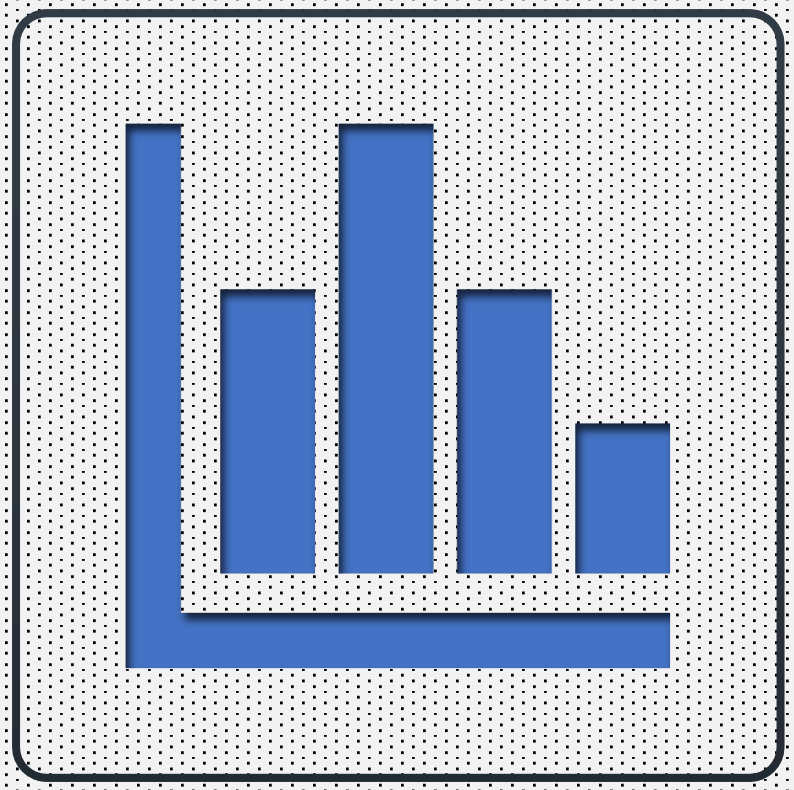


STAR Forward Upgrade Face to Face Meeting July 2020

Z-dependent Light Collection Efficiency
Update On HCal Calibration

Navagyan Ghimire

07/21/2020

HCal Z-dependence Light Collection Efficiency

- It is assumed that all towers have longitudinal uniform-light collection efficiency.
- Beam Test by Oleg at FNAL shows there is longitudinal non-uniformity light collection, and this non-uniformity is different for different towers due to defect in Wavelength Shifting (WLS) bars used to collect light.
- Ideally, response from every tower is the sum of energy deposited in each scintillating tiles in the tower. However, due to different longitudinal non-uniformity light collection for different tower, Oleg suggested two weighting method for energy deposited in tiles
  - Normal (for normal towers)
  - Bad (for bad towers)
- Akio implemented these weighting method in the Geometry xml file.
  https://www.star.bnl.gov/protected/spin/akio/fcs/lcz/index.html
- Now StFcsFastSimulationMaker has 3 different option to select different weighting method
  - Unmodified (energy response without any parametrization)
  - Normal
  - Bad

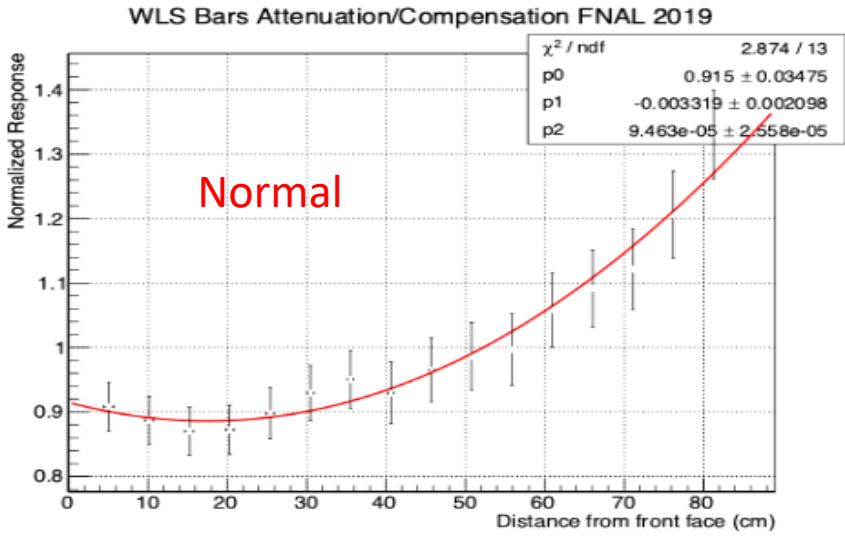


Fig1:weights for Sc. Tiles in normal towers

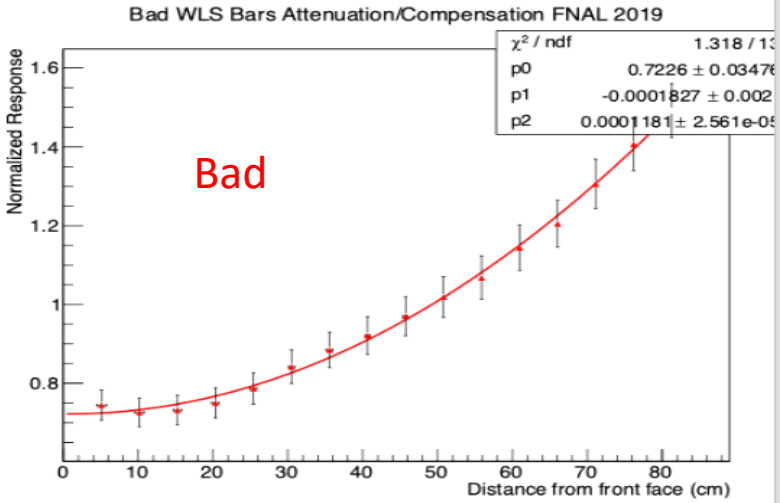


Fig2:weights for the Sc. Tiles in bad towers

*Plots are form Oleg's Study

HCal Z-dependence Light Collection Efficiency

- Shooting Particle:
  - Single pi+ 100k event
  - Energy = 6,10,20,30,60,100 GeV
  - Eta~ 3
  - Phi=0 to 2*pi
  - Ecal on, Hcal on
  - No Cut in individual tower Energy,
  - Total Energy in HCal+ECal>0.6 GeV

- Energy Resolution $\left(\frac{\sigma}{E}\right)$ is calculated with Gaussian Fit Range = Mode ± 25% of histogram for different weighting method.

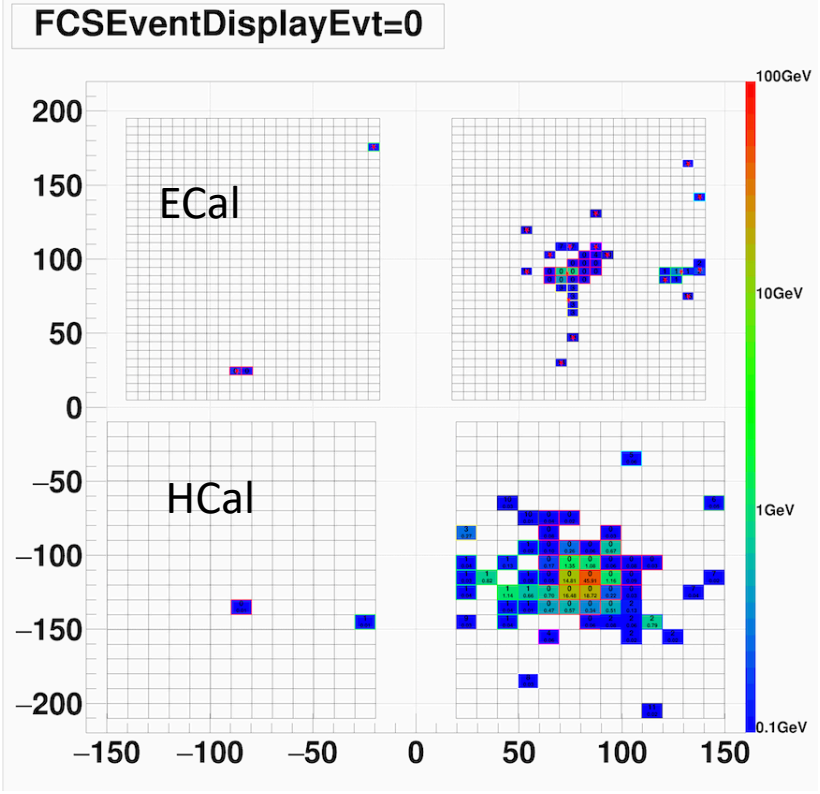
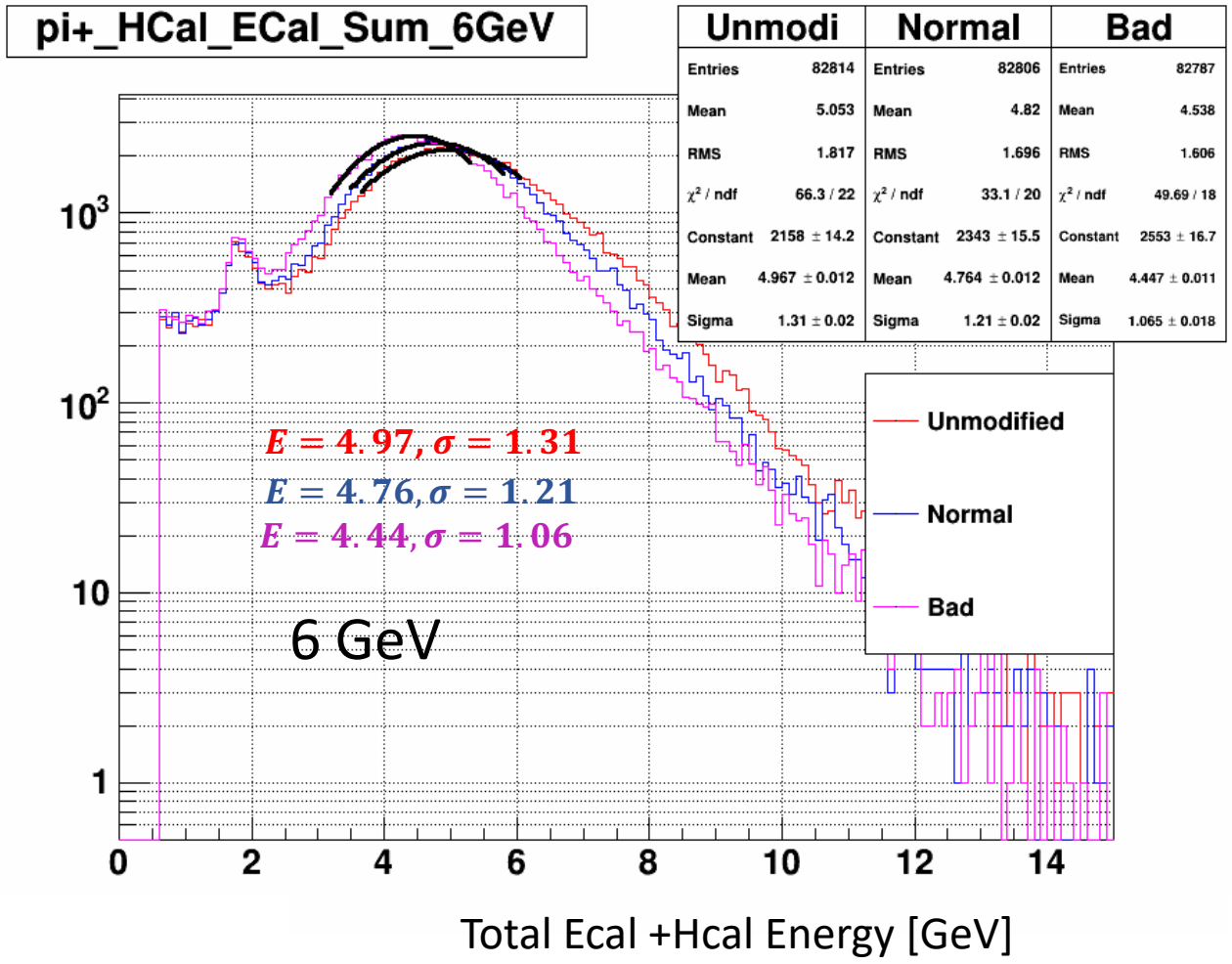
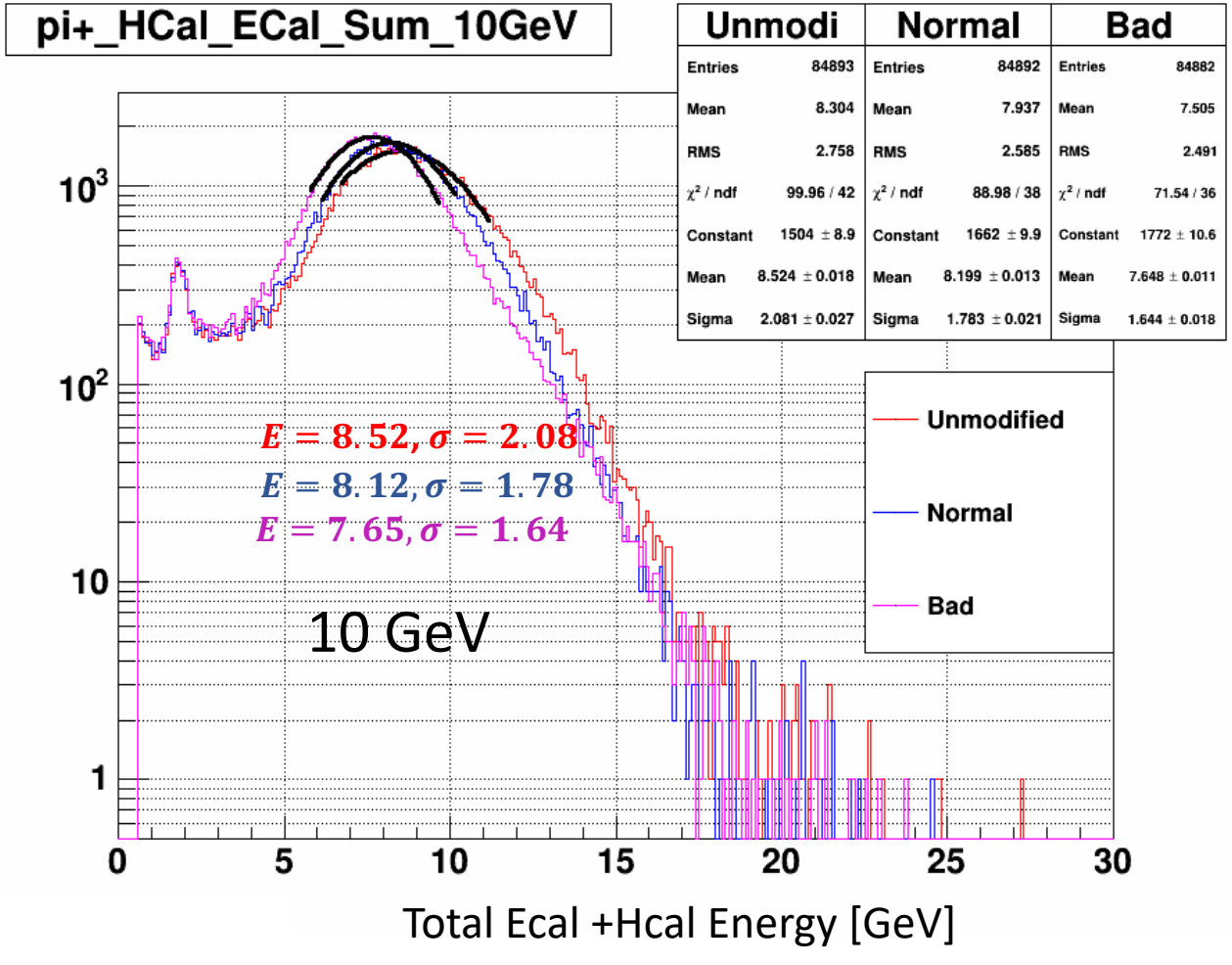


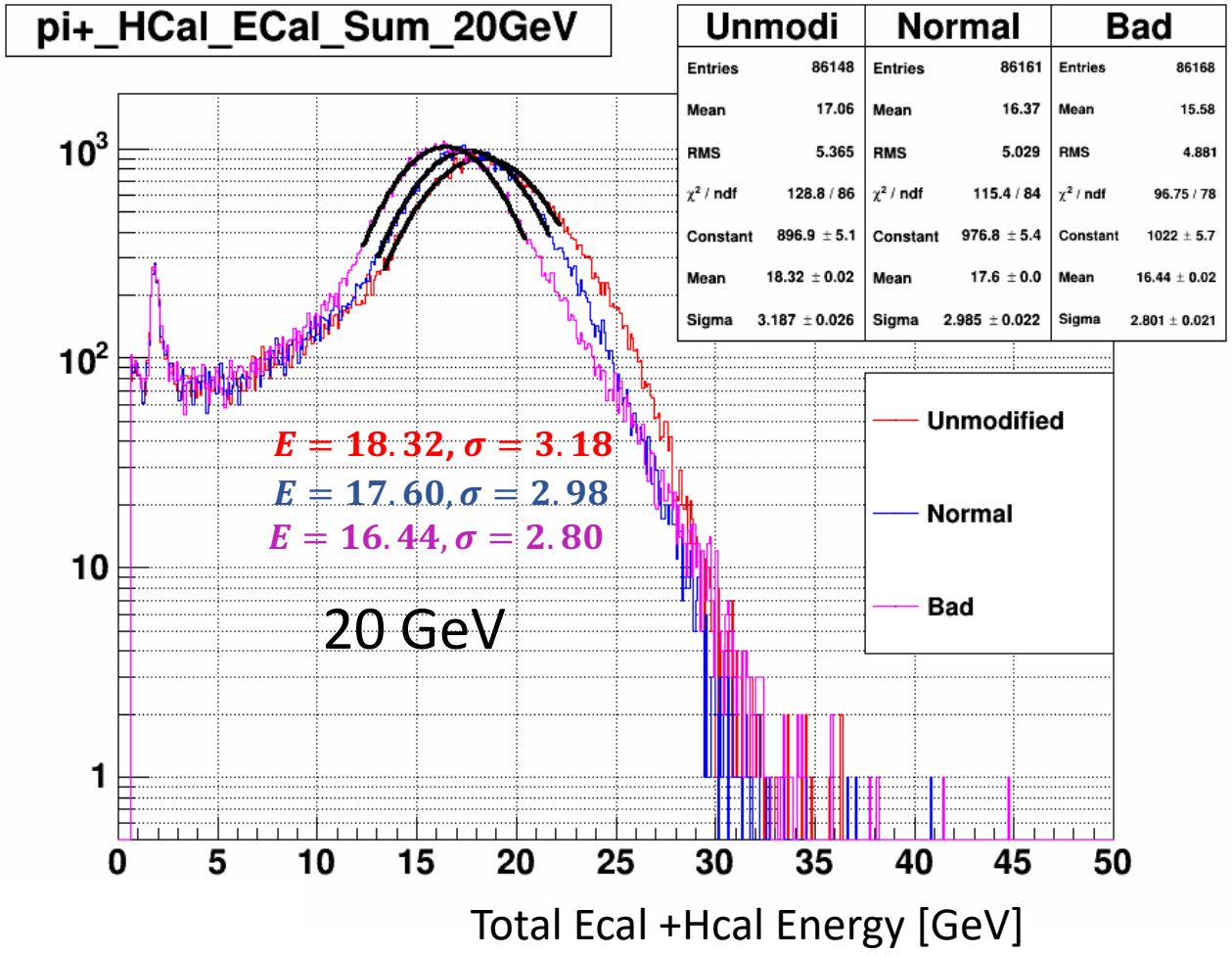
Fig: pi+ event in event display

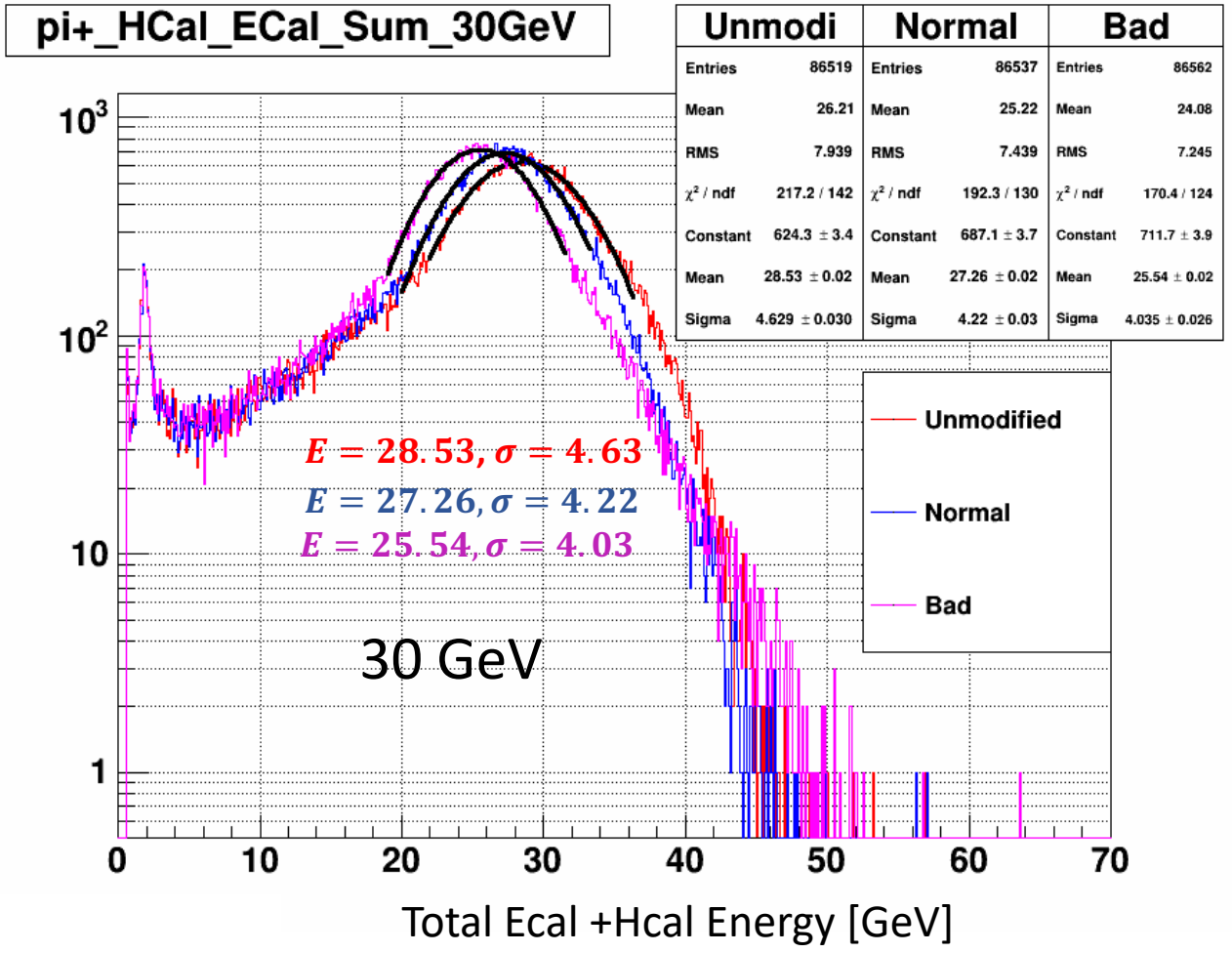
pi+


pi+_HCal_ECal_Sum_6GeV
Unmodi
Entries 82814
Mean 5.053
RMS 1.817
χ² / ndf 66.3 / 22
Constant 2158 ± 14.2
Mean 4.967 ± 0.012
Sigma 1.31 ± 0.02
Normal
Entries 82806
Mean 4.82
RMS 1.696
χ² / ndf 33.1 / 20
Constant 2343 ± 15.5
Mean 4.764 ± 0.012
Sigma 1.21 ± 0.02
Bad
Entries 82787
Mean 4.538
RMS 1.606
χ² / ndf 49.69 / 18
Constant 2553 ± 16.7
Mean 4.447 ± 0.011
Sigma 1.065 ± 0.018
$E = 4.97, \sigma = 1.31$
$E = 4.76, \sigma = 1.21$
$E = 4.44, \sigma = 1.06$
6 GeV
Unmodified
Normal
Bad
Total Ecal +Hcal Energy [GeV]

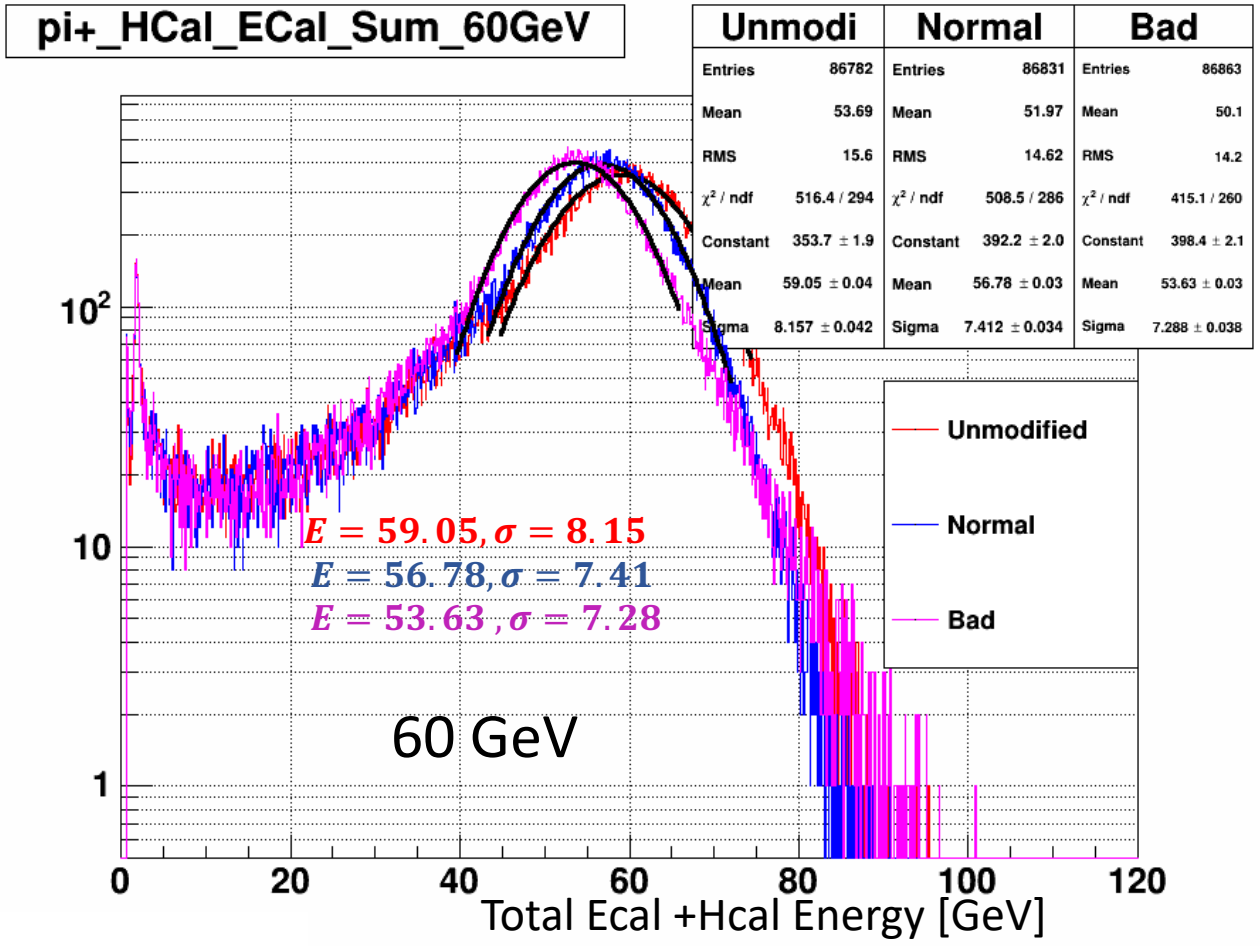

pi+_HCal_ECal_Sum_10GeV
Unmodi
Entries 84893
Mean 8.304
RMS 2.758
χ² / ndf 99.96 / 42
Constant 1504 ± 8.9
Mean 8.524 ± 0.018
Sigma 2.081 ± 0.027
Normal
Entries 84892
Mean 7.937
RMS 2.585
χ² / ndf 88.98 / 38
Constant 1662 ± 9.9
Mean 8.199 ± 0.013
Sigma 1.783 ± 0.021
Bad
Entries 84882
Mean 7.505
RMS 2.491
χ² / ndf 71.54 / 36
Constant 1772 ± 10.6
Mean 7.648 ± 0.011
Sigma 1.644 ± 0.018
$E = 8.52, \sigma = 2.08$
$E = 8.12, \sigma = 1.78$
$E = 7.65, \sigma = 1.64$
10 GeV
Unmodified
Normal
Bad
Total Ecal +Hcal Energy [GeV]

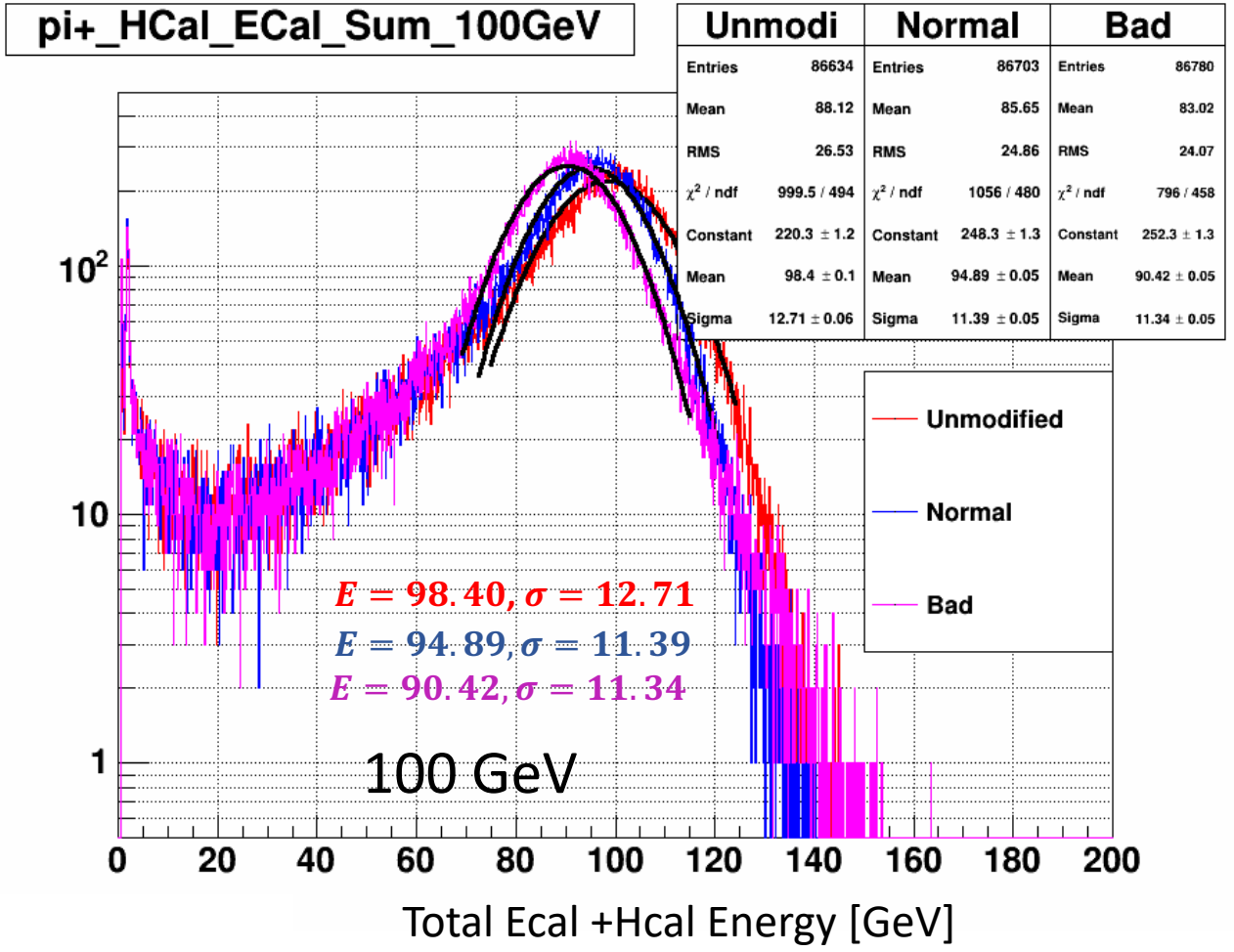
pi+


pi+_HCal_ECal_Sum_20GeV
Unmodi
Entries 86148
Mean 17.06
RMS 5.365
χ² / ndf 128.8 / 86
Constant 896.9 ± 5.1
Mean 18.32 ± 0.02
Sigma 3.187 ± 0.026
Normal
Entries 86161
Mean 16.37
RMS 5.029
χ² / ndf 115.4 / 84
Constant 976.8 ± 5.4
Mean 17.6 ± 0.0
Sigma 2.985 ± 0.022
Bad
Entries 86168
Mean 15.58
RMS 4.881
χ² / ndf 96.75 / 78
Constant 1022 ± 5.7
Mean 16.44 ± 0.02
Sigma 2.801 ± 0.021
$E = 18.32, \sigma = 3.18$
$E = 17.60, \sigma = 2.98$
$E = 16.44, \sigma = 2.80$
20 GeV
Unmodified
Normal
Bad
Total Ecal +Hcal Energy [GeV]


pi+_HCal_ECal_Sum_30GeV
Unmodi
Entries 86519
Mean 26.21
RMS 7.939
χ² / ndf 217.2 / 142
Constant 624.3 ± 3.4
Mean 28.53 ± 0.02
Sigma 4.629 ± 0.030
Normal
Entries 86537
Mean 25.22
RMS 7.439
χ² / ndf 192.3 / 130
Constant 687.1 ± 3.7
Mean 27.26 ± 0.02
Sigma 4.22 ± 0.03
Bad
Entries 86562
Mean 24.08
RMS 7.245
χ² / ndf 170.4 / 124
Constant 711.7 ± 3.9
Mean 25.54 ± 0.02
Sigma 4.035 ± 0.026
$E = 28.53, \sigma = 4.63$
$E = 27.26, \sigma = 4.22$
$E = 25.54, \sigma = 4.03$
30 GeV
Unmodified
Normal
Bad
Total Ecal +Hcal Energy [GeV]

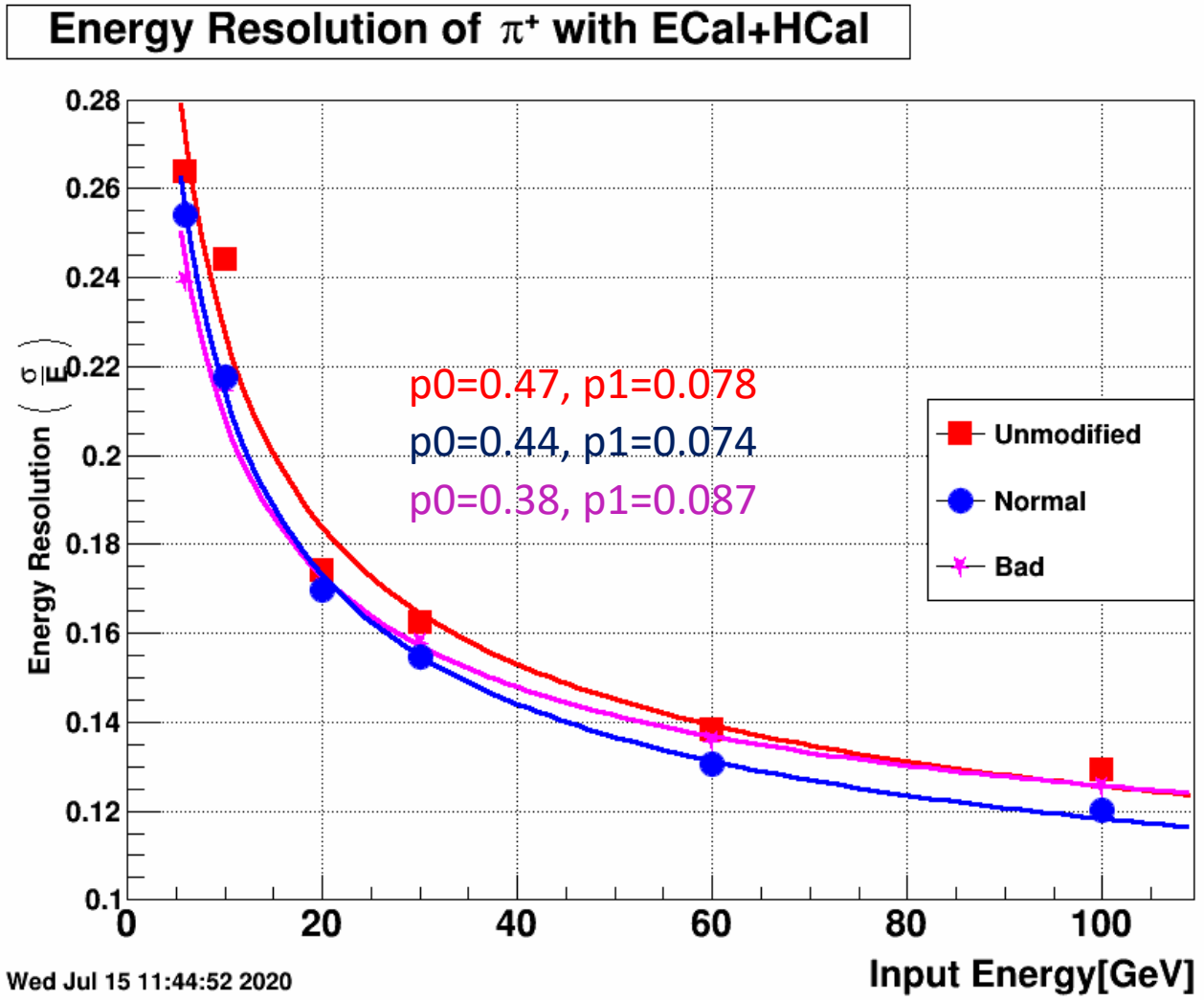
pi+


pi+_HCal_ECal_Sum_60GeV
Unmodi
Entries 86782
Mean 53.69
RMS 15.6
χ² / ndf 516.4 / 294
Constant 353.7 ± 1.9
Mean 59.05 ± 0.04
Sigma 8.157 ± 0.042
Normal
Entries 86831
Mean 51.97
RMS 14.62
χ² / ndf 508.5 / 286
Constant 392.2 ± 2.0
Mean 56.78 ± 0.03
Sigma 7.412 ± 0.034
Bad
Entries 86863
Mean 50.1
RMS 14.2
χ² / ndf 415.1 / 260
Constant 398.4 ± 2.1
Mean 53.63 ± 0.03
Sigma 7.288 ± 0.038
Unmodified
Normal
Bad
$E = 59.05, \sigma = 8.15$
$E = 56.78, \sigma = 7.41$
$E = 53.63, \sigma = 7.28$
60 GeV
Total Ecal +Hcal Energy [GeV]


pi+_HCal_ECal_Sum_100GeV
Unmodi
Entries 86634
Mean 88.12
RMS 26.53
χ² / ndf 999.5 / 494
Constant 220.3 ± 1.2
Mean 98.4 ± 0.1
Sigma 12.71 ± 0.06
Normal
Entries 86703
Mean 85.65
RMS 24.86
χ² / ndf 1056 / 480
Constant 248.3 ± 1.3
Mean 94.89 ± 0.05
Sigma 11.39 ± 0.05
Bad
Entries 86780
Mean 83.02
RMS 24.07
χ² / ndf 796 / 458
Constant 252.3 ± 1.3
Mean 90.42 ± 0.05
Sigma 11.34 ± 0.05
Unmodified
Normal
Bad
$E = 98.40, \sigma = 12.71$
$E = 94.89, \sigma = 11.39$
$E = 90.42, \sigma = 11.34$
100 GeV
Total Ecal +Hcal Energy [GeV]

Energy Resolution for pi+

$$Fit = \frac{p0}{\sqrt{E}} + p1$$



Summary

- “from our previous studies with Pb/Sc calorimeter where we saw constant term exploding to 15% from 7% with non-uniform light collection along Z and were surprised when we have not seen this with Fe/Sc structure running GEANT4.”-Oleg Tsai

- Our result is consistent with Oleg Tsai result.

- Overall longitudinal non-uniformities in light collection efficiency along Z has very little effect in high energy range.

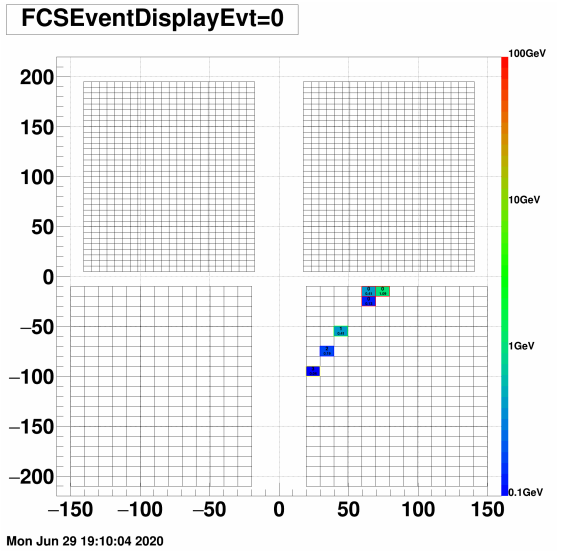
Update On HCal Calibration

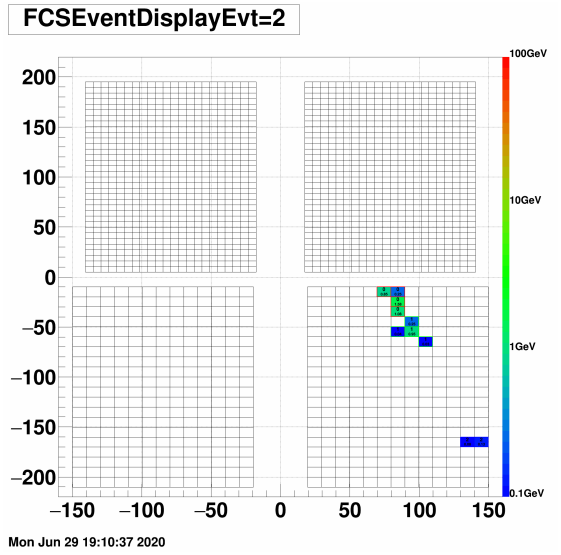
- In initial stages and most of the things are on progress.
- Trying to figure out best and feasible method to calibrate Hcal.
- Simulating cosmic muons and trying to see any peak that can be used for Calibration.

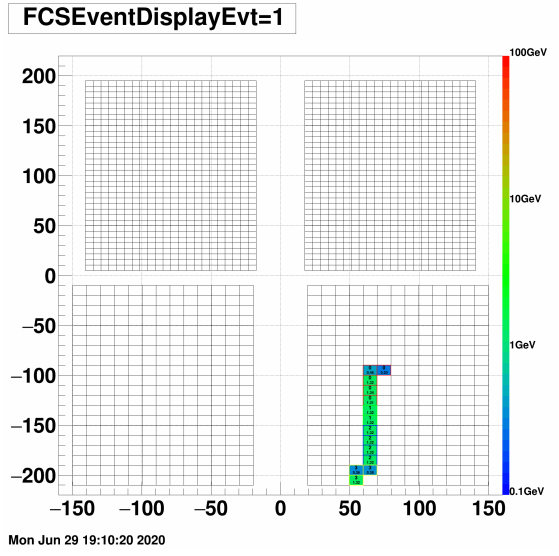
Cosmic Muon Response

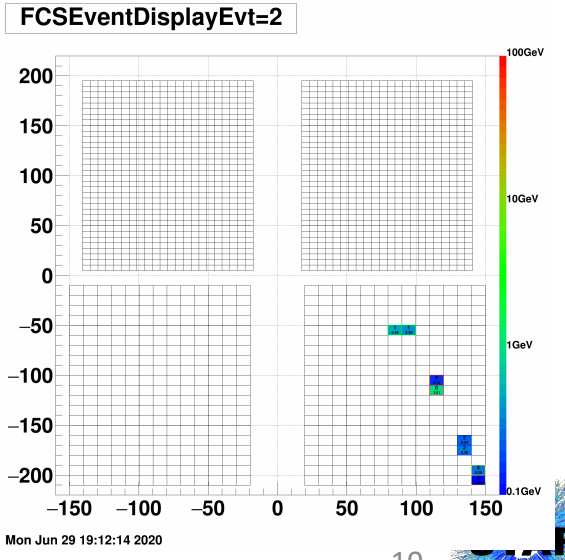
- For simple model, randomize the Vertex in X and Z direction and azimuthal angle only

- Shooting Particle:
  - Single mu+ event
  - 100k events
  - Energy = 1 GeV to 115 GeV
  - Vertex =(x_vertex,200,z_vertex)
  - 20<x_vertex<150
  - 805<z_vertex<890
  - $\eta \approx 0.01$
  - $\varphi \approx -0.7$ to -2.5
  - Smearing = (0,0,0)
  - Ecal on, Hcal on









Tower Energy and MC Phi

- In the simple 2D mode (varying phi only) we could see relation between phi angle and tower energy.
- This information might be useful to calibrate to individual tower.

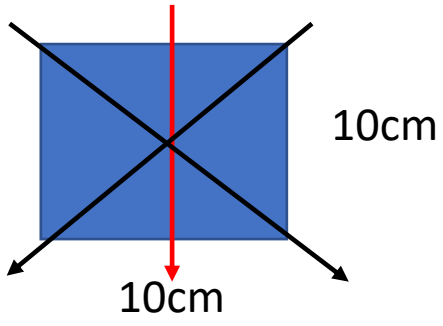
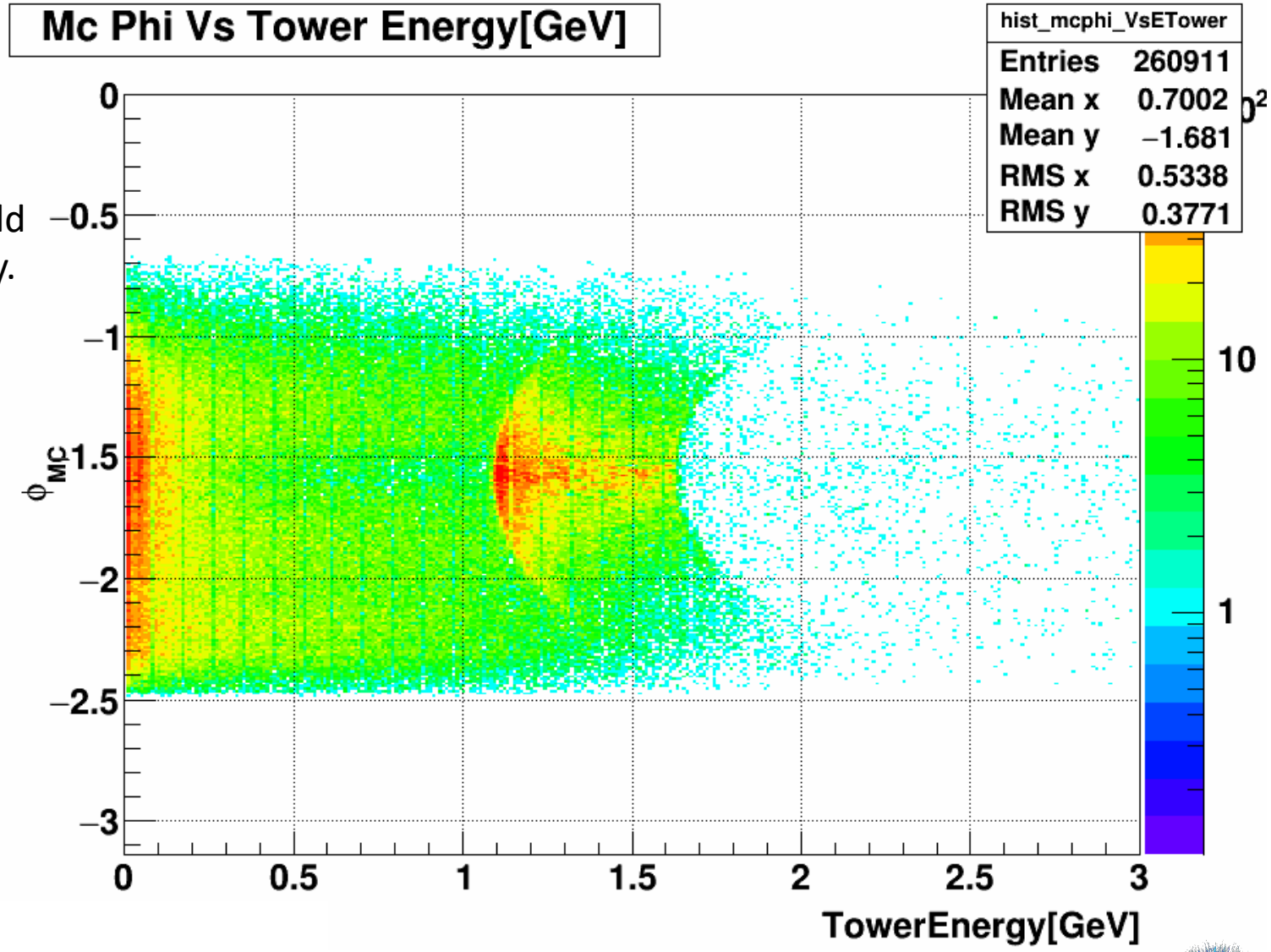
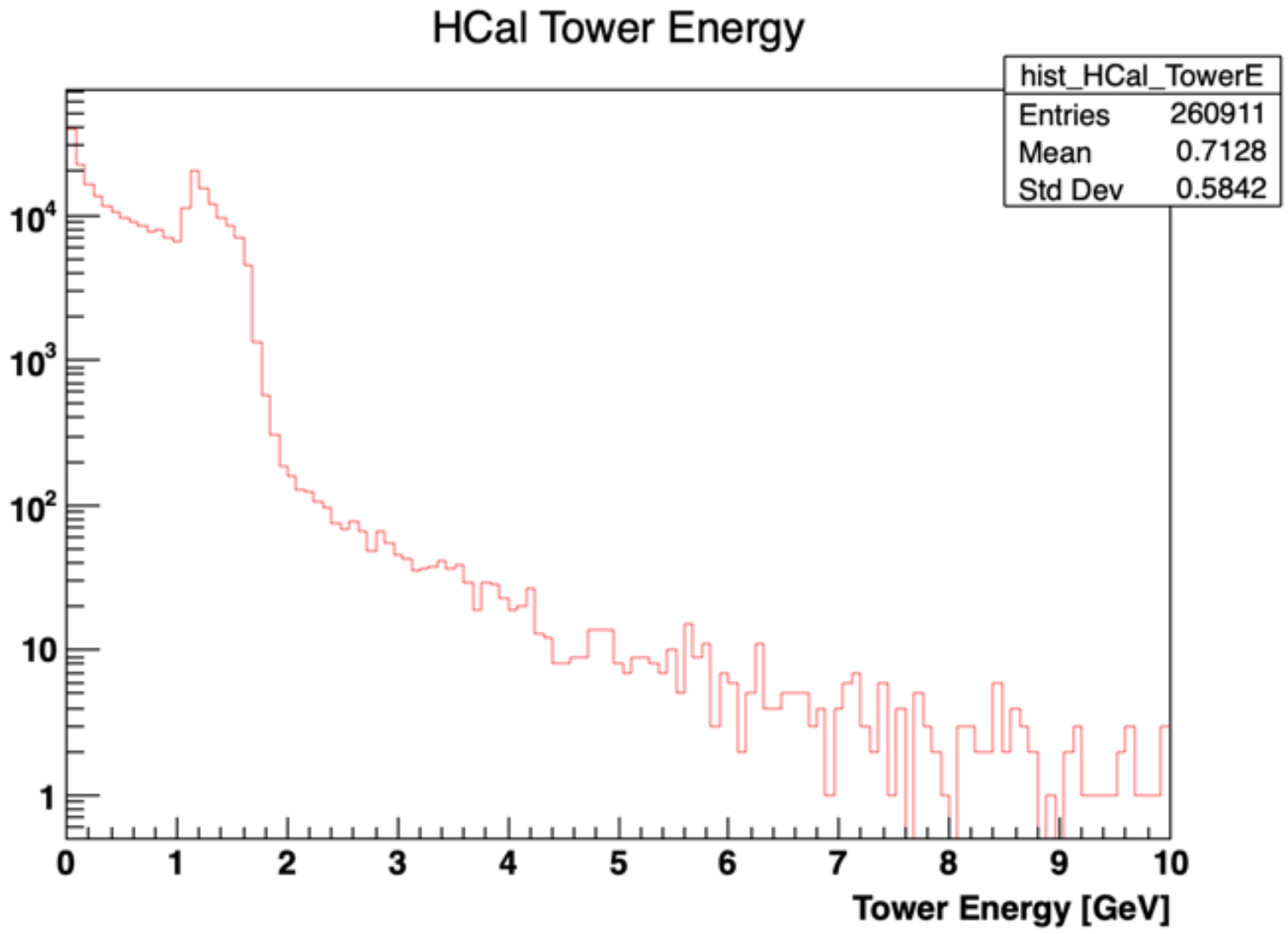


Fig: Sc plate



Tower Energy

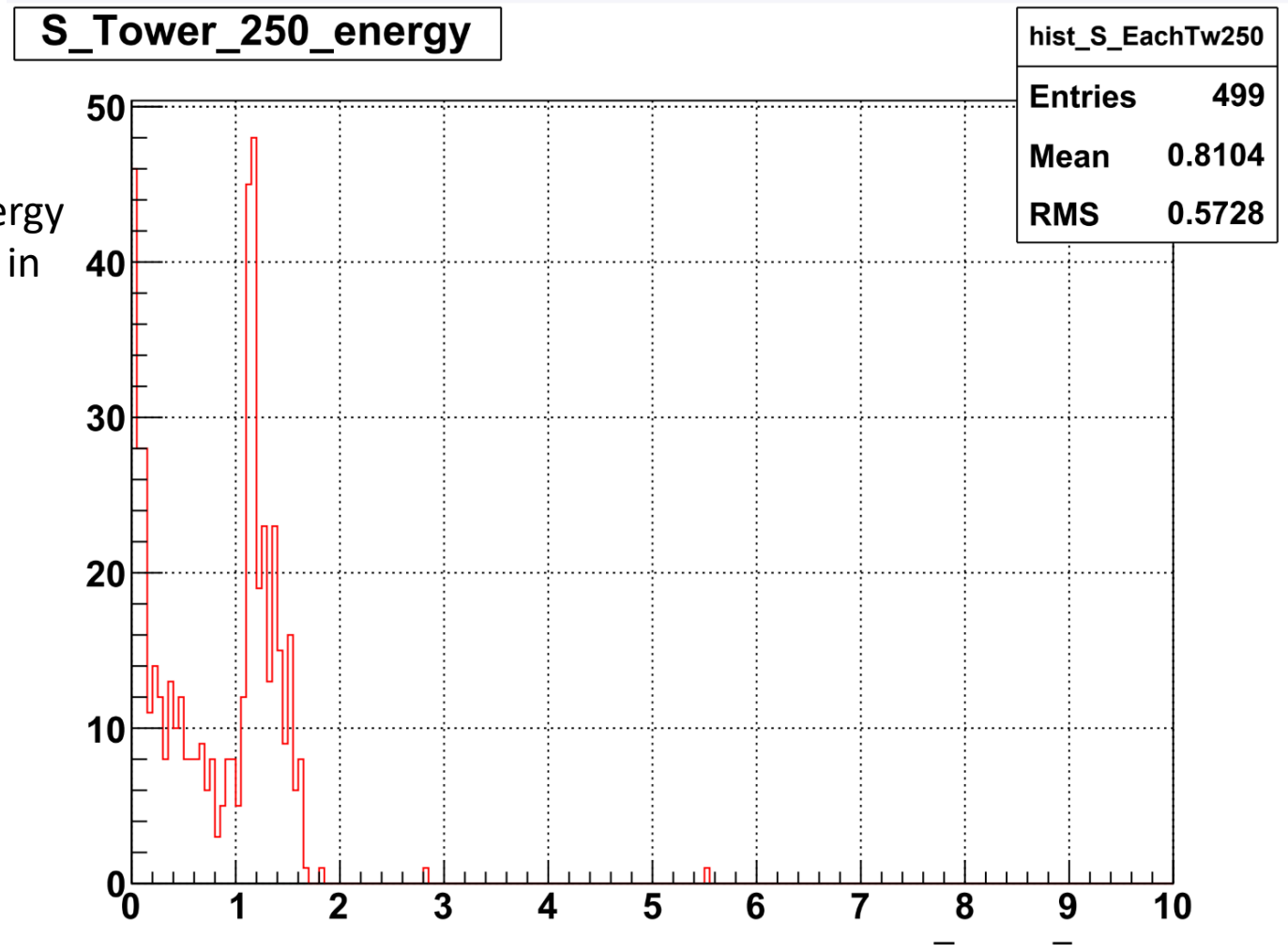


Hcal tower energy

Individual Tower Energy

- Each Tower could deposit around 1.2GeV energy
- Energy response from each tower can be find in the link below.

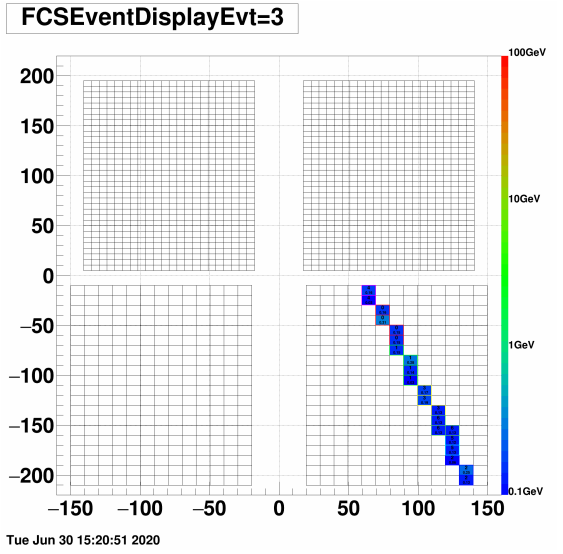
Link to individual tower of South Hcal_V6

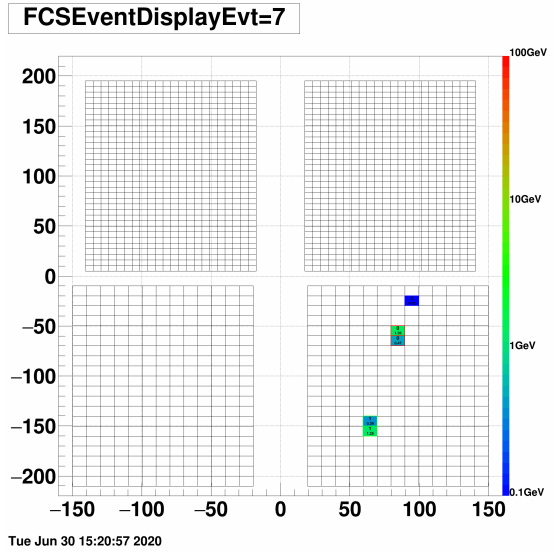


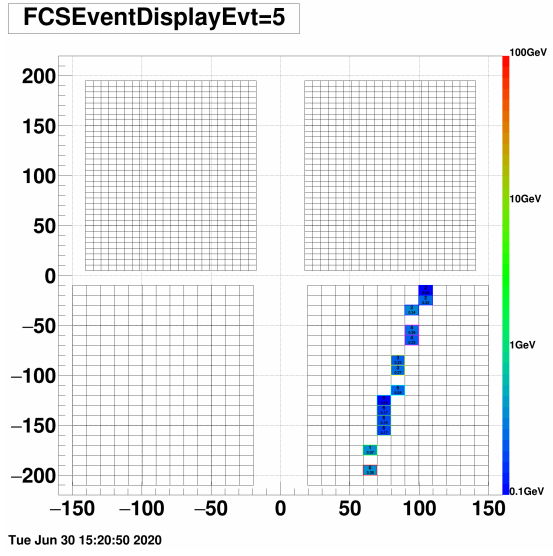
Cosmic Muon Response

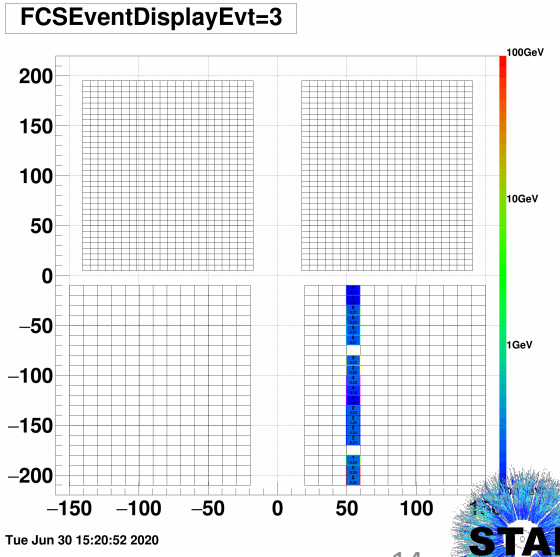
- For more realistic model, randomize vertex in X and Z direction, and varying Eta and Phi.

- Shooting Particle:
  - Single mu+ event
  - 300K events
  - Energy = 1 GeV to 115 GeV
  - $\eta \approx -0.80$ to 0.80
  - $\varphi \approx -0.70\ to\ -2.5$
  - Vertex =(x_vertex,200,z_vertex)
  - 20<x_vertex<150
  - 805<z_vertex<890
  - Smearing = (0,0,0)
  - Ecal on, Hcal on



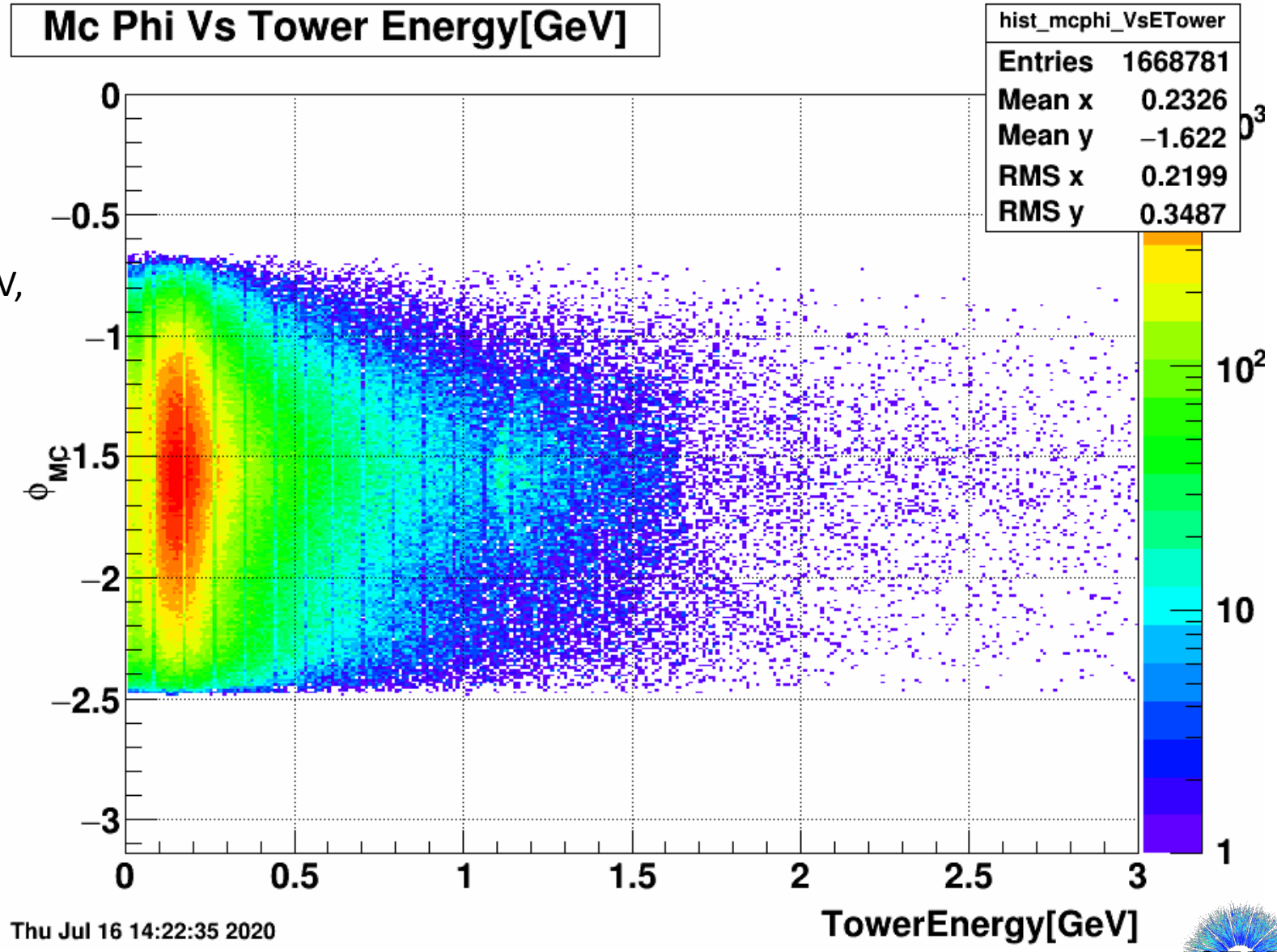




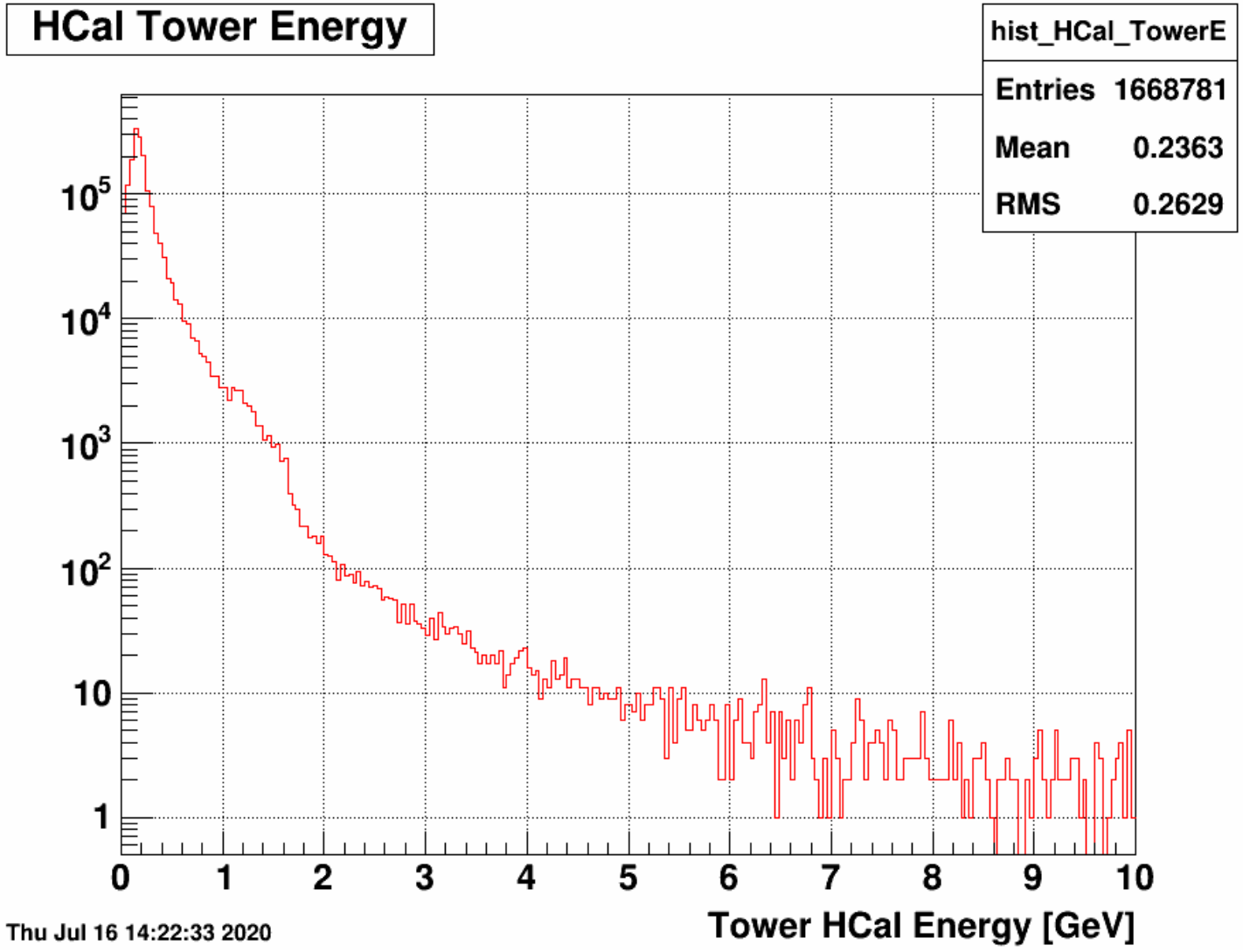


Tower Energy Vs Mc Phi

- Most of the tower energy is around 0.2 GeV, with 300K event we can see some of the tower has energy around 1.2GeV
- Need to investigate vertical lines in energy.



Tower Energy

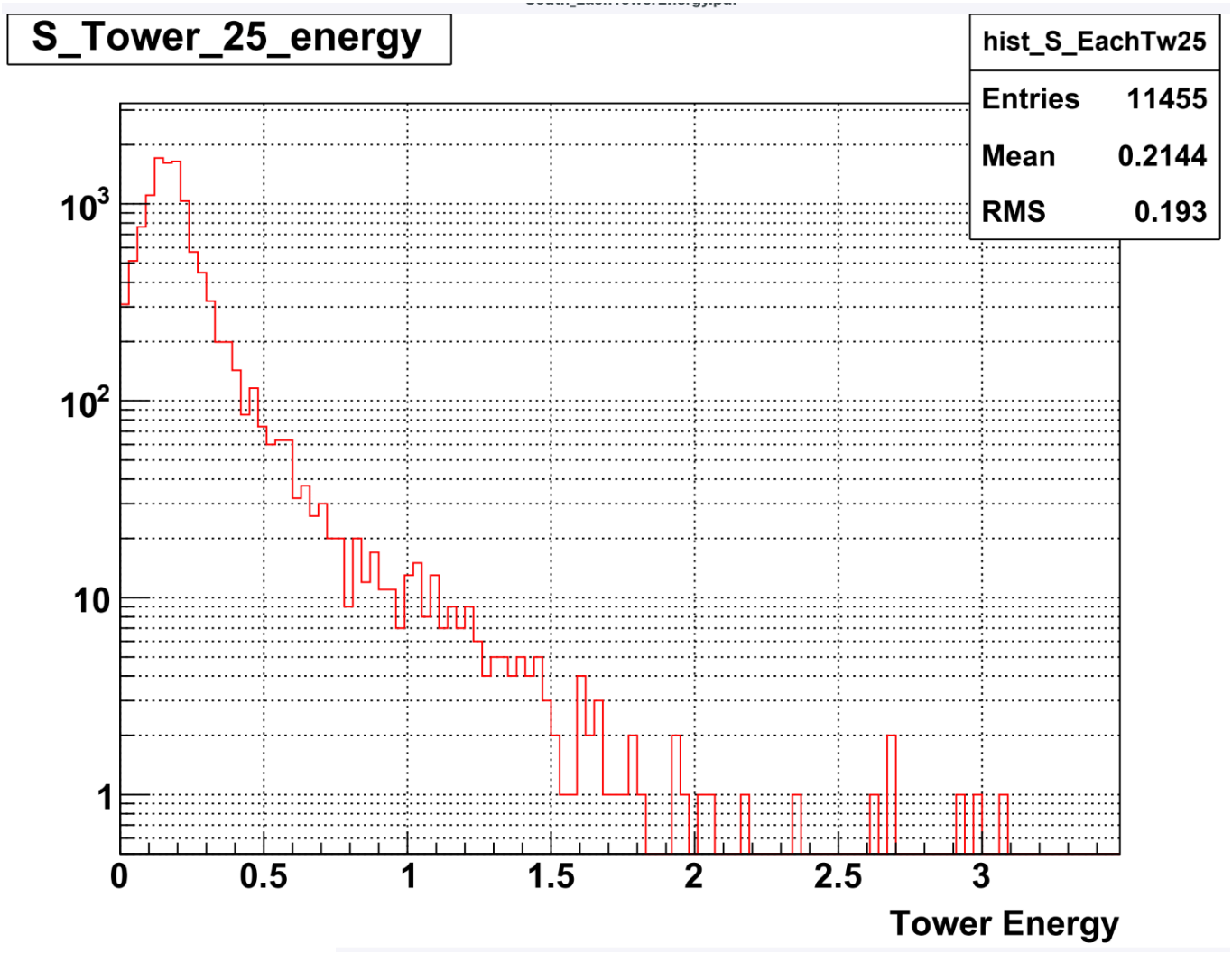


Hcal hit tower energy

Individual Tower Energy

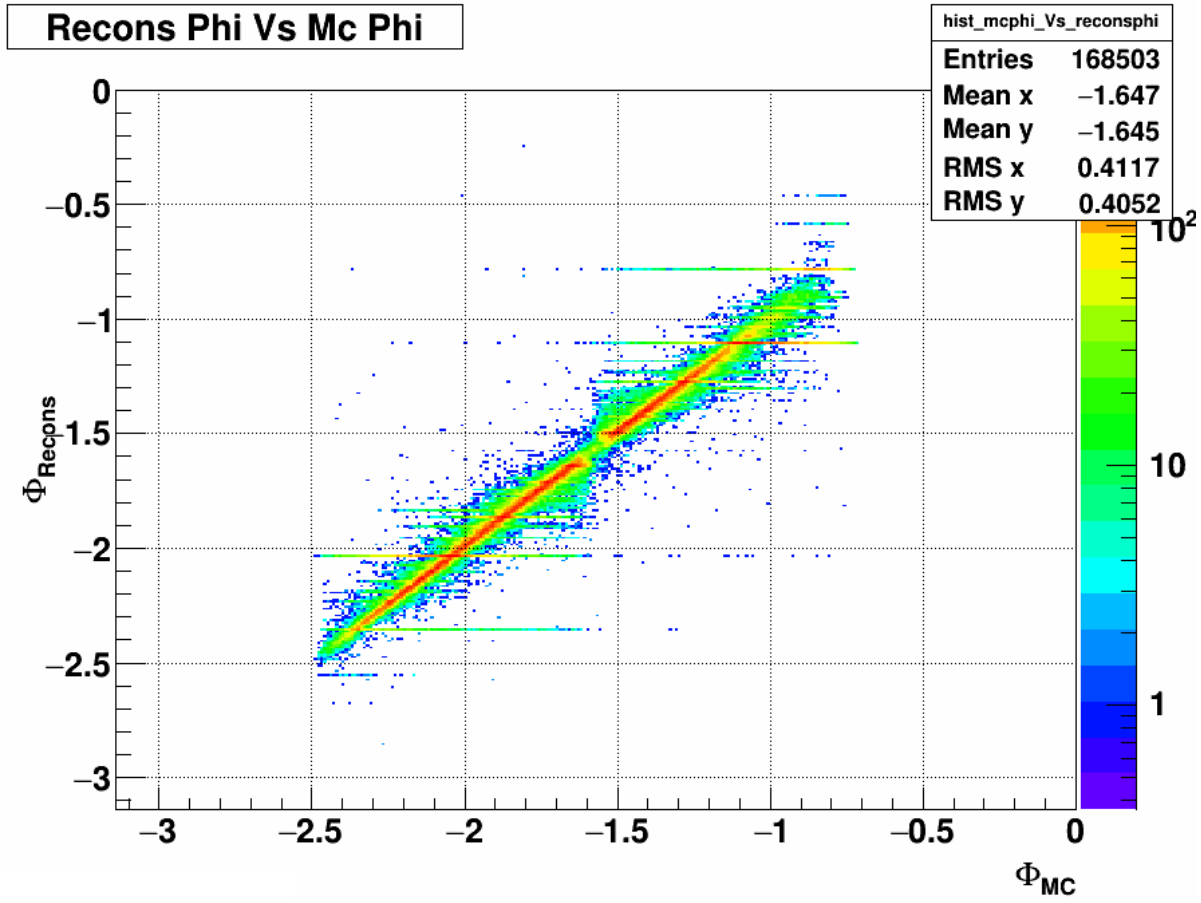
- Most of the tower have energy around 0.2 GeV
- Energy response from each tower can be find in the link below.

Link to individual tower of South Hcal_V10



Phi Angle Reconstruction

- Used Line of Best Fit(Least Square Method) to reconstruct the Phi angle
- 1/Slope = $\frac{(n*\Sigma xy-\Sigma x\Sigma y)}{(n*\Sigma y^2-(\Sigma y)^2)}$
  - n = number of hit tower
  - x = STAR X-coordinate of tower
  - y = STAR Y-coordinate of tower
- Working on to optimize reconstructed phi angle.



Muon Flux

Very Basic Calculation:

- Average Muon Flux = 1 Muon per square centimeter per minute at sea level*.
- Hcal Top Cross section area(South HCal only) = 130cm X 85cm = 11050 cm^2
- So 100k Event of mu+ requires 10^5/(11050) ≈ 9 min
- 300k Event of mu+ requires 30^5/(11050) ≈27min

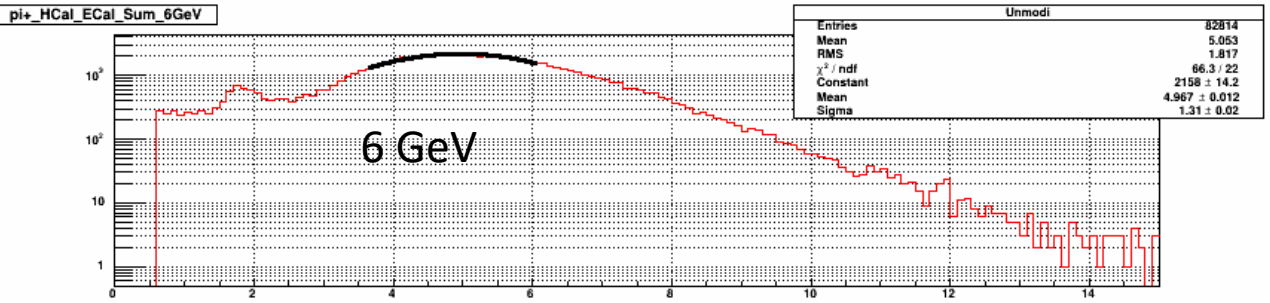
*https://cosmic.lbl.gov/SKliewer/Cosmic_Rays/Muons.htm

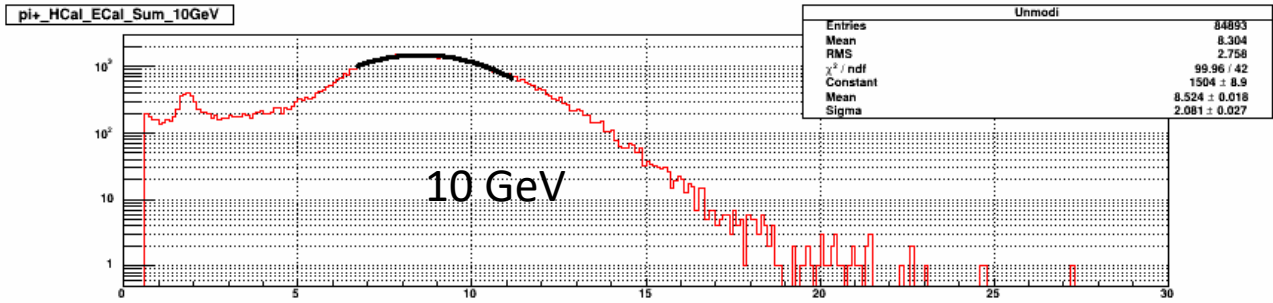
Summary

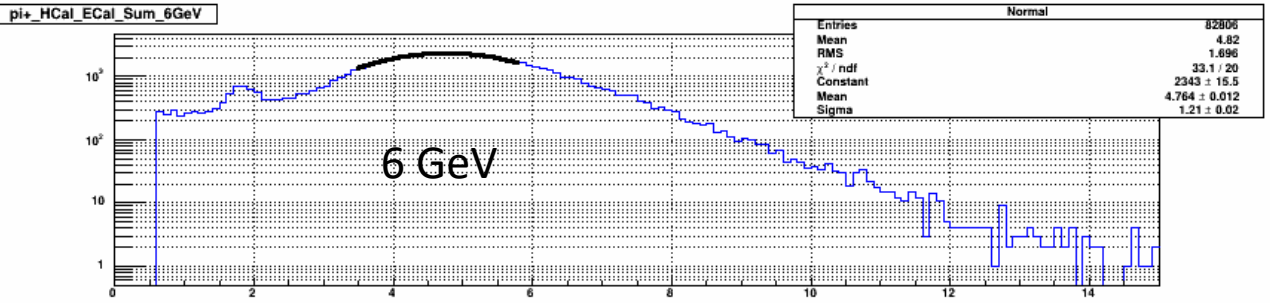
- In a simple model varying phi angle only (fixing Eta at 0.01), towers deposit around 1.2 GeV energy.
- In more realistic model, varying both eta(-0.8 to 0.8) and phi(-0.7,-2.5), most of the tower deposit around 0.2GeV energy.
- Investigating if this information will be useful or background will affect this energy peak.
- If we have enough statistics at very low eta tracks, then we can calibrate each tower with 1.2GeV energy peak.

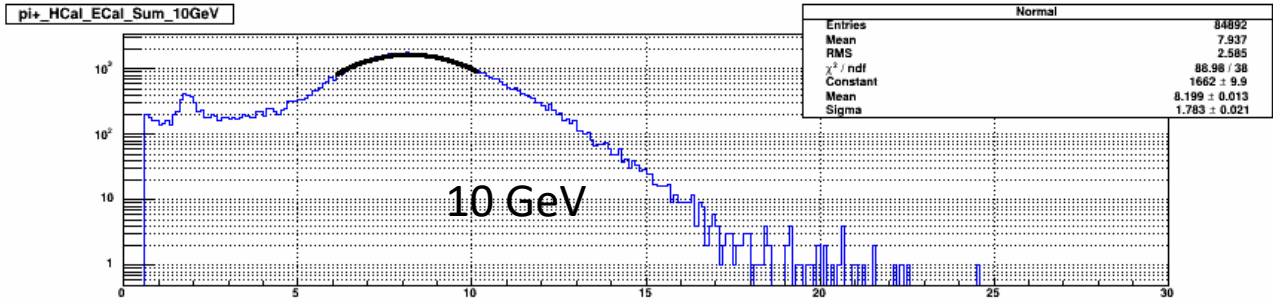
Backups

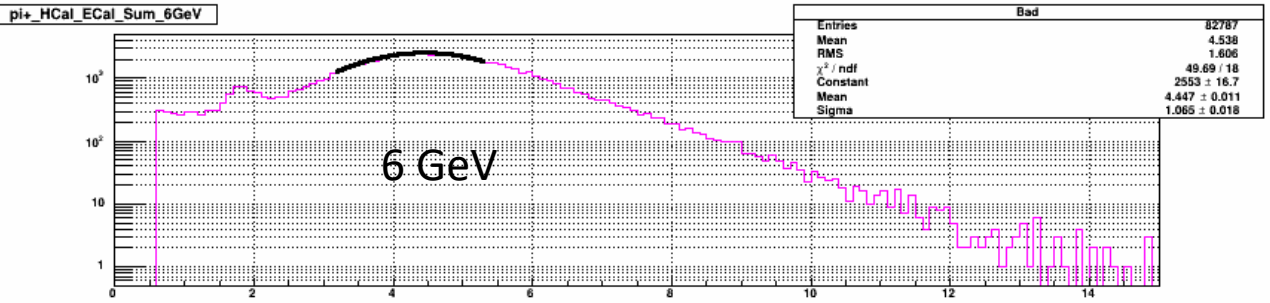
Backup: pi+ Individual method

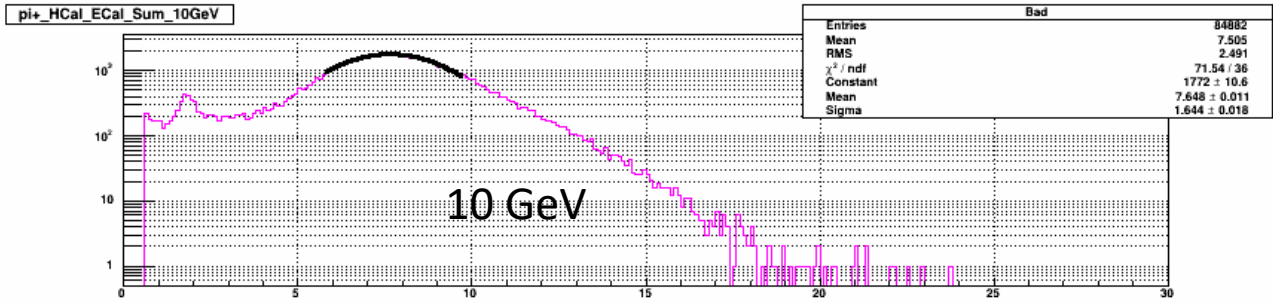








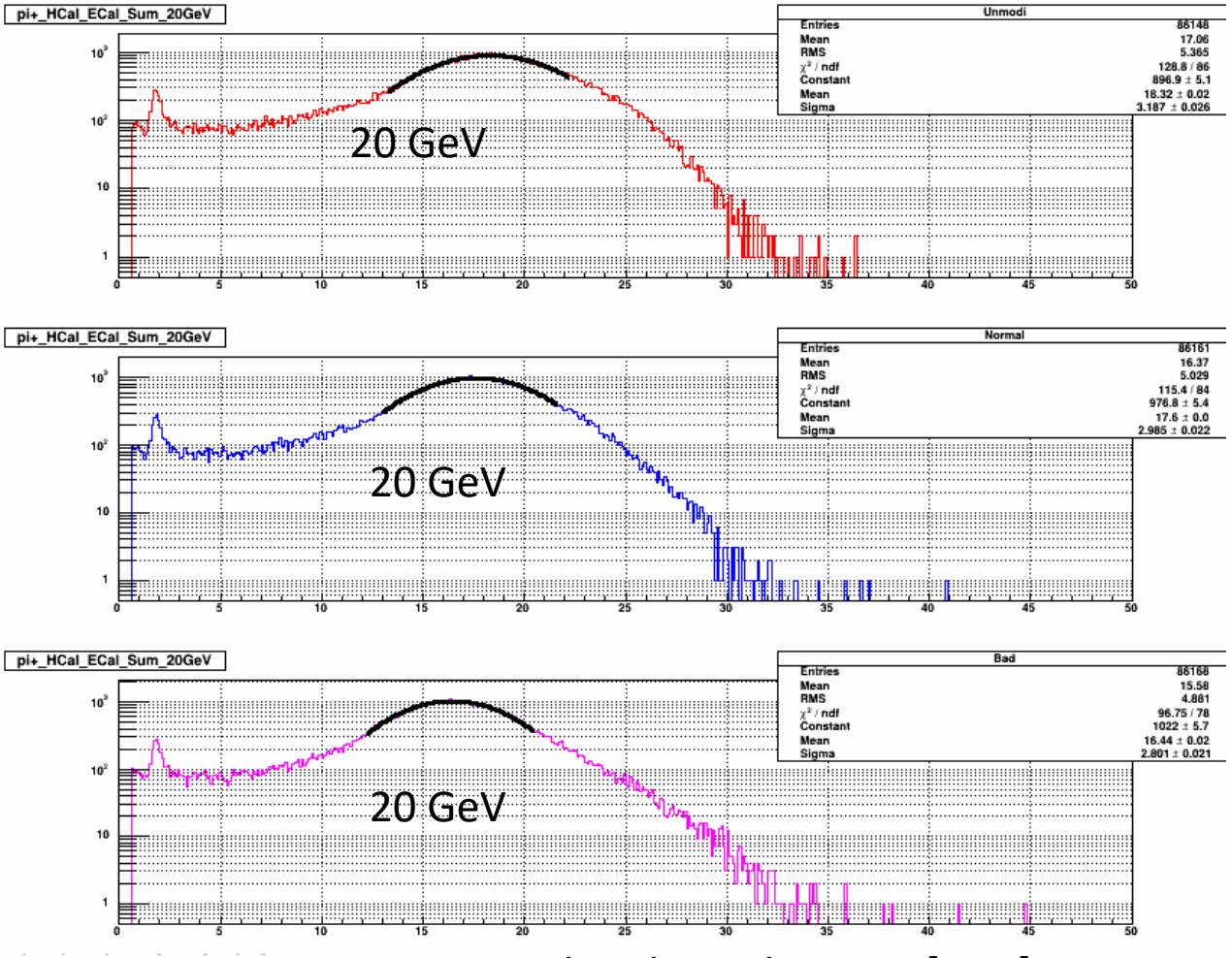


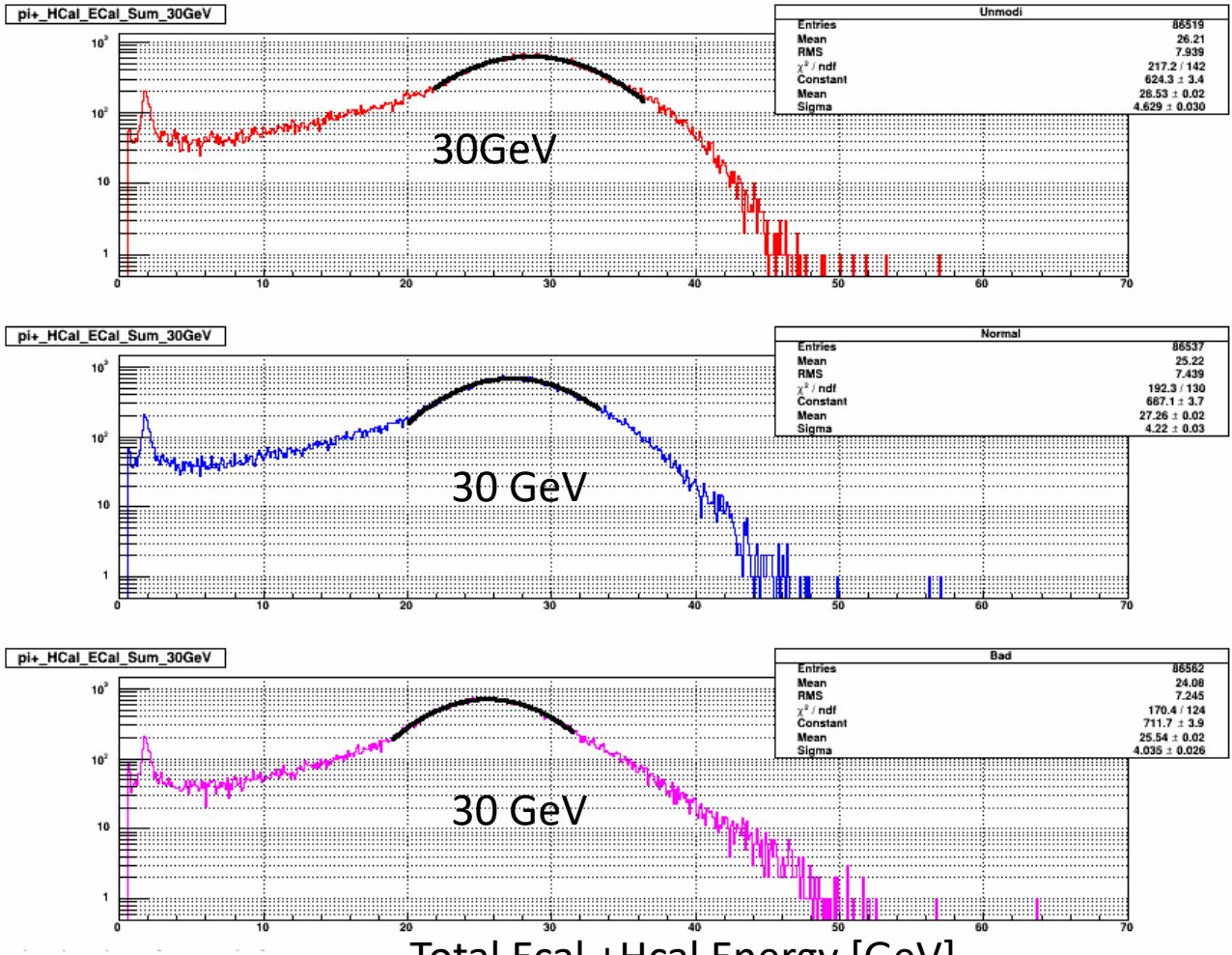


Total Ecal +Hcal Energy [GeV]

Total Ecal +Hcal Energy [GeV]

Backup: pi+ Individual method

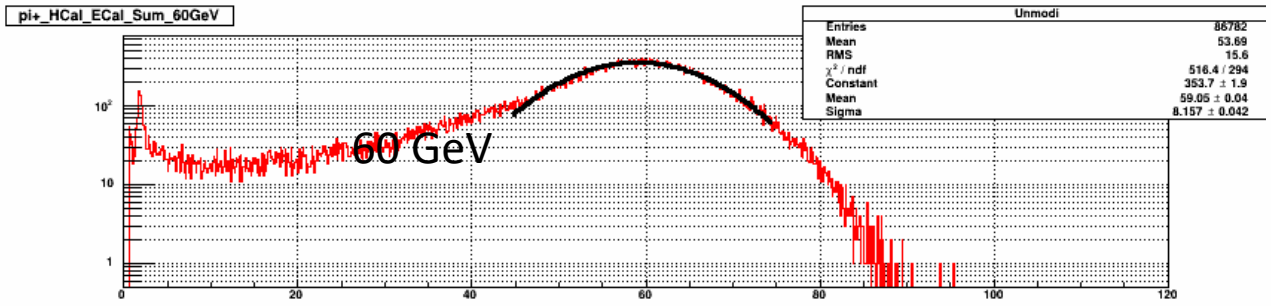


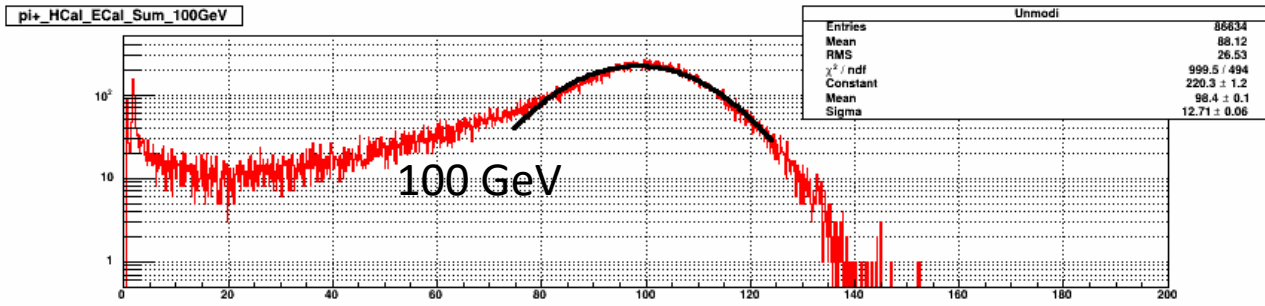


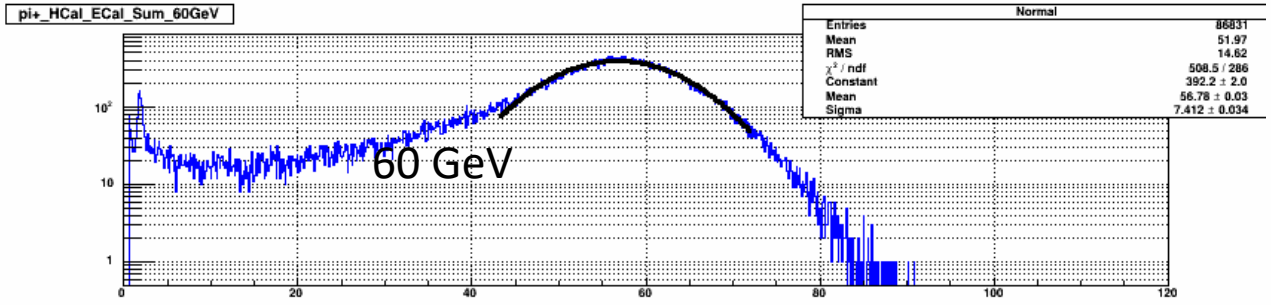
Total Ecal +Hcal Energy [GeV]

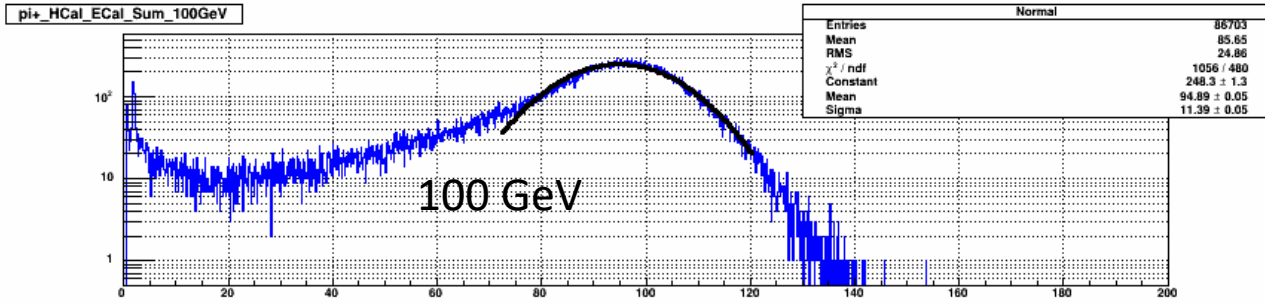
Total Ecal +Hcal Energy [GeV]

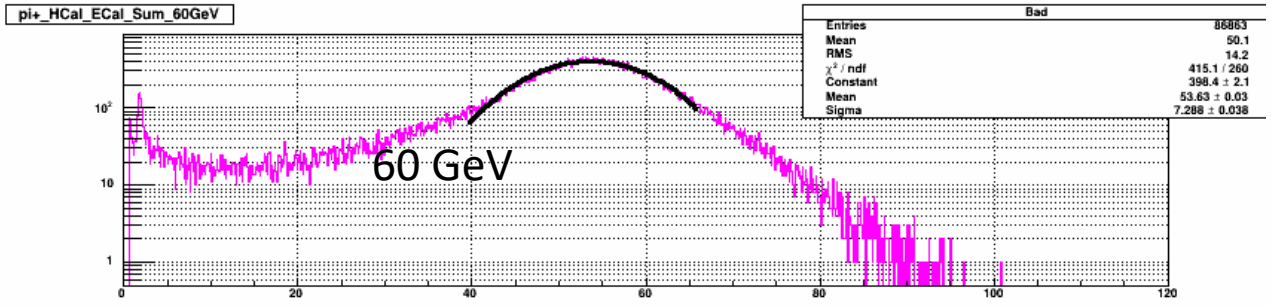
Backup: pi+ Individual method

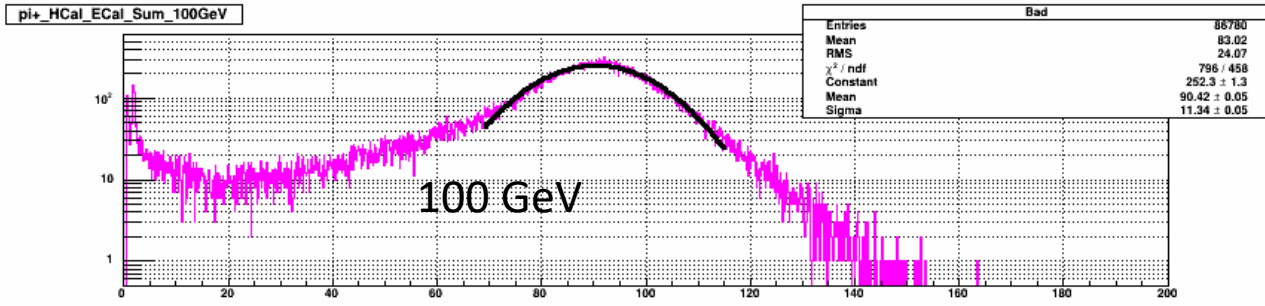








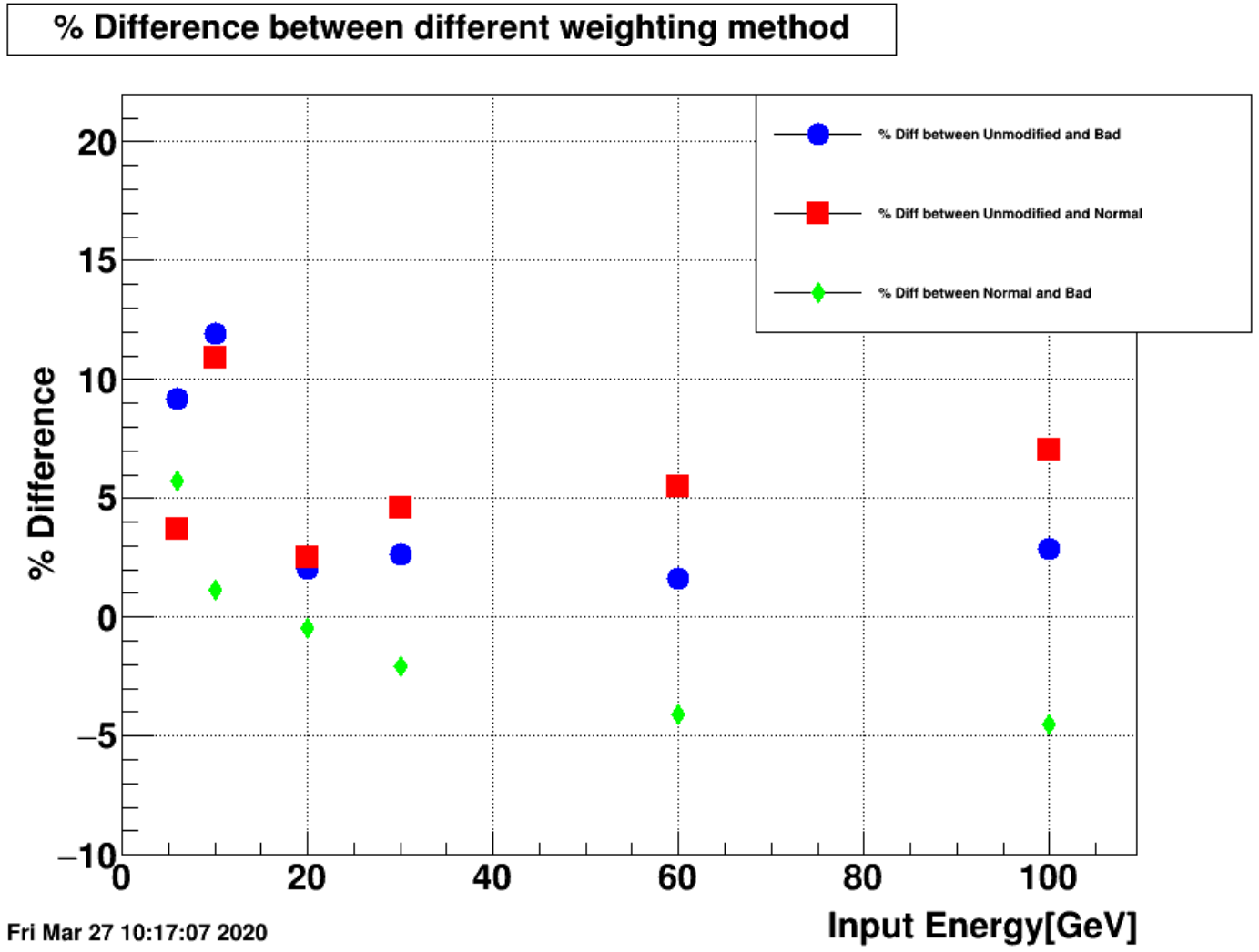




Total Ecal +Hcal Energy [GeV]

Total Ecal +Hcal Energy [GeV]

% Difference in Energy Resolution

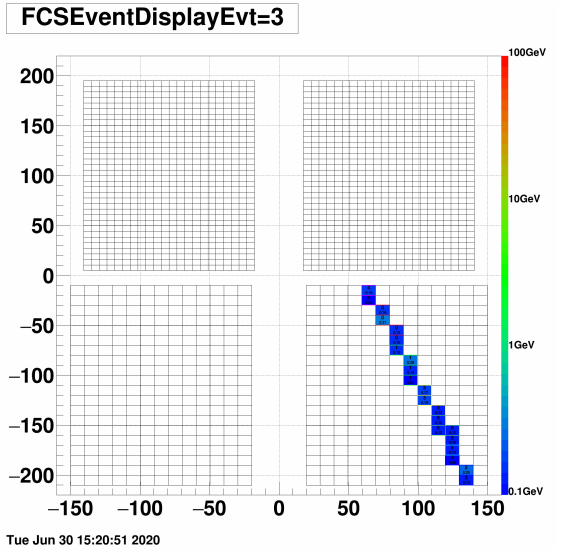


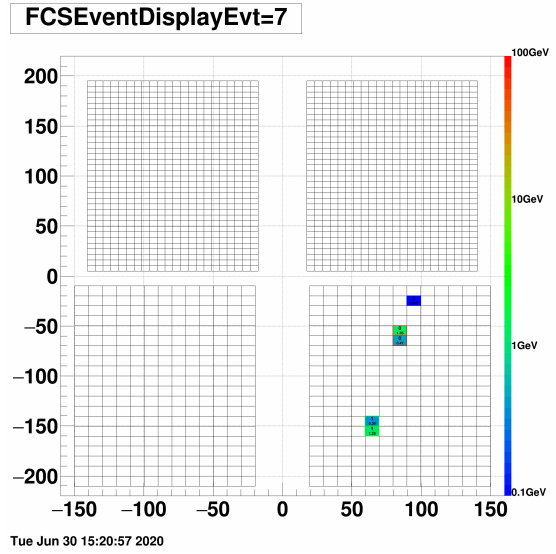
Cosmic Muon Response

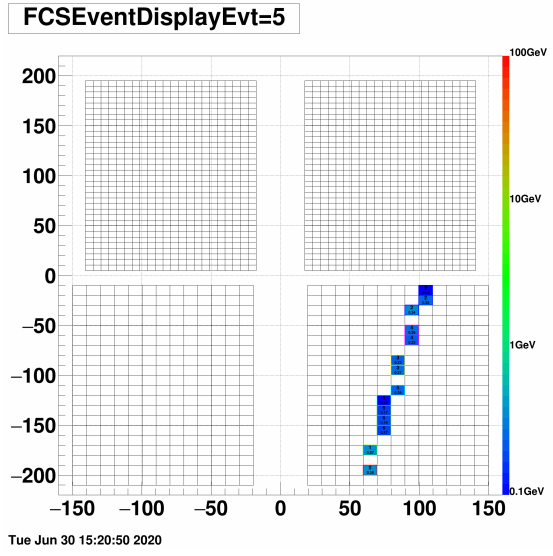
V9_Test

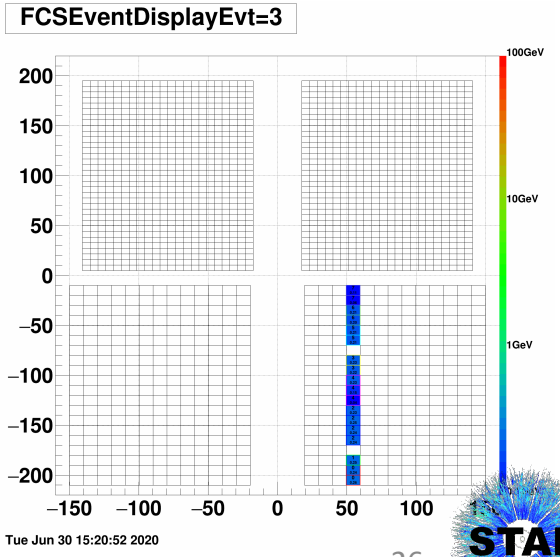
- For more realistic model, randomize vertex in X and Z direction, and varying Eta and Phi.

- Shooting Particle:
  - Single mu+ event
  - 1M events
  - Energy = 1 GeV to 115 GeV
  - $\eta \approx -0.80$ to 0.80
  - $\varphi \approx -0.70\ to\ -2.5$
  - Vertex =(x_vertex,200,z_vertex)
  - 20<x_vertex<150
  - 805<z_vertex<890
  - Smearing = (0,0,0)
  - Ecal on, Hcal on



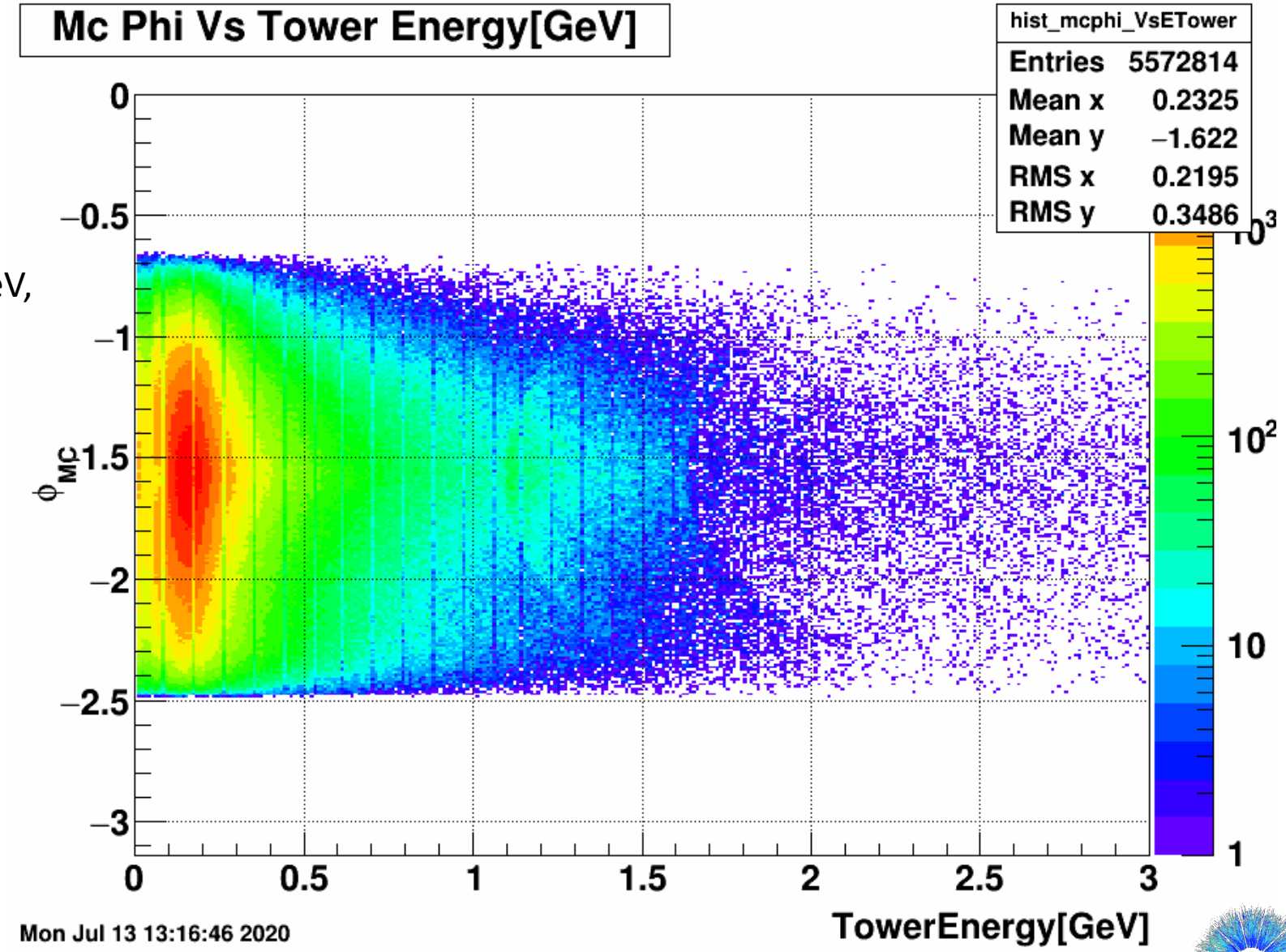




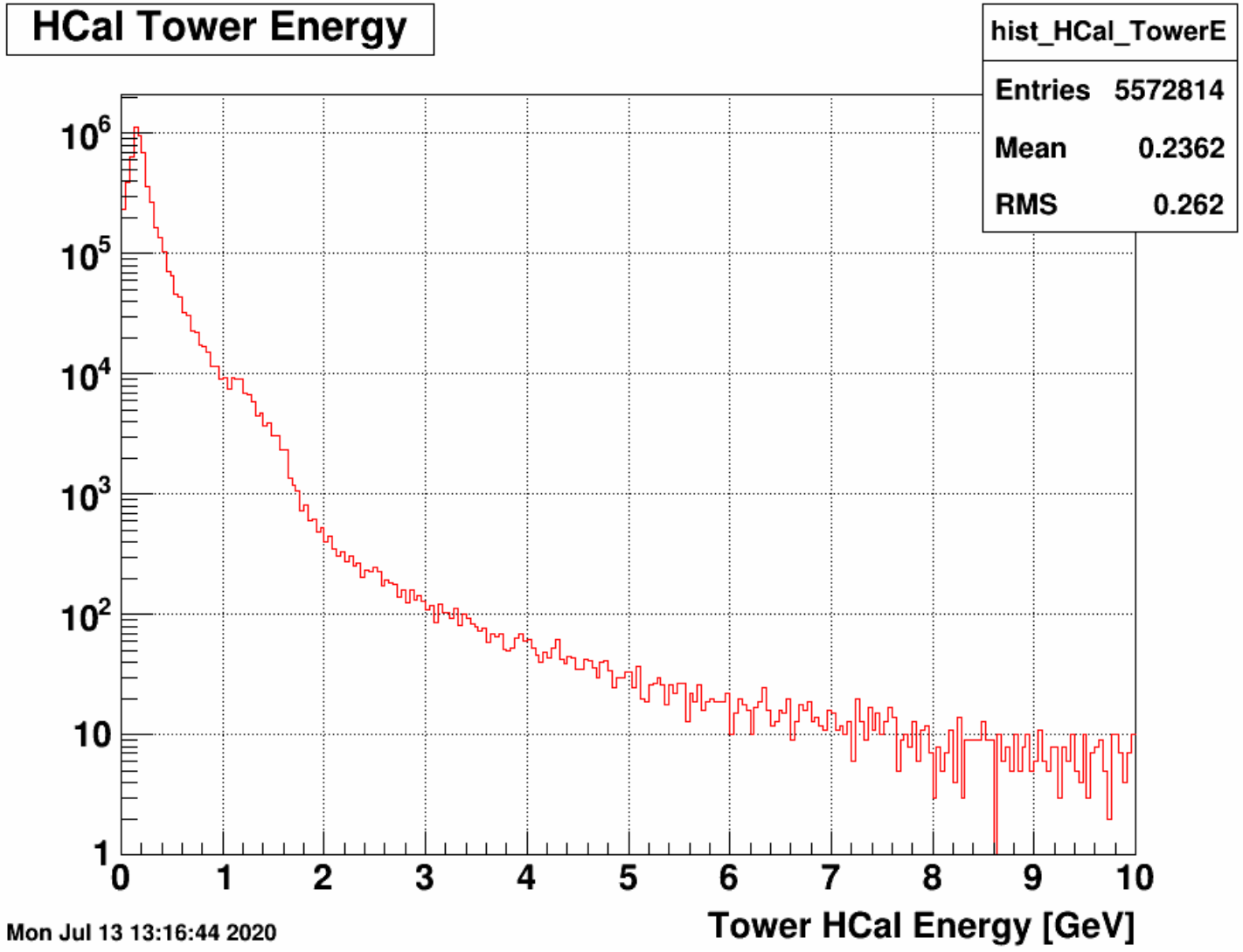


Tower Energy Vs Mc Phi

- Most of the tower energy is around 0.2 GeV, with 1M event we can see some of the tower has energy around 1.2GeV



Cosmic Muon Response



Hcal hit tower energy

Individual Tower Energy

- Each Tower could deposit around 1.2GeV energy
- Energy response from each tower can be find in the link below.

[Link to individual tower of South Hcal_V9]