The ATLAS Tile Calorimeter Software Tools for Data Quality Monitoring

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on behalf of the ATLAS collaboration

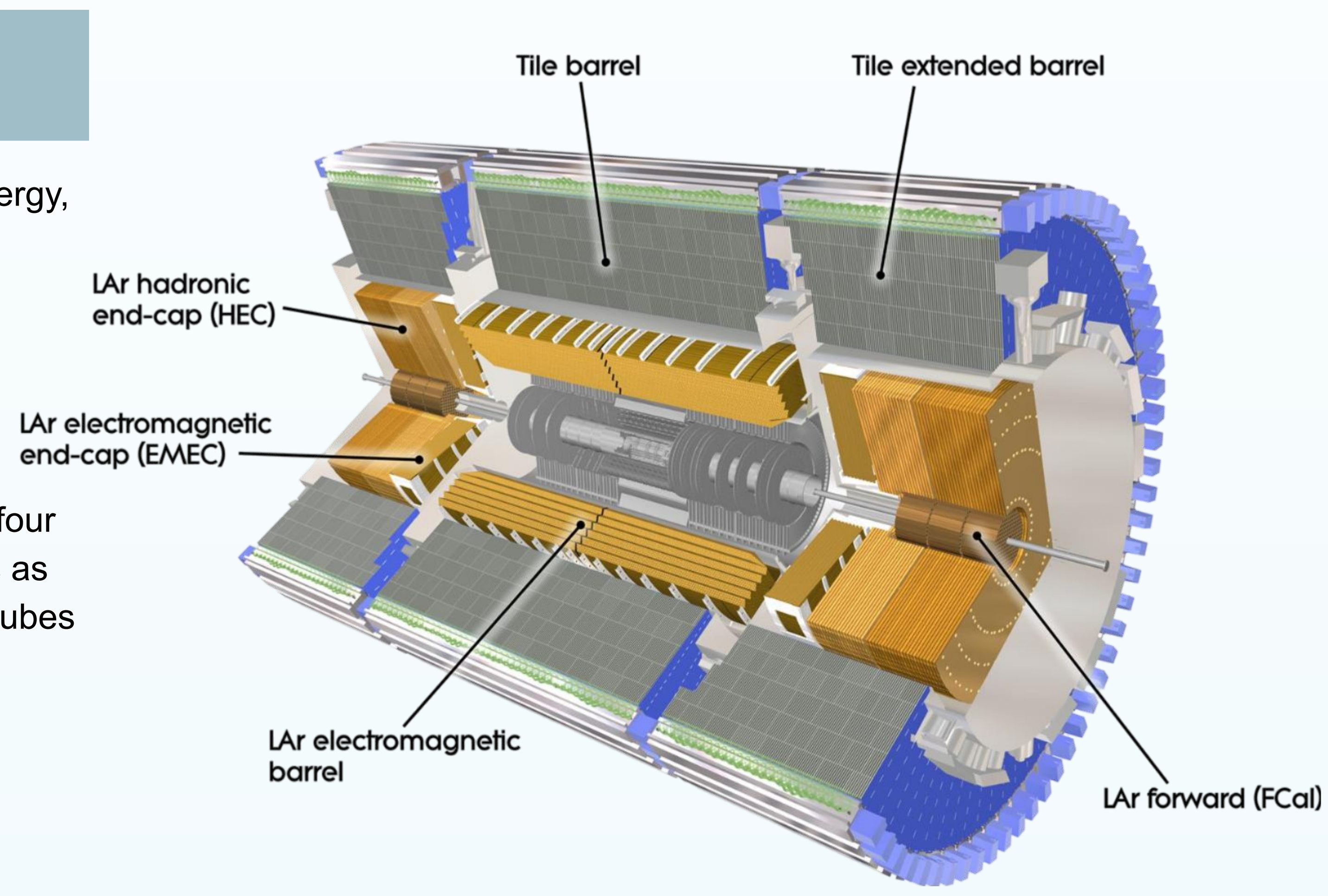
1. ATLAS Tile Calorimeter

The **ATLAS Experiment** [1] at CERN's **Large Hadron Collider** is a versatile detector designed for measuring particle momentum, energy, and identification. Its core component, the **Tile Calorimeter (TileCal)** [2] plays a crucial role in hadronic calorimetry, contributing to:

- Jet energy measurements
- Tau lepton decays
- Missing transverse energy
- Muon identification and trigger inputs

TileCal consists of three main sections: a **long barrel** (|η| < 1) and two **extended barrels** (0.8 < |η| < 1.7). The readout is divided into four readout partitions: **LBA**, **LBC**, **EBA**, and **EBC**, with a total of 4x64 modules. This **sampling calorimeter** utilizes plastic scintillator tiles as the active medium and steel as the absorber. Signals from the scintillator tiles are transmitted through optical fibers to photomultiplier tubes (PMTs), where they are converted into electrical signals. Key features of TileCal include:

- There are **5182 readout cells** and **9852 channels**, each cell is read out by two PMTs (except the special ones).
- **Signal amplification** through two amplifiers with a gain ratio of 1:64.
- **Digitization** via 10-bit Analog-to-Digital Converters (ADC) at a sampling rate of 40 MHz over 7-sample windows.
- Electronics for each module are controlled by **Data Management Unit (DMU)** chips, with up to 16 DMUs per module.



2. Data quality monitoring

The signal from each channel in the TileCal is first converted from ADC counts to electric charge (pC), and then to energy (GeV). This conversion is calibrated through test beam campaigns, while continuous monitoring is necessary to adjust for factors like scintillator aging and voltage or electronics stability. TileCal employs several calibration systems:

- **Cesium Source Calibration**: Emits gamma rays to calibrate the analog parts of the readout and monitors changes in the electromagnetic scale over time.
- **Laser Calibration System**: Measures the response of PMTs.
- **Charge Injection System (CIS)**: Injects a known charge to test the electronics' conversion between pC and ADC counts, and it performs scans to assess both linearity and stability.
- **Electronic Noise Measurement**: Is evaluated by analyzing runs with no signal.

Raw data from calibration runs are processed using Athena [3] software, producing histograms for further testing. Two types of tests are conducted: one to check data consistency from DMU chips and another to monitor signal quality from individual channels. Each channel or DMU is assigned a **Data Quality Monitor (DQM) status**, which can be:

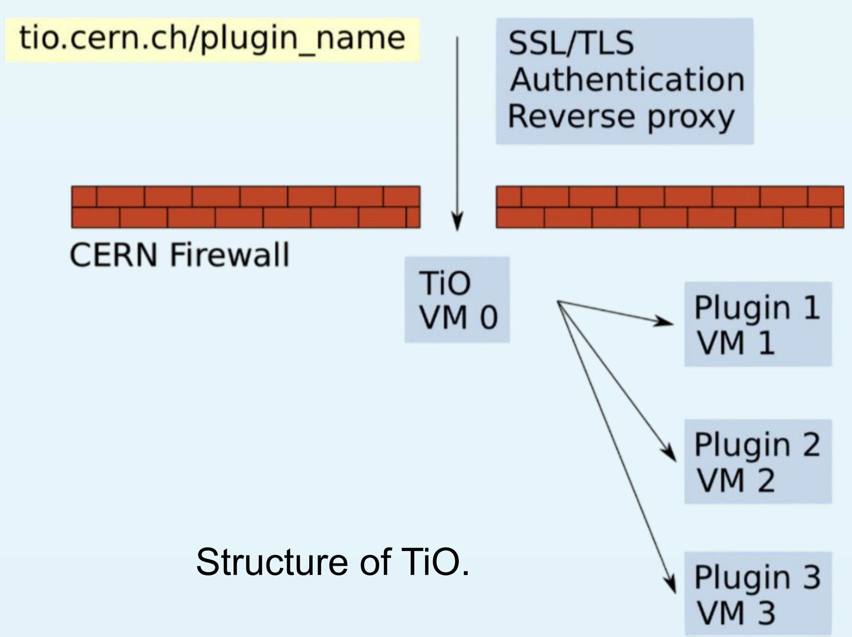
- **Green**: All results are within the expected range.
- **Yellow**: Minor issues, usually affecting one channel.
- **Orange**: More serious issues, affecting two or more channels.
- **Red**: Serious problems, affecting multiple channels or the entire module.
- **Undefined**: No / low statistics to evaluate.

The module's overall status is determined by the worst test result. Although this process is automated, **Data Quality Validators (DQVs)** manually review and submit the final reports, which are then used by **Data Quality Leaders (DQLs)** for further discussion and evaluation.

3. Tile-in-One

The **Tile-in-One (TiO)** [4,5] platform provides a unified space for all TileCal-related web applications.

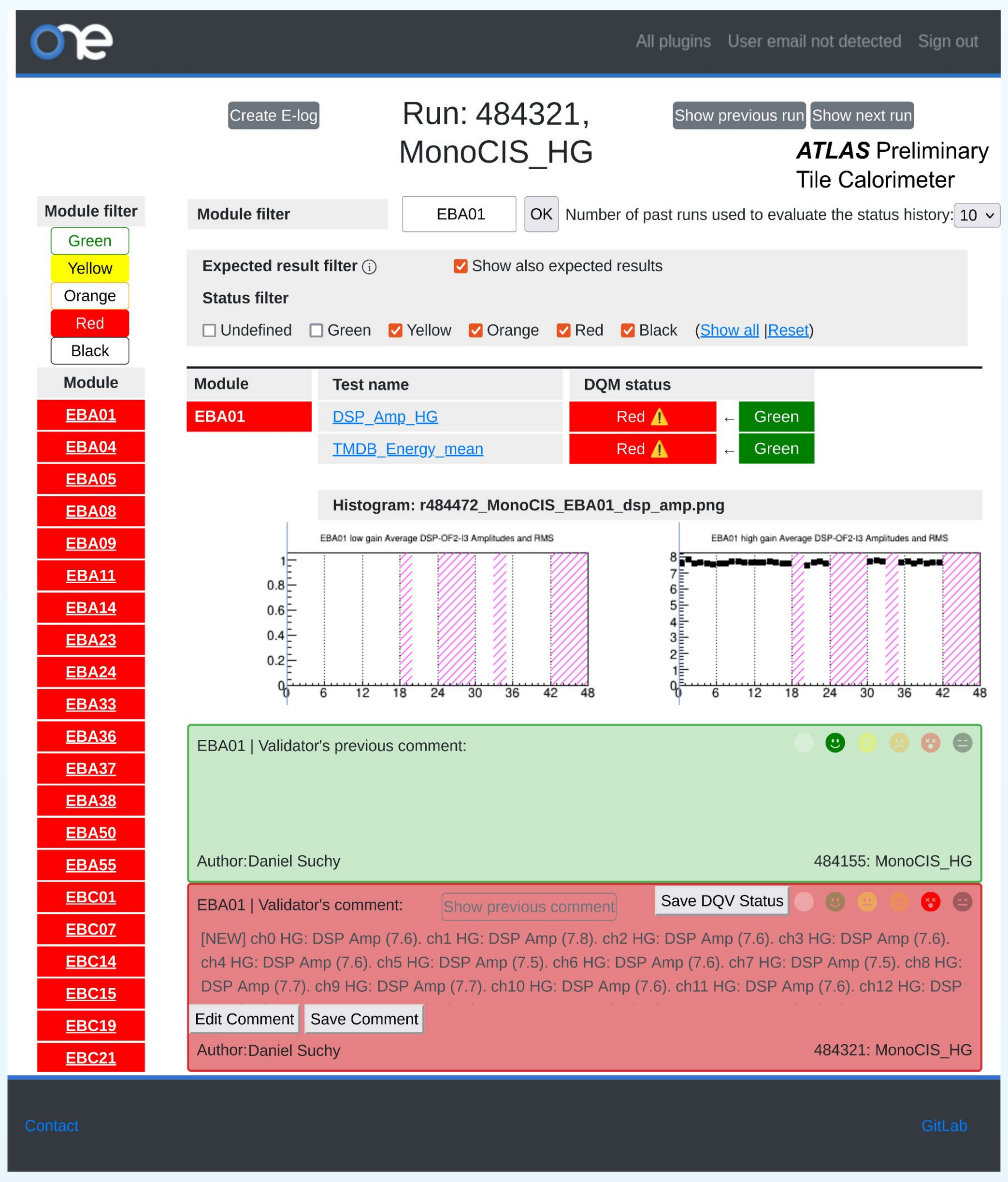
It is structured around a central server that manages user authentication and acts as a proxy for individual web applications, known as plugins. These plugins operate on their own virtual machines, typically utilizing a shared template with Python-based tools like uWSGI and Bottle. Such setup enables direct access to data files through CERN's ROOT framework.



Structure of TiO.

5. Analysis of problematic modules

The analysis starts by selecting the specific run. During this process, the DQV can efficiently filter identified issues in individual modules based on their severity. These filtered results are presented through the existing DQ History plugin, which is integrated as an iframe within the calibration runs analysis plugin.

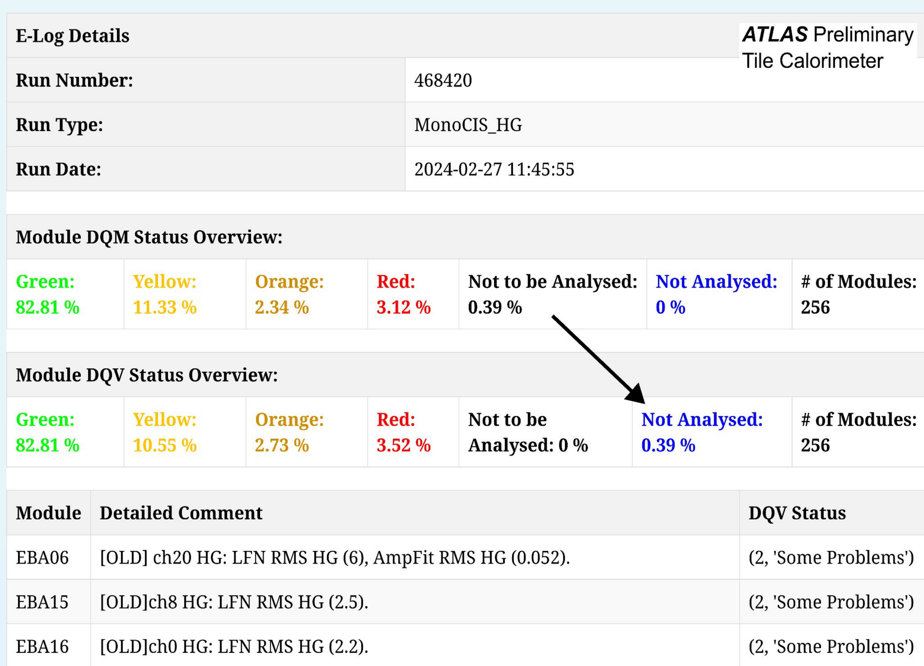


The DQ History plugin provides detailed information about the current status of the module, including:

- **DQM status**
- **Name of the problematic test**
- **Occurrence history** of DQM statuses in previous runs
- **Relevant plots** illustrating the issue

The DQV can also see previously logged comments on the module's issues and its status. They can add new comments about the current status of the module and update the DQV status as needed.

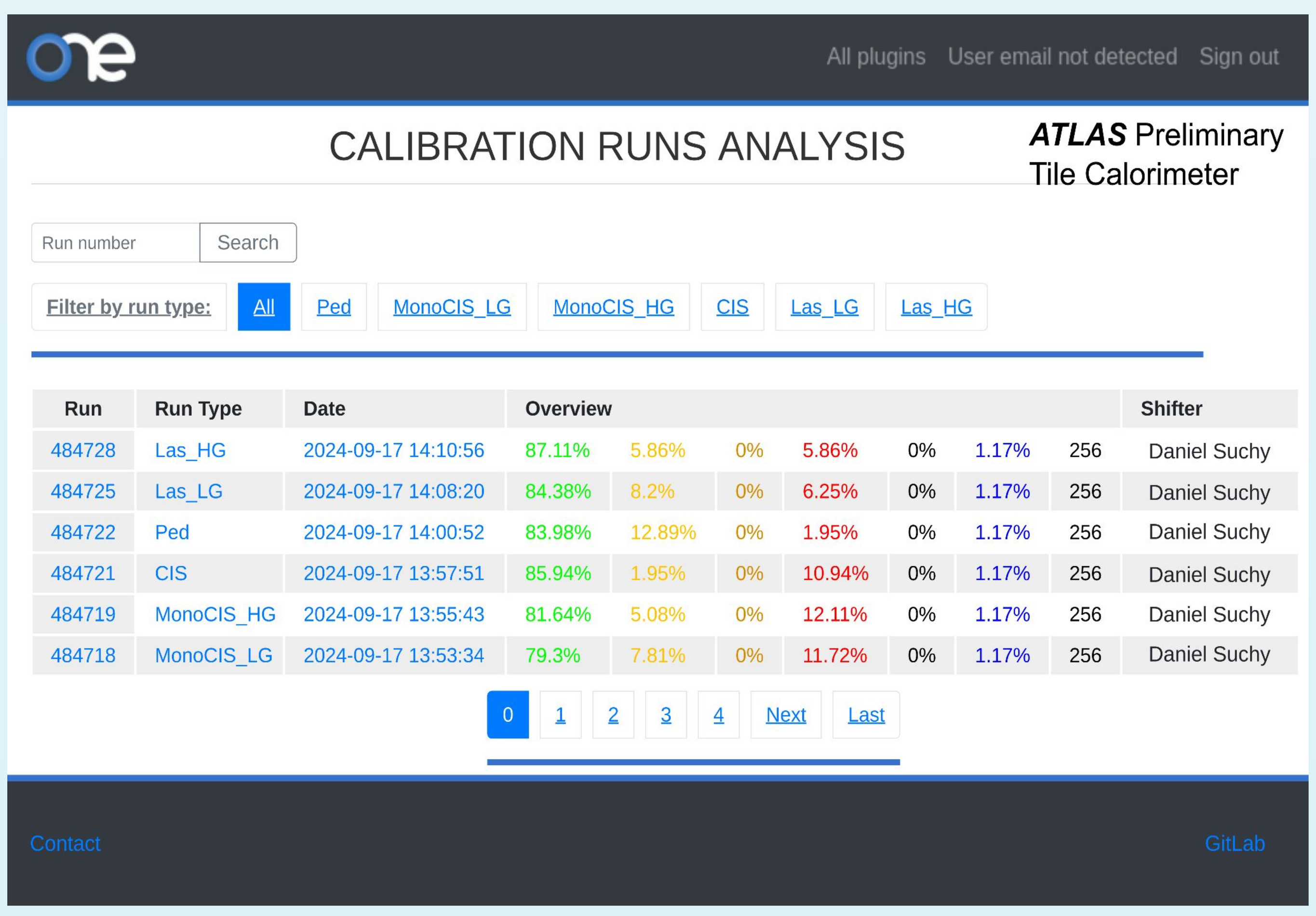
When comment or status updates are saved, they are stored in the testing database, with the name of the DQV associated with each entry, ensuring transparency in the editing process.



The plugin facilitates seamless navigation between modules with a single click, loading all necessary data. This simplifies the analysis process, allowing the DQV to efficiently continue the validation work across modules.

Upon completion of the analysis, the final output is an E-log that consolidates the details of individual modules and their associated issues. This E-log is made accessible to the DQLs providing a comprehensive summary that enables them to efficiently present and compare the current problems with those observed in previous calibration runs. This offers a concise and structured format for further reporting and decision-making.

4. Analysis of calibration runs



The analysis of calibration runs is conducted by **DQVs**, who require access to relevant information to diagnose issues identified by automatic tests. The **calibration runs analysis** plugin is designed to streamline the validation process currently managed through the **TileCal Web Interface for Shifters** [6], reducing the time required and simplifying the overall workflow.

The main interface of this plugin closely resembles the existing **DQ History** plugin main page. The **DQVs** can select which run to analyze and filter runs by type or run number. Key features include:

- **Run Type**: Indicates the calibration method used to generate the data.
- **Date**: Specifies when the run was conducted.
- **Overview section**: Presents a proportional breakdown of the statuses for all modules, displaying the percentage of each status (e.g., green, yellow) in relation to the total number of modules. This is similar to the automatically generated DQM, but these statuses are specifically defined by DQVs and referred to as **DQV statuses**.
- **Shifter**: This column shows the name of the DQV whenever they save a DQV status or comment on a module.

6. References

[1] ATLAS Collaboration. In: JINST 3 (2008), S08003.
[2] ATLAS Collaboration, Eur. Phys. J. C 78, 987 (2018), 1806.02129
[3] The ATLAS Experiment's main offline software repository, https://gitlab.cern.ch/atlas/athena
[4] Tile-in-One, https://tio.cern.ch/documentation/index.md
[5] EPJ Web of Conferences 245, 01010 (2020) https://doi.org/10.1051/epjconf/202024501010
[6] TileCal Web interface for shifters, https://pcata007.cern.ch/tcws/dashboard/current/showRunList.php

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