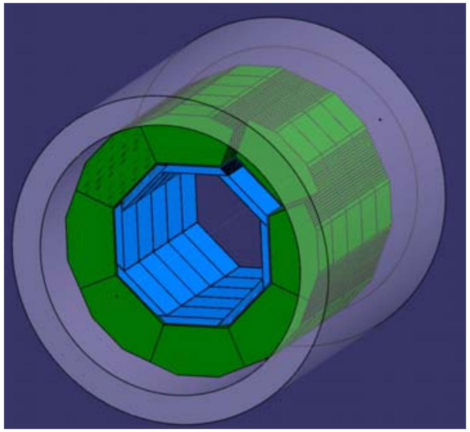
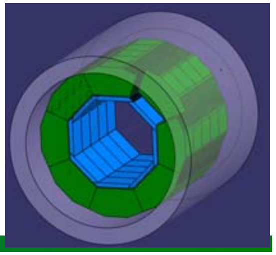


Calibration and Monitoring

Sebastian Schätzel
Felix Sefkow

Sep 13, 2007



R&D review panel:

(draft)

"The future test beam program will and needs to assess the impact of long term stability, failure rate, aging and monitoring (time-dependence, LED monitoring) issues.

Also the mip and calibration procedures in major systems need to be understood.

(...)

The inclusion of calibration data methods, i.e. mips and test pulses, is also important in understanding what data is needed to maintain the performance of these high granularity calorimeters in an experiment."

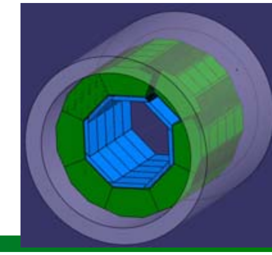
To be done:

- Work out ILC performance requirements
- Develop a concept for ILC calorimeter calibration
- Calibrate the test beam prototype
- Understand its performance limitations
- In parallel: develop technological options

Performance requirements

- $\sigma_E^{had} / E = \text{stoch.}/\sqrt{E} \oplus \text{const} \oplus \text{noise} / E$
- $\sigma_{jet} = \sigma\,(\sigma_E^{had}, \text{noise, cluster recognition,....})$
- The performance requirements are not yet finalized
- Little has been said so far on the requirements for
    - the constant term (high energy limit): calibration!
    - noise term (low energy limit)
    - dynamic range
  - The terms depend on completely different features of the detector technology
- Detector performance studies (benchmarks) - with detector effects included - to assess sensitivity to parameters

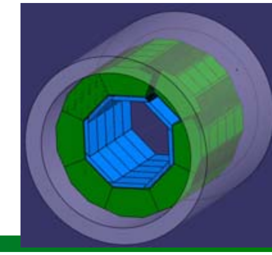
Calibration concept



- MIP calibration: regular, but not instantaneous: long-term
- Monitoring (LED, gain, temperatures): short term variations

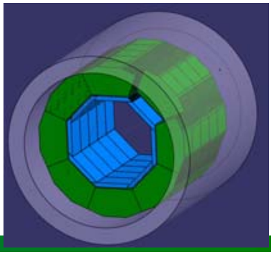
- MIP calibration at the ILC
  - Deep site, power pulsing, detector not rotating ➔ cannot (fully) rely on cosmics
  - Imaging calorimeter has MIP segments in “every” hadron shower
  - Does it work??
    - Can we find them? Deep analysis starting point
    - Efficiency vs accuracy trade-off
    - Systematics: purity, track angle effects,…
    - Validate with test beam data
    - Estimate realistic rates at the ILC
  - Determine the time intervals to be bridged by monitoring system

Monitoring concepts



- Correct for (mostly) temperature-induced short-term variations using
  - Temperature sensors
  - SiPM gain ("auto-calibration")
  - LED reference pulses
- The first 2 methods need coefficients from the test bench
  - Gain, 1/G dG/dV, total response 1/A dA/dV
  - Temperature affects breakdown voltage: $dx/dT = - dx/dV * dV_0/dT$
  - dV_0/dT quite uniform: 0.057(8) V / K
  - Expected to cancel in ratio: (dG/dT) / (dA/dT); check!
- Test beam analysis (theory)
  - Get corrections (and errors)
  - Cross-check
  - Validate with – fortunately frequent – MIP calibrations

Monitoring in practice



- Treatment of data much more involved than we thought
- Temperature data suffer from finite granularity and offsets
  - Use physics-motivated profiles for smoothing (→ V.Morgunov)
- LED data require PIN monitoring which suffer from
  - High amplitude – large non-linearity corrections
  - Pedestal instabilities
  - Only low statistics, but can test the concept
- Gain data: major data processing effort (grid), inefficiencies (2006)

- MIP data
  - Incomplete (also a big effort)
  - Still systematic and reproducibility problems to be understood

Correction of HCAL temperature dependence

S. Schätzel

23 August 2007

a writeup will be released next week

done

CALICE Scintillator HCAL Temperature Dependence and Correction Methods using LEDs

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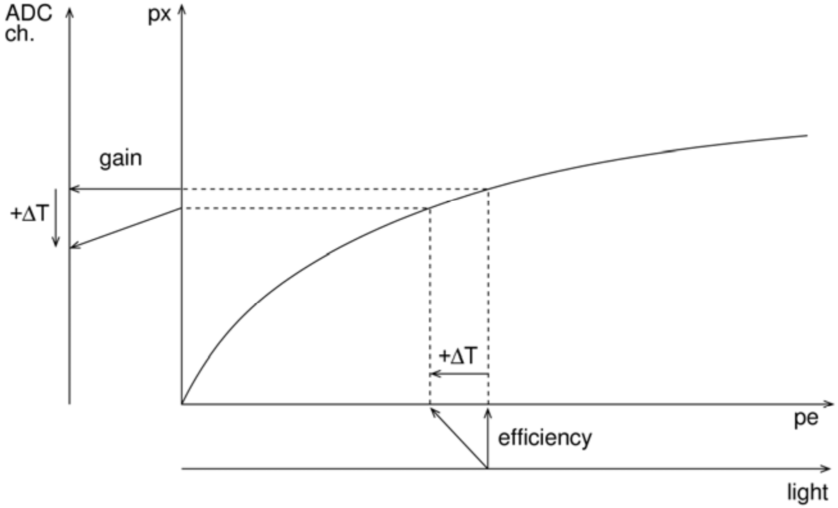
August 22, 2007

Abstract

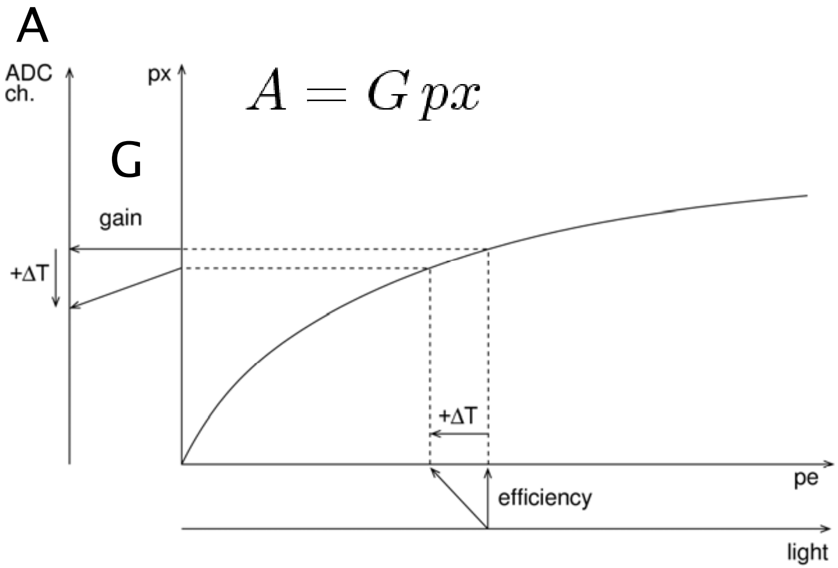
The CALICE Collaboration has built a prototype of a scintillator/steel sandwich hadronic calorimeter with novel silicon photosensors (SiPMs) to read out the scintillation light. The response of the photosensors is sensitive to temperature variations and a light injection system with LEDs was installed to study the dependence and correct for it. This article presents measurements of the temperature dependence and correction methods.

T dependence and correction strategy



SiPM less sensitive to ΔT at high amplitudes

T dependence and correction strategy



$$A = G\,px$$

$$px = \frac{pe}{1+\epsilon\, pe} \qquad \epsilon = 0.0007(2)$$

$$\frac{1}{A}\frac{dA}{dT} = (1-\epsilon\, px)\frac{1}{pe}\frac{dpe}{dT} + \frac{1}{G}\frac{dG}{dT}$$

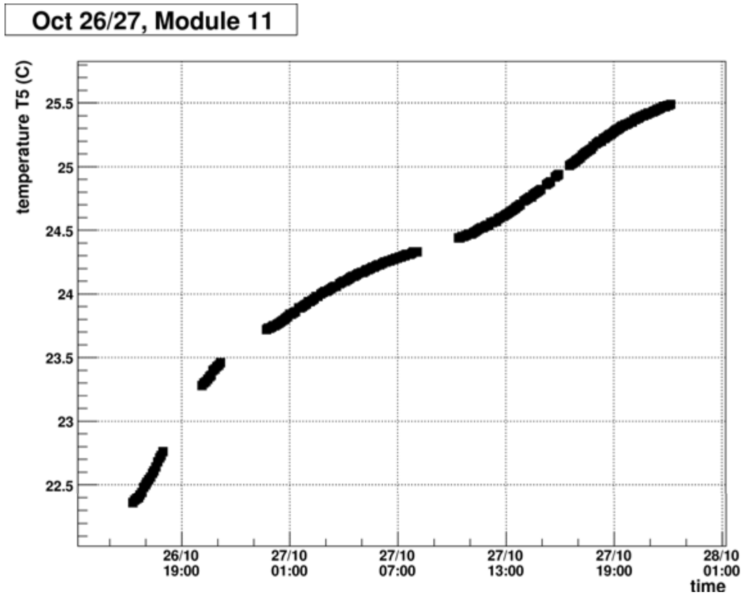
$$\frac{1}{pe}\frac{dpe}{dT} = \frac{1}{1-\epsilon\, px}\frac{1}{px}\frac{dpx}{dT}$$

SiPM less sensitive to ΔT at high amplitudes

1. measure $\frac{1}{pe}\frac{dpe}{dT}$ at LED monitoring point
2. calculate correction factor at arbitrary amplitude

Data sample

October 26-27, 2006
20 Modules with T read-out
ΔT artificially enhanced to +3K by removing cooling fans



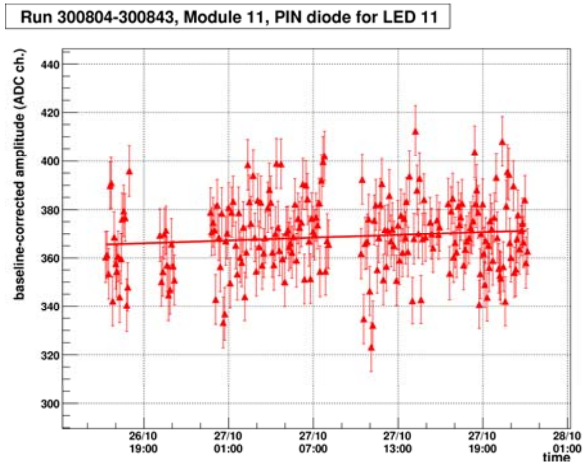
Sensor → SiPM assignment

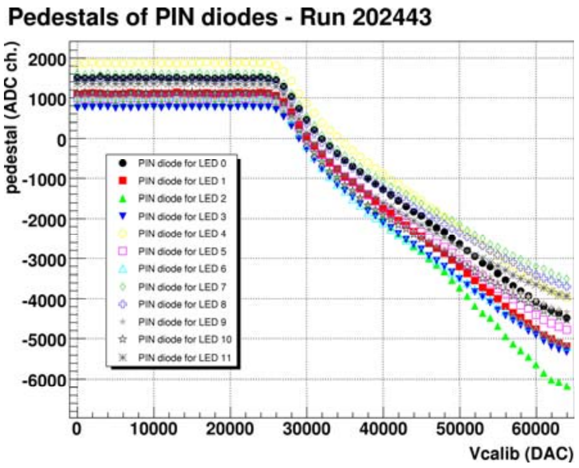
ASIC chip	temperature sensor
0	T1
1-3	T2
4-7	T3
8-10	T4
11	T5

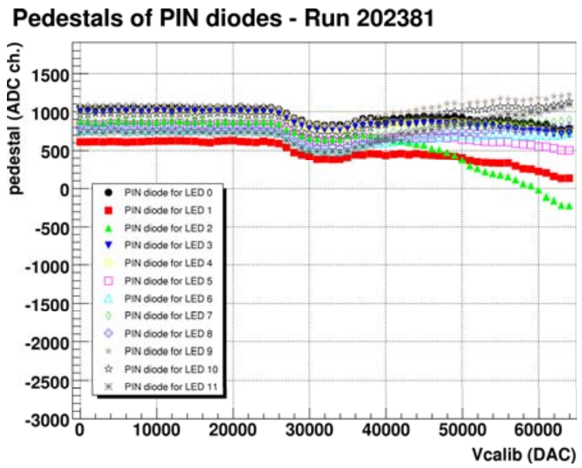
Selection of stable LEDs

normalisation of PIN diode amplitude is unknown (V_{calib} dependent, so far shift is not measured reproducibly)

use PIN diodes as a veto against LED fluctuations





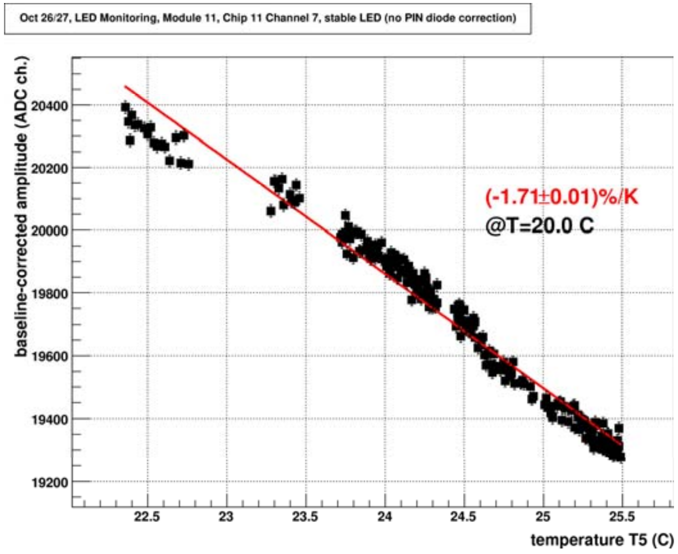


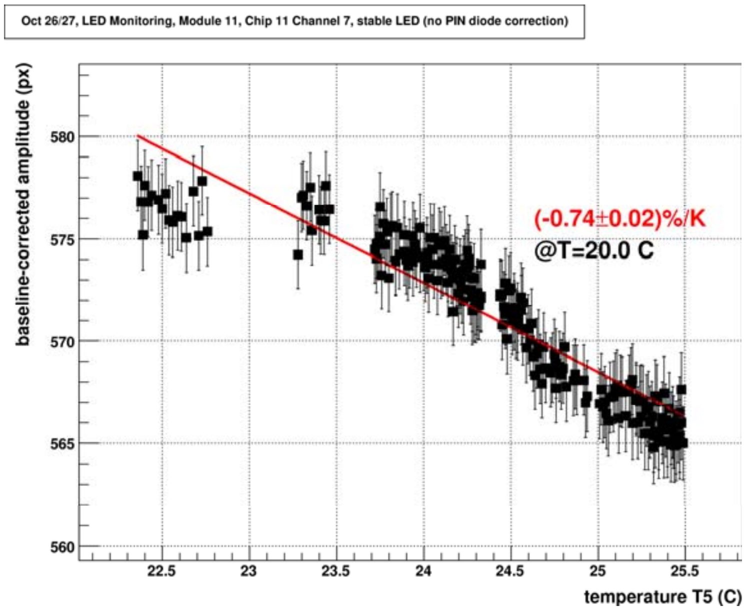
5 LEDs of 240 (2%) in 20 modules classified as stable

T dependence of amplitude

$$\boxed{\frac{1}{A}\frac{dA}{dT}} = (1-\epsilon\,px)\frac{1}{pe}\frac{dpe}{dT} + \frac{1}{G}\frac{dG}{dT}$$

$$\frac{1}{pe}\frac{dpe}{dT} = \frac{1}{1-\epsilon\,px}\boxed{\frac{1}{px}\frac{dpx}{dT}}$$





using G(T) in DB

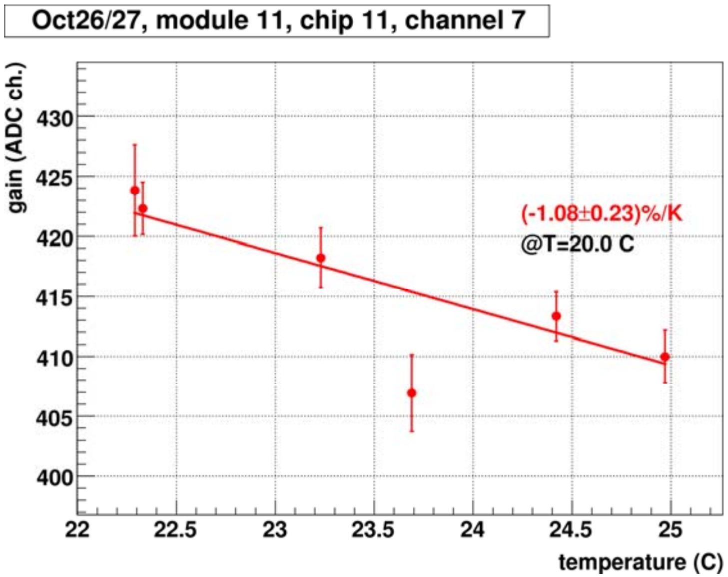
(PIN diode not sensitive enough
to resolve normalisation changes)

T dependence of Gai

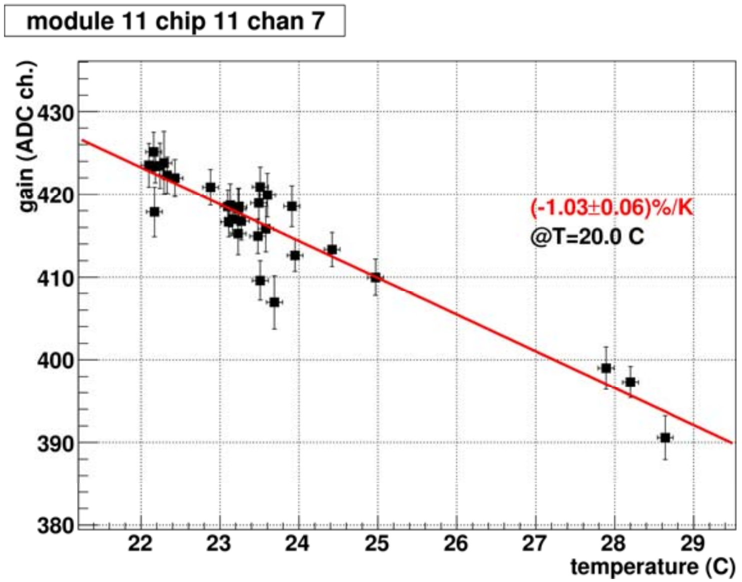
$$\frac{1}{A}\frac{dA}{dT} = (1 - \epsilon\, px)\frac{1}{pe}\frac{dpe}{dT} + \boxed{\frac{1}{G}\frac{dG}{dT}}$$

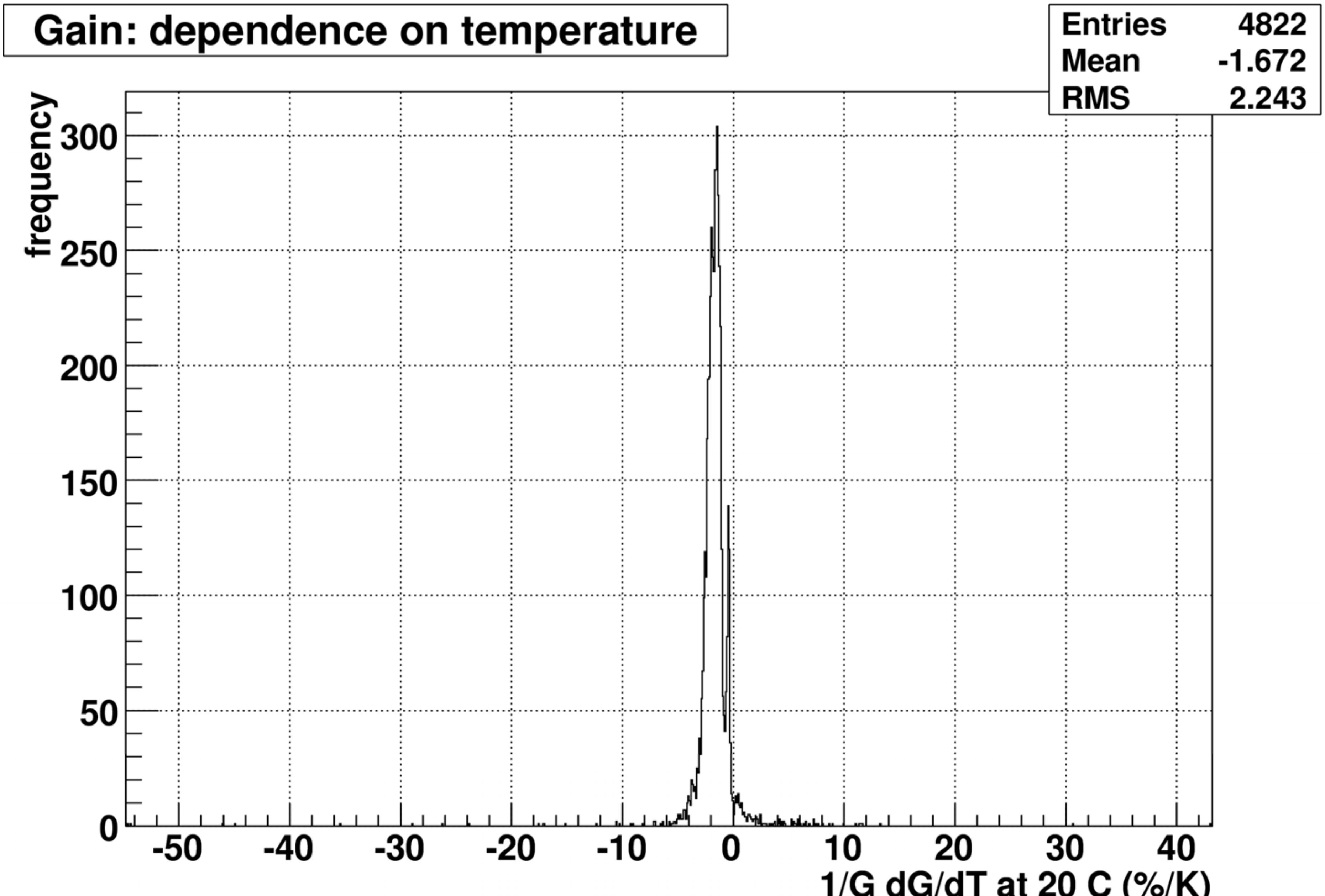
gain fits by Beni
ROOT analysis by Sebastian Schmidt
SiPM gains at bias voltage U_0+0.6V

Only Oct. 26/27

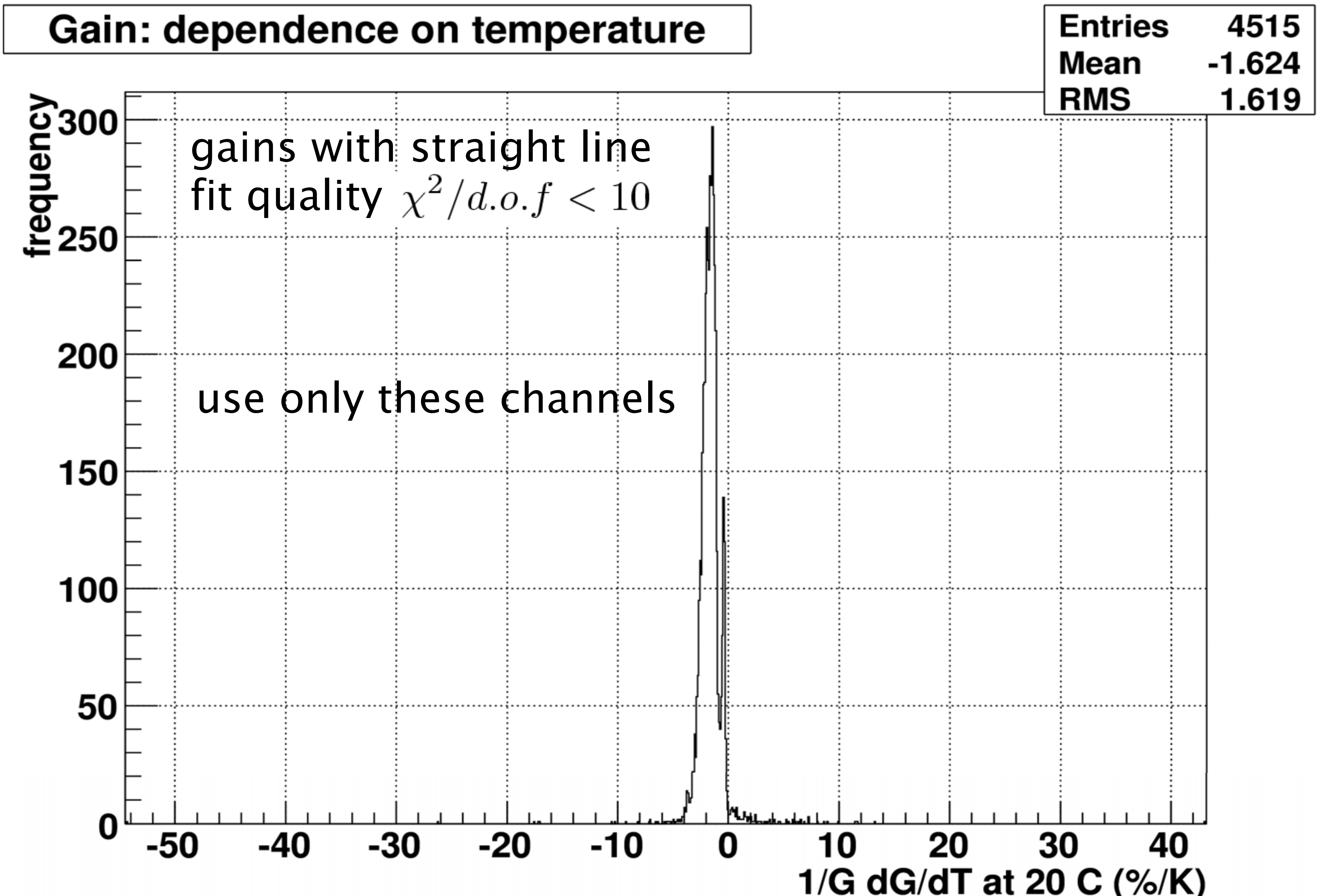


Full 2006 gain sample





Gain: dependence on temperature
Entries 4822
Mean -1.672
RMS 2.243
frequency
300
250
200
150
100
50
0
-50
-40
-30
-20
-10
0
10
20
30
40
1/G dG/dT at 20 C (%/K)


Gain: dependence on temperature
Entries 4515
Mean -1.624
RMS 1.619
frequency
gains with straight line
fit quality $\chi^2/d.o.f < 10$
use only these channels
1/G dG/dT at 20 C (%/K)
0
50
100
150
200
250
300
-50
-40
-30
-20
-10
0
10
20
30
40

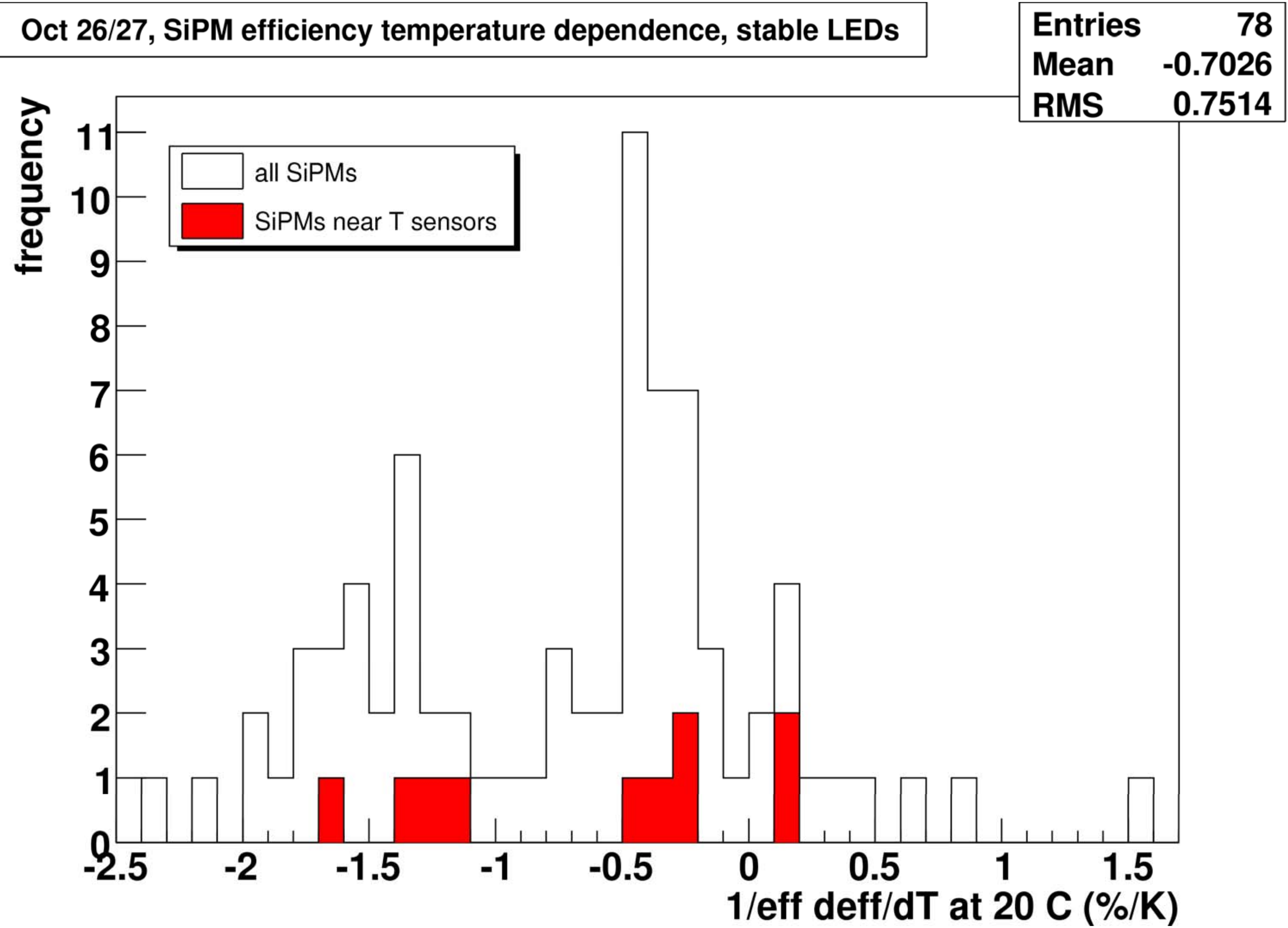
T dependence of efficiency

$$\frac{1}{pe}\frac{dpe}{dT} = \frac{1}{1-\epsilon\, px}\frac{1}{px}\frac{dpx}{dT}$$

$$\frac{1}{A}\frac{dA}{dT} = (1-\epsilon\, px)\frac{1}{pe}\frac{dpe}{dT} + \frac{1}{G}\frac{dG}{dT}$$

Module	Chip	Channel	$\frac{1}{pe}\frac{dpe}{dT}$ (from pixels)	$\frac{1}{pe}\frac{dpe}{dT}$ (from slopes)
11	11	7	$-1.3(3)\%/K$	$-1.2(3)\%/K$
11	11	8	$-1.5(2)\%/K$	$-1.3(2)\%/K$
11	11	15	$-1.6(1)\%/K$	$-1.5(2)\%/K$

agreement within uncertainties
both methods use the same information
$\rightarrow$ consistency checked



Oct 26/27, SiPM efficiency temperature dependence, stable LEDs
Entries 78
Mean -0.7026
RMS 0.7514
frequency
all SiPMs
SiPMs near T sensors
0
1
2
3
4
5
6
7
8
9
10
11
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
1/eff deff/dT at 20 C (%/K)

Charge amplitude T dependence at 1 MIP

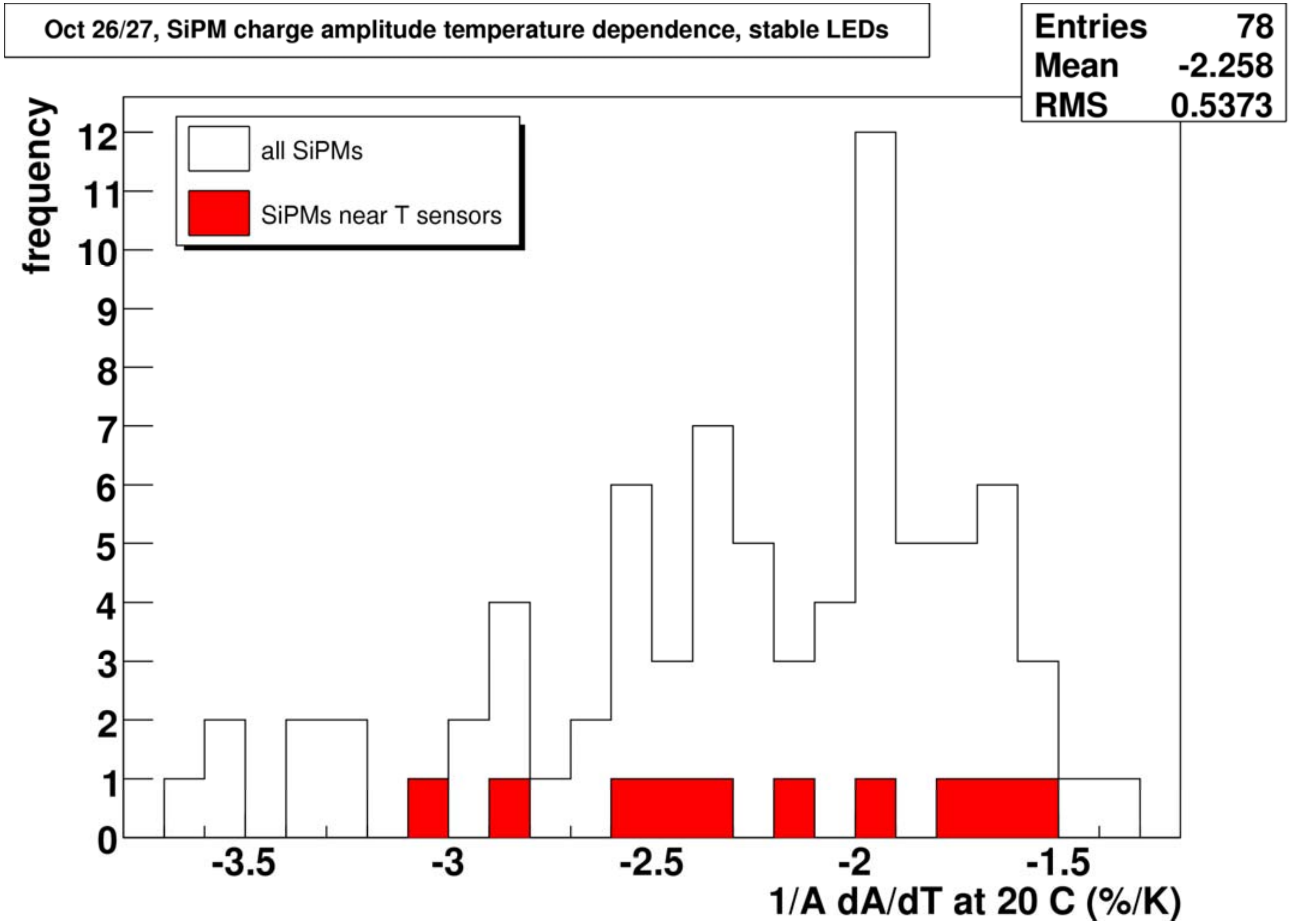
15(1)

$$\frac{1}{A}\frac{dA}{dT} = (1 - \epsilon\, px)\frac{1}{pe}\frac{dpe}{dT} + \frac{1}{G}\frac{dG}{dT}$$

Module	Chip	Channel	$\frac{1}{A}\frac{dA}{dT}(15\ px)$	$\frac{1}{A}\frac{dA}{dT}(LED)$
11	11	7	$-2.3(3)\%/K$	$-1.71(1)\%/K$
11	11	8	$-2.5(2)\%/K$	$-2.14(1)\%/K$
11	11	15	$-2.8(2)\%/K$	$-2.43(2)\%/K$

to do: comparison with Moscow coefficients

(which tend to be higher)



Correction factor for physics analysis:

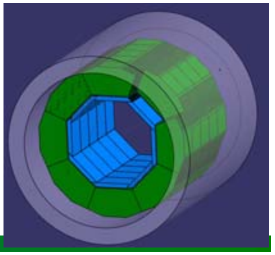
$$A(T) = A(T_0)\left(1 + \Delta T \frac{1}{A(T_0)} \left.\frac{dA}{dT}\right|_{T_0}\right)$$

Summary

- a procedure to correct the HCAL temperature dependence was presented
- gain, efficiency and amplitude T dependence was measured
- amplitude T dependence depends on amplitude
- only <2% of channels measured so far
  - rest has unstable LED
  - PIN diode correction needs knowledge of PIN pedestal vs. V_{calib}
- Next:
  - application to MIP
  - comparison with Moscow measurements
  - a writeup will be available

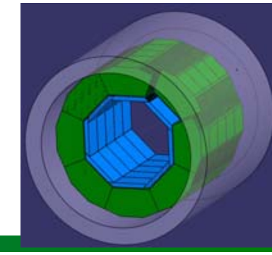
Study MIP at different bias-V

Understand performance



- We need to understand quantitatively the impact of calibration uncertainties on the performance
  - To guide and focus our efforts
  - To provide feedback to detector developers
- Implement detector effects in simulation / digitisation
  - Noise
  - SiPM non-linearity
  - Calibration uncertainty
    - MIP, gain, response function systematics
    - Incoherent (random), coherent (temperature effects)
- Reproduce observed resolution
  - As function of energy: impact on stochastic, noise, constant terms
- Study sensitivity to potential improvements or simplifications

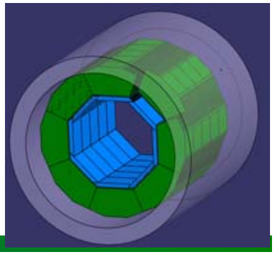
Technological options



- Optical signal distribution
  - central pulser and light source (one or few per layer)
  - Minimized cross-talk to readout (photo-sensors and FEE)
  - Monitoring of light source possible
  - Most frequently made choice, experience
- Electrical signal distribution
  - Many pulsers and LEDs, one per single or few channels
  - Avoids optical coupling problems (stability, uniformity)
  - Can work with very small electrical and optical pulses
  - Not yet tried
- NB: nobody* works on optical signal distribution so far

*** HCAL**

Summary: projects



- Calibration concept:
  - MIPs from hadron showers, test beam and ILC

- Monitoring concept:
  - Develop and validate temperature corrections

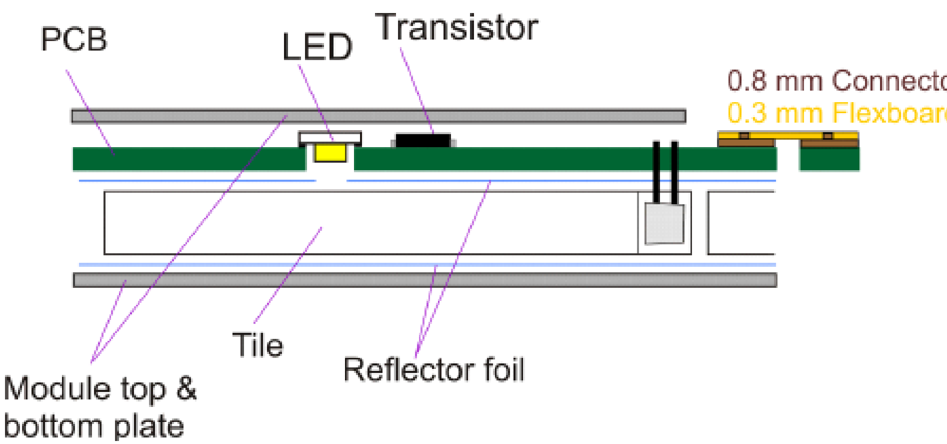
- Understand performance:
  - Model the data and guide the optimization

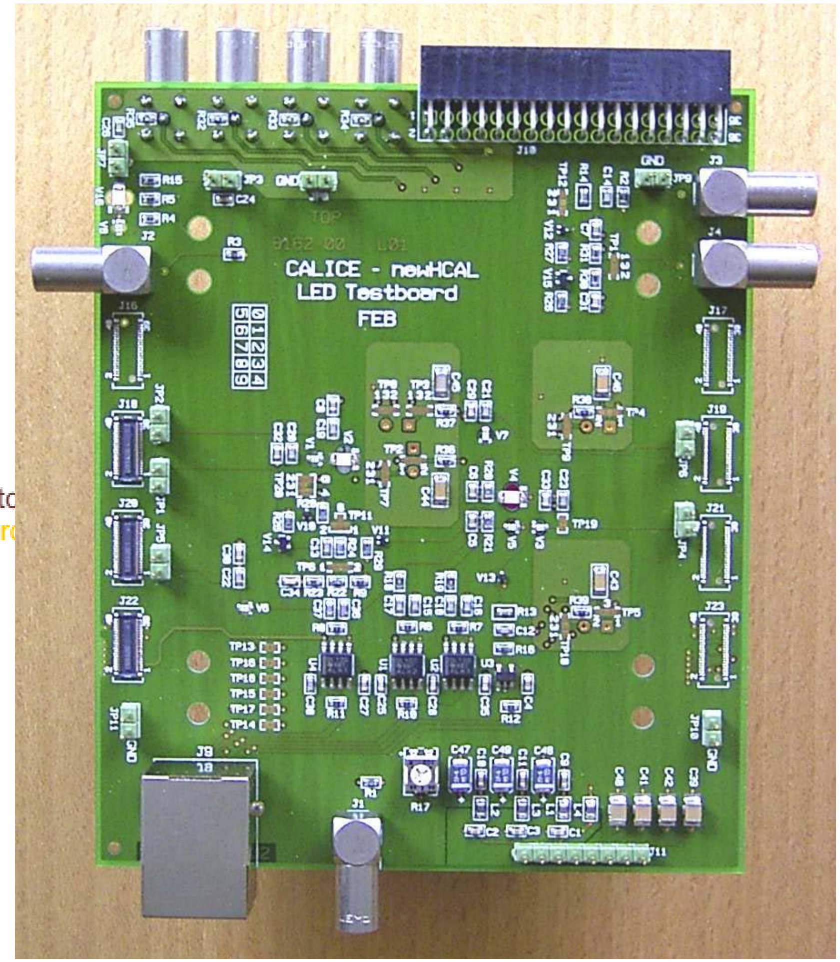
- Technologies:
  - Develop light injection system for large scale application

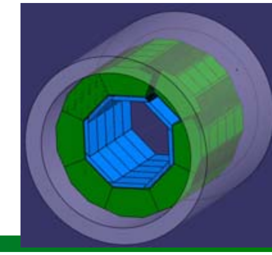
Backup slides

LED test board

- Proof-of-principle, check for cross-talk, uniformity, heat
- Test also
  - Different driver schematics
  - Small connector
  - SiPM coupling







Way forward

- Define procedures
  - and stick to them – even if they are not perfect yet
- Make tools available in a form such that we can ask old and new collaborators for help
- Define validity ranges

- Make results available in a central place
  - data base, n-tuple, flat file,…
  - such that we can study correlations

- Conceptual studies focus on 2006 while 2007 clean-up goes on

- Assess accuracies, maybe GOTO 1