Pulse Shapes for Signal Reconstruction in the ATLAS Tile Calorimeter

Imai Jen-La Plante[1], Maja Tylmad[2], on behalf of the Tile Calorimeter System

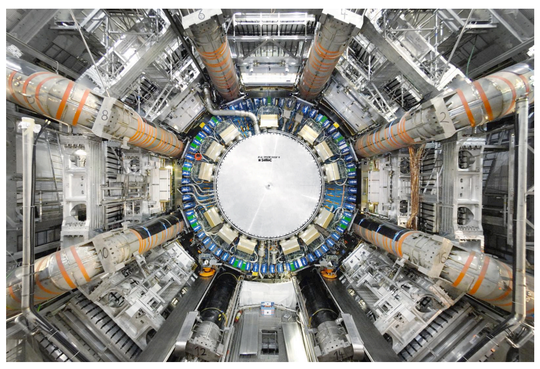
THE UNIVERSITY OF CHICAGO

[1]Enrico Fermi Institute and Department of Physics, University of Chicago, Chicago, IL 60637, USA;
[2]Deparment of Physics, Stockholm University, 10691 Stockholm, Sweden

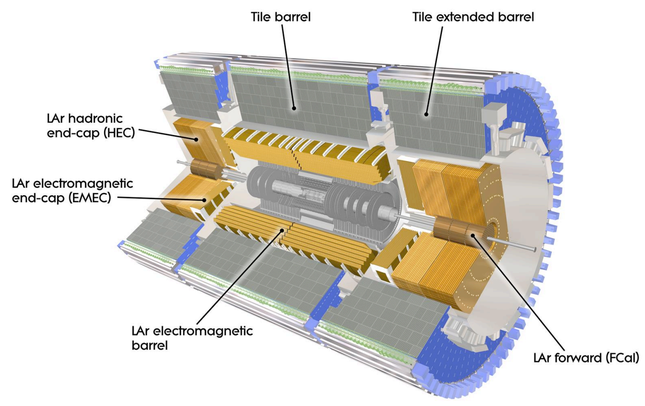
Stockholm University

Introduction

The ATLAS detector will record proton-proton collisions produced in the Large Hadron Collider at center of mass energies of up to 14 TeV. Its design allows for precision measurements as well as searches for new physics. Energy measurement using the calorimeters is crucial to these efforts.



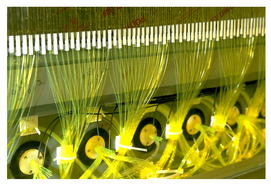
Tile Calorimeter



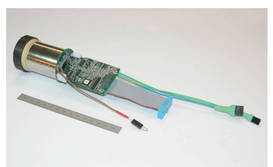
The central hadronic calorimeter consists of steel absorber plates interspersed with scintillator tiles. Barrel and extended barrel cylinders are each constructed of 64 azimuthal wedges, with three depth layers divided into projective cells of 0.1 or 0.2 in pseudorapidity, η, covering |η| < 1.7.

Readout System

Light from the scintillating tiles is delivered to the photomultiplier tubes (PMTs) via optical fibers.



The PMT output is a current pulse with its amplitude proportional to the energy deposited in the associated cell. Electronics mounted on the PMT amplifies and shapes the output pulse.

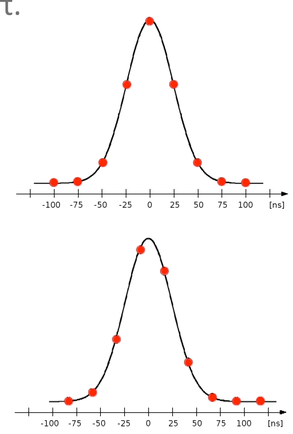


Depending on the signal size, the pulse is amplified at high or low gain, with a ratio of 64:1. Pulse shaping increases the full width at half maximum to 50 ns, for digitization at the 40 MHz bunch crossing frequency with samples at the peak and half maxima.

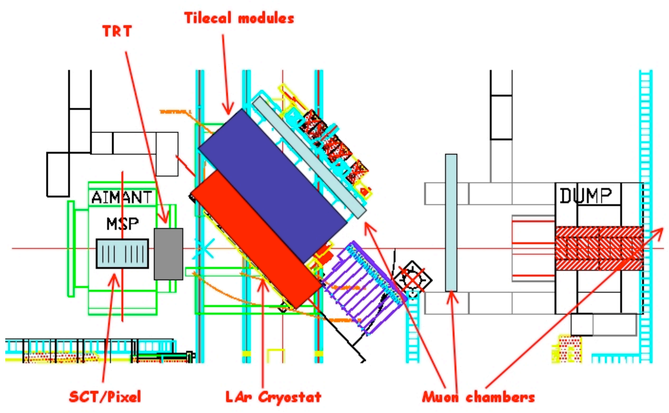
Pulse Shapes

Samples digitized at 25 ns intervals are used to reconstruct the peak amplitude of the shaped analog signal. The reconstruction uses knowledge of the underlying pulse shape to combine information from the individual samples. This reduces sensitivity to electronics noise and baseline shift.

To measure the pulse shape using test beam data, samples from events with different peak times are combined. This method provides information at points all along the pulse. Test beam data is ideal for this purpose as the beam is not bunched and supplies asynchronous signals.



Test Beam



Data from pion runs taken during the Combined Test Beam was used to measure the pulse shapes. Runs with different beam energies and incident angles produced a range of energy depositions in individual cells.

"Q-bins"

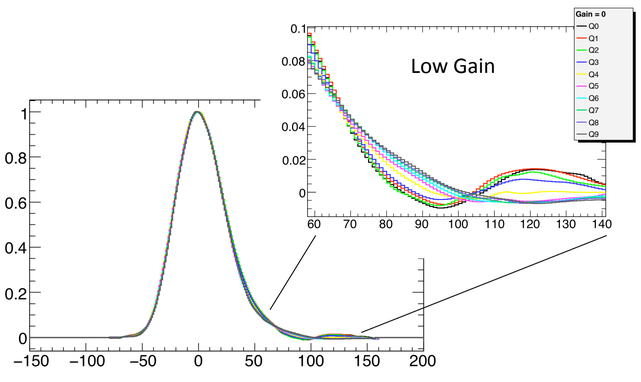
The digital readout uses units of ADC counts, where a peak amplitude of 100 counts at low gain corresponds to an energy of approximately 75 GeV.

Ten different energy bins were defined over the range for each gain based on the sum of the digitized samples in each event, S_i, minus the baseline offset determined from the first sample, S_0. The pulse shape was then measured separately for each bin.

$$Q = \sum_{i=1}^{8} S_i - 8 \cdot S_0$$

	Low gain	High gain
Q-bin	Q-value (counts)	Q-value (counts)
Q0	$30 < Q < 50$	$0 < Q < 10$
Q1	$50 < Q < 70$	$10 < Q < 50$
Q2	$70 < Q < 90$	$50 < Q < 100$
Q3	$90 < Q < 140$	$100 < Q < 200$
Q4	$140 < Q < 200$	$200 < Q < 400$
Q5	$200 < Q < 250$	$400 < Q < 800$
Q6	$250 < Q < 300$	$800 < Q < 1200$
Q7	$300 < Q < 350$	$1200 < Q < 1600$
Q8	$350 < Q < 400$	$1600 < Q < 2000$
Q9	$400 < Q < 800$	$2000 < Q < 10000$

Energy Dependence



The measured pulse shape varies slightly with signal size, particularly in the tail region and at low energies. In the signal reconstruction, a single pulse shape is used over the full energy range for each gain scale. The energy dependent bias in the assumed pulse shape leads to a small bias in the reconstructed energy, which can be corrected.

Effect on Reconstruction

Q-bin	Low gain	High gain
0	0.21 %	No data
1	0.14 %	No data
2	0.15 %	0.35 %
3	-0.12 %	0.01 %
4	-0.22 %	-0.06 %
5	-0.30 %	-0.19 %
6	-0.52 %	-0.30 %
7	-0.63 %	-0.31 %
8	-0.71 %	-0.34 %
9	-0.79 %	-0.35 %

Energy bias in different energy bins

Q-bin	Low gain	High gain
0	-0.03 %	No data
1	-0.01 %	No data
2	0.04 %	0.22 %
3	-0.06 %	0.03 %
4	0.06 %	-0.01 %
5	0.10 %	-0.14 %
6	-0.01 %	-0.24 %
7	-0.06 %	-0.27 %
8	-0.09 %	-0.29 %
9	-0.13 %	-0.29 %

Energy bias for pulse shapes cutoff at 60 ns

Impact on the energy reconstruction was determined using a toy Monte Carlo. Pseudo-events were generated from the pulse shape in each energy bin, including Gaussian electronics noise, and reconstructed with the shape averaged over all bins. The resulting fractional bias in the reconstructed amplitude is shown. Reconstruction neglecting samples in the tail region was also considered, resulting in decreased bias.

Conclusions

Signal reconstruction in the Tile Calorimeter uses knowledge of the analog readout pulse shape to determine the energy deposited in each cell from a set of samples digitized at 40 MHz.

Test beam data has been used to measure the pulse shapes and their energy dependence by combining the digitized samples from asynchronous events at different energies.

While pulse shape variation of up to 2% is observed in the tail of the pulse, the resulting effect on the energy reconstruction is less than 1%. The effect could be further reduced by excluding from the fit all samples more than 60 ns after the peak of the pulse.

Acknowledgements: This work was supported by the efforts of all collaborators on the Tile Calorimeter.