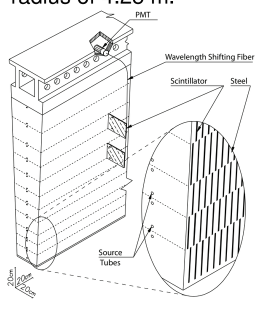
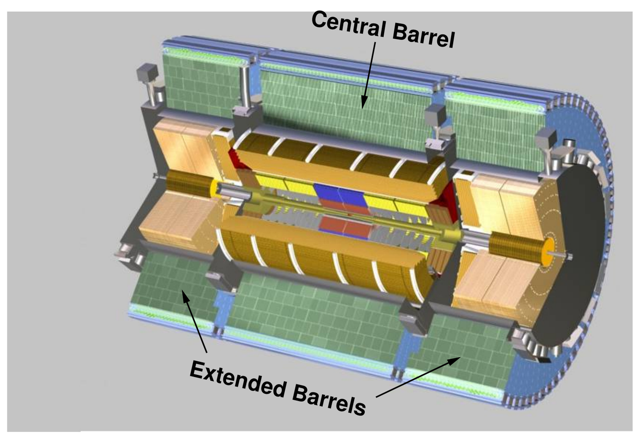
Tile Calorimeter at work in the collision era

Tibor Zenis, on behalf of the ATLAS Tile Calorimeter Group
Comenius University Bratislava

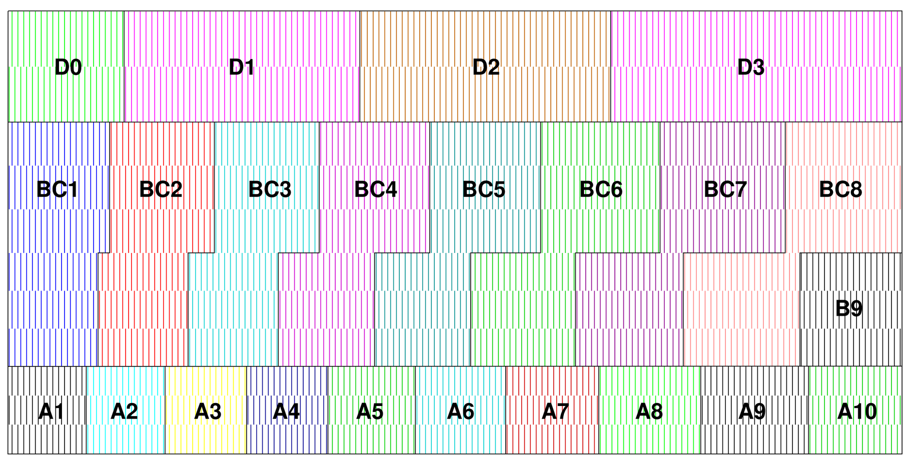
The ATLAS Tile Calorimeter

The Tile Calorimeter is a sampling calorimeter using steel as the absorber and scintillator as the active medium. It is divided into a central barrel, 5.8 m in length, and two extended barrels, 2.6 m in length and each having an inner radius 2.28 m and an outer radius of 4.25 m.





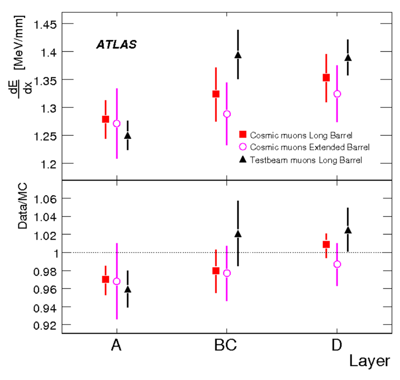
Each of the barrels is composed of 64 azimuthal modules subtending $\Delta\phi = 0.1$. The Tile scintillator plates are placed perpendicular to the colliding beam axis, and are radially staggered in depth. The structure is periodic along the beam axis. Two sides of the scintillating tiles are read out by wave–length shifting fibers into two separate photomultipliers (PMTs).



By the grouping of WLS fibers to specific PMTs, modules are segmented in pseudorapidity η and in radial depth. The resulting typical cell dimensions are $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$. This segmentation defines a quasi–projective tower structure. Altogether, Tile Calorimeter comprises 4672 read–out cells, each equipped with two PMTs that receive light from opposite sides of the tile.

Validation of EM Scale with Cosmics

The truncated mean of the dE/dx for cosmic and test beam muons shown per radial compartment and, at the bottom, compared to Monte Carlo. For the cosmic muon data, the results were obtained for modules at the bottom part of the calorimeter. The error bars shown combine both statistical and systematic uncertainty.
Good agreement between data and MC in test beam and cavern is shown.
EM scale was validated with cosmics with the precision of 3%.



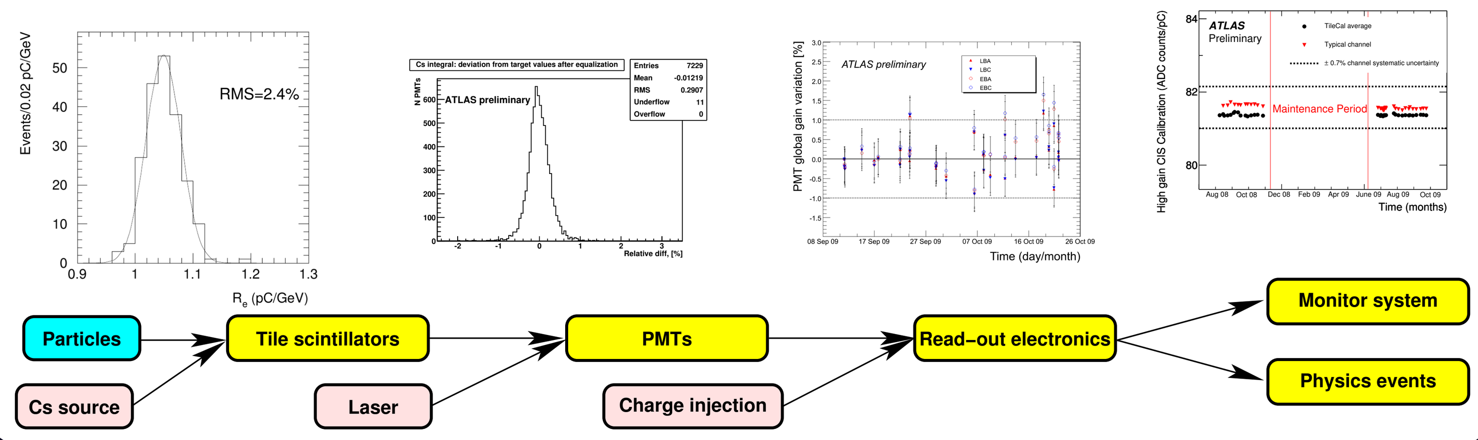
Tile Calorimeter Calibration

The EM scale of 11% of the Tile modules is set with a beam of electrons and propagated to the rest of the modules with the calibration system.
The RMS is dominated by local variations in individual tile responses.

The radioactive Cesium source allows for uniform cell response at level 0.3%.

The laser system is designed to calibrate and monitor the response of the PMTs with a precision better than 0.5%.

The charge injection system is designed to calibrate the relative response of the read–out electronics system across all PMTs of the calorimeter at accuracy of 1%.

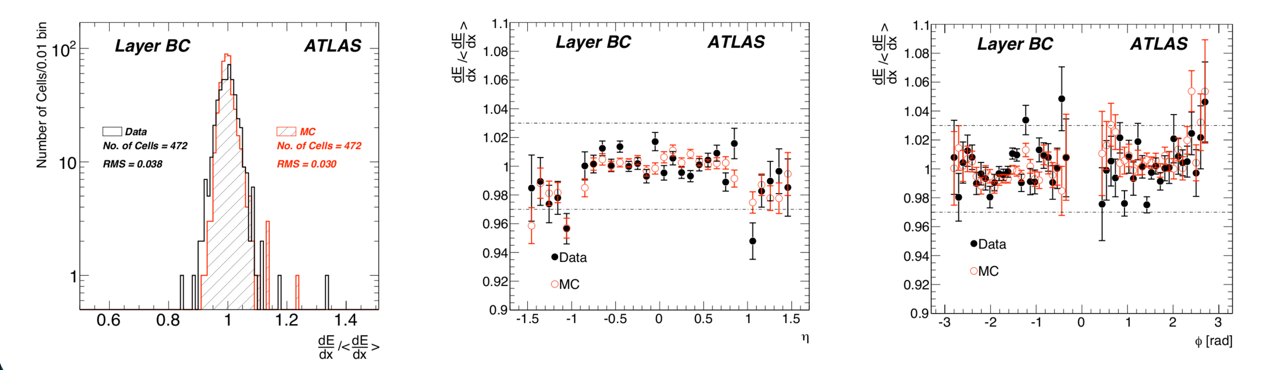


Uniformity of Response to Cosmic Muons

Distribution of the truncated mean dE/dx per BC cell for data and Monte Carlo normalized to respective averages. The momentum range of the cosmic muons was restricted to be between 10 and 30 GeV/c.

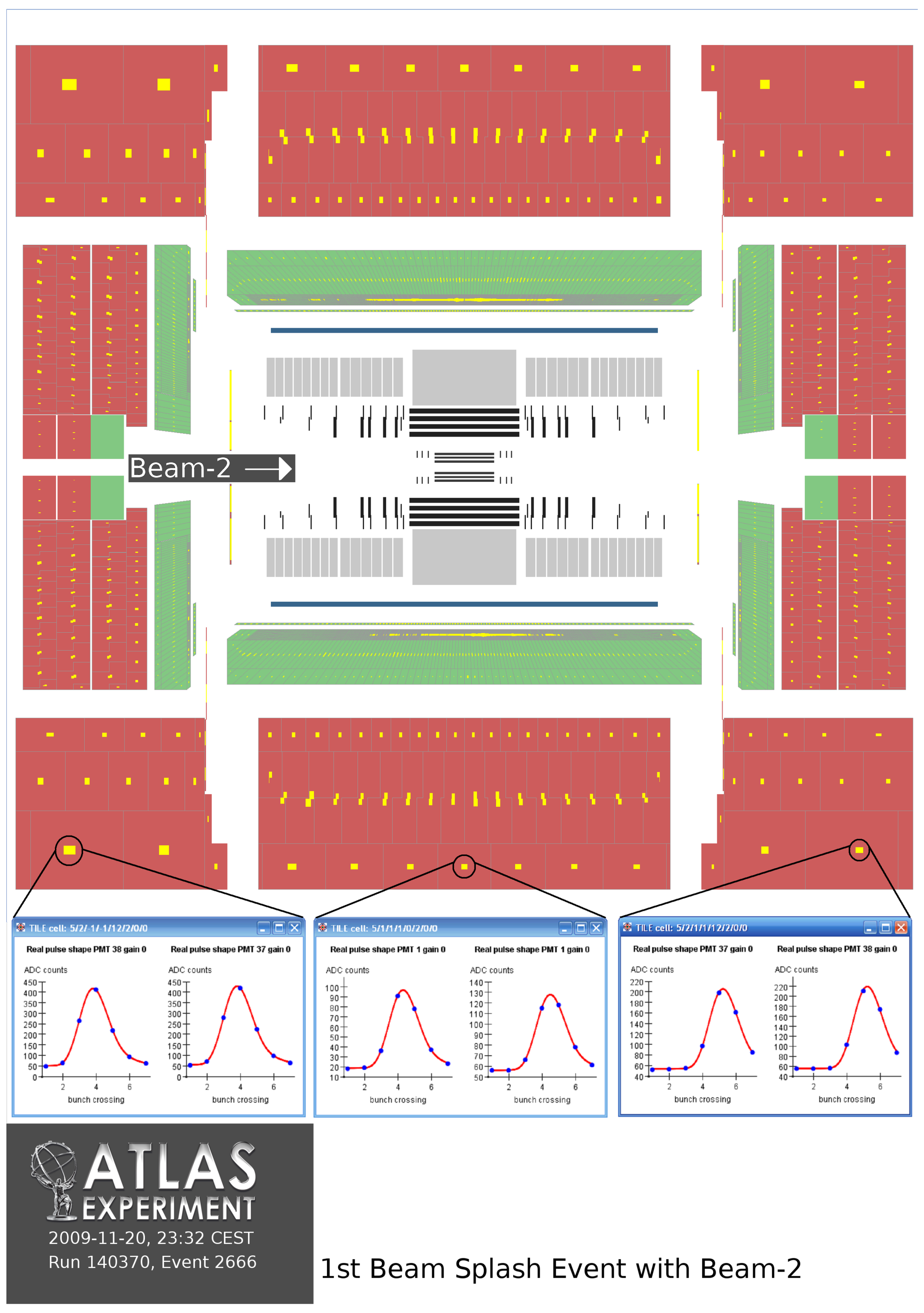
Uniformity of the BC cell response to cosmic muons, expressed in terms of normalized truncated mean of dE/dx, as a function of pseudorapidity η and azimuthal angle ϕ (module). The response is integrated over all cells in each pseudorapidity (module). The results for data are compared to Monte Carlo simulations.

The cells uniformity is well below 4%.



Splash Events

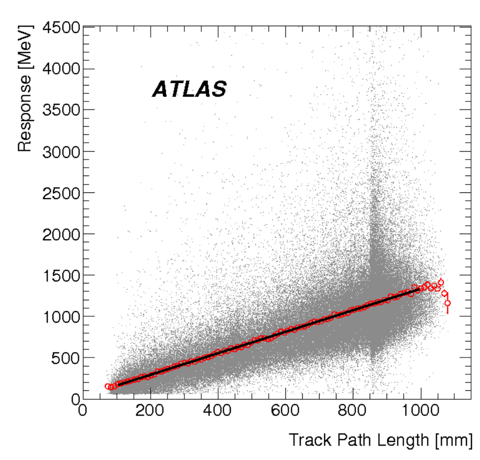
The picture shows a splash event (the LHC beam hit a completely closed collimator 140 m far from the center of ATLAS). The yellow squares on the radially external red cells show the Tile Calorimeter energy measurements. The bottom plots show the reconstructed signal pulses from the cells in the third radial layer. The progression of the peak position from left to right shows the expected time–of–flight dependency.



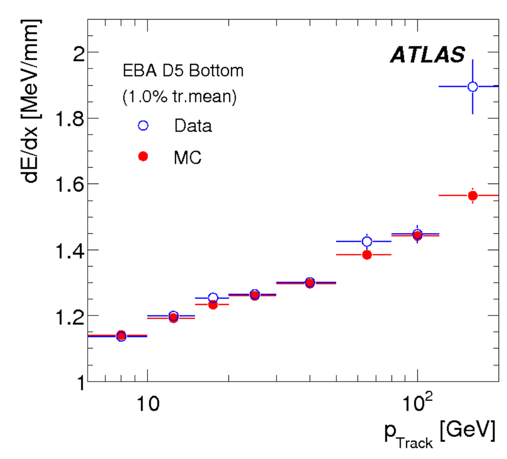
1st Beam Splash Event with Beam-2

Cosmic Muons Analysis

Response of the barrel module BC cells as a function of track path length. A linear fit to the corresponding distribution of mean values is superimposed.

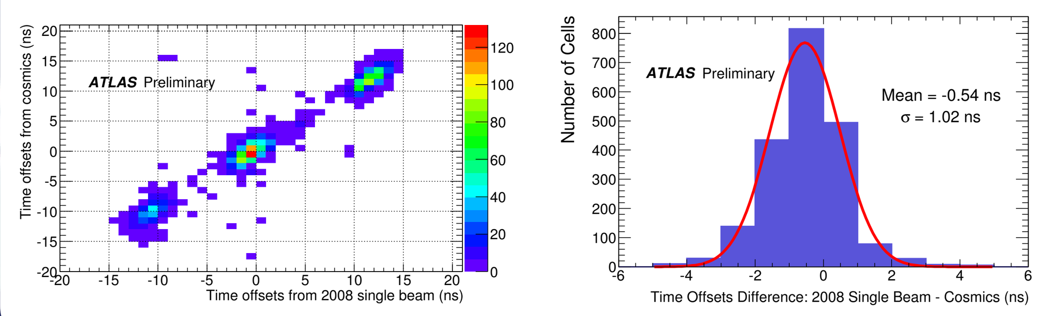


Tile Calorimeter response (dE/dx) to muons as a function of momentum as measured in the inner detector, estimated with the truncated mean for both data and Monte Carlo.



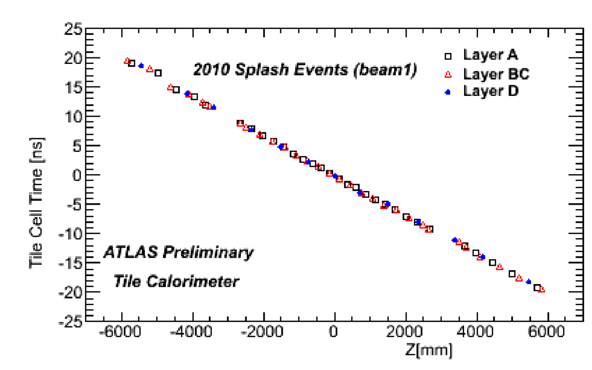
Time Validation with Cosmics

The difference of time offsets seen in the single beam and cosmic data is shown for BC and D cells of the Tile Calorimeter. Cosmics agree with single beam results with precision of 1 ns.

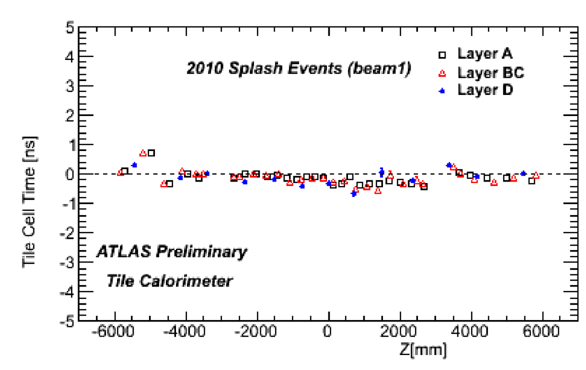


Time Calibration with Splashes – 2010

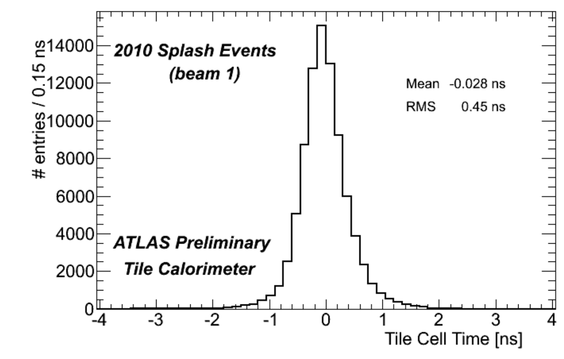
Timing of Tile Calorimeter signals recorded with single beam data. The average time over all cells with the same azimuthal coordinate is shown as a function of the cell z coordinate (along beam axis). The observed slopes match the time the muons take to cross the calorimeter along the z direction.



Timing of the Tile Calorimeter signals after the cell times were corrected for the time–of–flight of the particles through the calorimeter.



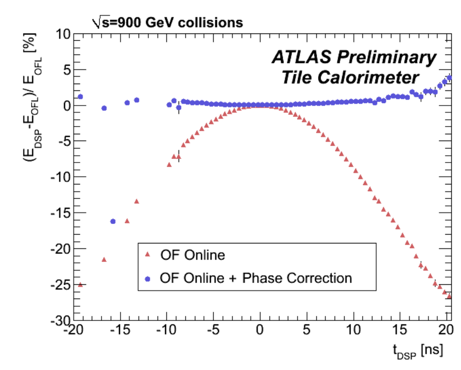
Distribution of the timing of the Tile Calorimeter signals recorded with single beam data. Only cells with a proper time calibration (97% of all Tile cells) are involved.
Excellent RMS = 0.45 ns was achieved.

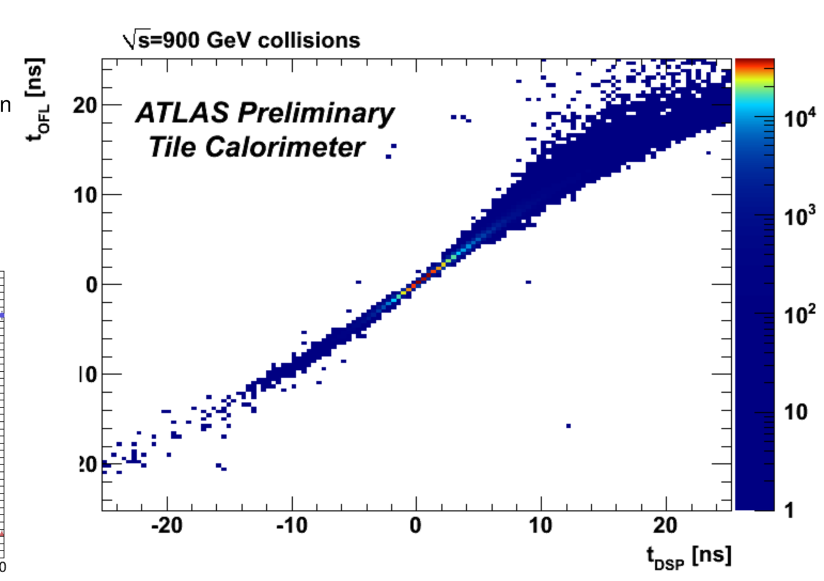


Validation of Signal Reconstruction with Collision Data

Performance of the ROD/DSP Optimal Filtering Non Iterative signal reconstruction with collision data (900 GeV) is shown. Collision events as well as out of time events as cosmics and single beam events populate the plot, in order to evaluate the DSP reconstruction performance in a wide time window.
The 90% of the pulses are in the time range [−5, 5] ns. The plots show that in the significant time range [−10, 10] ns reconstructing the signal by the online algorithm works very well (linearity within few percent).

Note, the RMS of the Tile Calorimeter signal timing for cells with proper time calibration is below 1 ns.



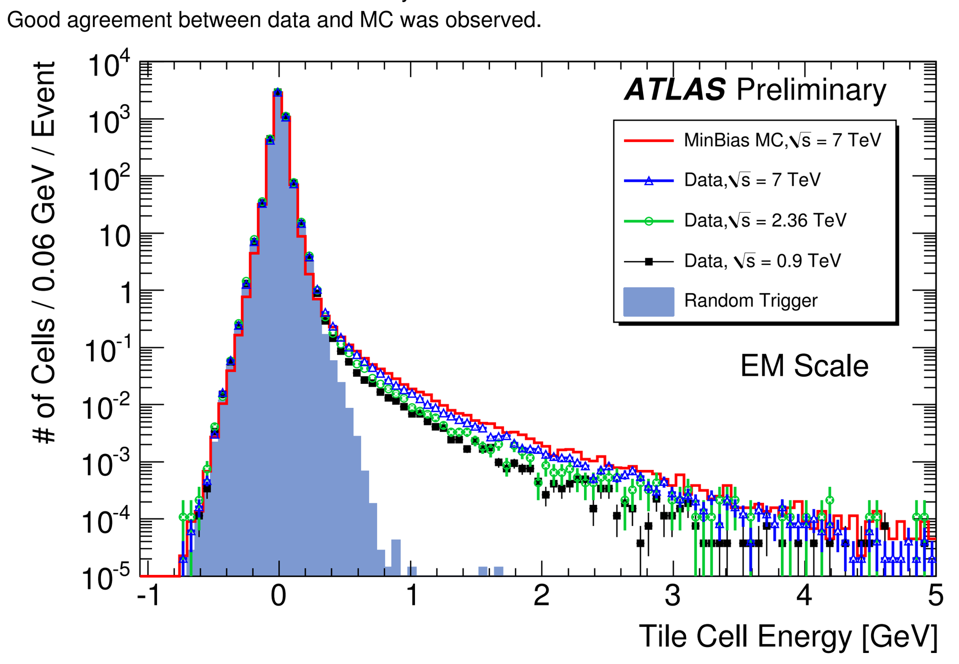


Offline cell time reconstruction as a function of the online time reconstruction

Collisions

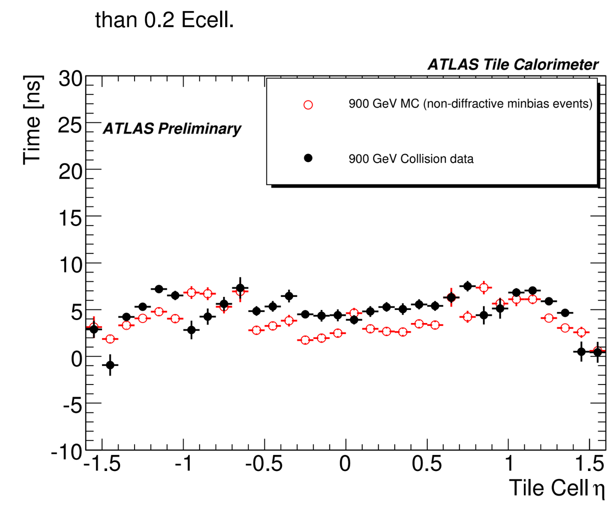
Tile Cell Response in Collision Data

The distributions of Tile Calorimeter cell response from collision data at 7 TeV, 2.36 TeV, 900 GeV are superimposed with Pythia minimum bias Monte Carlo and randomly triggered events. Each distribution is normalized by the number of events.
Good agreement between data and MC was observed.



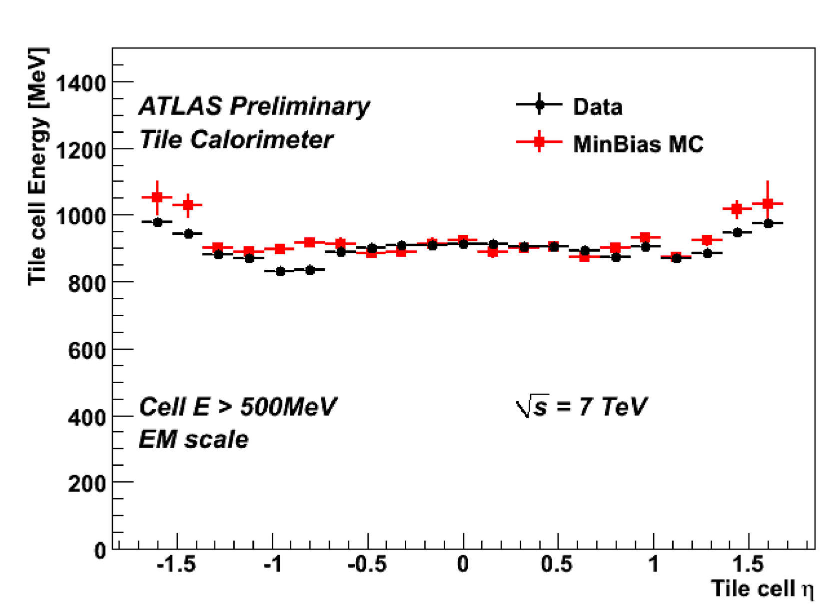
Time Validation with Collision Data

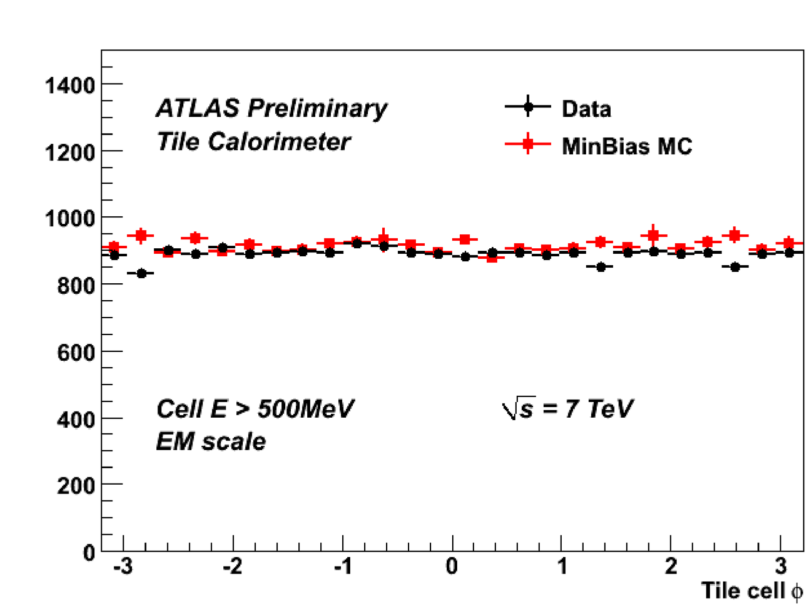
Time distribution of the Tile Calorimeter cells. Cells were selected with an energy cut of 300 MeV and difference between the energies of the two read–out channels of the cell less than 0.2 Ecell.



Tile Cell Response Uniformity in Collision Data

Average Tile Calorimeter cell energy as a function of pseudorapidity η and azimuthal angle ϕ in collision candidate events at 7 GeV. Only cells energies above 500 MeV at the EM scale are considered. Non–diffractive minimum bias Monte Carlo events with the same energy cut are superimposed with the collision candidate events.
Nice match between MC and data is seen.





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