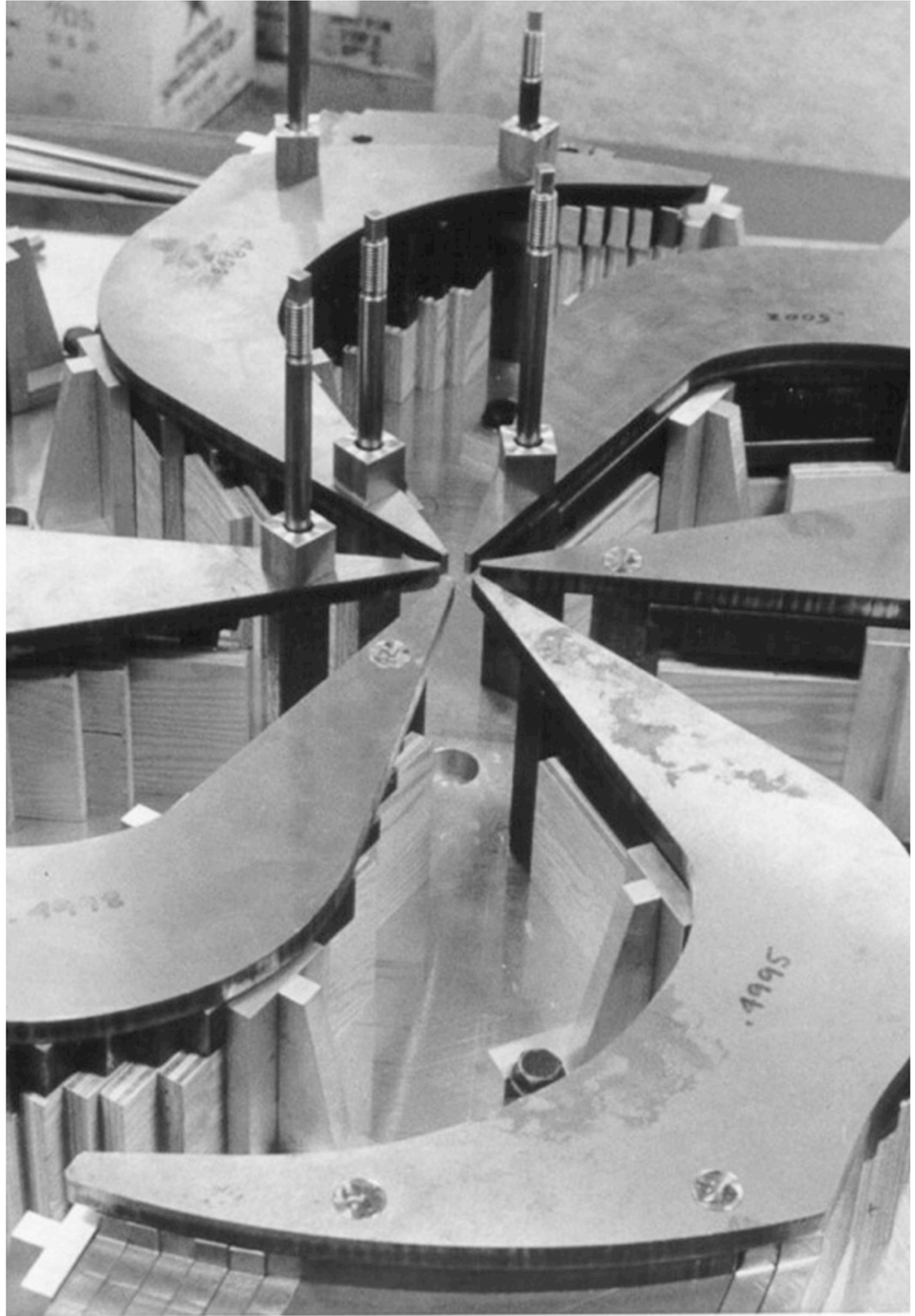
Software and Simulation Update

Laura Miller
on behalf of the software and simulation group

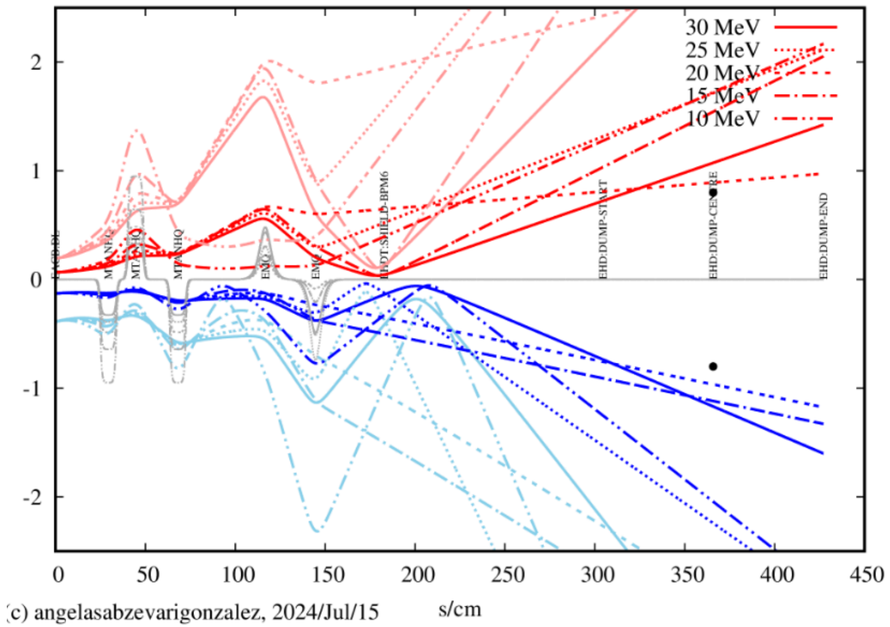
DarkLight collaboration meeting @ TRIUMF
January 15th, 2024



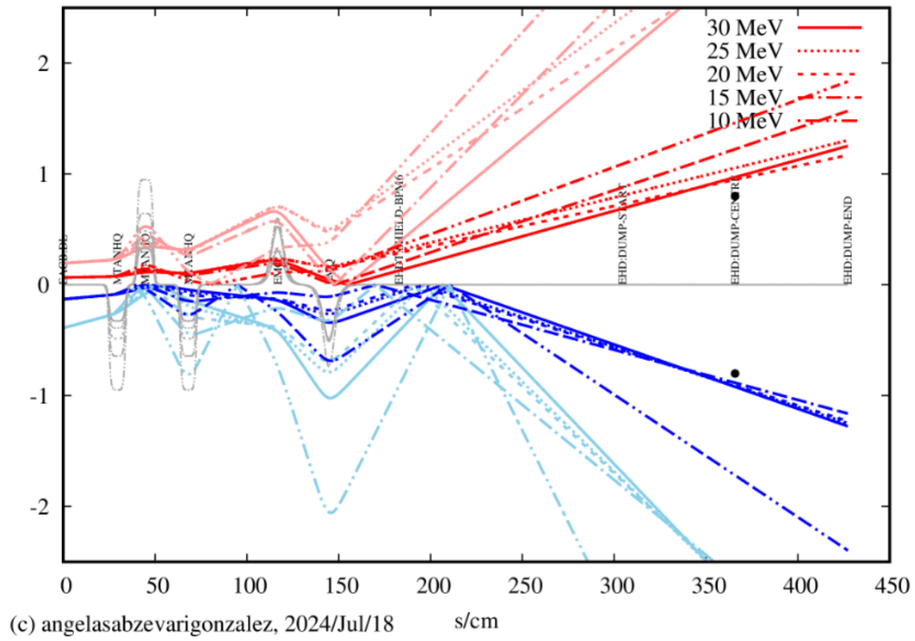
Discovery, accelerated

Beam Optics and Shielding

- See Ethan's talk that just happened for FLUKA updates
- Over the summer, Angela figured out beam optics solutions for commissioning runs using the original set of PMQs we ordered
  - PMQ and EMQ placement for 1um C target for 10, 15, 20, 25 and 30 MeV is constant, only EMQ strength changes

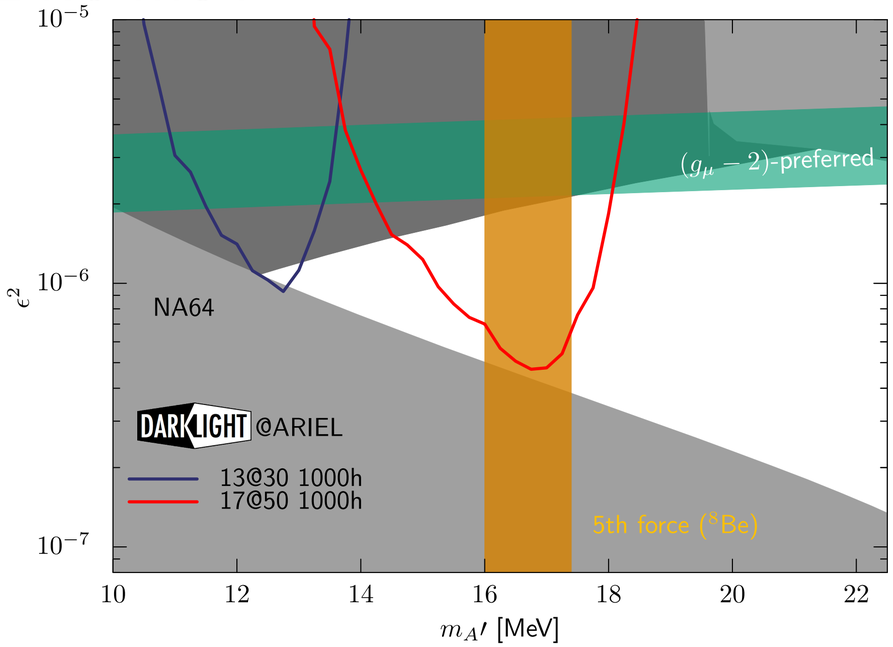


See Angela's report here



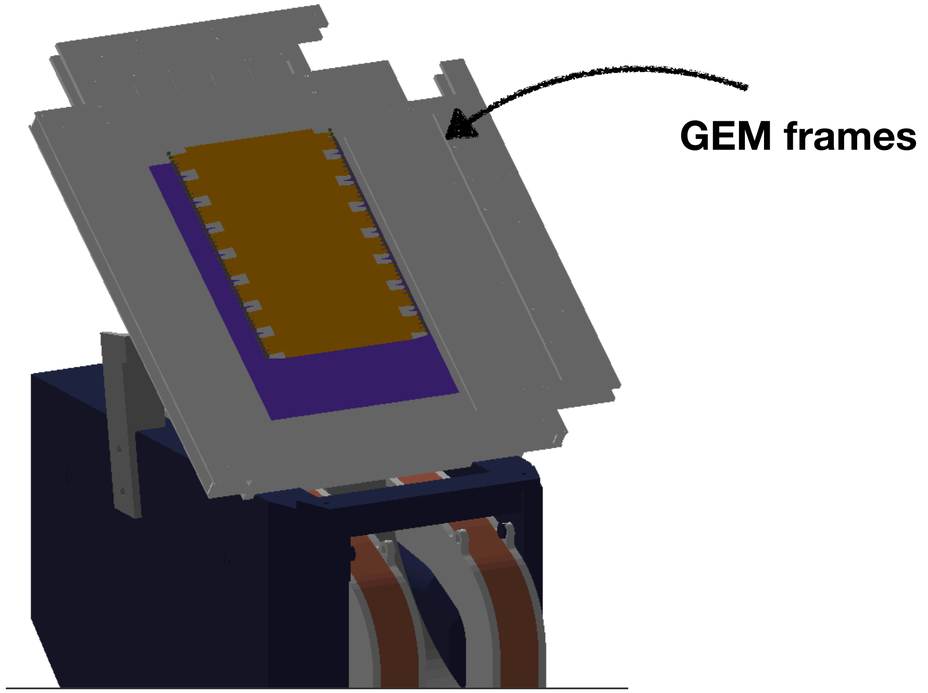
Monte Carlo Simulation

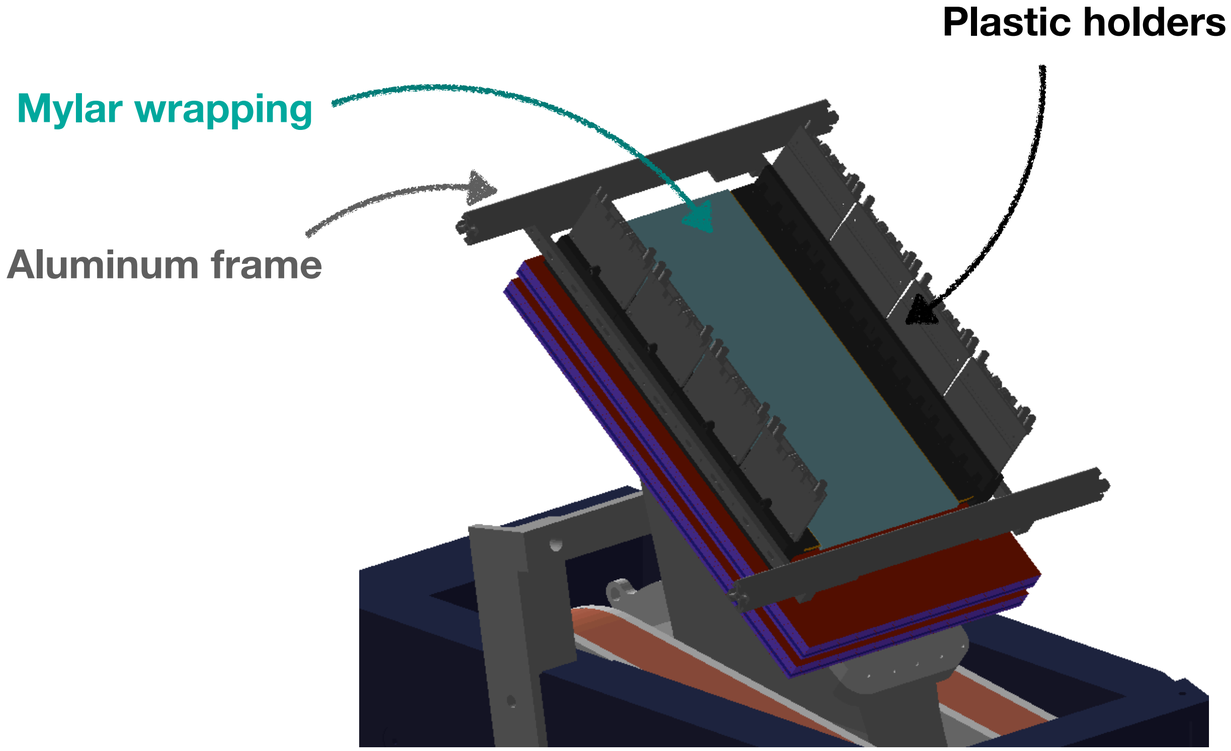
- MainzGen: configuration has been confirmed, resulted in some changes:
  - Central momentum optimized for 30 MeV runs: e^- arm = 11.0 MeV, e^+ arm = 17.2 MeV
  - Angles and central momentum reoptimized for 50 MeV scenario: 21 degree arms, e^- arm = 23.4 MeV, e^+ arm = 24.3 MeV
  - Updates to exclusion plots
    - Also includes updated mass resolution, see later slides



Geant4 Simulation

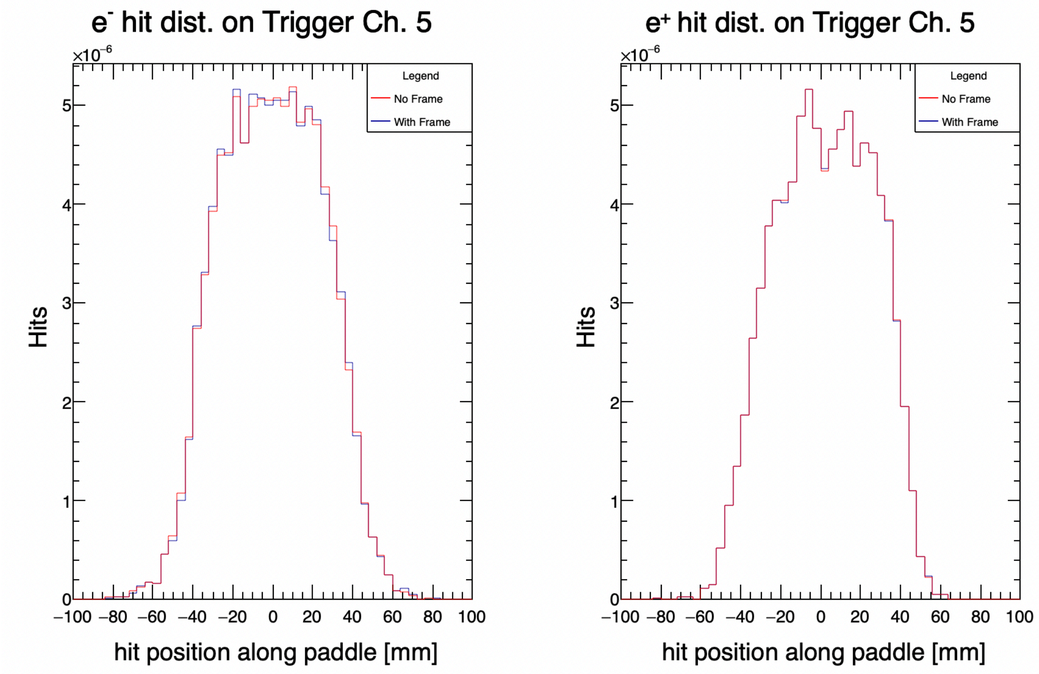
- Updates ongoing to match with the finalized model from MIT, along with some detector updates
  - Daniel @ SBU working on adding frames and updating .stl files with new geometry (to be pushed soon)

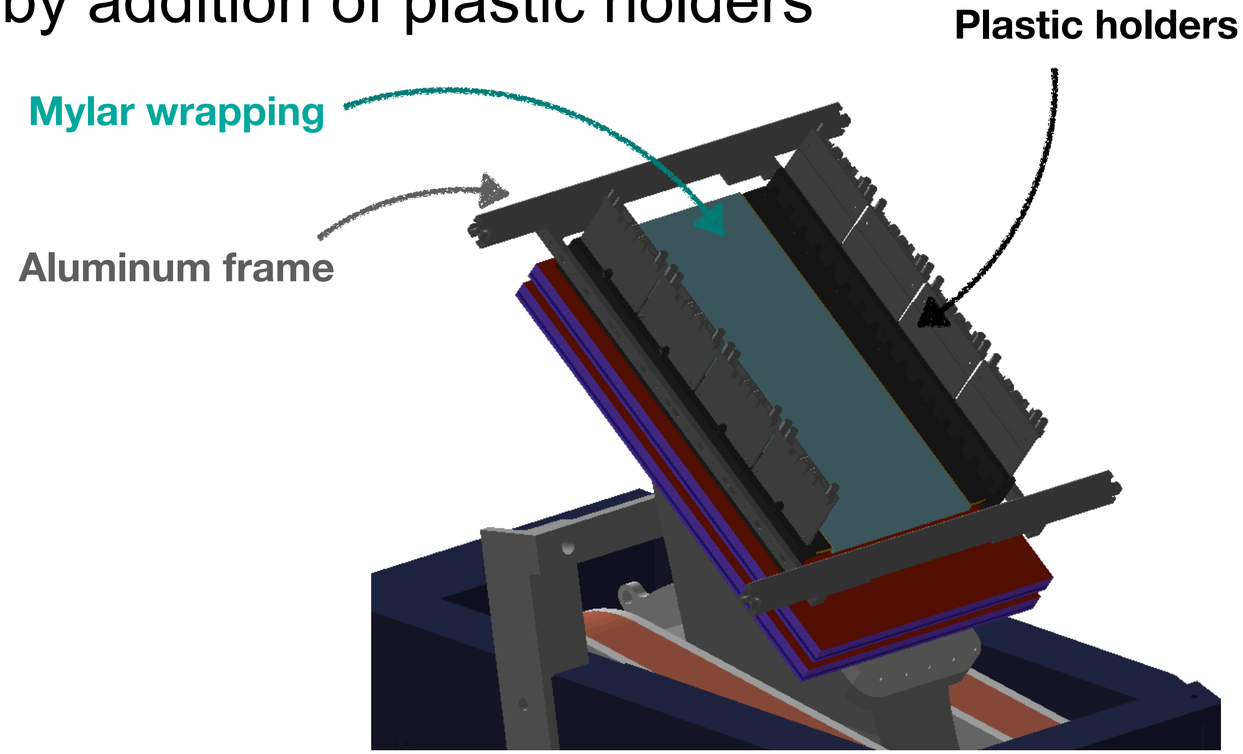




Geant4 Simulation

- Updates ongoing to match with the finalized model from MIT, along with some detector updates
  - Daniel @ SBU working on adding frames and updating .stl files with new geometry (to be pushed soon)
    - Trigger acceptance unaffected by addition of plastic holders





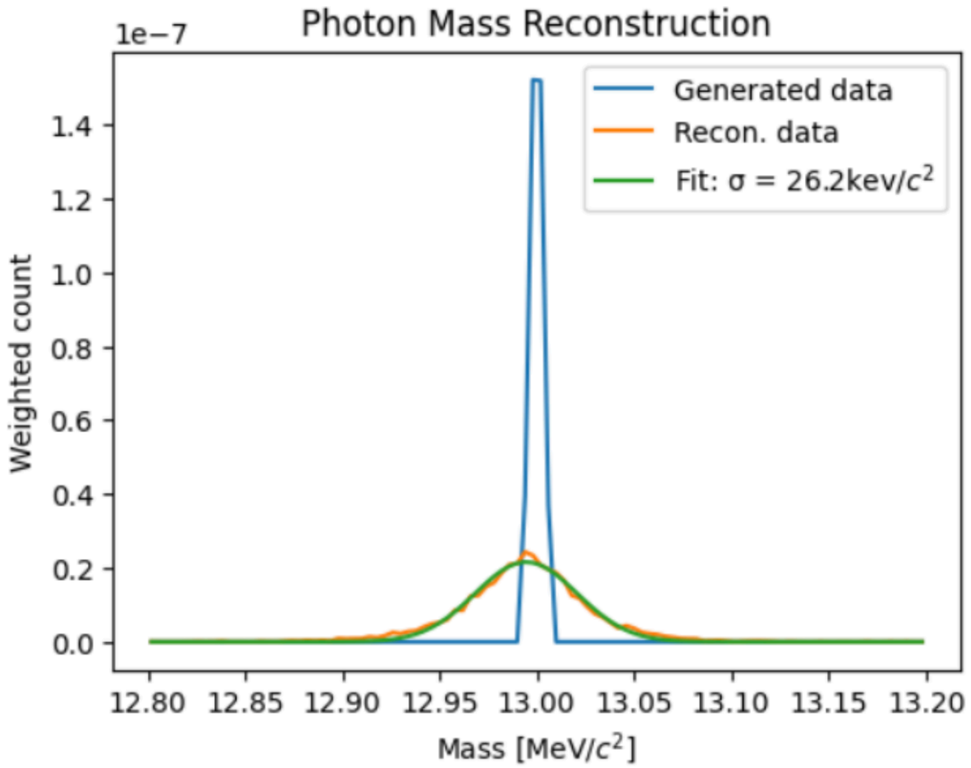
Geant4 Simulation

- Updates ongoing to match with the finalized model from MIT, along with some detector updates
  - Daniel @ SBU working on adding frames and updating .stl files with new geometry (to be pushed soon)
  - Xavier @ SBU updated GEM active layers to match DL GEMs instead of MUSE

0.005 mm, density 0.020, Copper
0.050 mm, density 0.020, Kapton
0.005 mm, density 0.085, Copper
0.120 mm, default density, Fiber glass

G4: Mass Resolution and Beam Properties

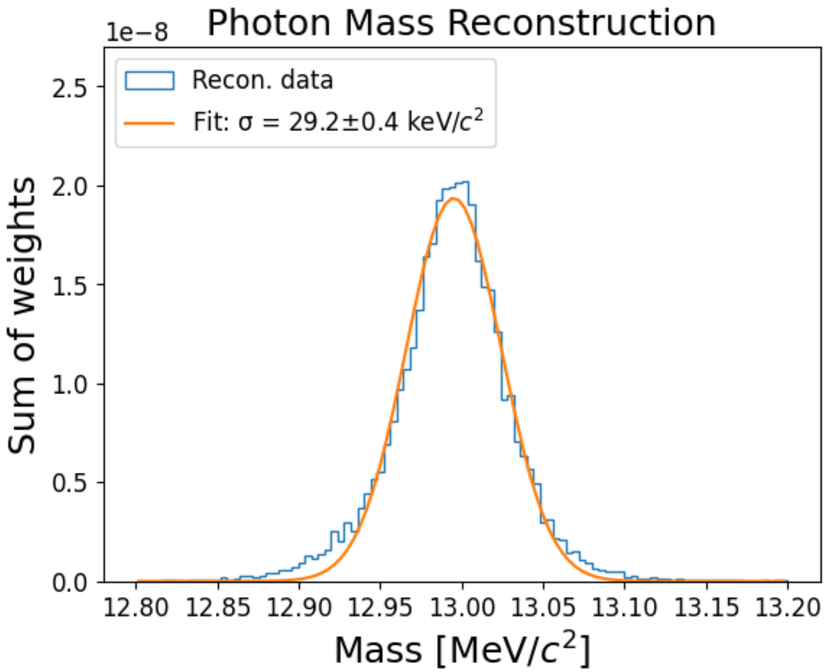
- Bug found in mass resolution code
- Signal resolution improves from around 120 keV to 26.2 keV with point beam
  - Only calculated from G4 output, no resolution effects from the detectors yet
  - Updated exclusion plots use 60 keV to be conservative



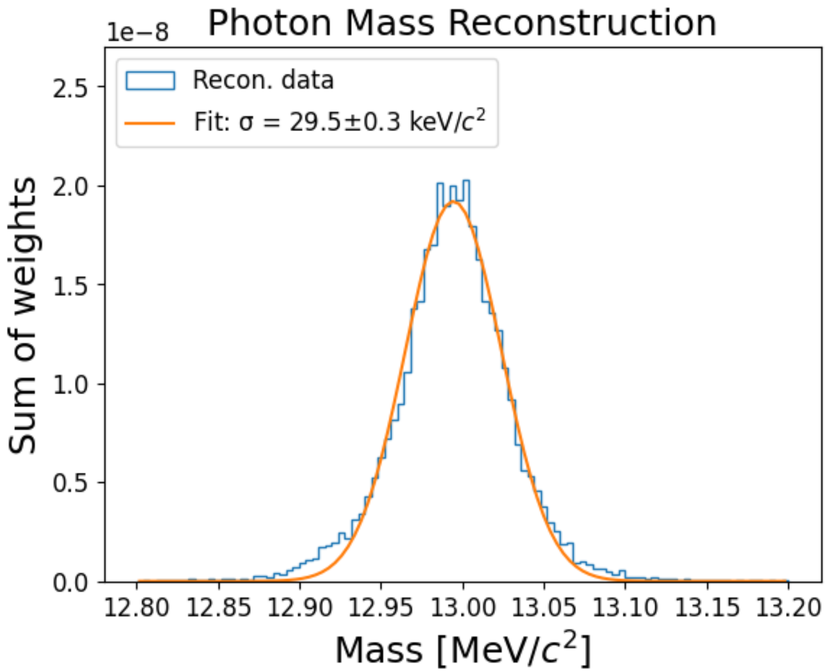
G4: Mass Resolution and Beam Properties

- Bug found in mass resolution code
- Signal resolution improves from around 120 keV to 26.2 keV with point beam
- Nominal beam spot added to G4, expected worst-case scenario fluctuations also examined, effect on mass resolution is minimal

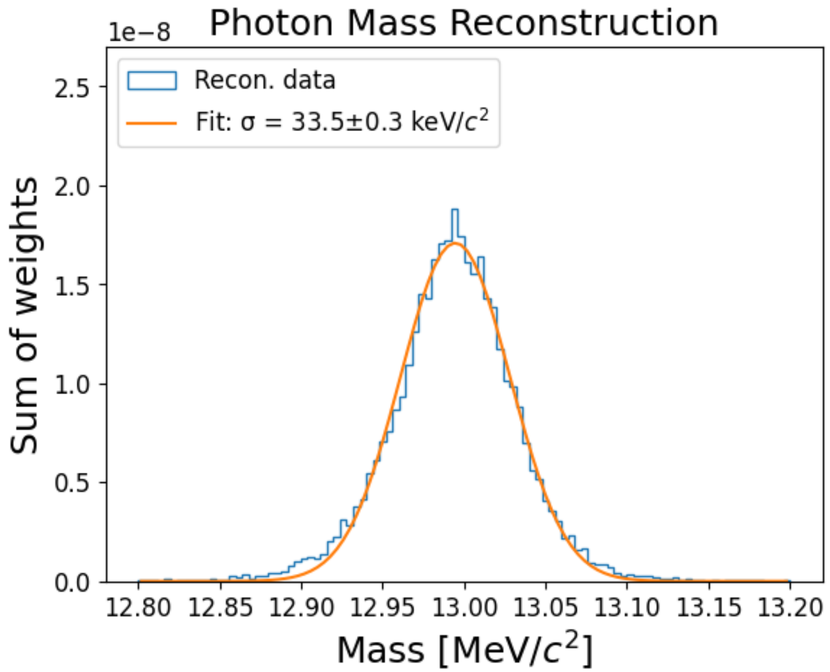
Nominal beam width (0.325, 0.650) mm



Beam width +0.4 mm in x

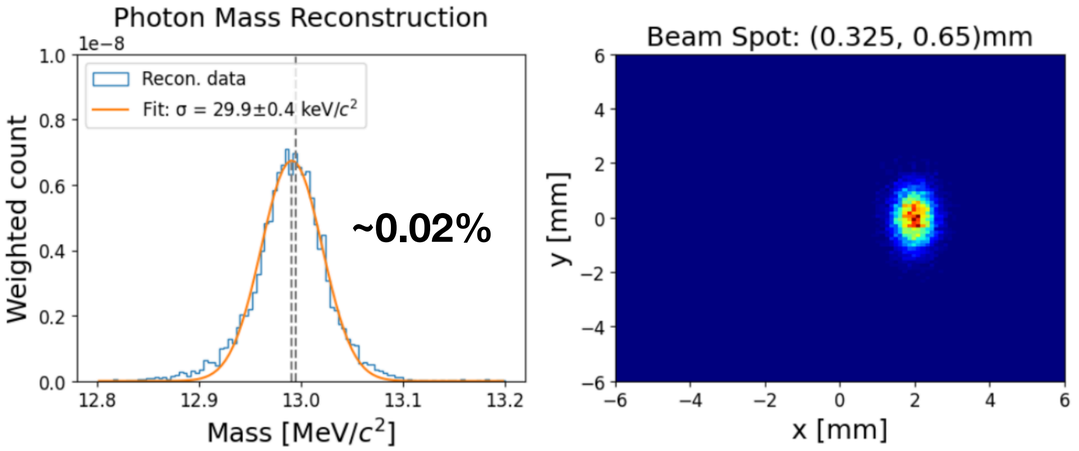


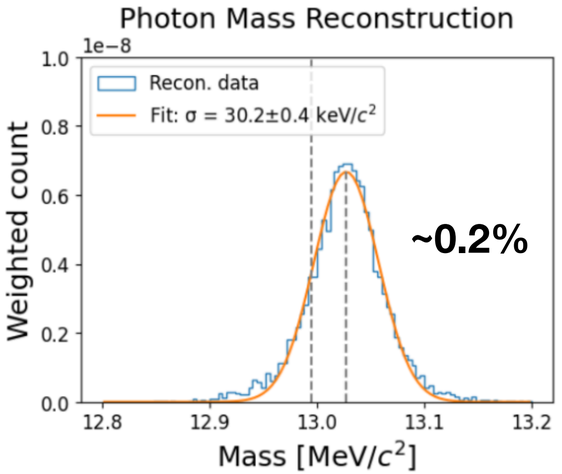
Beam width +0.4 mm in y

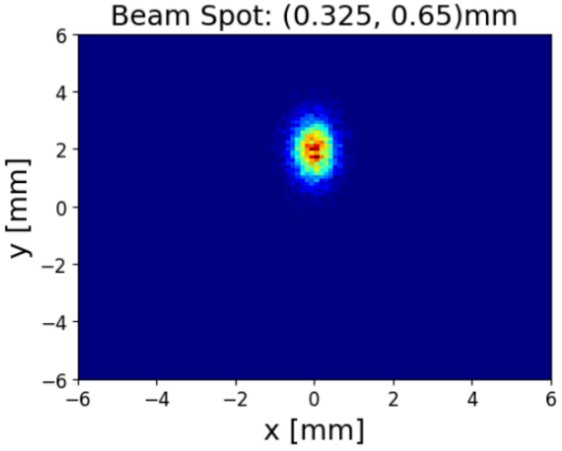


G4: Mass Resolution and Beam Properties

- Bug found in mass resolution code
- Signal resolution improves from around 120 keV to 26.2 keV with point beam
- Nominal beam spot added to G4, expected worst-case scenario fluctuations also examined, effect on mass resolution is minimal
- Movement of beam spot centre (± 2 mm) results in shift of mean (< 0.02% for x, 0.2% for y)
  - Not a big deal as long as we know what the shift is



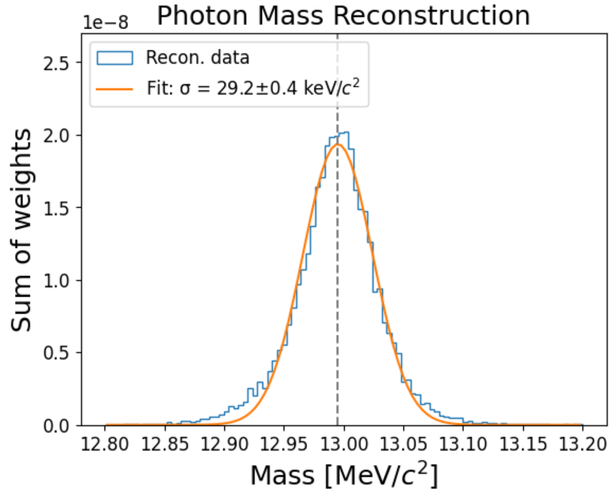




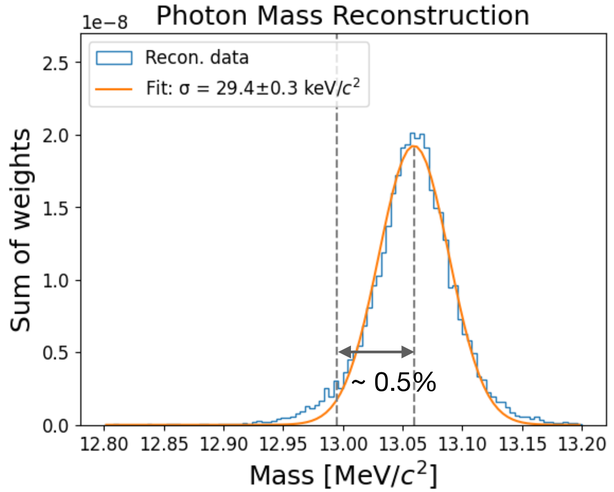
G4: Mass Resolution and Beam Properties

- Bug found in mass resolution code
- Signal resolution improves from around 120 keV to 26.2 keV with point beam
- Nominal beam spot added to G4, expected worst-case scenario fluctuations also examined, effect on mass resolution is minimal
- Movement of beam spot centre (± 2 mm) results in shift of mean (< 0.02% for x, 0.2% for y)
- Mass resolution also minimally affected by energy calibration offset

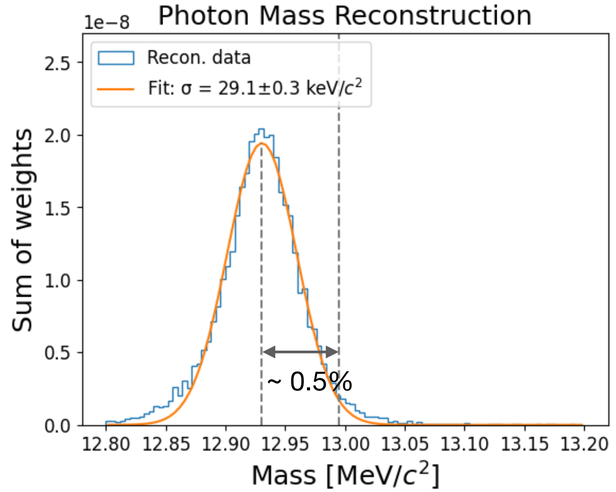
Nominal beam width (0.325, 0.650) mm



+1%p in spec. calib



-1%p in spec.

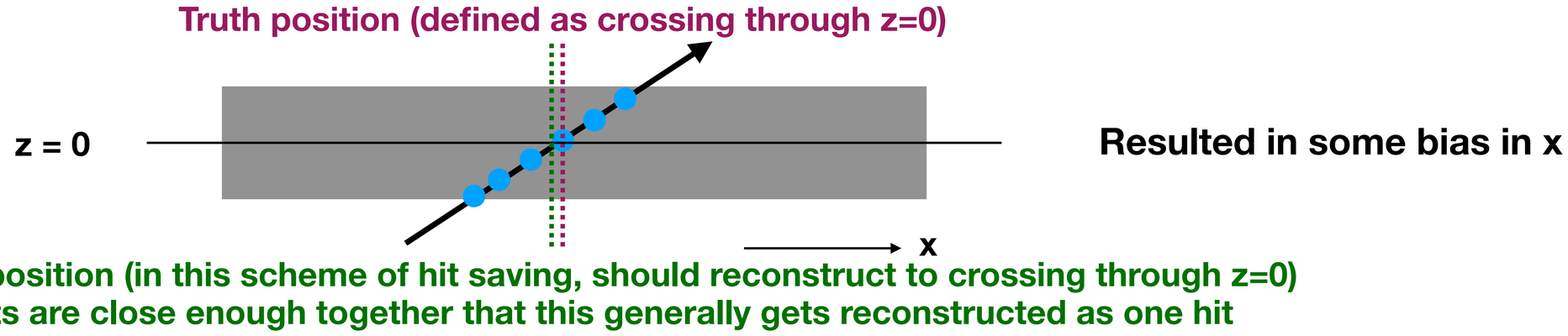


G4: Mass Resolution and Beam Properties

- Bug found in mass resolution code
- Signal resolution improves from around 120 keV to 26.2 keV with point beam
- Nominal beam spot added to G4, expected worst-case scenario fluctuations also examined, effect on mass resolution is minimal
- Movement of beam spot centre (± 2 mm) results in shift of mean (< 0.02% for x, 0.2% for y)
- Mass resolution also minimally affected by energy calibration offset
- Alex @ SBU is studying the effect of the GEM position and pitch on the mass resolution

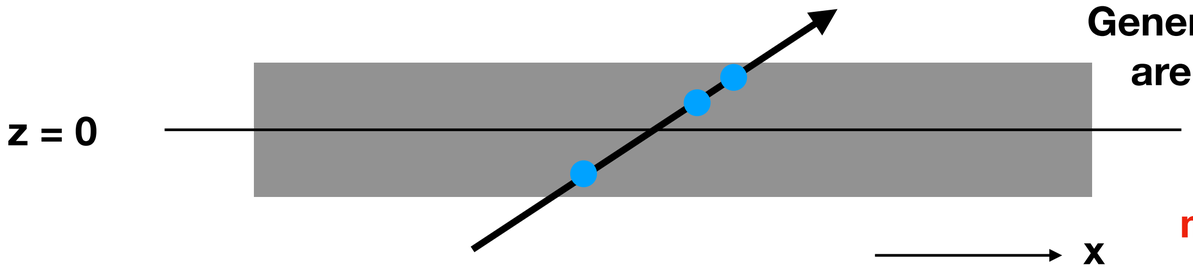
Digitization and Reconstruction

- Trigger and GEM digitization and reconstruction were implemented prior to the last collaboration meeting
- Trigger digi/reco waiting for more finalization on the detector/DAQ side of things
- Development ongoing for the GEM reco, angled planes create some issues (results should be coming soon)
  - Previously, saved all hits with pre-step position as electron passes through GEM



Digitization and Reconstruction

- Trigger and GEM digitization and reconstruction were implemented prior to the last collaboration meeting
- Trigger digi/reco waiting for more finalization on the detector/DAQ side of things
- Development ongoing for the GEM reco, angled planes create some issues (results should be coming soon)
  - Previously, saved all hits with pre-step position as electron passes through GEM
  - Updated 1) the hits to save at a random position along the step, 2) the hit only saves if the energy deposited is larger than the average ionization energy



Generally, results in more individual hits that are easier to match to individual G4 hits

Have implemented hit-by-hit matching, just working out the kinks

Tracking

- Cooker plugin has been implemented by Sid to analyze GEM tracks and to study correlation between tracks and trigger hits

- Plugin name: GemTrack
  Input trees: lumigemcooked, TrigScint ← Output from GEM and trigger reco
  Output tree: tracks

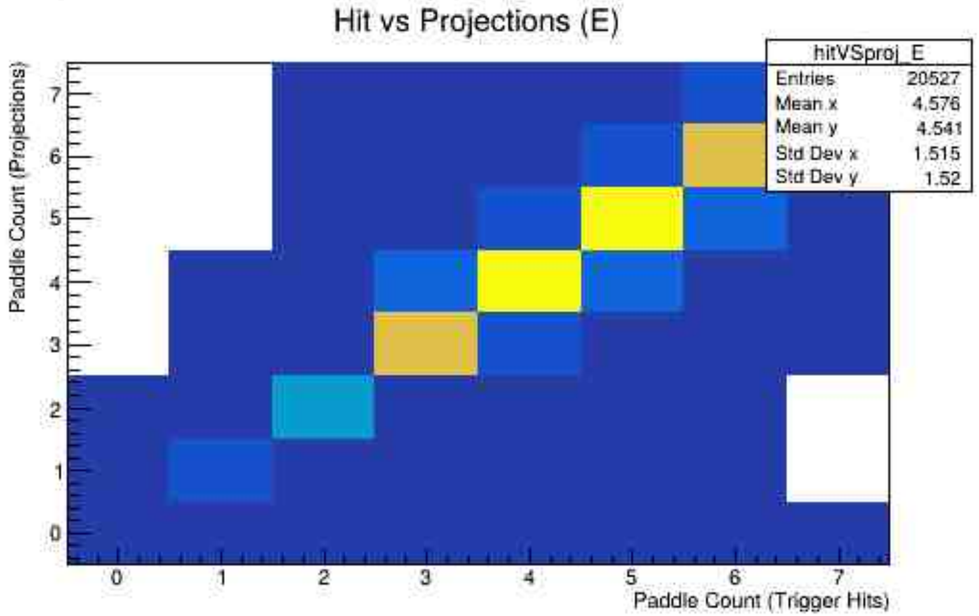


Figure Trigger Hits vs GEM track Projections (Electron Trigger)

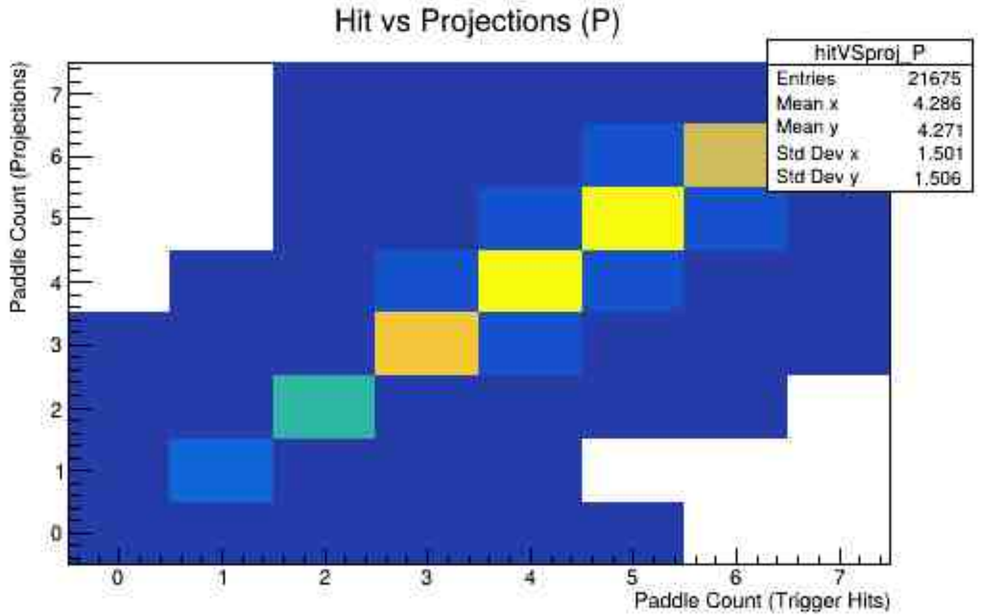


Figure Trigger Hits vs GEM track Projections (Positron Trigger)

Tracking

- Cooker plugin has been implemented by Sid to analyze GEM tracks and to study correlation between tracks and trigger hits

- Plugin name: GemTrack
  Input trees: lumigemcooked, TrigScint ← Output from GEM and trigger reco
  Output tree: tracks

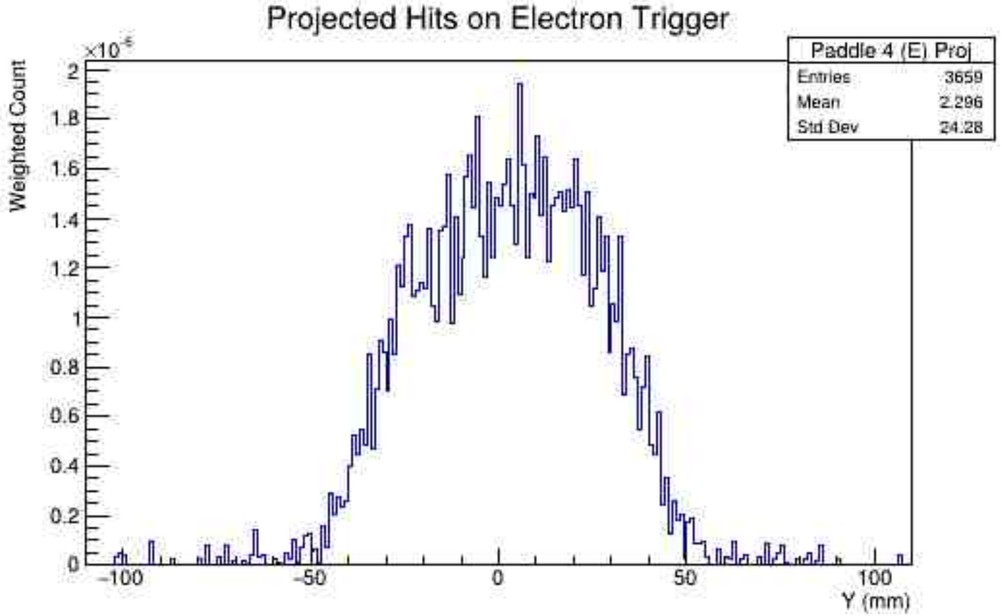


Figure GEM track projections on electron trigger paddle 4

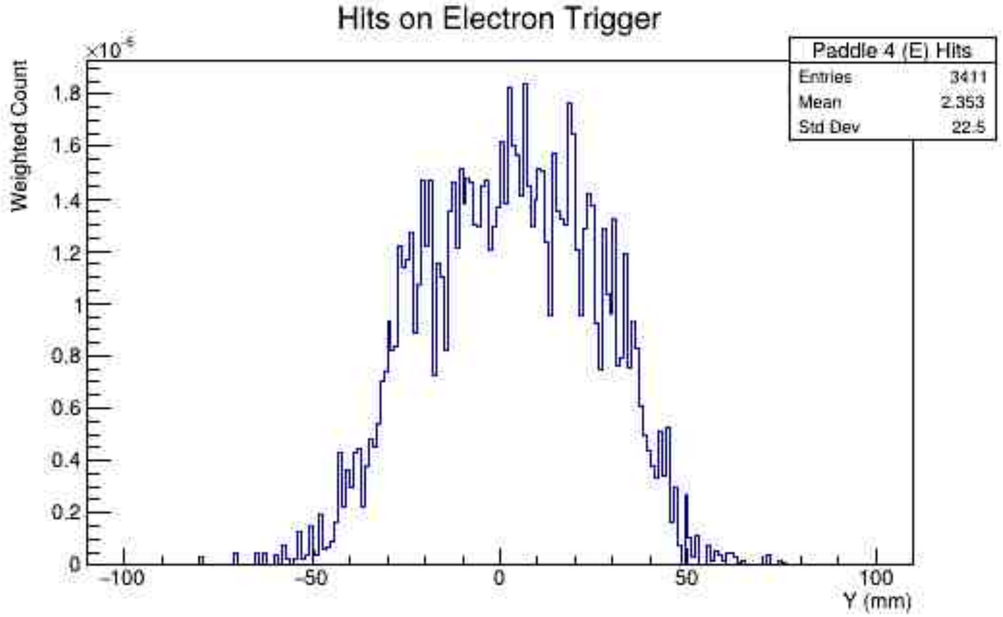


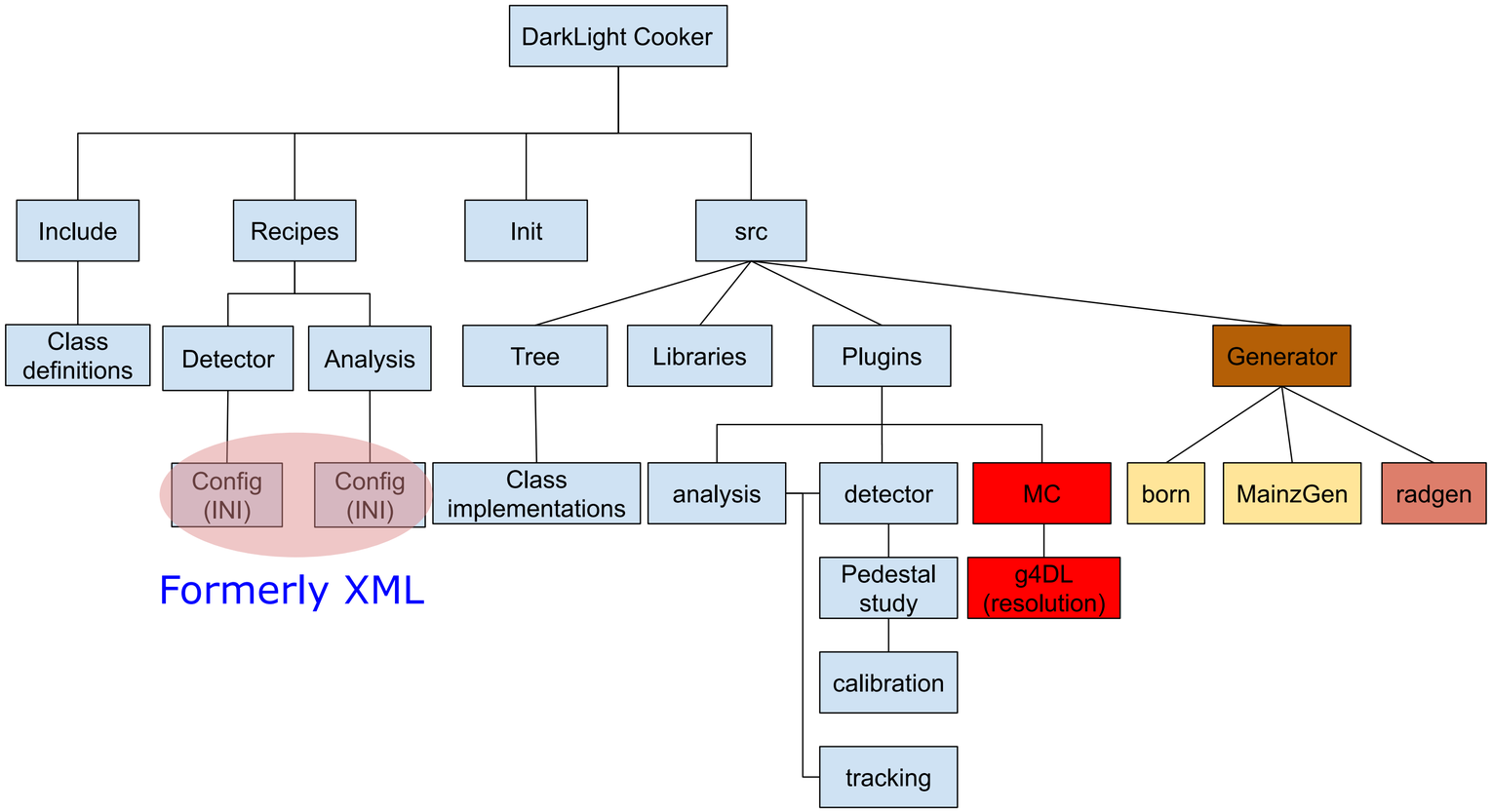
Figure Hits reported by electron trigger paddle 4

Data integration

- As we get closer to DAQ being finalized, can start to implement code to run the reconstruction algorithms on the actual data
- So far, have implemented the midas to root converter to work with the GEM files from Hampton
  - Mapper has been updated to no longer have all the MUSE objects
  - Working on getting the root files to work with the reconstruction
- Further updates to come as this evolves

Cooker Framework

- Bishoy is making an important set of updates to the config structure within cooker
- Code is currently on a separate branch, and xml method will be deprecated once testing is complete



customConfig Recipe

- `Xqilla` is deprecated/discontinued since 2018 and removed from package managers (self-build)
- Need new hierarchical configuration architecture
- Structurally `Cooker` remains the same
- Human-friendly data serialization
- Get rid of `XML parsers`
- `customConfig:` handle loading of plugins and configuration files (`init files`)
- `plugin(s)` are `keyed` by `name`
- `TOML:` ✗
- `YAML:` ✗

Cooker Framework

- Bishoy is making an important set of updates to the config structure within cooker
- Code is currently on a separate branch, and xml method will be deprecated once testing is complete
- Current status:

  - Branch of new config: default is to use INI
  - cmake ../ -DUSE_XML=ON to turn on XML parsing
  - **Not tested if XML parsing if fully working.** Cedar keeps hanging
  - Use std::map as look-up table
  - key: runnumber, id (channel no.), detector element
  - Not all detector elements and/or channels are changed for all run numbers
  - Changed elements get overwritten
  - eetsumMorConfig creates a map of runnumber and sequence of config items
  - Might be buggy, and some functionality still to be added

Central MC Samples

- A reminder that central samples are available for collaboration use
  - Signal and background samples for both 30 MeV and 50 MeV
- Link and password available upon request to me
- Currently contain generator level events only
  - Instructions for appropriate scaling can be found here (for now, better documentation will follow)
  - Geant4 output will also be added to these soon

Summary

- Beam optics are finalized and safety report is published
- Geant4 simulation is undergoing updates to match with the final detector design from MIT
- Mass resolution studies under various conditions indicate decent robustness
- Reconstruction algorithms are on their way to being more fleshed out
- Tracking algorithm has been implemented
- Initial steps have been taken to start working with data
- Cooker framework updates are in progress to eliminate xquilla dependency

Win will be taking over as simulation coordinator after the collaboration meeting!
It was great working with you all, and best of luck Win!