Analysis of electromagnetic showers in CALICE Analog Hadron Calorimeter prototype (AHCAL)

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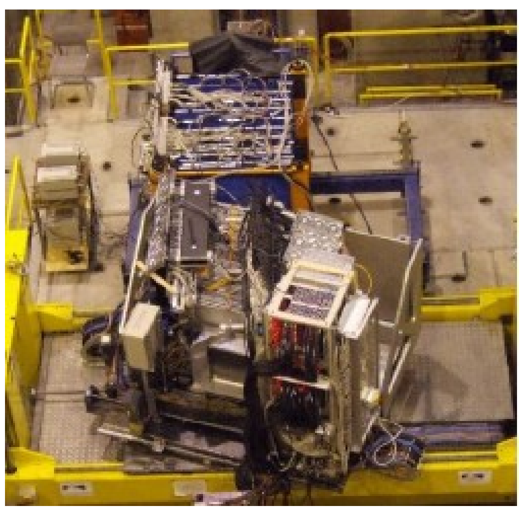
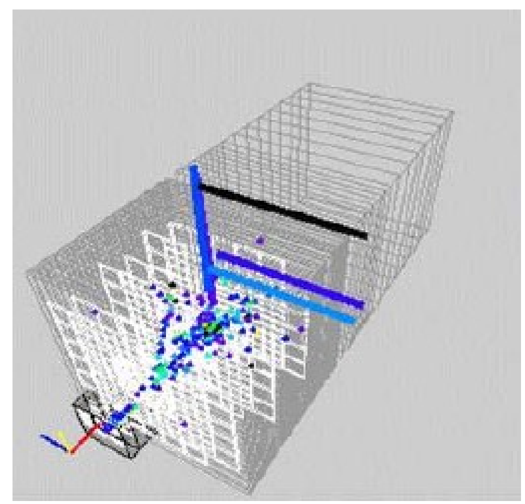
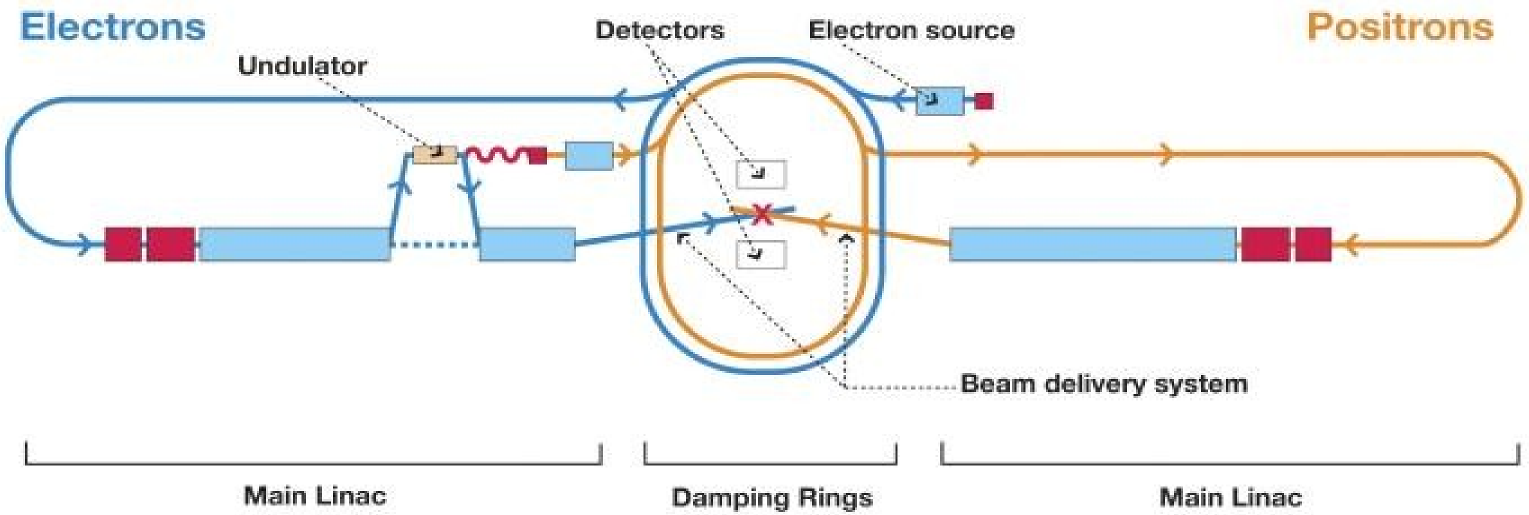


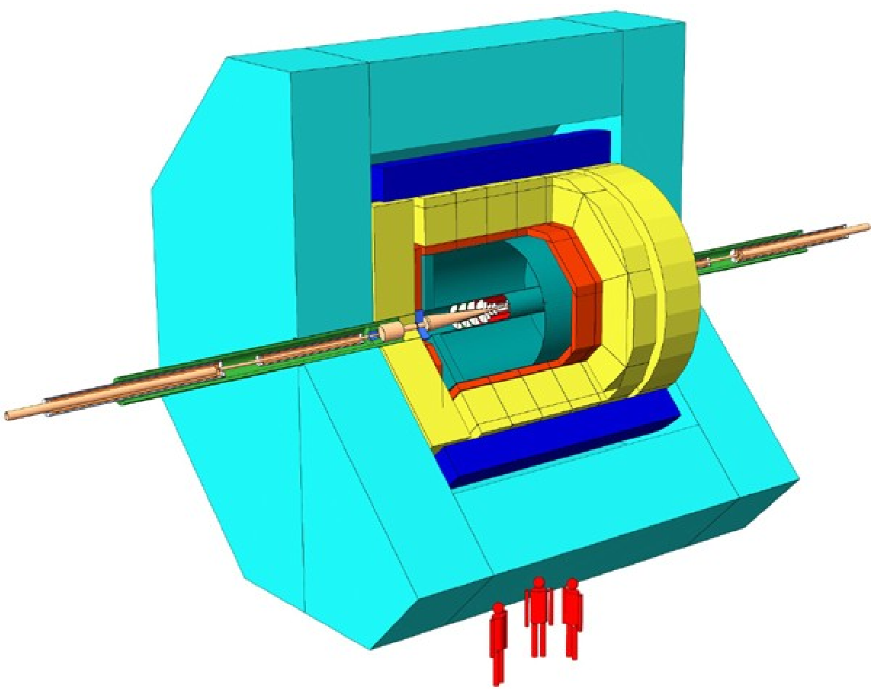


Universität Hamburg

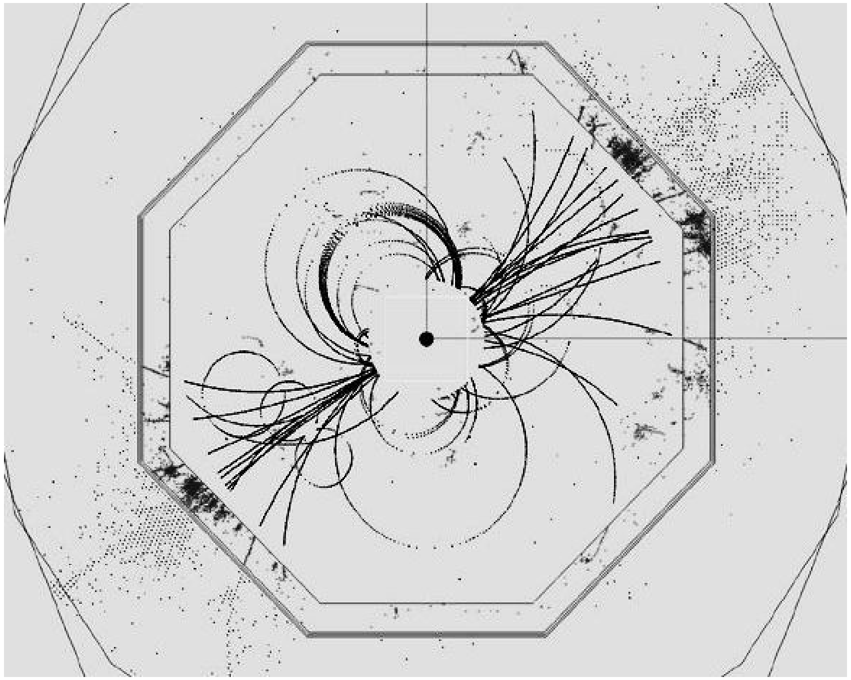
Calorimeter for ILC



A schematic layout of the International Linear Collider (ILC)

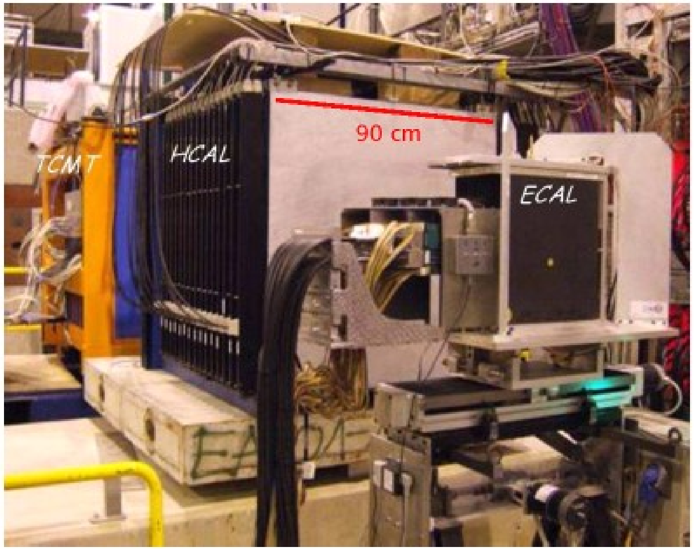


The Large Detector Concept

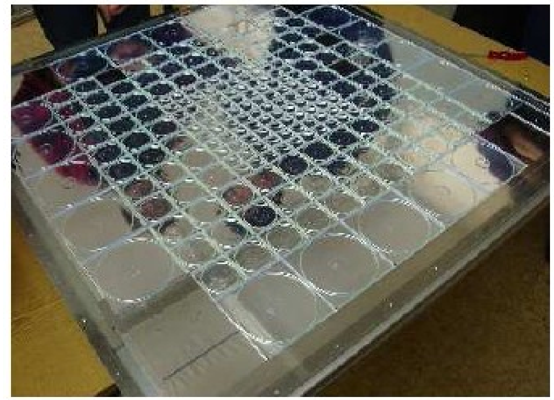


A Higgs decay event (simulation)

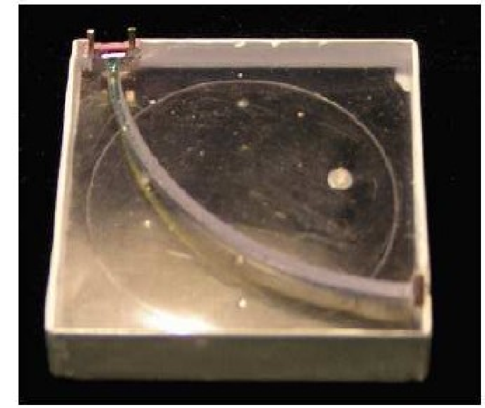
Analysis of electromagnetic showers in CALICE AHCAL prototype



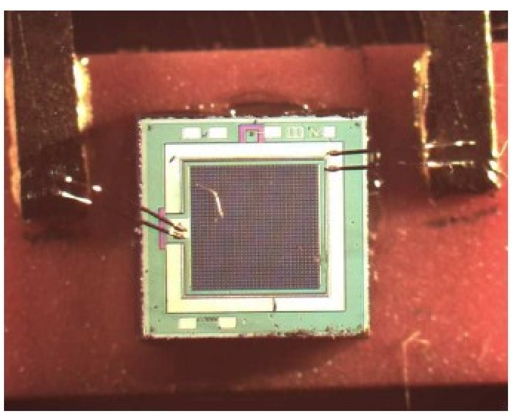
AHCAL prototype at CERN testbeam



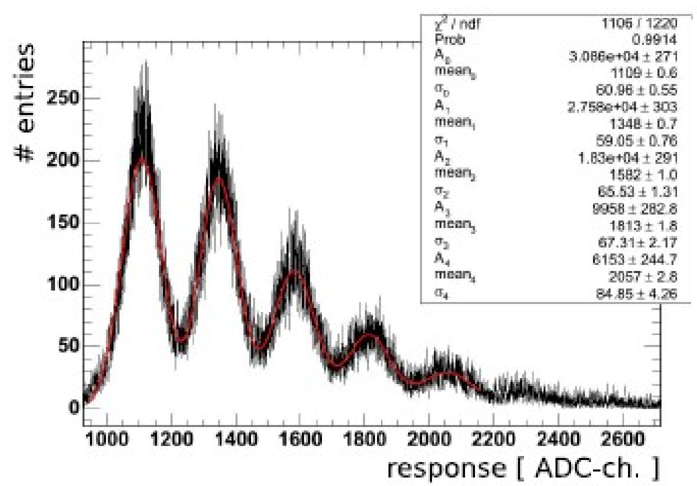
HCAL layer with 216 tiles (3x3, 6x6,12x12 cm)



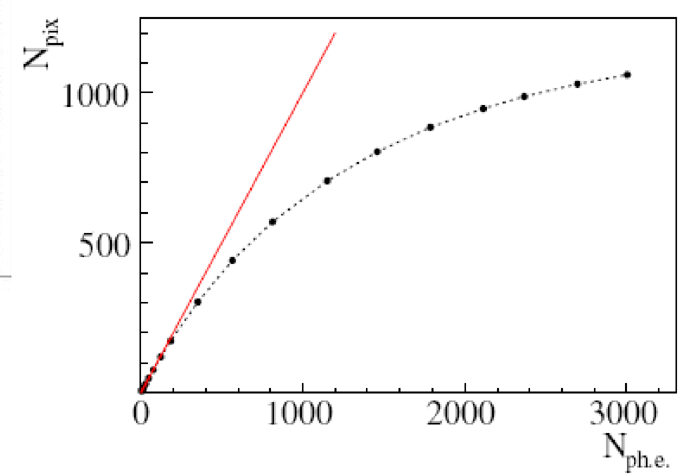
3x3 scintillator tile with WLS fiber and SiPM



Silicon Photo Multiplier (SiPM) size ~ 1mm , 1156 pixels

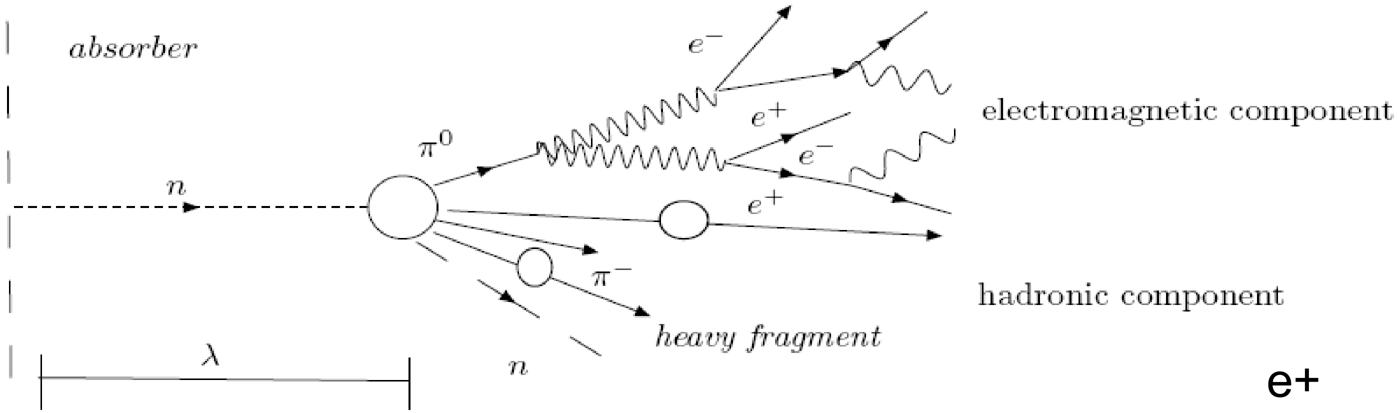


A SiPM's single photo-electron peaks

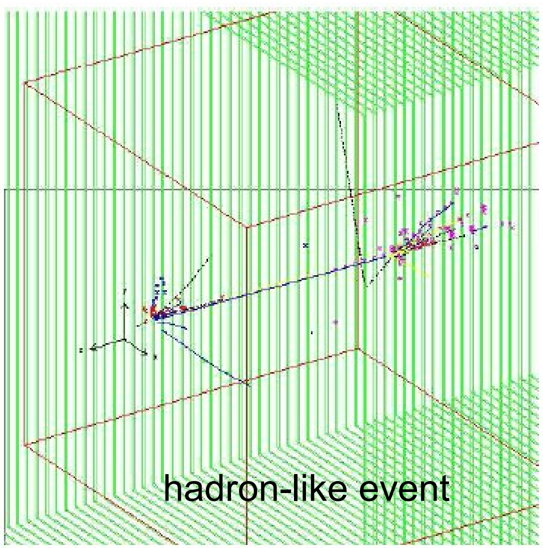


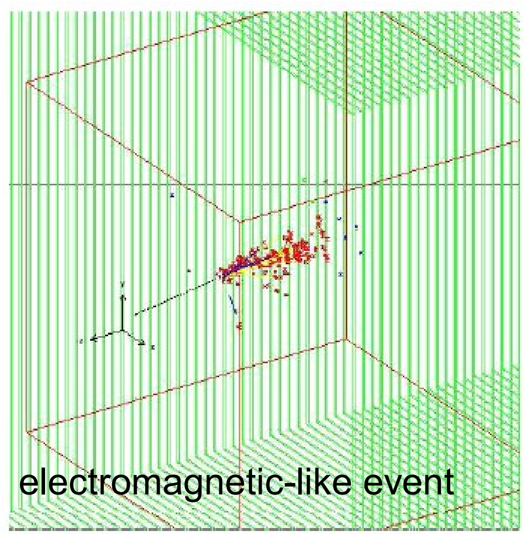
A pixel saturation effect

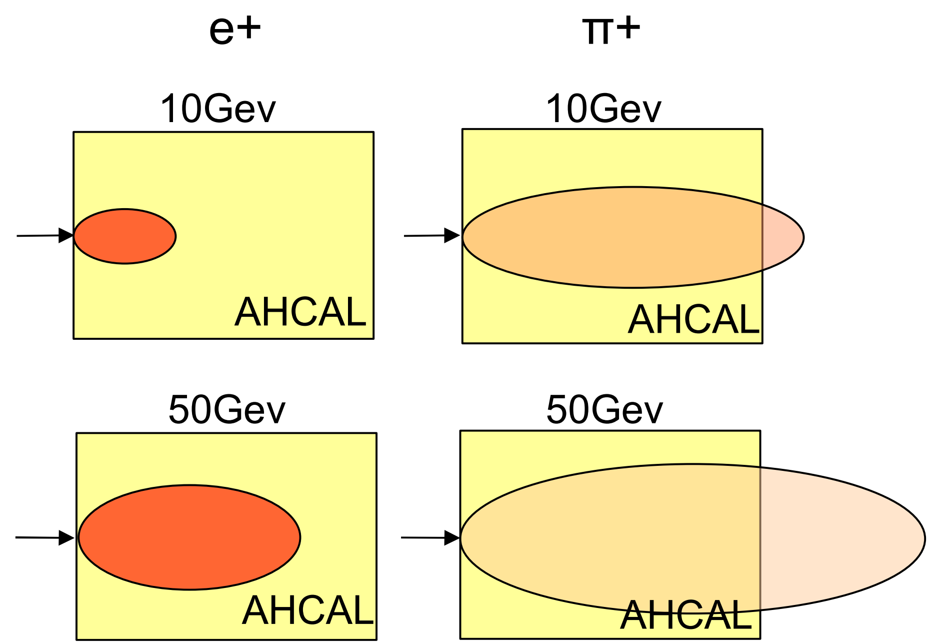
Analysis of electromagnetic showers in CALICE AHCAL prototype



A schematic view of hadronic shower development



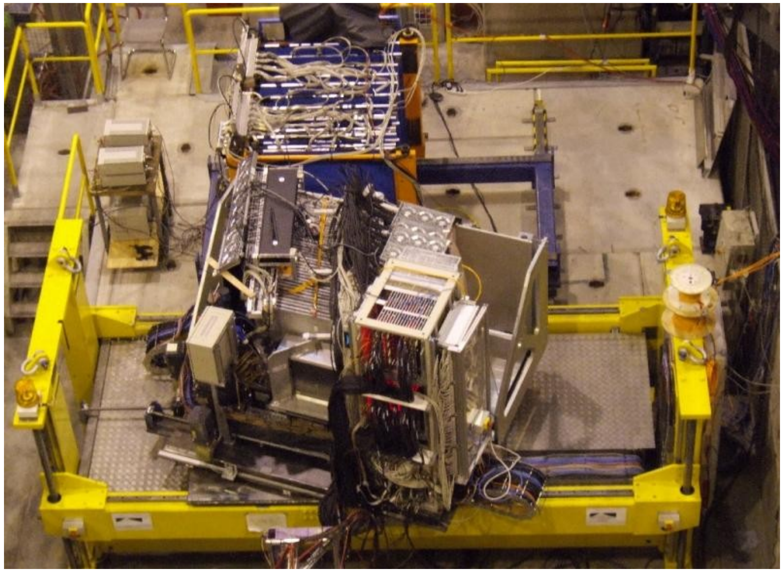




Electromagnetic shower in a hadron calorimeter is a useful tool :

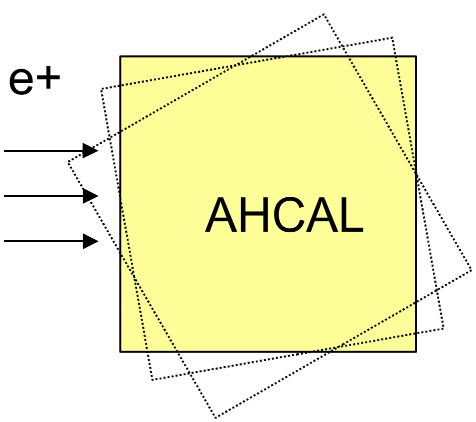
- high density of energy losses => to study the saturation effects and to validate calibrations
- EM shower develops completely in calorimeter volume => to check reconstruction of energy and energy resolution
- well understood physics (~2% level of uncertainty) => to validate MC digitization

CALICE tile AHCAL prototype at CERN 2007 test beam facility



AHCAL prototype:

- 38 layers (30 with high granularity at central region)
- each layer has 2cm of absorber (steel) and 0.5cm of active scintillator layer
- length: 114.57 cm, hadronic: 5 λ_0, e/m: 43.7 X_0

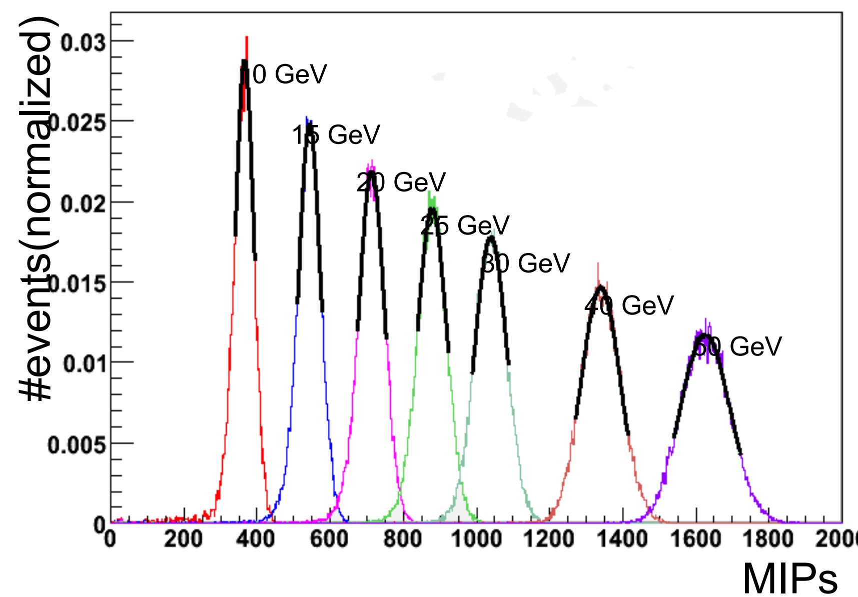


Positron runs collected:

Energy: 10 - 50 GeV

Position of beam: 0, +6cm, -6cm

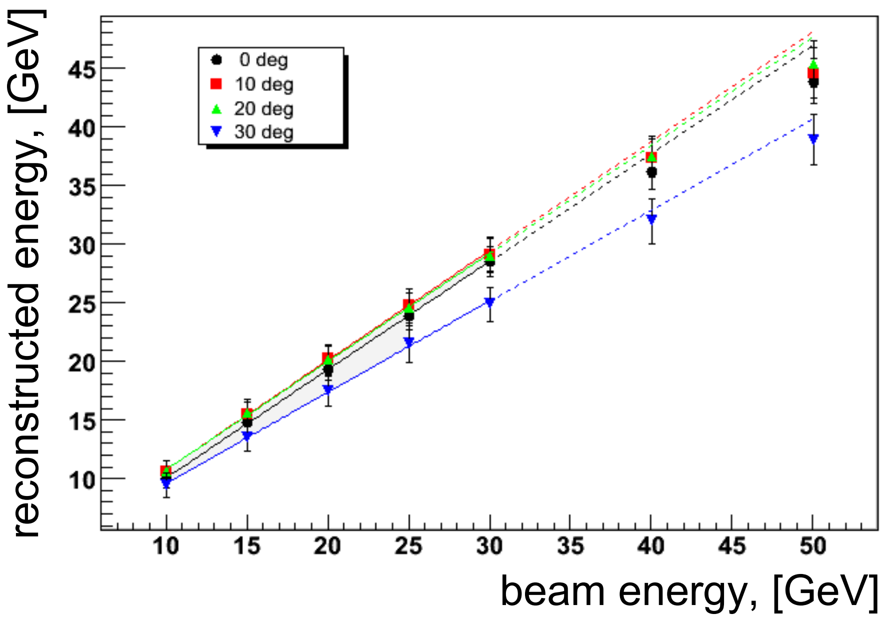
Angles: 0,10,20,30 degrees

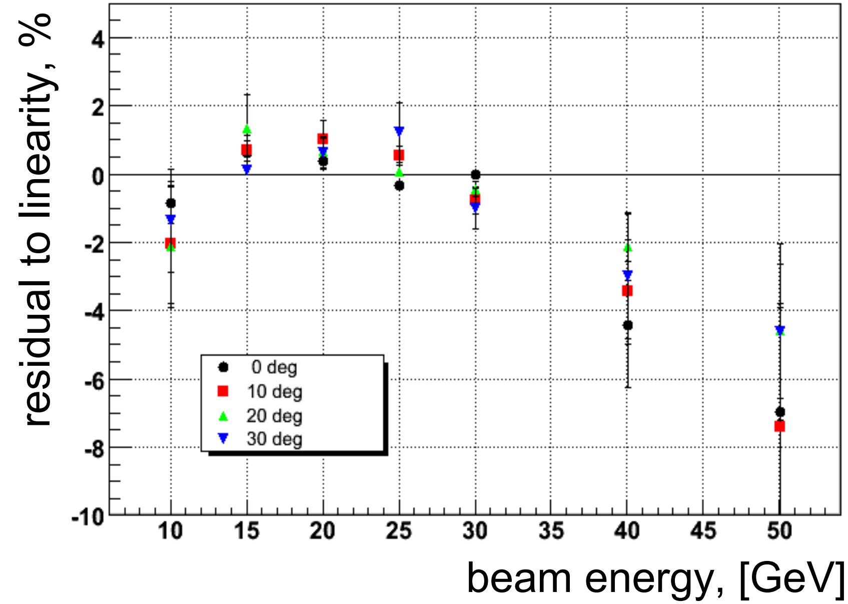


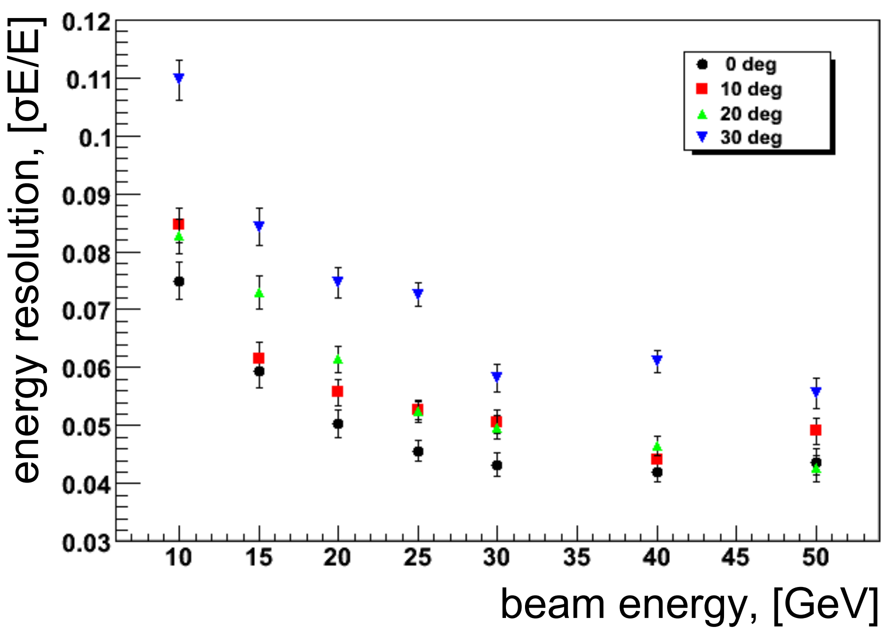
e+ energy reconstructed spectrum in Minimum Ionizing Particle (MIP) scale

Analysis of electromagnetic showers in CALICE AHCAL prototype

the very first results from e+ data analysis..







- 4 data samples have been analyzed: large variations in the reconstructed energies expected to be consistent

- residual to linearity is about 4% at 40 GeV and 7% at 50 GeV – too big!

- large variations in the energy resolution curves is a hint to problems in the calibration procedure which can be improved

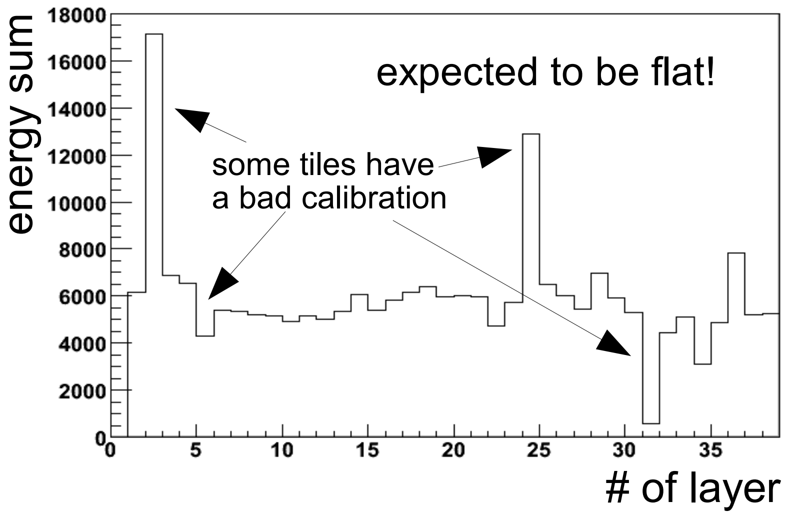
Further investigations are needed!

Analysis of electromagnetic showers in CALICE AHCAL prototype

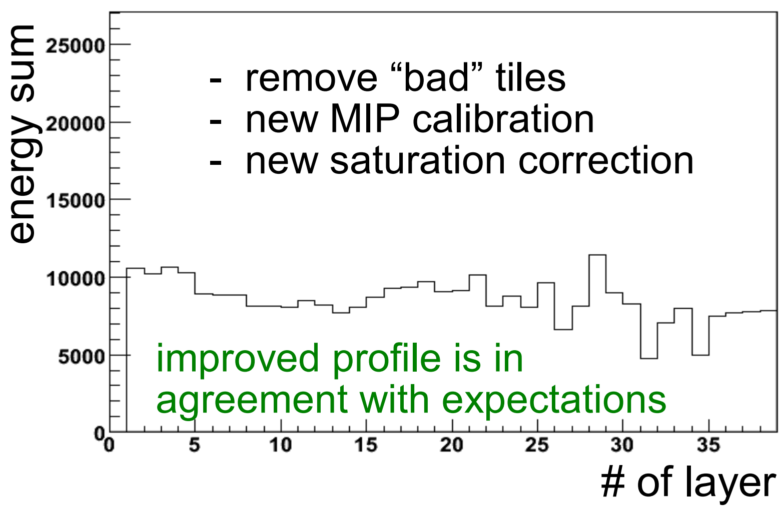
..a lot of work was done to improve the energy reconstruction..

Improvement of calibration

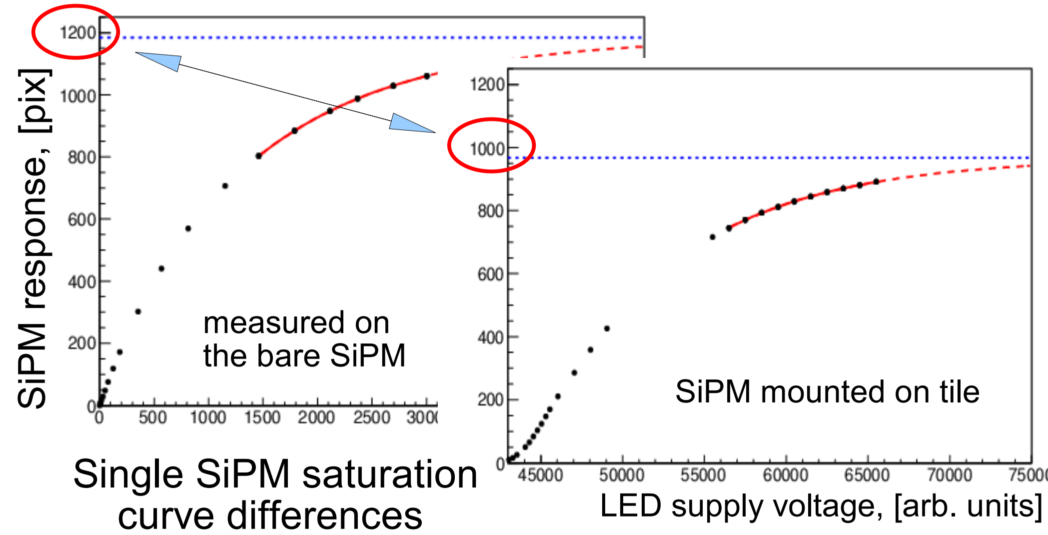
Longitudinal energy profile of muons

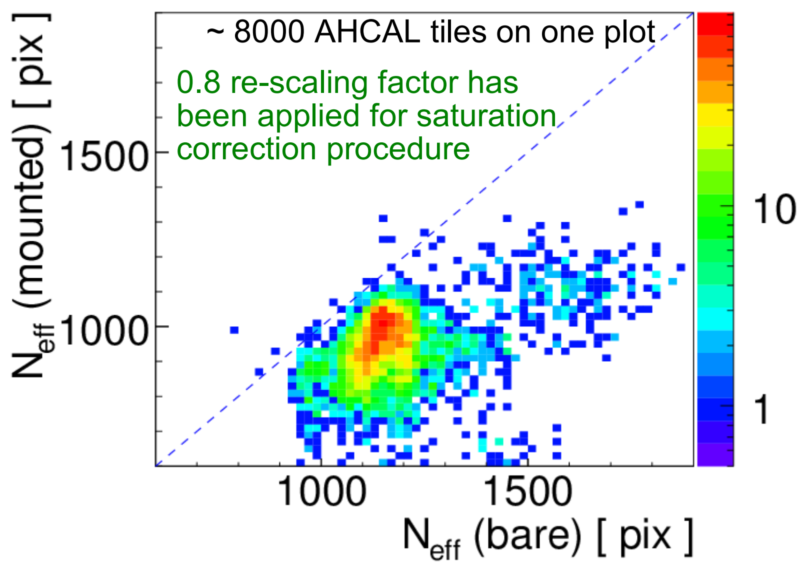


Longitudinal energy profile of muons



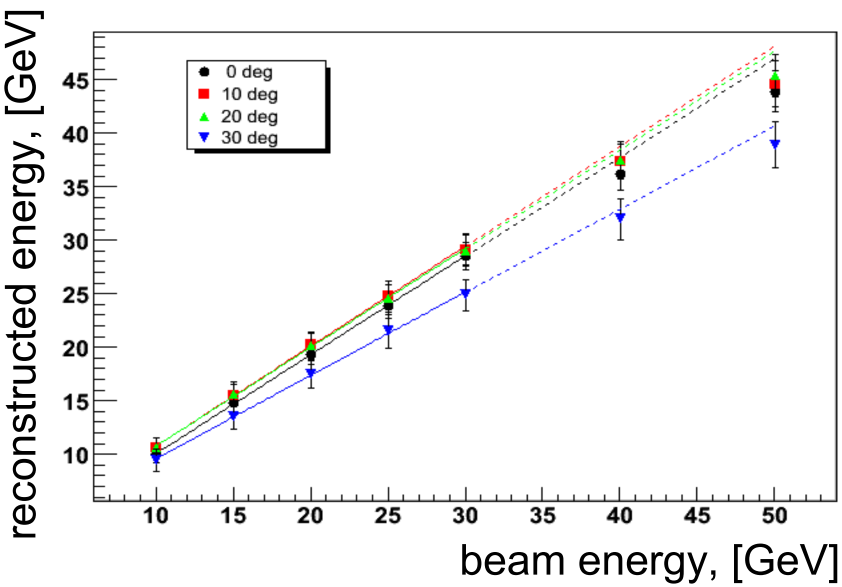
re-scaling of SiPM saturation correction curves

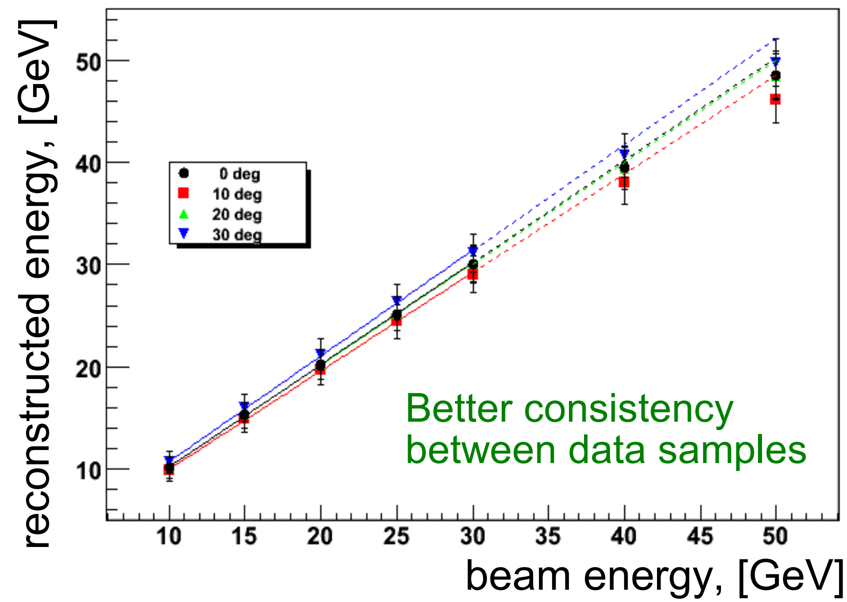


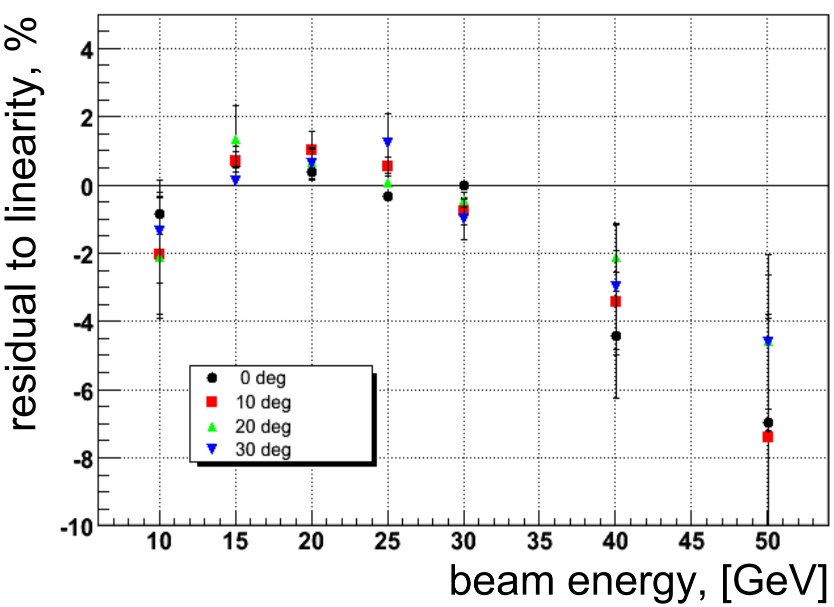


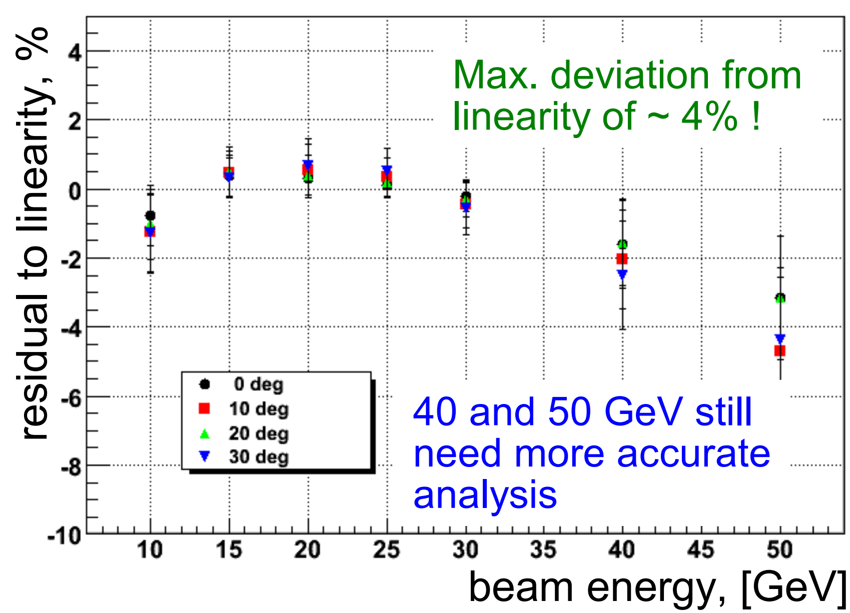
+ temperature correction of SiPM response has been applied for all tiles

All corrections have been applied - improvement of linearity

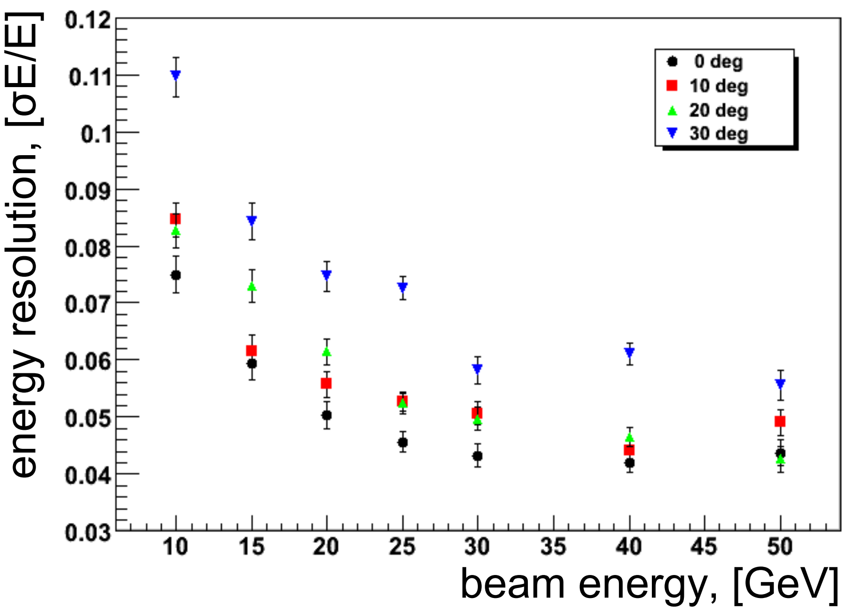


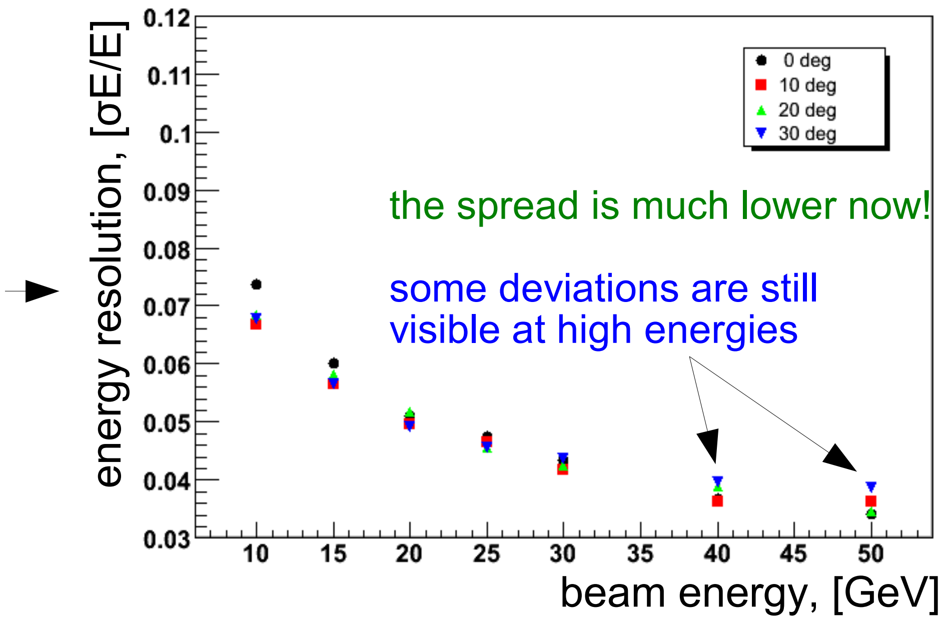


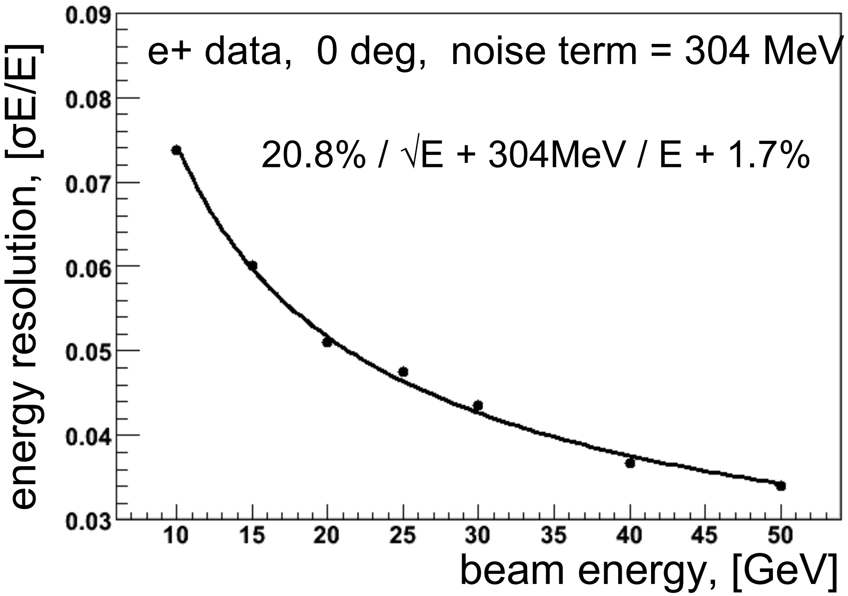




Improvement of energy resolution after all corrections have been applied







- removing “bad” tiles from analysis
- more accurate calibration
- temperature correction for SiPM

can really improve the data!

Longitudinal profile study..

An electromagnetic shower's energy profile:

$$dE/dt = p_1 \cdot t^{p_2} \cdot e^{-p_3 \cdot t}$$

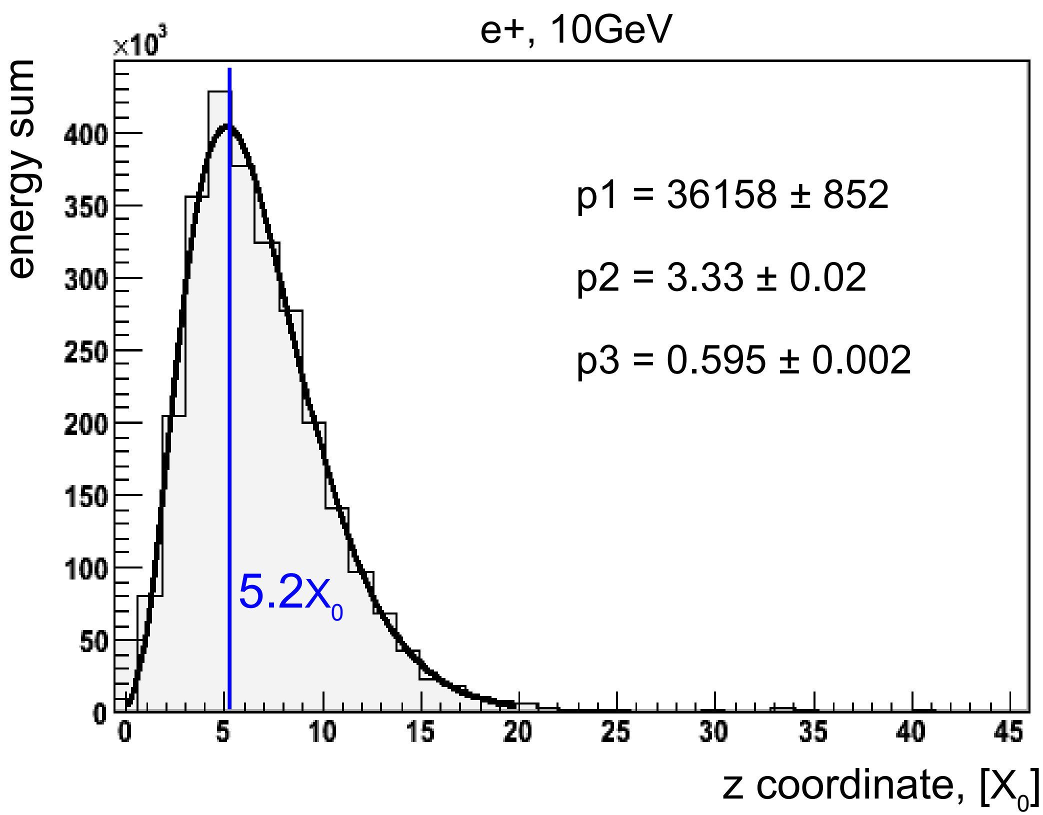
where E – energy deposited, t – depth in calorimeter

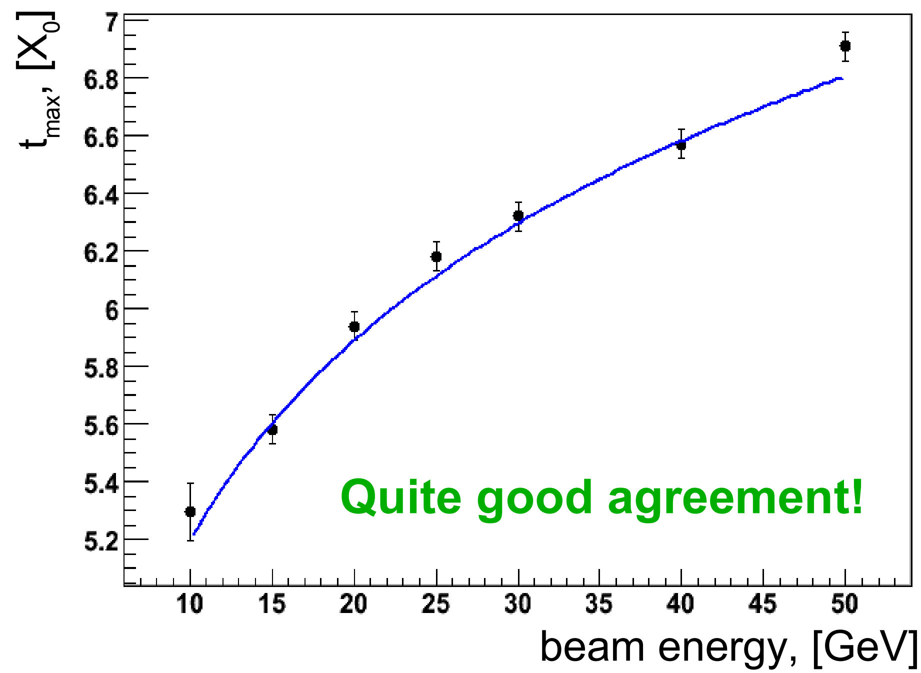
The maximum depth of an e/m shower in calorimeter for e+(e-):

t_{max}= [ln(E/e_c) - 0.5] [X_0]

E – particle energy
e_c – critical energy (≈ 33.6 MeV)

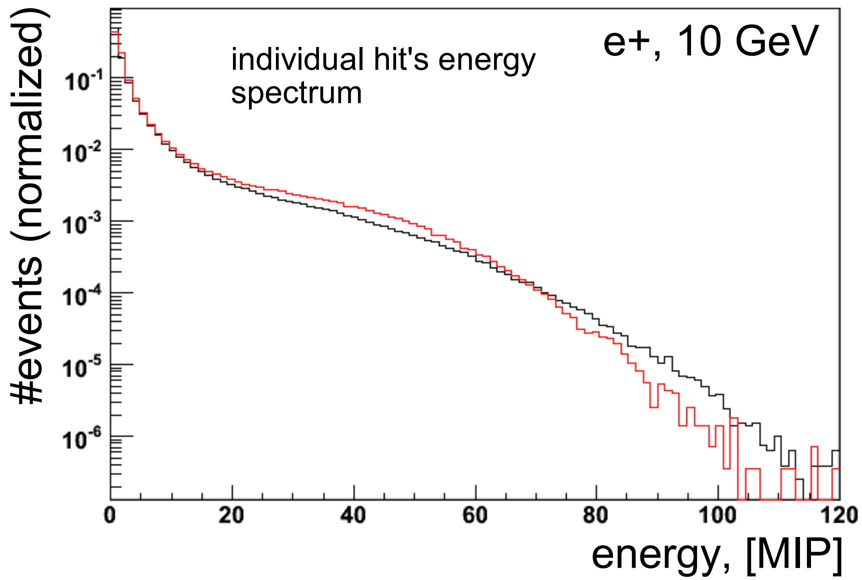
Calculated:	From data:
$t_{max} \approx 5.2\ X_0$	$t_{max} \approx 5.3\ X_0$

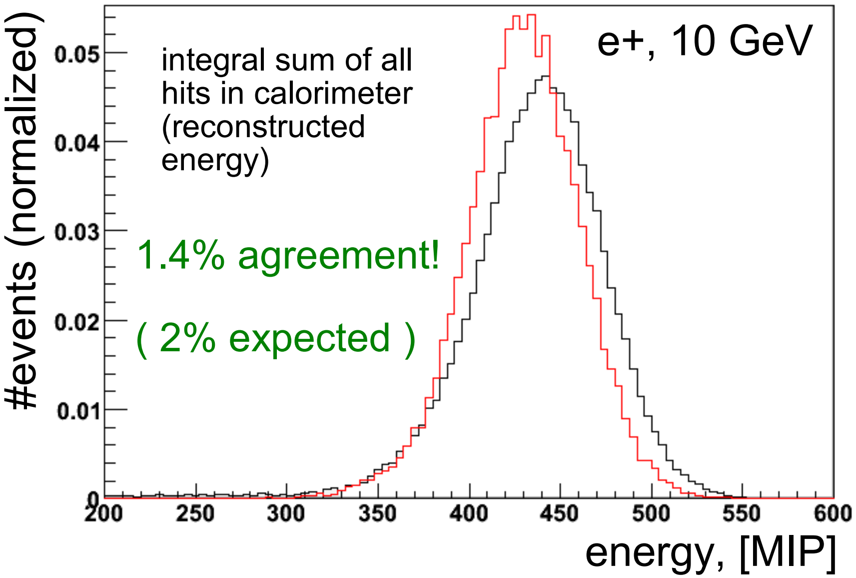


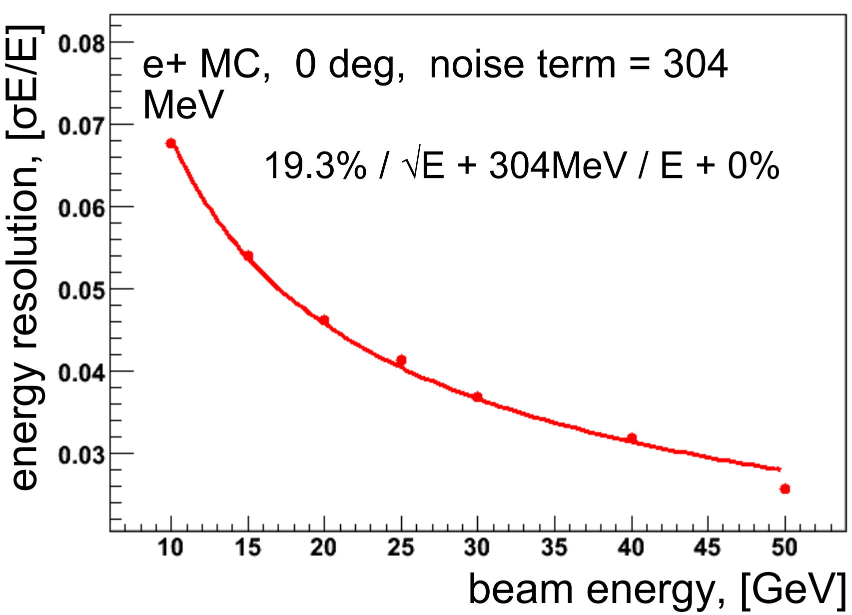


Analysis of electromagnetic showers in CALICE AHCAL prototype

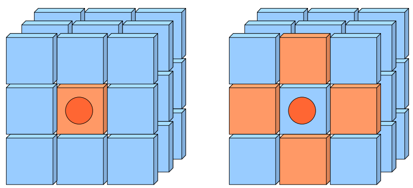
data (all correction applied) (black) and fully digitized MC (red)







We can also study an individual tile response (we have a highly granular calorimeter!)

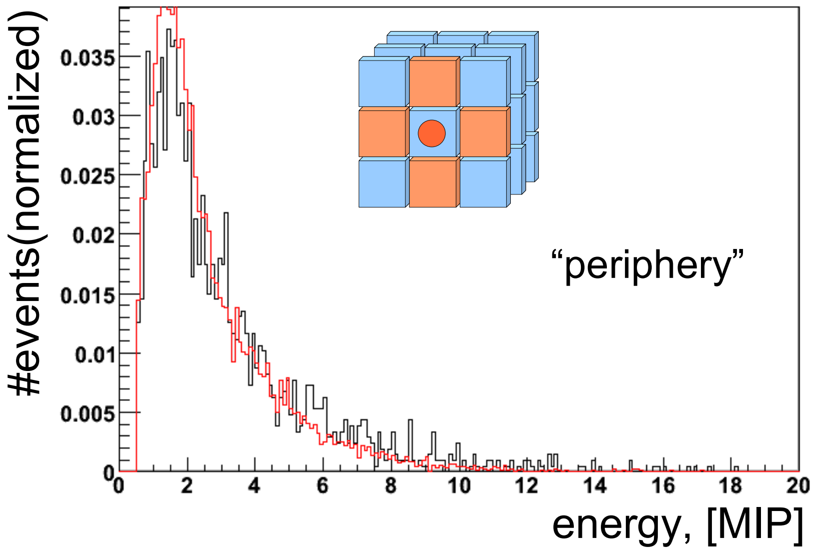


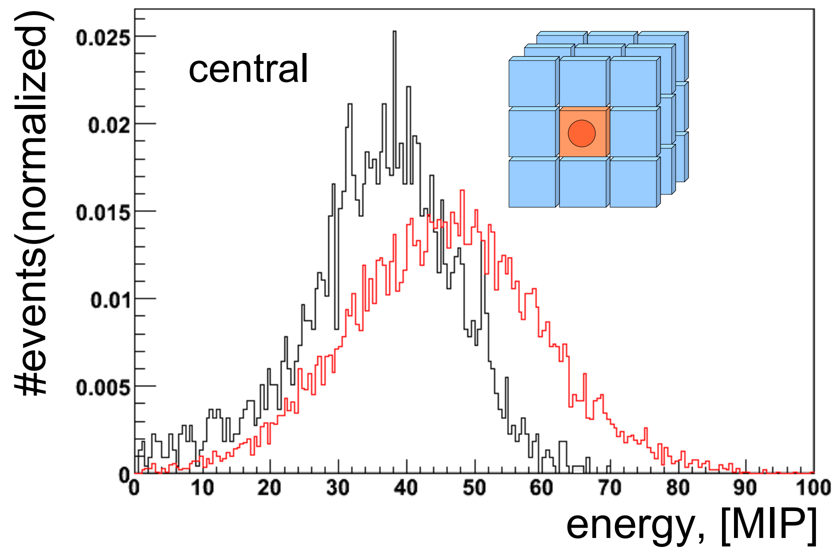
The idea is:

- study a "tower" of 3x3 tiles around the beam impact point
- compare the data and MC in:
  the central tile: high signal, big saturation
  the peripheral zone : low signal, small saturation
- study the calibration quality for single tiles

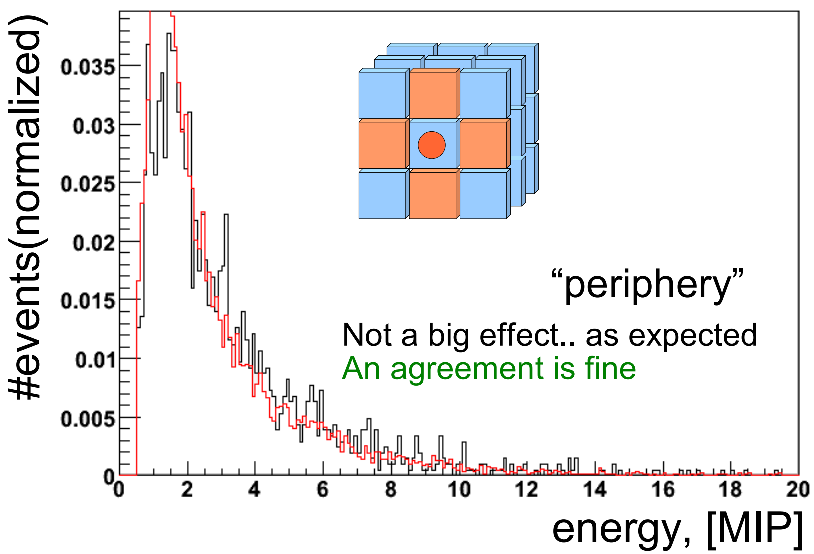
Analysis of electromagnetic showers in CALICE AHCAL prototype

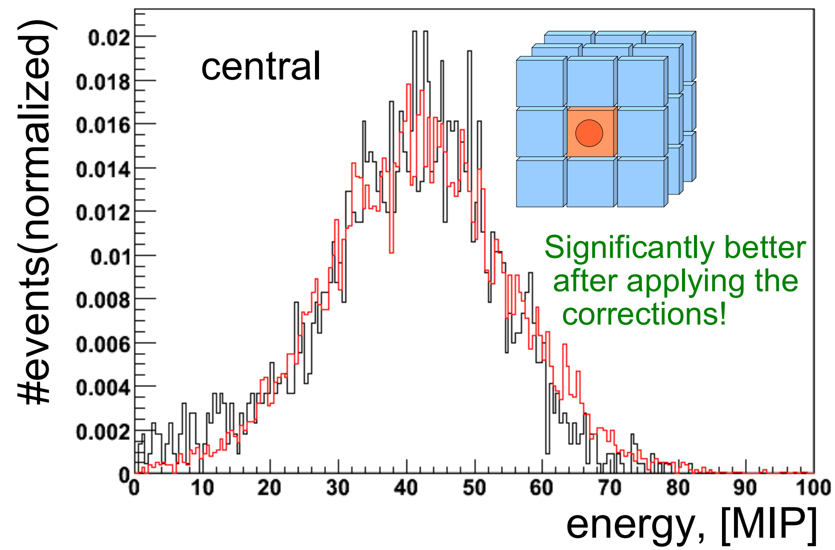
data (before corrections) (black) and MC (red)





data (all correction included) (black) and MC (red)





Summary & Outlook

- Electromagnetic showers in Analog Hadron Calorimeter is a very good tool for validating the calibration procedure

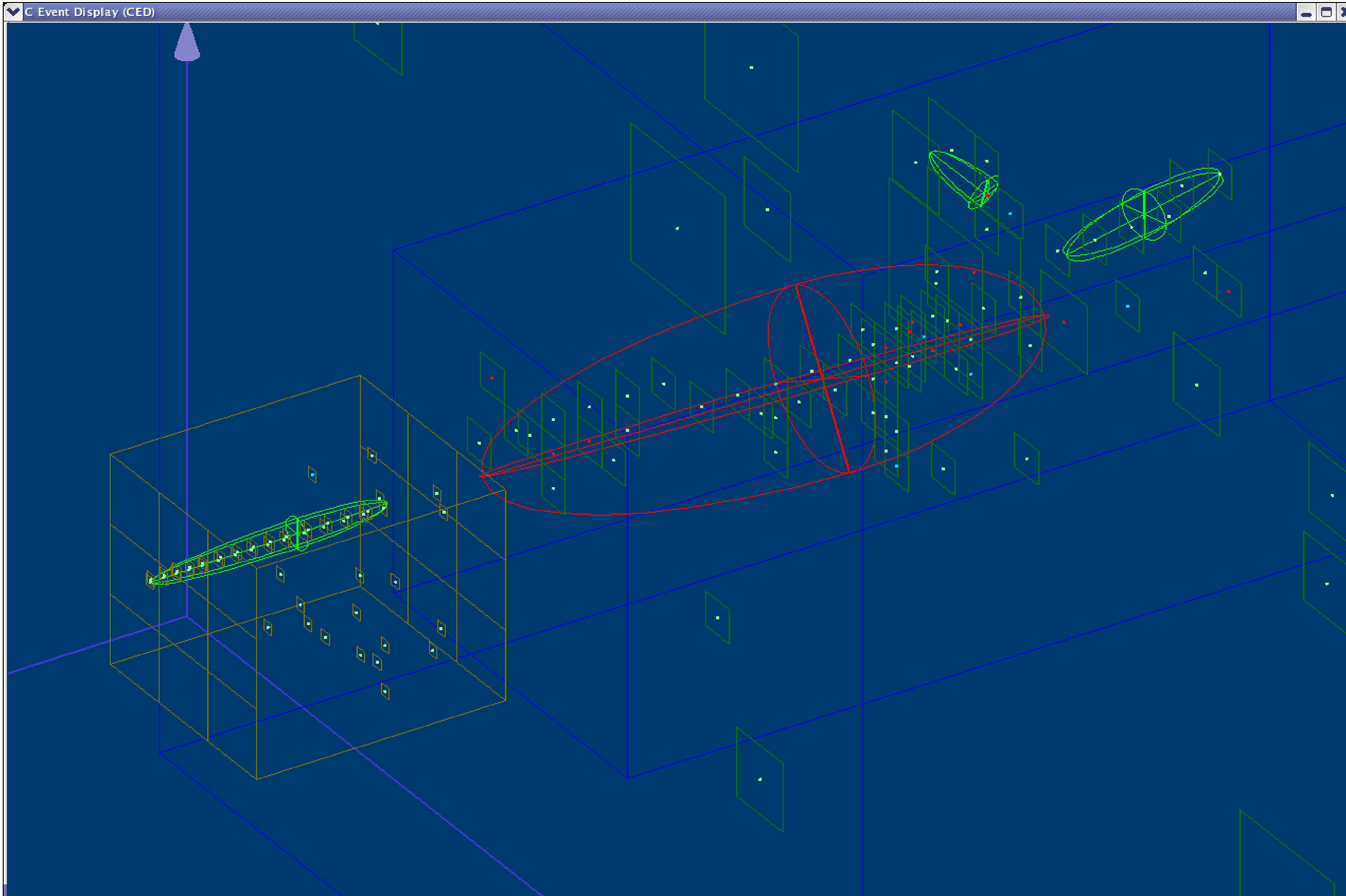
- An expected 2% level of uncertainties in reconstructed energies of positrons is achieved after an accurate and precision calibration and corrections

- The linearity of the calorimeter response for positrons is less then 4% (residuals to the linear fits) in 10 – 50 GeV range

- Monte Carlo study shows quite good agreement with a data in integral scale

Backup slides

Deep Analysis - ON!

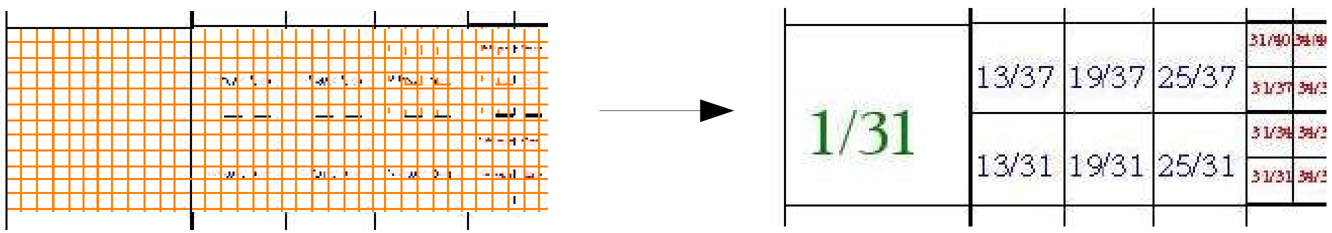


Monte Carlo simulation..

CALICE Mokka based GEANT4 framework simulation:

- detailed CERN'2007 test beam setup geometry

- high granularity layers (1x1cm tiles) with “ganging” after the simulation to AHCAL prototype tile pattern (3x3, 6x6, 12x12 cm tiles)



- digitization (conversion energies to MIP, MIP to SiPM pixel, add the pixel statistics, add saturation, conversion back to ADC counts, x-talk (~10% per tile) included)

- all calibration and saturation are from testbeam condition DataBase!

- using the same processors of CALICE Marlin to analysis