Test Beam Performance of the CALICE Si-W Electromagnetic Calorimeter Physics Prototype

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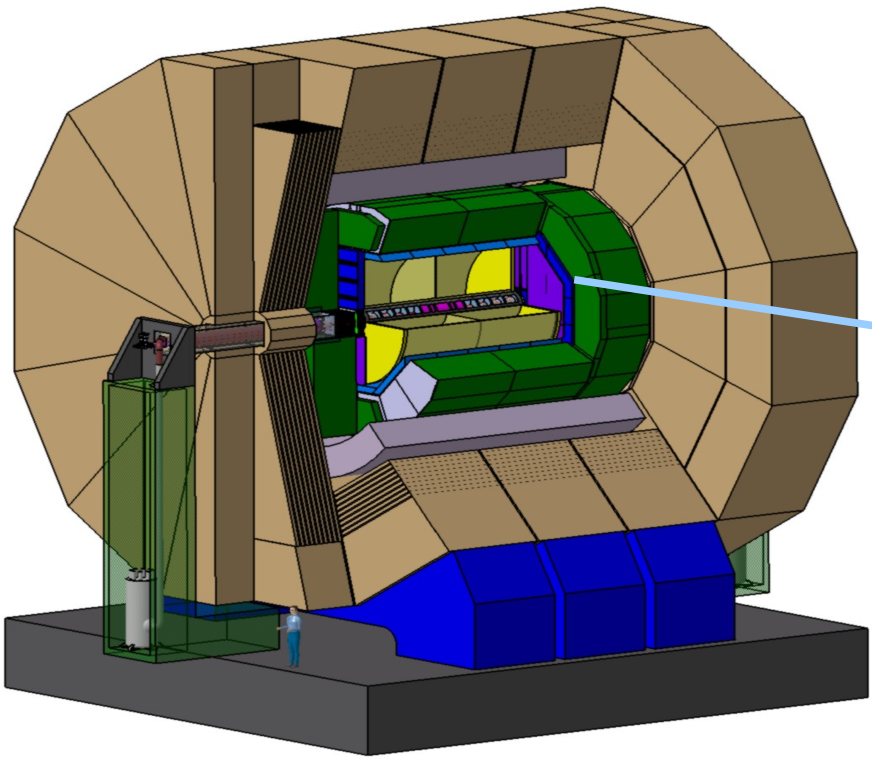
11th Pisa Meeting on Advanced Detectors

CAlorimeter for the LInear Collider Experiment

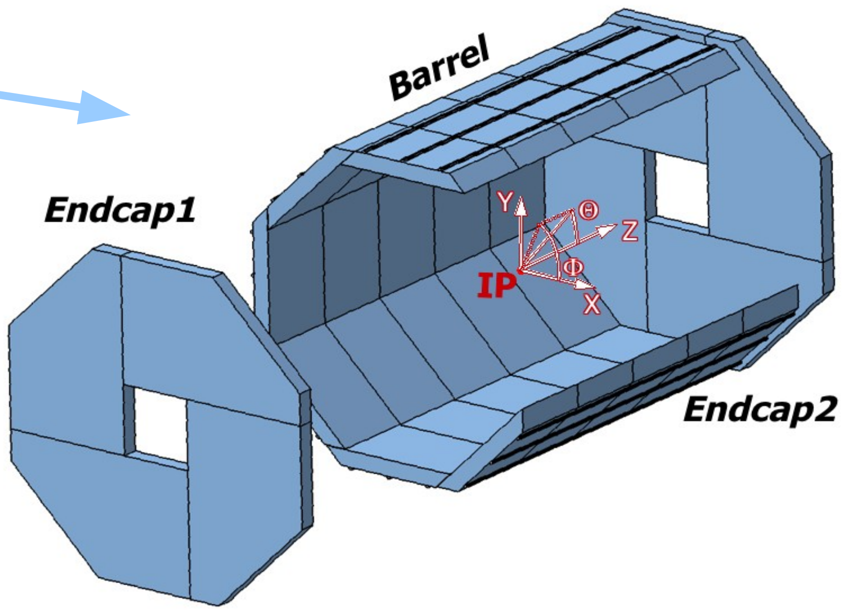
ILC → electron-positron collider at 500 *GeV* CME
30% $/\sqrt{E/GeV}$ jet energy resolution



The **International Large Detector** concept
Particle Flow Algorithms
→ increase measurement precision (most suitable subdetector)
→ require perfect reconstruction of particle trajectories even in calorimeters

CALICE Collaboration → R&D into calorimeter systems
Calorimetry requirements for ILC detectors:

- Compactness (low cost, narrow showers)
- Fine transverse and longitudinal granularity (high position resolution)
- Hermeticity (whole solid angle)



ECAL
- Barrel modules are identical
- Cracks b/w barrel modules at large angle with respect to the radial direction

The Electromagnetic Calorimeter

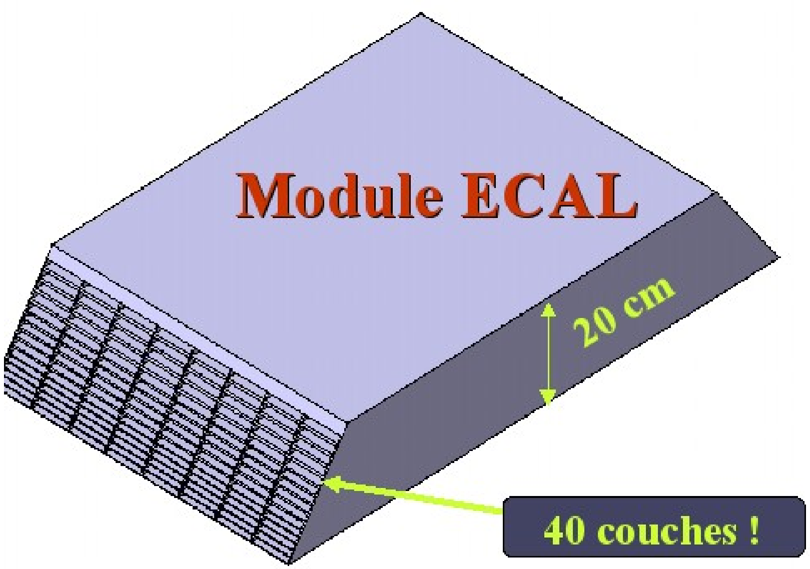
Si-W ECAL – A Silicon Tungsten sampling calorimeter

Absorber material: Tungsten
- small Moloière radius 9 mm
- small radiation length X_0 = 3.5 mm

24X_0 to absorb electrons and photons

Sensitive material: high resistive silicon
- free choice of diode size (granularity)
- compactness and simplicity
- 3000 m² surface for the final detector

Half W incorporated into a supporting alveolar composite structure to reduce the dead area
Space left for detection units (slabs) to slid in.



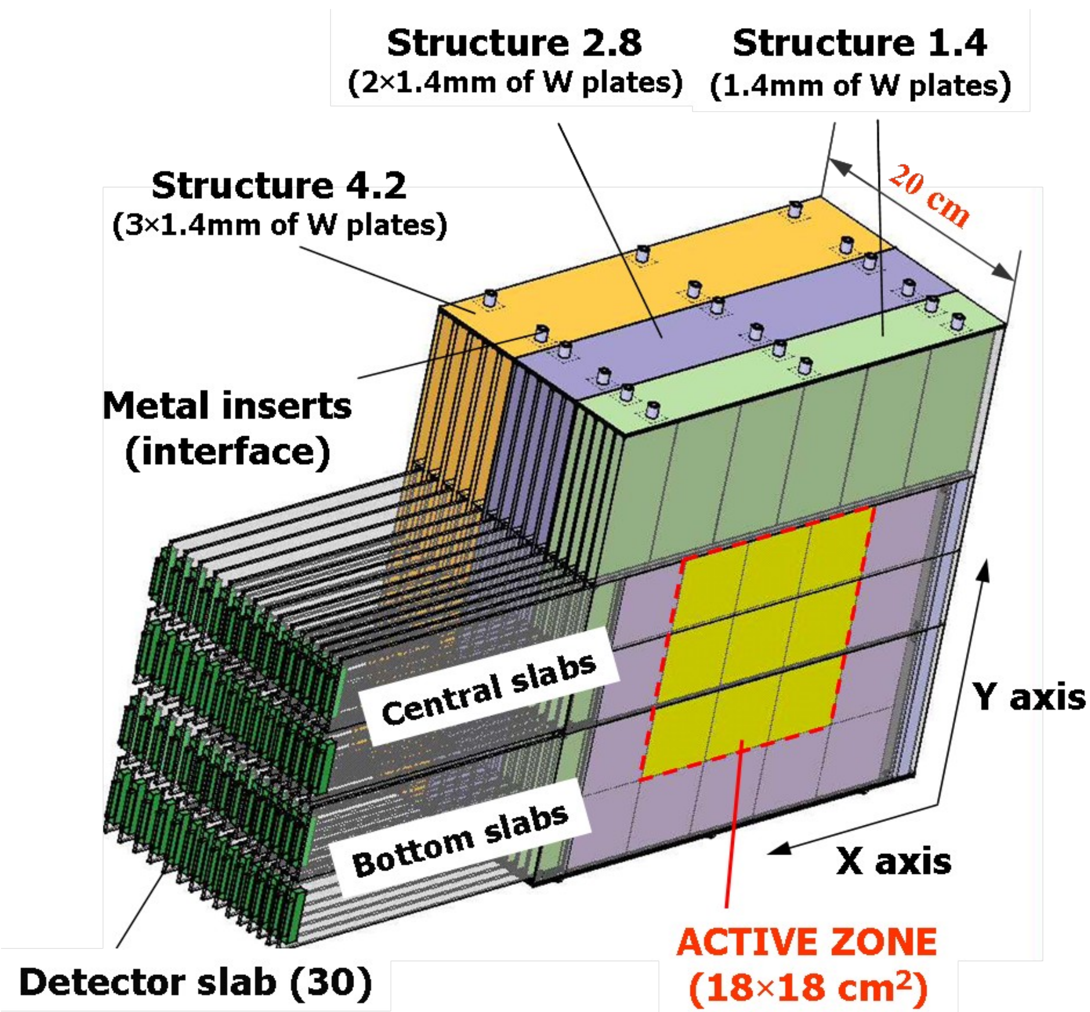
Prototypes:

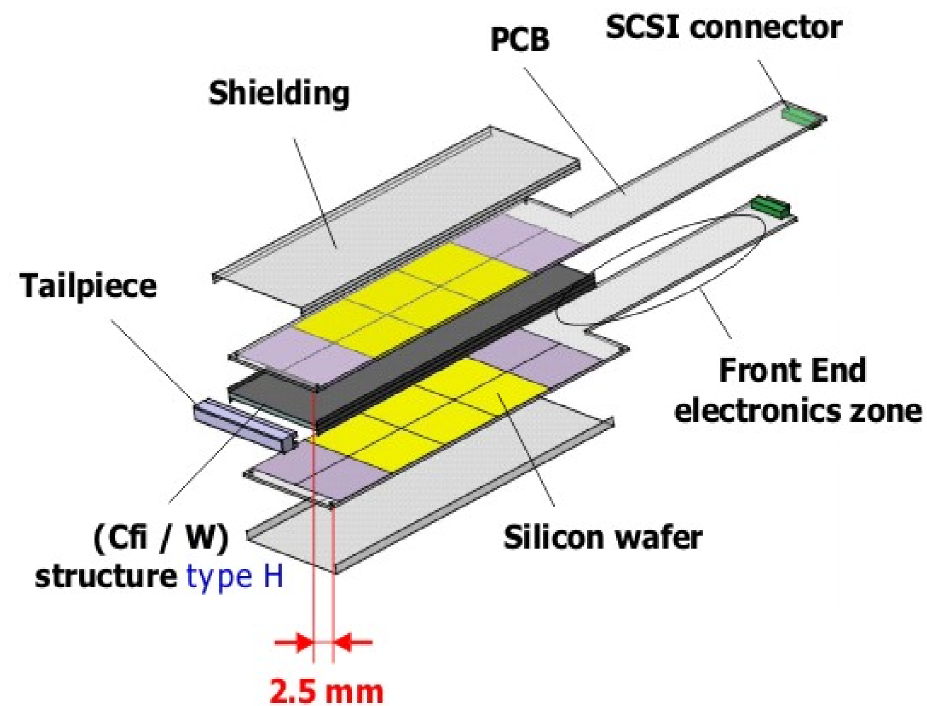
1. The first small physics prototype (current talk)
2. The next generation representative technological prototype – the EUDET module (see the poster session)

Prototypes are exposed to test beam to study performance

The Physics Prototype

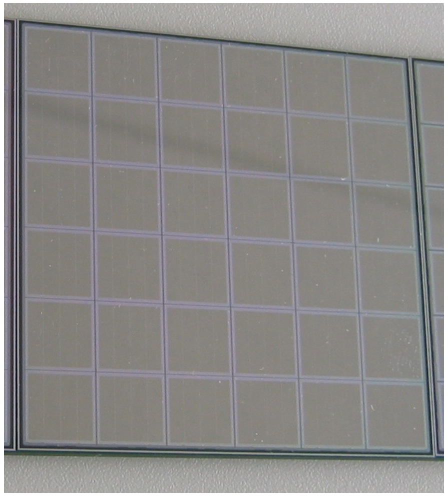
3 stacks x 10 layers with different W thickness increasing with depth, 24 radiation lengths in total

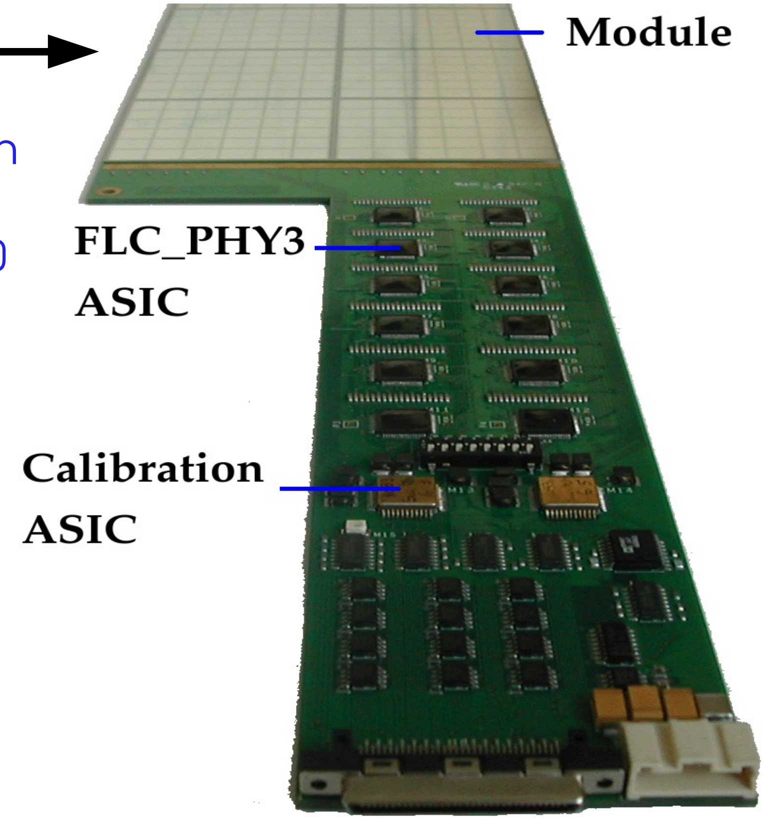




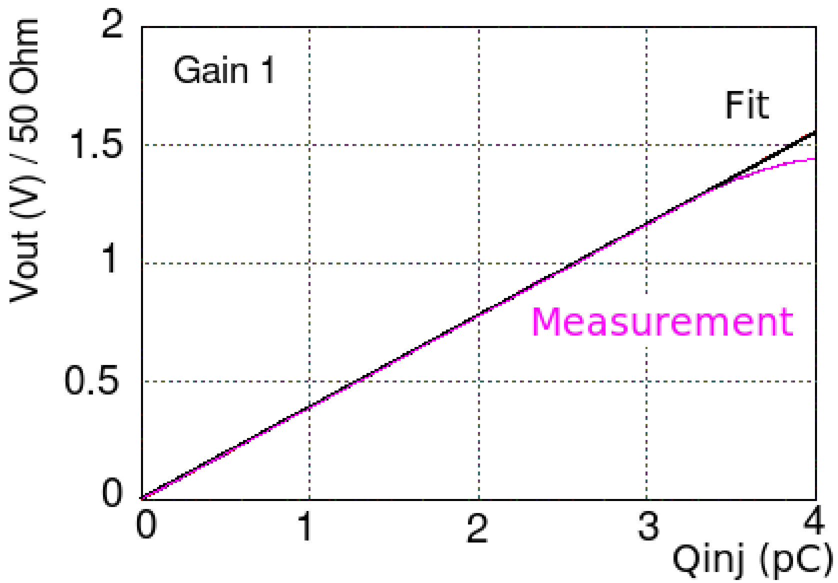
3 x 3 wafers
a wafer = 6 x 6 pads
a pad = 1 x 1 cm
~ 10000 channels

Active Layers





Wafers, each with 6 x 6 silicon pads fixed to the PCB using conductive glue EPOTEC 4110

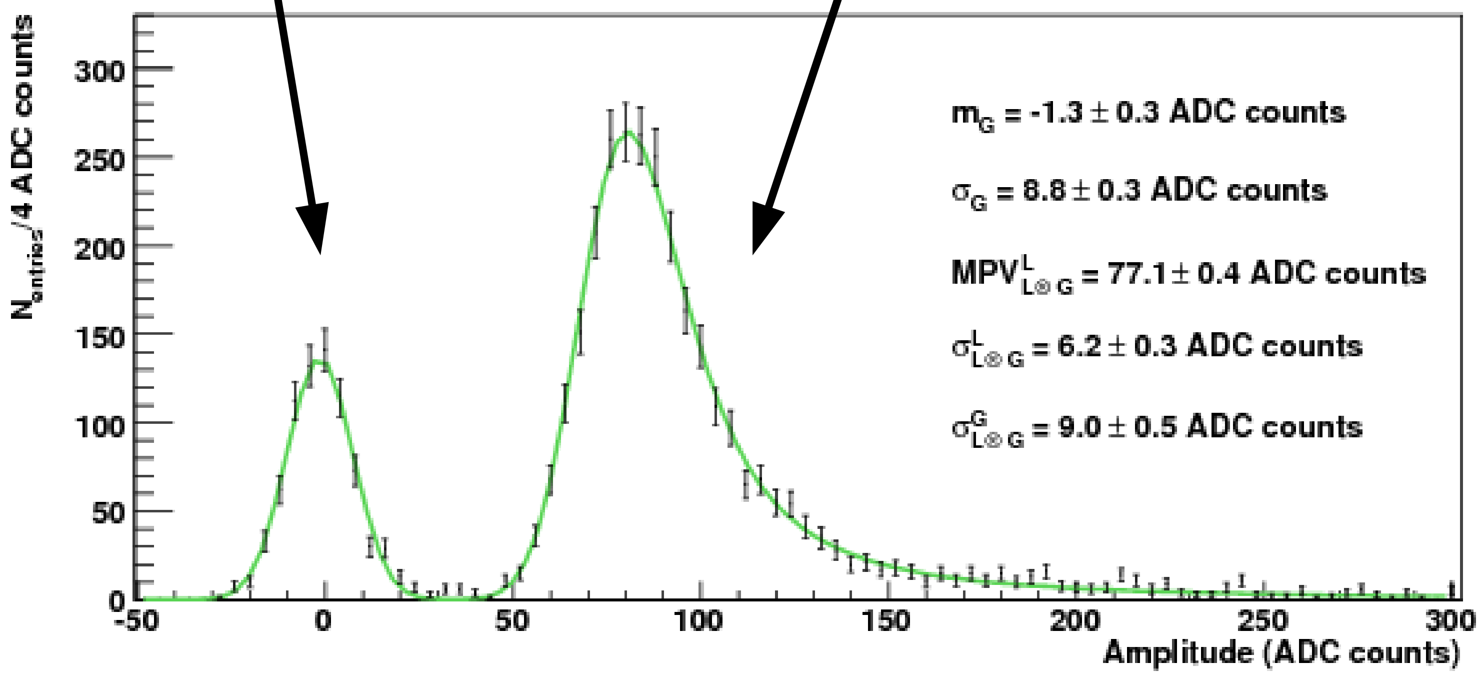


- Pads are read out by VFE ASICs
- ADC is done by off-detector electronics

Slab Calibration

No beam (electronics noise)
Pedestal = RMS
Noise = standard deviation

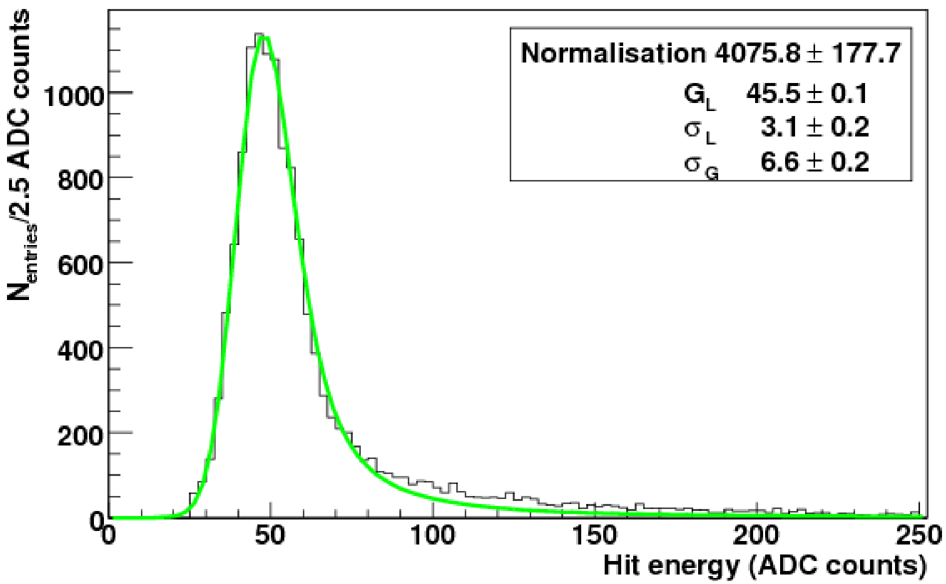
Cosmic muons
MIP signal



Similar studies
with muon beam measured
electronics noise
~13% of a MIP

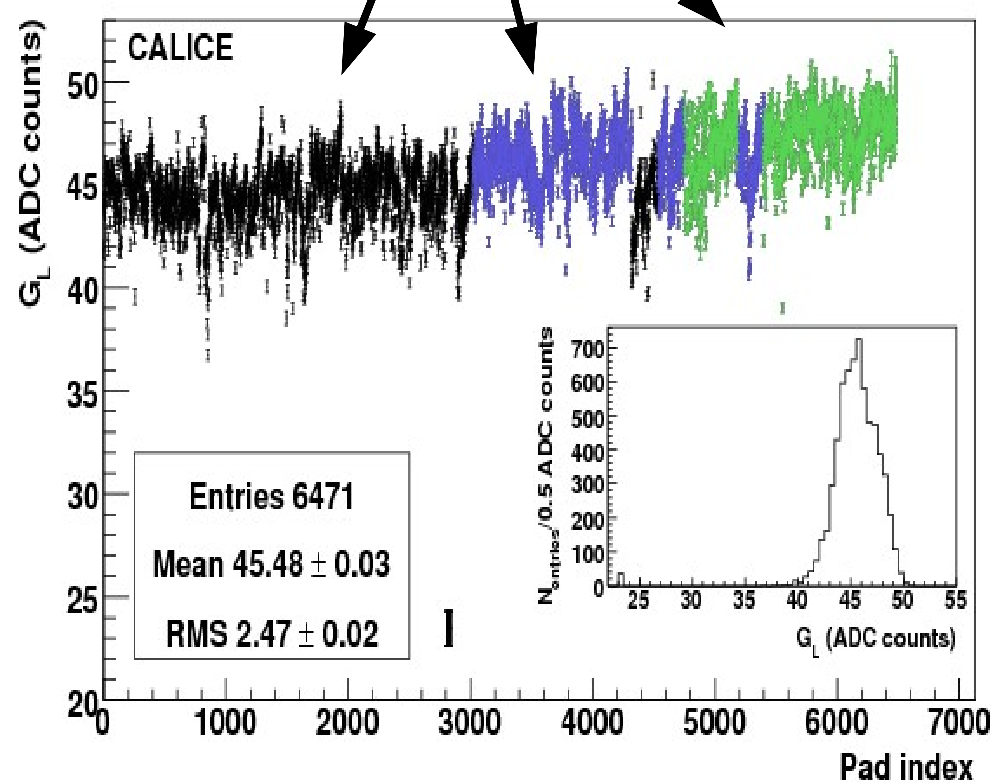
Calibration Constants

Extracted per channel from 18 M muon events, only 0.14% dead cells



A single channel energy spectrum:
The most probable value from a fit to Landau is the calibration constant (ADC counts for 1 MIP)

All channels – good stability in time and uniformity across the detector
Small differences observed for different Si pad manufacturers

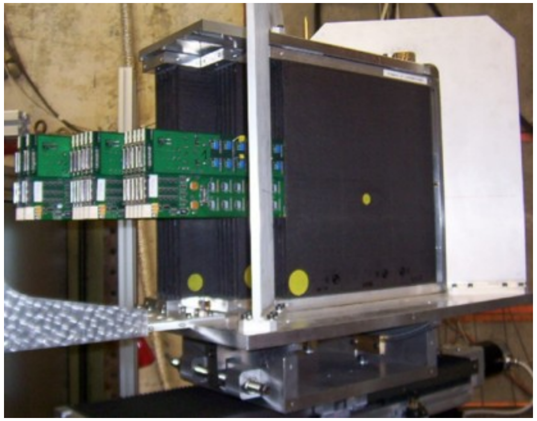


Beam Test Setup

ECAL Testbeam:

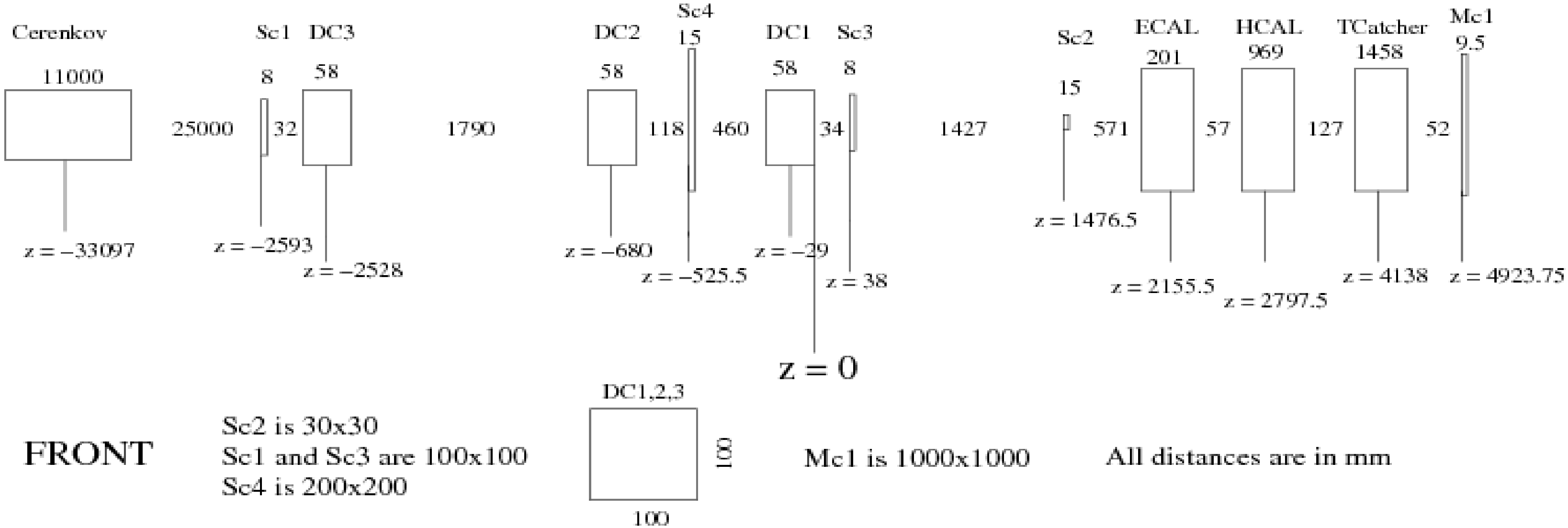
- 2006 at DESY
- 2007 at CERN
- 2008 at FNAL

ECAL prototype rotated at 45°
Modules are shifted to ensure beam particles passing through the active area



- Scintillator counters provide a trigger signal
- Delay drift chambers for track reconstruction

CERN - October 2006



Response to Electrons

Electron selection:
Based on event energy:

$$E_{raw} = \sum_{hits} \alpha_i E_i$$

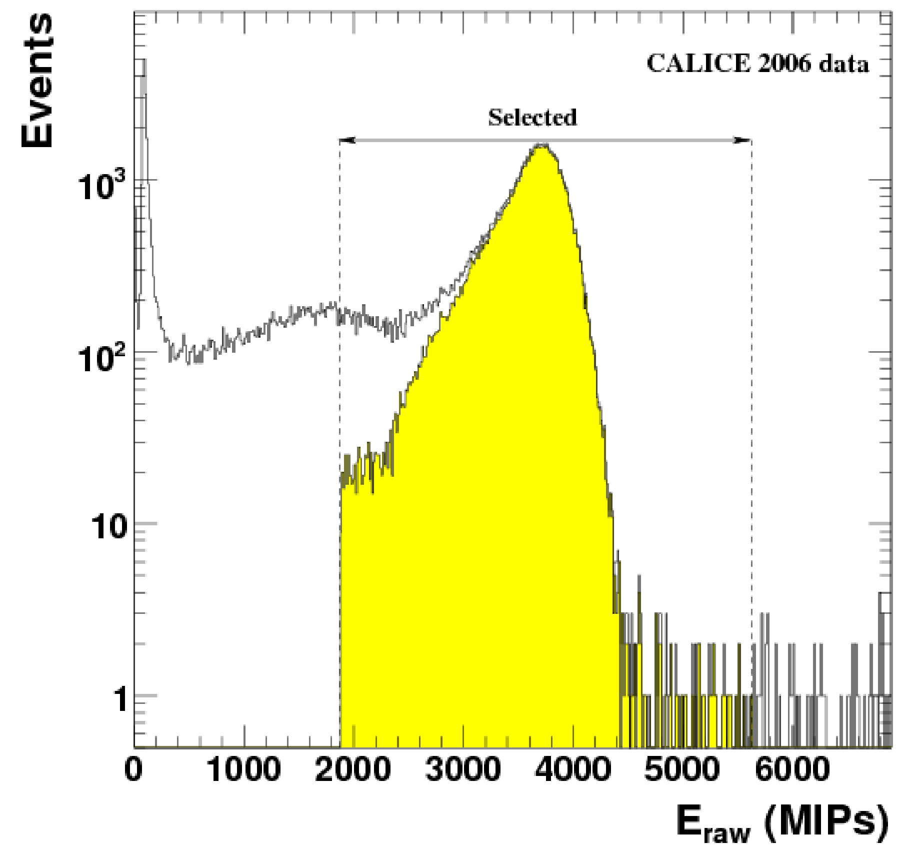
α accounts for the absorber thickness in different stacks

Selection:

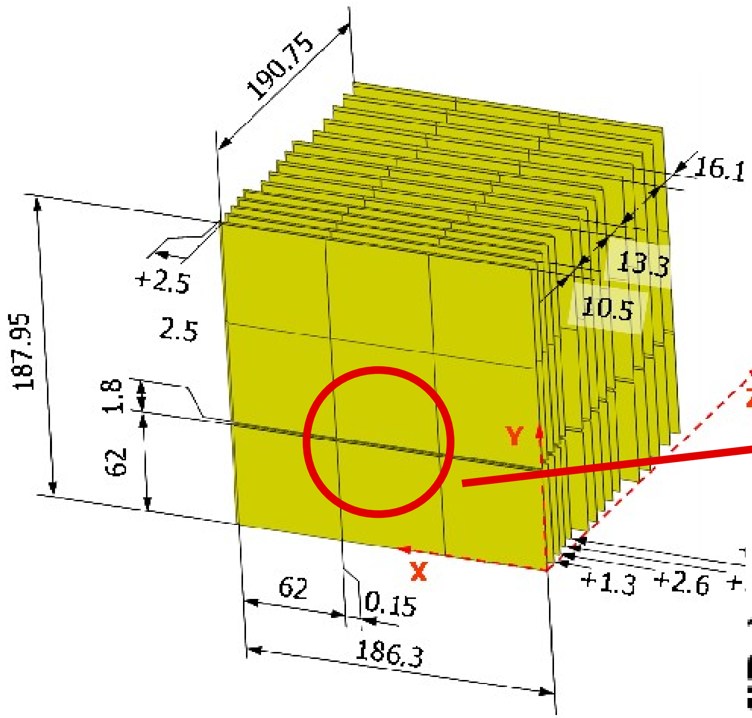
• Energy window:
125 < Eraw(MIP) / Ebeam(*GeV*) < 375

• Cherenkov detector on:
Rejects pion contamination (yellow area)

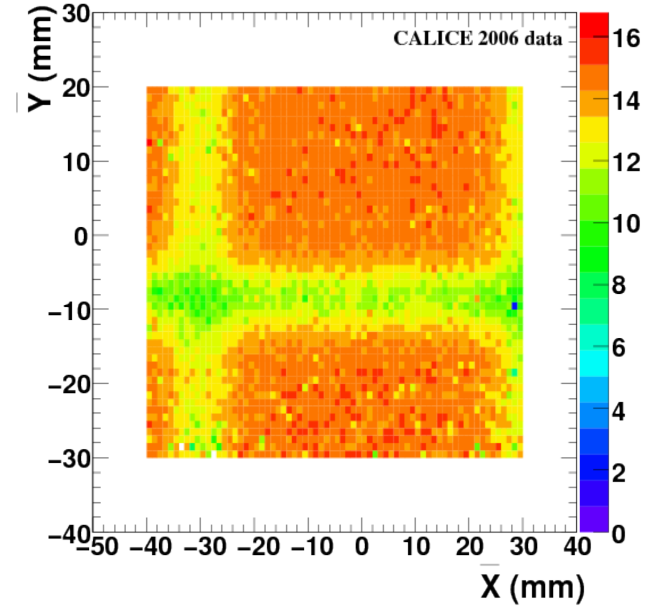
15 *GeV* electron selection



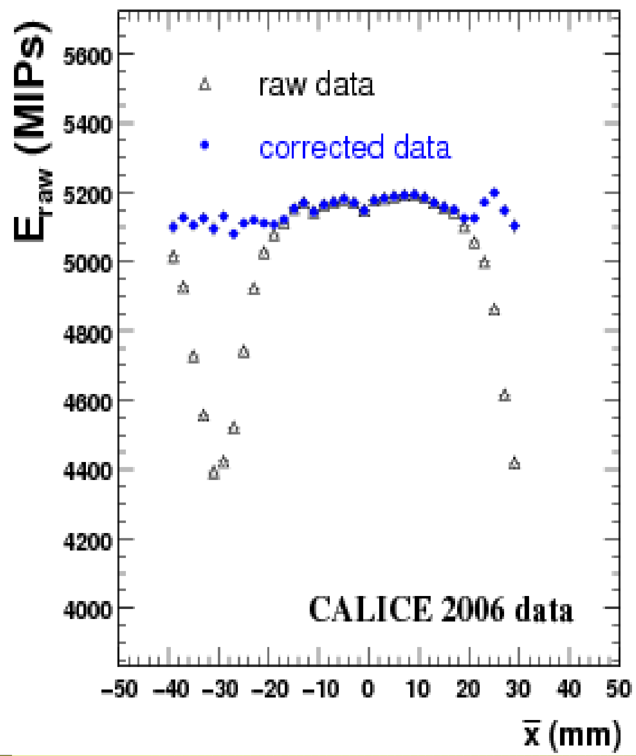
Energy Correction

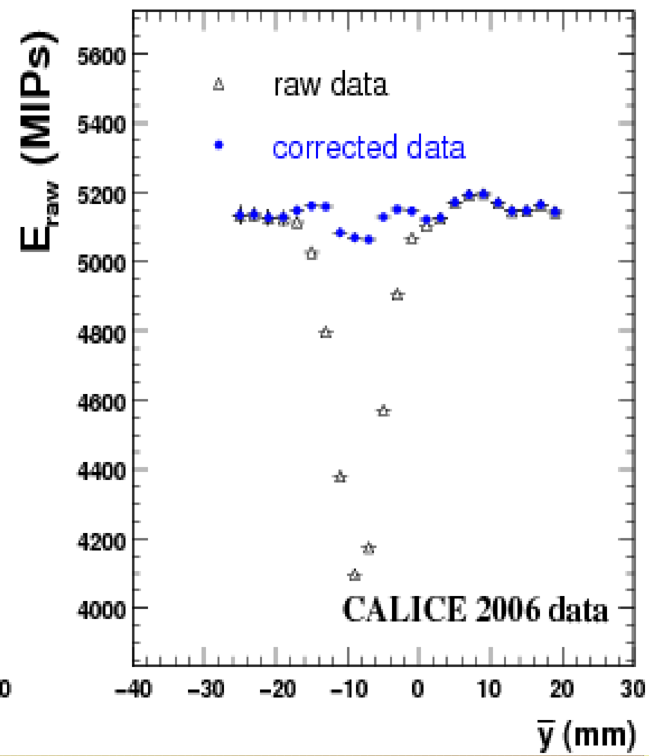


- Active layers are shifted in ***x*** to reduce energy leakage through passive areas
- Passive areas in ***y*** overlap

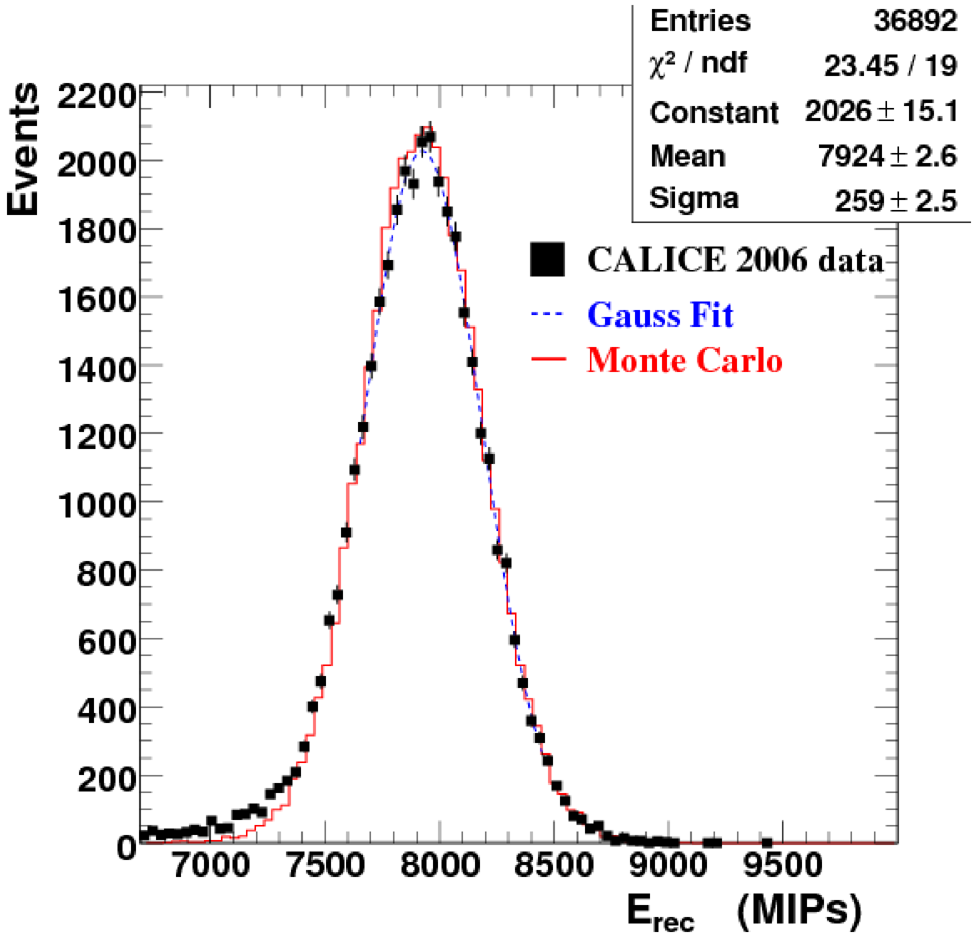


The event energy correction as a function of the mean shower position for 20 *GeV* electrons



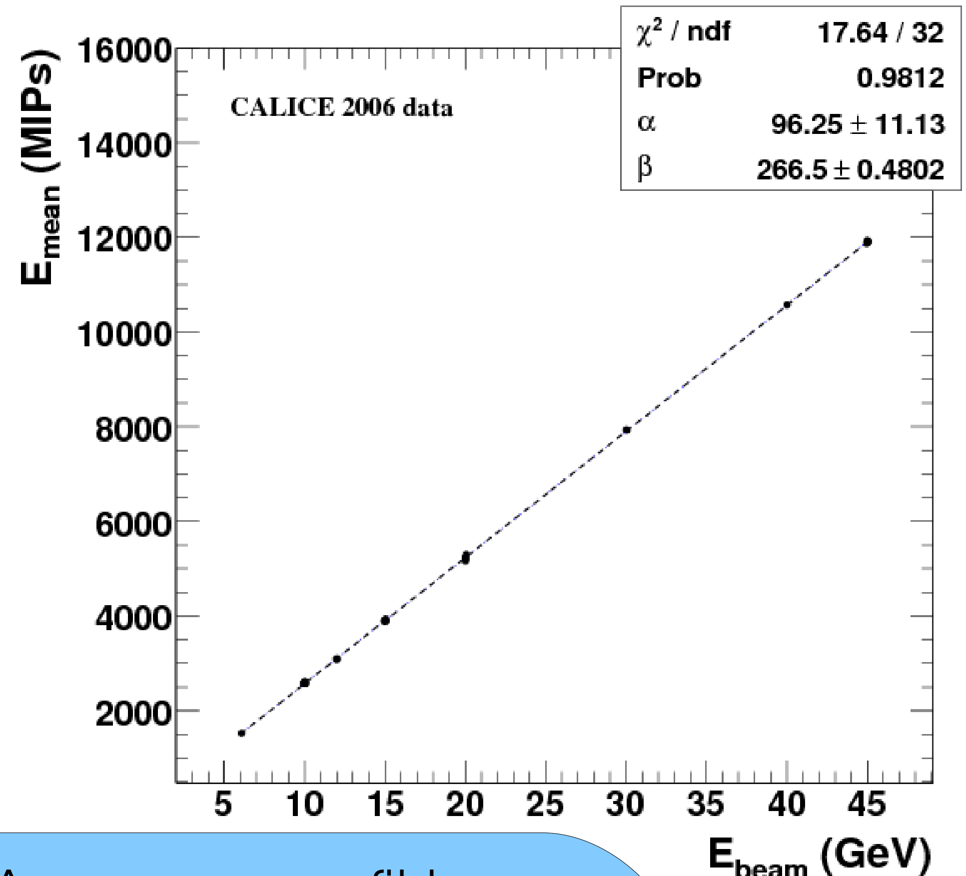


Energy Response



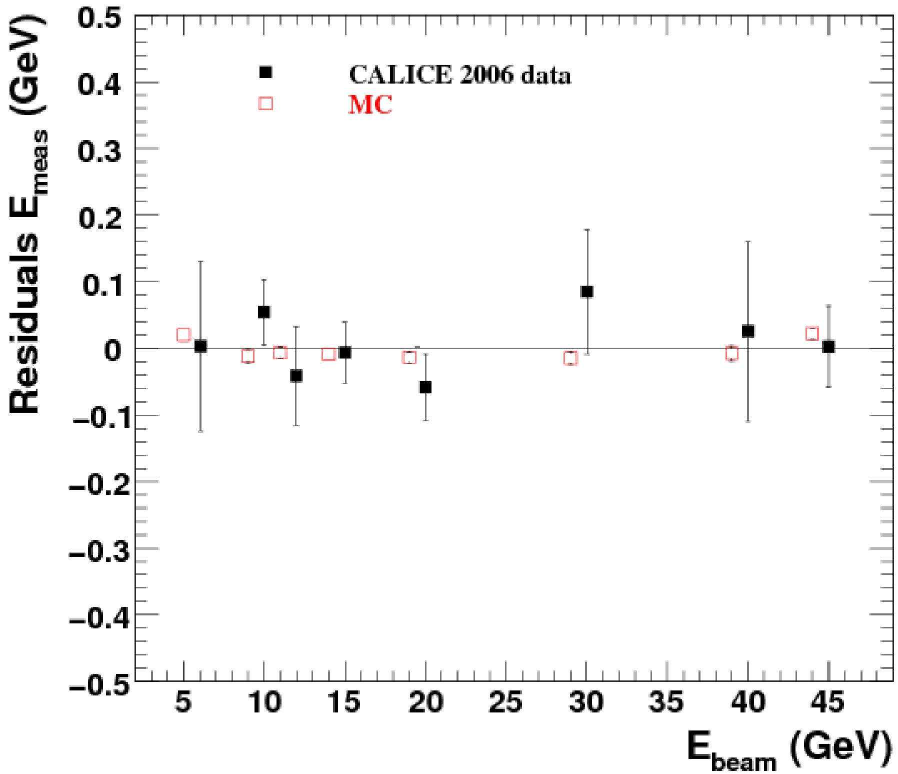
30 *GeV* electrons
Energy spectrum
Fit to Gaus {-σ; +2σ}

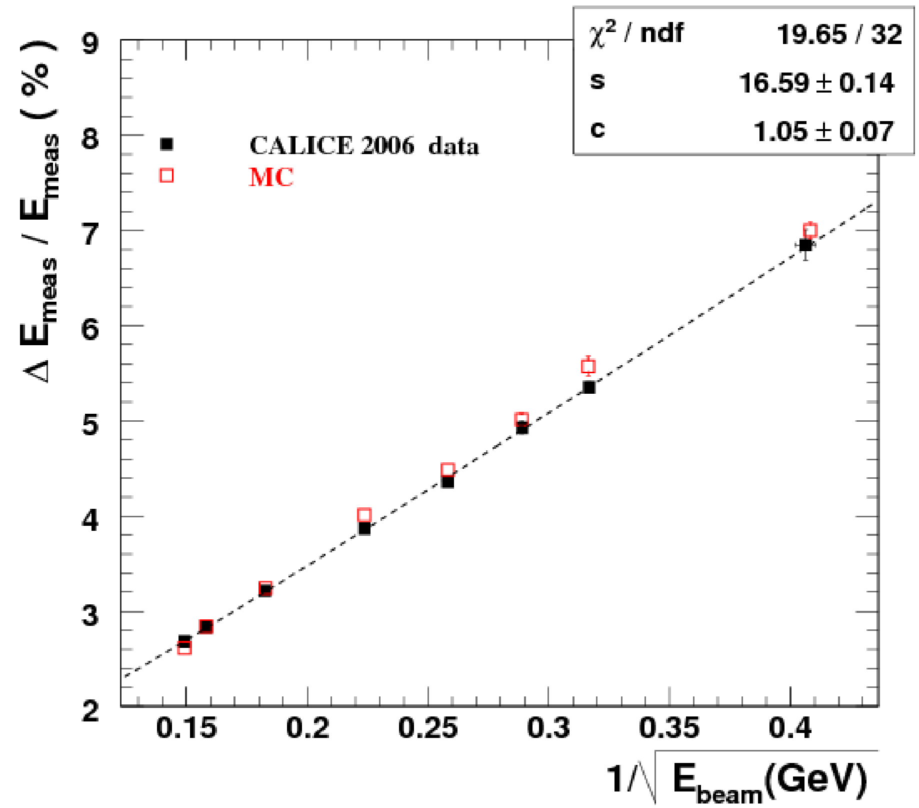
The mean energy response for various beam energies



A mean energy fit to
E,mean = β E,beam - α
Global MIP to *GeV* calibration factor
β = 267 MIP/*GeV*

Linearity and Energy Resolution



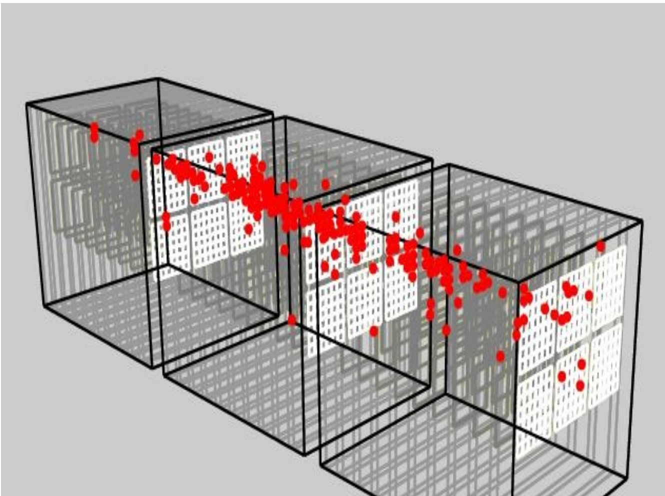


Residuals to linearity
Unlinearity within 1%

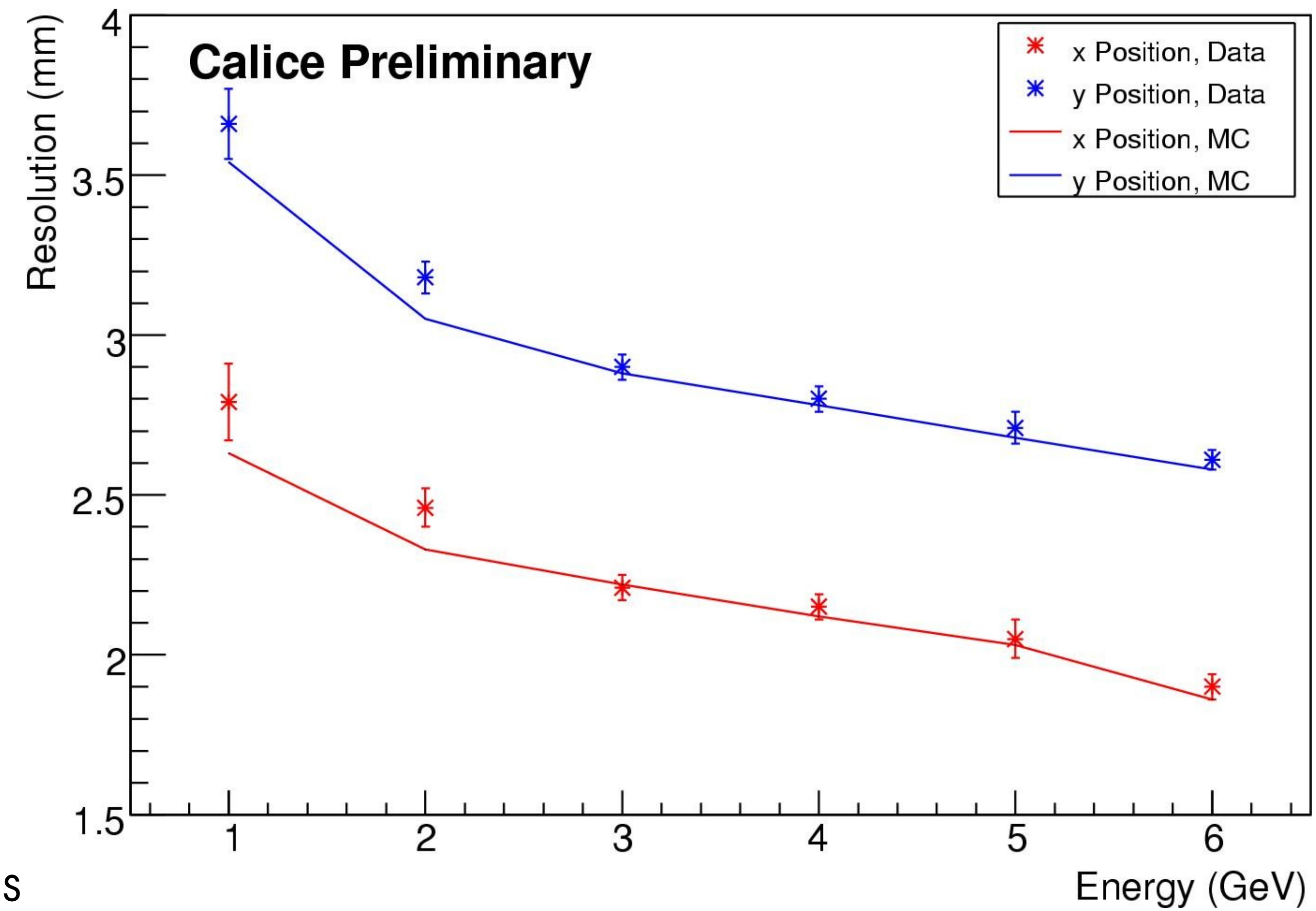
Data: $\frac{\Delta E}{E} = \frac{16.6 \pm 0.1}{\sqrt{E(GeV)}} \oplus 1.1 \pm 0.1$ %

Monte Carlo: $\frac{\Delta E}{E} = \frac{17.3 \pm 0.1}{\sqrt{E(GeV)}} \oplus 0.5 \pm 0.1$ %

Position Resolution



A 10 *GeV* electron shower Hits with red

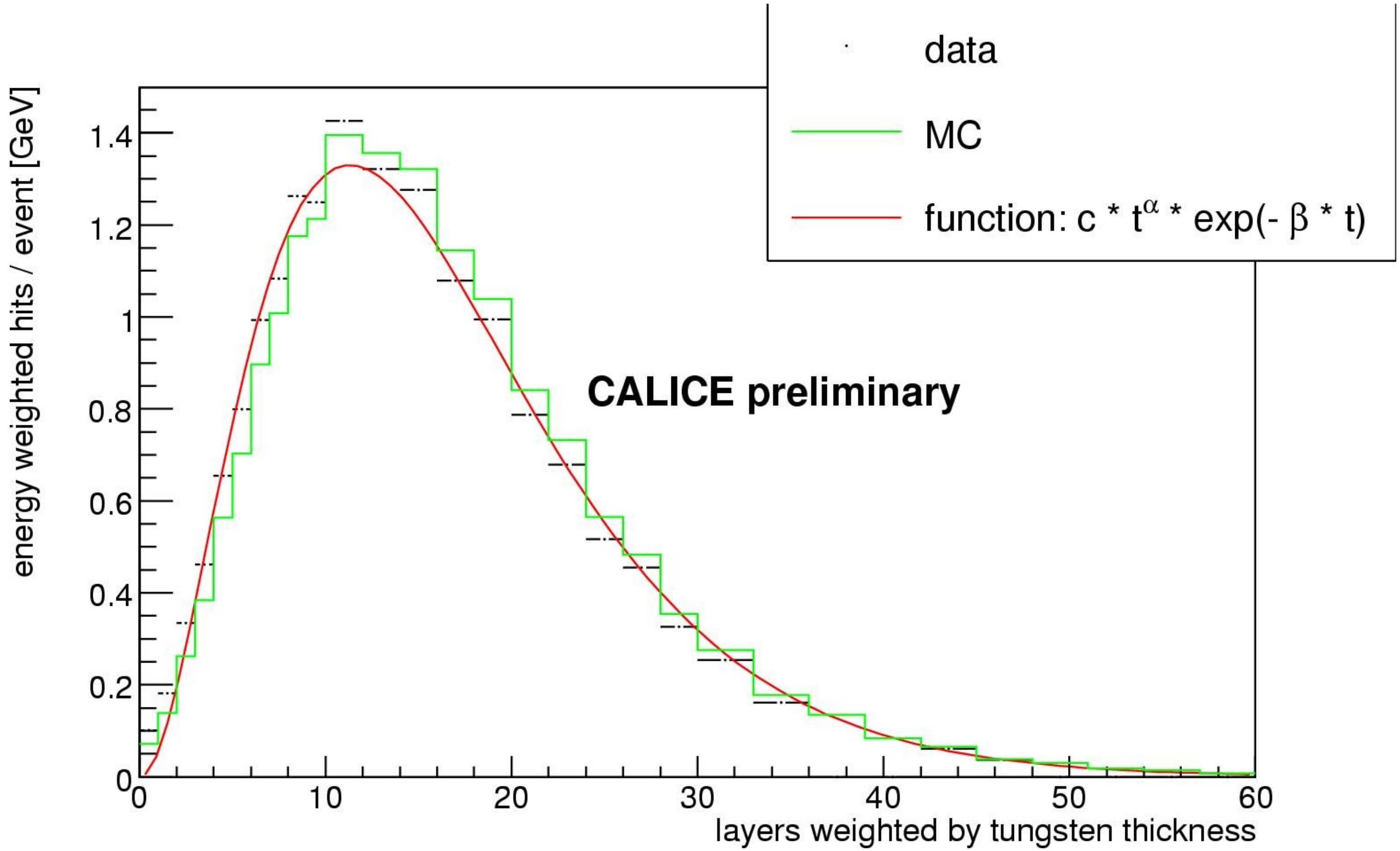


Calorimeter "tracks" reconstructed by fit to energy weighted hit positions

Tracks reconstructed in drift chambers used as a reference

The worse resolution in *y* is explained with the passive areas overlap in *y*

Longitudinal Shower Profile



The longitudinal energy distribution for 20 *GeV* electrons against the calorimeter depth, *t*

Shower variables – an important tool for particle id and separation

Conclusions

- A Si-W electromagnetic calorimeter for particle flow is under development by the CALICE collaboration

- A physics prototype was already constructed and tested

- The performance has been studied in terms of stability, linearity and energy resolution

- Current results are well within the International Linear Collider Reference Design Report requirements

- Additional position resolution and shower profile measurements are necessary to verify the particle flow capabilities of the facility, studies are ongoing

- A technological prototype is under construction (see poster session)