Pion reconstruction from the prototype test data

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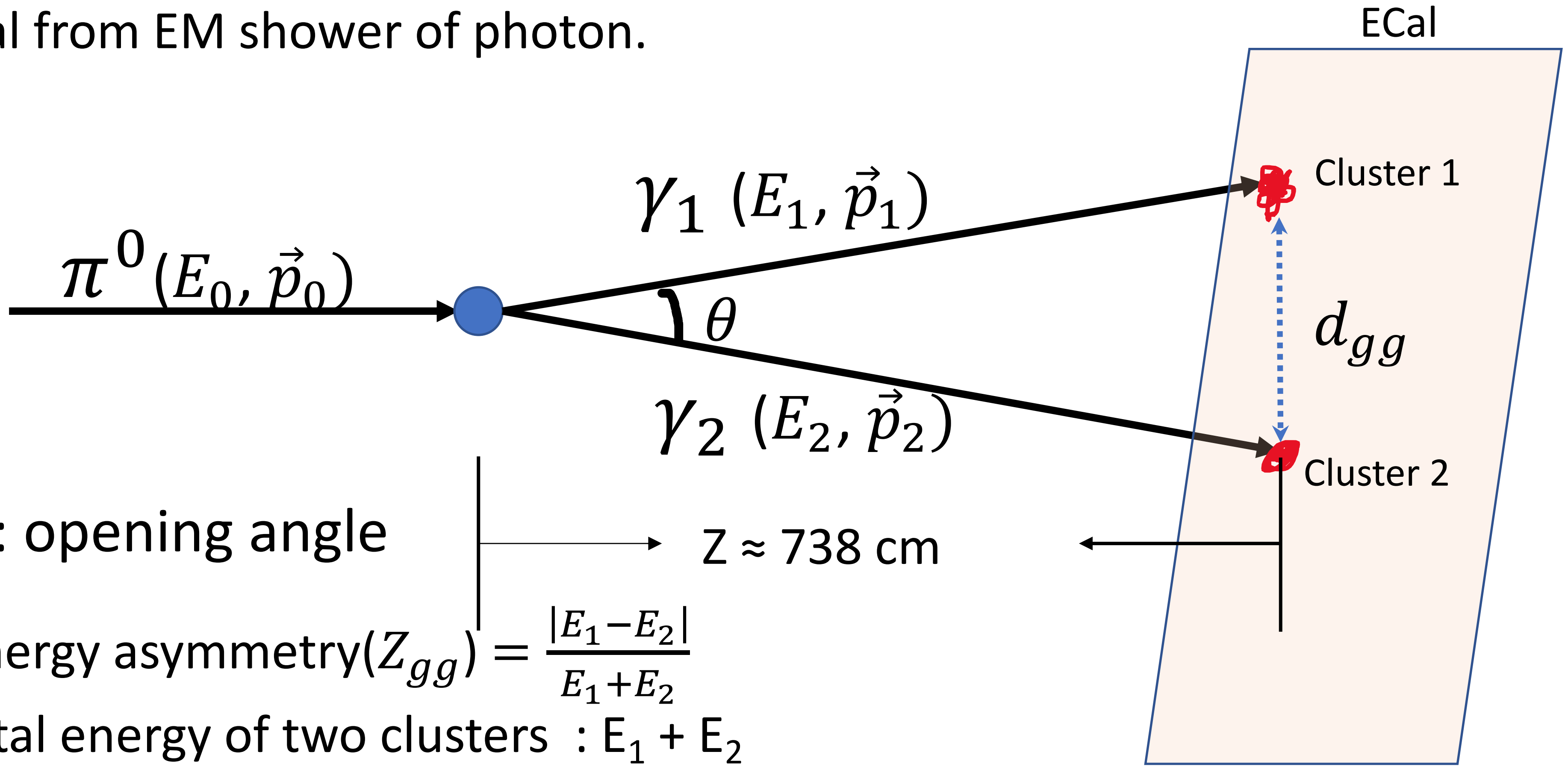
Introduction

- Sanity check of Ecal prototype by using π^0 at run19 AuAu200 data.
- π^0 decays to two photons, whose branch fraction is 98.8%.
- Below is the schematic of π^0 decay, where cluster represents a group of cells fired on Ecal from EM shower of photon.



θ: opening angle

Energy asymmetry(Z_{gg}) $= \frac{|E_1 - E_2|}{E_1 + E_2}$

total energy of two clusters : $E_1 + E_2$

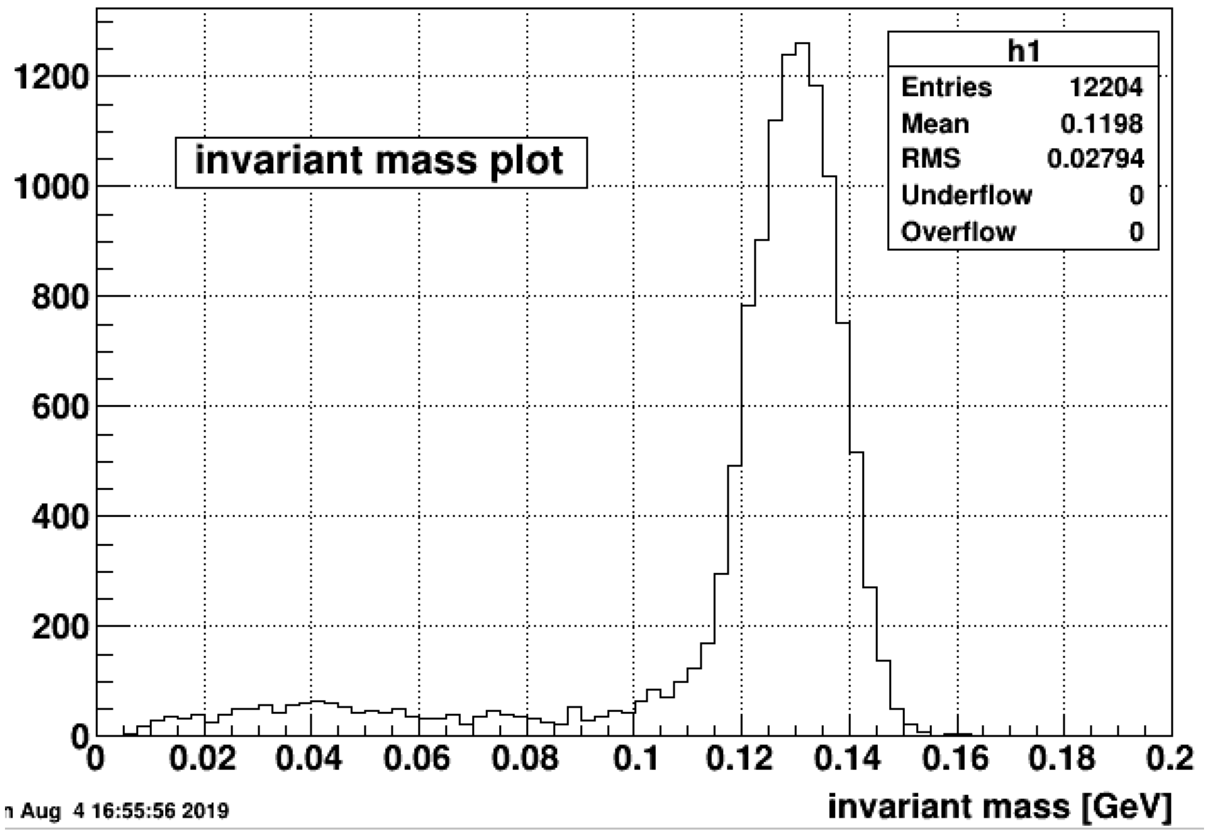
MC simulation

- Generate 20 k $\boldsymbol{\pi}^0$ single particle event (using full FCS design).
  - η = 3 ; full 2$\boldsymbol{\pi}$ coverage.
- Event selection:
  - Keep only clusters at Ecal
  - Each cluster energy > 0.5 GeV
  - Energy asymmetry (Z_{gg}) < 0.7
- If there are two or more clusters in each event, loop all the possible pair of clusters and keep all the possible pair fit the event selection criteria.

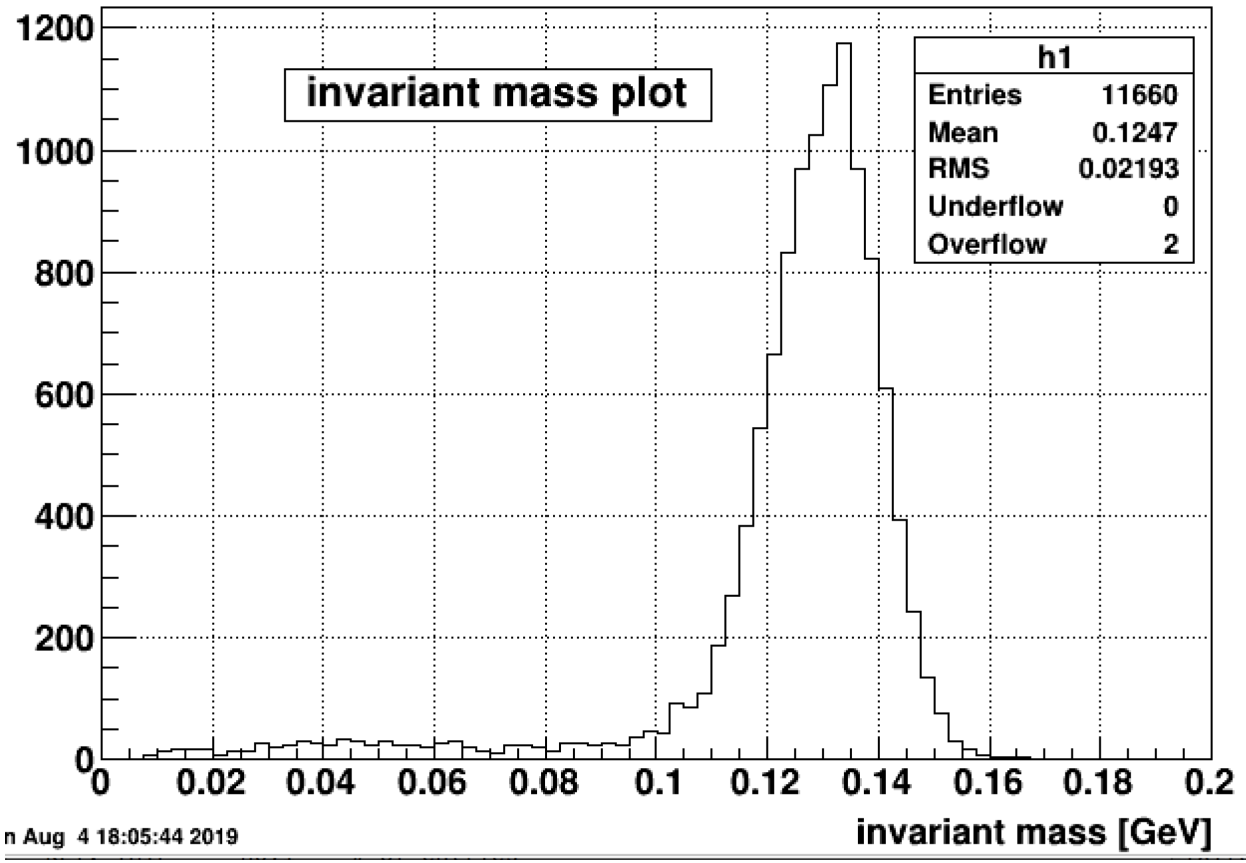
Invariant mass plot for MC simulation

From MC result, the peak is at about 0.135 GeV, which is π^0 invariant mass.

Generate 20 k of 10 GeV $\boldsymbol{\pi}^0$ events



Generate 20 k of 20 GeV $\boldsymbol{\pi}^0$ events



Data set

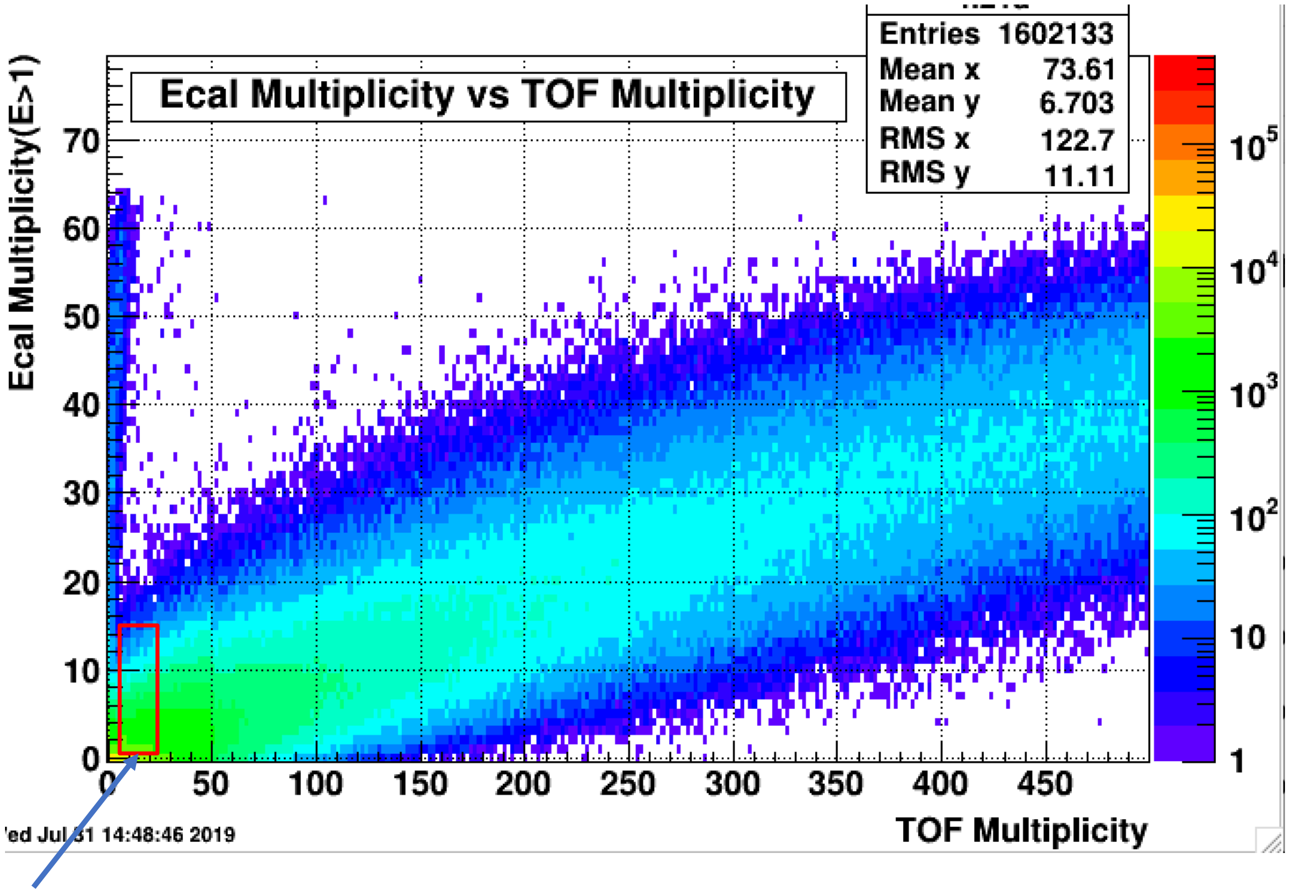
- We use the AuAu200 data in run19 from STAR detector.
- Total amount of the data we use is about 29.5 M.
- Rough gain assigned to each channel is 0.02 GeV / ADC Channel
- The energy of a cell = sum of ADC in time bin [35 , 60] × gain.

Event selection (5 steps)

- Step 1: Select clusters only at Ecal
- Step 2: Clusters energy cuts
  - Each cluster energy > 1 GeV
  - $Z_{gg} < 0.7$
  - 10 GeV < $E_1 + E_2$ < 20 GeV
- Step 3: Detector multiplicity cuts (detail in slide 8)
  - 5 < Tof multiplicity < 20
  - Ecal multiplicity (energy of hit > 1 GeV) < 15
- Step 4: Select the best pair of clusters
  - In each event, choose the pair of clusters whose total energy is highest
- Step 5: Cluster position cuts (detail in slide 9)
  - Keep only towers within the fiducial cut and discard the edge tower

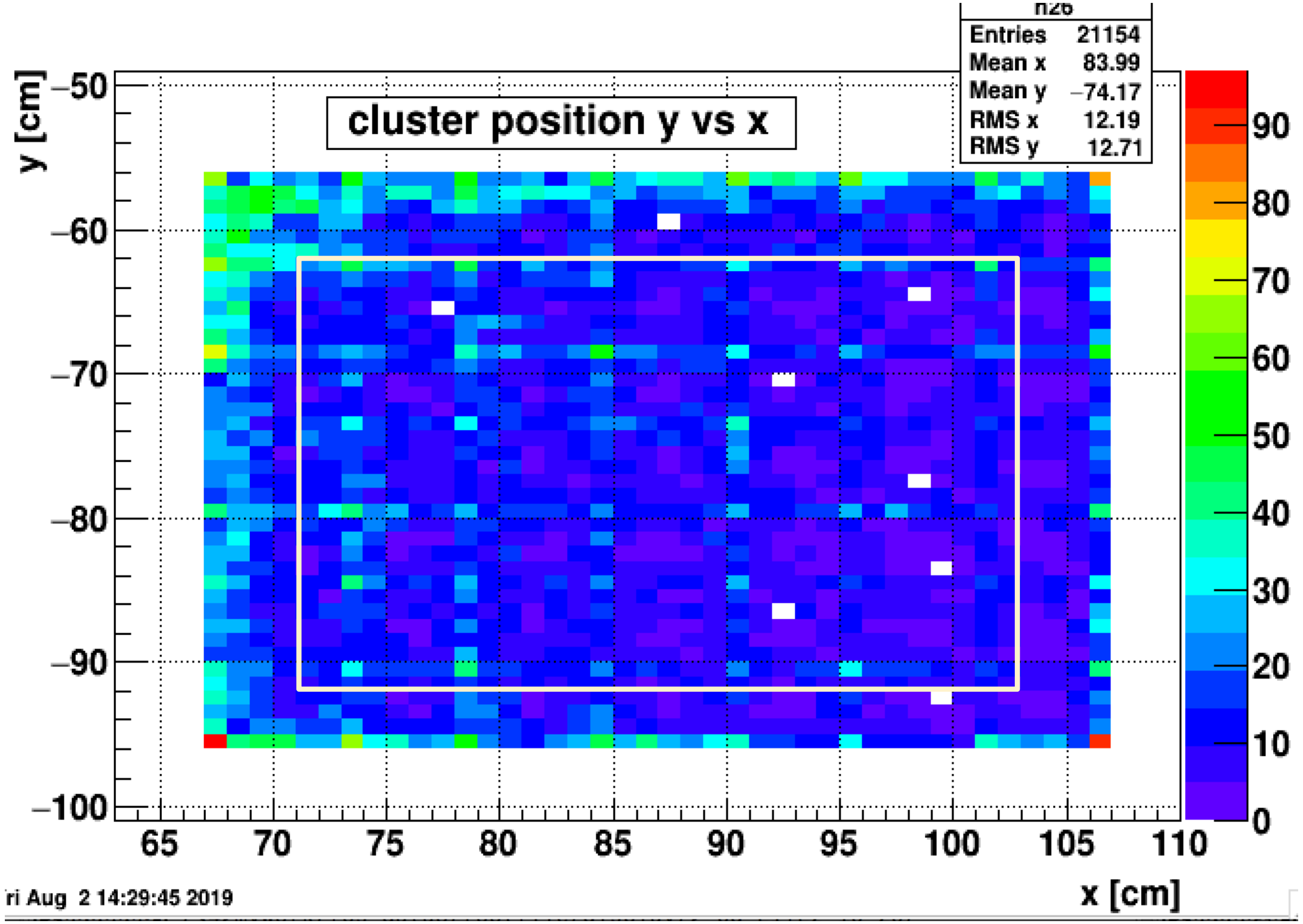
Ecal multiplicity vs Tof multiplicity

Count the Ecal multiplicity when energy of hit > 1 GeV



Choose Ecal Multiplicity <15 and 5< TOF multiplicity <20

Cluster position distribution and cuts



This is the plot for cluster position distribution at Ecal.

From this plot, we cut the clusters at the boundary of Ecal detector:

$72 < x < 103$ cm

$-92 < y < -61$ cm

(discard the edge towers)

Ecal cell size: 5.6 × 5.6 (cm^2)

Gain match analysis

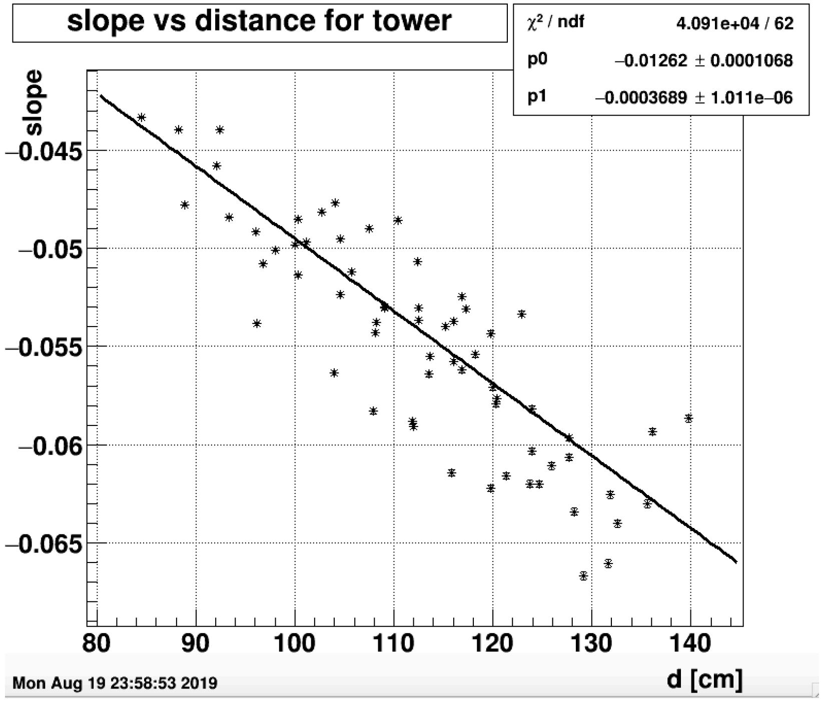
- Purpose: We need to make each tower's hit energy response similar by matching their gain because we assume all tower's performance is equal and response of cells in same η should be similar.

- Procedure:
  - First, we draw the energy spectrum for each tower in Ecal, which are the plots recording the energy of every hit for all the events.
  - Next we use exponential function (f(x)=exp([0]+[1]*x)) to fit the energy spectrum, where [1] is the slope from the fit.
    - Fitting range [30, 130] (GeV)

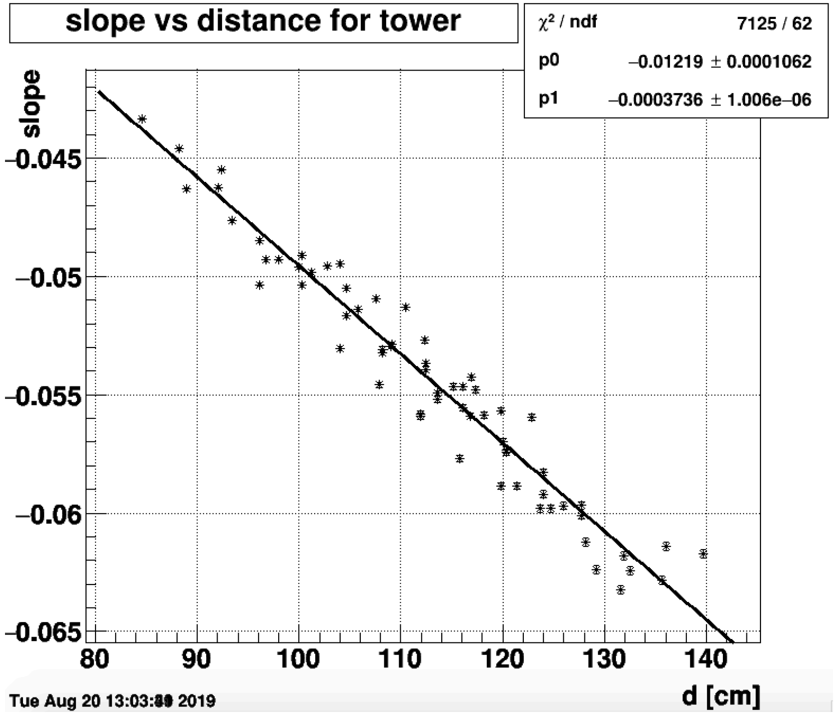
Gain match analysis

- Next we plot the slope from the fit for energy spectrum vs the distance for each tower.
  - Distance is the distance between center of tower and origin in xy plane.
- Then we do the linear fit for this plot and calculate the gain match factor.
  - Gain match factor = $\frac{slope}{linear\ fit\ result\ for\ corresponding\ distance}$
- Finally we apply the gain match factor for each tower.

Before gain match



After gain match

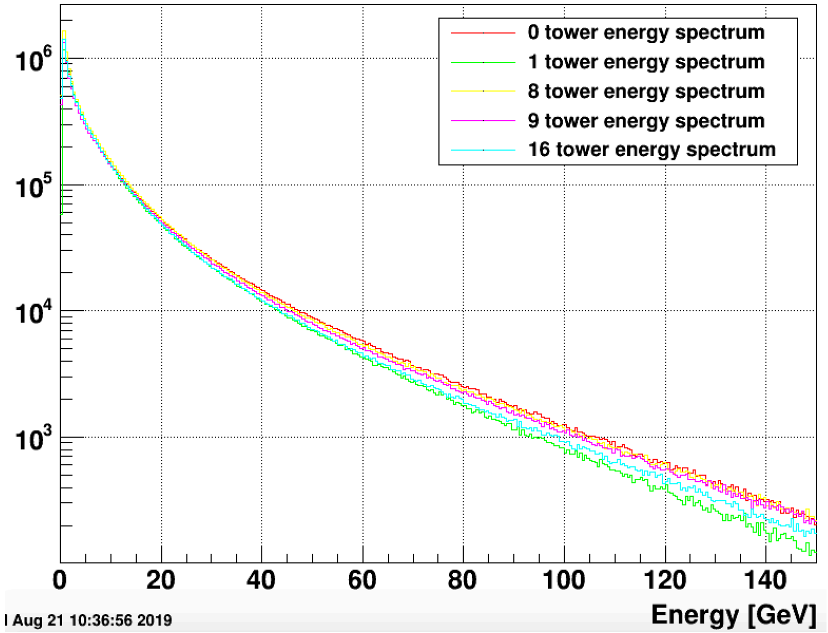


Tower energy spectrum comparison

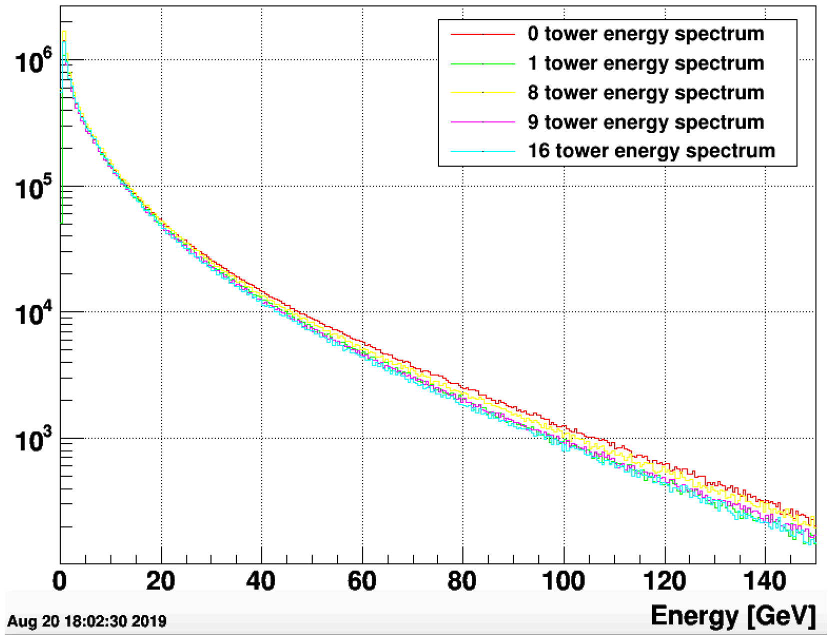
To show the results for gain match more explicitly, we separate these towers into 7 groups and compare their energy spectrum before and after gain match. Here we show the result for the first group.

The first group are the tower # 0,1,8,9,16, whose distance are range from 84.0 cm to 92.5 cm.

Before gain match

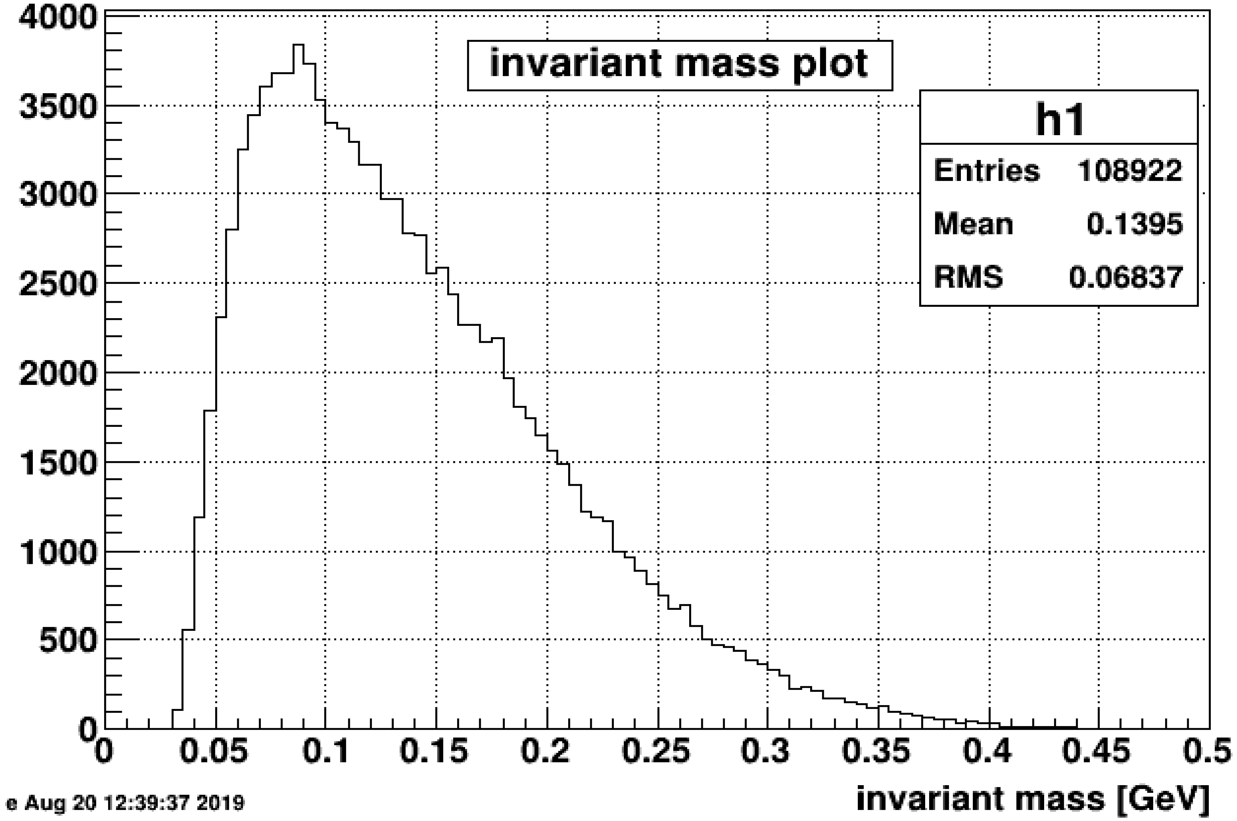


After gain match



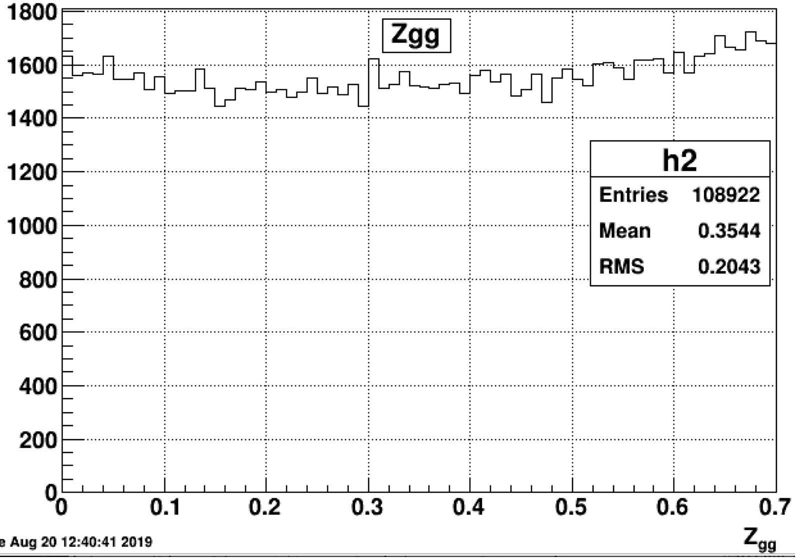
Invariant mass plot

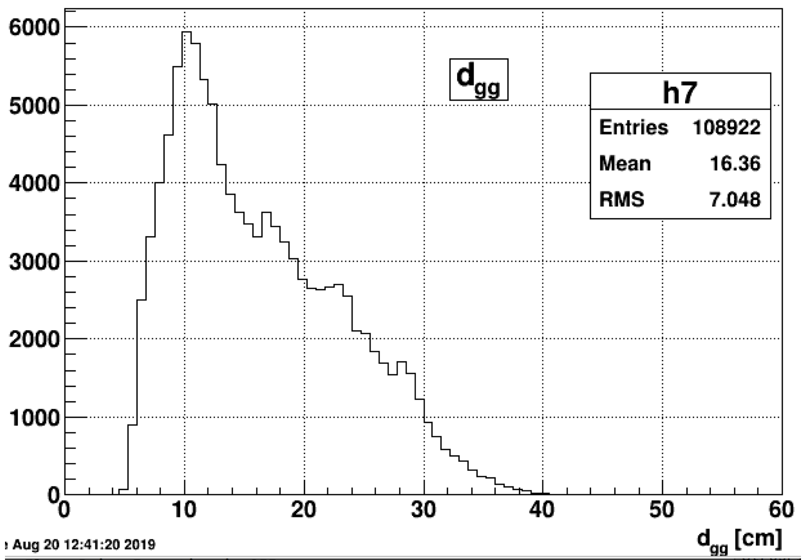
- From the invariant mass plot, we can see the peak is about 0.08 GeV, which shows hint of a π^0 peak, but it still can not be sure. It still contains some background so more cuts are needed to get the clear peak .

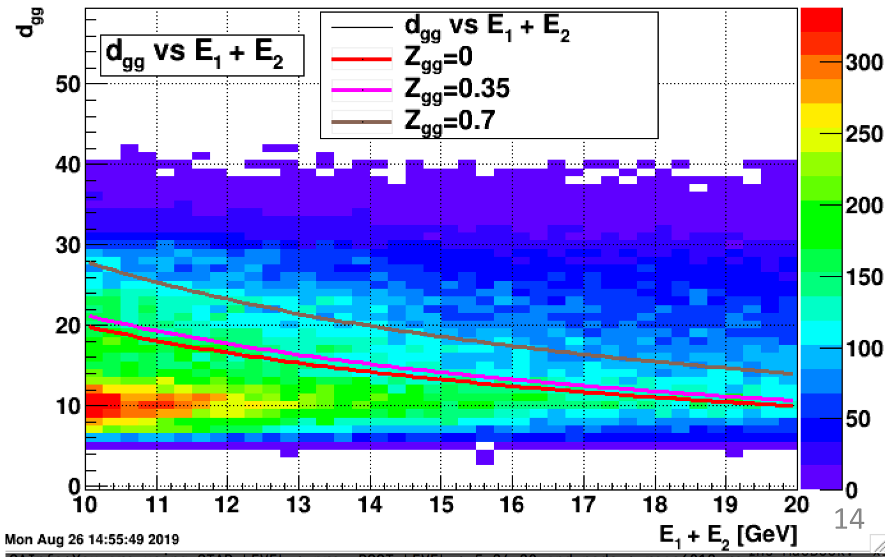


More plots for the result

- These three plots are the analysis based on the best gain we assume. The exact gain for run19 is still needed to be determined.
- Z_{gg} plot: Mostly it is evenly distributed.
- d_{gg} plot: Most data are at the range of 10 cm – 22 cm (2 - 4 cell size), which shows chance to see 10 GeV – 20 GeV π^0.
- d_{gg} vs $E_1 + E_2$ plot: these three lines indicate the expected d_{gg} position for π^0 for given energy asymmetry (Z_{gg}) .

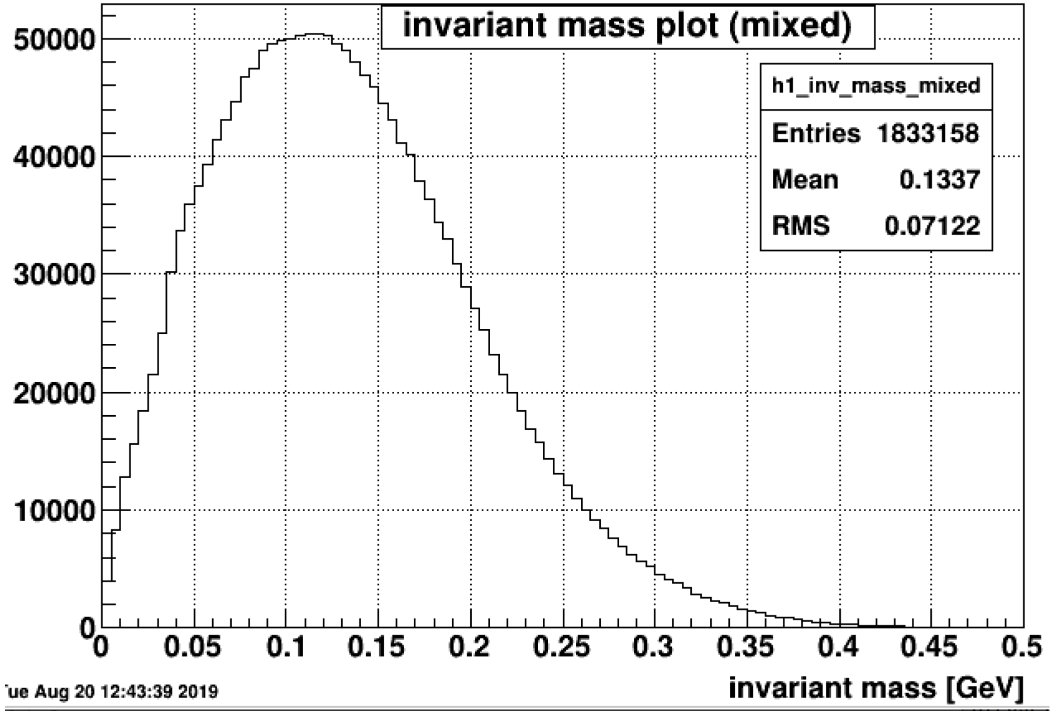


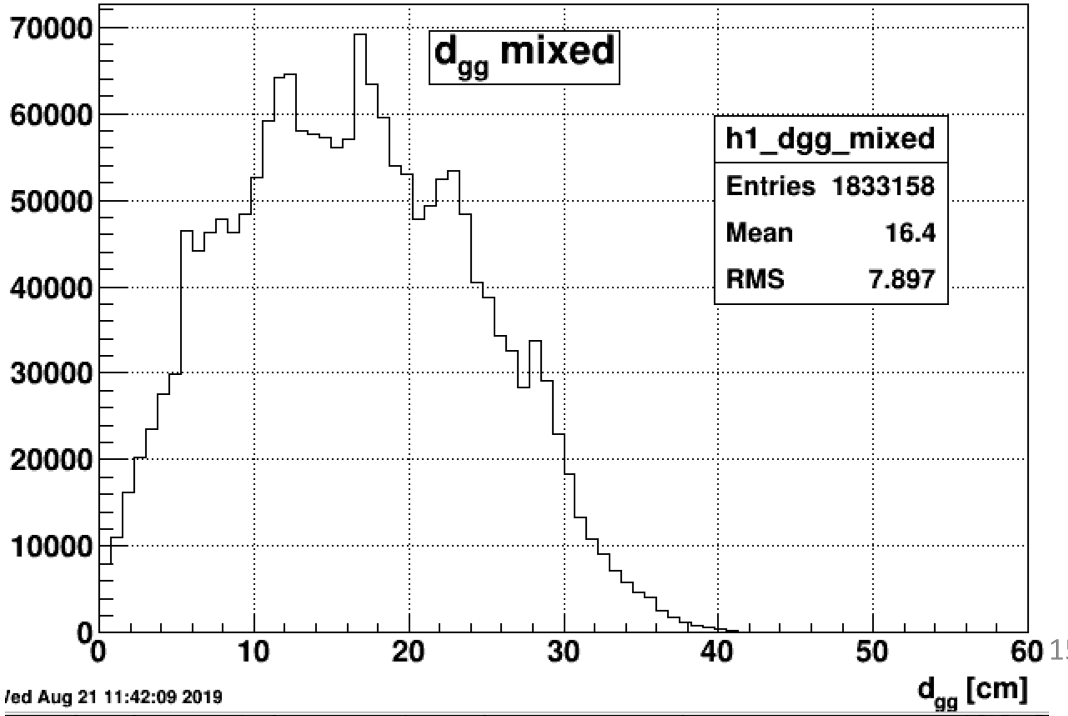




Mixed event background analysis

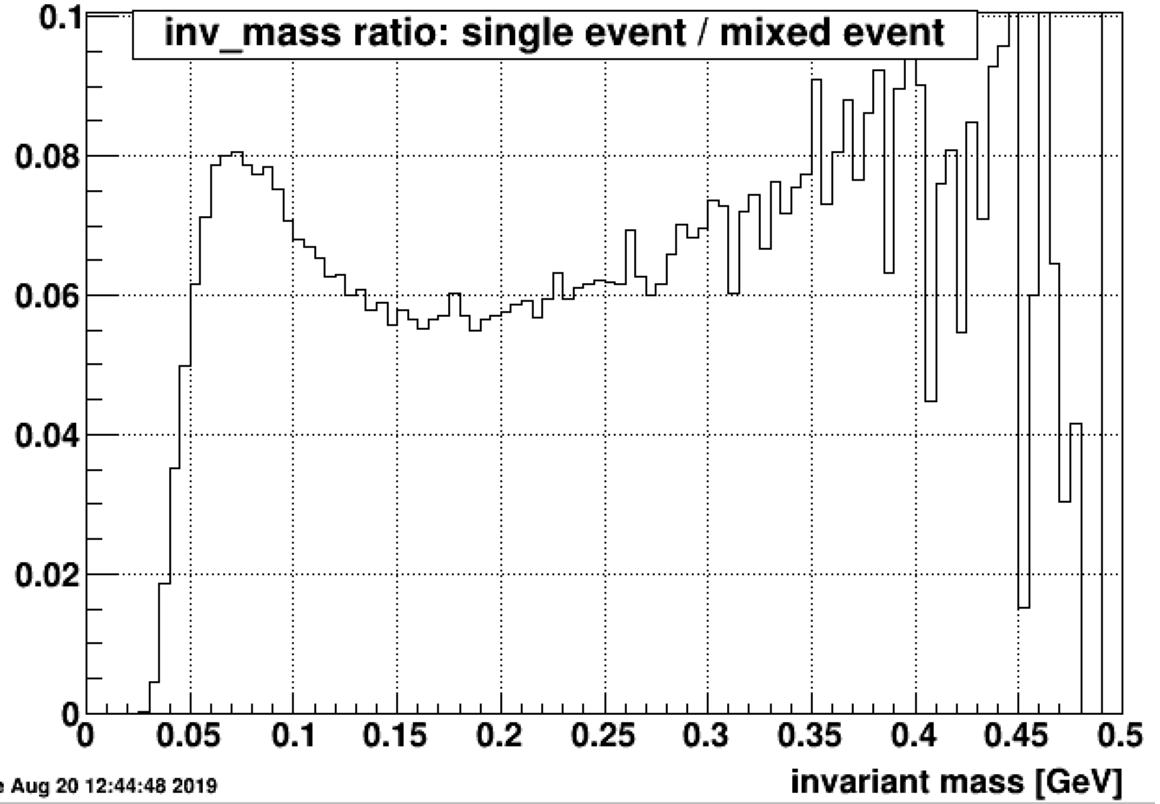
- We mix 10 nearby events to calculate the invariant mass to estimate the background.
  - That is: we use the highest energy cluster in one event to mix the second highest energy cluster in another event to calculate the invariant mass; use the second highest energy cluster in one event to mix the highest energy cluster in another event to calculate the invariant mass.

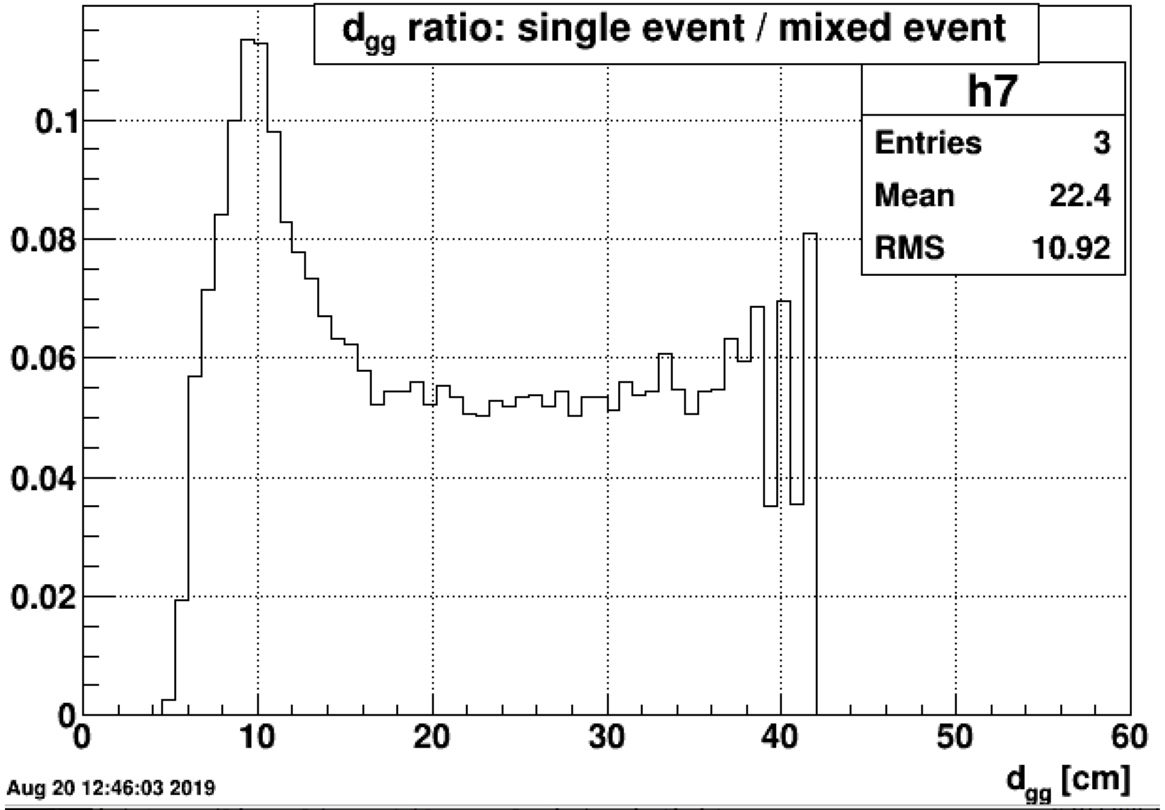




Mixed event background analysis

- Then we calculate the ratio of single event and mixed events for invariant mass plot and d_{gg} plot.
- But it does not show more hints to find out π^0.
- Maybe we need to try to mix all the clusters, not only the two highest energy clusters.





Conclusion and outlook

- The promising π^0 peak like structure was obtained by using prototype test data, but more background studies are required to make sure it's a π^0 peak.
- Next step is to figure out more ways to cut the background.
- Also we need to get correct calibration for these data.

Thank you for your attention!

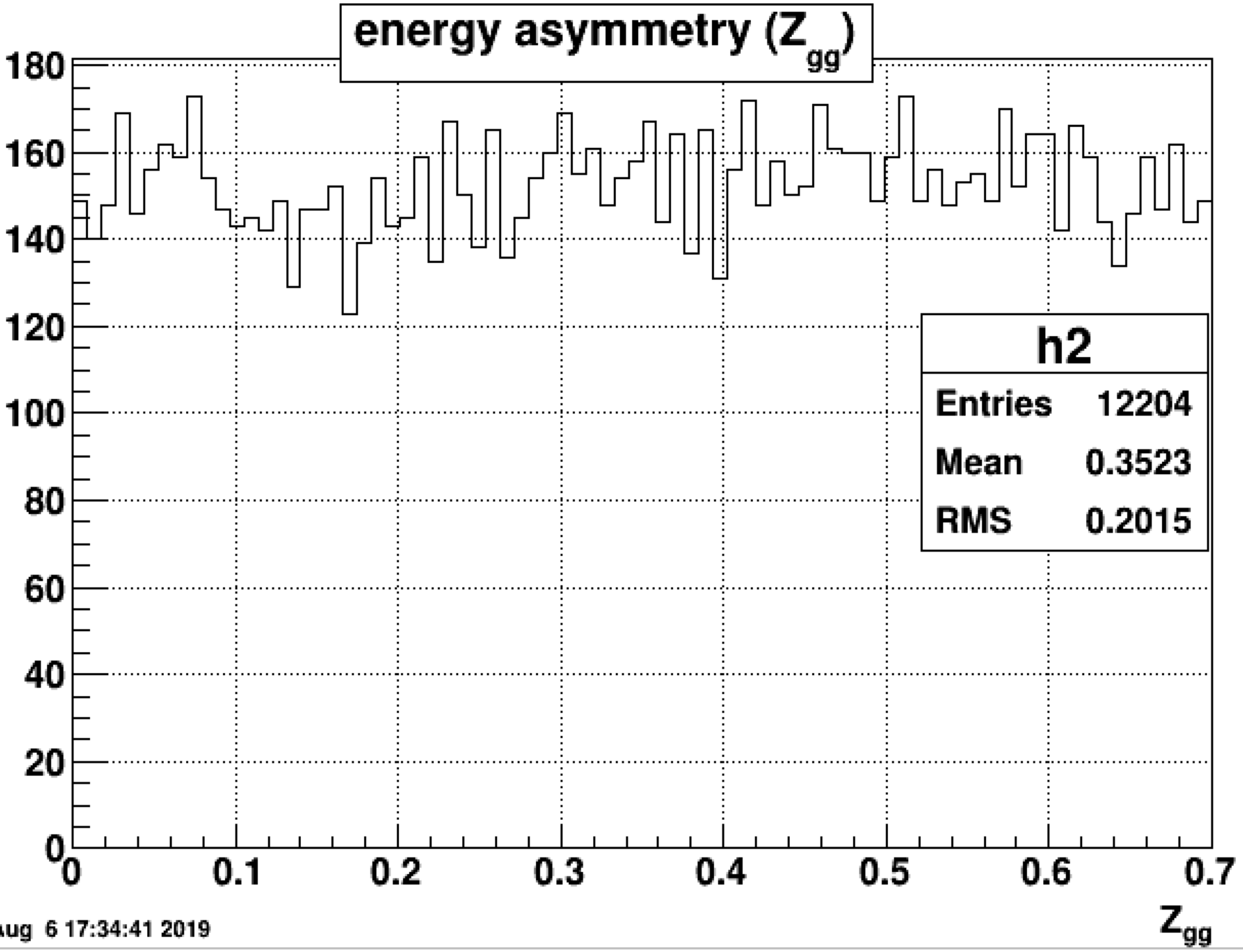
Back up

MC simulation

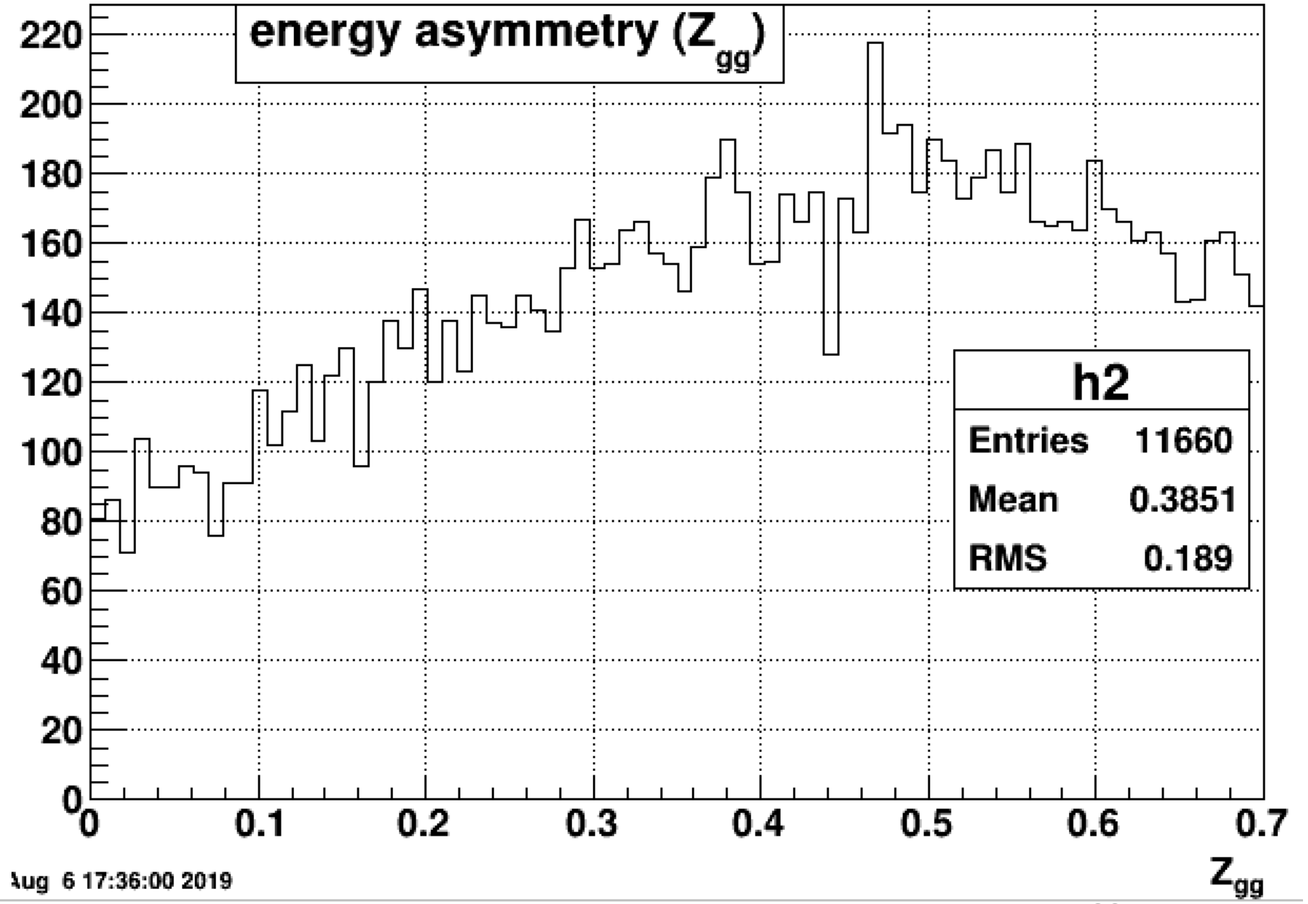
- Energy asymmetry plot
- Distance between two clusters at Ecal plot
- Two clusters total energy plot

Energy asymmetry plot (Zgg)

Generate 10GeV π^0 events

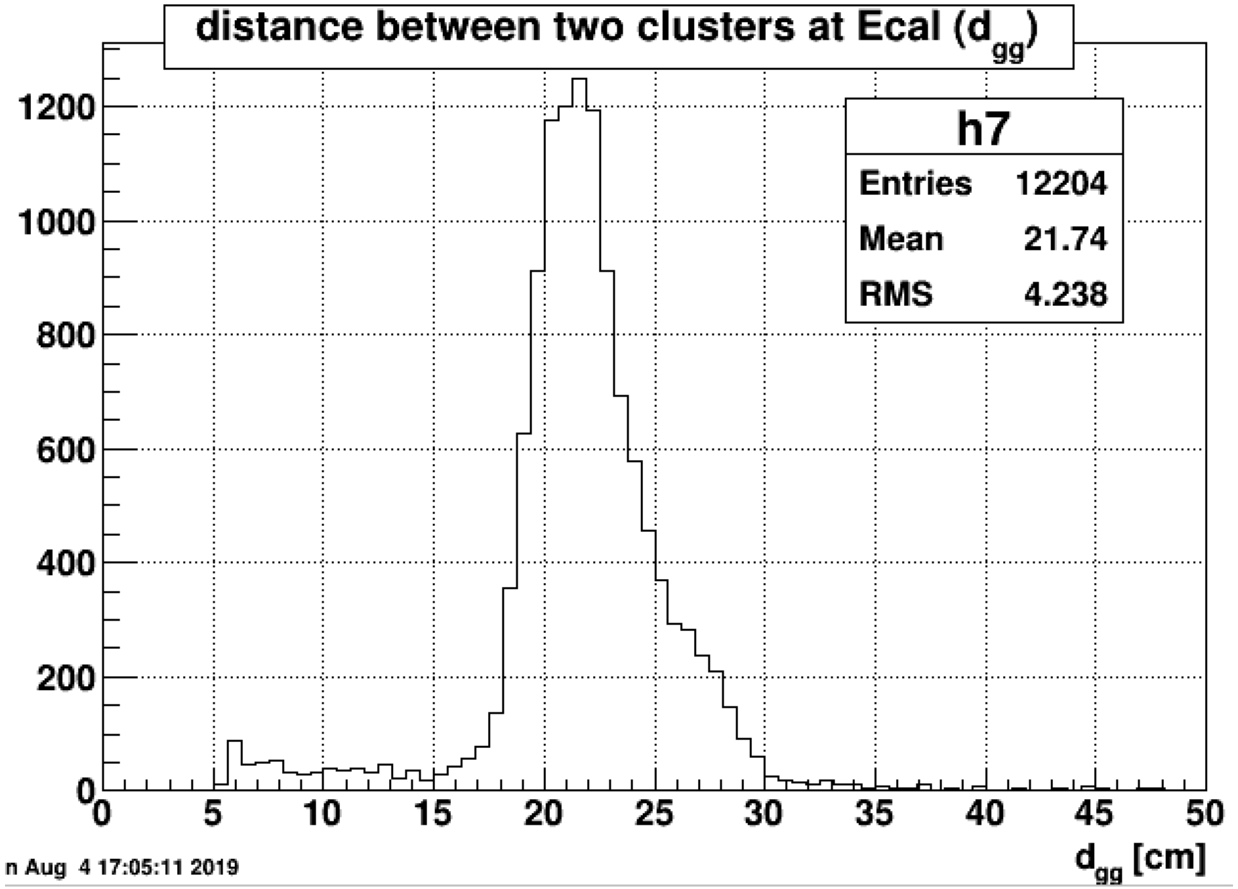


Generate 20GeV π^0 events

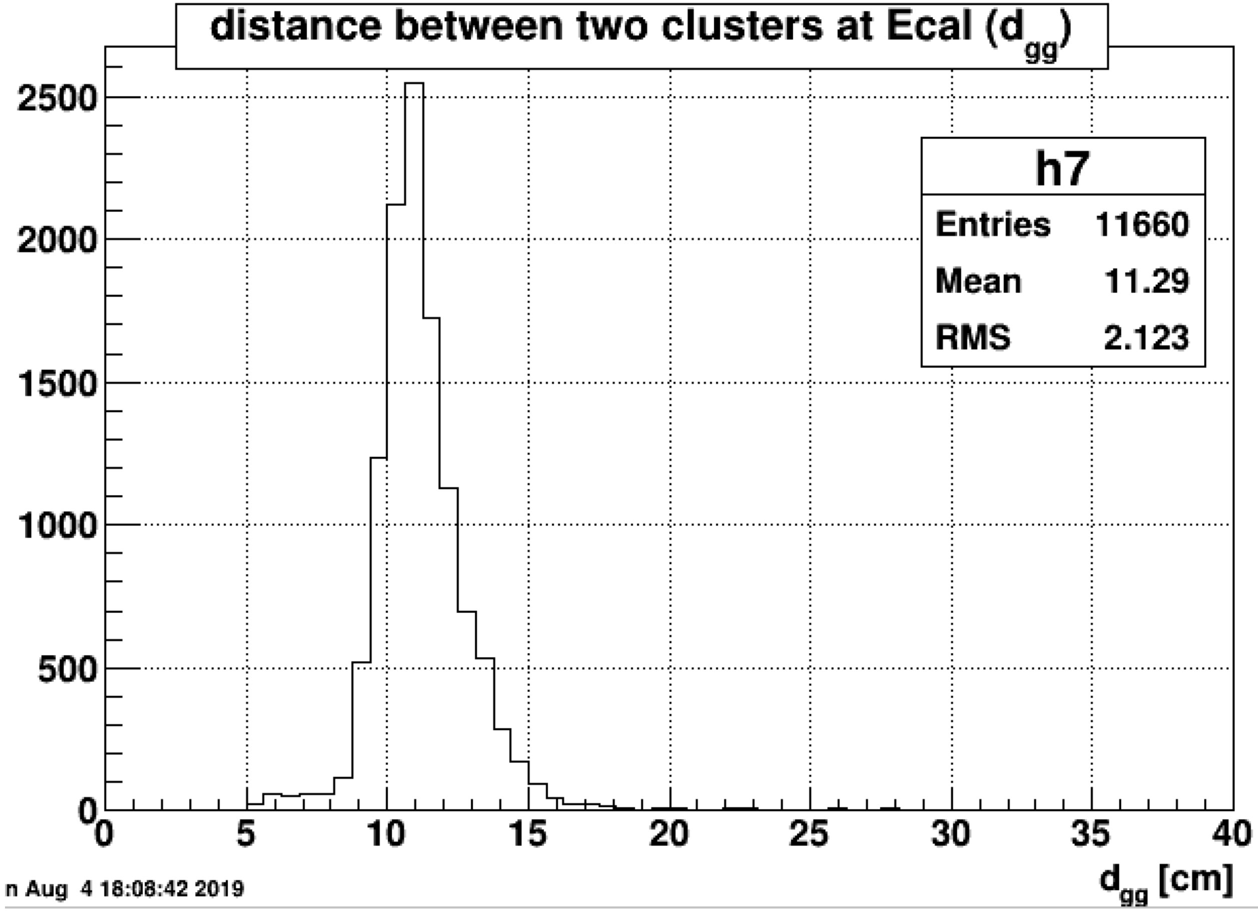


Distance between two clusters at Ecal (dgg)

Generate 10GeV π^0 events

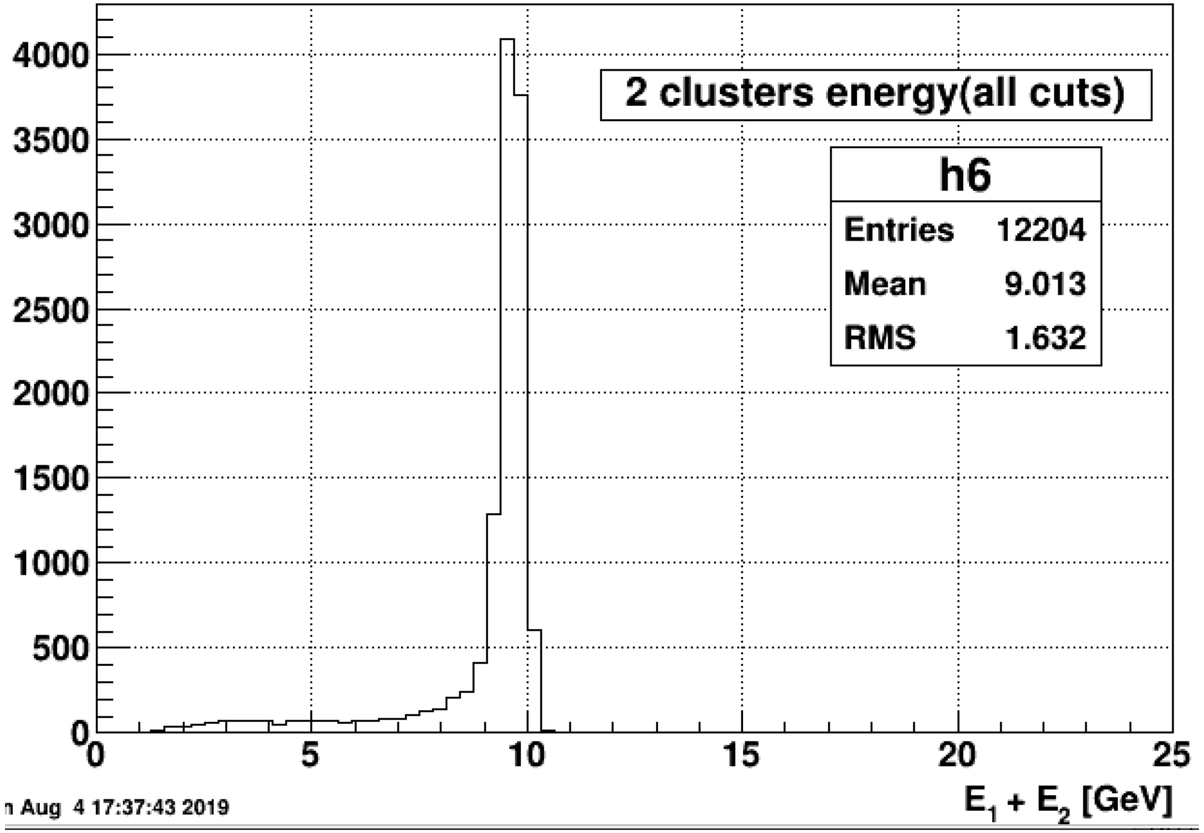


Generate 20GeV π^0 events

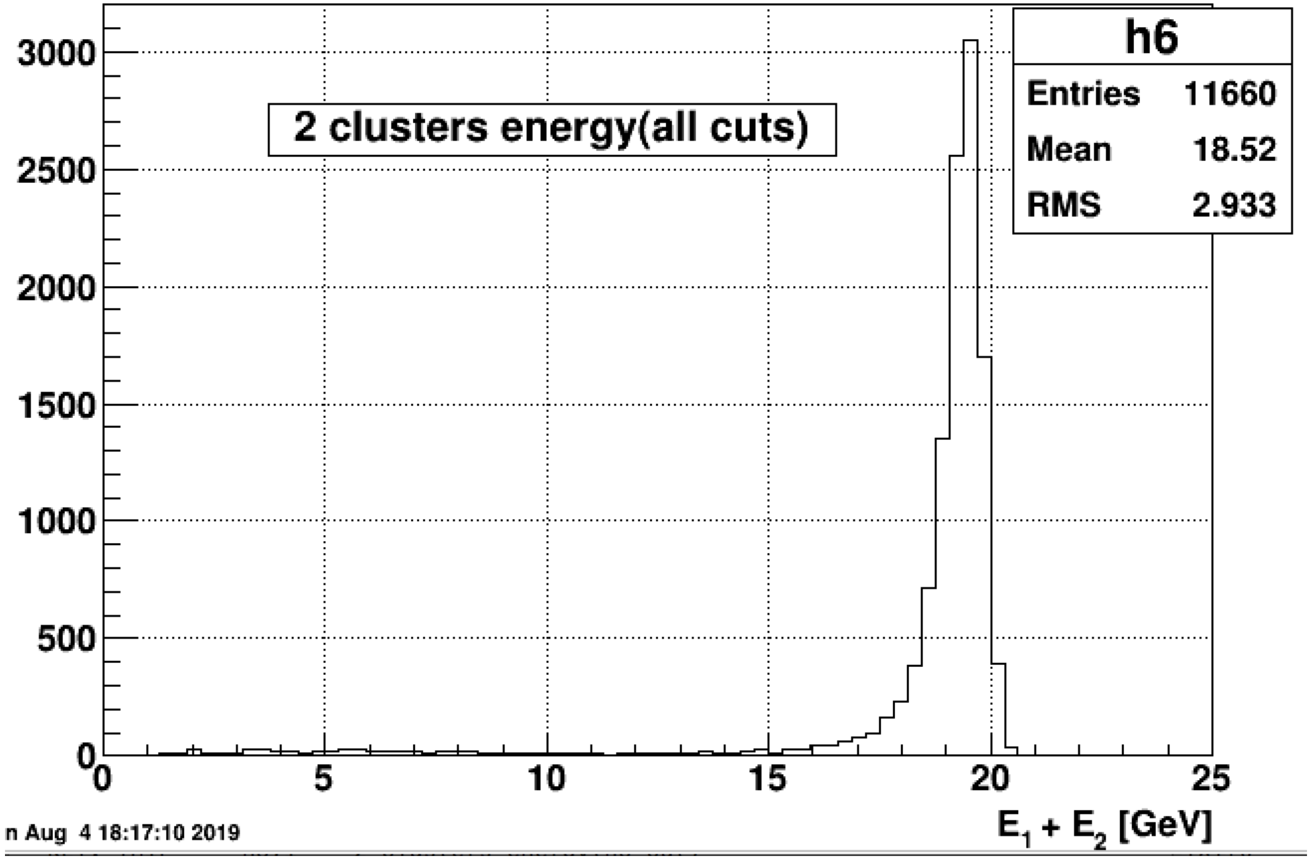


Two clusters total energy

Generate 10GeV π^0 events



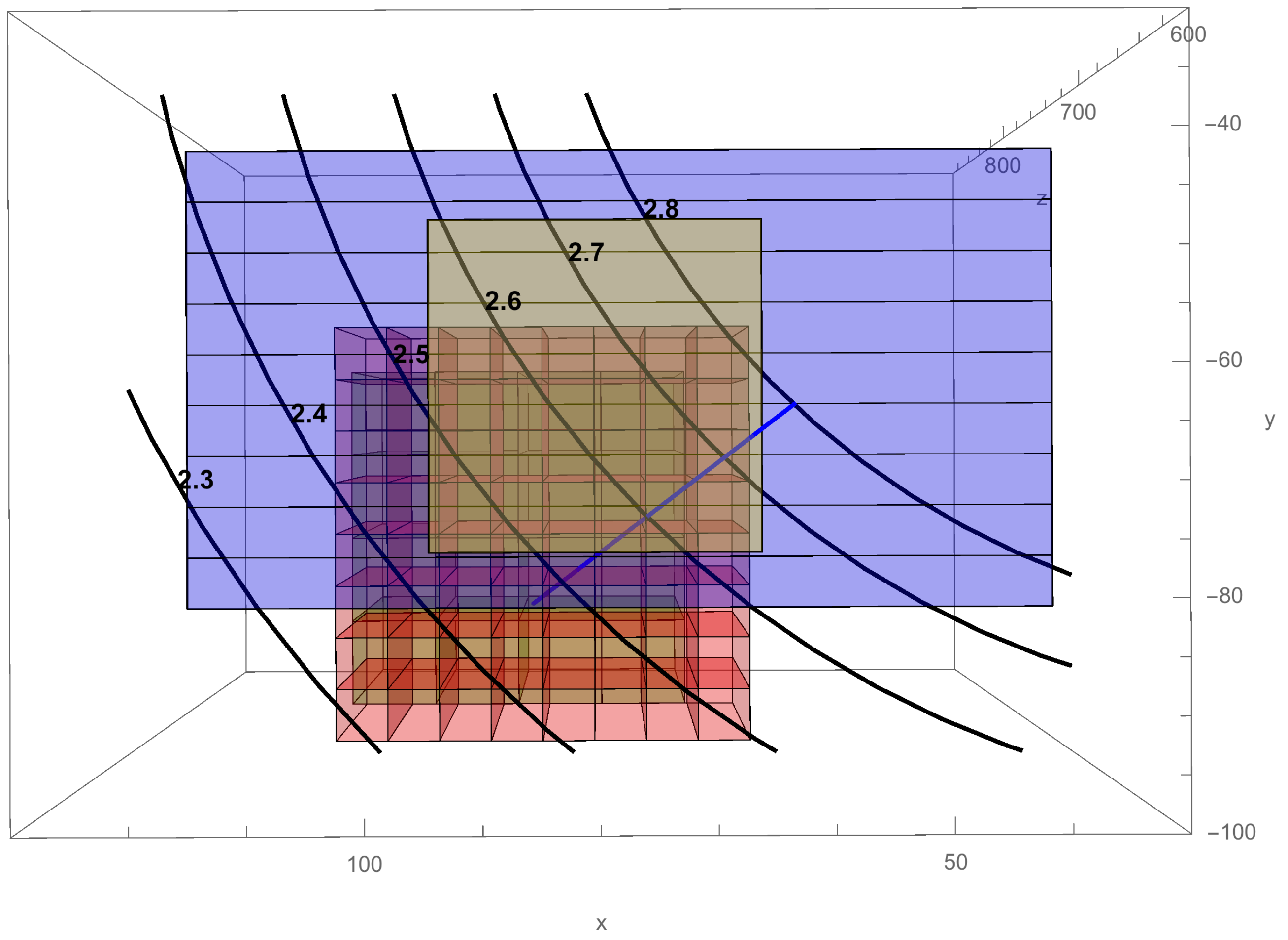
Generate 20GeV π^0 events



Back up for data

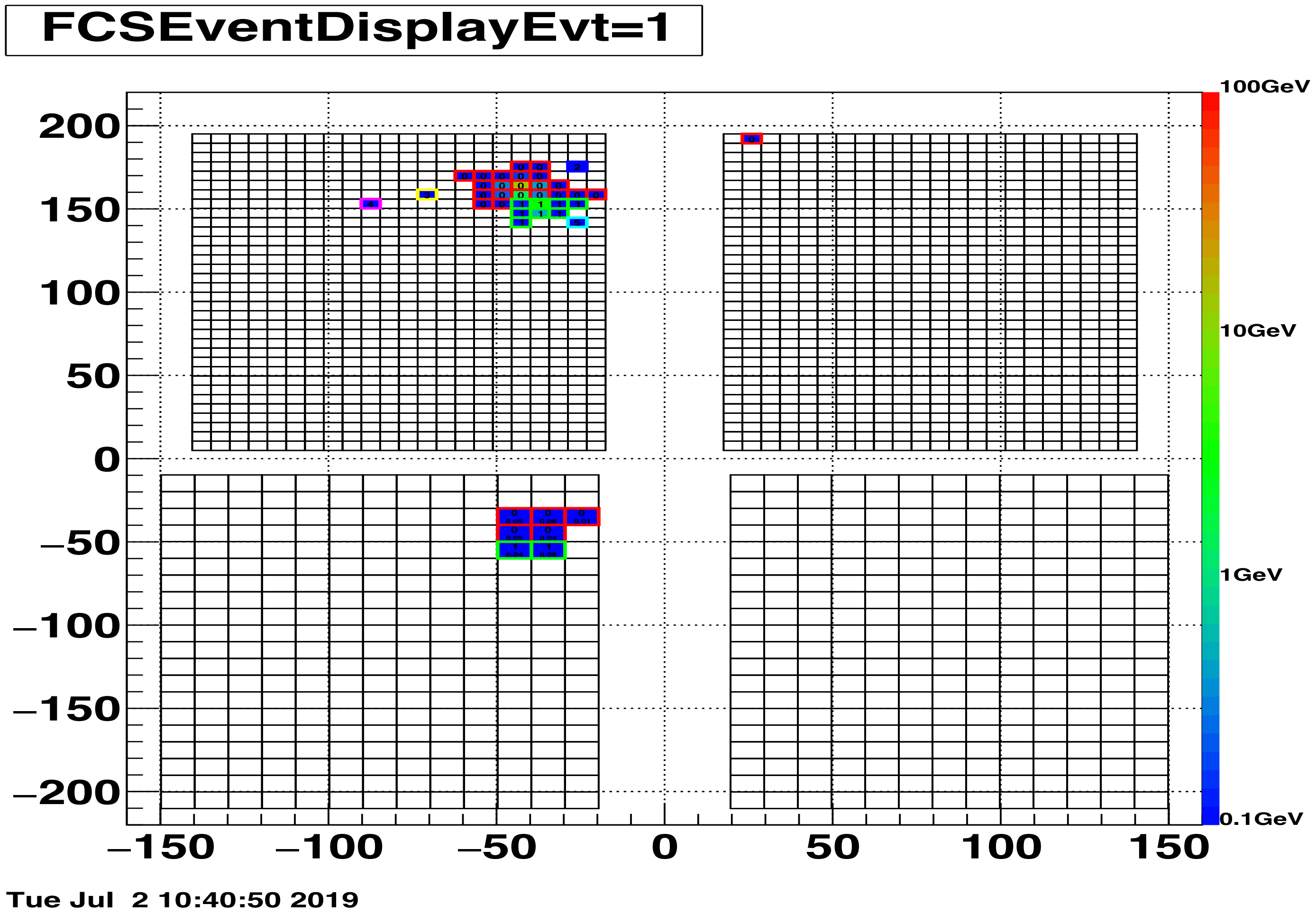
- Geometry for eta rings
- Example for cluster
- Data set in detail
- Gain match result for every tower
- Tower energy comparison
- Invariant mass sorted by highest tower

Geometry for eta rings



Example for clusters in one event

In the picture, the number represents the cluster # that this hit belong to.
The color show the energy of this hit.



Data set

Time bin sum: 35 – 60
Gain: 0.02 GeV/ ADC Channel
All of these data set are AuAu200

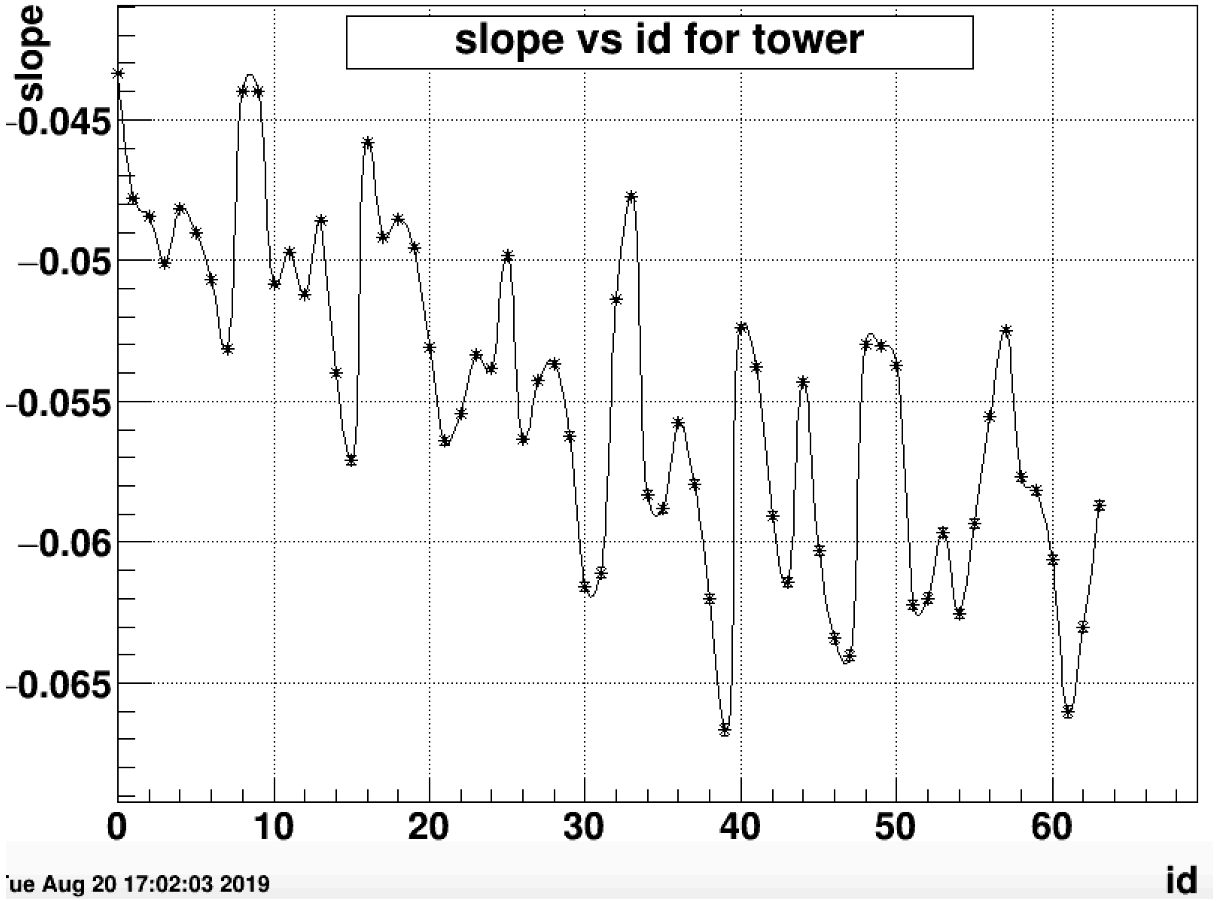
- Run20191005 (totally about 1.6M events)
- Run20191010 (totally about 1.7M events)
- Run20191013 (totally about 2.9M events)
- Run20191016 (totally about 2.3M events)
- Run20192002 (totally about 7.2M events)
- Run20192008 (totally about 7.2M events)
- Run20193004 (totally about 4.6M events)
- Run20193015 (totally about 2.0M events)

Tower energy spectrum analysis

Separate 64 towers to 7 groups to compare the energy spectrum and the slope for the fit

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

Ecal 8 × 8 tower



Gain match analysis result

Gain match factor = $\frac{slope}{linear\ fit\ result\ for\ corresponding\ distance}$

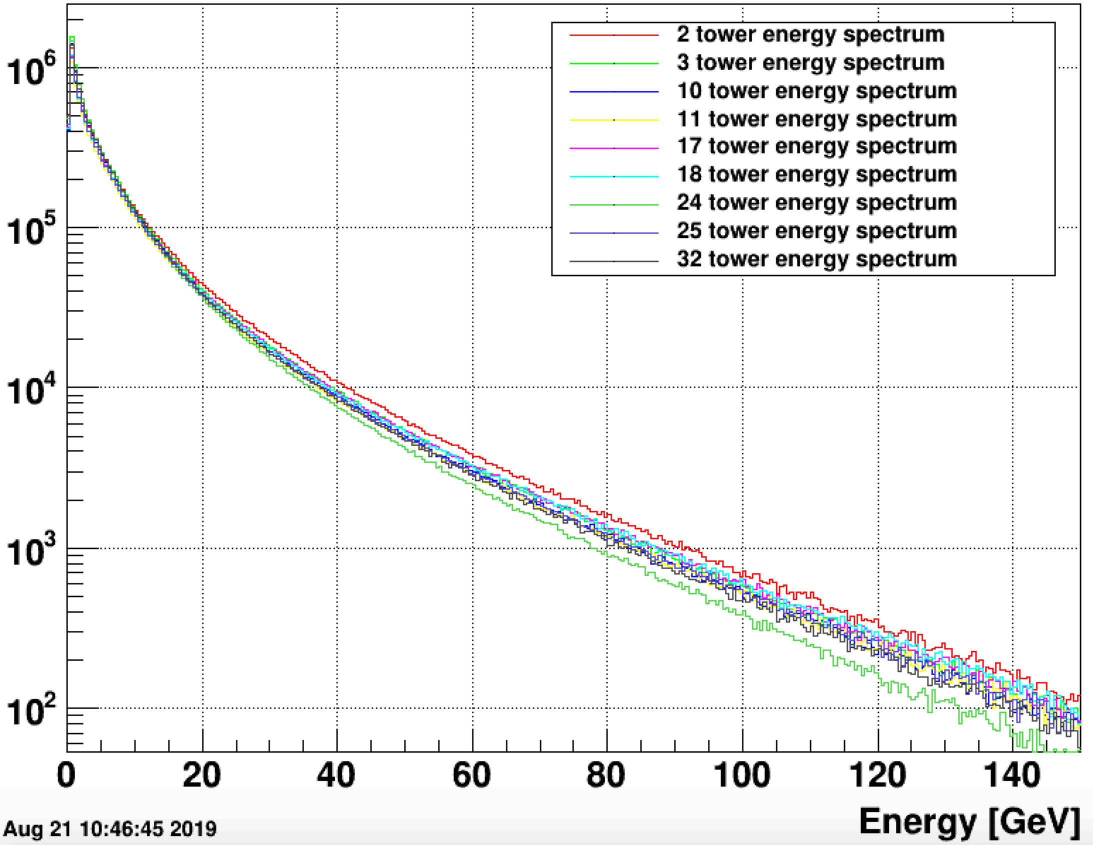
Id	gain correction	Id	gain correction	Id	gain correction	Id	gain correction
0	0.989499	16	0.98278	32	1.03545	48	1.00243
1	1.05203	17	1.02266	33	0.935724	49	0.979802
2	1.02881	18	0.977725	34	1.11212	50	0.96872
3	1.02697	19	0.967359	35	1.09135	51	1.09518
4	0.953004	20	1.00432	36	1.00587	52	1.06404
5	0.93709	21	1.03511	37	1.01628	53	0.998994
6	0.937224	22	0.98601	38	1.05781	54	1.02113
7	0.950193	23	0.920491	39	1.10634	55	0.944442
8	0.973737	24	1.12006	40	1.0224	56	1.01809
9	0.941911	25	1.00638	41	1.02335	57	0.941275
10	1.0518	26	1.10535	42	1.09557	58	1.01161
11	0.994961	27	1.03351	43	1.1099	59	0.997079
12	0.99138	28	0.99166	44	0.956142	60	1.01507
13	0.910397	29	1.0087	45	1.03394	61	1.07961
14	0.979906	30	1.07321	46	1.05843	62	1.00578
15	1.00352	31	1.03401	47	1.04083	63	0.914436

Tower energy spectrum comparison

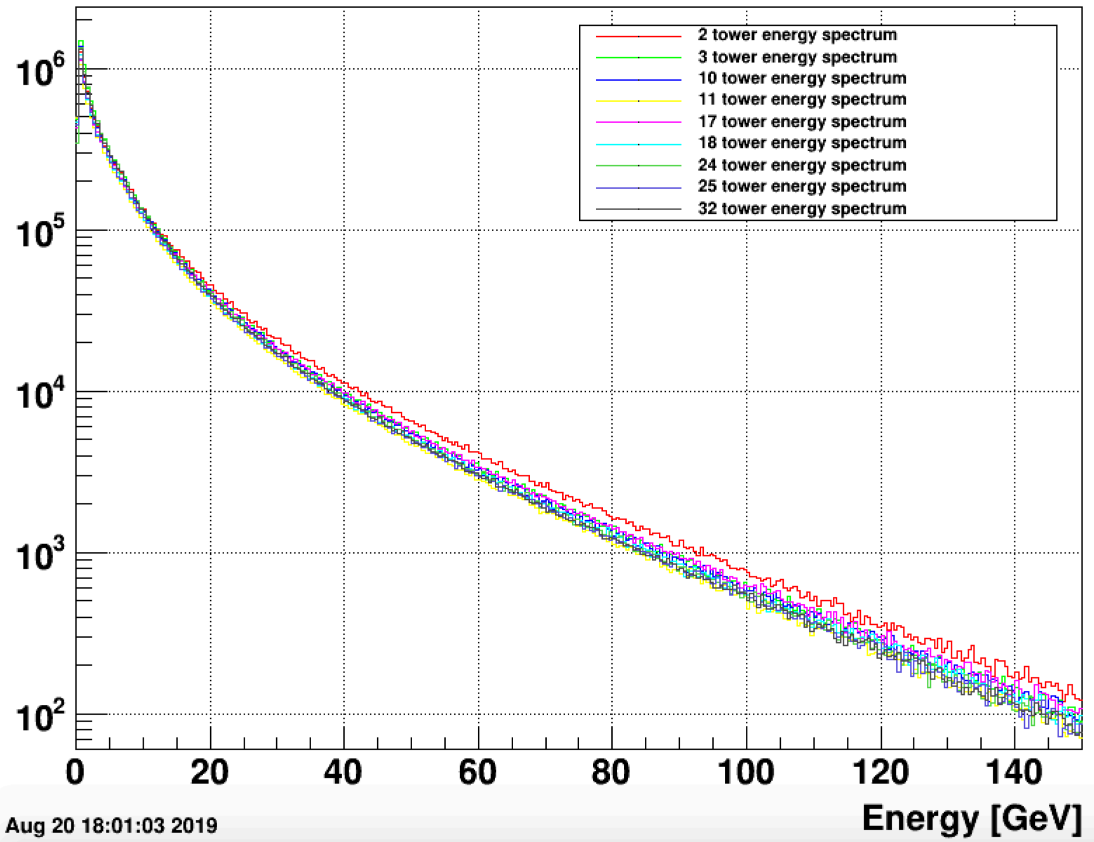
Group 2
Compare #
2,3,10,11,17,18,24,25,32

Distance range from 92.5 – 101.2 cm

Before gain correction



After gain correction



Tower energy spectrum comparison

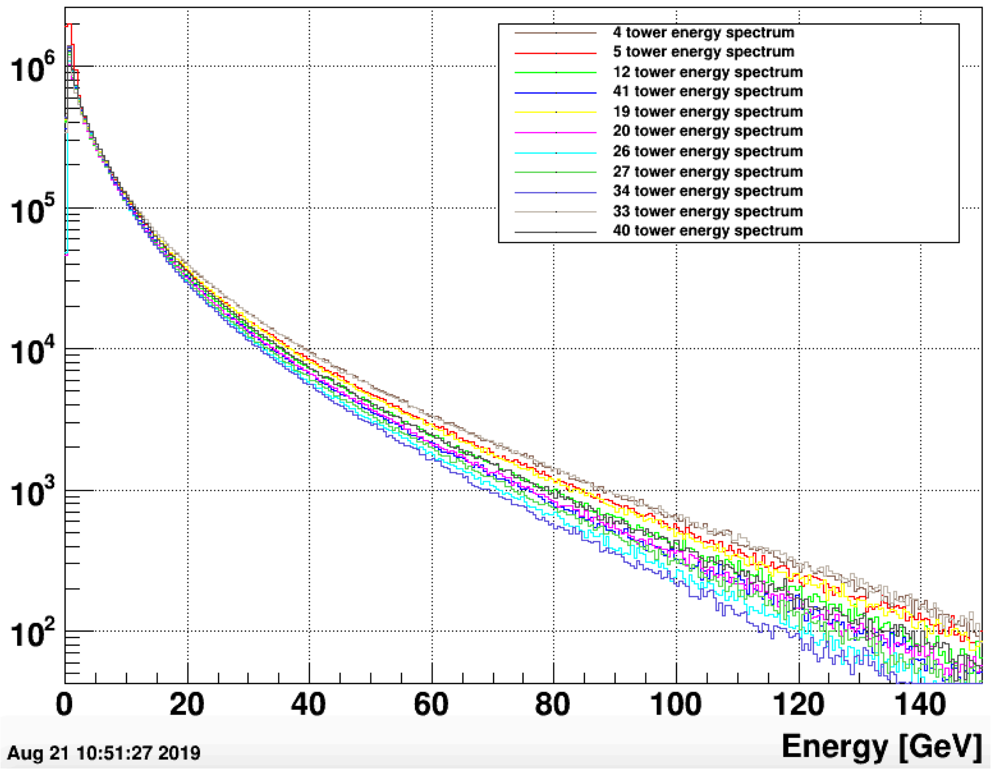
Group 3

Compare #

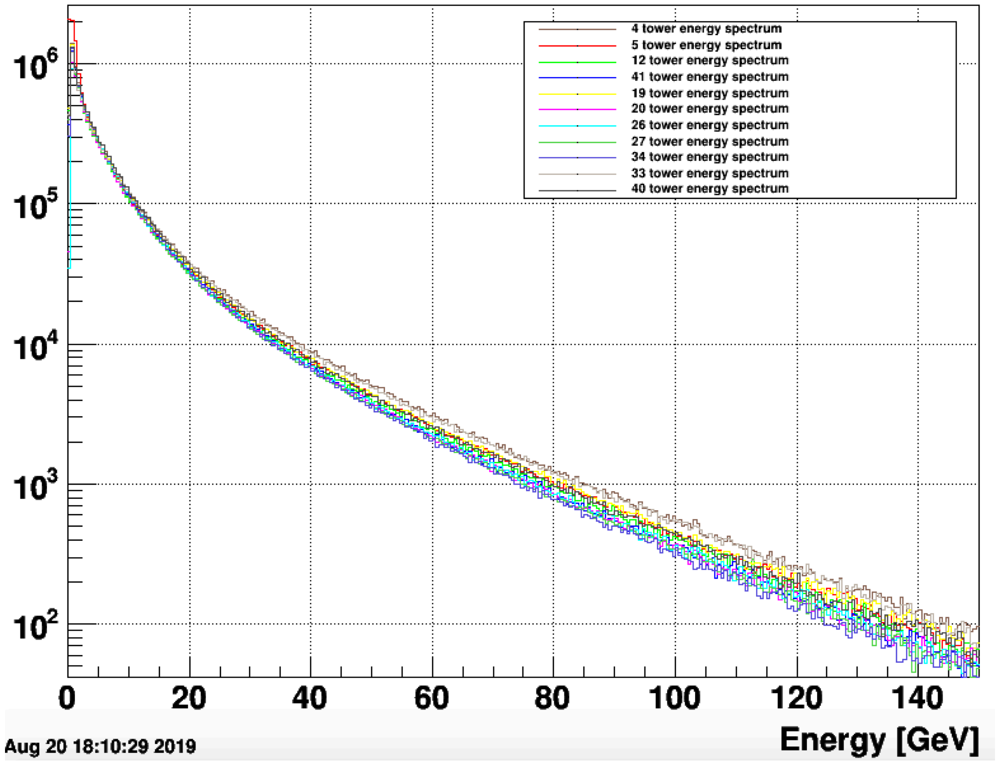
4,5,12,19,20,26,27,33,34,40,41

Distance range from 101.2 – 109.2 cm

Before gain correction



After gain correction

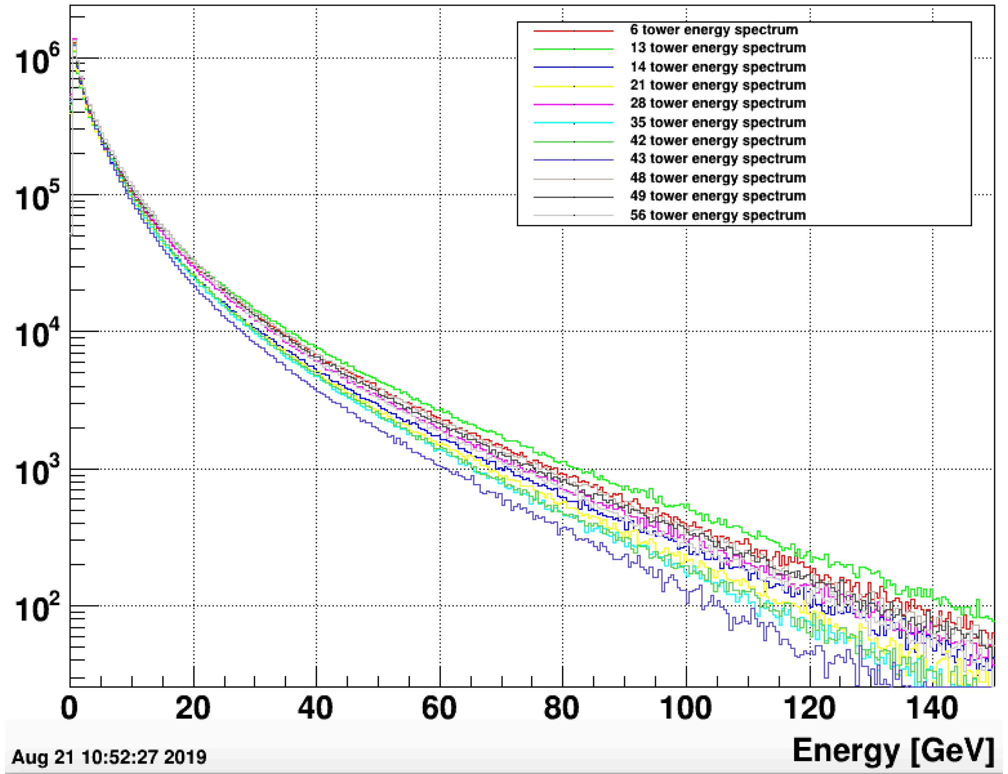


Tower energy spectrum comparison

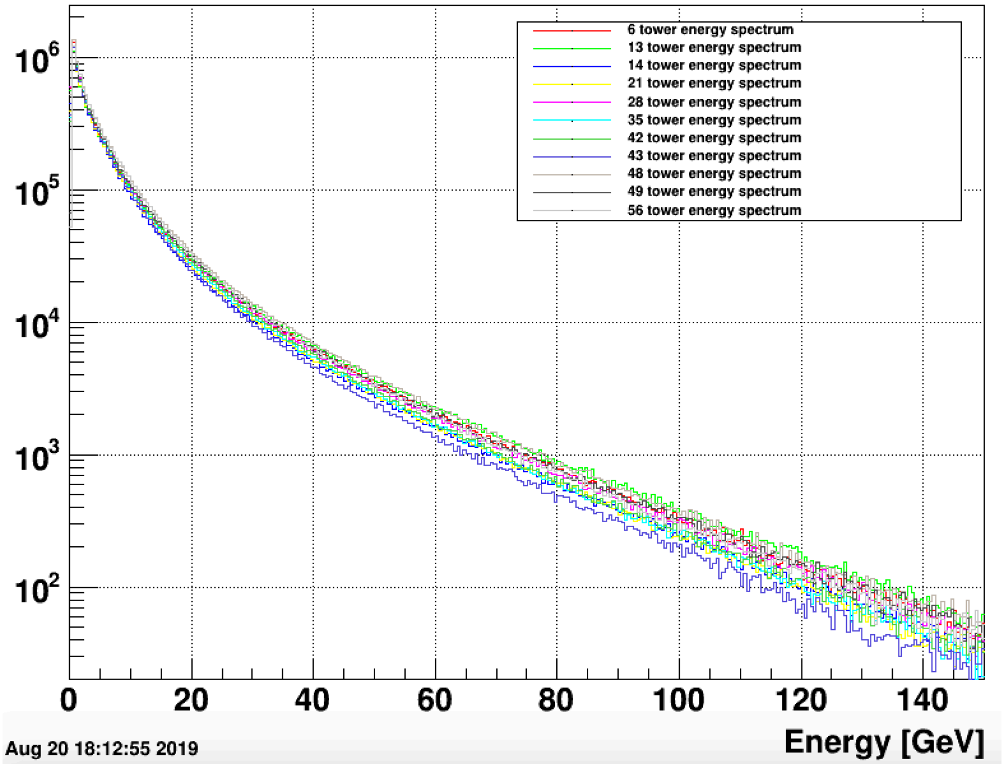
Group 4
Compare #
6,13,14,21,28,35,42,43,48,49,56

Distance range from 109.2 – 115.8 cm

Before gain correction



After gain correction

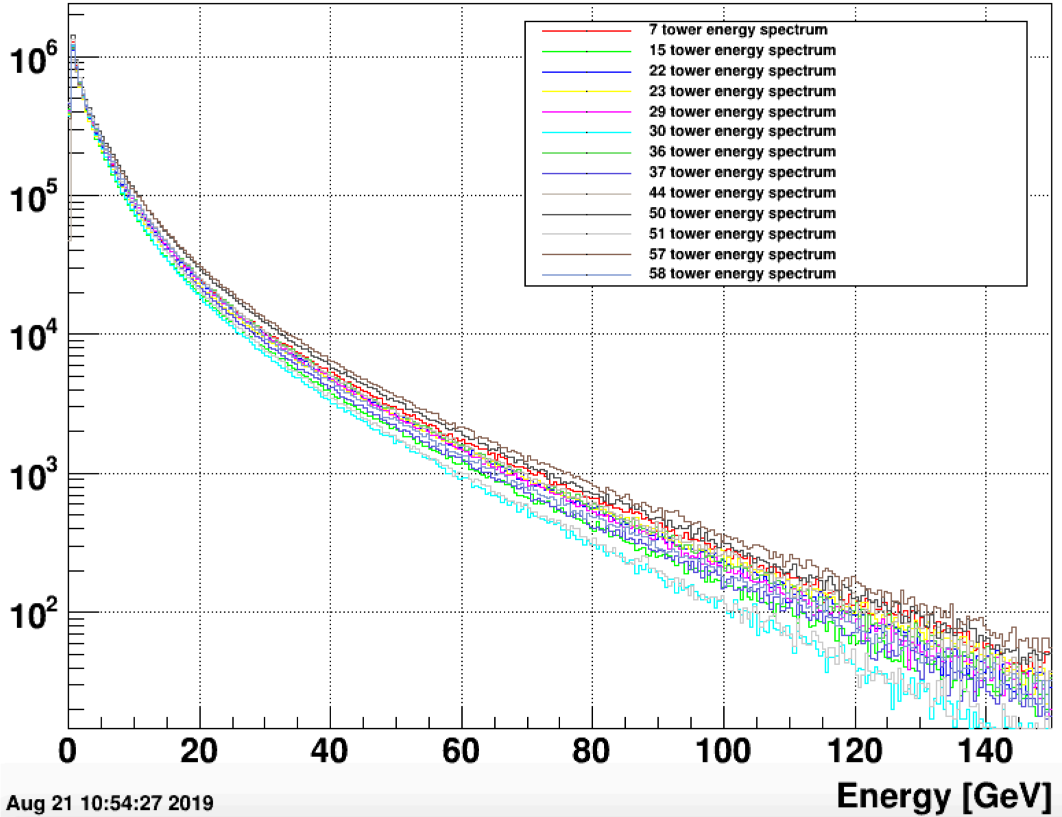


Tower energy spectrum comparison

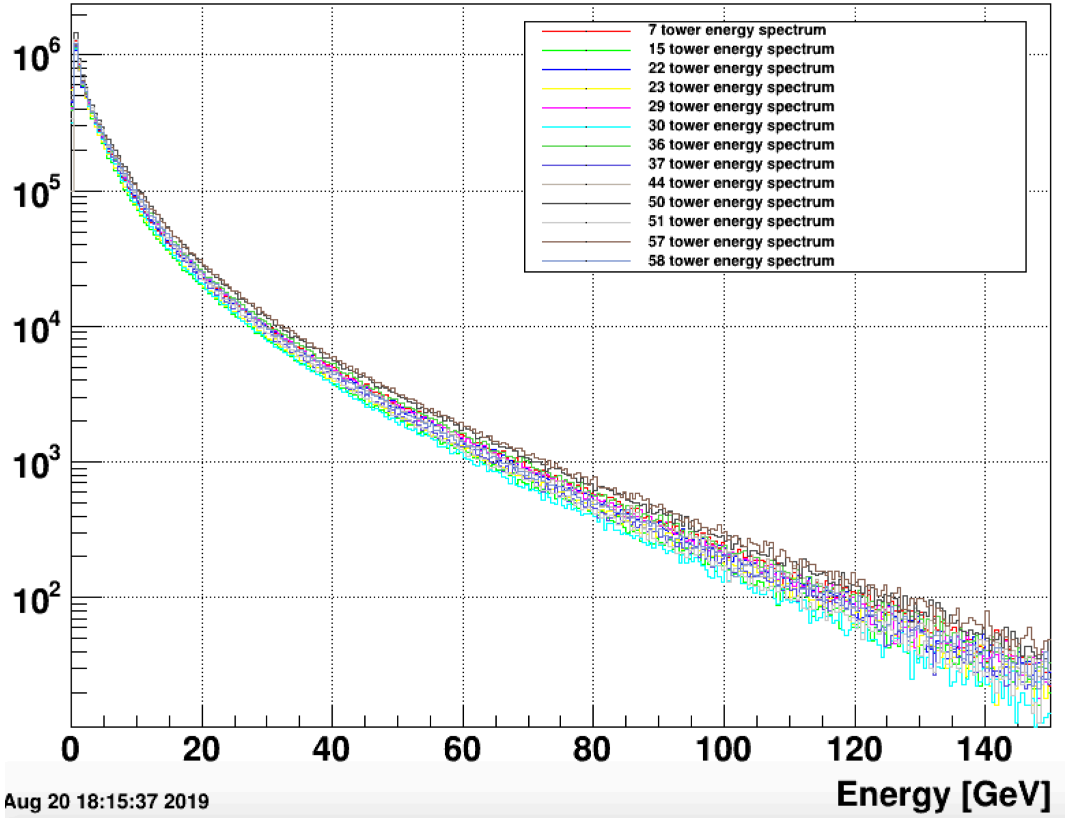
Group 5
Compare #
7,15,22,23,29,30,36,37,44,50,51,57,58

Distance range from 115.8 – 122.8 cm

Before gain correction



After gain correction

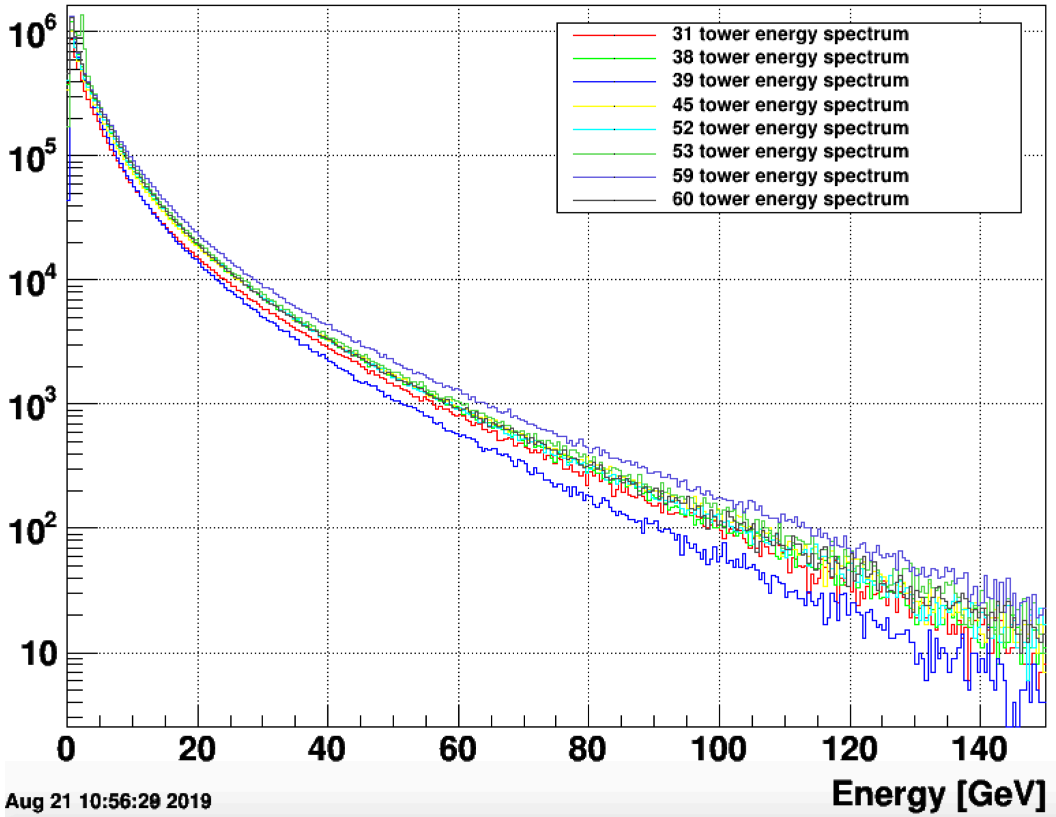


Tower energy spectrum comparison

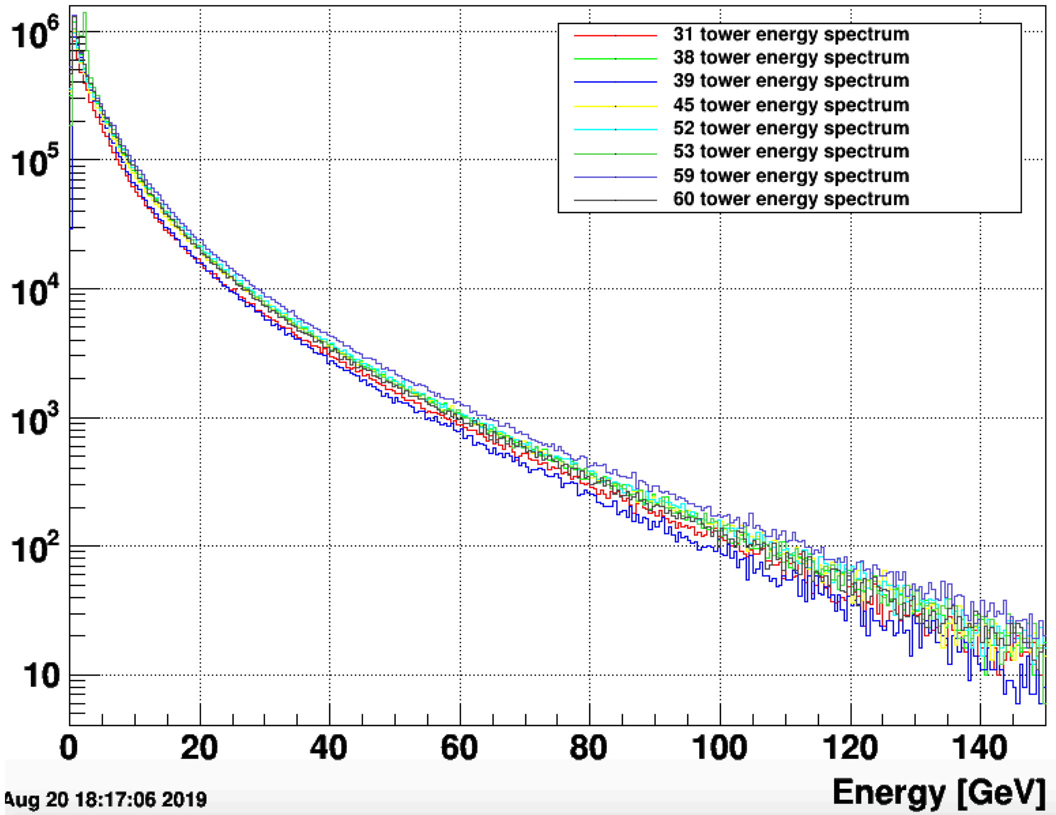
Group 6
Compare #
31,38,39,45,52,53,59,60

Distance range from 122.8 – 129.2 cm

Before gain correction



After gain correction

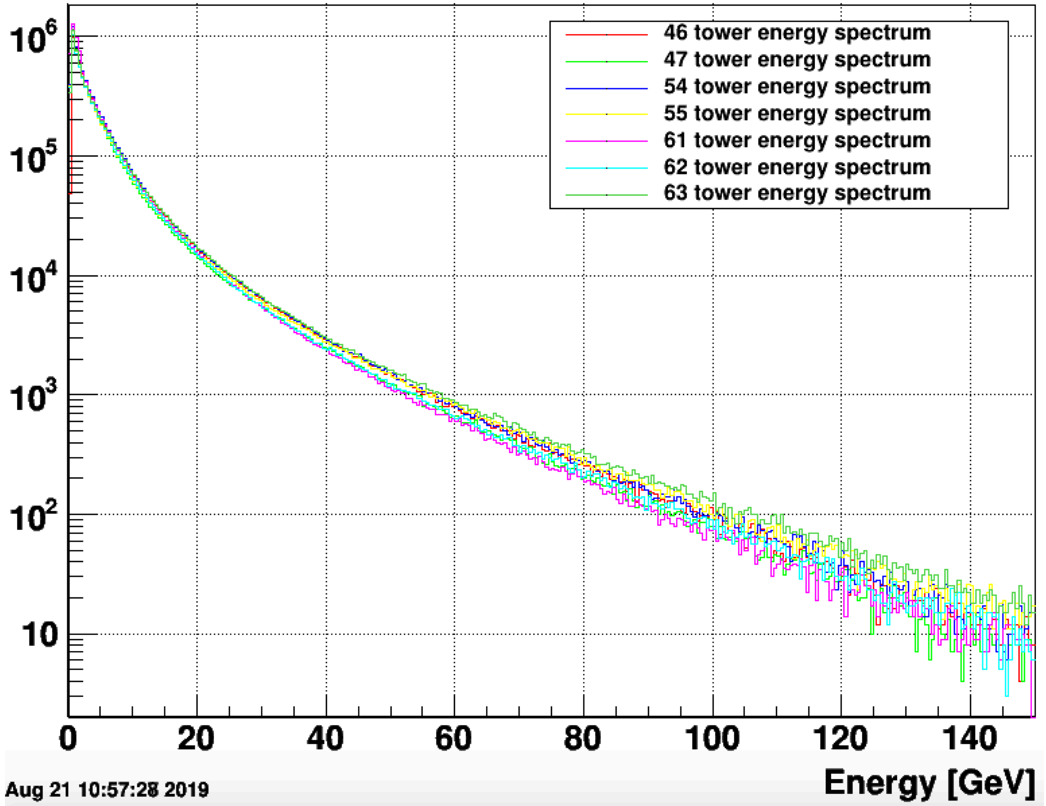


Tower energy spectrum comparison

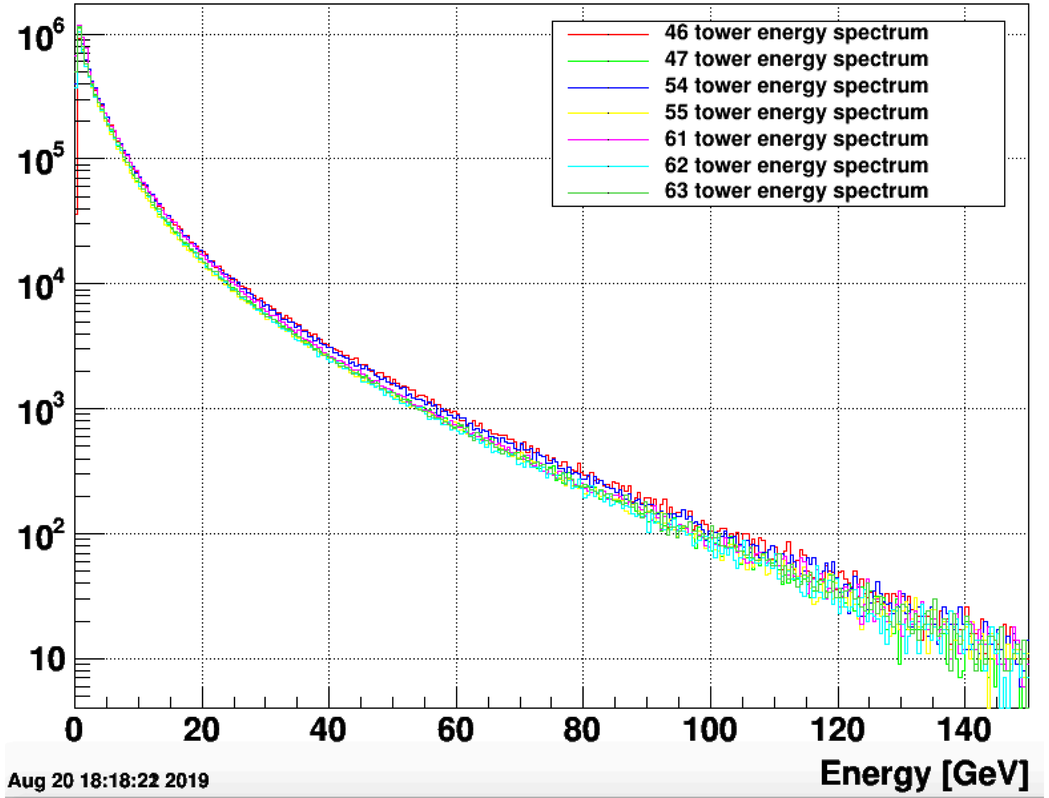
Group 7
Compare # 46,47,54,55,61,62,63

Distance range from 129.2 – 139.8 cm

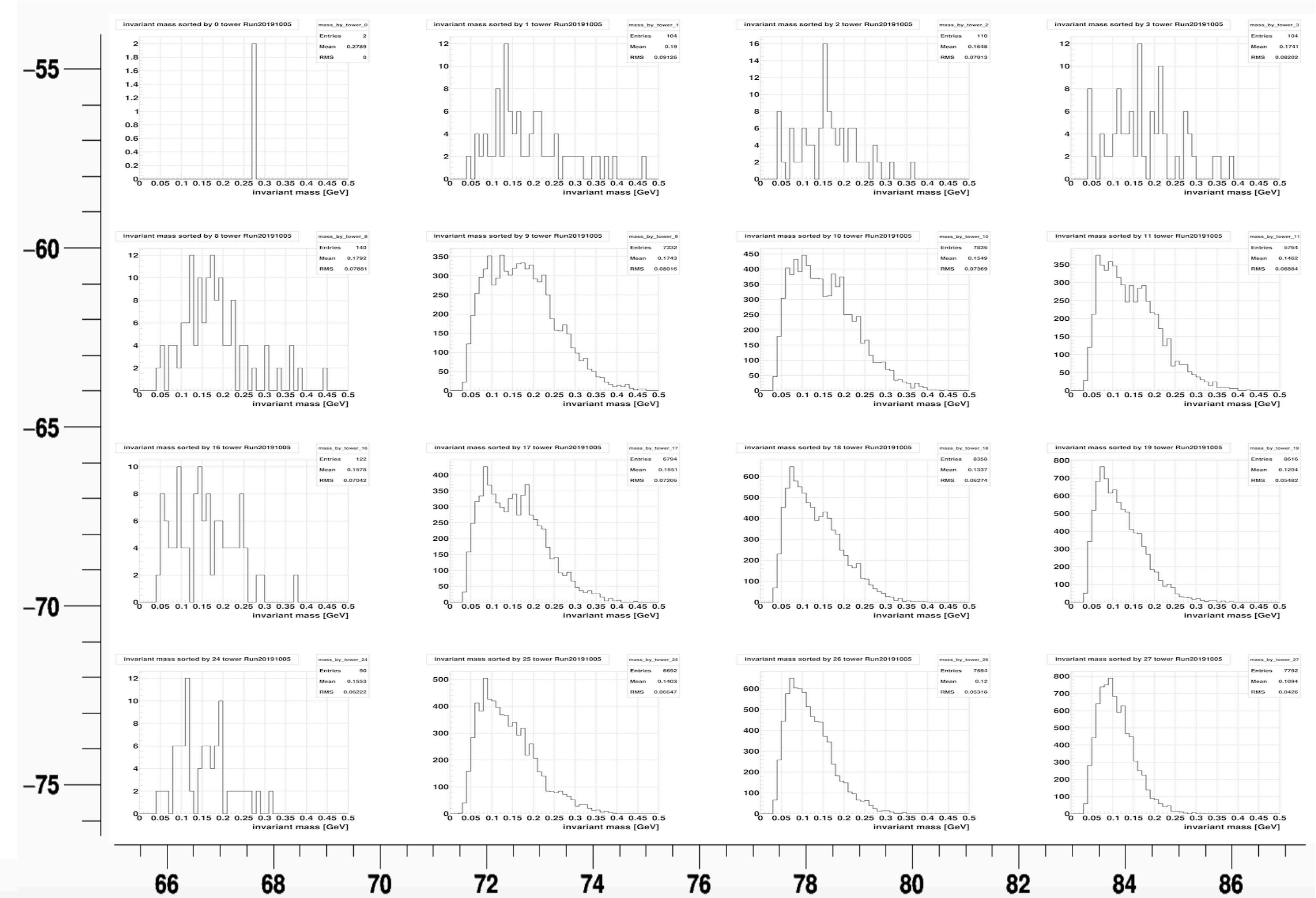
Before gain correction

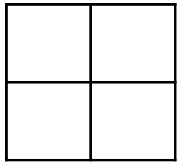


After gain correction

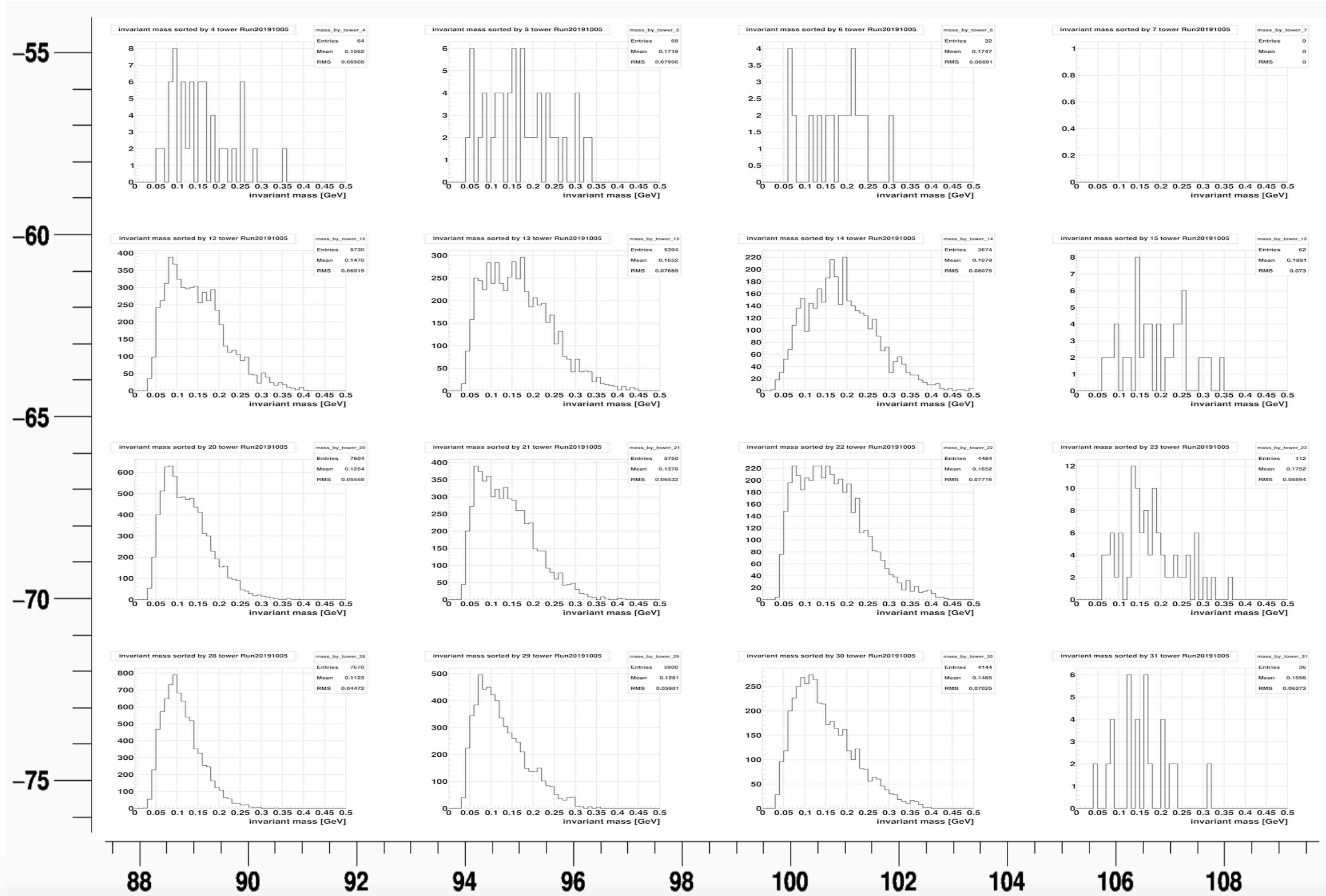


Invariant mass sorted by highest tower (Part 1)

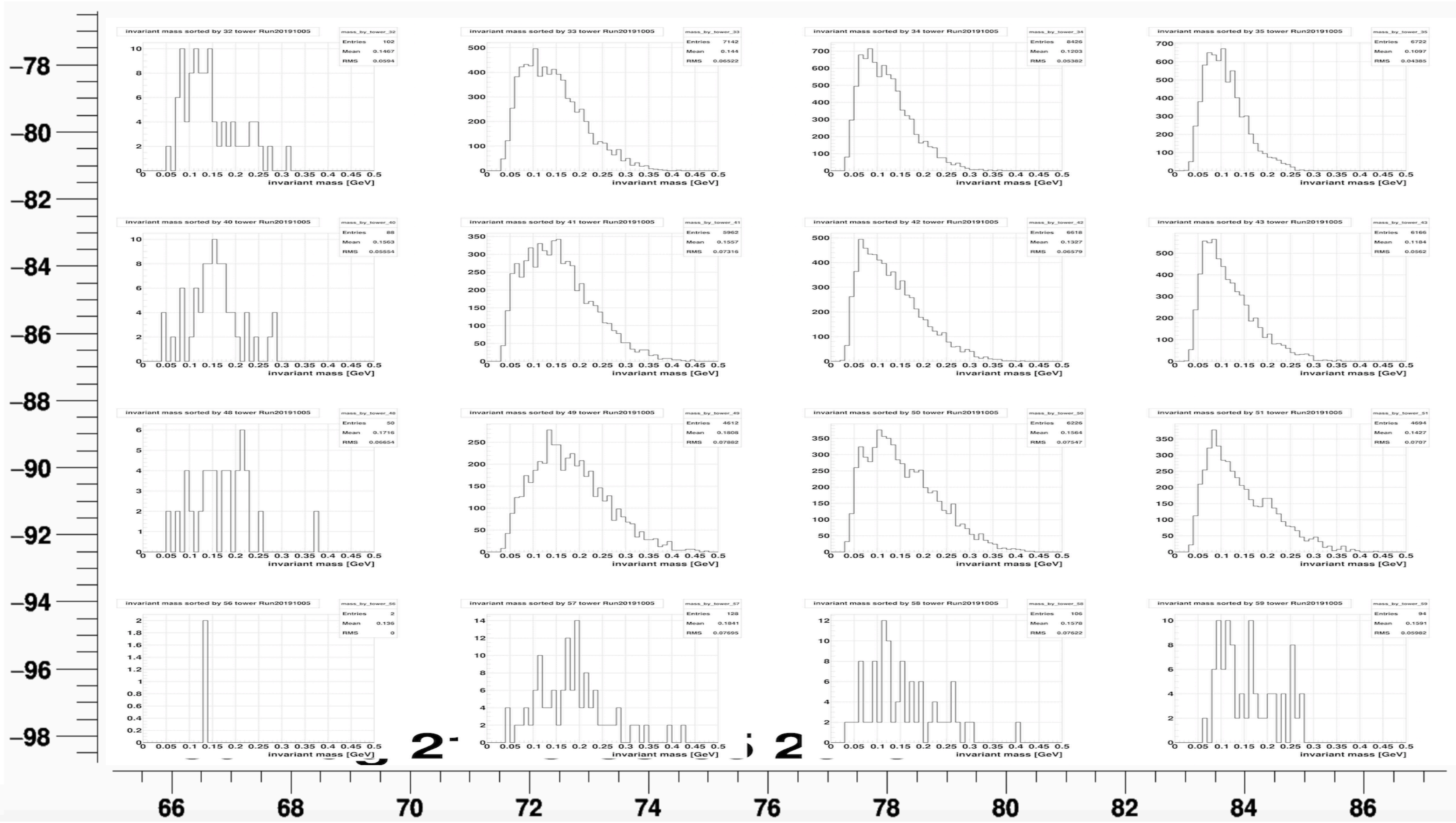




Invariant mass sorted by highest tower (Part 2)



Invariant mass sorted by highest tower (Part 3)



Invariant mass sorted by highest tower (Part 4)