Data Quality system of the ATLAS hadronic Tile calorimeter

Stanislav Nemecek, on behalf of the ATLAS Tile Calorimeter group
Prague AS, Czech Republic
E-mail: nemecek@fzu.cz

Abstract. The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of the ATLAS experiment. It is subdivided into a large central barrel and two smaller lateral extended barrels. Each barrel consists of 64 wedges, made of iron plates and scintillating tiles. Two edges of each scintillating tile are air-coupled to wave-length shifting (WLS) fibres which collect the scintillating light and transmit it to photo-multipliers. The total number of channels is about 10000. An essential part of the TileCal detector is the Data Quality (DQ) system. The DQ system is designed to check the status of the electronic channels. It is designed to provide information at two levels - online and offline. The online TileCal DQ system monitors continuously the data while they are recorded and provides a fast feedback. The offline DQ system allows a detailed study, if needed it provides corrections to be applied to the recorded data and it allows to validate the data for physics analysis. In addition to the check of physics data the TileCal DQ systems also operate with calibration data. The TileCal calibration system provides well defined signals and the response to the calibration signals allows checking the behaviour of the electronic channels in detail. The Monitoring and Calibration Web System supports data quality analyses at the level of channels. All online, offline and calibration versions of the TileCal DQ system also provide automatic tests, the results of which allow fast and robust feedback.

1. Introduction
ATLAS[1] is one of two general purpose experiments installed at Large Hadron Collider at CERN. Proton-proton collisions at a centre-of-mass energy of 7 TeV started in 2010; in 2011 ATLAS recorded 5.25/fb. The Tile calorimeter (TileCal)[2] is a sampling hadronic calorimeter of ATLAS with iron absorber and scintillating plastic tiles as active material which are read by WLS fibers. TileCal is located in the region $|\eta| < 1.7$ extending radially from an inner radius of 2.28m to an outer radius of 4.25m. Its main goal is to contribute to the determination of jet energy and missing $E_T$. Analog signals from TTileCal are used in level one trigger. It is divided into three cylindrical sections along the beam line, each cylinder is composed of 64 equal wedges, creating granularity in phi = 0.1. By appropriate grouping of WLS fibers the granularity in pseudorapidity $\eta$ is also 0.1 except last third radial layer with a granularity of 0.2. Long central cylindrical section contains two Tile partitions – LBA and LBC, while partitions EBA and EBC is each contained in shorter extended (side) cylindrical section. Digitized signals from ~10 000 channels are transmitted by optical cables to back-end electronics in shielded against radiation technical cavern about 100m away. The TileCal DQ group is responsible for the Data Quality Assessment (DQA) of the detector and for developing the Data Quality tools. The assessment is done online during the data taking and offline from physics data (Tier0) and calibration data (CAF). Offline data quality assessment is performed on TileCal calibration runs and on the express stream of physics runs and is crucial for the go/no-go decision for bulk
reconstruction. The decision must be taken within 48 hours from the end of the run and it involves both data and detector status checks. The DQA on calibration runs is called CAF DQ and the DQA on express stream data is called Tier0 DQ. The two assessments are very different in the way the data is processed and in the infrastructure involved.

2. Tile DQ on calibration runs
Commissioning of TileCal detector at ATLAS cavern started in 2005. In parallel development of DQ tools started yielding the Tile Commissioning Web System - automated tasks needed to analyze the TileCal Commissioning runs through the Web. Today’s version is called The Monitoring and Calibration Web System (MCWS) [3] and is used for TileCal calibration runs analysis and MCWS functionality manages also the calibration constants by updating their values in COOL database [4]. Calibration data is acquired and stored with ATLAS Trigger and Data AcQuisition (TDAQ) systems and reconstructed with ATLAS offline software - ATHENA[5] within CERN Analysis Facility (CAF) for ATLAS Users. The reconstruction generates a large number of detailed plots for analysis by the TileCal DQ group. An automatic system evaluates each of these plots as green (no problem), yellow or red (require inspection) reducing the number of plots requiring inspection by the DQ group. Figure 1 demonstrates the usage of Web Interface for Shifters (WIS) for evaluating calibration runs.

![TileCal DQ WEB interface to analyze Calibration RUNs](image)

Automated tests on each electronic channel mark those outside normal limits. If some channel problem is identified during DQ analysis process, COOL DB should be updated as fast as possible.

Outliers are inspected by the Tile DQ validator – he/she inspects them using detailed plots as on figure 2.
3. Tile DQ on collision data

The ATLAS general DQ tool, Data Quality Monitoring Framework (DQMF), was successfully commissioned in the beginning of 2010 with wide scope allowing to analyze data and operational conditions, automatic checks and data archiving, visualization locally and remotely. Members of TileCal community are active in the continued development of this tool. This is a highly scalable distributed framework that is used to assess the quality of the data and the operational conditions of the detector, trigger and data acquisition system. DQMF provides quick feedback to the user about the correct functioning and performance of different parts of the detector. It quickly spots problems related with data quality and allows one to determine the origin of these problems. Many monitoring applications run online, this same DQMF framework is reused also offline.

3.1. Tile DQ ONLINE

Important part of DQMF is Data Quality Display - the visualization tool that allows great flexibility for displaying the histograms (with an overlay of reference histograms when applicable), configurations used for automatic checking of those histograms, the data quality flags, and much more. Single data quality tests are handled by DQParameters. Each DQParameter specifies what input
histogram(s) to use, what algorithm to apply (DQAlgorithm), what are the thresholds to define good or bad result (DQResult). DQParameters are grouped in DQRegions, DQRegions also have DQResults associated - the mechanism to combine the results of the subparameters is specified in the configuration. DQRegions can be grouped in parent DQRegions thus creating a DQ tree. The whole TileCal detector is represented in “Data quality layout” – next part of DQMF allowing easier understanding of the actual status of the TileCal and faster navigation to problematic regions see figure 3.

![Figure 3 Tile Layout in DataQuality Monitoring Display](image)

In 2010 frequent trips of low voltage power supplies (LVPS) located close to FE electronics of TileCal started appear in coincidence with collisions. Automatic procedures were worked out to restart LVPS and reconfigure the module as soon as possible. In rare cases this recovery procedure fails and reconfiguration has to be repeated. DQMD for TileCal was adapted to spot this problem and no module goes long time without sending good data. Special histograms showing fraction of digital errors during the data taking in each Lumi Block (usually a time period of one minute) were added. Automated evaluation of this histogram takes into account 7 Lumi Blocks i.e. the maximal time to recover the module after trip – if digital errors went up and down the result is YELLOW, only warning. The RED result is issued when fraction of digital errors did not decrease and shifter has to take the action, see figure 4.
3.2. **Tile DQ OFFLINE**

The DQ group in TileCal is headed by two coordinators, DQ leader is assigned for one month period, while DQ validator for 1-2 weeks. Their goal is to validate raw data before reconstruction of entire data starts using a sampled data set called express-stream preferentially reconstructed at the computer farm Tier0. In 2011 Data Quality assessment system of ATLAS was upgraded in manner which allows users to extract as much information (of the data) for their particular analyses as possible. In the new system, the detector flags were replaced with defects[6]. A defect represents a specific problem with the detector rather than a final DQ decision. The essential aspects of the upgraded system are: The Detector Control System (DCS) Calculator using conditions database information to automatically determine the status of sub detector components and calculate defects and The Defect Database allowing for categorization and storage of detector problems for a dynamic and flexible quality assessment. Defects come in two types: Primary defects are made directly from detector conditions; Virtual defects are logical combinations of primary and other virtual defects. Primary defects may be tolerable. The role of the virtual defect is to encapsulate the higher level logic which combines primary defects and leads to the production of good run lists for analyzers. A defect is a deviation from a nominal detector condition, a defect is either present or absent for a given Luminosity block. For the TileCal the defect “significant loss of detector covered” is INTOLERABLE, while trip of one module belongs to TOLERABLE defect. The DQ software within Tile group is all time evolving, i.e. recently was add method, when TileCal laser triggered (f=1 Hz) during the physics RUNs in empty bunch crossings is used to assess deviation from correct timing. Figure 5 illustrates the INTOLERABLE Tile defect, where several non running groups of modules (blue) create significant loss of detector coverage. Tile tolerable defect is a module trip, never more than 2 modules tripped at the same time, see detailed status of tripped module on figure 6.
4. Summary

TileCal has appropriate tools to assess the quality of the data, in 2011 the luminosity weighted relative detector uptime and good quality data delivery during stable beam in pp collisions reached 99.2% - see table below[7]. Automatic tools for LVPS trip recovery and to check correct function after trip are in usage – trip rate will substantially decrease after LVPS replacement during long shutdown in 2013-2014. The DQ tool of TileCal are under continuous development and improvement.

| Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beam in pp collisions at $\sqrt{s}=7$ TeV between March 13$^{th}$ and October 30$^{th}$ (in %). |
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4. References

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