# TCS Trigger Update

## Recoil proton detection and tracking feasibility

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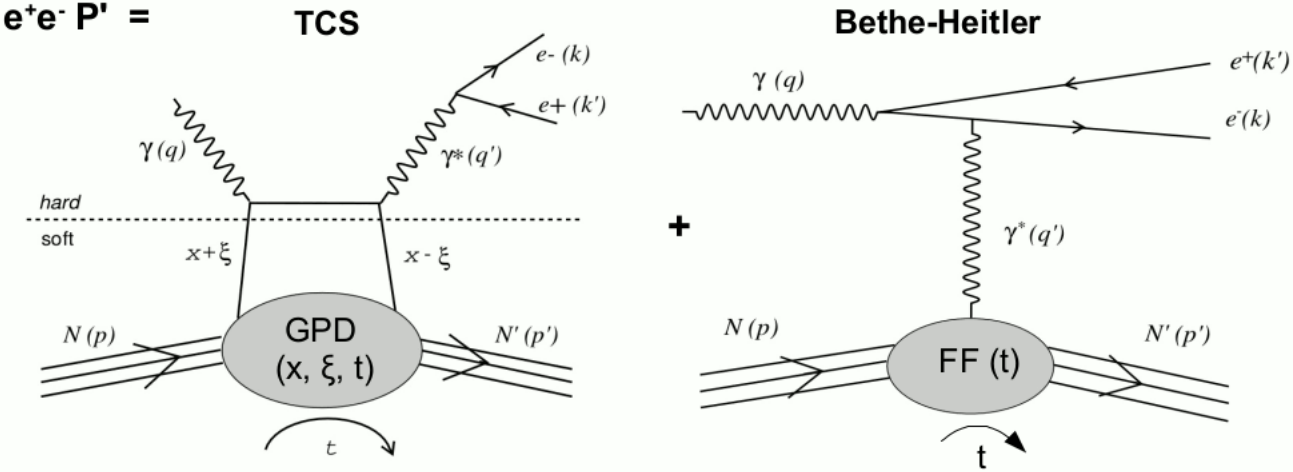
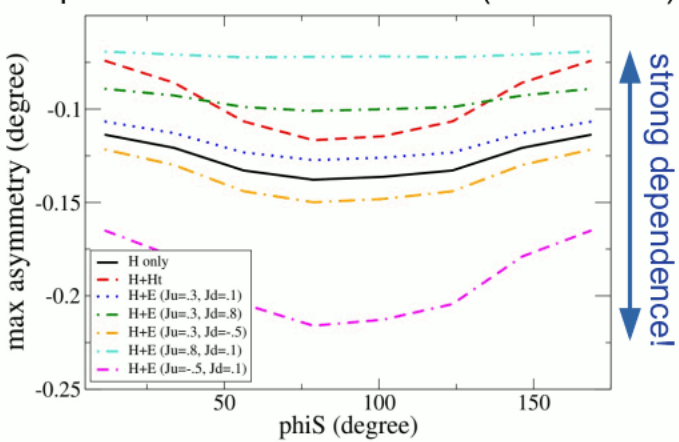
06/18/2021

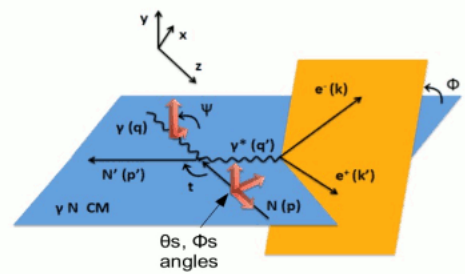
# Physics goals

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




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




**TSA as a function of φ and $\varphi_S$**

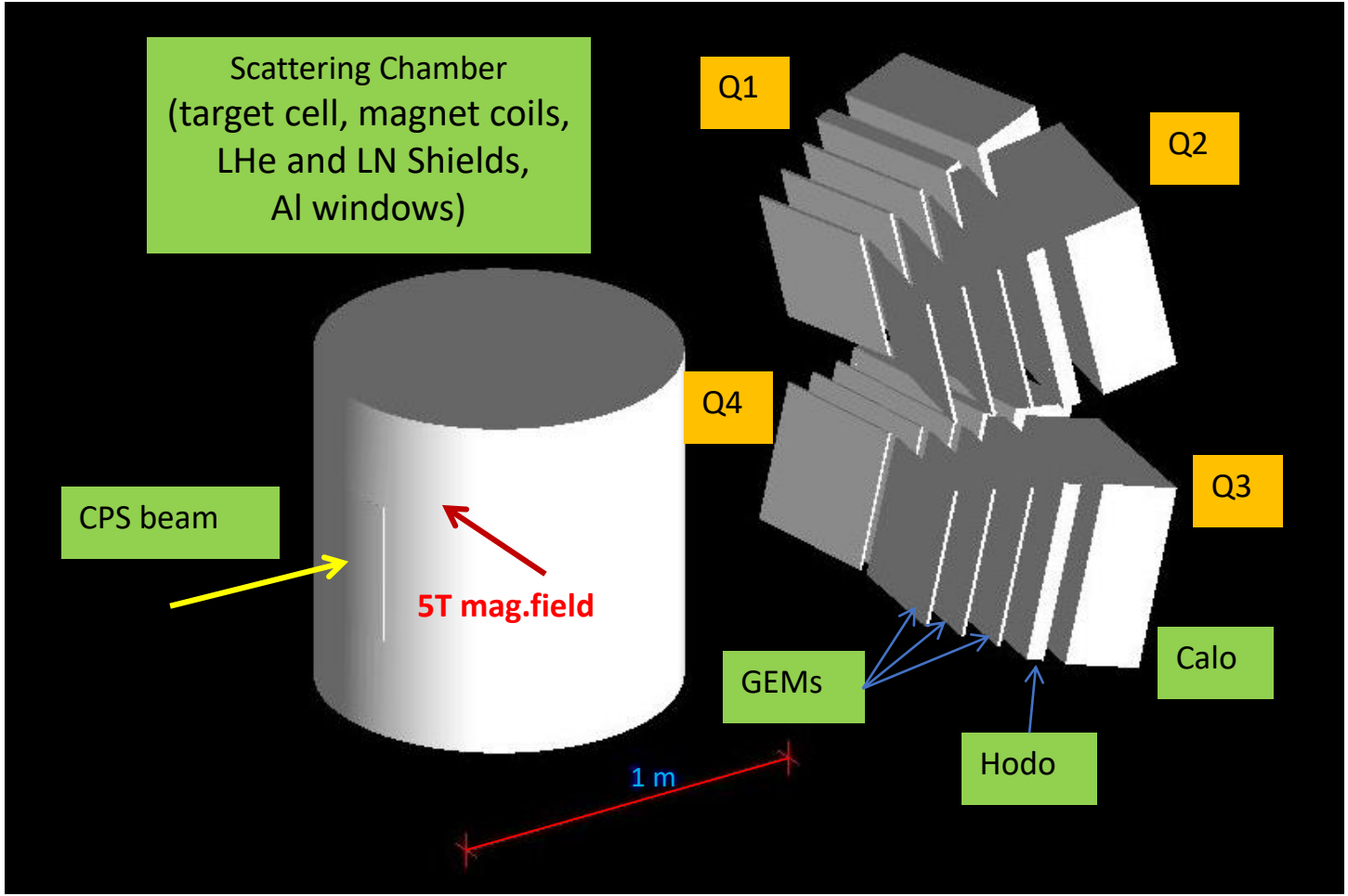
- Sensitive to Im(interference), BH cancels
- Strong dependence in angular momenta,

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**

# Status as of now

Trigger based on e+e- coincident detection in the opposite calorimeters

- High threshold on e+, e- cluster energies, 2.5 GeV, and 5 GeV on the sum
- Crystals close to the beam pipe removed ($\theta > 8°$)
- 72% trigger efficiency
- Tolerable trigger rate, ~ 60 kHz

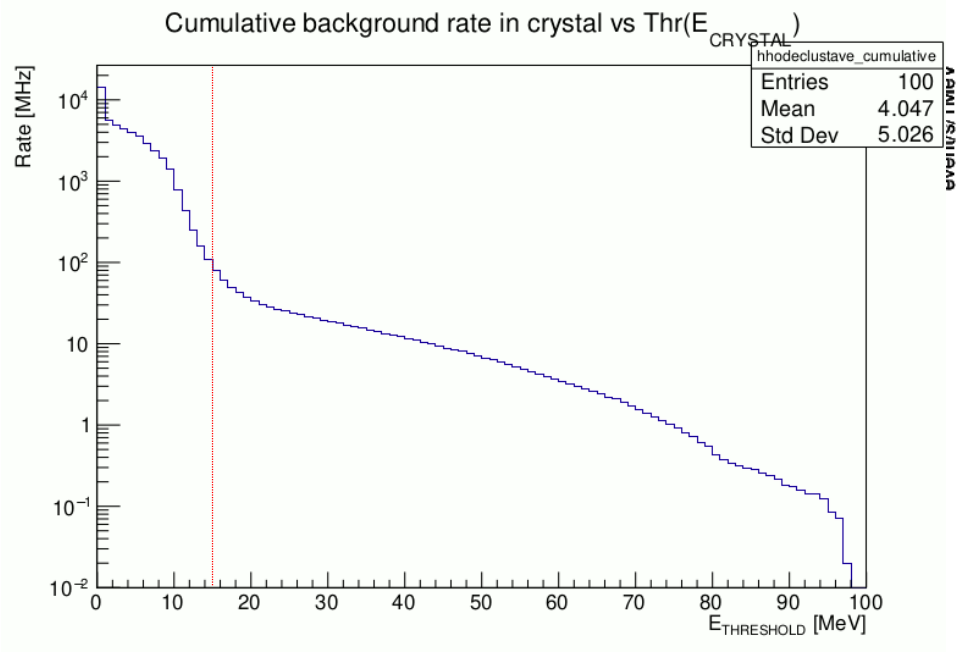
e+, e- off-line analysis:

- Cluster analysis in the calorimeters -> energy and (coarse) coordinate reconstruction
- Track reconstruction with GEM-s (feasible)
  - Spot size to search in GEM-s ~1 $cm^2$, or less
  - At the center of GEM-s, for 50 ns time window -> 0.07 stray track in the spot; ~10 times more close to the median plane and beam pipe

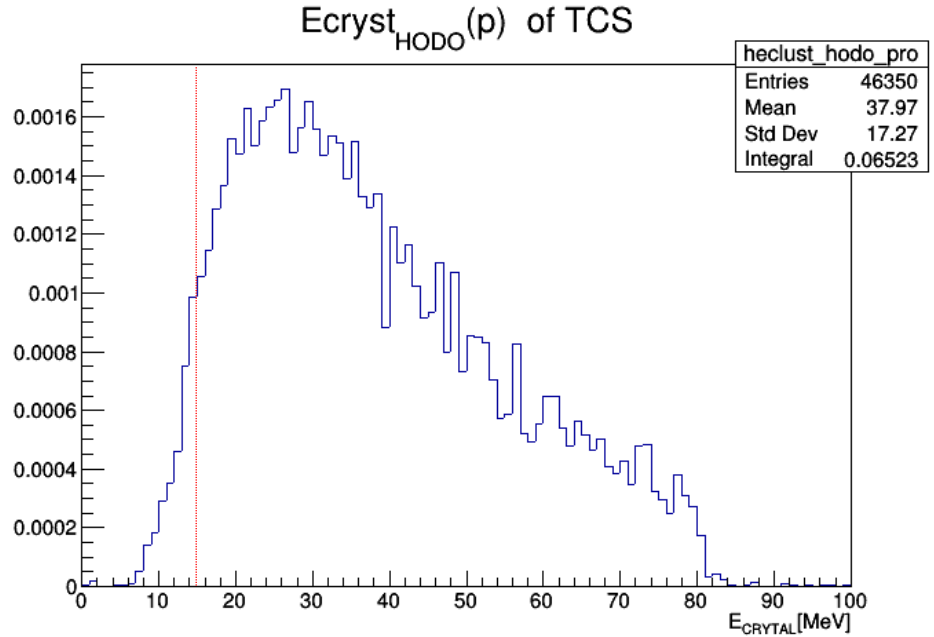
Recoil proton off-line analysis:

- 100 MeV kinetic energy, typically
- Escape target assembly ($\sigma \sim 1.5\ cm$ spot size at the detectors)
- Use combined signals from hodo-s and calo-s to select p-rec. and reject background (to be demonstrated)
- Use GEM-s for track reconstruction (similar to e+,e-; to be demonstrated)

# Background and TCS recoil proton in Hodo-s

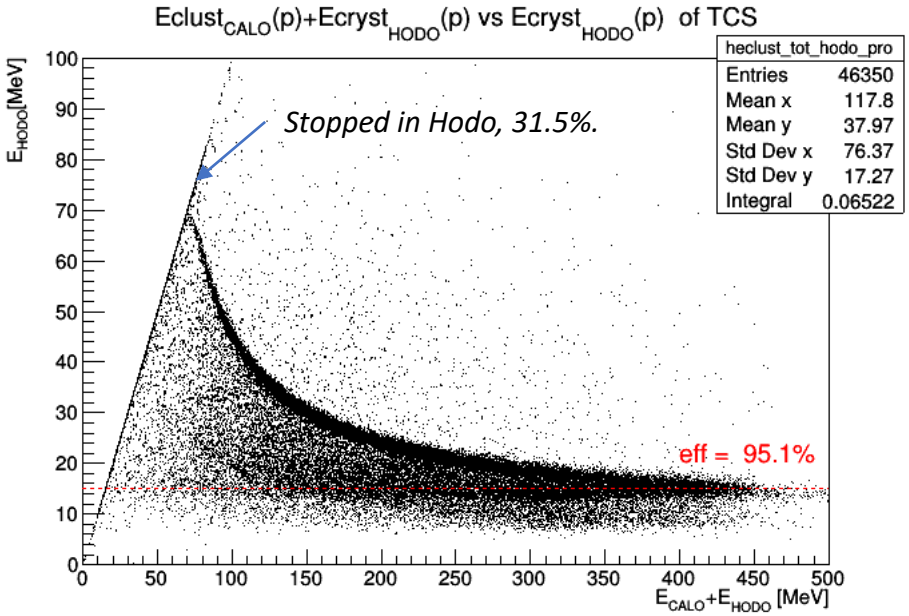


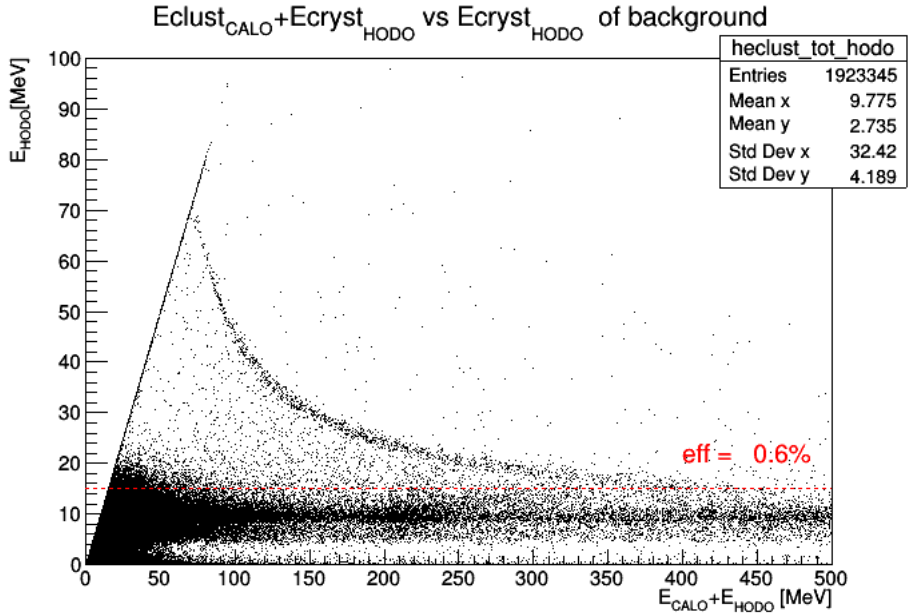

Background rate in the hodoscope versus threshold on maximum energy deposition in a crystal.



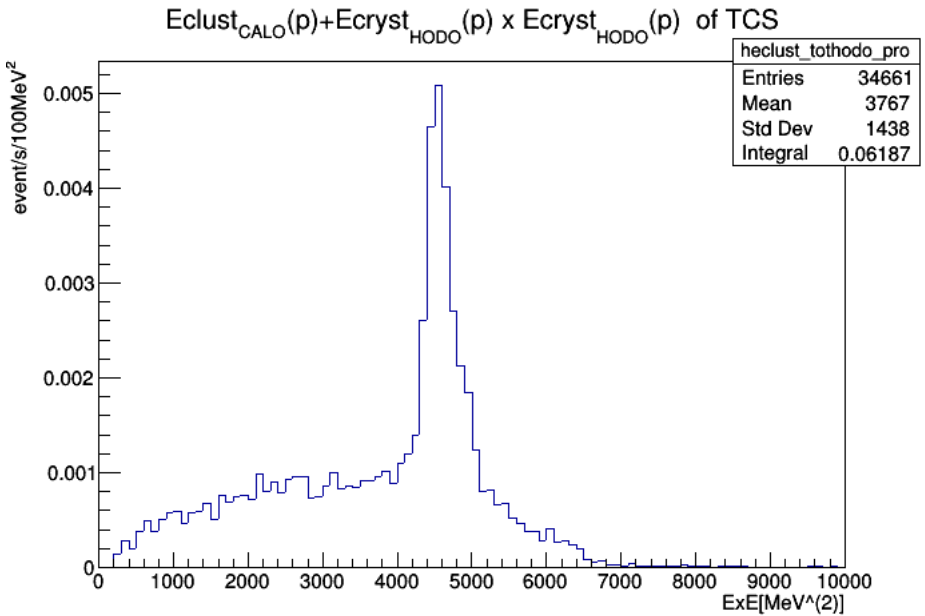

Maximum energy deposition from the TCS recoil protons in the hodoscope crystals.

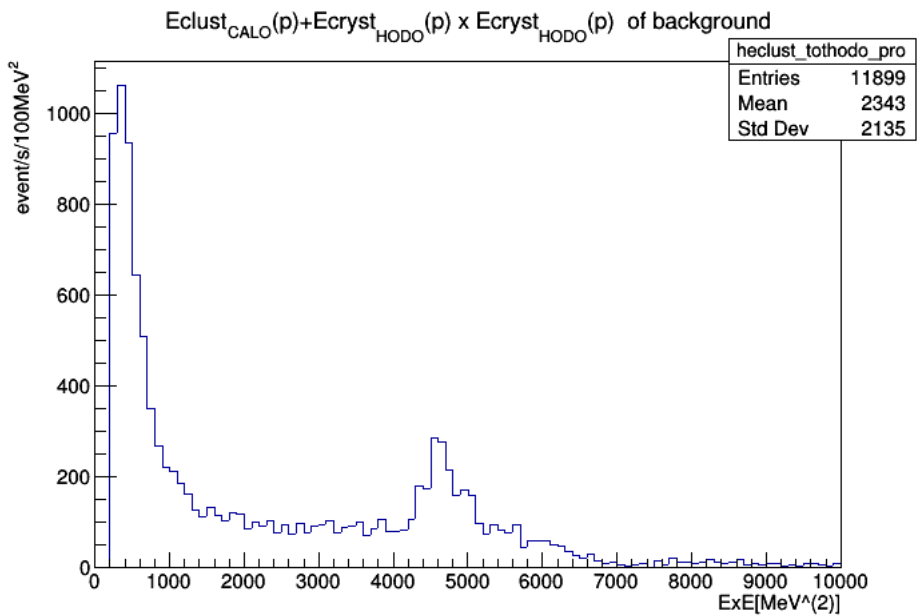
# TCS recoil proton and background in Hodo-s and Calo-s



# TCS recoil proton and background in Hodo-s and Calo-s

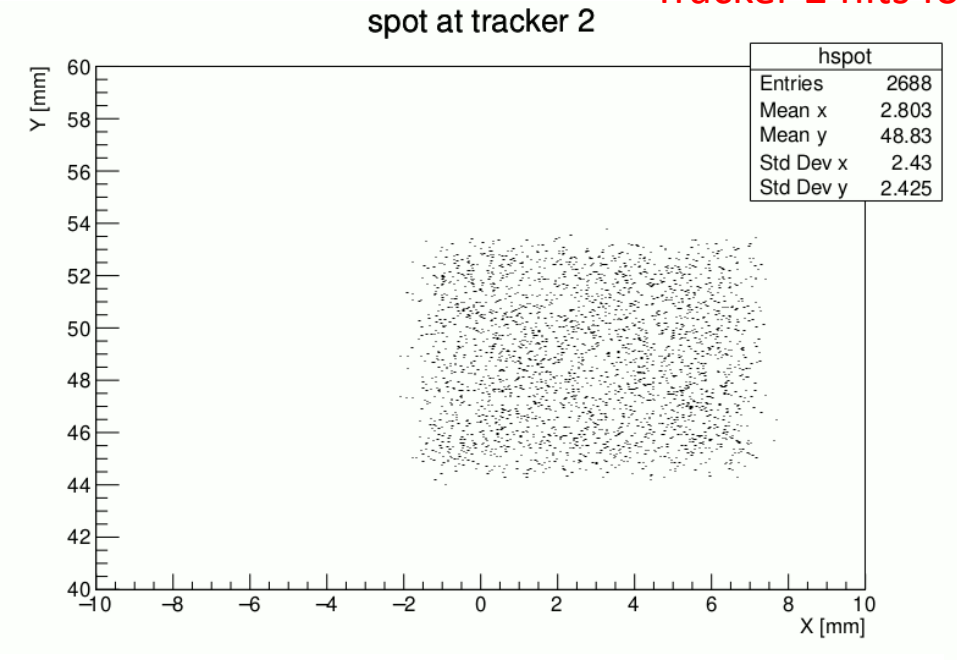


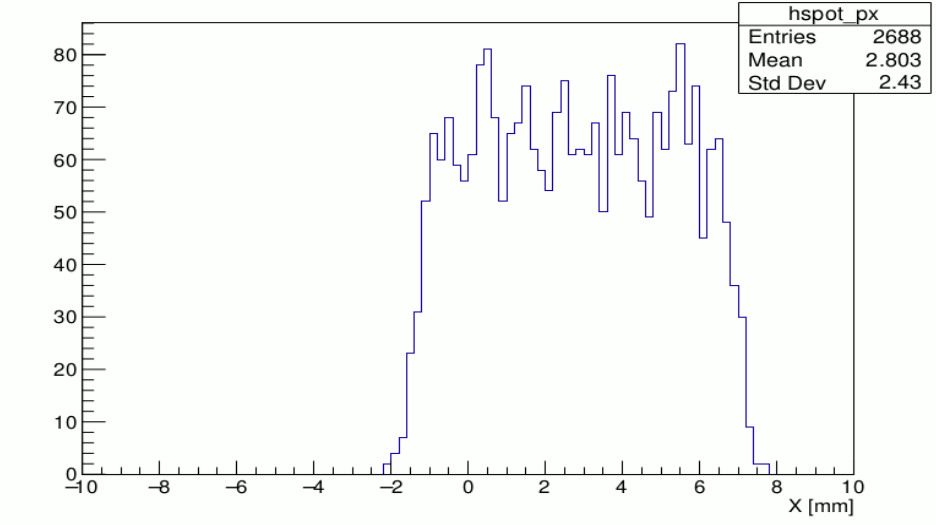



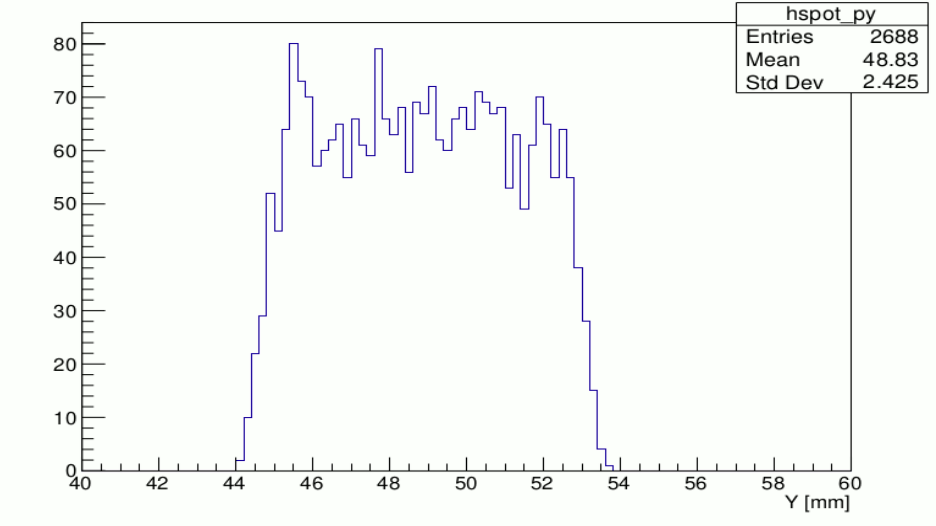

*Can cut on $E_{TOT} \times E_{HODO}$ to further suppress background by few times.*

# Backup slides

# Tracker 2 hits for 2.5 GeV/c tracks

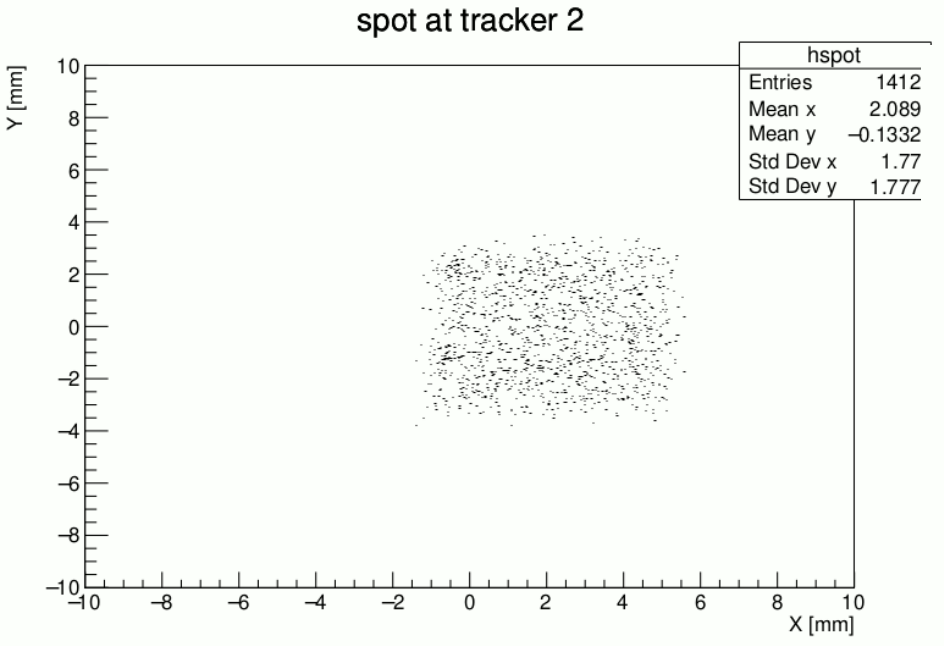


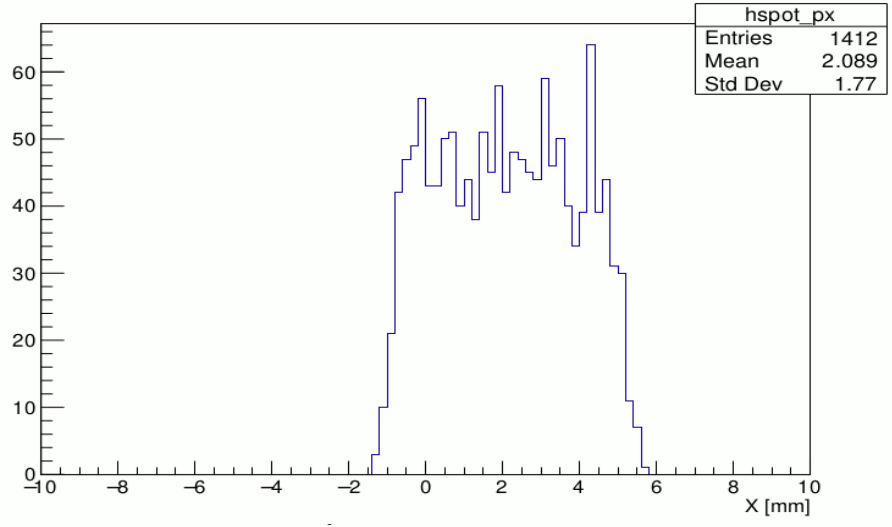



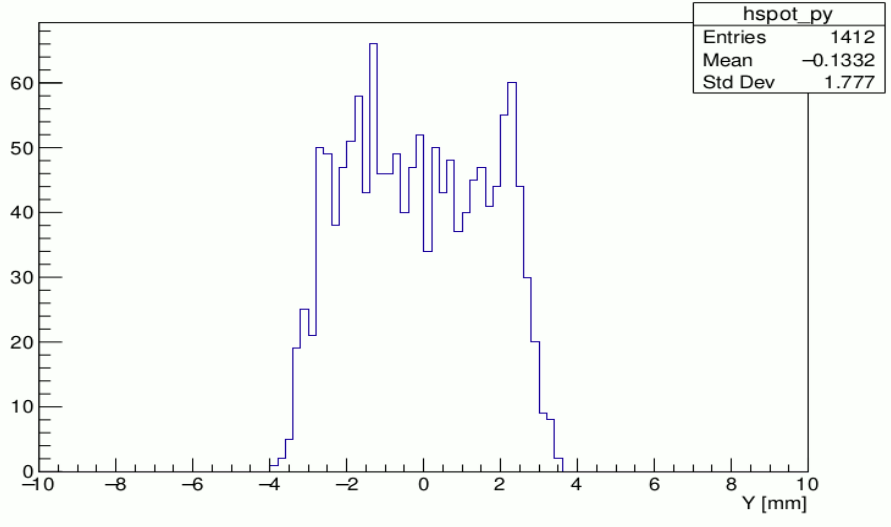




- Area size ~1 cm$^2$.
- For tracks at center (rate ~1.4 MHz/ cm$^2$), 50 ns time window: $1.4 \times 10^6 \times 1 \times 50 \times 10^{-9} =$ $\mathbf{0.07}$ **stray track** per TCS $e^{\pm}$ track.
- Bigger by a magnitude close to vertical median plane and beam pipe.

# Tracker 2 hits for 5 GeV/c tracks

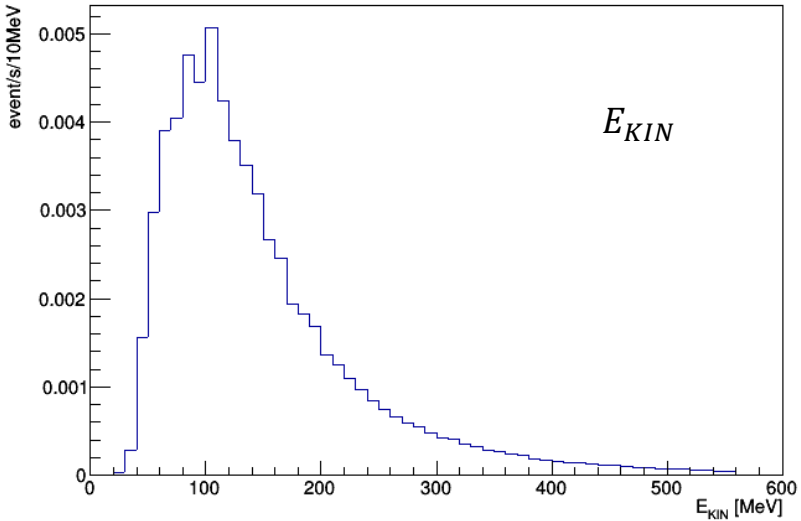


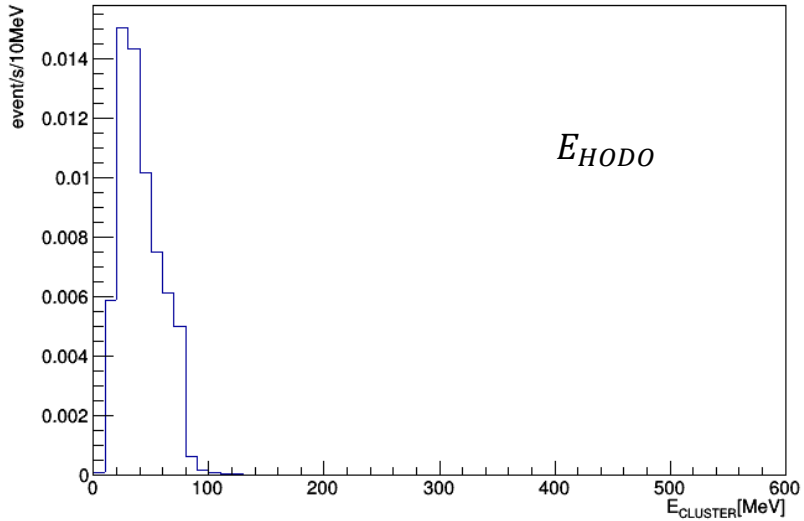



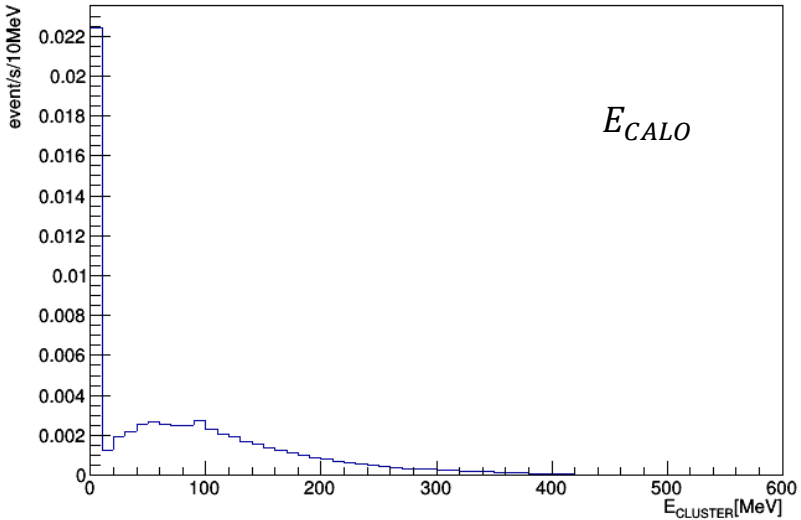



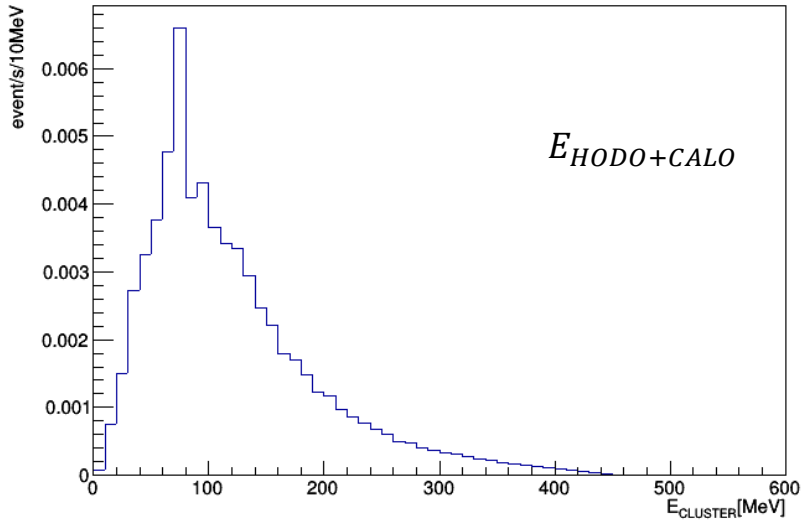

- Area size ~0.6 cm$^2$.
- For tracks at center (rate ~1.4 MHz/ cm$^2$), 50 ns time window: $1.4 \times 10^6 \times 0.6 \times 50 \times 10^{-9} =$ $\mathbf{0.04}$ **stray track** per TCS $e^{\pm}$ track.
- Bigger by a magnitude close to vertical median plane and beam pipe.

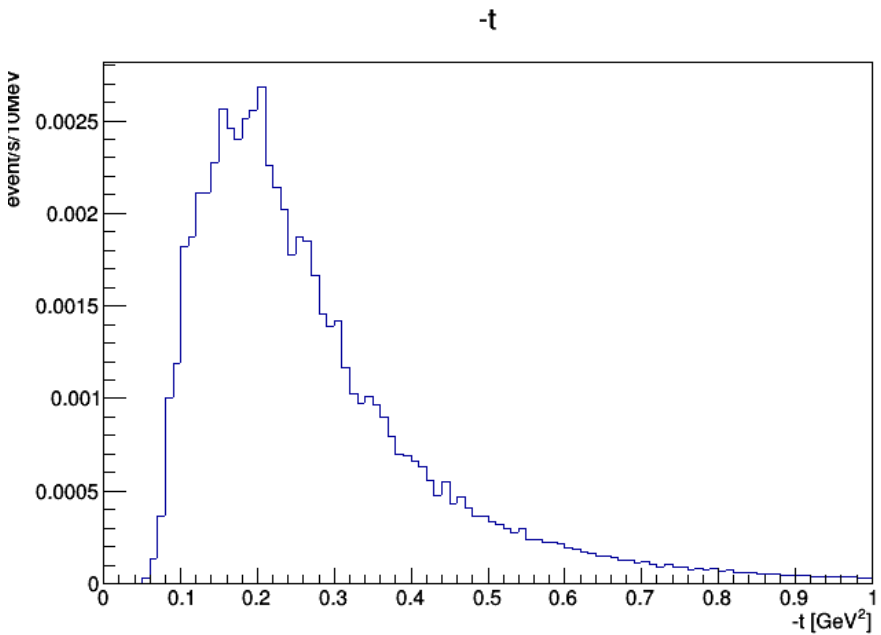
# TCS recoil proton in Hodo-s and Calo-s

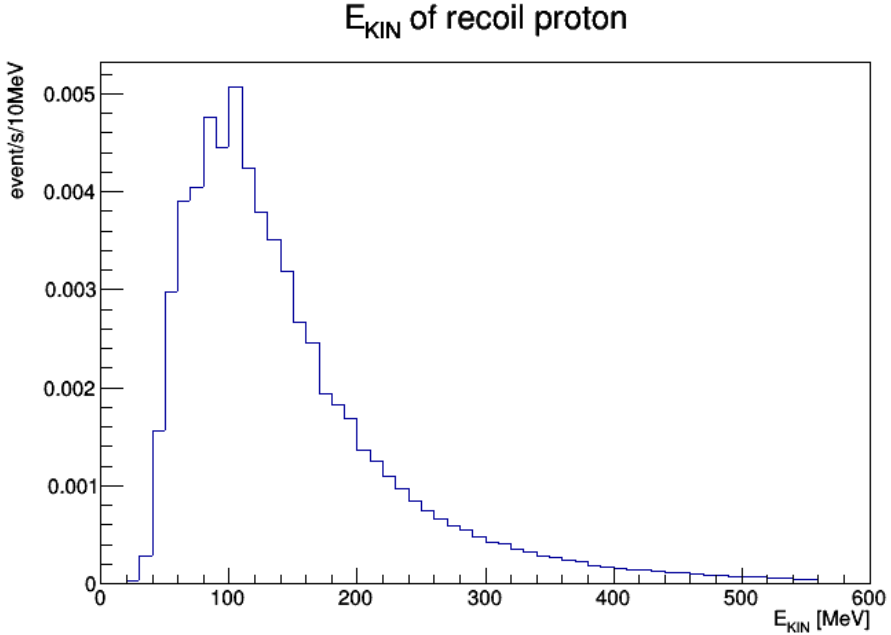


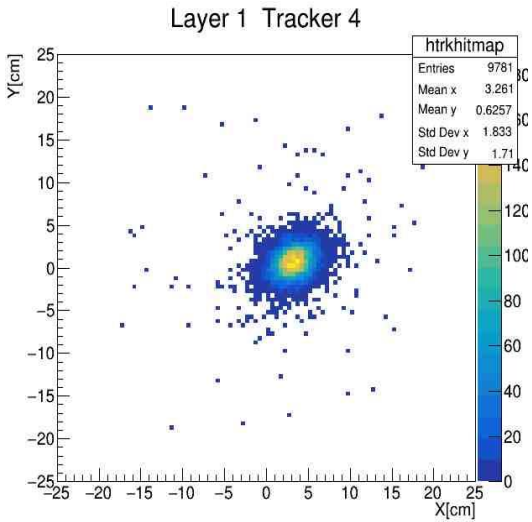




-t
event/s/10MeV
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-t [GeV$^2$]


$E_{KIN}$ of recoil proton
event/s/10MeV
0.005
0.004
0.003
0.002
0.001
0
0
100
200
300
400
500
600
$E_{KIN}$ [MeV]

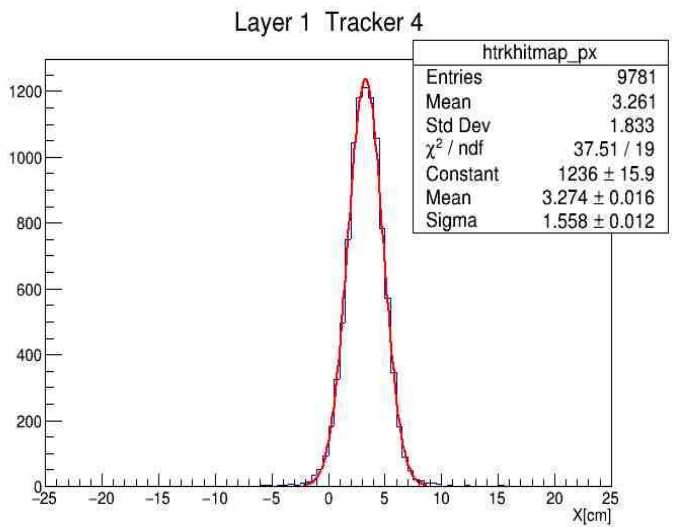
# 400 GeV/c proton in GEMs (Apr. 20)

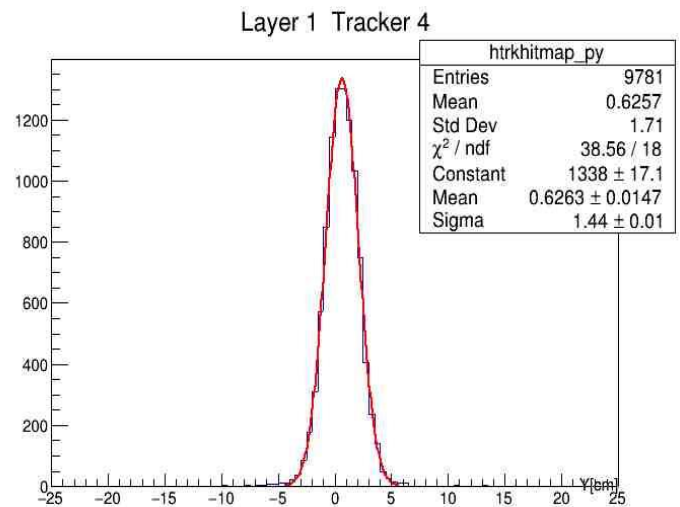
## Hit pattern




Tracks with $\theta_Y$ = 15° at vertex:

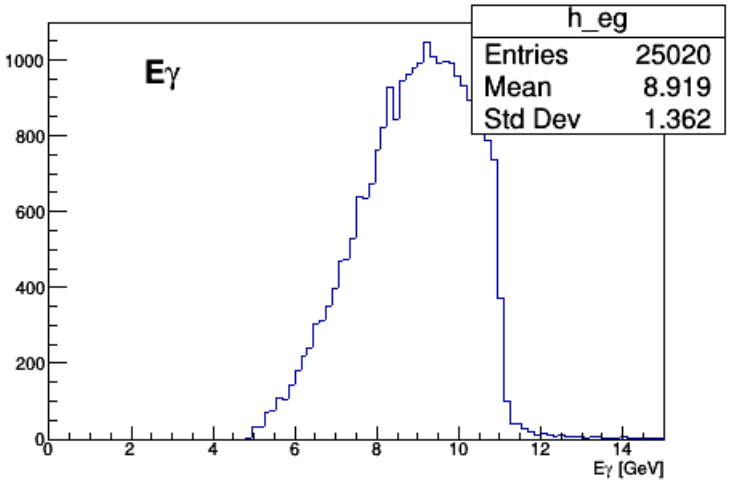
- Hit spot size $\sigma \sim 1.5cm$
- Noticeable fraction of wide scatted tracks
- Fraction of hits within $R < 4.5cm$ -- 94.5%

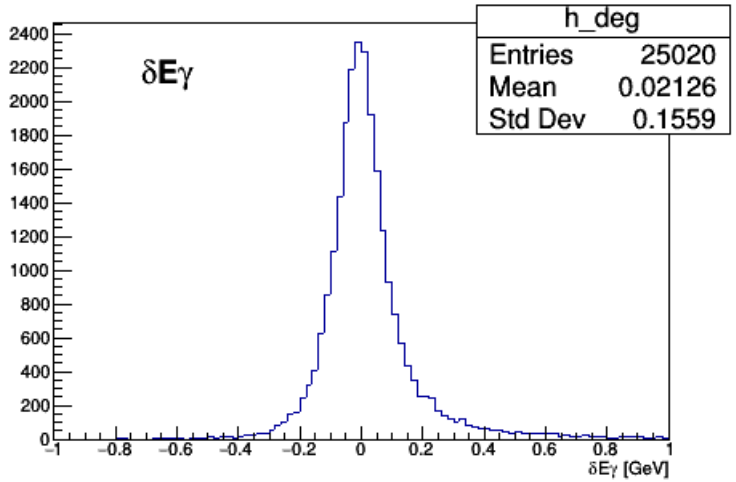


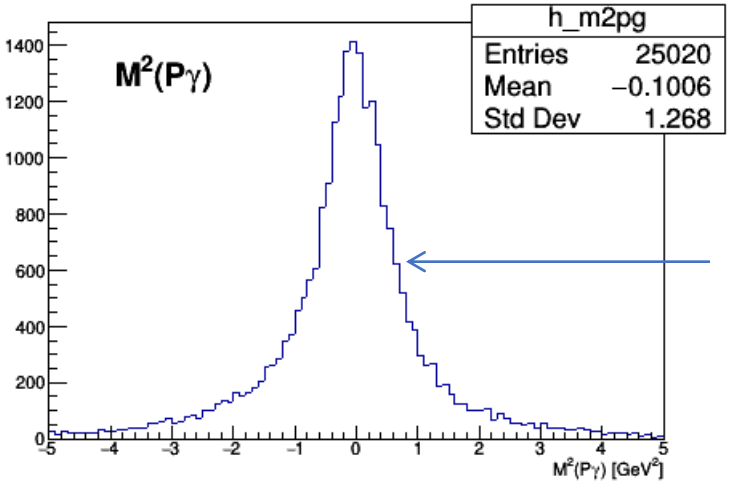



# TCS missing mass reconstruction (Feb. 20)

γ incident reconstruction

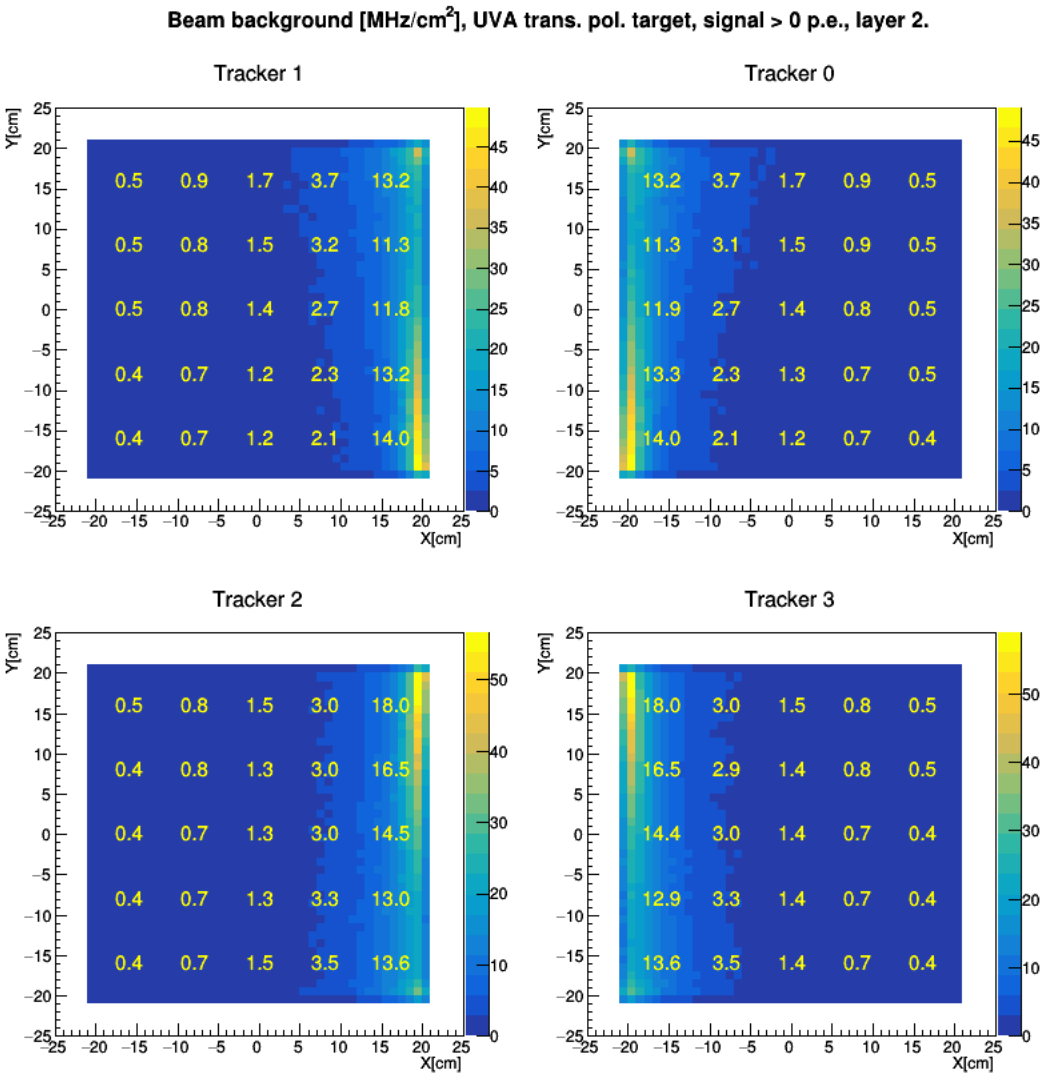



$M_X^2$ (exclusivity cuts to be applied)

# Background at GEM trackers




Beam background particle fluxes at GEM-s:

γ -- 82%
e- -- 11%
e+ -- 6%

Detected in GEM-s (EDEP > 0):

e- -- 65%
e+ -- 33%

Rate at the middle ~1.4 MHz/cm$^2$, and tens of MHz close to median plane and beam.

Max. tolerable rates:

COMPASS -- 25 kHz/mm$^2$
(*PDG'20, chapter 35 Particle Detectors at Accelerators, p.32*)

COMPASS after upgrade -- > $10^5$ Hz/mm$^2$
(*M. Krämer, et al., IEEE Nuclear Science Symposium Conference Record (2008)*)

**TCS rates manageable for MPGD-s.**