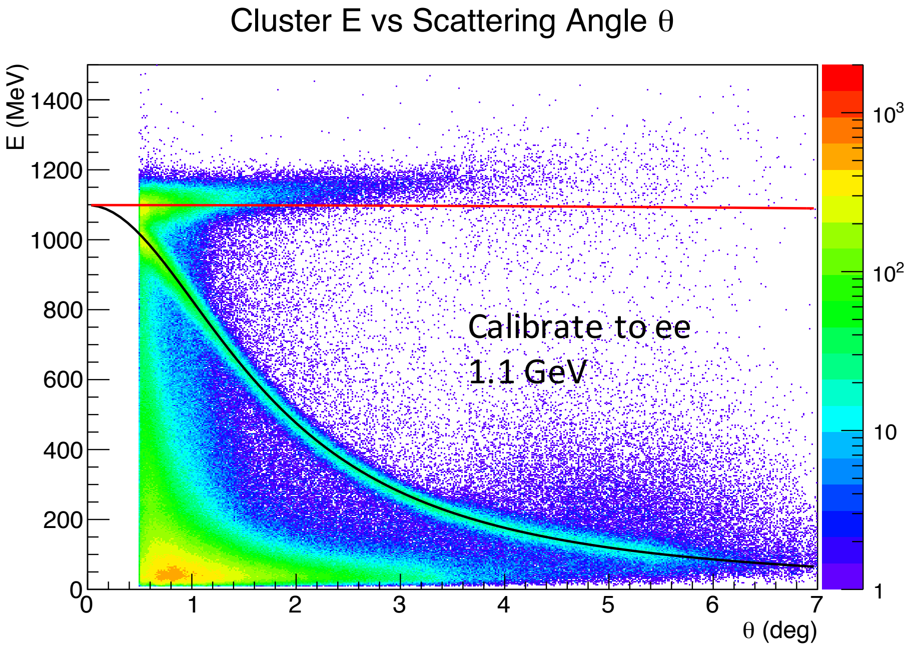
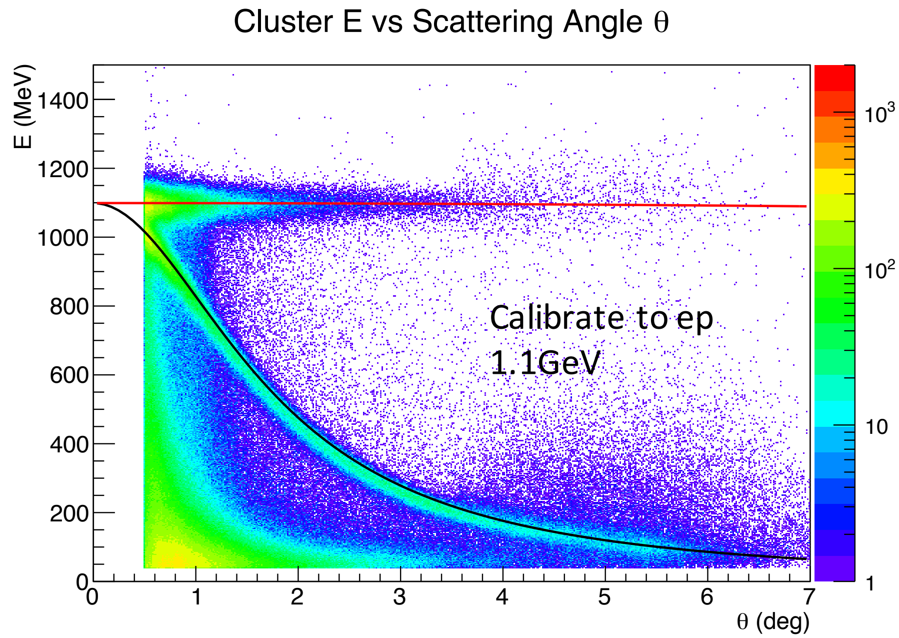
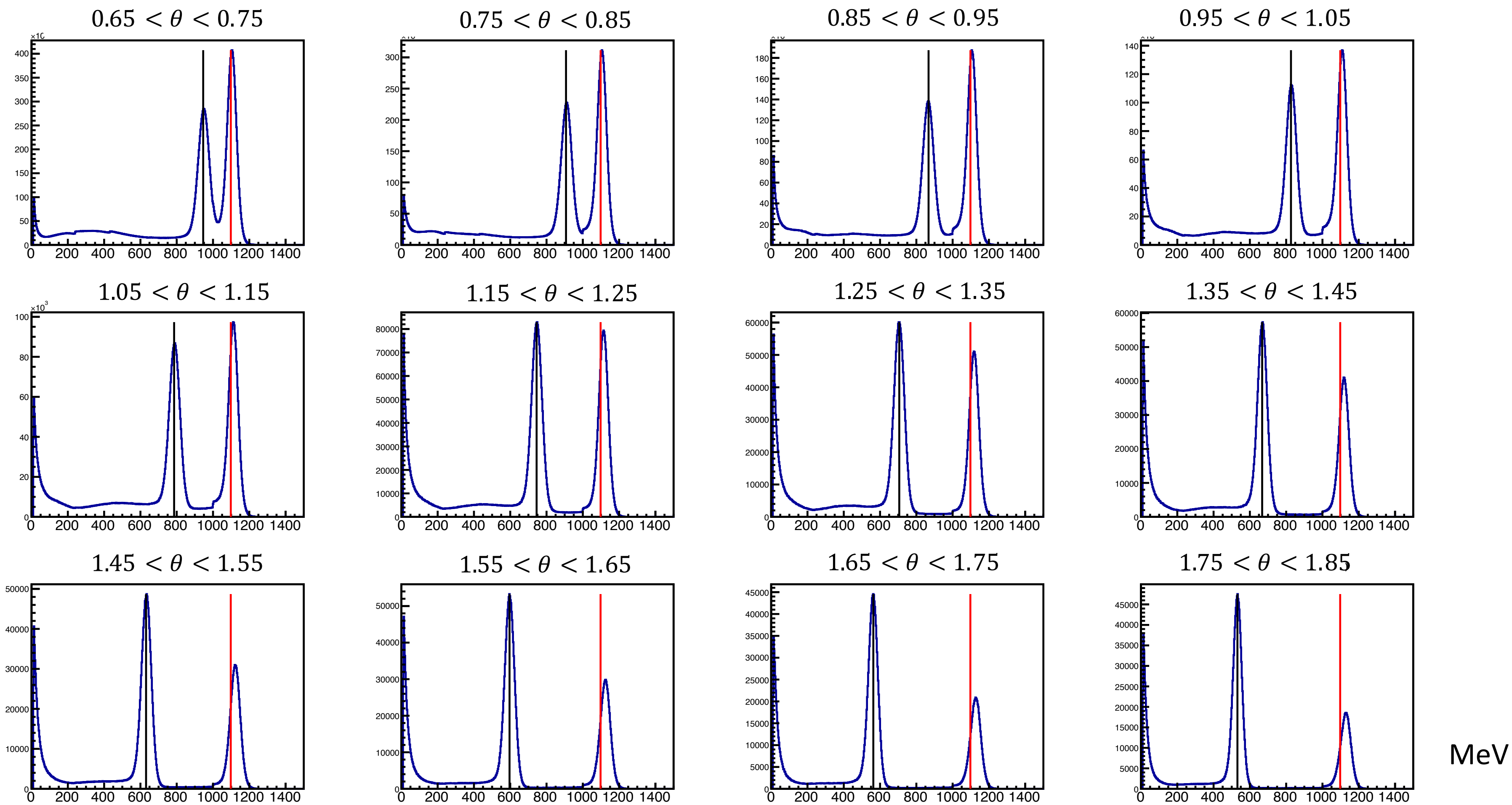
HyCal Physics Calibration – Non-Linearity



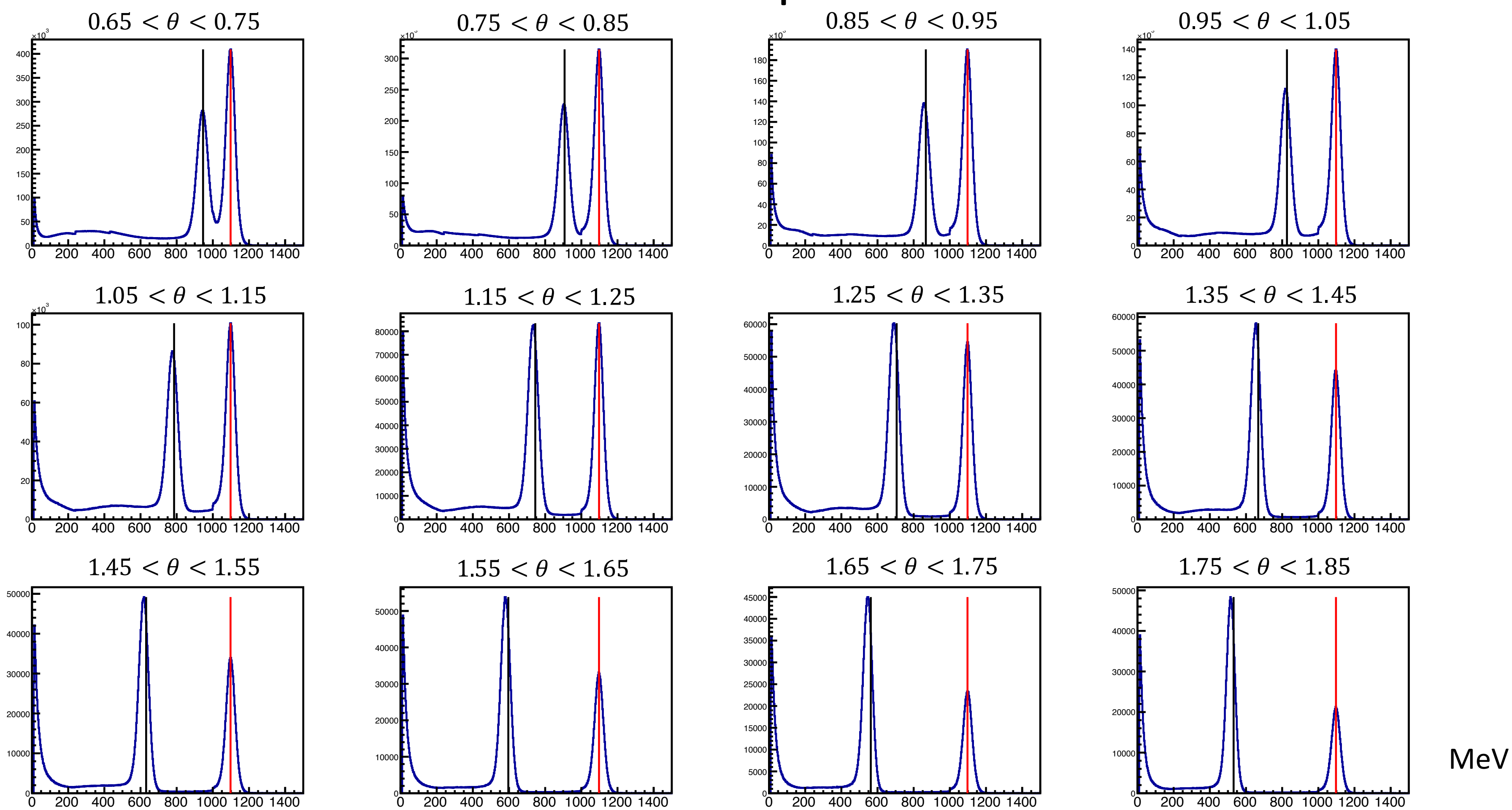


- A linear calorimeter has a constant response (average signal per unit of deposited energy)
- Electromagnetic calorimeters are in general linear, if not linear might due to instrumental effects (saturation, leakage…) (see www.roma1.infn.it/people/bini/seminars.lecture2.pdf)
- But this is not the case for HyCal, we need the non-linearity correction in order to have unbiased distribution for ee and ep at the same time

Calibrate to ee – 1.1 GeV

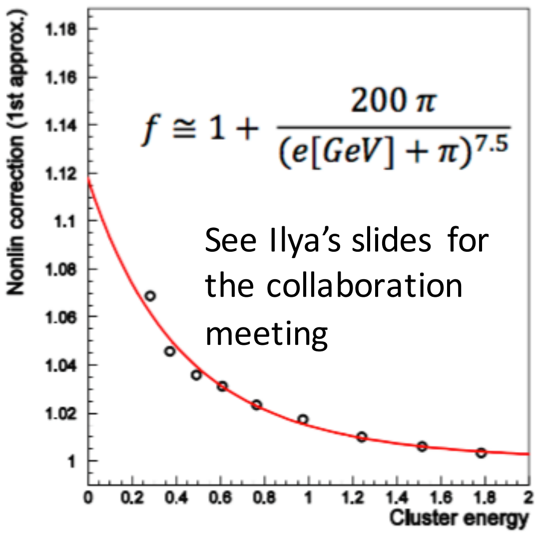


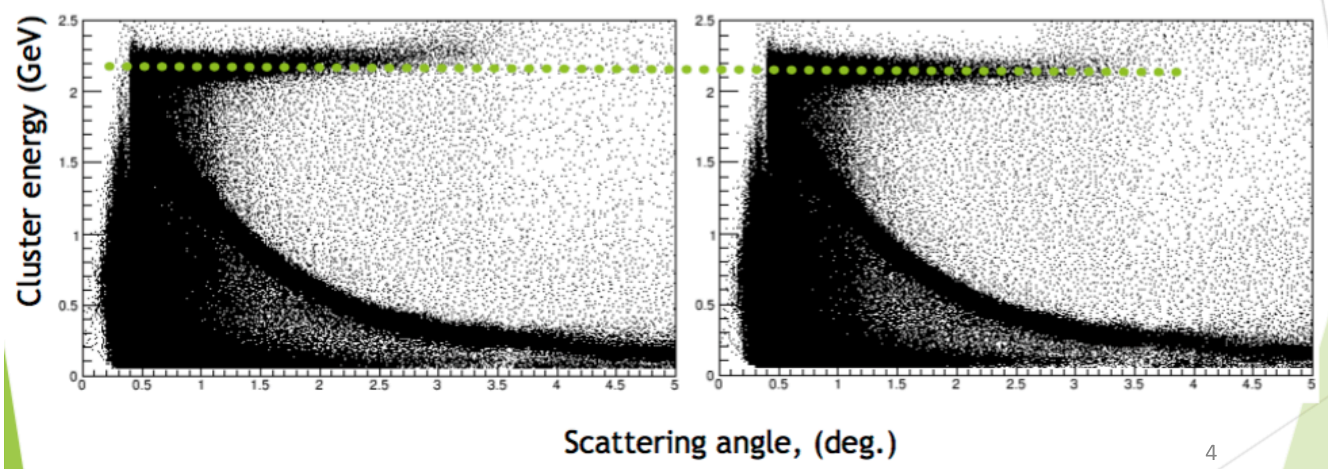
Calibrate to ep – 1.1 GeV



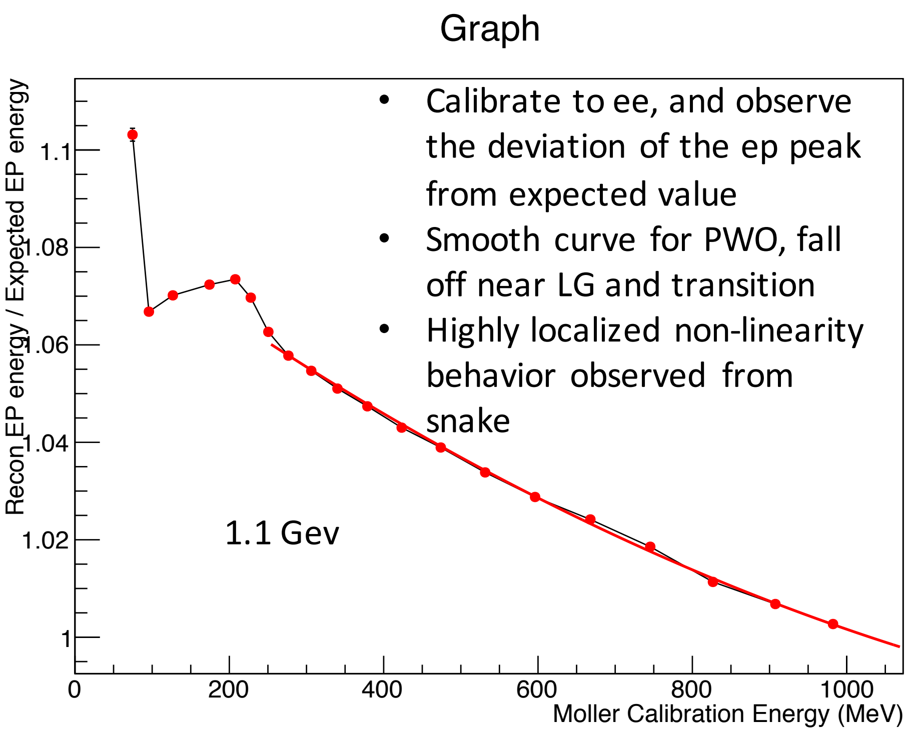
How to Deal With the Non-Linearity Problem

- Method I: Parameterization functions
  - Using Parameterization function to describe the non-linearity behavior
  - Require rather uniform non-linearity behavior for all modules
  - May need multiple parameterization functions (LG, PWO, transition non-linearity behavior not the same)
  - Ilya has shown that it works for PWO part at 2.2GeV in the collaboration meeting
  - Might not work well if non-linearity behavior is highly localized



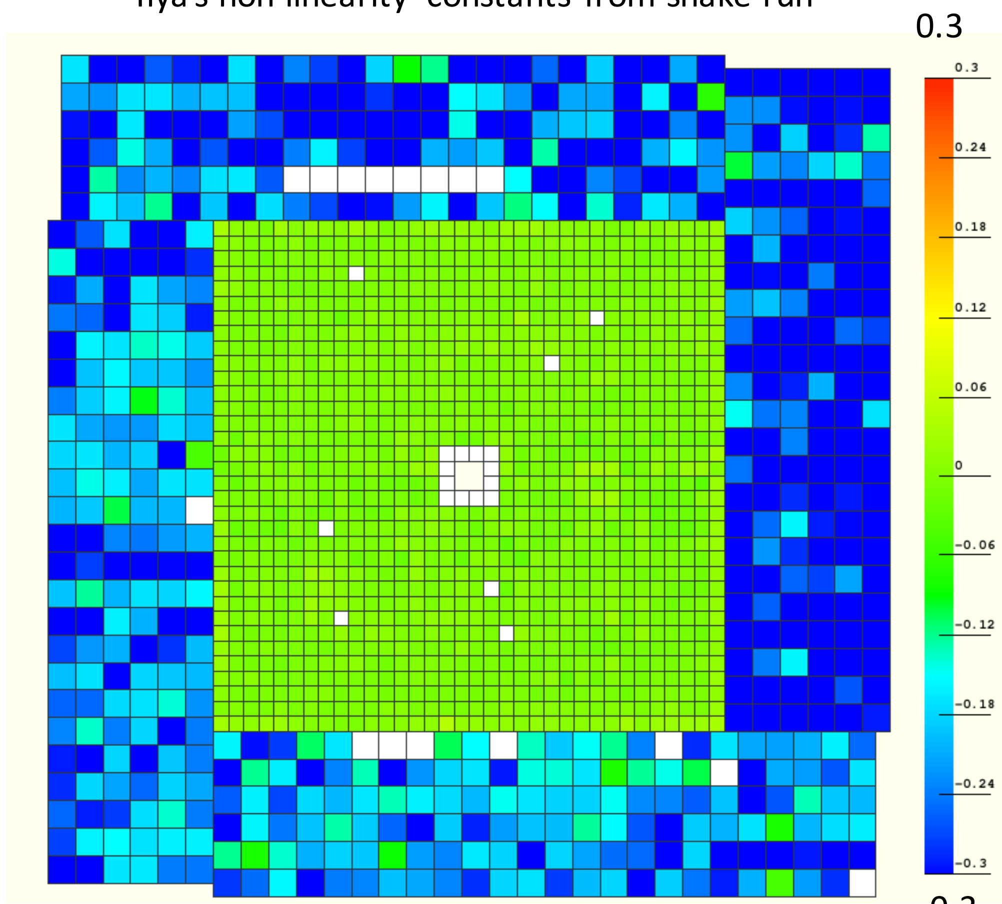


Using Parameterization Functions



- Calibrate to ee, and observe the deviation of the ep peak from expected value
- Smooth curve for PWO, fall off near LG and transition
- Highly localized non-linearity behavior observed from snake

Ilya's non-linearity constants from snake run



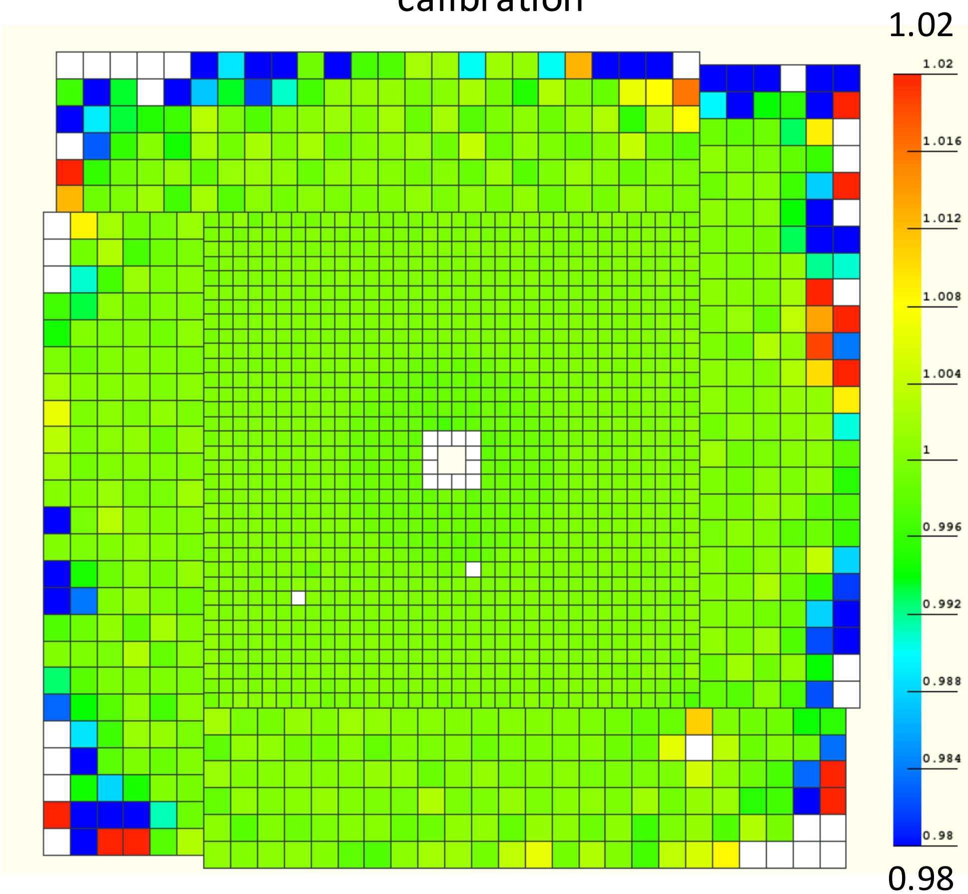
How to Deal With the Non-Linearity Problem

- Method II: Obtain non-linearity constant module by module
  - For each module, obtain two calibration constants, one from ep and the other from ee
  - Similar to what we did with the snake run, for each module:

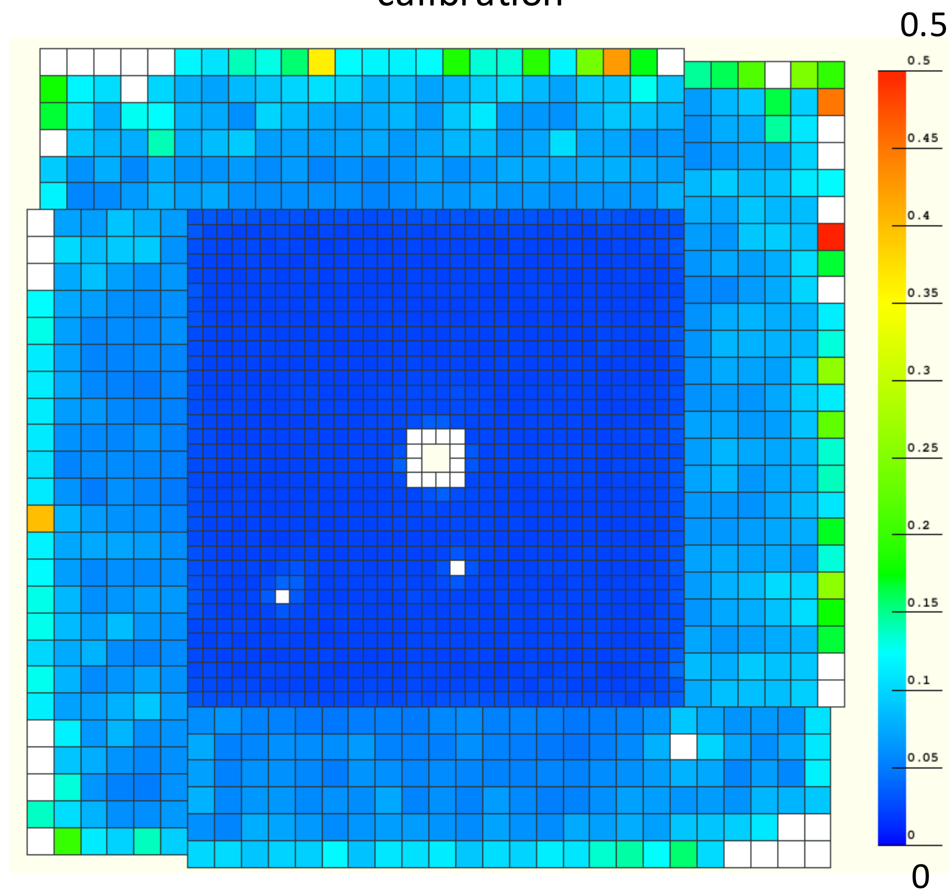
$$E_{Corr} = \frac{E_{Recon}}{1 + \alpha(E_{Recon} - E_{Cali})}$$

  - E_{cali} is the calibration energy that we used to calibrate the module, E_{recon} is the reconstructed energy on this module, alpha is the non-linearity constant
  - For physics calibration, we only have two points for each module, one from ee and the other from ep
  - One of the two points need to be used as the calibration energy, so we are basically solving equation, not even fitting
  - This doesn't work if the module is missing one of the two points (happen quite often near edge and corner)
- Currently, I have two sets of calibration constants for run 1288 ~1345, each after 5 iterations

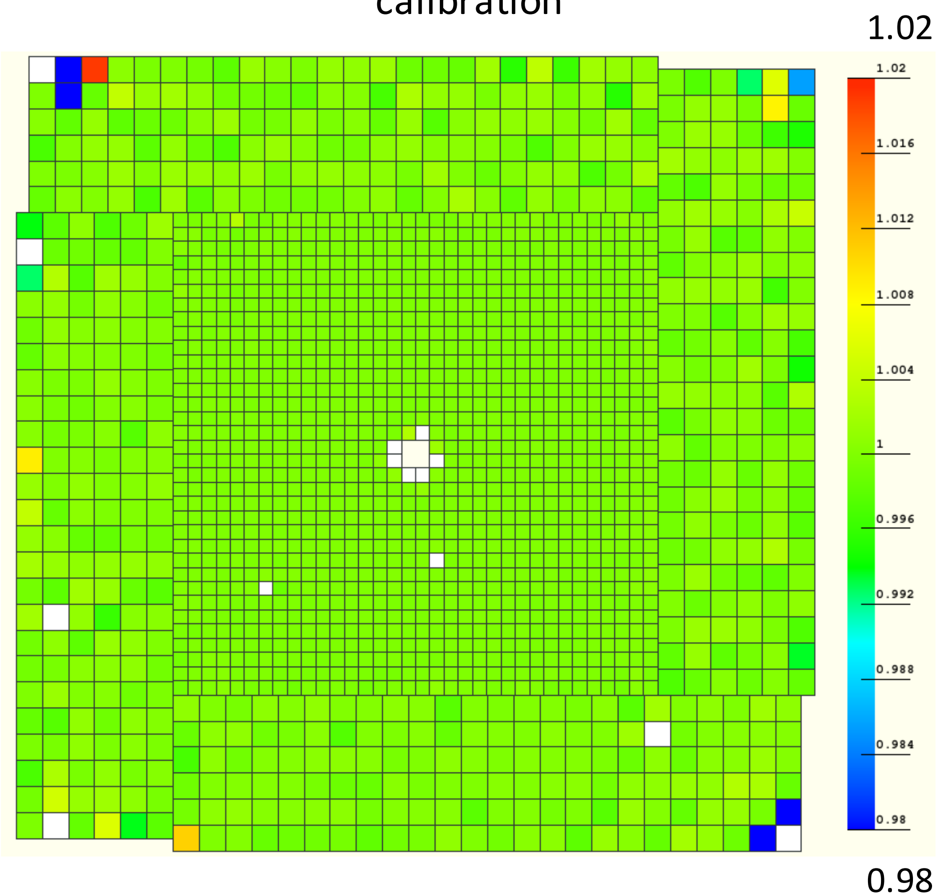
Mean value of (E Recon / E Eexpect) for ep calibration



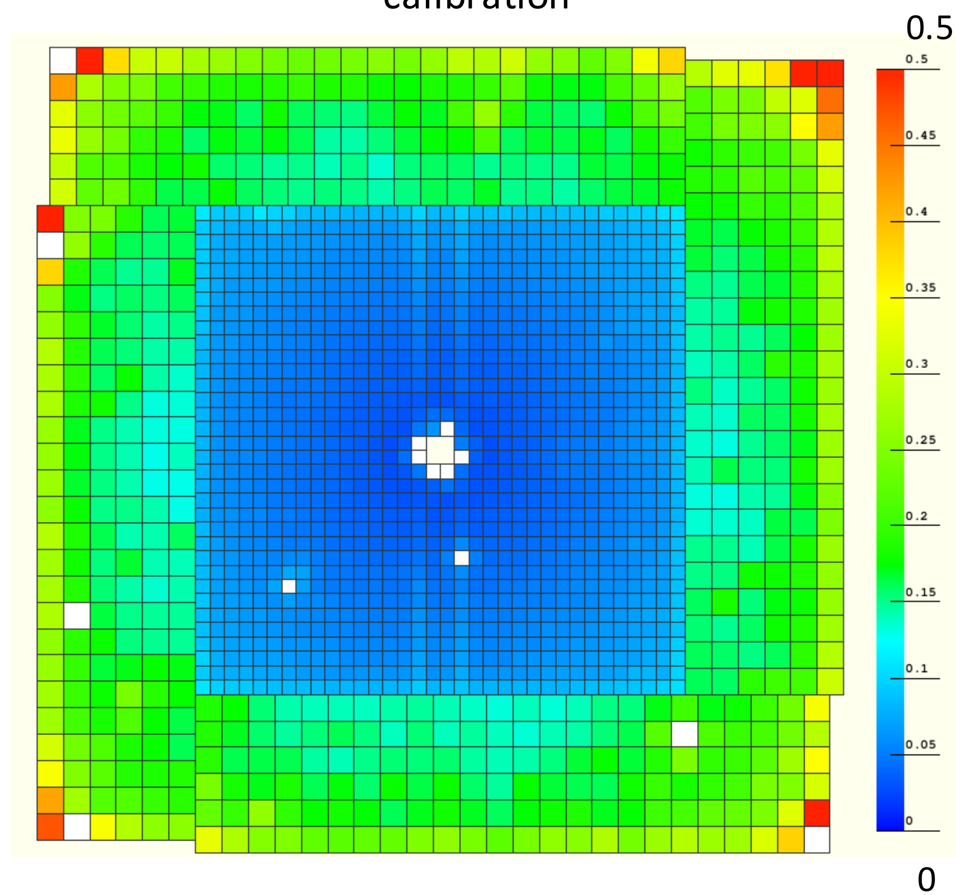
Sigma of (E Recon / E Eexpect) for ep calibration



Mean value of (E Recon / E Eexpect) for ee calibration



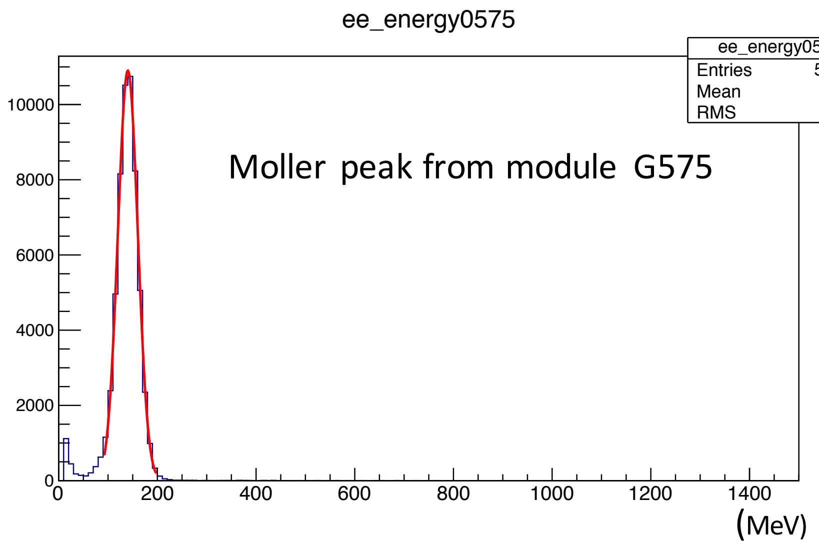
Sigma of (E Recon / E Eexpect) for ee calibration

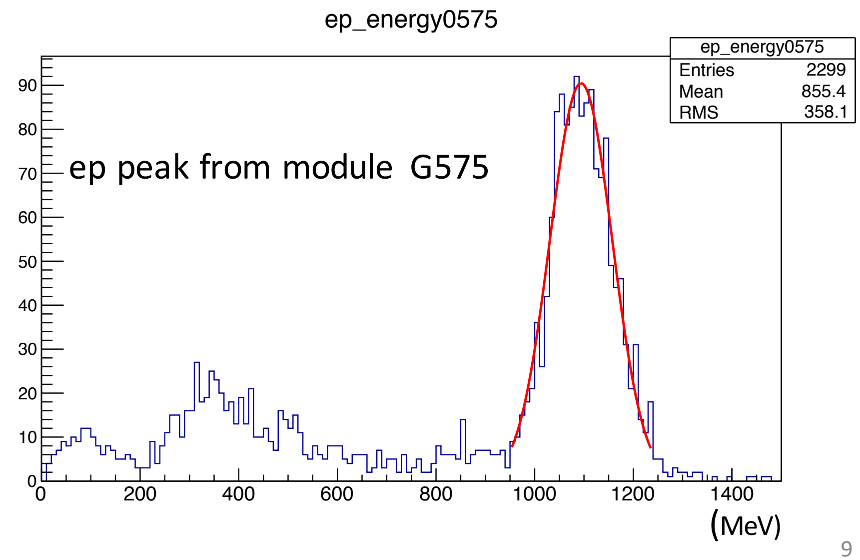


- Solving the following equation to get alpha:

$$\alpha = \frac{\frac{E_{Recon}}{E_{Expect}} - 1}{E_{Recon} - E_{Cali}}$$

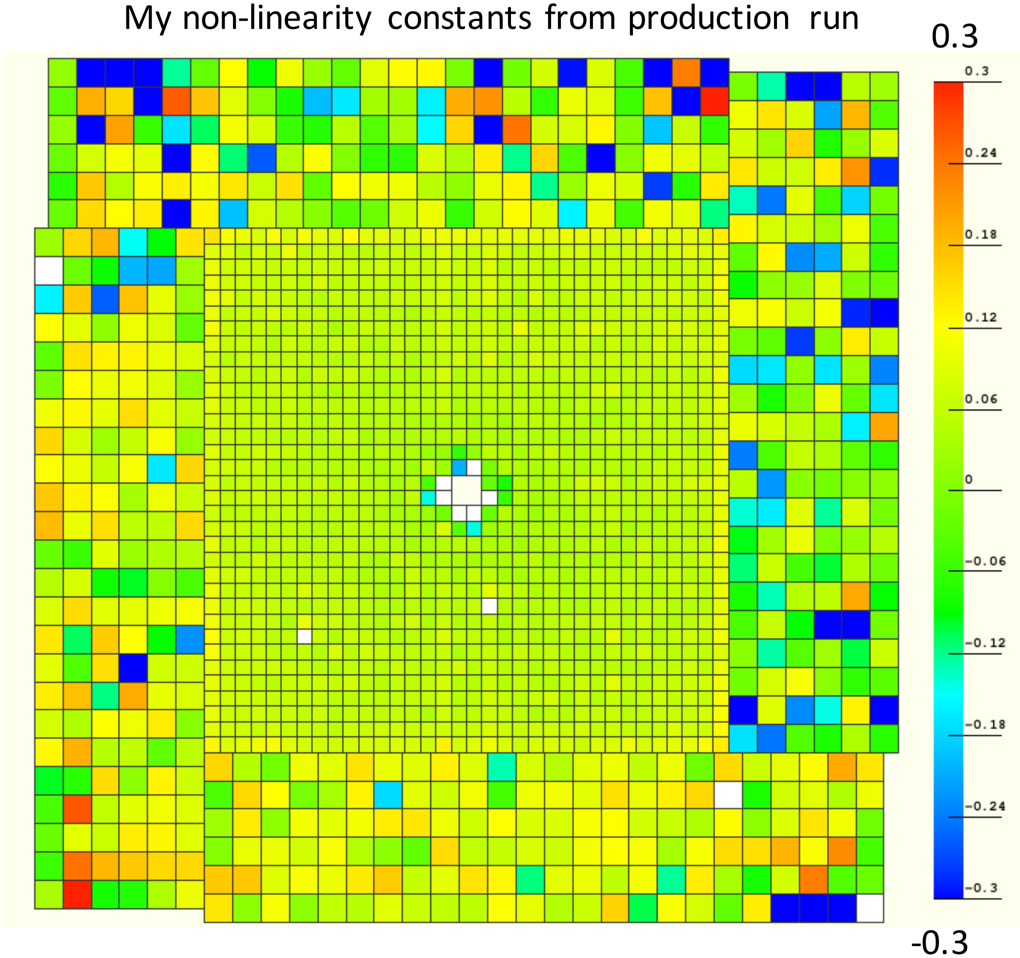
- E_{recon}/E_{expect} very close to the ratio between the two calibration constans
- E_{recon} and E_{cali} obtained from fitting energy distribution of each module



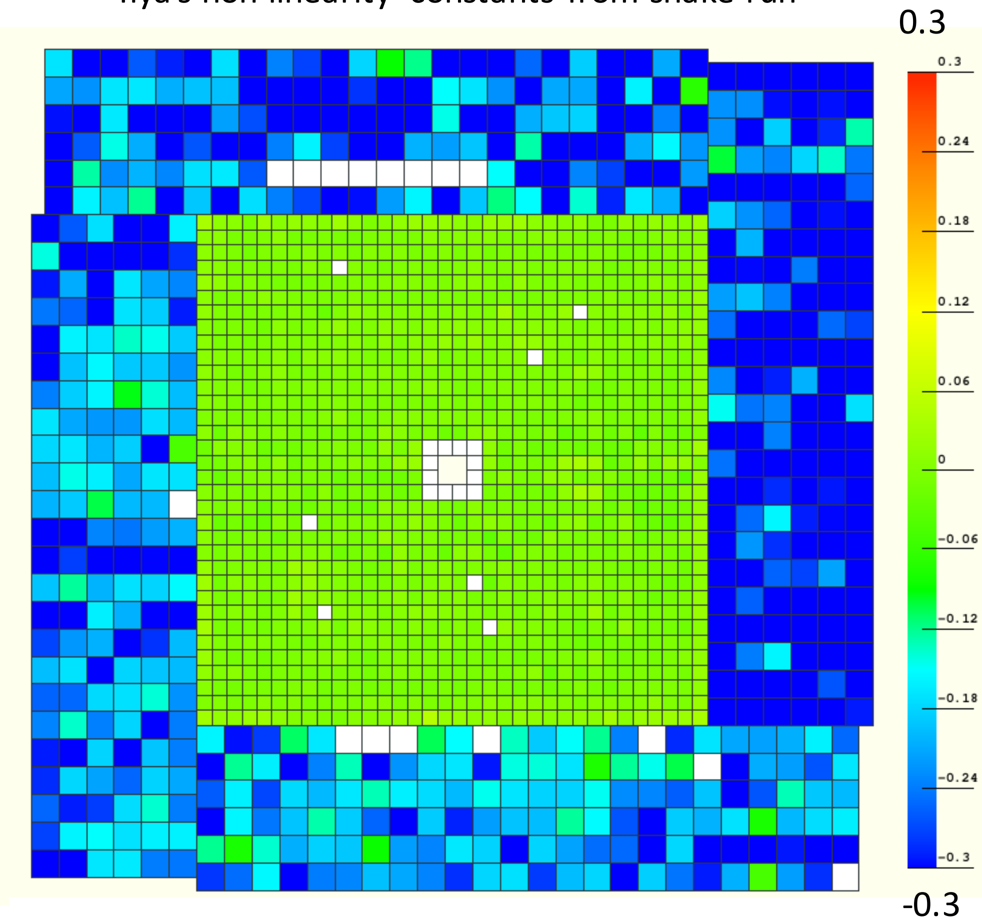


Compare Non-linearity Constants

My non-linearity constants from production run

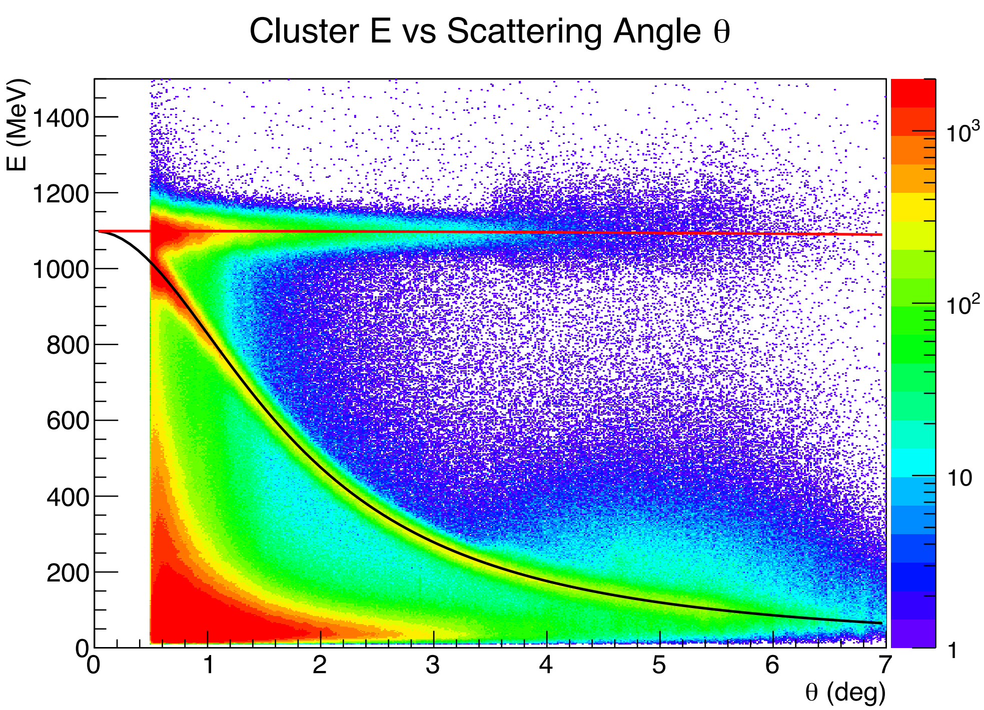


Ilya's non-linearity constants from snake run

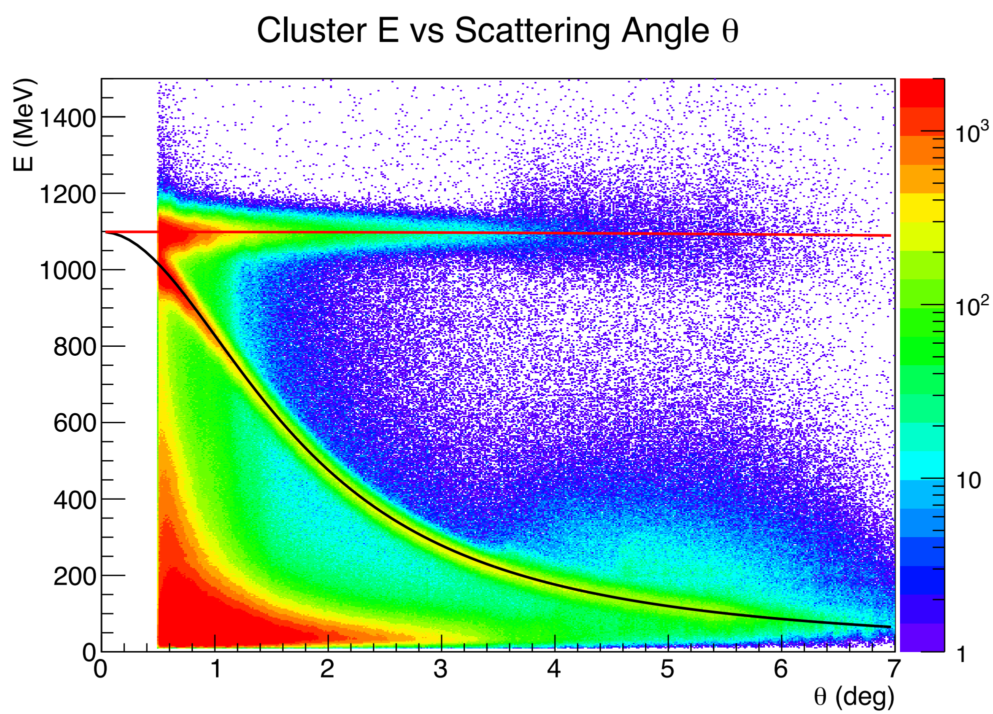


Applying the Non-linearity Constants

Start with calibration constants from ep

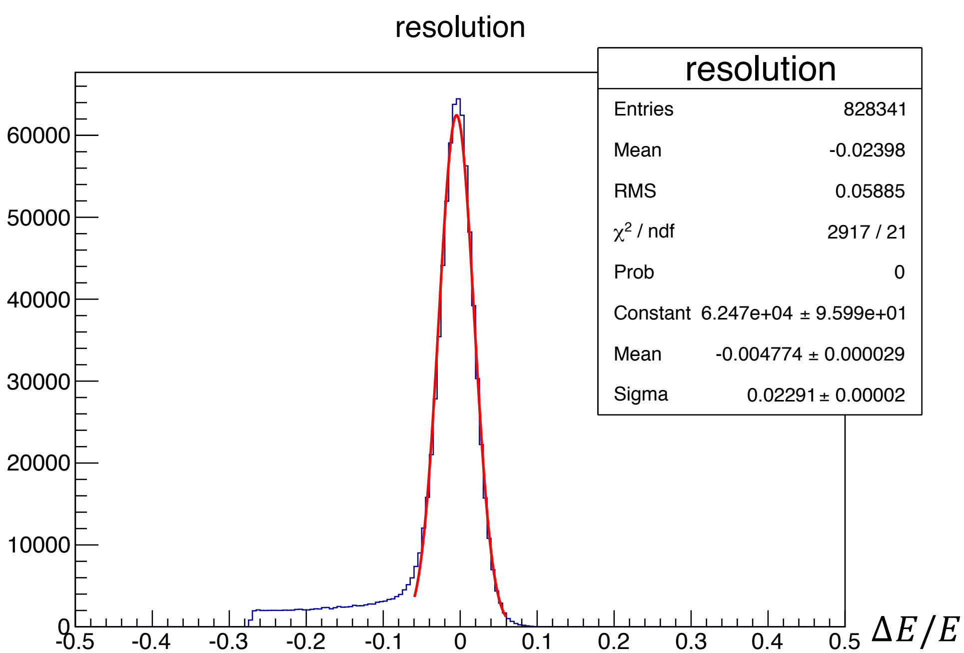


Start with calibration constants from ee



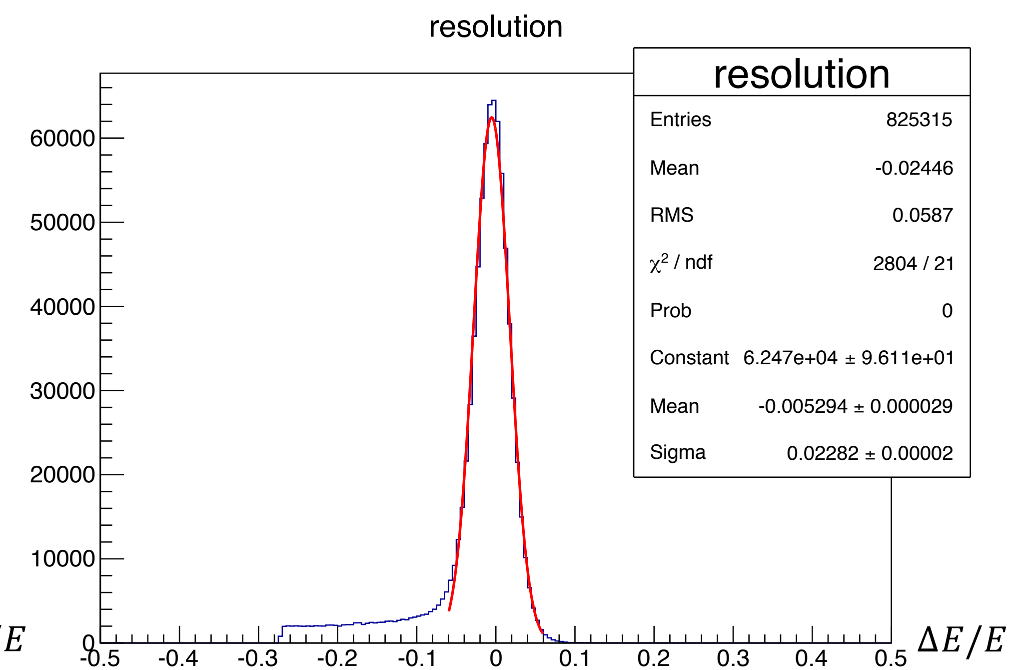
Resolution PWO for ep Events

Start with calibration constants from ep



$$\sigma = 2.3\,\% \times \sqrt{1.1} = 2.4\,\%$$

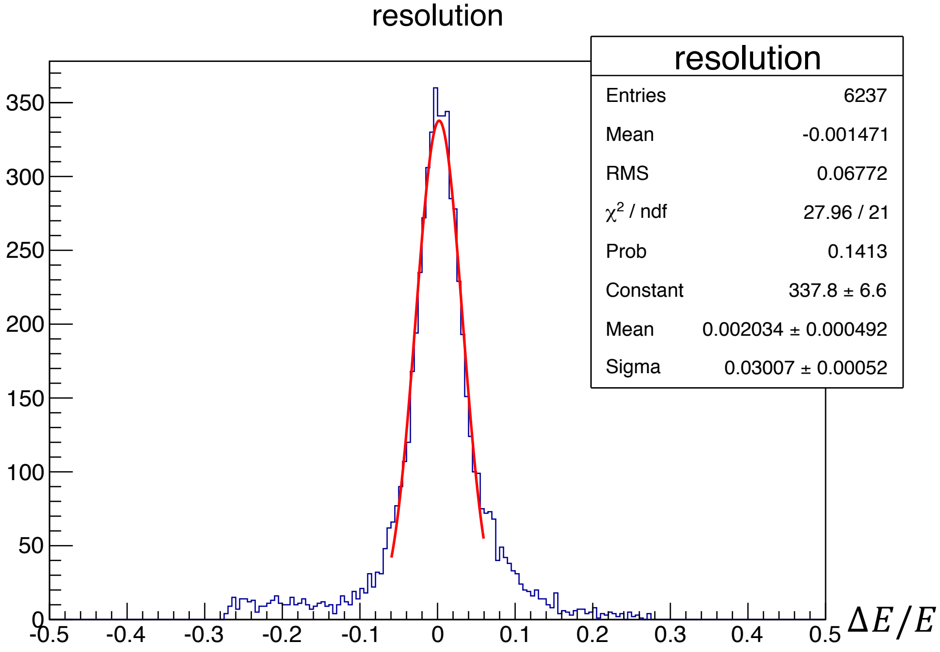
Start with calibration constants from ee



$$\sigma = 2.3\,\% \times \sqrt{1.1} = 2.4\,\%$$

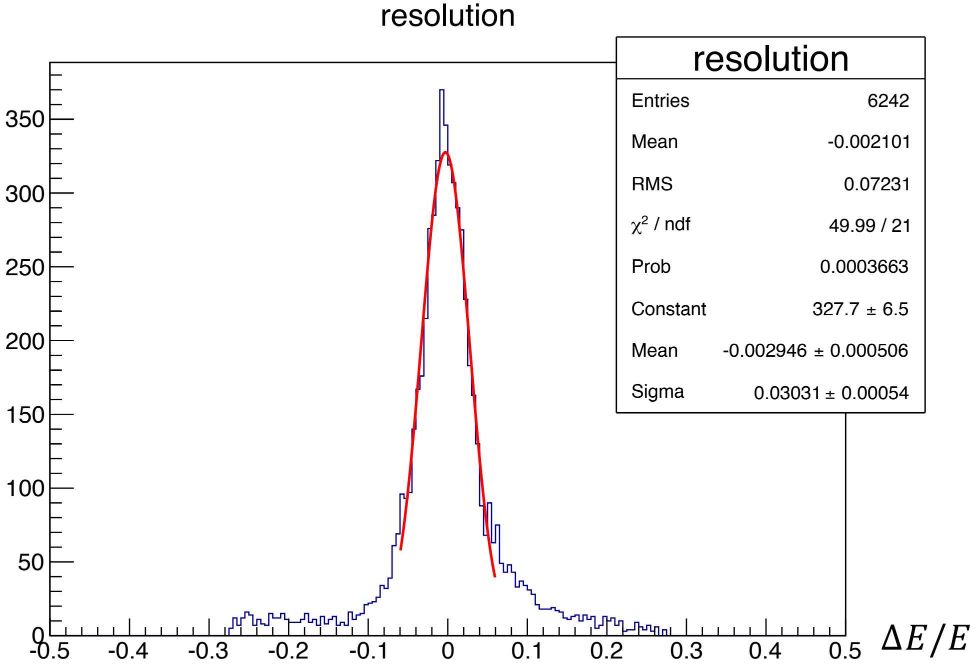
Resolution Transition for ep Events

Start with calibration constants from ep



$$\sigma = 3.0\ \% \times \sqrt{1.1} = 3.1\ \%$$

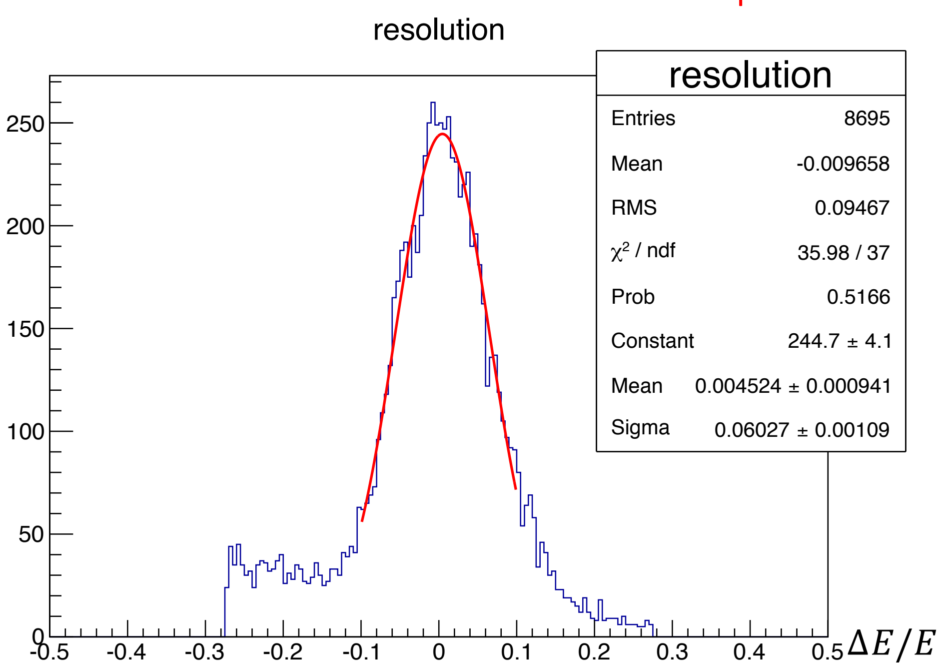
Start with calibration constants from ee



$$\sigma = 3.0\ \% \times \sqrt{1.1} = 3.1\ \%$$

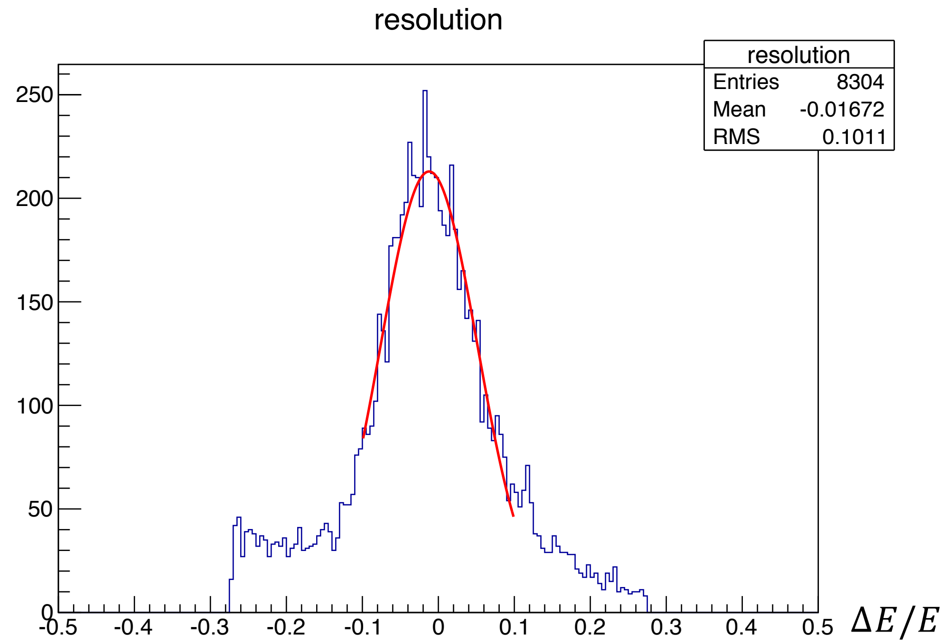
Resolution LG for ep Events

Start with calibration constants from ep



$$\sigma = 6.0\ \% \times \sqrt{1.1} = 6.3\ \%$$

Start with calibration constants from ee

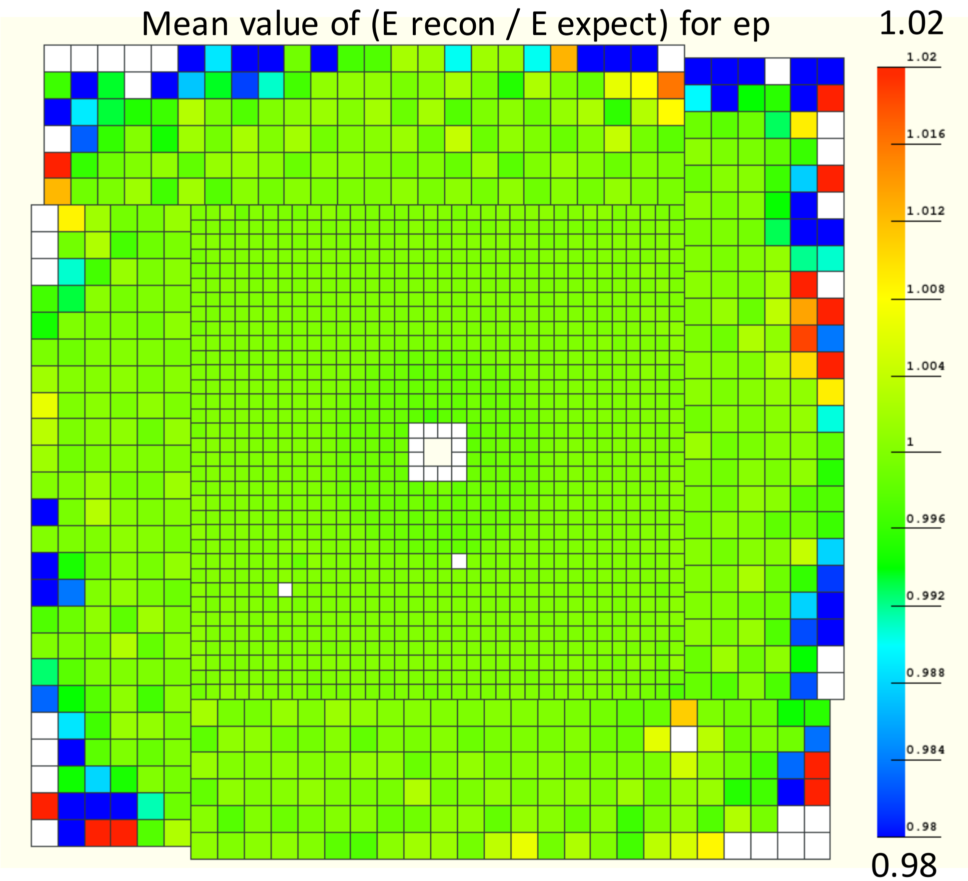


$$\sigma = 6.4\ \% \times \sqrt{1.1} = 6.7\ \%$$

Module by Module Comparison

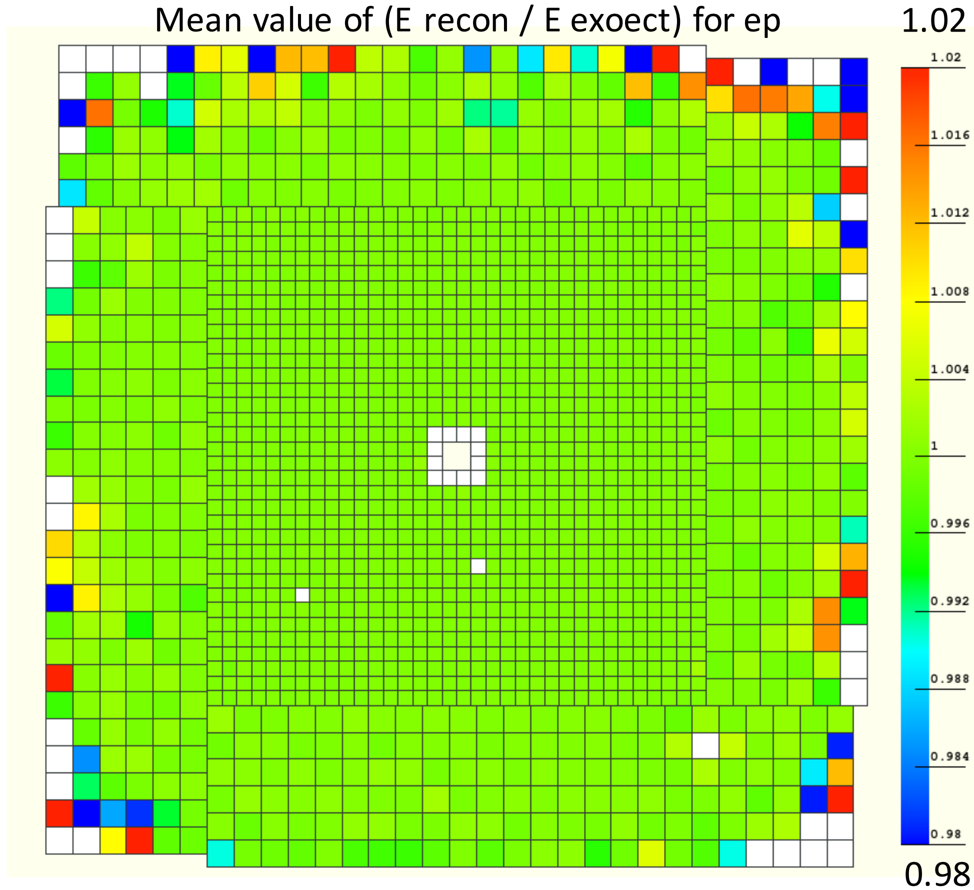
Before non-linearity correction

Mean value of (E recon / E expect) for ep



After non-linearity correction

Mean value of (E recon / E exoect) for ep

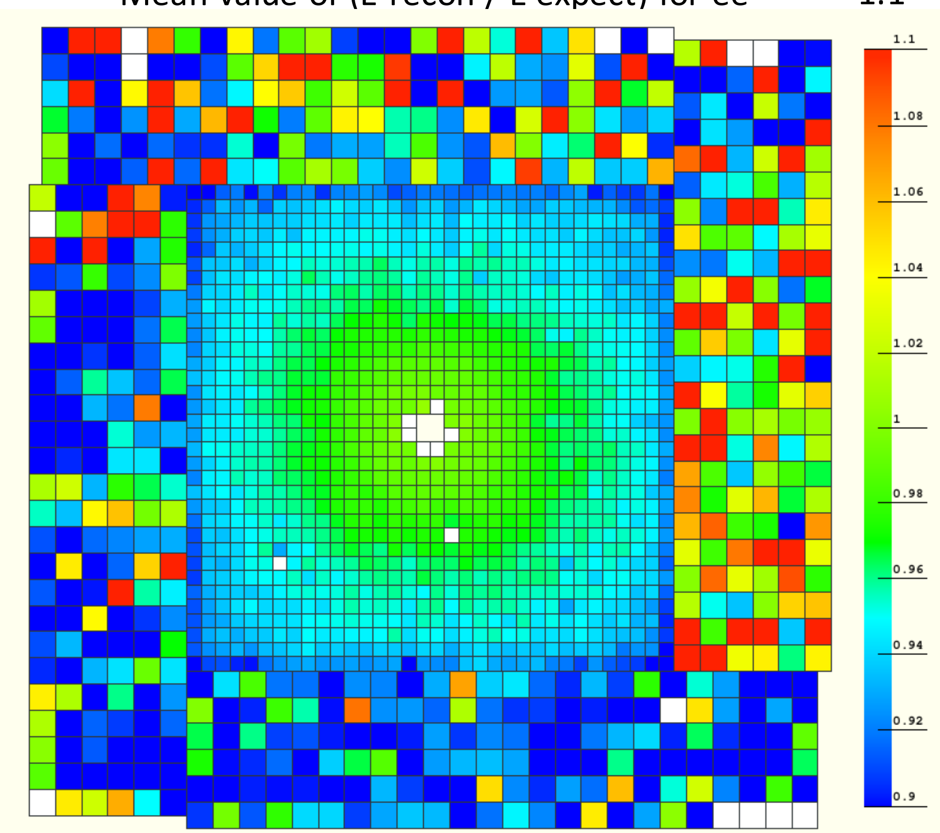


Start with calibration constants from ep

Module by Module Comparison

Before non-linearity correction
Mean value of (E recon / E expect) for ee

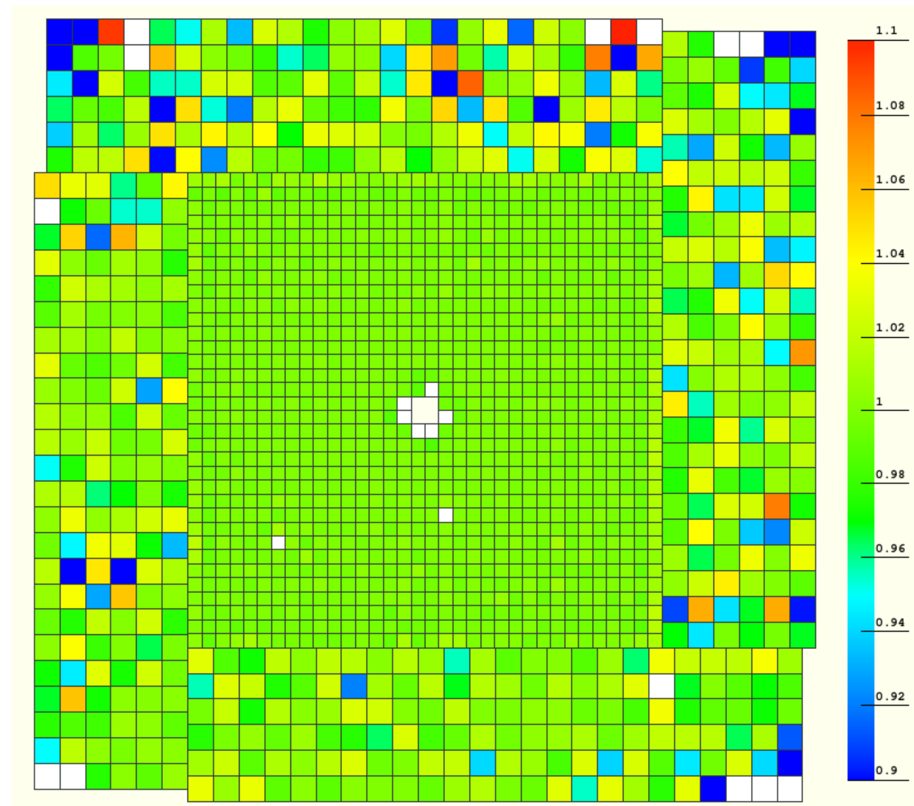
1.1



0.9

After non-linearity correction
Mean value of (E recon / E exoect) for ee

1.1

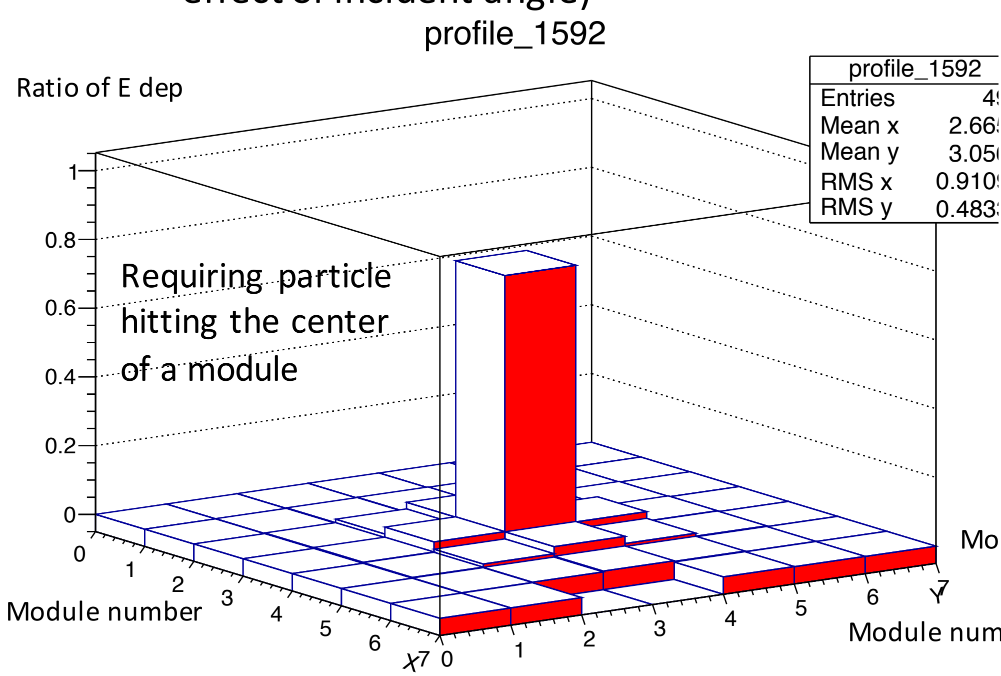


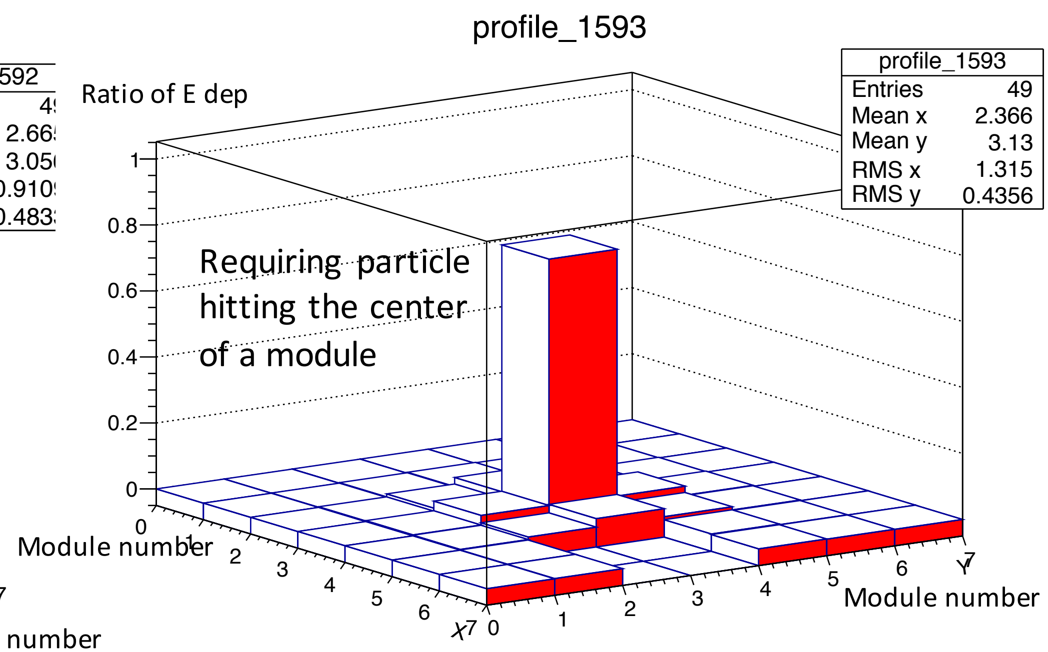
0.9

Start with calibration constants from ep

Calibrating the Inner Modules

- Inner modules are behind collimator, hard to calibrate directly
- But we can use the shower profile and the tail of a cluster hitting module right next to them
- For particle hitting the center part of a module, the profile should be symmetric (other than the effect of incident angle)





Better use GEM projected position for this purpose

To do

- Non-linearity correction shows improvement on the bias of the distribution, but cannot be fully corrected
  - Better approach for the problem?
  - Is it really just the issue with linearity for LG, is there something else?

- Calibrating modules near the central hole seems doable, want to use GEM projected position in order to get rid of the dependency on HyCal reconstructed position