TCS Simulation:
low momentum proton tracking

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04/16/2020

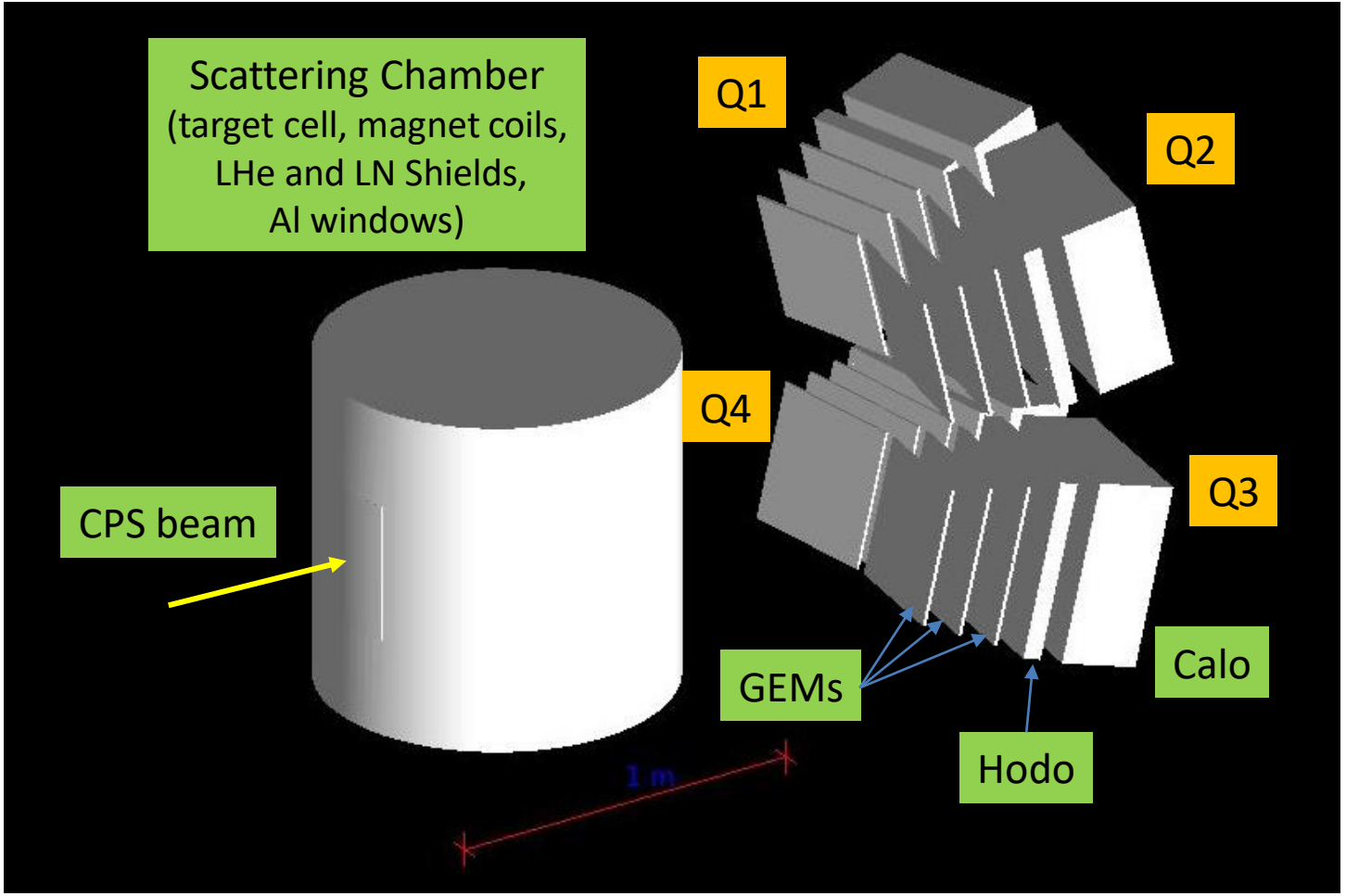
CPS Action Items

CPS Science: Timelike Compton Scattering

- Determine quantitatively if low energy protons can be measured after the polarized target high magnetic field – do they leave the field? Do they leave the scattering chamber?
  - Make a 3D simulation and for selected bins show the trajectories of proton (and electron) and where they hit the detector in t, phi, etc., in particular at low momentum
  - Check the simple example of phi plot correlations: plot phi=0/theta=0, phi=0/theta=45, phi=0/theta=90deg, etc., and see if the correlation, and where the detector is hit, changes
- Show how one can select exclusive TCS events with photon beam energy unknown and detection of positron, electron and proton in area of large background.
- Show how certain particle backgrounds can be reduced in the data analysis (π^0, γ, $\pi^{+/-}$)
- Quantify the unique impact of TCS with polarized target on hadron imaging studies
- Show how TCS with polarized target complements other approved Compton Scattering experiments (DVCS, TCS, WACS) at JLab.

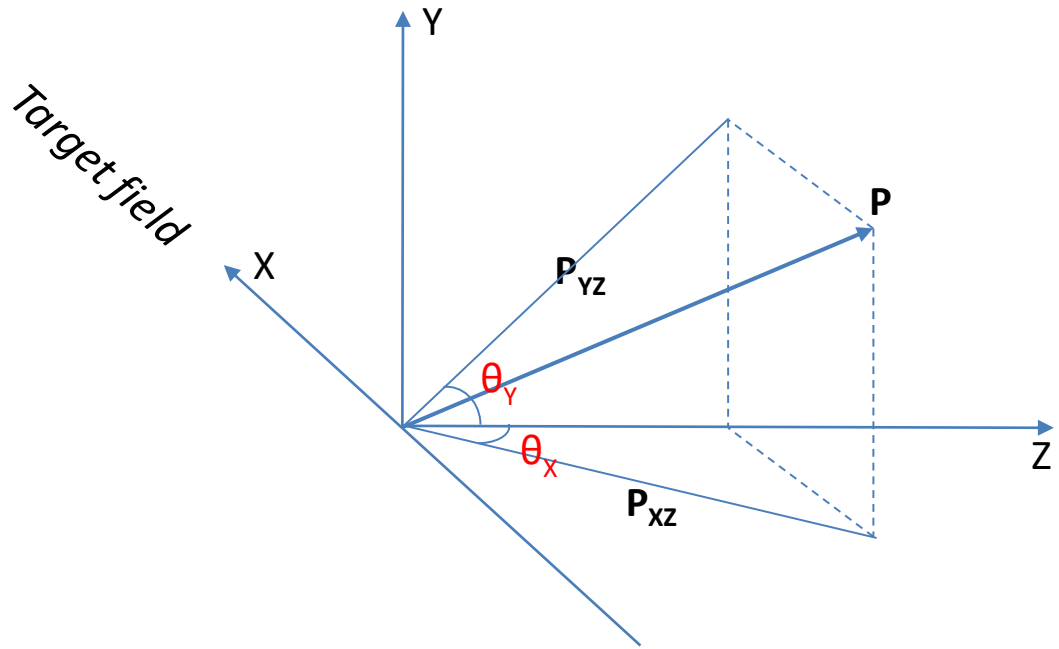
Exempt from CPS Action Items 2020

Setup



- CPS photon beam
- JLab/UVA NH_3 (g2p) polarized target (rotated 90^o)
- Triple-GEMs for e^+, e^-, p tracking
- Hodoscopes for p detection/PID
- $PbWO_4$ calorimeters for e^+, e^- detection/PID

Conventions

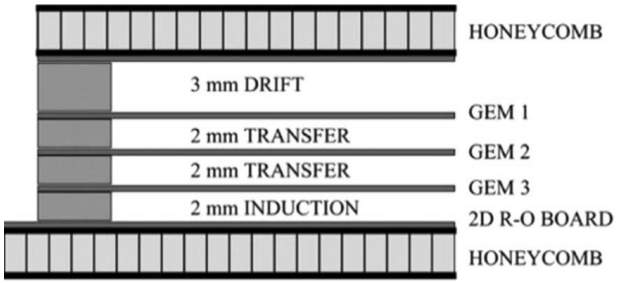


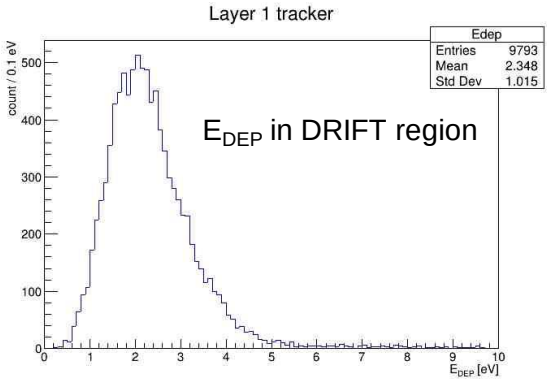
Beam direction

Note: detectors positioned at $\theta_X = \pm 10.034°, \theta_Y = \pm 14.042°$; layer 1 GEM trackers at 120 cm from target.

Sampling

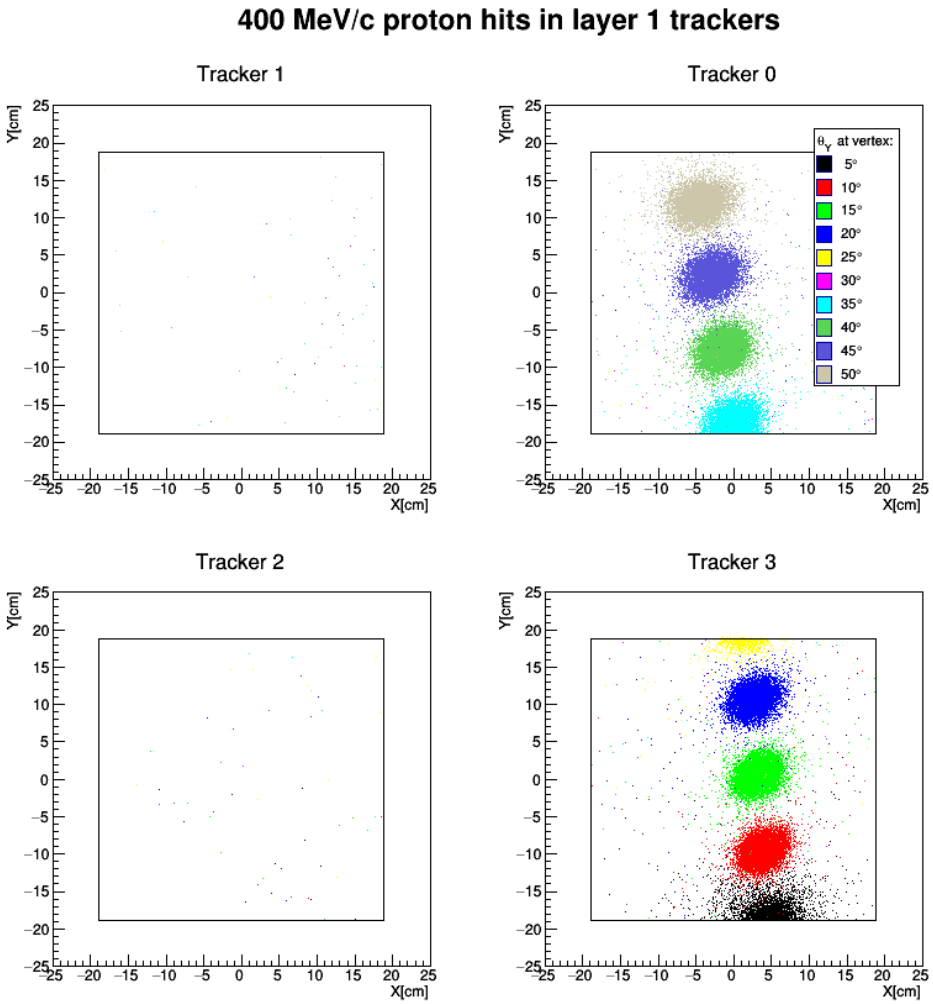
- Choose proton momentum 400 MeV/c
- Choose θ_X = 10° at target (pointing to quarters 1, 4)
- Increment θ_Y in steps of 5°
- Sample 10k events at origin for each (θ_X, θ_Y)
- Look for hits in layer 1 trackers:
  - PID(track) == PID(vertex) → proton
  - Track ID == 1 → original track
  - E_{DEP} > 0 eV → signal





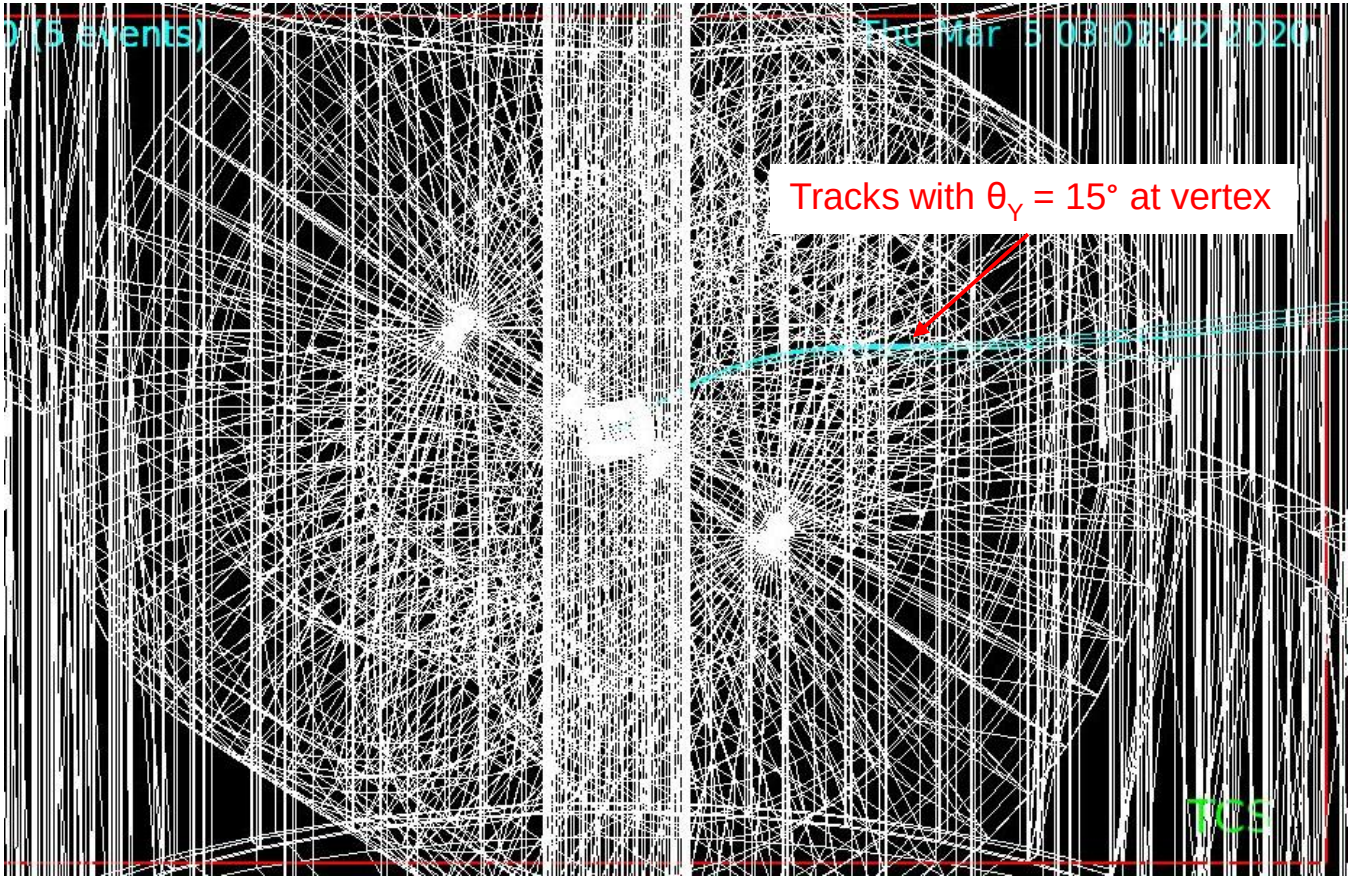
Note: for $P = 0.4\ GeV/c$, $\int Bdl = 0.7\ T \cdot m \Rightarrow \Delta\theta = 0.3\frac{\int Bdl}{P} = 0.53rad = 30°$

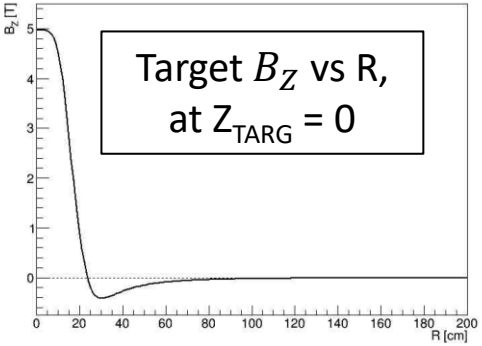
Hits



Note: tracks with $\theta_Y = 30°$ are lost in between quarters 1 and 4.

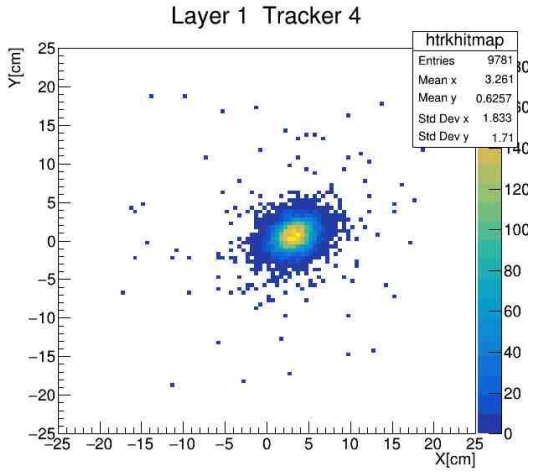
Tracks at vertex





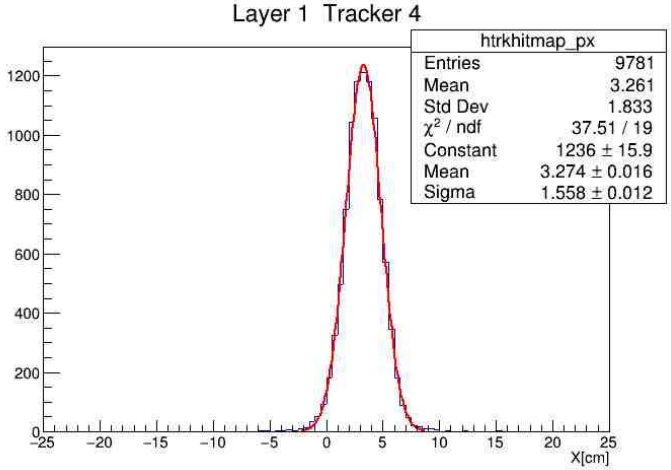
- Deflection within R<20cm
- Track wiggling due to field flip

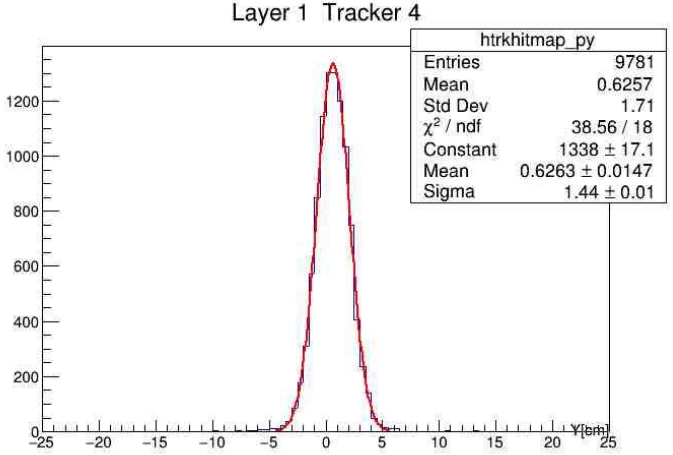
Hit pattern



Tracks with θ_Y = 15° at vertex:

- Hit spot size $\sigma \sim 1.5cm$
- Noticeable fraction of wide scatted tracks
- Fraction of hits within $R < 4.5cm$ -- 94.5%



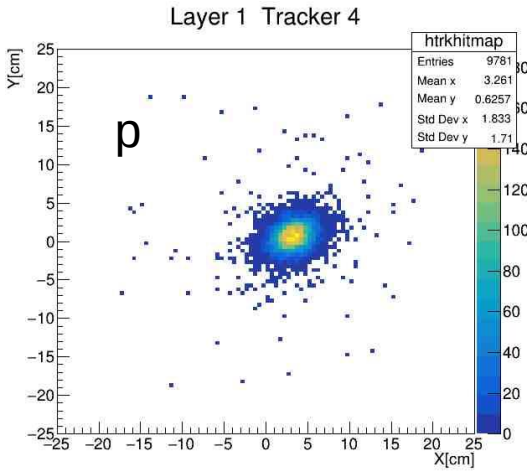


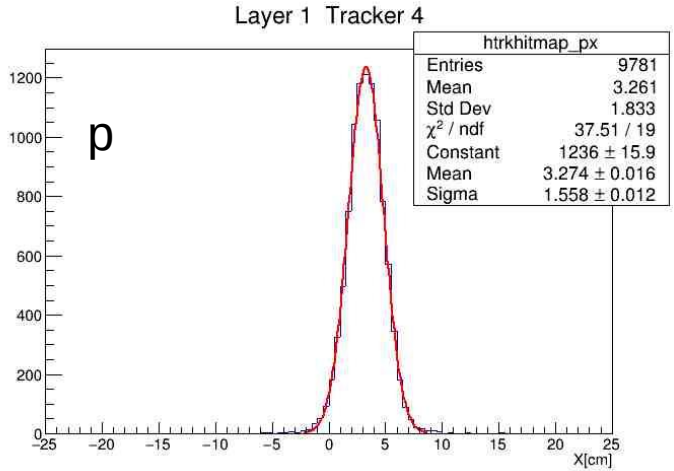
Conclusions

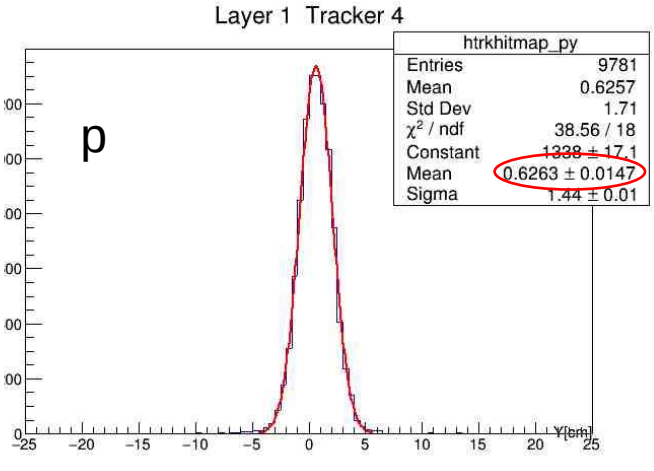
- Significant fraction of 400 GeV/c protons escape target and scattering chamber
- Hit pattern at layer 1 trackers correlates with vertical tracks' deflection angle at vertex
- Noticeable effect from particle interaction with matter on pass:
  - Hit spot of size $\sigma \sim 1.5 cm$
  - Fraction of wide scattered events $\sim 5\%$

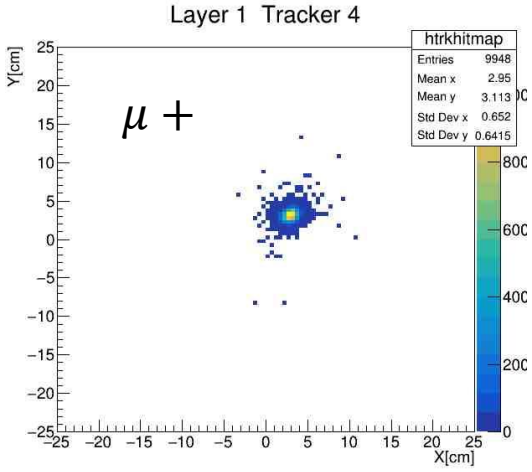
Back up

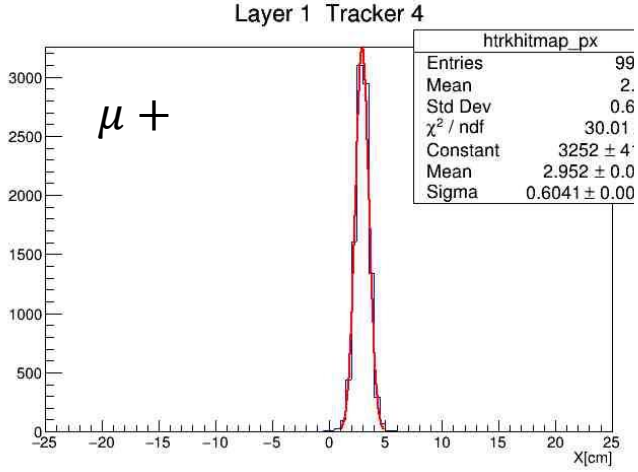
Hit pattern

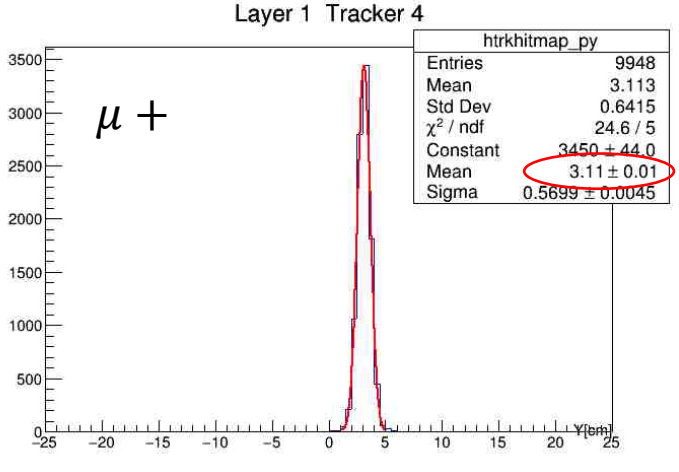

Layer 1 Tracker 4
htrkhitmap
Entries 9781
Mean x 3.261
Mean y 0.6257
Std Dev x 1.833
Std Dev y 1.71
p
Y[cm]
X[cm]


Layer 1 Tracker 4
htrkhitmap_px
Entries 9781
Mean 3.261
Std Dev 1.833
χ² / ndf 37.51 / 19
Constant 1236 ± 15.9
Mean 3.274 ± 0.016
Sigma 1.558 ± 0.012
p
X[cm]


Layer 1 Tracker 4
htrkhitmap_py
Entries 9781
Mean 0.6257
Std Dev 1.71
χ² / ndf 38.56 / 18
Constant 1338 ± 17.1
Mean 0.6263 ± 0.0147
Sigma 1.44 ± 0.01
p
Y[cm]


Layer 1 Tracker 4
htrkhitmap
Entries 9948
Mean x 2.95
Mean y 3.113
Std Dev x 0.652
Std Dev y 0.6415
μ +
Y[cm]
X[cm]


Layer 1 Tracker 4
htrkhitmap_px
Entries 99
Mean 2.
Std Dev 0.6
χ² / ndf 30.01
Constant 3252 ± 4
Mean 2.952 ± 0.0
Sigma 0.6041 ± 0.00
μ +
X[cm]

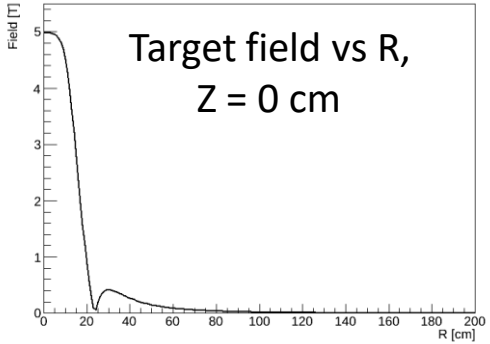

Layer 1 Tracker 4
htrkhitmap_py
Entries 9948
Mean 3.113
Std Dev 0.6415
χ² / ndf 24.6 / 5
Constant 3450 ± 44.0
Mean 3.11 ± 0.01
Sigma 0.5699 ± 0.0045
μ +
Y[cm]

CPS beam

- 2 mm rastered collinear bremsstrahlung photon beam , E_{MAX} = 11 GeV
- Intensity: 1.5x10^{12} equivalent γ/s → 2x10^{13} γ/s in [10 MeV, 11 GeV] range

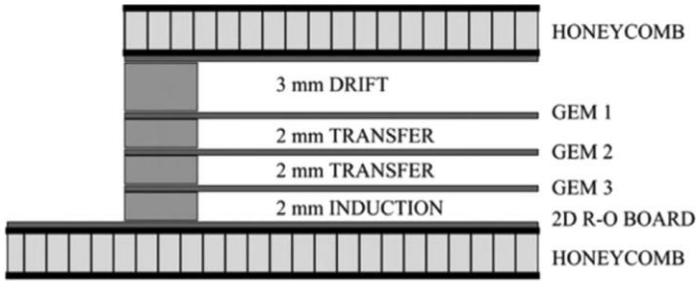
Target assembly

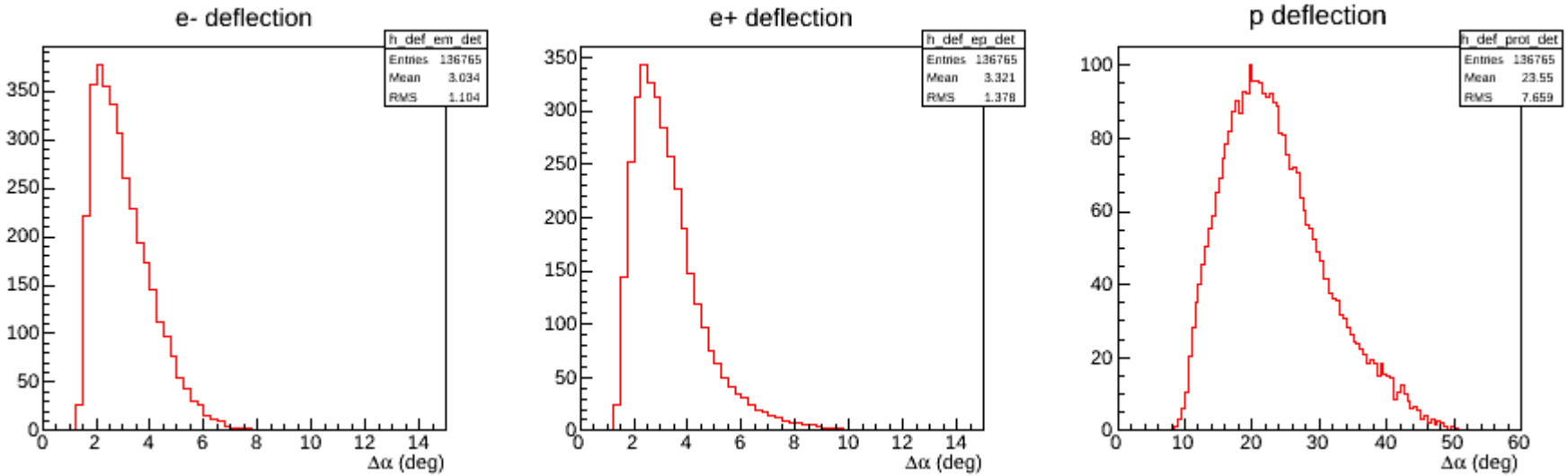
- Scattering Chamber with thin Al windows
- 3 cm target cell, with ammonia beds in LHe
- Magnet coils, LHe and LN Shields
- Chamber & magnet rotated 90^{o}
- Magnetic field map, 5T at center



Trackers

- Like COMPASS triple-GEM detectors
  (F.Sauli , NIMA 805 (2016) 2-24)
- Working gas: 70% Ar, 30% CO_2, ρ = 1.7 mg/cm^3
- Hit signal: energy deposition in the DRIFT region





Deflections of accepted tracks in the target magnetic field (BdL~0.7 Tm) relative to directions at target (from *old* simulations, w/ tracker hodoscopes, w/o GEM trackers).