Monitoring Tool for Digital Errors in the ATLAS Tile Calorimeter Readout

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The ATLAS Tile Calorimeter

ATLAS is a general purpose experiment installed at the Large Hadron Collider (LHC) at CERN. LHC is delivering stable proton beams since 2009 and currently provides collisions at a center of mass energy of 8 TeV. The Tile Calorimeter (TileCal) is the central section of the ATLAS hadronic calorimeter. It detects hadrons, jets and taus, while also contributing to the jet energy and Missing E_T reconstruction, as well as assisting the spectrometer in the identification and reconstruction of muons.

The Tile Calorimeter

TileCal is a sampling calorimeter using plastic scintillating tiles as the active medium and steel plates as the absorber. It covers the pseudorapidity range up to $|\eta| < 1.7$ with one central Long Barrel (LB) and two Extended Barrels (EB). Each barrel is segmented in Φ in 64 modules. Radially each module is divided into three layers which are approximately 1.5, 4.1 and 1.8 λ (nuclear interaction length for protons) thick for the LB and 1.5, 2.6 and 3.3 λ for the EB. The total number of cells is 5182, while the number of channels is ~ 10000 , as most cells are read by two PMTs.

Each cell is composed of several steel and scintillating plates, the latter being read out on each side by wavelength shifting fibers. Each side of a cell is being read by a different PMT. This improves the response uniformity and provides readout redundancy.

Distribution of cells in pseudorapidity and distance from the beam axis in a module.

Cell granularity

First two layers:
 $\Delta\eta \times \Delta\Phi = 0.1 \times 0.1$
Outermost layer:
 $\Delta\eta \times \Delta\Phi = 0.2 \times 0.1$

Digital Errors

The Tile Calorimeter Front-End readout can encounter errors signaled by the Tile Data Management Unit (DMU) chip. One TileDMU chip receives the digitized data from 6 ADCs and implements circuitry for pipeline memories, buffer memories, memory parity checking, gain selection, bunch-cross identification and CRC computing. Data sent by each DMU is preceded by headers that implement the status of the error-checking done on the chip. A digitizer serves 6 PMTs and houses the associated 12 ADCs, 2 DMUs, as well as a Timing, Trigger and Control receiver (TTCrx) chip for ATLAS-wide timing and control.

A digital error is signaled in any of the following cases:

- wrong CRC generated by the DMU
- wrong bunchcross identifier
- parity error in the pipeline memories
- parity error in the buffer memories
- parity error in the header
- wrong signaling from TTCrx chip

Tile Calorimeter Digitizer and its components

Digital errors can be caused by a wide array of factors, such as electromagnetically noisy environments or fluctuations in the power supply. Moreover, considering the fact that these components are on the detector, the DMUs are susceptible to single event upsets that are caused by ionizing radiation. This is partly mitigated by the fact that the DMUs are produced using a radiation tolerant process.

Implementation

The system is implemented on a CERN virtual machine and addresses the issue of parsing large amounts of data and allowing easy access, through a web interface, to the evolution of the quantity of the digital errors of the Tile Calorimeter. The flexibility of the system allows one to perform well-defined analyses in order to identify past problems.

The output provided by the tool is:

- percentage of digital errors as a function of time
- ranking of the most problematic modules or DMUs with each of these being able to be presented both as a plot as well as a table.

Analysis configuration panel.

Time evolution of the total error rate in the Tile Calorimeter. Modules that are powered off report as having digital errors. Brown squares represent the integrated luminosity for each run.

Ranking of modules in the Tile Calorimeter for 2011, excluding the modules that are powered off.

Example of a module whose digital errors were usually cleared by power cycling. Power cycling, as well as trips of the power supply show up as dips in the 5VDIG line.

Tool Architecture

The ATLAS systems fill databases with monitoring data and run information, while the events and their associated errors are stored on the Grid.

The back end system keeps the internal database up to date with DCS and run data information. However, since grid policies require a certificate, the step that updates the database with the error rates of the Tile Calorimeter DMUs needs to be run manually, by a user who has a grid certificate.

The user interface can be accessed through a web browser. It prepares and runs the user specified analysis using a simple system (see the Implementation and Usage blocks).

Choosing the output to be presented as a plot provides an intuitive means of displaying the query results, at the expense of being rather demanding on the client machine, both in terms of CPU as well as memory.

Digital Error Monitoring Tool user interface

Usage

Applicability

This tool has been used in the maintenance periods of the Tile Calorimeter in order to spot modules that have been giving digital errors so they can be repaired. During data taking it was observed that not all digital errors are cleared by power cycling the module.

Input data filtering

Regardless of the type of analysis, input filtering can be performed on all available data or with some cuts. These can be tuned to specific needs by adjusting the following selection criteria:

- run start time. One can limit the analysis to a specific time frame
- minimum integrated luminosity. The user can require that just the subset of runs with the specified minimum integrated luminosity be considered
- minimum run length
- exclude modules. Given that the analysis may be heavily biased by the modules that are off (and have 100% of events with digital errors) or by modules that are known to cause issues, one may need to remove these. Excluding these is a key point in identifying less obvious problems
- types of errors to be considered. One can track the evolution of the rate of digital errors as a whole, not making a distinction between the type of error(s) that occurred, or turn the analysis towards a single type of digital error
- mask status. Either all errors can be included in the analysis or just the ones that are not masked

Types of analyses

Time evolution of digital errors of:

- the whole Tile Calorimeter
- a single partition
- a particular module
- a certain DMU
- a digitizer (two DMUs)

Ranking of issues:

- all modules in TileCal
- all modules in a partition
- all modules in TileCal, based on the performance of a single DMU/Digitizer
- all modules in a partition, based on the performance of a single DMU/Digitizer

System security

While total system security cannot be assured, this aspect was embedded in the design, some of its elements being:

- application of the principle of least privilege
- sanitizing strings before embedding them in MySQL queries