Imperial College London

Resolution Studies of the CMS ECAL in the 2003 Test Beam

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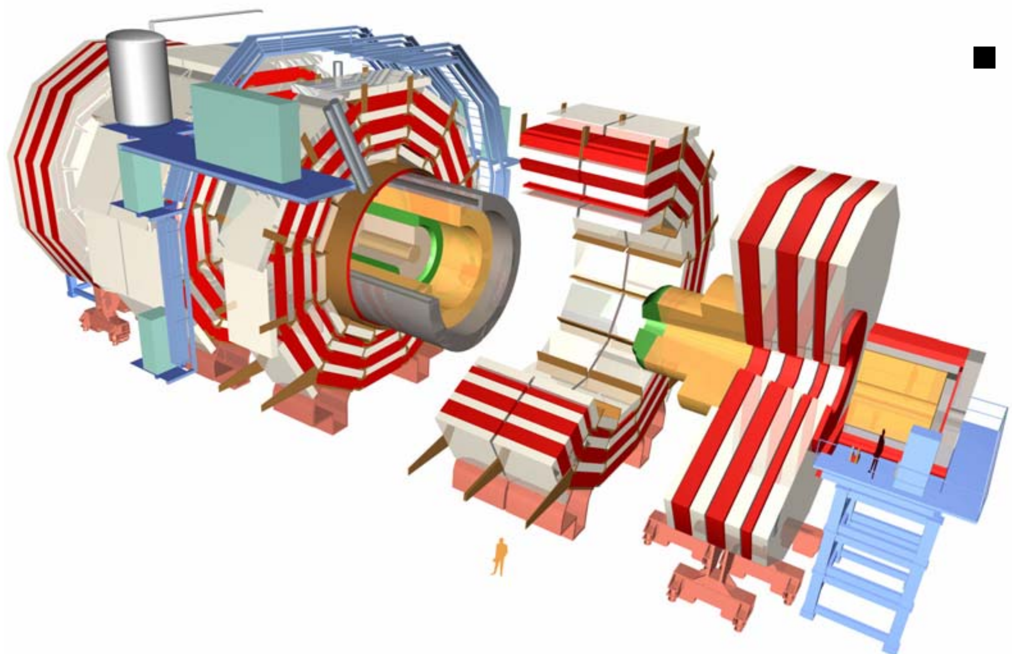
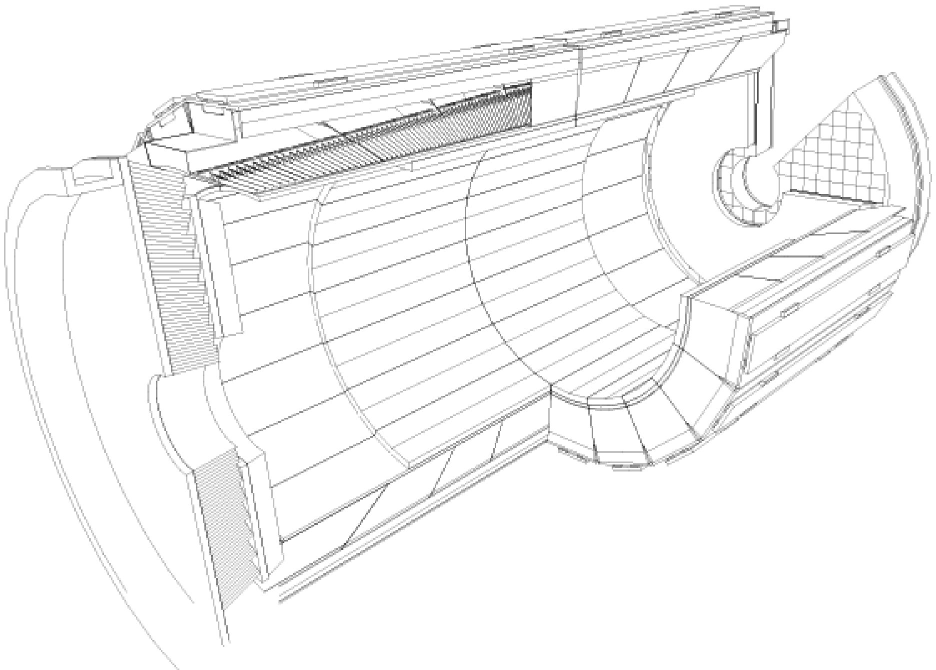
The CMS Detector



- General purpose detector situated on the LHC at CERN
- Centre of mass energies up to 14 TeV
- Structure:
  - Analogue pixel and strip silicon tracker
  - Lead tungstate crystal electromagnetic calorimeter
  - Hadronic calorimeter
  - Superconducting magnet, 4T
  - Muon system
- ECAL compact, radiation tolerant with good resolution

CMS ECAL and the Test Beam

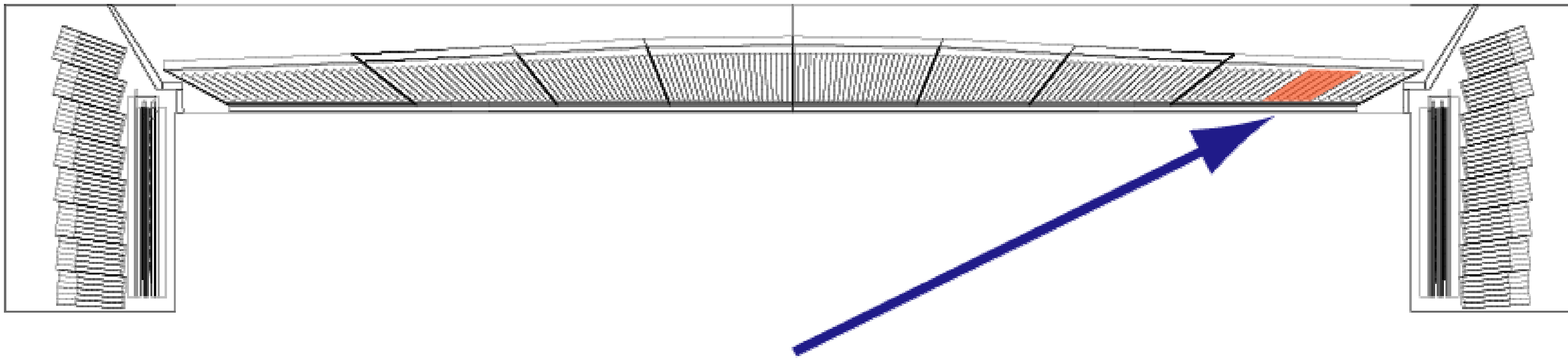


- Target energy resolution (TDR '97)

$$\frac{\sigma}{E} = \frac{155\text{MeV}}{E} \oplus \frac{2.7\%}{\sqrt{E}} \oplus 0.55\%$$

- Design features tested and qualified in test beam
  - Startup intercalibration values
  - Detailed comparison with Monte Carlo
  - Verification of final laser monitoring system
- Performance of new front end electronics, redesigned in mid 2002, verified in 2003 test beam

Test Beam Overview



- ECAL supermodule SM1 placed in an electron beam from the SPS at CERN
- 50 Channels populated with a prototype of the final version of the CMS electronics
- This was one of the first system tests for the front end electronics
- Beam taken during heavy ion run over a week long period
- Runs using electrons of energies 25, 50, 70 and 100 GeV taken

ECAL Readout

Multi-Gain Pre-Amplifier

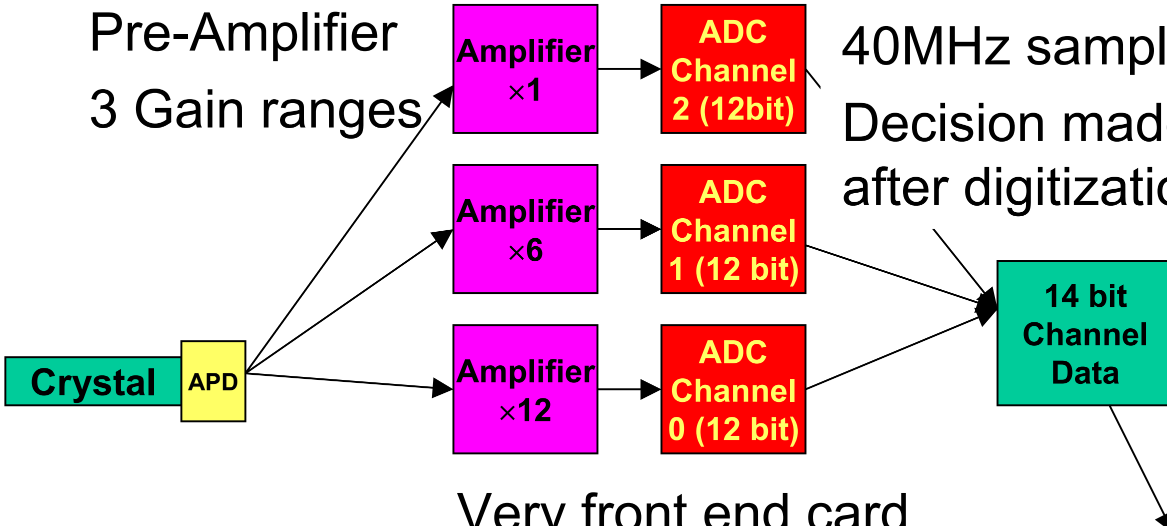
3 Gain ranges

ADC

40MHz sampling

Decision made after digitization

All ASICs use radiation tolerant 0.25μ technology (DSM)

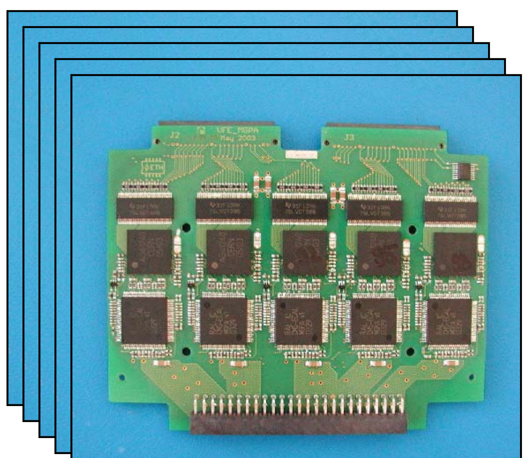


Optohybrids

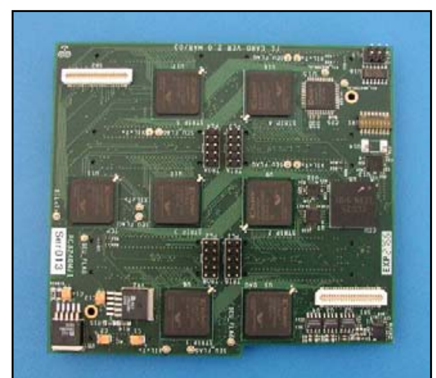
Trigger primitives

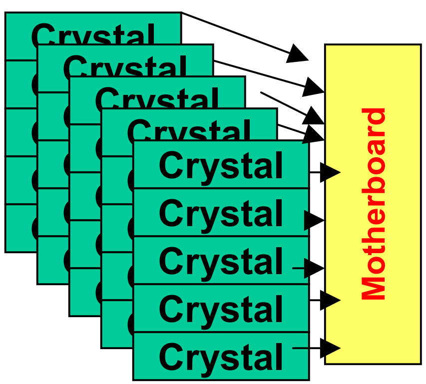
Data (on level 1 trigger)

Very front end card



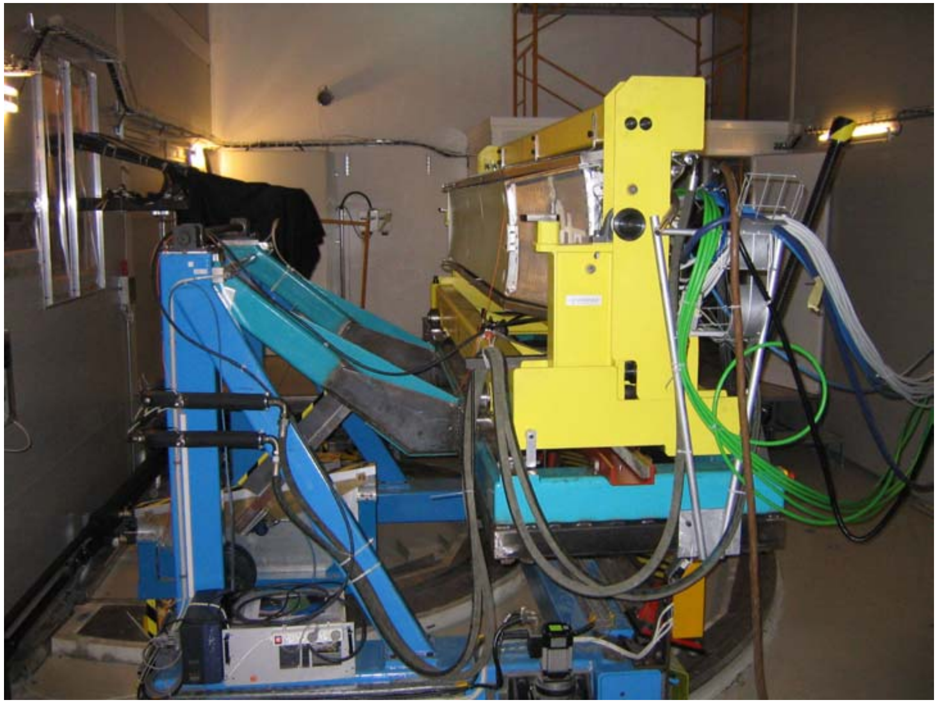
Front end card





Test Beam Setup

- Module mounted on movable table
- Beam aligned as from CMS center
  - Hodoscope used to measure impact point
- Beam is asynchronous
  - TDC used to measure phase
- 14 time samples taken per event to describe the pulse



- Low frequency noise
  - Frequency much lower than sample rate
  - Similar effect to an unstable pedestal

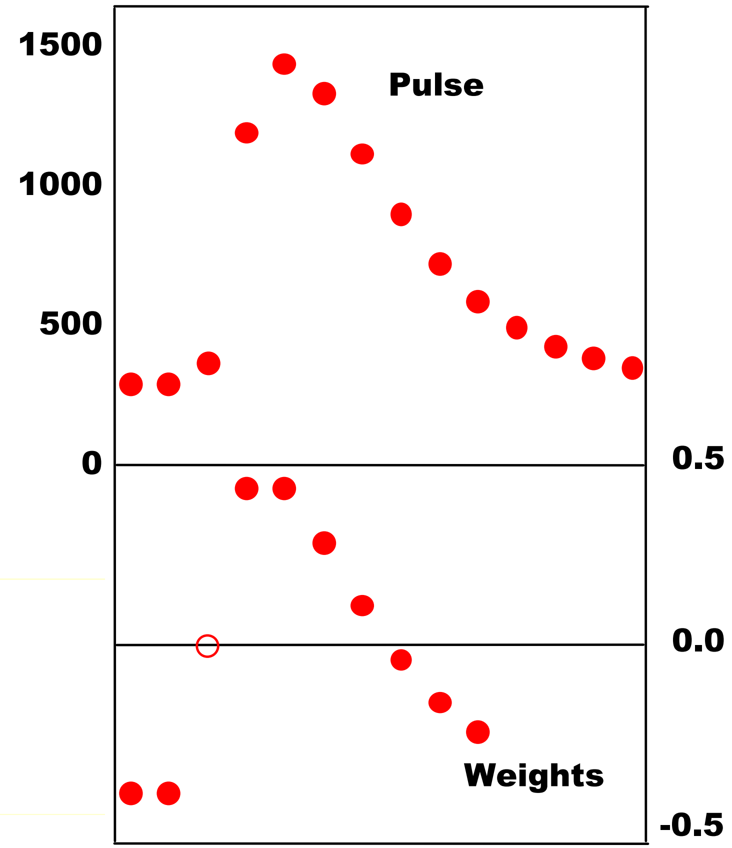
Weights Method

$$Amplitude = \sum w_i s_i$$

- Amplitude calculated using a weights method.
- Set of weights calculated to subtract pedestal event by event
  - Use least squares method:

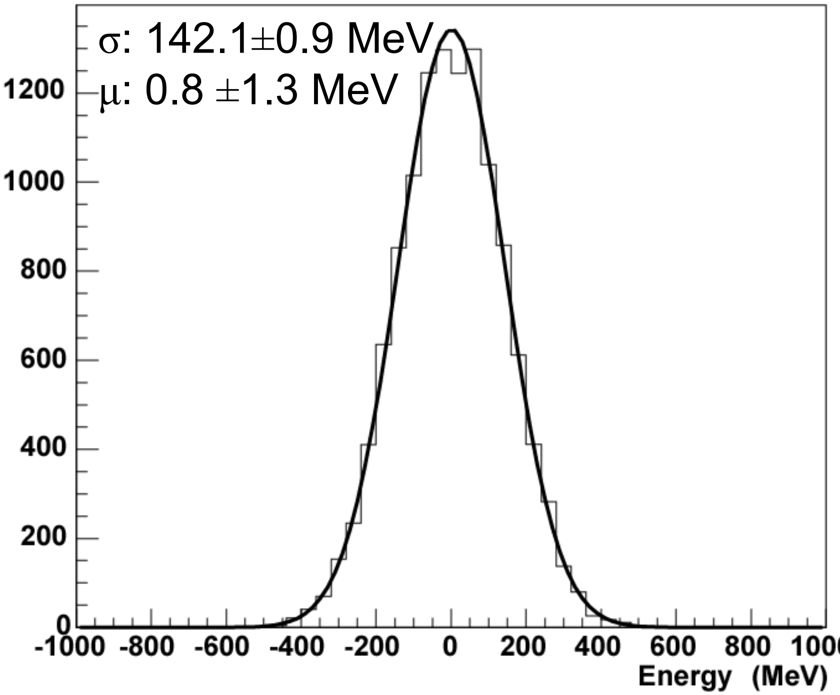
$$\chi^2 = (\vec{S} - A\vec{F} - P)Cov^{-1}(\vec{S} - A\vec{F} - P)$$

    - S: samples, A: amplitude,
      F: functional description,
      P: pedestal level
      cov: sample to sample noise correlation matrix
  - Correlation matrix taken as the unit matrix



Noise Performance

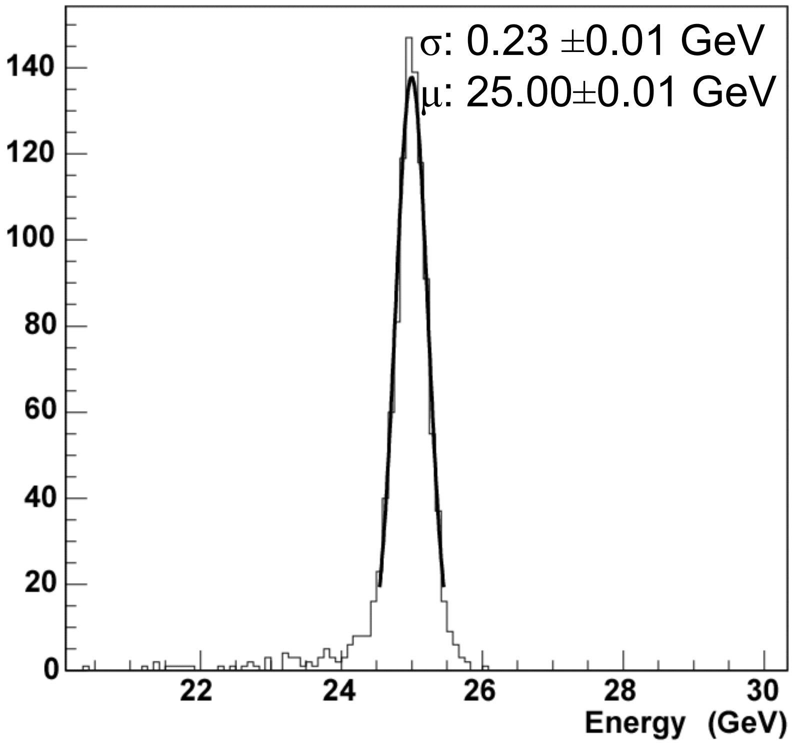
- Level of noise calculated using randomly triggered data
- Noise level is 142 MeV for the sum of 9 channels and 238 MeV for the sum of 25
- Equates to about 47 MeV of noise per channel
- Very little residual correlated noise



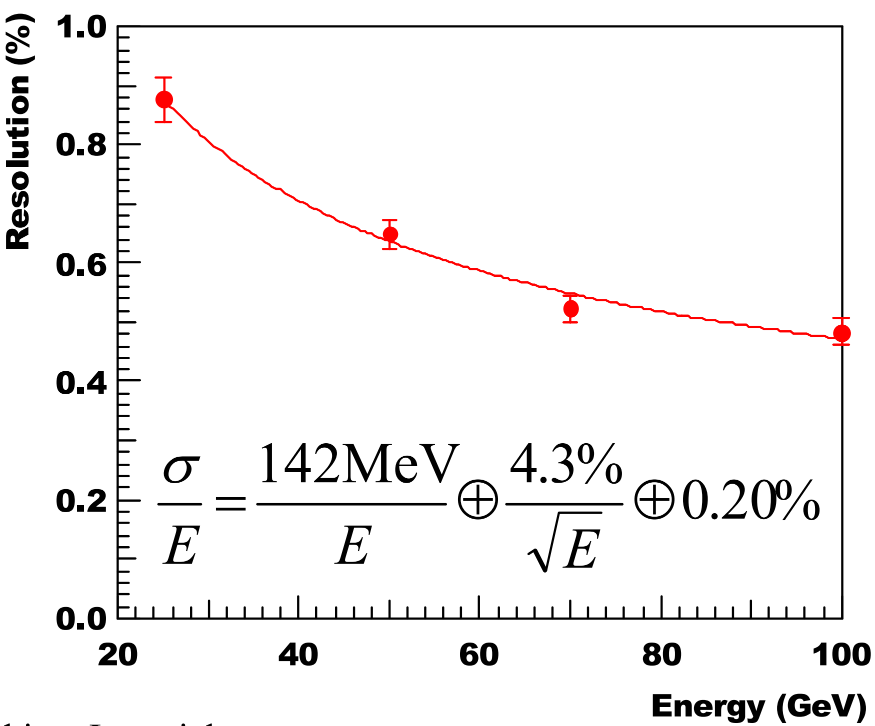
Noise from the sum of 9 channels.

Resolution

Reconstructed energy of 25 GeV electrons using the sum of 9 crystals



- Resolution evaluated with a cut of 4x4mm^2 on position of incident electron
- Momentum spread on beam is subtracted (0.2% for 100 GeV)



Conclusions

- Low frequency noise removed through subtracting pedestal event by event
- New DSM electronics capable of low noise performance
- Resolution down to target levels
- Low frequency noise understood by electronics experts and eliminated
- Complete supermodule in 2004 test beam