Time-like Compton Scattering with transversely polarized target in Hall C

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Hall A & C Collaboration Meeting, 06/16-17/2022

Outline

Physics case and motivation

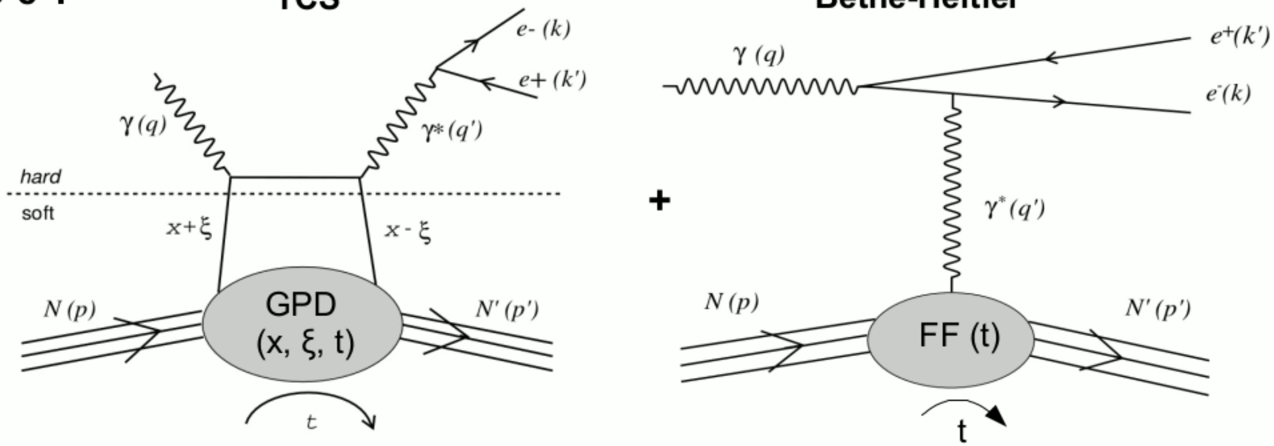
Experimental setup

Remarks on analysis

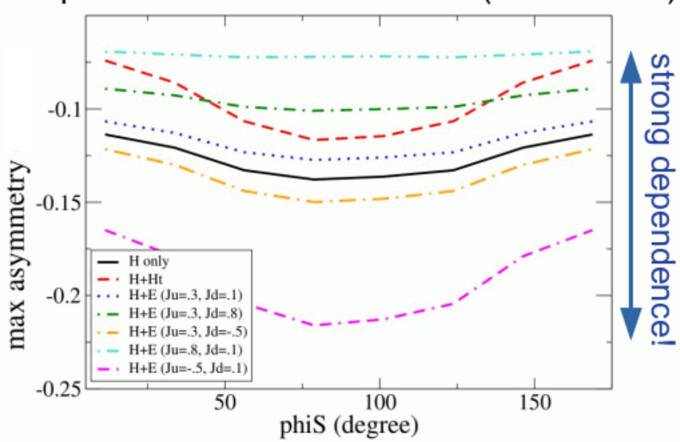
Summary

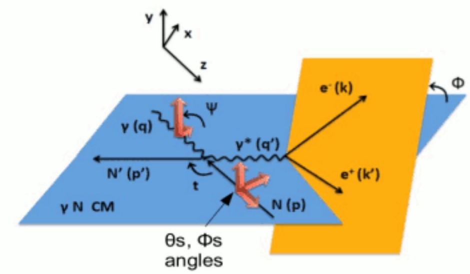
Physics goals

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



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





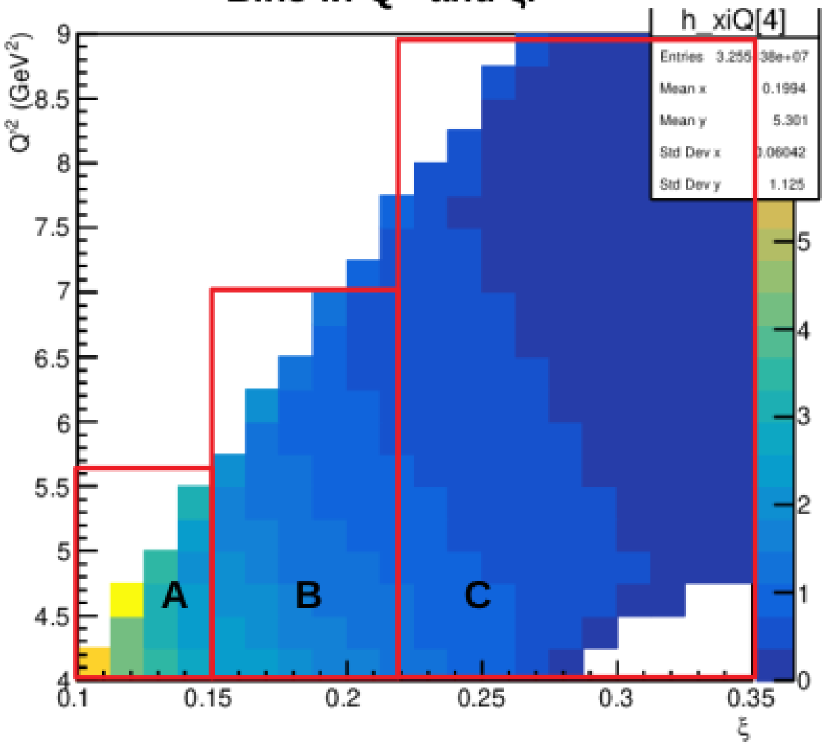
TSA as a function of φ and φ_s

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

Sensitivity to GPD E (also to H, Ht)

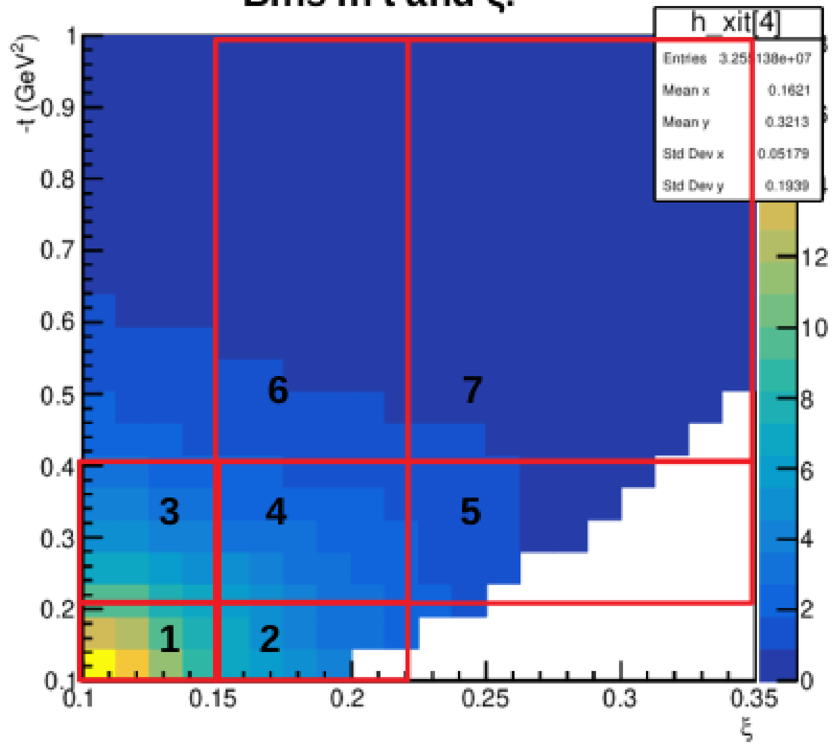
Courtesy M.Boer

Bins in Q'² and ξ:



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

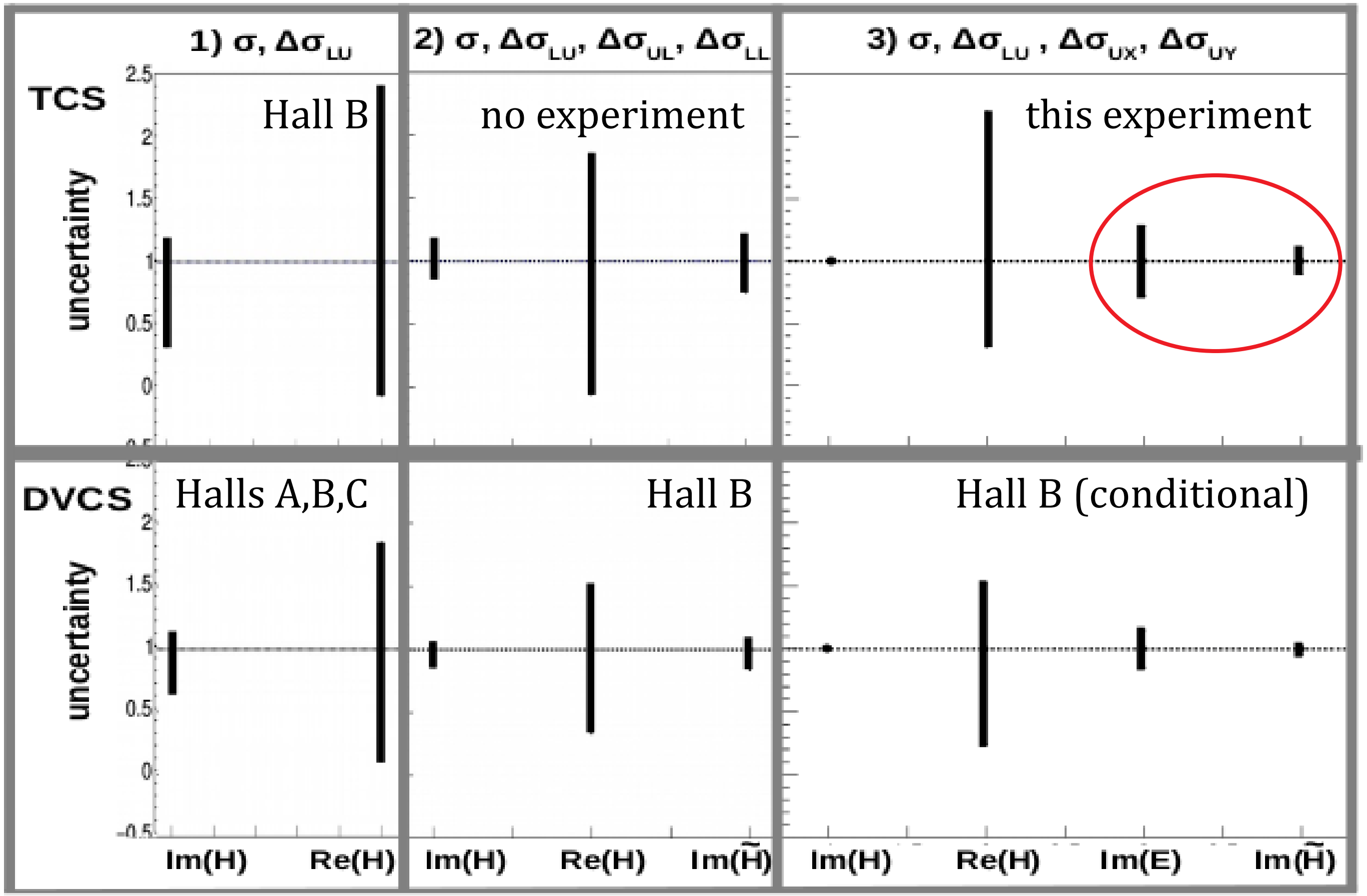
Bins in t and ξ:



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

Kinematic region out of pion resonance production

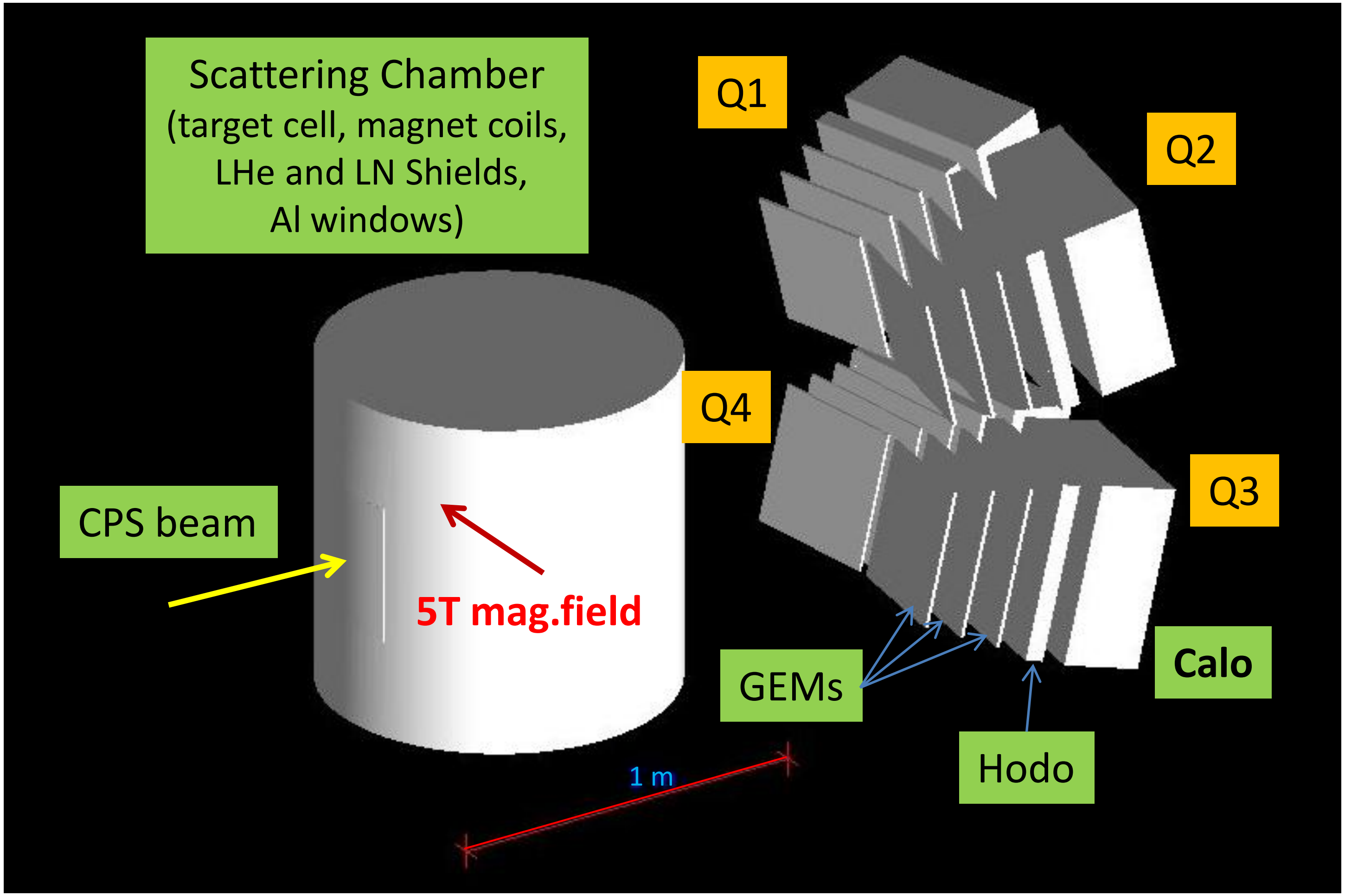
Physics case: Extraction of CFFs from TCS versus DVCS



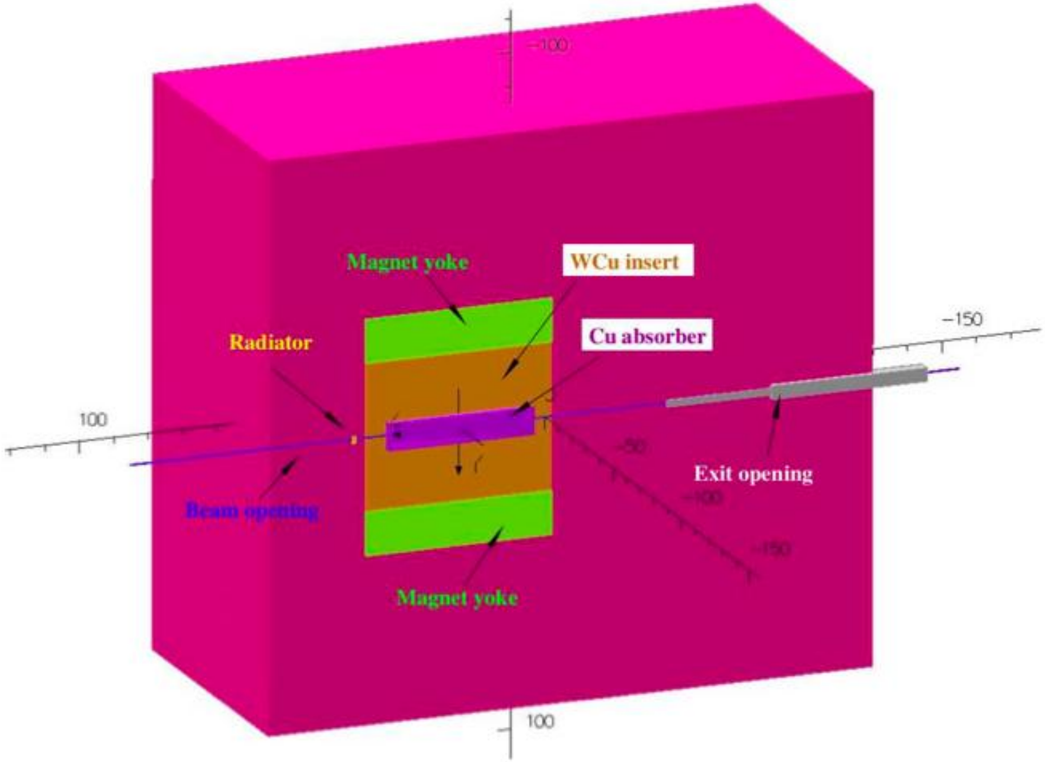
Example estimates of accuracies on the model extraction of CFFs.
TCS with trans. pol. target allows extraction of Im(E).

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



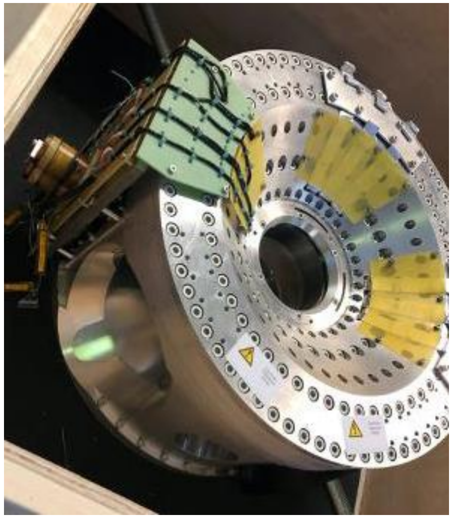
Compact Photon Source under development in Hall C at JLab:

- Combines polarized photon source, collimator and beam dump;
- High intensity directed 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.

D.Day et al., NIMA 957 (2020) 163429

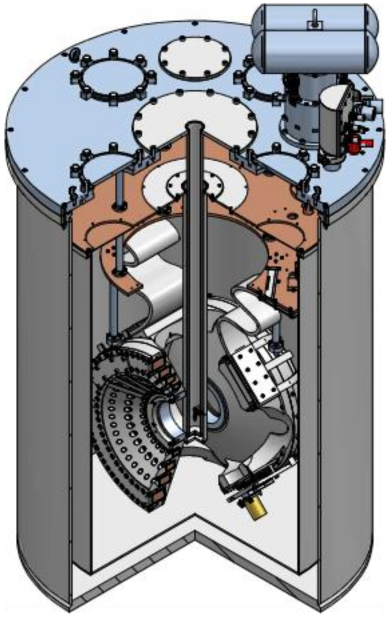
Experimental apparatus: Polarized target

- Target material: ^{15}**NH$_3$**, in LHe **at 1°K**.
- Packing fraction 0.6.
- Magnetic field generated by superconducting Helmhotz coils.
- **DNP polarization** by 140 GHz, 20 W RF field.
- Polarization monitored via NMR.
- **Depolarization mitigated** by combined rotation (~1 Hz) around horizontal axis and vertical up/down movement (~10 mm).



<u>New polarizing magnet arrived in September 2021!</u>

- Drop-in replacement for old Jlab-UVA target
- 5 T magnetic field, 100 ppm uniformity
- **±25° horizontal opening angle** in transverse filed configuration (**increase from ±18°** of JLab-UVA -> increase of TCS acceptance, help with background rates.)



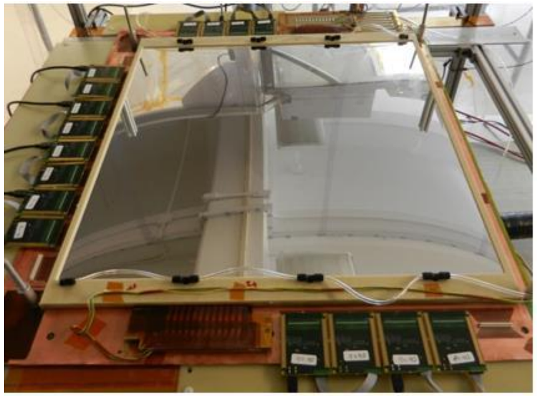
Horizontal field orientation

Experimental apparatus: trackers, hodoscopes

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



SBS BT GEM prototype (*K.Gnanvo et al., NIMA 782 (2015) 77-86*)

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**:

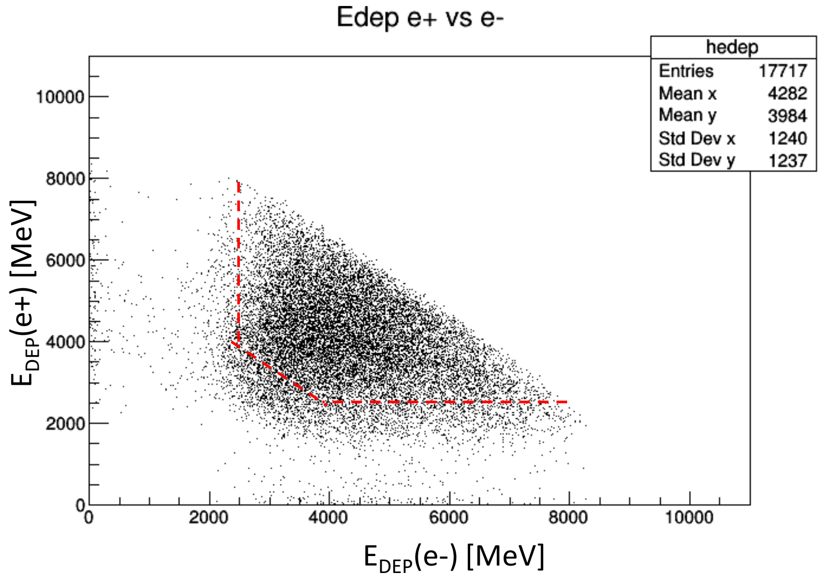
- 2x2x20 cm^2 **$PBWO_4$ scin. crystals**, optically isolated
- Modules arranged in a mesh of carbon fiber/μ-metal
- Expected **energy resolution** 2.5%/√E + 1%
- Expected **coordinate resolution** ~3 mm at 1 GeV
- Modules arranged in 4 "fly's eye" assemblies of 23x23 matrix

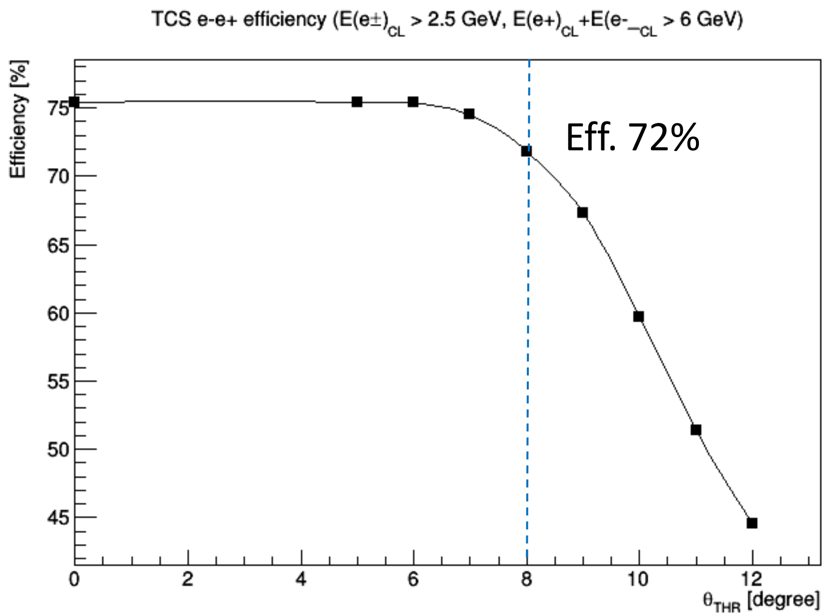
Total number of modules needed **2116**.

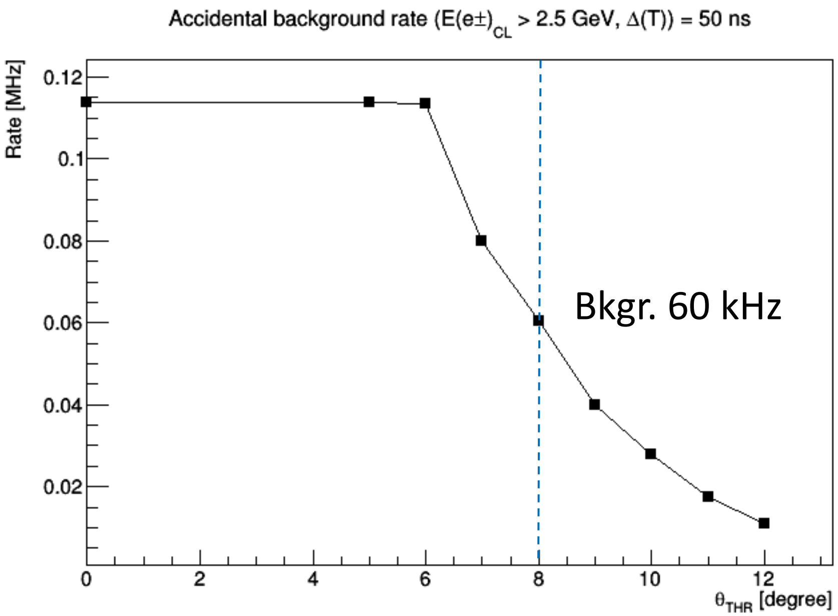
Assembling of NPS calorimeter (June 2022)

Trigger concept

- Trigger based on e+ and e- coincident signals from calorimeters in opposite quarters
- Establish high thresholds on $E_{DEP}(e+)$, $E_{DEP}(e-)$, $E_{DEP}(e+)+E_{DEP}(e-)$ to control background
- Exclude high background region close to beam pipe







TCS triple coin. detection efficiency and beam background rate vs cut on polar angle Θ.

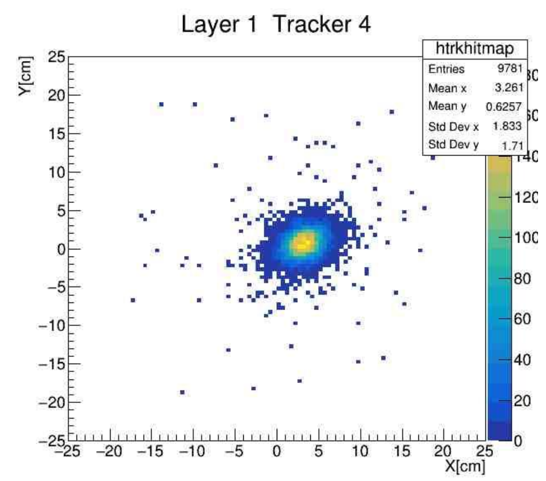
Recoil proton ID

Low energy protons, E_{KIN} from ~30 MeV to 450 MeV

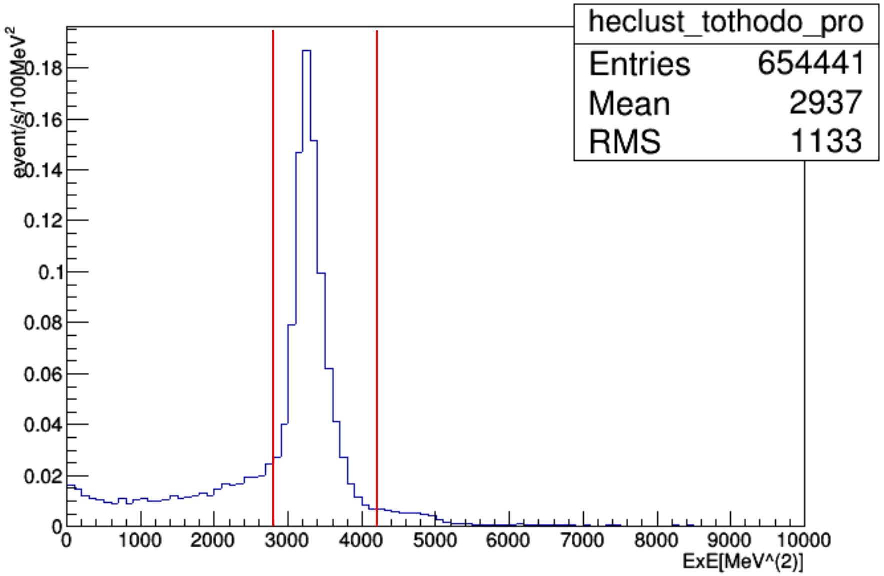
Cuts to select good protons:

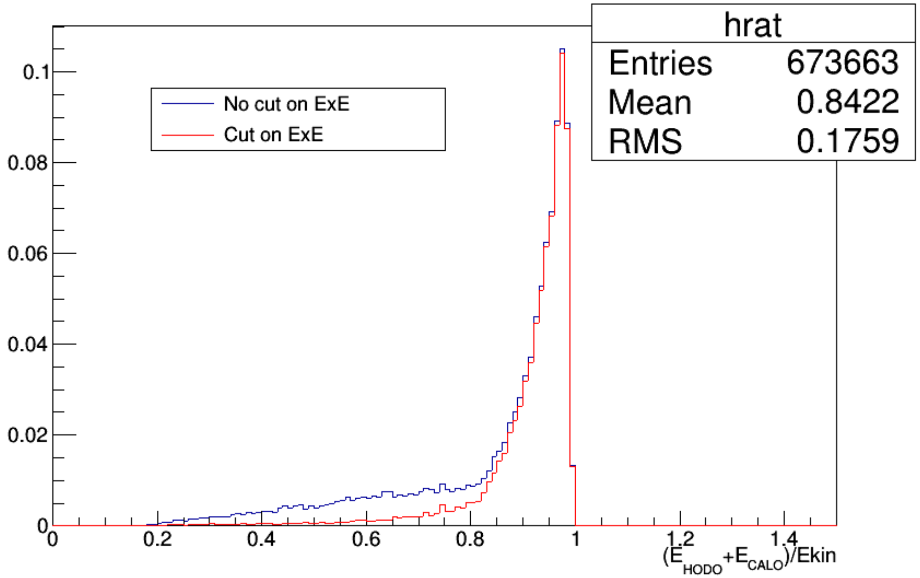
- $E_{HODO} > 15\ MeV$
- $90\ MeV < E_{HODO} + E_{CALO} < 450\ MeV$
- $2800\ MeV^2 < ExE < 4200\ MeV^2$,

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



GEM hit pattern from 400 MeV/c protons.





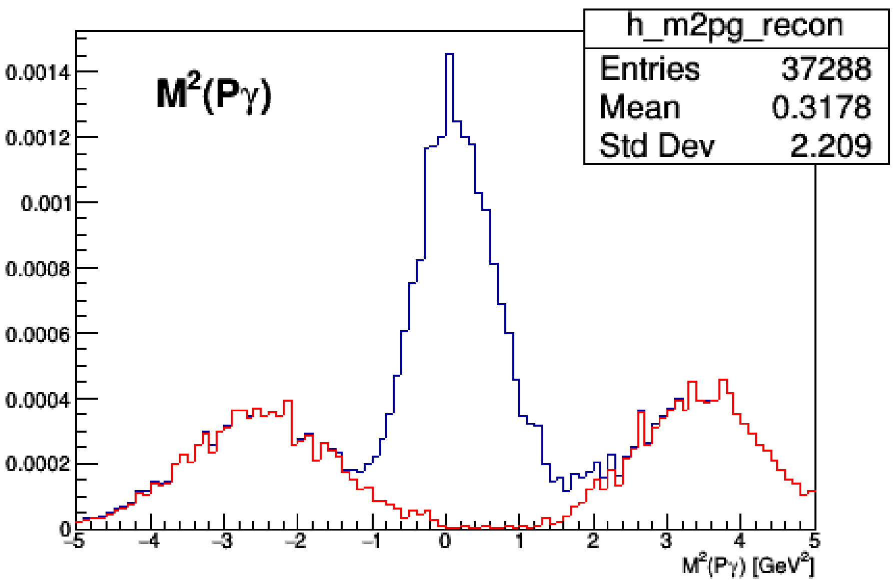
5T target field localized at target cell

Field behind scattering chamber too weak to distinguish pos. and neg. tracks.

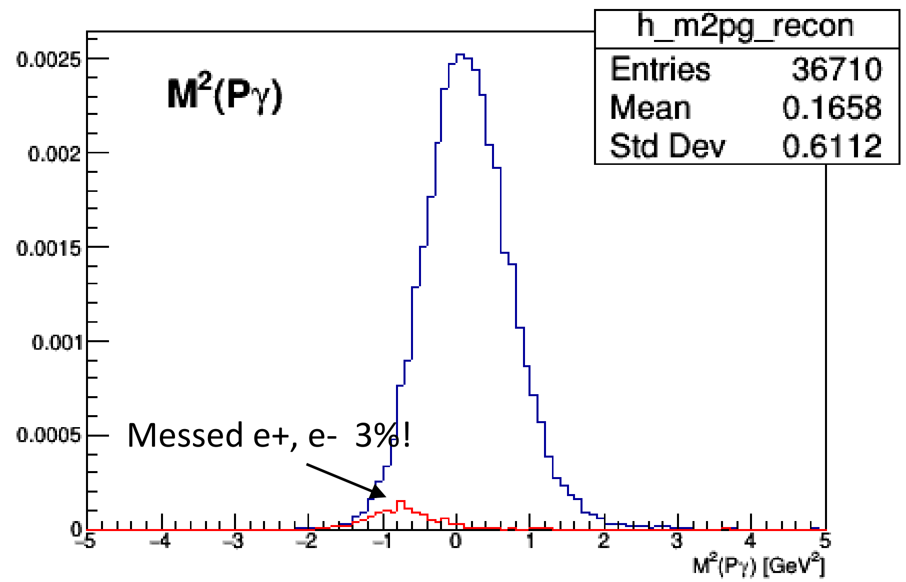
Alternative: use reconstructed incident photon mass:

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

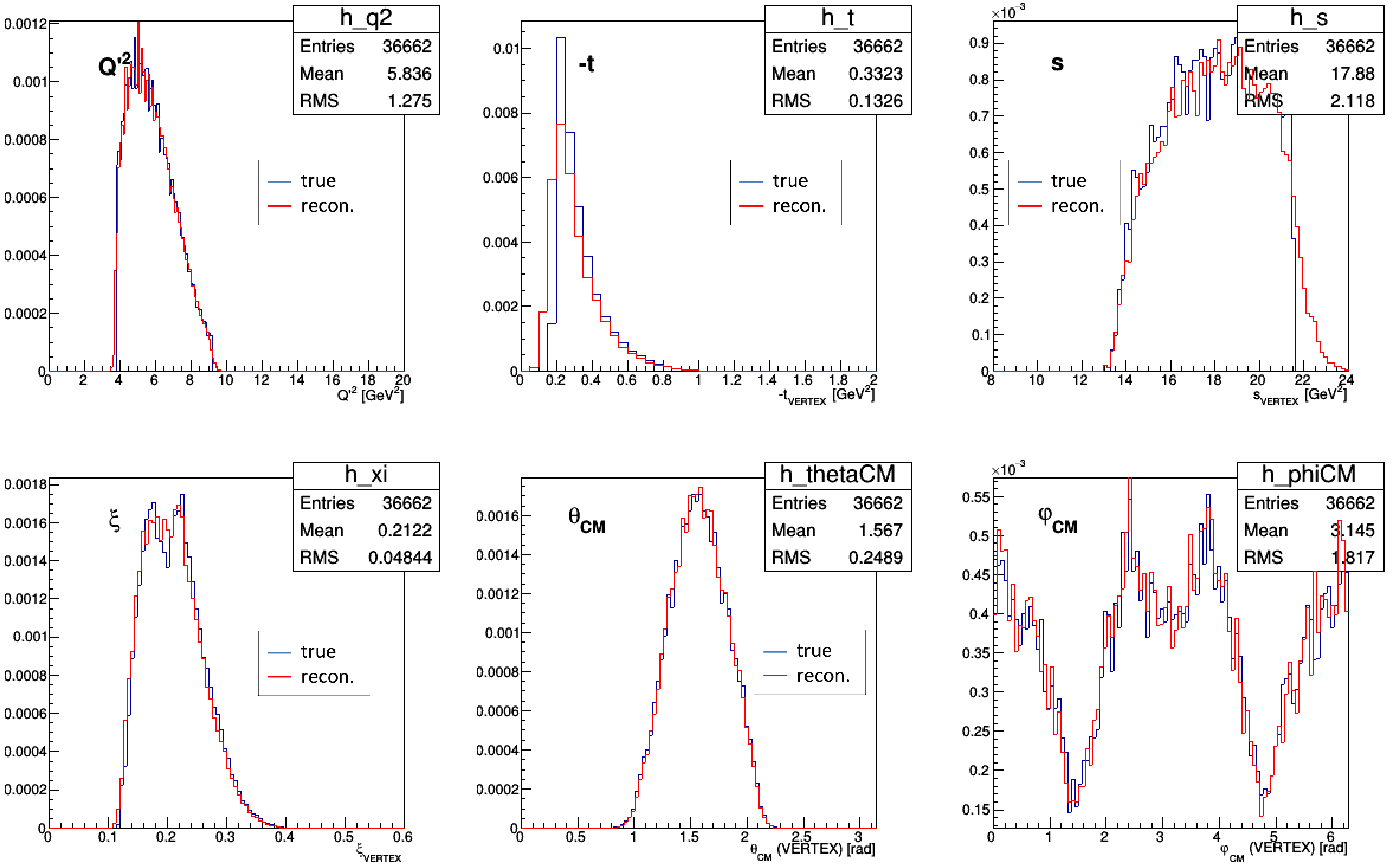
Random lepton charge assignment



Lepton charges according selection criteria



Reconstructed versus true quantities



Summary

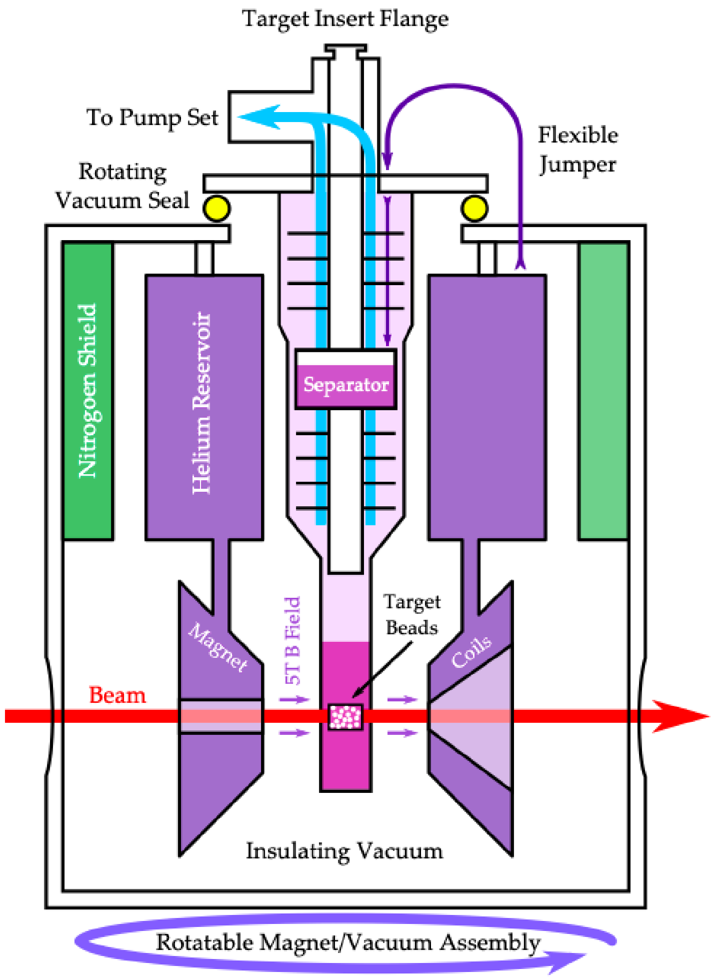
TSA measurement with transversely oriented target spin is sensitive to Im(E) CFF, hence to GPD E and OAM of partons.

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**.

The proposal C-12-18-005 was conditionally approved by PAC 48, is presented to PAC 50.

Backup slides

Experimental apparatus: UVA/JLab polarized target



UVA target, nominal configuration

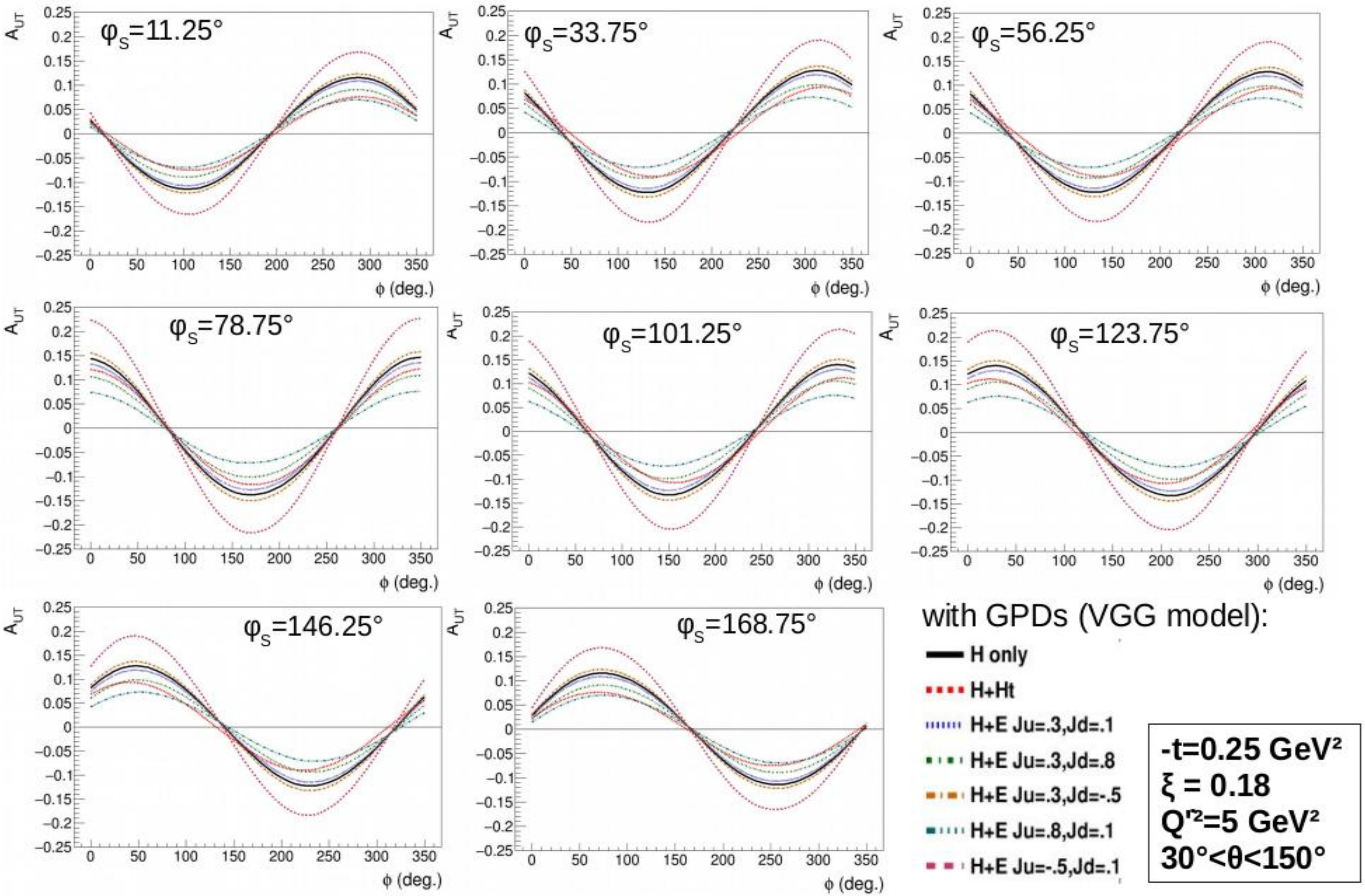
- Target material: $^{15}NH_3$, in LHe at 1°K.
- Packing fraction 0.6.
- 5T (uniform to 10^{-4}) mag field generated by superconducting Helmhotz coils.
- DNP polarization by 140 GHz, 20 W RF field.
- Polarization monitored via NMR.

<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 will be available with new magnet*).

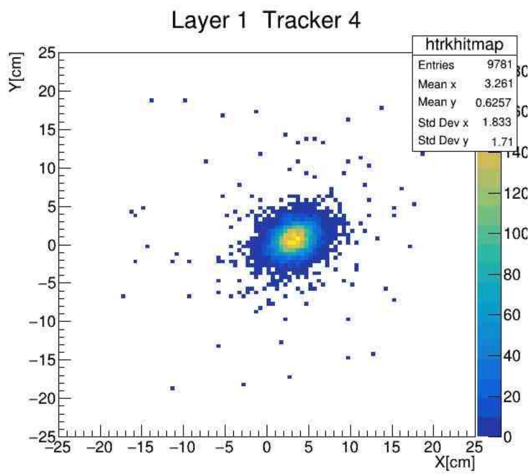
<u>Depolarization mitigated</u> by combined rotation (~1 Hz) around horizontal axis and vertical up/down movement (~10 mm).

Anticipated results: target asymmetries



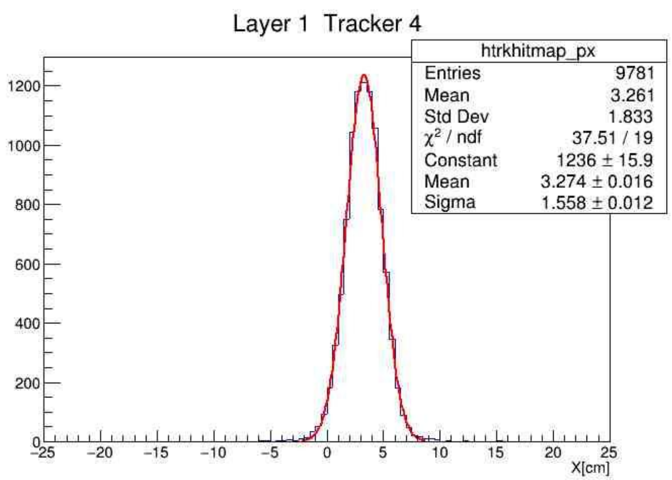
- Shows strong dependence on angular momenta
- 8 bins: fit of 2x2 orthogonal bins (4 independent ones) for CFFs global fits

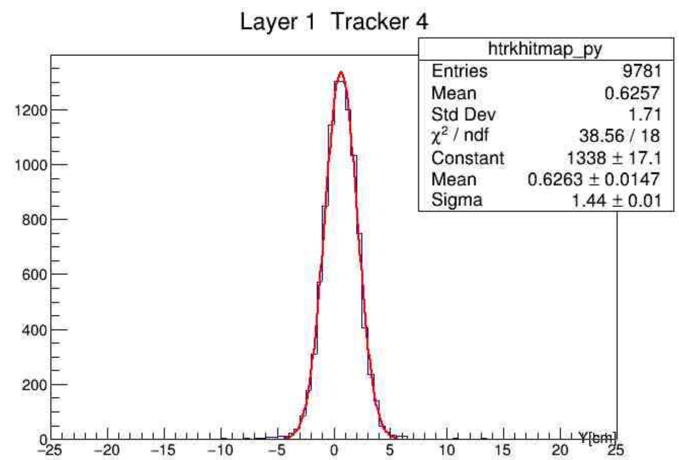
$400\ MeV/c\ (E_{KIN} = 81\ MeV)$ proton passed from target to 1-st layer GEM.



Tracks with θ_Y = 15° at vertex:

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





Proton selection

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