2019 Calibration Update

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HPS Fall Collaboration Meeting
November 18, 2020

ECal

- See Andrea's talk tomorrow!
- ECal gains derived from FEEs are ~complete.
- "Sampling fraction" defined as correction for loss of energy in interstitial regions or in crystals below clustering threshold (7.5MeV $\rightarrow$ 30MeV)
- Sampling fractions for e^-, e^+ and γ derived from MC
  - Large statistics MC samples at many energies and angles have been generated.
- Sampling fractions refined via analysis of data WABs
- Correction code and parameters included in hps-java (git branch iss732-refactor).
- Cluster timing and position corrections being worked on.

ECal Calibration via $\pi^0 \rightarrow \gamma\gamma$?

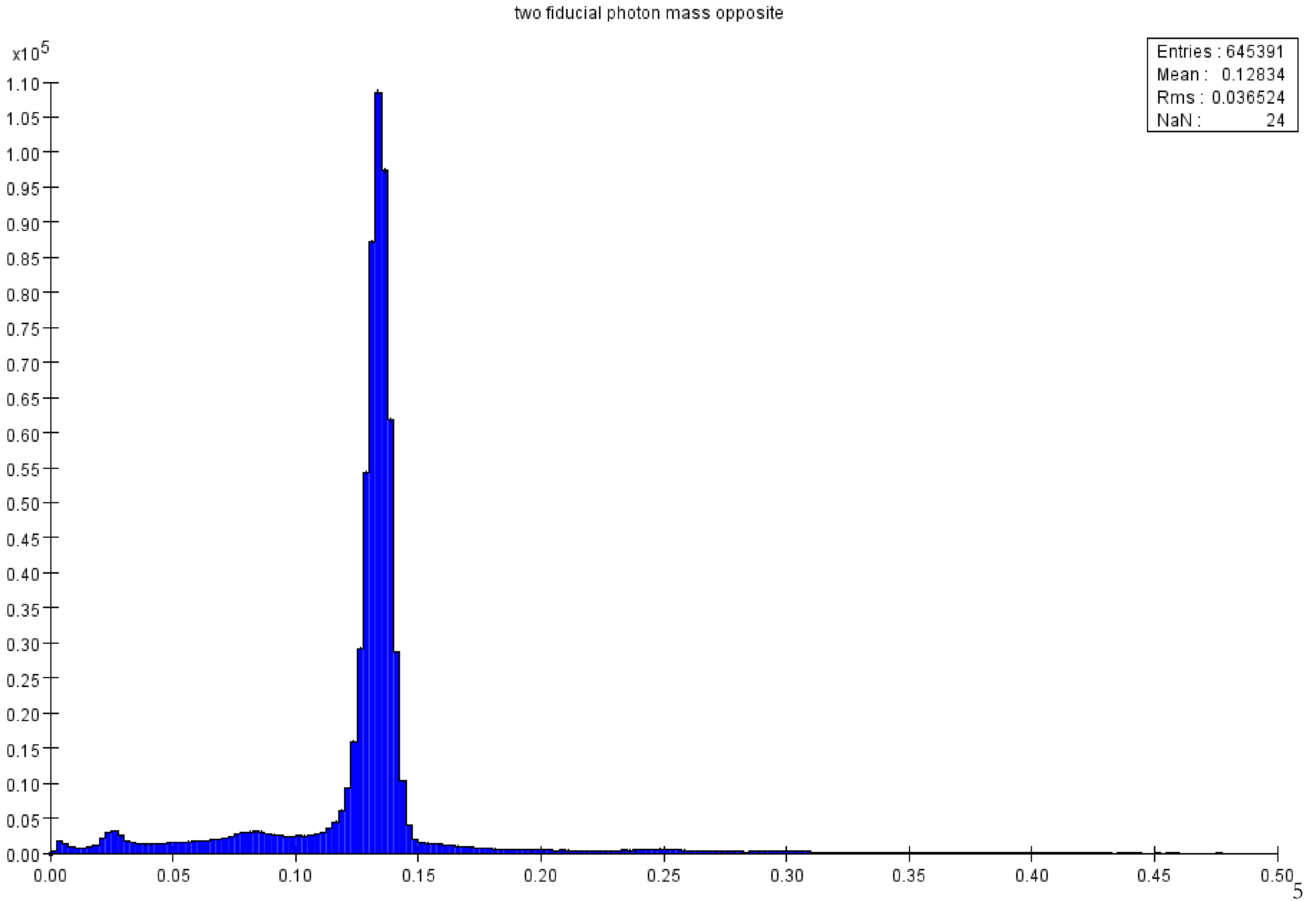
- $\pi^0 \rightarrow \gamma\gamma$ would provide a nice *in situ* mass peak to test both energy and position resolution in the ECal
- Using data from the 2019 “good” runs.
- Nathan skimmed off the mult2 triggers

  /mss/hallb/hps/physrun2019/production/evio-skims/mult2/
- Reconstructed with master version of hps-java
  - 2852 files, ~120 million events
- Loop over “photons” in event, create invariant mass of the pairs.
- Cuts:
  - Both fiducial: seed crystal not on edge of calorimeter
  - Cluster $\Delta t < 5$ ns

MC Samples

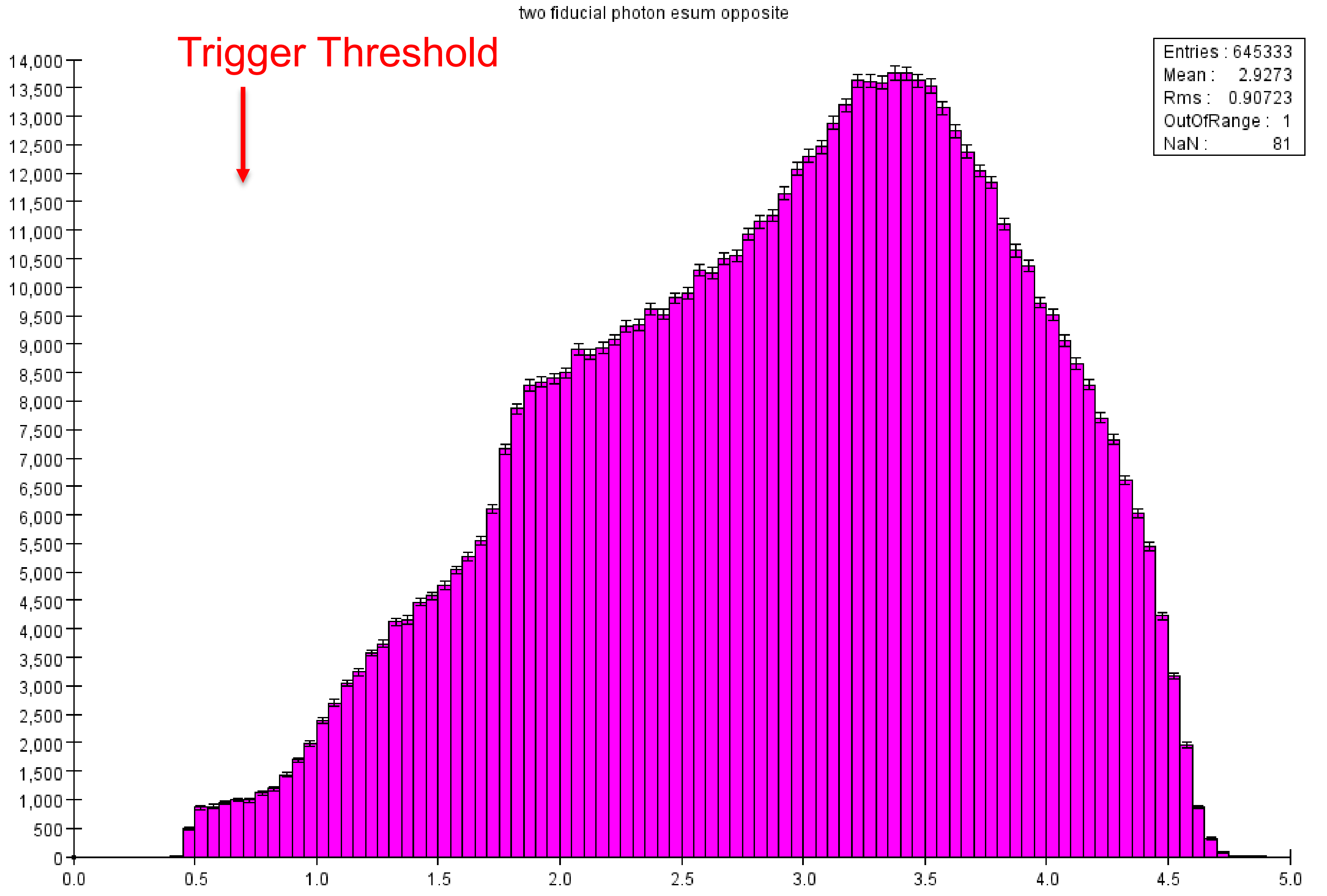
- Generated MC samples of individual $\pi^0 \to \gamma\gamma$ with π^0 energies flat between 500MeV and 4GeV.
- π^0 direction along z, within +/- 3° of the z axis.
- Simulated with slic
- Processed through full chain of:
  - spacing (but no beam overlay)
  - trigger (using pulser trigger, not mult2)
  - readout
  - reconstruction
- Analyzed using same analysis as data.

MC Two-Photon Invariant Mass

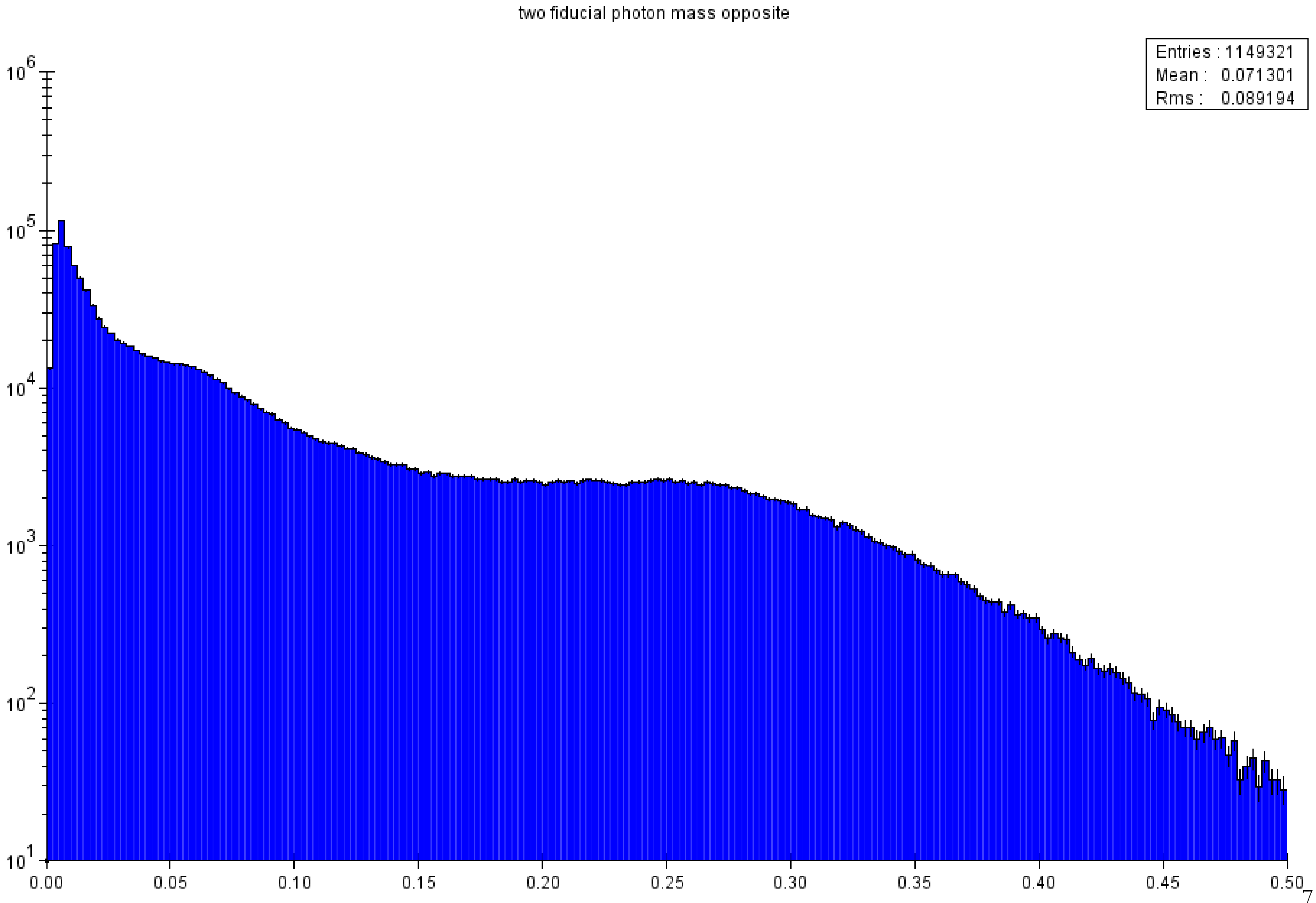


MC Two-Photon ESum

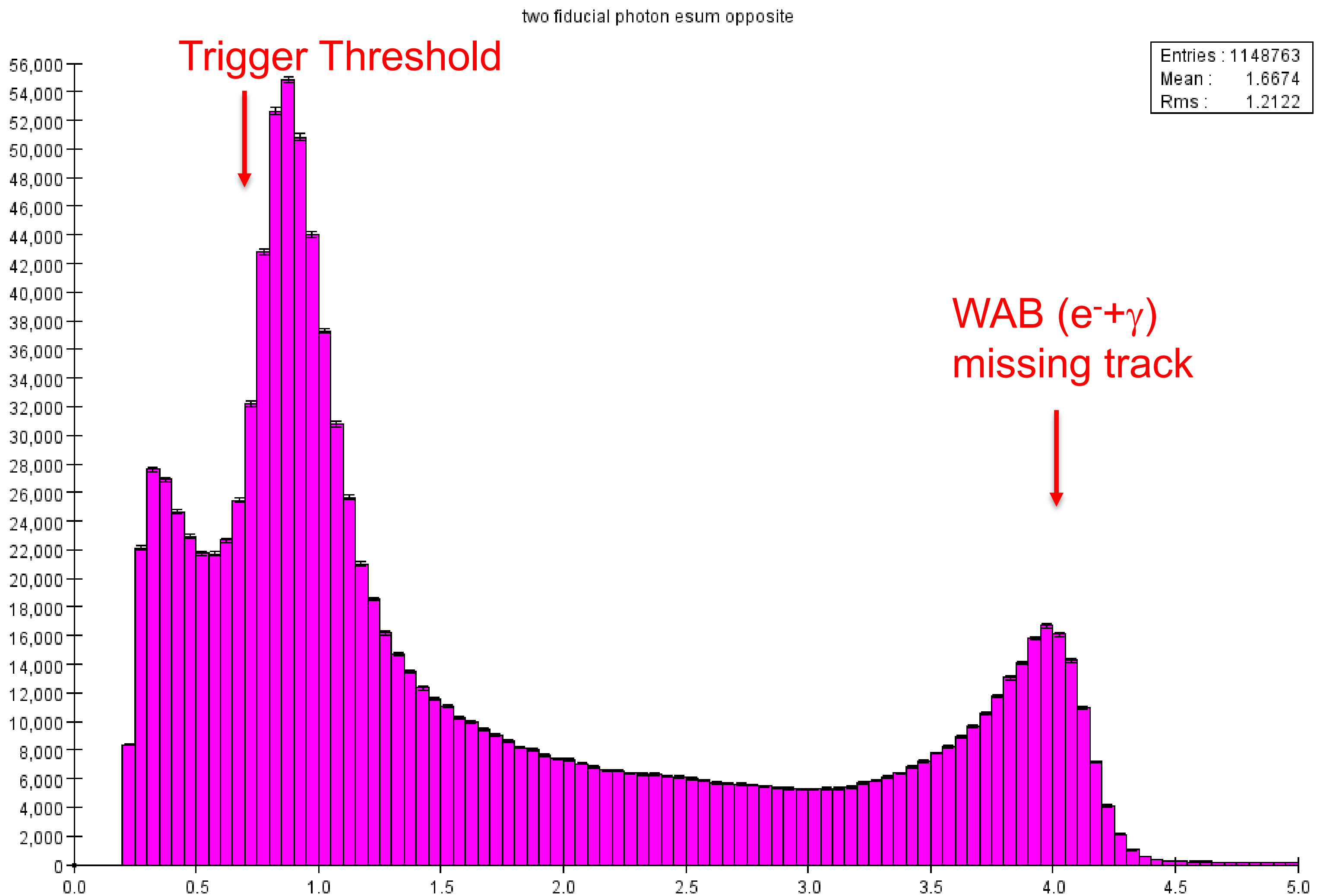
Trigger Threshold



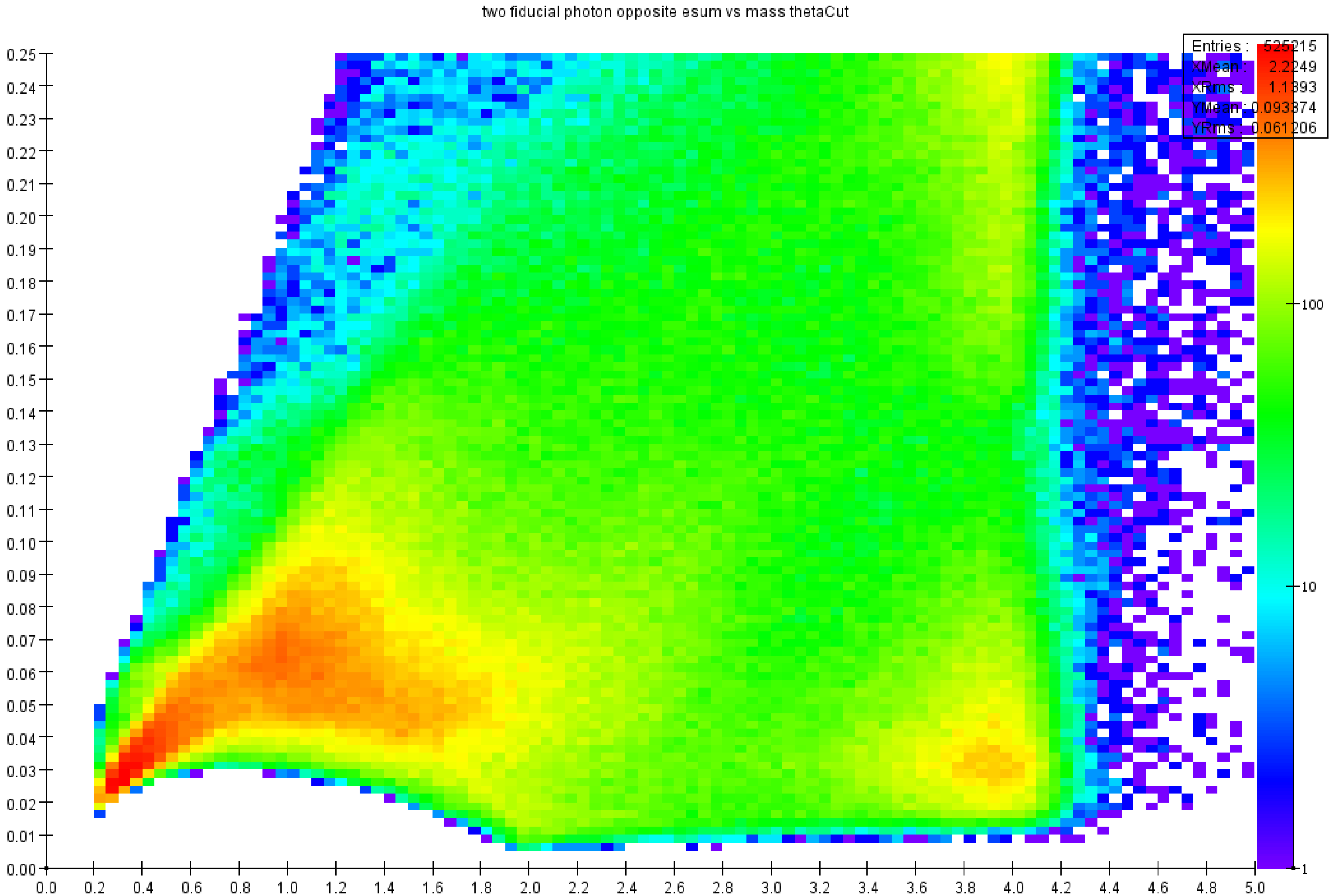
Data Two-Photon Invariant Mass



Data Two-Photon ESum

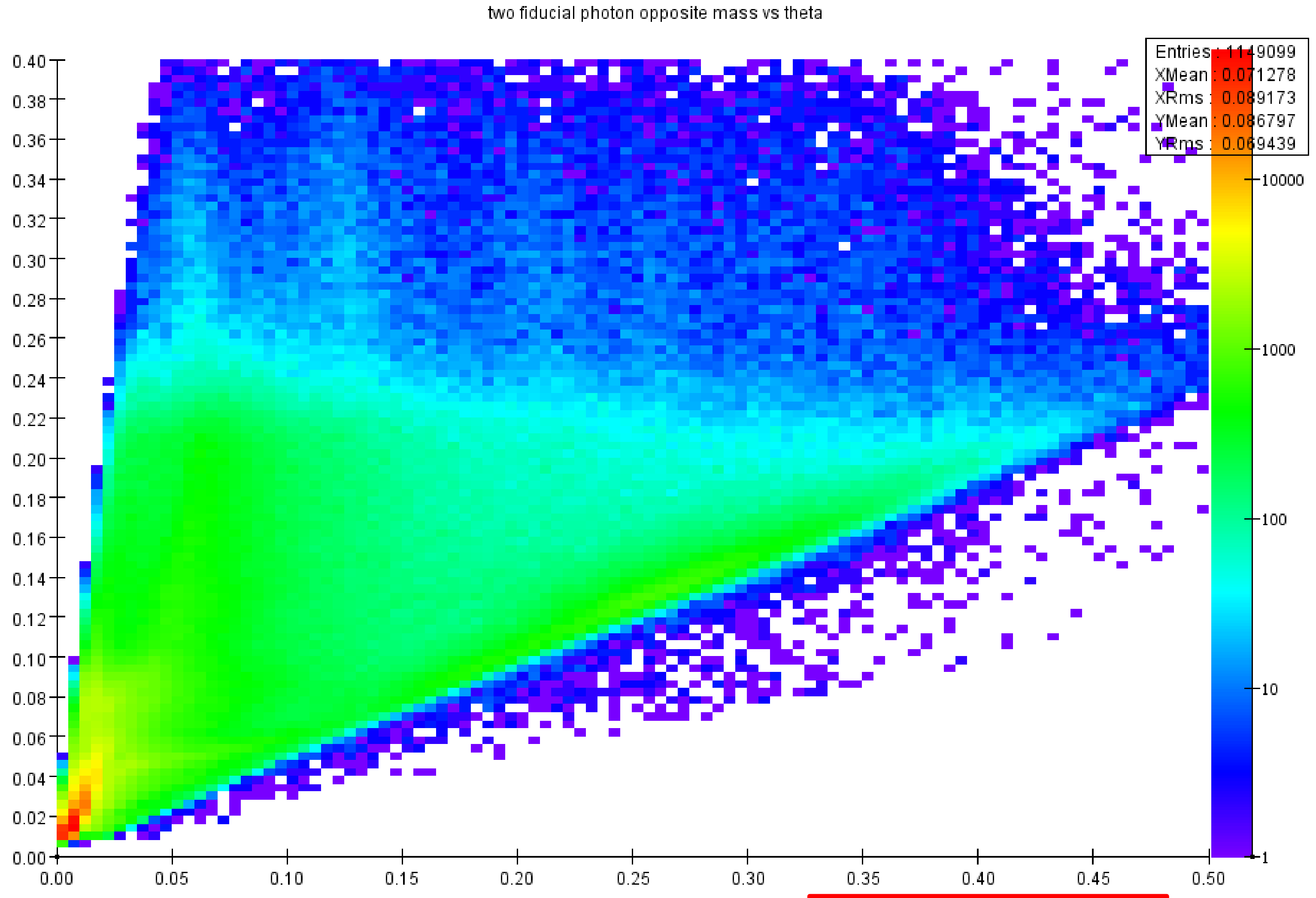


Two-Photon ESum vs Mass



Compare to MC

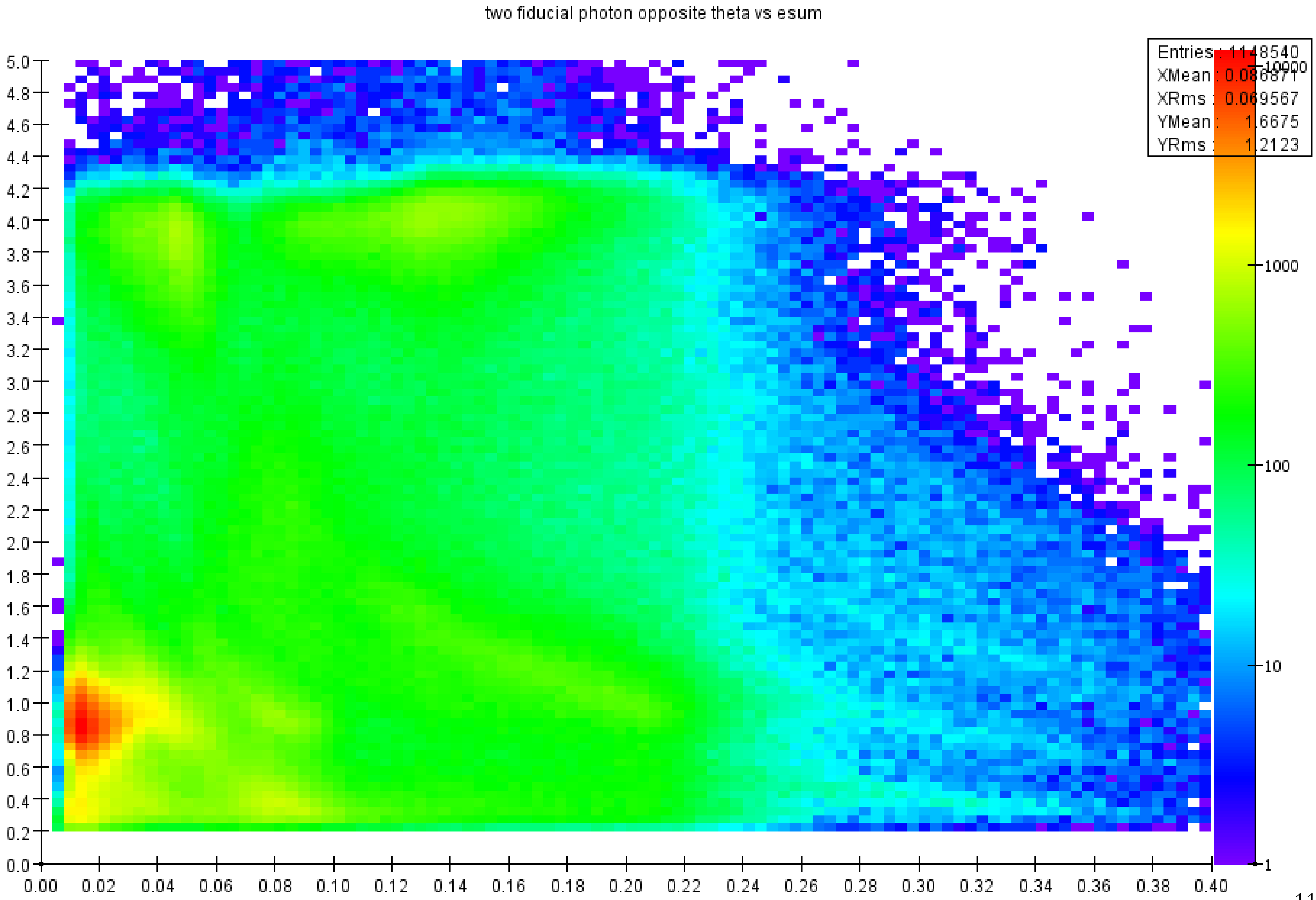
Two-Photon Mass vs Opening Angle



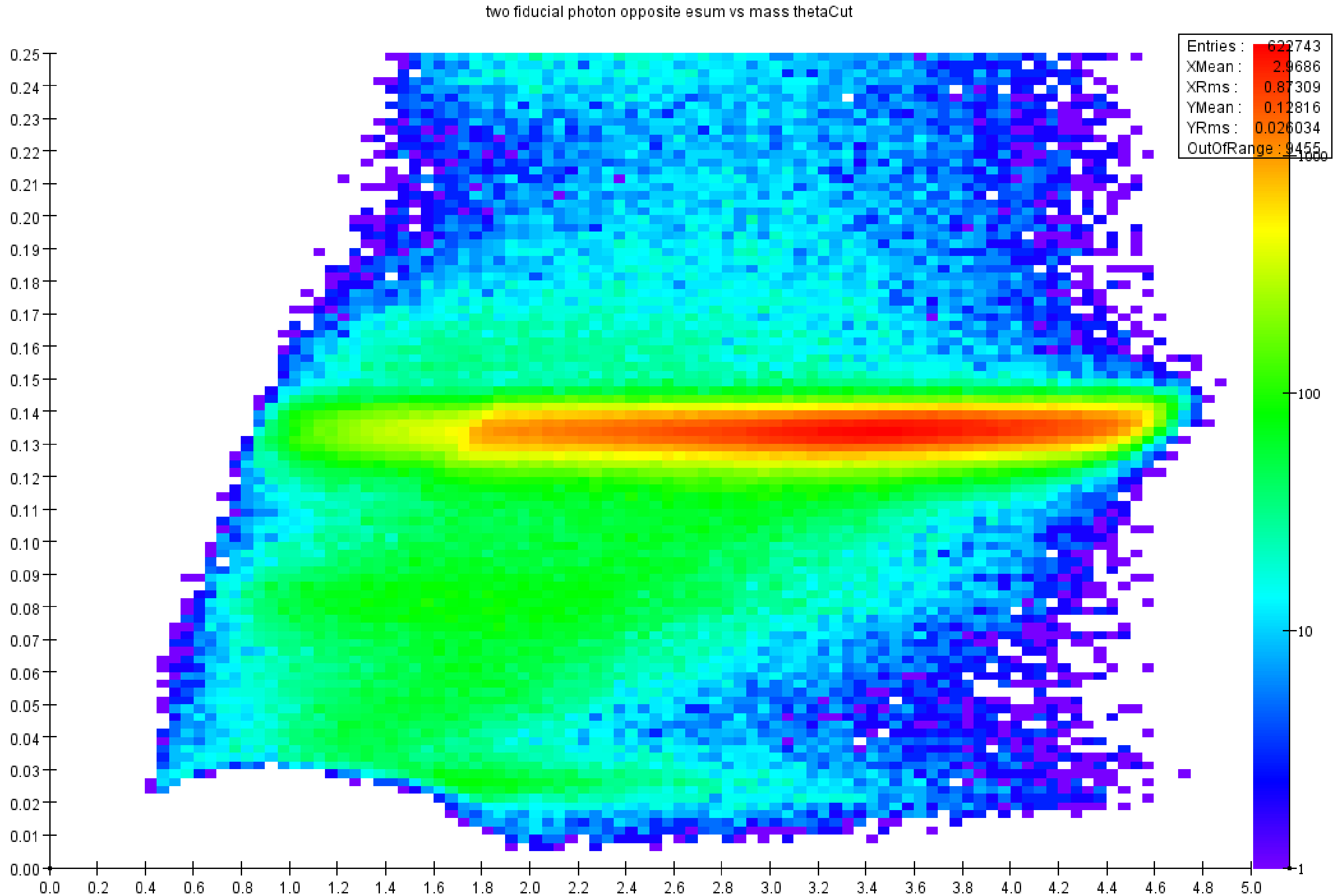
Compare to MC

Theta vs ESum

Compare to MC

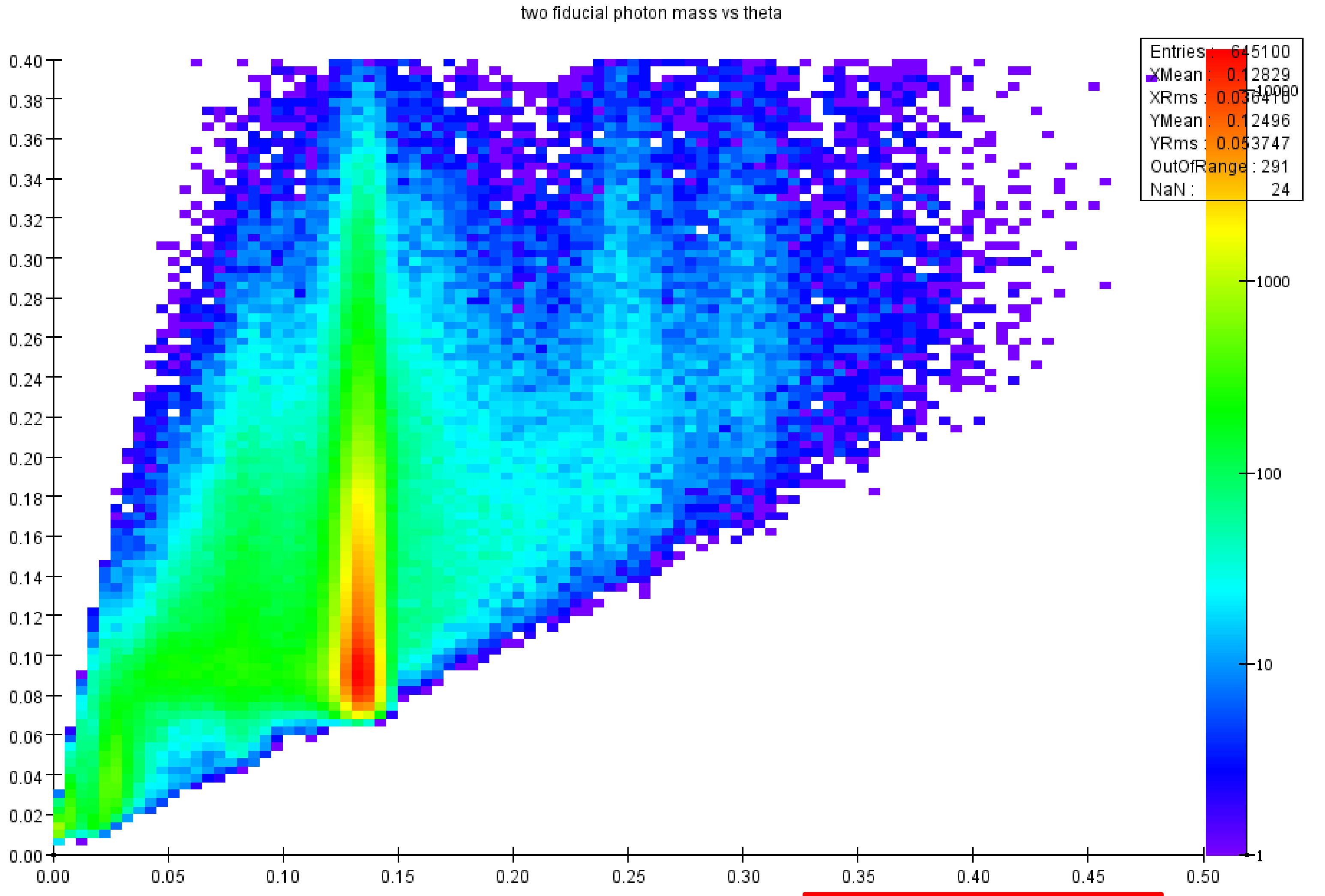


MC Two-Photon ESum vs Mass



Compare to Data

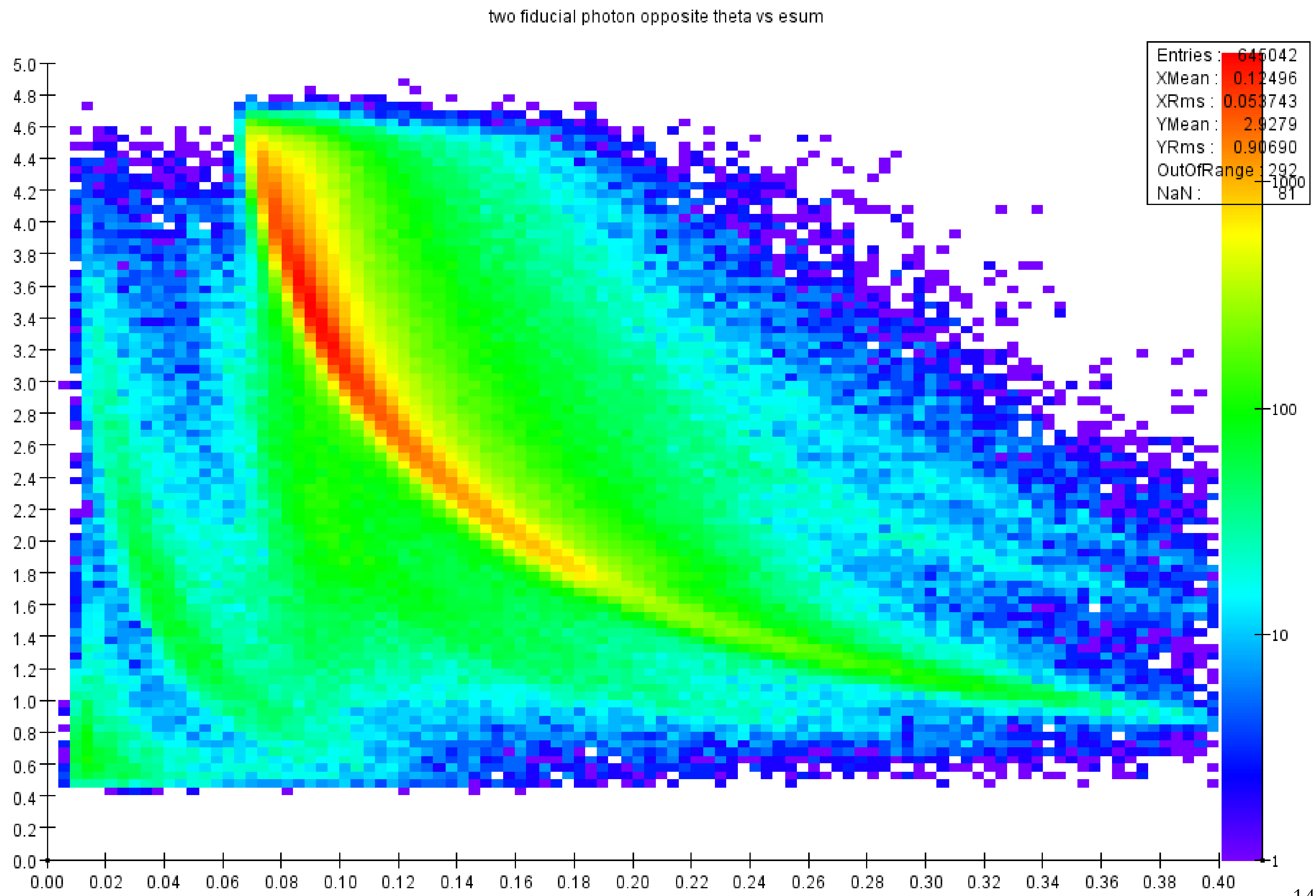
MC Mass vs Opening Angle



Compare to Data

MC Theta vs ESum

Compare to Data



$\pi^0 \to \gamma\gamma$ Summary

- A search has been conducted for the process $\pi^0 \to \gamma\gamma$ using the mult2 trigger skims from the 2019 set of “good” runs.
- 120 million events have been reconstructed and the invariant mass distribution of “photon” pairs has been analyzed.
- Selection cuts have been minimal:
  - Both clusters are in the fiducial region of the calorimeter
  - Clusters are within 5ns of each other in time
- MC samples of $\pi^0 \to \gamma\gamma$ with π^0 energies between 500MeV and 4GeV have been generated and analyzed.
- No evidence for a peak at the π^0 mass has been found in the data.
  - CLAS also does not report a $\pi^0 \to \gamma\gamma$ signal below 6GeV beam energy.

ECalibration with FEEs

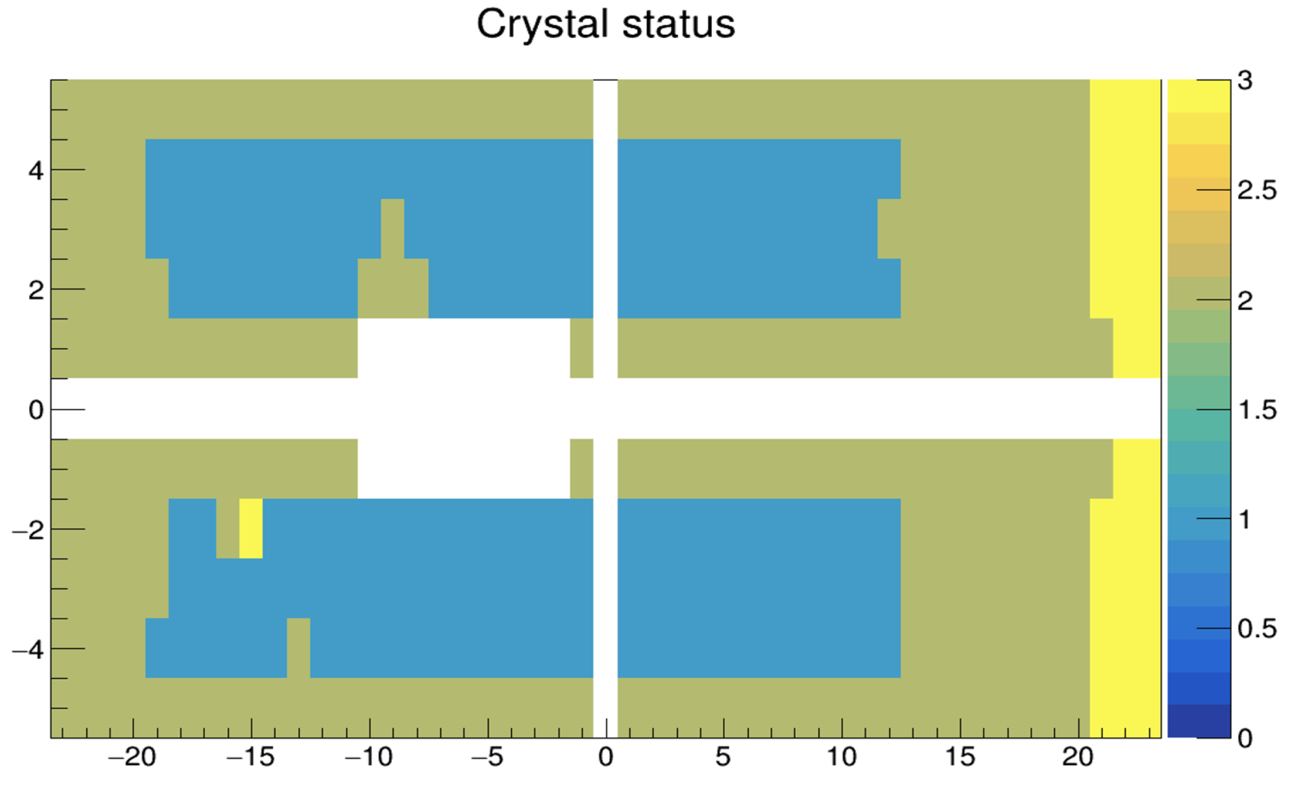
Calibration status after 4 iterations:

Crystals in the centermost region of ECAL are properly calibrated (blue)

Crystals in the lateral regions are not calibrated (brown /yellow)

Crystals with Y=-5, Y=5, Y=-1, and Y=1 are ignored since the FEE peak was not visible

See Andrea's talk tomorrow!

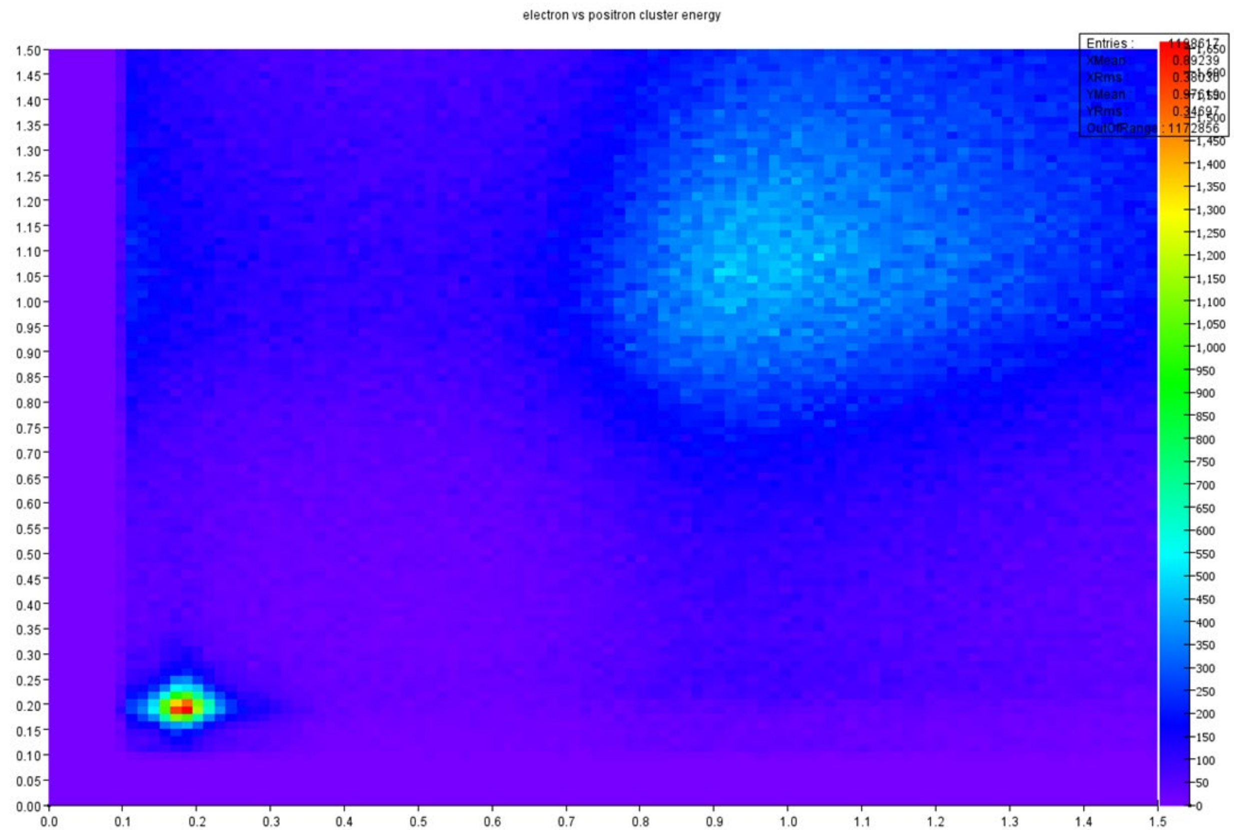


ECalibration with muons

- Nathan has skimmed off events in evio format for events exclusively firing Pairs3 trigger
- Reconstructed these events using the latest git master snapshot.
- Select single-crystal clusters
  - Cluster energy should be "MIP" deposit
  - Use cluster energy to determine gains.
  - Using ADC sums with Gain=1 to determine *ab initio* gains
- This analysis is based on dimuon events from run 010261 (early in "golden" portion of the run).
- Generated and simulated single-muon (μ^+ and μ^-)
  - Used to determine muon-momentum dependent "MIP" depositions

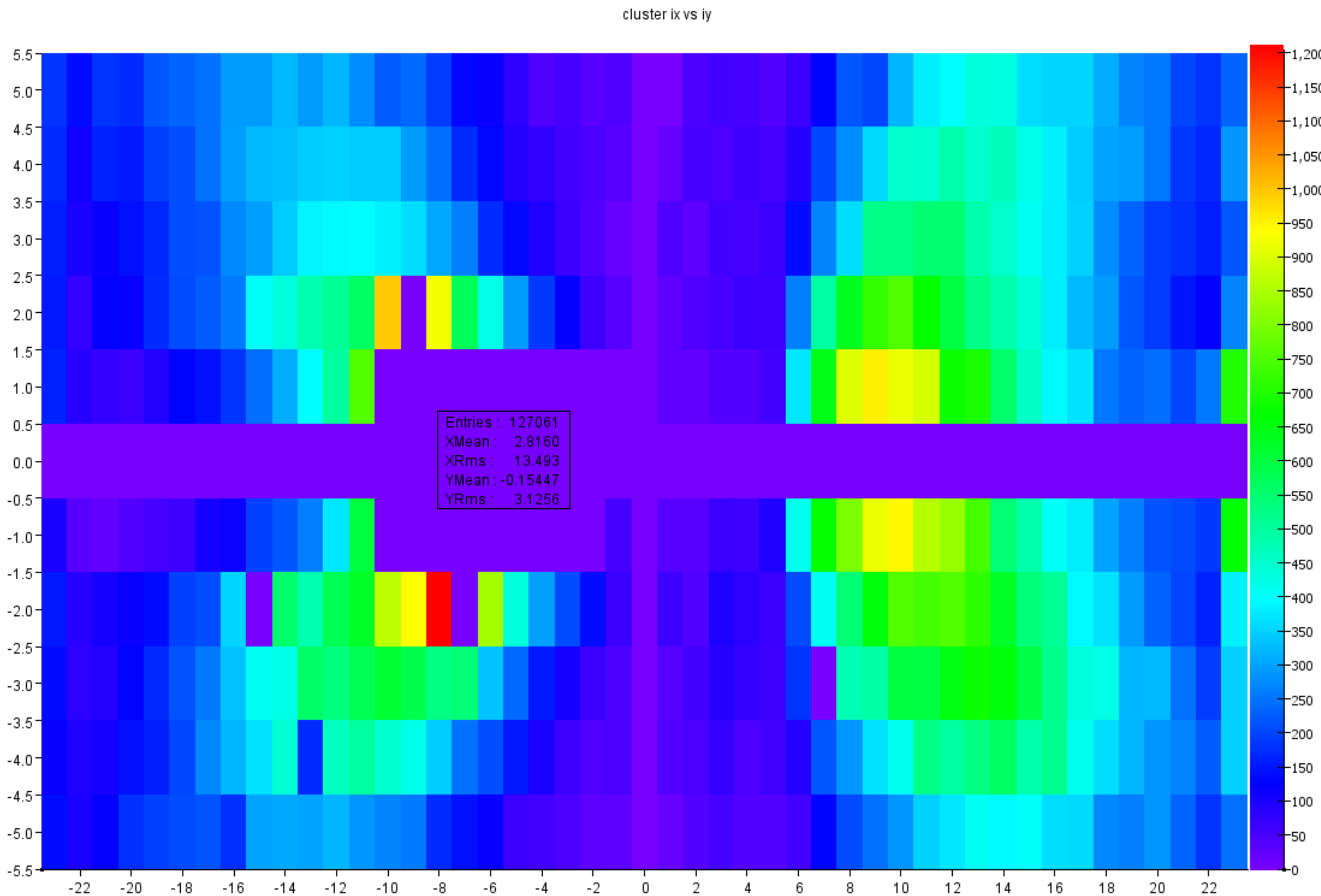
Events Consistent with $\mu^+\mu^-$ production

- Selected V0s in 2019 data to search for $\phi \to K^+K^-$
- Didn't find any, but did find $\mu^+\mu^-$
- Plot cluster E1 vs E2.

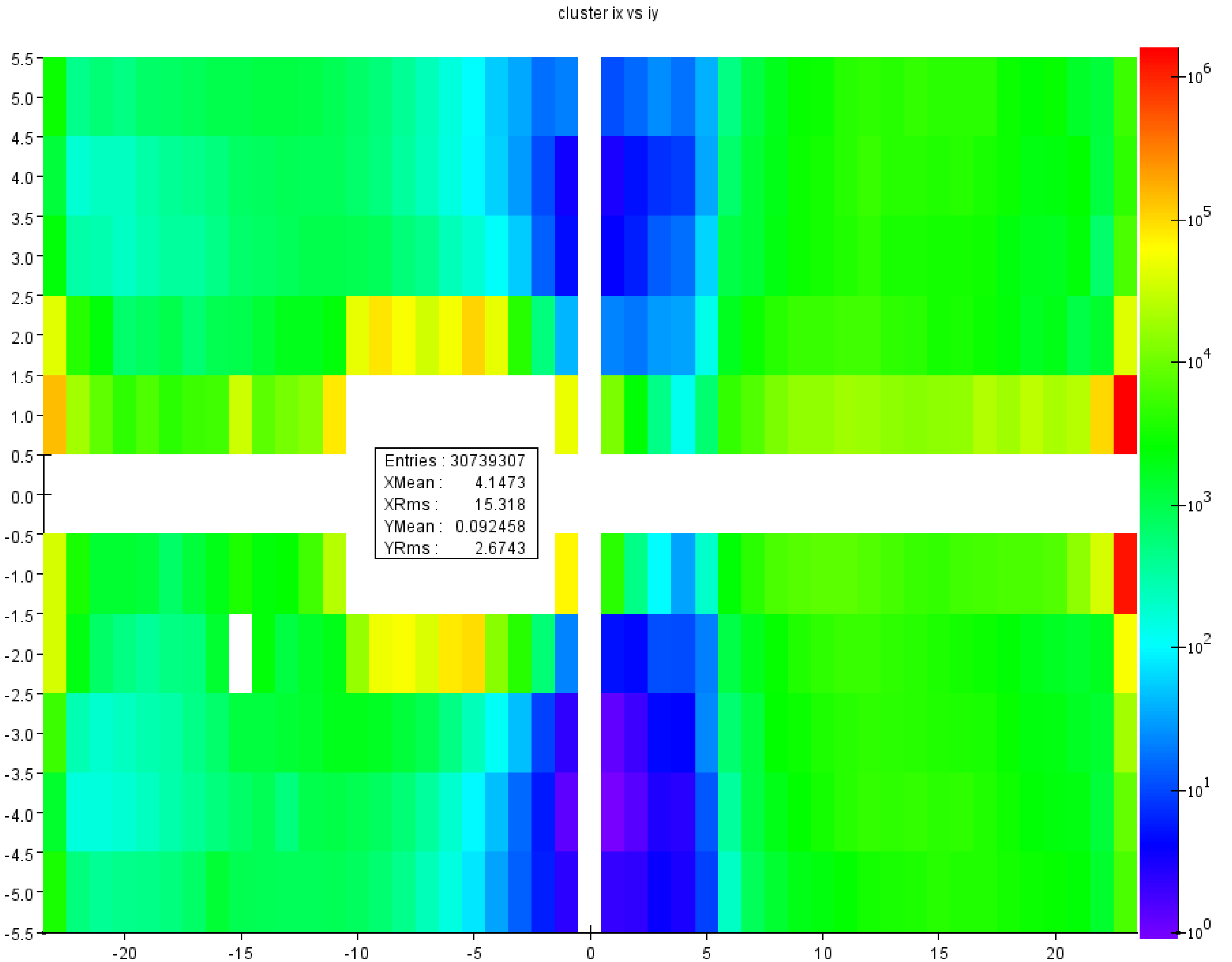


Two clusters consistent with MIP deposition

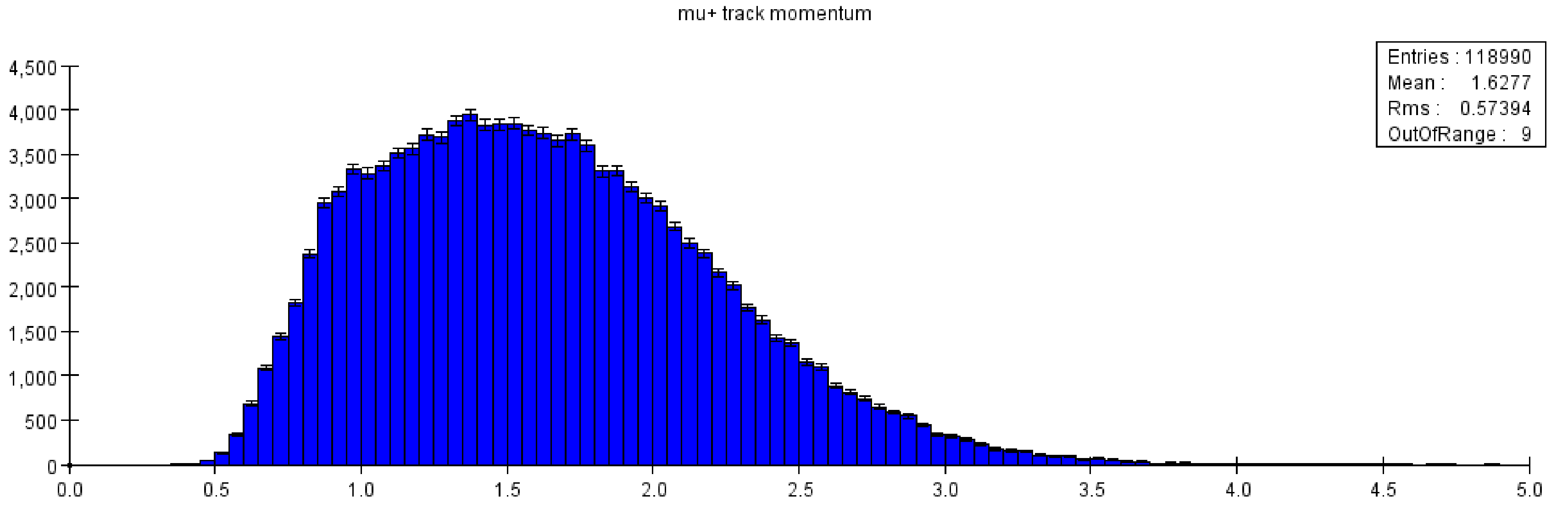
Single-Crystal $\mu^+\mu^-$ Coverage

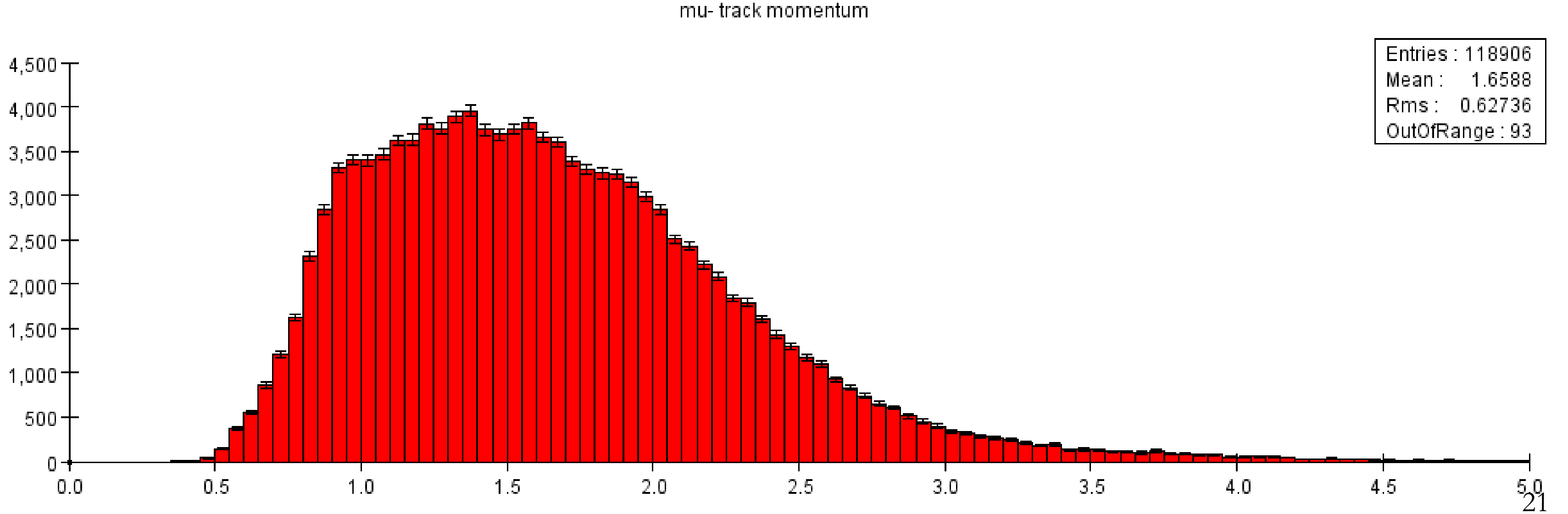


Single-Crystal Single μ Coverage

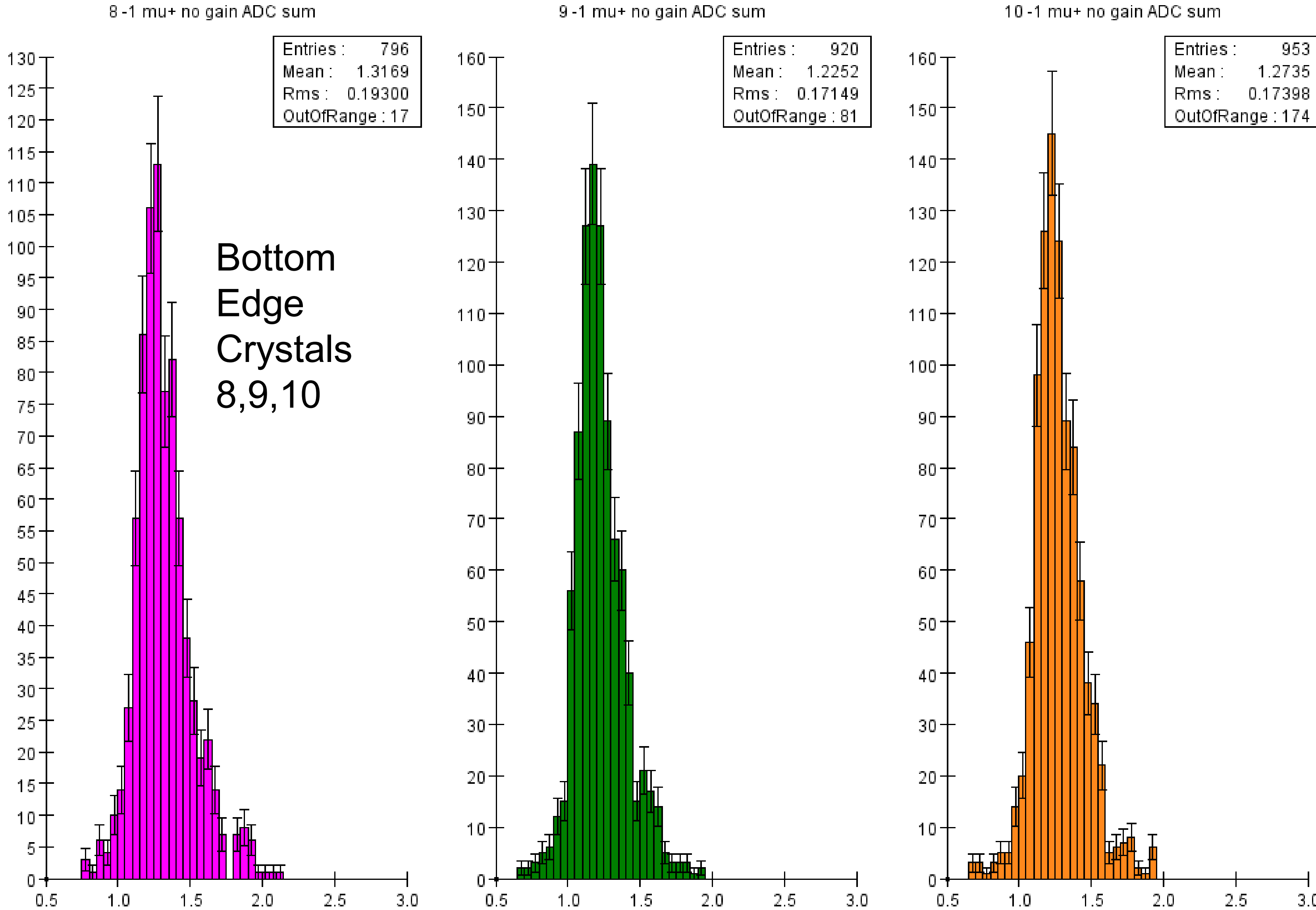


$\mu^+\mu^-$ Track Momenta

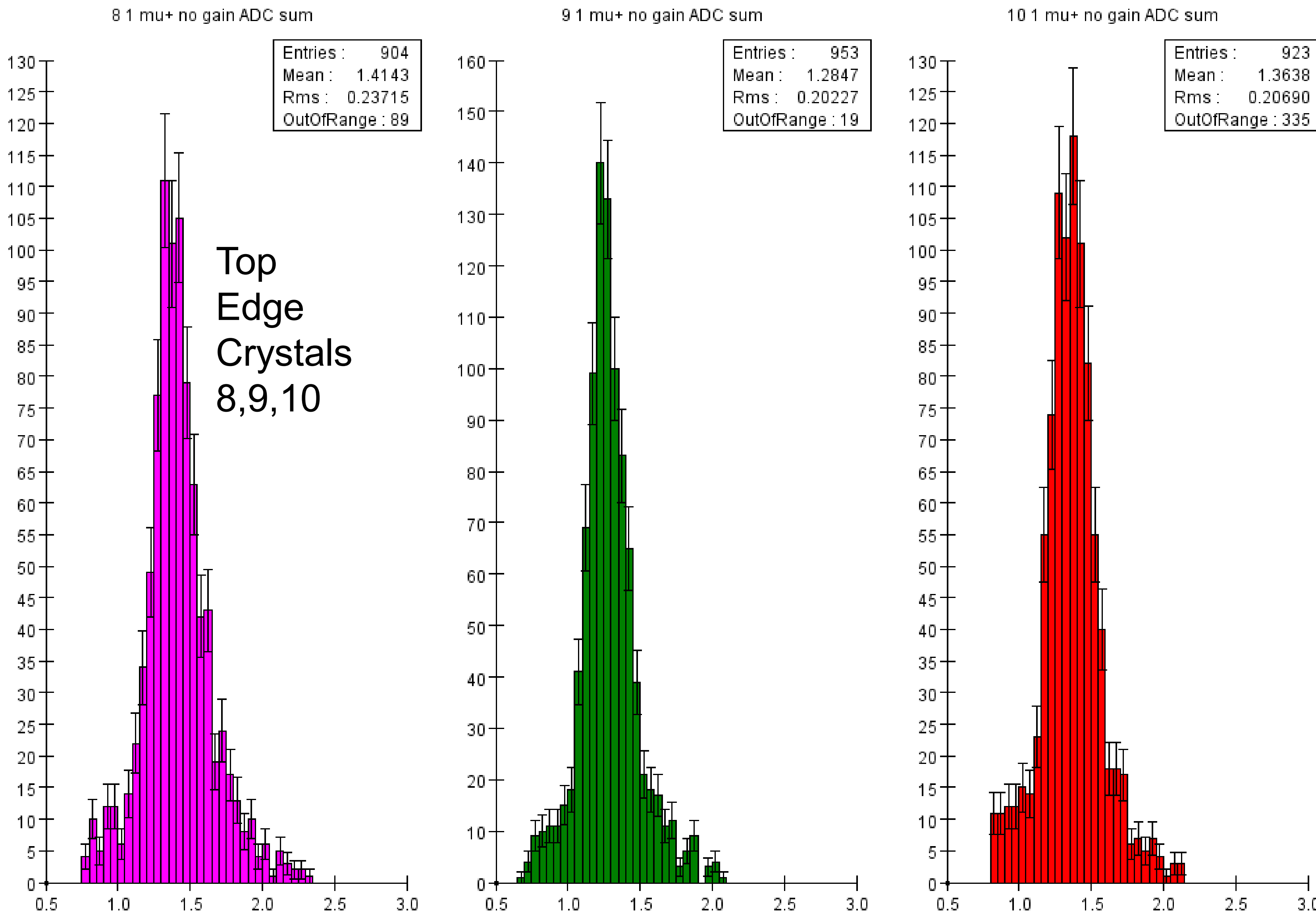




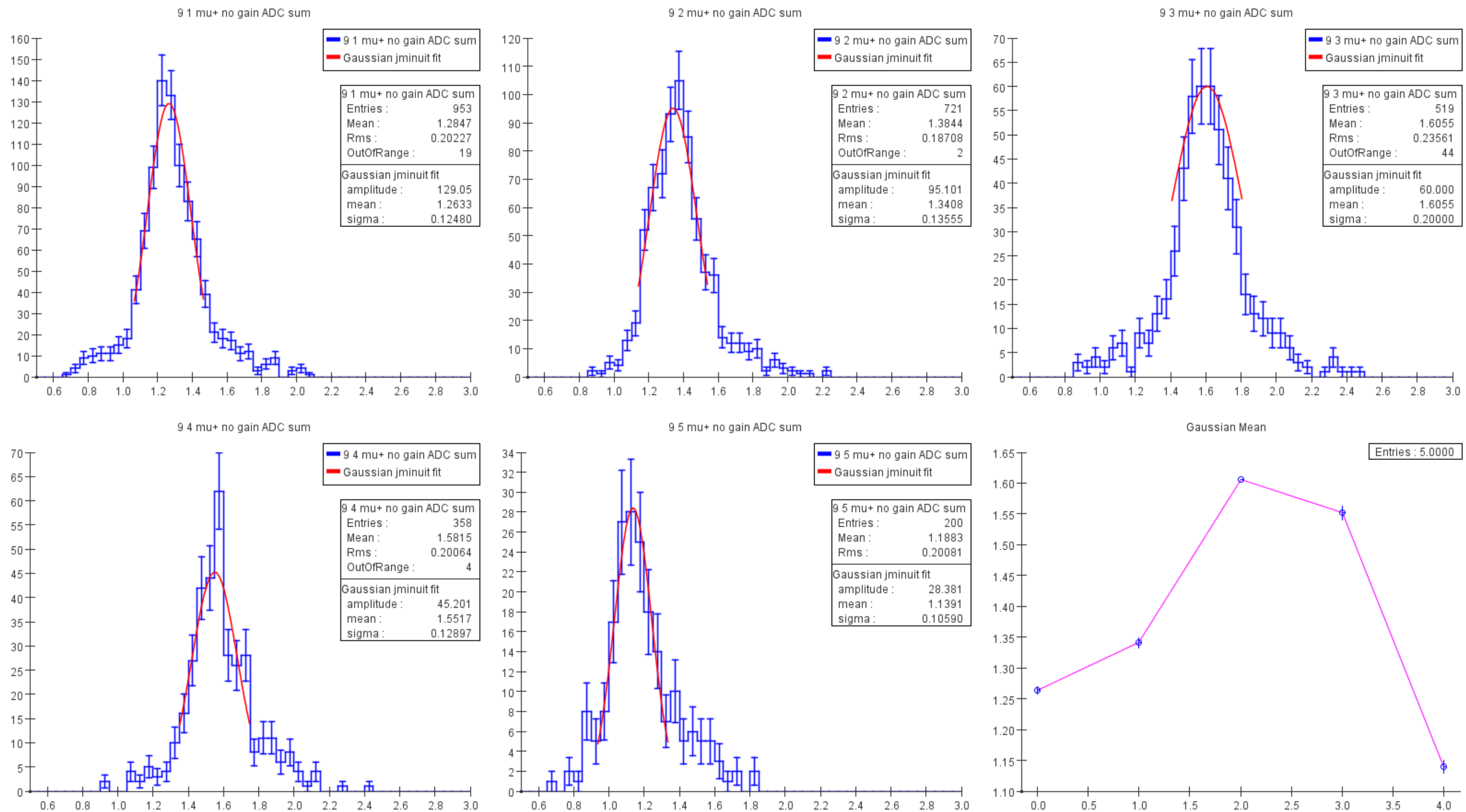
Individual Crystal Cluster ΣADCs



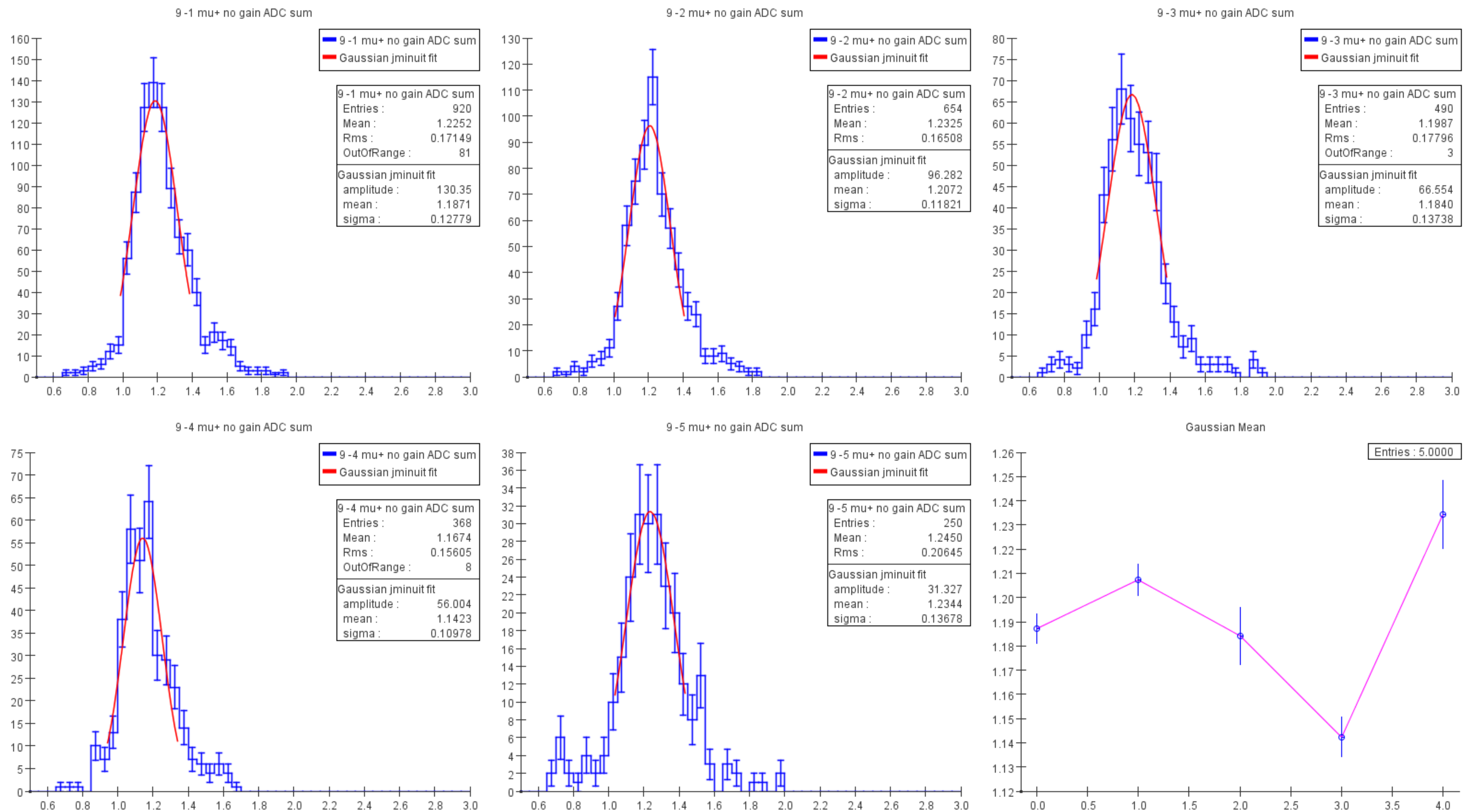
Individual Crystal Cluster ΣADCs



Individual Crystal Fits (top Column 9)



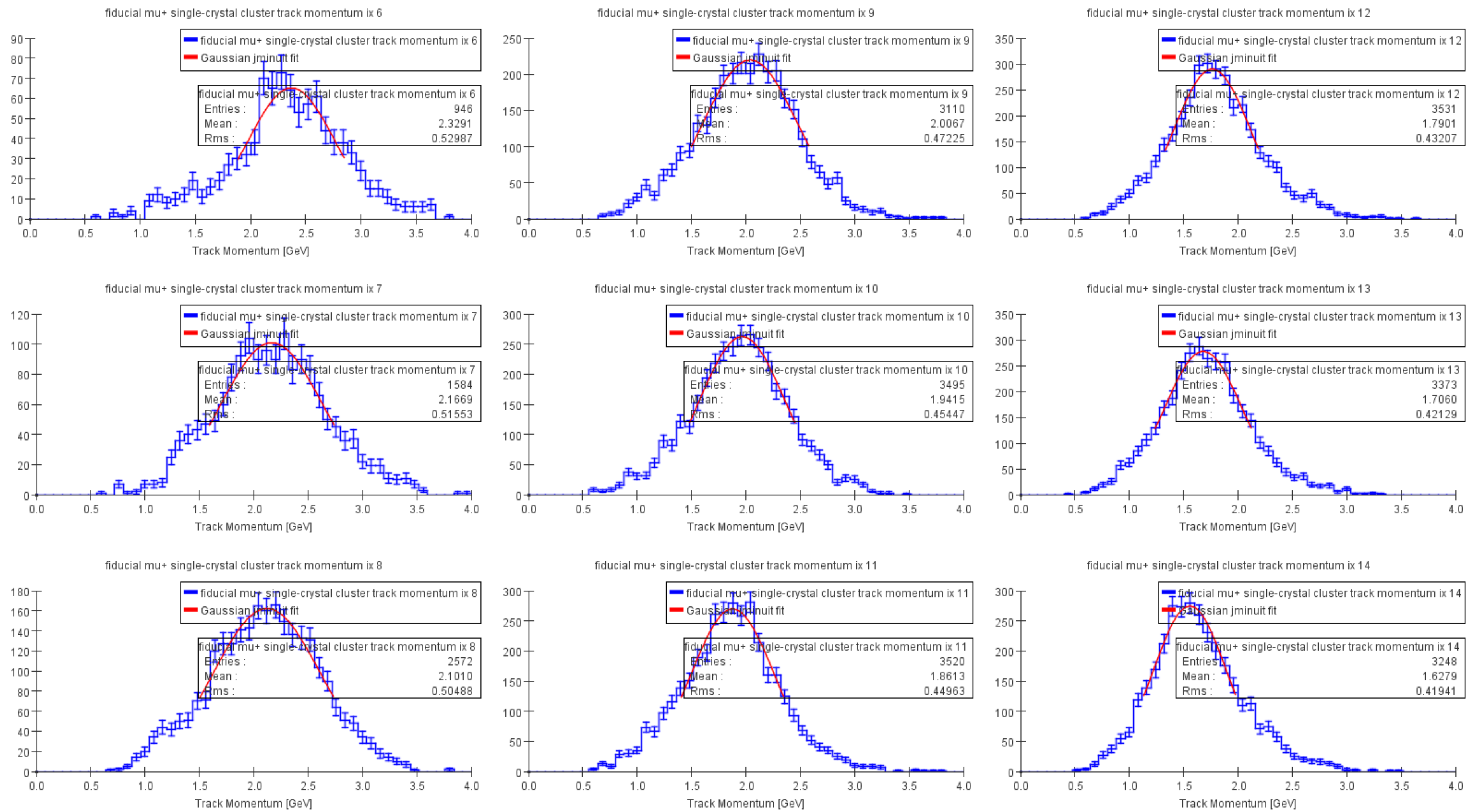
Individual Crystal Fits (bot Column 9)



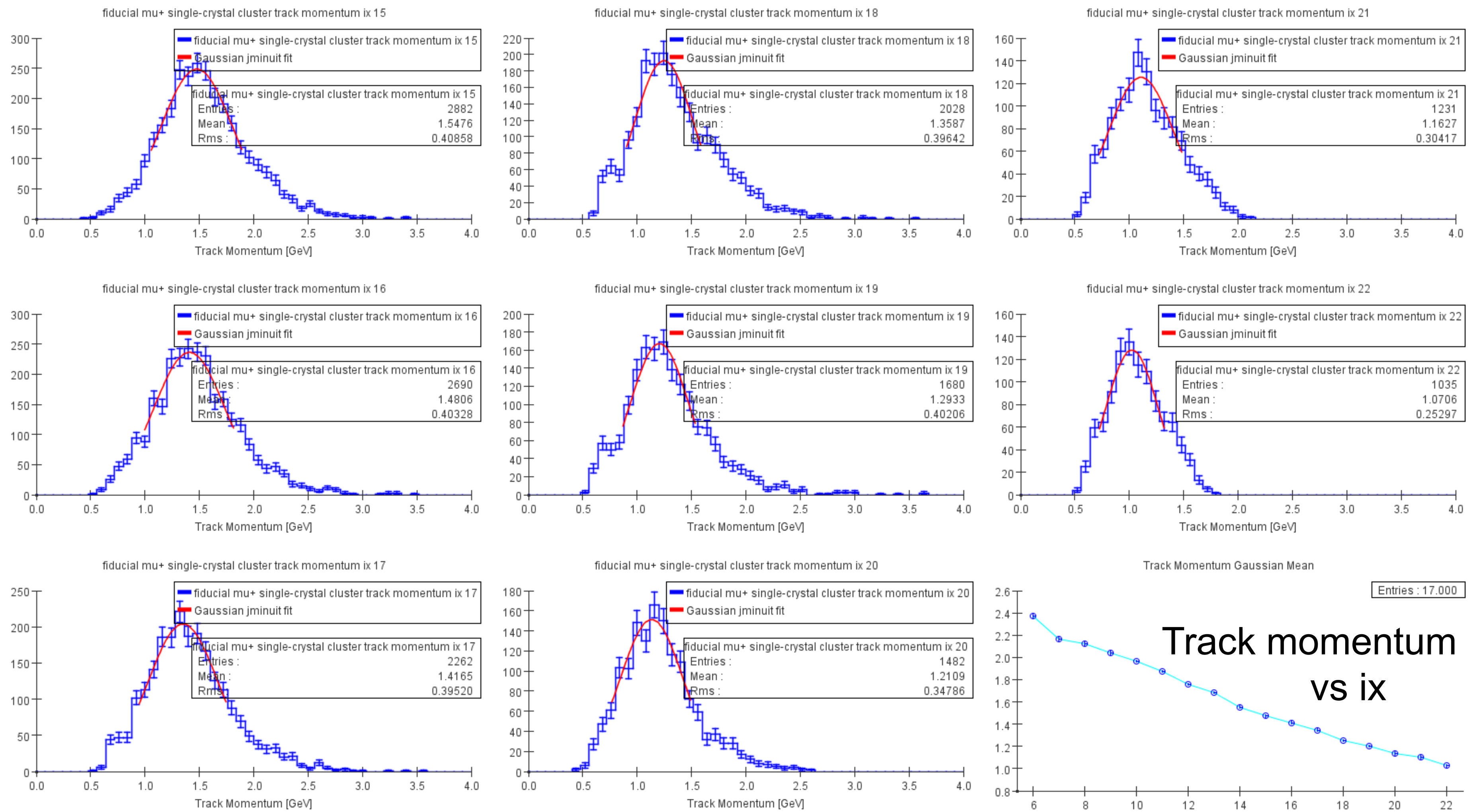
Muon Momentum Corrections

- Muons in our range of momenta are not strictly MIPS, and although the large aspect ratio of our crystals constrains the variation in path length, there are systematic differences in the amount of energy deposited in different crystal regions.
- Plot momentum of track associated with each single-crystal cluster.
- Fit momentum vs ix to extract mean momentum for each calorimeter column.

μ^+ Track Momenta



μ+ Track Momenta

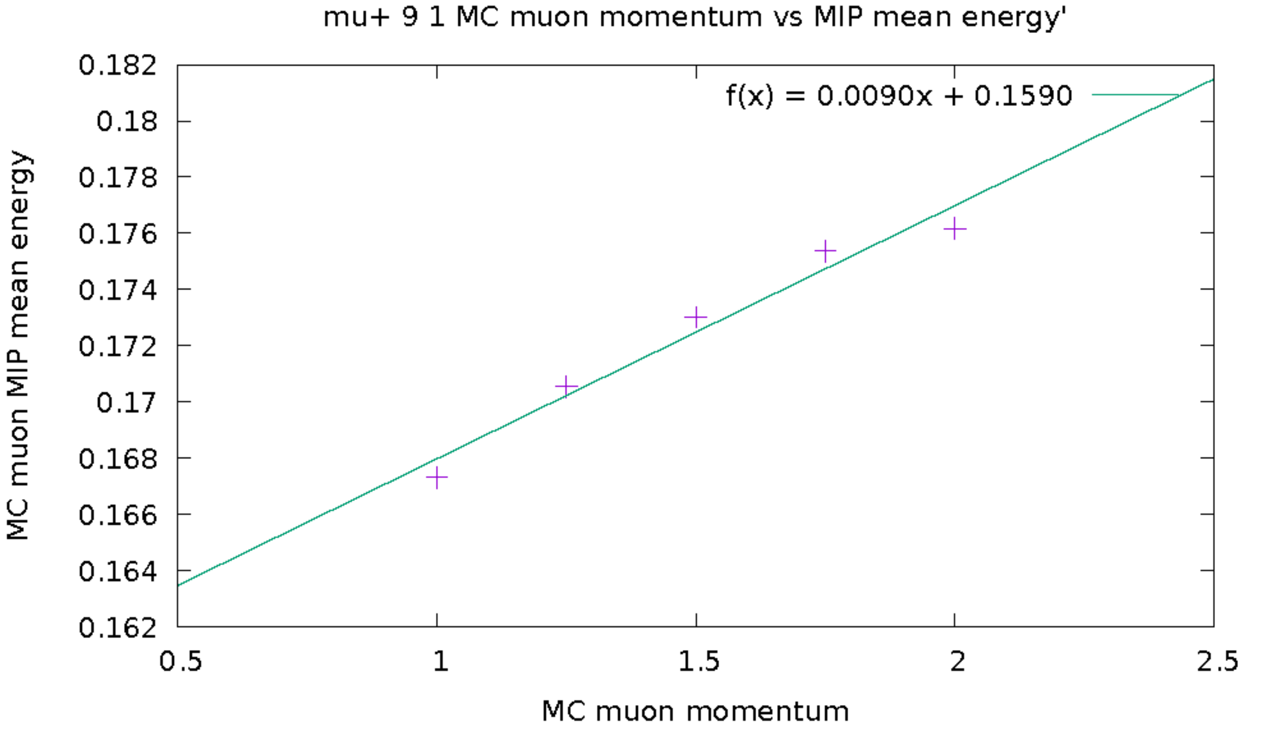


Muon Momentum Corrections: MC

- Generate single μ^+ and μ^- evenly covering the ECal face with energies of
  - 1.00, 1.25, 1.50, 1.75, 2.00GeV
- Plot and fit single-crystal response as a function of MC momentum.
  - Should account for both dE/dx and geometric effects.

Monte Carol Single μ^+ Response

- Crystal ix = 9, iy = 1
- Single-crystal energy vs momentum



Putting it all together

- Select run (or runs to gather statistics) (261)
- Select dimuon events to reduce backgrounds.
  - Can also use single-muon events in fiducial regions to gather higher statistics.
- Select single-crystal clusters.
- For each crystal:
  - Fit ADC sum to extract mean of crystal energy deposition
  - Fit track momentum for all crystals in each column (ix).
  - Use MC events to determine expected single-crystal energy deposition based on momentum for each column.
  - Divide MC expected energy deposition by crystal ADC sum to determine crystal gain.
- Repeat for all runs (or run ranges).

ECalibration with muons summary

- Muons produced in collisions at HPS provide a clean source of “MIP”s with sufficient statistics to calibrate individual crystals over most of the calorimeter.
- Currently very close to closing the loop and having first-pass gains for most of the crystals.
- Will compare to FEE-derived gains on electron side of the ECal and cosmic ray-derived gains on the positron side of the ECal.
- Will use WAB events to test.

SVT

- As you just heard in PFs talk, a lot of work has been (and continues to be) done to align and calibrate the SVT.
- Several alignments are being characterized, e.g.
  - HPS_PASS1_iter3
  - HPS_PASS3_iter4
  - HPS_TY_iter4
- Using primarily FEEs to determine, and WABS and tridents to characterize the alignments.
- $\phi \rightarrow K^{+}K^{-}$ at this time does not appear to provide us with a process that we can use to align and calibrate the SVT as was done with the Møller events in 2016.

Data Samples

- FEE, WAB and V0 skims
- Have reconstructed the "sample partitions" from the set of "good" 2019 runs using:
  - HPS_TY_iter3 detector (pass1-dev_fix)
  - ECal gains and SF (iss732-refactor)
- Available at JLab and SLAC
  - /volatile/hallb/hps/ngraf/physrun2019/samplePartitions/recon/20201113/
  - /nfs/slac/g/hps_data2/data/physrun2019/samplePartitions/recon20201113/

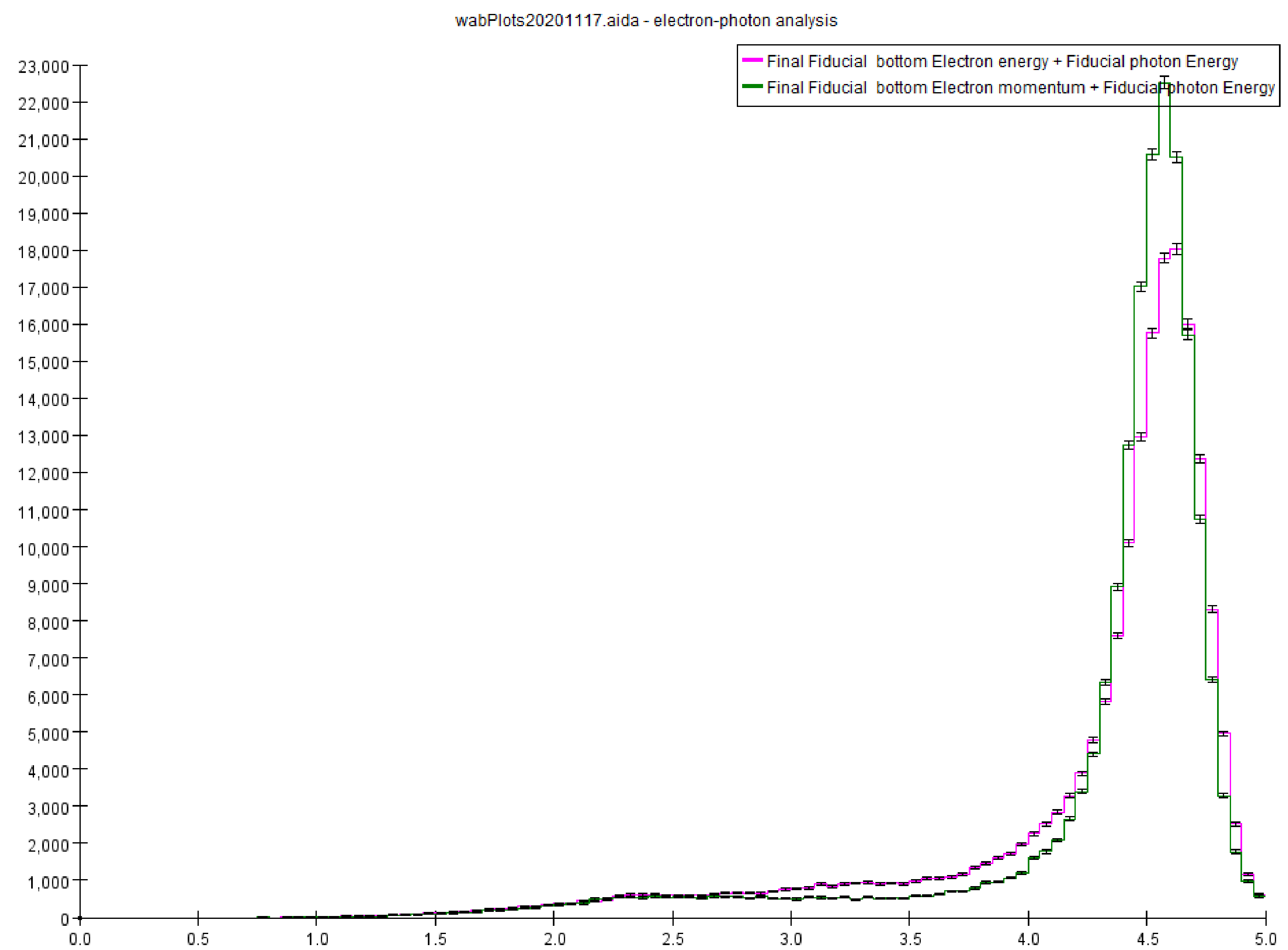
WAB Data Samples

- Processed run 10105 using latest set of ECal gains
- Select loose WAB candidates
  - Two ECal clusters in opposite hemispheres with Esum>3 GeV
- Position of the two-cluster energy sum provides test of energy scale calibration (gain+SF)
- Width of the two-cluster energy sum provides test of energy resolution
- Position and width of the electron momentum + photon energy tests momentum scale and resolution.
- Fraction of electron+photon to photon+photon provides electron track-finding efficiency.

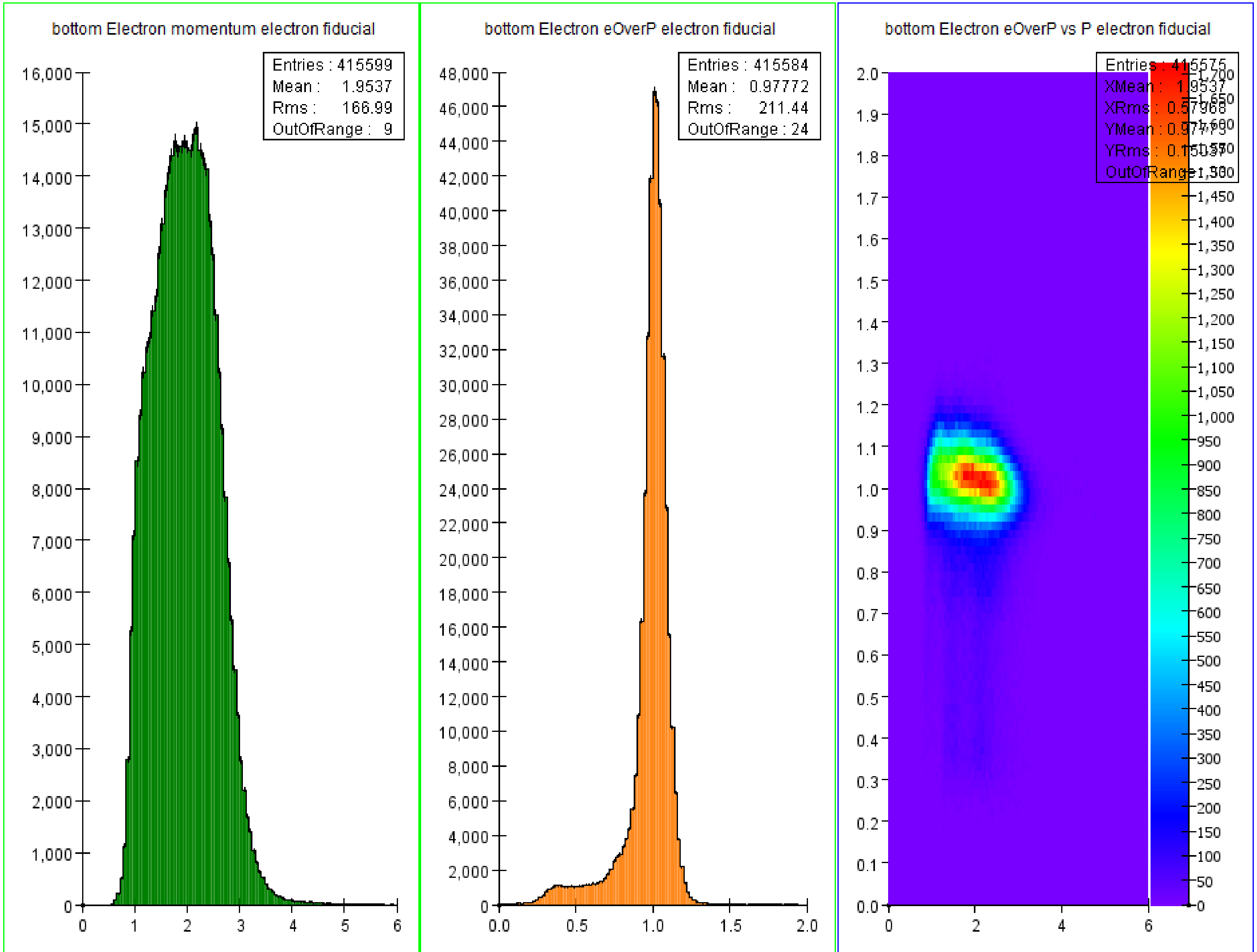
WABs for SVT Calibration

- Have spent a lot of time calibrating the ECal energy scale and resolution (see Andrea's talk for details and results).
- For this presentation, WABs provide a sample of well-measured lower energy electrons to provide momentum constraints in the SVT alignment.

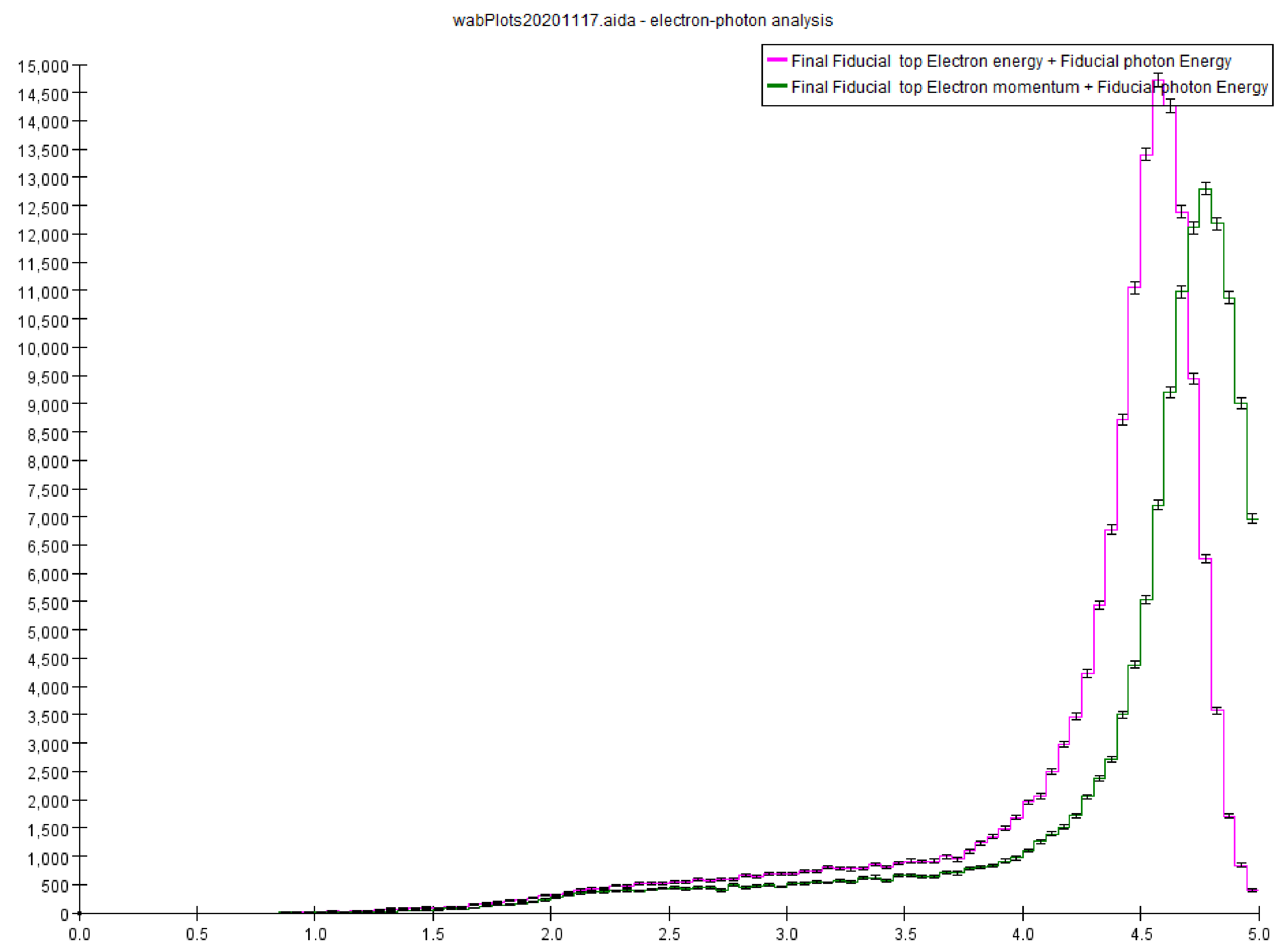
WAB Esum vs Energy Momentum (b)



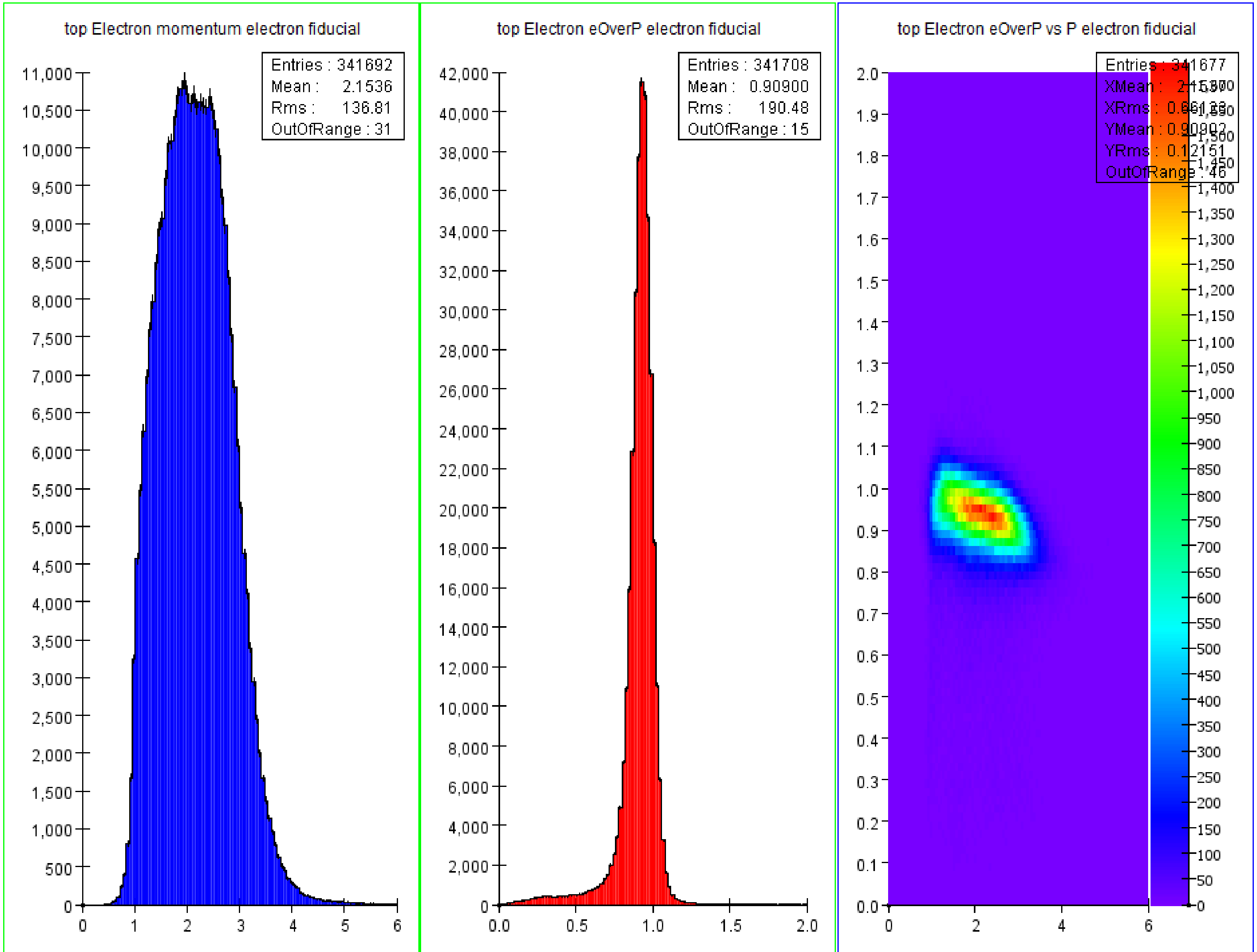
WAB E/p bottom



WAB Esum vs Energy Momentum (t)



WAB E/p top

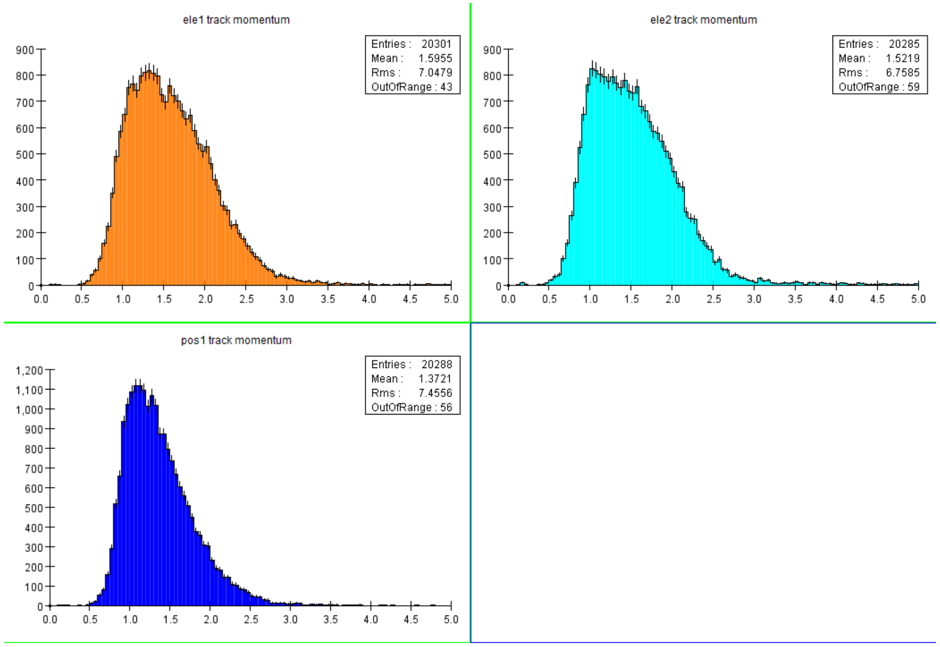


top Electron momentum electron fiducial
Entries : 341692
Mean : 2.1536
Rms : 136.81
OutOfRange : 31
top Electron eOverP electron fiducial
Entries : 341708
Mean : 0.90900
Rms : 190.48
OutOfRange : 15
top Electron eOverP vs P electron fiducial

Tridents

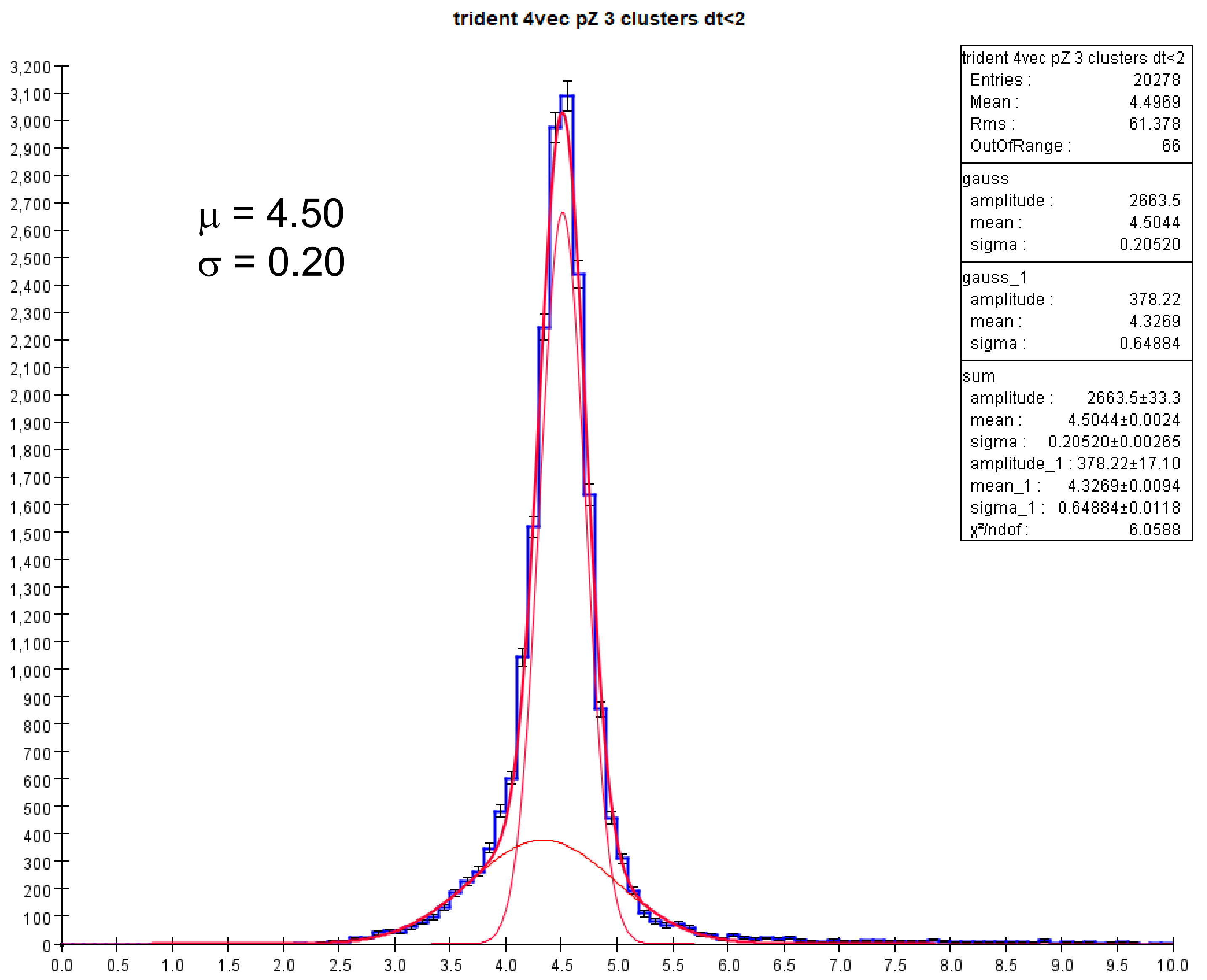
- Finding and fitting all of the trident final state particles would allow us to reconstruct the beam four-vector, allowing us to measure the beam position, direction and energy.
- Provides low energy electrons for momentum-constrained track alignment.
- Provides well-measured positron energies for momentum-constrained track alignment of “slot” SVT sensors.
- Comparing vertex position from same-side tracks vs opposite-side tracks probes top/bottom SVT relative alignment.
- Beamspot-constrained alignment with high-purity sample of events.

- Select events with two electrons and one positron, each associated with an ECal cluster, within 2 ns of each other.



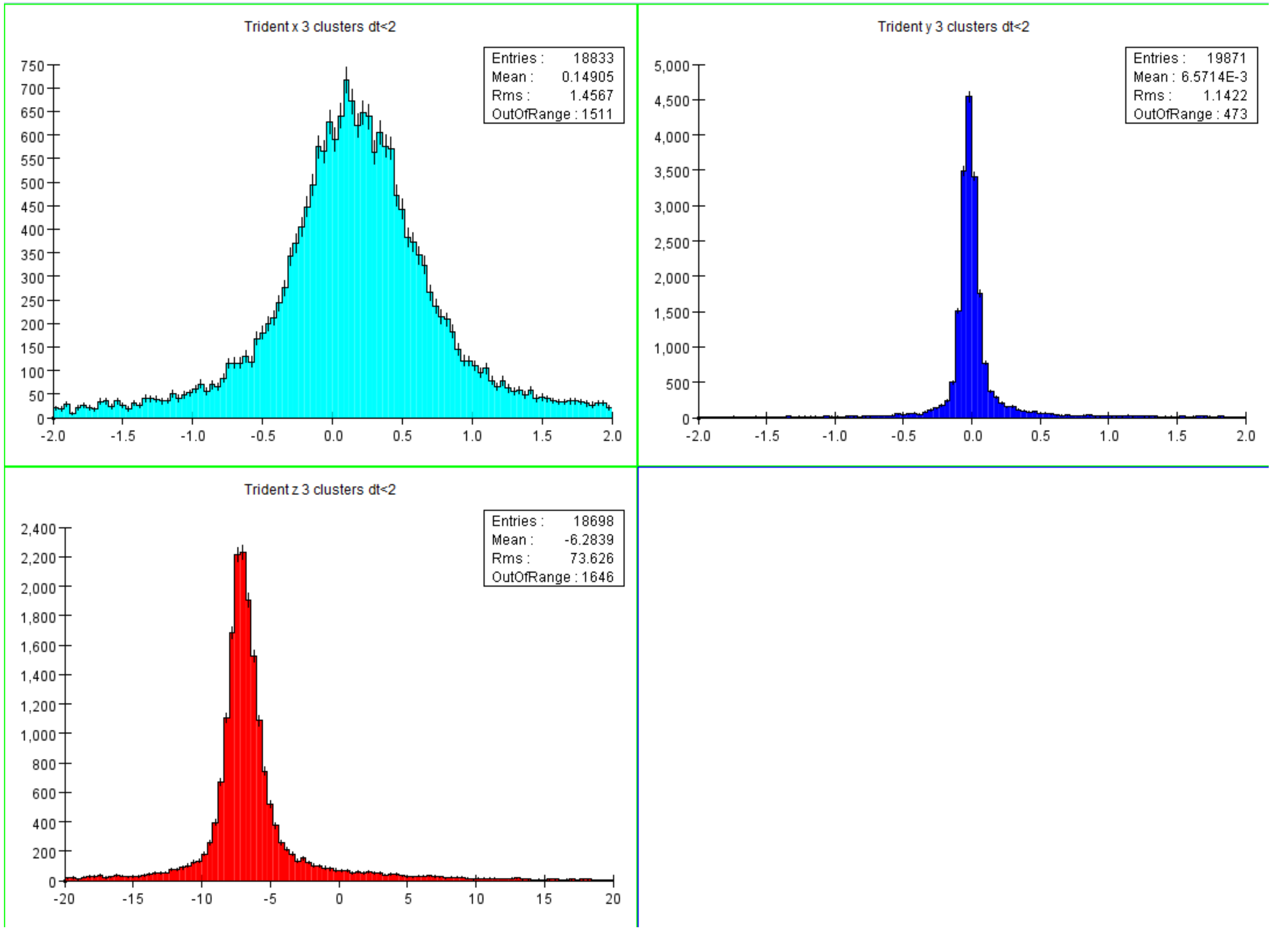
Trident pZ

μ = 4.50
σ = 0.20

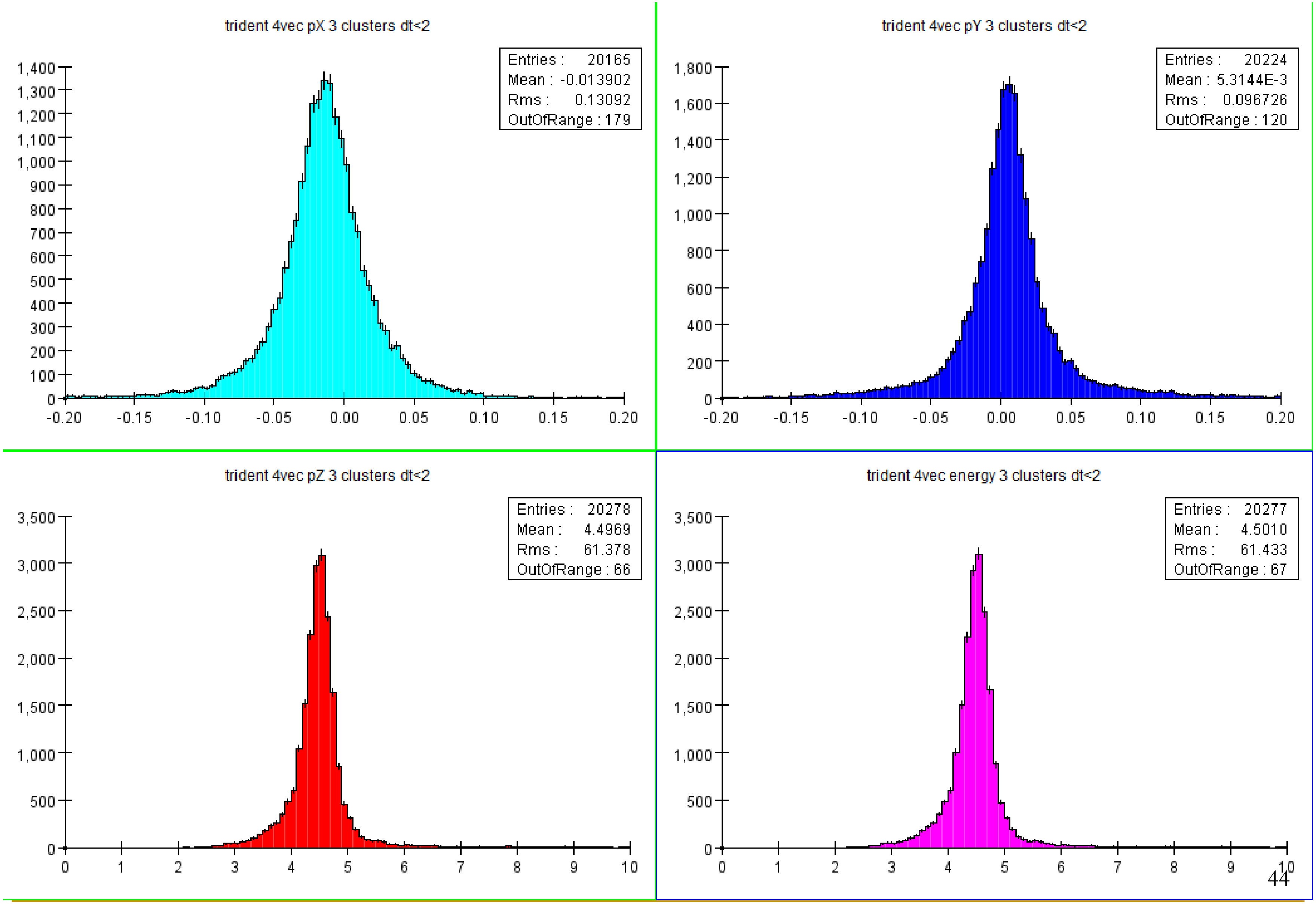


Where's the beam and target? (tridents)

- As seen in PFs talk, this is somewhat ill-defined "where do you want the target to be?"



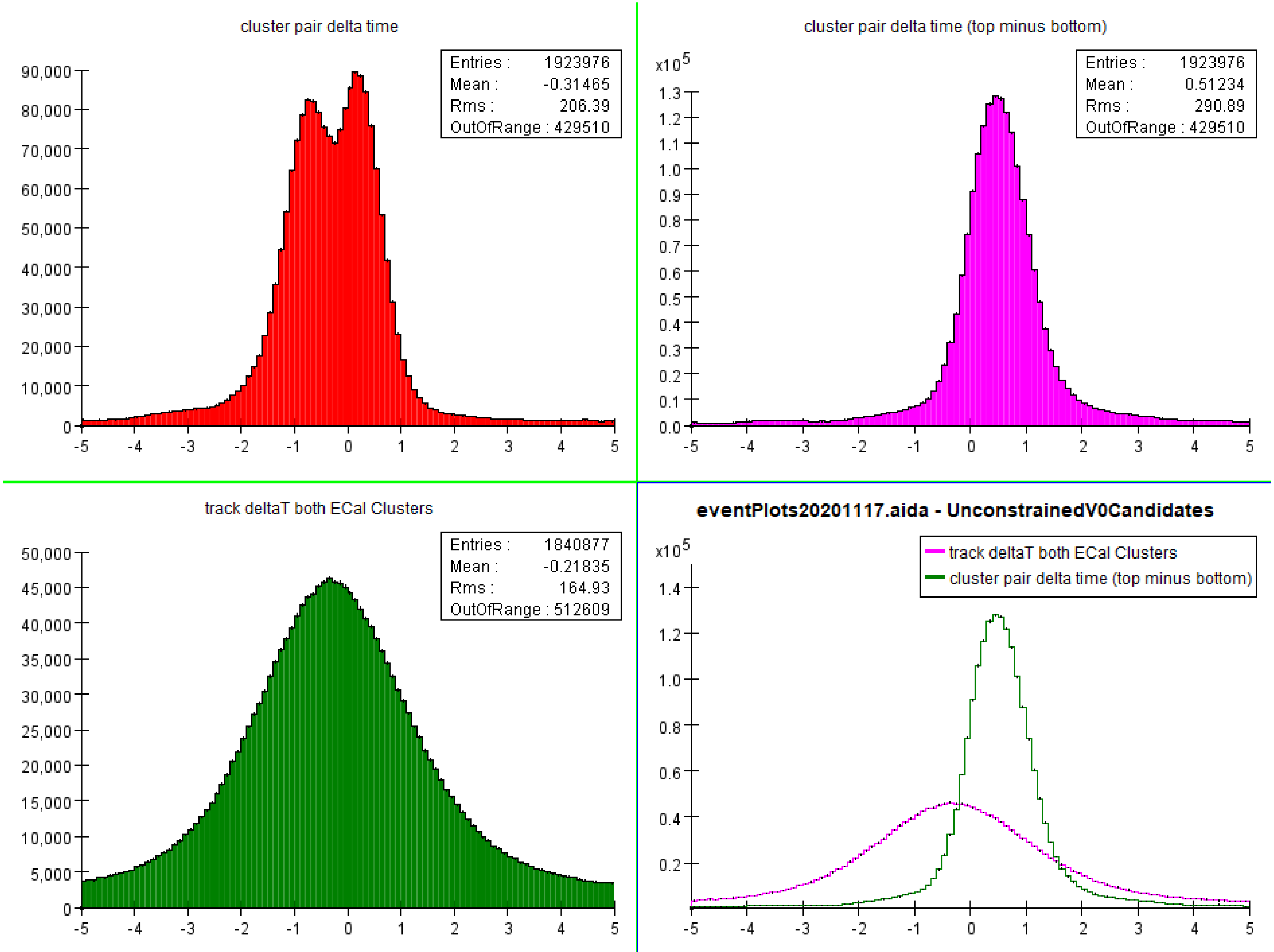
Where's the beam going? (tridents)



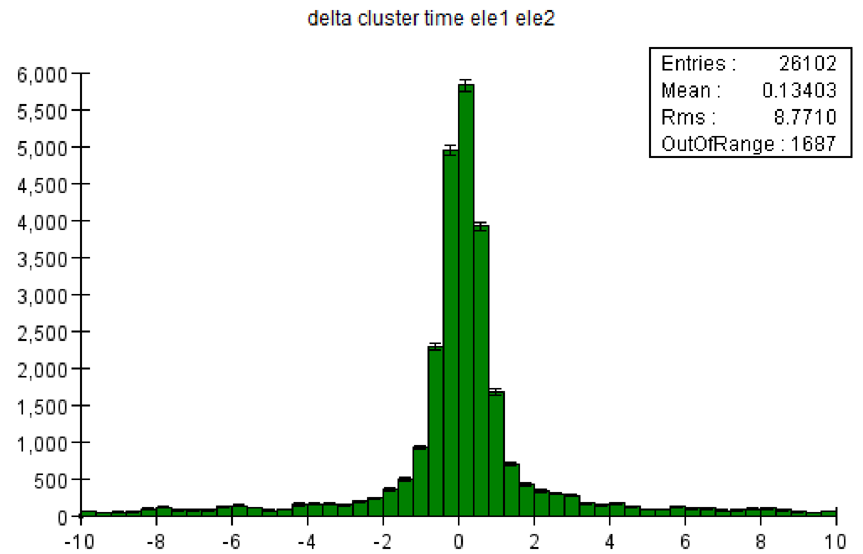
ECal / SVT Cross-Calibration

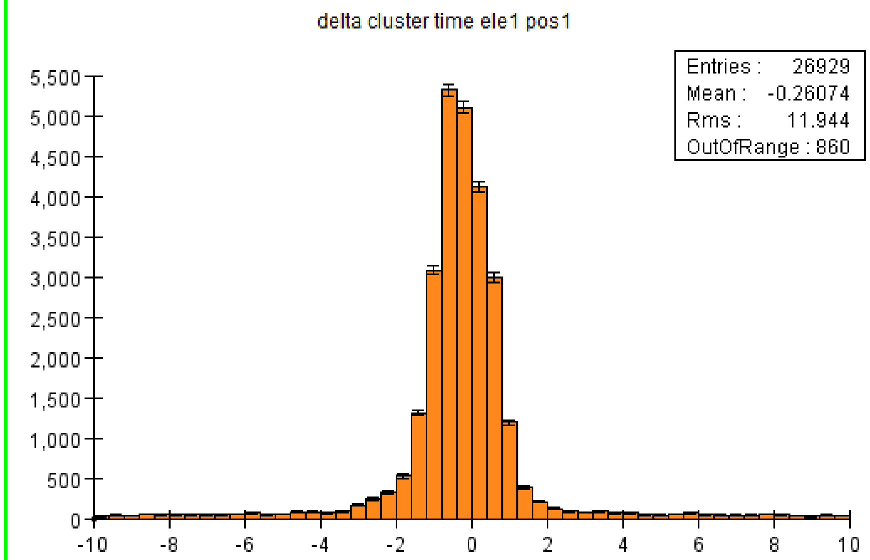
- Gesamt-detector analysis of energy/momentum, position, and timing resolution.
- See Luca's studies of ECal cluster position corrections in Andrea's talk tomorrow.
- See Alic's studies of track/cluster position matching in PF's talk tomorrow.
- 2016 V0 analyses required ECal clusters to be associated with both ReconstructedParticles. Cluster time coincidence was a powerful tool in reducing backgrounds.
- Positron trigger in 2019 enables V0 analyses with track-only electrons. Track-track or track-cluster timing cuts now become important.
  - Track time not as precise as cluster time.
  - Might be improved by better APV25 waveform fitting.
    - Currently would take more CPU time $\rightarrow$ cost/benefit

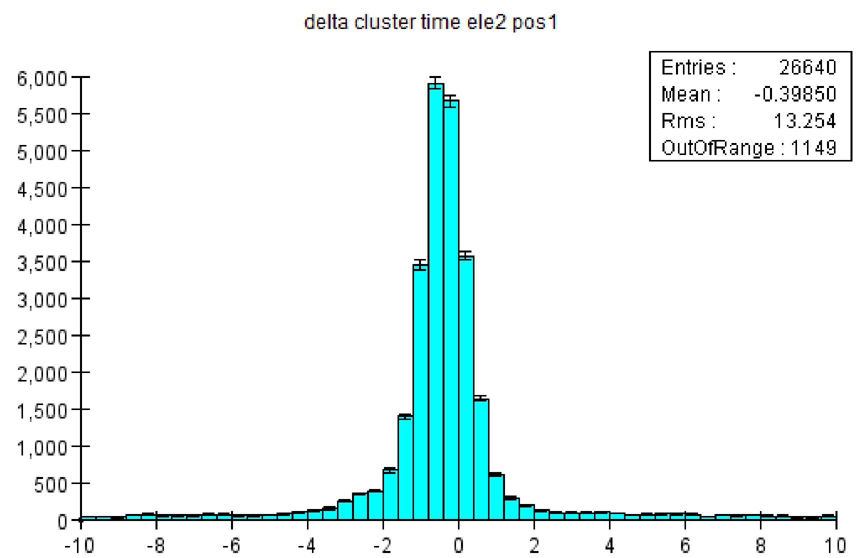
V0 Cluster / Track timing



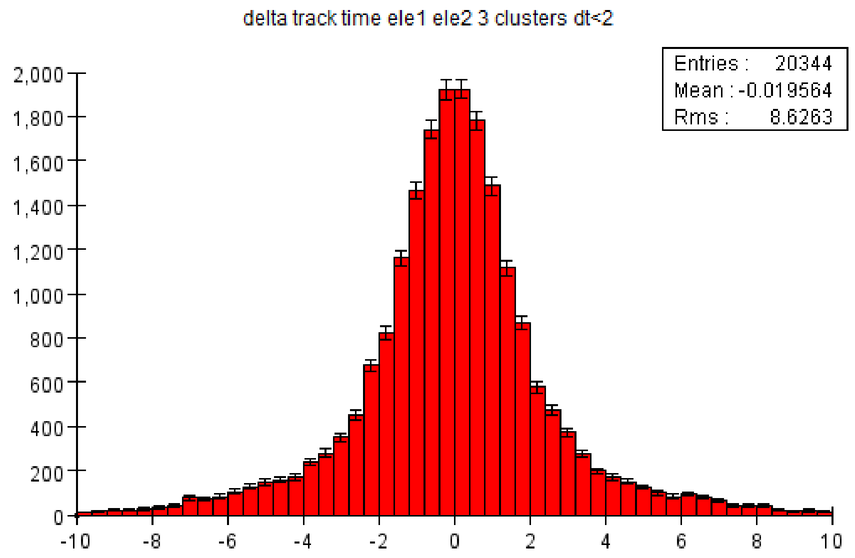
Trident cluster timing

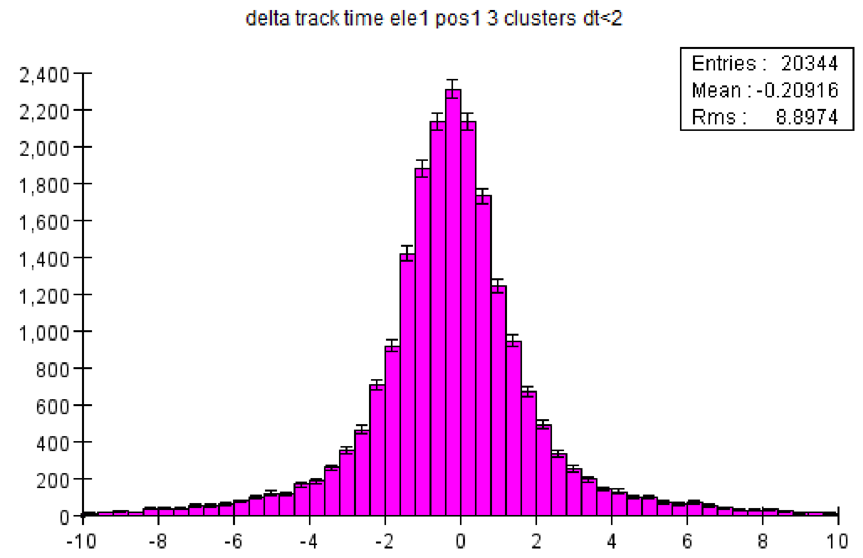


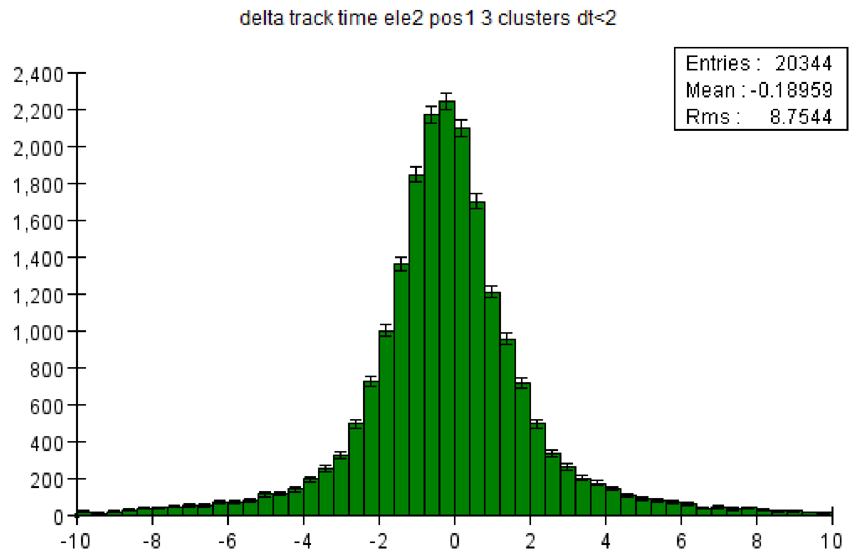




Trident track timing

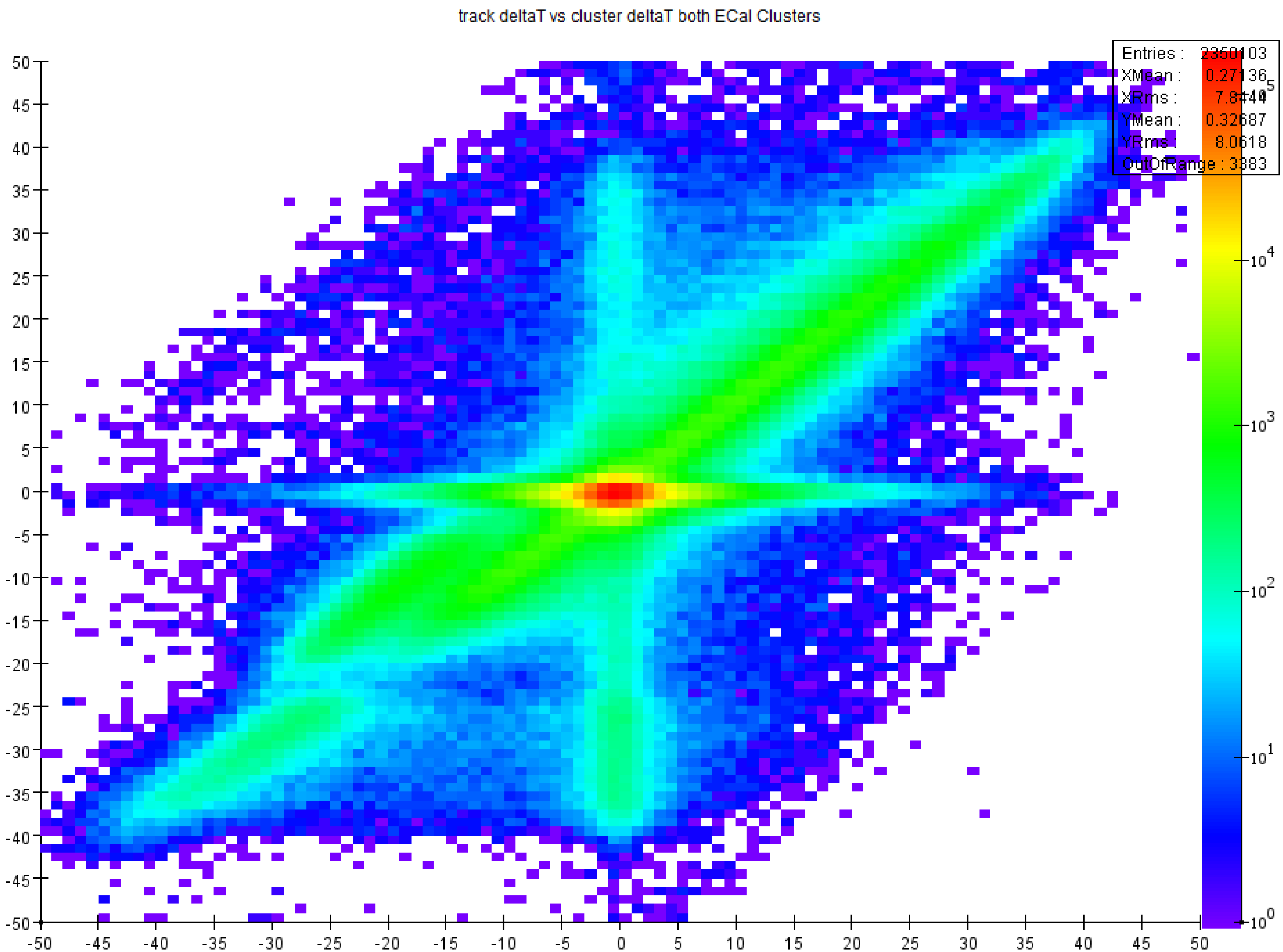






Is this good enough?
Need input from analysis groups!

V0 Track-Track vs Cluster-Cluster dt



Summary

- ECal energy calibration essentially done, timing and position corrections in progress.
- SVT alignment is progressing, leading to higher track-finding efficiencies as well as improved momentum scale and resolution.
  - HPS_TY_iter4 looks promising
- "Sample partitions" from each of the "good" runs have been reconstructed using the latest ECal gains and sampling fractions and the HPS_TY_iter4 detector.
  - Can study performance as a function of run number, etc.
- Samples of FEEs, WABs, V0s and tridents available for alignment/calibration analysis.
- $\mu^+\mu^-$ added to HPS' final states. Currently used for calibration and alignment but should also be added to physics analysis list.
- Need more involvement and feedback from other members of the collaboration!