Status of HCAL
for ILD

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IPN-Lyon

Outline

HCAL options : AHCAL, DHCAL

Expected performance

Current and future R&D

Calibration and alignment for ILD

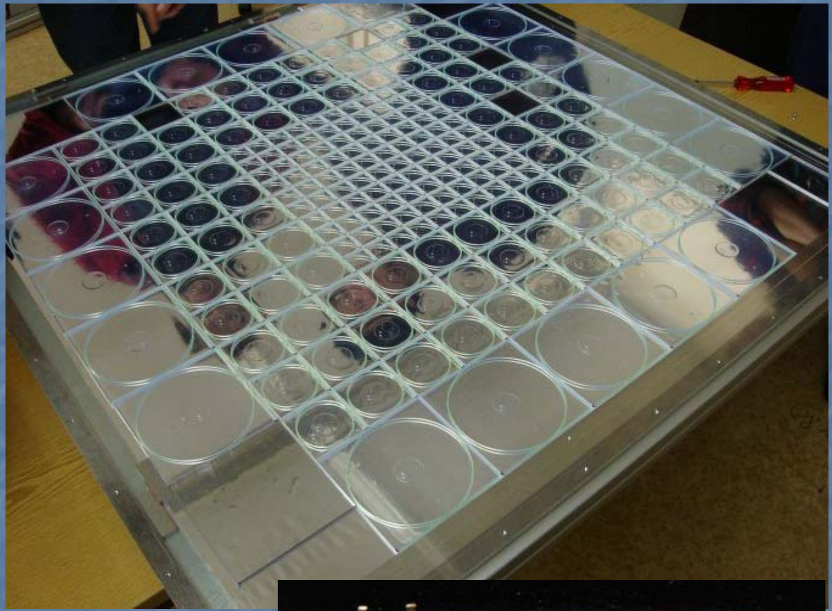
Mechanical structure

Discussion

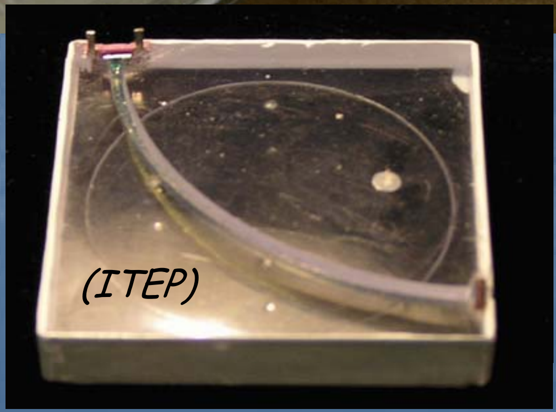
Scintillator HCAL

Tile solution

- Novel multi-pixel Geiger mode photo-diodes (SiPMs)
  - B-field proof, small, affordable
- High granularity with scintillator at reasonable cost (3X3 cm^2)
  - photo-sensors integrated
- Opens revolutionary design options:
  - embedded analogue electronics and calibration system for minimal dead zones
  - thin readout gap
- Compact, hermetic



(DESY)

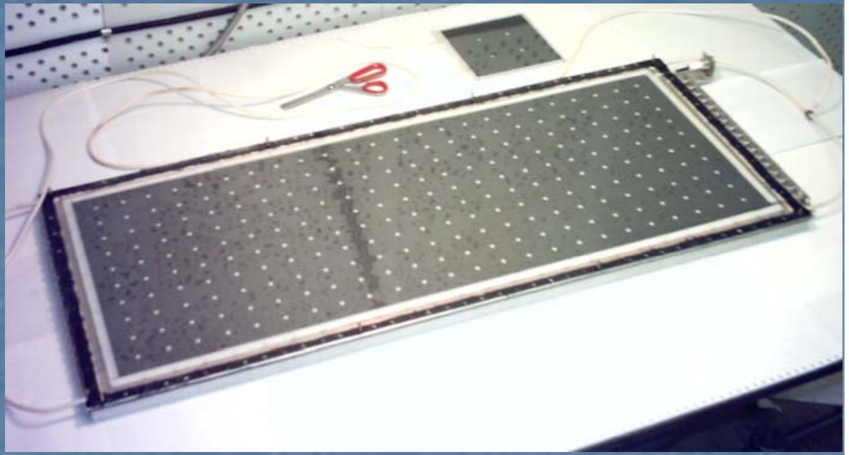


(ITEP)

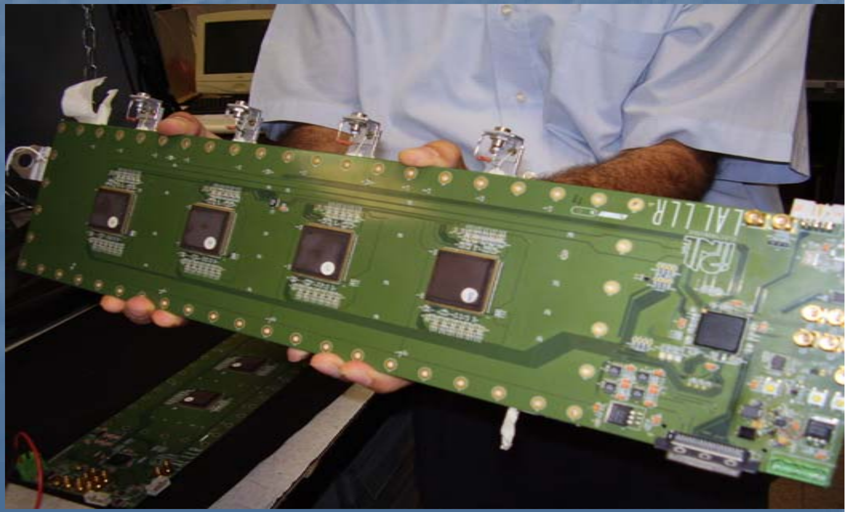
Gas HCAL

GRPC solution

- Very thin gas detector (<3 mm)
  - Efficient, cheap, good knowledge from previous experiments
  - No B-field effect.
- Very high granularity ($1X1\ cm^2$)
- Revolutionary design options:
  - embedded semi-digital electronics
  - thin readout gap
- Compact, hermetic



(IHEP)



(in2p3)

Expected performances with PFA

Comparison of Energy Resolutions

Semi-digital

$$\frac{\sigma}{E} = \sqrt{\frac{\sigma_{stochastic}^2}{E} + \sigma_{constant}^2}$$

- Analog : $\sigma_{sto} = 48.9 \pm 0.6\,\%$
  $\sigma_{con} = 5.0 \pm 0.2\%$
- Digital : $\sigma_{sto} = 37.0 \pm 0.9\%$
  $\sigma_{con} = 13.8 \pm 0.2\%$
- Semi : $\sigma_{sto} = 45.1 \pm 0.6\%$
  $\sigma_{con} = 6.8 \pm 0.1\%$
- Real data (analog) :
  $\sigma_{sto} = 46.7 \pm 0.6\%$
  $\sigma_{con} = 0.9 \pm 0.9\%$

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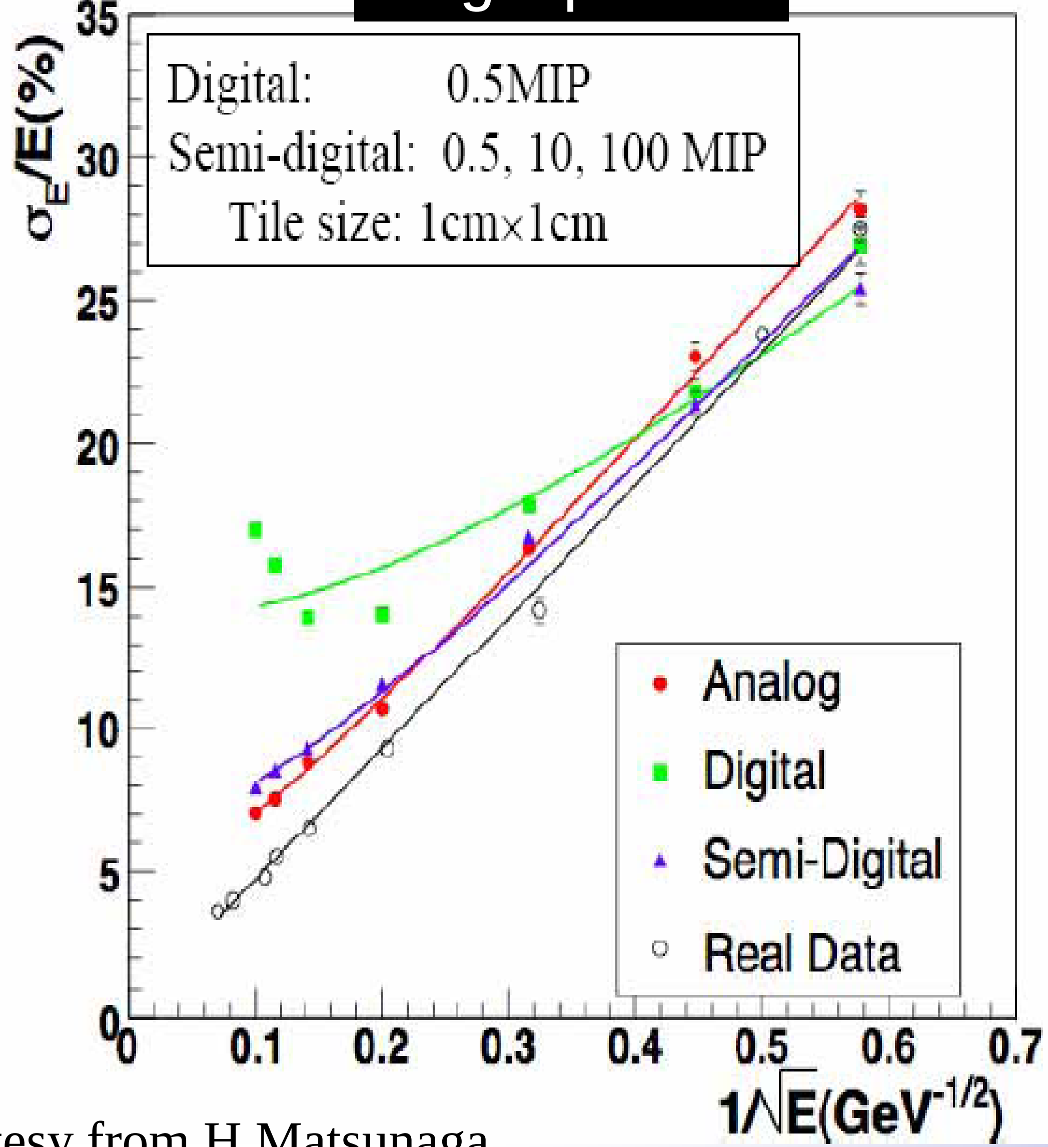
Single particle

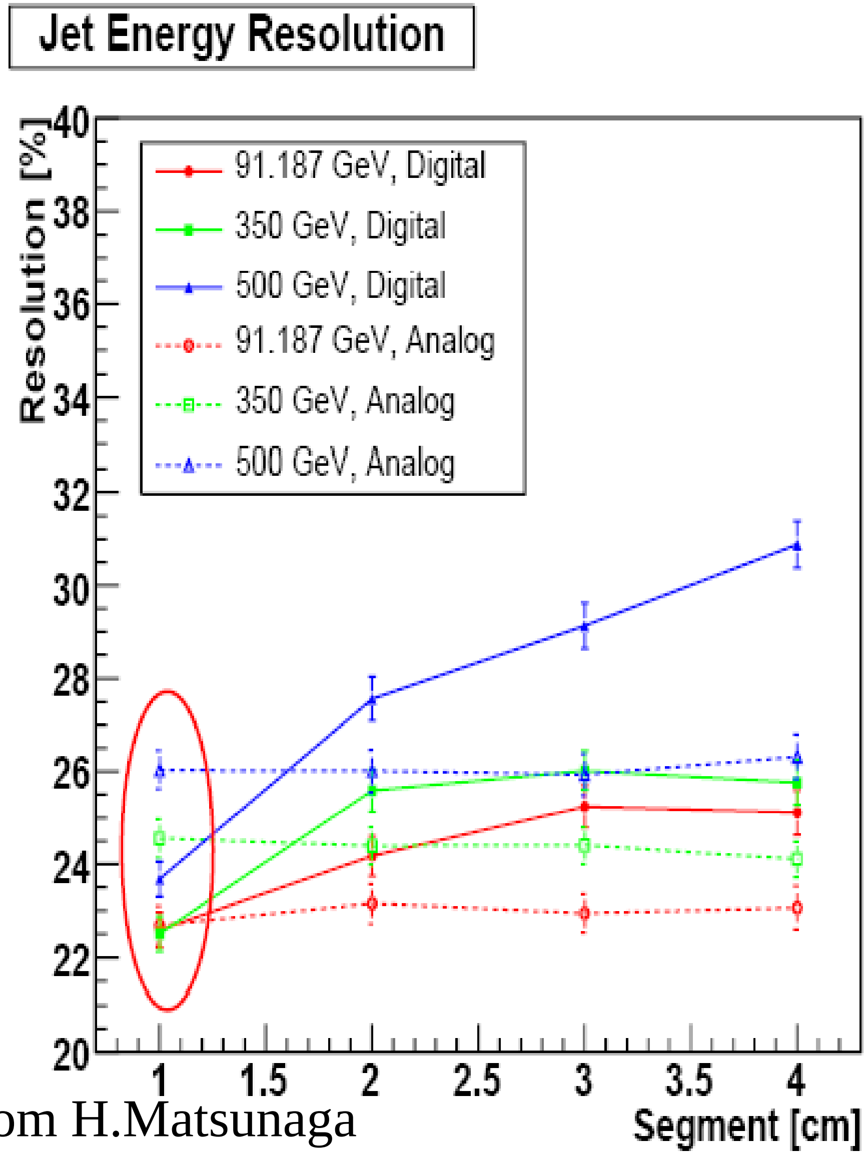


courtesy from H.Matsunaga

Jet Energy Resolution

Semi-dig

- $e^+e^- \rightarrow qq$ (u/d/s)
  - $\sqrt{s}$ = 91, 350, 500 GeV
- Energy measurement with (perfect) PFA
- In case of 1×1 cm² tile size, digital calorimeter achieved similar or slightly better jet energy resolution



courtesy from H.Matsunaga

PFLOW performance

Analogue

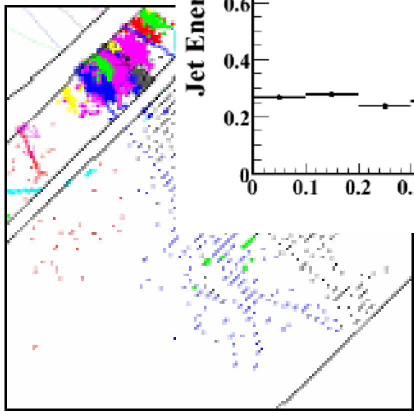
- From M. Thomson:

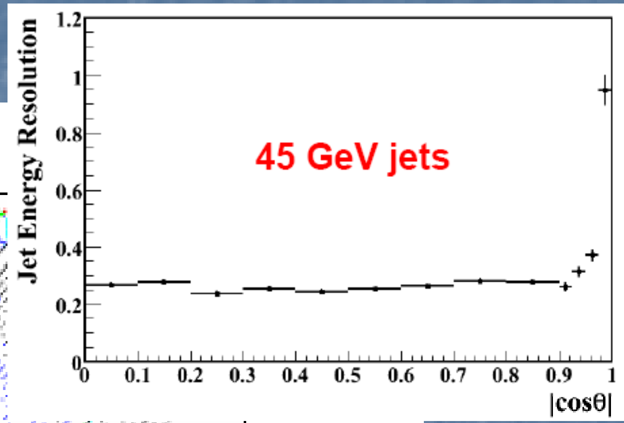
★ Validated using full reconstruction chain, e.g.

PandoraPFA v02-01 + FullLDCTracking

rms90

E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
45 GeV	0.24	3.5 %
100 GeV	0.31	3.1 %
180 GeV	0.43	3.2 %
250 GeV	0.56	3.6 %





★ For 45 GeV jets, performance equivalent to **24 % / √E**

★ Performance degrades at higher energies
  - particles in jets become less well spatially separated

★ But **σ_E/E < 3.8 %** for jet energies less than 250 GeV

★ Will improve, but probably already "good enough" for ILC @ 1 TeV
  - mostly dealing with 4+ fermion final states

Analogue

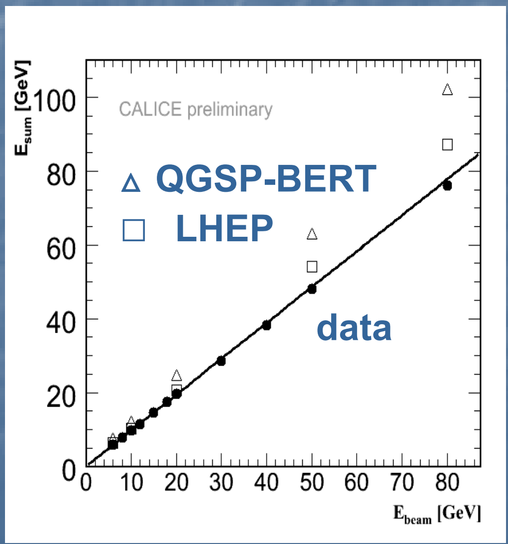
Shower models

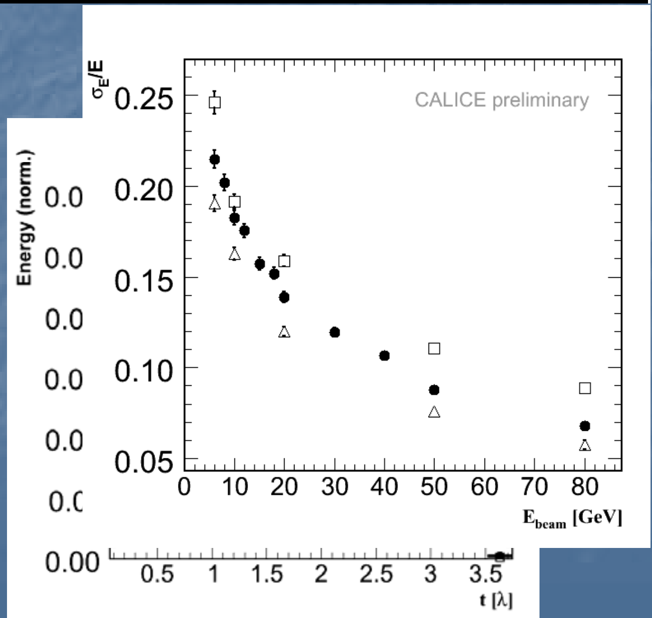
1. Model uncertainties on PFLOW performance

M. Thomson (Cambride)

(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 %

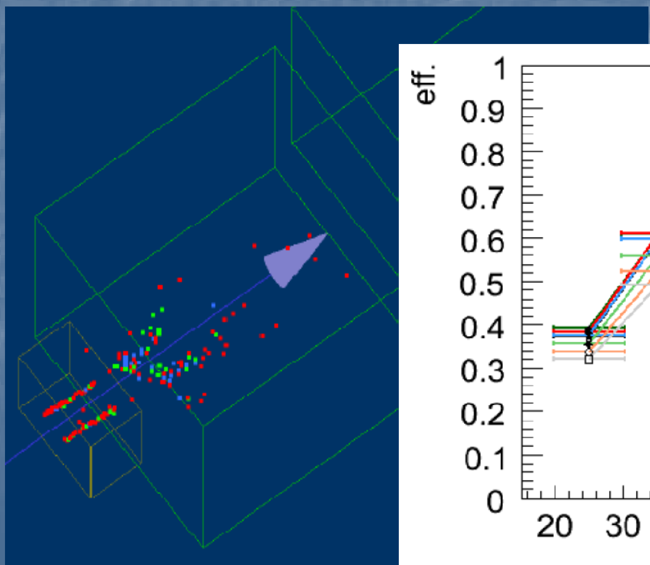
2. Confront shower models with test beam data
   - First results on global properties
   - Next: fully exploit granularity for fine structure

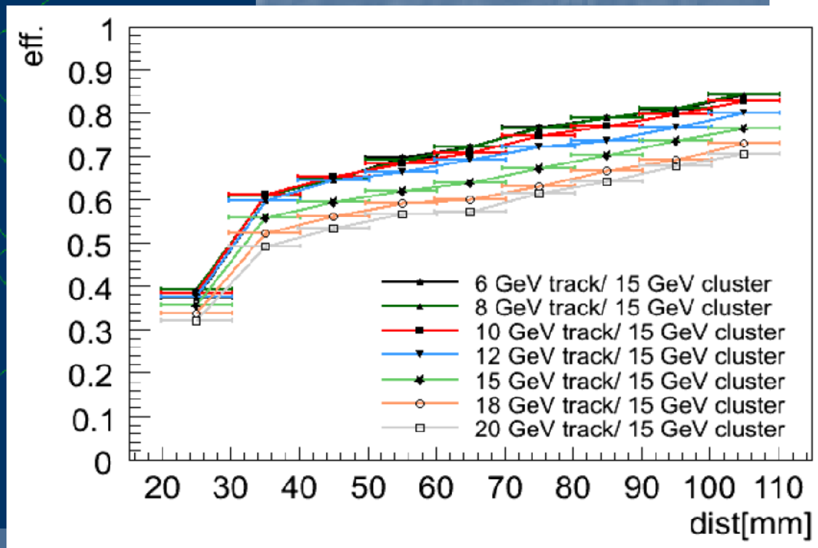


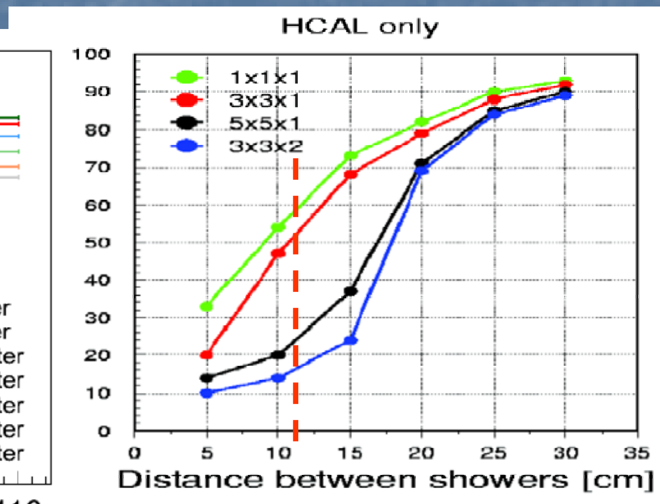


Validate PFLOW performance

- 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:

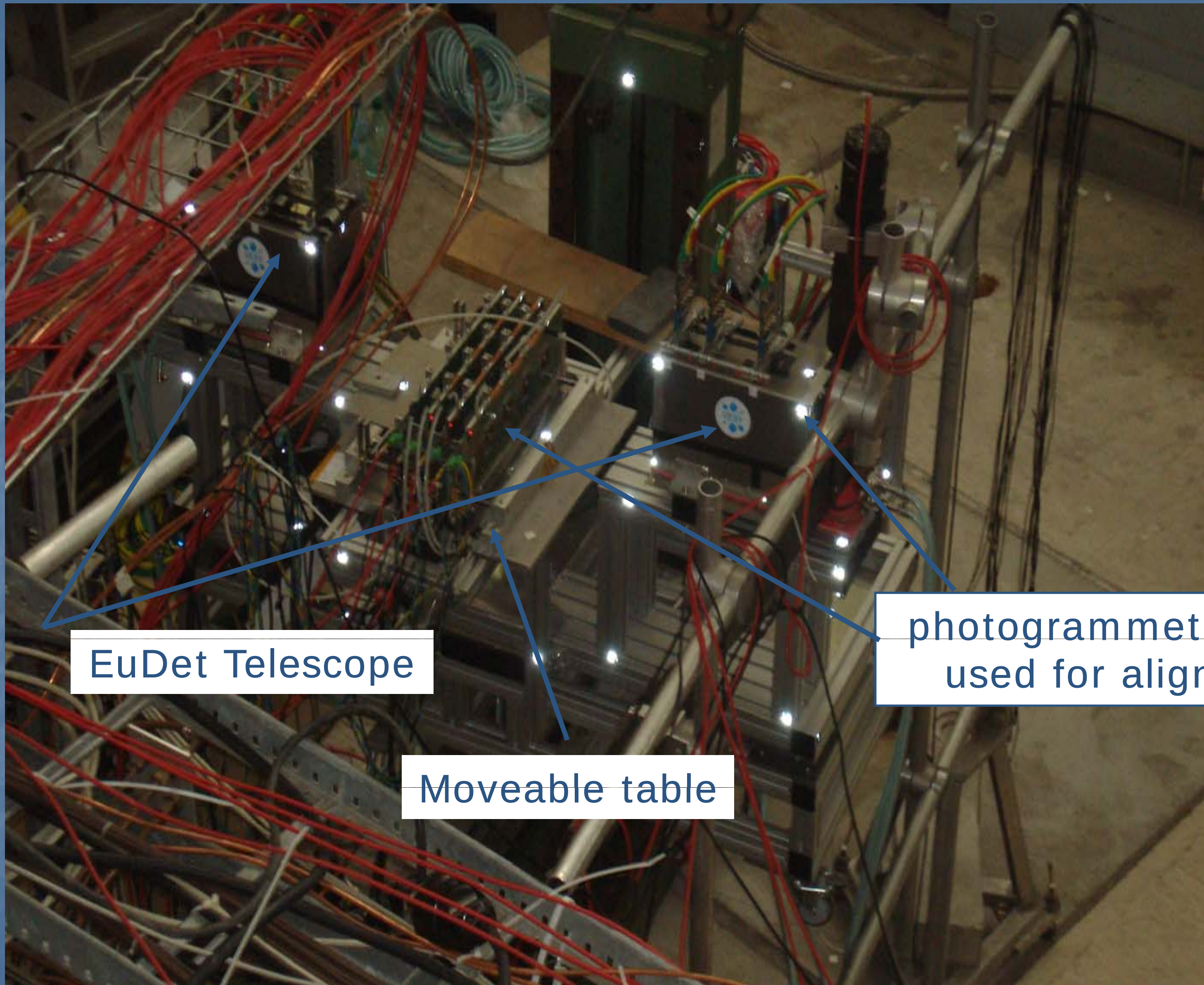






A. Raspereza

DHCAL beam test at cern+Eudet Telescope

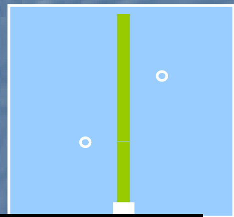


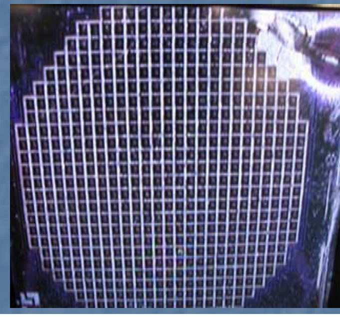
HCAL present and future R&D

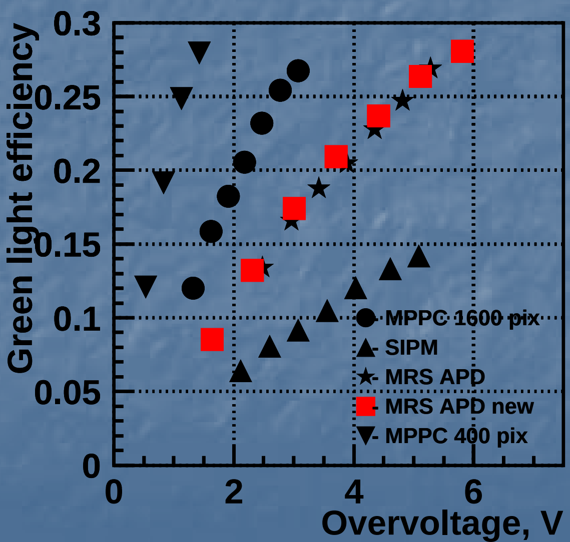
Analogue

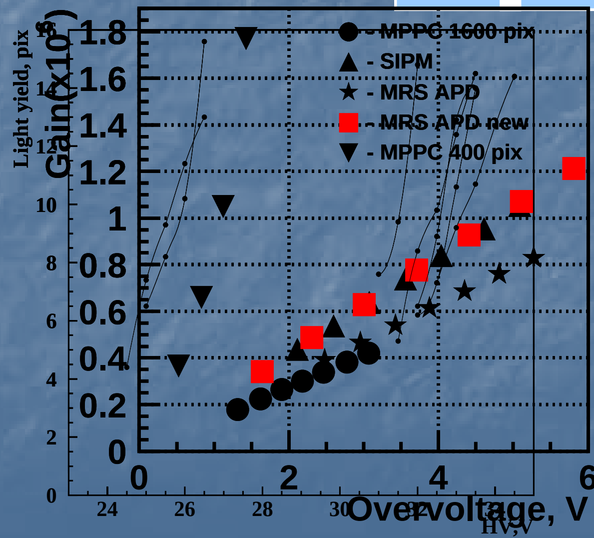
Tile sensor systems with WLS fibre

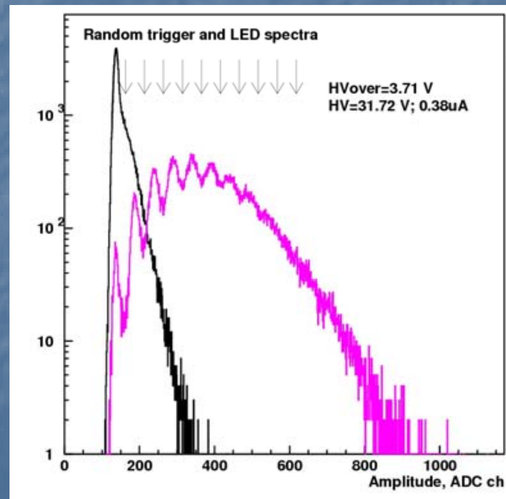
- Present test beam system
  - 5mm thick tile with fibre, MEPHI/ PULSAR SiPM, 15 pixels/MIP
- Several new options: reduce to 3 mm thick tiles
  - Hamamatsu MPPC-1600
  - MRS APDs (CPTA)

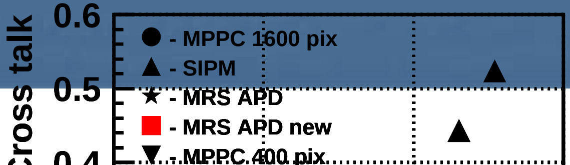


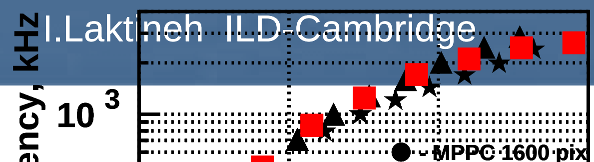












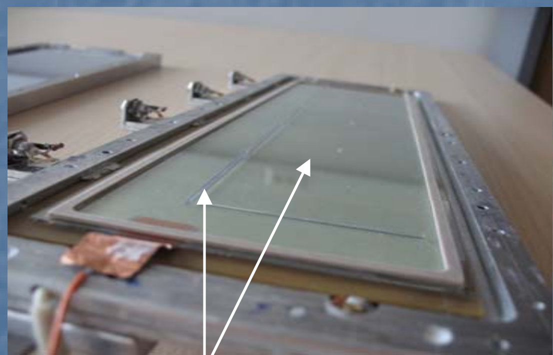
Semi-digital

Glass Resistive Plate Chamber

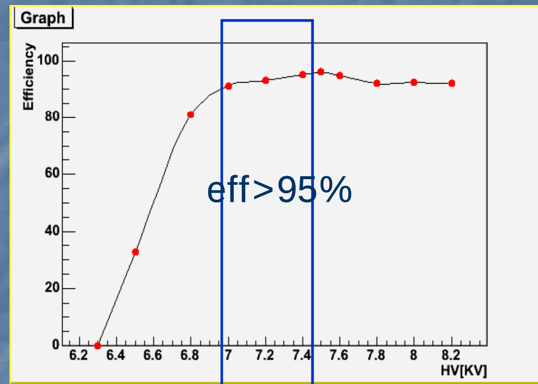
GRPC is a well proved detector (Belle, OPERA, ALICE) but for ILD one Can:

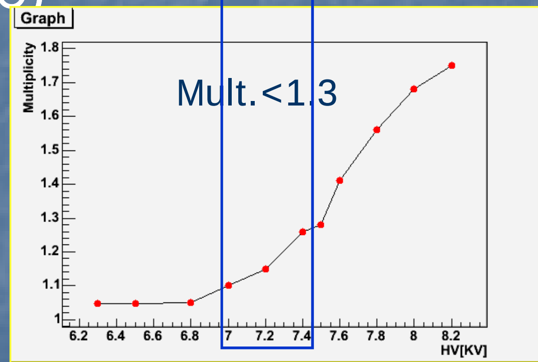
- Reduce dead zone : spacers, frame
- Reduce noise : Spacers, H.V connectors
- Reduce multiplicity : diff. resistive painting
- Rethink the gas distribution system to reduce gas consumption
- Reduce the mip charge spectrum (multigap GRPC)

Frame=hollow peek



Replacing fishing line by ceramic spheres

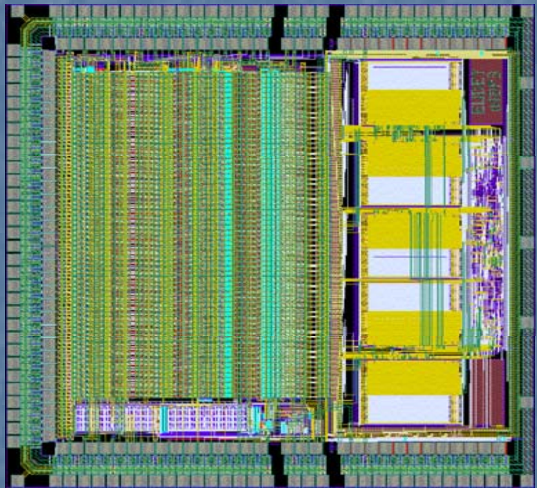




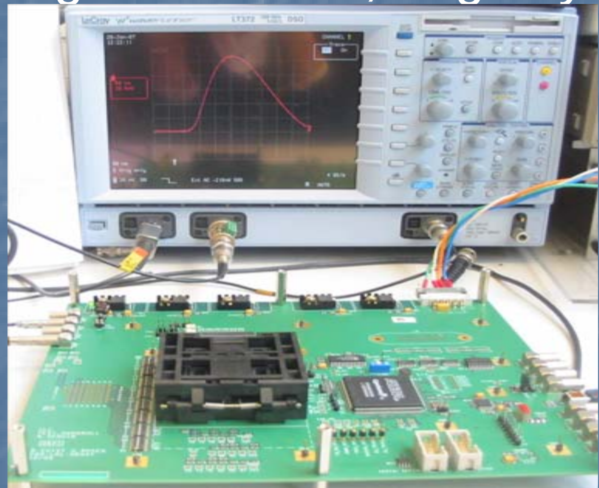
More resistive paintings

Semi-digital Electronics for Gas HCAL

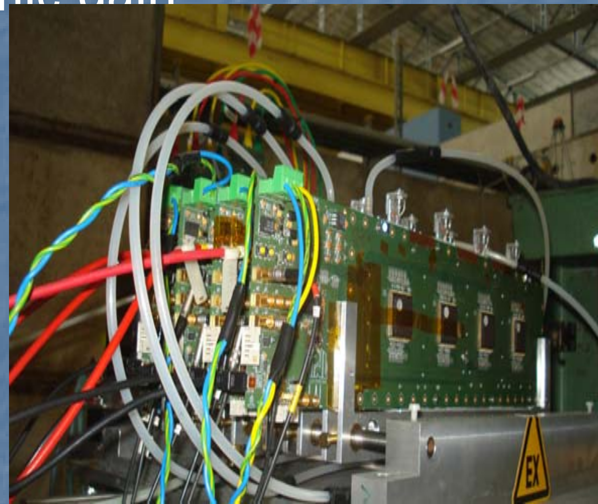
HARDOC ASIC: embedded 64-ch, full power pulsing (<10μW/ch), auto-triggered, semi-digital readout , large dynamic gain



produced



Lab test



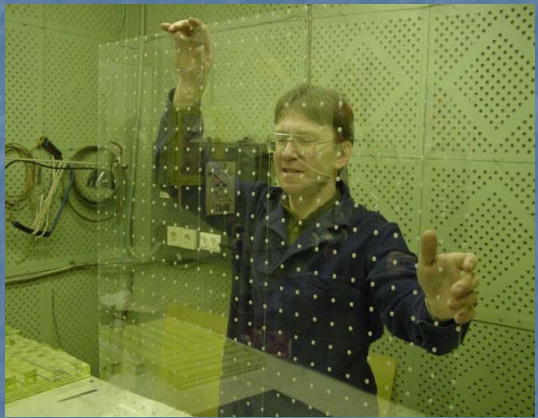
Beam test

ASU+connection+DIF for large size detector produced and under test

ASU for 24 asics(ipnl)

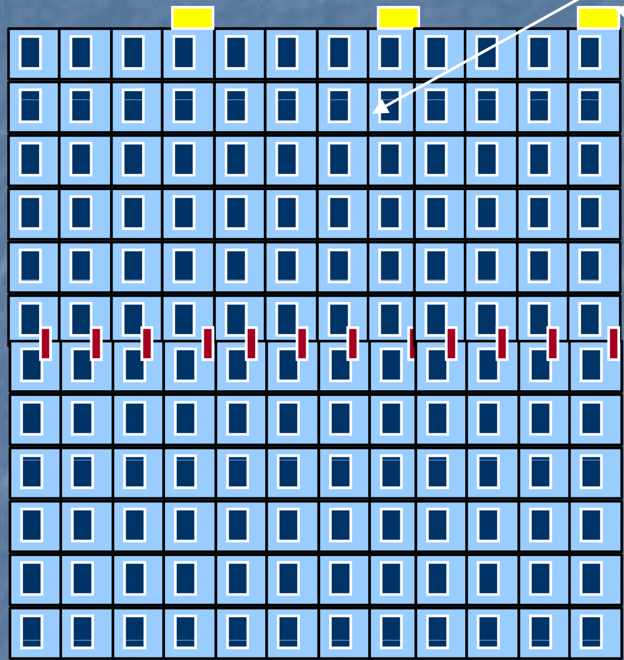
DIF card (lapp)

- A fully equipped 1 M2 GRPC is expected for November 2008
- A technological prototype (ANR) is to be built in 2009-2010

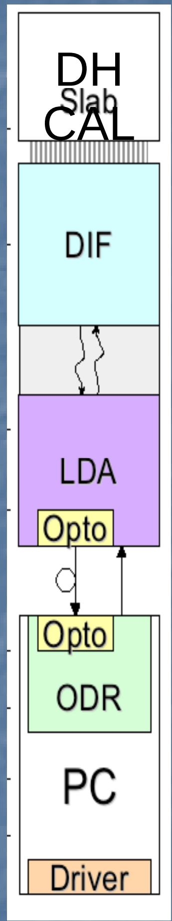


1M² GRPC already buit (IHEP)

Absorber realisation study has started at CIEMAT



Electronics board is under construction



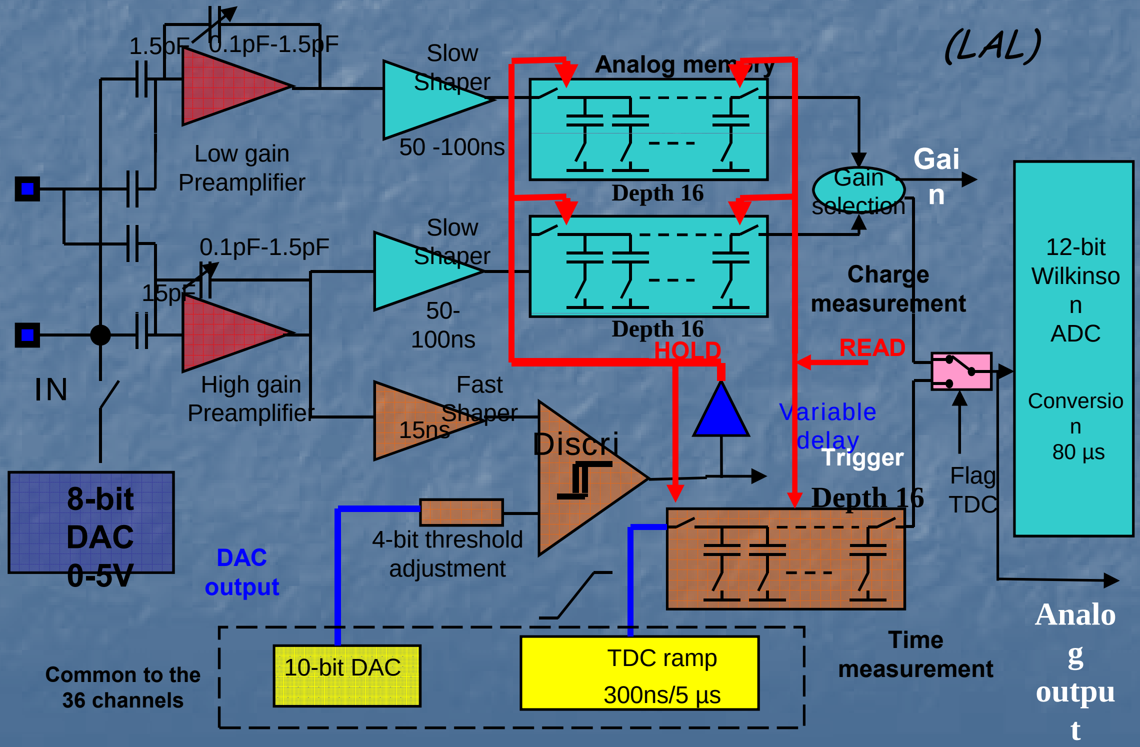
DAQ system well advanced (LLR+IPNL+U.K)

Electronics for Scintillator HCAL

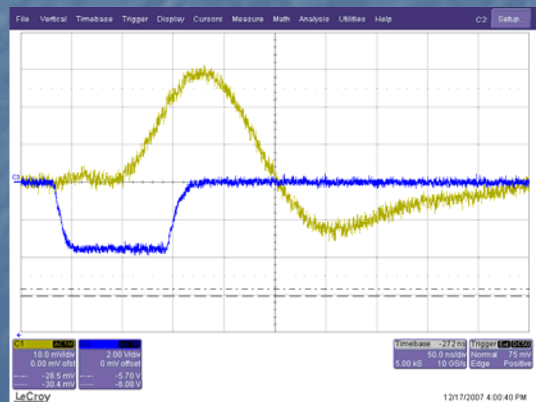
Analogue

Spiroc asic:

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

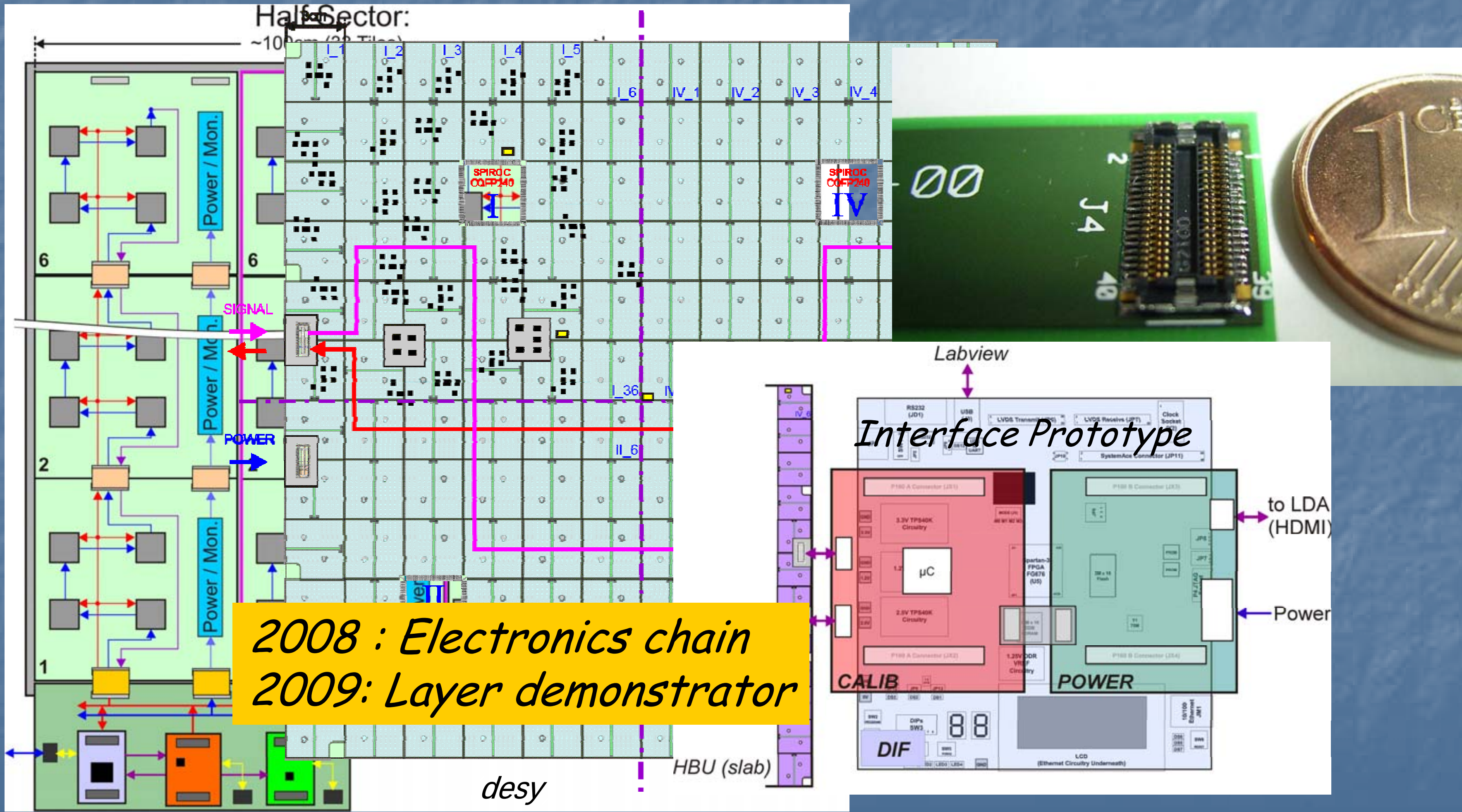


(LAL)



(DESY)

EUDET prototypes

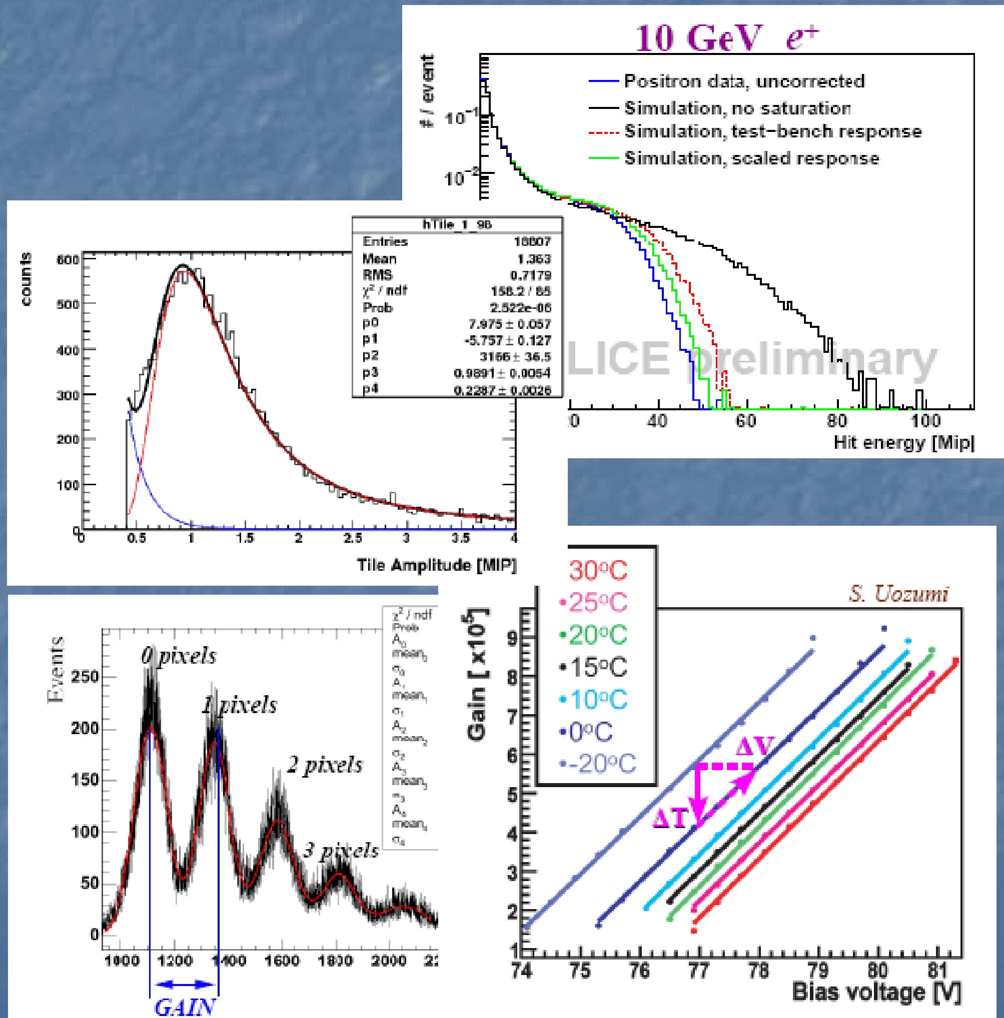


Calibration

Analogue

Calibration procedures

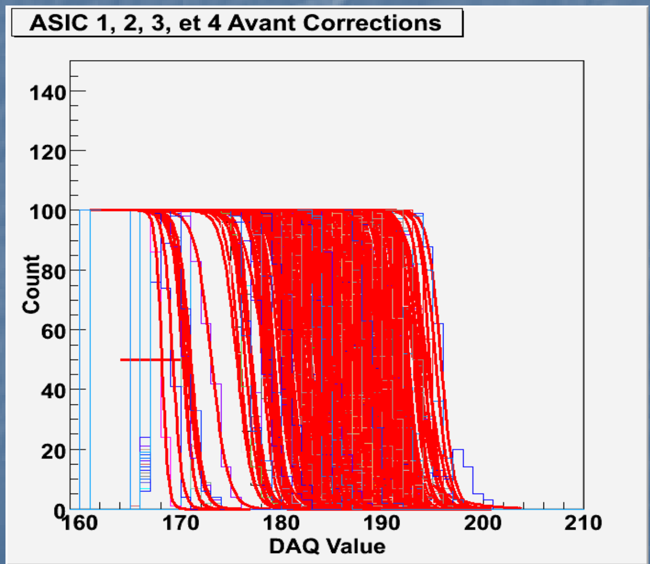
- Non-linearity correction: test with electron data
- MIP calibration: in test beam data, explore use of MIP segments in hadron showers
- Correct for temperature-induced variations
  - Use T-sensors and measured T dependences
- Use gain monitoring, adjust voltage



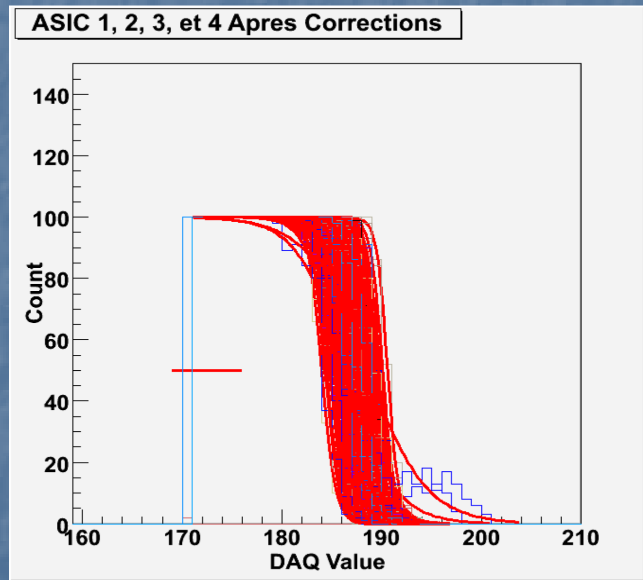
Semi-digital

Calibration procedures

Electronics Calibration : The different channels should have the same response for the same amount of deposit charge.



After gain correction

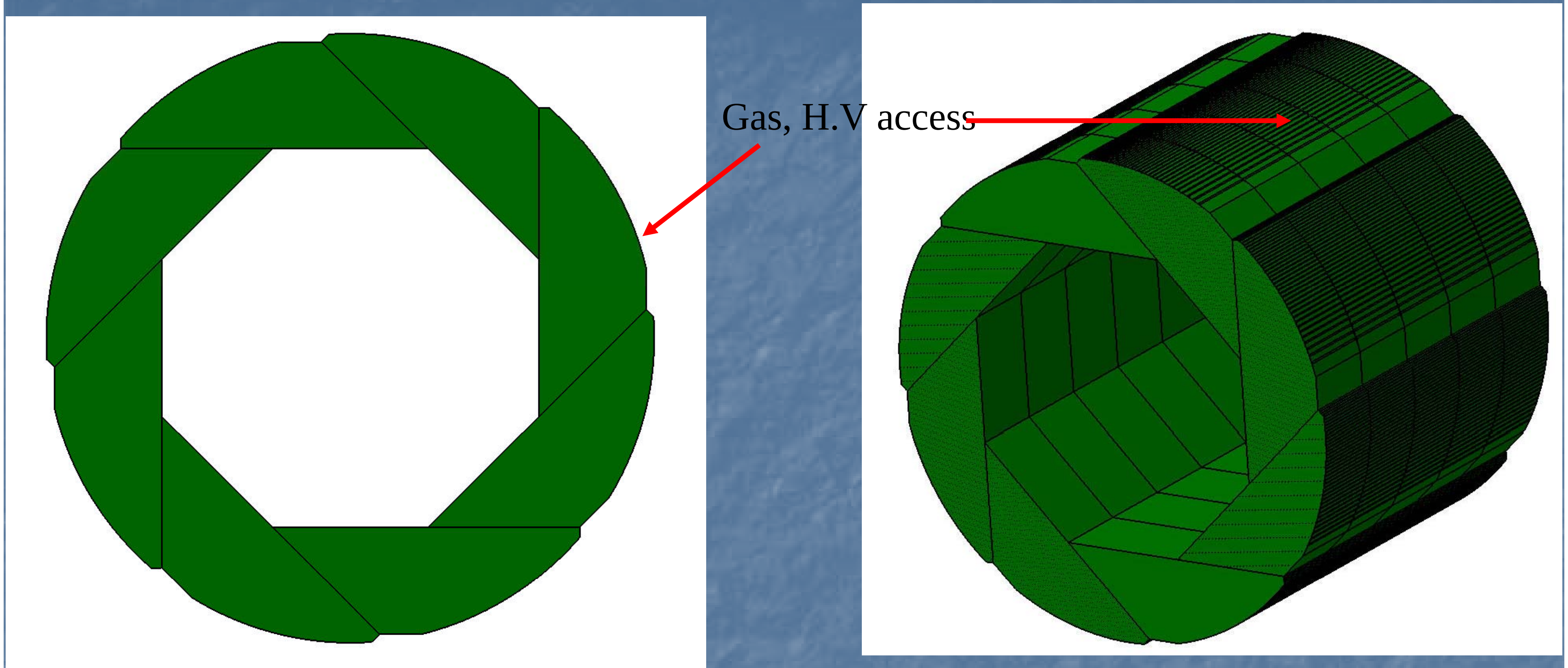


Dispersion<1,3 fc

Automatized procedure

Mechanical Structure

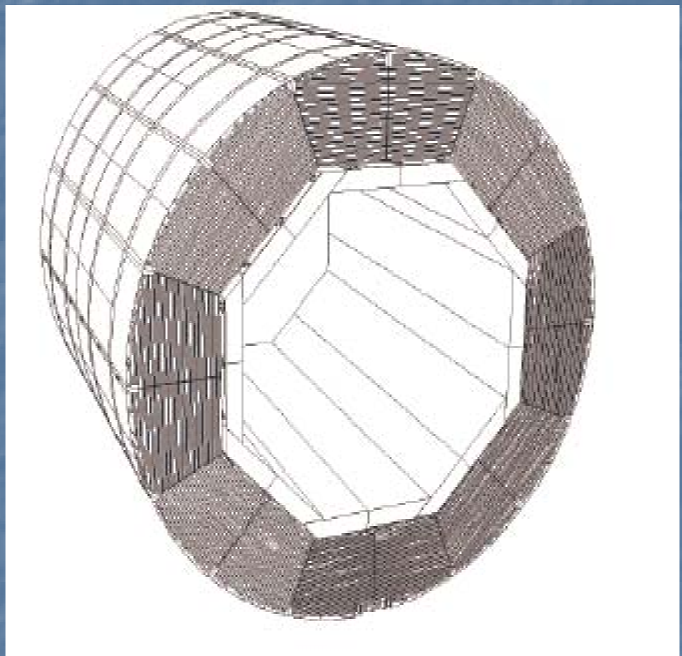
For gas HCAL: Favoured solution is the H.V. one

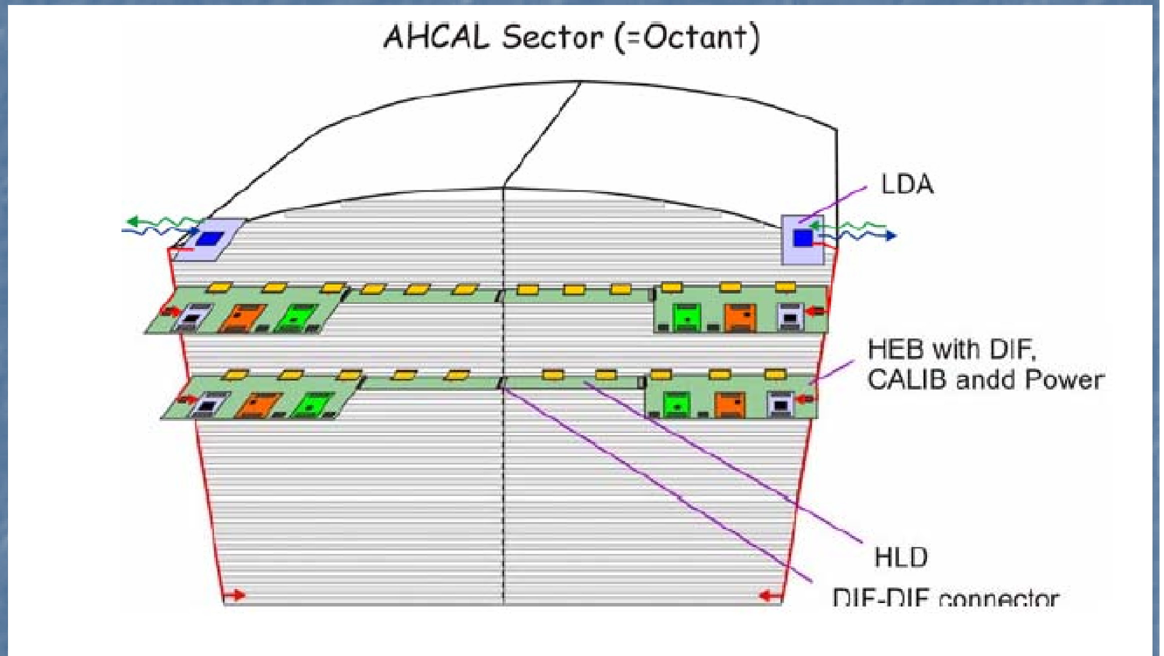


- No cracks: Each particle crossing the same number of detectors
- no problem concerning particles produced with the $\theta = \pi/2$

8-fold

For scintillator HCAL: Favoured solution is the TESLA one

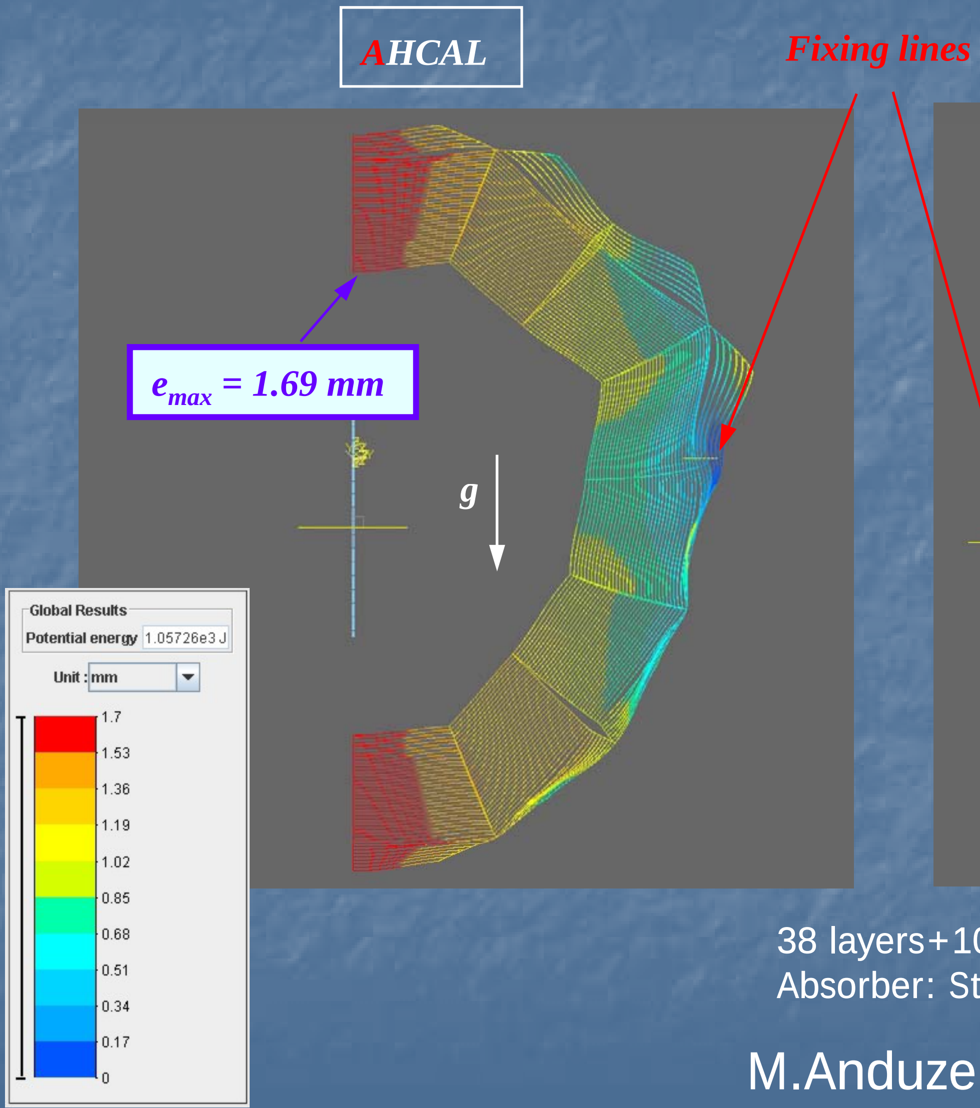


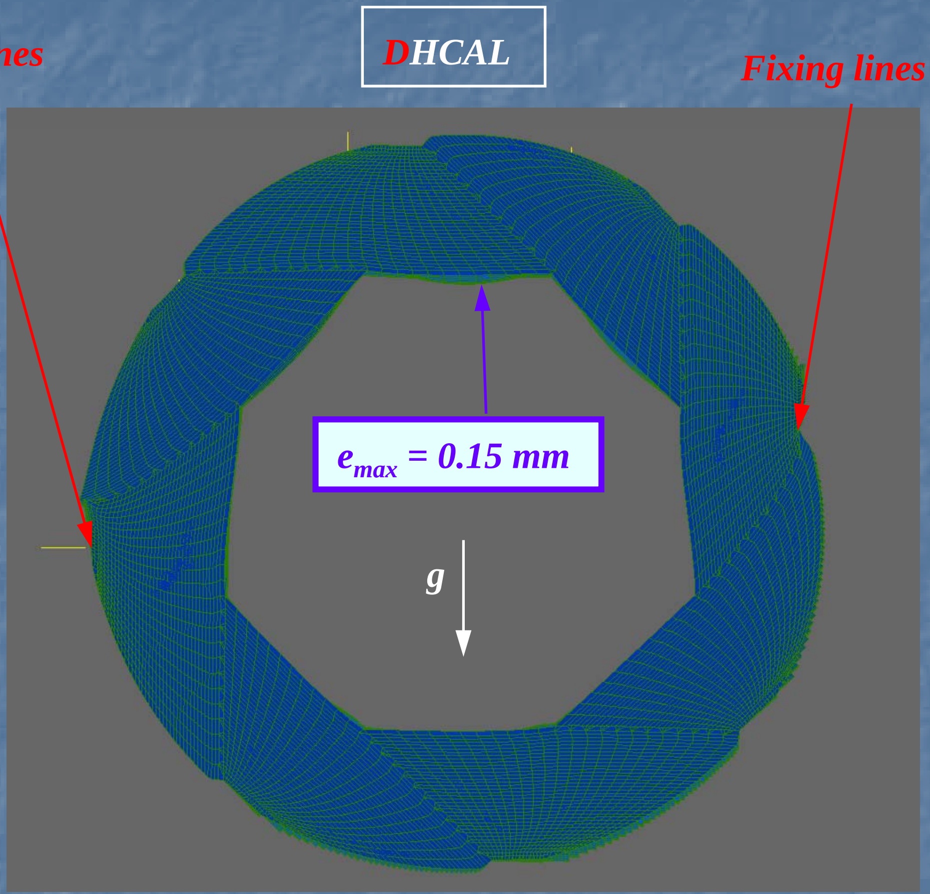


- Flexible ,stable
- planes are easily accessible

8-fold

AHCAL vs DHCAL structures





38 layers+10mm wal
Absorber: Steell

M.Anduze (LLR)

Summary

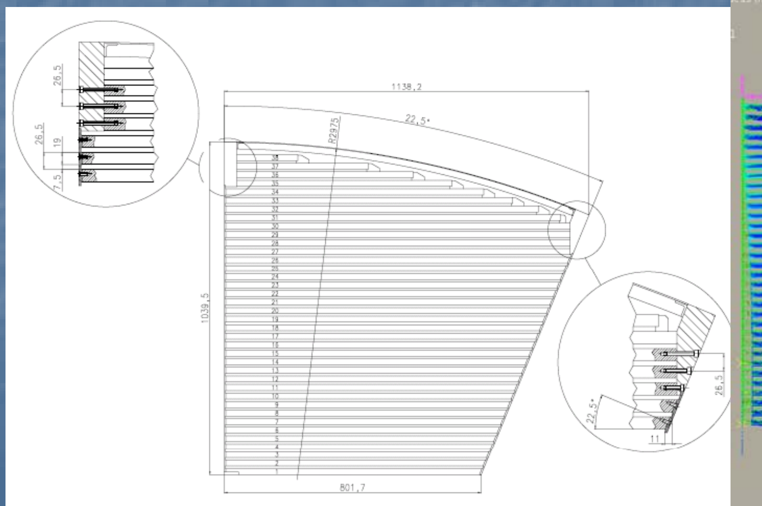
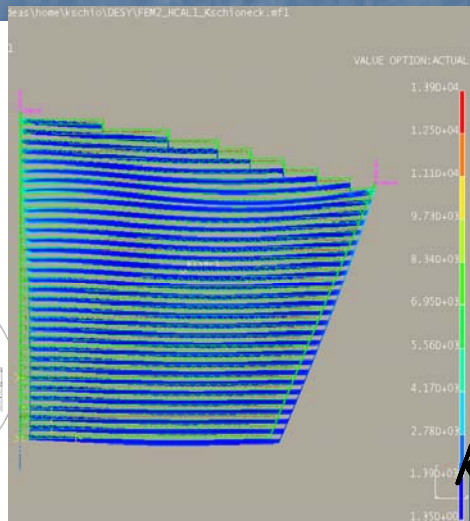
FEM Model	*deflection$_{max}$ (mm)*	*TSAI-HILL (TS)*	*Margin of safety MoS (>1)*	*Von Mises stresses max (Mpa)*
ECAL-8-2	0,17	1,23E-02	2	7,23 (rails)
ECAL-8-3	0,07	4,82E-03	3,8	3,06 (rails)
ECAL-12-3	0,15	3,59E-03	4,56	
DHCAL	0,15			84 (fixing lines)
AHCAL	1,69			135 (fixing lines)
DHCAL + ECAL-8-3	0,35	2,01E-02	1,35	27
AHCAL + ECAL-8-3	0,85	2,28E-02	1,21	56
AHCAL + ECAL-8-2	1,09	1,18E-02	2,08	42

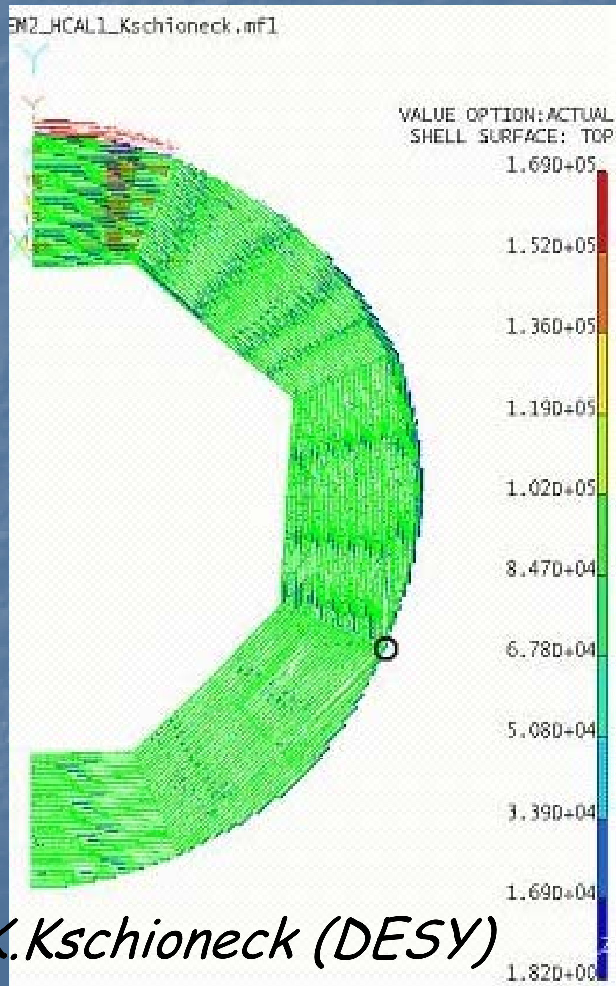
With: $MoS = \frac{1}{K.\sqrt{TS}} - 1$; K= 3 (global safety factor)

M.Anduze (LLR)

Mechanical structure, integration

- Aggressive design: 3mm walls
- No additional spacers
- FEM calculation with sector details for full barrel
  - Max displacement 2mm, stress ✓
  - Integration with cryostat and ECAL



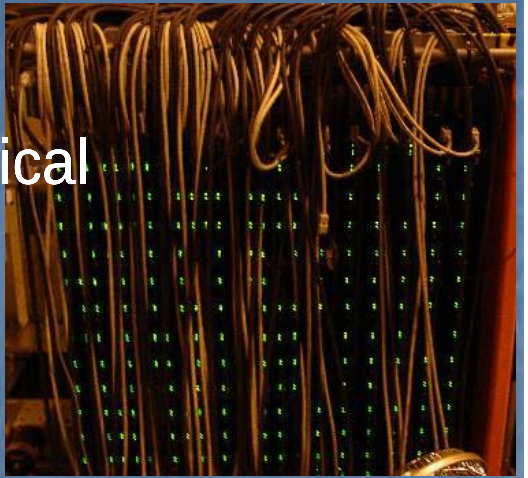
K.Kschioneck (DESY)

Critical aspects of the 2 HCAL options

Gas HCAL

- concept : new, never tested before but
  1M^3 physics and technological prototypes
  are coming soon both in Europe, U.S
- Problems related to gas : Safety, services
  Isobutane->CO_2?, SF_6 ecology? Gas cost
- Detector : Large size detector (> 2M^2) building capacities?
  Stability: temperature, pressure, HV, aging ?
  (BELLE solved almost all of them)
  Radiation in the FW regions?
- Mechanical structure : For H.V. solution space between
  HCAL and Cryostat should ≈10 cm for HV, gas, electronics
  services.

Scintillator HCAL



- Concept : new, never tested before but physics prototype is there and technological prototype is coming soon in Europe
- Detector :
  → PMMC:
  New device, few producers→ price?
  stability with temperature? sensitivity to voltage variation? (incorporated calibration device)
  sensitivity to Radiation in the FW directions,
  → Scintillators: Saturation effect at high energy
  Non uniformity
  Neutrons (cf Adrian talk)
- Mechanical structure : Standard Tesla solution
  $\theta = \pi/2$, Φ craks....can be solved

Summary

- The two HCAL concepts proposed for ILD are very promising
- Many efforts are going on to achieve $1M^3$ ILC-like prototypes by 2010.
- AHCAL optimization for ILD is ongoing (cf Angela talk)
- DHCAL optimization for ILD has started

- CALICE collaboration is a natural place to exchange expertise between the two concepts and also with the two proposed ECAL options and of course with our U.S. colleagues.