CALICE SiW Electromagnetic Calorimeter

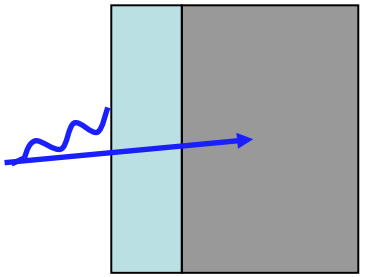
Testbeam performance and results

Roman Pöschl
LAL Orsay

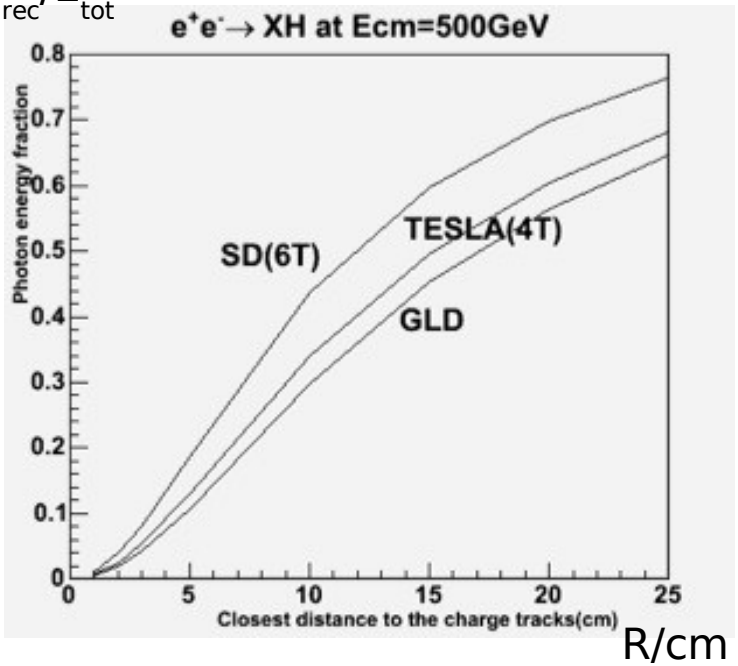
- An Ecal for an ILC Detector
- The Calice Collaboration
- SiW Ecal Prototype
- Testbeam Results
- Future Developments
- Summary and Conclusion

Ecal - Main Task

Photon measurement and photon/hadron separation



E_{rec}/E_{tot}



A. Miyamoto, LCWS05

"Known" basic tools: Large R and B
If small R: Force created by Large B-Field might compromise detector stability
Limit: $BR^2 < 60\ Tm^2$

Separation gets difficult if hadron and photon are within R_M

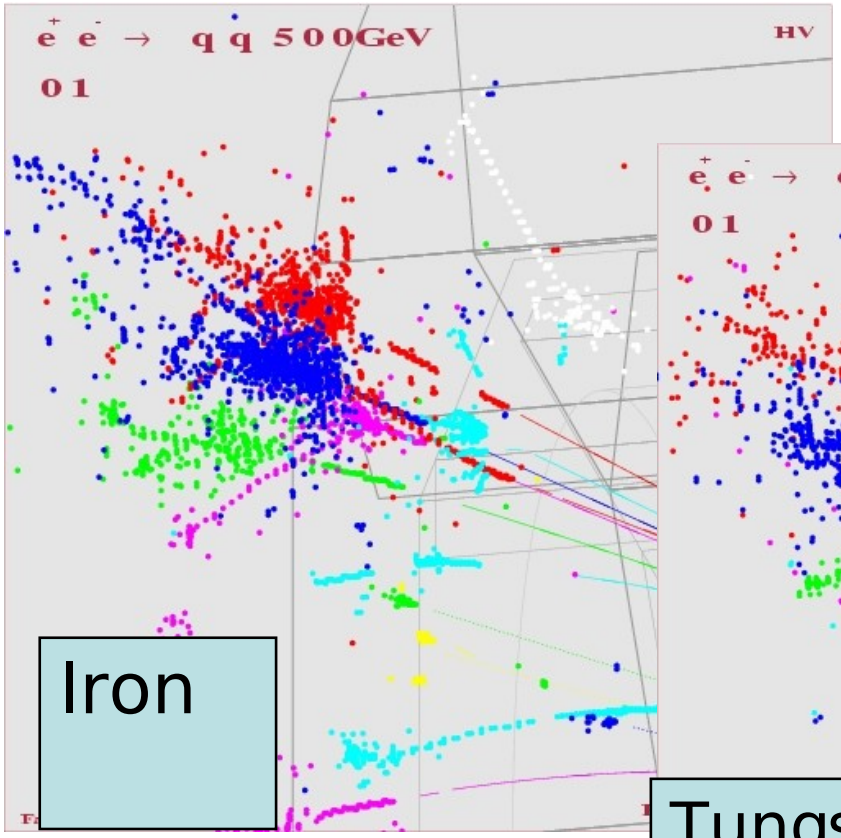
Photon Energy gets assigned to close-by Hadron and vice versa

"Calorimetric" tools to improve photon-hadron separation?

Choice of Absorber Material - Tungsten vs. Iron

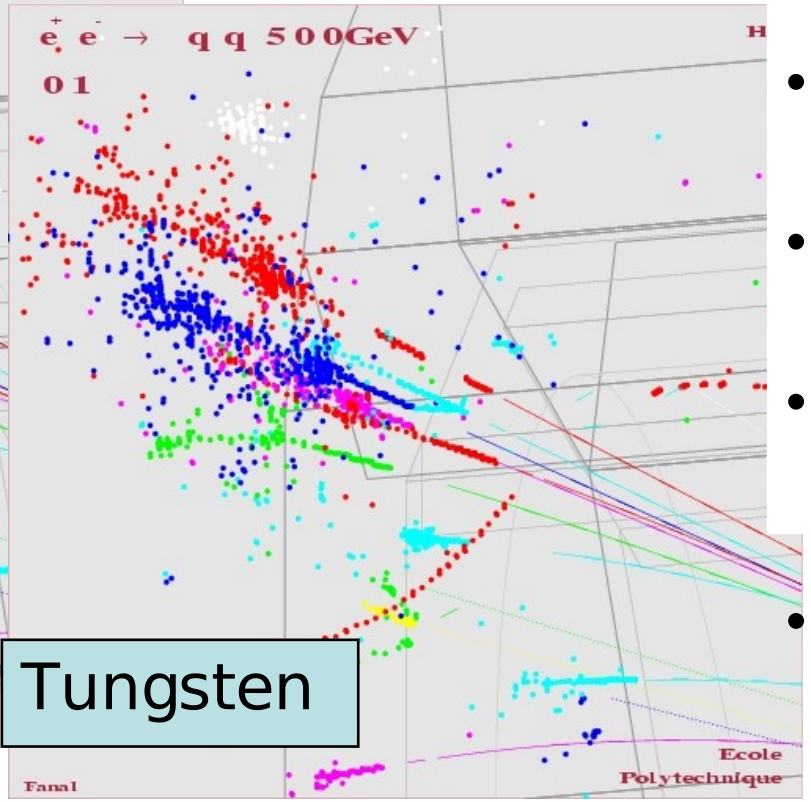
- elm./had separation:
  keep X_0 / λ_I small

X_0 = 1.8cm, λ_I=17cm



Iron

X_0 = 0.35cm, λ_I=9.6cm



Tungsten

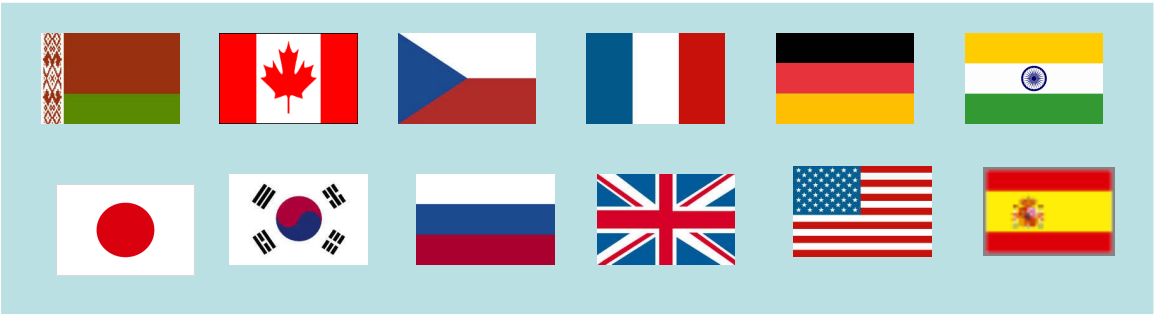
(images courtesy H.Videau)

- Molière Radius for W: R_M = 0.9cm
- Cell Size need to match R_M !
- effectively a factor (1 + Gap /2.5mm) more
- technology challenge: thin readout gap

The CALICE Collaboration

Calorimeter for ILC

Calorimeter R&D for the ILC



~230 physicists/engineers
from 12 Countries 3 Regions

- Integrated R&D effort

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

Projects within Calice

First generation prototypes

- W-Si **ECAL** almost complete, in use in testbeam
  (European Project)
- W-Scintillator strip **ECAL** in construction,
  test beam@DESY , **Spring 2007**
  (Asian Project)
- Tile **HCAL** with SiPM (MEPHI/Pulsar) r/o largely ready
  and in use in testbeam

- Digital **HCAL** in plan
  (Advanced) Effort in North America
  Recent start up of European Project
- **Tail Catcher** and **Muon Tracker TCMT** (North America)

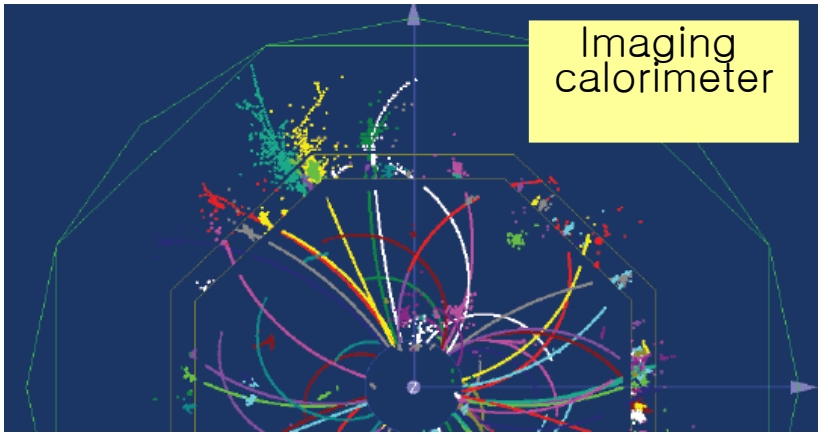
Projects benefit from

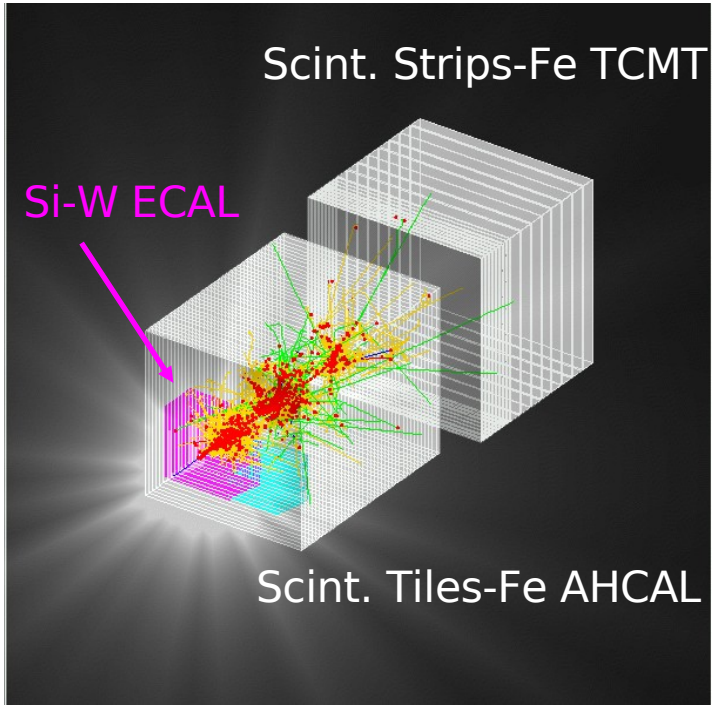
Common DAQ
Common Software
Common infrastructure, e.g. DESY testbeam
Common testbeam planning

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



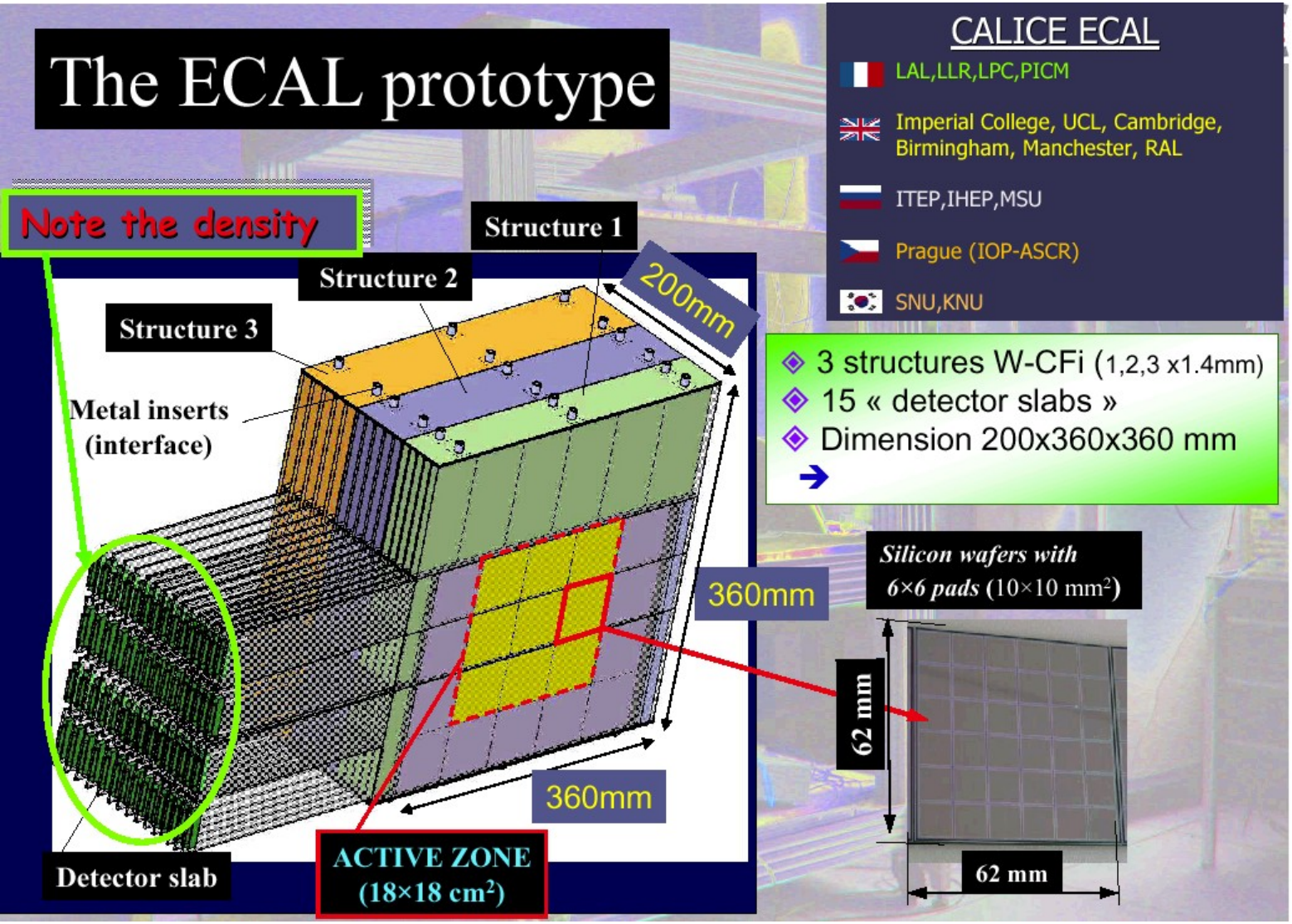


Intermediate task:

Build prototype calorimeters to
- Establish the technology
- Collect hadronic showers data

with unprecedented granularity to
- tune clustering algorithms
- validate existing MC models

Ecal Prototype - CALICE Collaboration

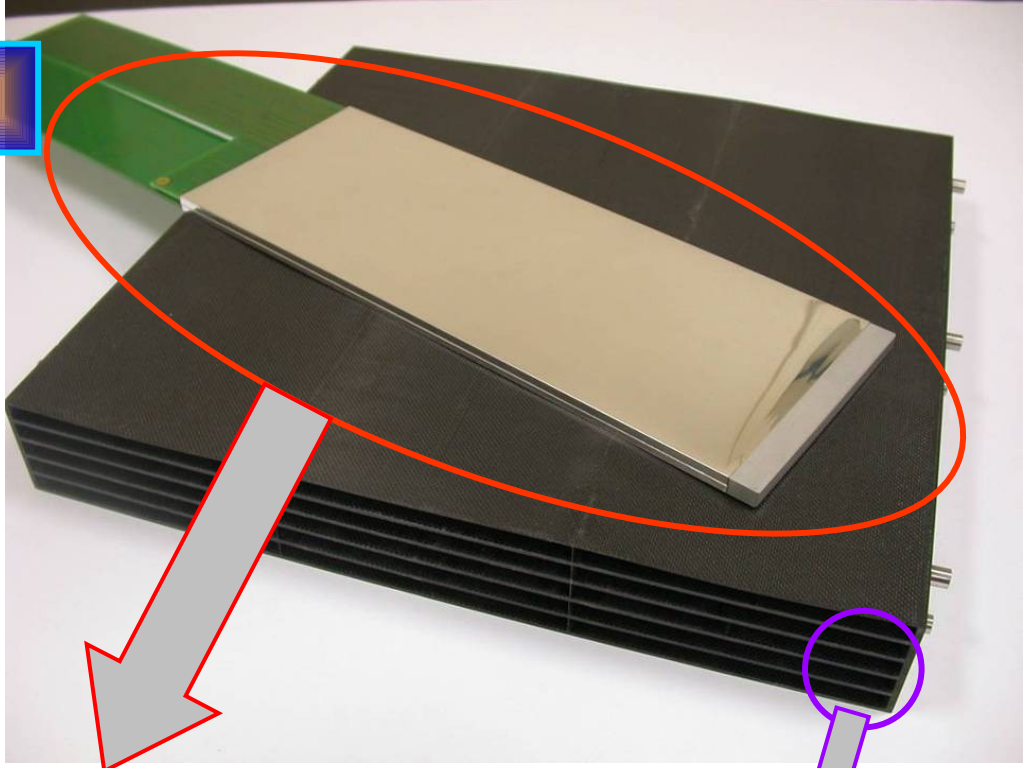


- W as absorber material
- Signal extraction by “Silicon Wafers”
- Extreme high granularity 1x1 cm^2 cell size
- Detector is optimized for particle separation

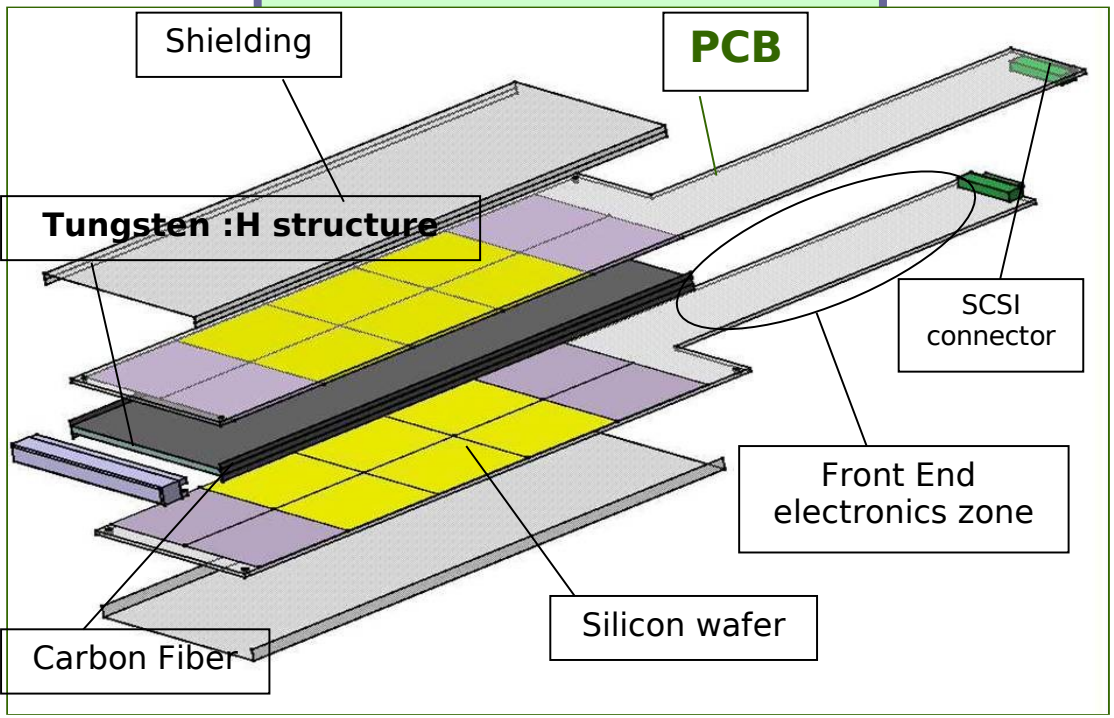
Alveolar structure & Slab

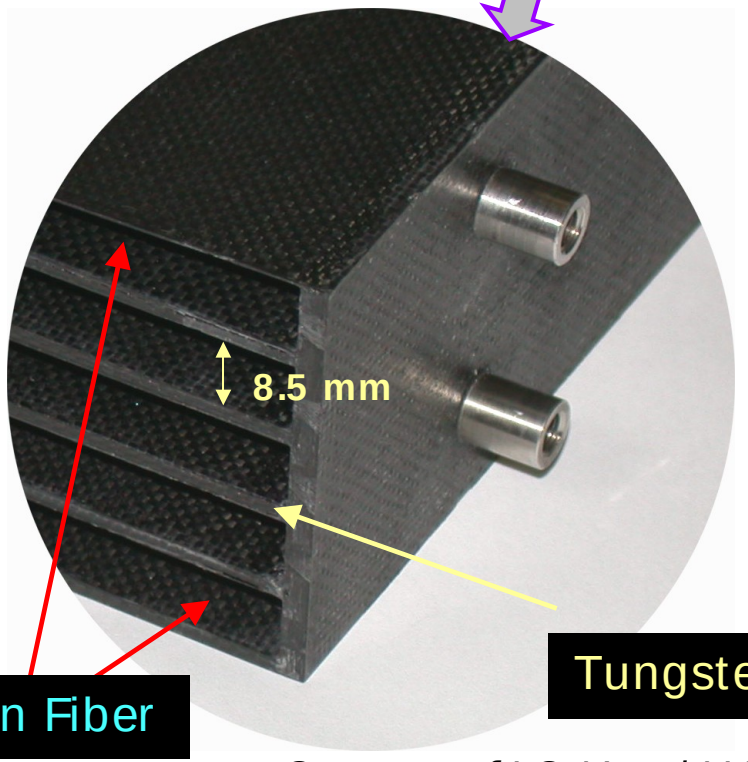
- Design and fabrication of alveolar structures
  with associated moulds
  - Alveolar structures : 3 / 3

- Design and fabrication of 30 type H structures with associated moulds
  - H with W = 1.4 mm : 10 / 10
  - H with W = 2.8 mm : 10 / 10
  - H with W = 4.2 mm : 10 / 10



Detector slab





Courtesy of J.C. Vanel LLR

Front-end PCB

6 active wafers

Made of 36 silicon PIN diodes

216 channels per board

Each diode a 1 cm^2 square

2 calibration switches chips

6 calibration channels per chip

18 diodes per calibration channel

12 FLC_PHY3 front-end chip

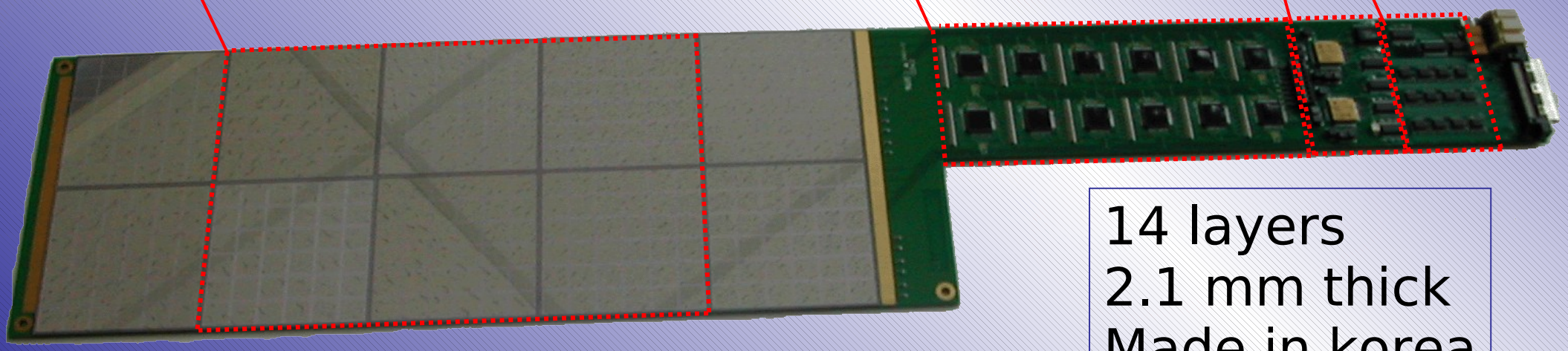
18 channels per chip

13 bit dynamic range

Line buffers

To DAQ part

Differential



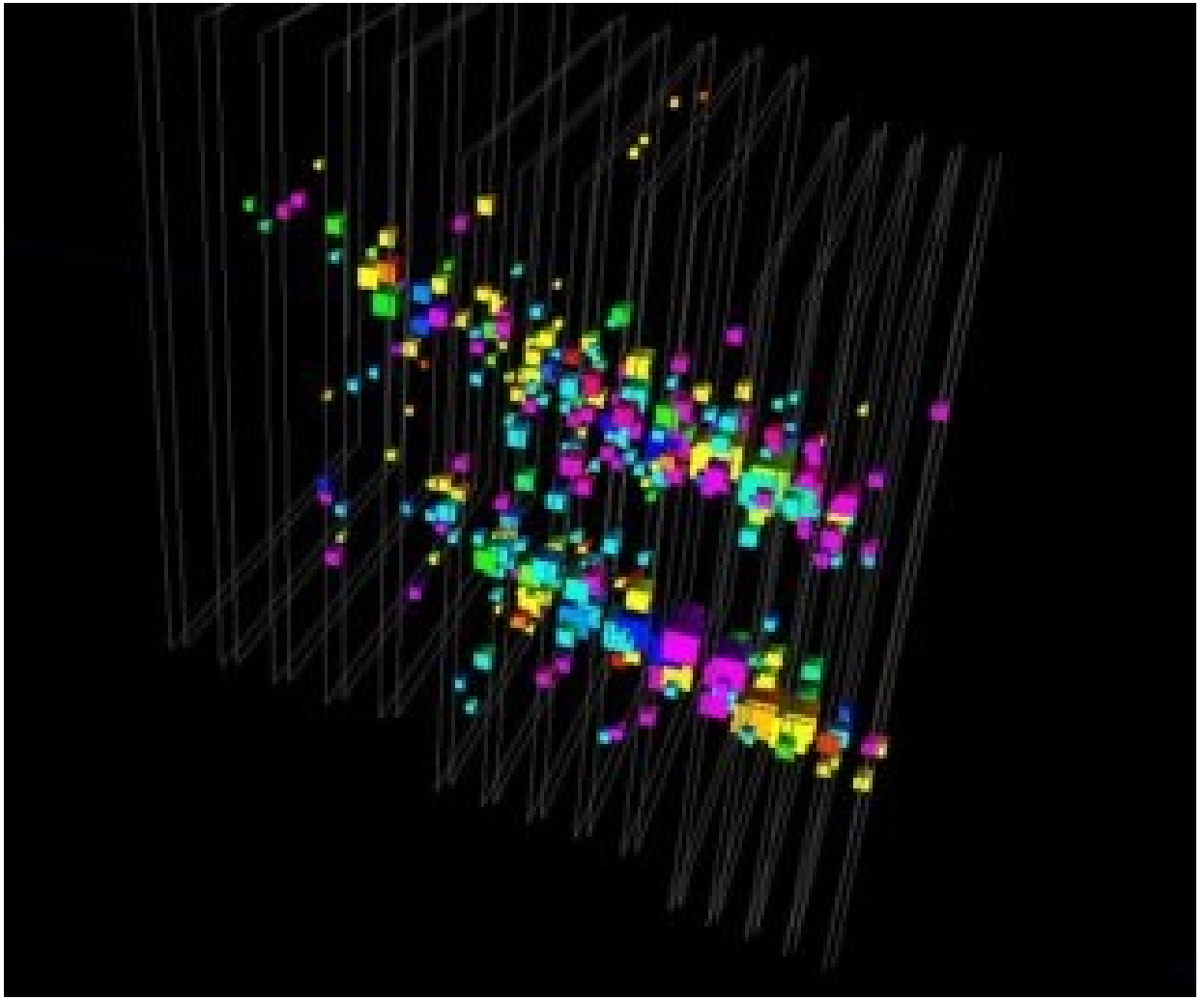
14 layers

2.1 mm thick

Made in korea

Courtesy of J.C. Vanel LLR

Ecal in Testbeam @ CERN

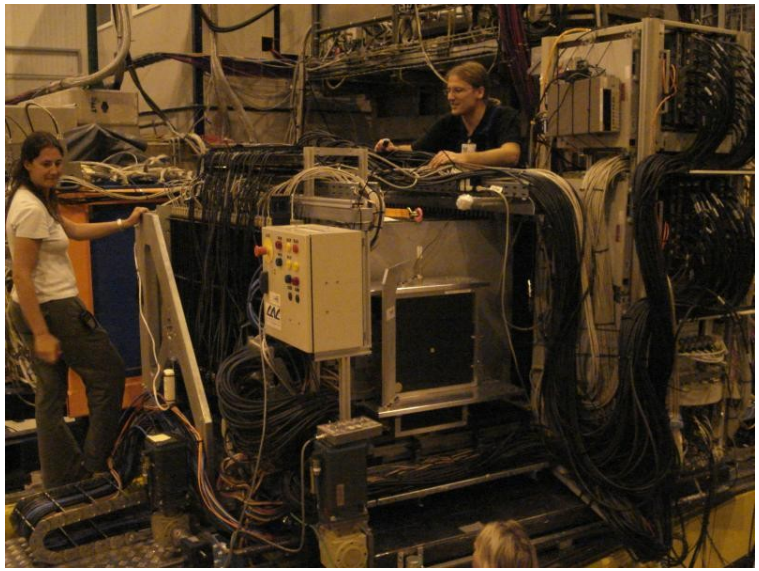


... and indeed it can separate particles !!!

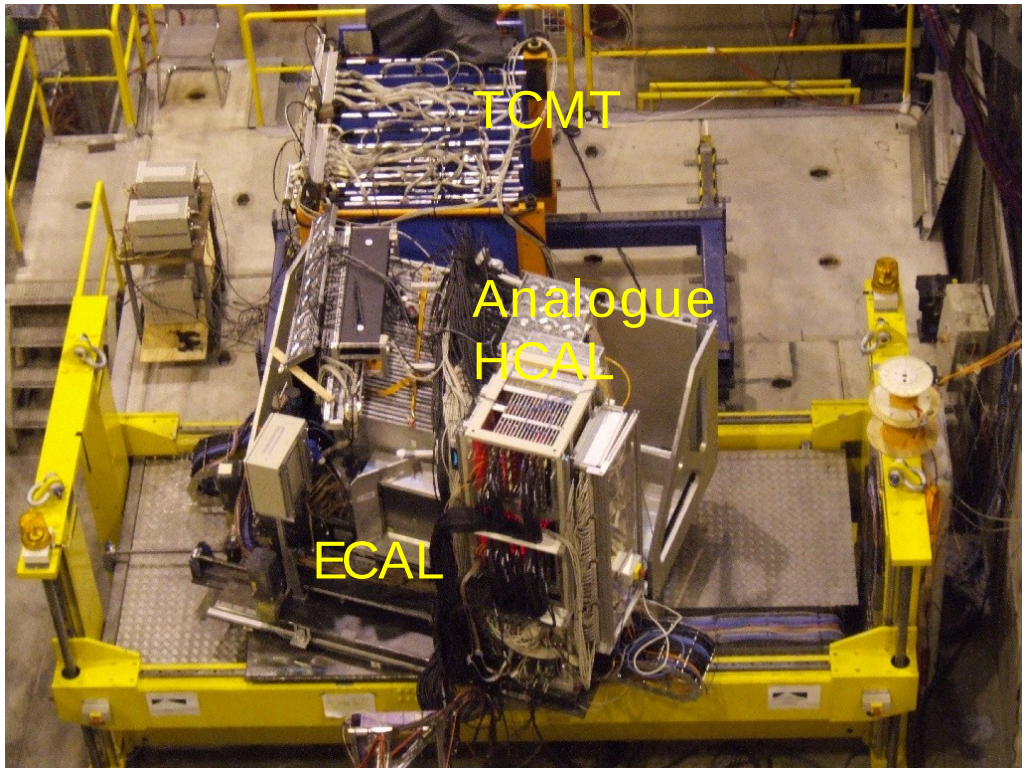
Particle distance ~5cm – No confusion!!!!

CALICE Testbeam Data Taking

CALICE collaboration is preparing/performing large scale testbeam
Data taking in Summer 2006/2007



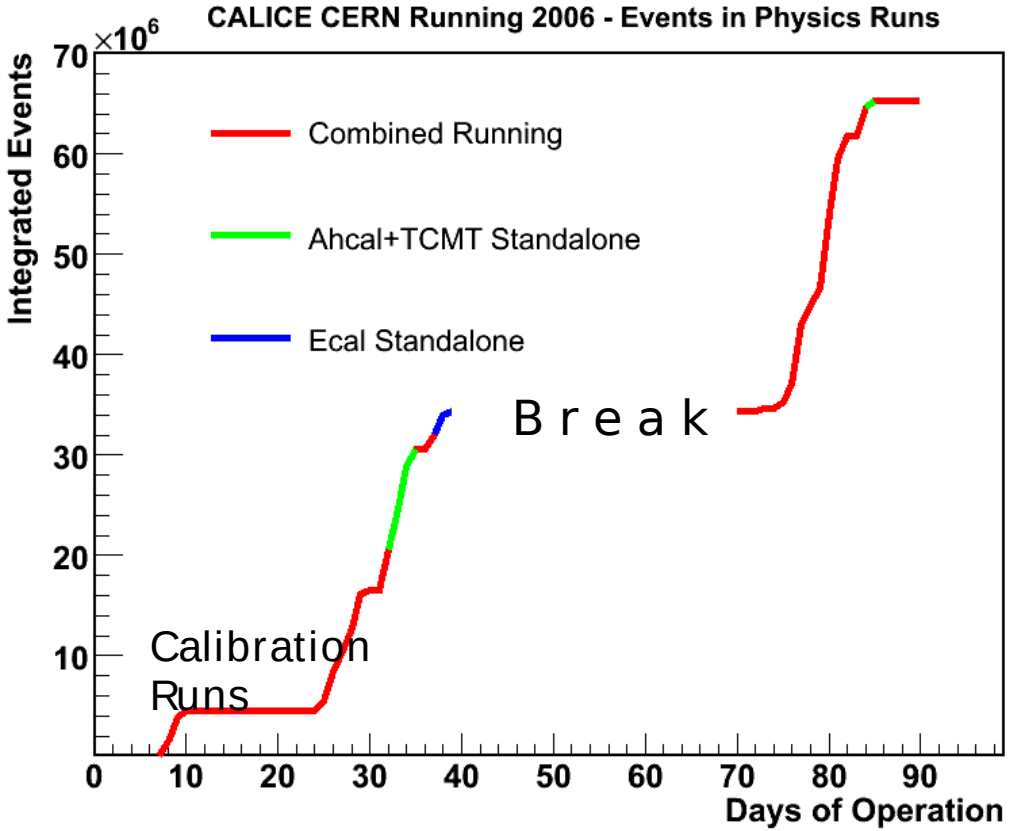
Testbeam Setup at CERN 2007

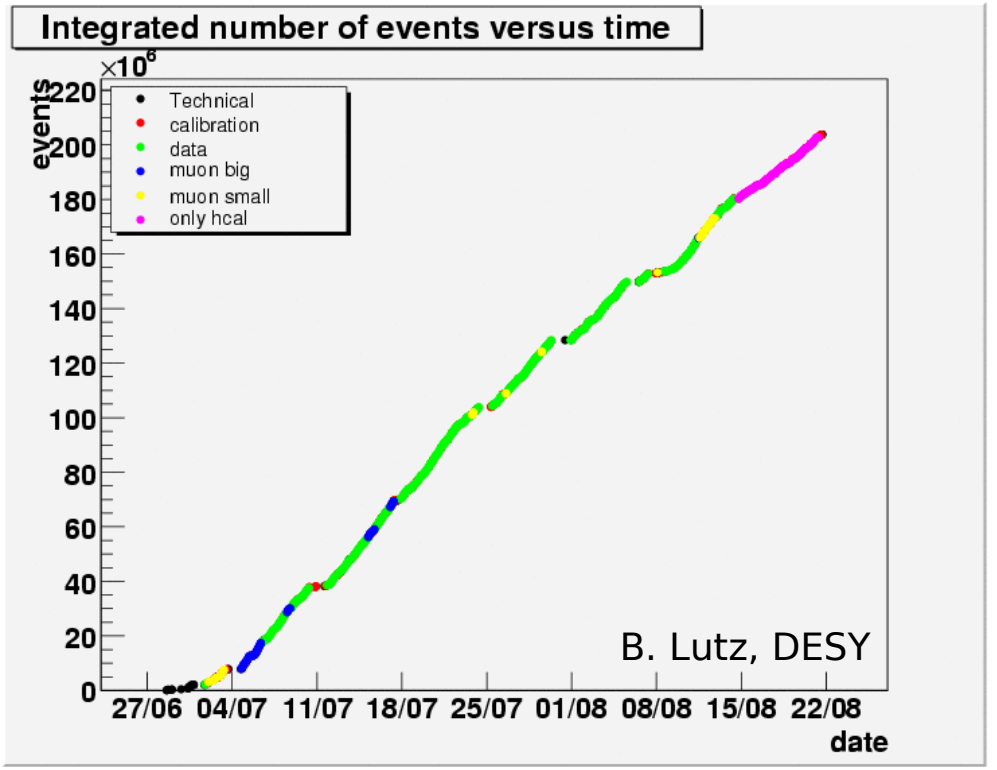


Slabs slit into alveolas

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

CALICE - CERN Data taking 2006/2007





~200 Millions Events in 'Physics' Runs

+

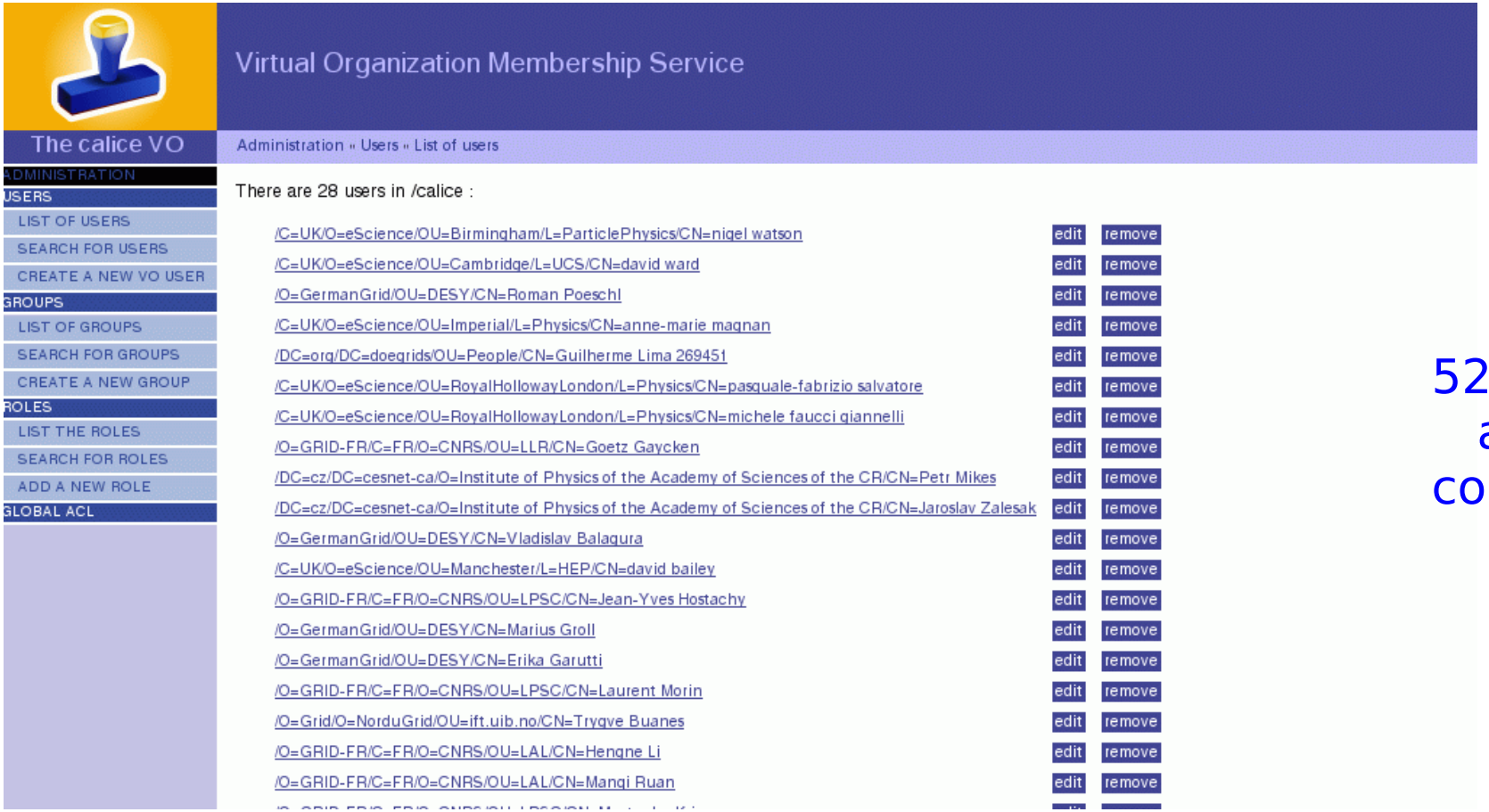
O(50 Mio). Muon Calibration Events)

~90%of the statistics collected with SiW Ecal included

ALCPG 07 Fermilab Oct. 2007

The Virtual Organisation - vo calice

Hosted by DESY:
Page for registration is https://grid-voms.desy.de:8443/voms/calice



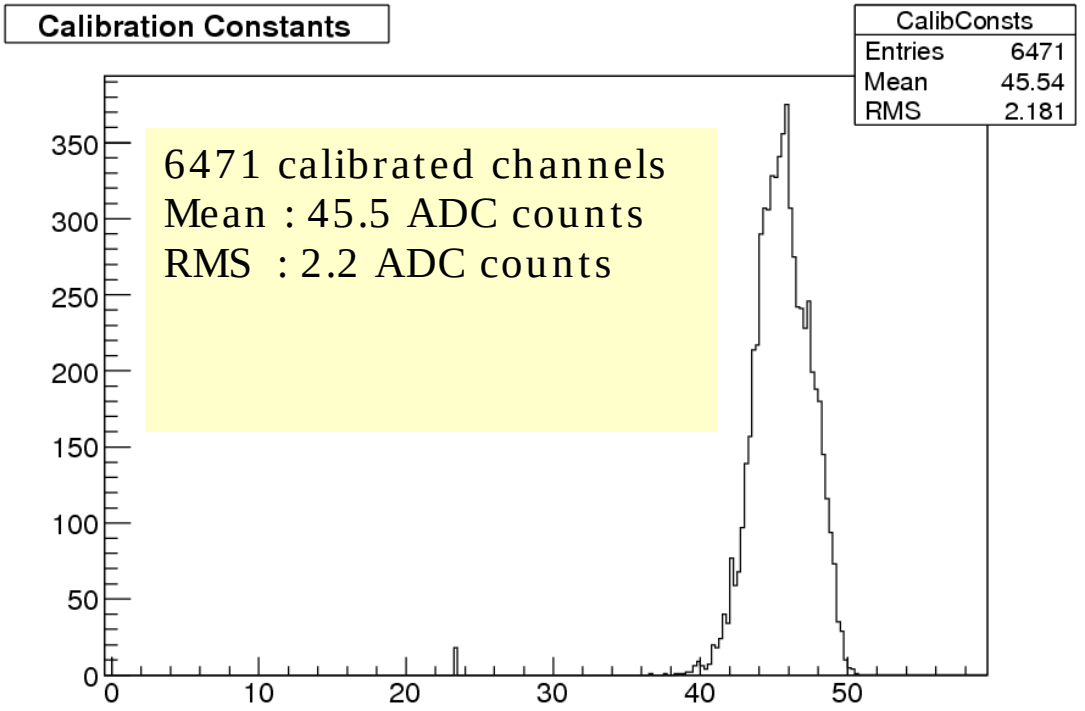
52 Members and counting ..

VO Manager: R.P./ LAL, Deputy: A. Gellrich/ DESY

Data management and processing by using the grid

ECAL (relative) calibration 2006

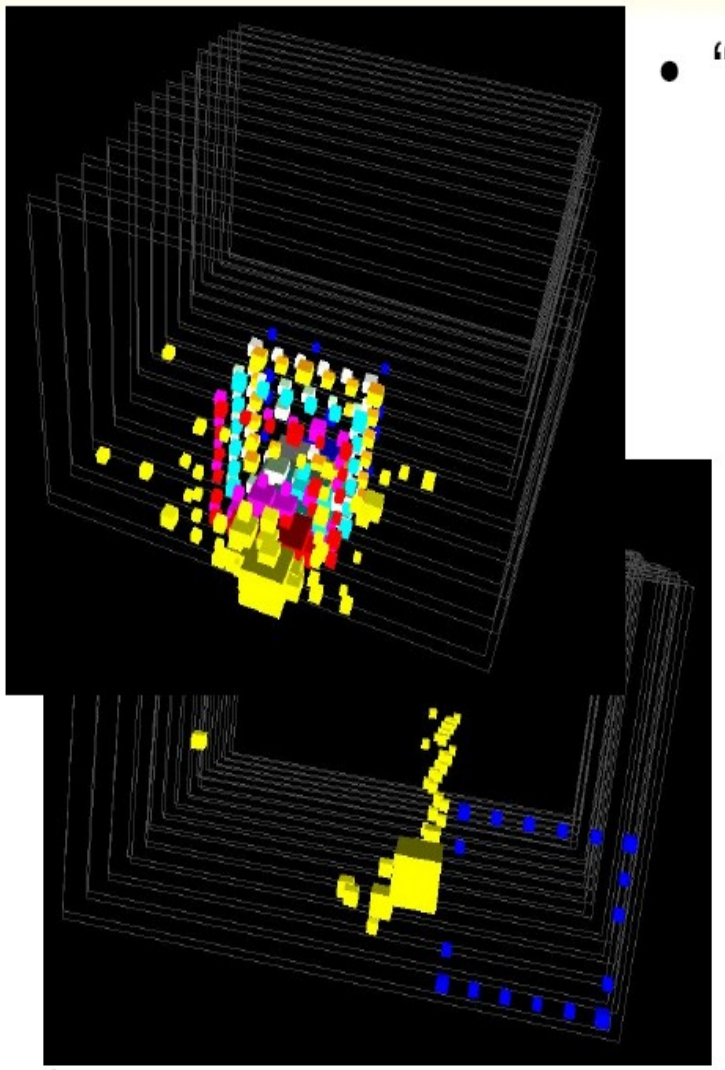
- Statistics ~18M events
- Taken with another experiment upstream ➔ wide spread muon beam
- Procedure:
  - reject noise with a fixed cut at 25 ADC counts (~0.5MIP)
    - selection of MIP-like tracks : $15 \leq N_{hits} \leq 40$, in a 2 cm tower
    - fit with a Landau convoluted with a Gaussian



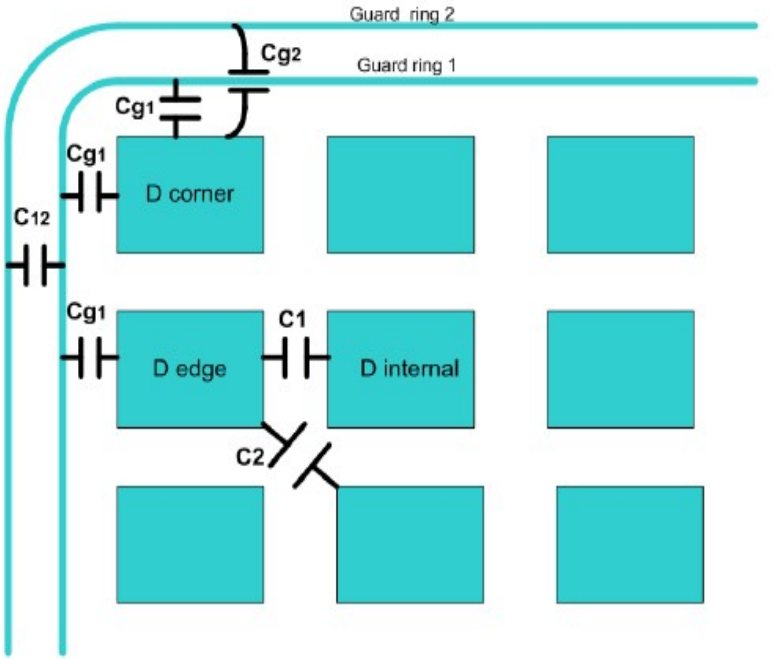
➔only 9 dead channels: 1.4‰ !!
➔ 6403/6471 : 98.9% convergent fit.
➔ 18/6471 needed a special treatment because of high noise.
➔14/6471 have been calibrated using signals in adjacent pads.
➔ One wafer (=36 cells) with a relative calibration : appears to be not fully depleted, 0.517×normal signal !!

A.M. Magnan LCWS07

Not yet perfect -Odds observed during operation



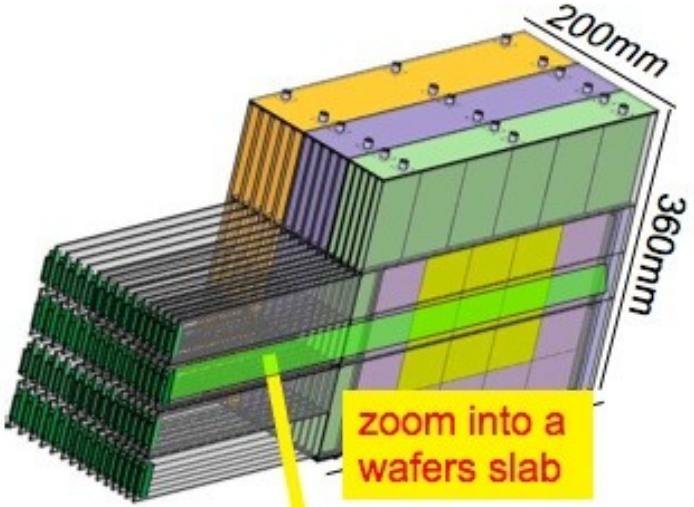
- "Square events"
  - cross talk between guard rings and pixels

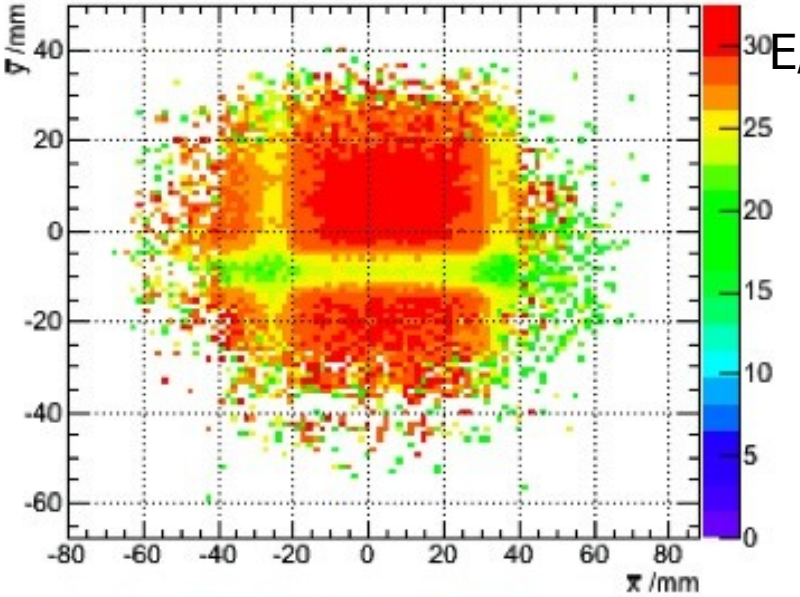


A.M. Magnan LCWS07

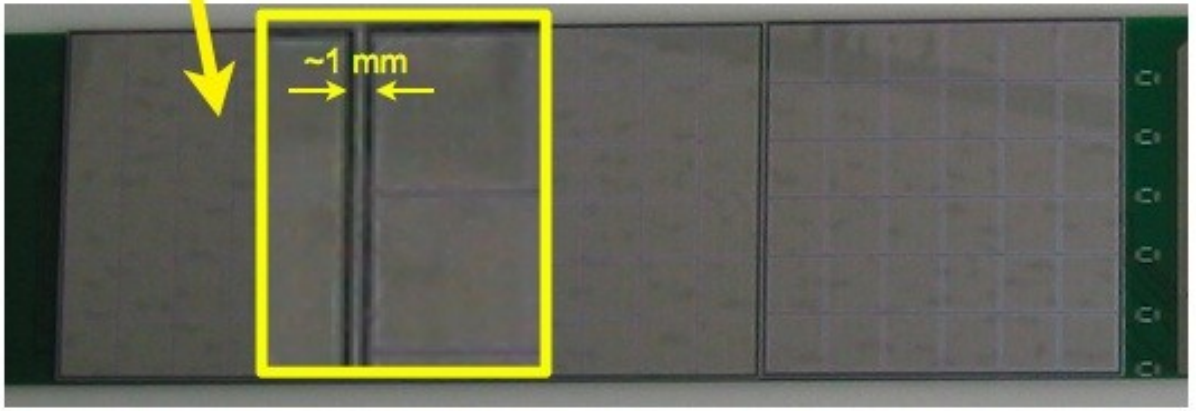
Ecal Energy Resolution I

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





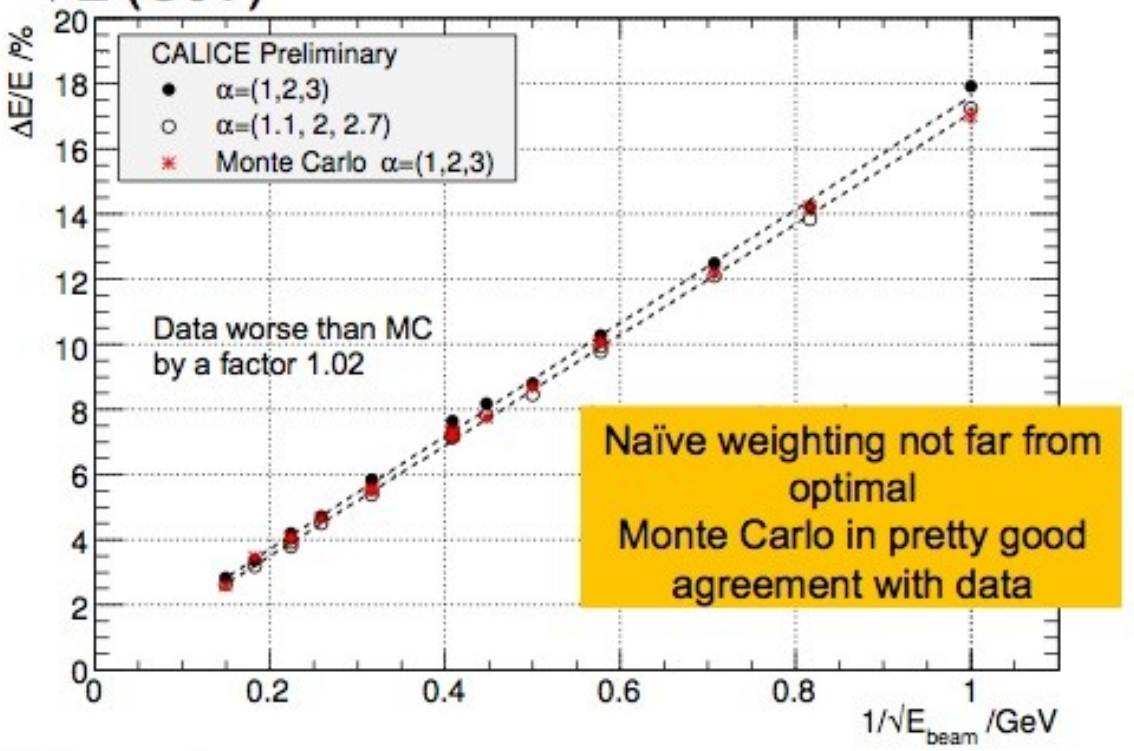
Absolute calibration by comparing E_{dep} on MIP level with beam energy



Need to take geometrical acceptance into account

Energy Resolution II – Results for 2 models of Sampling Fraction

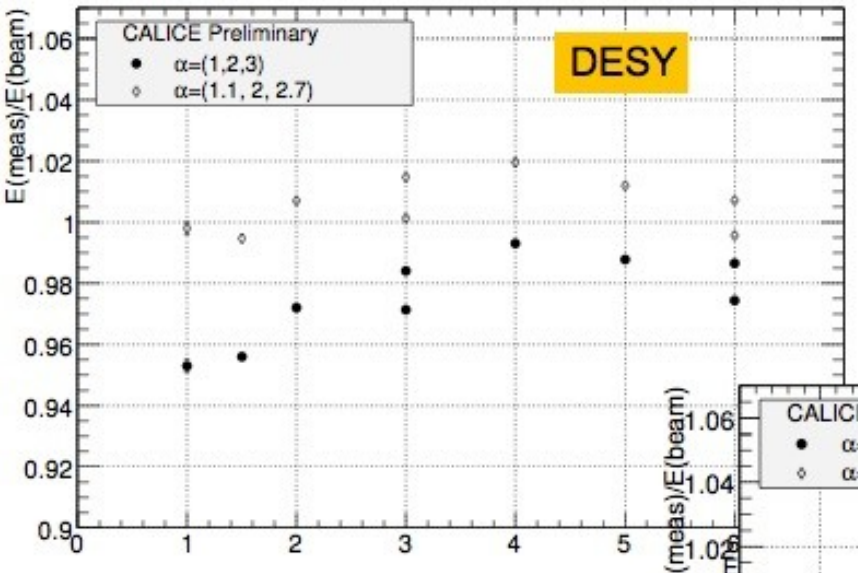
$$\frac{\Delta E}{E}(\%) = \frac{17.7 \pm 0.07}{\sqrt{E\,(\mathrm{GeV})}} \oplus (1.1 \pm 0.08) \qquad (\alpha_1, \alpha_2, \alpha_3) = (1, 2, 3)$$



$$\frac{\Delta E}{E}(\%) = \frac{17.1 \pm 0.07}{\sqrt{E\,(\mathrm{GeV})}} \oplus (0.5 \pm 0.15) \qquad (\alpha_1, \alpha_2, \alpha_3) = (1.1, 2, 2.7)$$

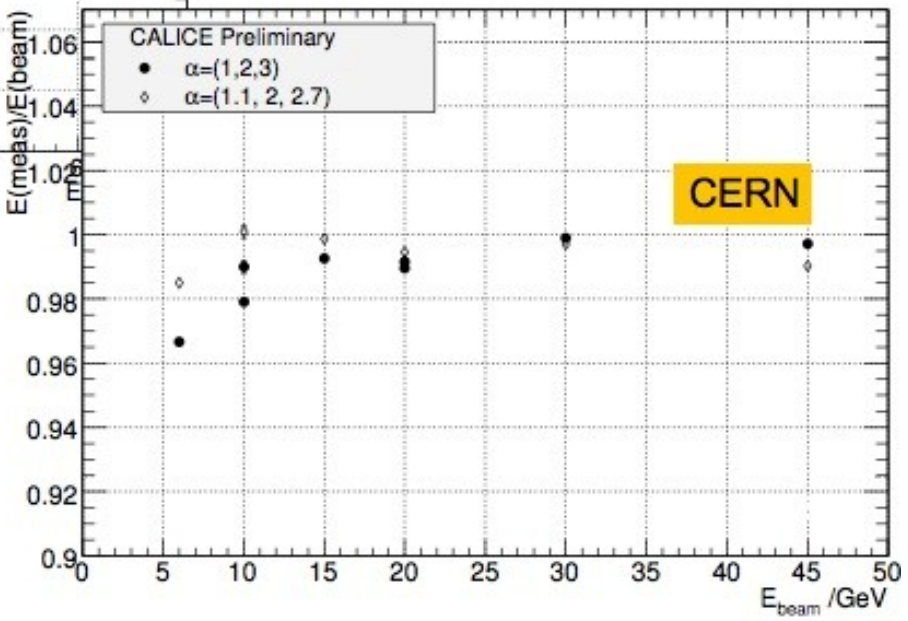
Statistical Term independant of “Sampling Factors”
Good description by Monte Carlo – Mokka/G4
Correct weighting under investigation

Linearity



Low Energy points
measured at DESY
May 06

High Energy Points
measured at CERN
Summer/Autumn 06

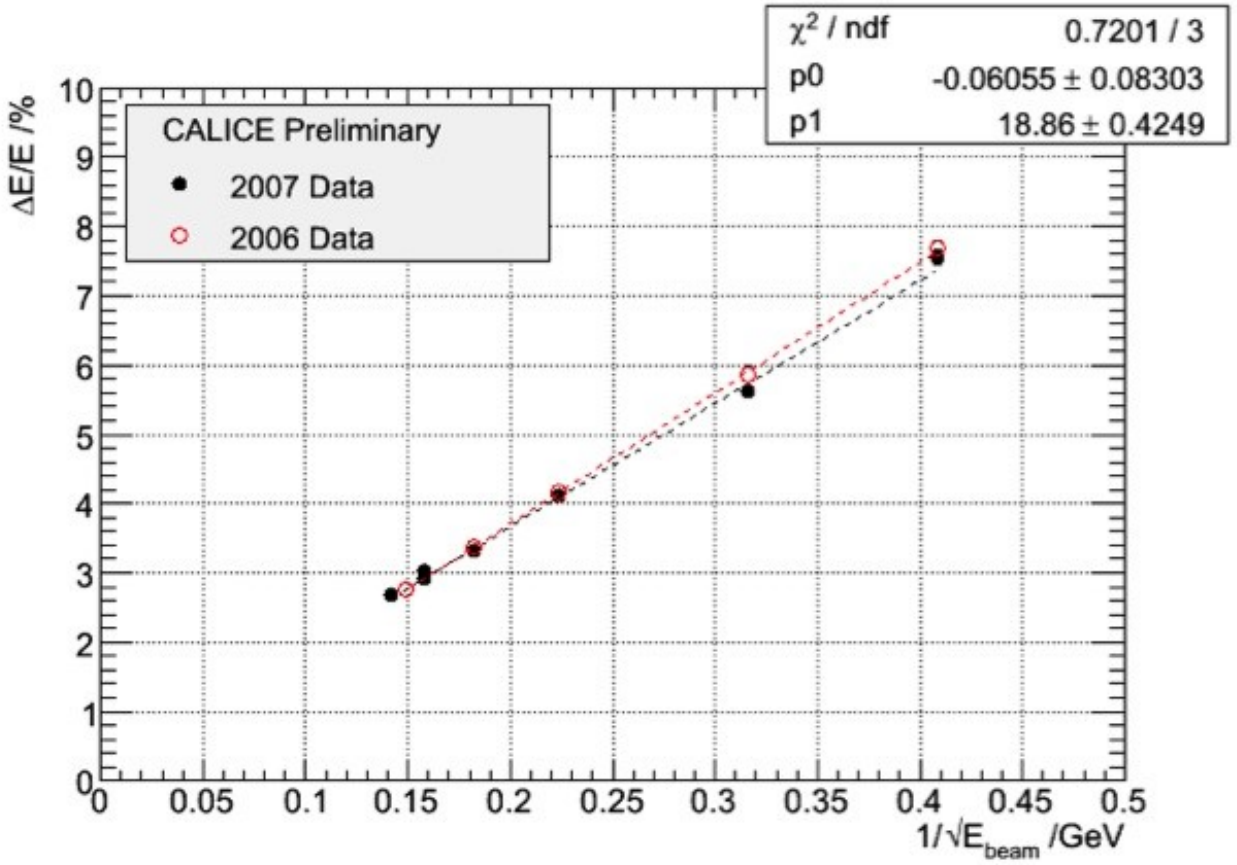


Linearity better than 2% -
Deviations towards low energies might be coupled
to worse beam quality -> under investigation

Towards Analysis of 2007 Data I

Energy Resolution

Results obtained during monitor phase 2007
Calibration for 2006 applied

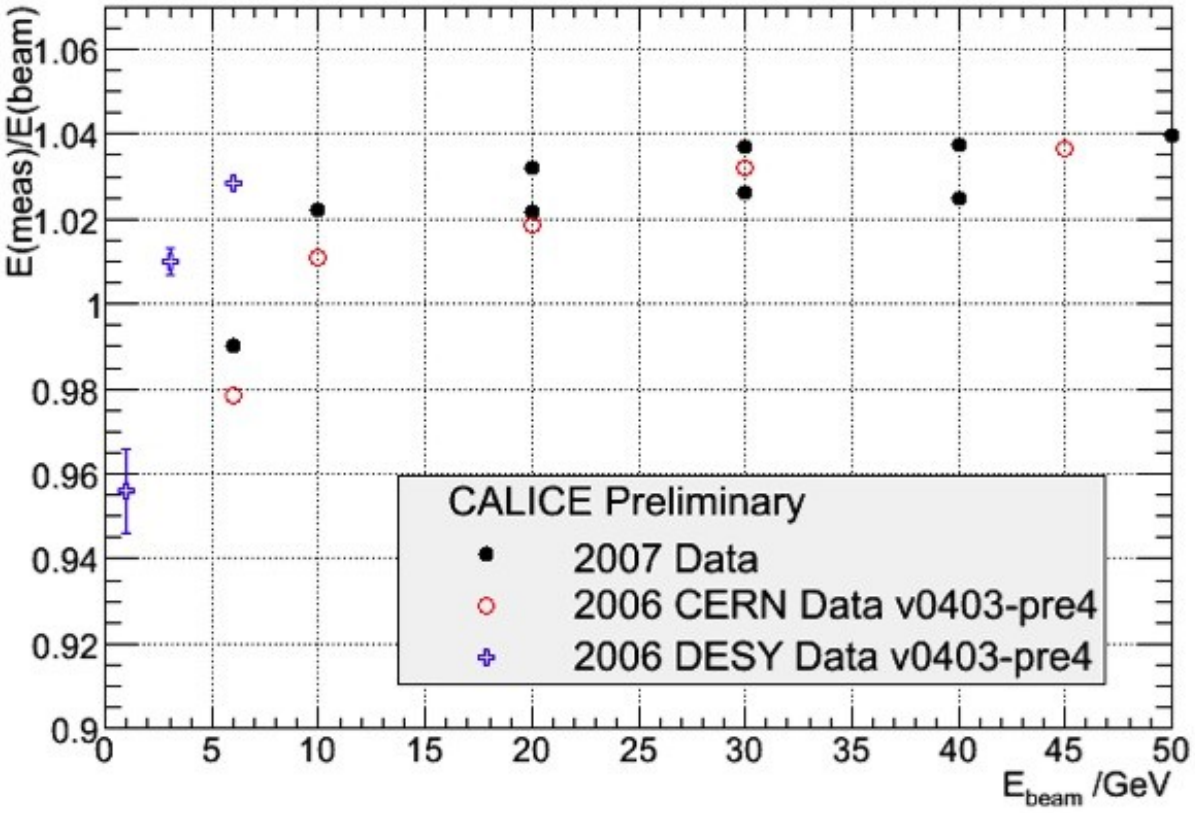


2006 and 2007 are compatible
Details to be understood

Towards Analysis of 2007 Data II

Linearity

Results obtained during monitor phase 2007
Calibration for 2006 applied

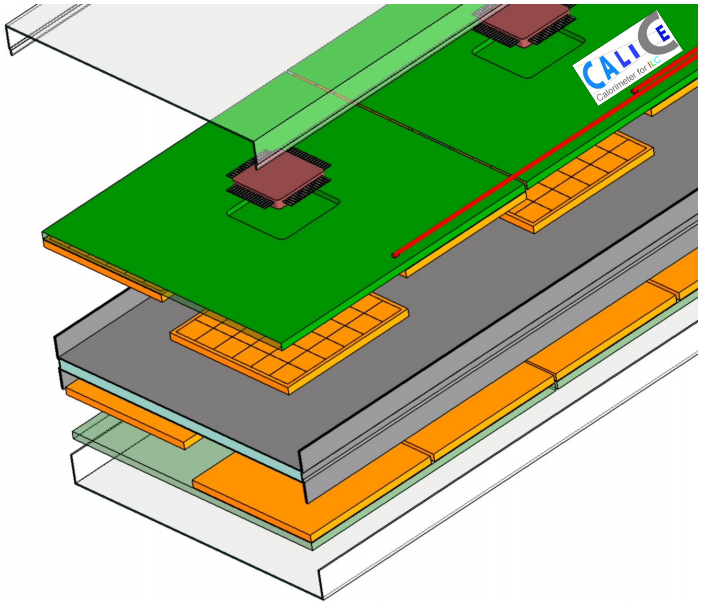


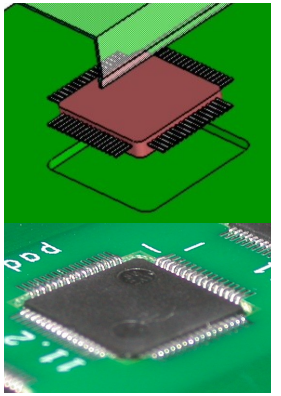
2006 and 2007 data are compatible
Details to be understood

D. Ward

Towards an ILC Detector – Interleaved Electronics Test 2007

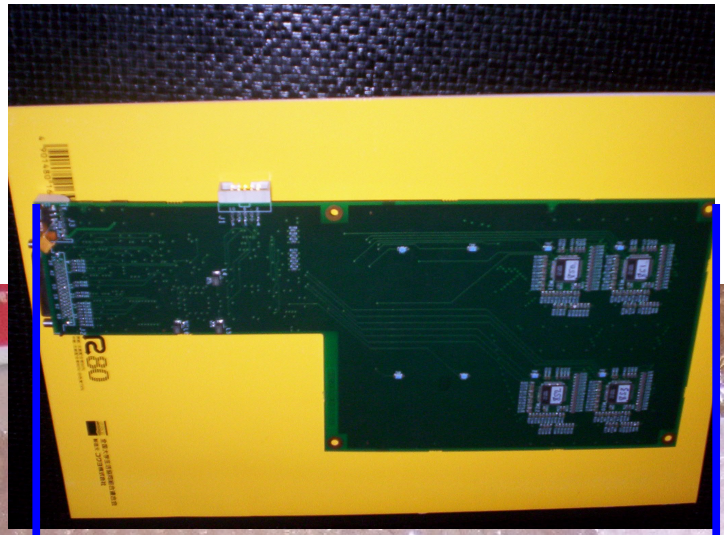
Calorimeter Electronics to be interleaved with layer structure



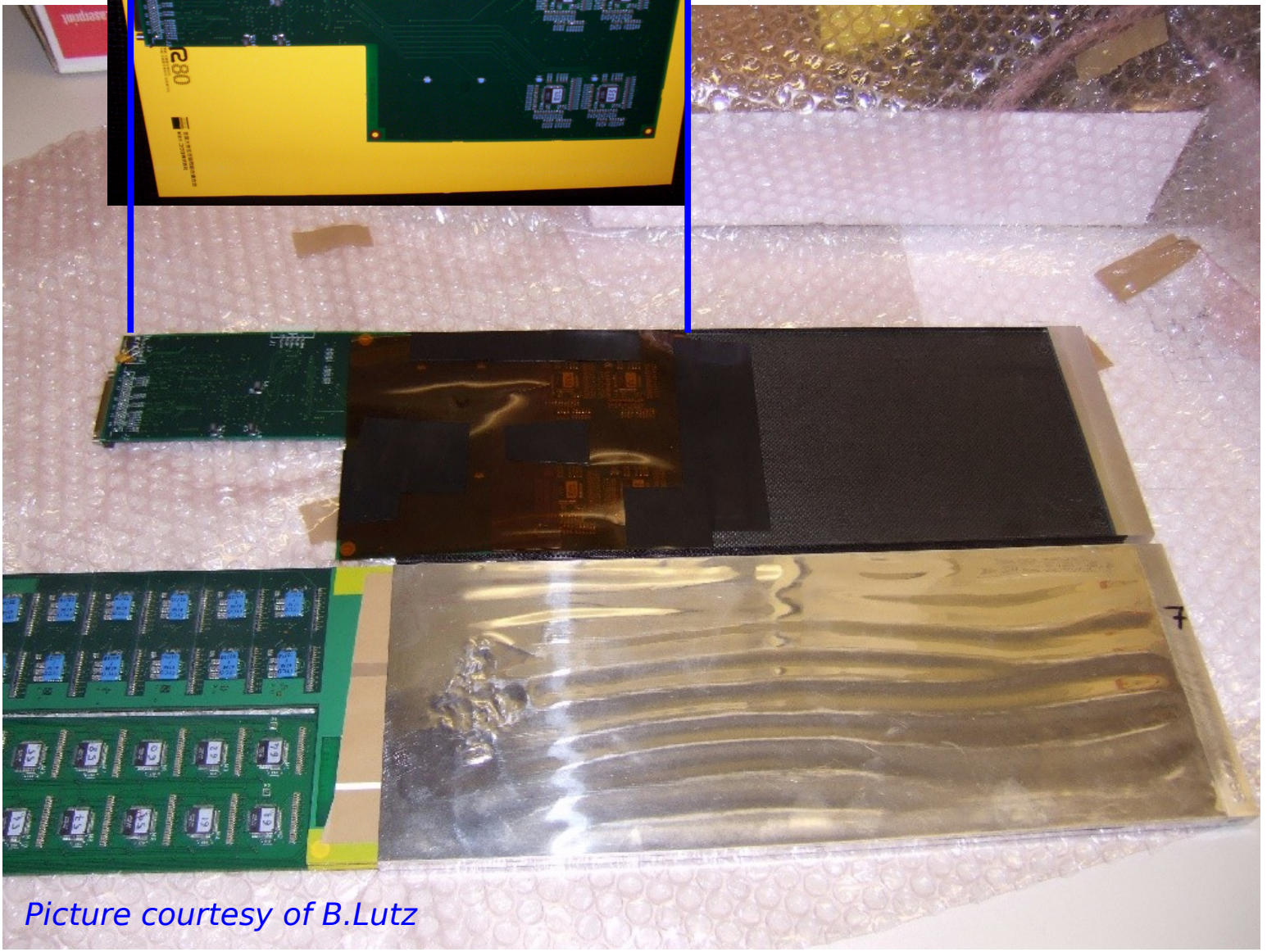


Do high energetic showers create signals directly in electronics ?
If yes, rate of faked signals ?

Special PCB in Ecal Prototype during CERN 07 Testbeam – Experimental Setup I



Test PCB
- equipped with
  PHY3 Chip Set



Prepared Slab
- W dummy
- capton and paper
  for electrical shielding

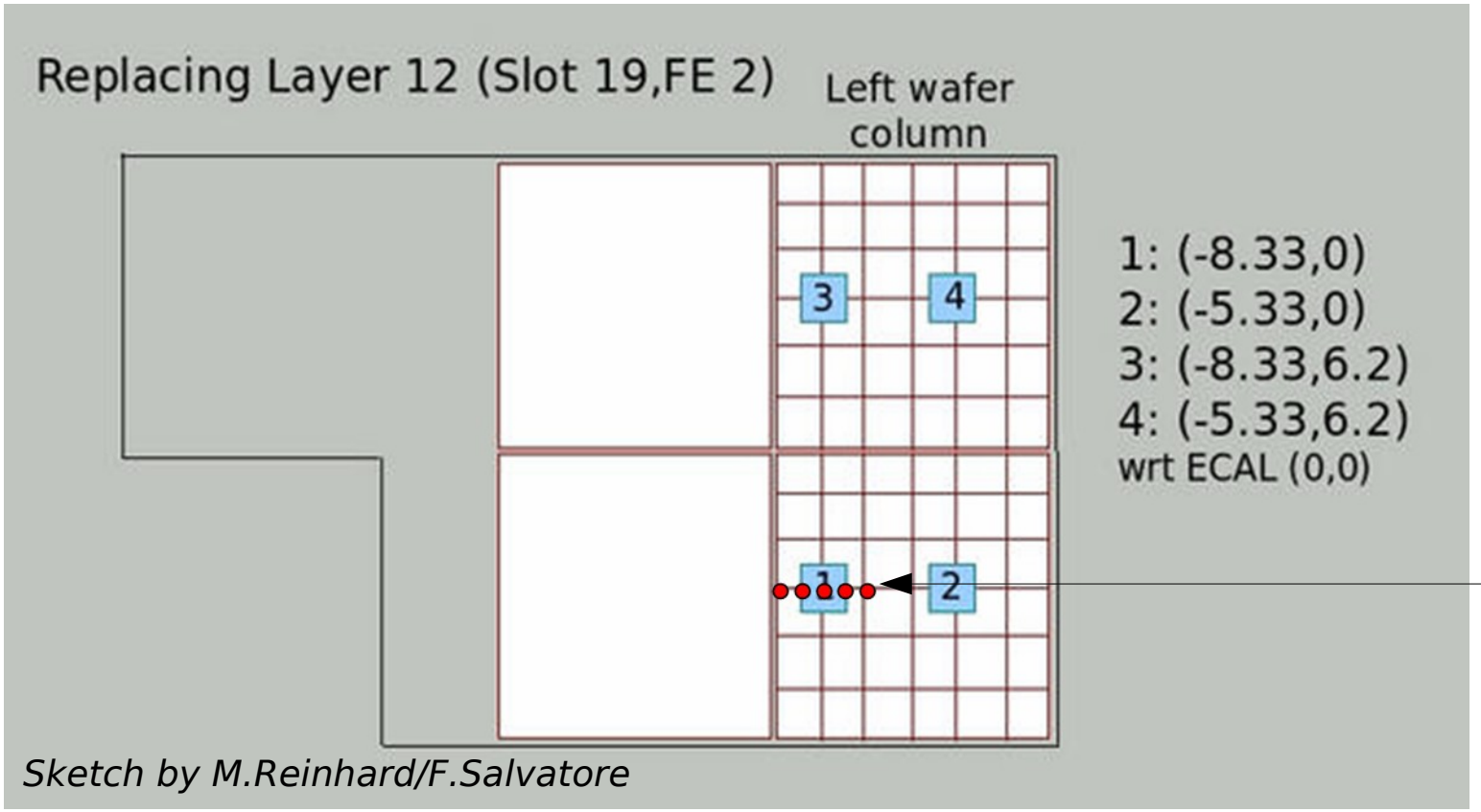
Usual Slab

Picture courtesy of B.Lutz

Special PCB in Ecal Prototype during CERN 07 Testbeam – Experimental Setup II

- PCB positioned at ~ shower maximum

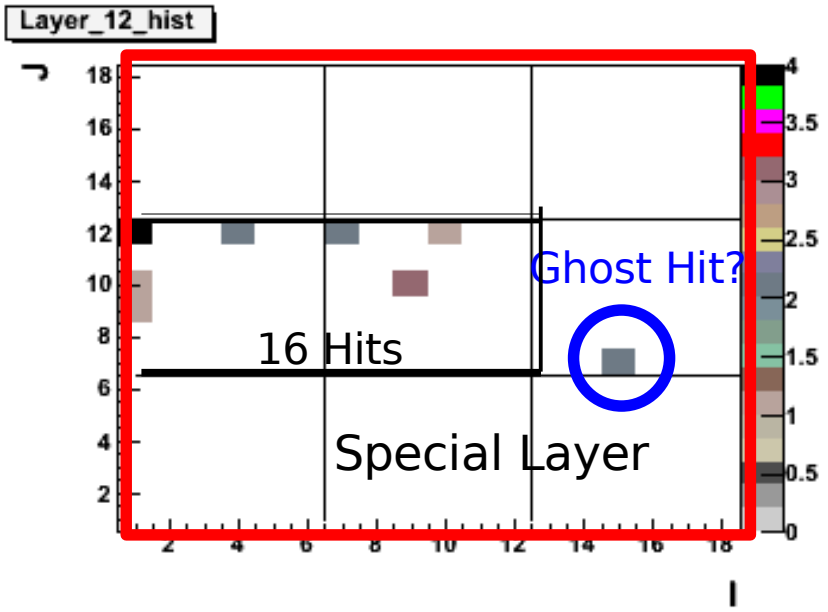
- Schematic view of test PCB - 'Expect' signals from 72 pads, 4x18 = 2 Wafer

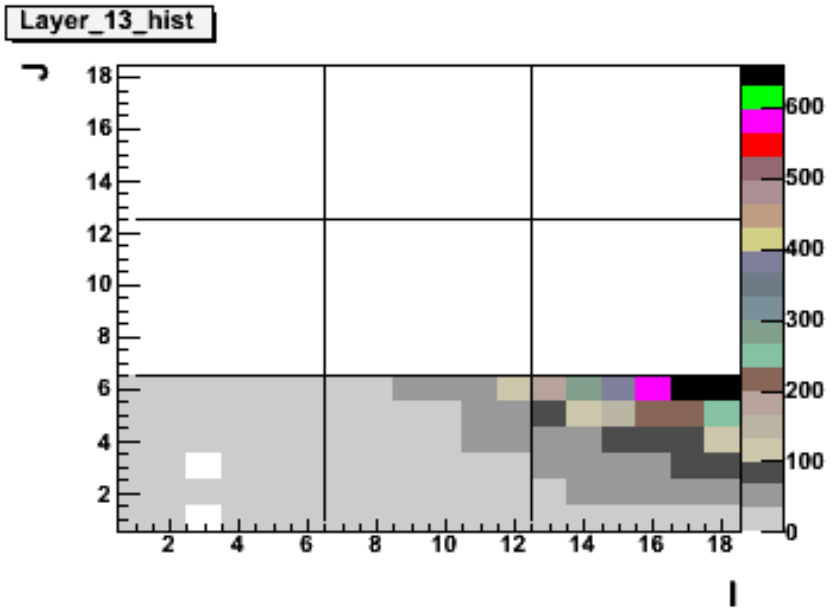


- 7 10^6 Triggers with 90 GeV Electrons (- 1 10^6 with 70 GeV Electrons)
  At least 250 K at each scanning point
  Today: Analysis of 10k Events per analysed run

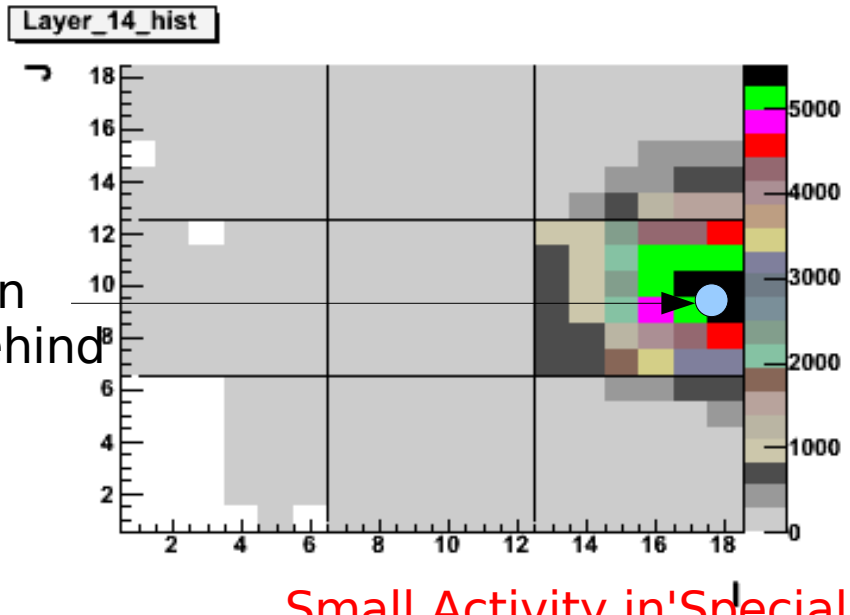
Activity in Special Layer

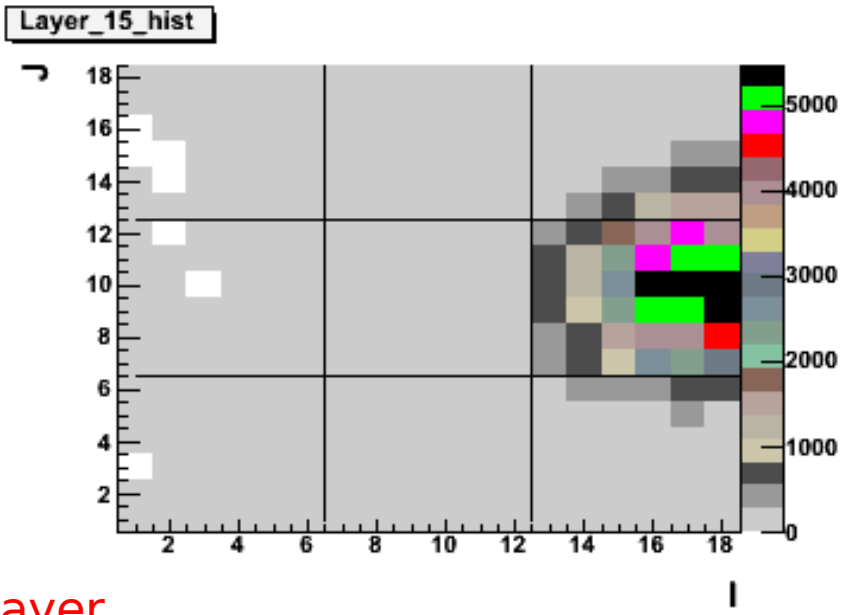
70 GeV e- - Beam Impact at nominal center of Chip 1 (-8.33,0) cm





Projection of Chip I position onto layer behind special layer





Small Activity in'Special' Layer

Result indicates that an ILC detector can be operated with interleaved electronics

Summary and Outlook

- SiW Tungsten Ecal with up to 9400 cells operated successfully during testbeam campaigns 2006 and 2007

- Stable operation with only 1.4% dead cells

- Important hints for design of ILC Calorimeter e.g. Square Events

- Energy resolution well described by MC Linearity O(2%)

- For a full overview on results see LCWS Calorimeter Sessions 2 papers on 2006 data under preparation

- First analysis of test with interleaved electronics revealed no show stopper for this technology

- More data/further tests on future electronics at Fermilab test beam start in spring 2008