Gain calibration systematics and saturation correction

CALICE Collaboration Meeting

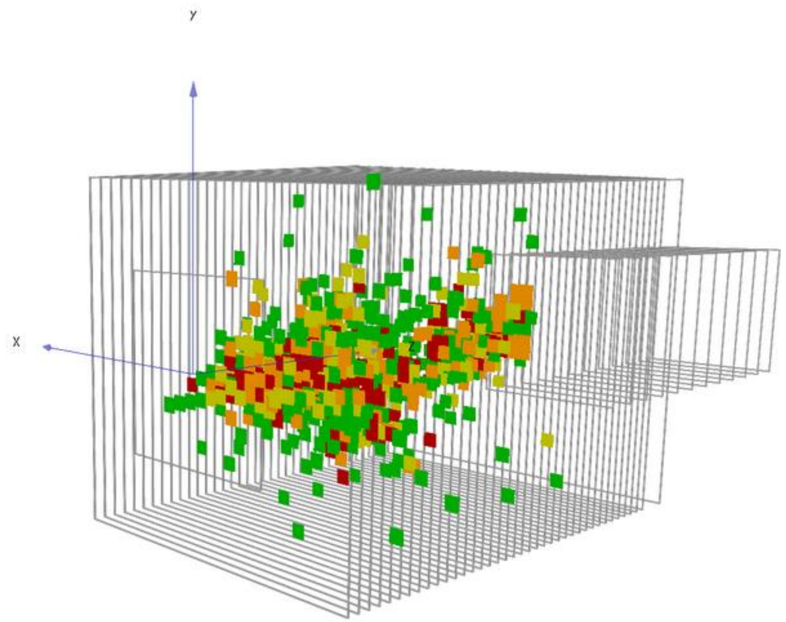
Olin Pinto
DESY, 11^{th} April 2019

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Outline

- ✓ Introduction of AHCAL prototype
- ✓ Gain calibration
  - ✓ Systematics
- ✓ Saturation correction
- ✓ Summary

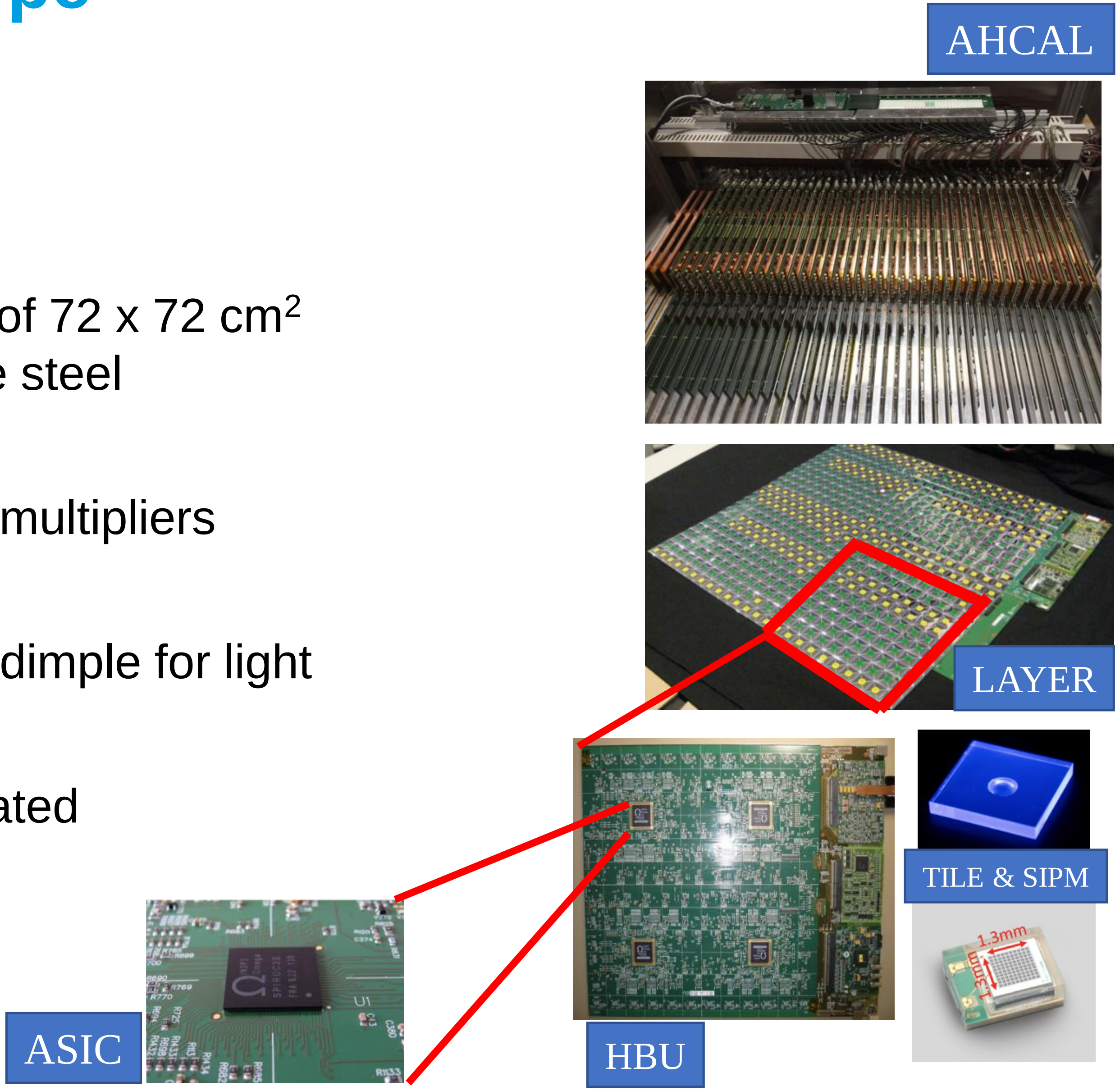


AHCAL technological prototype

Detector

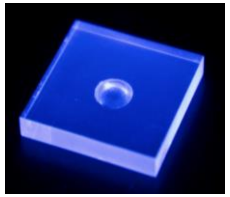
Prototype:

- ✓ Sampling calorimeter: 38 active layers of 72 x 72 cm^2 alternating with ~ 1.72 cm thick passive steel absorbers
- ✓ Based on scintillators and silicon photomultipliers (SiPMs)
- ✓ Scintillator tiles of size 3 x 3 x 0.3 cm^3, dimple for light focussing, wrapped in reflecting foil
- ✓ HCAL base unit (HBU) with fully integrated electronics

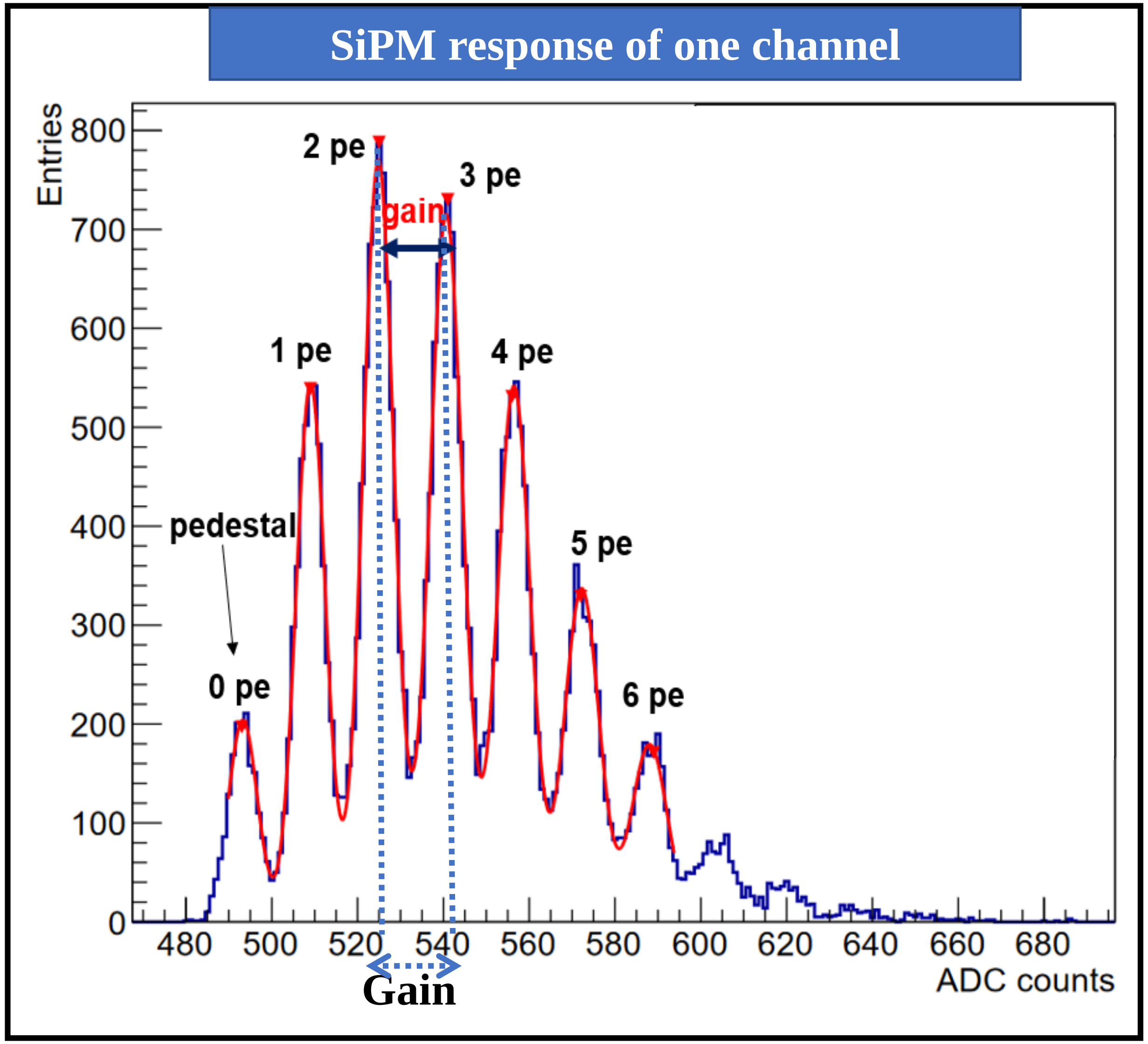


Gain calibration

Using dedicated LED runs



- ✓ Gain in terms of physics: is the charge that comes out of one fired pixel (and we measure it in ADC)
- ✓ A peak corresponds to a certain number of photoelectrons (0 pe, 1 pe) in one SiPM
- ✓ n = 0 (no photon detected) pedestal
- ✓ **Definition:** Gain is the distance between two consecutive photo-electron peaks
- ✓ Spectrum is fitted with multi-Gaussian function with a single peak-to-peak distance

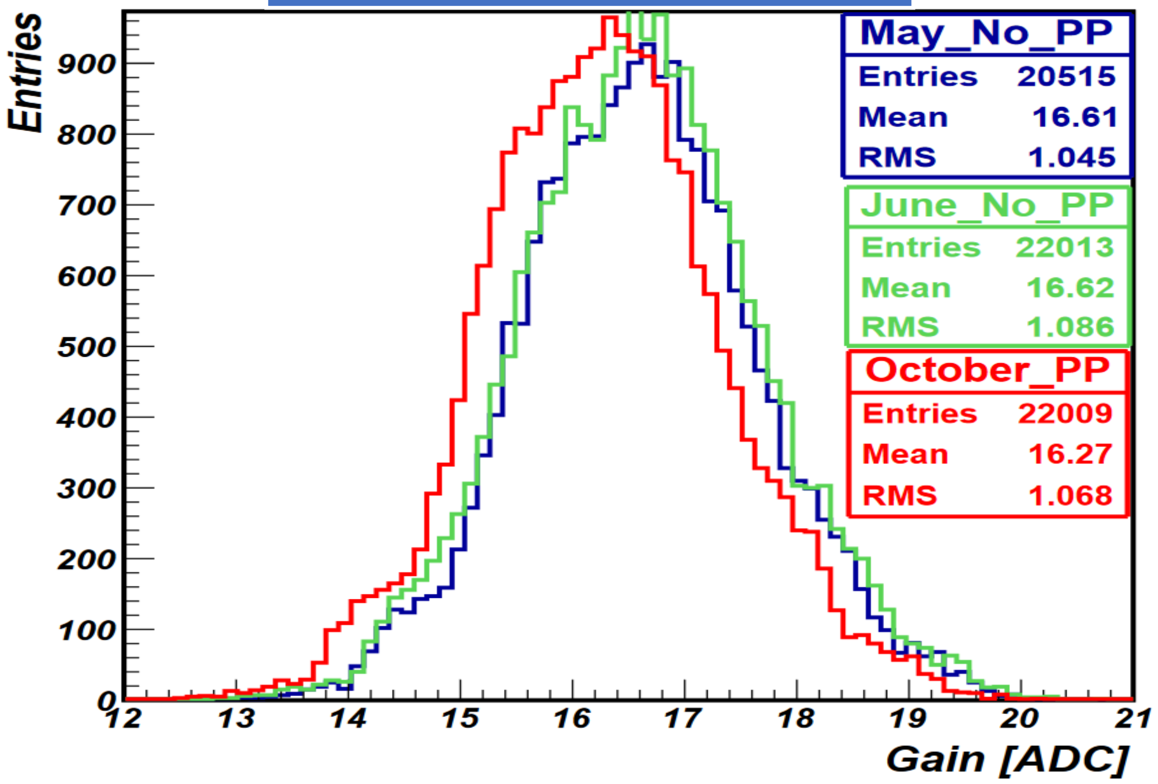


Gain distribution - AHCAL

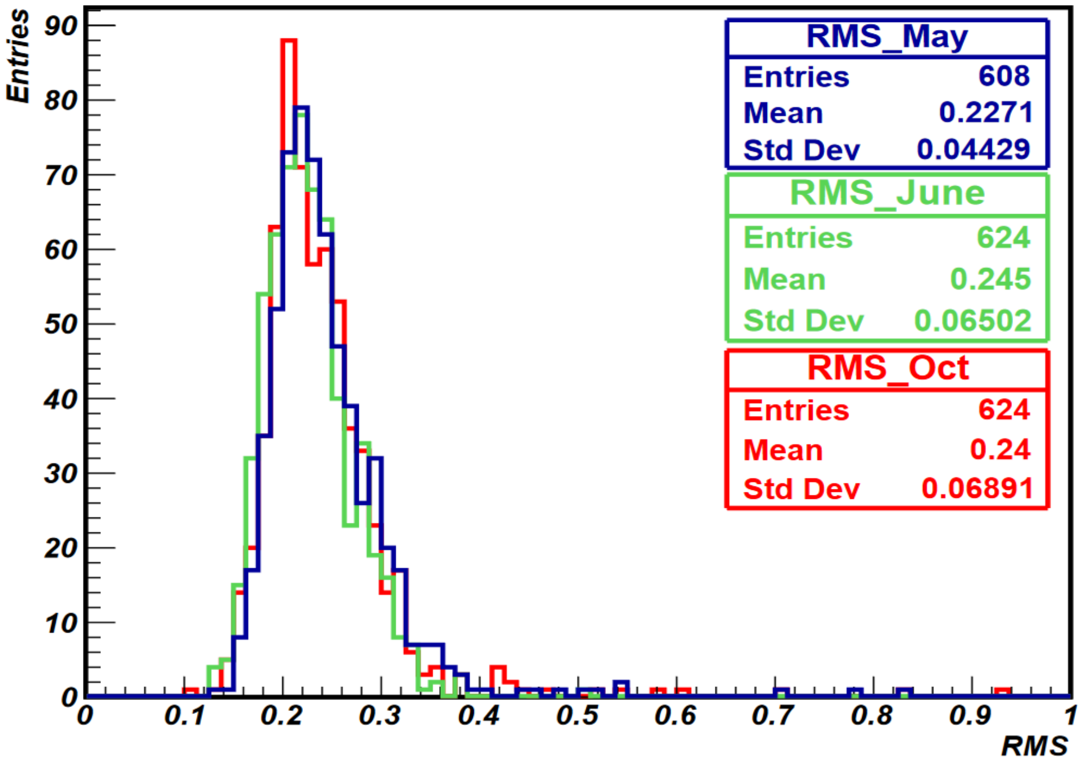
Gain from May, June and October 2018

May : No power pulsing
June: No power pulsing
October: Power pulsing

Gain from all the channels



RMS of the gains from ASICs



- ✓ 2 % global shift is observed between power pulsing (PP) and no power pulsing (No PP)
- ✓ The distribution within a ASIC is much narrower
- ✓ 95 % of the channels are calibrated individually,
- ✓ For 5 % the fit does not work, they are calibrated with chip average values

Gain systematics

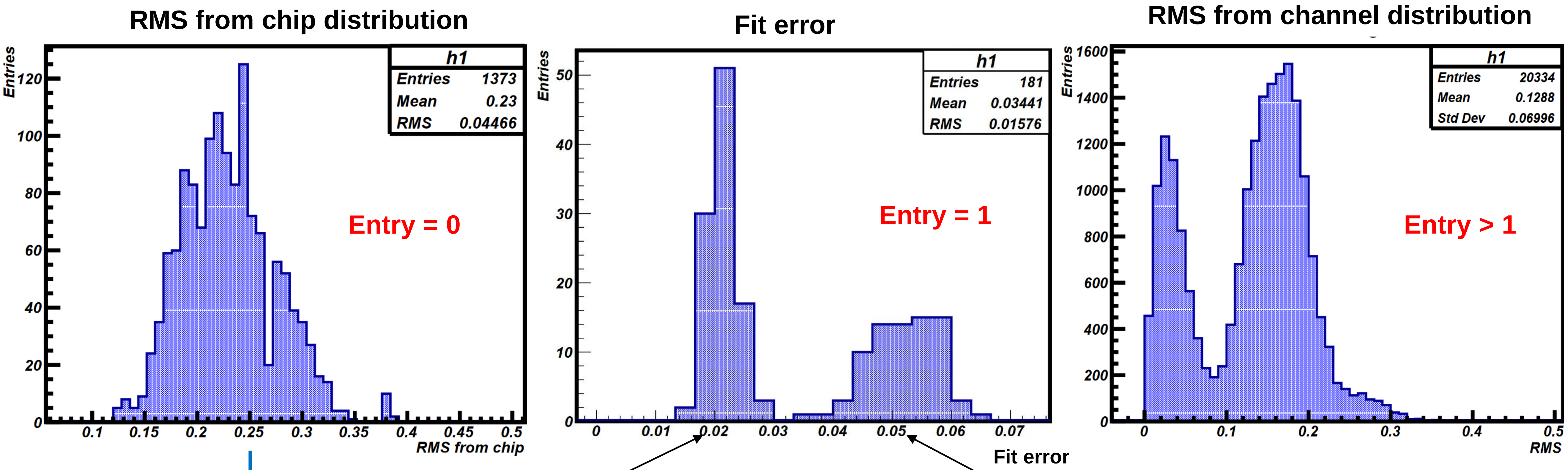
- ✓ The usable V_{calib} range differs between channels because of differing LED responses between channels
- ✓ This makes scanning over several V_{calib} values a necessity for calibration

Idea to calculate:

- ✓ Channels which fit more than once get directly the RMS
- ✓ Channels which fit only once get the uncertainty from the fit
- ✓ Channels which do not fit at all get the RMS of the corresponding chip

Gain systematics

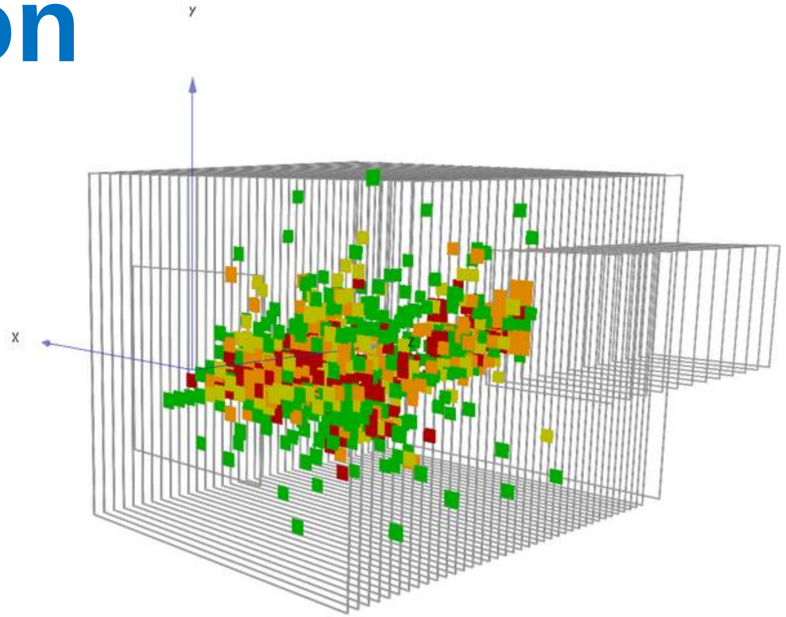
Work in progress



Two population at 0.02 and 0.05 contributed from fits at small and large LED voltages

For channels with zero entries an uncertainty of ~ 2 - 3 % for an average gain of ~ 16 ADC/pixel is observed

Saturation correction

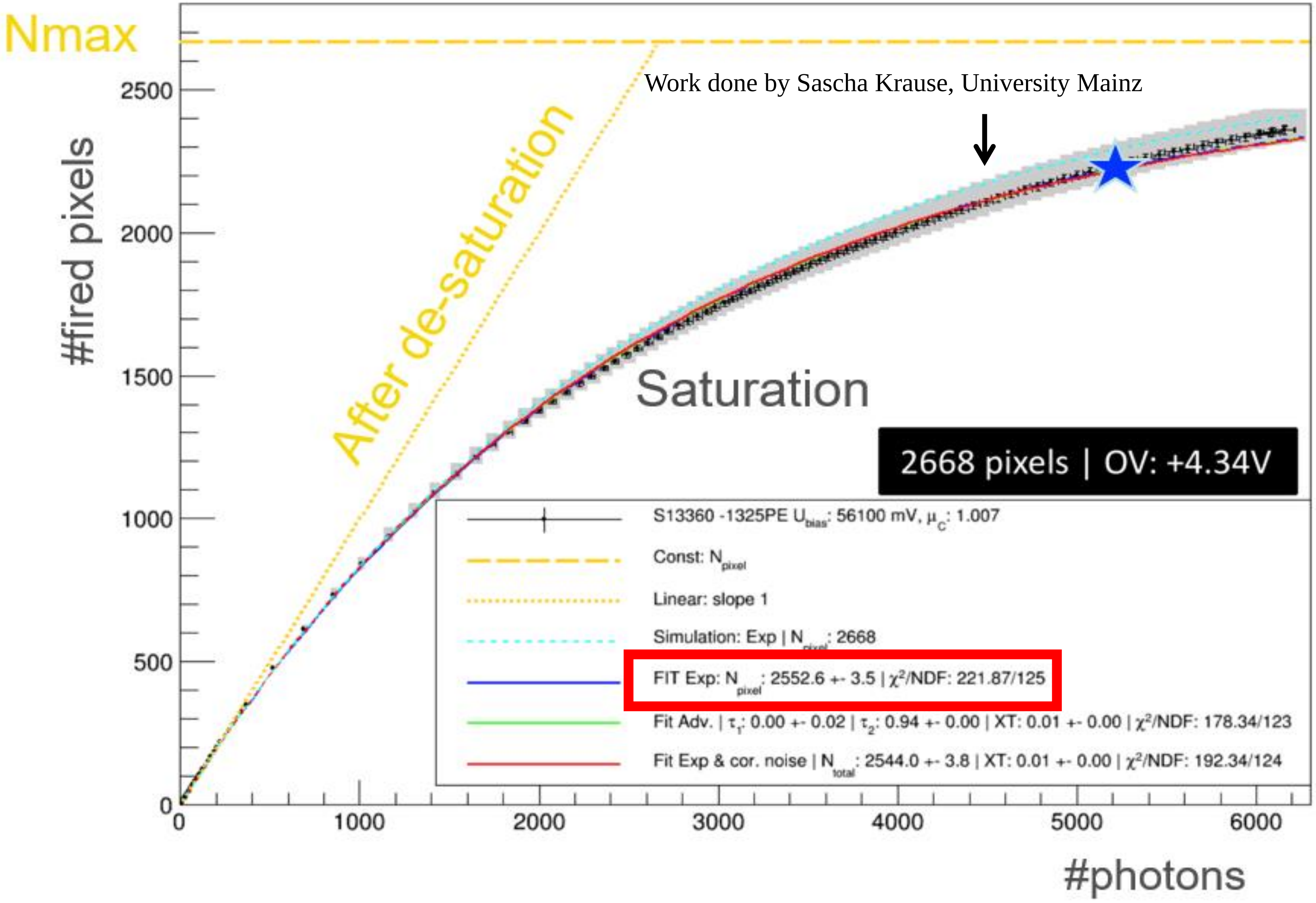


Saturation correction for 2668 pixels

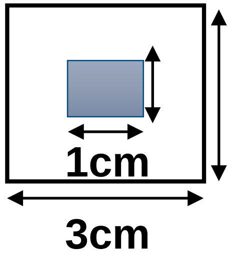
Work done by Sascha

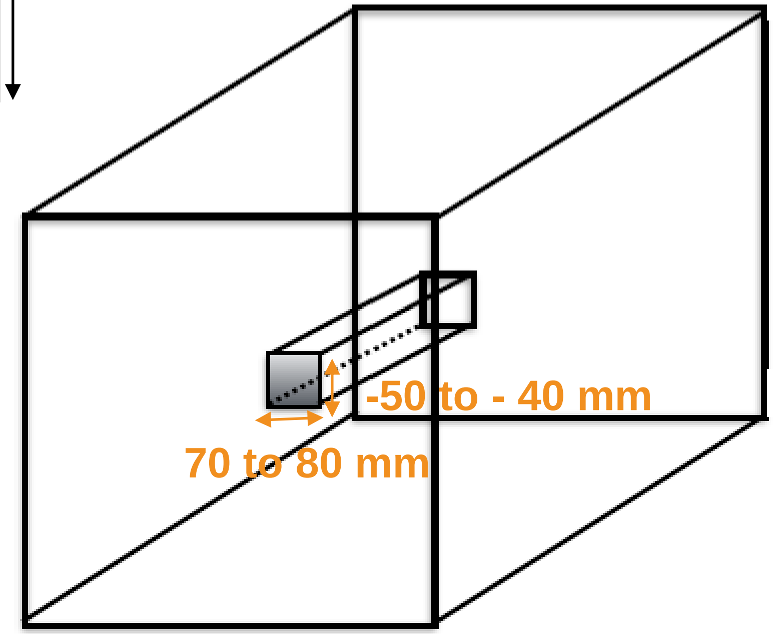
https://indico.gsi.de/event/6990/session/5/contribution/21/material/slides/0.pdf

- ✓ Measurements performed on bare SiPM using laser light
- ✓ Calculated the effective number of pixels to be 2533 which is 10 % less than the nominal value (2668)



Data samples and selection





Selection applied for both data and simulation

- ✓ Tiles chosen in X direction: from 70 mm to 80 mm
- ✓ Tiles chosen in Y direction: from -50 mm to -40 mm

Wire chamber information is used to apply cuts on data

Electron energy	CoG Z direction [mm]	Number of hits
80 GeV Run number: 61156	Between 180 to 280	Between 200 to 300
100 GeV Run number: 61159	Between 200 to 300	Between 250 to 400

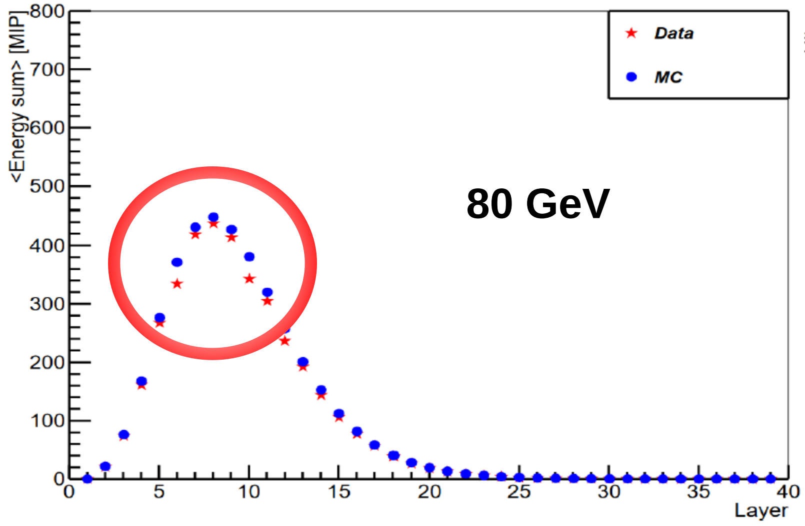
<Energy sum> and <number of hits>

Electrons

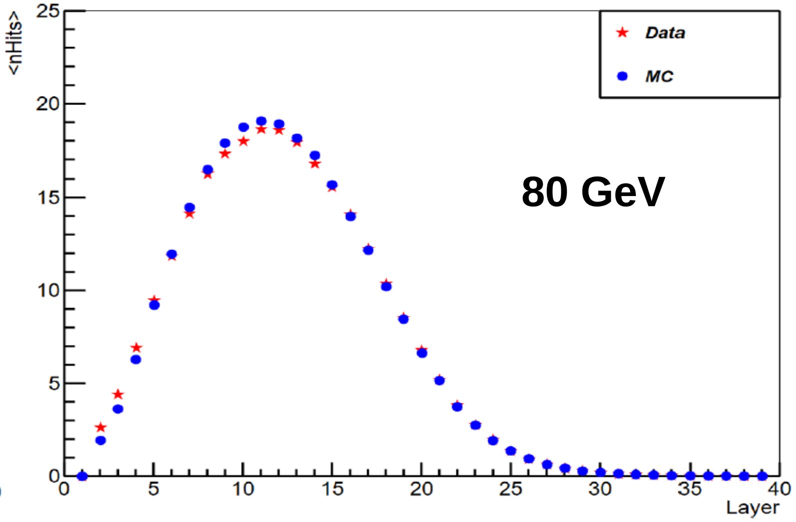
Electron energy	CoG Z direction [mm]	Number of hits
80 GeV Run number: 61156	Between 180 to 280	Between 200 to 300
100 GeV Run number: 61159	Between 200 to 300	Between 250 to 400

Difference in <energy sum> observed mainly during shower maximum

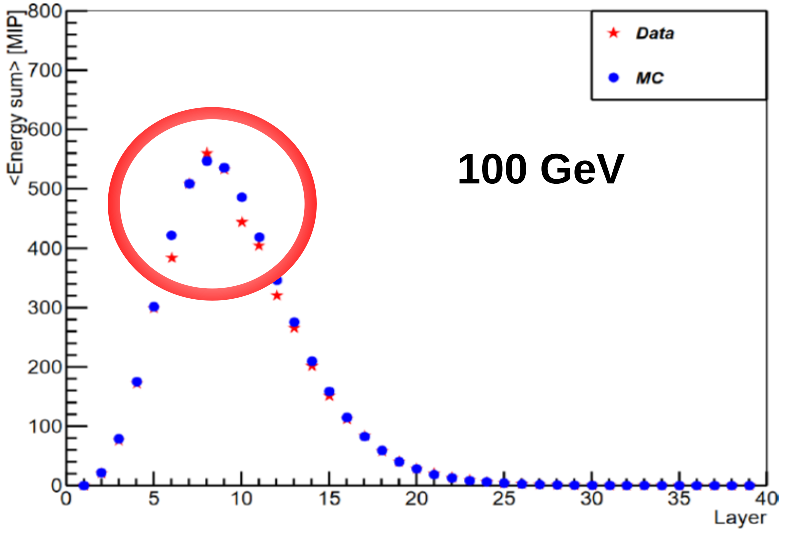
Mean energy per layer - 80 GeV electron



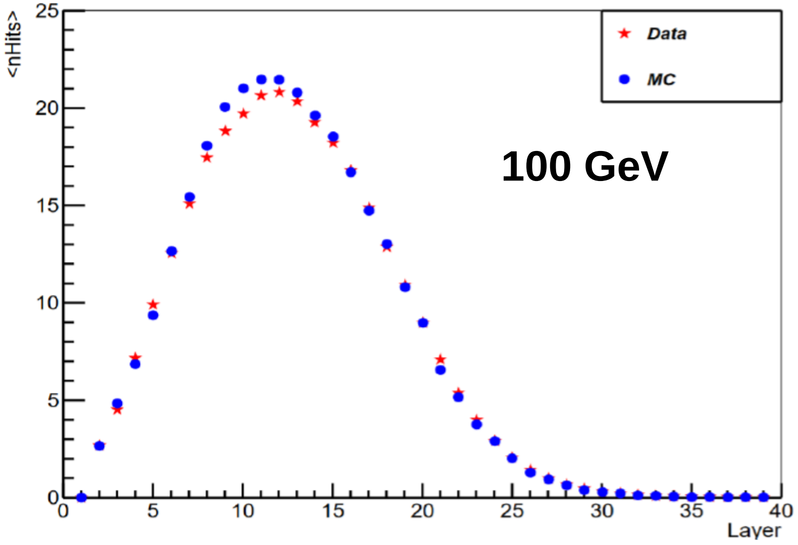
Mean hits per layer - 80 GeV electron



Mean energy per layer - 100 GeV electron

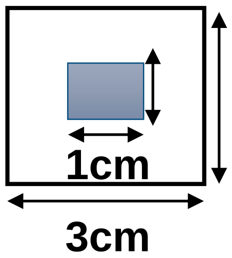


Mean hits per layer - 100 GeV electron



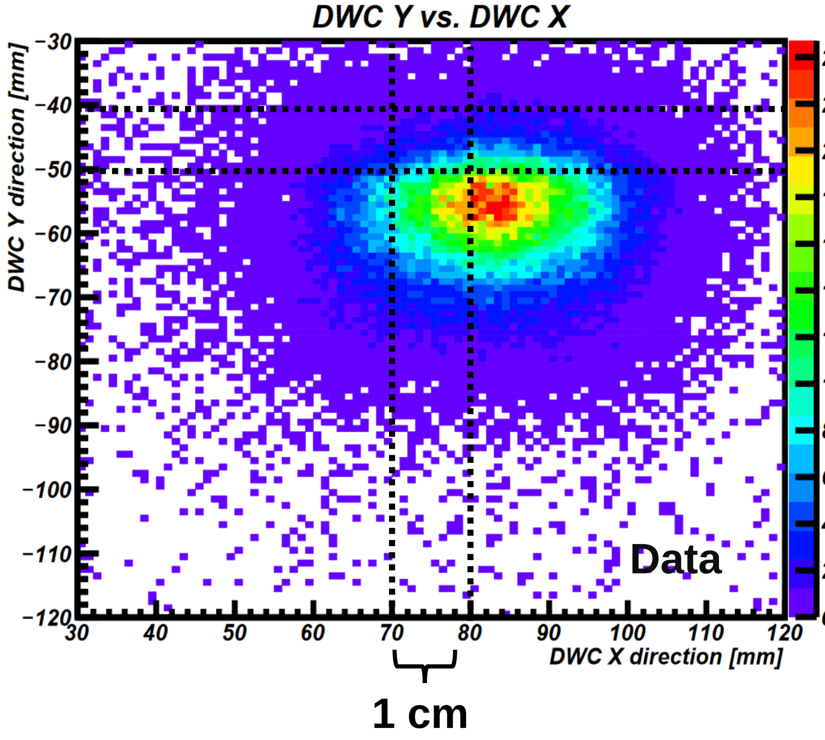
Beam profiles

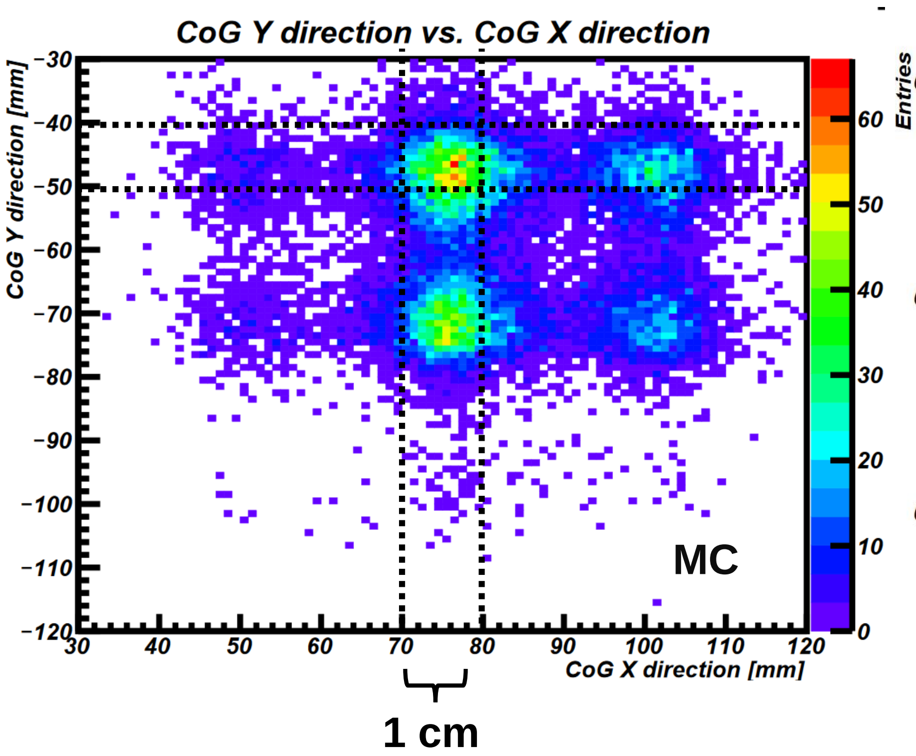
80 GeV electron

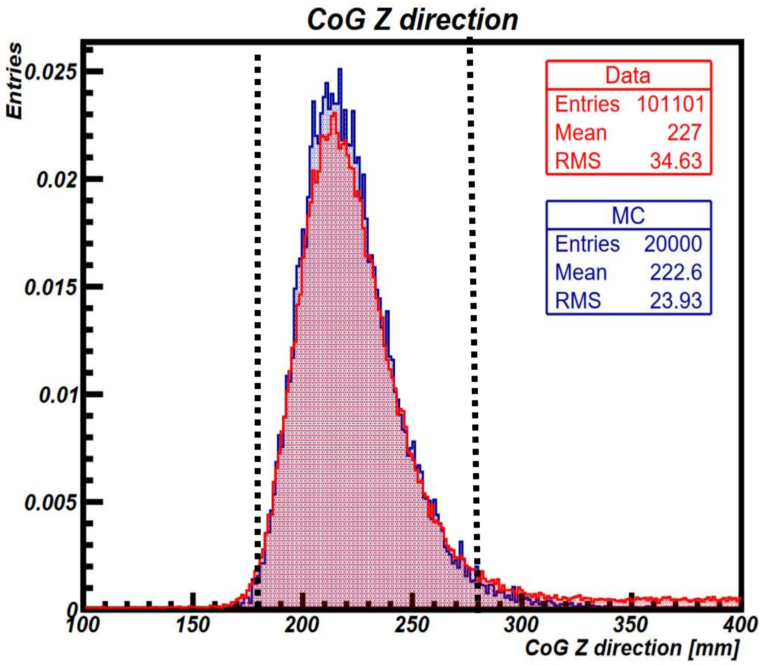


Beam profiles of data and simulation tuned in close proximity

Electron energy	CoG Z direction [mm]	Number of hits
80 GeV Run number: 61156	Between 180 to 280	Between 200 to 300





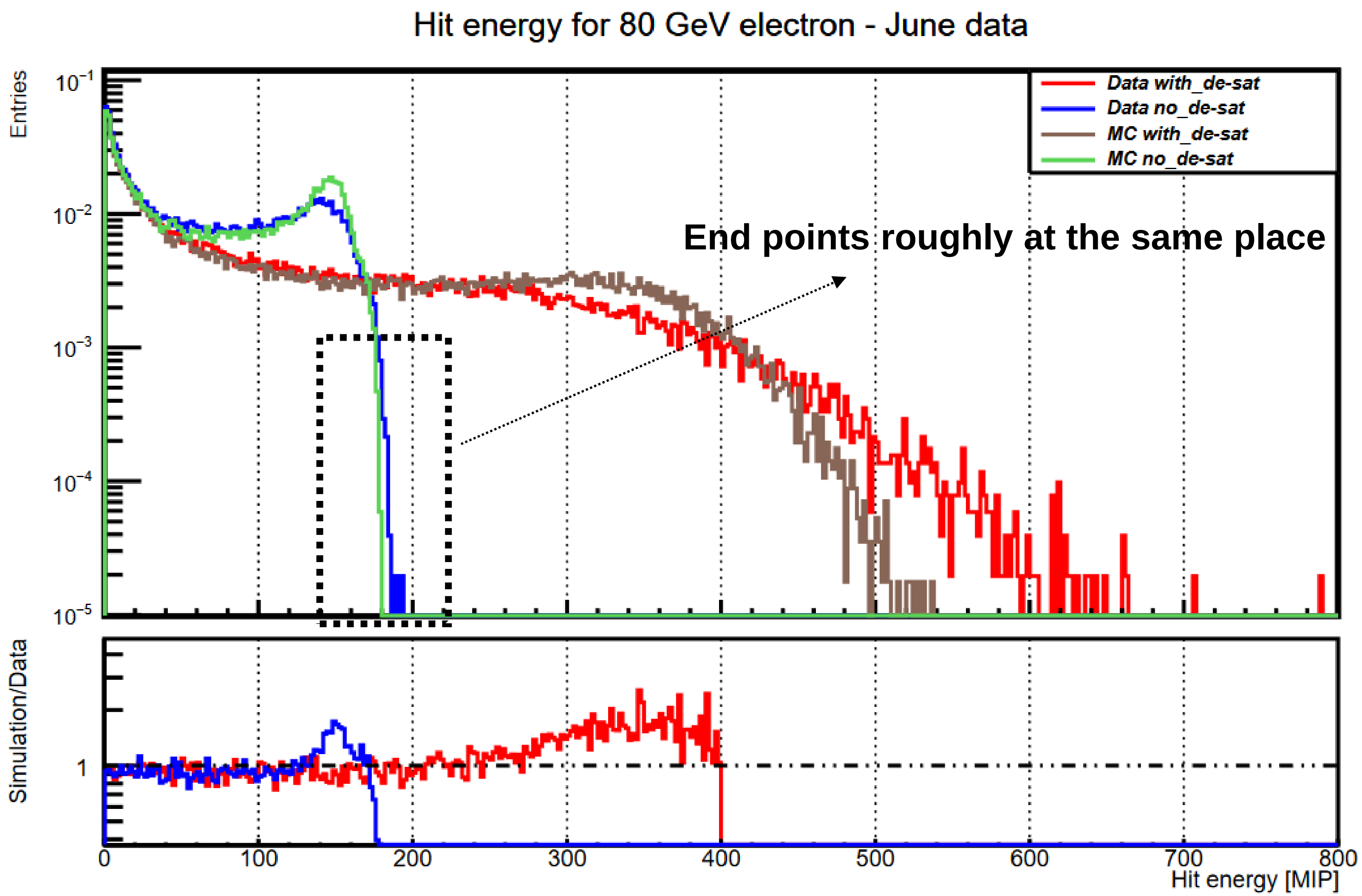


Hit energy distribution

80 GeV electron

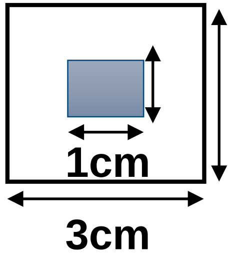
- ✓ Looking into a distribution in our data that is especially sensitive to the effect of saturation
- ✓ Look where large energy is deposited in a single tile (shower maximum of high energy electron showers)
- ✓ 2533 pixels agrees with independent measurement of a SiPM (without tile) with laser light

http://www.desy.de/~opinto/80GeV_Run_61156layer_wise_1to15.pdf



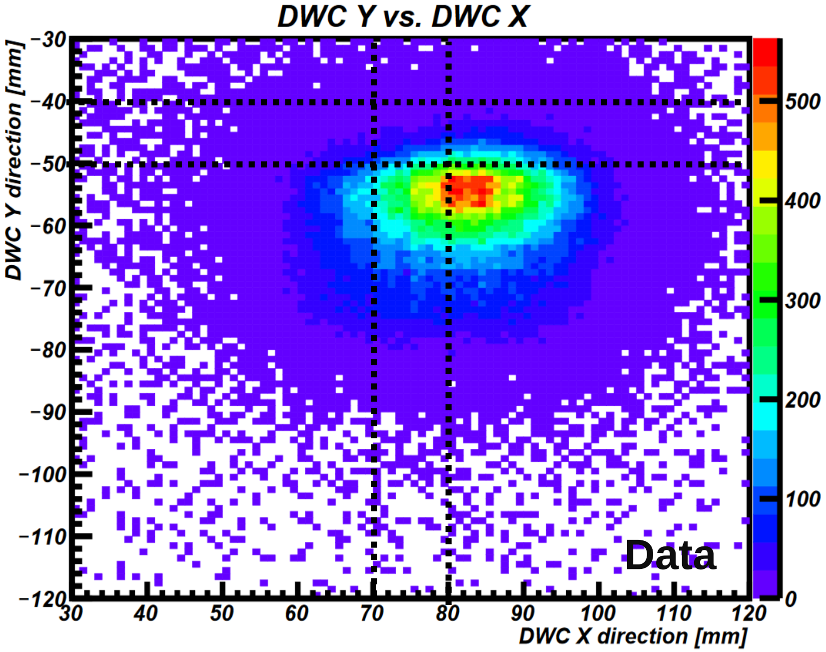
Beam profiles

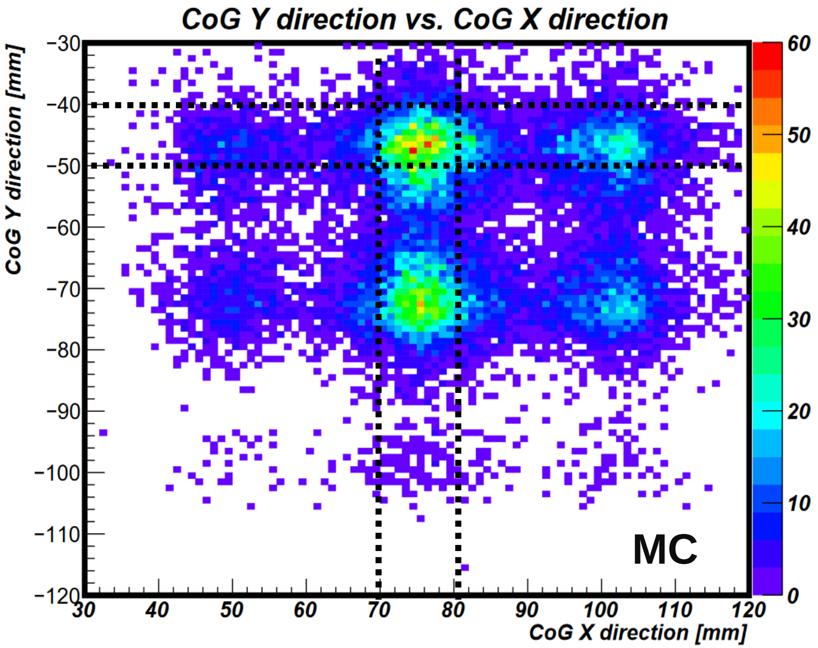
100 GeV electron

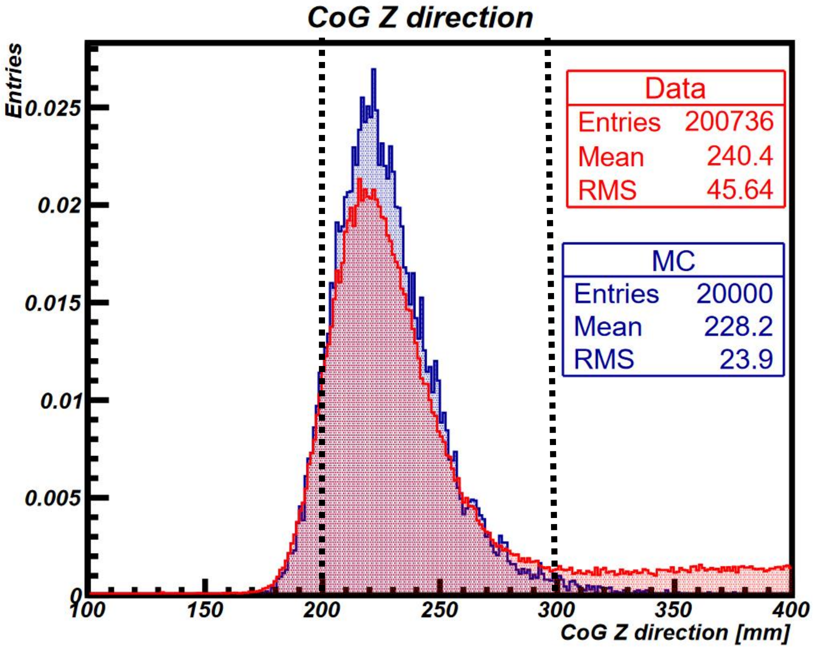


Beam profiles of data and simulation tuned in close proximity

Electron energy	CoG Z direction [mm]	Number of hits
100 GeV Run number: 61159	Between 200 to 300	Between 250 to 400

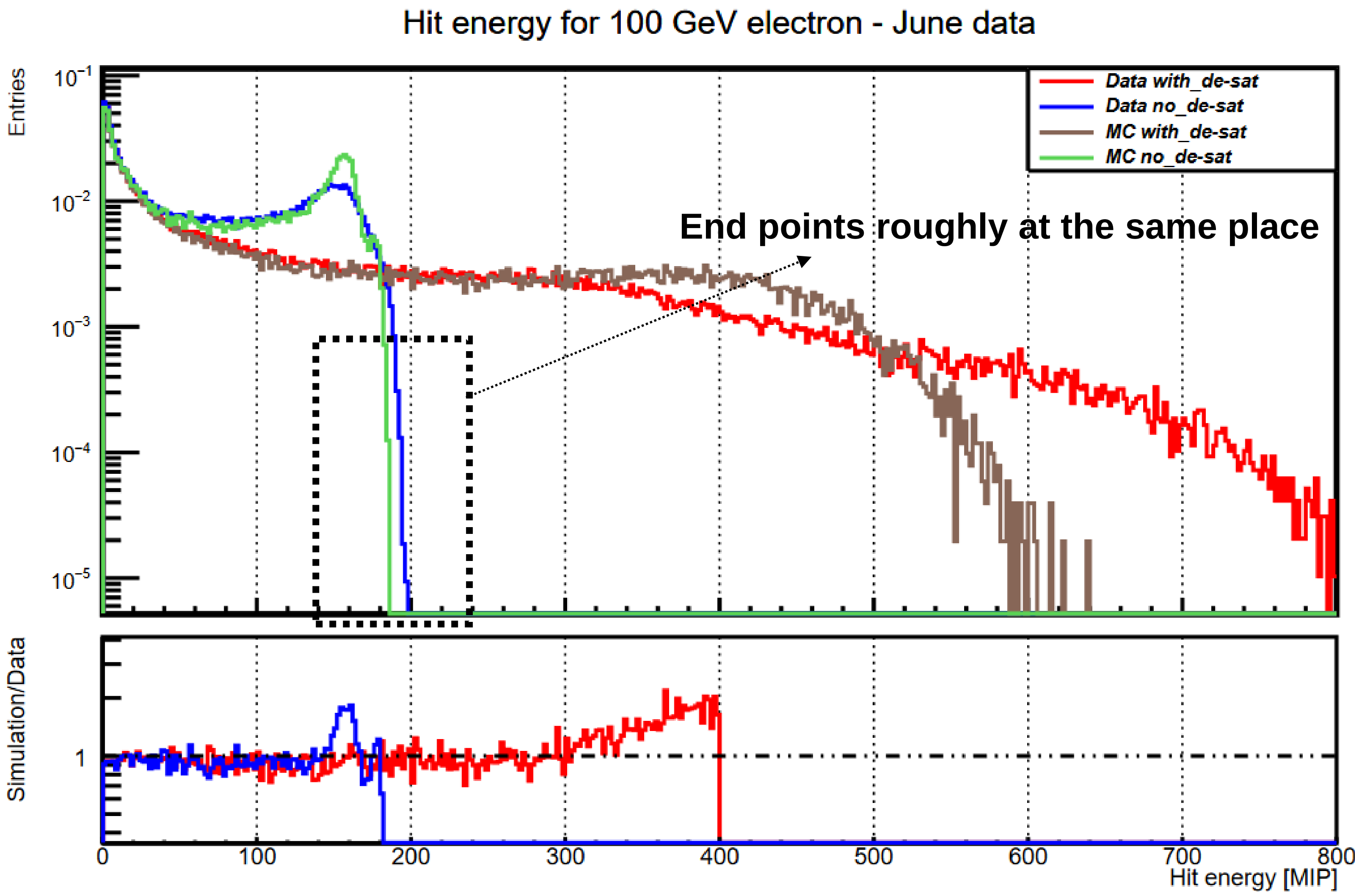






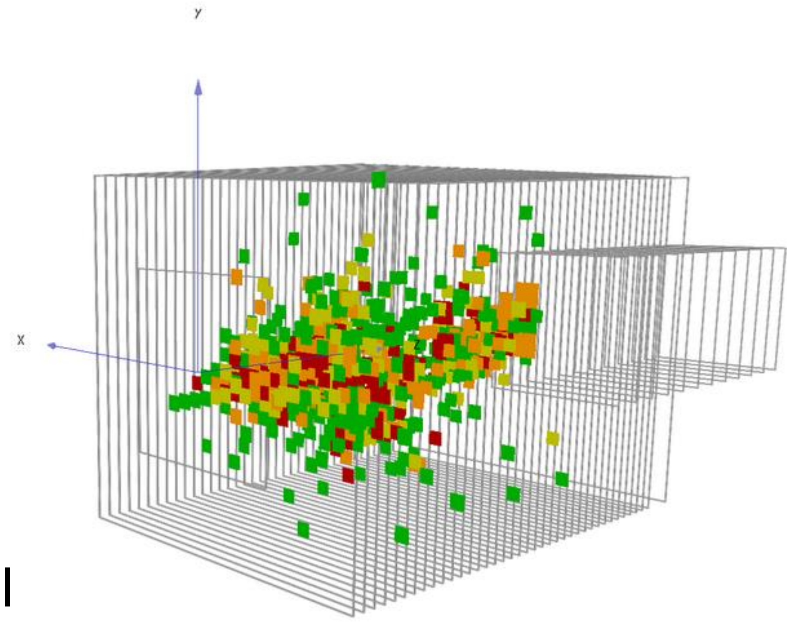
Hit energy distribution

100 GeV electron



http://www.desy.de/~opinto/100GeV_Run_61159layer_wise_1to15.pdf

Summary



Gain systematics (work in progress):

The overall uncertainty ~0.13 for an average gain of ~ 16 ADC/pixel

Saturation:

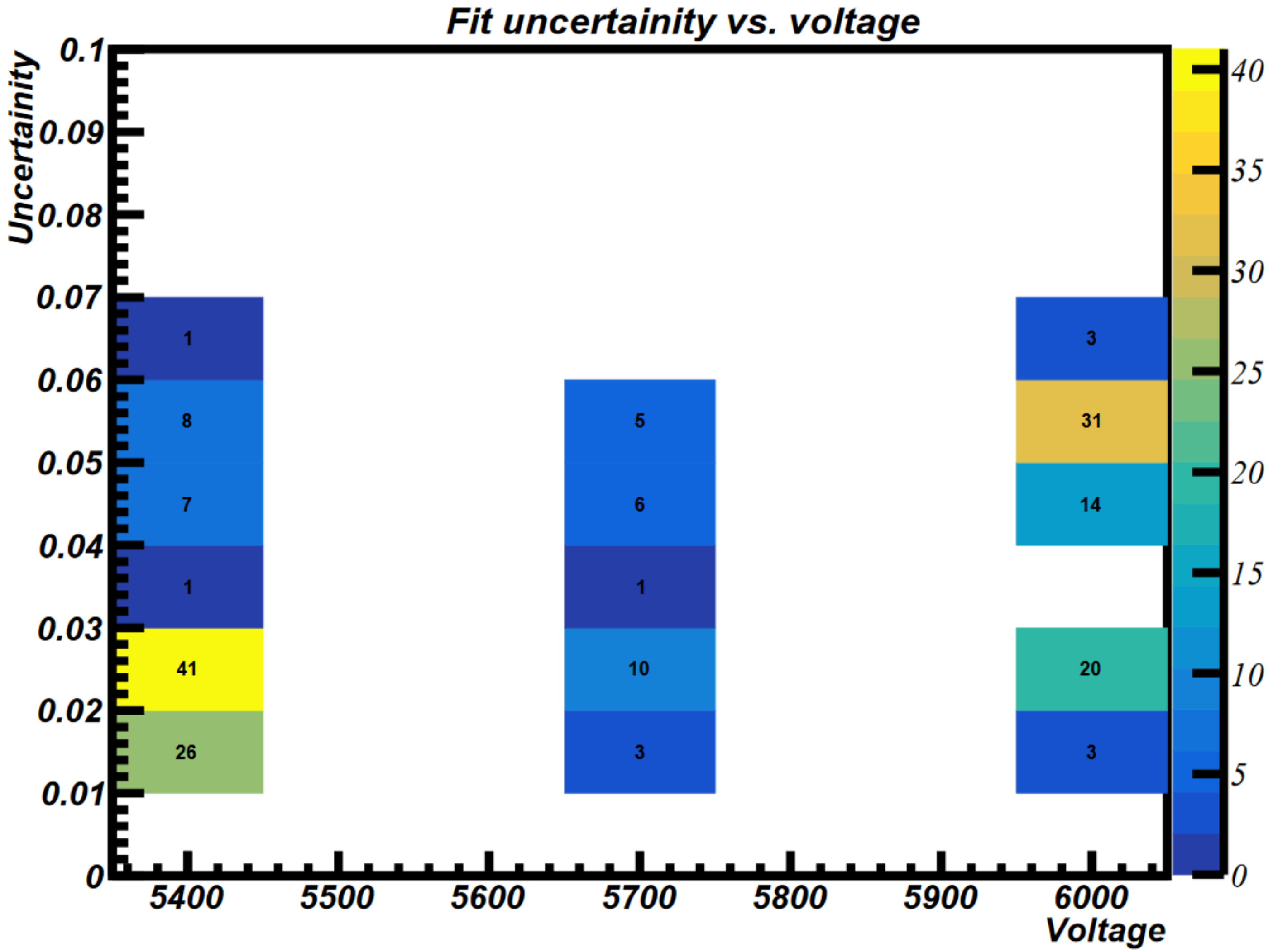
The number of effective pixels looks reasonable, differences in the shapes needs to be understood

THANK YOU

SPARES

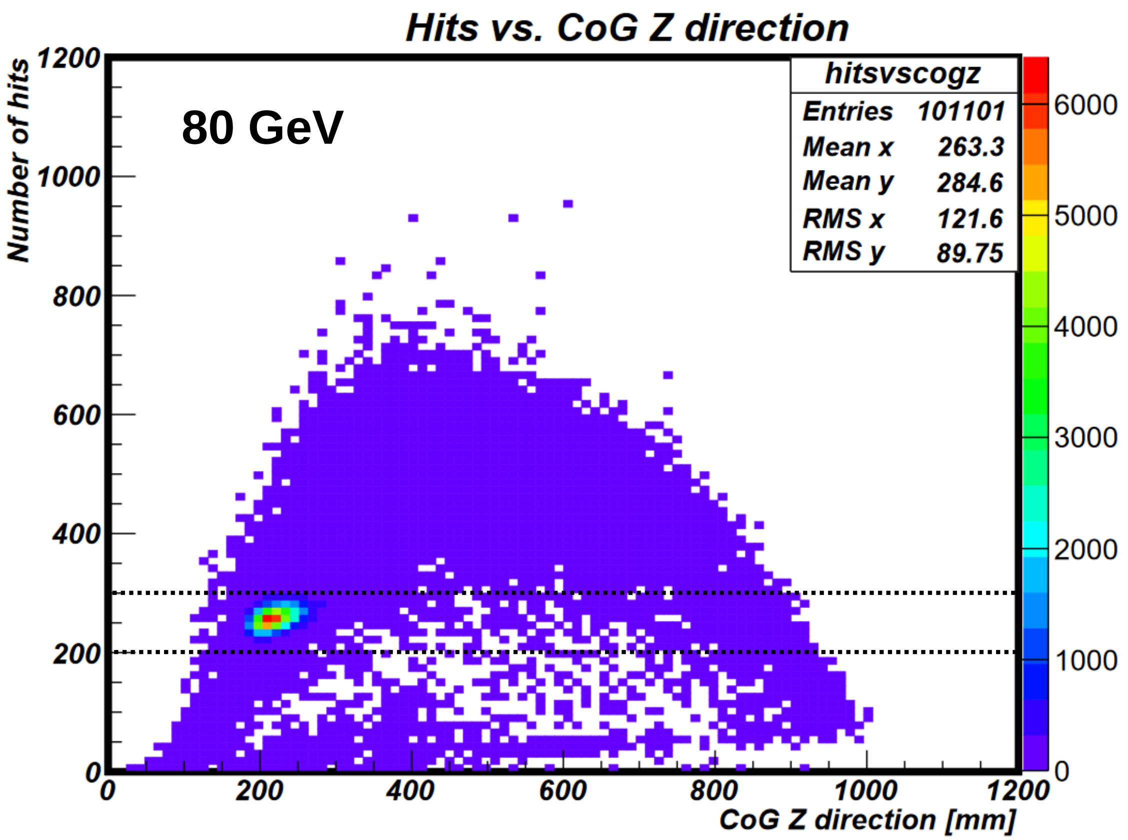
Fit uncertainty vs. LED voltage

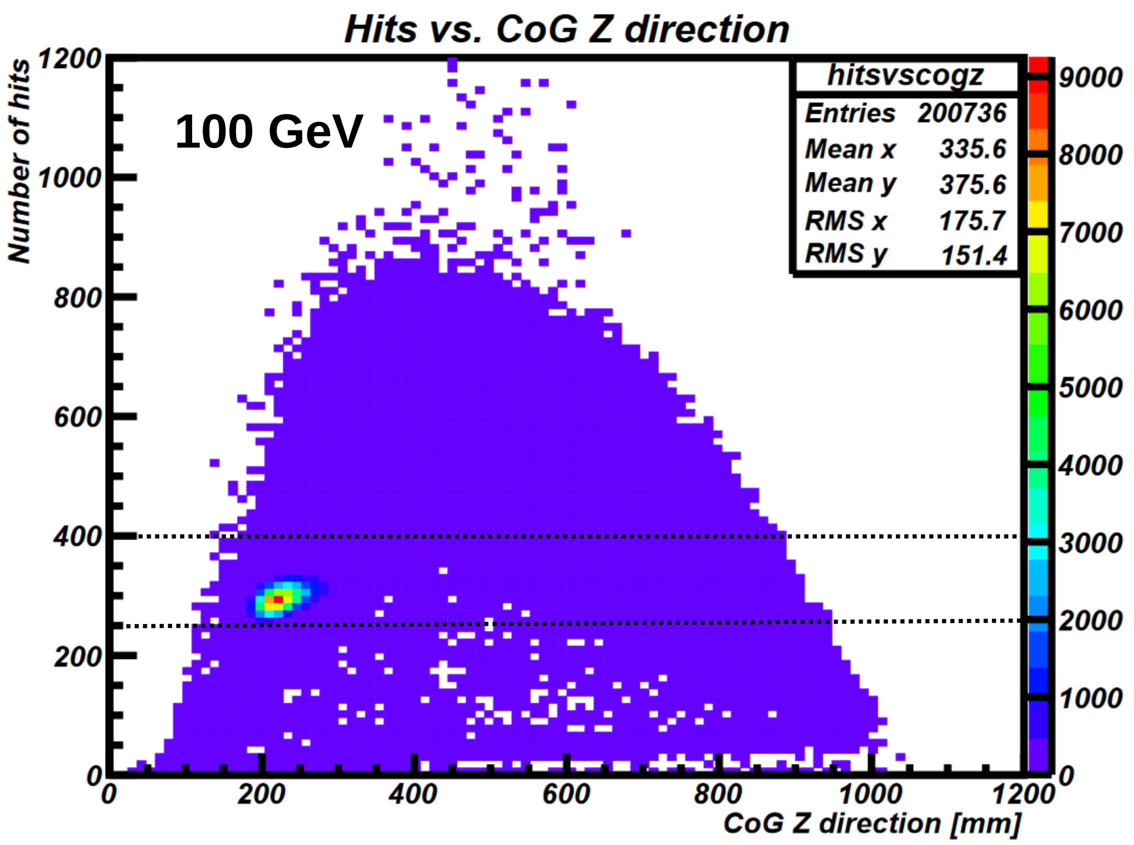
For entries = 1



Few channels with large fit uncertainty and few with small fit uncertainty

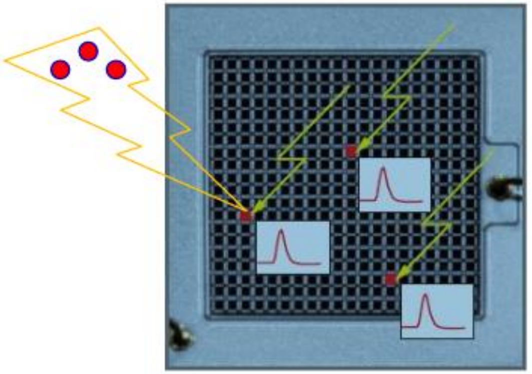
Number of hits vs. center of gravity in Z direction

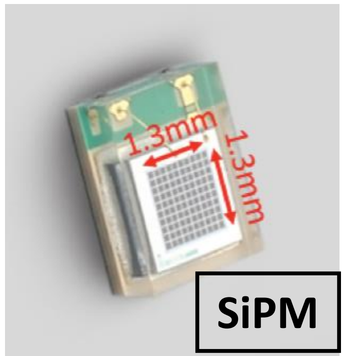




SiPM saturation

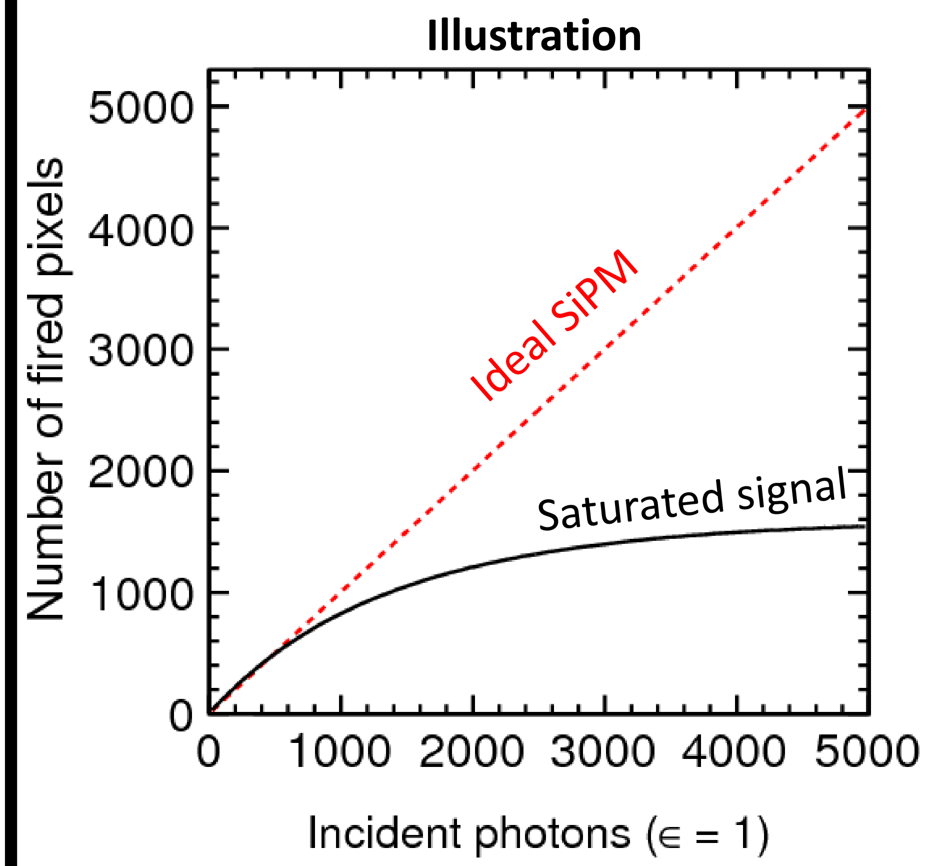
Why saturation and how to correct it?





- ✓ Due to limited number of pixels in SiPM (2668 pixels) and finite pixel recovery time (20 – 500 ns)
  - ✓ Need to correct the non-linear response of SiPM at high energy deposition
- ✓ Apply the de-saturation function during reconstruction

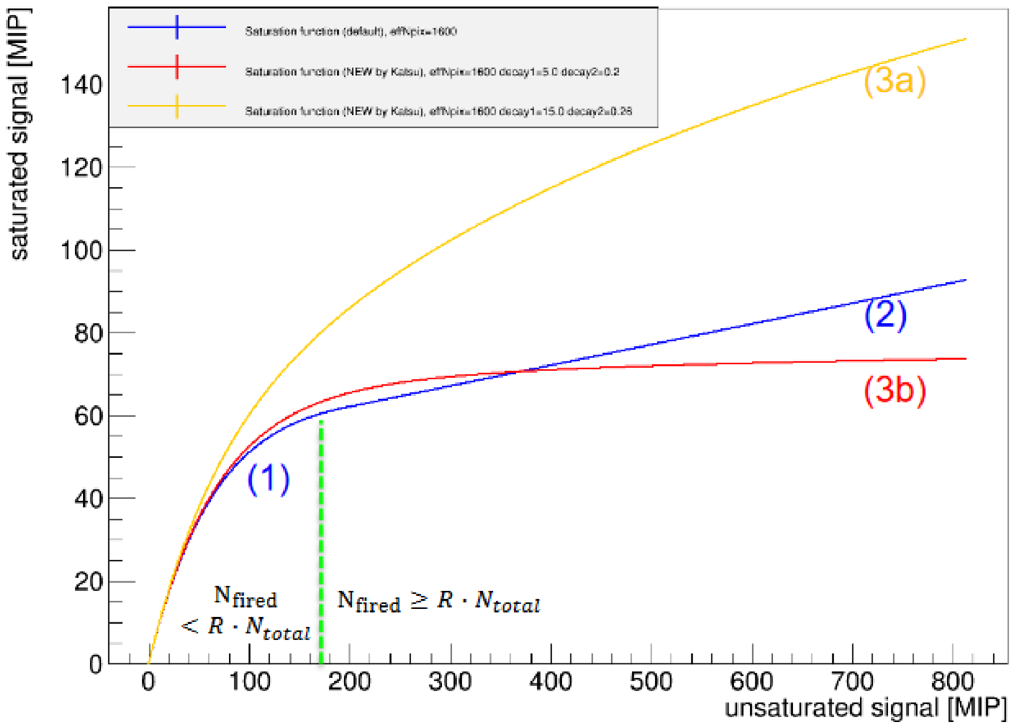
$$\boxed{\textbf{Signal}_{\ \textbf{desaturated}} = \textbf{function}_{\ \textbf{desaturation}} \left(\textbf{Signal}_{\ \textbf{saturated}} \right)}$$



arXiv:1510.01102

Describing saturation

Work done by Sascha



No correlated noise covered:

Simple saturation function: (1)

$$N_{fired} = N_{total} \cdot \left(1 - exp\left(-\frac{N_{seed}}{N_{total}}\right)\right)$$

Linear extended saturation function used in CALICE to handle over saturation: (2)

If $N_{fired} \geq R \cdot N_{total}$, than:

$$N_{fired} = R \cdot N_{total} + (1 - R) \cdot \left(N_{seed} + N_{total} \cdot log(1 - R)\right)$$

for $R = 95\%$

Correlated noise covered:

Katsu's advanced SiPM function includes NLO corrections: (3a) (3b)

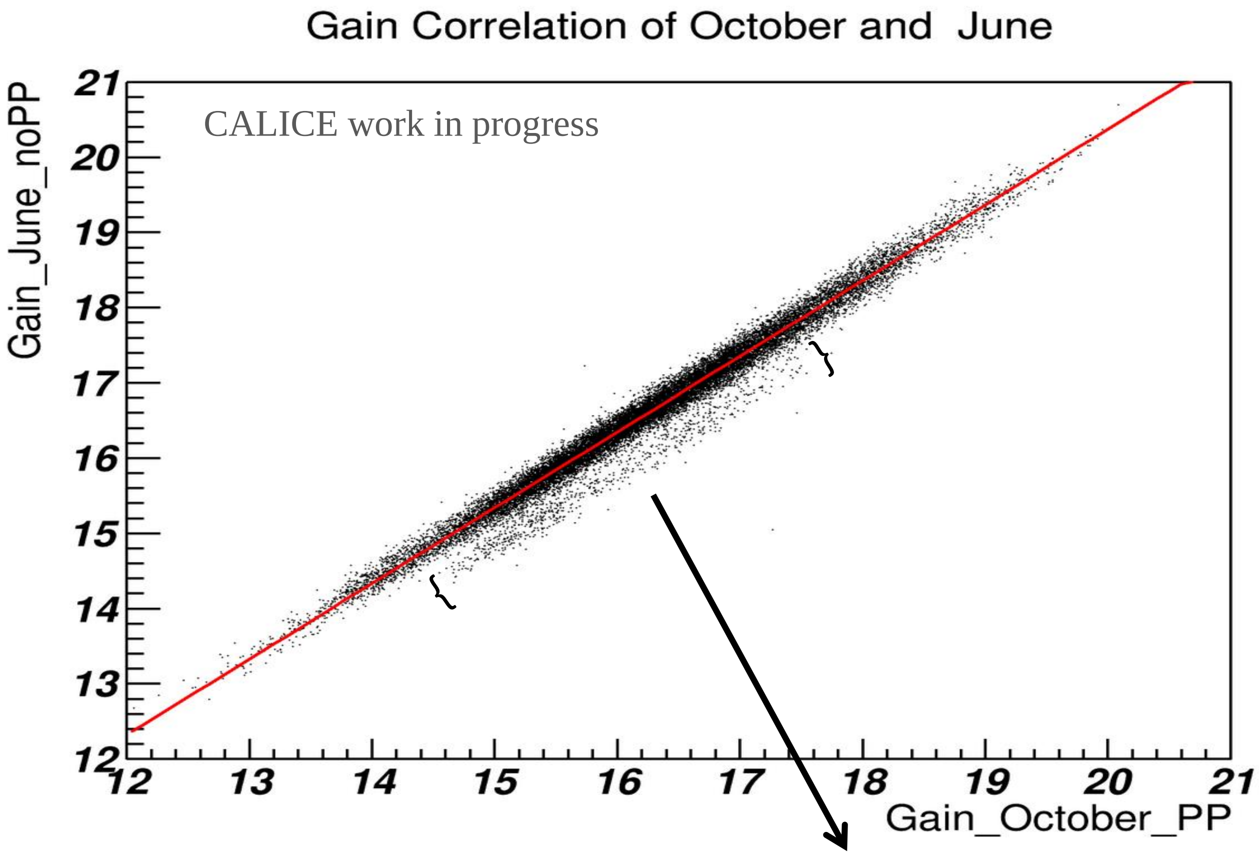
6 parameters:

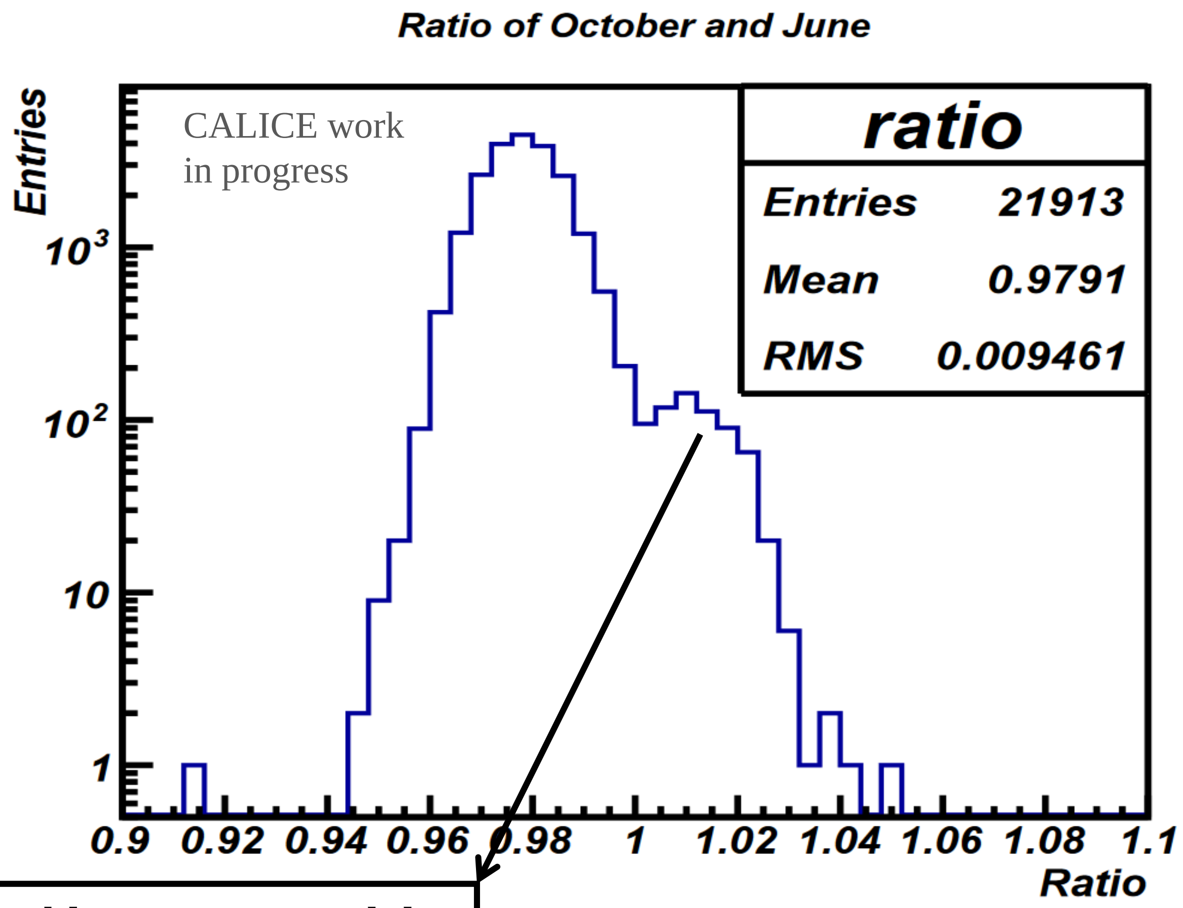
- N_{total}, fixed to total number of pixels
- scale factor, fixed to 1
- 2x decay-/recovery time variables, describes **over-saturation**
- Crosstalk- & Afterpulse prob. includes **correlated noise**

Gain correlation

October PP and June No-PP

Good correlation – gain of AHCAL between two test periods was very stable





High voltage setting problem on one module

Temperature and gain dependence

Gain and temperature variations

- ✓ The temperature of each detector module is monitored by 6 sensors
- ✓ The SiPM breakdown voltage varies with temperature – the gain changes with temperature, too
- ✓ SiPM gain with temperature compensation
  - ✓ ~ 4% difference in the gain is observed between PP and no PP mode