TCS vertex reconstruction

Update

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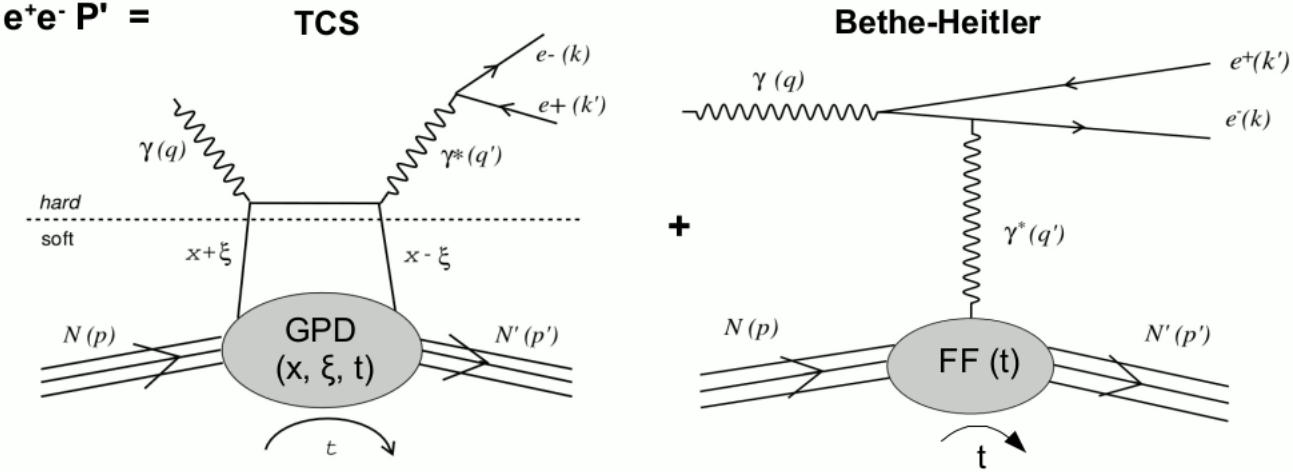
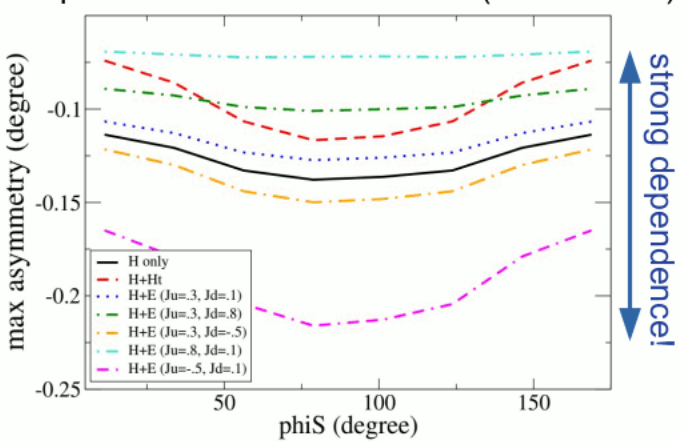
CPS Meeting
12/03/2021

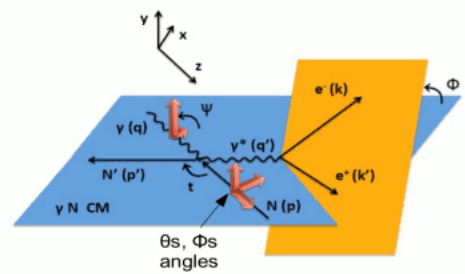
Physics goals

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



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

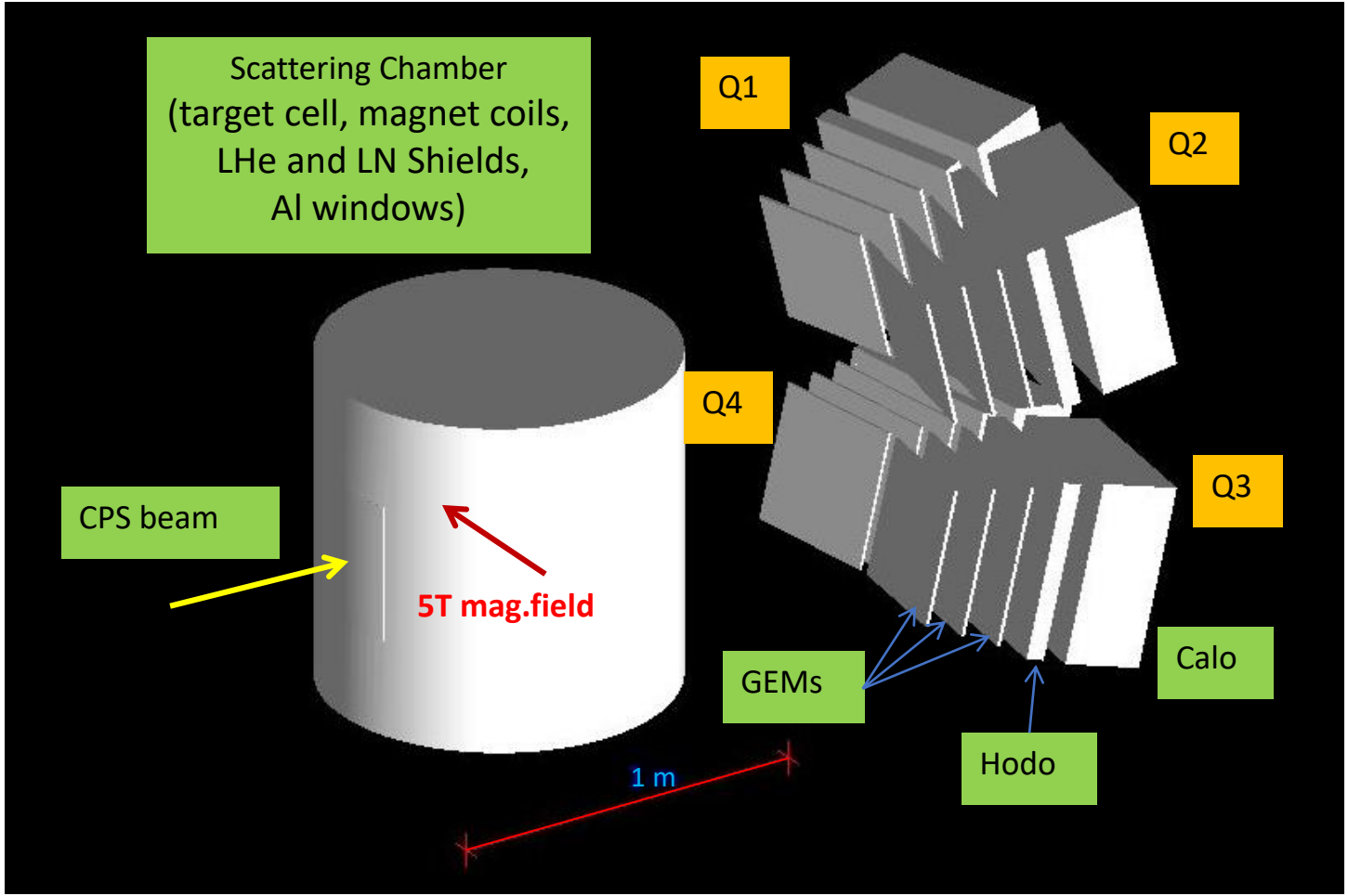
- Sensitive to Im(interference), BH cancels
- Strong dependence in angular momenta,

Sensitivity to GPD E (also to H, Ht)

Courtesy M.Boer

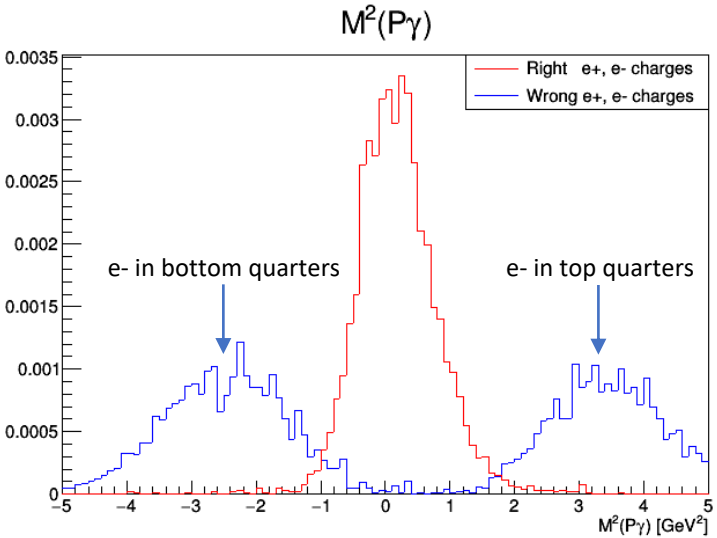
Proposed TCS setup

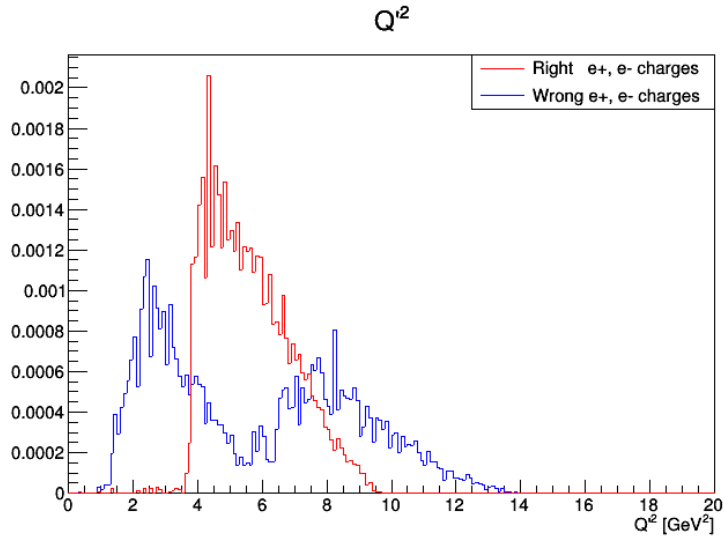
$$\gamma + p \rightarrow \gamma^* (e^+ + e^-) + p'$$

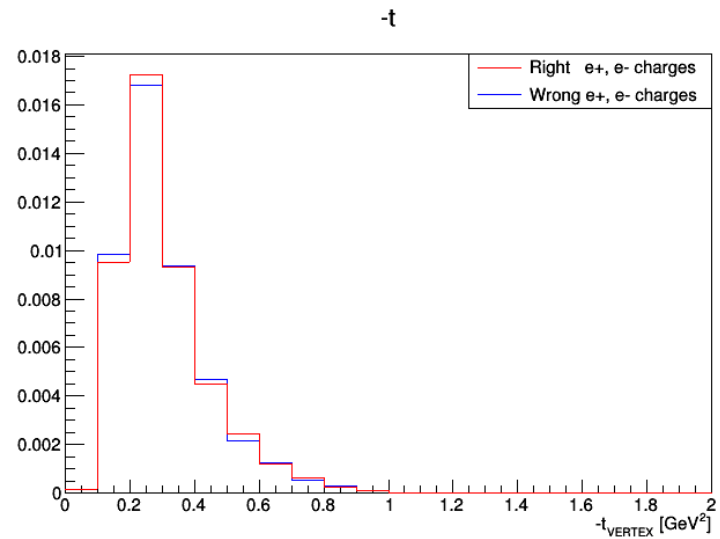


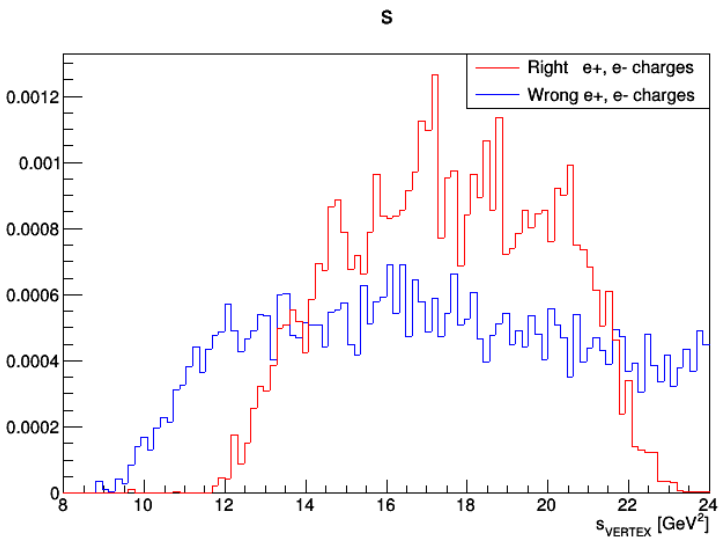
- Detect e^+, e^-, recoil p' in coincidence
- CPS bremsstrahlung photon beam
- UVA/Jlab NH_3 target, transversely polarized
- Detectors arranged in 4 quarters, oriented to target
- Triple-GEMs for e^+, e^-, p tracking
- Hodoscopes for recoil proton detection/PID
- $PbWO_4$ calorimeters for e^+, e^- detection/PID
- **Trigger based on calorimeter signals**
- Added Forward Tracker (not shown)

Reconstructed TCS quantities
(with right and wrong lepton charges)

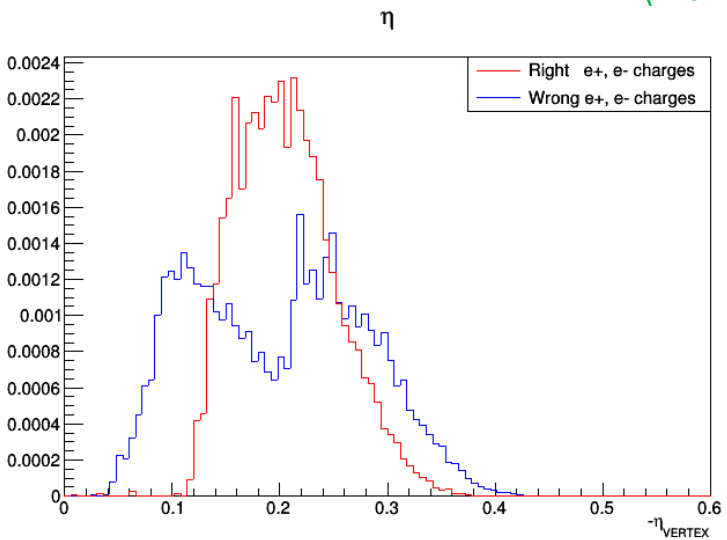


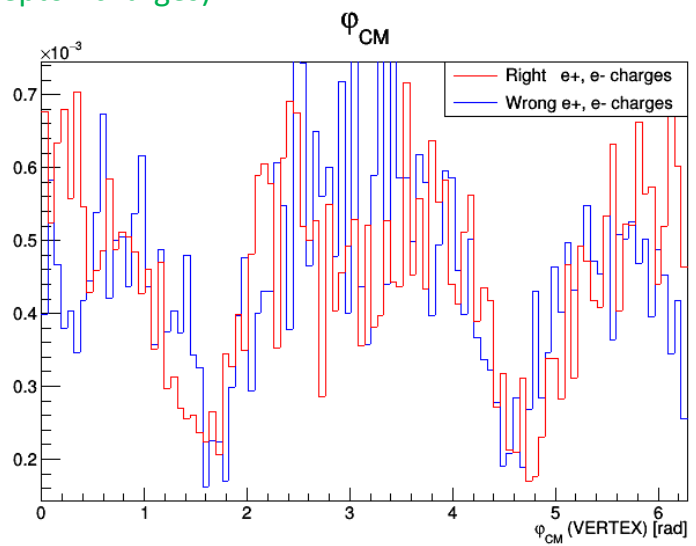


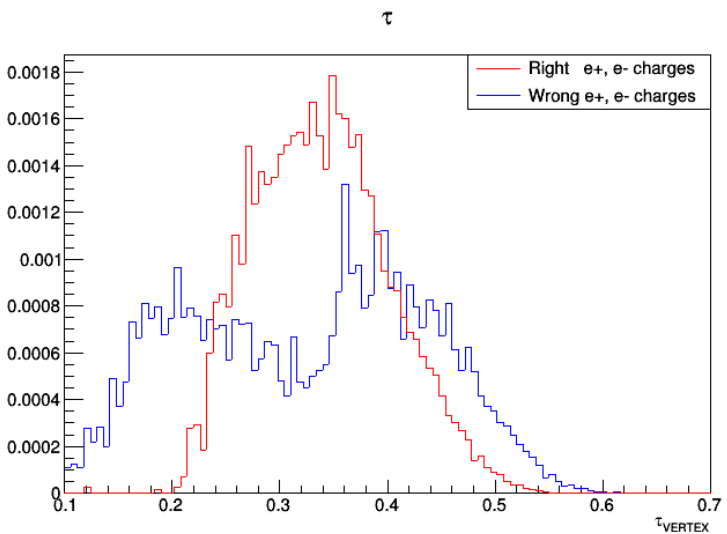


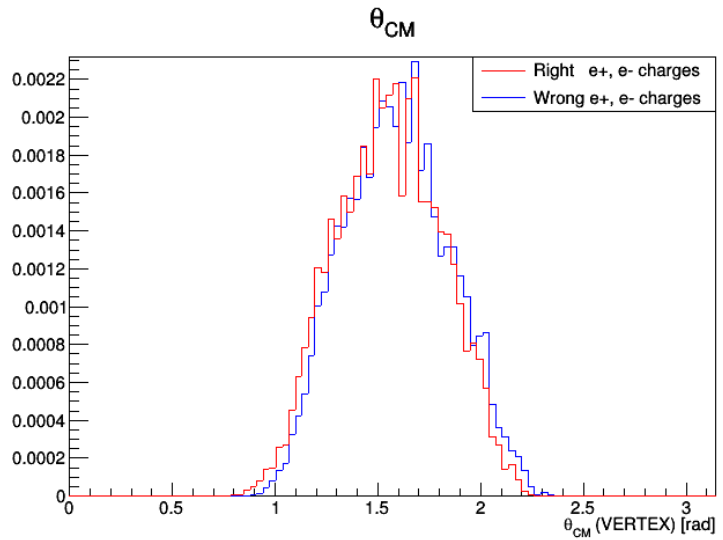


Reconstructed TCS quantities
(with right and wrong lepton charges)









SANE tracking, Forward Tracker

Vertex reconstruction in SANE

- Regression technic
- Machine Learning, AI (done separately for e-, e+)

Forward Tracker (for charge differentiation, e+ rejection)

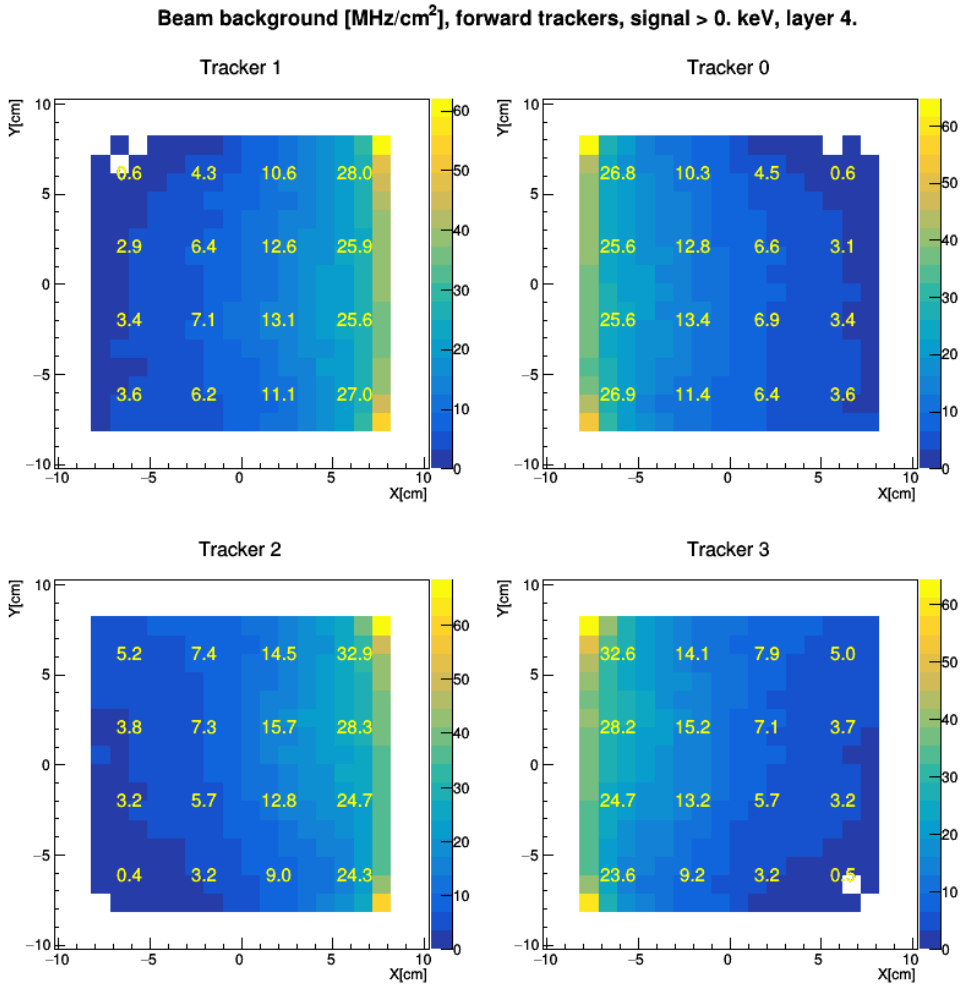
- Track momenta < 1.2 GeV/c, expected deflections ~ several mm.
- 3 mm thick scintillators (X, Y, Y' planes; Y' shifted by 1.5 mm)
- Positioned by Scattering Chamber exit windows
- Was not used, particularly due to high background

Hand calc. estimate for TCS:

- Forward Tracker at 50 cm from target
- Rear trackers at ~130 cm
- $\int BdL \sim 0.033\ Tm$
- For 2.5 P = 2.5 GeV/c, deflection 4 mrad, or **2.8 mm**

Thanks to Donal and Oscar for pointing to relevant sources!

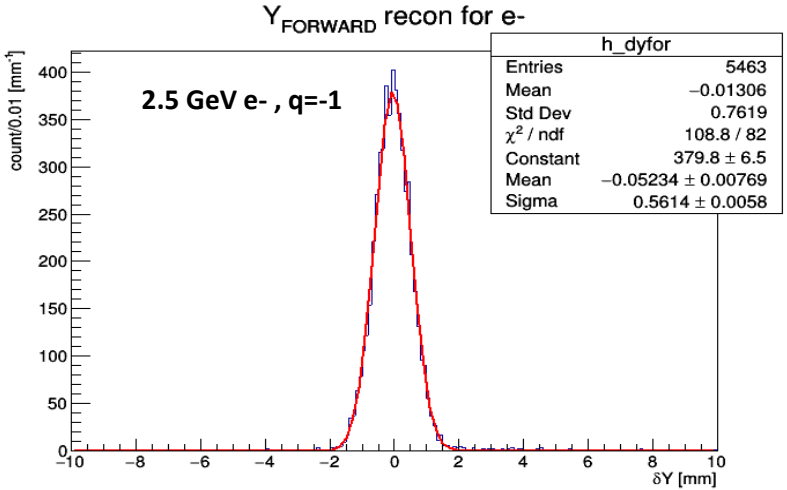
Forward Tracker, beam backgrounds

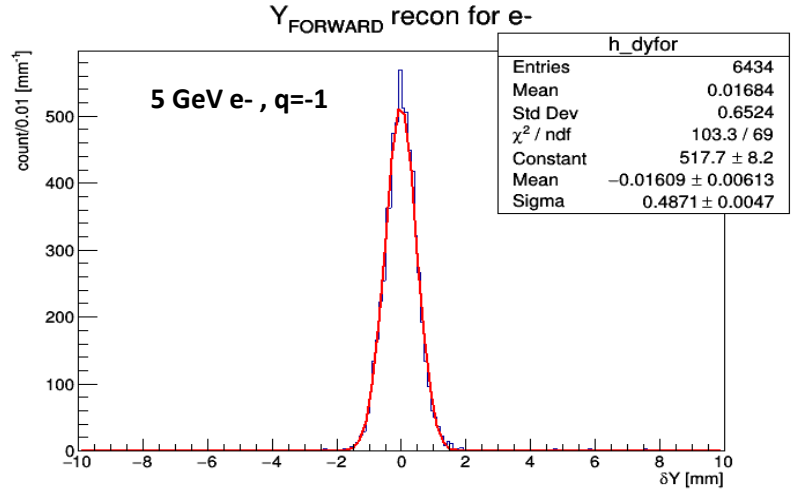


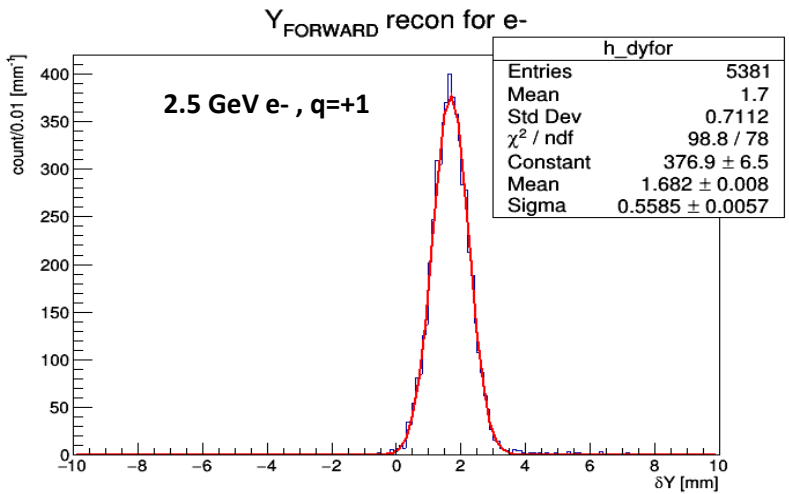
GEM Forward tracker

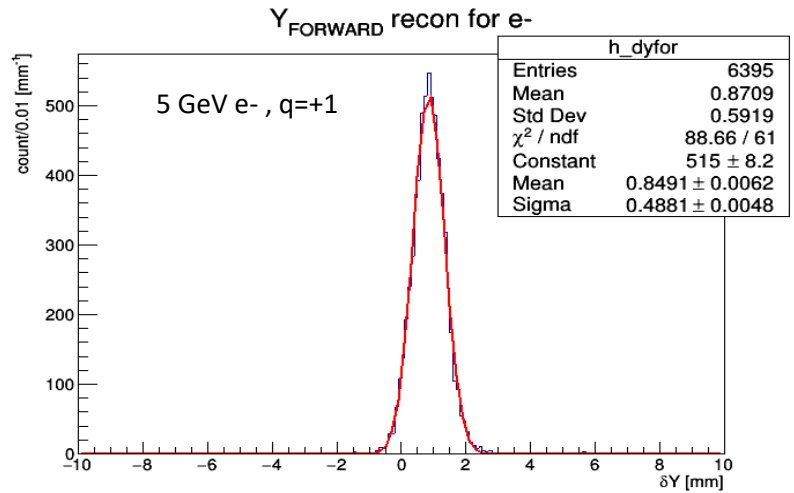
- At 52 cm from target
- Tilted as rear trackers
- Background rates acceptable, < 100 MHz/cm^2

Backtracking to Forward Tracker
(with right and wrong e- charge)









Offline Analysis outline

- 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

     $2800 < E_{DEP}(\text{hodo}) \times E_{DEP}(\text{calo}) < 4200\ \text{MeV}^2$
  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

Rates from Offline Analysis

tcs_rate = 13.5158 Hz
trig_rate = 0.768044 Hz 5.68258 %
ee_recon_rate = 0.547675 Hz 4.05212 %
eep_recon_rate = 0.0158118 Hz 0.116988 %

good_lep_tracks_rate = 0.549367 Hz 71.5281 %
eff.at_sc_lep_rate = 1.09796 Hz
at_win_lep_rate = 1.09633 Hz
at_tar_lep_rate = 1.09626 Hz
hodoclust_p_rate = 0.296839 Hz
caloclust_p_rate = 0.0527895 Hz 17.7839 %
eff.clustmatch_p_rate = 0.034704 Hz 65.7405 %
eff.exe_p_rate = 0.0276591 Hz 79.7 %
eff.hodocalo_p_rate = 0.0276591 Hz
good_p_track_rate = 0.0168446 Hz 60.9009 %
eff.at_sc_p_rate = 0.0168446 Hz
at_win_p_rate = 0.0158122 Hz
at_tar_p_rate = 0.0158118 Hz

Backup slides

Before:

Demonstrate accuracy of reconstruction of TCS quantities, by vertex reconstruction and comparison of the reconstructed quantities with **true** quantities. Makes use of **true** parameters of tracks: particle ID, particle ID of origin, track ID, charge.

Now:

Demonstrate feasibility of offline analysis. Use only detector hit information. Select useful hits (energy clusters), backtrack (or regress) to obtain tracks at vertex.

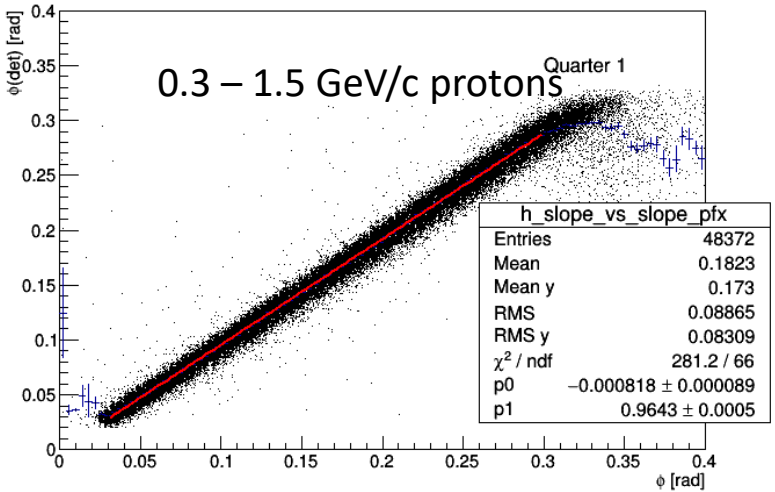
Possible offline Analysis outline:

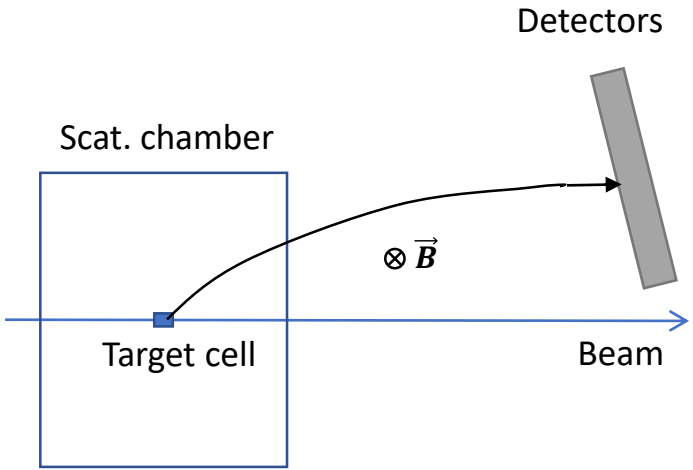
- ✓ Trigger: single crystal hits with Edep > 2.5 GeV in opposite calorimeter quadrants.
- ✓ Cluster calorimeter hits
- ✓ In each quadrant, find cluster of Max. Edep in calorimeter
- ▪ Take pair of max. Edep clusters in opposite quadrants, with max. sum of energy deposits, as e+ and e- candidates.
- ✓ Calculate ΔX and Δ Y widths of the clusters
- ▪ Search trackers for hits within Δ X and Δ Y (at least 2 hits in different layers needed)
- ▪ Construct straight track through tracker hits, make sure it hits calo. cluster
- ▪ Assign opposite charges to the pair of tracks, and momenta from calo. Edep-s
- ▪ Backtrack the assigned e+ and e- tracks to target

- ✓ Cluster hodoscope hits
- ▪ From the remaining calo. clusters, select calo. cluster and overlapping hodo. cluster such that 2800 < Edep(hodo)xEdep(calo) < 4200 MeV^2
- ▪ Search for hits (at least 2 in different layers) in the trackers before the clusters (in ΔX x Δ Y ~ 2x2 cm^2 area)
- ▪ Derive momentum of the proton candidate from Ekin = Ehodo + Ecalo
- ▪ Backtrack proton candidate to target

Calculate TCS quantities

Vertex reconstruction options



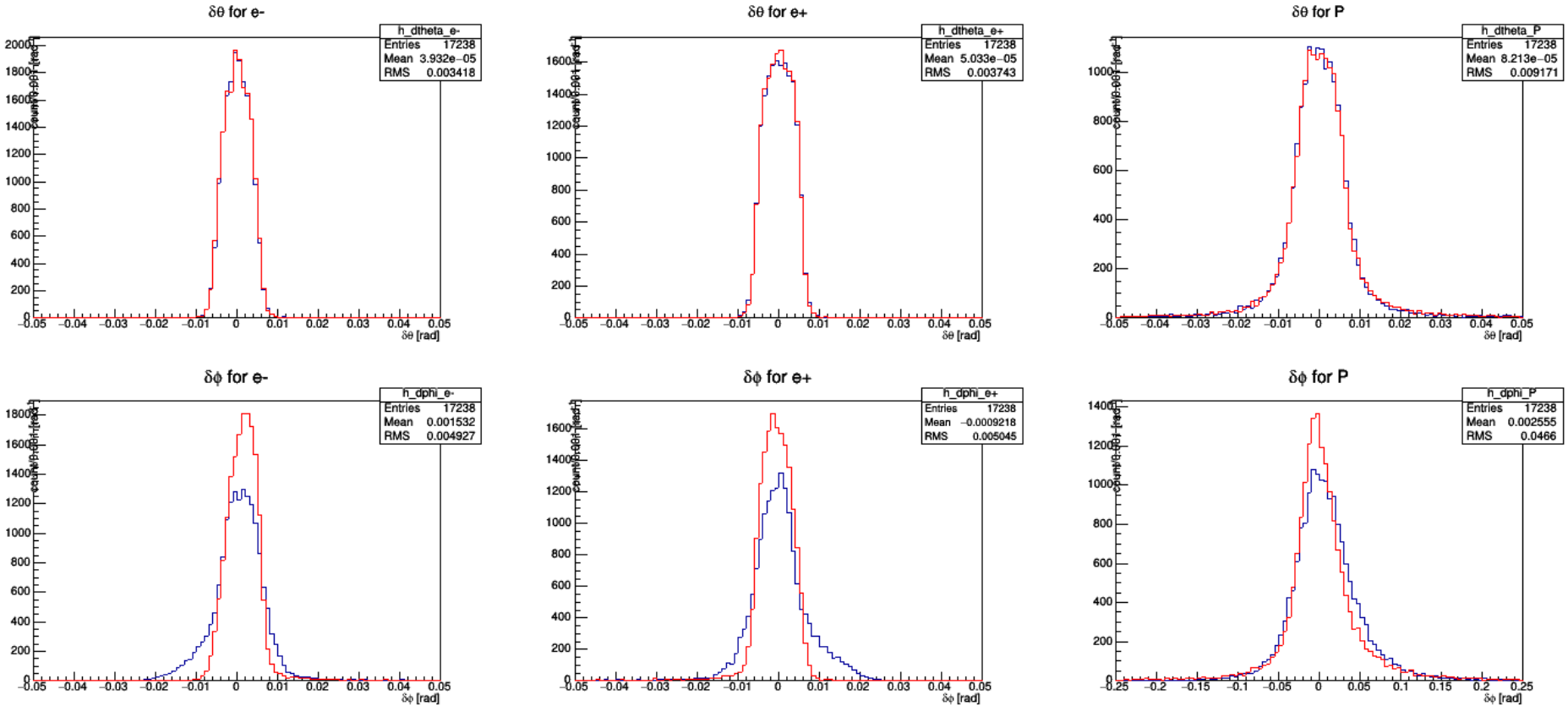


φ at vertex can be reconstructed by linear regression from φ (measured) at GEMs.

Charged track in target magnetic field, can be reconstructed by backtracking.

Accuracies of angle reconstruction

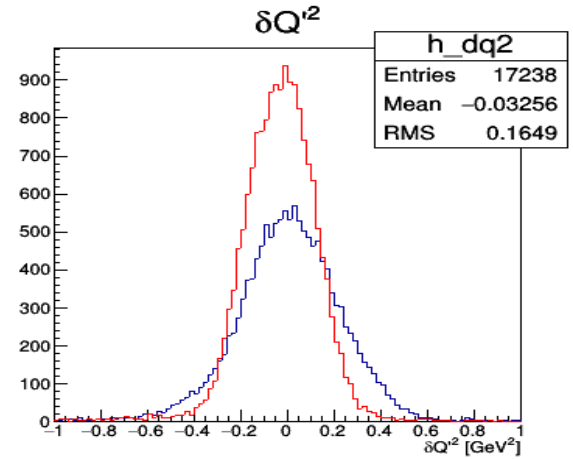
Red – backtracking, blue – regression.

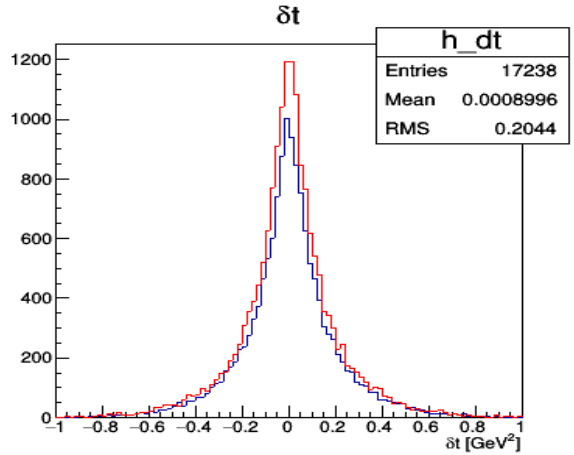


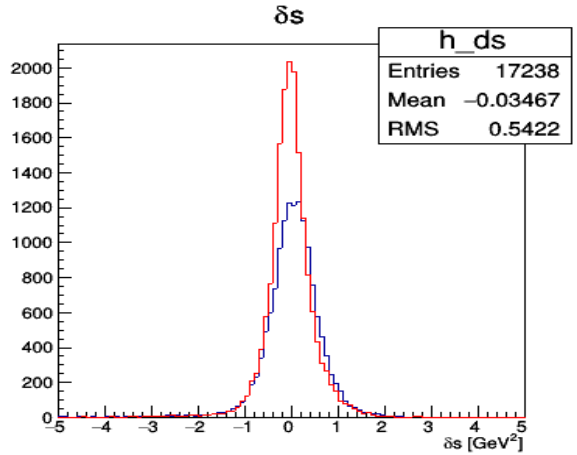
Note: histograms normalized to common integral. Note also different scale for proton.

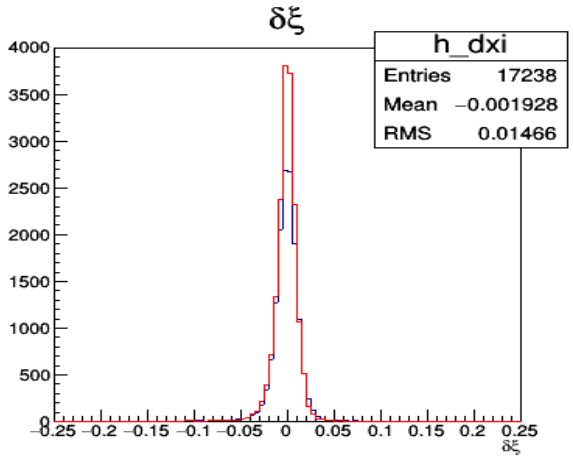
Accuracies of reconstruction of TCS quantities

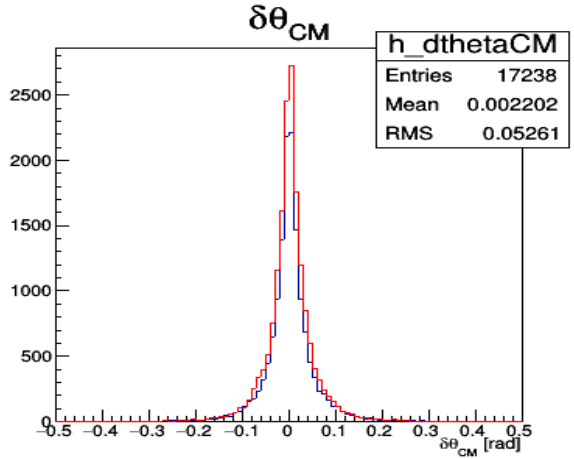
Red – backtracking, blue – regression.

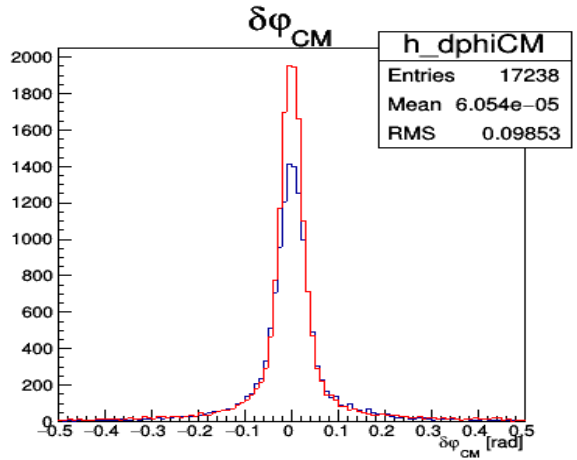






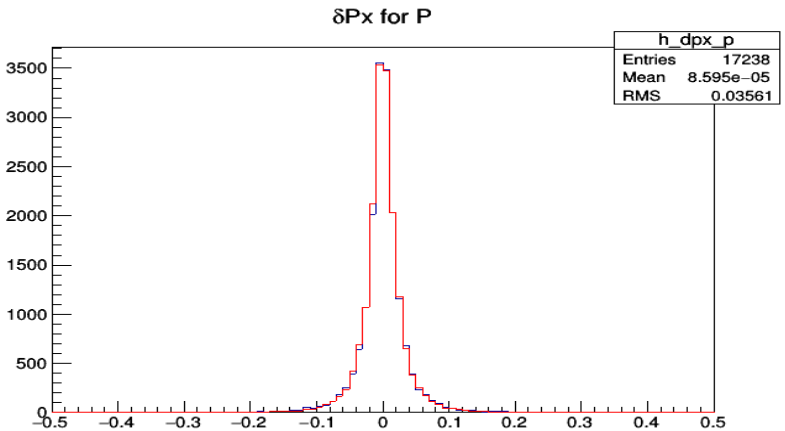


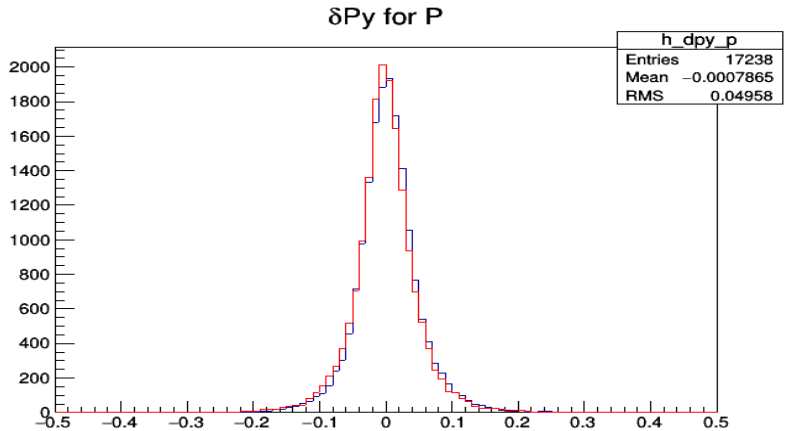


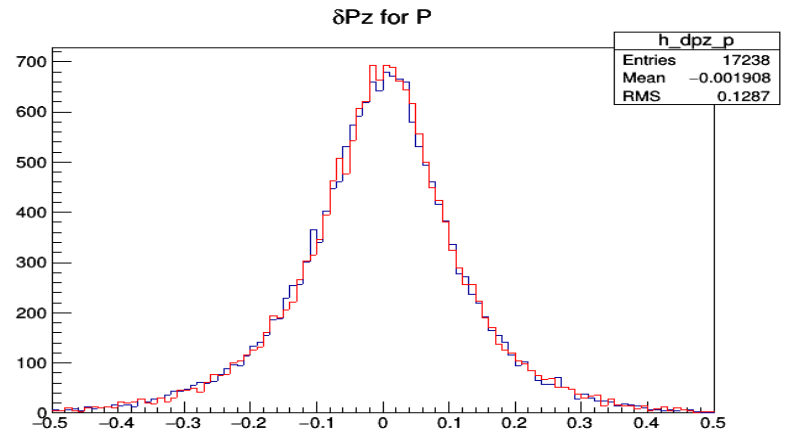


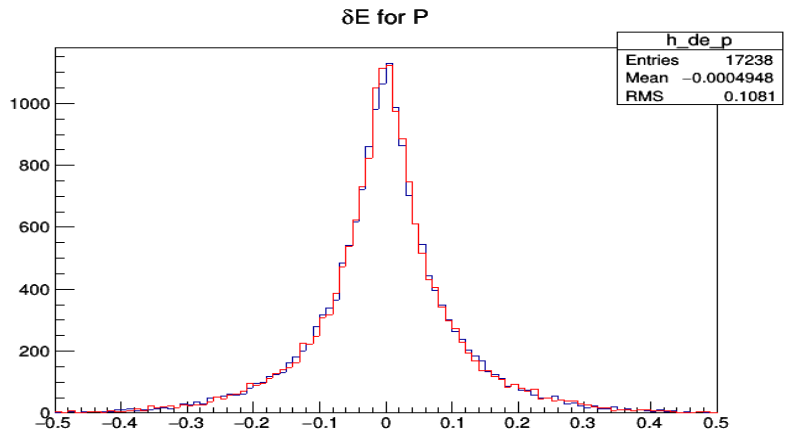
Accuracies of recoil proton reconstruction

Red – backtracking, blue – regression.

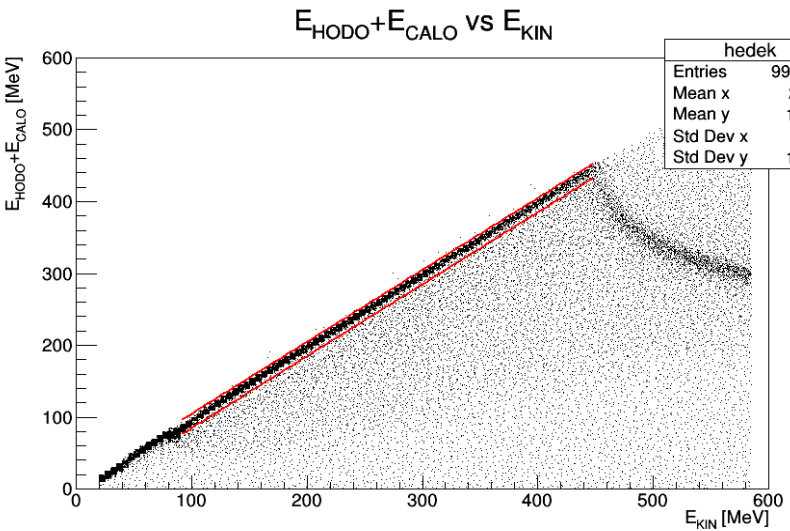


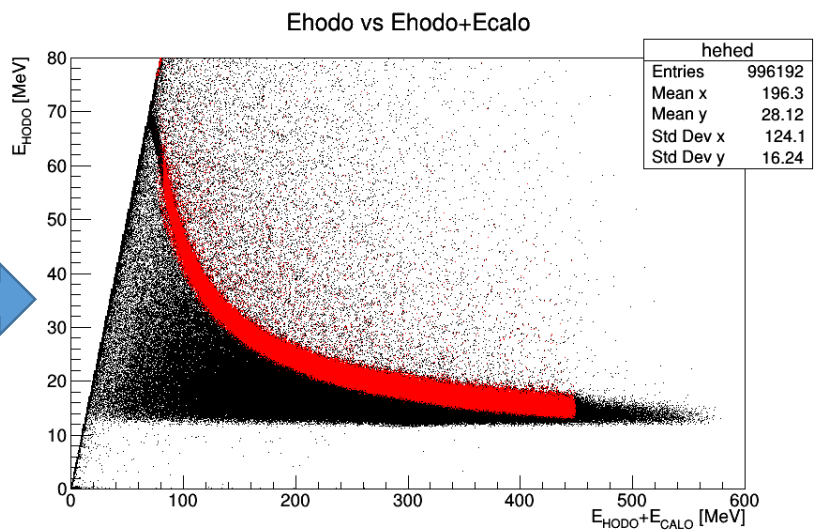


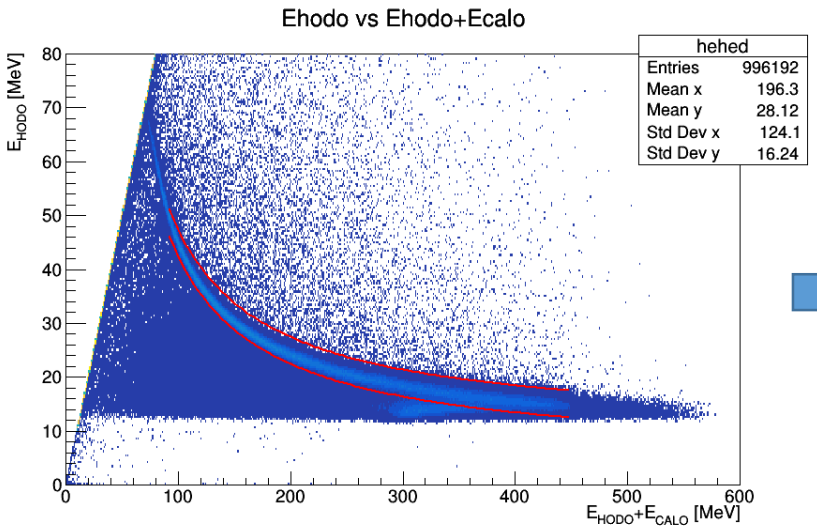


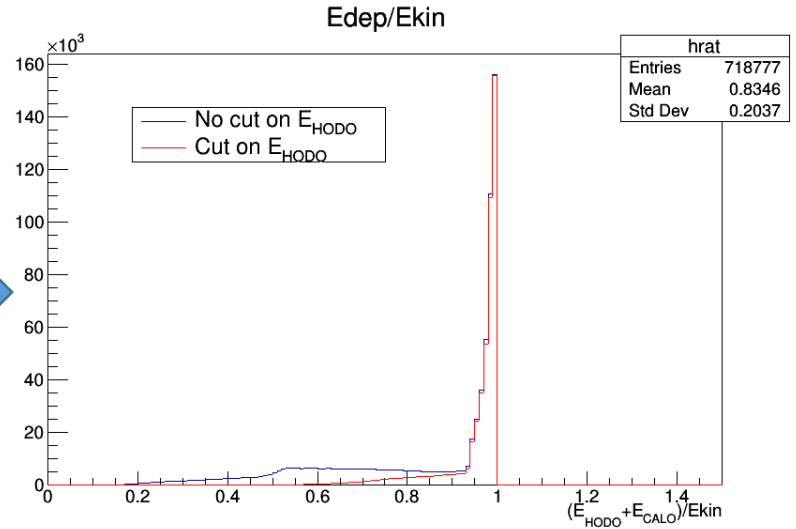


Proton E_{KIN} from hodoscopes and calorimeters









Note: proton tracks perpendicular to detector surface