Pass0 Reconstruction Analysis

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HPS Analysis Meeting

August 8, 2023

Data Quality Assurance

- Primary goal is to assure the quality of the reconstruction of the 2019 and 2021 data sets
- Focus is on the characterization of detector performance
- Comparing tracking and calorimeter performance
- Analyzing single-track performance with an emphasis on momentum scale and resolution
- Studying track-finding efficiencies for electrons and positrons using low-background event samples
  - FEEs
  - WABs
  - Three-prong Tridents
- Providing data samples for use by the wider collaboration

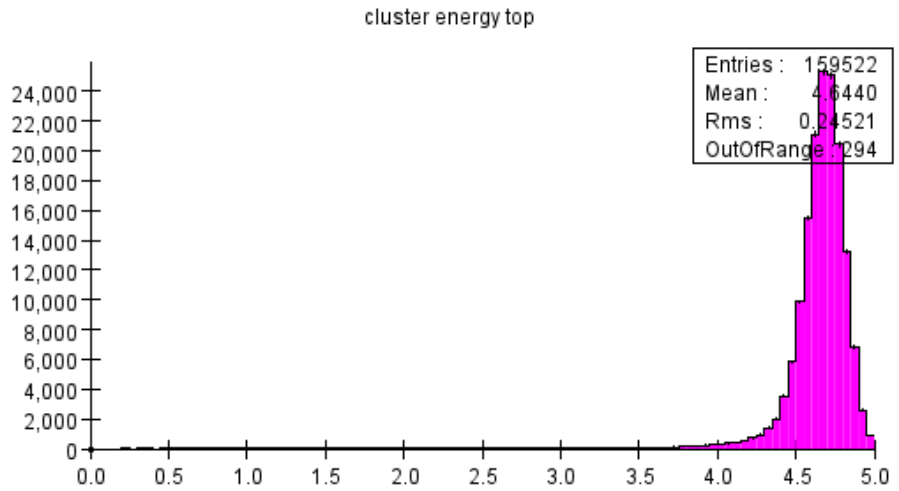
Momentum & Energy

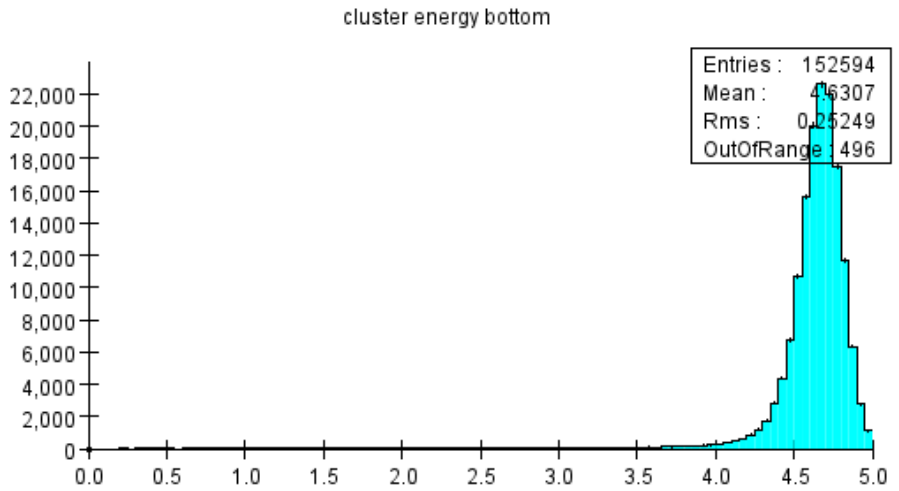
- Use a series of simple cuts to provide samples of events which can be used for energy and momentum calibration, tracking efficiency studies and beam position/direction determination
- Full Energy Electrons (FEEs)
  - Single monochromatic particles at beam energy
- Wide-Angle Bremsstrahlung (WABs)
  - Two-particle system whose sum equals beam energy and direction
  - Lower-energy and wider angular coverage
  - Checks electron and photon cluster corrections
- Three-prong Tridents
  - Three-particle system whose sum equals beam energy and direction
  - Lower-energy and wider angular coverage
  - Checks electron, positron and photon cluster corrections
  - Vertexing positron+same-side electron and positron+opposite-side electron checks global alignment of top/bottom in same event.
  - Low-background sample for positron track-finding efficiency studies

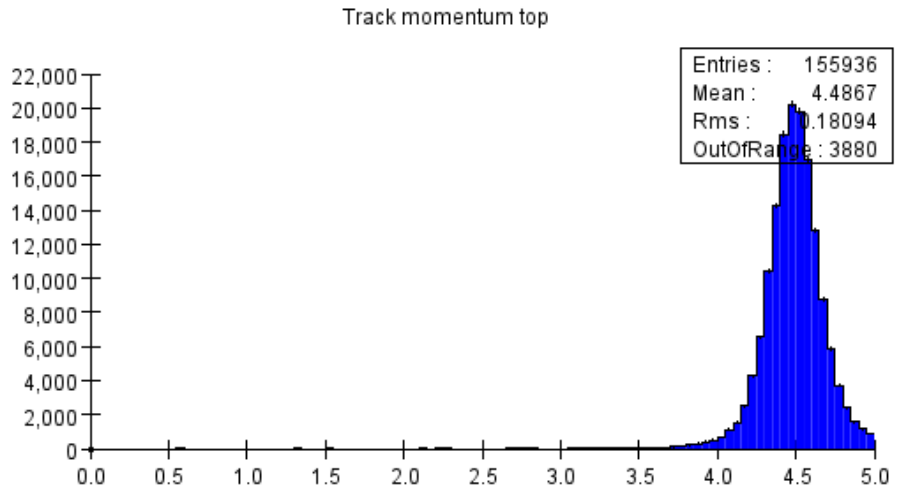
Track-Calorimeter Matching

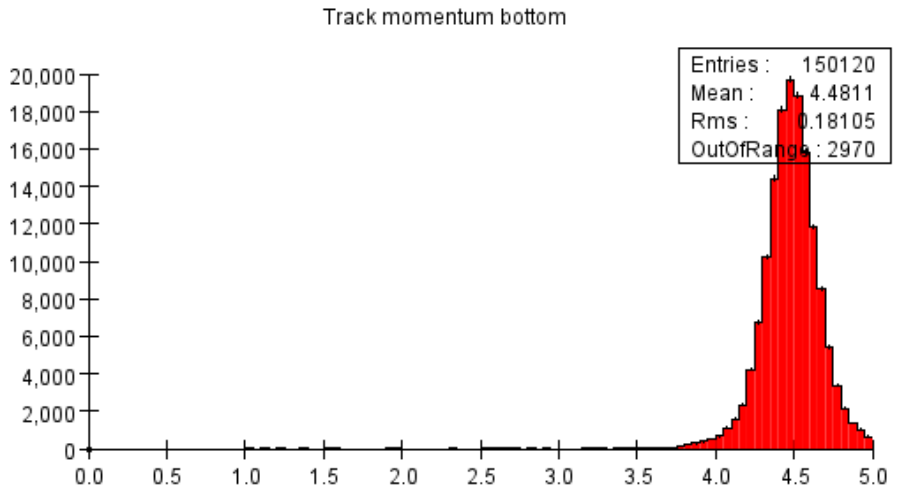
- Although the SVT defines the HPS coordinate system, it is important to realize that the Ecal also provides important position information.
  - It has been surveyed before and after both the 2019 and 2021 runs
  - Provides cluster positions with a resolution of a few mm
- Severe discrepancies have been shown between the position of tracks projected to the calorimeter face and the position of the associated cluster

2019 4.55GeV FEE Analysis

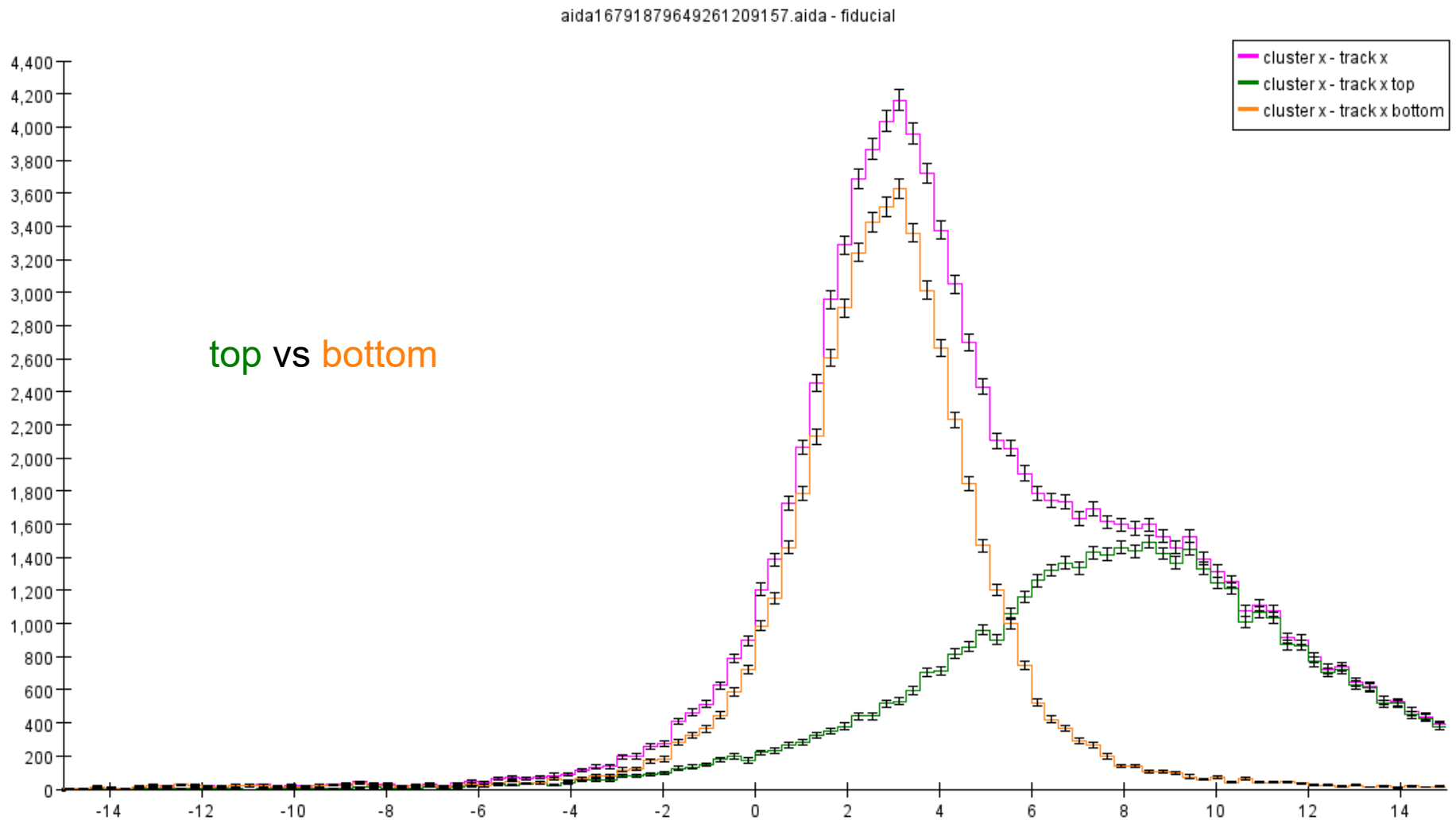




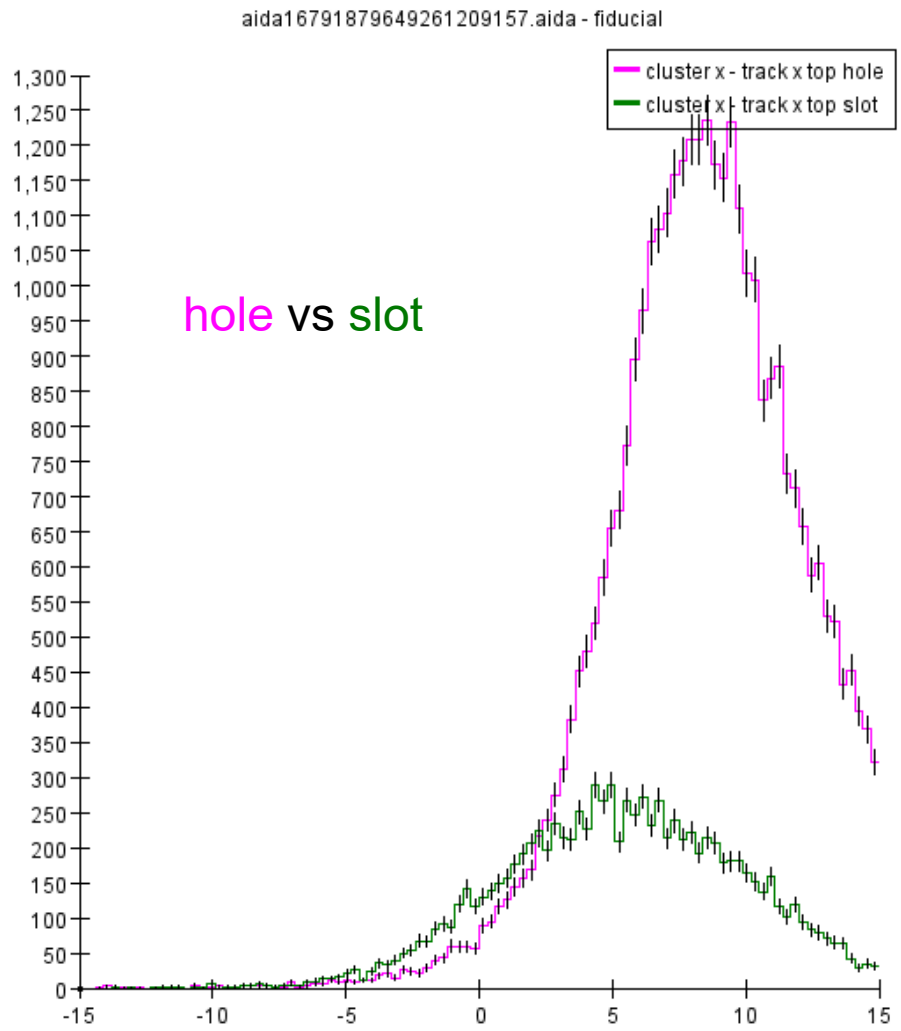


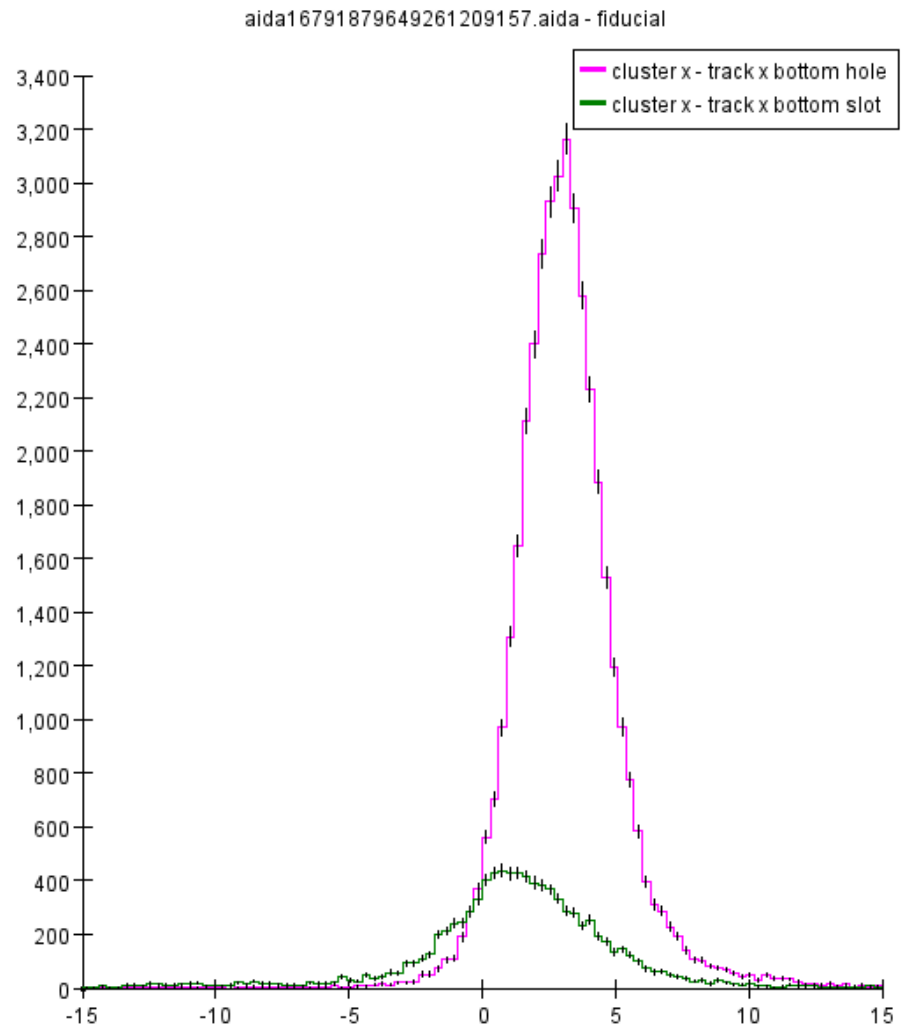


2019 FEE Cluster X – Track X

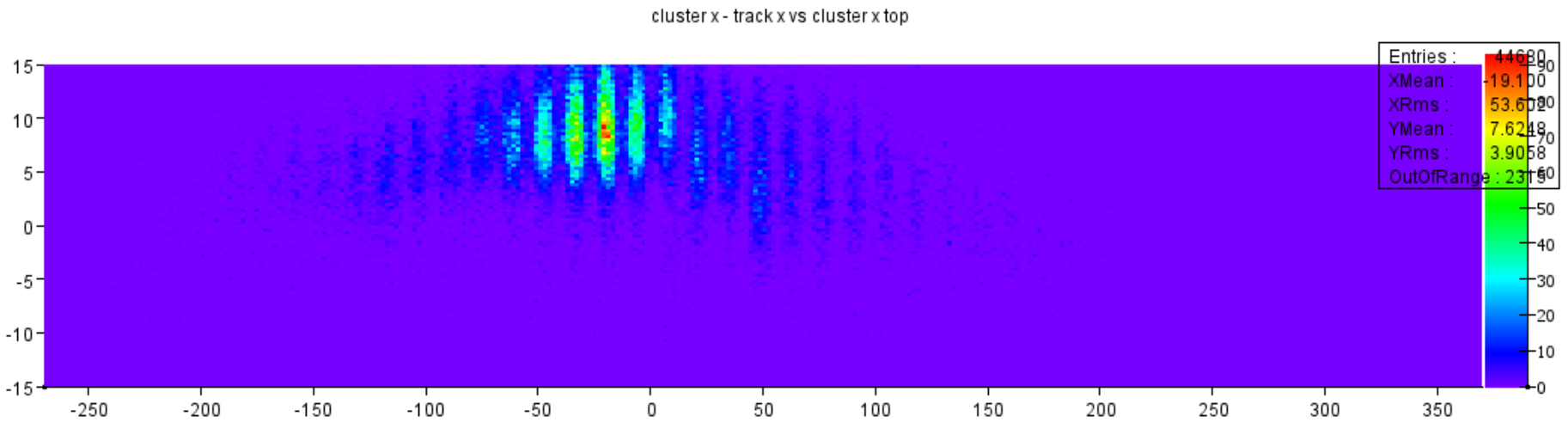


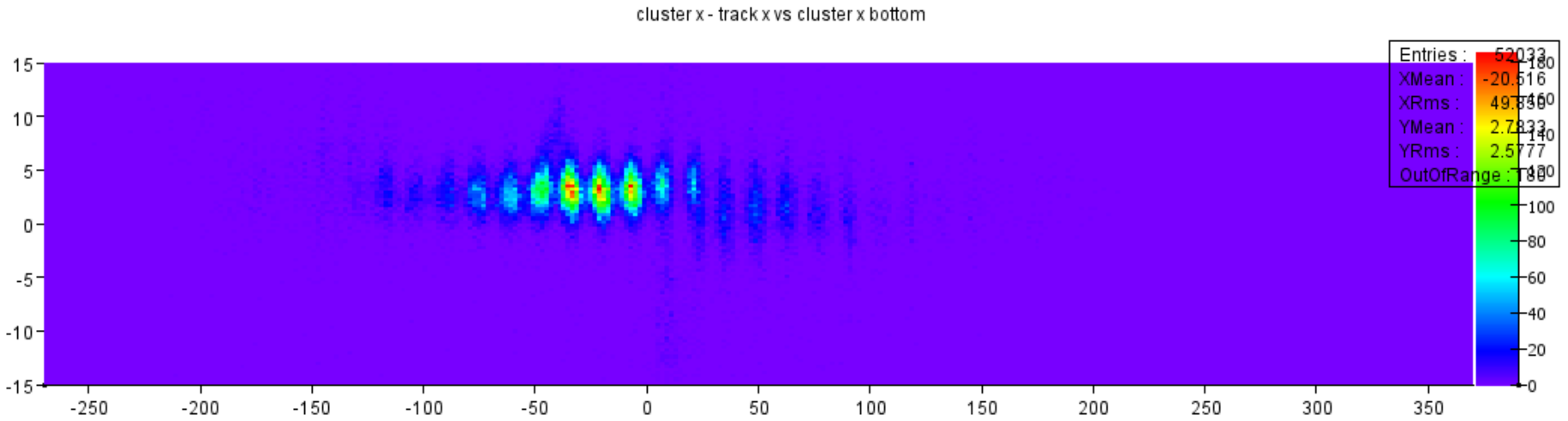
2019 FEE Cluster X – Track X



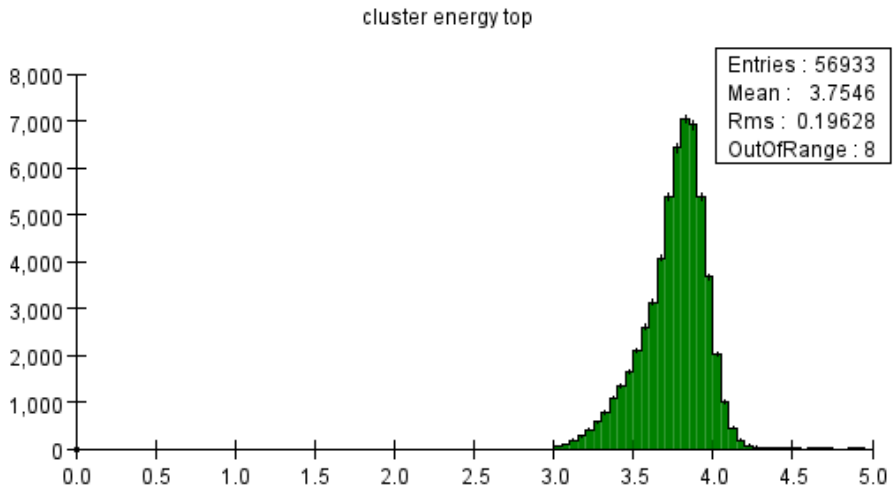


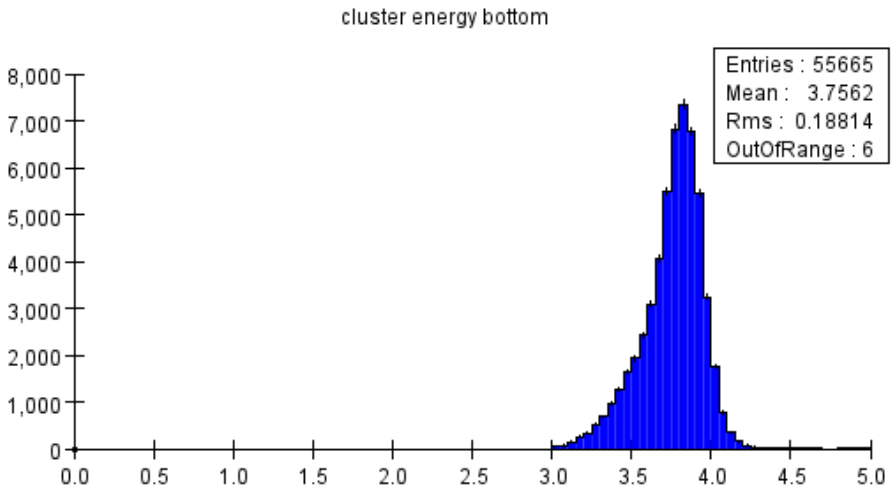
2019 FEE Cluster X – Track X vs X

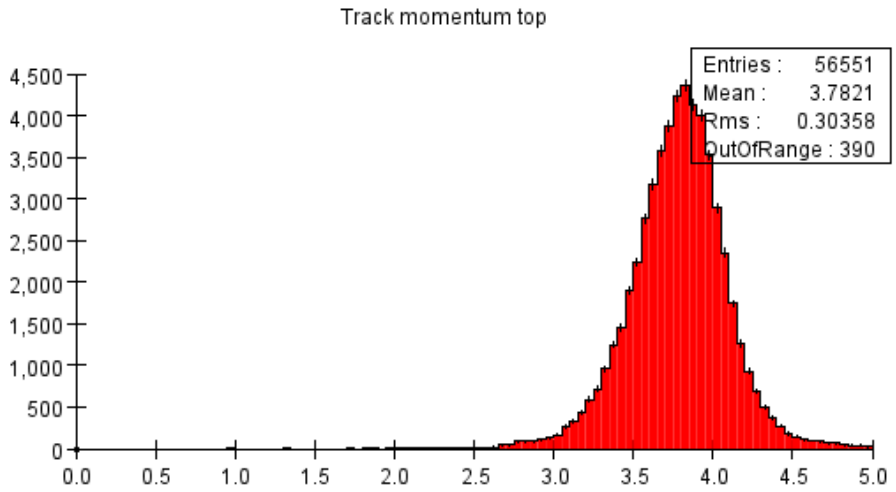


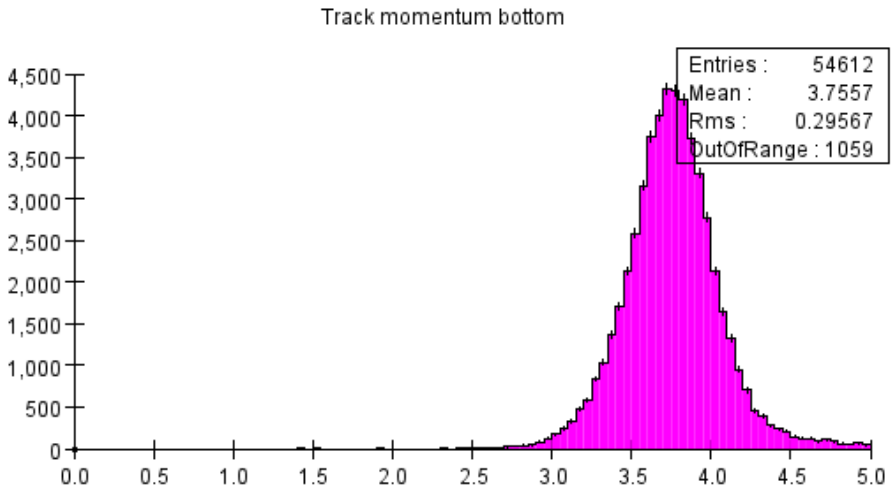


2021 3.74GeV FEE Analysis

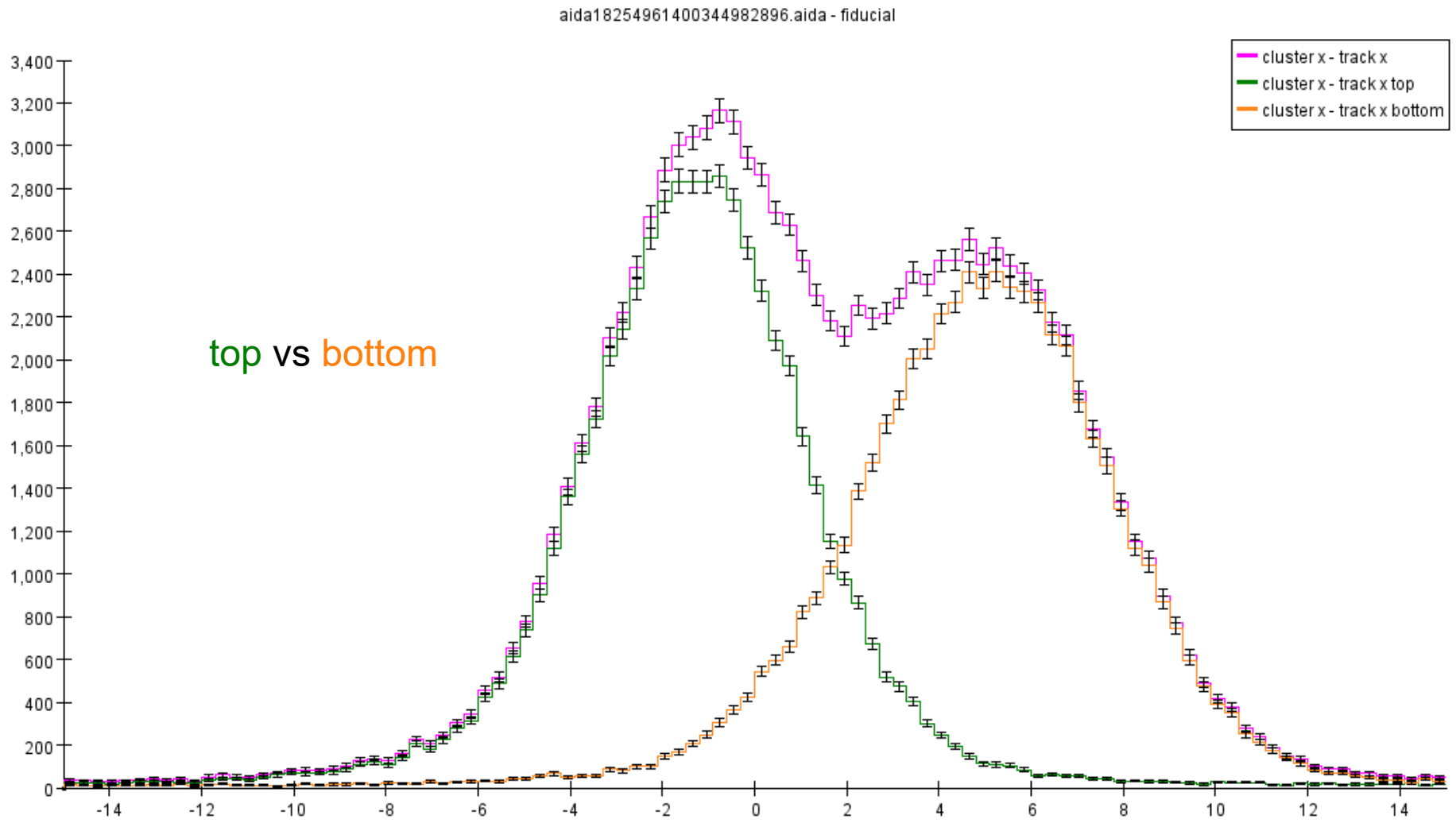




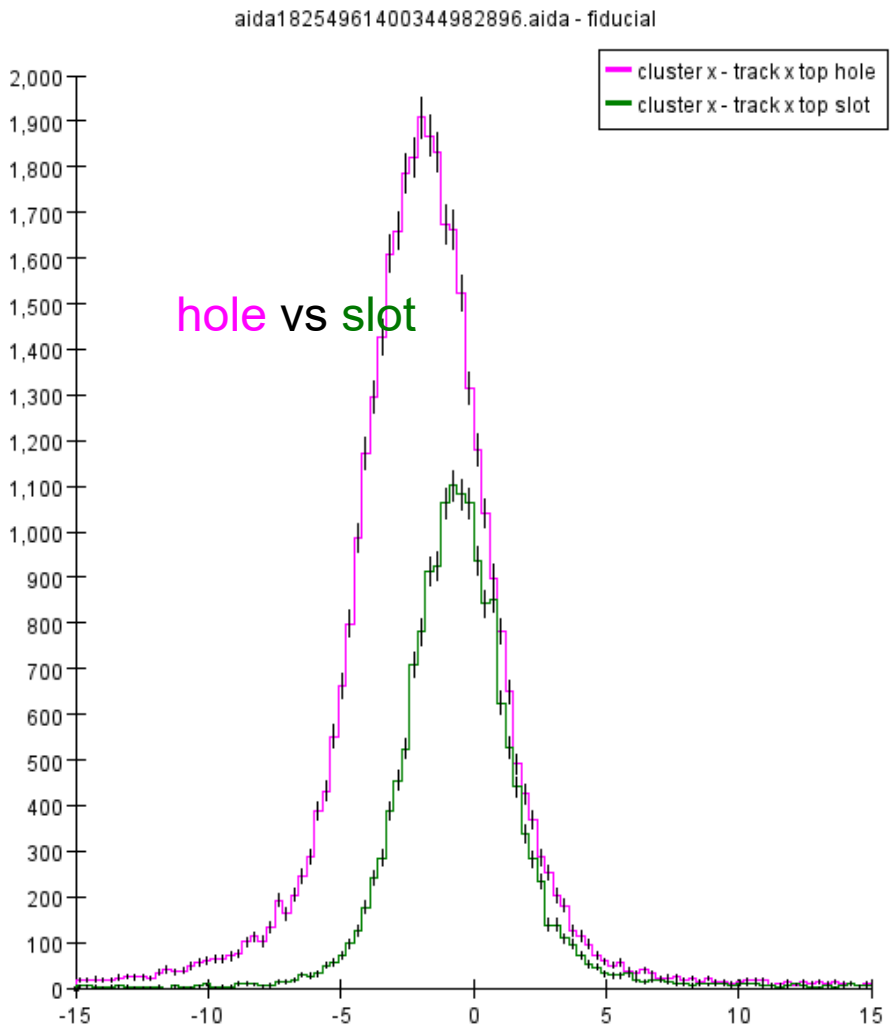


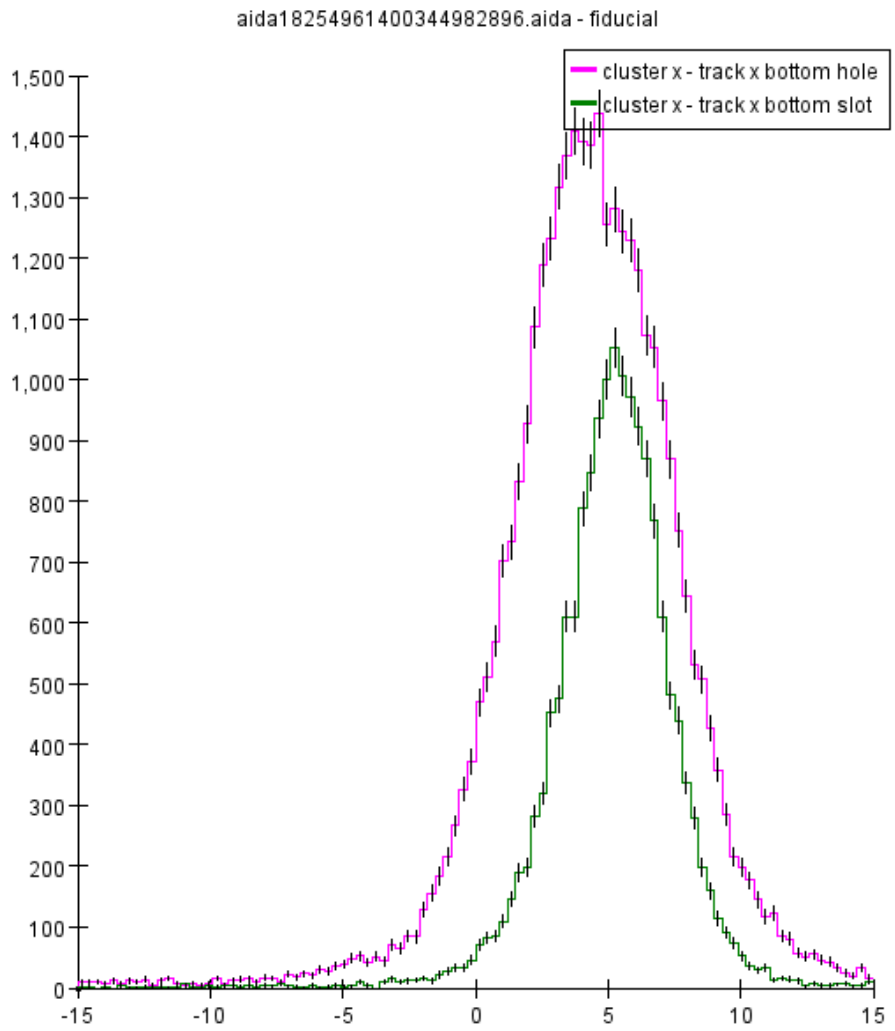


2021 FEE Cluster X – Track X

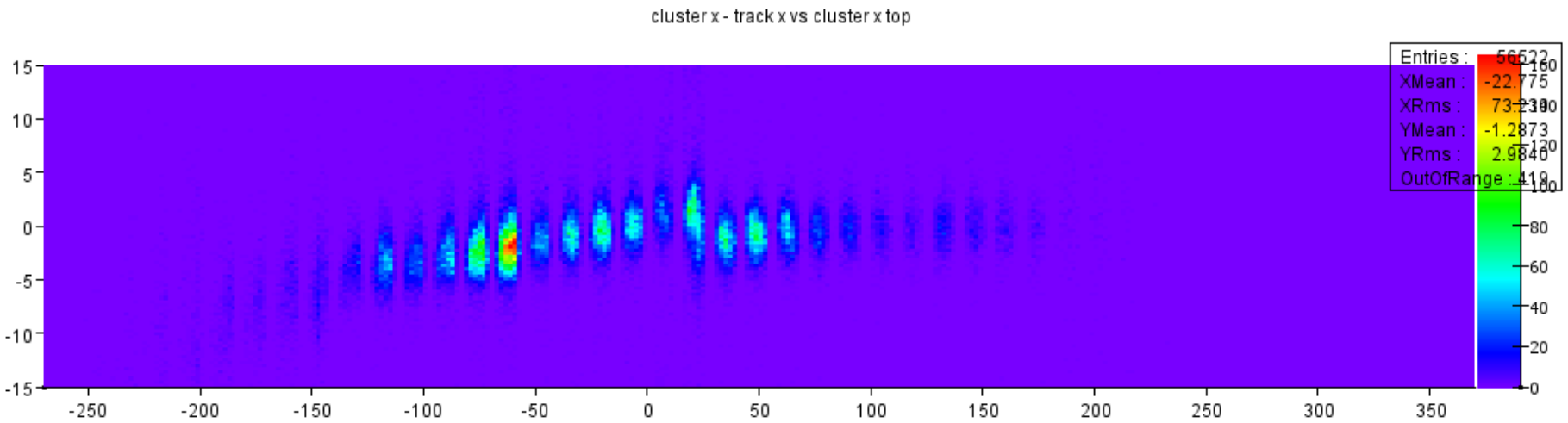


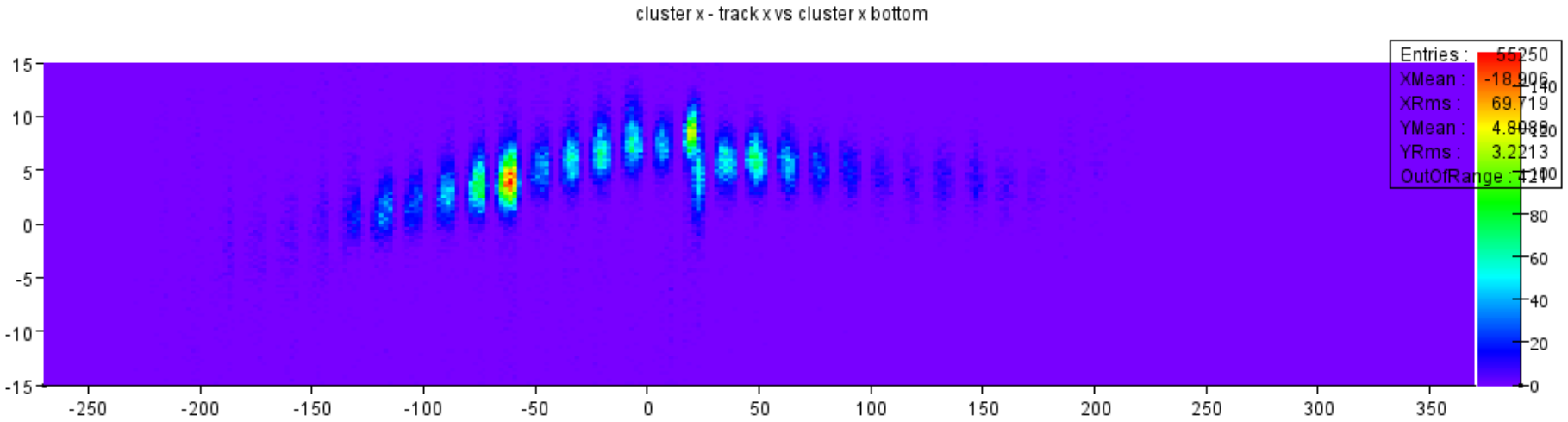
2021 FEE Cluster X – Track X





2021 FEE Cluster X – Track X vs X

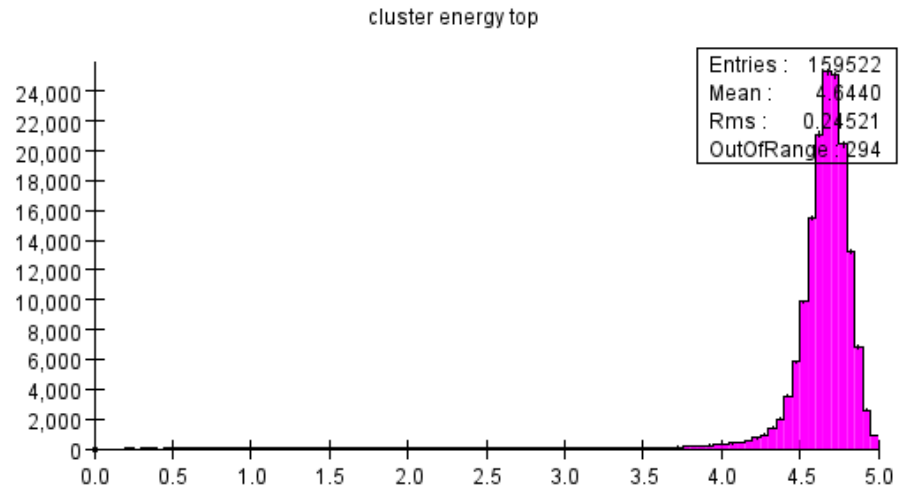


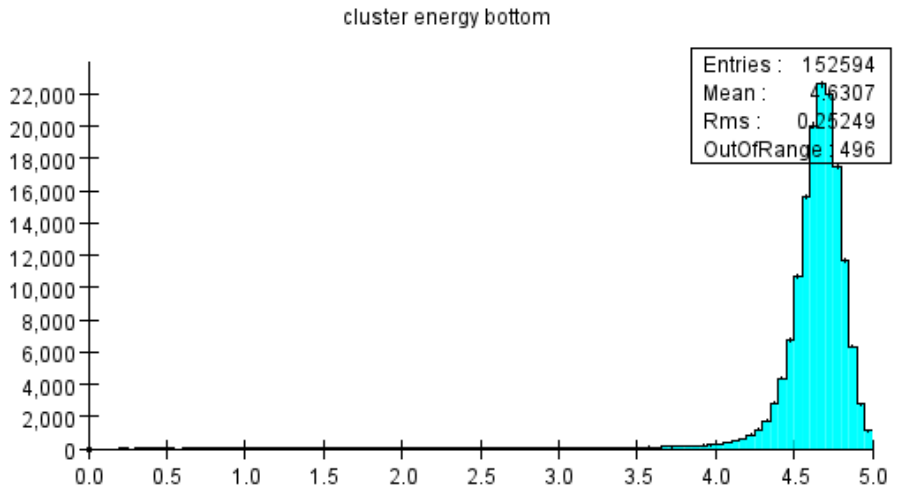


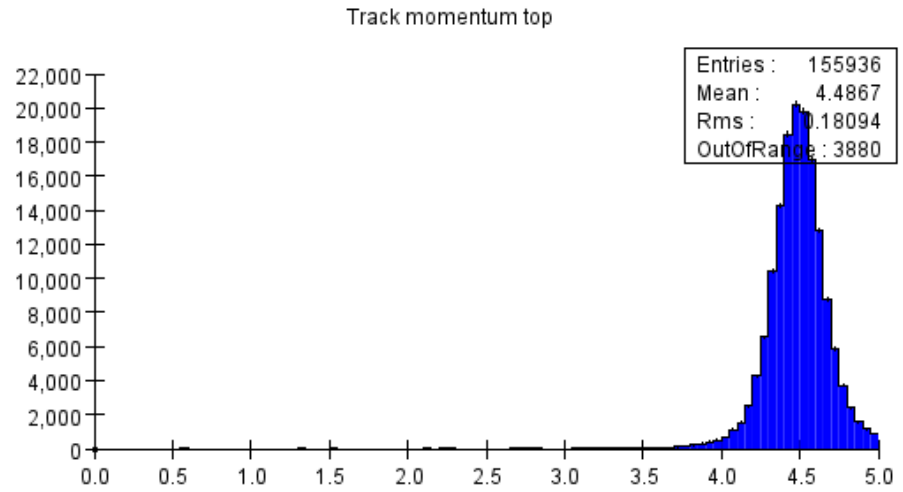
Cluster vs Track Matching

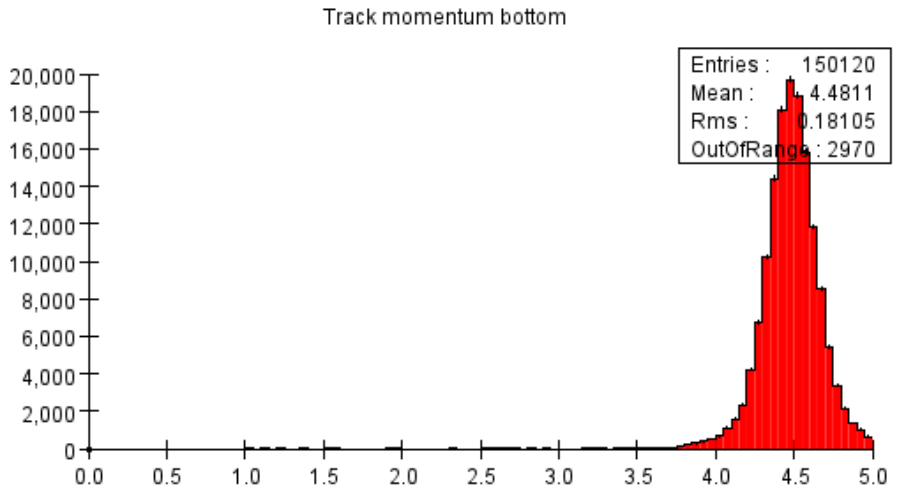
- Concerns were raised regarding the technique used to propagate the tracks to the face of the calorimeter
- Analyze behavior in MC, using single 4.5GeV electrons in the 2019 detector

MC 4.5GeV electron Analysis

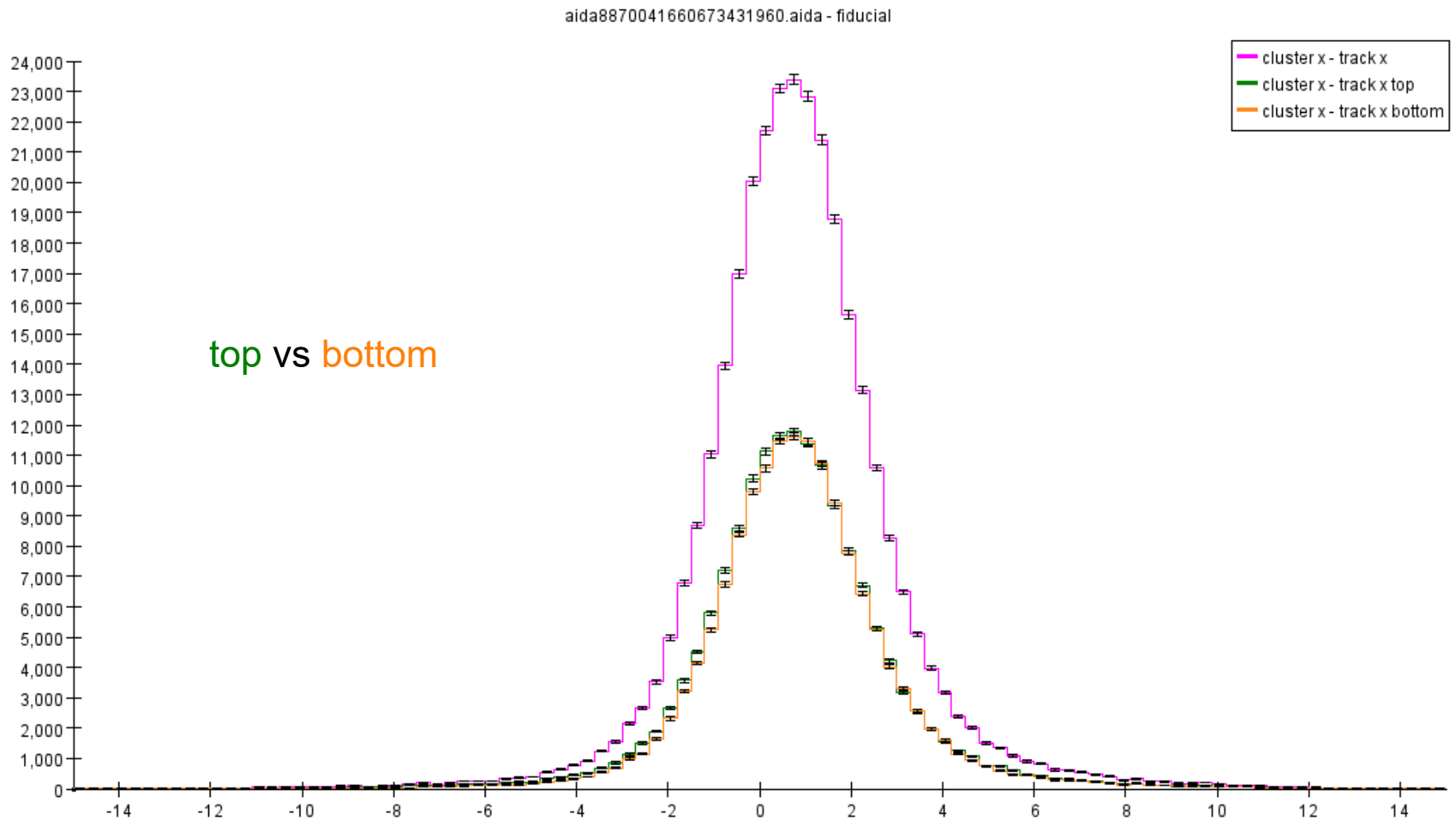




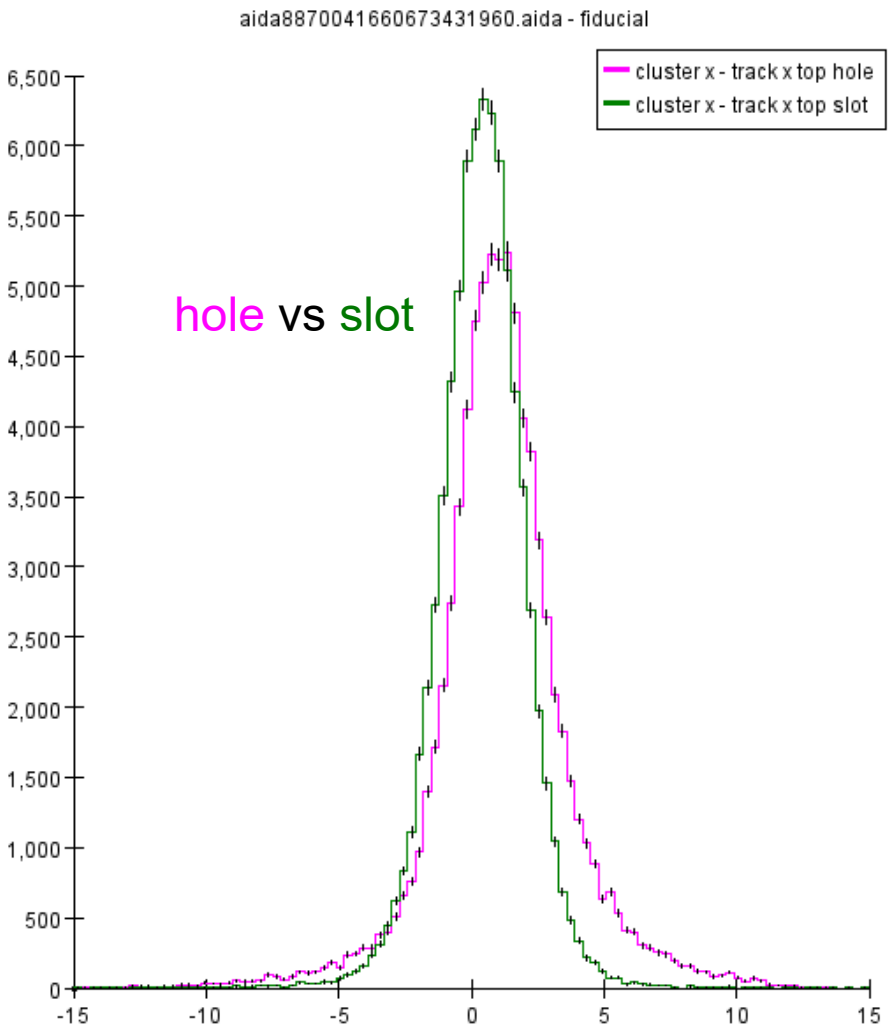


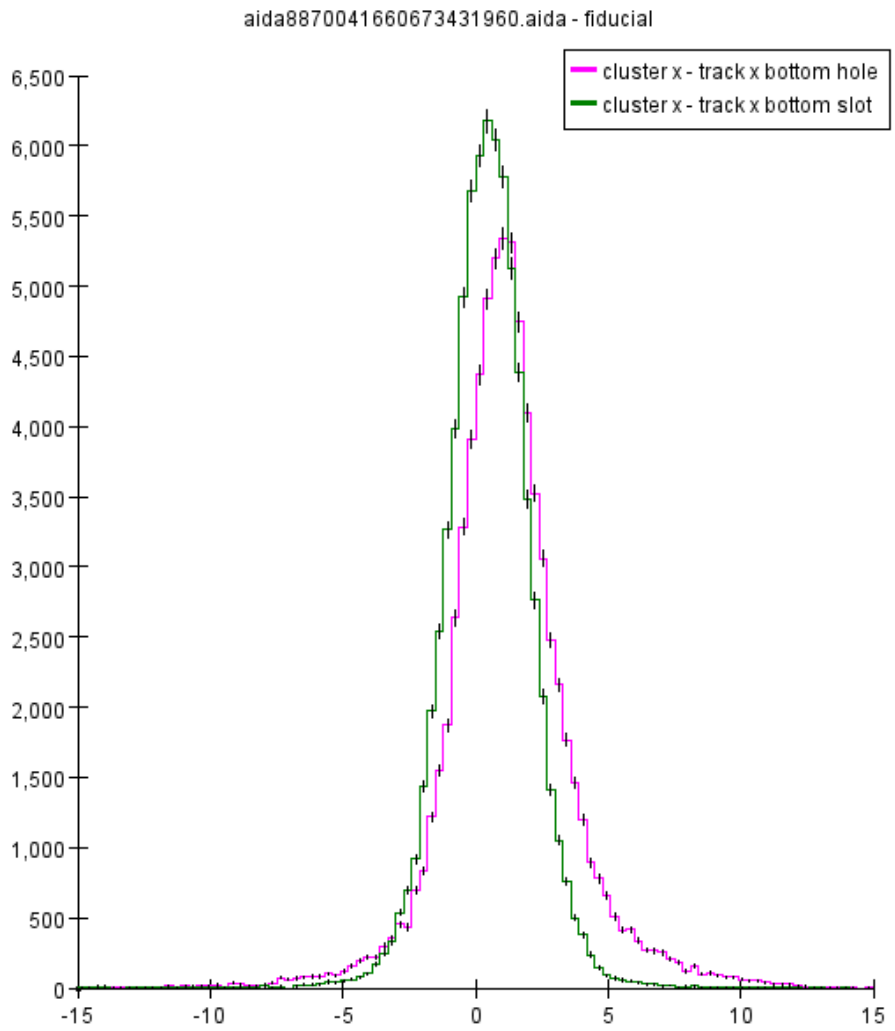


MC 4.5GeV Cluster X – Track X

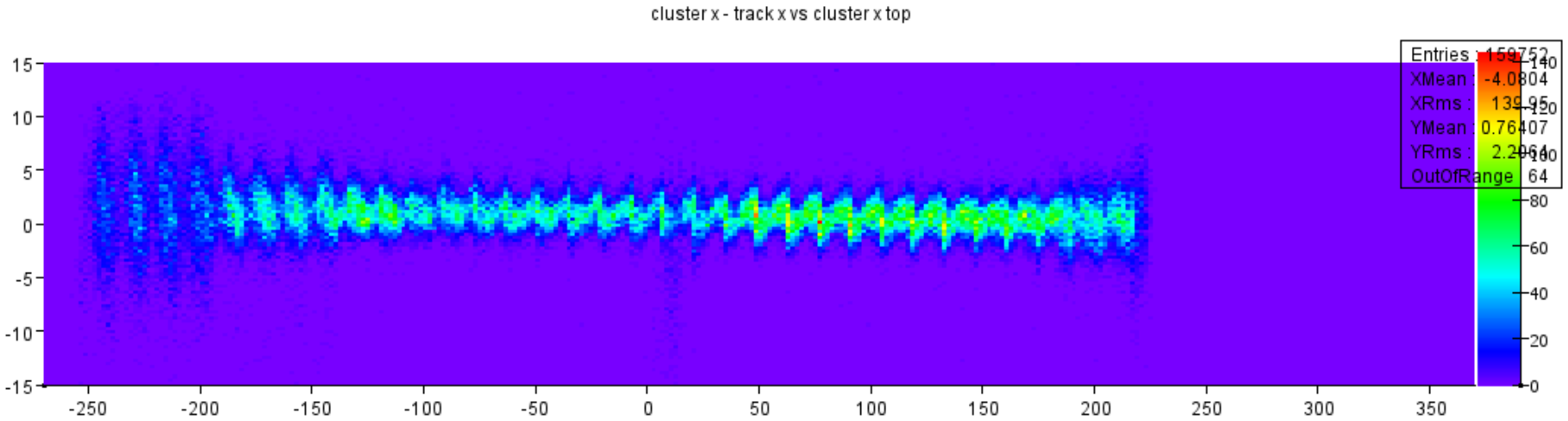


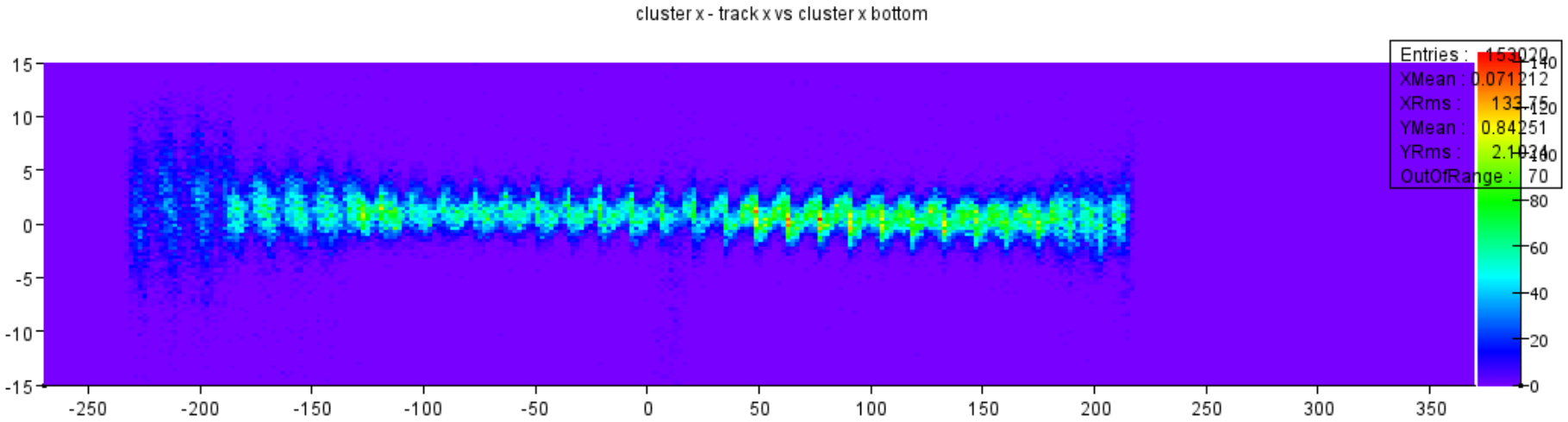
MC 4.5GeV Cluster X – Track X





MC 4.5GeV Cluster X – Track X vs X





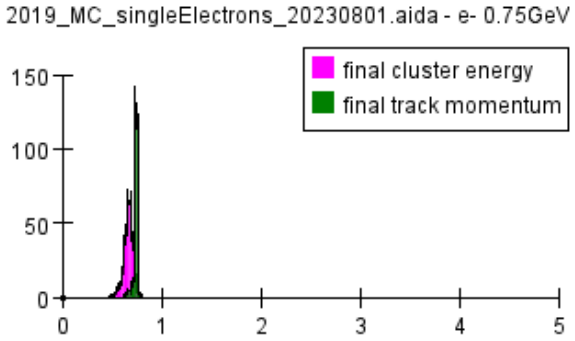
Cluster vs Track Matching

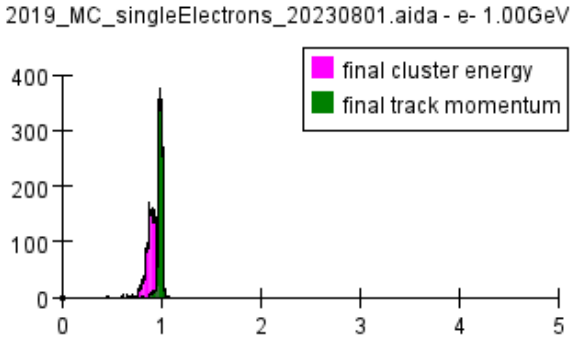
- MC exhibits behavior one would expect.
- It's clear that systematic differences between top and bottom, hole and slot, and 2019 and 2021 are due to SVT misalignments
- Analysis of these distributions should be a standard part of any SVT alignment

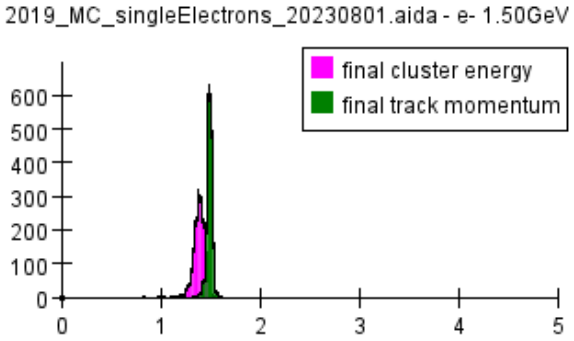
Energy and Momentum Calibration

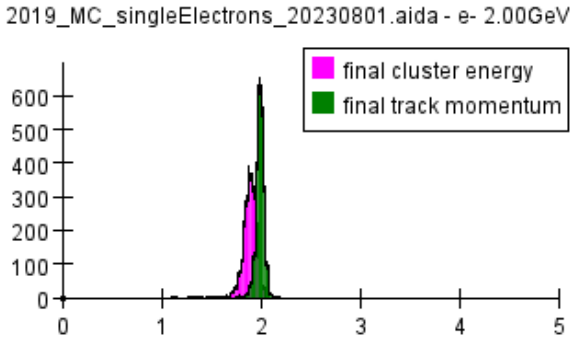
- Have generated single particles (e+, e-, gamma) for the derivation of the Ecal “sampling fractions”
- Recently re-reconstructed by Maurik using the latest MC readout/reconstruction chain using the 2019 detector
- Use a subset to study the electron calorimeter energy resolution and tracking momentum resolution
- Gives us a handle on what to expect/push for in the data
- Gives us an idea of how much we might expect to gain by including the cluster energy in the track fit
  - See the recent track-fitting work done by Robert

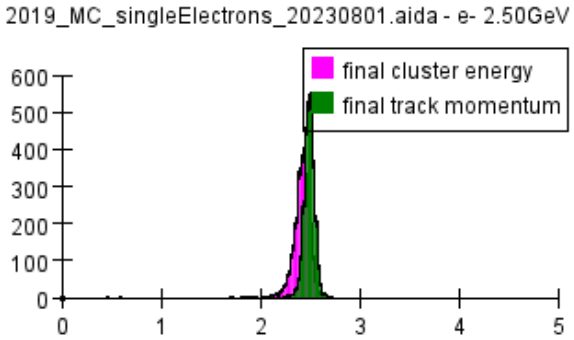
Single Particle Electron MC

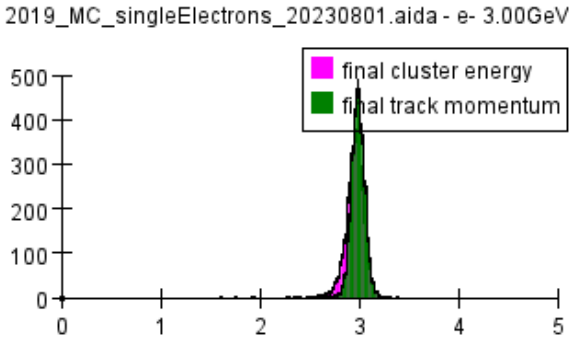


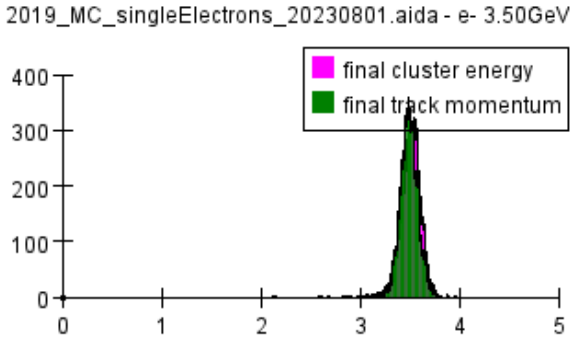


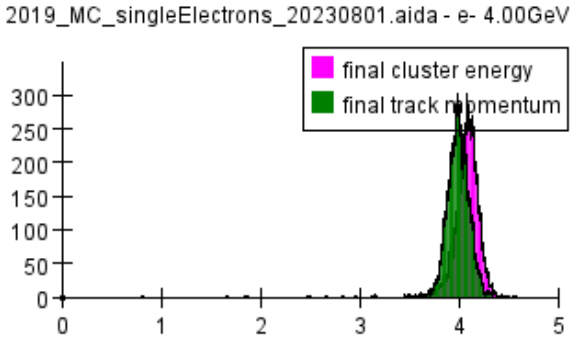


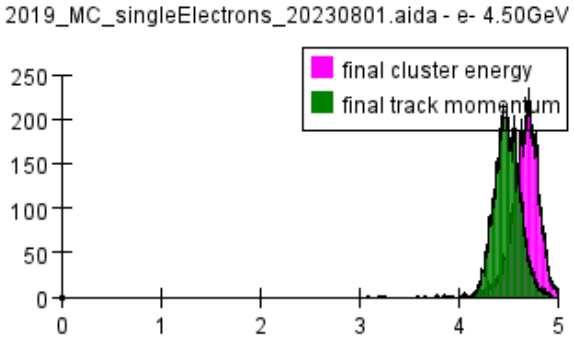








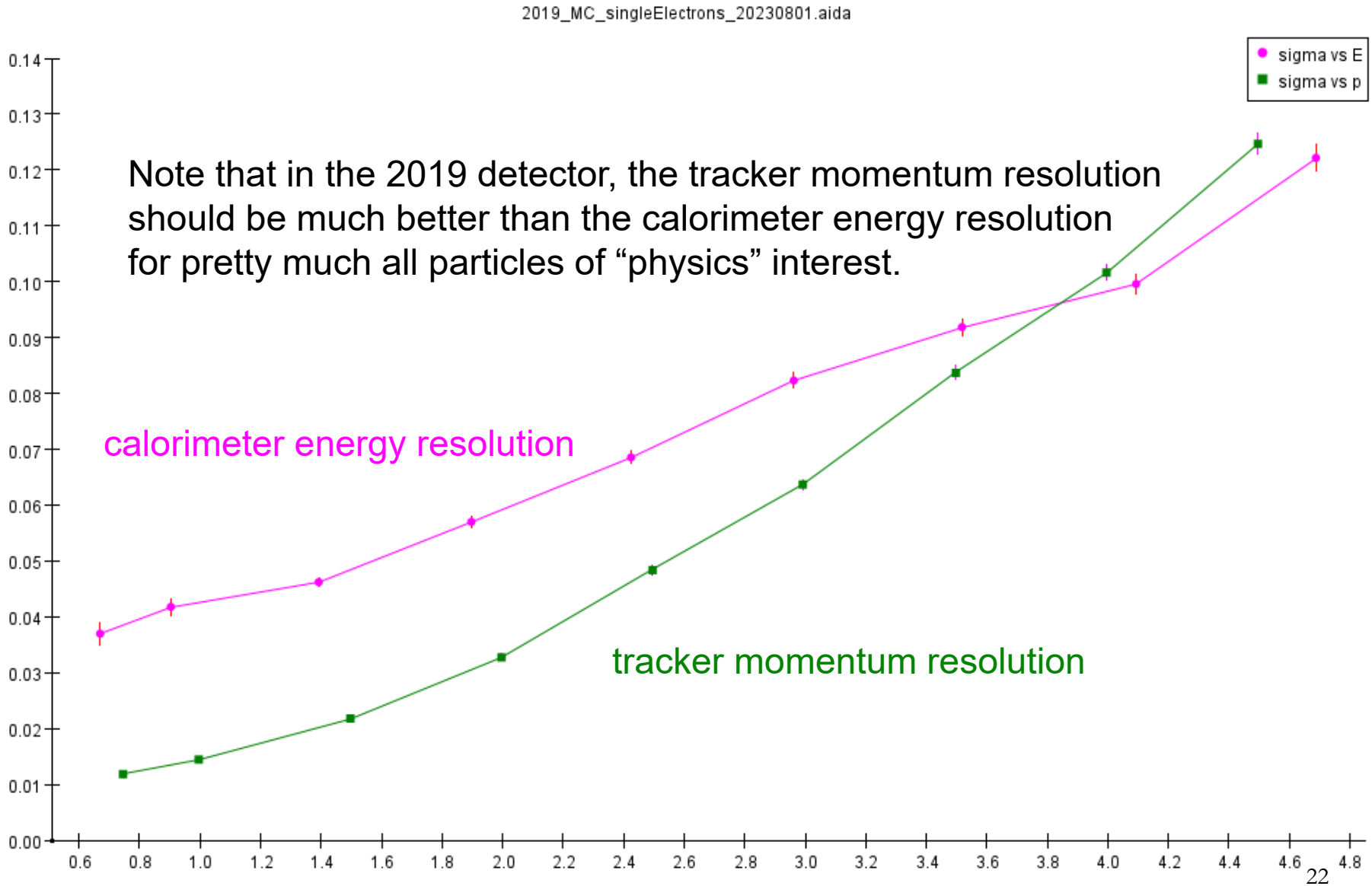




Single Particle MC

- First time I had noticed the error in the calorimeter cluster energy response
  - Undershoots at low energy, overshoots at high energy
  - Might be due to how we are simulating the underlying event / electronic noise.
    - See, for instance, Tongtong's talk from yesterday.
  - Clearly needs to be investigated and resolved.
- Concentrate on energy/momentum resolution

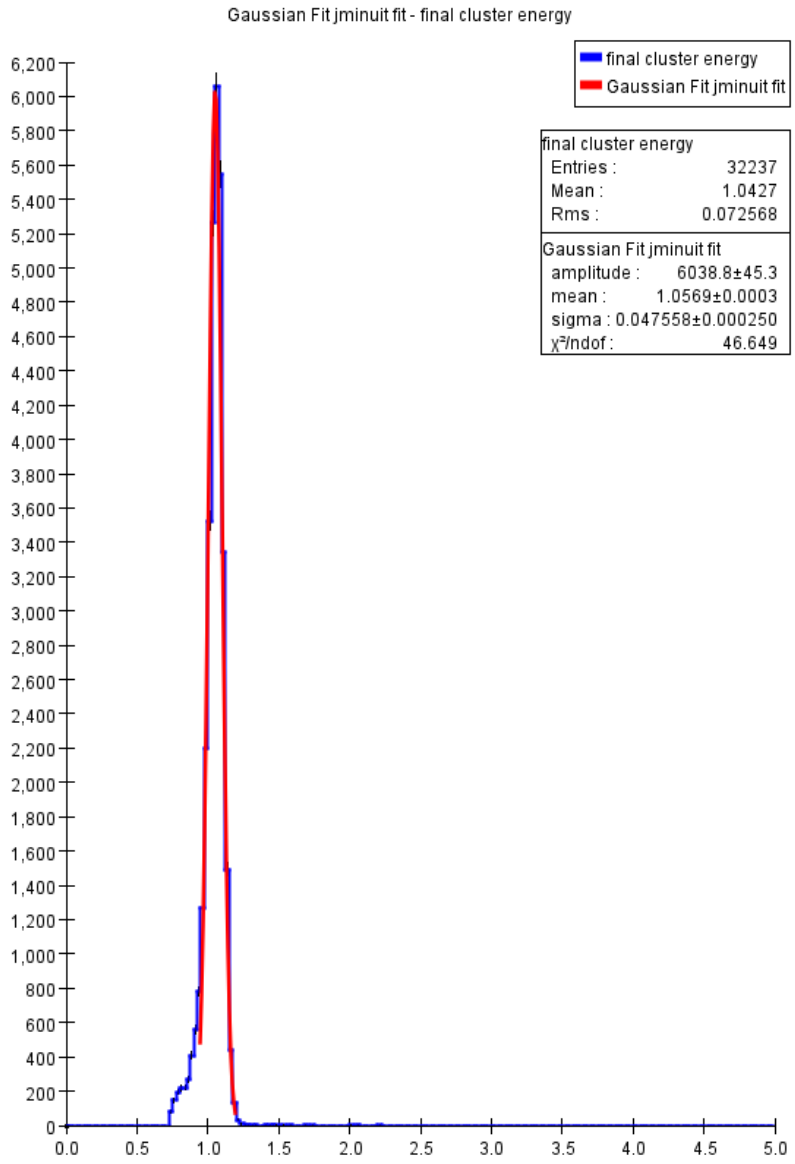
MC Energy/Momentum Resolution

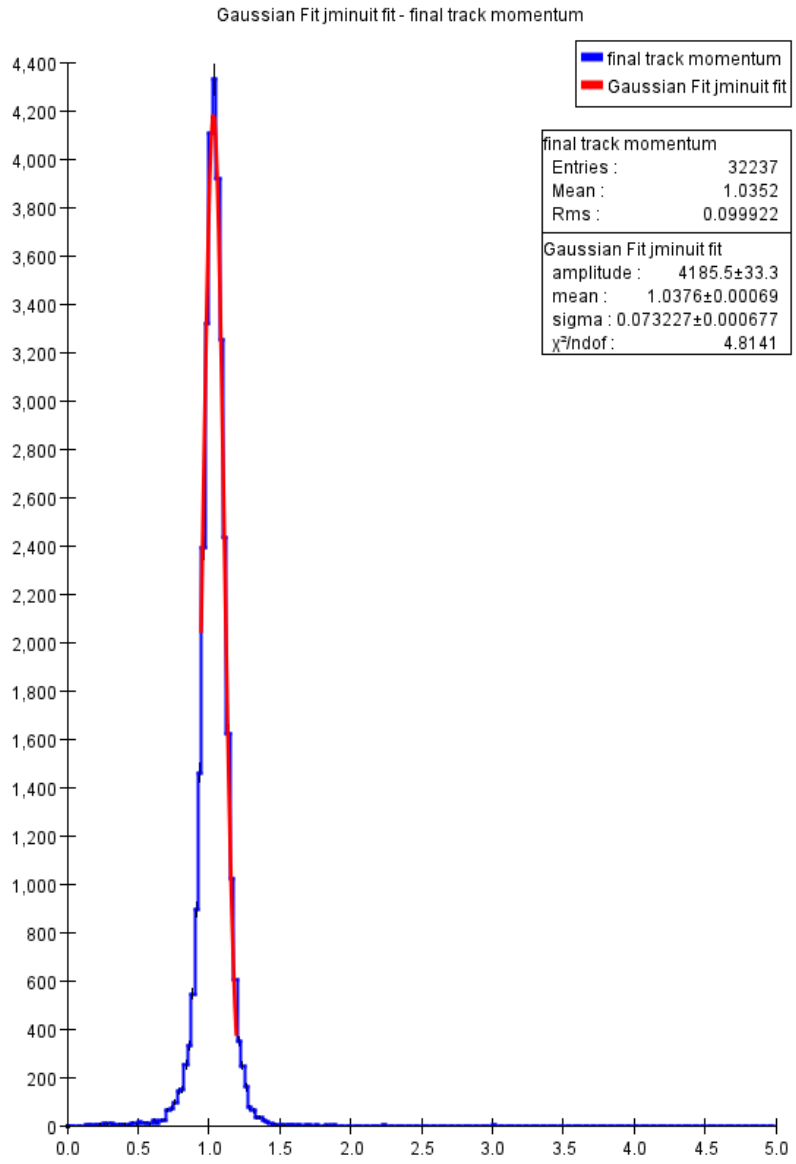


Data Energy/Momentum Resolution

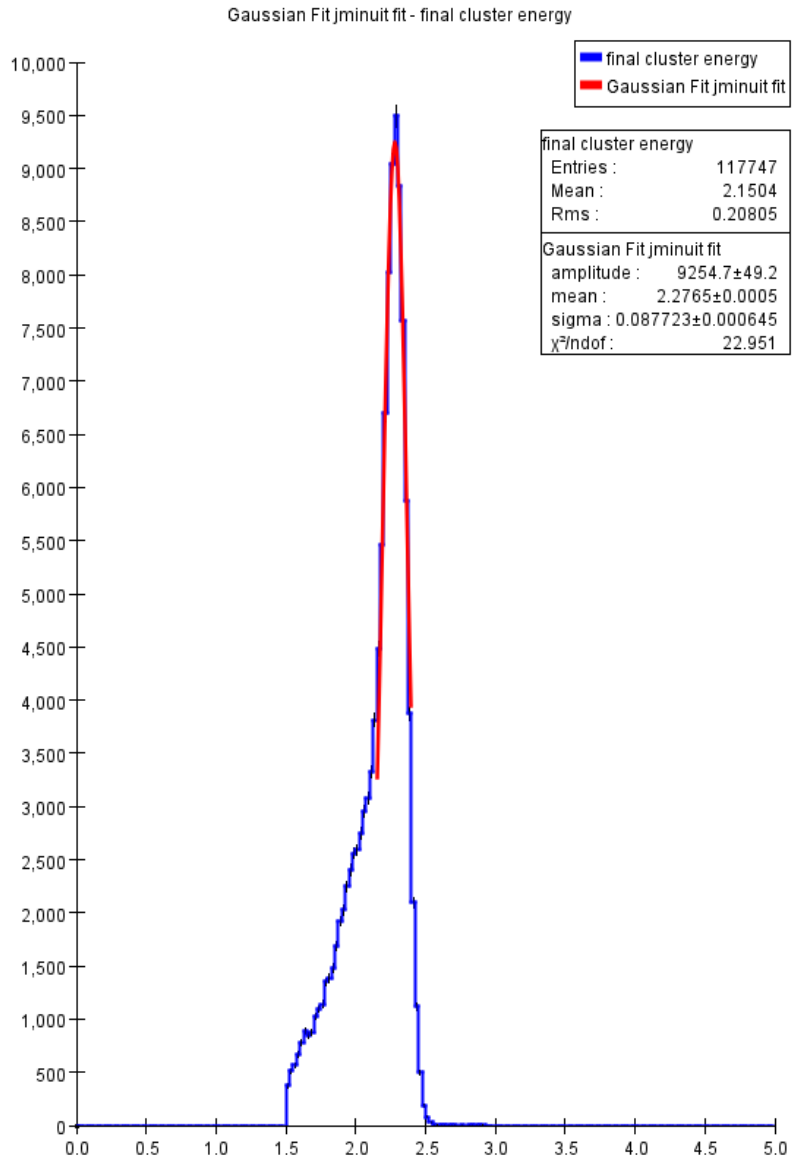
- Double-check our performance by comparing energy and momentum reconstruction using FEEs at the five beam energies we have accumulated.
- Clearly need to be more systematic
  - Split into top/bottom
  - Study as a function of number of hits on track
  - etc.
- In principle, the momentum resolution should differ only by the difference in multiple scattering, since the curvature for FEEs is always the same.
- Would like to see a dedicated MC study done by simulating FEEs under the five different run conditions

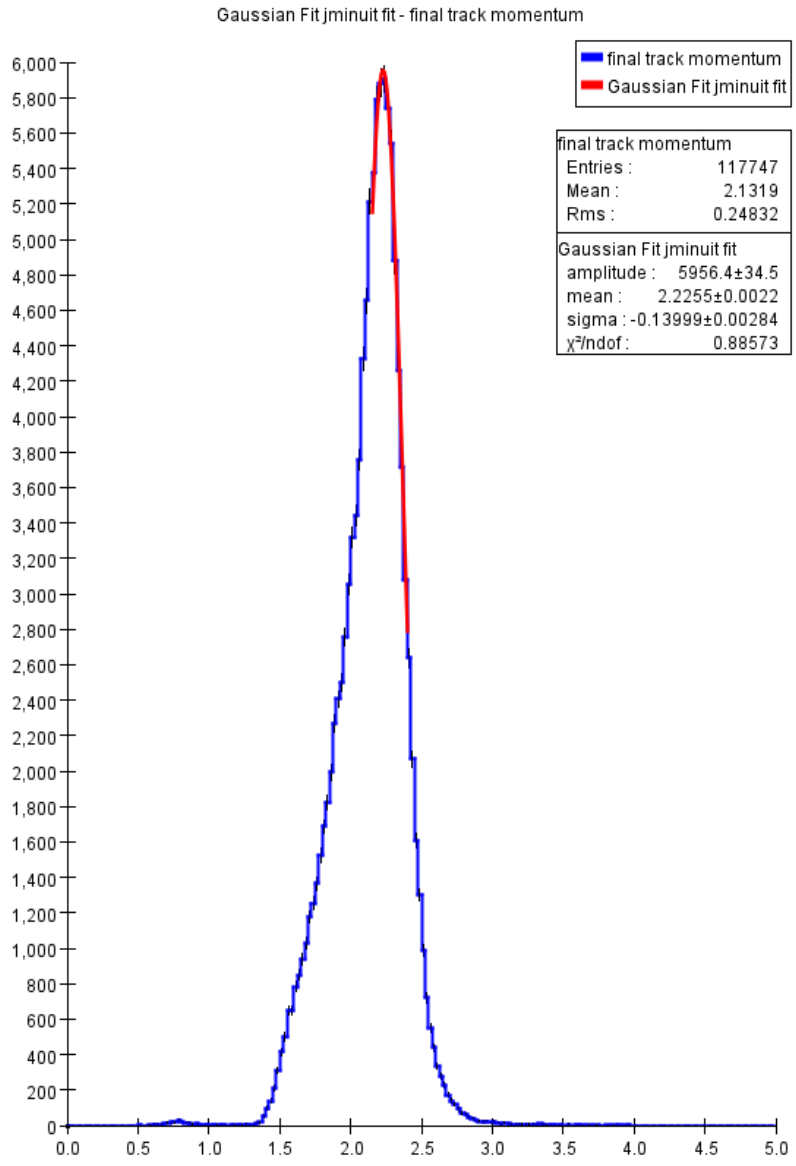
FEE Energy & Momentum 2015 1.056



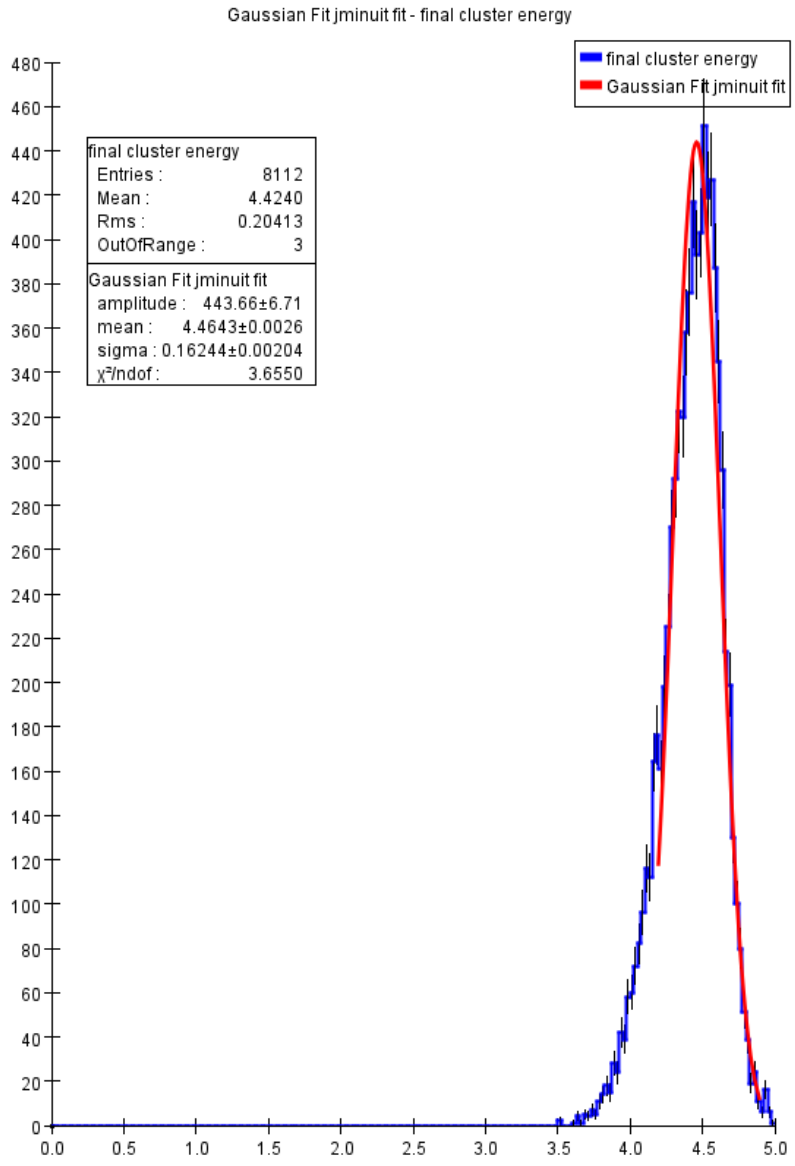


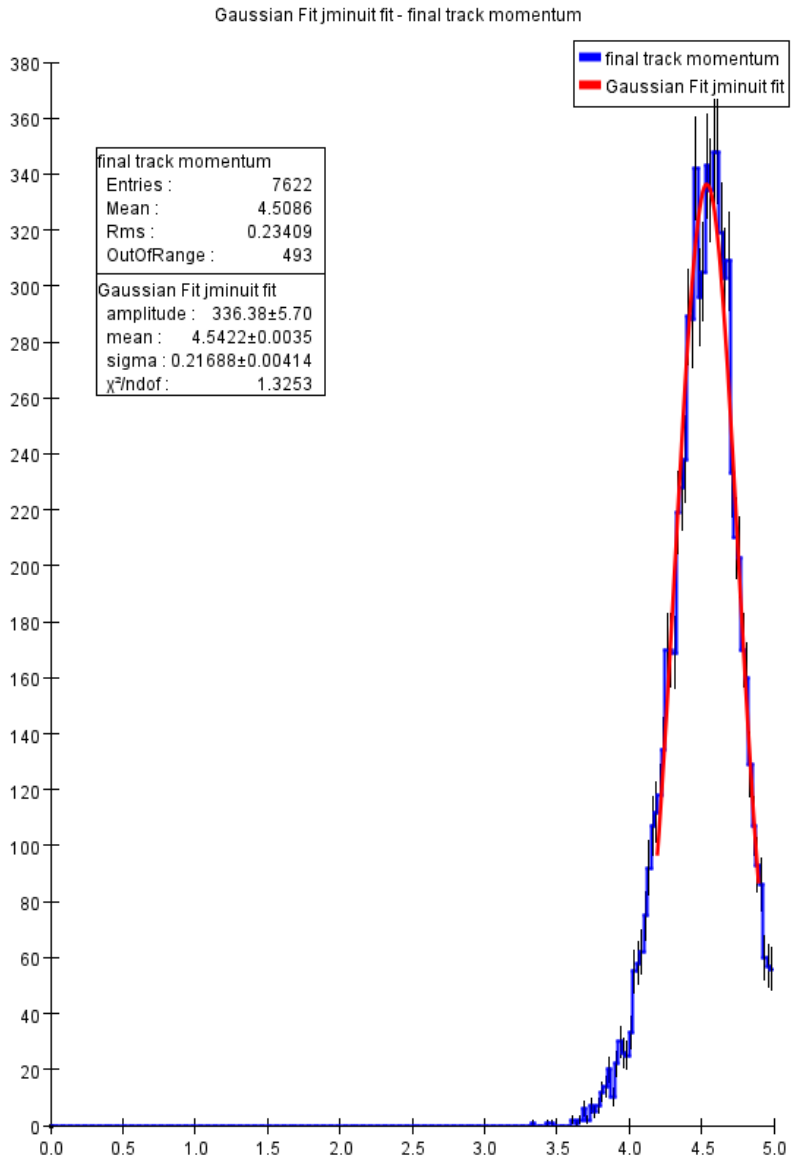
FEE Energy & Momentum 2016 2.3



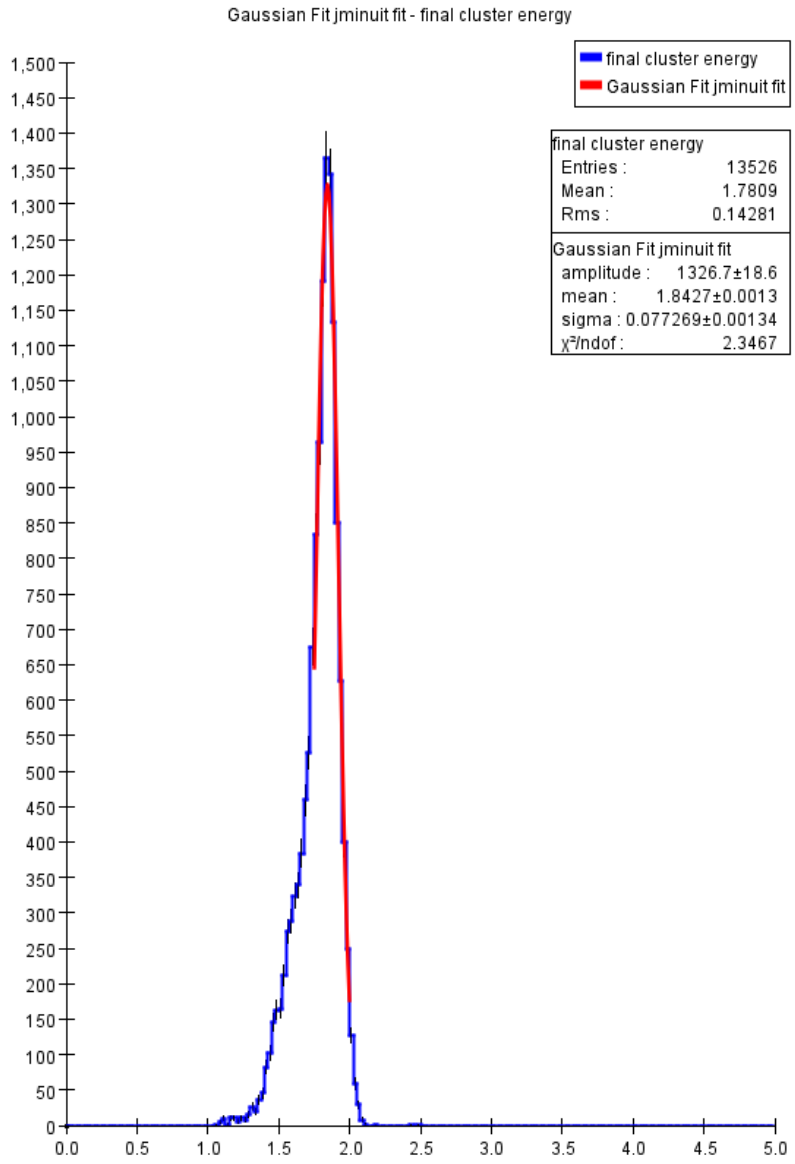


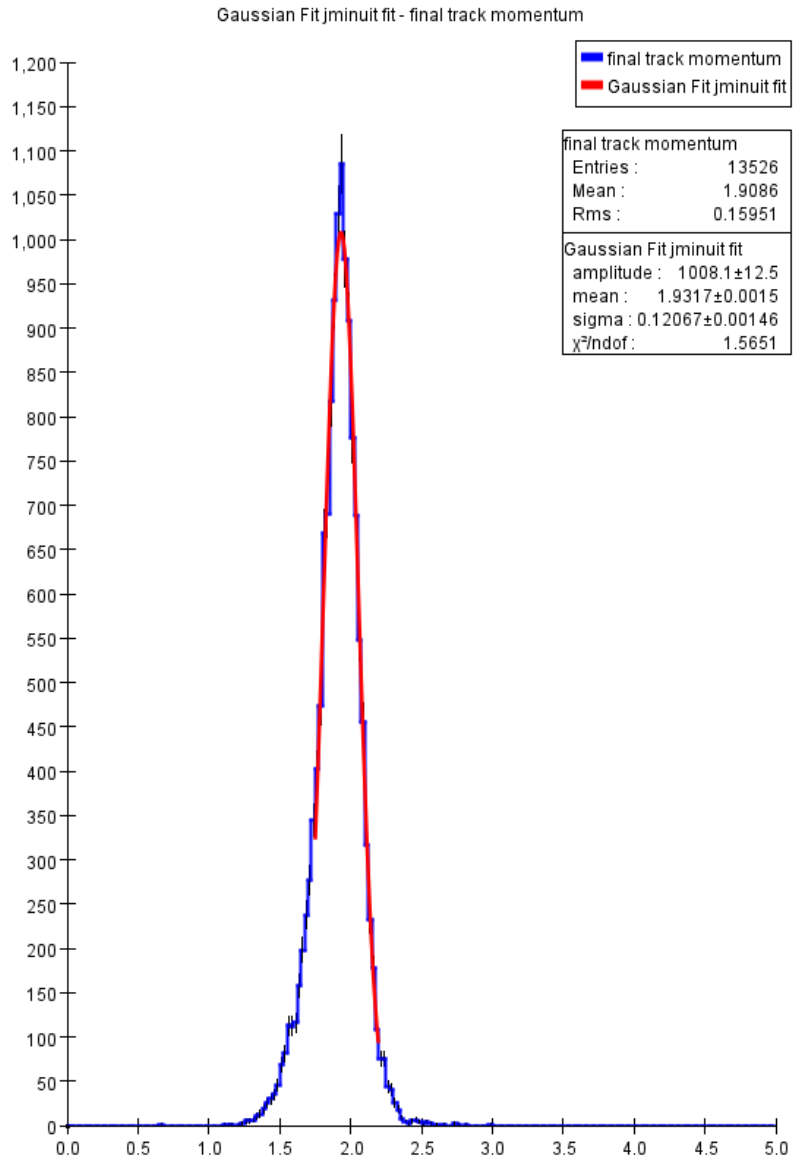
FEE Energy & Momentum 2019 4.55



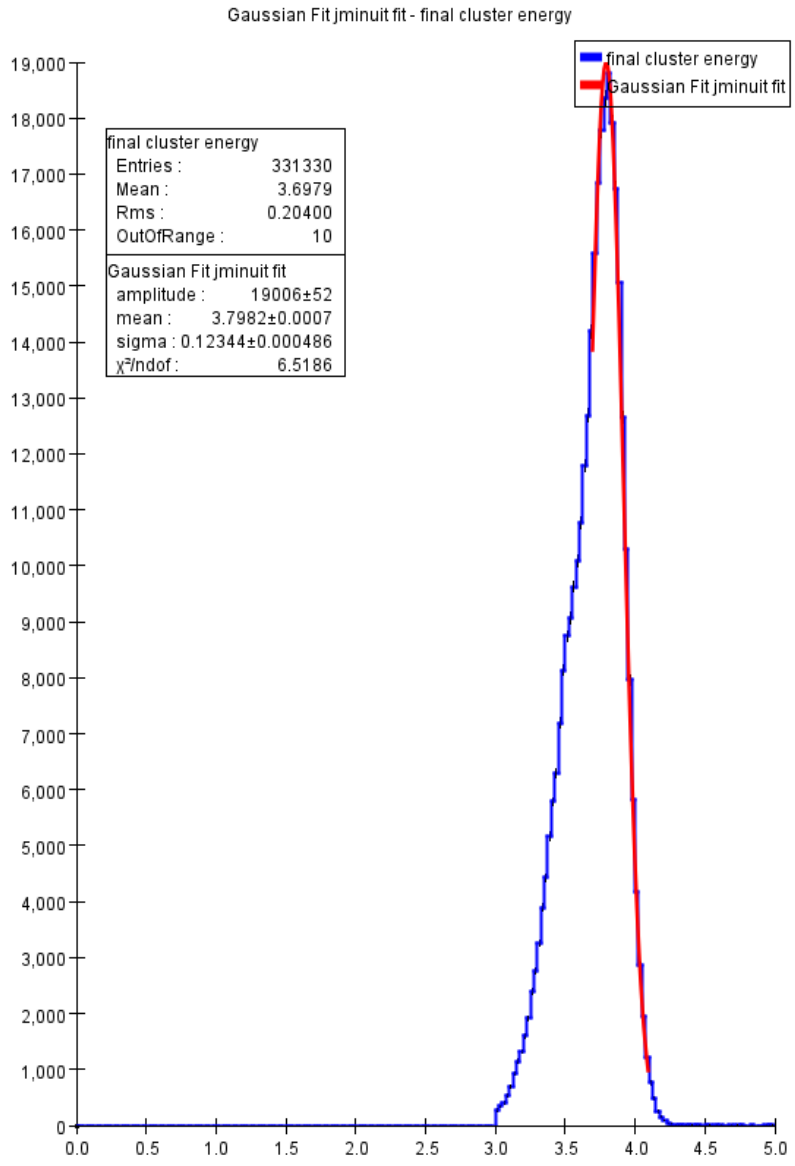


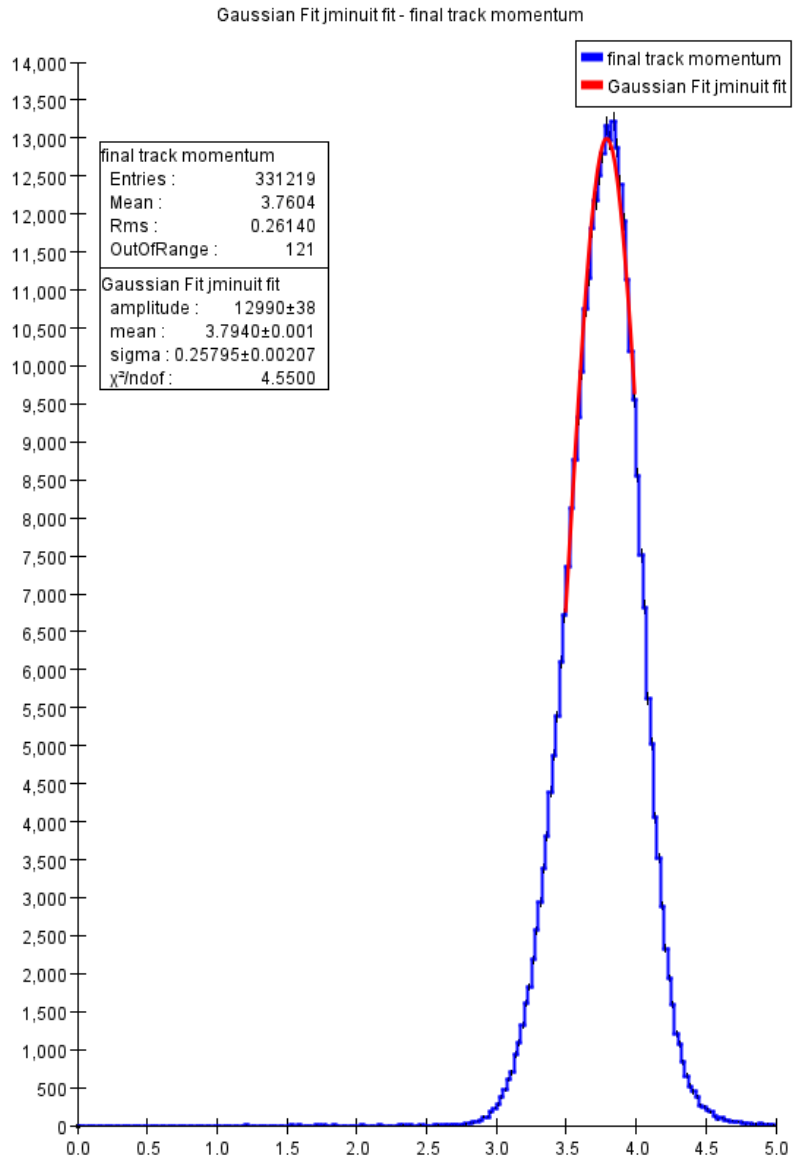
FEE Energy & Momentum 2021 1.92



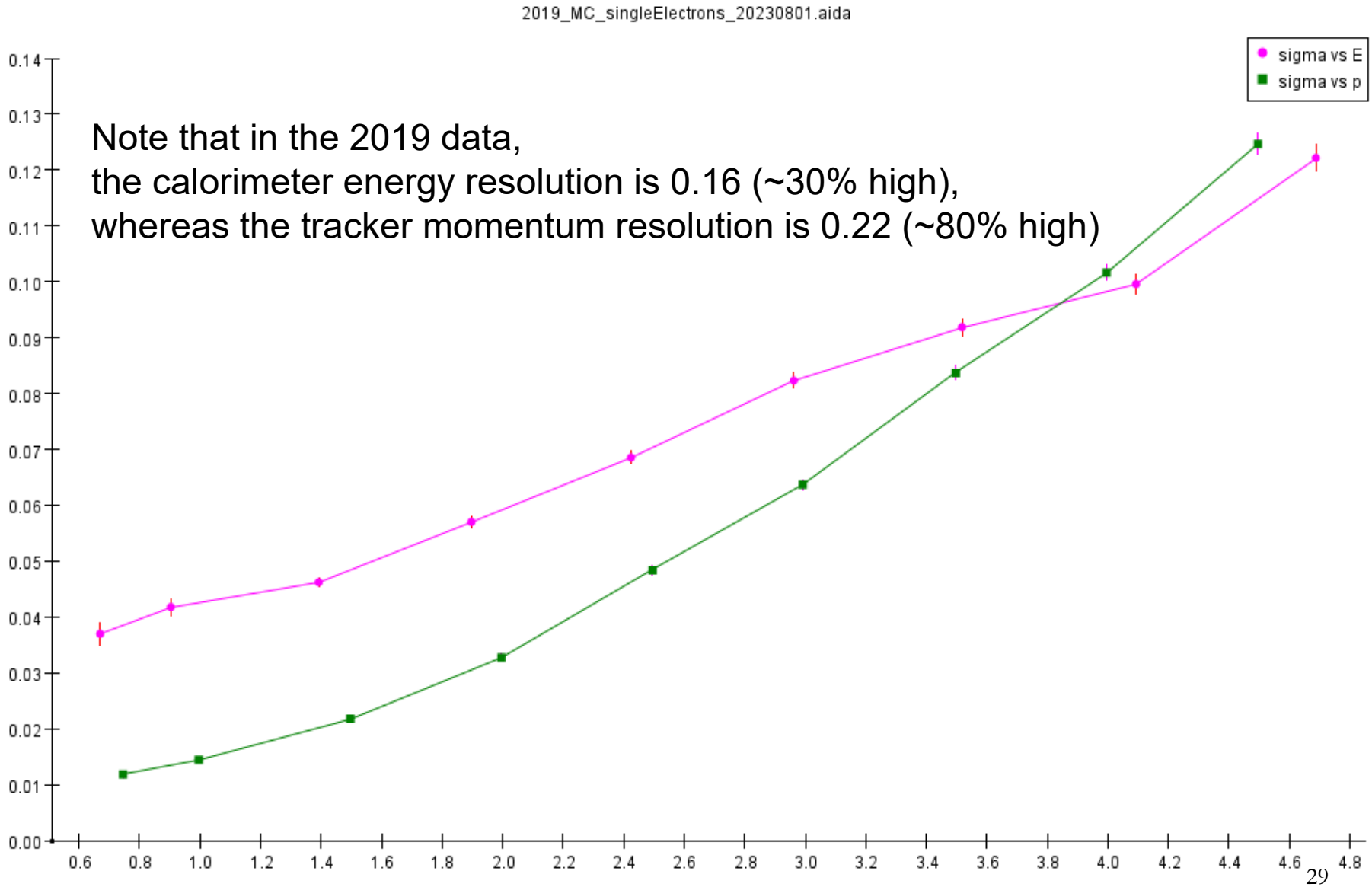


FEE Energy & Momentum 2021 3.74





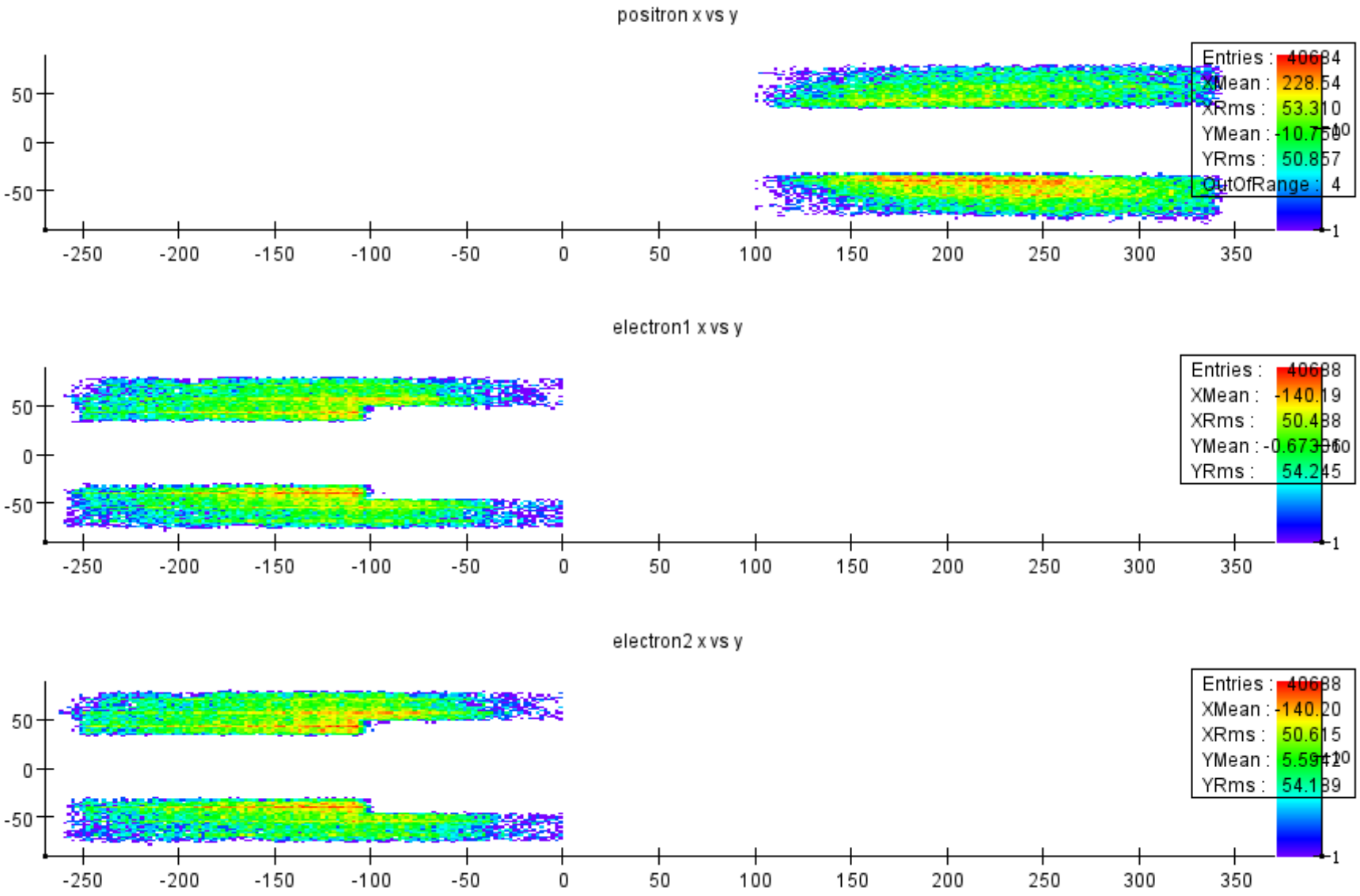
2019 Energy/Momentum Resolution



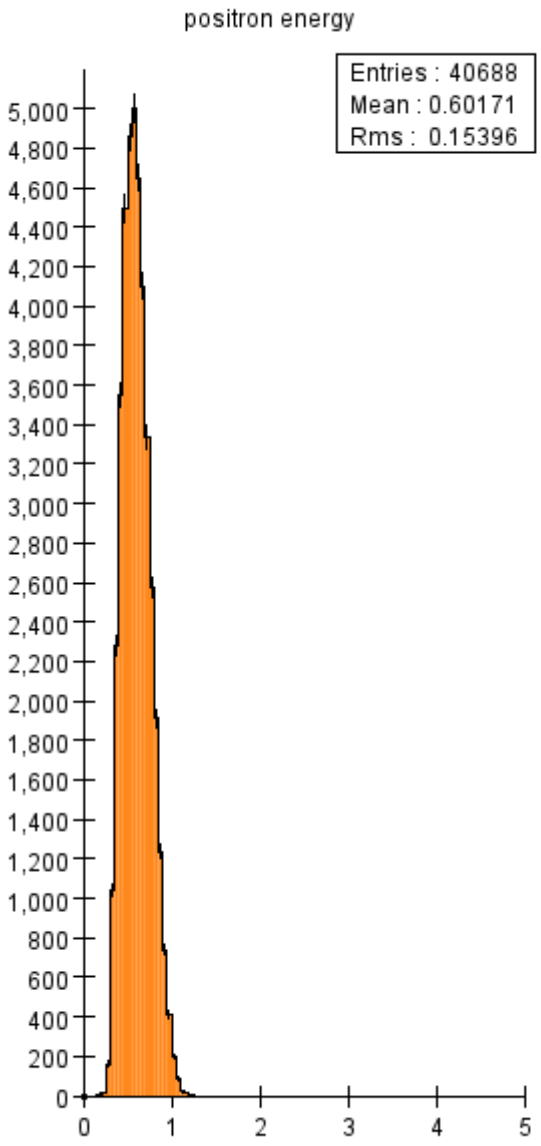
E vs p Resolution in the data

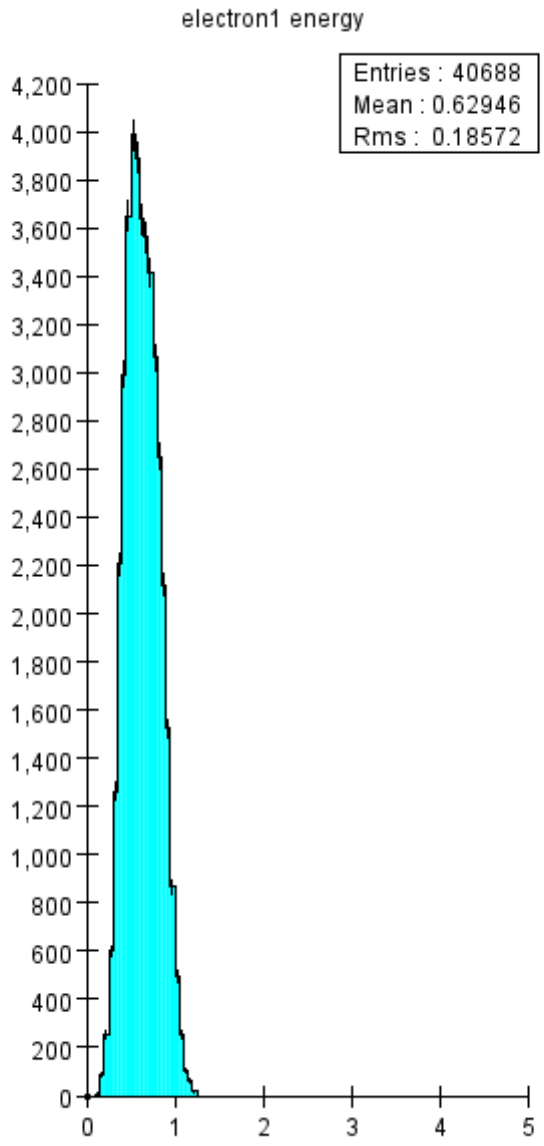
- Have advocated use of calorimeter cluster energies to impose momentum constraint on tracker alignment
- Planning to use calorimeter energy in track fit
- Should challenge some of the assumption going into this reliance on the calorimeter cluster energy
- Although calorimeter FEE energies are well calibrated, the response need not be linear
- Investigating energy vs momentum calibration and resolution in “physics” regions of phase space motivates the study of tridents.
- Data from single-pass run 014661 at 1.92GeV
- Reconstructed with HPS_Run2021Pass0_v1_1pt92GeV detector
- Standard Trident Ecal-only selection cuts
- After selection, require all three clusters to be fiducial and have a correctly-signed track associated to it.
- Compare calorimeter-only momentum sums to tracking momentum sums
  - For true trident events momentum sum = beam, i.e. pX = pY = 0.0, p = Ebeam

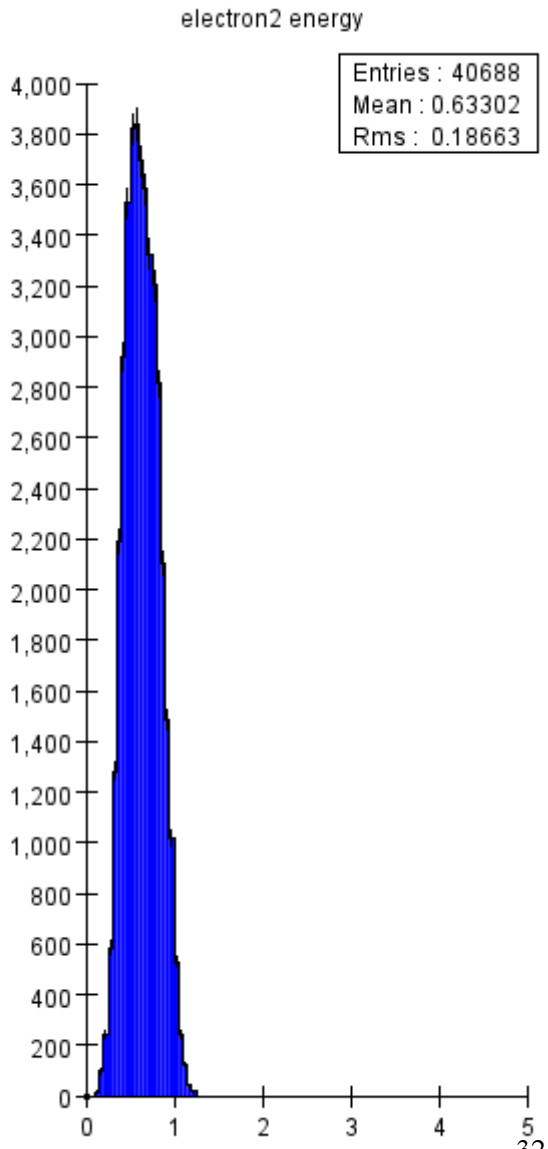
Cluster Positions



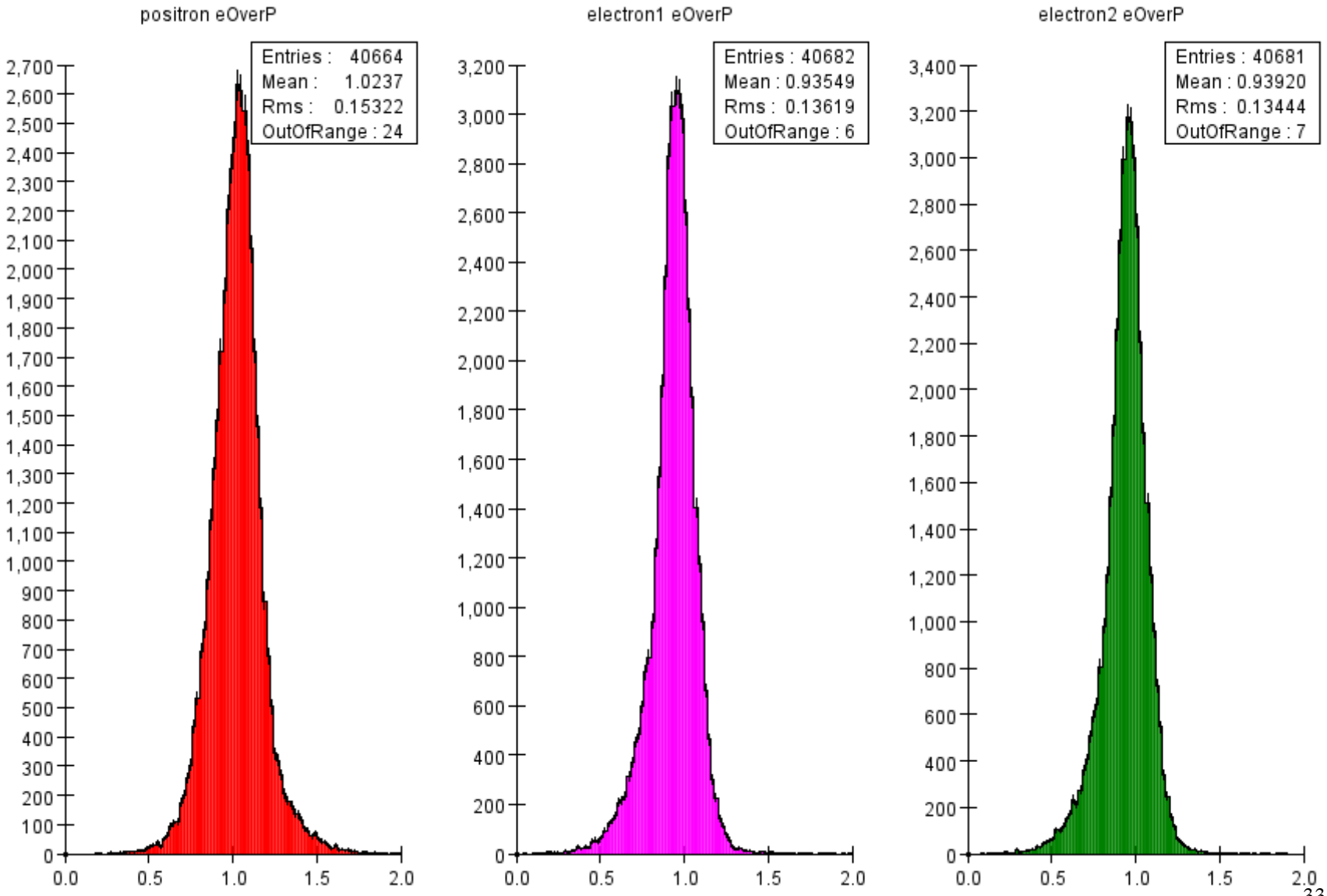
Cluster Energies



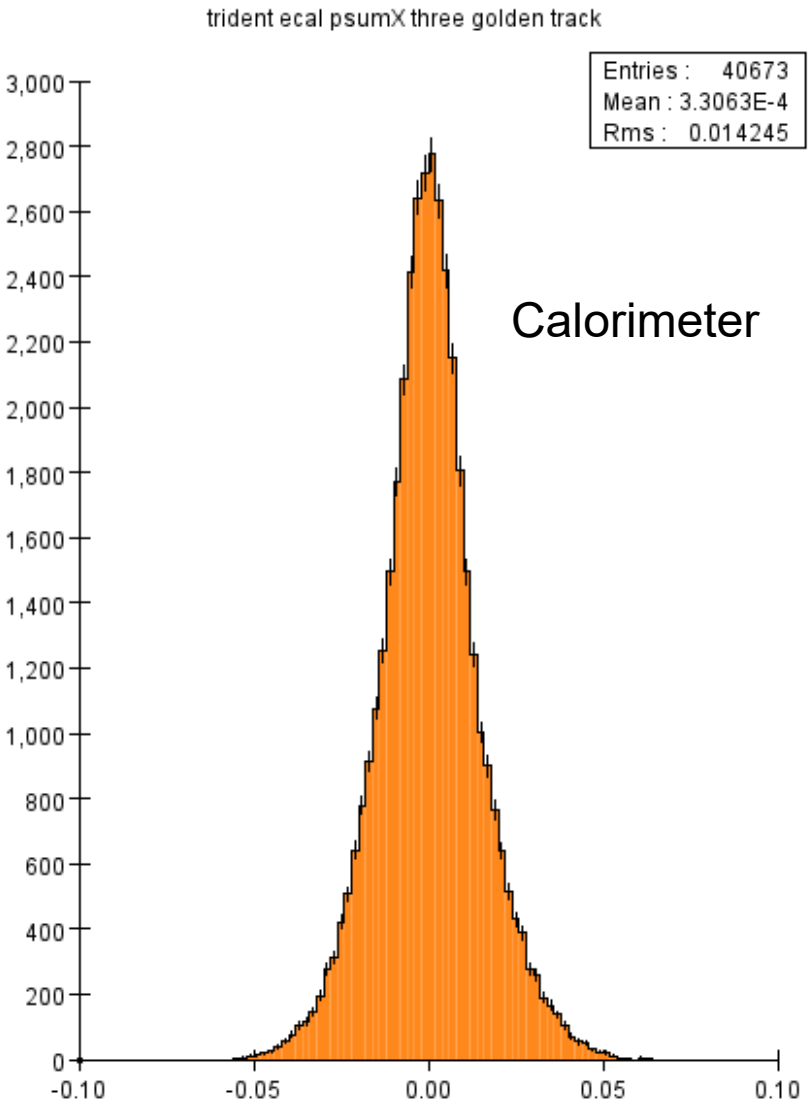


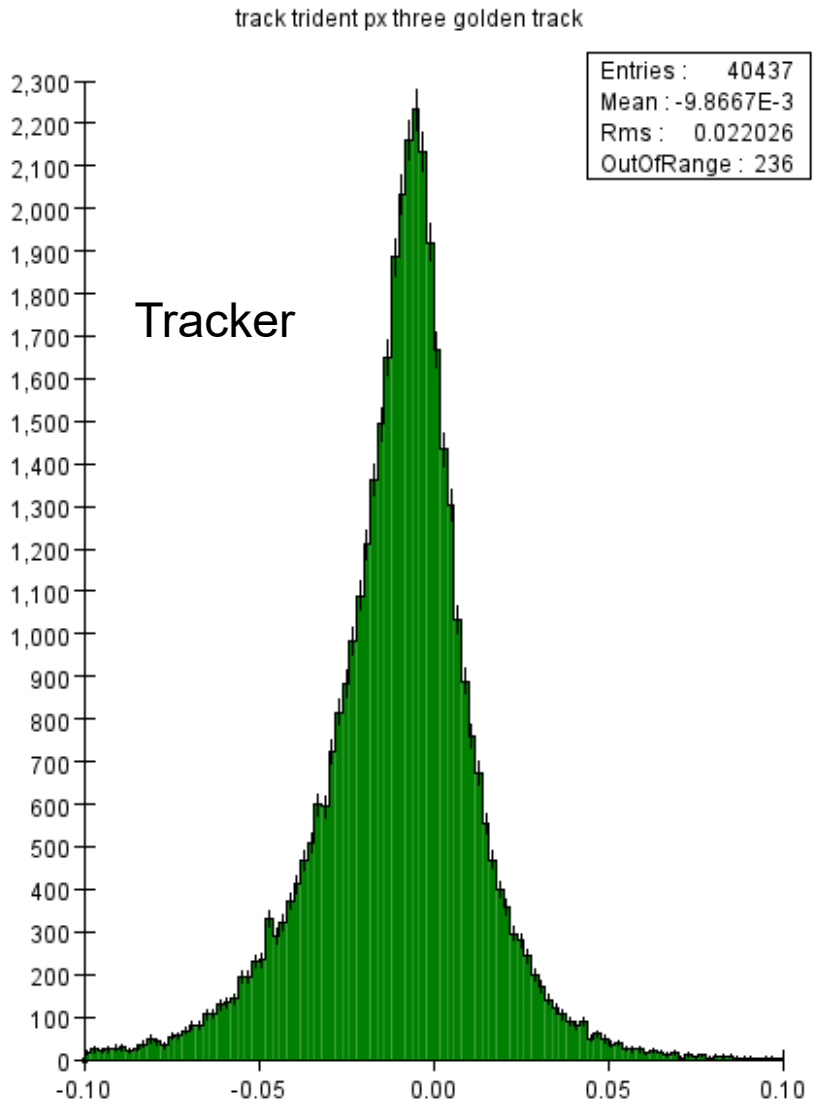


Cluster E/p

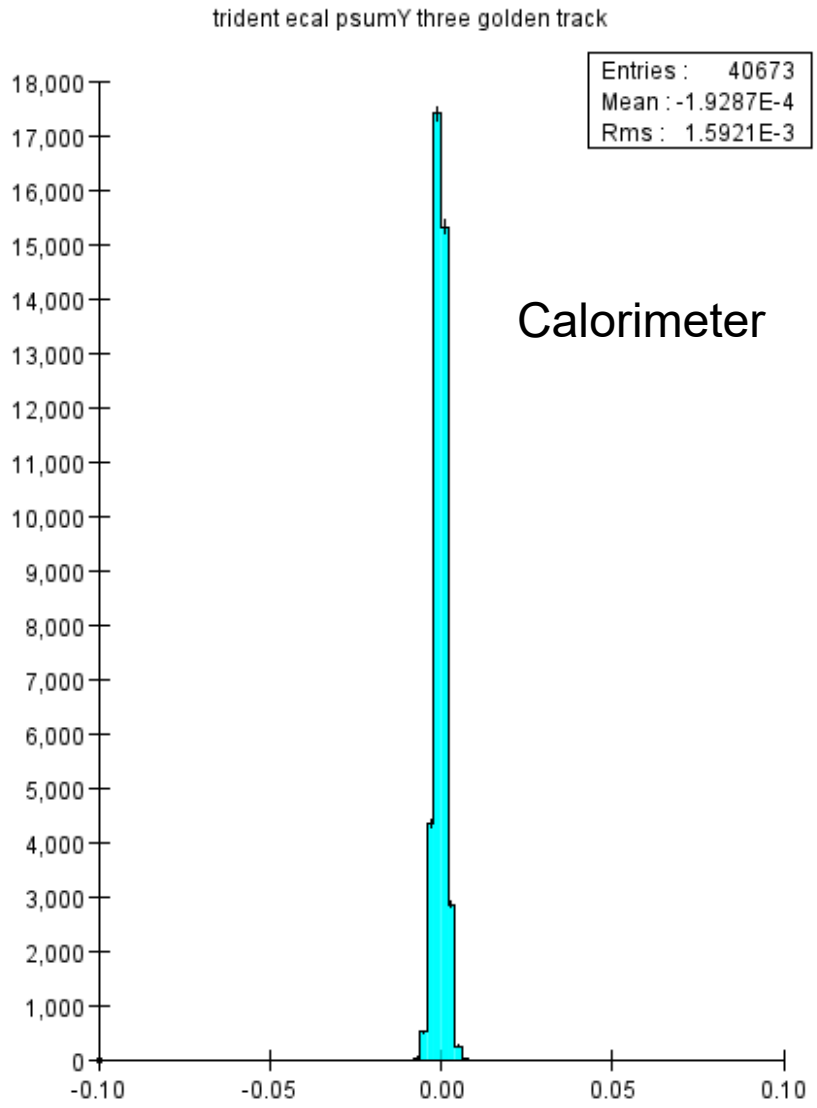

positron eOverP
Entries : 40664
Mean : 1.0237
Rms : 0.15322
OutOfRange : 24
electron1 eOverP
Entries : 40682
Mean : 0.93549
Rms : 0.13619
OutOfRange : 6
electron2 eOverP
Entries : 40681
Mean : 0.93920
Rms : 0.13444
OutOfRange : 7

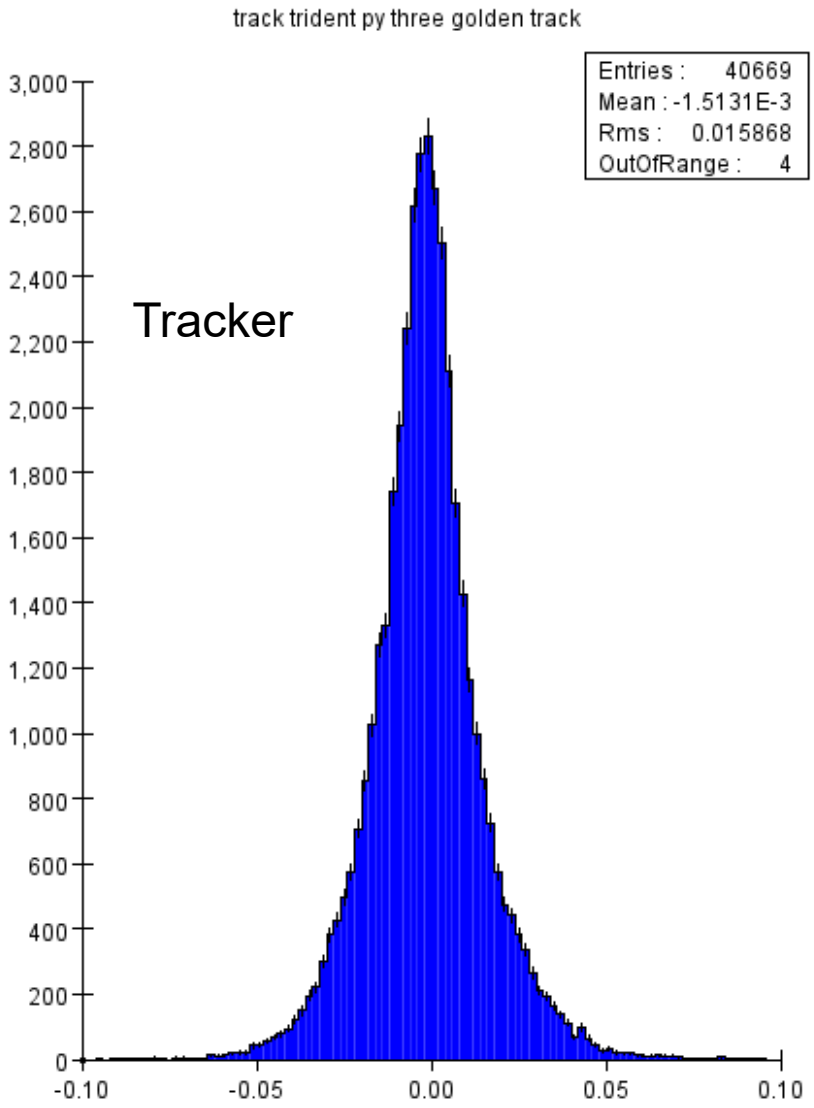
Momentum X


trident ecal psumX three golden track
Entries : 40673
Mean : 3.3063E-4
Rms : 0.014245
Calorimeter
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-0.10
-0.05
0.00
0.05
0.10

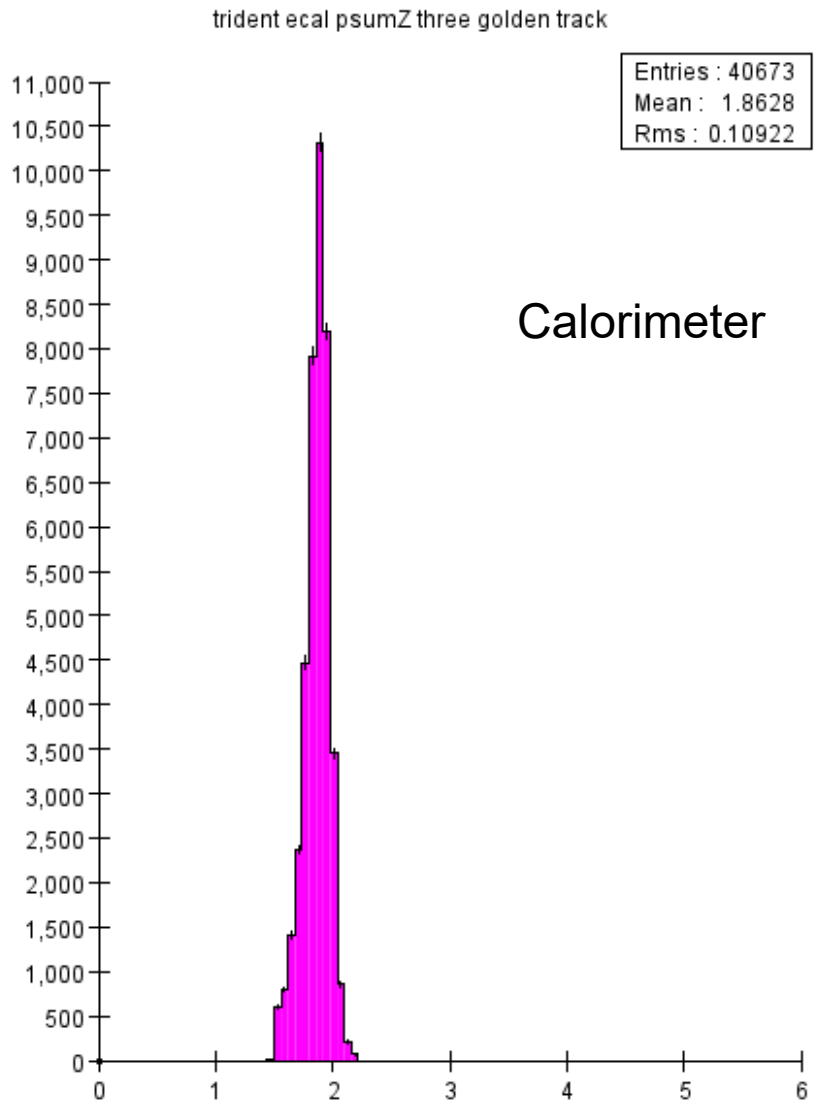

track trident px three golden track
Entries : 40437
Mean : -9.8667E-3
Rms : 0.022026
OutOfRange : 236
Tracker
2,300
2,200
2,100
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
-0.10
-0.05
0.00
0.05
0.10

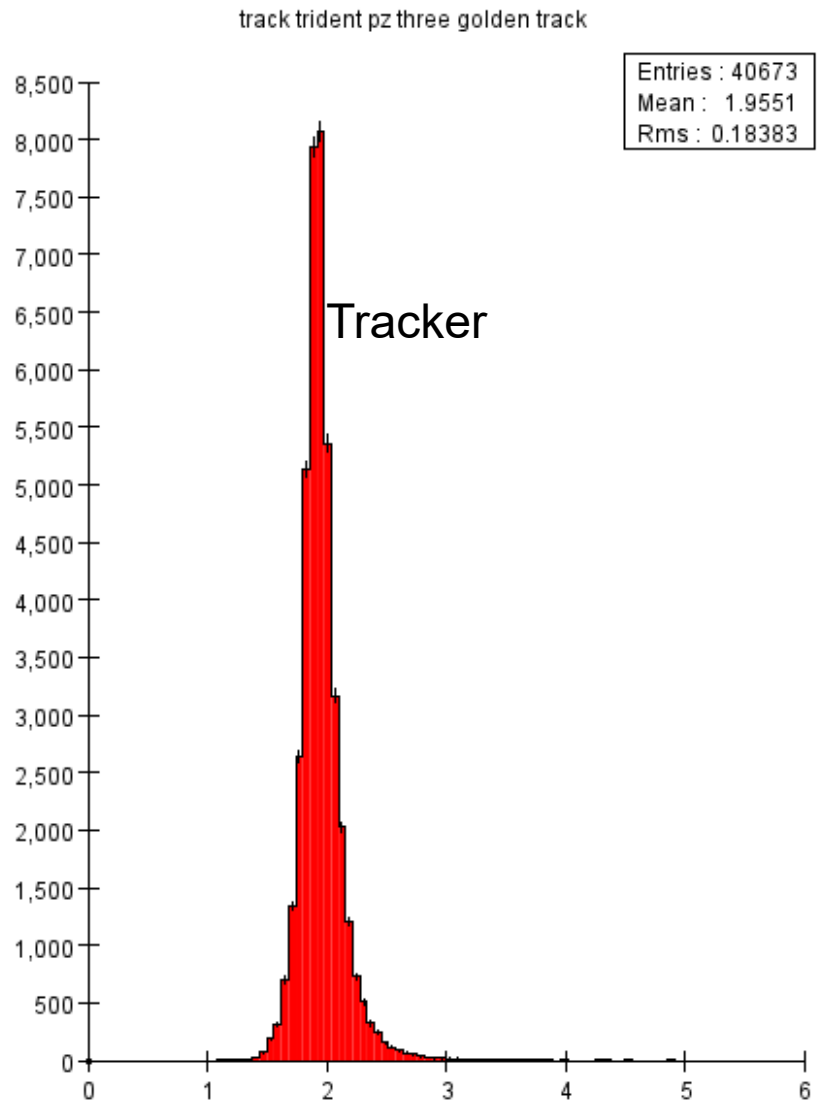
Momentum Y


trident ecal psumY three golden track
Entries : 40673
Mean : -1.9287E-4
Rms : 1.5921E-3
Calorimeter
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
-0.10
-0.05
0.00
0.05
0.10

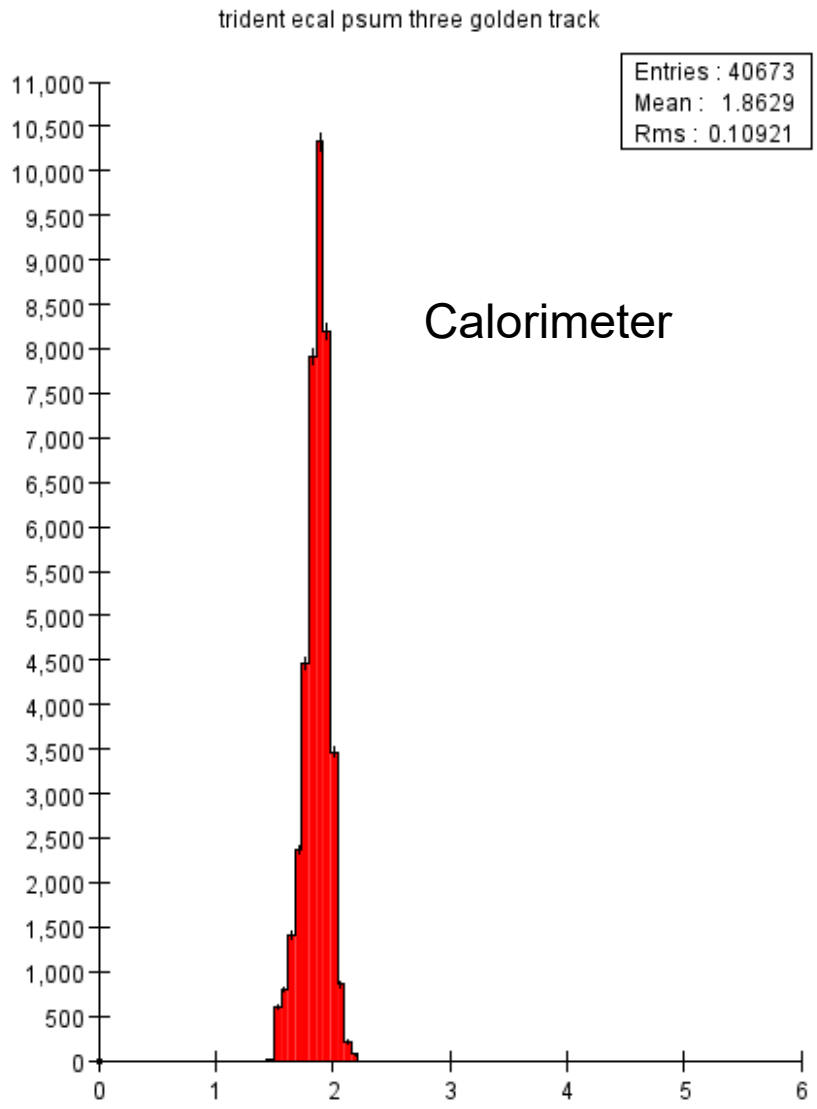

track trident py three golden track
Entries : 40669
Mean : -1.5131E-3
Rms : 0.015868
OutOfRange : 4
Tracker
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-0.10
-0.05
0.00
0.05
0.10

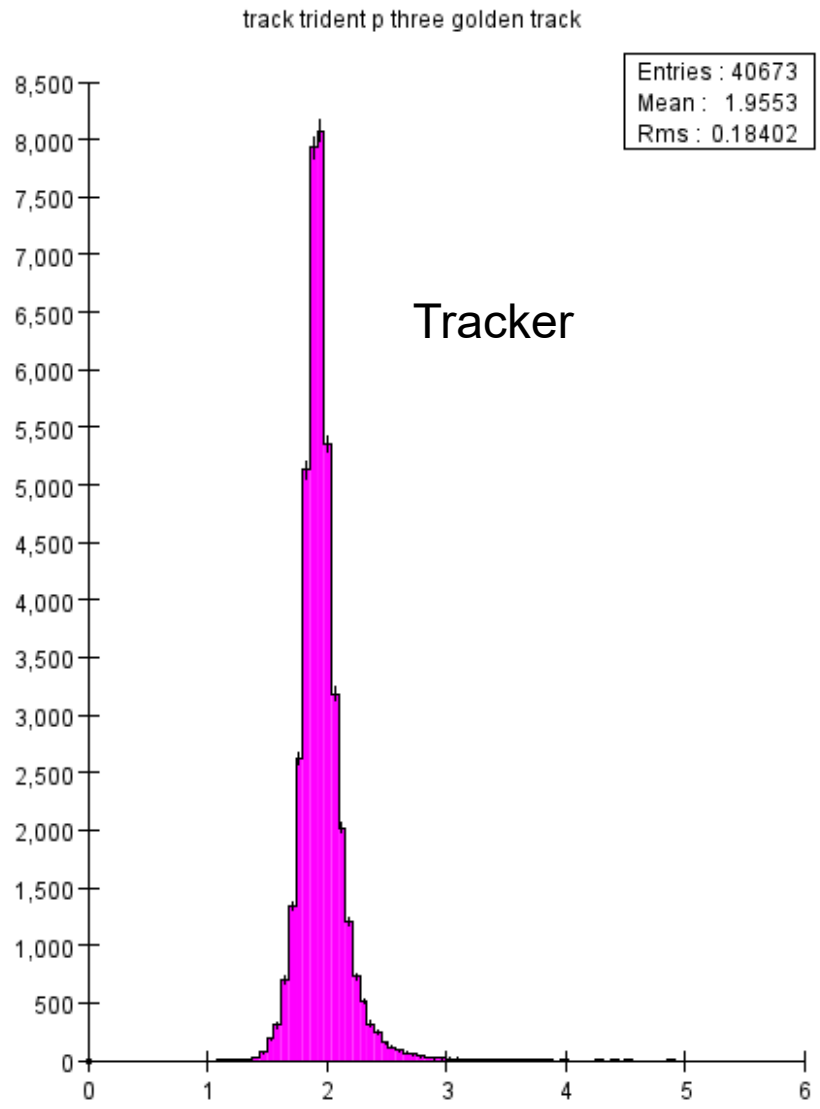
Momentum Z


trident ecal psumZ three golden track
Entries : 40673
Mean : 1.8628
Rms : 0.10922
Calorimeter

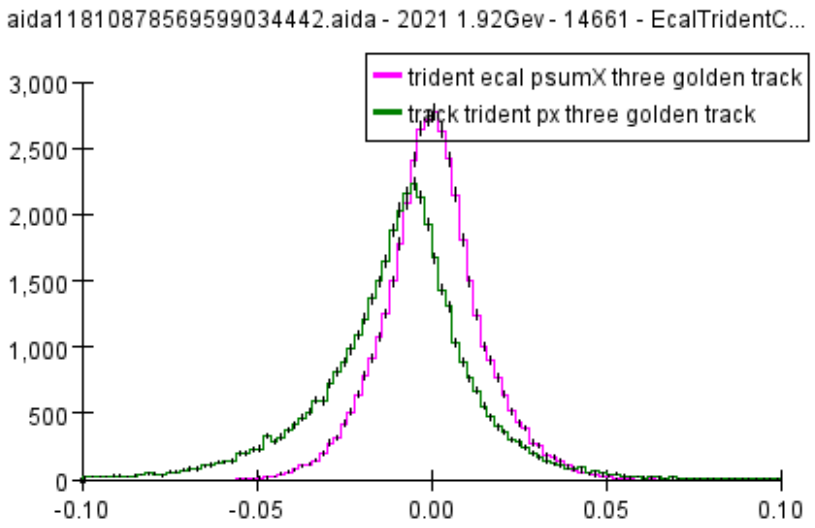

track trident pz three golden track
Entries : 40673
Mean : 1.9551
Rms : 0.18383
Tracker

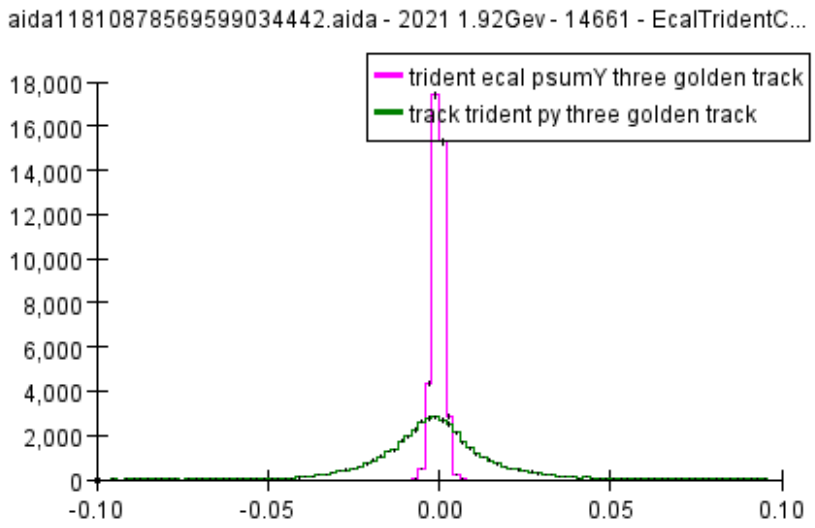
Momentum

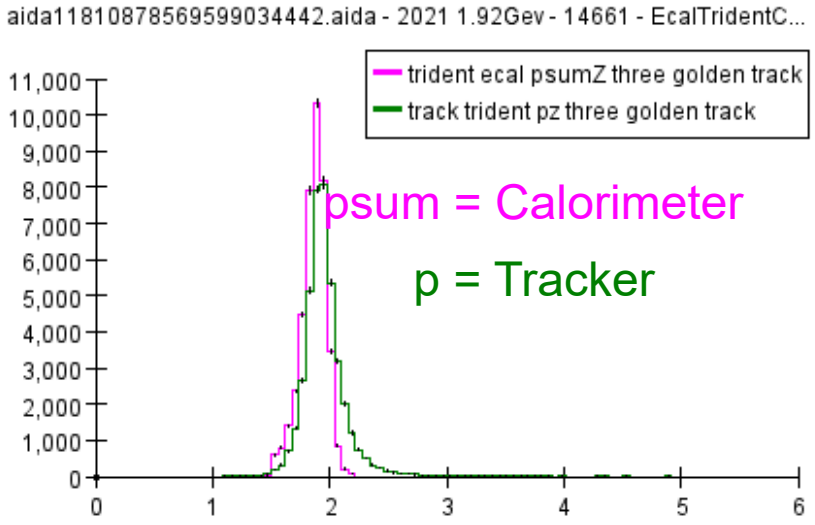

trident ecal psum three golden track
Entries : 40673
Mean : 1.8629
Rms : 0.10921
Calorimeter


track trident p three golden track
Entries : 40673
Mean : 1.9553
Rms : 0.18402
Tracker

Trident Candidate Four Momentum

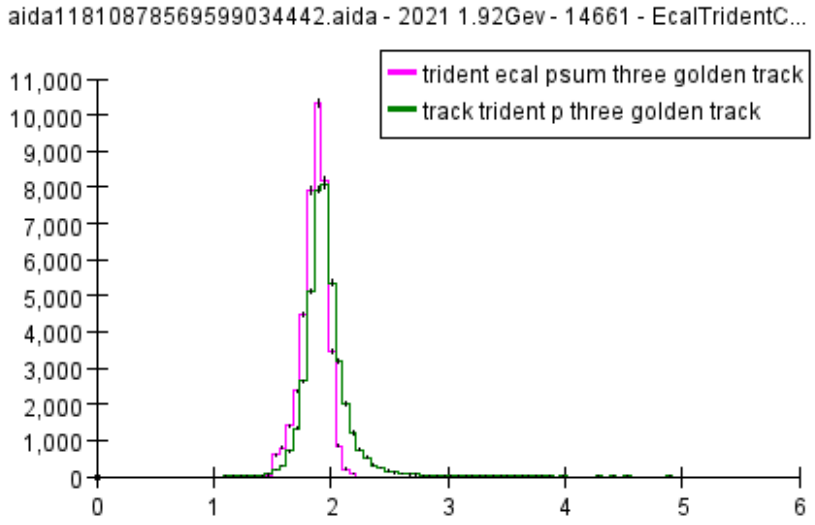






psum = Calorimeter

p = Tracker



1.92GeV Trident Analysis

- Calorimeter-only momentum sums appear to perform much better than those calculated using tracking information
- Both energy and position appear to be measured better in the calorimeter than in the tracker
  - No evidence seen for calorimeter energy non-linearity in the data
    - Need to investigate spurious behavior in the MC
- The 2019 data, both single-pass at 1.92GeV and two-pass at 3.74GeV, contain copious numbers of Møller events which can be used for momentum calibration, but this technique can be applied to the 2021 data, which is devoid of such a calibration source.

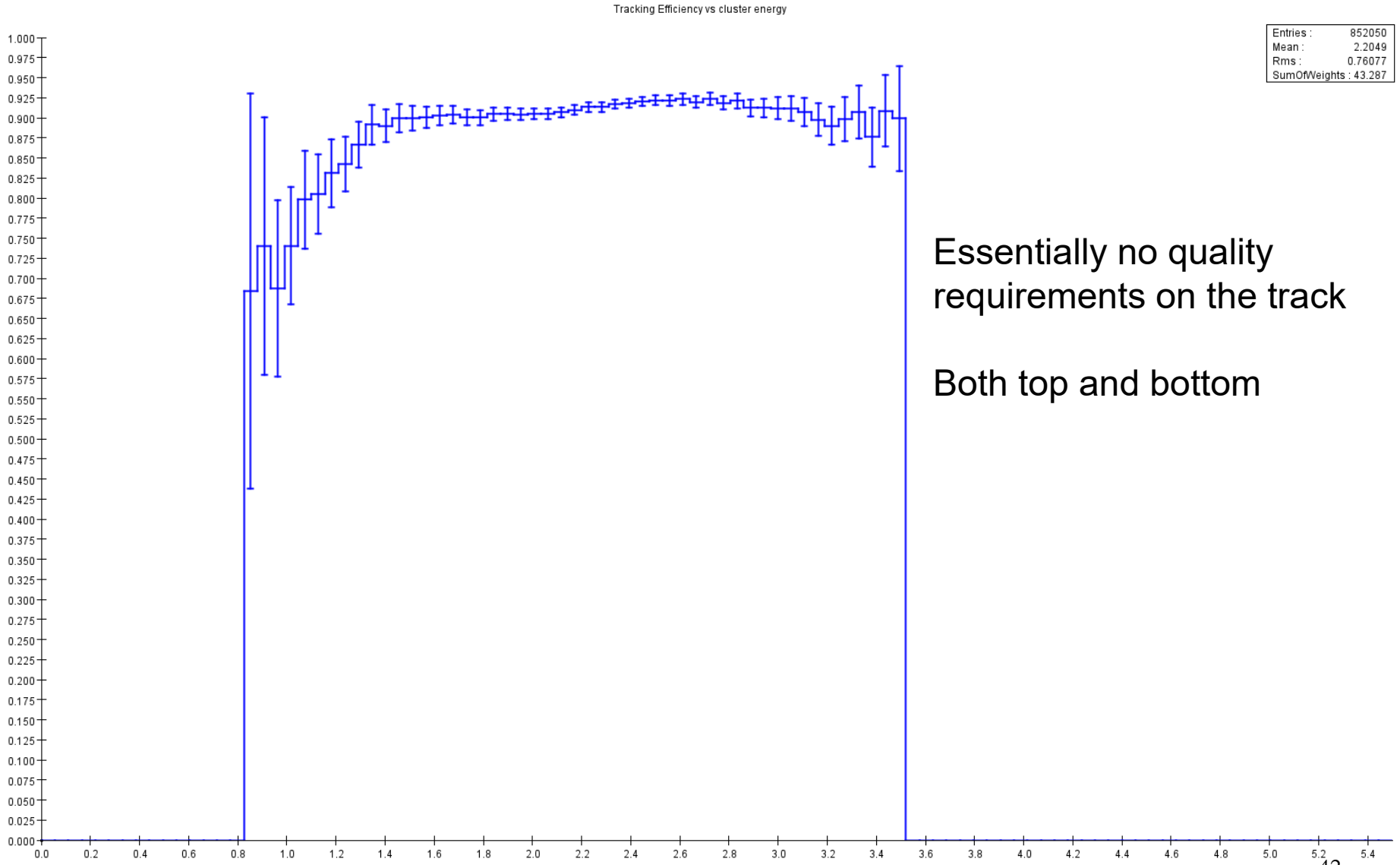
Track-finding Efficiencies in Data

- Using FEEs to determine track-finding efficiency is complicated by the possibility of "catastrophic bremsstrahlung" where essentially all of the energy is taken by the photon.
  - Important to check as a part of monitoring, but will not be used as a primary source of track efficiency studies
- WABs provide a nice set of "tag and probe" clusters in the event
  - Requiring both clusters to be fiducial ensures best energy reconstruction
  - Requiring energy sum to equal the beam energy provides clean sample of events where one cluster should clearly be identified as an electron
- Three-prong tridents allow us to study lower energy electrons and positrons

WAB Track Finding Efficiencies

- Reconstructed the file partitions from the runs that Rory had staged for his SVT baseline studies.
- Skimmed FEEs, WABs and Tridents for these studies
- Preliminary analysis of track-finding efficiency as a function of cluster energy and also overall as a function of run during the two data-taking campaigns.
- Standard WAB calorimeter-only selections
- Require photon on the positron side of the calorimeter, plot ratio of cluster on electron side identified as electron divided by all clusters.

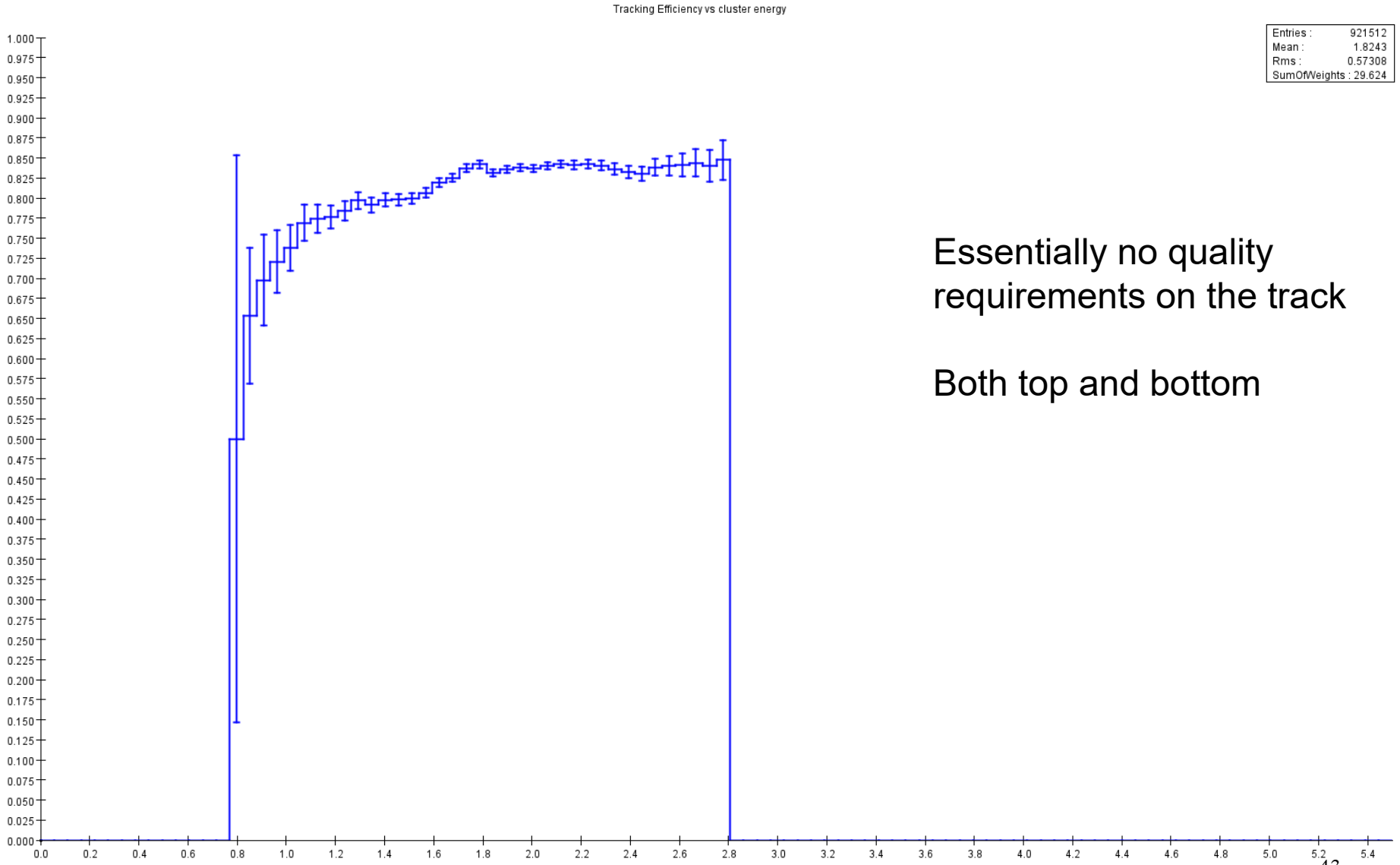
WAB Tracking Efficiency vs E 2019



Essentially no quality requirements on the track

Both top and bottom

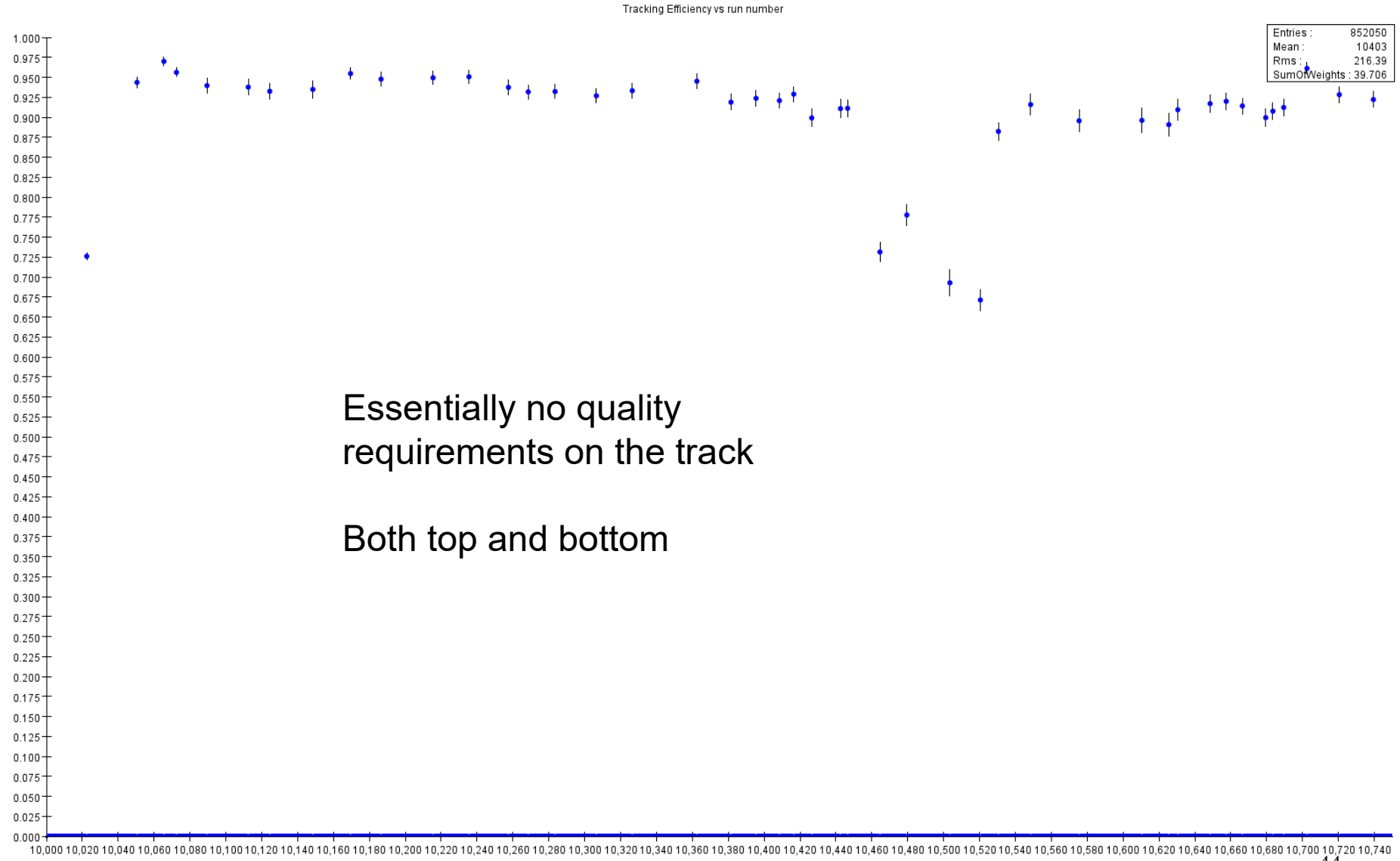
WAB Tracking Efficiency vs E 2021



Essentially no quality requirements on the track

Both top and bottom

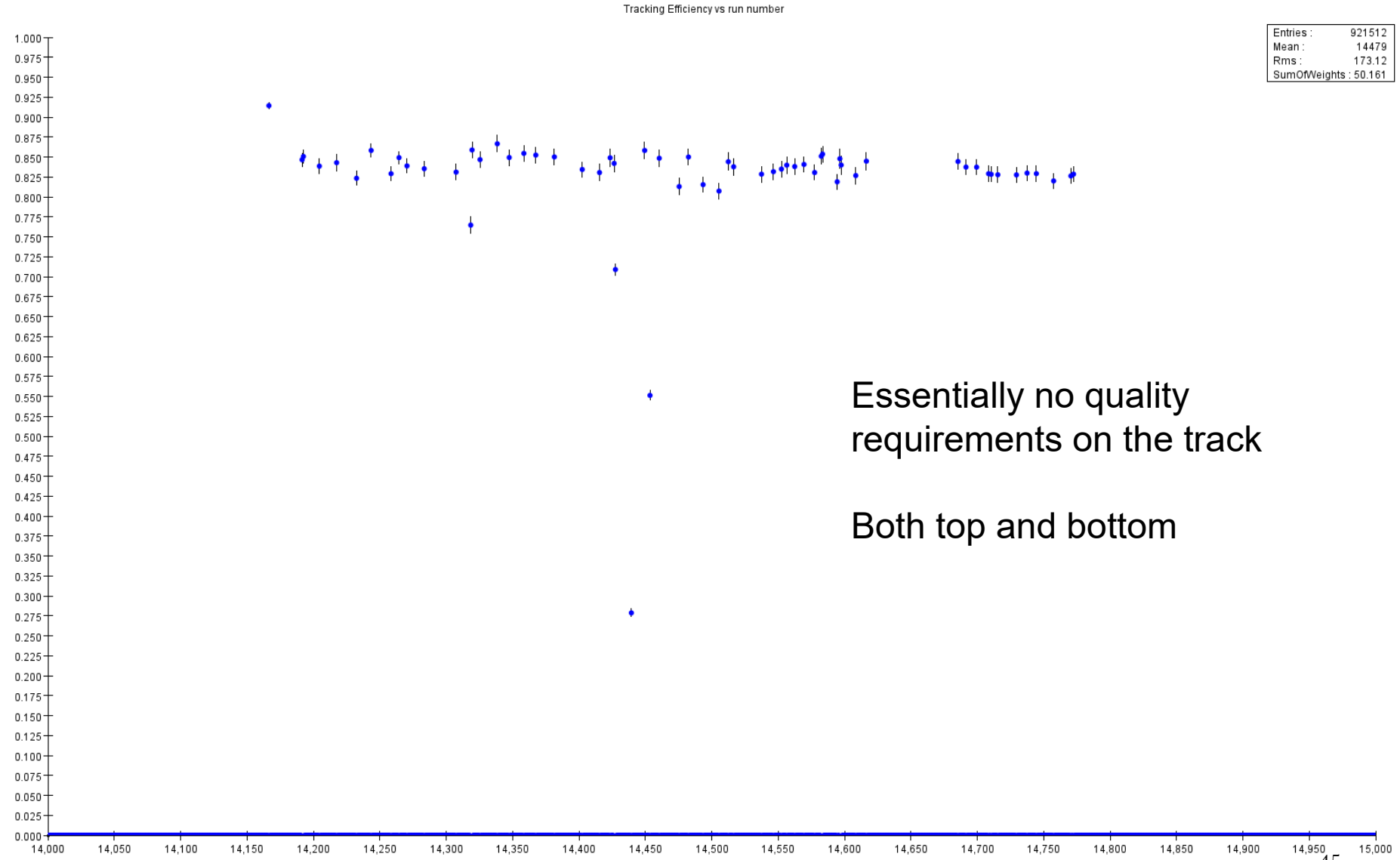
WAB Tracking Efficiency vs run 2019



Essentially no quality requirements on the track

Both top and bottom

WAB Tracking Efficiency vs run 2021



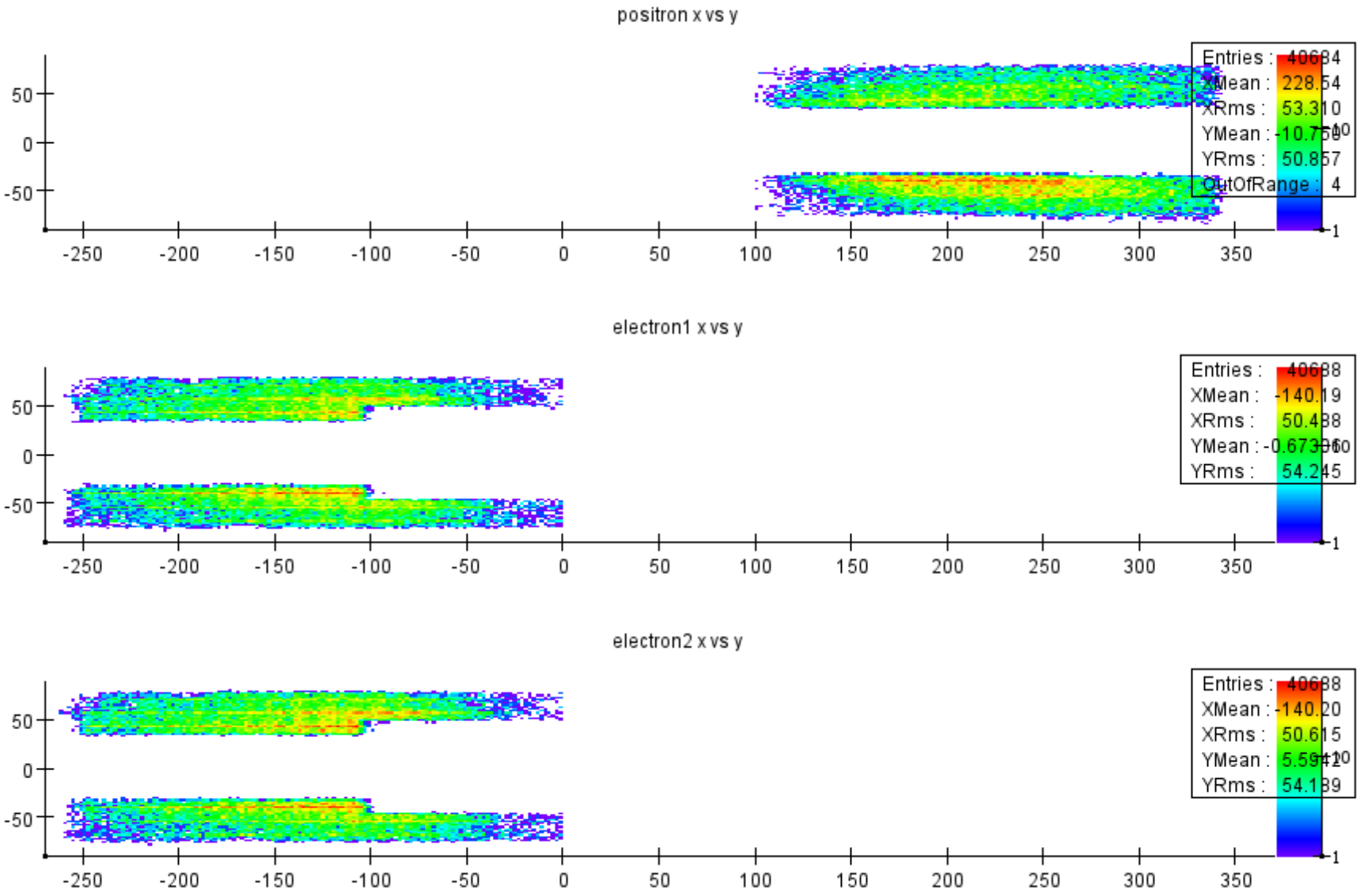
Essentially no quality requirements on the track

Both top and bottom

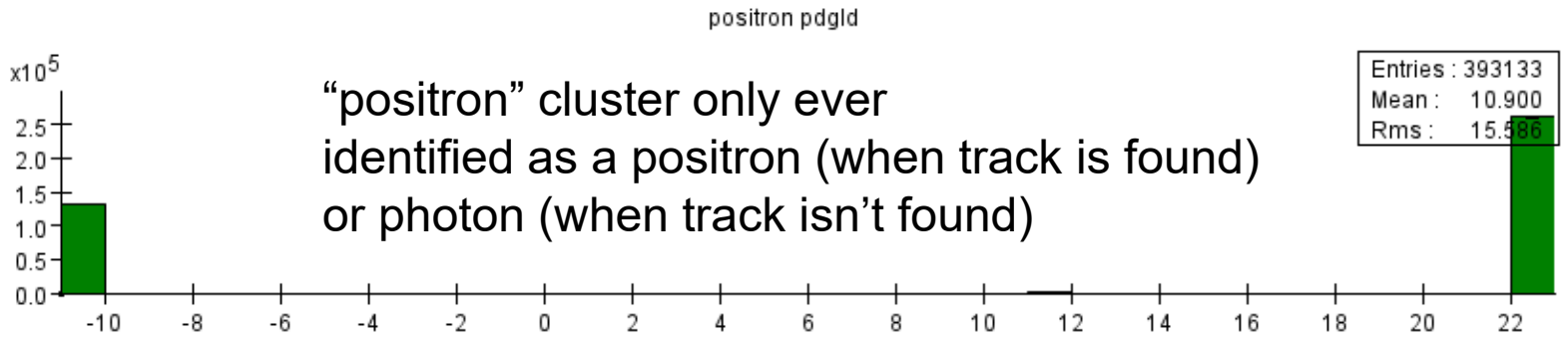
Trident Tracking Efficiency

- Standard trident calorimeter-only event selection
- “positron” is cluster x > 100
- “electron” is cluster x <0
- Require one “positron”, one “electron” in opposite half, and one other “electron” called here “recoil”
- Require two clusters to have associated tracks, then probe the third cluster to check whether or not a track was found.
- Essentially no quality requirements on the track
- Mixed both top and bottom

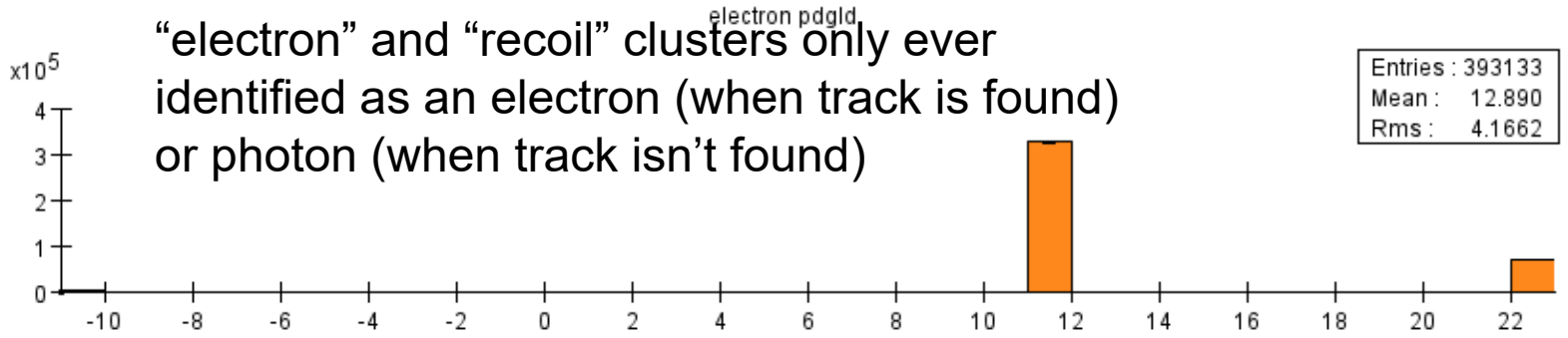
Cluster Positions



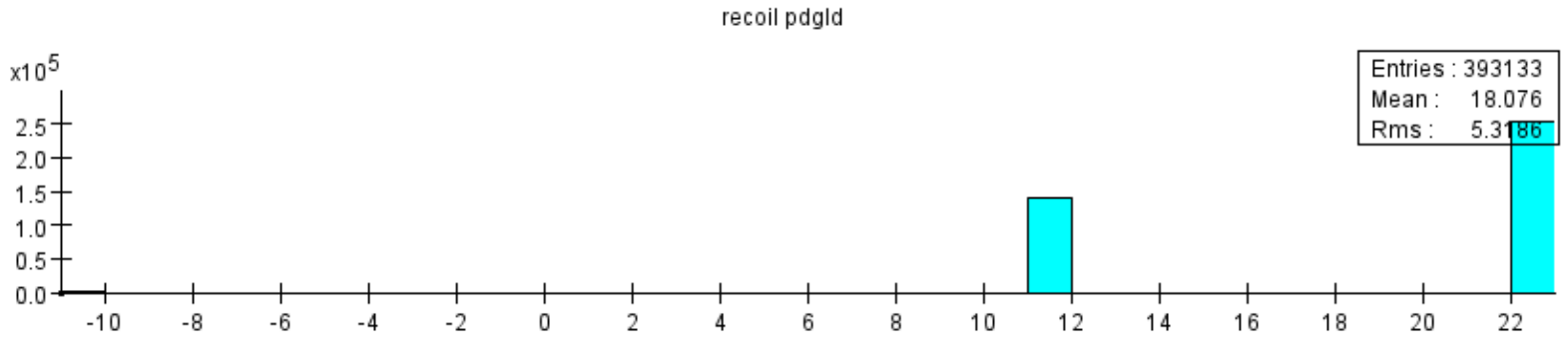
Cluster PDG ID when track found



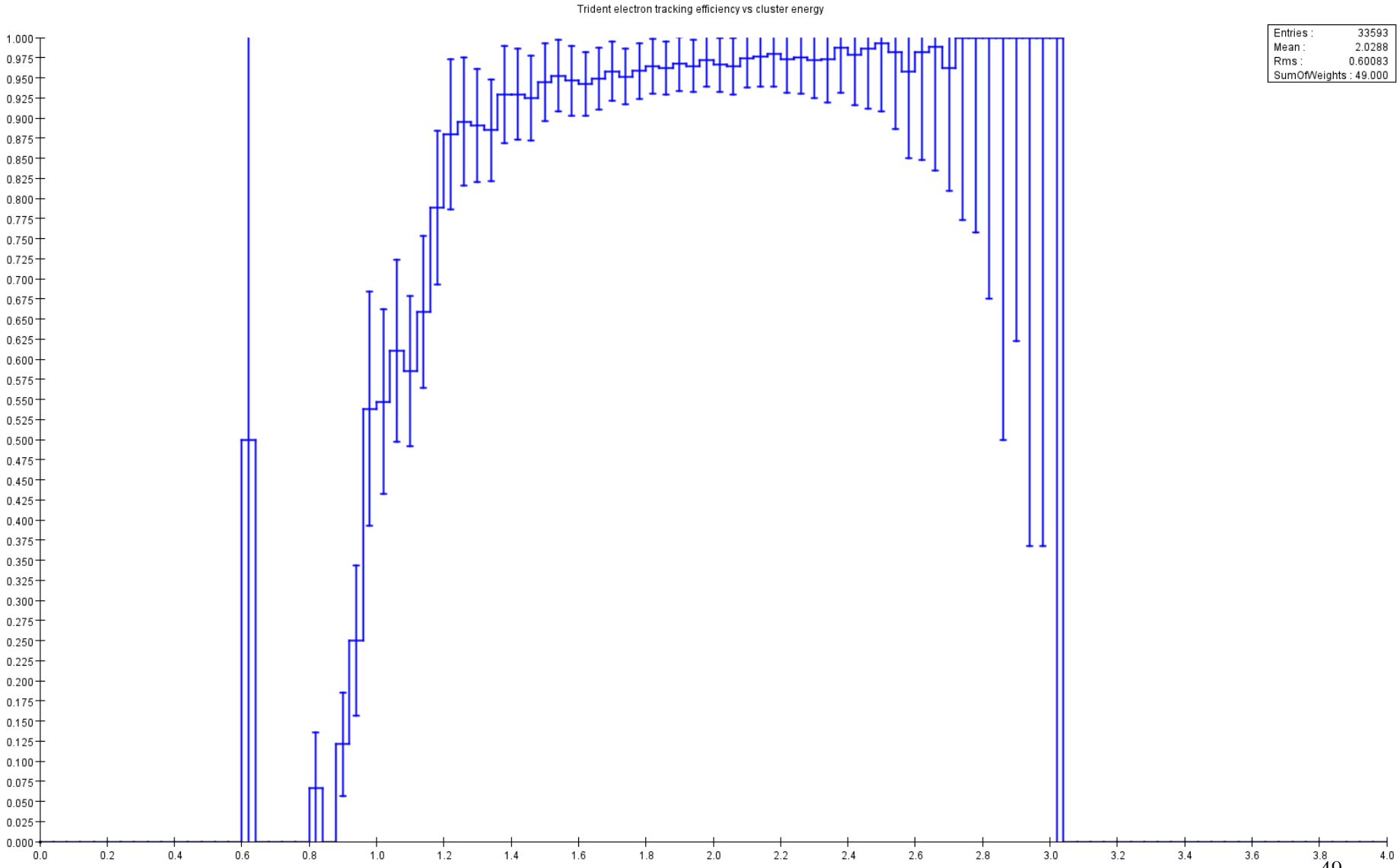
"positron" cluster only ever identified as a positron (when track is found) or photon (when track isn't found)



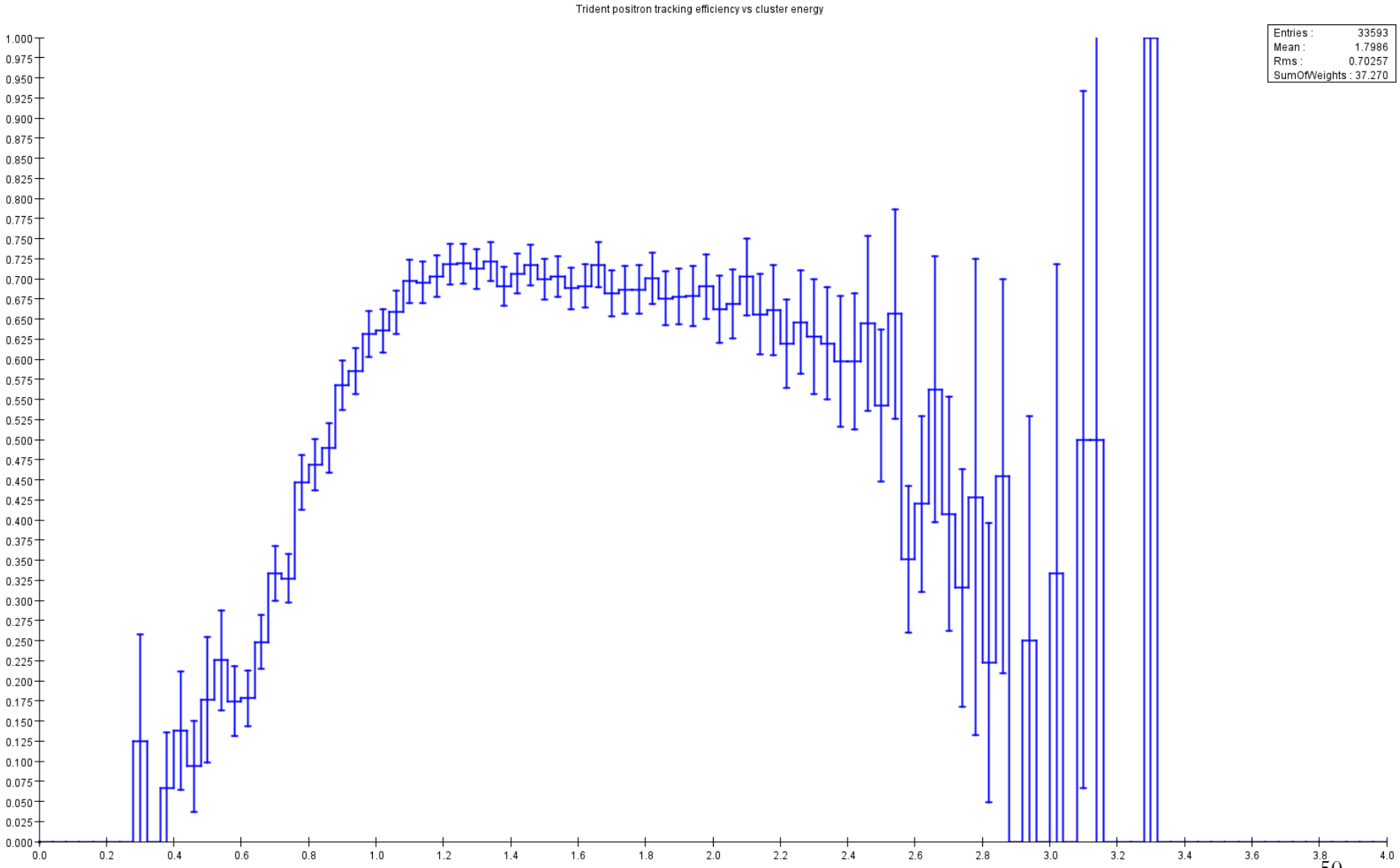
"electron" and "recoil" clusters only ever identified as an electron (when track is found) or photon (when track isn't found)



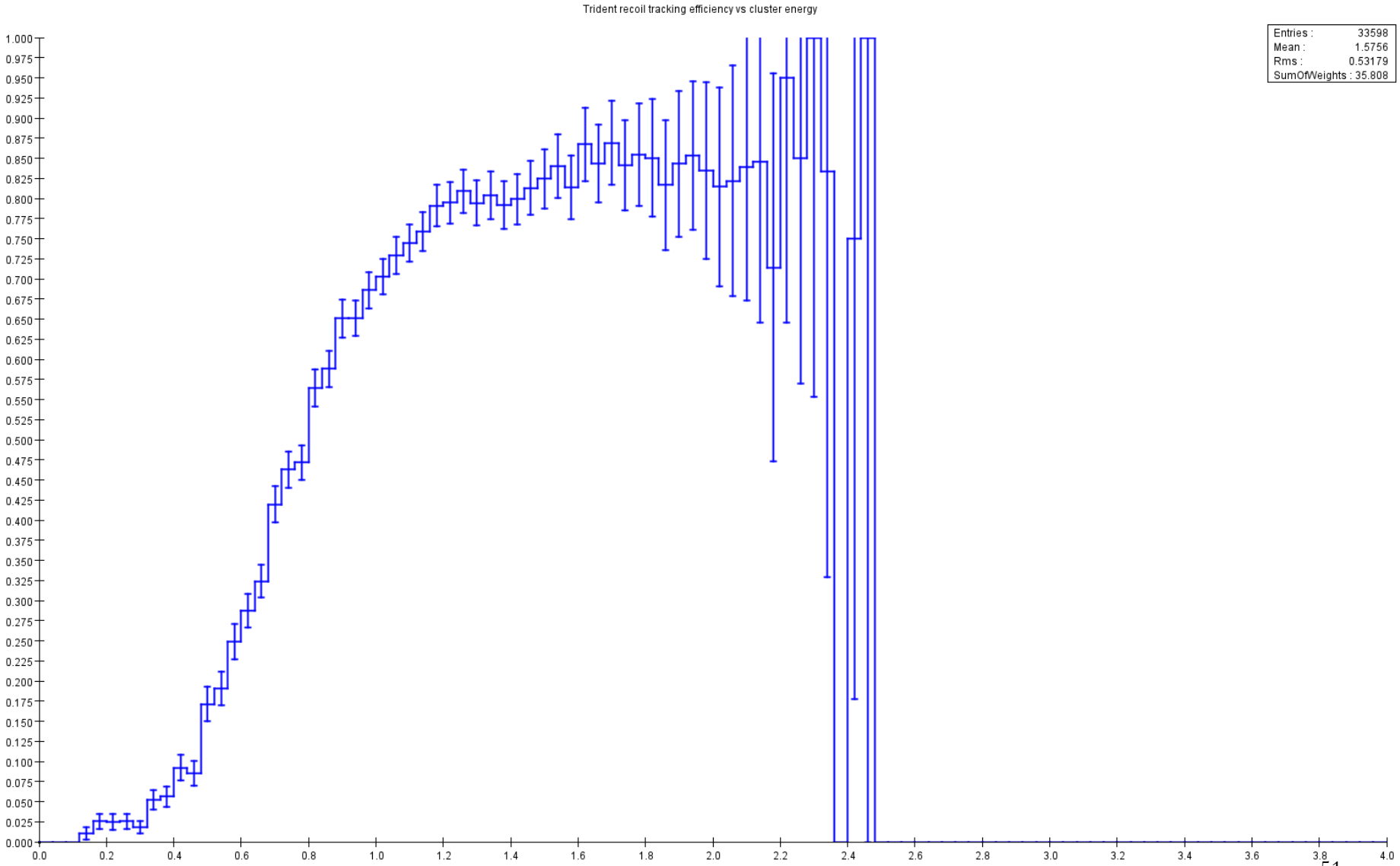
Electron Track Efficiency vs E 2019



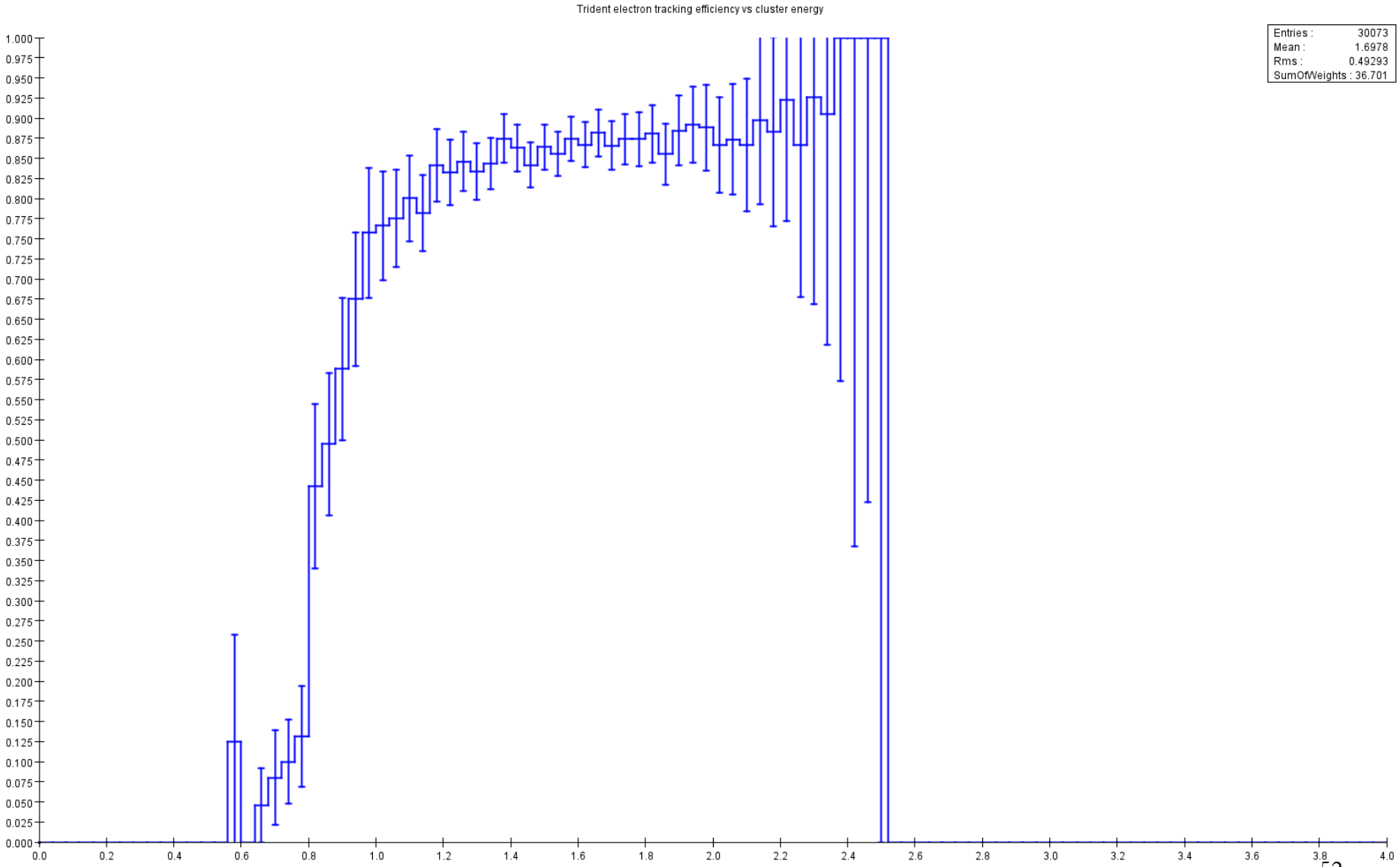
Positron Track Efficiency vs E 2019



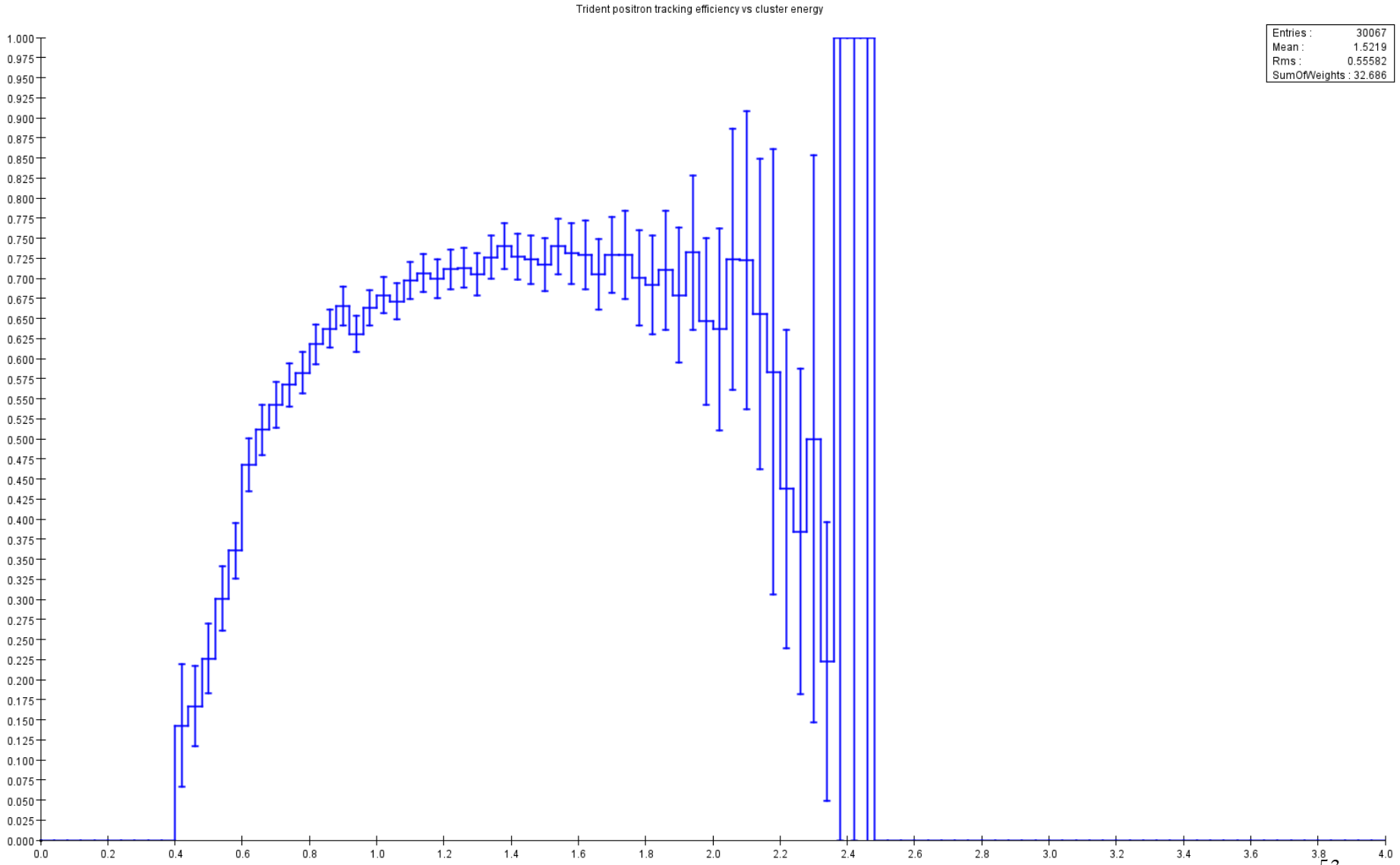
Recoil Track Efficiency vs E 2019



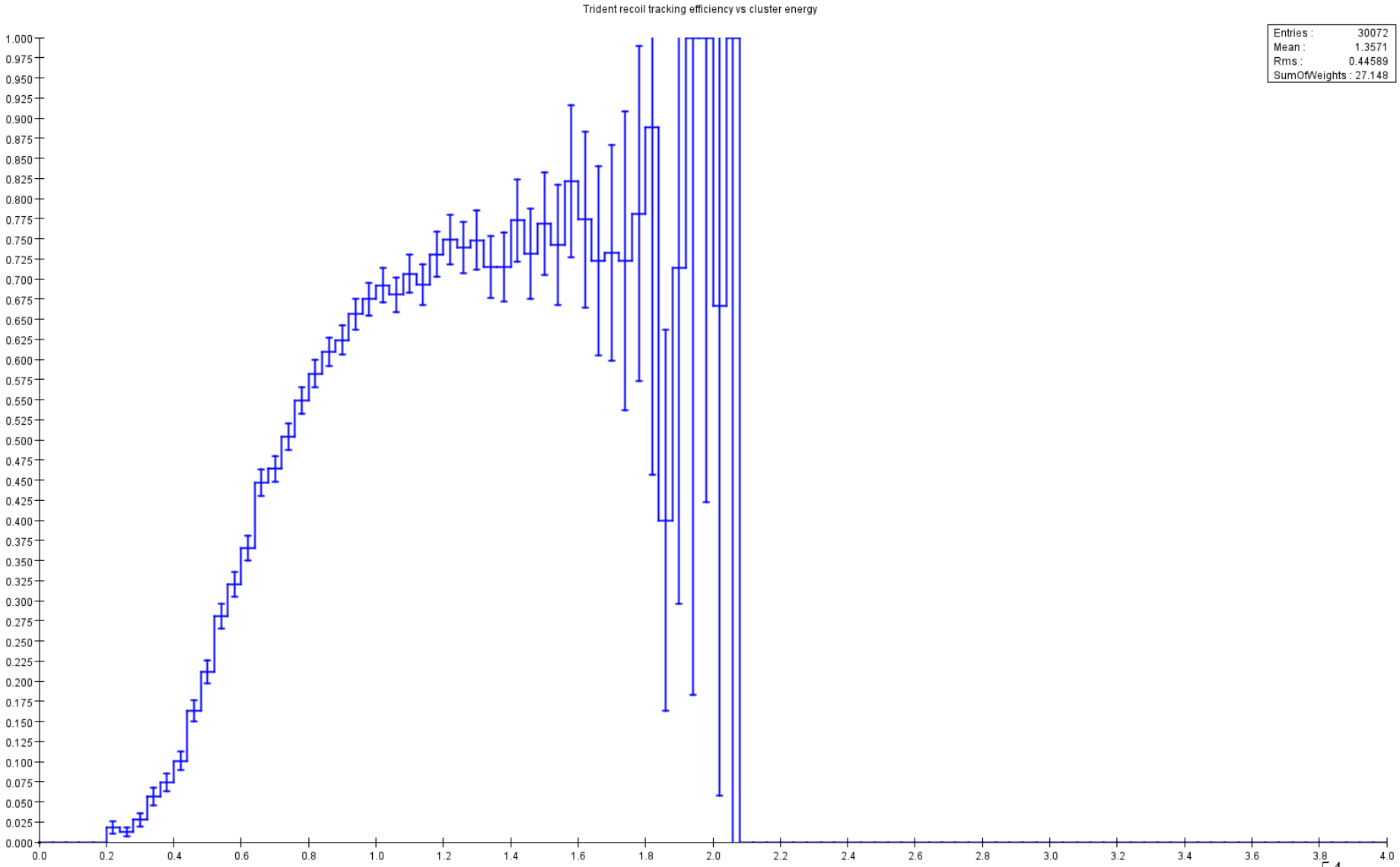
Electron Track Efficiency vs E 2021



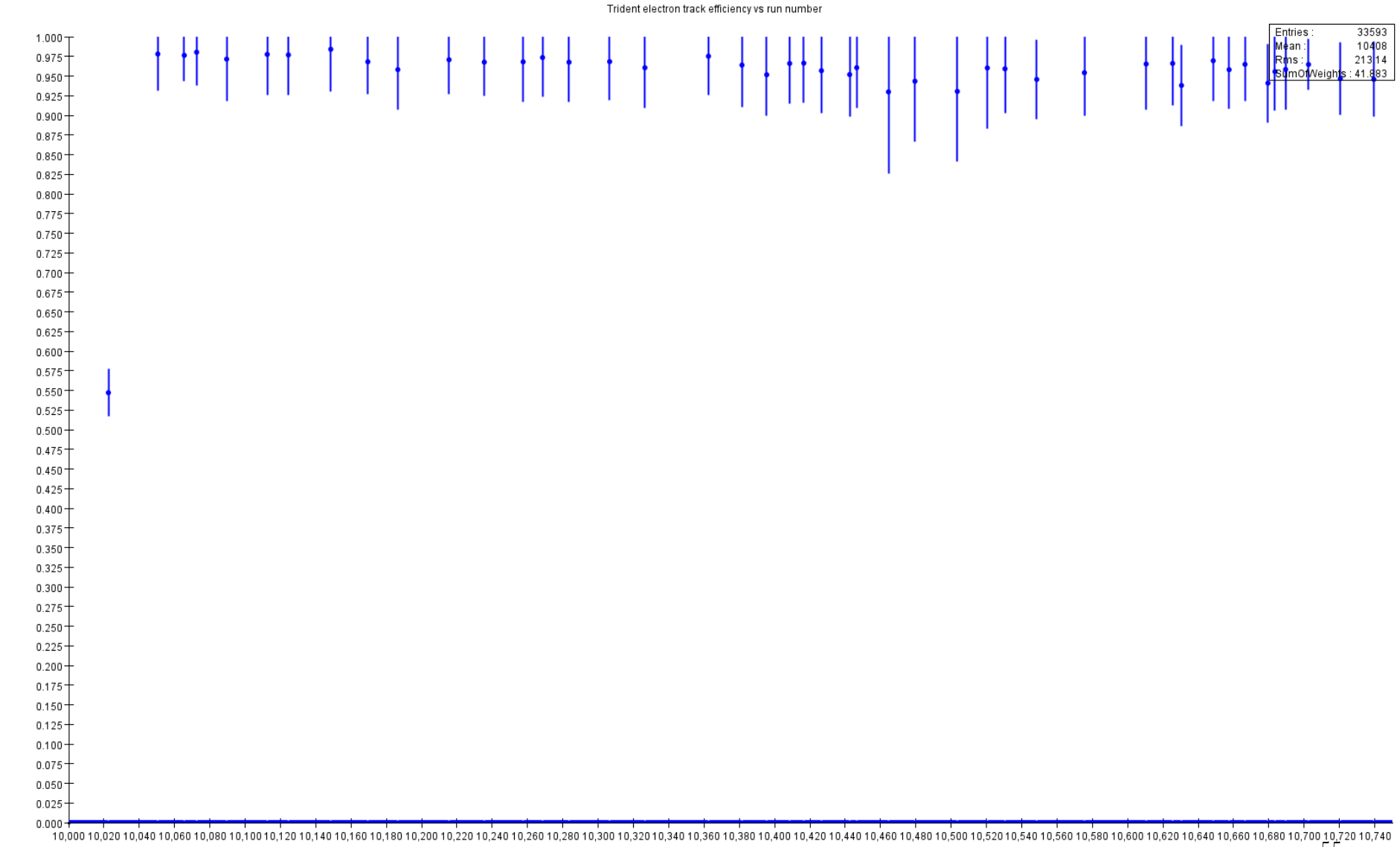
Positron Track Efficiency vs E 2021



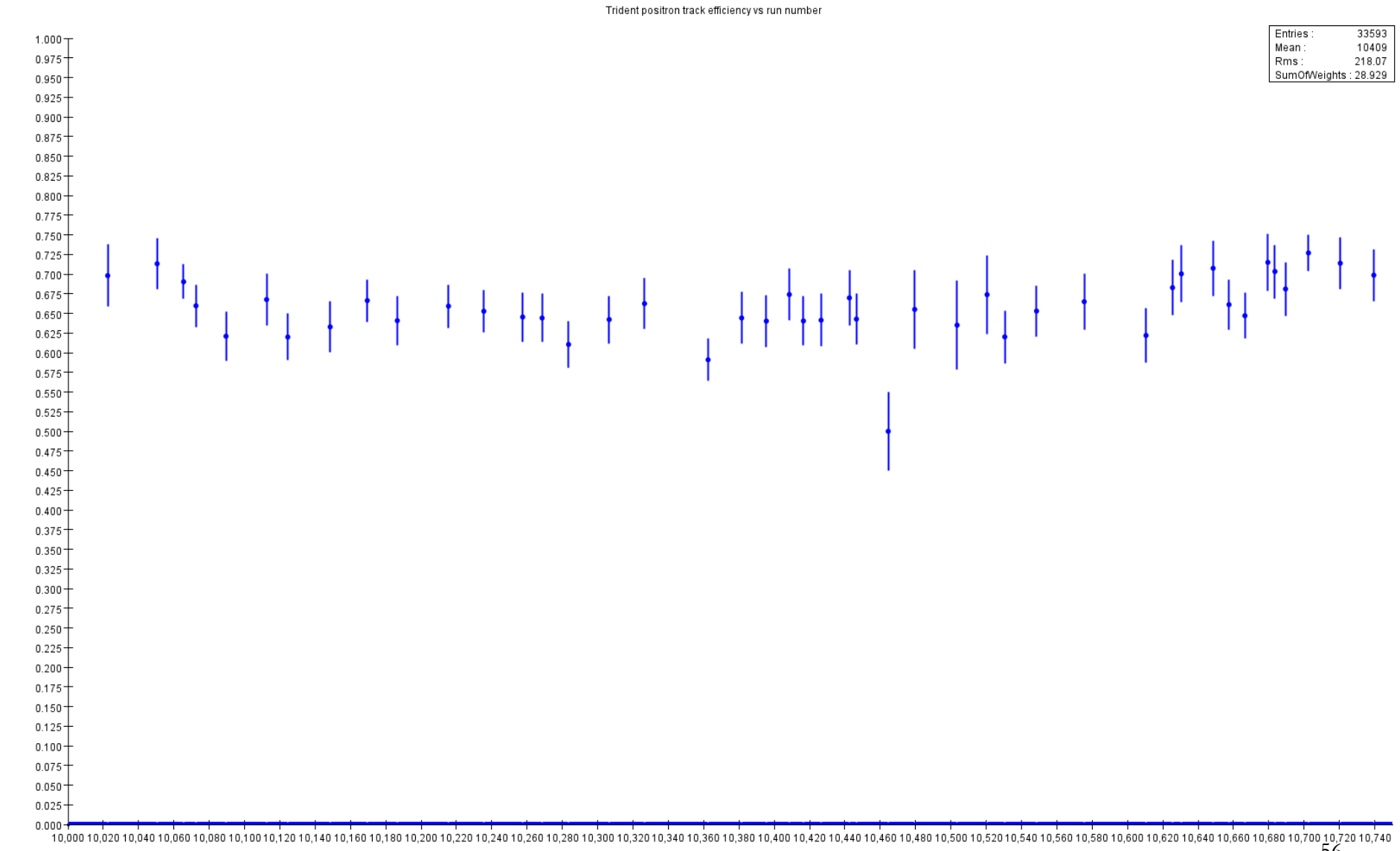
Recoil Track Efficiency vs E 2021



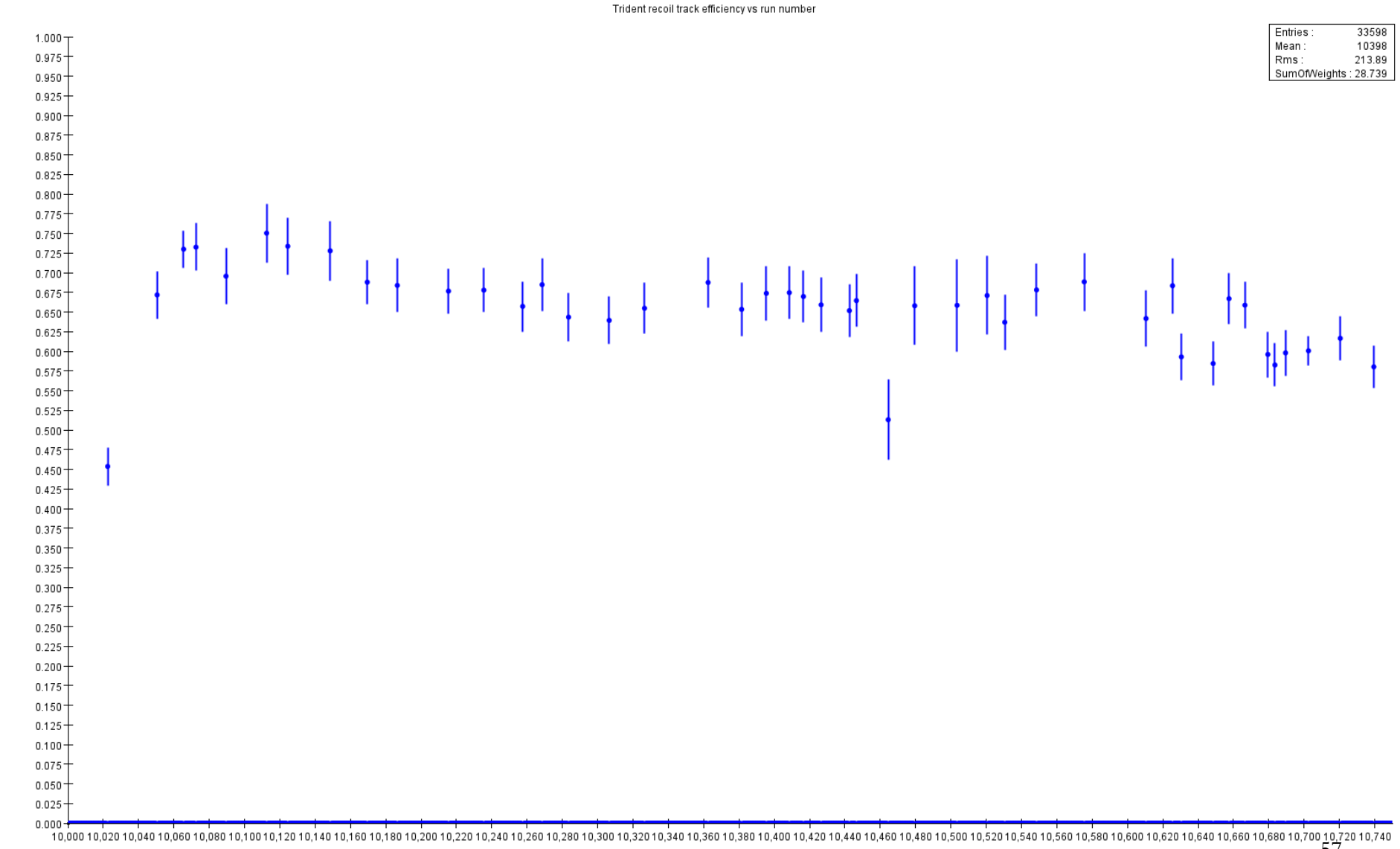
Electron Track Efficiency vs Run 2019



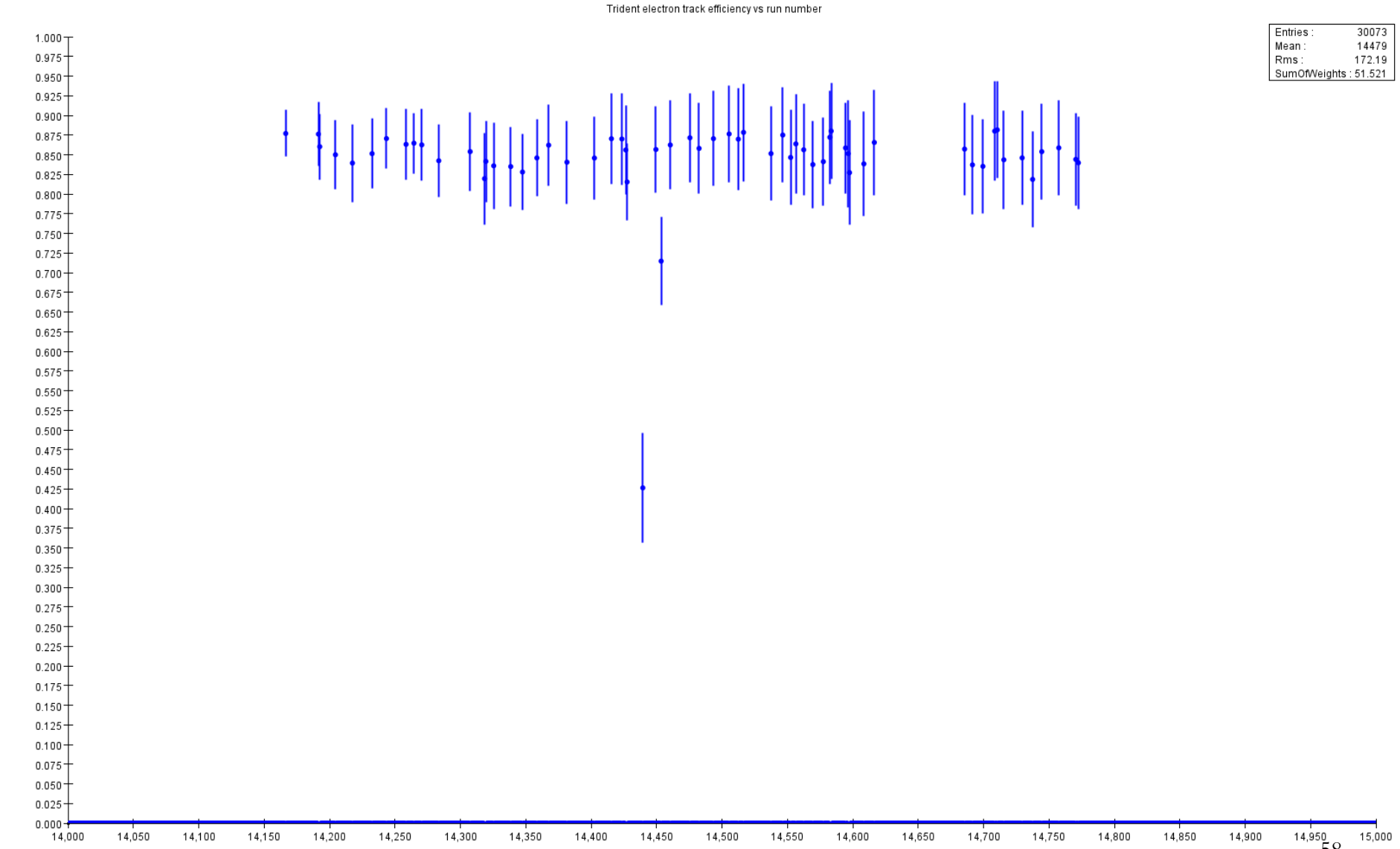
Positron Track Efficiency vs Run 2019



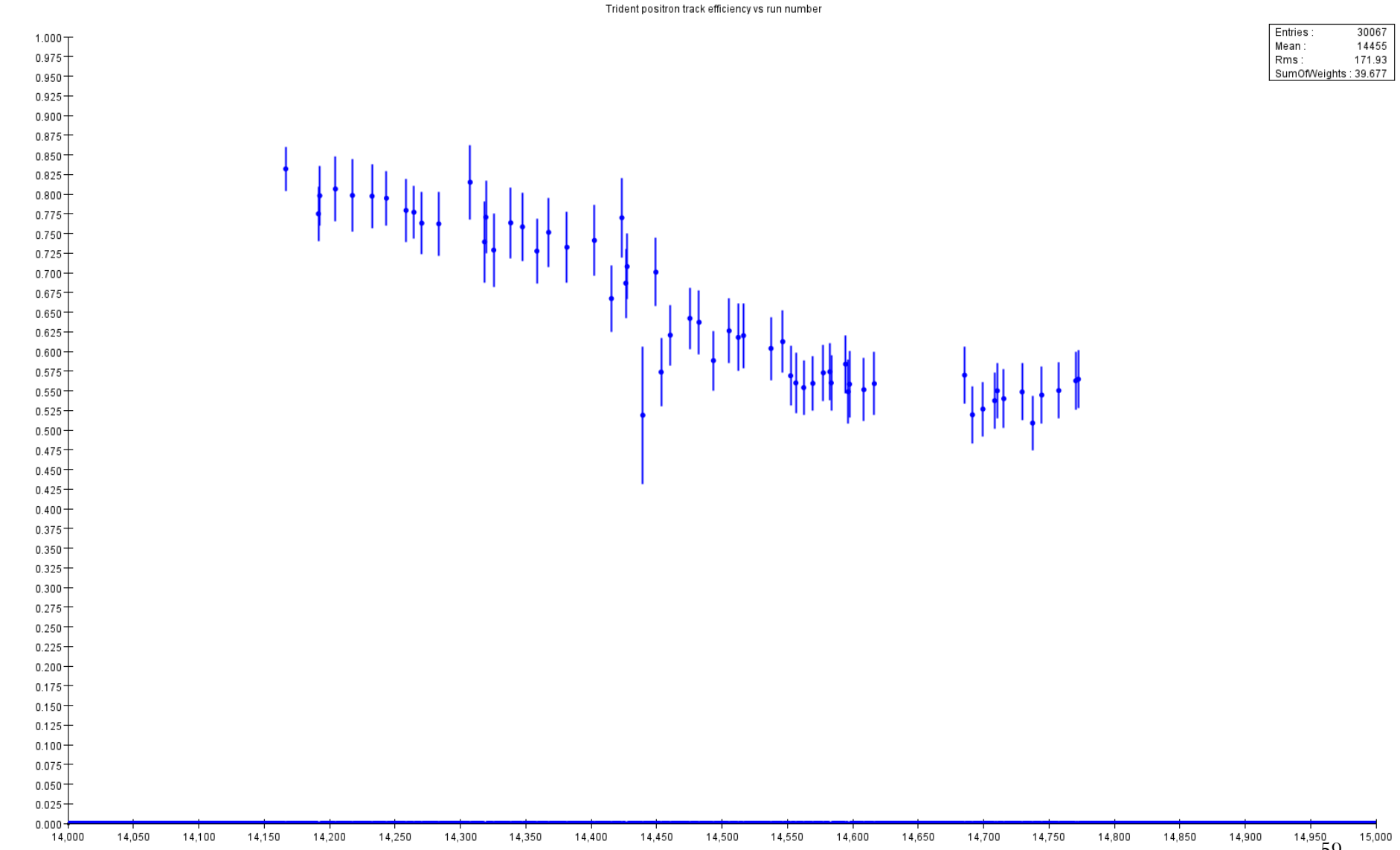
Recoil Track Efficiency vs Run 2019



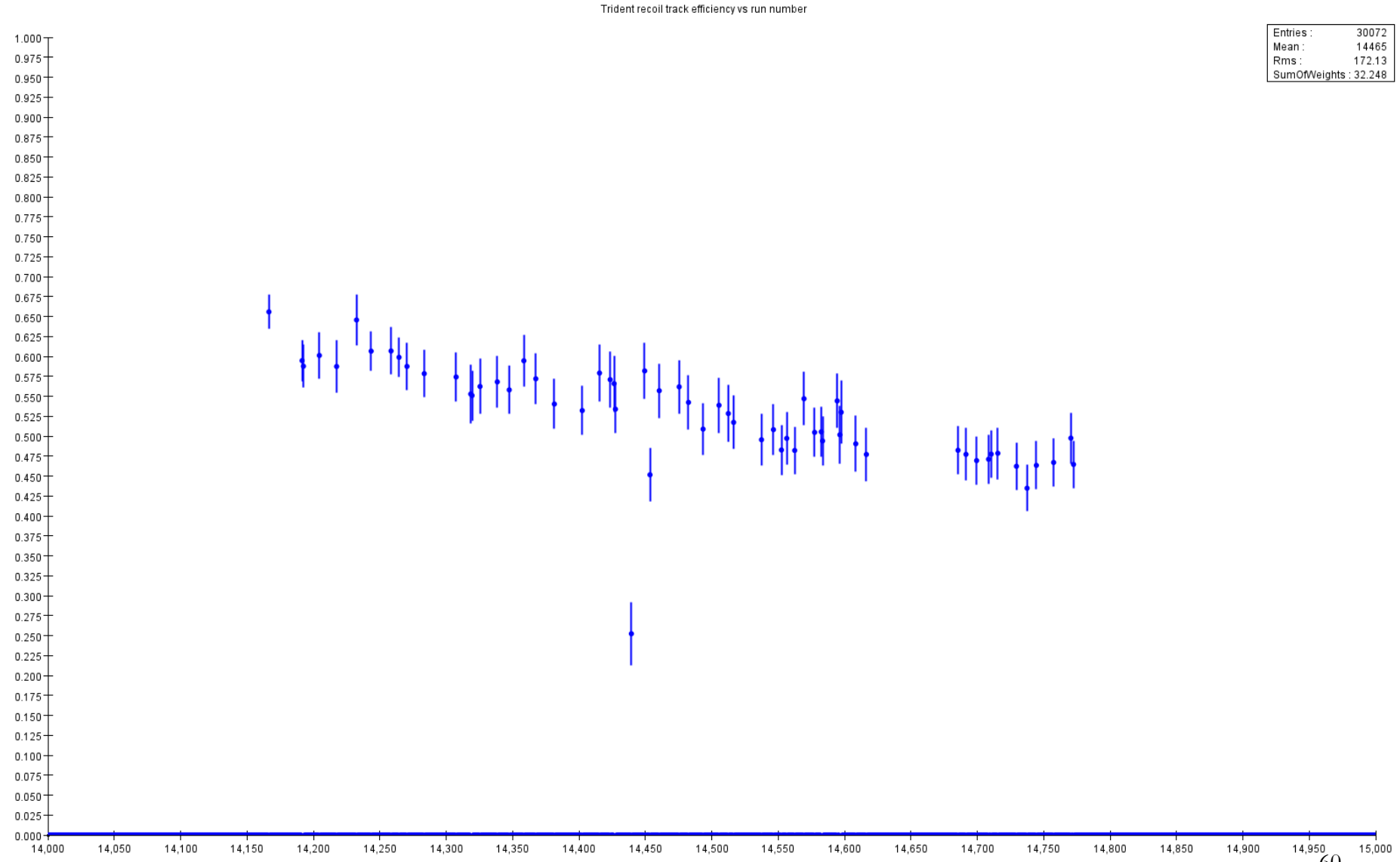
Electron Track Efficiency vs Run 2021



Positron Track Efficiency vs Run 2021



Recoil Track Efficiency vs Run 2021



Track-Finding Efficiencies

- Machinery exists to determine track-finding efficiencies from the data.
- These plots are the most basic ones I could put together
- We have a long way to go to improve the overall efficiencies before worrying about details of the inefficiencies.
- Hopefully the recent work by Rory on baselines and hope-for future improvements to the tracker alignment will bring these efficiencies to more reasonable values.
- Skims of events missing tracks can be made available to anyone wishing to investigate this in more detail

Pass0

- It's been almost eight months since we finished the pass0 reconstruction!
- There is a wealth of information in that data that can be used not only to identify deficiencies in our current detector calibration and event reconstruction but also to provide clues on how to improve it.
- I strongly encourage more collaborators to analyze the data
- There are lots of opportunities for you to contribute
  - If you're unsure on where or how to start, ask me how.