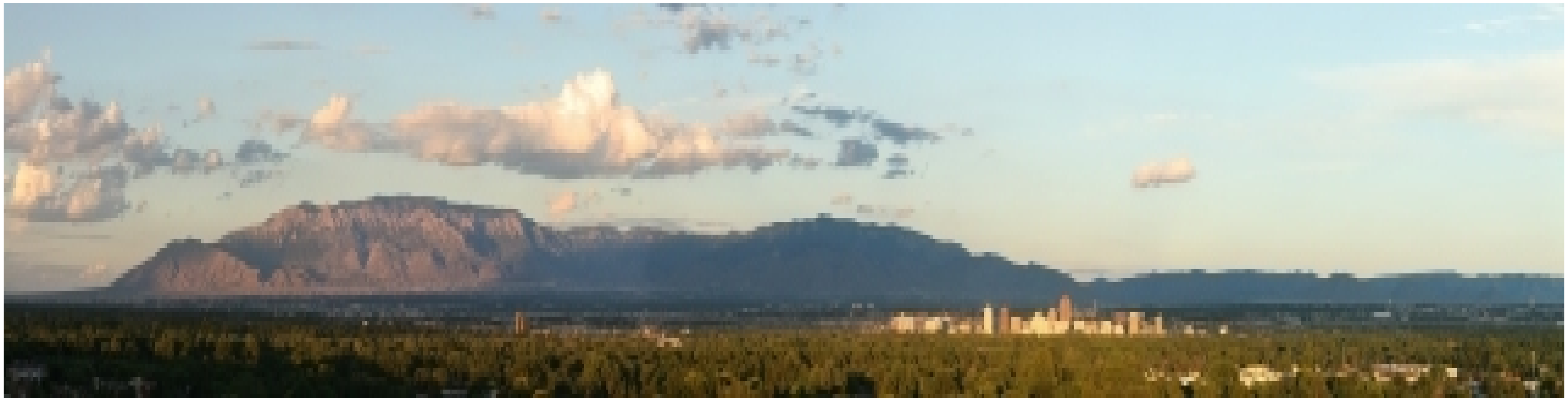
CALICE SiW Ecal

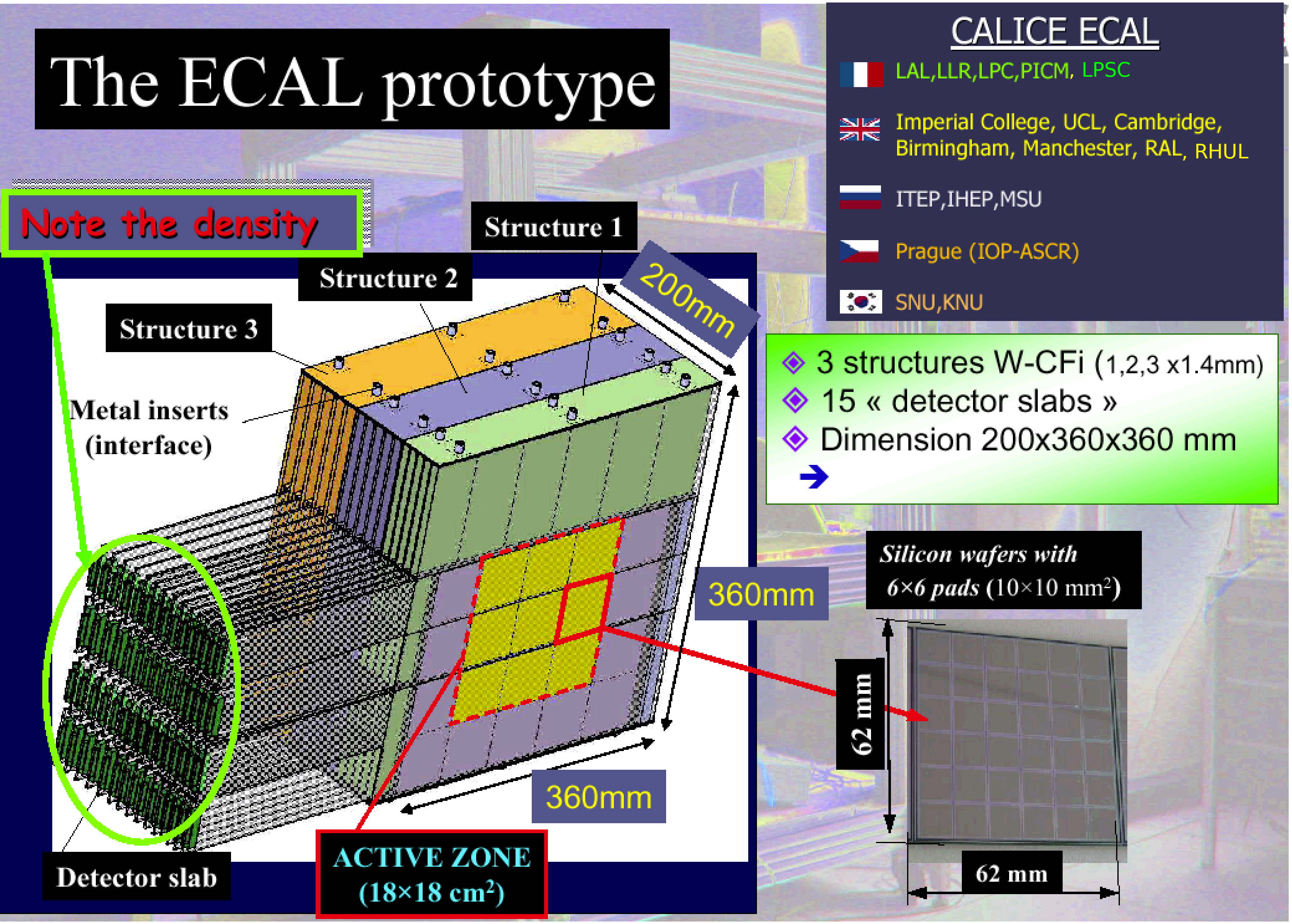
- Results and Plans -

Roman Pöschl
LAL Orsay



Linear Collider Workshop LCWA09 Albuquerque NM Sept./Oct. 2009

Ecal Prototype - CALICE Collaboration

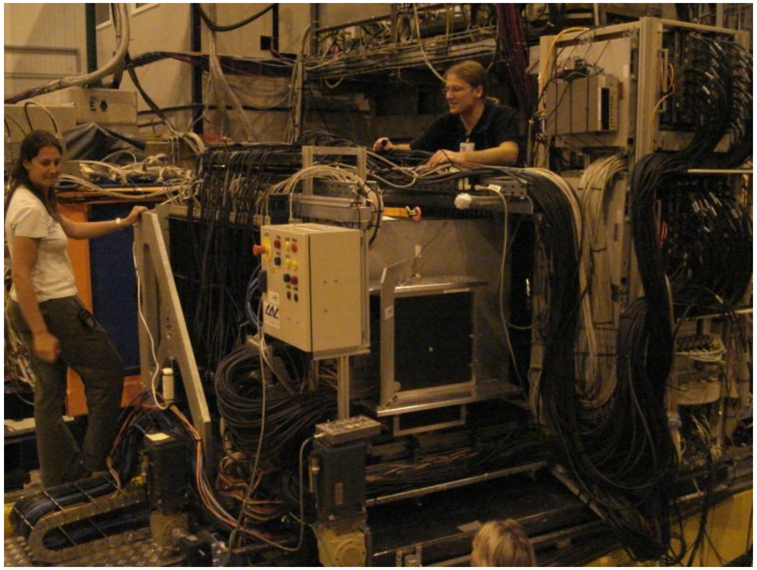


- W as absorber material
- Signal extraction by “Silicon Wafers”
- Extreme high granularity $1x1\ cm^2$ cell size
- Detector is optimized for particle separation

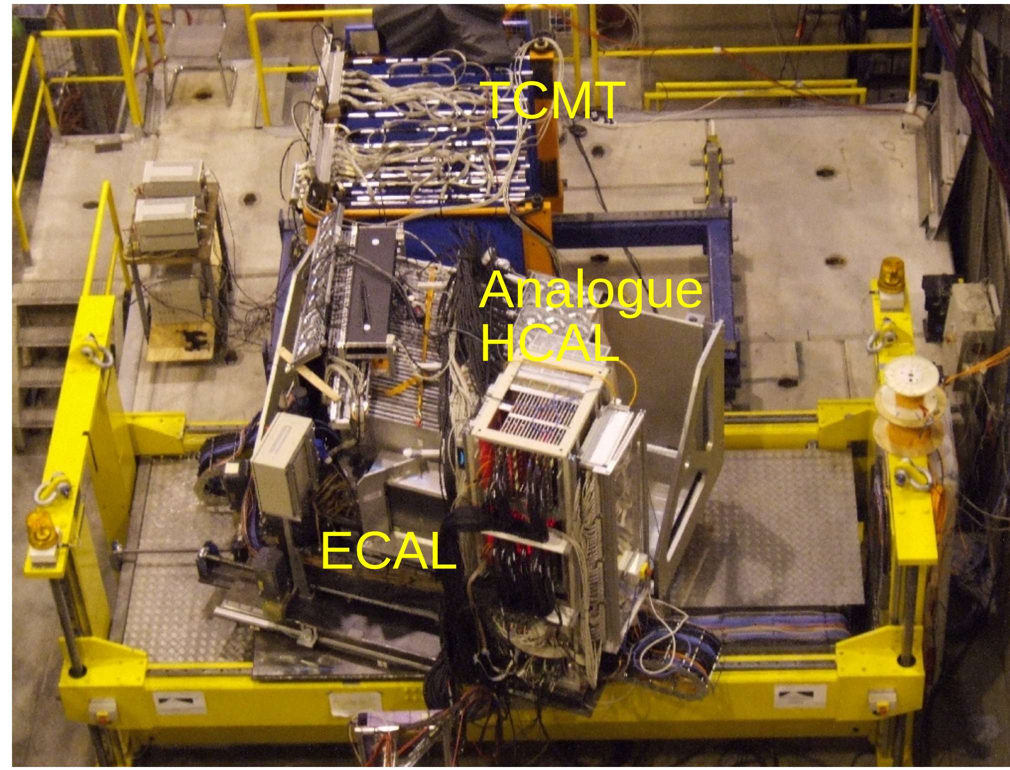
CALICE Testbeam Data Taking

Large scale testbeam effort by CALICE Collaboration

Data taking 2006, 2007, 2008



Testbeam Setup at CERN 2007

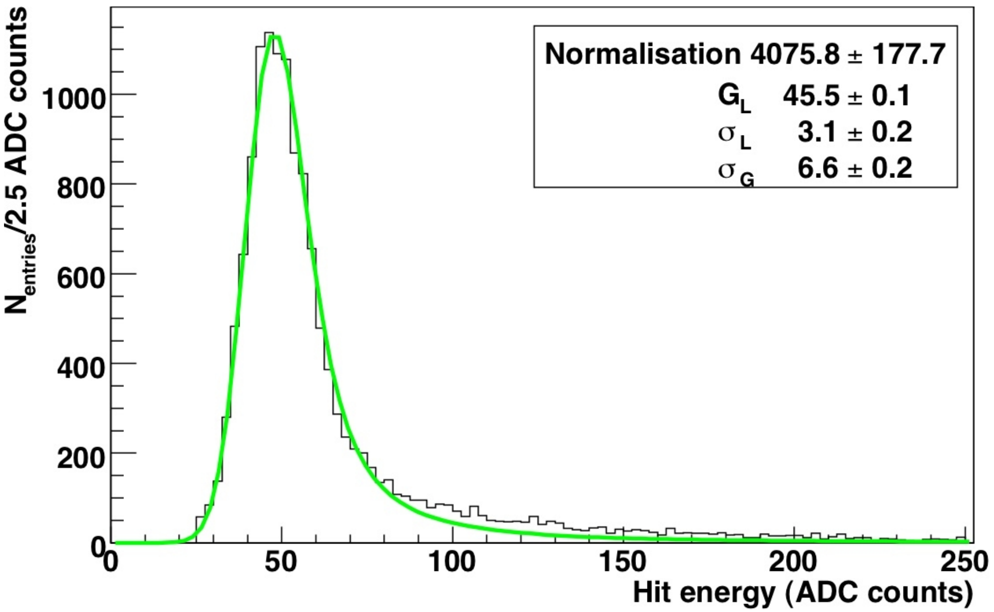


Slabs slit into alveolas

Data taking 2006 2/3 equipped Ecal
Data taking 2007 (nearly) fully equipped Ecal
Data taking 2008 fully equipped Ecal

Today: Analysis of 2006 Data

Calibration – Uniformity of Response

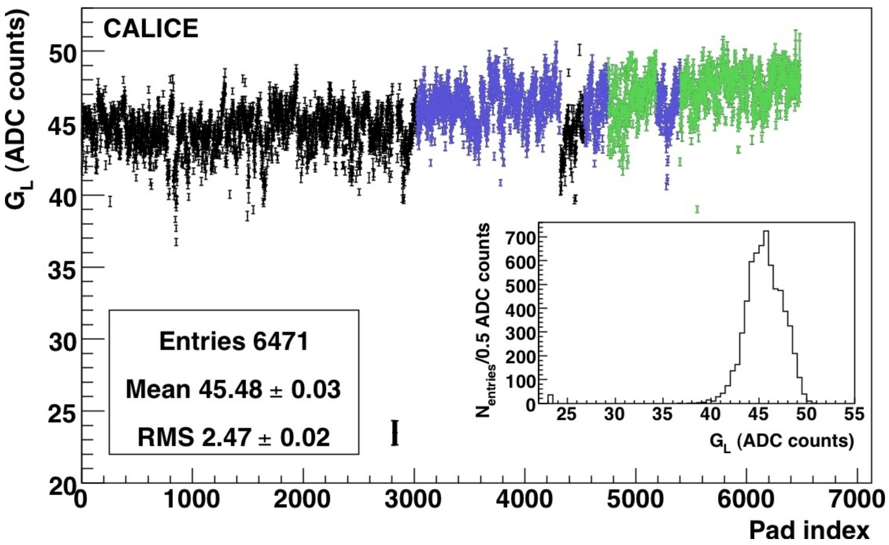


Calibration with with wide spread μ-beam

18 Mio. Events
Uniform response of all cells
only 1.4‰ dead cells

Differences in Response can attributed to different

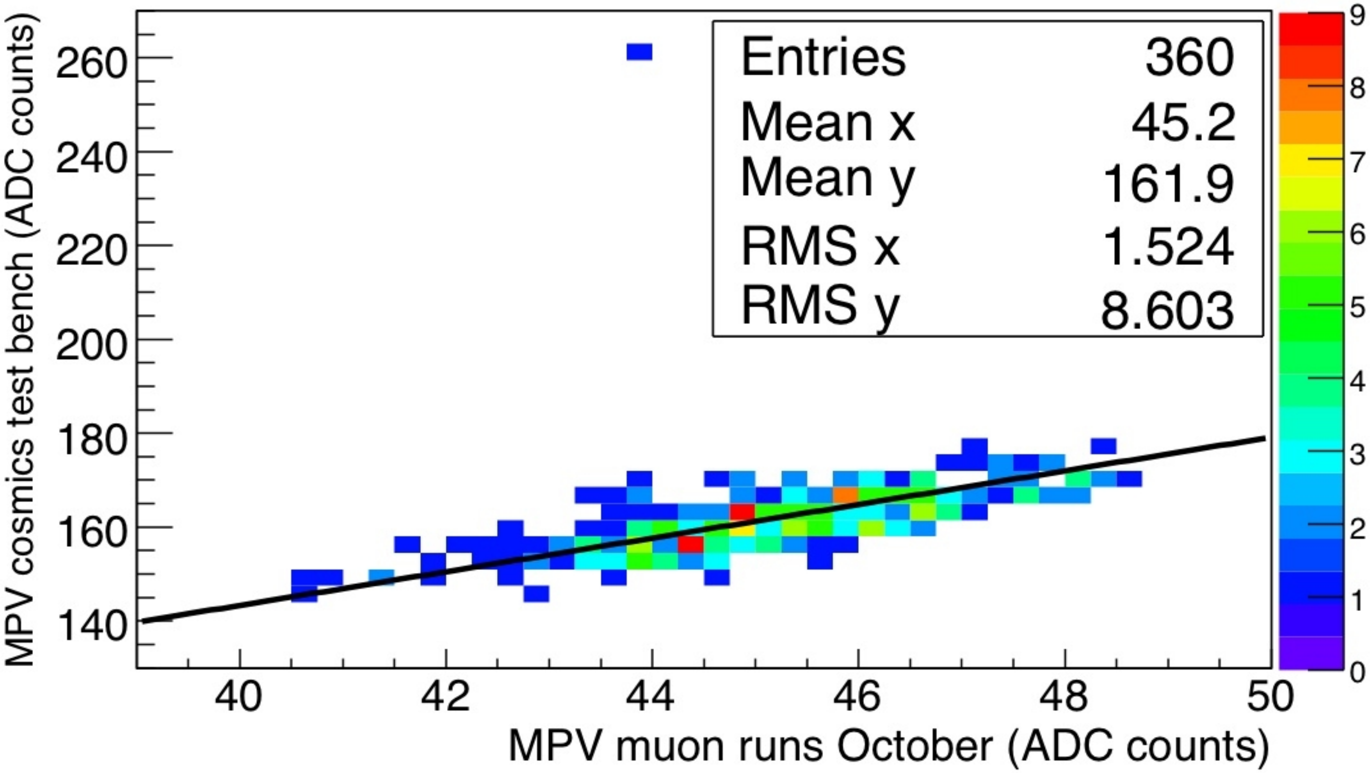
- Manufacturers
- Production series



Experience to deal with different manufacturers and production series
Essential for final detector
~3000m^2 of Silicon needed

Stability

Comparison between calibration constants achieved in situ and on a dedicated testbench

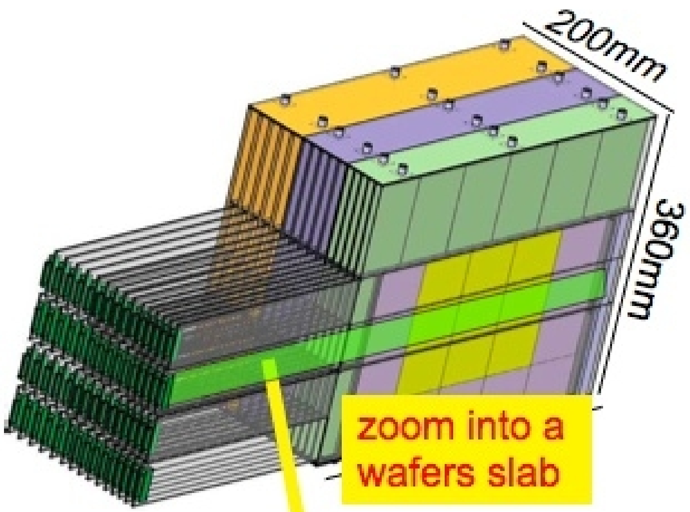


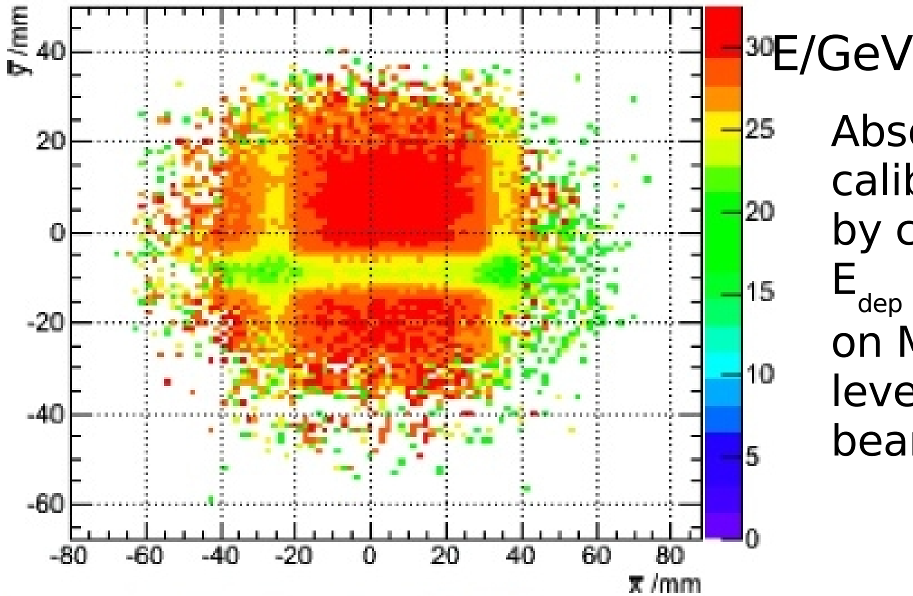
Calibration once achieved can be transported

Important for taking testbeam data at different locations

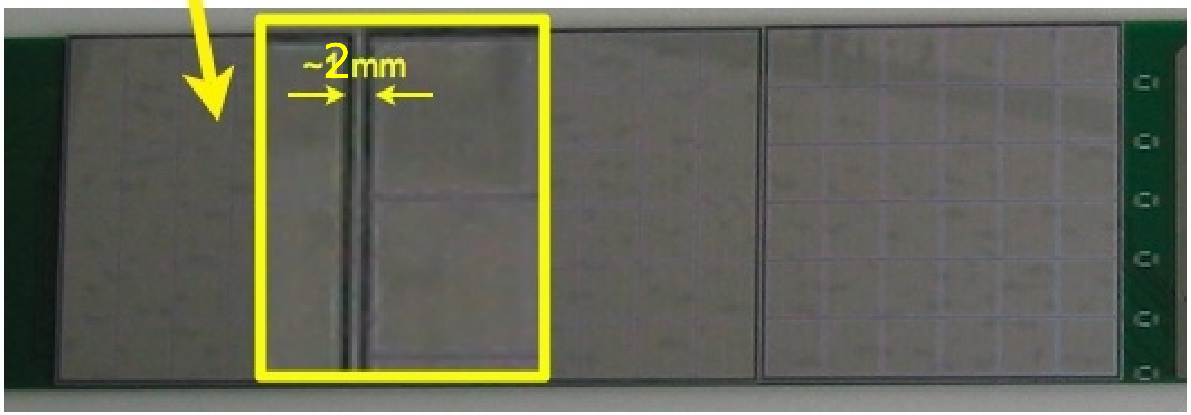
Ecal Correction of Energy Deposition - Acceptance

Dips in energy measurement by inter wafer gaps (needed for isolation)



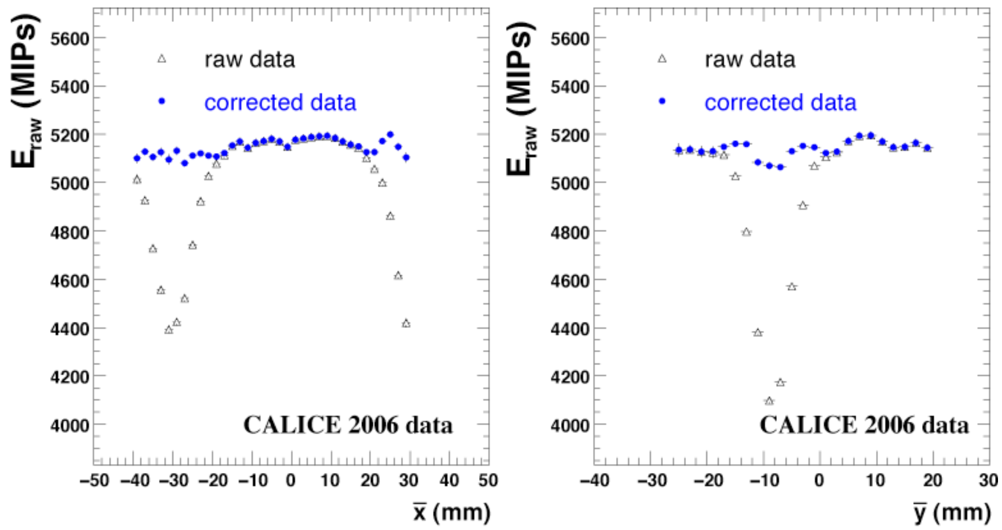


Absolute calibration by comparing E_{dep} on MIP level with beam energy



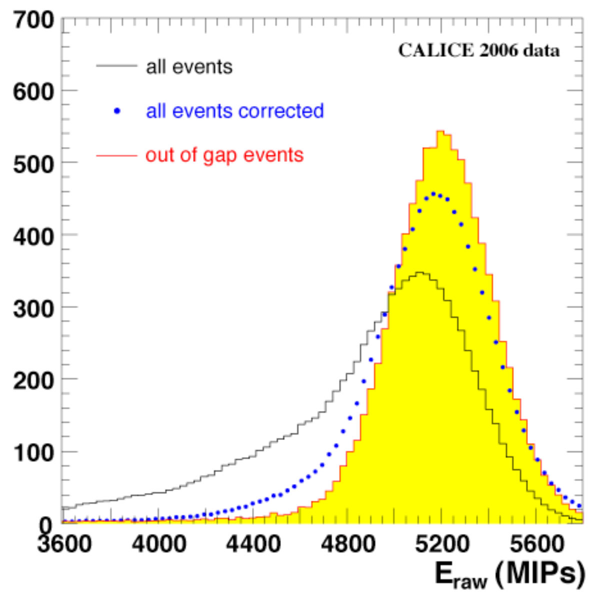
Need to take geometrical acceptance into account in analysis

Correction of Energy Deposition I – Acceptance Correction



Restoring homogeneous response with correction function

$$f(\bar{x},\bar{y}) = \left(1 - a_x e^{\frac{\bar{x}-x_{gap}{}^2}{2\sigma_x^2}}\right)\left(1 - a_y e^{\frac{\bar{y}-y_{gap}{}^2}{2\sigma_y^2}}\right)$$



Energy loss due to acceptance limits not fully recovered

Important issue for future R&D

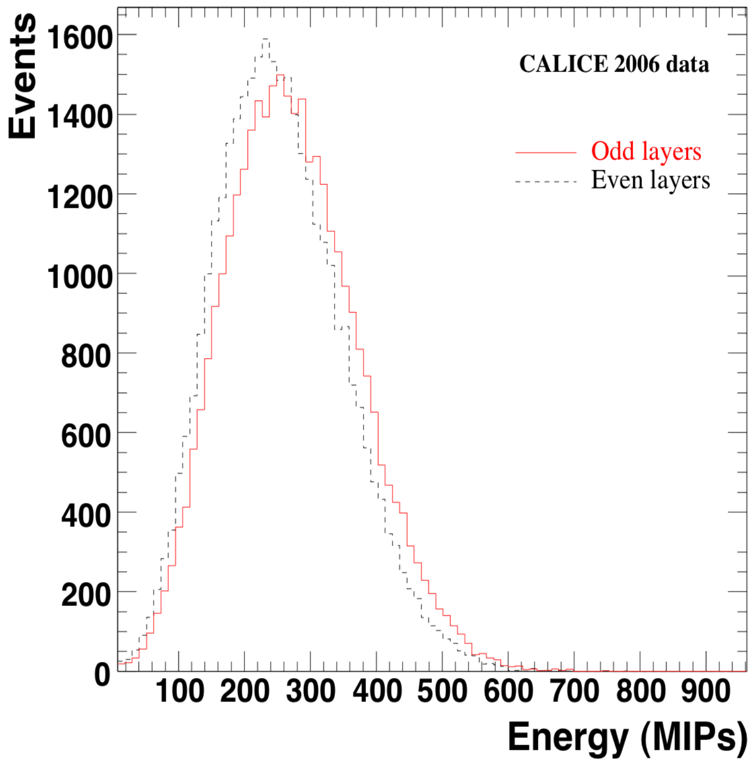
Requires close collaboration between CALICE and SiWafer Suppliers

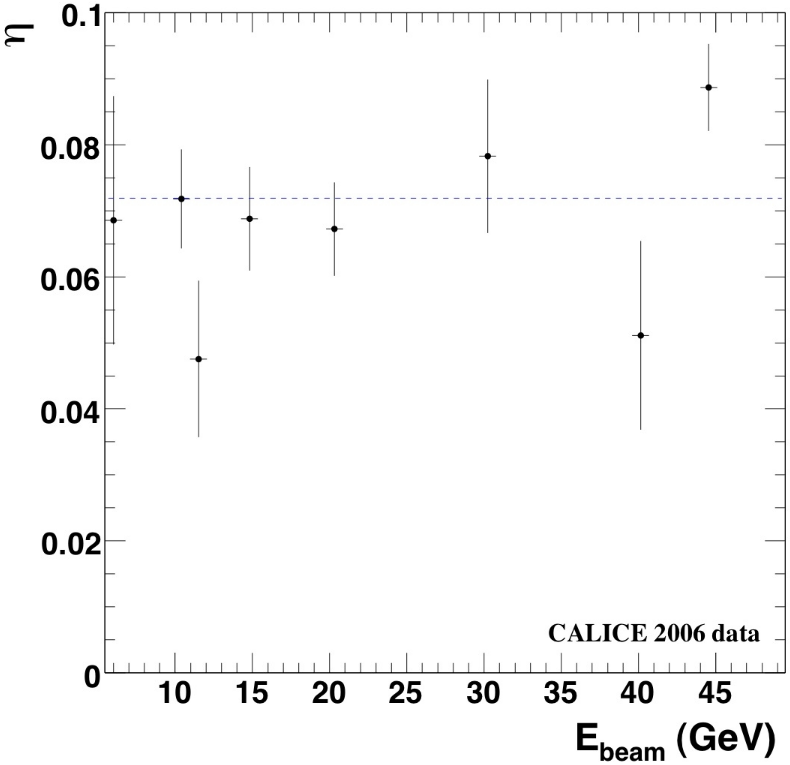
Correction of Energy Deposition II – Sampling Fraction

Sampling Fraction increases with calorimeter depth

Naive Weighting: $E_{\text{rec}} = \sum_i w_i E_i$ with $w_i = 1$ for $i = 0,9$; $w_i = 2$ for $i = 10,19$; $w_i = 3$ for $i = 20,29$

Accounting for varying amount of supplementary material



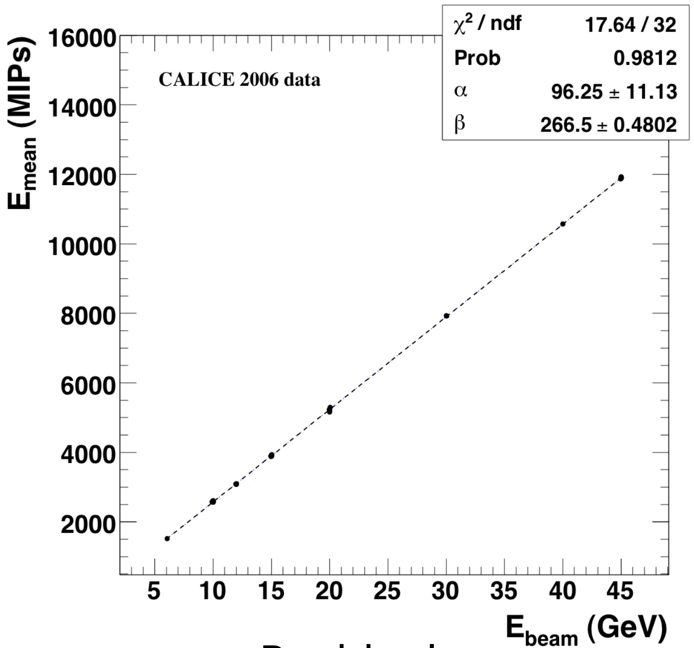


$w_i \rightarrow w_i'$ with $w_i' = w_i + \bar{\eta}$ for odd layers; $w_i' = w_i$ for even layers

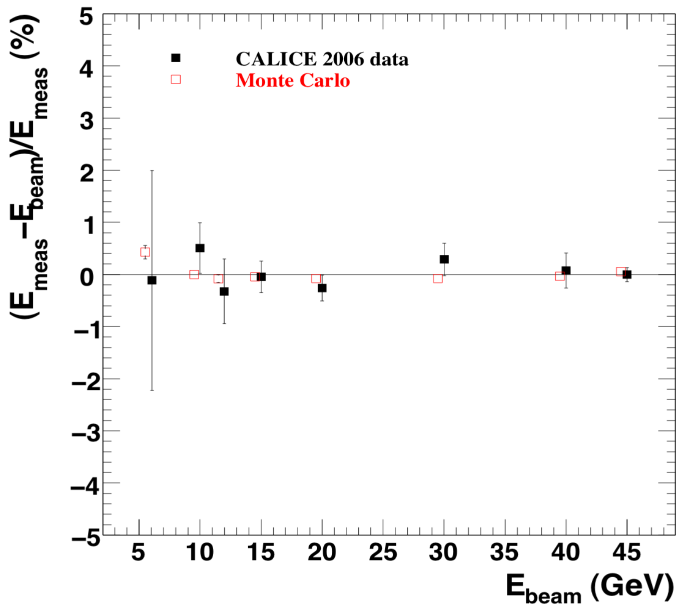
$\bar{\eta} = (7.2 \pm 0.2 \pm 1.7)\%$

Linearity of Response

Overview



Residuals



- Highly linear response over large energy range

- Linearity well reproduced by MC

  MIP/GeV ~ 266.5 [1/GeV]

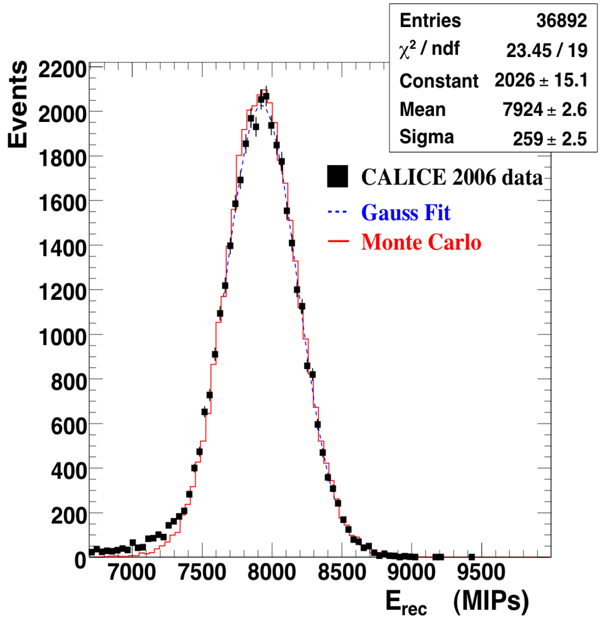
- Offset O(1MIP)

- Linearity O(1%)

- Residuals from low energetic signals in cells

  Might be reflection of guard ring effect

Energy Resolution

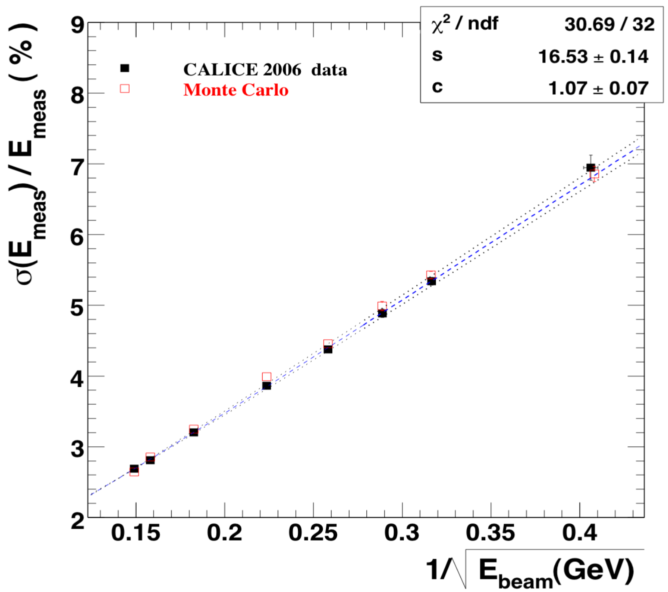


Example 20 GeV e- beam:

Gaussian like Calorimeter Response

Resolution curve shows typical √E dependency

$$\frac{\Delta E_{meas.}}{E_{meas.}} = \left[\frac{16.7 \pm 0.1(stat.) \pm 0.4(syst.)}{\sqrt{E\,[\mathrm{GeV}]}} \oplus (1.1 \pm 0.1(stat.) \pm 0.1(syst.)) \right] \%$$

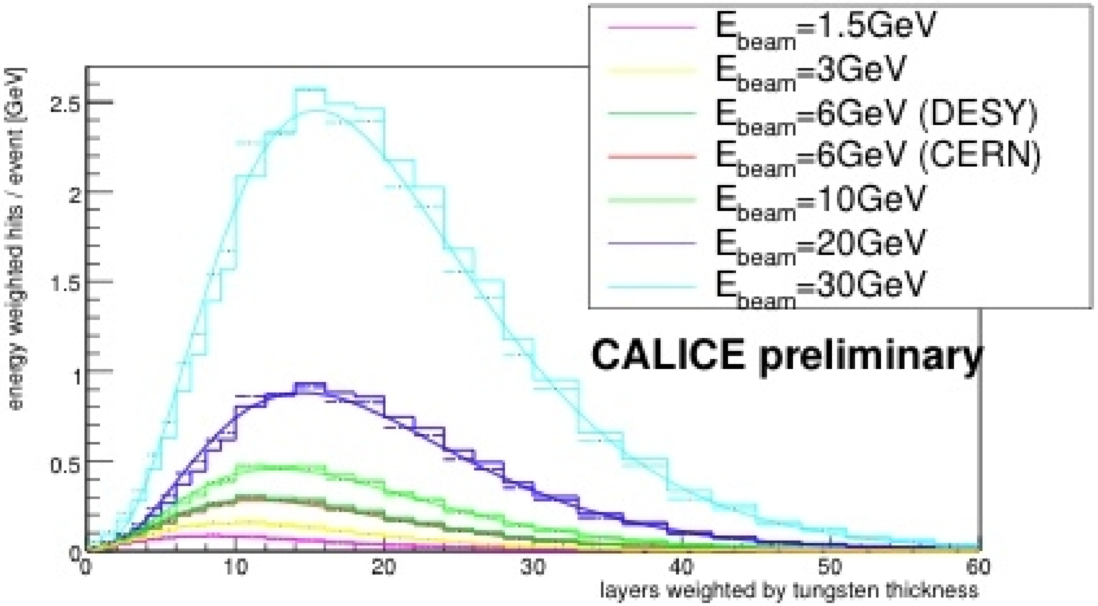


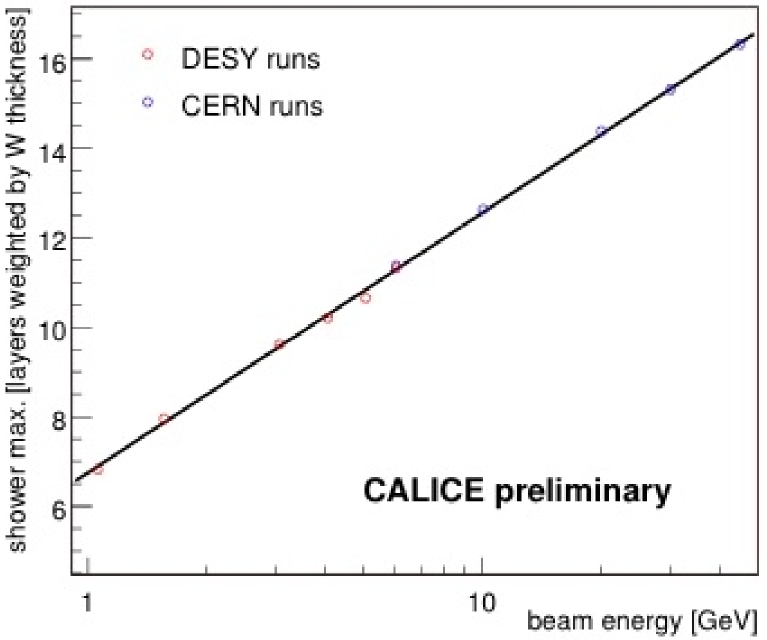
- Resolution well describes by MC
- Actual number not overwhelming for electromagnetic calorimeters but

Design emphasises spatial granularity over energy resolution

Calorimeter for Particle Flow

Longitudinal Shower Development



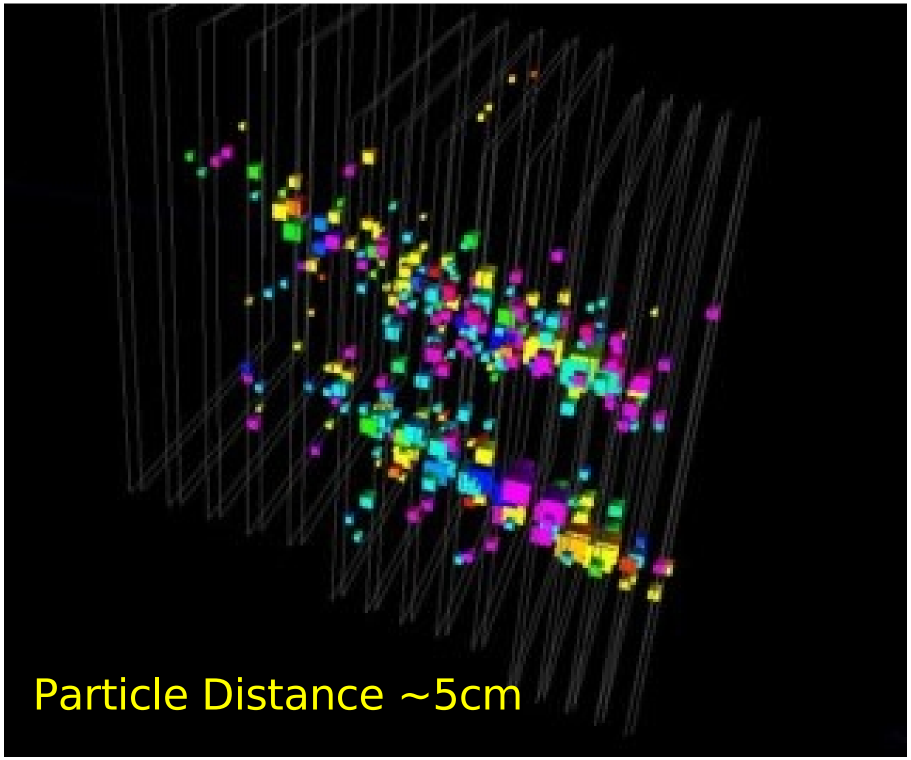


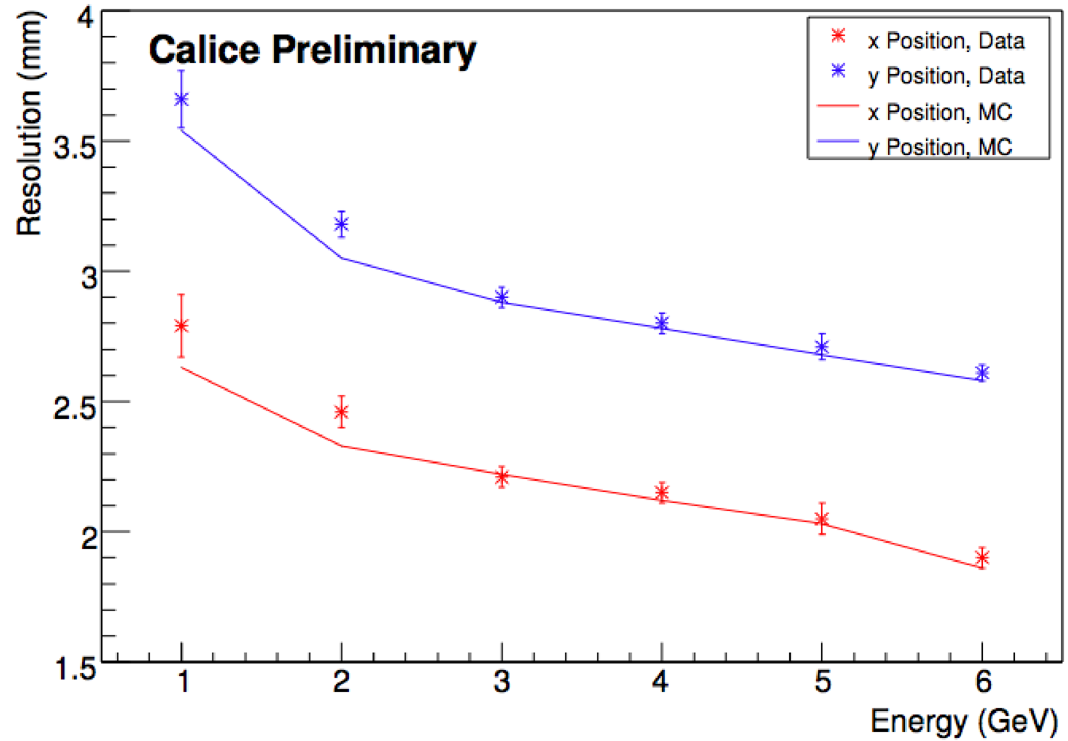
Logarithmical Grow of Shower Maximum as expected by Theory

Position Resolution

Essential for good Particle Separation

Double Particle Event in SiW Ecal





Tracks in Calorimeter by
energy weighted cell positions

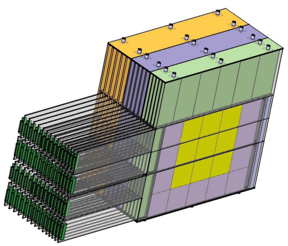
Reference by Tracking Chamber

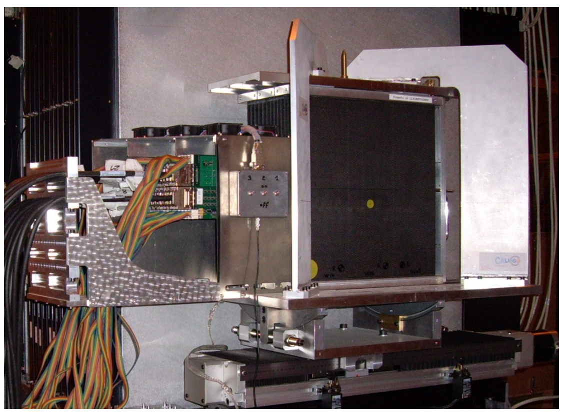
Better than 2mm
towards higher energies

Worse reslution in y due
to overlap of passive areas

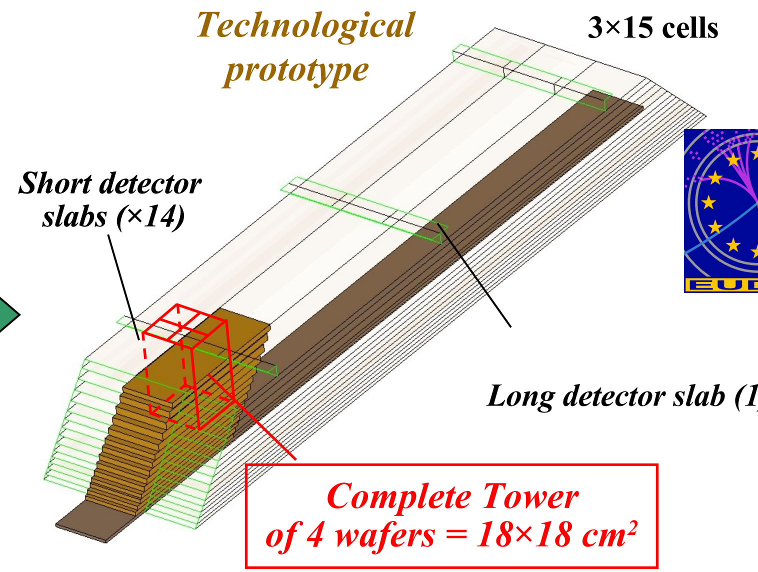
EUDET Prototype

- Logical continuation to the physical prototype study which validated the main concepts : alveolar structure , slabs, gluing of wafers, integration
- Techno. Proto : study and validation of most of technological solutions wich could be used for the final detector (moulding process, cooling system, wide size structures,…)
- Taking into account industrialization aspect of process
- First cost estimation of one module





- **3 structures : 24 X_0 (10×1,4mm + 10×2,8mm + 10×4,2mm)**
- **sizes : 380×380×200 mm3**
- **Thickness of slabs : 8.3 mm (W=1,4mm)**
- **VFE outside detector**
- **Number of channels : 9720 (10×10 mm²)**
- **Weight : ~ 200 Kg**



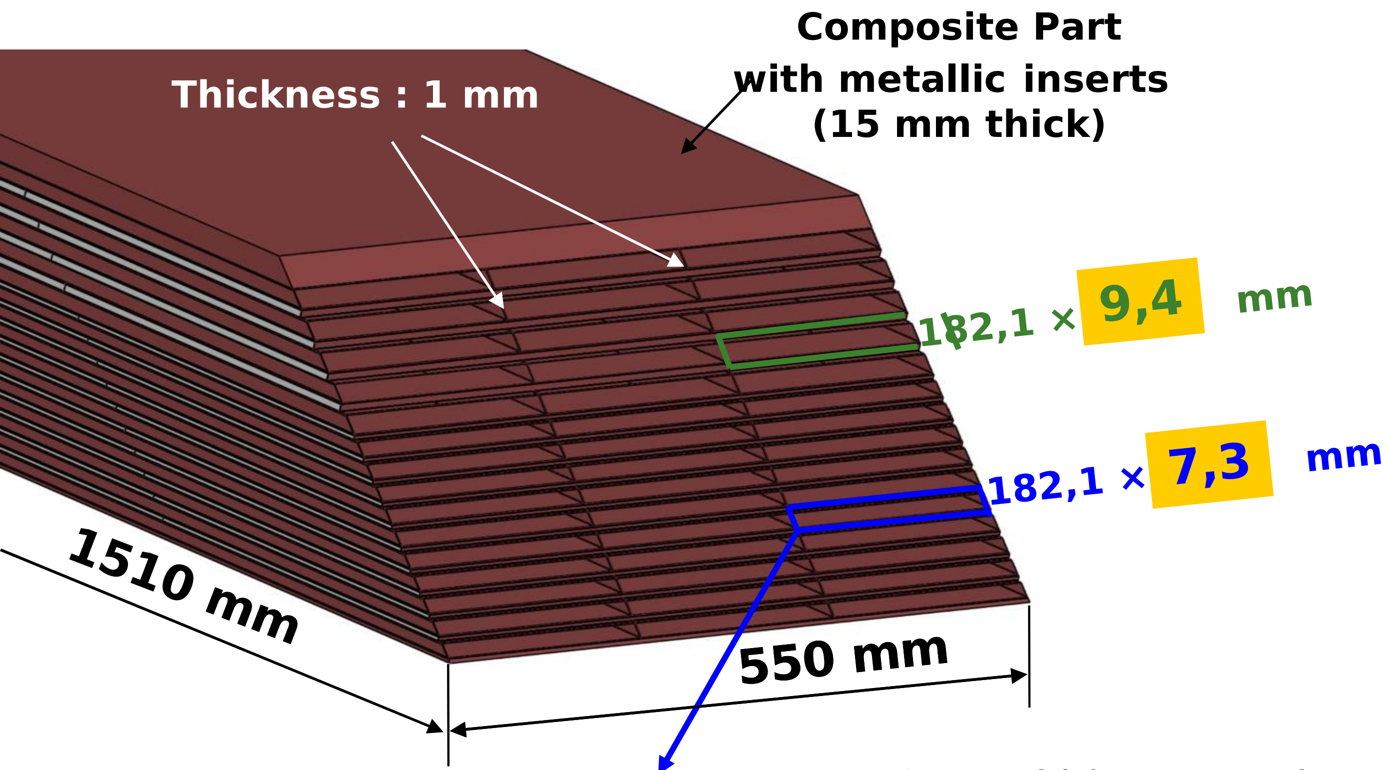
- **1 structure : ~ 23 X_0 (20×2,1mm + 9×4,2mm)**
- **sizes : 1560×545×186 mm3**
- **Thickness of slabs : 6 mm (W=2,1mm)**
- **VFE inside detector**
- **Number of channels : 45360 (5×5 mm²)**
- **Weight : ~ 700 Kg**

The groups working on the EUDET Electromagnetic Calorimeter

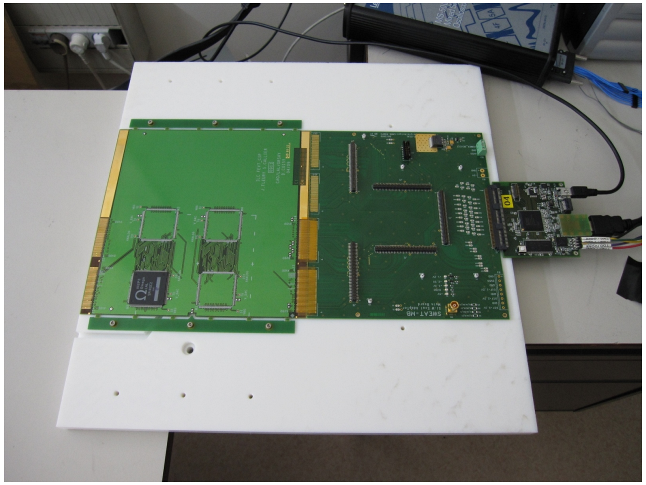
- What we call “EUDET Module” is in fact the <u>next SiW Ecal CALICE Prototype</u>

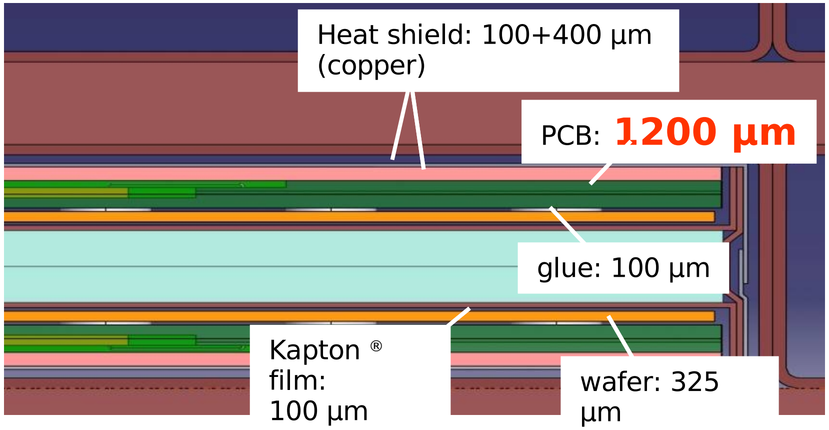
- Financial support by EU

Module EUDET – Current Design (final – developped 2008)



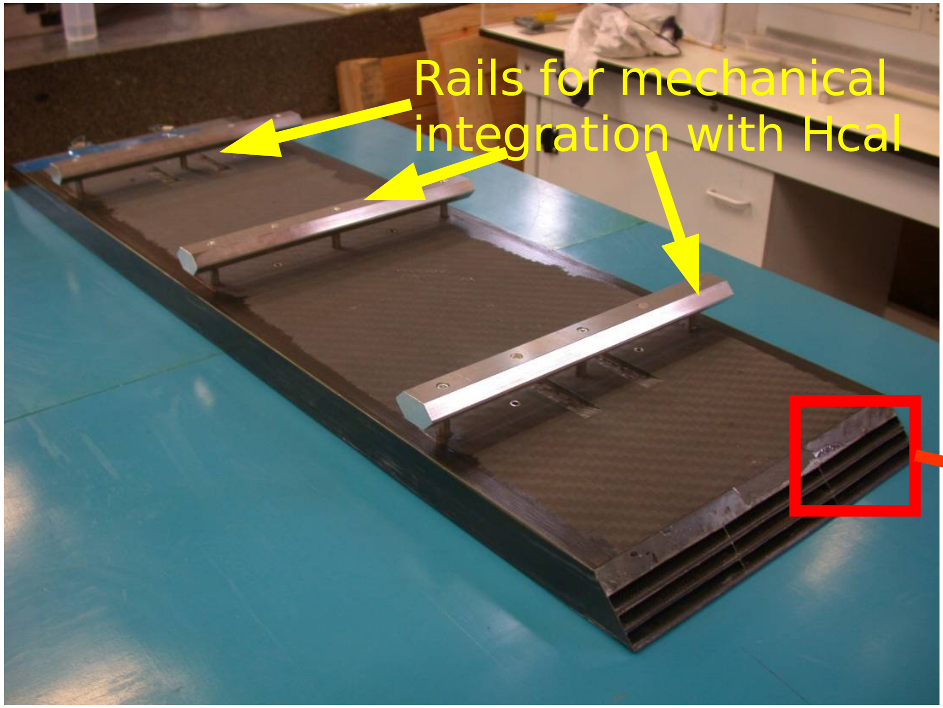
Prototype oF VFE

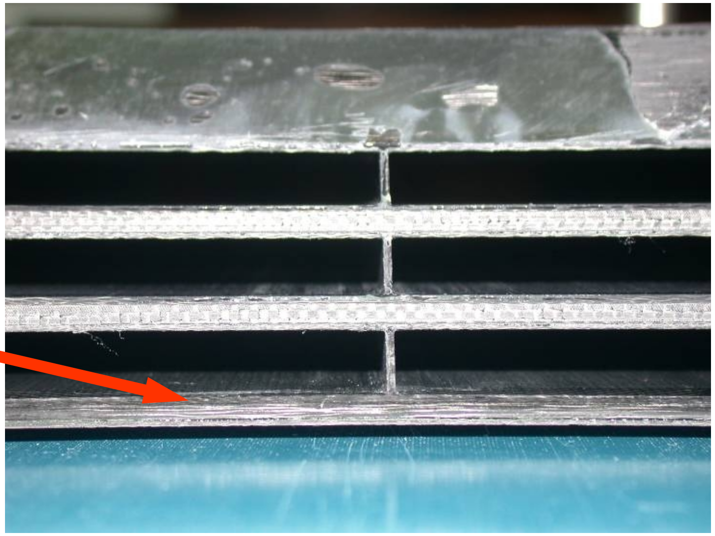


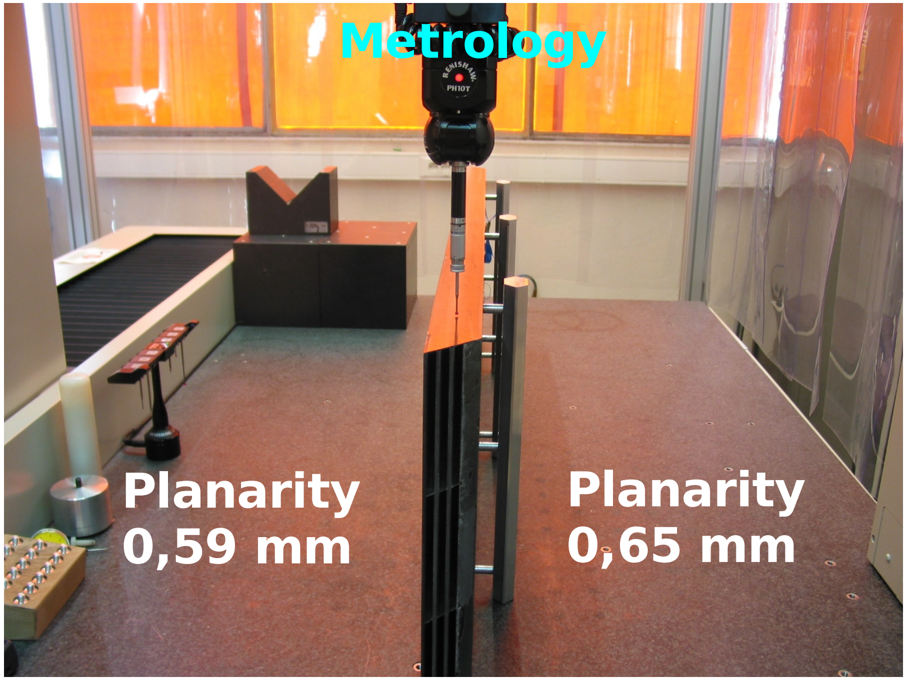


- ⇨ Gaps (slab integration) : 500 µm
- ⇨ Heat Shield: **400 µm ?** Validation with the demonstrateur
- ⇨ PCB : **~1200 µm**
- ⇨ Thickness of Glue : 100 µm
- ⇨ Thickness of SiWafer : 325 µm
- ⇨ Kapton® film HV : **100 µm ?**
- ⇨ Thickness of W : 2100/4200 µm (± 80 µm)

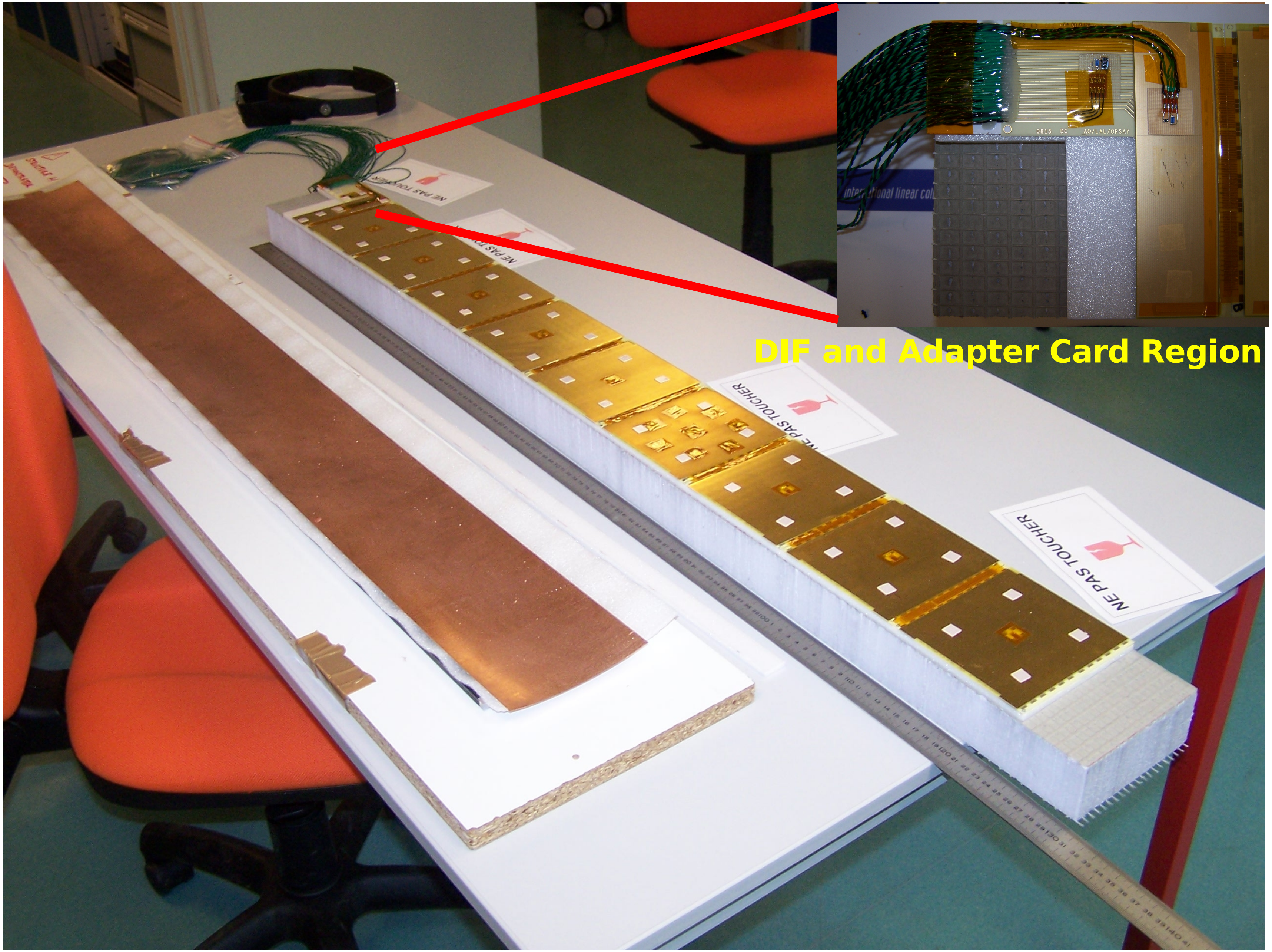
Alveolar Structures with (~) ILC Dimensions







Thermal Layer – Developping the Techniques for Layer Construction



Proof-of-principle to build long layers

Silicon Sensors

We are facing a real show stopper !!!!

The cost issue

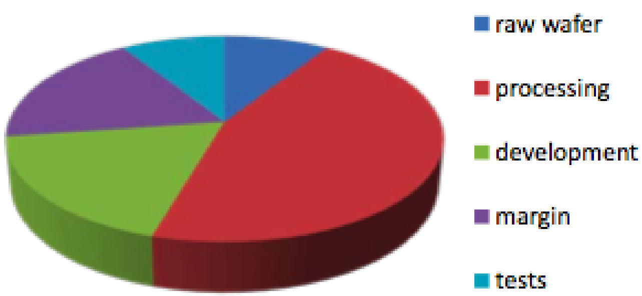
The cost estimate of a financially viable ECAL for ILD assumes this input :

A cost at the level 2 € / cm^2

Now we are at the level of 10 to 20 €/cm^2 Might save a bit if a big amount is ordered

About 2500 m^2 of sensors needed for SiW ECAL of ILD = 300 000 sensors (actual design)

price ?



What could we do / rely on?
Savings due to the change on scale ?
Create a competition between manufacturers ?
  specific production…
  financial weight of our orders
Do things ourselves ?
  manpower, equipment
Optimize financial impact being opportunistic ?
  order when markets are low
  share production among various small batches
Optimize the yield ?
Deal with consumer devices manufacturers ?
  eg. OnSemi

It's time to act!!!!
Top Priority in R&D in coming years!!!

Summary and Outlook

- SiW Tungsten Ecal with up to 9400 cells operated successfully during testbeam campaigns 2006 (and 2007 and 2008)
  Today: Selected Results from 2006 campaign

- Stable operation
  uniform response to MIPs, robust calibration
  only 1.4‰ dead cells

- Energy resolution and Linearity well described by MC
  Linearity O(1%)
  Resolution $(16.5\%/\sqrt{E} \oplus 1)\%$

- Promising results for Shower development and Spatial Resolution

- Technological Prototype (EUDET Module) on its way

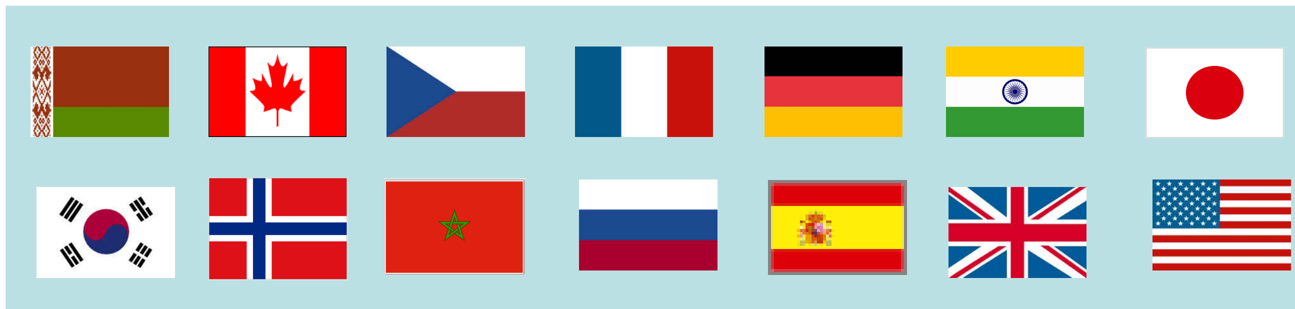
- **The whole SiW Ecal project depends on the price of the SiW Wafers**

Backup ...

The CALICE Collaboration

Calorimeter for ILC

Calorimeter R&D for the ILC



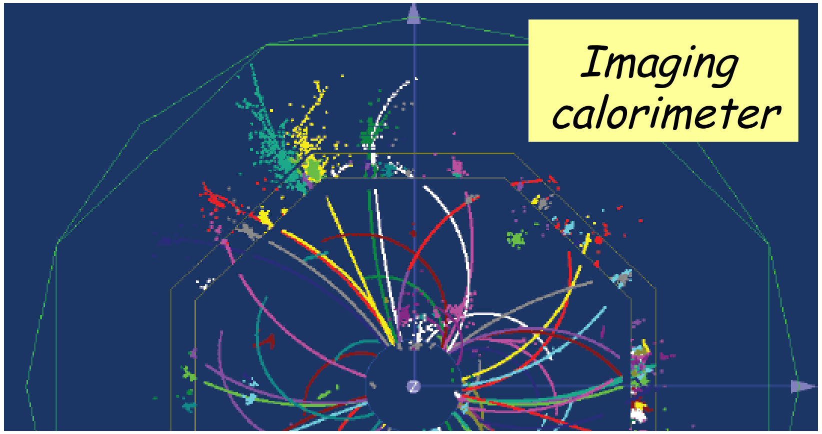
~293 physicists/engineers from 51 Institutes and 13 Countries from 4 Continents

- Integrated R&D effort

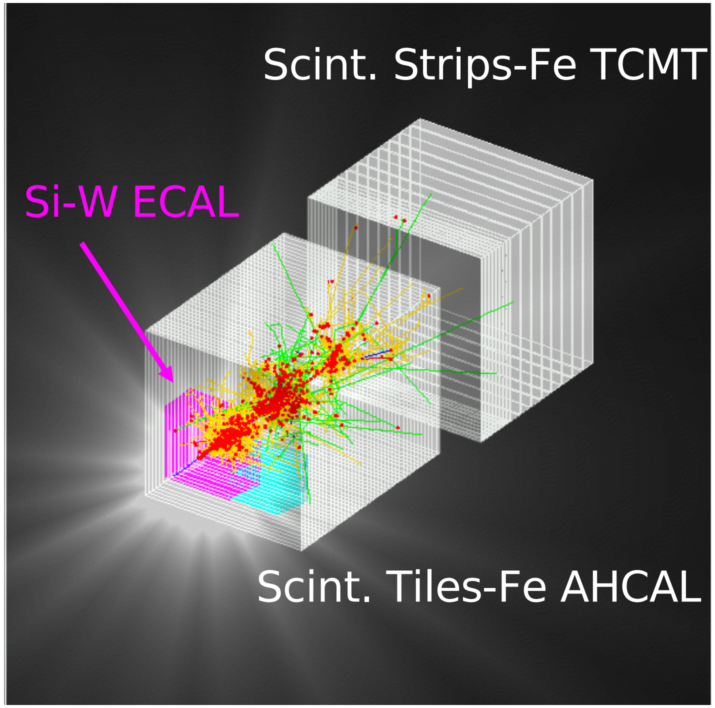
- Benefit/Accelerate Detector Development due to *common* approach

The Calice Mission

Final goal:



A highly granular calorimeter optimised for the Particle Flow measurement of multi-jets final state at the International Linear Collider



Intermediate task:

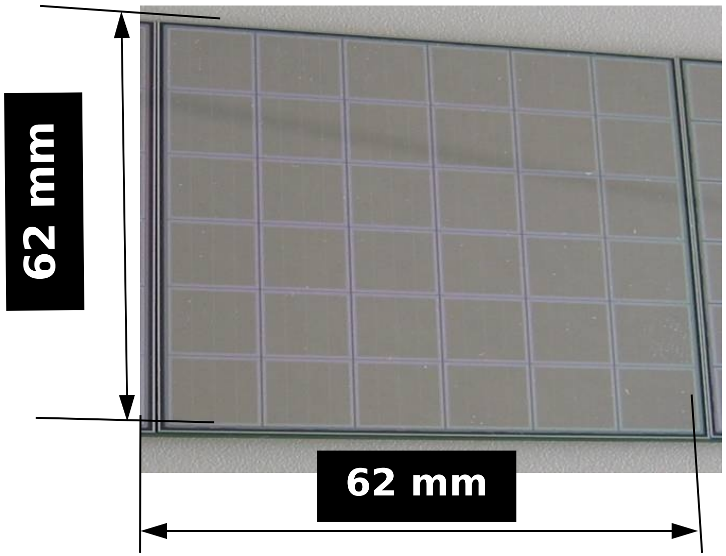
Build prototype calorimeters to
- Establish the technology
- Collect hadronic showers data with unprecedented granularity to
  - tune clustering algorithms
  - validate existing MC models

E. Garutti ECFA Valencia

Silicon sensors : Matrices

- 4” High resistive wafer : **5 KΩcm**
- Thickness : 525 microns ± **3 %**
- Tile side : **62.0** $^{+0.0}_{-0.1}$ mm
- 1 set of guard rings per matrix
- In Silicon ~80 e-h pairs / micron ~ **42000 e^- / MiP**
- Capacitance : ~21 pF (one pixel)
- Leakage current @ 200 V : < 300 nA (Full matrix)
- Full depletion bias : ~150 V
- Nominal operating bias : 200 V
- Break down voltage : **> 300 V**

Si Wafer :
6×6 pads of detection
(10×10 mm²)



Important point : manufacturing must be as simple as possible to be near of what could be the real production for full scale detector in order to :

- Keep lower price (a minimum of step during processing)
- Low rate of rejected processed wafer
- good reliability and large robustness

Wafers passivation Compatible with a thermal cooking at 40° for 12H, while gluing the pads for electrical contact with the glue we use (conductive glue with silver).

Front-end PCB

6 active wafers

- Made of 36 silicon PIN diodes
- 216 channels per board
- Each diode a 1 cm²square

2 calibration switches chips

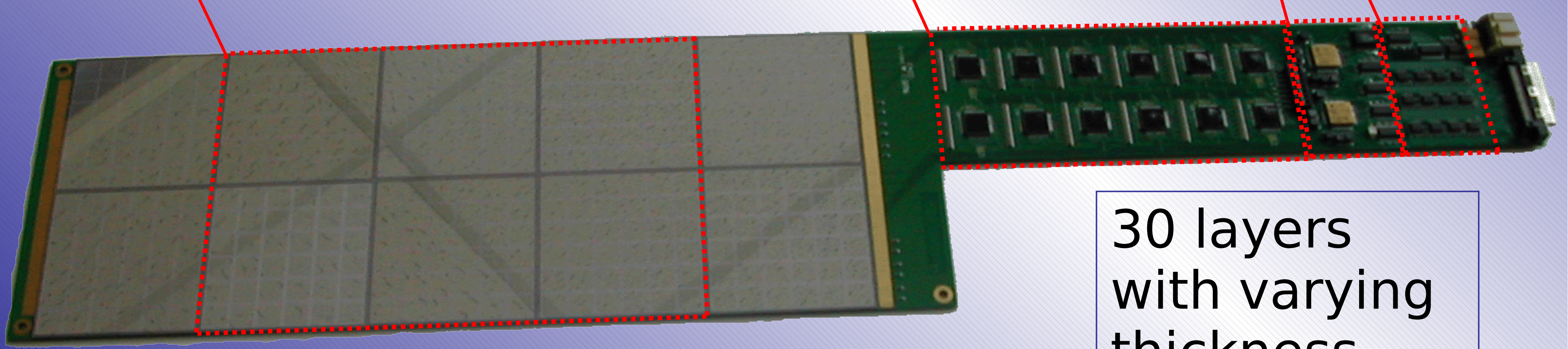
- 6 calibration channels per chip
- 18 diodes per calibration channel

12 FLC_PHY3 front-end chip

- 18 channels per chip
- 13 bit dynamic range

Line buffers

- To DAQ part
- Differential



30 layers with varying thickness

Courtesy of J.C. Vanel LLR