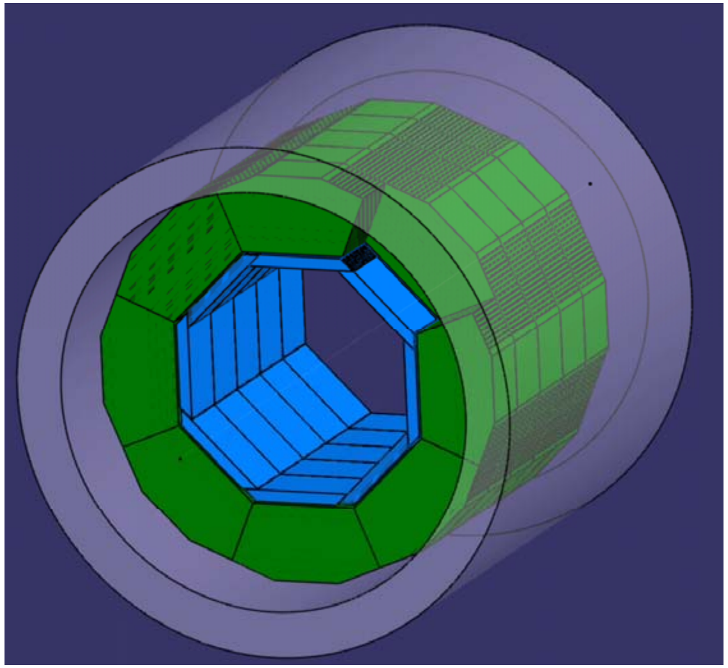
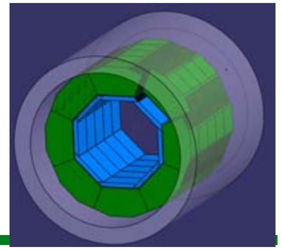


Calorimeter R&D in CALICE Scintillator HCAL

Felix Sefkow

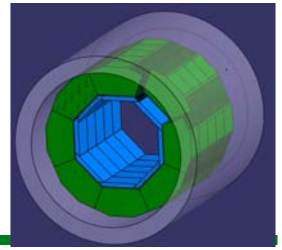
CLIC08 workshop
CERN, October 15, 2008

Outline



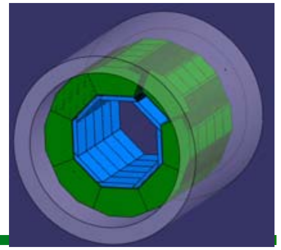
- The CALICE approach to particle flow calorimetry
- ECAL and HCAL projects
  - More detailed talks by N. Watson, J. Blaha
- Scintillator HCAL technology and test beam
- Towards higher energies

CALICE



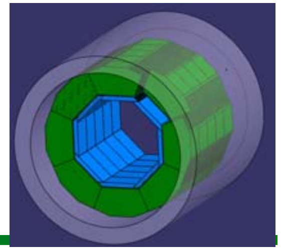
- We are more than 200 physicists and engineers from ~ 40 institutes in America, Europe and Asia
- Our goal: develop highly granular calorimeter options based on the particle flow approach for an e+e- linear collider
- Twofold approach:
  - Physics prototypes and test beam
    - Operational experience with new technologies
    - Test of shower simulation models
    - Development of reconstruction algorithms with real data
  - Technical prototypes
    - Realistic, scalable design (and costing) early next decade

Technology options and synergies

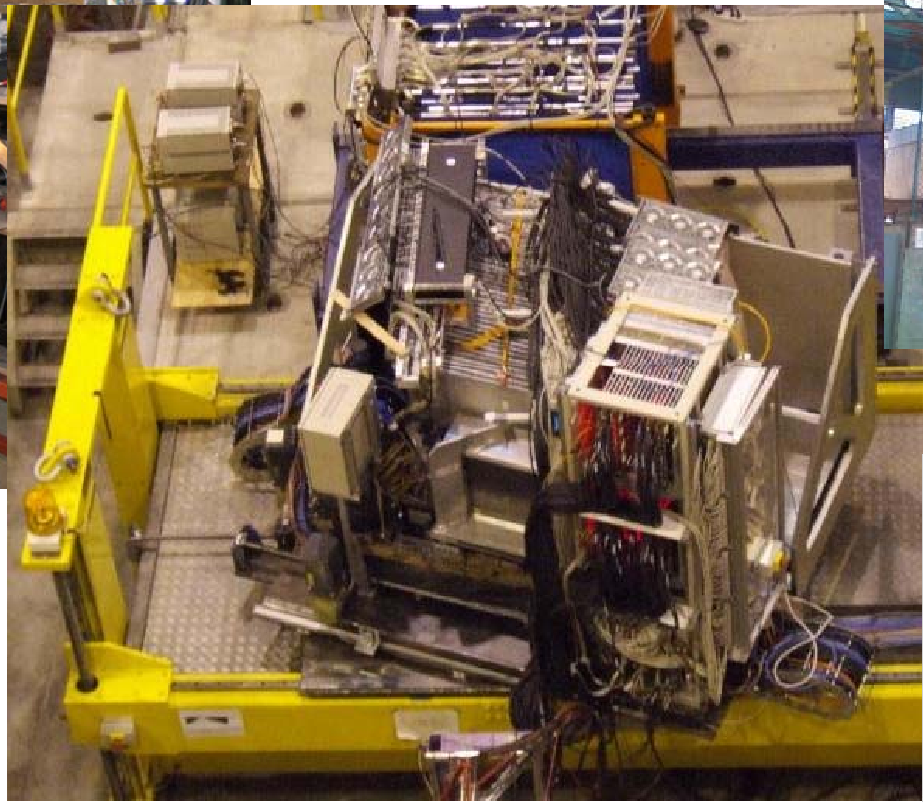


- The effort comprises the different options under consideration in the ILC detector concept groups ILD = LDC$\cup$GLD, SiD
- ECAL:
  - Si W with 1x1 or 0.5x0.5 cm^2 pads, or MAPS
  - Scintillator strips + W
- HCAL
  - Scintillator tiles + Fe ("analogue HCAL")
  - Gaseous read-out + Fe ((semi-) digital HCAL)
    - RPCs, GEMs, Micromegas
- Common use of infrastructures and frameworks
  - Versatile absorber structure and movable stage
  - Variants of coherent front-end micro-electronics design
  - Common DAQ
  - Common online software and analysis framework

Test beam experiments

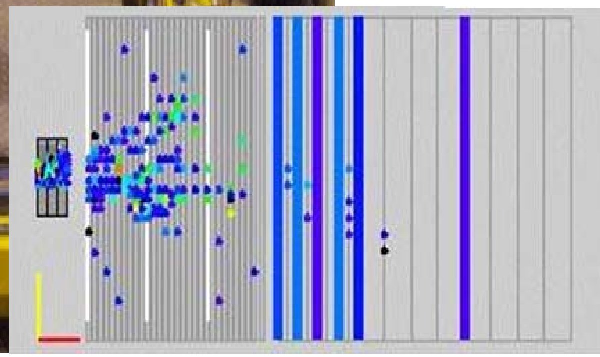


DESY 2005

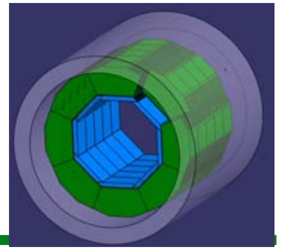


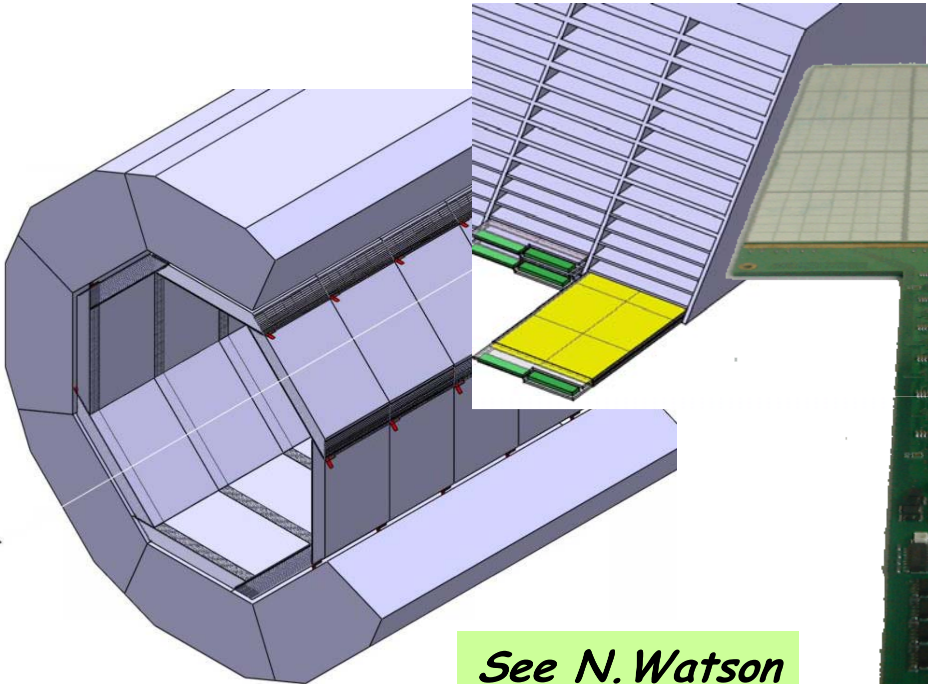
CERN 2006-2007

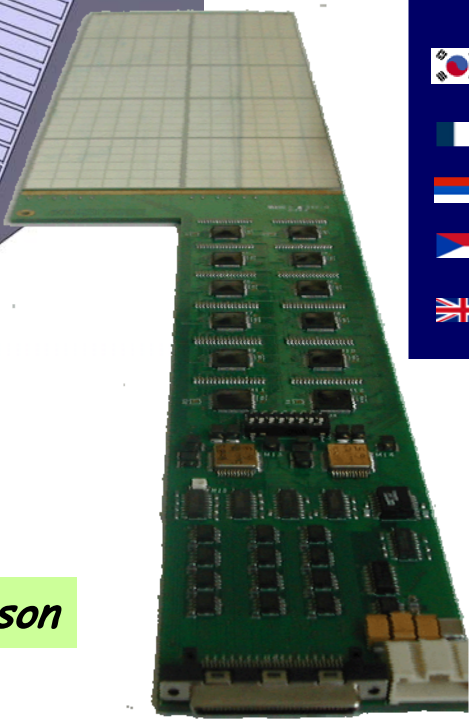
FNAL 2008



Si W ECAL prototype

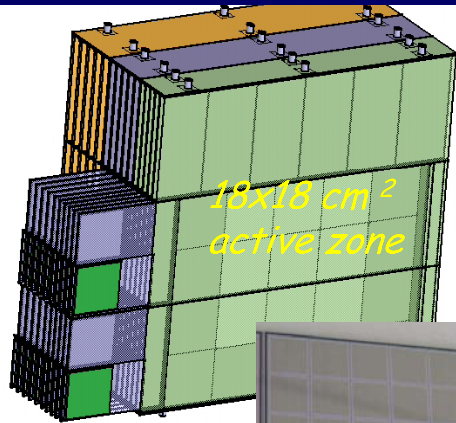






CALICE – ECAL

- Ewha Univ., Sungyunkwan Univ., Kangnung NU , Yonsei Univ.
- LAL,LLR,LPC-Ct, LPSC, PICM
- ITEP,IHEP, MSU
- Prague(iop-ascr)
- Imp. Coll, UCL, Cambridge Birmingham, Manchester,RAL, RHUL



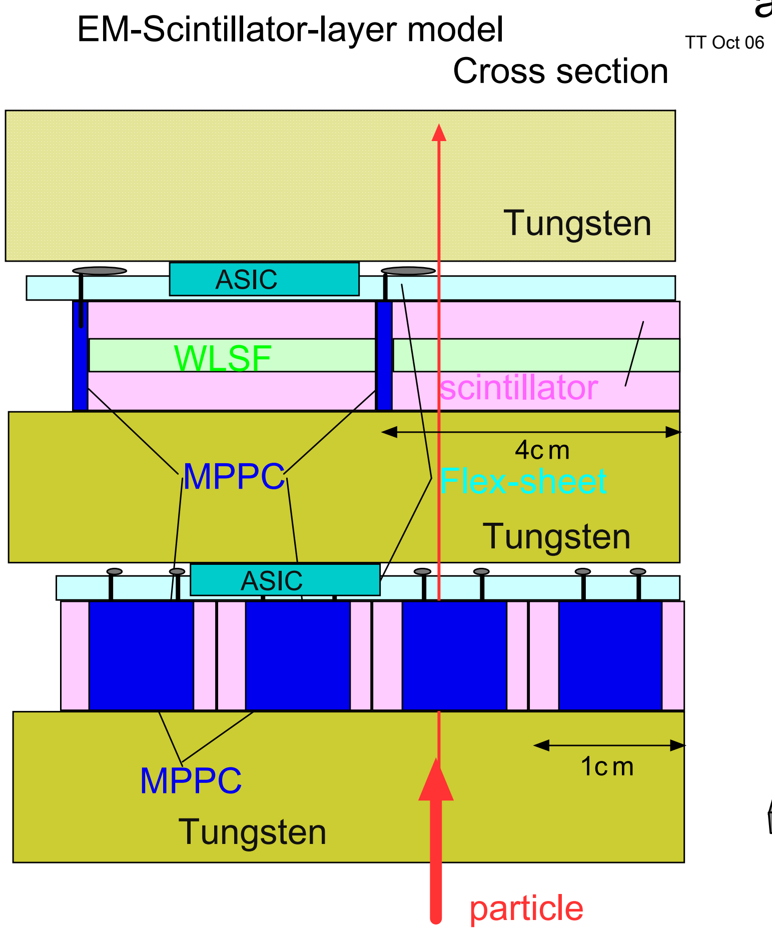
See N. Watson

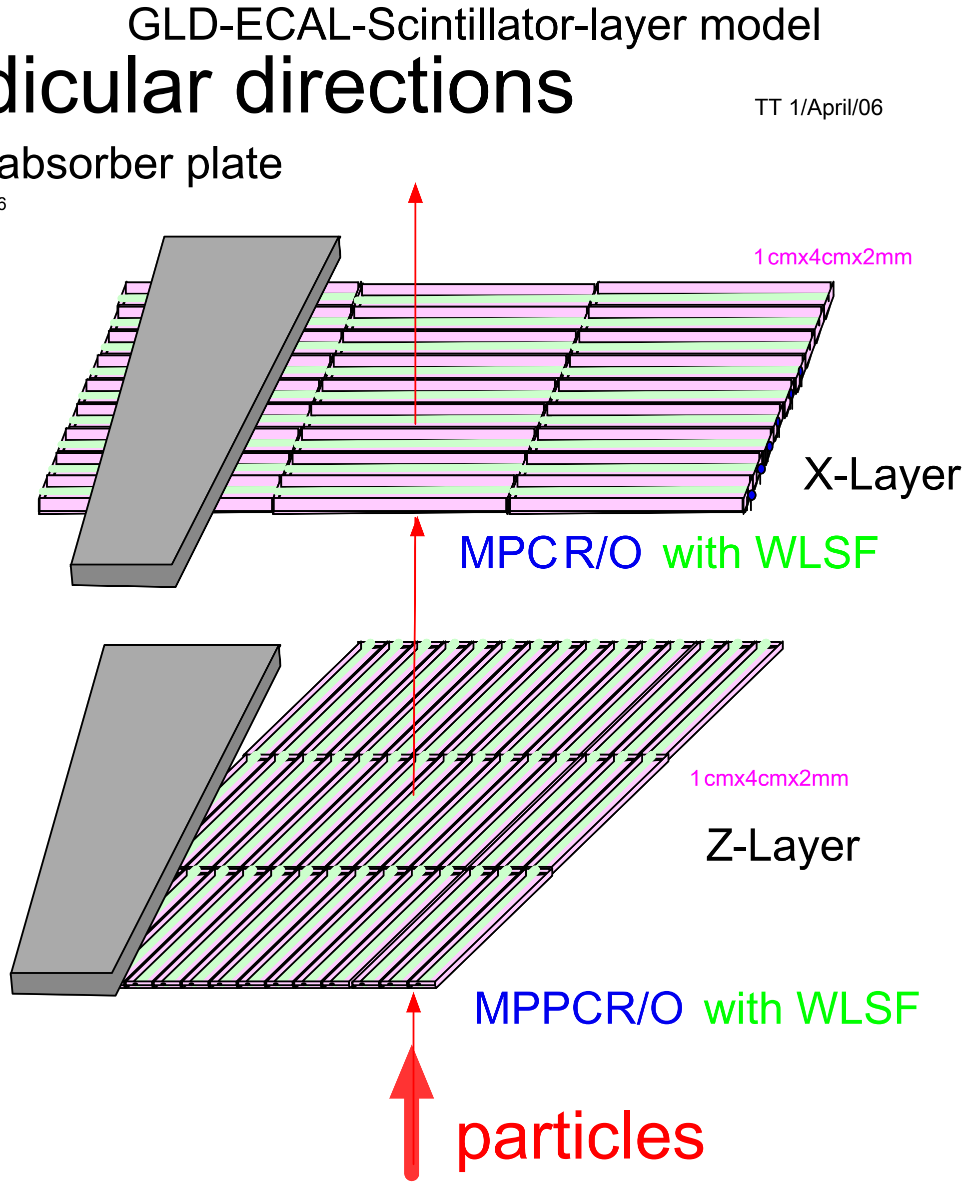
- 30 layers, 24 X_0 (20 cm)
- Alveolar structure, carbon wrapped W
- 9720 channels – in an (18 cm)^3 cube

1 x 1 cm granularity

scintillator ECAL

- strips in perpendicular directions

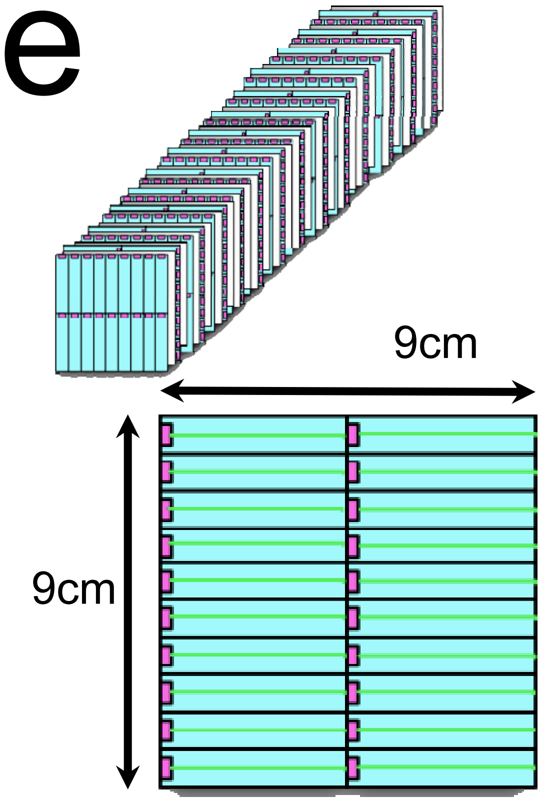


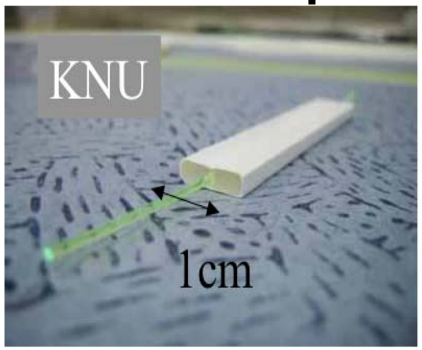


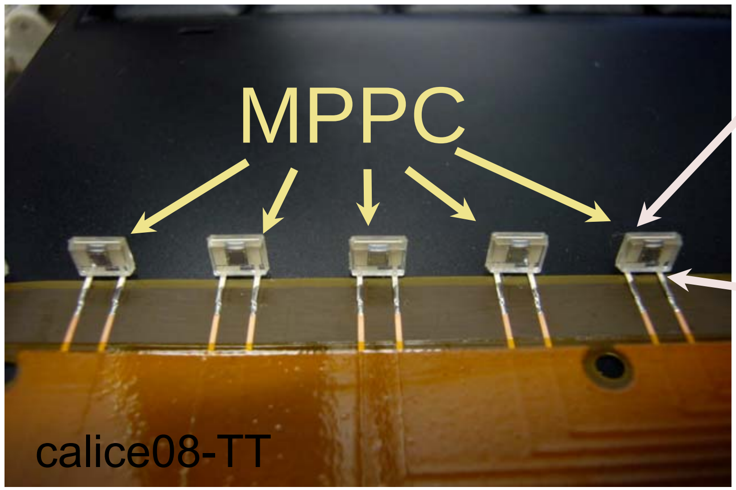
T.Takeshita@Cambridge ILD Sep08

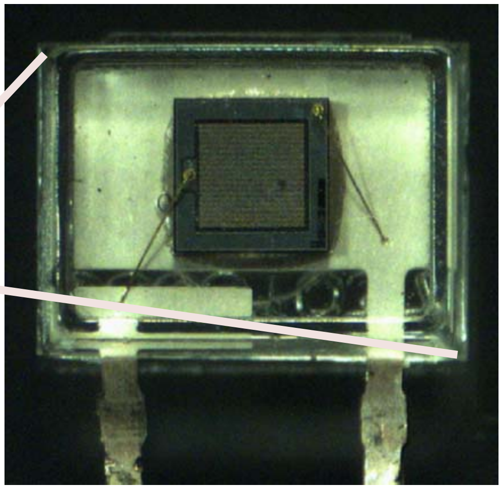
small prototype at DESY

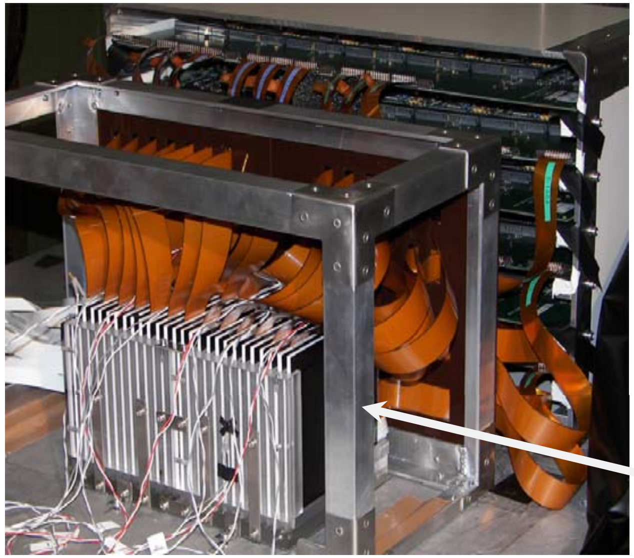
- 9x2 strips / layer x 26 (468ch)
- 1cm x 4.5cm x 0.3cm strip
- fibre in a hole
- without fibre
- MPPC read out







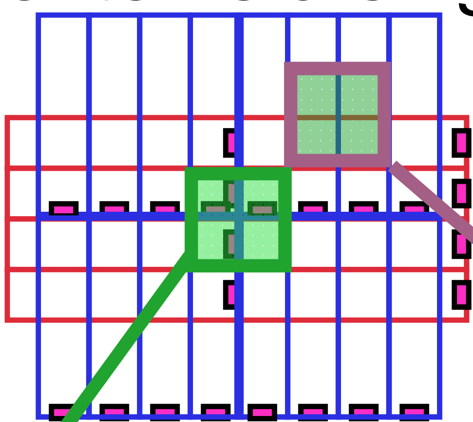




energy resolution

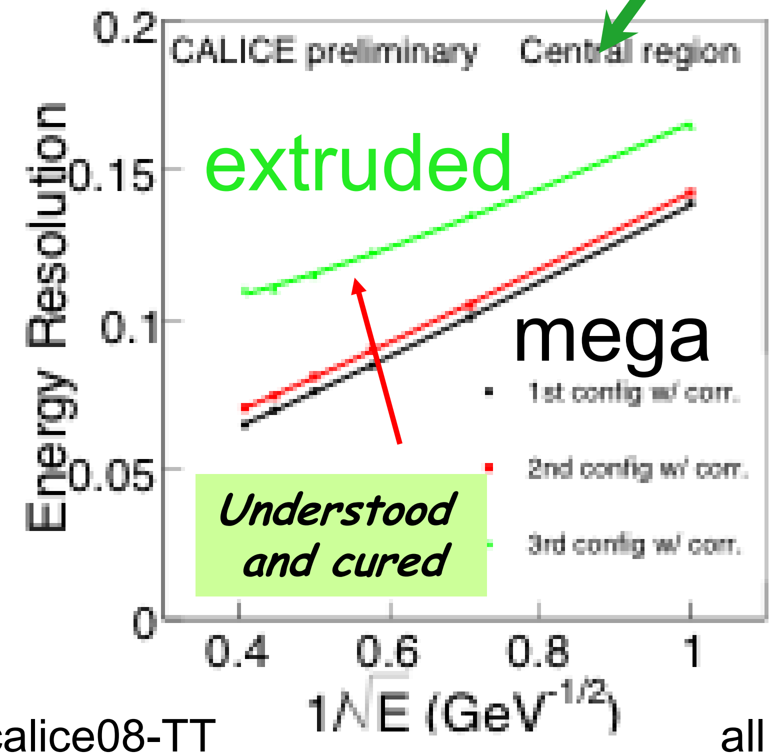
detector center is a singular point

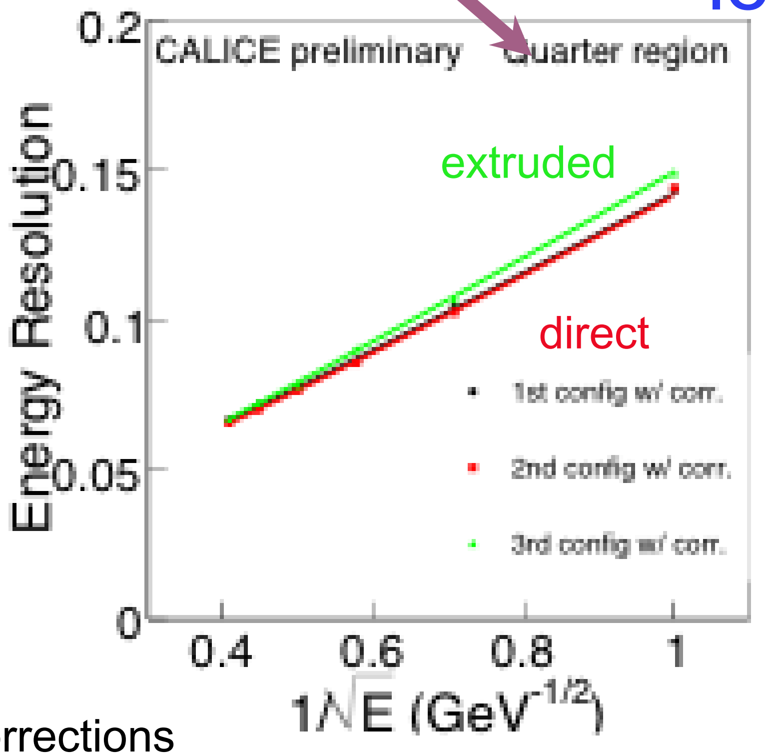
without saturation correction



$$\frac{13\%}{\sqrt{E\,(GeV)}}\ 5\ 3\%$$

shower leakage





calice08-TT

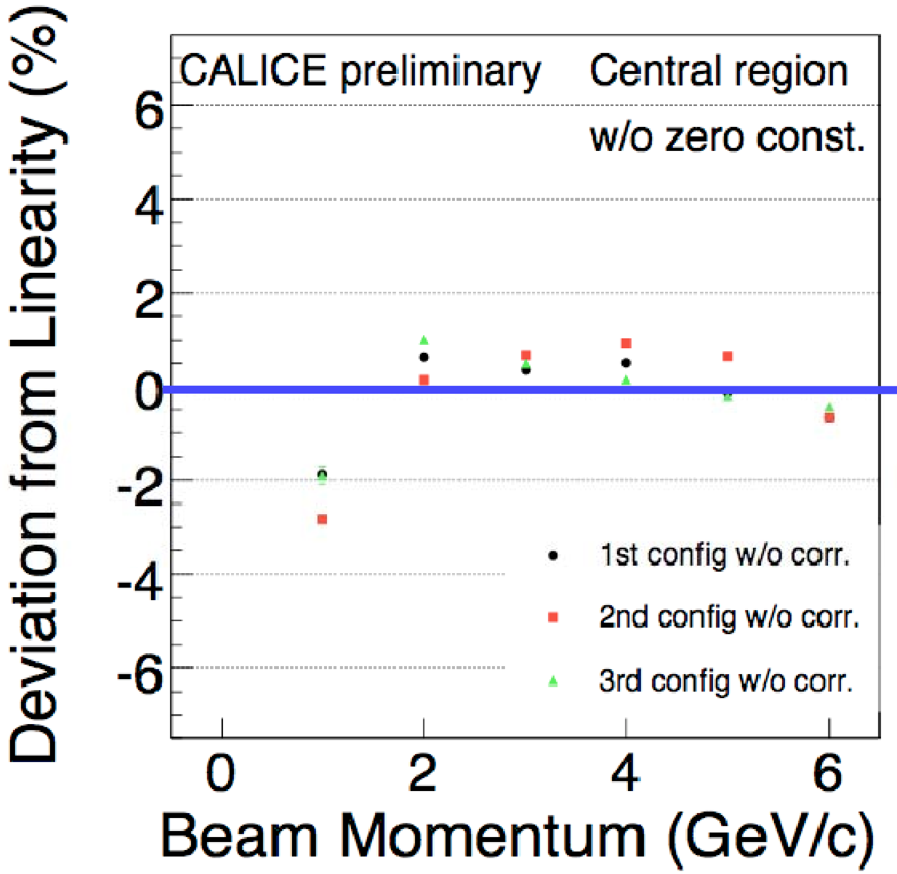
all corrections

linearity

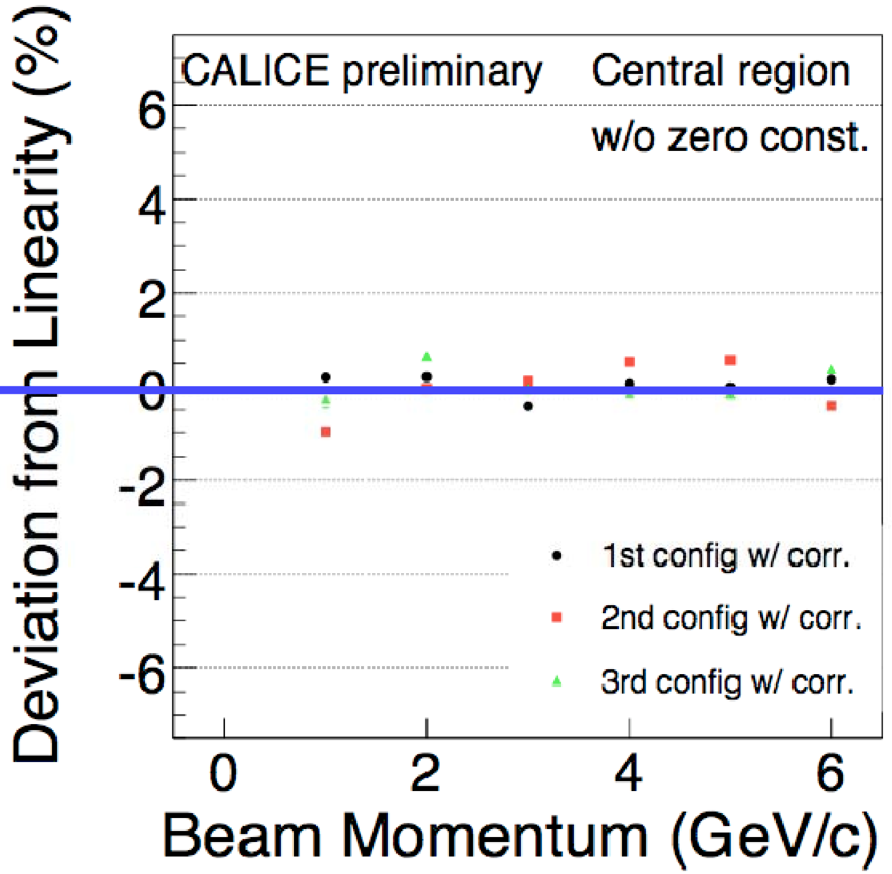
without/with saturation correction

- saturation correction
- improves linearity

before correction



saturation corrected



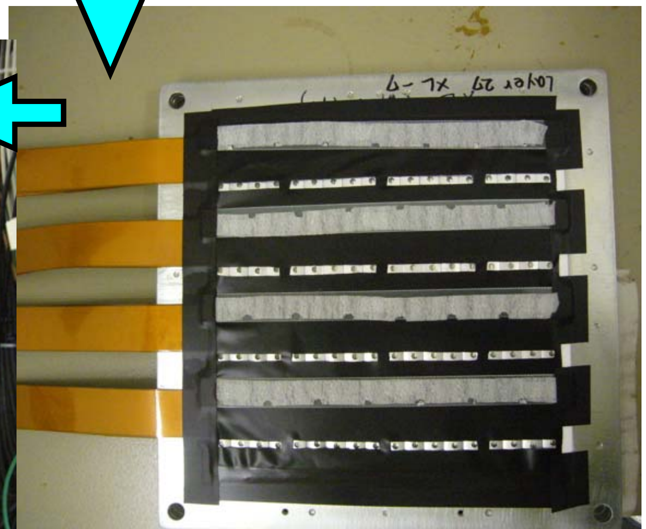
installation at MT6

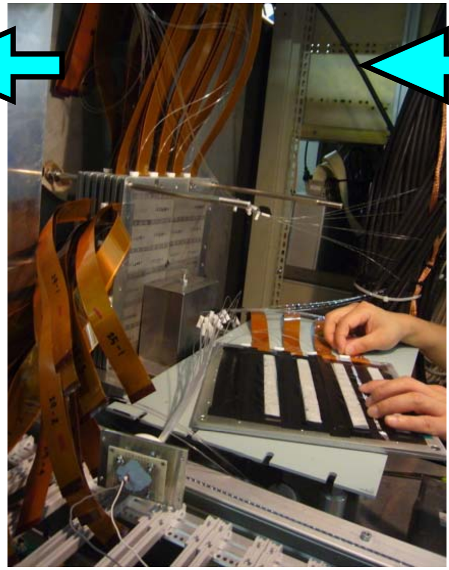
- scecal : 18 x 4 strips / layer
- 30 layers : ~22cm
- 2160 ch MPPC/strip

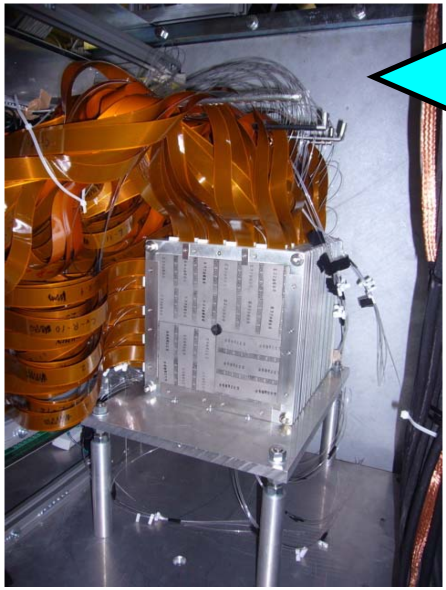
4.5cm x 1cm

0.3cm thick
extruded

18cm x 18cm



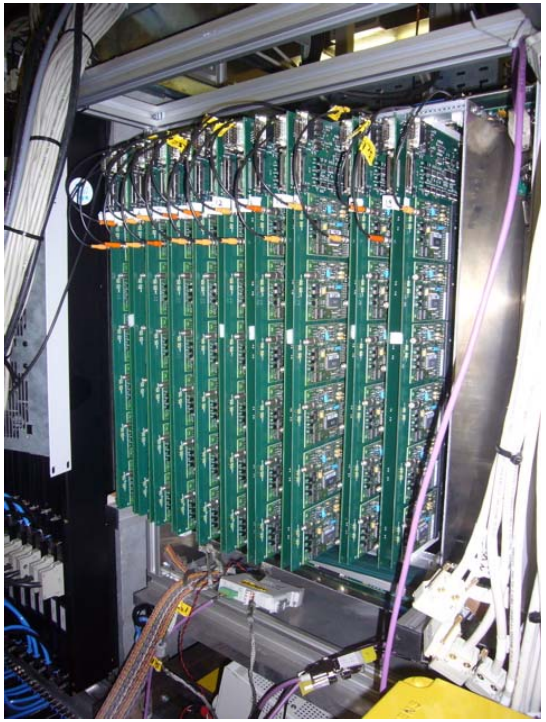




MT6/ Fermilab

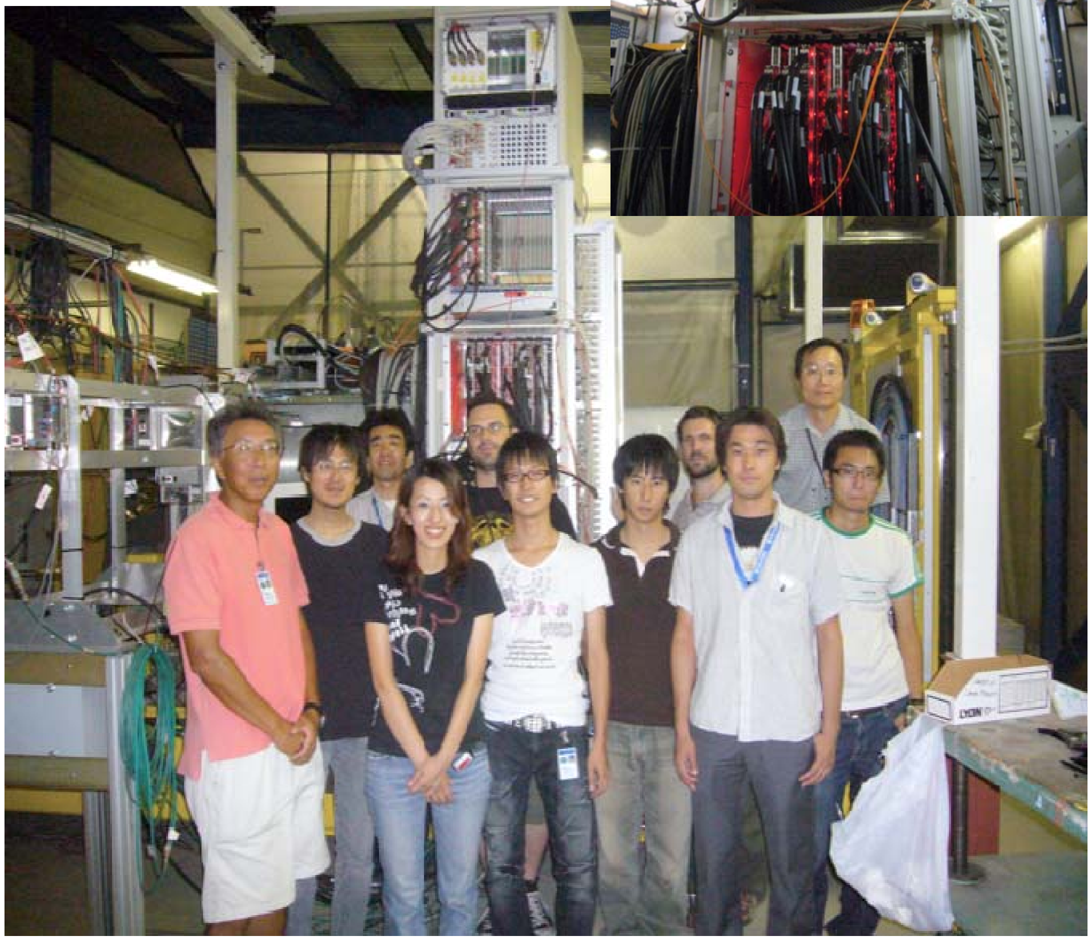
- with electronics

FE (=AHCAL)

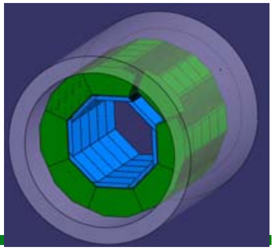


HCAL electronics (DESY)
based on mod. SiW ASIC (LAL)

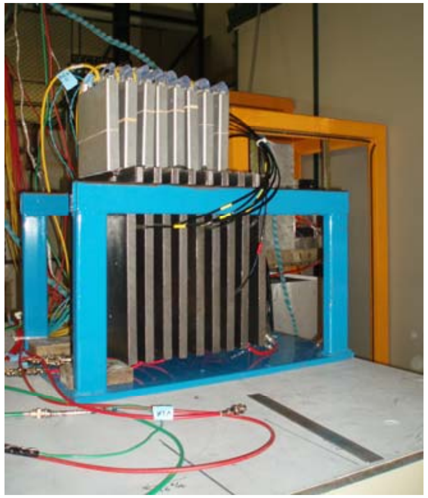
bias and ADC
on top of it

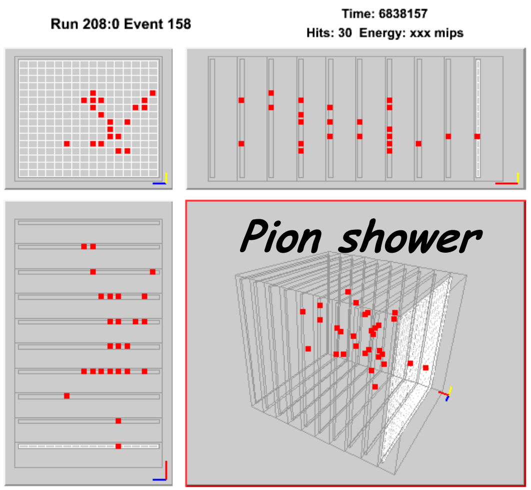


DHCAL projects

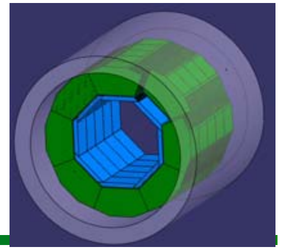


- In the US:
  - RPC based digital HCAL
    - First test beam data with small 9 layer stack
    - Next: $1m^3$ prototype
  - GEM option also being developped
- In Europe:
  - Semi-digital prototype based on EUDET electroncis
  - RPCs and Micromegas
- See J.Blaha's talk

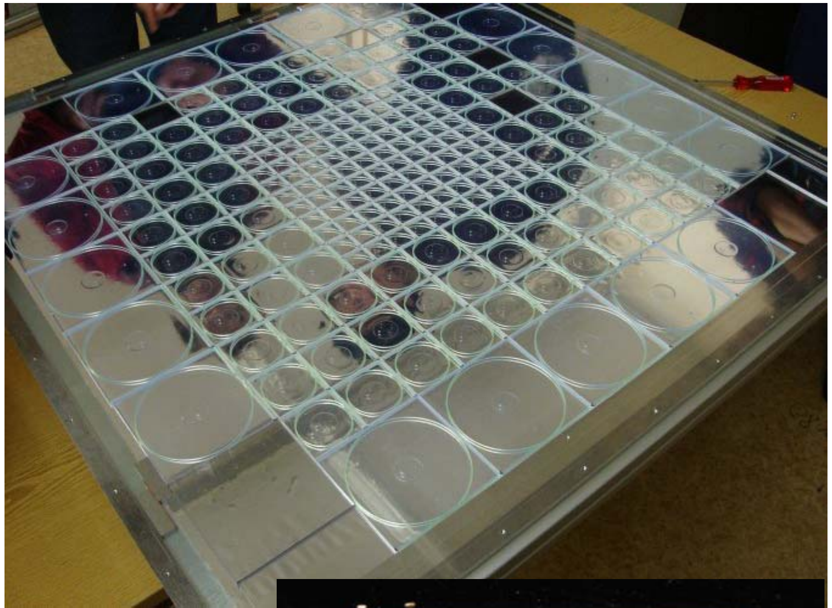




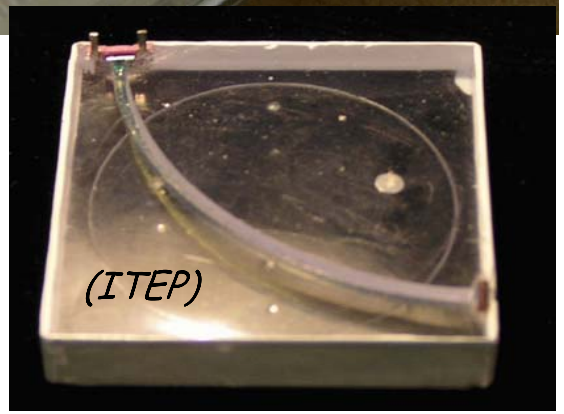
Scintillator HCAL



- Novel multi-pixel Geiger mode photo-diodes (SiPMs)
  - B-field proof, small, affordable
- High granularity with scintillator at reasonable cost
  - photo-sensors integrated
- Opens revolutionary design options:
  - embedded electronics and calibration system for minimal dead zones
  - thin readout gap
- Granular, compact, hermetic



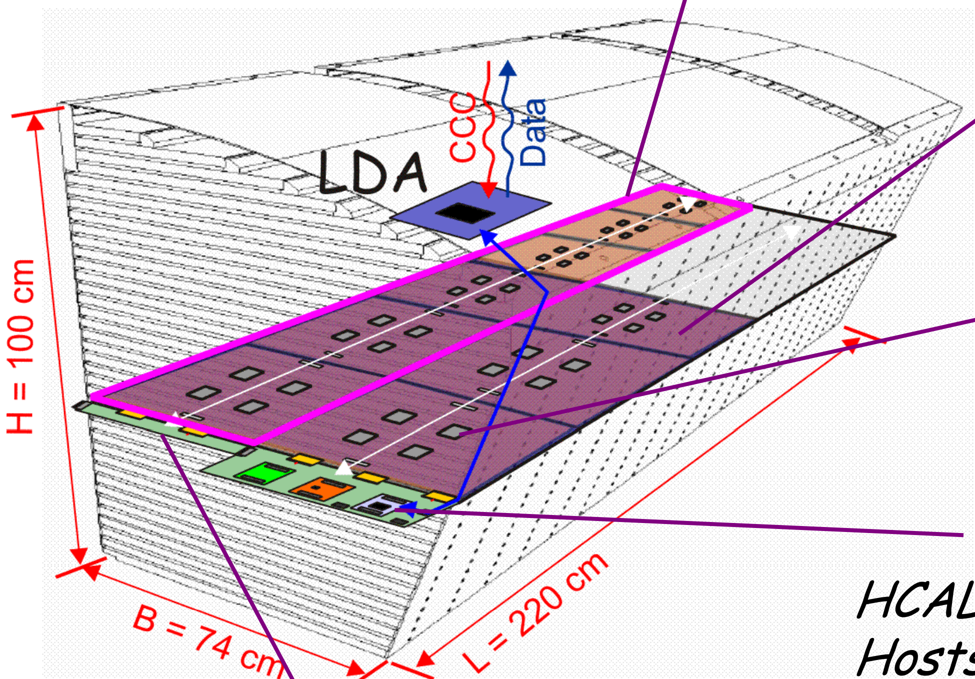
(DESY)



(ITEP)

Integrated electronics

1/16 of barrel half



AHCAL Slab
6 HBUs in a row

Front end ASICs embedded
Interfaces accessible

HBU
HCAL Base Unit
12 x 12 tiles

SPIROC
4 on a HBU

HEB
HCAL Endcap Board
Hosts mezzanine modules:
DIF, CALIB and POWER

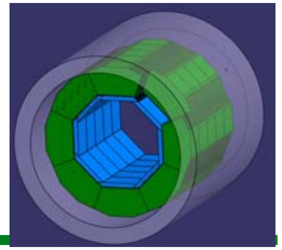
HLD
HCAL Layer Distributor

Power:
40 μW / channel

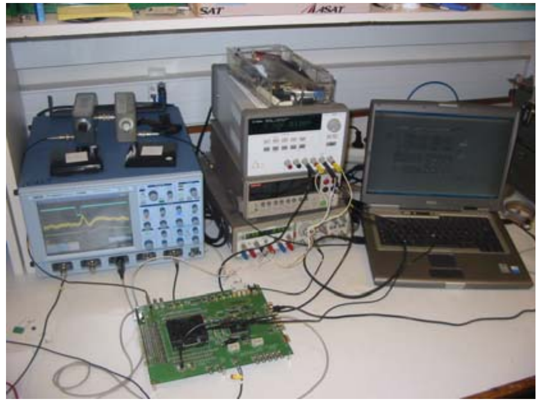
Heat:
T grad. 0.3K/2m
Time constant: 6 d

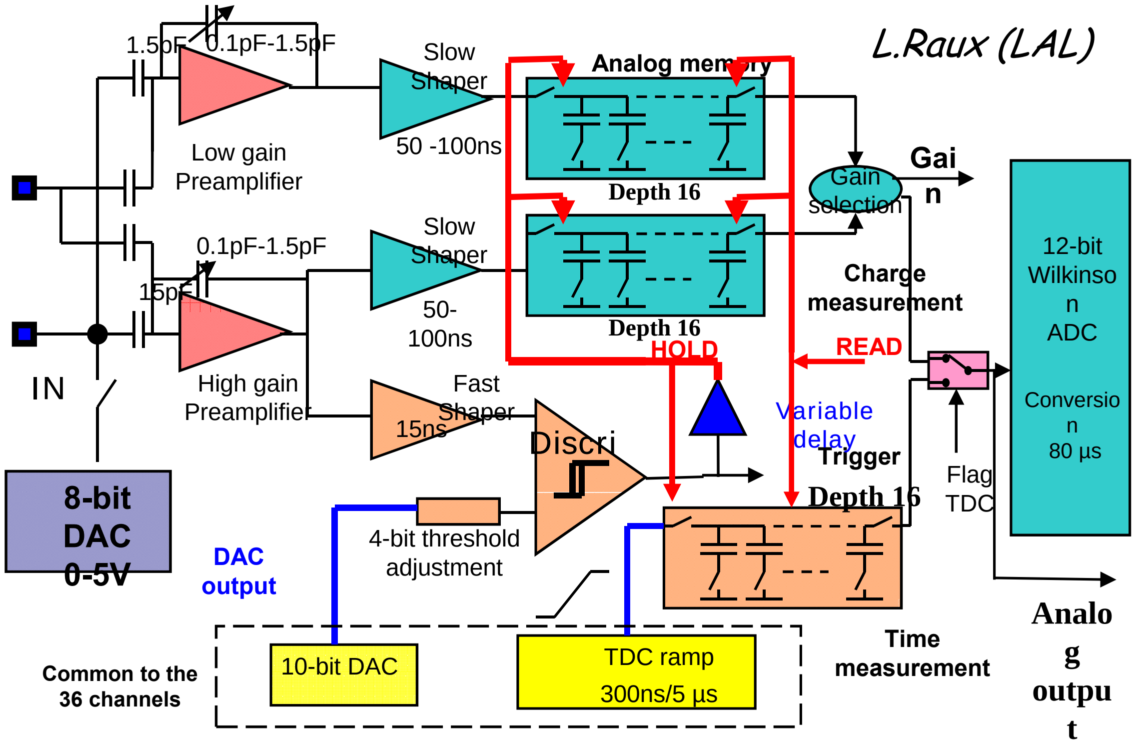
P.Goettlicher (DESY)

New ASIC on the test benches

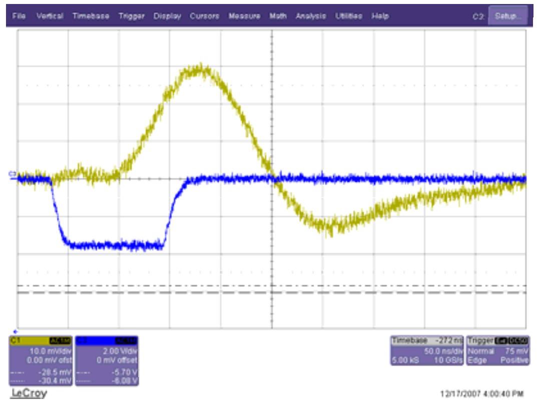


- Auto-triggering and time measurements
- ADC and TDC integrated
- Power pulsing, low (continuous) power DAC



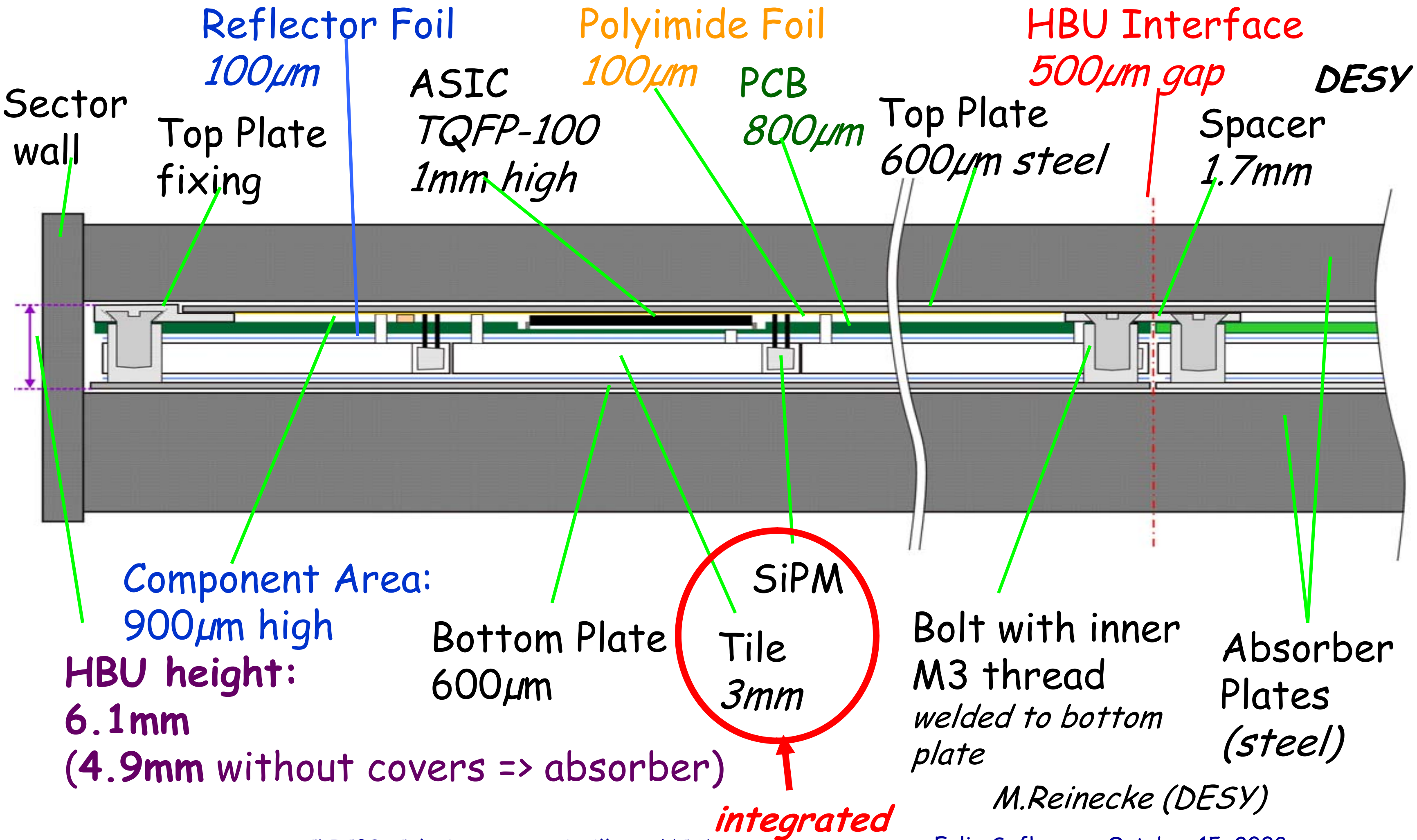


L.Raux (LAL)

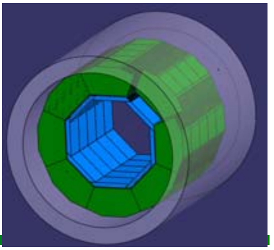


R.Fabbri (DESY)

Compact layer design

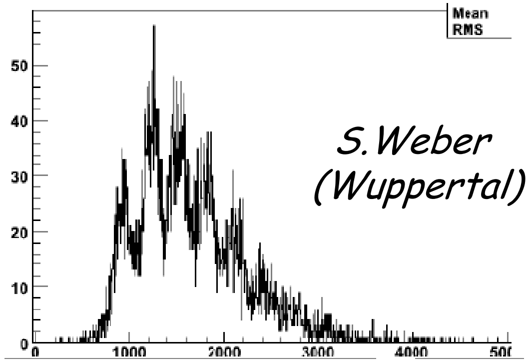


Embedded LEDs

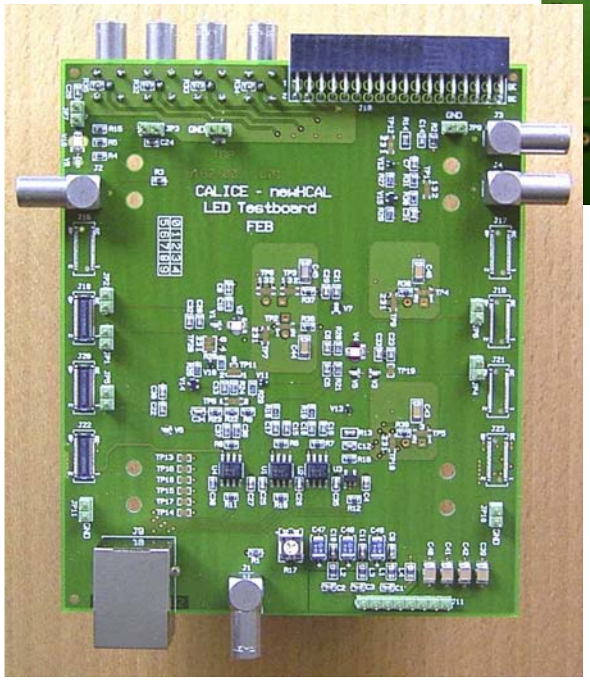


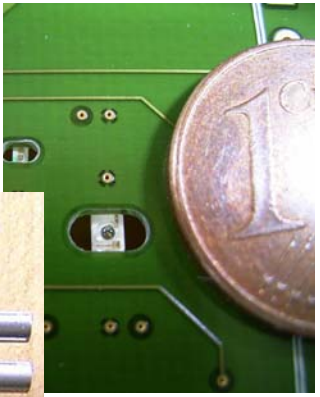
M.Reinecke (DESY)

- electronic signal distribution
- tested, no cross-talk to sensors seen
- To be optimized: dynamic range, LED uniformity
- Followed up by Wuppertal group (non-EUDET)

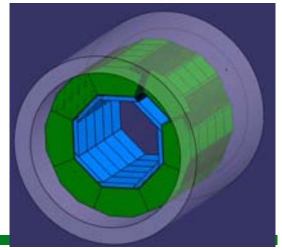


S.Weber (Wuppertal)

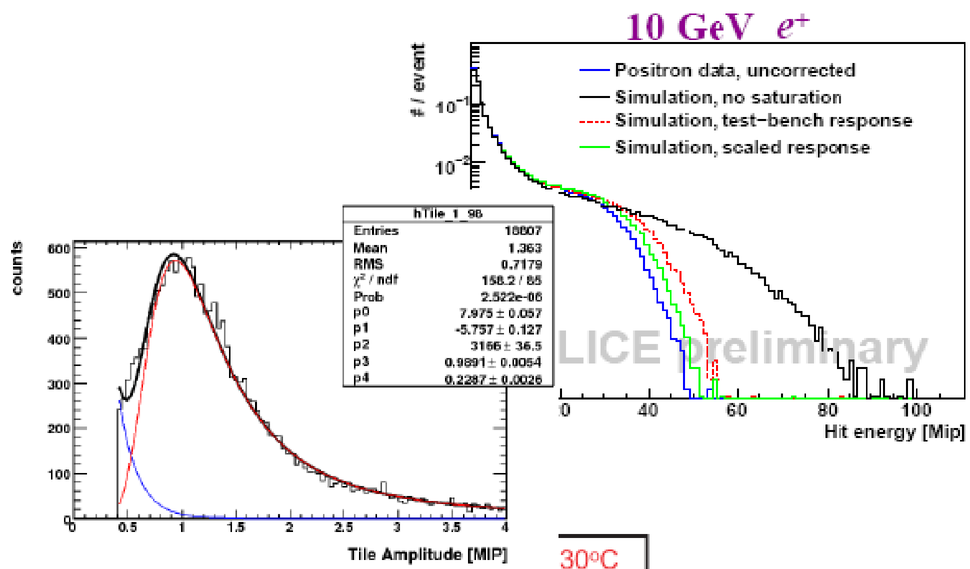


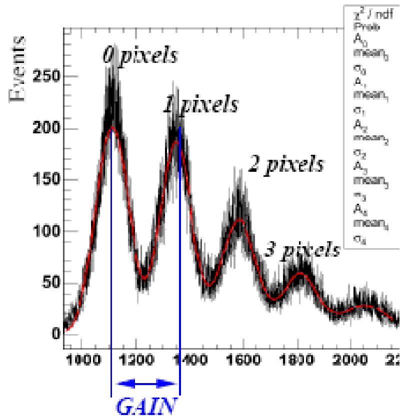


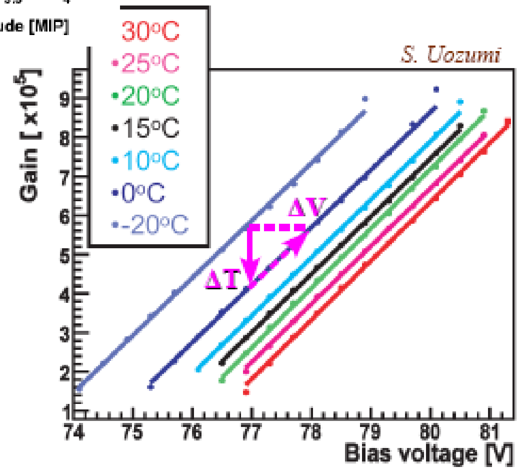
Calibration procedures



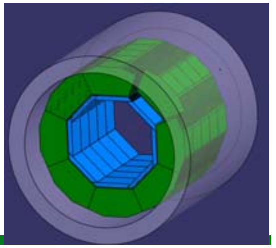
- Non-linearity correction: test with electron data
- MIP calibration: in test beam data, explore use of MIP segments in hadron showers
- Correct for temperature-induced variations
  - Use T-sensors and measured T dependences
- Use gain monitoring, adjust voltage

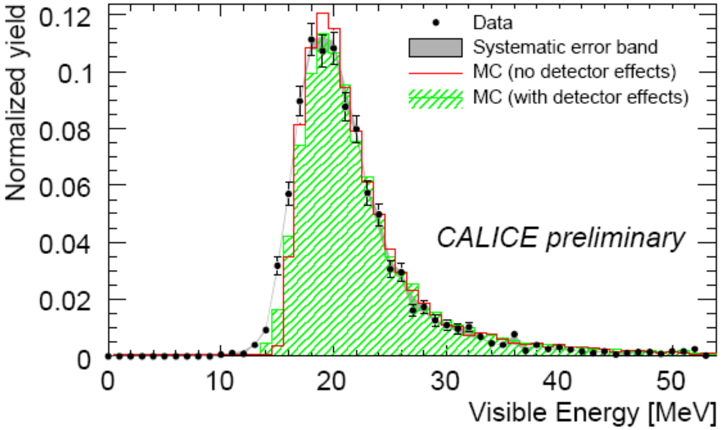


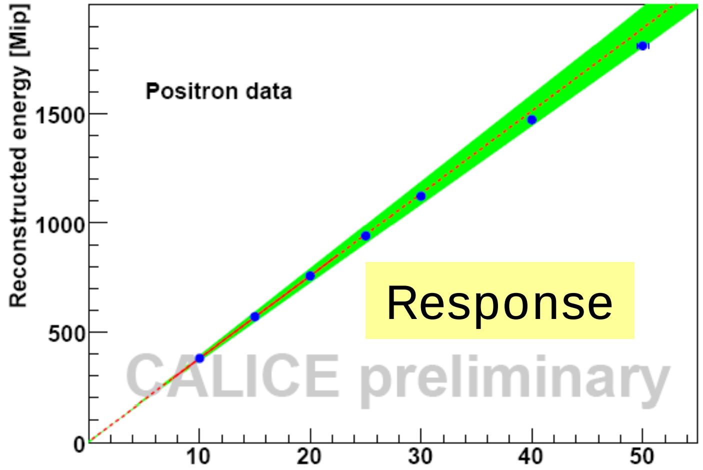


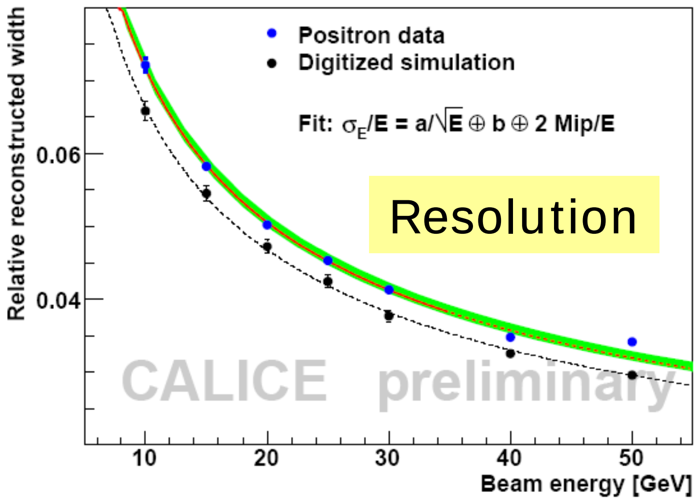


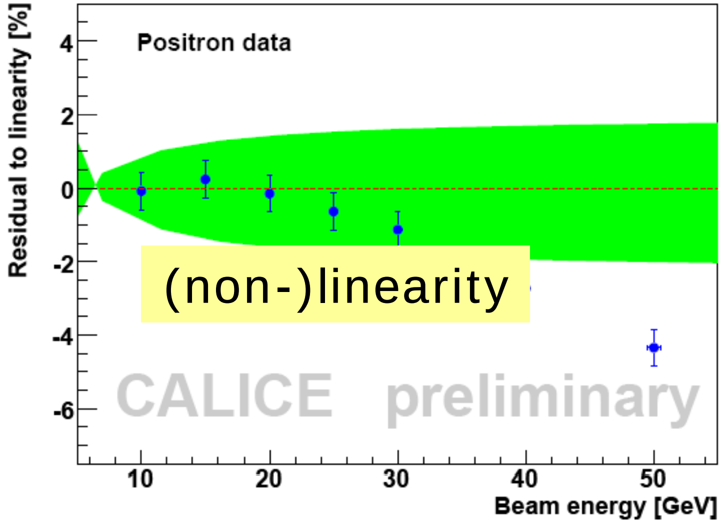
μ and e response of AHCAL











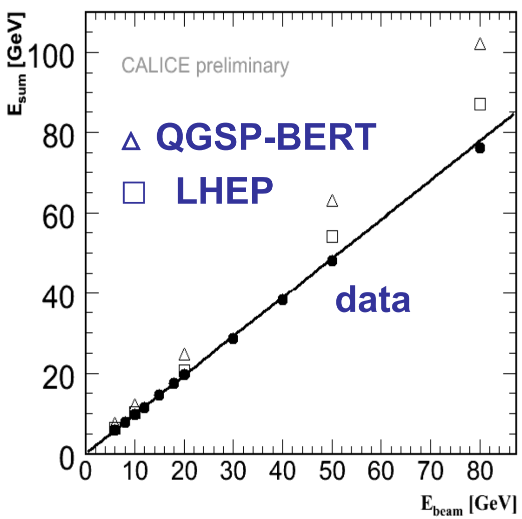
Pion data: test shower models

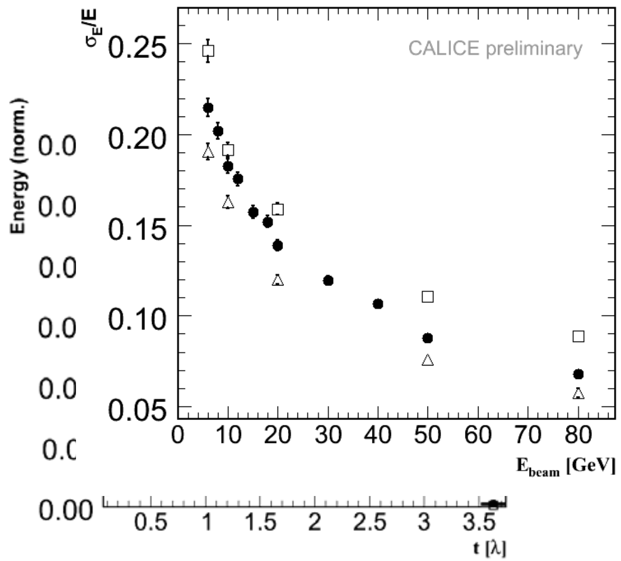
M. Thomson (Cambride)

1. Model uncertainties on PFLOW performance

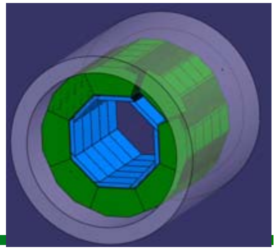
(PandoraPFAv02 +trackCheater)		E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$
LDC00Sc	QGSP_BERT	45 GeV	22.6 %
LDC00Sc	LHEP	45 GeV	23.2 %
LDC00Sc	QGSP_BERT	100 GeV	29.3 %
LDC00Sc	LHEP	100 GeV	30.2 %

2. Confront shower models with test beam data
   - First results on global properties
   - Next: fully exploit granularity for fine structure

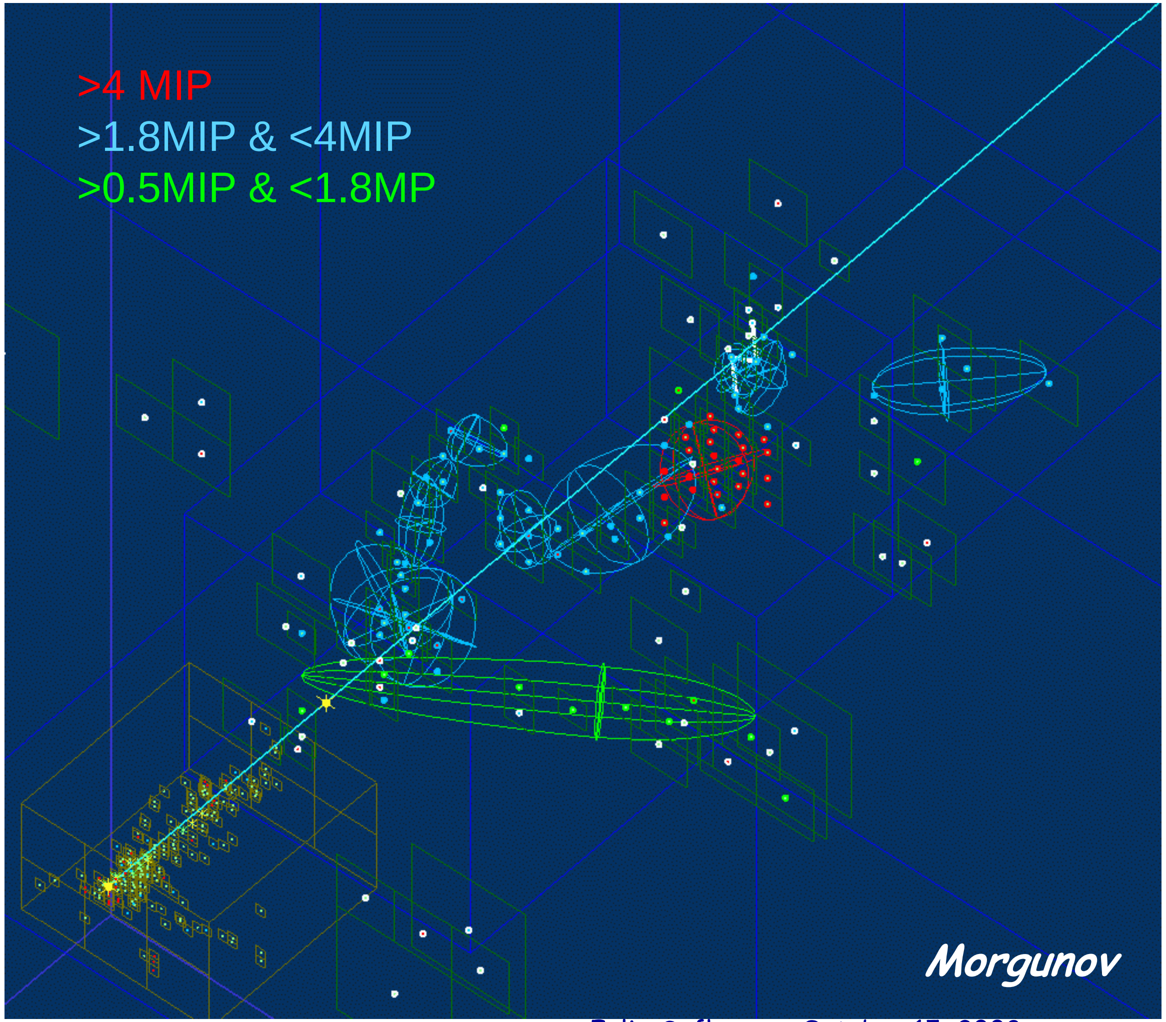




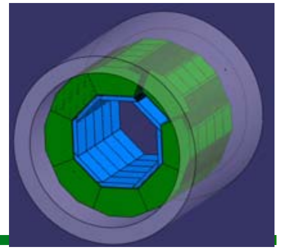
Imaging HCAL



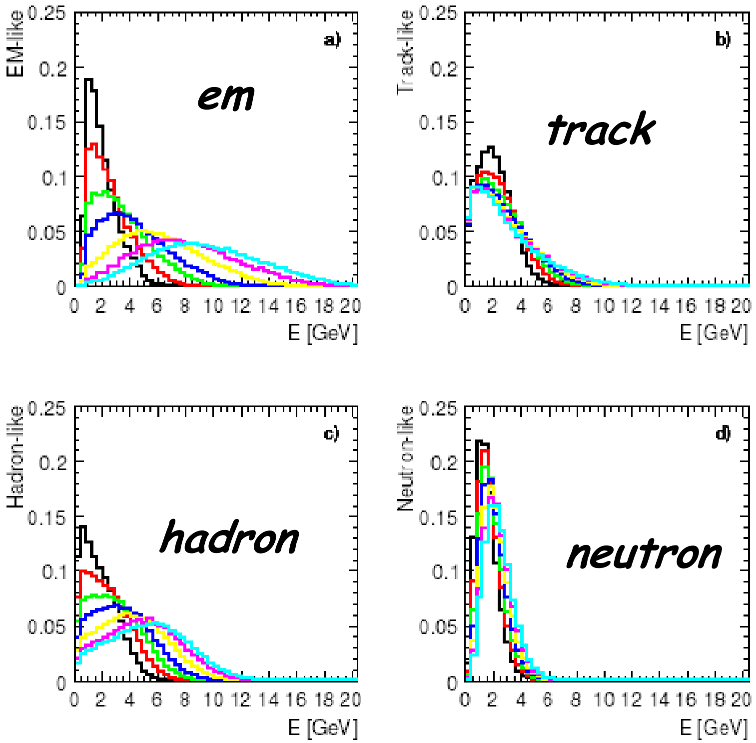
- Substructure visible
- Classification according to amplitude and topology
  - EM like
  - MIP like
  - Hadron like
  - Neutron like
- Starting point for weighting procedures

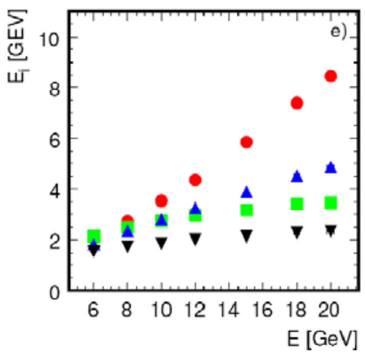


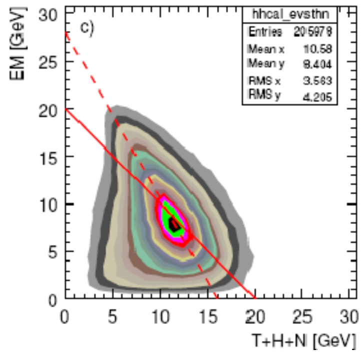
“Deep analysis”



- Ideas V.Morgunov, first steps M. Groll (PhD thesis)
- Shower decomposition, using energy and topology



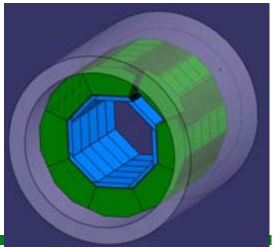




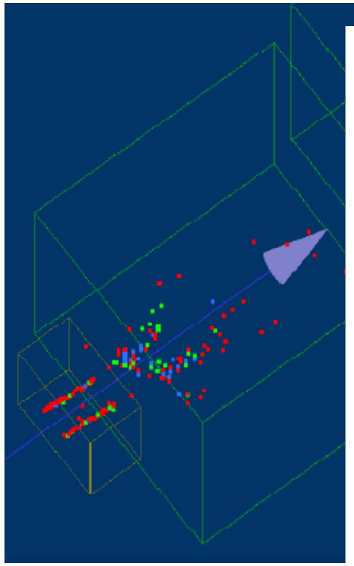
Energy dependence, correlation

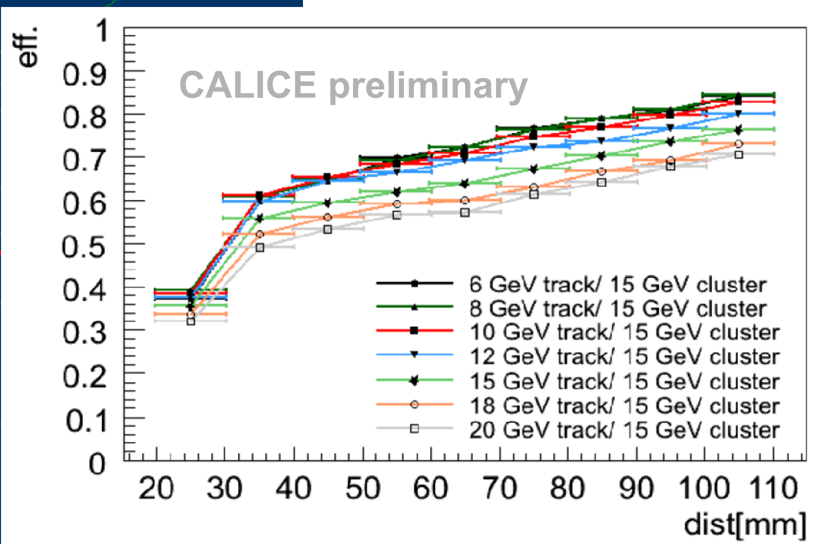
Novel quality of input to shower model development

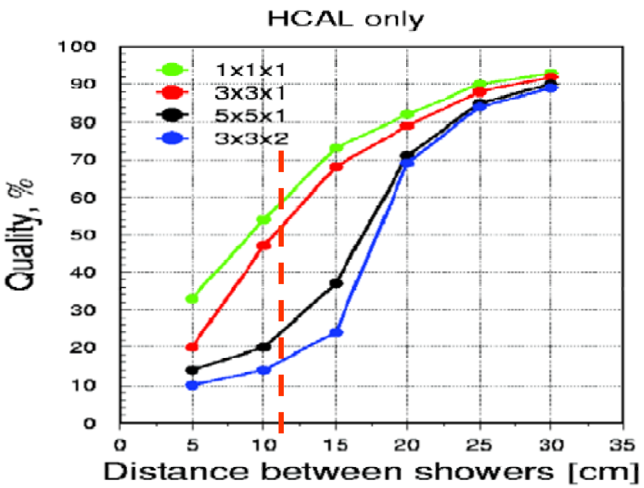
Validate PFLOW performance



- Test beam 'jets' would require magnet and tracker (future)
- Jet energy resolution depends on hadronic energy resolution and confusion
- High granularity, low occupancy: use event overlay techniques
- Two particle separation in test beam data and Monte Carlo:

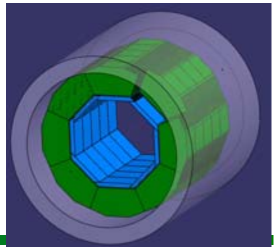




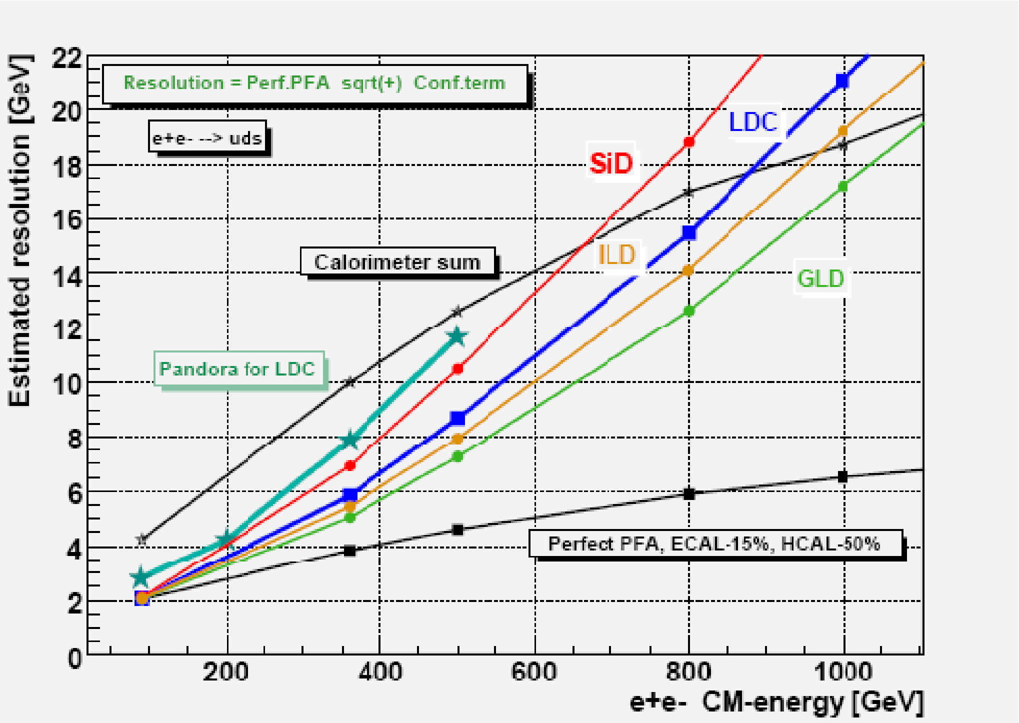


A. Raspereza

PFLOW and 2-particle separation

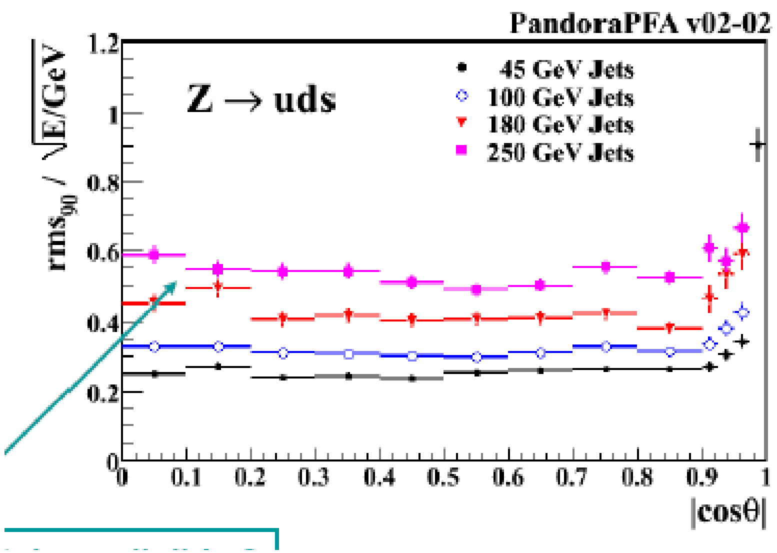


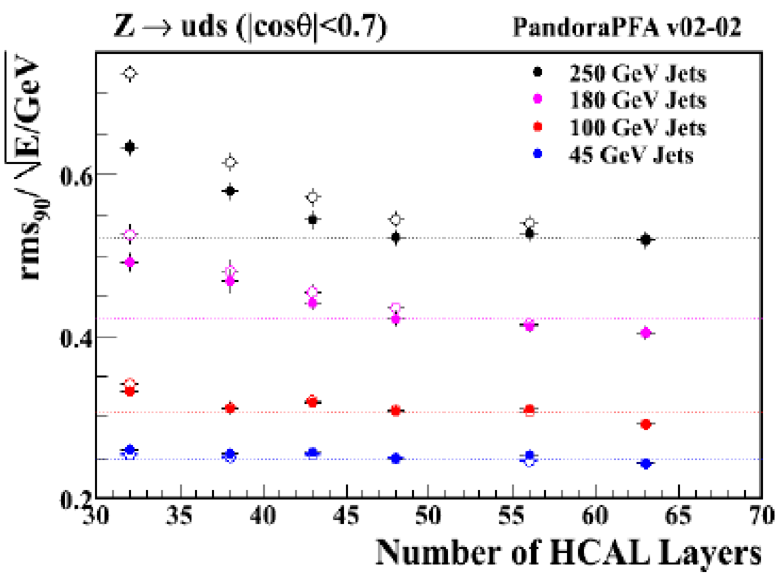
- Parameterize confusion term as function of 2-particle separation
- Still optimization potential in PFA – fully exploit topology
- At a few 100 GeV classic calorimetry takes over – transition to be designed



At high energy

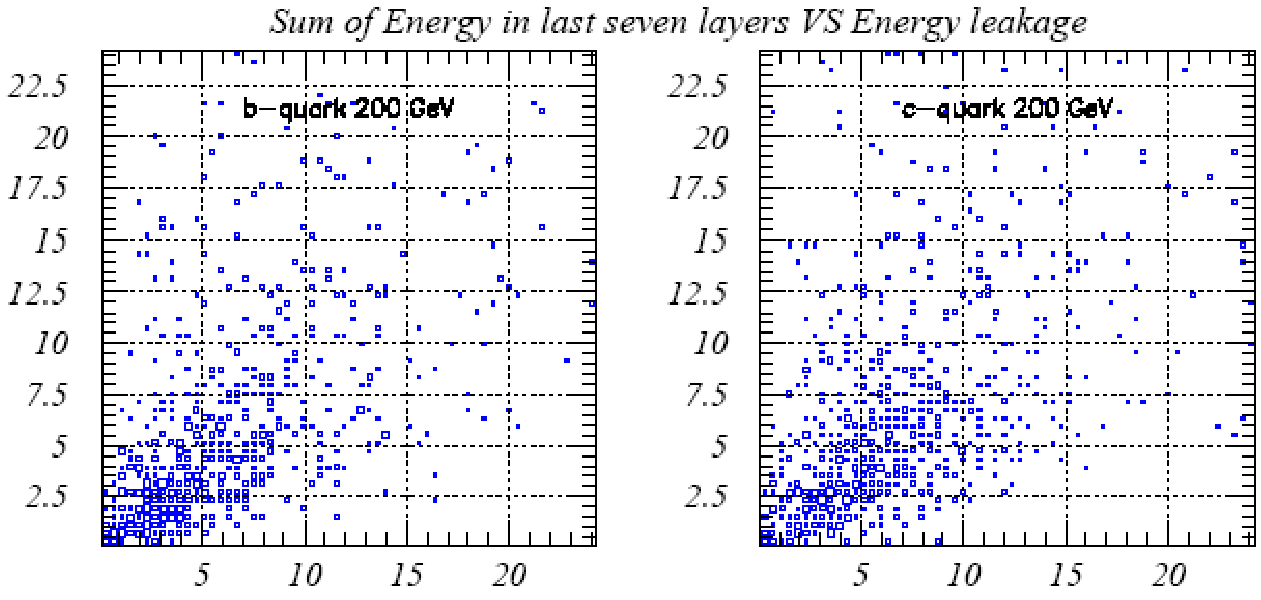
- HCAL and jet performance limited by constant term:
  - Calibration and monitoring
  - uniformity
  - Compactness and dead material
  - And leakage!





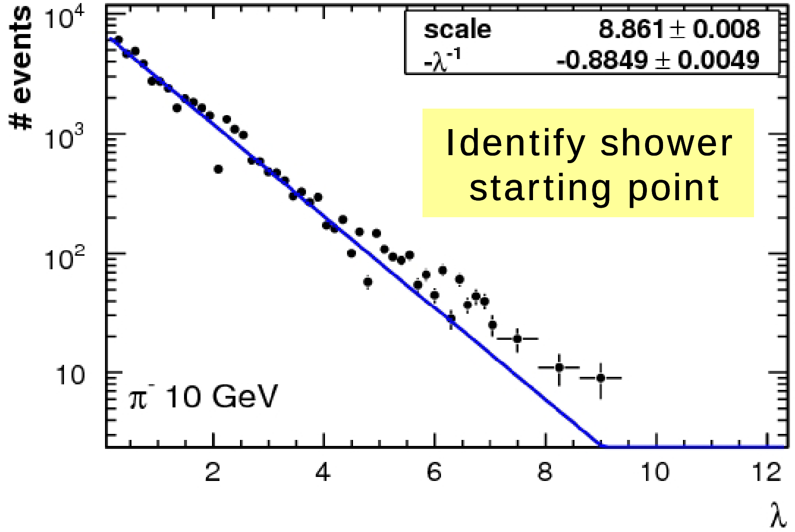
Shower extrapolation?

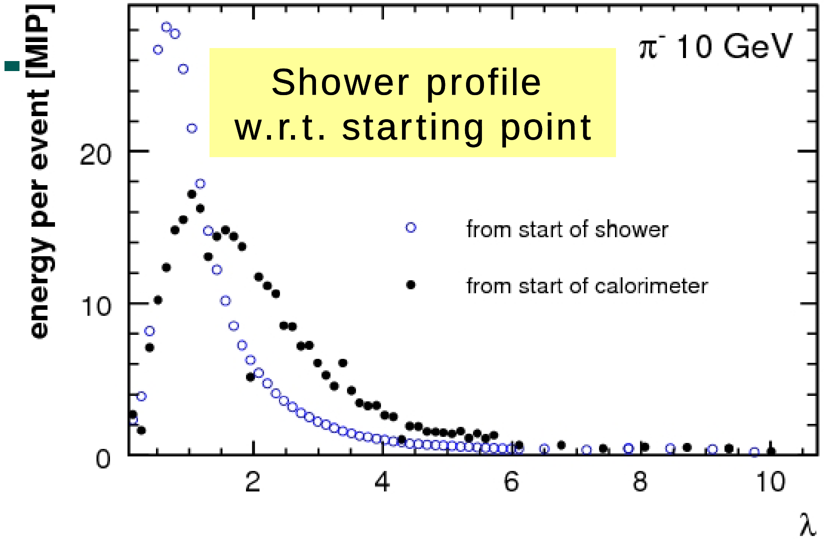
- Naively: check the rear section of HCAL whether shower "ended"
- Problem: large shape fluctuations and disconnected fragments
  - Does not work as well as for e.m. showers

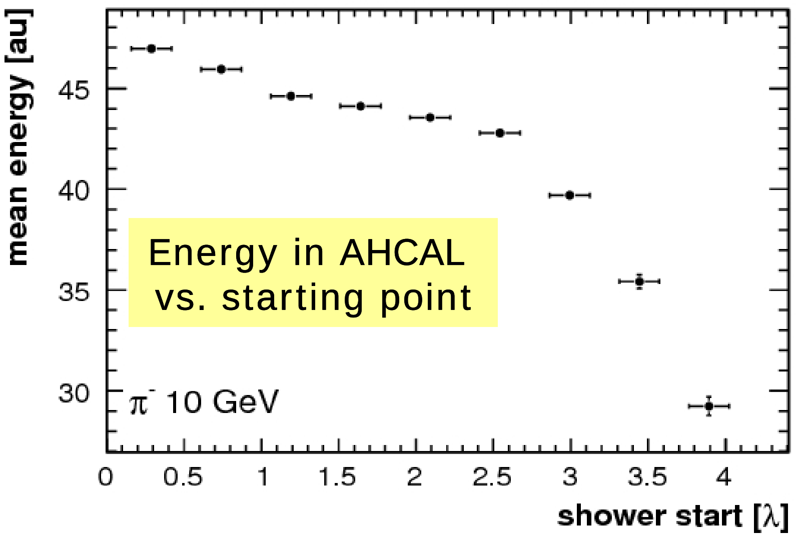


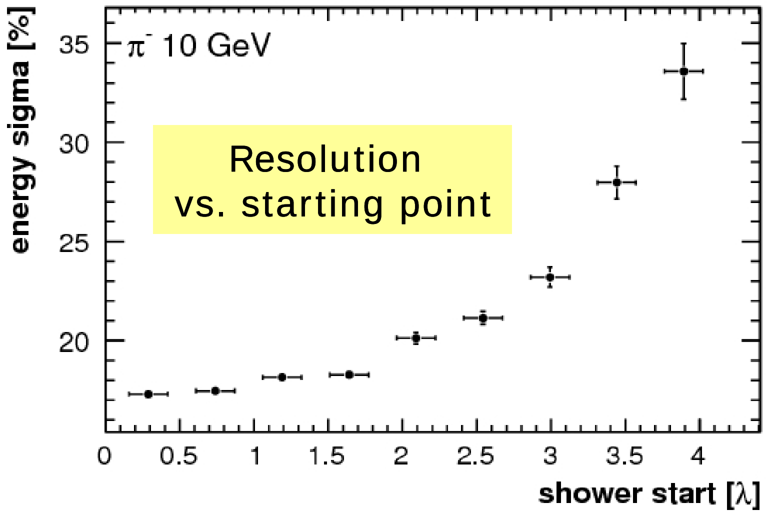
V.Morgunov

HCAL shower leakage study

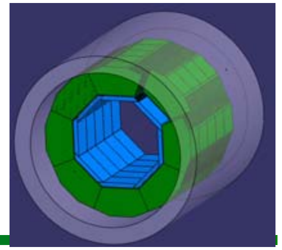






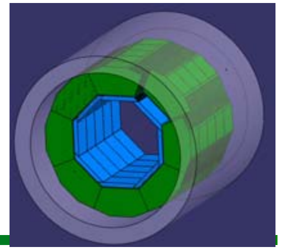


High energy:



- Need to get the best out of particle flow
- Intelligent design of transition to classical calorimetry
- Leakage estimation from topology: just a start
- Combination of observables to be studied
- New ideas and contributions welcome !

Conclusion



- CALICE program in full swing
- Data analysis is reaching precison for confrontaion with shower simulatiosn
- Full use of imaging power still ahead
- Unmapped territory at high energy
- Technical prototypes underway addressing the right issues: compactness, integration