The Monitoring and Calibration Web Systems for the
ATLAS Tile Calorimeter Data Quality Analysis

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Abstract. The Tile Calorimeter (TileCal) is one of the ATLAS sub-detectors. The read-out is
performed by about 10,000 PhotoMultiplier Tubes (PMTs). The signal of each PMT is digitized
by an electronic channel. The Monitoring and Calibration Web System (MCWS) supports the
data quality analysis of the electronic channels. This application was developed to assess the
detector status and verify its performance. It can provide to the user the list of TileCal known
problematic channels, that is stored in the ATLAS condition database (COOL DB). The bad
channels list guides the data quality validator in identifying new problematic channels and is
used in data reconstruction and the system allows to update the channels list directly in the
COOL database. MCWS can generate summary results, such as eta-phi plots and comparative
tables of the masked channels percentage. Regularly, during the LHC (Large Hadron Collider)
shutdown a maintenance of the detector equipments is performed. When a channel is repaired,
its calibration constants stored in the COOL database have to be updated. Additionally MCWS
system manages the update of these calibration constants values in the COOL database. The
MCWS has been used by the Tile community since 2008, during the commissioning phase, and
was upgraded to comply with ATLAS operation specifications. Among its future developments,
it is foreseen an integration of MCWS with the TileCal control Web system (DCS) in order to
identify high voltage problems automatically.

1. Introduction

The ATLAS experiment [1] is one of the main detectors installed at LHC (Large Hadron Collider) at
CERN (European Organization for Nuclear Research). The ATLAS detector can be divided in four main
systems: inner tracker, calorimeter, muon spectrometer and magnet system.

The Tile Calorimeter (TileCal) [2] is the barrel of the ATLAS calorimeter outer section. It consists of
a cylindrical structure designed to absorb the energy of the particles that cross the detector. It is made of
scintillating tiles as active material and iron as absorber. The read-out is performed by photo-multipliers
(PMT).

TileCal can be divided in one long barrel section (split in two sides, A and C, respectively) and two
extended barrel sections, for a total of four read-out partitions, as illustrated in Figure 1. Each section is
divided in 64 independent wedges, the so-called modules, and their read-out is performed by up to 45
PMTs per module, which are fed by High Voltage sources (HV). The signal of each PMT is digitized by
an ADC and read-out as an electronic channel. In total, almost 10,000 channels need to be monitored.
The identification of the problematic channels during data quality analysis and the stable management of the power sources that feed the electronic channels are necessary for the optimal operation of the calorimeter.

The ATLAS experiment stores all detector conditions data in a single database, known as COOL database (COOL DB) [3]. TileCal analysis results are regularly updated in the COOL DB in order to be used in the data reconstruction.

![Figure 1. Layout of the ATLAS Tile Calorimeter (in green, with its four read-out partitions) surrounding the liquid argon electromagnetic calorimeter. The ATLAS muon chambers and the toroidal magnetic systems surrounding TileCal, are not shown.](image-url)

2. Tile Calorimeter Data Quality Assessment

The TileCal quality assessment and validation are performed through a systematic analysis process. Data are acquired and stored by ATLAS Trigger and Data AcQuisition (TDAQ) systems [4] and reconstructed by the ATLAS offline software known by the collaboration as Athena [5].

Athena is configured according to the calorimeter conditions data stored into the COOL DB. Damaged components and disconnected PMTs are taken into account in the data reconstruction. The data reconstruction is automatically started soon after a data taking session has finished. The Data Quality algorithms generate detailed results that are analyzed by the TileCal data quality (DQ) group.

As soon as data are reconstructed, an automatic system (Data Quality Monitoring Framework, or DQMF) [6] generates status report flags (good, represented by a green color; to be investigated, represented by a yellow color; or bad, represented by a red color) that certify the quality of the data, minimizing the number of channels that should be manually analyzed. A web system was developed to integrate the graphical results into a single interface, in order to support the DQ group analysis. Figure 2 shows the mentioned web system (Dashboard Web System) [7].

With the purpose of having a fast reference analyzing the TileCal channels, the DQ group accesses a list of known damaged channels, which is stored into the ATLAS conditions database. If a problem on a channel is identified during the DQ analysis process, the COOL DB is updated within one working day, so that the updated information can be used in the bulk reconstruction of the data.

The most common types of problems are: low PMT light yields, no data transmission, no PMT high voltage, data corruption, etc. Periodically, the detector is opened and faulty components are substituted. Once a read-out component is repaired or replaced, the calibration constants values, which are also stored in the COOL DB, should be promptly updated.
MCWS and DCS web systems support the work of the DQ group in the analysis of the quality of the PMTs and electronic channels. The DCS web system provides an easy and fast access to the high voltage settings of the PMTs, when a problem related to their source feed needs to be investigated.

The Monitoring and Calibration Web System (MCWS) provides the bad channels list and the calibration constants values through web interfaces. It is also possible to update the COOL DB content with the same web system.

At the end of each analysis, an automatic report is generated and the results are presented regularly to the collaboration.

### 3. Monitoring of the TileCal channels and HV settings of the PMTs

Two web systems were created for the TileCal DQ group to analyze the channels status and the HV settings of the PMTs. Both systems display data for quick reference, generate graphical results and update the COOL DB when necessary.
3.1. The Monitoring & Calibration Web System

The DQ group analysis of the TileCal channels consists in three steps: the first one occurs when the run is being taken. At this stage, the list of known problematic channels is used to correctly configure the data reconstruction; after the reconstruction process is done, the DQ validators analyze the channels information, comparing it with the calorimeter conditions data stored into the COOL DB. This is necessary to discover new damages and update constants calibration, when needed. Finally, the DQ validators report their findings to the DQ team leader, who will assess the analysis and update the COOL DB.

MCWS is composed by two interfaces that are fully described below.

(i) The Bad Channels List interface provides the list of known problematic channels, retrieved from the COOL DB, in order to help the DQ validator to find new faulty channels. One of the DQ group tasks is to assure the quality of the data as quickly as possible. It is extremely important that the validators identify new problems before the bulk of the data reconstruction begins. The graphical representation of the application consists of four circles, which represents the TileCal partitions, split into 64 slices, representing their respective modules. Figure 3 shows the Bad Channels List application.

![Figure 3. The Monitoring and Calibration Web System Bad Channels List interface.](image)

Depending on the quantity of bad channels, the modules are colored with a tone taken from a gradient scale going from red to green. By accessing a module, the user can visualize the details of the channels (Figure 4), describing the problem and the severity the damage: red color means that the channel has at least one serious problem; yellow means that the channel has problems degrading its performance, but it is still functional, and green means that the channel has no problems; The white color indicates that the PMT is not installed, while black indicates the selected channel. The selection of a channel triggers the appearance of a pop-up frame, where it is possible to to see and update the list of problems of the channels. Through this interface, it is also possible to generate a SQLite file to update the COOL DB, when necessary. After updating the conditions database, it is possible to generate eta-phi plots and summaries with the fraction of bad channels, as shown on Figure 5.

The system is protected by a password to avoid unauthorized changes to the COOL DB.
Figure 4. The Monitoring and Calibration Web System Bad Channels List interface - Channels details.

(a) Eta-phi summary plots generated by MCWS after updating the COOL DB. The summary plot can be downloaded.

(b) Summary table showing the number of bad channels.

Figure 5. MCWS summary results accessible through the interface after updating COOL DB.

(ii) If a channel is replaced or fixed during the ATLAS maintenance periods, new calibration constants values need to be updated in the COOL DB.

For the optimal operation of each TileCal channel, up to ten calibration constants are needed. The monitoring and update of these 100,000 values requires a dedicated system, the Calibration Constants interface, that is currently under development. This interface displays the constants values in a friendly way, allowing the detector expert to update the values in the COOL DB, when needed. After updating the database, the web system provides summary information on the calibration constants changes.

3.2. The DCS Web System

The TileDCS Web System helps physicists and engineers to monitor the TileCal control system. It provides information about the Low Voltage (LV) and High Voltage (HV) power supplies and monitor
their behavior [8].

The HV system is a key element of the calorimeter performance since the gain of the PMTs depends on the input voltage applied to them [9]. Each module is powered by one channel which delivers approximately 800 V to each PMT. A special regulator inside the drawer provides fine adjustment of the voltages for each PMT over a 350 V range [10]. Monitoring the stability of the 10,000 input is an important task for the performance of the calorimeter.

The DCS Web System calculates regularly the standard deviation for the PMT input voltages measurements of the past fifteen days and makes available the results through its interface dedicated to the HV system. The main interface shows the graphical representation of the TileCal barrels where each wedge corresponds to one module. These are colored with a tone taken from a gradient scale that goes from red to green according of the number of problematic PMTs (a PMT is considered problematic if the standard deviation of its HV readings is above 0.05 V), as shown in Figure 6.

The DCS Web System - PMTs status

The user can check detailed information about the channels by selecting one or more modules. Pop-up windows show the channel map colored by green (for the good ones) and red (the ones requiring a detailed check). The mean value, standard deviation and nominal value of the PMTs HV can be shown in a table.

The web system also highlights the channels where the difference between the nominal voltage and the mean value is greater than 1 V. As the PMT gain is related to its input voltage, it is very important to identify the problematic cases. A gap greater than 1 V between the preset value and its measurement is an indication of a faulty behavior, such as a malfunctioning regulator system, an incorrect setting of the nominal voltage, incorrect load of the HV value, malfunctioning hardware, etc.).

4. Conclusions

The developed web systems allow the TileCal data quality group to analyze the status of the 10,000 electronic channels of TileCal. The MCWS offers the functionalities required to update the channels status in the COOL DB and the DCS Web System monitors the high voltage sources that feed the PMTs.

The data stored into the conditions database are used in the reconstruction of the data.

1 A variation of 1 V of the PMT HV settings corresponds to a variation of the signal gain of about 1%. 
The development team foresees the integration of DCS Web System with the MCWS. When a channel problem is related with the high voltage system, MCWS will identify it automatically, employing the DCS Web System results.

The optimal performance of each of the almost 10,000 read-out channels of TileCal requires up to 10 calibration constants. The monitoring and update of these constants by the MCWS is under development.

The usage of the applications described here can be performed remotely via their web interfaces, that are protected from unauthorized access by the CERN authentication system.

Every day these web applications installed at CERN web server are used by the ATLAS DQ team to assess and update the TileCal status.

5. References