Status of CALICE

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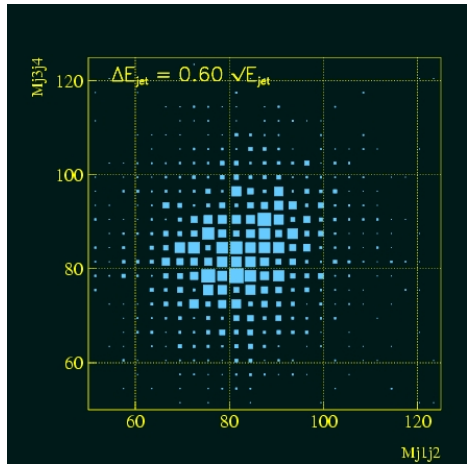
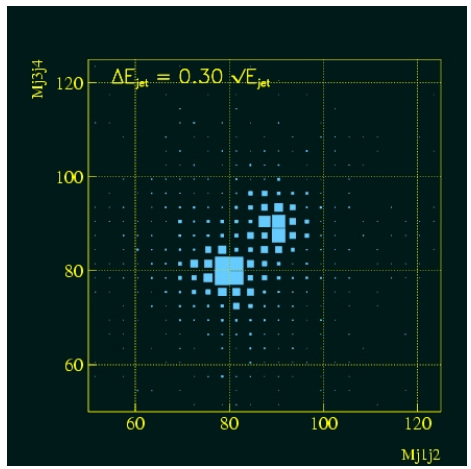
CALICE

- Collaboration of 178 physicists (28 institutes; Europe, US, Asia). Include Birmingham, Cambridge, Imperial, Manchester, UCL.
- R&D on calorimetry; working towards beam tests of prototypes in a common framework (hardware+software) to evaluate and compare hardware concepts and validate simulation tools.
- Focus on highly granular calorimetry, optimised for energy flow.
- ECAL – Si-W with ~ 1x1cm^2 pads and up to 40 layers.
- Analogue HCAL – Scintillating tiles (≥ 3x3cm^2) + Fe.
- "Semi-digital" HCAL – small tiles with dual thresholds for readout.
- Digital HCAL – ~1x1cm^2 cells - RPCs or GEMs.

Physics Motivation

- Many important multijet final states in e^+e^- at ILC, e.g. tth, Zhh, $\nu\nu$WW, $\nu\nu$ZZ.
- In order to resolve Z and W hadronic decays, need resolution on jet-jet mass comparable with Z and W widths (2 GeV).
- Corresponds to needing to measure jet energies with precision ~30%/√(E/GeV).
- n.b. beam energy constraint less powerful than at LEP (ISR/beamstrahlung).

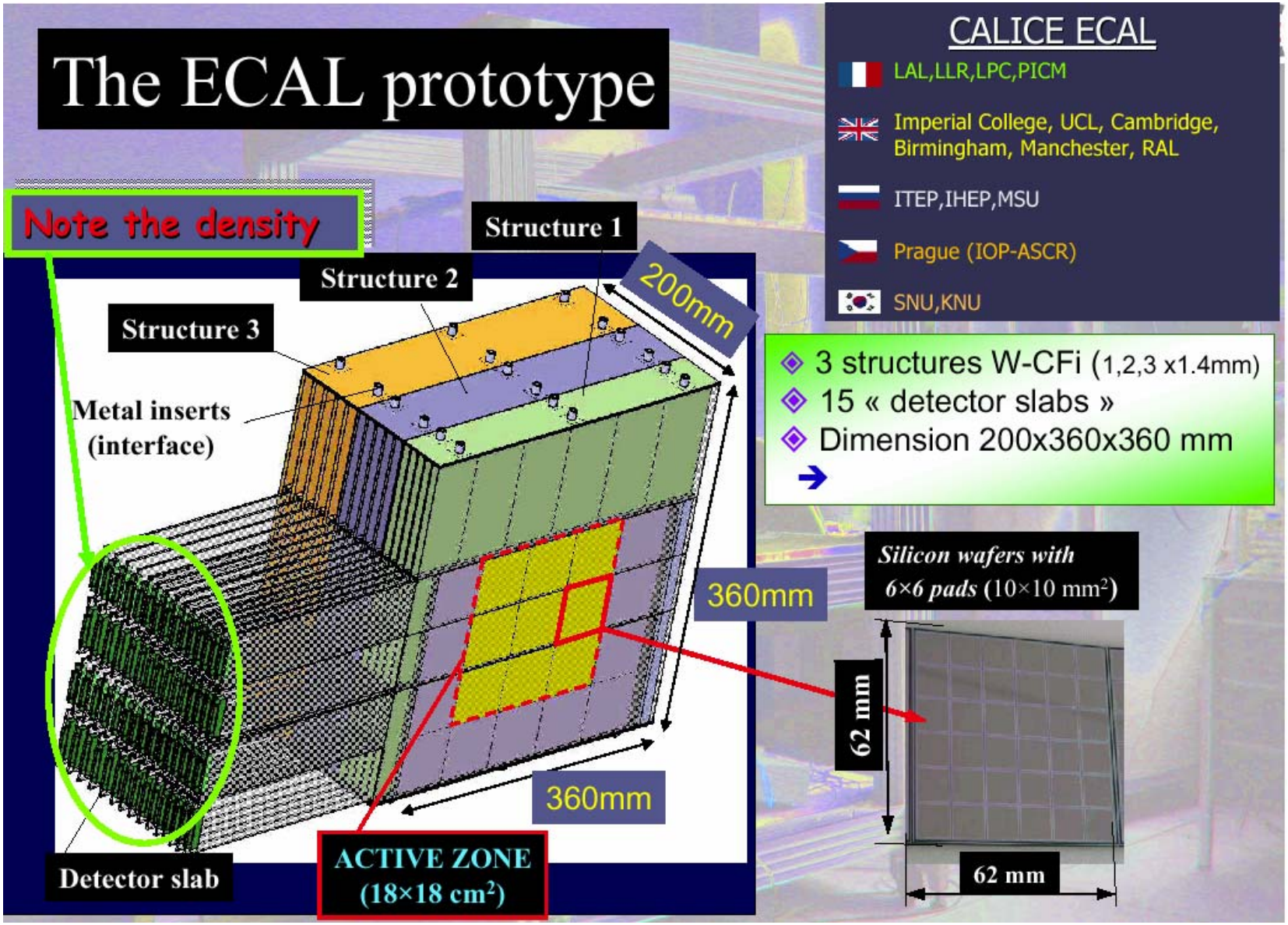




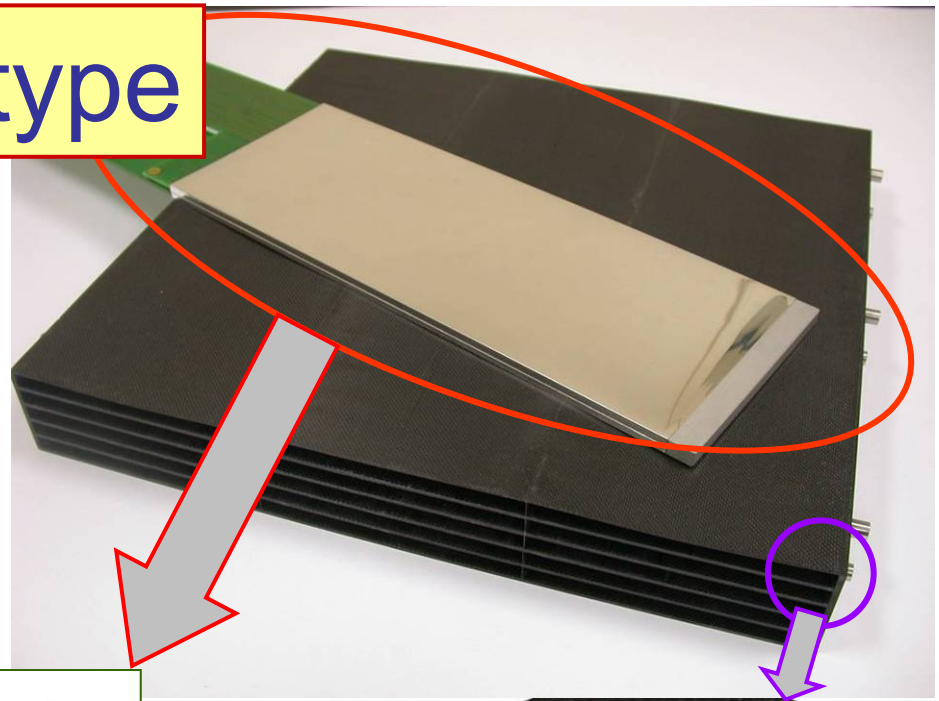
Particle Flow Paradigm

- On average, 65% of a jet's energy in charged particles – measure using tracking.
- Measure photons and neutral hadrons in calorimetry (ECAL and ECAL+HCAL respectively).
- Need to disentangle different energy deposits. Implies good spatial resolution more important than ultimate energy resolution.
- Accords with LEP experience.
- Leads one to a highly granular calorimeter system (both longitudinal and transverse); located inside magnet coil to minimise confusion caused by preshowering.

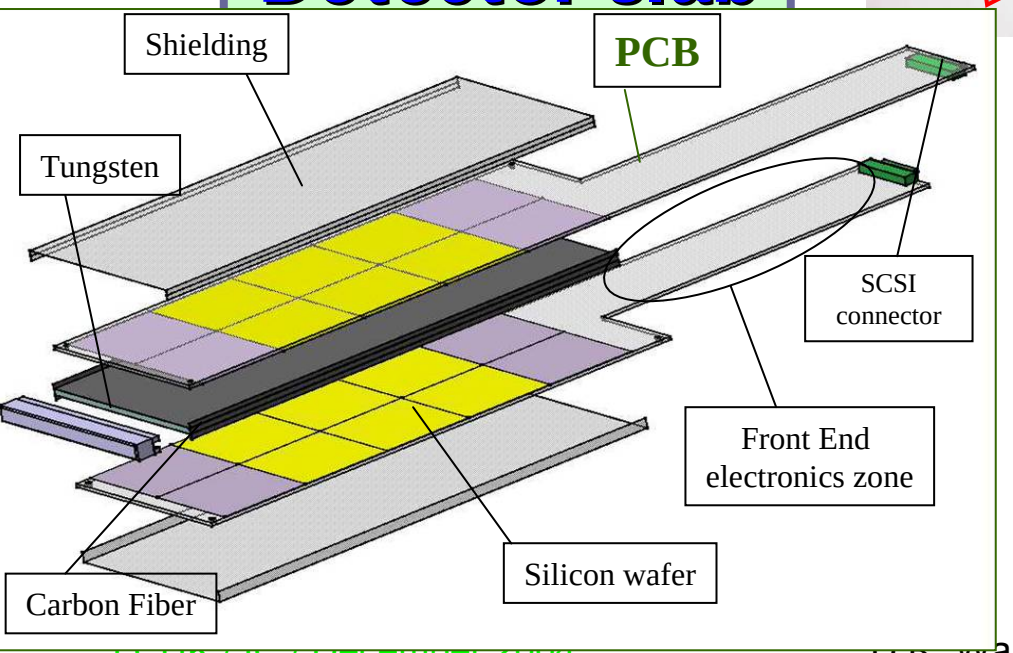
The ECAL prototype

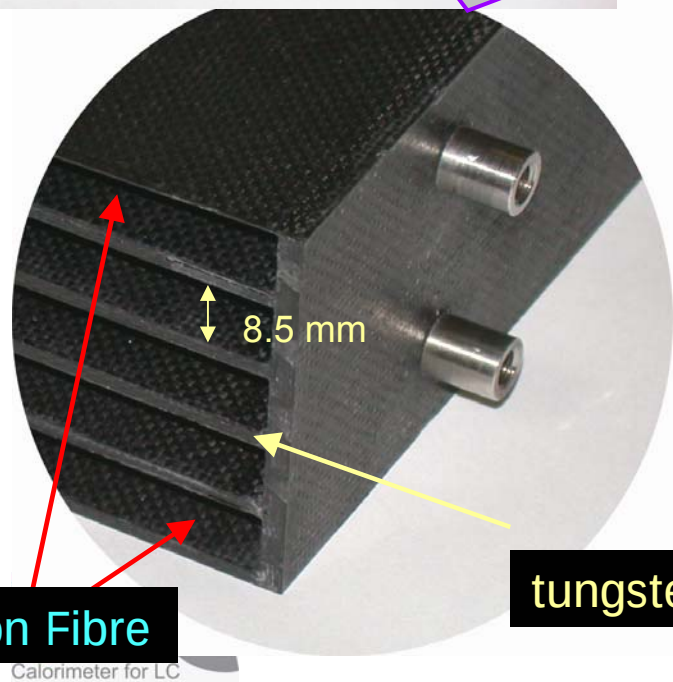


The ECAL prototype

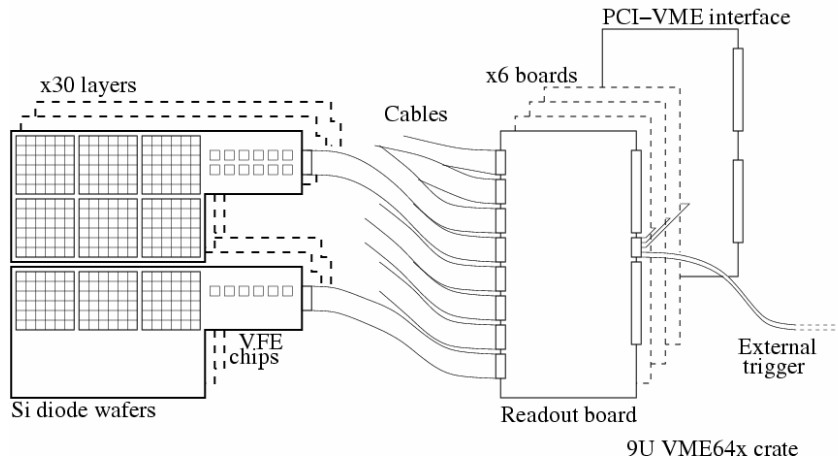


Detector slab

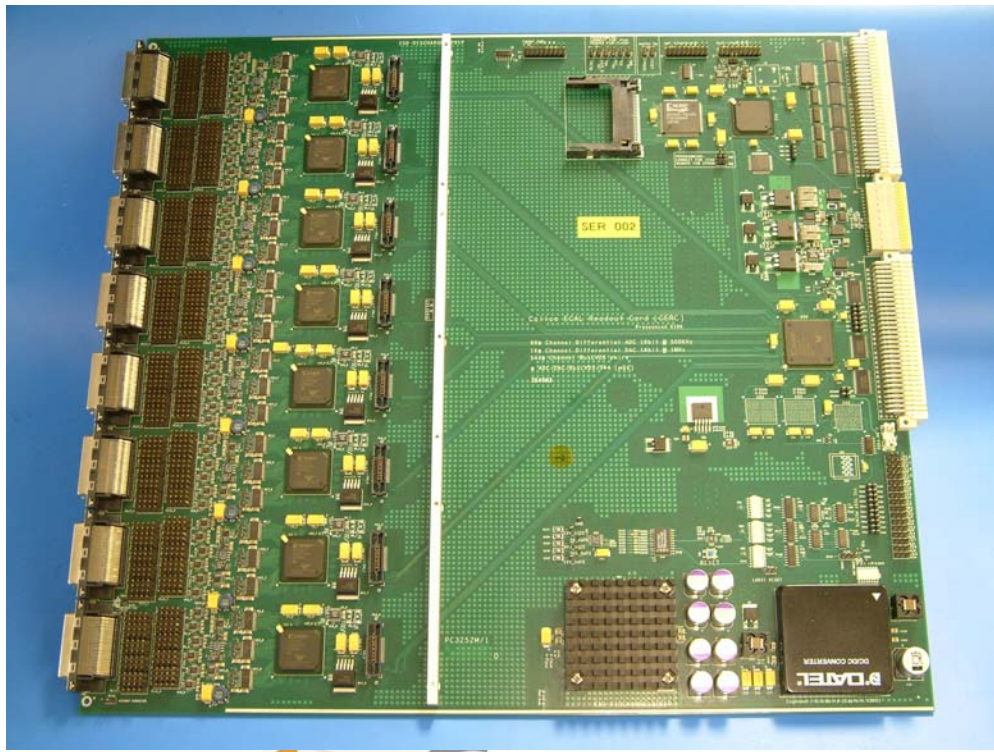




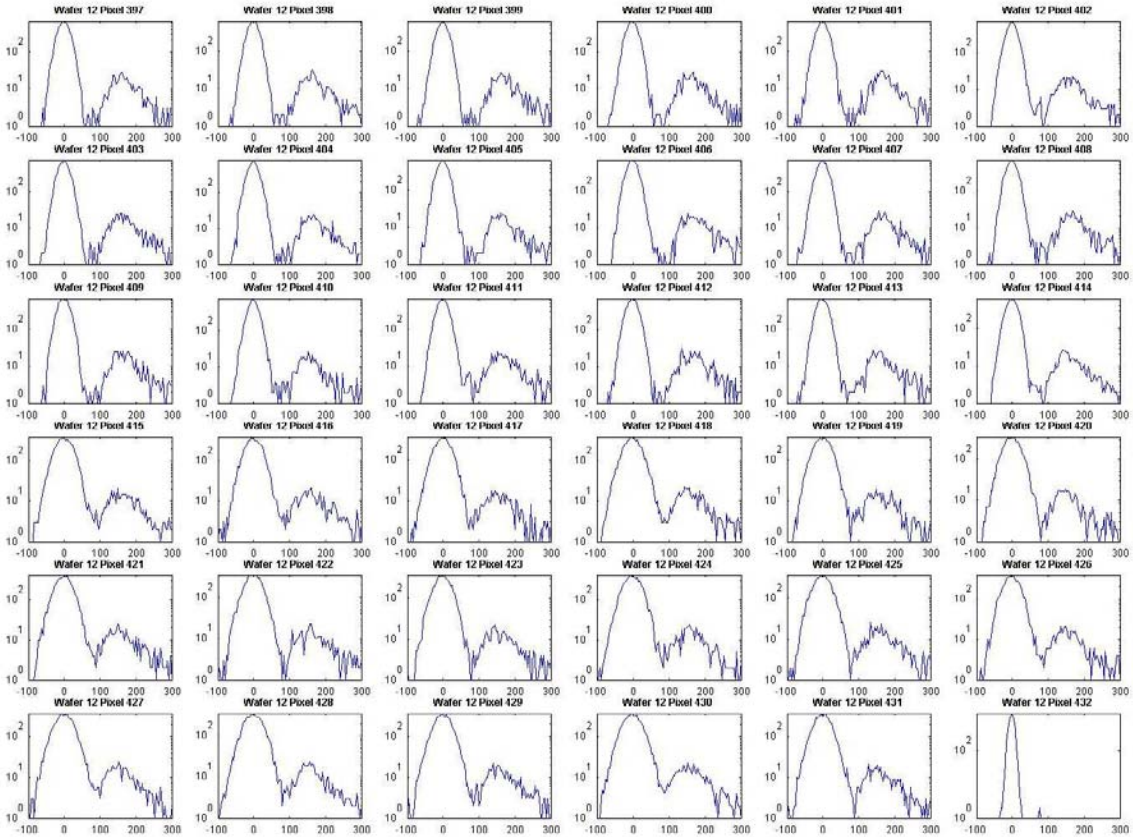
ECAL Electronics



- Calice Readout Card (CRC)
- Development based on CMS tracker front-end driver board.
- Receives 18-fold multiplexed analogue data from up to 96 VFE chips.
- Digitises; on-board memory to buffer ~2000 events during spill.
- Also trigger logic and control provided by one board.
- Prototypes tested summer 2004. First two production boards received November. Remaining 7 boards by January.



Cosmic Test Bench (LLR)

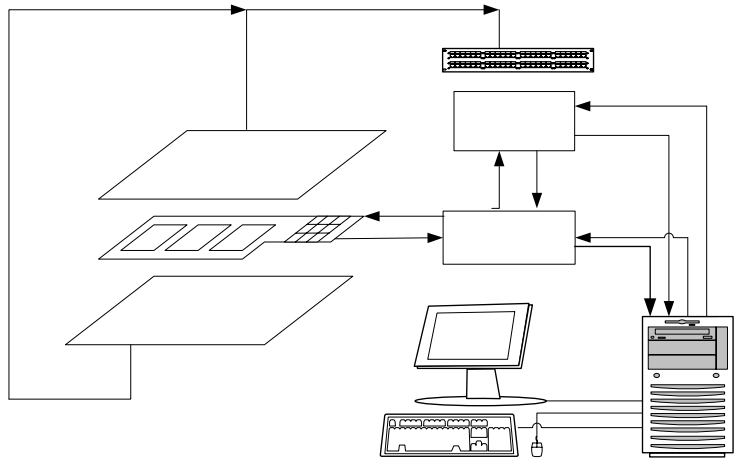


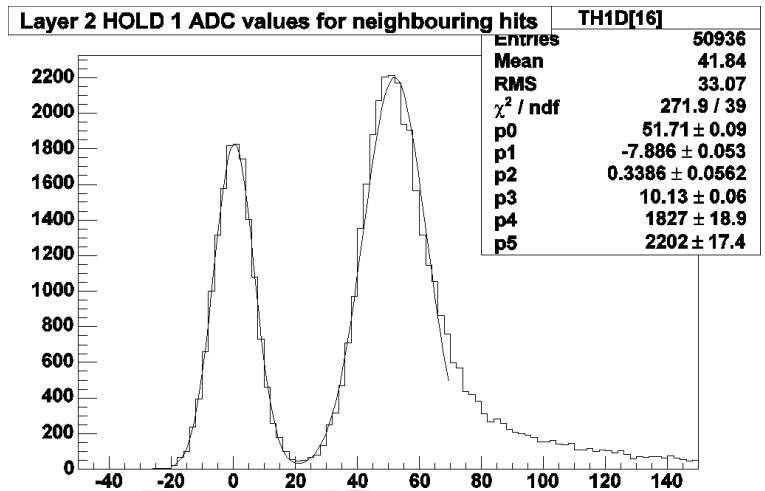
Tests on a complete wafer (6x6 pads)

CALICE Calorimeter for LC

Cosmic test rig

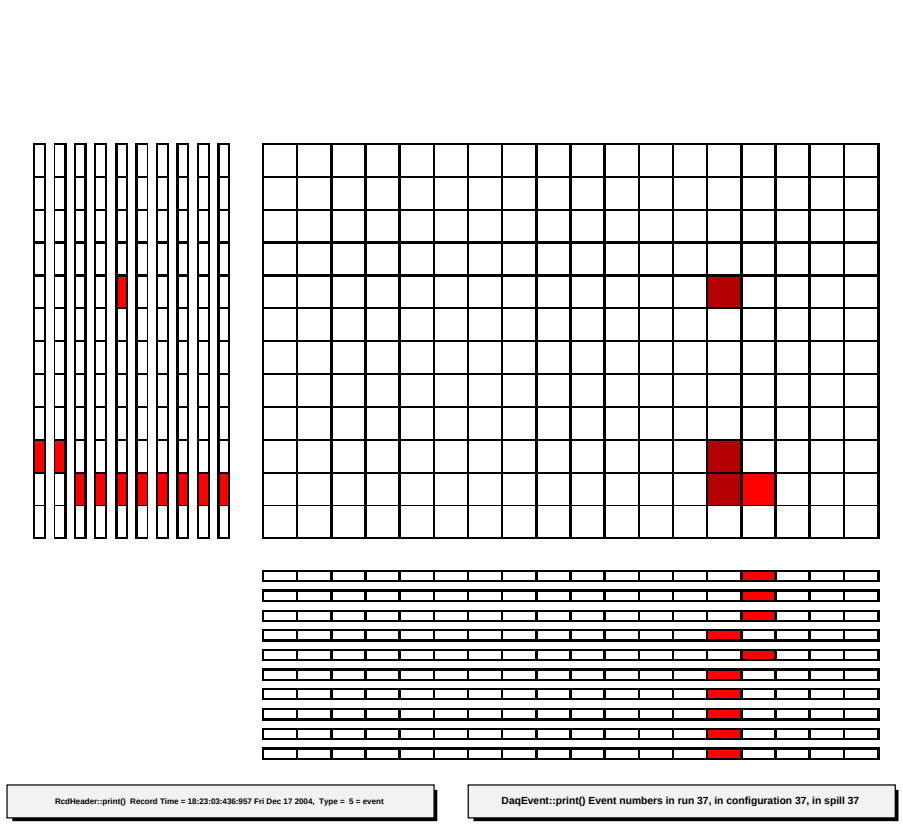
- First production modules (Tungsten + Si Pads + PCB + VFE ASIC) equipped with UK electronics and DAQ currently under cosmics test in Paris.
- MIP peak seen above pedestal;
- noise ~6.5 ADC counts;
- S/N ~ 8:1

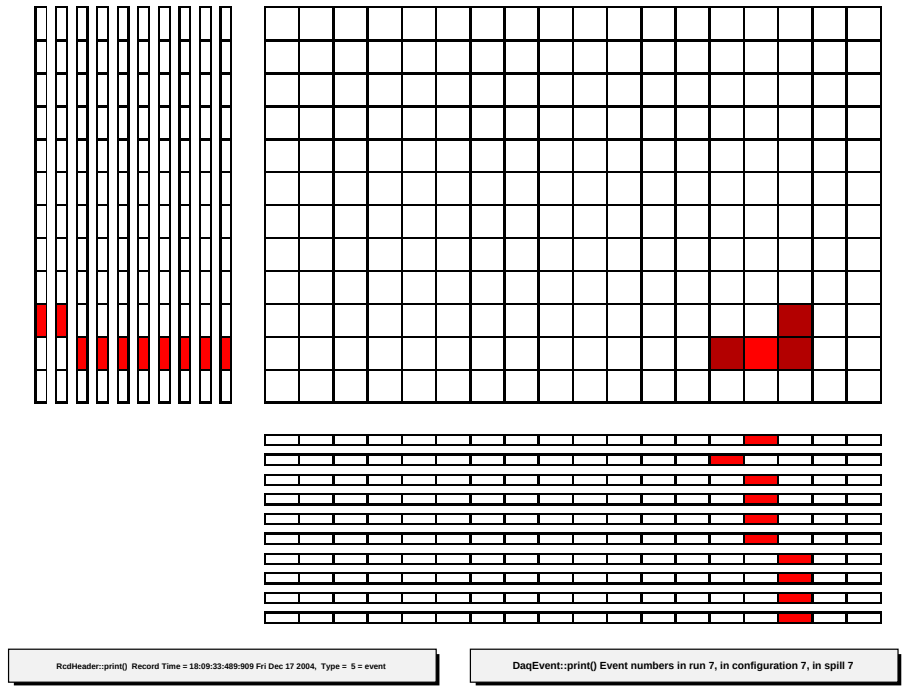




Cosmic events

Ten layers instrumented at this stage (last week).

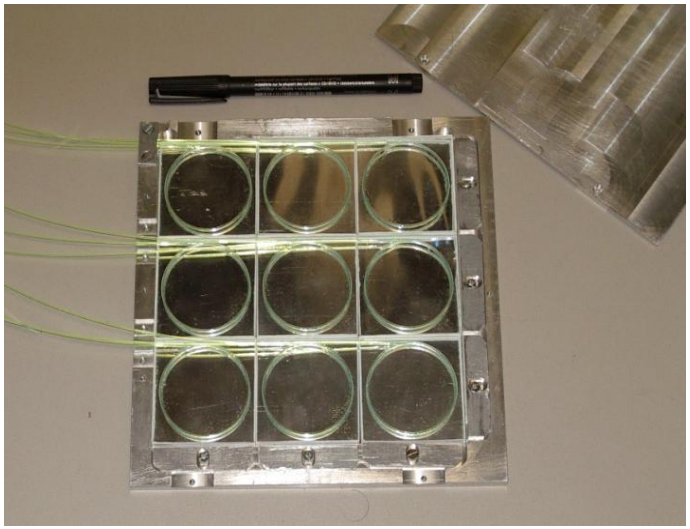


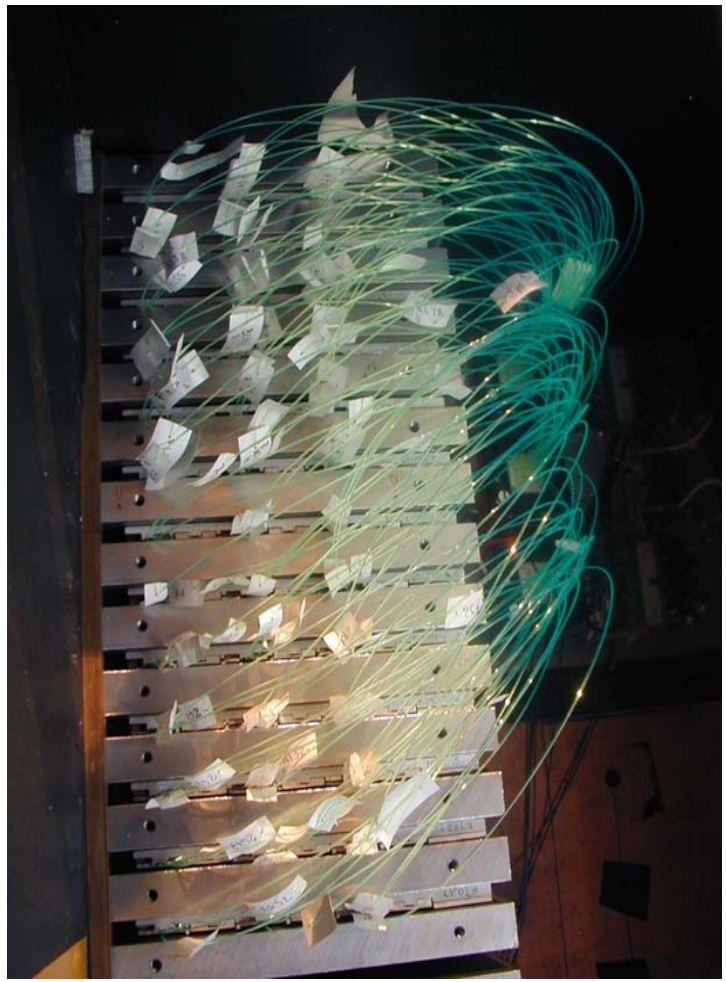


CALICE ECAL status

- All items required for first full prototype are in hand or in production.
- Aim: exposure of first 10 layers of full prototype to low energy electron test beam at DESY in January 2005; building up to full detector by Easter 2005. Then extended electron tests.
- Autumn 2005 onwards: expose prototype to higher energy electron beam, and hadron beam at FNAL in combination with HCal prototypes (various options) through 2006.

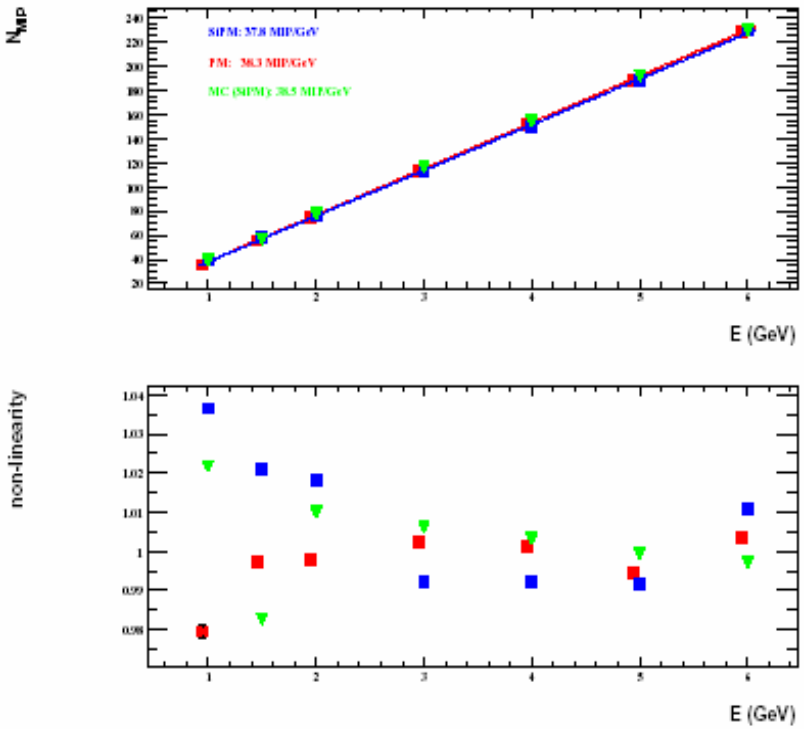
MiniCAL – preparation for HCAL prototype

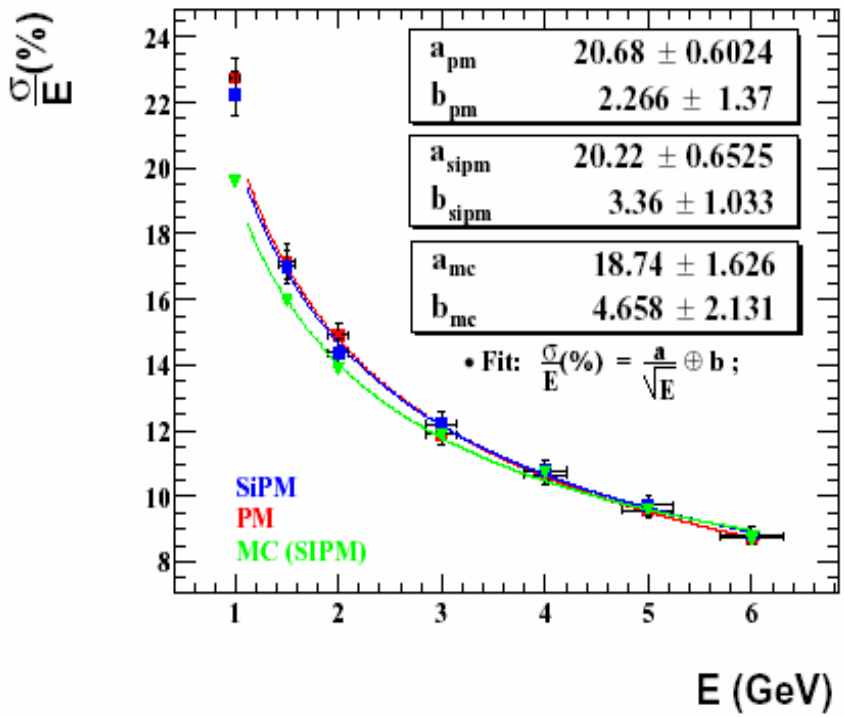




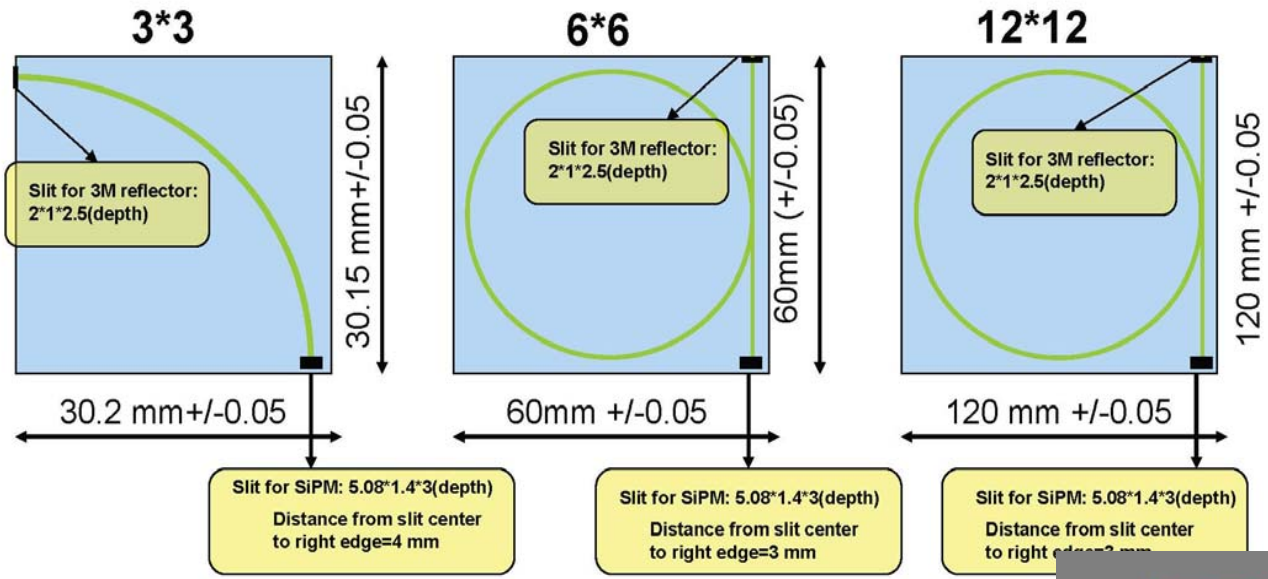
- Small test module for 5x5cm^2 tile AHCAL already tested in electron beam at DESY, with various photodetectors.
- Plan to include RPC modules soon.

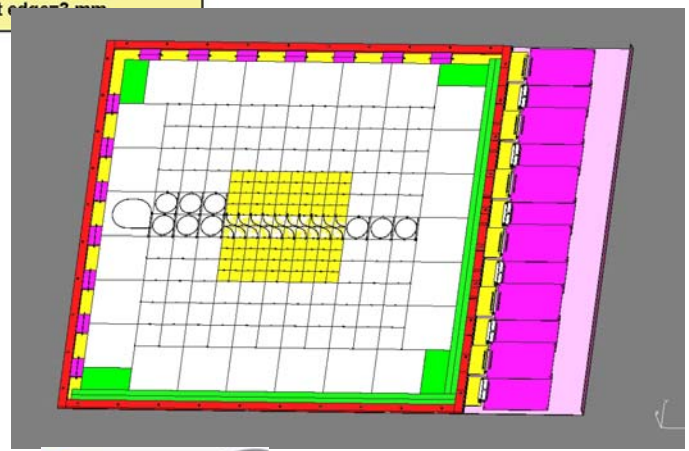
Minical results





AHCAL Scintillating Tile prototype

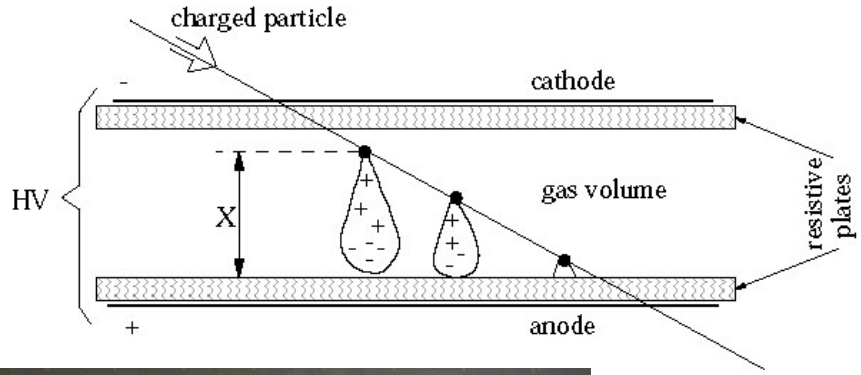


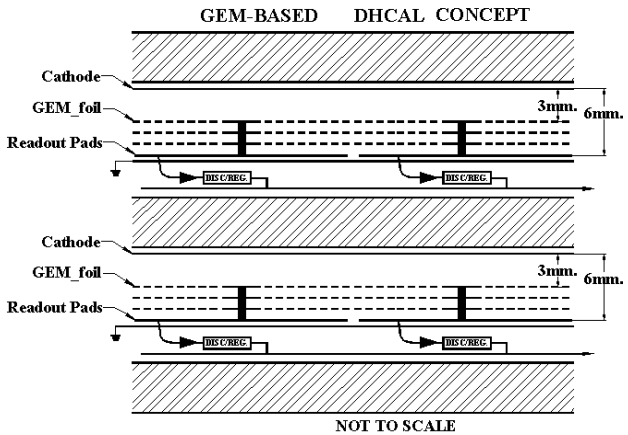


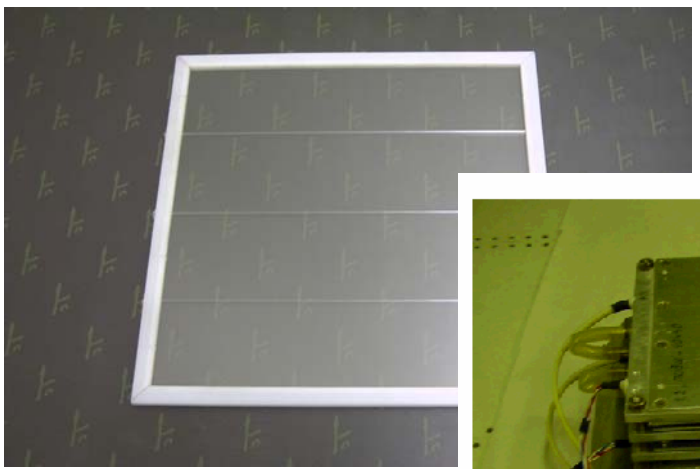
Constructing 1m^3 prototype; 40 layers of Fe; to be integrated with ECAL and tested with hadron beam.

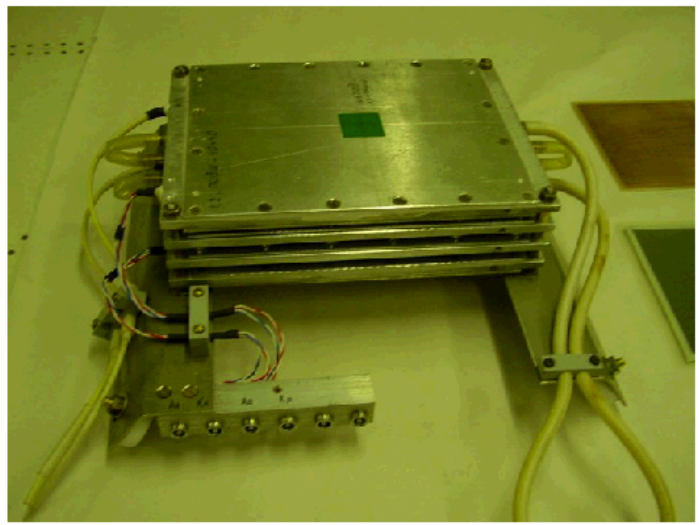
Will use UK off-detector electronics

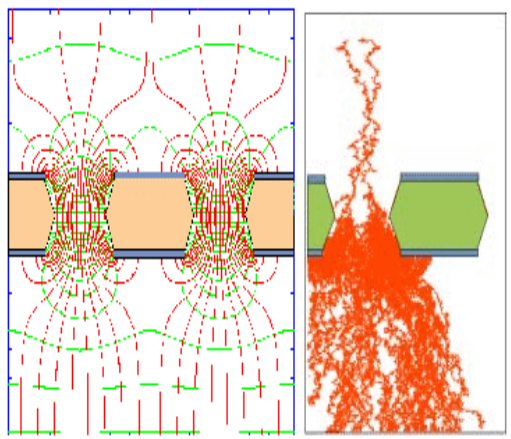
DHCAL options – RPC or HCAL





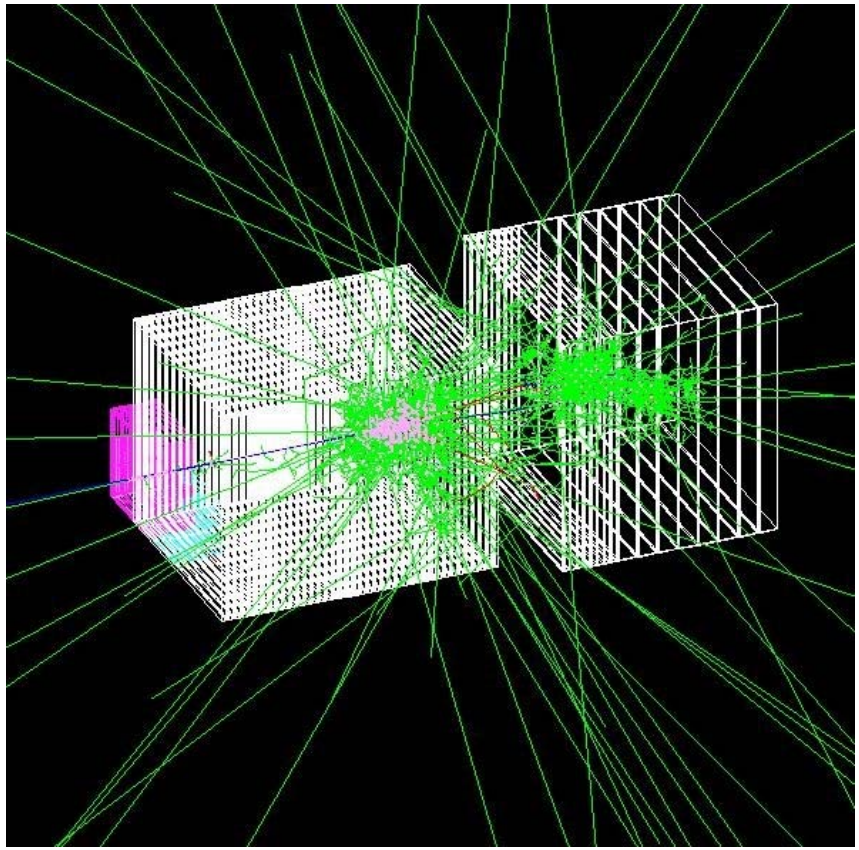




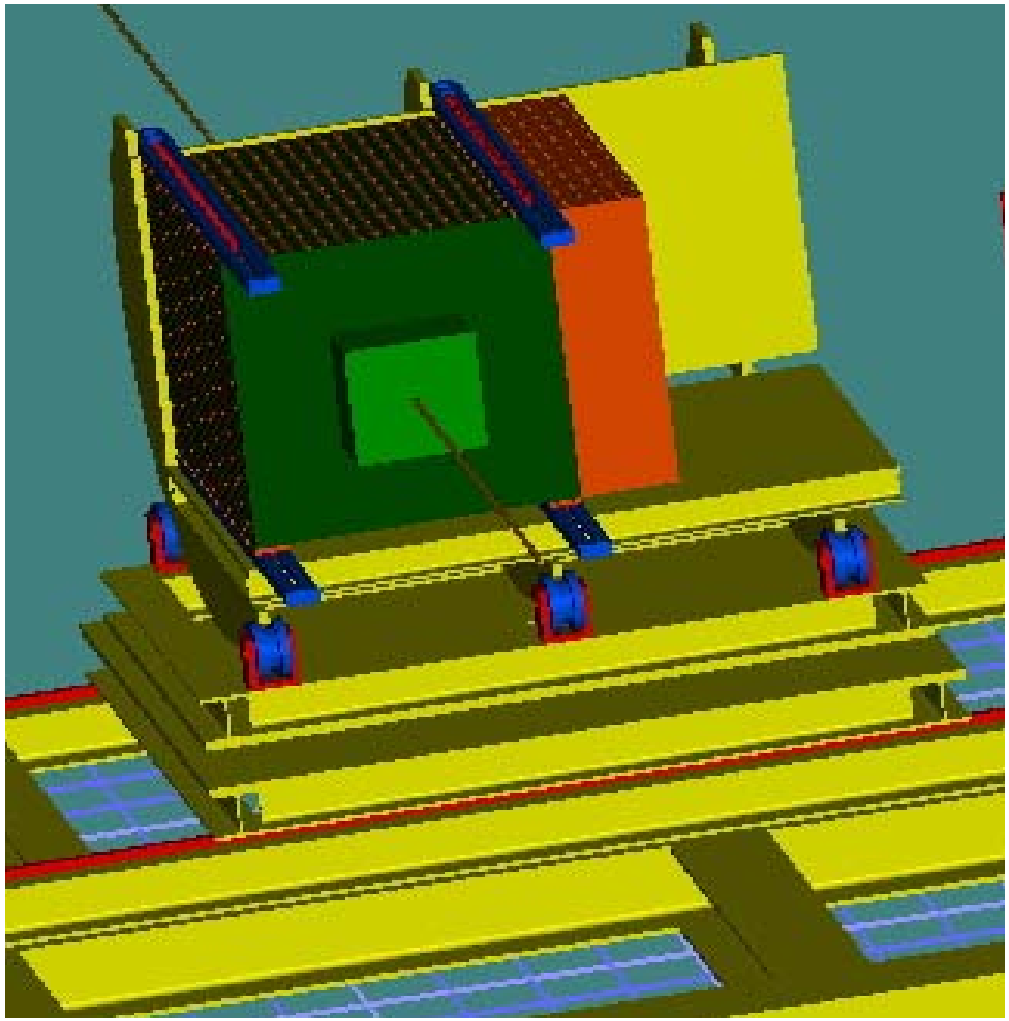


Tail Catcher/Muon Tracker (TCMT)

- Detect leakage from HCAL
- Fine" section (8 layers)
  2 cm thick steel
- "Coarse" section (8 layers)
  10 cm thick steel
- 5mm thick, 5cm wide strips
- Tyvek/VM2000 wrapping
- Alternating x-y orientation
- Si-PM photo detection
- Common readout with AHcal
- Weight ~10 tons



Prototype setup

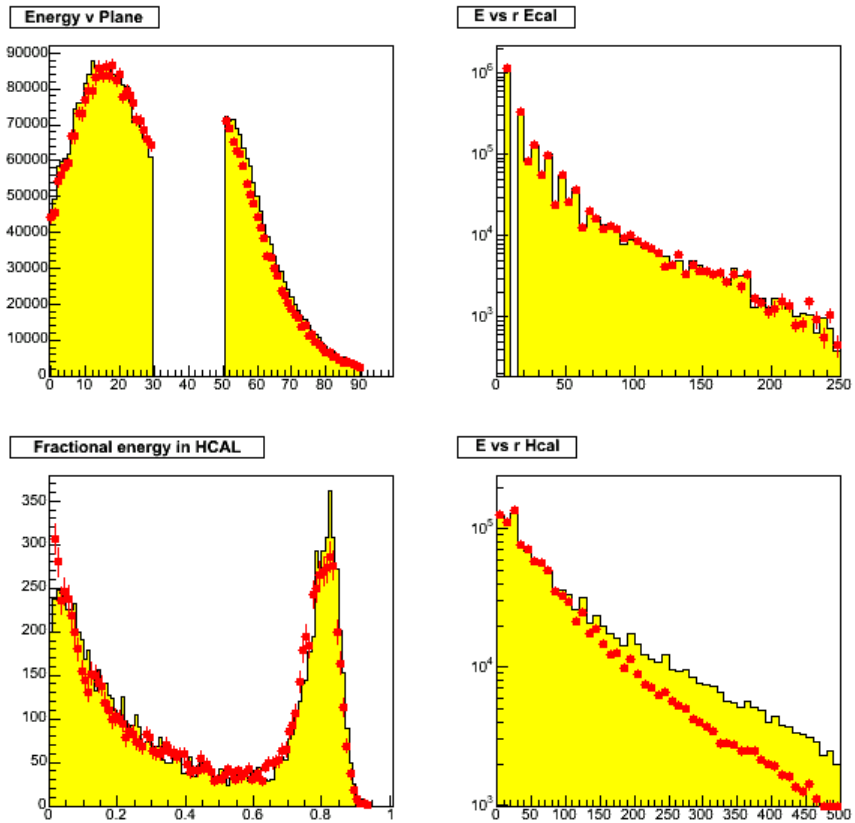


- Iron plate structure (1 m^3 40 layers), in which various detectors will be placed (tiles, RPC, GEM).
- ECAL prototype in front.
- Rotatable table.
- Also tail catcher (scintillator strips) to be installed behind

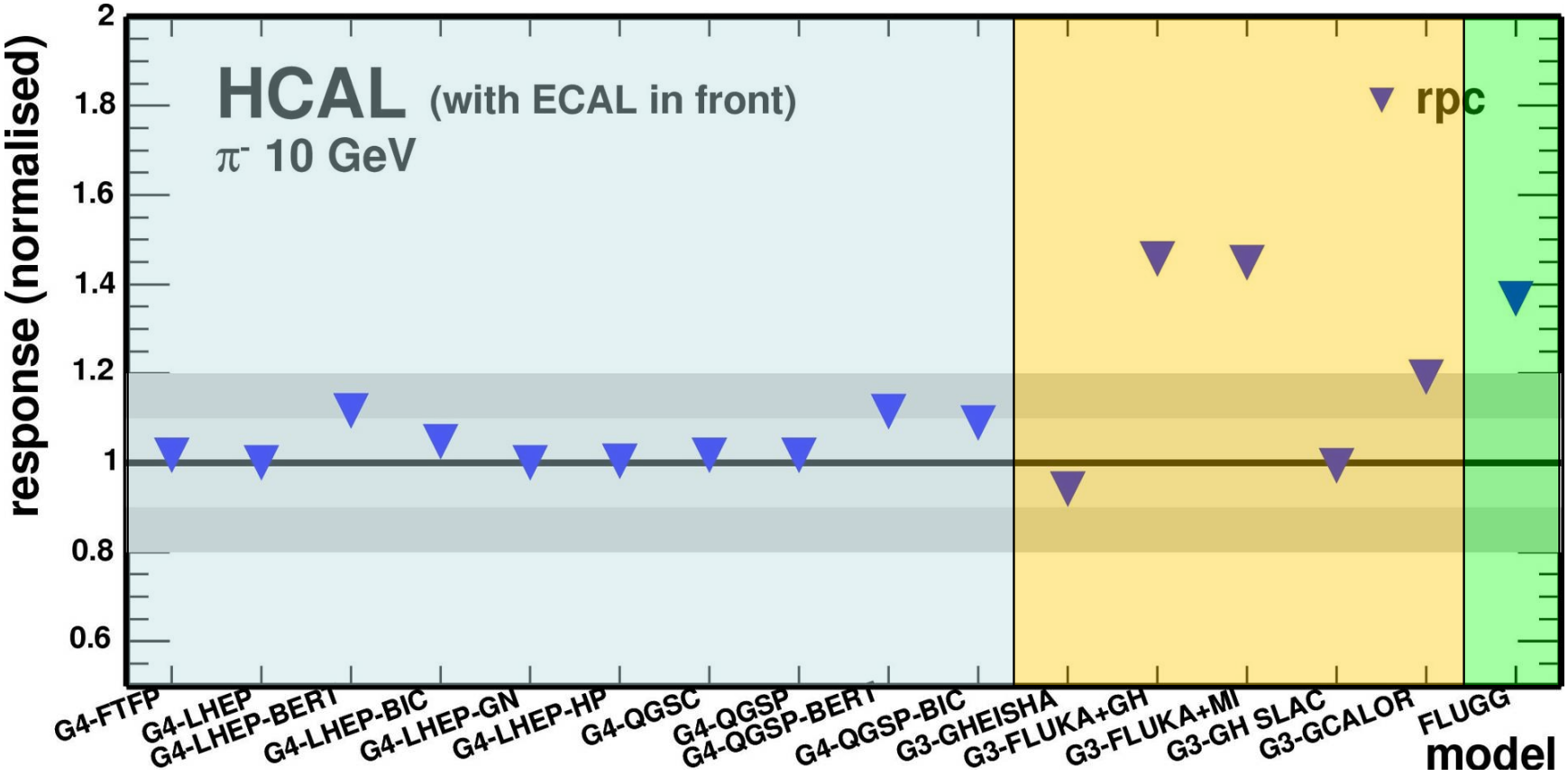
Test beam requirements?

- Use MC studies to indicate what data would be most useful in validating MC models.
- Compare samples of 10^4 5 GeV π^+ in Geant3 (histo) and Geant4 (points)
- Prototype geometry; scintillator Hcal model
- Significant differences seen at the level of 10^4 events, especially in the Hcal

5 GeV π^+



Studies of hadronic models



Summary of test beam needs

- 1% precision suggests >10^4 events per particle type and energy.
- Try to range from 1-80 GeV (~10-15 energy points?).
- Pions and protons desirable (→Čerenkov needed). Also electrons (+ muons?) for calibration.
- Both DHCAL (e.g. RPC) and Scintillator AHCAL needed.
- Position scan – use beam width ("a few cm at FNAL-MTBF"). Need MWPCs etc for position determination. But would need more statistics if splitting up data. Aim for 10^6 events per energy point/angle/detector configuration?
- Also some data at 30-45^o incidence.

Test Beam Plans

2005

ECal exposure to low energy electron beam (up to 6 GeV) at DESY (January – June).

2005-6 e/μ/π/p up to ~80GeV. FNAL/Protvino?

Starting with ECAL/AHCAL (autumn 2005), followed by DHCAL as funding permits.

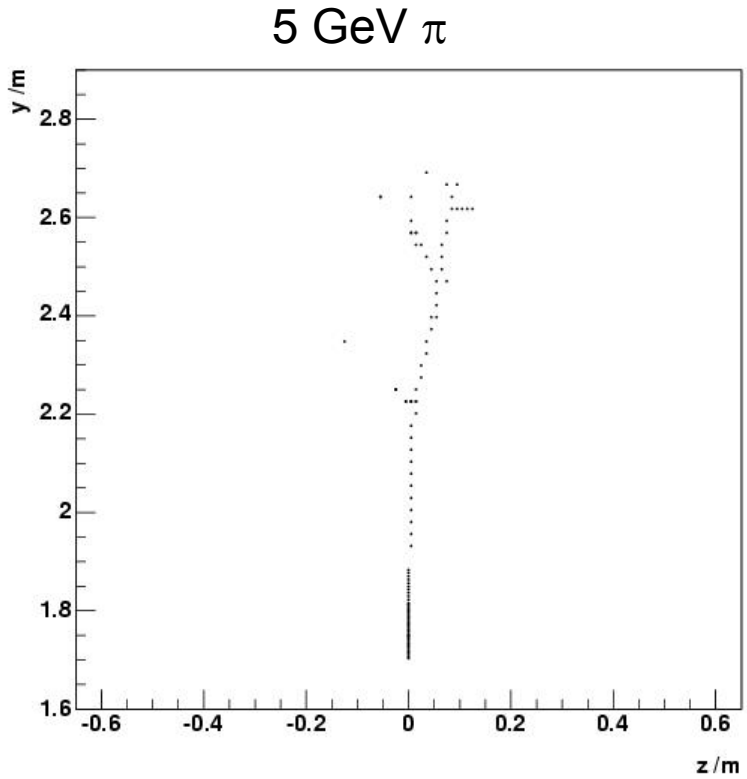
Module combinations currently envisaged:

CALICE ECal $\oplus$ AHCal - tile 1m^3 prototype
DHCal – RPC/GEM 1m^3 prototype

$\oplus$ Tail Catcher

Energy flow work in UK

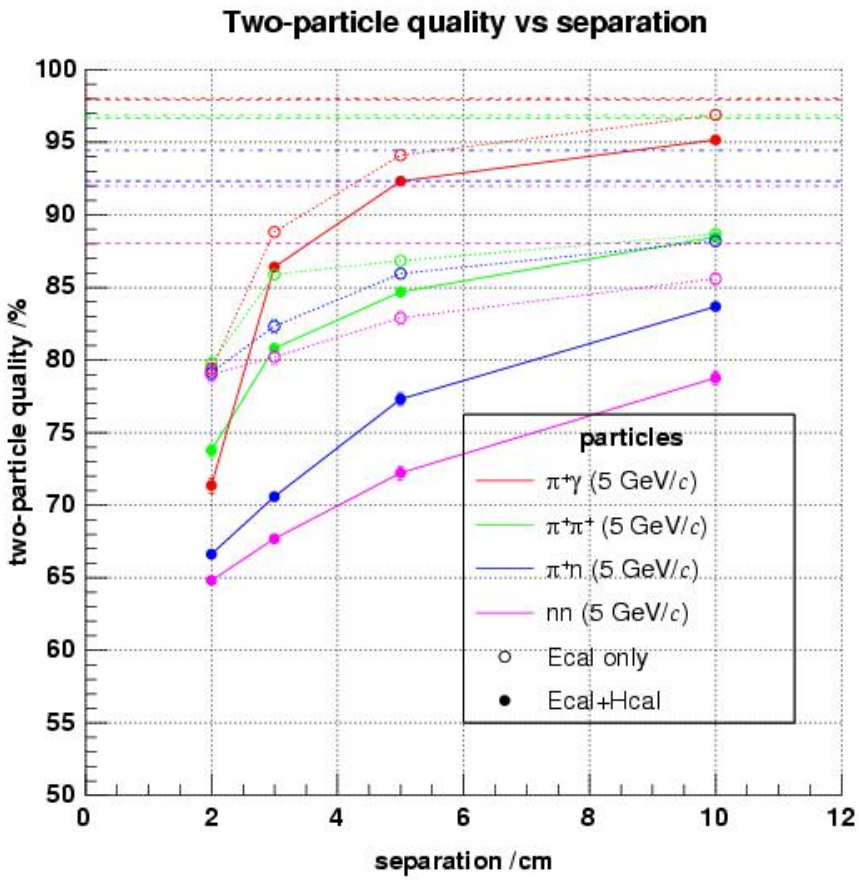
- Typical jet – energy divided ~65:25:10 between charged, photons, neutral hadrons.
- With expected resolutions for tracks, ECAL (~10%/√E) and HCAL (~40-50%/√E), ideally could achieve ~15%/√E for jets. In practice the jet energy resolution is determined by confusion, not intrinsic calorimeter energy resolution.
- Hence, pattern recognition in calorimeters is crucial. Need cunning algorithms to exploit potential of high granularity.



Note track-like quality of many showers in the calorimeter

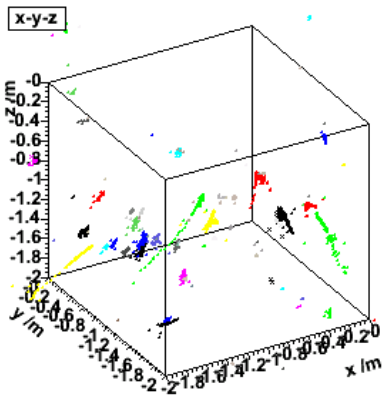
Clustering / Energy flow

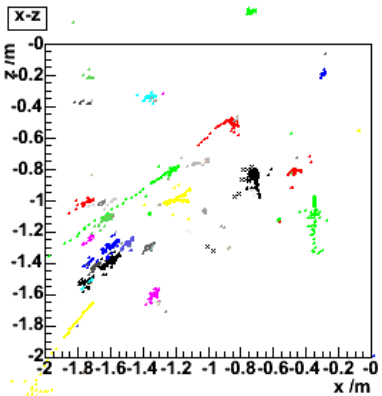
- Two complementary algorithms under development in UK:
- Bottom-up "tracking-like" algorithm. Track outwards through layers matching hits to existing clusters (using directional info) or seeding new clusters. Example of performance:
- Top-down Minimal Spanning Tree algorithm. Cluster all cells into MST, then cluster by cutting longest branches.

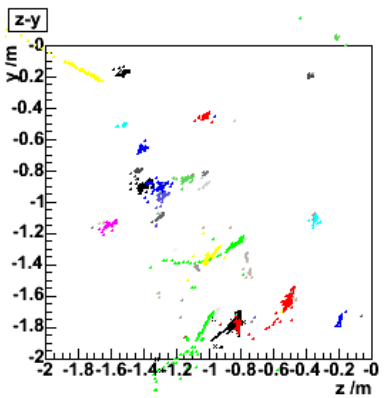


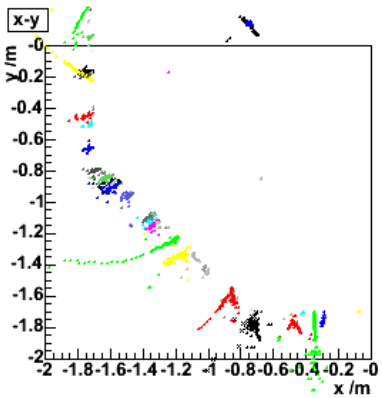
Zoom of a jet (Z^0) event

Reconstructed clusters

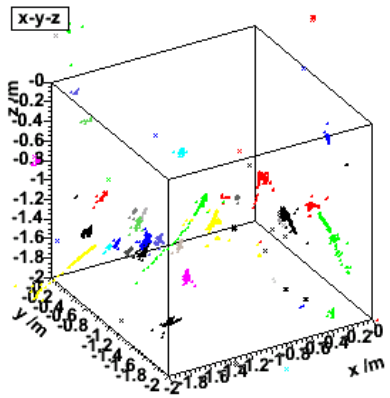


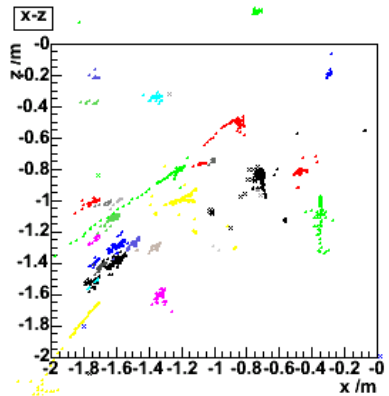


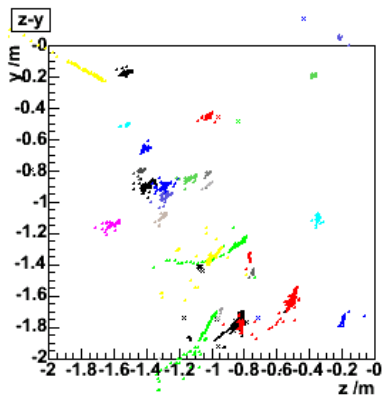


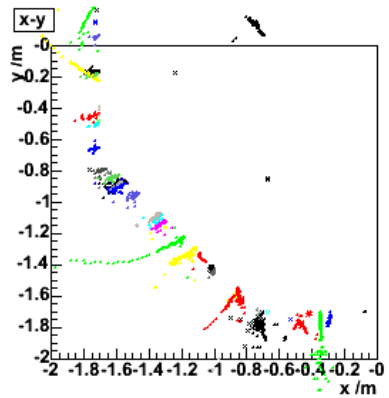


True particle clusters









CALICE Calorimeter for LC

Summary

- Just about 2 years since Calice-UK approval.
- Electronics + DAQ constructed and working. Beam tests imminent (2005-6).
- Good progress on software side – simulation and reconstruction.
- Future plans – about to return to PPRP to seek future funding for:
  1. Completion of test beam program
  2. Generic DAQ R&D
  3. Investigation of MAPS sensors for digital ECAL
  4. Mechanical and thermal studies
  5. Continued software work