

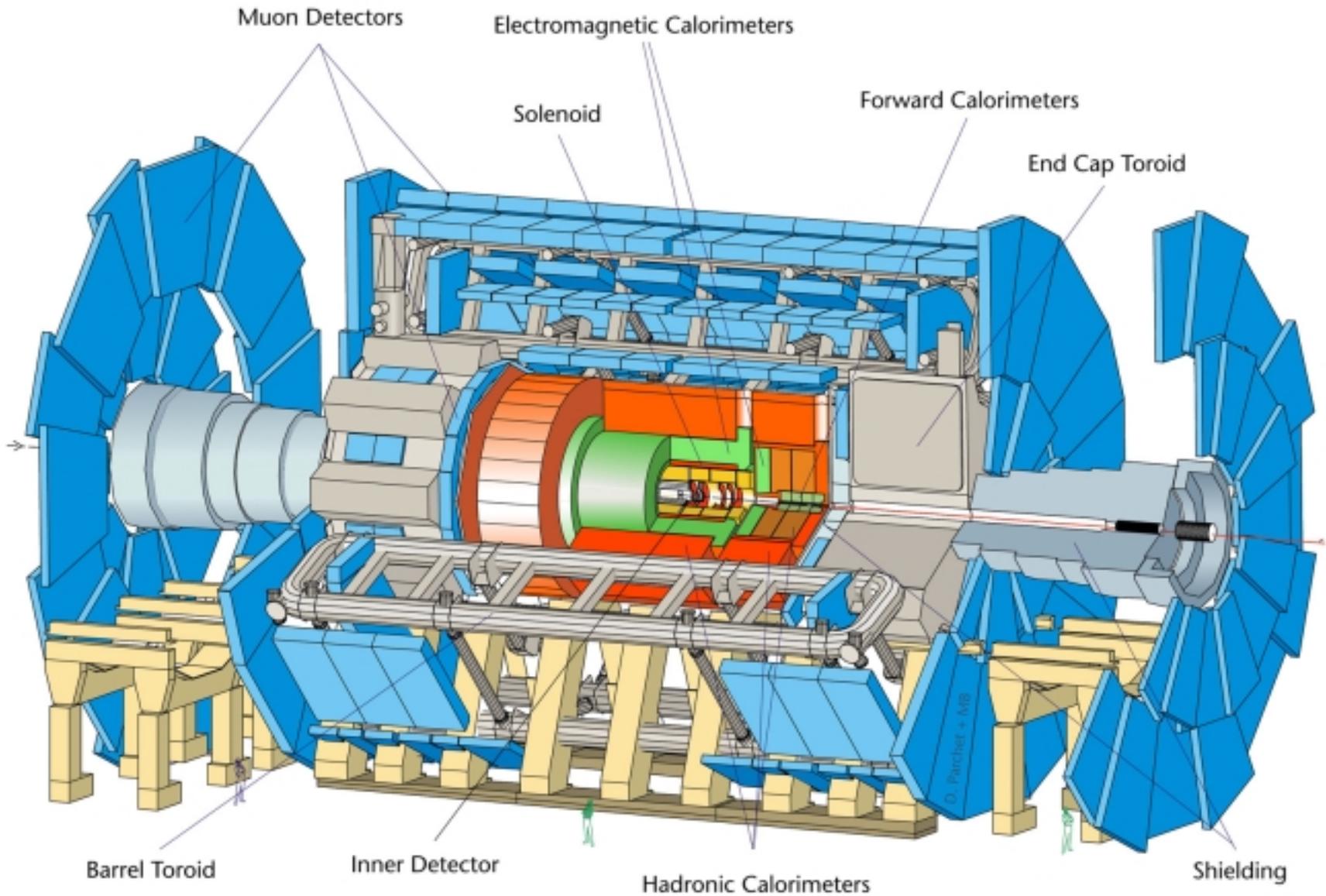


**Dario Barberis**

**Evaluation of GEANT4  
electromagnetic physics  
in ATLAS**

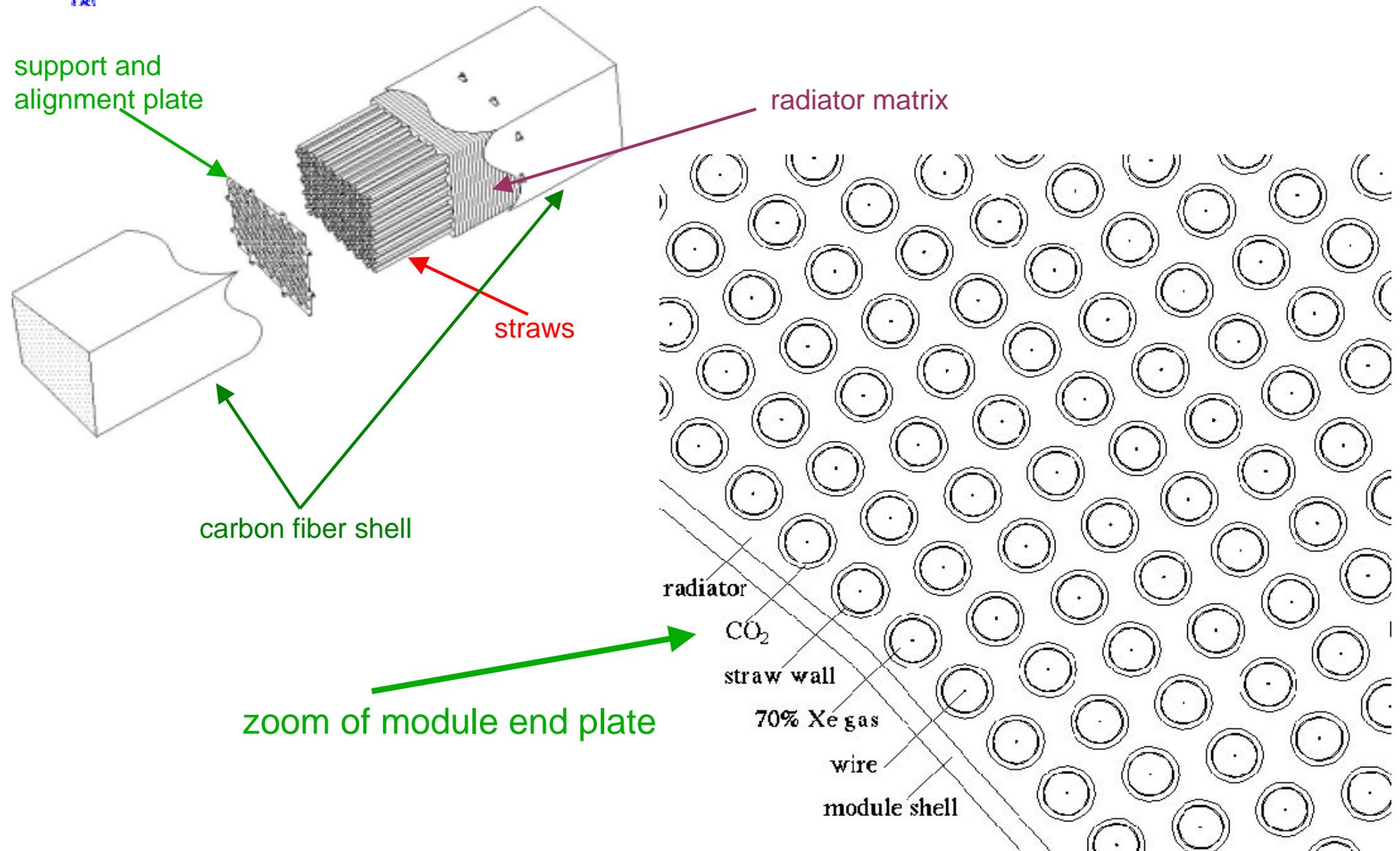


# The ATLAS detector



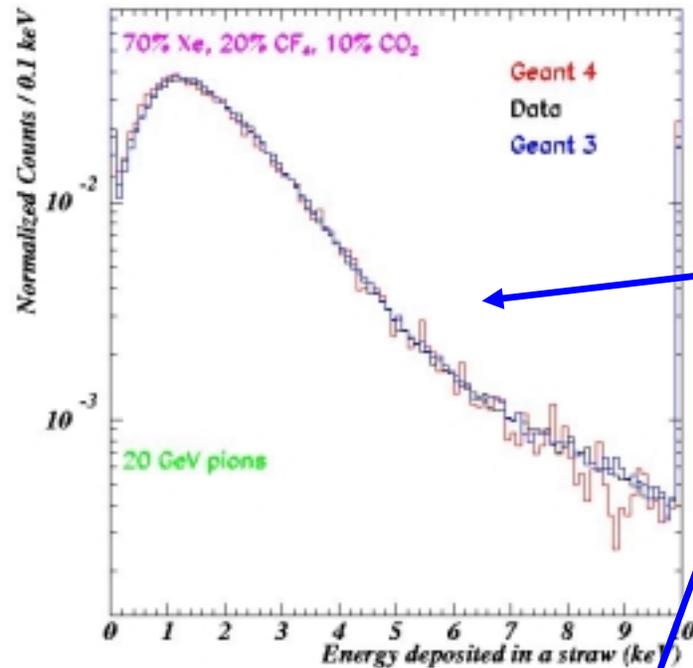


# Transition Radiation Tracker





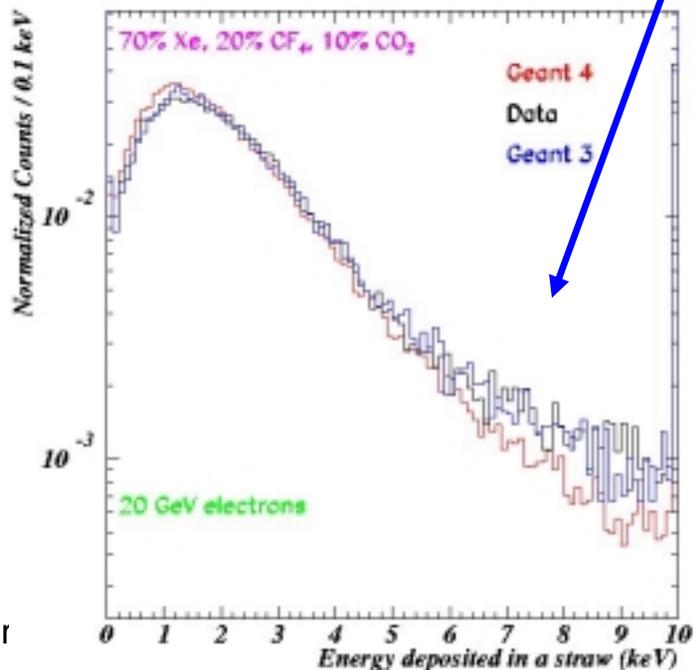
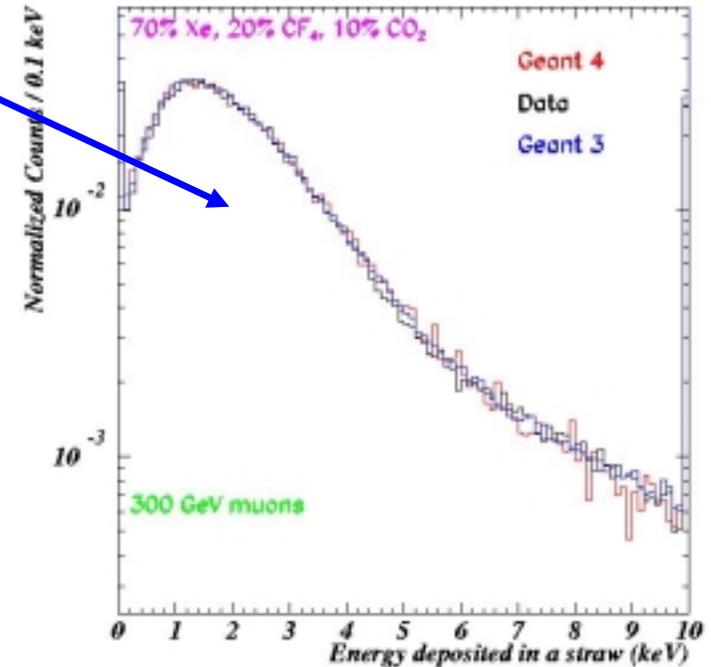
# TRT: Energy Loss in Straws



300 GeV muons

20 GeV pions

20 GeV electrons

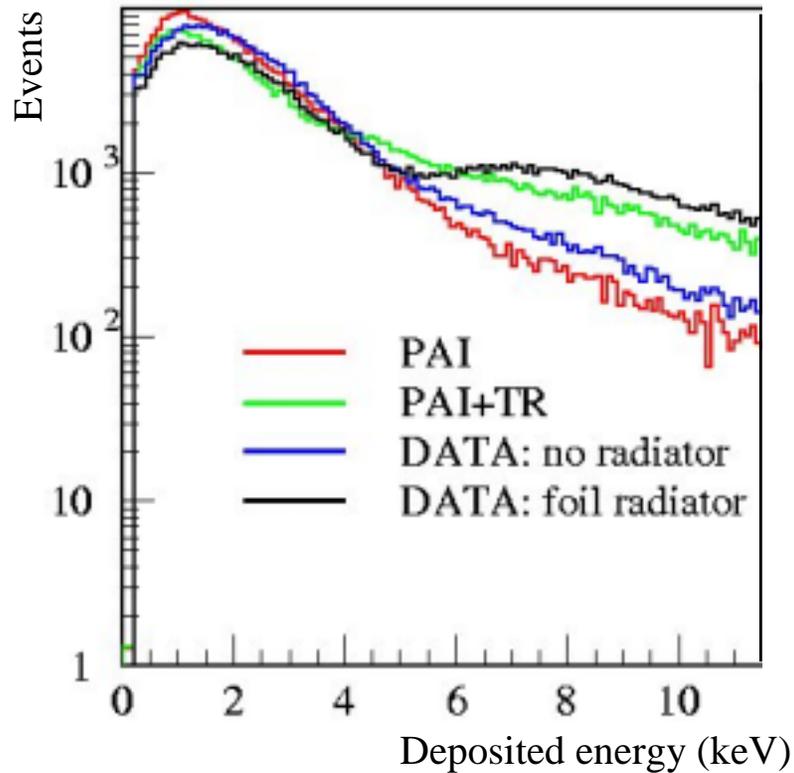


Energy loss measured in ATLAS test beam compared to Geant-3 and to Geant-4 simulations (PAI model) including effects of detector and electronics:

- spectra match reasonably for different particles and energies
- some more checks needed for electrons



# TRT: Transition Radiation



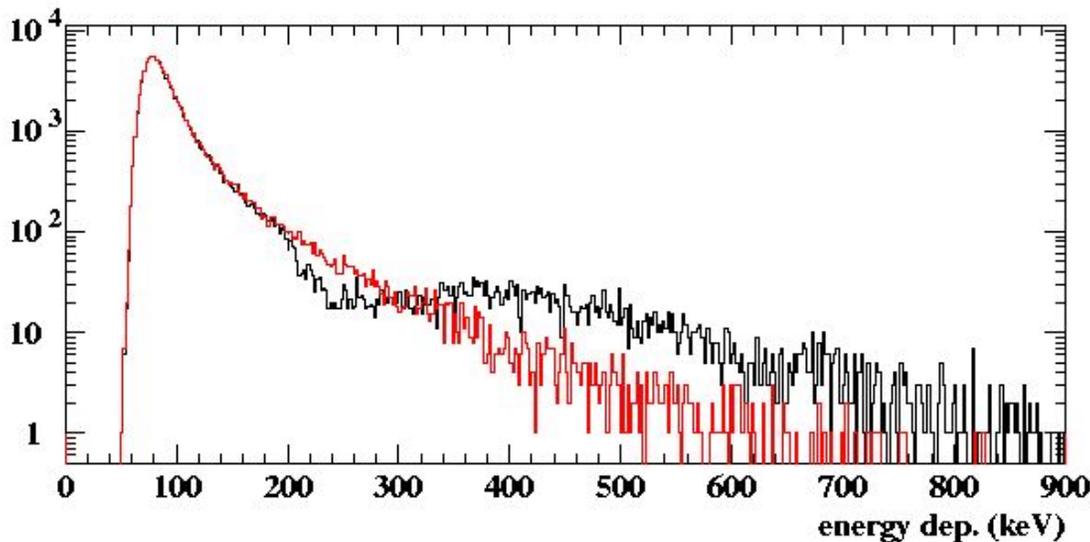
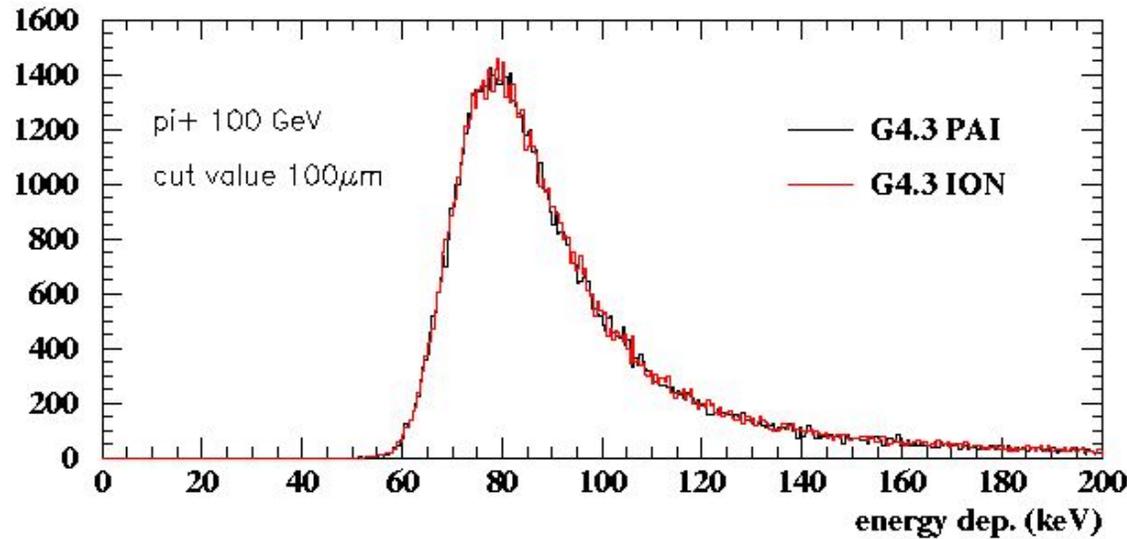
Spectrum of energy deposited by 20 GeV electrons in TRT straws, with and without foil radiator in front of the detector:

- PAI = Geant-4 with PAI model
- DATA = 1999 TRT test beam data

- Transition Radiation is produced in foam and foil radiators placed between the straws
- The fraction of hits above a given threshold (5 keV) is used to discriminate electrons from hadrons and muons
- Test beam data can only measure the convolution of energy loss by ionisation, emission and absorption of TR photons
- Geant-4 offers several ways of describing the radiator (as a more or a less regular medium)
- So far none of them reproduce the test beam spectra (but see V.Grachine's talk!)
- More work is needed!



# Silicon Detectors



Standard ionisation model compared to PAI model for 100 GeV pions crossing a Pixel detector module (280  $\mu$ m thick silicon):

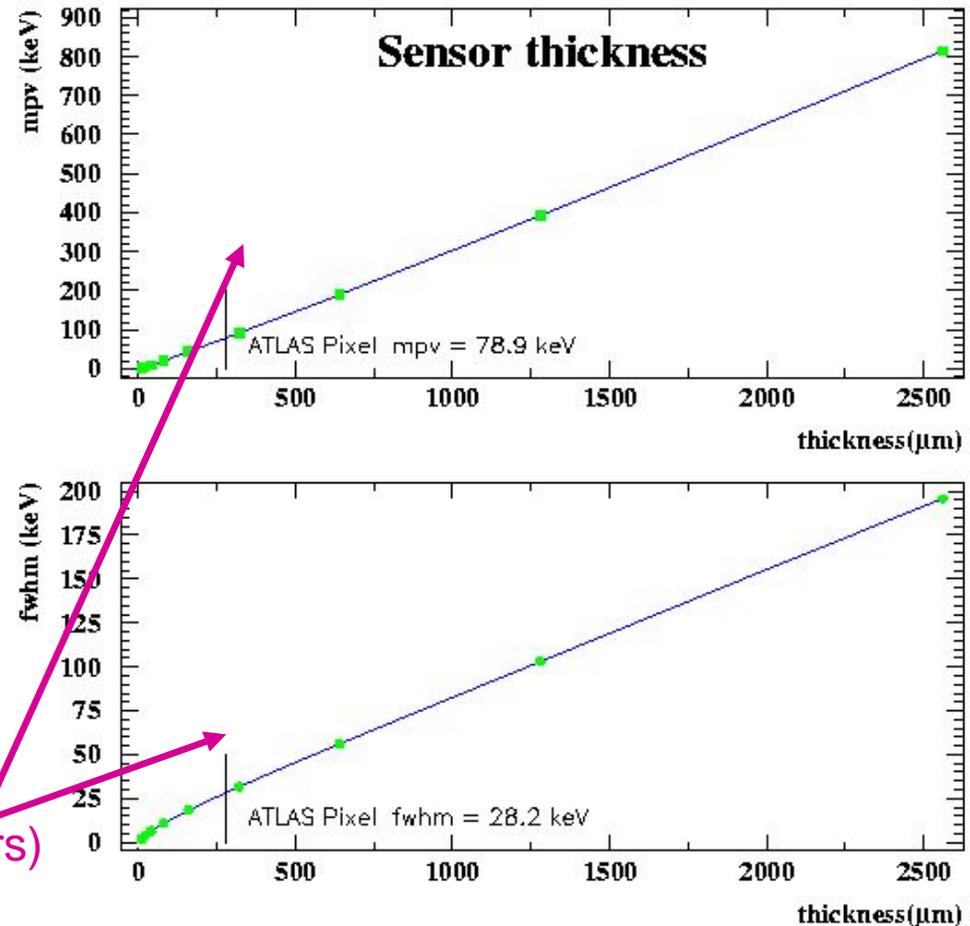
- distribution around peak identical
- PAI model does not link properly to  $\delta$ -ray production
- PAI model in any case not really applicable for ATLAS silicon detectors
- more important is the correct spatial distribution of ionisation energy loss: range cut should match detector resolution (10  $\mu$ m for Pixels)



# Silicon Detectors

r-cut	mpv	fwhm fit	fwhm hand	mean	rms
1.5 mm	79.8	19.5	25	102.8	61.6
1.0 mm	79.2	19.5	24	101.9	55.7
500 $\mu\text{m}$	78.7	20.1	26	100.4	48.7
100 $\mu\text{m}$	78.0	21.8	27	99.3	45.3
50 $\mu\text{m}$	78.0	22.6	28	99.4	45.2
10 $\mu\text{m}$	78.5	23.7	29	99.5	45.2
5 $\mu\text{m}$	79.9	24.6	28	99.4	44.9

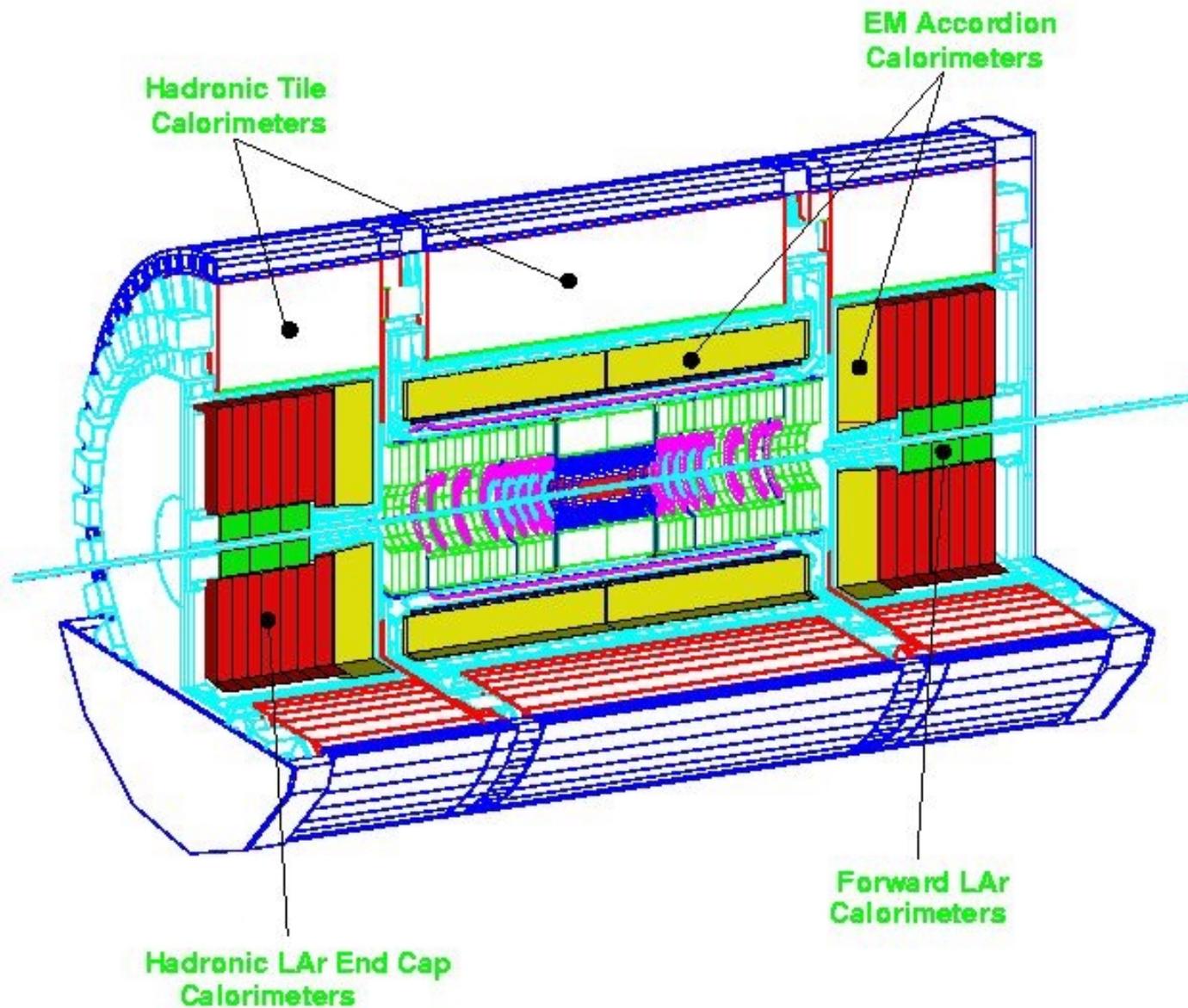
Expected: 78.9    28.2 (from data on Si detectors)



- Variation of Landau width with range cut somewhat disturbing
- Need small r-cut as detector resolution  $\sim 10 \mu\text{m}$
- Investigating alternative geometry descriptions of Pixel module ( $\sim 50\text{k}$  pixels/module, 1750 modules in ATLAS...)



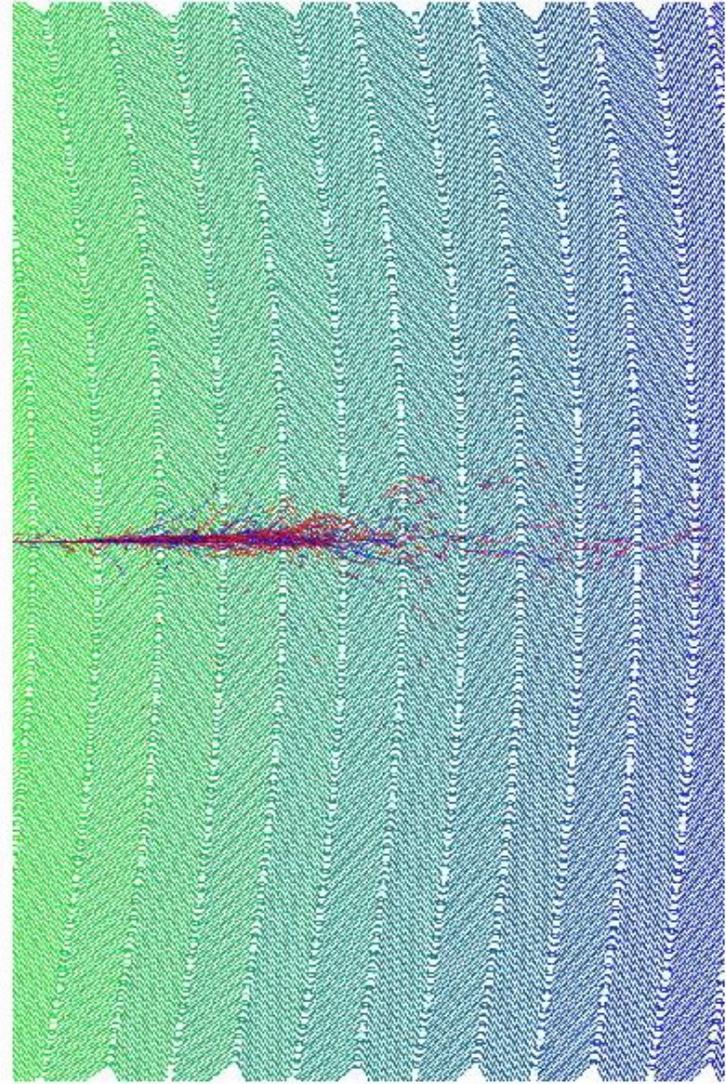
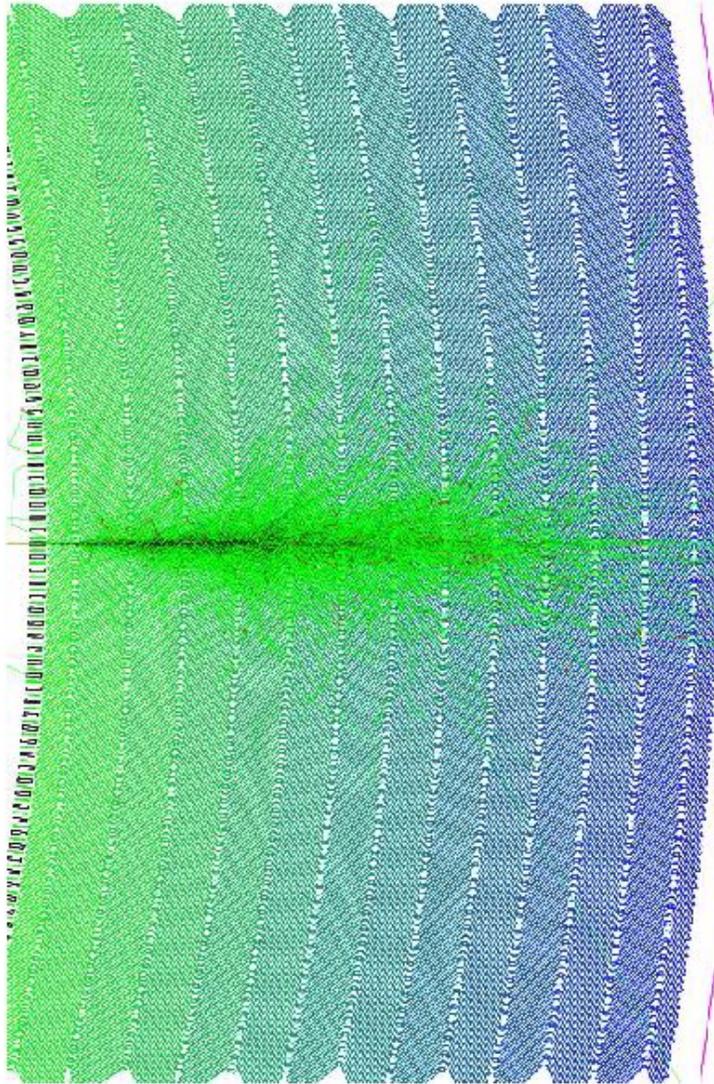
# Calorimetry





# Liquid Argon EM Calorimetry

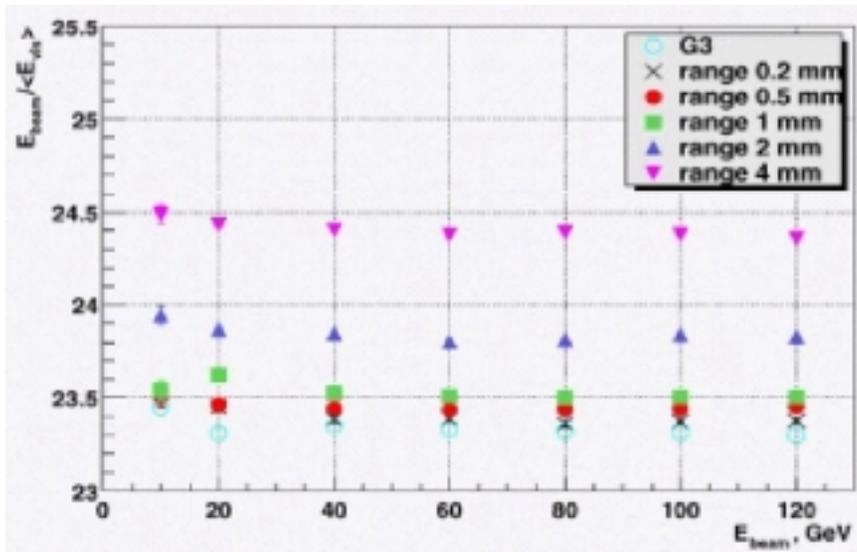
a single photon and a single electron in the LAr e.m. barrel:





# Liquid Argon Calorimetry

- Initial geometry problems solved by:
  - optimisation of voxel size (smartless = 0.2 mm) to have acceptable memory usage
  - new G4Solid (LArWheelSolid) inheriting from G4VSolid for EM end-cap: **not visible in DAWN!**
- Energy loss for muons compatible with test beam data after inclusion of detector effects (noise)

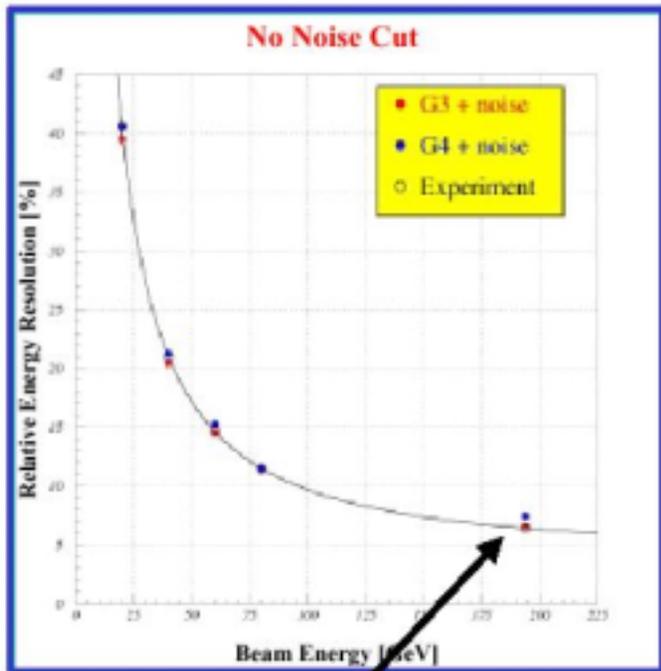


- Sampling fraction for electrons depends on range cut and material
- Resolution somewhat too good for EM calorimeters and HEC, too bad for FCAL at high energy
- More work needed! But need tunable range cut and PhysicsList for each (sub)detector

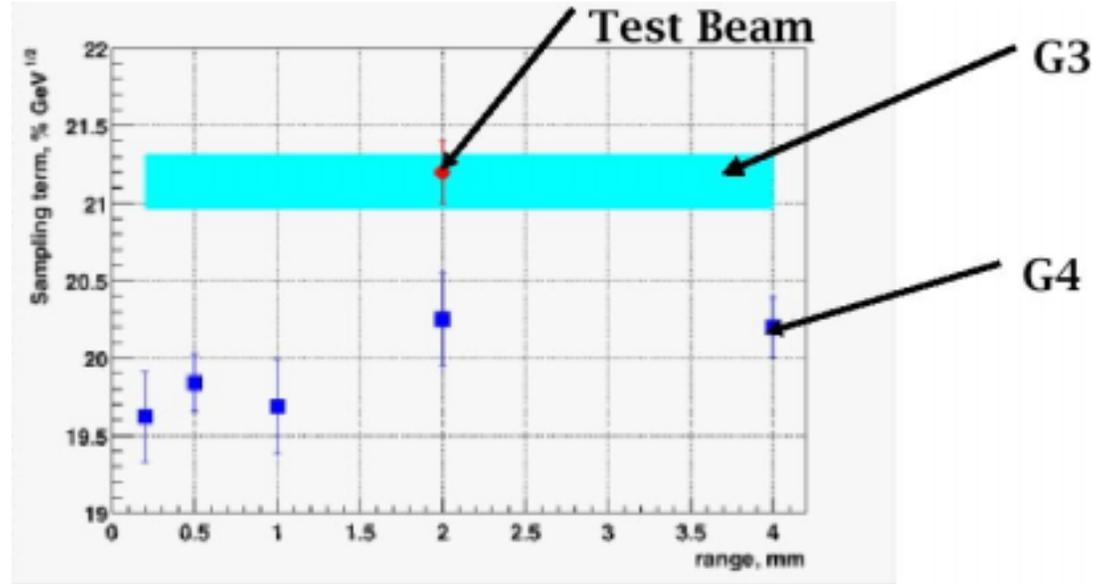


# Liquid Argon Calorimetry

HEC energy resolution



G4 resolution slightly too high



G4 EM resolution looks a bit too good

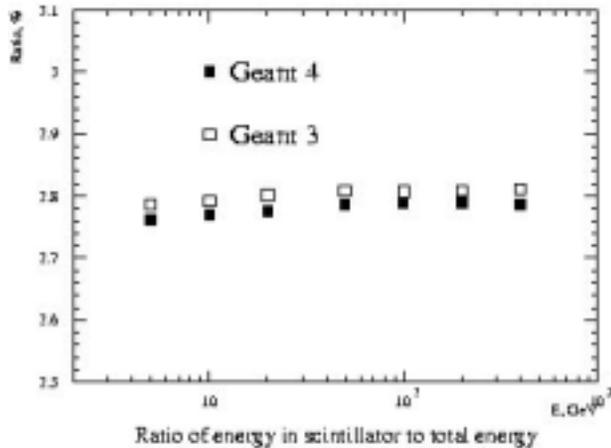
FCAL energy resolution



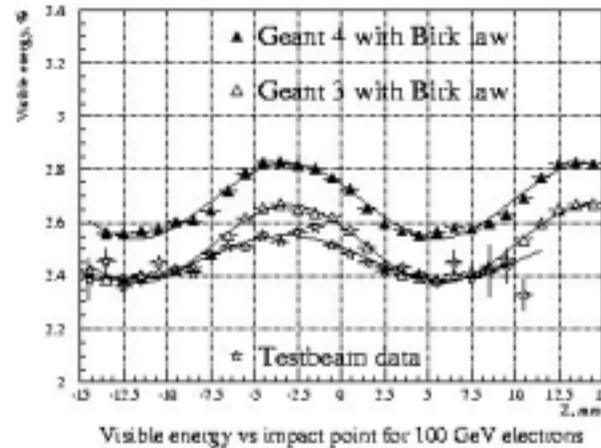


# Tile Calorimeter: electrons

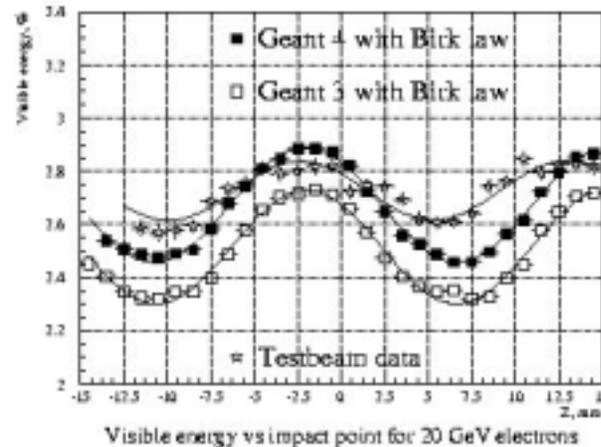
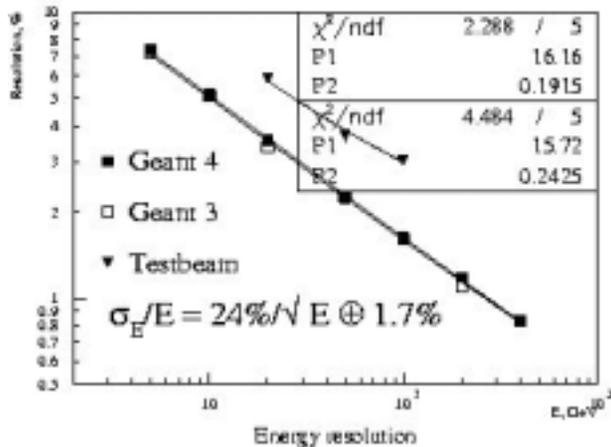
Electrons at 90 degrees in TileCal



Electrons at  $\eta=0.35$  in TileCal module 0



- Electron energy resolution somewhat too good: sampling term 16% instead of 24% (was the same for Geant-3)



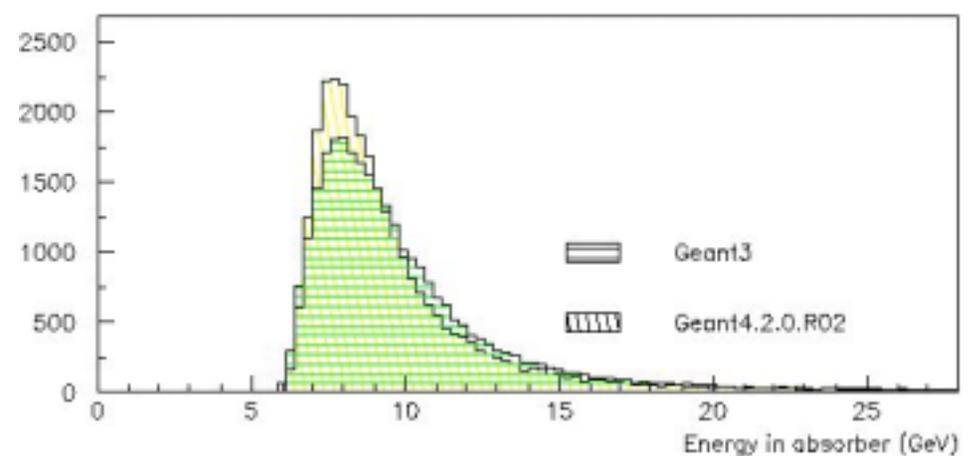
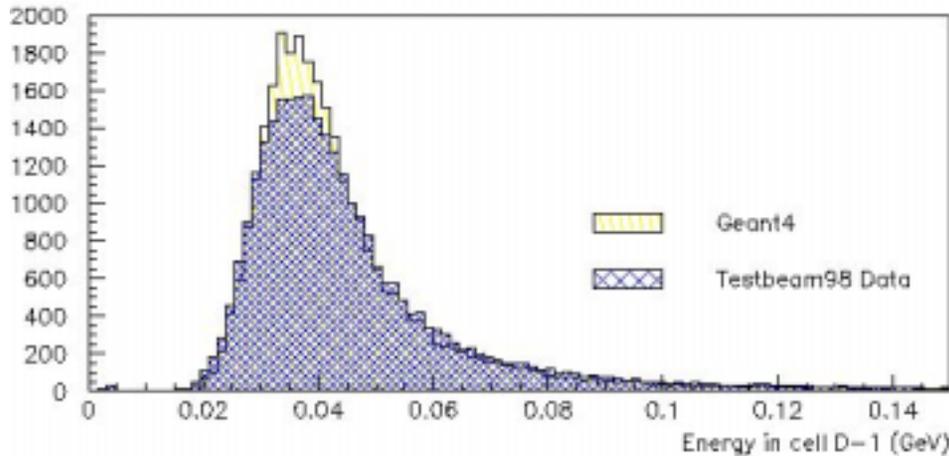
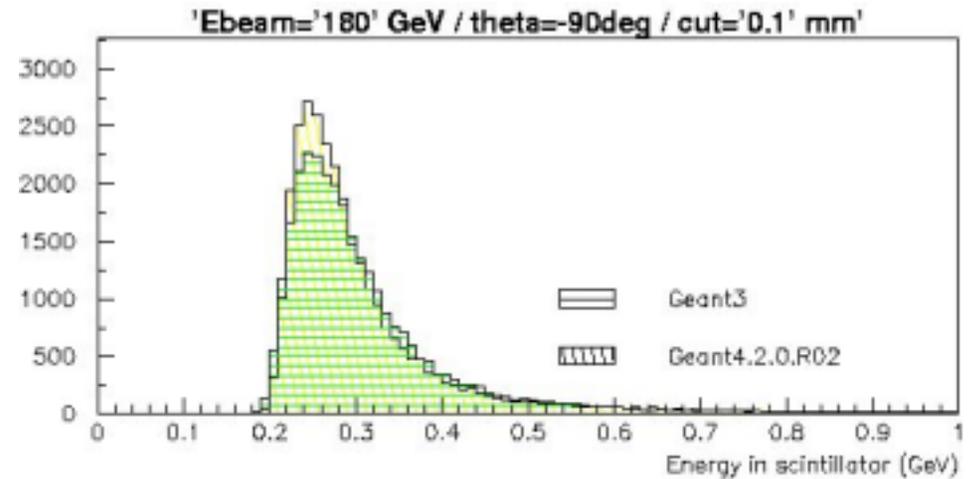
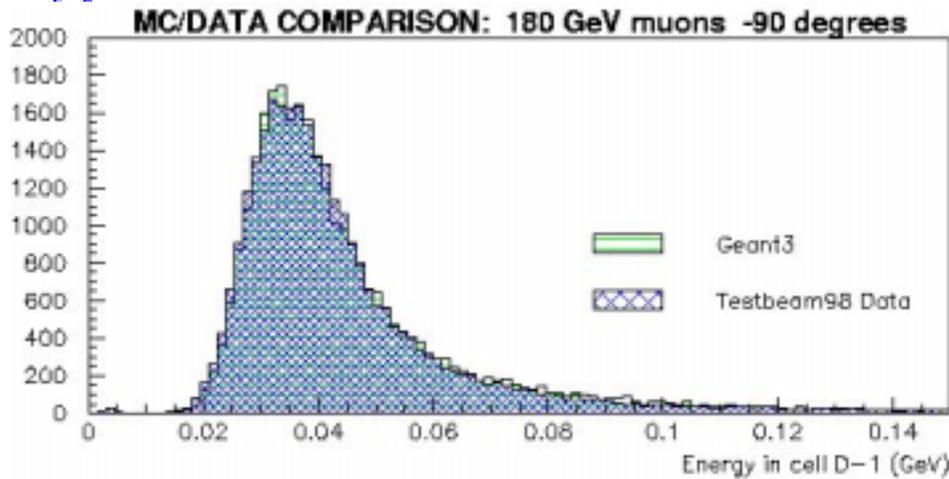
- Visible energy vs impact point has the correct shape but amplitude of variations and energy dependence do not match test beam data

Electron energy resolution

Visible energy vs impact position for 100 GeV and 20 GeV electrons



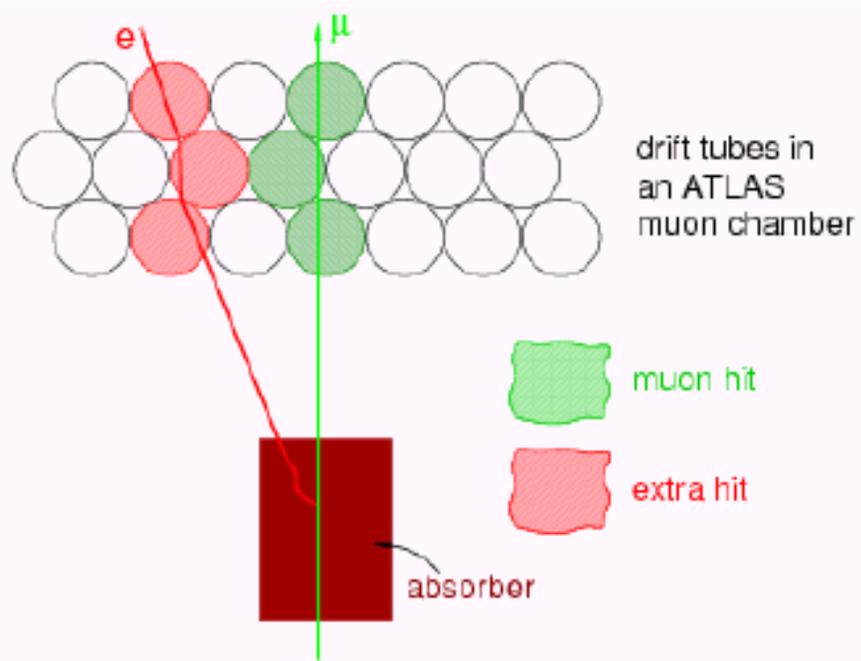
# Tile Calorimeter: muons



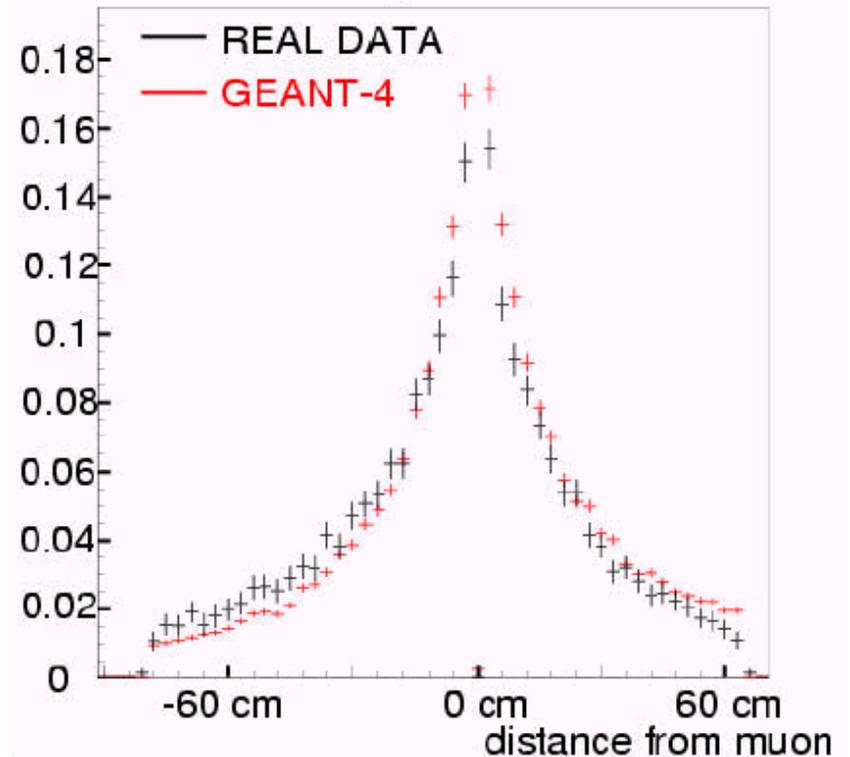
- Energy loss distribution “fatter” than Geant-3 for both Fe and scintillator:  
⇒ therefore it does not match perfectly test beam data
- but remember: energy loss distribution in silicon narrower than in real data!



# Muon Detector



Extra hits in first layer, 300 GeV, 20 cm iron



EM shower production by muons in absorber: extra hits in Muon Drift Tubes

- Transverse distance of extra hits from muon track in Geant-4 broadly reproduces test beam data
- Detailed agreement better for lighter absorber material



# Conclusions

- Large progress in the last year in understanding electromagnetic processes, both in tracking and calorimetry.
- Interplay between geometry and physics processes being addressed.
- Work is continuing on both sides (ATLAS and G4) to improve understanding and produce optimised geometries as well as PhysicsLists.
- Possibility to set different cuts and use different PhysicsLists for each detector (by Logical Volume) would help considerably.
- There are still issues that remain to be clarified, but the gradient is positive!
- Collaboration between ATLAS and G4 people on a very good level, there could be faster progress if there was more manpower (especially on our side!).