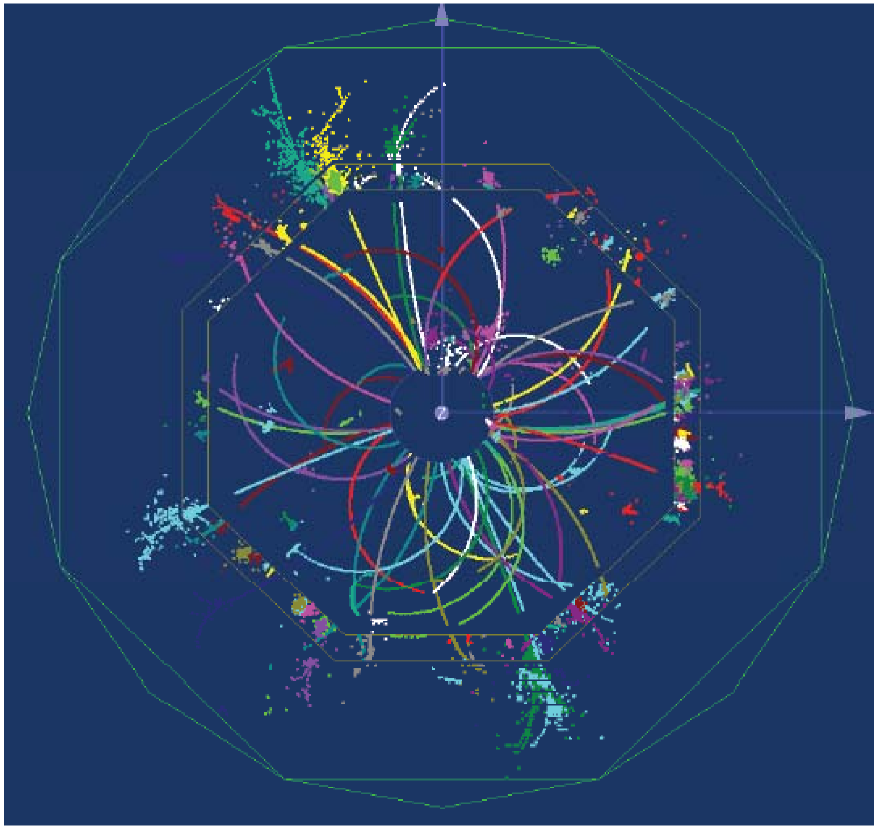


Scintillator HCAL read-out and calibration

Felix Sefkow

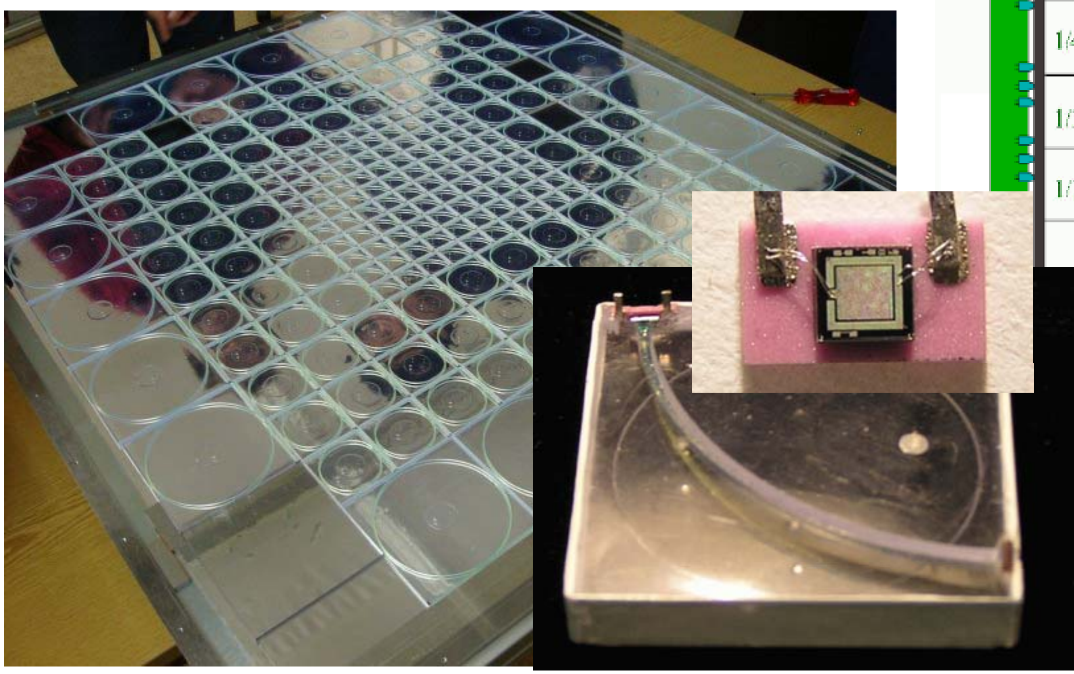
TILC08 at Sendai, Japan
March 4, 2008

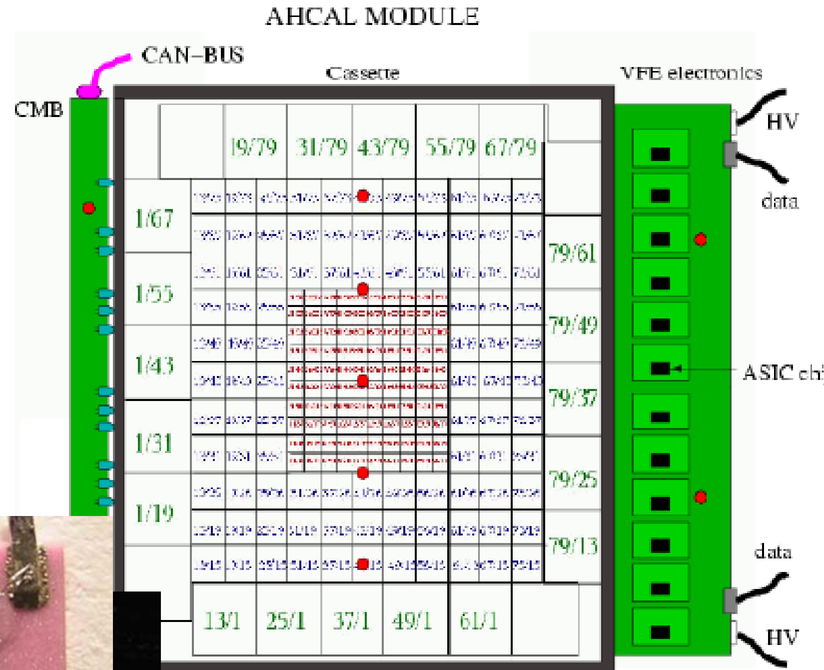
Outline

- Test beam
- Calibration and monitoring methods
- New read-out electronics under test

Scintillator HCAL prototype

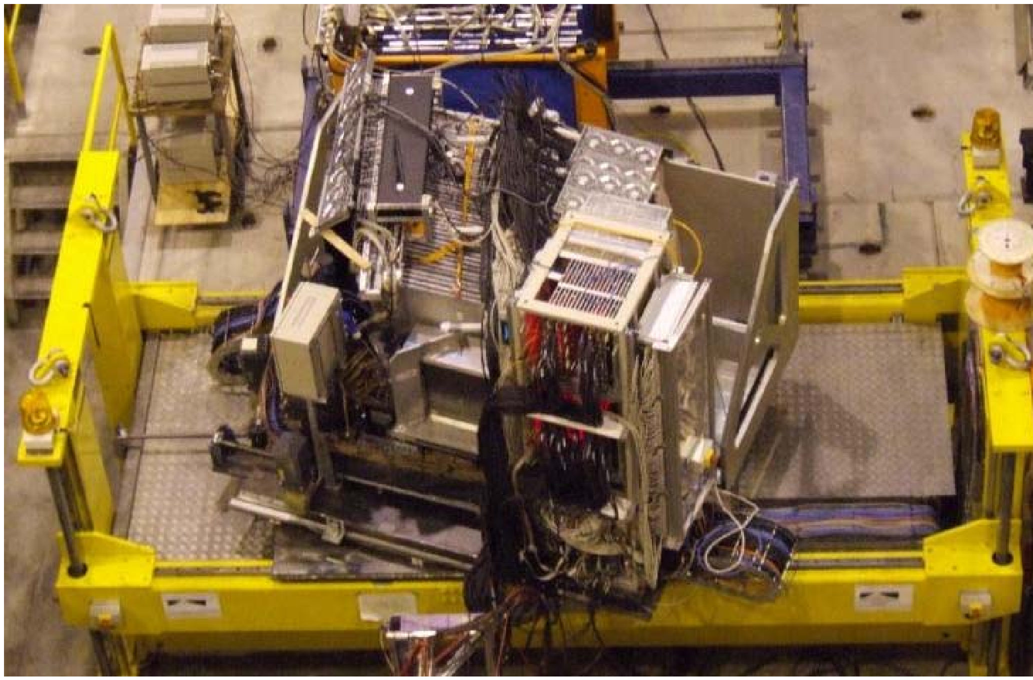
- Steel scintillator sandwich
- 38 layers, 2cm steel absorbers
- Scintillator tiles 3x3x0.5cm^3
- 7608 SiPMs (MEPhI / Pulsar)

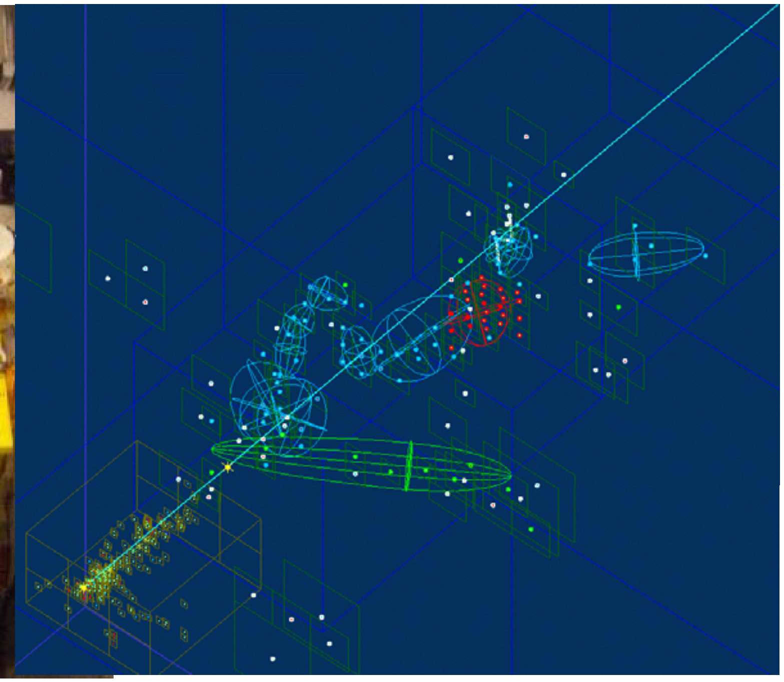




Versatile calibration and monitoring system

Test beam experience

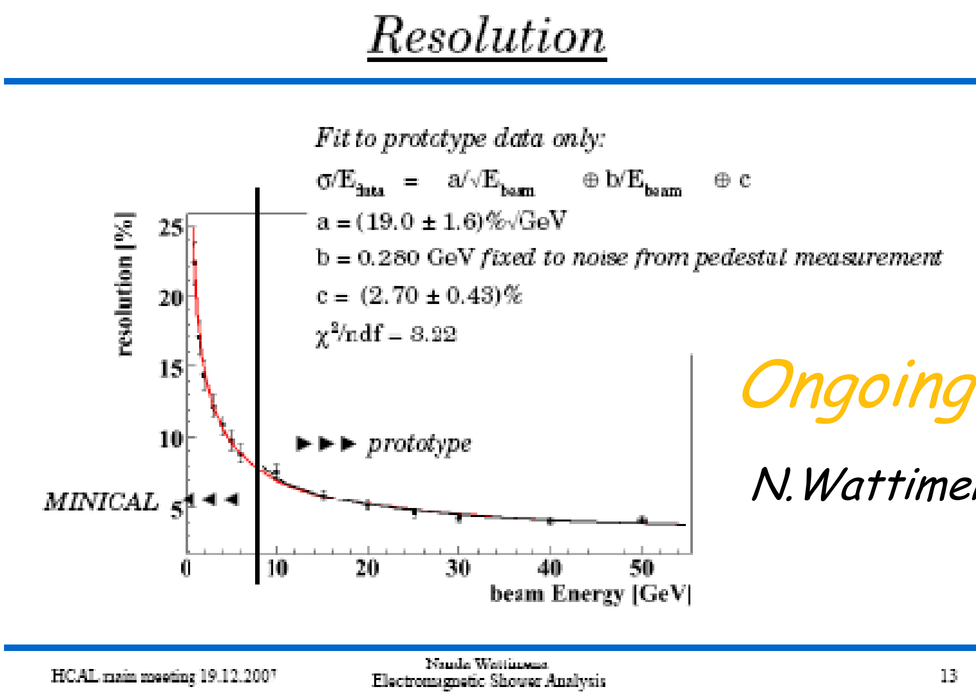




- Established the scintillator SiPM technology on large scale (7608 SiPMs)
  - Robust and stable operation, 95% up-time, 1.6% dead channels (mostly solder)
  - Noise occupancy 10^{-3} as expected, 0.8 MIP = 25 MeV / hit
  - Imaging capability nicely demonstrated, millions of events collected

Analysis ongoing

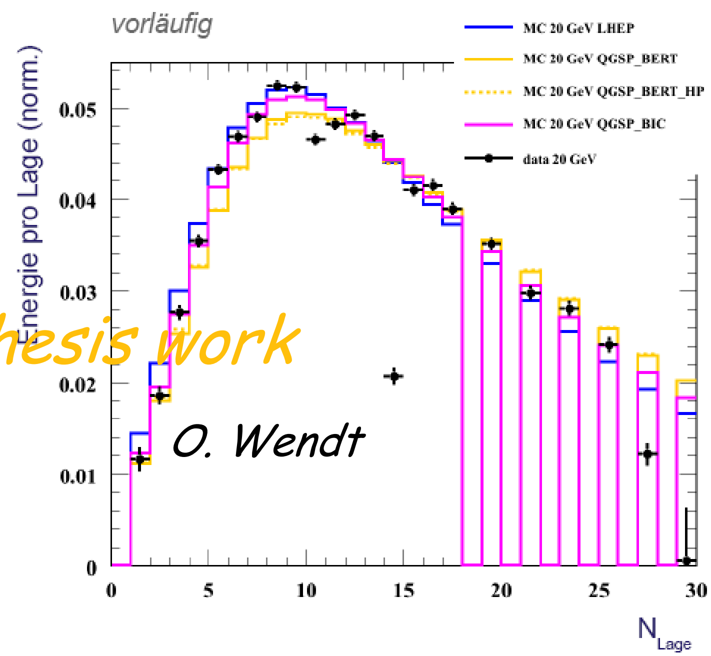
- Electromagnetic showers: Verify detector model and calibration procedures
- Hadrons: test simulation models and particle flow performance



Ongoing thesis work

N.Wattimena

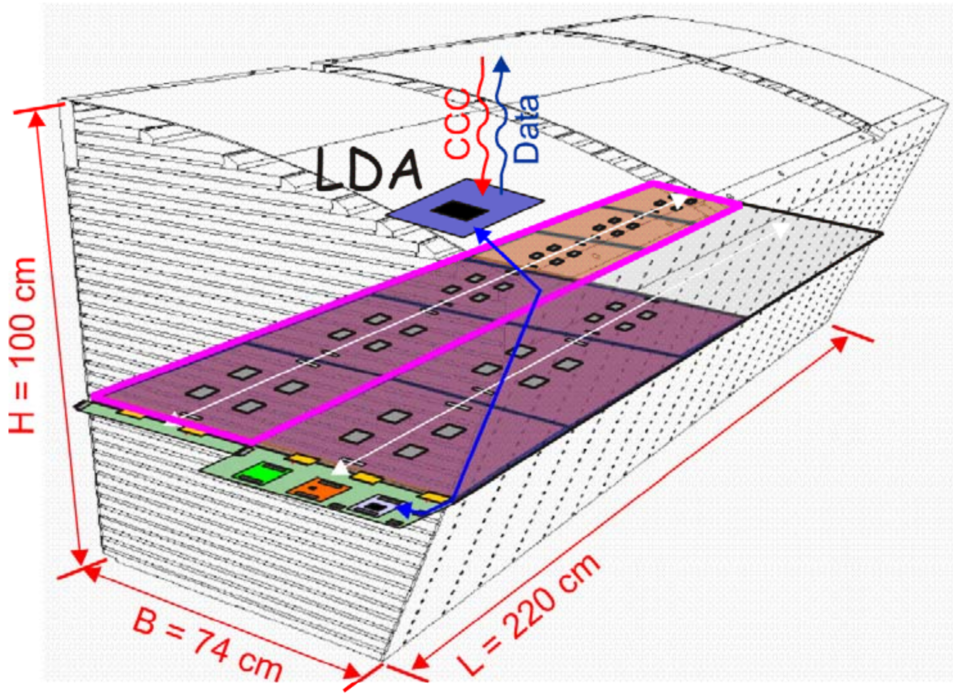
O. Wendt



Next: technical prototype

- Goal: A compact and realistic (i.e. scaleable) scintillator HCAL structure with embedded electronics

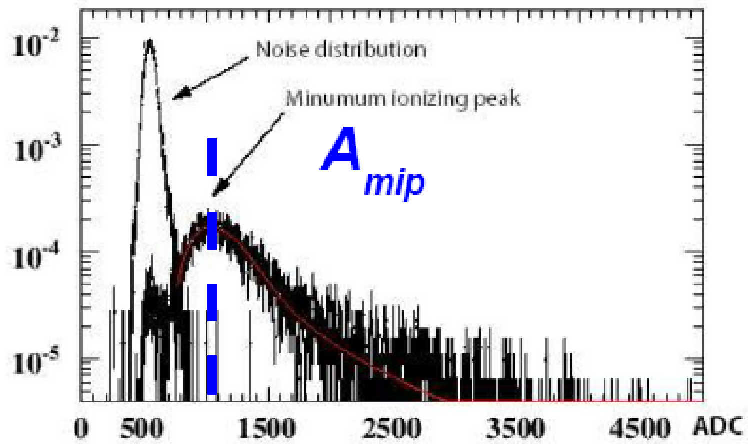
- Integration issues
  - Readout architecture
  - Ultra-low power ASICs
  - Calibration system
  - Tile and SiPM integration
  - Absorber mechanics with minimal cracks
- See V.Zutshi's talk

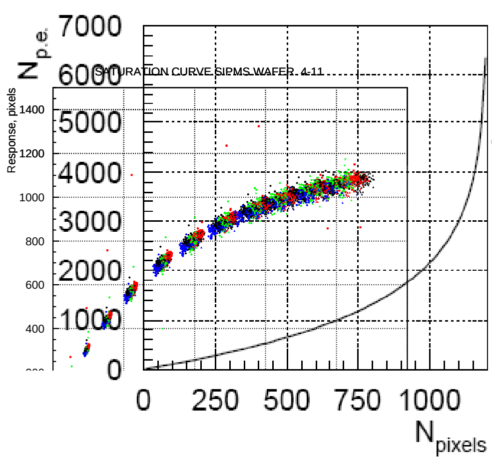


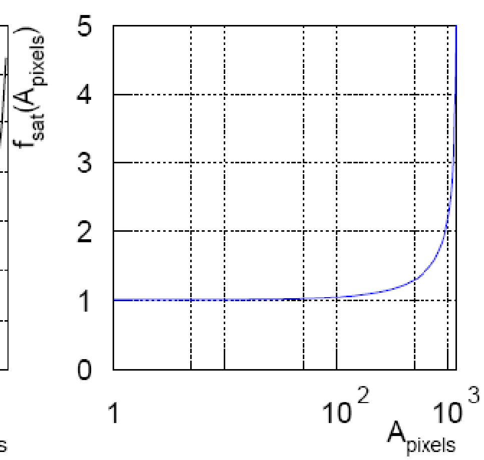
- Feed-back from test beam essential
  - Calibration concept

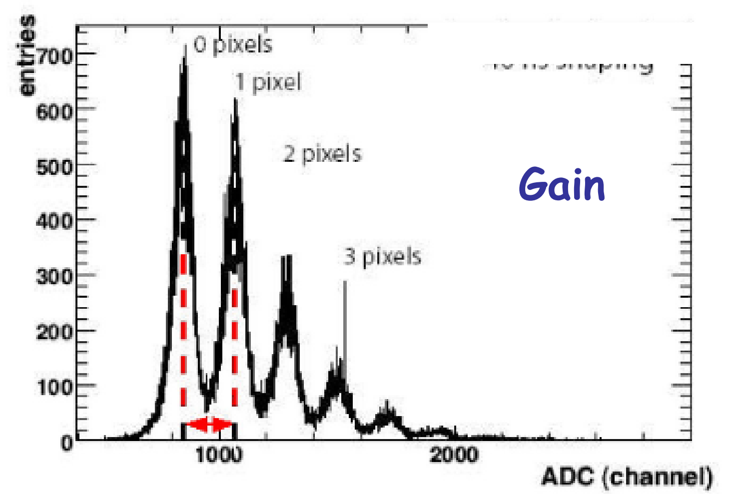
Calibration

- Pixel photo-diode is non-linear: need 2 reference scales
  - MIP: muon test beam
  - Gain: low intensity LED light
- Energy deposition
  - $E[MIP] = A / A_{MIP} * f (A / A_{pixel})$
- Saturation correction f



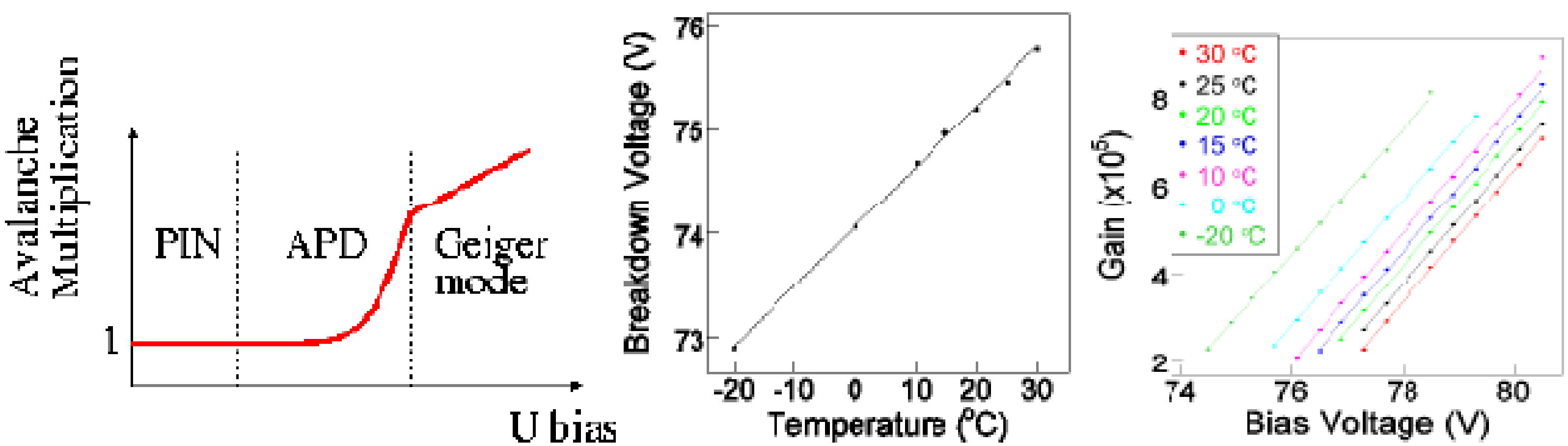






Temperature and voltage

- Signal (charge) depends on gain and Geiger efficiency: $A \sim \varepsilon * G$
- Both depend on overvoltage $\Delta U = U_{bias} - U_{breakdown}$
- Breakdown voltage $U_{breakdown}$ depends on temperature

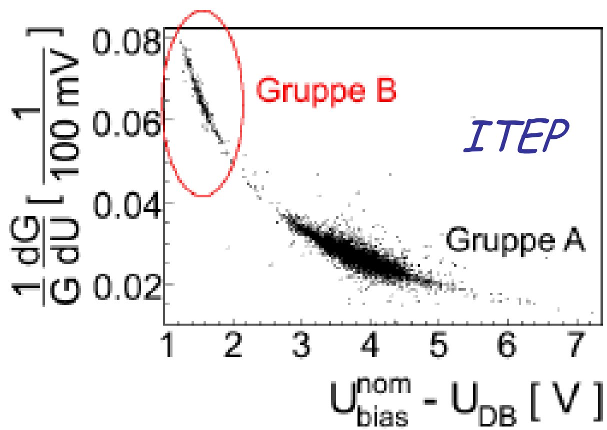


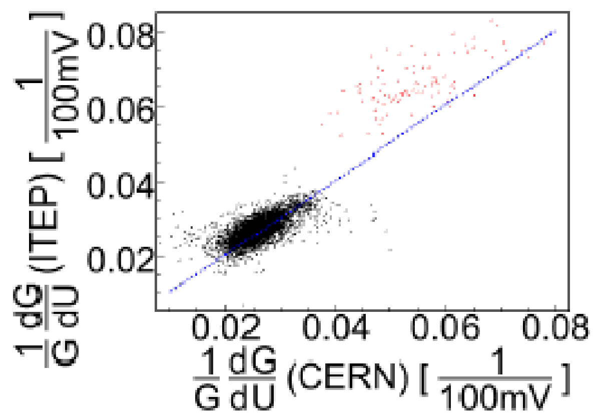
Figures: S.Uozumi

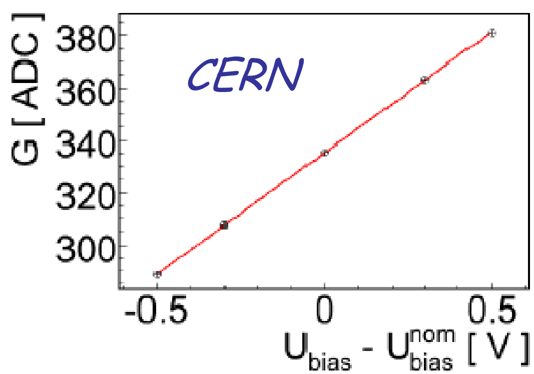
- For x = A, G: $dx/dT = - dx/dU * dU_{breakdown}/dT$
- Ratio of amplitude and gain coefficient is the same for U and T dependence

Voltage dependence

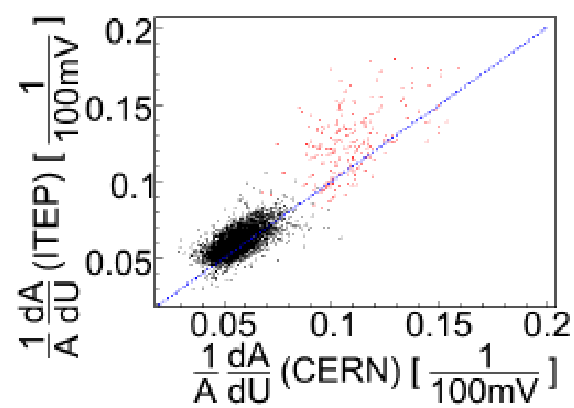
- Measured for A and G at ITEP test bench, stored in data base
- Reproduced in CERN test beam set-up





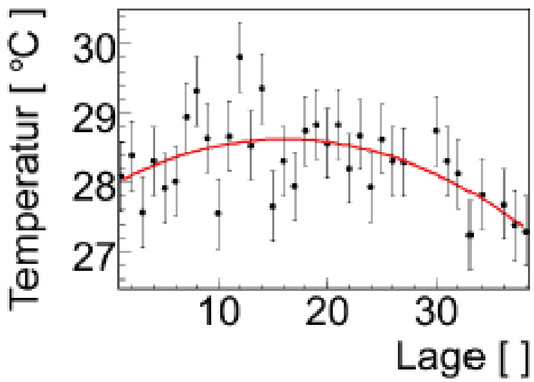


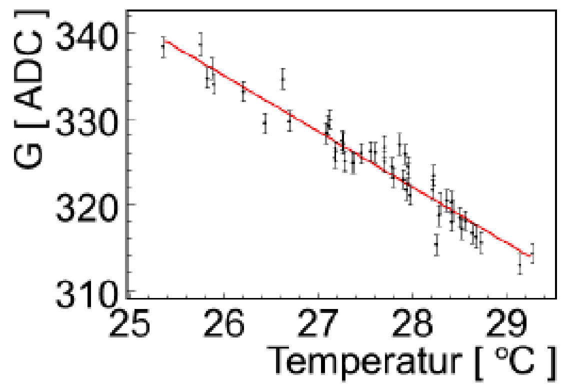
This and following slides: N.Feege, A.Kaplan

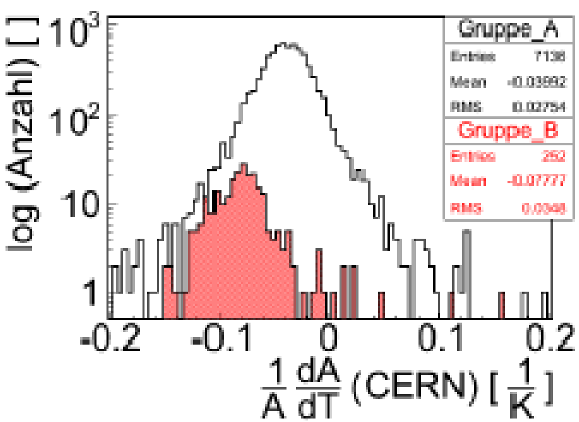


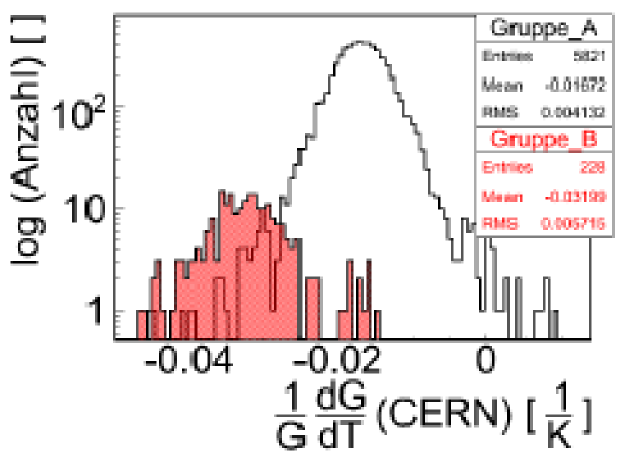
Temperature dependence

- Measured in test-beam only







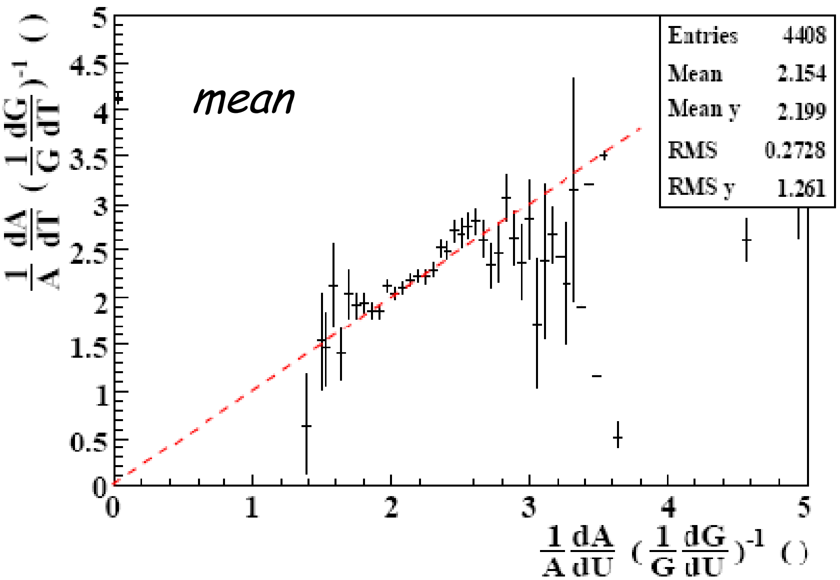


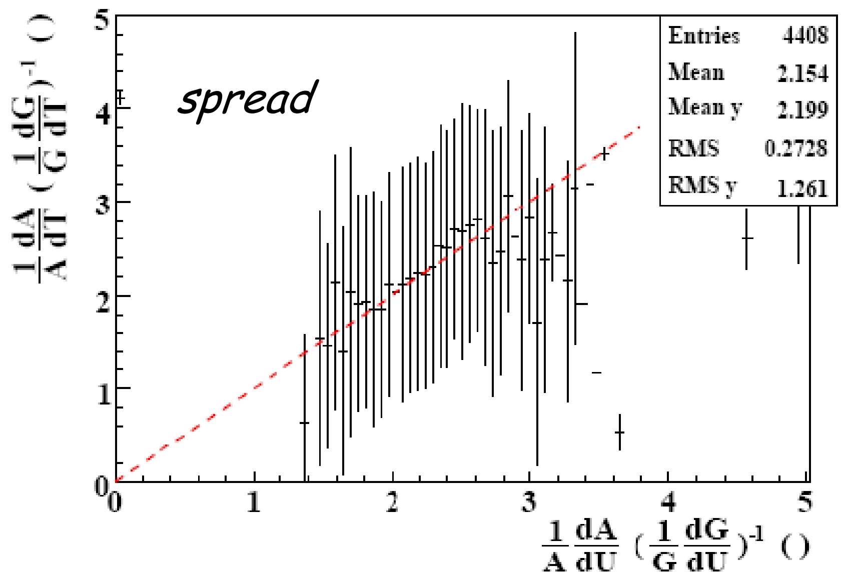
Red: low ΔU group

Amplitude and gain coeff.s

- Check model: dA/dT / dG/dT = dA/dU / dG/dU ?

- Mean (norm) -4.0 -1.7 5.6 -2.6 %/(K or 0.1V)
- RMS (norm) 2.8* 0.4 0.8 0.4



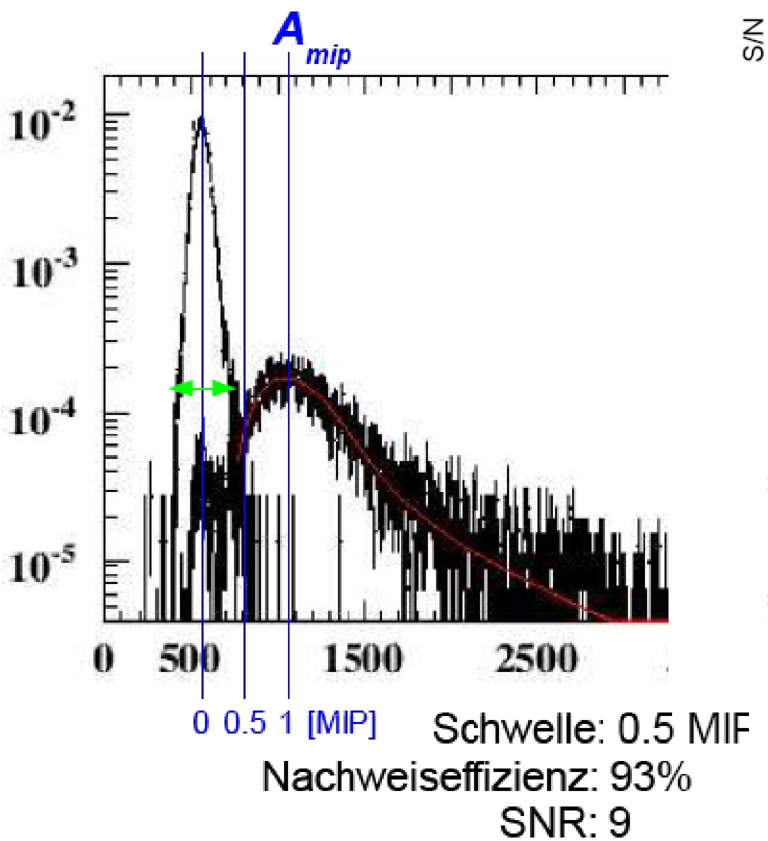


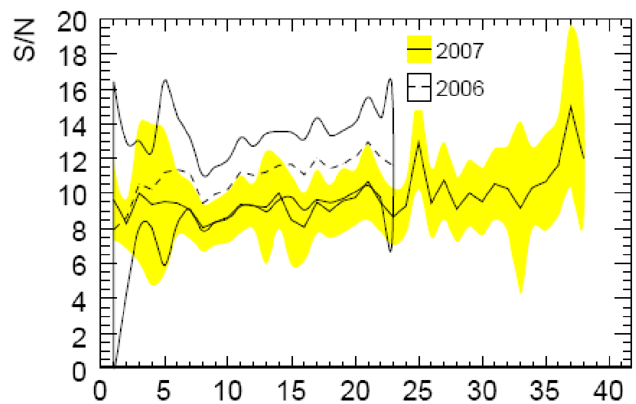
Correction methods

- Temperature correction: $x = x_0$ [1 + dx/xdT $(T-T_0)$] ,   x = A, G
  - Instantaneous, but non-local
- Gain correction $A = A_0$ [1 + { dA/AdU / dG/GdU } $(G-G_0)$]
  - Local, but not instantaneous
- Combination of both – all to be tried
  - Success not guarenteed – may introduce additional errors
- Voltage adjustment $U = U_0 + (G - G_0) / dG/dU$
  - More radical, but most effective

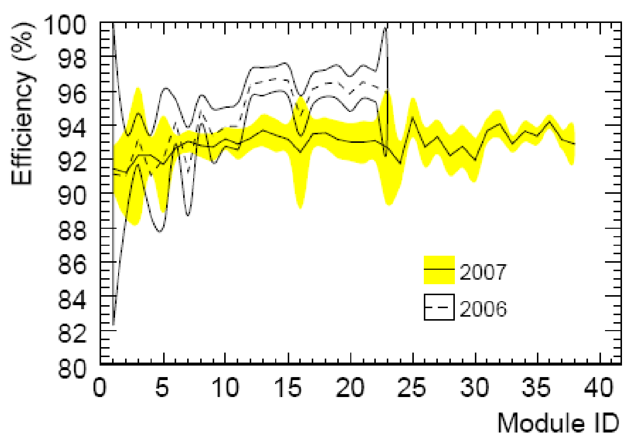
Bias working point

- Critical for signal / noise optimization, not recoverable offline





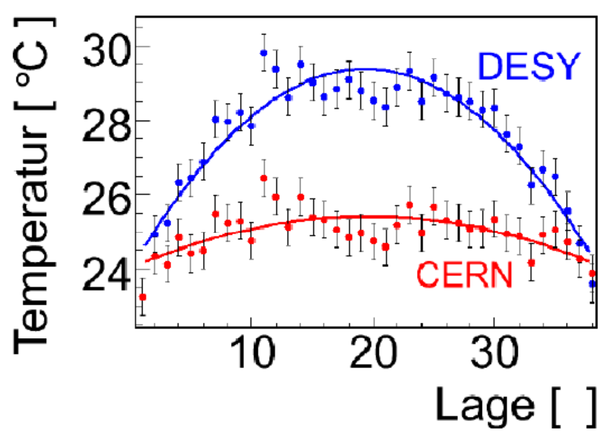
Derived from
Light yield = A/G

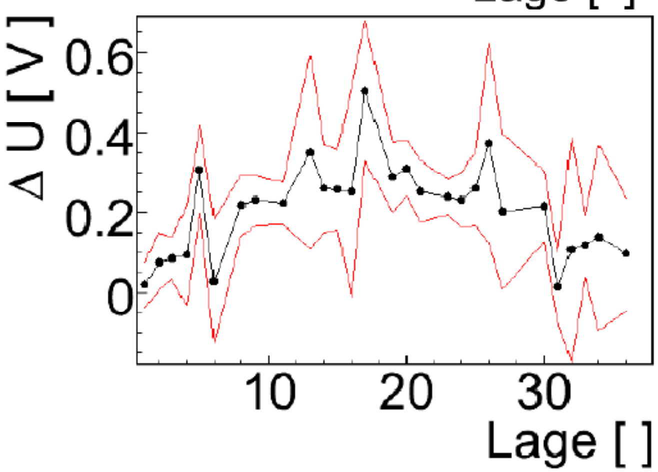


N.D'Ascenzo

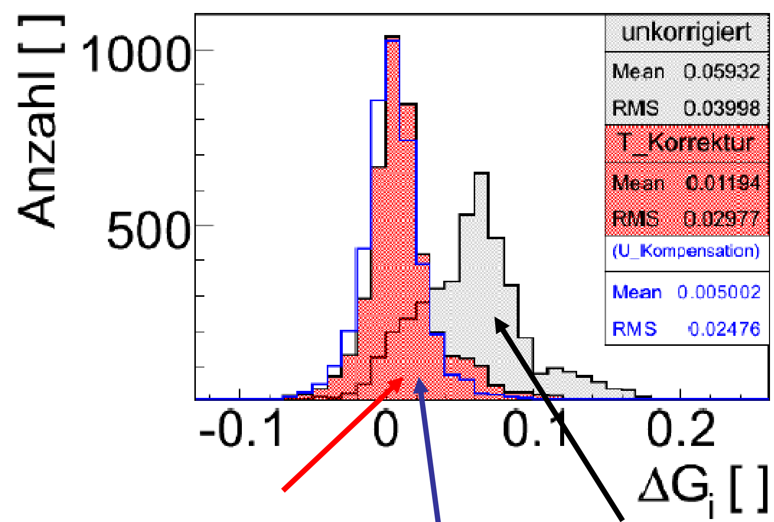
Voltage adjustment

- Test beam preparation at DESY vs. CERN





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



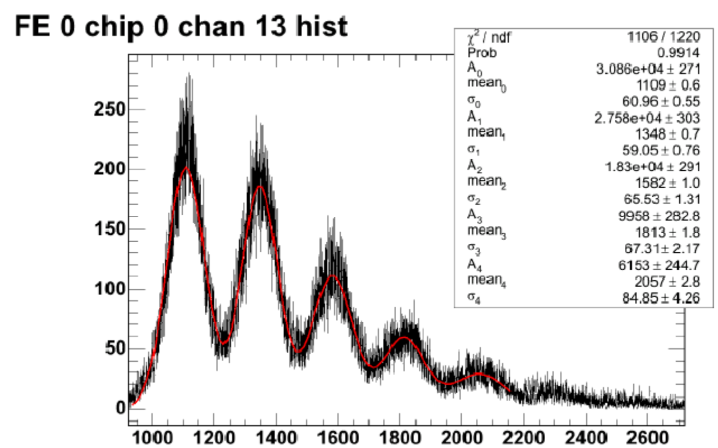
Temperature-corrected

observed

Voltage-corrected (prediction)

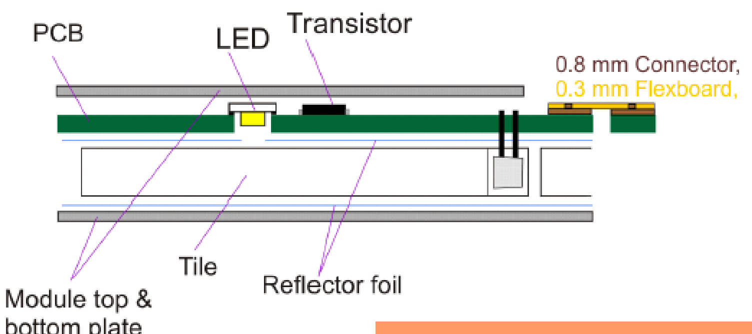
Auto-calibration

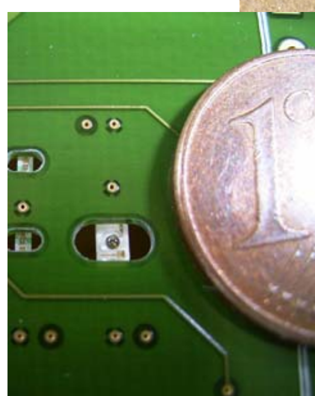
- With single photo-electron (pixel) peaks the pixel photo-diode provides its own reference scale
- Promising tool for monitoring temperature-induced response variations
- Opens possibilities for further simplification of calorimeter design
  - No external reference
  - Small amplitudes
  - Loose stability requirements
- Stability of saturation correction
  - Under study, so far OK

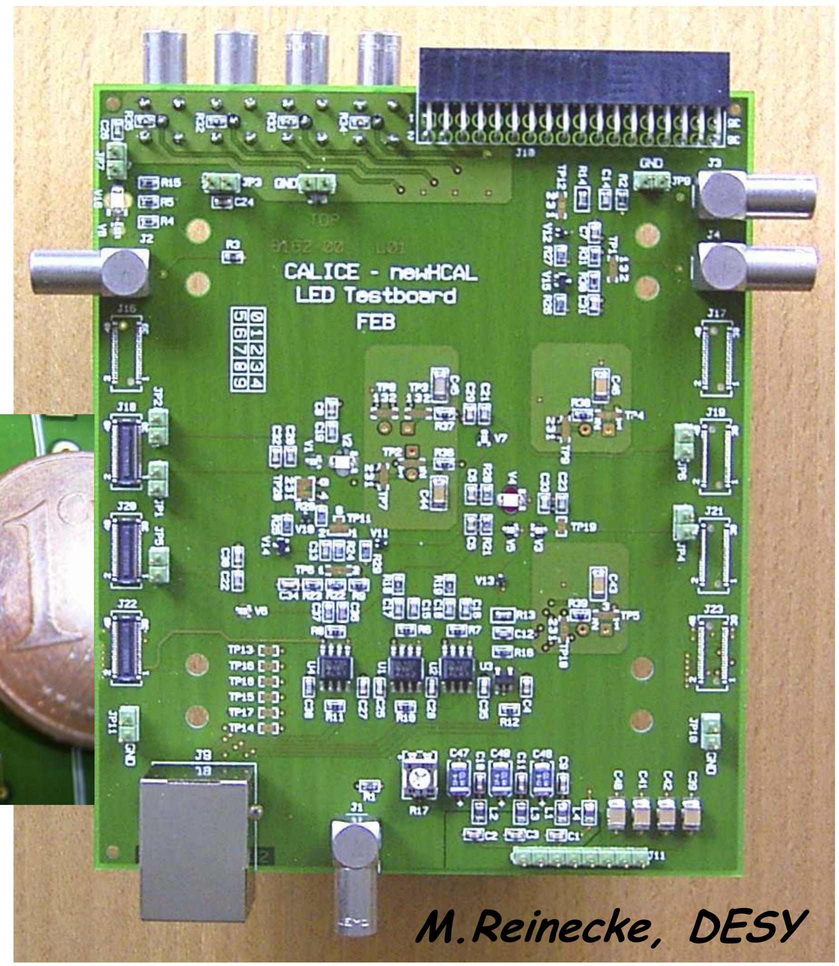


LED on board

- Attractive option - **if** auto-calibration of SiPM sufficient
- Proof-of-principle test borad, check for cross-talk, uniformity, dynamic range,...



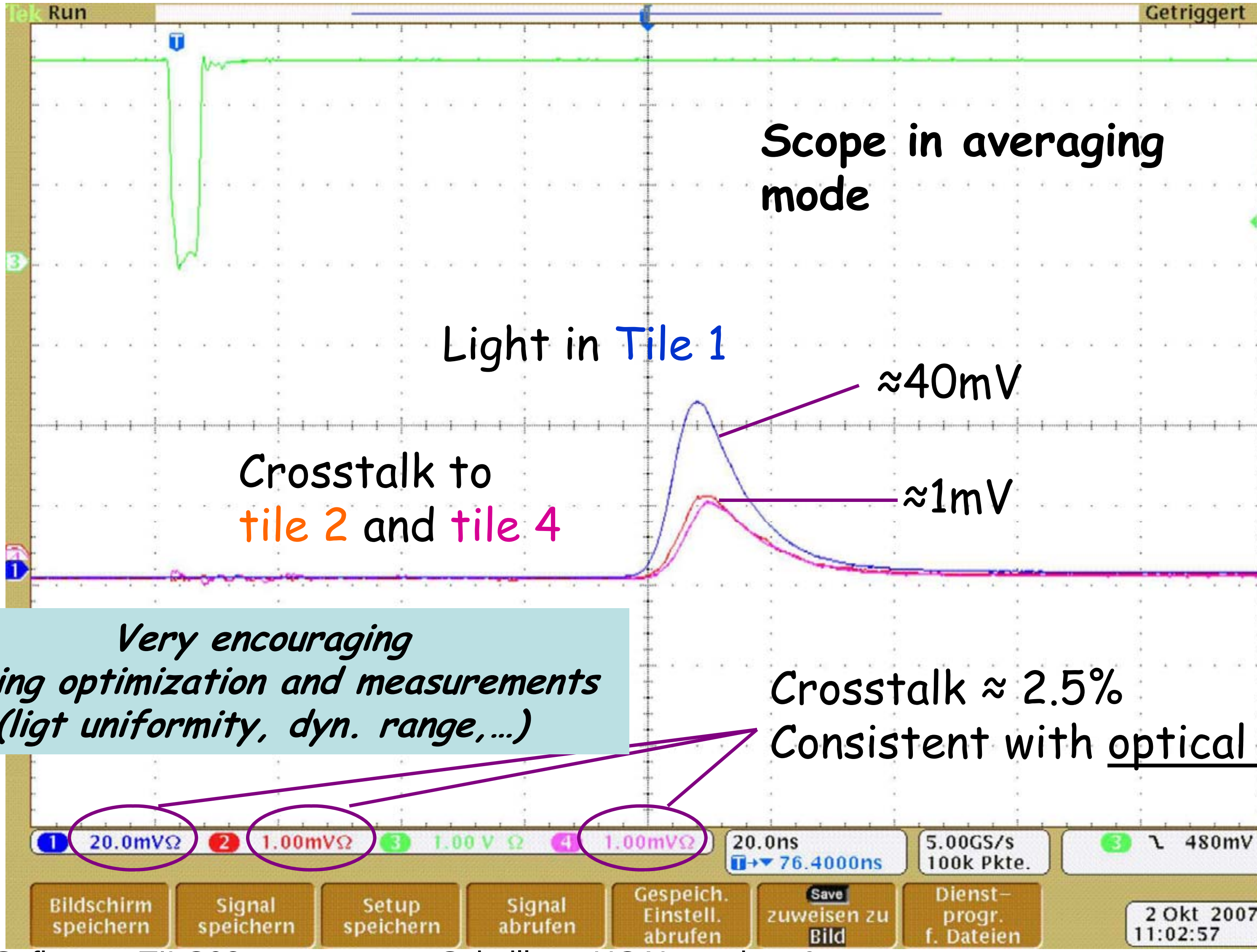




First tests:
electrical cross-talk small

Estimate Crosstalk

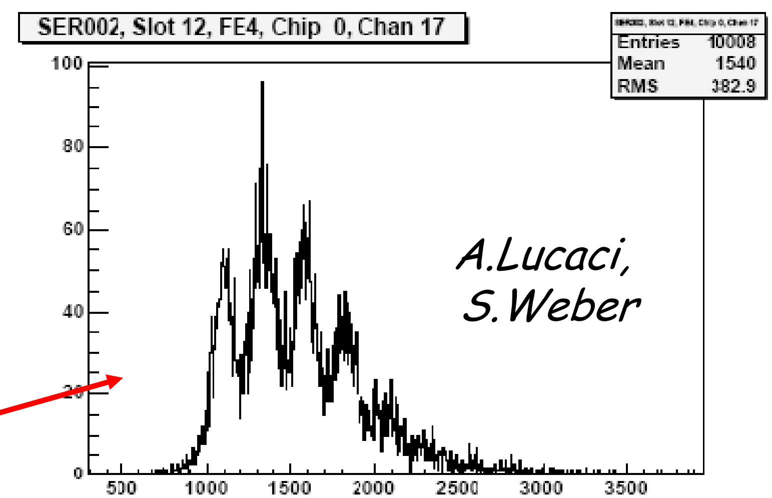
FEB



Very encouraging
Ongoing optimization and measurements
(ligt uniformity, dyn. range,…)

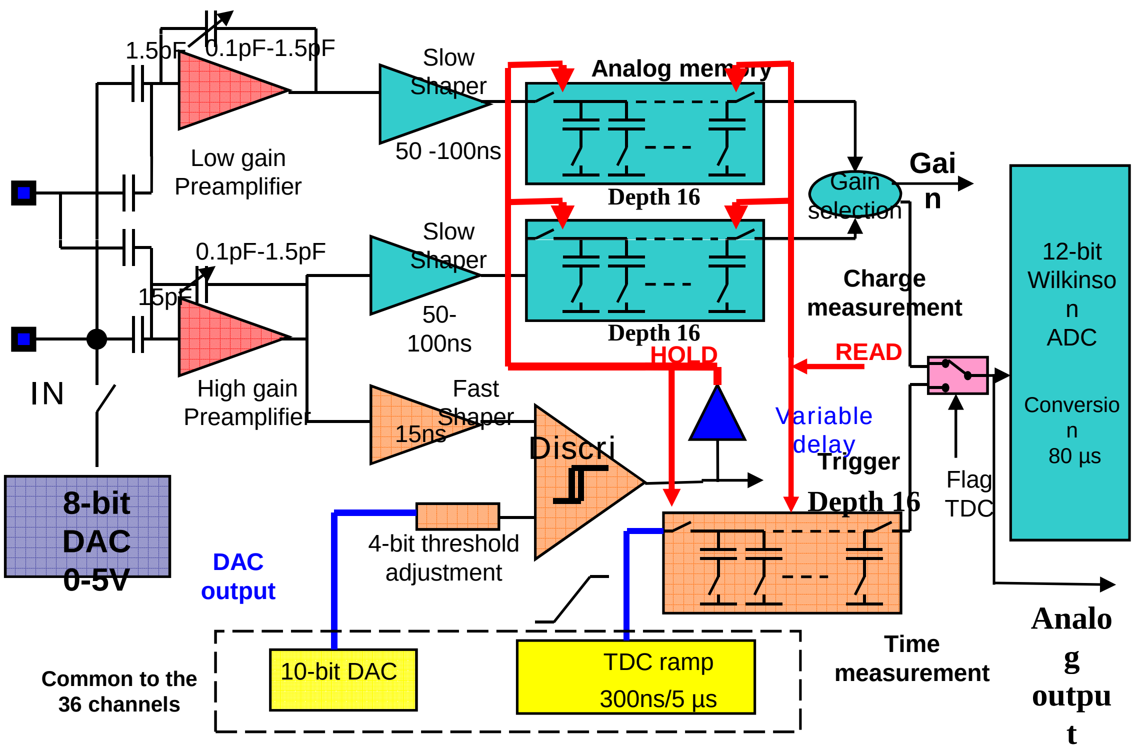
LEDs: to be continued

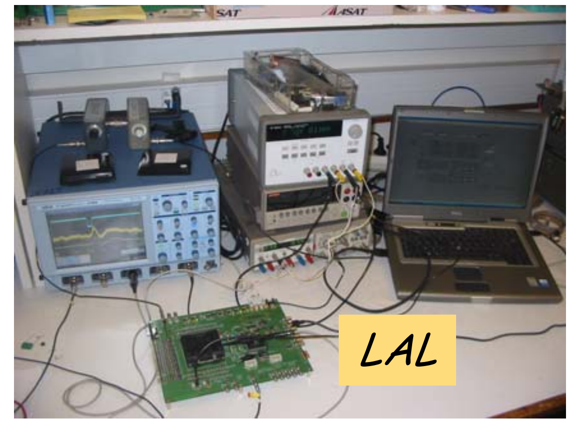
- Uniformity not yet sufficient (LED to LED variation)
  - Do not want to –remote- control or tune each driver
  - Discussions with manufacturer
  - Could in principle be solved with pre-selection
- Driver uniformity?
- Dynamic range – the more, the merrier
- Systematic investigation using CALICE DAQ
  - ILC-SiPM ASIC and CRC

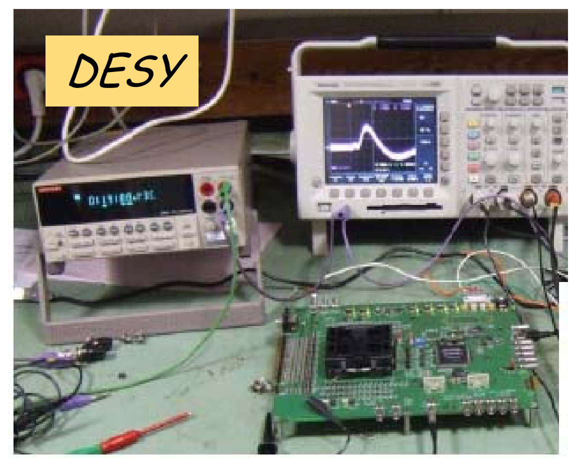


New ASIC on the test benches

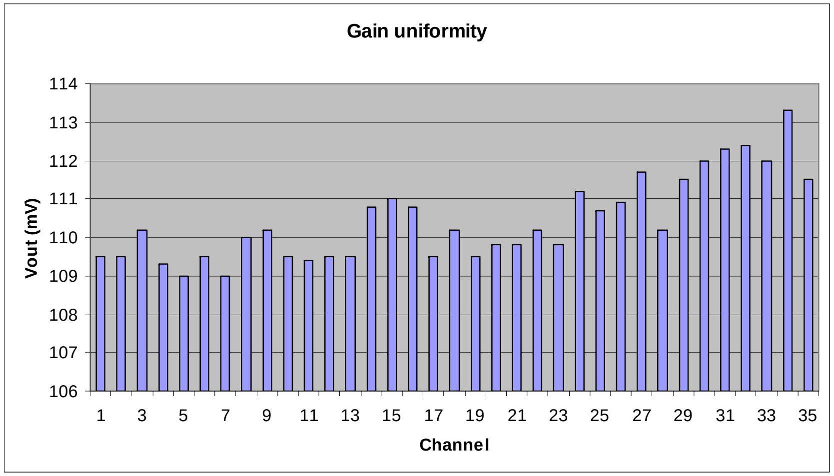
- Auto-triggering and time measurements
- ADC and TDC integrated
- Power pulsing, low (continuous) power DAC

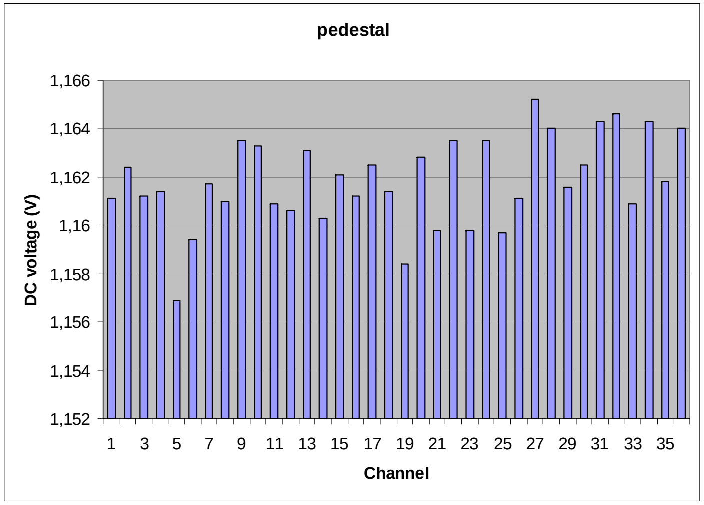


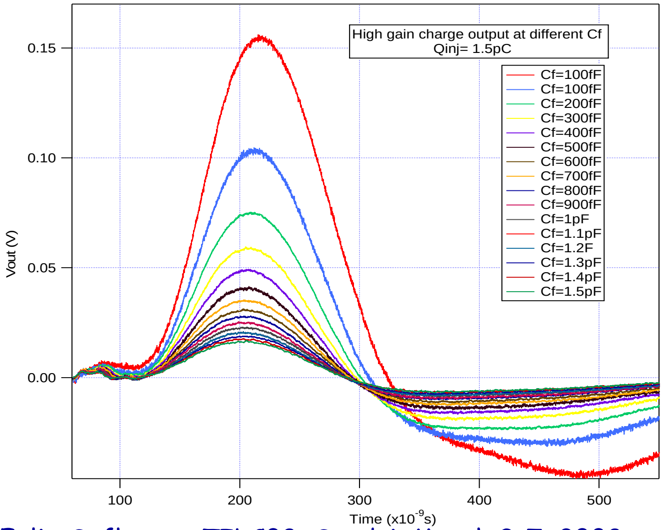




Analogue part





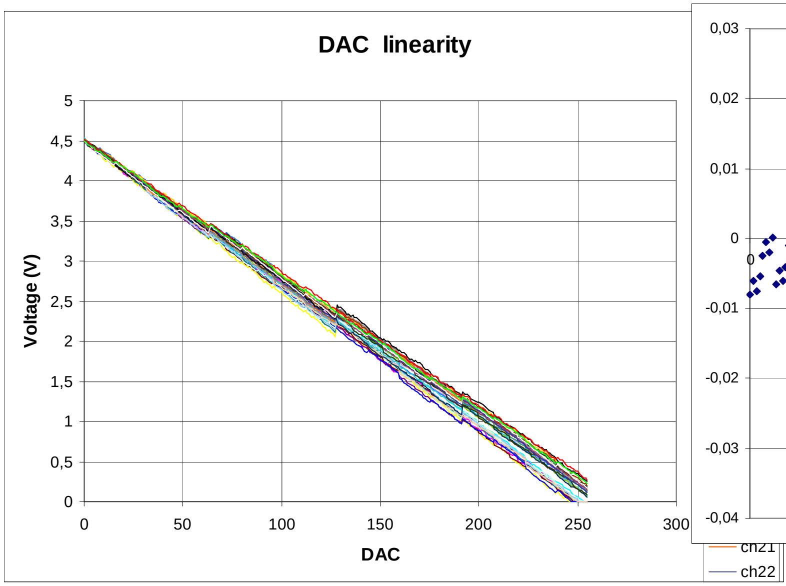


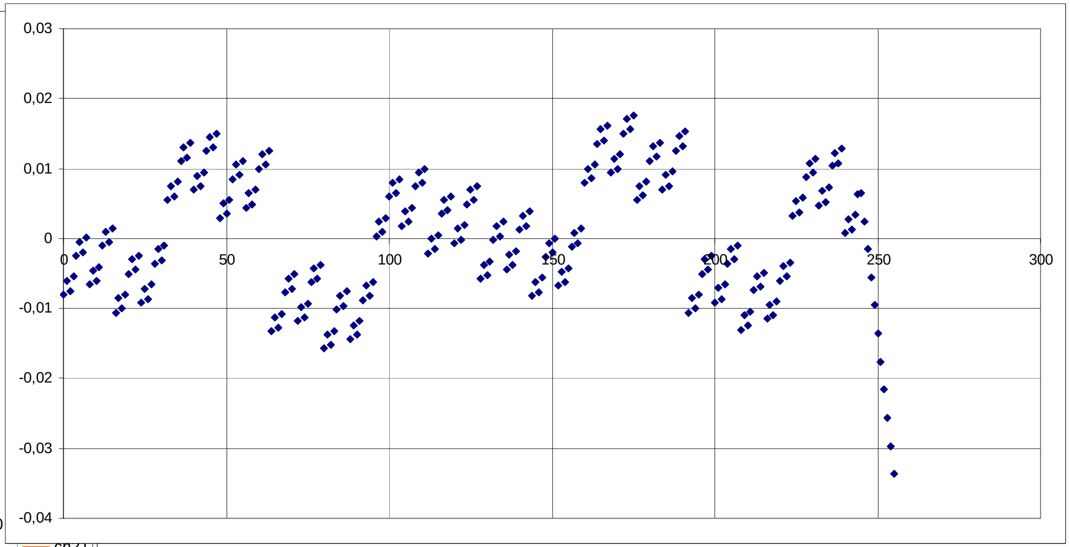
L.Raux, S.Callier

- Gain and pedestal uniformity good (as expected from SiGe 0.35)
- Somewhat smaller gain and larger noise than in simulation

Input DAC

- SiPM bias adjustment
- Must be extremely low power (~10µW), since always on!
- Non-linearity ~2%, just OK

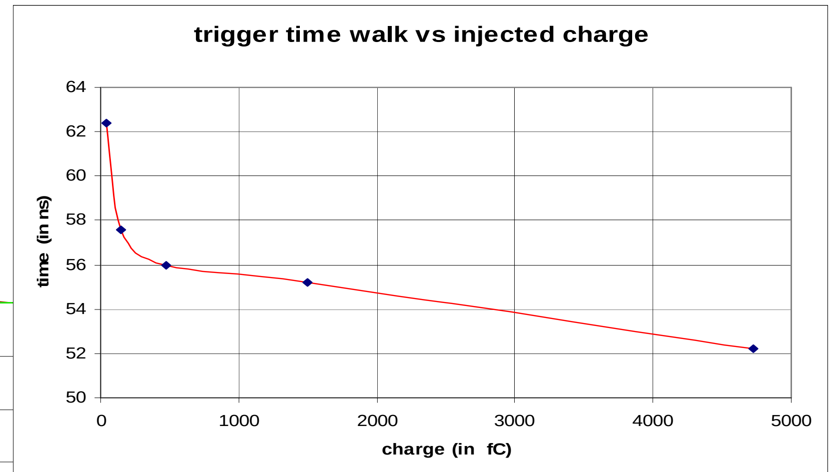


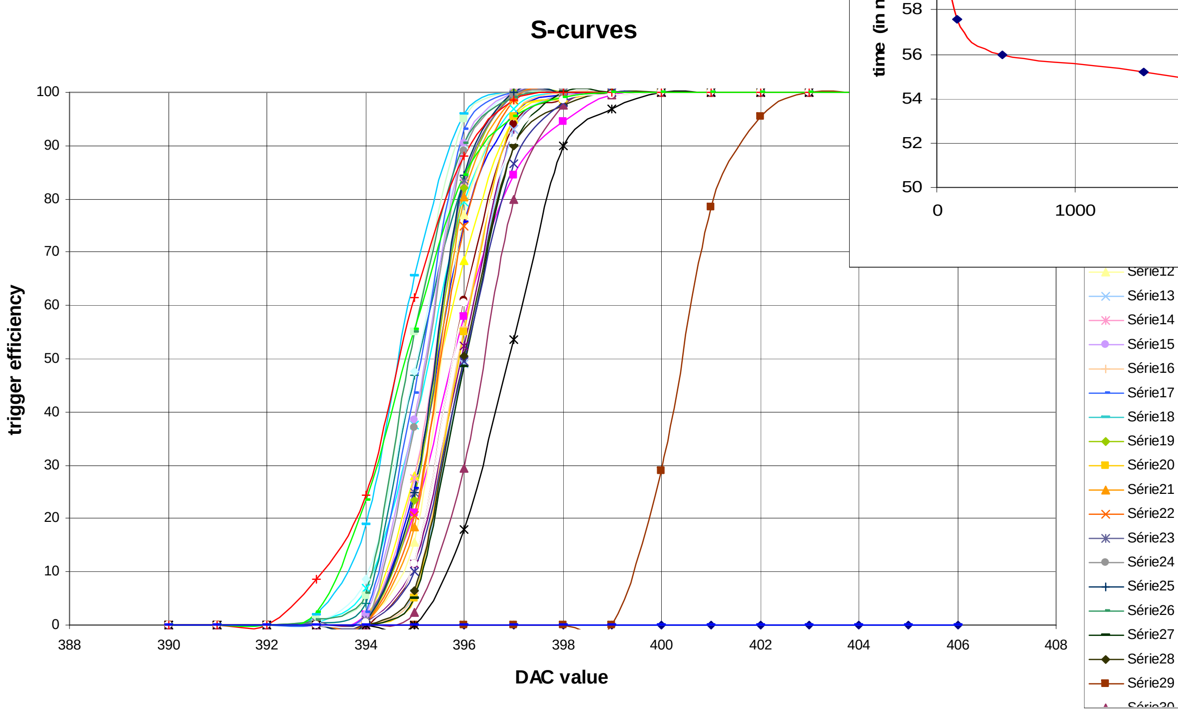


L.Raux, S.Callier

Autotrigger

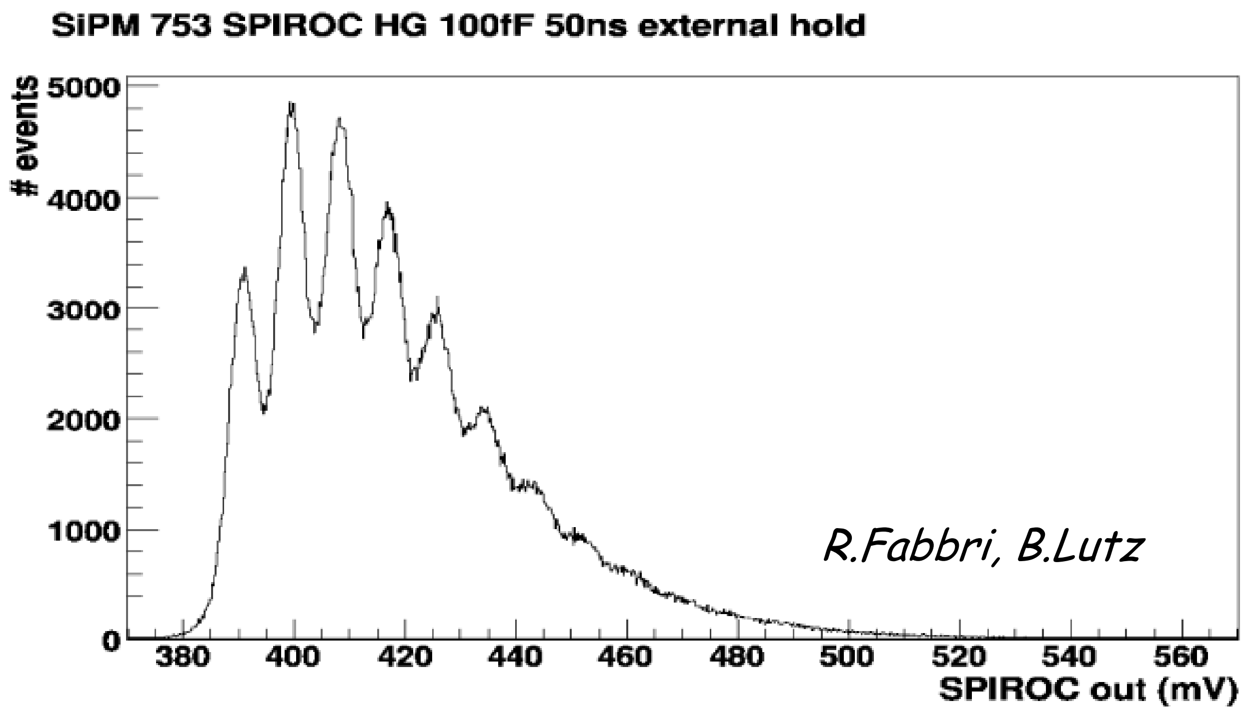
- Fast shaper (10ns) and discriminator
- Can triger on 0.5 p.e.
- Small threshold dispersion
- Cross-talk 0.3%
- Time walk 6ns





L.Raux, S.Callier

SPIROC meets SiPM



- Still a lot of tests to be done
- Understand response with auto-trigger, control thresholds
- Internal ADC not yet usable

Summary

- A nice concept for the 2nd generation HCAL prototype with embedded electronics and calibration system is emerging
- Readout with many new features
  - Auto-trigger (zero-suppression)
  - On-chip digitization
  - Time measurement
  - Power pulsing
- Auto-calibration of PPDs is a very powerful tool – but remains a challenge for sensor and electronics design
- Test beam experience vital and rich source to develop calibration concept

Back-up slides

Integrated layer design