Calorimetry at/for the ILC

and beyond

Roman Pöschl
LAL Orsay

Facts and Trends at ECFA 2008

ECFA Study
Physics and Detectors for a Linear Collider

International Linear Collider
ECFA Workshop
9-12 June 2008
Warsaw, Poland

Disclaimer

- This talk is addressed to the broad audience – Not to calorimeter experts

Will focus on topics interesting for the whole ILC community
Will discard detailed R&D work

Apologizes to those efforts not represented together
with my deep respect for that important work

- I will highlight the results of testbeam efforts
Technologies facing the truth

- I will outline ways beyond the initial prototypes

Detector Concepts and Calorimeter R&D

	ILD	SiD	4th concept
CALICE Calorimeter for ILC	X	X	
DREAM			X
SiD Ecal Group		X	
FCAL Collaboration High precision design	X	X	X

Calorimeter R&D organized in Collaborations (and in 2 cases) beyond concept boundaries

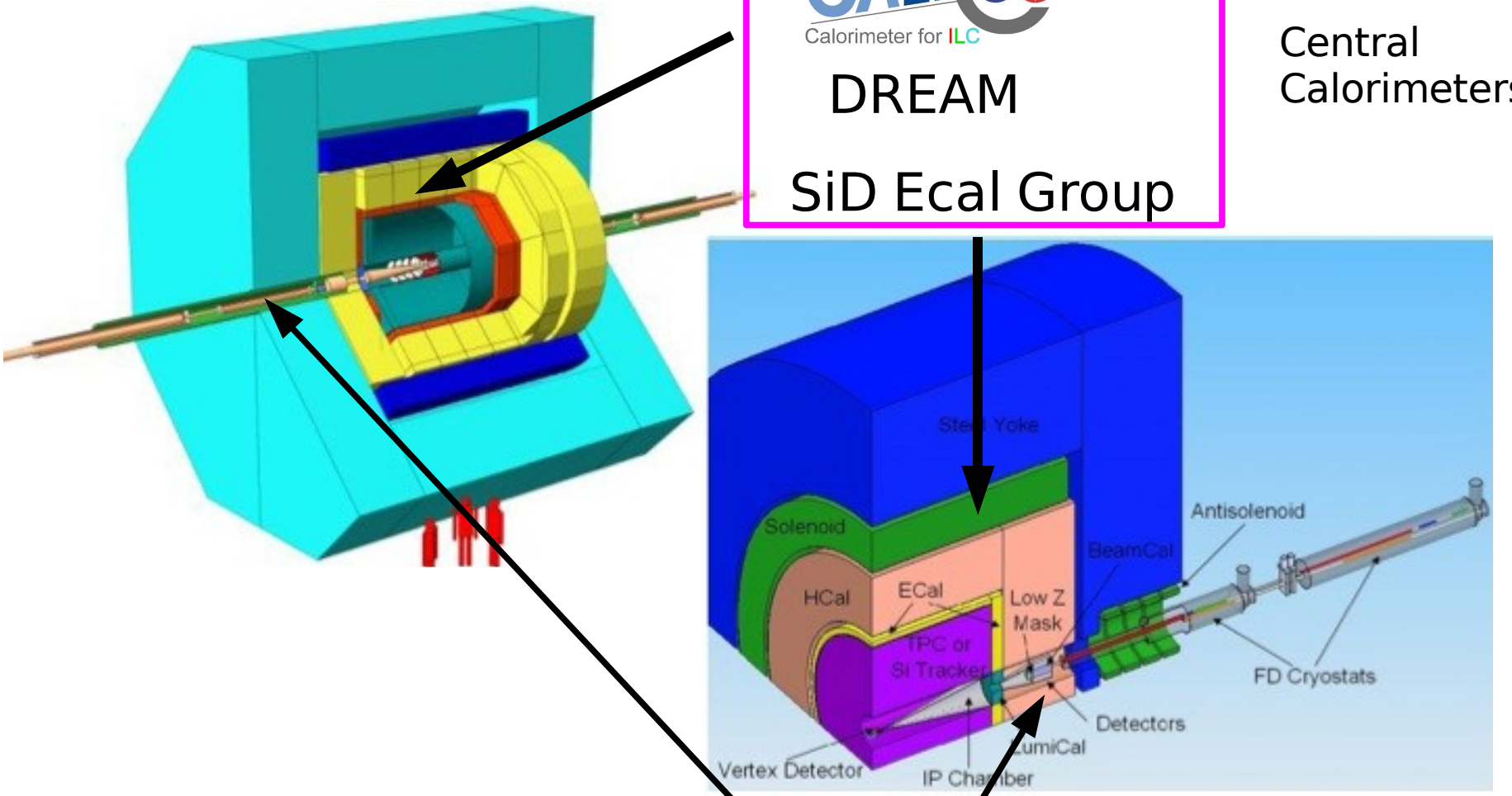
Covering Detector Regions

CALICE Calorimeter for ILC

DREAM

SiD Ecal Group

Central Calorimeters



FCAL Collaboration High precision design

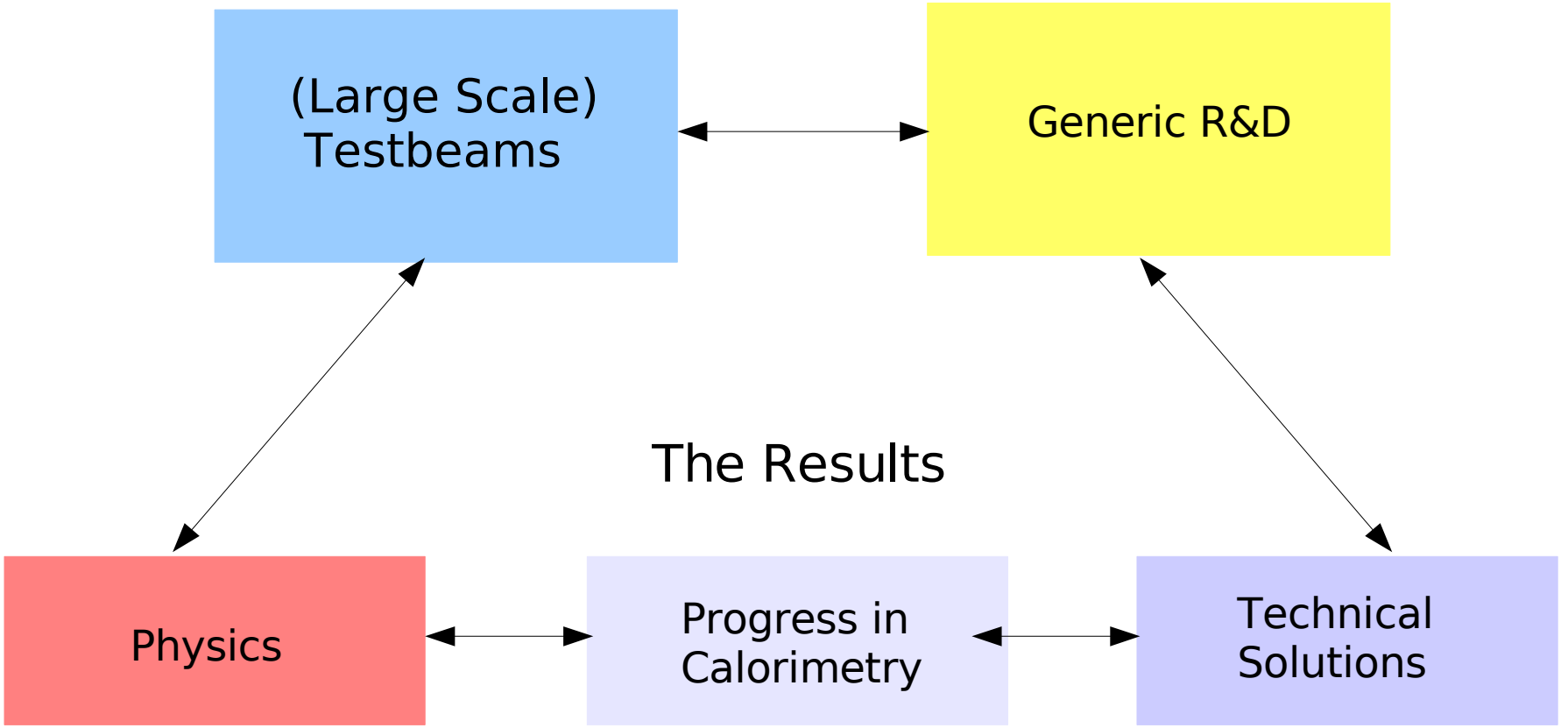
Forward Calorimters

The Calo Machinery

The driving force

ILC Physics and
Detector Optimization

The Programs

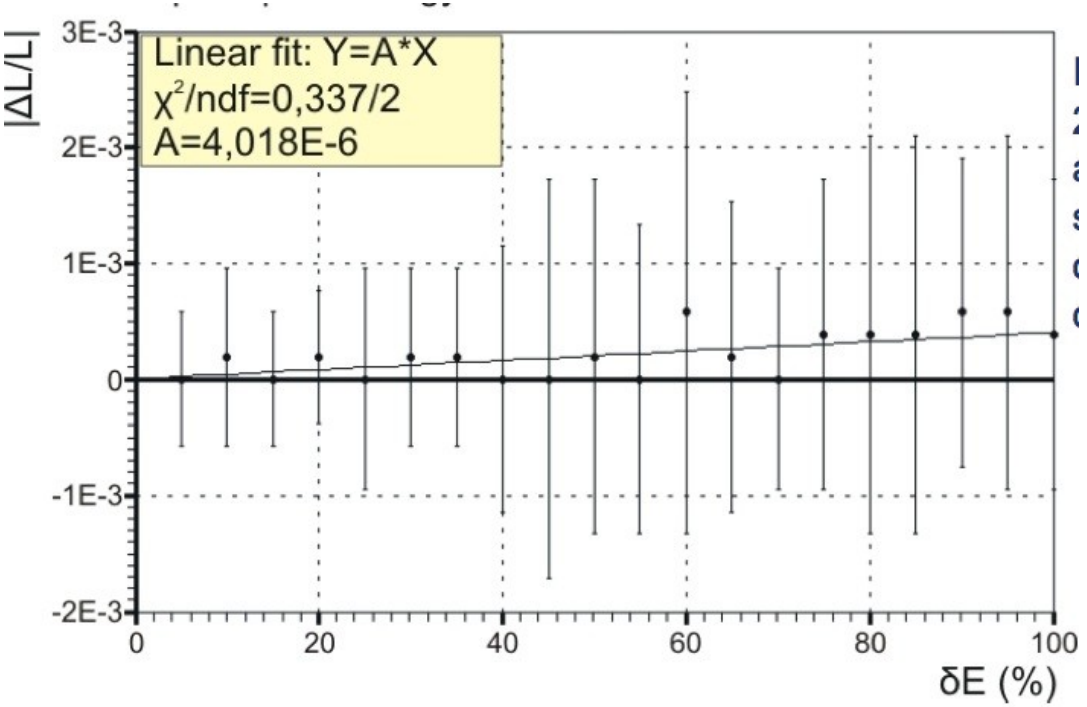


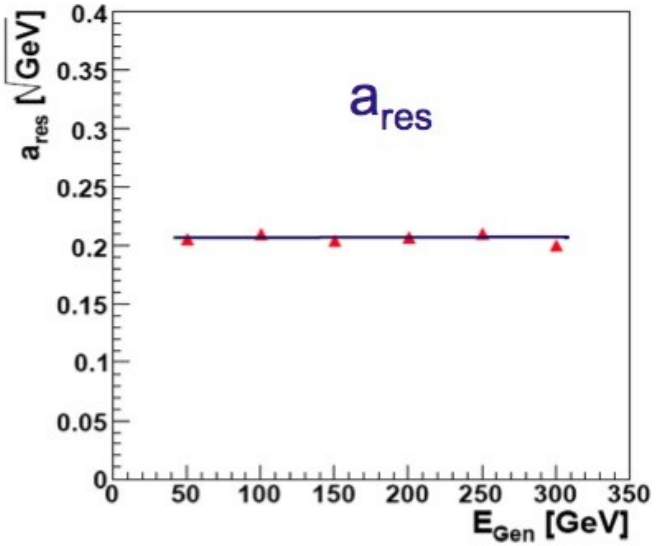
All issues addressed in Calorimeter Development for the ILC

Precision Physics starts with Luminosity mearsurement

Simulation Studies on Luminosity Precision using LumiCals

E_{CUT} = 150 GeV to suppress bkgr. From ffbar production





To achieve δL ~10^{-4} Energy resolution has to be controlled to the 25% percent level

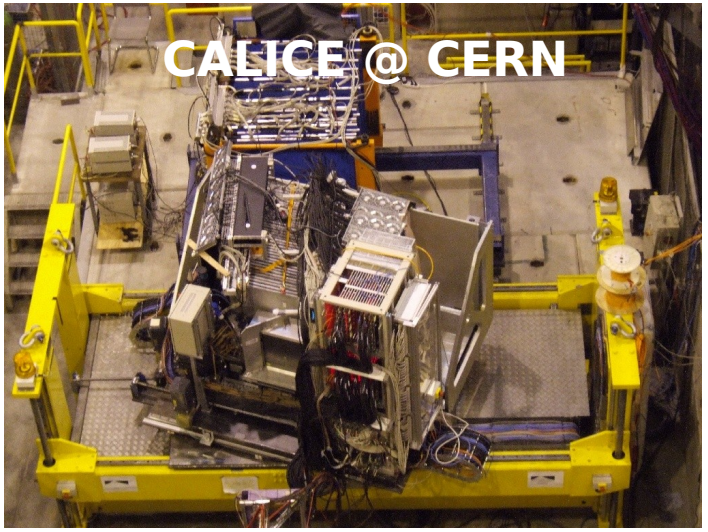
- Relative energy resolution:

$$\frac{\sigma_E}{E} = \frac{a_{res}}{\sqrt{E_{beam}\ (\mathrm{GeV})}}$$

$$a_{res} \approx 0.21\ \sqrt{(\mathrm{GeV})}$$

Testbeam Programs (2005 - today)

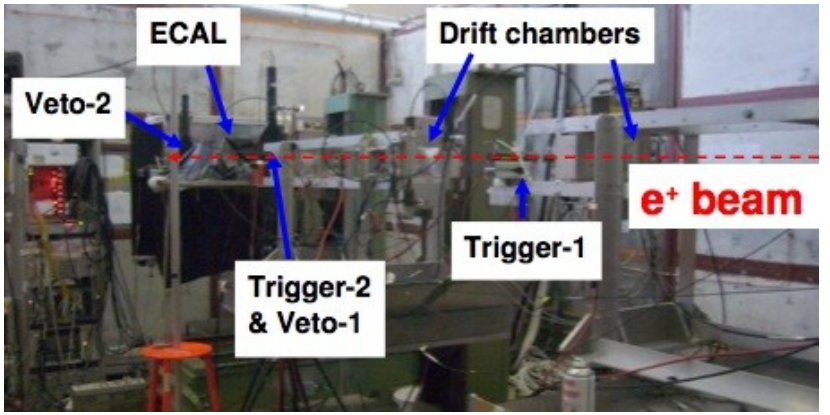
High granularity calorimeters and PFA
Testbeam programs at DESY, CERN, FNAL and KEK



SiW Ecal, Ahcal TCMT

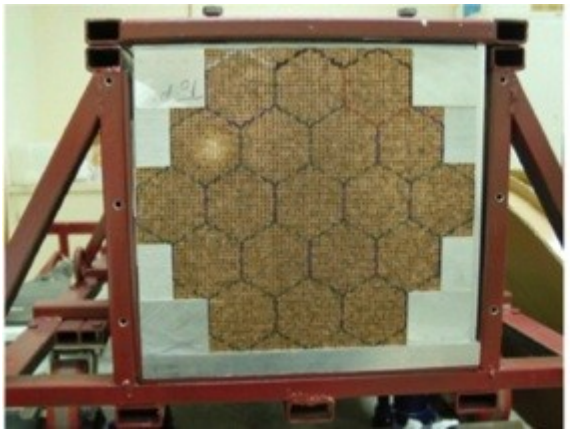
DHCAL with RPC

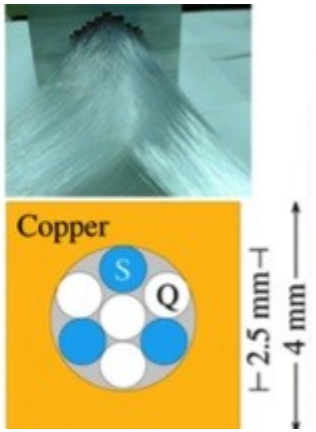
CALICE @ DESY

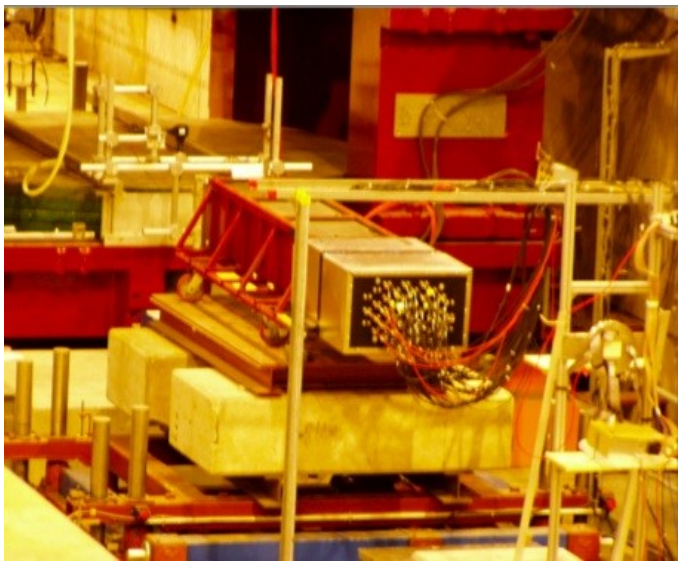


SiW and Scint Ecal, MAPS

DREAM Project:
Optimising the energy resolution for hadronic showers

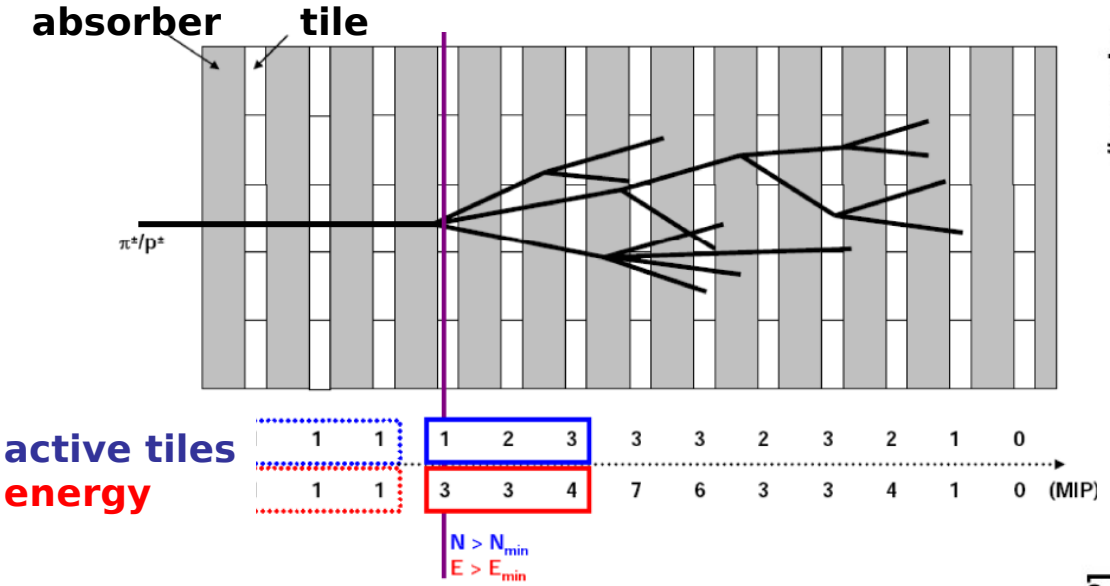


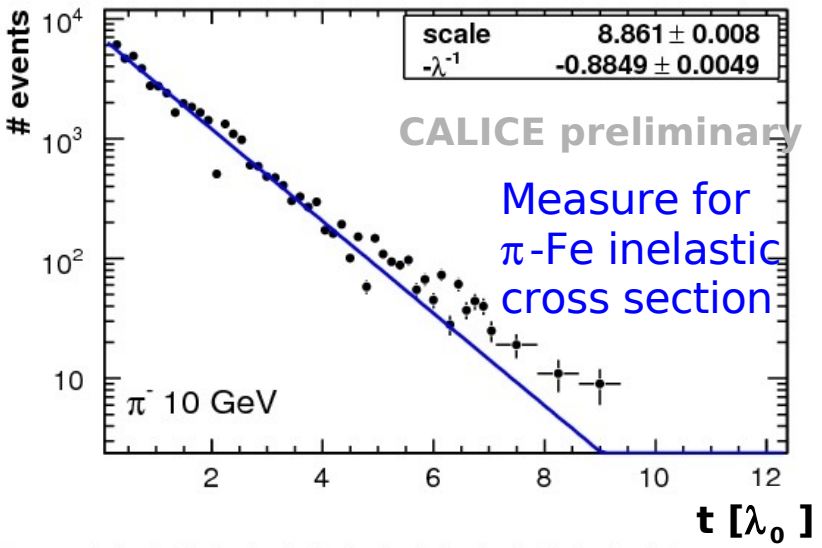




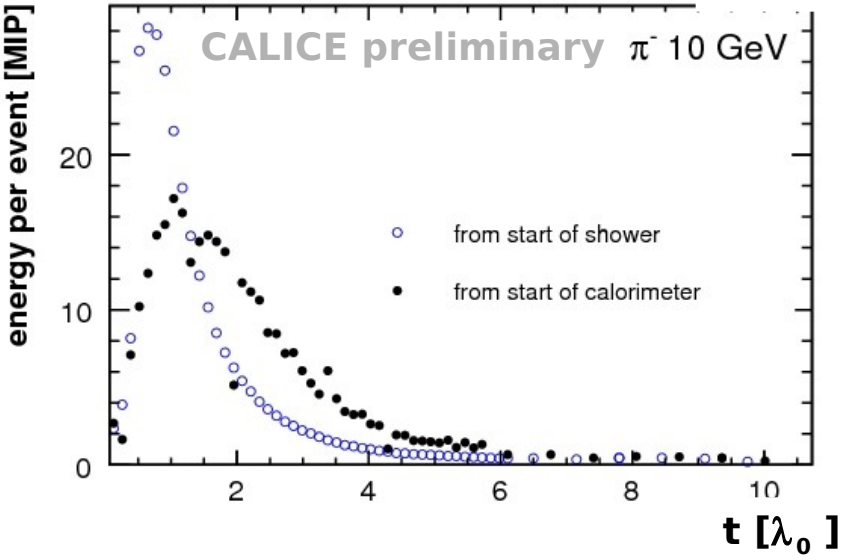
Physics with Calo Prototypes - I

Shower Starting Point





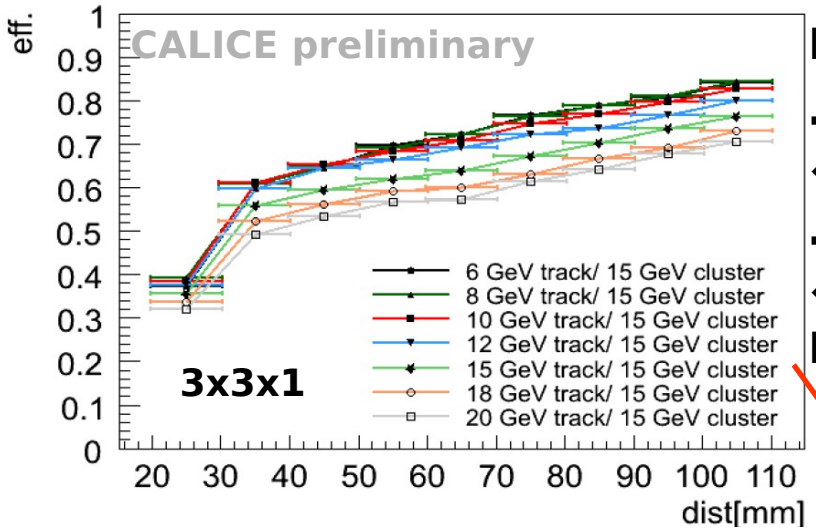
determine start of shower activities from increase of number of active tiles and energy
in the 38 AHCAL layers



- distribution has expected exponential fall
- longitudinal shower profile after ev.-by-ev. correction allows independent data/MC comparison

Physics with Calo Prototypes - II

Particle Separation in highly granular Ecal

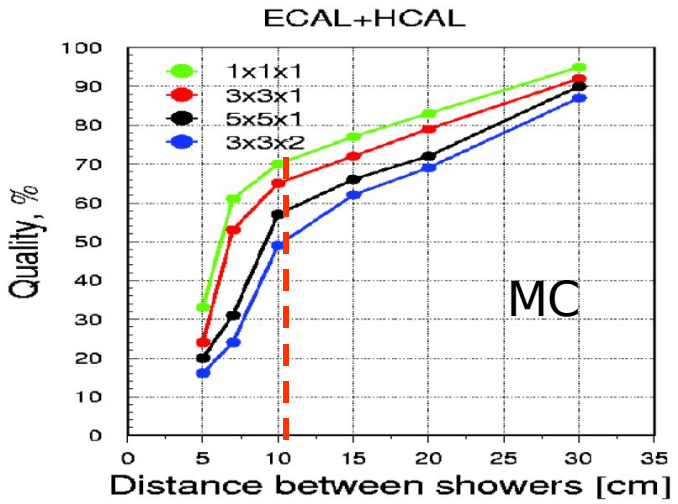


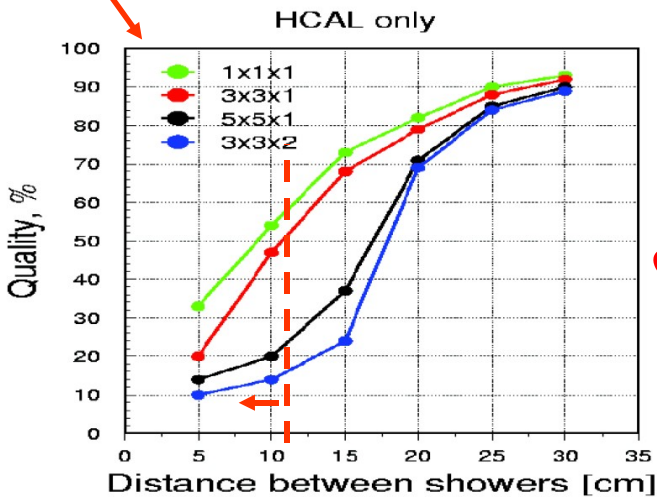
MC studies for AHCAL geometry optimization

➔ MC 1 charge + 1 neutral hadron simulated
➔ data 2 charged pions

➔ MC with HCAL only
➔data contained showers in AHCAL but ECAL used as tracker

qualitative good agreement





only distances <10cm probed by data

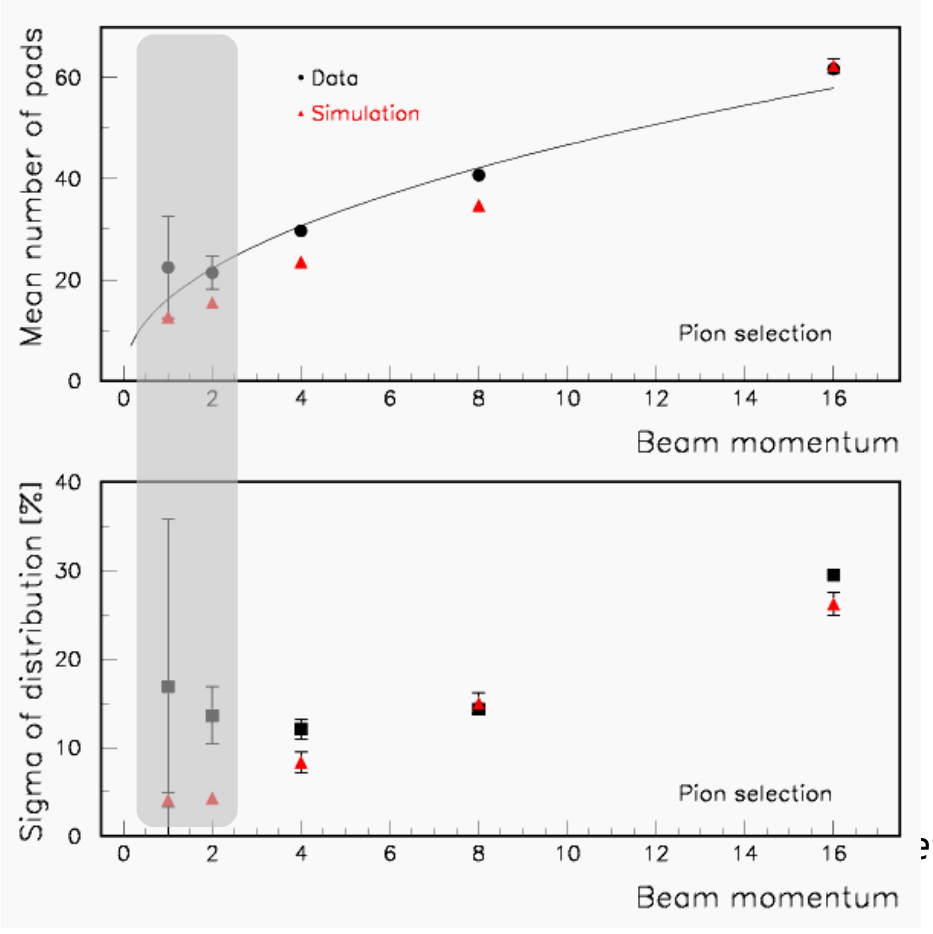
A. Raspereza, 2004

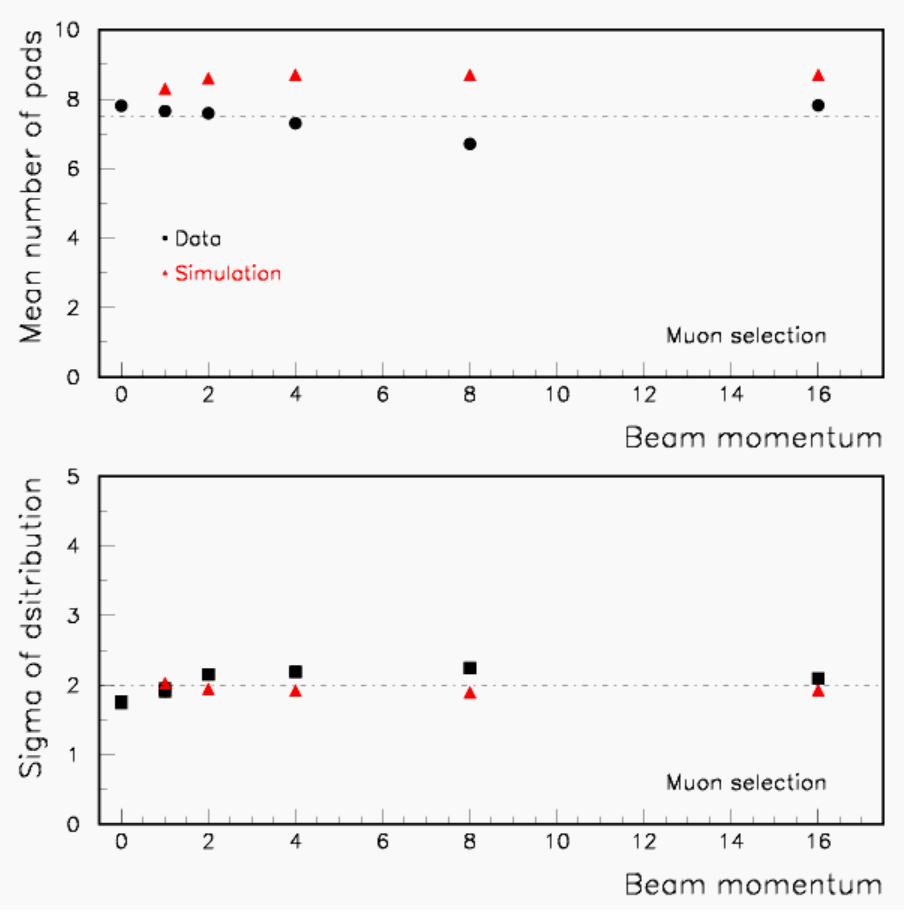
Particle Flow in Real Data !!!

Invesigating the Calorimetric Response I – Test with small DHCAL

MIP selection

Mean and sigma ~independent of beam momentum
Mean not very well reproduced by simulation
→ Beam contains muons, simulation does not
(data are cleaner !!!)
Width of distributions adequately reproduced





Pion selection

Measurements at 16, 8 and 4GeV/c
Not sufficient statistics at 2, 1 GeV/c
Non-linearity due to leakage
Adequate agreement with simulation

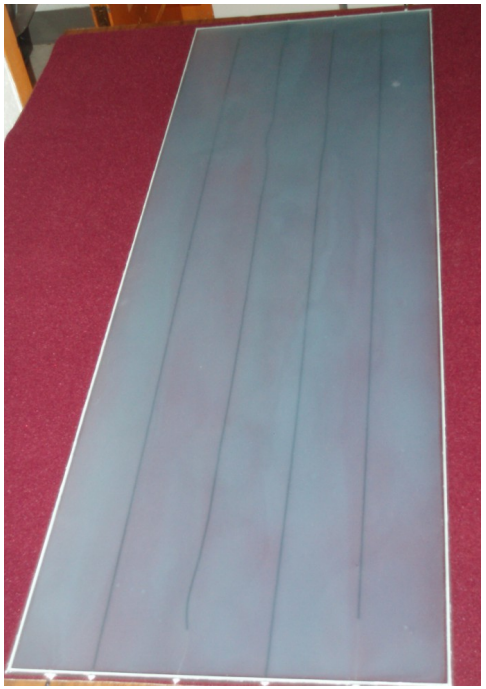
Growing up - Towards 1m^3 DHCAL protoypes

Larger prototype section needed to

Measure hadronic showers in detail
Gain experience with larger system
Compare performance with scintillator approach to granulated calorimetry

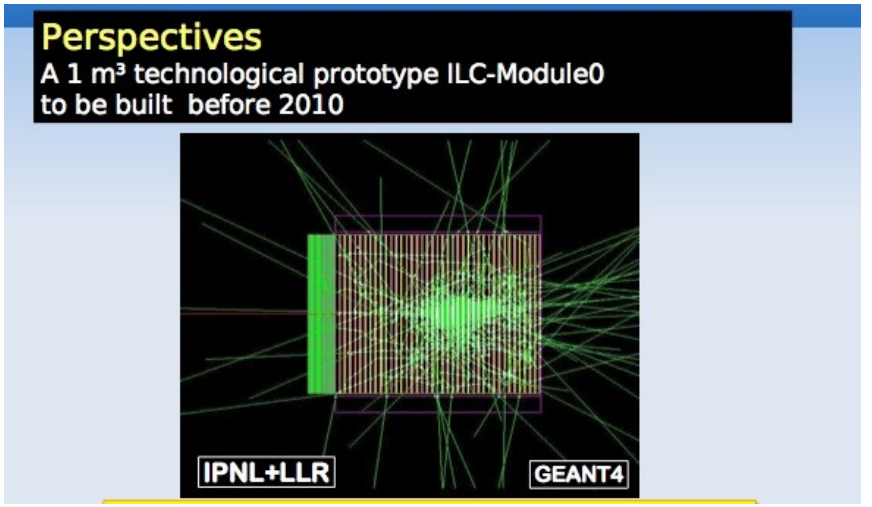
2 prototype projects

US-DHCAL



- Module Production during 2008/09
- Testbeam with SiW Ecal
- To be installed on stage which currently houses AHCAL

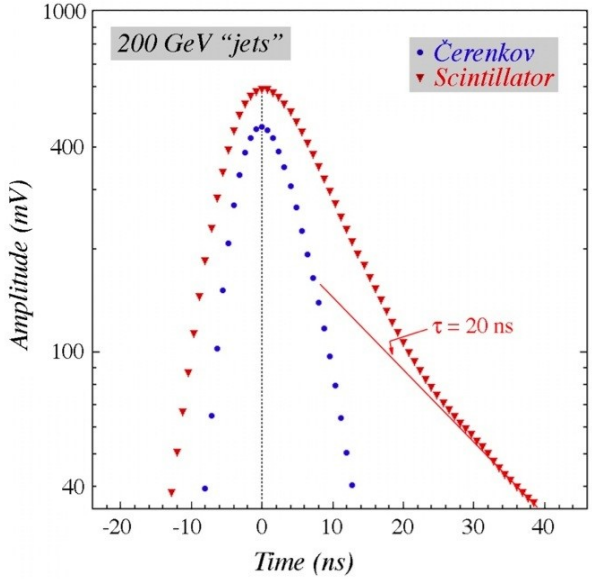
European DHCAL

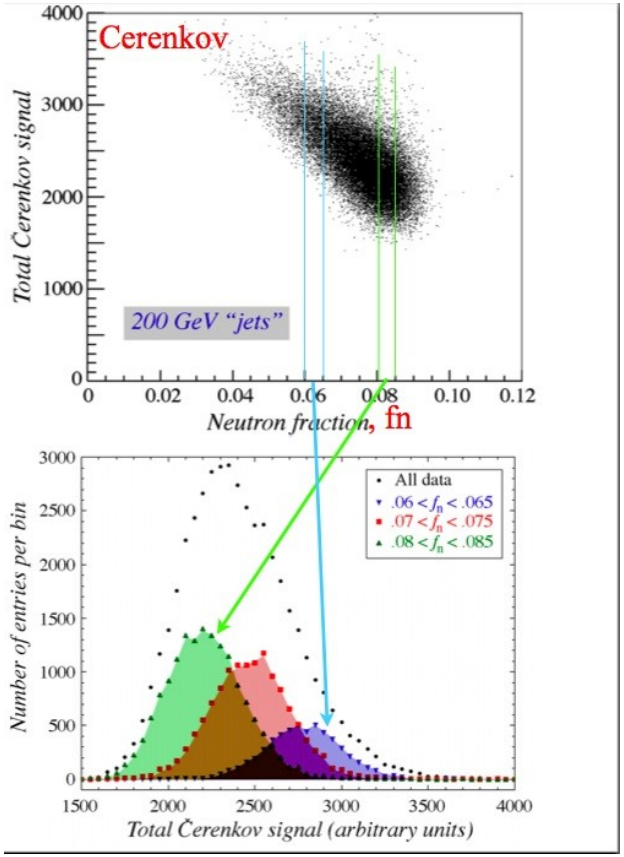


Equipped with next generation FE Electronics

Exploration of 'technology matrix' within CALICE collaboration

Investigating the Calorimetric Response II – Neutron Identification with DREAM



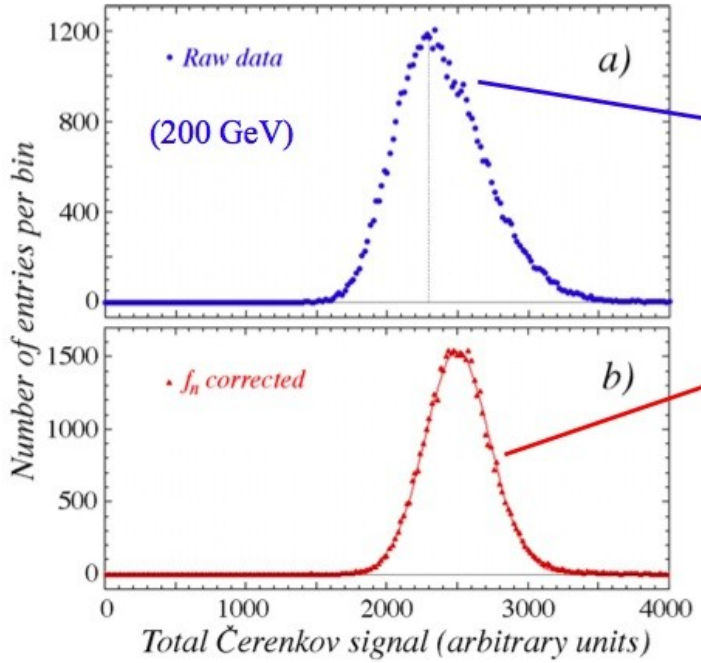


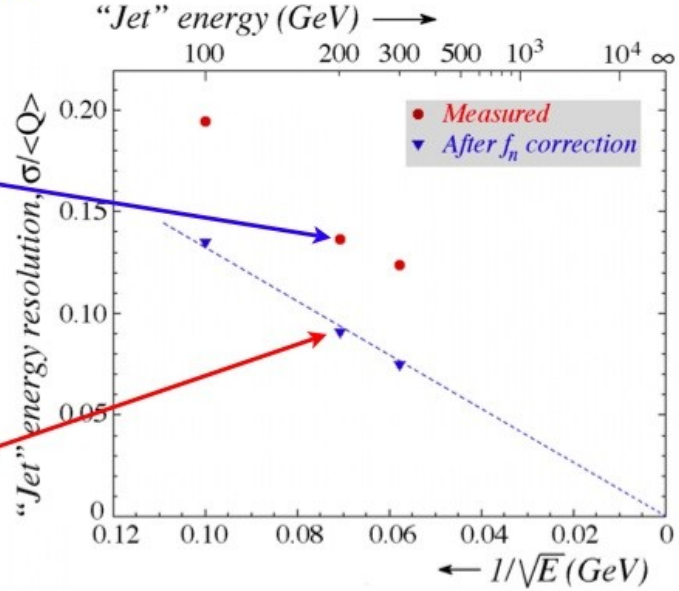
DREAM technology allows for distinction of elm. And hadronic component of shower

- Cerenkov Light by electrons with large v/c
- Scintillation light bypions with smaller v/c

Slow neutrons create tail in pulse spectrum

Linearly correcting each Cerenkov distribution in an fn bin to fn=0.07 (arbitrary, middle value) results in the "fn corrected" distribution



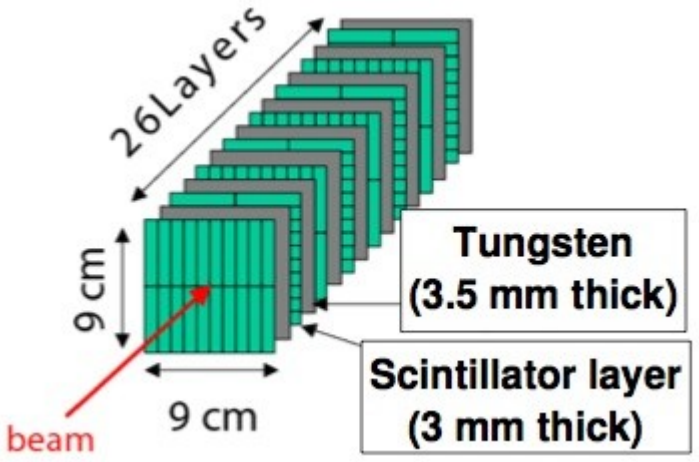


(1) fn-corrected Cerenkov resolution improves with shower energy ... AND ...

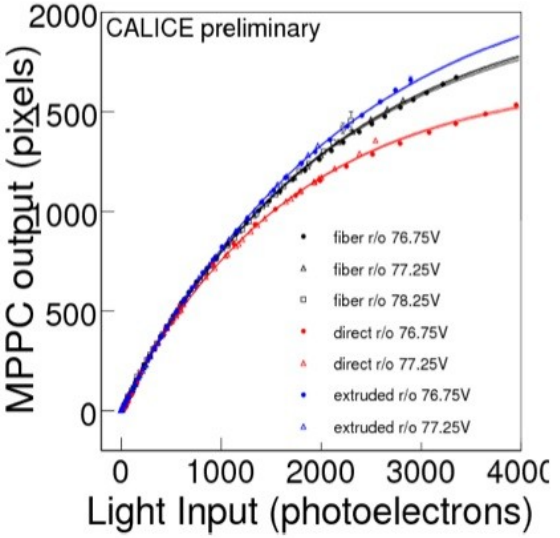
(2) Its dependence leaves no "constant term"

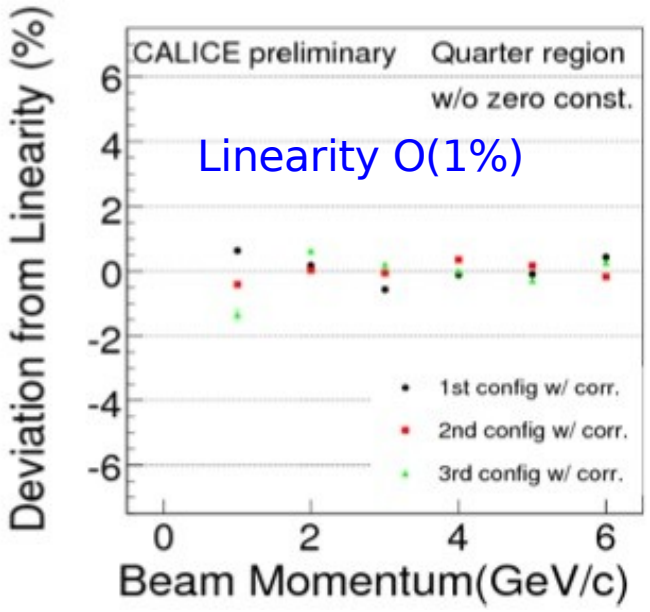
Investigating the Calorimetric Response III – Scint Ecal

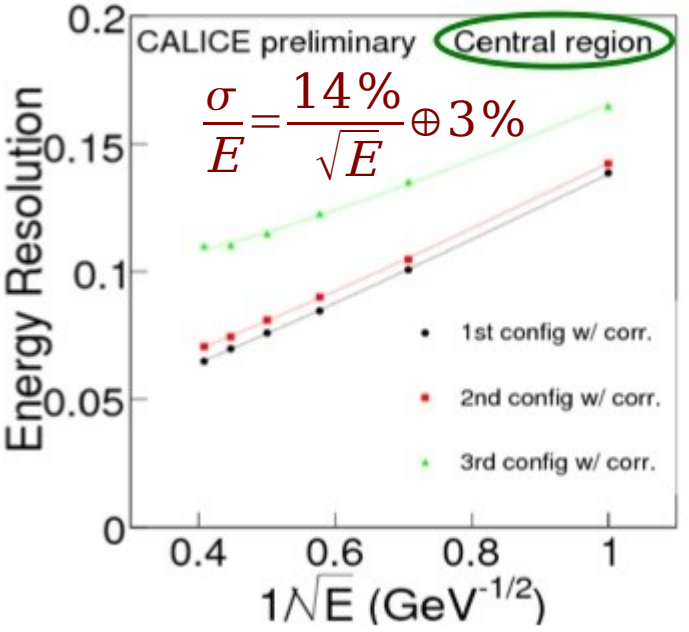
Scint Ecal



MPPC (SIPM) Saturation

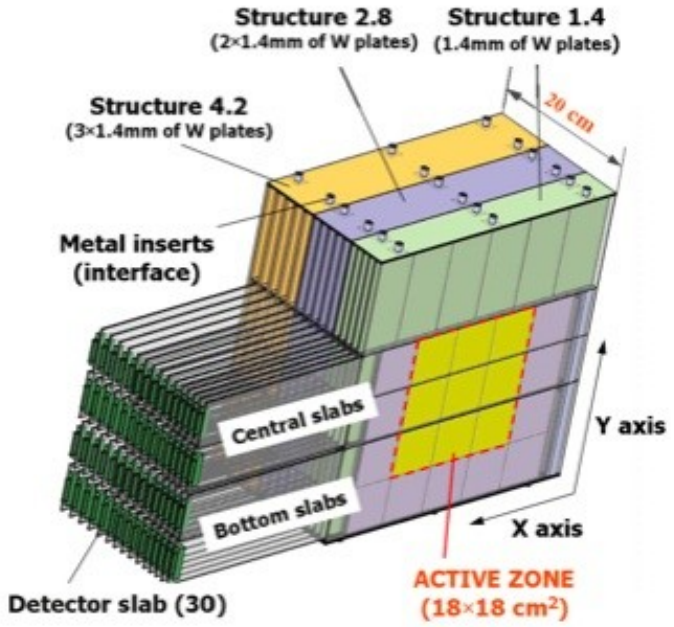


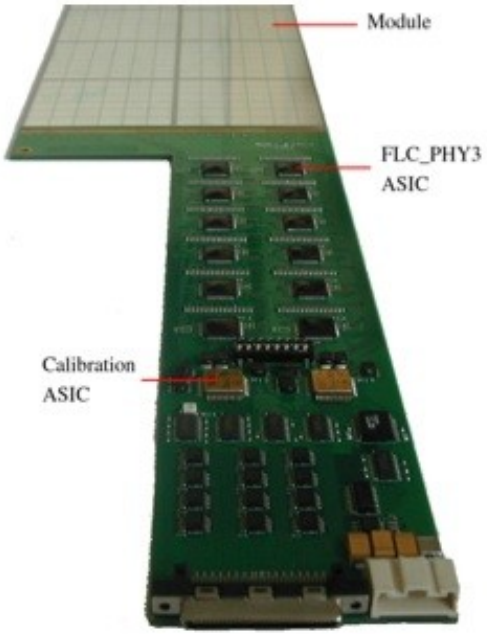




Next step is 4x larger Prototype in FNAL testbeam

Investigating the Calorimetric Response IV – SiW Ecal



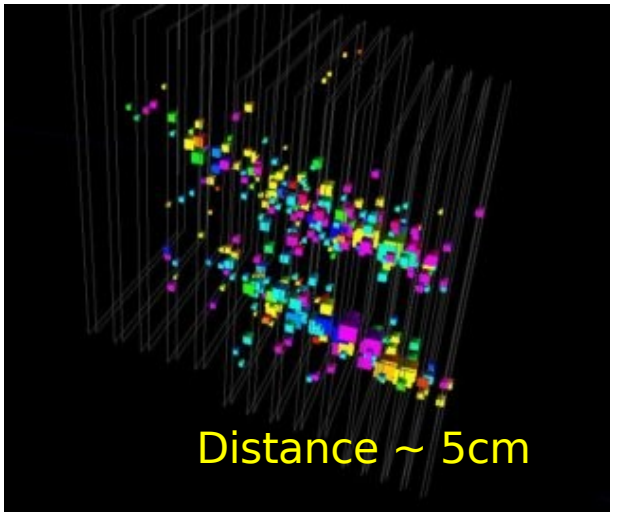


- W as absorber material

- Signal extraction by “Silicon Wafers”

- Extreme high granularity
  1x1 cm^2 cell size

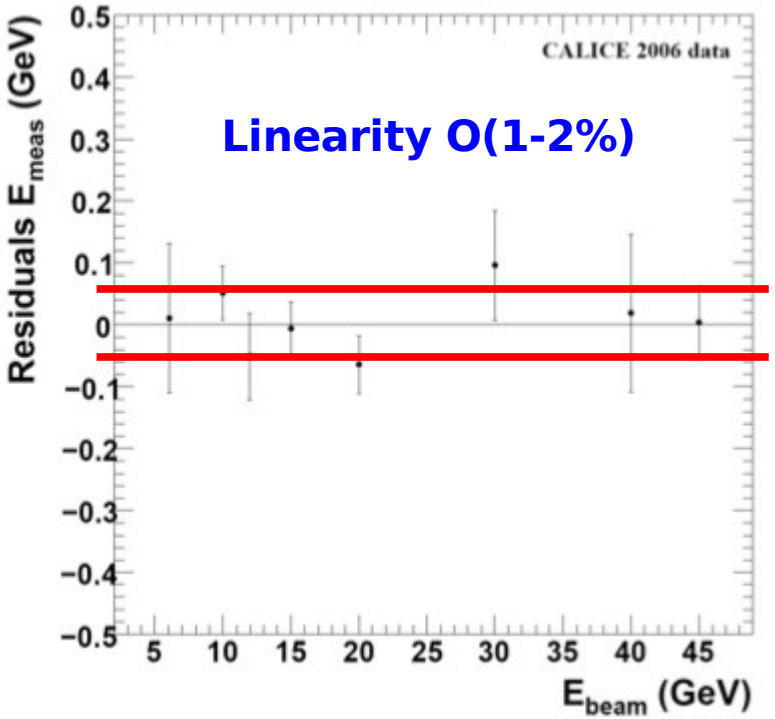
- Detector is optimized for particle separation

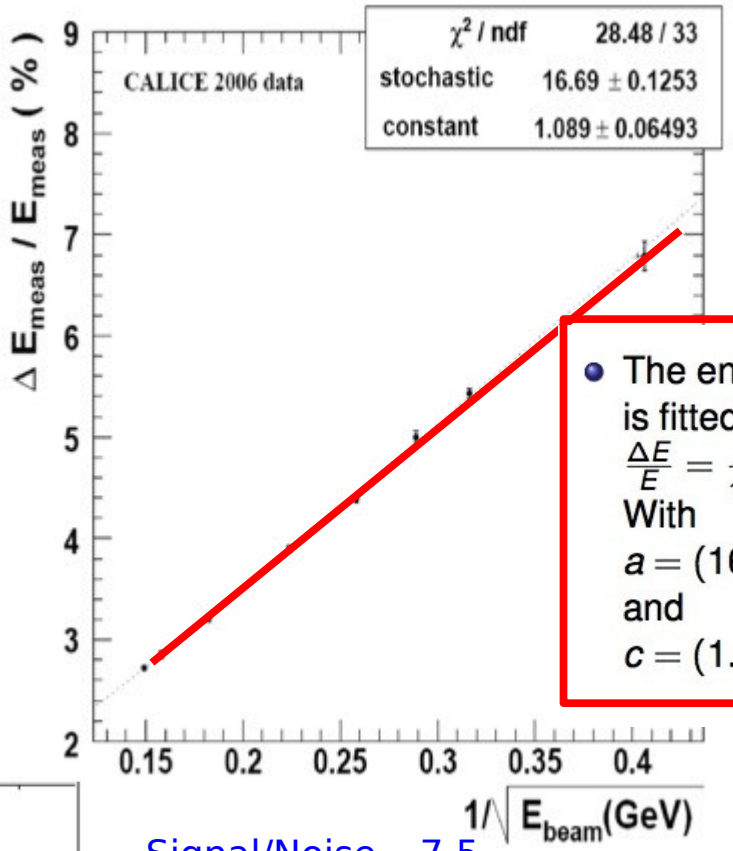


Close by Showers clearly separated

Investigating the Calorimetric Response V – SiW Ecal

Linearity and Resolution





- The energy resolution is fitted by :

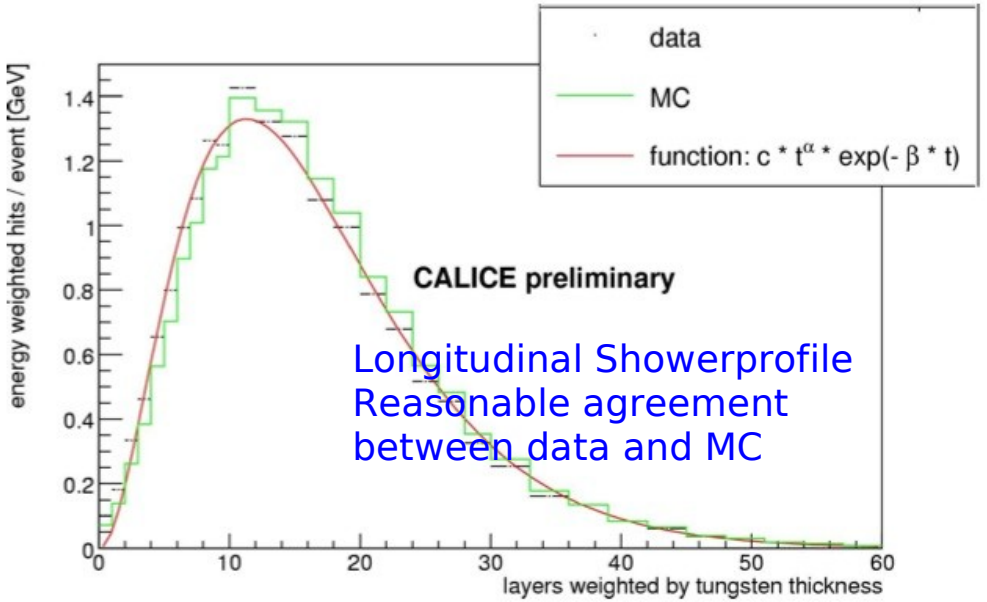
$$\frac{\Delta E}{E} = \frac{a}{\sqrt{E}} \oplus c$$

With

$a = (16.69 \pm 0.13)\,\%$

and

$c = (1.09 \pm 0.07)\,\%$.



Longitudinal Showerprofile
Reasonable agreement between data and MC

Signal/Noise ~7.5

2 papers on
- commissioning (submitted to JINST)
- elm. Response well advanced

- analysis of response to hadrons started

- Testbeam campaigns together with AHCAL between 2006 and 2008

June 2008

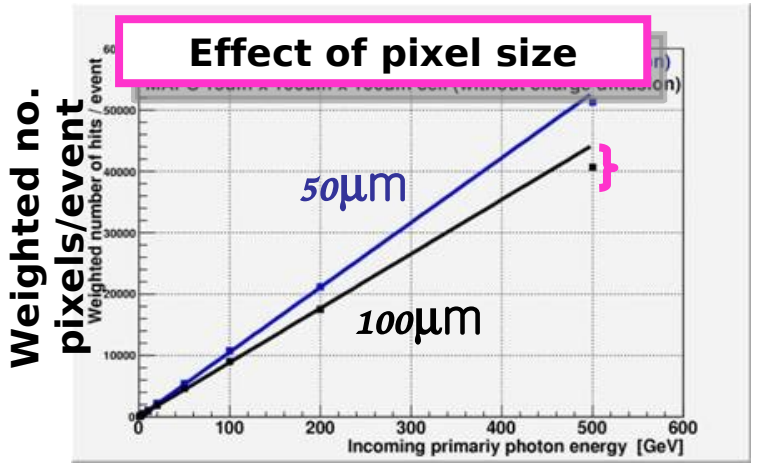
-Campaign with DHCAL envisaged

Going to Extremes – 'Calorimetry' with MAPS

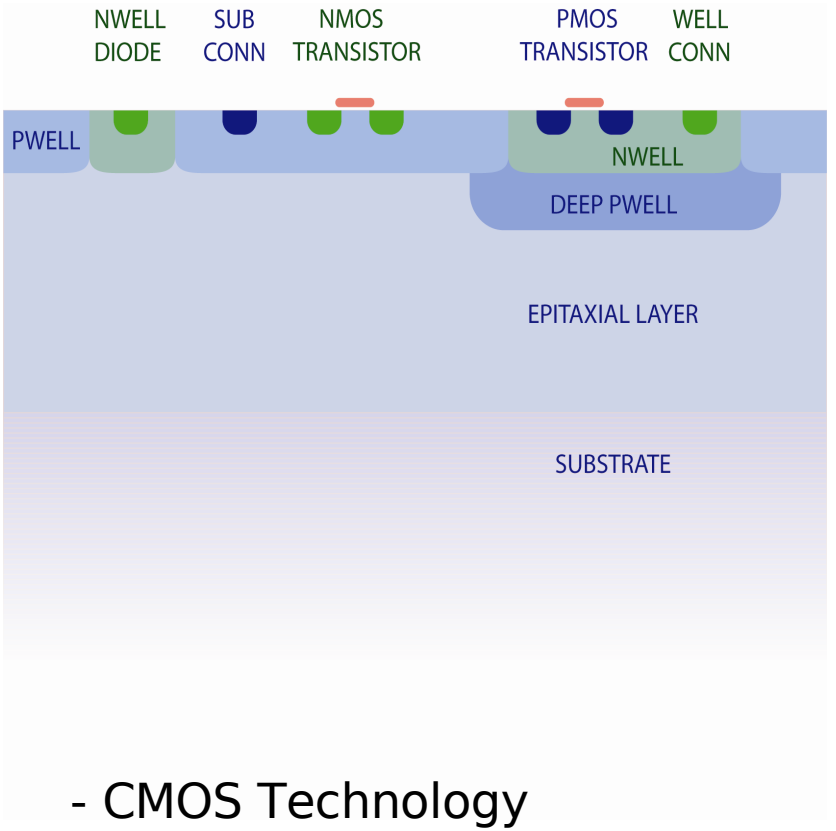
- At 500 GeV, shower core density is ~100/mm² (1 particle per 100 x 100 μ m²)

  pixel size = 50 x 50 μm² ensures a low probability of >1 hit in pixel.

Ultra Pixelization -> Preserving PFA idea at 'CLIC' energies



MAPS Sensor

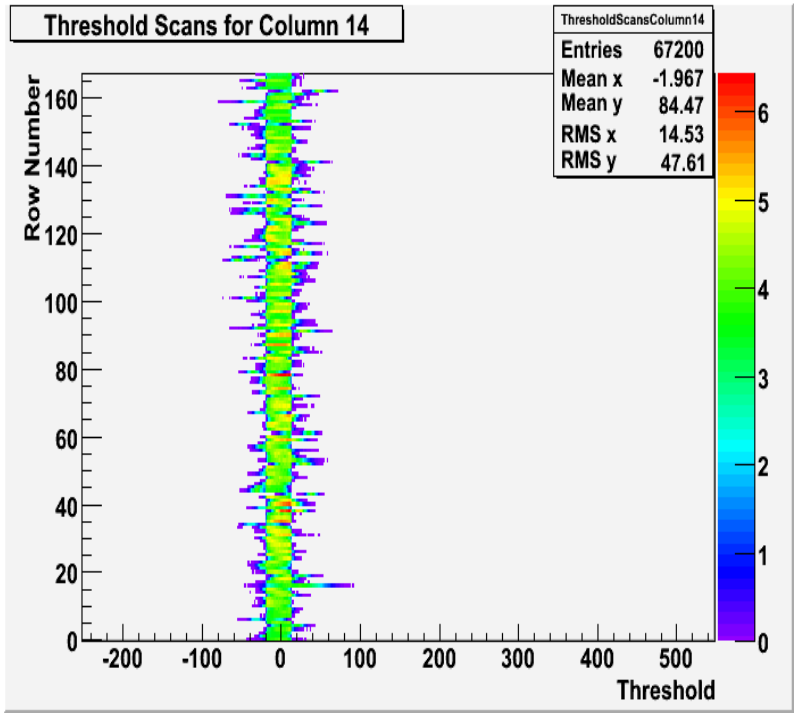


- CMOS Technology
- Charge Collection in N Wells
- Collection by diffusion not drift

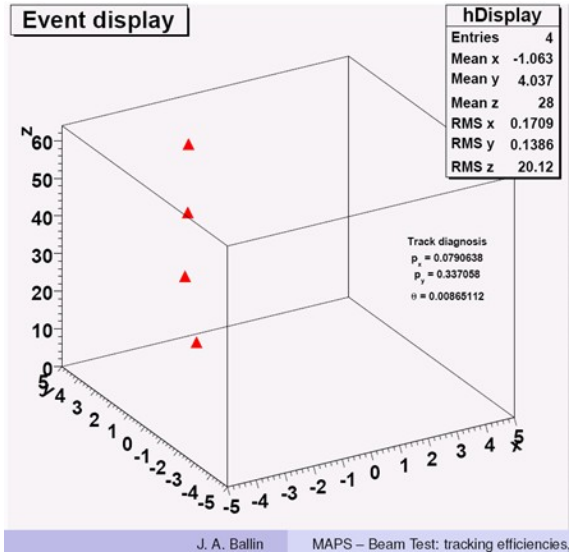
MAPS Technology – First Testbeam

Challenge: Obtain same threshold for all pixels

Threshold Scan



Reconstructed Tracks



Rare but present

Pixel cross talk enhance noise

-> Difficult to reconstruct particle tracks

Optimization of threshold trimming needed

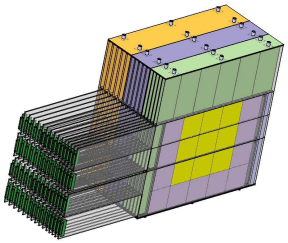
First Steps towards mastership of MAPS for calorimeters

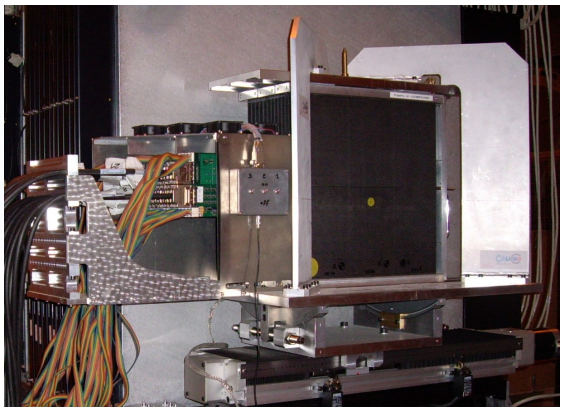
What's next ?

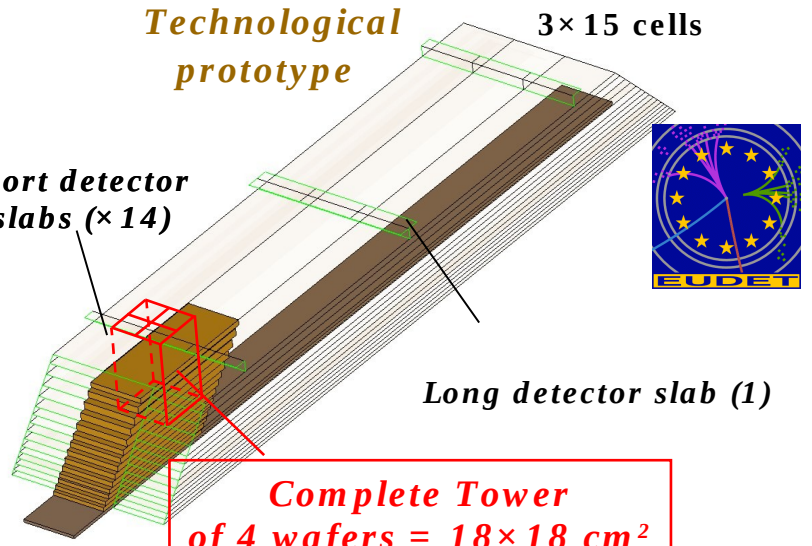
Steps towards the real detector

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





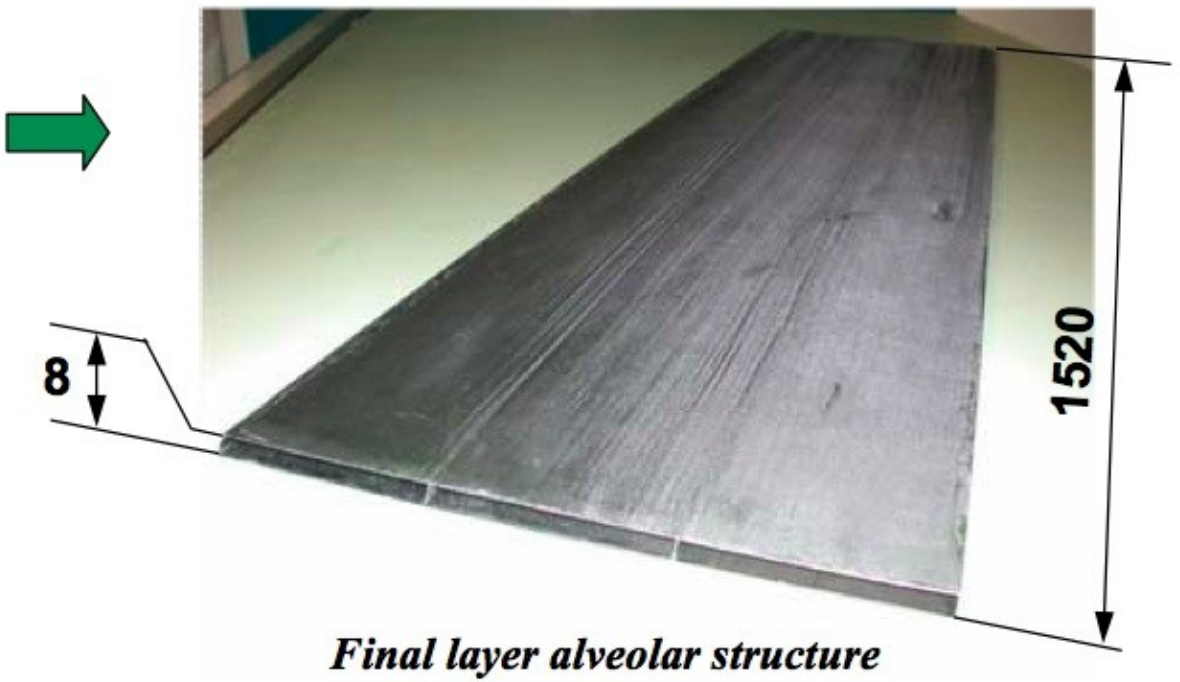


- **3 structures : 24 X_0 (10×1,4mm + 10×2,8mm + 10×4,2mm)**
- **sizes : 380×380×200 mm3**
- **Thickness of slabs : 8.3 mm (W=1,4mm)**
- **VFE outside detector**
- **Number of channels : 9720 (10×10 mm²)**
- **Weight : ~ 200 Kg**

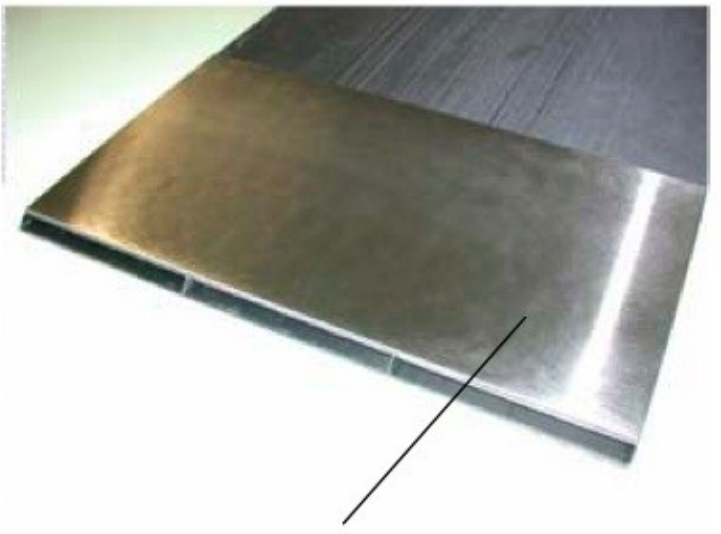
- **1 structure : ~ 23 X_0 (20×2,1mm + 9×4,2mm)**
- **sizes : 1560×545×186 mm3**
- **Thickness of slabs : 6 mm (W=2,1mm)**
- **VFE inside detector**
- **Number of channels : 45360 (5×5 mm²)**
- **Weight : ~ 700 Kg**

Building the first real pieces

First alveaolar structure produced



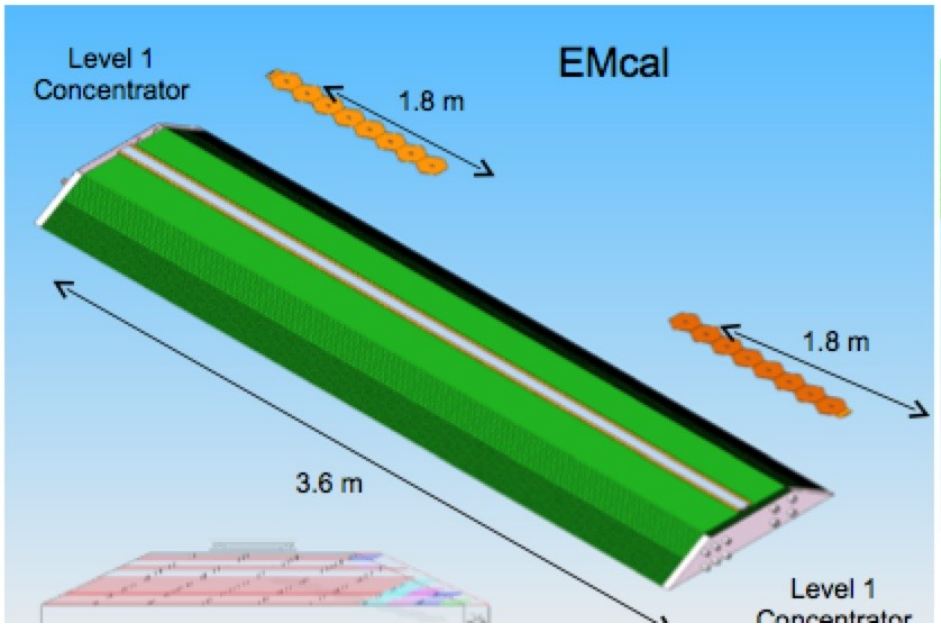
Final layer alveolar structure

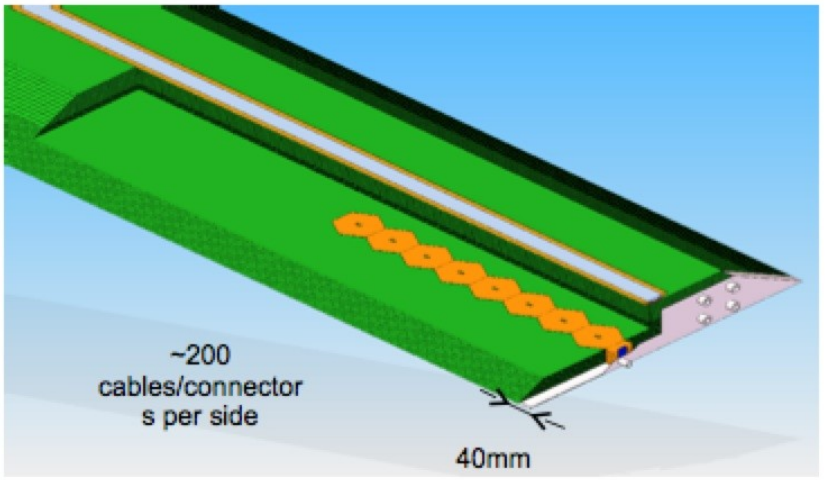


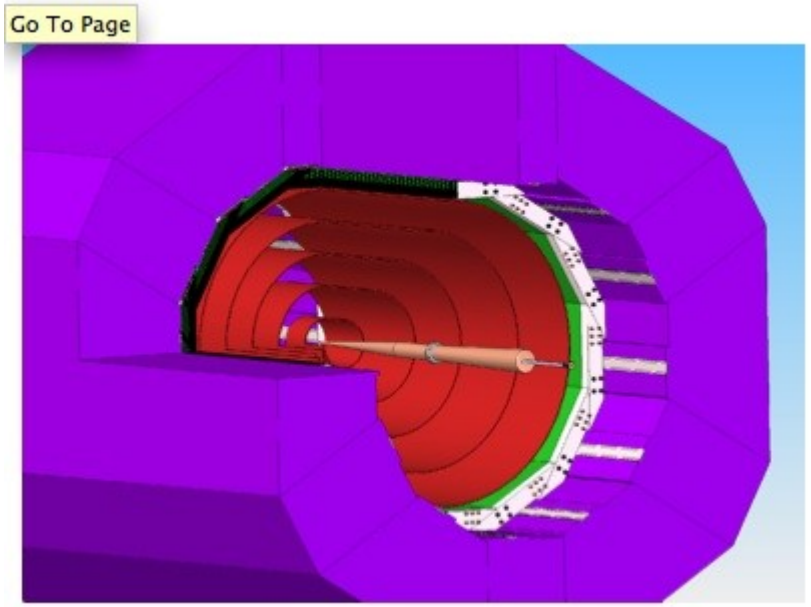
W plate (2.1 mm thick)

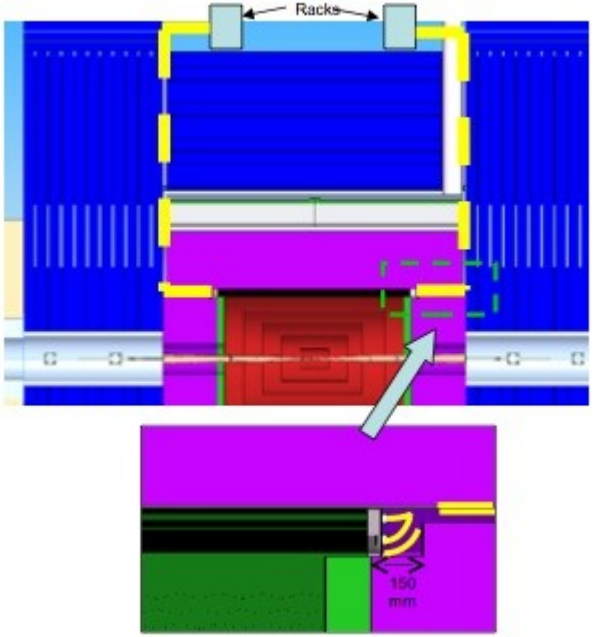
EUDET Ecal Module aims mainly towards integration into ILD detector

Ecal Integration into SiD Detector



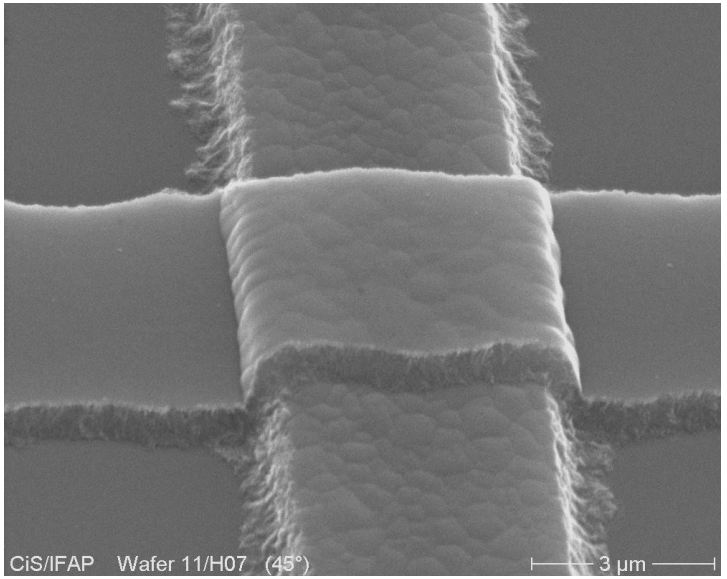






Detector Integration studies are ongoing in all three studies

Simplifying SiPMs?

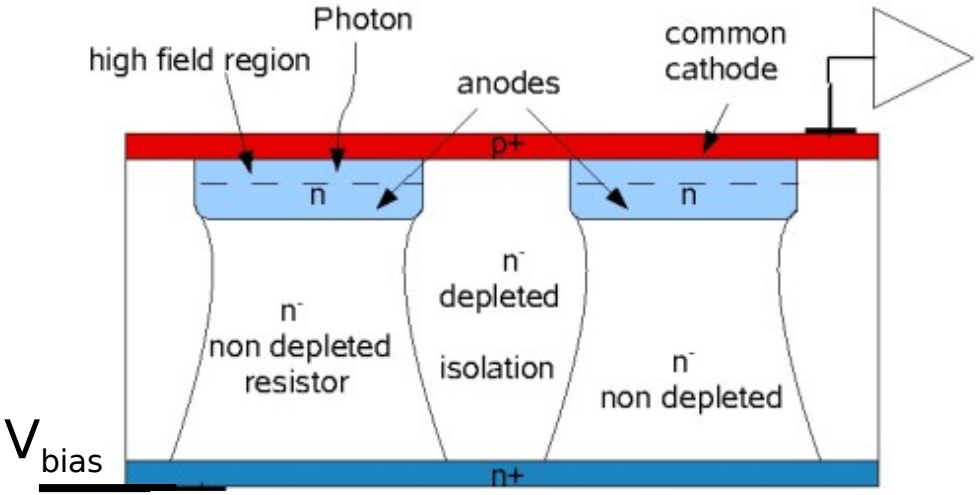


Polysilicon sheet resistor under the microscope

This resistor sheet has been identified as an unreliable piece in the chain and as a

COST DRIVER

Can one simplify the implementation ?



'SIMPL'

Main idea common cathode and anode

- Pixelization below cathode

Reducing cost and increase reliability is key issue (not only) for analogue HCAL technology

R&D for mass production of SiPM's

Conclusions

- Calorimeter R&D is wide field of efforts

- Calorimeter R&D for the ILC delivers first very interesting testbeam results
  - First steps towards PFA with real data
  - Compensation by instrumentation with DREAM
  - Ecal's protoypes perform close to expectation

- Getting prepared if the LC energy is to be increased

- Huge collaborative effort leading to large synergies
  e.g. CALICE:
  US-DHCAL, SiW Ecal and ScintEcal on AHCAL stage
  Common DAQ

- Collaborations start to pave the road towards the real detector