Short Introduction

• GPDs contain a wealth of information about the quark and gluon structure of the nucleon, they are combined nucleon form factors and ordinary PDFs.

• The theoretically cleanest process sensitive to GPDs is the DVCS, where in contrast to Bremsstrahlung the photon is not emitted by the lepton but by one of the quarks inside the nucleon.

• The BH/DVCS interference term in the total photon production amplitude offers the possibility to directly access the DVCS amplitudes.

• The imaginary part of the interference term can be isolated by measuring the angular dependence of the produced photon with polarized lepton beams.

• To access the real part in addition, lepton beams of both charges are needed

• In TCS the real part of the scattering amplitude can be accessed through the azimuthal angular asymmetry of lepton pair (unpolarized beam and target) or through the spin asymmetries (polarized beam and/or polarized target).

• TCS with transverse target is sensitive to GPD "E" while other measurements sensitive to "H" and that such a measurement may also make a contribution to globally constraining GPDs.

• Measurement of *both* spacelike DVCS and Timelike Compton Scattering (TCS) can test the universality of GPDs.

• First studies of TCS using quasi-real untagged and real tagged photons were carried out in Hall B at Jlab 6 GeV using the CLAS detector. These measurements has been demonstrated the feasibility to access GPDs through experimental studies of TCS. But, a dedicated 12 GeV experiments is required to reach the resonance-free region.

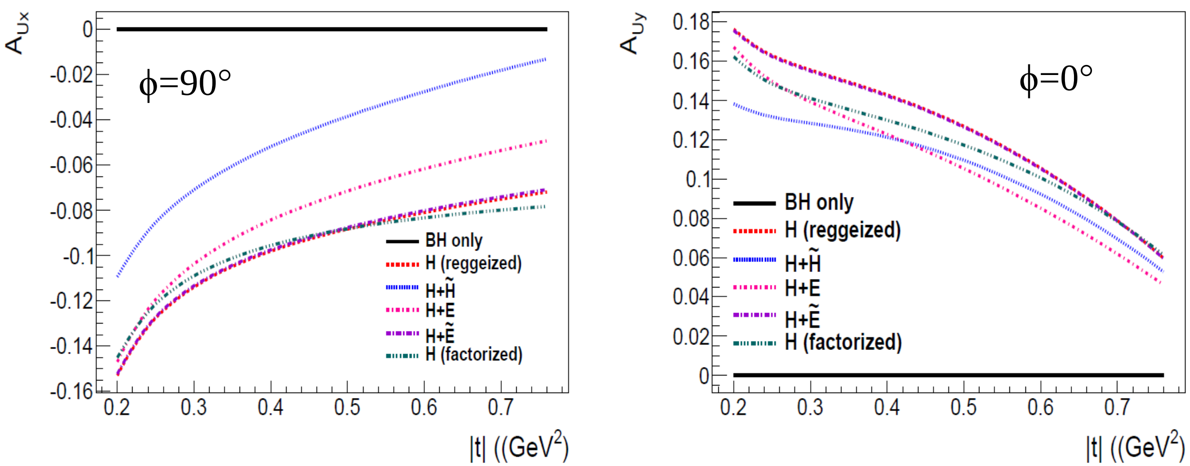
TCS measurements at JLab 12 GeV

- With polarized beam and unpolarized target (CLAS 12 /E12-12-001 & SOLID)

  With polarized photons will measure TCS differential cross section and weighed cross section (R) as a function of –t. and Q'^{2} in wider kinematic ranges, which is essential for understanding factorization.

- With polarized beam and transversely polarized target in Hall C

"transverse"



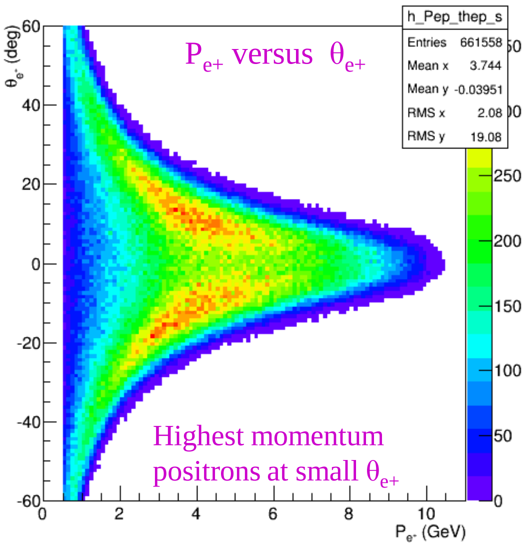
- Theoretical calculations for TCS on polarized target (Boer & Guidal) show that Transverse asymmetries are very sensitive to GPDs
- Predictions for asymmetries with different assumption of GPDs vary up to 20% (experimentally measurable).
- Asymmetries for the B.-H. which is main background for TCS is zero !

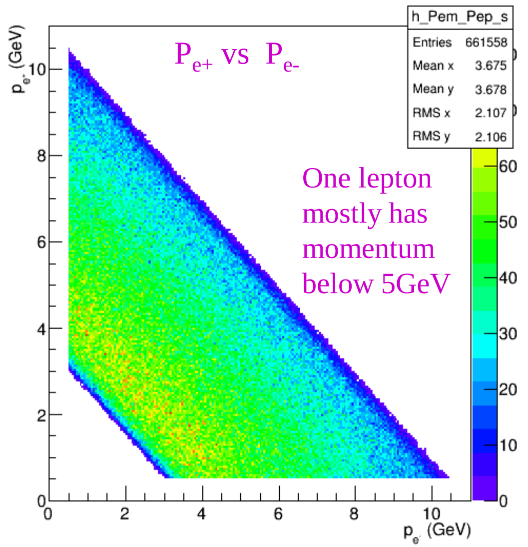
Theoretical predictions for TCS on polarized target (M. Boer, M. Guidal, arXiv:1412.2036, Dec 2014)

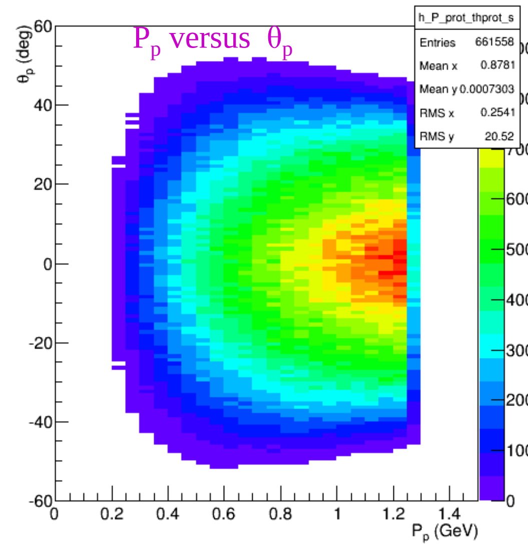
Transversely polarized target opens interesting opportunities to probe GPD

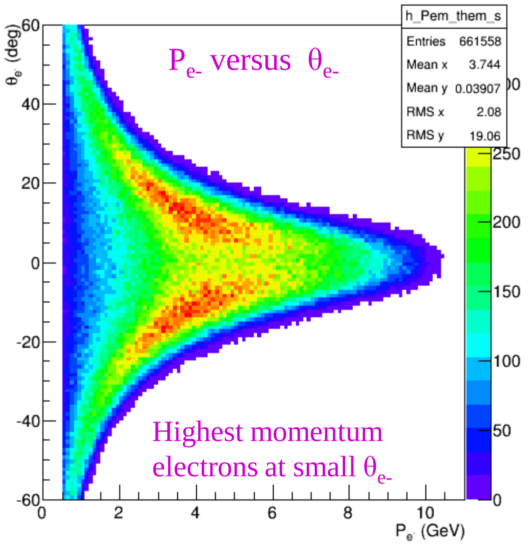
TCS kinematic phase space

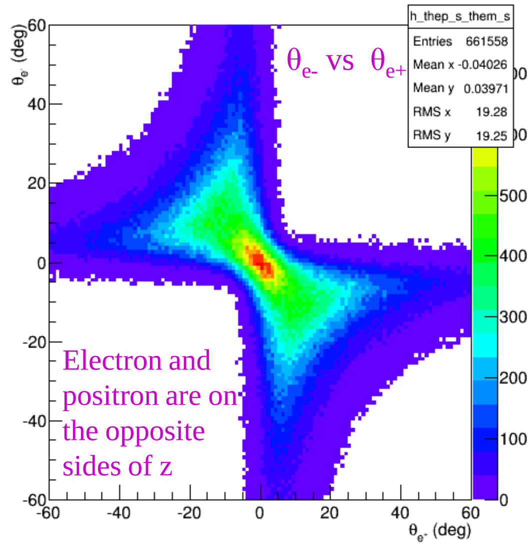
General cuts: Photons Energy range 4-11 GeV, $-t < 1.2\ GeV^2$, $Q^2 < 9\ GeV^2$ and $2 < M_{ee} < 3$ GeV

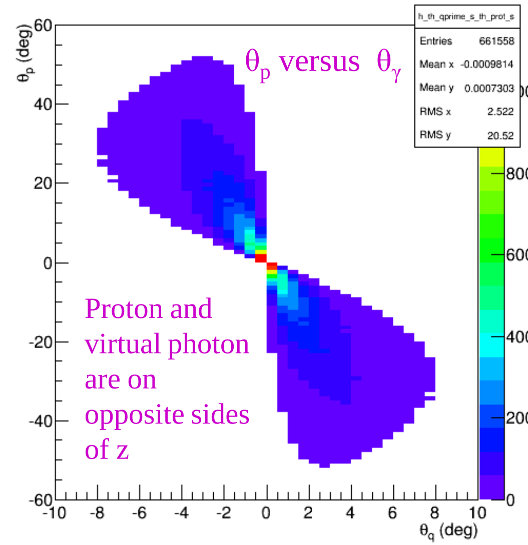




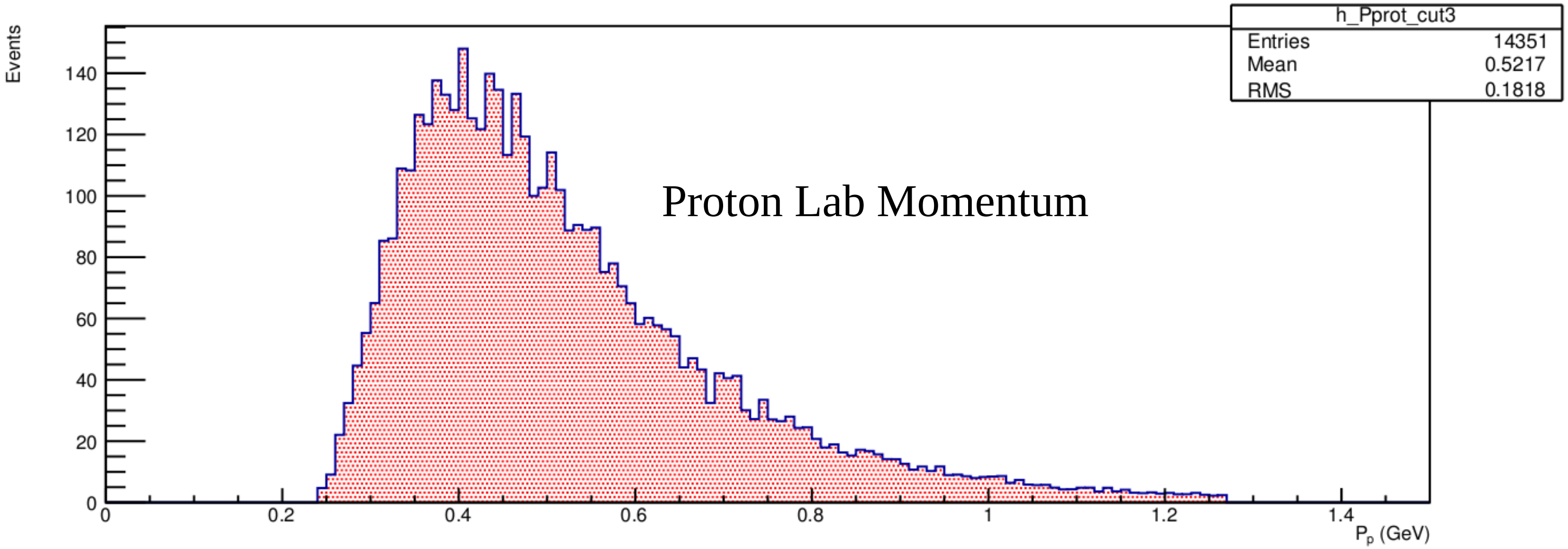


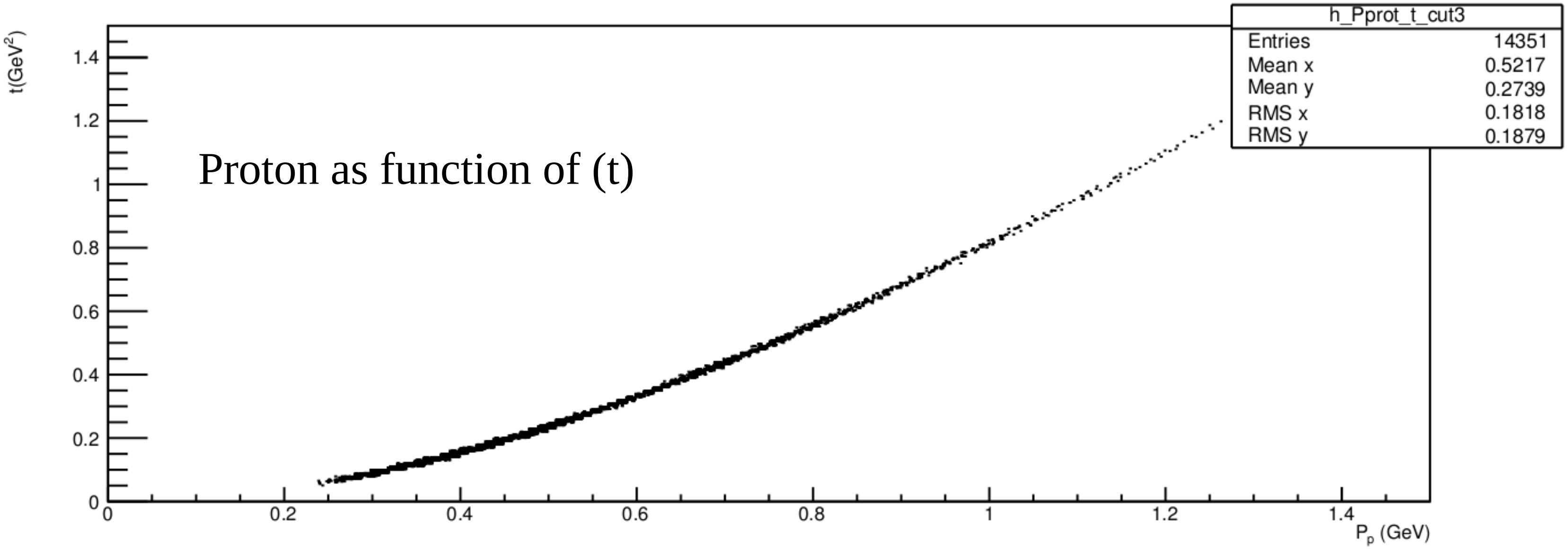




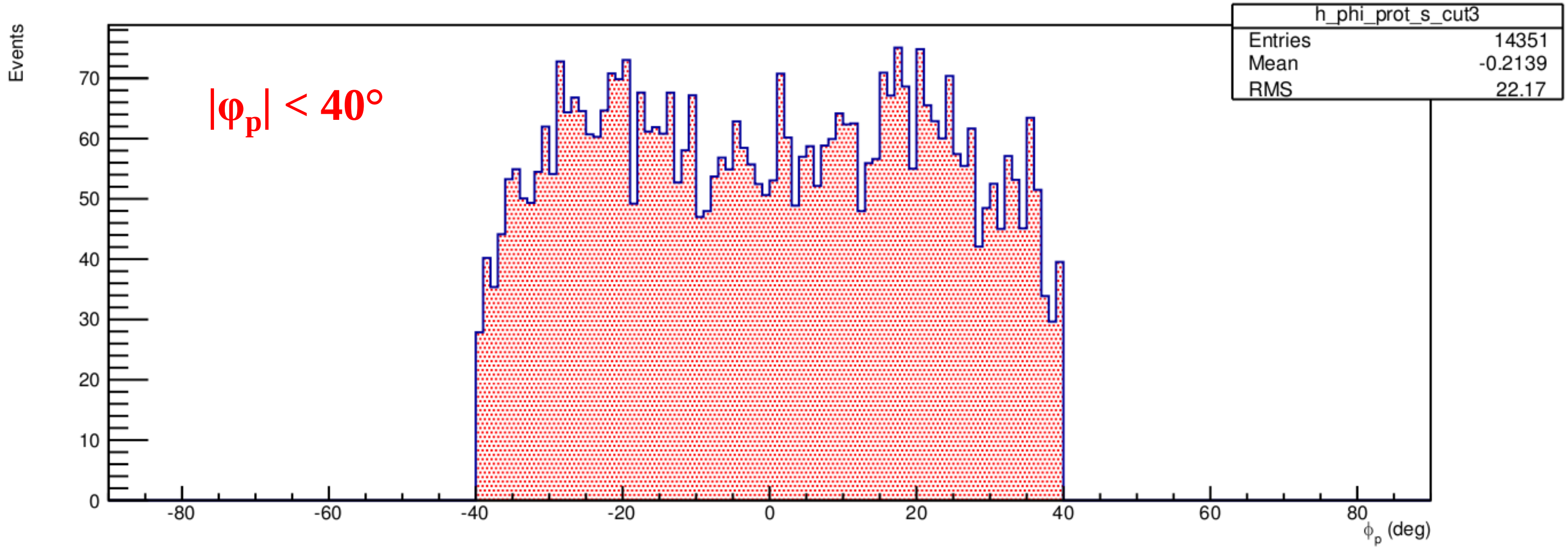


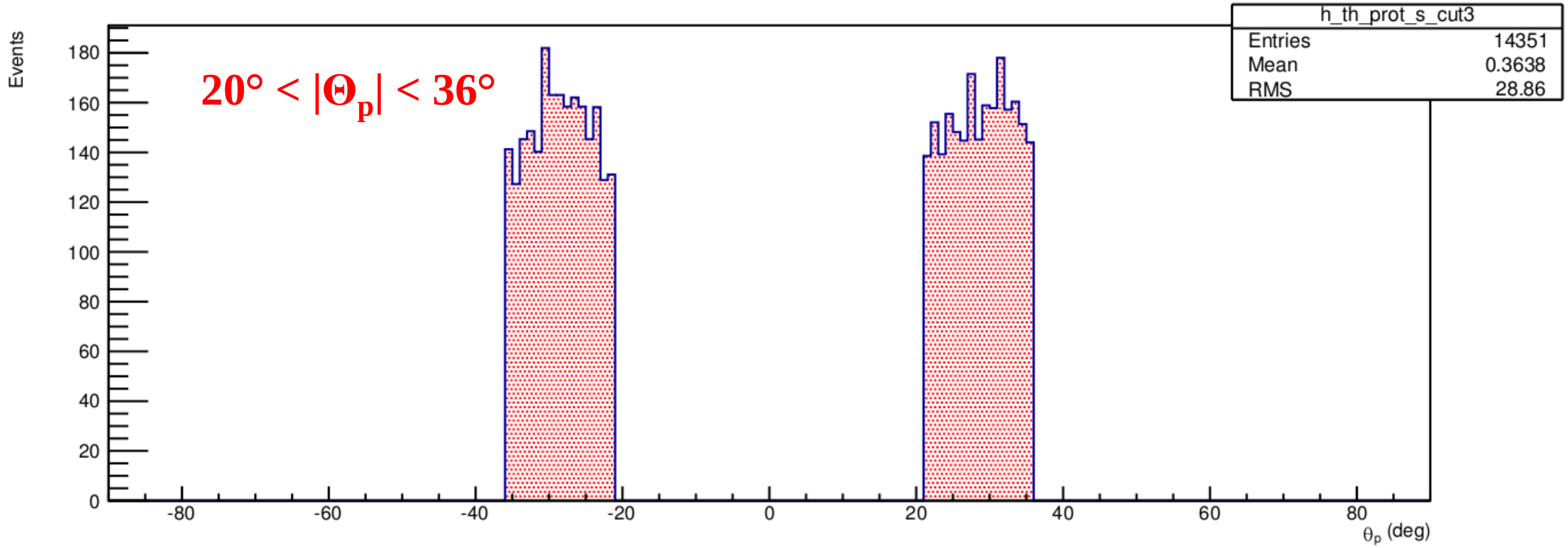
Proton Lab Momentum and Proton as function of (t)





Proton angular distribution





Required accuracy to recoil proton's P_p, θ_p and φ_p

- Lets take accuracy for missing mass square MM^2 on the level of ~0.05 GeV^2 (as was used in Rafael's analysis) and roughly estimate required accuracy for the recoil proton theta angle.

- Neglecting contributions from uncertainties of leptons momentum and angles and proton momentum, recoil proton angle accuracy related to accuracy of MM^2

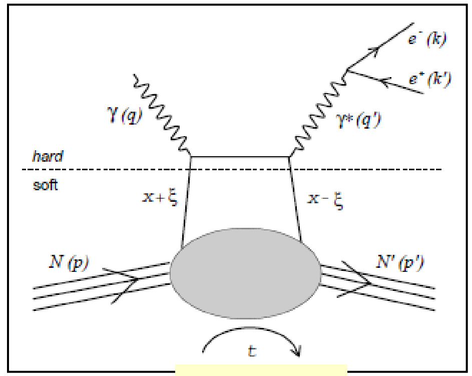
$$\mathbf{q} + \mathbf{p} = \mathbf{q}' + \mathbf{p}'$$

$$\mathbf{q} = \mathbf{q}' + \mathbf{p}' - \mathbf{p}$$

$$\mathbf{q}^2 = (\mathbf{q}' + \mathbf{p}' - \mathbf{p})^2 \Longrightarrow \mathbf{MM}^2$$

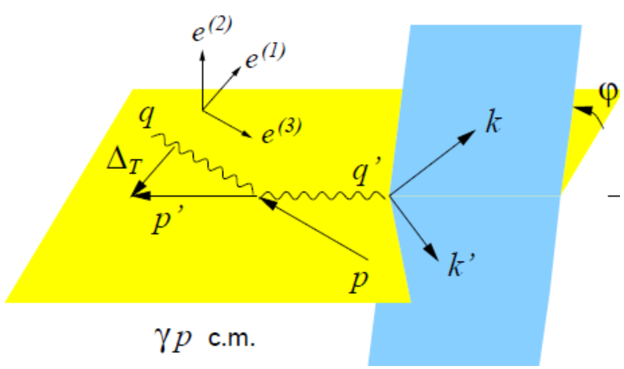
$$d\mathbf{q}^2 \equiv d(\mathbf{MM}^2) \approx 2|\vec{\mathbf{q}}'||\vec{\mathbf{p}}'| \sin\theta \, d\theta$$

$$d\theta \approx \frac{d(\mathbf{MM}^2)}{2|\vec{\mathbf{q}}'||\vec{\mathbf{p}}'|\sin\theta}$$

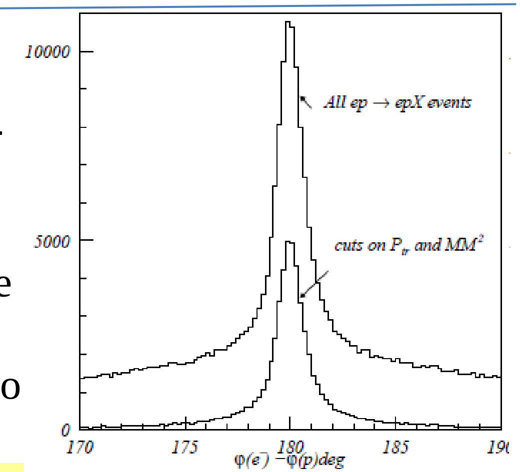


$t = (p - p')^2$

If $d(MM^2) = 0.05\,GeV^2, \theta \approx 15^\circ$, $|\vec{p}'| \approx 0.6\,GeV$ **and** $|\vec{q}'| \approx 10\,GeV$, **then** $d\theta \approx 0.02$ **or** $d\theta \sim 1^\circ$

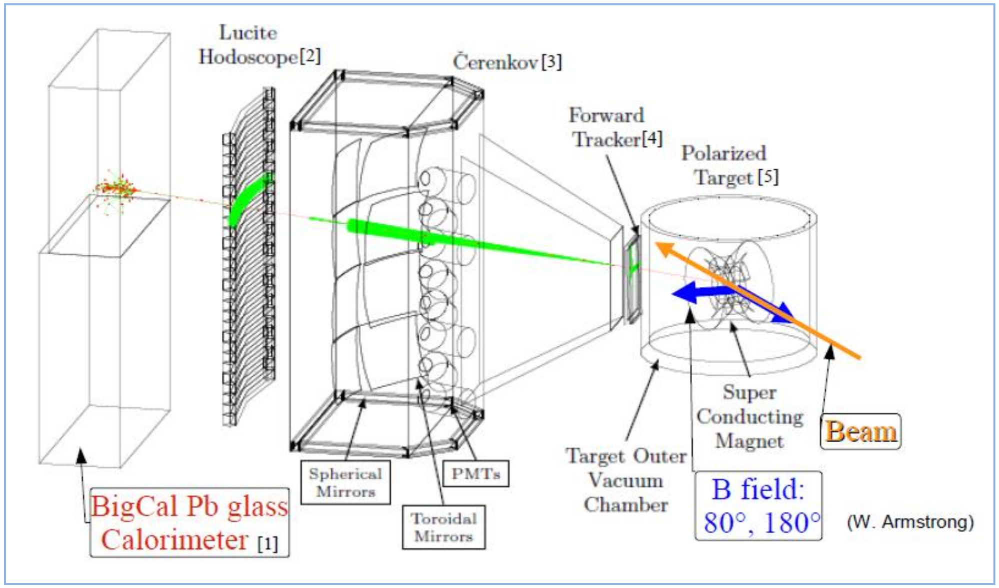


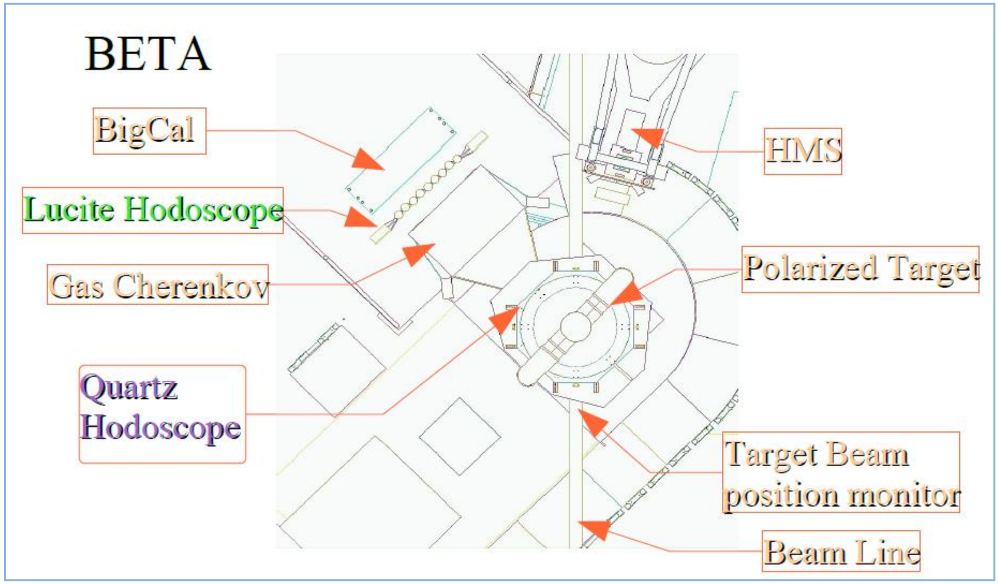
Another kinematical variable that can be used to select quasi-real elastic scattering events is $\delta\phi$, in CM system difference between azimuthal angles of the reaction plane and the recoil proton, which should be equal to 180°.



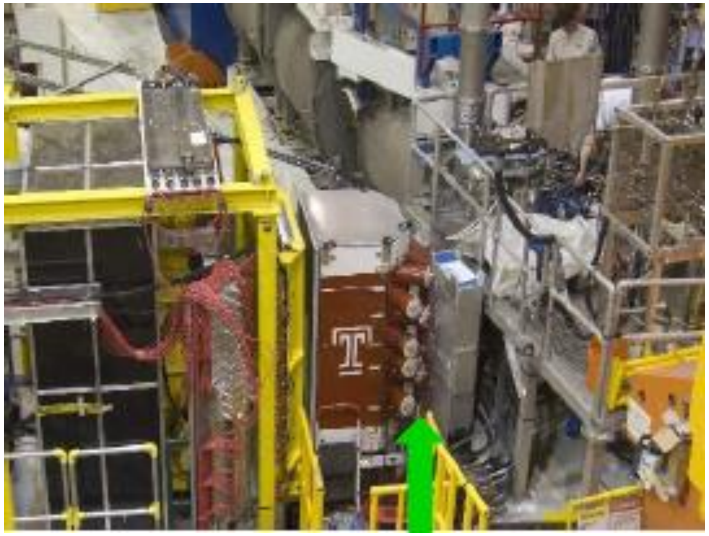
This required θ_p and φ_p resolutions to be better than ~1°. Hodoscope at distance of ~2m with coordinate resolution ~1 cm will resolve this problem. Tracked can be made from 1-3 mm diameter scintillation fibers, but 3 mm is preferable for better time & amplitude resolutions.

Polarized Target previously used in Hall C





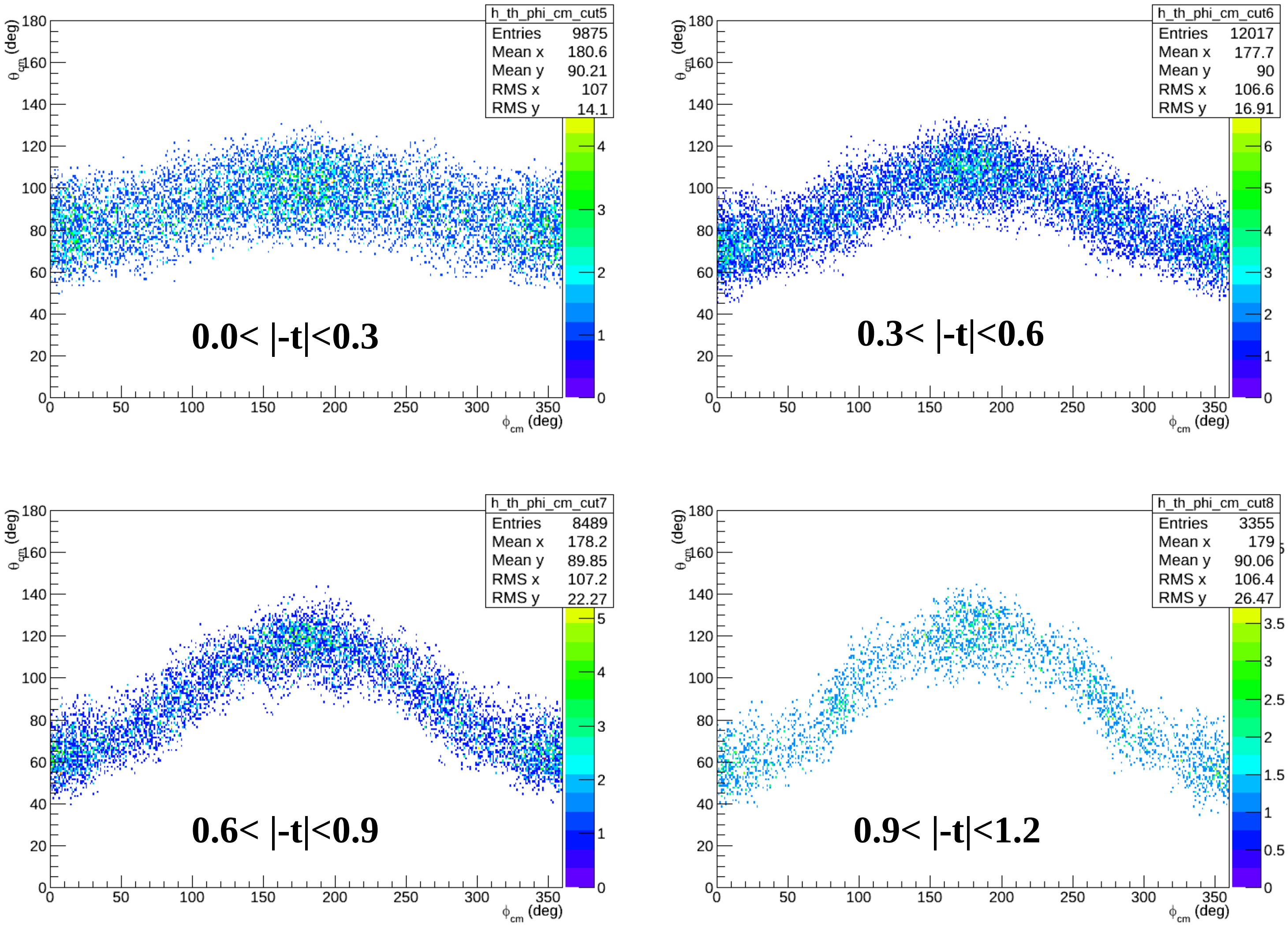
- Target was installed in scattering chamber with about 1m diameter.
- Potentially, it was possible to install any detector after scattering chamber that fits on pivot (or additional 1m due to pivot).
- Limiting factors to operate close to scattering chamber were high fringe field of the polarized target and high low energy background rates.
- At least 2 m distance needed from the pivot to avoid impact of magnetic field on the PMTs



UVA Polarized target in Hall C SANE experiment

TCS events θ - ϕ_{cm} coverage at 11 GeV for t-bins

After applied acceptance cuts full -t range (0.1 to 1.2 GeV^2) are divided into 4 bins.

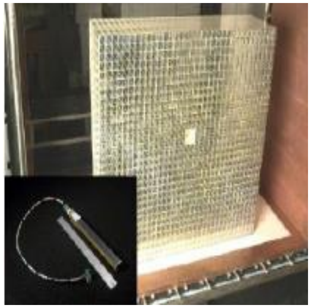


proton cut
$20° < |\theta_p| < 36°$, $|\varphi_p| < 40°$, $P_p > 0.3$GeV/c.

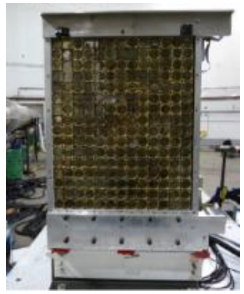
leptons cut
$6° < |\theta_e| < 18°$, $|\varphi_e| < 14°$, $P_e > 0.3$ GeV/c

After applied cuts there is not full ϕ_{cm} coverage at given θ.

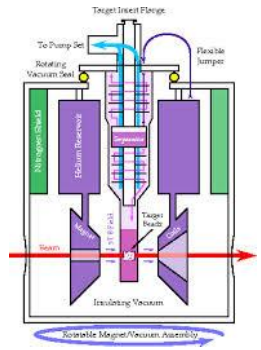
TCS events detection in Hall C



$PbWO_4$

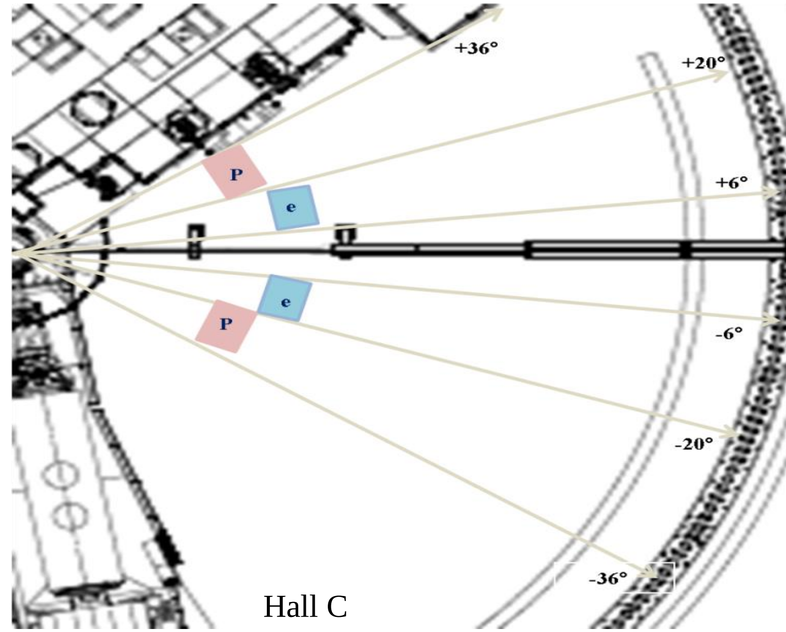


PbF_2



NH_3 Target

Possible versions for the NPS



Hall C

- Area between beam line and HMS and SHMS magnetic spectrometers.
- Leptons pair from reaction $e + p \rightarrow e^- + e^+ + p'$ (e') will be detected by pair of NPS
- Recoil protons will be detected by combination of Tracker and Hodoscope
- Tracker, ~3 mm diameter scintillation fibers t minimal distance from the target
- Polarized NH_3 target can handle electron beam intensity up to 200-300 nA (~10^{12} e/sec).
- Selection of TCS events from background required recoil proton θ_p and φ_p angular resolutions to be better than ~1°, and missing mass square MM^2 resolution on the level of ~0.05 GeV^2
- Based on these assumptions will estimate TCS event rates at ~2 m distance from the target.

Work needed to have LOI ready

•More complete list of collaboration

•Physics motivation (need input from Boer and Guidal ?)

•Need specifically justify transversely polarized target measurements (why this important and what information we can get from such type measurements which is not accessible from other measurements (CLAS12 or SOLID)

•Finalize geometry of experiment, select optimal location and acceptance for the detectors

•Final kinematics of experiment, and what and how will be measured

•Estimate counts and required statistic (accuracy) for proposed measurements

•More detailed description of experimental setup (detectors)

•If possible, estimate sources of backgrounds, systematic errors and cost needed for detectors ?