Processing and Quality Monitoring for the ATLAS Tile Hadronic Calorimeter Data

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Abstract. An overview is presented of Data Processing and Data Quality (DQ) Monitoring for the ATLAS Tile Hadronic Calorimeter. Calibration runs are monitored from a data quality perspective and used as a cross-check for physics runs. Data quality in physics runs is monitored extensively and continuously. Any problems are reported and immediately investigated. The DQ efficiency achieved was 99.6% in 2012 and 100% in 2015, after the detector maintenance in 2013-2014. Changes to detector status or calibrations are entered into the conditions database (DB) during a brief calibration loop between the end of a run and the beginning of bulk processing of data collected in it. Bulk processed data are reviewed and certified for the ATLAS Good Run List if no problem is detected. Experts maintain the tools used by DQ shifters and the calibration teams during normal operation, and prepare new conditions for data reprocessing and Monte Carlo (MC) production campaigns. Conditions data are stored in 3 databases: Online DB, Offline DB for data and a special DB for Monte Carlo. Database updates can be performed through a custom-made web interface.

1. Introduction
The ATLAS [1] Tile Calorimeter is a hadronic calorimeter situated just outside the Liquid Argon (LAr) Calorimeter (Fig. 1), and covers the $|\eta| < 1.7$ (barrel) region of the detector. Tile is split into Long Barrel (LB) and Extended Barrel (EB) sections, roughly corresponding to $|\eta| < 1.0$ and $|\eta| > 1.0$, respectively. The crack region between the Tile LB and EB and the LAr electromagnetic barrel and hadronic end-cap sections are covered with special cells with a reduced size. In addition to ordinary Tile cells, Minimum Bias Trigger Scintillator (MBTS) covers the $2.1 < |\eta| < 3.9$ region, and is used in low-luminosity runs.

Tile uses steel absorbers and plastic scintillator tiles, which are read out with approximately 10,000 photomultipliers and related readout electronics (Fig. 2). Tiles are organized into 5,182 cells, with normal cells (not in the crack region) having two readout channels for redundancy. Tile cells and electronics are organized into 4 partitions, LBA and LBC for the A side (positive “z” direction) and C side of the barrel region, and separate EBA and EBC partitions in the extended barrel region. Each partition is divided into 64 symmetric phi slices (modules), with 45 instrumented channels in LB modules and 32 channels in modules from the EB.

2. Physics Monitoring and Data Quality
Tile monitoring includes identifying and masking problematic channels (Fig. 3), correcting for timing jumps, monitoring data corruption or other hardware issues, and (since 2015) monitoring and correcting for changes in pedestal. Immediately after a physics run ends, a subset of data,
Figure 1. Layout of ATLAS Calorimeter systems. [1]

Figure 2. Structure of a Tile Calorimeter module, including alternating layers of steel absorber and scintillating plastic tile. [2]

Figure 3. Time evolution of masked Tile cells and channels. The stability improvement from the start of 2015 correlates with the installation of new Low Voltage Power Supplies (LVPS) during the long shutdown period (2013-2014). [3]

called the “Express Stream”, is processed and reviewed. There is a short delay, known as the calibration loop, which typically lasts 48 hours, before the full dataset is processed, during which any problems identified in the express stream may be corrected with or accounted for in conditions updates. Changes to Tile timing within collision runs are monitored by Laser calibration events in the empty bunch crossings of physics runs, used to apply timing offset corrections to data.

The Tile Data Quality Validator (DQV) remote shifter reviews the express stream processing of each run to check for any issues. Tile uses a specialized web interface to generate an initial report for the shifter to finish, based on the results of automated data quality monitoring tests. The Tile Data Quality Leader (DQL) shifter reviews the DQVs report and takes any necessary action. If a problem cannot be corrected, it is entered into the ATLAS Defect database. If the
problem is considered intolerable, then the affected data are removed from the ATLAS Good Run List and are not used in physics analyses.

![Data Loss vs Date](image)

**Figure 4.** Data losses during the $\sqrt{s} = 8$ TeV data taking period (2012). Some losses, including power cuts and timing jumps, are correlated with LVPS trips. [3]

A fraction of Tile data losses in Run 1 were related to sporadic tripping of Low-Voltage Power Supply (LVPS) units, including changes to timing after trip recovery (Fig. 4). Redesigned LVPS units were tried on a part of the detector in 2012, and found to virtually eliminate the problem. All older units were then replaced by the new ones during Long Shutdown 1 (2013-2014). This exercise is also thought to have led to a significant reduction in the number of bad channels from Run 1 to Run 2, as well as a reduction in timing jumps. Tile achieved 99.6% DQ efficiency in 2012 and 100% in 2015, with minor (< 1%) losses by the start of October, 2016.

### 3. Calibration

A Cs-137 radioactive source is used to calibrate Tile response. The Laser calibration system [4] is used to correct for drifts in photomultiplier response between Cs scans, validated against drifts seen in the Minimum Bias integrator system (Fig. 5). Laser, Charge Injection, and Pedestal calibration runs are used to monitor timing, stability, and noise. [5]

Calibration runs also undergo assessment from a data quality perspective. This serves as an additional cross-check for any problems that may be seen in physics runs, and allows the DQ team to continue monitoring detector status during technical stops or shutdown periods, to help prioritize maintenance tasks. Slightly different sets of monitoring histograms are produced for each run type, as appropriate, to monitor channel response, timing, pedestal and noise, as well as stuck bits and various other forms of data corruption, which are not always easy to monitor in physics runs. Automatic tests are run to identify and flag channels with problems, and cross reference with known issues from the conditions database.

A specialized web interface is used by the Tile shifters to analyze calibration runs approximately twice per week, excluding Cs scans, which are taken about once every 6 weeks. This displays the results of the automated tests, as well as the corresponding monitoring plots, and is used by the shifter to assess the severity of a problem and classify it accordingly, and to automatically file a summary report when finished.
4. Conditions and Data Preparation

The conditions database (CondDB) is split into separate instances for online data taking, offline data (re)processing, and the production of simulated Monte Carlo (MC) data. Conditions data within each instance are organized into a hierarchical folder structure, similar to a filesystem. Folders in the offline and MC databases support multiple tagged versions, while the online database uses single tag folders. Each tag contains a set of condition which are split into Intervals of Validity (IOVs) to allow for conditions to be different from run to run, or from minute to minute within a run. One tag from each folder is linked to the global CondDB tag, and linked tags are restricted from making changes to IOVs for runs in the past, to ensure reproducibility of results.

Changes to detector status or calibrations are entered into the CondDB during the brief calibration loop between when a run ends and the full (“bulk”) processing begins. The updated conditions may be added to the database manually through command line tools, but this process is most often expedited using a custom Tile web interface, referred to as the “robot”, which simplifies many common tasks and automates much of the update process.

A new tag may also be created to include changes to runs that are no longer in the calibration loop. This is often done shortly before any major data reprocessing or MC production campaigns. The data quality and calibration teams use reprocessing campaigns to correct any problems which could not be fixed at the time of the original processing. This can occur when a change in detector status cannot be corrected for until after the next set of calibration runs. In such cases, the affected channels are masked in the original processing, and may be unmasked in the reprocessing. Channels which remain masked often have the masking extended to the beginning of the data taking period, to simplify detector modeling in MC data.

5. Conclusion

The ATLAS Tile Calorimeter is used to measure energy from the hadronic component of jets. Tile shifters monitor the quality of the data from collision runs and cross validate against
calibration runs. Calibrations are taken at least once per week, and are used to correct for changes to detector conditions, including drift of readout gains, changes in pedestal, and timing jumps. Shifters and experts store these changes in the Tile Conditions Database, which are then used for data (re)processing and Monte Carlo production.

References
[1] ATLAS Collaboration, 2008 JINST 3 S08003,
[2] ATLAS Collaboration, 2013 JINST 8 P01005,
[3] ATLAS Collaboration, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTile,
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[5] ATLAS Collaboration, EPJC 70 (2010) 1193.