2019 Track & Vertex Reconstruction

Norman Graf (SLAC)

HPS Spring Collaboration Meeting

May 14, 2020

Overview

- Too many topics to cover in any detail!
- Software updates
- Hit Finding
- Track Finding
- Track Momentum Calibration
- Alignment
- Vertexing Mass Calibration

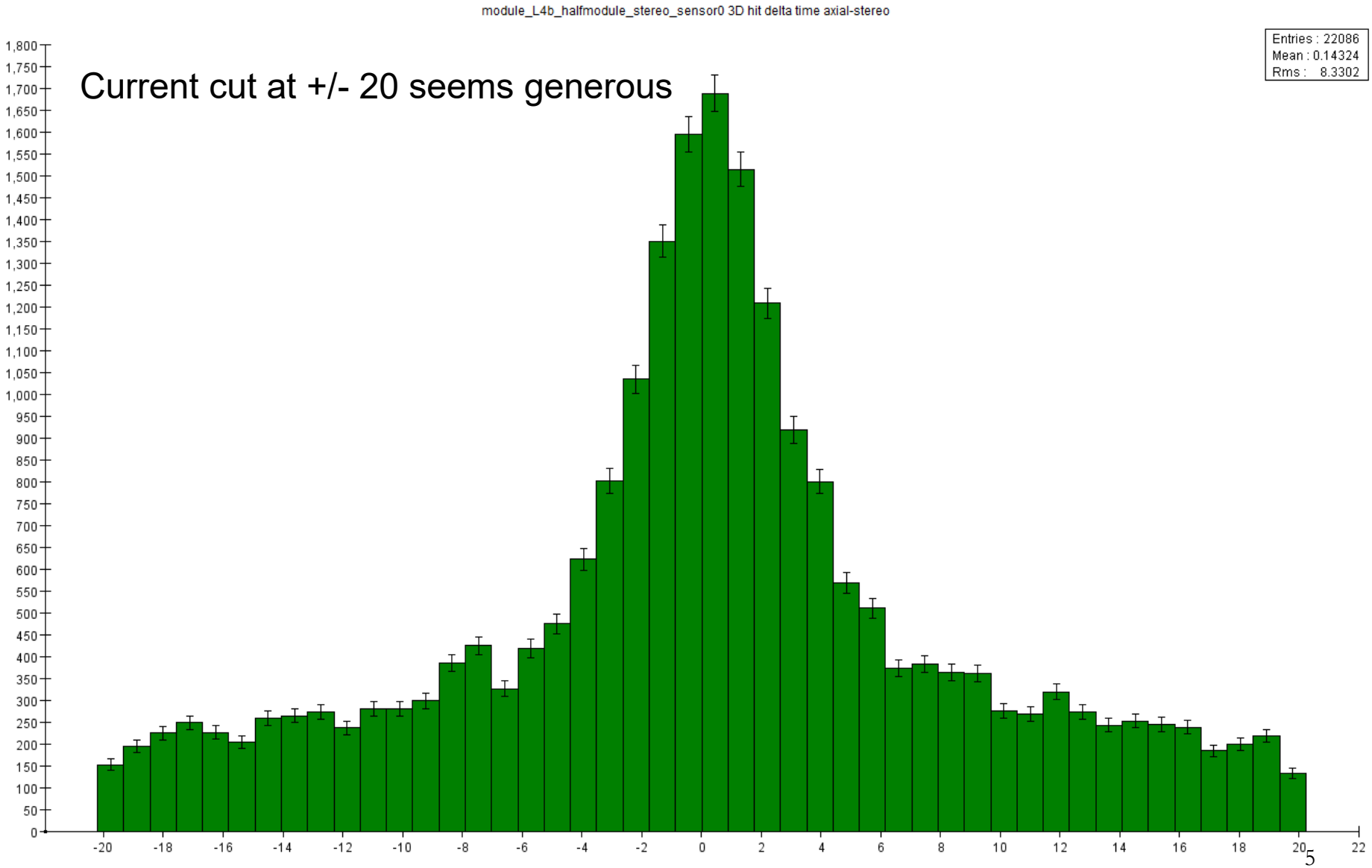
Software Updates

- New Strip Pixel class introduced to handle the new split-strip sensors by Omar
- millepede constants sorted out for 2019 detector
- Have belatedly removed the object standardization (aka MOUSE) cuts from the default reconstruction.
  - Cuts were optimized for a mature reconstruction
- We have several working steering files for the reconstruction
  - Has been used to process 1054 partitions (two or more from each “good” run)
- Have exercised the full tracking/vertexing chain and have identified critical path issues to address

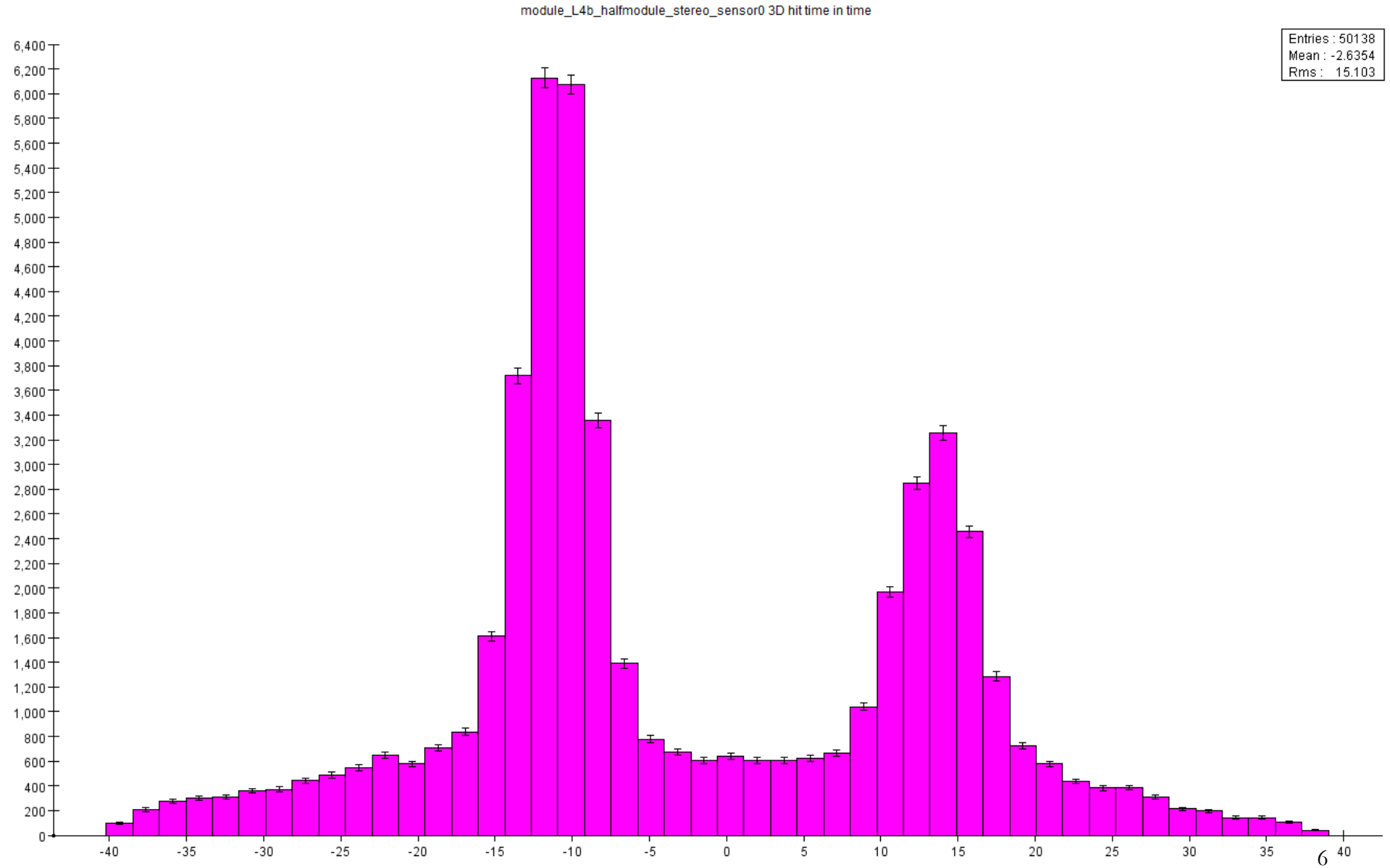
Hit Finding

- Extracting channel t0 and pulse area by fitting the APV25 waveform samples is second only to track-finding pattern recognition in CPU time.
  - Have not yet addressed improvements in fitting algorithm or code.
  - Have, however, methods in place to only have to do this once. Can re-run from the persistent LCIO file.
  - Code to extract channel-by-channel baselines being worked on by Alic & Cameron.
  - Better t0 determination would improve track timing
    - With higher occupancies, could improve our strip clustering.
    - Could improve our axial-stereo strip cluster association, reducing “ghost” hits.
    - No longer require ECal cluster to be associated with track, so cannot rely on cluster deltaT, need to use track timing.

Axial Stereo deltaTime

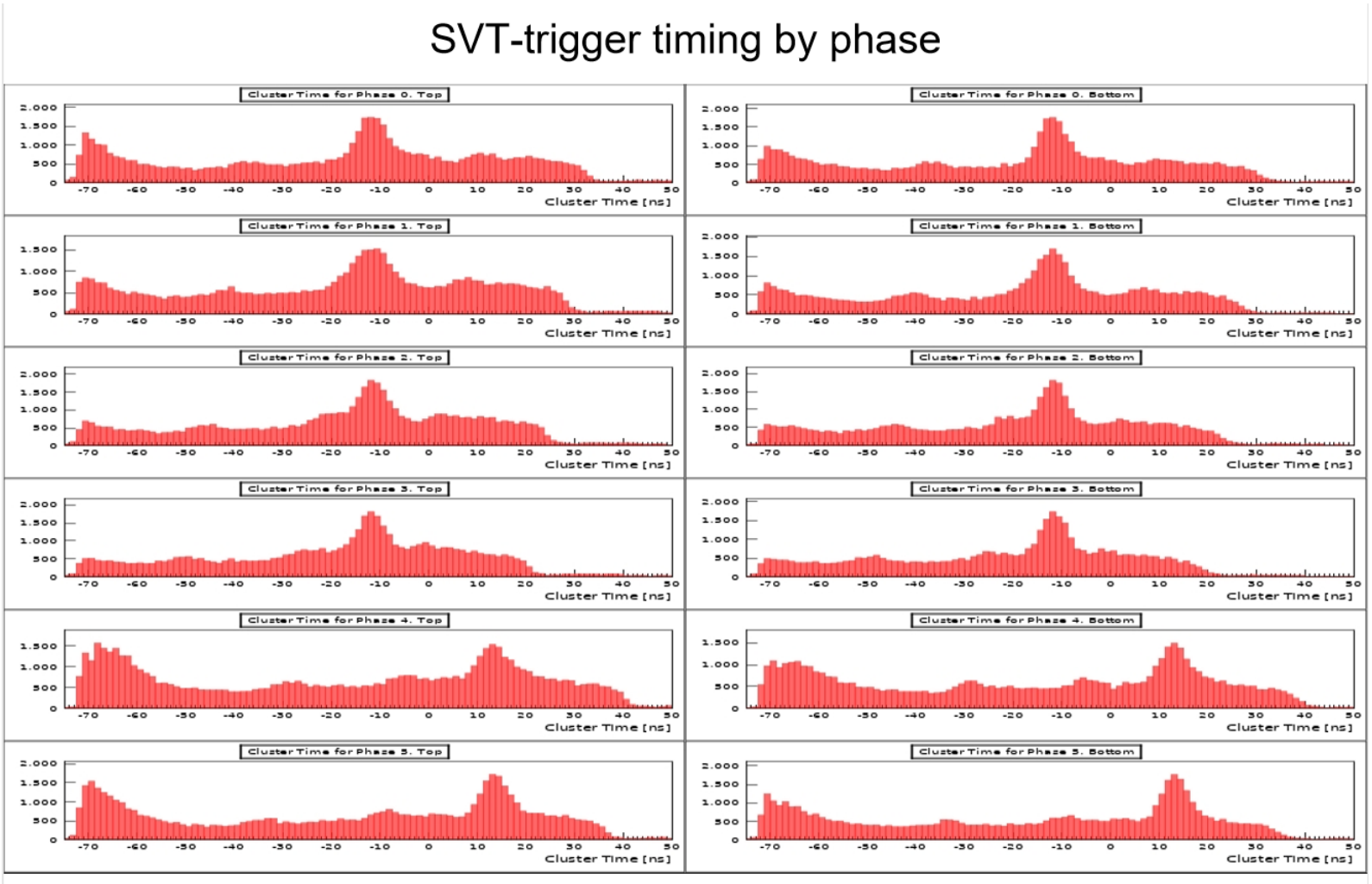


3D Hit Time


module_L4b_halfmodule_stereo_sensor0 3D hit time in time
Entries : 50138
Mean : -2.6354
Rms : 15.103
6,400
6,200
6,000
5,800
5,600
5,400
5,200
5,000
4,800
4,600
4,400
4,200
4,000
3,800
3,600
3,400
3,200
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
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40

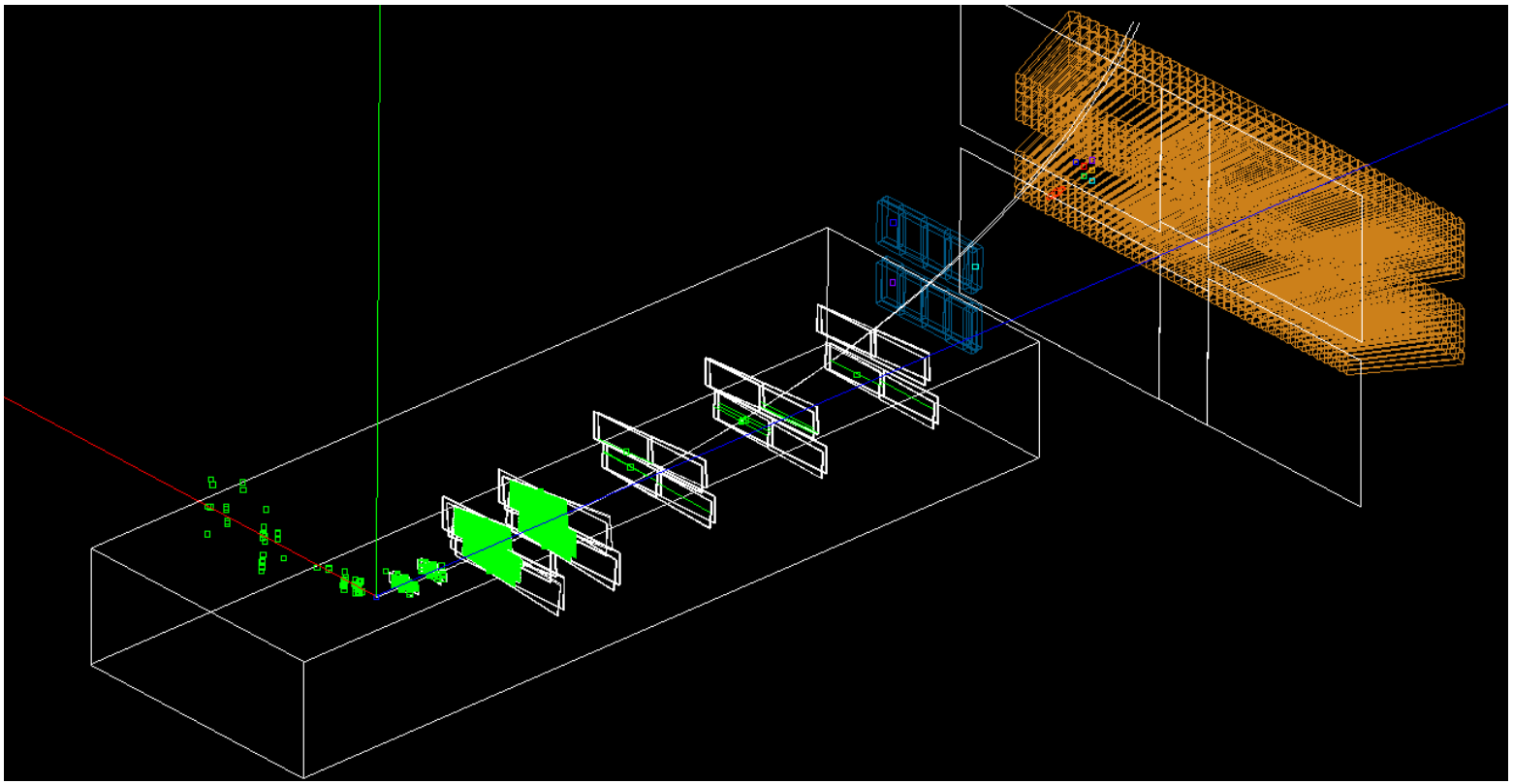
Trigger Timing by Phase

- Need to identify runs with this issue and correct



Event Flag Filter

- Need to identify and flag “bad” events such as the SVT “monster” events.
  - Essentially every channel is on.



Track Finding: Pattern Recognition

- A number of new SeedTracker tracking strategies have been introduced for 2019.

```
<driver name="TrackReconSeed567Conf4Extd123"/>
<driver name="TrackReconSeed456Conf3Extd127"/>
<driver name="TrackReconSeed356Conf7Extd124"/>
<driver name="TrackReconSeed235Conf6Extd147"/>
<driver name="TrackReconSeed234Conf6Extd157"/>
```

- Not optimized for our known detector inefficiencies, and definitely takes a lot of time
- Also have Kalman Filter pattern recognition.
  - See Robert's talk.
- Will need to invest analysis time to save CPU time.

Track Finding: Tracking Efficiency

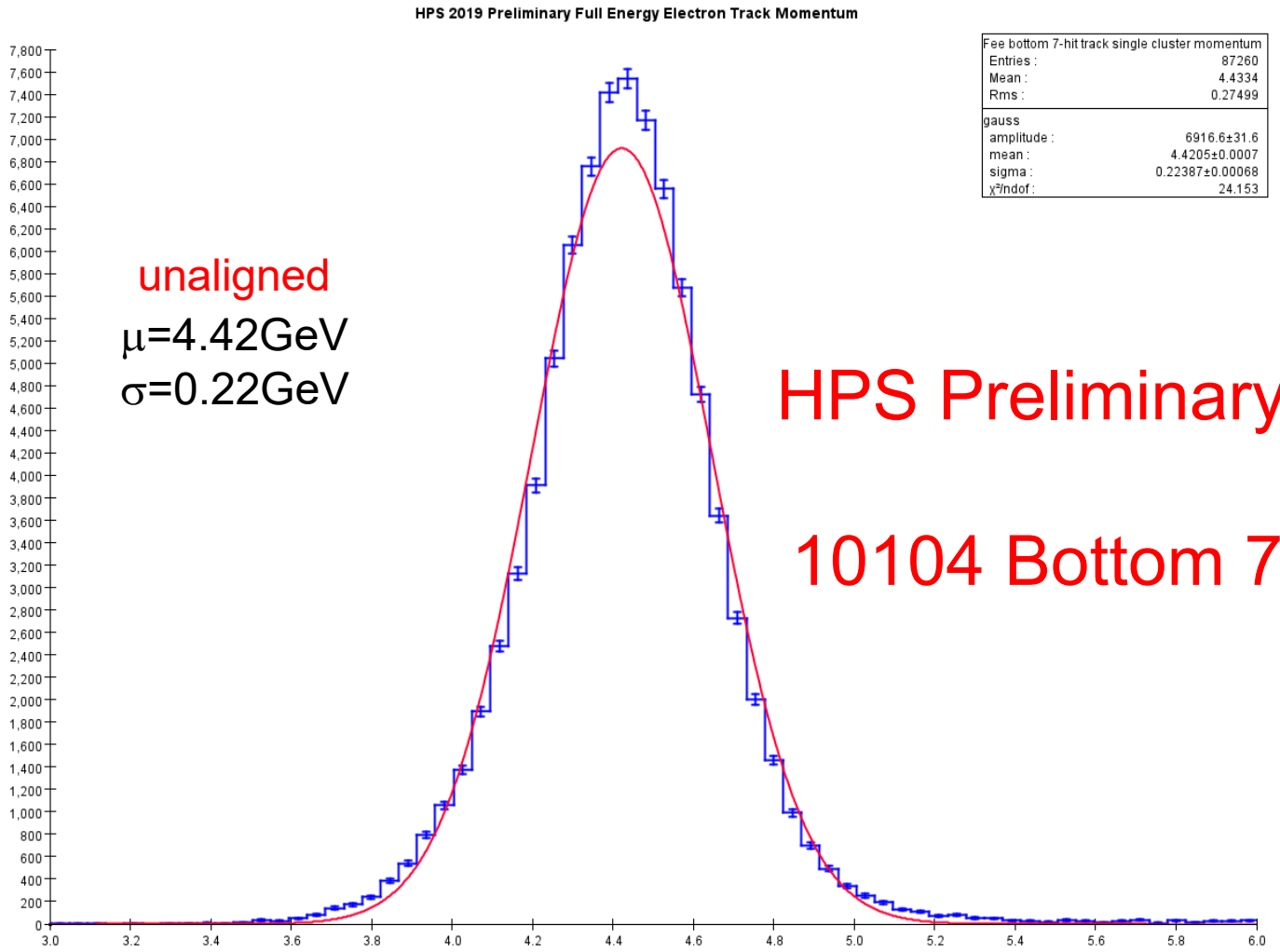
- Some studies of track-finding efficiency have started
- Multiple approaches being developed:
  - Tag-and-probe method used in 2016.
  - Using associated hodoscope hits and calorimeter cluster to tag track candidate and check for found track.
  - Use two-cluster WAB candidates to check track finding efficiency.
- Final results will have to wait until the detector is aligned and calibrated.

SVT Calibration & Alignment

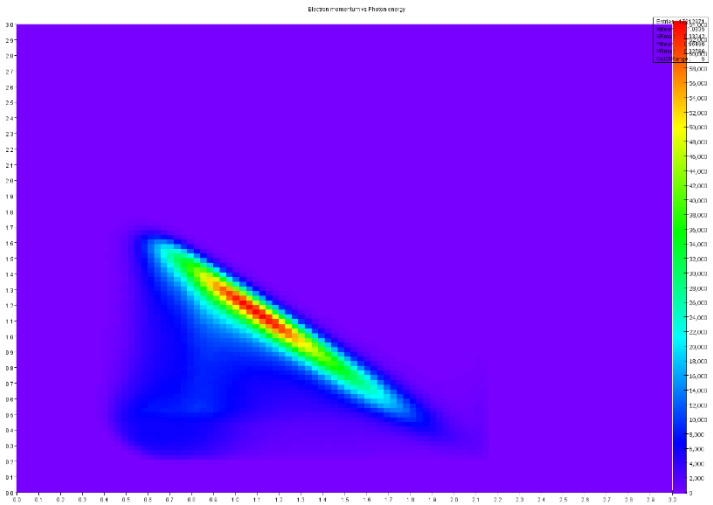
- Elastically scattered beam electrons (FEEs) can be used to internally align the individual SVT halves and to calibrate the momentum scale of the SVT.
- Bremsstrahlung events can be used to extend the calibration to lower momenta and to study the track-finding efficiency.
- The Møller peak was critical in establishing & confirming the global (top+bottom) SVT alignment and to pin down the target z location.
  - Final confirmation was when the Unconstrained and TargetConstrained Møller masses agreed.
- The Møller peak was also used to set the invariant mass resolution for the A' searches

Field-On FEE Track Momentum

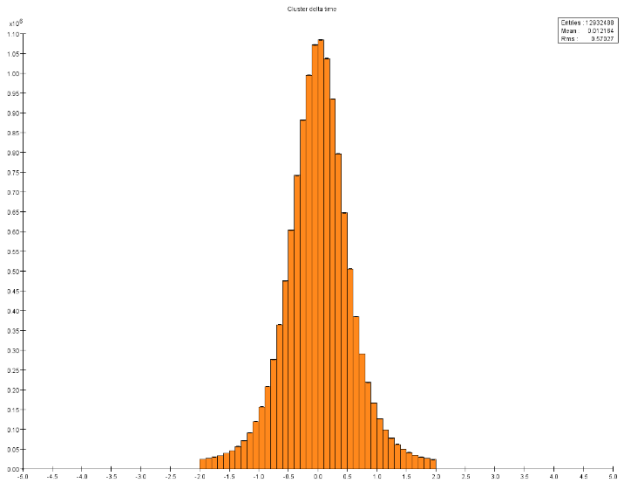
- Select single, high-energy cluster events



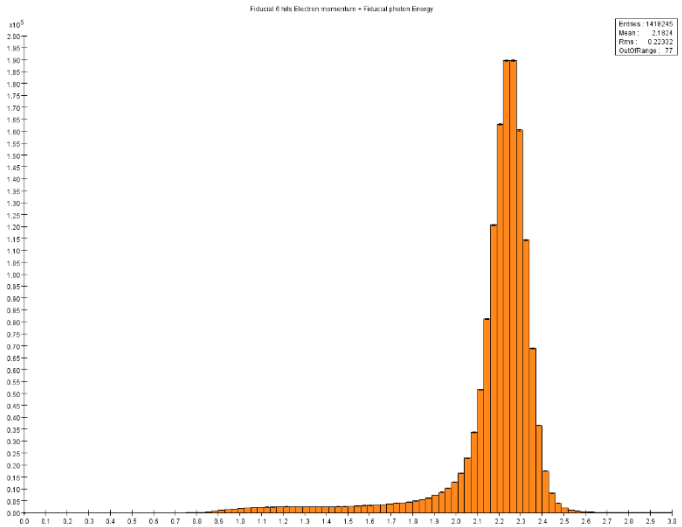
Wide Angle Bremsstrahlung (WAB)



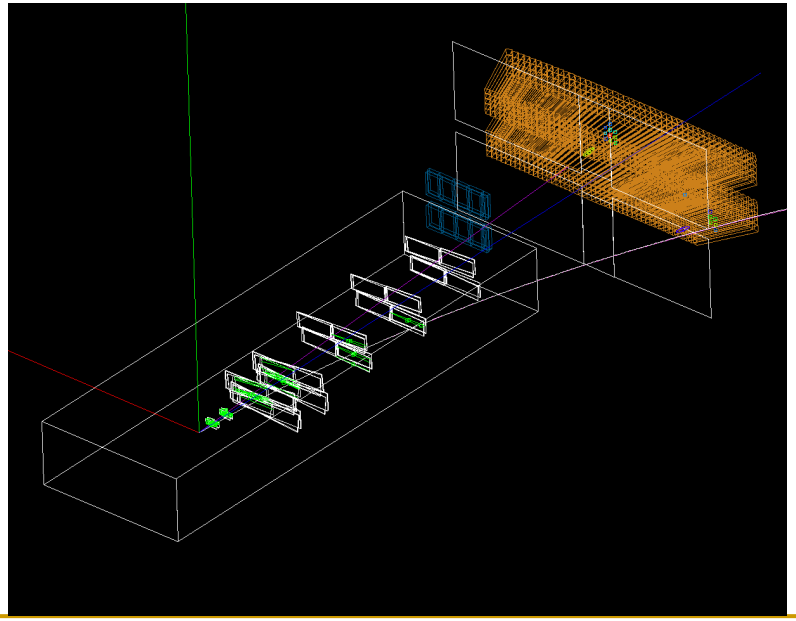
Track Momentum vs Cluster Energy



Two Cluster delta T



Track Momentum + Cluster Energy

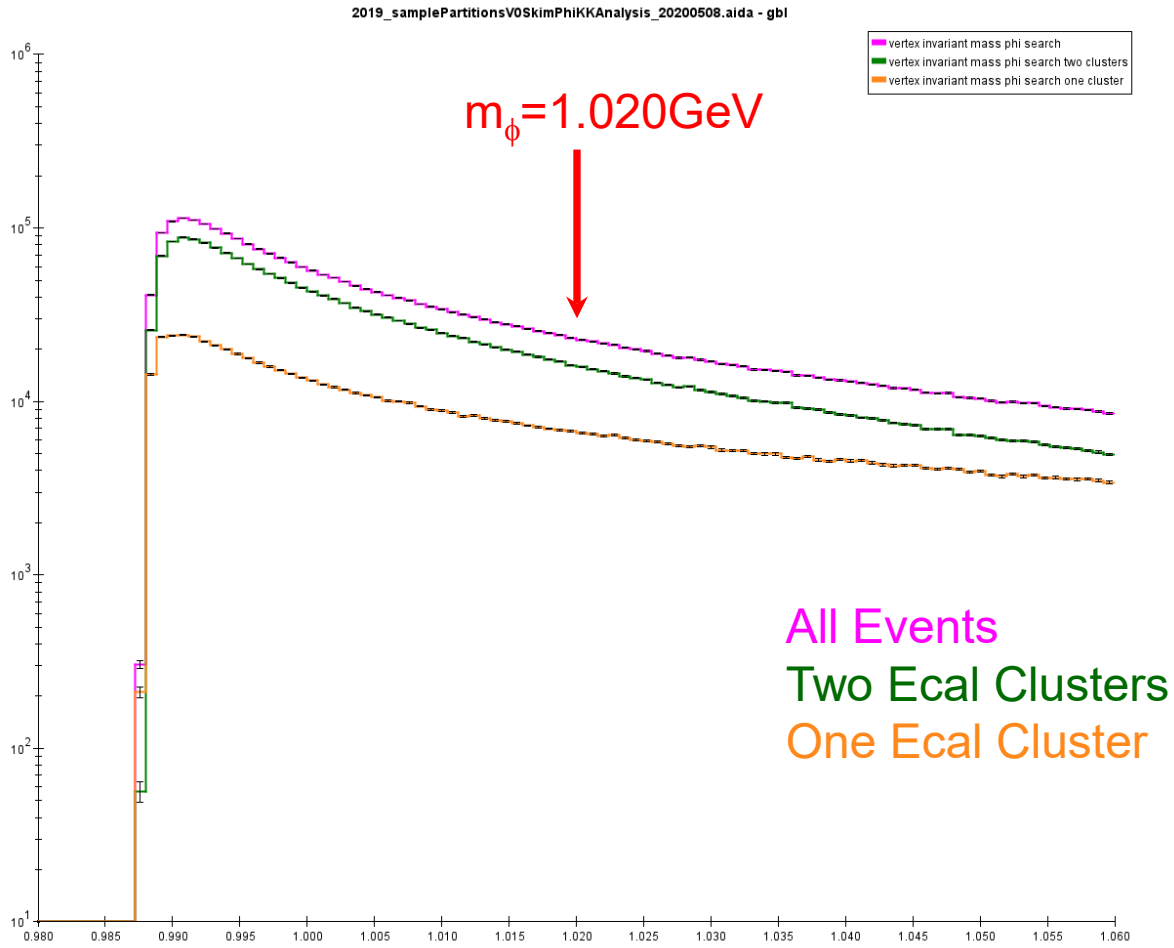


$\phi \rightarrow K^+K^-$

- There is no acceptance for Møller electrons in the 2019 data.
- Are there other calibration lines we might use?
- One resonance which could possibly provide a calibration & alignment line is the ϕ meson, with its subsequent decay to kaon pairs.
- Can analyze existing reconstructed events by looping over V0 collection and assigning kaon mass to vertex constituent tracks and recalculating resulting invariant mass.
  - Current reconstruction treats all tracks as coming from electrons or positrons.

2019 Sample Partitions

- Plot V0 mass from UnconstrainedV0Vertices with kaon particle mass

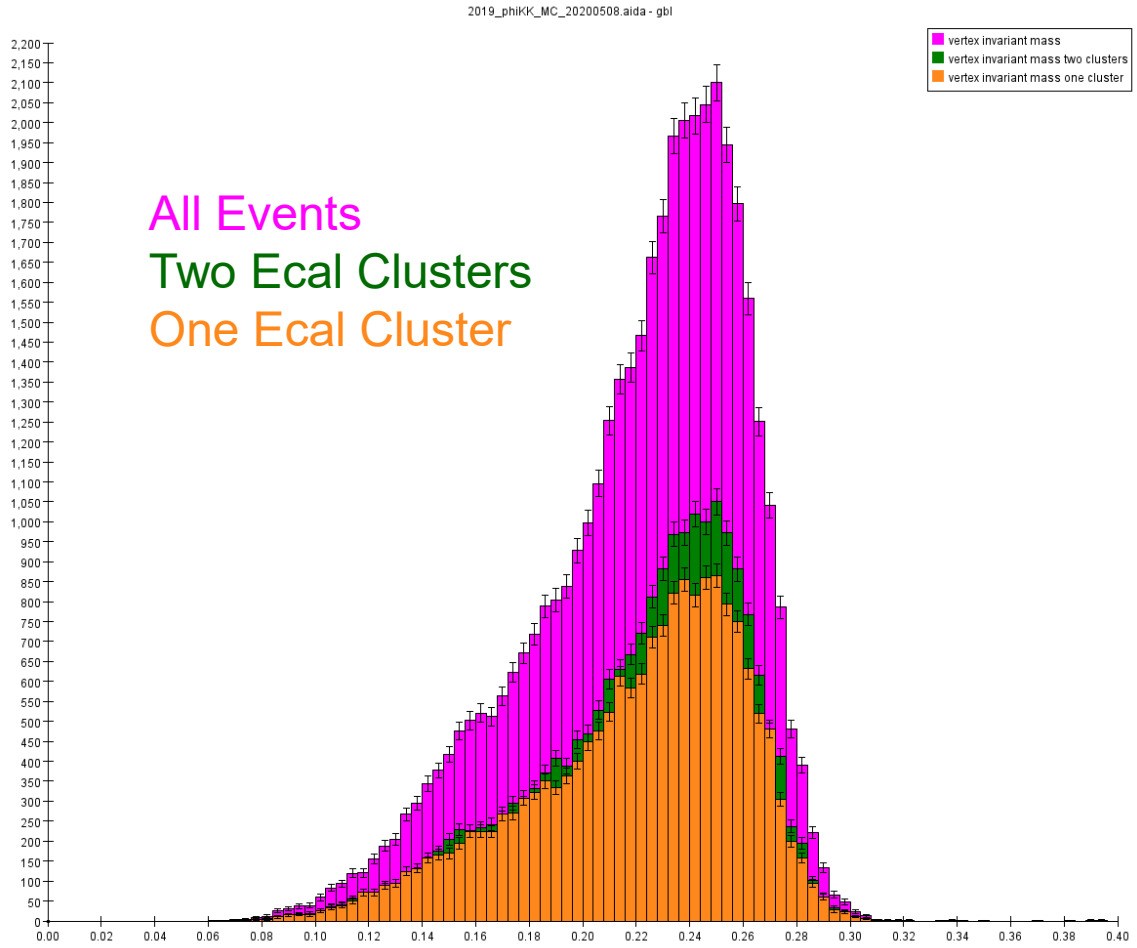


Further Analysis

- Unfortunately nothing obvious in the data.
- Use MC simulations to inform further analysis
- FX Girod generated samples of $\phi \rightarrow K^+K^-$ resulting from 4.55 GeV electrons impacting thin tungsten target
- Convert the output events in Lund text format to our binary stdhep format and displace vertex upstream using LundToStdhepConverter
- Process 10 million events through slic & hps-java recon
- Select events with V0s (40k pass acceptance)

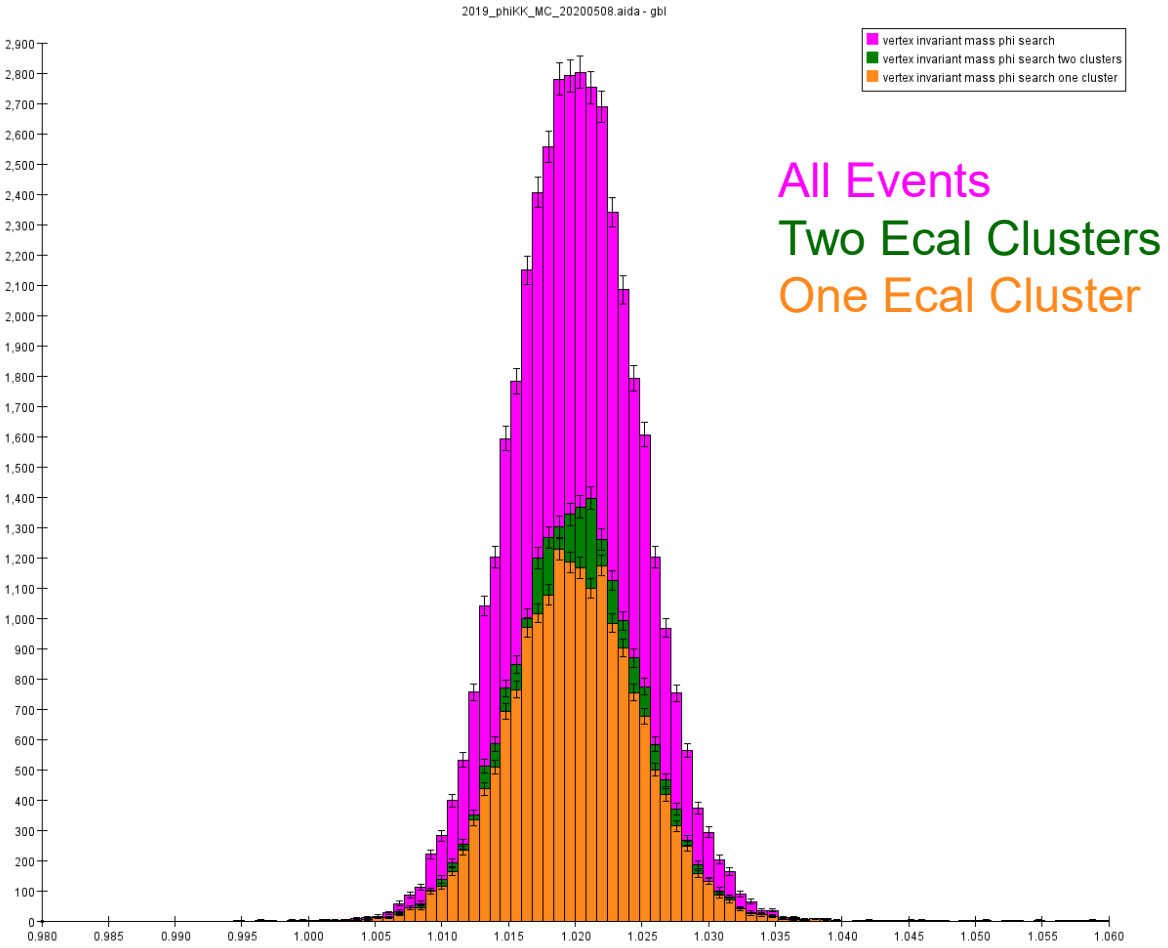
$\phi \rightarrow K^+K^-$ Monte Carlo

- Plot V0 mass from UnconstrainedV0Vertices
  - Electron/positron particle hypotheses



$\phi \rightarrow K^+K^-$ Monte Carlo

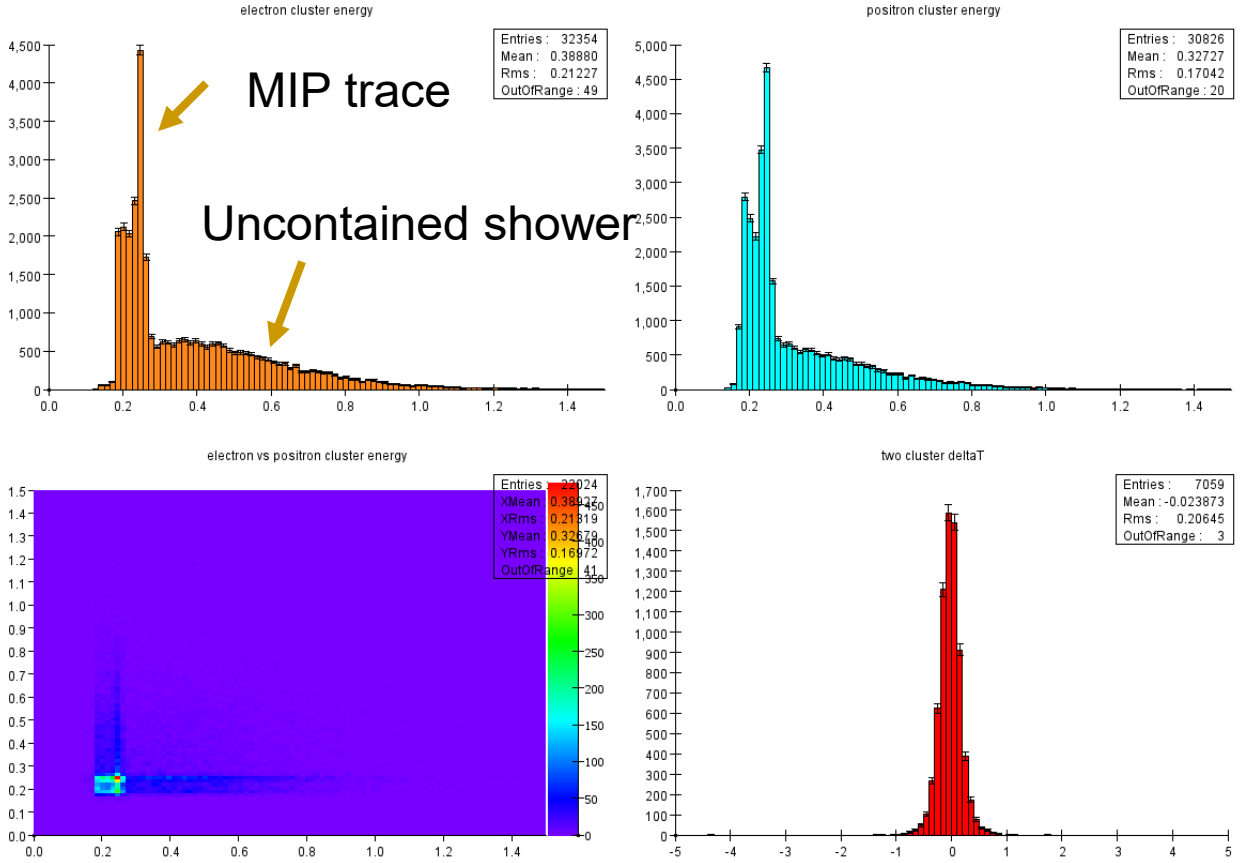
- Plot V0 mass from UnconstrainedV0Vertices with kaon particle mass



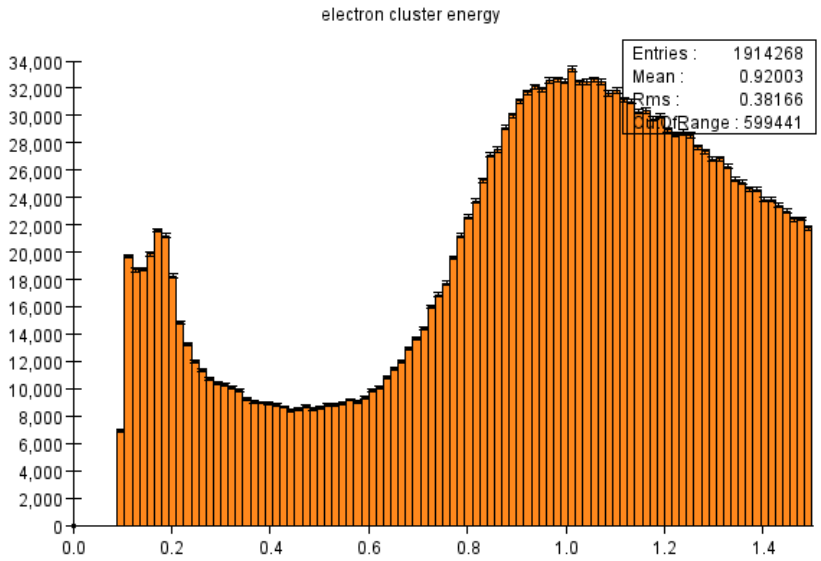
Adding Calorimeter Information

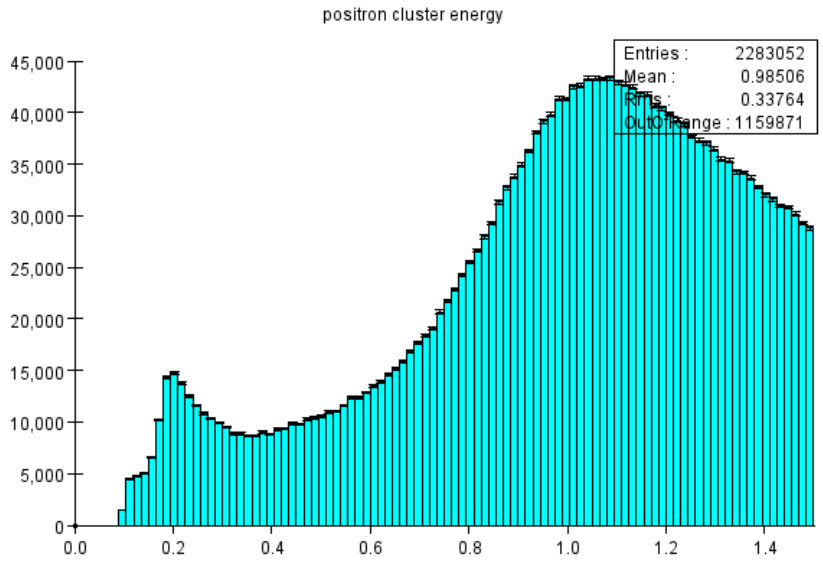
- Our electromagnetic calorimeter is not very efficient as a hadronic calorimeter, so inspect ECal cluster energies +ive vs -ive

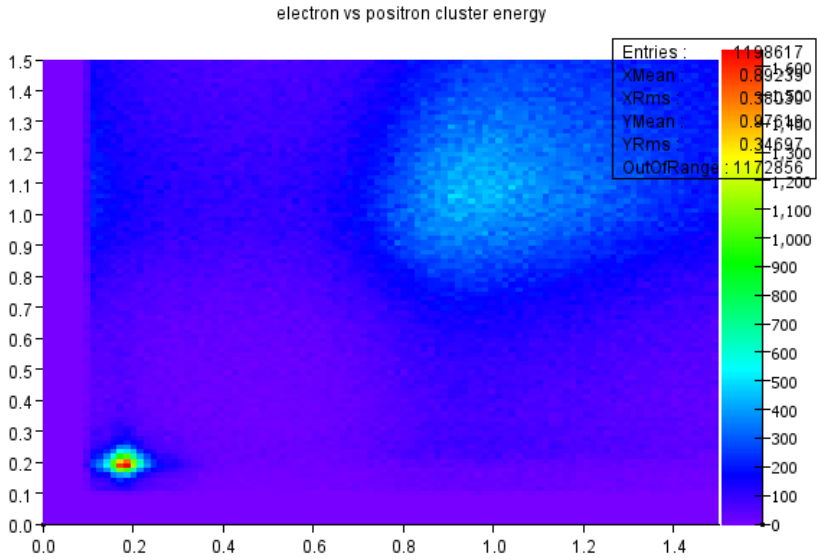
Expect 180MeV for a MIP traversing the length of a single crystal

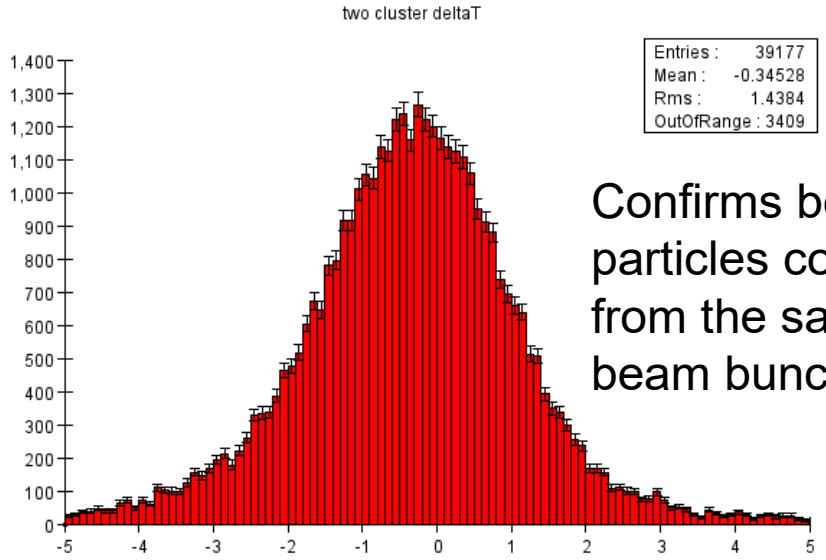


Ecal Cluster Energies & Δt in Data



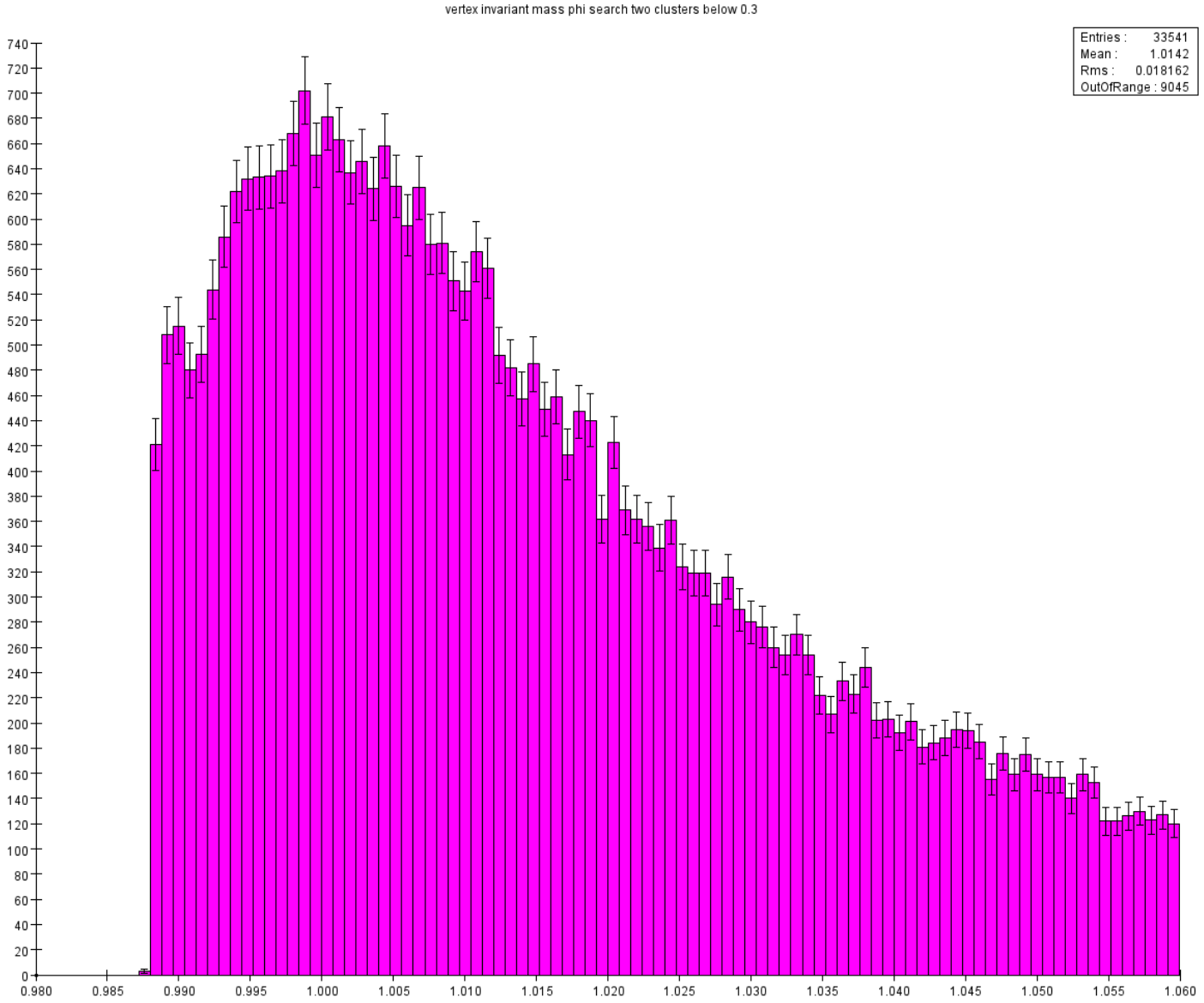




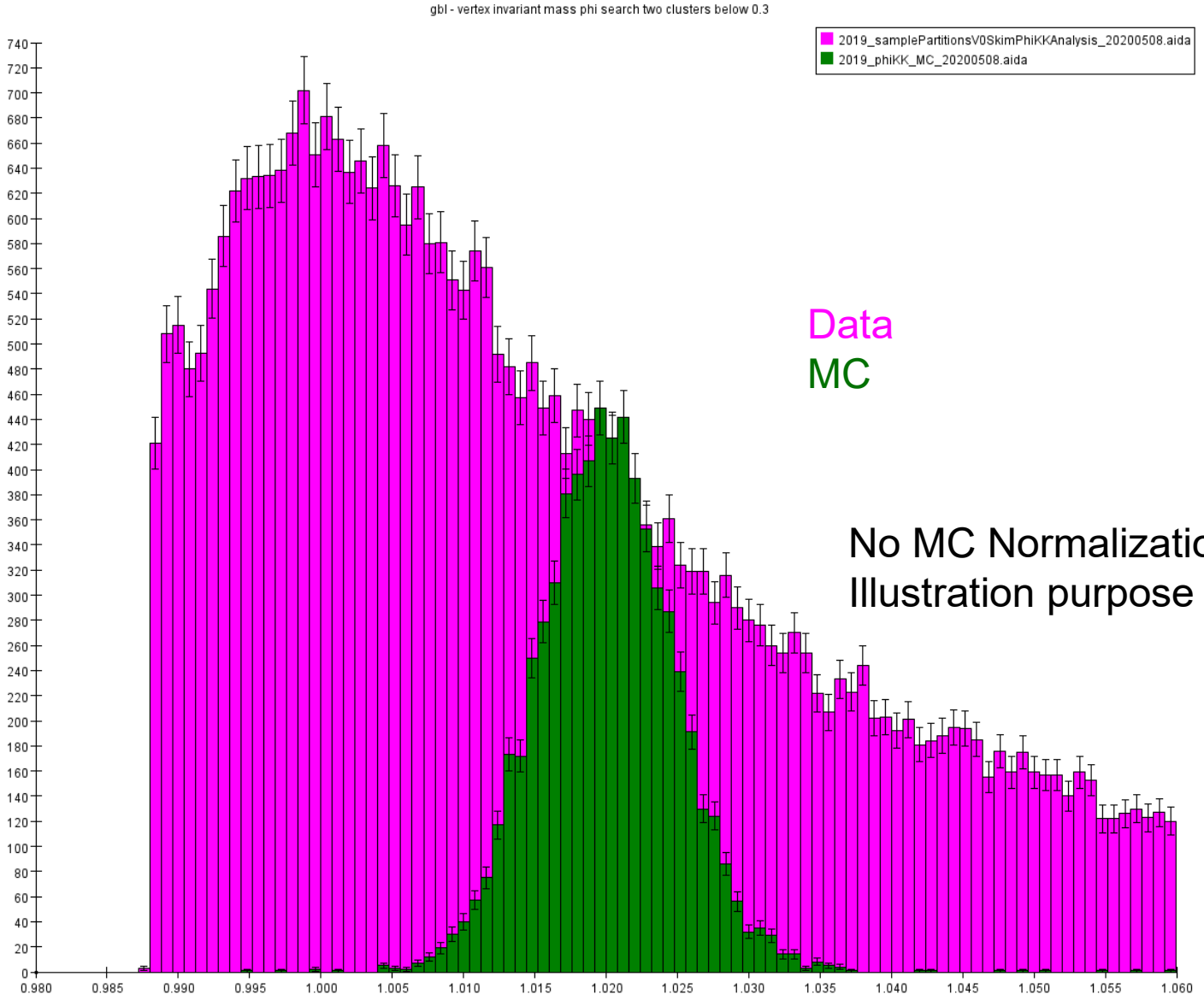


Confirms both particles come from the same beam bunch

Select two MIP Clusters in ECal



Select two MIP Clusters in ECal

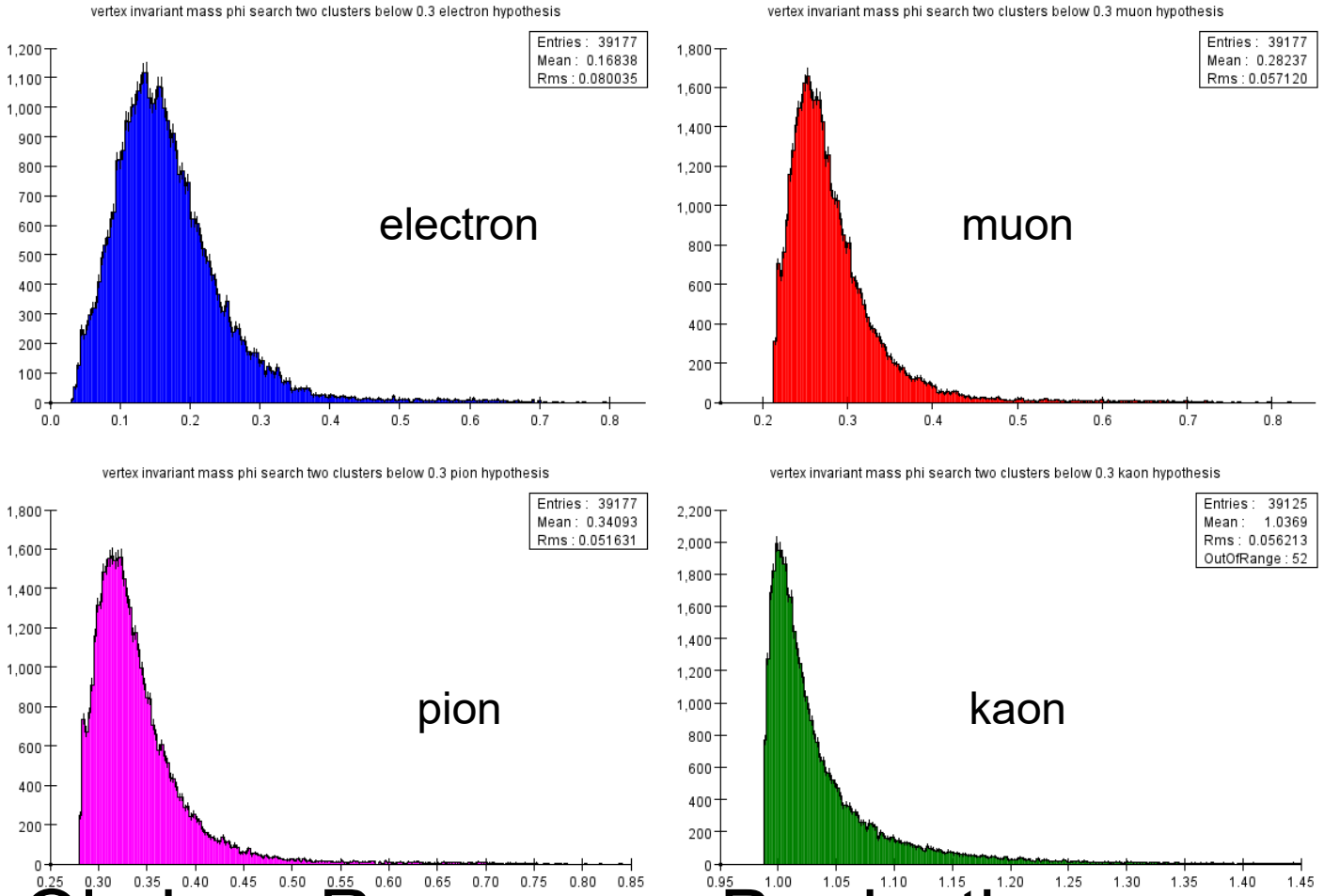


Data
MC

No MC Normalization!
Illustration purpose only!

So… what are these two-MIP events?

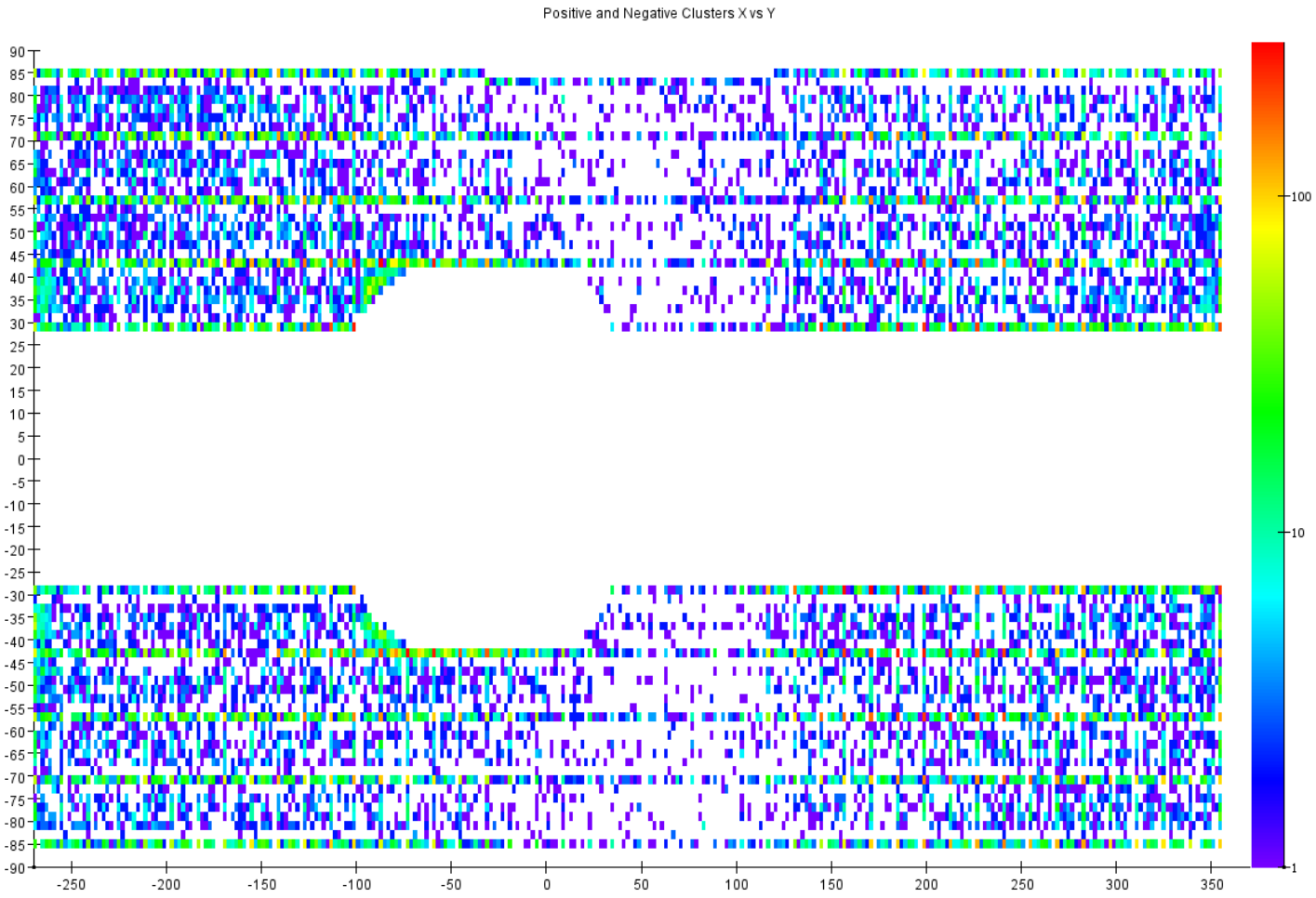
- Calculate mass with e, μ, π, K hypotheses



- No Obvious Resonance Production

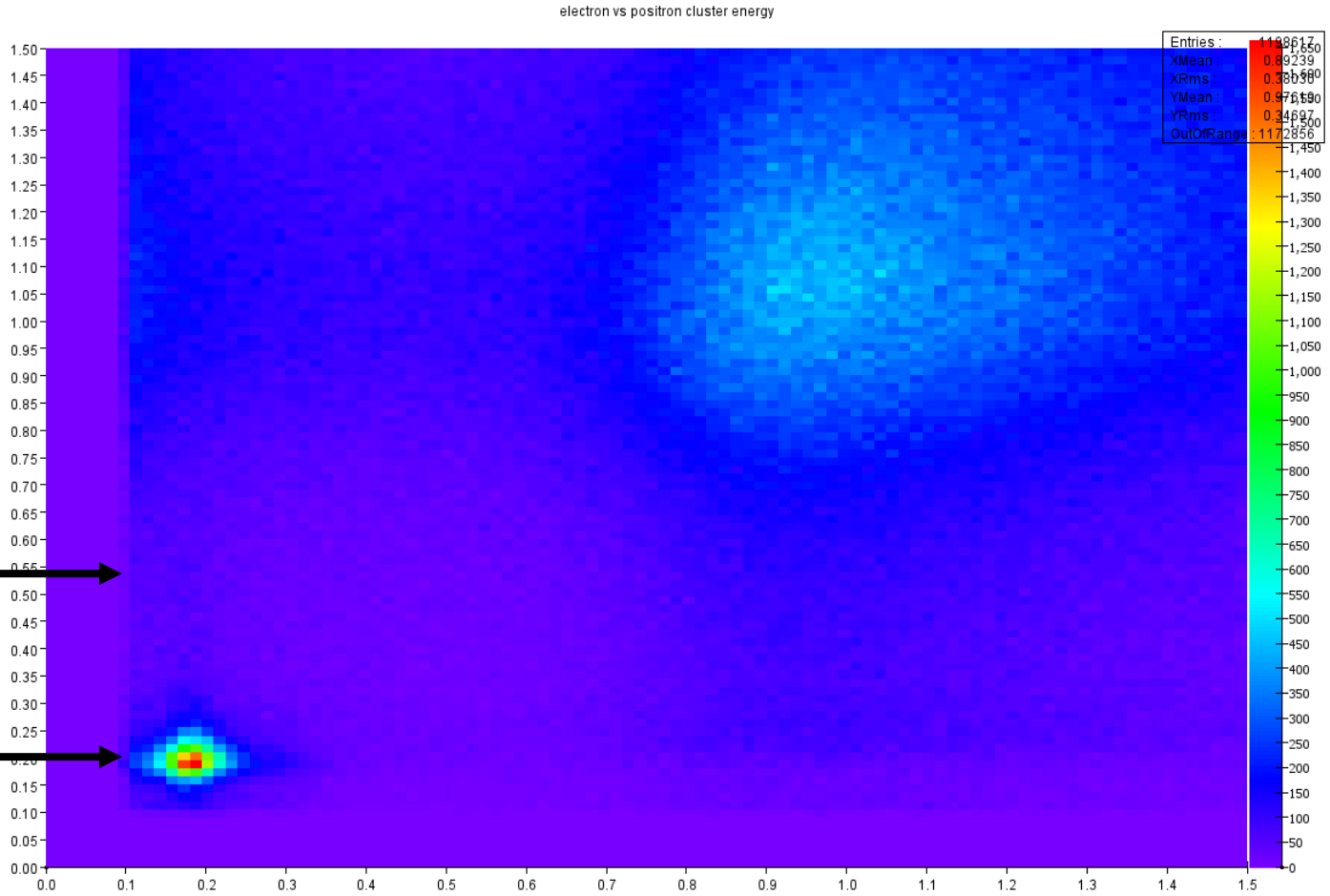
Calorimeter Energy Deposition

- Clusters are smoothly distributed over the calorimeter. No strong indication of clipping edges



Calorimeter Energy Deposition

- Cluster energies are consistent with MIPs traversing crystal, no indication of hadronic showering

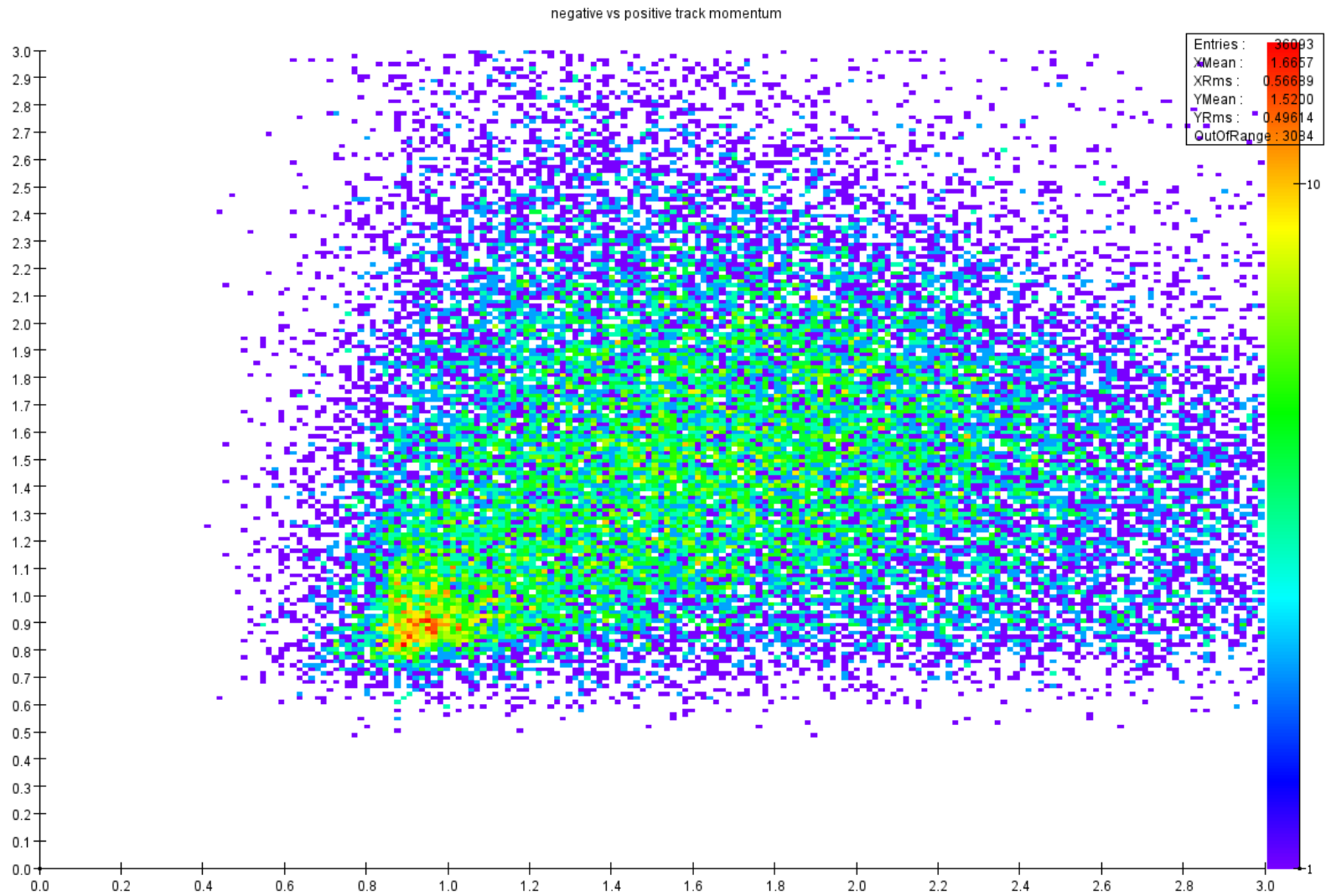


Little sign of hadronic showering near MIP peaks

Peak at 180MeV consistent with two MIP tracks

Continuum $\mu^+\mu^-$ production

- Consistent with Bethe-Heitler production



Calibration Peak Search Summary

- $\phi \rightarrow K^+K^-$ 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.
- Have identified source of continuum $\mu^+\mu^-$ production.
  - Can be used for alignment and vertexing studies since multiple scattering is less for $\mu^+\mu^-$ than e^+e^-.
- Opens up possibility of search for $A' \rightarrow \mu^+\mu^-$!

Moving Forward

- Pieces are in place to bring everything together
  - MC simulation now working
    - Thanks to Omar for fixing SVT digitization code
    - Thanks to Tongtong for timely generation of WAB & tritrig samples
    - Can now generate samples with known misalignments to test alignment procedures.
  - SVT channel calibrations, time offsets and “monster” event handling improvements being worked on.
  - Kalman Filter track finding & fitting software maturing. Will need to compare to existing SeedTracker/GBL.
    - Replace or augment?
    - See Robert’s talk.
  - Large samples of clean FEE and WAB events are available for:
    - Momentum scale and resolution calibration, track-finding efficiency, alignment
  - GBL/Millepede alignment chain is operational
    - See PF’s talk
  - $\mu^+\mu^-$ added to HPS’ final states. Will be used for calibration and alignment but should also be added to physics analysis list.
- Stay tuned.