Performances of the signal reconstruction in the ATLAS Hadronic Tile Calorimeter

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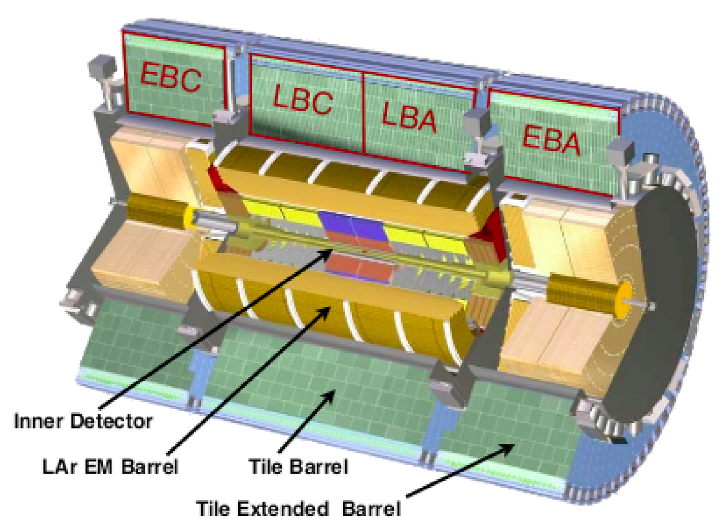
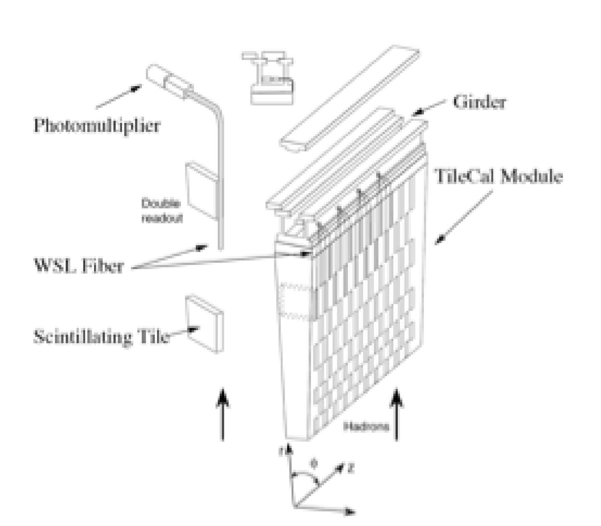
Introduction



The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of the ATLAS detector at the LHC collider at CERN.
It is a key detector for the reconstruction of hadrons, jets, taus and missing transverse energy.
We present the performances of the signal reconstruction algorithm on the data collected in the proton-proton collisions at $\sqrt{s}$ = 7 TeV.

The Tile Calorimeter



Performance goals:
Resolution: $\frac{\sigma(E)}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$. Jets Linearity: within 2% up to few TeV.

Technology: sampling calorimeter: steel/scintillating tiles coupled to wavelength shifting fibres read out by PMTs; composed of 3 radial layers with $\Delta\eta \times \Delta\varphi$ = 0.1 x 0.1 cells (0.2 x 0.1 outer layer).
Characteristics: hermeticy: tiles perpendicularly to the beam axis; redudancy: double PMT readout for each cell;
good granularity: 10K readout channels in 256 Front End modules.

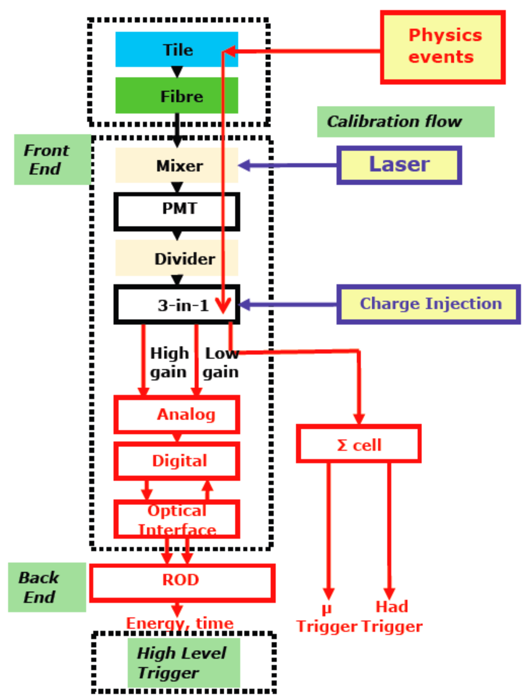
See also, the following contributions:

Y. Hernandez,	*The ATLAS Tile Calorimeter performance at LHC*
D. Boumediene,	*Calibration and Monitoring systems for the ATLAS Tile Hadron Calorimeter*
F. Carrio Argos,	*Upgrade for the ATLAS Tile Calorimeter readout electronics at the High Luminosity*
F. Seifert,	*Upgrade plans for ATLAS Calorimeters*

The TileCal ReadOut Principle

Designed to measure energy in a cell between 30 MeV ÷ 1.6TeV; dynamic range covered with good resolution using a bi-gain readout chain:

- PMT output signals are shaped and amplified separately for High and Low Gain signal path;
- Signals are sampled at the LHC bunch-crossing frequency (40 MHz);
- A gain-switch sends digitalized samples to the Read-Out Driver Boards (RODs);
- The RODs perform an online reconstruction to feed the High Level Trigger (HLT) with amplitude, phase, quality of the signal for each cell;
- The reconstruction algorithms are implemented in Digital Signal Processors (DSP);
- All samples for channels above a noise threshold (>70 MeV) are stored on disk.

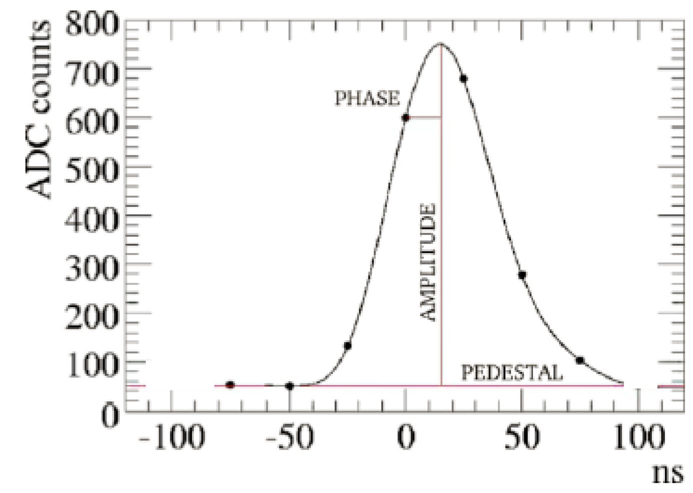


Optimal Filtering Algorithm

The online and offline signal reconstruction are performed using the Optimal Filtering Algorithm (OF)[1]:

$$A = \sum_{i=1}^{n} a_i S_i \qquad A\tau = \sum_{i=1}^{n} b_i S_i \qquad p = \sum_{i=1}^{n} c_i S_i$$

- OF weights (a,b,c) are defined by pulse shape, noise and the expected signal phase.
- Two Implementations:
  - iterative method: for asynchronous signals (cosmic muons, laser calibration data, etc) assumes an arbitrary signal phase;
  - non iterative method: for synchronous signals (collision events) uses precise timing offset for every channel.



The iterative method is slower and more sensitive to noise fluctuation and pileup. The non iterative method allows to cope with the acquisition high rate, it is the design method, employed in online and also in the offline. It is crucial demonstrate that these methods give similar performances under suitable conditions.

[1] Ref: W. E. Cleland and E. G. Stern, "Signal processing considerations for liquid ionization calorimeters in a high rate environment", NIM A, 338:467-497, 1994.

Comparisons of online and offline reconstruction

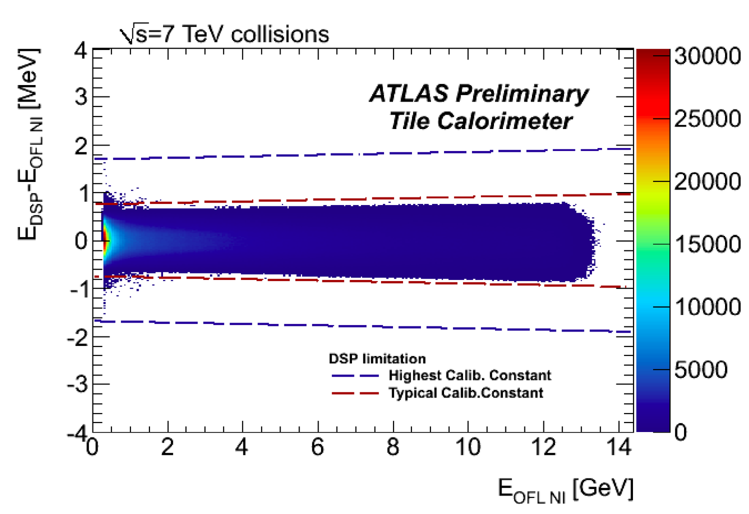
Small differences between online and offline OF are expected:

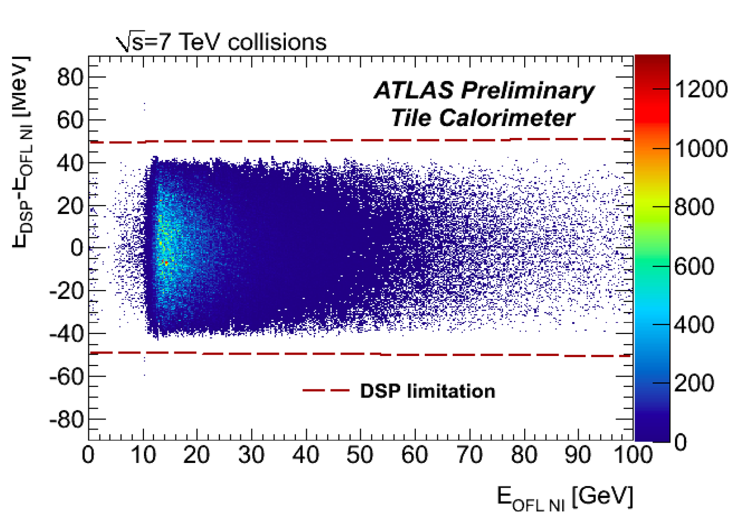
- Parameters needed by reconstruction algorithm (weights, phases, calibration constants) are uploaded into ROS/DSP (fixed point arithmetic: constants and parameters described by 16 bits);
- Look-up Tables (LUT) used in DSP to evaluate the phase.

The ROD can be configured to send out both the reconstructed quantities and the raw data samples up to a LVL1 trigger rate of 45KHz.
Used first ATLAS data at 7 TeV to validate the DSP reconstruction.

Validation of online reconstruction with offline non iterative method

The offline non iterative method (OFLNI) uses full numerical precision instead of fixed point arithmetic.



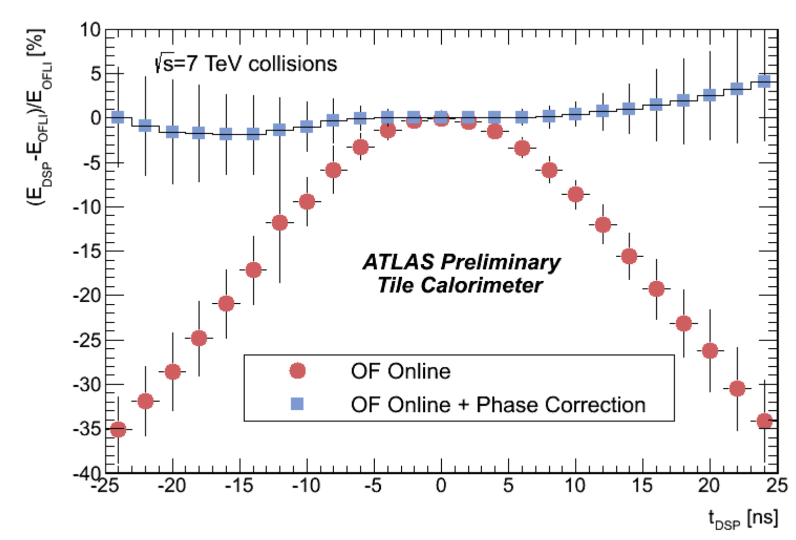


The degradation is slightly energy dependent.

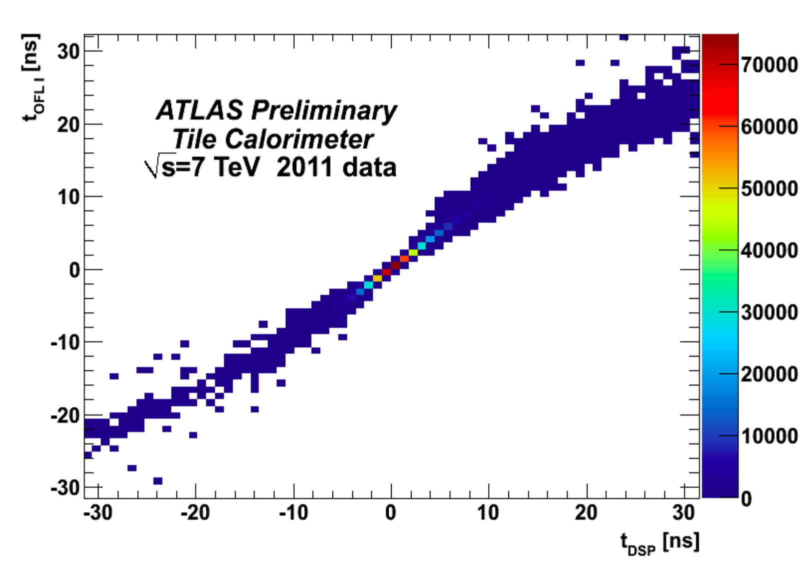
Precision in HG for 99% of channels is within ± 1 MeV (± 50 MeV in LG). The values are within the expectations.

Validation of online reconstruction with offline iterative method

Variation in phase of pulses in the non iterative method causes an underestimation of amplitude.
Deviation of the energy for small time variations within 1 bunch crossing can be corrected. After the correction the bias is reduced to less than 1%.



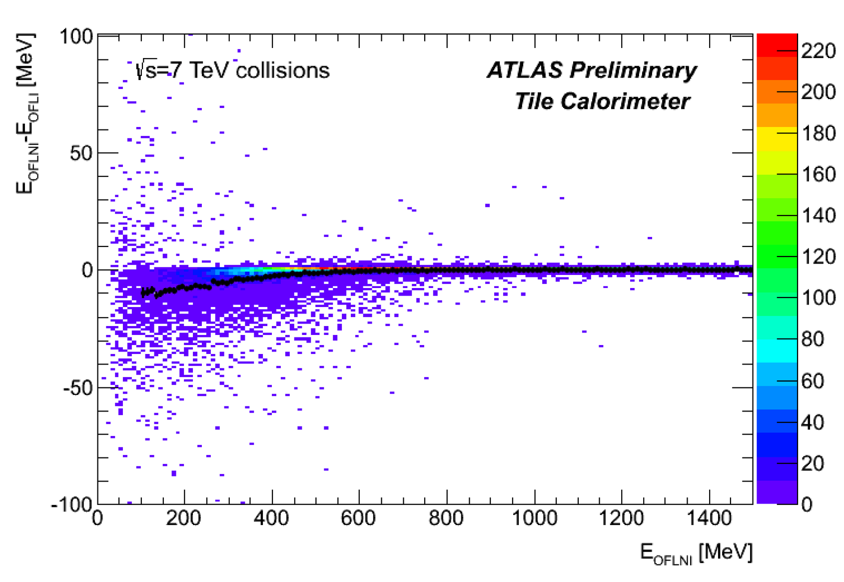
Good correlation between DSP and offline iterative method (OFLI) in the ± 1 bunch crossing range is observed for the [-25,25] ns range.



Comparisons of offline non iterative and iterative method at low signals

A clean sample of muons is selected requiring: pT >20 GeV, cell track path length > 100 mm and an azimuthal and longitudinal distance between the muon track extrapolated at the TileCal layer and the center of the cell of $\Delta\varphi$<0.048 $\Delta\eta$<0.048.

The most probable energy ranges from 400 MeV÷ 1 GeV depending on the cell size. For energy deposits >200 MeV the difference between the two methods is < 50 MeV for the majority of events, and the mean of the distribution < 10 MeV.



Conclusions

The online reconstruction of the DSP has been validated with the LHC data using the offline reconstruction as reference. The precision of the online reconstruction is adequate and within the expectations. Currently the DSP reconstruction is used in the HLT.

The performances of the OFLNI and OFLI are very close to each other up to very low energy ranges.