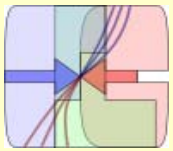
Results from the first tile-HCAL prototype

E. Garutti, DESY
for the CALICE collaboration

- Tile-HCAL prototype: structure and readout
  - tile-fiber system optimization
  - used photo-detectors: PM, SiPM, APD
- MIP calibration:
  - stability
  - tile homogeneity
- MC studies
- Linearity and Energy Resolution
- Conclusion and Outlook



Goal of MiniCal

First working prototype to test the concept of high granularity tile-calorimeter:

- light yield optimization
- tile uniformity
- test of novel photo-detector
- MIP calibration
- stability monitoring
- MC simultation

MiniCal prototype has been operational since May 2003 at the DESY test beam: 1 – 6 GeV e

It is a collaborative effort of various institutes:
HH-university, DESY, MEPHI, Prague, LPI, ITEP

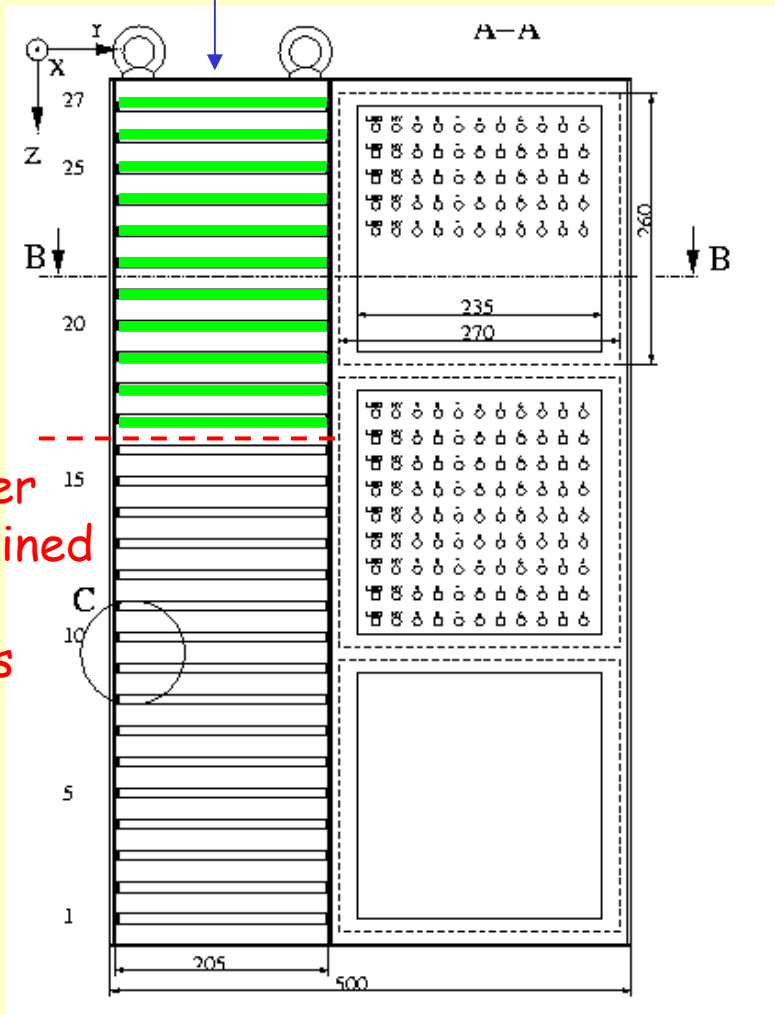
get detector hardware under control !!!

Get ready for studies on Physics Prototype …

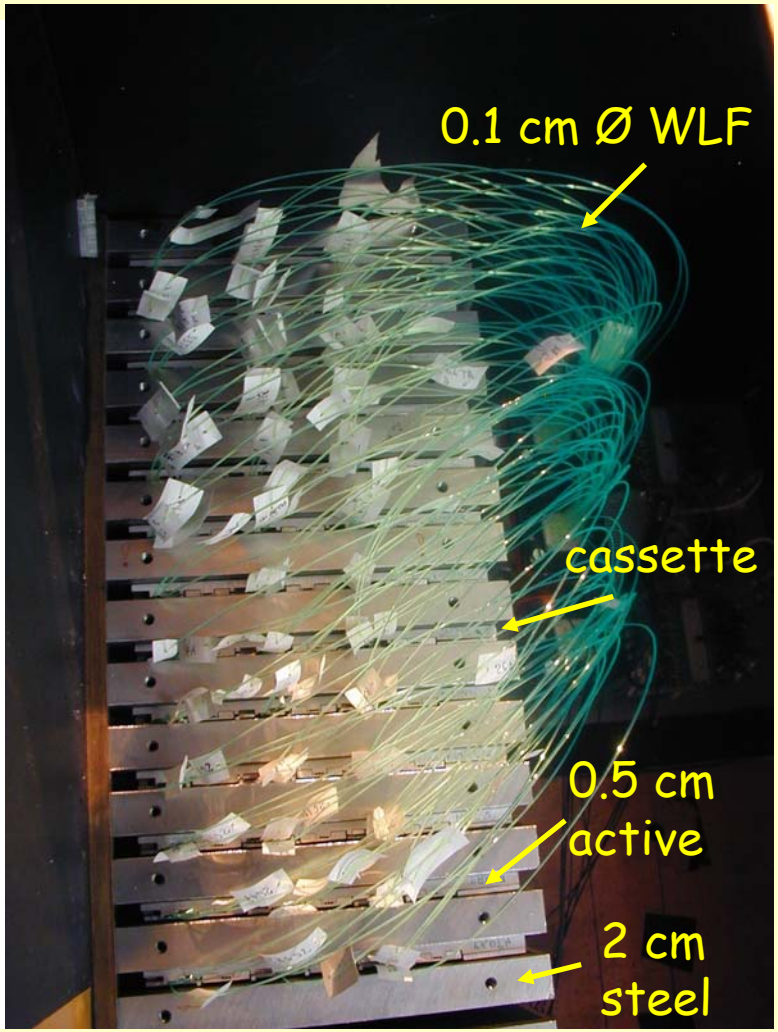
➔ see M. Danilov talk

The MiniCal Prototype

e^+ 1-6 GeV



97% shower contained in 11 layers

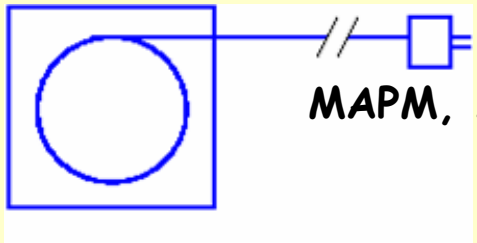


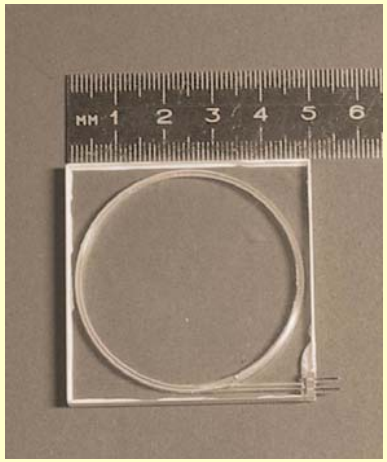
The Cassette Structure

Tile size: 5x5x0.5 cm^3
Tile material: Bicron BC408, Protvino, Vladimir

1-loop or curve-diagonal
WLS-fiber (Y11)
placed in groove (not glued)
Single tiles covered by 3M reflector

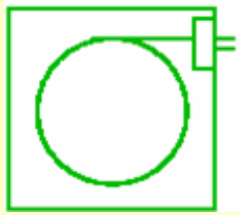
Conventional coupling

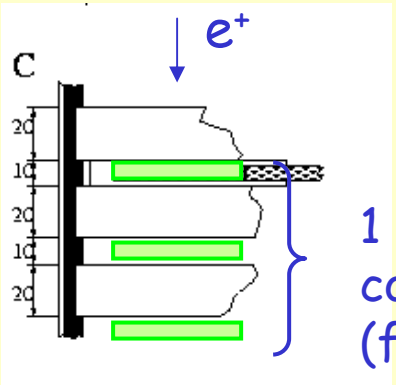




Direct coupling

higher light yield





1 cell = 3 tiles combined in depth (for PM/APD)

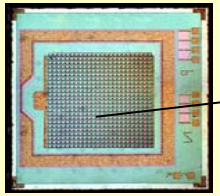
Test of 3 types of Photo-Detector

MA-PM –16 channels (Hamamatzu):
- best photo-detector
- cannot be operated in magnetic field
- single tile or cell read out

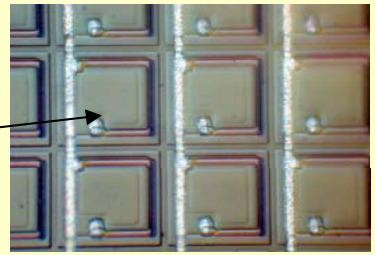
} Only for reference

Silicon PhotoMultiplier (SiPM)
MEPhI&PULSAR

Silicon photo-multiplier (SiPM):
- new detector concept, first test with beam
- sizes: 1x1mm^2, 1024 pixels/mm^2
- gain ~ 1*10^6 ➔ No preamplifier needed
- quantum eff. ~ 15-20%
- single tile read out / mounted directly on tile

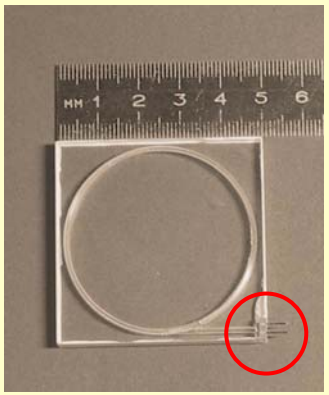


SiPM



Pixels of the SiPM

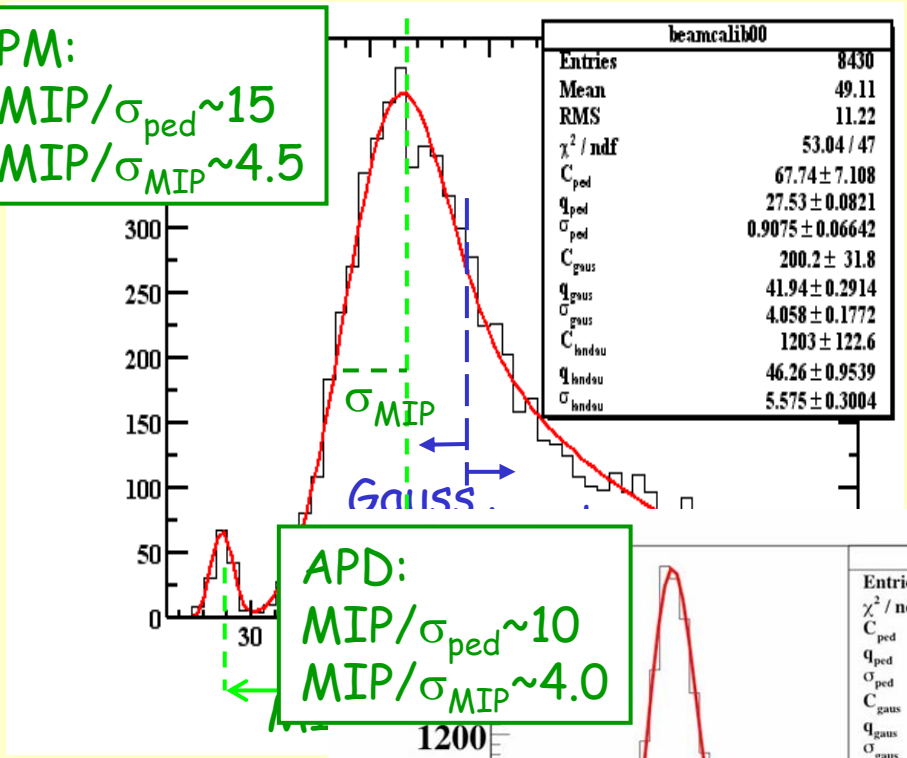
Avalanche photo-diode (APD,Hamamatzu S8664-55spl):
- different from those used by CERN experiments
- 3x3mm^2 low capacity
- gain ~ 200 ➔various preamp board tested @ DESY
- quantum eff. ~ 75%
- cell read out: 3 tiles



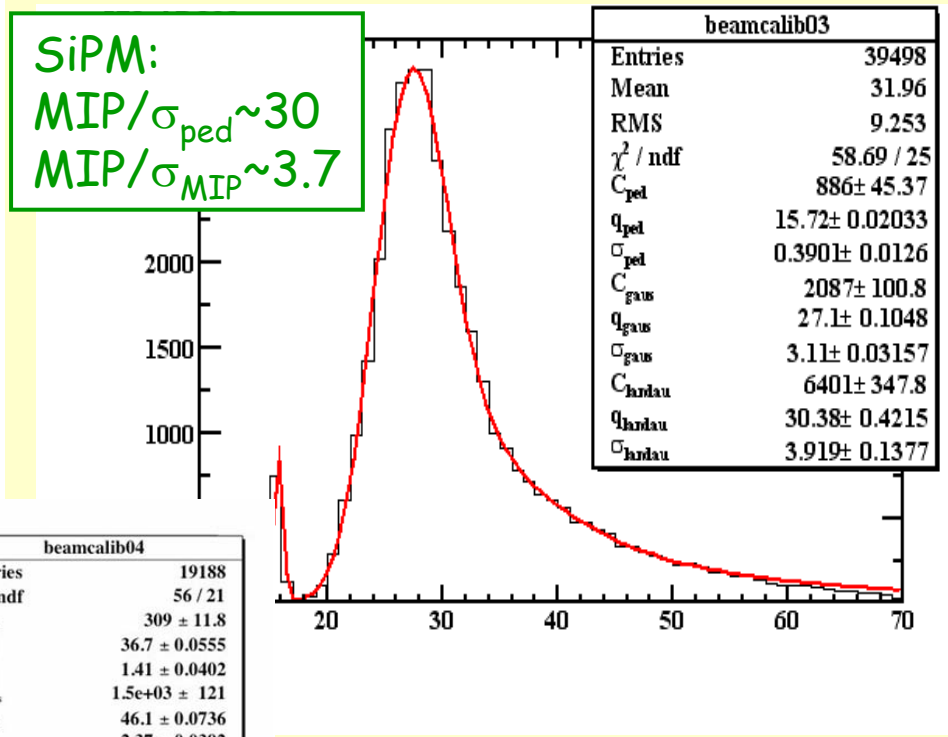
MIP Calibration

➔ Obtained using 3 GeV electron beam on single tile, w/o absorber in front

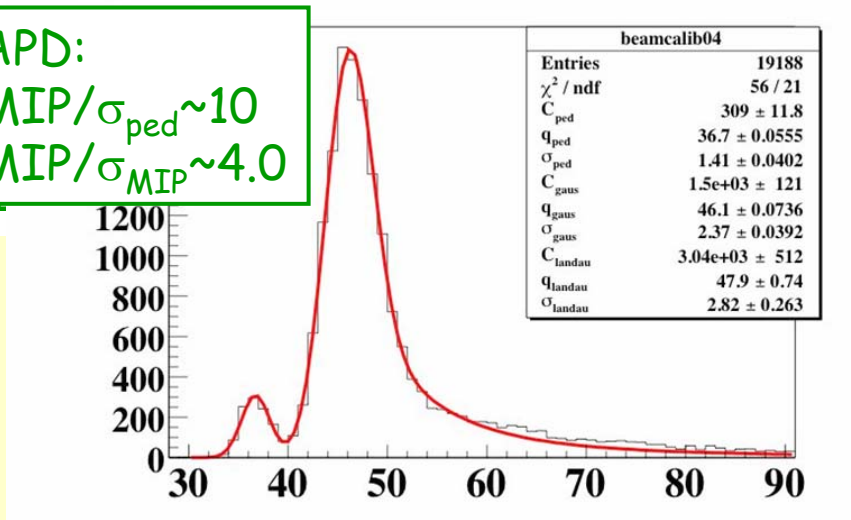
PM:
MIP/σ_{ped}~15
MIP/σ_{MIP}~4.5



SiPM:
MIP/σ_{ped}~30
MIP/σ_{MIP}~3.7



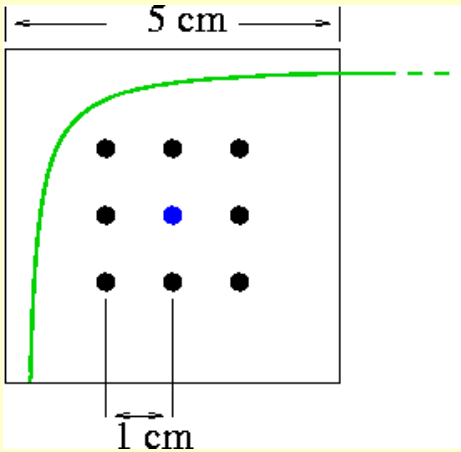
APD:
MIP/σ_{ped}~10
MIP/σ_{MIP}~4.0

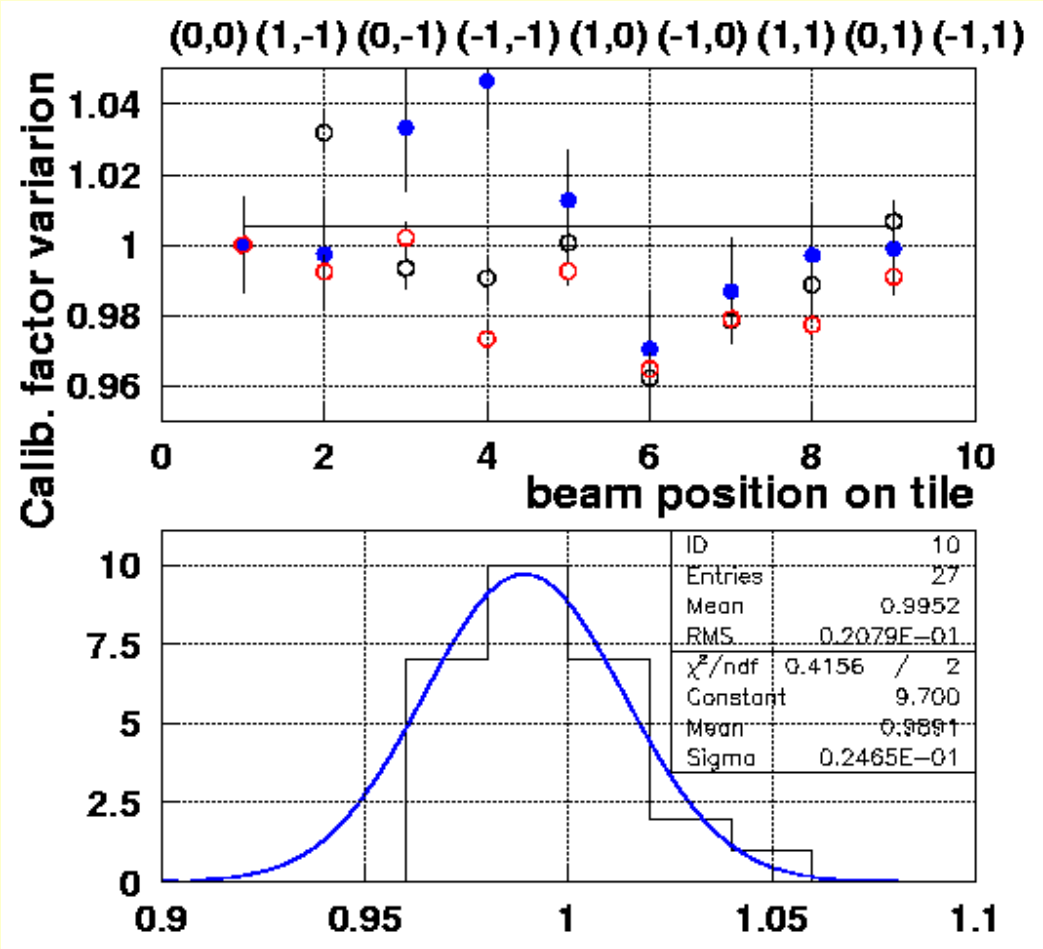


MIP := MPV-pedestal

Tile Calibration Scan

9 point scan of the tile centre according to:





➔2% possible calibration uncertainty due to tile inhomogeneity

Slow Control Monitor

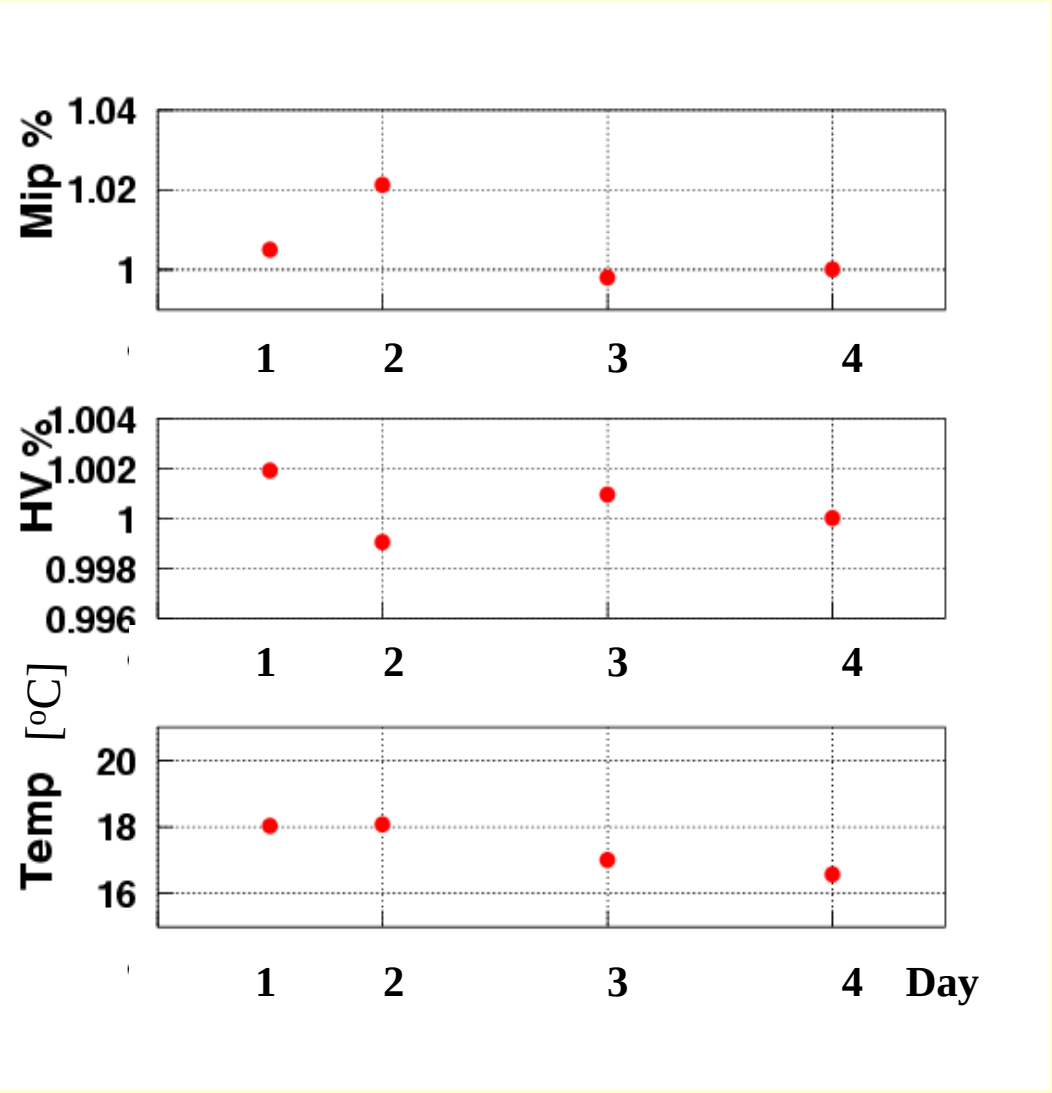
Daily monitor of MIP calibration versus:
- temperature fluctuations
- High Voltage stability

(example for PM monitoring)

➔ 2% calibration reproducibility

➔ good HV stability
➔ 1-2 °C temperature variation crucial for APD monitoring

➔ see J. Cvach talk



SiPM Calibration

- MIP calibration with beam of all tiles w/o pre-amplifier

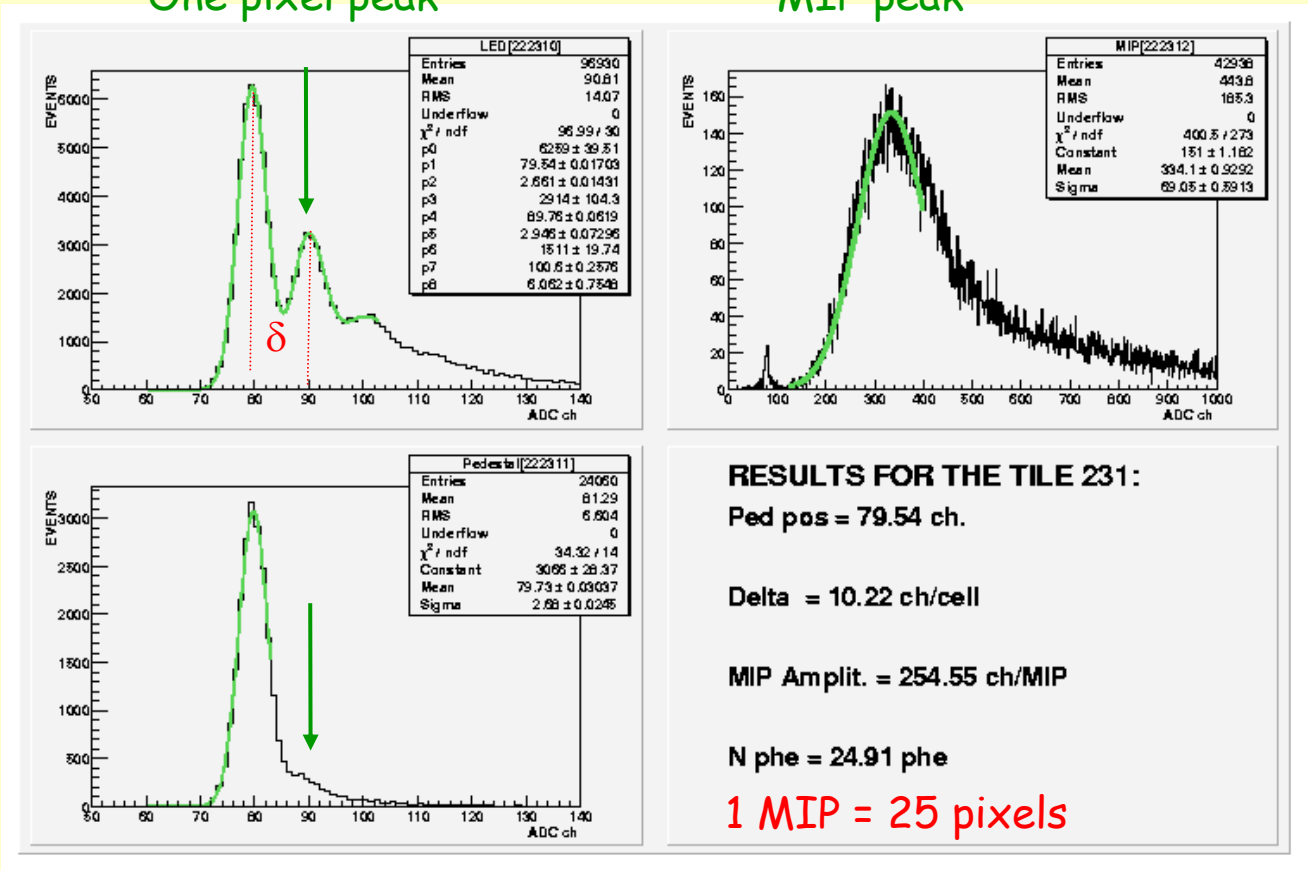
- Single pixel peak visible <u>with fast pre-amplifier</u> ➔ for calibration only

One pixel peak

MIP peak

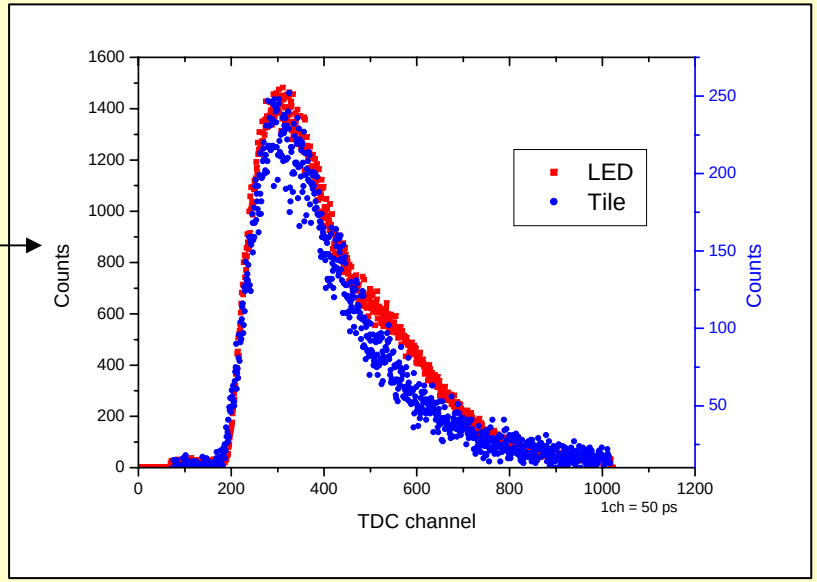
With low intensity LED

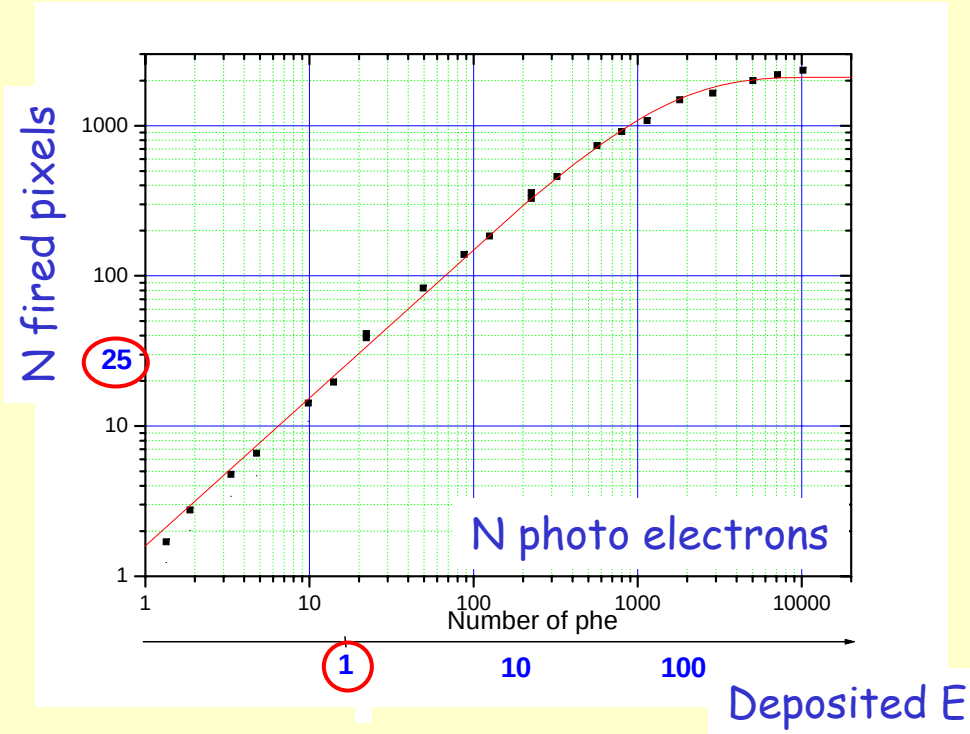
Without LED light
1 pixel noise visible



SiPM response function

Response curve measured with LED pulse shape similar to tile response to MIP (~ 15 ns FWHM)





➔1024 pixel SiPM saturates at ~ 2000 effective pixels:

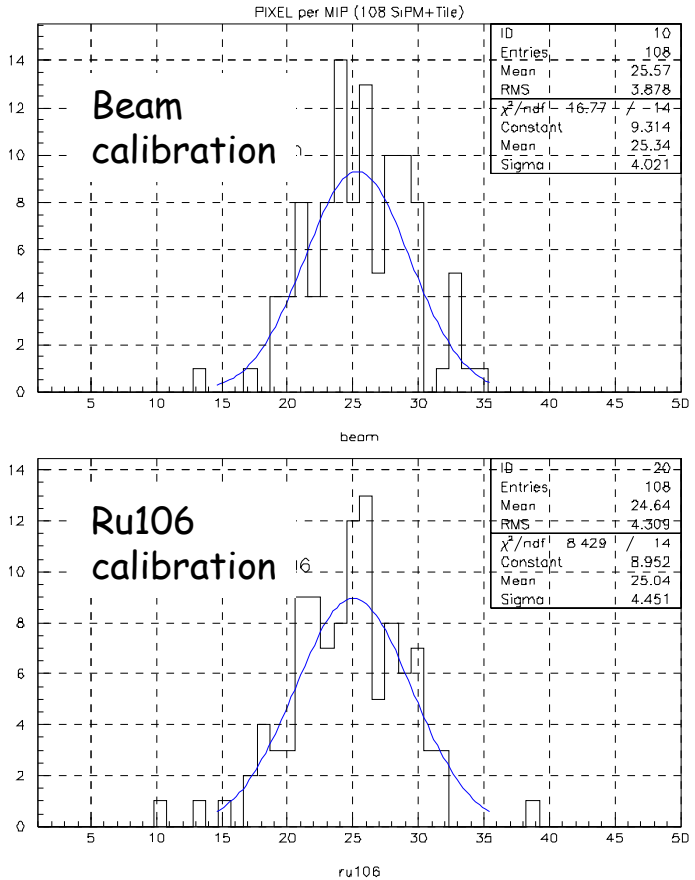
- very short recovery time ~ 10 ns

- each pixel can fire twice during the duration of the tile+WLS fiber signal

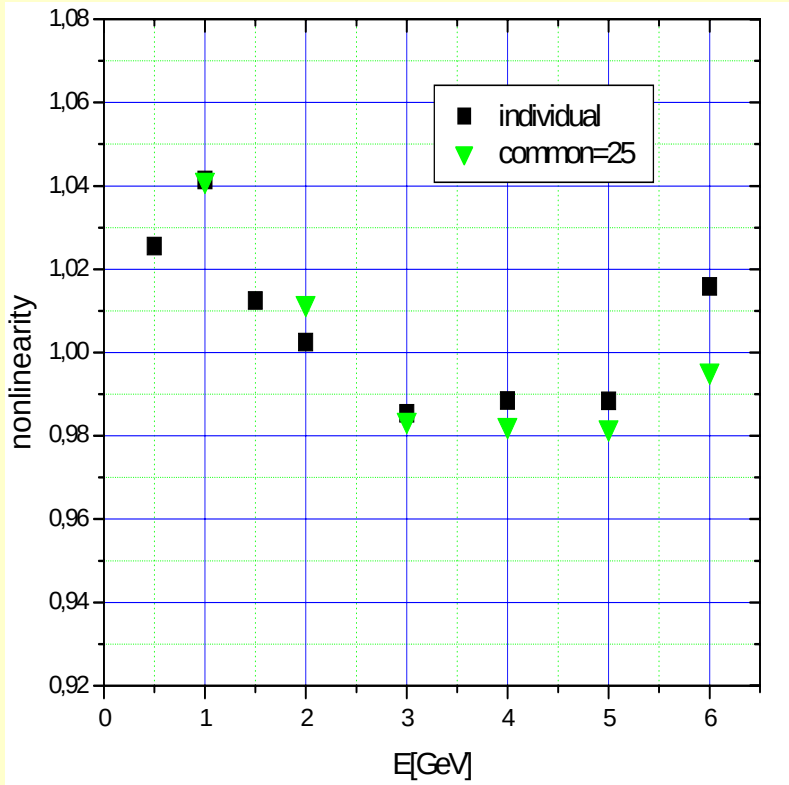
SiPM Calibration

Pixel /MIP

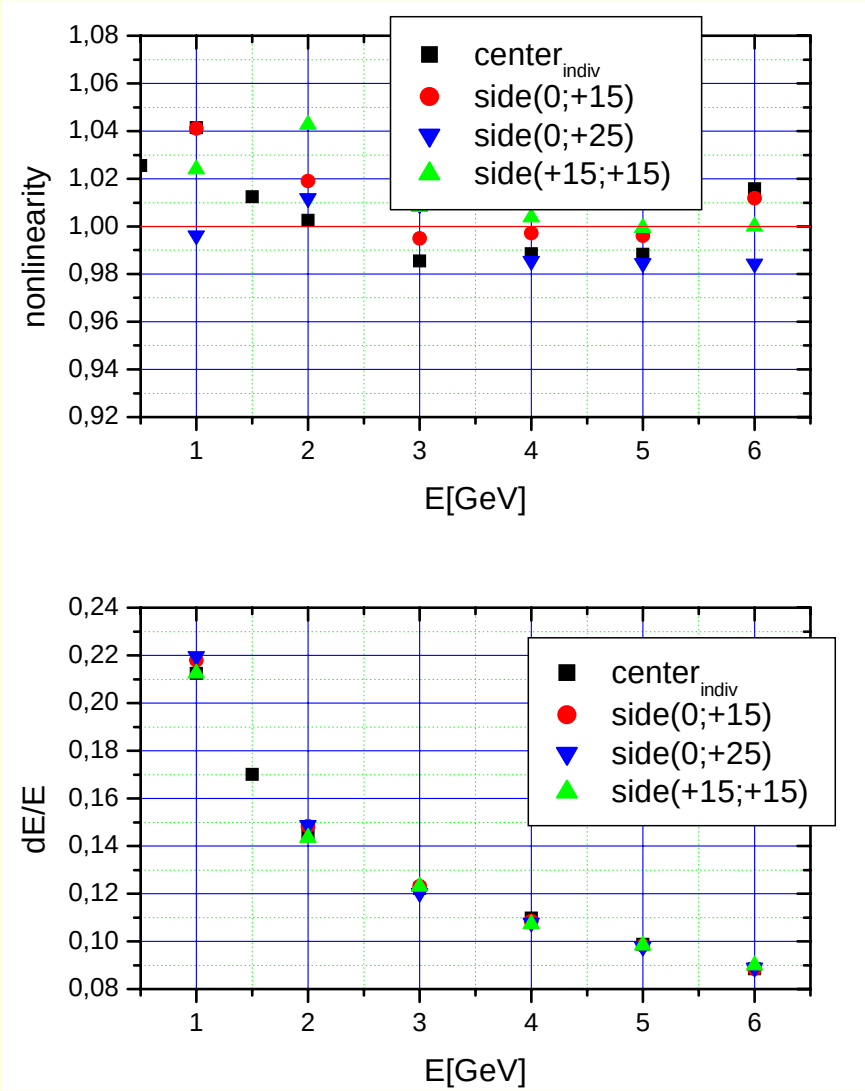
Ru106/beam comparison



- ➔ N Pixels/MIP extracted for >100 SiPM
- ➔ 1 MIP = 25 ± 4 pixels
- ➔ the average number can be used to calibrate all SiPM



Reproducibility



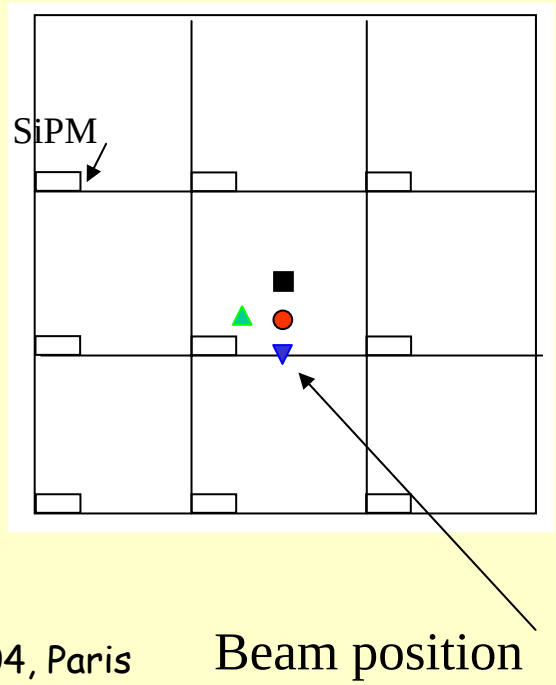
energy scan with different beam positions

➔ vary energy shearing between tiles

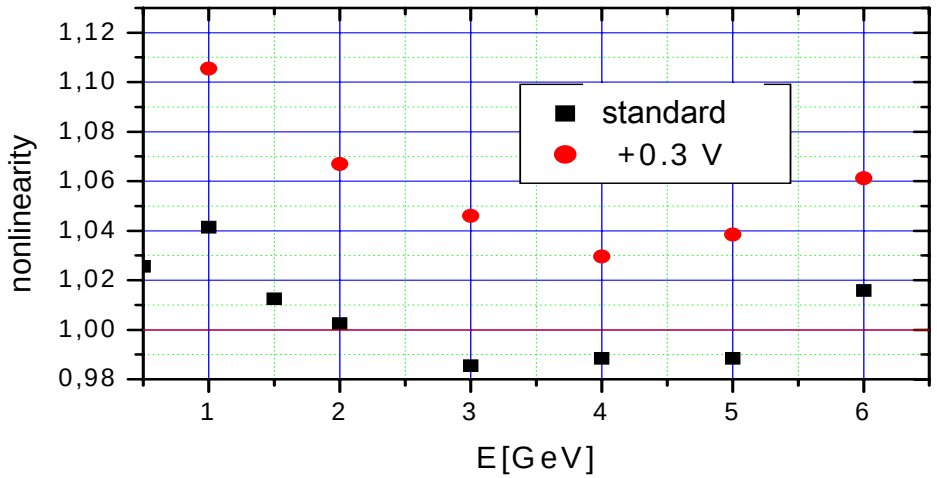
➔ different saturation correction

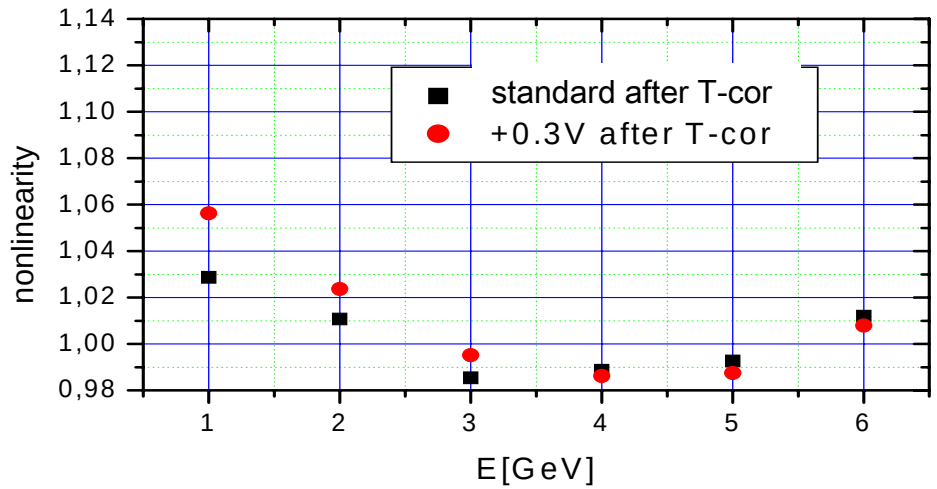
results in very good agreement

➔ Saturation correction well under control



SiPM Stability





➔ Voltage variation applied

➔ Corrected by temperature dependence correction

Temperature and voltage dependence:

variation of -14 °C ≈ + 0.3 V

➔ + 6 % gain and photo-detection eff.

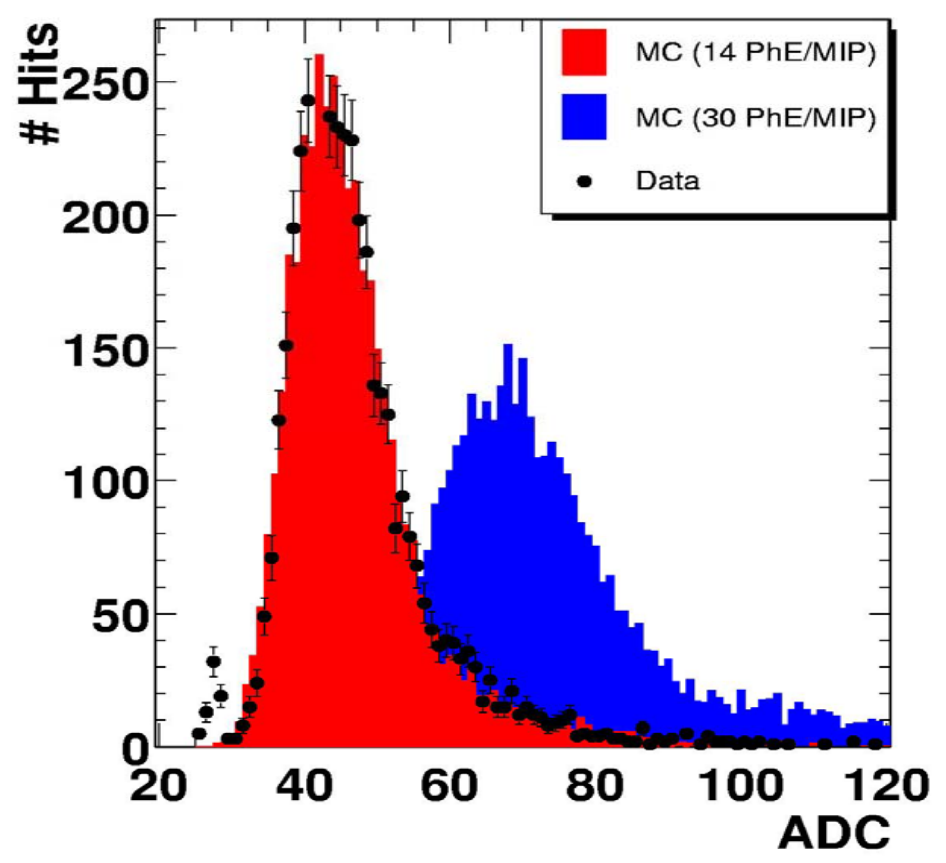
MC simulation of MIP

- detector description implemented in GEANT4
- MC has to be smeared according to detector properties

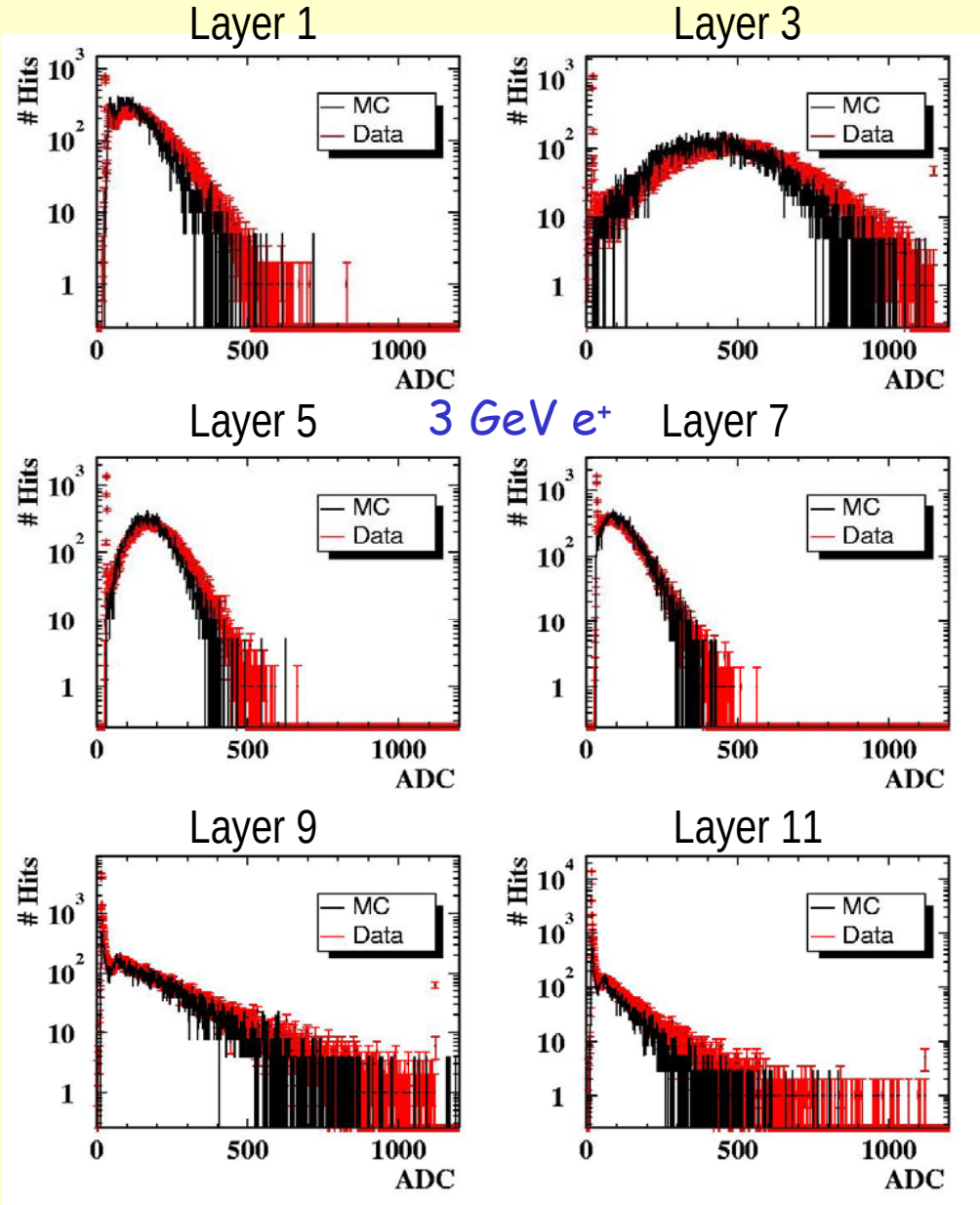
- single tile MC calibration needed:
  - # ph.e/MIP
  - width of 1st photo electron peak

- good description of MIP shape after MC calibration

➔ MC tune for PM

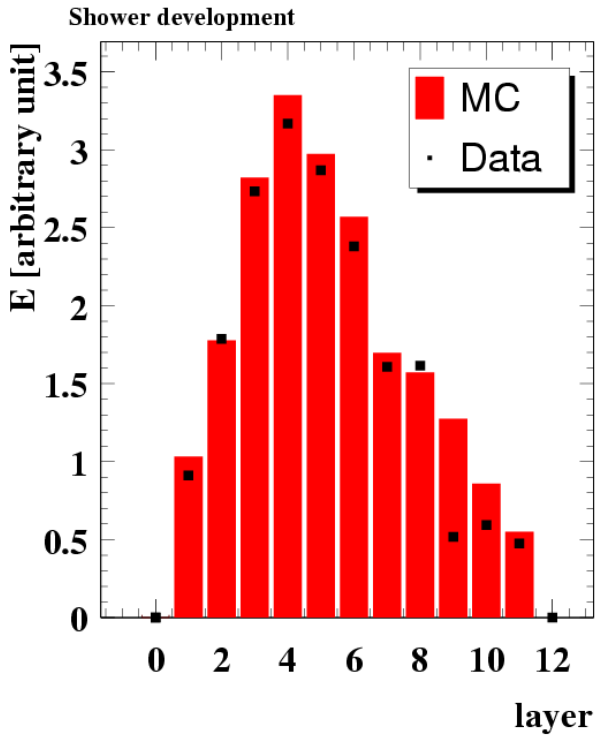


Shower Shape

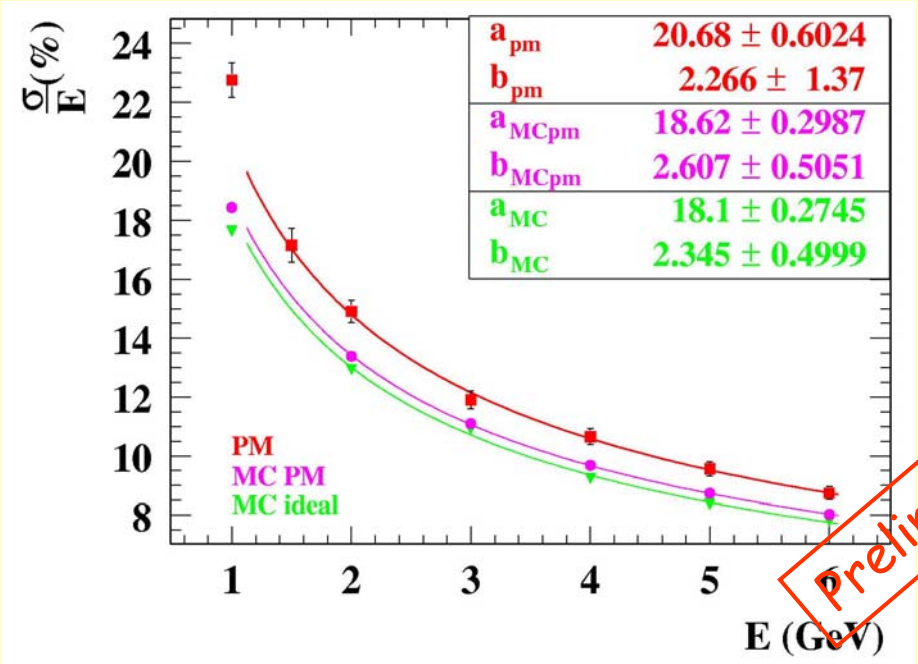


After single tile calibration and smearing

➔ MC well describe PM shower shape



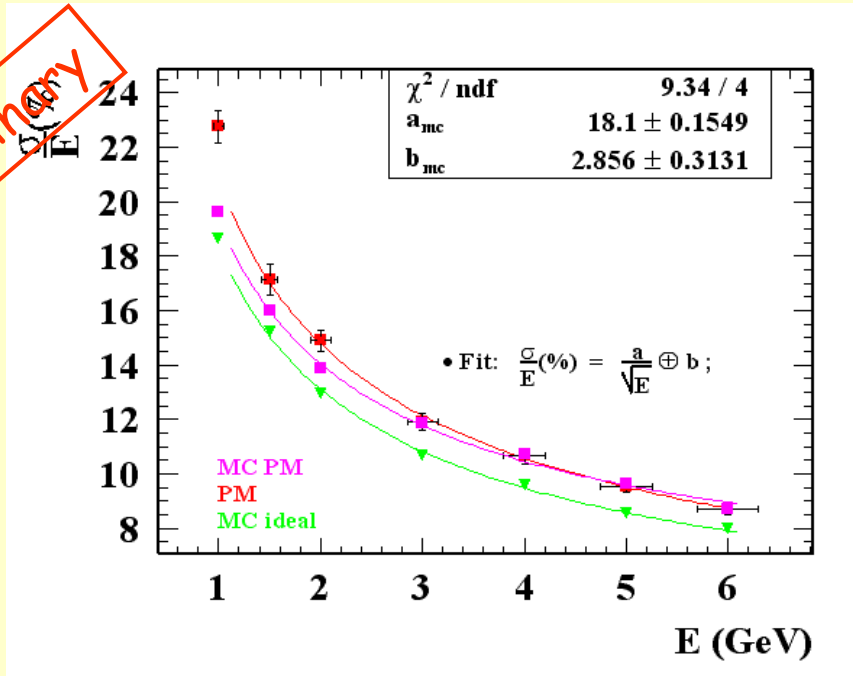
MC Results



➔ Ideal MC includes only MiniCal geometry description

➔ After single tile calibration MC resolution is decreased

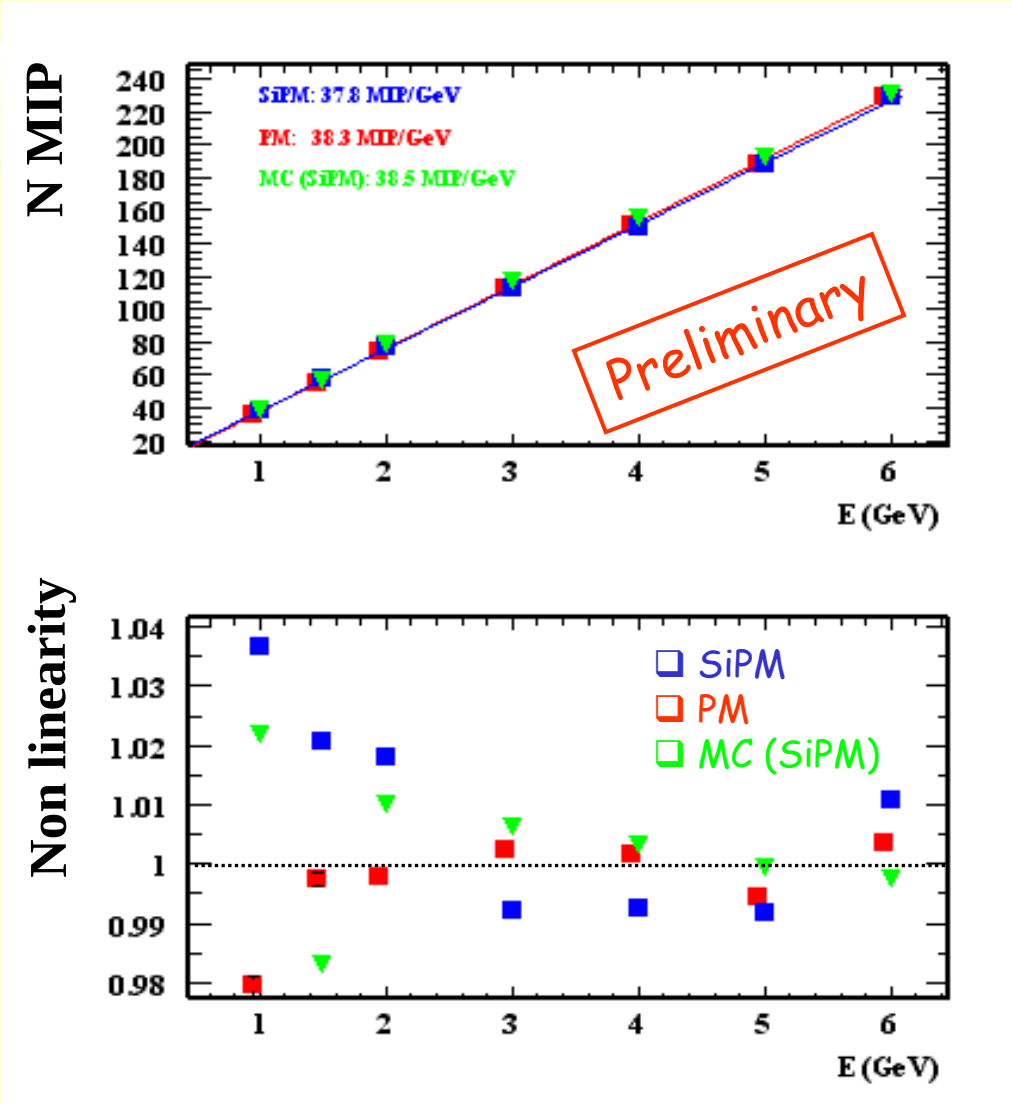
But still does not match the data



➔ Applying 5% smearing on calibration factors the high energy data are well describes

➔ at low energy MC 6% lower than data

Results comparison: N MIP

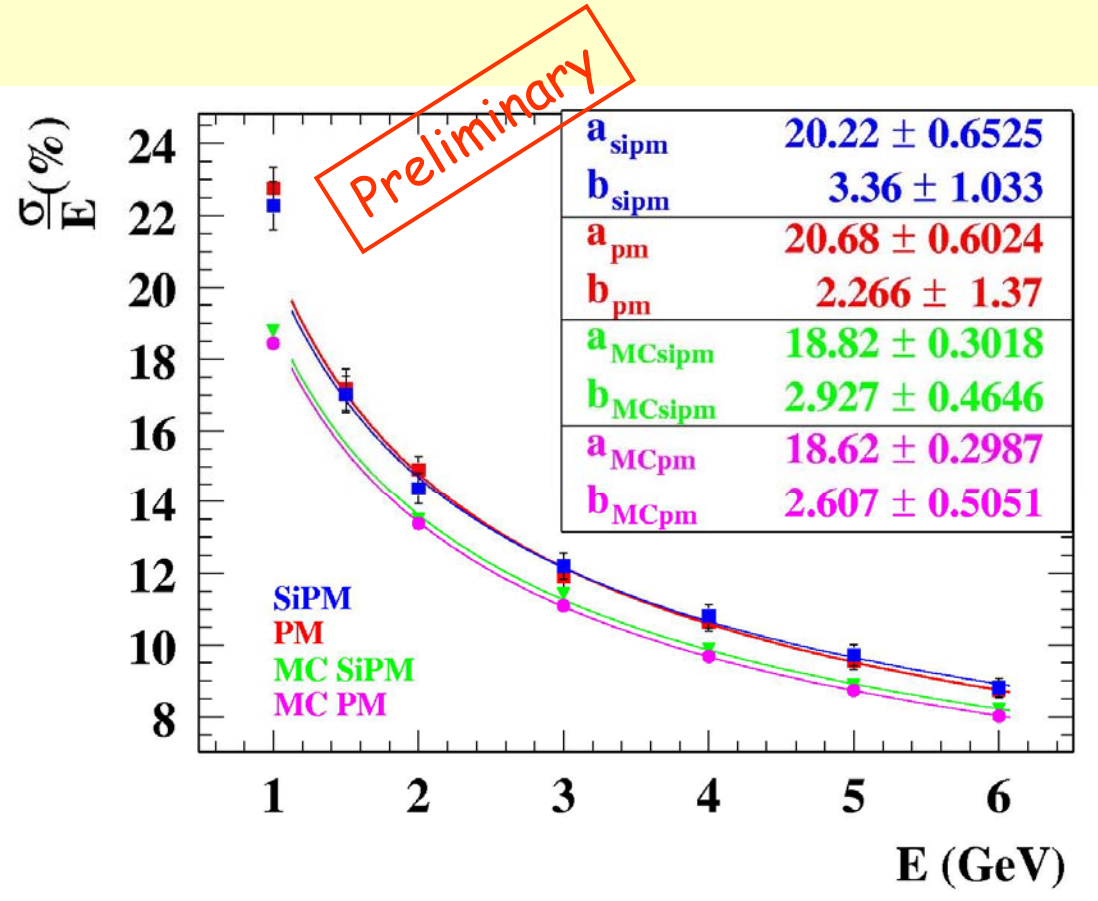


Sum of total energy deposited in calorimeter calibrated in number of MIPs

➔Very good agreement between SiPM and PM

➔MC tuned to SiPM properties gives good description of the data

Energy Resolution



➔Very good agreement between PM and SiPM on the whole range 1 - 6 GeV

➔Low sensitivity to constant term due to limited energy range

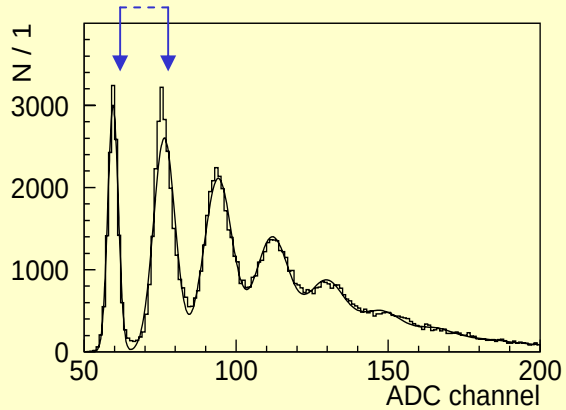
➔MC tuning still in progress
include more effects:
-beam energy spread
-steal thickness tolerances

Monitoring System

Next studies will focus on a reliable monitoring system
for large number of tiles (>8000 for the physics prototype)

Requirements:

- low light yield (~ 5-10 ph.e.) pre-amplification is required
  - ➔ to monitor SiPM gain ➔



- medium light yield (~ 25 ph.e ~ 1 MIP)
  - ➔ to monitor stability of MIP calibration
- high light yield (~ 200-500 ph.e.)
  - ➔ to monitor saturation behaviour

Options under investigation:

- LED system, single or multiple tile per fiber
- Laser system

Conclusion & Outlook

- Beam tests with MiniCal at DESY have been rather successful ☺
  - Optimized light yield in tile readout
  - Studied different readout systems (PM, SiPM, APD ➔ presently undergoing)
  - Established reliable calibration system
  - Checked long term stability
  - Established detailed MC simulation ➔ still to be finalized
  - Developed stability monitoring system ➔ see J. Cvach talk
  - Gained lots of experience for constructing physics prototype
- In 2005 move to hadron beam to fully test HCAL performance