ECAL Studies – Sampling Fraction

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Introduction

- Leo recently pushed new code into the repository
    - He took my bug-fixes (which were hacks) and did them correctly – thanks, Leo!
    - I ran a new sample and made some basic checks – looks good
- The code also introduced a new Sampling Fraction from Francisco (Reco/SiPMHitFinder.fcl) for both ECAL and MuID
    - Old value was 2.726, and the new value is 2.852
        - I believe he used Geant and thickness of Scintillator/absorber to derive the SF

    - Some comparison plots using single electrons – check two ways:
        - (a) look at all recoHits/Clusters in event – very simple – just look at all hits in event
        - (b) E/p of electron – needs backtracker information to associate clusters to electron

Variable	New	Old
<Electron E>	2.99 GeV	3.01 GeV
<SimHit E>	0.0052 GeV	0.0051 GeV
<DigiHit ADC>	584.8 (counts)	585.5 (counts)
<RecoHit E>	0.216 GeV	0.206 GeV
<Cluster E>	2.068 GeV	2.003 GeV

h_elecP
Entries 1000
Mean 3.01
Std Dev 0.9863

Electron P (GeV)
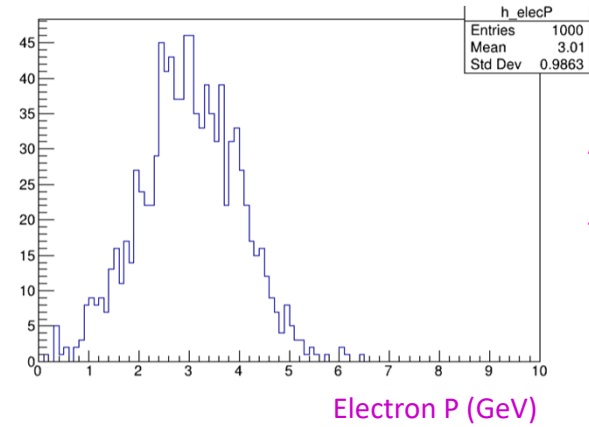
Aimed along the beam direction from TPC center

Sim/Digi metrics are unchanged – as expected

RecoHit E: In new sample <E> of hits is ~5% higher, in line with the Increase in the sampling fraction

New vs. Old sampling fractions: *SimHit plots are unchanged – as expected*
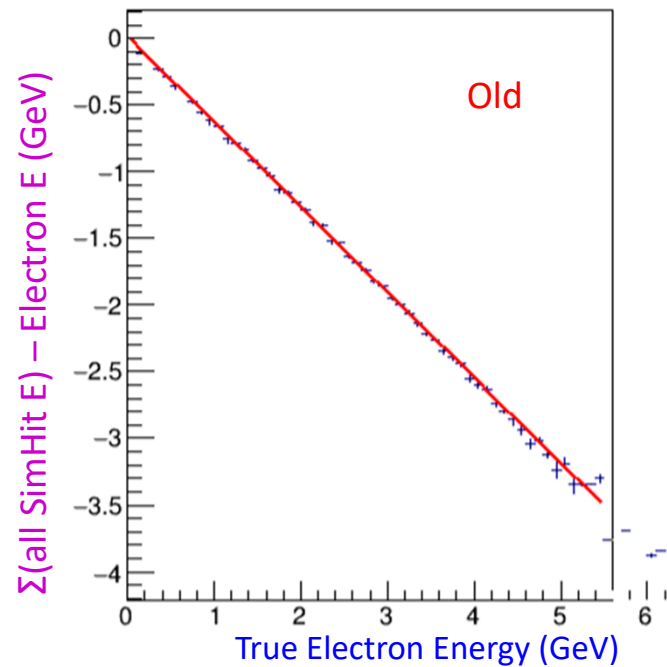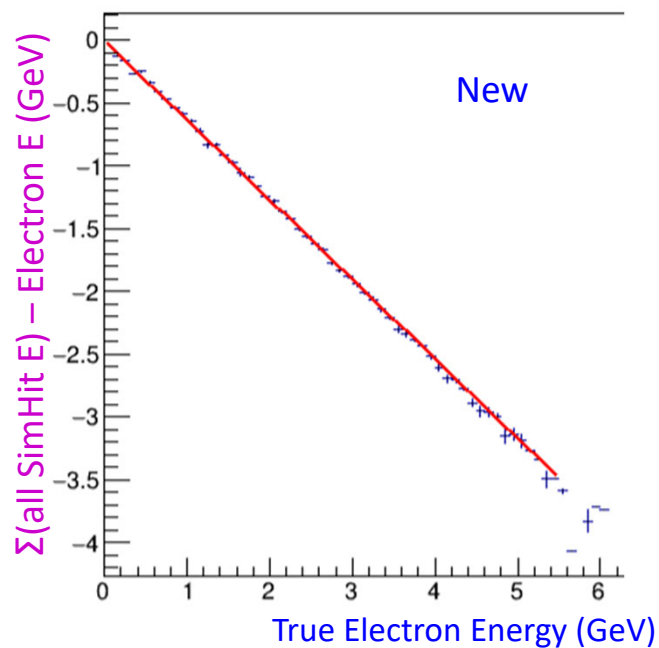
Slope/Intercept: -0.6329/-0.0043   -0.6395/0.01502

Sim Hit Energy

Calculated residual
at 3 GeV: *-1.903 (GeV)*   *-1.90 (GeV)*

New vs. Old sampling fractions: *All RecoHits in event*
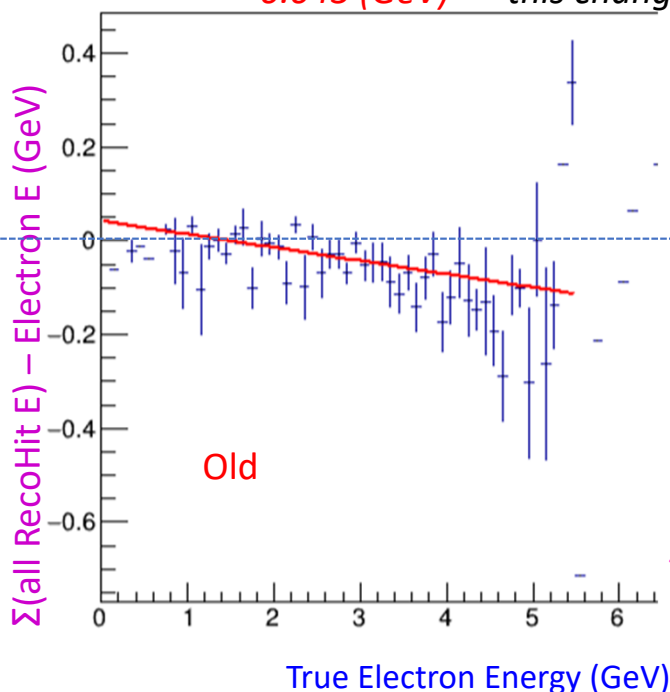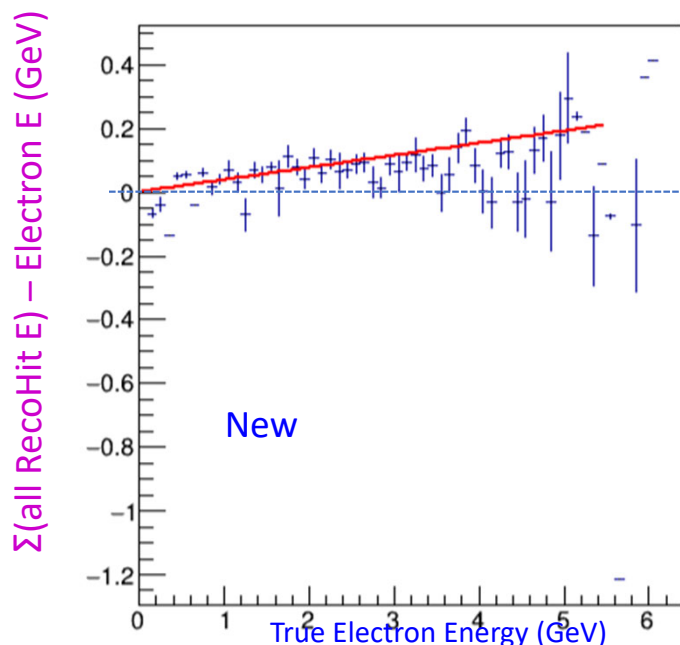
Slope/Intercept: 0.0383/0.0011   -0.0283/0.042

Reco Hit Energy

Calculated residual
at 3 GeV: *+0.116 (GeV)*   *-0.043 (GeV)   - this change is +5%*

The residual at 5 GeV changes from
-0.1 GeV to +0.19 GeV, i.e., +5.8%

Slope of fit gives the impression that
we might be over-correcting, but I
am not sure. Was expecting the new
fit to be flatter.

New vs. Old sampling fractions: *All Clusters in event*

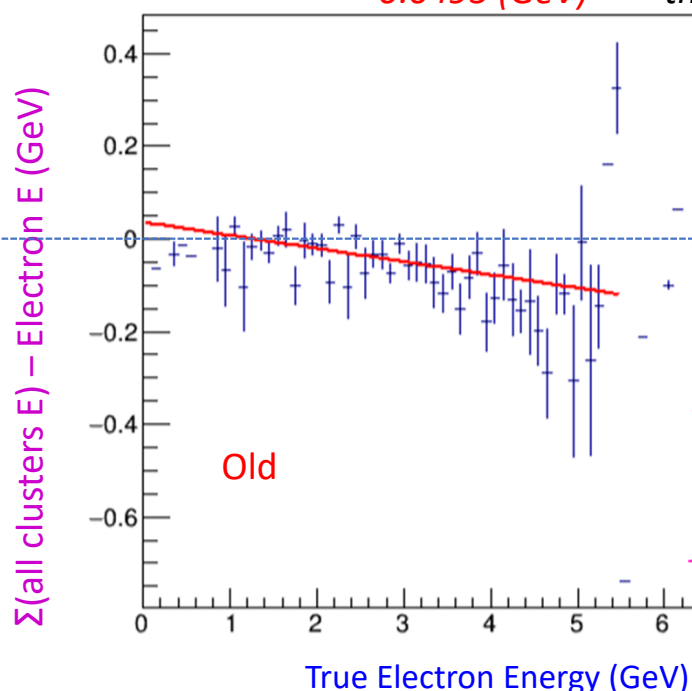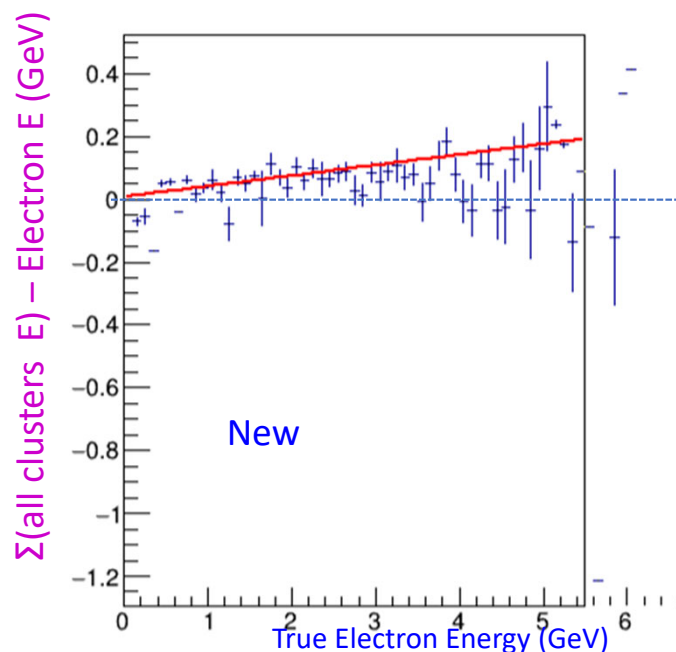Slope/Intercept: 0.0336/0.0079   - 0.0284/0.0357

Clusters Energy

Calculated residual
at 3 GeV: *+0.109 (GeV)*   *-0.0495 (GeV)*   *- this change is +5.3%*

The residual at 5 GeV changes from
-0.11 GeV to +0.18 GeV, i.e., +5.8%

Slope of fit gives the impression that
we might be over-correcting, but I
am not sure. Was expecting the new
fit to be flatter.

Fit profile plots for allSimH, allRecoH, allCluster – Ad-hoc Mean value of SF (=2.789)
X-axis: True electron Energy, Y-axis: Residuals (all<Sim/Reco/Clus>E – electron E)

Slope/Intercept: -0.6329/-0.0043   0.015/-0.00252   0.0112/0.0022
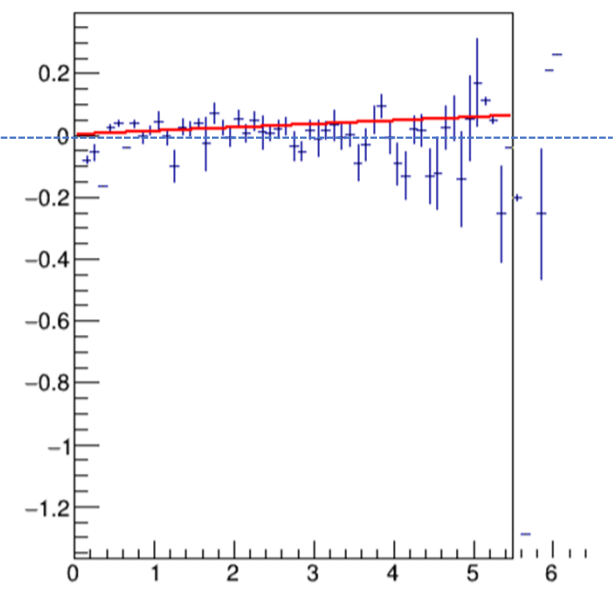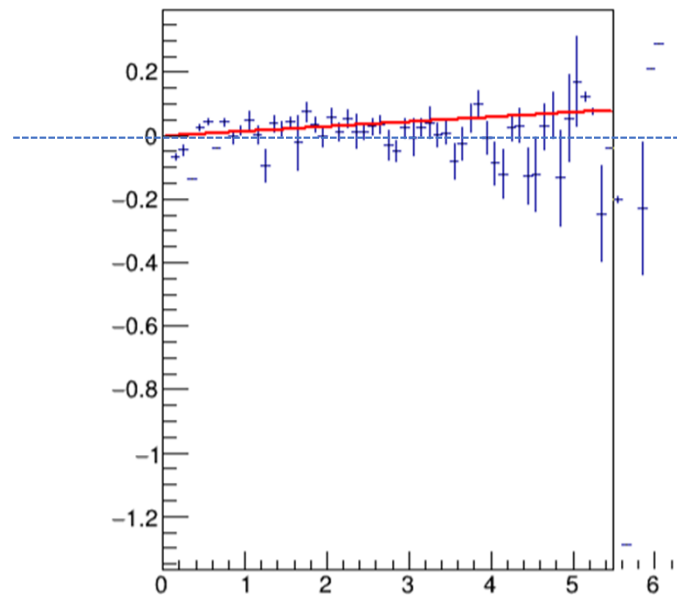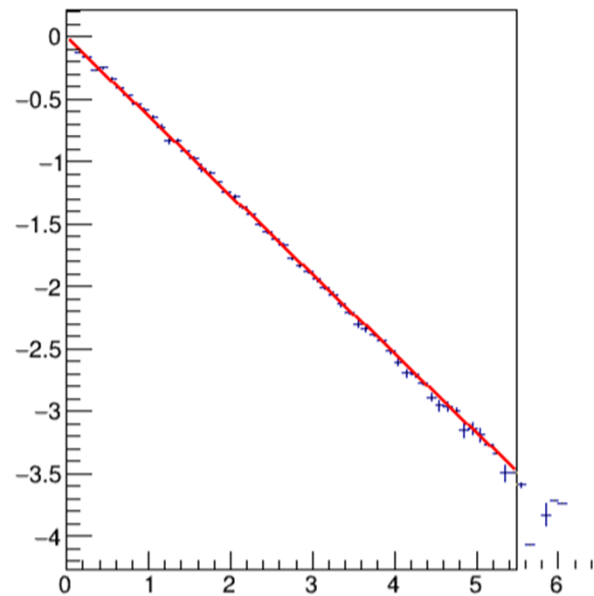
Sim   Reco   Clusters

Calculated Residual@E = 3 GeV:

-1.903   +0.043   +0.036

Using E/p of electron

- There is a potential issue in this approach, i.e., we have to rely on the BackTracker to associate hits/clusters with the particle that created them
  - The comparison becomes more "model-dependent", so it's not obvious if we should use this technique, even though the BackTracker is the same in the new and old samples

- In a handful of cases, the BackTracker "hallucinates" !!
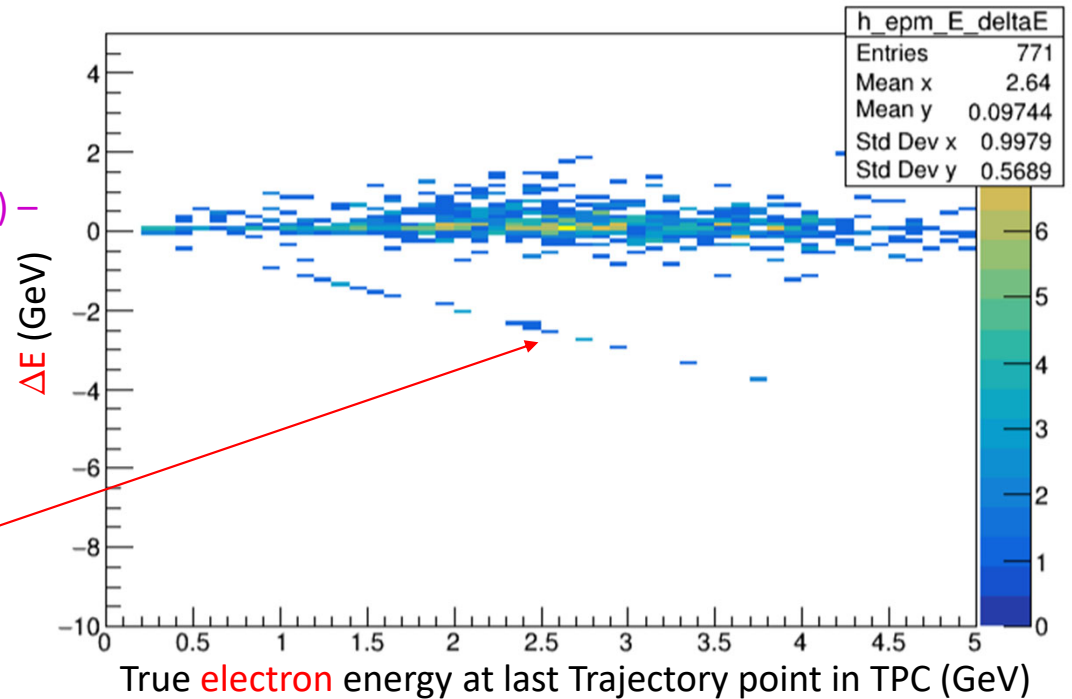 - See next two slides (made with old sample)

Plot is filled when the back-tracker finds at least one cluster matching the electron (Old sample)

Y-axis: $\Delta E = \Sigma(E$ of all clusters* back-tracked to the electron) – Energy of electron at last point in TPC

(* if I were to include ClusterMCFrac, the main body shifts down ~ 0.5 GeV, while the diagonal band remains unchanged – see backup)

Looked at a few events and see that primary electron and Brem photon end very close to each other in the ECAL. There is one cluster with all the energy and 1-2 very small ones -> see next slide

It seems the energetic cluster is being assigned to the photon, whereas some random cluster (usually far away) gets assigned to the electron

h_epm_E_deltaE	
Entries	771
Mean x	2.64
Mean y	0.09744
Std Dev x	0.9979
Std Dev y	0.5689

ΔE (GeV)

True electron energy at last Trajectory point in TPC (GeV)

- Out of the 982 electrons that ended in the ECAL, only 771 get into this plot

- In other cases, clusters are matching brems from the electron (or daughters of brems from electrons), and once we include them, we recover all entities that actually make it to the CALO
  - In about ½ the cases, cluster that is back-tracked to a brem (or its daughter) is closer to electron end-point in the ECAL – being studied

9

Event = 18 (in the diagonal band)

Sim/Digi/Reco hits/Clusters 283, 283, 208, **2**

Cluster #, No. of hits, Energy -- 0, 200, **5.25** ---- XYZ 15.7, -33.6, 296.3
 --> PDG of particle matching this cluster 22 at index 4 – ClusterMCFrac = 0.533

Cluster #, No. of hits, Energy -- 1, 2, **0.0081** ---- XYZ 30.7, -231.0, 175.7
 --> PDG of particle matching this cluster 11 at index 0, ClusterMCFrac = 1.

Starting Prim Lepton mom 5.04

Prim Lepton mom at last trajectory point **3.73**
------>   ends in ECAL at XYZ 17.7, -40.0, 296.0

 energy of brem matched to a cluster **1.25**
---------> ends in ECAL at XYZ 15.0, -29.3, 278.0

!!!!!
num of clusters, back-tracked to prim lepton, to brems, to bremDauts 2, 1, 1, 0
deltaE, delta E'' -3.73, 0.226

Clearly, there is a problem!
Cluster #0 has E = 5.25 GeV, but matches
a brem photon, whose energy (1.25 GeV)
Is << than ClusterMCFrac*ClusterE (2.8 GeV)

The endpoints of the primary E and the brem
are near to each other, and I think cluster #0,
which is near both particles, contains energy
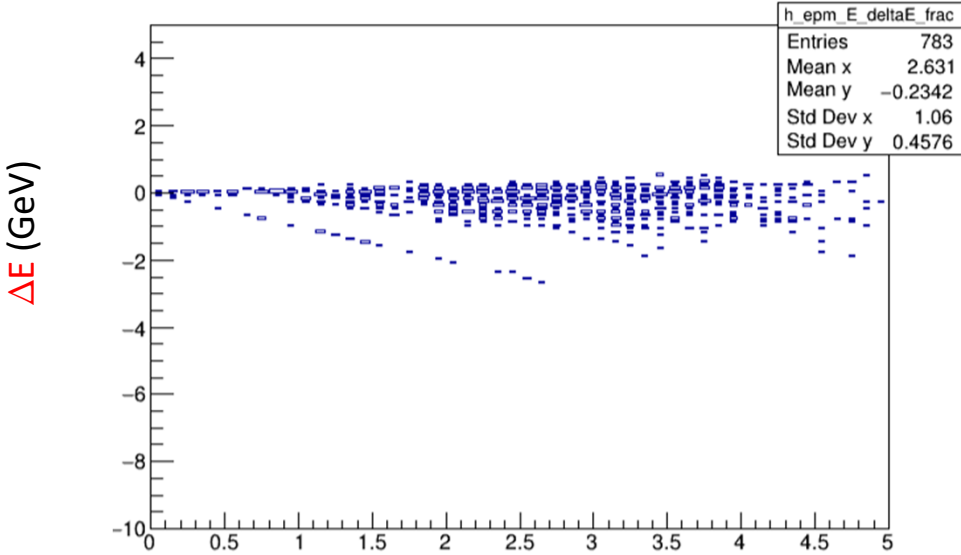from both of them.

Cluster #1 (8 MeV) is very far away from the
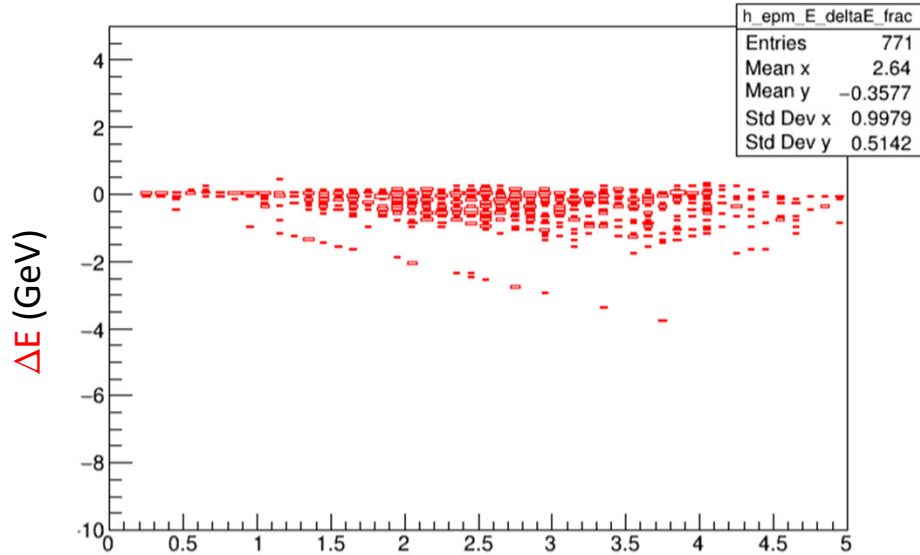electron, and has nothing to do with it.

Summary

- Not sure what to conclude about Sampling Fraction
  - Should we use Geant-based value or an ad-hoc one?

- Using E/p has limitations

- Will look at new sample made by Leo – "…events with ν_e interactions in the gas. Interactions in the calorimeter are also there, simulating overlays from a 10μs spill…"

Y-axis: $\Delta E = \Sigma$(E of all clusters back-tracked to the electron*ClusterMCfrac) $-$ Energy of electron at last point in TPC

New Sampling Frac.

Old SF

h_epm_E_deltaE_frac	
Entries	783
Mean x	2.631
Mean y	−0.2342
Std Dev x	1.06
Std Dev y	0.4576

h_epm_E_deltaE_frac	
Entries	771
Mean x	2.64
Mean y	−0.3577
Std Dev x	0.9979
Std Dev y	0.5142

ΔE (GeV)

True electron energy at last Trajectory point in TPC (GeV)

The shift in $\langle\Delta E\rangle$ is consistent with the 5% increase in SF

Extra slides
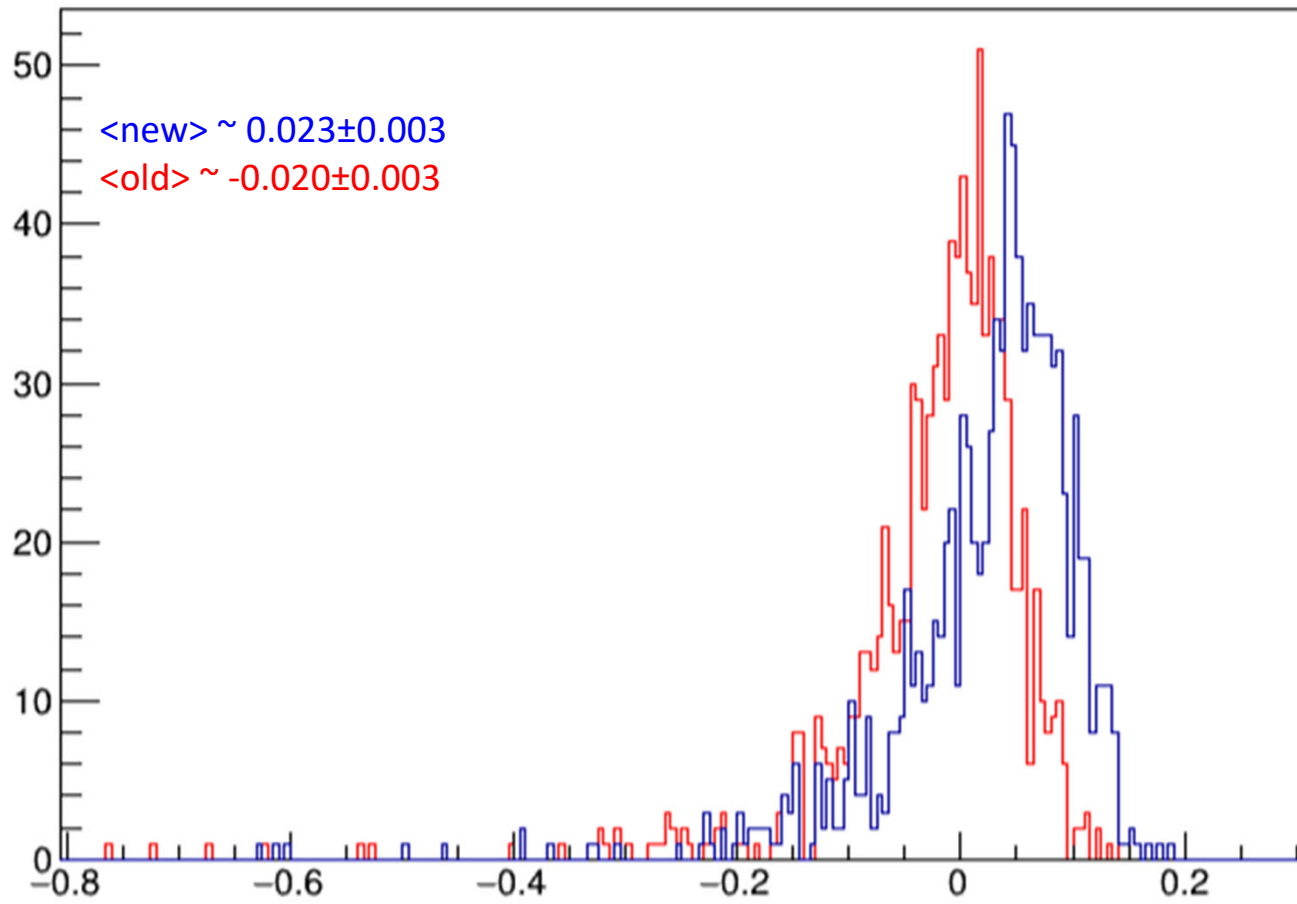
Sum All Reco Hits - prim E (tot) vs. prim E (tot)

<new> ~ 0.07±0.01 GeV
<old> ~ -0.07±0.01 GeV

Sum All cluster - prim E (tot) vs. prim E (tot)

<new> ~ 0.06±0.01 GeV
<old> ~ -0.07±0.01 GeV
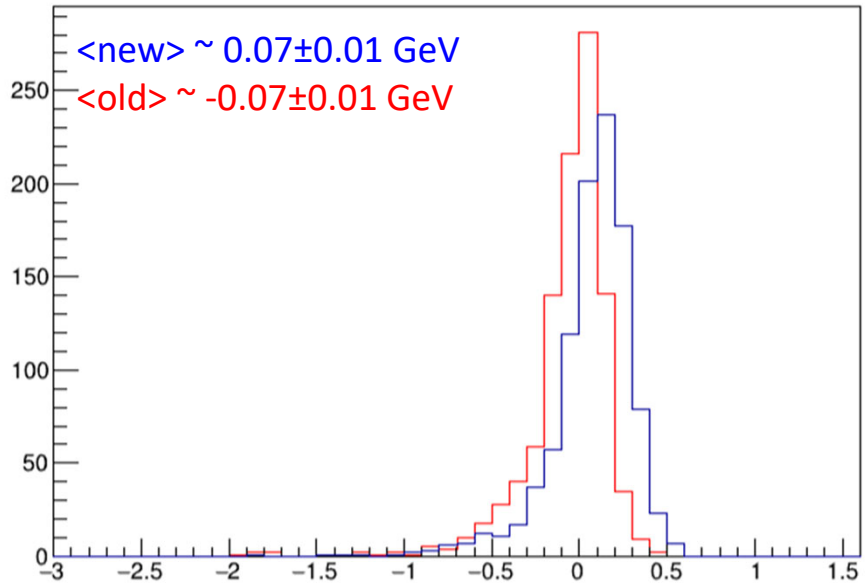
These are residuals
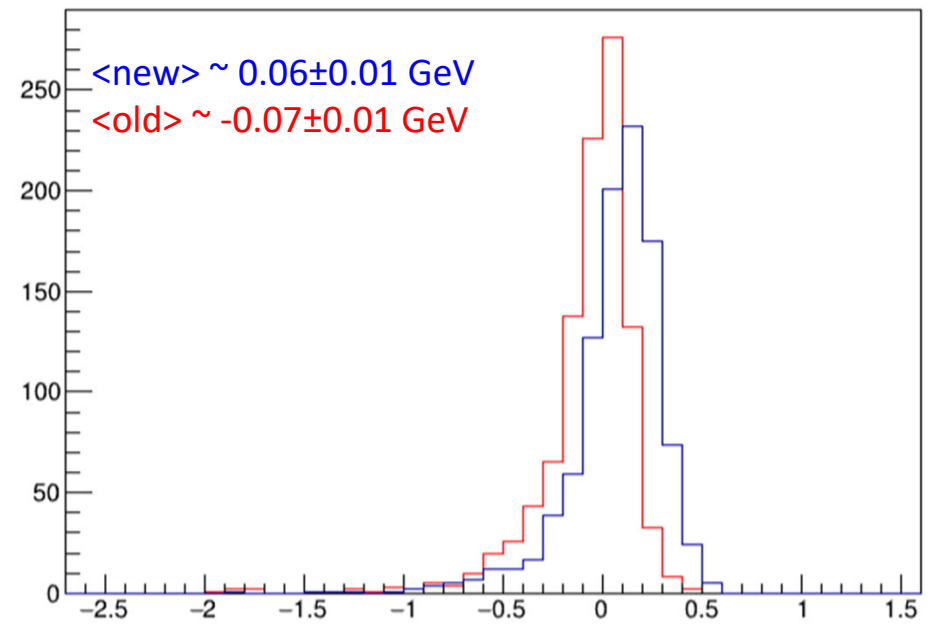
Sum All RecoE - prim E (tot)/primE vs. prim E (tot)

<new> ~ 0.023±0.003
<old> ~ -0.020±0.003

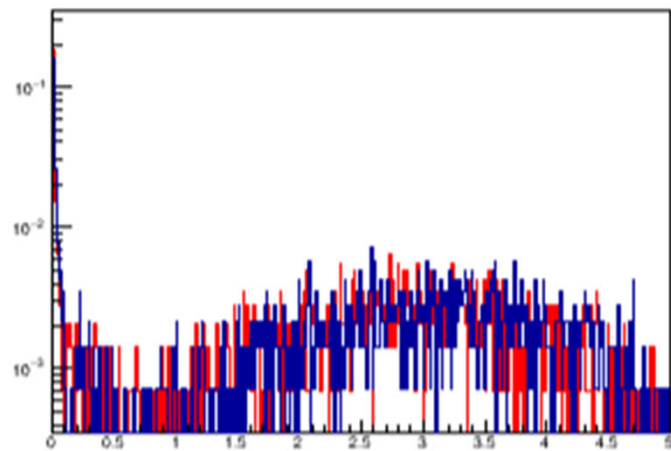| Variable	New (numbers)	Old (numbers)	(in GeV)	New (all in GeV)	Old (all in GeV)
# Electron	1000	1000	<Electron E>	2.993±0.032GeV	3.010±0.032 GeV
# Sim hits/electron	210.4	212.2	<Sim E>	0.00515	0.00514
#Digi hits/#SimHits	0.999463	0.999986	<Digi ADC>	584.8	585.5
#Reco hits/#DigiHits	0.67433	0.67411	<Reco E>	0.216	0.2058
#Cluster/electron	1.433	1.44	<Clus E>	2.068	2.003

Sim E
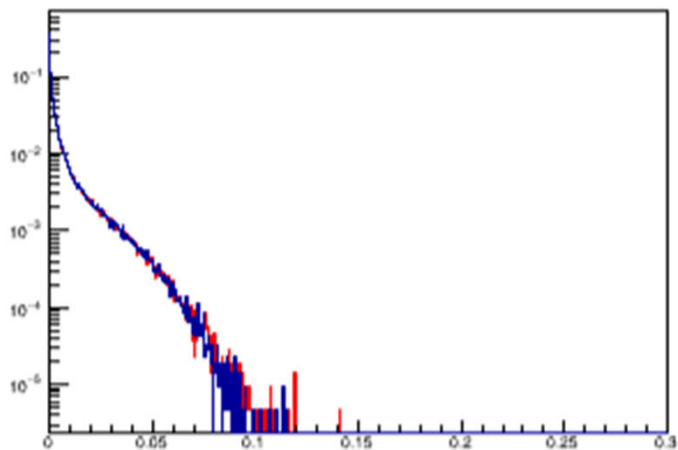
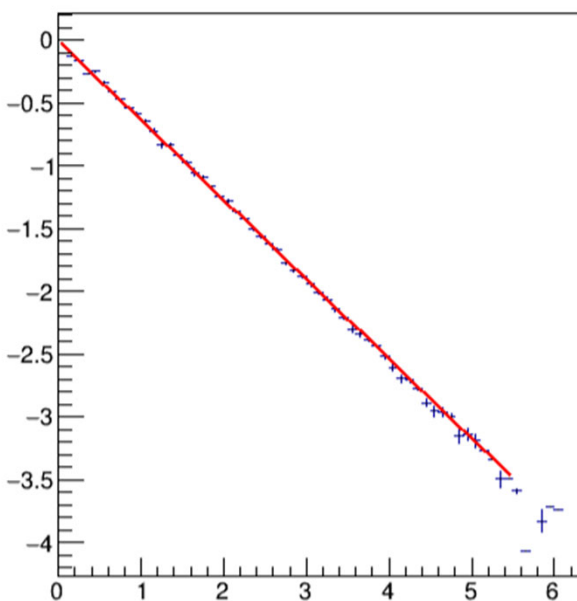Digi ADC
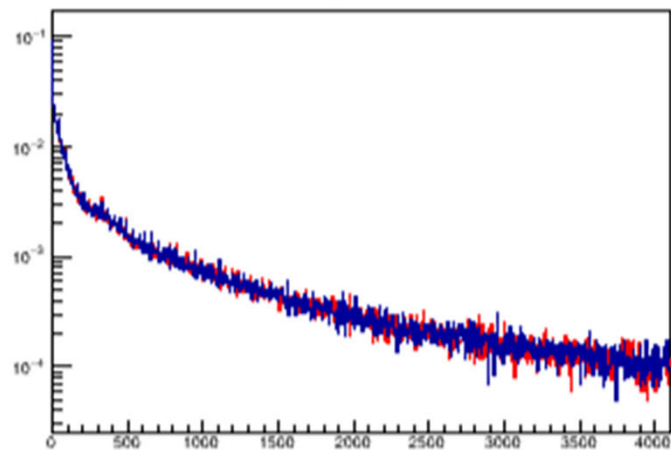
Reco E
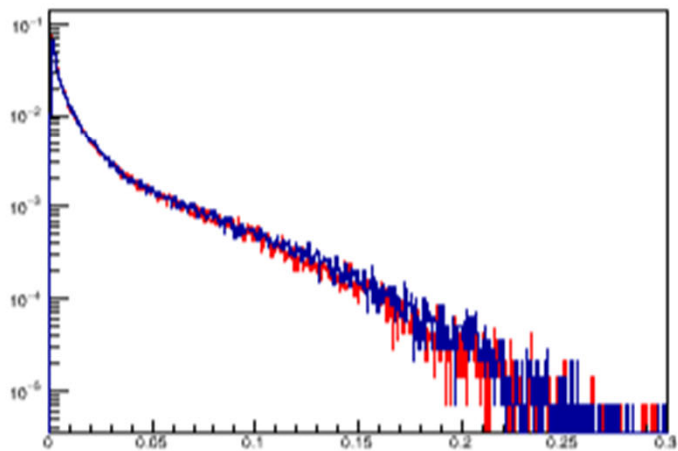
Cluster energy

New vs. Old

Normalized to unity

Not very useful

Fit profile plots for allSimH, allRecoH, allCluster – New
X-axis: True electron Energy, Y-axis: Residuals (all<Sim/Reco/Clus>E – electron E)

Slope/Intercept: -0.6329/-0.0043   0.0383/0.0011   0.0336/0.0079

Sim   Reco   Clusters
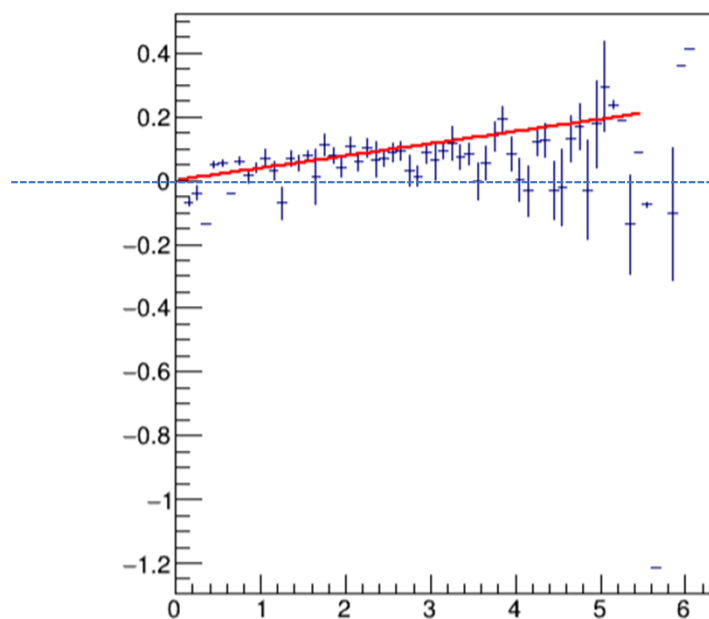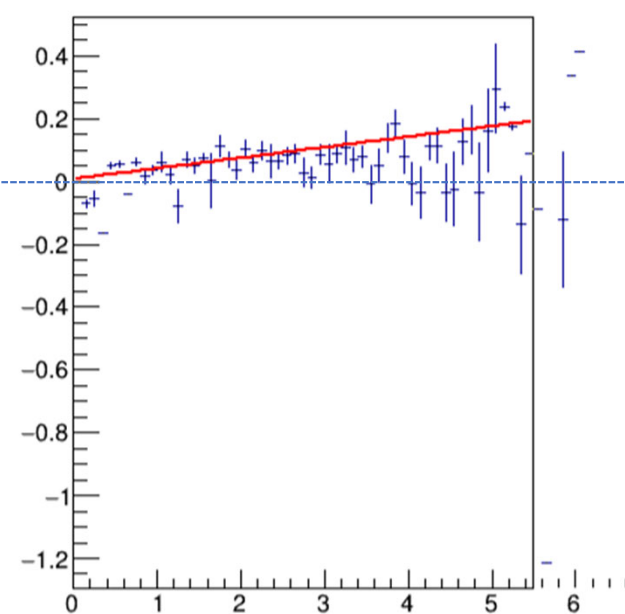
Calculated Residual@E = 3 GeV:

-1.903   +0.116   +0.109

Fit profile plots for allSimH, allRecoH, allCluster – <u>Old</u>
X-axis: True electron Energy, Y-axis: Residuals (all<Sim/Reco/Clus>E – electron E)

Slope/Intercept: -0.6395/0.01502   -0.0283/0.042   -0.0284/0.0357
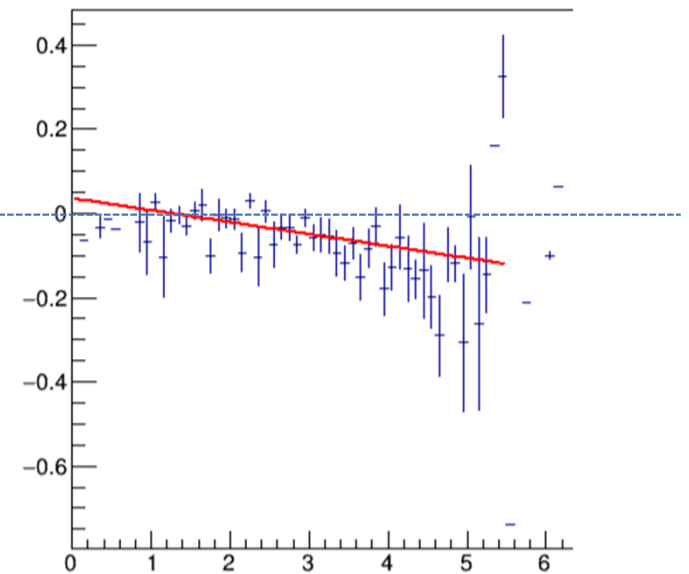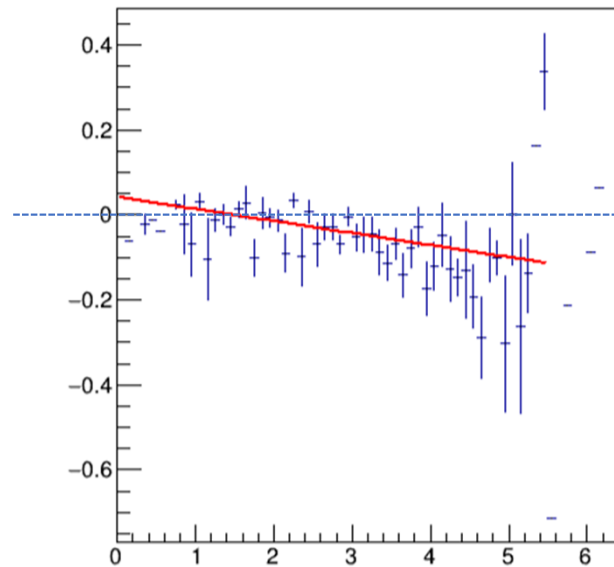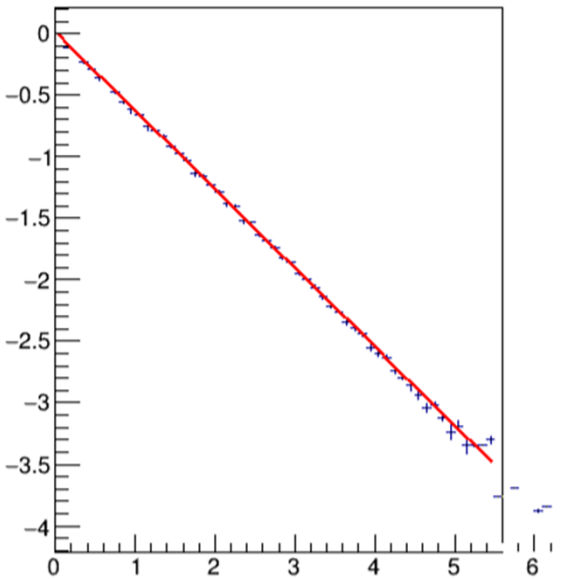
Sim   Reco   Clusters

Calculated Residual@E = 3 GeV:

-1.90   *-0.043*   *-0.0495*

Fit profile plots for allSimH, allRecoH, allCluster – Mean value of SF (=2.789)
X-axis: True electron Energy, Y-axis: Residuals (all<Sim/Reco/Clus>E – electron E)

Slope/Intercept: -0.6329/-0.0043   0.015/-0.00252   0.0112/0.0022
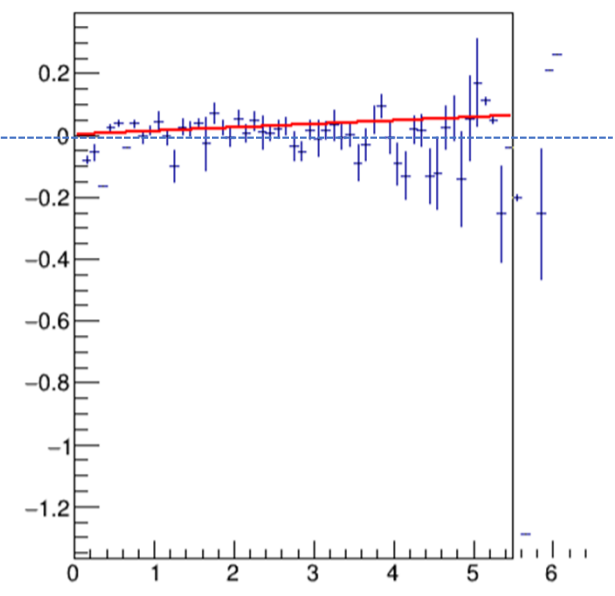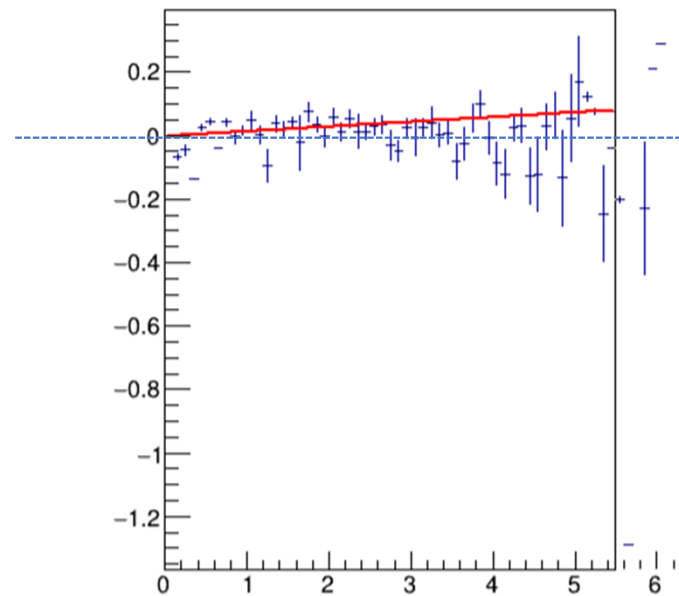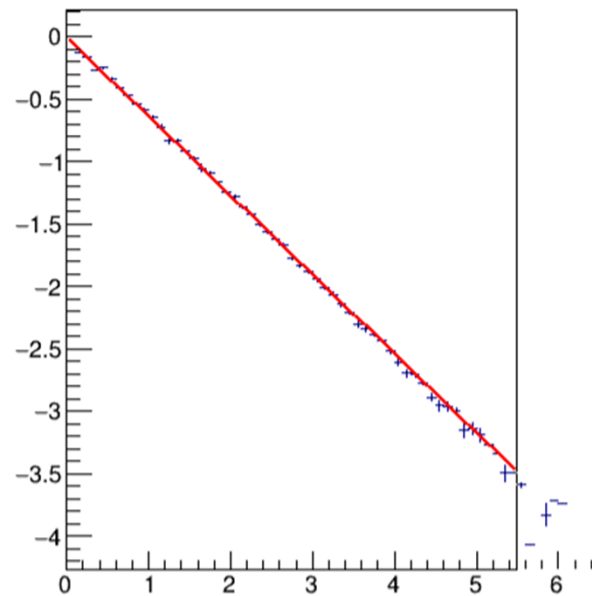
Sim   Reco   Clusters
                          Calculated Residual@E = 3 GeV:
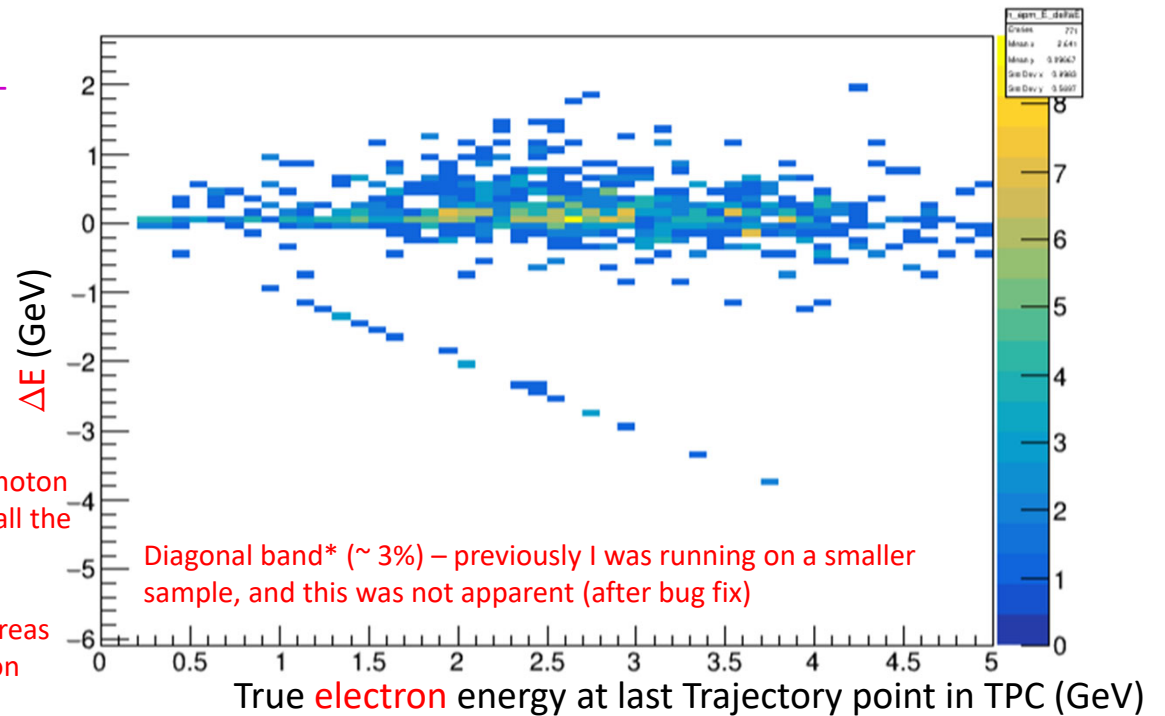-1.903   +0.043   +0.036

Y-axis: Σ(all clusters back-tracked to the electron) – Energy of electron at last point in TPC

Plot is filled when the back-tracker finds at least one cluster matching the electron

*Looked at a few events and see that primary electron and Brem photon end very close to each other in the ECAL. There is one cluster with all the energy and 1-2 very small ones.

It seems the energetic cluster is being assigned to the photon, whereas some random cluster (usually far away) gets assigned to the electron (see one event in backup)


ΔE (GeV)

Diagonal band* (~ 3%) – previously I was running on a smaller sample, and this was not apparent (after bug fix)

True electron energy at last Trajectory point in TPC (GeV)

- Out of the 982 electrons that ended in the ECAL, only 771 get into this plot

- In other cases, clusters are matching brems from the electron (or daughters of brems from electrons), and once we include them, we recover all entities that actually make it to the CALO
    - In about ½ the cases, cluster that is back-tracked to a brem (or its daughter) is closer to electron end-point in the ECAL – being studied

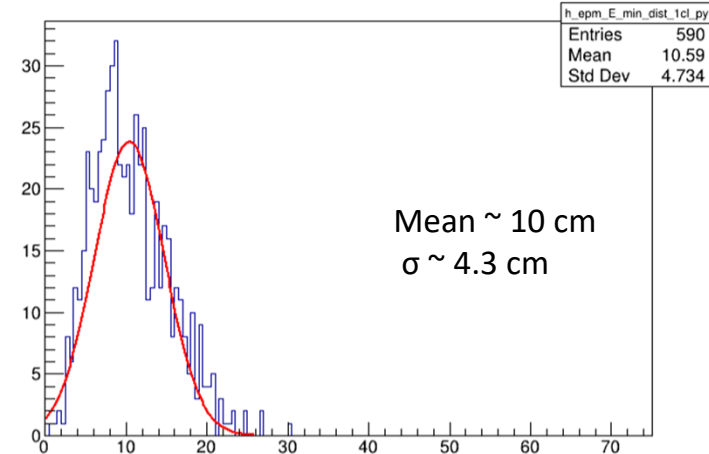## Look at cases where only 1 cluster matches the primary electron
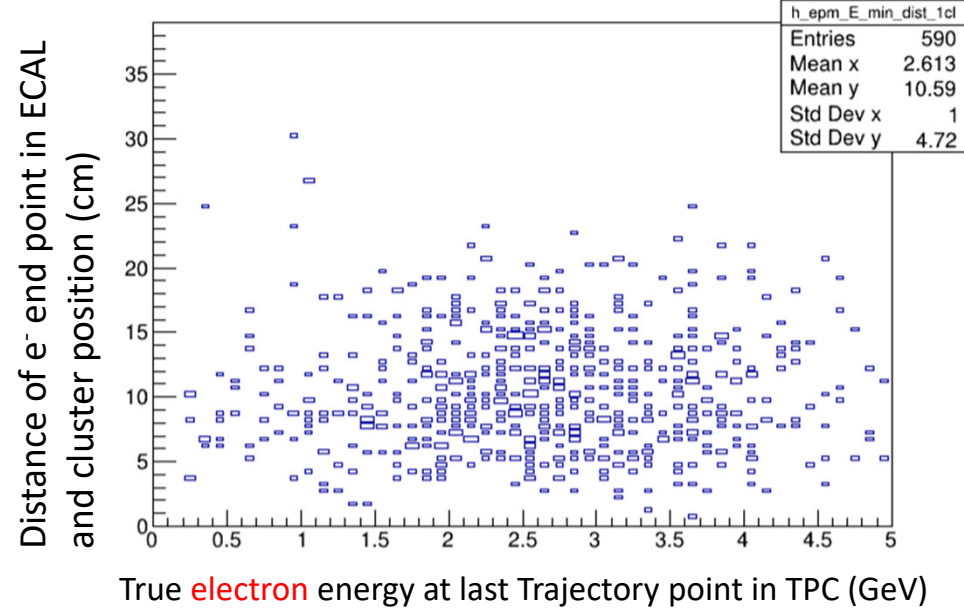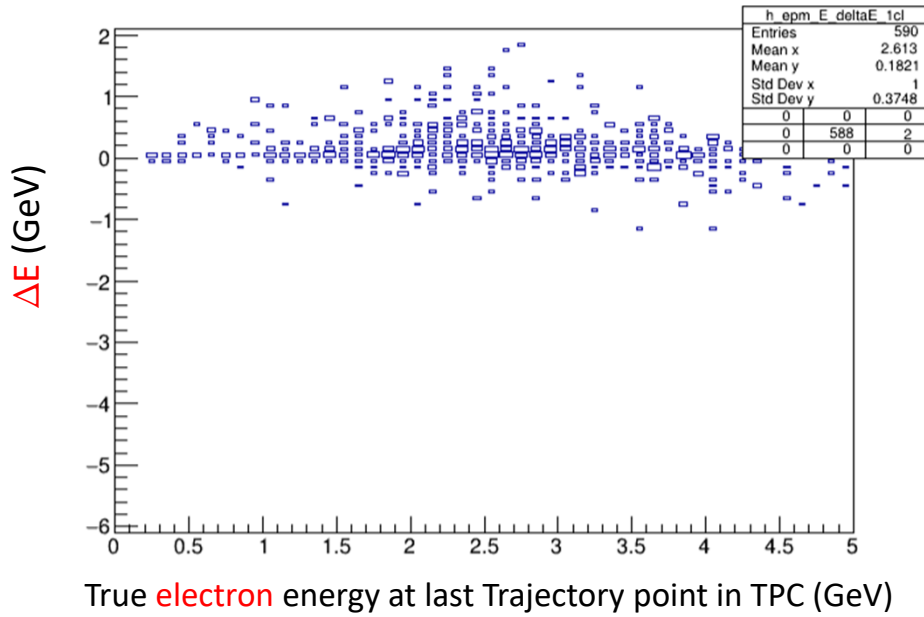
Fit to
Y-projection

Misses the peak
By a lot

Fit to
Y-projection

Mean ~ 10 cm
σ ~ 4.3 cm
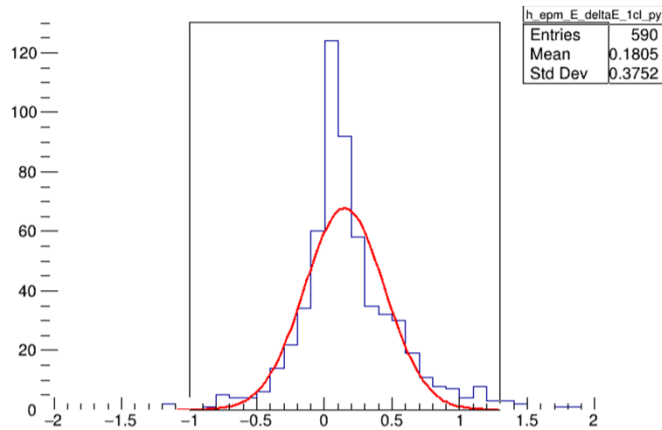
ΔE'' = Σ(all clusters back-tracked to electron) + Σ(all clusters back-tracked to brem from electron)
  + Σ(all clusters back-tracked to daughters of brems from electron)
  - Electron energy at production point

(# entries is now 981)

Should use a asymmetric Gaussian

Single Gaussian Fit:

Mean: -18±6 MeV
Sigma: 146±5 MeV

h_epm_startE_deltaE_wBrem_daul_py	
Entries	981
Mean	−0.0701
Std Dev	0.2426

ΔE'' (GeV)

ΔE'' (GeV)

h_xcre_startE_deltaE_wBrem_daul	
Entries	981
Mean x	2.972
Mean y	−0.07237
Std Dev x	0.9148
Std Dev y	0.252

True electron energy at starting point (GeV)