SoLID 2022/23 beam test : GEM and Tracking

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(for Jimmy Caylor, Michael Nycz, Ye Tian, Darren Upton, Jixie Zhang, Zhiwen Zhao, Xiaochao Zheng

And the SoLID Collaboration)

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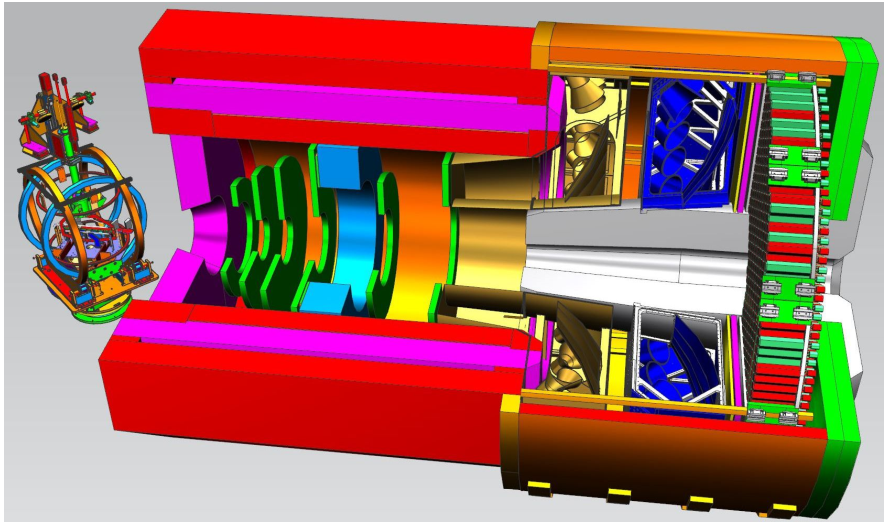


SoLID Tracking Status Overview

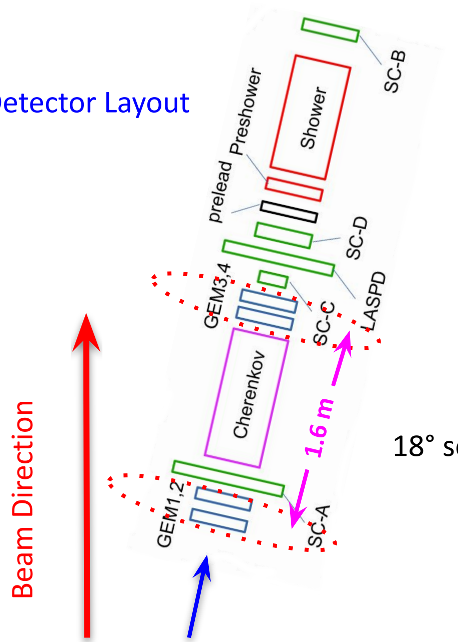
- Tracking software for SoLID is developed already (using SoLID G4 simulation data)
  - Main authors: Ole Hanson, Weizhi Xiong, et al
  - Software: https://github.com/xweizhi/SoLIDTracking
  - Tracking under magnetic field
  - Both PVDIS and SIDIS configuration
- This talk focuses on tracking for SoLID beam test 2022/2023 in Hall C
  - Straight line tracking under high background
  - Main purpose – help Calorimeter study – event selection purpose

Hall C Beam test setup (high rate)

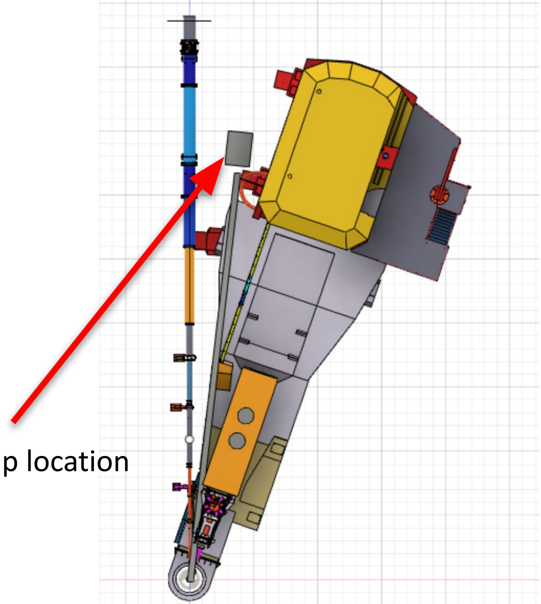
- Front to back GEM1+2, SC-A, Cer, GEM3+4, SC-C, LASPD, Preshower, Shower, SC-B
- Two test conditions: 7 and 18 degree
- GEM 1+2 and GEM 3+4 separation: 1.6 meters

See Mike's talk for all configurations

Detector Layout



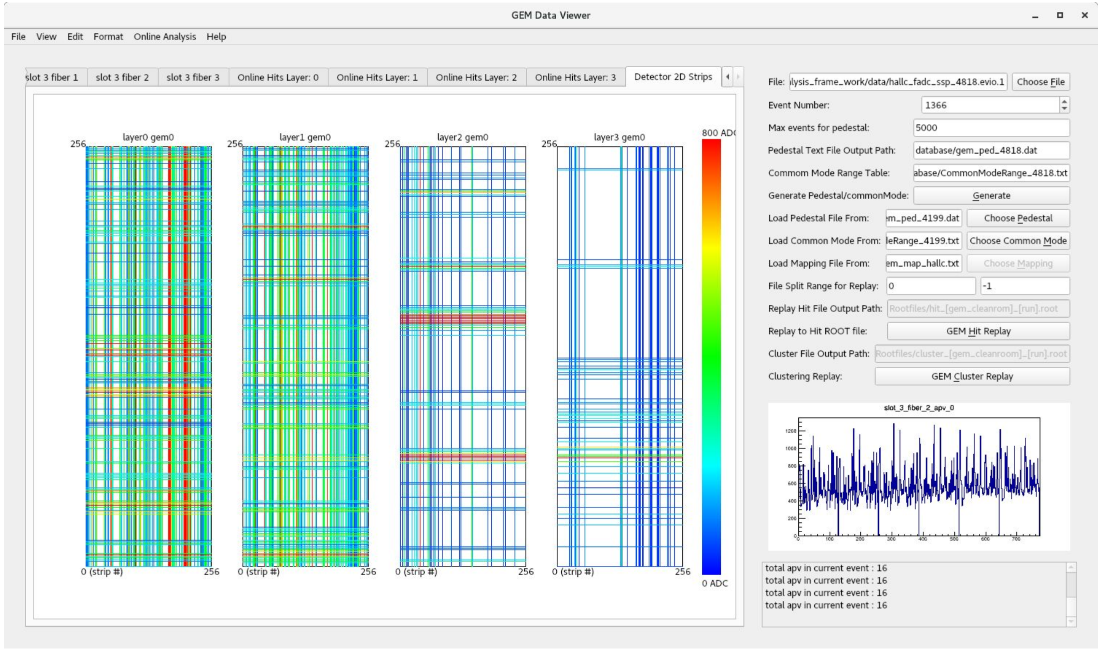
18° setup location



GEM Data Overview

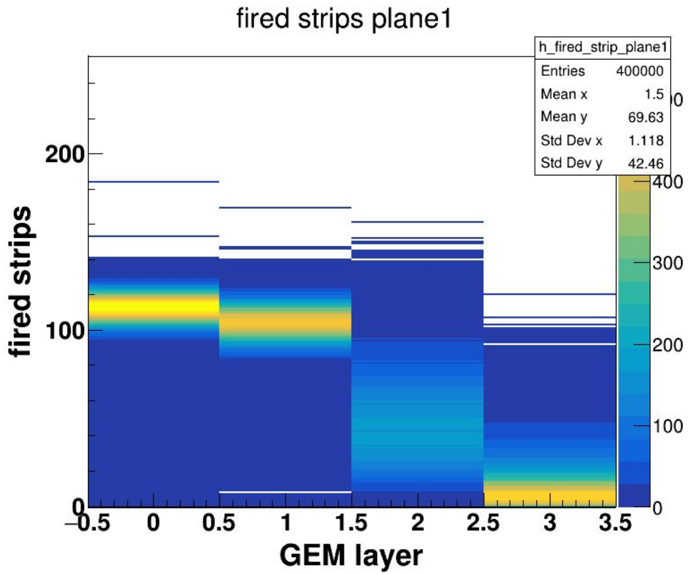
- 4 GEM layers, each layer 10 cm X 10 cm, in total 16 readout APVs
- Upstream two layers has significantly higher hits than the downstream two layers due to geometry coverage

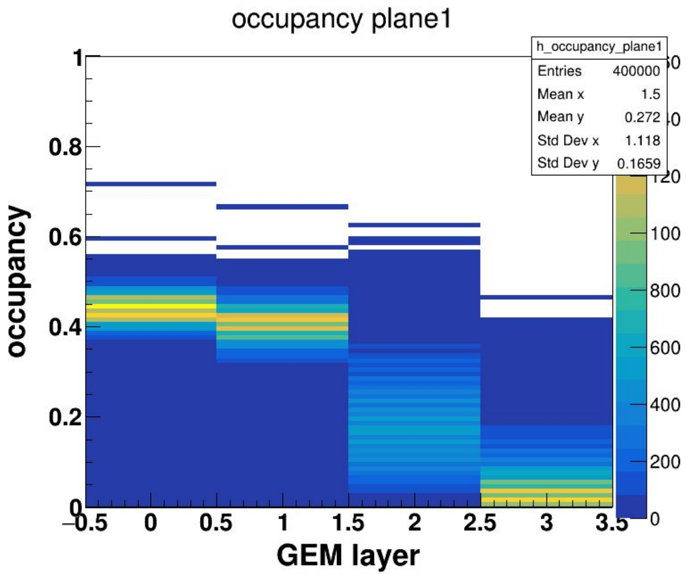
- Typical event after zero suppression
- Fired strips color-coded by ADC values
- Interested physics track quantity per event : 1 ~ 2



GEM Data Overview

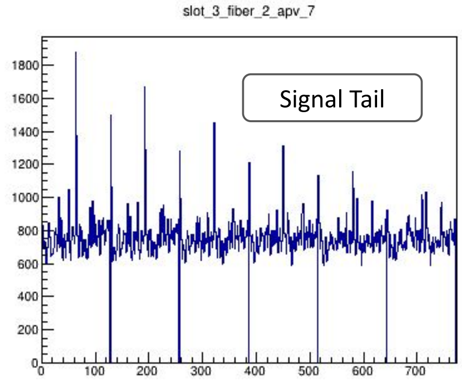
- Data from 18 degree configuration (beam current ~70 uA)
- Occupancy for the upstream (downstream) 2 detectors : around 40% (around 10%)

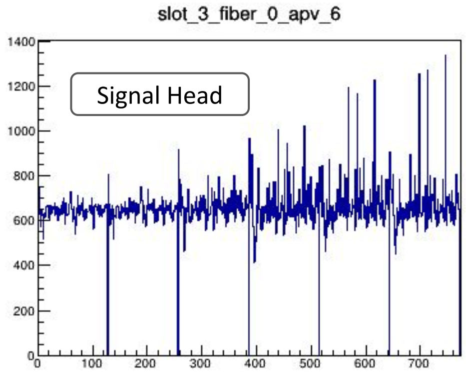


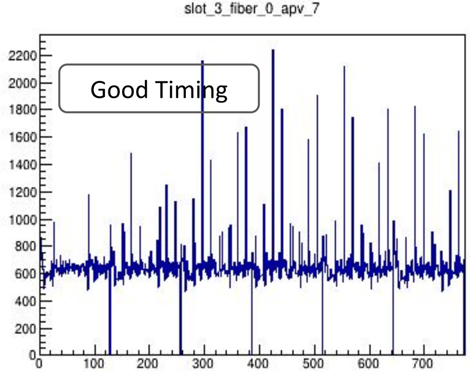


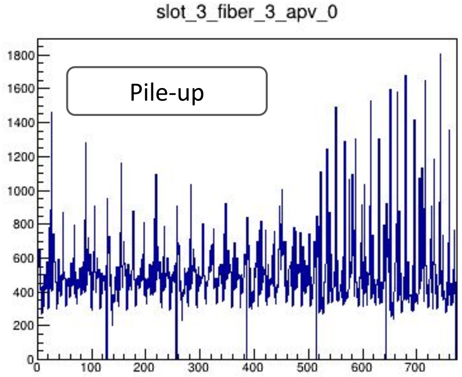
GEM Data Overview – All Types of Signals

- High background – observed all types of signals – good reference data for benchmark SoLID simulation



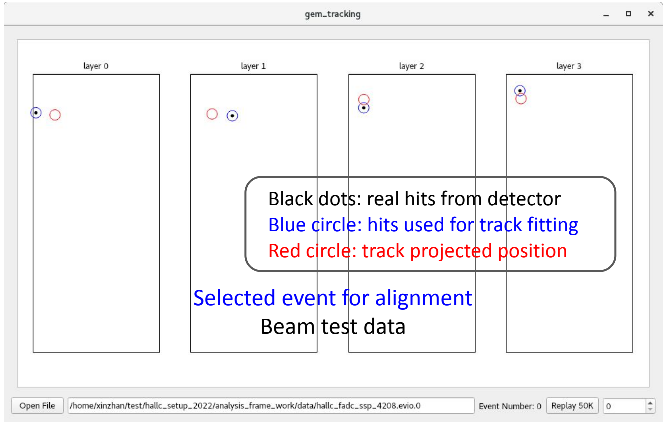


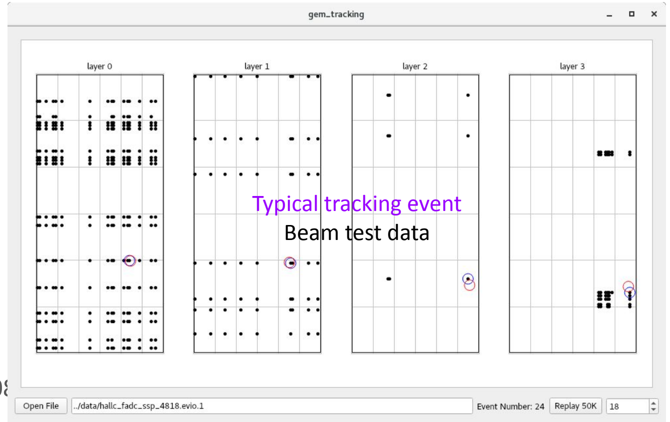




Beam Test Tracking Overview

- Alignment
  - Beam test is parasitic, we don't have dedicated optics run
  - Use low multiplicity events for alignment
  - Choose low beam current runs
- Tracking
  - Track finding – assigning hits to tracks
  - Track fitting (we used 2 algorithms)
    - Standard chi2 minimization
    - Extended Kalman Filter – testing ongoing

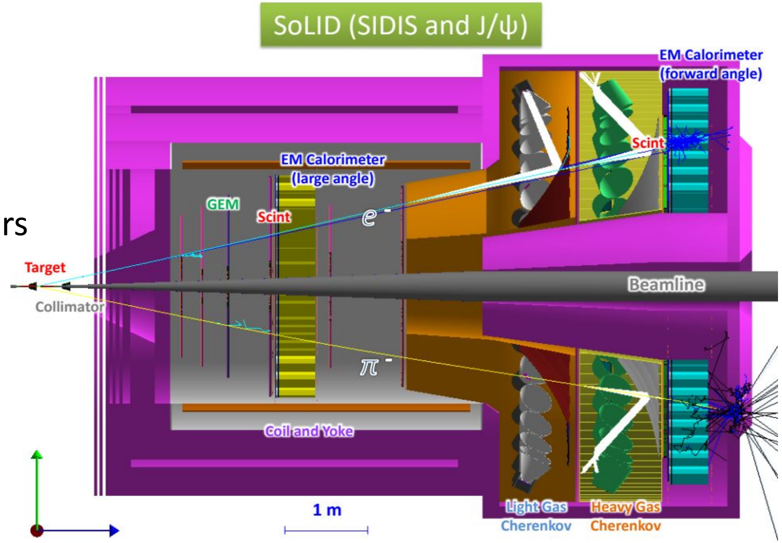




J. Phys. G: Nucl. Part. Phys. 29 (2003) 561–574

Alignment Algorithm

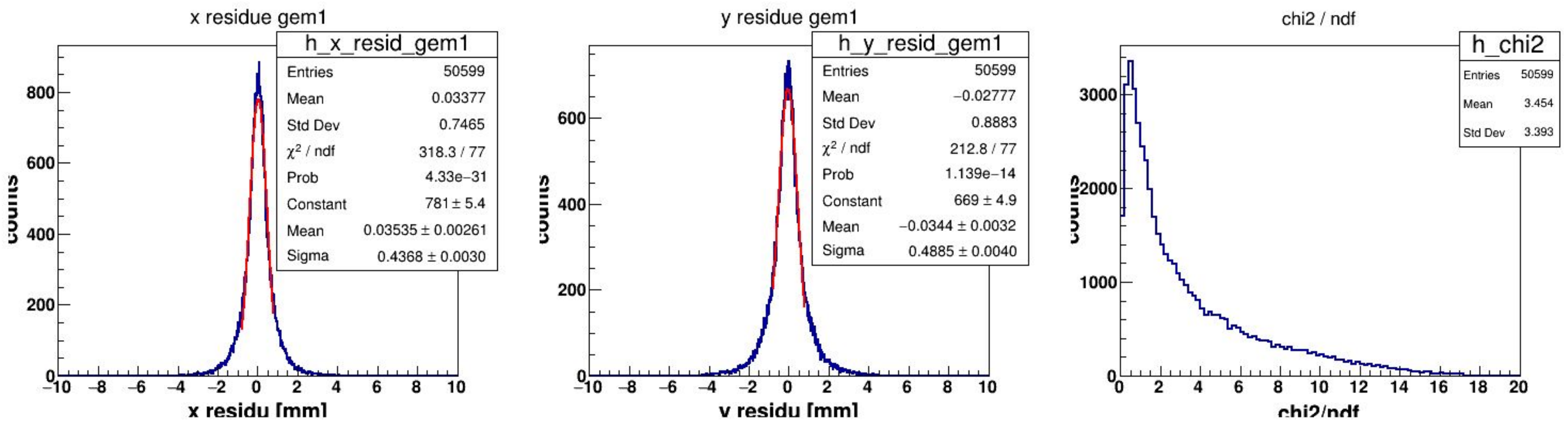
- For beam test, 24 alignment parameters in total (including 3 offset parameter and 3 rotation parameter for each detector)
- Future SoLID spectrometer: several thousand alignment parameters
- We implemented Millepede Algorithm for alignment – also commonly used in LHC-Alice/CMS/Atlas experiments
  - Chi2 minimization
  - Proved ability to handle 10^4 level alignment parameters
  - Translation, Rotation, Deformation parameters
  - Accounts for multiple scattering along the track
  - Constraints added through Lagrange Multipliers



V. Blobel, Nuclear Instruments and Methods in Physics Research A 566 (2006) 5–13

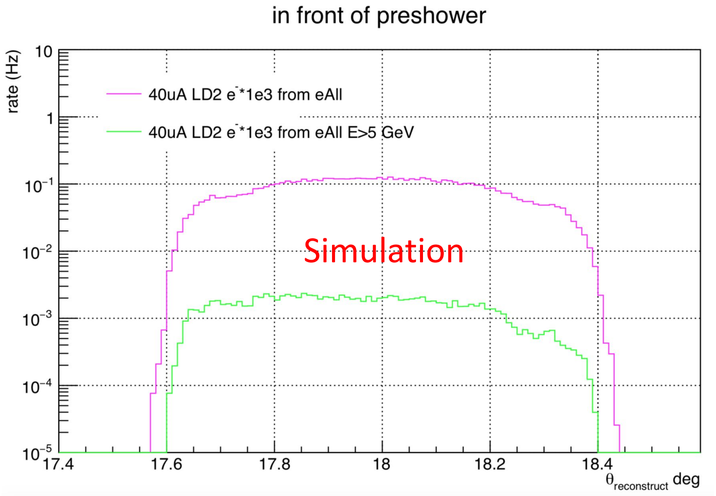
Beam Test Alignment Results

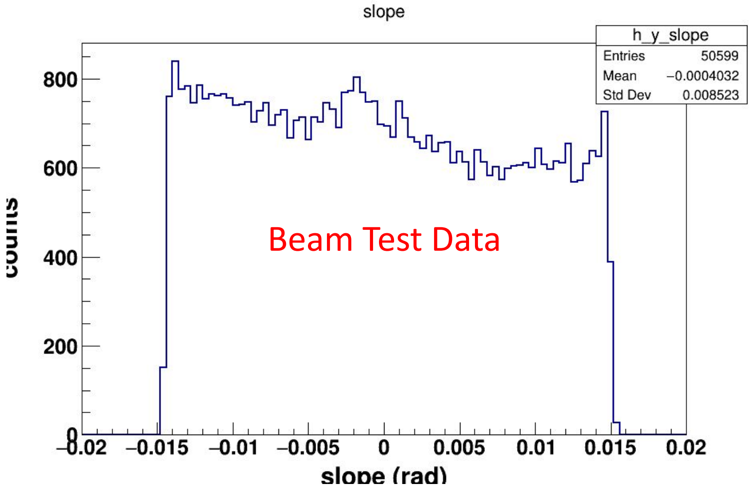
- Major issues: high background hits, no dedicated optics run, no survey data
- Didn't find many events that are good for alignment purpose – have to use high multiplicity events
- Residue standard deviation after alignment: 0.5 mm, still needs to improve (main reason is assigning hits to tracks is not reliable)



Beam Test Alignment Results

- Use simulation study to help beam test data analysis
- Get track characteristics from simulation, and use these characteristics as cuts for beam test data
- Right side is lower due to a low-gain APV card

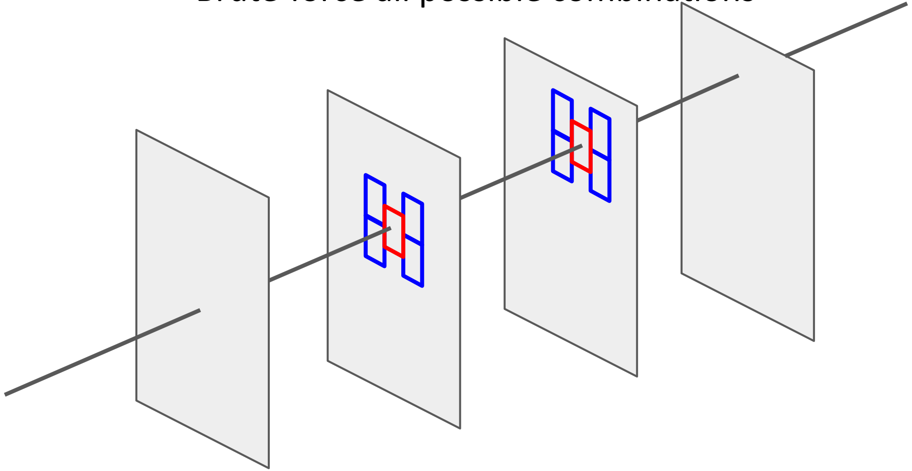


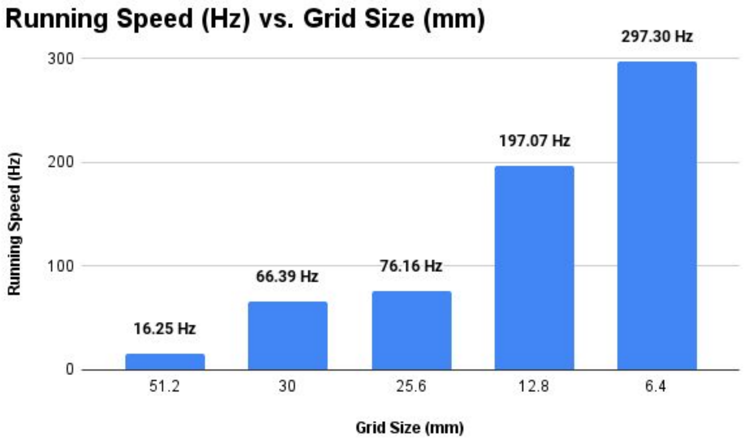


Simulation plot from Ye Tian (Syracuse)

Beam Test Tracking Algorithm

- Grid each middle layer
- 1st layer and last layer no grid, use all reconstructed hits
- Loop through all combinations between the first layer and the last layer
- Brute-force all possible combinations

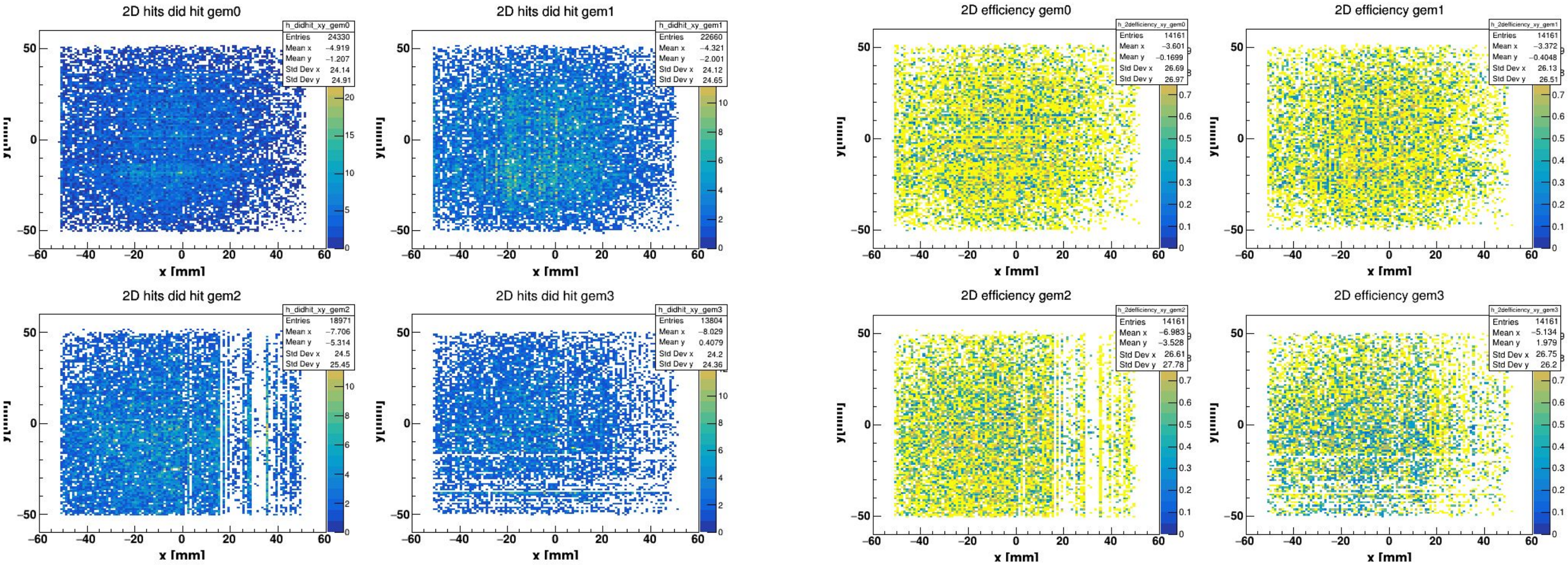




Offline data analysis speed

Beam Test Tracking Result

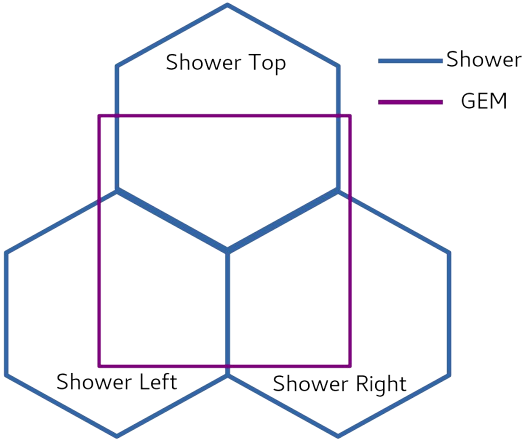
- We have a low gain APV cards 3rd GEM detector (right section of X axis)
- Average tracking based GEM detector efficiency > 70%

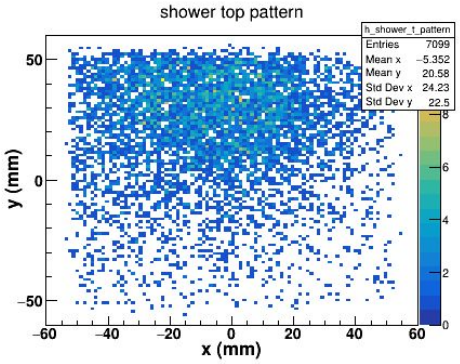


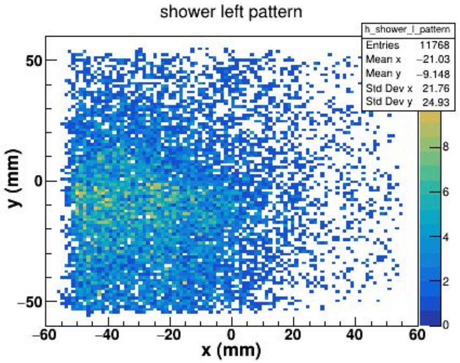
Beam Test Tracking Result

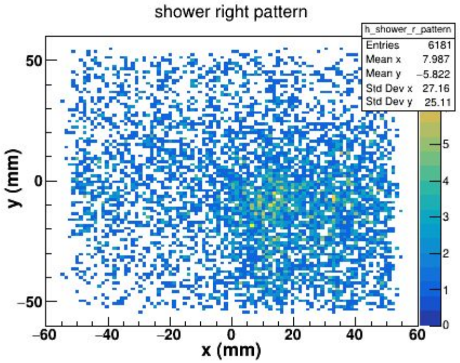
- Track projected hit pattern under different Shower energy Cut

GEM and Shower Layout



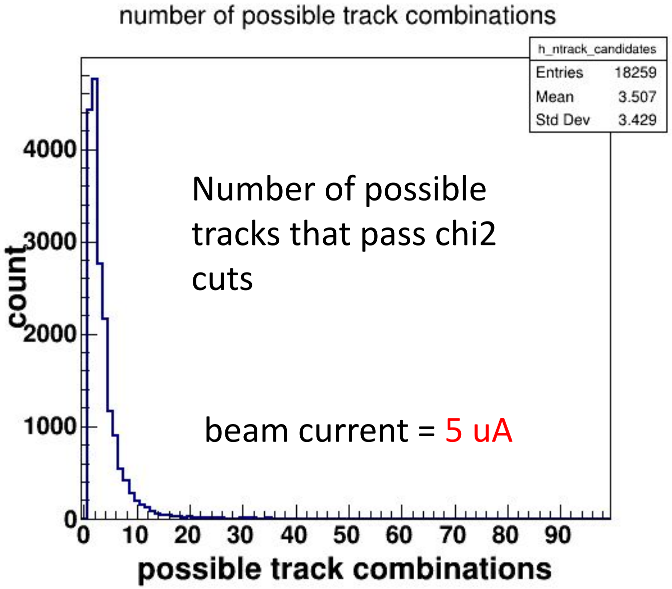


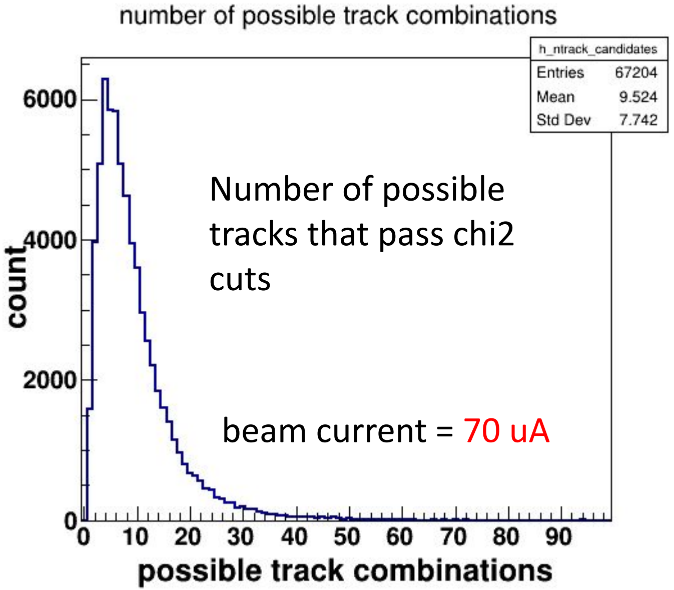




Beam Test Track Reconstruction Efficiency

- Due to higher background under higher beam currents, number of possible track combinations increases with beam current
- More fake tracks under high beam current – decreased probability of finding the real track
- Fraction of a track being true 82.6% (5 uA), 54.6%(70 uA) – very rough estimation





Summary & Remarks

- Current concerns
  - Beam test is a parasitic run, no dedicated optics run, no GEM survey data
  - Due to high background, there’s really not many events that are proper for alignment (even low beam current runs have high background hits)
  - Track finding stage is not very reliable, leading to unreliable offset correction
- What could be done to improve next
  - Continue fine-tuning GEM raw signal cuts to further optimize reconstructed hit multiplicity from GEM detectors
  - Choose low beam current periods, especially beam ramp-up period after beam trip for each run

Backup Slides

Track Validation for Beam Test

- Rough estimation of whether a track is true or fake
- Using shower module cut, if the track projected position falls within the mapped shower module range, then the track is likely true, otherwise false
- Low beam current (5 uA), 82.6% of tracks falls within corresponding shower module range
- High beam current (70 uA), 54.6%