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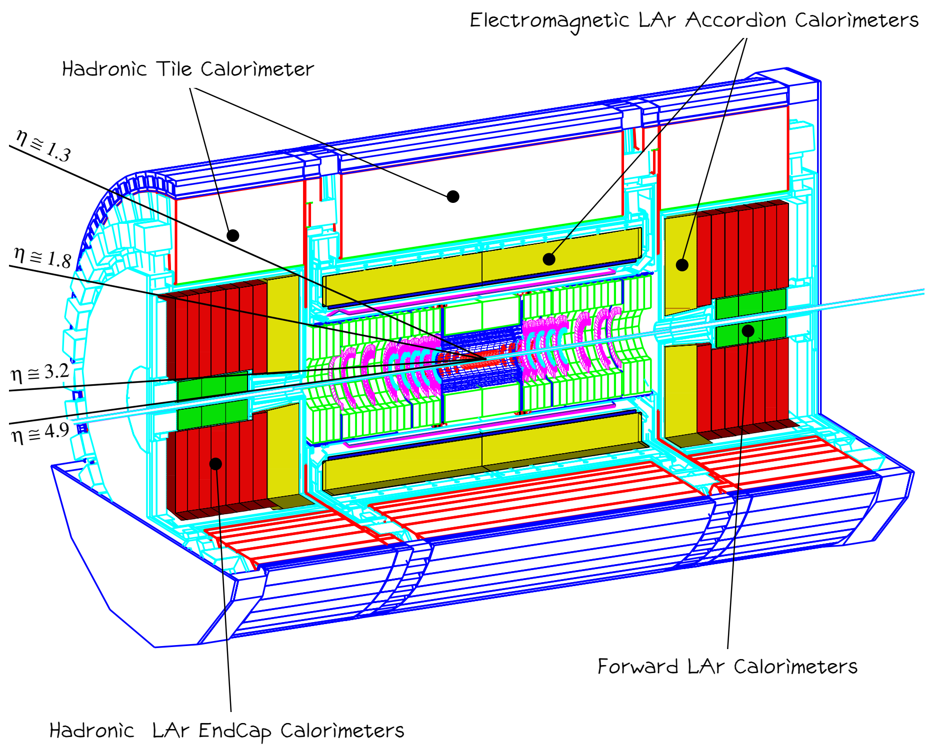
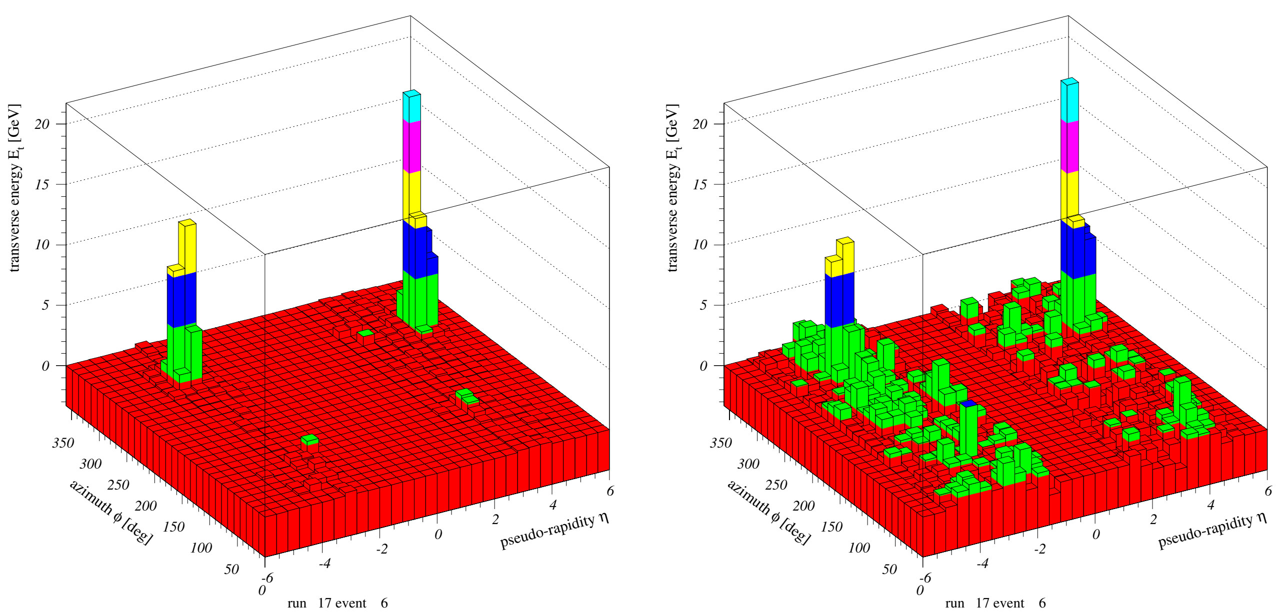
Comparison of Experimental Electron Signals with GEANT3 and GEANT4 Simulations for the ATLAS Forward Calorimeter Prototype

- Overview of the Forward Calorimeter (FCal) in ATLAS
- FCal Module 0's
- Monte Carlo set up with Geant4
- Results
- conclusions and Outlook

ATLAS Calorimetry



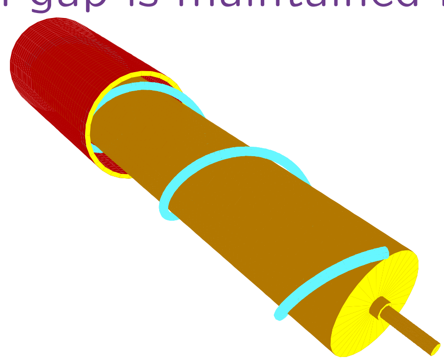


ATLAS FCal

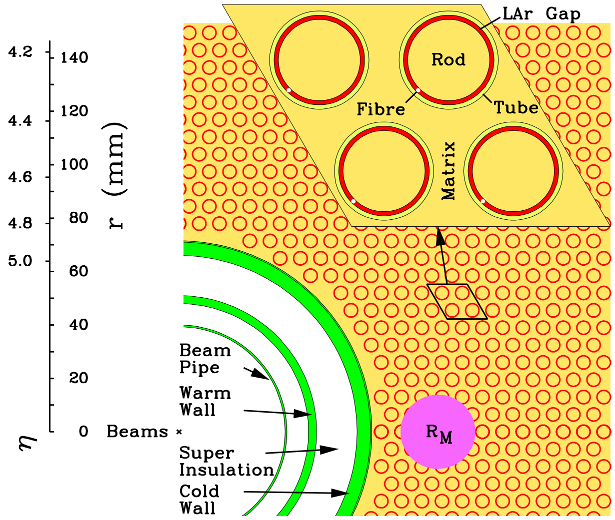
- one electromagnetic liquid argon/copper (FCal1) and two hadronic liquid argon/tungsten sections (FCal2/3) integrated into a common cryostat with the electromagnetic endcap calorimeters;
- cylindrical section 45 cm deep with 90 cm diameter;

	Depth[X_0]	Depth[λ]	Weight[t]
FCAL1	27.6	2.7	2.1
FCAL2	91.2	3.7	3.9
FCAL3	89.5	3.6	3.8

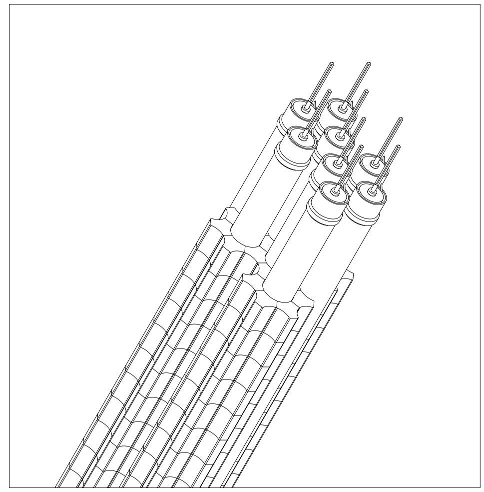
- thin gaps of liquid argon are required to avoid positive charge build-up;
- Electrode Design:
  - tube/rod electrodes assembly with cylindrical shell gap of 250/375/500 μm and tube spacing is 7.5/8.18/9.0mm centre-to-centre in FCal1/2/3
  - Tube material is copper, rods are copper in FCal1 and pure tungsten in FCal2/3. About 12330/10320/8120 electrodes in FCal1/2/3
  - liquid argon gap is maintained by peek fibre spacers



ATLAS FCal

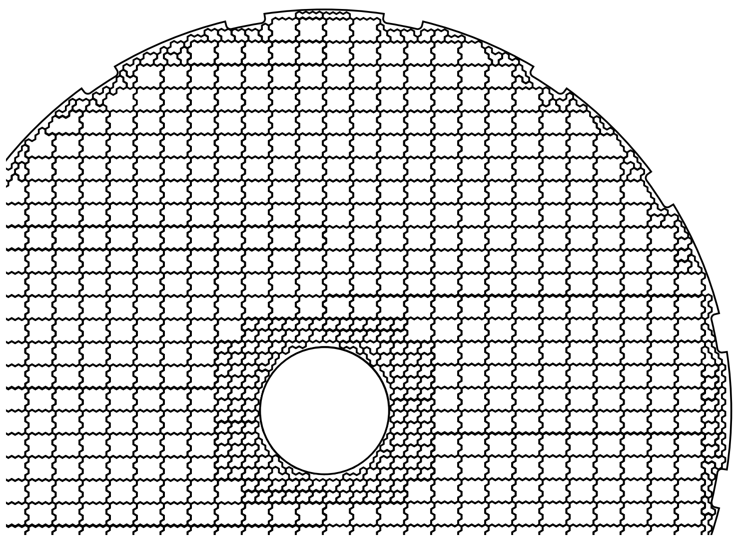


Hexagonal tube/rod pattern



Tungsten "slugs" in FCal2/3

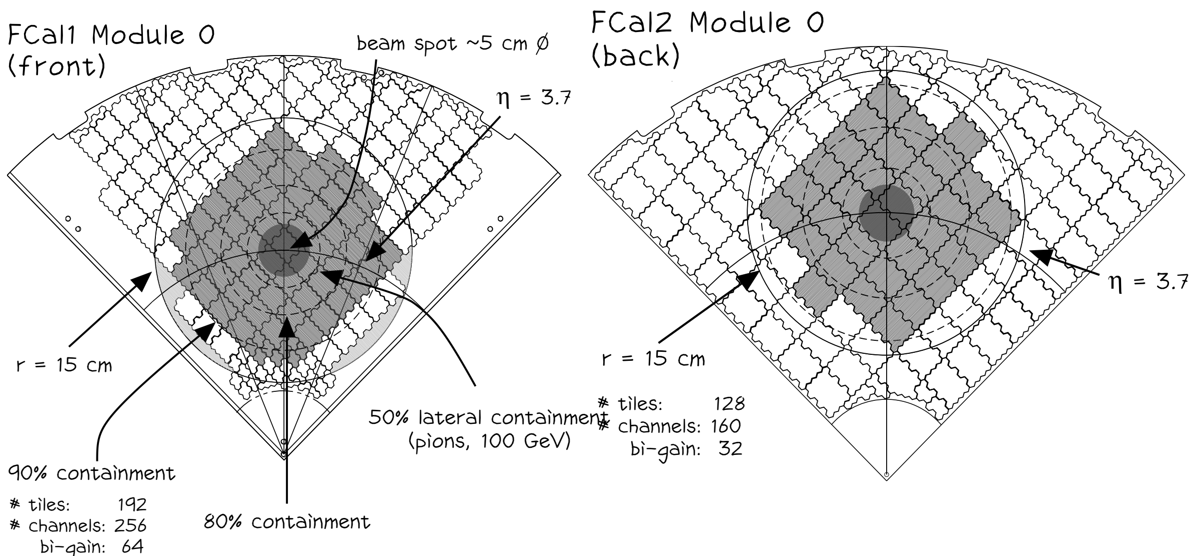
- Two stage summing of electrodes (4/6/9 $\longrightarrow$ 16/24/36) leads to "tiles" readout geometry;



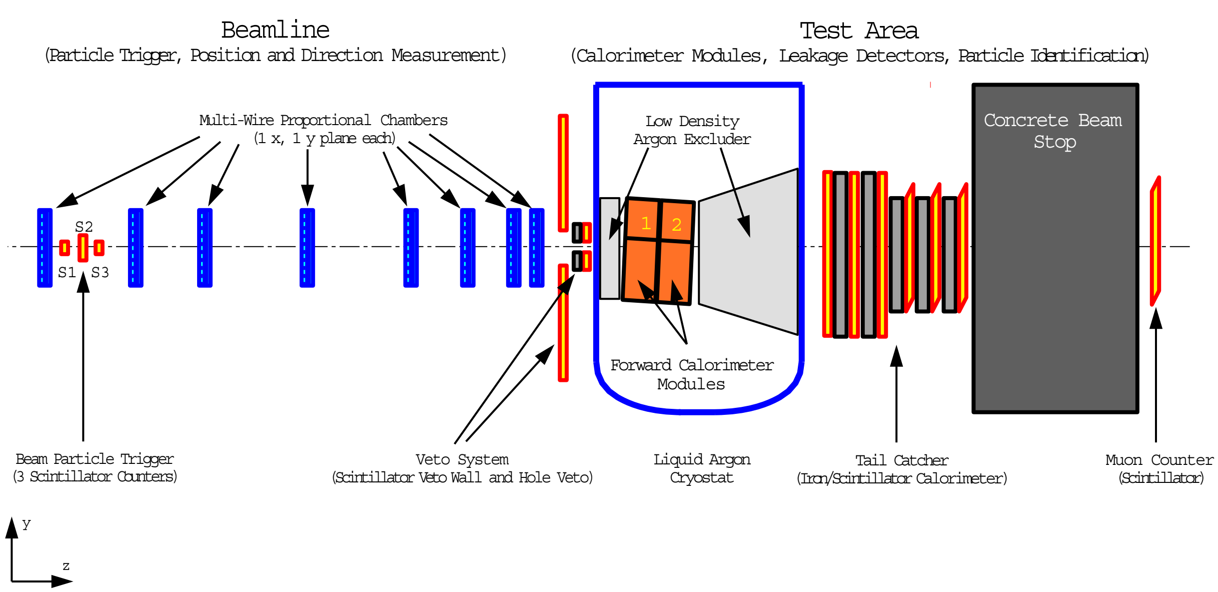
- typical tile size is 0.2×0.2 in $\Delta\eta \times \Delta\phi$

FCal Module 0

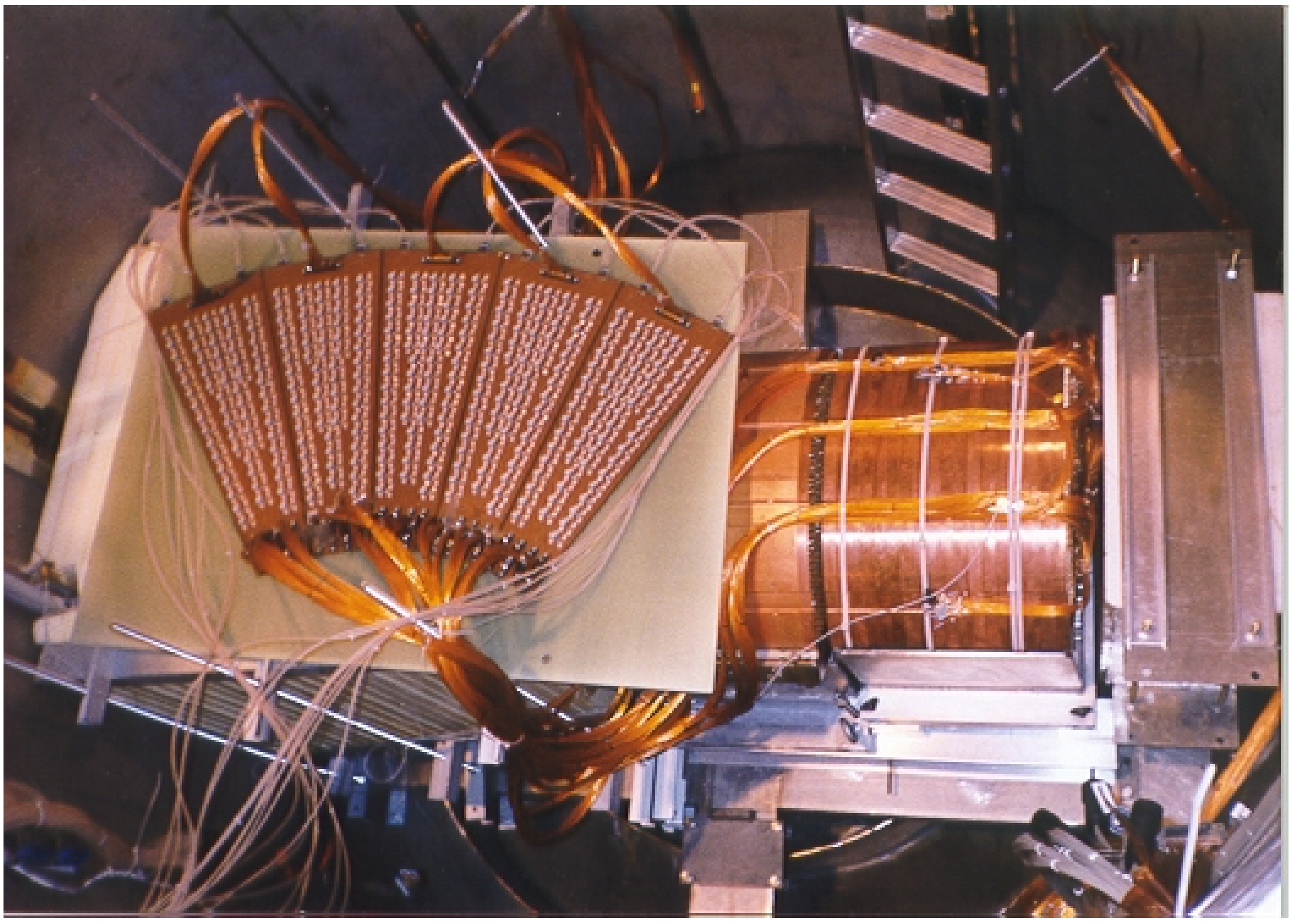
- prototypes for the electromagnetic (Fcal1) and one hadronic module (Fcal2);
- 1/4 ring modules at full depth sufficient for lateral electromagnetic and hadronic shower containment; 6.4 λ total hadronic depth $\longrightarrow$ longitudinal acceptance limitations at higher energies;



- Testbeam setup at CERN: H6(North area beam line; 10-200 GeV/c pions, electrons and muons:)



- FCal modules in cryostat



Monte Carlo Simulation

GEANT 3.21/11 and GEANT4.2.0R2 base simulation program;

Geometry Description

- **Beam line:** MWPC's, S1/S2/S3 scintillators, Hole veto including Pb shielding, lead and iron walls in front of cryostat, Tail-Catcher, concrete beam stop, muon counter;
- **Cryostat:** wall structure with superinsulation and front/back liquid argon excluders;
- **FCal1 and FCal2 modules:**
  - Dimensions of electrodes and modules measured (FCal1) or from drawings (FCal2);
  - Electrode positioning (x, y) read from external file describing the readout;

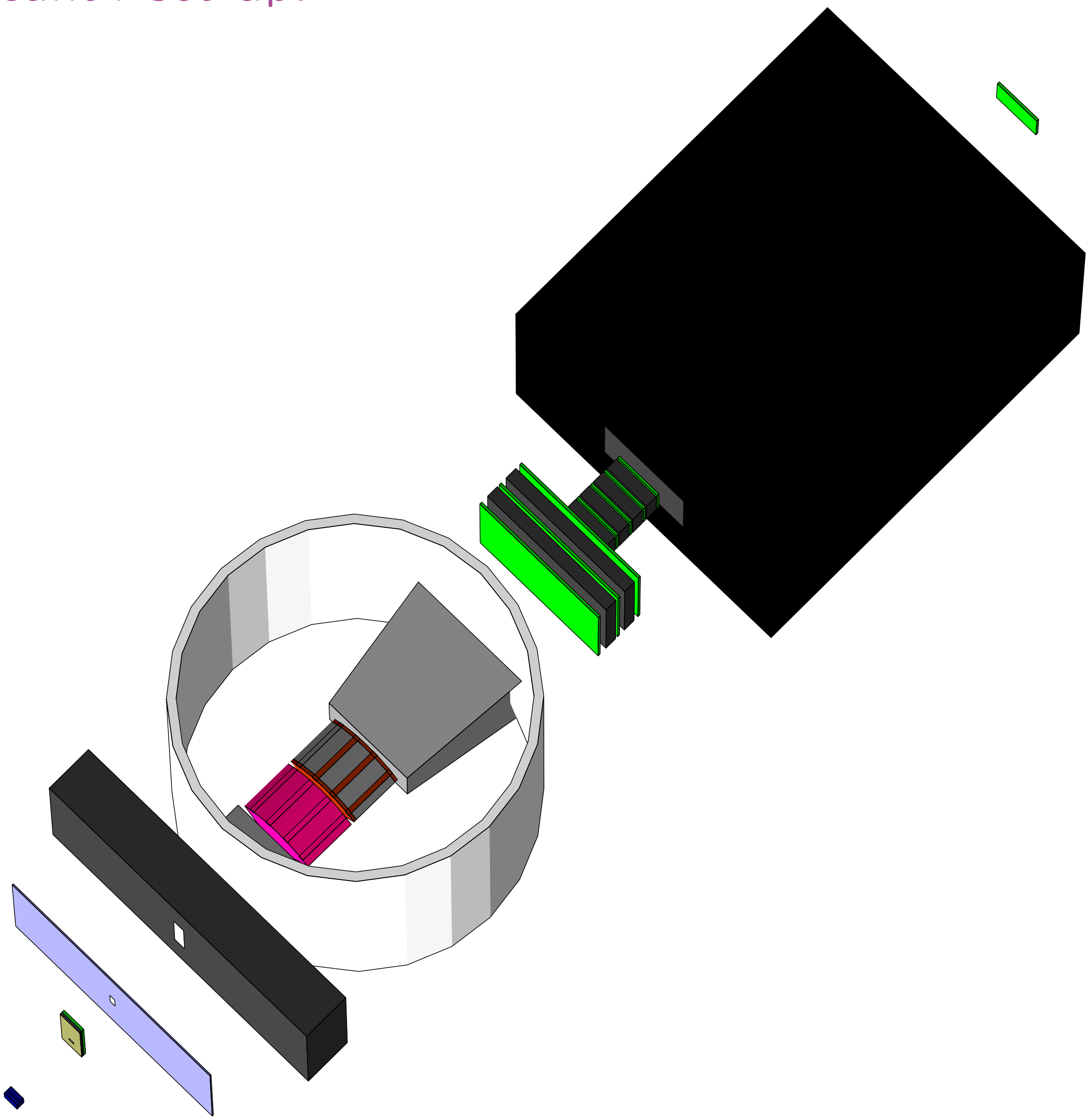
Particle generation:

- particle vertices in (x, y) and directions from reconstructed experimental data; correlation between vertex and direction (beam focusing) is automatically included; the same data files are used for both Geant3 and Geant4;
- particle momentum (20-200 GeV) smeared by an estimated 0.5% beam momentum spread.

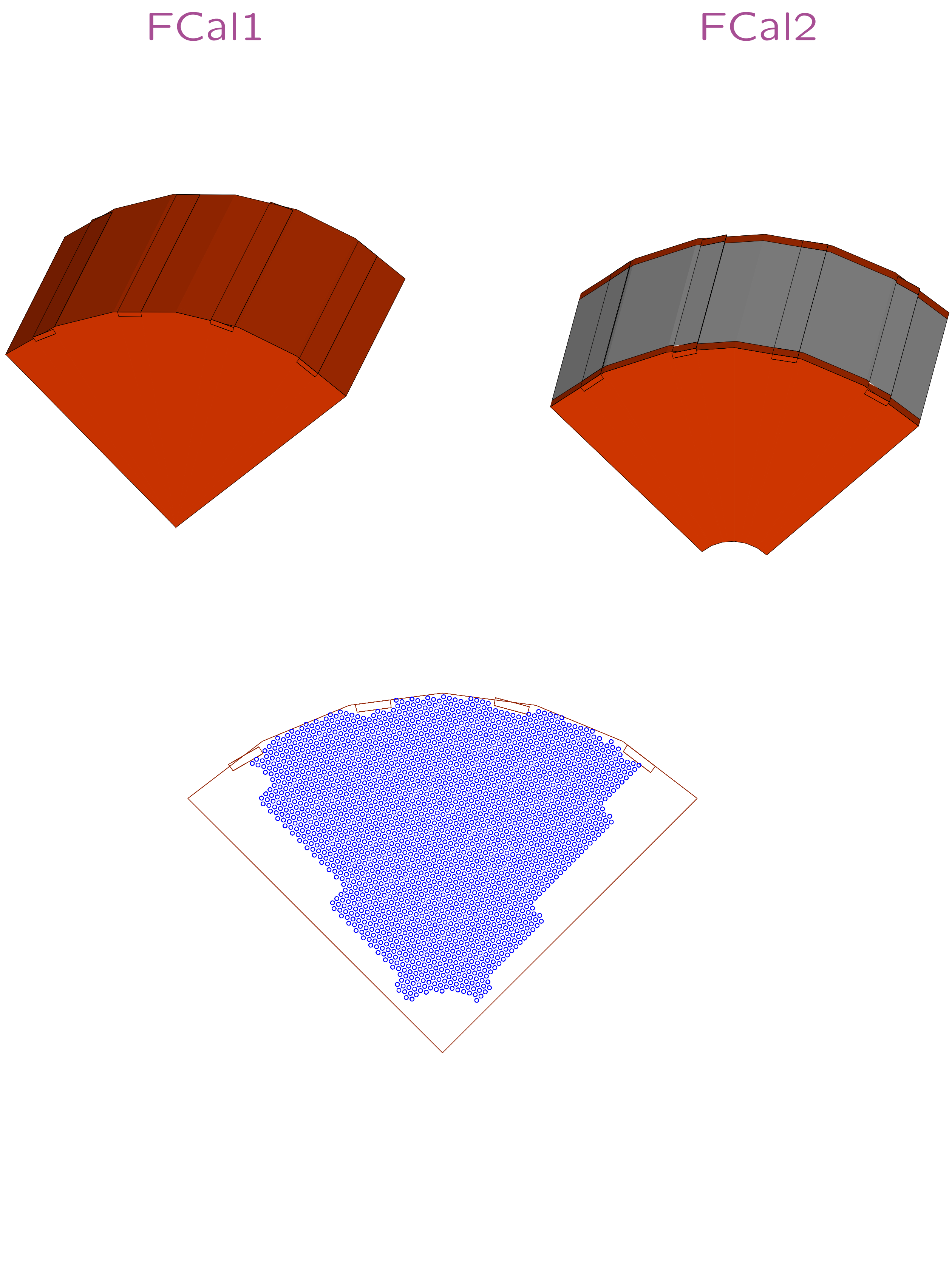
CUTS:10 KeV (Geant3) and 0.5, 1, and 2mm range cut (Geant4):

	G3	G4(0.5mm)	G4(1mm)	G4(2mm)
E_{LAr}(KeV); γ	10	4.4	6.18	8.67
E_{Cu}(KeV); γ	10	17.1	24.6	35.7
CPU (s/GeV)	3.8	0.75	0.68	0.61

Geant4 set up:



FCal Modules in Geant4



Reconstruction of Monte Carlo Data

- visible energy in individual electrodes collected into tiles using the experimental cabling/readout description database;

- experimental noise from randomly triggered "empty" events is added cell by cell, using the experimental and Monte Carlo electron calibration constants c_{exp} (in GeV/ADC) and c_{MC} (inverse sampling fraction):

$$E_{rec} = c_{MC} E_{vis} + c_{exp} A \qquad (GeV)$$

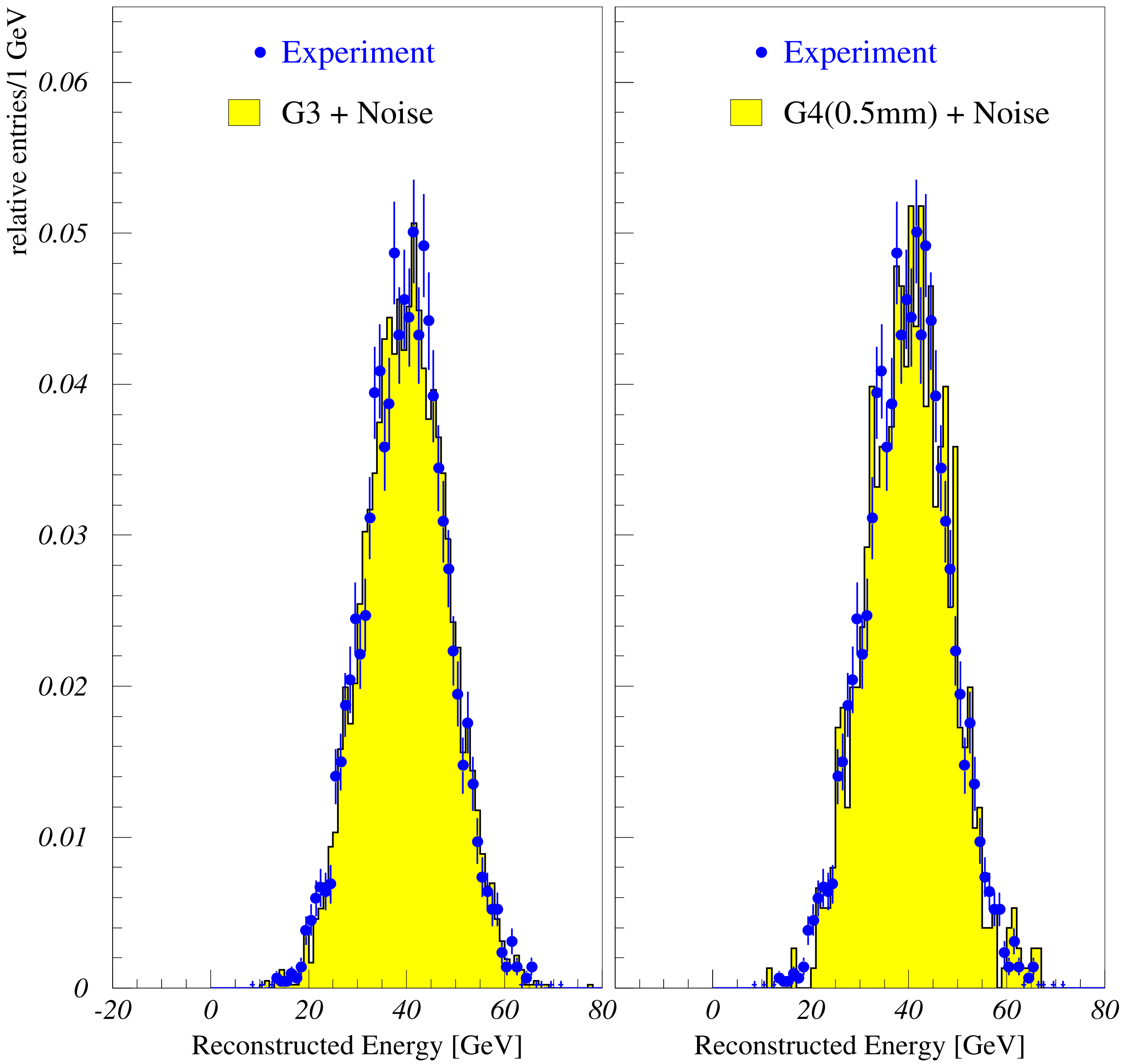
  in any given tile; A is the noise signal in ADC counts.

- c_{exp} and c_{MC} are both calculated from the average 60 GeV signal.

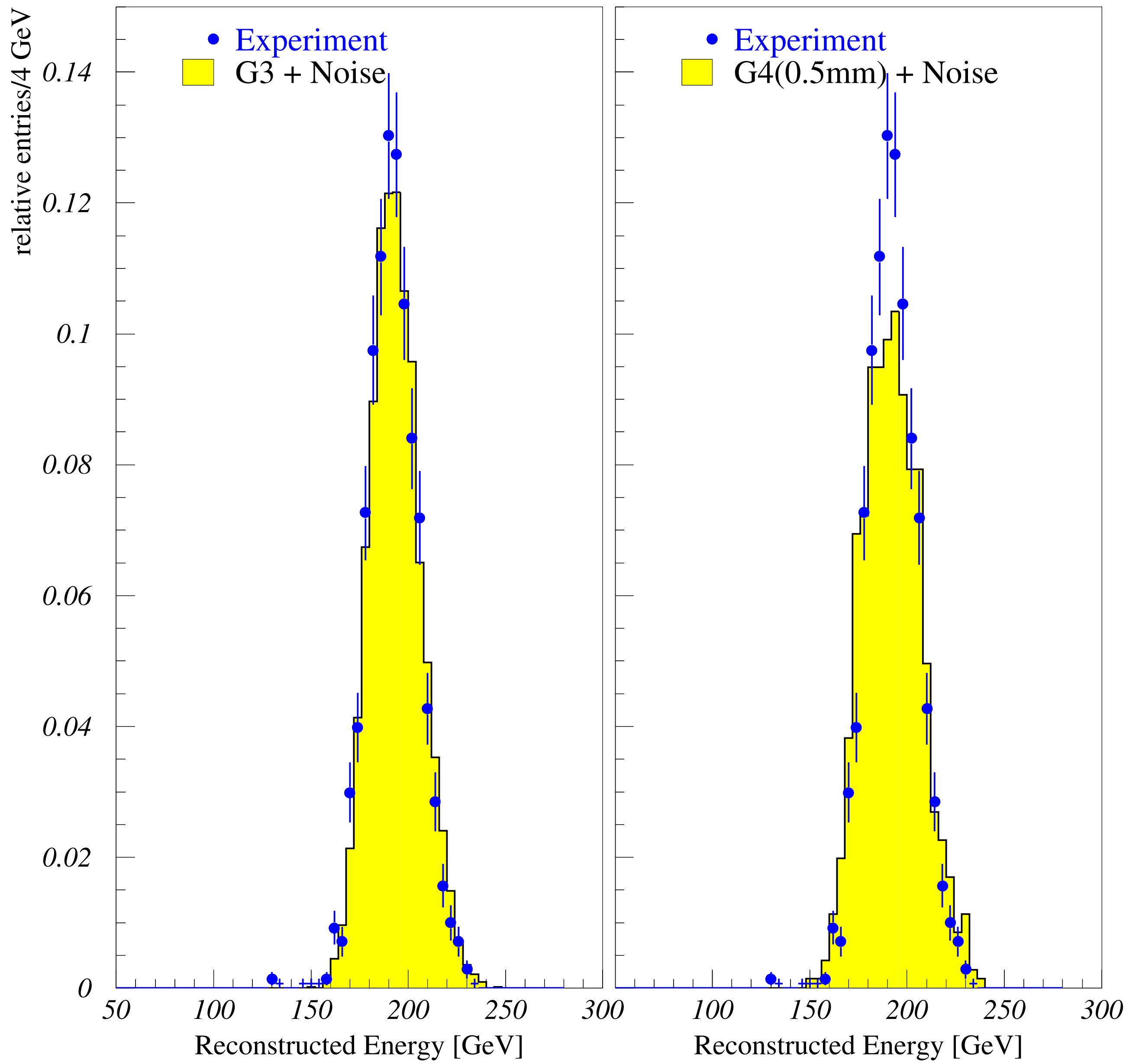
Sampling fraction:

	G3(10KeV)	G4(0.5mm)	G4(1mm)	G4(2mm)
c_{MC}^{-1}(%)	1.44	1.42	1.41	1.36

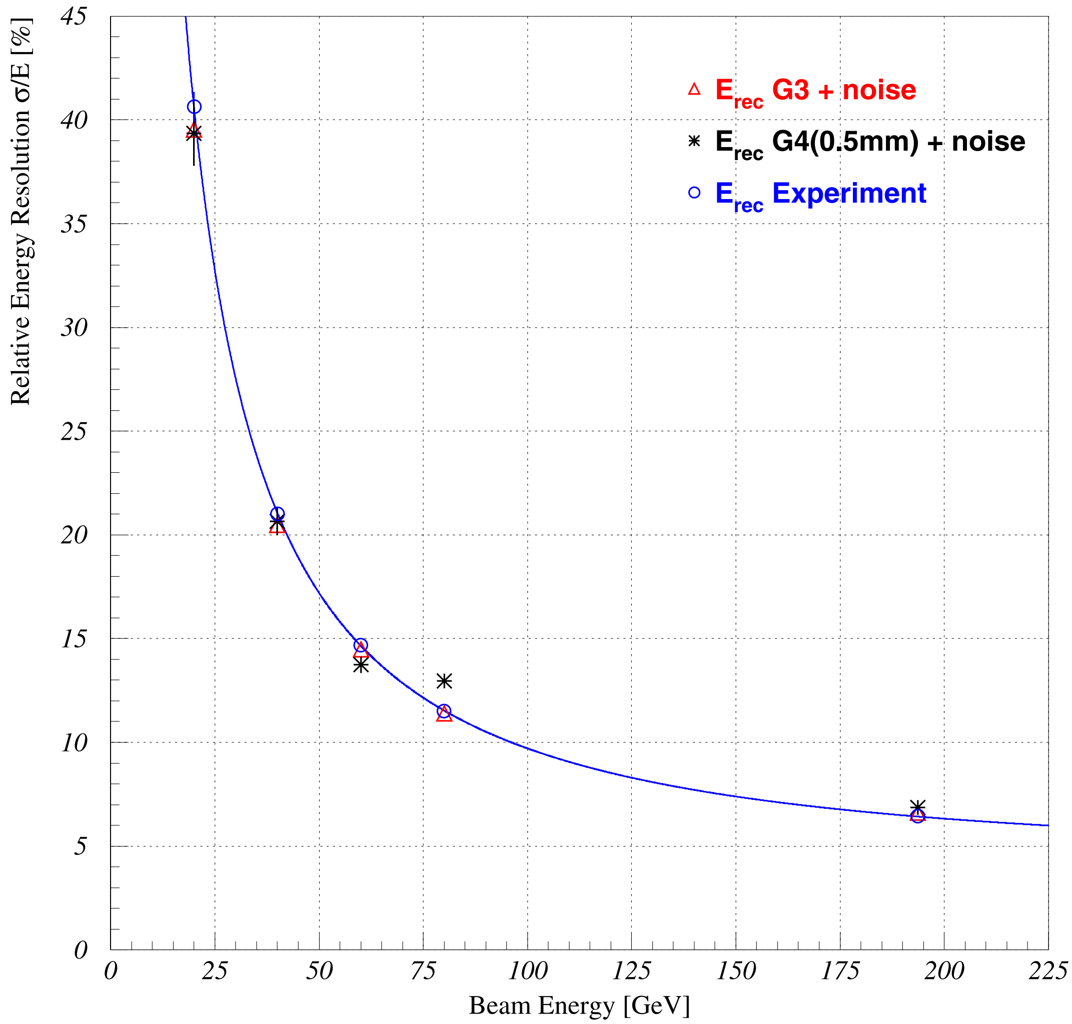
40 GeV Electron Signal Distributions



200 GeV Electron Signal Distributions



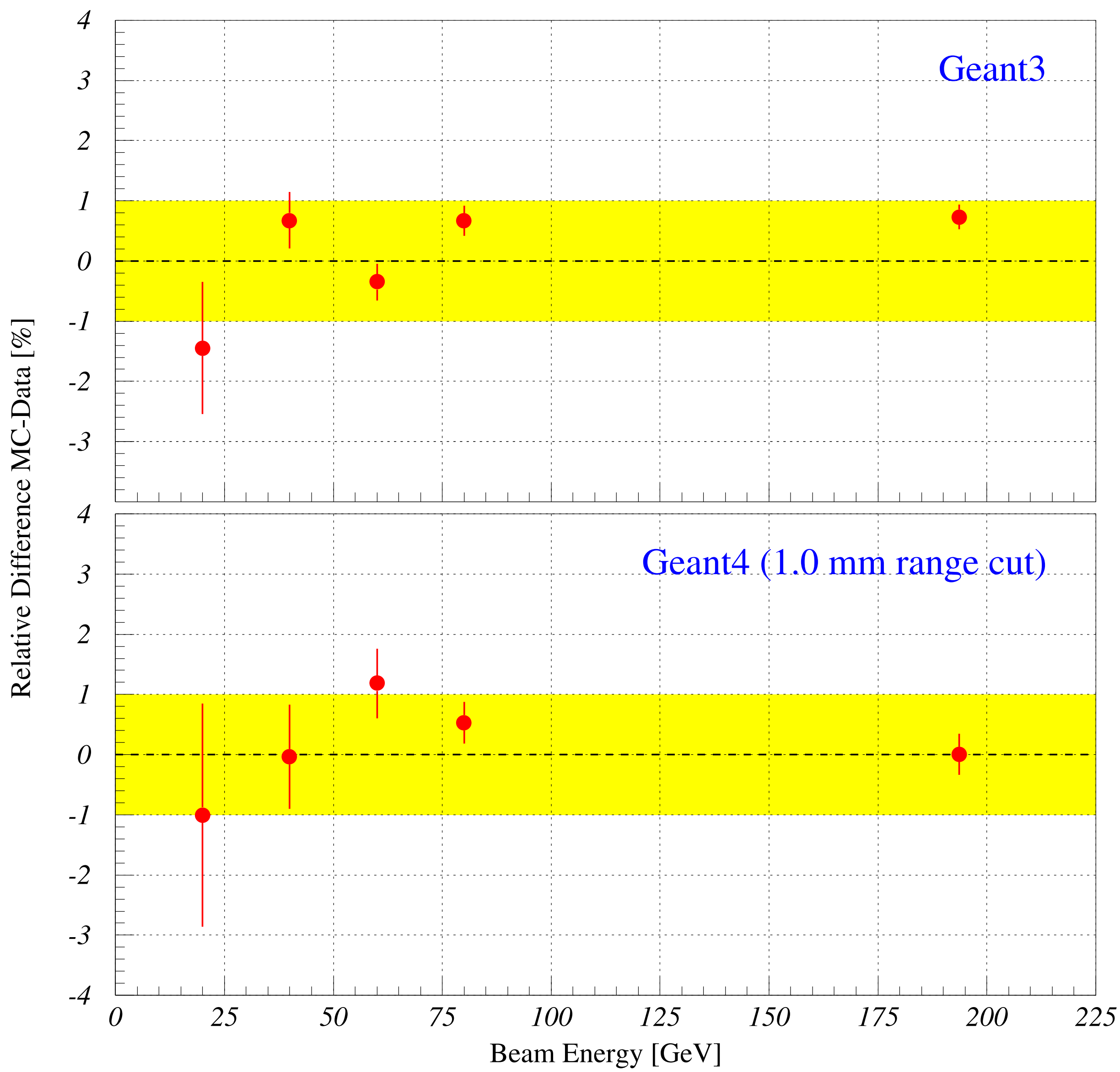
FCal1 Electron Energy Resolution



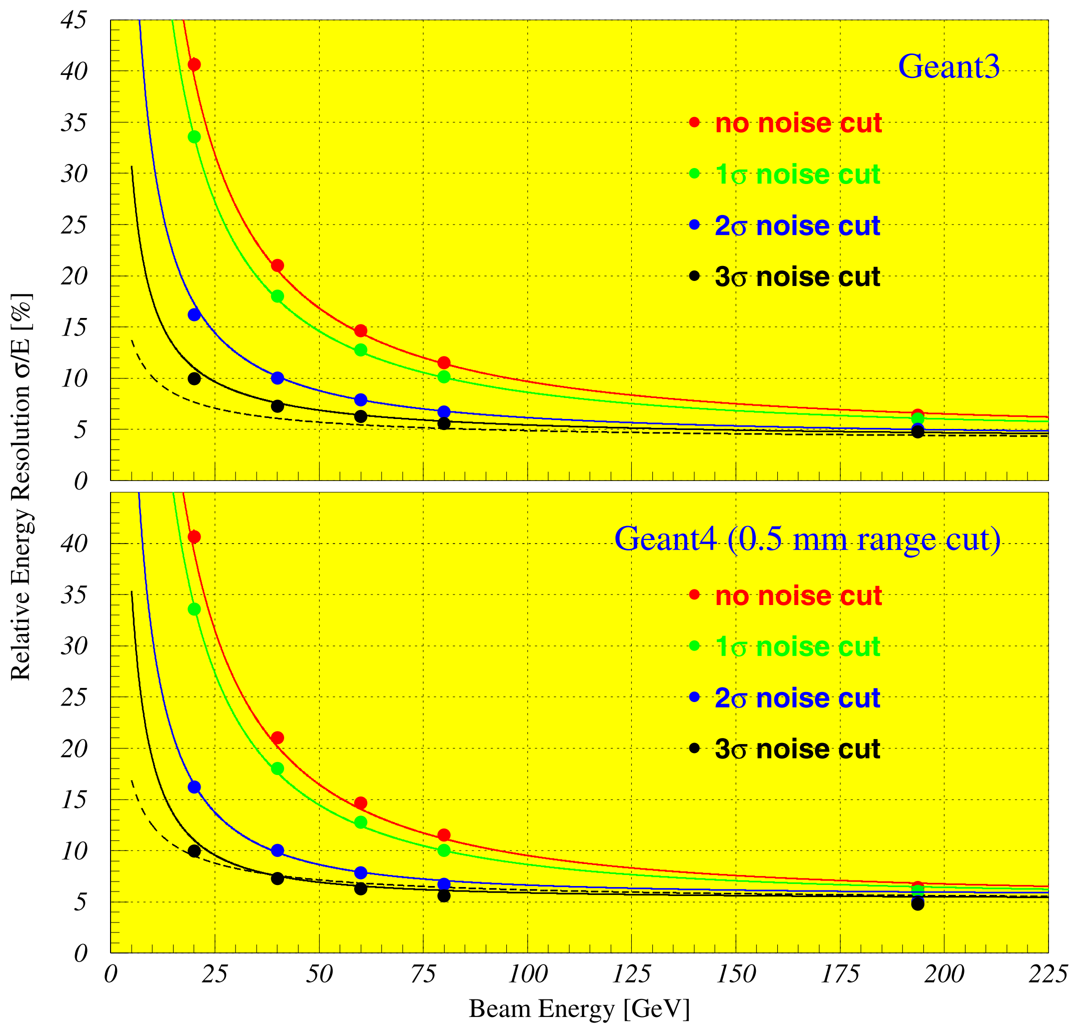
	Exp.	G3(10KeV)	G4(0.5mm)	G4(1mm)	G4(2mm)
A	39.2±10.9	38.4±9.1	30.5±13.1	30.8±14.8	45.9±29.9
B	7.87±0.21	7.64±0.17	7.54±0.16	7.73±0.17	7.55±0.62
c	4.1±0.5	4.5±0.4	5.2±0.6	5.6±0.3	4.9±1.3

A[%GeV$^{-1/2}$], B[GeV] and C[%] are the fitted resolution parameters

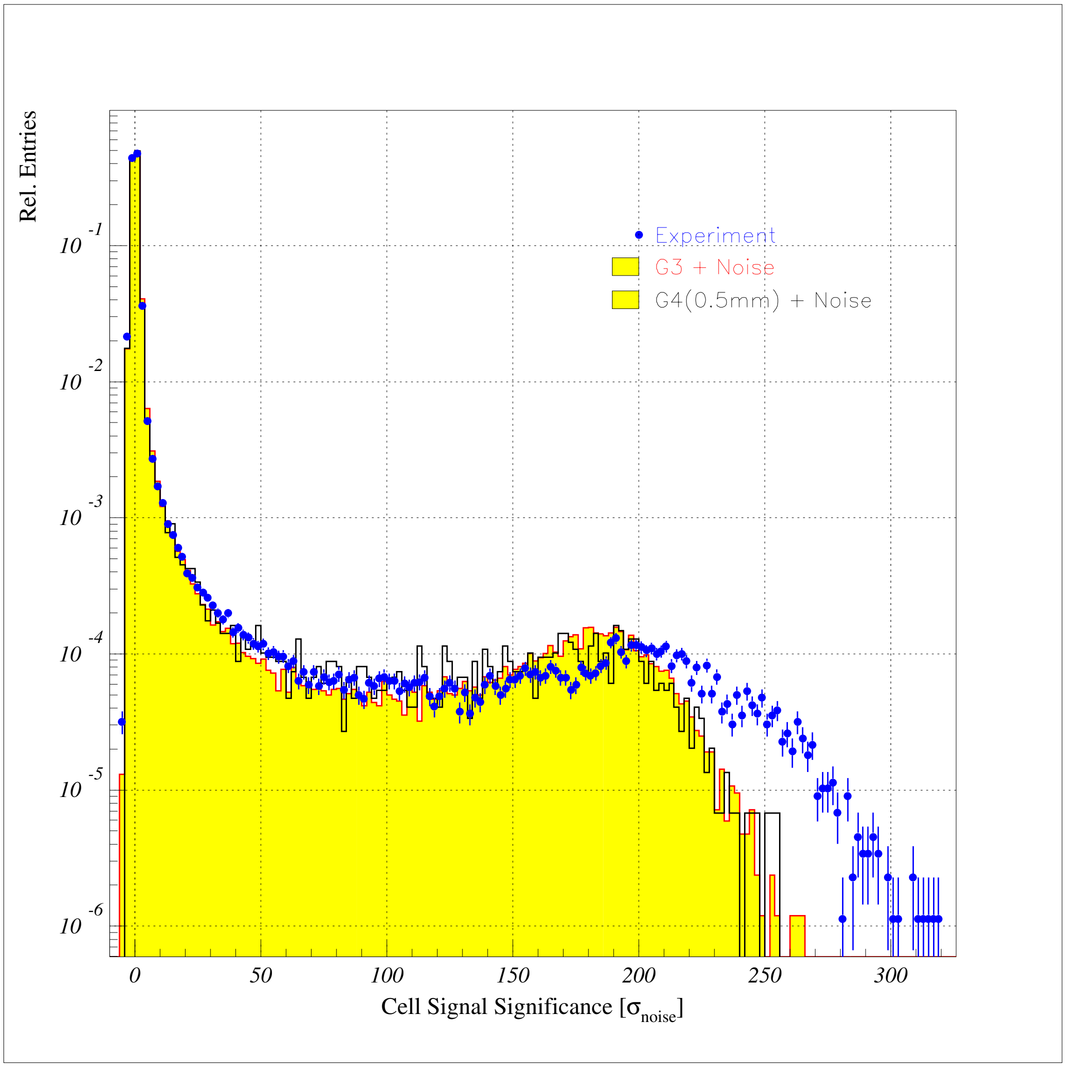
FCal1 Electron Signal Linearty



FCal1 Electron Energy Resolution for Various Noise Cuts



Detailed Look at Signal Composition



More highly significant signals in experiment than in both Geant3 and Geant4!

Conclusion and Outlook

- comparison of Geant3 and Geant4 for FCAL1 Module 0 shows a good agreement for both signal and energy resolution;
- adding noise to simulated data at cell level produces a rather good agreement between data and Monte Carlo for global; energy sums and resolution, at the level of (few) percent;
- Geant4 compares well to the experimental data. However, more statistics is going to be produced for more detailed comparisons of shower development and signal fluctuations