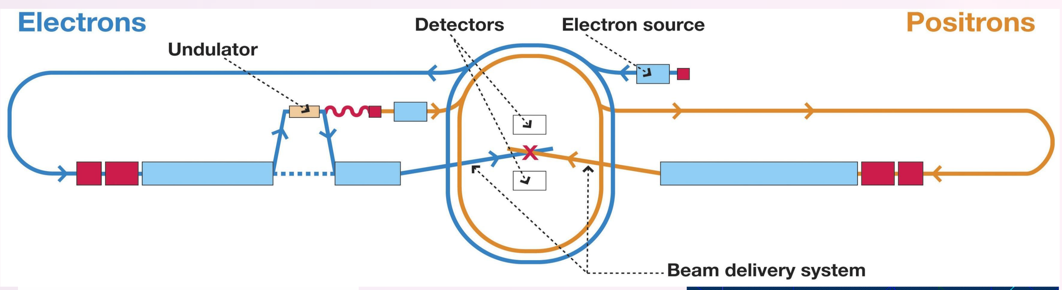
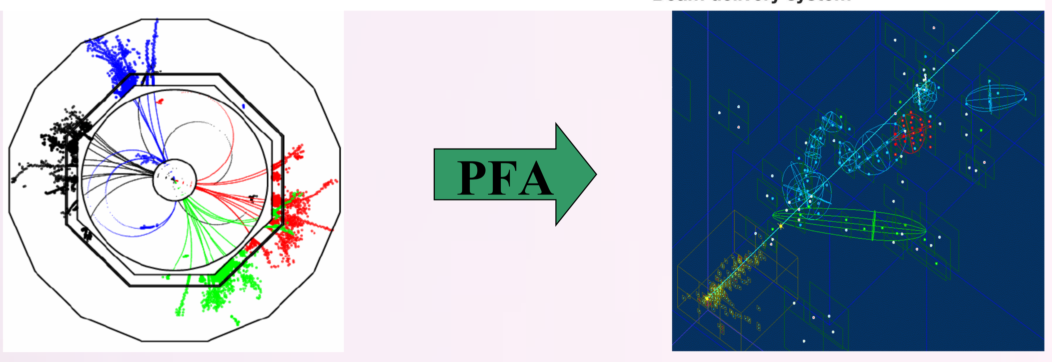
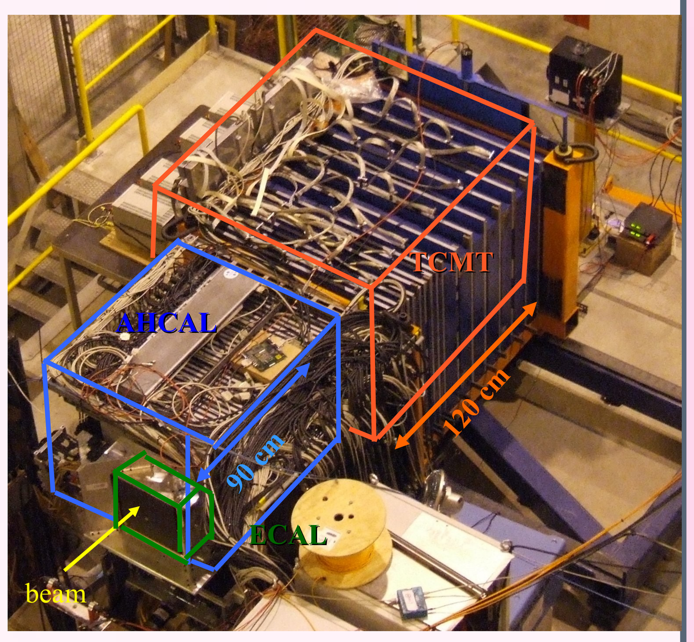
Calibration of the Hadronic Calorimeter Prototype for the CALICE Experiment

Jaroslav Zalesak, for the CALICE Collaboration
Institute of Physics of the Academy of Science, Prague, Czech Republic

ILC: Proof of Principle ➨ Reality



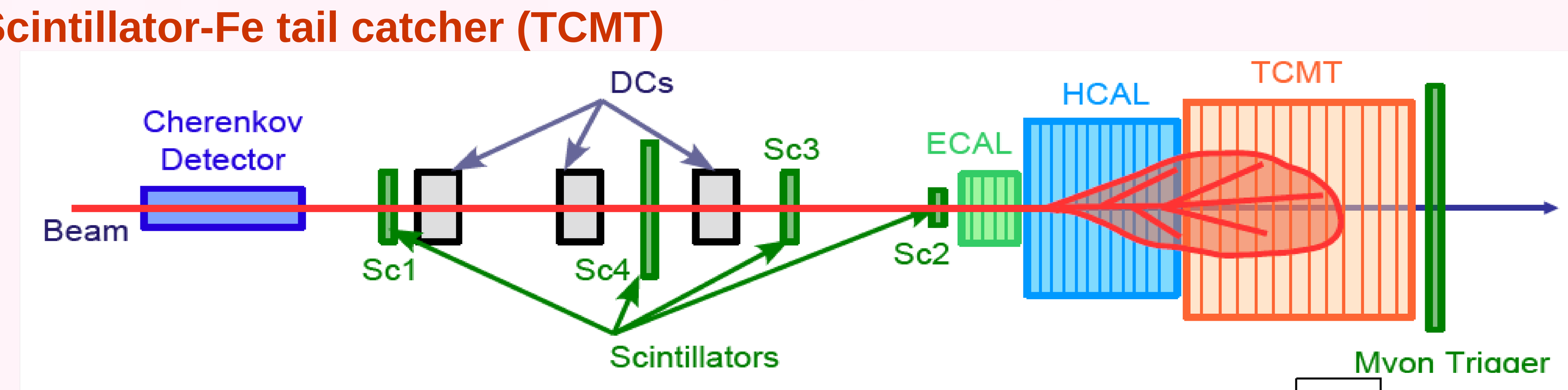




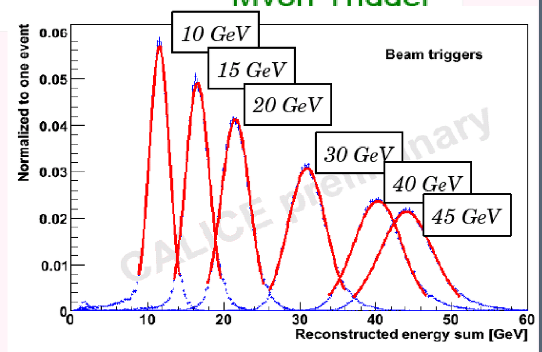
❑ *Anticipated physics at ILC: unprecedented jets energy resolution*
❑ *Promising candidate to achieve this goal is PFA* ➧ *based on high granularity of EM and Hadronic calorimeters*
(possibility of detection particle tracks and energies in jets)

The CALICE Experiment

Beam test of the calorimeters optimized for the particle flow (PFA) at the future ILC
- SiW electromagnetic calorimeter (ECAL)
- Scintillator-Fe hadronic calorimeter (Analogue HCAL)
- Scintillator-Fe tail catcher (TCMT)

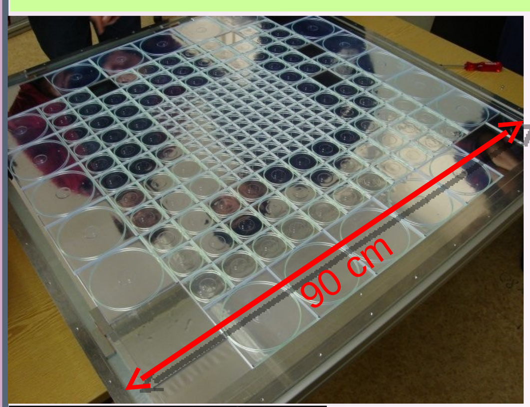


Test beam campaigns at CERN (2006, 2007) and FNAL (2008, 2009)
- *Different particle species: e±, π±, p, μ*
- *Wide range of energies: 1 GeV to 180 Rotation up to 30°*

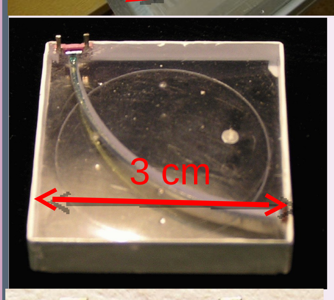


The Scintilator Tile AHCAL

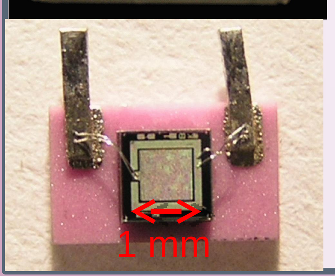
- 1 m³ instrumented, 4.5 λ deep
- 38 layers, 2 cm Fe absorber plates
- 7608 channels with individual readout



__One active layer__:
- *216 scintillator tiles, size 3x3 to 12x12 cm², highest granularity in the center (10x10 cells)*
- *UV LED calibration system with 12 LEDs and PIN diodes to monitor LED intensity. Light distribution via clear fibers*
- *5 temperature monitoring sensors per layer*



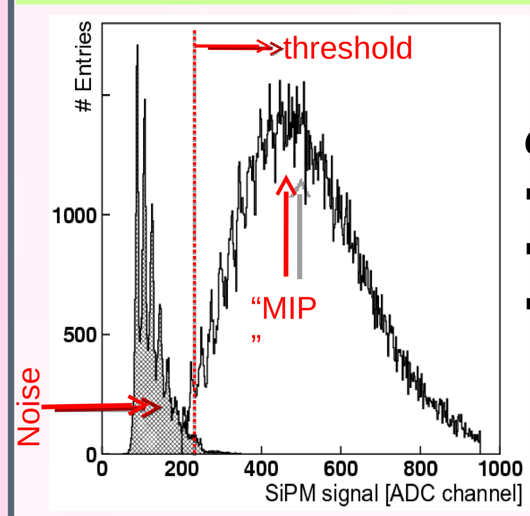
__One scintillator cell__:
- *Embedded WLS fiber absorbs UV scintillator light (~400nm) and emits green light at 500 nm*



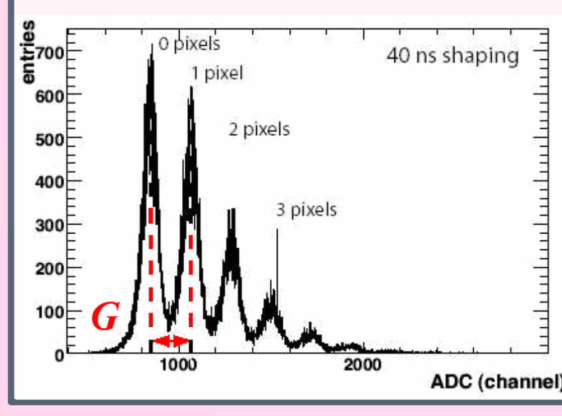
__Silicon Photomultiplier (SiPM)__ as a new type of photodetector:
- *1156 pixels, working as avalanche photodiode in Geiger mode*
- *High gain of ~ 10^6 at low U_{bias}*
- *Signal = sum fired pixels ↔ saturation effects*

HCAL Calibration

Two-step cell-by-cell calibration of the analogue HCAL:
- MIP calibration with muons
- SiPM gain calibration with low-intensity LED light

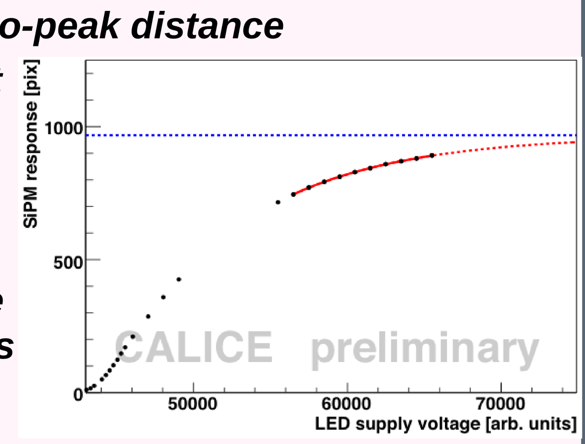


Calibration runs with muon beam for whole detector
- *Measure the response to minimum ionizing particles for each cells*
- *Most probable value (MIP) extracted from the fit*
- *This provides an unbiased energy scale*



Calibration data with low intensity LED light
- *Single photons can be resolved*
- *Gain determined from peak-to-peak distance*
- *Self calibration: independent of the LED light stability*

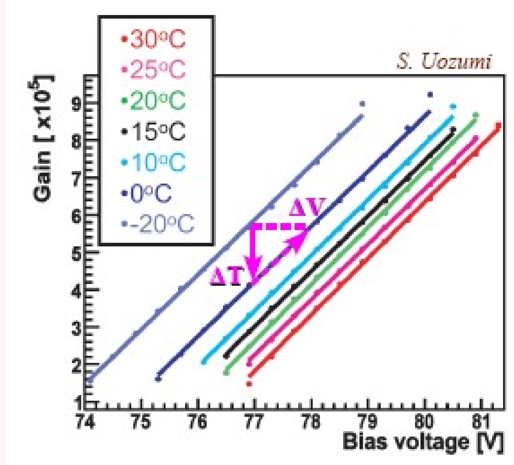
➨ *Knowledge of the SiPM gain (number of pixels) is crucial to correct for the nonlinear response due to the limited number of pixels in the SiPM*



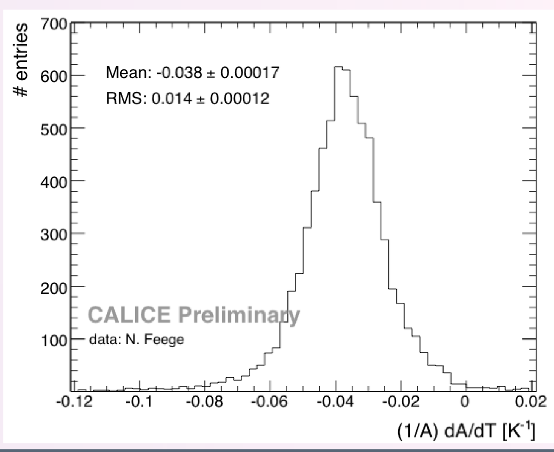
Temperature & Voltage Dependence

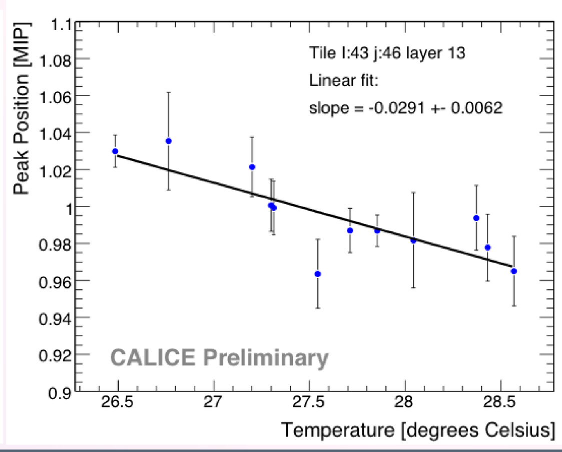
SiPM gain is strong temperature and voltage dependence.
- *Significant variations of the detector temperature over the available data set (up to 4 K for some cells)*
- *Temperature variations over data taking period are substantial*
- *We need to correct raw energy measurement for T variations*

➨ *Calibration system used to monitor T and U induced gain changes*



Correction Possibilities:
- *LED calibration data to study the gain variations*
- *Muon data at some temperatures to study amplitudes*
- *Hadron data (track segments) over the full temperature range*





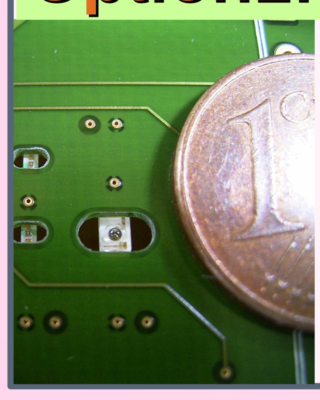
Light Calibration System (LCS)

A gain–calibration and –monitoring system (LCS) is needed
- *due to strong temperature and voltage dependence: dG/dT = -1.7% / K dG/dU = 2.5% / 100mV*

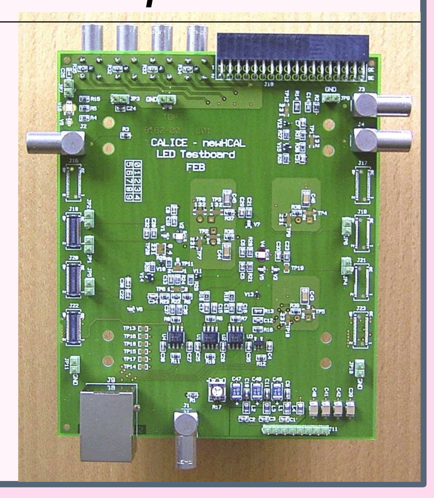
High dynamic range demand:
- *at __low__ light intensities:*
  distance of single-photon peaks defined gain
- *at __high__ light intensities:*
  SiPm shows saturation behaviour (~100MIPs)

New concepts – 2 option under investigation:
1. *One LED per tile: integrated into detector gap*
   no fibers needed for light distribution
2. *One strong LED outside detector*
   light distribution via notched opt. fibers

Option1: Embedded LEDs

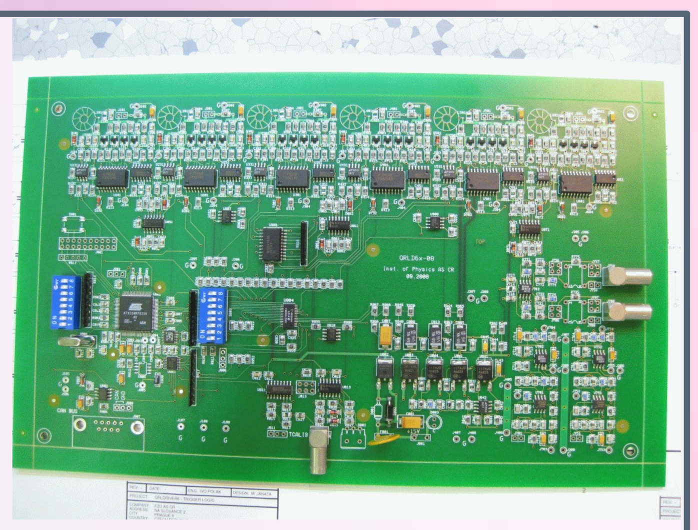


LED test board realized:
- *Ultraviolet LEDs are mounted up-side-down*
- *Crosstalk is purely optical (coupled tiles: ~2.5%),*
- *No electrical crosstalk due to good GND system.*
- *Dynamic range promising*

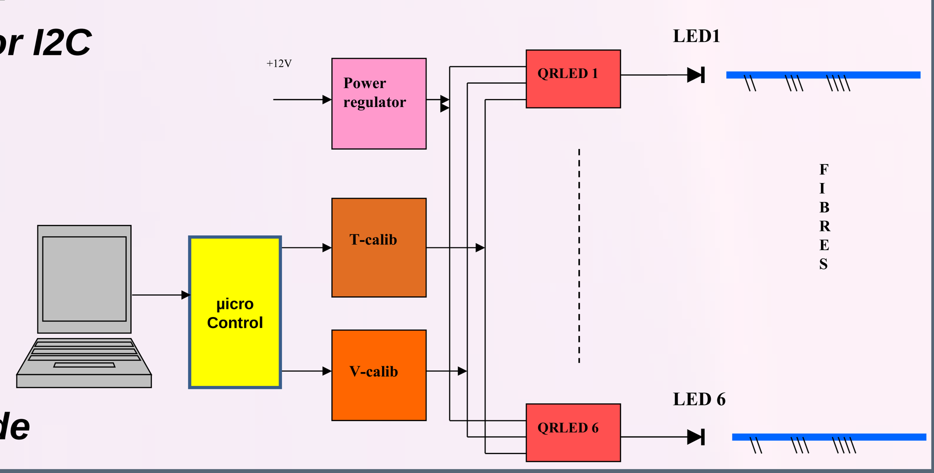


Option 2: LED driver

Option with optical light fiber distribution:
- *Electronics: multi-channel prototype complete*
- *Optical system: uniformity again competitive*
- *Integration LED pulsing system into active layer*



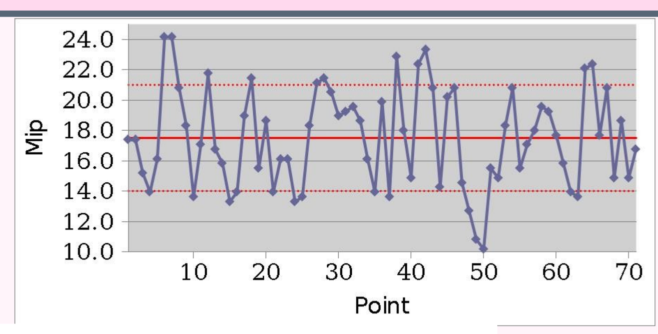
Multichannel LED driver:
- *1 PCB with the communication module μC, power regulator, 6 channels of QRLed driver*
- *Communication module to PC via CAN bus or I2C*
- *Controlling the amplitude and monitoring temperature and voltages*



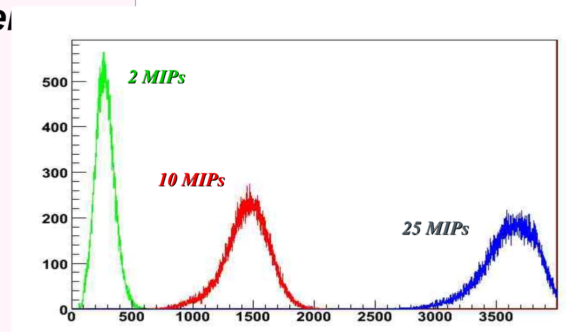
- *LED pulse width ~ 5 ns fixed, tunable amplitude up to 50-100 MIPs controlled by the V-calib signal*
- *2 LEDs can be monitored by a PIN photodiode*

Option 2: Optical system

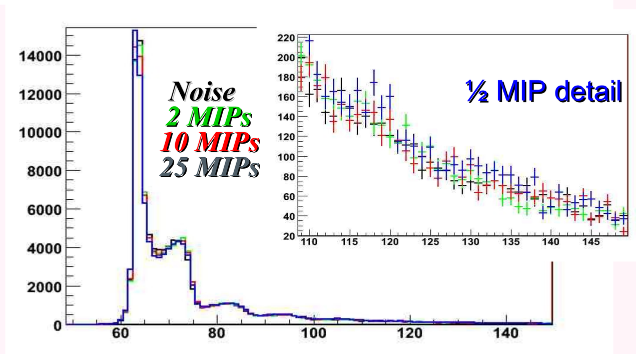
Idea: use one fiber for one row of tiles (72)
- *Uniformity of distributed light*
- *Enough intensity of distributed light*
- *Concentration of LED light into one fiber*

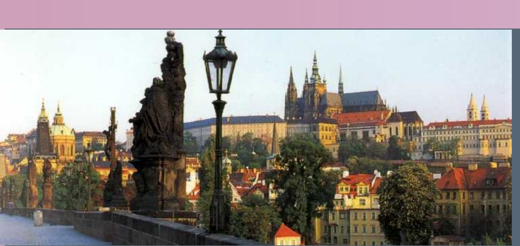


Two possibilities fibers:
- *Side-emitting*
  - *exponential fall of intensity*
- *Notched fiber*
  - *better uniformity of distributed light*
  - *need to mechanize production - R&D*



No optical cross talk seen (< 1-2 %):
- *No differences at various amplitudes*
- *no dependence on chosen pair of notches*
- *and light input direction*





ADVANCED STUDIES INSTITUTE: SYMMETRIES AND SPIN
Prague, Czech Republic July 26 - August 2, 2009