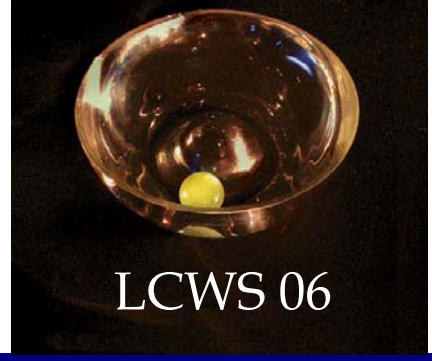
CALICE Calorimeter for ILC



Scintillator HCAL prototype commissioning and calibration

J.Cvach
Institute of Physics AS CR, Prague

DESY

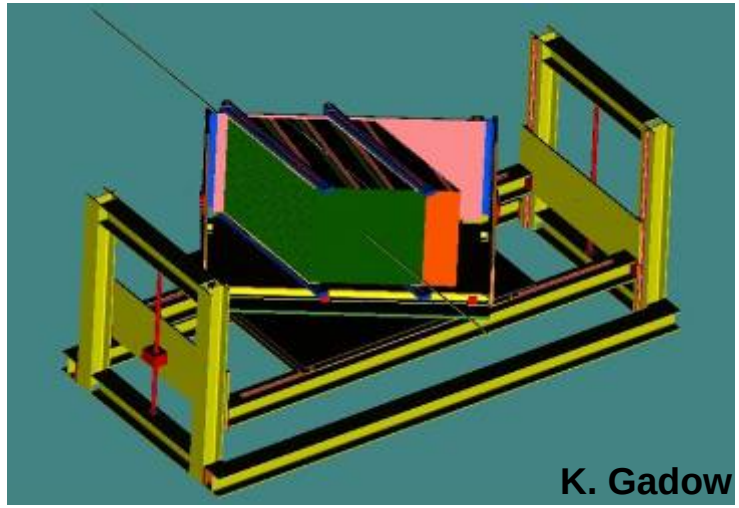
Fyzikální ústav Akademie věd ČR

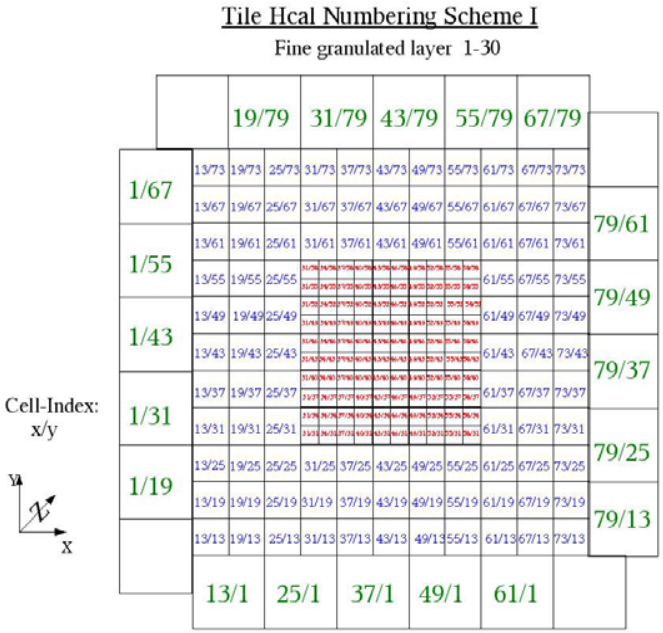
- Calibration basics
- Test results
- Outlook

HCAL test beam prototype

1 m^3 tile HCAL prototype: 38 modules ~ 8000 scintillator tiles equipped with SiPM

- module has a sandwich structure: scintillator plane + 2cm steel absorber plate
- at present 6 planes in tests, 4 planes under construction

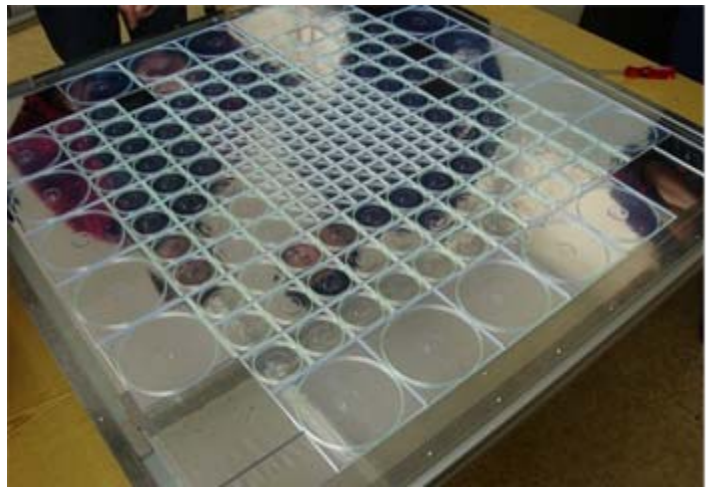




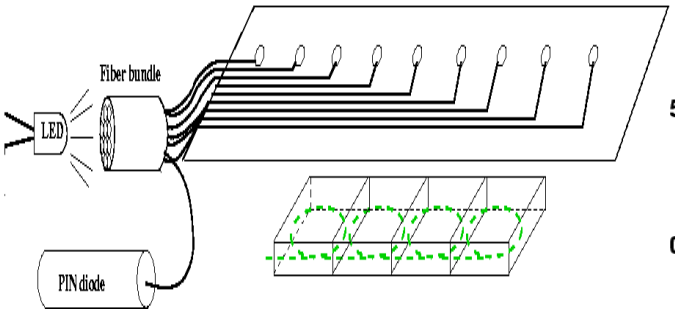
HCAL:
High granularity scintillator tiles

3x3cm^2 in the core with individual readout

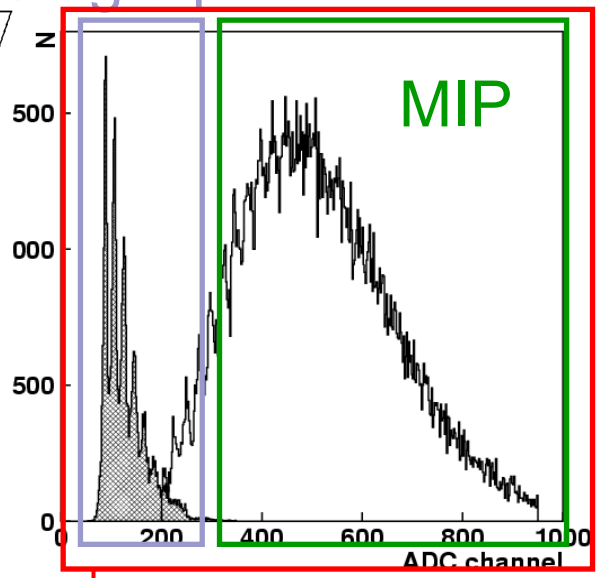
ECAL:
Silicon-tungsten
40 layers, 1x1cm^2

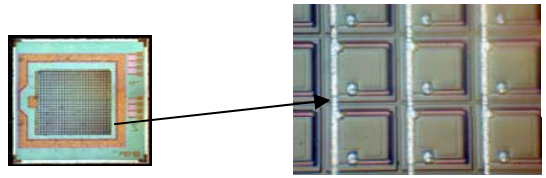


The calibration concept (each channel)

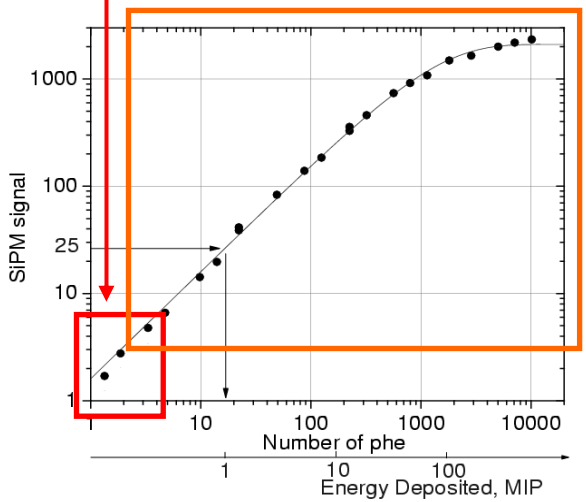


Single pixel





- MIP calibration
- Gain calibration: scintillator, pixel
- SiPM response function

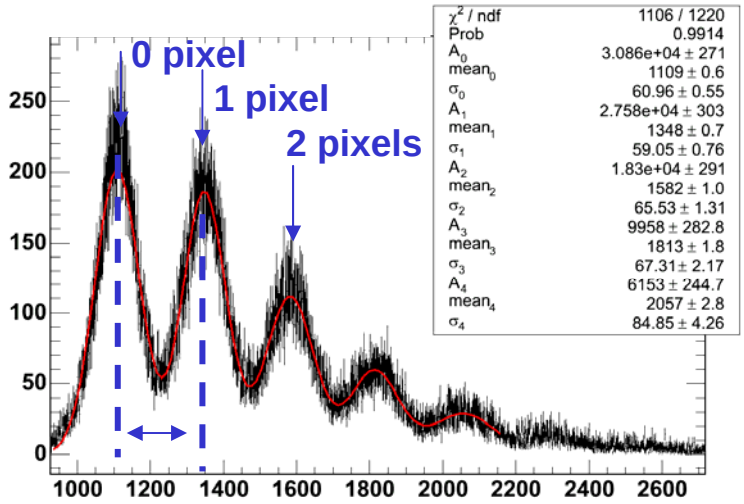


E (GeV) = A(ADC) *
px/ADC *
pe/px *
MIP/pe *
GeV/MIP

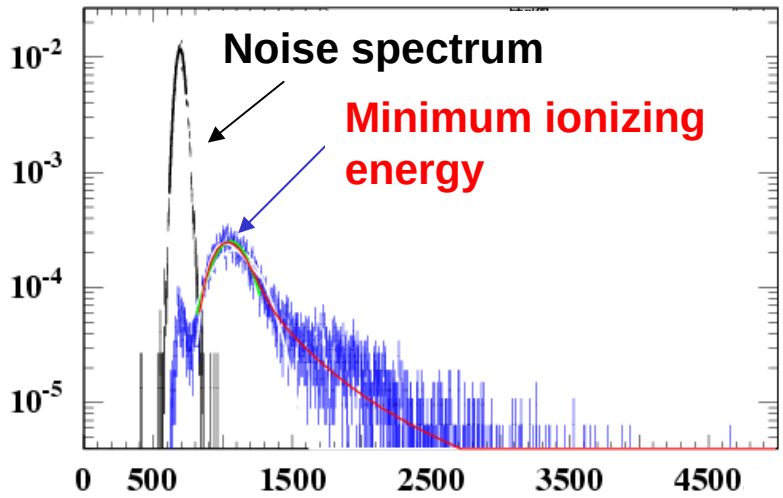
Energy = ADC-count *
electronics *
SiPM response *
Light yield *
sampling

Calibration procedure

SiPM gain calibration
with low intensity LED light



MIP calibration of each tile
with 3 GeV e^+ beam



using ASIC chip in 2 modes:

"calibration mode"
shaping time 40ns
highest gain

"physics mode"
shaping time 180 ns
medium gain

intercalibration

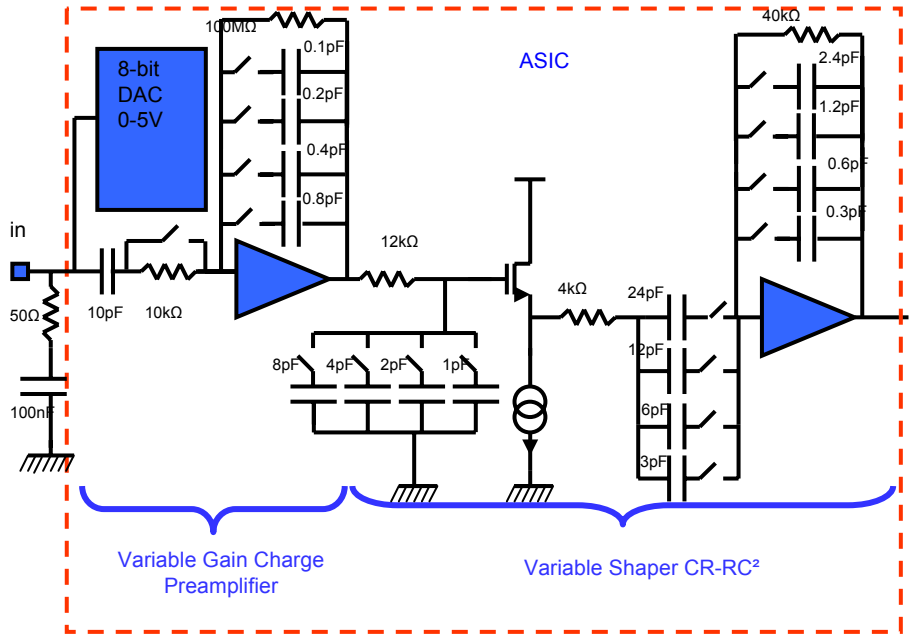
$$LY = \frac{A_{MIP}}{gain} * \frac{A_{LED}^{calib}}{A_{LED}^{physic}} [\text{pixs}]$$

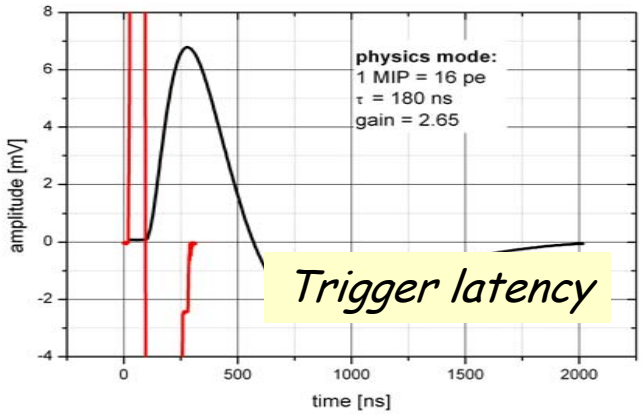
intercalibration term

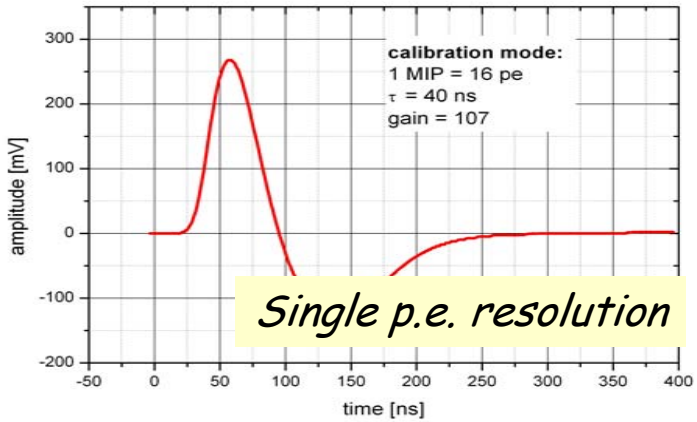
Very Front-End Electronics

ILC-SiPM chip: 18channel - based on CALICE SiW ECAL chip

- SiPM bias voltage adjustment (0-5 V)
- Global gain settings and shaping
- Track & hold, multiplexing







A redundant monitoring system

The stability of the system in between MIP calibrations is checked by monitoring:

1. SiPM response for fix intensity LED light

   dG/dT ~ -4.5% / K

   dG/dV ~ 7% / 0.1V

➔ stability of LED system after PIN diode correction <1%

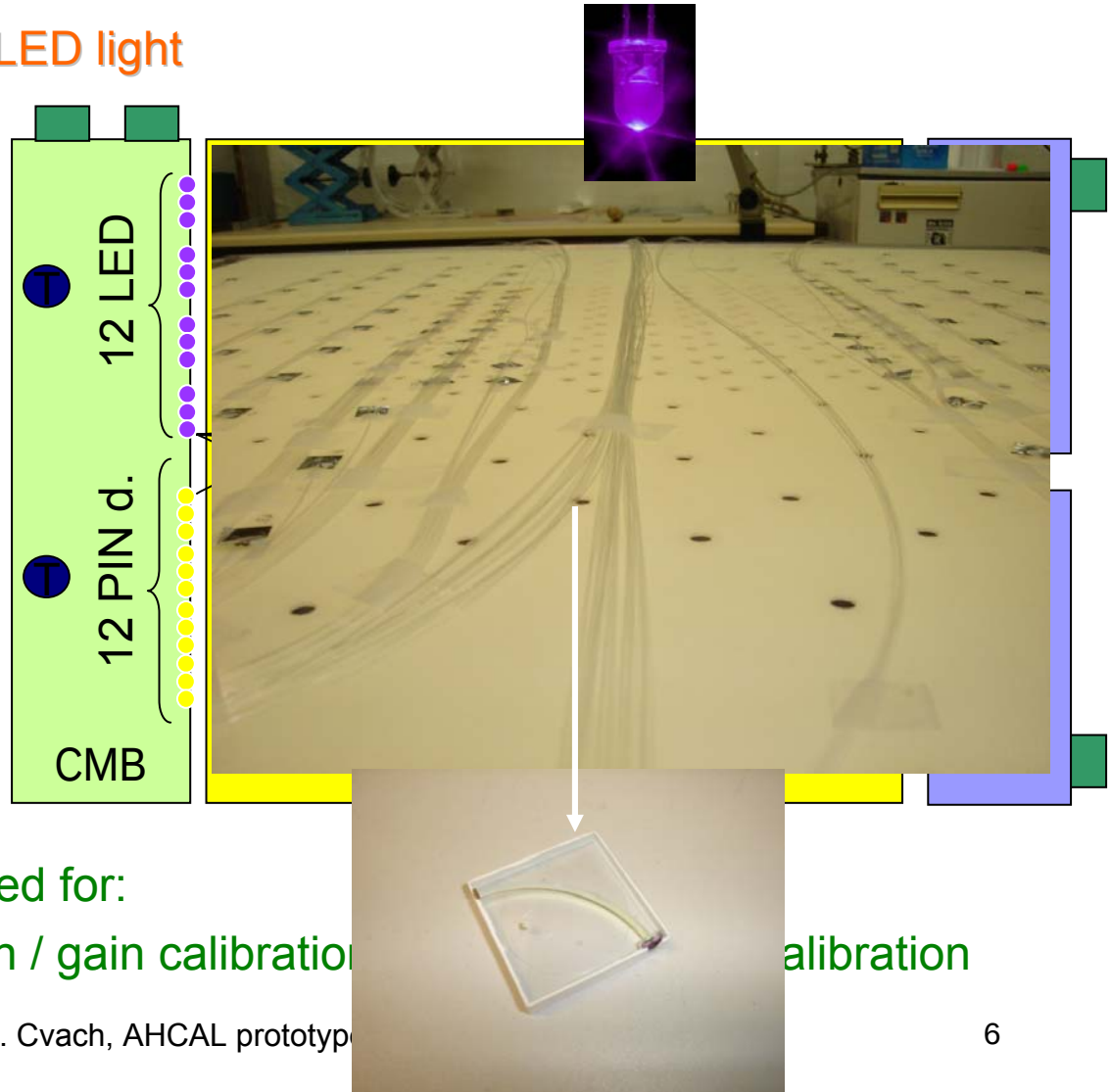
2. Gain of SiPM

   dG/dT ~ -1.7% / K

   dG/dV ~ 2.5% / 0.1V

3. Temperature and voltage

   monitoring from slow control

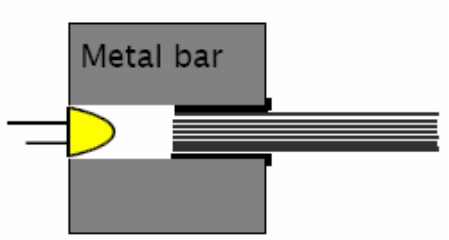


➔in addition the LED system is used for:

monitoring SiPM response function / gain calibratio alibration

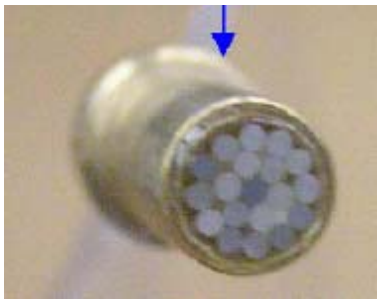
Calibration and monitoring system I

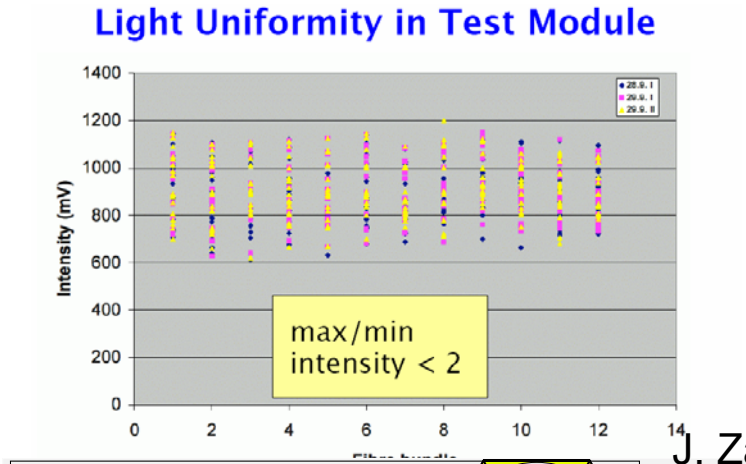
- LED fibres to all tiles
- Good uniformity of light
- LED to fibre coupling
- Coupling of fibre light into tiles
- LED light emission unisotropy
  - angular < 15%
  - Intensity (?) - measured now



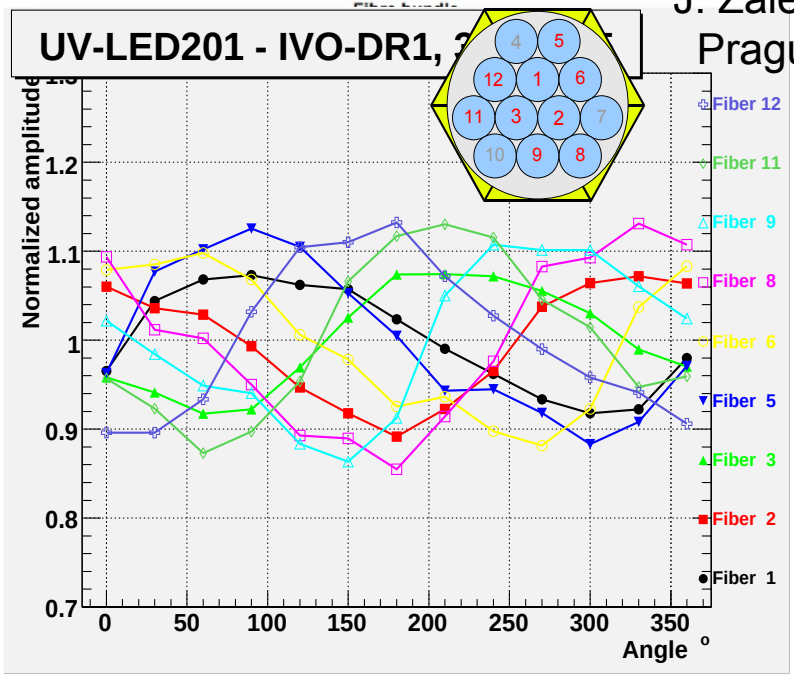
K. Gadow
DESY

metal sleeve





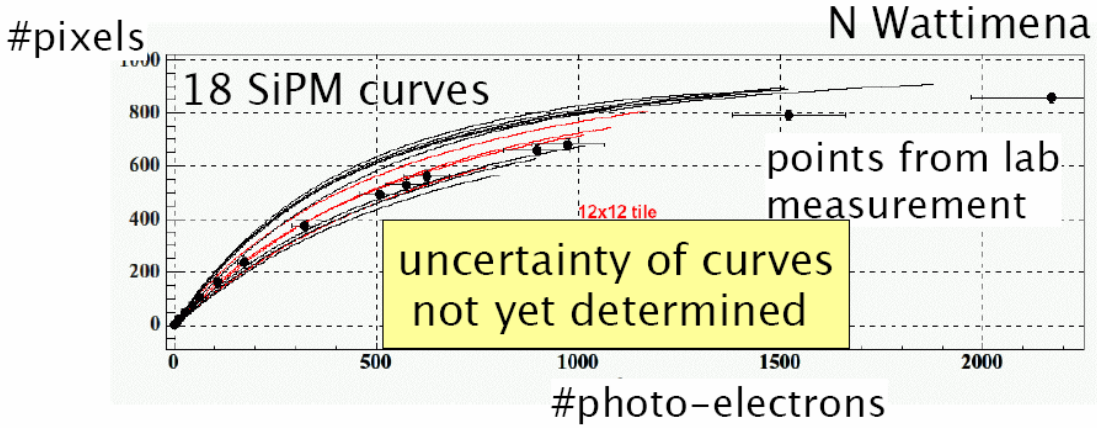
J. Zálešák
Prague



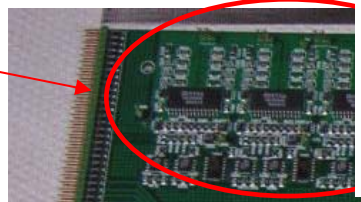
Calibration and monitoring system II

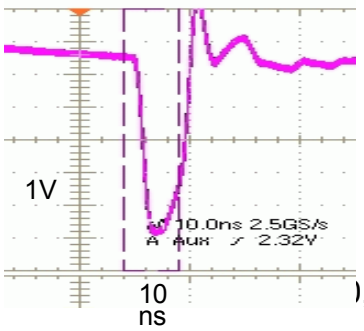
- **Calibration & monitoring board – to deliver LED light**
  - dynamic range 0.5 – 100 MIP
- **Functions**
  - LED control
    - Amplitude (via DAQ, CANbus, standalone)
    - Pulse width: 5 ns ↗
    - Enable
  - PIN diode readout
  - Temp monitoring

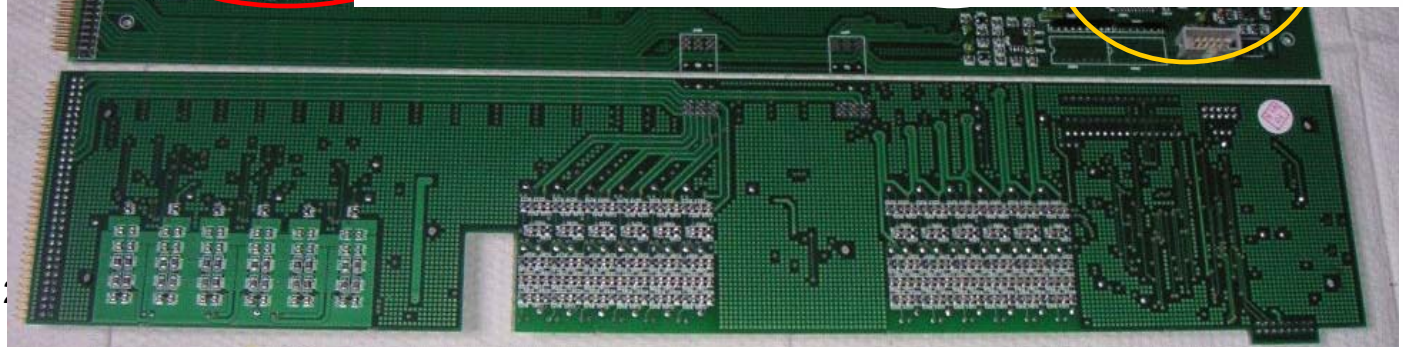
- **Measurement of nonlinearity**
  - LED intensity varied by DAQ
  - Intensity measured by PIN
  - Absolute calib from linear part



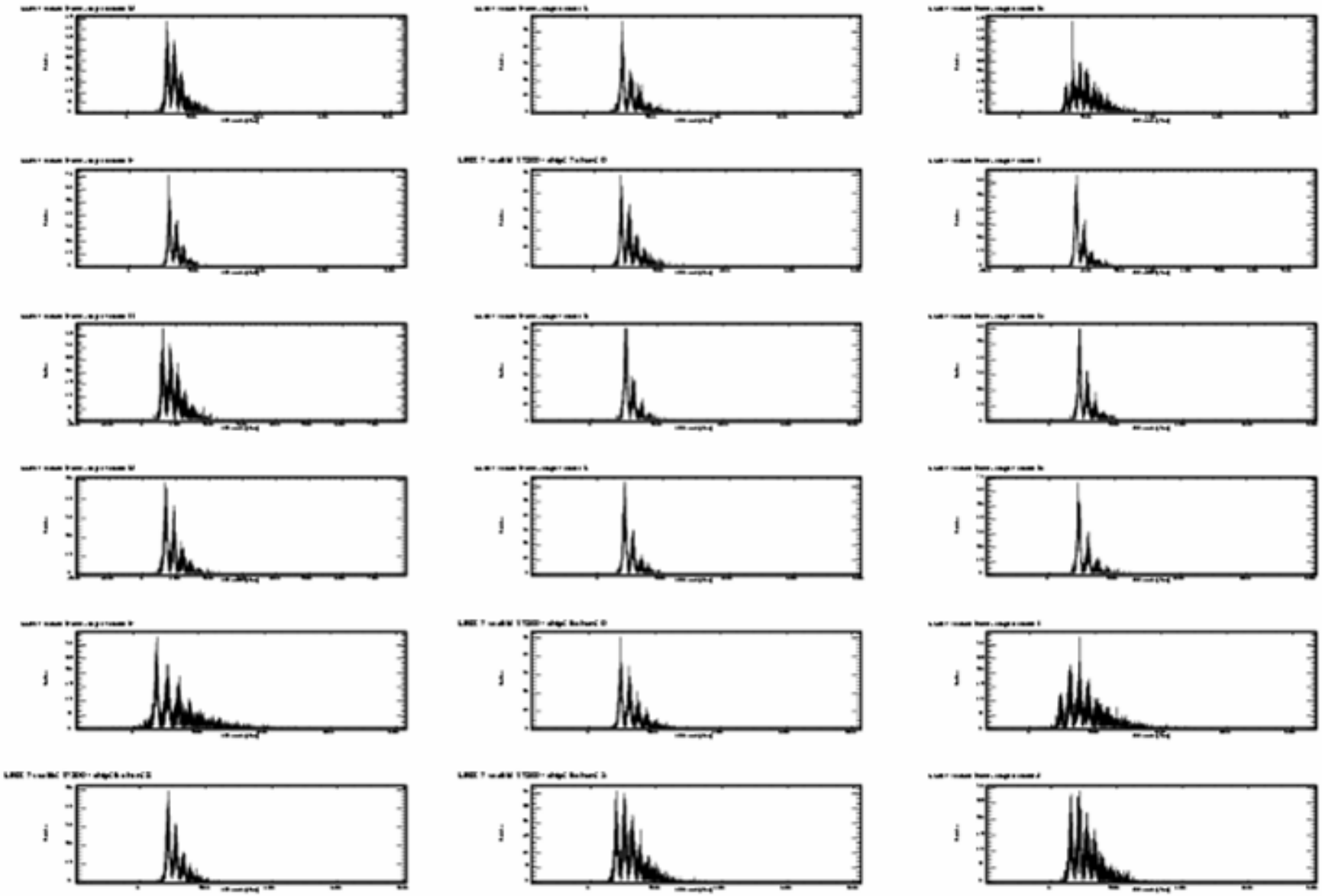
3 pulse generators







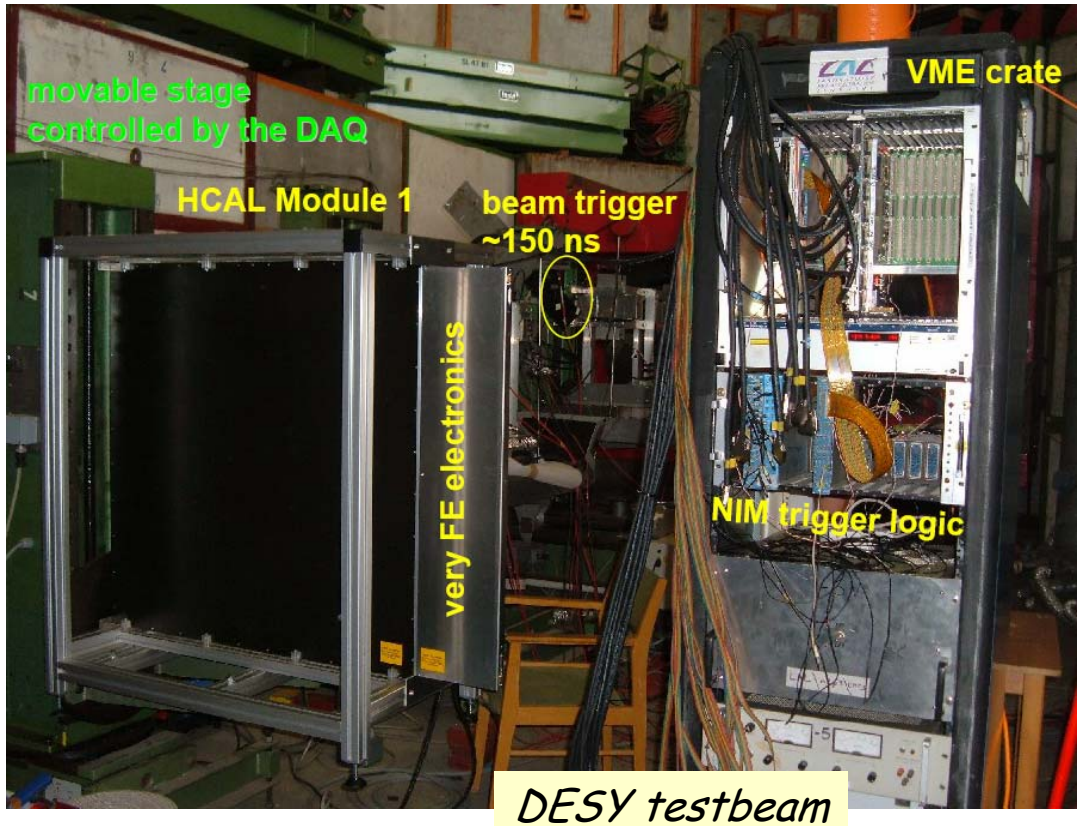
Calibrating 18 SiPM with one LED



Gain calibration for a matrix of 18 SiPM connected to the same LED

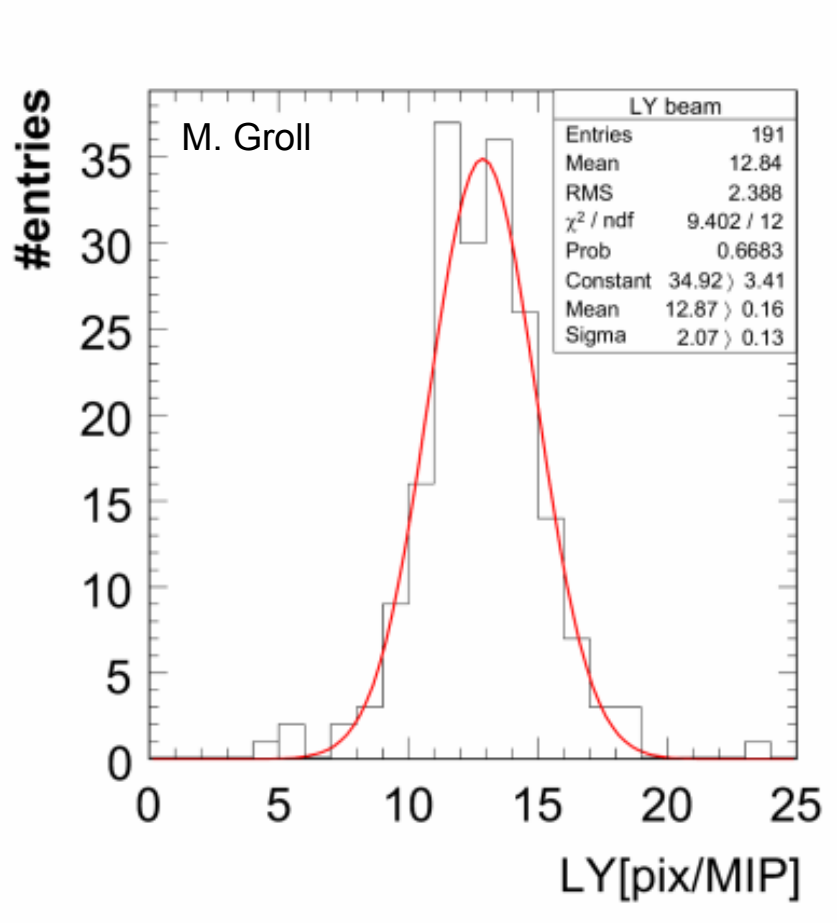
HCAL tests: Sept 2005 – Feb 2006

- 1st beam test successful DESY test beam area September
  - 1 plane, FE electronics & DAQ (CRCs VME)
  - Confirmation of the calibration with LED light & MIP on large scale & homogenity over plane
- Continued through the Christmas with cosmics
  - 3 complete modules
  - Test of sensitivity to temperature variations & correction
- 2nd beam run period April 2006
  - 3 planes with CMBs
  - Training of shift crews for summer beam tests
- In between cosmic run with ECAL



DESY testbeam

MIP and LY calibration – comparison



$$LY = \frac{A_{MIP}}{gain} * \frac{A_{LED}^{calib}}{A_{LED}^{physic}}$$

Gain calibration

MIP calibration

Inter calibration

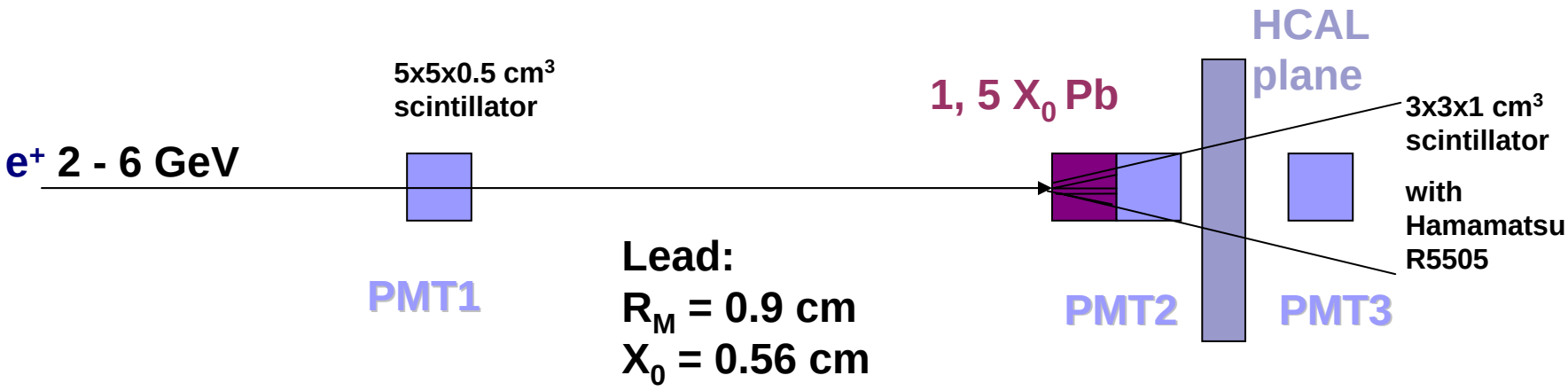
DESY beam (Sept. 05)
LY: 13 pix/MIP, RMS 2 pix/MIP
DESY Lab (Dec. 04)
LY: 15 pix/MIP, RMS 2 pix/MIP

Error on LY:
13.0 ± 0.3 ± 0.7 pix/MIP
stat. sys.
➔ Δ~1 pix/MIP due to temp diff during the two measurements

sys. err.: pedestal fluctuation ~2% , T fluctuation ~2.5%

Calib. procedure & beam shower

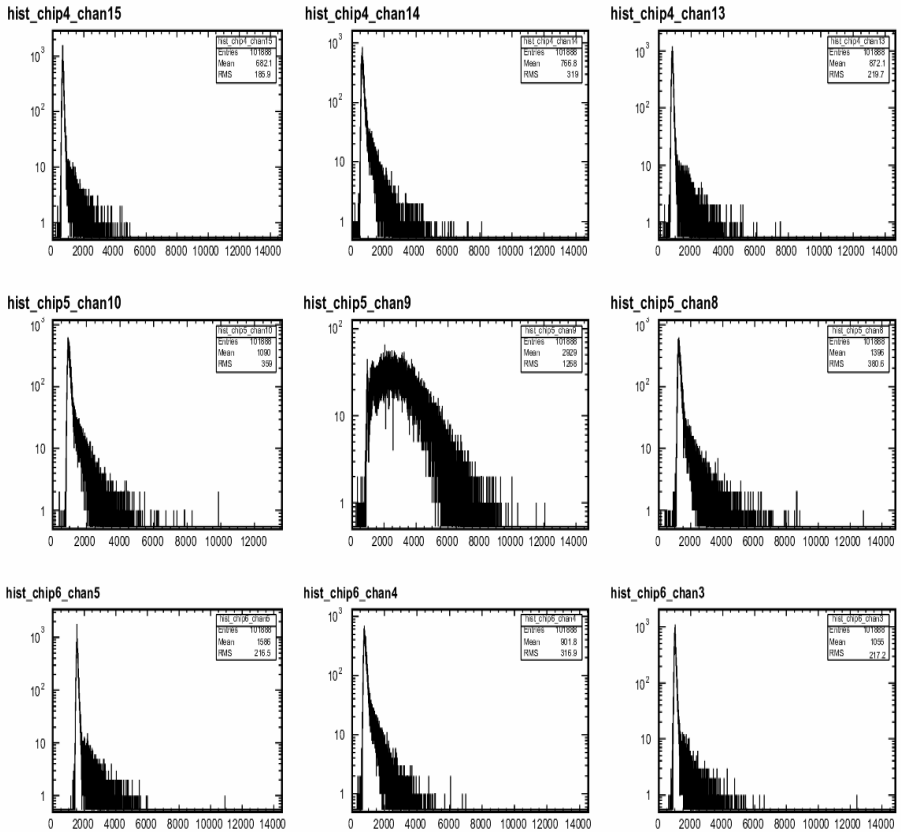
- HCAL plane scanned with e^+ 2-6 GeV and monitored by LED
  - ➔ MIP calibration, LY calibration
- Beam scan on plane surface (with 1 X_0 lead) ~ <6 MIPs> at PMT2
  - ➔ check uniformity of module response
- Beam scan on plane surface (with 5 X_0 lead) ~ <30 MIPs> at PMT2
  - ➔ check SiPM saturation correction
- Comparison of PMT, SiPM with MC
  - ➔ check the corrections

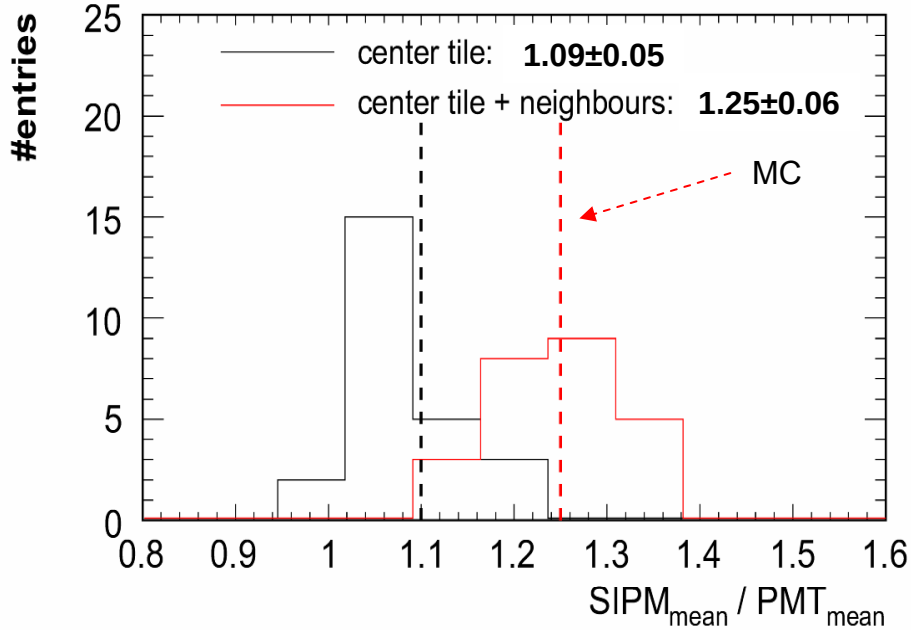


Uniformity studies

Scan of HCAL plane with 3 GeV beam and $1X_0$ in front

➔Energy = Σ shower energy on a 3x3 matrix of tiles (~99%)



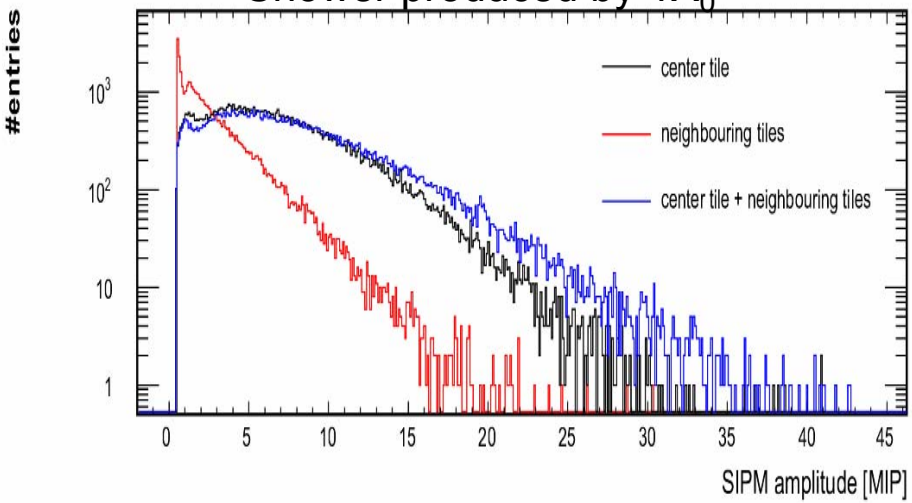


25 matrices of 3x3 cm² tiles scanned:
- SiPM/PMT3 – to eliminate beam spread
  - average in agreement with MC
- 5% spread over the HCAL core w/o temperature & pedestals corrections

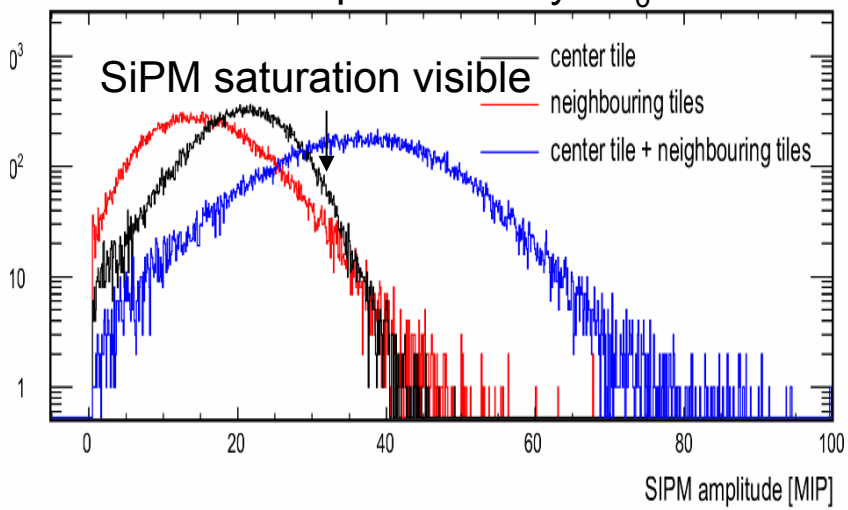
➔ Good uniformity within the meas. accuracy

Shower analysis

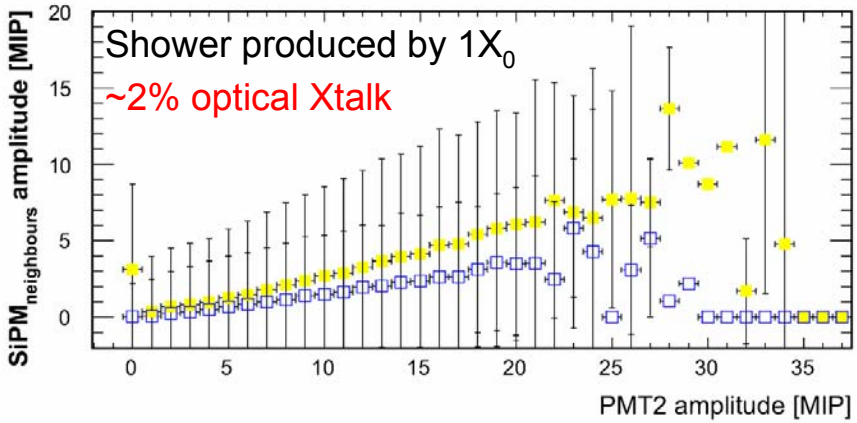
Shower produced by $1X_0$



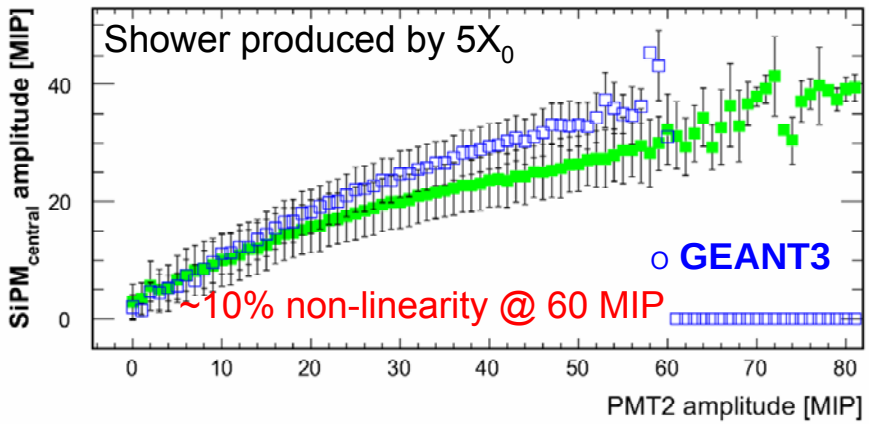
Shower produced by $5X_0$



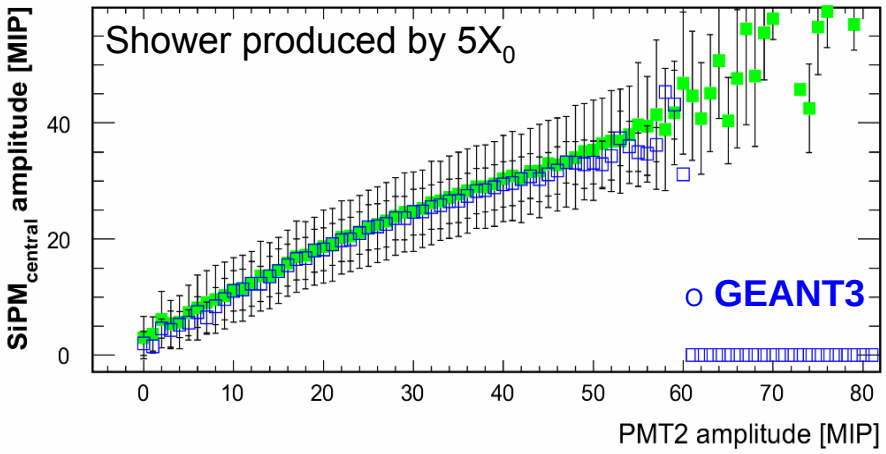
neighbours w/o optical Xtalk correction



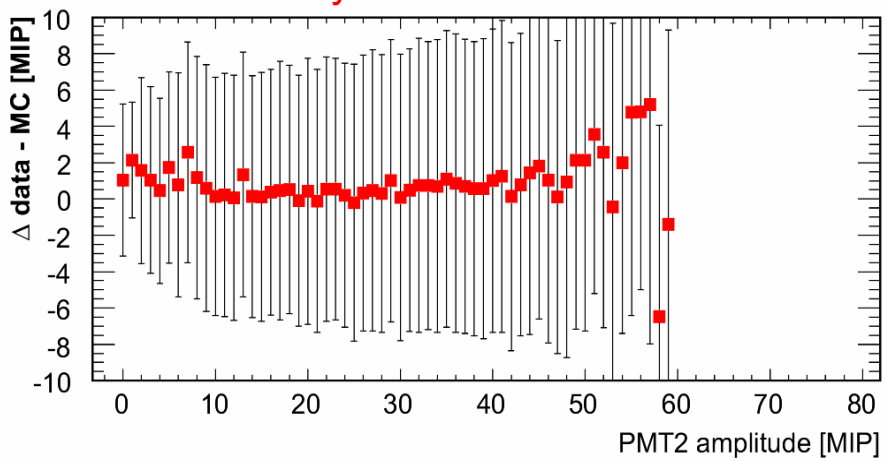
central tiles w/o saturation correction

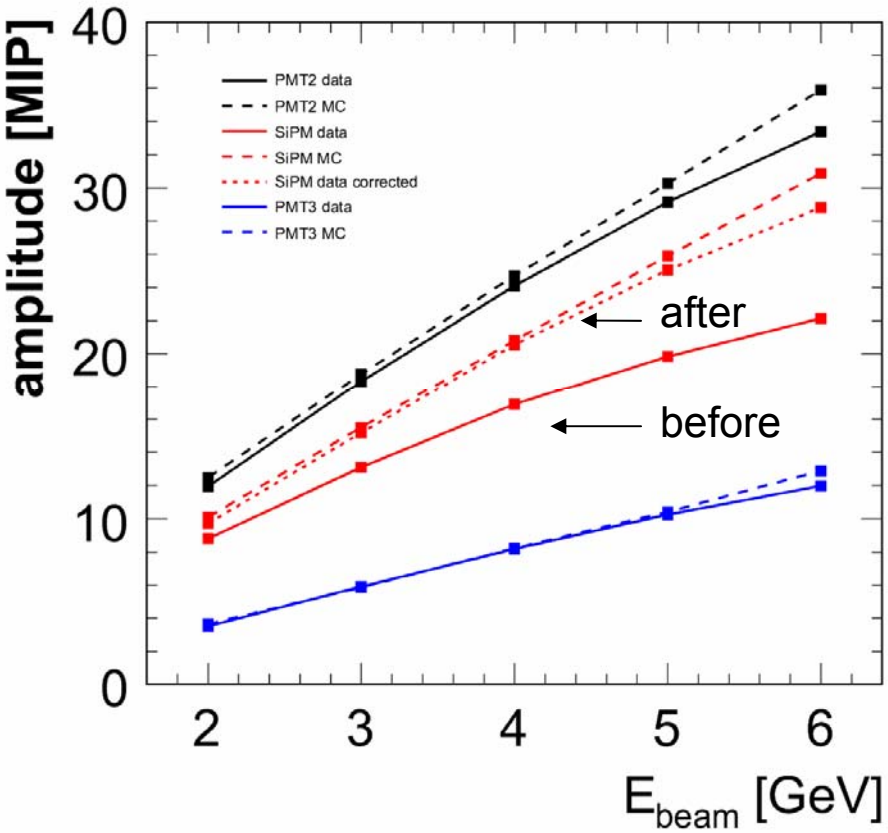


Saturation correction



non-linearity corrected





Good agreement between data/MC after SiPM saturation correction

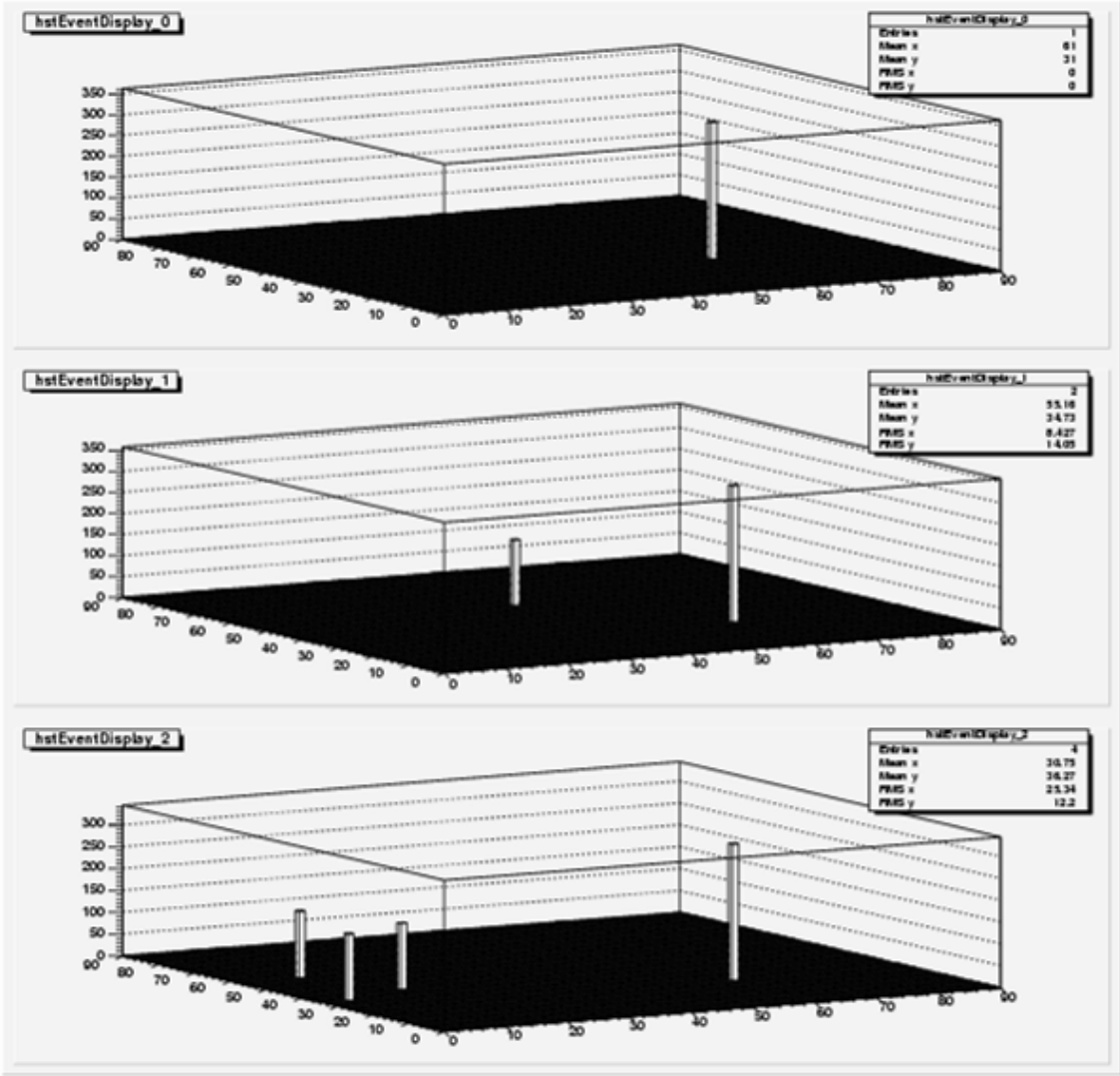
@ 5-6 GeV lateral leakage in ref. scintill.

M. Groll, Y. Soloviev

Xmas cosmic run

- Xmas run lasted from December 23rd till January 9th
- Modules connected: #4, #5, #6
- Monitoring done only for module #5:
  - 3 LED driven with prototype LED driver, steered by DAQ
  - + 3 PIN diodes r/o on prototype preamp. boards
  - all components from standard CMB board
- In addition 16 ECAL slabs were connected and "partially" in operation ➔trigger distribution problems + high leakage current
- Cosmic trigger: coincidence of two 30x40 cm^2 scintillator plates ~1m apart

Cosmics data taking with 3 modules



← Cosmic muon passing three modules

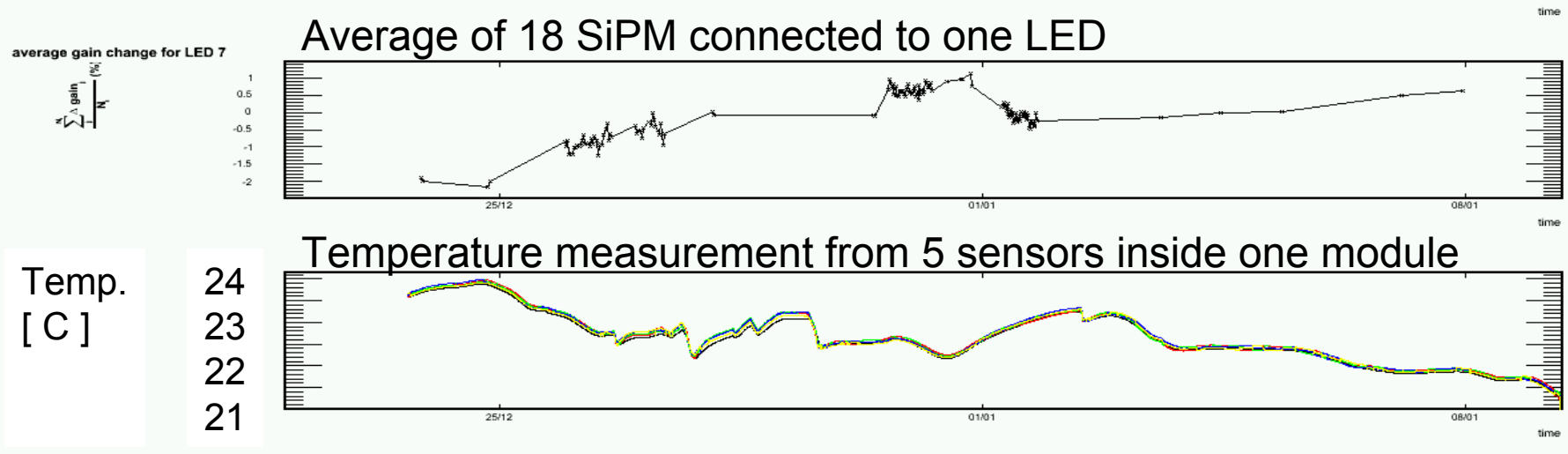
Many data on tape

Gain analysis at low LED light done –
sensitivity to temperature demonstrated

Analysis of corrections
from LED monitoring system,
PIN diodes and slow control

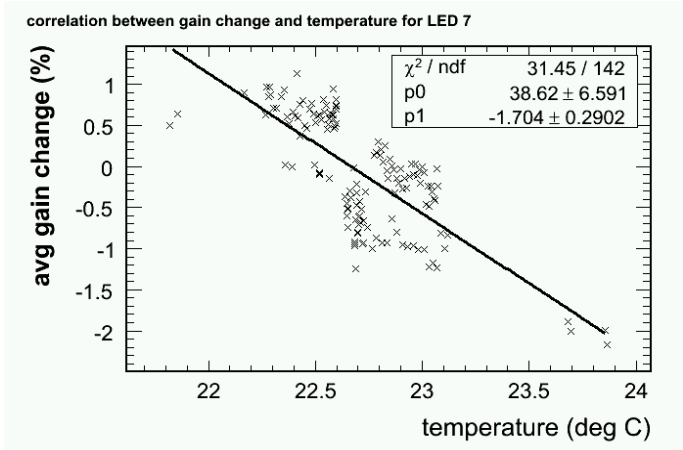
… and other analyses
in progress

Gain variation over two weeks



MEPHI measurement:
dG/dT ~ -1.7% / K

From average of 18 x 3 SiPM in HCAL:
dG/dT ~ -(1.6 +/- 0.5)% / K



Conclusions

- Time schedule tough – group looks forward to the comming tests
- Proof of principles
- Answers to many open questions:

  - Is the level of calibration accuracy sufficient ?
  - How to get MIP calibration in the ILC calorimeter ?
  - Is the LED light needed for gain measurement ?
    alternatives:➔ gain from high stat. pedestal (optical crosstalk)
    ➔ better pixel resolution @ higher amplitude (low noise)
  - Can the gain be used to measure amplitude changes ?
    implication: ➔ maybe no need of LED system ?
  - Is the temperature measurement needed ? Can it replace the monitoring system ?
  - Is the SiPM response function stable enough ?

➔ Experience with the HCAL prototype + future R&D will give the answer

Back-up slides

SiPM response function

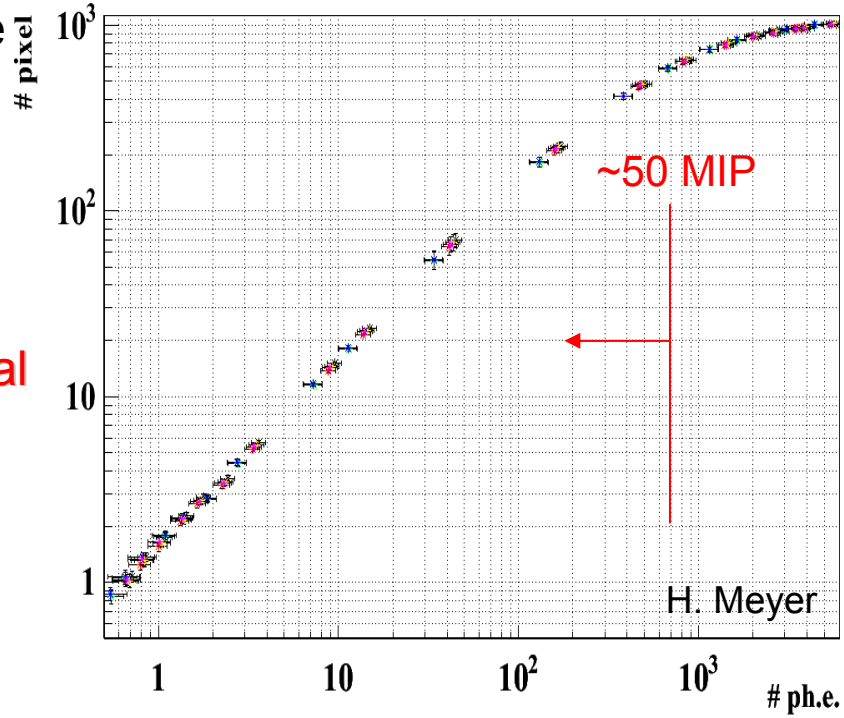
Ideally:

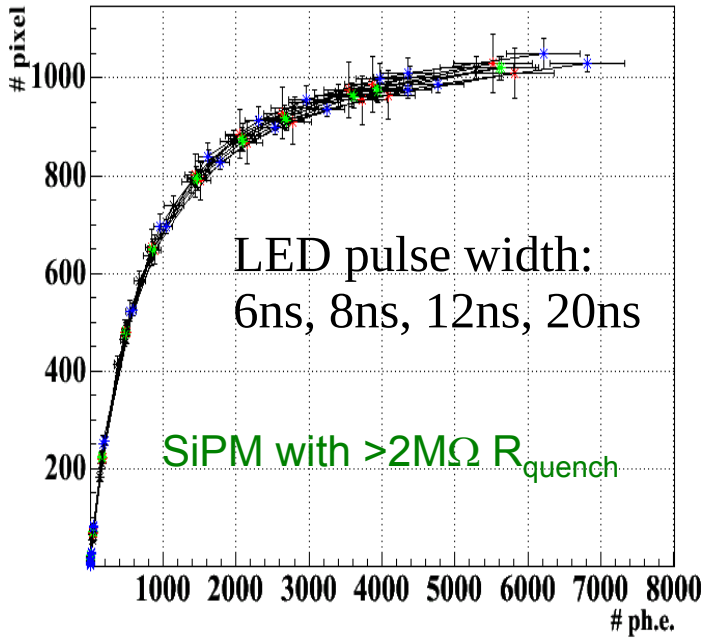
Correct “all” SiPM with one unique response function which describes:

- Geiger discharge efficiency
- effective number of pixels
- inter-pixels crosstalk

➔ It worked for 100 channels in the technical prototype (Minical)

measured in lab with 10% accuracy



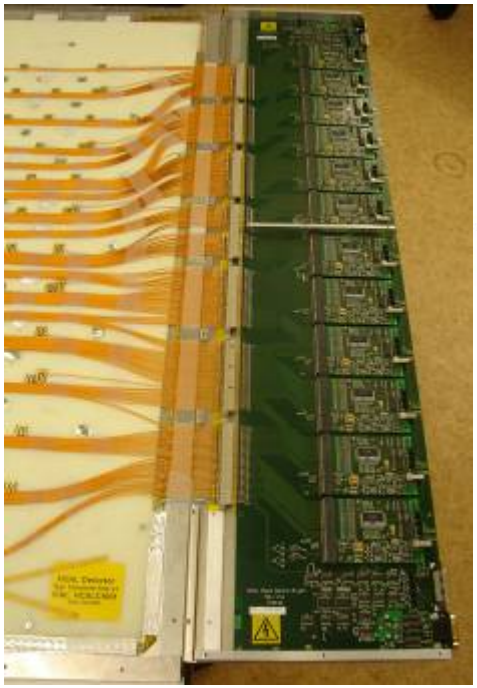


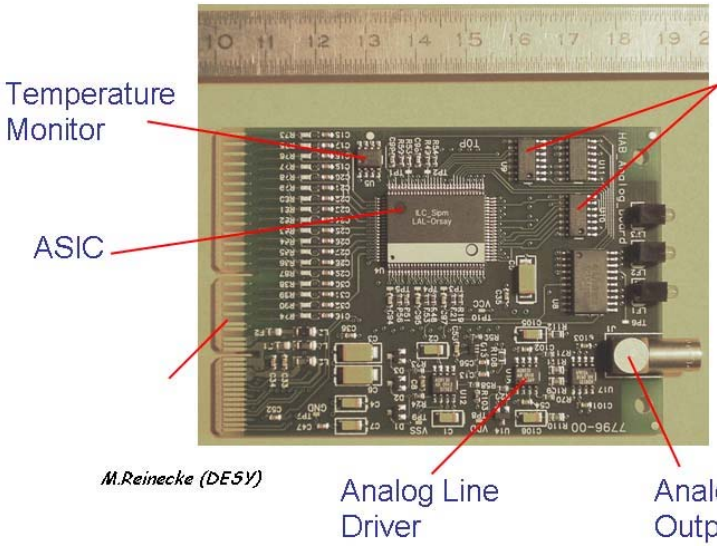
To apply a unique correction function for all SiPMs:

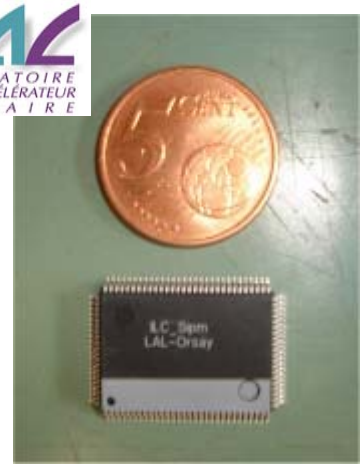
➔ calibrate curve for each SiPM using Light Yield

➔ correct T & V dependence of response function

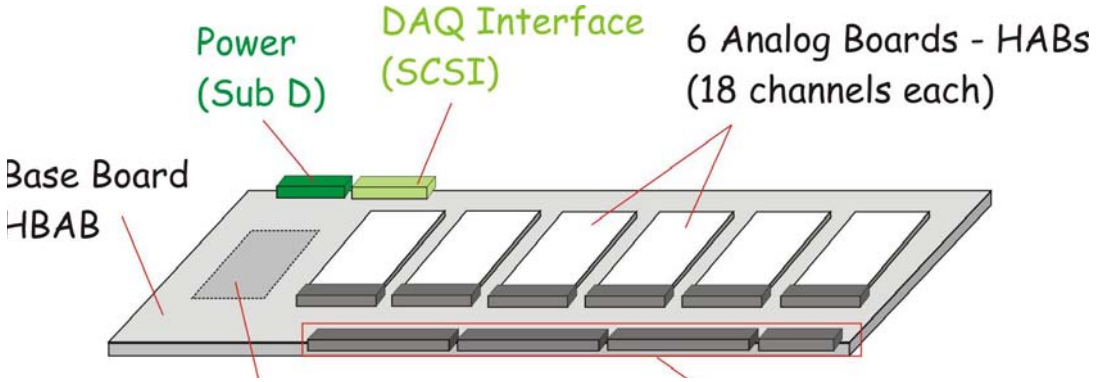
HCAL readout architecture



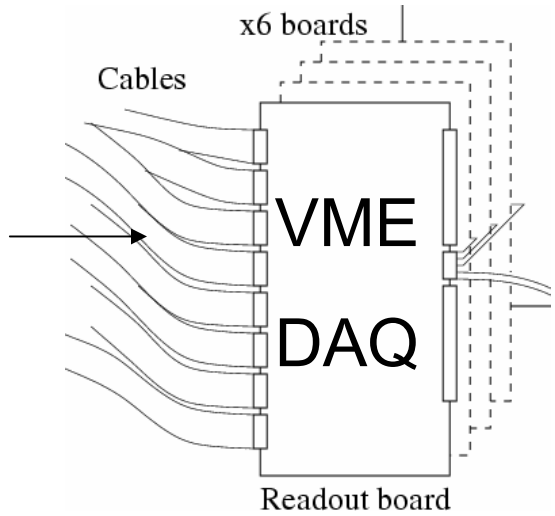




18 analog channels

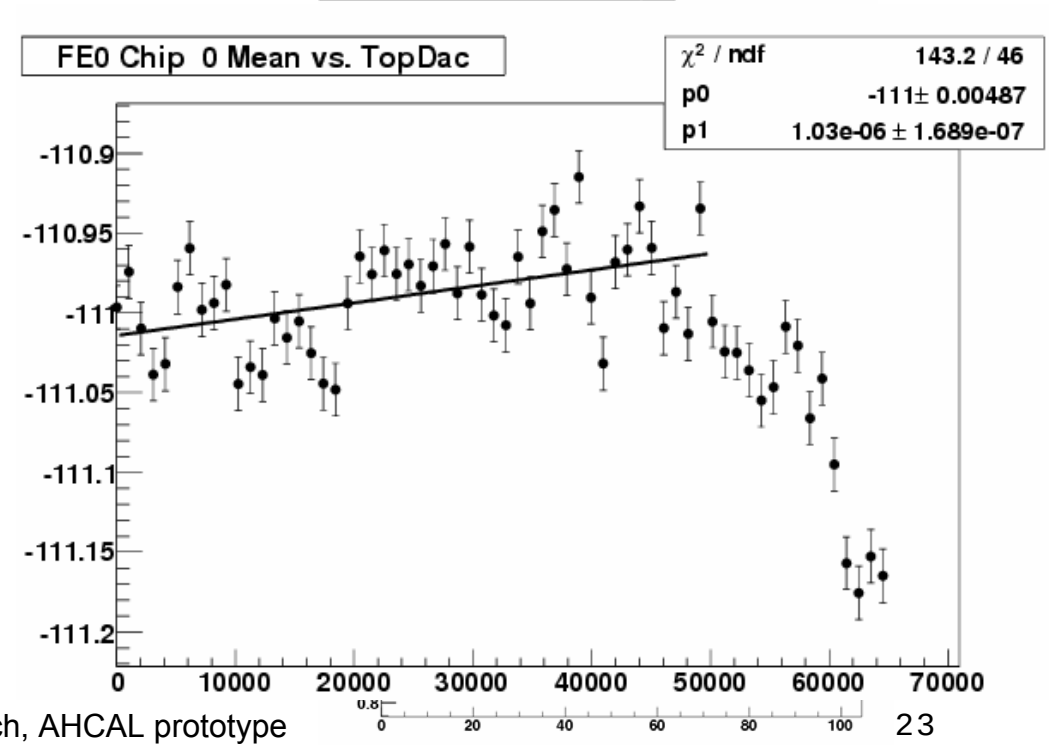


*Base boards with 2*6 piggy backs / layer*

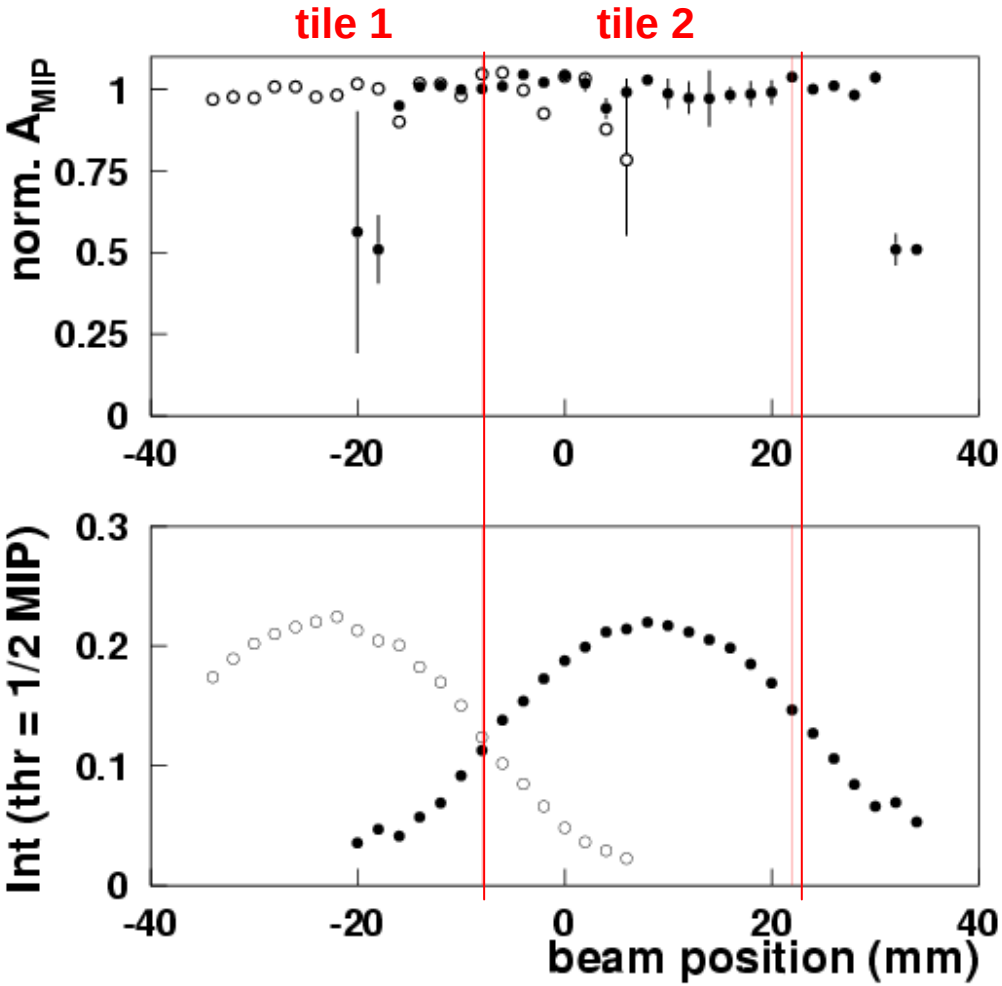


CALICE Readout Card

- Ordered 7 CRC boards for AHCAL
  - Identical design to ECAL CRCs
  - Produced through Rutherford
  - JTAG tests at Rutherford
  - Tests in DAQ system at Imperial
- With no VFE input, good CRC has:
  - Pedestals within 100 ADC counts of zero (within ±32k range)
  - Noise around 1.4 counts but can vary down to 0.8, up to 2.0
- Measure of crosstalk; good channel sees almost nothing until near saturation
- Present status
  - Four CRCs are running at DESY tent in ECAL + AHCAL cosmic tests
  - Three CRCs expected in March



Tile Uniformity Check with Beam



Beam scan on tile surface in 1mm steps

🡐MIP amplitude meas. at each step
max variation ~10%,
RMS = 4.7%
(remember 2% reproducibility !!)

🡐Integrated energy deposited above ½ MIP at each step gives an idea of the beam profile

Problems:
➔The beam is too broad for a precise measurement of edge eff.

Summary: 1X0 analysis

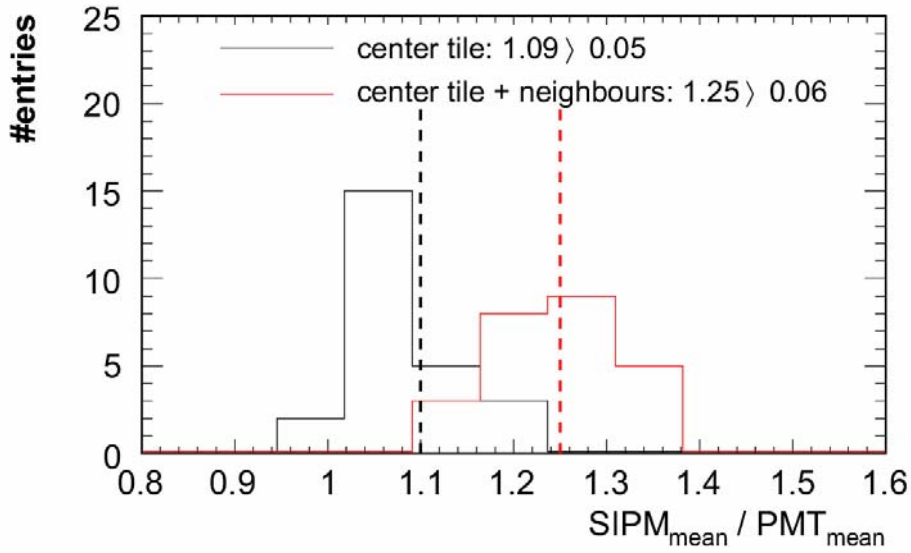
For 25 3x3 cm tiles:

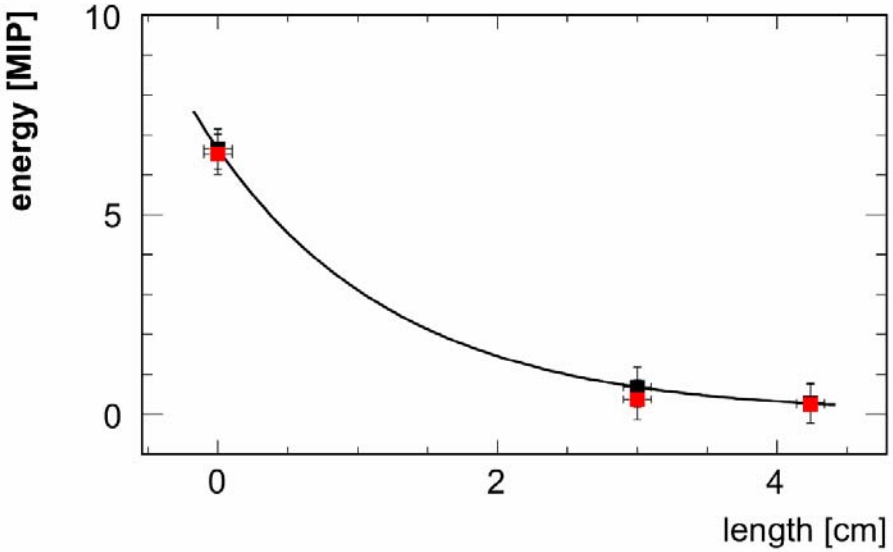
- **General agreement to MC**
  only 5% spread between channels w/o a
  temperature & pedestals corrections

MC prediction

- **Some physics:**
  determination of lead moliere radius

  data: R_M = 0.76 ± 0.07 cm
  MC: R_M = 0.92 cm





Toward the beam test

- HCAL beam tests – 8 weeks at H6b CERN beam area in August – October
- The goal – to start with 18 HCAL modules in August
- Commissioning of the monitoring system – now
- Production of 12 modules started in February
- Movable table construction: February - April
- Commissioning of the assembled stacks with cosmics – June
- Transport to CERN – beginning of July, tests with DAQ
- H6 beam
  - 5 – 205 GeV/c, up to 10^8 π^+/spill (5 GeV/c ~ 1000 particles/spill)
  - 5 – 100 GeV/c electrons
  - Parasitic μ runs possible