Offline Software, Simulation, and Tracking Updates

02-12-2020

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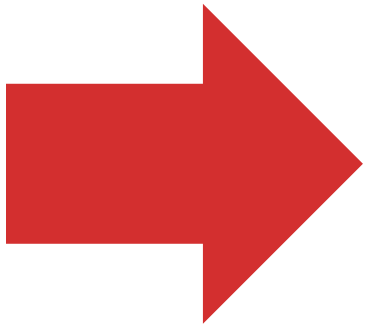
StRoot Tracking : https://github.com/jdbrice/star-fwd-integration

Forward Software : Bird's-eye view

- Online Systems
  - Slow Controls
  - Online Plots
  - Online Database
  - HLT for real-time analysis
- Simulation and Tracking
  - Detector Geometries
  - Detector Response Simulations
  - Offline Tracking Software
  - Track 2 Calo Matching
- Data Reconstruction
  - Offline Database
  - Alignment Calibration
- Documentation



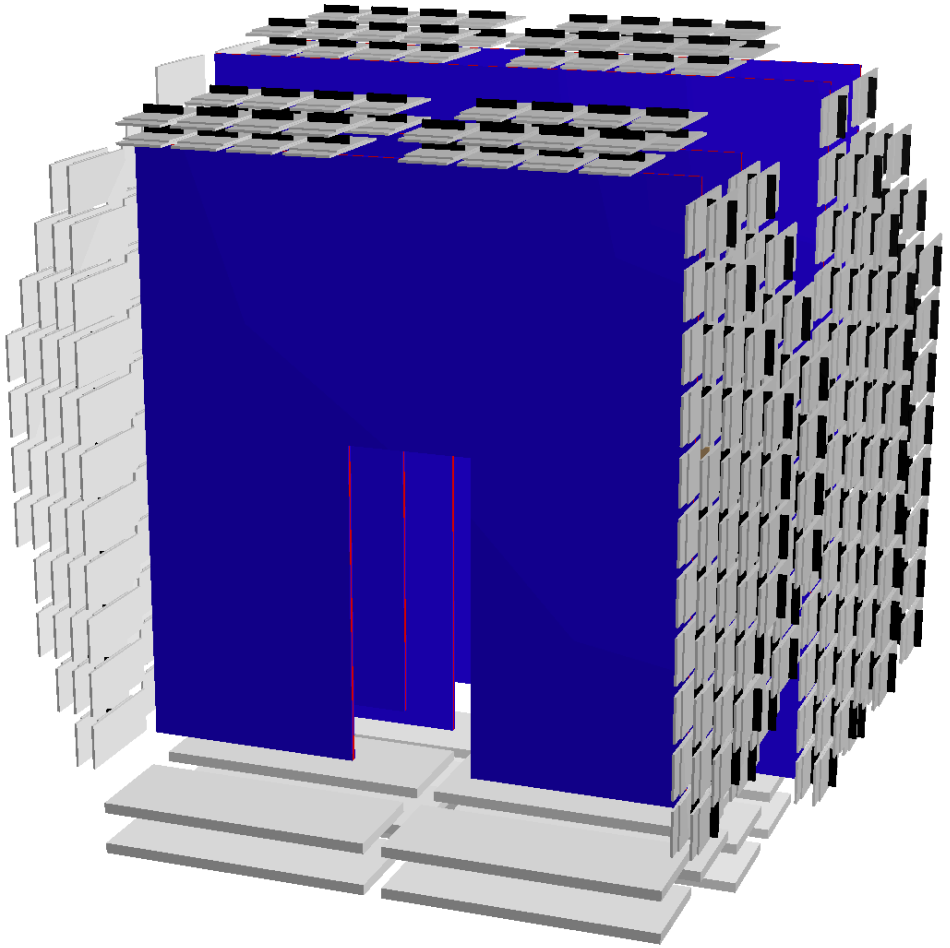
- Forward Tracking
  - Forward Silicon Tracker
  - Forward sTGC Tracker
- Forward Calorimeter System
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter
  - …

Outline

- sTGC Tasks:
  - sTGC Geometry updates for symmetric pentagon
  - sTGC software progress
  - sTGC Online plots
- FST updates
  - FST precise z-locations
- Tracking and simulation
  - Differential tracking performance
  - First results from full Pythia8 events

Current geometry

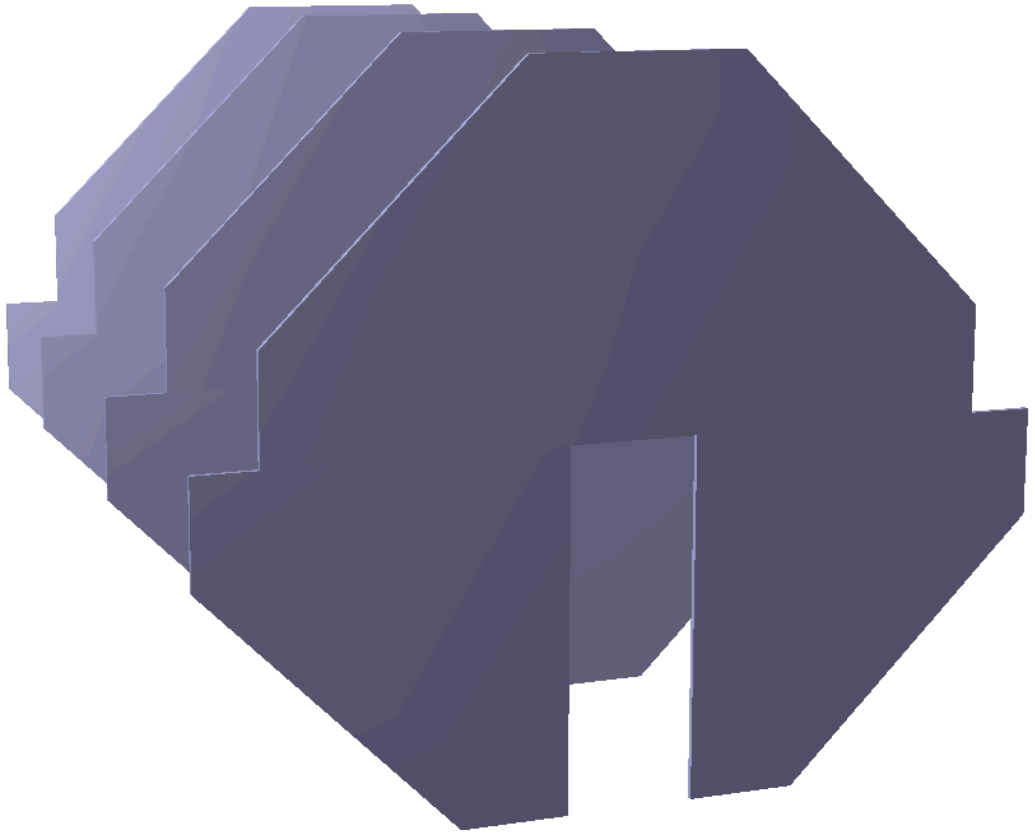
- Current geometry uses the rectangle sections with (a lot of) TPC FEES
- New geometry is hard because pentagon is not an option from TGeoXXXXX classes
- Simplest approach is TGeoXtru



Pentagonal geometry

- Current geometry uses the rectangle sections with (a lot of) TPC FEES
- New geometry is hard because pentagon is not an option from implemented TGeoXXXXX classes
- Simplest approach is TGeoXtru
  - BUT not supported by AGML
  - I spent some time trying to implement it, very non-trivial
  - Requires significant updates to AgML core and parsers
- Following up with Jason

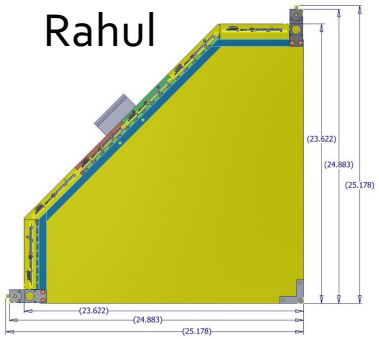
sTGC geometry using TGeoXtru in ROOT

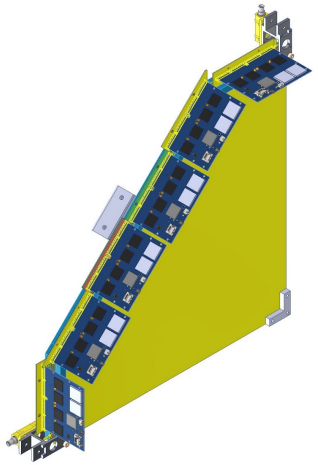


ROOT sTGC Geometry

- Build sTGC geometry with TGeoXXXXX (ROOT classes)
- Jason can convert this to AgML
  - One of us still will need to implement the TGeoXtru class
- Includes: PCBs, Gas volume, metal brackets, plastic support, cooling tubes (partial)
- Some updates needed:
  - Supports and cooling tubes -> full station instead of single pentagon
  - Build tube curves / holes in plastic
- https://gist.github.com/jdbrice/d425410556e9f1ac22d7567872598e90

Based on CAD reference from Rahul





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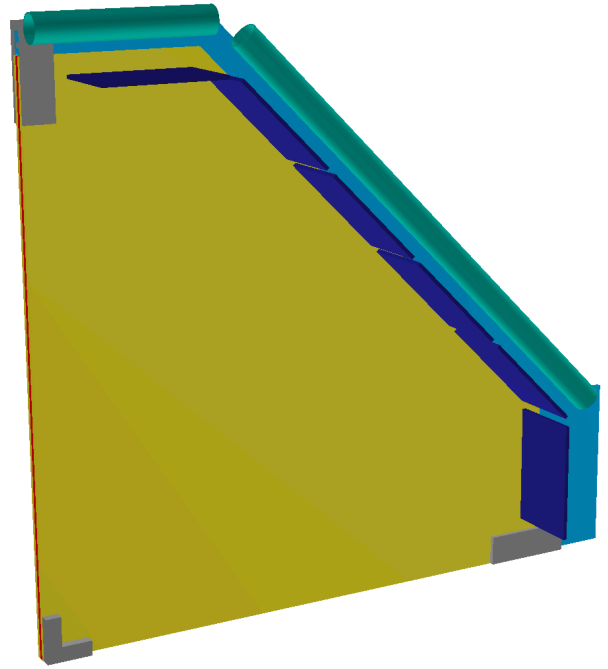

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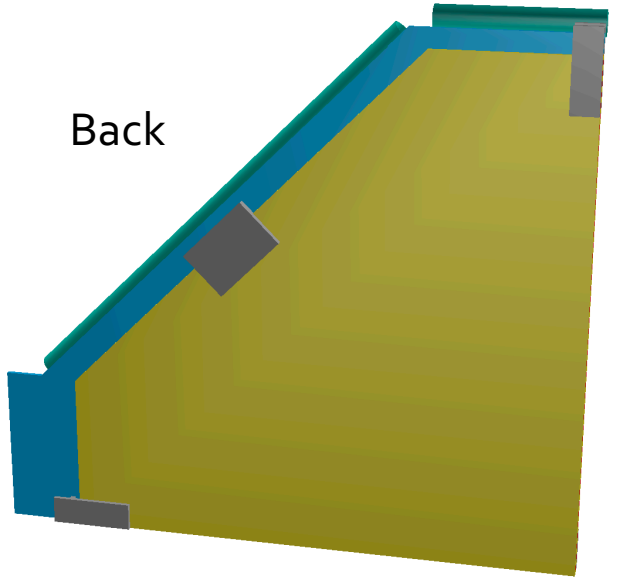
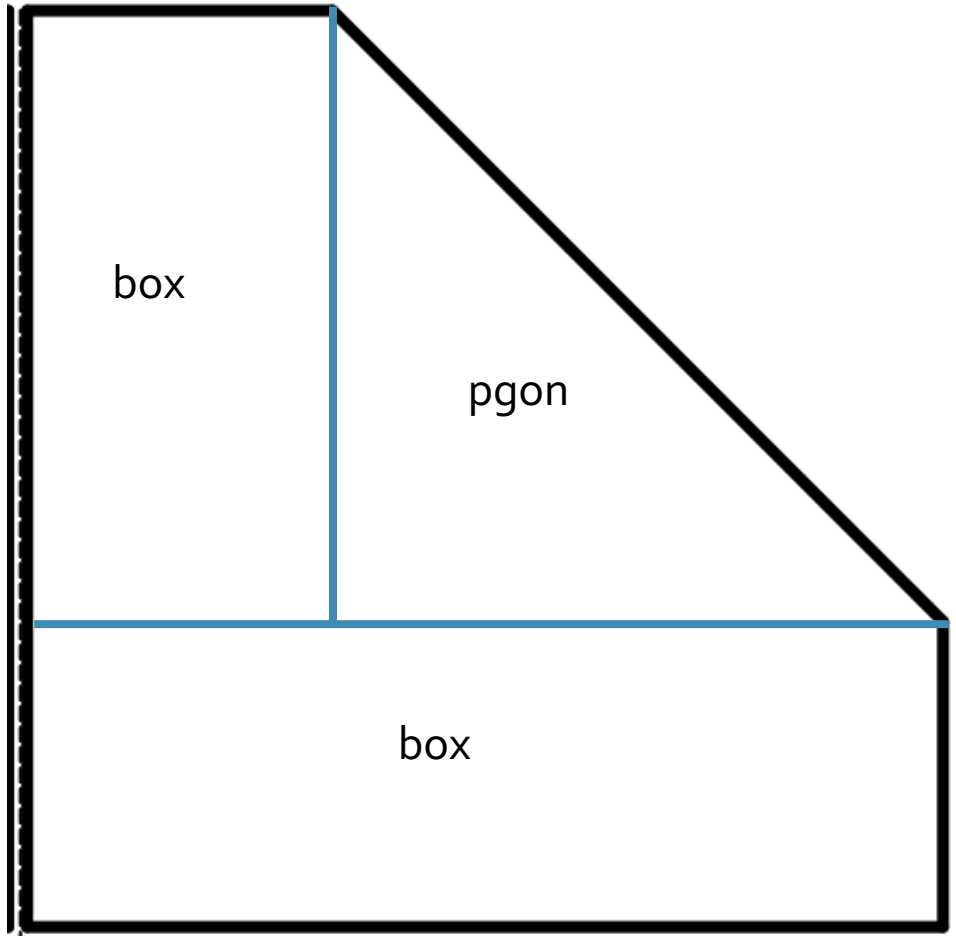


Pentagonal geometry

- If TGeoXtru is too much work
- Instead segment the pentagon into two rectangles (box) and triangle segment (pgon)
- Easy enough, some concern about edges – possible for overlap or missing hits?
- However, even though pgon is listed as supported in AgML – no use in any other STAR geometries, and couldn't get it to work.
- Will discuss with Jason



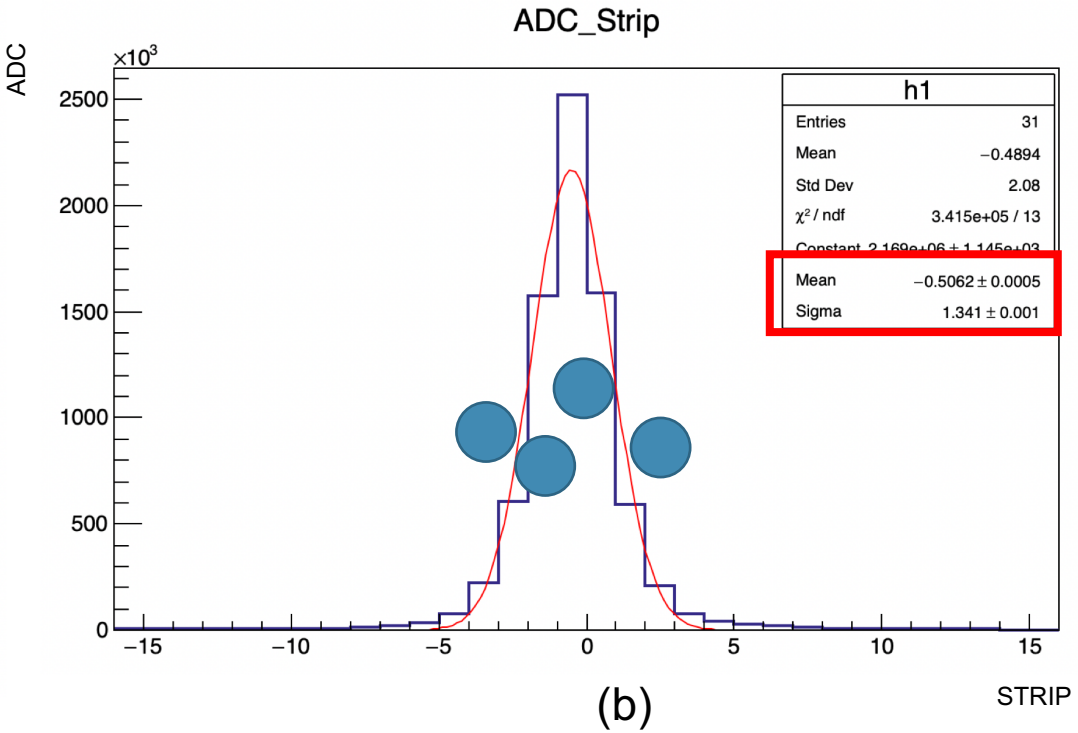
sTGC Cluster Simulator

- Integration of Zhen Wang's work on sTGC cluster sim + reco
- New StRoot Packages
- `StFttSimMaker`
  - `StFttClusterSimMaker : Generates ADC level clusters for sTGC. Based on earlier work from Daniel and Zhen`
- `StFttUtil`
  - `StFttClusterMaker : Cluster algorithm (if online, incorporate into StFttClusterSimMaker)`
    - `OUTPUT : Cluster parameters x3 for (X, D, Y)`
  - `StFttSpacePointMaker : Converts clusters into space points. Maps into local + world cords, algorithm for X+D+Y combination?`
    - `OUTPUT: Space points and covariant matrices`
- These are all setup as skeletons for now
  - ClusterSimMaker & ClusterMaker : Basically working per Zhen's last version
- However, 'glue' is missing → StEvent structures needed for all this
  - Still unsure of VMM format, but working on structures for later formats (space points)

Clusters in sTGC

- Proposed update to FastSim based on work from SlowSim:

- Sometimes tracks produce showers/secondaries
- Common for multiple hits very nearby (within one cluster width)
- Currently very challenging for tracker to handle
- Basic clustering of hits in FastSim via gravity center?
  - Add basic parameters to control how aggressively it combines hits



GEANT hit

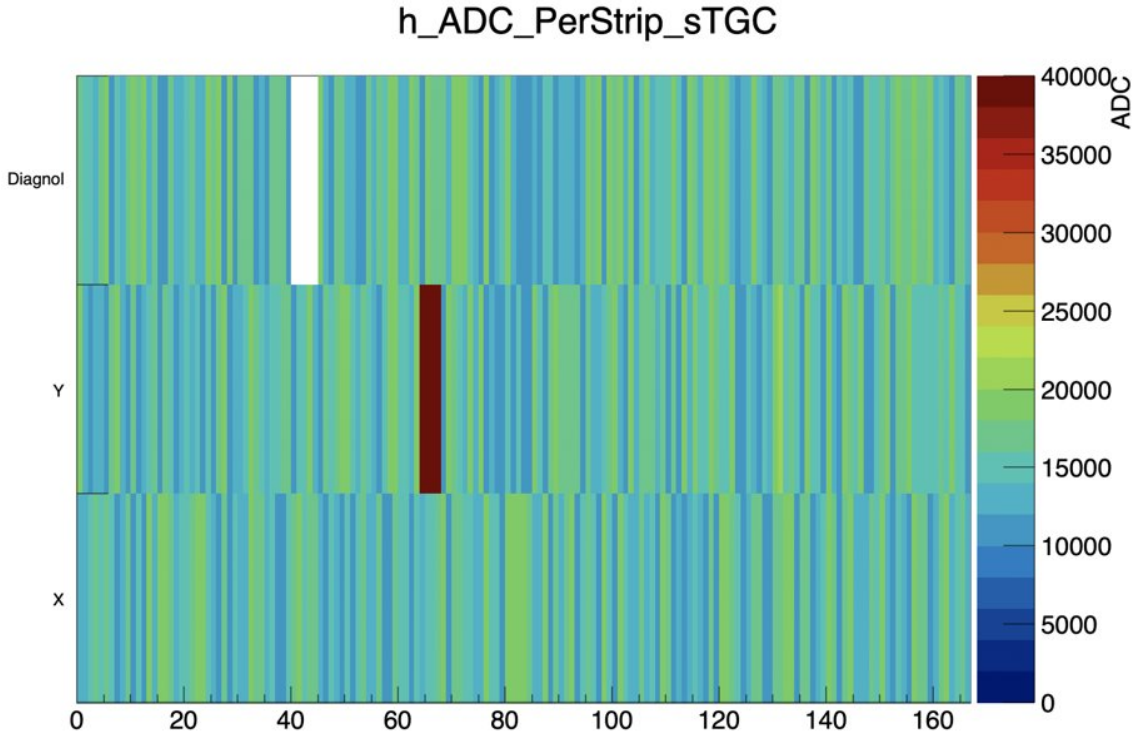
sTGC Online plots

1. Raw ADC per strip
2. # of Clusters per event (multiplicity)
3. Hitmap (combine clusters into space points)
4. Efficiency plots
5. Possible Additional Plots

Raw ADC per strip readout

- DEMO similar to ETOF layout
- ADC integrated over course of run
  - Identify hot strips/readouts
- Show X, Y, diagonal separately
- ADCs reported directly in readout channels (no mapping)

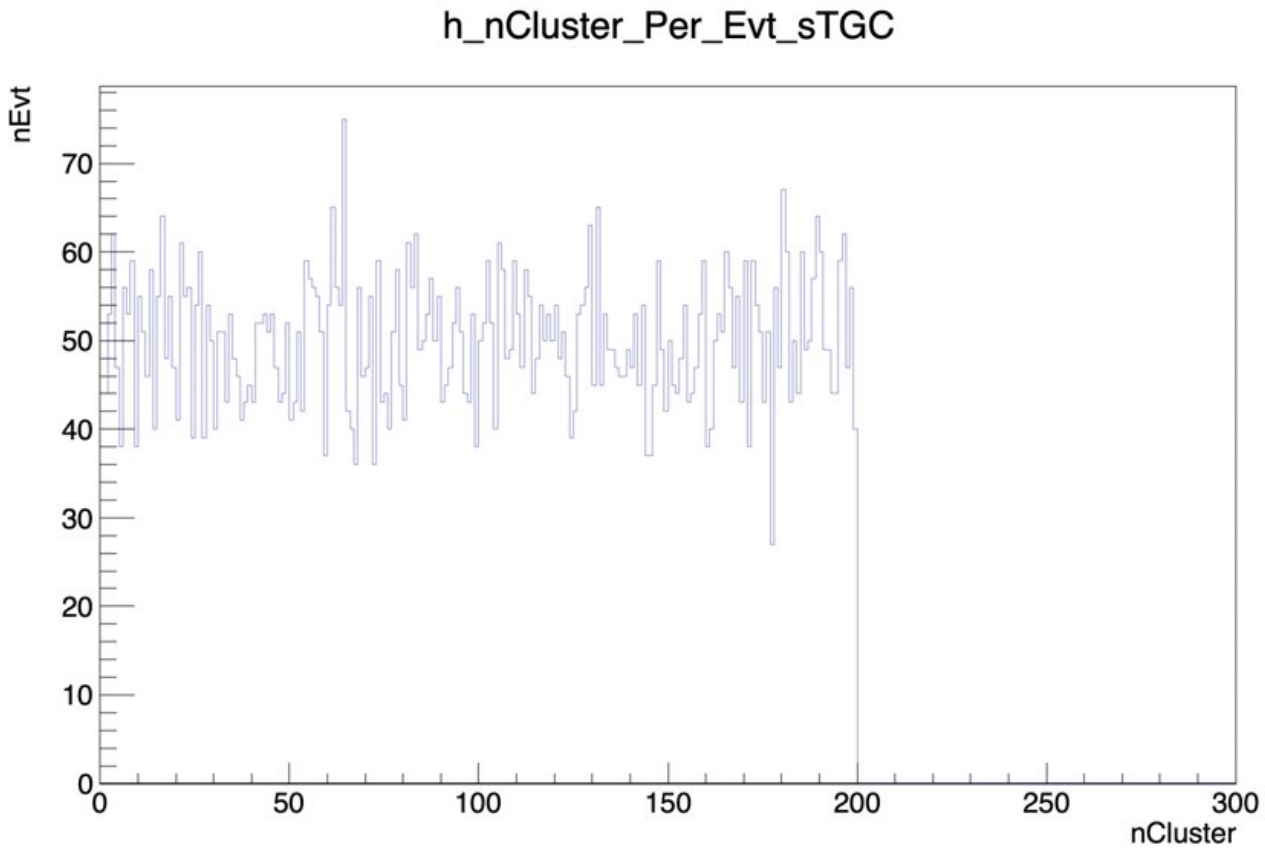
- x4(modules) x4 disks = 16 plots



#Clusters / Event

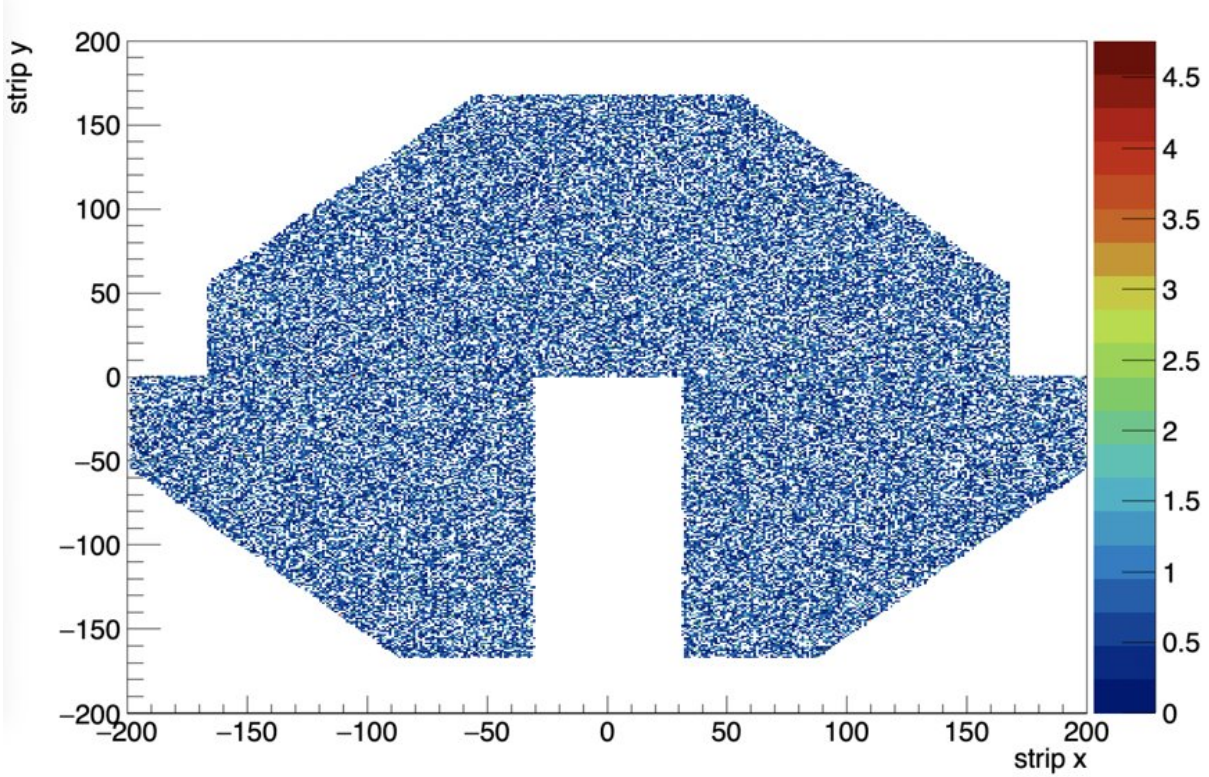
- DEMO similar BTOF hit multiplicity plots
- Number of clusters/event recorded over course of run
  - Already some idea of efficiency
- Show X, Y, diagonal separately (separate curve, same plot)
- Motivation for online cluster finding

- x4(modules) x4 disks = 16 plots
- Could add more showing clusters in total sTGC, or difference between overlapping modules



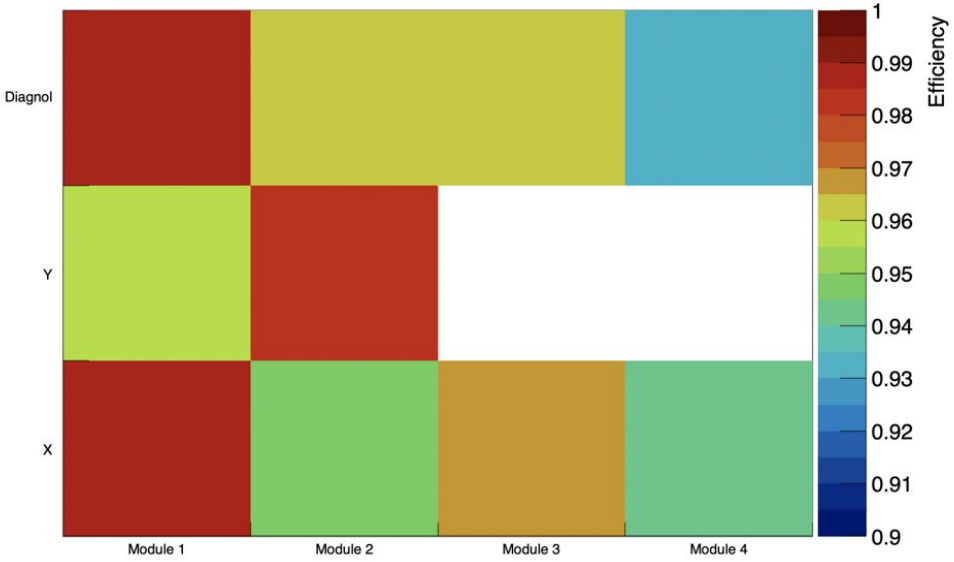
Raw ADC per strip readout

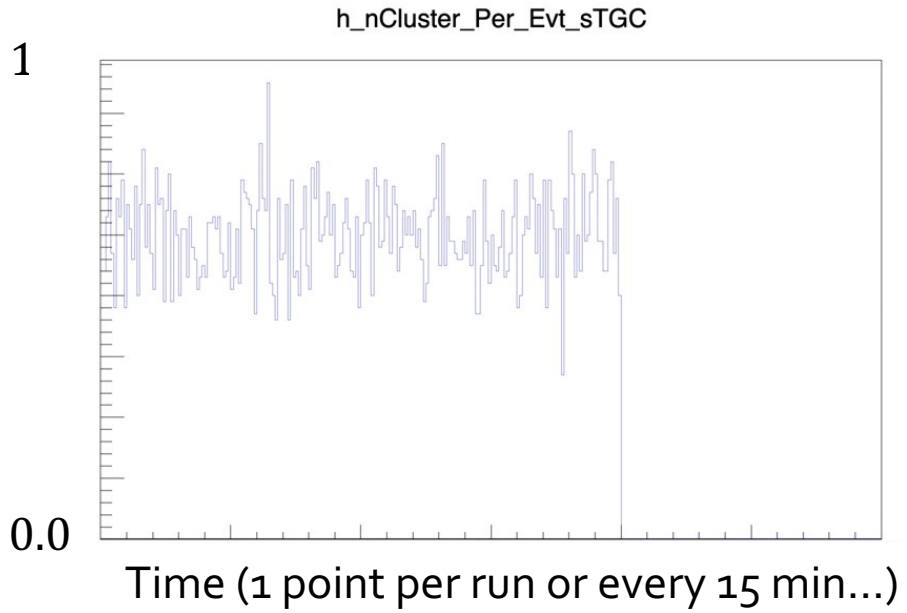
- DEMO similar to EPD detector hitmap
- Requires channel maps
  - Map electronics -> local
  - Map local -> world
- Requires space point algorithm
- Identify hot regions of detector
- x4 disks = 16 plots
  - If plotted as full disk shown here
- Optional: Space points / event plotted as phi & eta distribution



Raw ADC per strip readout

- DEMO Efficiency plot
  - TOP: Efficiency within this run averaged
  - BOTTOM: efficiency vs. time
- Most challenging plot by far
- How to measure efficiency with raw sTGC data only?
- Plot vs. time requires new framework Jeff is still implementing
  - Save to, read from online DB
  - Allows flexible time-based plots

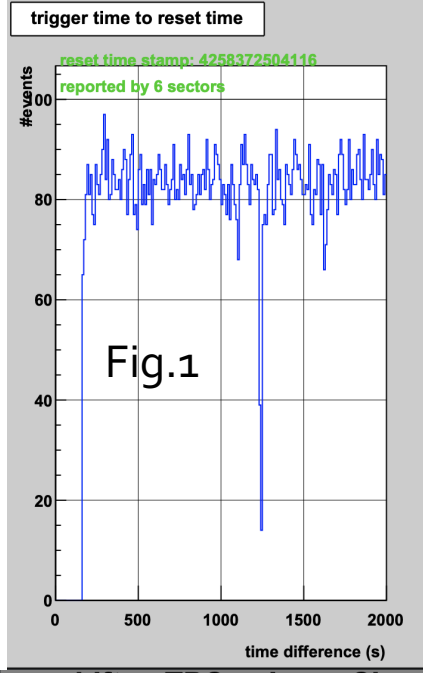


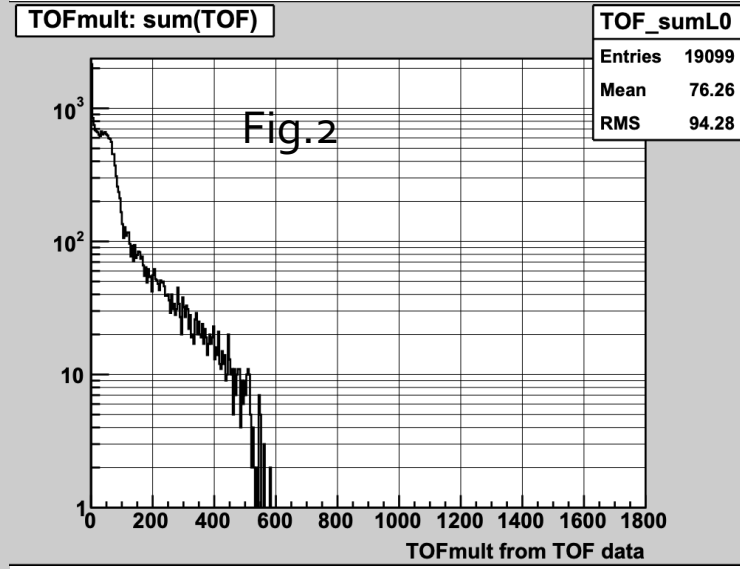


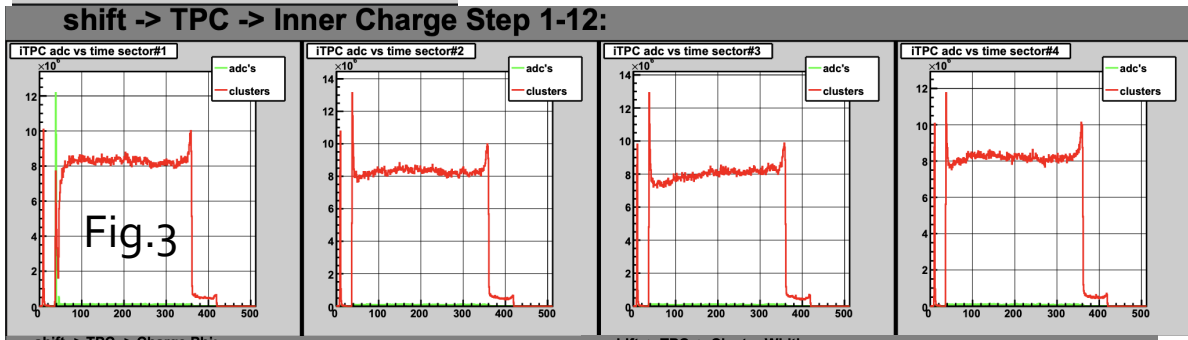
Additional Plots

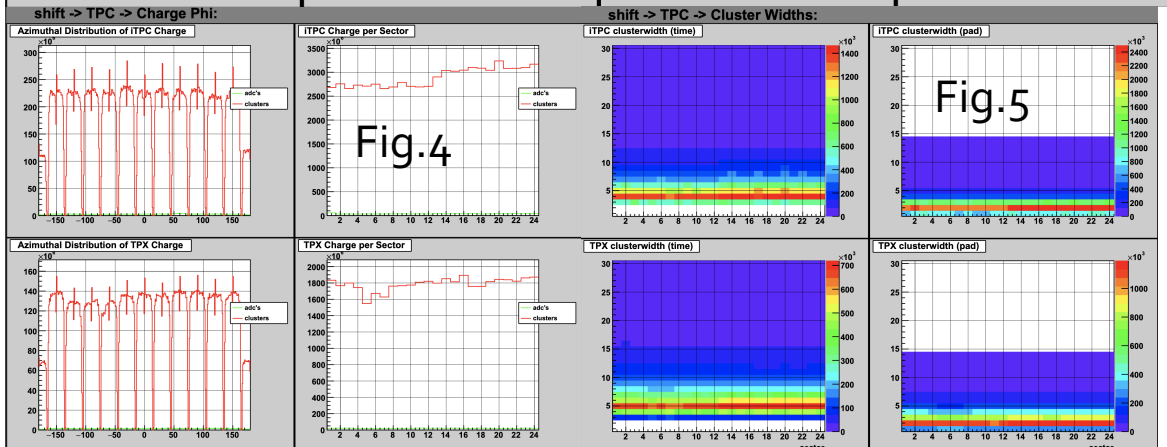
More Plots:

1. Time information plots? Some plots like trigger or time difference. (Fig.1)
2. sTGC refmult? Requires some basic tracking (better for HLT) (Fig.2)
3. <nClusters> vs time? (Fig.3)
4. Azimuthal Distribution of cluster or ADC? (Fig. 4)
5. Cluster width? Time and strip width







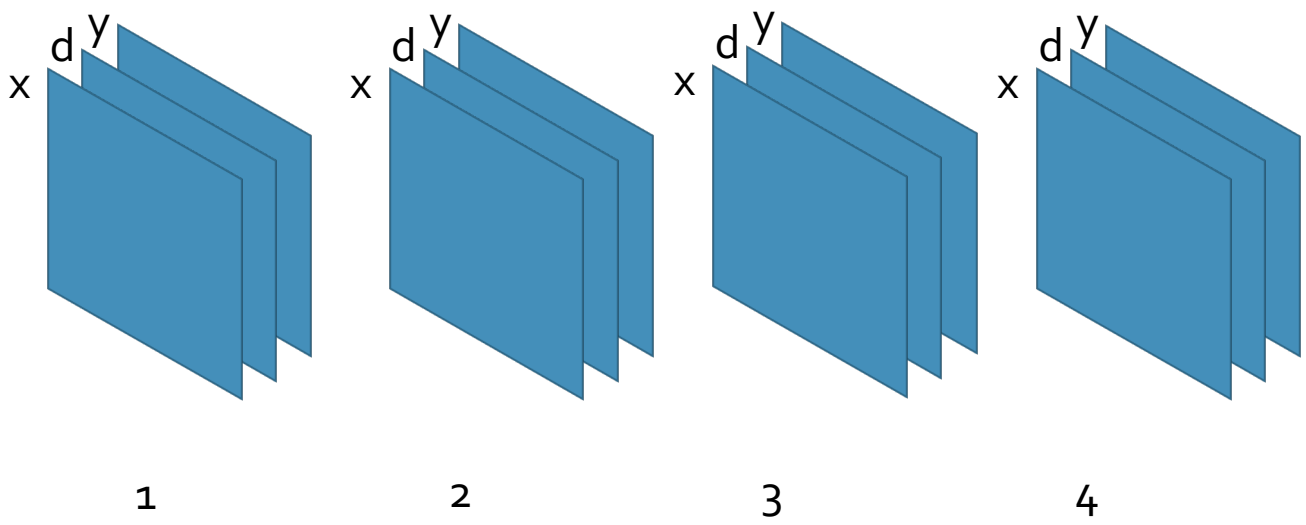


Daniel would like to add the efficiency plots to check gas.

Using one layer as trigger of another layer to get the efficiency

collision point

D = diagonal



- Which layer to use as trigger?
  - Use y layer in each module – assume cluster in farthest layer (from IP) means particle went through all layers.
- Use single disk as trigger for other disks
  - Good cluster in X+D+Y (disk=4) as trigger, test disk 1, 2, 3?

Tracking Update

- Solved Major FST Geometry slowdown
  - Significant effort in Oct, Nov 2020 to find source of issues
  - Flemming fixed several small overlaps, geometry inconsistencies
  - Key issue: adding `assembly=true` for the FSTW volume

✓ Allow consistent geometry for GEANT simulation AND GENFIT tracking

✓ GENFIT experts still suggest an effective geometry for tracking (more later)

- FST fine-tune z-locations

Geant Cut of wheel

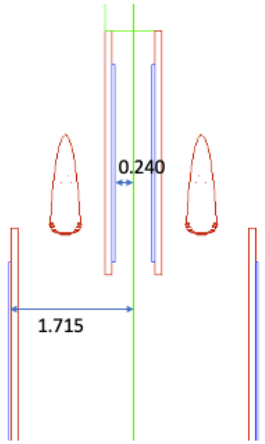
Inner difference to center position

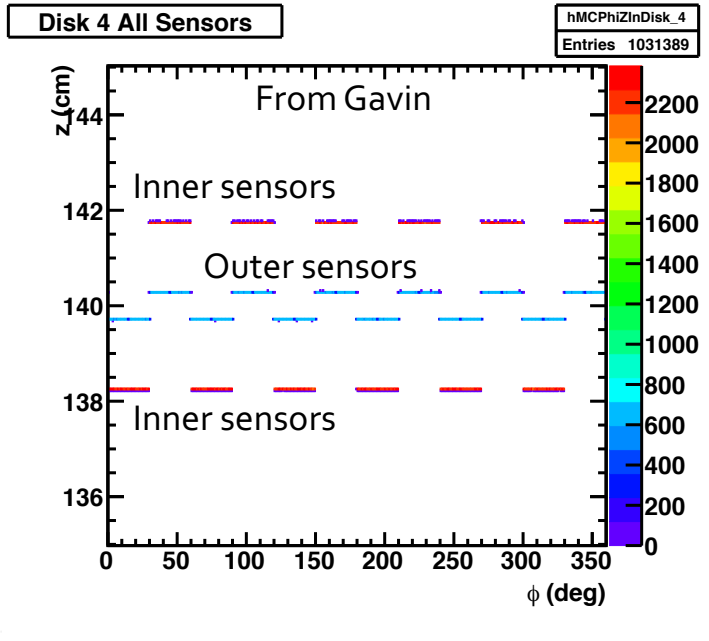
+- 1.715

Outer difference to center position

+- 0.240

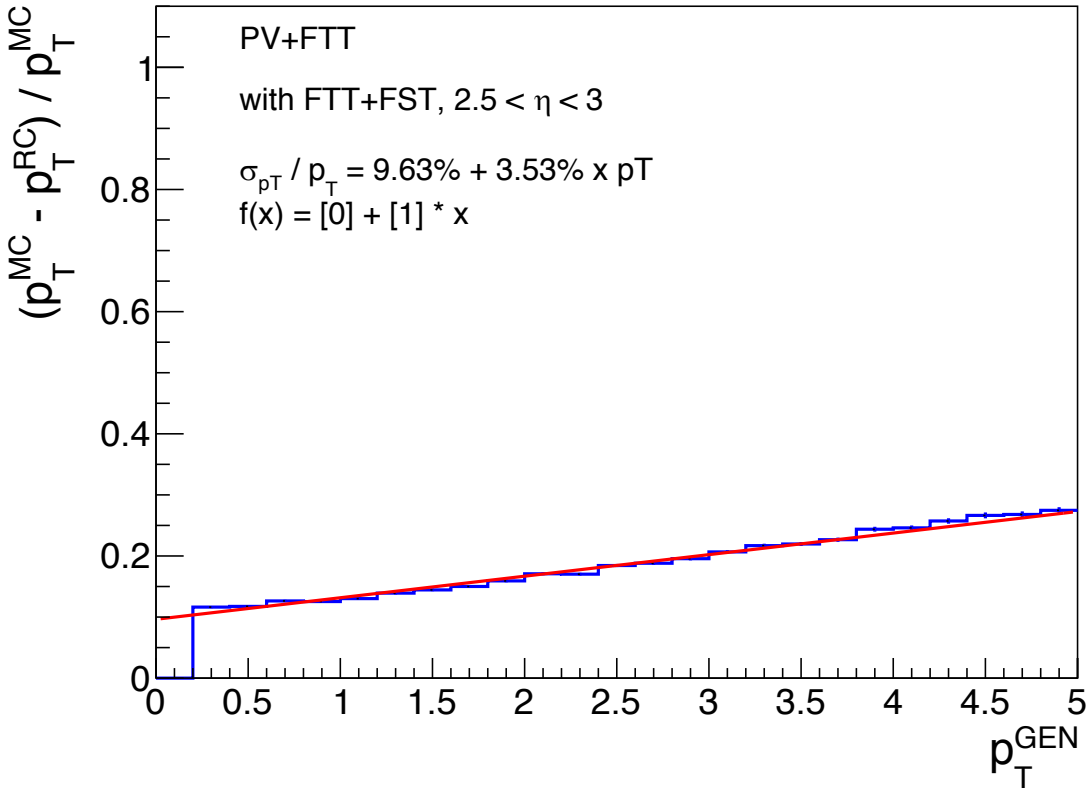
Distance is to center of Silicon wafer (300 micron)





p_T Resolution with/without FST

- PV ($\sigma_{XY} = 500\mu m$) + FTT + FST



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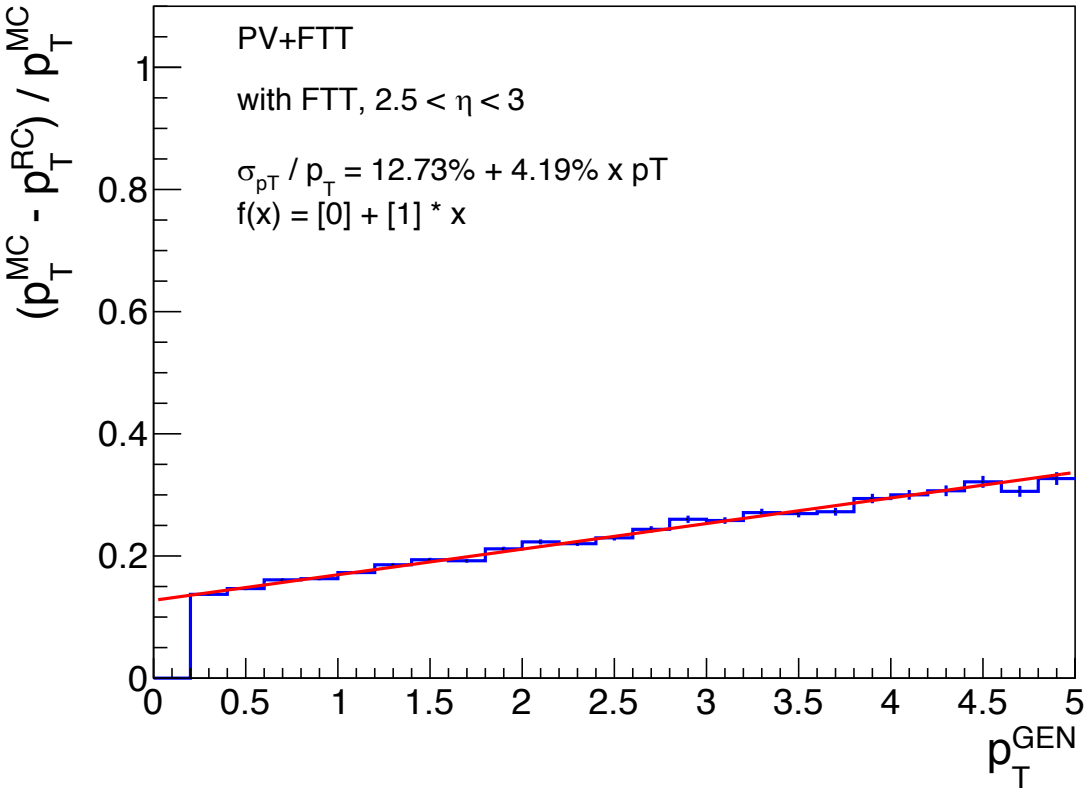
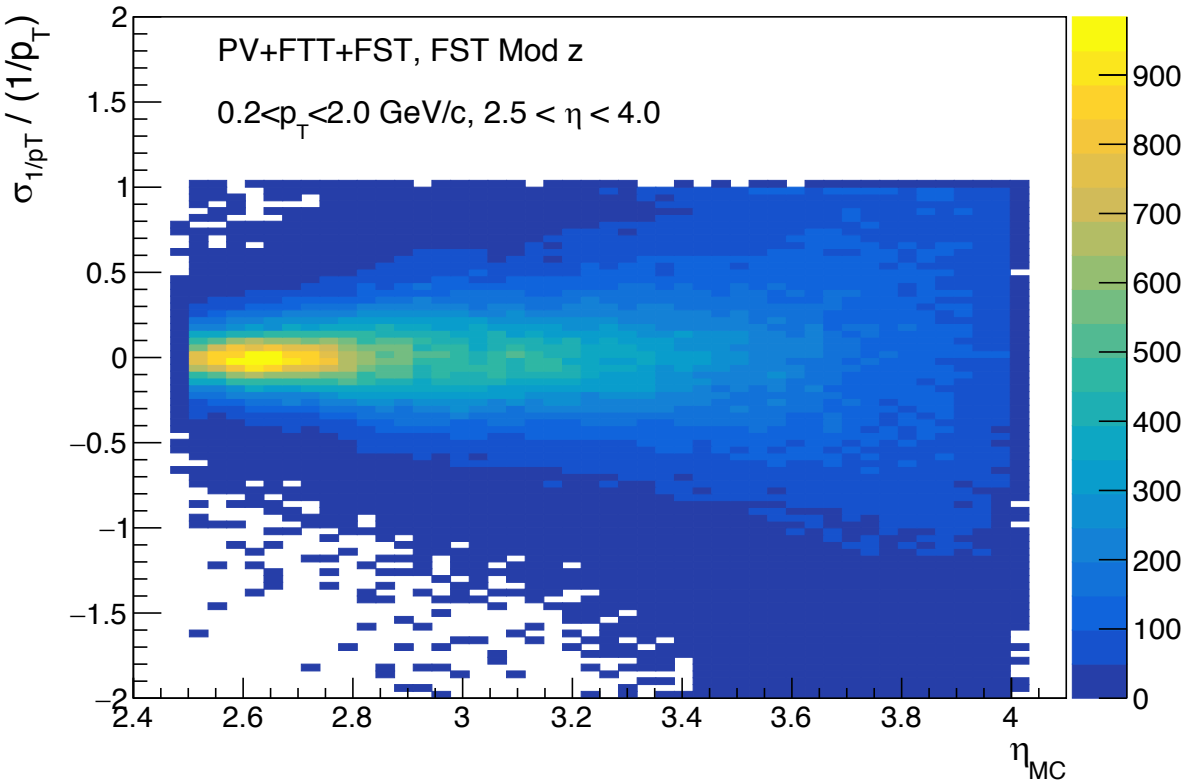


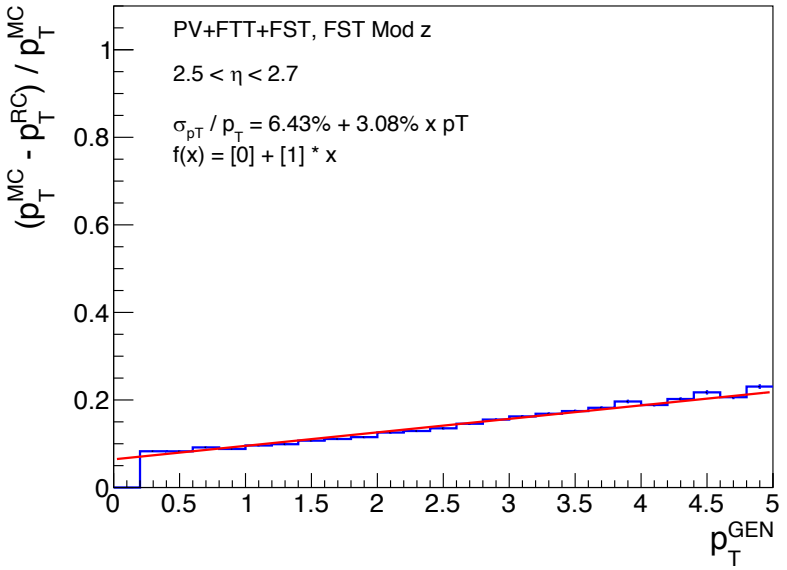
Events using muon gun: 5 muons / event

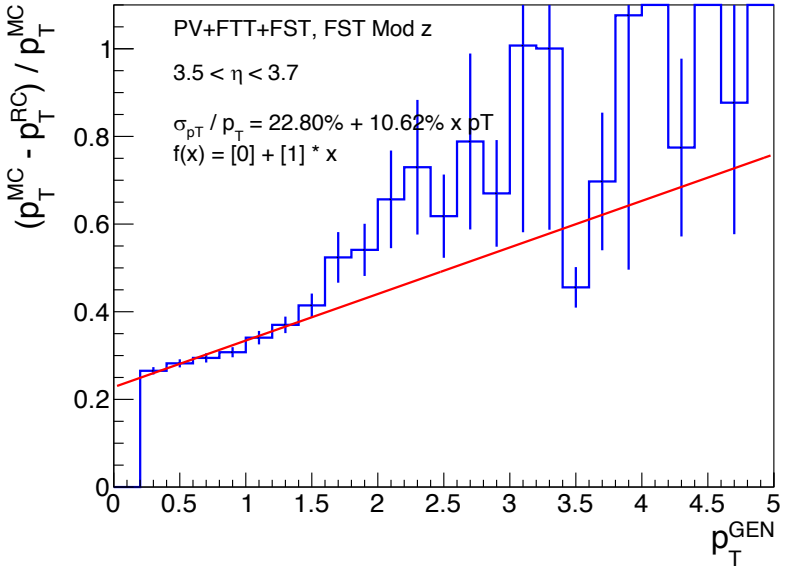
Tracking: Use MC track finding (perfect track finding)

- This is to test GENFIT track fitting directly – shown previously that real track seed finding is almost as good (next with pythia)

Resolution vs. Eta







- Resolution shows significant η dependence
- High-eta appears to have significant reduction in resolution, even at low p_T
- More investigation is needed

Tracking in Pythia 8

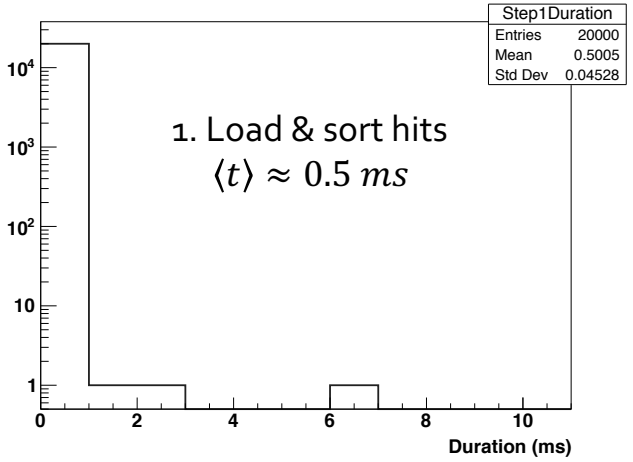
- Youqi has run realistic tracking (no help from MC truth) on Pythia8 events (details in her talk)
- Default seed finding parameters
  - Slightly optimized for higher pT
  - Single tracking iteration, process events in 8 phi "slices" – clearly misses some low pT tracks

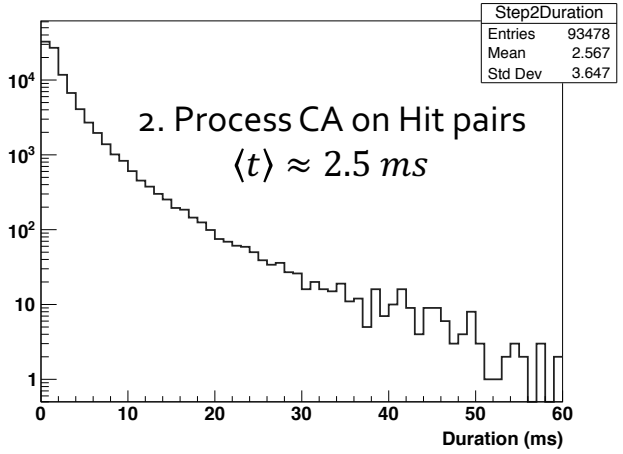
Default track seed parameters

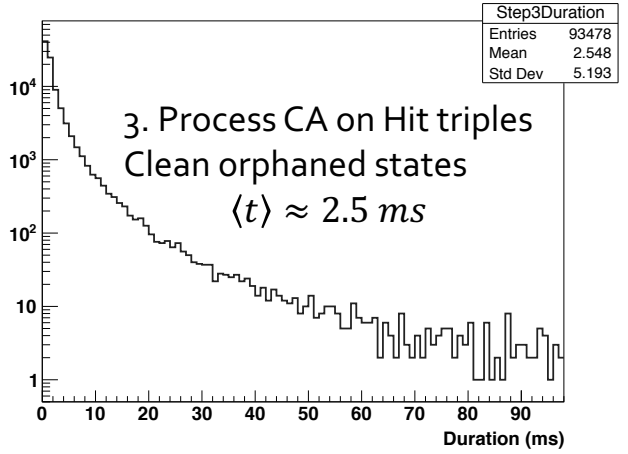
```
<Iteration nPhiSlices="8">
    <SegmentBuilder>
        <Criteria name="Crit2_RZRatio" min="0.999" max="1.131" />
        <Criteria name="Crit2_DeltaRho" min="-6.1" max="9.9"/>
        <Criteria name="Crit2_DeltaPhi" min="0" max="13.4" />
        <Criteria name="Crit2_StraightTrackRatio" min="0.81" max="1.35"/>
    </SegmentBuilder>

    <ThreeHitSegments>
        <Criteria name="Crit3_3DAngle" min="0" max="20" />
        <Criteria name="Crit3_PT" min="0" max="100" />
        <Criteria name="Crit3_ChangeRZRatio" min="0" max="1.11" />
        <Criteria name="Crit3_2DAngle" min="0" max="15" />
    </ThreeHitSegments>
</Iteration>
```

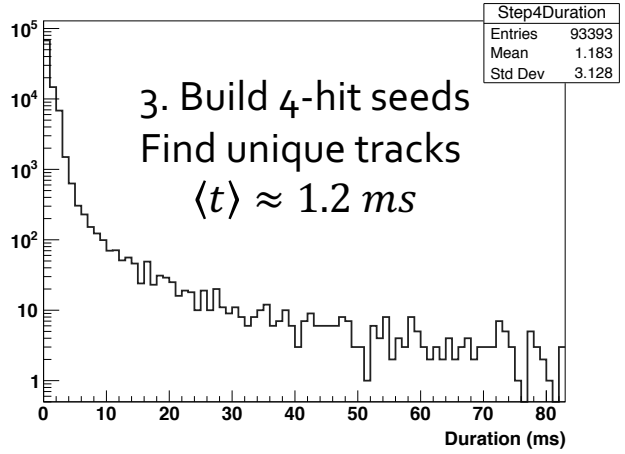
Will give details about these in youqi's slides

Processing time:



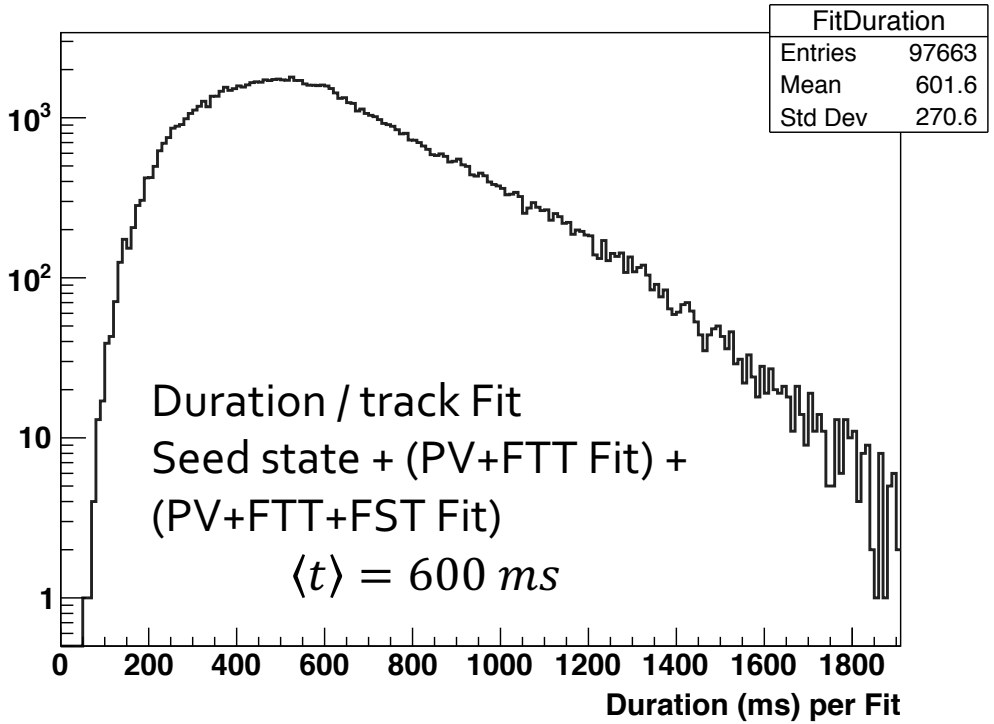


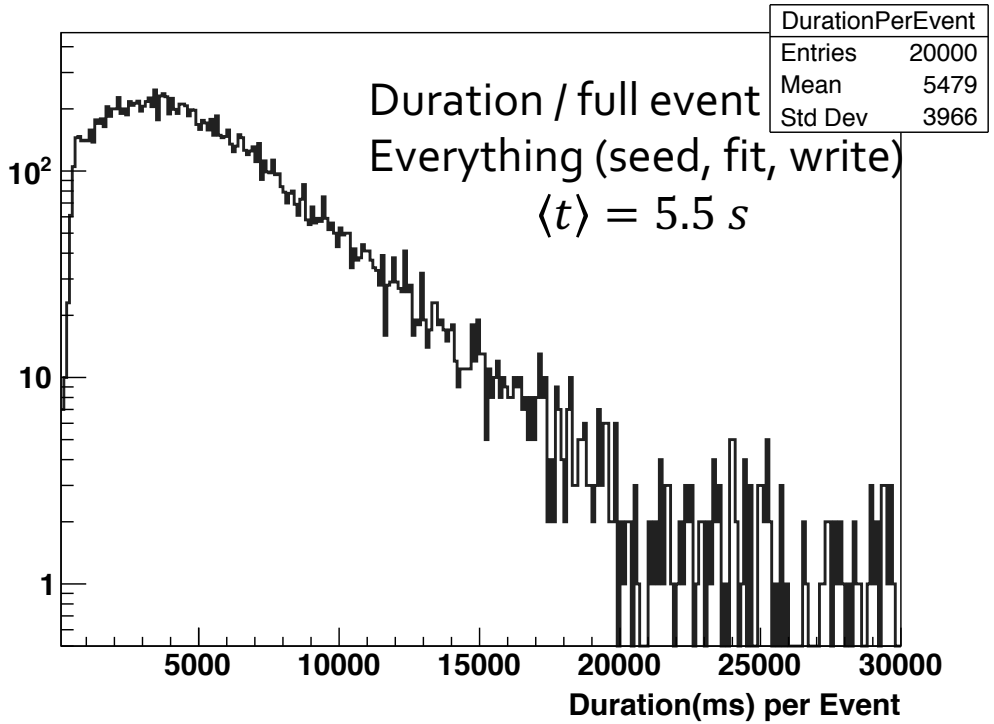




Tracking in Pythia 8

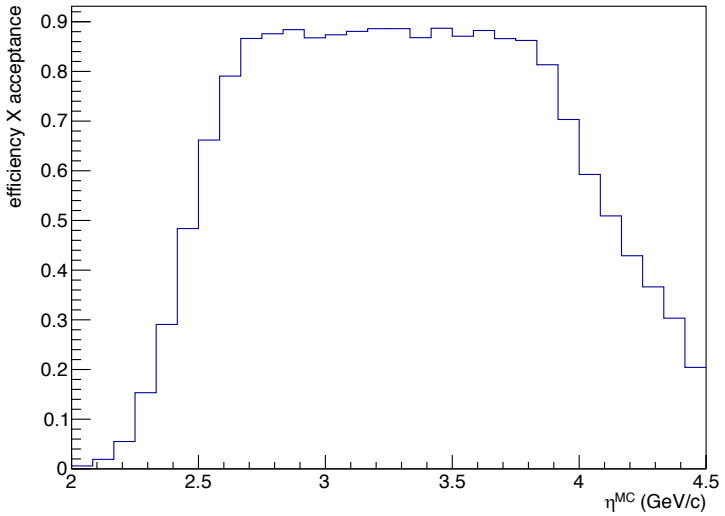
Processing time:

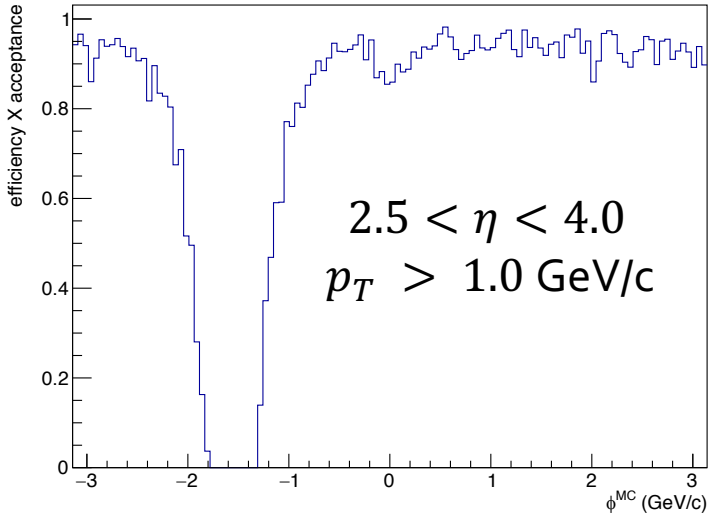


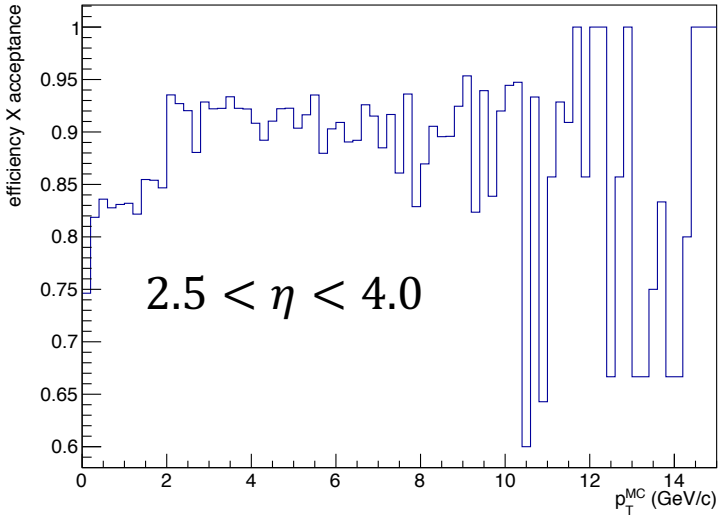


- Track fitting is ~well behaved – no serious outliers
- Track fitting <u>with GenFit still takes too long</u> → Full event takes ≈ 5s
- Daniel is discussing with GenFit experts
  - Main issues: low quality track seeds (Youqi's slides), need to optimized $\vec{B}$-Field lookup and GenFit geometry traversal.
  - May require simplified geometries for GenFit

Tracking Finding Efficiency



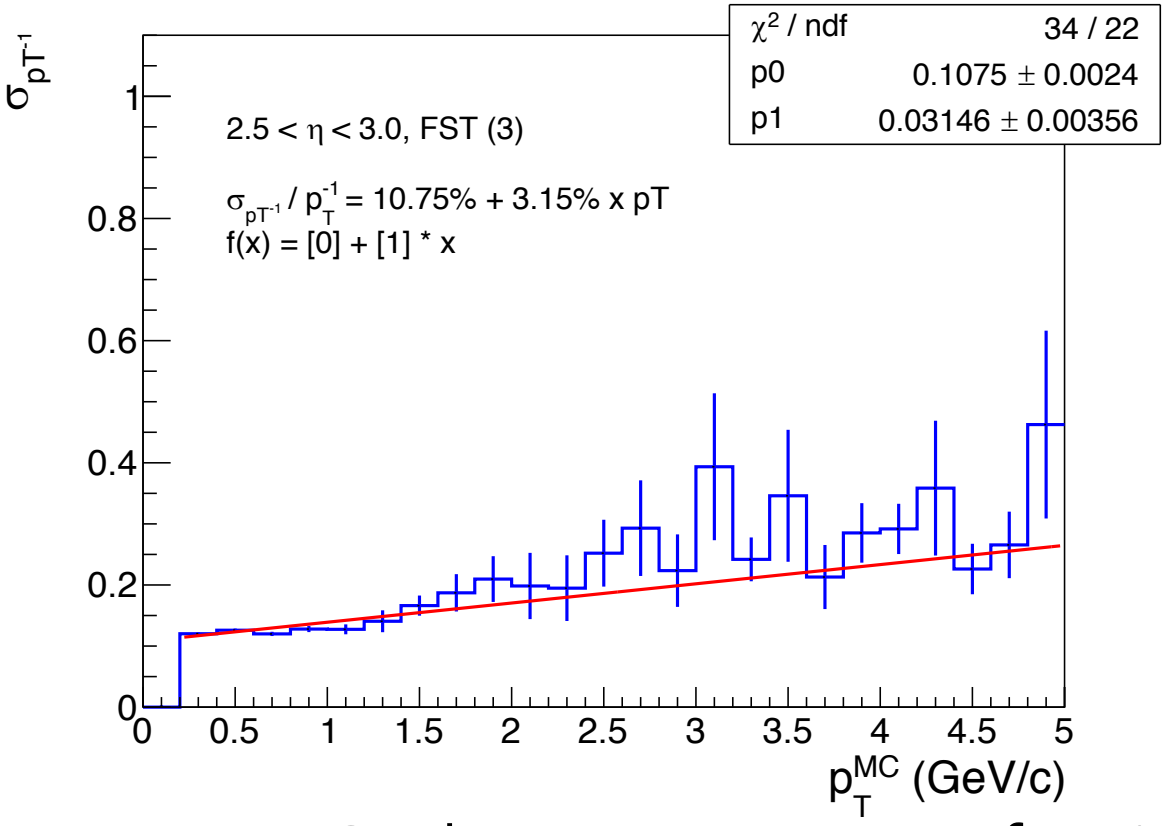




- Reasonably good track finding with default parameters
- ~10% room for improvement (acceptance effect here is small, require MC track in $(2.5 < \eta < 4.0)$
- Issue at low-pT: Optimize parameters / run extra iteration for low pT tracks.
- Youqi is developing optimized criteria

p_T Resolution with/without FST

- PV ($\sigma_{XY} = 500\mu m$) + FTT + FST



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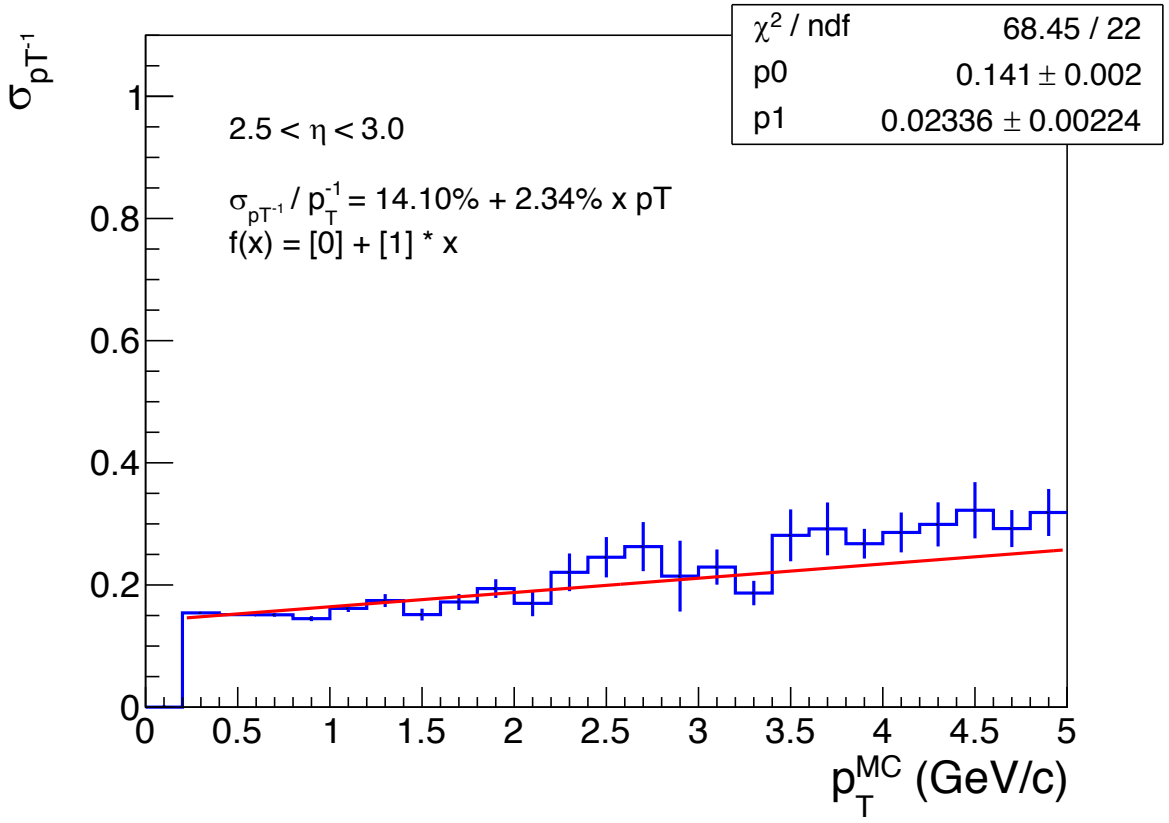
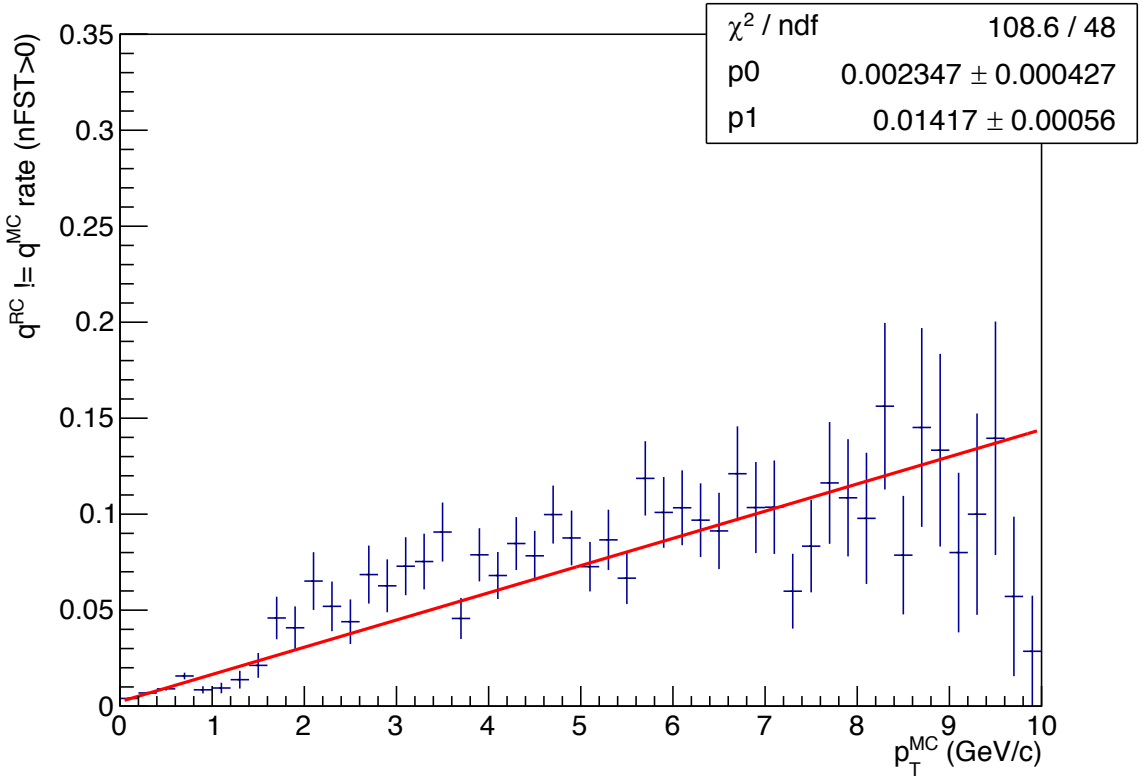


FST shows improvement of ~30% over tracking with FTT alone

p_T Resolution with/without FST

- PV ($\sigma_{XY} = 500\mu m$) + FTT + FST



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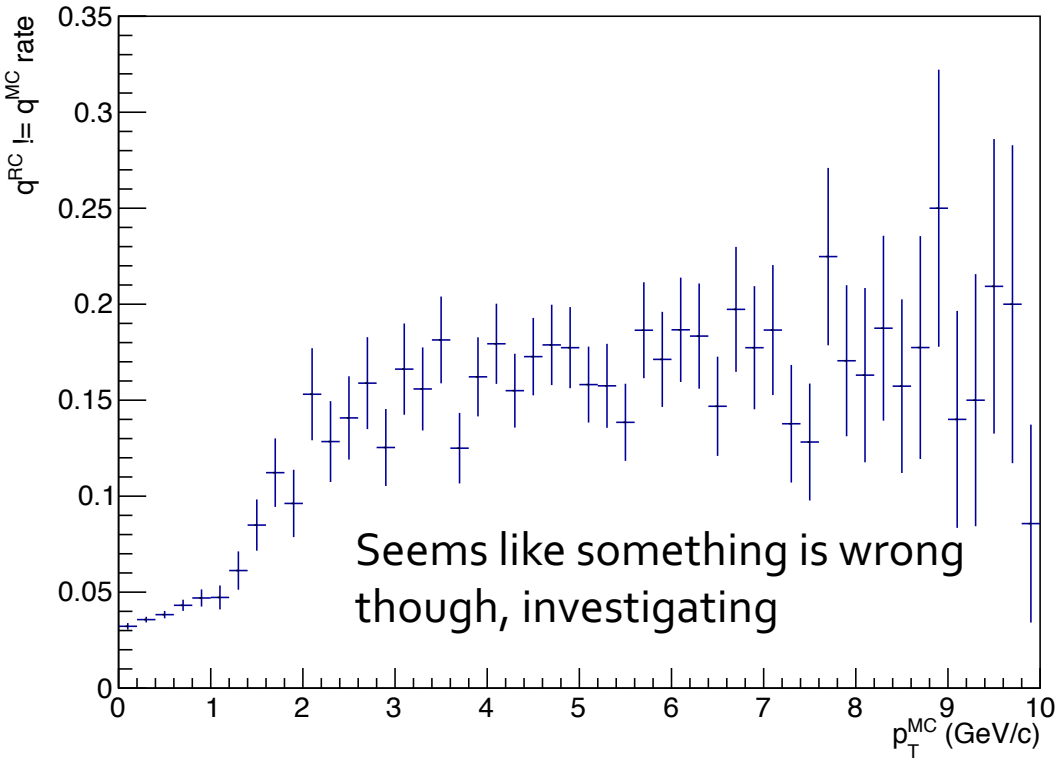
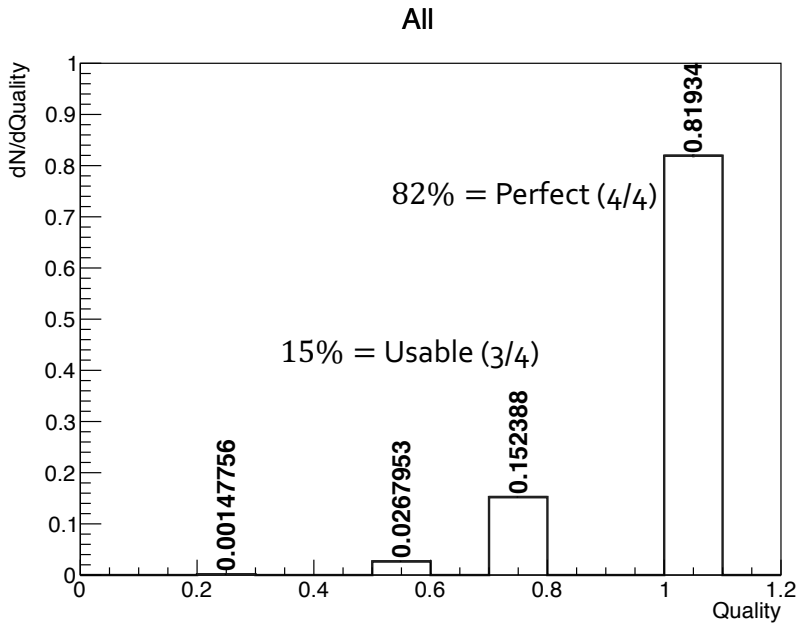
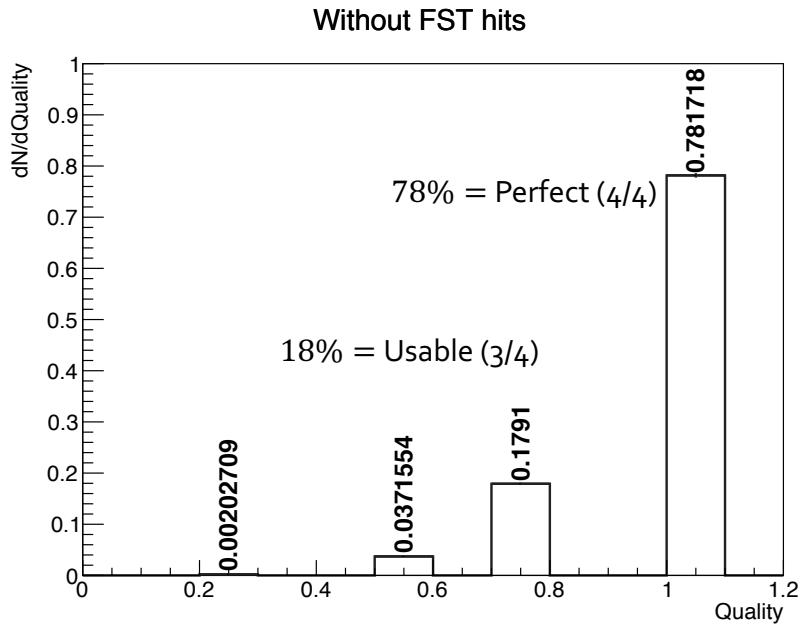


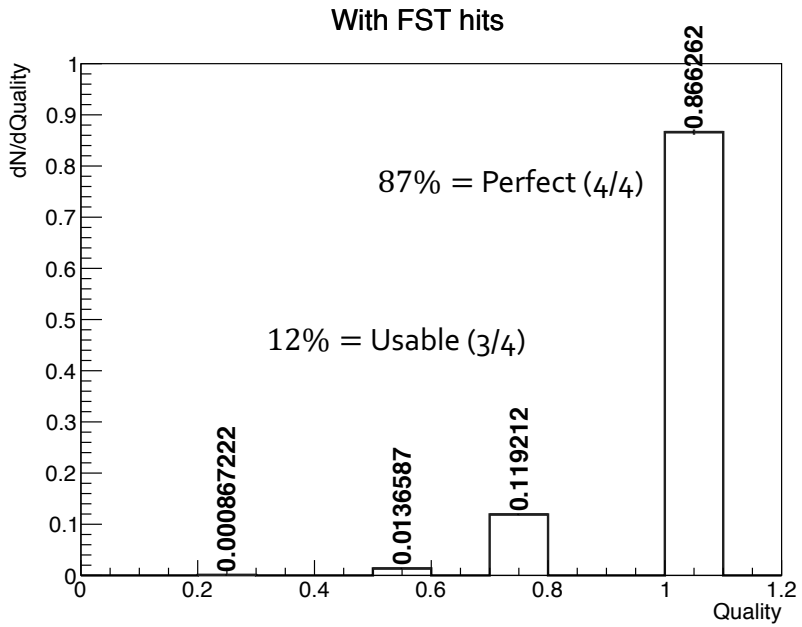
FST shows significant improvement in charge-Id

Track Seed Quality

- Track seed are formed from FTT hits (maximum 4 hits)
- Reminder: this is averaged over pT and eta
- Seed finding is hardest at low pT (large curvature) and current parameters are optimal for high pT
  - **Need optimization of track seed parameters**







- **Tracks with FST hits -> 7% more perfect (quality=4/4)**
- **Tracks with FST: ~99% usable (quality 3/4 or better)**
- **Low track seed quality is the #1 issue for slow fits / reduced p_T res and charge-Id**

Summary

- sTGC Task
  - Final Geometry : Simple ROOT geometry implemented. Need help from Jason to implement missing AgML geometries
  - Update FastSim with basic hit clustering?
  - Demo and plan for online plots
    - Work with Jeff to implement / test new framework for efficiency vs. time plots
- FST Update z-locations to precise sector-by-sector z
  - Track refit with FST shows clear improvement (at low eta) in both muon gun events and Pythia8 Drell-Yan events
- Track fitting (GenFit) is consistent, but still slow ~5 s / Pythia event
- Requiring FST hits provides higher quality tracks in real events (Pythia)

Pentagon sTGC Design

- sTGC uses symmetric pentagonal design

Symmetric pentagon chambers