Tracking Overview
“Fix it in Software!”

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HPS Autumn Collaboration Meeting JLab
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Running Conditions

The 2019 run was “challenging,” to say the least.
See yesterday’s talks for summaries of issues with the machine and SVT.
With only ~50% of the data we expected to accumulate, we will have to work hard to extract as much physics as we can from the data we have.
Don’t have the luxury of only using “golden” runs.
Will have to dig deep.

Short-term vs Long-term Planning

Immediate target is the deliverables necessary to get us through Jeopardy!
But keep in mind that the reconstruction/ analysis of the full dataset requires investment in tracking infrastructure.
Delicate balance between “Git ‘er done!” and “Do it right!”
Concentrating on demonstrating our ability to align and calibrate the detector, provide good quality, high-efficiency tracks & vertices.

Short-term Tracking Strategy (Tracktics)

- Concentrate on a few dedicated runs to minimize exposure to varying conditions.
- Use elastically scattered beam electrons to calibrate the energy scale of the calorimeter and the momentum scale of the SVT.
  - Use field-off straight tracks to start the SVT alignment.
- Use bremsstrahlung events to extend the calibration to lower energies/momenta and to study the track-finding efficiency.
- Use Hodoscope+Calorimeter matches to determine track efficiency

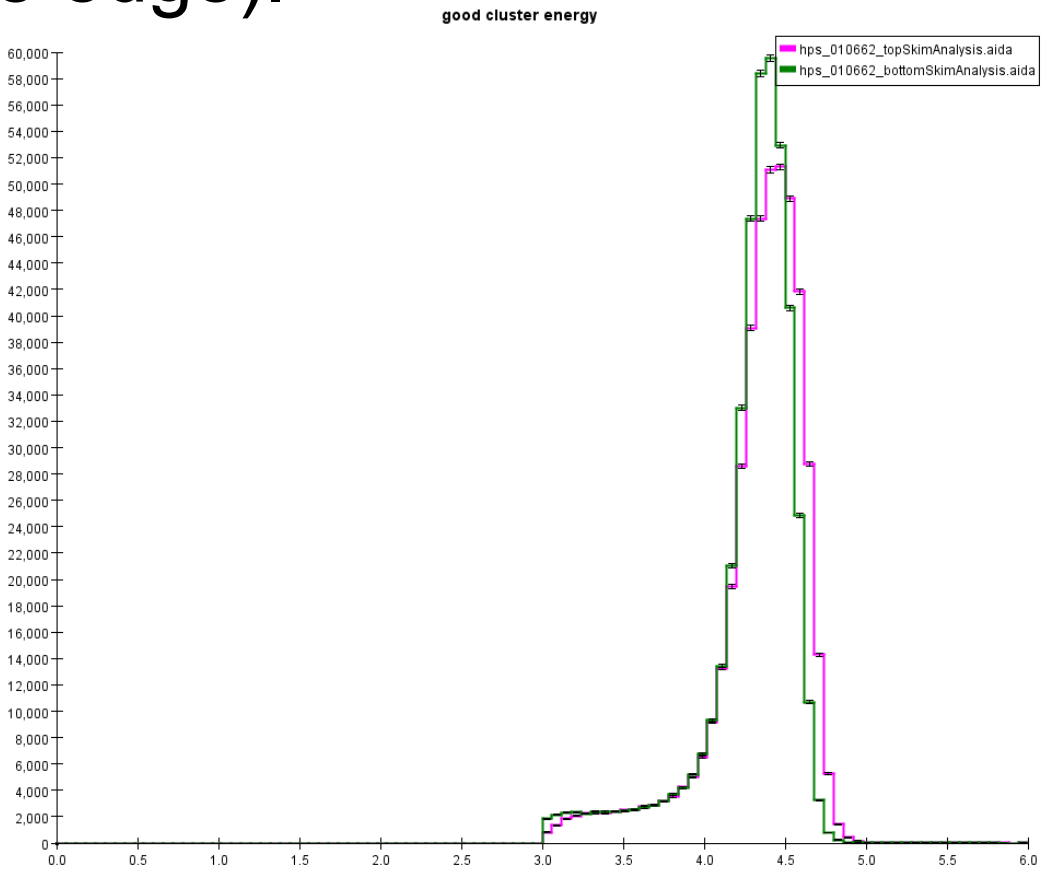
Calibration Data

- FEE triggers were taken throughout the run.
  - Maurik has written a nice evio file processor which can skim off events based on their trigger.
  - Can efficiently select events from any run.
- Dedicated FEE runs
  - 9371,9593,9898, 9899,9920, 9921,10716, 10717, 10718
- Dedicated Field-Off Runs
  - 10101,10333,10662,10734

Ecal Energy Scale (Full Energy)

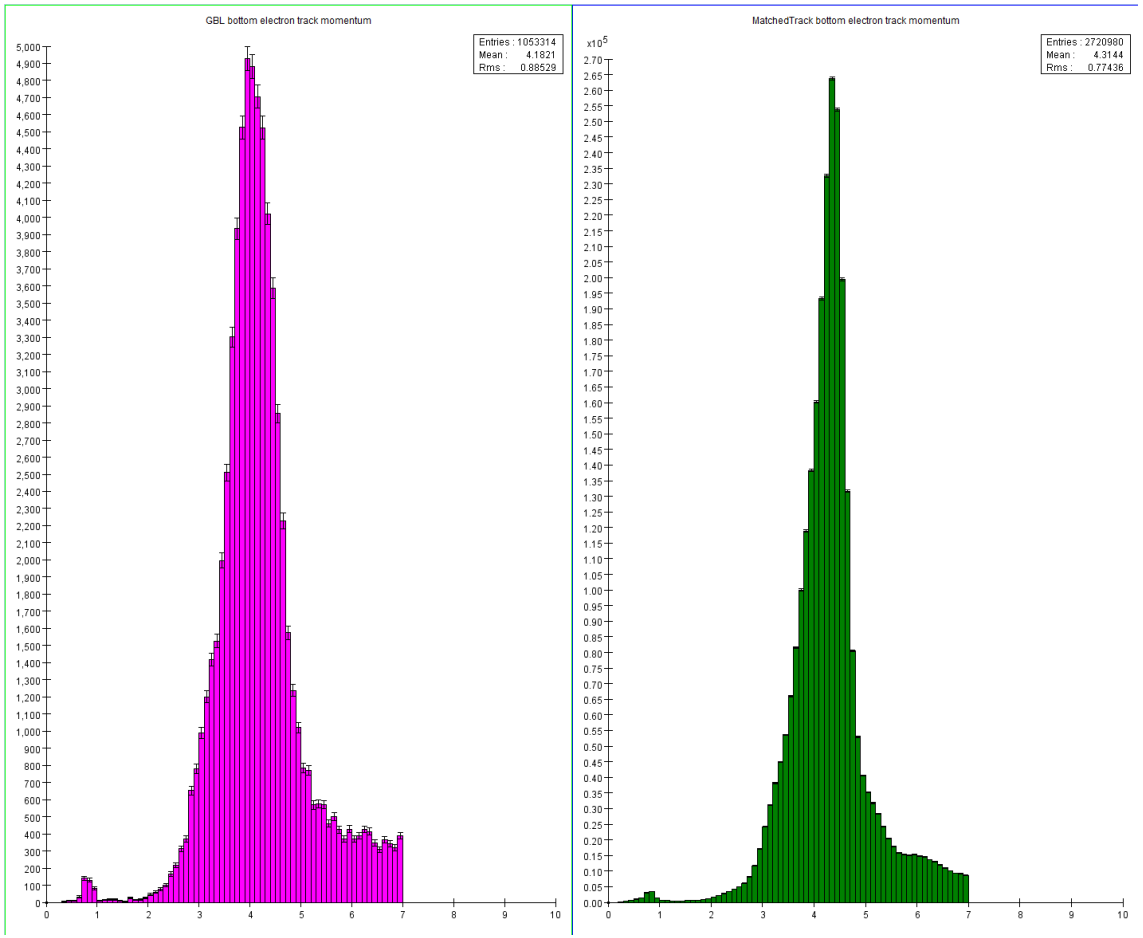
- Select events with one and only one cluster in the fiducial region of the calorimeter (viz. seed crystal is not on the edge).

Looks pretty good right out of the box!
Slight differences in absolute scale and resolution between top and bottom.



SVT Momentum Scale

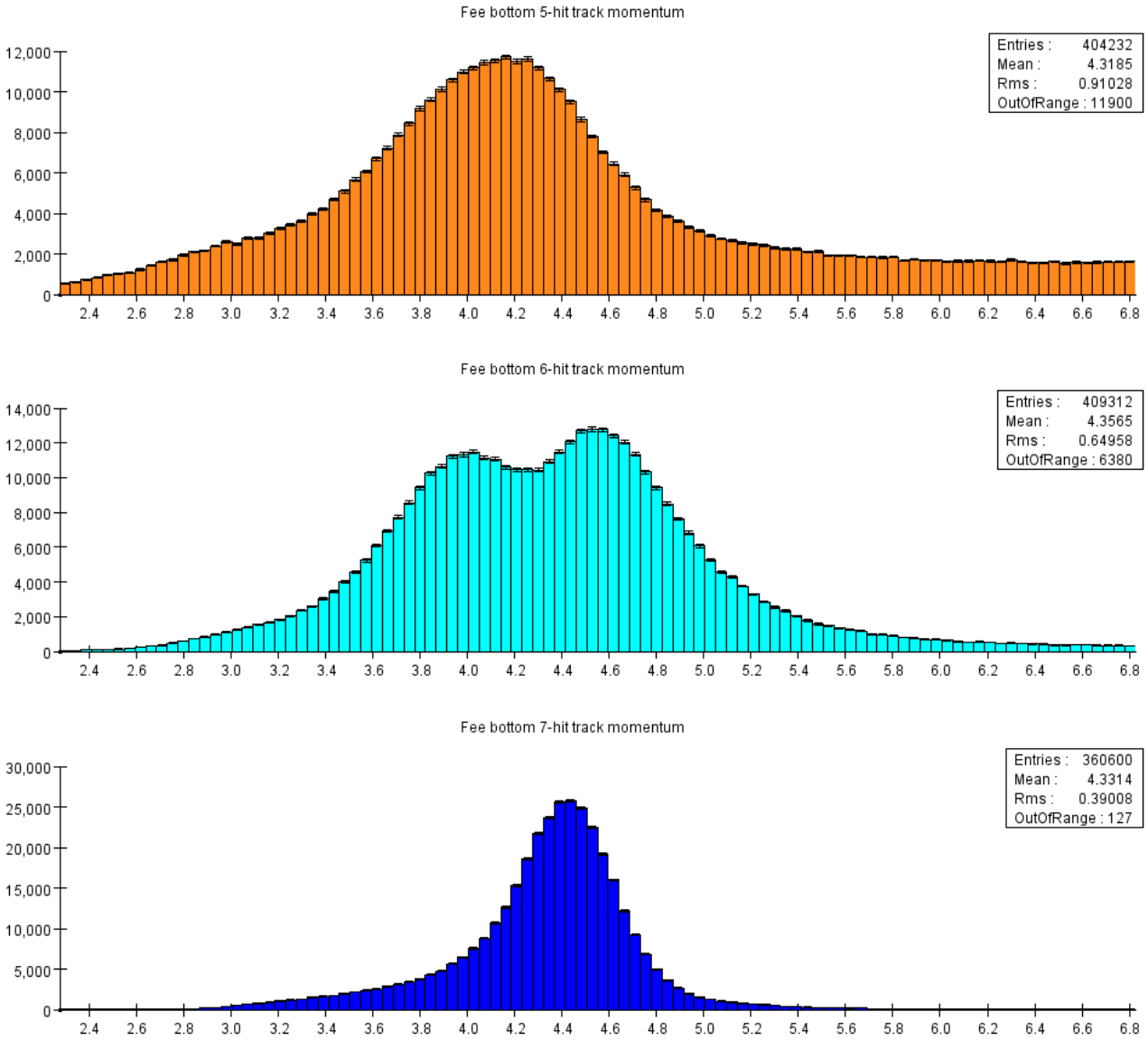
- Compare GBL and Matched Tracks (helical fit)
- Clearly work to be done.



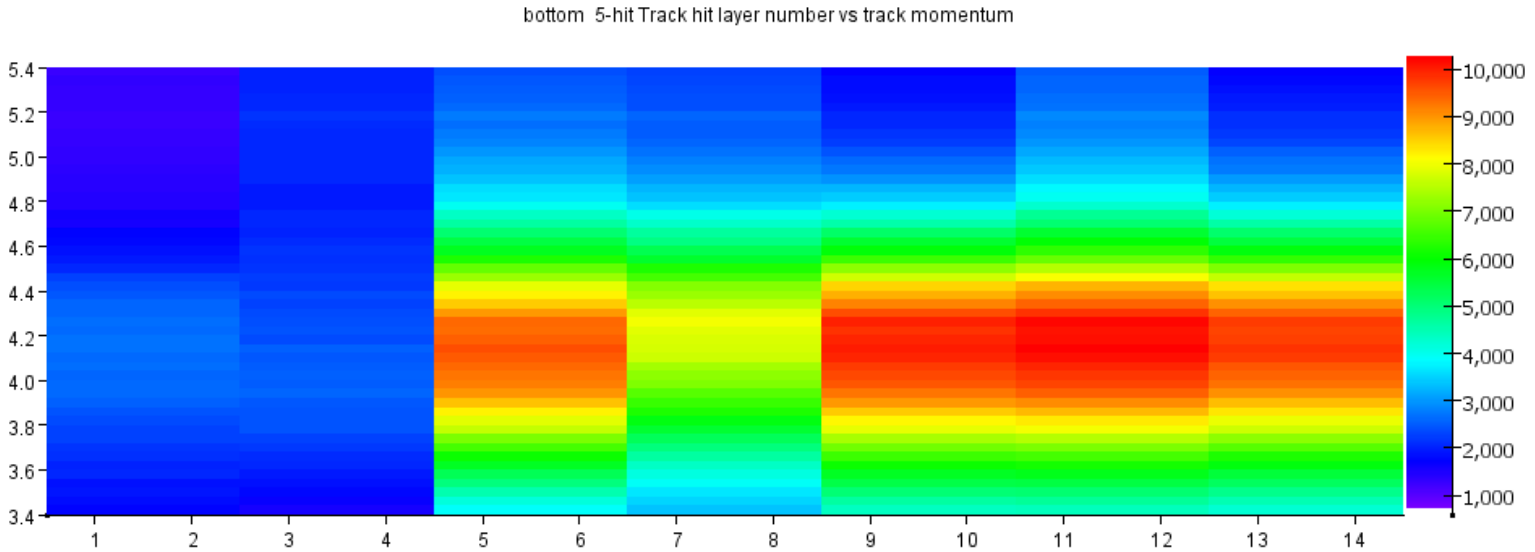
hps_010104 FEE Run

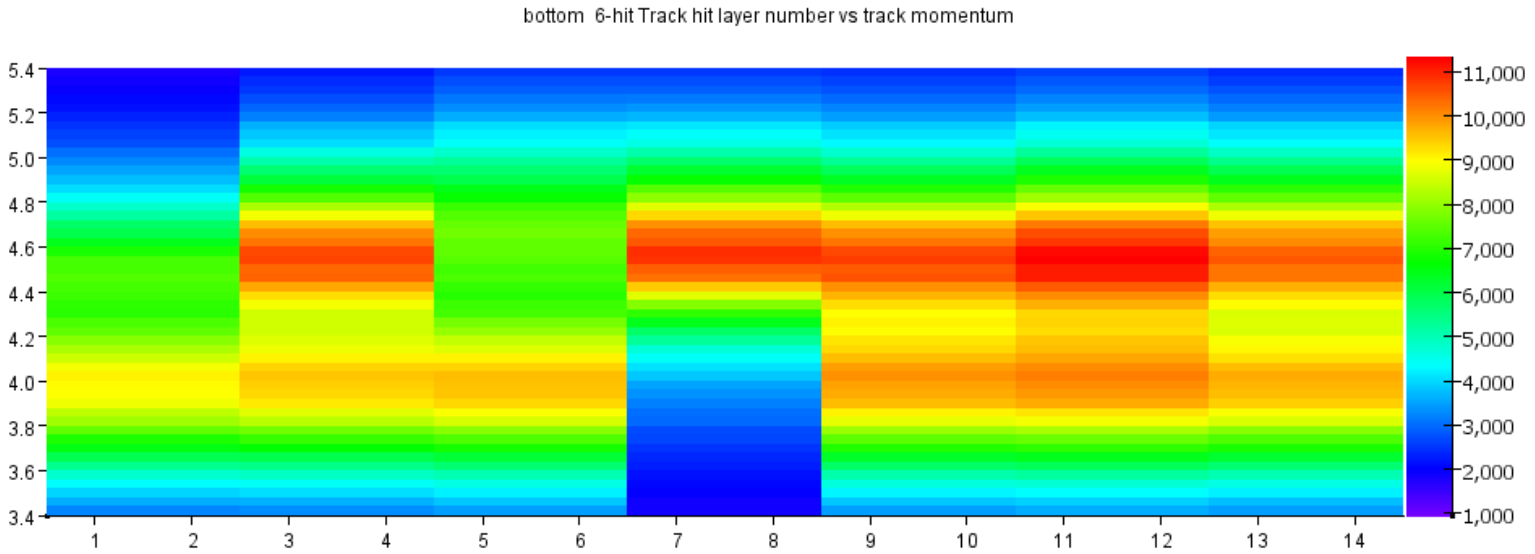
- Processed events from one of the early dedicated FEE runs.
  - All bottom layers were working -> 14 hits tracks.
- Reconstructed using standard steering file
- Skimmed events separately from top and bottom.
- Selected events with one and only one cluster and track.

FEE 10104 Bottom Momenta

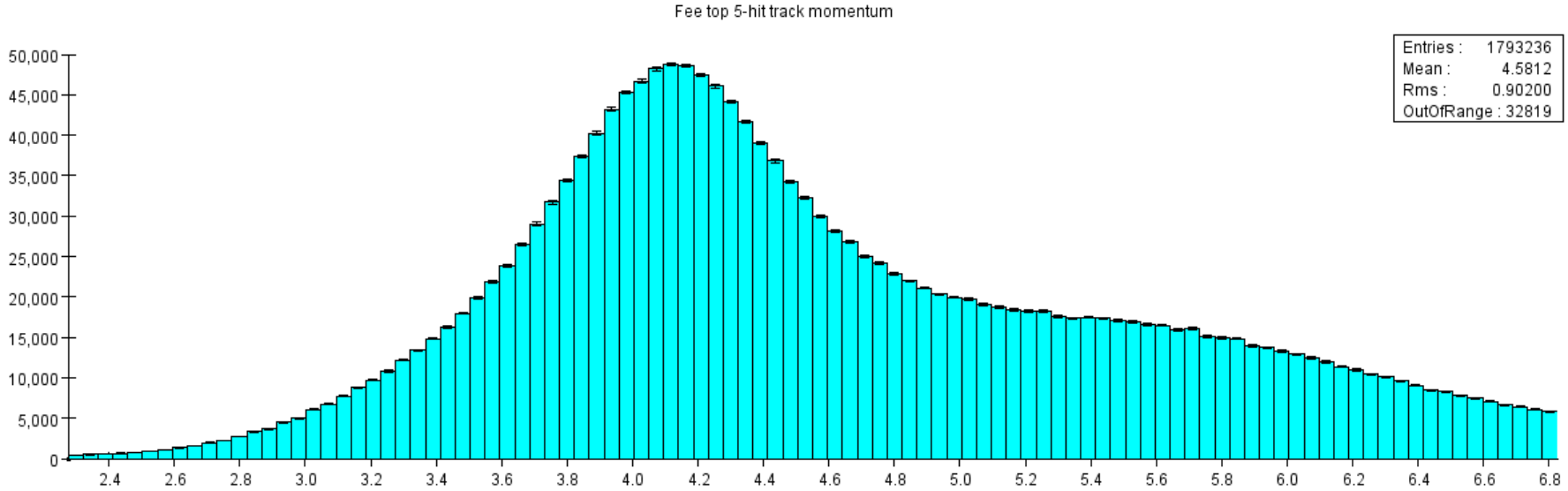


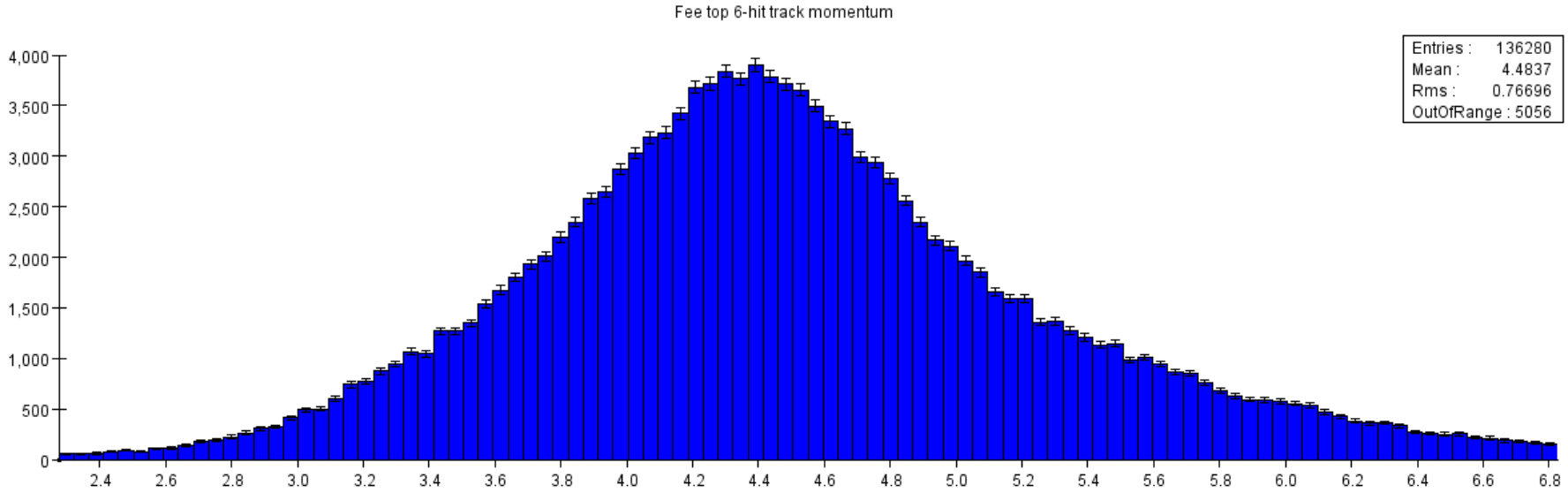
FEE 10104 Bottom Momenta vs Layer



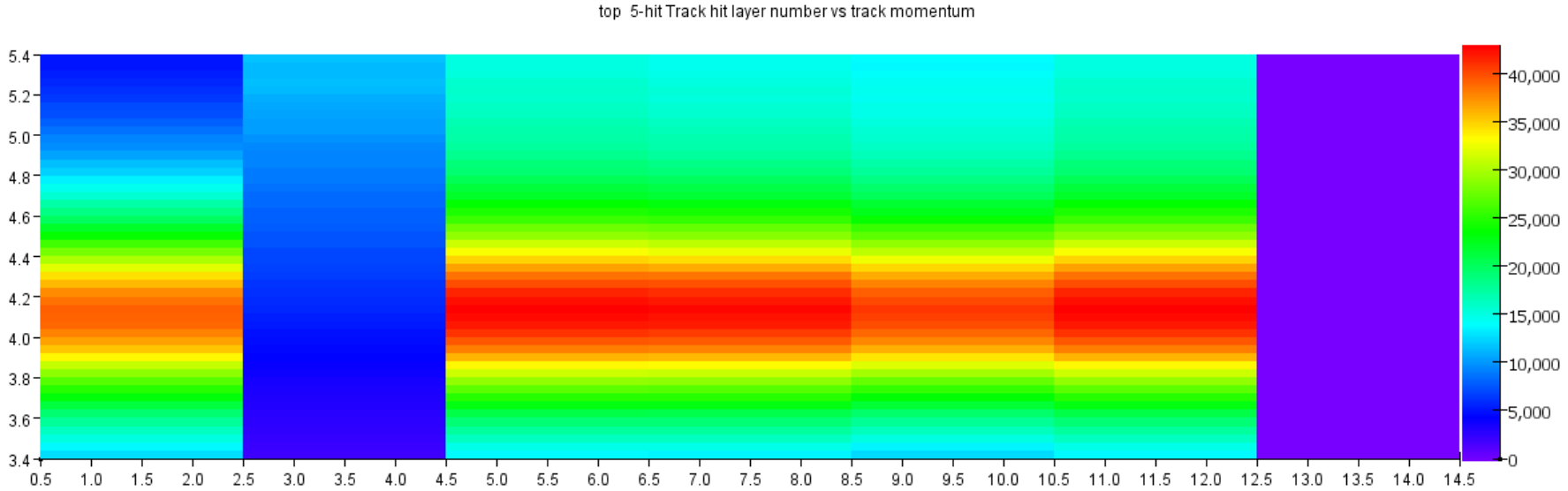


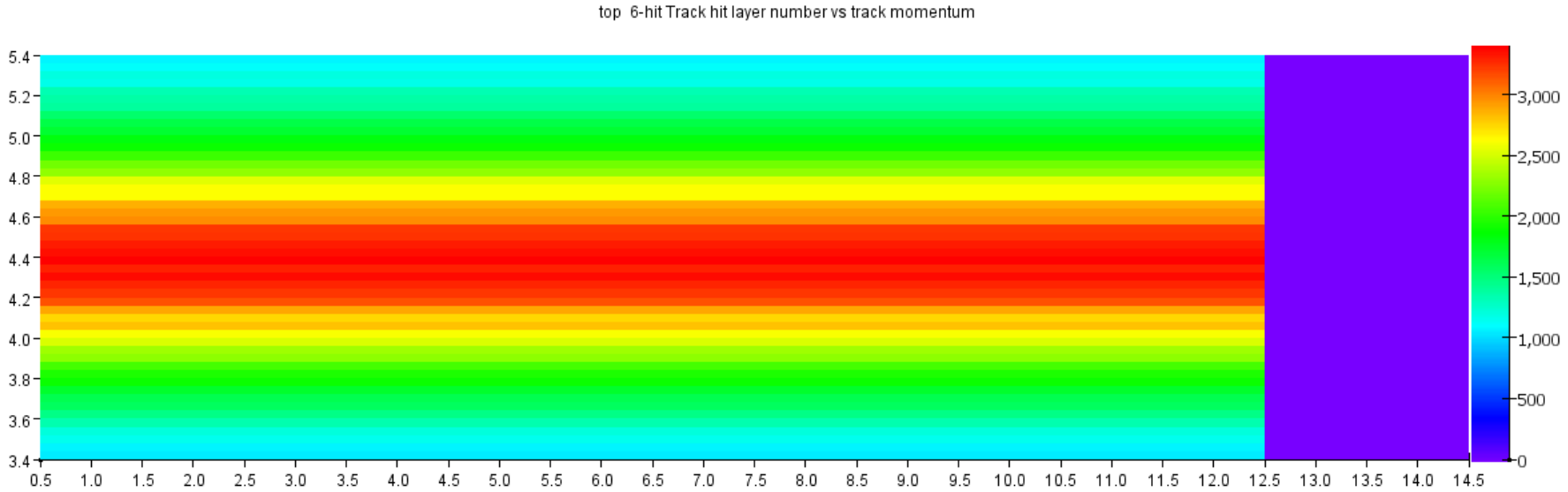
FEE 10104 Top Momenta



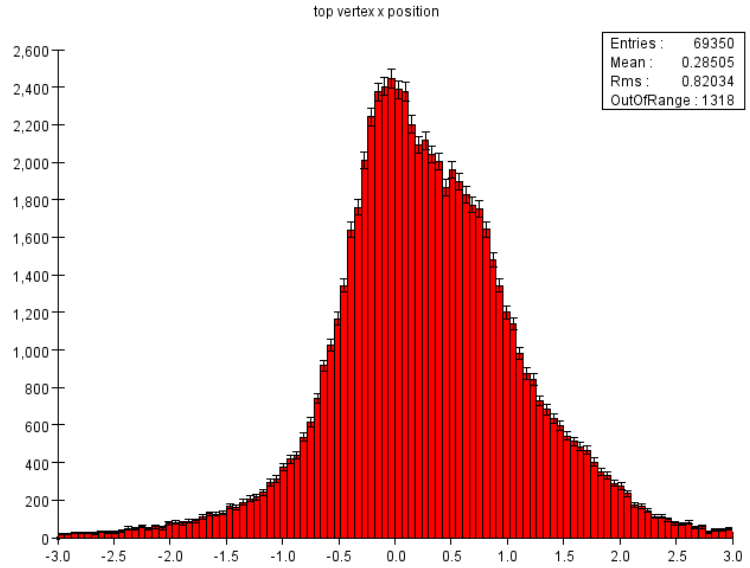


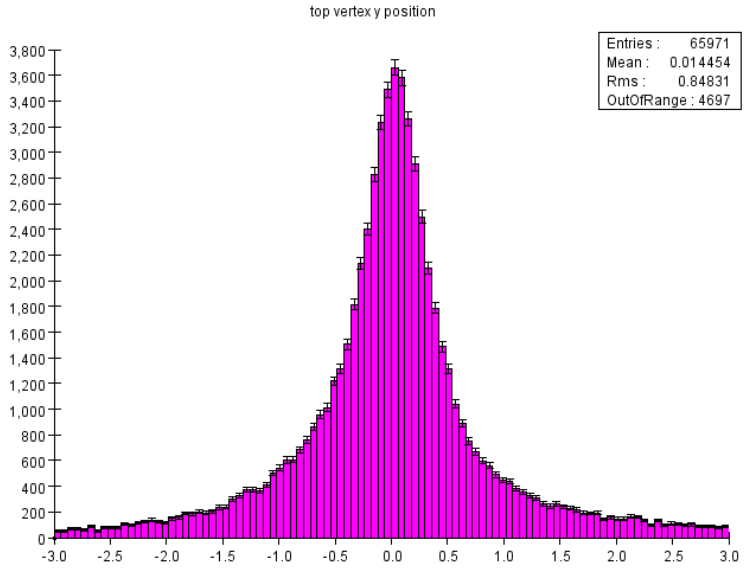
FEE 10104 Top Momenta vs Layer

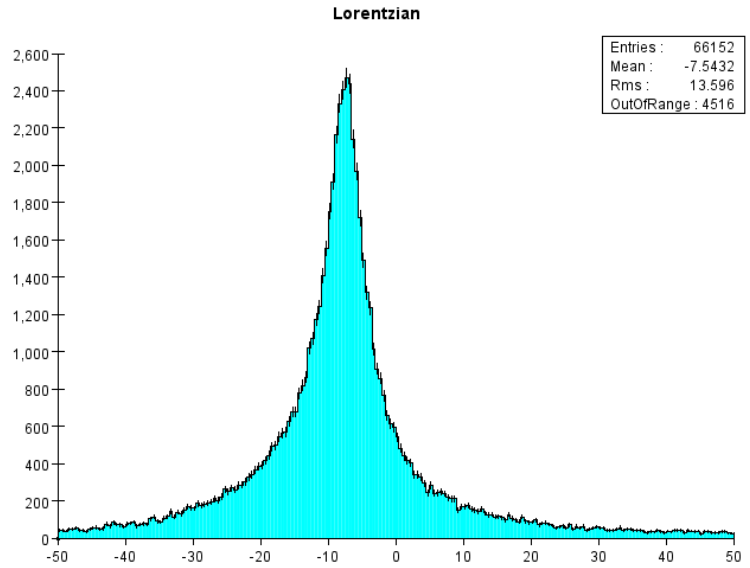


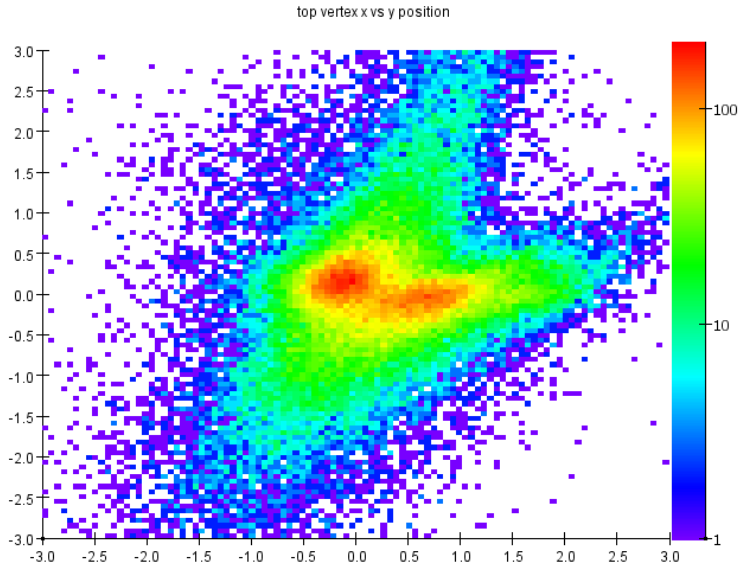


FEE 10104 Two Top Track Vertices

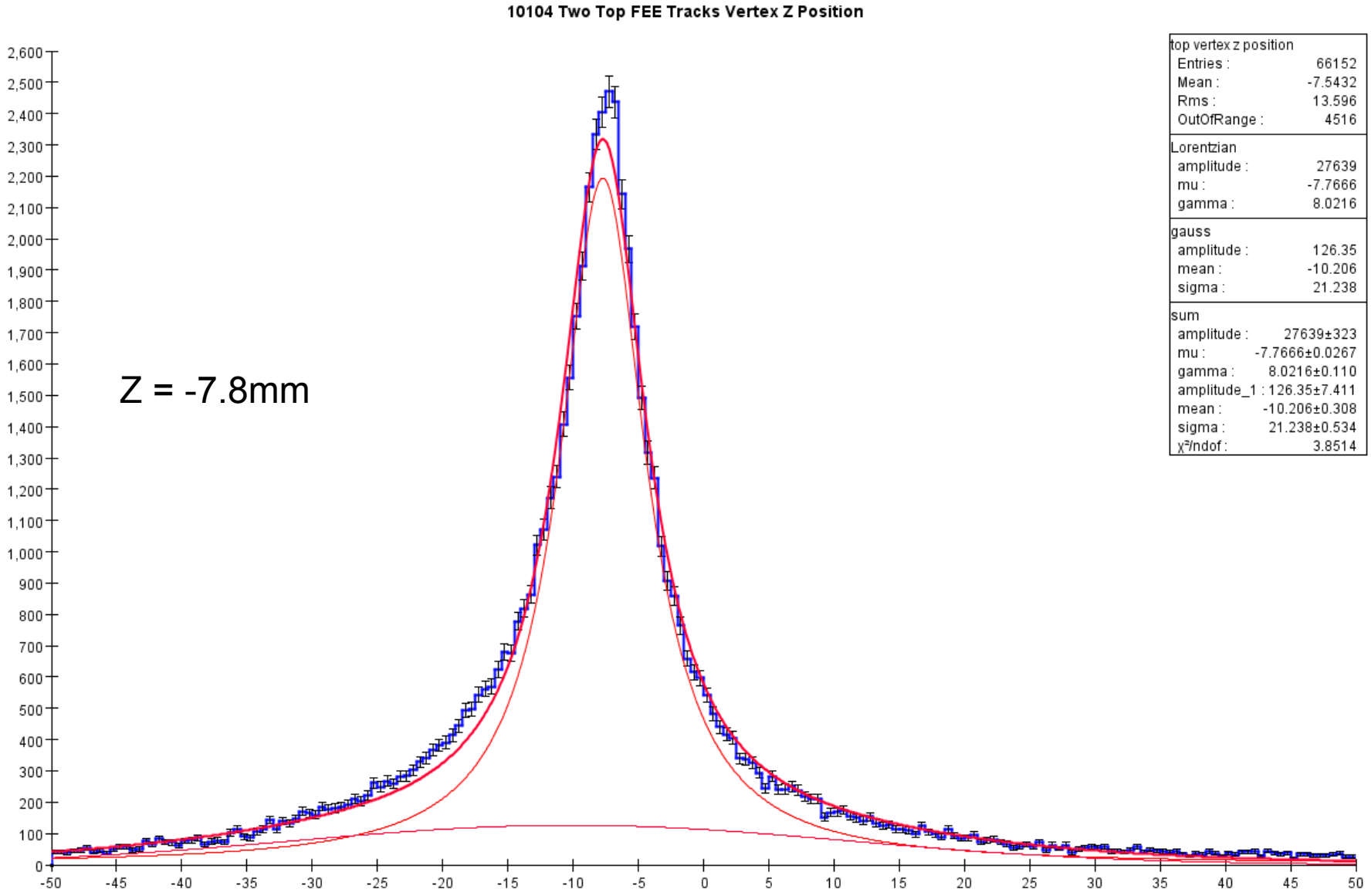




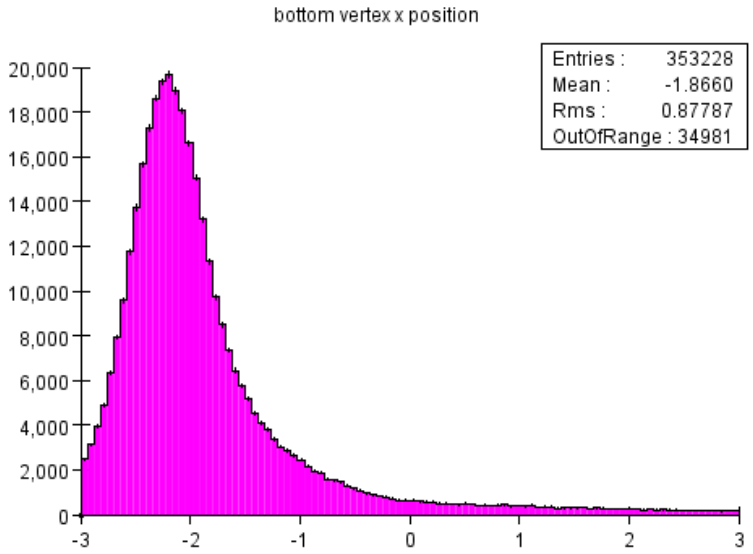


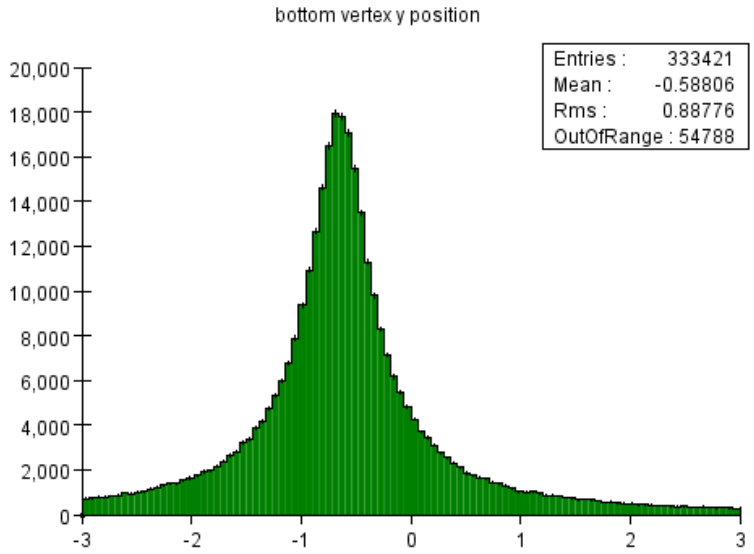


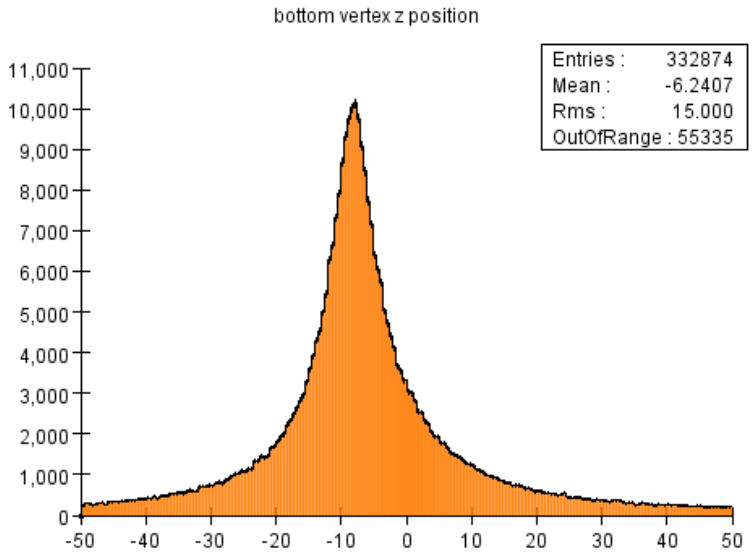
FEE 10104 Two Top Track Vertices

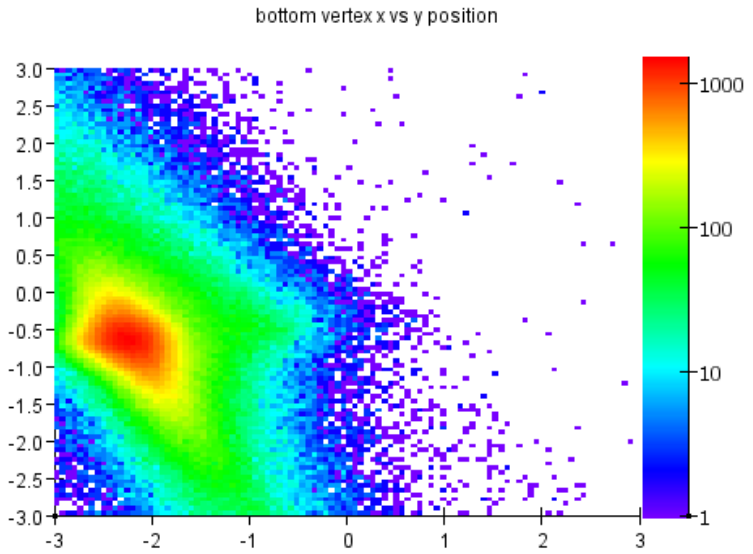


FEE 10104 2 Bottom Track Vertices

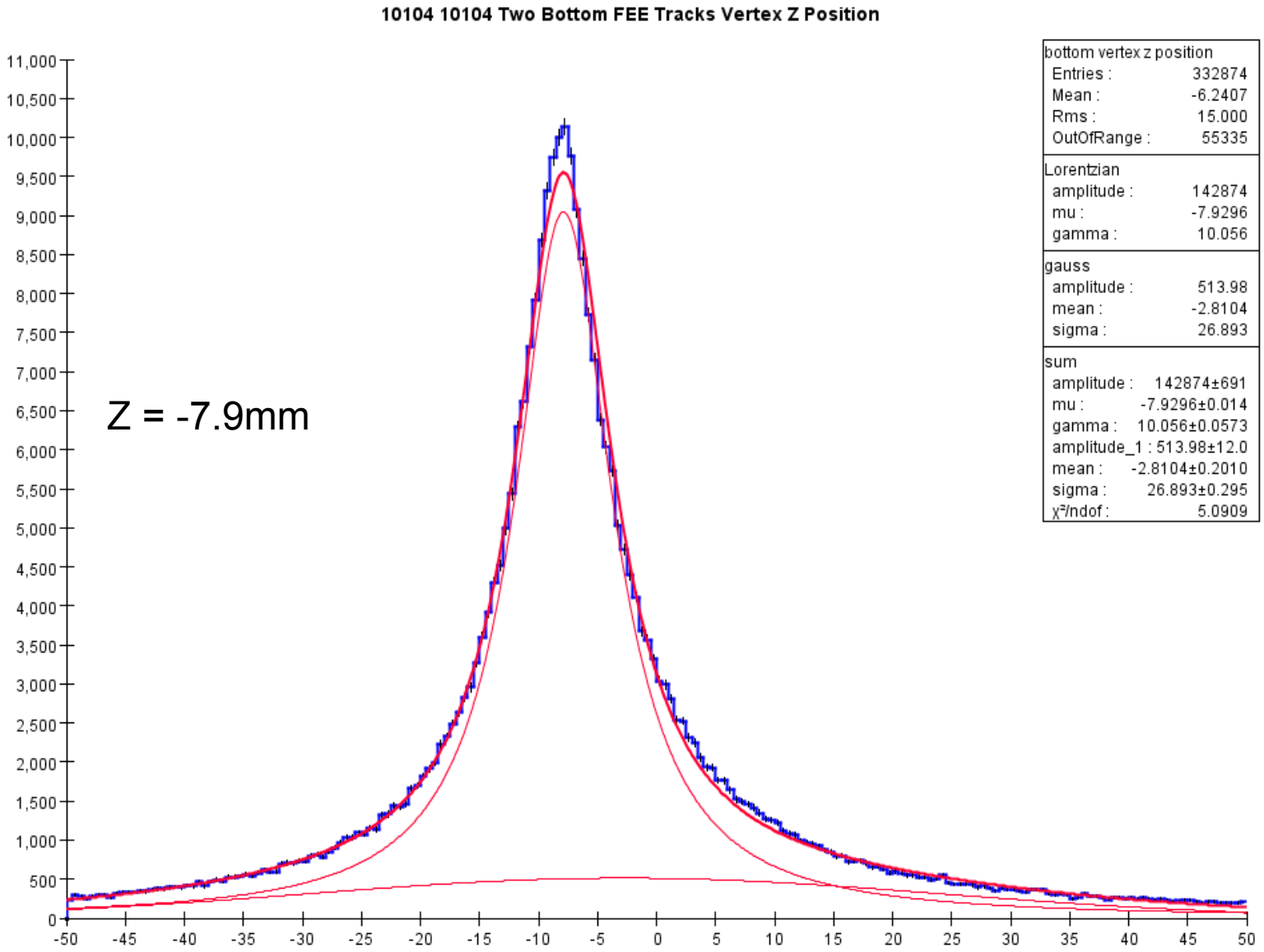








FEE 10104 Two Top Track Vertices

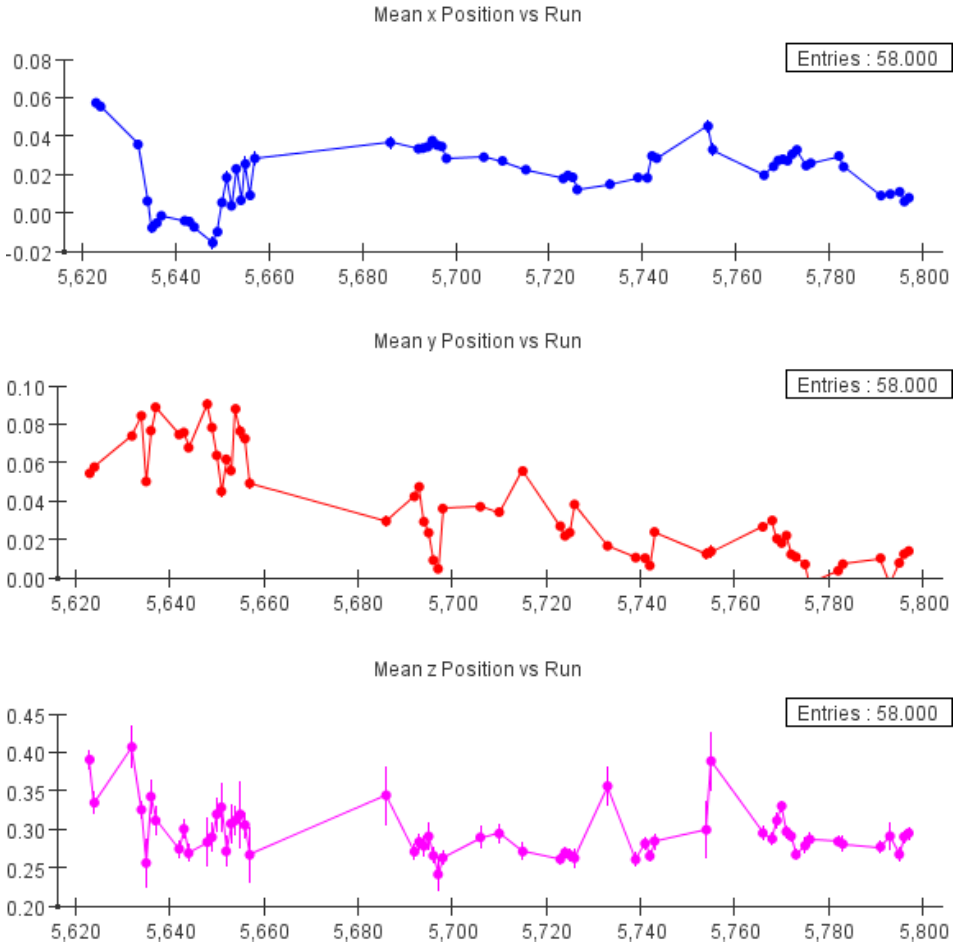


Intermediate-term Strategy

- Need to relax / disable the object standardization cuts (aka MOUSE) as these were intended for mature reconstruction analysis pass.
- Spin through Pass -1 data set
  - All partitions ending in 041 or 042 have been staged and pinned to /cache
  - Provides faithful subset of run conditions.
- Extract / Derive necessary conditions (baselines, pedestals, gains, etc.)
- Determine beam spot positions
  - Not sure how to determine beam slopes w/o Mollers
- Determine track efficiencies
  - In 2015/2016 analyses used only one “efficiency”
- Populate conditions database
- Respin through Pass -1 data with calibrated / aligned detector(s) and provide required Jeopardy! plots.

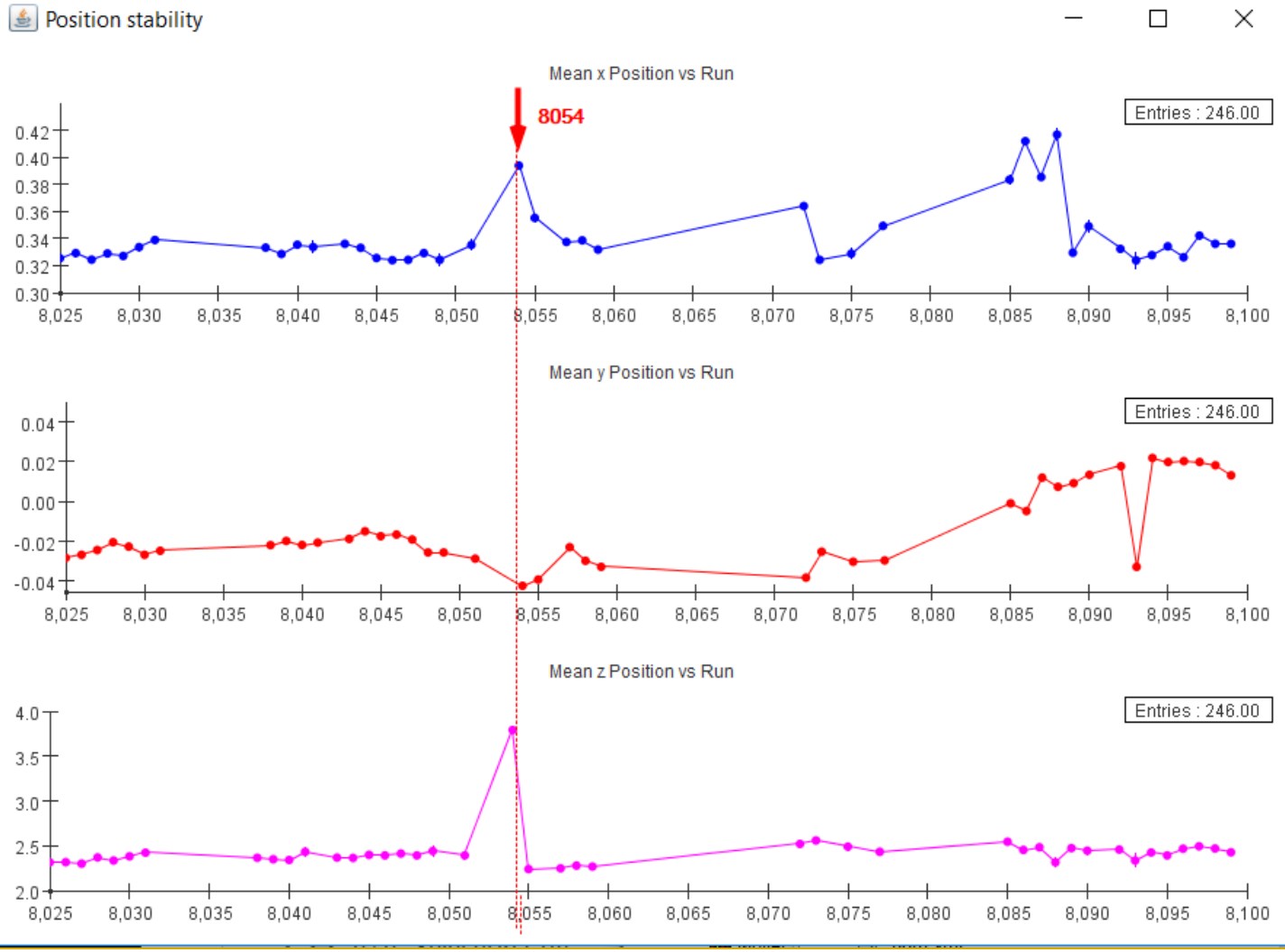
2015 Beam Position Variability

- Check variability in the beam position (and rotation?) as a function of time. X vs Y distribution of the unconstrained vertices from the pass8 Møller skims.



2016 Beam Position Variability

- Check variability in the beam position (and rotation?) as a function of time. X vs Y distribution of the unconstrained vertices from the pass1 Møller skims.



Pattern Recognition

- Possible improvements:
  - Improved axial/stereo matching (L4-L6)
  - Improved and/or more strategies using 3D points
    - Needed for L1/2 in any case, different for top/bottom
  - Cluster-seeded tracking (at least for positrons)
    - ECal cluster position and energy define a trajectory which originates from the beam-spot (HPS Note 2015-006).
    - Find tracks consistent with that hypothesis.
  - Implement pattern recognition based on 1D strip hits.
    - No “ghost” hits, or parallax issues, important in high-occupancy events.
    - Could see increased efficiency by not requiring hits in both axial and stereo layers per station.
    - See Robert’s talk.

Track Fitting

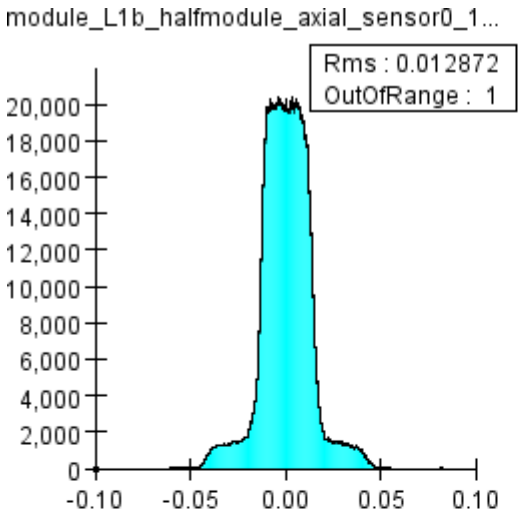
- Track fit quality is not chi-squared distributed
- Discrepancy between data and MC
- Resolution of issues complicated by:
  - Strip cluster position
  - Module position (alignment)
  - Track extrapolation (non-uniform field)
  - Multiple scattering and energy loss
- GBL refit under review (see PF's talk)
- Kalman fit might expose issues
- Whole chain needs better documentation
  - Javadoc on what the code is expected to be doing
  - Documentation on procedure, algorithm, math

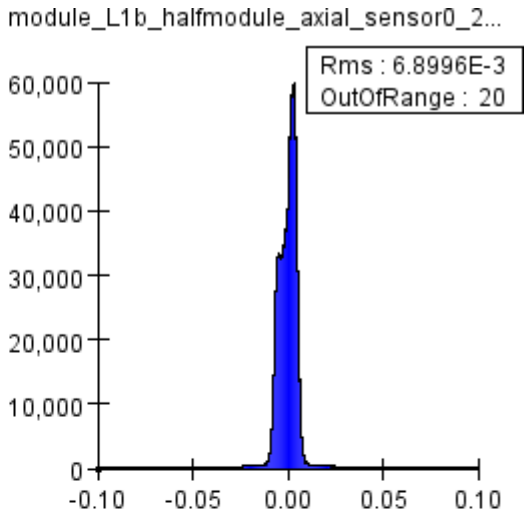
Tracking Down Tracking

- My quest to understand our track reconstruction has led me back to hits.
  - Recall that our track fit metric is not χ^2 distributed.
- Analyze MC hits to check our input to track fitting.
- Analyze latest set of tri-trig-wab-beam events.
- Compare measurement (u) of strip cluster hits to the SimTrackerHit position as a function of sensor as well as number of hits in the strip cluster.

Hit Residuals (measured-predicted)

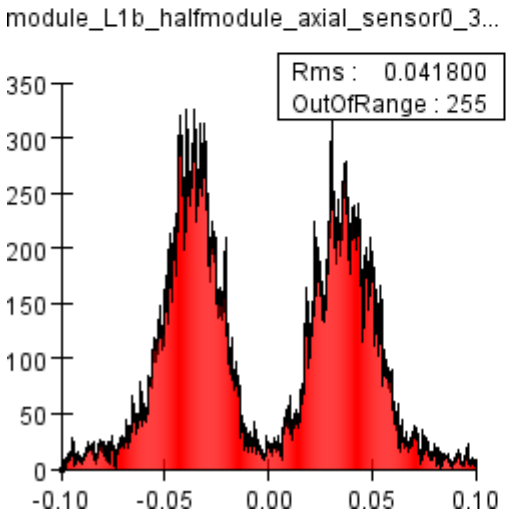
1 strip

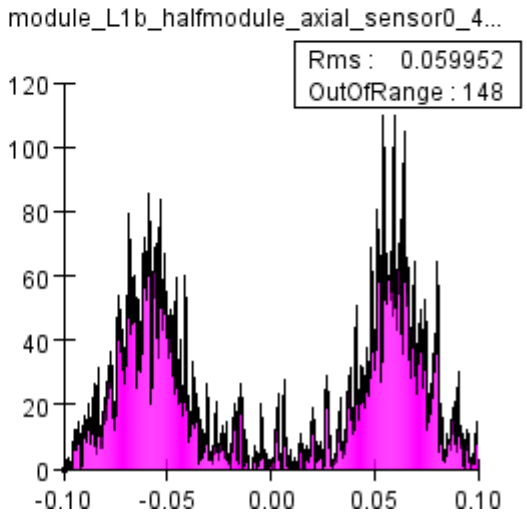




2 strip

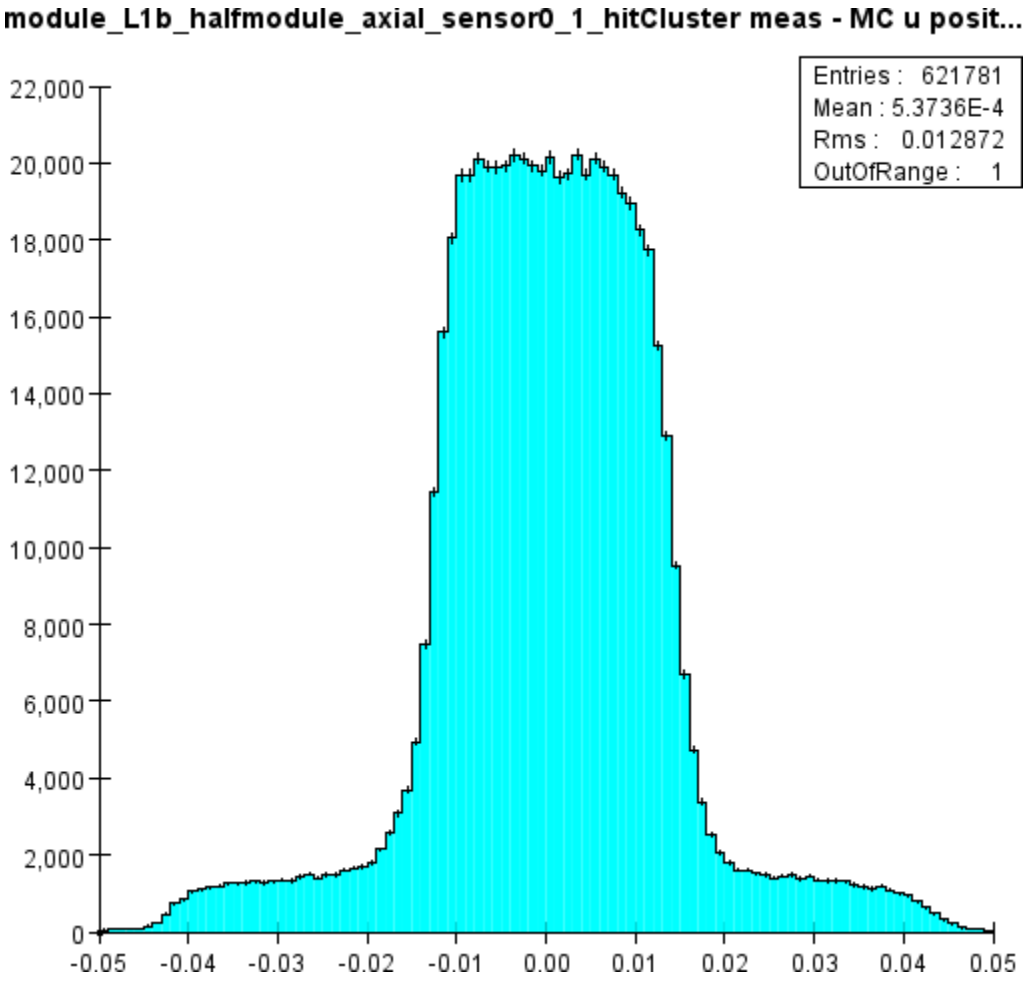
3 strip



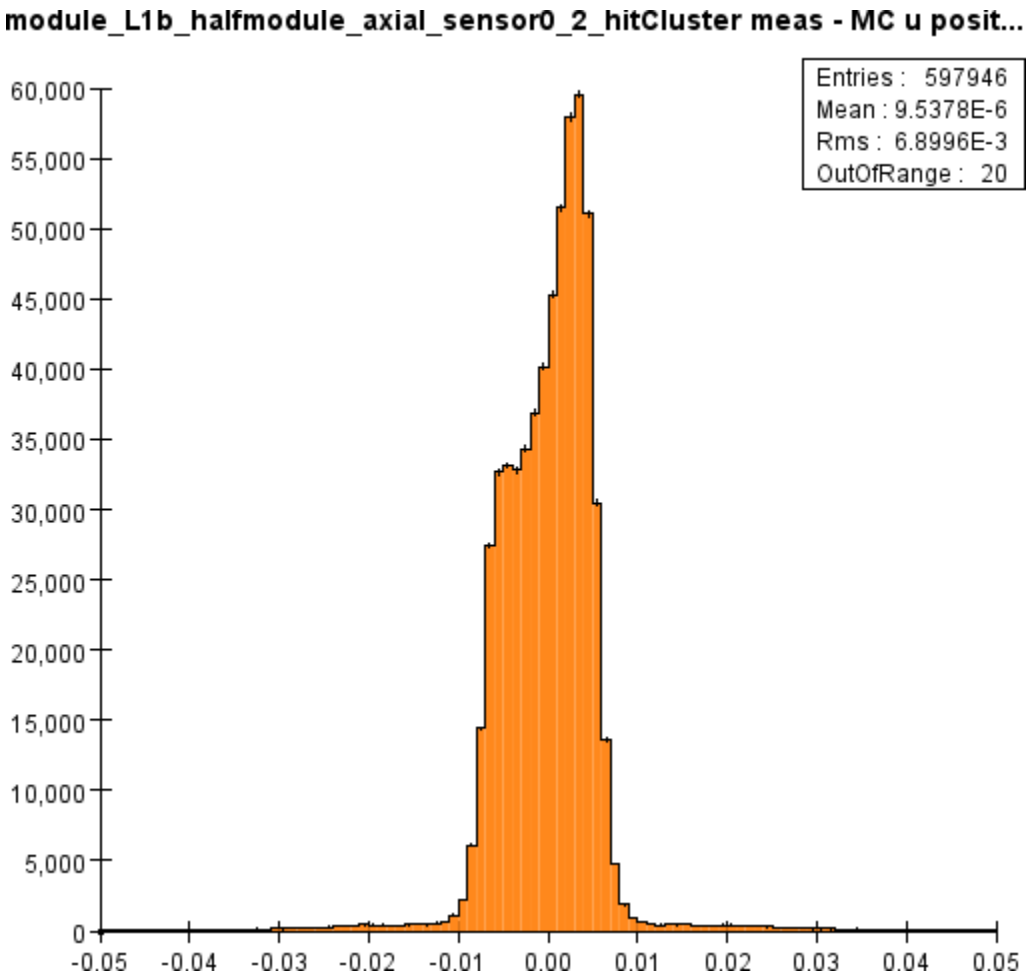


4 strip

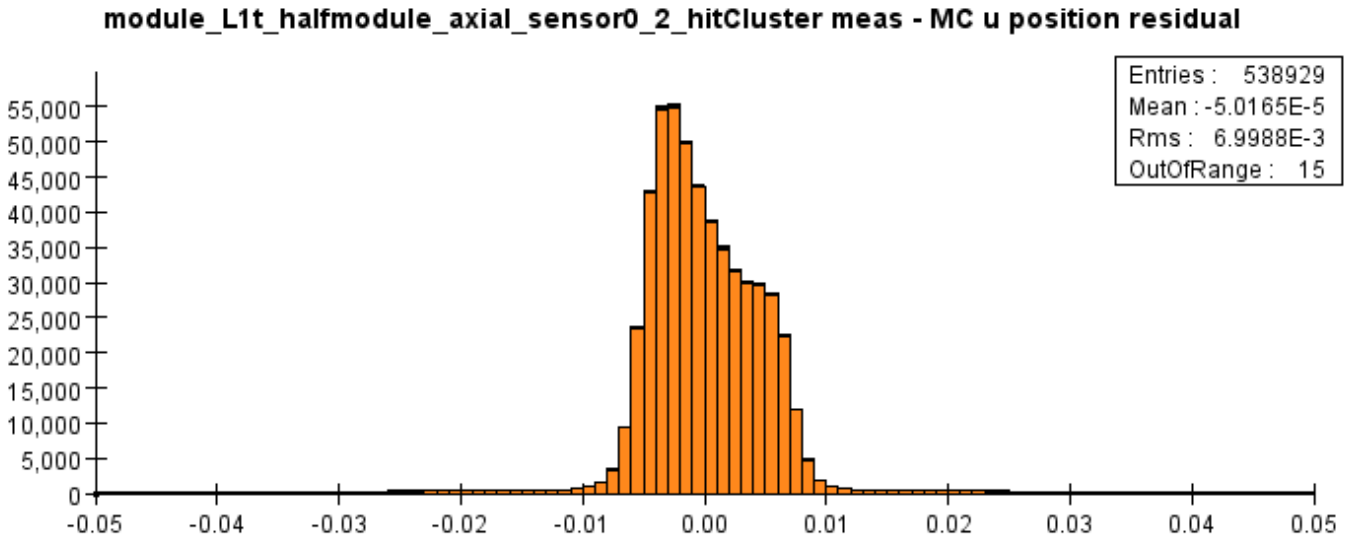
1 Strip

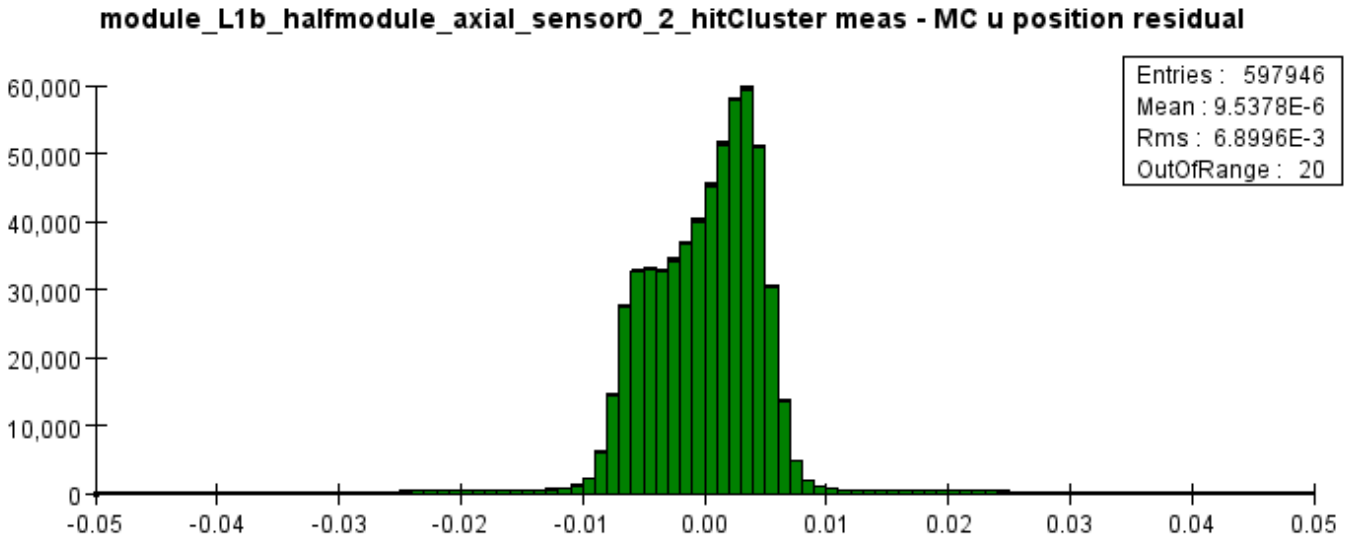

module_L1b_halfmodule_axial_sensor0_1_hitCluster meas - MC u posit...
Entries : 621781
Mean : 5.3736E-4
Rms : 0.012872
OutOfRange : 1
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-0.05
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
0.05

2 Strip

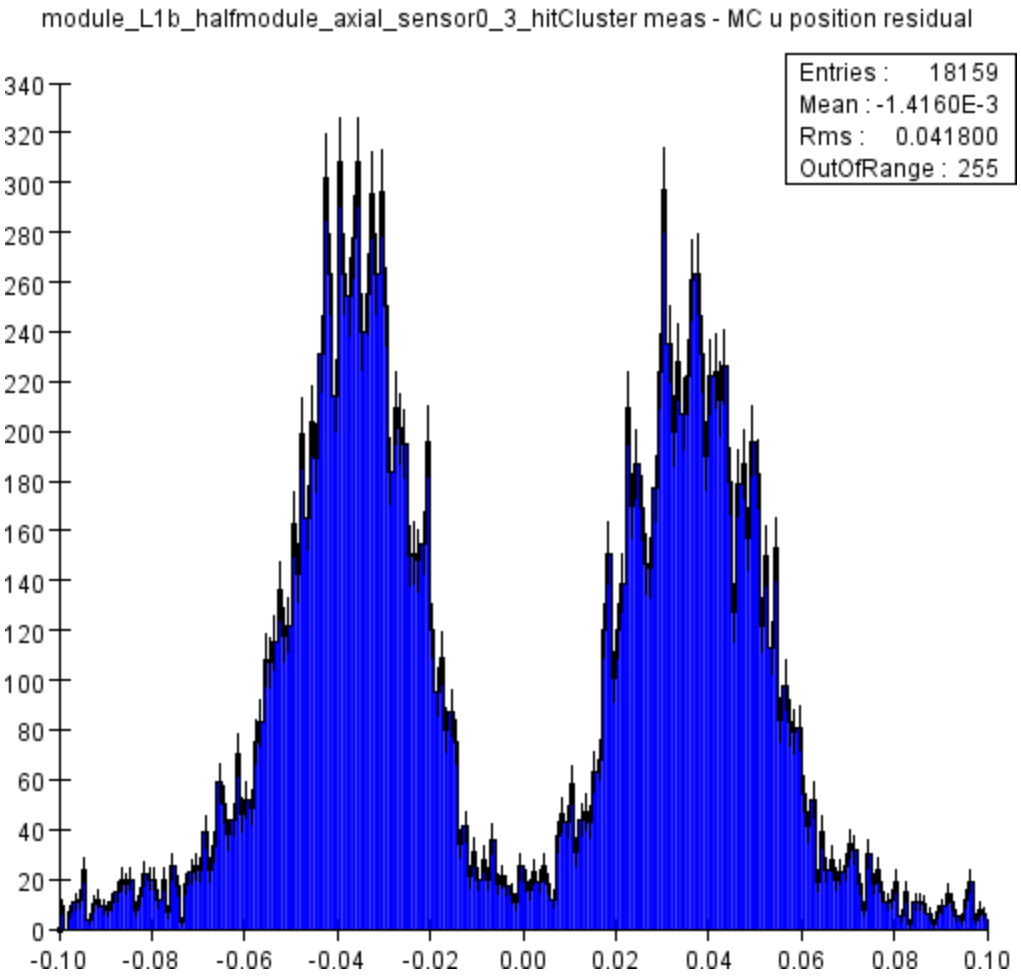

module_L1b_halfmodule_axial_sensor0_2_hitCluster meas - MC u posit...
Entries : 597946
Mean : 9.5378E-6
Rms : 6.8996E-3
OutOfRange : 20
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
-0.05
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
0.05

2 Strip (top vs bottom)

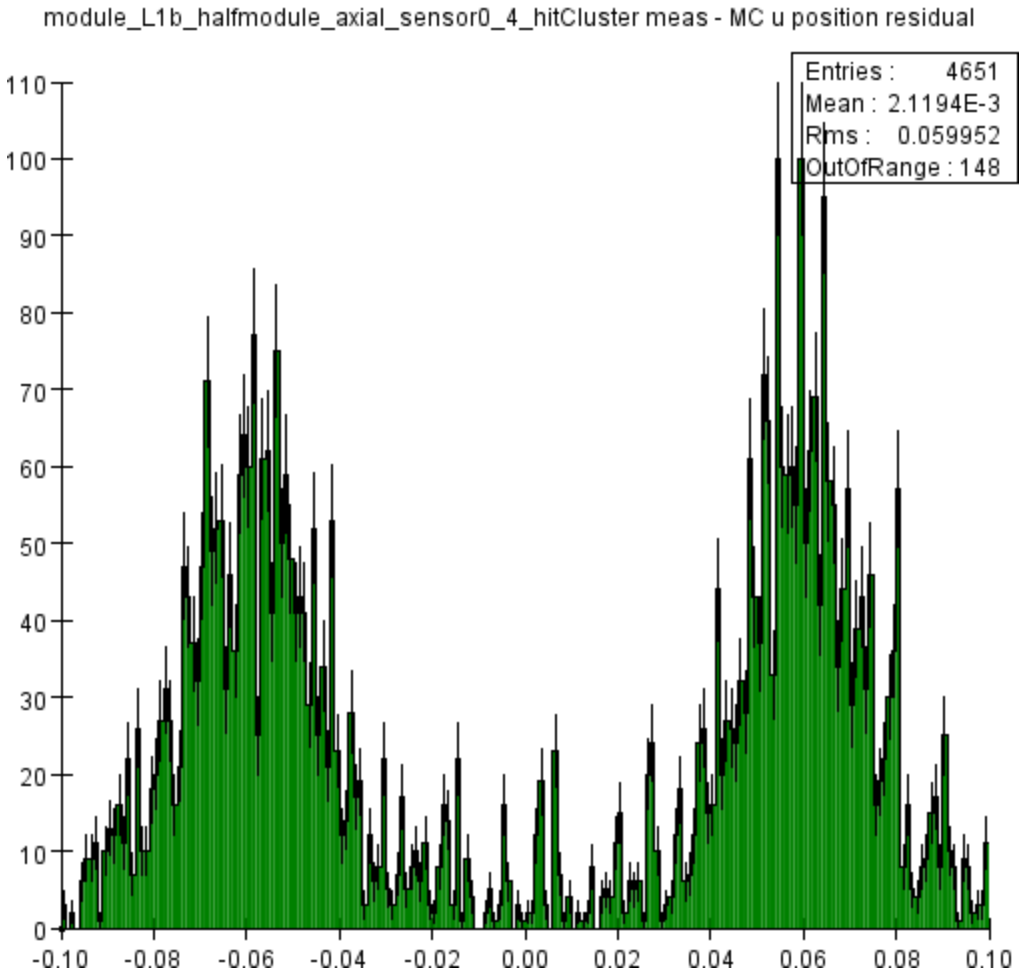




3 Strip


module_L1b_halfmodule_axial_sensor0_3_hitCluster meas - MC u position residual
Entries : 18159
Mean : -1.4160E-3
Rms : 0.041800
OutOfRange : 255
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
0.06
0.08
0.10

4 Strip


module_L1b_halfmodule_axial_sensor0_4_hitCluster meas - MC u position residual
Entries : 4651
Mean : 2.1194E-3
Rms : 0.059952
OutOfRange : 148
110
100
90
80
70
60
50
40
30
20
10
0
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
0.06
0.08
0.10

MC Hit Summary

- No resolution (yet) to the resolution
- Single strip clusters seem to be OK
- Two-strip clusters are asymmetric
- Recall that the majority of hits in data (except for slim layers) are split roughly 50-50 between 1- and 2-strip hits.
- Three- and four-strip clusters are bimodal, rare in data
- Could we improve our millepede alignment by analyzing only 2-strip hits in the planes that we are floating? Will factor of 2 better in resolution make up for factor of 2 worse in statistics?

Software CPU Performance

- Our tracking software is SLOW!
  - Maurik has shown timing breakdown
  - Overall CPU budget dominated by tracking, primarily track-finding/fitting, followed by raw hit-fitting
  - Not (necessarily) an issue for 10% pass0, but action should be taken before full recon

- Fitting readout samples to determine hit time and pulse height
  - Currently using generic minuit fit
  - Need to evaluate possible gains from a dedicated fitter
  - Only do once, in evio -> lcio step, re-reconstruct (if needed) from lcio.

Long-term Recon Plan

- Need to intensify (start?) our efforts to improve the performance of our tracking reconstruction
  - Speed up hit wave-form extraction with dedicated fitter
  - Speed up / improve pattern recognition (Kalman?)
  - Push recoil-electron track finding/fitting/vertexing
  - Reduce our output LCIO file size
    - e.g. drop raw SVT wave-forms after fits, eliminate duplicate tracks, clusters, etc.
  - Implement “smart” strategies for pass-N re-reconstruction, e.g.
    - Re-run over lcio skims, not evio
    - Don’t re-calculate hit pulse heights and times
    - Don’t re-run pattern recognition, simply re-fit tracks with new, better geometry, re-associate tracks with ecal clusters, …

Summary

- Current code and algorithms are working, and we will need to rely on them to get out of Jeopardy! but…
- Improvements to the Alignment, Calibration, Tracking and Vertexing feed directly into improvements in the bump-hunt and vertex analyses and our discovery reach
- Great opportunities for new contributors!