Commissioning of AHCAL electronics in the test beam

Marius Groll

Universität Hamburg

on behalf of the CALICE analogue HCAL group

- **Hadronic Calorimeter with scintillator tiles**
- **Innovative photodetector technology: SiPM**
- **VFE electronics specific for test beam data taking**
- **First test beam results**

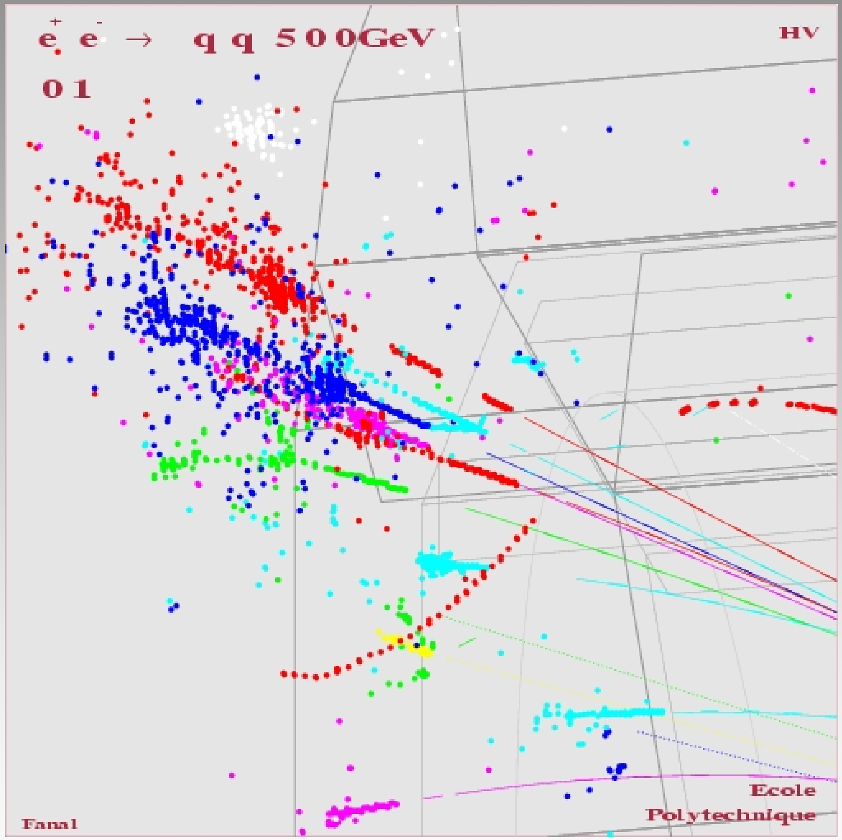
An HCAL for the ILC

The internal structure of hadronic showers is not fully known

➔ important issue for simulation improvement (detector studies)

➔ Idea: Tracking calorimeter = high granularity to reconstruct single particles in the shower

➔ Particle flow:
optimisation of the detector performance by reconstruction of each particle individually



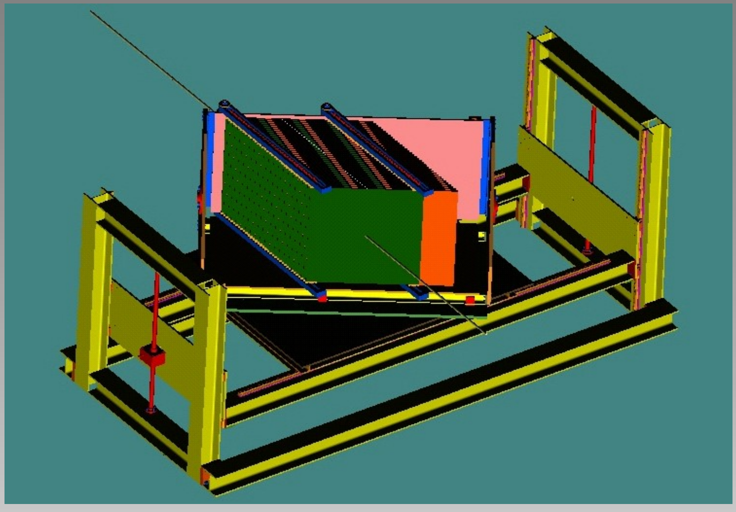
An HCAL for the ILC

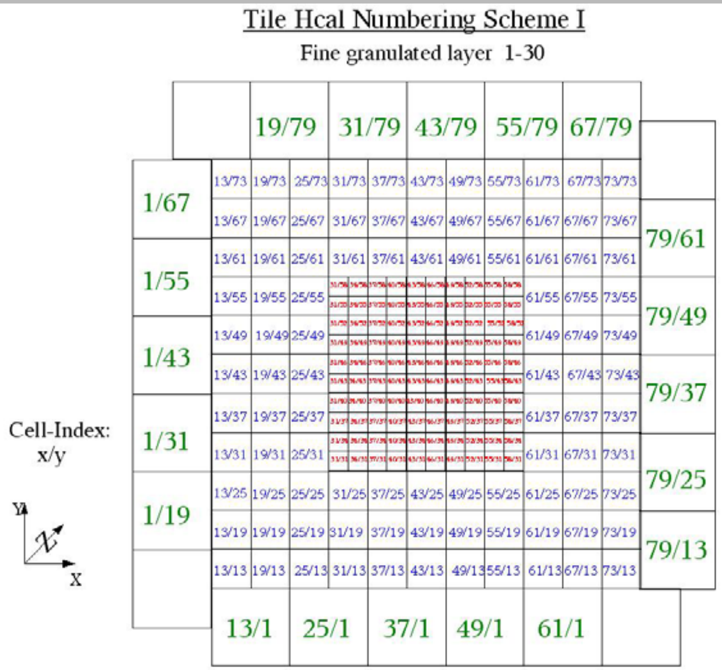
In the framework of CALICE:

1 m^3 Tile HCAL prototype ~ 8000 calorimeter tiles equipped with SiPM

➔ at present under construction

38 layers of sandwich structure with scintillator tiles + 2cm steal absorber plates

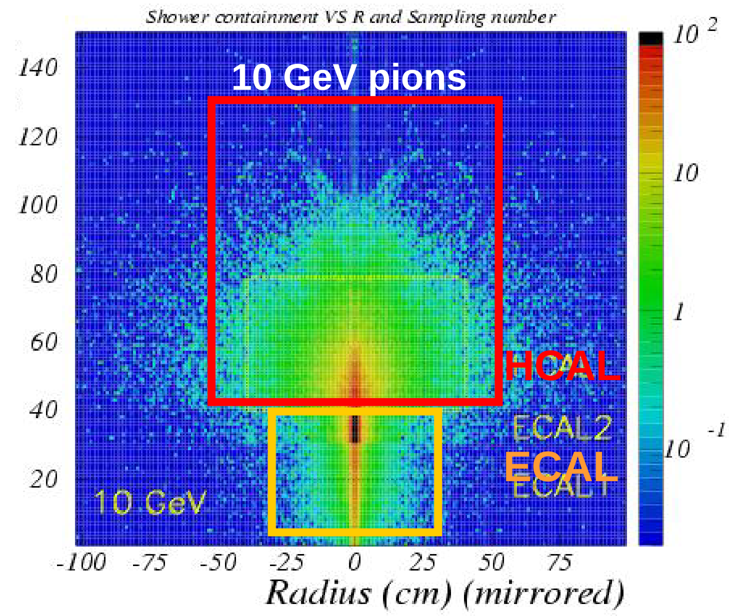




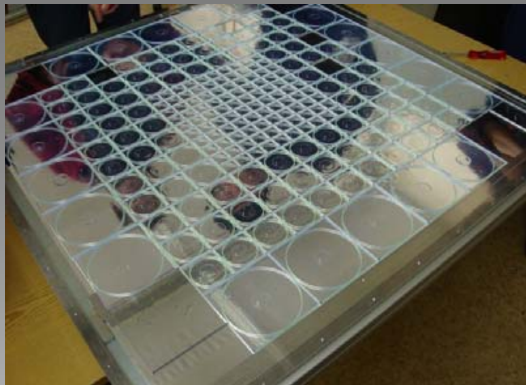
HCAL:
High granularity scintillator tiles

3x3cm² in the core with individual readout

ECAL:
Silicon-tungsten 40 layers, 1x1cm²

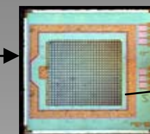


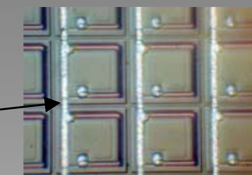
The HCAL readout chain



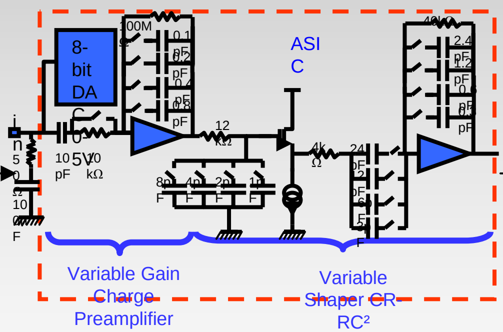
Read out 216 tiles/module
~8000 channels

Single tile readout with SiPM

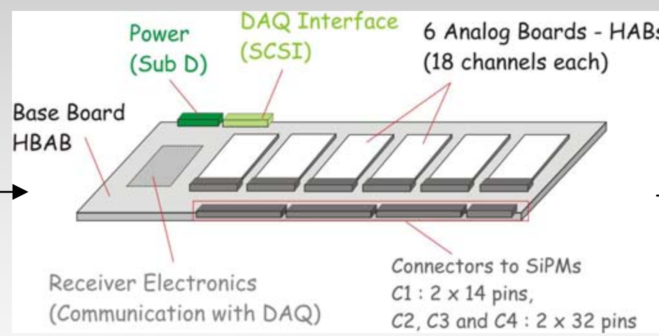




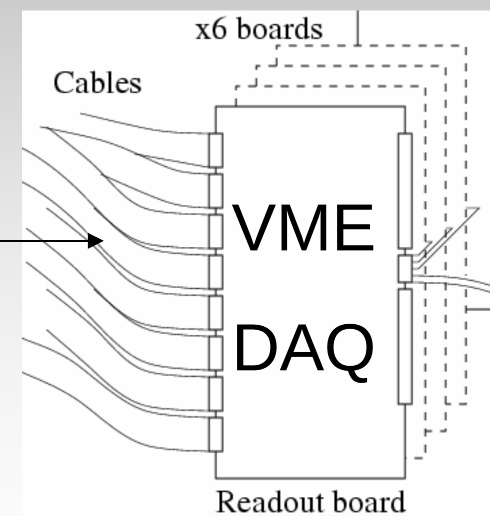
SiPM: pixel device operated in Geiger mode



ASIC: amplification + shaping + multiplexing



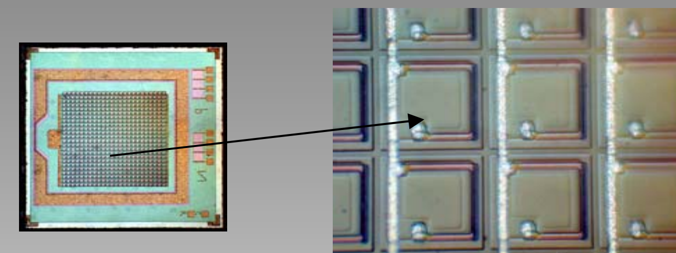
VFE: control 6 ASICs connect to SiPM



Silicon PhotoMultiplier

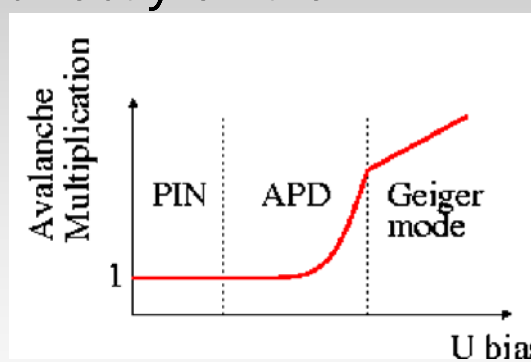
- Multipixel avalanche photodiode operated in geiger mode
- new detector concept, first test with beam
- sizes: 1x1mm^2, 1156 pixels/mm^2
- gain ~ 10^6
- photon detection eff. ~ 10-17%
  = Q.E. × geiger discharge (U) × geom. eff.
  = 80% × 60% × 35%
- single tile read out / mounted directly on tile

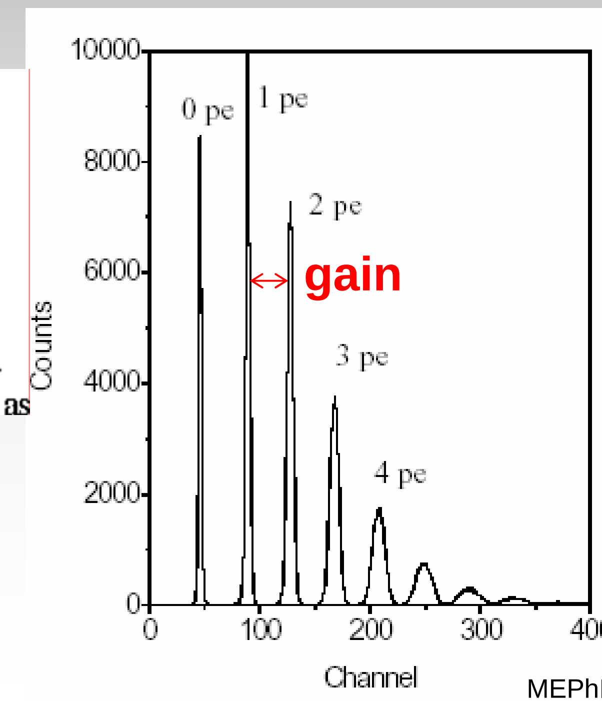
Silicon PhotoMultiplier (SiPM)
MEPhI&PULSAR



SiPM

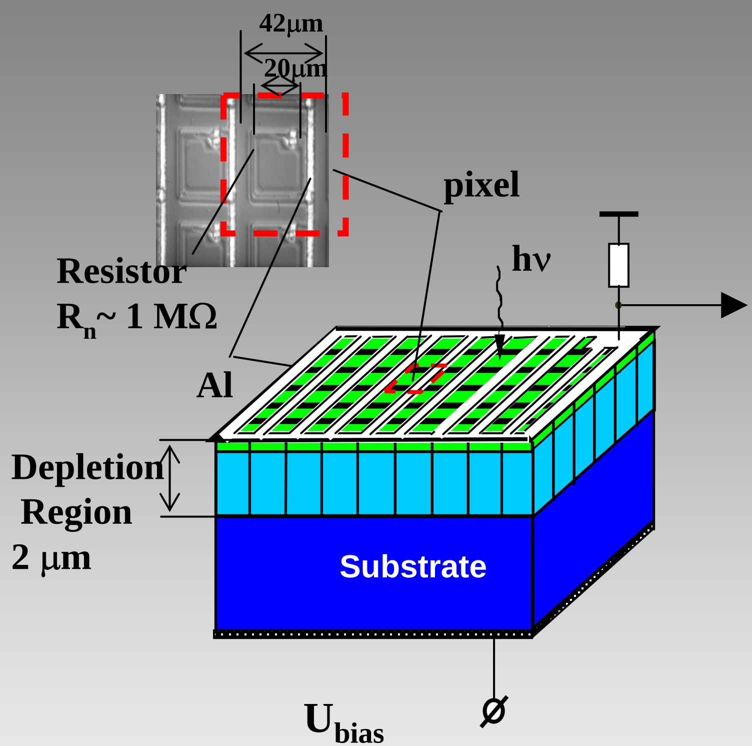
Pixels of the SiPM





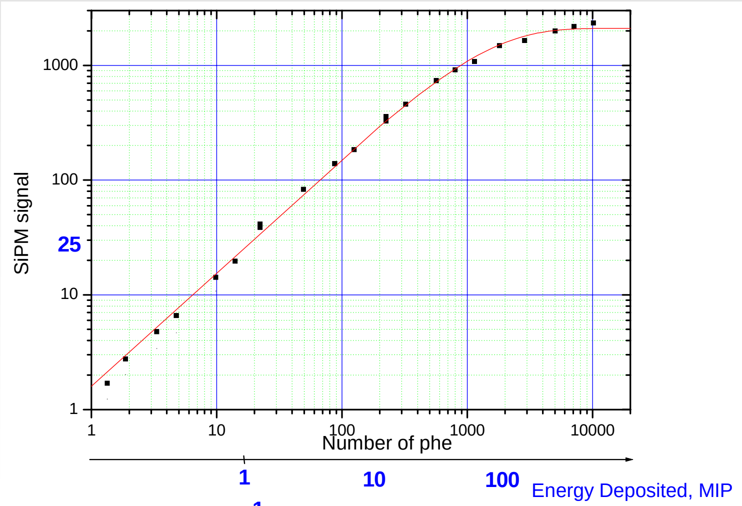
Geiger mode:
Quenching R ~ 1MΩ
➔fast signal
➔Proportionality to energy is lost for each pixel signal
➔Obtain back due to the high amount of pixels
➔Semi digital device

SiPM main characteristics



Working point: $V_{Bias} = V_{breakdown} + \Delta V \sim$ 50-60 V
ΔV = 10-15% above breakdown voltage
Each pixel behaves as a Geiger counter with
$Q_{pixel} = \Delta V\, C_{pixel}$
with C_{pixel}~50 fF ➔ Q_{pixel}~300 fC ~ 10^6e
Small depletion region ~ 2µm
➔strong electric field (2-3) 10^5 V/cm
➔carrier drift velocity ~ 10^7 cm/s
➔fast Geiger discharge < 500 ps
➔pixel recovery time = $(C_{pixel} \times R_{pixel})$ ~ 100 ns

Dynamic range ~ number of pixels
➔ saturation



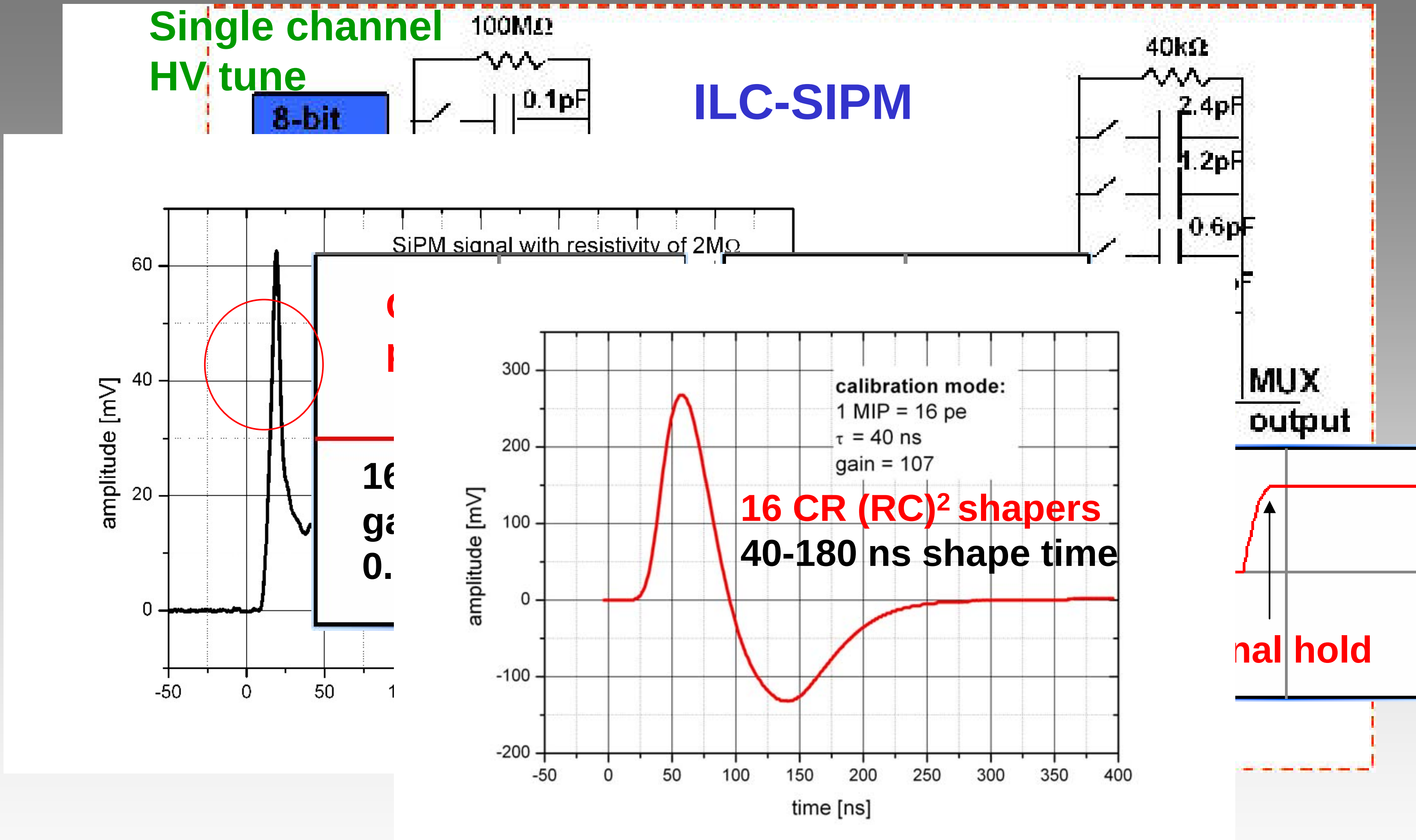
Specification for the VFE electronics

1) Operate 8000 SiPM with individual bias voltage adjustment

2) Decouple charge signal of SiPM, preamplify and multiplex it before the ADC

3) The HCAL prototype has to operate in a test beam setup
   → time needed for beam trigger logic ~150 ns
   → need to delay the SiPM signal to wait for the creation of the hold signal

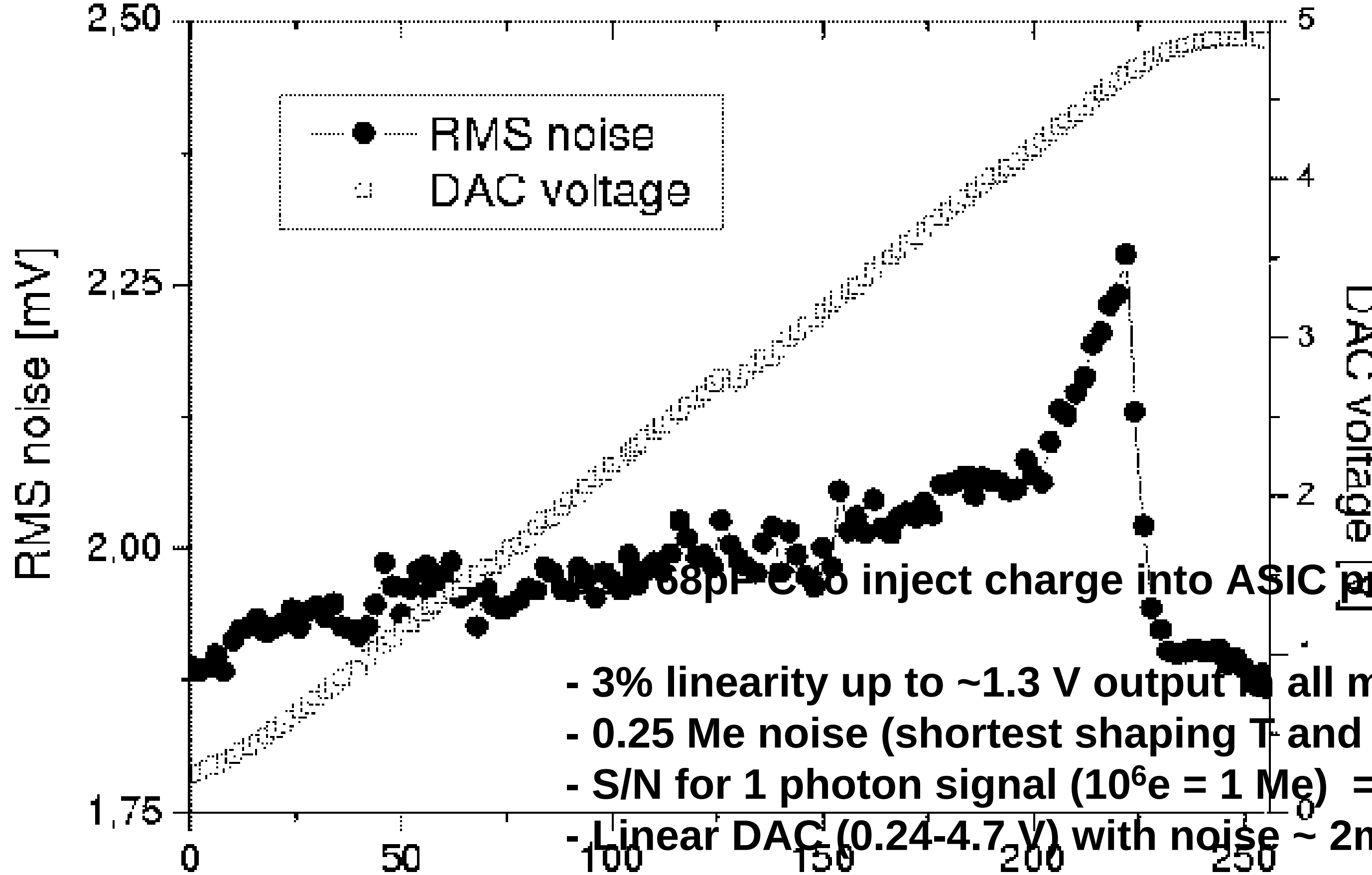
4) Need to exploit the SiPM gain calibration possibility
   → minimize ASIC preamplifier noise
   → minimize noise contribution from SiPM dark rate
   → shortest possible integration time



C. de La Taille
L. Raux

ASIC chip properties

DAC Linearity



68pF C to inject charge into ASIC preamp:

- 3% linearity up to ~1.3 V output in all modes
- 0.25 Me noise (shortest shaping T and highest G)
- S/N for 1 photon signal (10^6e = 1 Me) = 4
- Linear DAC (0.24-4.7 V) with noise ~ 2mV

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- S/N
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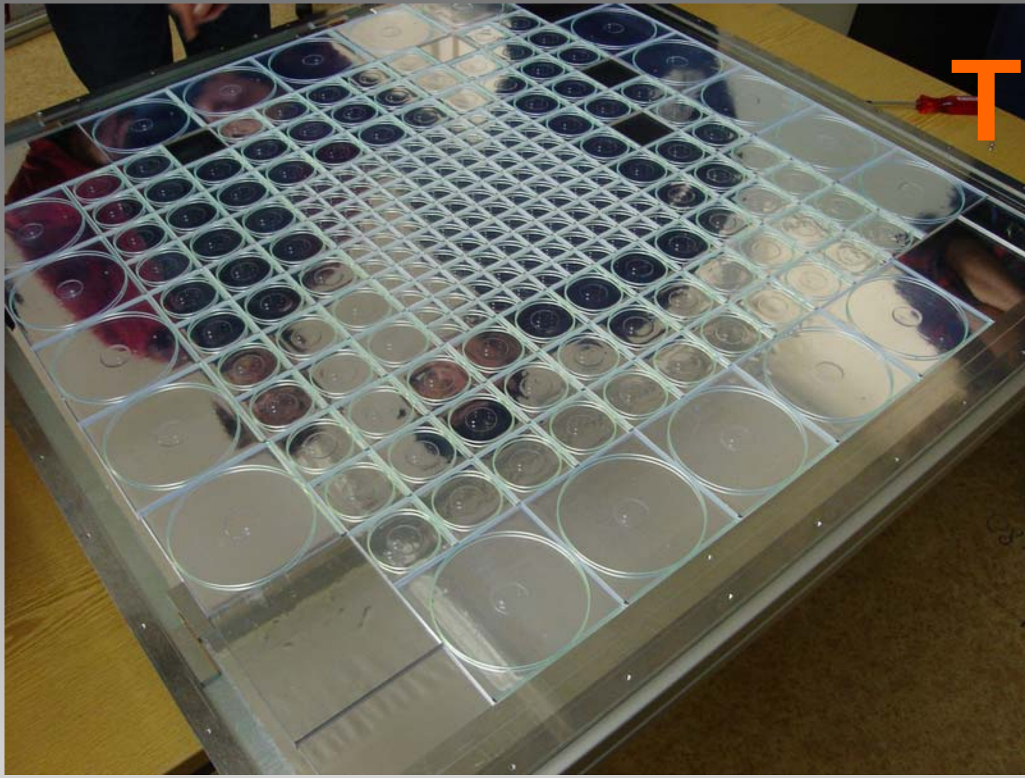
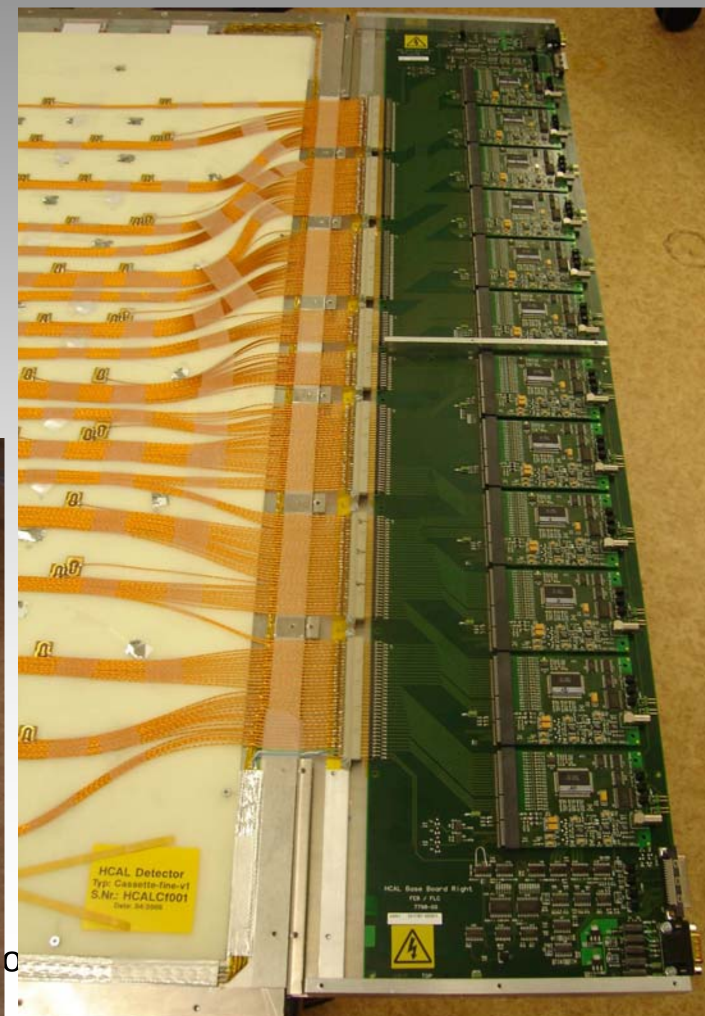


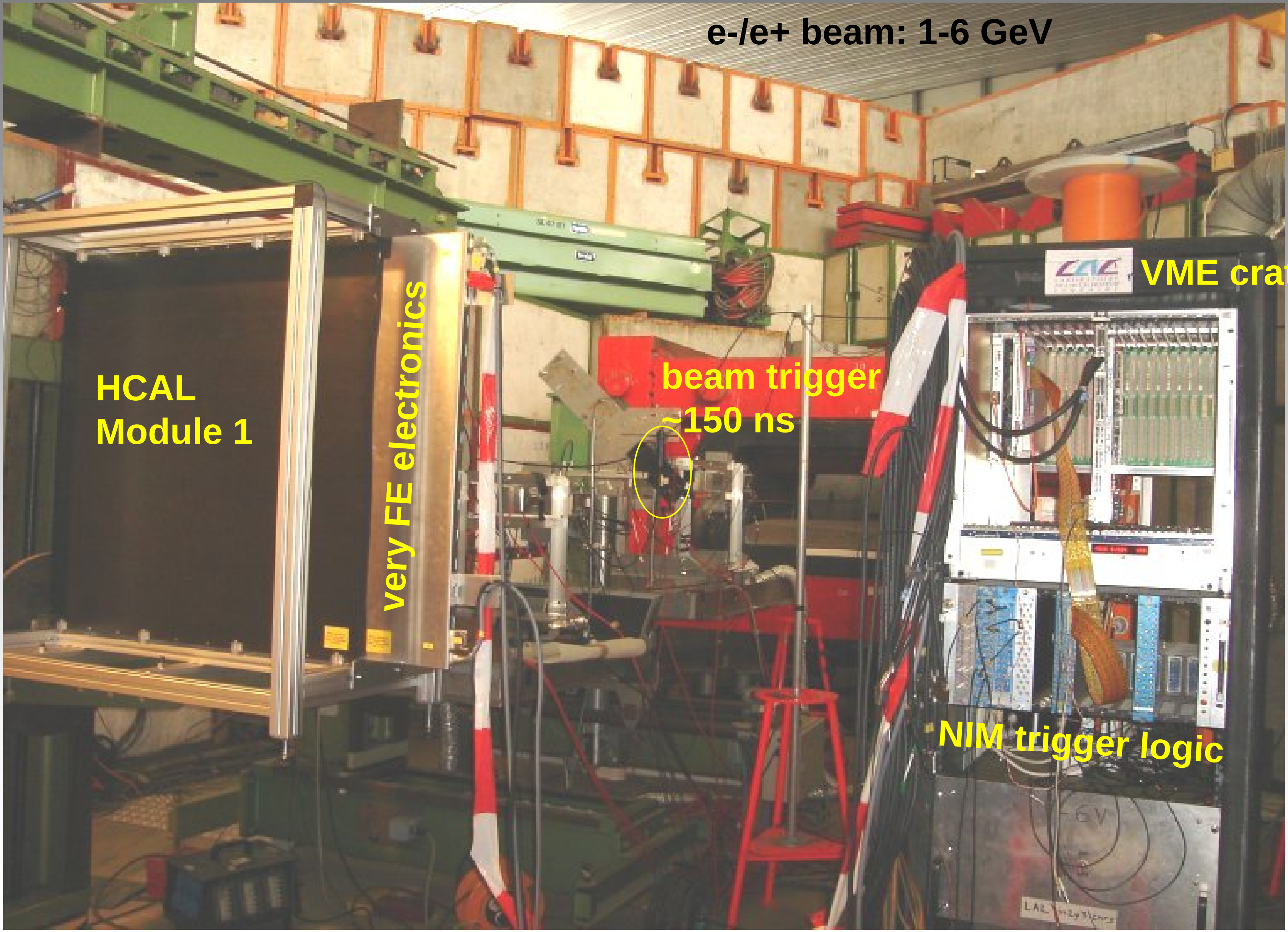
The first module

216 tiles with SiPM readout

very front-end electronics

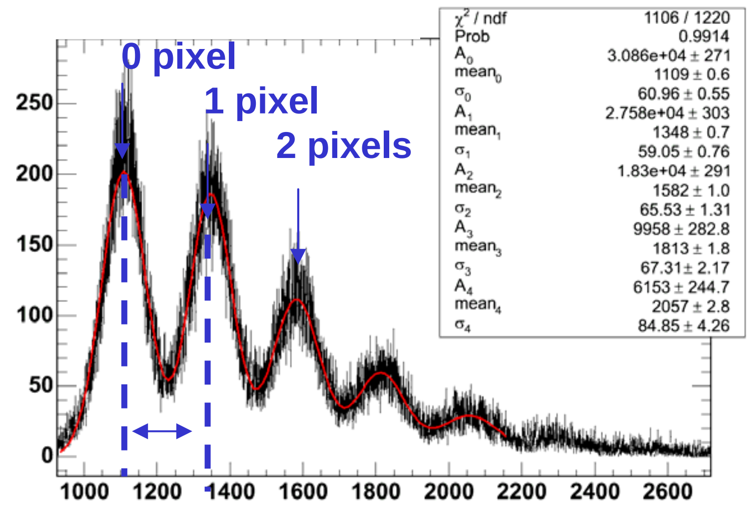


DESY test beam: 1st module test



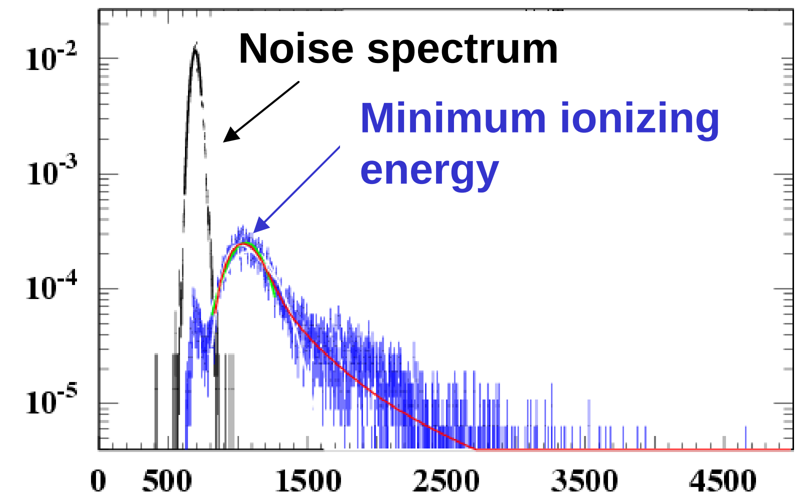
Calibration procedure

SiPM Gain calibration
with low intensity LED light



gain / noise ~ 4

MIP calibration of each tile
with 3 GeV e- beam

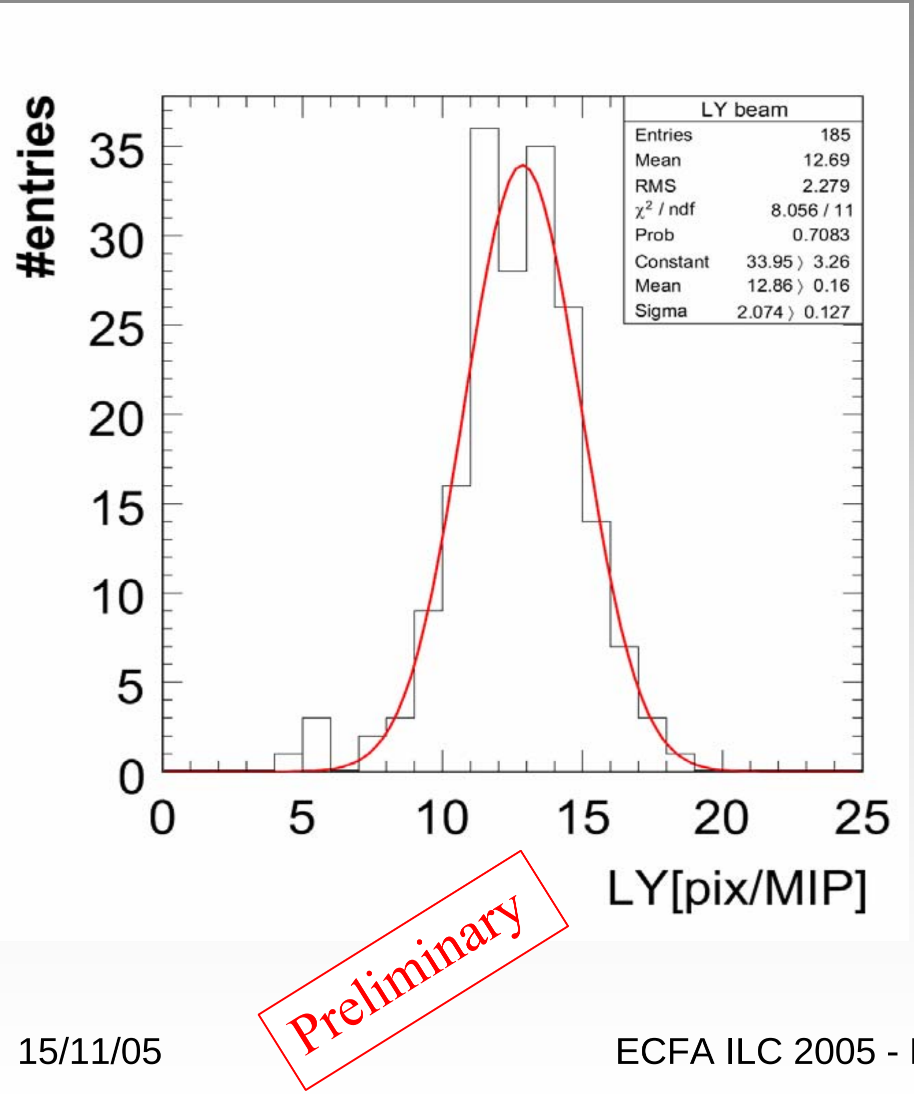


using ASIC chip in 2 modes:

“calibration mode”
short shaping time (40ns)
highest gain

“physics mode”
longest shaping time (180 ns)
medium gain

LY calibration on module #1

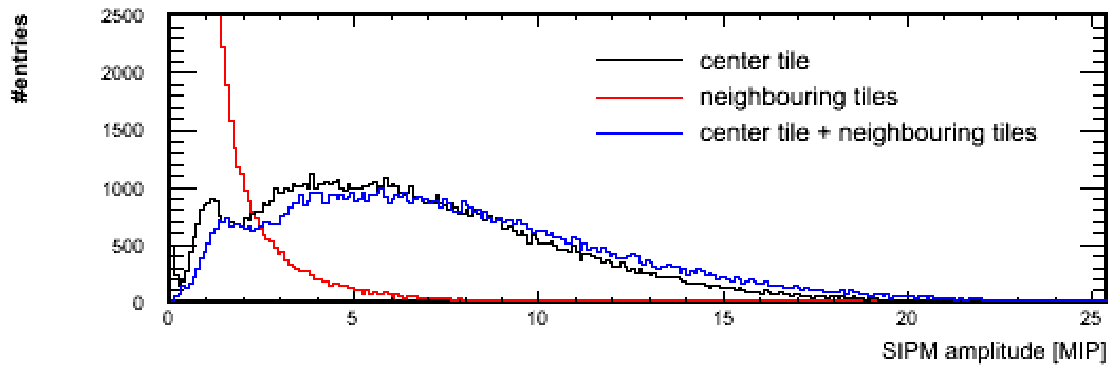


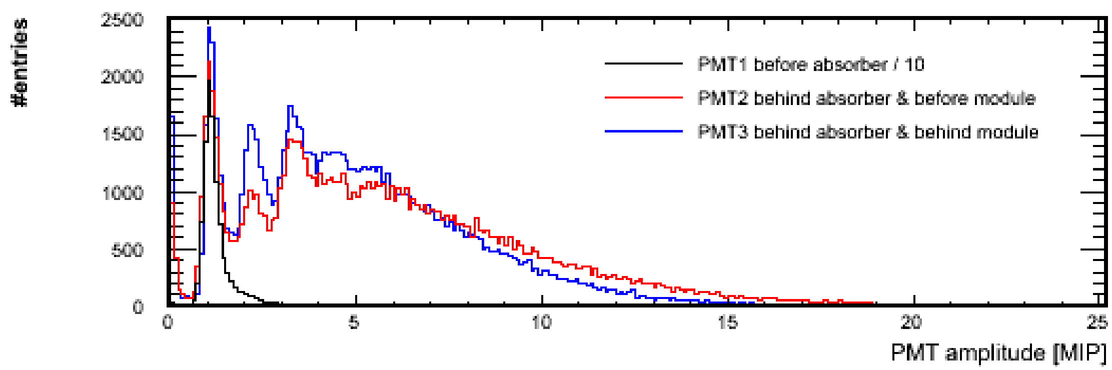
$$LY = \frac{A_{MIP}}{gain} * \frac{A_{LED}^{calib}}{A_{LED}^{physic}}$$

MIP calibration
Gain calibration
Intercalibration

Lightyield: 13 ± 2 pix/MIP
LY spread is as expected

Absorber studies on module #1





Analysis ongoing:

- uniformity study
- selection of 1,2,3 MIP signals

➔ better determination of the lower part of the SiPM response function

- also 5 X_0 data are available

➔ apply SiPM response function for correction

Conclusion & Outlook

- We are commissioning a multi-channel system
- The major functionality proof of the front-end electronics is the successful application of the calibration procedure

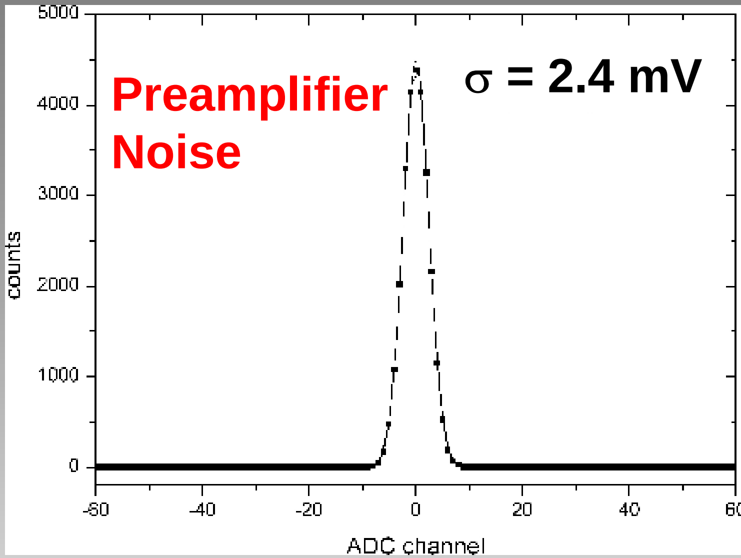
  - MIP and LY calibration applied to ~200 ch.

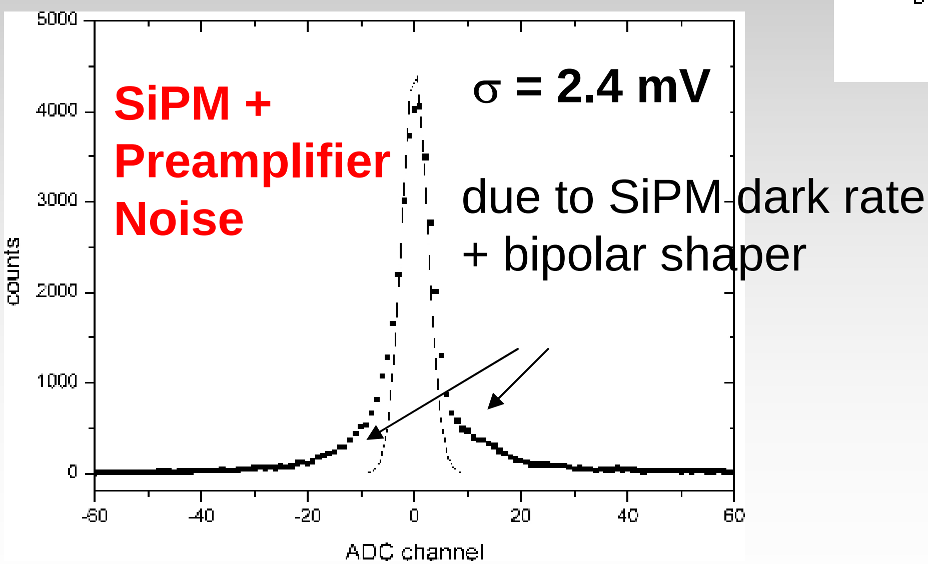
  - now to be extended to 8000 ch.

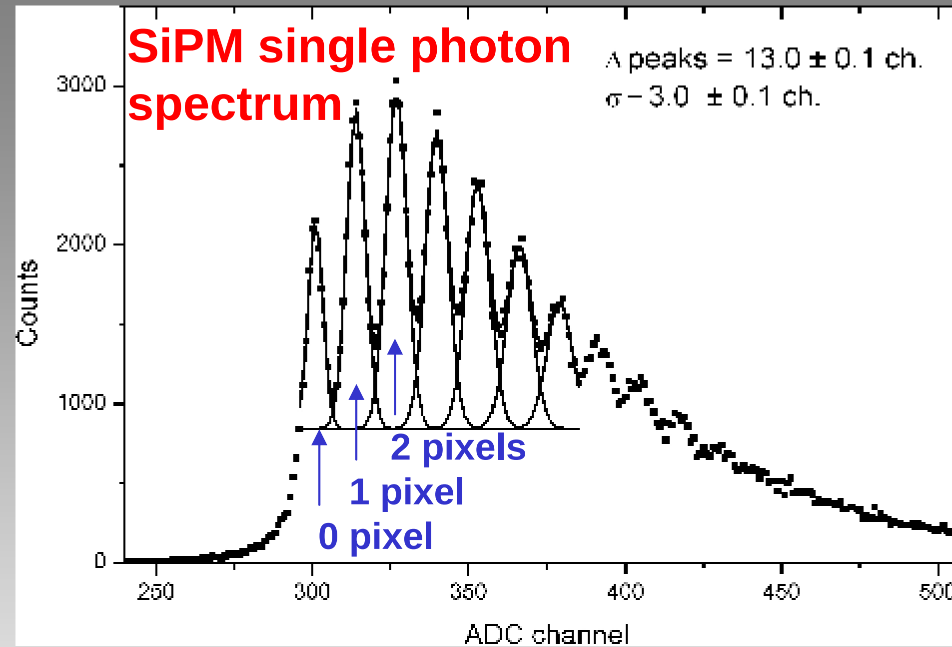
  - integration of the final calibration-monitoring LED system
  ➔ temperature corrections
- High amplitude data are available:
  ➔ test of the correction for the SiPM response function
  ➔ completion of the full calibration chain

BACKUP

SiPM readout with ASIC chip







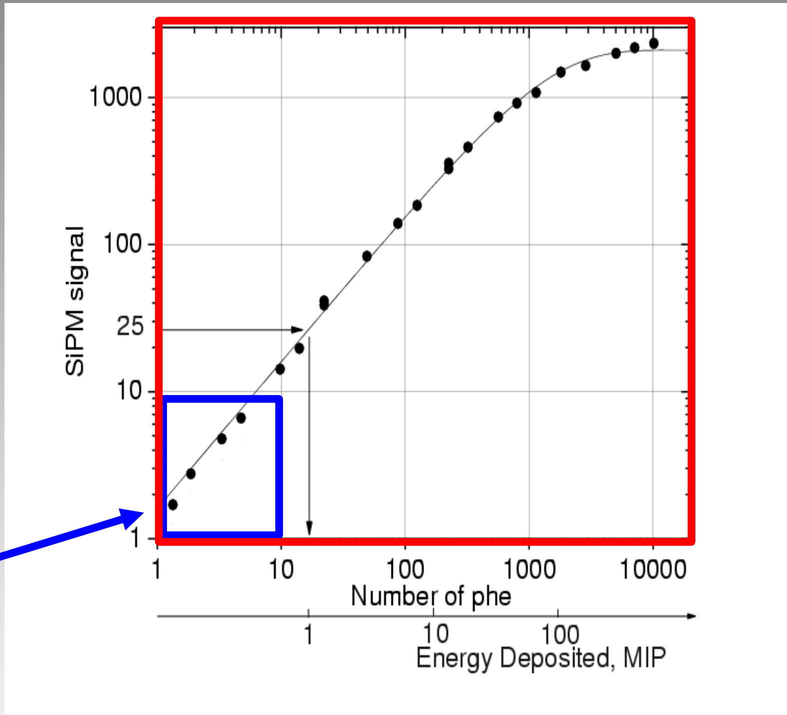
Use shortest shaping T and highest G for SiPM gain calibration:

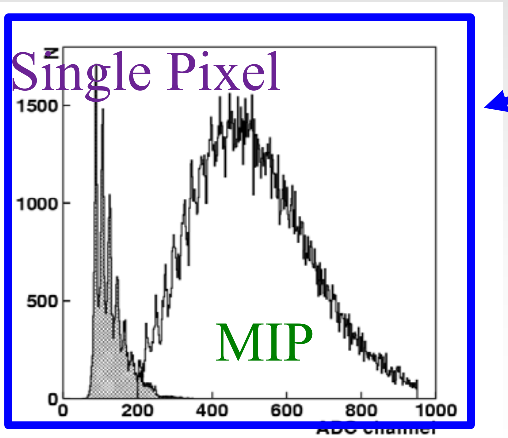
- Good separation between peaks
- gain / noise ~ 4 (as expected)

The calibration concept

For a calorimeter with linear readout:
E = ADC * MIP/ADC * E/MIP

BUT SiPM is nonlinear:
Energy = ADC counts
* gain (pixel calibration)
* SiPM response (SiPM response function)
* light yield (MIP calibration)
* sampling





E = ADC * pxl/ADC * ph.e./pxl * MIP/ph.e. * E/MIP