Performances of the signal reconstruction in the ATLAS Hadronic Tile Calorimeter

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Abstract

The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of ATLAS. It is a key detector for the reconstruction of hadrons, jets, tau leptons and missing transverse energy. TileCal is a sampling calorimeter using steel as absorber and plastic scintillators as active medium. The scintillators are read-out by wavelength shifting fibers coupled to photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped and digitized by sampling the signal every 25 ns. The read-out system is designed to reconstruct the data in real time fulfilling the tight time constraint imposed by the ATLAS first level trigger rate (100 kHz). The signal amplitude and phases for each channel are measured using Optimal Filtering algorithms both at online and offline level. We present the performances of these techniques on the data collected in the proton-proton collisions at center-of-mass energy of 7 TeV. We show in particular the measurements of low amplitudes, close to the pedestal value, using as probe high transverse momenta muons produced in the proton-proton collisions.

Key words: LHC, ATLAS, Hadron Calorimeters, Tile Calorimeter, Optimal Filtering
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1. Introduction

TileCal [1] is a sampling calorimeter made of steel as absorber material and scintillator tiles as active medium. It is required to measure particle energies in a wide range extending from typical muon energy deposition of a few hundreds of MeV to the highest energetic jet of particles, which in rare cases can deposit up to two TeVs in a single cell. The light produced in the scintillator tiles is read-out by wavelength shifting fibers coupled to PMTs. The analogue signal from the PMTs are amplified, shaped and digitized in the front-end electronics in two separate branches to cover the large dynamic range [2]. The digital samples are transmitted to the back-end electronics through high speed optical links at the ATLAS first level trigger rate (100 kHz). The Read-Out Drivers (RODs) [3] are the interface between the front-end electronics and the general data acquisition system (DAQ) of the ATLAS detector. The main function of the RODs is to reconstruct the signal amplitude and phase at the first level trigger rate and to transmit them to the DAQ system for offline analysis. The signal amplitude is also provided to the High Level Trigger (HLT) to form the calorimetric trigger signals. The RODs can also compress and transmit all the digital samples for channels with amplitude above a configurable threshold for offline reconstruction. The core of the RODs are the Digital Signal Processors (DSPs) that provide the high processing power required to execute these algorithms within the tight time constraint defined by the first level trigger rate.

Optimal Filtering [4, 5] is the algorithm used to reconstruct the channel energy, proportional to the amplitude of the pulse, and the phase, that corresponds to the time of the pulse peak. The algorithm extracts the three parameters of the shaped signal: the amplitude , the phase and the pedestal level using linear combinations of the samples with a set of weights. The calculation of the weights is based on the precise knowledge of the signal shape and peak position time. The Optimal filtering algorithm has been developed with two different flavors for synchronous or asynchronous signals. In the first case the peak position is assumed to be located within a short time distance (10 ns) from the default peak position and the signal phase is then calculated with respect to this. The algorithm is perfectly linear only for signal phases equal to zero, however the small deviation introduced by a small phase shift can be precisely calculated and corrected. This method is indicated as non-iterative Optimal Filtering algorithm. In order to reconstruct asynchronous data (e.g. cosmic rays signals), or to avoid the use of a priori definition of phases, an iterative method can be used in the reconstruction. The iterative method however is slower and more sensitive to noise fluctuations. It is worth noting that the sample acquisition window is larger than the separation between consecutive proton bunches therefore the iterative algorithm can pick up signals generated in bunch crossing different than the triggered one. For this reason the default method is the non-iterative one both at online and offline level. The iterative method has been used in the first phase of data taking and presently it is used for signal reconstruction studies.

2. Comparisons of online and offline reconstruction

All the parameters needed by the reconstruction algorithm, like weights, phases and calibration constants are downloaded into the ROD/DSPs at the configuration time. The DSP reconstruction is necessarily limited by use of fixed point arithmetic

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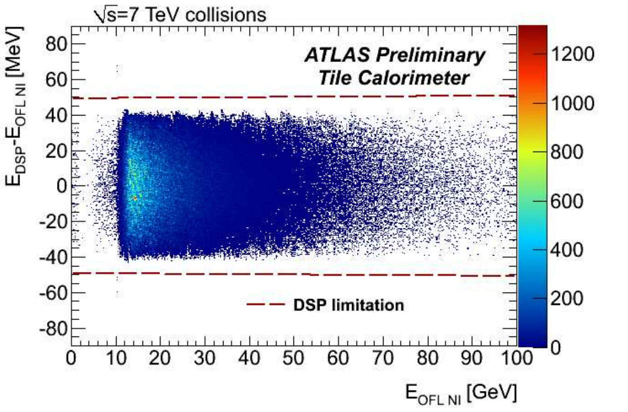

Figure 1: Absolute difference between the signal amplitude calculated on collision data with the non-iterative Optimal Filtering algorithm online (E_{DSP}), and offline (E_{OFLNI}) as a function of the energy reconstructed offline.

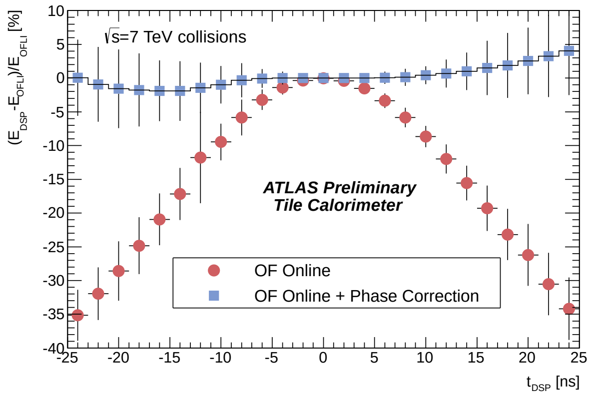

Figure 2: Relative difference between the energy reconstructed with the DSP non-iterative and the offline iterative methods as a function of the phase reconstructed by the DSP showing the bias due to the phase variations (red). The bias can be corrected applying a second order correction using the phase of the pulse (blue). The errors bars indicate the RMS of the distributions.

and the internal precision available to describe the weights and calibration factors. Moreover since the phase is computed through a division that is a time consuming operation in the DSP the phase is computed using a look-up table.

The RODs can be configured to transmit both the reconstructed quantities and the raw data samples. The raw data obtained in this way can be reconstructed offline and used to validate the DSP implementation. Figure 1 shows the absolute differences between the energy reconstructed using the non-iterative algorithm in the DSP (E_{DSP}) and the one reconstructed in the offline (E_{OFLNI}) as a function of E_{OFLNI}. The small observed differences are due to the DSP limitations discussed above and are consistent with the expectations (shown as the dashed red line).

The variation in the phase of the pulses causes an underestimation of the reconstructed amplitude in the non-iterative approach that can be parameterized. The deviation produced by small phase variations can be corrected as shown in Figure 2.

3. Comparisons of offline non-iterative and iterative method for low signals

Comparison between the non-iterative and iterative offline Optimal Filtering reconstruction are performed down to the region where the cell signals lie very close to the pedestal distribution. High transverse momenta muons produced in the proton-proton collisions constitute a powerful probe for such kind of studies. A clean sample of muons with p_T larger than 20 GeV is selected using Inner Detector plus Muon Spectrometer informations and extrapolated through the calorimeter. A track path length in the cell larger than 100 mm is required tighter with few additional cuts to assure the crossing trough the cell in a fiducial region. The most probable energy ranges from 400 MeV÷ 1 GeV depending on the cell size. Figure 3 shows that for energy deposits larger than 200 MeV the difference between the two methods is smaller than 50 MeV for the majority of events, and the mean of the distribution smaller than 10 MeV.

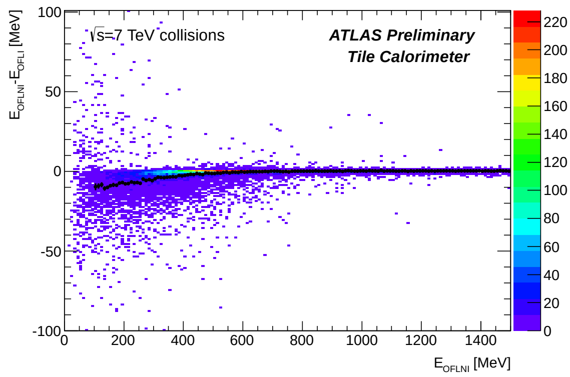

Figure 3: Cell energy difference between the non-iterative (E_{OFLNI}) and iterative(E_{OFLI}) method as a function of the E_{OFLI} determined as described in the text.

4. Conclusion

The online reconstruction of the DSP has been validated with proton-proton collisions using the offline reconstruction as reference. The precision of the online reconstruction is adequate and within the expectations. Currently the DSP reconstruction is used also as input for the HLT. The performances of the offline non-iterative method and the offline iterative are in good agreement down to very low energy ranges.

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