Calice Status

For the CALICE-UK groups: Birmingham, Cambridge, Imperial, Manchester, RAL, UCL

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Imperial College

LCUK Meeting - Lancaster
30th June 2004

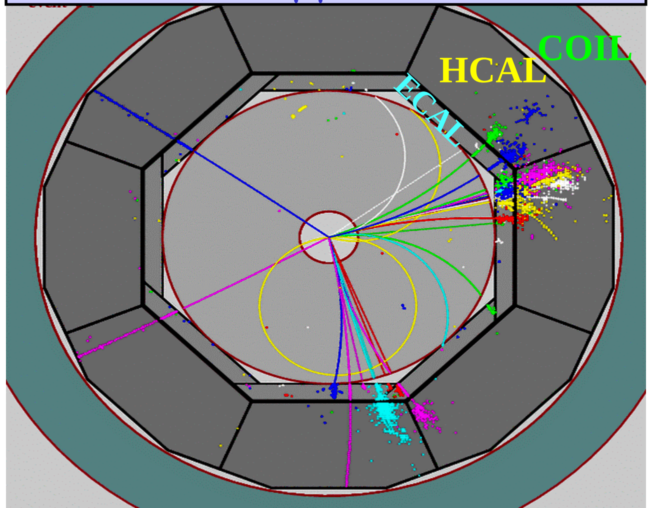
Overview

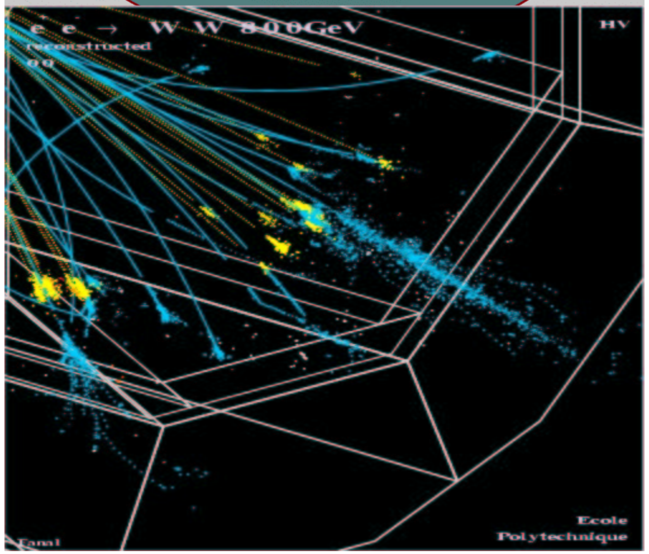
- **The Calice Project**
- **UK involvement in Calice**
- **ECAL Prototype**
  - **- Silicon and Front End status**
  - **- DAQ readout progress**
  - **- Full scale tests**
    - **Noise & Pedestals**
    - **DAC calibration scans**
    - **Cosmic events**
- **UK Simulation**
  - **- G3/G4 differences**
  - **- Clustering performance**
  - **- Detailed electronics effects**
- **Schedule and Beam tests**
- **Conclusions**

Calice concept

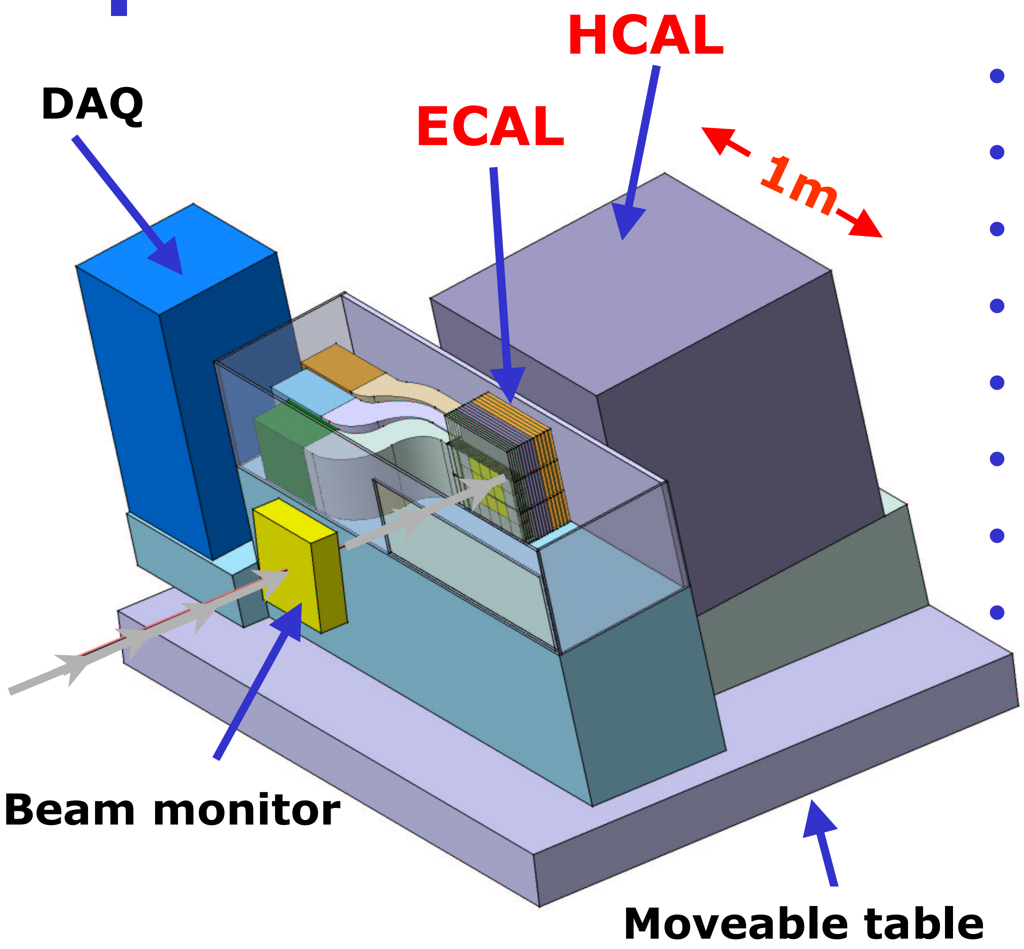
- **Goal is to develop reliable optimised Calorimeter designs for the Linear Collider**
- **Jet Energy resolution is key to LC detector performance**
- **Energy Flow technique gives best Jet Energy resolution**
- **Requires tracking calorimetry to resolve individual particles, avoid double counting**
- **Tracking Calorimeter requires high granularity/segmentation**
- **Ecal : Si-W sampling calorimeter, 40 layers, 1x1 cm^2 pads, 32 M channels, 24X_0 in 20 cm**
- **Hcal: High Granularity Analogue (Scintillator) or Digital (RPC, GEM) options.**
- **Shower development at required energies poorly understood**
- **Require Testbeam – Monte Carlo tuning to accurately determine possible jet resolution**

$e^+e^- \rightarrow ZH,\ Z \rightarrow \mu\mu$ at $\sqrt{s}$=500 GeV





Test Beam & Prototype



- Combined ECAL & HCAL
- Engineering Run December 2004
- in e^- beam at DESY
- (ECAL only)
- Physics Run in 2005
- Hadron beam at FNAL (TBC)
- HCAL: 38 layers Fe
- Insert combinations of:
  - "digital" pads
  - (350k, 1x1cm^2 pads)
    - GEM
    - RPC
  - "analogue" tiles
  - (8k, 5x5cm^2)
    - Scintillator tiles

UK Involvement

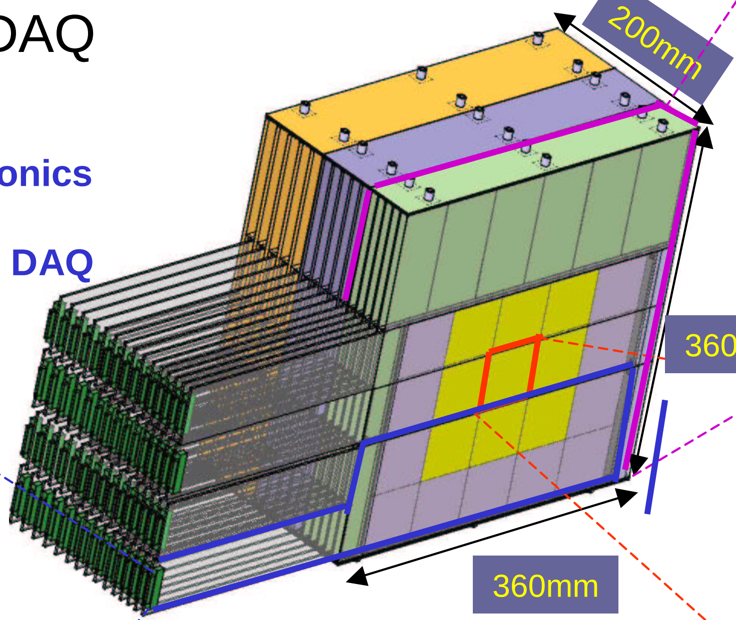
- **Readout and DAQ for test beam prototype (RAL, IC, UCL)**
  - Provide readout electronics for the ECAL
  - (Possibly use UK boards for some HCAL options)
  - DAQ for entire system, Full testing of ECAL system

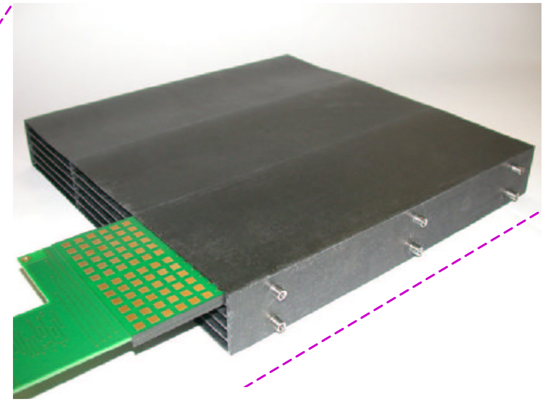
- **Simulation studies (Cambridge, Birmingham, IC)**
  - ECAL cost/performance optimisation
  - Impact of hadronic/electromagnetic interaction modelling on design.
  - Comparisons of Geant4/Geant3/Fluka

- **Reconstruction/Energy Flow (Cambridge)**
  - Started work towards ECAL/HCAL reconstruction
  - Ultimate goal – UK Energy flow algorithm

Ecal Prototype Overview

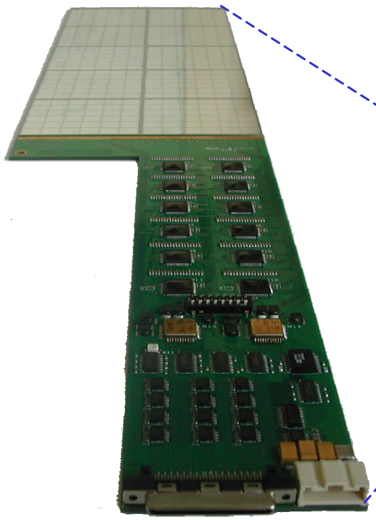
- 30 layers of variable thickness Tungsten
- Active silicon layers interleved
- Front end chip and readout on PCB board
- Signals sent to DAQ

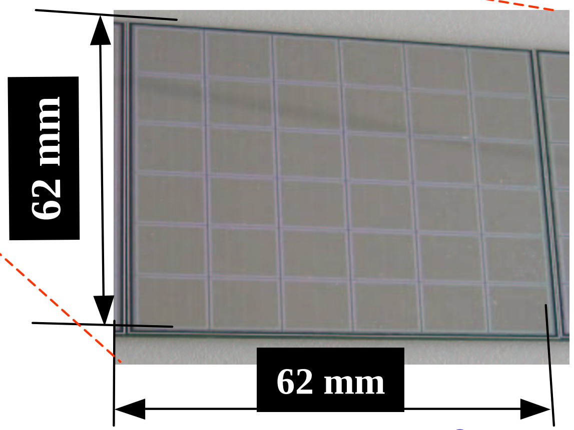




- **Tungsten layers wrapped in Carbon Fibre**
- **8.5 mm for PCB & Silicon layer**

- **PCB contains VFE electronics**
- **14 layers, 2.1mm thick**
- **Analogue signals sent to DAQ**



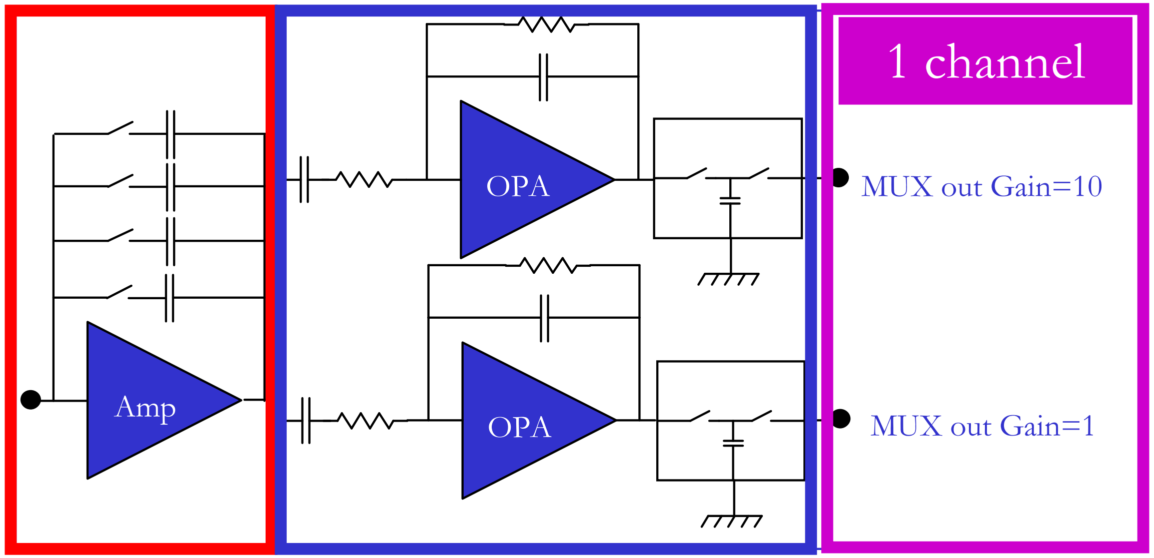


- **6x6 1x1cm^2 silicon pads**
- **Connected to PCB with conductive glue**

Very Front End Electronics

VFE consists of

- •Preamp with 16 gains (gain selected offline)
- •CR-RC shaper (~200ns), track and hold
- •18 channels in, one Multiplexed output



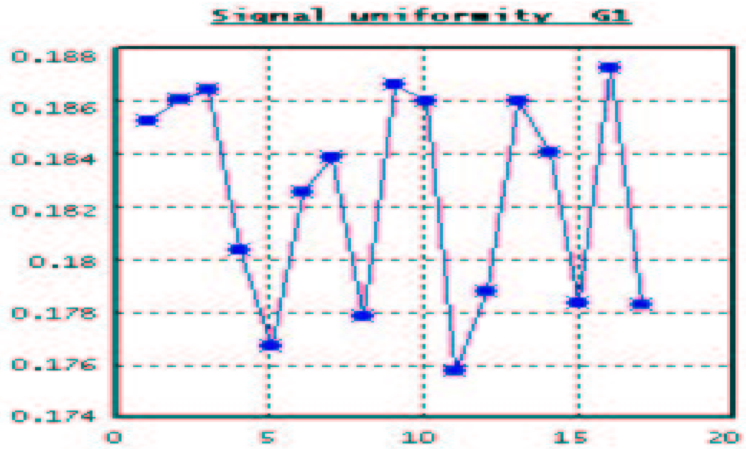
Each chip serves 18 channels

2 chips per wafer

Linearity: ± 0.2 %

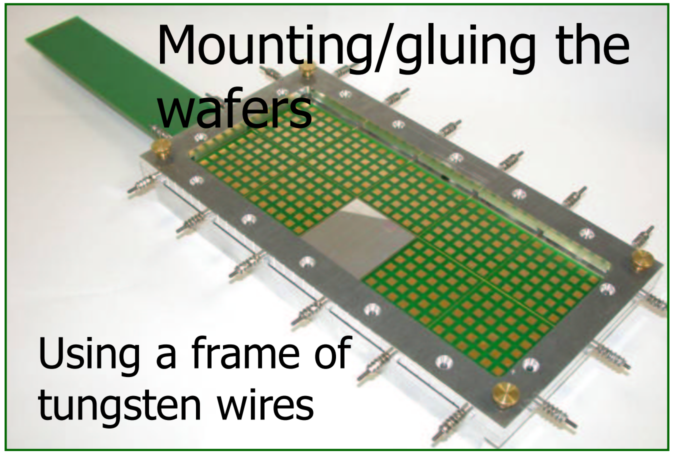
Range: ~1000 MIPS

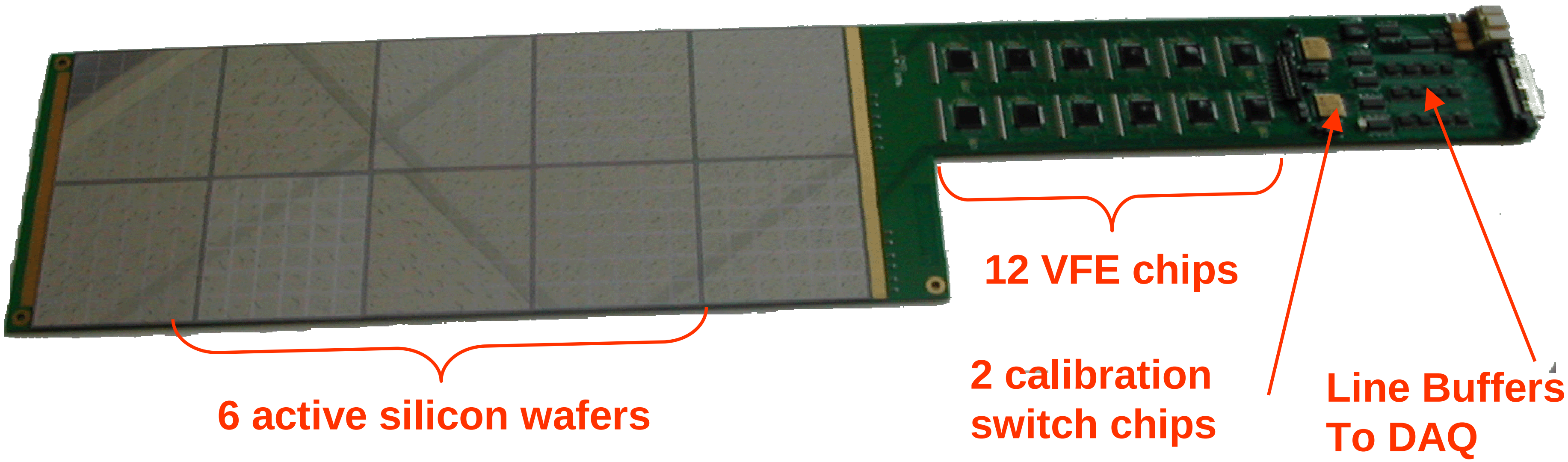
Crosstalk < 0.2%



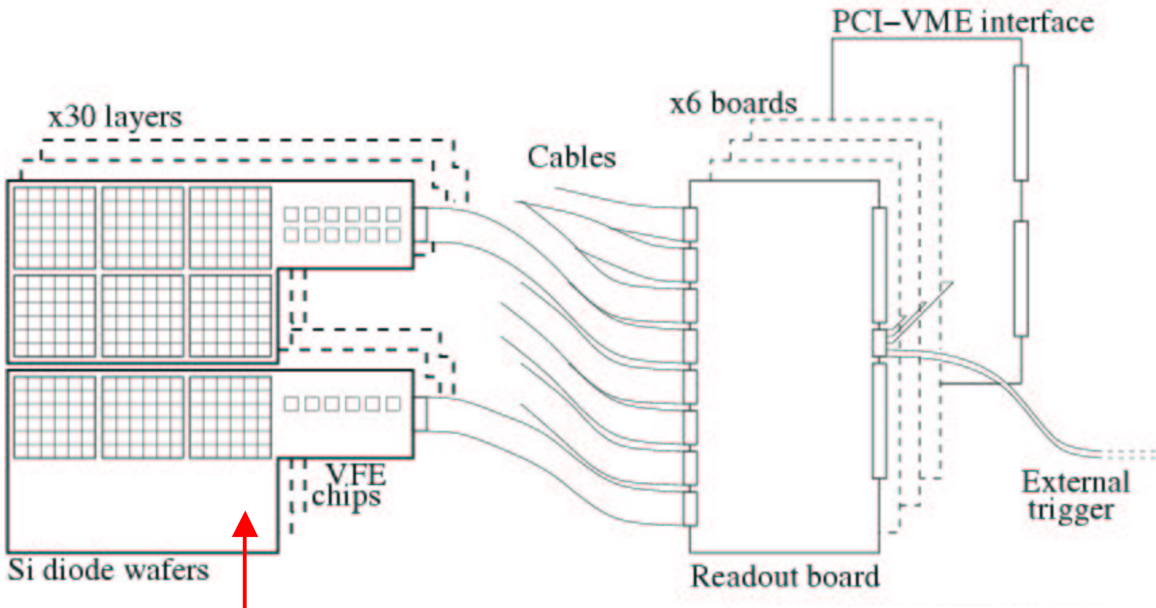
Production & Testing

- PCB designed in LAL-Orsay, made in Korea (KNU)
- 60 Required for Prototype, ready in July
- An automatic device is use to deposit the conductive glue : EPO-TEK® EE129-4
- Gluing and placement (± 0.1 mm) of 270 wafers with 6×6 pads, 10 000 points of glue
- About 10 000 points of glue.
- Production line set up at LLR





Prototype DAQ



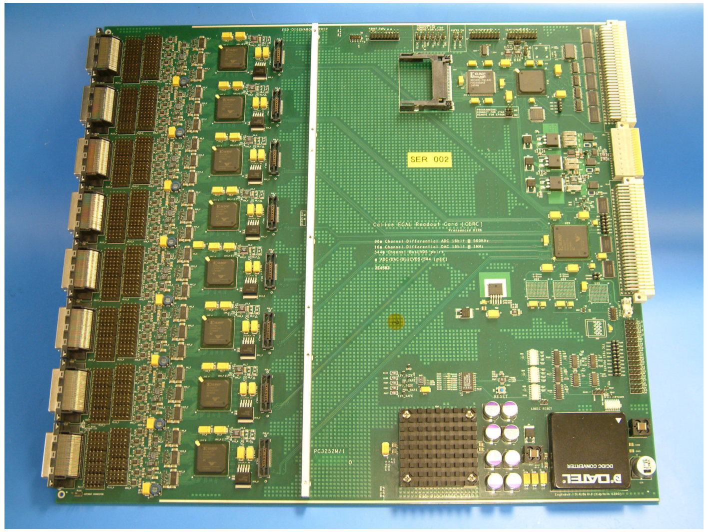
Layers face each other so have 2 types of half-filled VFE PCBs: right and left

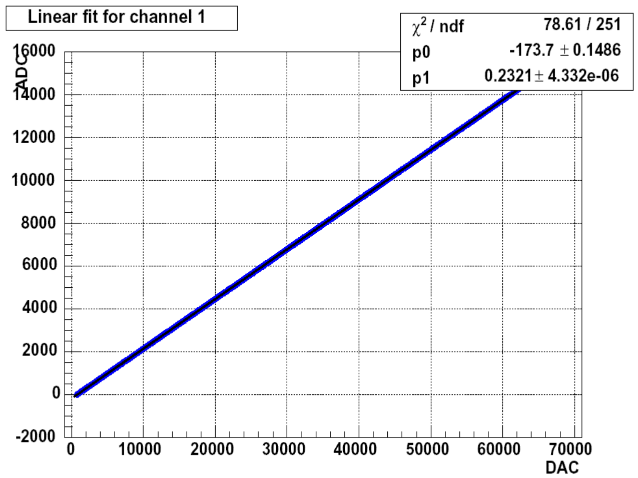
In 9U VME crate

- The 30 layers of VFE PCBs are read out through 6 readout boards when triggered
- The readout boards are housed in a 9U VME crate
- Boards developed by RAL, IC and UCL

Prototype DAQ

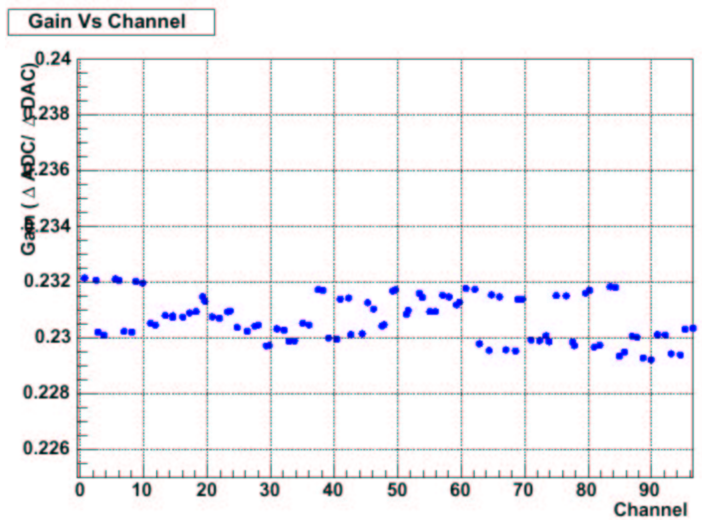
- Use **custom VME** readout board
- Based on **CMS tracker** front-end board (FED)
- Uses several **FPGA's** for main controls
- Dual **16-bit ADCs** (500 kHz) and **16-bit DAC**
- On-board buffer memory 8 Mbytes. **1.6k event buffer**, no data reduction





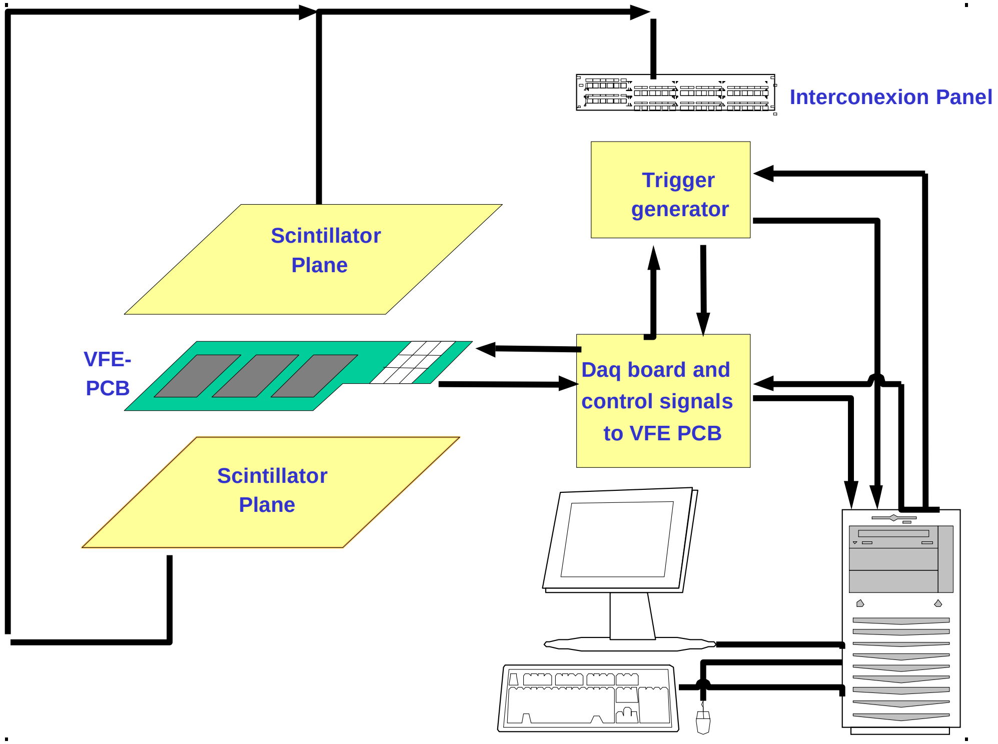
- Prototype design completed last summer
- Two prototype boards fabricated in November
- Noise ~ 1ADC count
- Linear to 0.01%
- Gains uniform to 1%

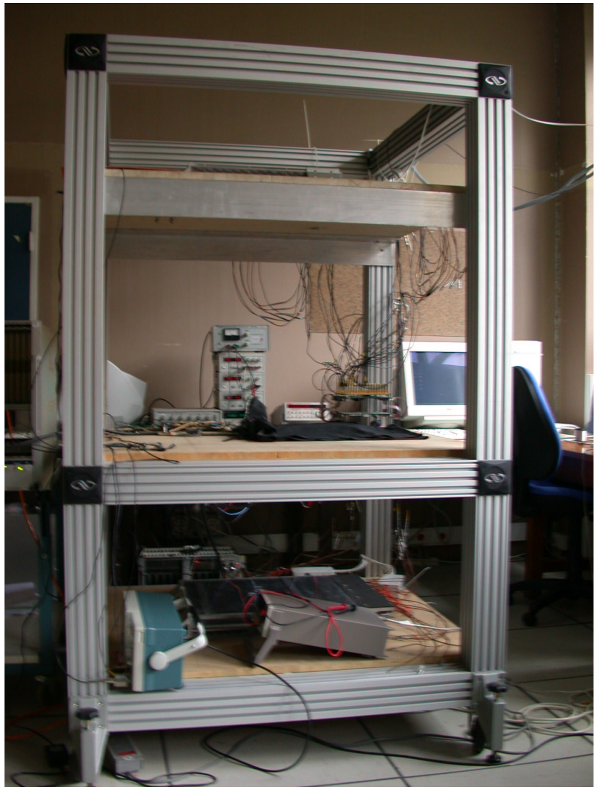
Further tests, final production ~ July



Production & Testing

- Must validate assembly, mounting and performance of each PCB
- Dedicated DAQ system to test individual PCBs
- Use UK DAQ in conjunction with Cosmic test bench, or ^{90}Sr β decay for full system tests





System Tests

Extensive tests in Paris over the last few months…

- **Noise**
- **Calibration with DAC**
- **Cosmics**

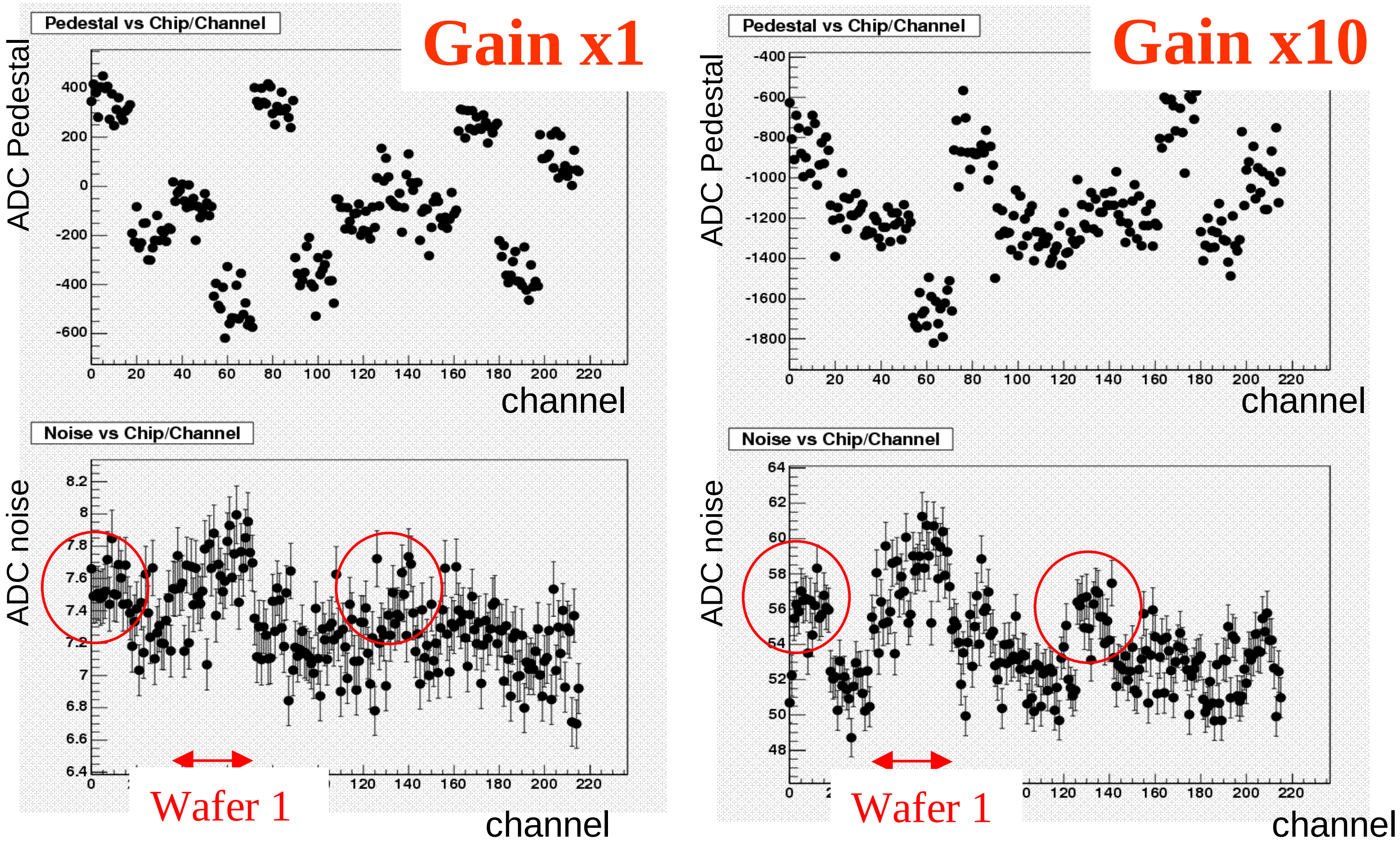
Aim To check

- **Problems: are there things which need to be changed?**
- **Uniformity: do all channels look similar?**
- **Stability: is the system stable with time?**
- **Dynamic range and signal/noise: are they sufficient?**
- **Optimisation: are there changes which will improve the system?**

All test results from P. Dauncey and C. Fry

Pedestals & Noise

- **Selectable gain on VFE PCBs; x1 or x10**
- **Currently have only half ADC range available: Will be able to recover rest**
- **Full PCB has 6 wafers mounted; wafer 1 does not deplete**



Gain x1

Noise = 7.2 ADC counts

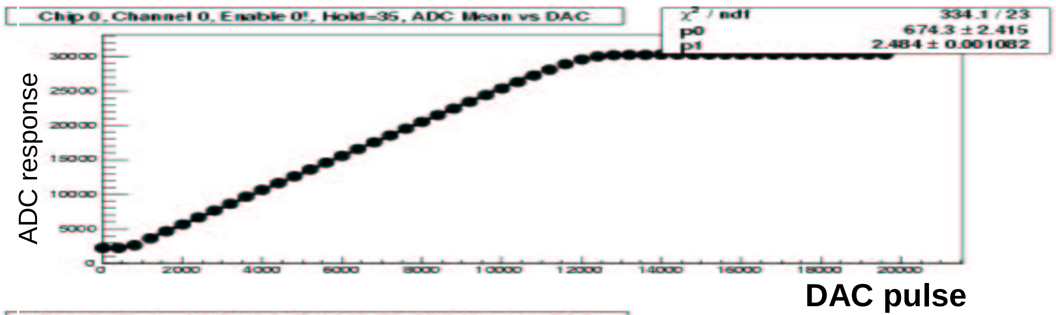
Gain x10

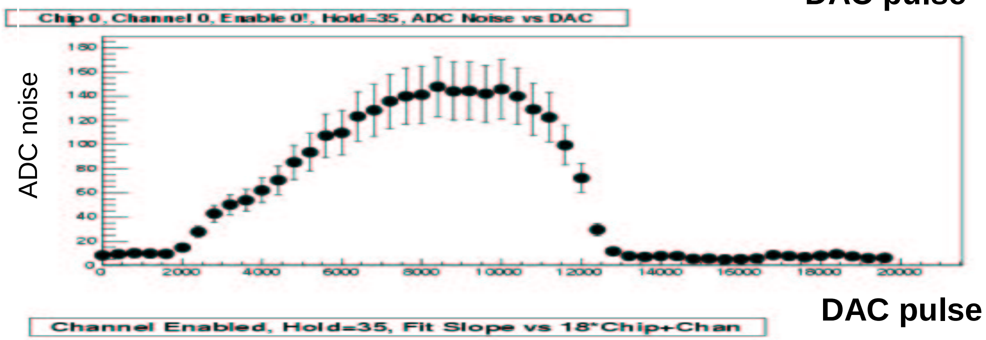
Noise = 52 ADC counts

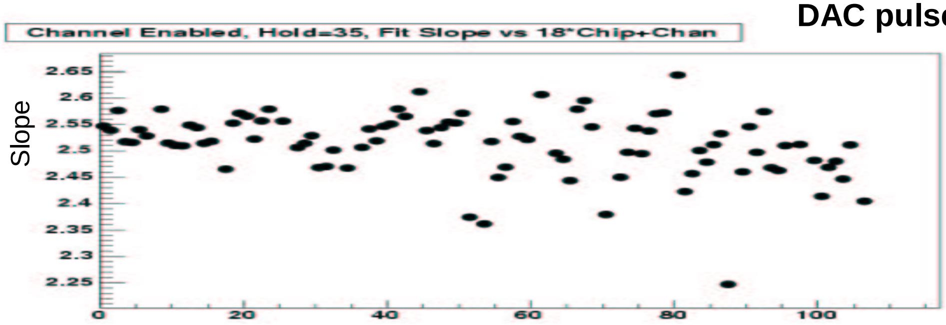
DAC Linearity calibration

- **Progressively pulse DAC and readout channels ADC value**
- **Typical channel (same as for DAC scan), gain x1**

- **Slope ~2.5 ADC counts/DAC count**
- **High end saturation at ~ 12000 DAC counts**
  - **Does not make good use of full DAC range**
  - **16-bits is 0-65535 counts; five times higher**
  - **Can adjust and recover**
- **Low end saturation from readout board; understood**
- **Good consistency across channels**
- **Extra noise ~ 0.025 ADC counts/DAC**
- **Equivalent to extra noise of 1% of signal size**
- **Unknown if from calibration circuit or present in real signals**



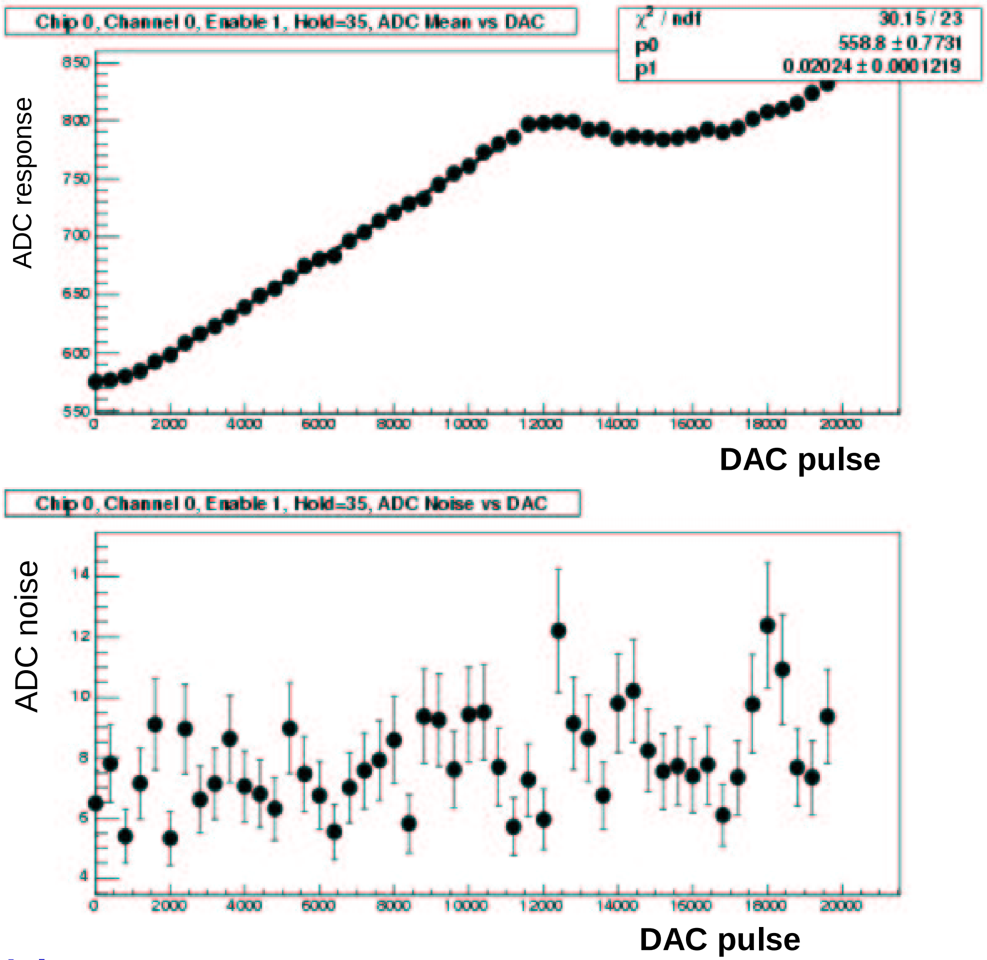




Crosstalk in DAC calibration

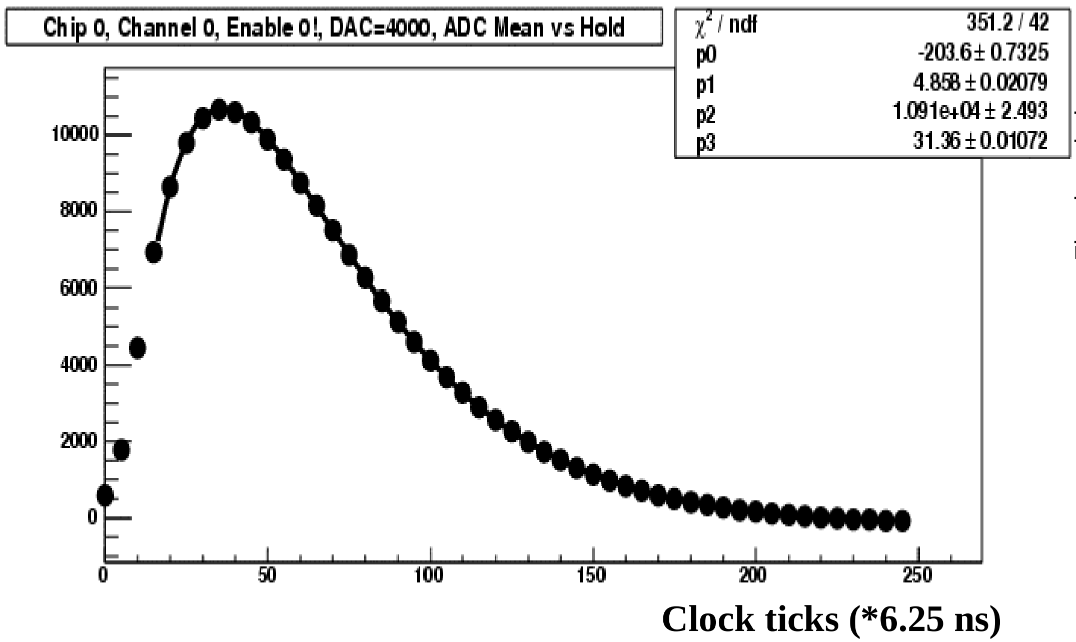
- Look at non-enabled channel (next to previous one)

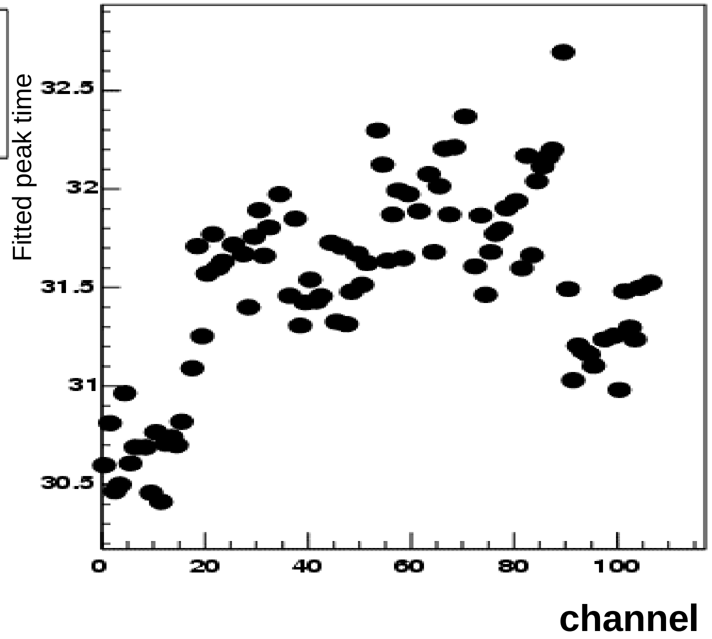
- Signal seen in neighbours
- Slope ~ 0.02 ~ 1% of signal slope
- Noise shows no increase
- Some examples where crosstalk is much greater
- Still trying to determine the origin



Measuring Shaping Time

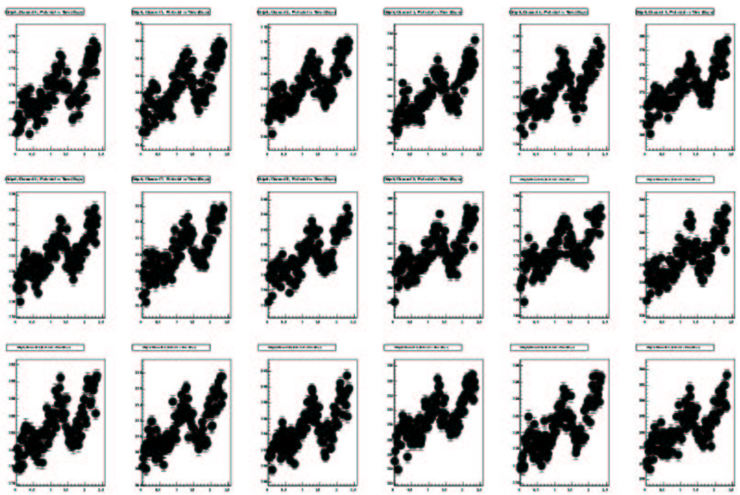
- Output signal is shaped by CR-RC circuit, shaping time ~200ns
- Set DAC and adjust sampling time to scan peak shape
- Typical channel, gain x1
- Fit xe^{-x} shape to response
- Shaping time = p3 = 31.36 units = 196 ns, good uniformity

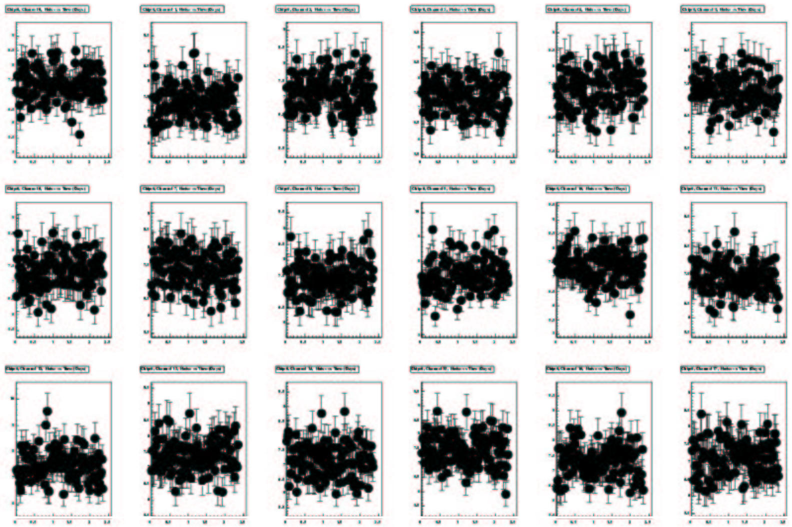




Stability of the System

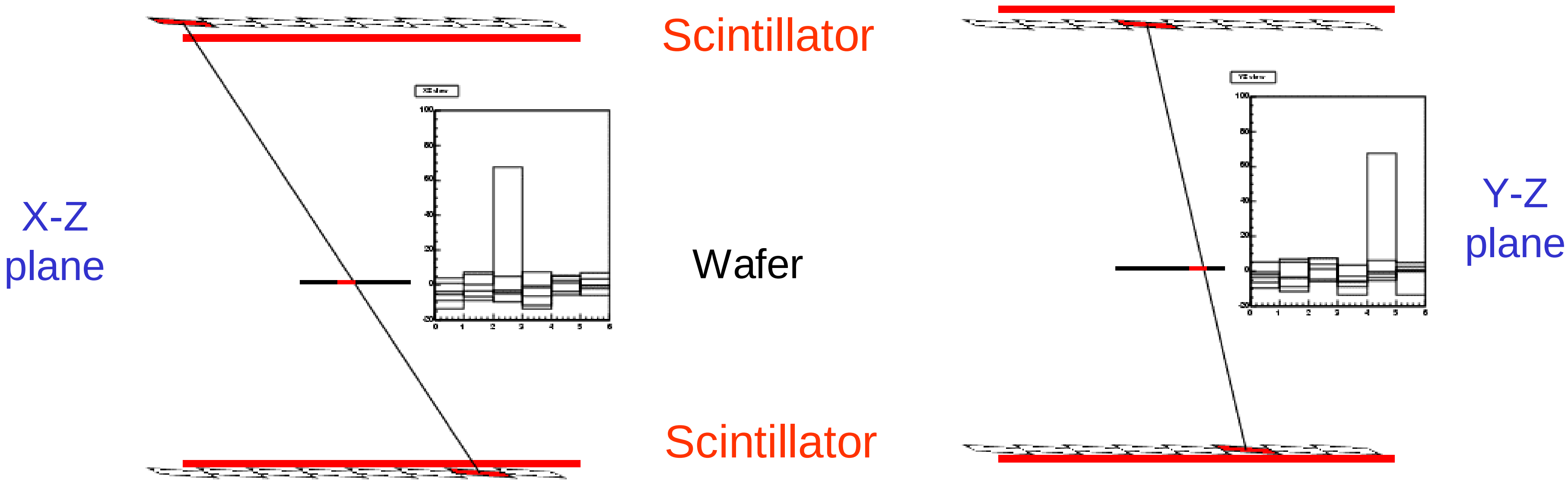
- Continuous data for 2.5 days; check pedestals vs time
- Drifts of up to 15 ADC counts (2σ) seen
- Same trend in all channels
  - Very similar within a chip, less so chip-to-chip

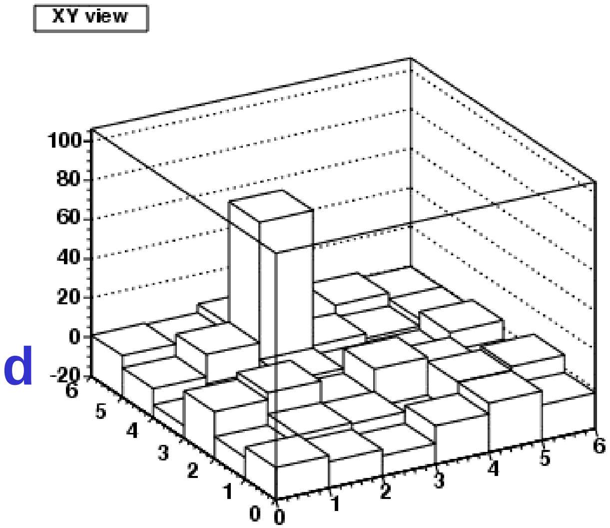




- Temperature, Power to the chip?
- Need to monitor temperature & power in future to check this

Full Chain - Cosmics

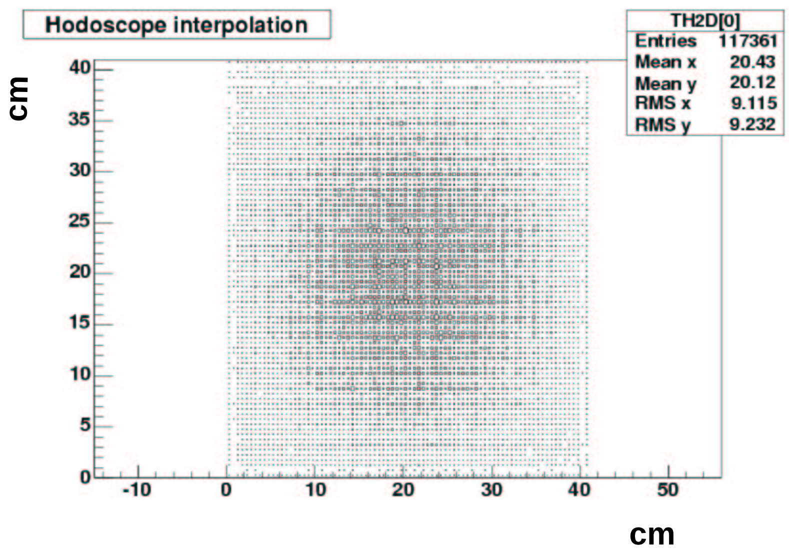


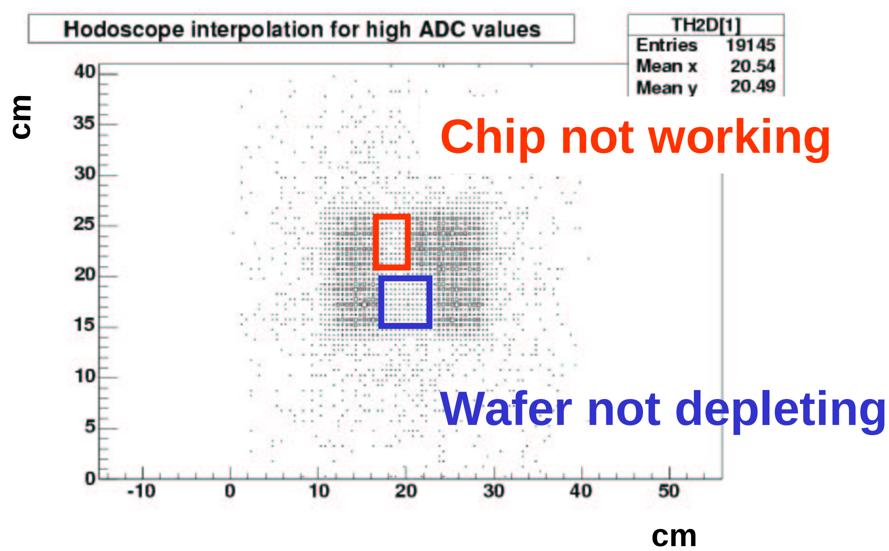


- Example of Cosmic Event
- Passes through scintillators
- Extrapolated through silicon
- Appears as clear signal above background

Cosmics Run

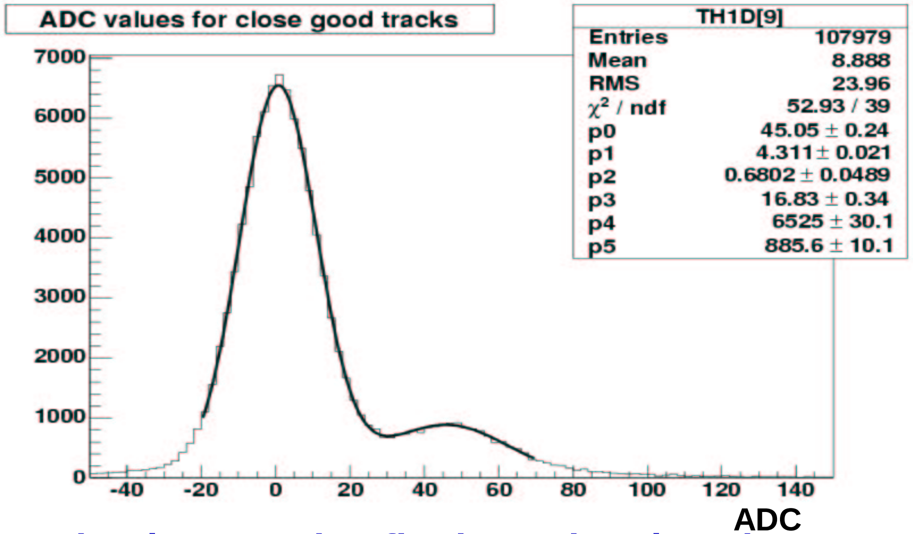
- Full PCB used in Ecole Polytechnique teststand, but…
  - Wafer 1 not depleted
  - Bad ADC on CERC for wafer 4; half the wafer has very high noise
- Ran over weekend 18-21 June
  - Total ~ 57 hours, 130083 events
  - Around 90% have unique track from scintillators
  - Interpolate into plane of PCB; check for ADC value > 40

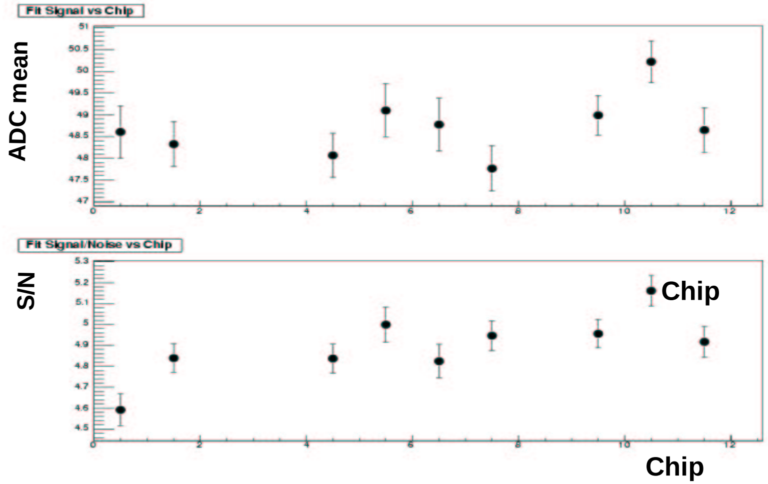




Cosmics Signal

- **Require interpolation within 0.9cm of pad centre**
- **All (good) channels combined**



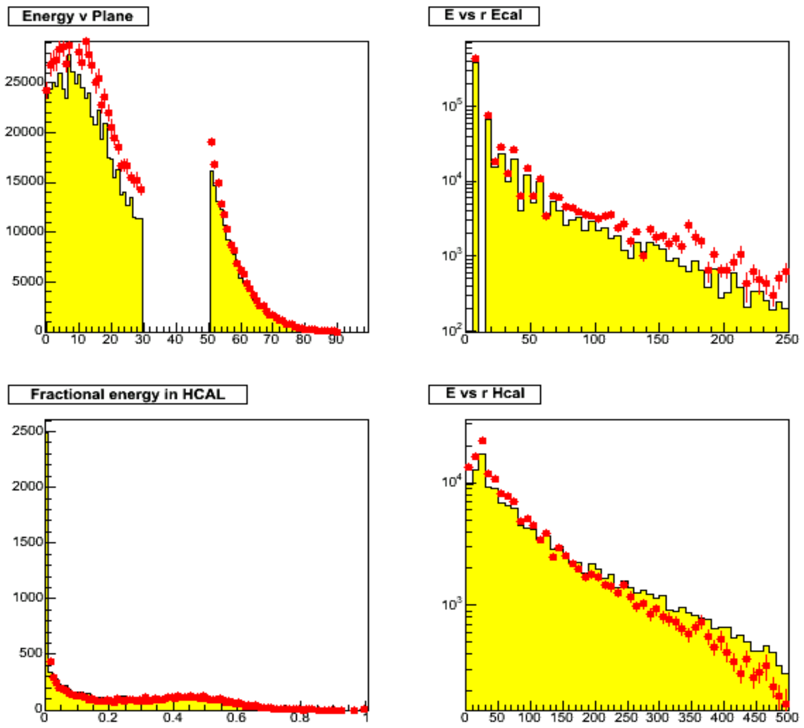


- **Simple Gaussian fit given signal peak at 45 ADC counts**
- **But S/N = 4.3, i.e. noise is 10.5 counts, not 7 counts**
- **Perform fit, chip by chip – get better results**
- **Both uniform to ± 3% (tolerance on the wafer thickness)**
- **Fit gives higher signal ~ 49, and hence S/N ~ 4.9**
- **Once Common mode noise and full pedestal shift removed, expect S/N of 7 for peak value**
- **Gives range of 800 MIPS in current configuration**

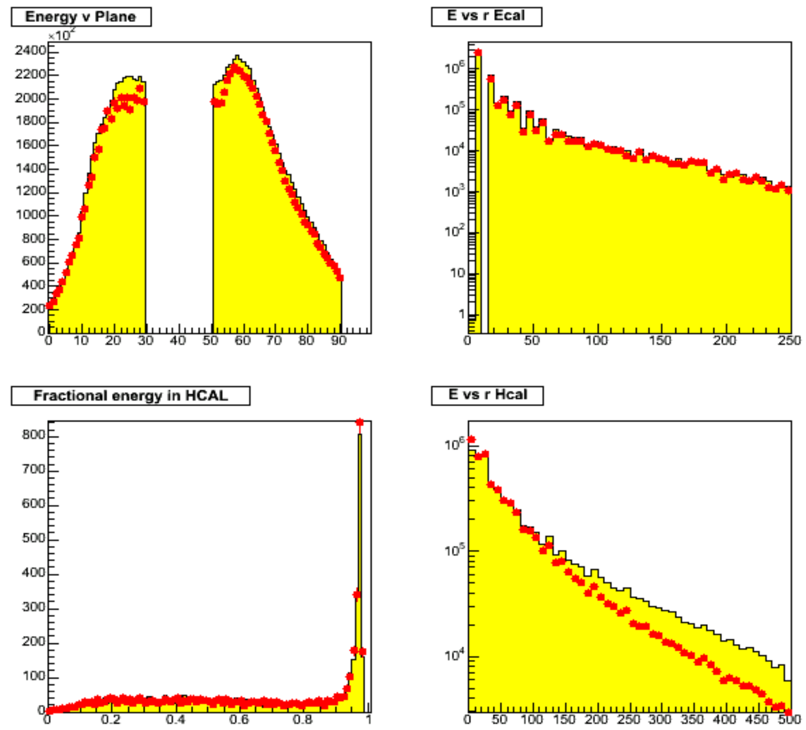
Very Good Progress on ECAL development

Simulation

1 GeV π^+

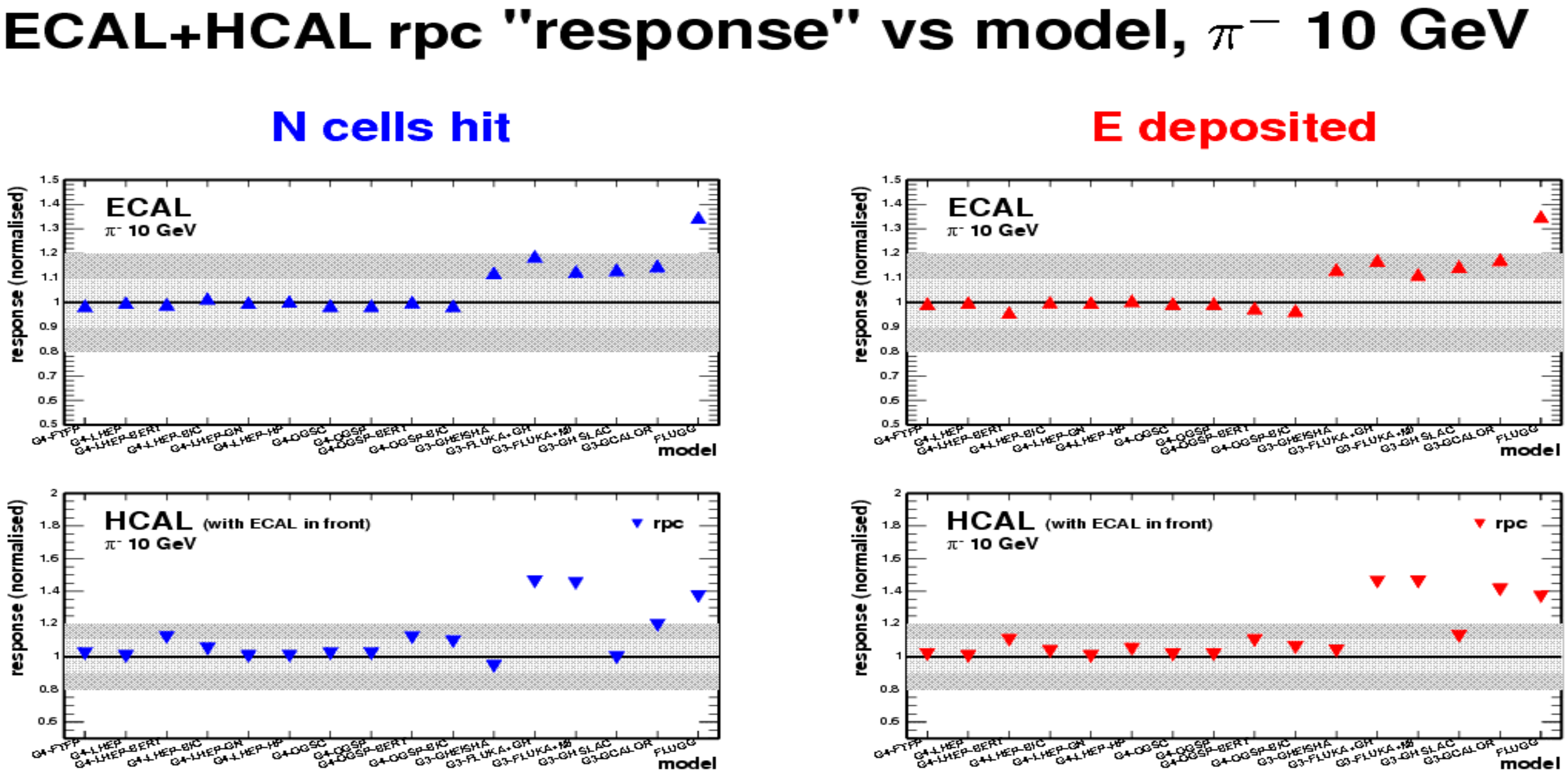


50 GeV π^+



- Development of Hadronic Showers not fully understood in Simulation
- Geant3 (histo) and Geant4 (points) show basic differences in shower development
- Aim to take the data and do detailed comparison of different models
- Allow us to optimise proposed detector for LC
- Work courtesy of D.Ward

Comparing the Models

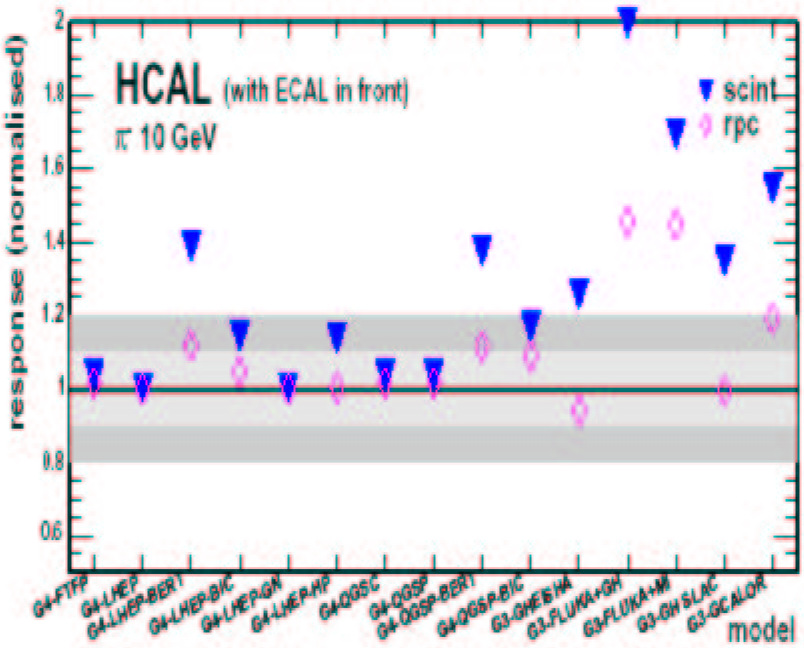


- Detailed comparison of the properties of different MC models underway
- Combine G3 and G4 with different 'physics' implementations
- ECAL shows EM discrepancies, but general consistent behaviour
- Much greater variation for HCAL

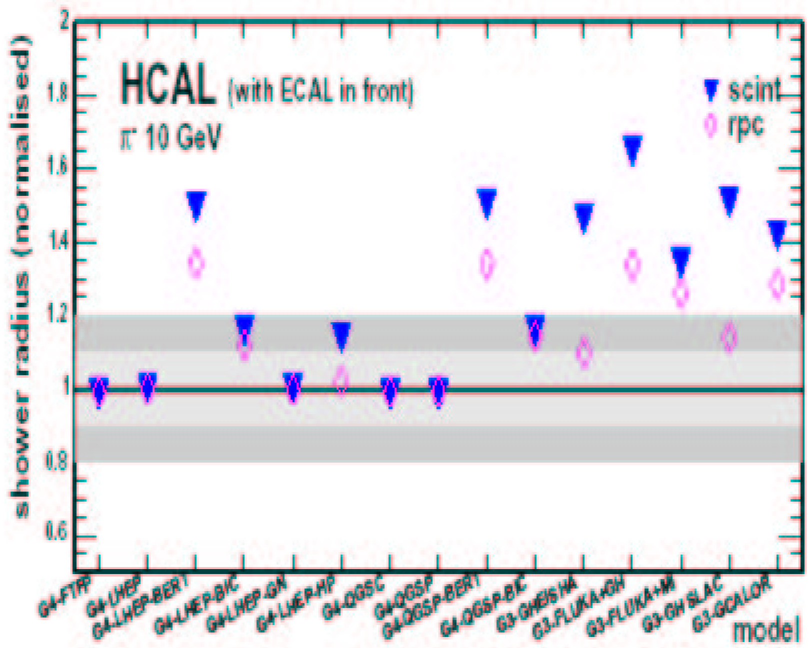
Work by G.Mavromanolakis and N.Watson

Comparing the Models

N cells hit



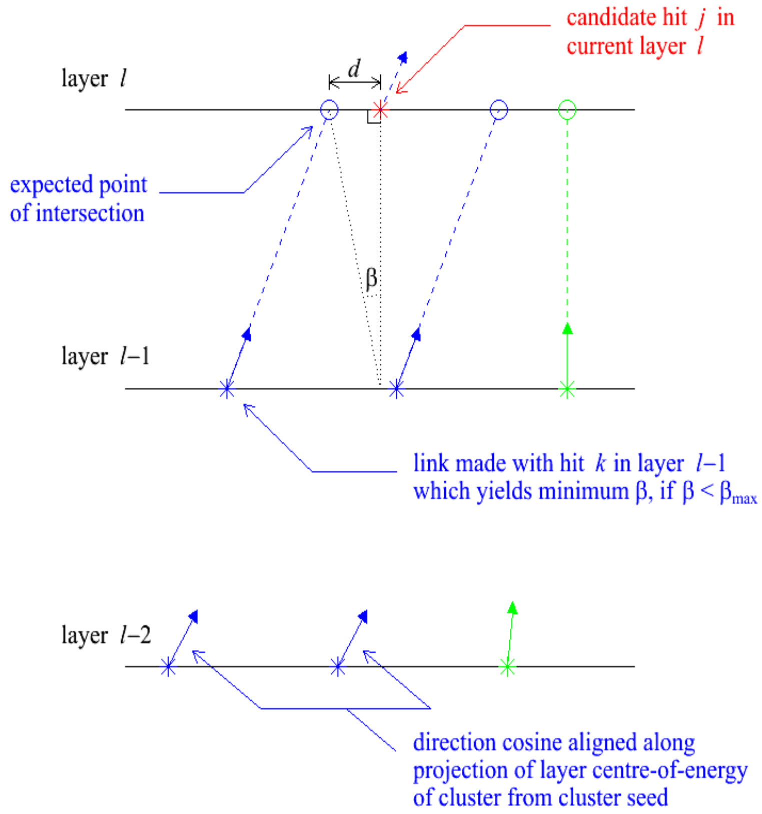
shower width



- **HCAL rpc less sensitive to low energy neutrons than HCAL scint**
- **Really shows that test beam studies are needed**

Particle Clustering Algorithm

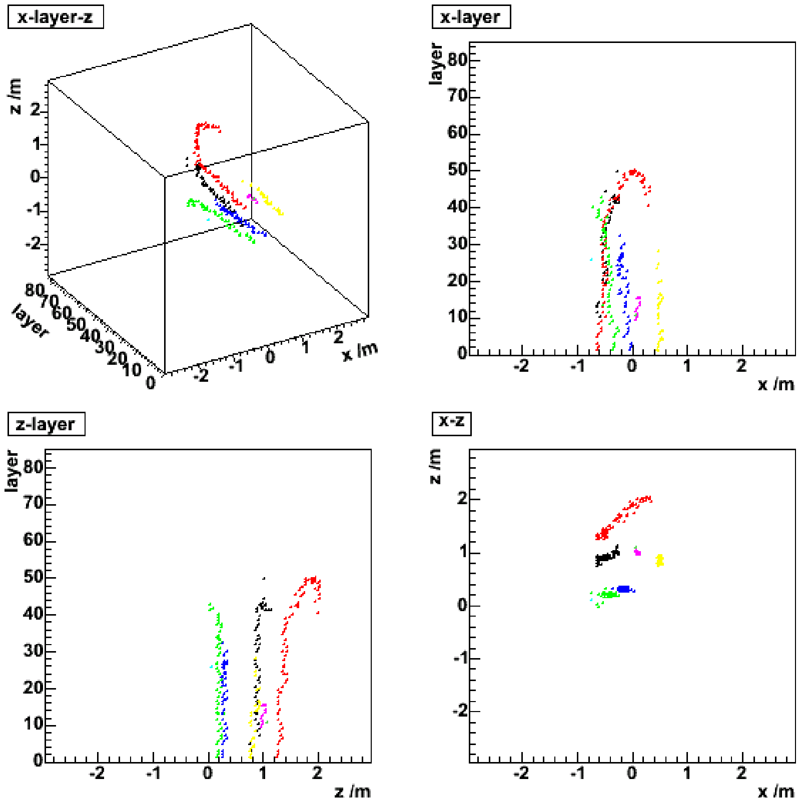
- **Algorithm mixes tracking and clustering aspects.**
- **Sum hits withn cell; apply threshold of ⅓ MIP.**
- **Form clusters in layer 1 of ECAL.**
- **Associate each hit in layer 2 with nearest hit in layer 1 within cone of angle α. If none, initiate new cluster.**
- **Track onwards layer by layer through ECAL and HCAL, looking back up to 2 layers to find nearest neighbour, if any.**



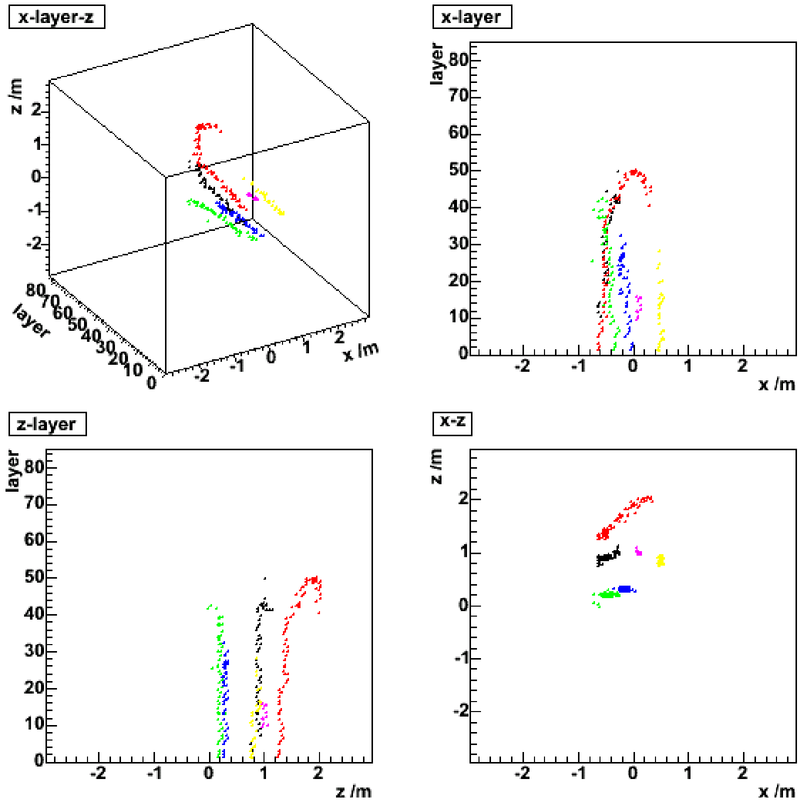
Work by C.Ainsley

Particle Clustering algorithm

Reconstructed clusters



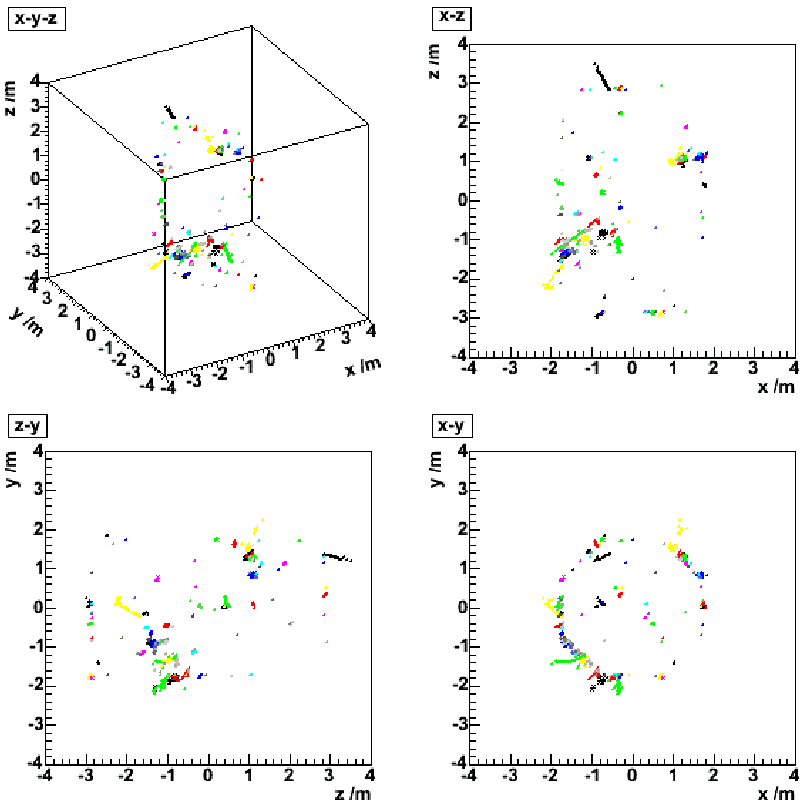
True particle clusters



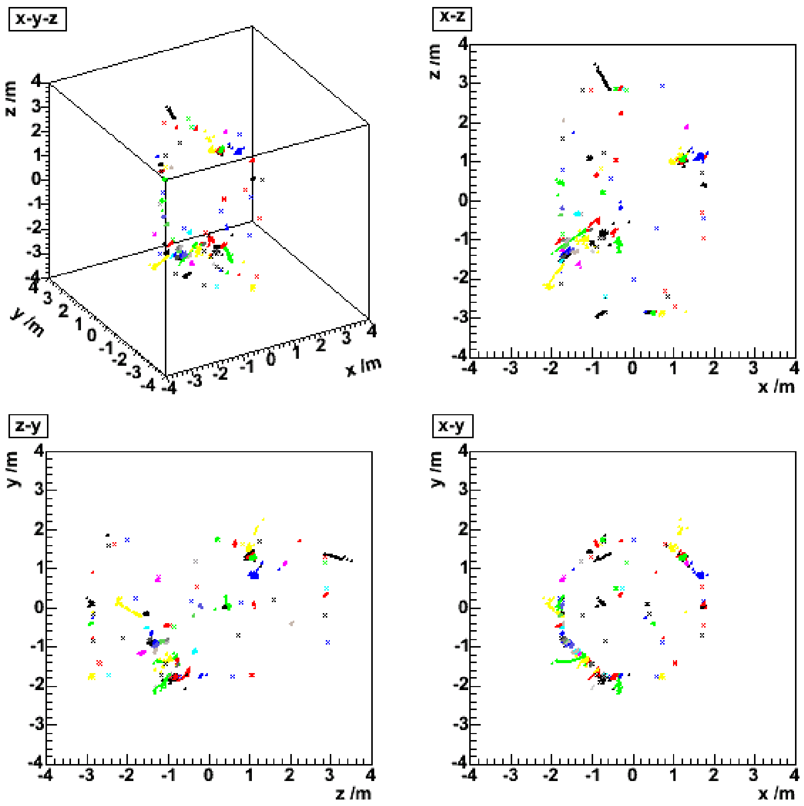
Part of a 91 GeV Z event in the Calorimeter – Looks Good

Full Z event

Reconstructed clusters

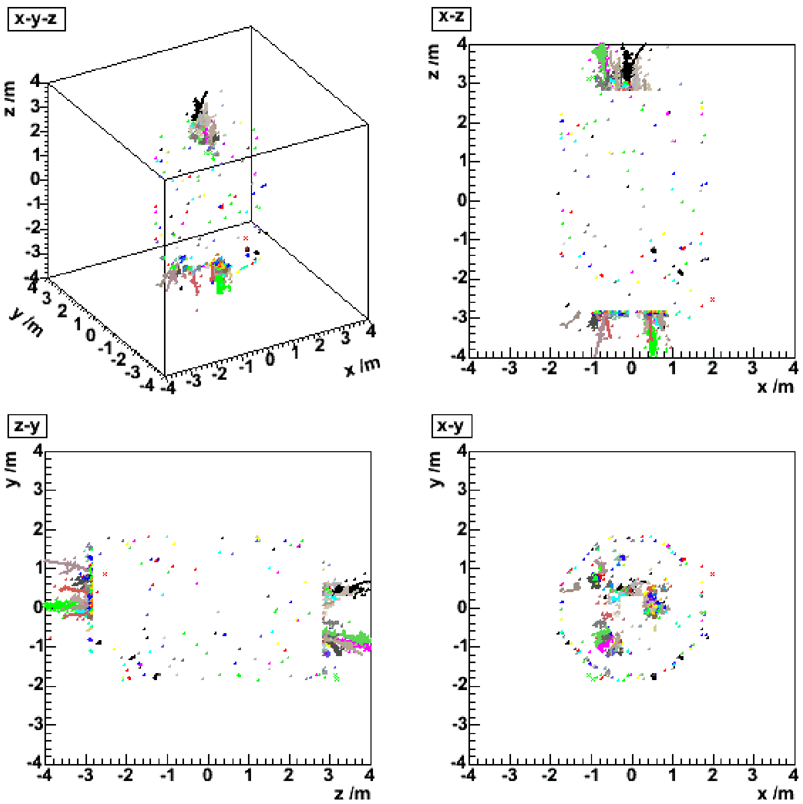


True particle clusters

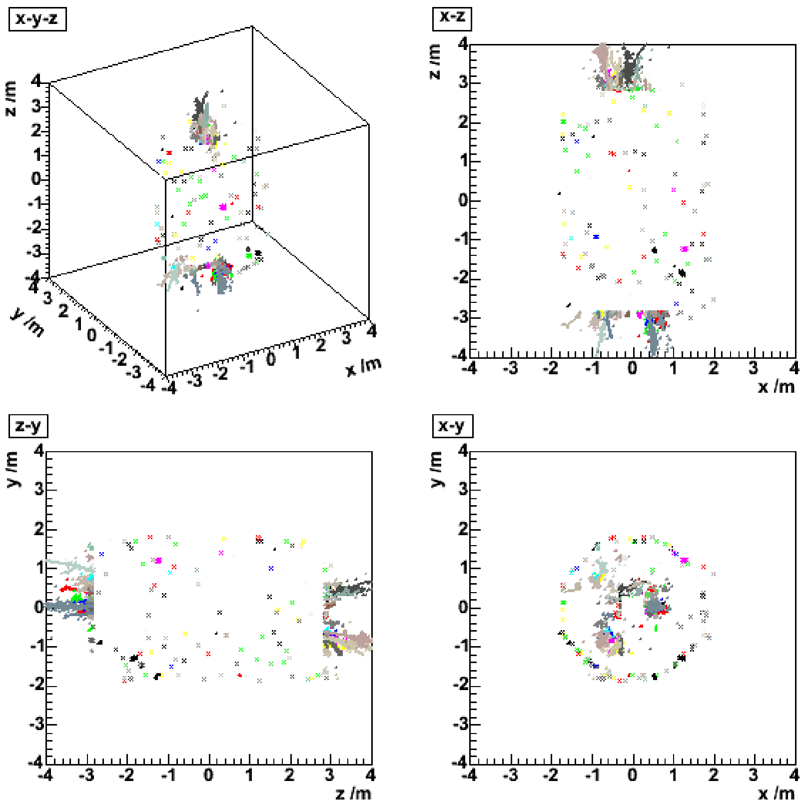


Full W^+W^- events – 800 GeV

Reconstructed clusters

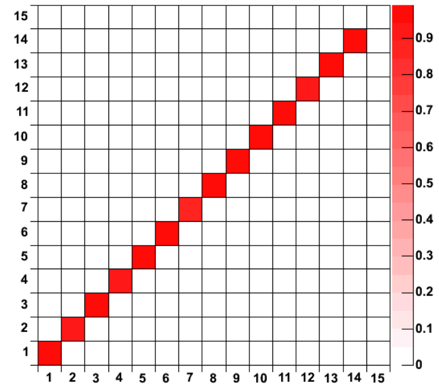


True particle clusters



Initial Clustering Results

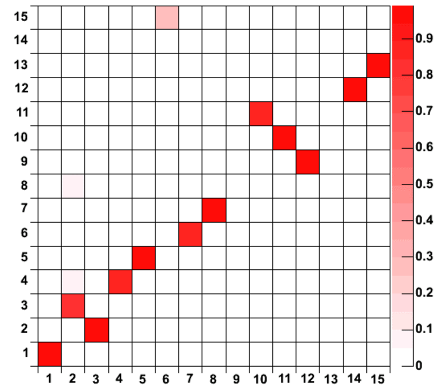
Fraction of true cluster energy in each reconstructed cluster



- Z to light quarks results – one Event

- 15 highest energy reconstructed and true clusters plotted.
- Reconstructed and true clusters tend to have a 1:1 correspondence.
- Averaged over 100 Z events at 91 GeV:
  – 97.0 ± 0.3 % of event energy maps 1:1 from reconstructed onto true clusters.

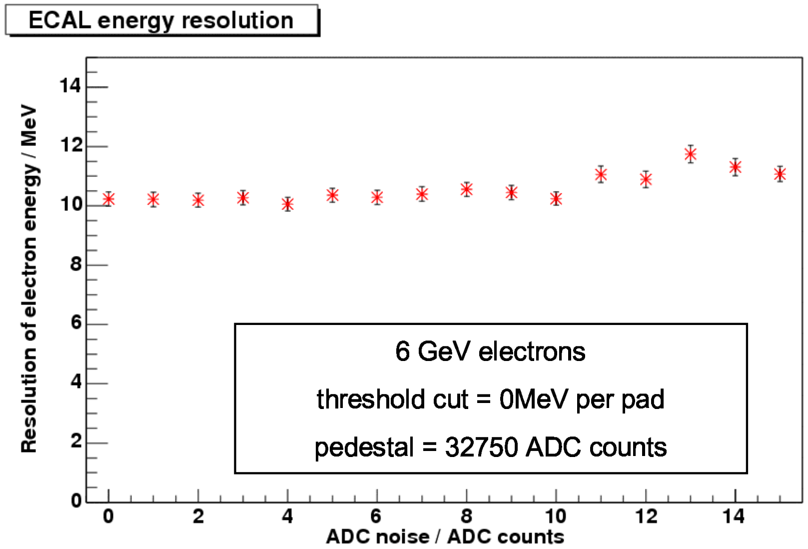
Fraction of true cluster energy in each reconstructed cluster

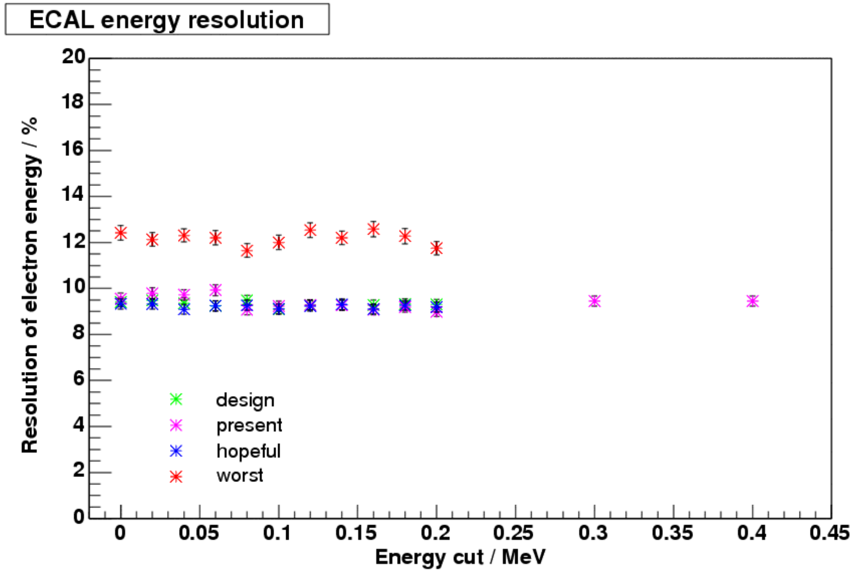


- WW at 800 GeV - one Event

- 15 highest energy reconstructed and true clusters plotted.
- Reconstructed and true clusters tend to have a 1:1 correspondence.
- Averaged over 100 W^+W^- events at 800 GeV:
  – 80.2 ± 1.0 % of event energy maps 1:1 from reconstructed onto true clusters.

Readout effects in Simulation





- Added a way for Readout effects to be included in the simulation
- Simple model adding noise with best to worst case scenarios
- For individual particles see acceptable loss in resolution
- Need to add realistic effects: Common Mode, Crosstalk…
- Interesting to see the effect on clustering

Work by C.Fry

Prototype Status and Timelines

ECAL prototype components status:

Items	Status	Comments
Tungsten plates	Funded and produced	Good production, no problem so far
Structure with carbon fiber	Funded, first structure produced, second and third in production	
Wafer sample 1	Produced by MSU, funded by IN2P3	Small problem of size not within tolerance; will delay mounting
Wafer sample 2	First test batch produced at Prague in April 2004	First batch of 15 wafers received
PCB for testing	Version KNU-1	Fill the requirement
PCB for prototype	Version KNU-2 in test	Would be the prototype version
VFE chip	Designed, produced	
Calibration DAQ	Tested and running	Ready for assembly validation and calibration
Full prototype DAQ	Under test at the LLR cosmic test bench	Board prototypes produced , firmware in development. Production this summer
Support table	Funded, designed at LAL-Orsay In construction	

All elements of the ECAL prototype are at or are close to schedule

All wafers/PCB's tested by October 2004

Plan for low energy electron test beam at DESY before the end of the year

High energy electron/hadron test beams with HCAL at FNAL/IHEP next year

Details of exact test beam program are being put together

US funding issues are of some concern for HCAL effort

Conclusions

- **Great deal of progress in recent months**
- All prototype components in production and at or close to schedule
- ECAL detector chain undergoing full testing
- Captured Cosmics
- Good initial performance: S/N, Linearity, Crosstalk
- Beginning Production; ready for DESY e^- test beam in December
- UK Simulation work shaping test beam requirements
- Key differences between G3/G4 and physics models
- Great progress on particle clustering/flow

UK groups at the heart of Calice

Well placed to take advantage of Test Beam data

Back Up Slides

Test Beam Requirements

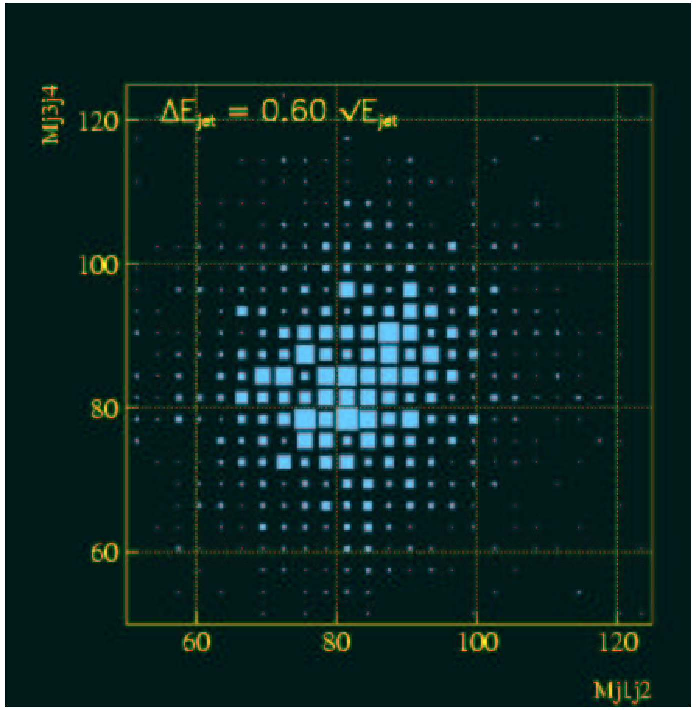
- 1% precision suggests >10^4 events per particle type and energy.
- Would like energies from 1-80 GeV (~10-15 energy points?).
- Pions and protons desirable (Čerenkov needed). +Electrons (+ muons?) for calibration.
- Need to understand beam
- Both RPC and Scintillator HCAL needed.
- Position scan – aim for 10^6 events/energy point?
- Also some data at 30-45^o incidence.

Calice Concept

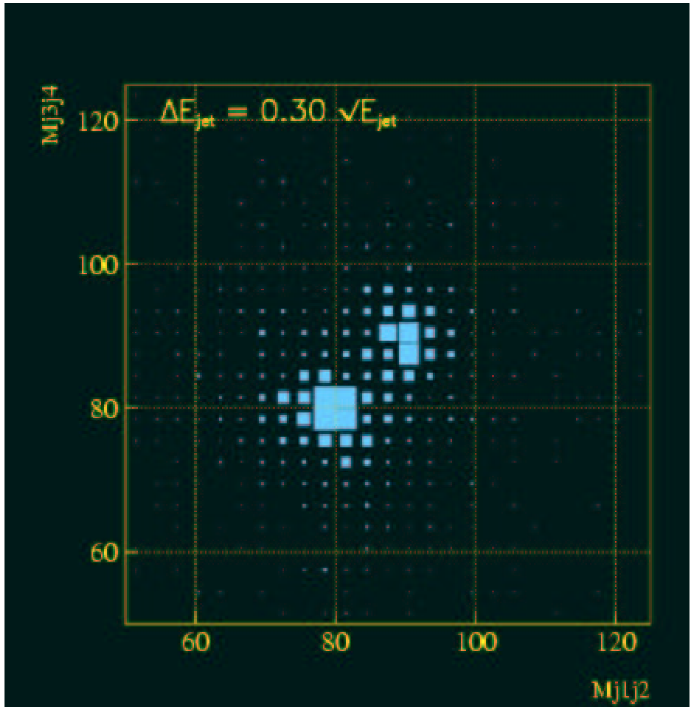
Importance of good jet energy resolution

Simulation of W, Z reconstructed masses in hadronic mode.

60%/√E



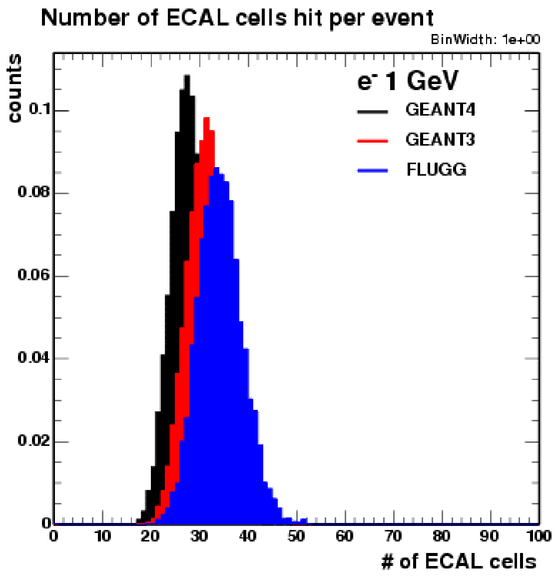
30%/√E



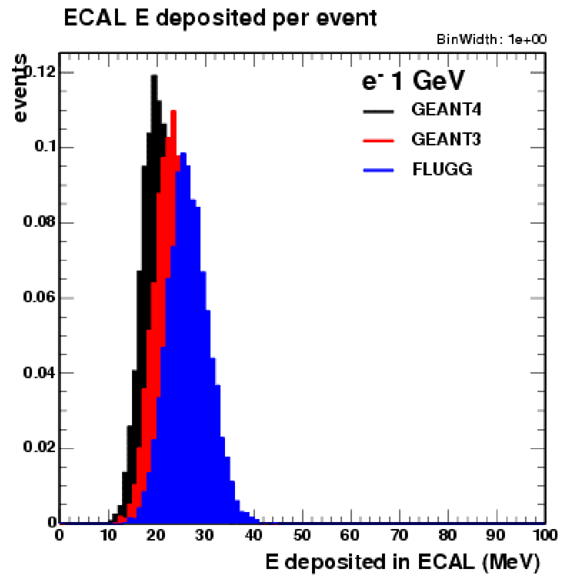
Basic issues with Simulation

discrepancies between frameworks

N cells hit



E deposited



GEANT3 14% higher than GEANT4

FLUGG 24% higher than GEANT4

GEANT3 14% higher than GEANT4

FLUGG 30% higher than GEANT4