ATLAS Tile Calorimeter performance to single particles in beam tests

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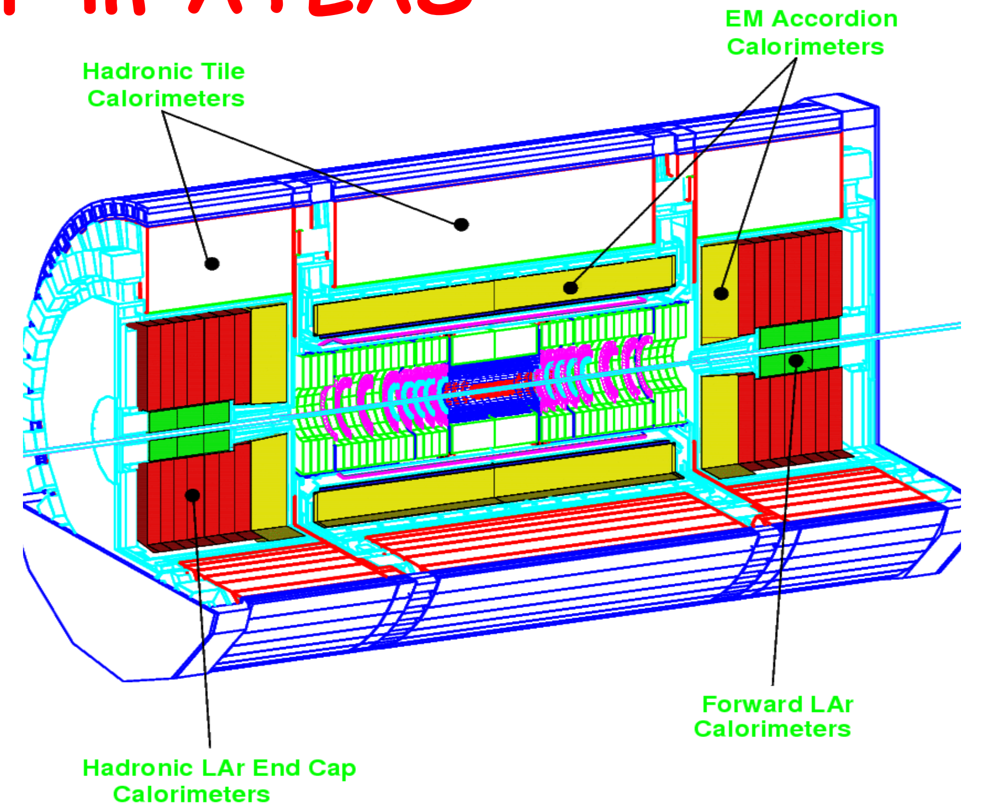
on behalf of the ATLAS Tilecal collaboration

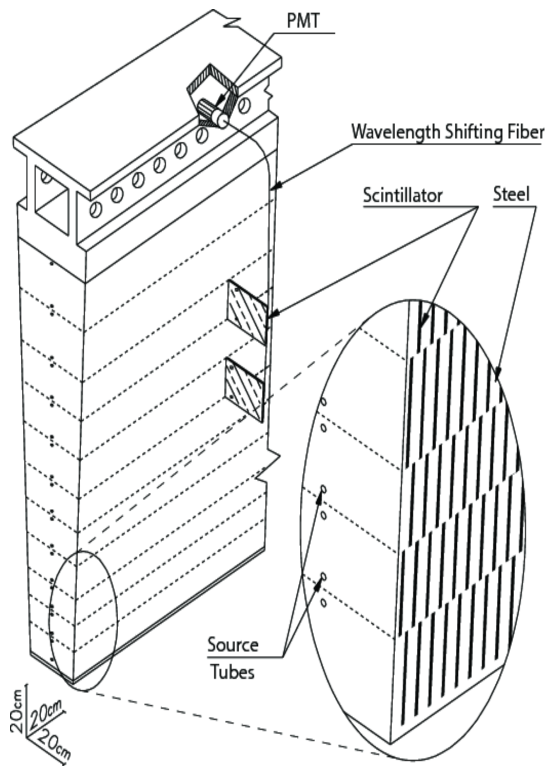
Outline

- Introduction to ATLAS/Tilecal and the testbeam program
- Tilecal calibration systems
- Event selection, particle separation
- Corrections applied to data
- EM scale determination
- Pion linearity and resolution
- Conclusions

Tile Calorimeter in ATLAS

- Tile Calorimeter:
  - iron/scintillator hadronic calorimeter
  - central region of ATLAS detector ($|\eta|<1.6$), 3 cylinders (1xB, 2xEB)
  - segmentation: 3 radial compartments, $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$ (last layer 0.2x0.1)

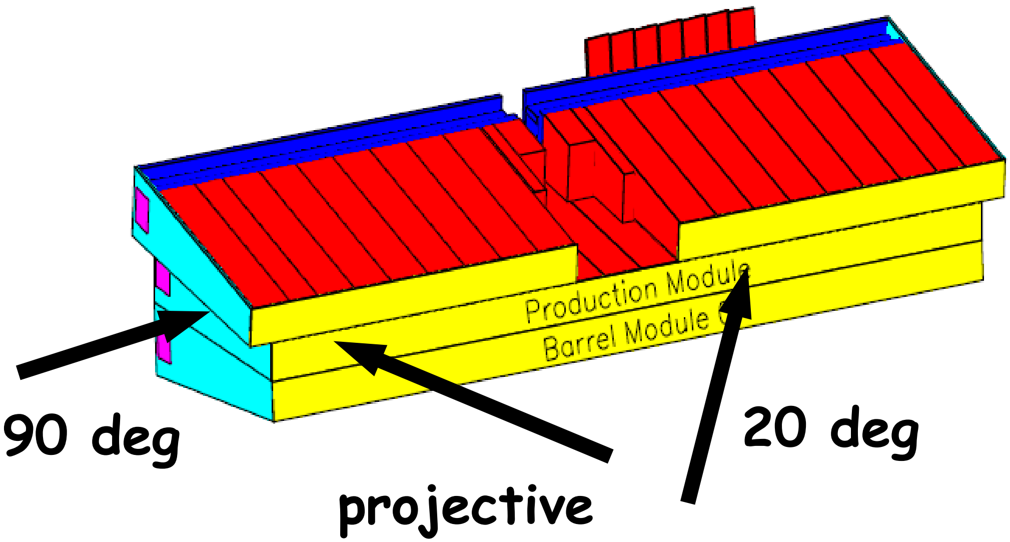




- Tilecal module ($\Delta\varphi=0.1$)
  - scintillating tiles staggered in depth, placed perpendicular to colliding beams
  - light collected by WLS fibers, routed to PMTs
  - each cell readout by 2 PMTs

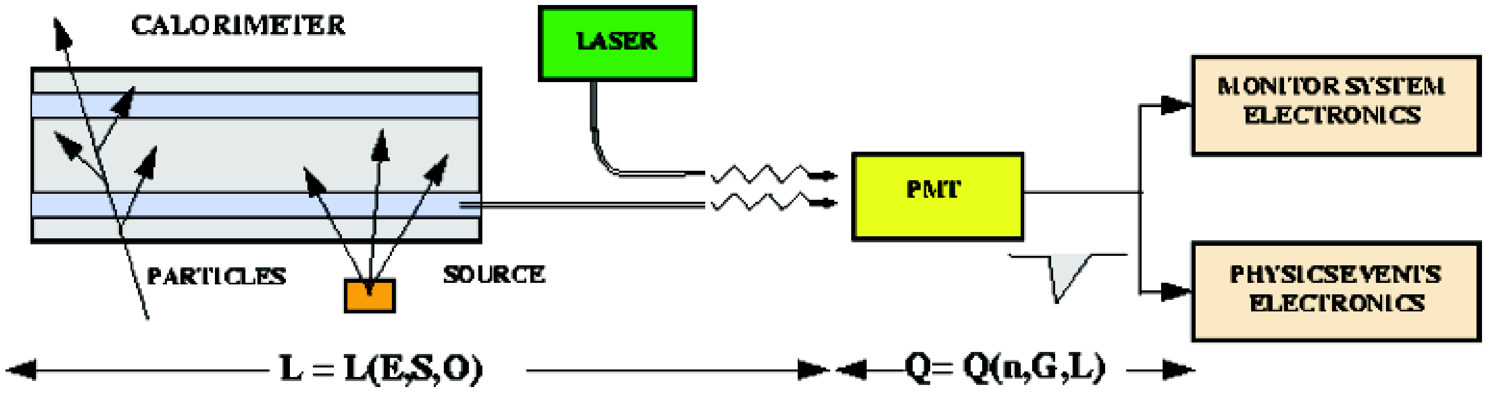
Tilecal in beam tests

- Production modules (final mechanics & electronics) tested in particle beams 2000 – 2003
- Results presented here come from re-calibrated data 2002-2003



- Tests in SPS H8-beamline:
  - energies from 10 – 350 GeV
  - muon, electron and hadron beams
  - typical setup (module 0, barrel module, 2 EB modules). The tests included:
    - EM scale settings: shooting electrons into individual cells at 20 deg (all cells of first radial compartment)
    - detector performance "as in ATLAS": particles shot at projective pseudorapidities, entering the centers of the cells
    - special studies at 90 deg: uniformity, hadronic shower profiles, light yield measurement, etc.

Tilecal Calibration Systems (1)



- Cesium System (more details in next page)
- Minimum bias system:
  - signal integration over ~10 msec
  - precise monitoring tool, (relative) luminosity measurement

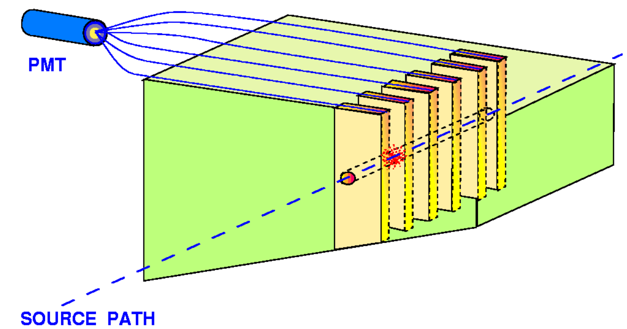
Integrator electronics

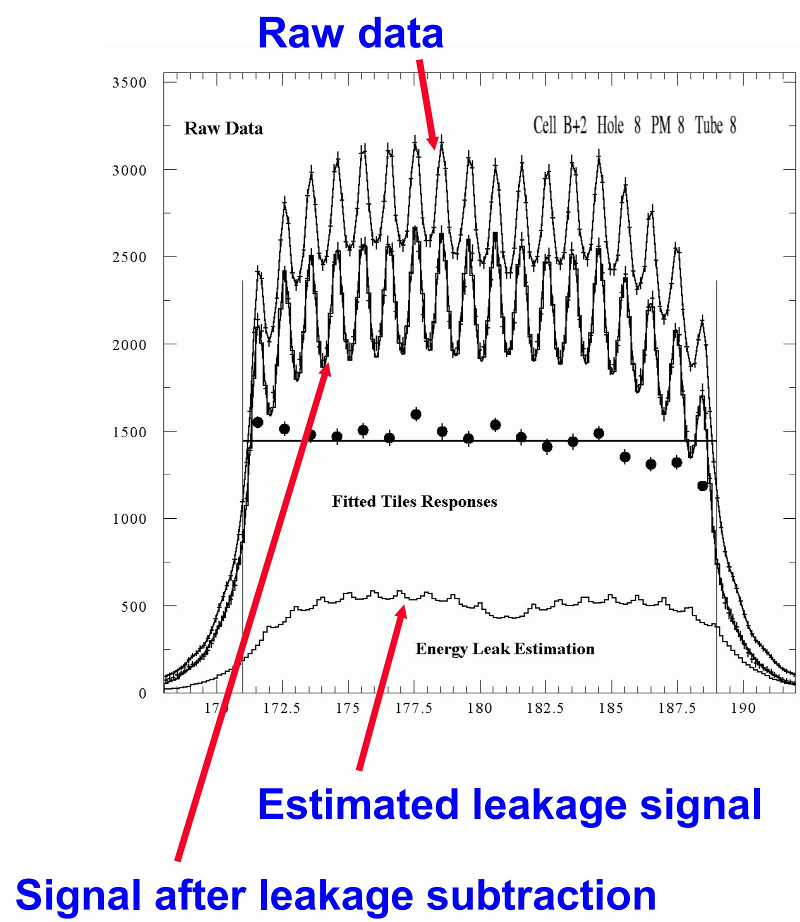
- Charge Injection System (see next pages for more details)
- Laser System:
  - inject pulsed laser light into all PMTs
  - monitors PMT non-linearity and stability

Fast readout electronics

Tilecal Calibration Systems (2)

- Cesium System:
  - passes through individual cells & tiles at 90 deg, signal readout through (slow) integrators
  - can reconstruct individual tile responses (amplitude method)
  - gain of all cells is equalized with Cs by setting the high voltage on the individual PMTs
  - primary tool to set up EM scale (using TB experience): pC/GeV

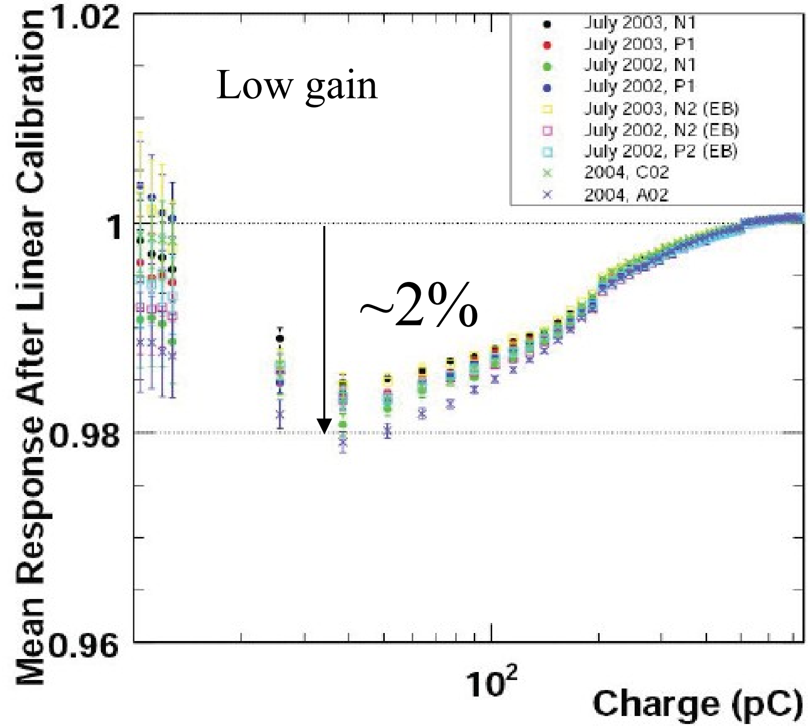


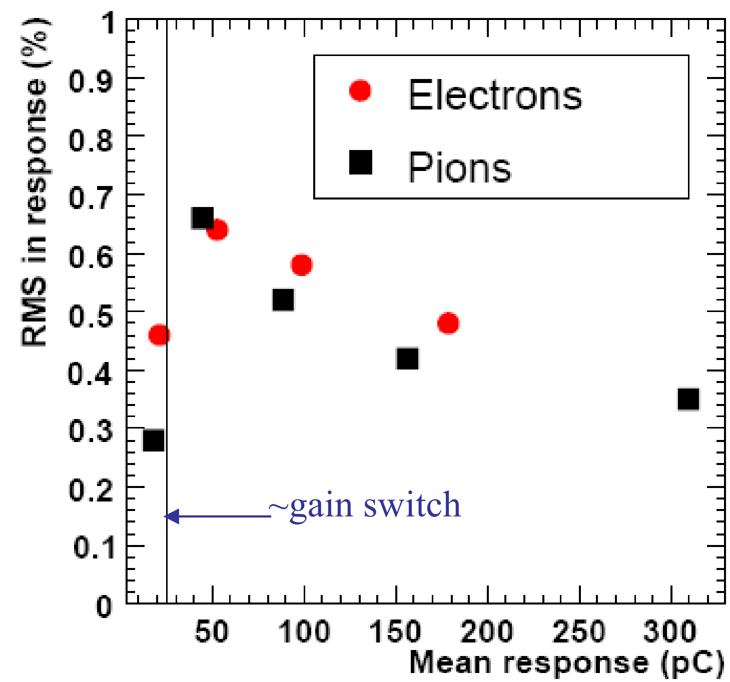


Tilecal Calibration Systems (3)

- Charge Injection System (CIS):
  - injects well defined charge into fast bi-gain electronics
  - provides ADC/pC conversion for both gains
  - offline correction for non-linearity in low-gain
  - uncertainty of mean measured response associated with the ADC performance and the calibration uncertainties: <1%

Impact on the jet energy measurement even smaller since more channels will be involved.



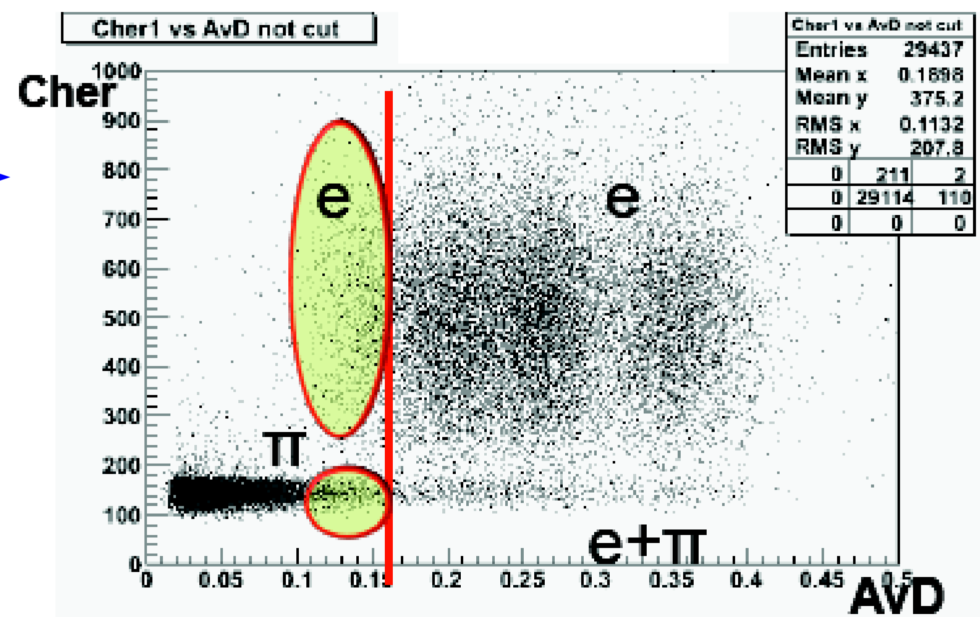


Physics Event Selection

- Beam cuts:
  - require a MIP-like signal in upstream beam scintillators, avoid upstream showering and/or double particle events
  - restrict angular spread and impact point with beam chambers, avoid halo particles with potentially bad energies

- Particle selection criteria:
  - muons taken out using total energy criteria
  - e/π separation:
    - exploit average density differences
    - Cherenkov counter info further improves selection for E_{beam}<=20 GeV
  - π/p separation:
    - positive beams only (50-180 GeV)
    - use of Cherenkov counter

$$AvD = \left(\sum_{i}^{Ncell} E_i / V_i\right) / Ncell$$

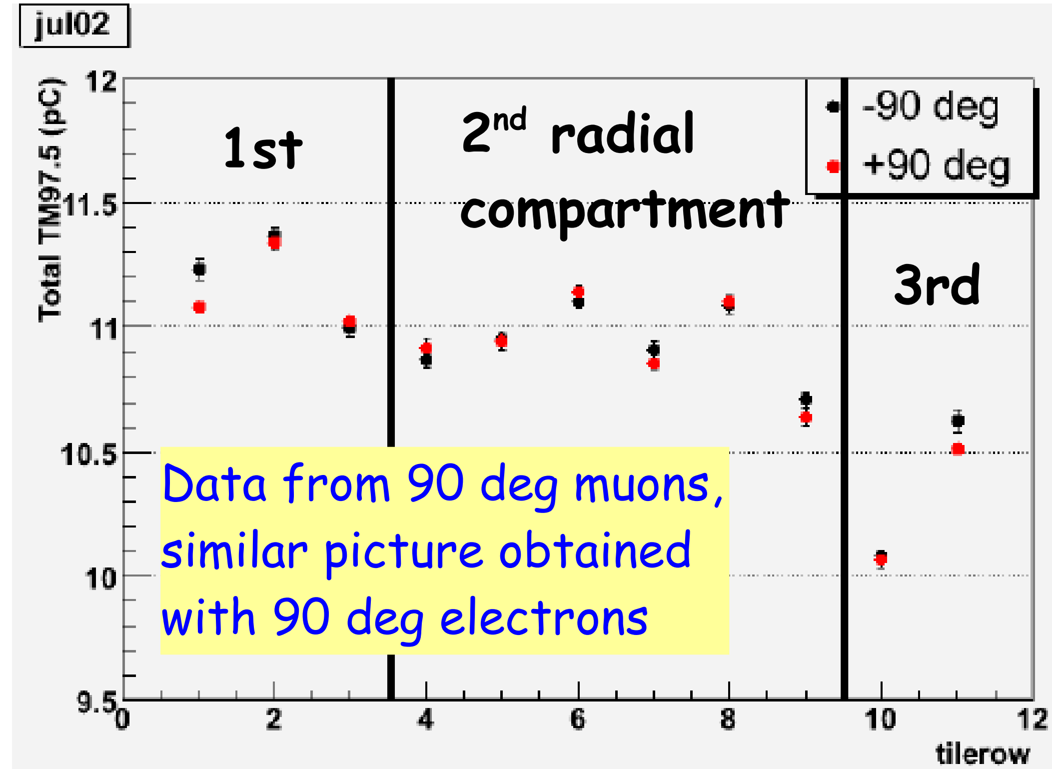


Corrections applied to raw data

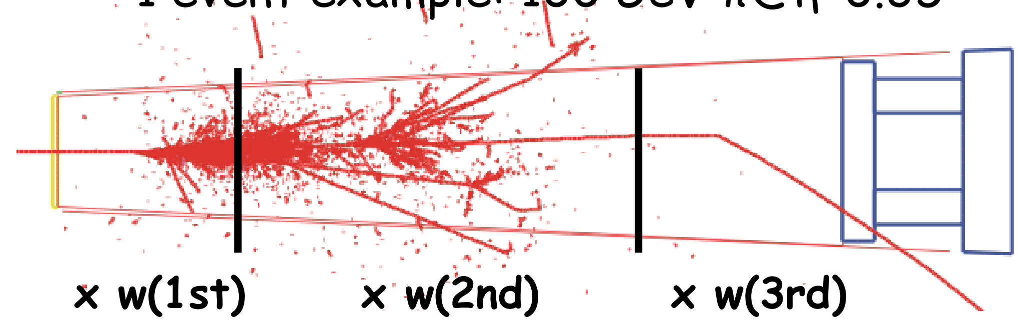
- correct for bad PMTs
- correct for bias introduced by particle separation criteria (e.g. average density)
- particle/Cs correction (see next pages)
- longitudinal leakage correction (see next pages)
- correct for real beam energies (calculated from known settings of magnets & collimators in the beamline)

Particle/Cs correction

- Difference particle/Cs:
  - particles at 90 deg entered the tile center, whereas Cs deposits energy at the tile edge.
  - non-uniform tile response across its surface causes systematic particle/Cs difference.
  - evaluate weights for individual radial compartment:
    - w(1st) = 1 (preserve EM scale)
    - w(2nd) = 1/0.975
    - w(3rd) = 1/0.922

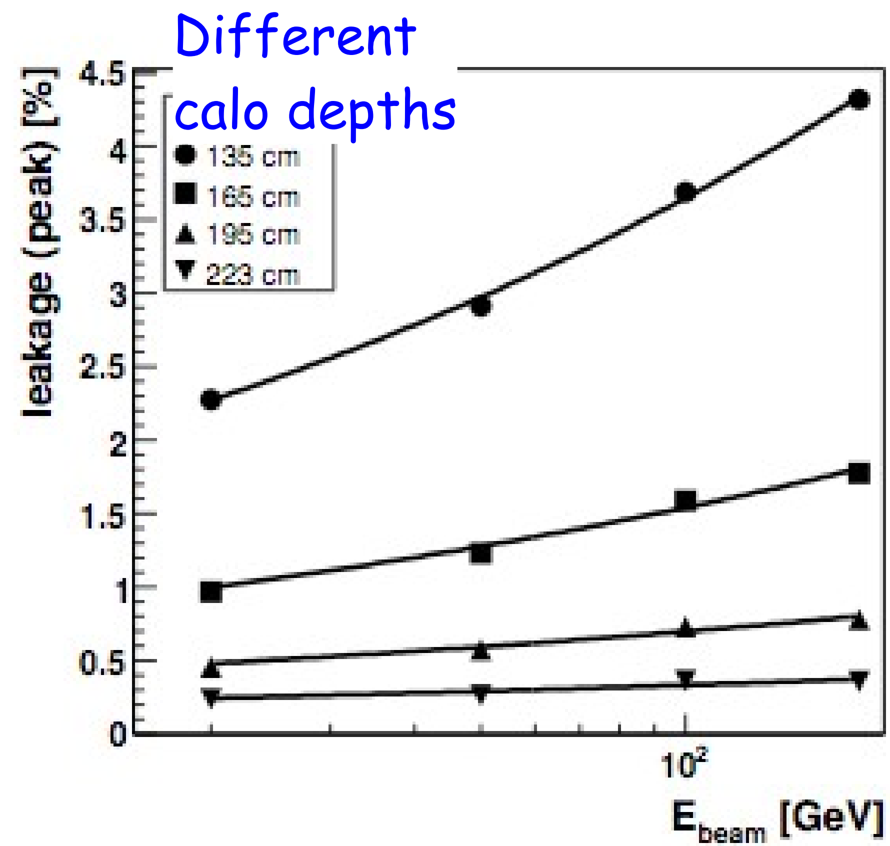


1 event example: 100 GeV π@η=0.35



Longitudinal leakage correction

- Want to compare the results with that of radially longer Tilecal prototype modules => scale resulting pion linearity and resolution for an "infinite" calorimeter
- Correction for peak value and resolution obtained from special 90 deg pion studies

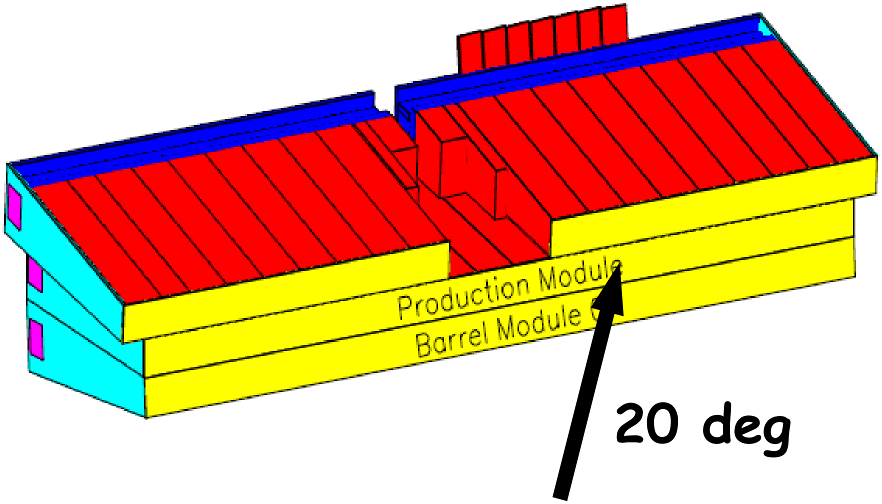


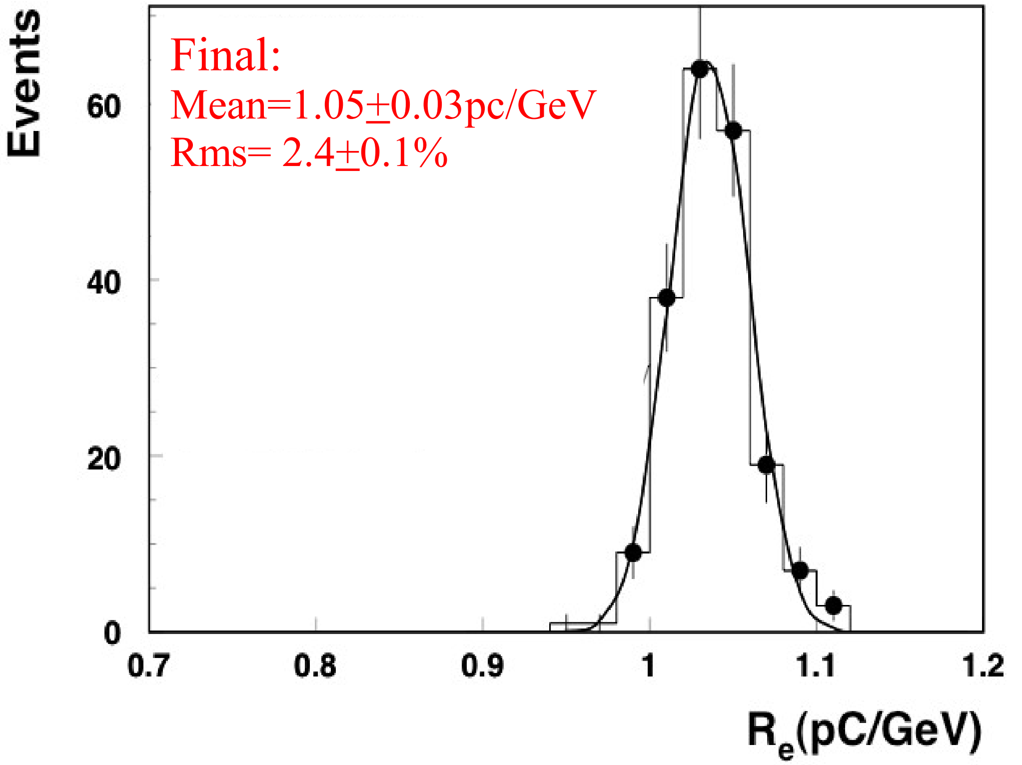
165 cm ~ production modules, η=0.35

195 cm ~ prototypes, η=0.35

Setting the EM scale

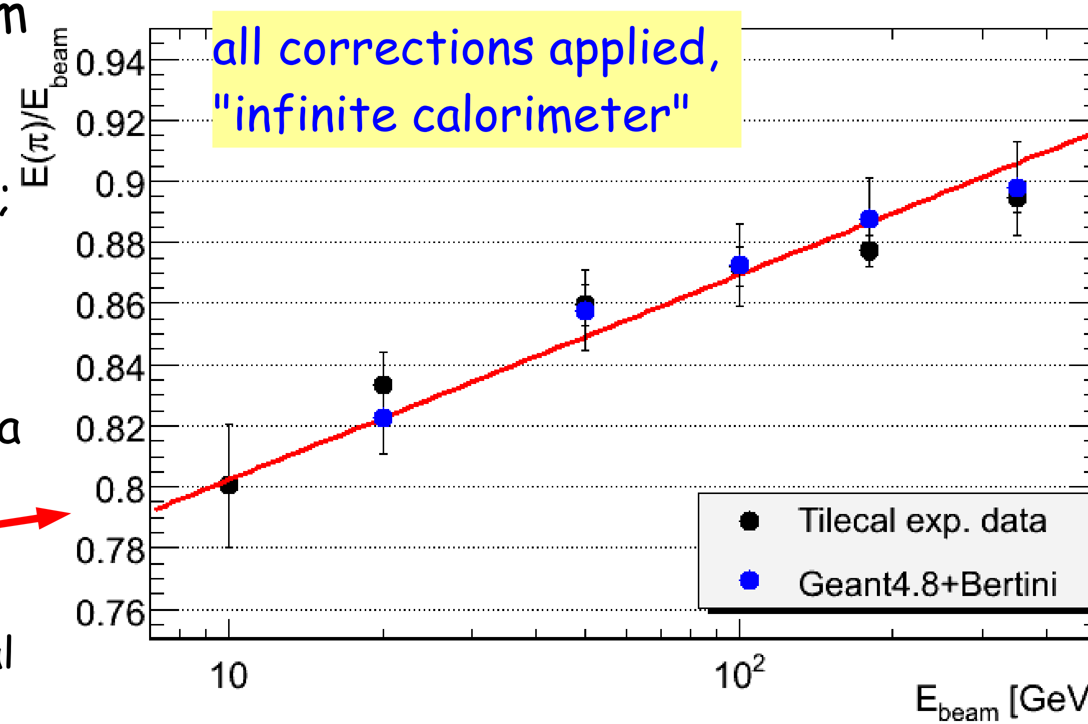
- EM scale determined with electrons entering at 20 deg
  - 11% of all Tilecal modules brought to beam tests
  - electrons shot in all cells of the first radial compartment
  - averaged over all tested modules, we got: 1.05 pC/GeV





Pion results (1)

- Pion response normalized to the beam energy:
  - data from several modules combined; modules are inter-calibrated with π@180 GeV
  - calorimeter is non-compensated, data in reasonable match with Wigmans' parametrization
    - e/h = 1.36, result from earlier Tilecal analyses
  - good agreement data vs. MC



- Comparison to earlier Tilecal prototype modules (+30 cm):

	Production mods (L=∞)	Prototypes (L=∞)
R(180 GeV/20 GeV)	1.059 ± 0.005	1.083

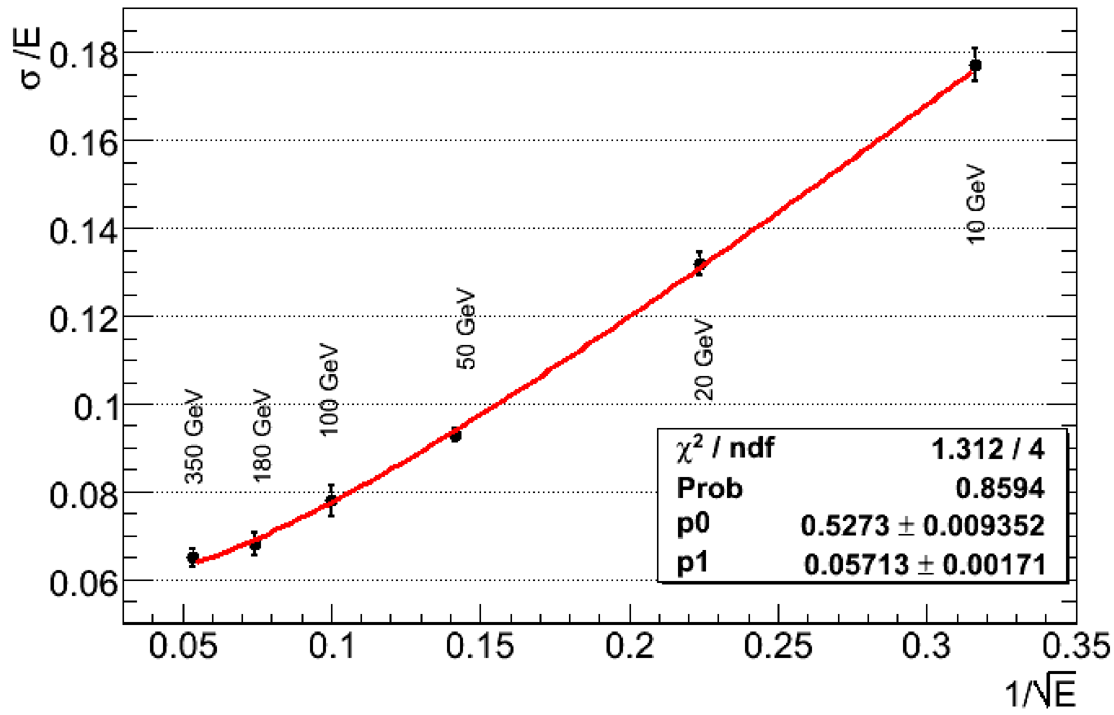
  - recent studies in ATLAS combined testbeam show the same value (1.059±0.008)

Pion results (2)

- Pion energy resolution:
  - data from several modules combined:

$\sigma/E = (52.7\pm0.9)\%/\sqrt{E} \oplus (5.7\pm0.2)\%$

  - result in good agreement with resolution obtained for prototype modules when accounting for different calorimeter lengths



Conclusions

- Big effort invested into understanding the details of the Tile calorimeter calibration and response to particles.
- The new calibration, involving also the correction for longitudinal leakage, restores the expected pion response curve as a function of energy.
- Reasonable agreement with recent MC.
- The gained experience should allow us to calibrate all 10k Tilecal channels at EM scale in ATLAS within 1-2%