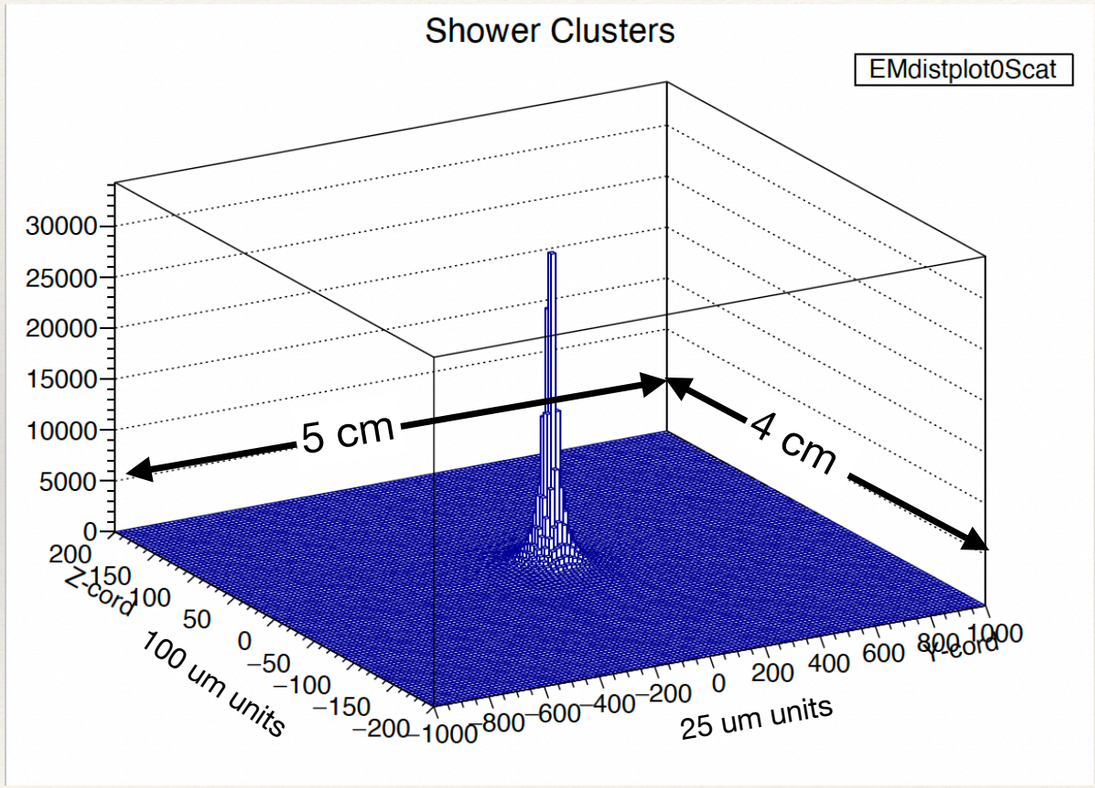
Two recent studies of SiD Digital ECal measurements

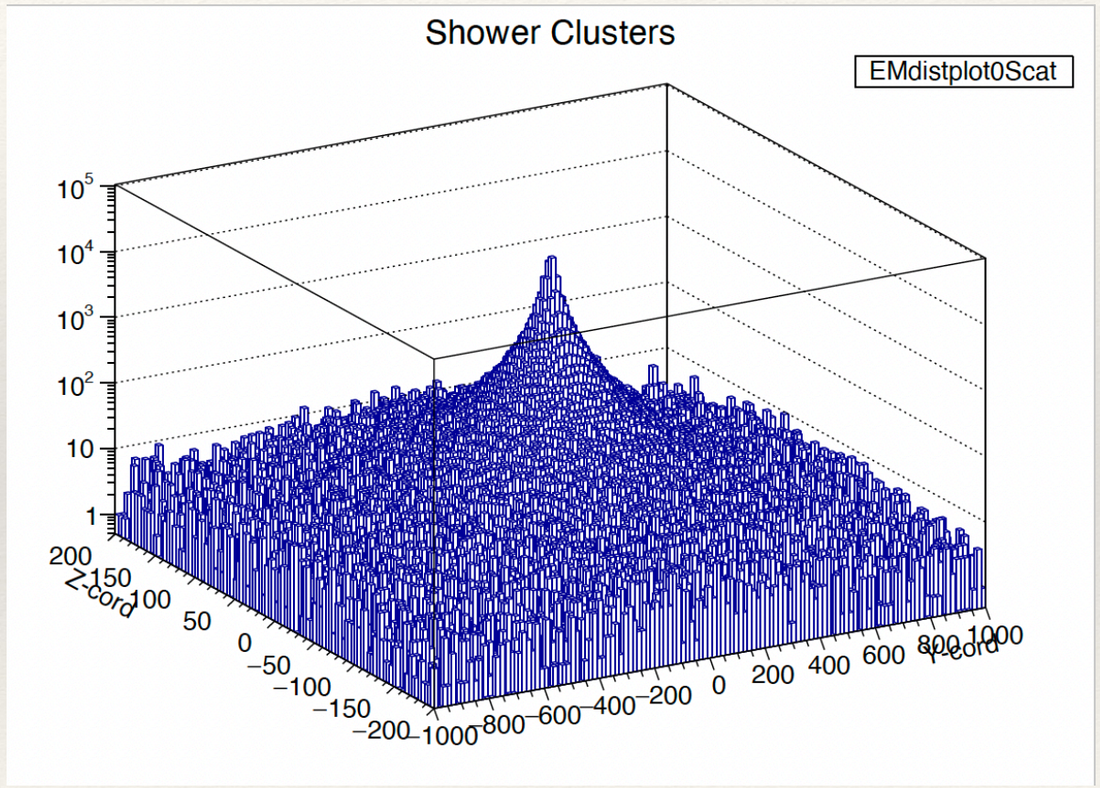
- **1. Effect of transverse cutoff of shower on energy measurement**
  - Motivated by question to Alex Habib at recent conference.
  - Cutoff in radius or cutoff in one direction.
- **2. Timing measurements in SiD ECal MAPS**
  - Update my ECal studies to include timing.
  - Study effect of MAPS response time.

1. Effect of cutoff of shower on energy measurement

- Alex Habib reported he was asked a question when he gave an update on the SLAC MAPS work at the **EP R&D WP1.2 general meeting** on Monday 20 Nov.
  - Alex reported "I got a question on the Digital MAPS for ECAL : 'wouldn't we lose information if there is a pileup of 2 or more events per pixel.' I replied that it depends on the hit rate, the pixel size, and the cluster size, and I referred them to Jim's paper where the effect of cluster size was studied."
- Motivated by this question, I followed up with these studies.
  - First response - only a few percent of pixels contain more than one hit.
  - Remaining question - what about interference from nearby showers?
    - Cut-off of shower radially or in one direction.

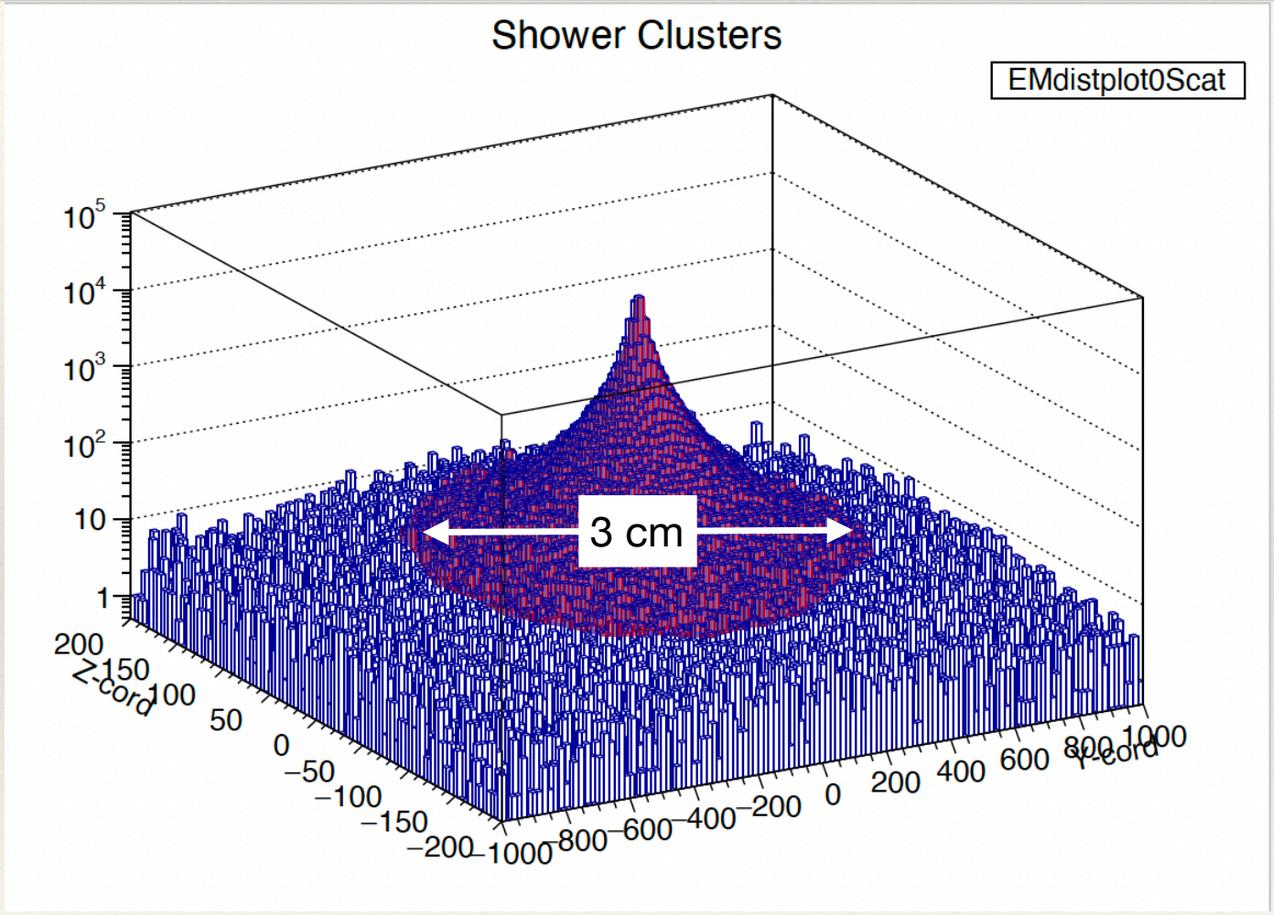
Transverse Shower Profile (10 GeV γ)



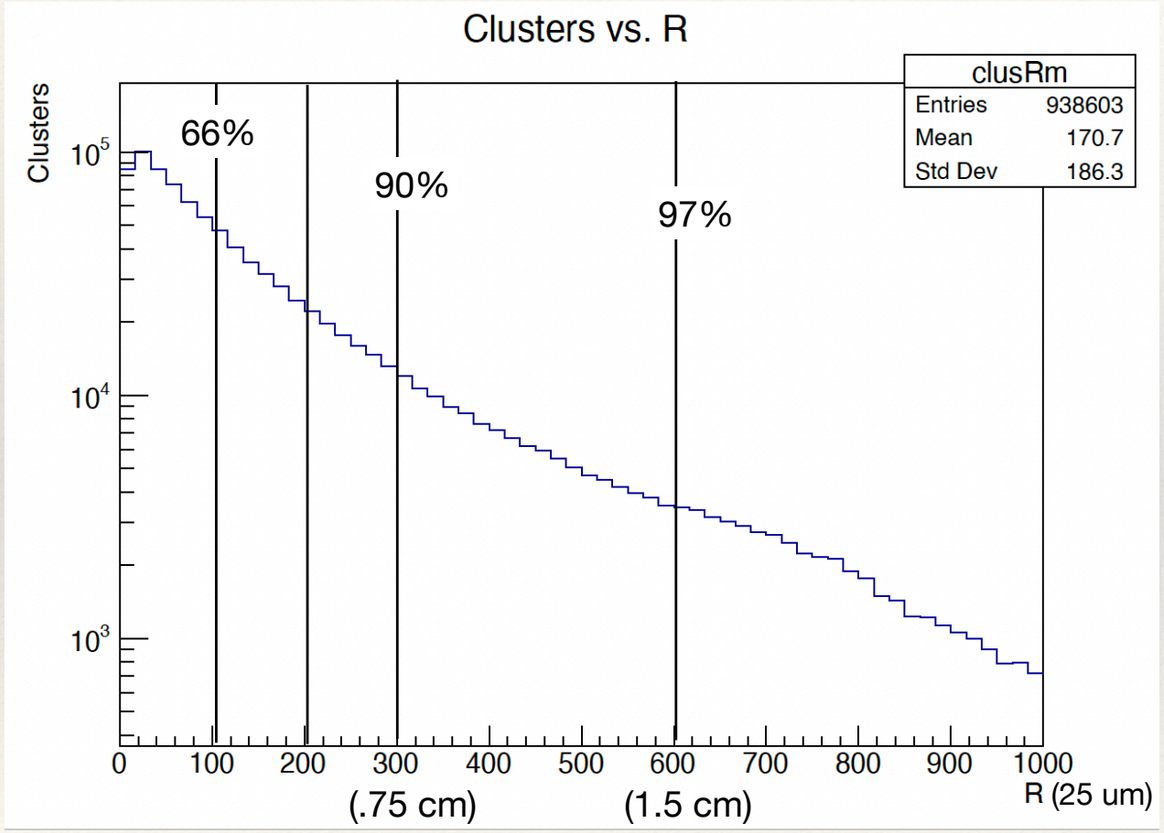


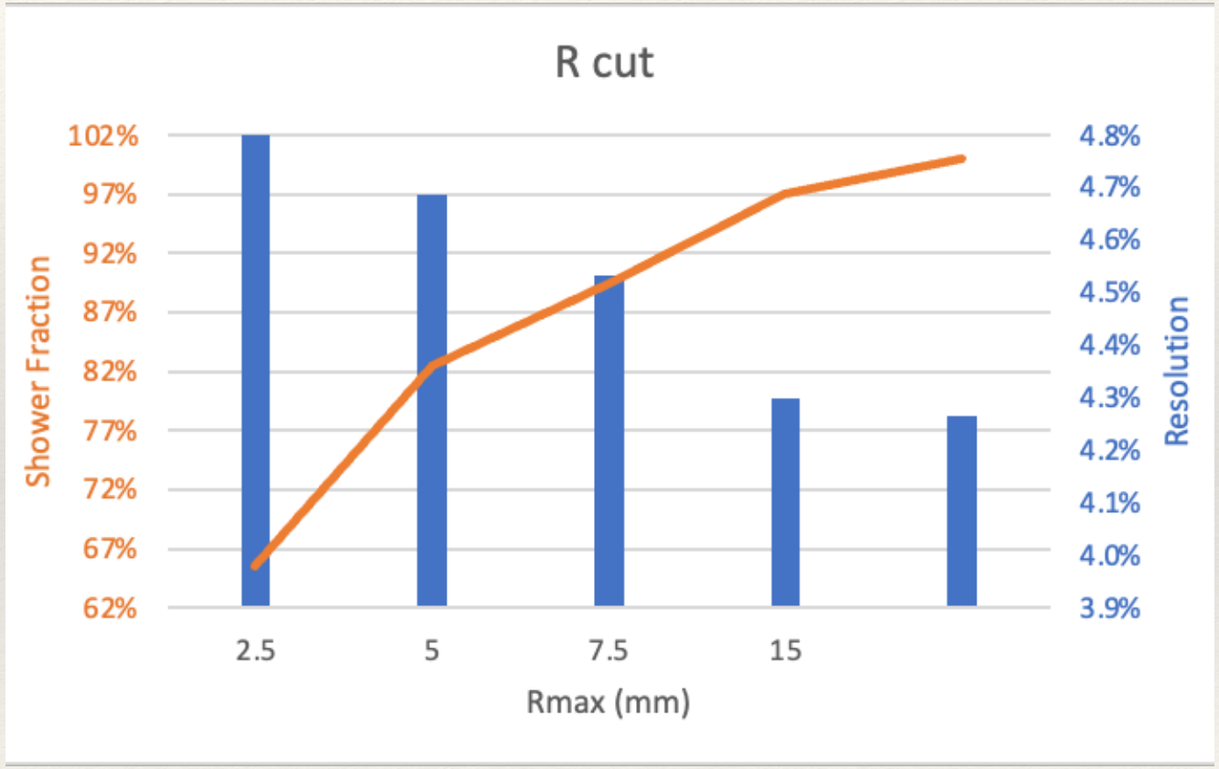
Transverse Shower Profile (10 GeV γ)

- Hits inside R = 600 Y = 1.5 cm colored red



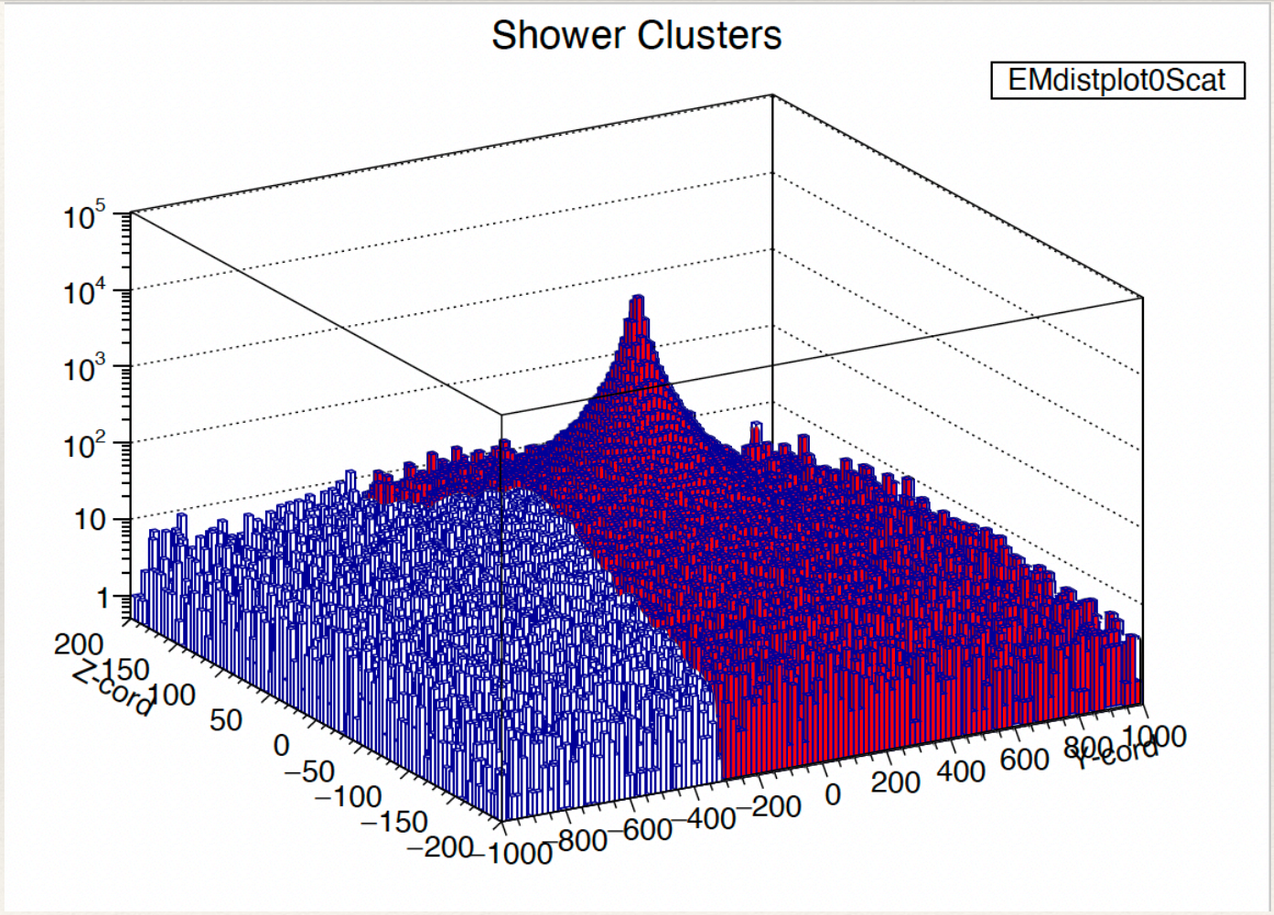
Effect of limited shower radius (10 GeV γ)



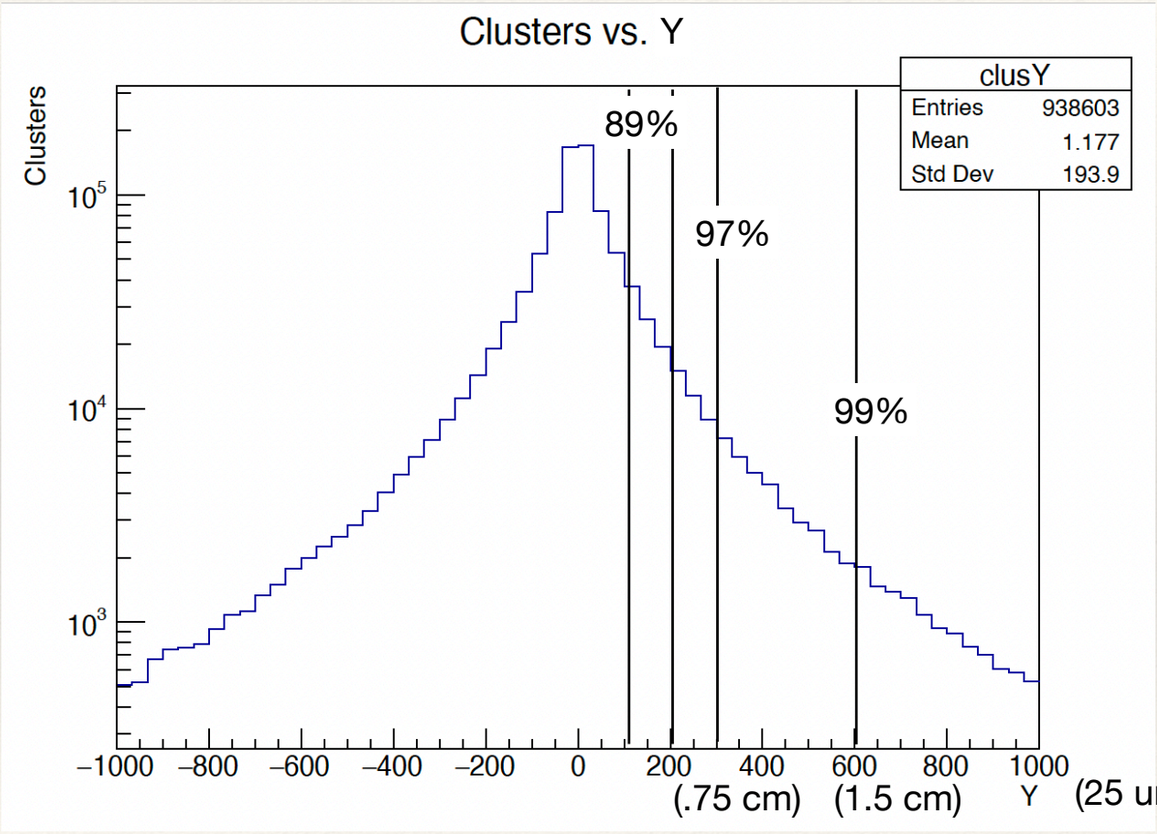


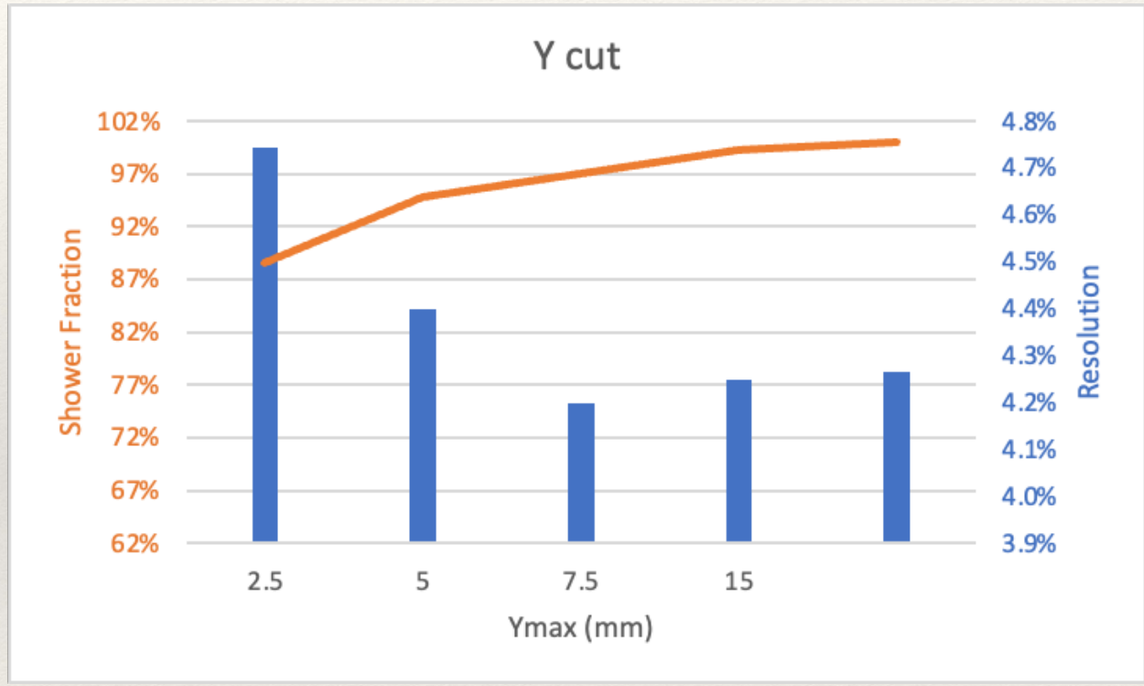
Transverse Shower Profile (10 GeV γ)

- Hits inside Y > -300 = -0.75 cm colored red



Effect pf limit shower in one direction (10 GeV γ)



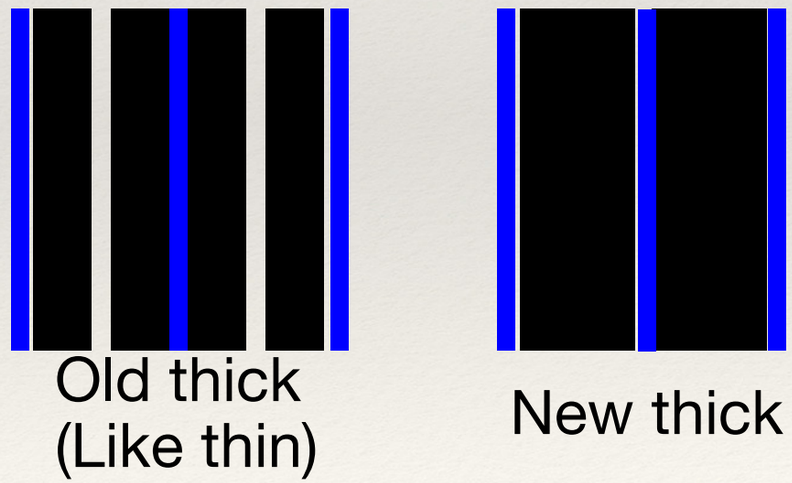


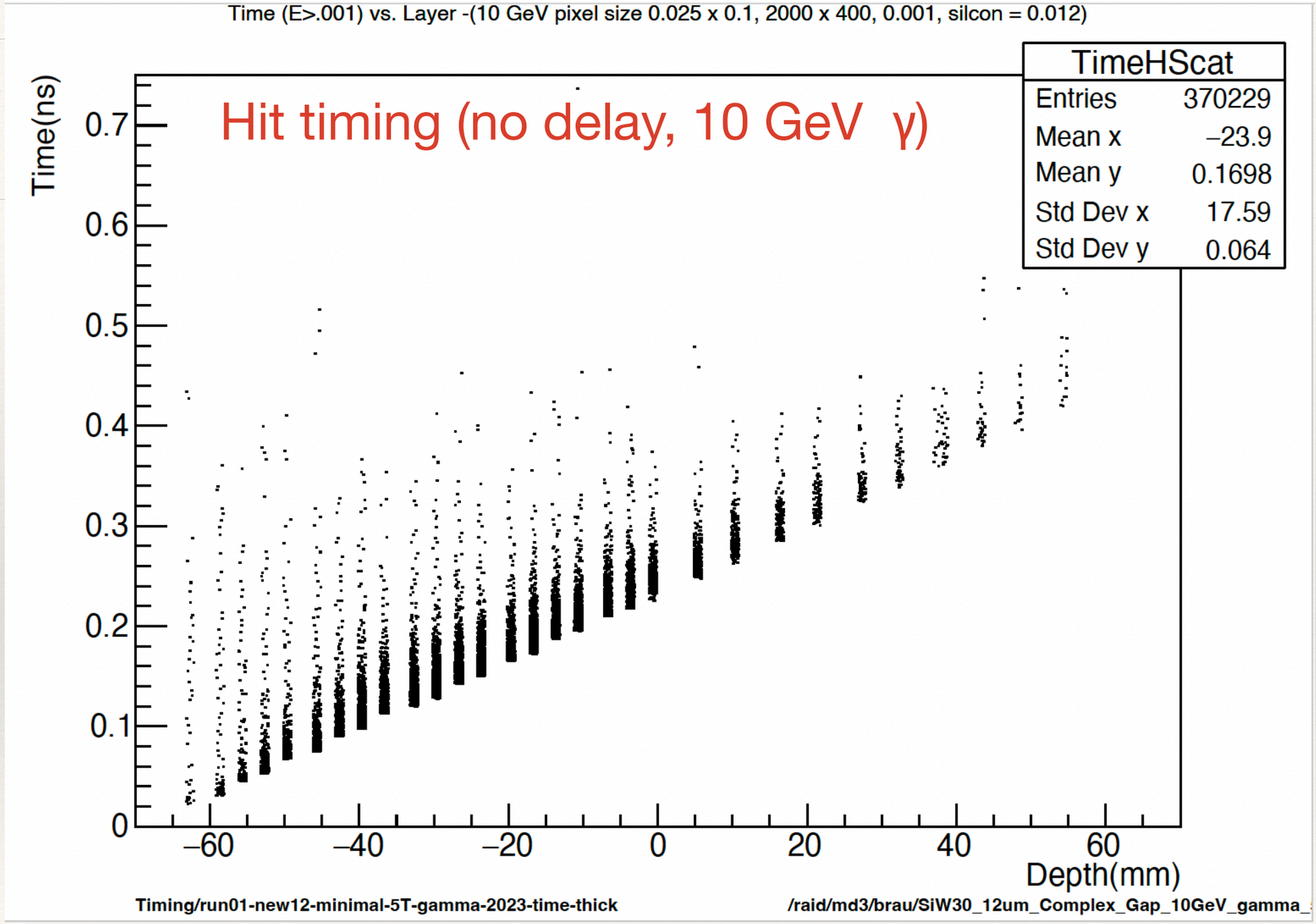
2. Timing measurements in SiD ECal MAPS

- Updated my Geant4 model of the SiD ECal to extract **hit times**.

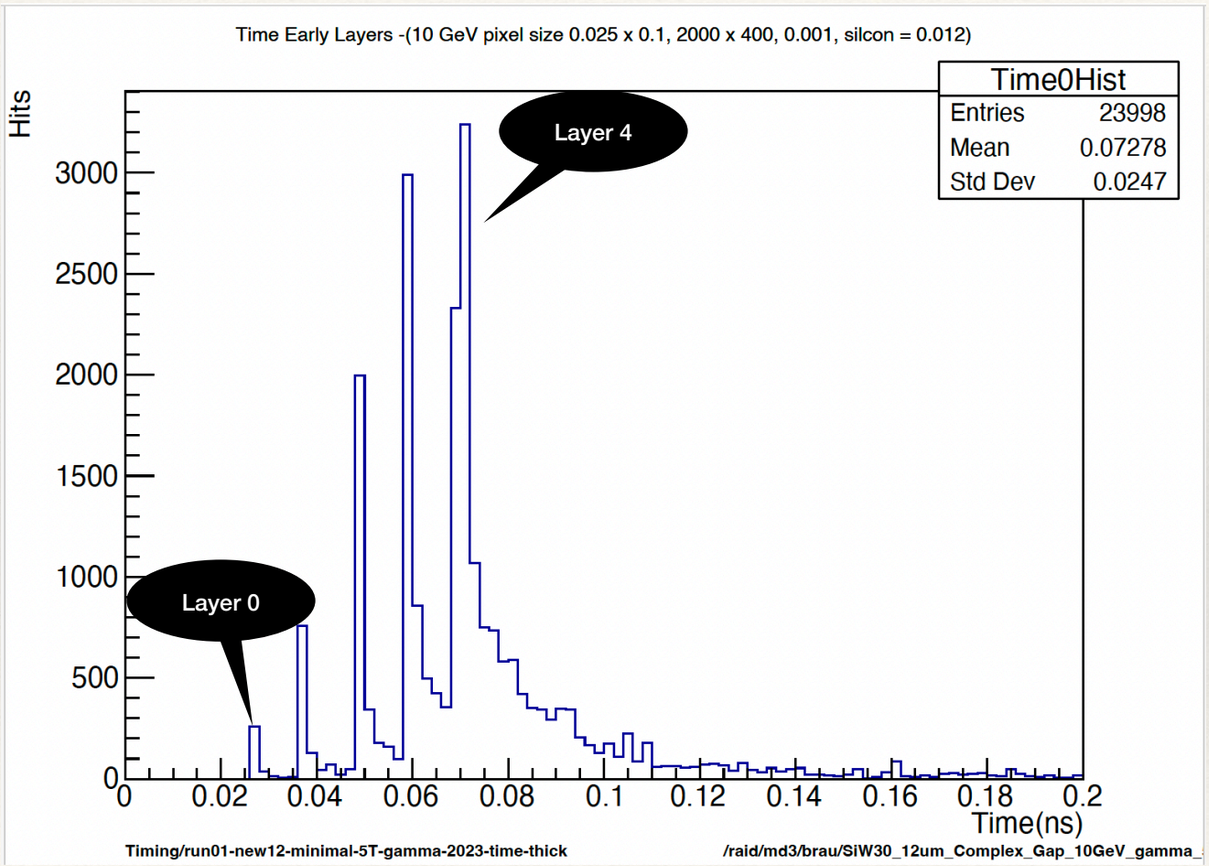
- Also **modified geometry** to more precisely model **thick layers**.
  - Past model used 40 thin layers, ignoring every other layer in last 20. (Simple)
  - New model has 20 thin and **10 thick layers**.
    - Since thick layers are **1 mm thinner** (only one gap) timing is affected.

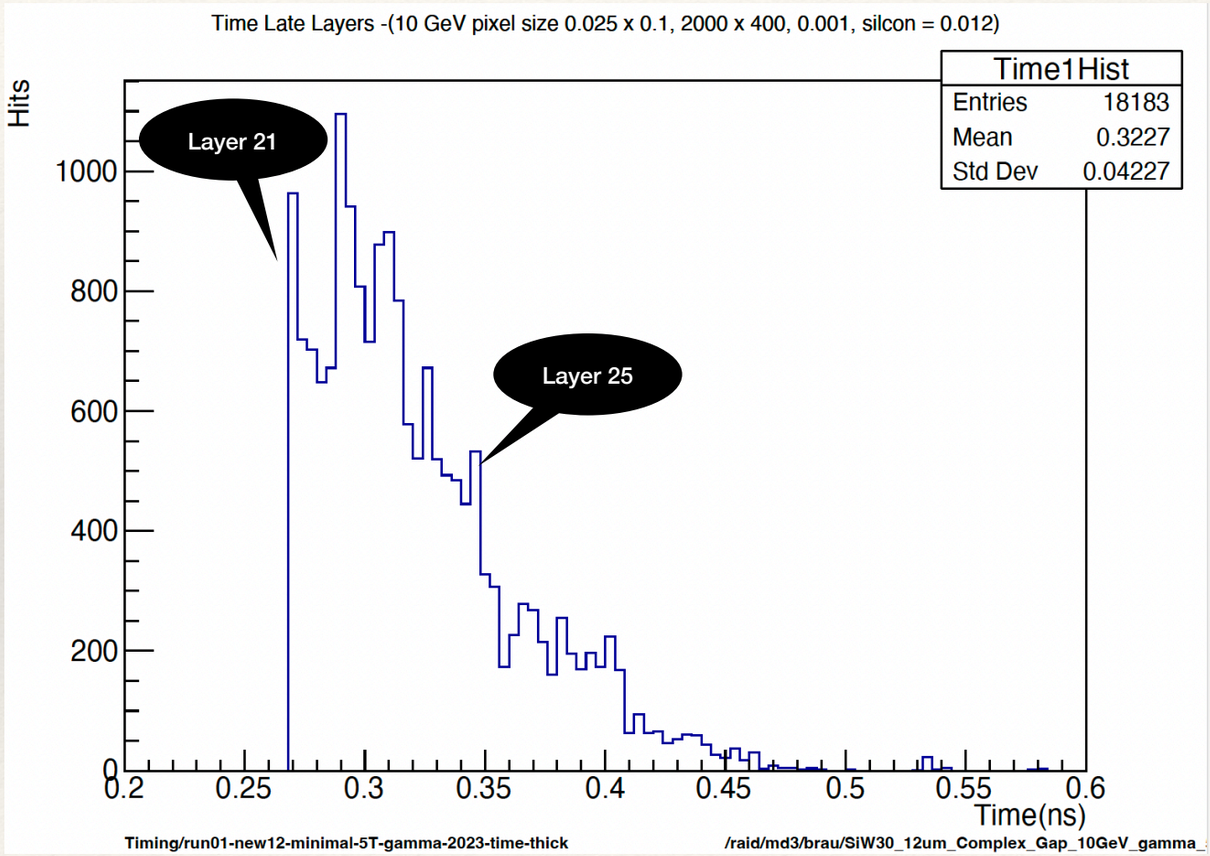
- Geant4 TestEm3 files revised to implement timing and improved thick layers:
  - RunAction.cc
  - SteppingAction.cc
  - DetectorMessenger.hh
  - DetectorMessenger.cc
  - DetectorConstruction.hh
  - DetectorConstruction.cc



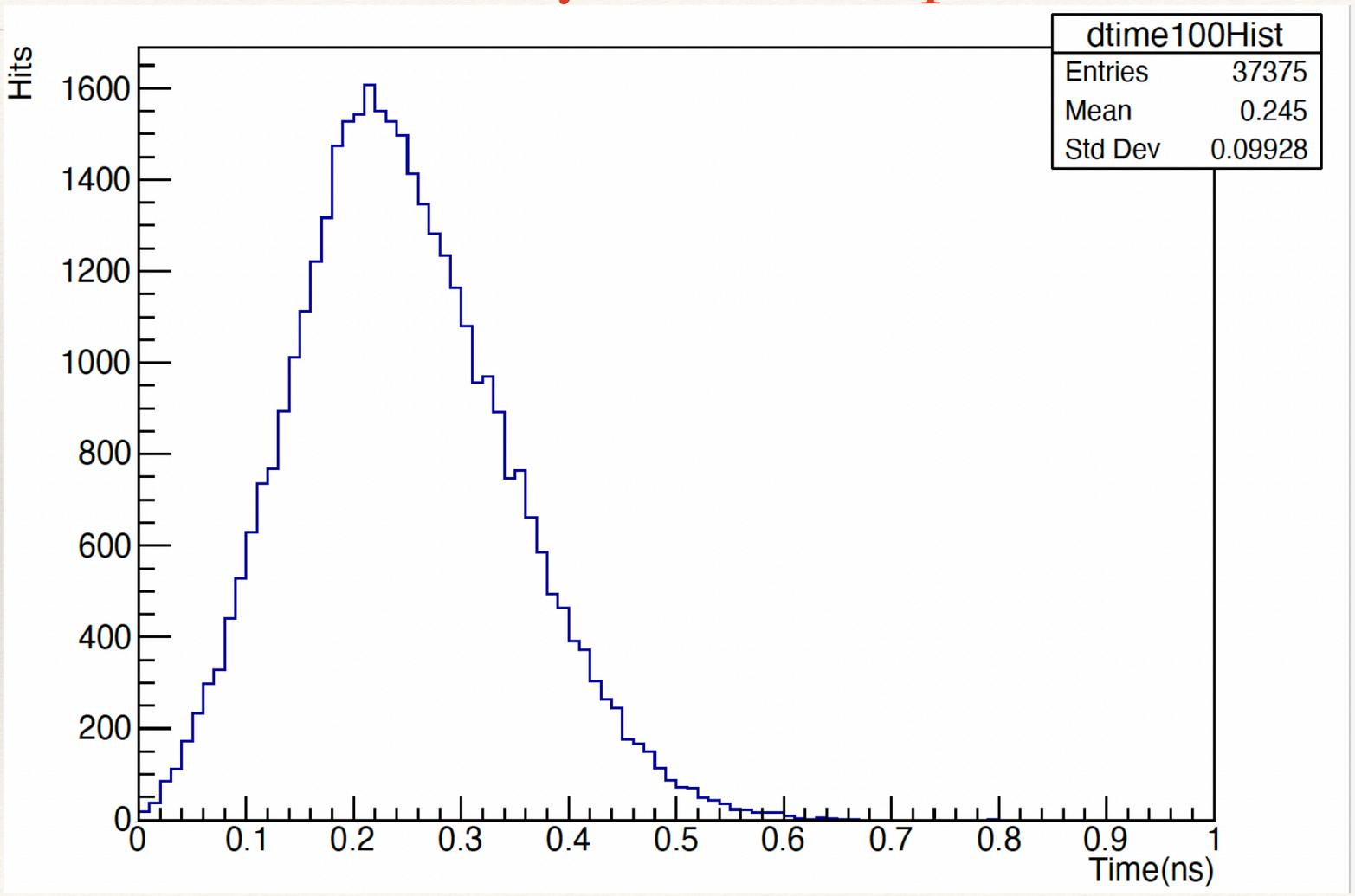

Time (E>.001) vs. Layer -(10 GeV pixel size 0.025 x 0.1, 2000 x 400, 0.001, silcon = 0.012)
Hit timing (no delay, 10 GeV γ)
TimeHScat
Entries 370229
Mean x −23.9
Mean y 0.1698
Std Dev x 17.59
Std Dev y 0.064
Time(ns)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
−60
−40
−20
0
20
40
60
Depth(mm)
Timing/run01-new12-minimal-5T-gamma-2023-time-thick
/raid/md3/brau/SiW30_12um_Complex_Gap_10GeV_gamma_

Timing by layer (no delay, 10 GeV γ)

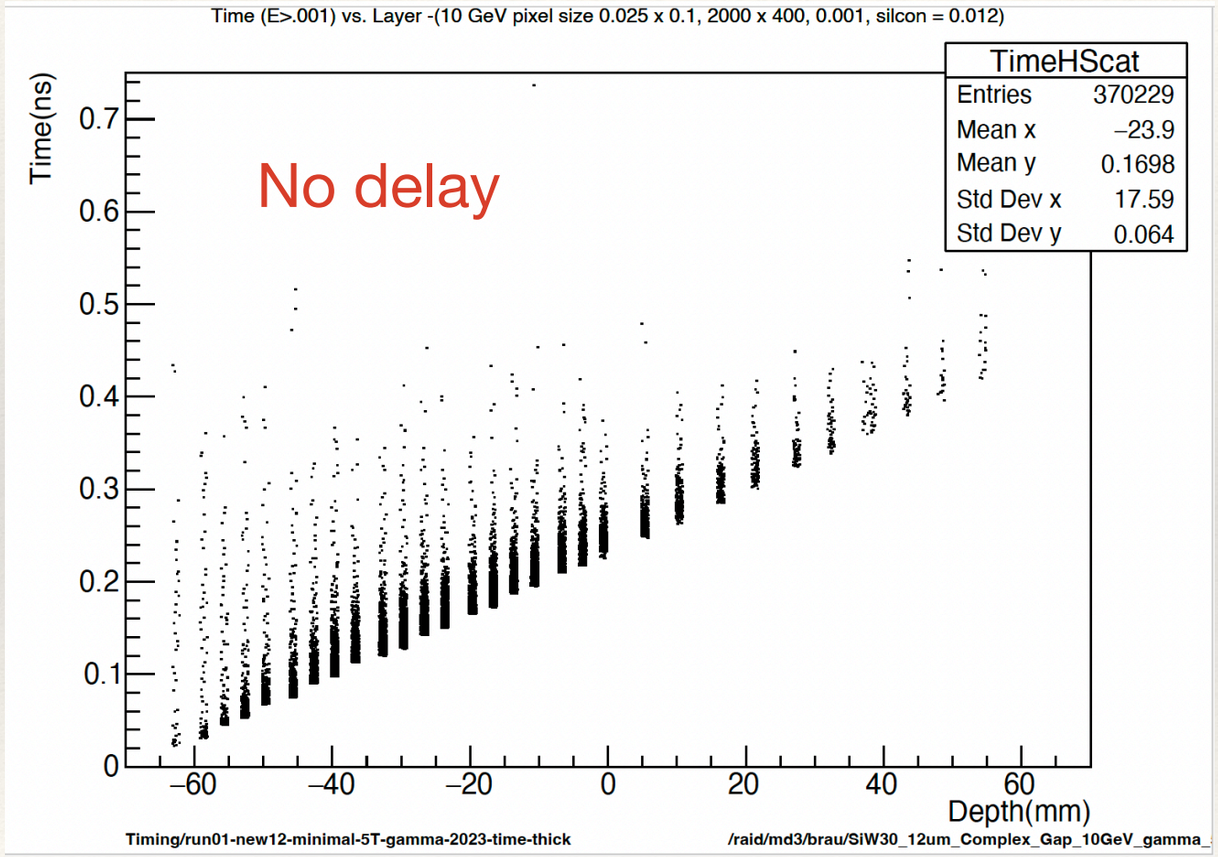


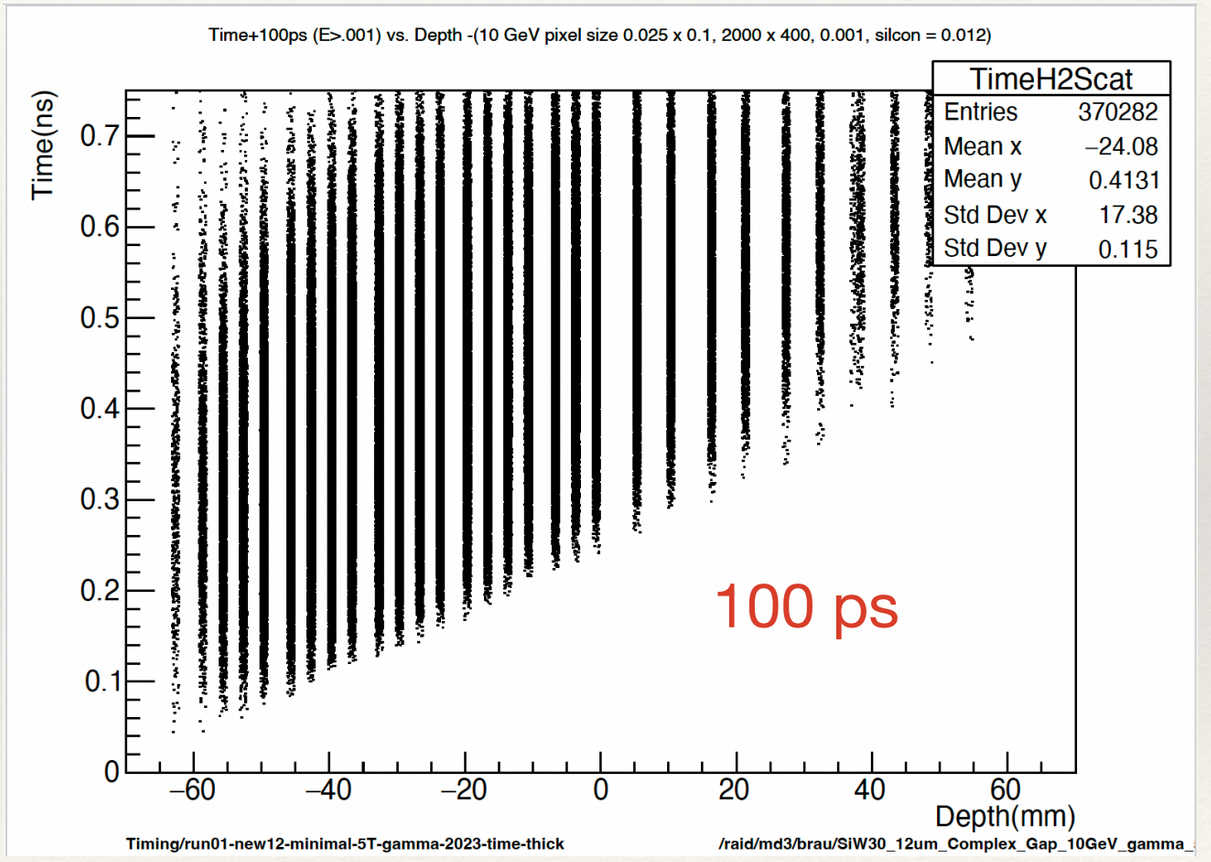


MAPS response function
my naive 100 ps model

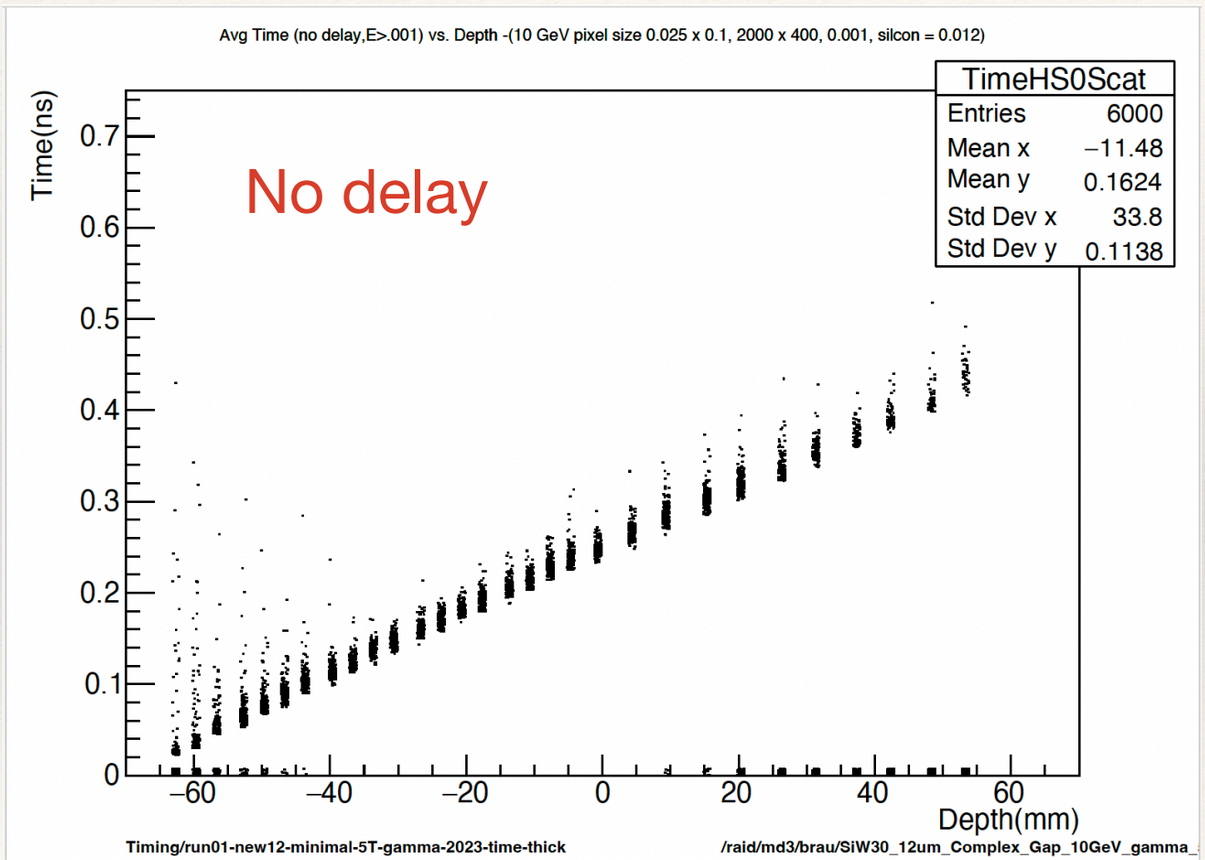


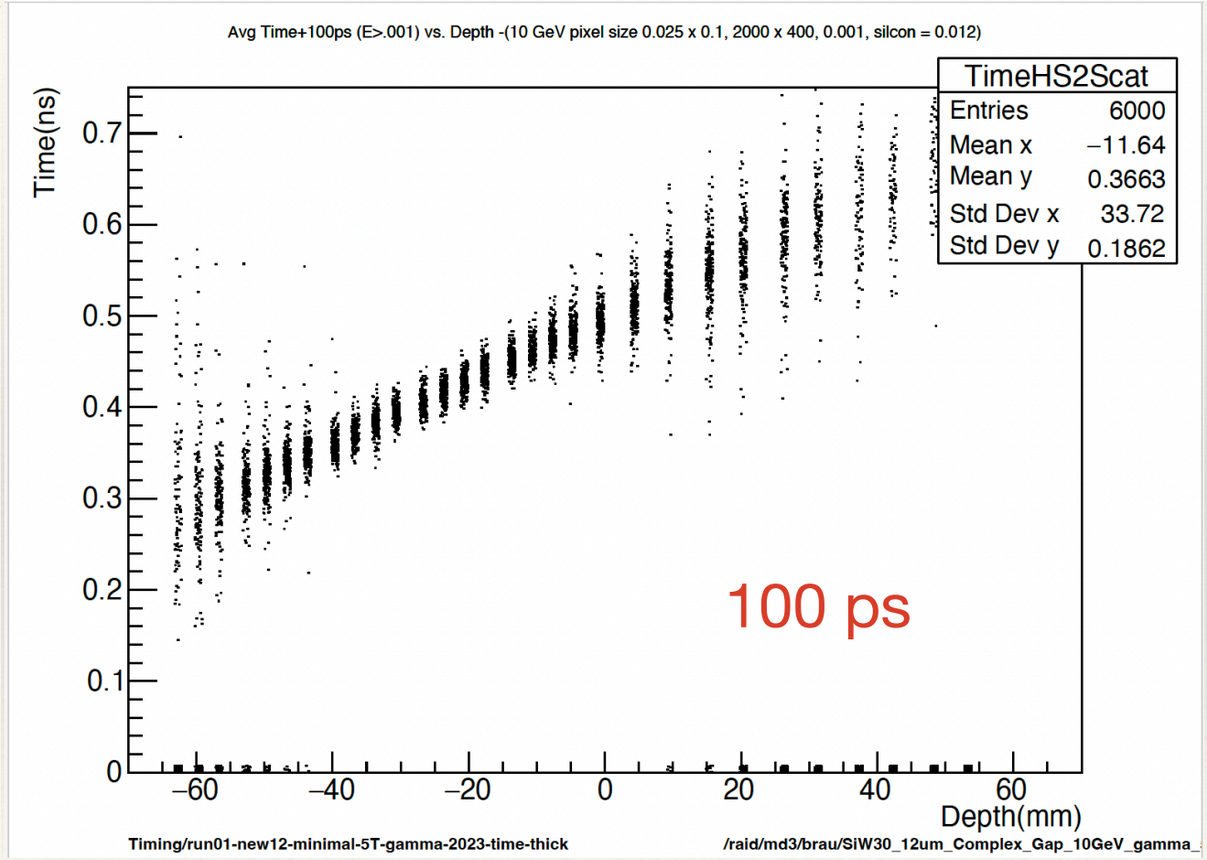
Effect of MAPS delay (10 GeV γ)



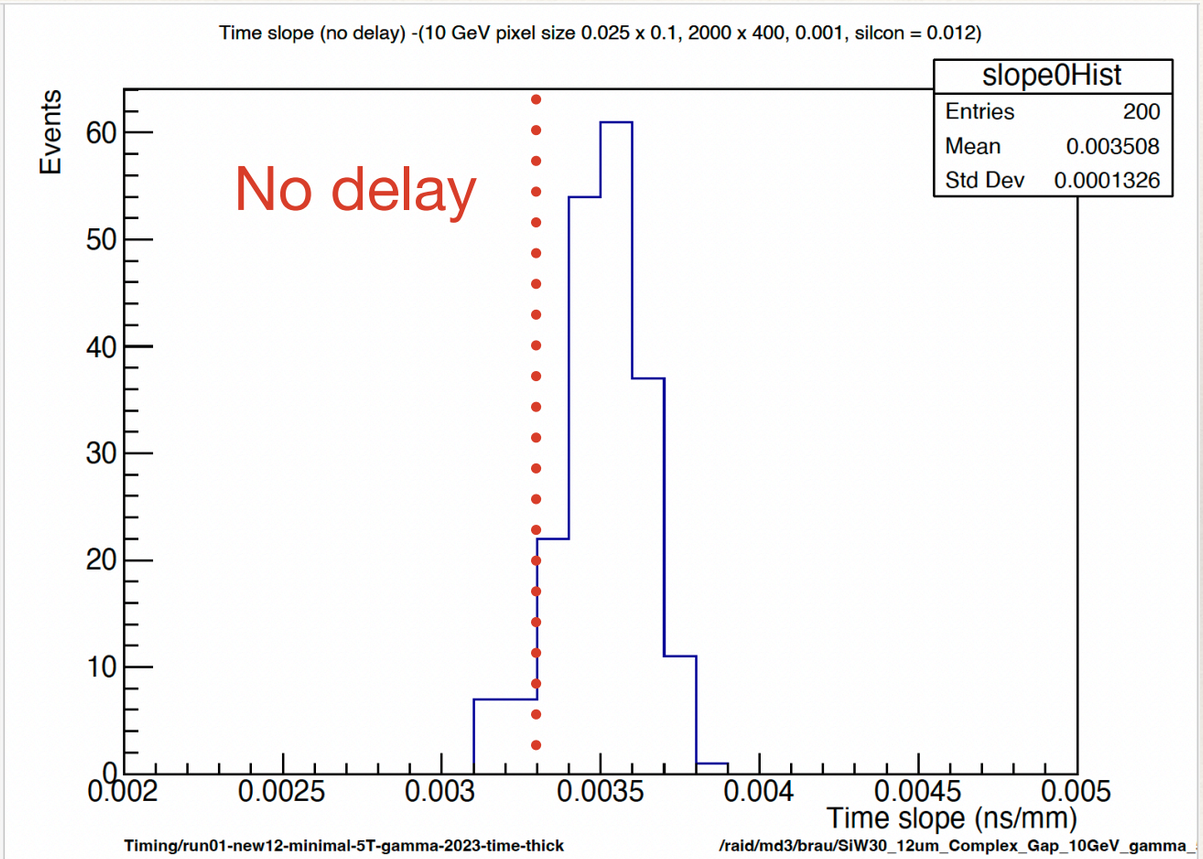


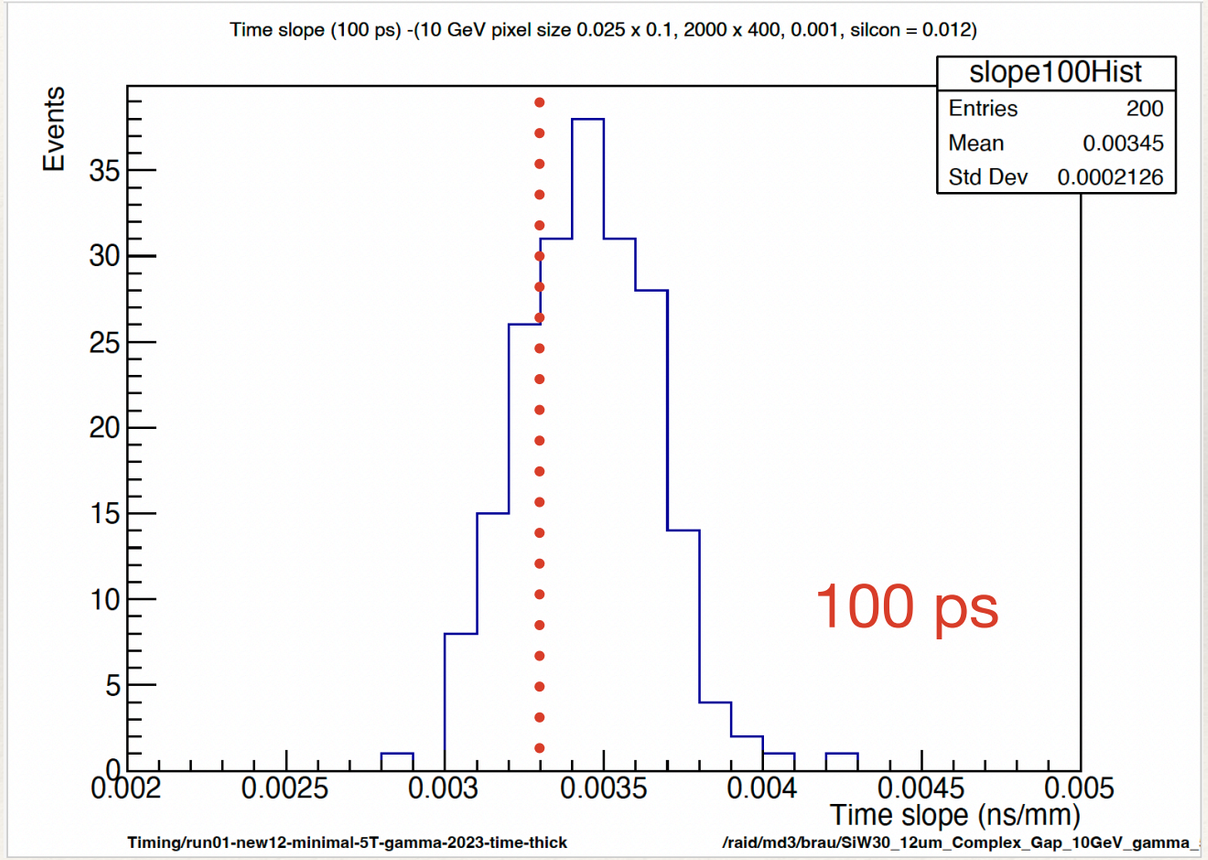
Effect of MAPS delay (10 GeV γ) average of layer hits time





Slope measurement (10 GeV γ)





Potential timing applications

- Tag multiple events within bunch train.
- Separate activity in ECal from nearby depositions.
- Assist separation of energy depositions in HCal based on timing in ECal.
- Use precise timing of tracks in ECal for PID (e.g. K identification for H - s sbar).
- Search for long-lived heavy particles.
- Dune calorimeter?

Thanks to Andy for suggestions!

“Updating SiD Detector concept”

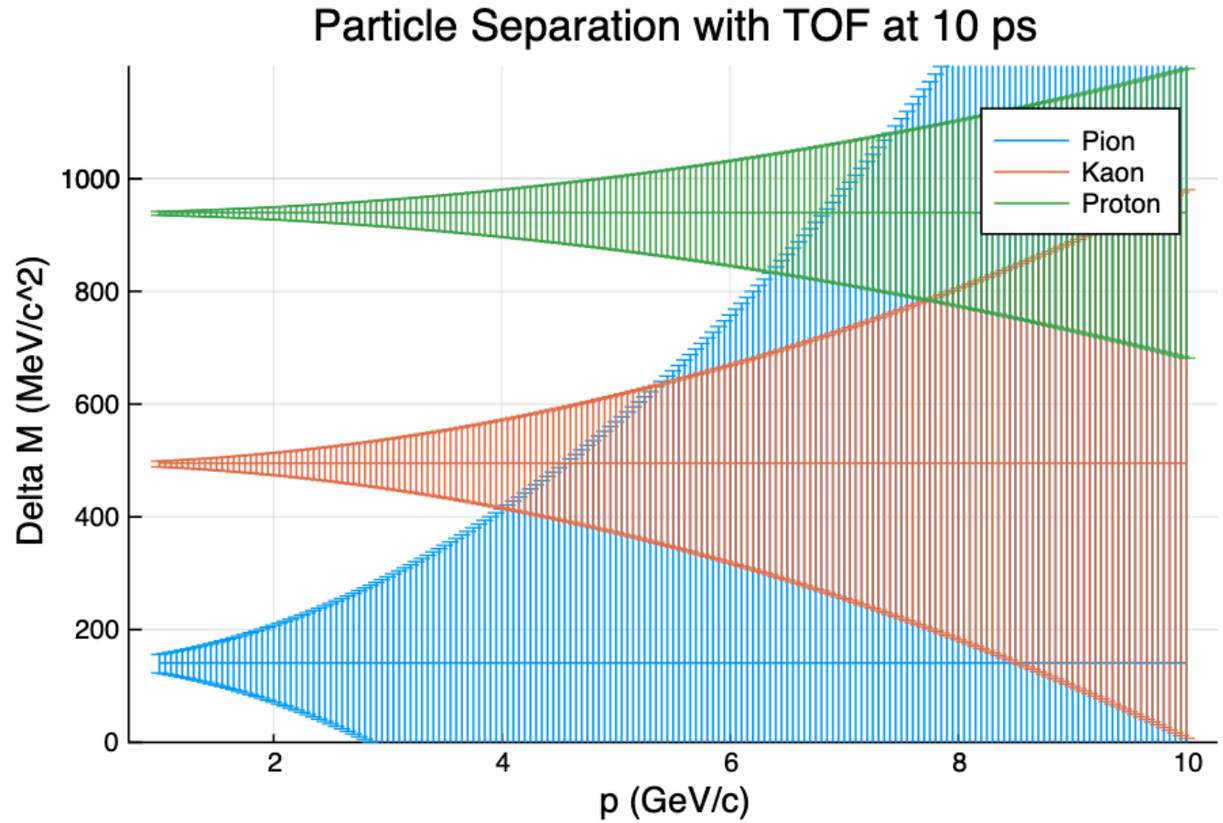


FIG. 16: Mass resolution for a TOF system with a performance of 10 ps in SiD

M. Breidenbach et al.,
“Updating the SiD Detector concept“
arXiv:2110.09965 [physics.ins-det]

Next steps

- Investigate specific physics channels
  - H -> s sbar
  - Tagging long-lived heavy particles
- Assess range of MAPS time precision
- Other suggestions and applications?