GEM and Trigger Simulation (and digitization & analysis) Status

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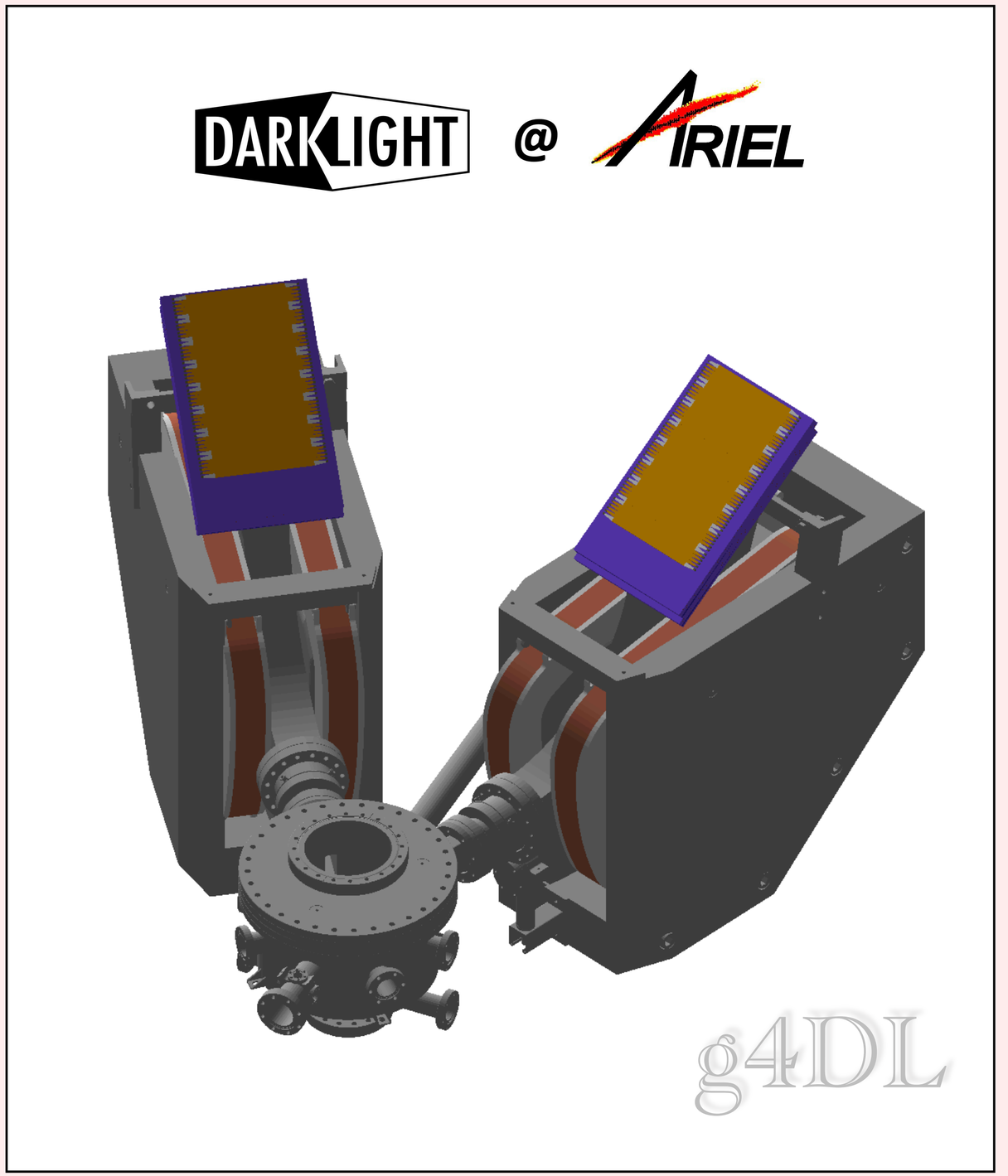
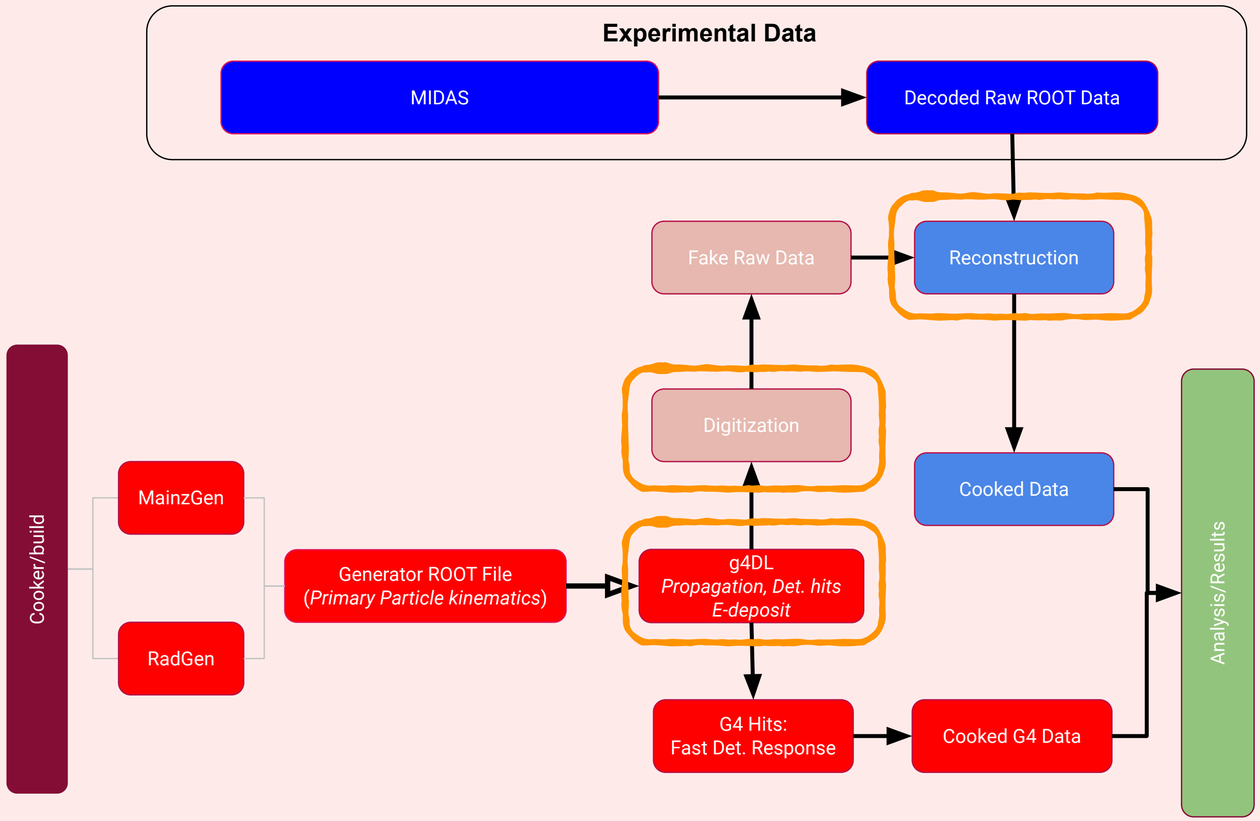
DarkLight Collaboration Meeting
10/07/2024

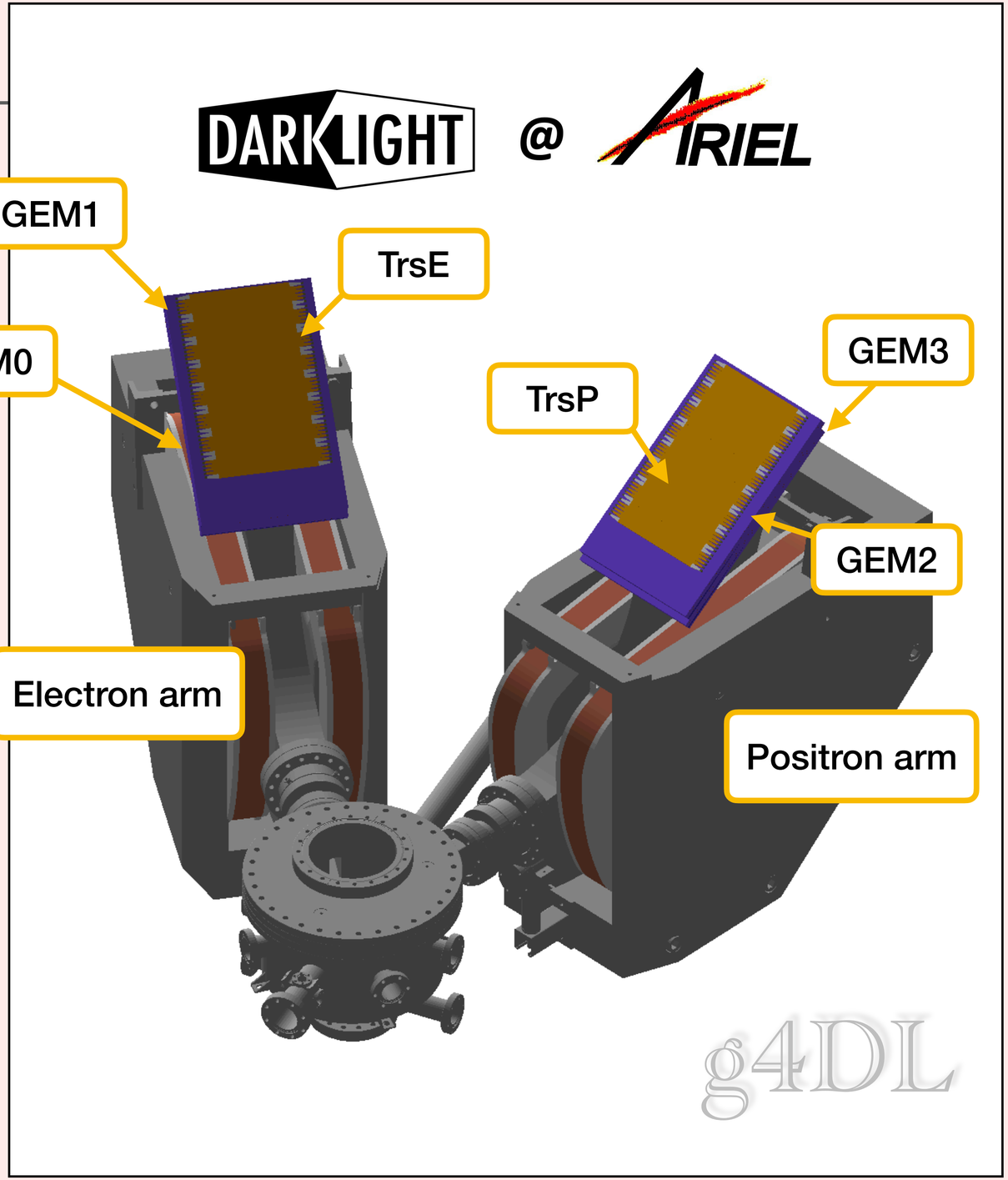
Stony Brook University



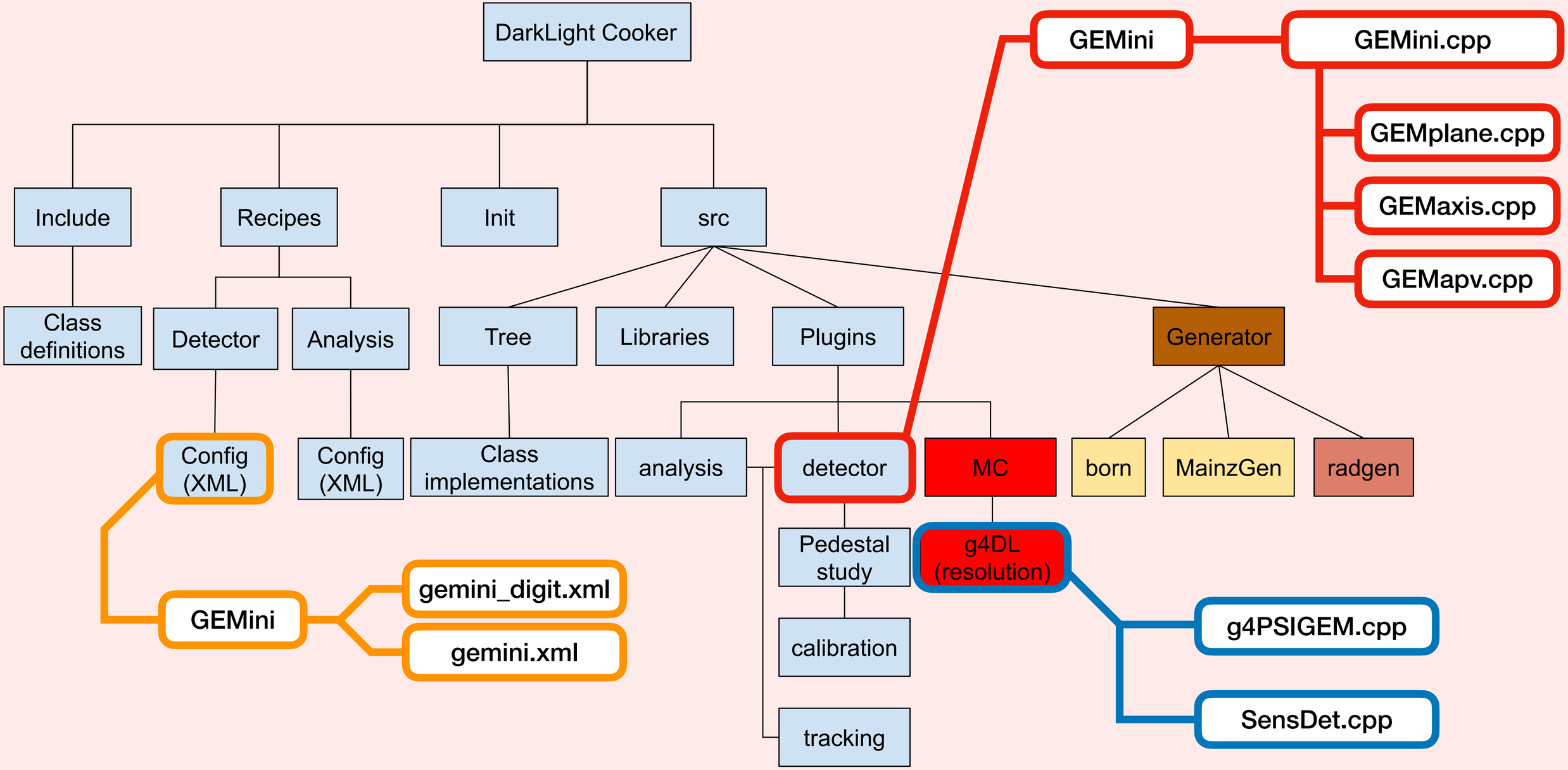
Overview

- All codes are within the cooker framework
  - g4DL simulation
  - Digitization
  - Analysis
- Both GEM and Trigger are implemented



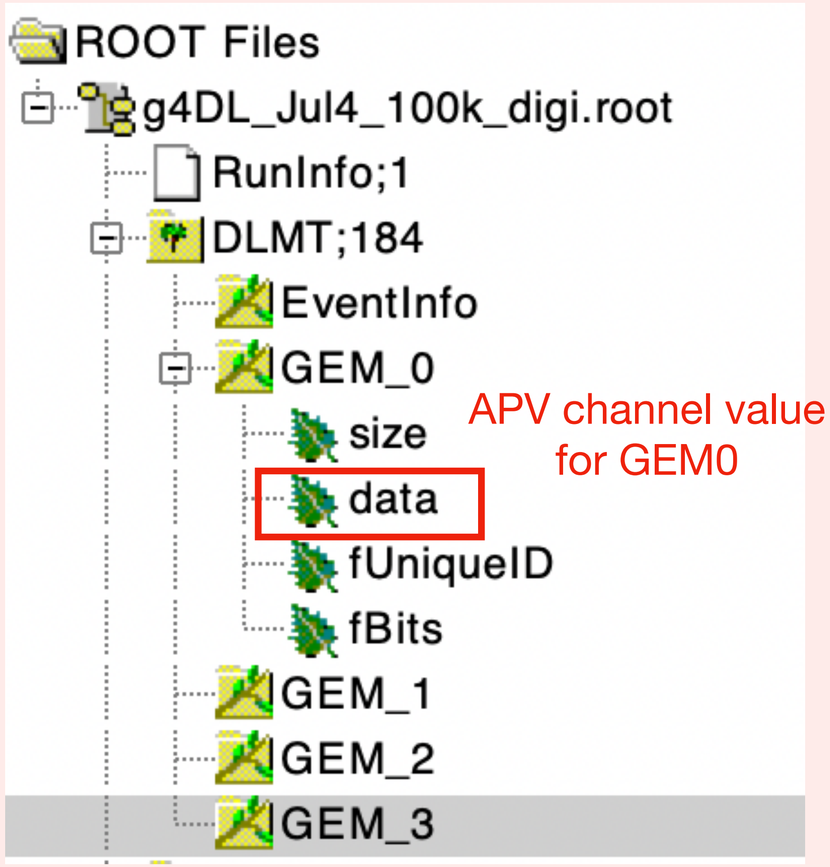


Code Structure - GEM



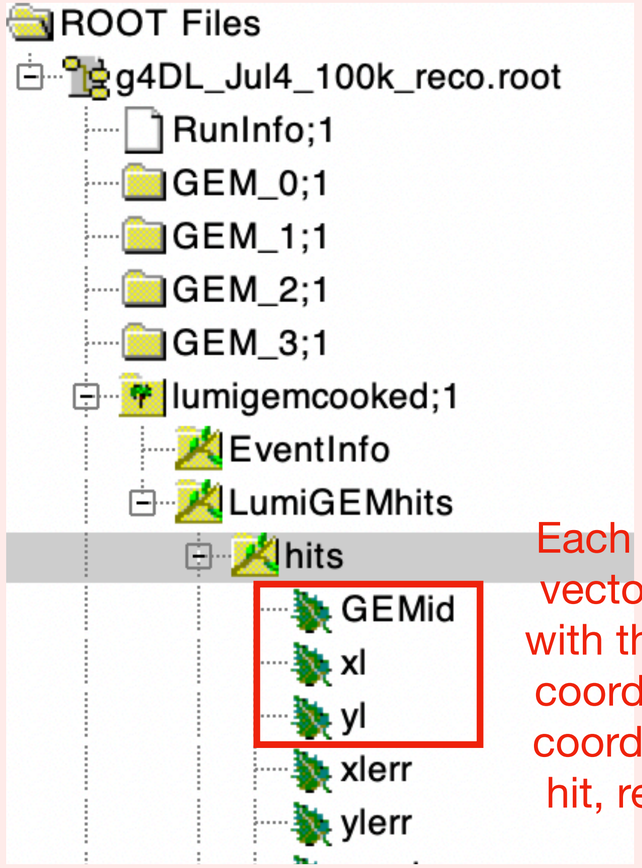
Output Structure - GEM

Digitization Output Branch



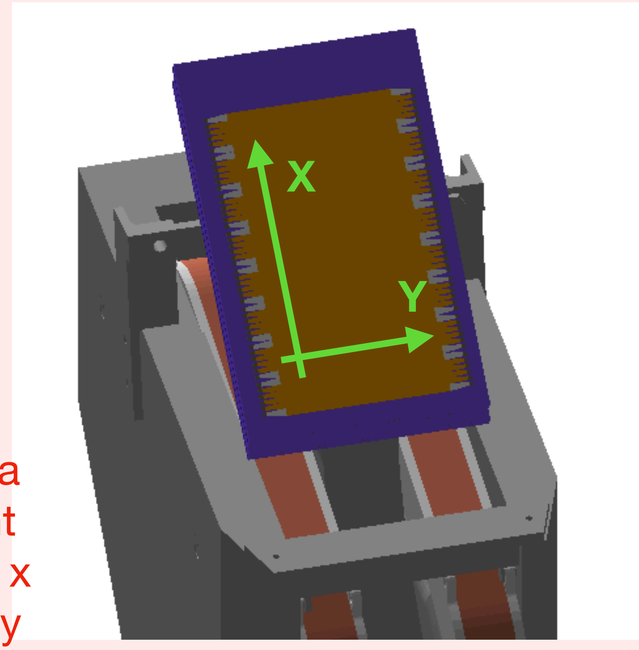
APV channel value for GEM0

Reconstruction Output Branch



Each branch is a vector per event with the GEM #, x coordinate and y coordinate of the hit, respectively

GEM Coordinate

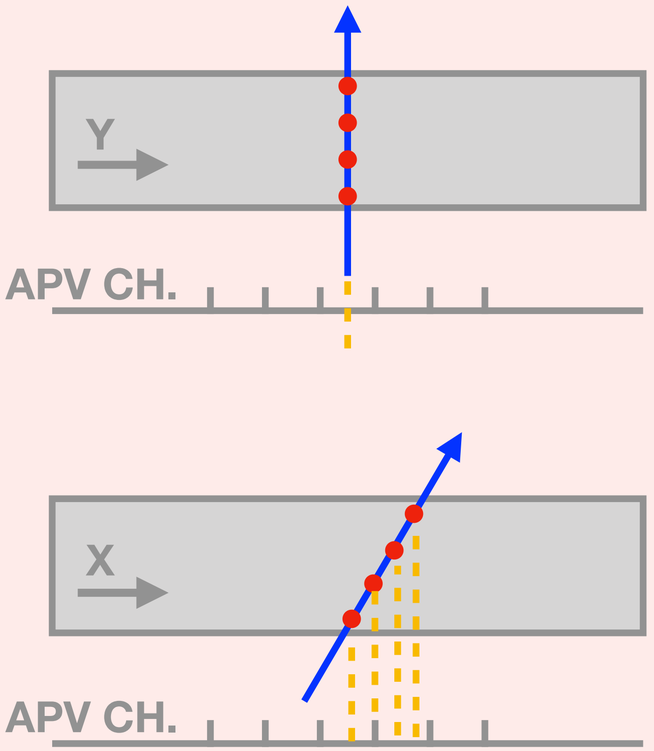


- Cooker command examples:
  - Digitization: **cooker recipes/GEMini/gemini_digi.xml <input Geant4 root file> <output file name>**
  - Reconstruction: **cooker recipes/GEMini/gemini.xml <output from digi> <output file name>**

GEM Simulation and Digitization

- In simulation, for each event, the hit position and energy of each step are recoded

- In digitization, the hit position is projected to the channels in each axis. Readout value is calculated and converted to apv values.



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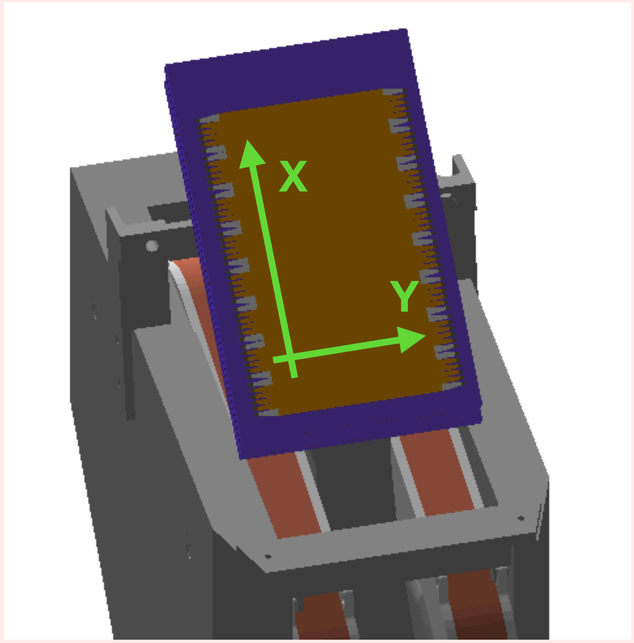
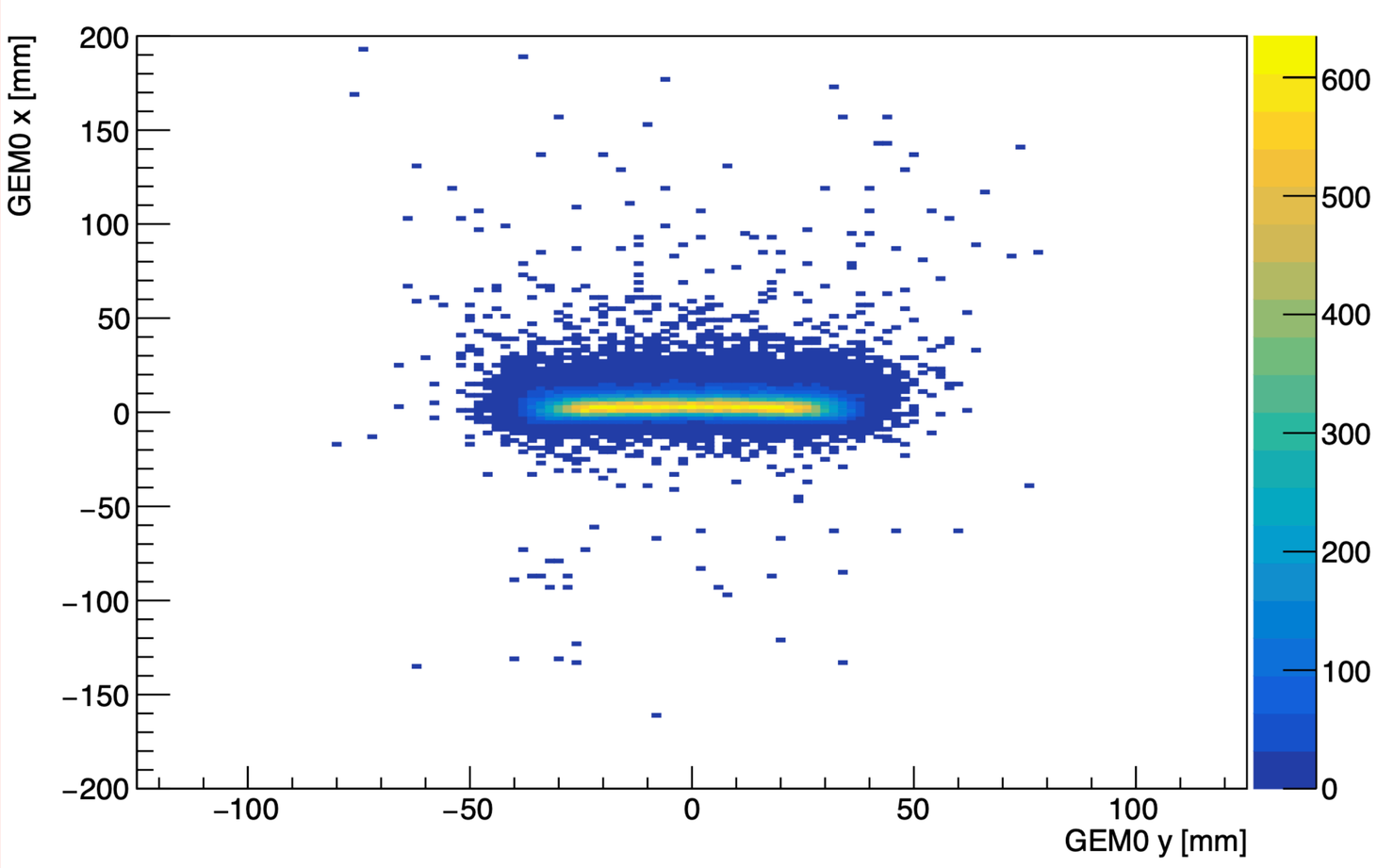


Example output

- Simulation with validation mode (central momentum for each arm, random angle within acceptance)

Example GEM Hit Map



Example output

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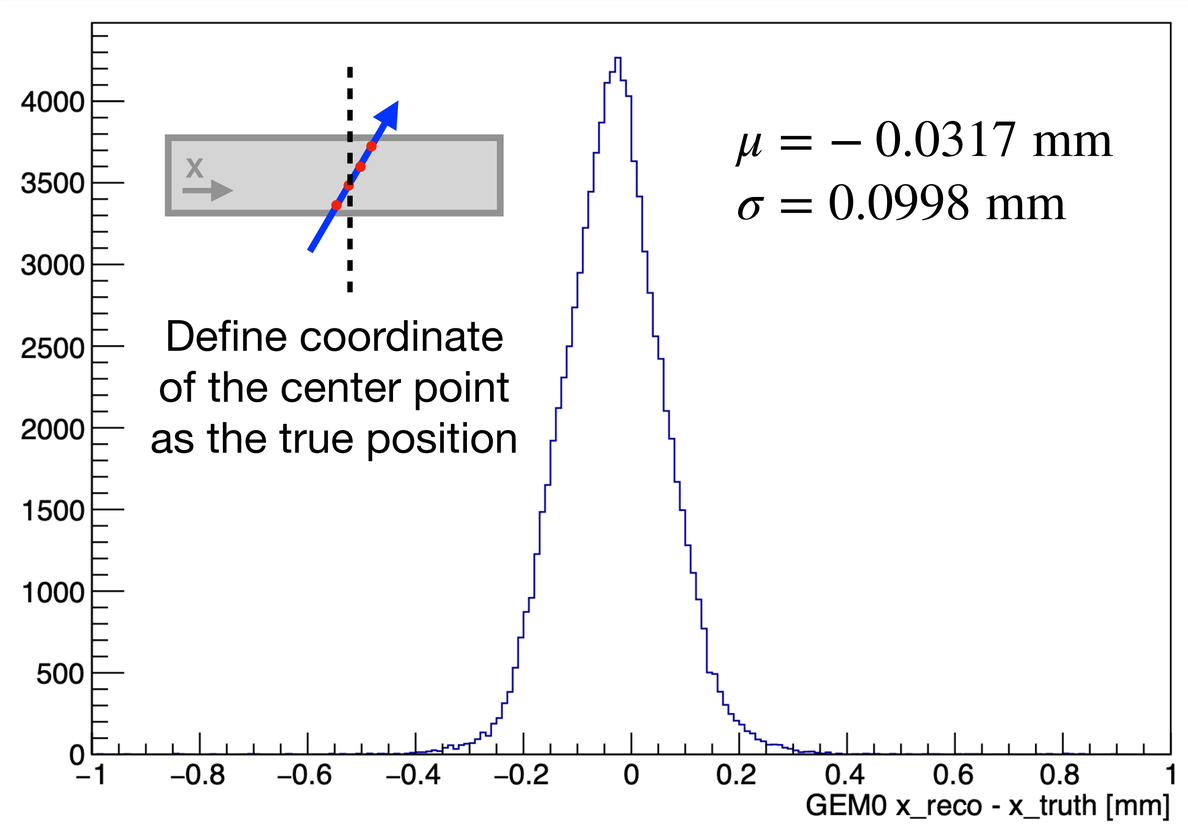
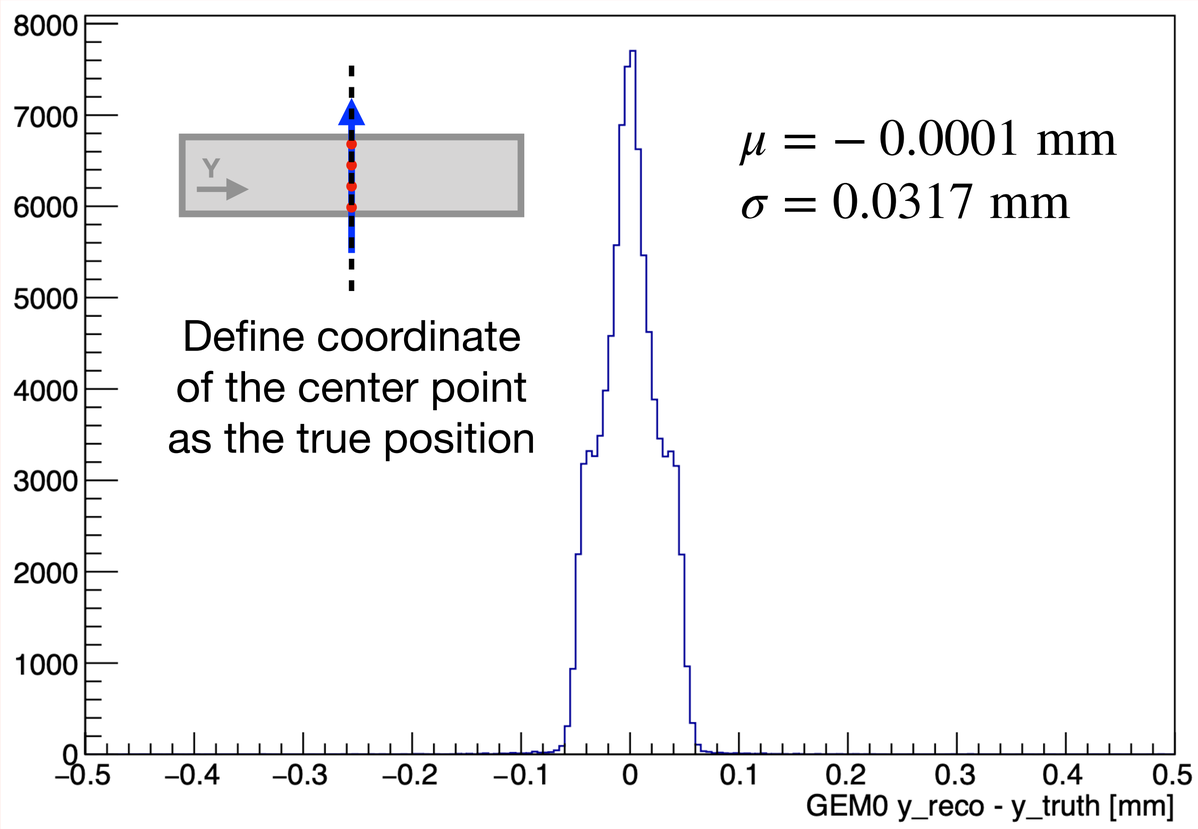
X Resolution (N = 100k)



Y Resolution (N = 100k)



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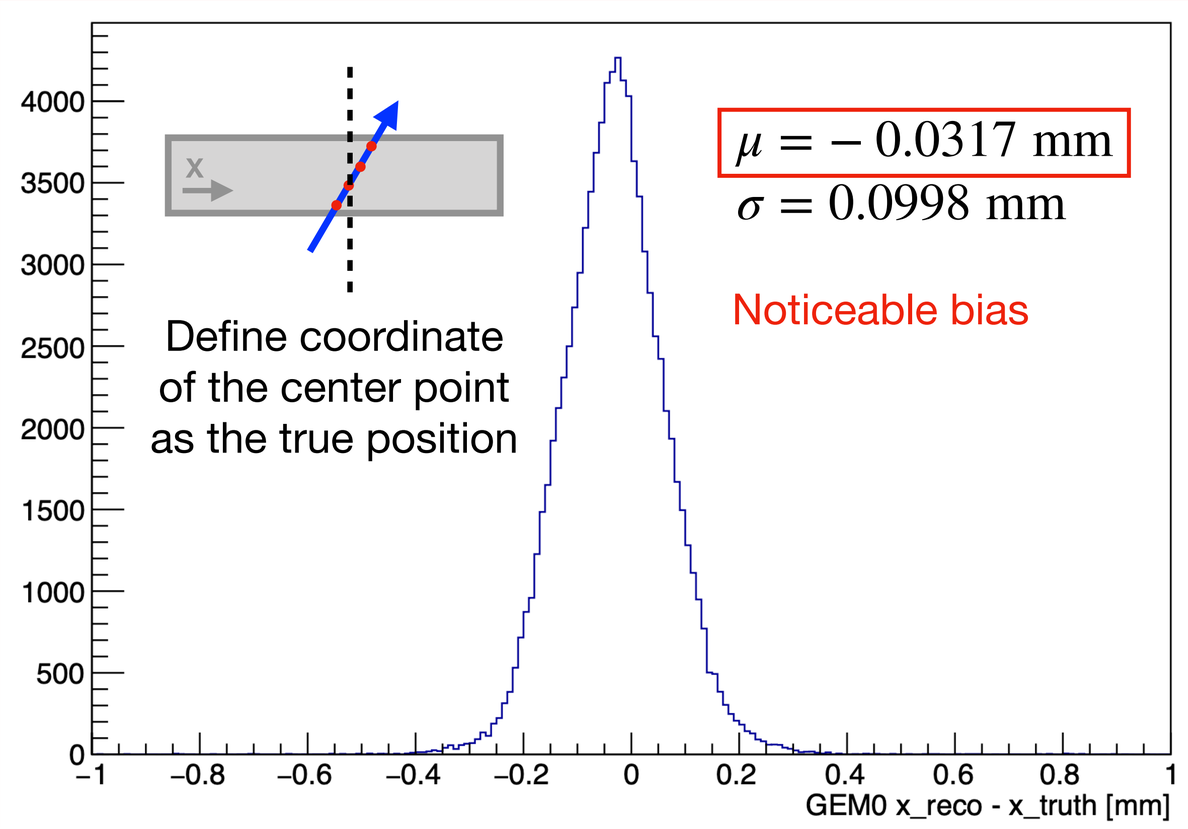
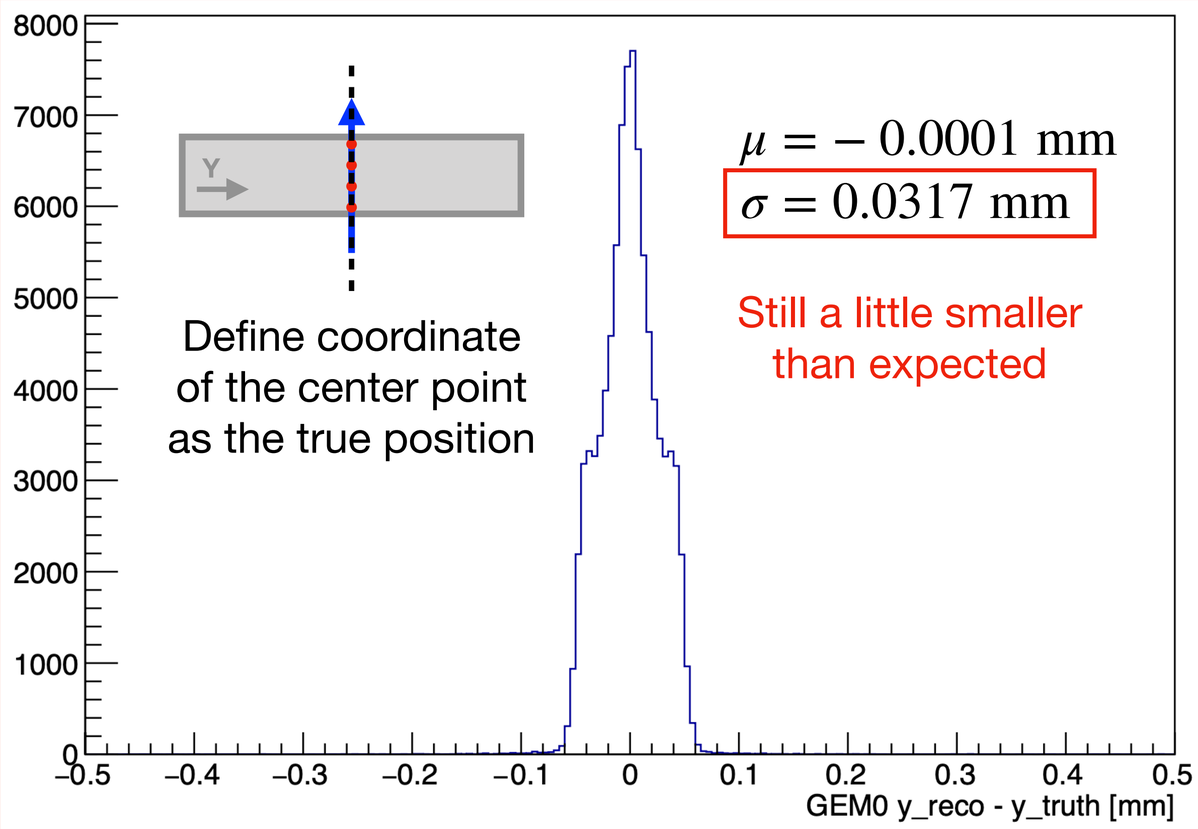


Y Resolution (N = 100k)



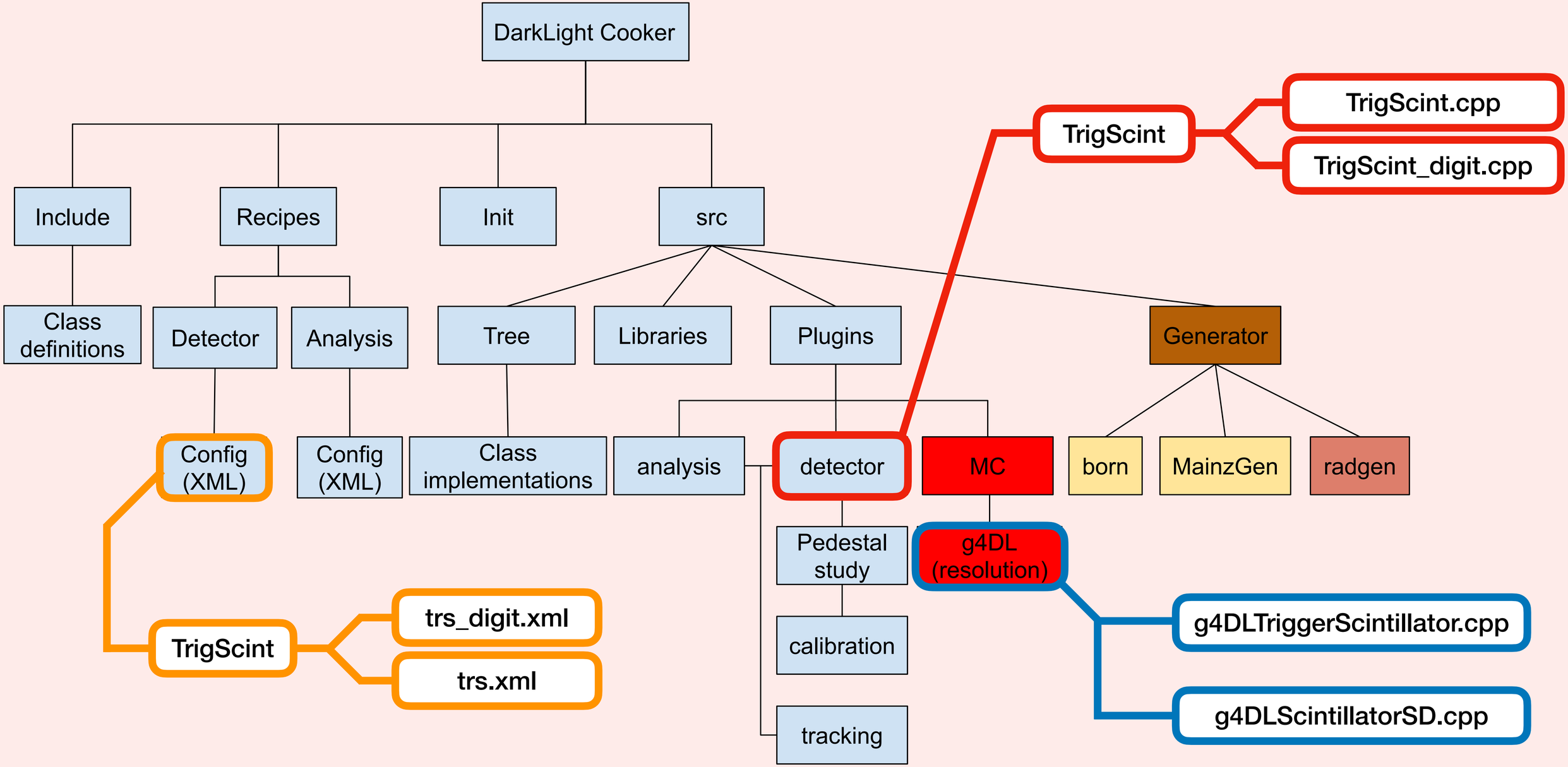
Summary for GEM

- Digitization and reconstruction are currently implemented with the proper geometry

- Some refinement to be done:
  - Noise should be tuned such that the y direction has proper resolution
  - Reason for the bias in the x direction needs to be determined
  - Resolution may suffer due to the angle?

- Need to collect pedestal values and gains once we can perform the measurement with the physical GEMs

Code Structure - Trigger



Code Structure - Trigger

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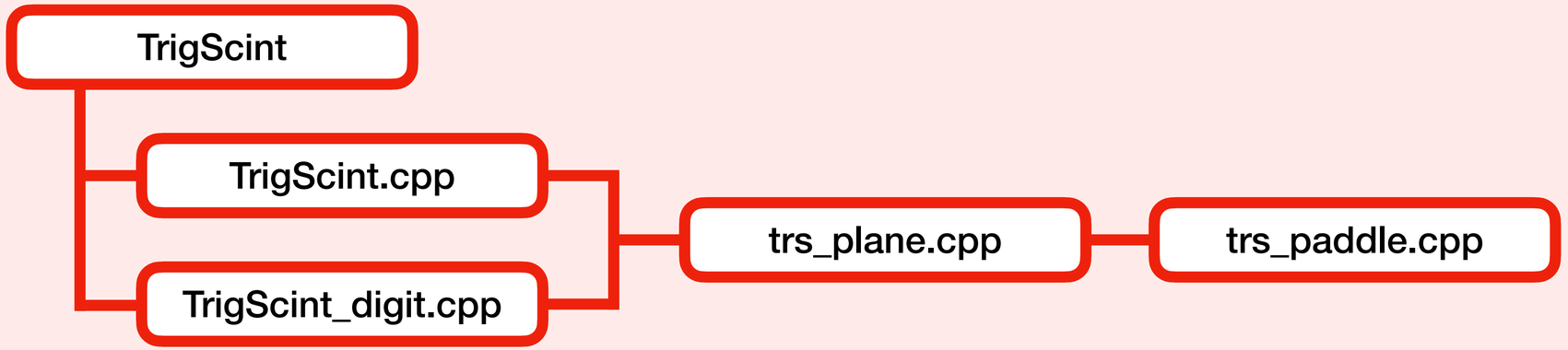


Parameters are set via Init/TrigScint.xml and stored to each paddle before startup:

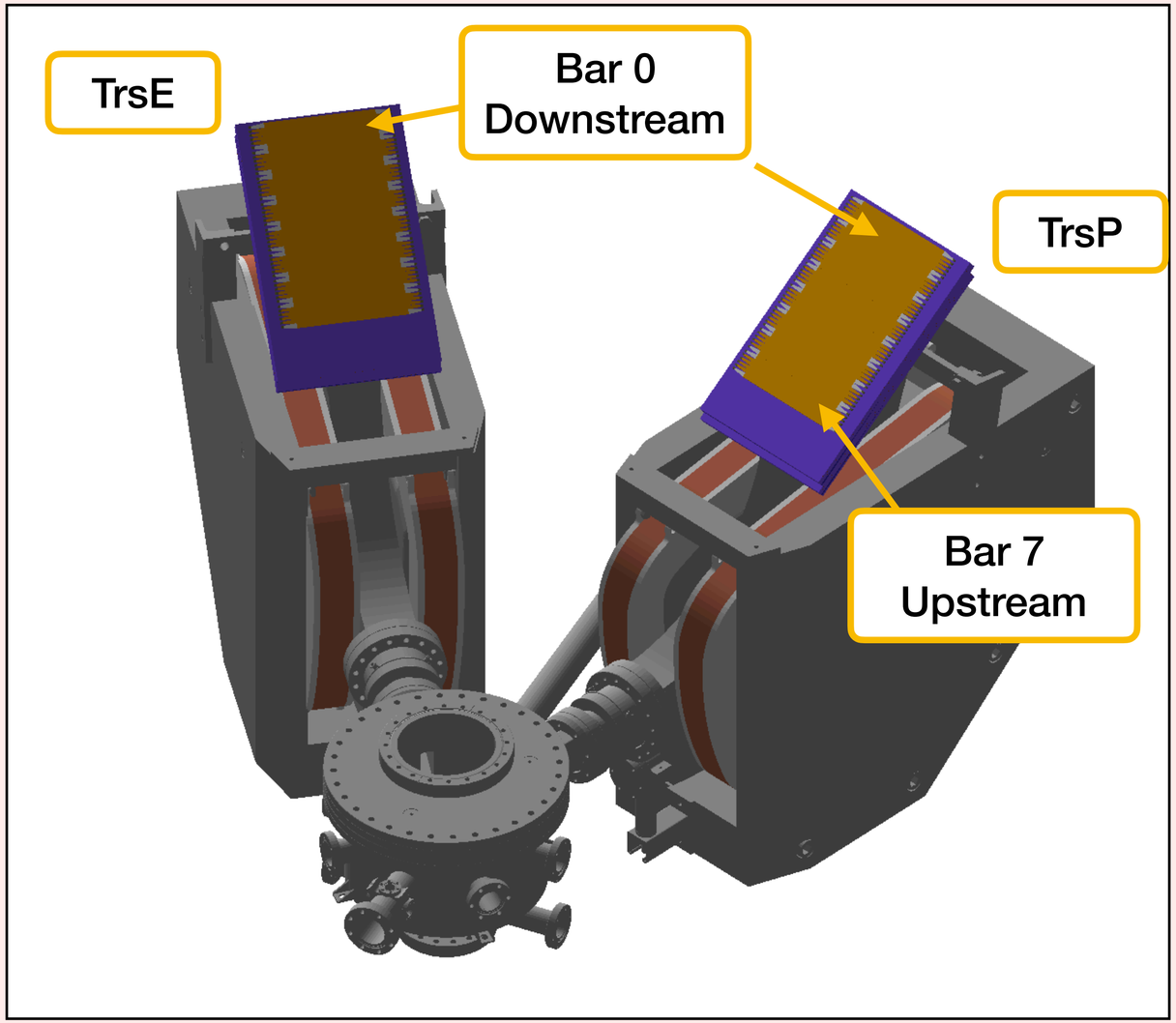
load_sc_calibration: set resolution, time alignment etc.

load_tdc_calibration: set time range of trigger events within trigger window

- Cooker command examples:
  - Digitization: **cooker recipes/TrigScint/trs_digit.xml <input Geant4 root file> <output file name>**
  - Reconstruction: **cooker recipes/TrigScint/trs.xml <output from digi> <output file name>**

Trigger Simulation

- Detector is added, but frame has not been added yet



Trigger Simulation

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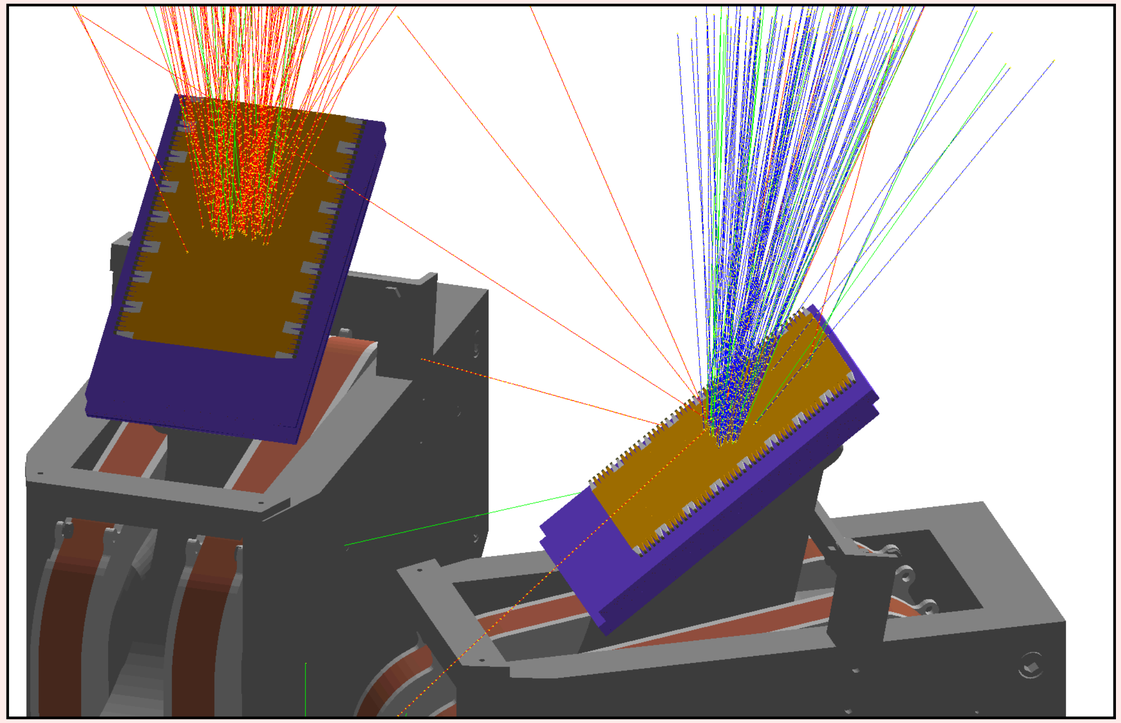
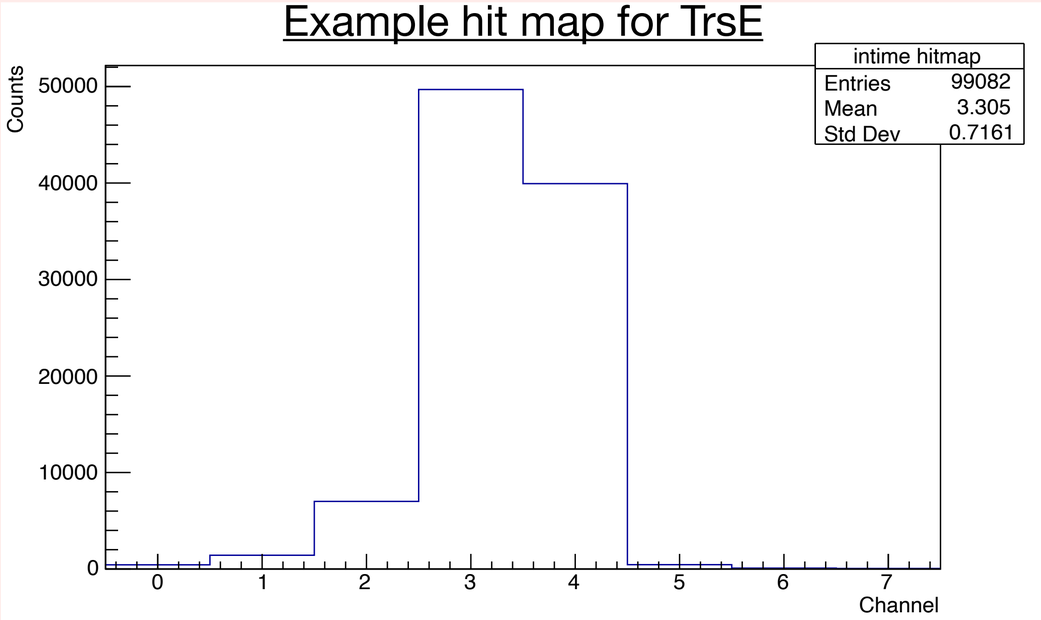
- Detector positions are chosen such that the beam particles hit roughly the centers

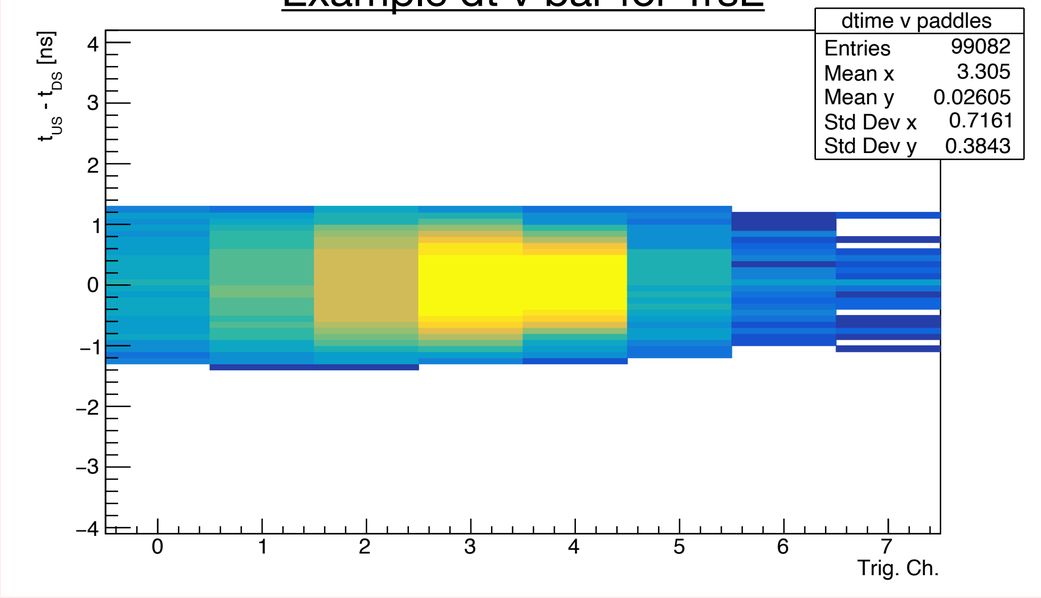
Validation mode with 30 MeV beam



Example hit map for TrsE



Example dt v bar for TrsE



Trigger Simulation

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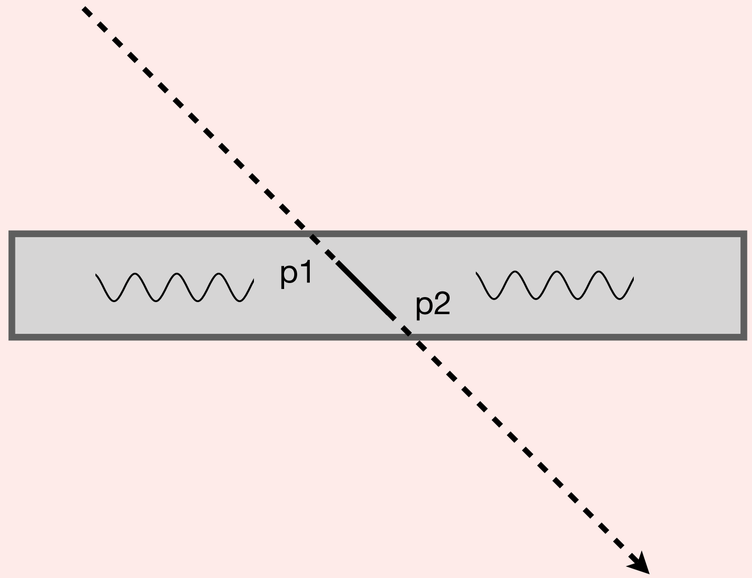
- For each event:
  - Total energy deposit in the scintillator is recorded
  - Hit time of beginning of the first step is recorded
  - Hit position is randomized between the beginning and ending of the first step: p1 + G4UniformRand() * (p2 - p1)



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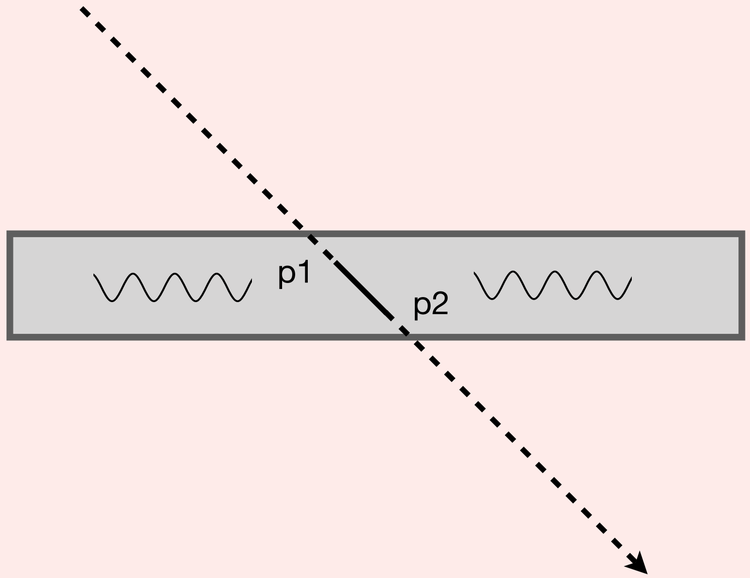

- dt = hit distance from end of bar / effective speed of light (need to be calibrated)
- Signal attenuation = $e^{-ax(1+bx+c\cdot x^2)}$, where x = hit distance from end of bar - 0.5; a, b and c are parameters that can be tuned (model used at MUSE)

Trigger Digitization

$$U = U_0 \cdot \exp\left(-\frac{1}{2}\left(\frac{\ln(t/\tau)}{\sigma}\right)^2\right)$$

$$U_0 = f \cdot E_{\text{hit}}$$

f : conversion factor related to SiPM efficiency

τ, σ : parameters that describe the shape of signal

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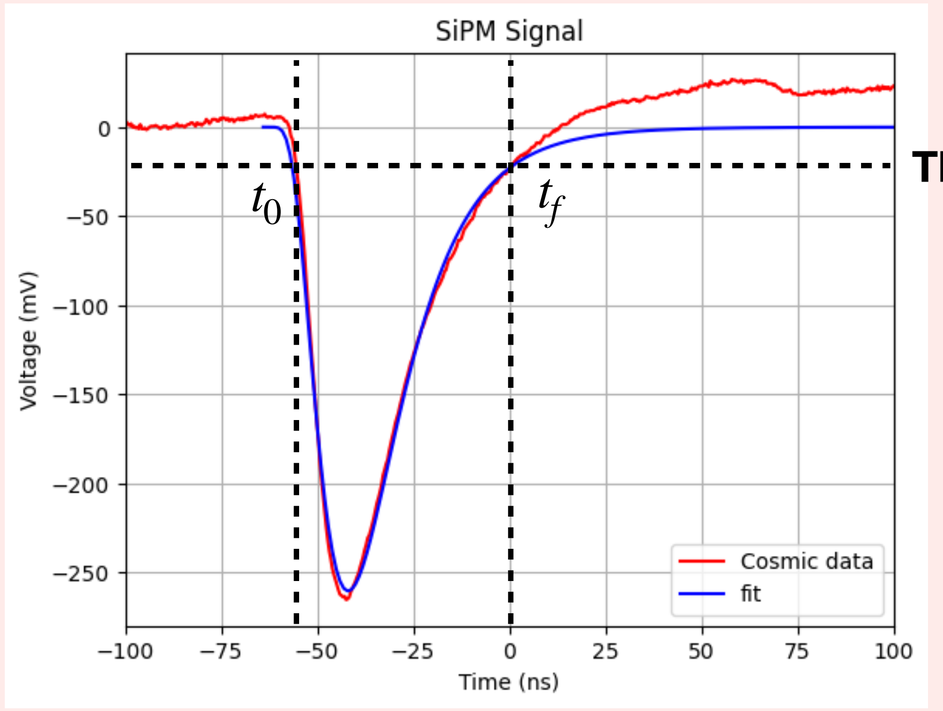
- Function is defined, with two parameters that can be adjusted for each channel
- For each event, the amplitude (U_0) is calculated from the attenuated signal
- To find t_0 and t_f, the code will solve the equation for the times when signal cross threshold (LD mode)



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- To find t_0 and t_f , the code will solve the equation for the times when signal cross threshold (LD mode)
- Once t_0 and t_f are found, t_0+dt and $t_f + \mathrm{dt}$ with added resolution are recorded for leading and trailing edge time

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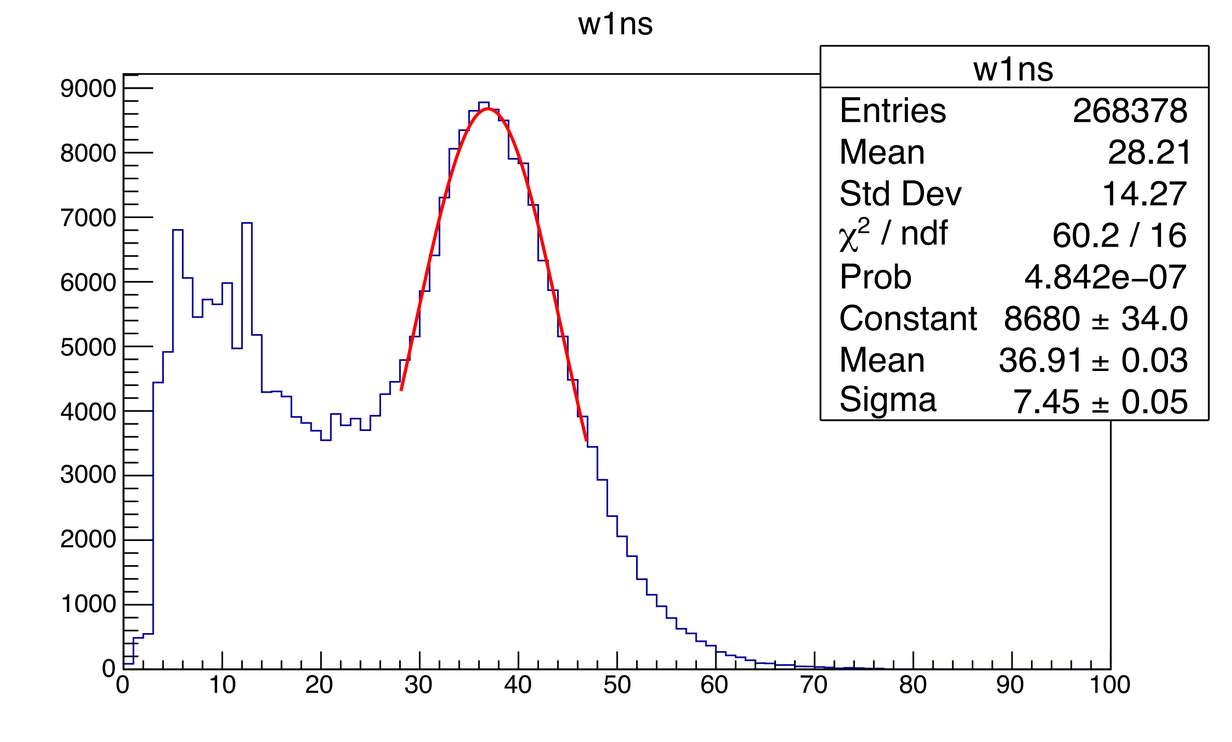
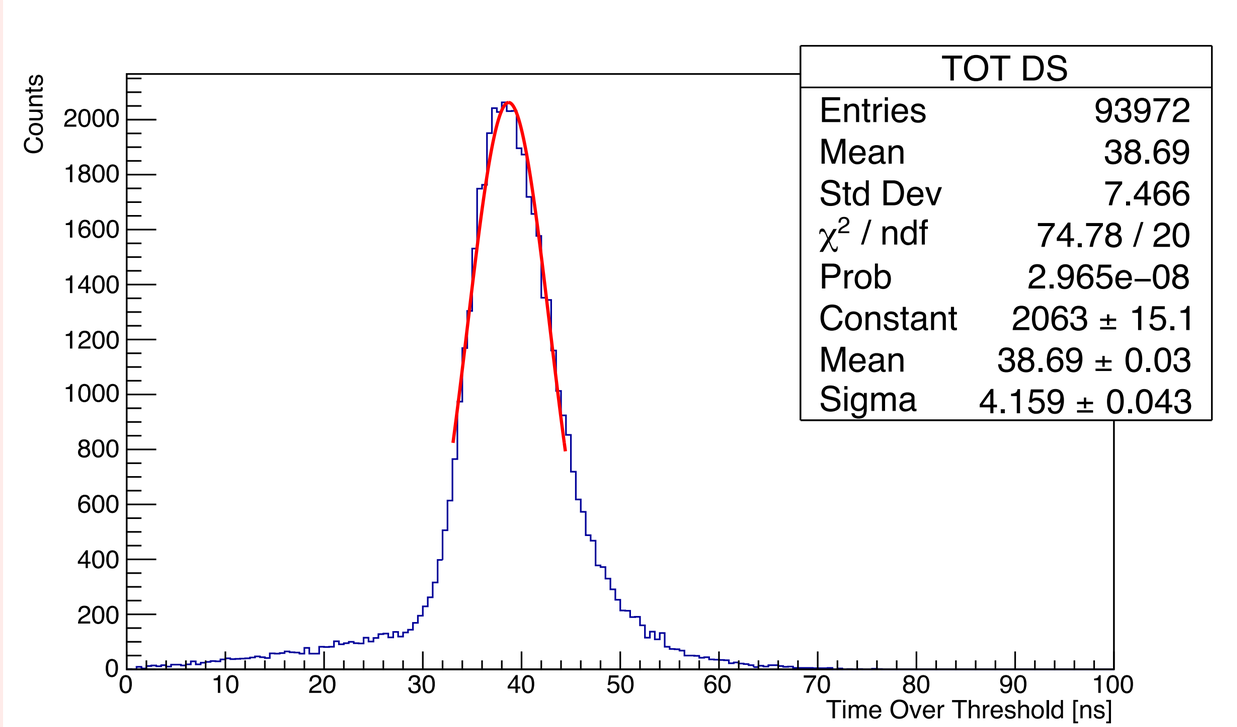
Timing comparison

Cosmic Data



Simulation, TrE03DS (with beam)



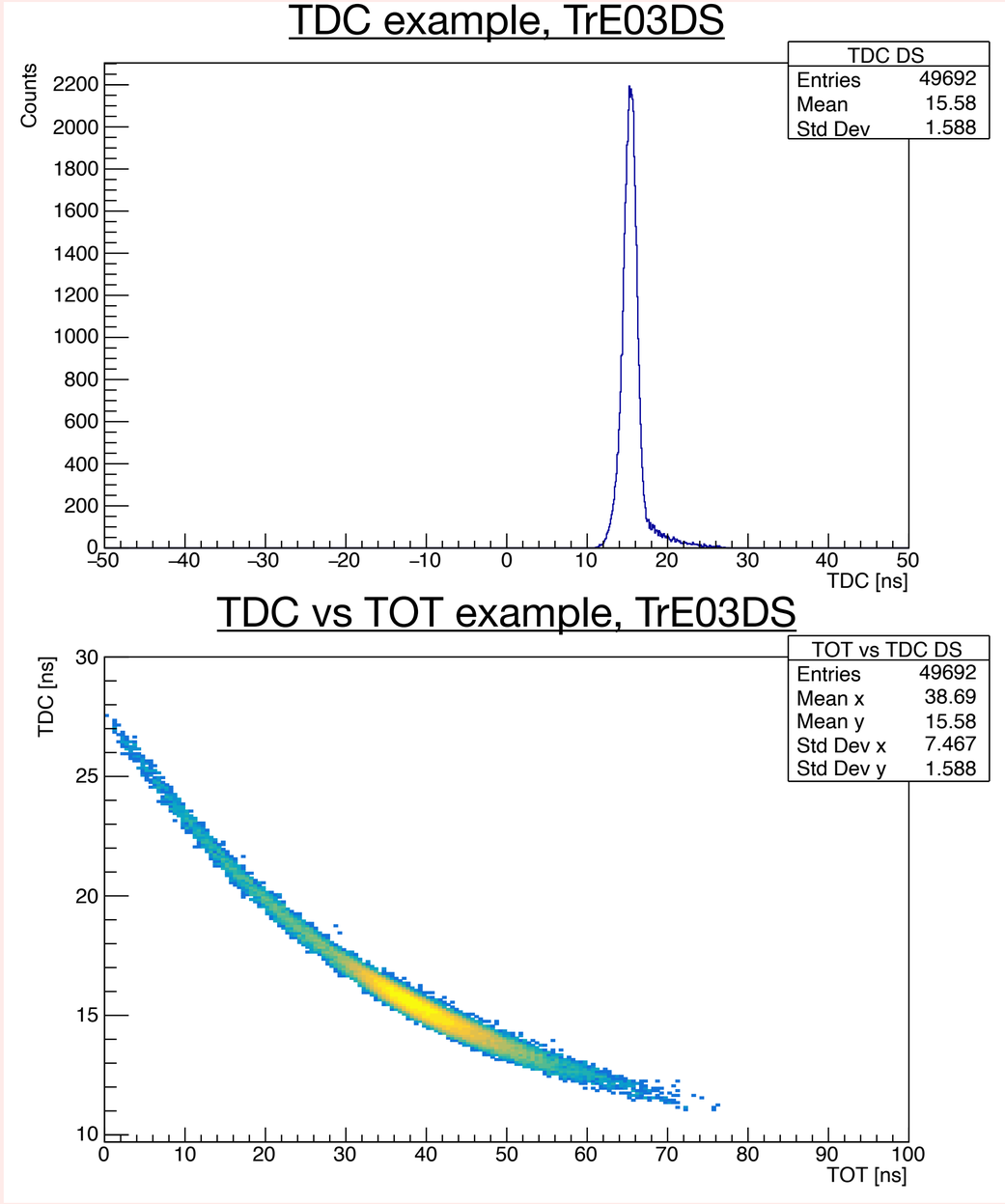
Current parameter used:

- Timing resolution added: 300 ps on each SiPM
- Threshold = 20 mV
- f = 70 mv / MeV, τ = 23, σ = 0.5

Trigger Analysis

- Only work for simulation right now. To analyse data we need mapping of electronics

- Simple timing and time over threshold plots are added
- Time over threshold will be used for time-walk correction
- Hitmaps and time difference plots are adde
- More are coming, will also look at correlation with GEM



Summary for Trigger

- Simulation, digitization and simple analysis are implemented

- To do:
  - Add detector frame to simulation
  - Fine tune digitization, compare simulated data with beam data
  - Acceptance study by varying the vertical position of the detector

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Thank you! :)

Questions? Comments?