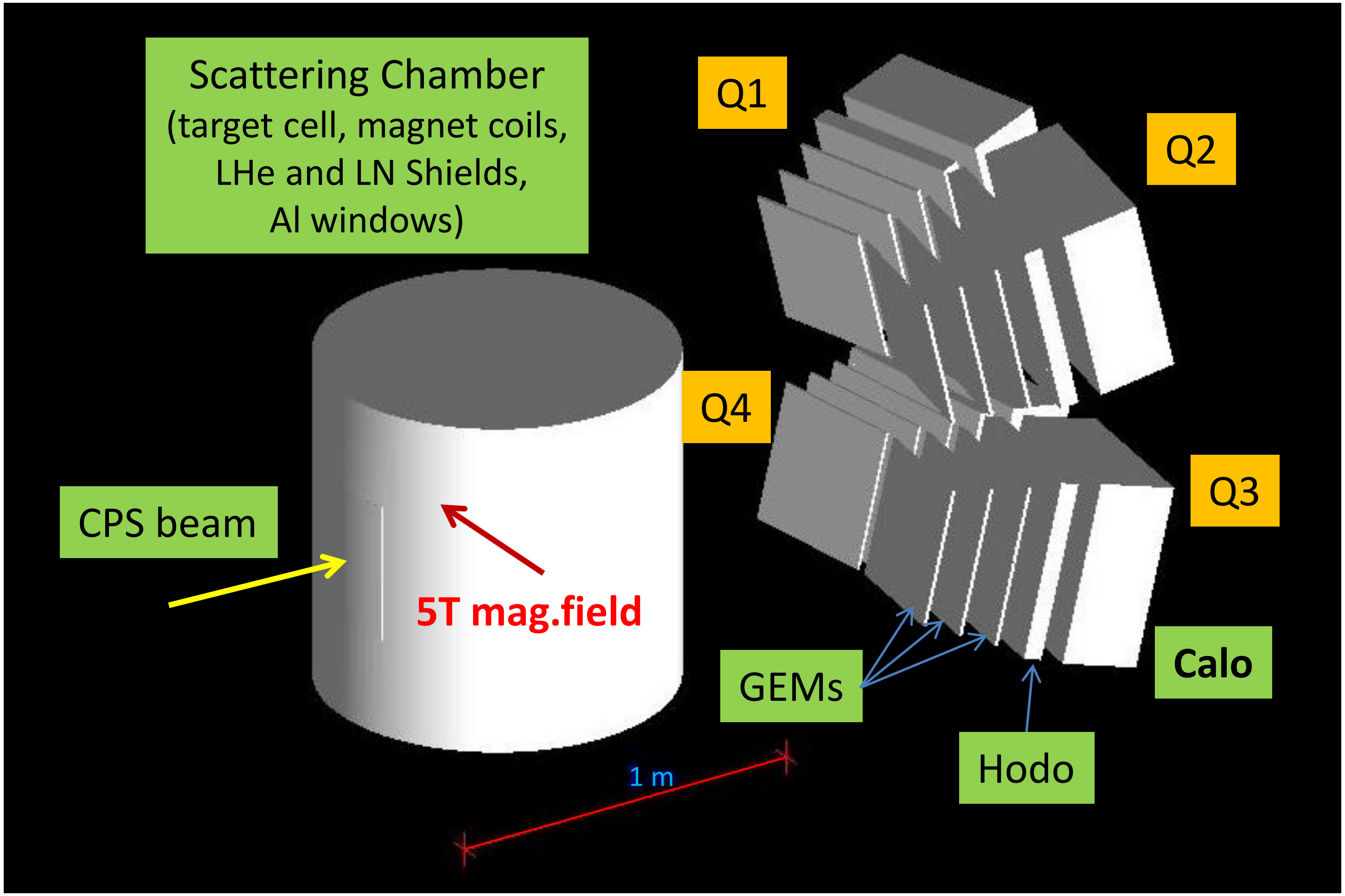
1, 2: .1 < -t < .2 GeV²
3, 4, 5: .2 < -t < .35 GeV²
6, 7: .35 < -t < .7 GeV²



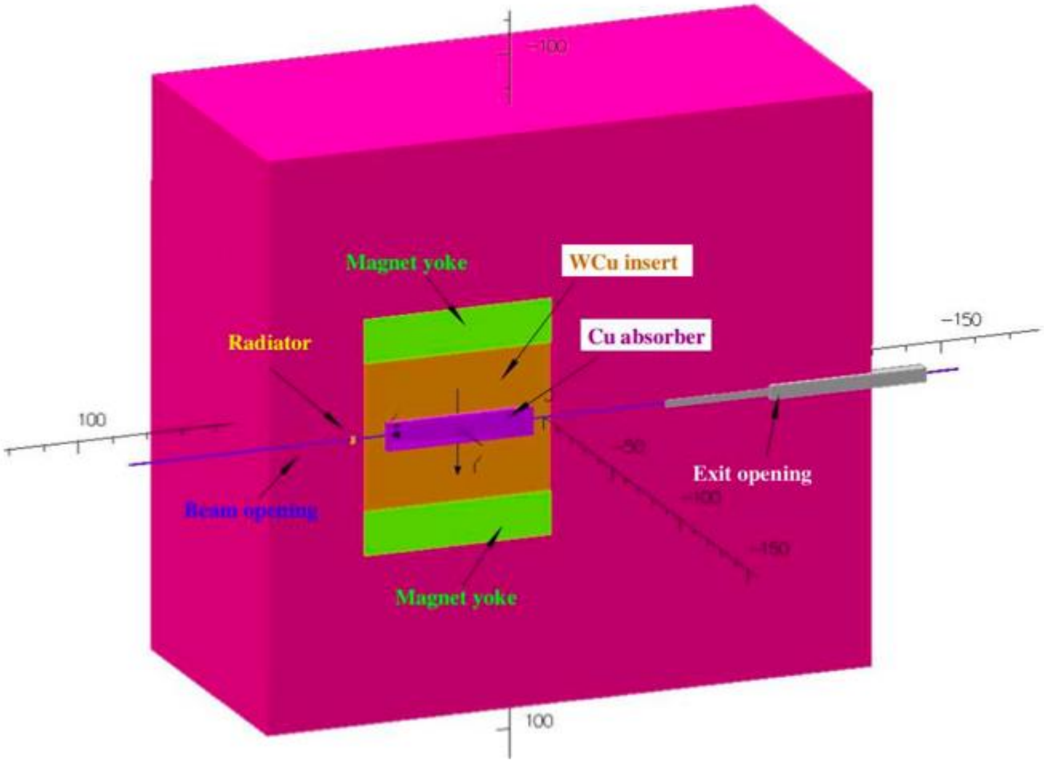
Example estimates of accuracies on the model extraction of CFFs.
TCS with trans. Pol. taget allows extraction of Im(E).

Experimental apparatus: Setup

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



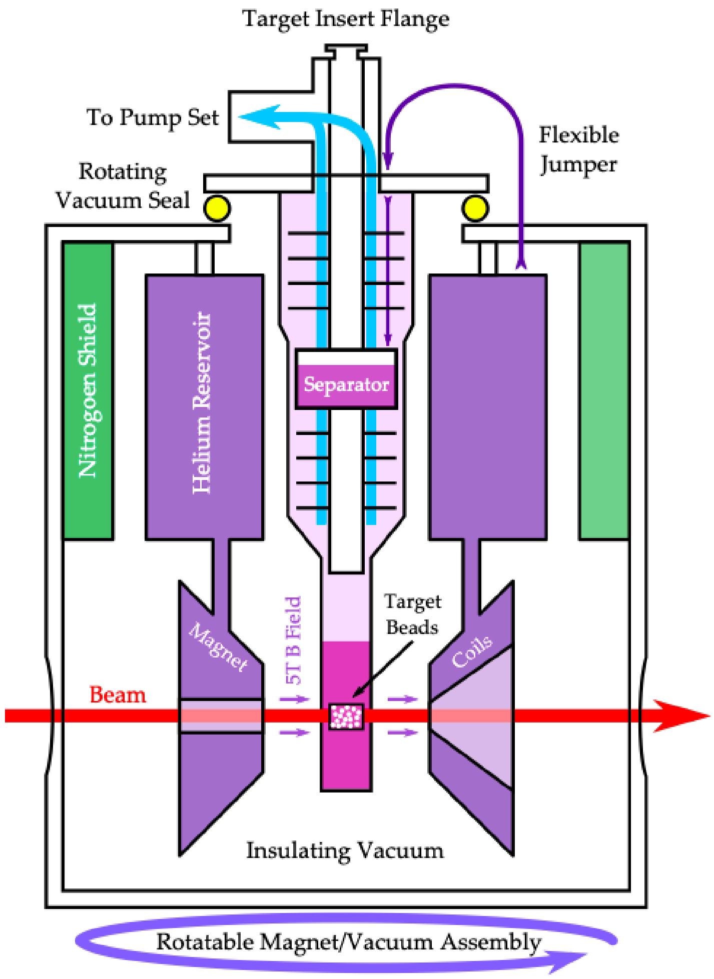
- Detect e^+, e^-, recoil p' in coincidence
- CPS bremsstrahlung photon beam
- UVA/Jlab NH_3 target, transversely polarized
- Detectors arranged in 4 quarters, oriented to target
- Triple-GEMs for e^+, e^-, p tracking
- Hodoscopes for recoil proton detection/PID
- ***$PbWO_4$* calorimeters** for e^+, e^-, p detection/PID



Compact Photon Source under development in Hall C at JLab:

- Combines polarized photon source, collimator and beam dump;
- High intensity collimated brem. photon beam (**1.5×10^{12} γ/s in [5.5 GeV, 11 GeV]** range from 2.5 µA primary e- beam on 10% X_0 Cu radiator , ~1 mm spot size at 2 m from radiator)
- 3.2 T warm magnet to bend incoming electrons to local beam dump;
- Highly shielded design (W/Cu alloy) to minimize prompt and residual radiation.

Experimental apparatus: UVA/JLab polarized target



UVA target, nominal configuration

- Target material: $^{15}NH_3$, in LHe at 1°K.
- Packing fraction 0.6.
- 5T (uniform to 10^{-4}) mag field generated by superconducting Helmhotz coils.
- DNP polarization by 140 GHz, 20 W RF field.
- Polarization monitored via NMR.

<u>TCS configuration</u>:

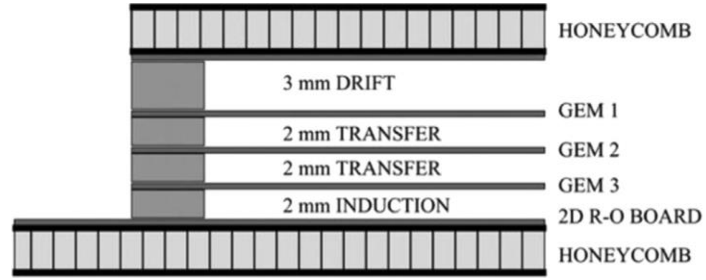
- **Setup rotated by 90°** around vertical axis.
- Sideways magnetic field and polarization.
- Angular acceptance ±17° horizontally, ±21.7° vertically (*±25 ° horizontally may be available in the future*).

<u>Depolarization mitigated</u> by combined rotation (~1 Hz) around horizontal axis and vertical up/down movement (~10 mm).

GEM trackers:

- Coordinate reconstruction accuracy ~80 µm
- Background rate tolerance up to 10^6 Hz/mm^2
- Minimum material thickness along particle pass
- Big size manufacturing

Use at Jlab: SBS, SoLID DDVCS, Prad



Layout of COMPASS GEM-s
(*F.Sauli, NIMA 805 (2016) 12-24*)

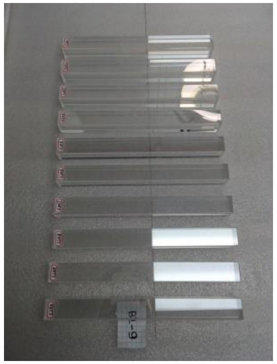
Hodoscopes:

- To provide dE/dX signal from low momentum recoil protons
- 2x2x5 cm^3 scintillators arranged in “Fly’s eye” hodoscopic construction

Calorimeters, **clones of the NPS calorimeter**:

- 2x2x20 cm^2 **$PBWO_4$ scin. crystals**, optically isolated
- Modules arranged in a mesh of carbon fiber/µ-metal
- Expected **energy resolution** 2.5%/√E + 1%
- Expected **coordinate resolution** ~3 mm at 1 GeV.
- Modules arranged in 4 “fly’s eye” assemblies of 23x23 matrix.

Total number of modules needed **2116**.



Simulations, analysis flow

- Use TCS events generated by DEEPGen generator from M.Boer.
- Trigger on calorimeter signals: 3x3 cluster of E_{DEP} > 2.5 GeV in opposite quadrants, sum of the cluster energies > 6 GeV.
- Select events with:
  - hits in GEM trackers from e+, e-, p (reject hits close to beam pipe);
  - proton deposited significant energies in the hodoscope and calorimeter.
- Take smeared energy of e+, e- (according to PbWO calorimeter resolution) as momenta at detectors.
- Take smeared energy of energy deposition in hodo. and calo. (by 20%) as kinetic energy, derive momentum.
- Backtrack e+, e-, p to target, reconstruct momenta and TCS quantities.

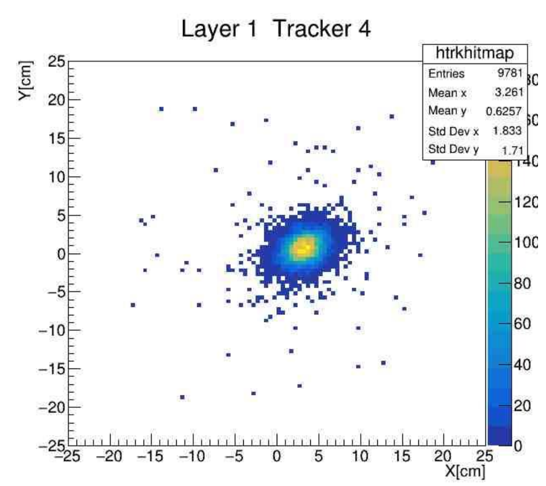
Purpose: elaborate particle identification for reconstruction, and backtracking to be used in real offline analysis.

Proton selection

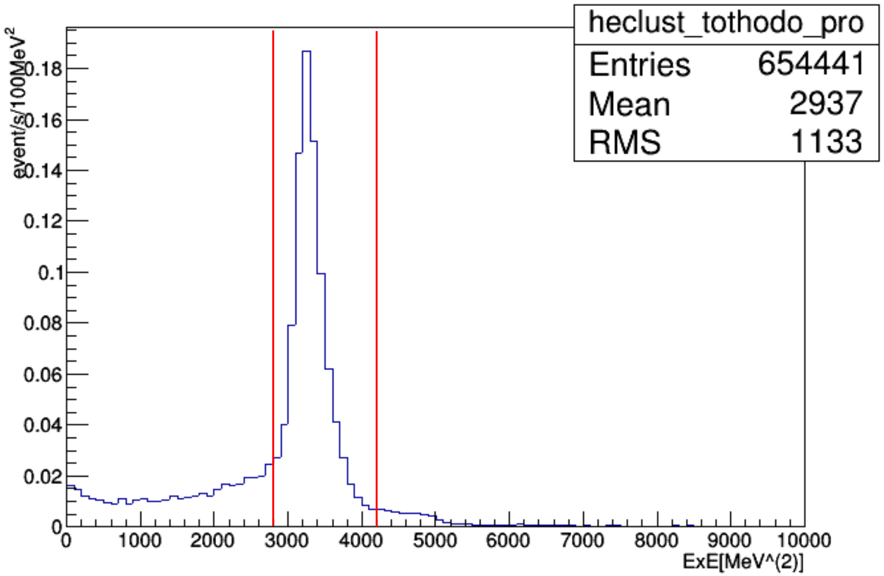
Cuts to select good protons:

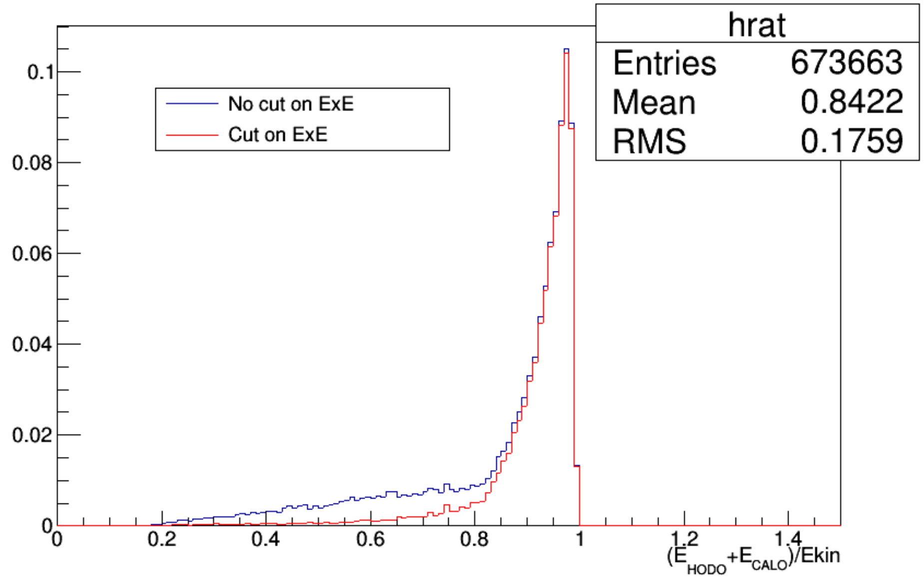
- $E_{HODO} > 15\ MeV$
- $90\ MeV < E_{HODO} + E_{CALO} < 450\ MeV$
- $2800\ MeV^2 < ExE < 4200\ MeV^2$,

$where\ ExE = (E_{HODO} + E_{CALO} - 12) \times (E_{HODO} - 7)$



GEM hit pattern from 400 MeV/c protons.



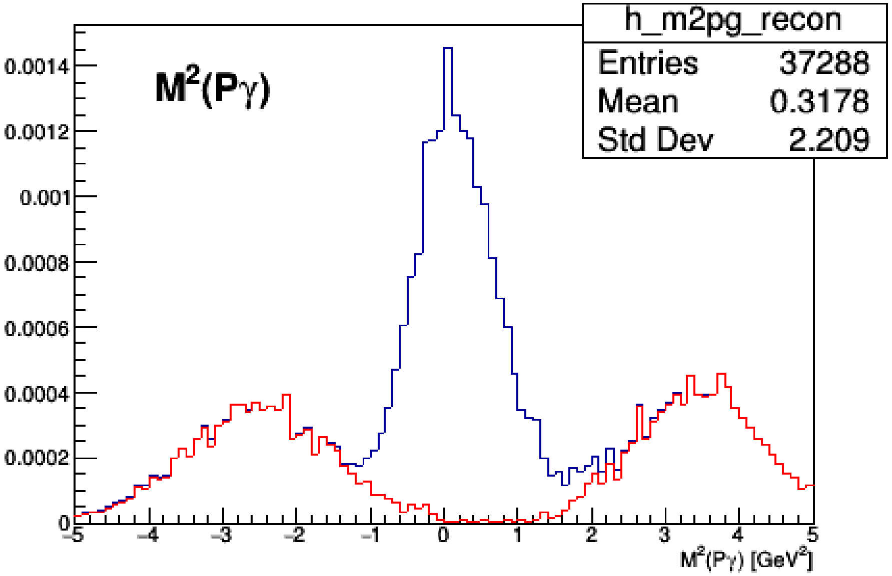


Target fringe field behind scattering chamber too weak to distinguish pos. and neg. tracks.

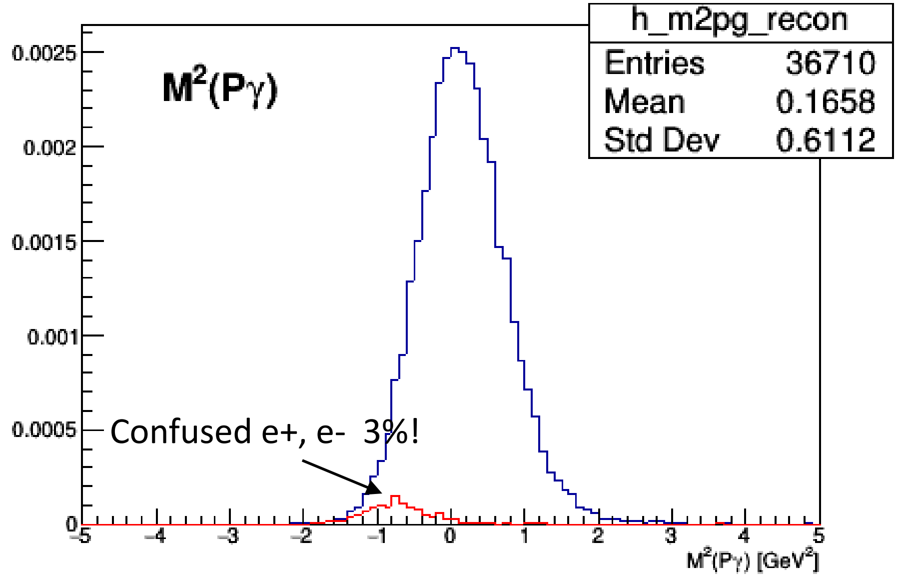
Alternative: use reconstructed incident photon virtuality:

- Reconstruct p;
- Reconstruct leptons twice, by assigning (+,-) and (-,+) charges;
- Combine with reconstructed proton to get 2 virtualities, choose smaller one.

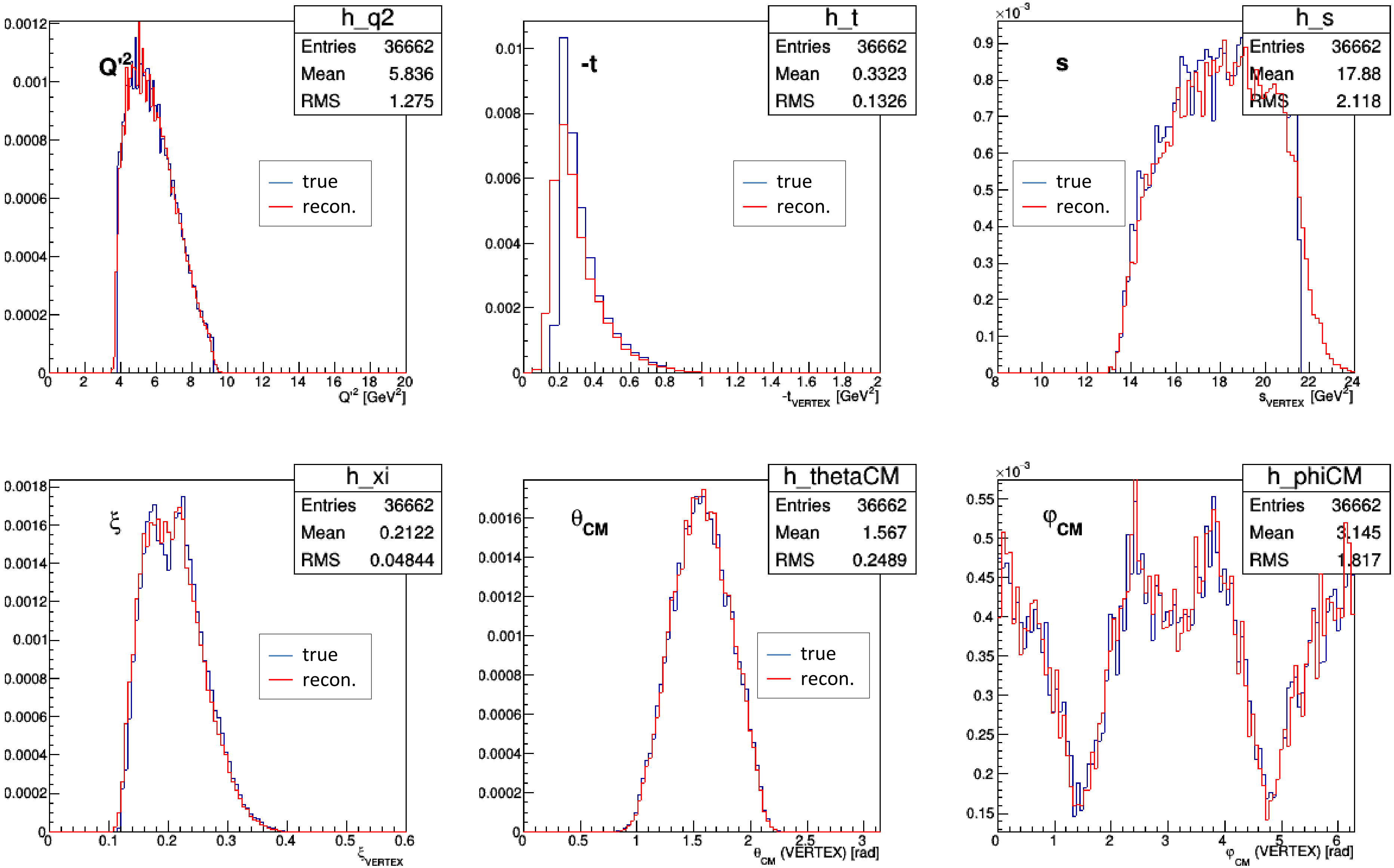
Random lepton charge assignment



Lepton charges according selection criteria



Reconstructed versus true quantities



Summary and Outlooks

TSA measurement with transversely oriented target spin is sensitive to Im(E) CFF, hence to GPD E and OAM of partons.

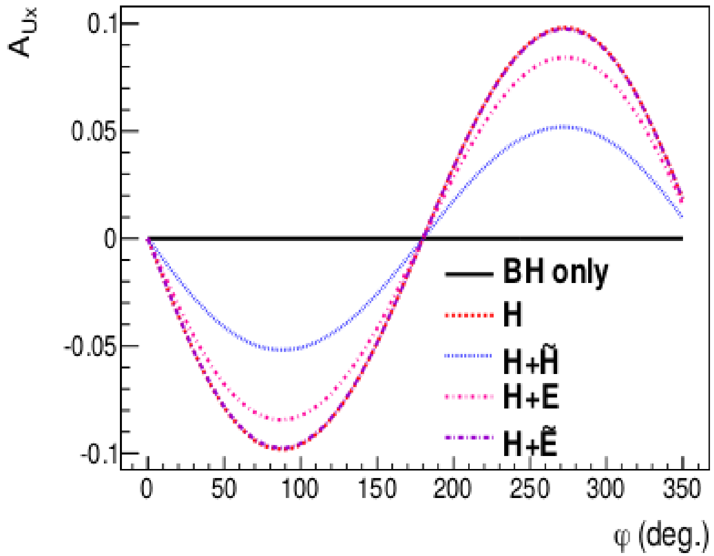
Adding data from TCS with transversely oriented target spin to the data bank from other TCS and DVCS experiments renders an opportunity to **probe the universality of GPDs**, contribute to data set for **GPD global fits**.

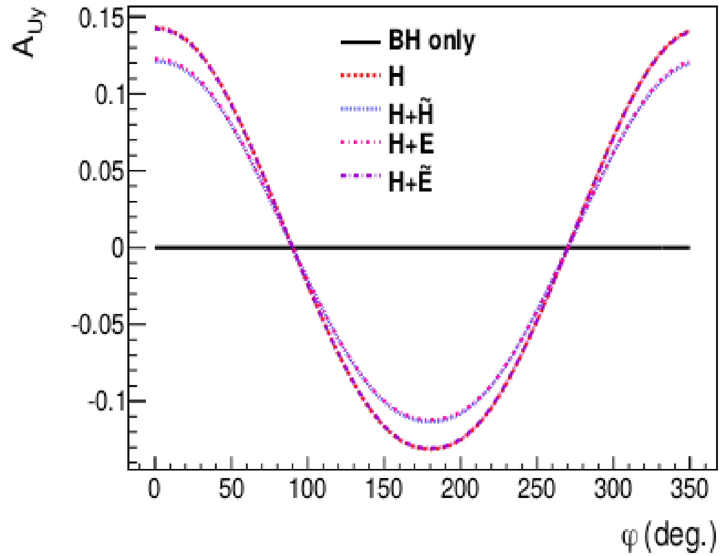
Proposal for the experiment PR-12-18-005 was conditionally approved by PAC 46, PAC 48, is being prepared for presentation to PAC 50.

Backup slides

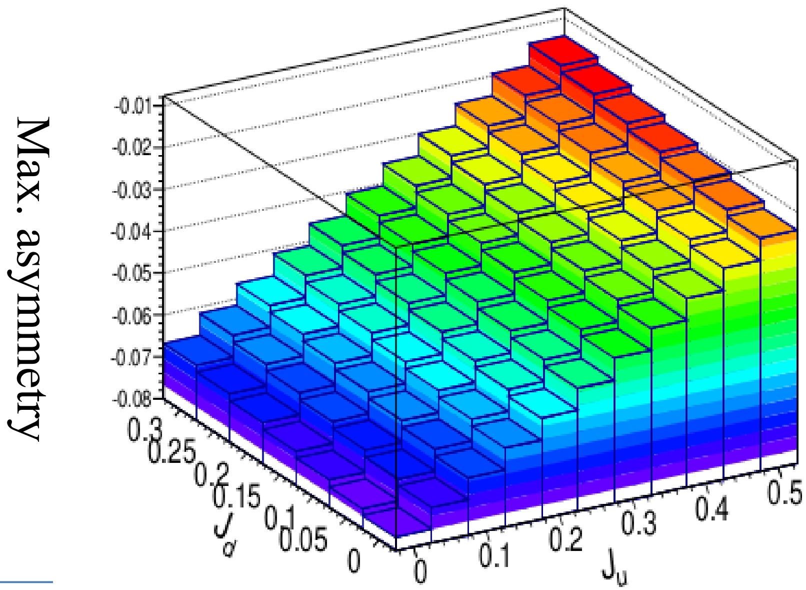
Physics case: Transverse target spin asymmetries

Orthogonal transverse spin asymmetries with different GPD parametrizations





“Size" of asymmetry when running Ju and Jd

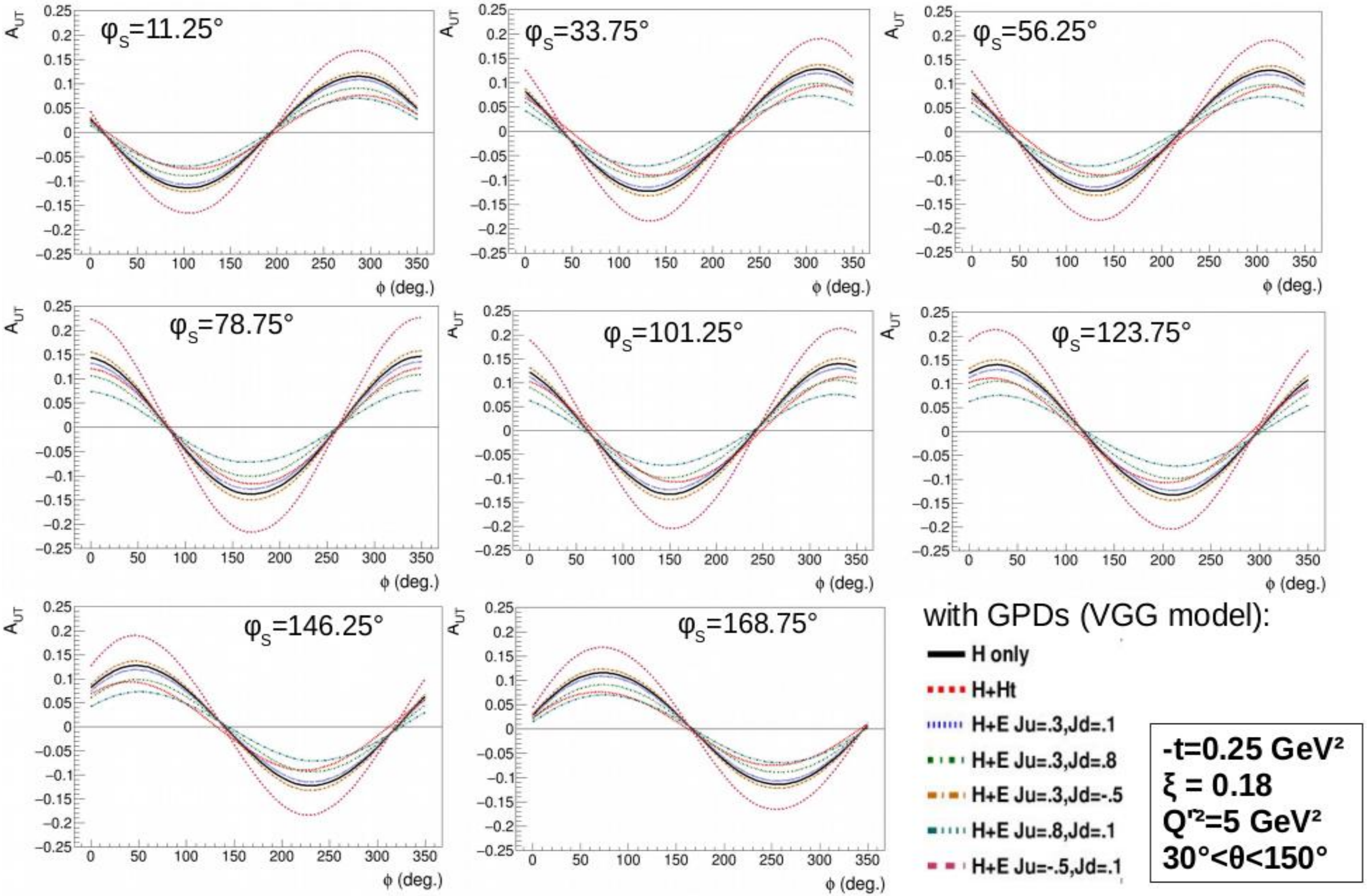


- Asymmetry sensitive to GPDs
- Reflect TCS contribution through interference

→purely imaginary, BH cancels

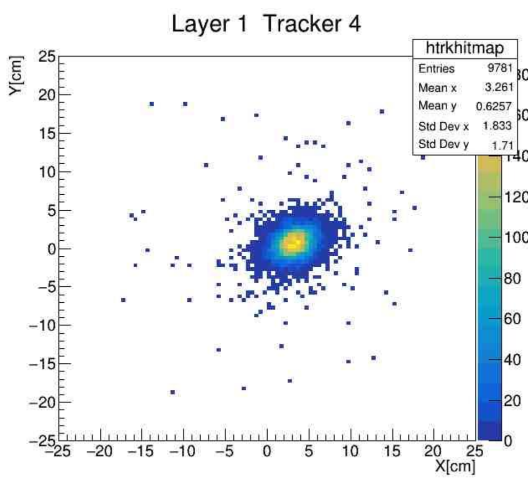
- Sensitive to angular momenta J_u, J_d and GPD E

Anticipated results: target asymmetries



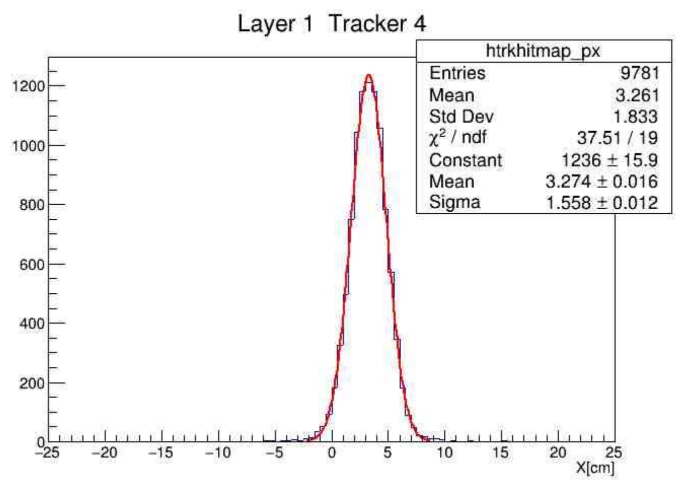
- Shows strong dependence on angular momenta
- 8 bins: fit of 2x2 orthogonal bins (4 independent ones) for CFFs global fits

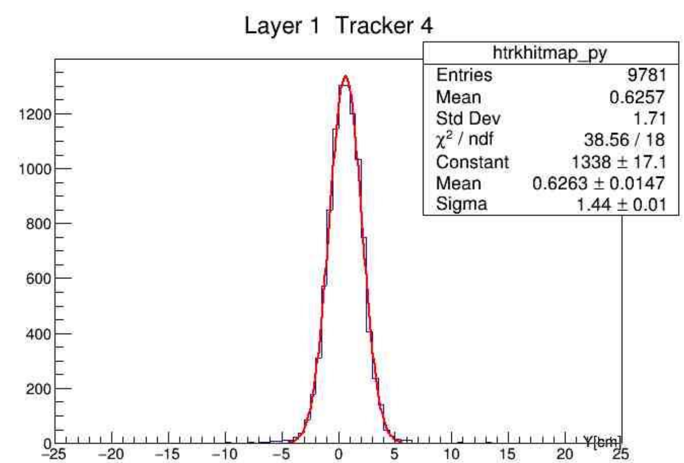
$400\ MeV/c\ (E_{KIN} = 81\ MeV)$ proton passed from target to 1-st layer GEM.



Tracks with θ_Y = 15° at vertex:

- Hit spot size $\sigma \sim 1.5cm$
- Fraction of hits within $R < 4.5cm$ -- 94.5%





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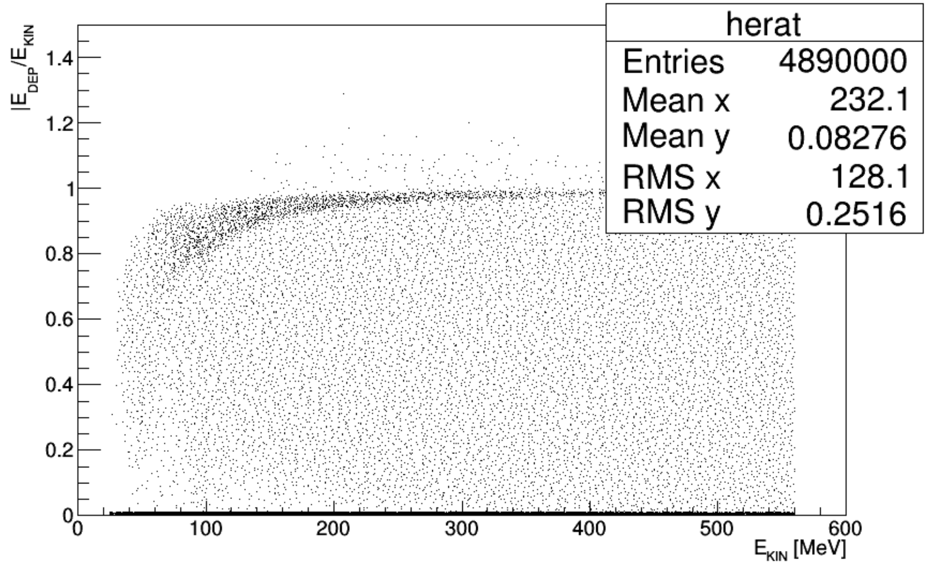

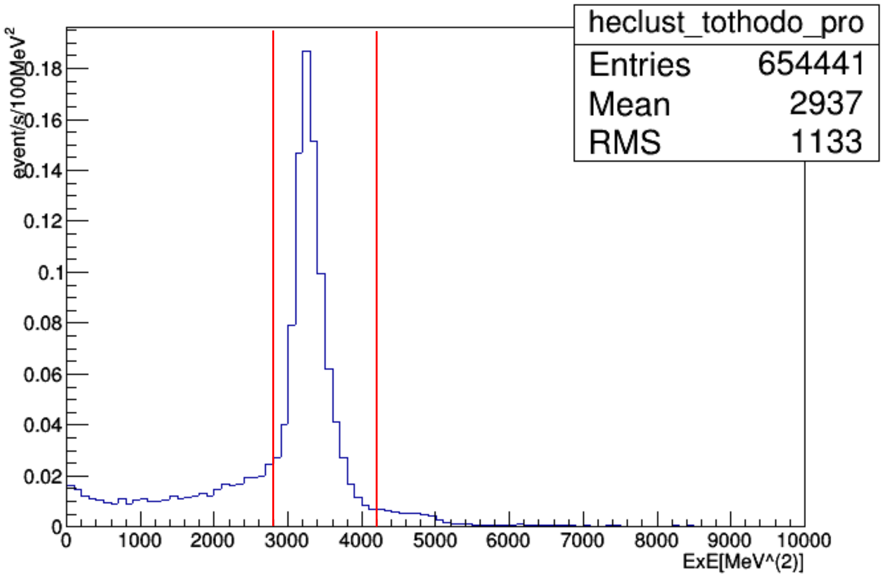

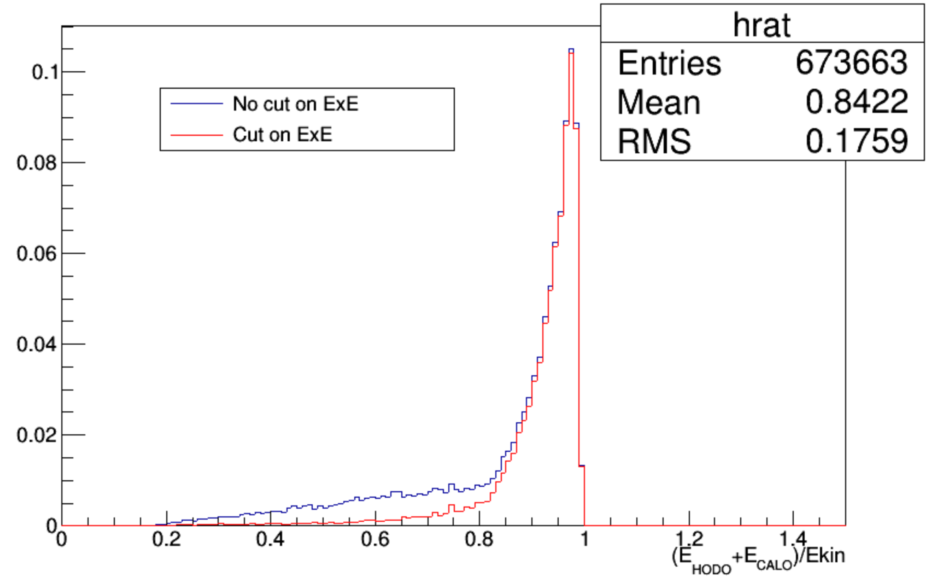

Trigger, vertex reconstruction

- Trigger
  1) Identify seeds (single crystals) of max. E_{DEP} in each calorimeter quarter.
  2) Calculate E_{DEP}-s in 5x5 clusters around seeds.
  3) For a pair of opposite quadrants, request cluster energies > 2.5 GeV, and sum of cluster energies > 6 GeV.

- e+, e- reconstruction

  In the triggered quadrants:
  1) Cluster calorimeter hits
  2) Take cluster with max. energy
  3) Calculate X, Y, and σ_X, σ_Y of cluster
  4) Search for hits in trackers before the cluster, in $1.75\sigma_X$ x $1.75\sigma_y$ area (at least 2 hits in different layers)
  5) Construct straight track through tracker hits, make sure it hits calo. cluster (within the area)
  6) Assign opposite charges to the pair of tracks, and momenta from calo. Edep-s
  7) Backtrack the assigned e+ and e- tracks to target

- Recoil proton reconstruction
  1) Cluster hodoscope hits, select clusters with E_{DEP} > 12 MeV
  2) From the remaining calo. clusters, select calo. cluster and overlapping hodo. cluster such that $2800 < E_{DEP}(hodo) \times E_{DEP}(calo) < 4200\ MeV^2$
  1) Search for hits (at least 2 in different layers) in the trackers before the hodoscope (in ΔX x Δ Y ~ 2x2 cm^2 area)
  2) Derive momentum of the proton candidate from Ekin = $E_{HODO} + E_{CALO}$
  3) Backtrack proton candidate to target

- Calculate TCS quantities