AHCAL Calibration and Temperature Corrections

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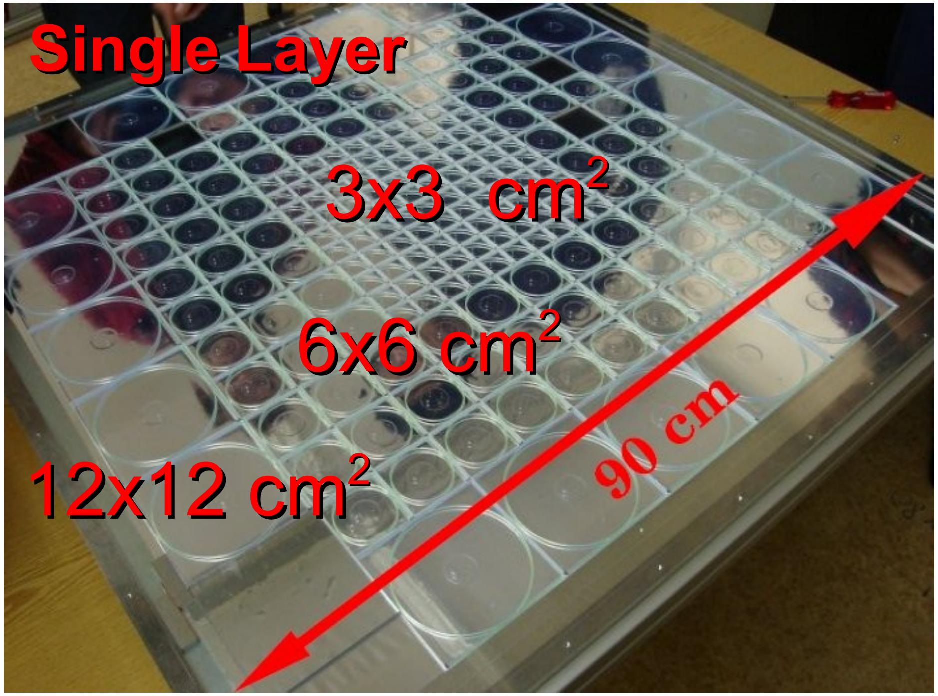
Outline

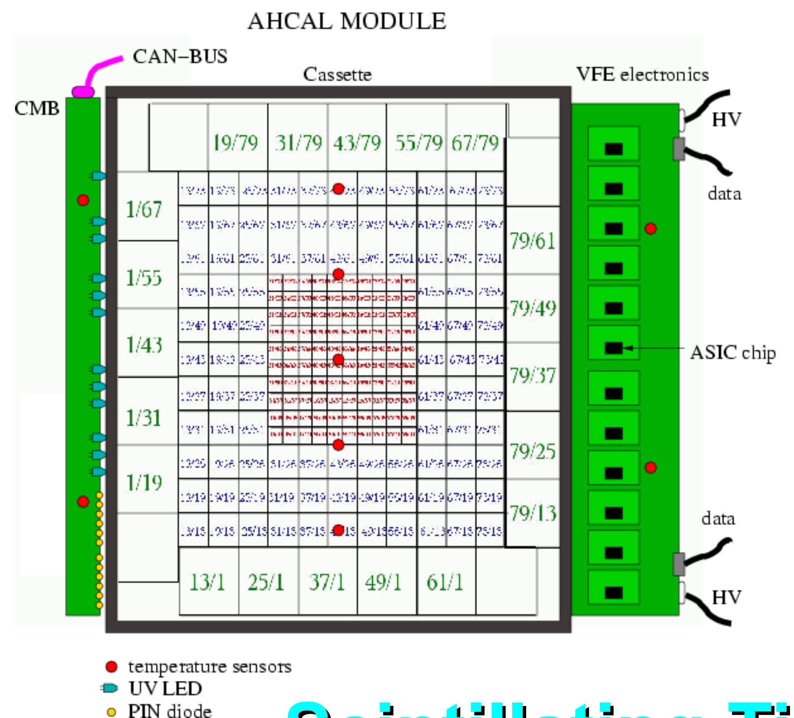
- Introduction
- Calibration 2006 / 2007
- Temperature Correction Studies

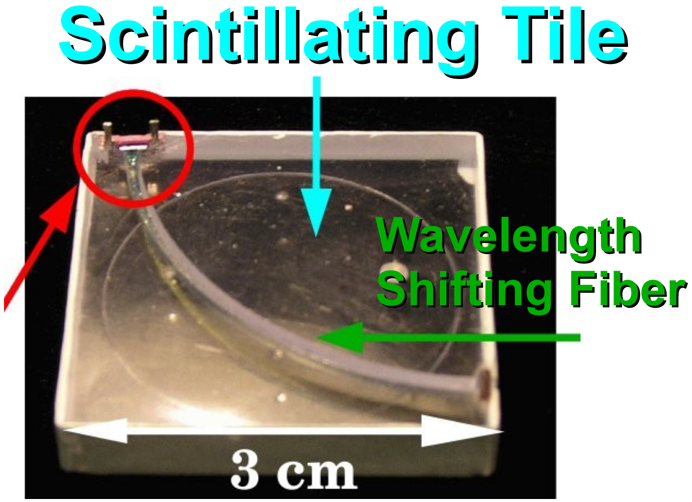
CALICE week Argonne, March 17-19 2008

The AHCAL Prototype

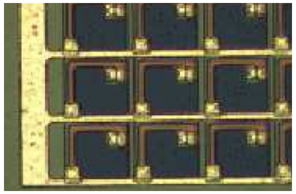
- 1m^3 steel/scintillator sampling calorimeter
- 38 active layers, 7608 channels

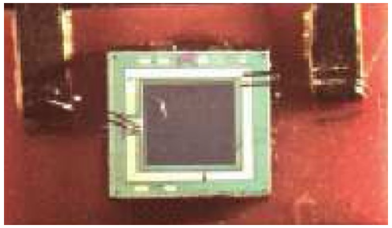






Silicon Photomultiplier (SiPM):
- Developed by MEPhi / PULSAR
- Matrix of independent pixels, each similar to an APD in Geigermode
- Gain: ~10^6
- Bias-Voltage: ~ 50 V

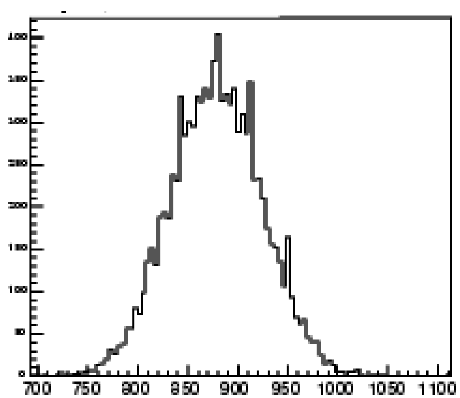




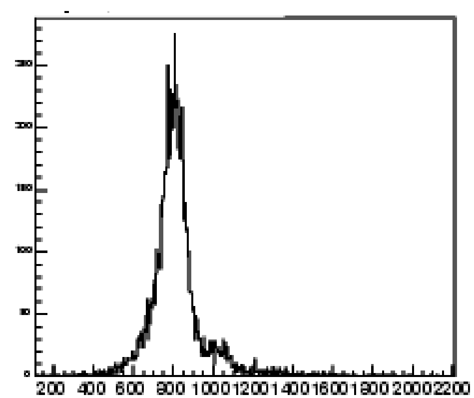
Dead Channels

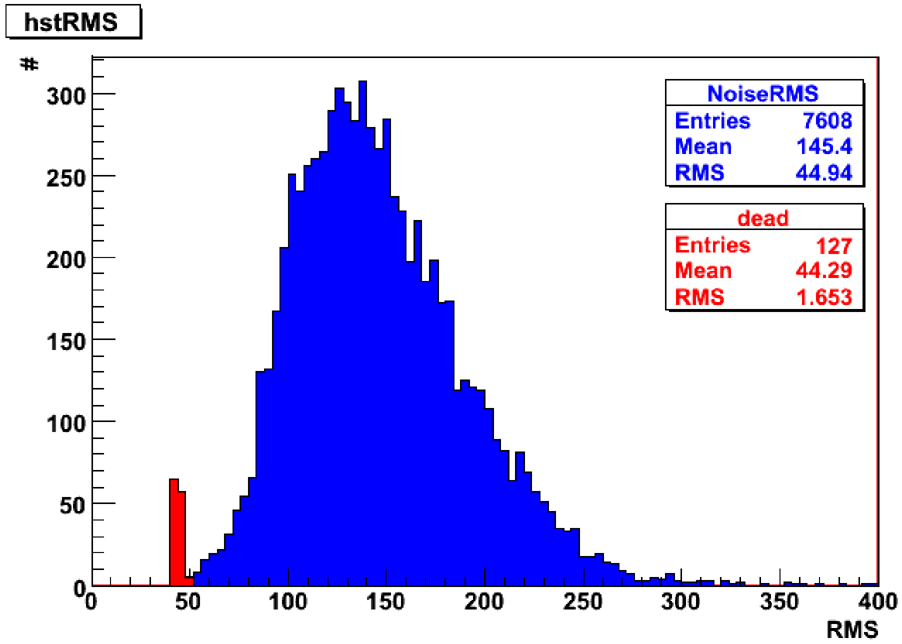
- Read out channels without beam and LED light.
- Criterion: standard deviation < 50 [ADC ch.] with SiPM bias voltage on.
- Total: 1,7 % dead channels.

Dead Channel:

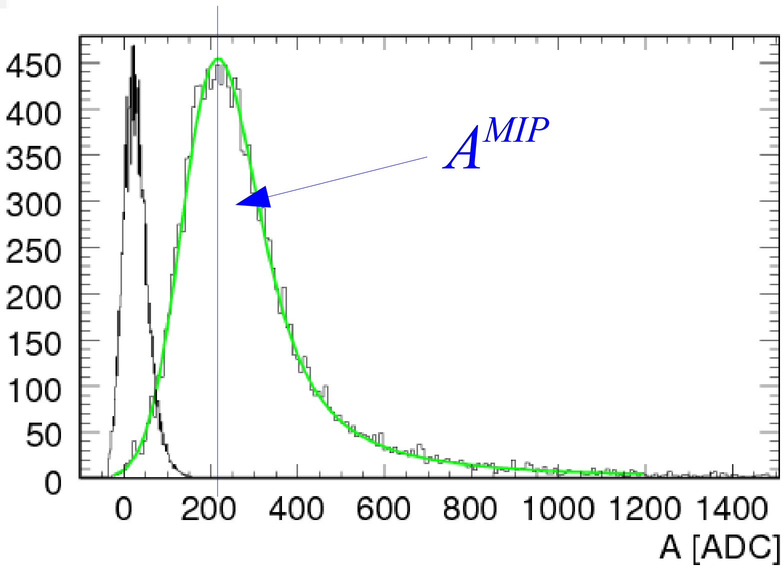


Working Channel:



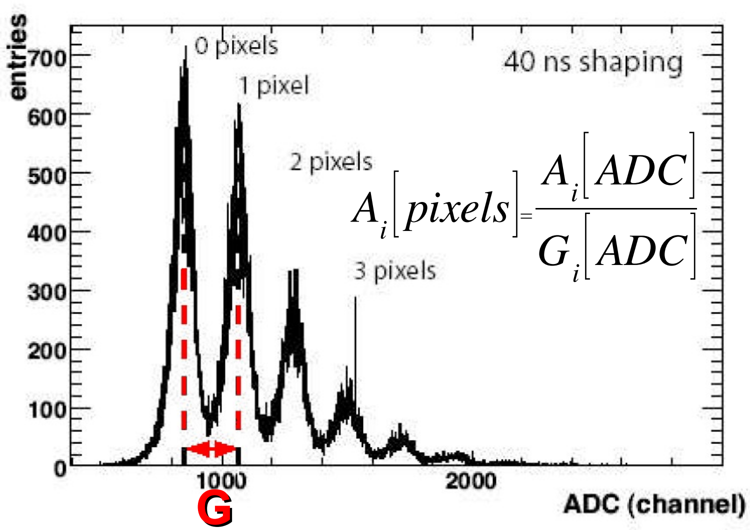


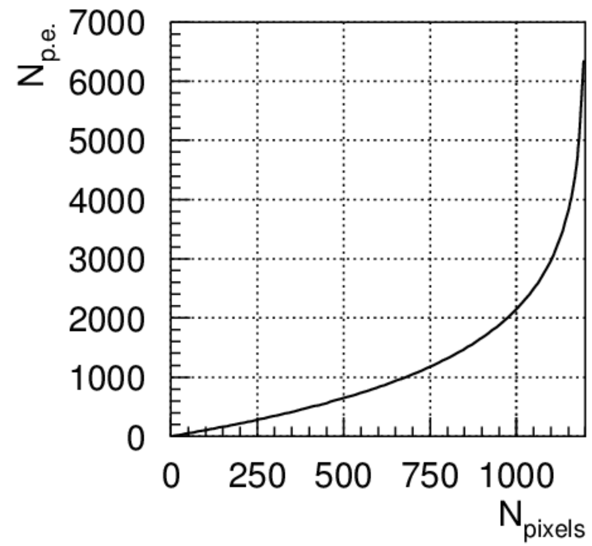
The AHCAL Calibration

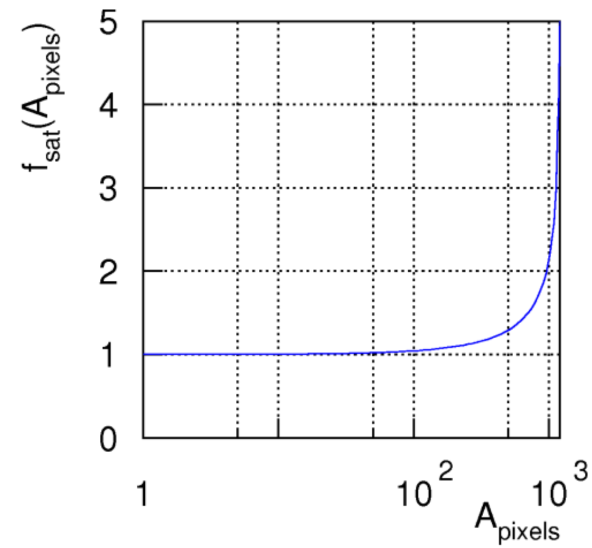


- Calibration via MIP-Signal
- Gain determination from single pixel spectrum
- Correction for SiPM non-linearity:

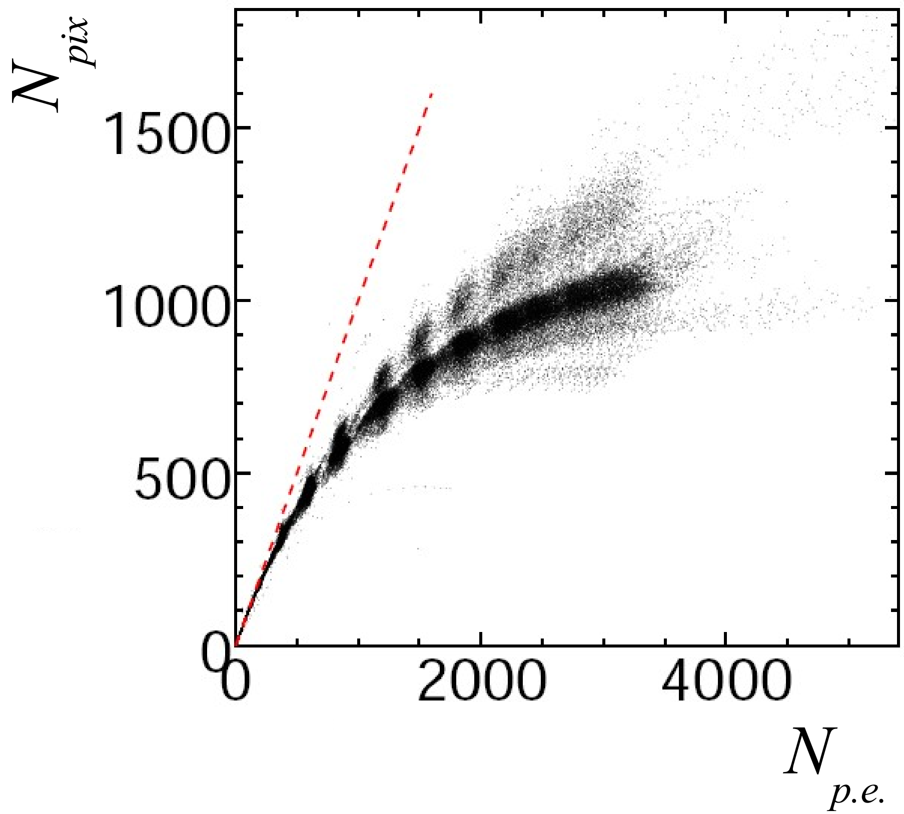
$$E_i\ [MIP] = \frac{A_i\ [ADC]}{A_i^{MIP}\ [ADC]} \cdot f_{sat}(A_i\ [pixels])$$

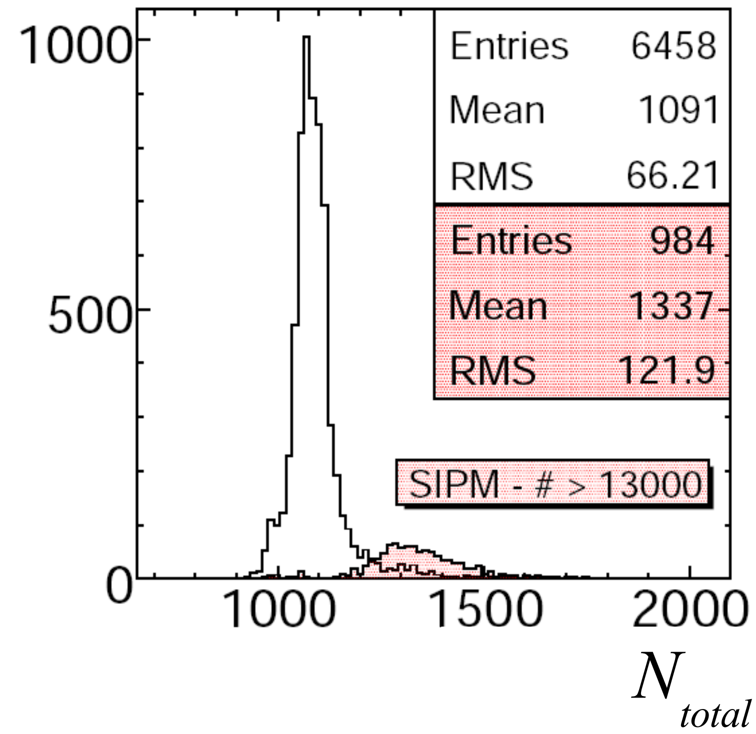






Saturation correction





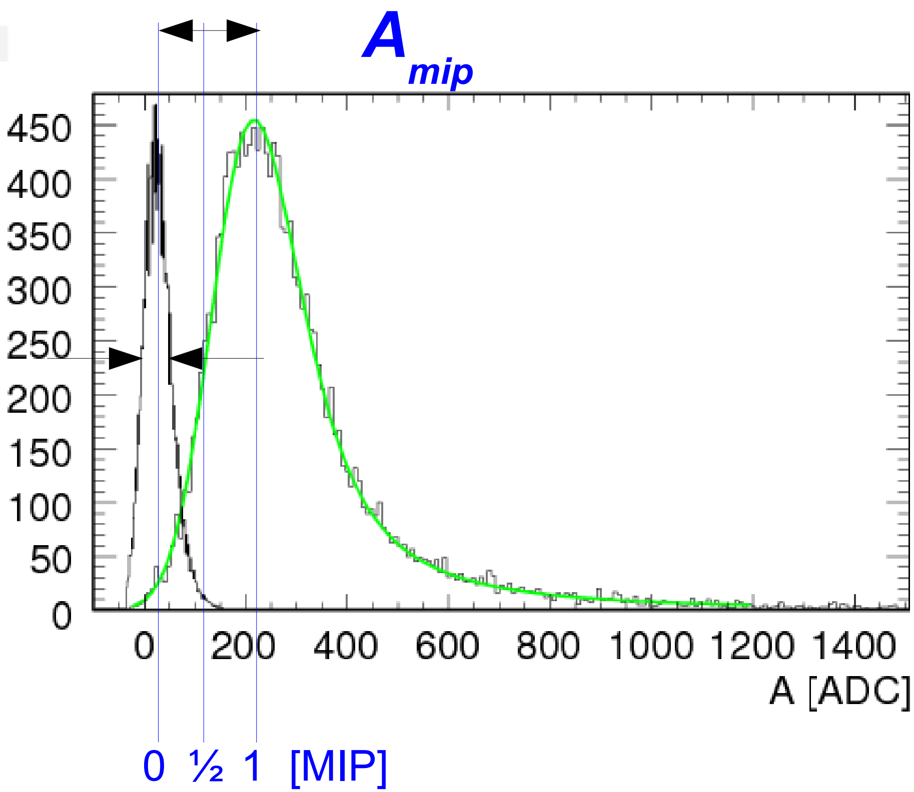
Plots by N. Feege

Simple model:

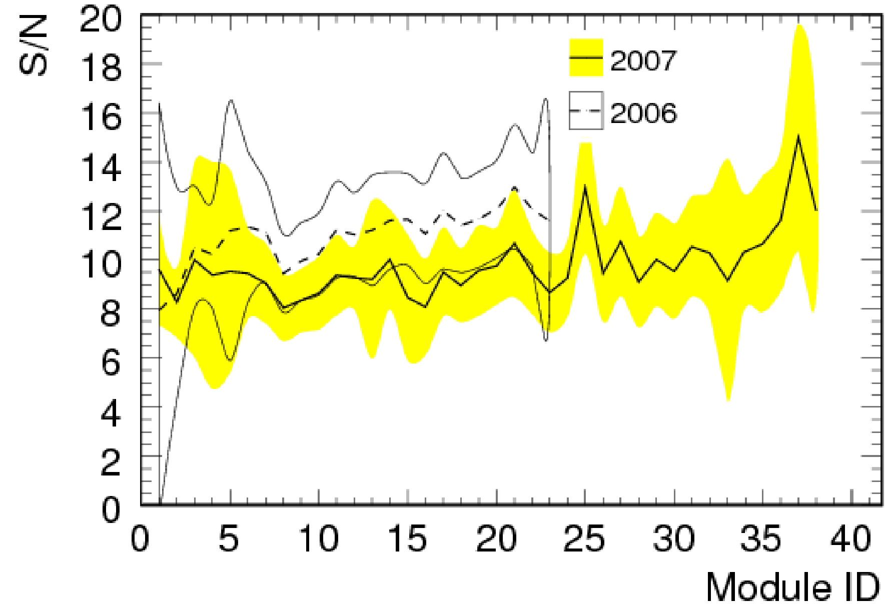
$$N_{pix} = N_{total}\left(1 - \exp\left[\frac{-N_{p.e.}}{N_{total}}\right]\right)$$

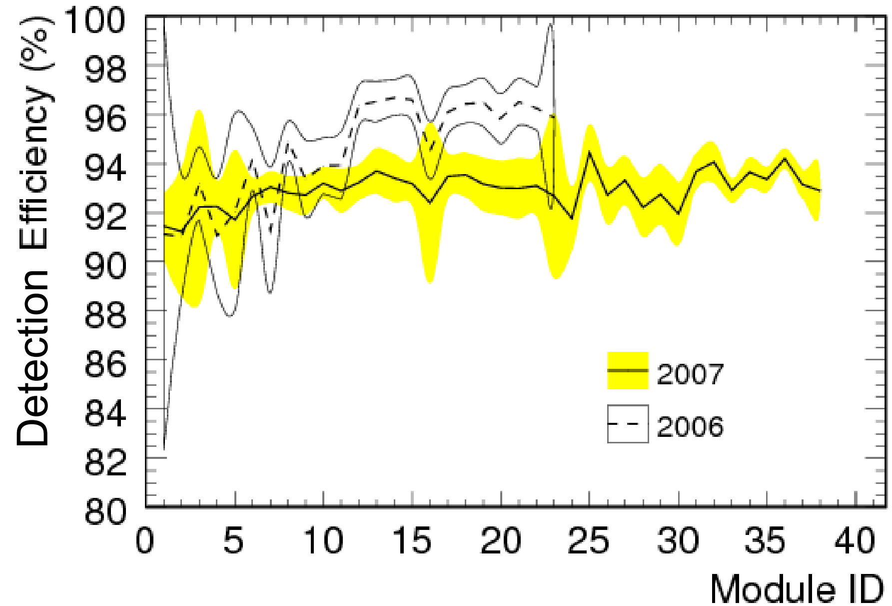
- SiPM signal = Σ pixels fired
- N_{total} is finite & recovery time → saturation
- Saturation curves provided by ITEP for each SiPM
- under study...

MIP: Detection Efficiency / SNR



Threshold: 0.5 MIP
Detection efficiency: 93%
SNR: 9

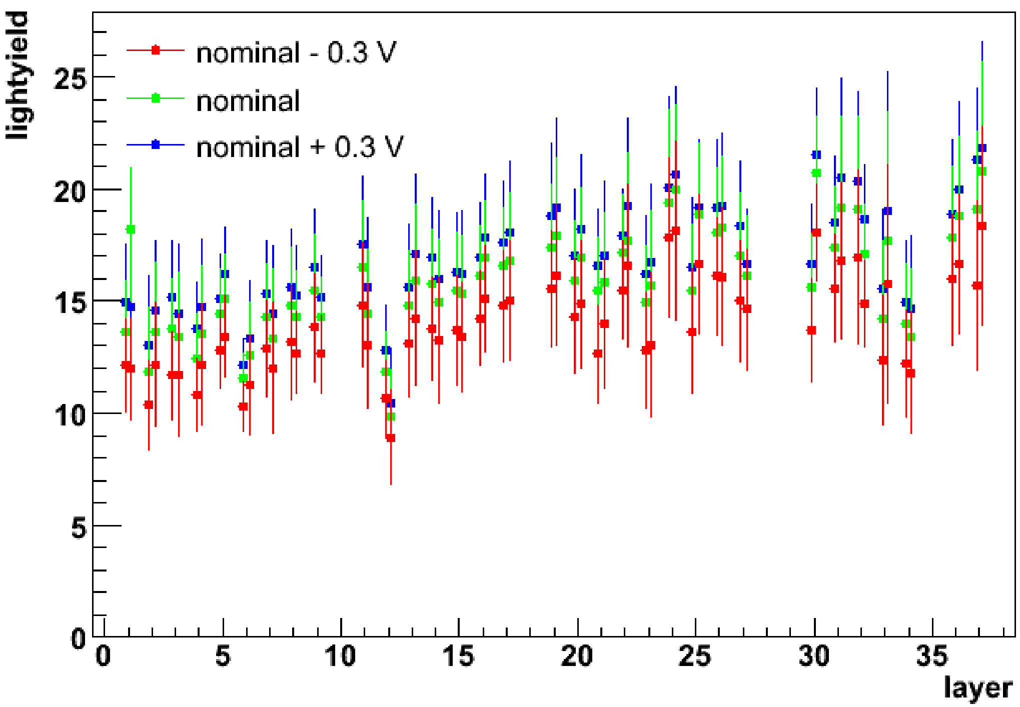




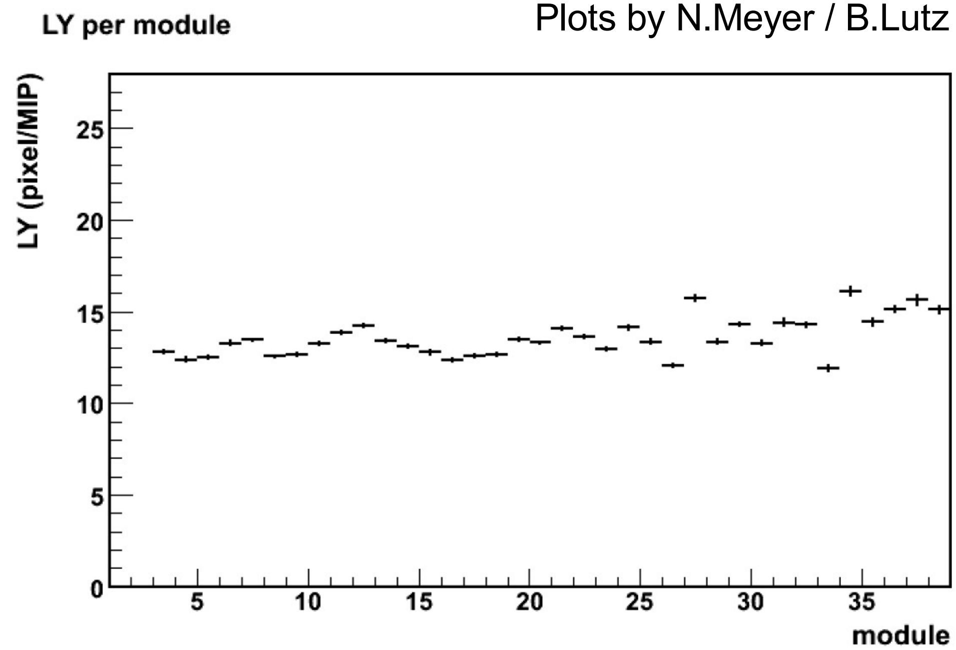
Plots by N. D'Ascenzo

Optimization of the Bias Voltage

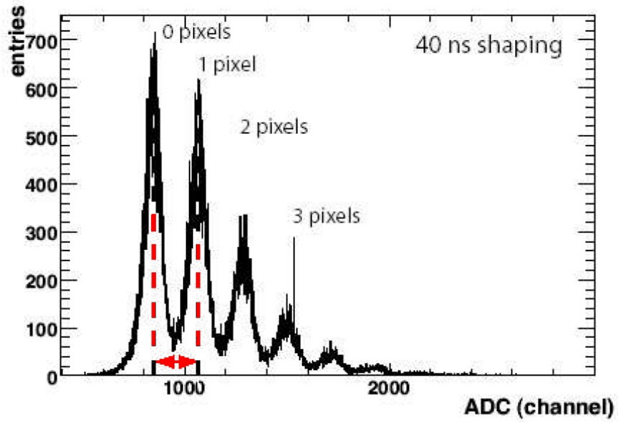
- Light Yield: $LY = A^{MIP}[\mathrm{ADC}] / G\ [\mathrm{ADC}]$
- Goal: max. MIP SNR & efficiency → LY=15 pixels / MIP
- Result: LY=13.5

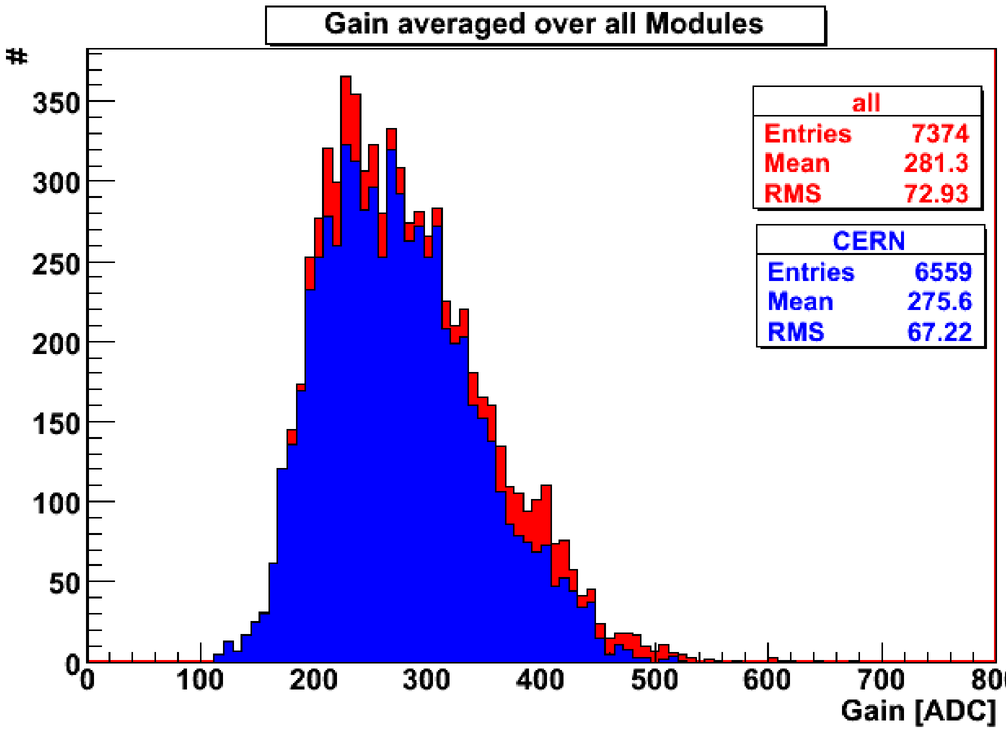


Plots by N.Meyer / B.Lutz



Efficiency of the Gain Calibration

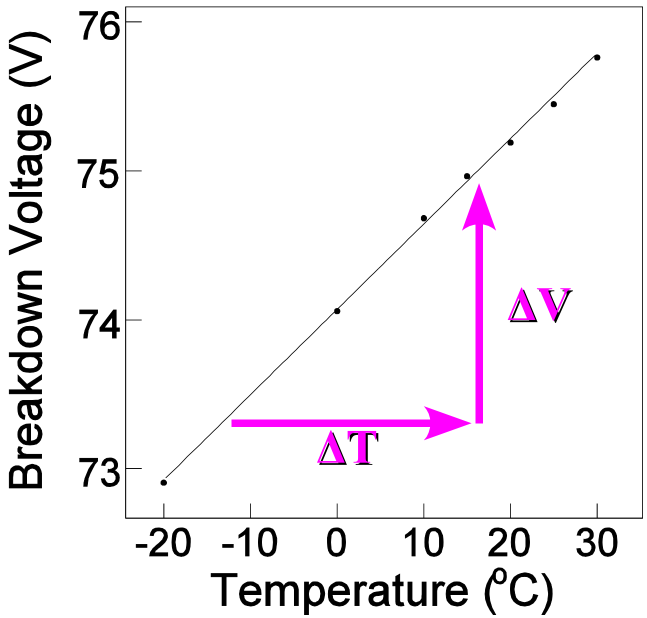


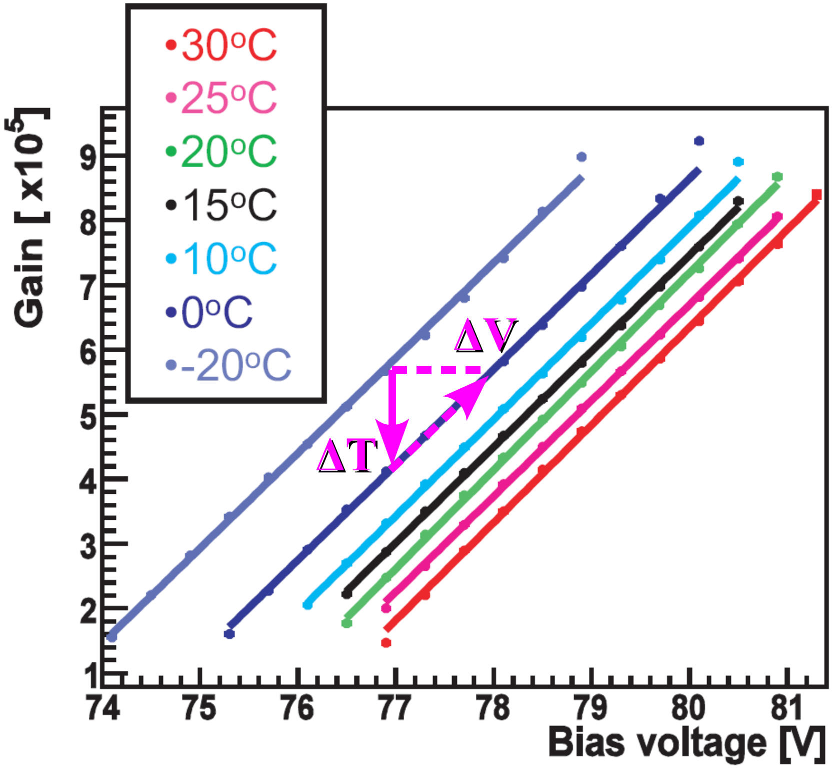


- Single modules were recalibrated at DESY
- Channels with gain calibration available: 96.9%
- 7 LEDs were turned off = 1.7% of the channels
- Stability: $\sigma = 2.6\%$ (without correction of the temperature shifts)

SiPM: Temperature and Voltage

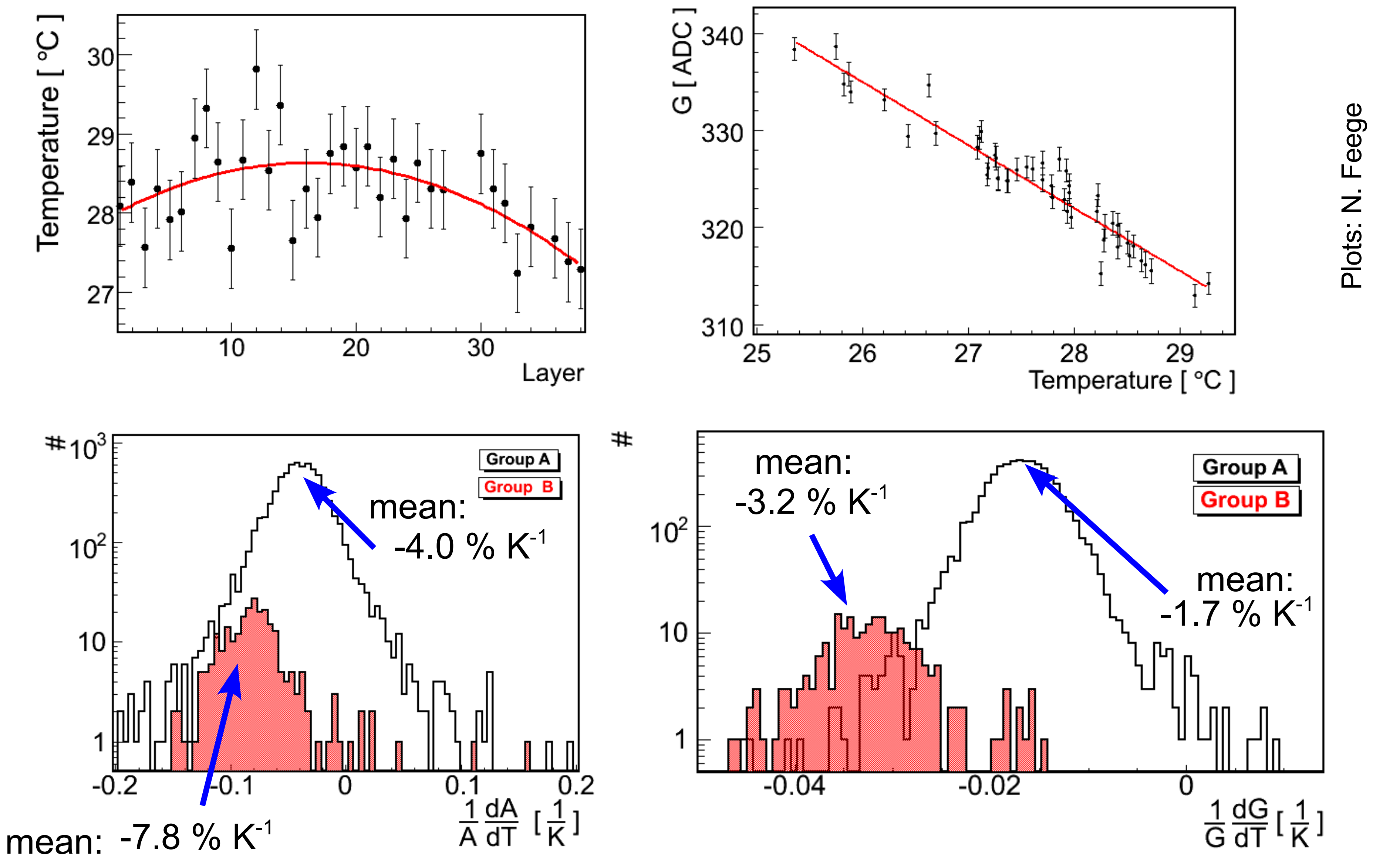
- SiPM signal depends on gain and efficiency: $A \sim G \cdot \varepsilon$
- Both depend on the overvoltage $U = U_{bias} - U_{breakdown}$
- $U_{breakdown}$ is temperature dependent



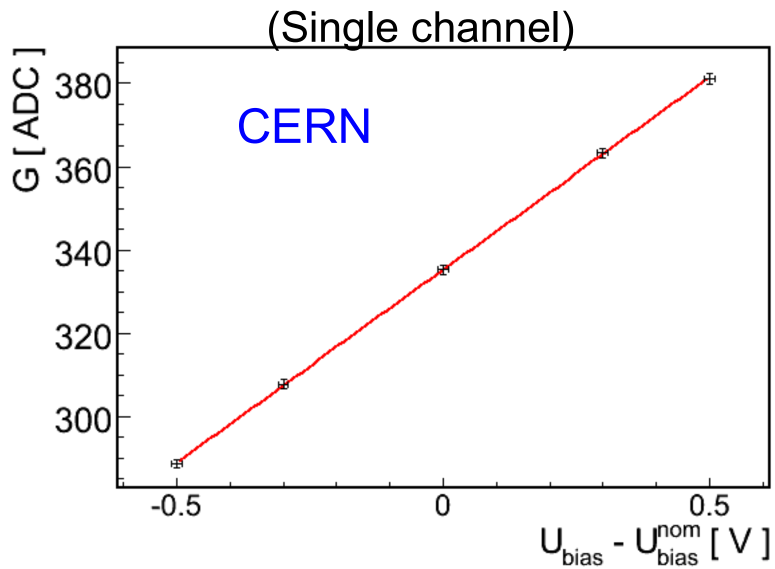


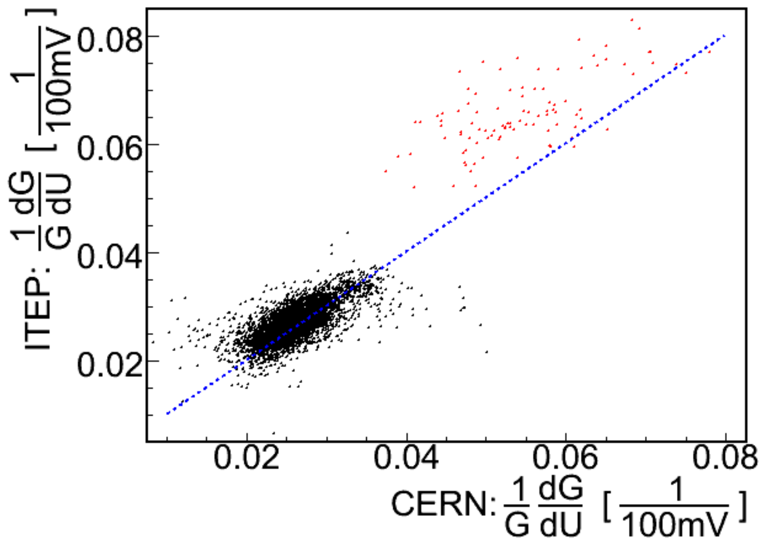
Figures by S.Uozumi

Temperature Dependence (CERN)

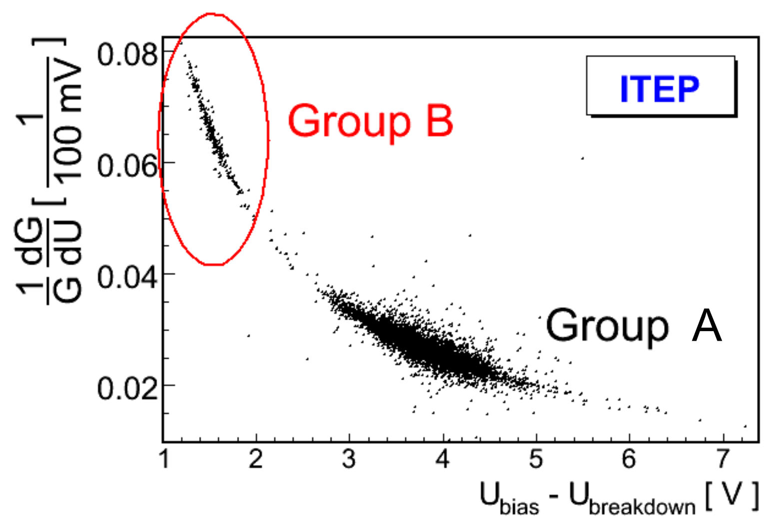


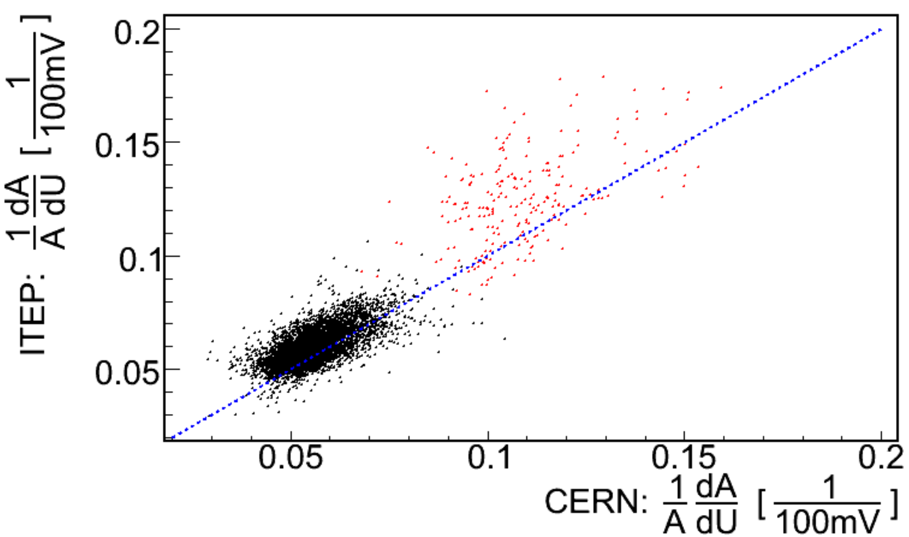
Voltage Dependencies: ITEP vs. CERN





Plots: N. Feege

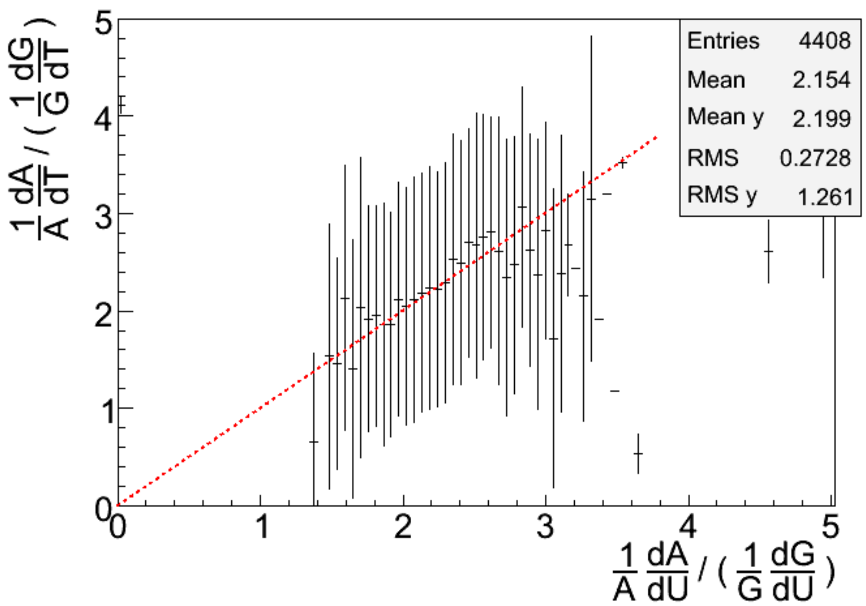


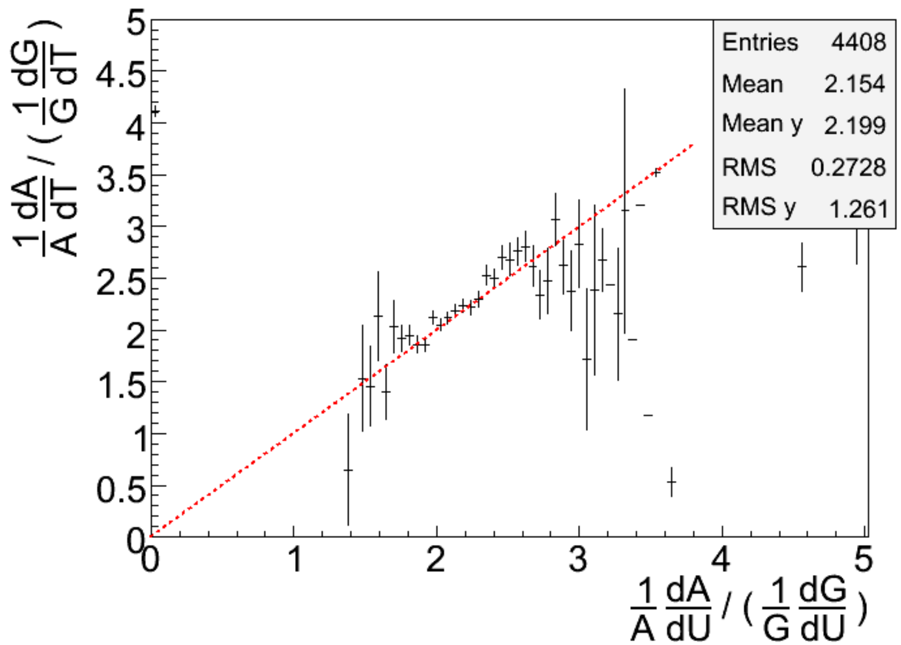


Relation of the Dependencies

- From $\frac{dG}{dT} = \frac{dG}{dU} \cdot \frac{dU}{dT}$ and $\frac{dA}{dT} = \frac{dA}{dU} \cdot \frac{dU}{dT}$ follows: $\boxed{\frac{dA/dT}{dG/dT} = \frac{dA/dU}{dG/dU}}$
- Testing this hypothesis:

Plots: N. Feege





Correction Methods

Method 1:
$$A = A_0 \cdot \left[1 + \frac{1}{A_0}\frac{dA}{dT}\left(T - T_0\right)\right] \qquad G = G_0 \cdot \left[1 + \frac{1}{G_0}\frac{dG}{dT}\left(T - T_0\right)\right]$$

- Instantaneous: temperature measured frequently during data taking
- Non-local: only 5 temperature sensors per module

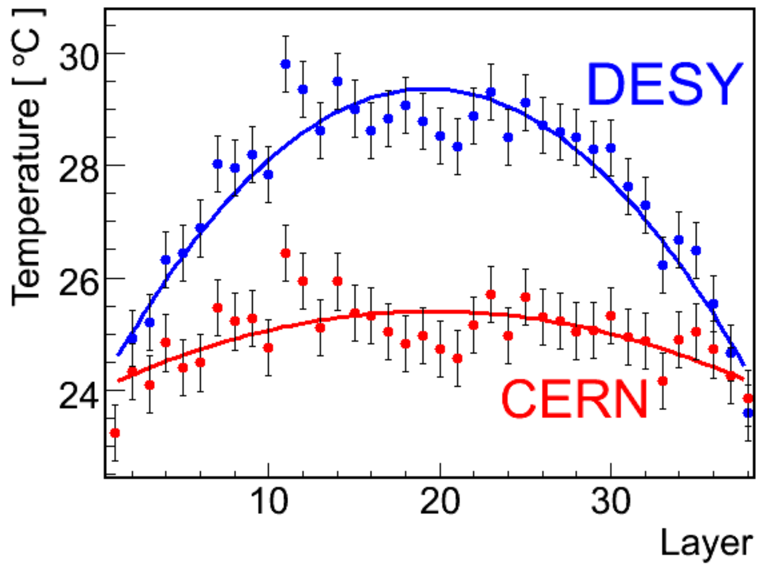
Method 2:
$$A = A_0 \cdot \left[1 + \frac{1}{A_0}\frac{dA}{dU} / \left(\frac{1}{G_0}\frac{dG}{dU}\right) \cdot \left(G - G_0\right)\right]$$

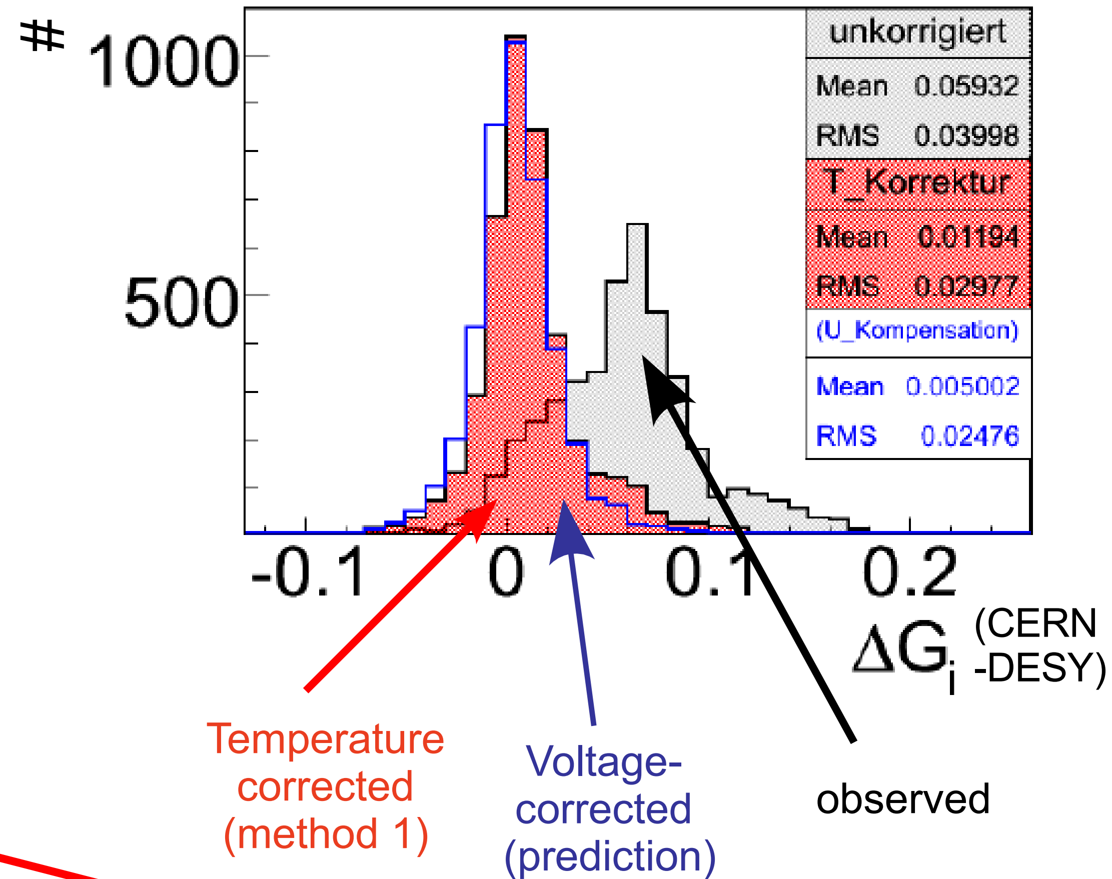
- Local: gain measured for every channel.
- Not instantaneous: gain measured few times per day in dedicated runs

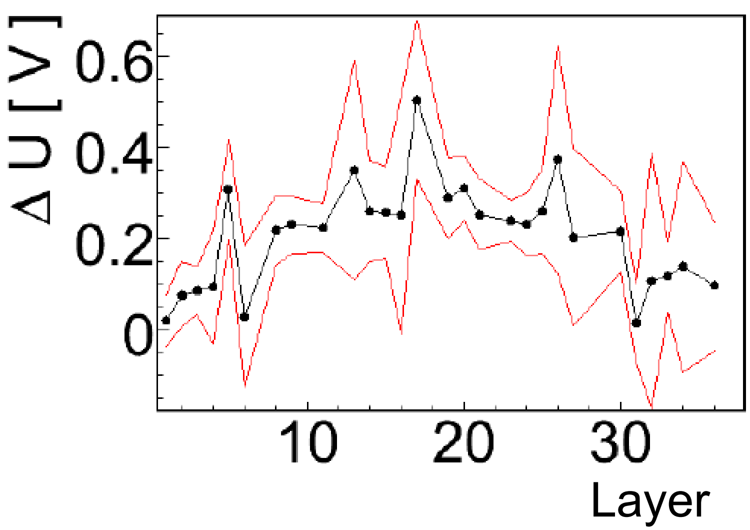
Voltage Adjustment:
$$U = U_0 + \left(G - G_0\right) / \frac{dG}{dU}$$

- can not be performed daily or weekly, long time adjustment
- more radical, but most effective

Equalizing G by Voltage Adjustment





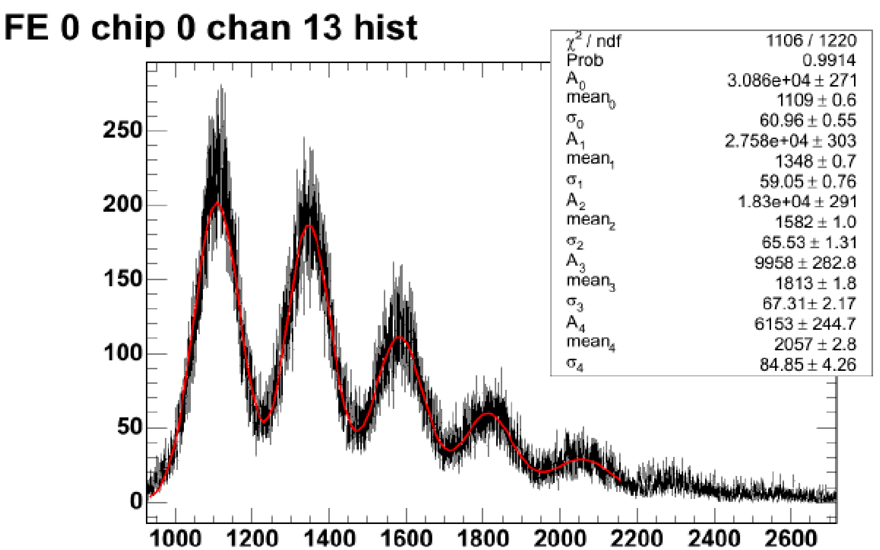


Required bias adjustment from observed gain shift (average per layer)

Plots: N. Feege

Auto Calibration

- Each SiPM provides its own reference scale: the single pixel spectrum
- Promising tool to monitor response variations induced by temperature
- Possibilities for further simplification of calorimeter design:
  - No external reference
  - Small amplitudes
  - Loose stability requirements
- Stability of saturation correction:
  - Currently under study



Summary

- Calibration 2006 / 2007:
  - Dead channels
  - Saturation
  - MIP (detection eff. & SNR)
  - Light Yield
  - Gain calibration efficiency
- Temperature and Voltage Dependencies:
  - determination, relations, correction methods
- The SiPM provides auto calibration...