The CALICE Scintillator HCAL Testbeam Prototype

G. Eigen, U. Bergen/DESY

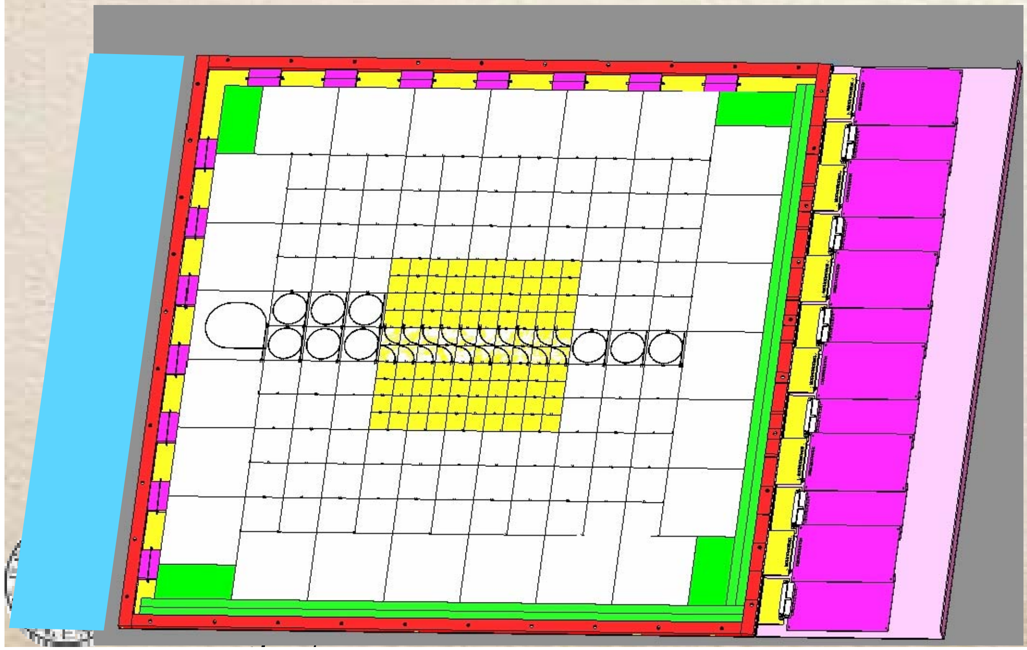
CALOR-06 09/06/06

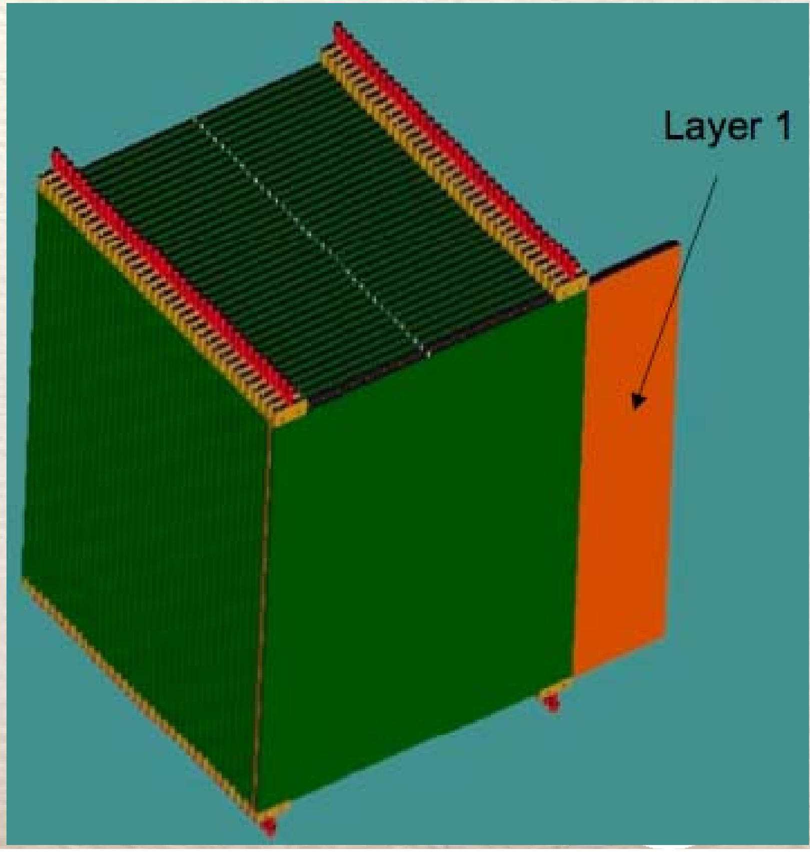
Introduction

- The physics at ILC requires excellent calorimetry to utilize the concept of particle flow
- To separate electromagnetic showers and neutral hadron showers from other particles, fine segmentation in the longitudinal and transverse directions in necessary both for the EM and hadron calorimeters
- At DESY, members of the Calice collaboration are constructing a 1 m^3 analog hadron calorimeter prototype, consisting of a 38-layer steel plastic scintillator tile sandwich structure (4.6 λ) that will be tested in hadron beams together with an ECAL and a tail catcher
- The design of the "physics" prototype is based upon the experience gained with a technical prototype (MiniCal) that operated 108 scintillator tiles read out with wavelength-shifting fibers coupled to SiPMs in a positron testbeam at DESY

Physics Prototype Stack

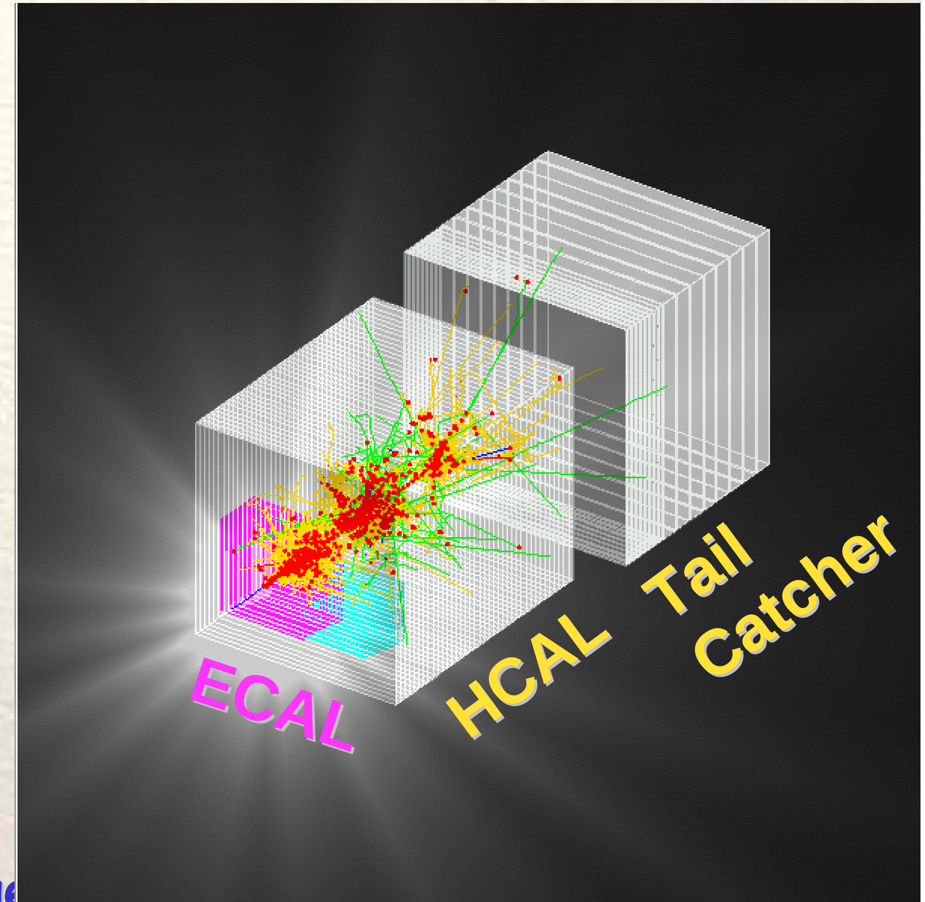
- 38 layer sampling calorimeter
- 2 cm steel absorber plates + 1/2 cm scintillator tiles
  - core 100 tiles: 3×3 cm^2 (reduce to 25 6×6 cm^2 in layers 31-38)
  - intermediate rings: 6×6 cm^2,
  - outer ring: 12×12 cm^2
- WLS fiber + SiPM readout of each cell (total of 7608 cells)





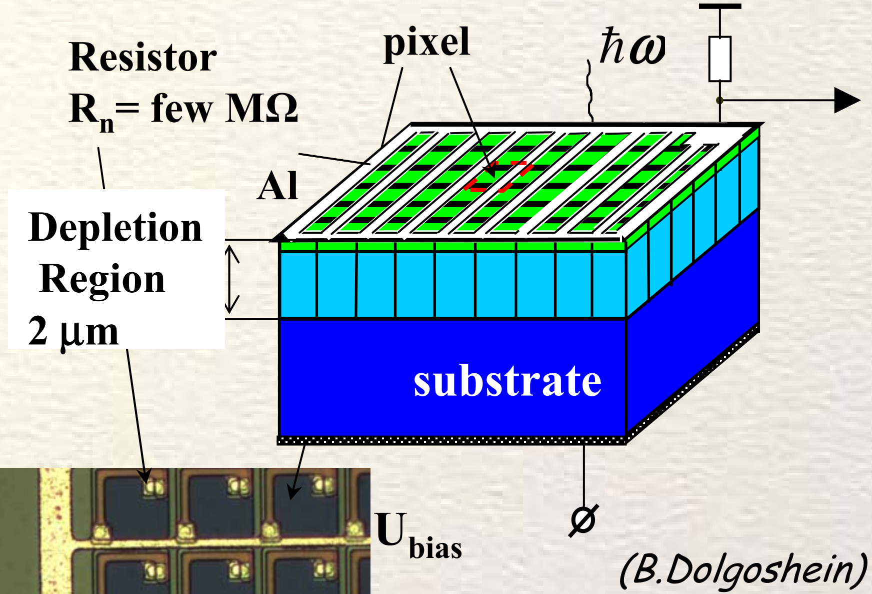
Goals for the Physics Prototype

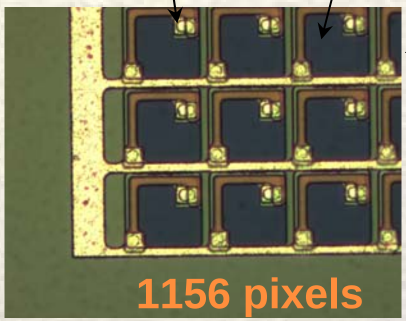
- Study structure of hadron showers for different energies and incident angles
- Validate simulation with measured showers
- Study separation of 2 adjacent showers needed for jet-energy reconstruction
- Gain large-scale, long-term experience with calorimeter based on SiPM readout
- Develop calibration strategy
- Identify critical operational issues (see F. Sefkow)

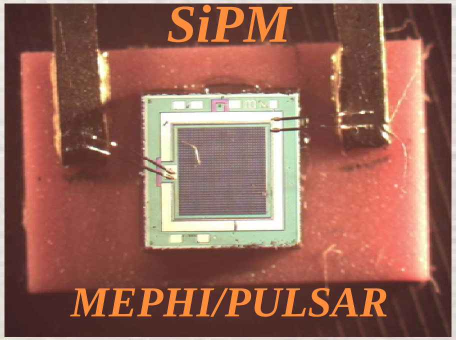


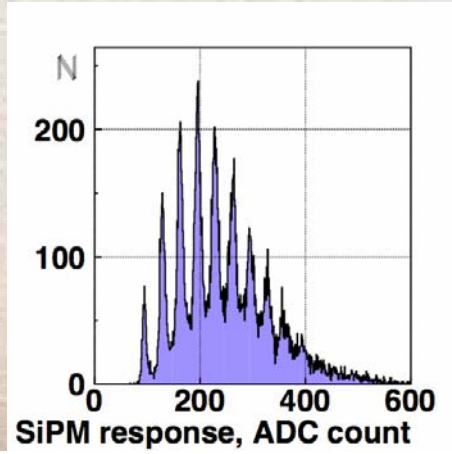
Properties of SiPMs

- Multipixel Geiger Mode APD
  - Gain 10^6
  - Bias U~50 V
  - Active area 1 mm^2
  - 1156 pixels, 20μm × 20μm
  - Efficiency 10-15%
  - Insensitive to B field
  - Each pixel has few MΩ quenching resistor
  - Recovery time < 100 ns
- SiPM detectors are auto-calibrating
- SiPM response is non linear





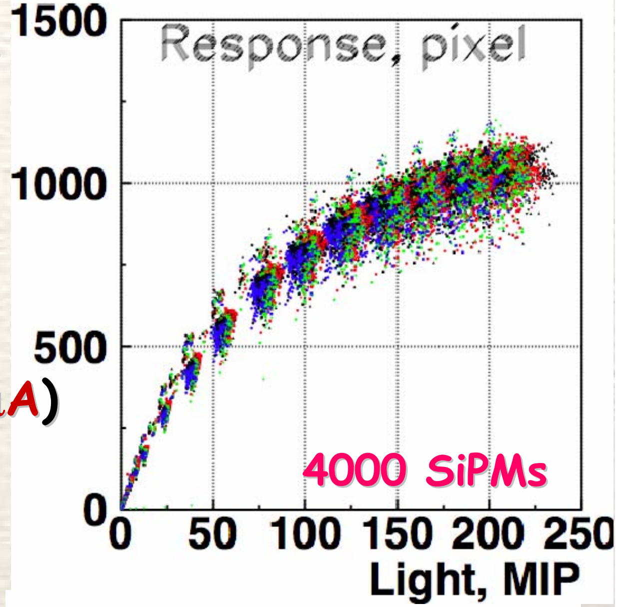


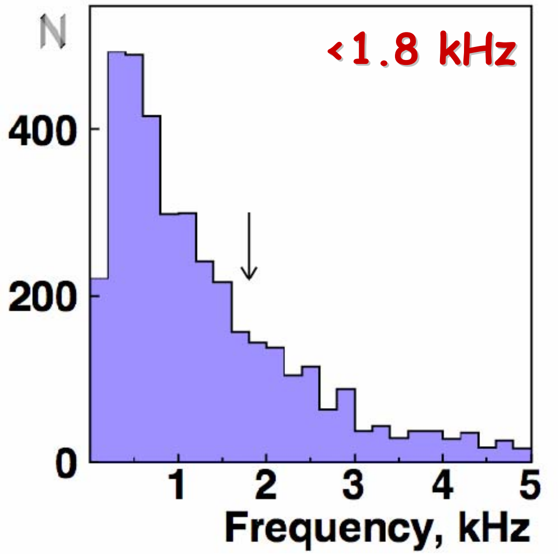


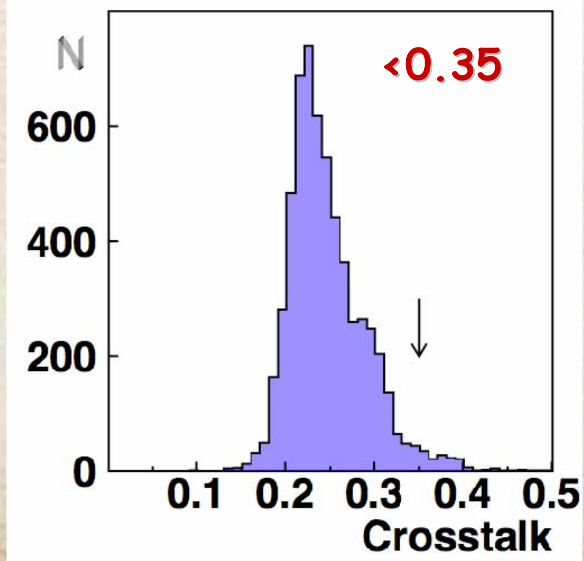
SiPM Tests at ITEP

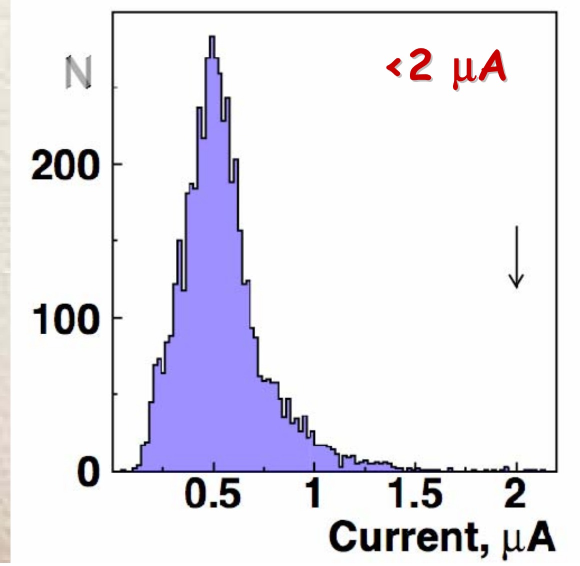
- In automatic setup illuminate 15 SiPMs simultaneously with calibrated UV LED light
- Operate with $U=U_{nominal}+2$ V for 48 hours choose operating point at 1 MIP=15 pixels
- Measure non-linear response
- Select SiPMs wrt gain ($>4\times10^5$), noise (<1.8kHz), cross talk (<1.8kHz), current ($<2\mu A$)
- Over 5000 SiPMs have been tested

(M. Danilov)





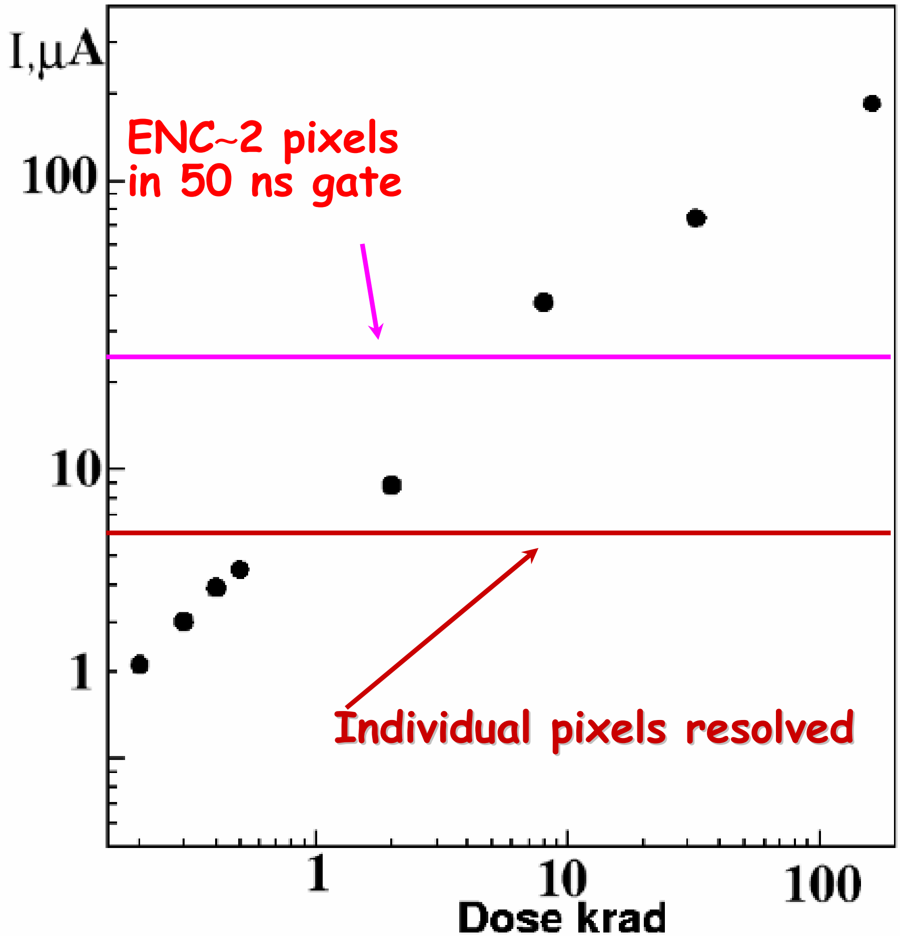




SiPM Radiation Hardness

- Irradiate SiPMs with 200 MeV protons at ITEP synchrotron
- Record current for accumulated dose
- After 0.8 krad irradiation, SiPM current increases to 5μA
  ➔ resolve single pixels
- Yield 5 μA also for $6\times10^{11}/cm^2$ thermal + $2\times10^{10}/cm^2$ 1MeV) n
- At ~5 krad, I_{SiPM}= 25μA
  ➔ MIP is still measurable
- For ILC operation we expect n flux of $<10^{10}$ $cm^{-2}/500$ fb^{-1} except for endcap inner layer close to beam pipe

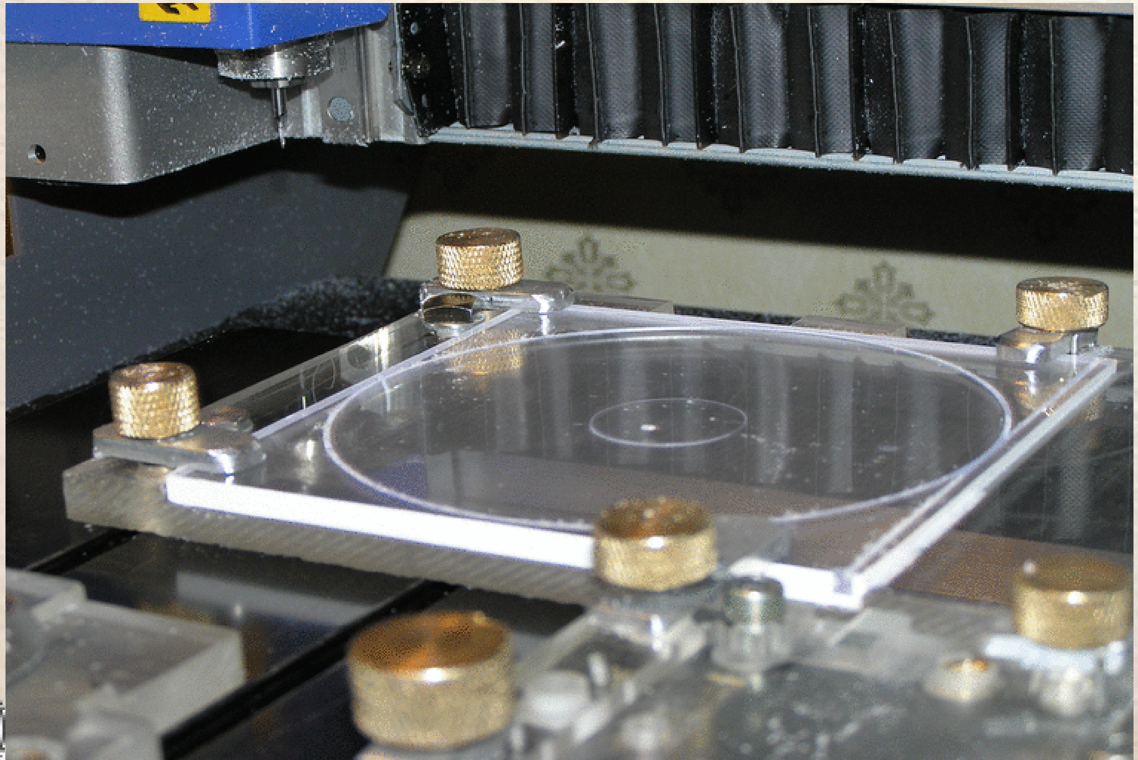
(M. Danilov)

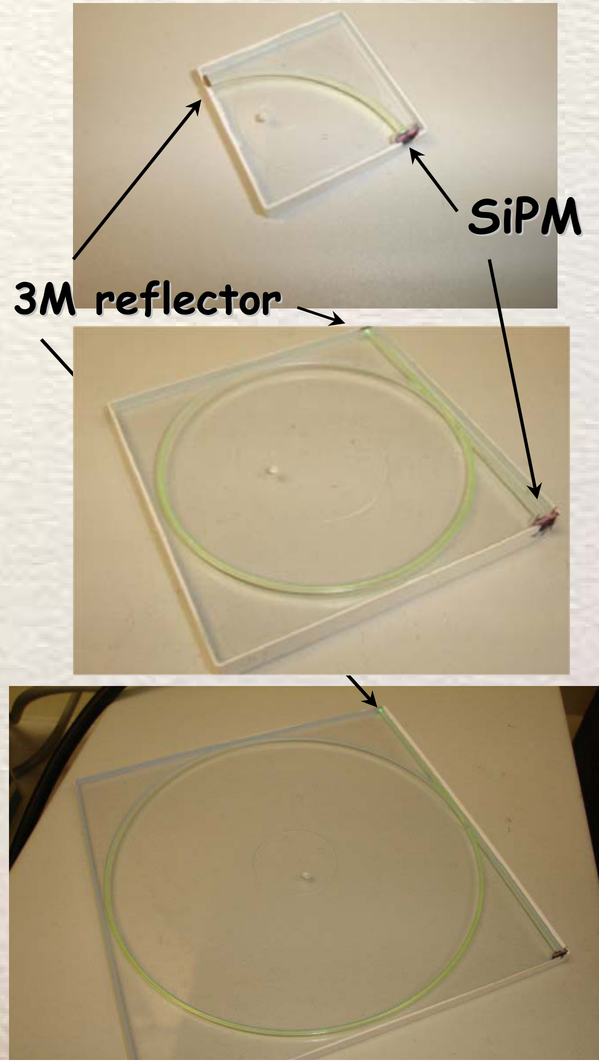


Tile Preparation at ITEP

- All tiles have been molded and edge treated (matting)
- Mill groove into tiles at ITEP and insert WLS fiber
- Insert SiPM on one side and cover other side of WLS fiber with 3M reflector

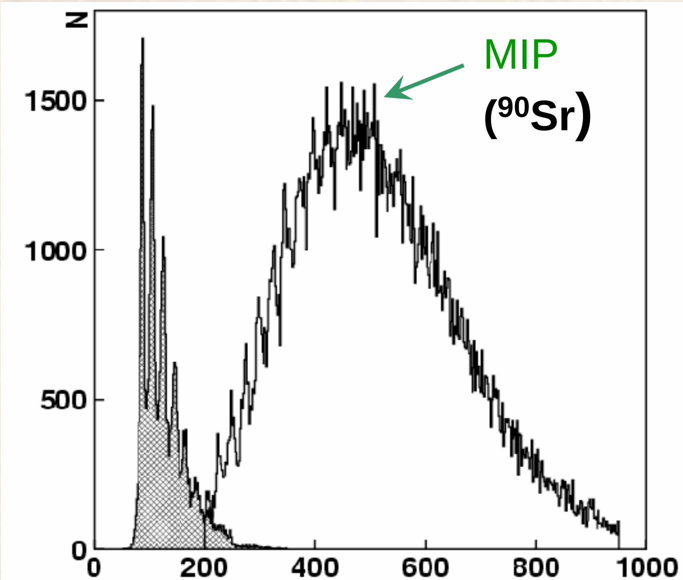
(M. Danilov)

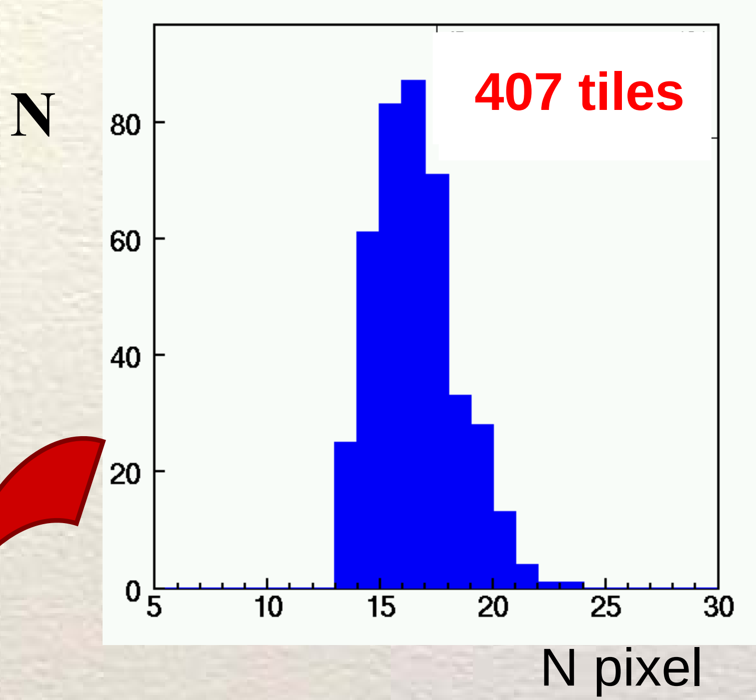




Measured Light Yield in Tiles

- Selected SiPMs are inserted into the tiles, (via air gap to fiber)
- With ^{90}Sr source the light yield of entire cell (tile + WLS fiber + SiPM) is measured (M. Danilov)
- To ascertain a sufficient dynamic range, we want MIP peak in 10-20 pixel range

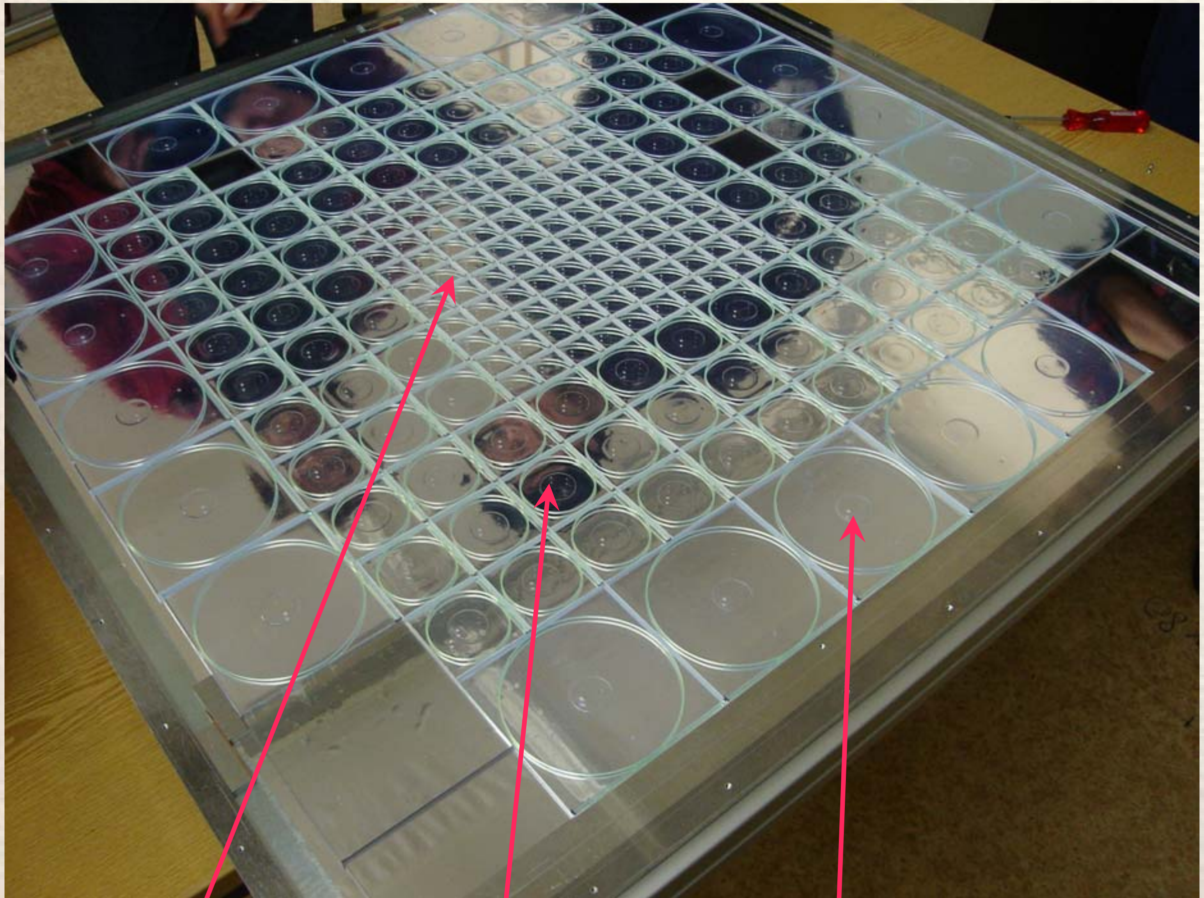




- <LY>= 16.6 pixels
- Spread =1.9 pixels

Module Layout

- 216 tiles with WLS fiber + SiPM readout mounted in one layer



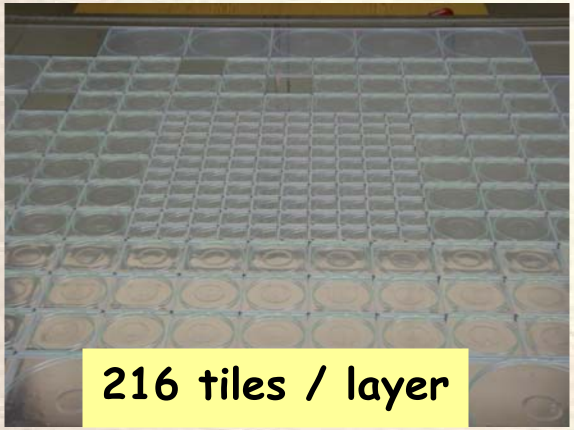
- Tiles are positioned and fixed in a frame
- The high granularity in the core is suited for a test of the semidigital readout option

3×3 cm² 6×6 cm² 12×12 cm²

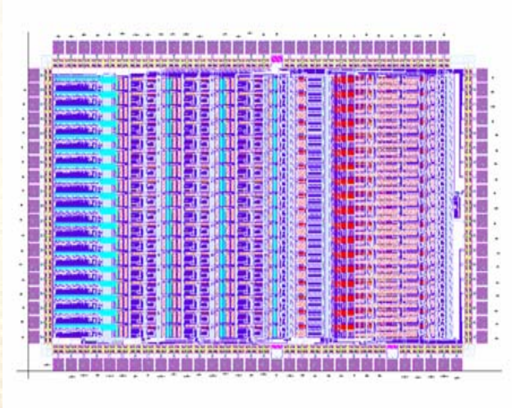
Routing of Fibers and Wires

- Measure SiPM positions
- Cover tiles with 3M super reflector
- Mount FR4 board
- Glue flexible pads
- Solder SiPMs & cables to pads
- Route fibers and test them
- Test readout

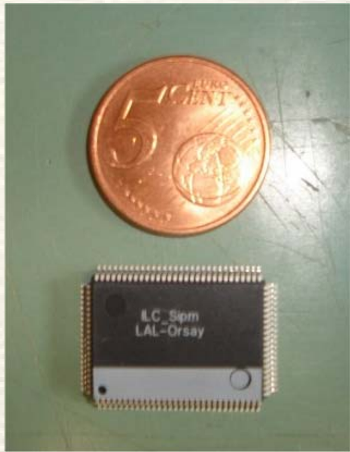
HCAL Readout Architecture



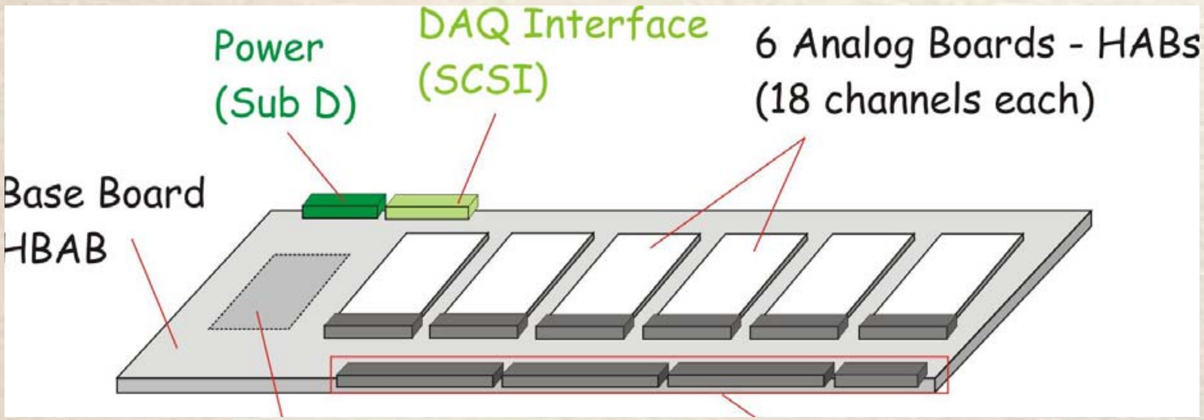
216 tiles / layer



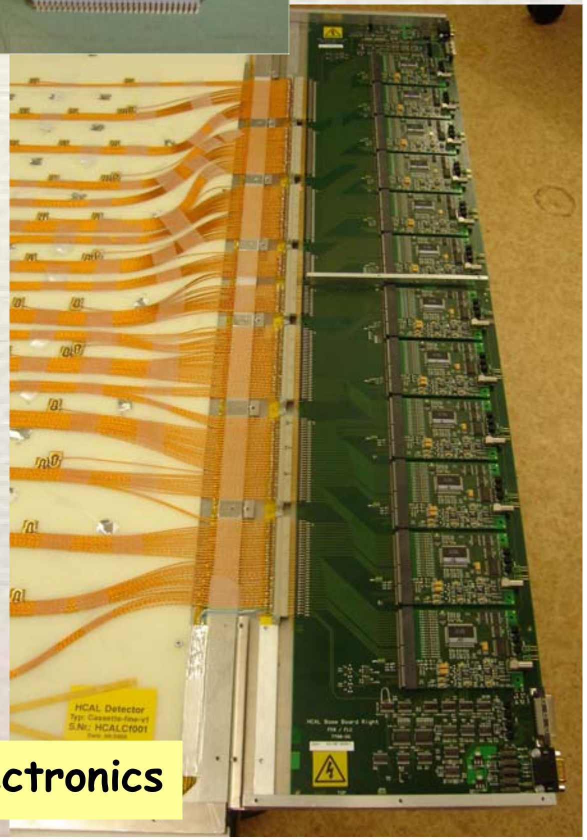
18 analog channels / chip



ILC_SiPM chip



2 base boards (12 piggy backs) / layer



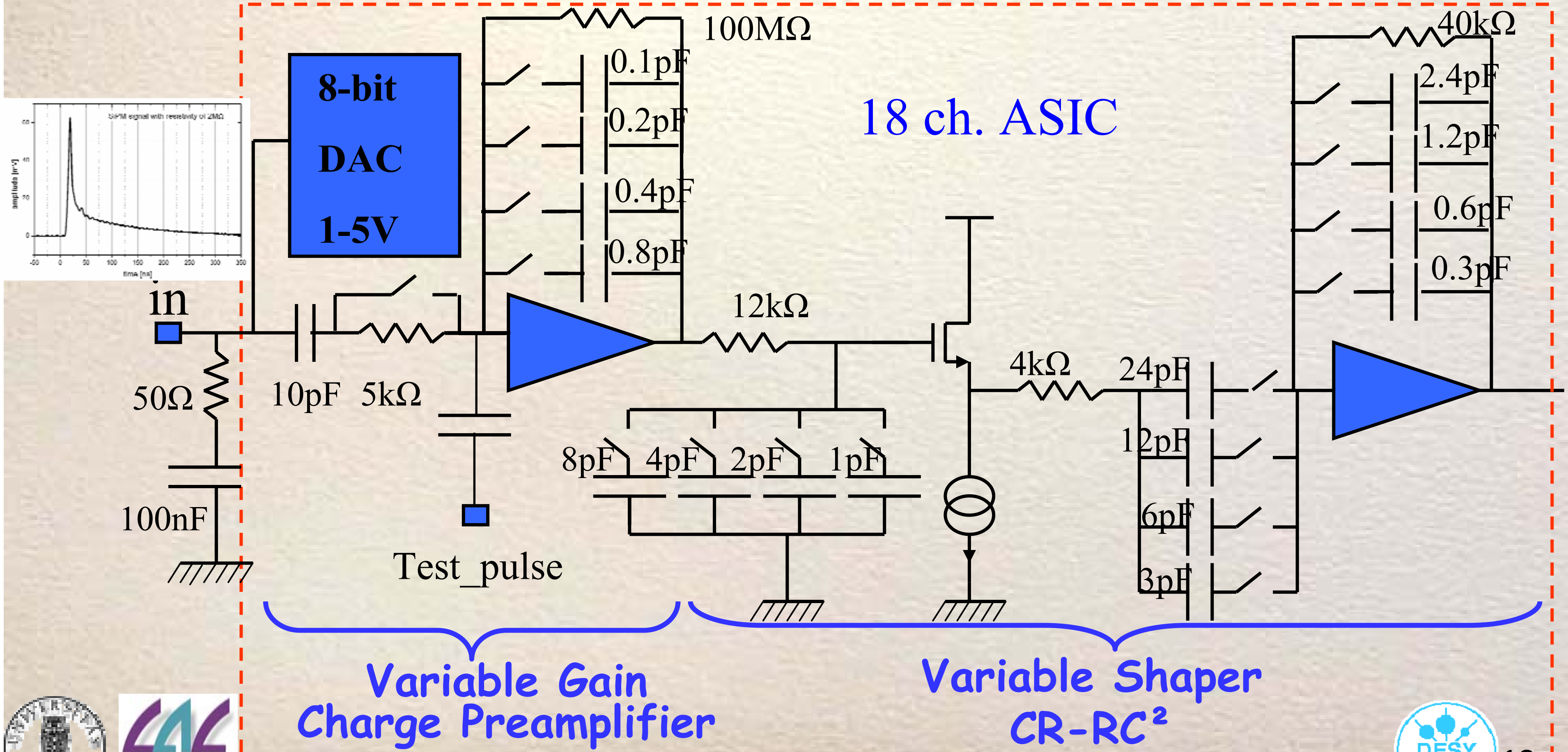
very front-end electronics

Frontend ILC SiPM Chip

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

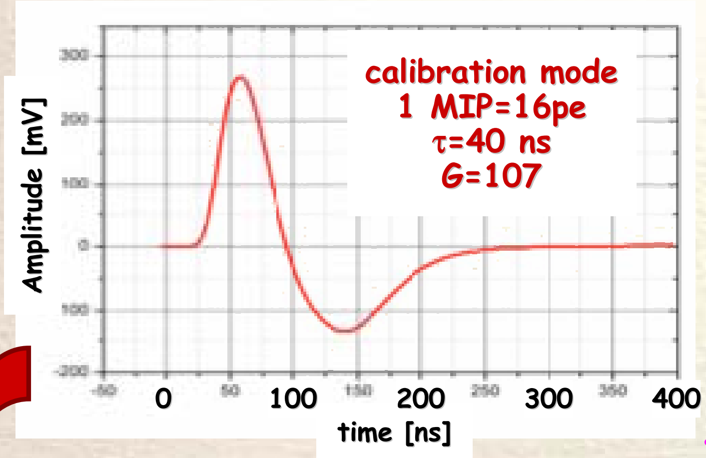
- Based on ECAL asic

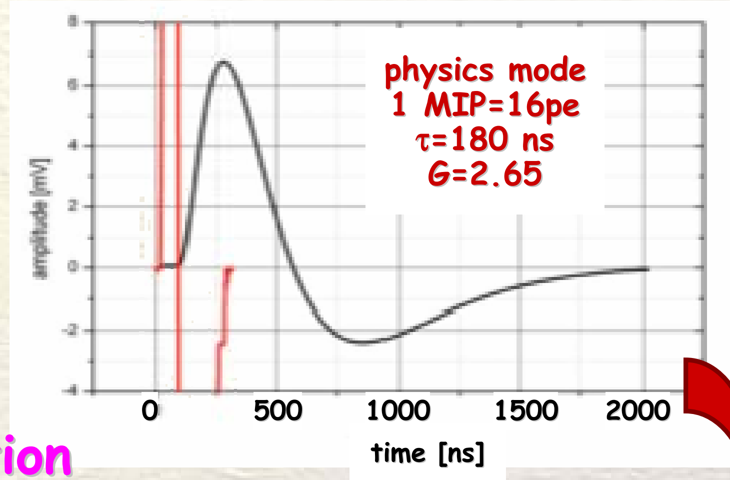
From L.Raux (LAL)



Calibration and Physics Mode Operation

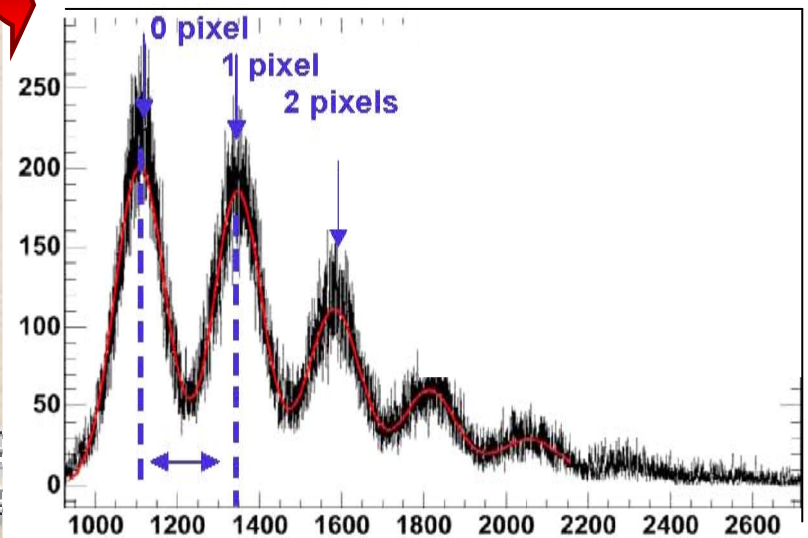
- Use high gain & fast shaping for calibration
- Use low gain & long shaping for beam mode



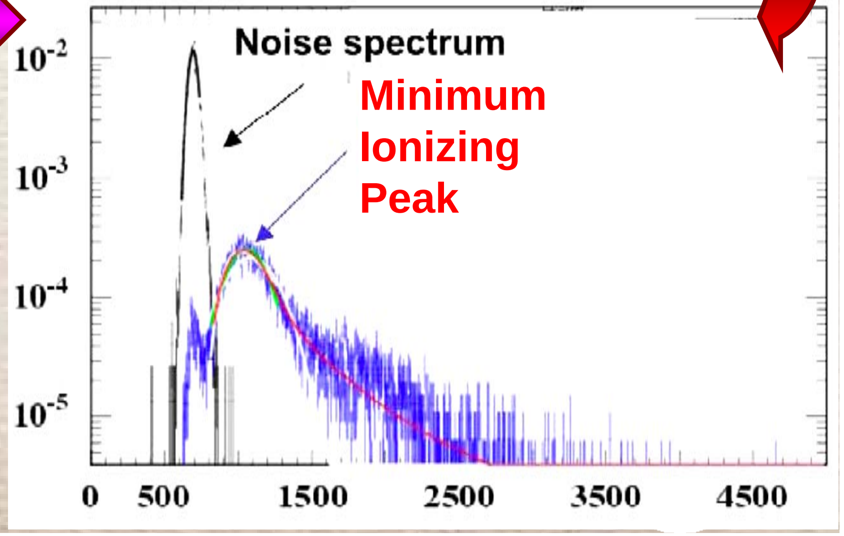


Intercalibration
(see E. Garutti)

Gain calibration



MIP calibration

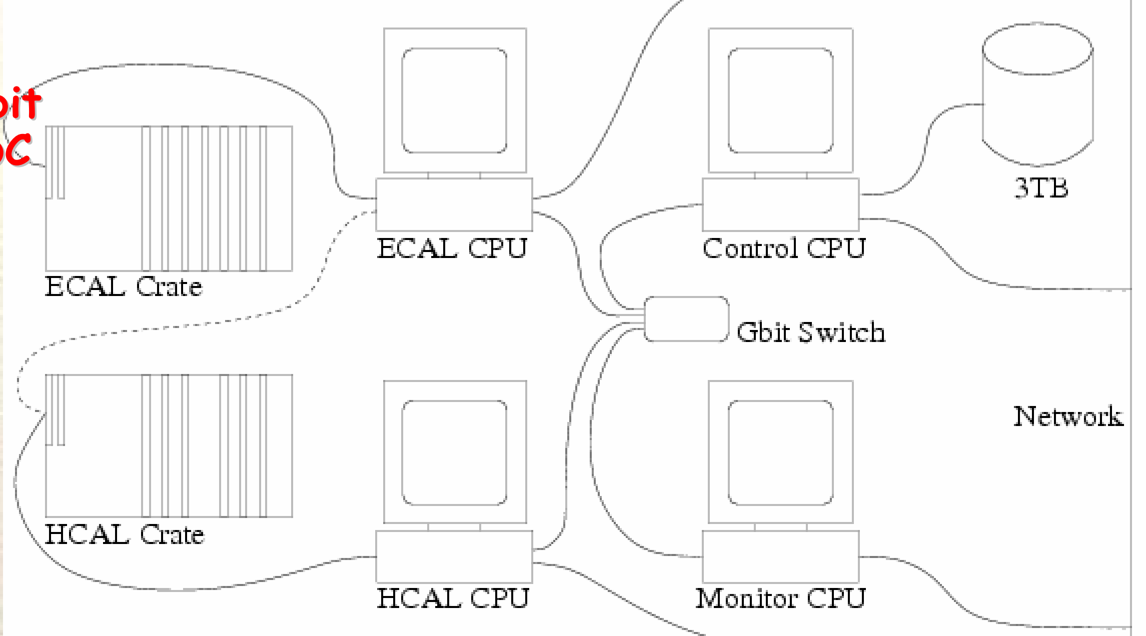


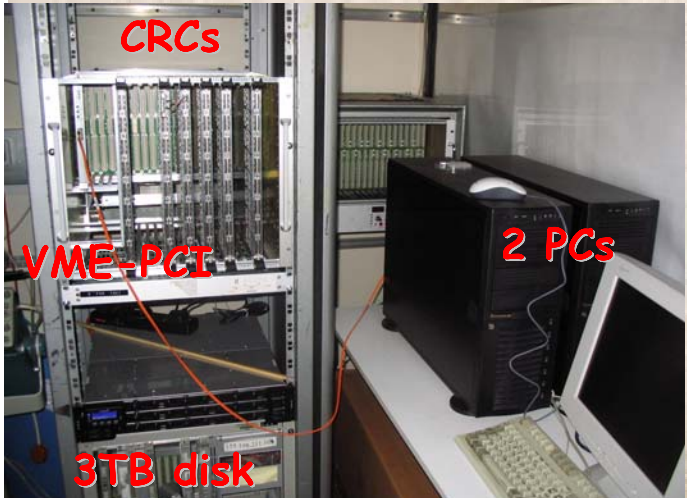
Data Acquisition

- VME-based DAQ modified from CMS Si tracker RO board, first adapted for the ECAL
- Does very front-end control, digitization and data buffering
- Need 5 cards, each having 8×216 channels
- >1 kHz inst. rate, 100 Hz average rate 2000 events buffer

16 bit ADC

(P. Dauncey)





CALICE Readout Card

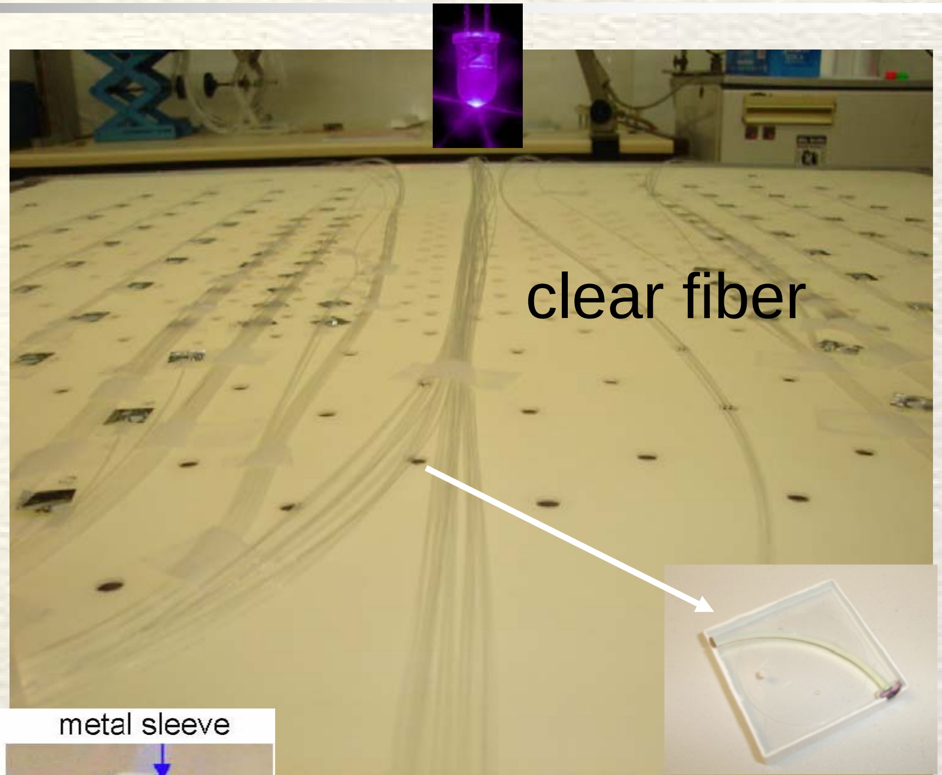
Calibration-Monitoring System

- Monitor stability of tile-fiber-SiPM system between MIP calibrations with fixed LED intensities
- Perform gain calibration
- Measure SiPM response function
- Determine intercalibration constants
- Temperature and voltage dependence of SiPM
  - dG/dT ~ -1.7% / K
  - dG/dV ~ 2.5% / 0.1V
- Temperature and voltage dependence of light yield at fixed light intensity
  - dQ/dT ~ -4.5% / K
  - dQ/dV ~ 7% / 0.1V

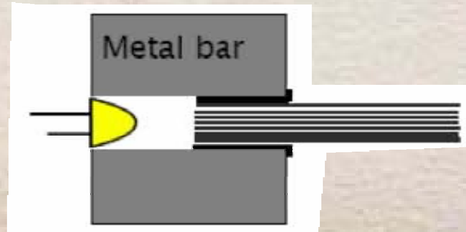
  ➔ stability of LED system after PIN diode correction <1%

Calibration-Monitoring System

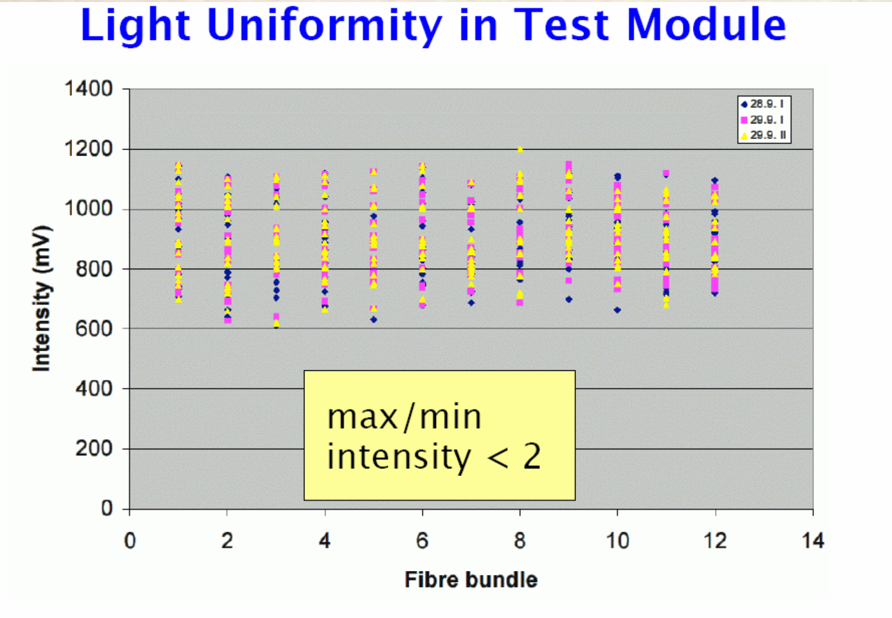
- Provide UV light to each tile via clear fiber
- Monitor each LED with PIN diode
- Record temperature & voltage with slow control system
  (4 temperature sensor/module)



bundle of 19 fibers
18 → tiles, 1 → PIN diode

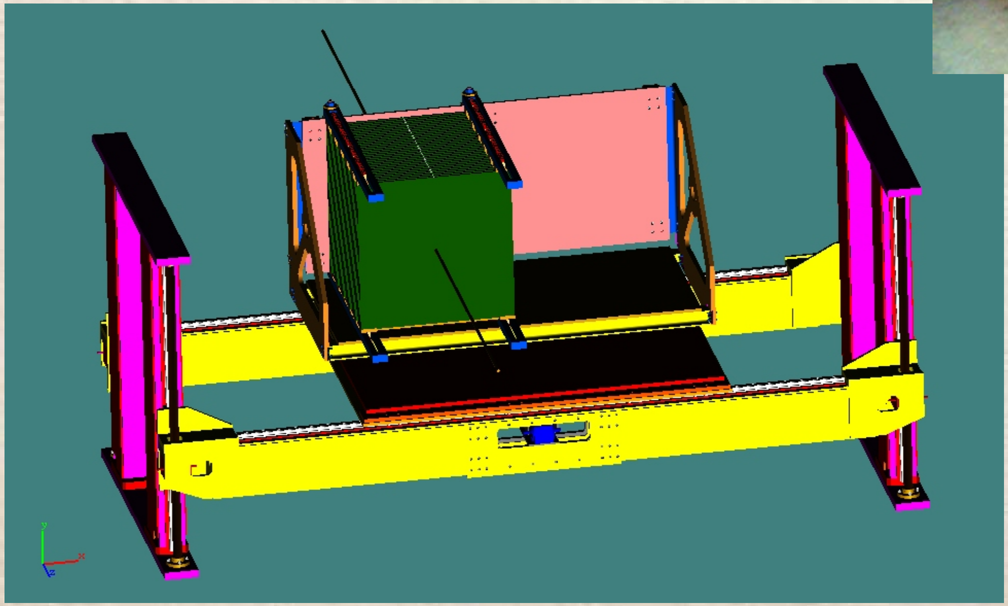


LED fiber coupling



Mechanical Support Structure

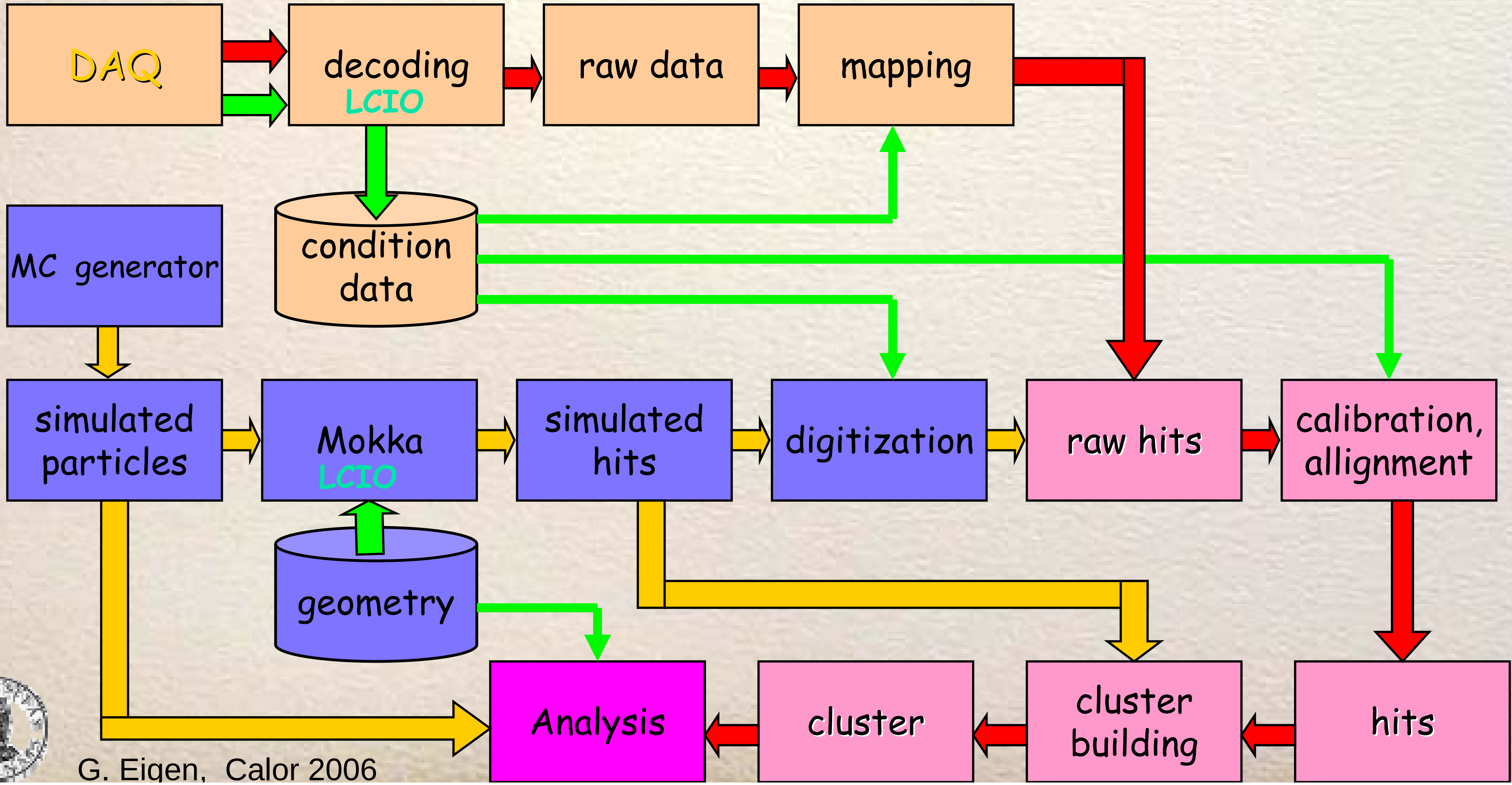
- Stack support for scintillator and gaseous HCALs built
- Movable table design for CERN and FNAL test beam runs



K.Gadow (DESY)

Software for Test Beam Data Analysis

- Use structured software → essential for distributed effort
- It is developed in close interaction with WWS software group
- Use same tools for testbeam analysis and detector optimization



Status of the Prototype

- Construction of 12 modules is completed
- For 8 modules MIP calibration has been performed with e^+ test beam at DESY
- 4 modules are being assembled
- Expect to have 16 modules ready for hadron test beam at CERN together with ECAL (20 slabs) prototype starting end of July (3 ~10 day periods in July, August and October)
- ~14 additional modules will be finished for the October run
- Expect entire 38 layers to be completed by the end of 2006 and to be ready for further beam tests in 2007

Conclusion & Outlook

- A high-granularity analog HCAL prototype is under construction that will study hadronic shower topologies
- It will operate ~8000 channels of scintillator tiles with WLS plus SiPM readout, arranged in 38 layers
- The electronics is designed such that a common DAQ serves for both ECAL and HCAL
- W use a calibration and monitoring system based on monitored UV light distributed to each tile via clear fibers
- The scintillator HCAL prototype is soon completed and commissioned for hadron beam tests at CERN and Fermilab

Collaborative Effort of Calice Subgroup

- **The institutions involved in this work:**
  DESY, Hamburg U.; Dubna; ITEP, MEPhI, LPI *Moscow, Prague, and help from LAL Orsay*