Calorimetry at/for the ILC

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LAL Orsay

Facts and Trends at TILC 2009

- Introduction
- The Ecal Landscape
- The Hcal Landscape
- Towards “real” detectors
- Summary and Conclusion

Detector Concepts and Calorimeter R&D

	ILD	SiD	4th concept
CALICE Calorimeter for ILC	X	X	
DREAM			X
SiD Ecal Group		X	

Calorimeter R&D organized in Collaborations beyond concept boundaries

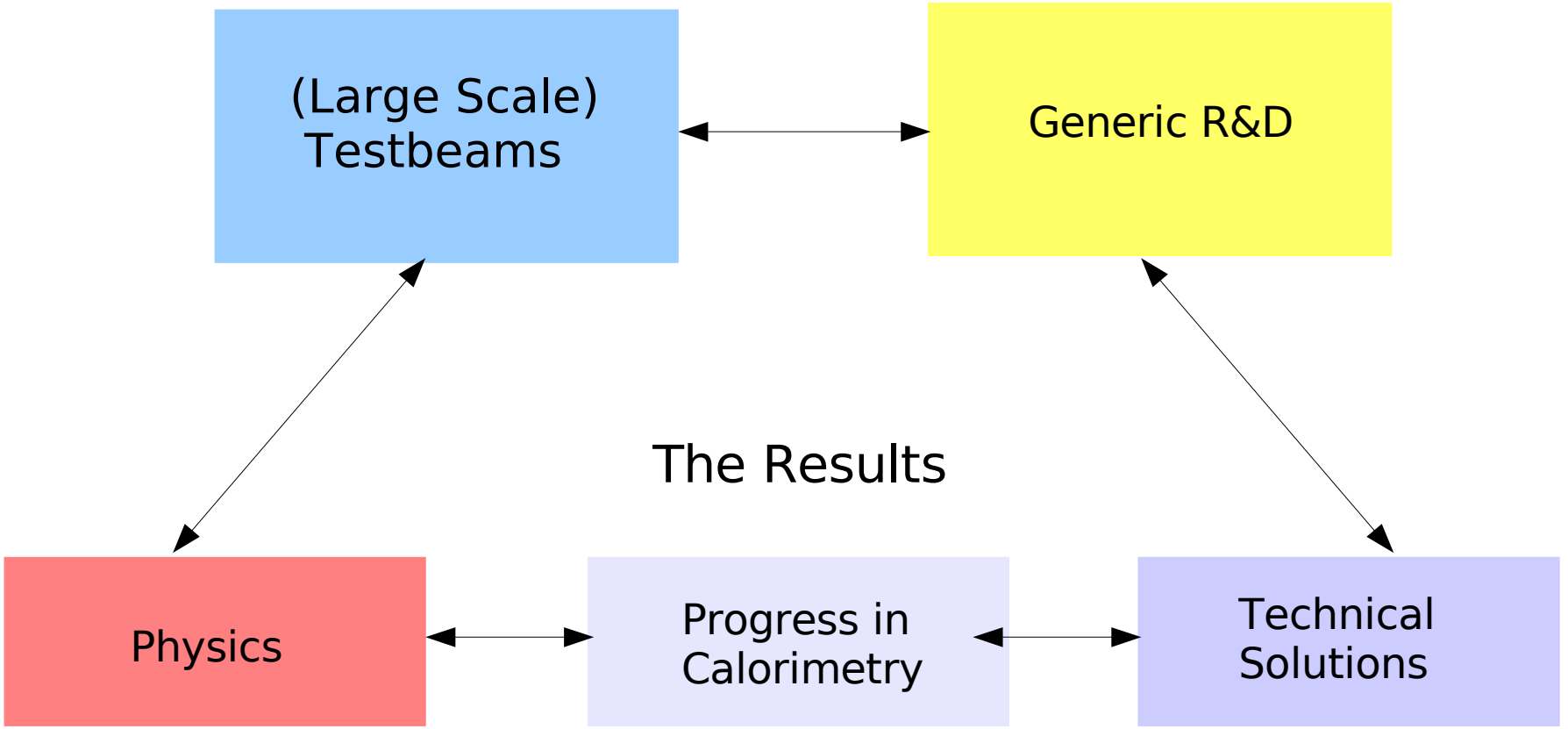
New horizontal approach in Dual Calorimetry?

The Calo Machinery

The driving force

ILC Physics and
Detector Optimization

The Programs



All issues addressed in Calorimeter Development for the ILC

The Ecal Landscape

Calorimeter for Energy measurement:

Xtal Calorimeter (BGO)
R&D within DREAM and ?

An Ecal for the ILC

Calorimeter for Particle Flow:

Scint/W Ecal

SiW Ecal

MAPS Ecal

R&D within CALICE

R&D within SiD

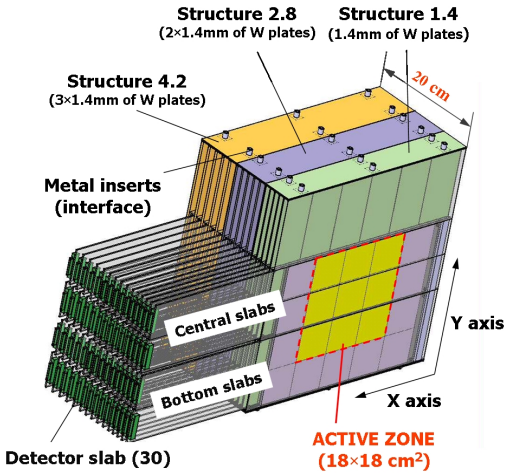
R&D within SiD and CALICE

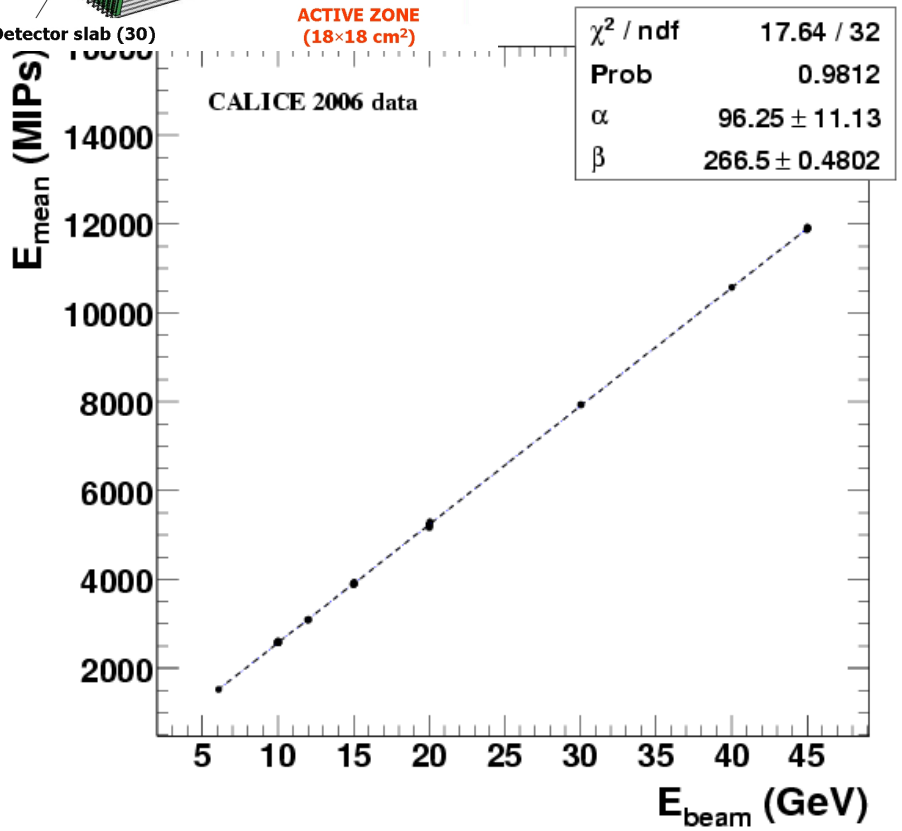
r/o by 'ROC' type Chips or predecessors

r/o by kPIX Chip

r/o under design

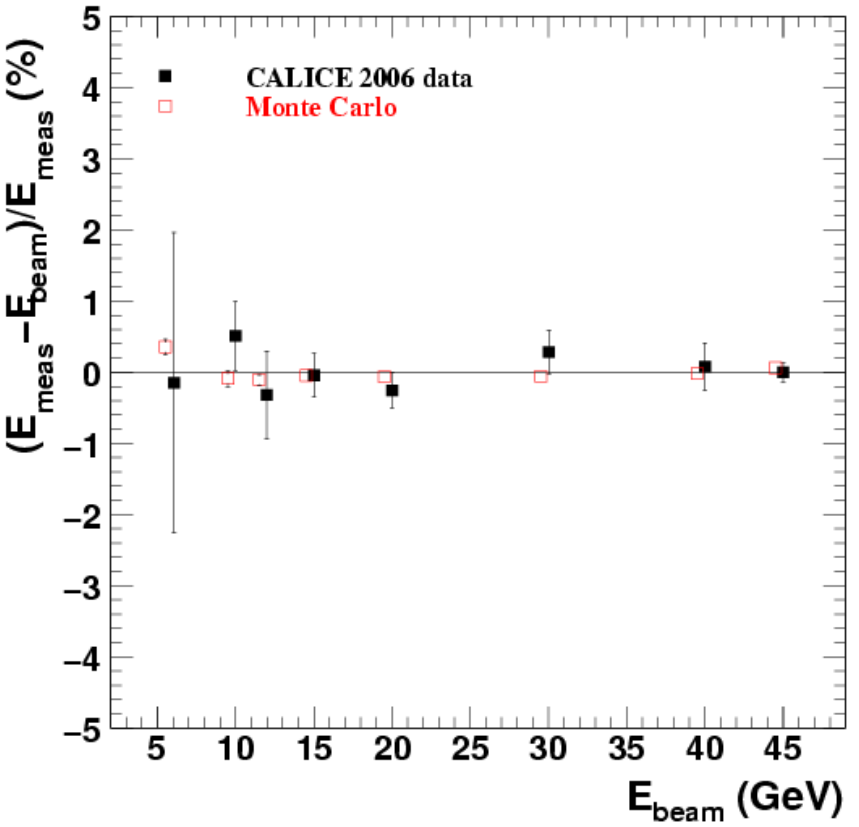
CALICE SiW Ecal – Testbeam Results





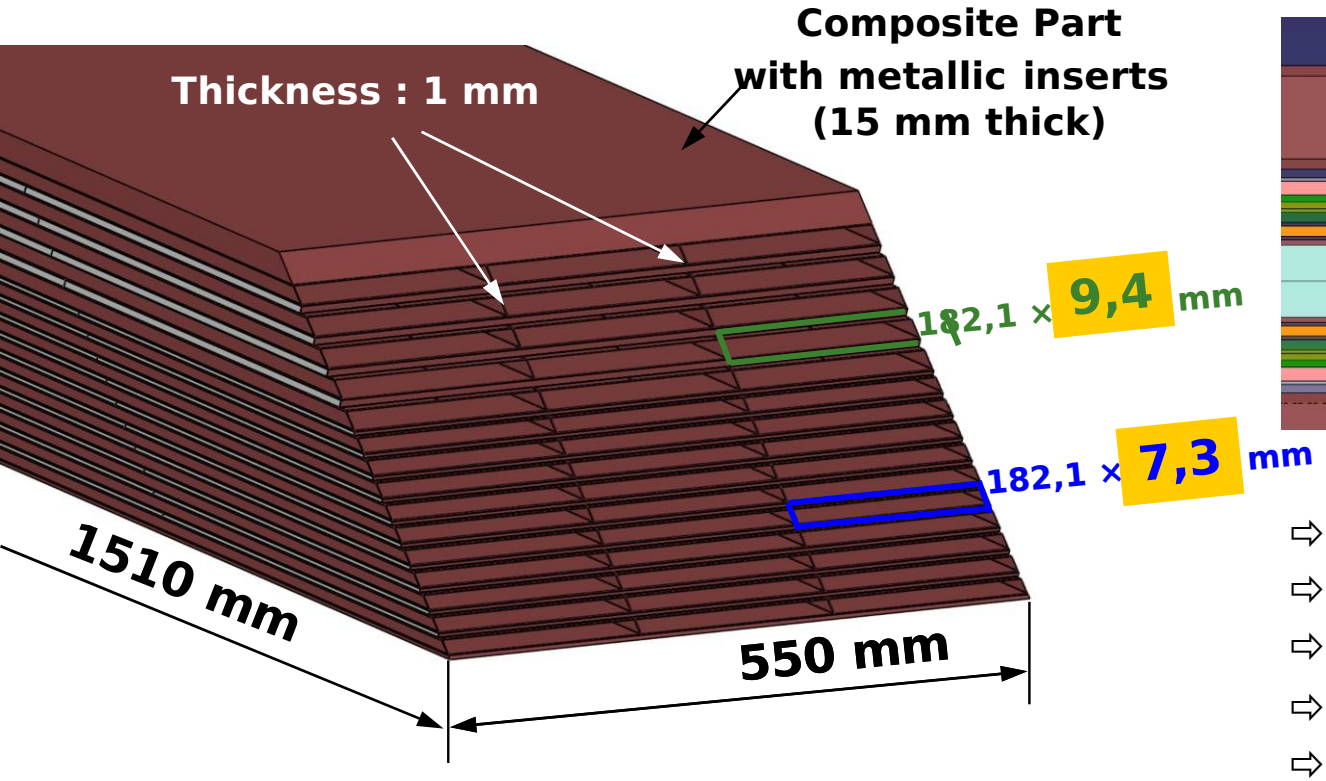
Good linearity over a large energy range

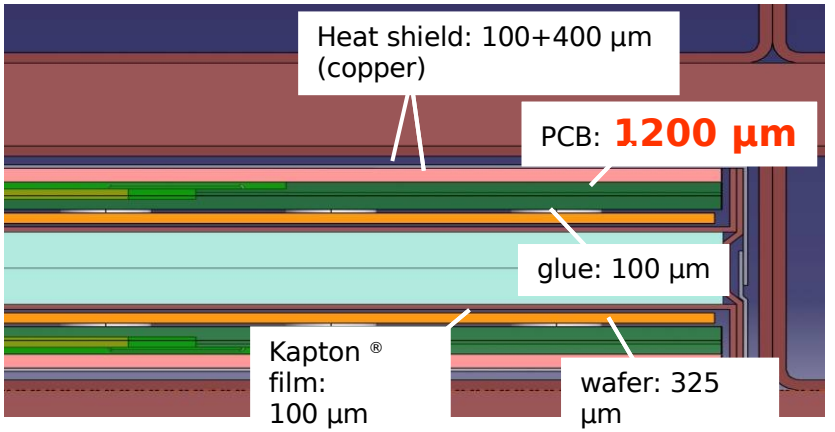
Good agreement between data and MC



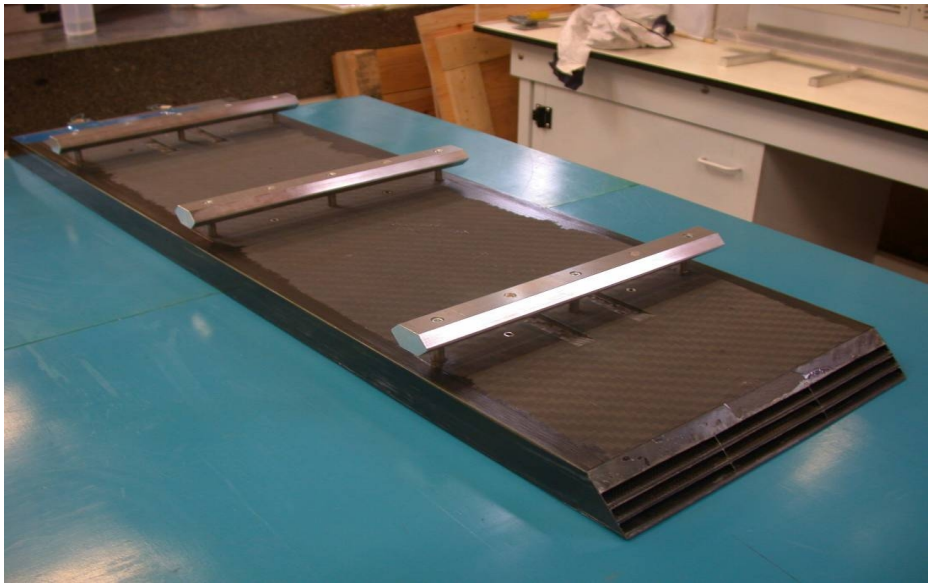
Linear response within 1%

Module EUDET – Current Design (final)

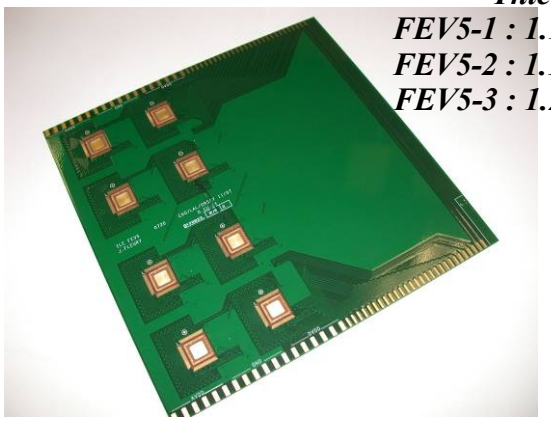




- ⇨ Gaps (slab integration) : 500 µm
- ⇨ Heat Shield: **400 µm ?**
- ⇨ PCB : 800 µm **~1200 µm**
- ⇨ Thickness of Glue : 100 µm
- ⇨ Thickness of SiWafer : 325 µm
- ⇨ Kapton® film HV : **100 µm ?**
- ⇨ Thickness of W : 2100/4200 µm (± 80 µm)

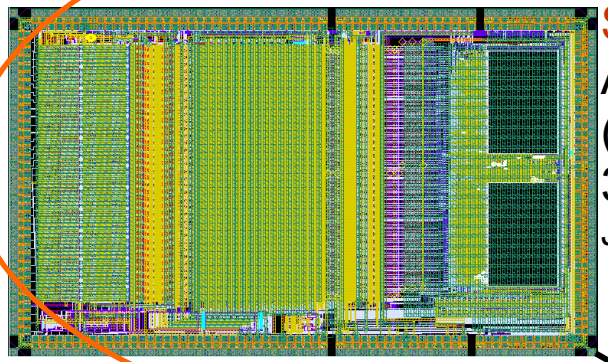


Thickness :
FEV5-1 : 1.17mm (+-0.04)
FEV5-2 : 1.19mm (+-0.04)
FEV5-3 : 1.20mm (+-0.02)

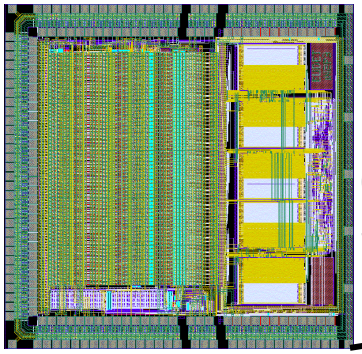


Very Front End Electronics: The ROCs

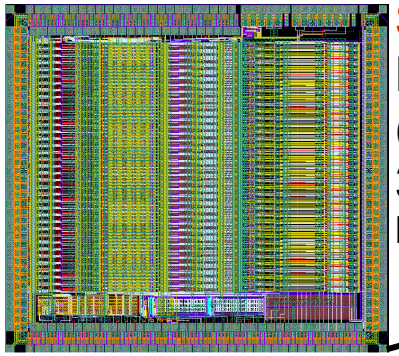
- EUDET Prototypes: large scale (~2m)
- Partially funded by EU (06-09)
- ECAL, AHCAL, DHCAL



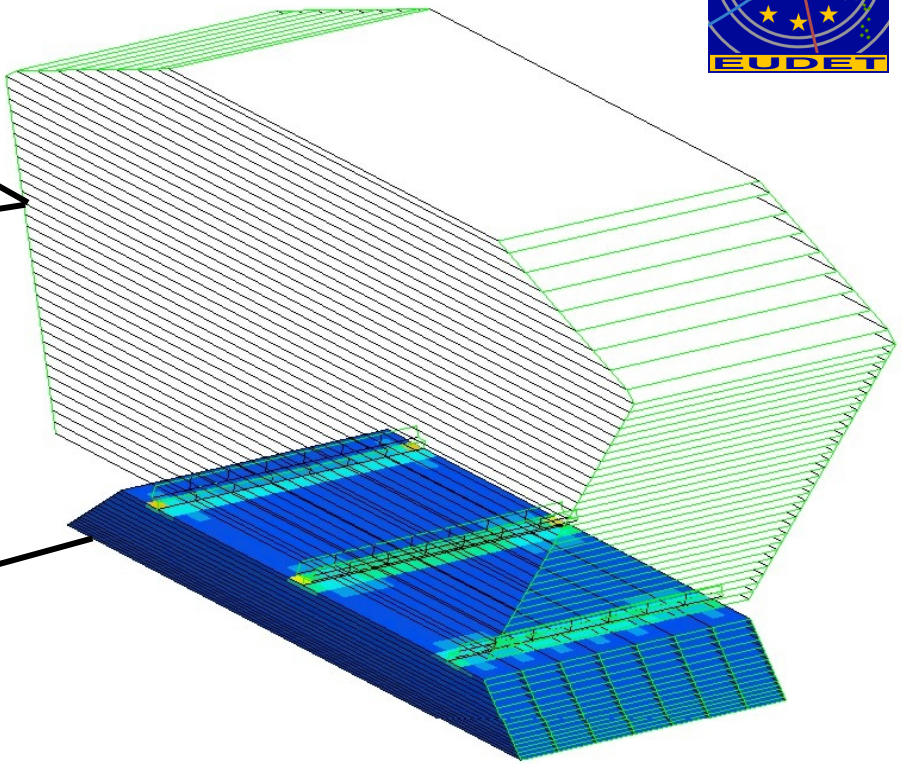
SPIROC
Analog HCAL
(SiPM)
36 ch. 32mm²
June 07



HARDROC
Digital HCAL
(RPC, μmegas or GEMs)
64 ch. 16mm²
Sept 06

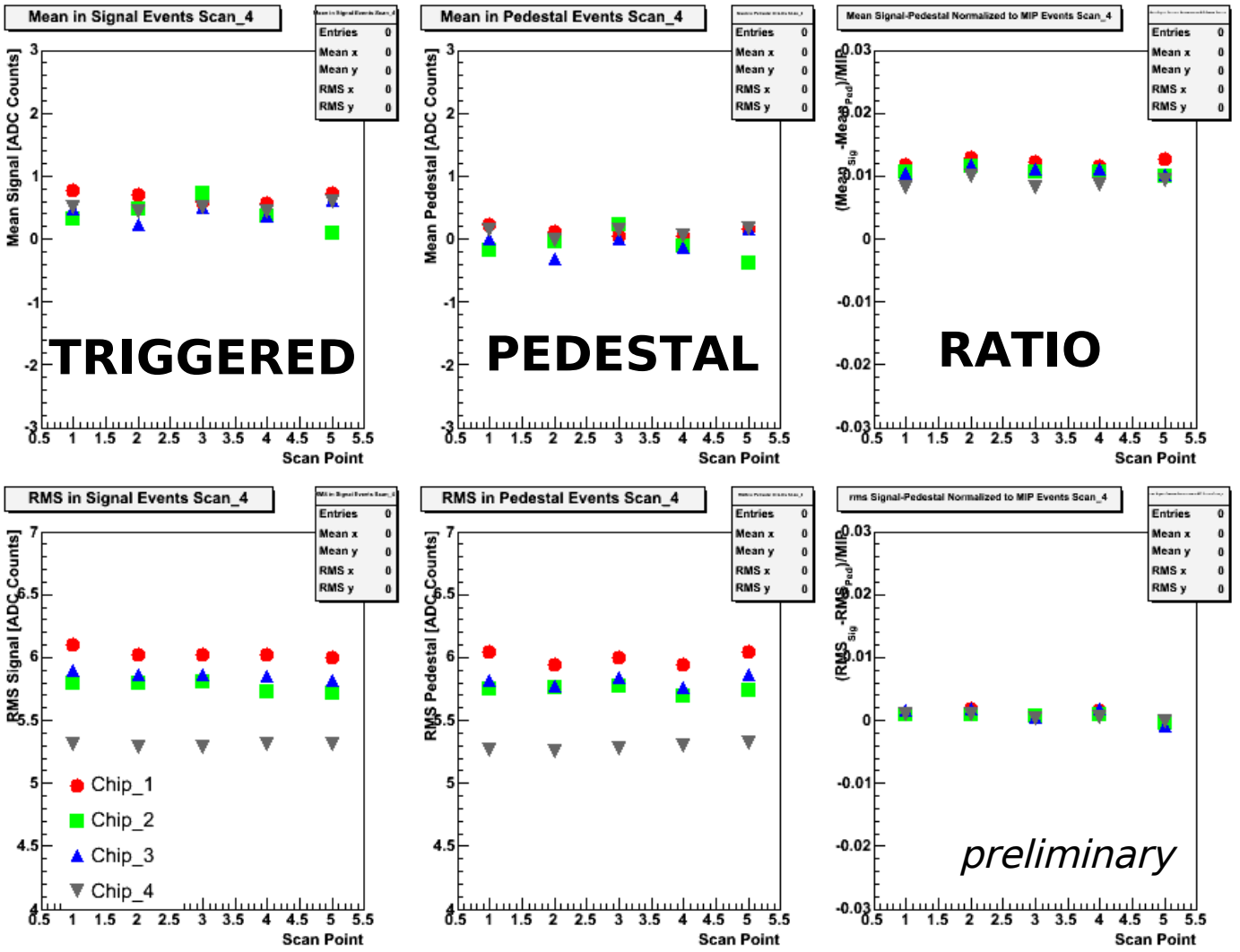


SKIROC
ECAL
(Si PIN diode)
36 ch. 20mm²
Nov 06



VFE exposed to shower – Parasitic Effects?

Beam Test with VFE integrated in Detector Layers



Scan of chip 4

Mean

Global effect of 1% of MIP

RMS

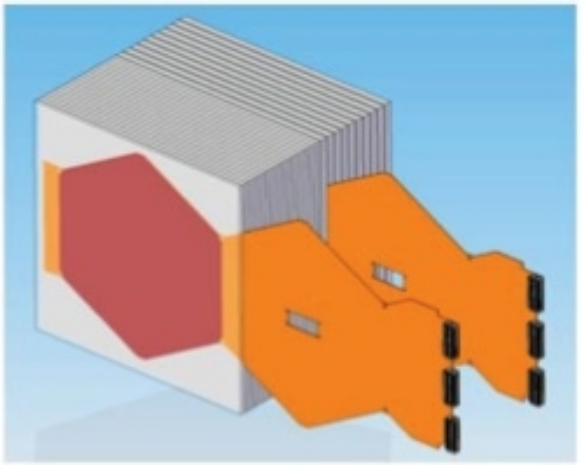
Global effect of <0.5% of MIP

No dependency on scan position visible

No evidence for parasitic effects

Prototype for SiD Ecal – Testbeam plans

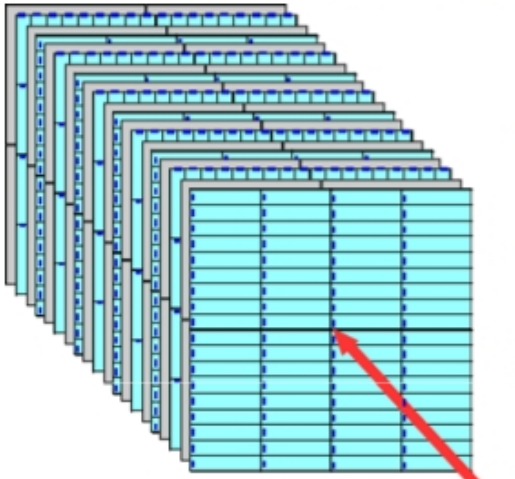
- For both options the aim is to produce a stack
- For the baseline
  - 30 layers with KPix
  - requires 1024 channel KPix
  - 30720 channel
  - Using steel to mechanical concept
- The MAPS option plans
  - 16 layers
  - 64 million channels
- Both plan to be done 2012

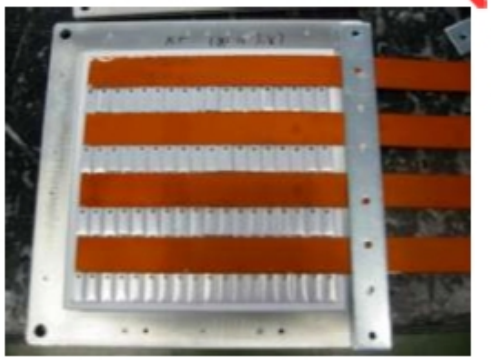


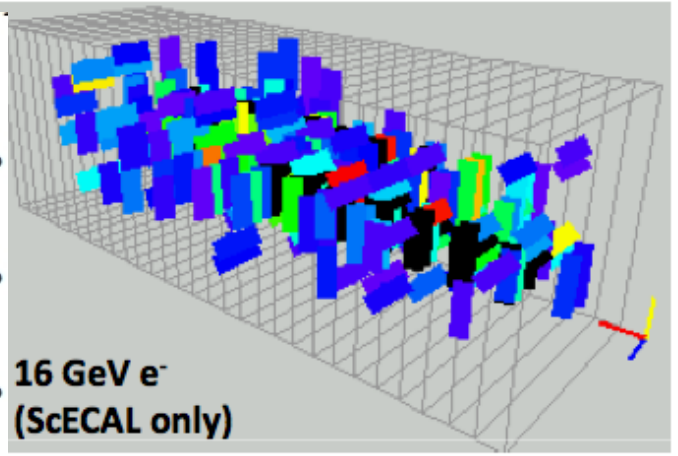
Investigating the Calorimetric Response I – Scintillator Ecal

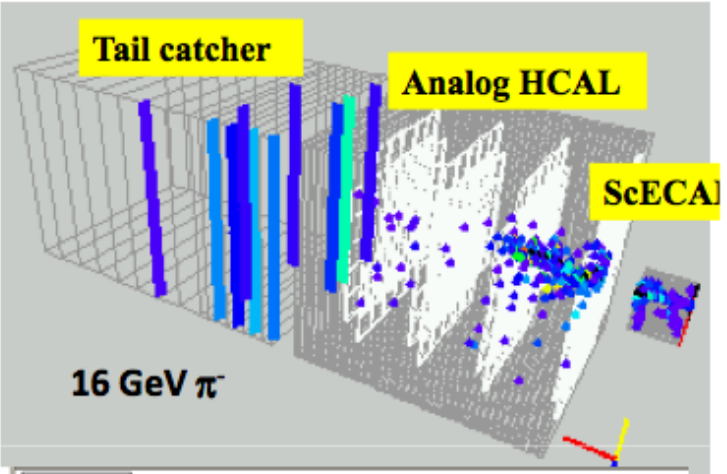
Testbeam FNAL 08

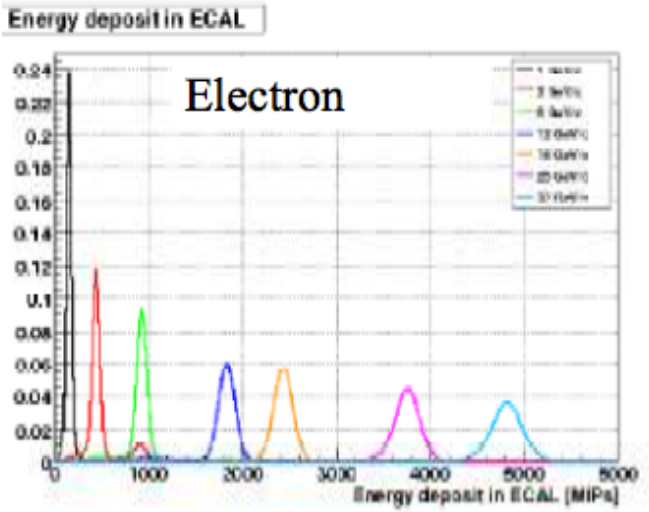
Very Preliminary Results

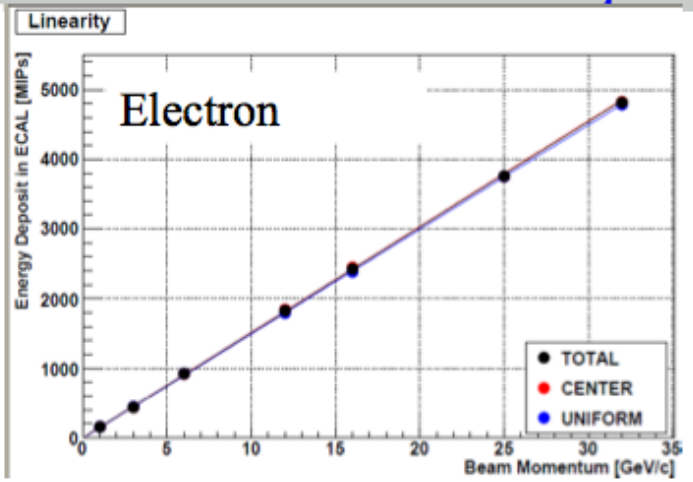








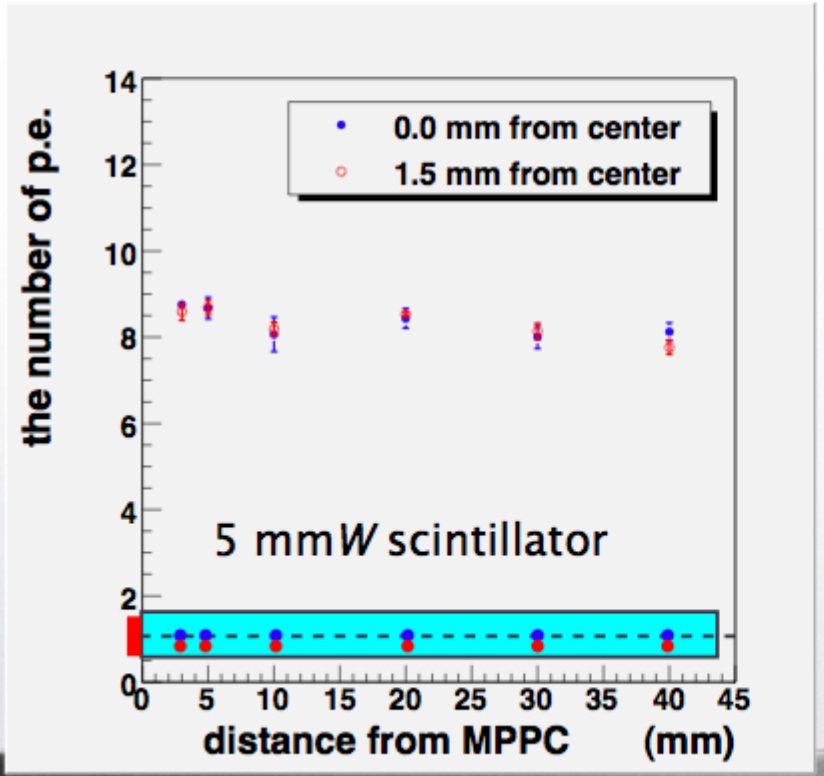


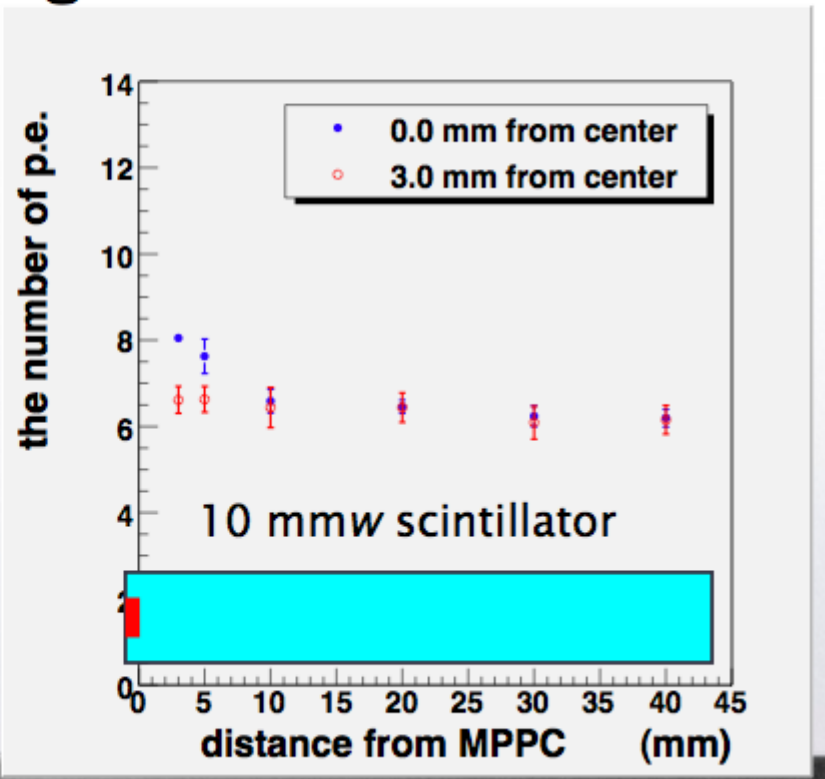


Promising Results

Higher Granularity

- 5mm wide scintillator
- without WLS Fiber
- looks uniform enough





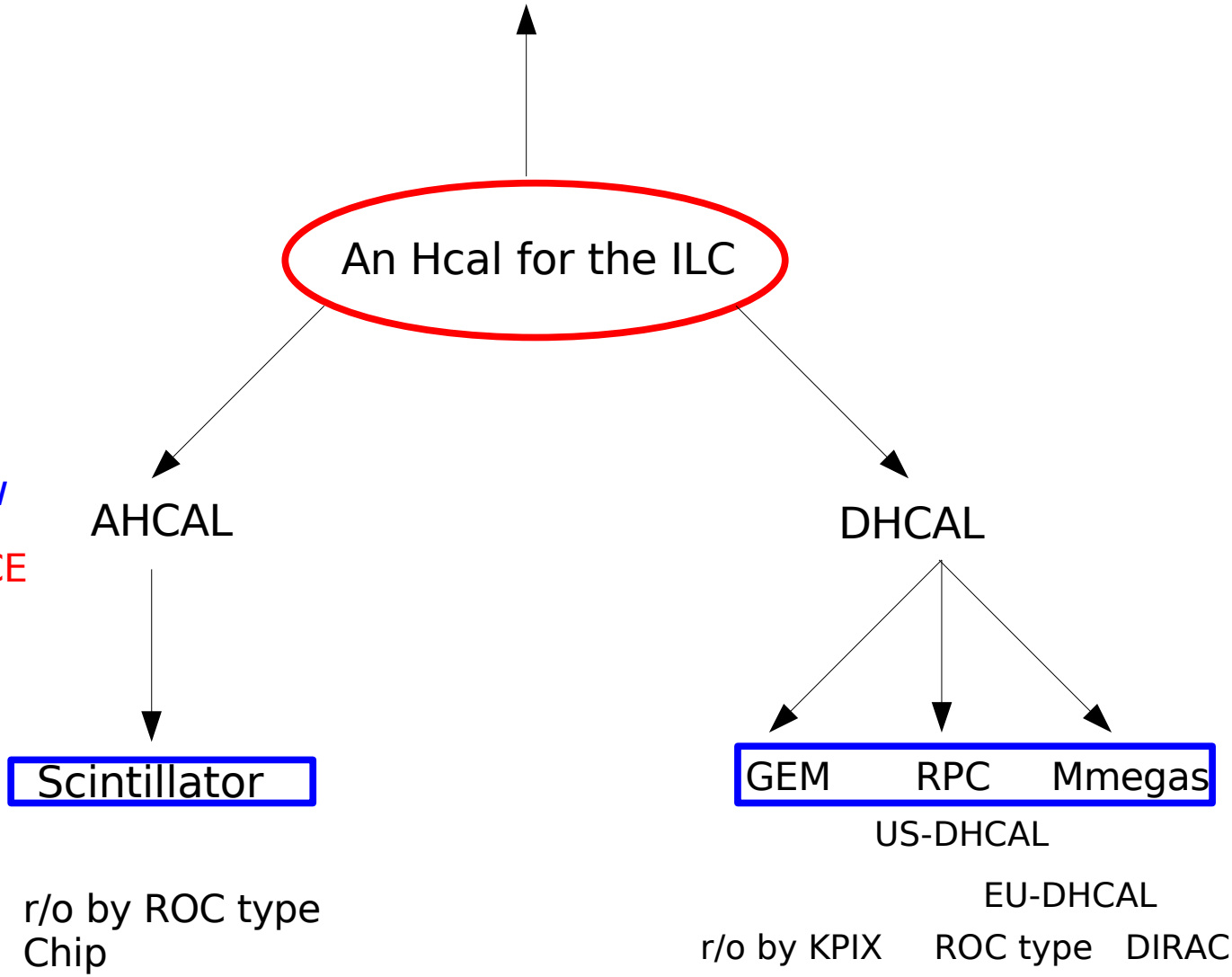
Narrower Strips – Less sensitive to MPPC position

The Hcal Landscape

Dual Readout (BGO)

R&D within DREAM and HRC(?)

Calorimeter for Energy measurement:



Calorimeter for Particle Flow

R&D within CALICE

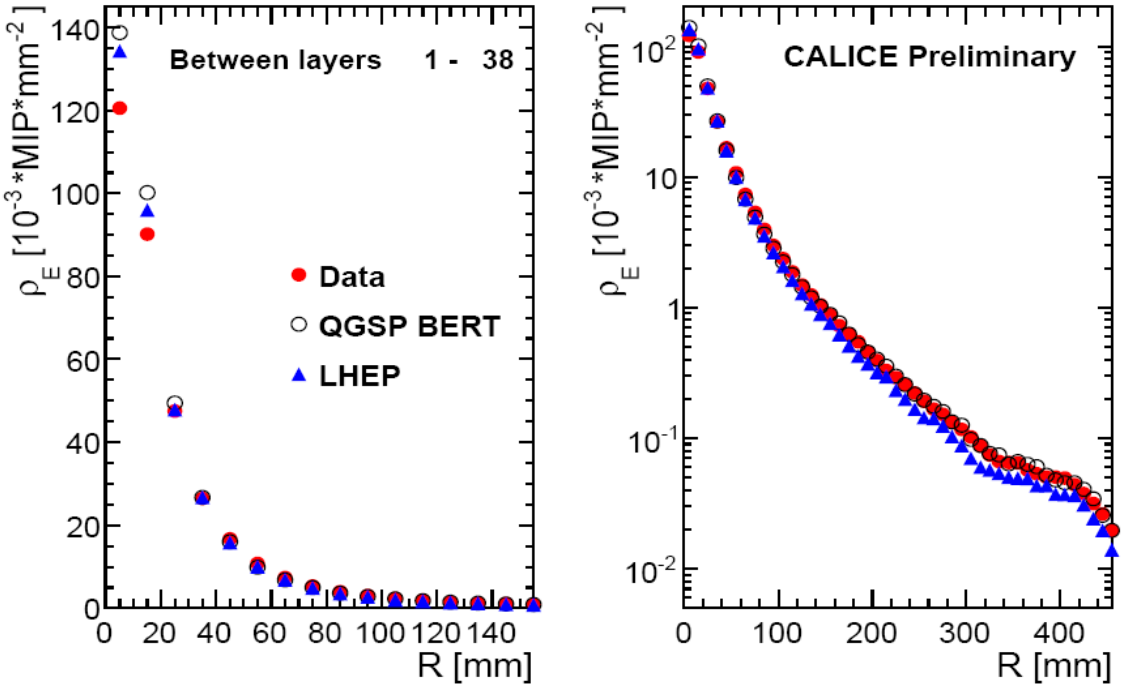
Lot's of interesting R&D – Crowded in the DHCAL branch

Investigating the Calorimetric Response – Scintillator Hcal

Transversal Shower Profiles

- Important shower property for particle flow performance
- New results, 2007 data
- 18 GeV pions, shower start in HCAL

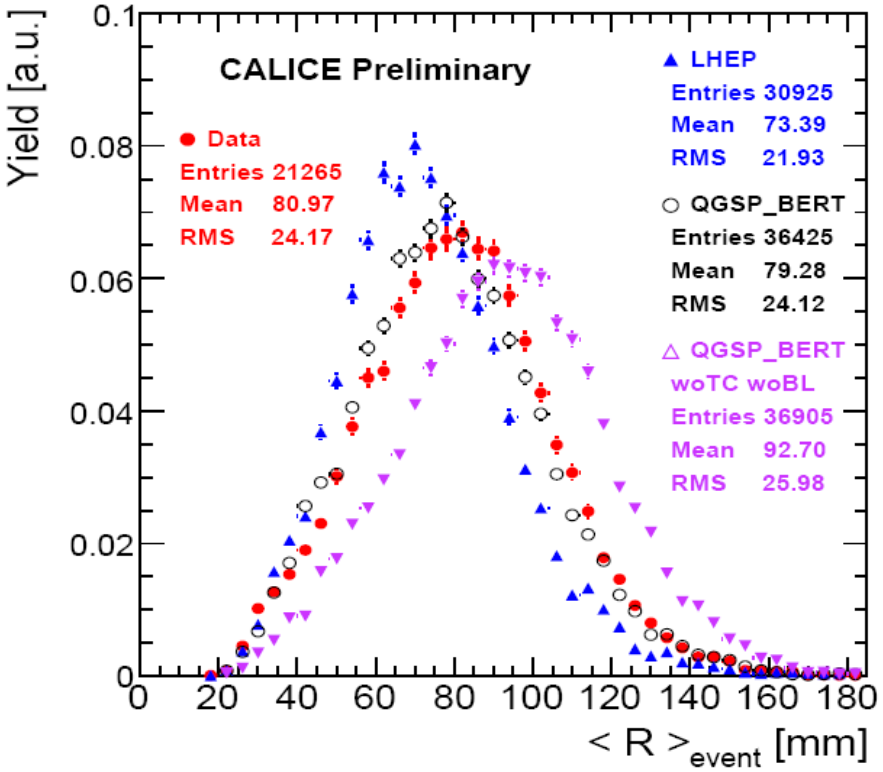
- Extrapolated DC track as reference axis
- Divide HCAL into rings of 10mm witdth
- Energy density: E(MIP) per ring area, summed in depth
- Remark: Need to include Birk's law to reproduce data with MC

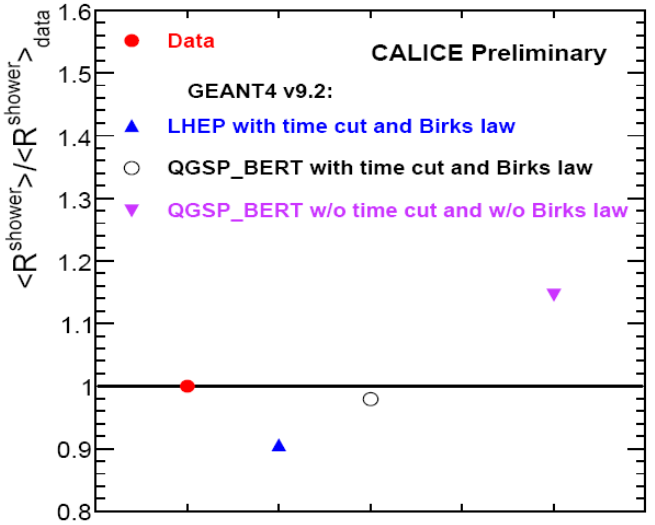


Investigating the Calorimetric Response – Scintillator Hcal

CALICE AHCAL – Mean Shower Radius

$$\langle R \rangle_{event} = \frac{\sum_i E_i \cdot R_i}{\sum_i E_i}$$



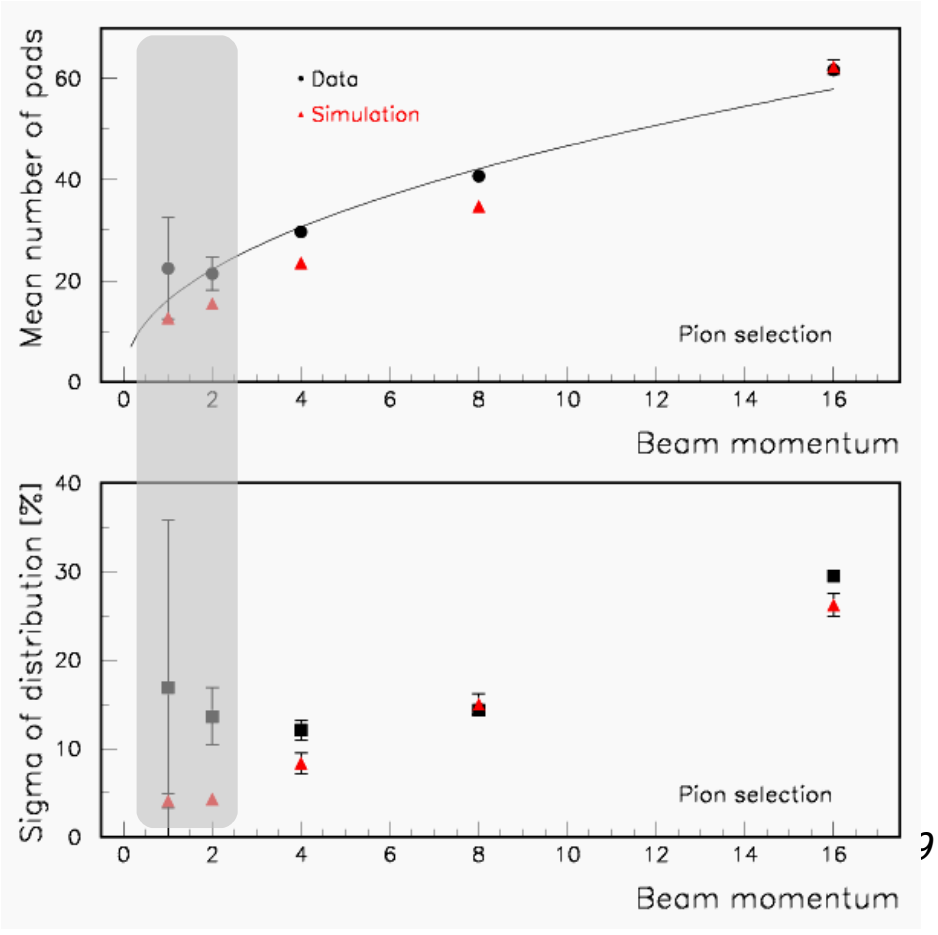


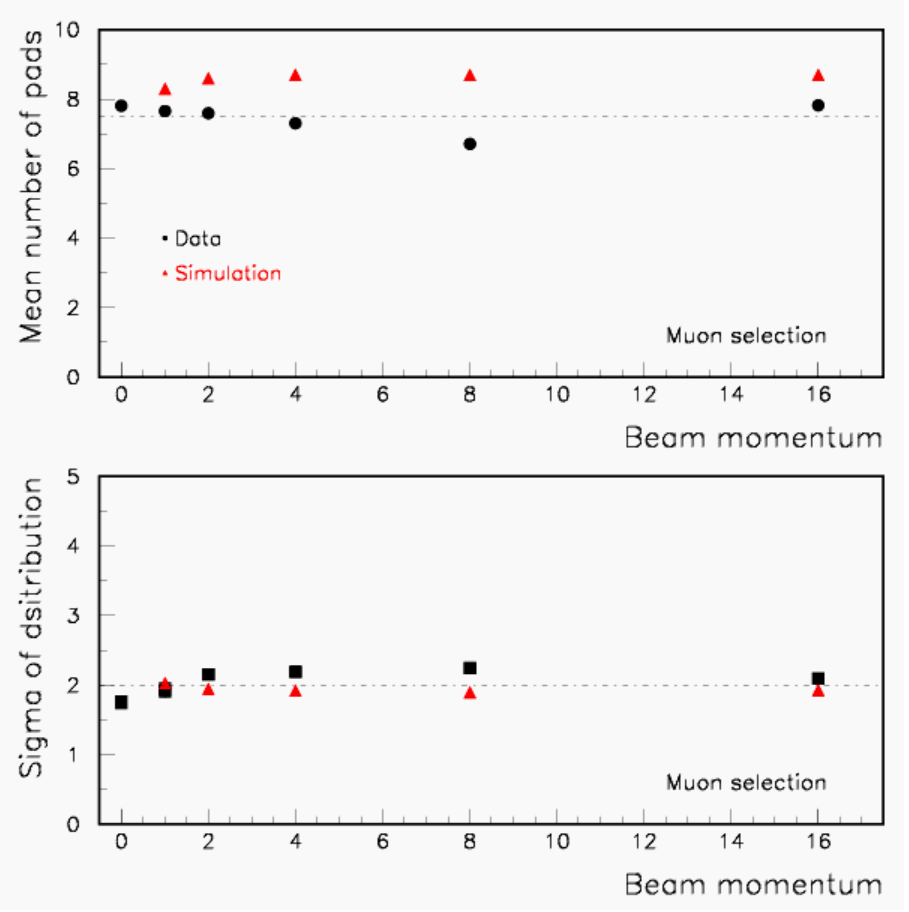
- Mean value and event-to-event fluctuations well described
- Proper treatment of neutrons in shower evolution **and** detector response critical

Investigating the Calorimetric Response – Test with small DHCAL – US 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

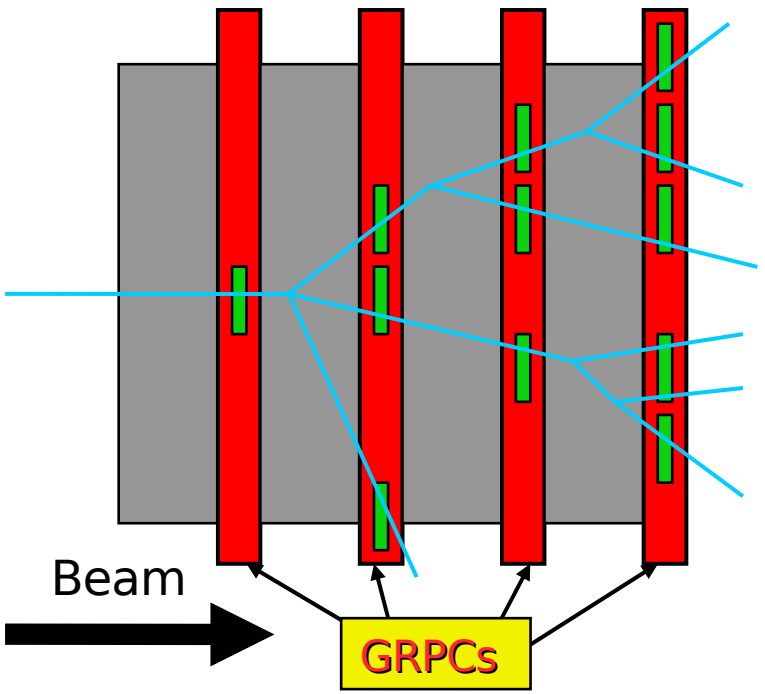


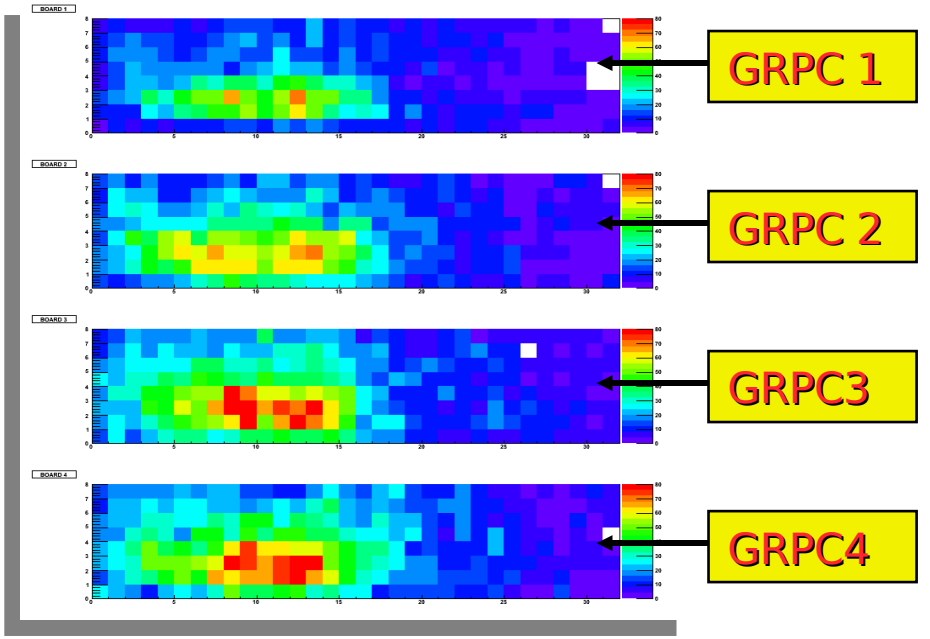


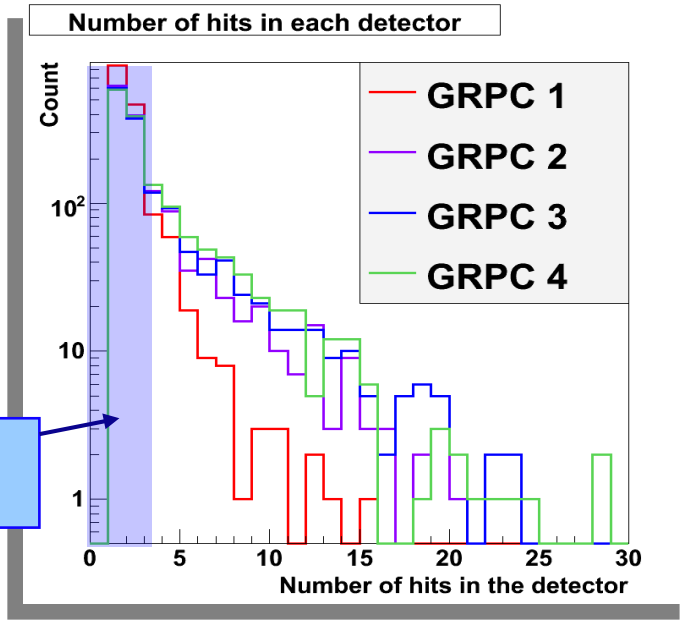
Pion selection

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

Hadronic Showers in EU (Semi)DHCAL







Hadronic showers are mostly uncontained in Mini DHCAL but these profiles give a first idea of shower development and energy deposition.

Muon contamination area

Towards 1m^3 DHCAL protoypes – 1m^2 Test Modules

Larger prototype section needed to

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

R&D in North America

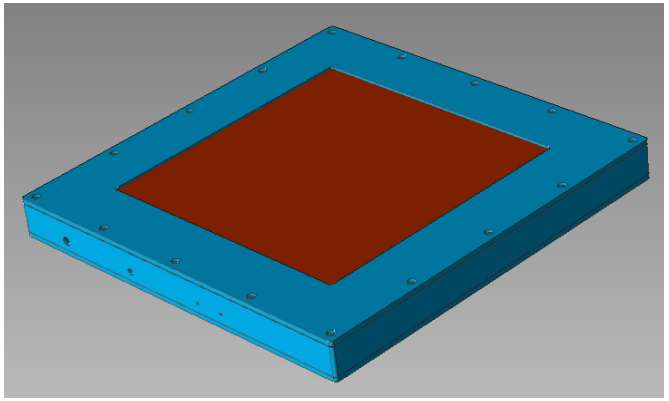
Glass RPC

- Module Production during 2009
- Testbeam with SiW Ecal
- To be installed on stage which currently houses AHCAL

GEM

-2nd Gener.VFE HARDROC

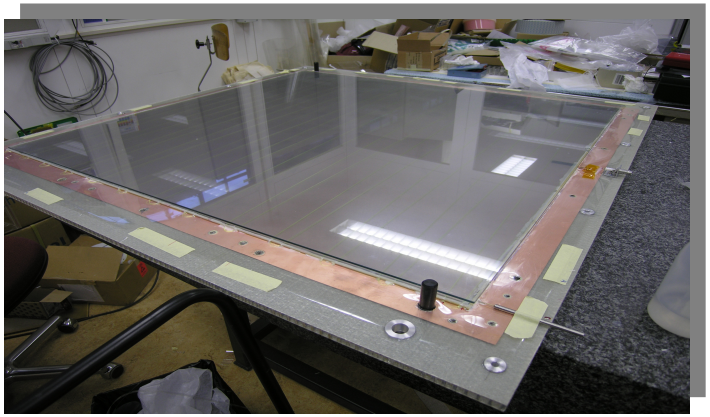
- New technique for GEM holes



R&D in Europe

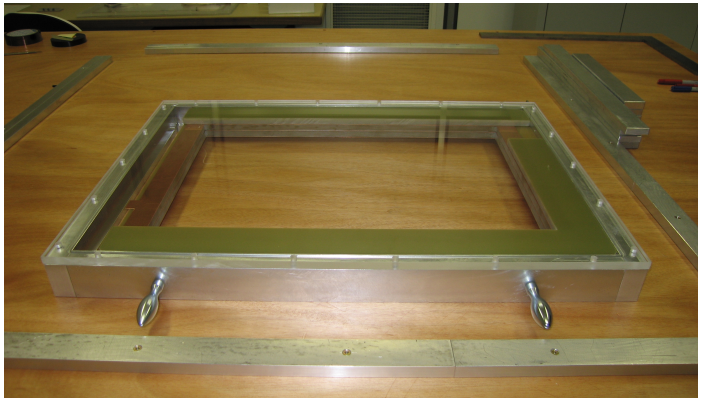
Glass RPC

2nd Gener.VFE HARDROC



Micromegas

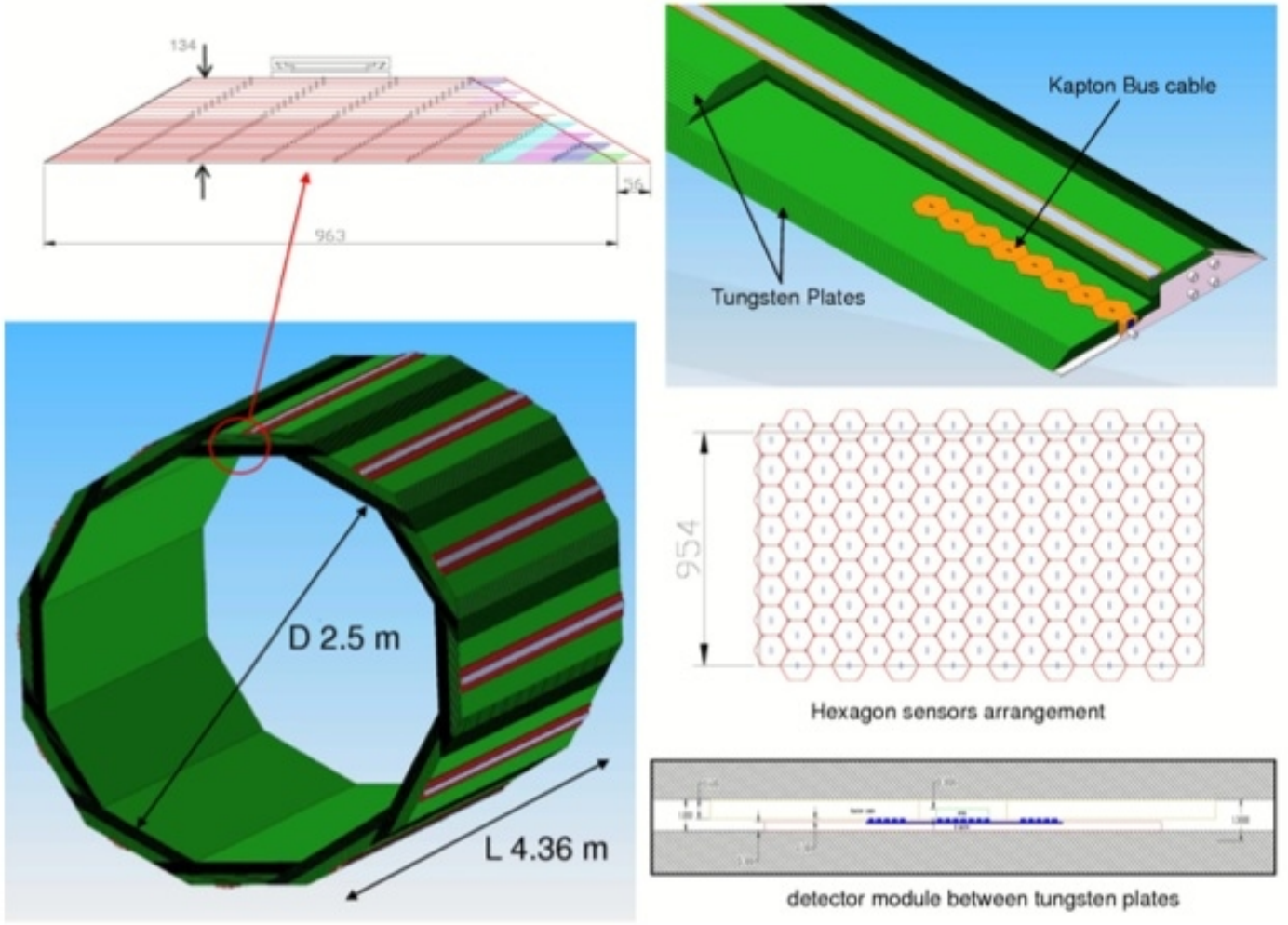
2nd Gener.VFE HARDROC, DIRAC



Exploration of 'technology matrix' within CALICE collaboration

Construction of SiW Ecal for SiD

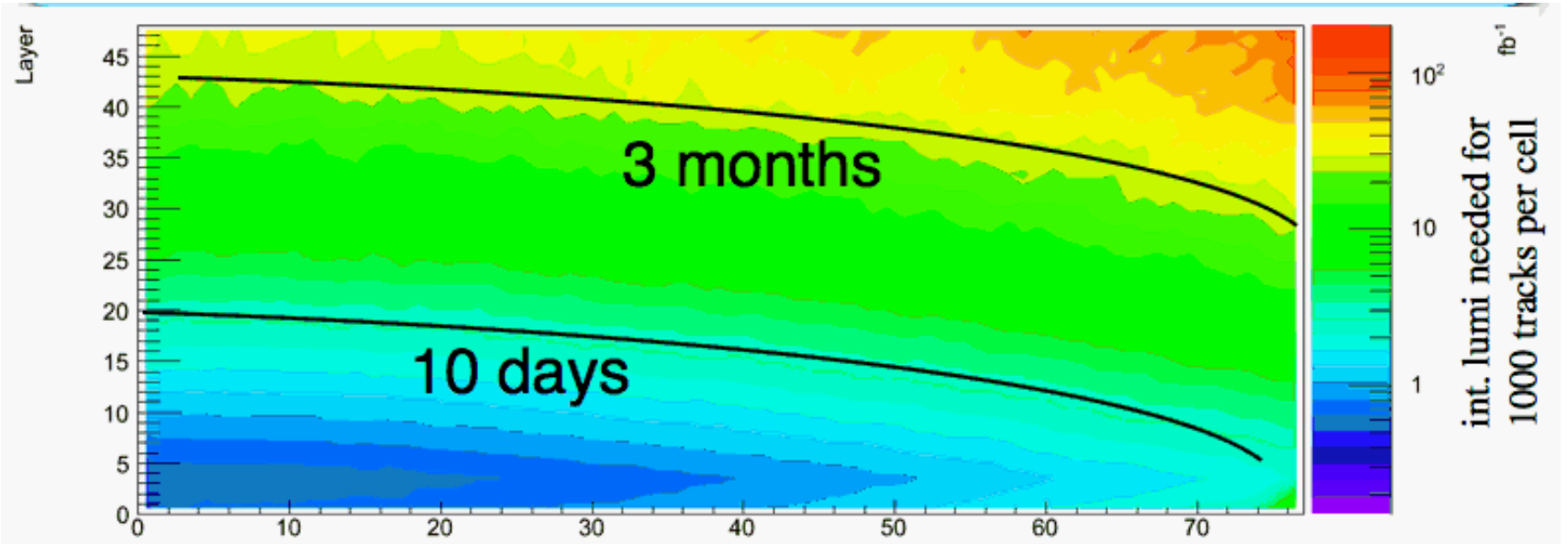
In detail



Integration studies for all Concepts reported in LOI

In situ Calibration – On Z-Pole – Analog Hcal

Calibration with track segments in qq-events

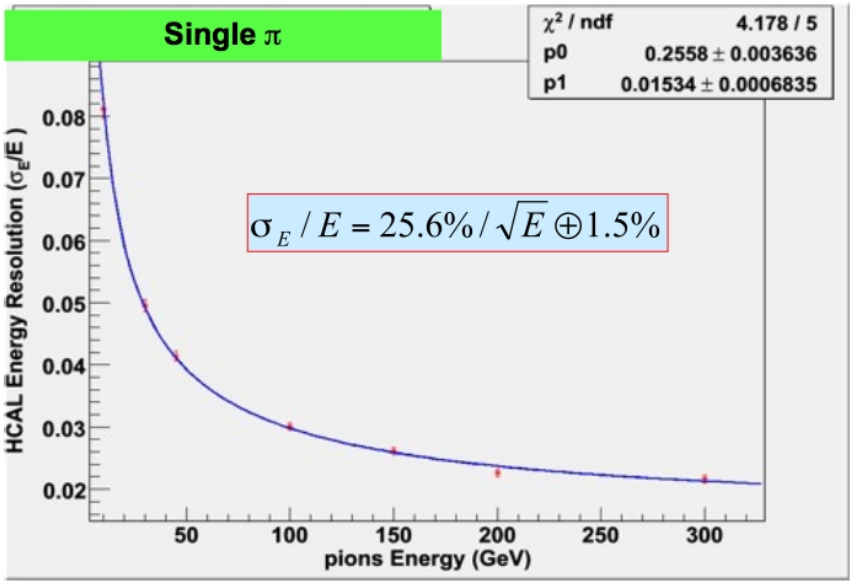


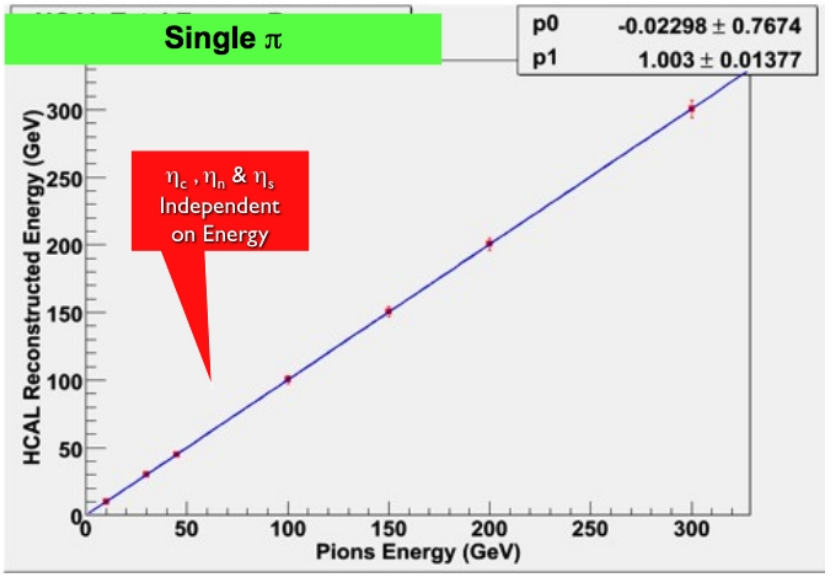
- For a good cell-by-cell calibration: 1000 entries per cell
- combining several cells will significantly reduce luminosity needs, does not compromise the calibration studies
  - Natural unit: One electronics board (HBU) with 144 scintillator tiles
  - already get somewhere with a few 10 pb^{-1}!
  - Hopeless for running of Z-Pole

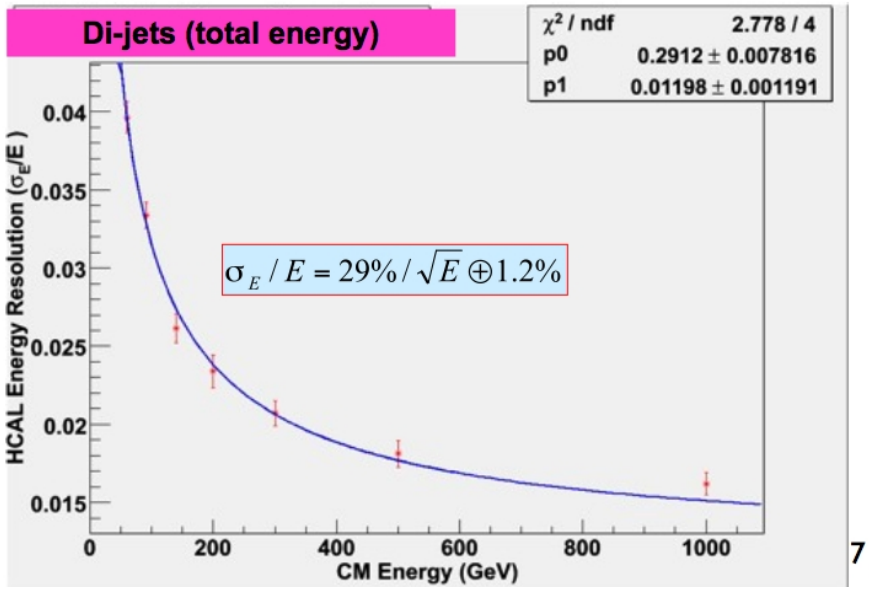
Calibrating a highly granular analog Calorimeter is not trivial

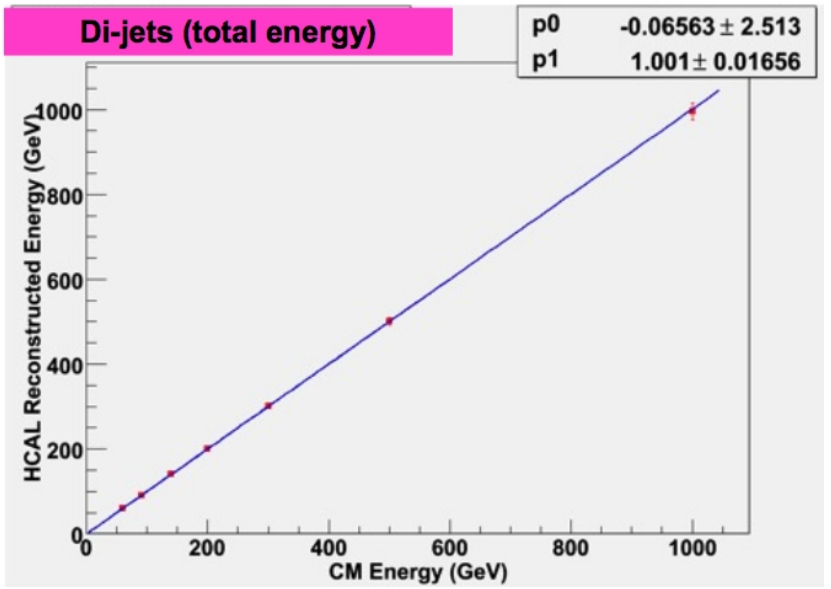
The Calorimeters in the 'real' Experiment

4th dual-readout simulation performance up to 1 TeV





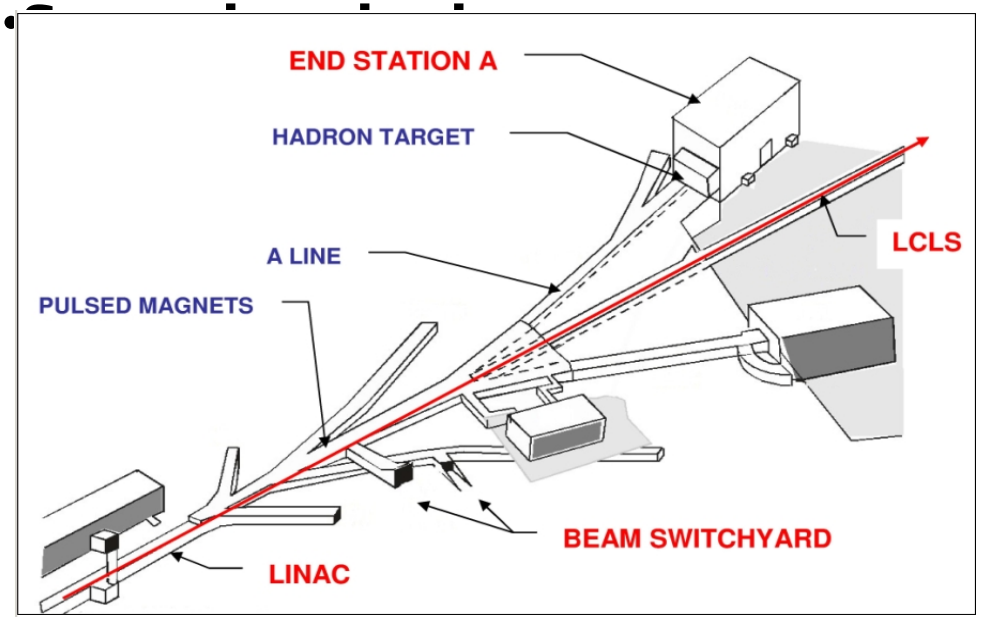




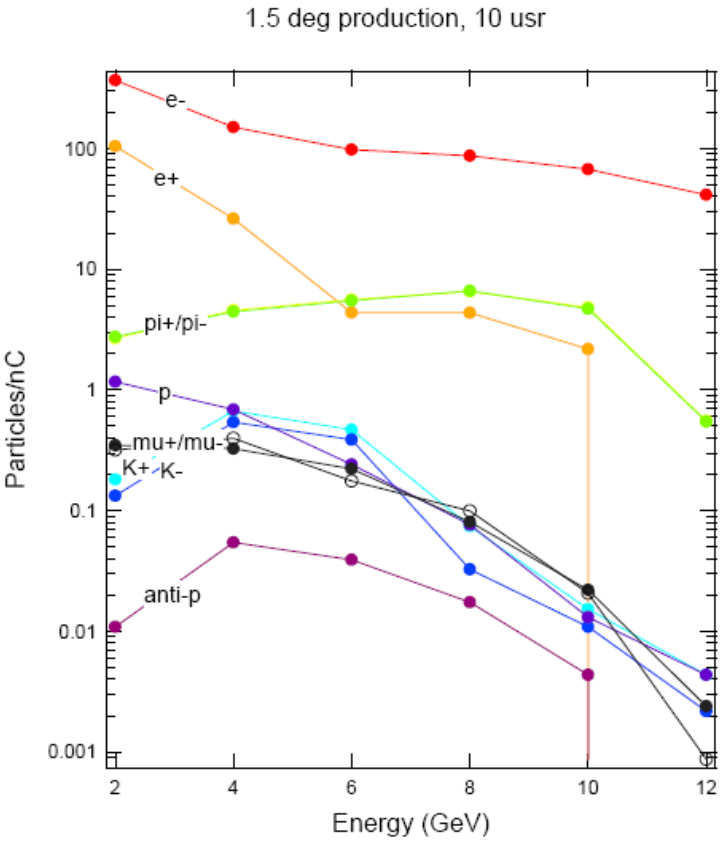
Testbeams – A "New" Facility

ESA Test Beam at SLAC Provides Electrons/Hadrons
up to 13.6 GeV, from single particles to full beam intensity

- **Kick 13.6 GeV LCLS beam to ESA**
  5 Hz, 2 x 10^9 e^-/ pulse primary beam
- **Clean secondary electrons/positrons**
  p<13.6 GeV, 0.1/pulse to 2 x 10^9 e^-/ pulse



Secondary Particle



Testbeam Workshop @ LAL 3/11/09 - 6/11/09

Conclusions

- Calorimeter R&D is wide field of efforts

- Calorimeter R&D for the ILC delivers first very interesting testbeam results
  - Towards Understanding the hadron shower with the AHCAL
  - Getting control on digital calorimetry
  - Ecal's protoypes perform according to expectation
  - Many interesting results not shown (Apologizes)

- Huge collaborative effort leading to large synergies
  e.g. CALICE:
  US-DHCAL, SiW Ecal and ScintEcal on AHCAL stage
  Common DAQ
  However the HCAL landscape well populated by (expensive) $1m^3$ prototypes
  Synergies in Ecal R&D?

- 2009 the year to develop strategy for coming 4-5 years
  Driven by: First conclusion from past R&D
  Homework from IDAG
  Directions from R&D panel

- Collaborations start to pave the road towards the real detector