Prototyping Electromagnetic Calorimeter for STAR Forward Calorimeter System using Au + Au at $\sqrt{s} = 200 GeV$ data

Xilin Liang, for the STAR Collaboration

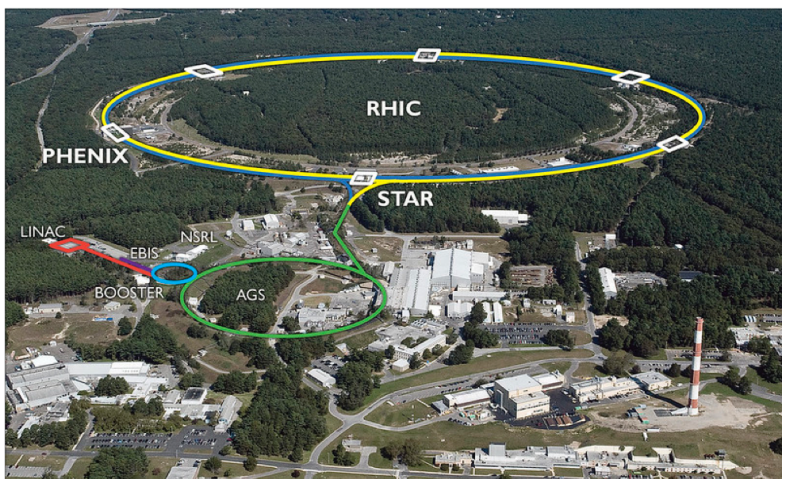
University of California, Riverside

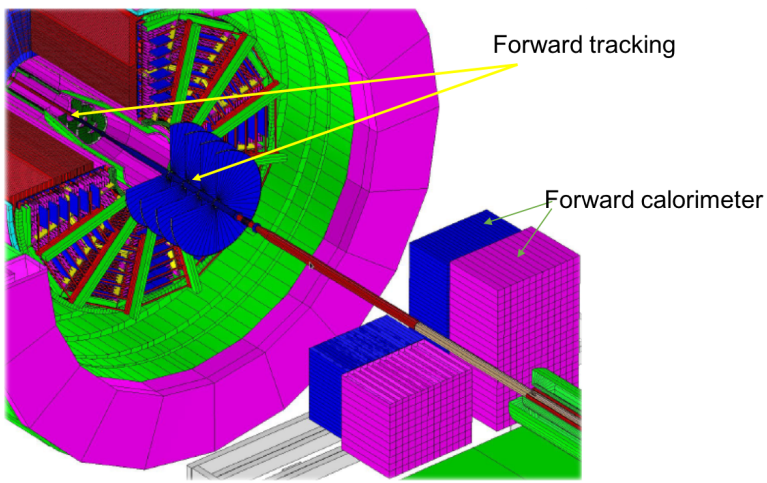
DNP2020, Oct.30, 2020

Supported in part by

STAR forward upgrade

- STAR: at Realistic Heavy Ion Collider(RHIC) located in Brookhaven National Laboratory (BNL).
- RHIC: the only polarized pp collider in the world.
- Focus on various of physics: proton (spin) structure, initial state of nuclear collisions, ...





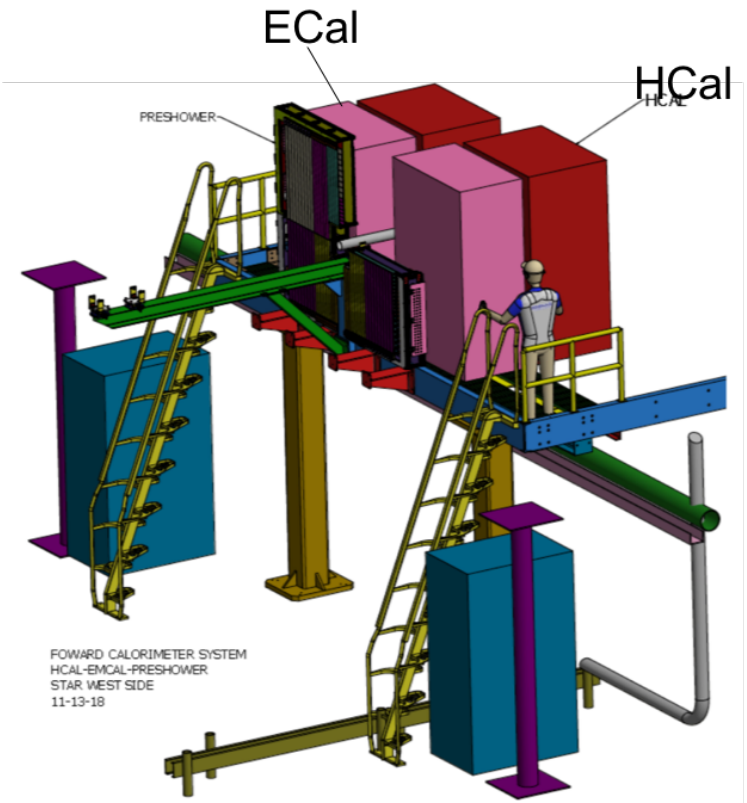
STAR forward calorimeter upgrade

Significantly improve identification of particles including π^0, γ, e^+/e^- and charged hadron.
Cover a pseudorapidity region of 2.5 - 4.

STAR Forward Calorimeter System(FCS) includes Electromagnetic Calorimeter (ECal) and Hadronic Calorimeter(HCal).

- ECal: Reuse PHENIX sampling ECal new readout.
- HCal: a sandwich iron scintillator plate sampling type with same readout as ECal.

Forward calorimeter detector upgrade is ongoing and will start data taking in 2022.



FCS ECal prototype

- Performance check of FCS ECal prototype using π^0 reconstruction for run19 Au + Au collision at $\sqrt{s} = 200 GeV$ data from min bias trigger.[1]
- Energy of tower = ADC $\times$ gain.

FCS ECal

34 rows and 22 columns for each side

FCS ECal prototype

- ECal south
- Row: 27 - 34
- Column: 9 - 16

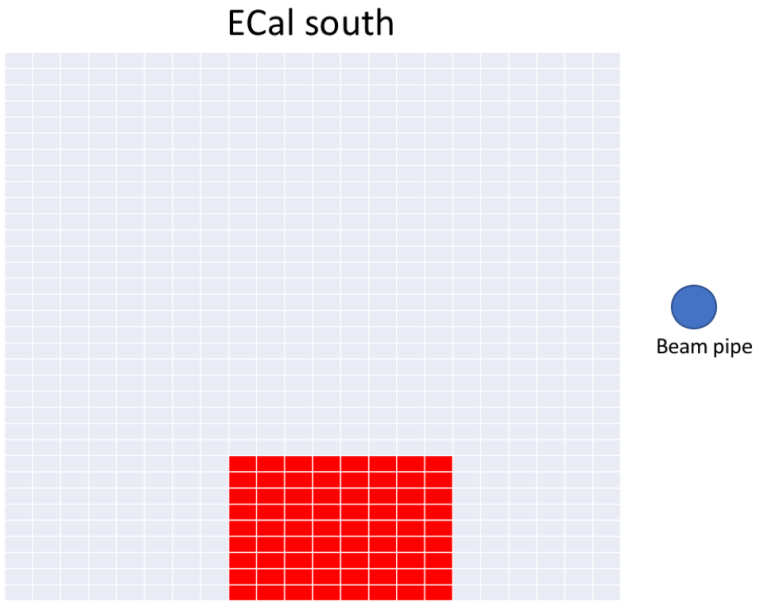
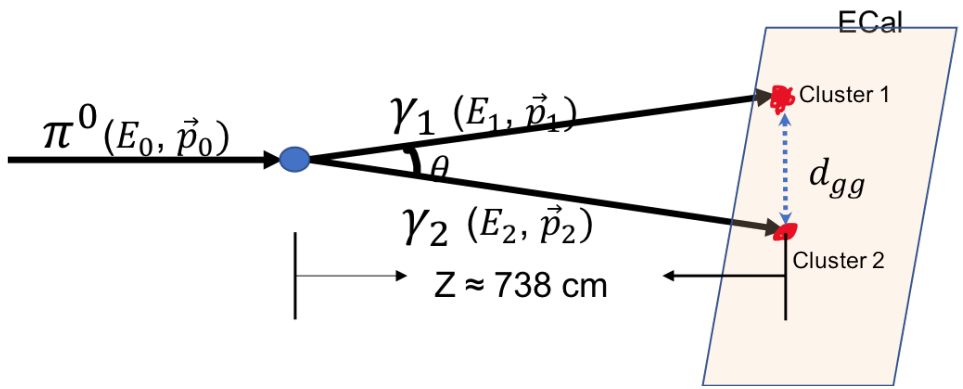


Figure: FCS ECal (south part) full geometry(whole table) and ECal prototype(red table)

[1] FCS ECal prototype was inserted in STAR hall during the run for this test.

Photon candidate obtain

- π^0 reconstruction using 2 photons.
- Use cluster finder to get all the clusters as photon candidates in each event.
- Cluster represents a group of cells fired on ECal from EM shower of photon.



Gain analysis between data and MC

- Data: initial try with gain 0.02 GeV/ch
- MC: 40 k MC using HIJING generator [1]

Procedure

1. Plot the energy spectrum for each ECal tower. These plots represent the energy of every hit for all the events.
2. Use exponential function to fit the energy spectrum, recording the slope from the fit.
3. Compare the slope for each tower between data and MC.

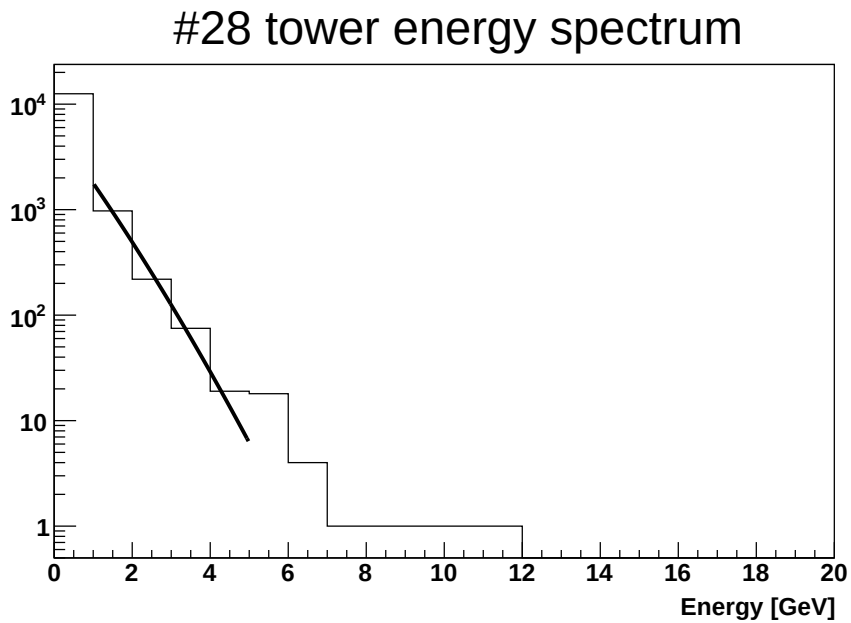


Figure: One example of energy spectrum with exponential fit (from MC)

[1] Heavy Ion Jet Interaction Generator

Gain analysis between data and MC

- Data: initial try with gain 0.02 GeV/ch
- MC: 40 k MC using HIJING generator

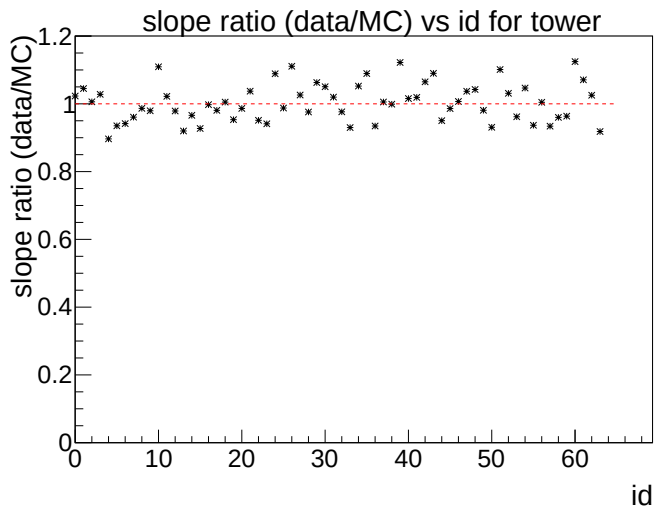
Compare the slope from fit for tower energy spectrum between data and MC:

$$corrected\ gain = \frac{slope\ from\ fit\ for\ data}{slope\ from\ fit\ for\ MC} \times 0.02 GeV/ch$$

Reason

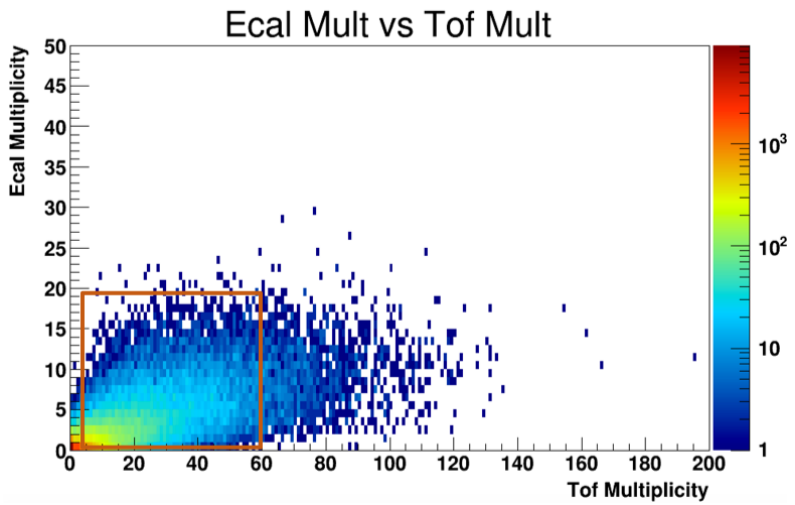
The energy spectrum for towers of data and MC should behave similarly. If we use exponential function to express their spectra, their slope should be same.

From this gain analysis, we obtain the corrected gain 0.00086 GeV/ch for prototype data.



Event selection for data with corrected gain

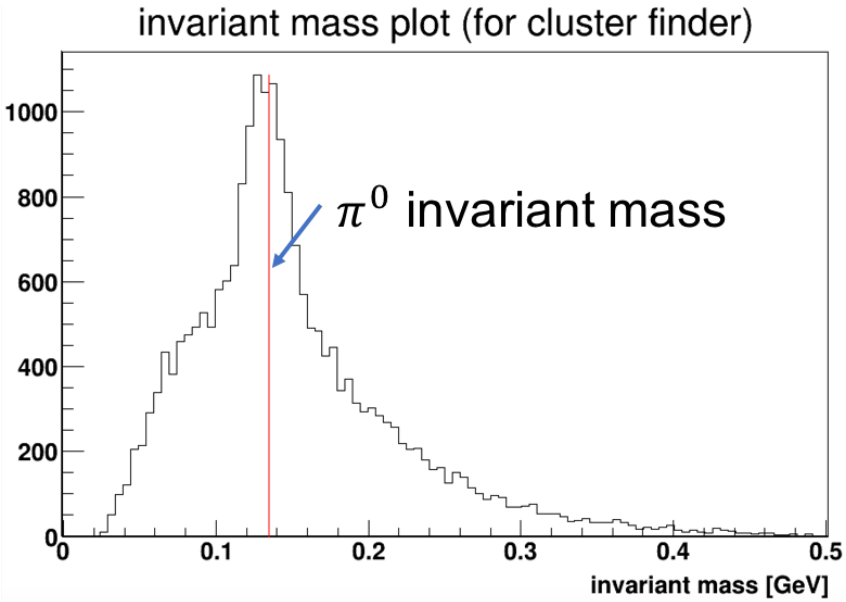
1. Select cluster only at ECal
2. cluster energy cuts:
   - Each cluster energy $> 1GeV$
   - Energy asymmetry $Z_{\gamma\gamma} < 0.7$ where $Z_{\gamma\gamma} = \frac{|E_1 - E_2|}{E_1 + E_2}$
   - $8GeV < E_1 + E_2 < 25GeV$
3. Detector multiplicity
   - $3 \leq TOF\ multiplicity \leq 60$
   - $ECal\ multiplicity(energy\ of\ hit > 1GeV) \leq 20$
4. Select the best pair of cluster by considering the pair of clusters which have the highest energy



Invariant mass plot result

Successful performance check for FCS prototype ECal

The plot shows an obvious peak right at π^0 invariant mass.
It shows that the gain 0.00086 GeV/ch is very close to the ideal gain for the data.



Conclusion

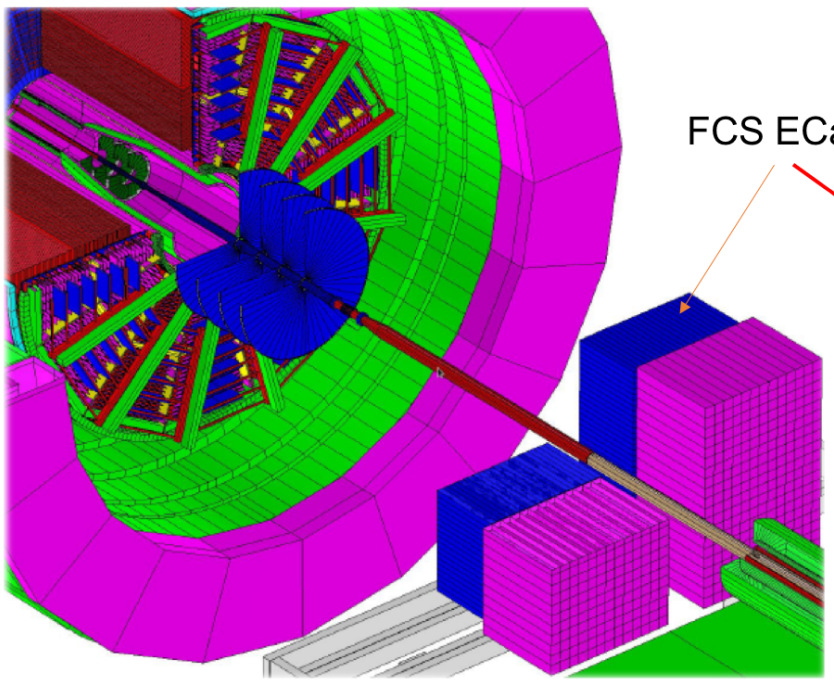
- The gain analysis with MC using Hijing generator works pretty well to get the gain close to the best gain for data.
- Applying gain 0.00086 GeV/ch and use data only from min bias trigger, one obtains invariant mass plot at correct π^0 mass for cluster finder method, proving it a successful performance check for FCS prototype ECal.
- The STAR forward calorimeter detector upgrade is ongoing and will start taking data in 2022.

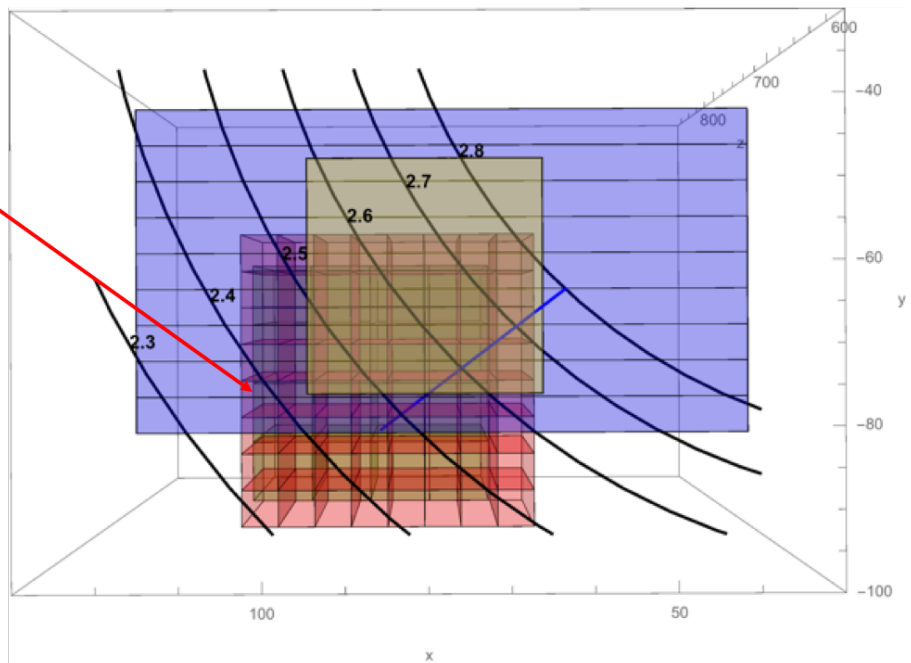
Acknowledge

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Medium Energy Nuclear Physics program under Award Number DE-FG02-04ER41325.

Back up

Forward upgrade detector design





Sample waveform

- Each time bin samples $1/8^{th}$ of RHIC tick (12ns) and generates 12-bit ADC (0-4095)
- Triggered Crossing at timebin $\sim$ 50
- HCal and ECal use same electronics so signal shown matches profile of ECal signal (same width)

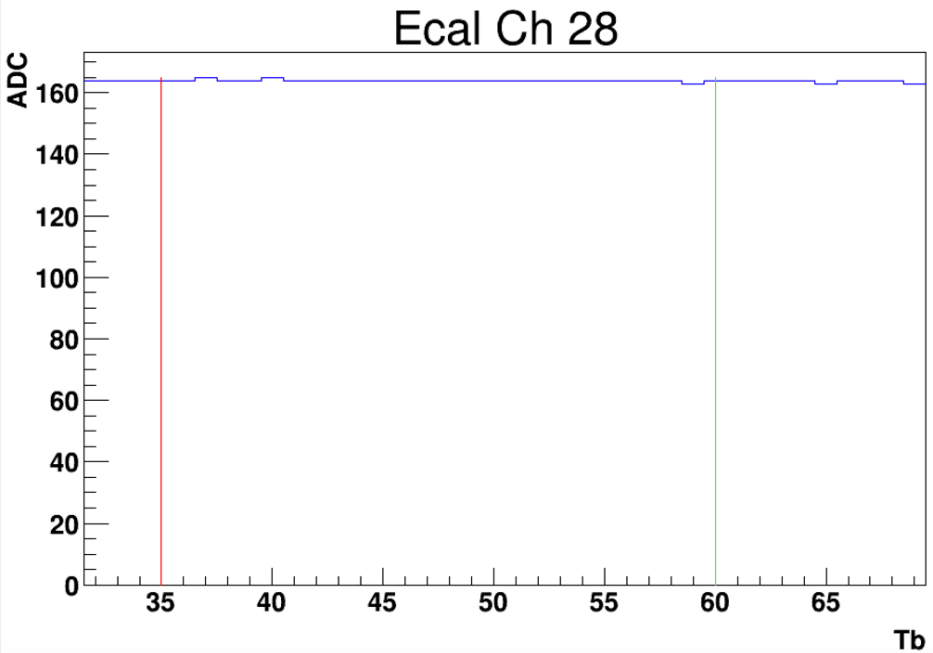


Figure: an example of signal from ECal channel

More plots for the results

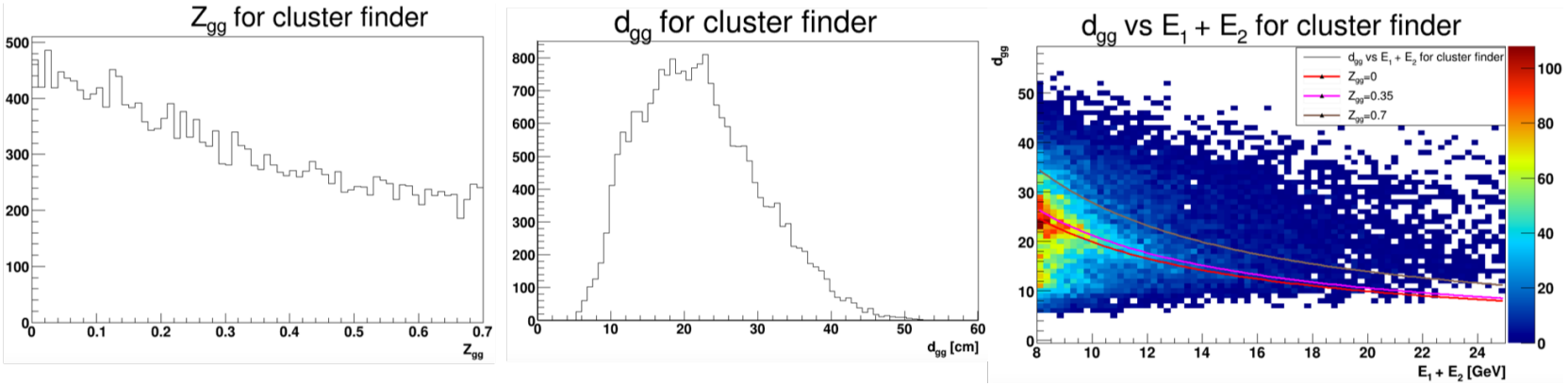


Figure: Plots for Z_{gg} [1], d_{gg} [2] and d_{gg} *vs* : $E_1 + E_2$ for cluster finder

[1] $Z_{\gamma\gamma} = \frac{|E_1 - E_2|}{E_1 + E_2}$

[2] d_{gg} is the distance between two clusters at ECal