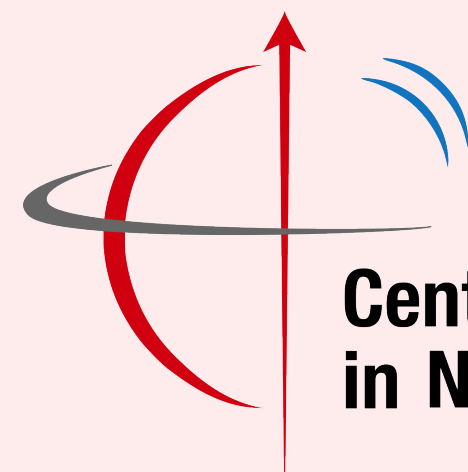


# Simulation Status

Win Lin  
Stony Brook University

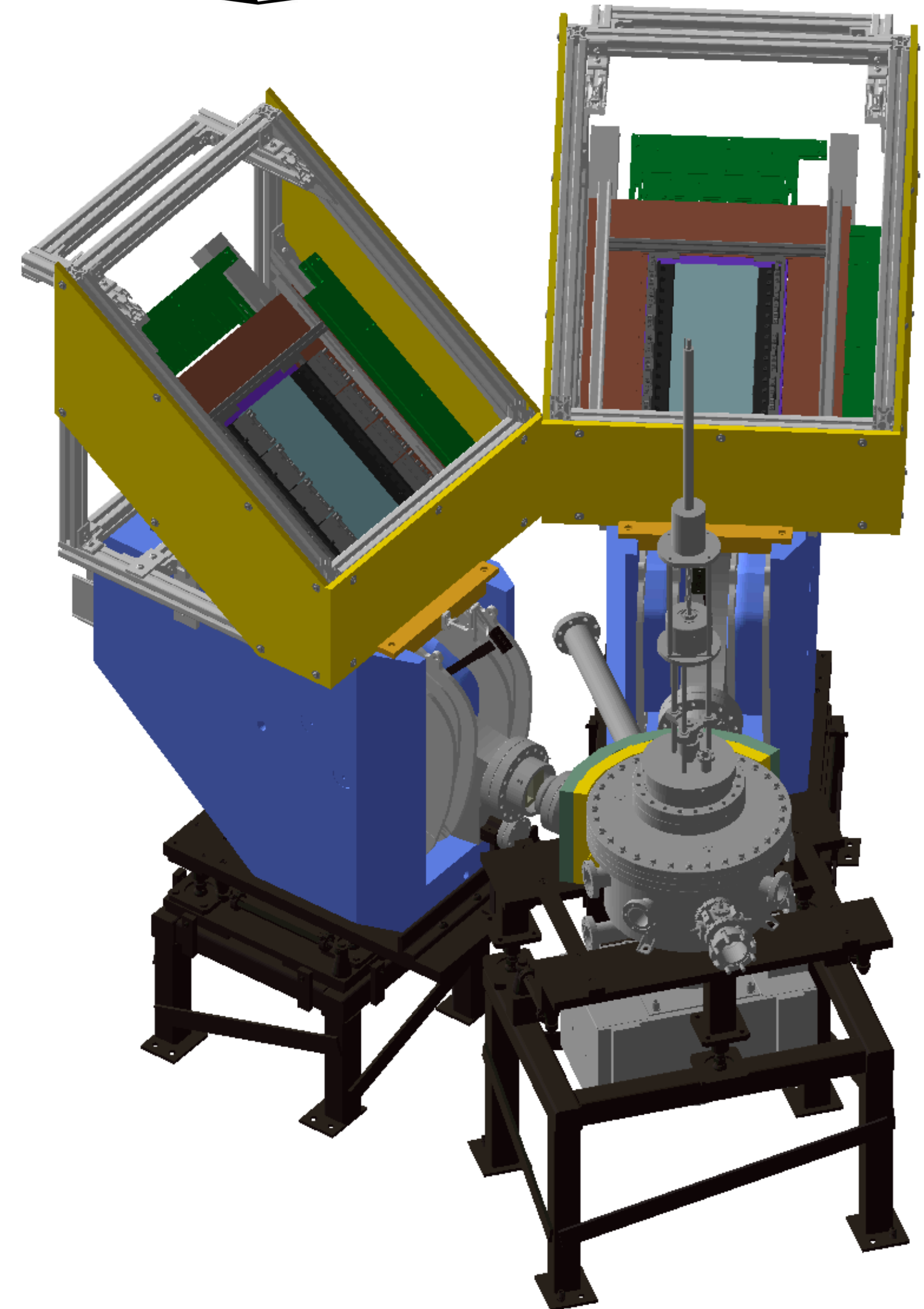
DarkLight Collaboration Meeting  
05/18/2026



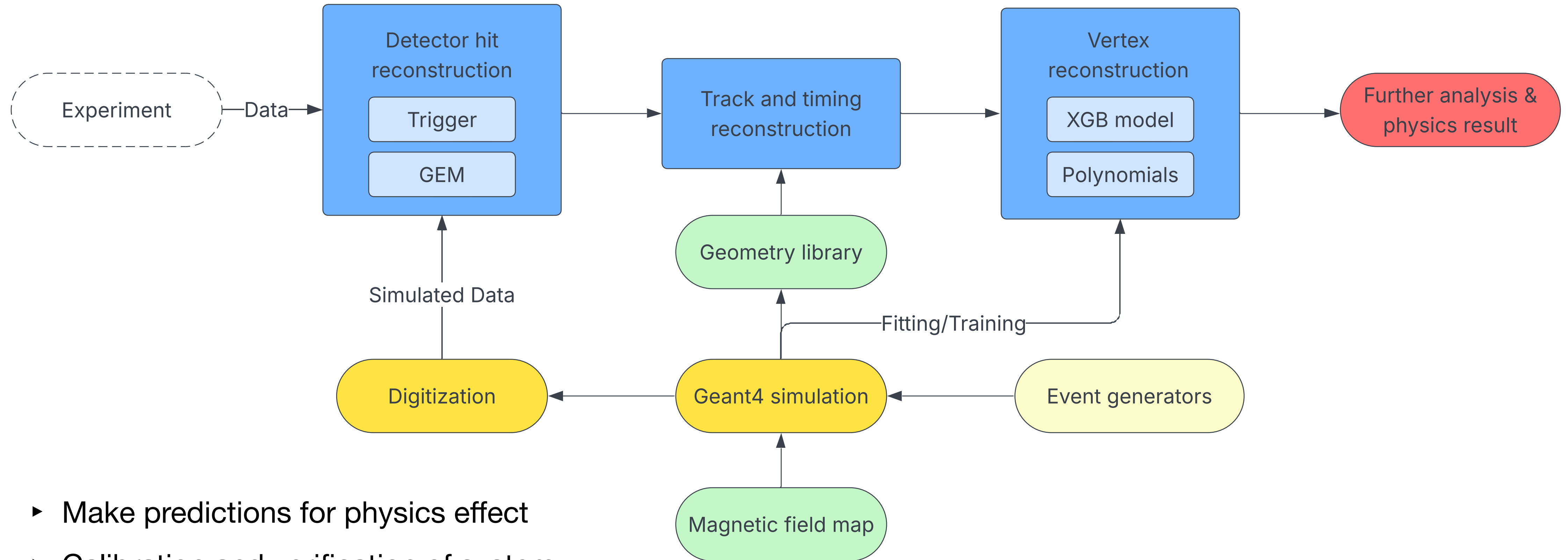
Center for Frontiers  
in Nuclear Science



Stony Brook  
University

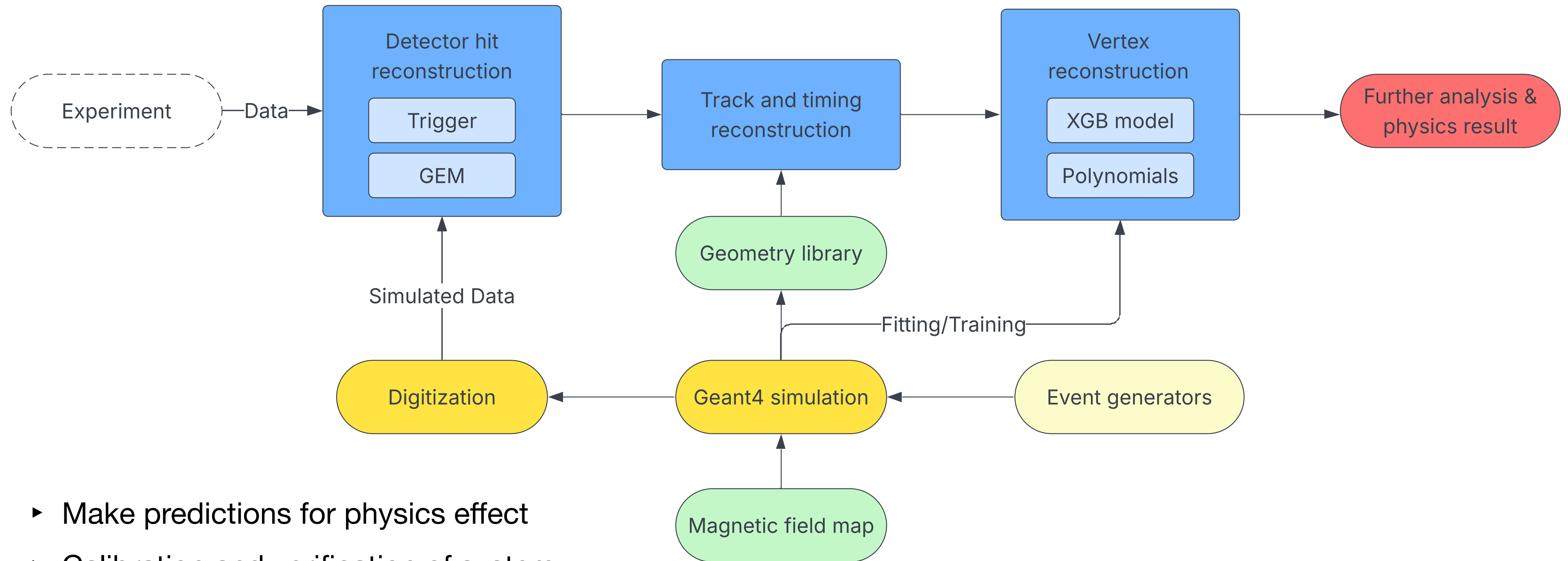


Simulation and analysis flow chart



- ▶ Make predictions for physics effect
- ▶ Calibration and verification of system
- ▶ Provide coordinates for detector hits
- ▶ Provide data for fitting / machine learning

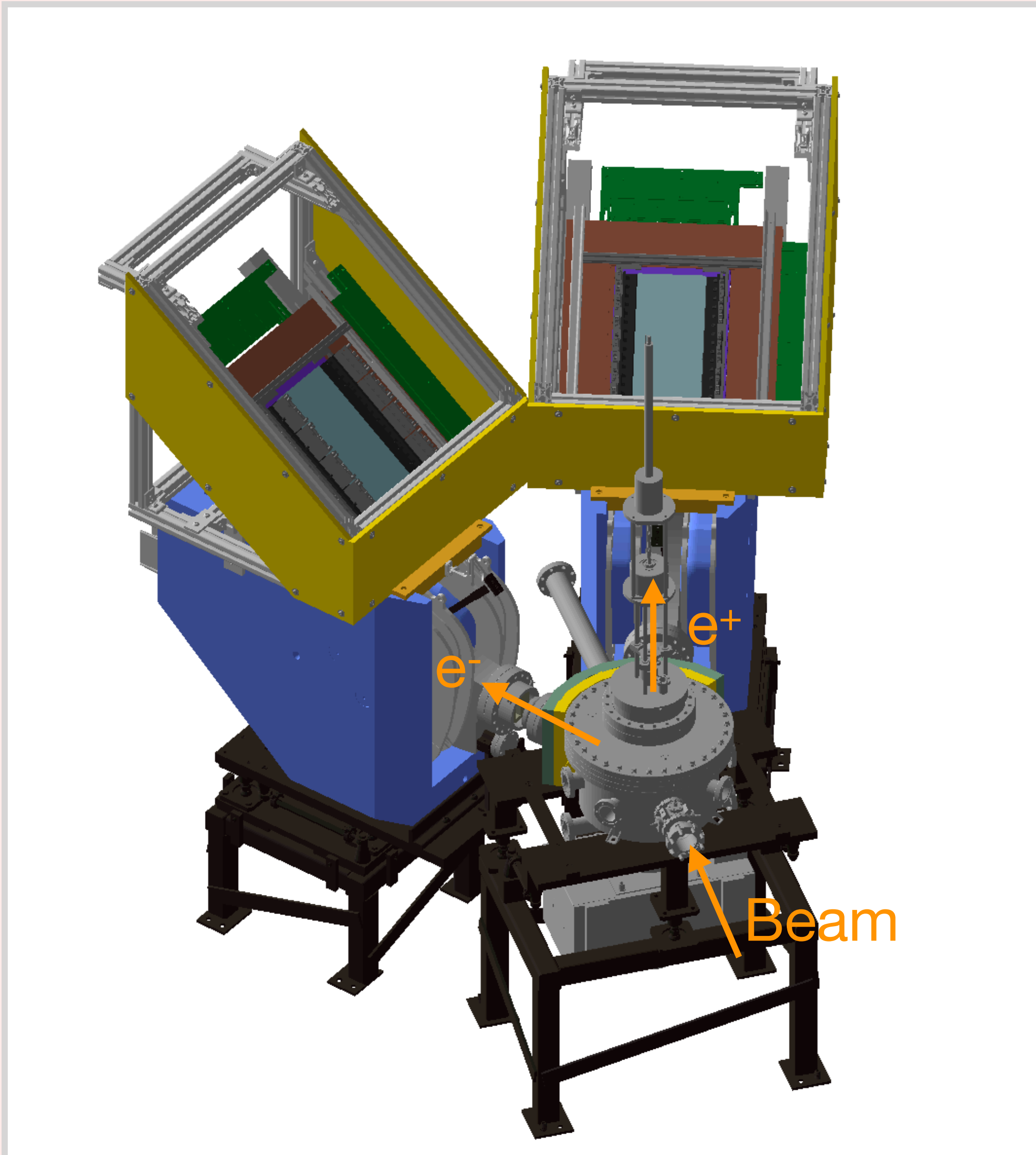
Simulation and analysis flow chart



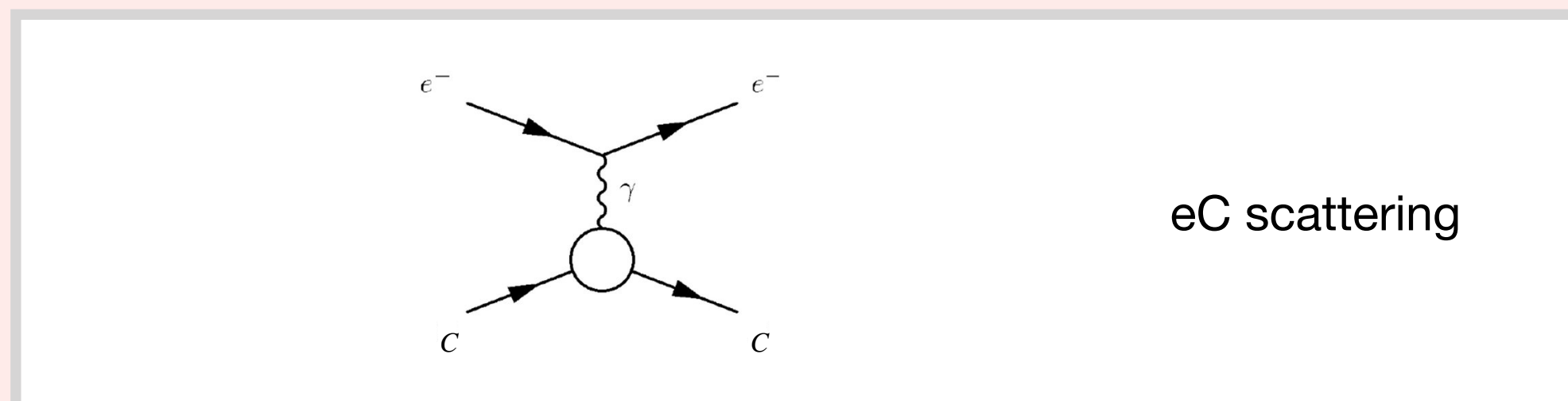
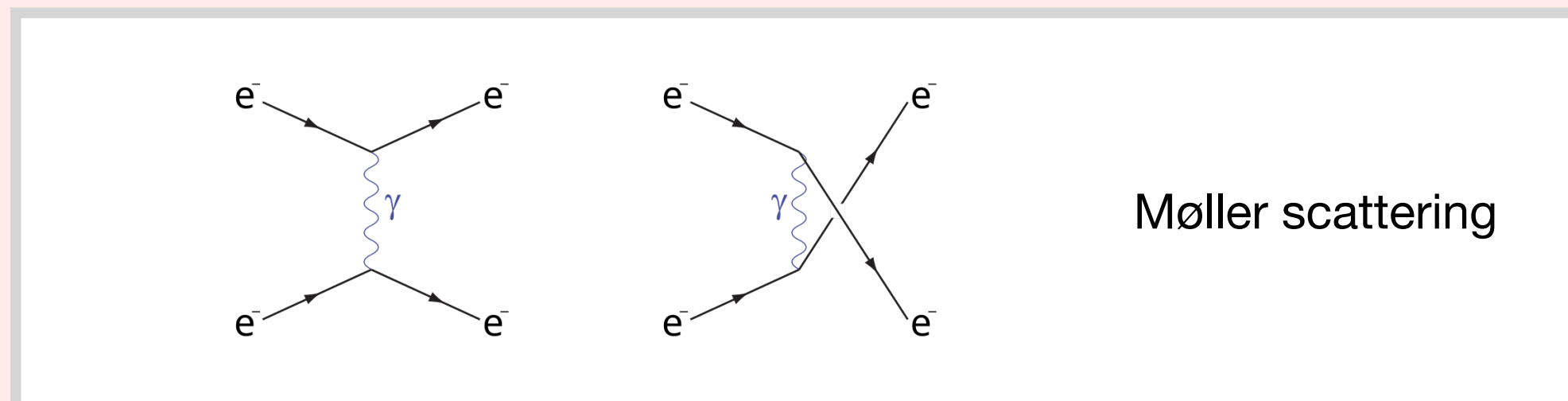
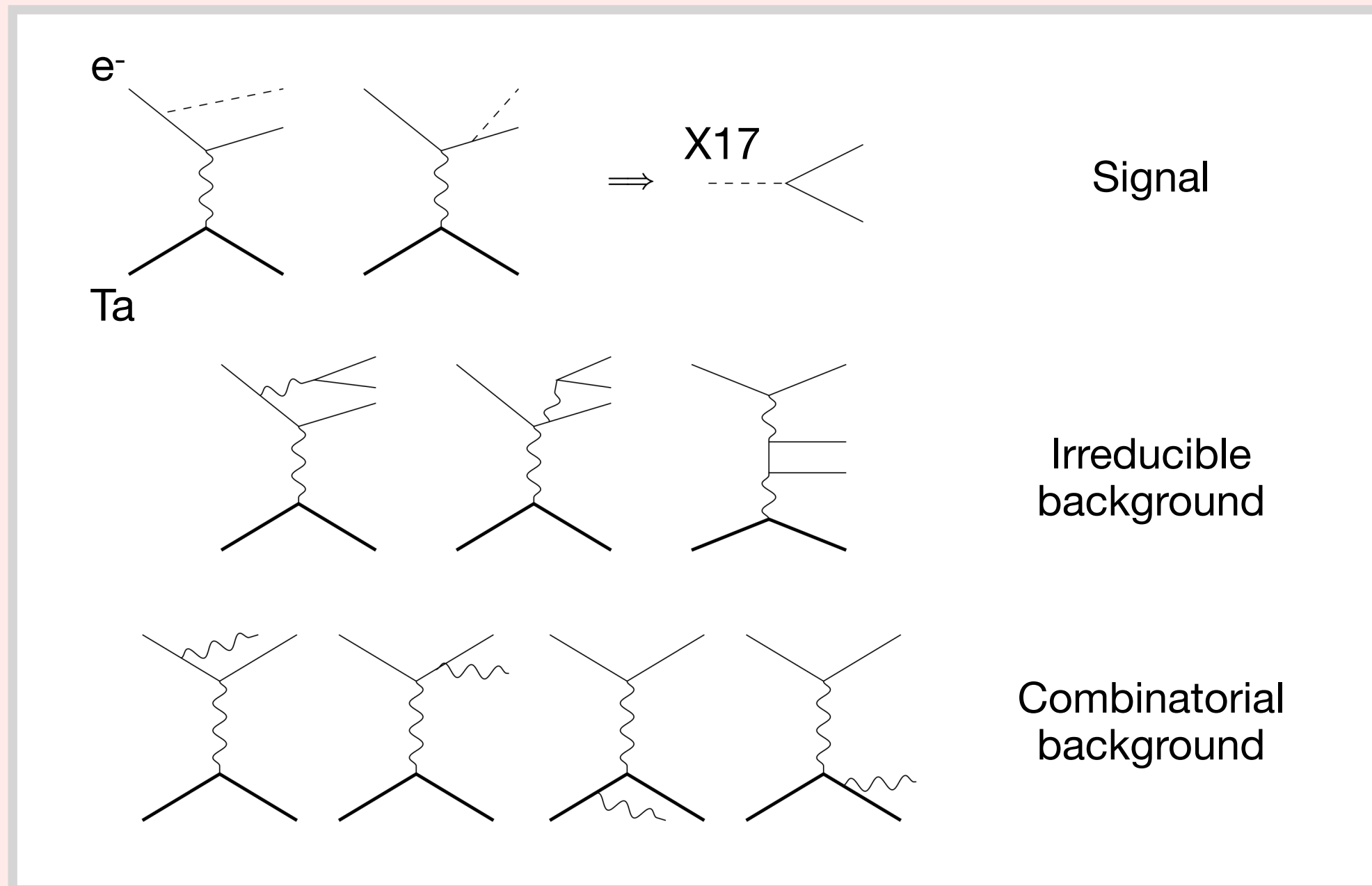
- ▶ Make predictions for physics effect
- ▶ Calibration and verification of system
- ▶ Provide coordinates for detector hits
- ▶ Provide data for fitting / machine learning

Analysis 🤝 Simulation

# What do we need for simulation?



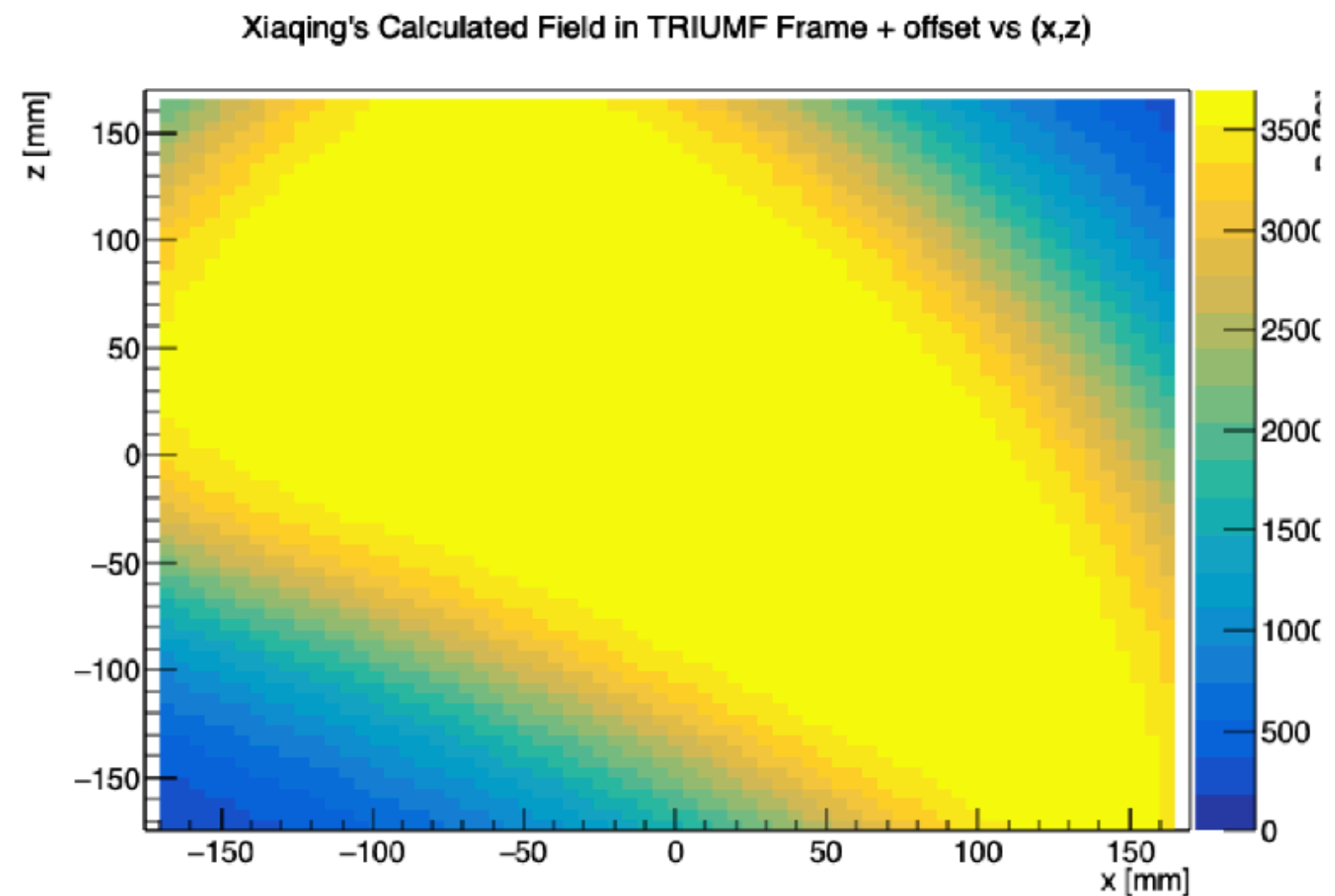
- Physics ← Event generator
- Magnetic field ← ANSYS-MAXWell
- Beam ← Input from acc. group
- Apparatus & Geometry ← Solidwork + Survey (+data)
- Detector Readout ← Gean4 + digitization



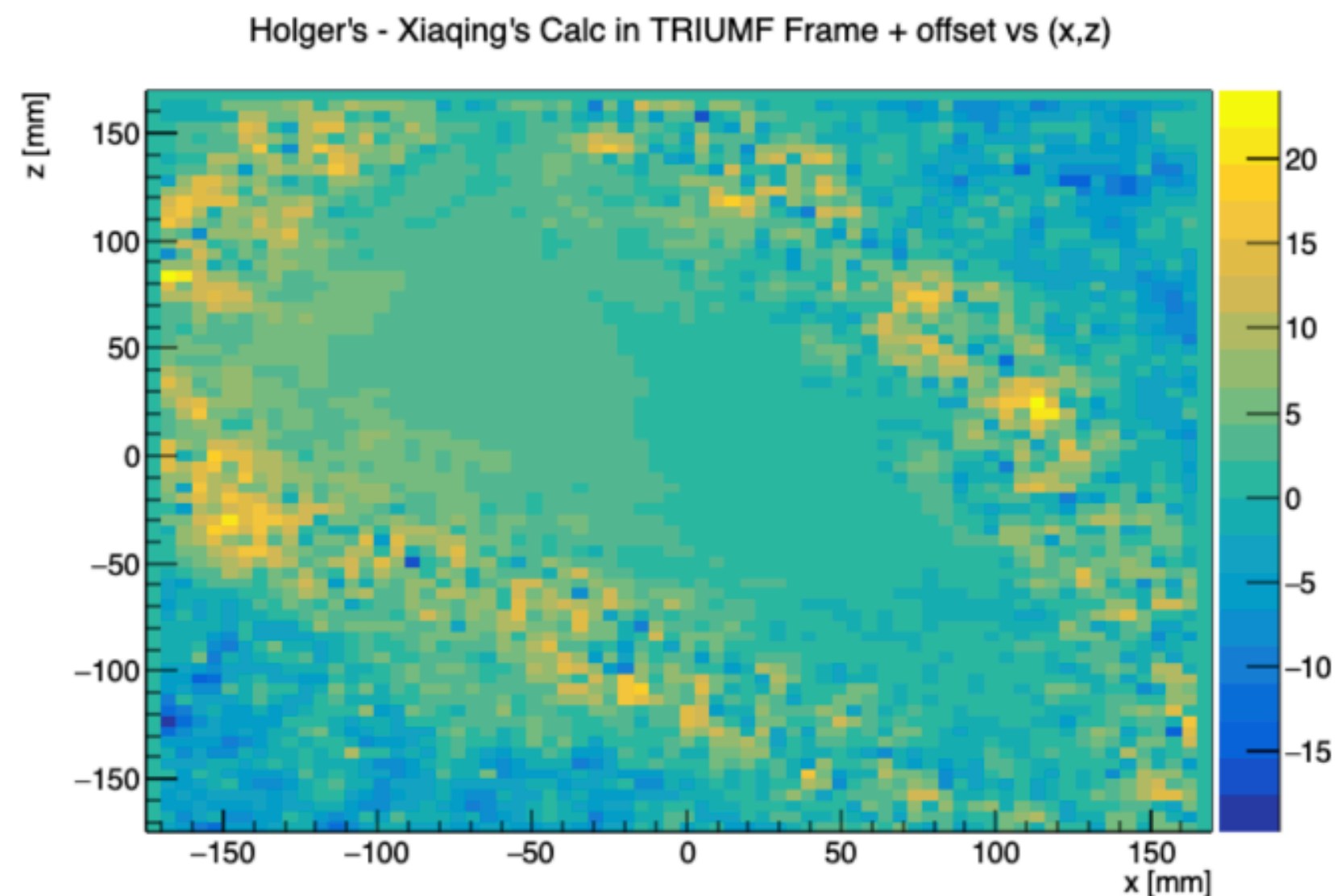
- ▶ MainzGen + RadGen ( ✓ Laura )
- ▶ Newest data available on OneDrive

- ▶ Epstein-Milner ( ✓ Ethan )
- ▶ Initial comparison to data was shown

- ▶ RadGen ( ✓ Win )
- ▶ eC\_BH ( ? )

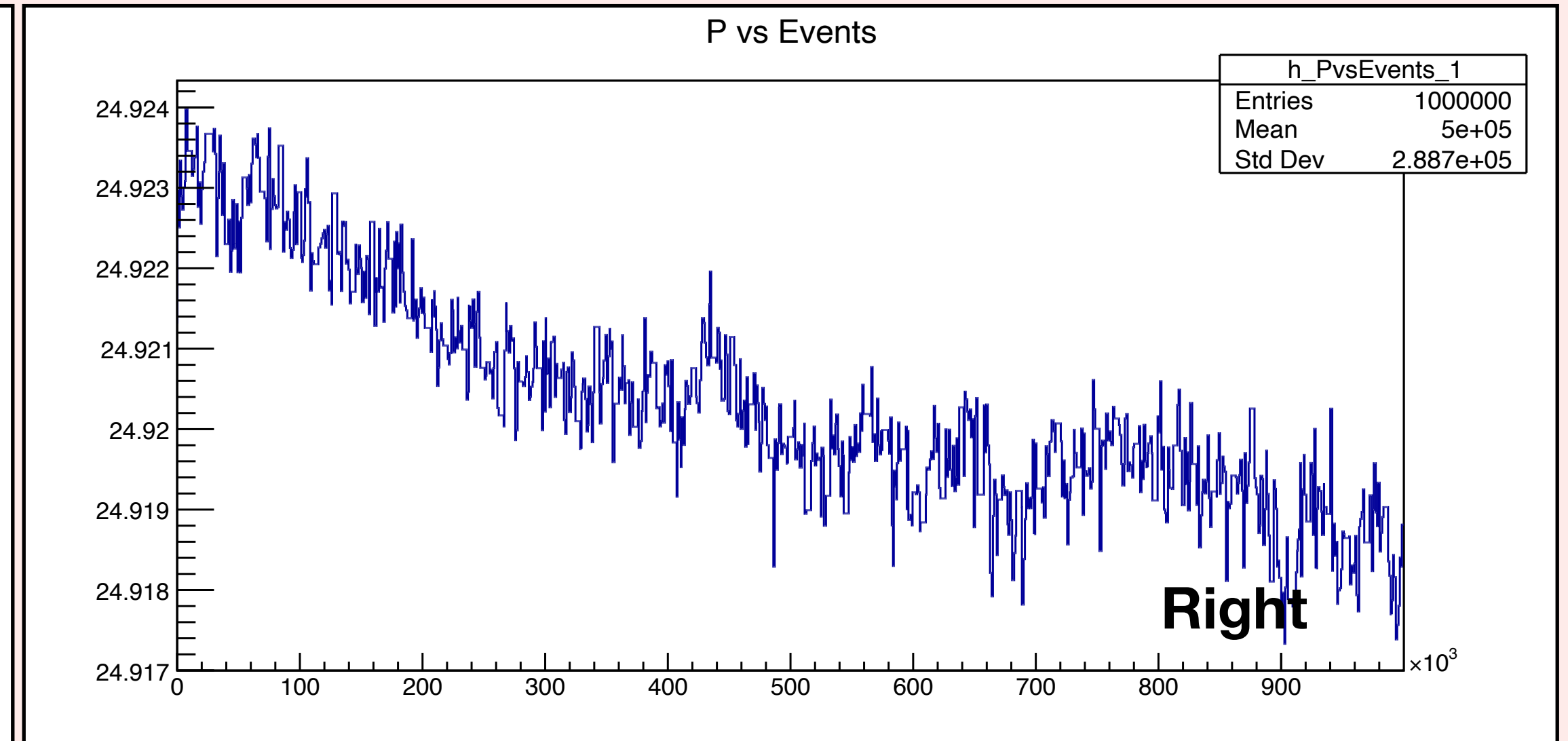
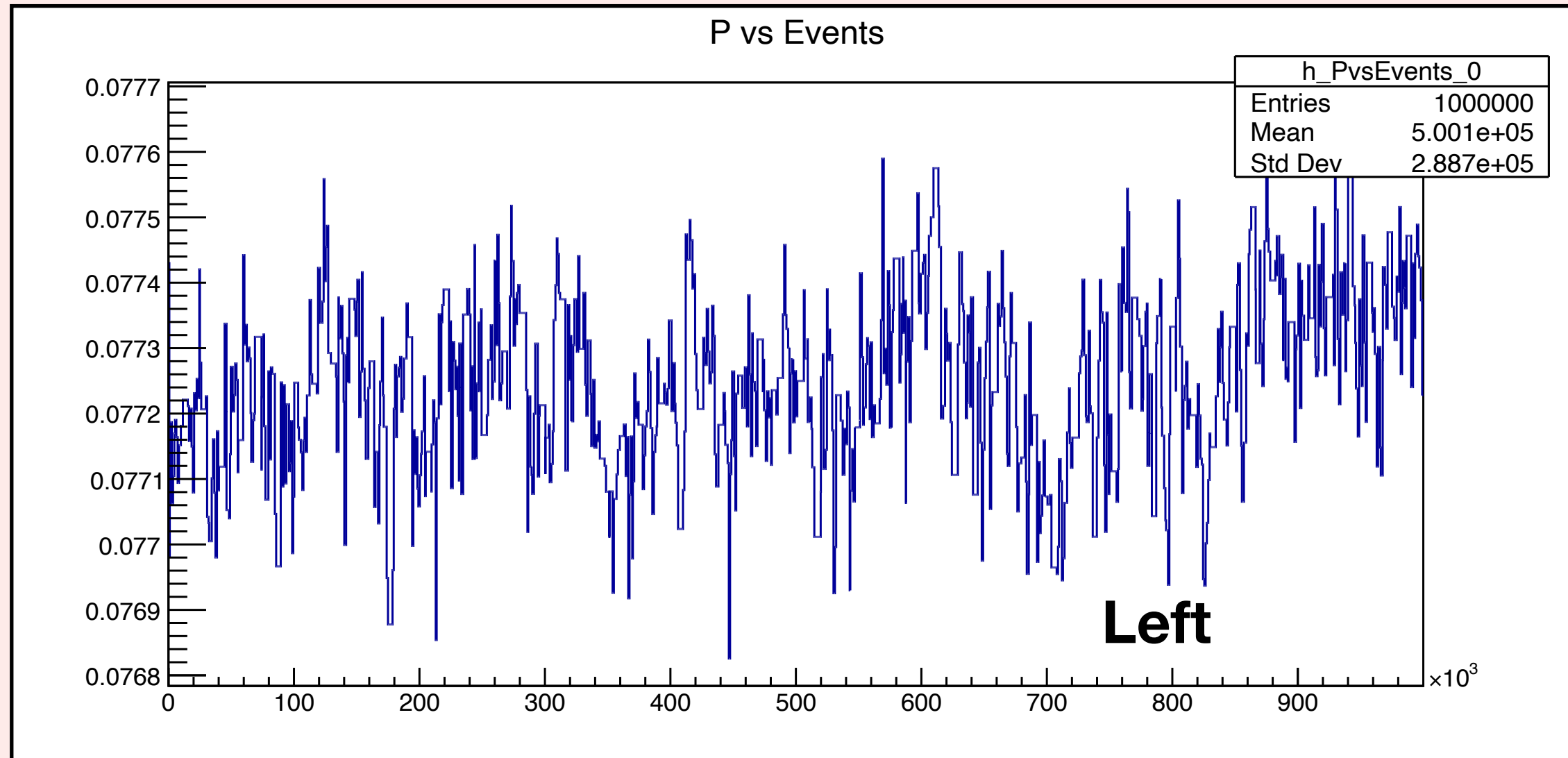
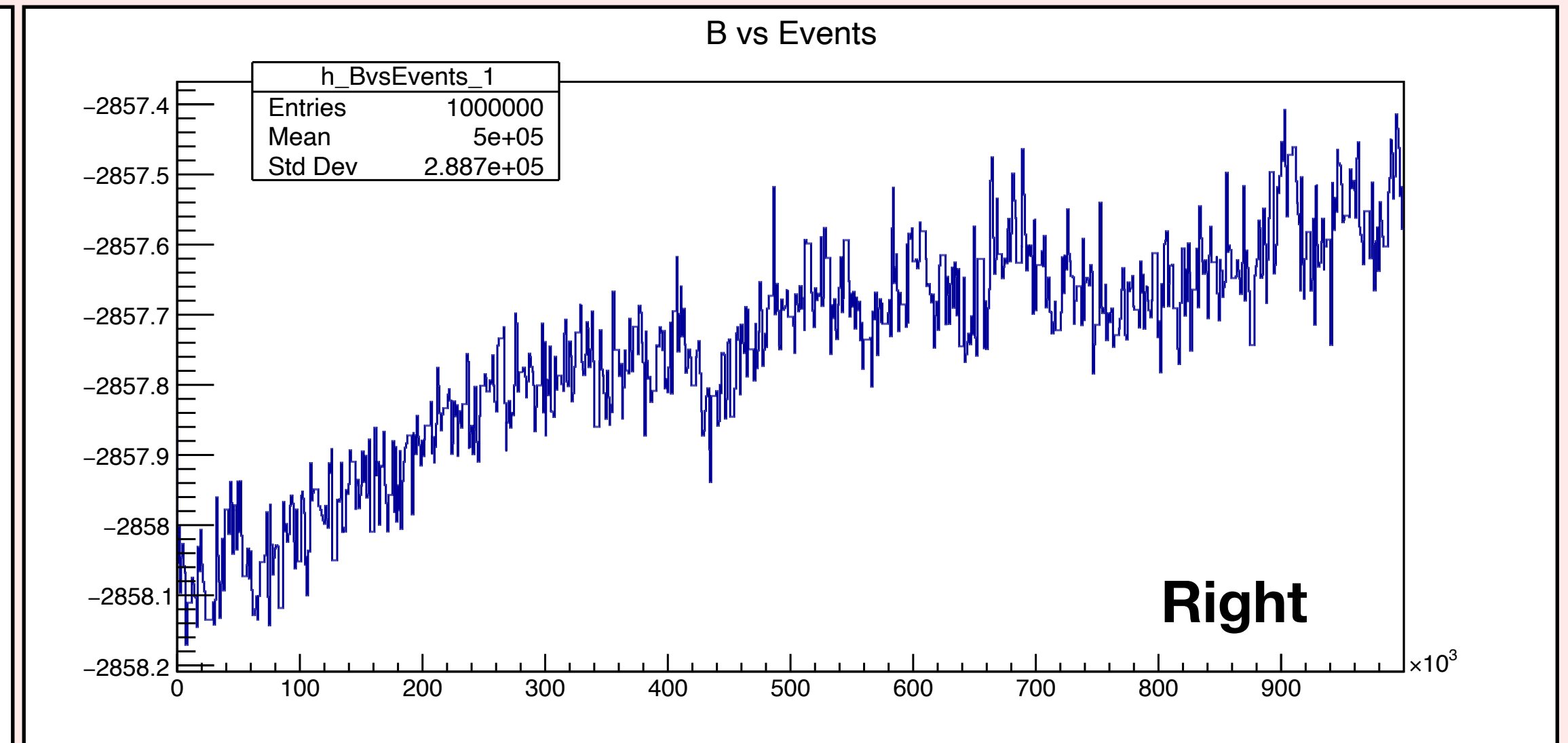
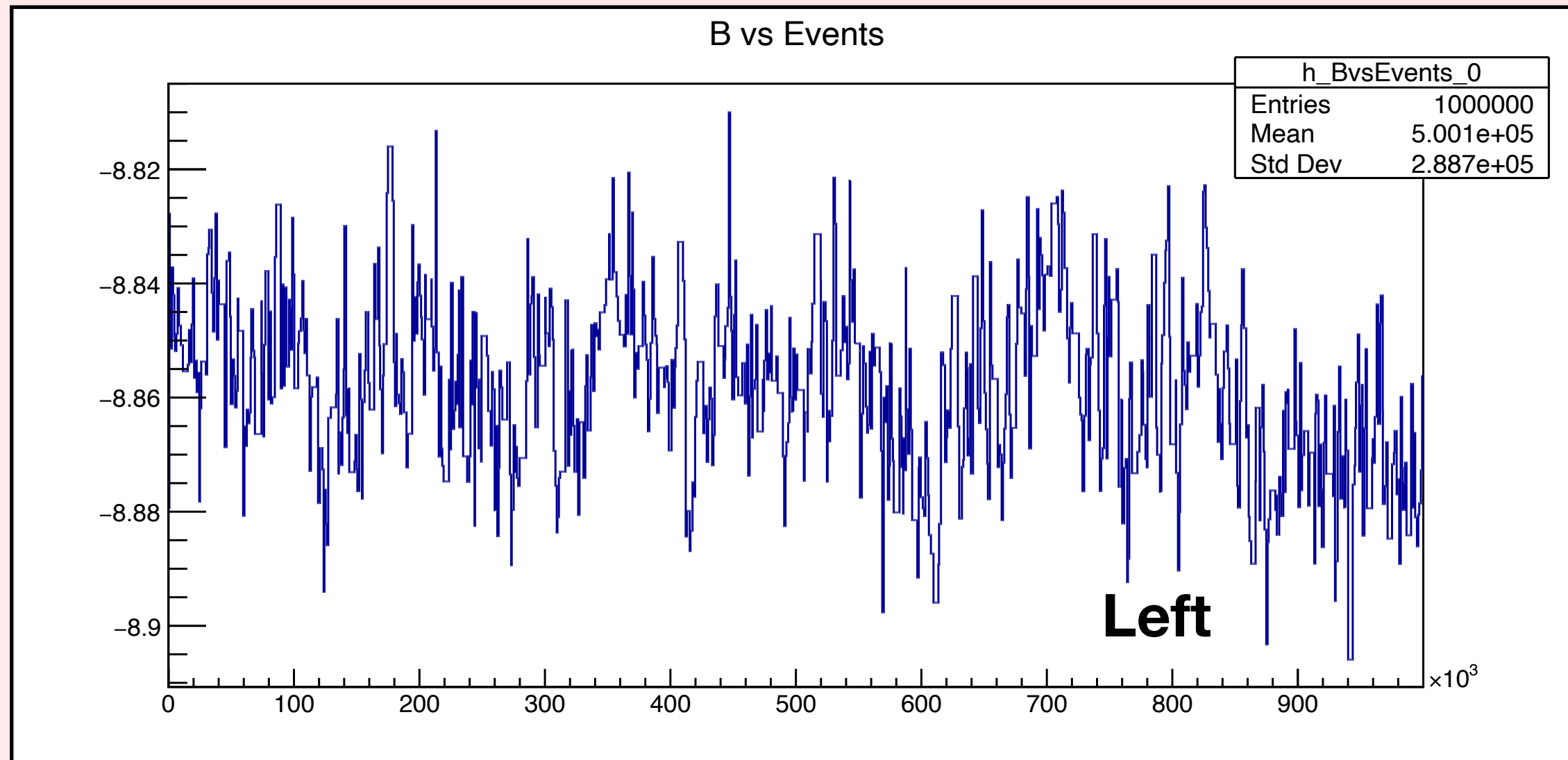


Calculated field in Gauss.



## Ethan's analysis

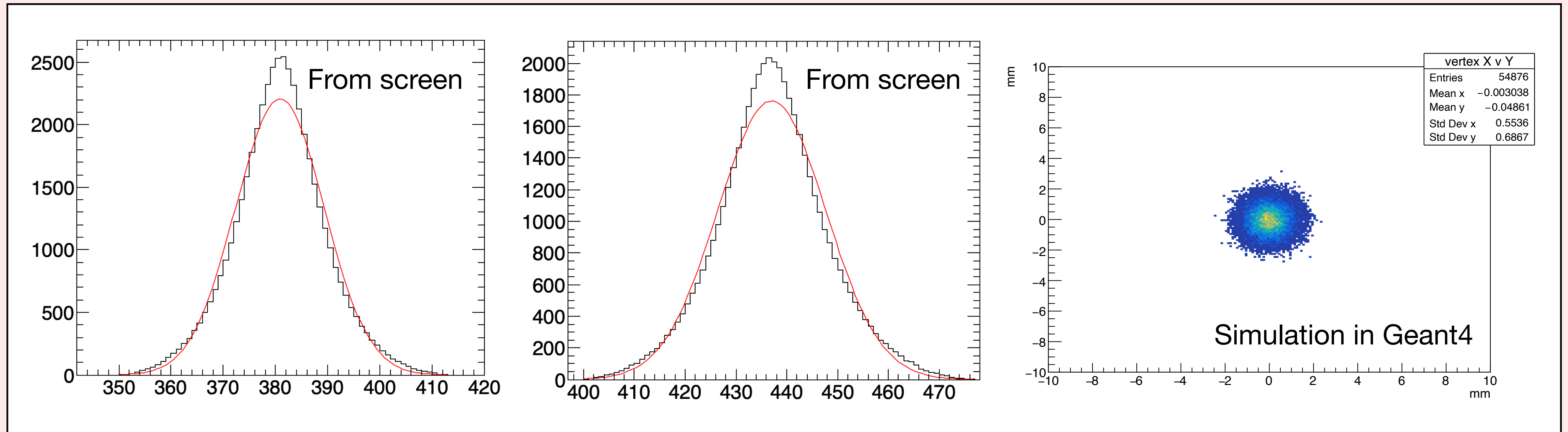
- ▶ ANSYS-Maxwell calculation by Xiaqing
  - ▶ COMSOL calculation by Holger
  - ▶ Measurement by Shaquielle
- } ~ agree



$$P_c = B_{\text{Hall}} \times \frac{40 \text{ A}}{716.722 \text{ G}} \times \frac{30 \text{ MeV}/c}{192.0 \text{ A}}$$

For simulation,  $B_{\text{Hall}}$  from slowctrl  
is used to set  $P_C$  in .mac

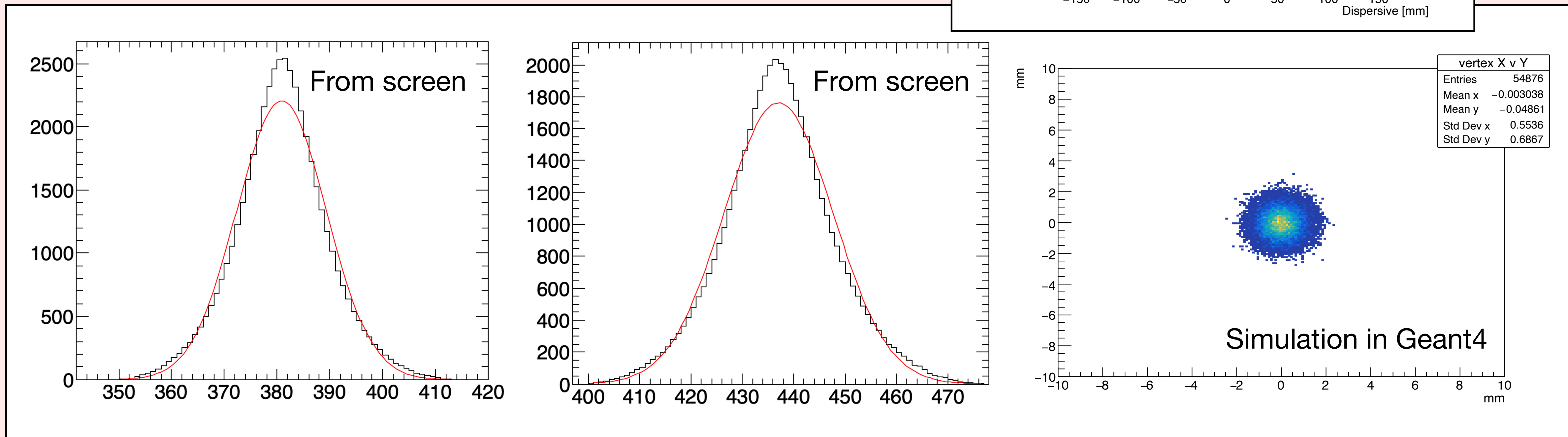
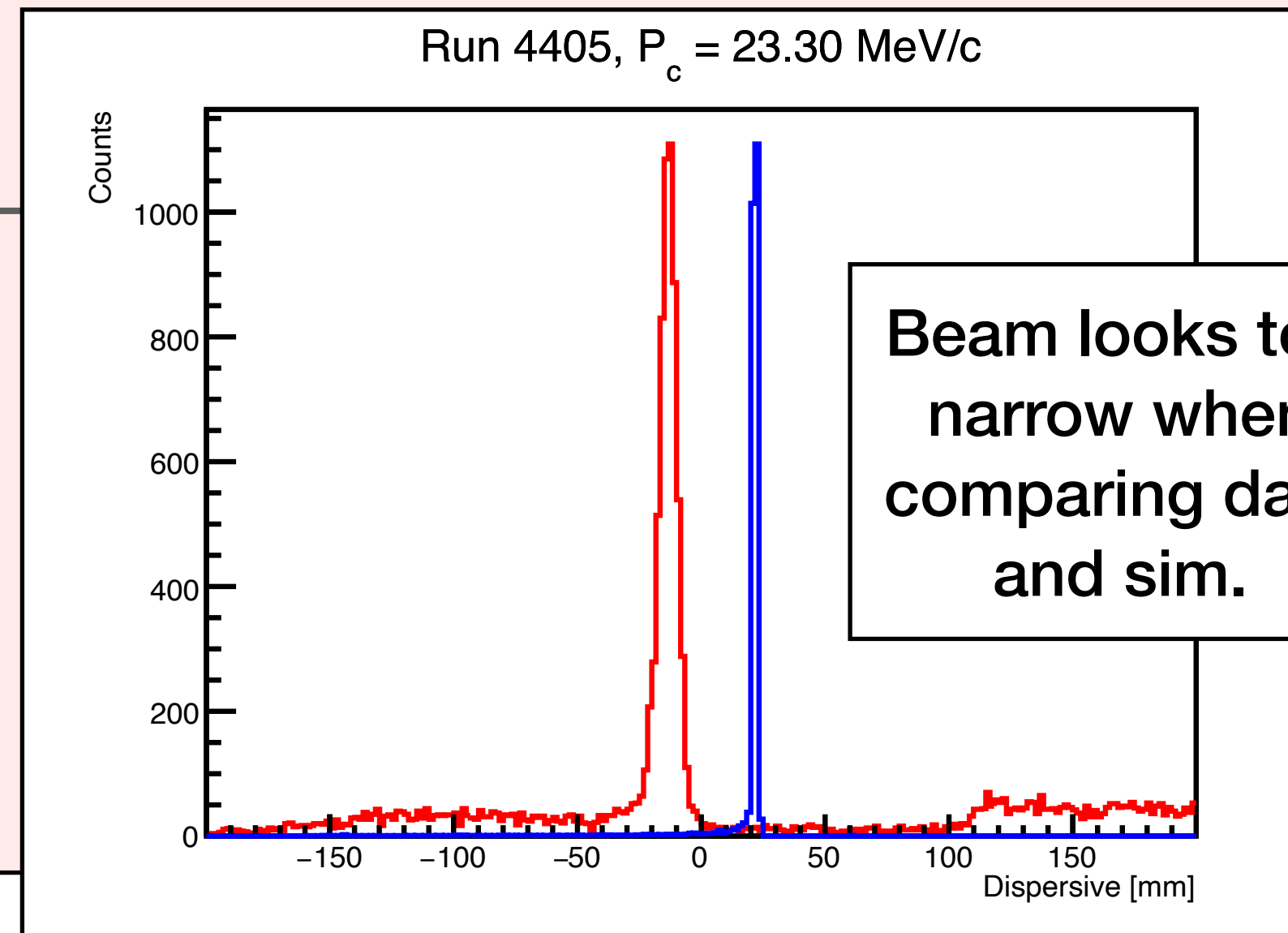
- ▶ Beam information provided by Kate and Hui Wen:
  - ▶ Focus beam at 25 MeV: 2 RMS in x = 1.35 mm, 2 RMS in y = 1.12 mm
  - ▶ No good image for other settings
  - ▶ Off compared to Transoptr



- ▶ Beam energy recored in slow control matches elog. Assume number is kinetic energy.

# Beam shape

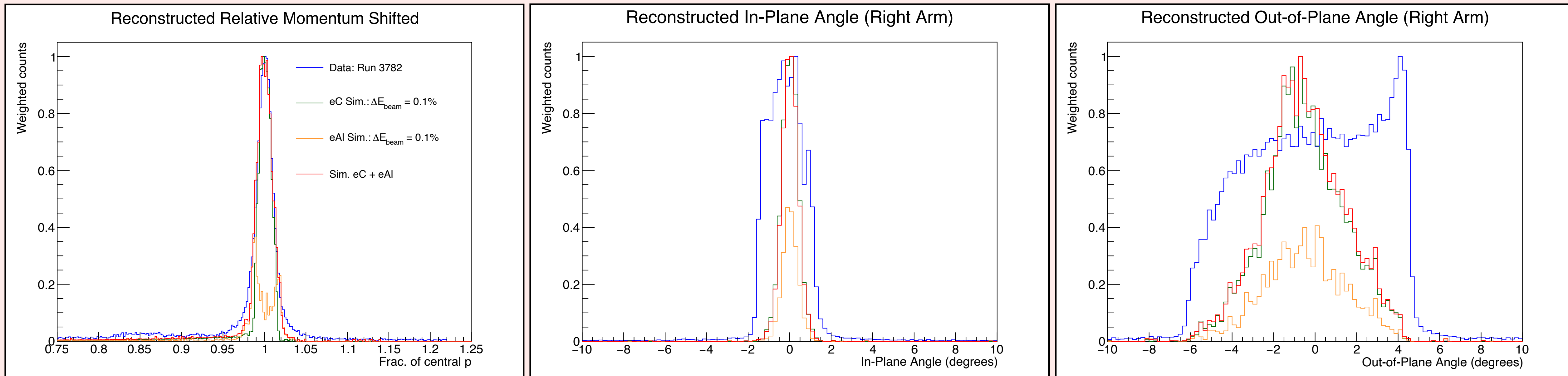
- ▶ Beam information provided by Kate and Hui Wen:
  - ▶ Focus beam at 25 MeV: 2 RMS in x = 1.35 mm, 2 RMS in y = 1.12 mm
  - ▶ No good image for other settings
  - ▶ Off compared to Transoptr



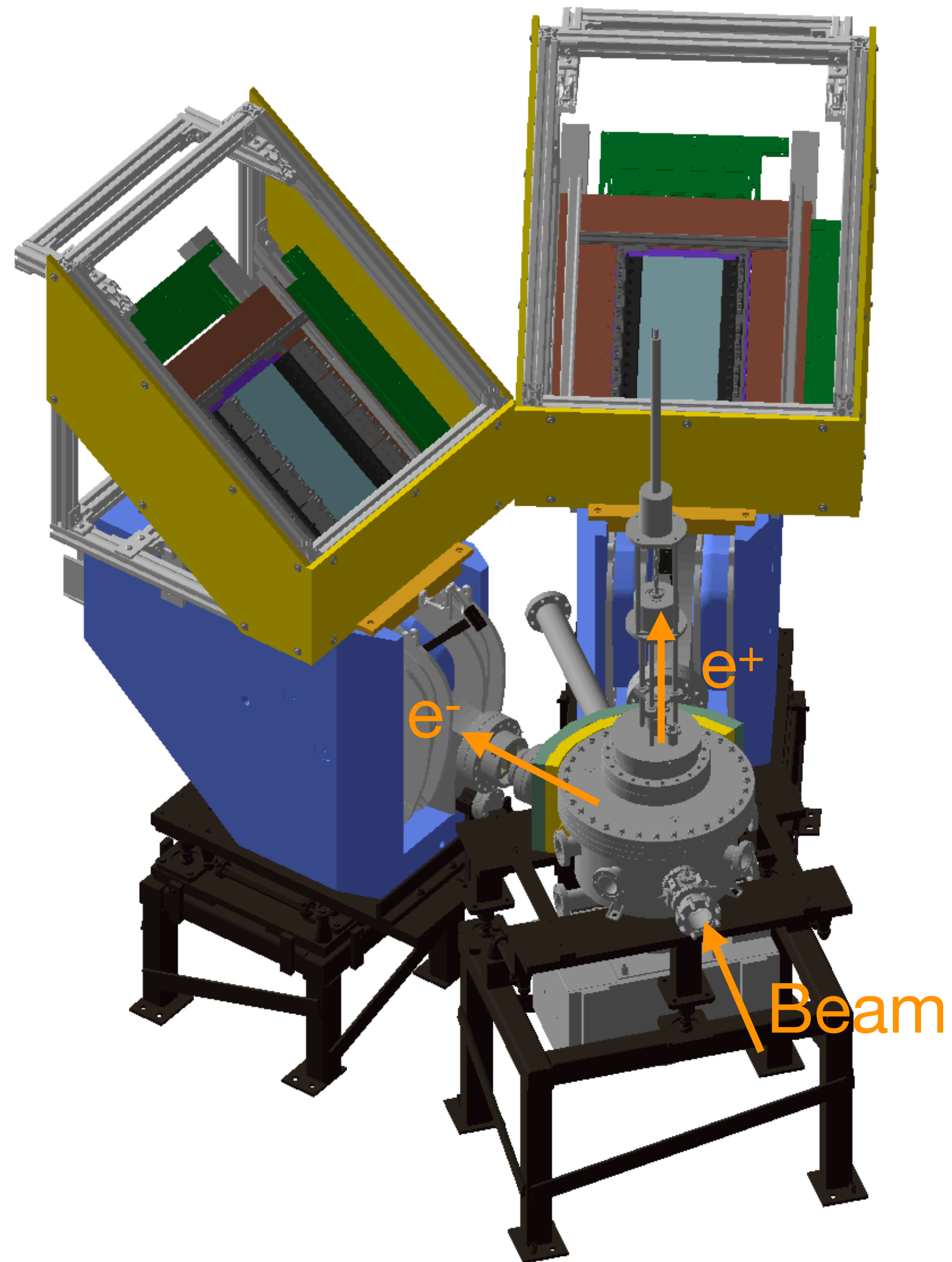
- ▶ Beam energy recored in slow control matches elog. Assume number is kinetic energy.

- ▶ In addition to the elastic peak width, the angular distributions of the beam are not well understood either

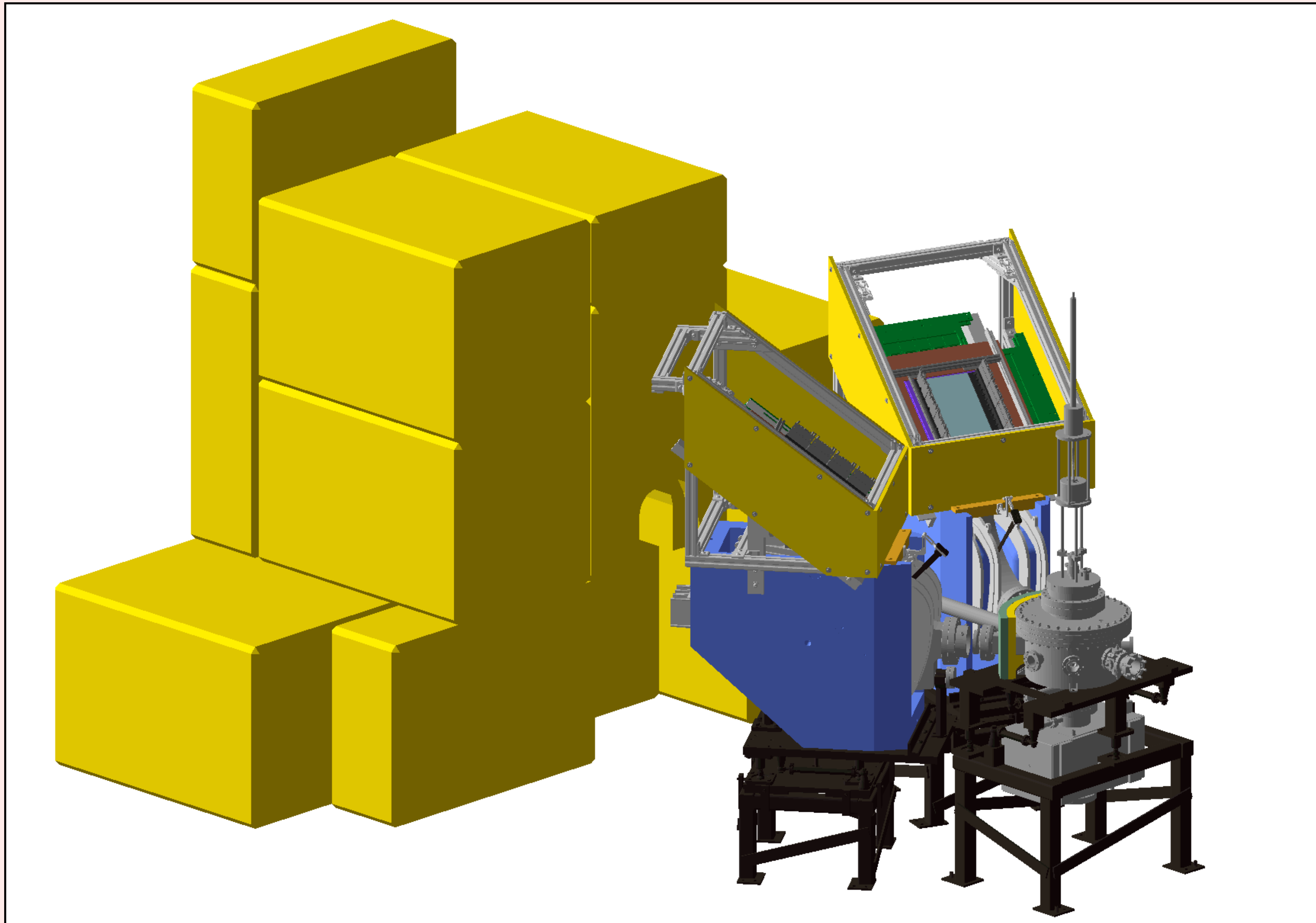
## 10 MeV eC scattering



$$\sigma_x = 1.5 \times 4.74 \text{ mm}, \sigma_y = 1.5 \times 4.47 \text{ mm}$$



- Physics ← Event generator
- Magnetic field ← ANSYS-MAXWell
- ? Beam ← Input from acc. group
- Apparatus & Geometry ← Solidwork + Survey (+data)
- Detector Readout ← Gean4 + digitization

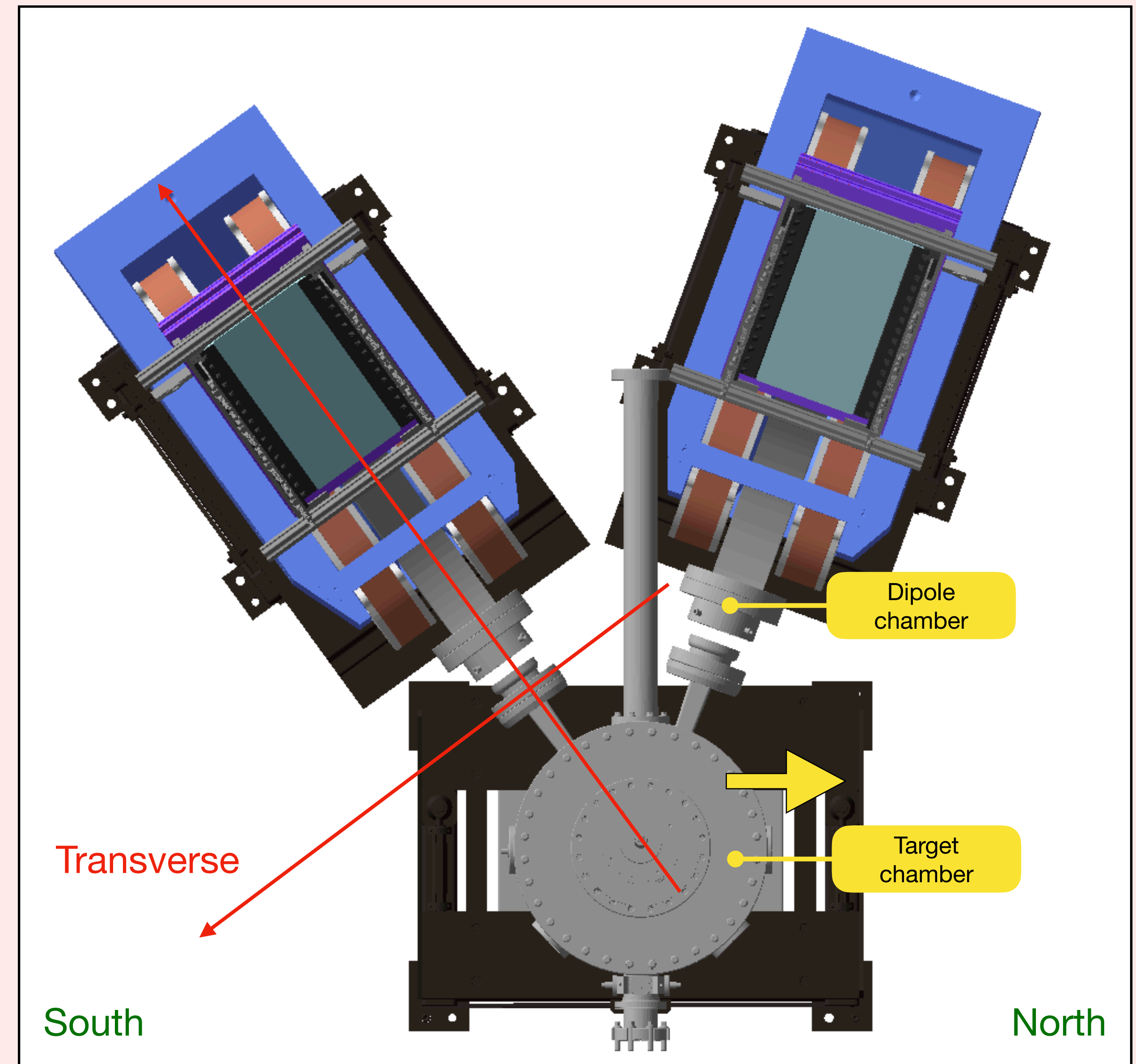


- ▶ All parts in SolidWorks drawing are added to g4darklight ( including the not so necessary parts :))
- ▶ Use .mac to select the components for simulation

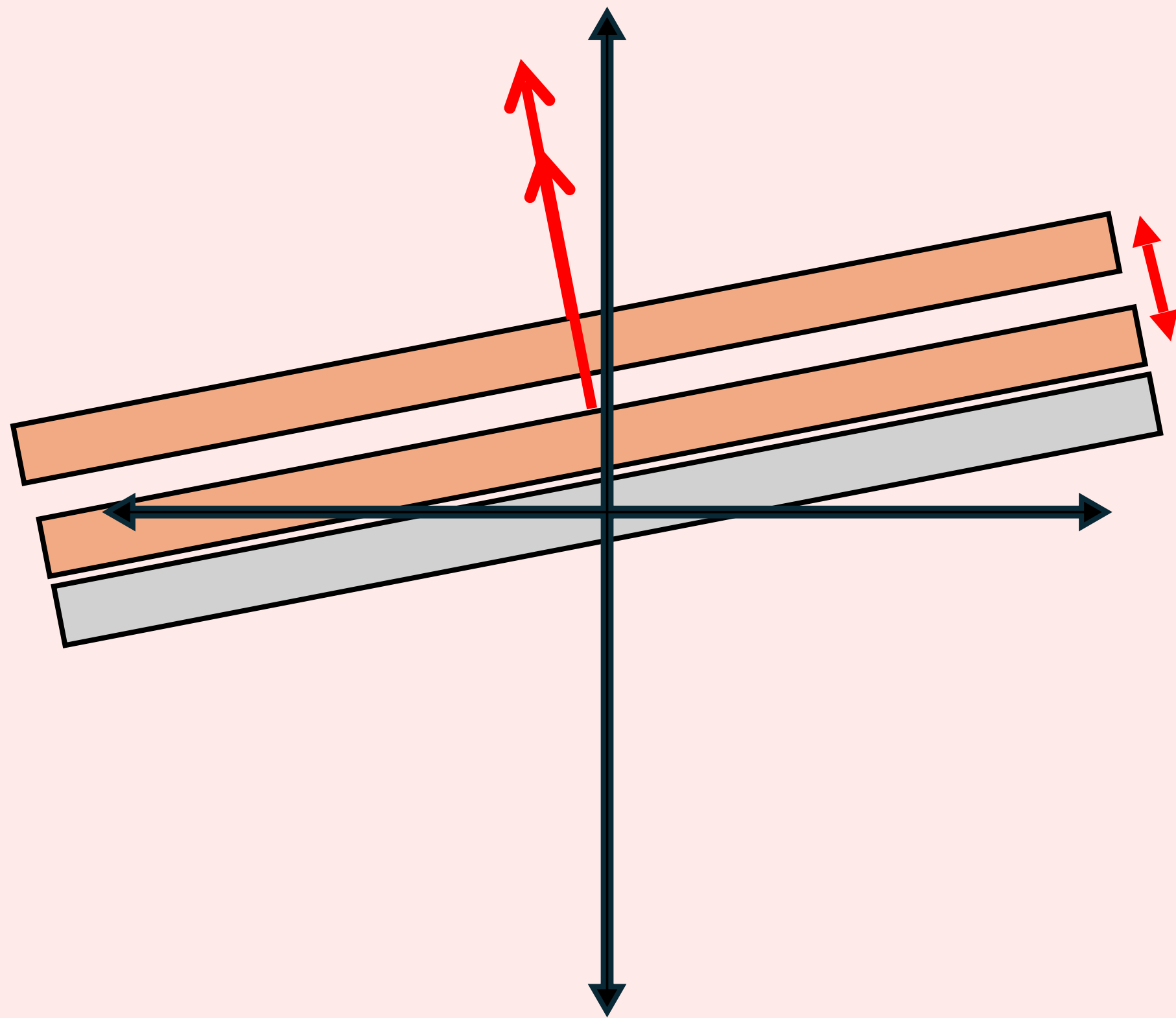
```
/det/setTarget C  
/det/setDetFrame true  
/det/setLead true  
/det/setTable true  
/det/setDipole true  
/det/setExitChamber true  
/det/setTargetChamber true  
/det/setTargetLadder true  
/det/setLeadPile true
```

From Doug's summary email on Oct. 19th:

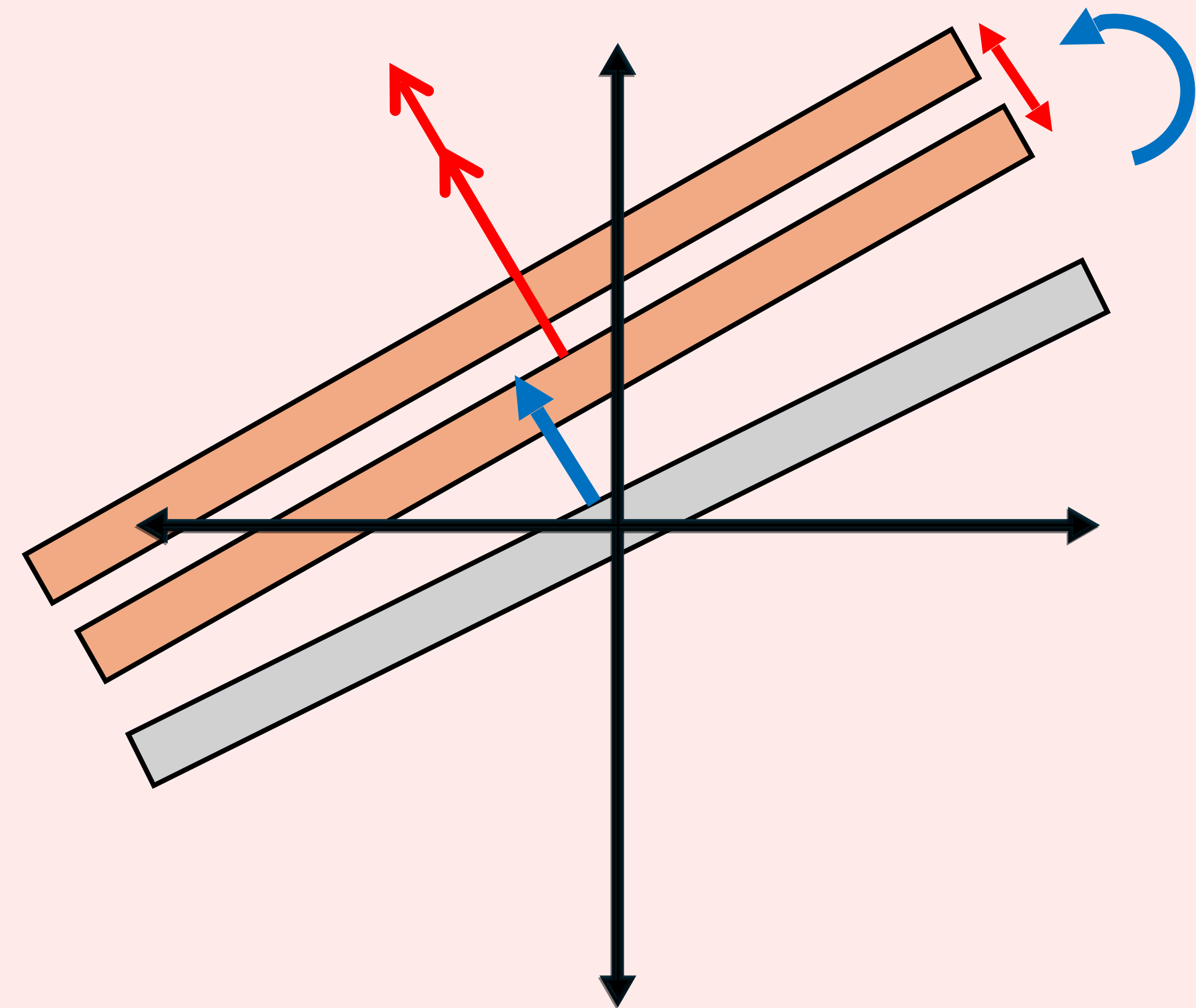
- ☑ Target center is 0.52 mm north
  - ▶ Scattering chamber upstream fiducial is 0.55 north
  - ▶ Scattering chamber south fiducial is 1.46 north
  
- ☑ Dipole magnets were positioned and surveyed to be very close to their nominal locations
  
- ☑ North dipole vacuum chamber: 0.87 mm closer to the target, shifted 0.41 mm transversely, 0.19 mm vertically
- ☑ South dipole vacuum chamber: 3.75 mm away from the target, shifted -1.1 mm transversely, -0.82 mm vertically



- ▶ Fixed distance between top and bottom GEMs
- ▶ GEMs remain parallel
- ▶ ~ 1 degree rotation, < 5 mm Translation

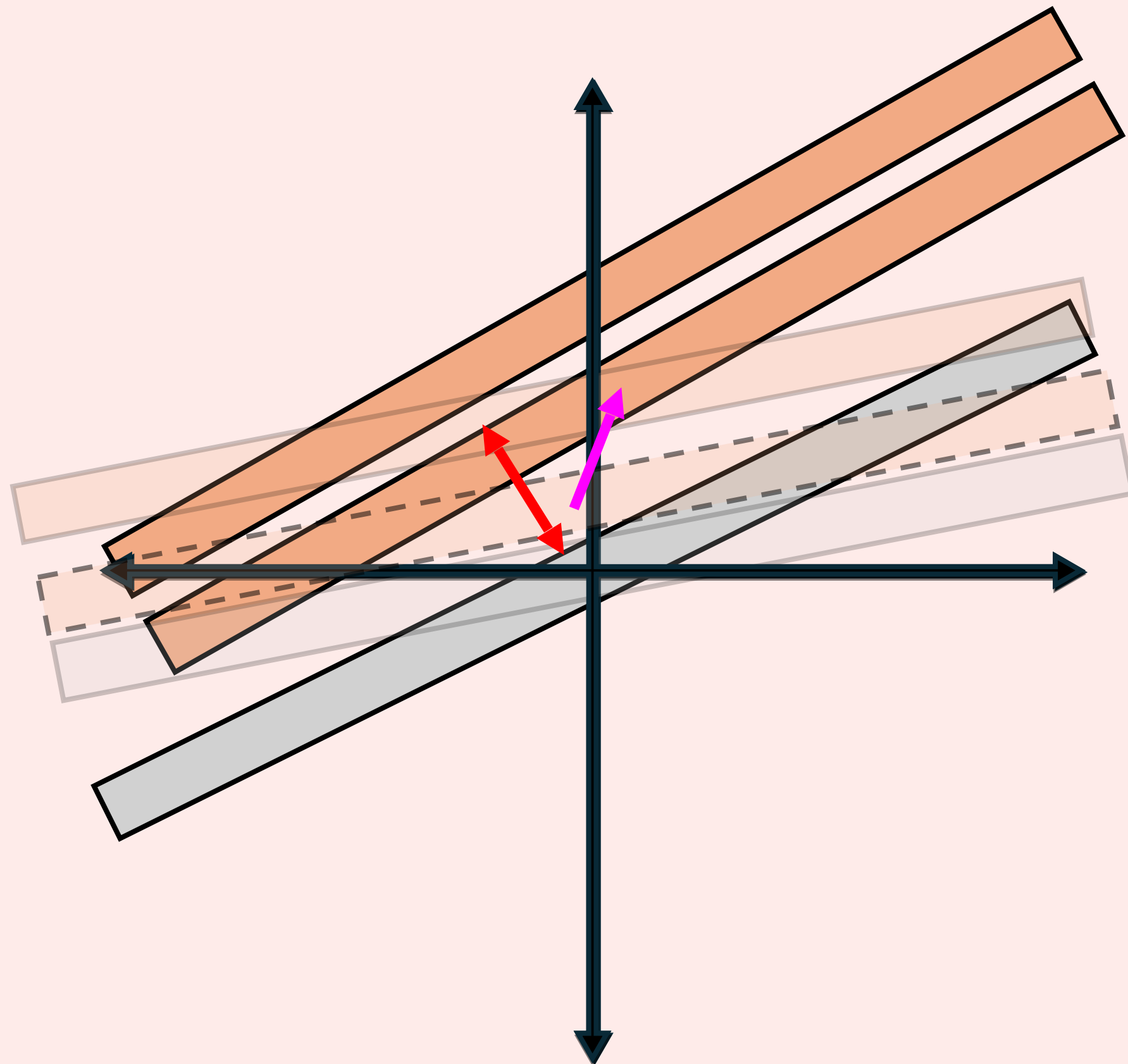


Before Latest Measurements

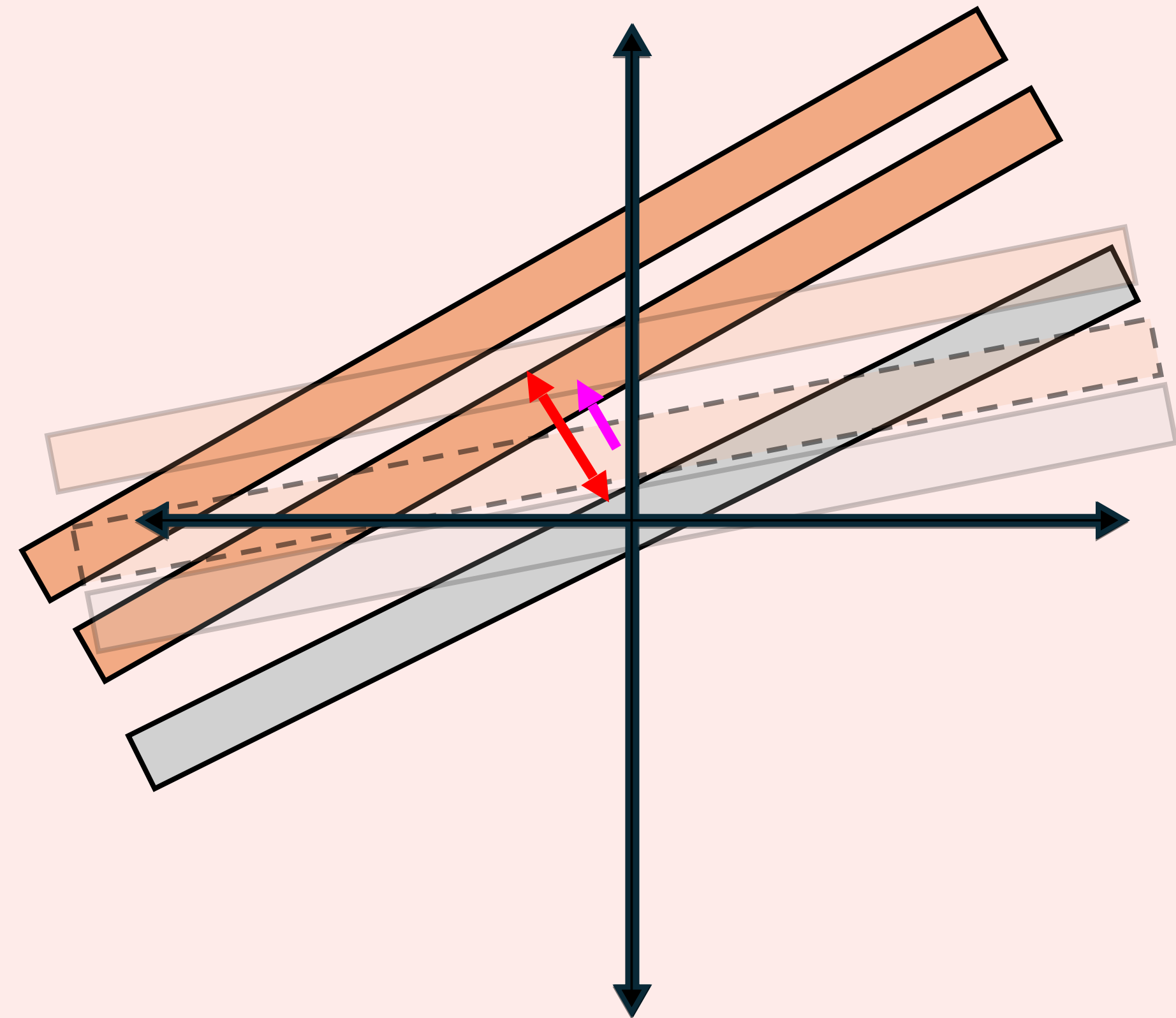


After (Exaggerated)

- Position of GEMs unconstrained -- only distance from flange measured (red)
- Assumed minimal translation of bottom GEM

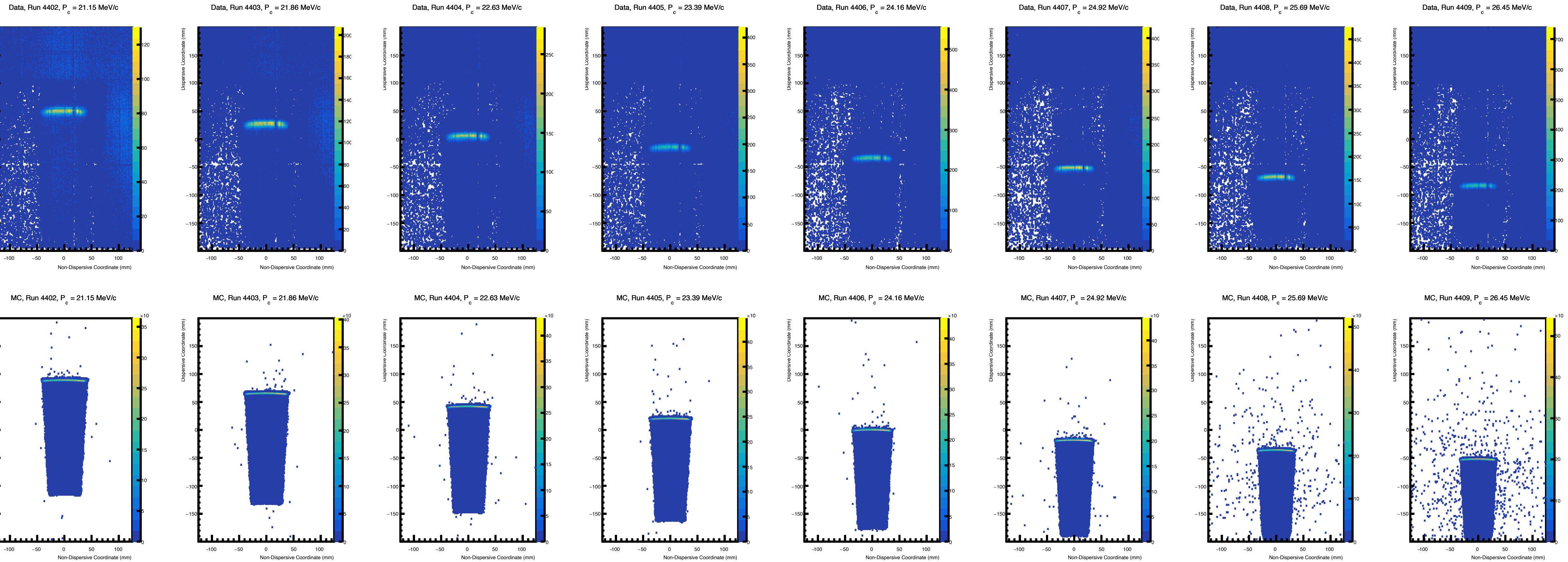


Possible Position of GEMs



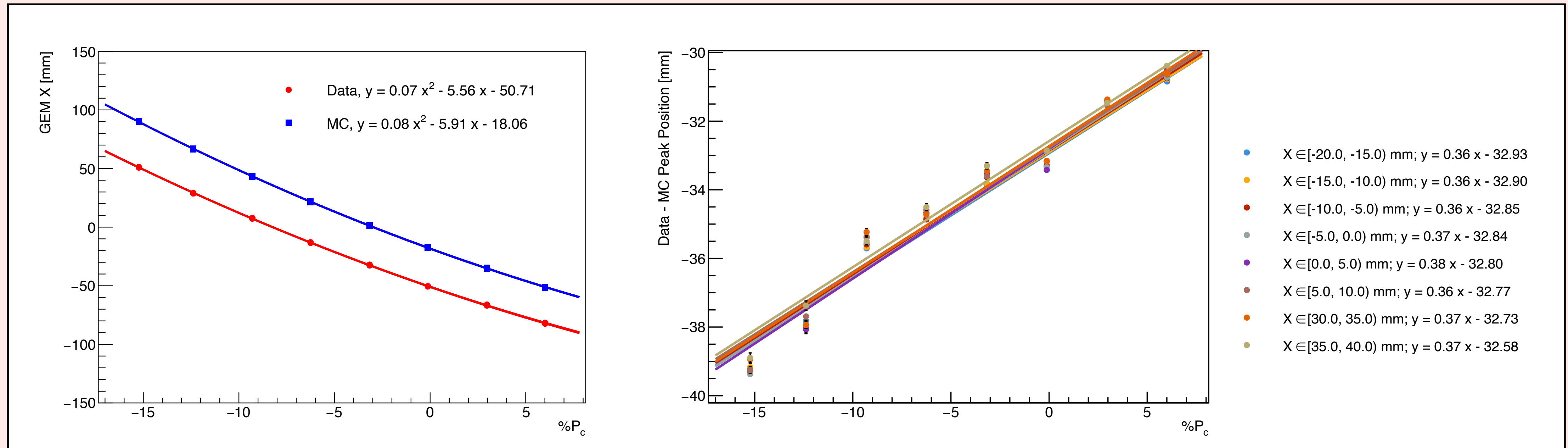
Position of GEMs with Minimum Translation

# Comparison and calibration with eC 25MeV

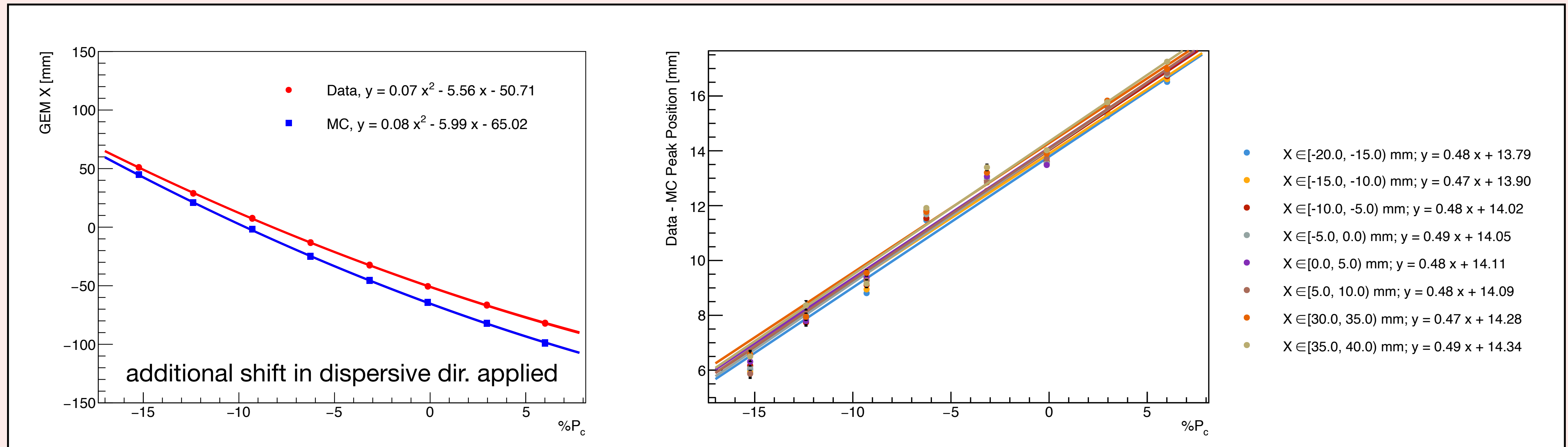


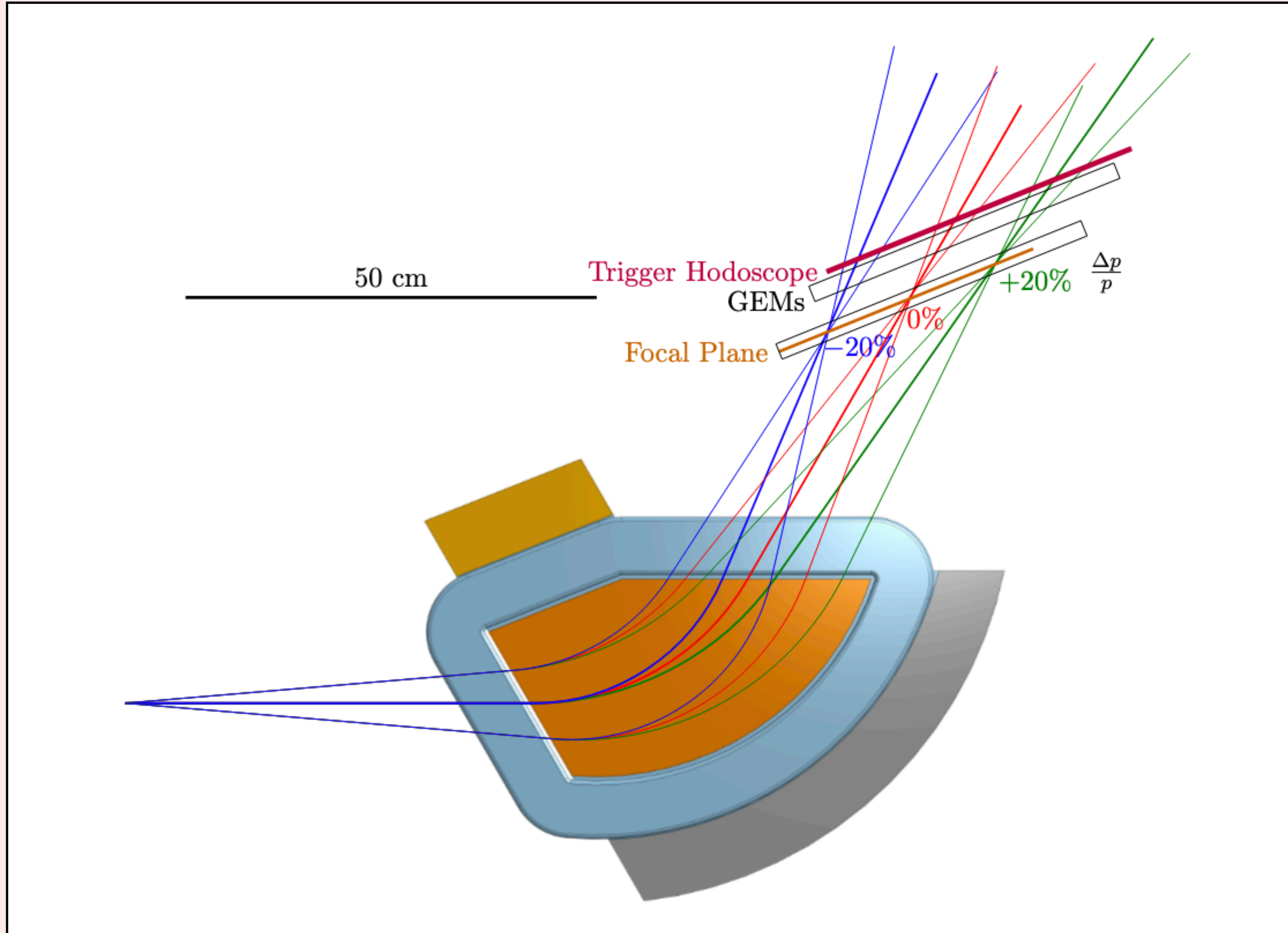
- ▶ elog 105, run 4402 - run 4407. eC scattering on the right arm
- ▶ No right top gem :(

Default from SolidWorks



With Survey

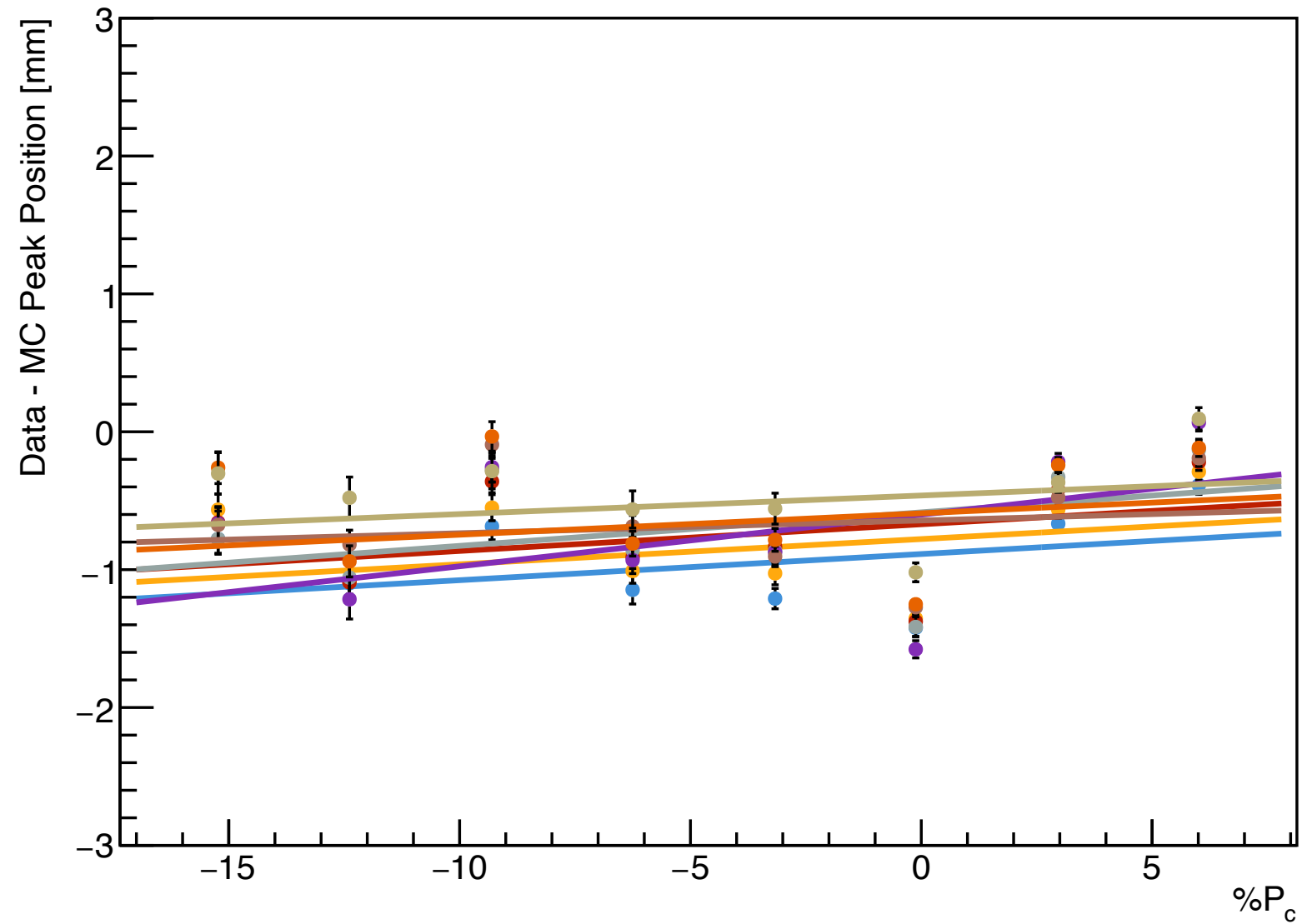
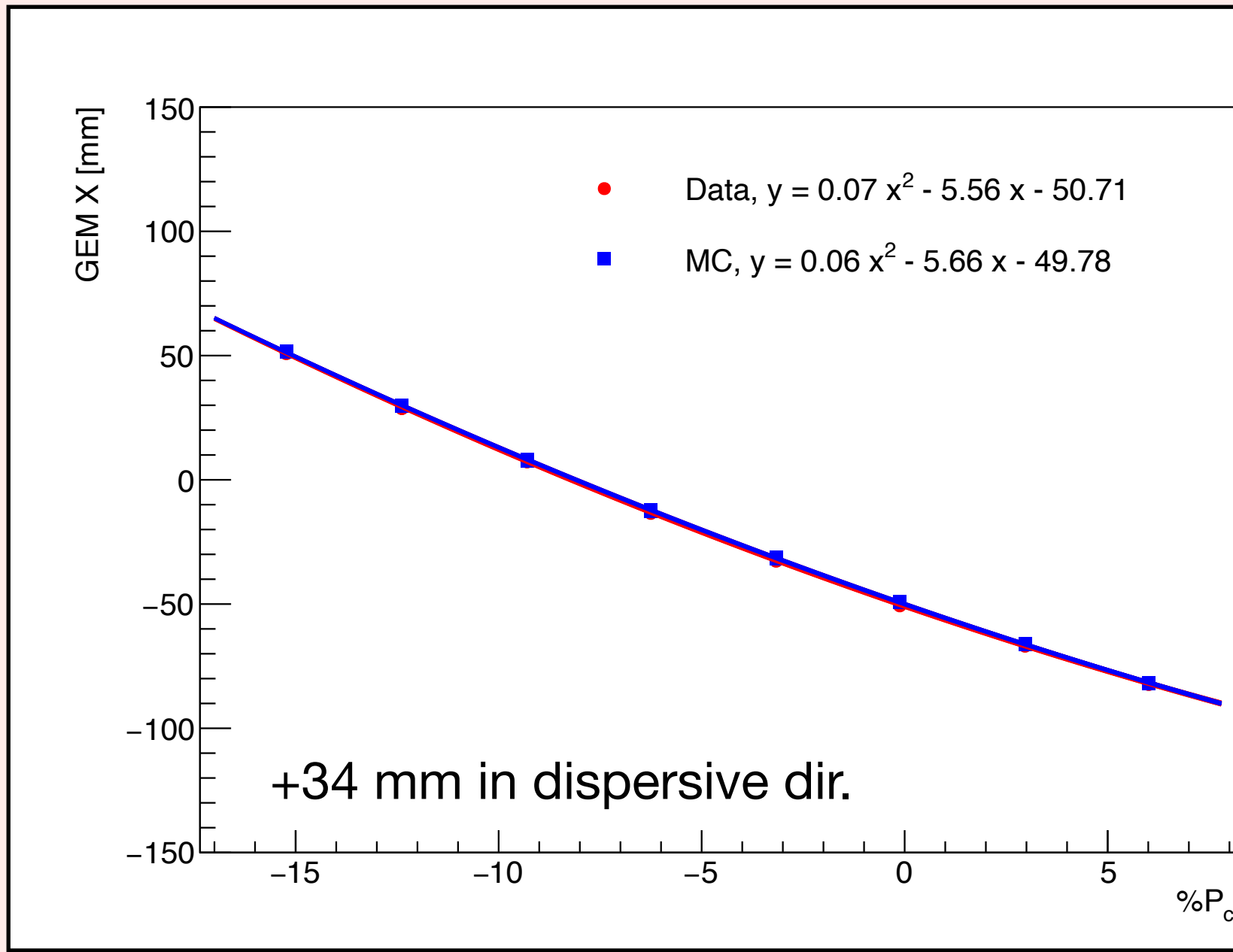
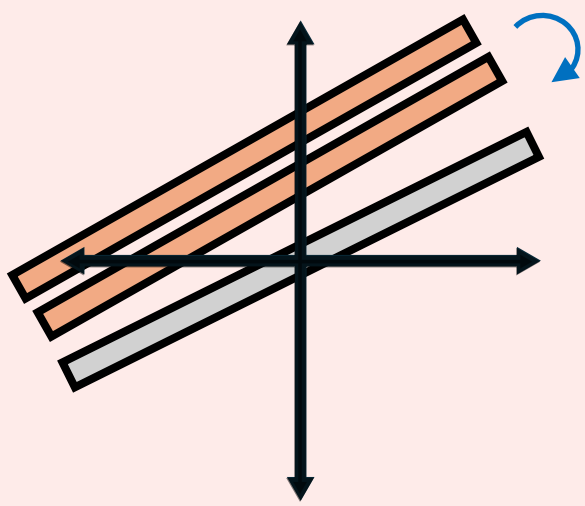




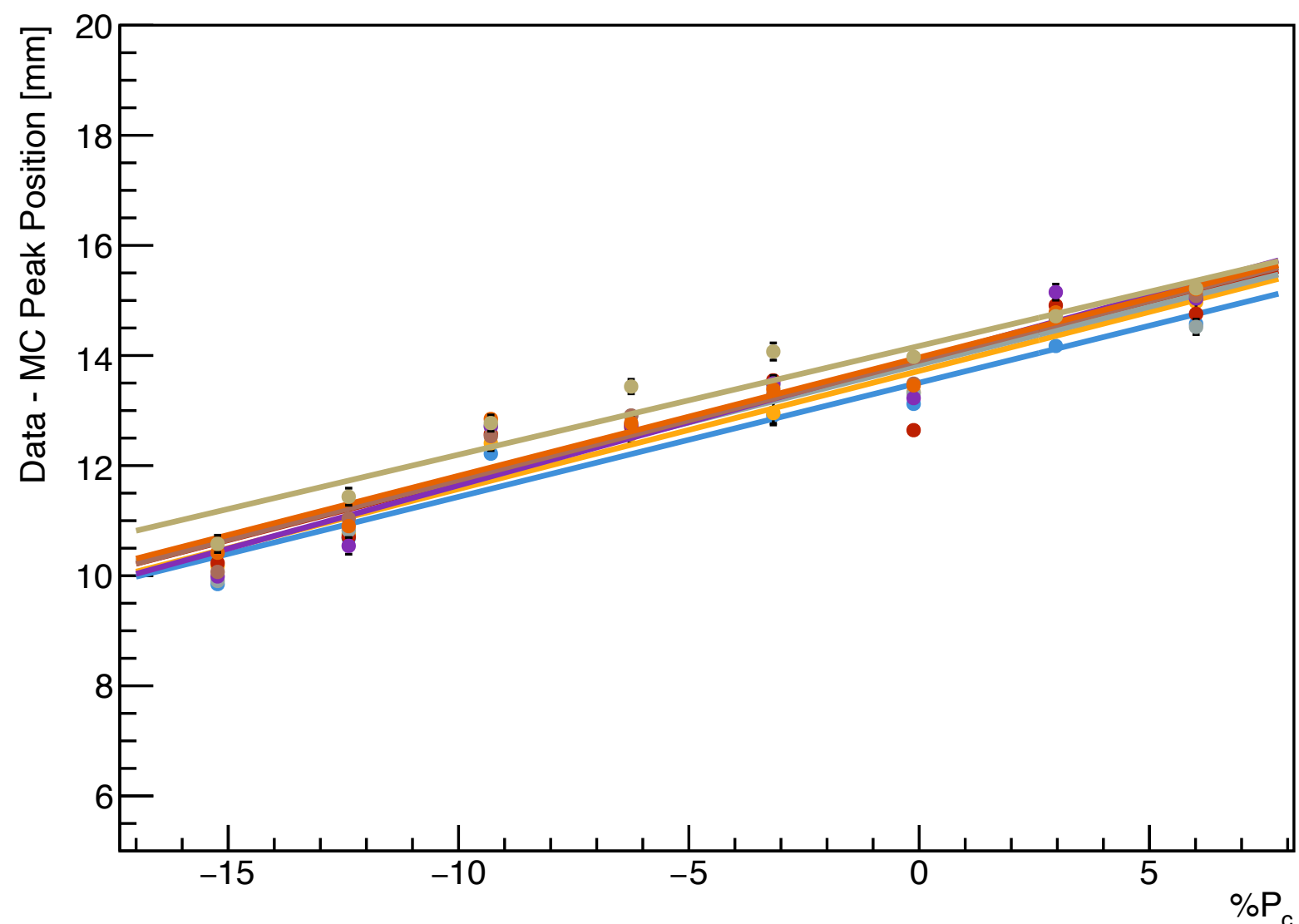
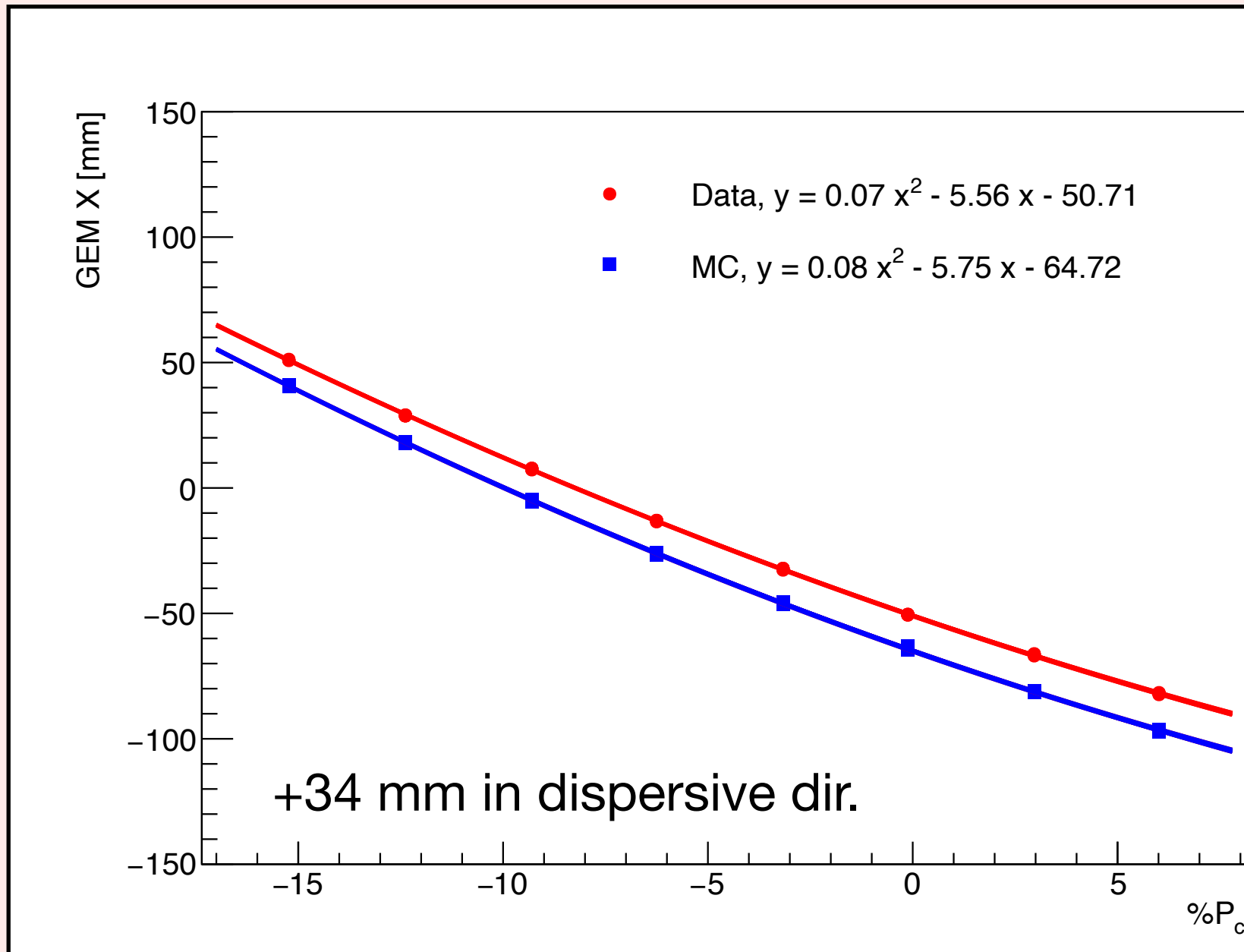
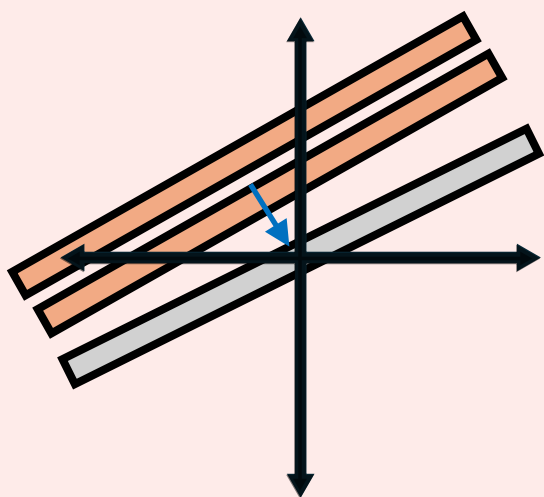
- ▶ We know magnetic field / momentum in the center of acceptance
- ▶ Assume we know beam energy
- ▶ First check distance from flange and plane angle, then position along dispersive direction

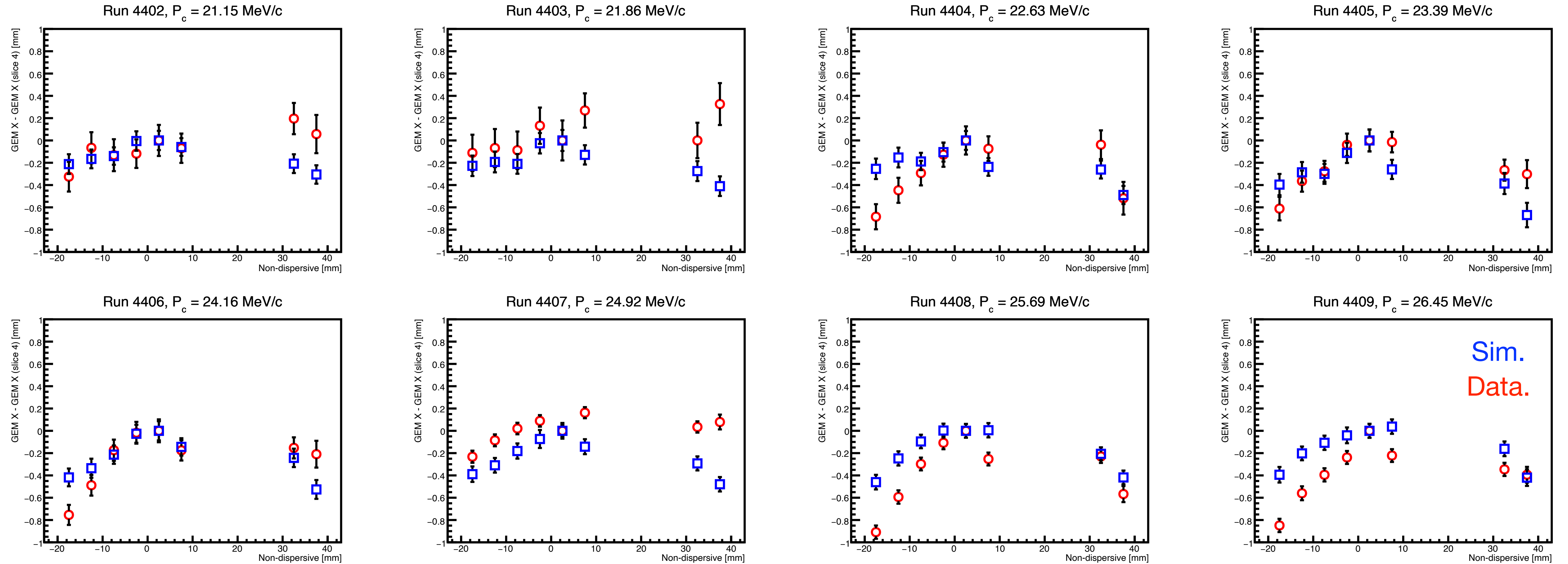
# Comparison and calibration with eC 25MeV

-2.5 deg  
around y (non-  
dispersive)  
from default

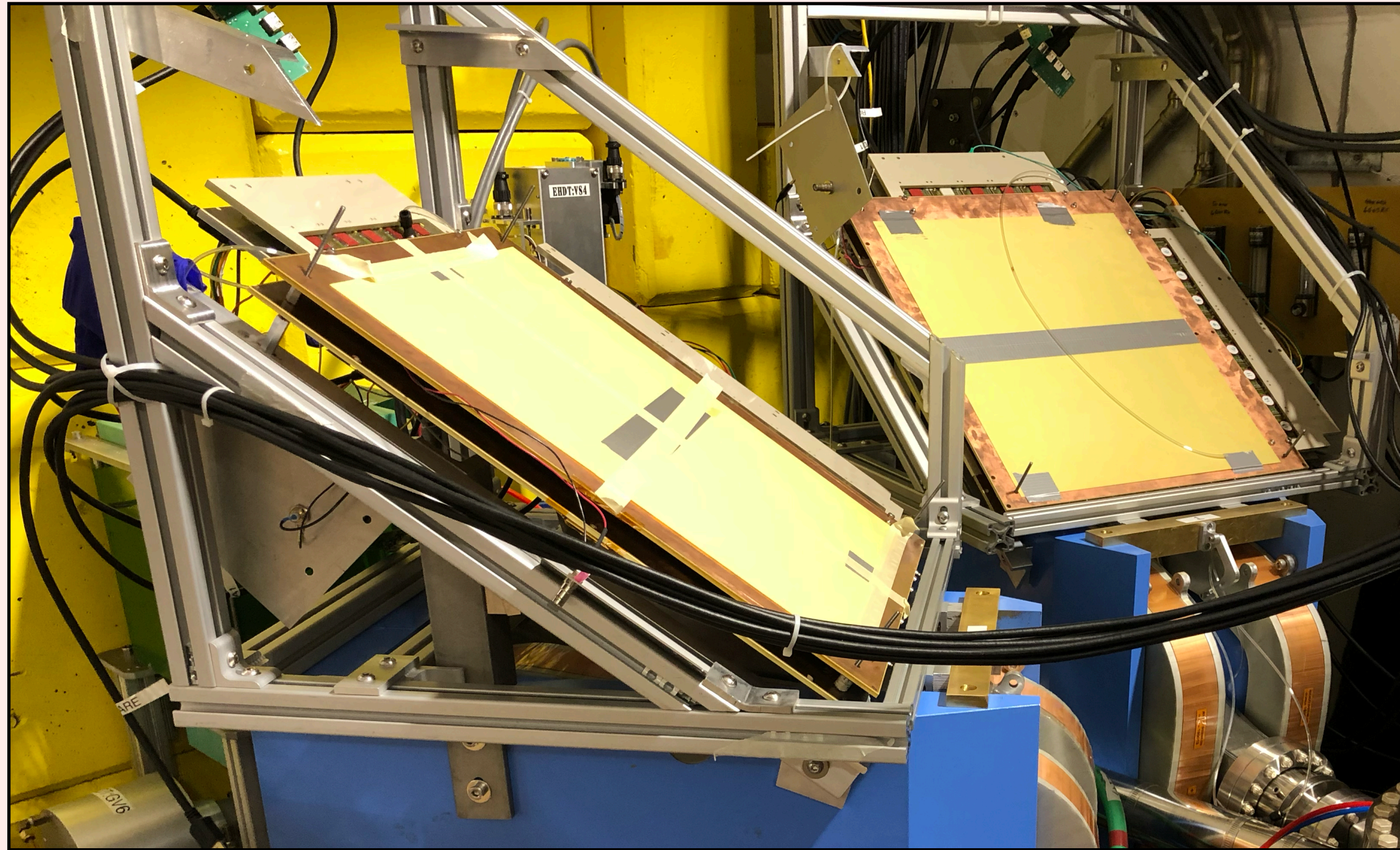


10 mm closer  
to flange

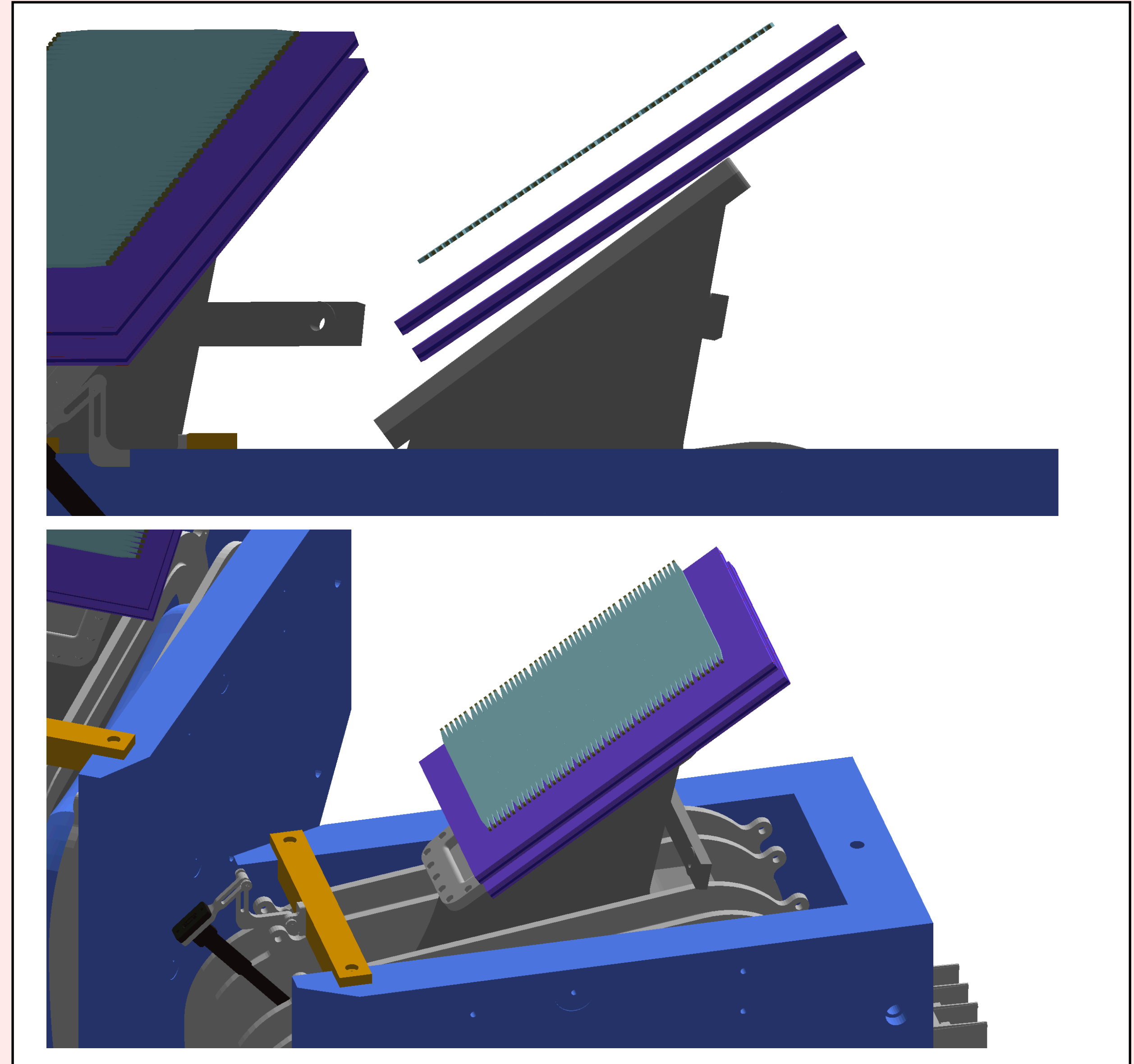


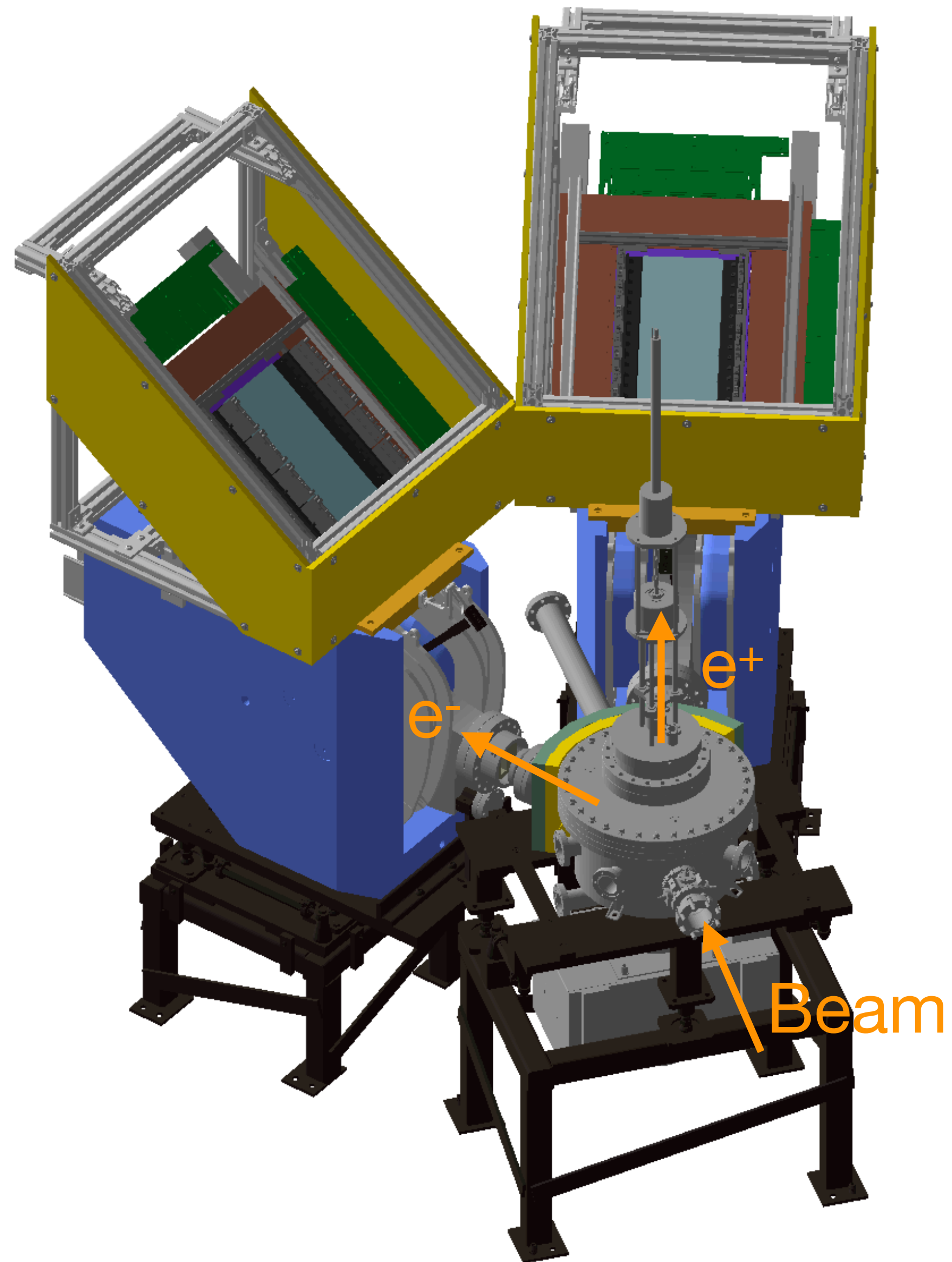


► -2.5 deg around y (non-dispersive) from default



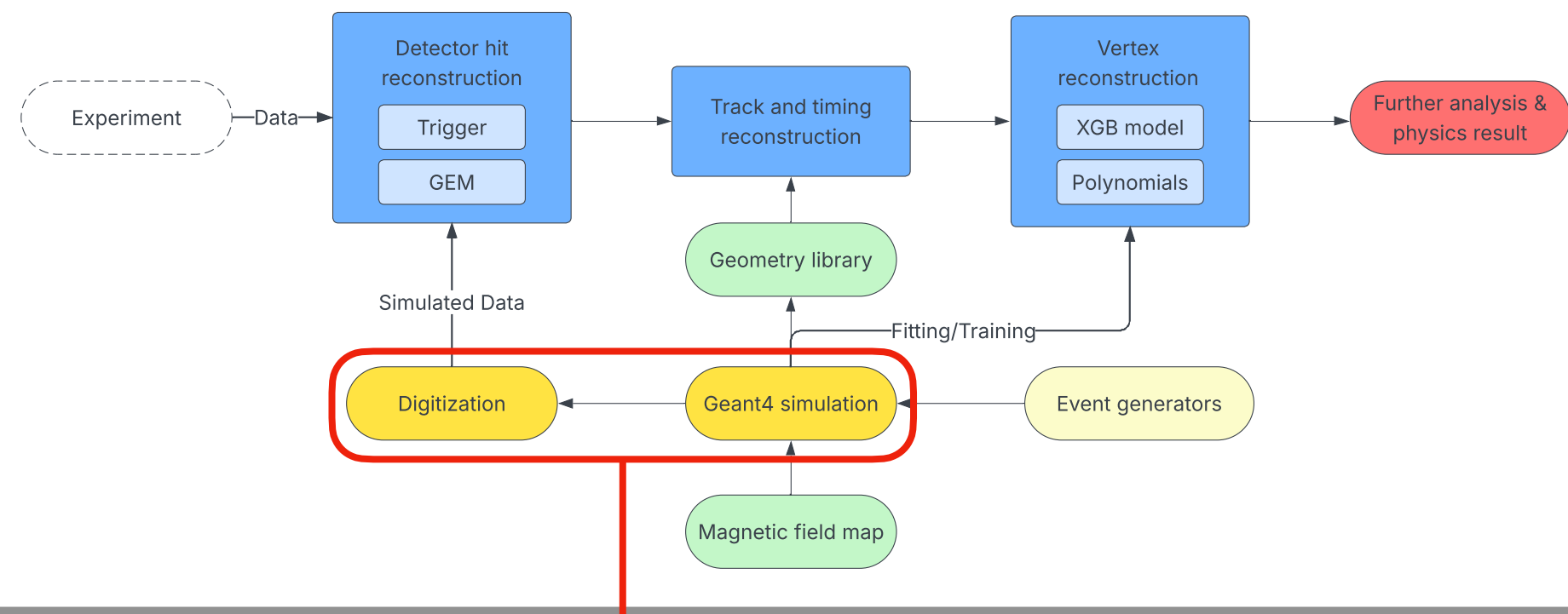
- ▶ -2.5 deg around y (non-dispersive) from default



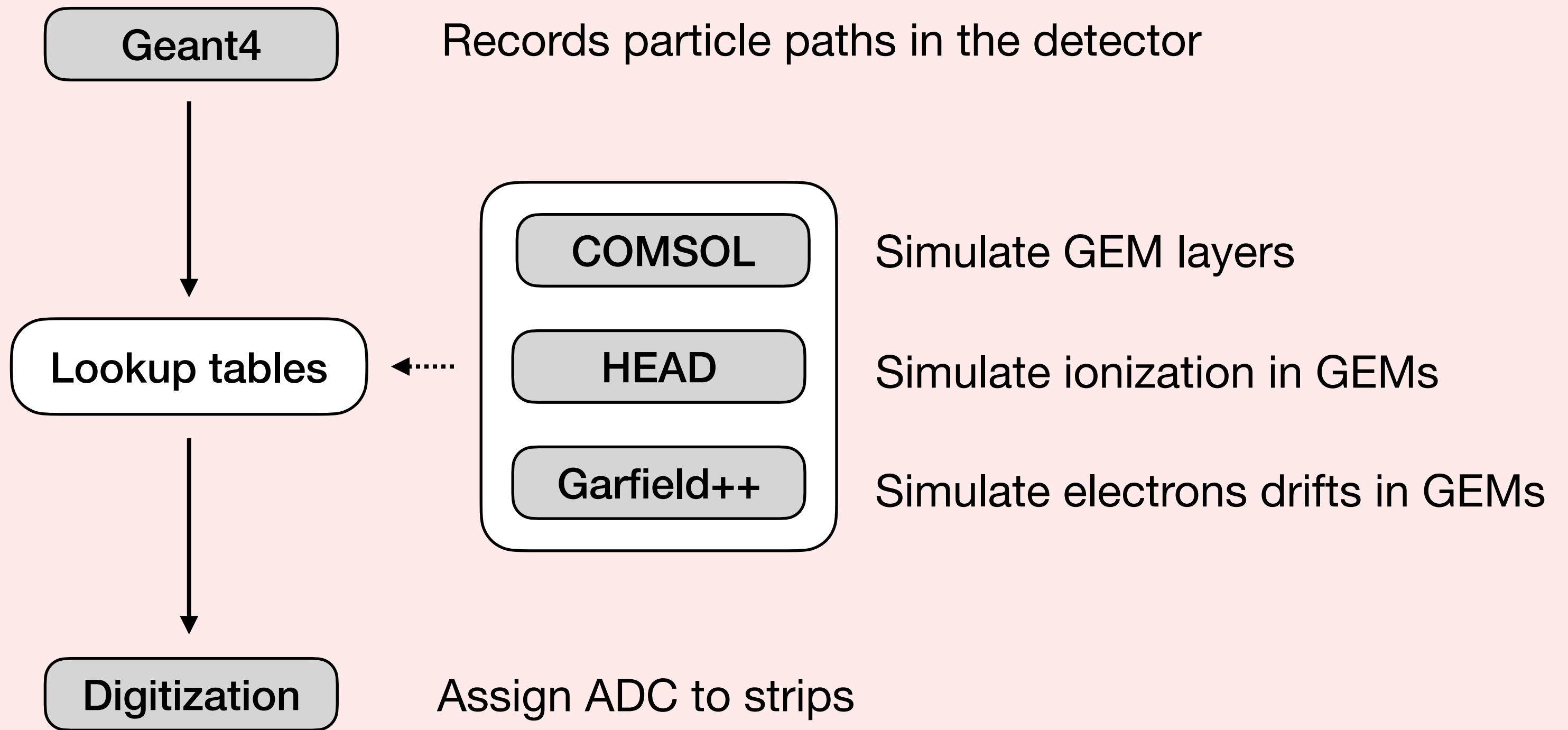


- Physics ← Event generator
- Magnetic field ← ANSYS-MAXWell
- ? Beam ← Input from acc. group
- Apparatus & Geometry ← Solidwork + Survey (+data)
- Detector Readout ← Gean4 + digitization

# Detector simulation - GEM

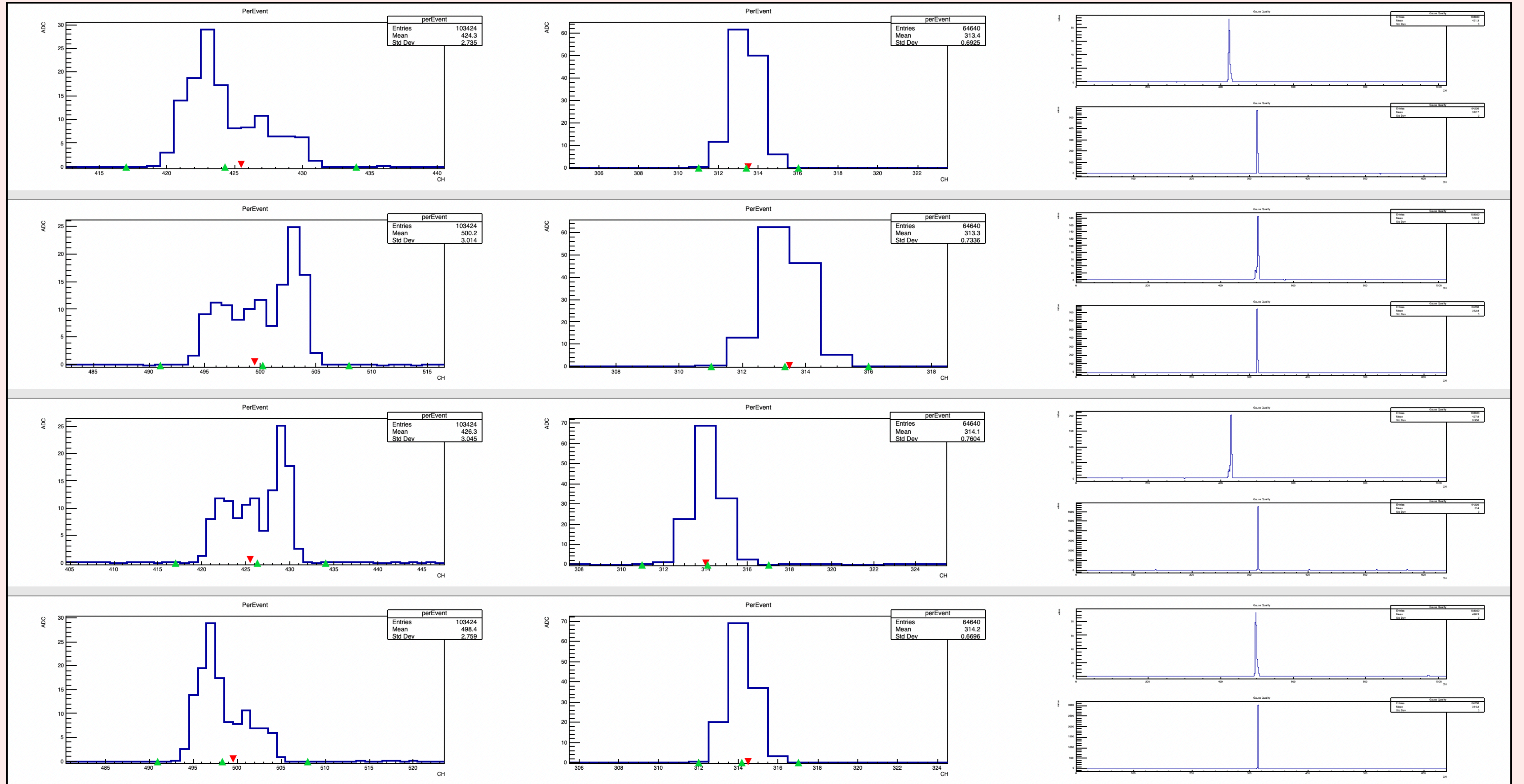


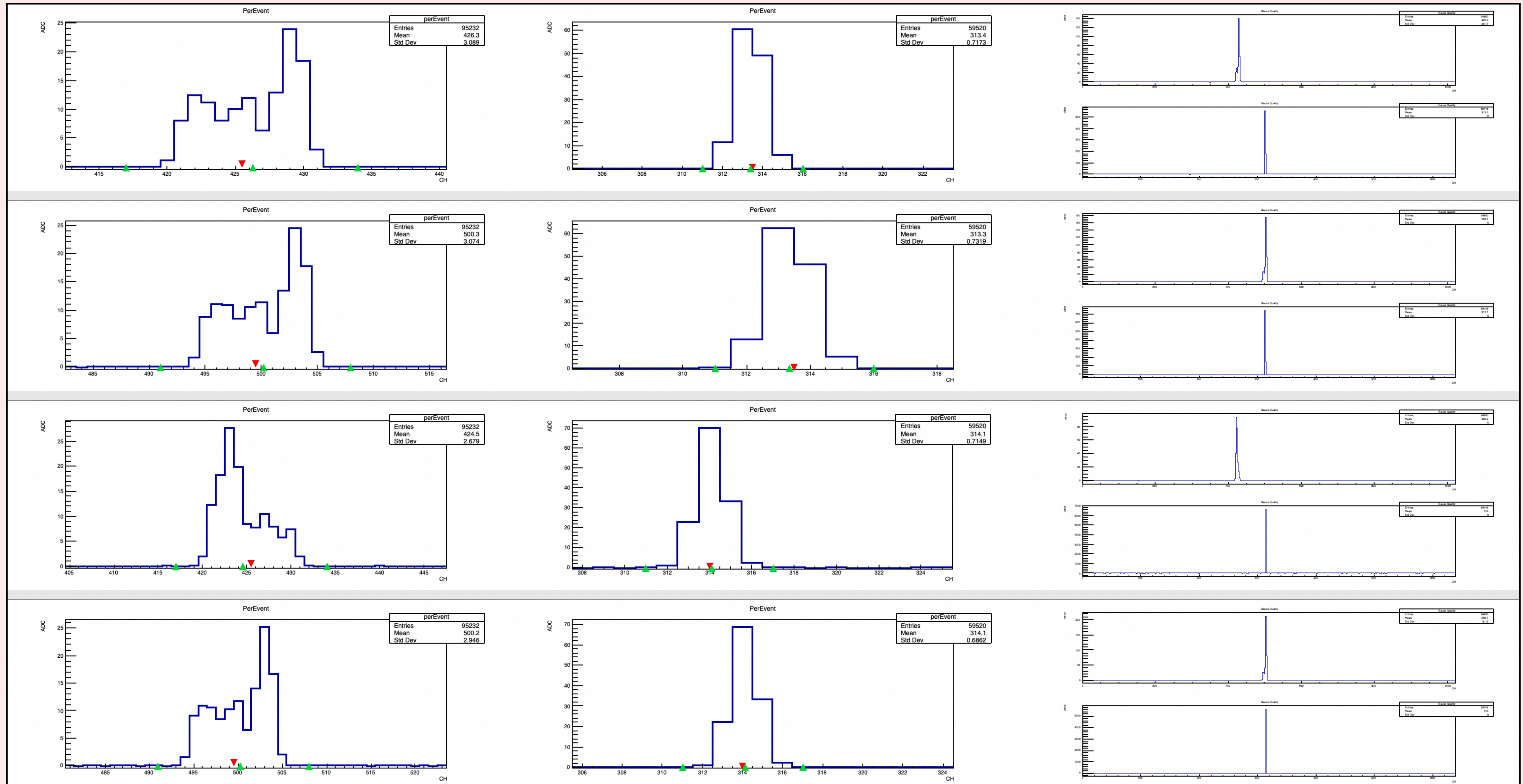
- ▶ Challenge: track angles can be large with respect to GEM planes. Need to know details of the electron avalanche distributions.
- ▶ Multiple softwares were use for more realistic simulation

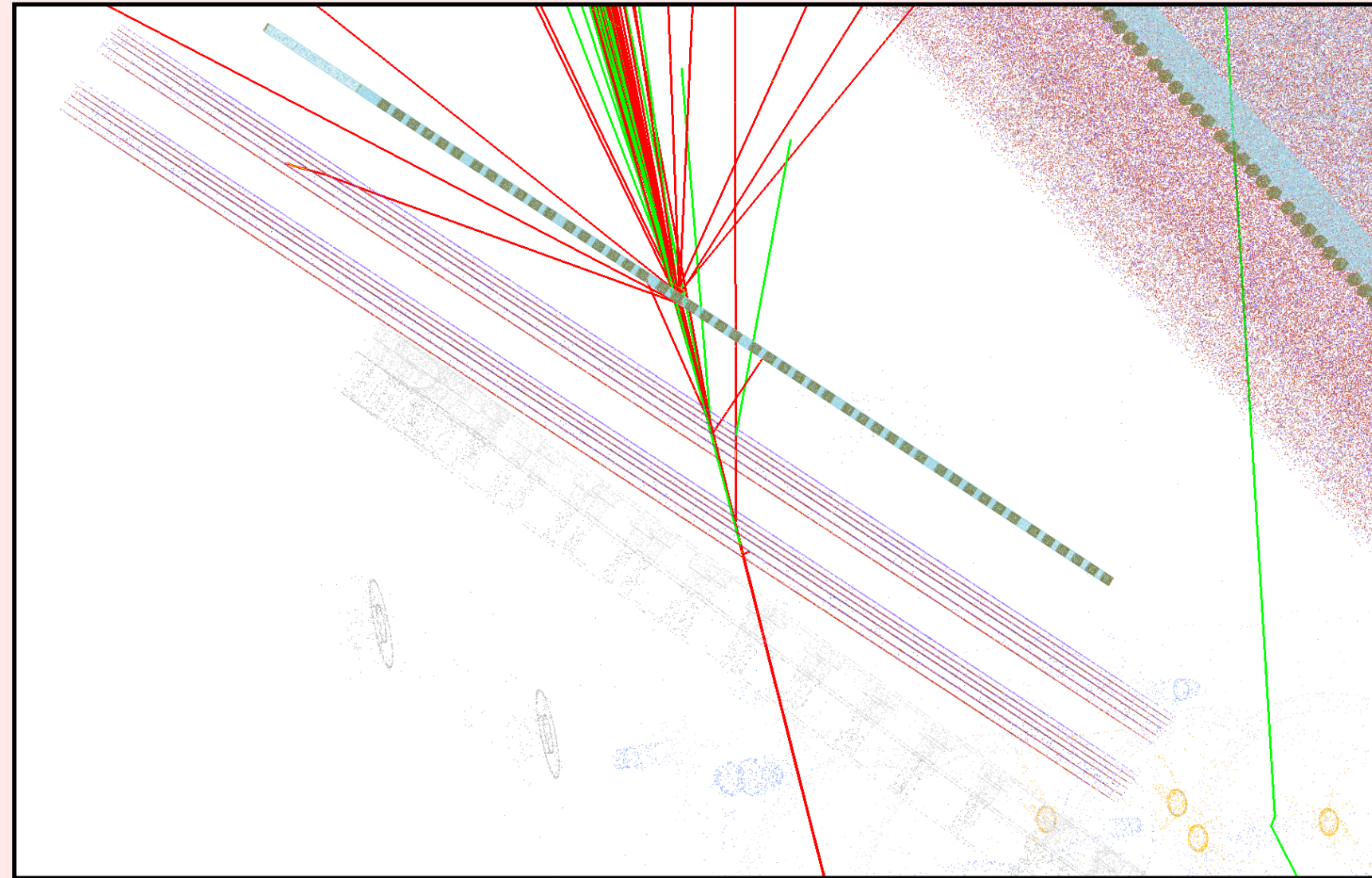


Work by H. Yang (Cornell)

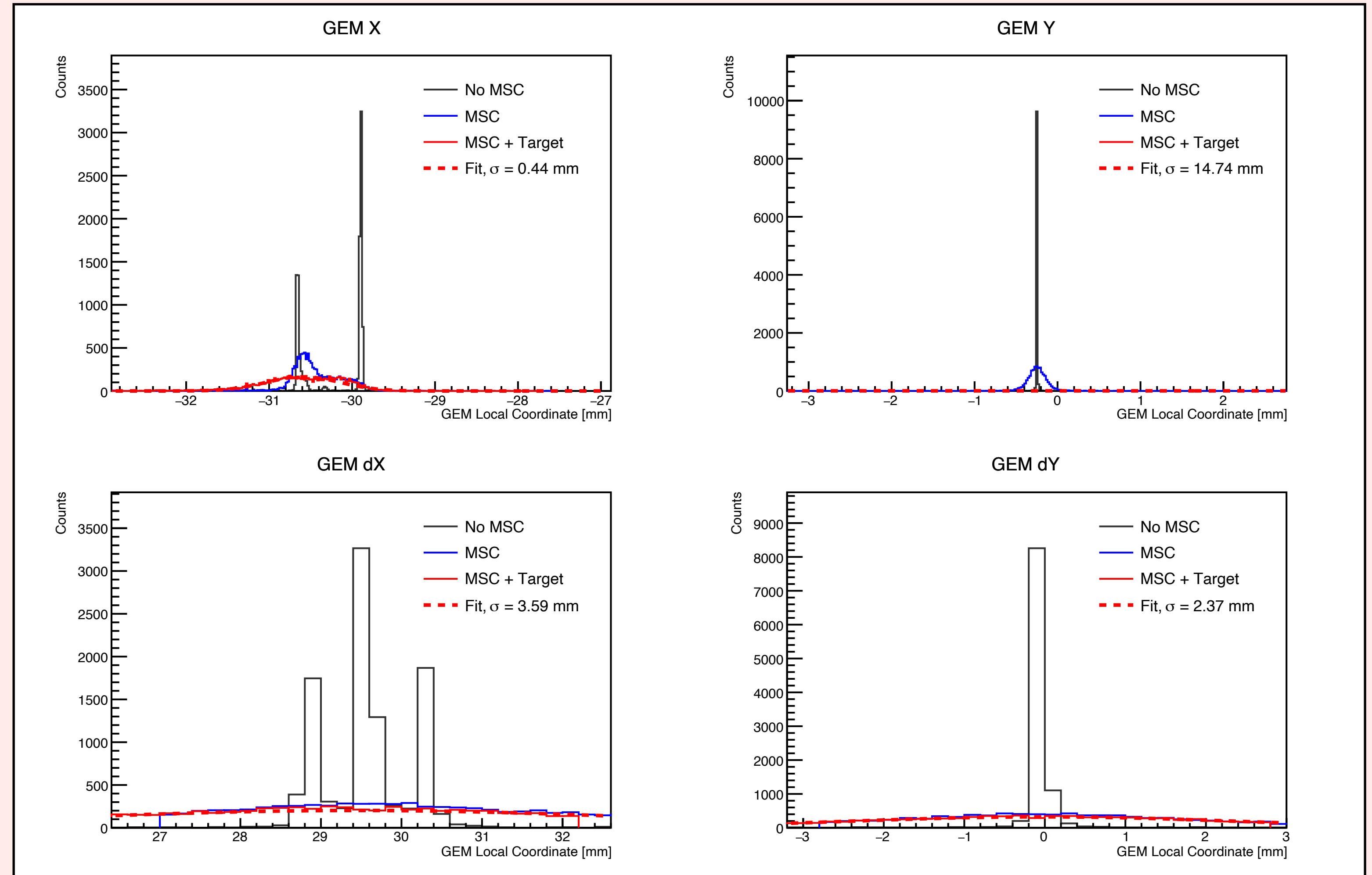
# Detector simulation - GEM

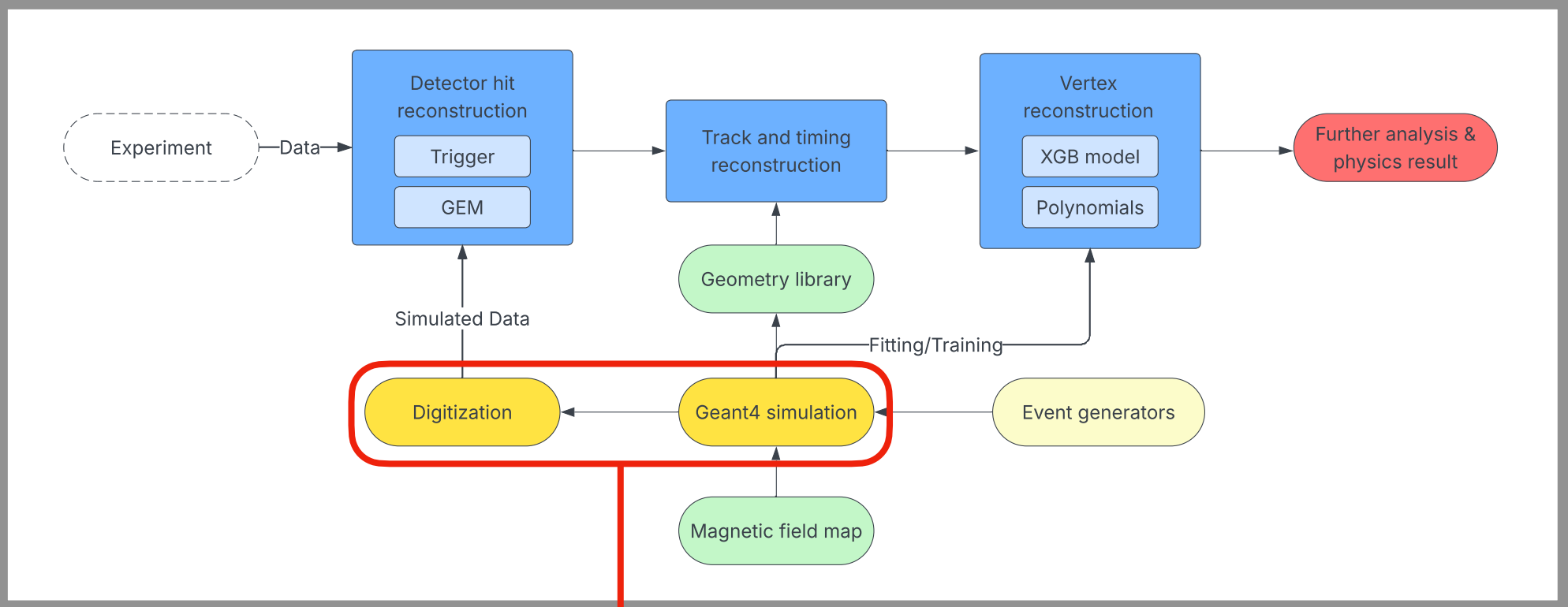






- ▶ Current clustering algorithm resolution  $\sim 1\text{mm}$
- ▶ Potential improvement from time based algorithm or ML algorithm

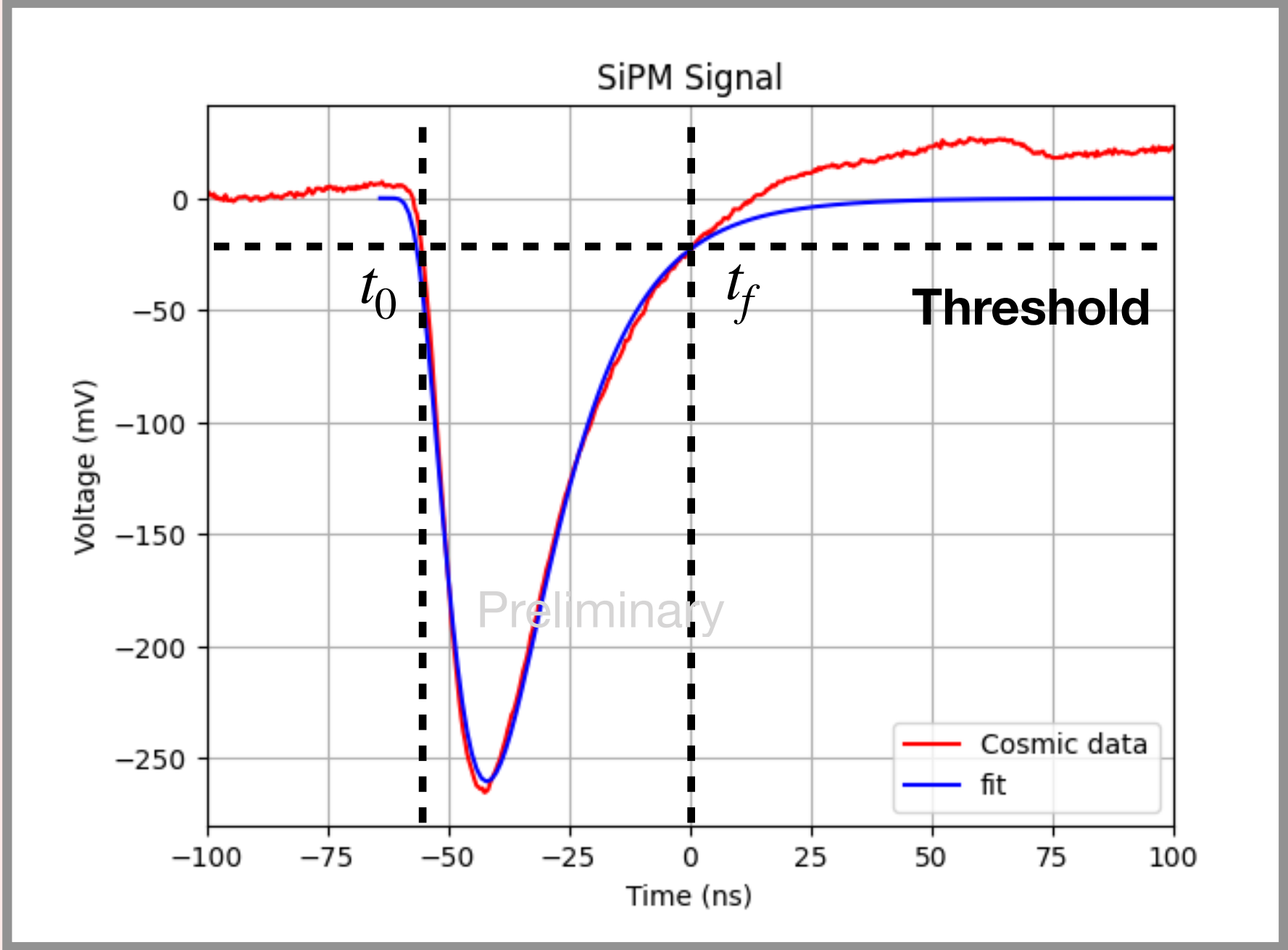
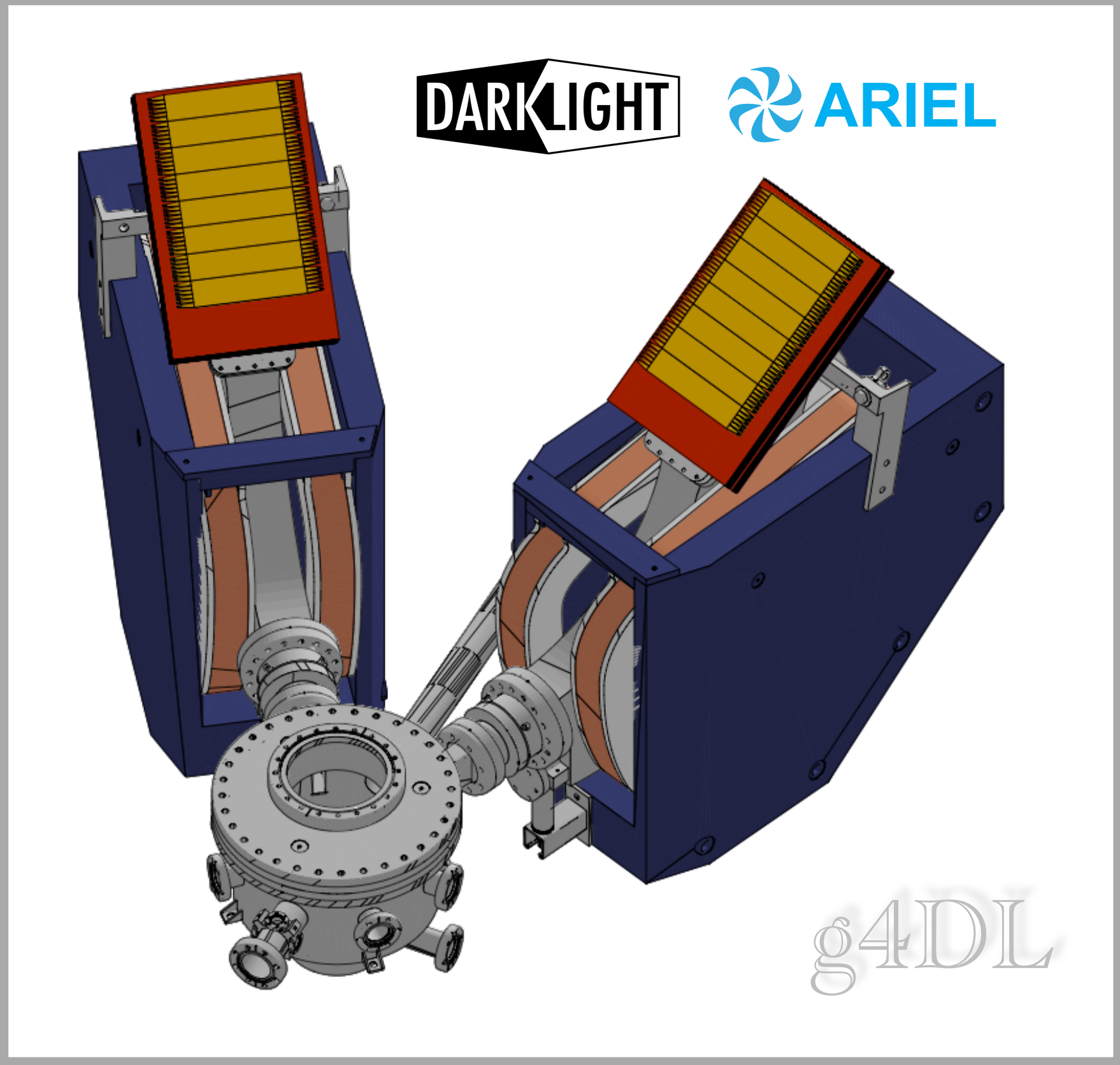




- ▶ Hit position and signal attenuation in scintillators are recorded and calculated from Geant4

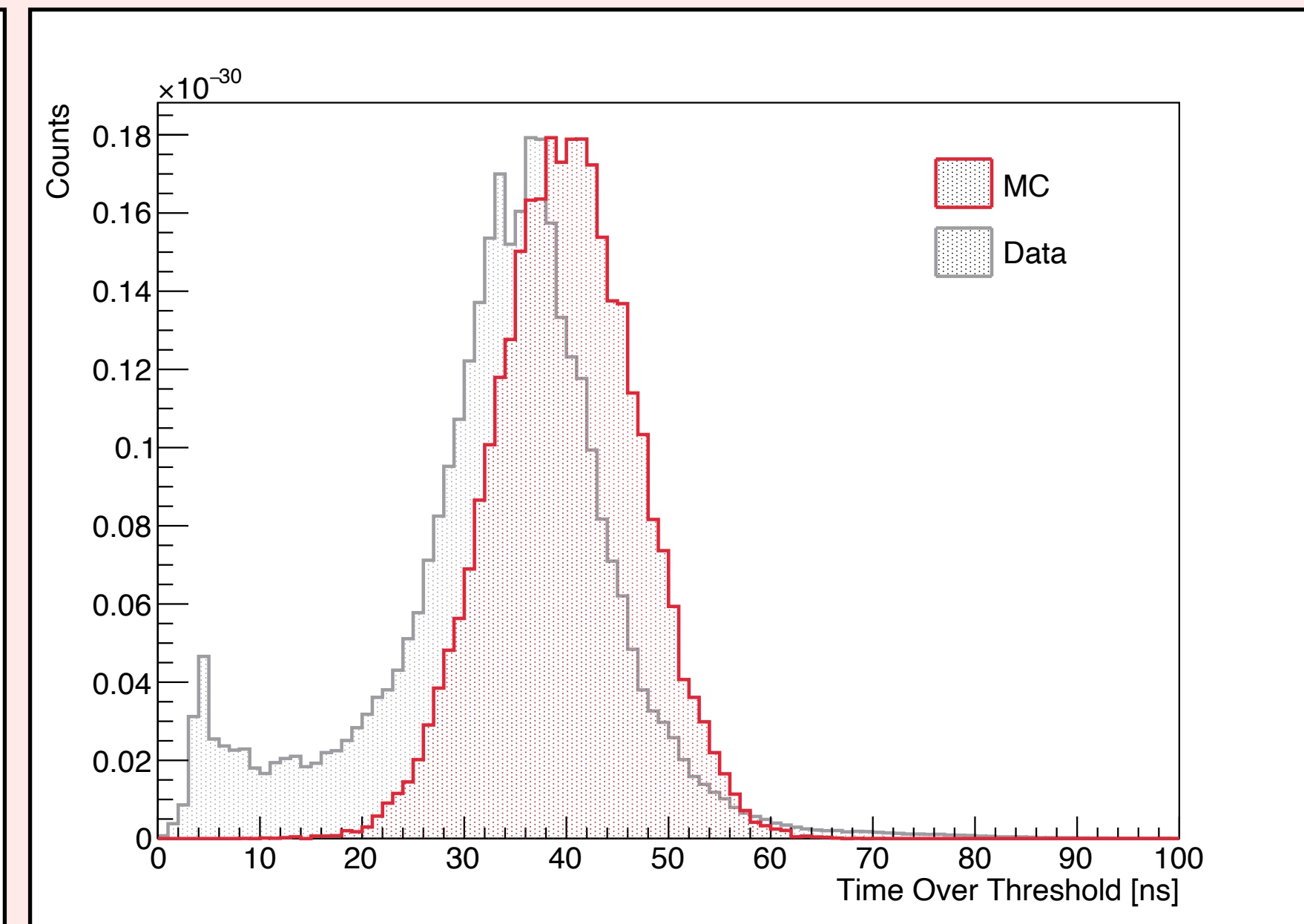
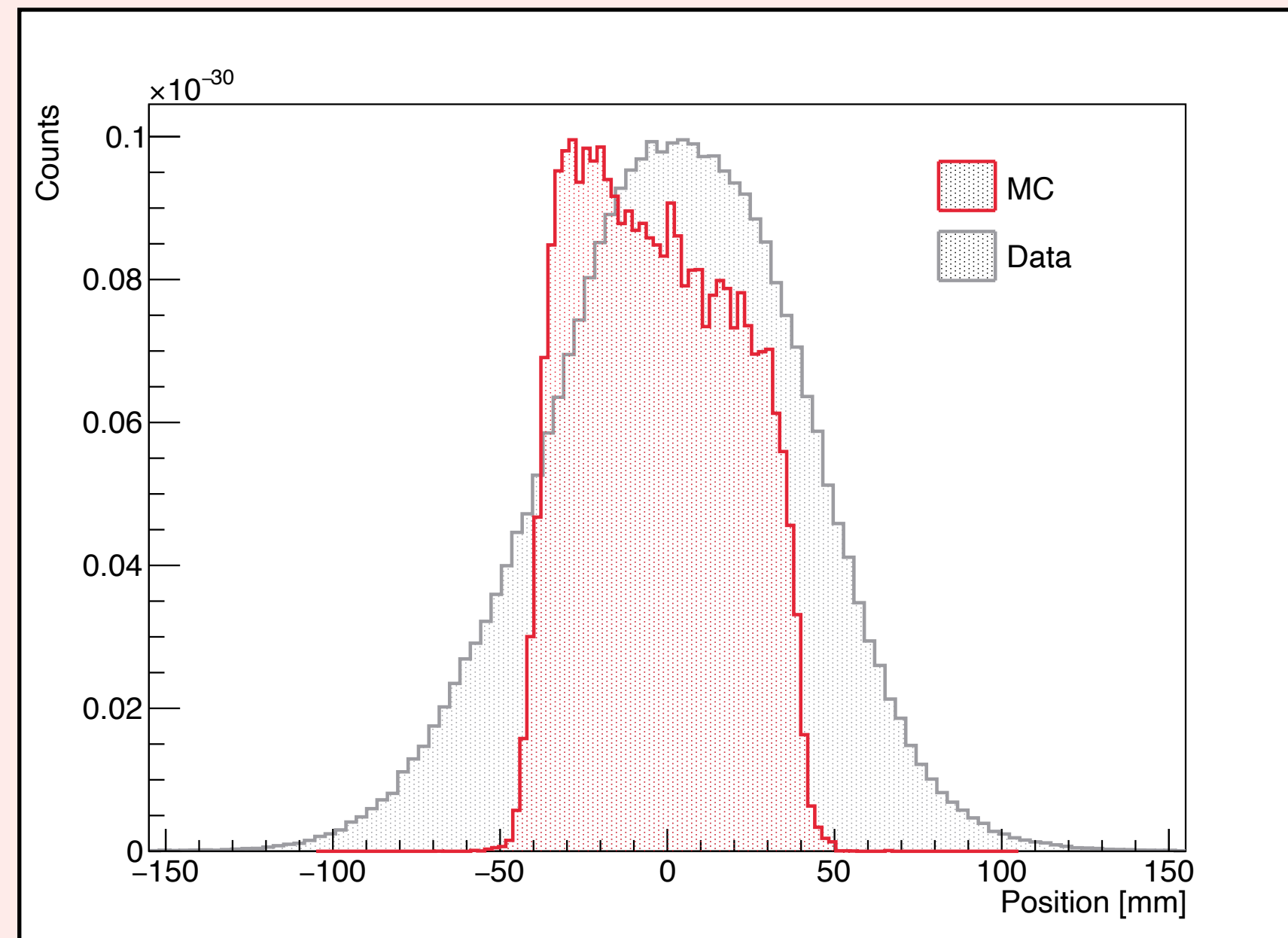
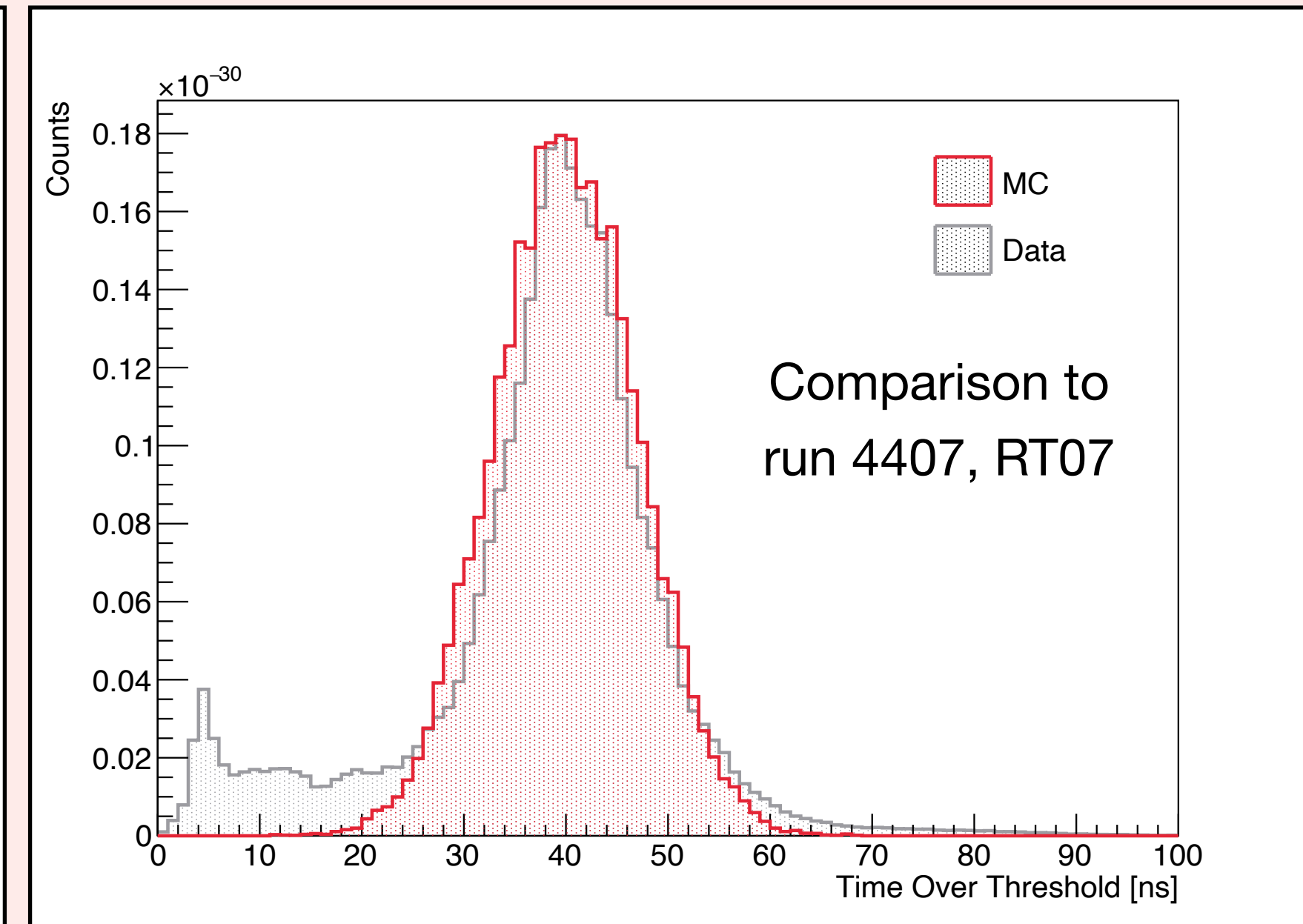
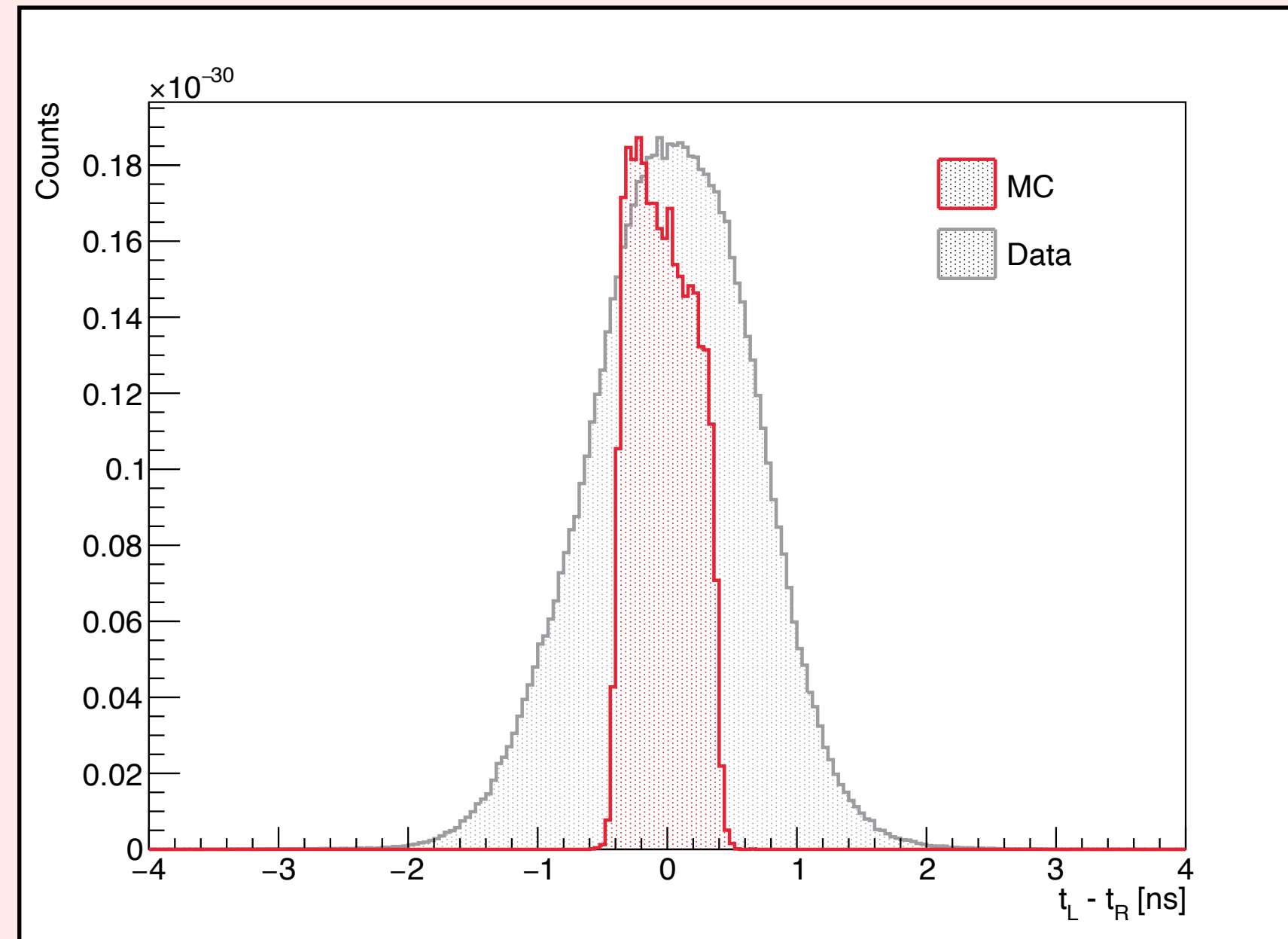
- ▶ Signal amplitude ( $U_0 = f \cdot E_{hit}$ ) is calculated from attenuated signal

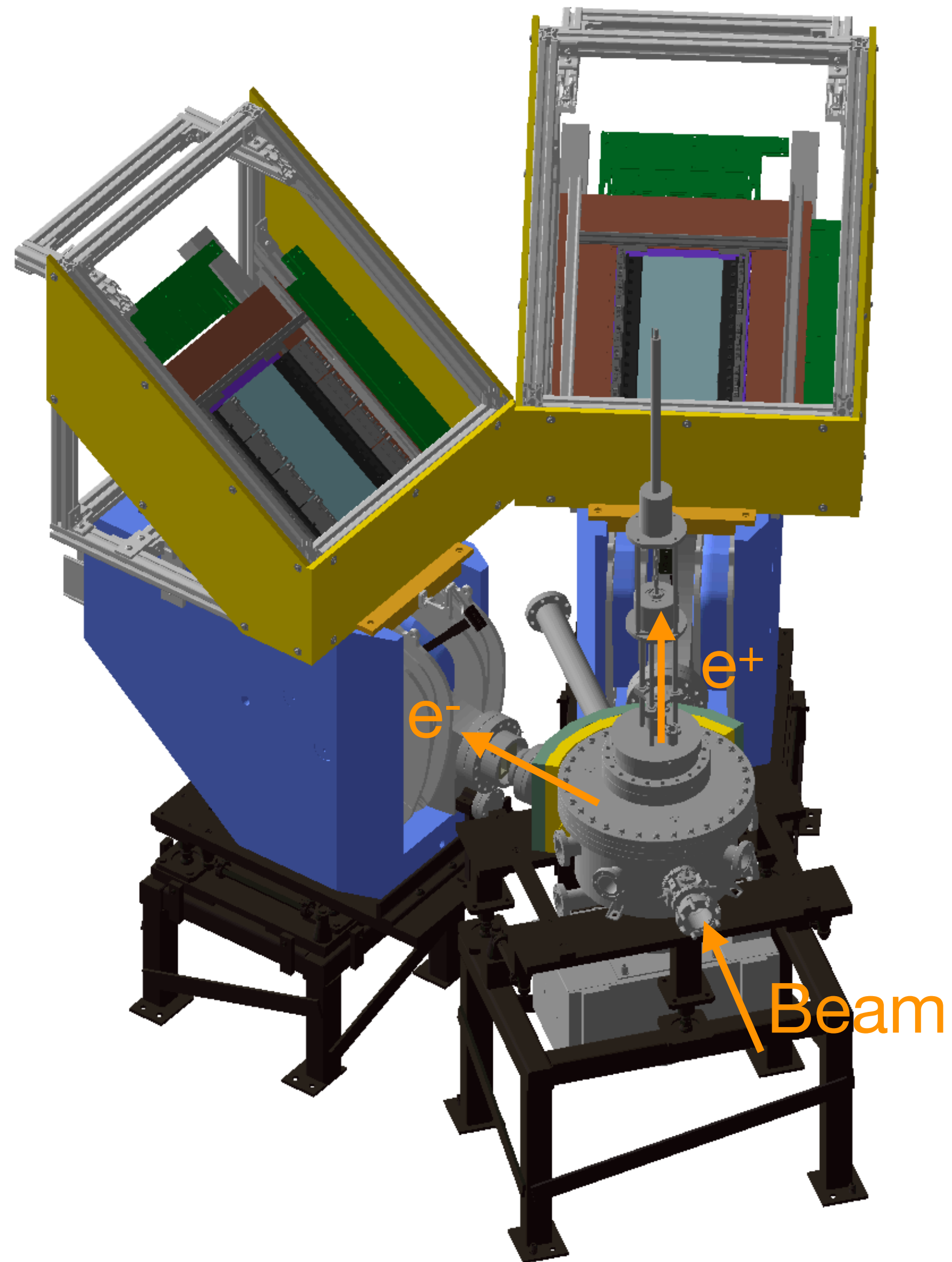
- ▶ Signal is modeled with:  $U = U_0 \cdot \exp\left(-\frac{1}{2} \left(\frac{\ln(t/\tau)}{\sigma}\right)^2\right)$



- $f$ : conversion factor related to SiPM efficiency
- $\tau, \sigma$ : parameters that describe the shape of signal

- ▶ Not enough data to calibrate for previous method
- ▶ Now using simplified digitization process
- ▶ Assume  $\sigma_t = 0.35$  ns
- ▶ Assume mean TOT of 40 ns and sigma of 7 ns
- ▶ Assume  $c_{\text{eff}} = 200$  mm/ns





- Physics ← Event generator
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