AHCAL Calibration and SiPM Saturation

CALICE AHCAL main meeting

- **Gain calibration**
- **Light yield determination**
- **SiPM saturation**

Olin Pinto
DESY, 12th December 2018

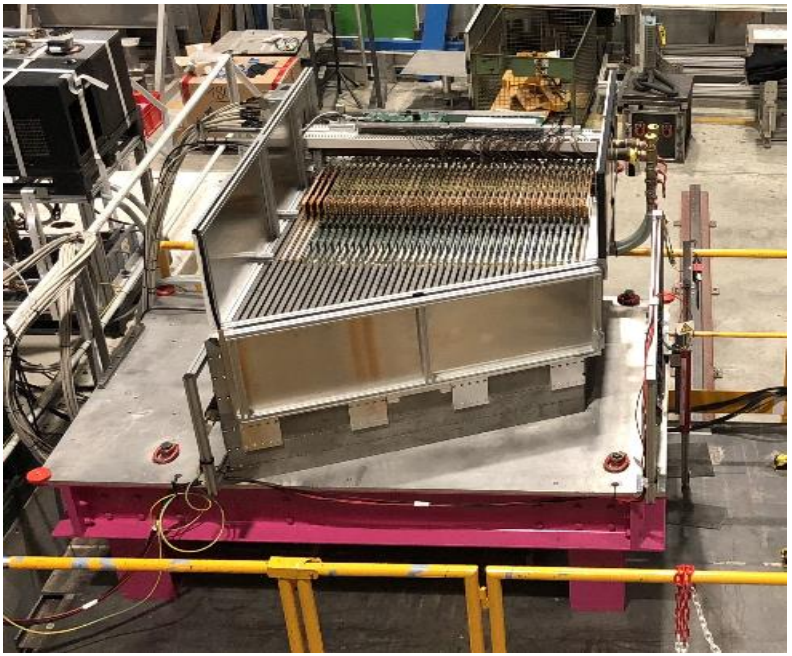
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

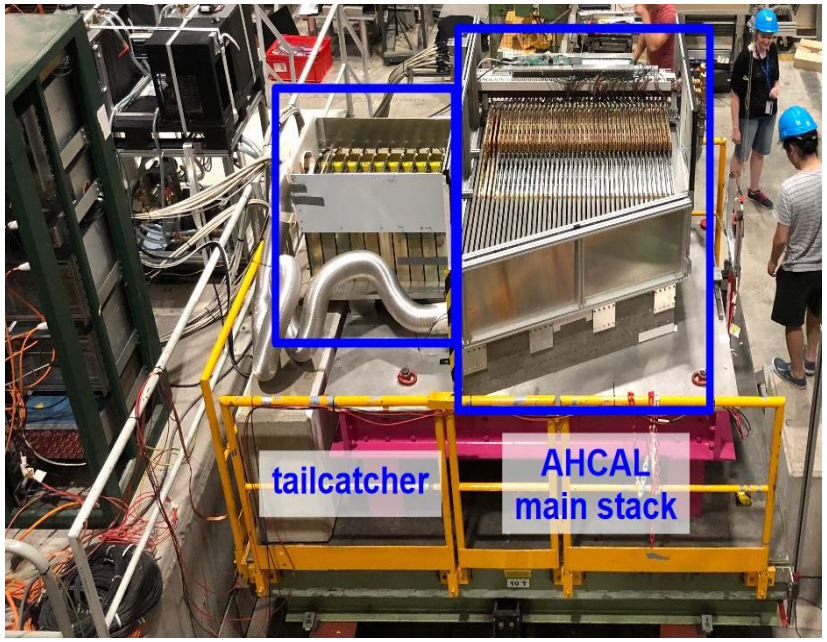
DESY.

Detector Set-up

May, June/July and October 2018



May



June/July

October

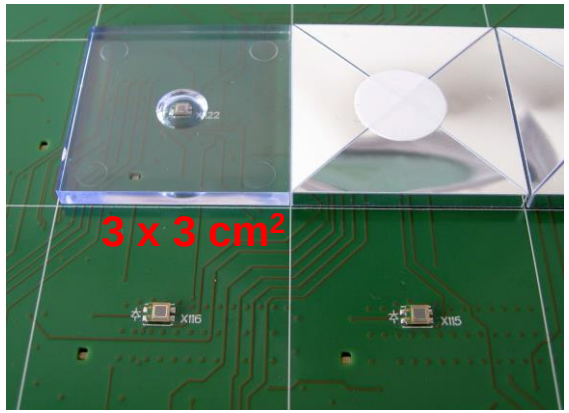
Calibration

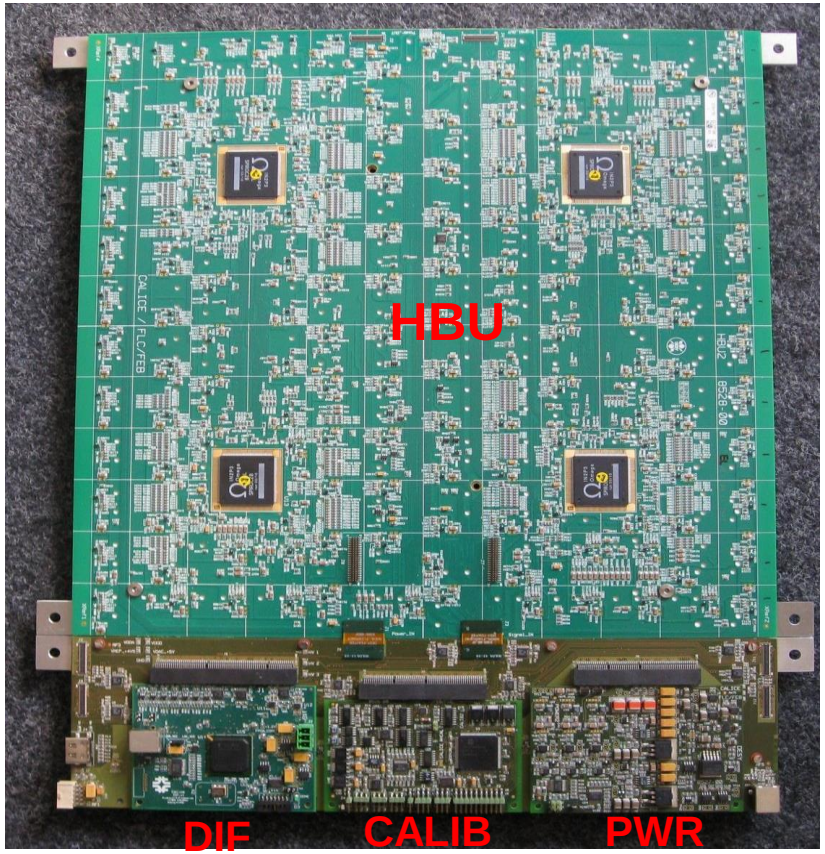
Need for gain calibration

- For trustworthy data measurements we need a well calibrated detector.
- LED system installed on each channel - monitors the stability of the SiPM in time (controlled by CALIB board on HBU).

Idea:

- Uniform response and stability with all the channels.
- Identifying dead, noisy or unstable channels.
- Acquire constants needed for analytical study.





Calibrated signal

A_i: Hit amplitude in MIP

P_i: Pedestal in ADC

IC_i: Inter-calibration

a_i: Cell amplitude

$Gain_i$: SiPM gain

f_i: Saturation function

If no saturation:

$$A_i\,[MIP] = \frac{(a_i[ADC] - Pi[ADC]) * ICi}{MIP_i[ADC]}$$

With saturation:

$$A_i\,[MIP] = \frac{(a_i[ADC] - Pi[ADC]) * ICi}{MIP_i[ADC]} * f_{sat}^{i\ -1}\left(\frac{(a_i[ADC] - Pi[ADC]) * ICi}{Gain_i[ADC]}\right)$$

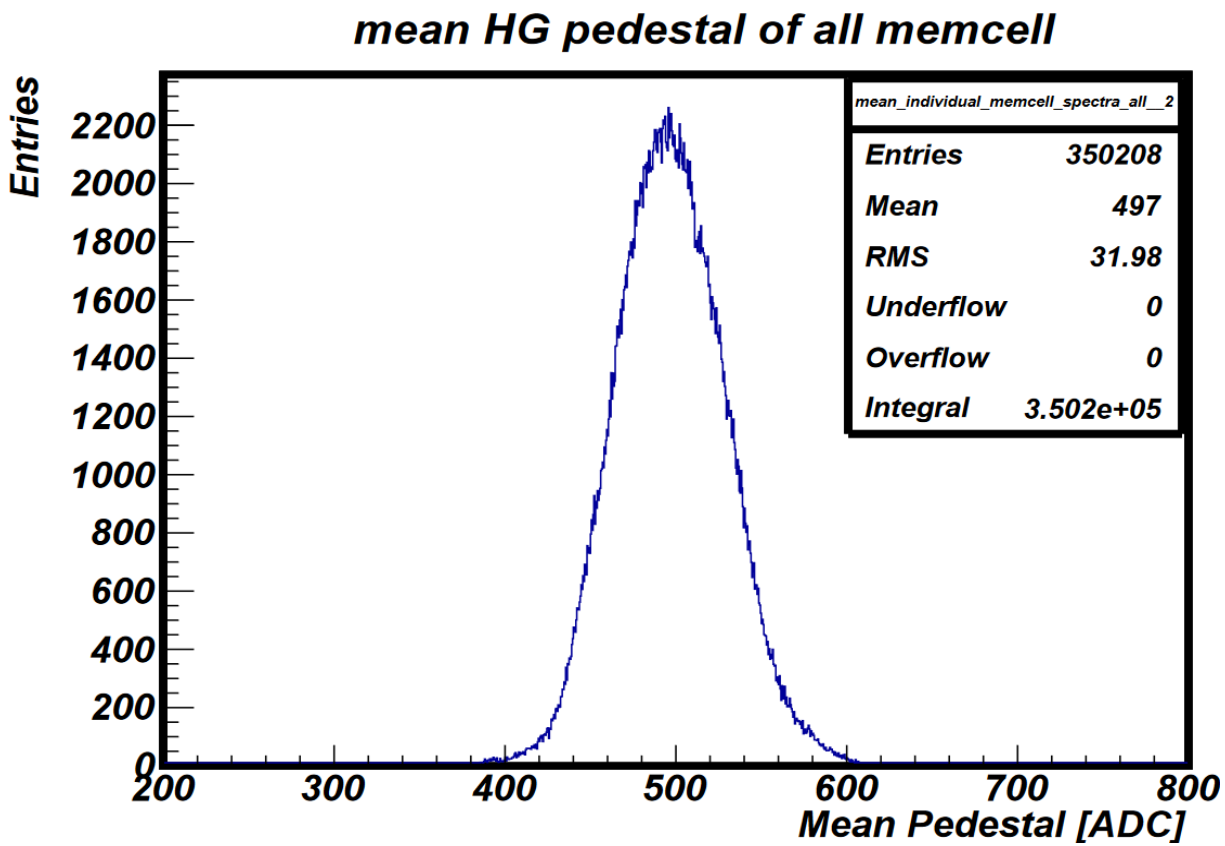
PEDESTAL

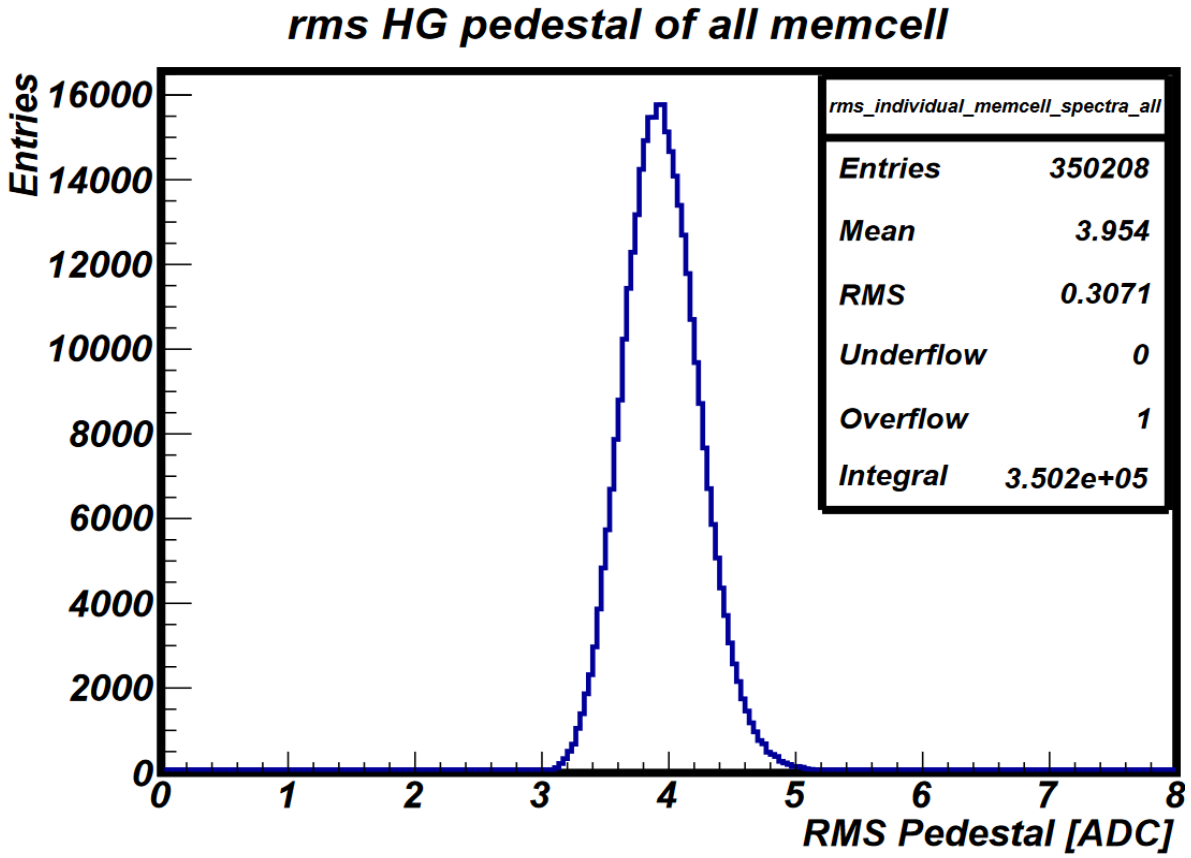
The ADC pedestal is extracted for each channel from random triggers - uncorrelated to incident LED light

HG Pedestal in external trigger mode

May data

- For every channel a gaussian like distribution centered around 400-500 ADC ticks ‘created mainly by electronic noise’.





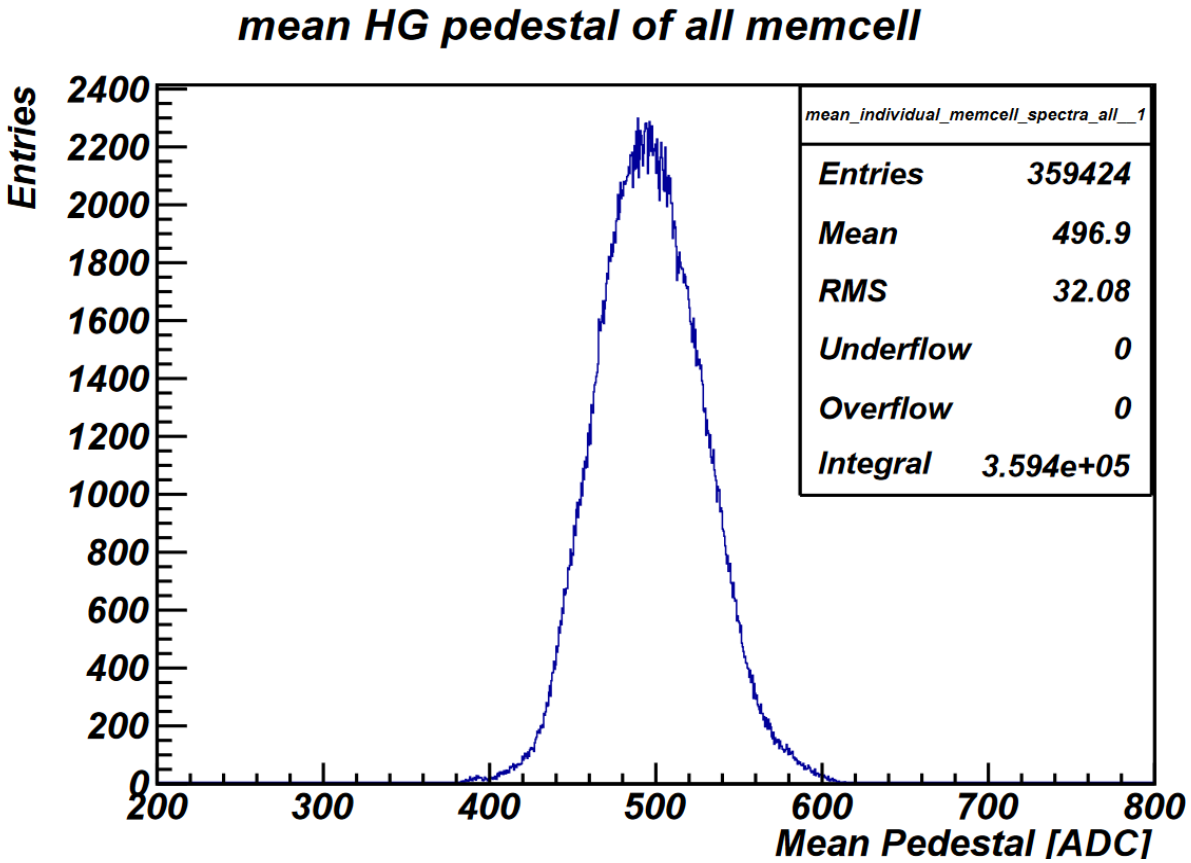
memory cells = 21,888 channels x 16 memory cells each = 350208

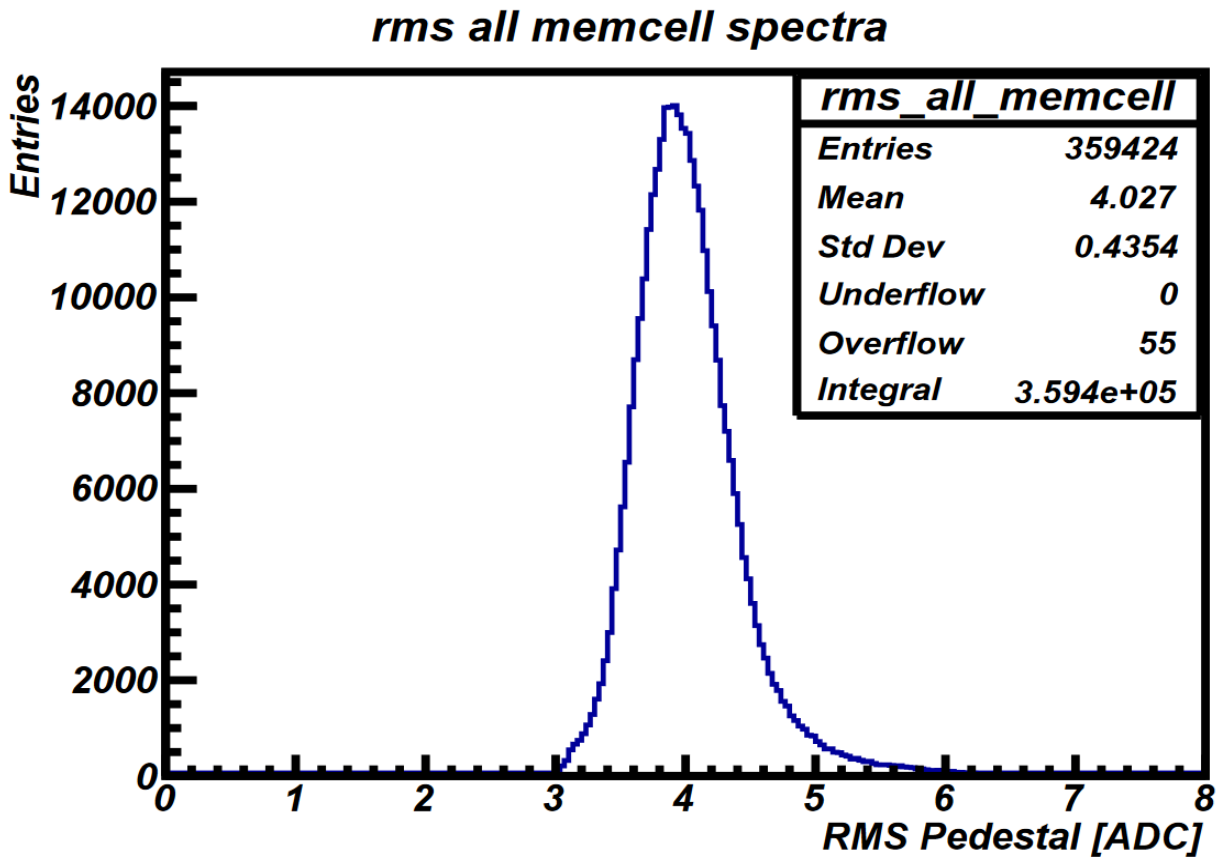
HG Pedestal in external trigger mode

June (Pre-shower + AHCAL + Tail Catcher)

Module	Chip	Channel	Memory cell
13	3331	5	0–15
30	7692	20	0-15
38	9737	31	0-15

The tail in the RMS region between 5 to 7 is widely distributed among the channels in AHCAL.

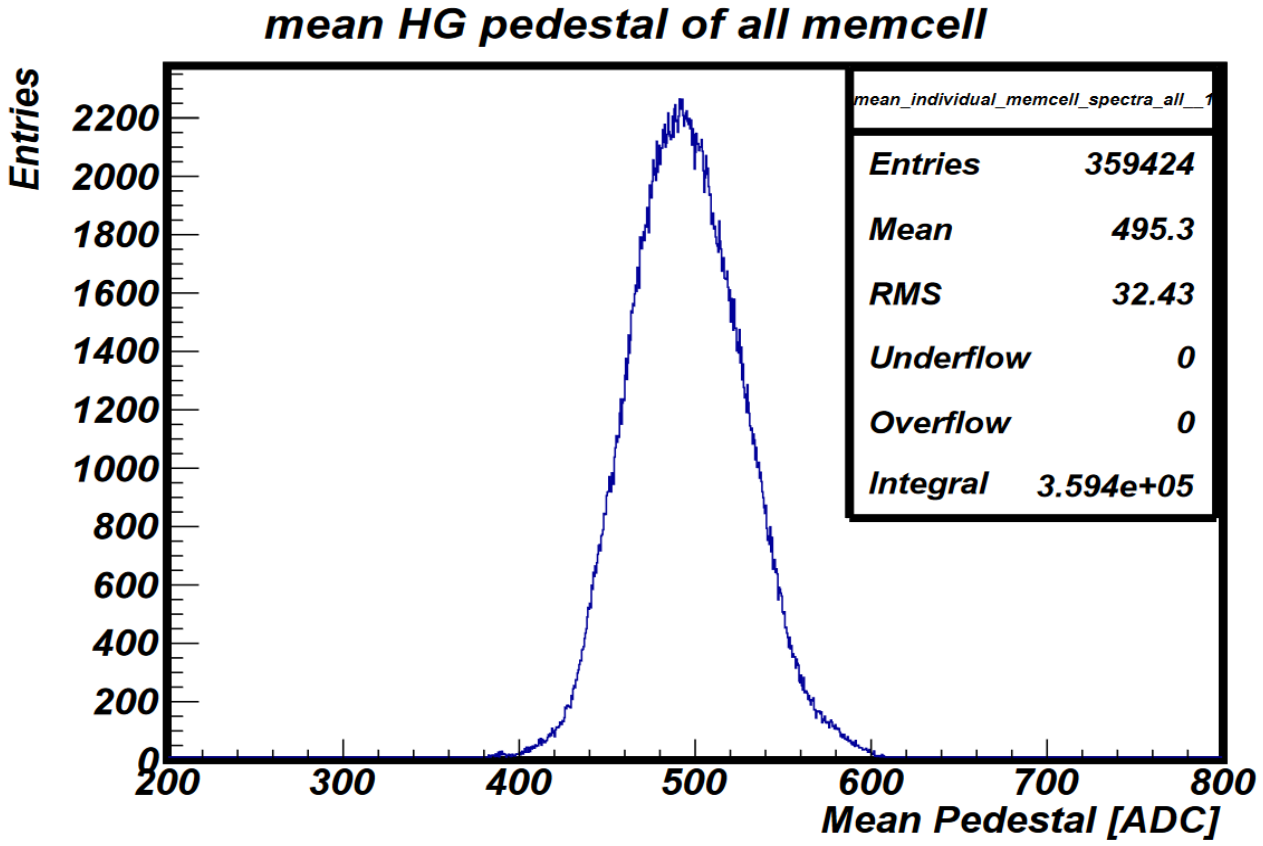


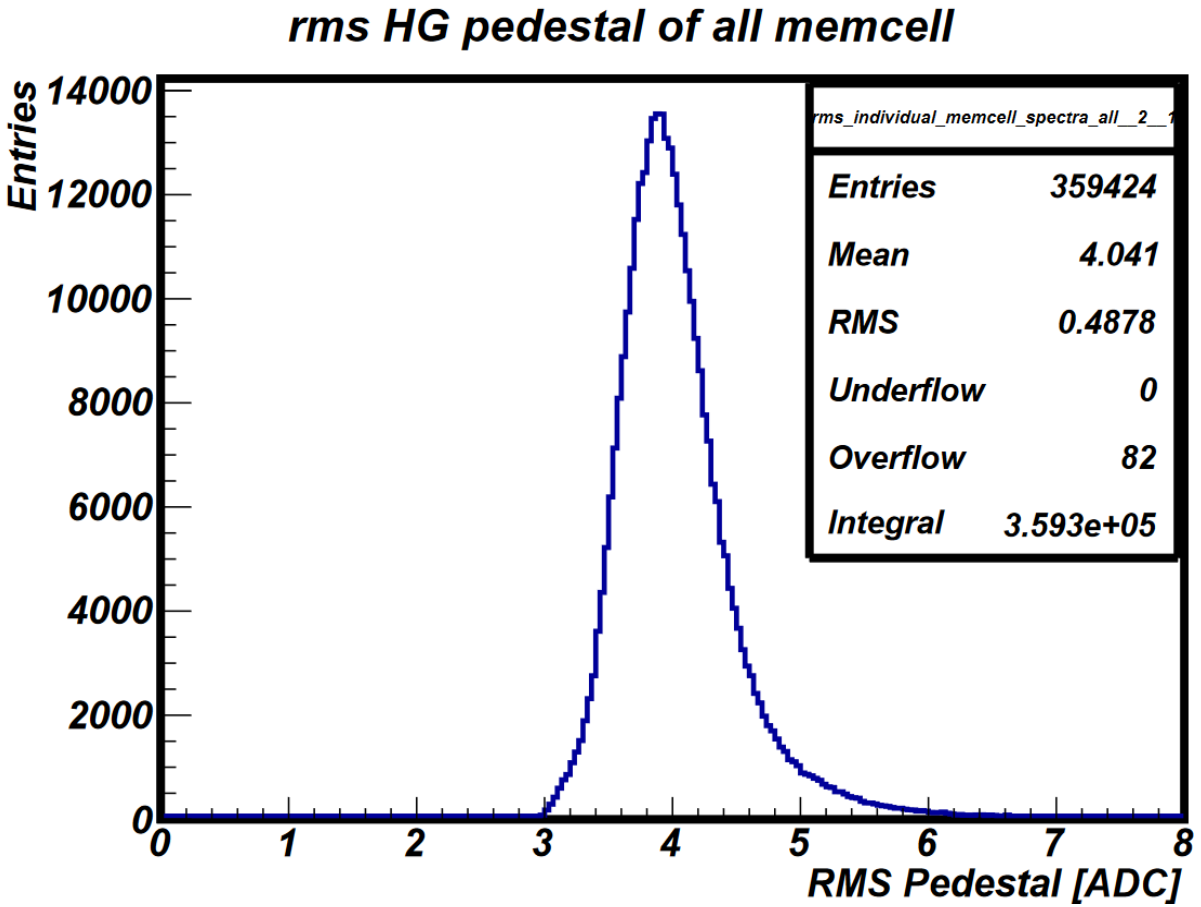


HG Pedestal in external trigger mode

October (AHCAL only)

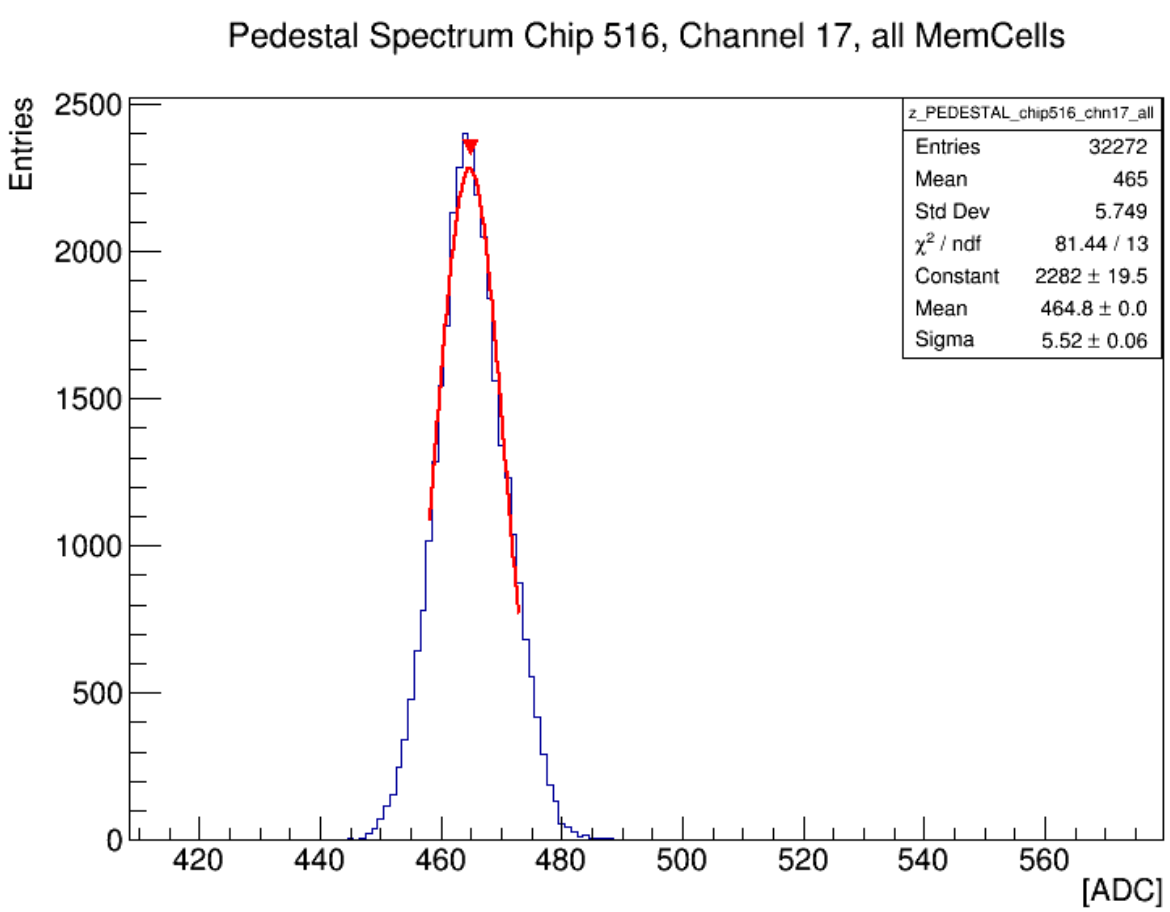
Module	Chip	Channel	Memory cell
13	3331	4,5	0–15
30	7692	20	0-15
14	3596	35	0-15



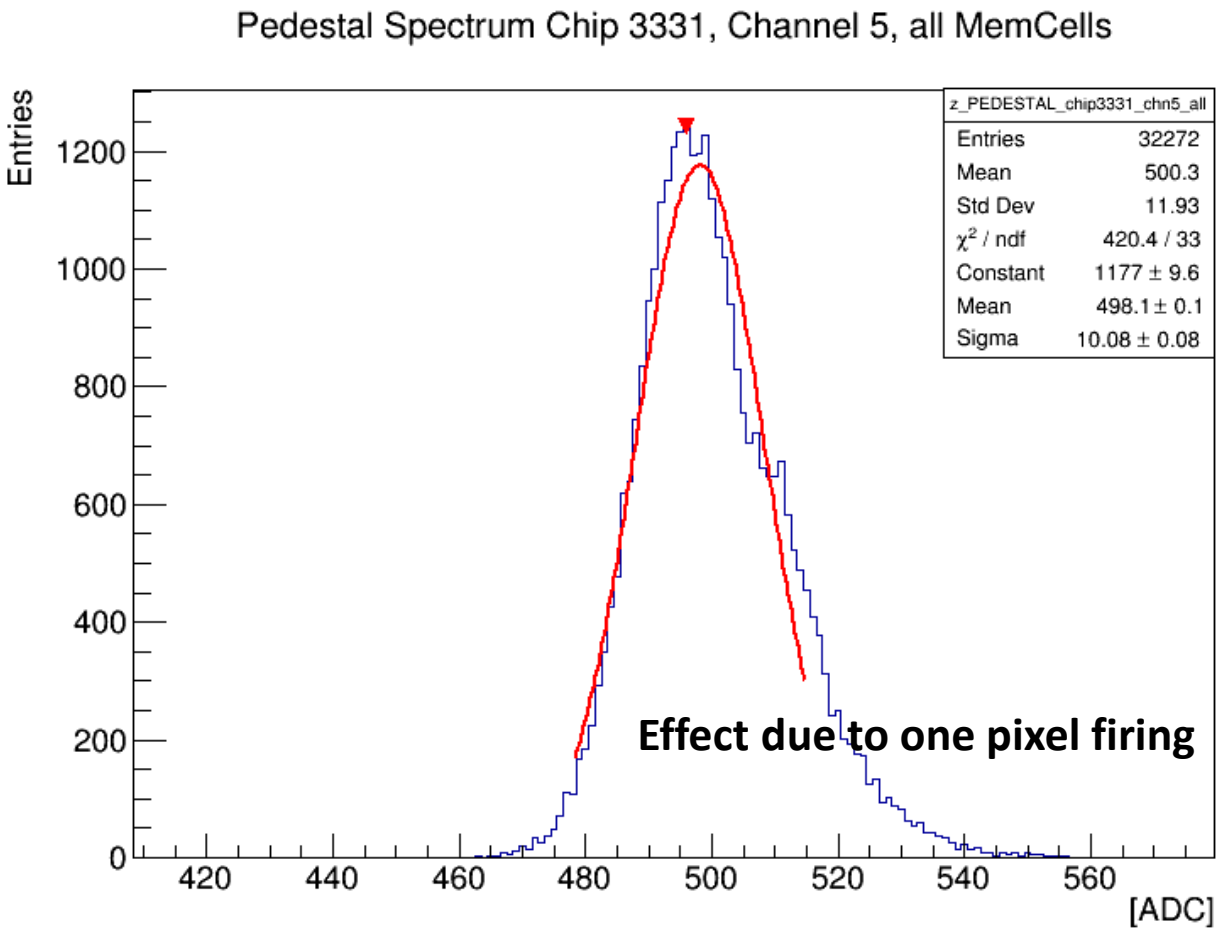


HG Pedestal from External trigger at channel level

May data



Pedestal of a good channel



Bad pedestal

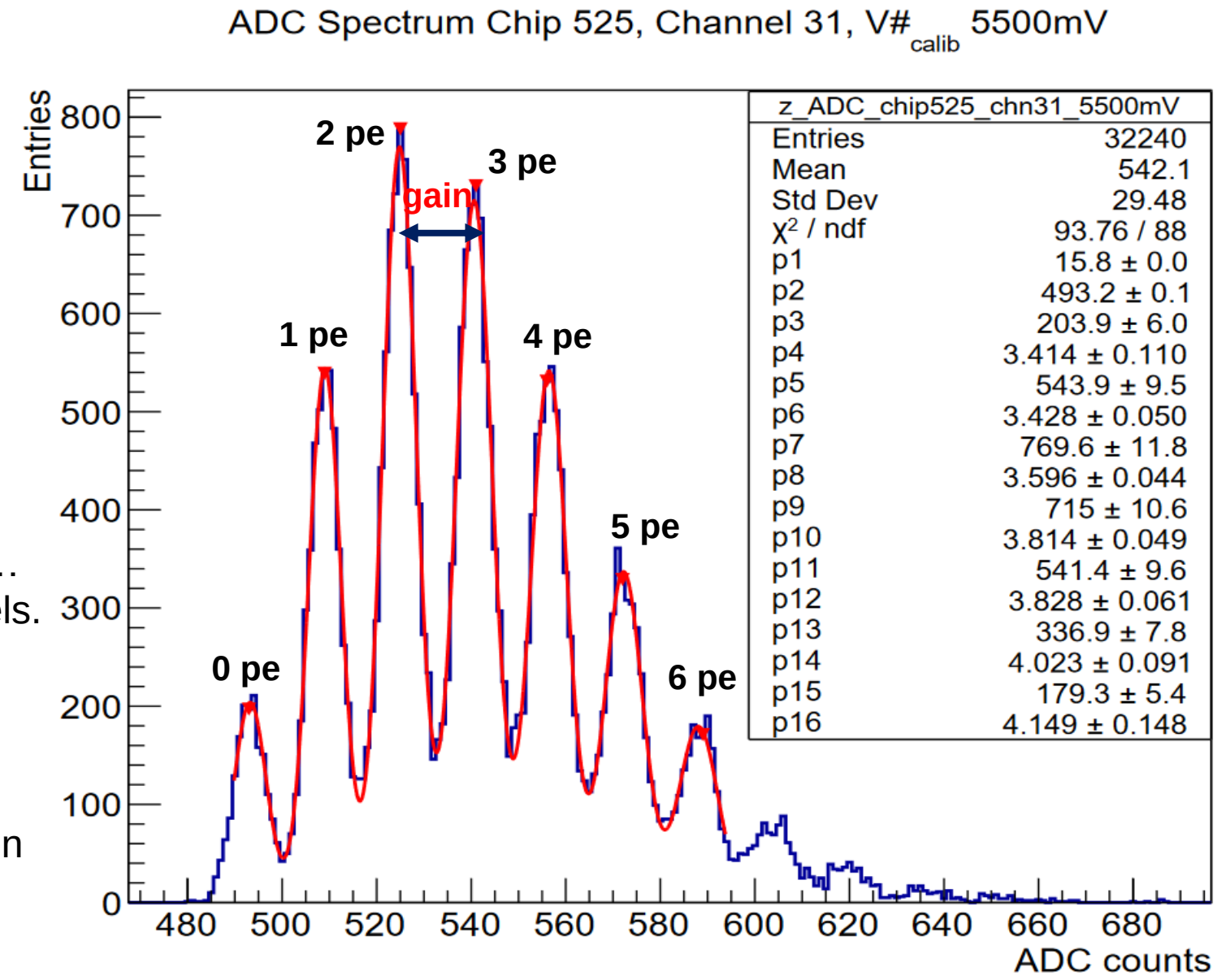
GAIN CALIBRATION

Gain calibration

Gain calibration spectrum

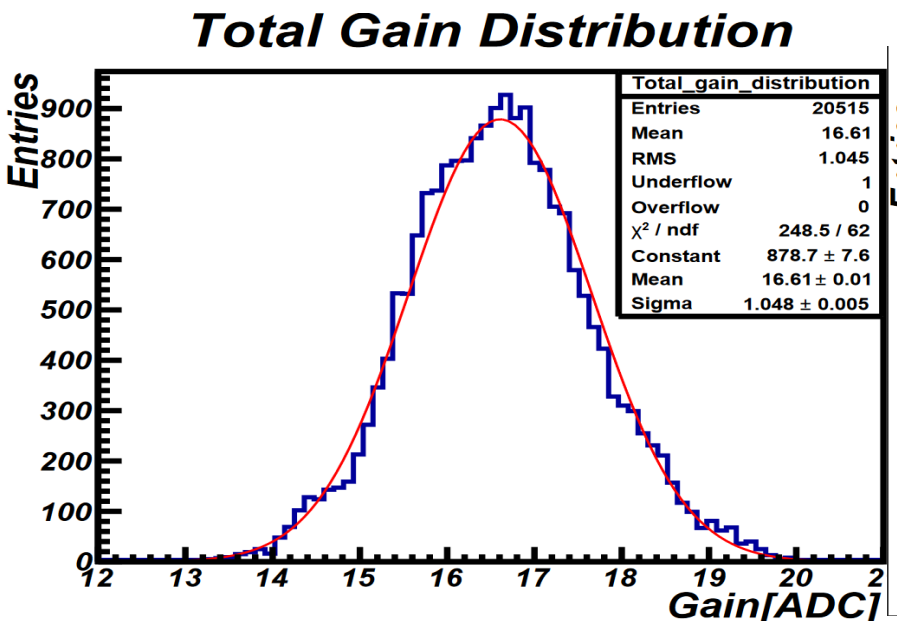
ASIC – operated in HG mode.
Measured: by illuminating the sensor with small light pulse.

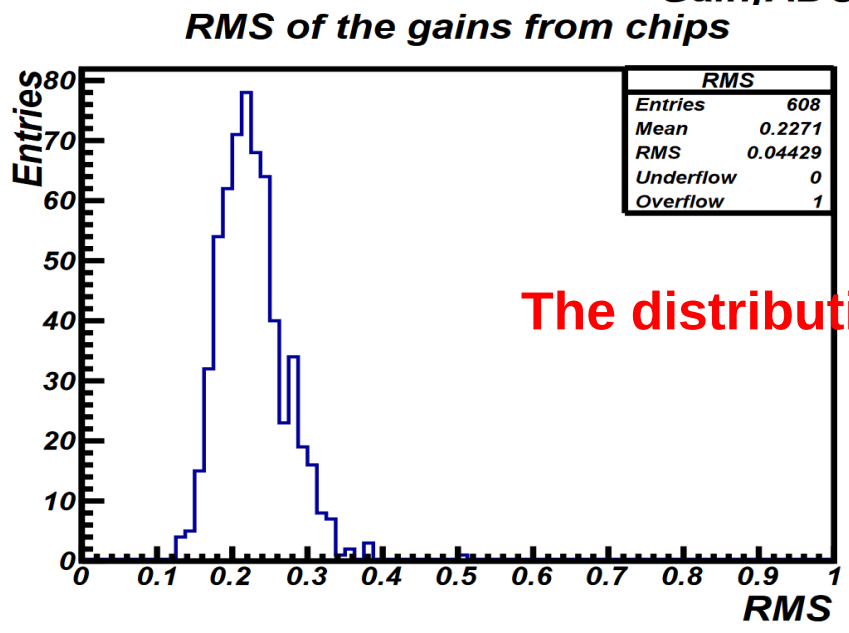
- A peak corresponds to a certain number of photoelectrons (0 pe , 1 pe).
- The events for n=0 (no photon detected) corresponds to the pedestal.
- The subsequent peaks are for n = 1,2,3… corresponds to simultaneously firing pixels.
- The spectrum is fitted with multigaussian function to measure the exact peak distance and the distance is forced to be the same.
- Corrected for pedestal difference between memory cell.



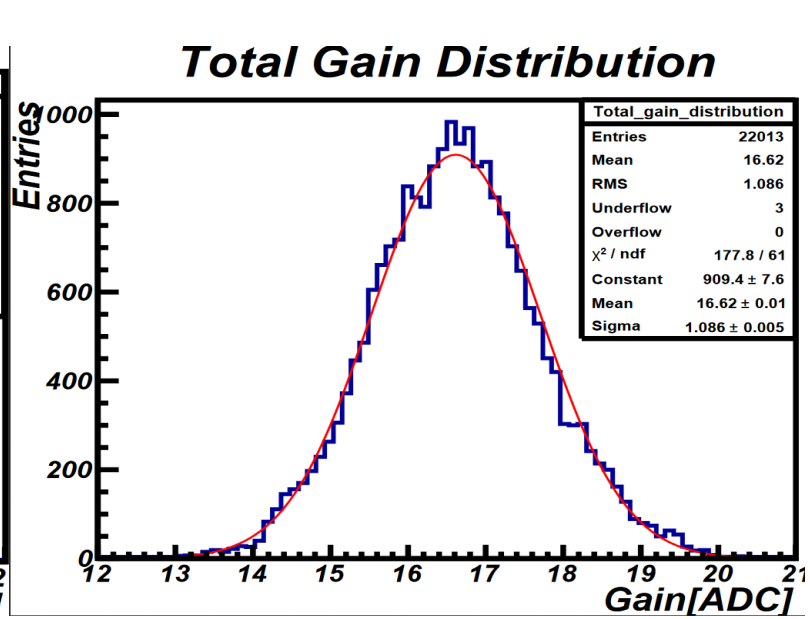
Gain calibration

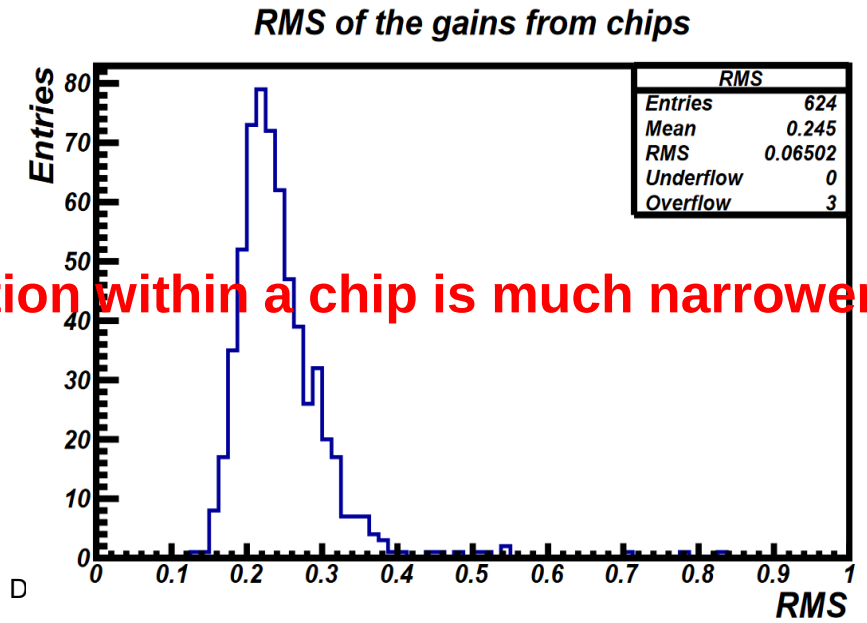
May 2018



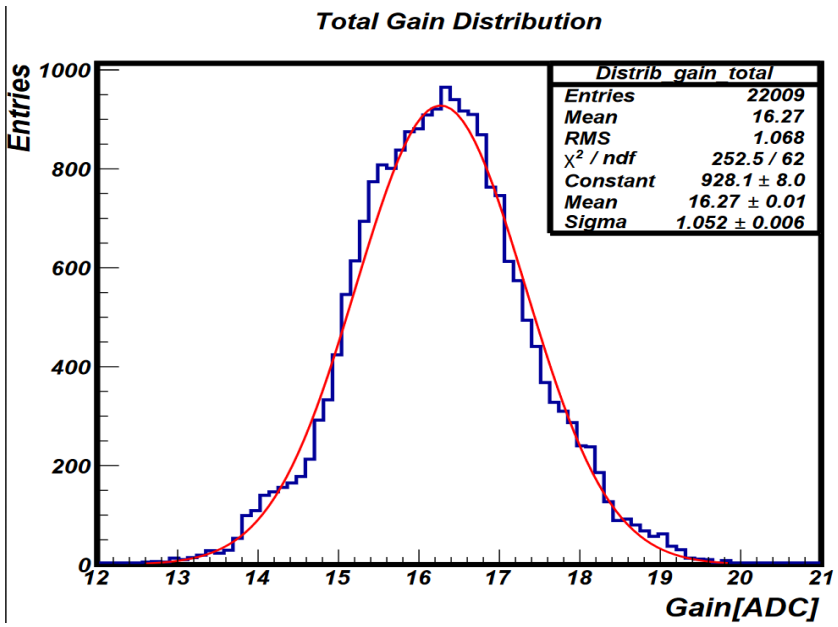


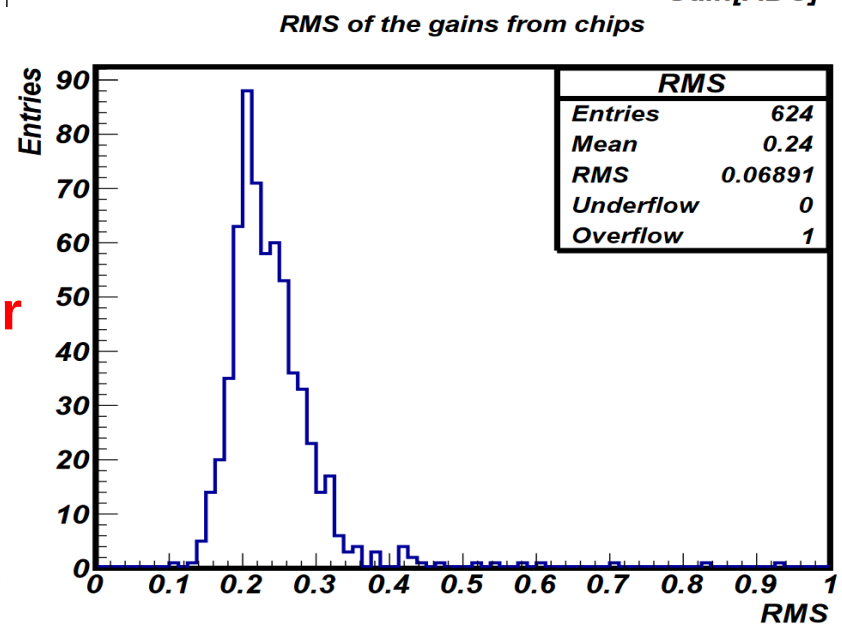
June/July 2018





October 2018





The distribution within a chip is much narrower

D

Gain Calibration

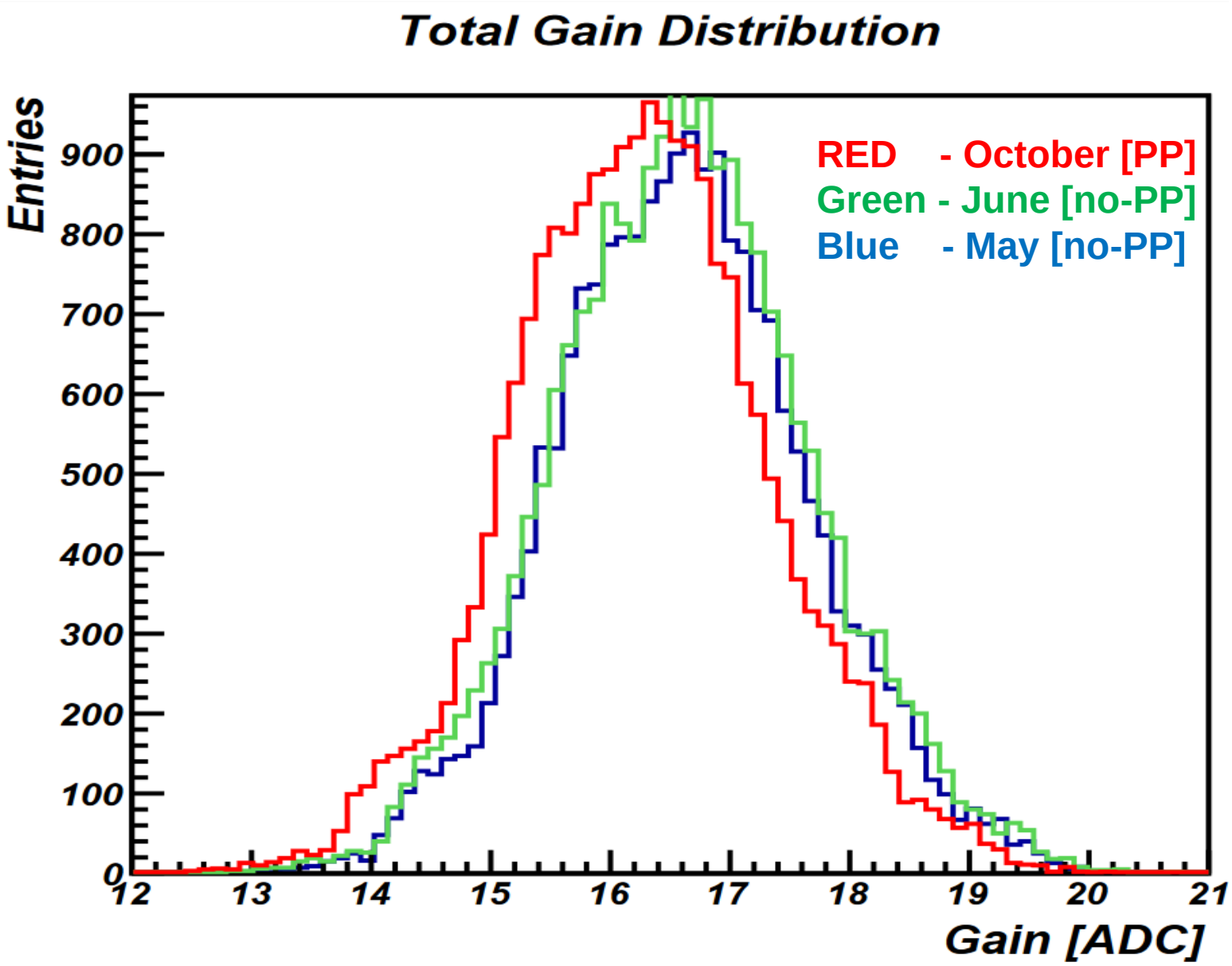
May: Short LED - no power pulsing run.
June: Long LED no power pulsing run on 25.06.2018
October: Long LED - power pulsing run on 17.10.2018

Month	Channels	Fitted channels(%)	Gain [ADC]
May	21,888	94	16.6
June/July	22,032[AHCAL + Tokyo]	98	16.6
October	22,032[AHCAL + Tokyo]	98	16.2

Total Gain

May, June and October 2018

- Gain in power pulsing mode is 2 % lower than no power pulsing mode.
  - Difference is from different temperature measurement in PP and no-PP mode.

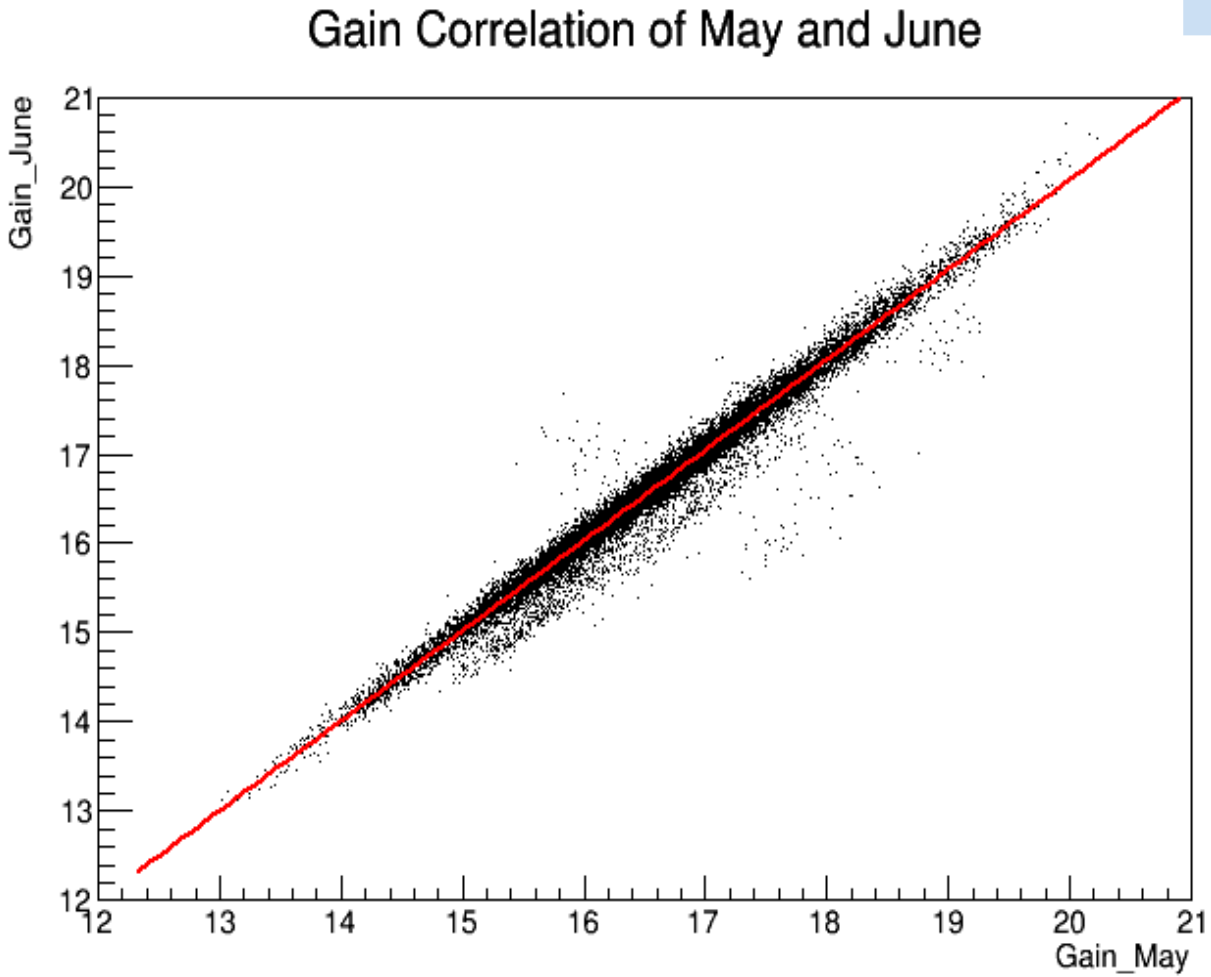


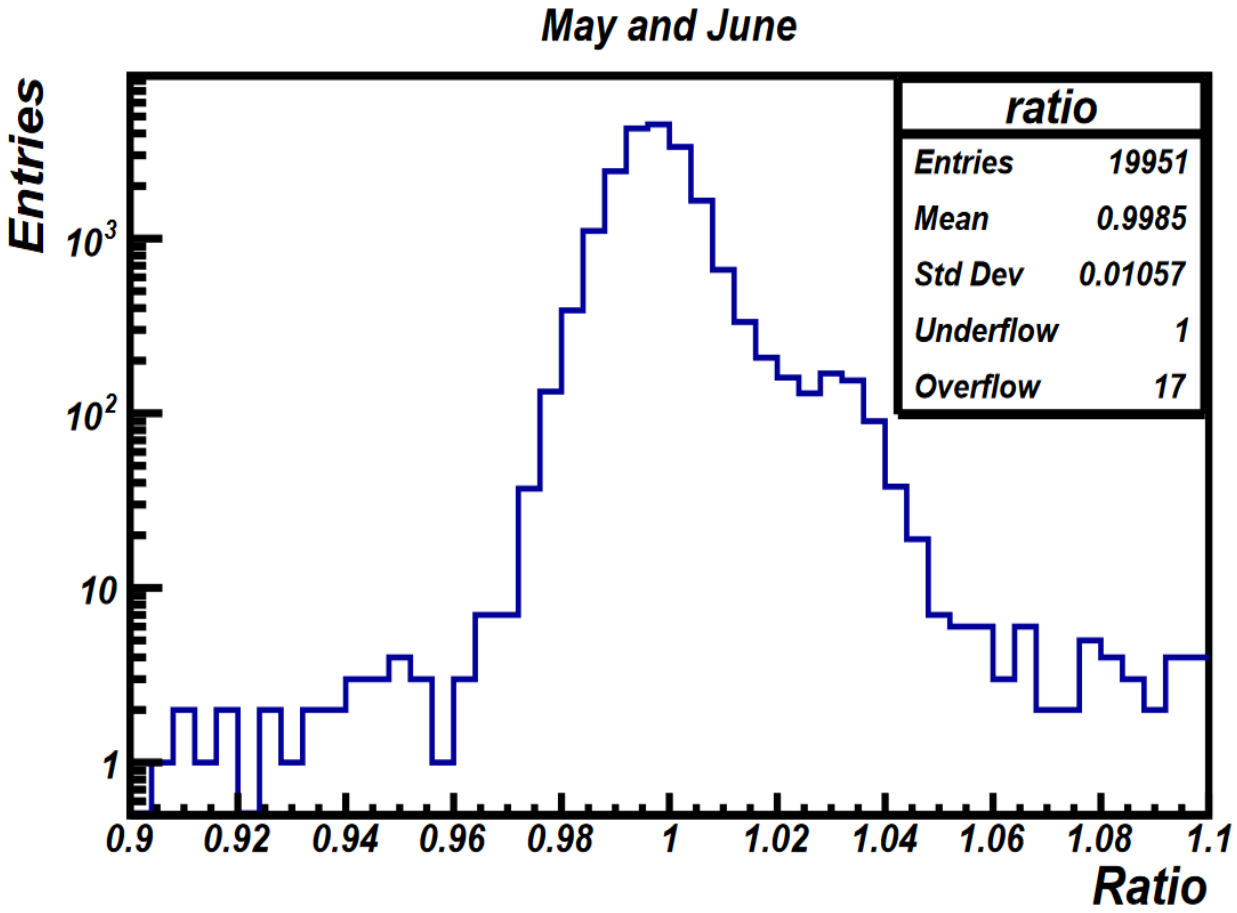
Gain correlation

Gain Correlation

May [Short run] and June AHCAL without Tail Catcher [Long run].

Module	Chip	Comment
14	3585, 3587	Large RMS
30	7688, channel 29	underflow
12 and 27	Most of the channels	Tail in RMS

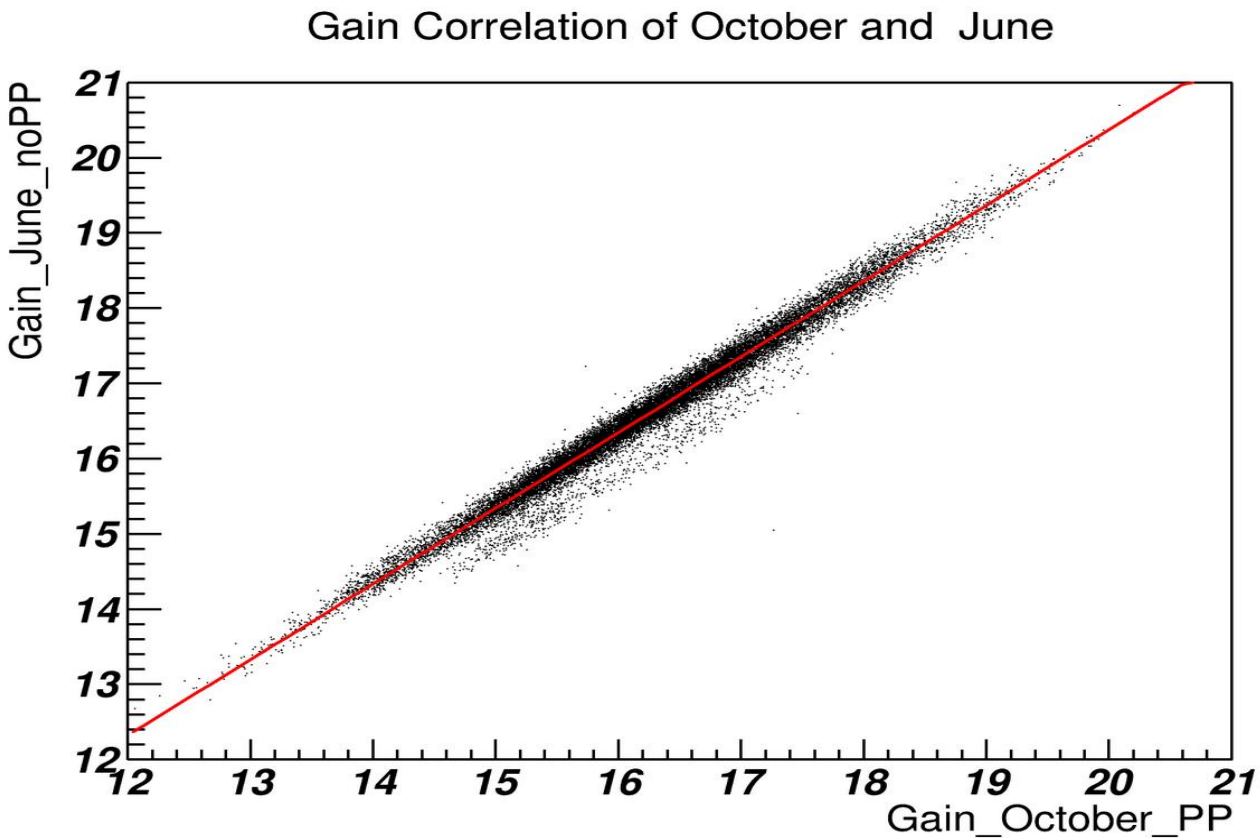


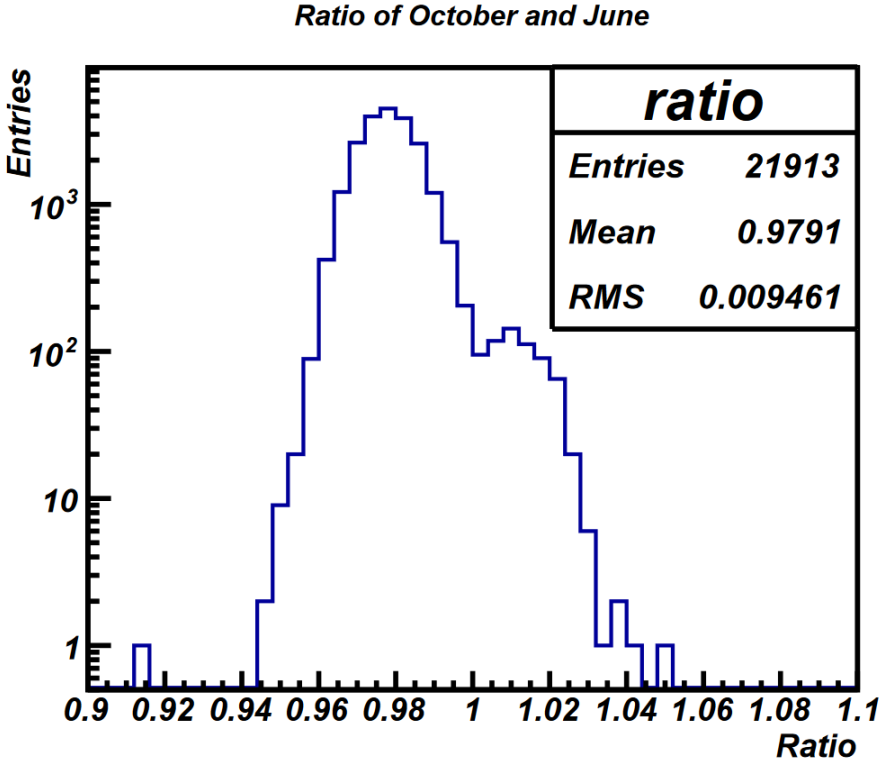


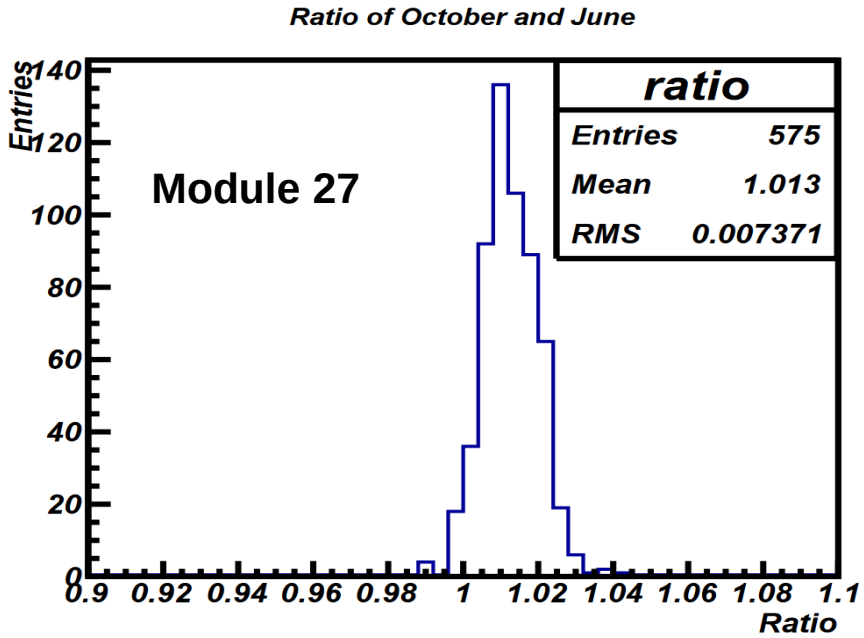
Gain Correlation

October PP and June No-PP

Module 27: Problem of HV settings found in May and June was corrected in October run.

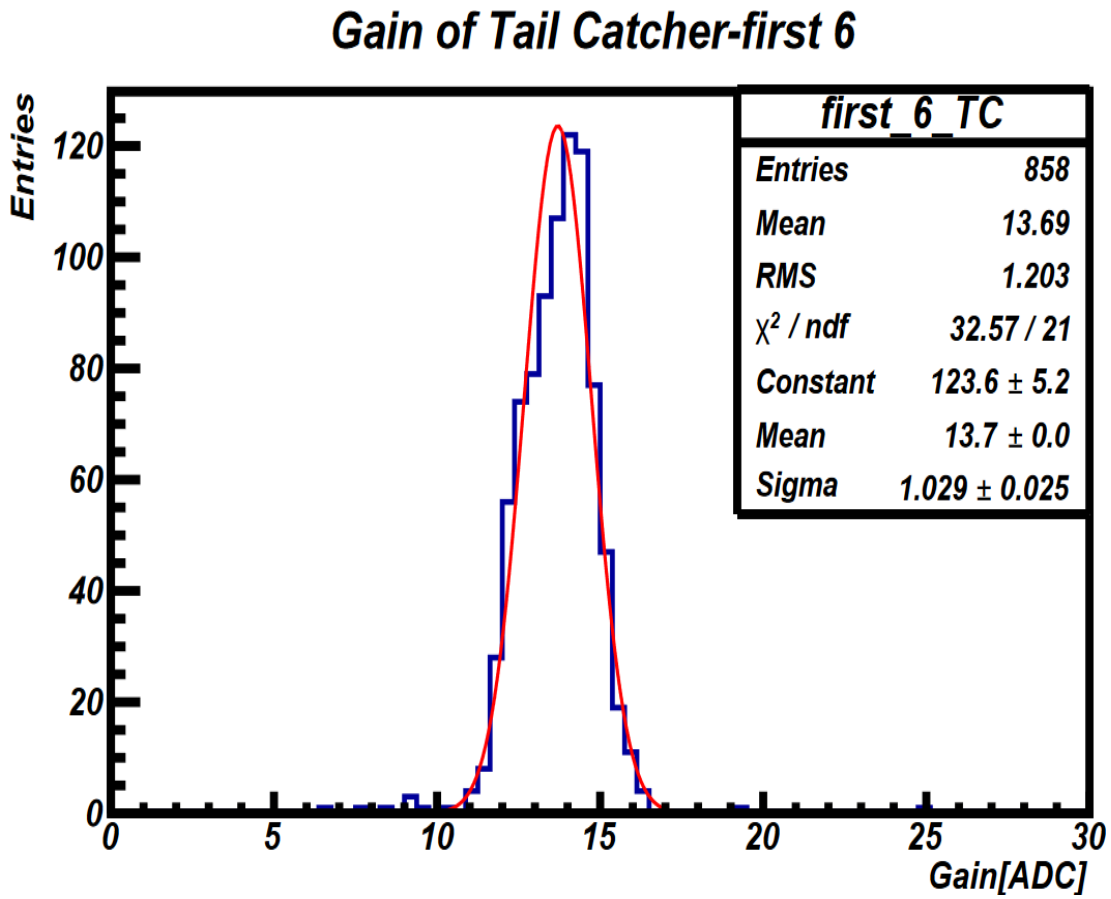


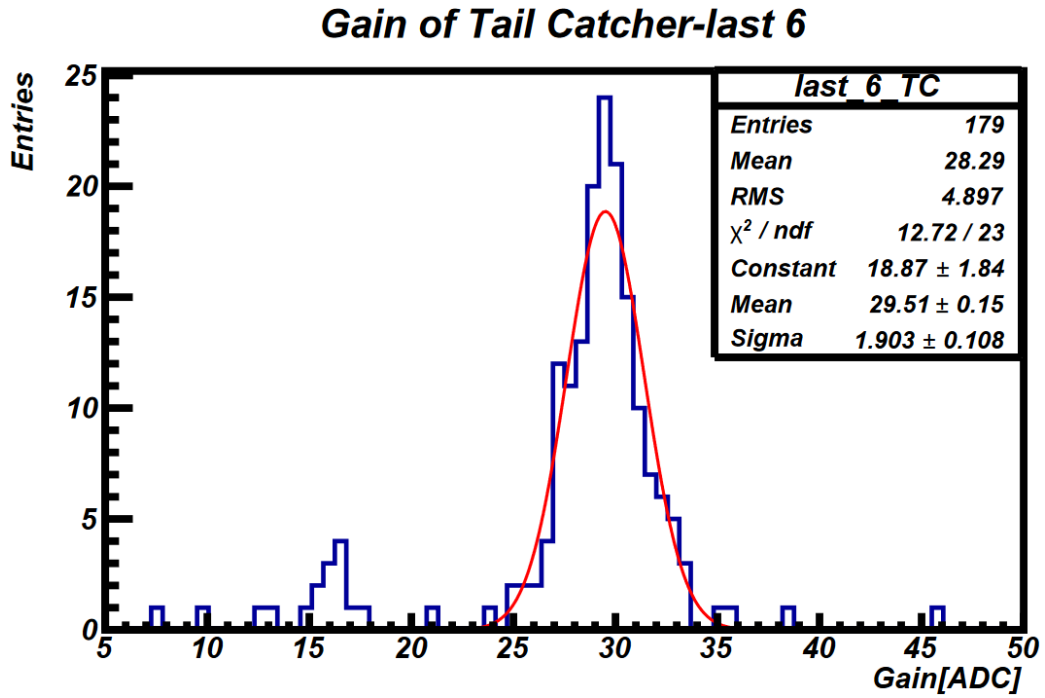


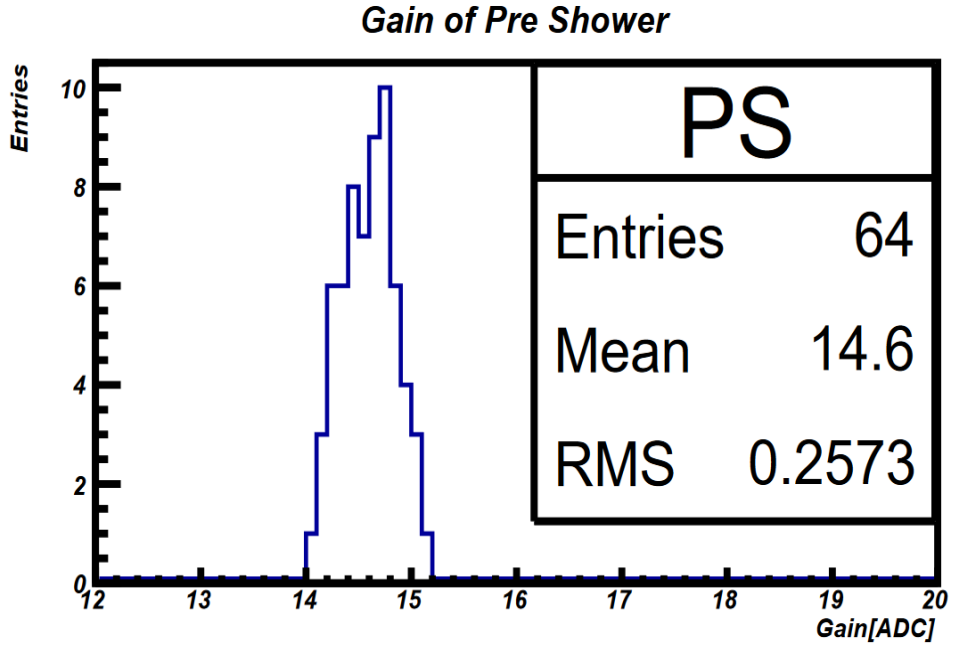


Tail Catcher and Pre shower

Gain





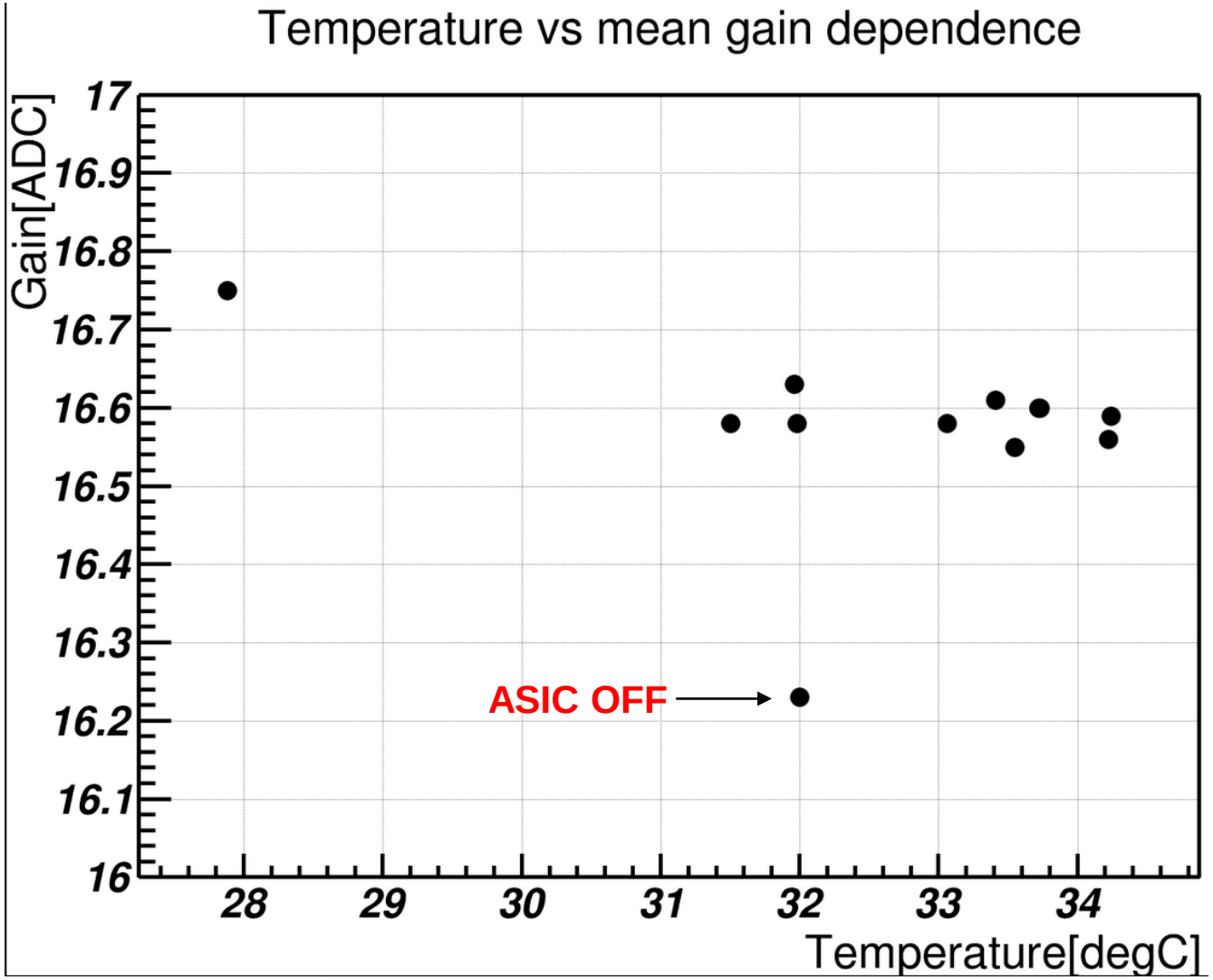


Gain of tail catcher for first 6 layer different from last 6 due to different SiPM on board

Temperature and gain dependence

- The SiPM breakdown voltage varies with temperature – The gain changes with temperature too.
- The temperature of each detector module is monitored by 6 sensors.

More discussion on Yuji's talk

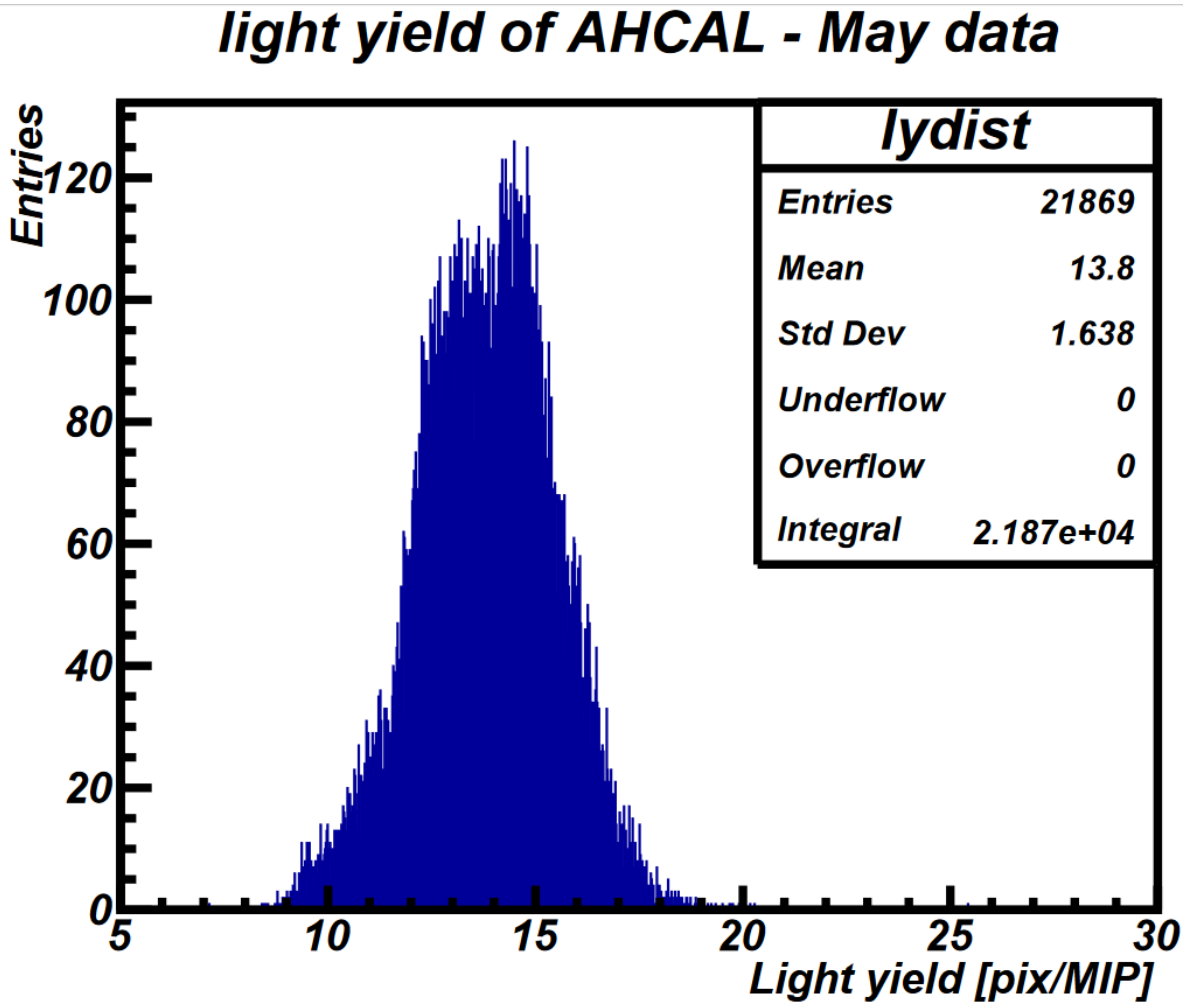


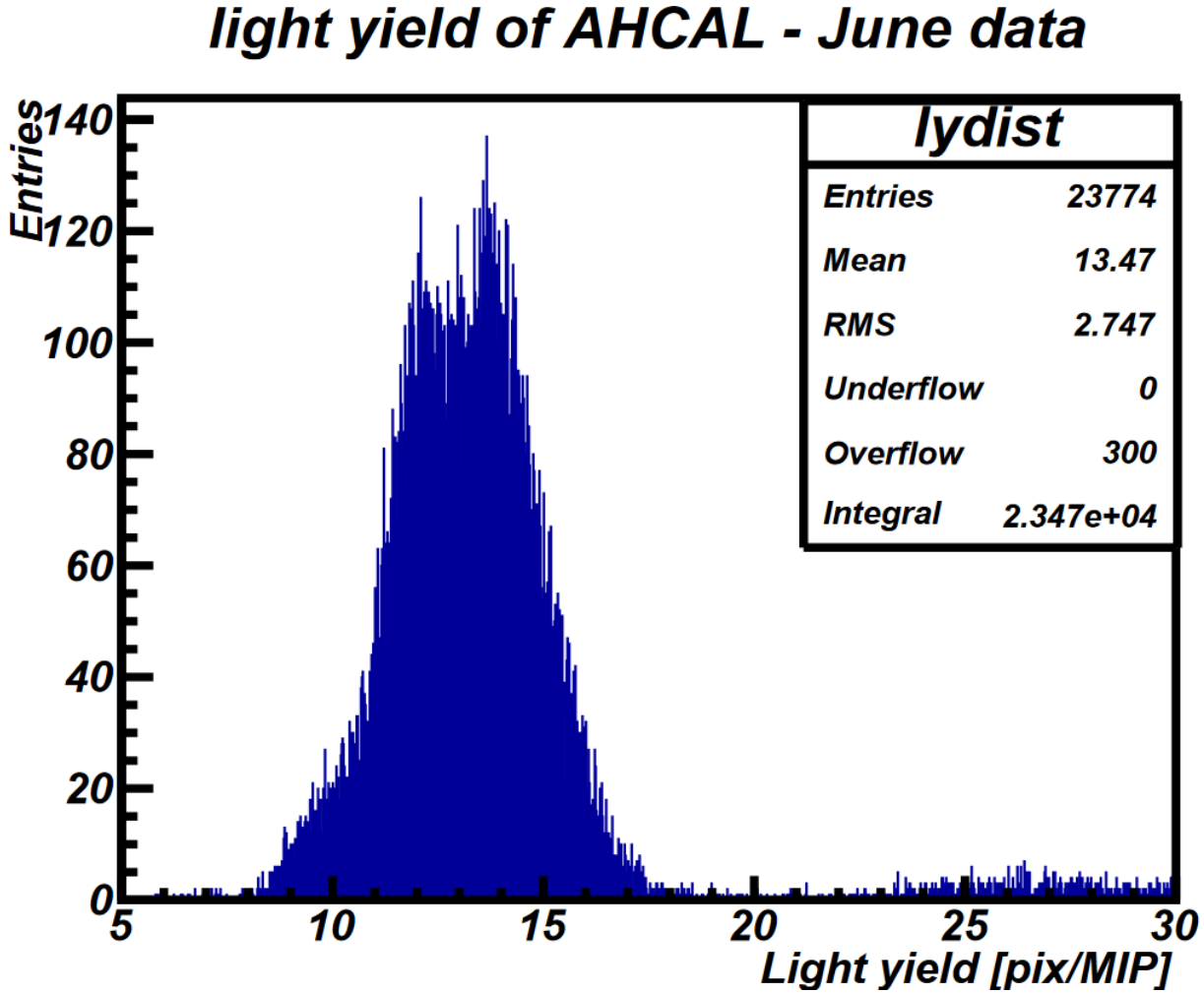
LIGHT YIELD

Most probable number of pixels fired per incident MIP

Light Yield

May and June



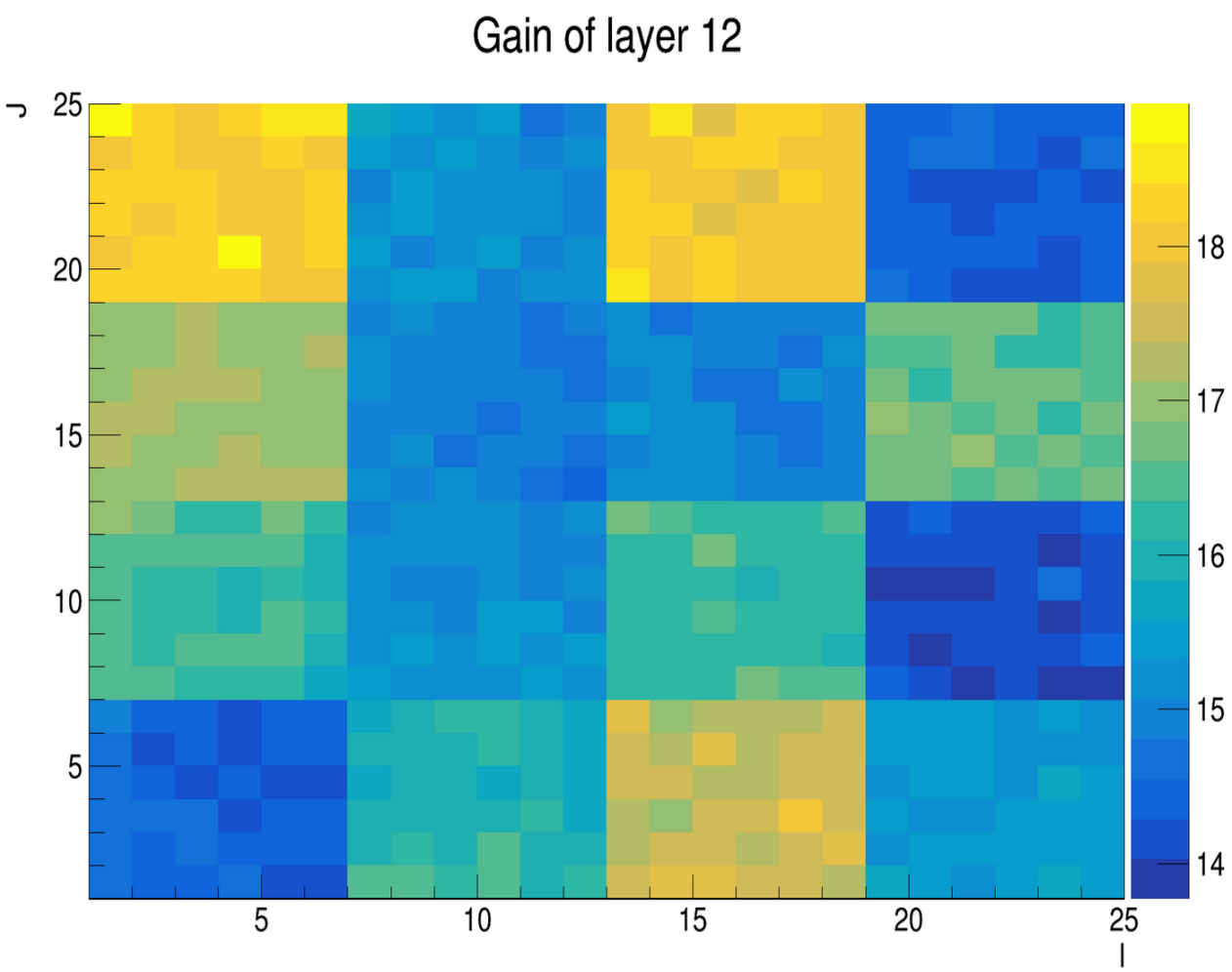


MIP values acquired from Daniel

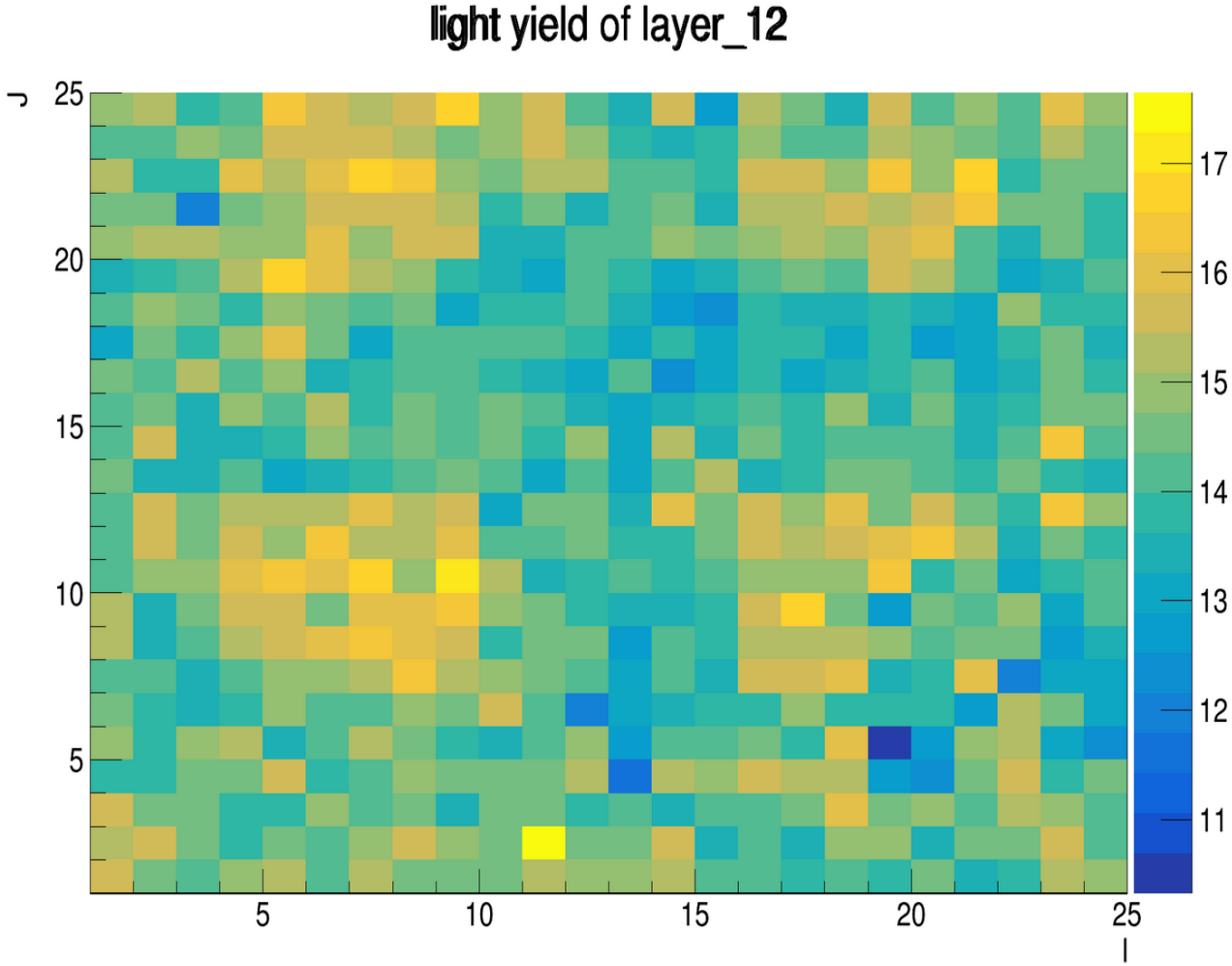
Layer 12

Gain and light yield

Structure of the chips are observed



Light yield within a HBU is quite homogenous



SATURATION CORRECTION

Saturation

Effective Pixels

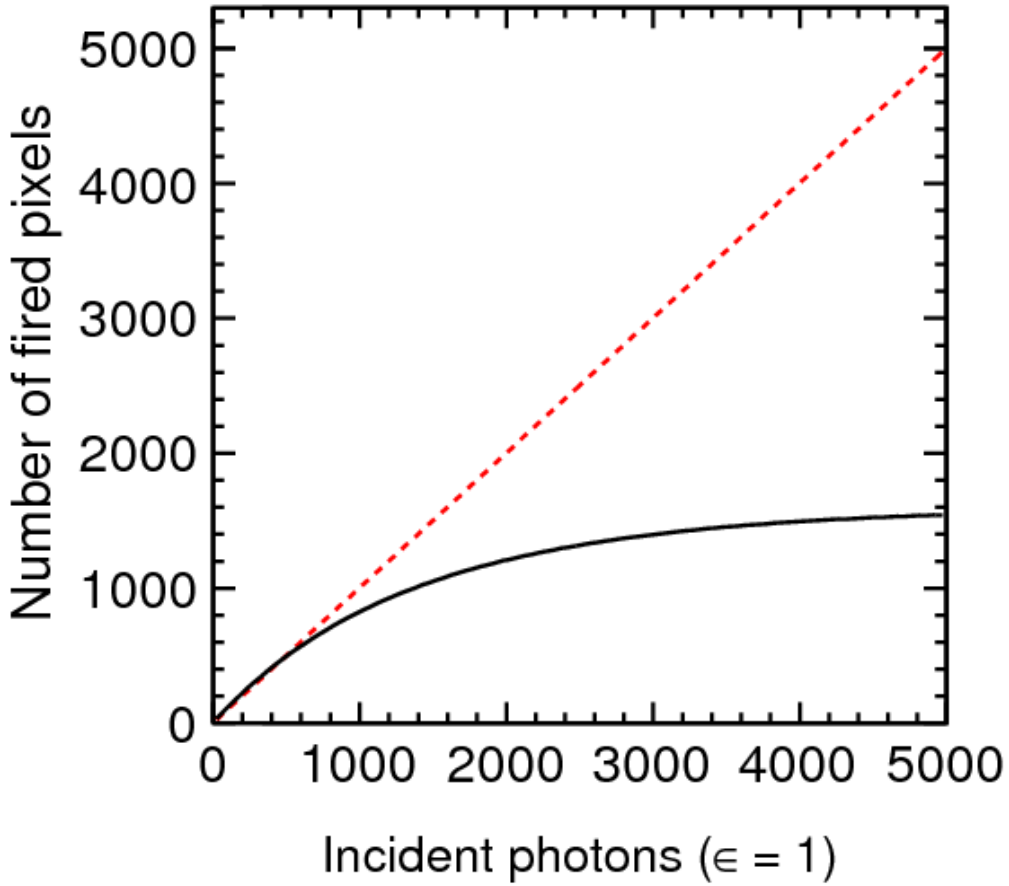
Why saturation?

- Due to limited number of pixels in SiPM (2668 pixels , 1.3 x 1.3 mm^2).
- Need to correct the non-linear response of SiPM.

The idea: Fit the SiPM response to a function and extract the saturation value from the fit.

General SiPM saturation function

$$N_{\text{fire}}^{\text{LO}'} = N_{\text{pix}}^{\text{eff}}\left(1 - \mathrm{e}^{-\epsilon N_{\text{in}}/N_{\text{pix}}^{\text{eff}}}\right)$$



- Saturated signal = Neff (1- exp (- de_saturated signal / Neff pixels)).
- De-saturated using inverse function: de-saturated signal = Neff pixels * log (1 – saturated signal / Neff pixels).
  - Apply linear continuation function for hits above certain threshold (> 0.95 * Neff pixels).

Saturation

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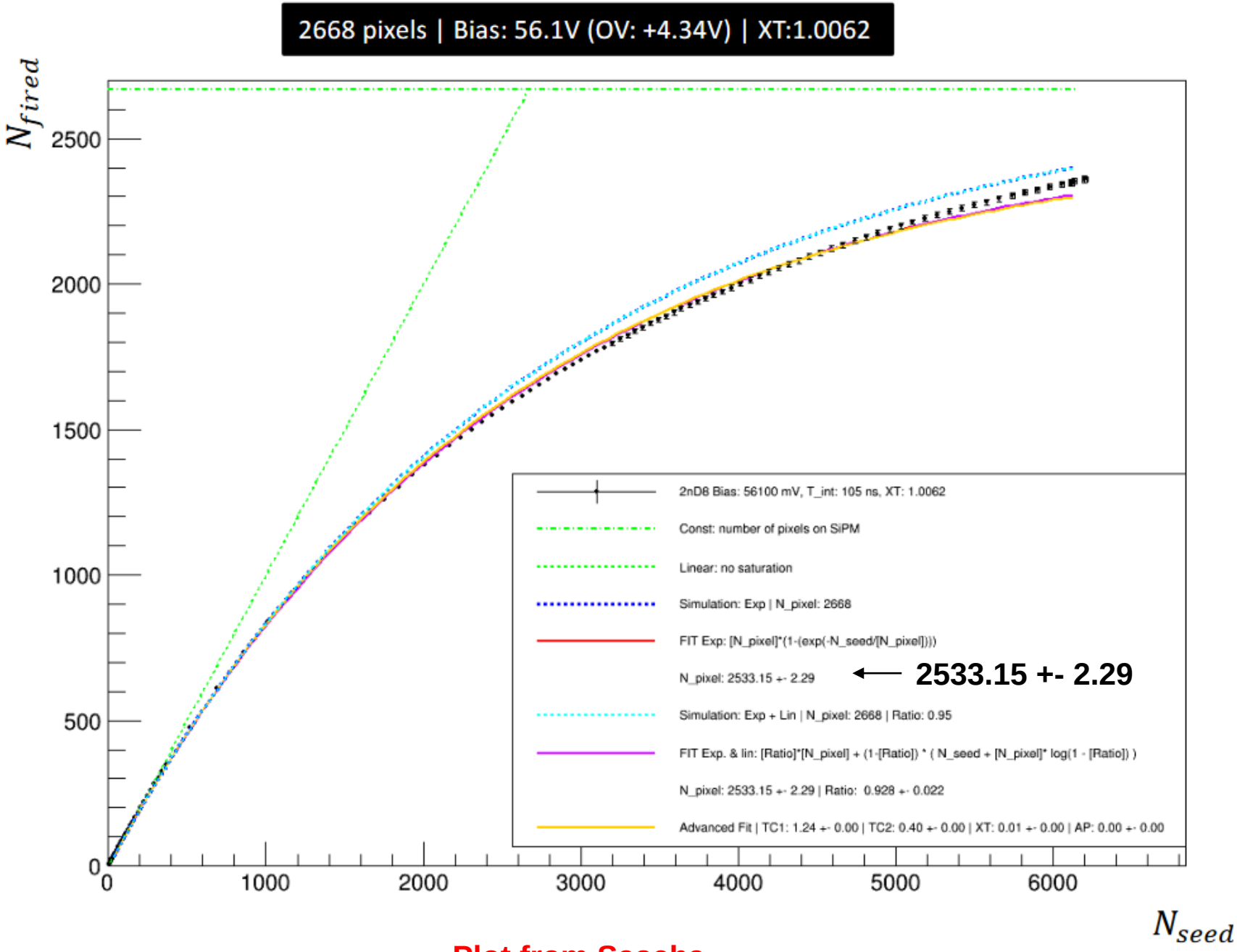
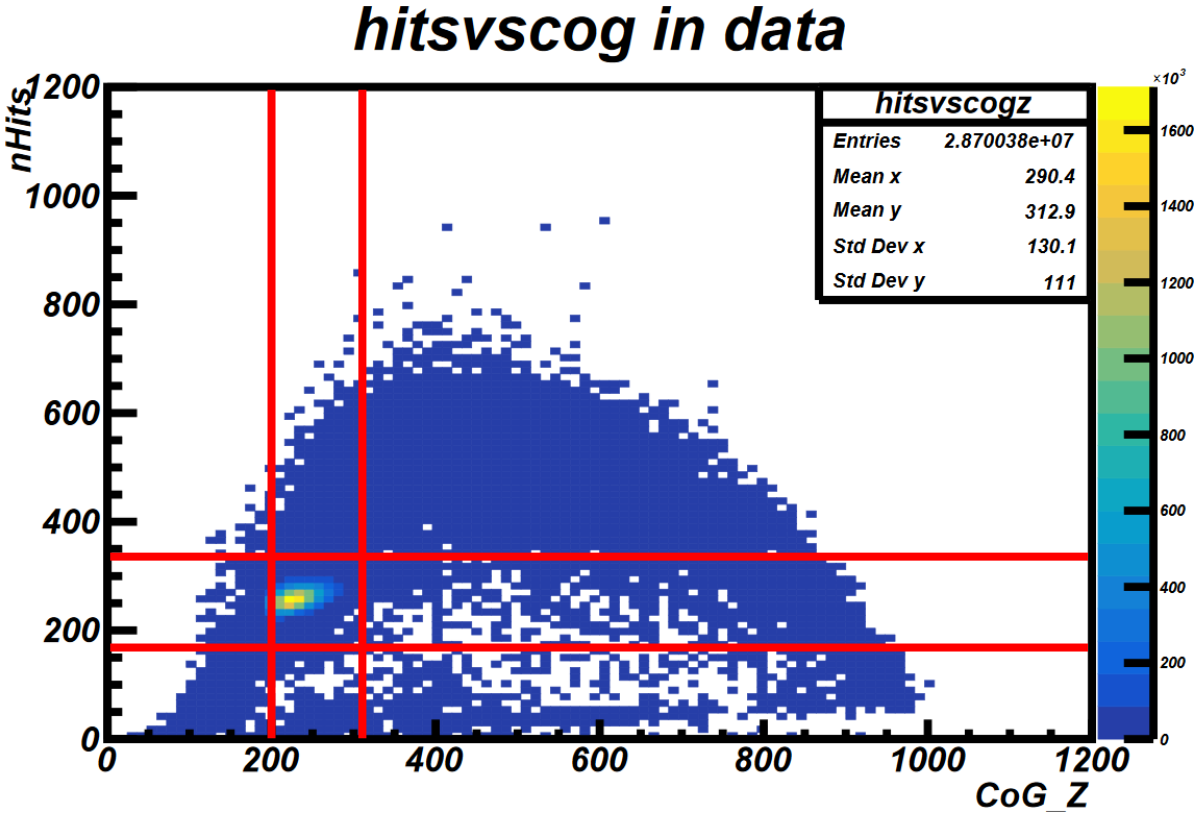


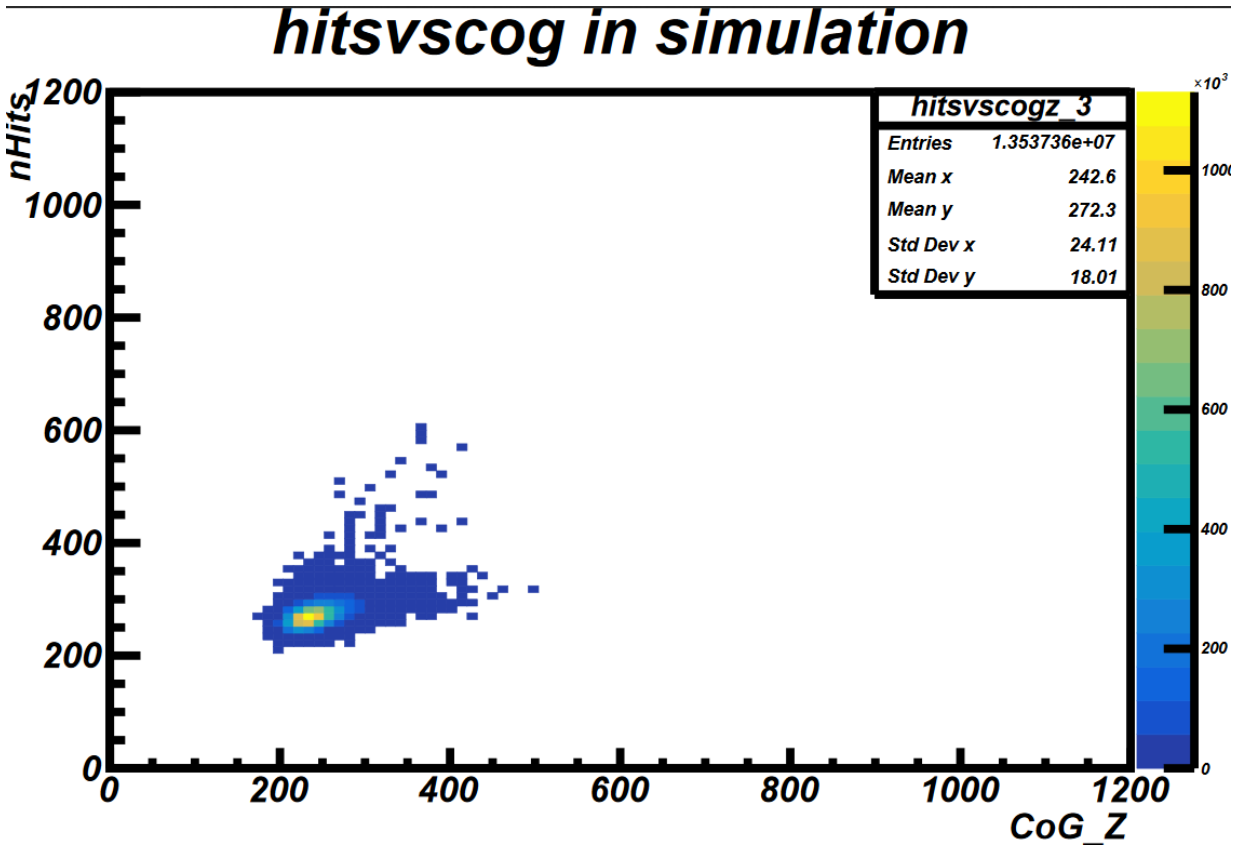
Plot from Sascha

Basic event selection for 80 GeV electron – June 2018 data

Run number: 61156

- Number of hits: Between 200 to 300 hits
- Center of gravity along Z: 180 mm to 280 mm





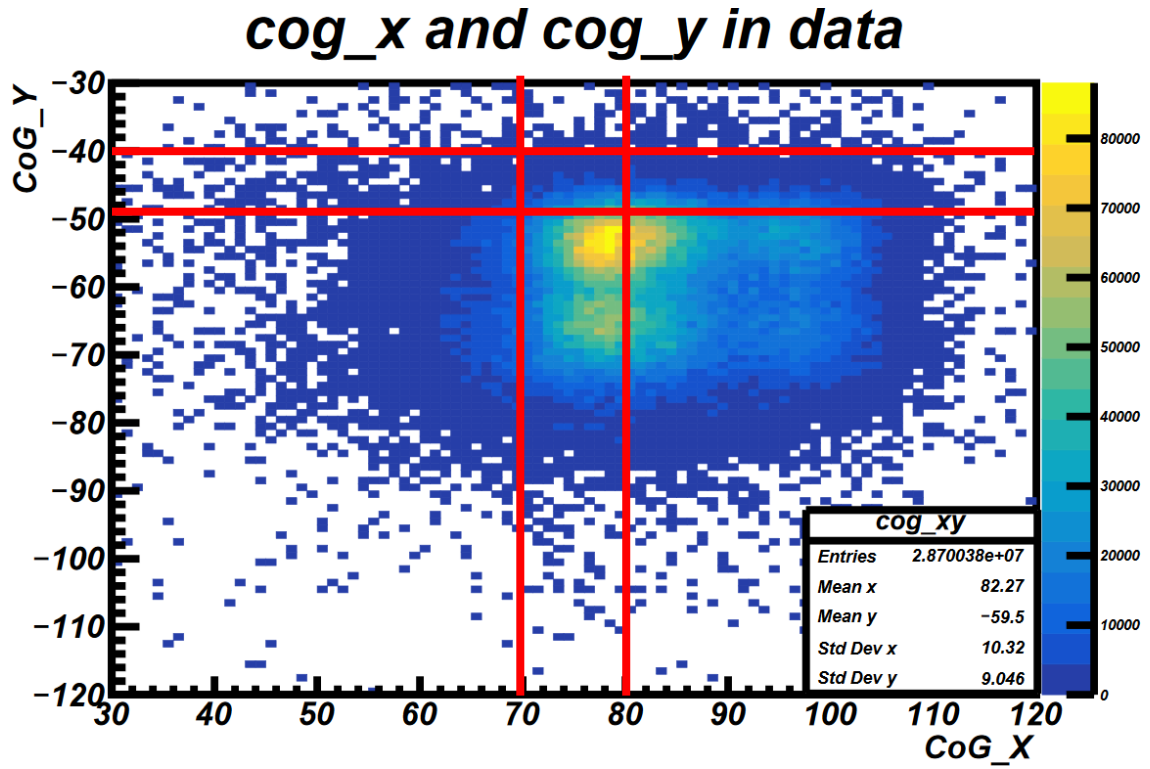
Basic event selection for 80 GeV electron – June 2018 data

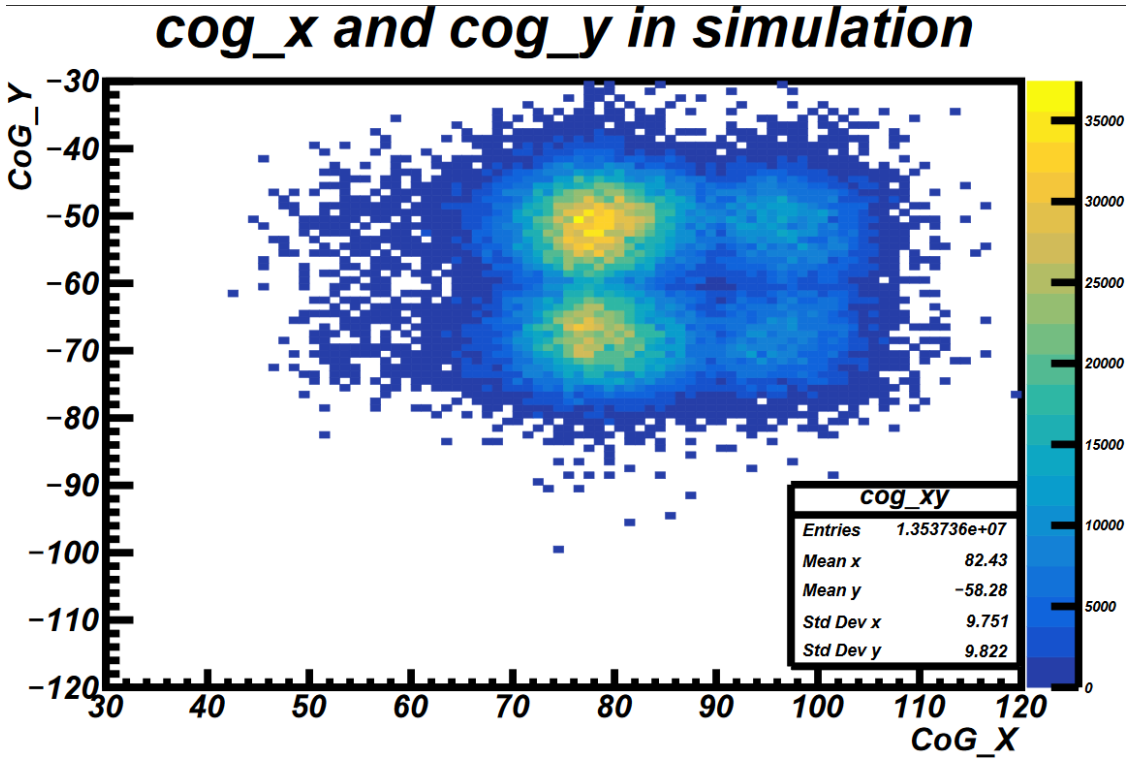
Run number: 61156

Centre of gravity X: Between 70 mm to 80 mm

Centre of gravity Y: Between -50 mm to -40 mm

Choosing 1cm in centre of a tile: Pick events with maximum amplitude



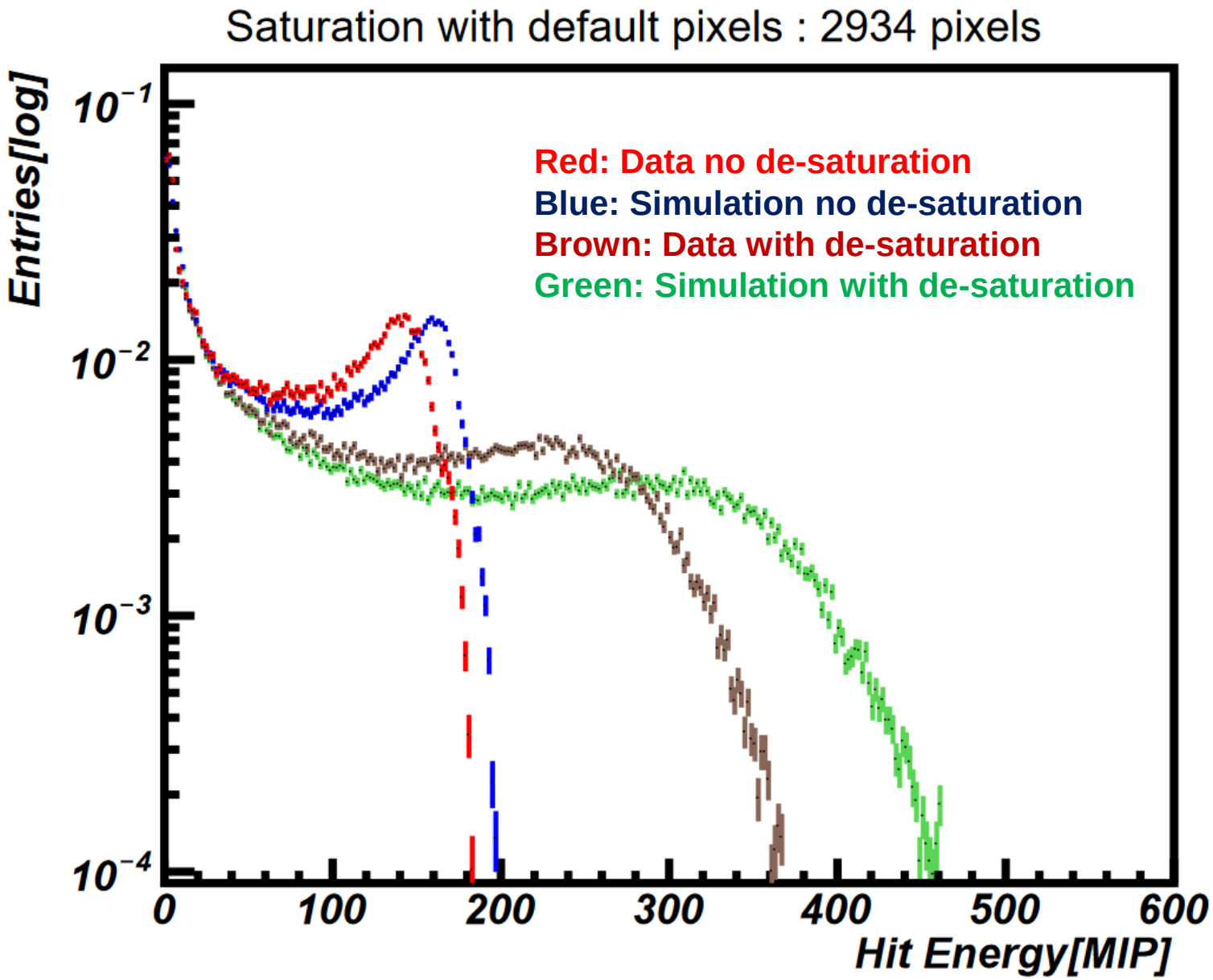


Saturation

Default pixels

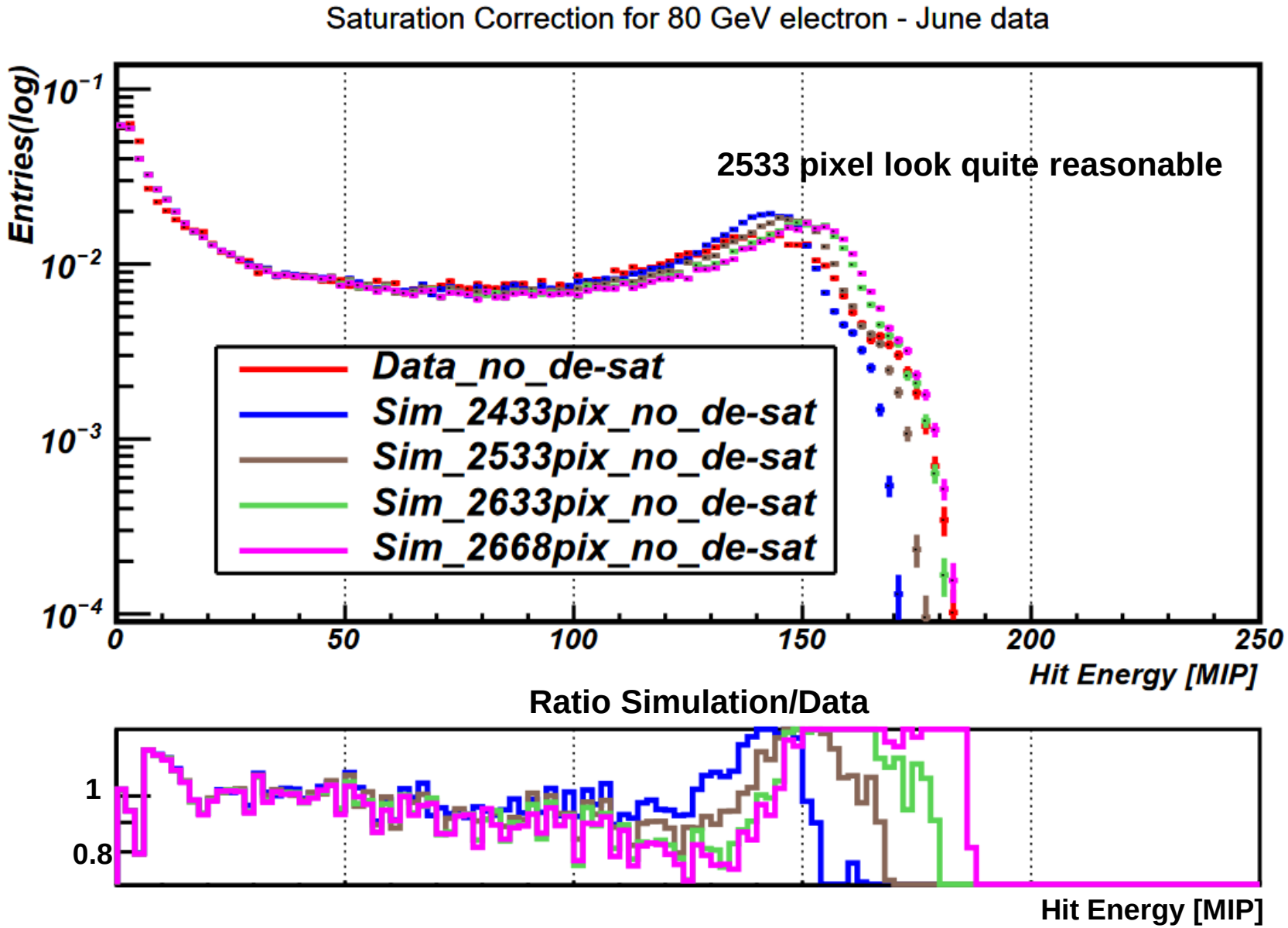
- +10% of the nominal value(2668).
- 80 GeV electron June data – Run number 61156
- Look into the central tile of each layer.
- First step: Add saturation to data and MC
- Second step: De-saturate the data and MC

Hit Energy in simulation is higher than data.



Saturation Correction

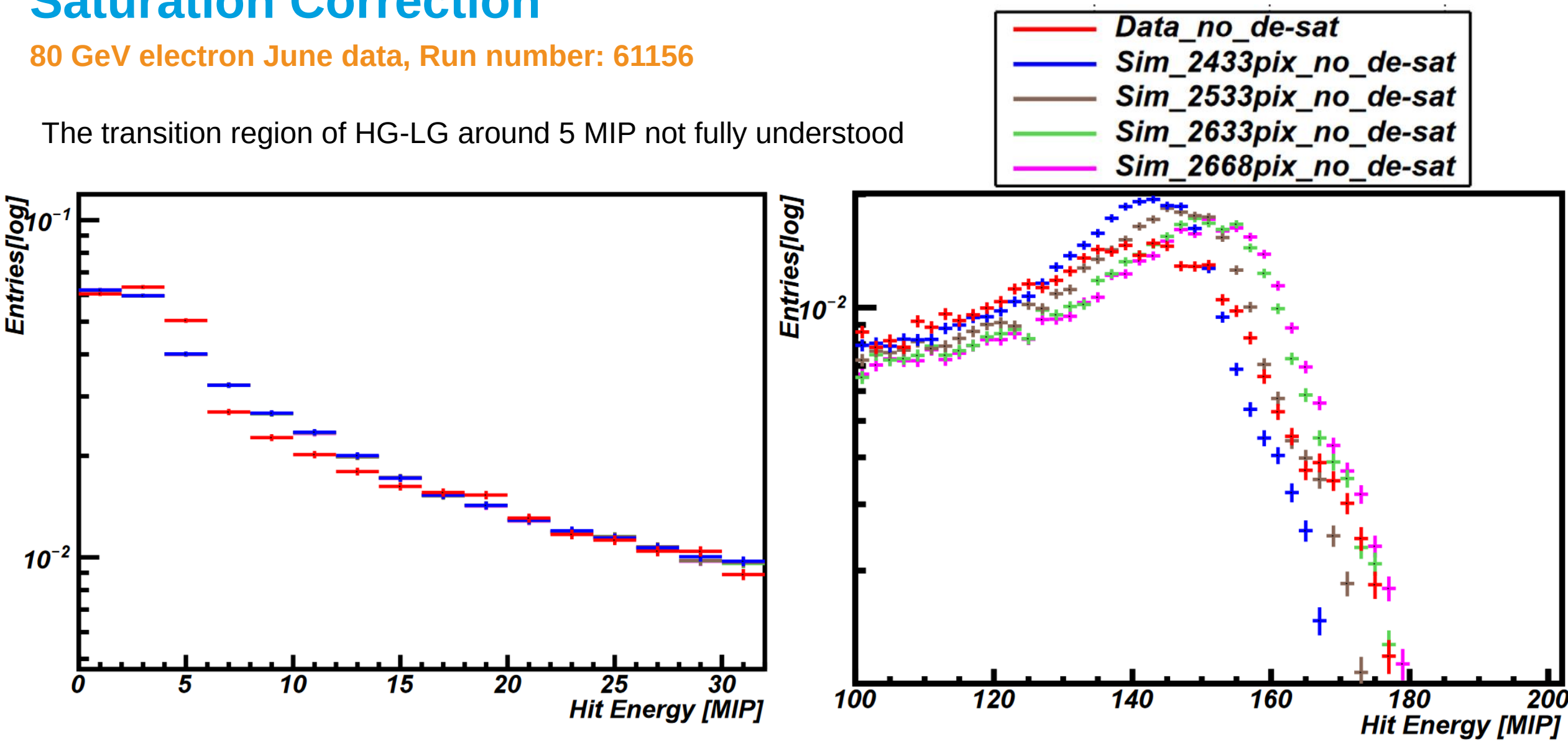
80 GeV electron June data, Run number: 61156



Saturation Correction

80 GeV electron June data, Run number: 61156

The transition region of HG-LG around 5 MIP not fully understood



Conclusion

Gain:

- Determined the gain and is calibrated for ~98% of the channels.
  - ~5 channels not behaving well.
- Gain of module 27 limited by HV settings in May and June was corrected in October.
- The gain values for May, June and October are uploaded in the data-base.

Light Yield:

- Determined the light yield – expected value was 15 pix/MIP, but found to be around14 pix/MIP with a RMS value of ~2.5.

SiPM Saturation:

- Checked for 80 GeV electron, the default value was too high.
- Measured value of 2533 pixels looks reasonable.

To do:

- Check the saturation effects for different energies and layer wise.

Thank you

BACKUP

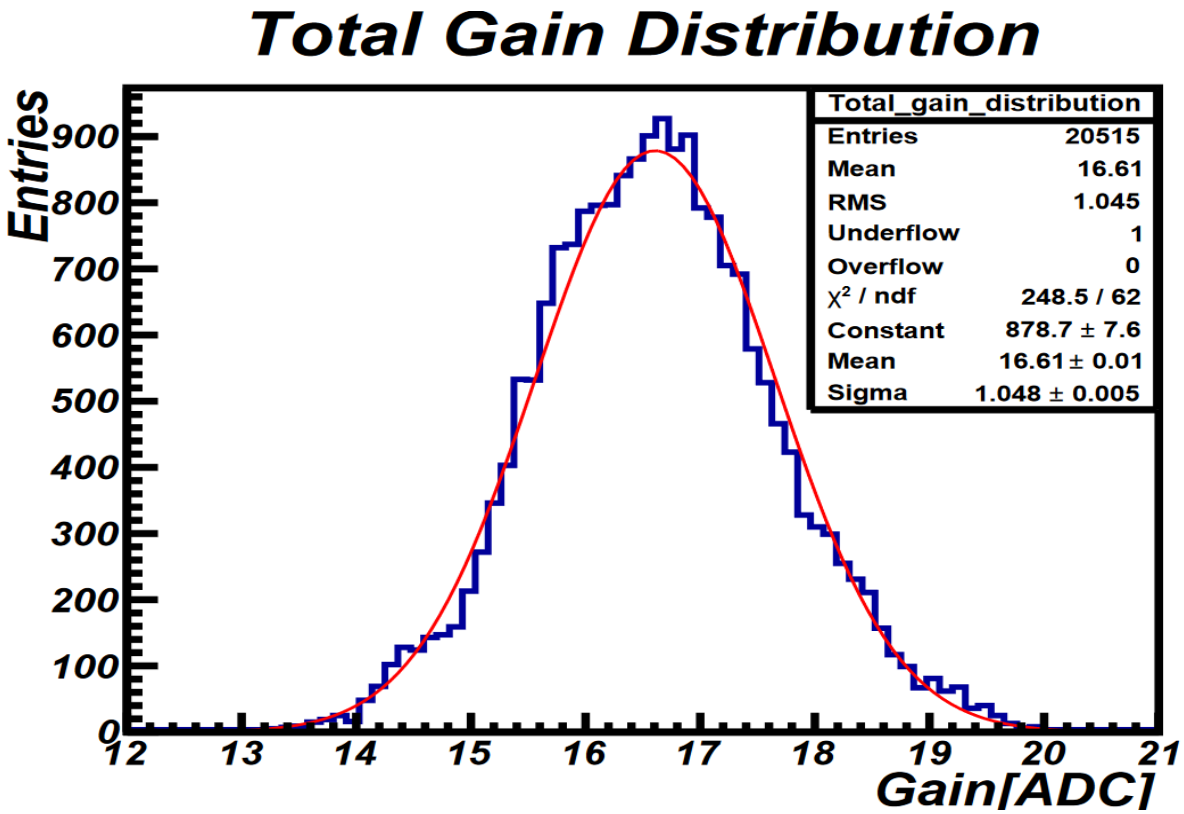
Gain Calibration

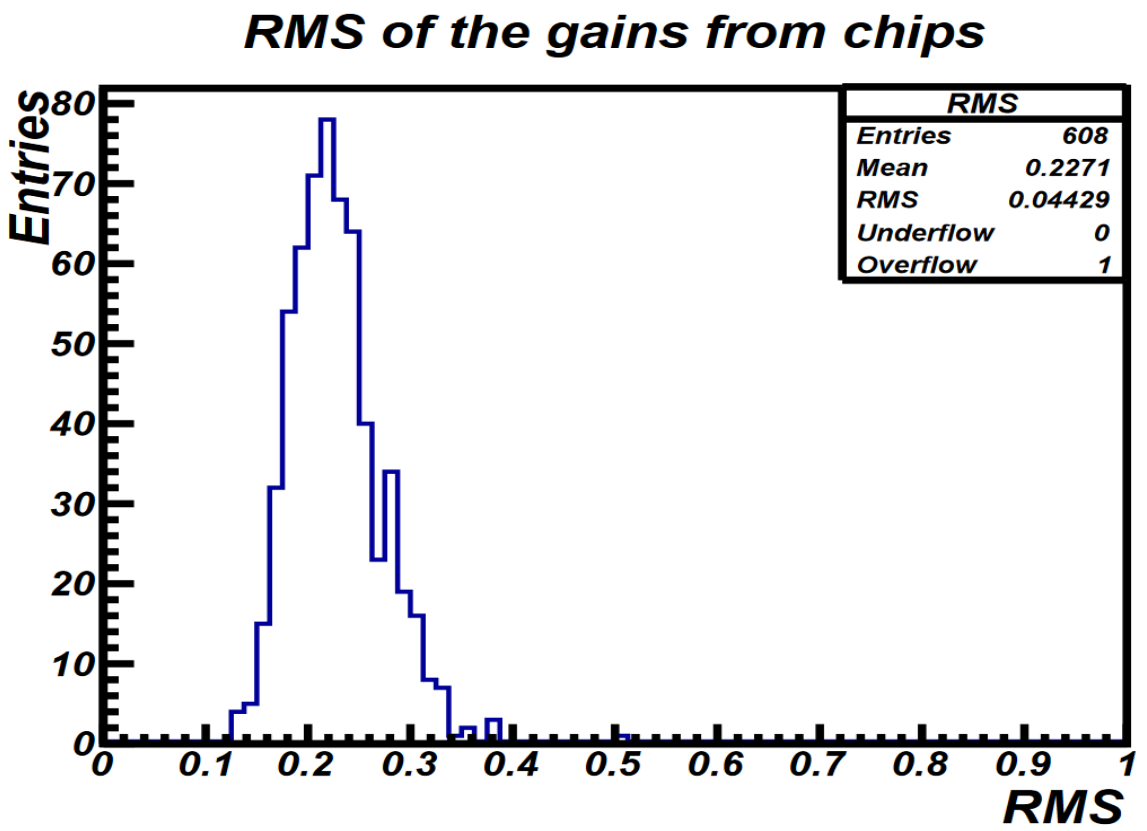
May 2018

- Fitted channels from each LED voltages are combined.

May: Short LED - no power pulsing run.

- Gain distribution for May which consists only AHCAL(21, 888 channels). **94% channels fitted**
- Remaining 1373 channels - acquire gain value from the mean of the corresponding chip.



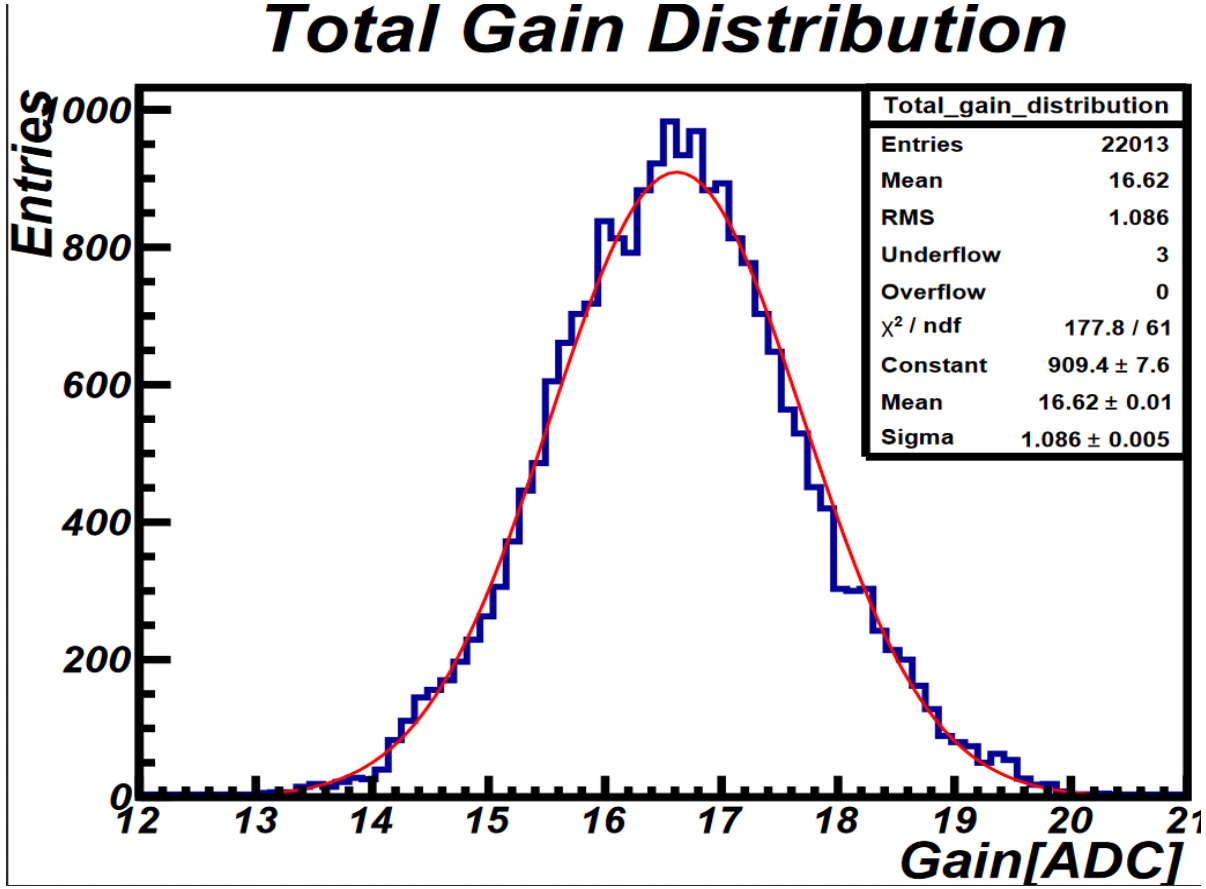


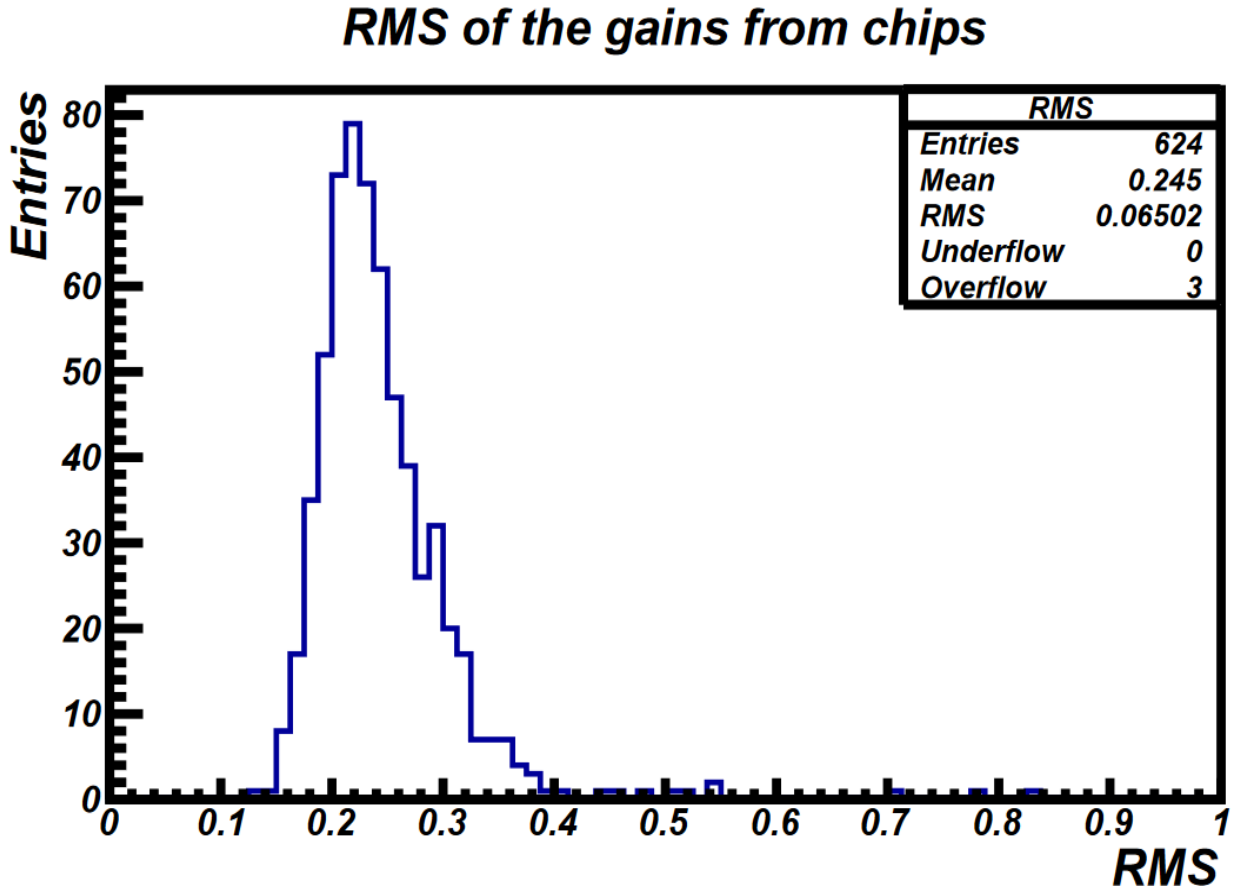
Gain Calibration

June 2018

- Gain distribution from June, includes the Tokyo layer (22464 channels).
- Long LED no power pulsing run on 25.06.2018

98% channels fitted



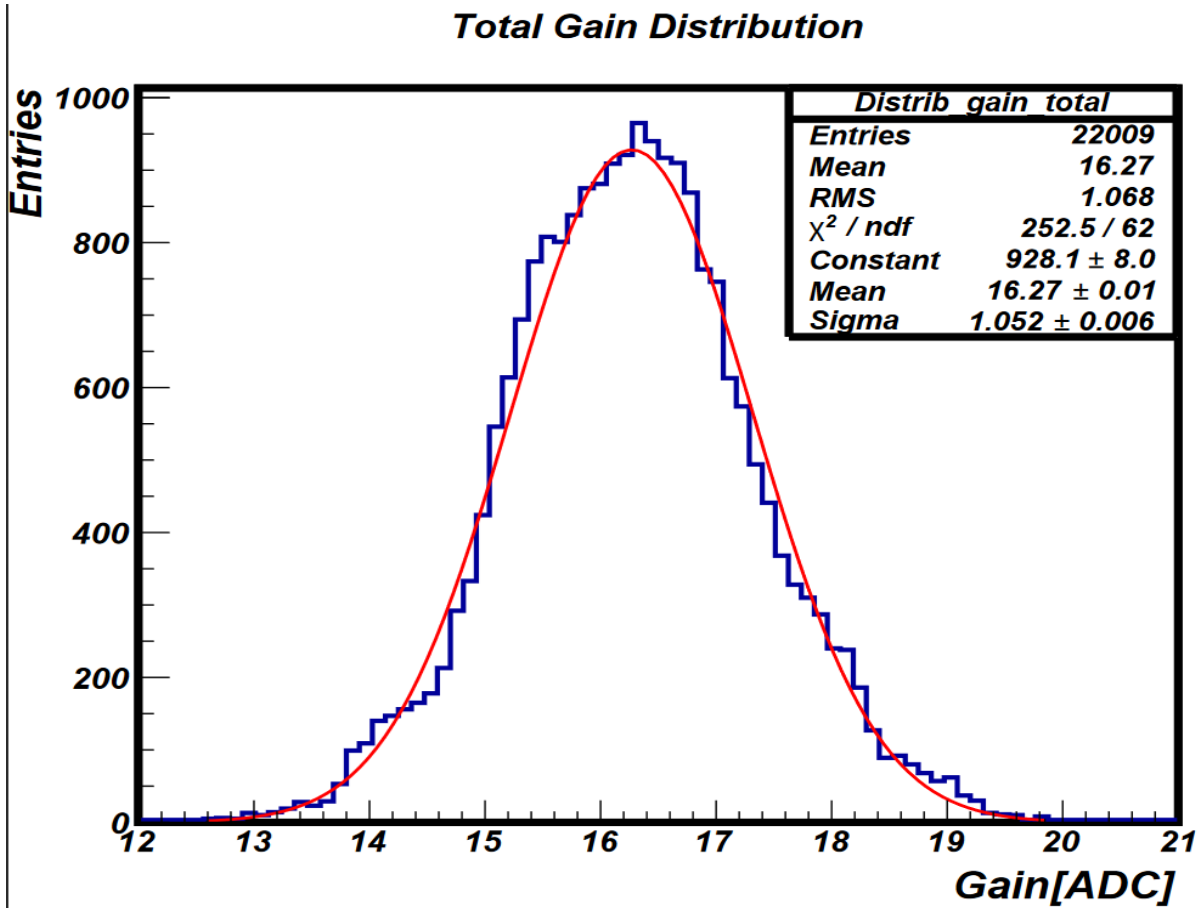


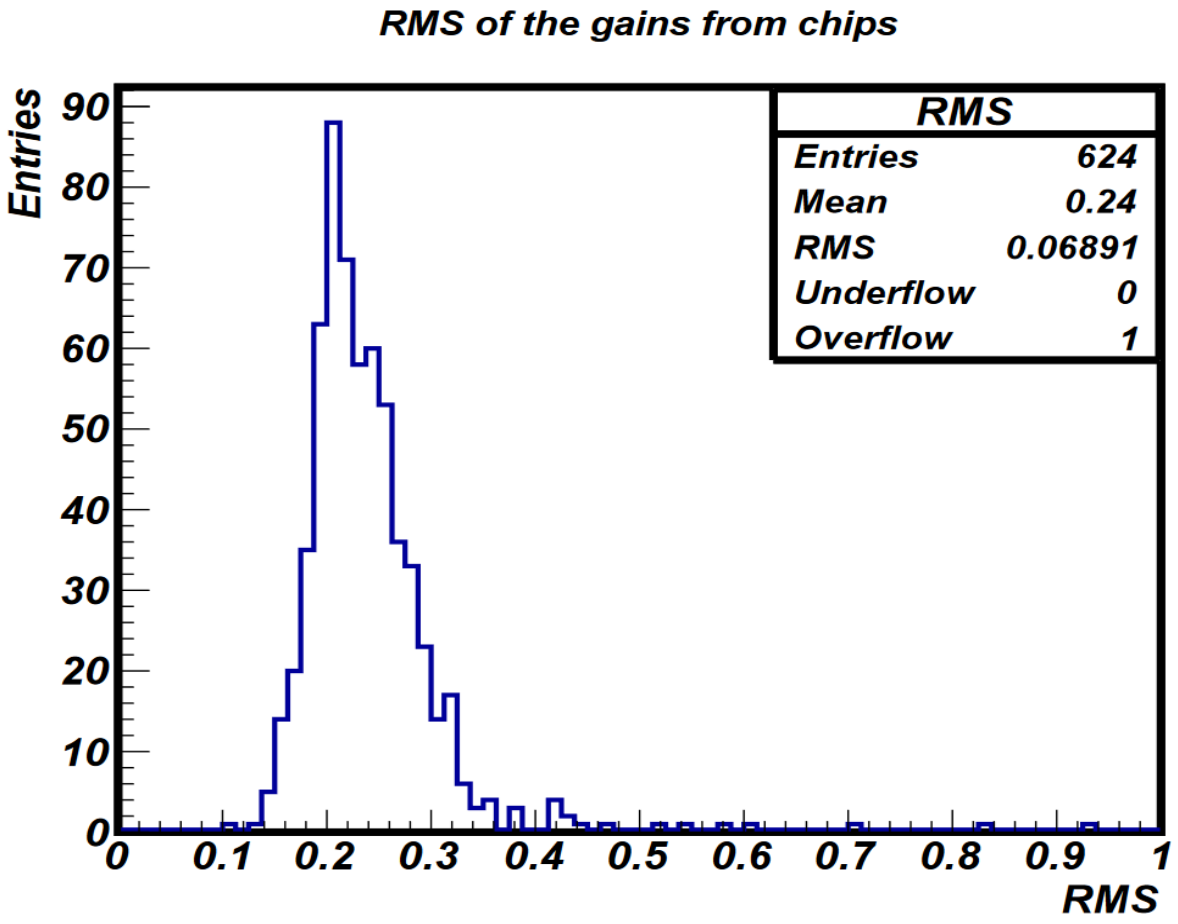
Gain Calibration

October 2018

- AHCAL + Tokyo layer.
- Long LED - power pulsing run on 17.10.2018
- 20 mV steps with 2000 cycles each run.

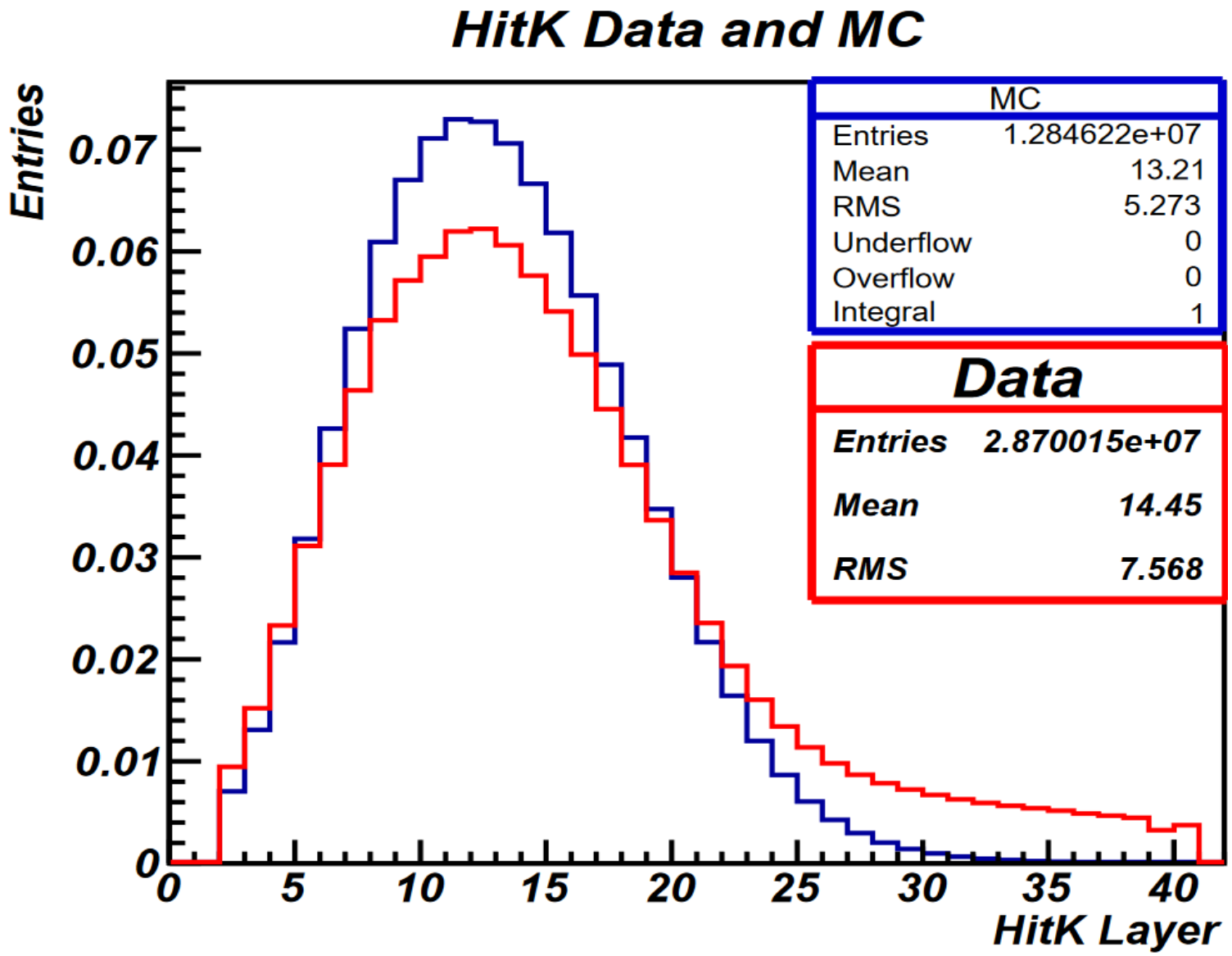
98% channels fitted





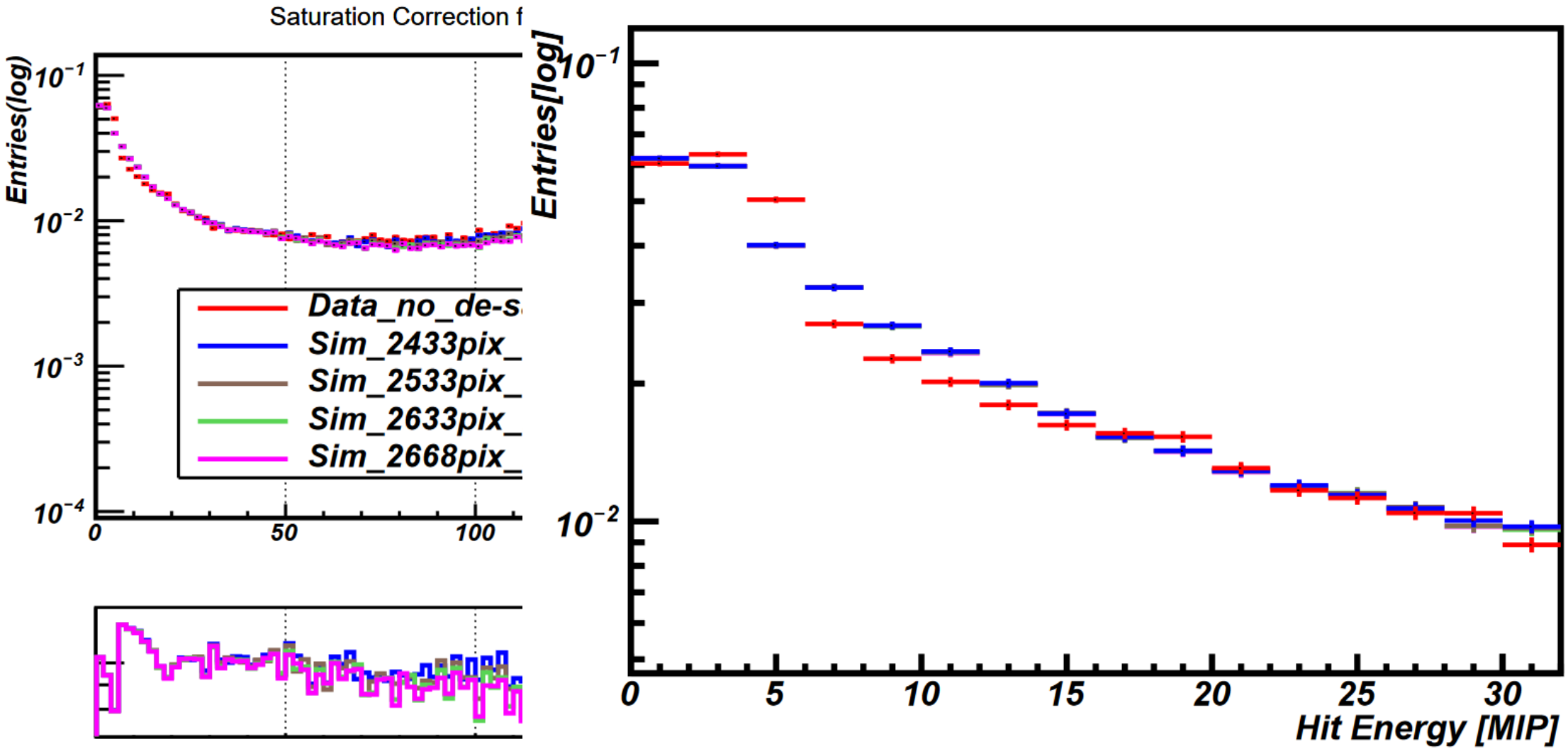
Hit K

Data and MC



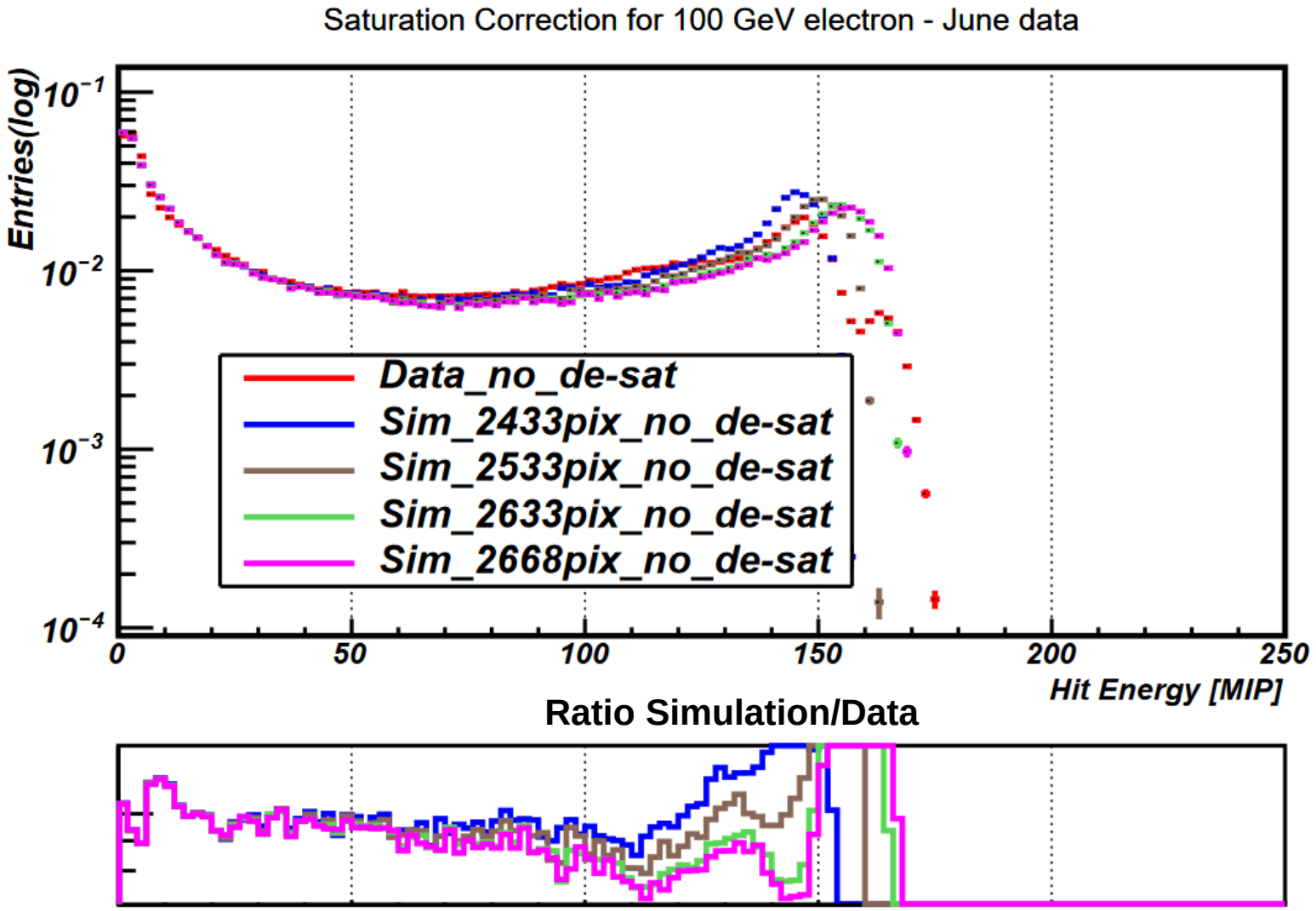
Hit energy

At lower MIP values



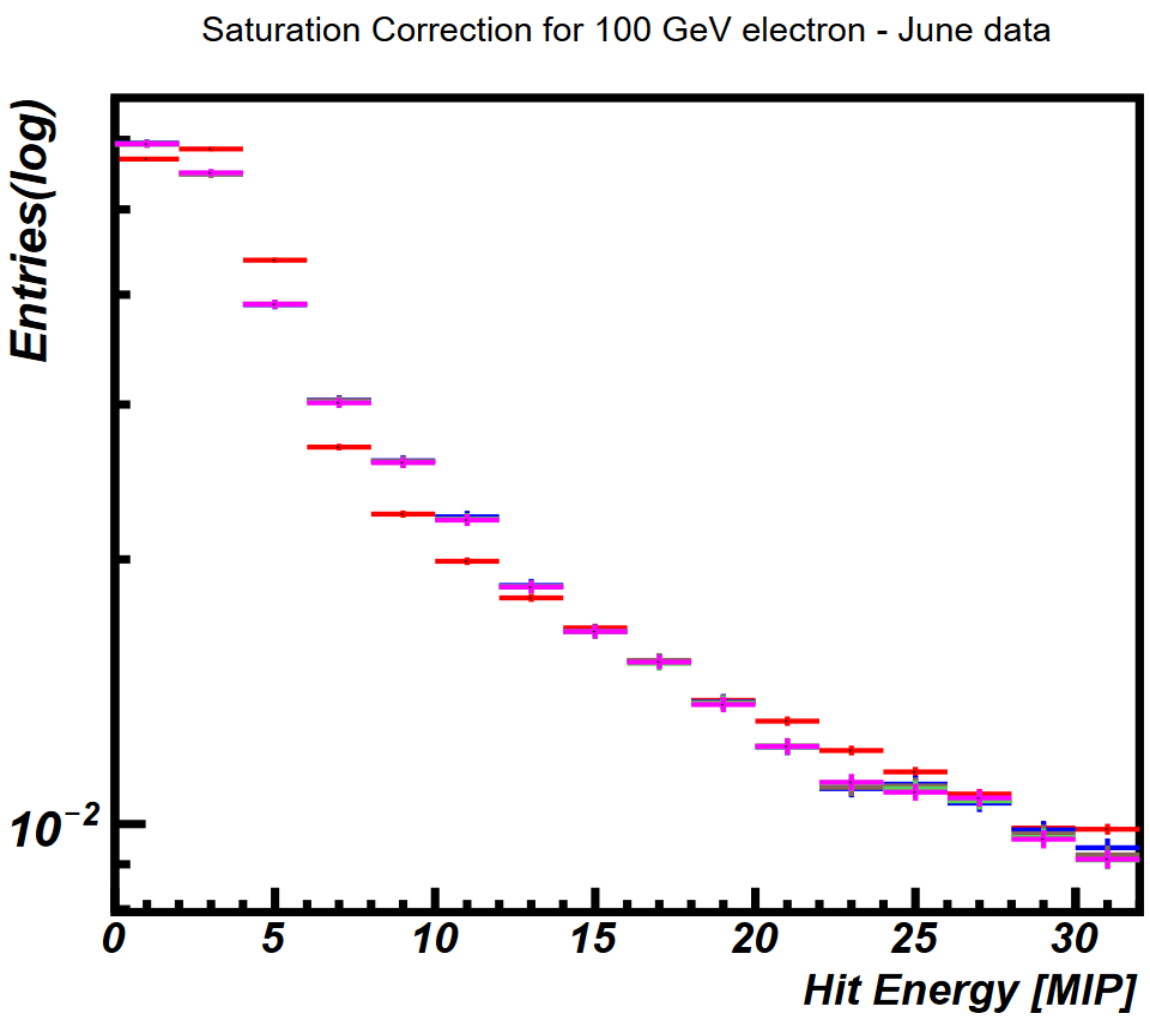
Saturation Correction

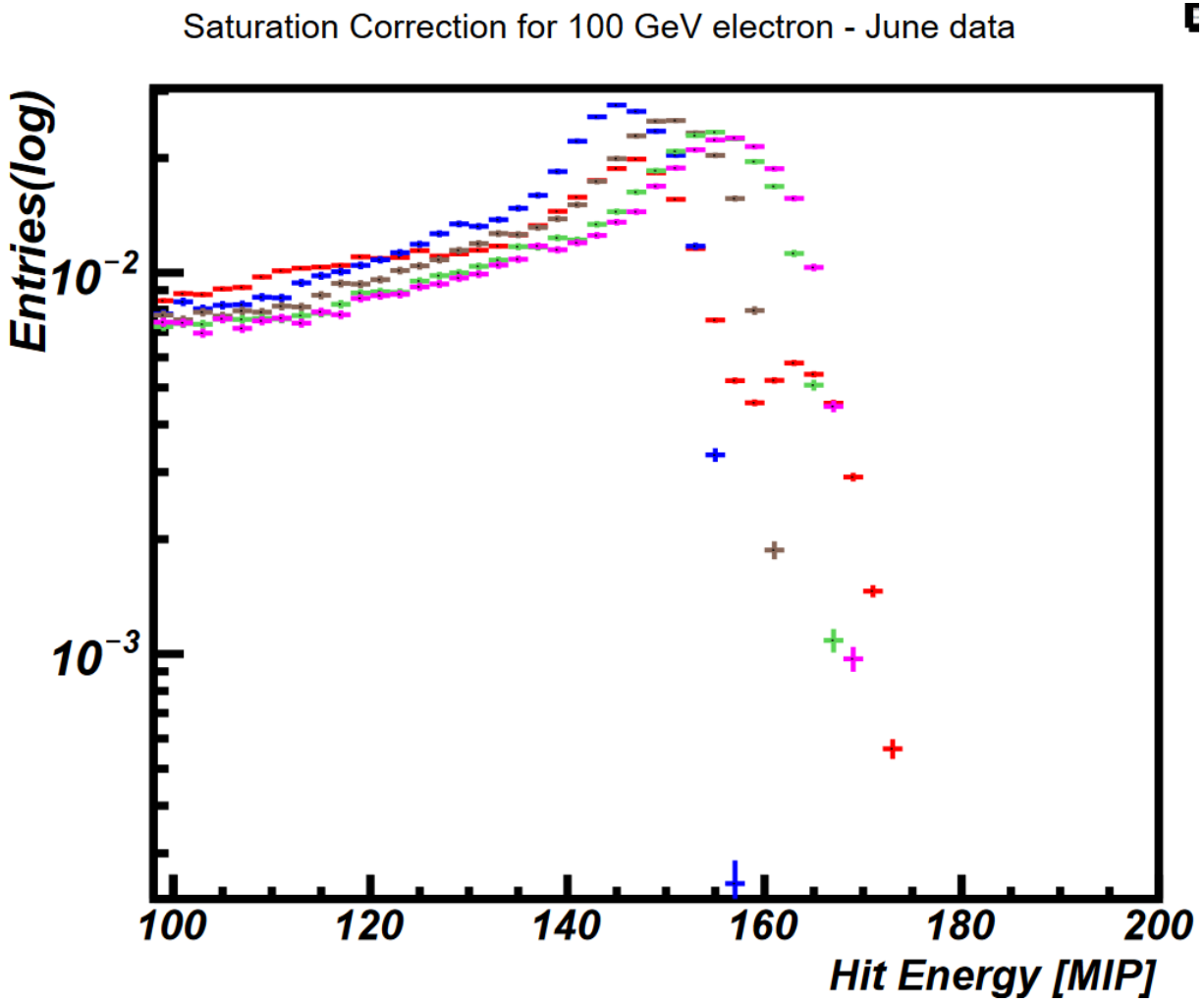
100 GeV electron June data, Run number: 61217



Saturation Correction

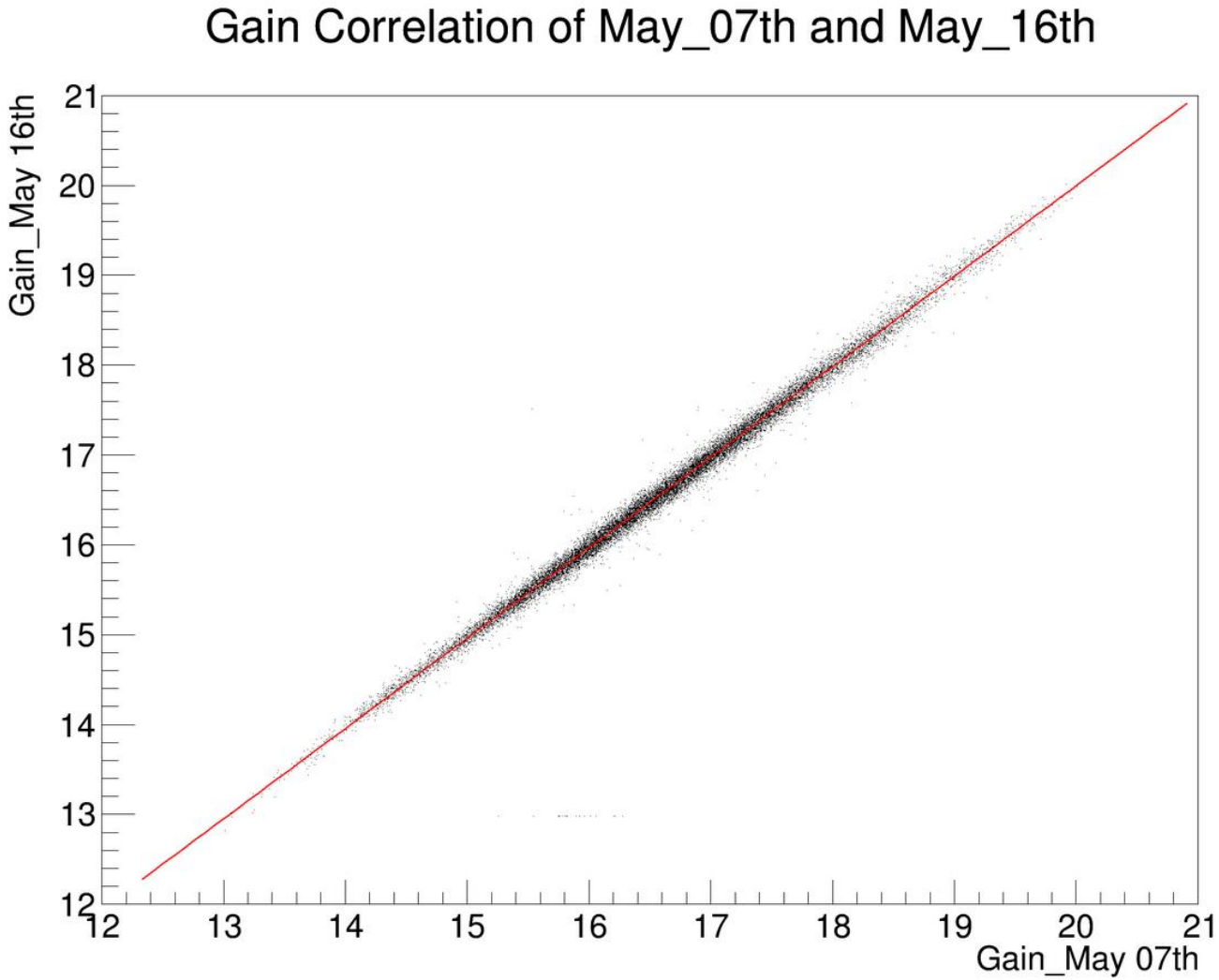
100 GeV electron June data, Run number: 61217





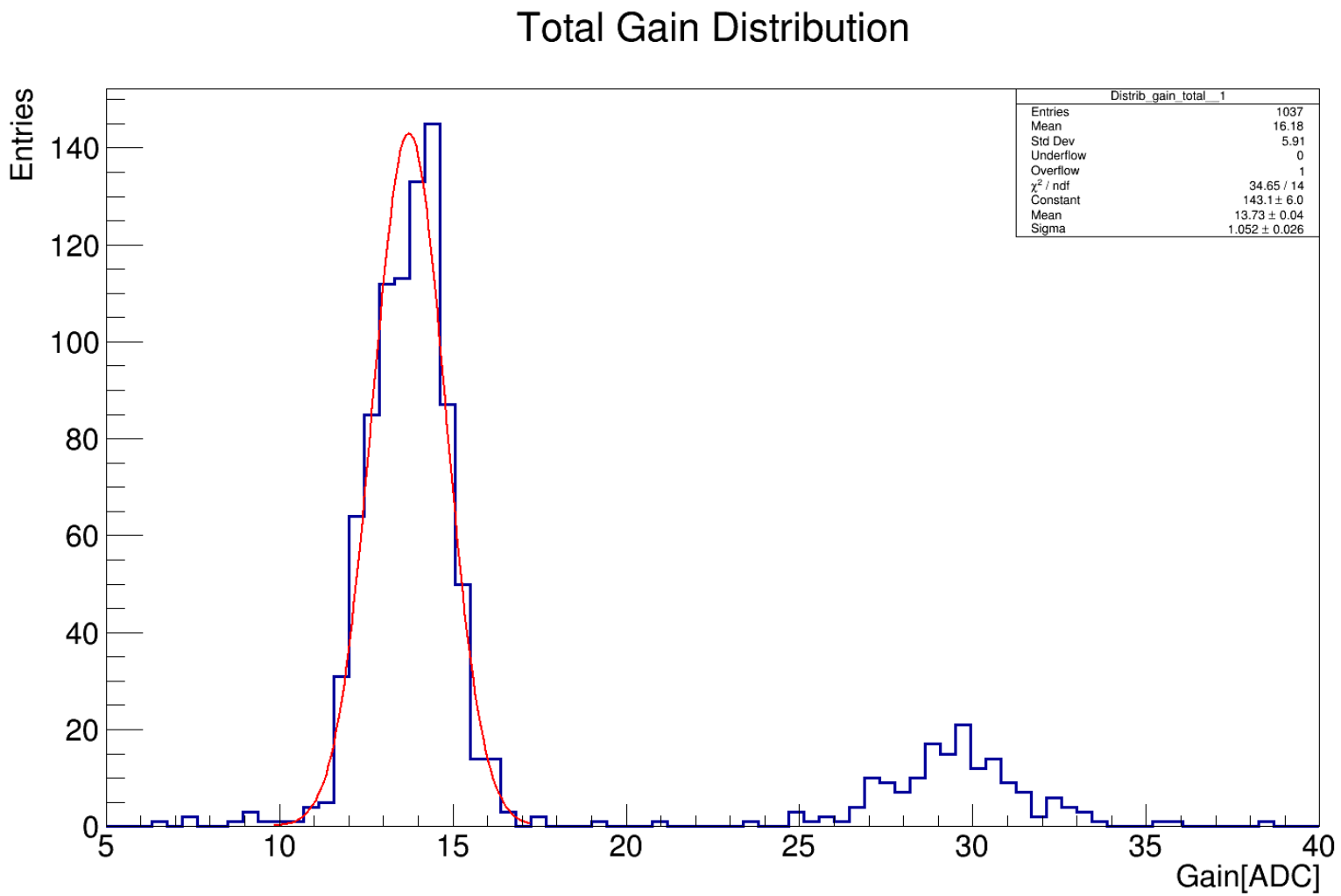
Gain Correlation

Between two days



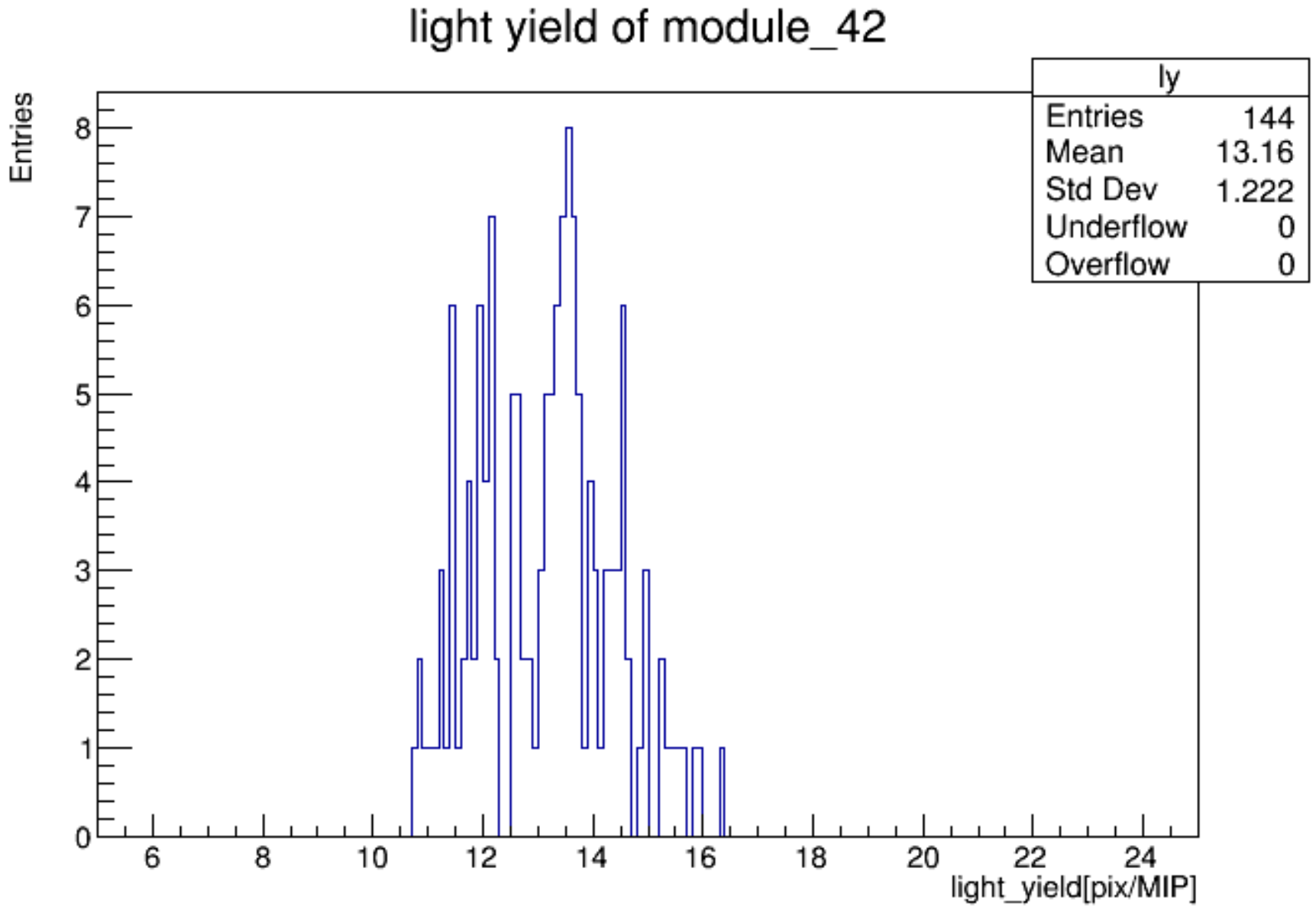
Gain of Tail Catcher

Module 43 to 54



Light Yield

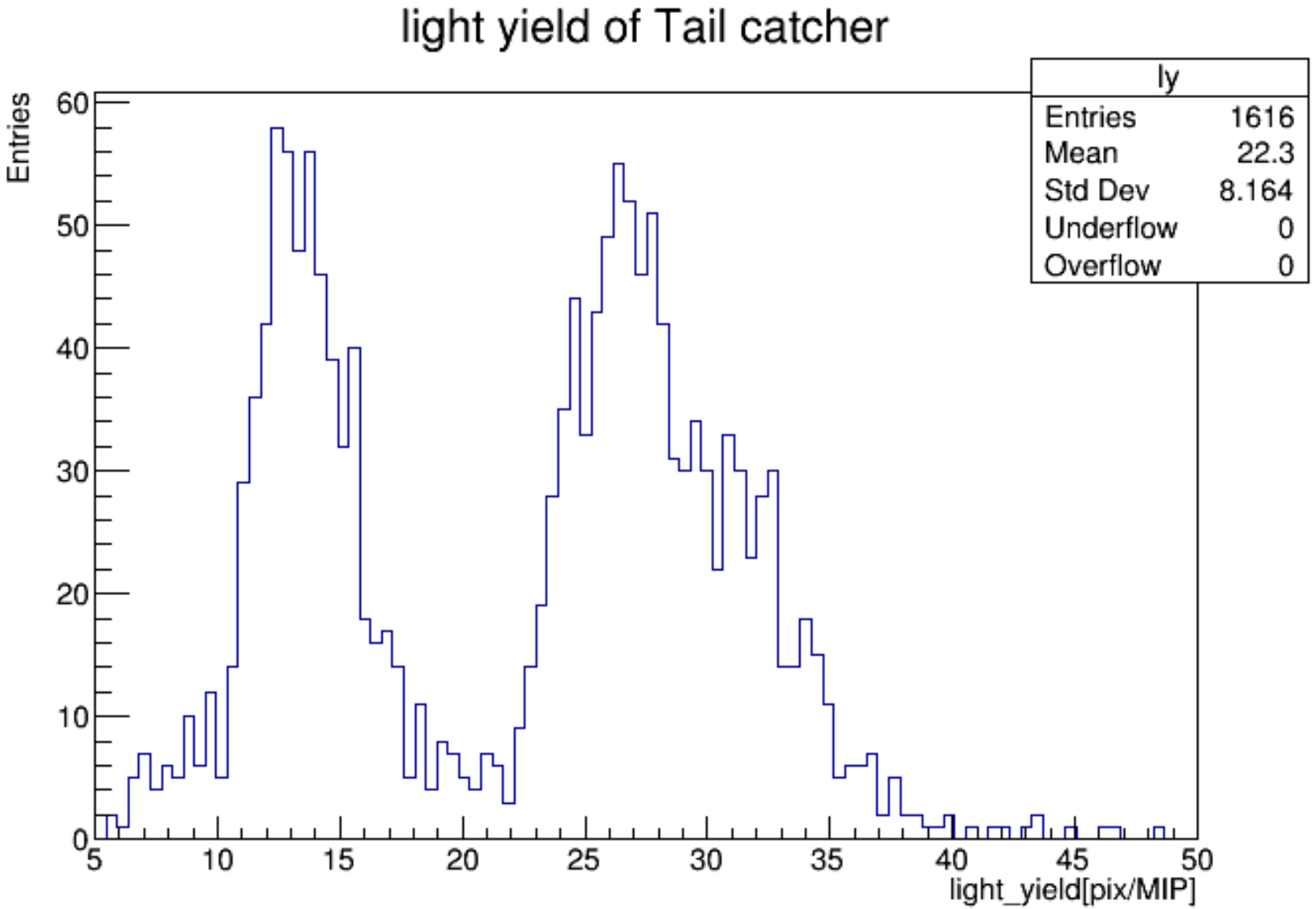
Pre-shower



Light Yield

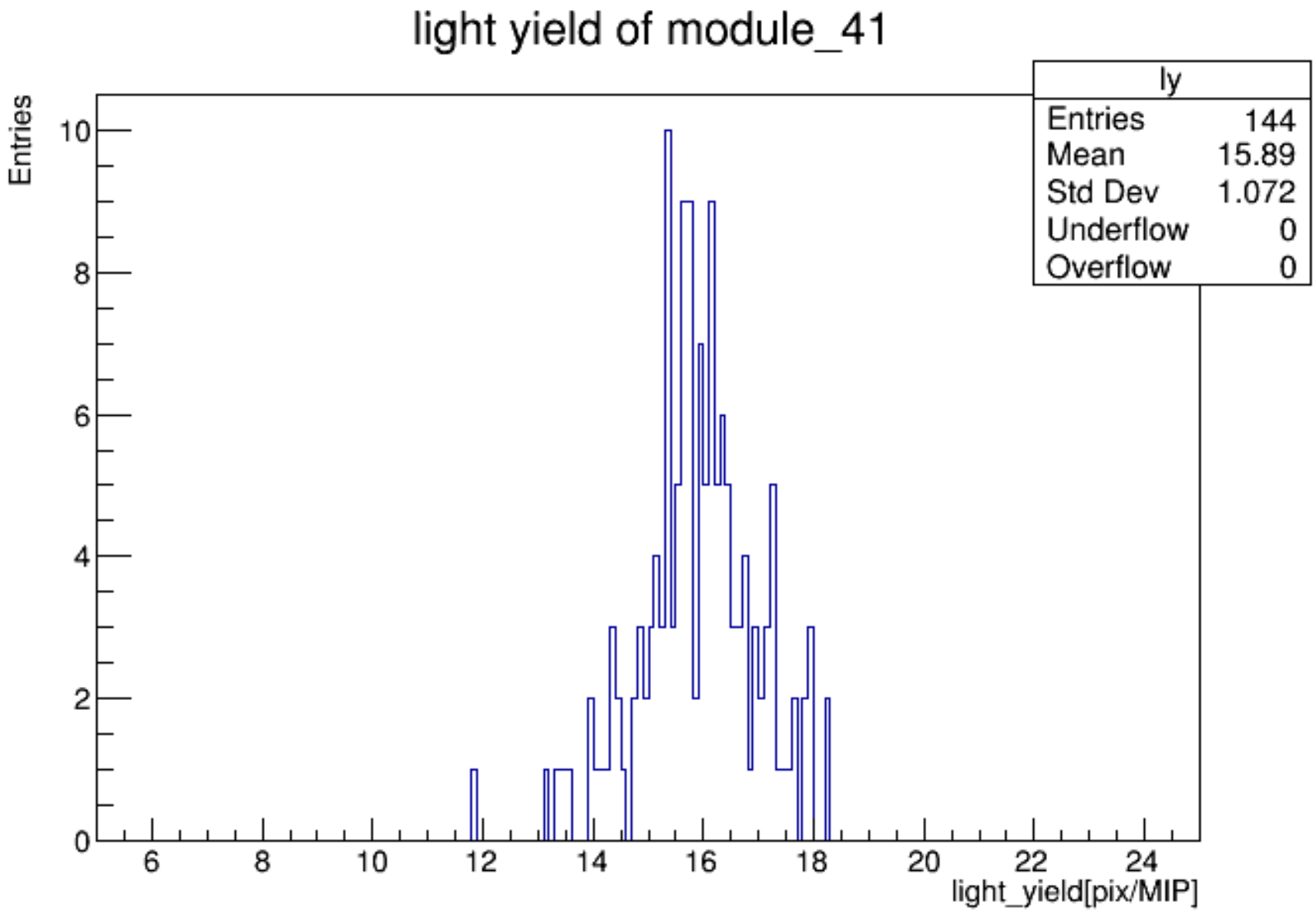
Tail Catcher

New one here



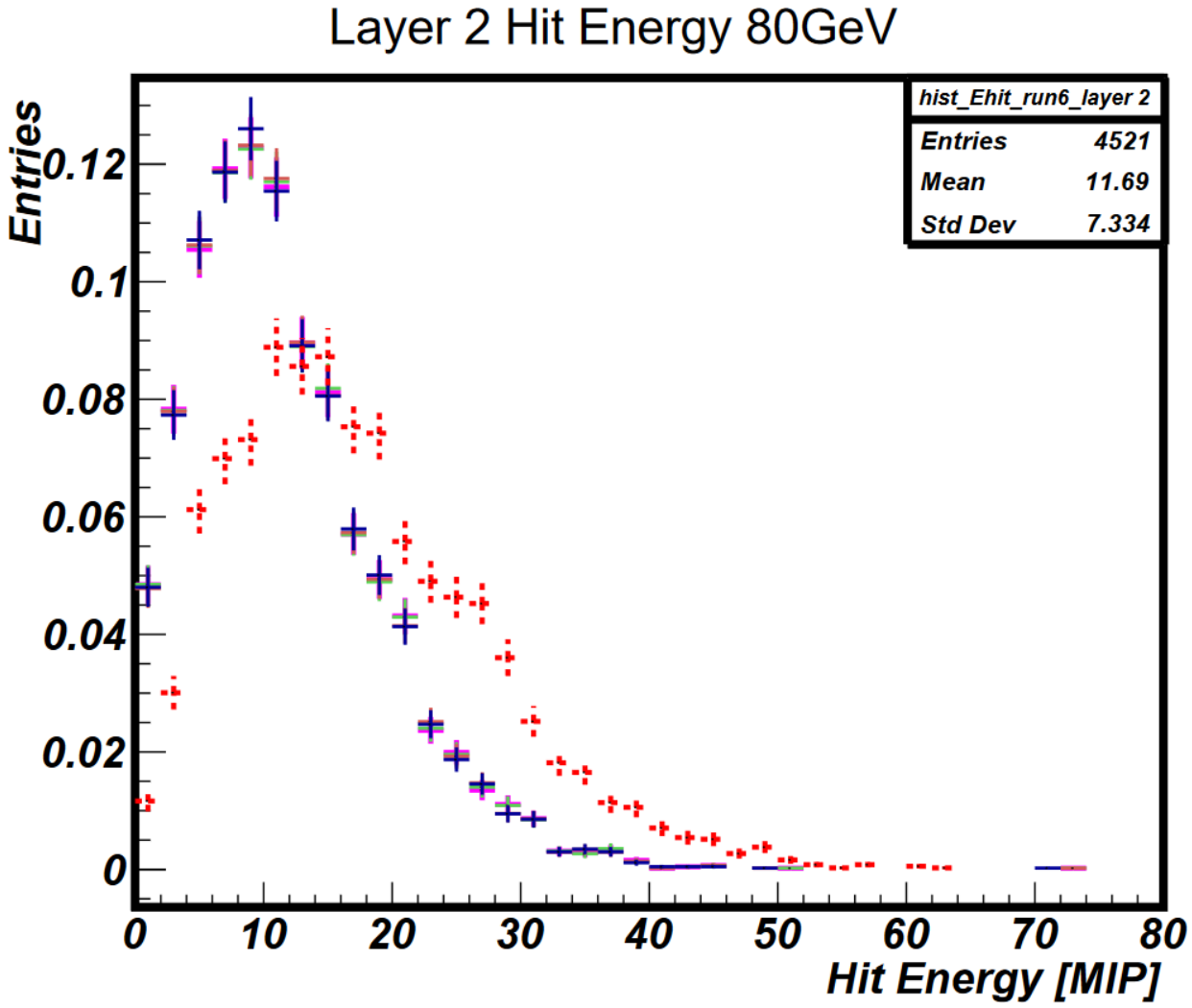
Light Yield

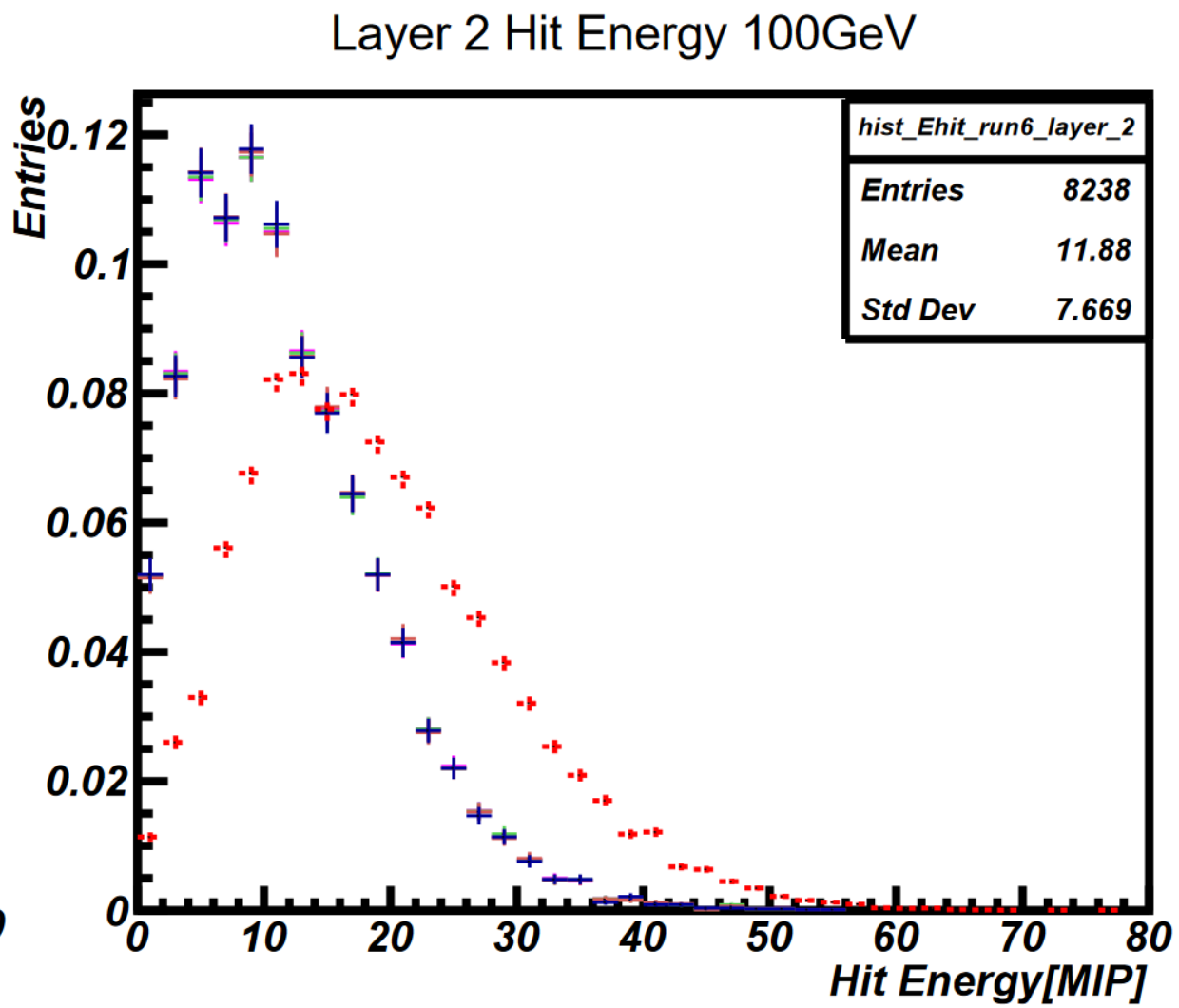
Tokyo layer



Hit energy for 80 GeV and 100 GeV electron

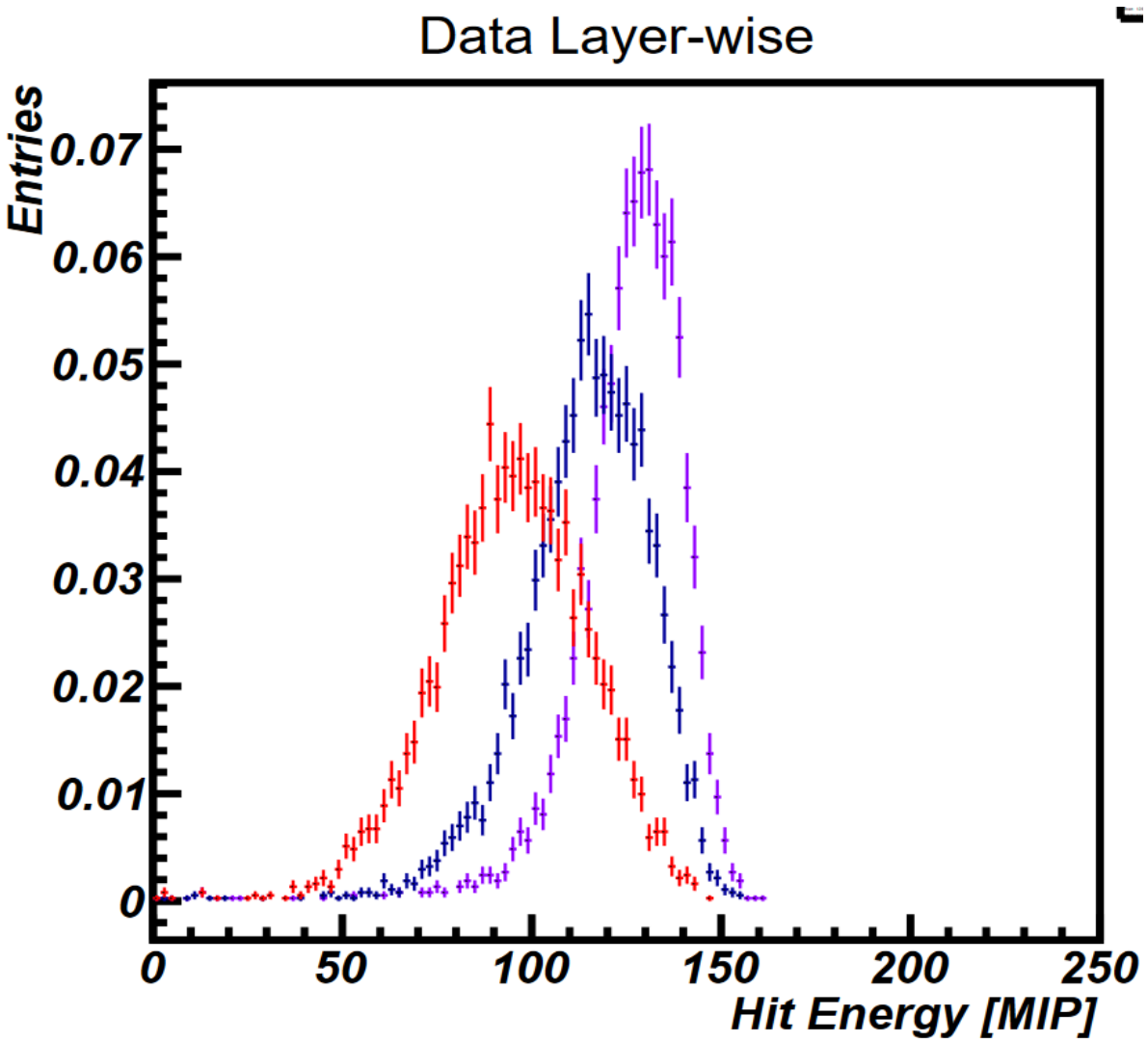
Layer 2

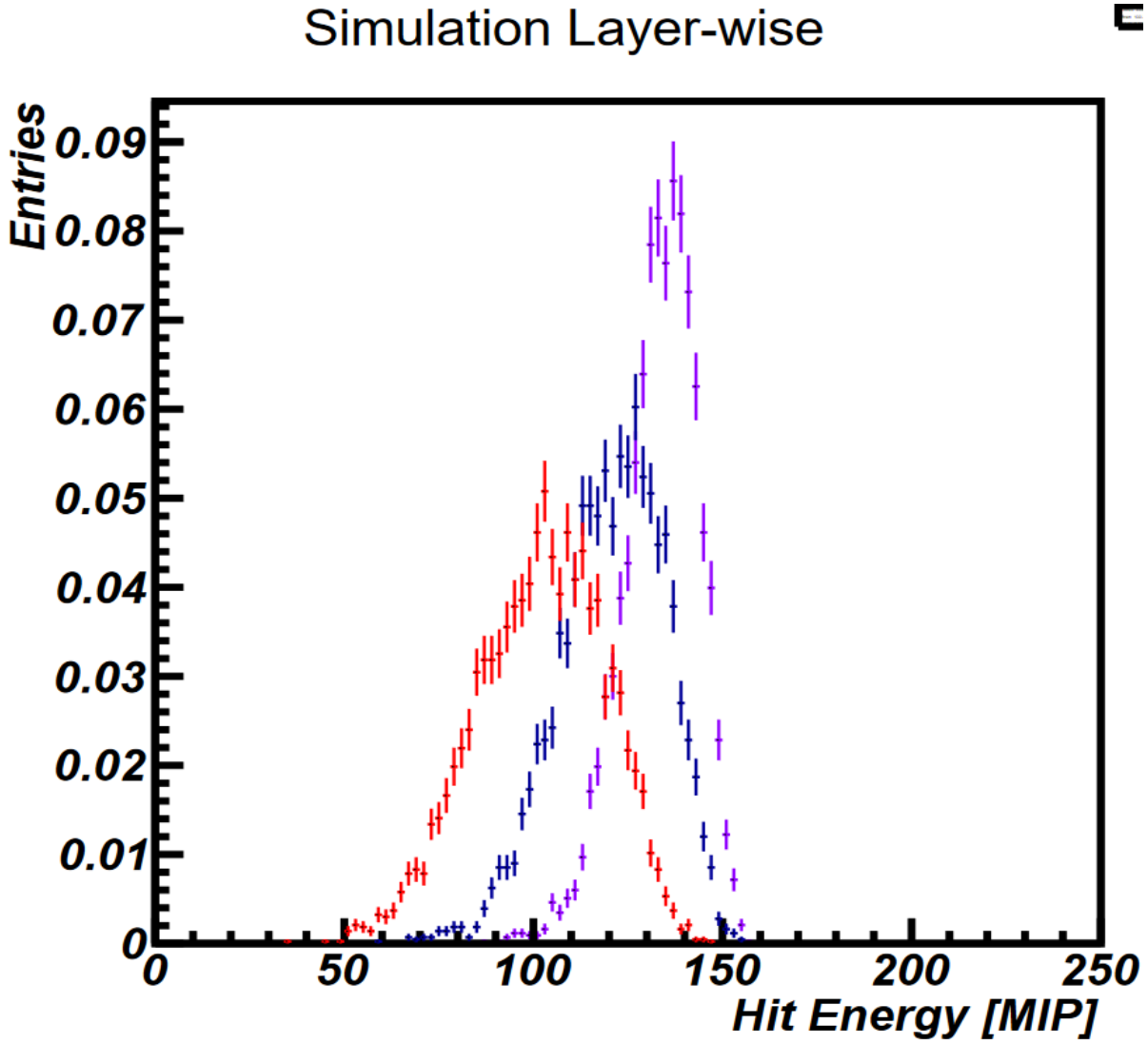




Hit energy layer wise

80 GeV electron

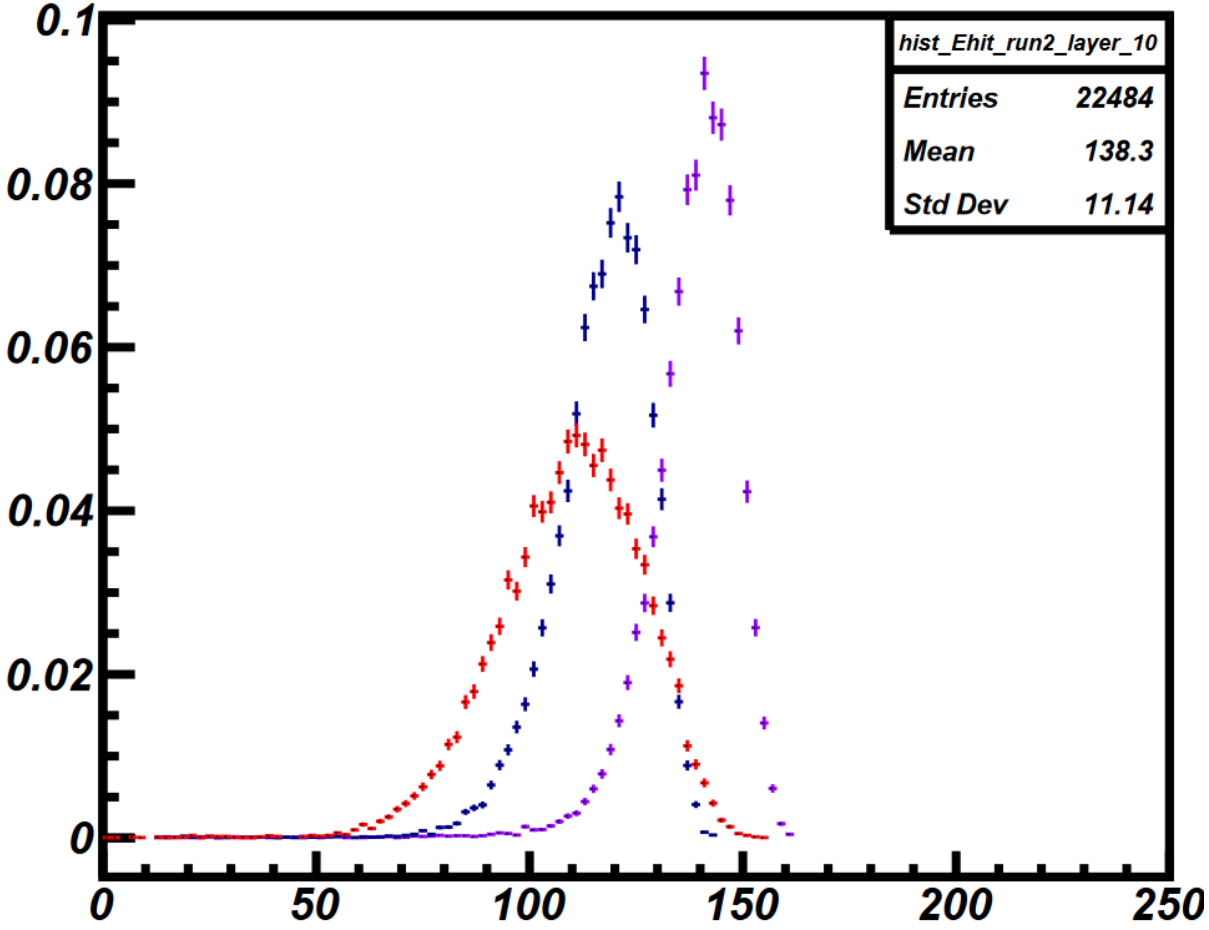




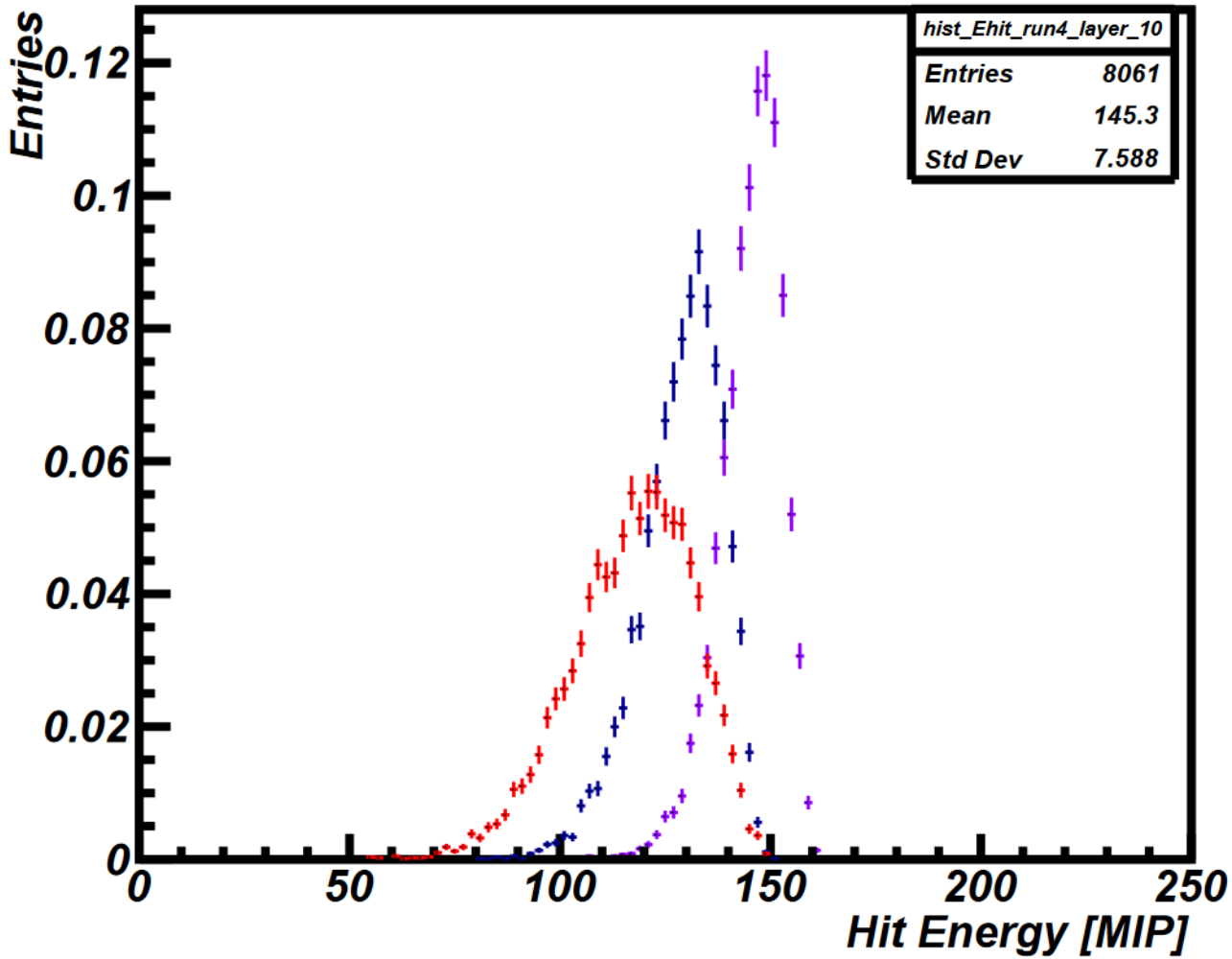
Hit energy layer wise

100 GeV electron

Data layer-wise



Simulation Layer-wise



Conclusion

	Gain	
AHCAL	Pre-Shower	Tail Catcher
~16 ADC	Varying from ~15-16 ADC	~15 and ~30 ADC
	Light Yield	
AHCAL	Pre-Shower	Tail Catcher
~14 pix/MIP	Varying from ~14 pix/MIP	~13 and ~27 pix/MIP
	Saturation Correction	
2433	2533 and 2668	2533
Under-estimates the data	Over-estimates the data	Agrees to certain extent with data