PROCEEDINGS OF SCIENCE

ATLAS Tile Calorimeter Temperature Data Analysis on a Continuous Basis

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ATLAS Tile Calorimeter (TileCal) is an experimental tool used in particle Physics for measuring the energy of particles produced in high-energy collisions. Its performance and stability depend on careful observation and analysis of several operating parameters, temperature data being especially important. This study presents the continuous approach to the temperature variation of the ATLAS TileCal drawers, extracted from the Detector Control System (DCS). The TileCal DCS continuously monitors all the hardware and infrastructure for each subsystem. The Tile-inOne (TiO) tool is used to visualize and analyse this temperature study. The TiO is a collection of small, independent web tools called plugins. Plugins assess the quality of data and conditions for ATLAS TileCal. A comparative analysis is done to determine the development of the leaks or improvements achieved in the cooling system and the stable values of the temperature in the drawers. The work aims to continuously study the variation of temperature in the module over a short period of time using the TiO platform and display it to a user in a friendly and intuitive manner using contemporary web technologies. The plugin ensure that temperature fluctuations remain within a specified 0.2 °C threshold, as deviations beyond this range significantly impact TileCal drawer components such as PMT gain variation. The study shows that the temperature variation is maintained at ±0.2 °C.

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1. Introduction

Understanding and monitoring the temperature dynamics within the Tile Calorimeter (TileCal) system are paramount, as temperature fluctuations can significantly influence the performance and stability of the TileCal components such as Photomultiplier Tubes (PMTs). The PMTs, responsible for converting scintillation light into electrical signals, are sensitive to environmental changes, including temperature variations. Consequently, a comprehensive analysis of temperature data on a continuous basis is indispensable for maintaining optimal PMT functionality and ensuring the accuracy of physics measurements within the ATLAS experiment at the Large Hadron Collider (LHC) [1]. Monitoring and analysing temperature data continuously is crucial to ensure optimal performance and accurate particle energy measurements. In this study Tile-in-One (TiO) web platform is utilised to create Temperature mapping under Detector Plugin. The ATLAS detector is a large general-purpose detector at the Large Hadron Collider (LHC) that investigates various physics topics, including the Higgs boson, dark matter particles, Standard Model investigations and searches for extra dimensions. It consists of sub-systems to identify particles and quantify their momentum and energy. The detector can perform collisions at 13.6 TeV and has instantaneous luminosities up to $2.03 \times 10^{34} cm^{-2} s^{-} 1$. ATLAS consists of sub-systems for particle identification and momentum and energy quantification, arranged in cylindrical layers around a 44m long barrel with a 25m diameter beam pipe. The central part of the hadronic calorimetry system is the TileCal shown in Figure 1, which measures the energy of jets, tau leptons decaying hadronically, and missing transverse energy. The TileCal is a sampling calorimeter composed of alternating pieces of plastic scintillating tiles acting as an active medium and iron used as an absorber. It has two Extended Barrels (EB) and one center Long Barrel (LB) covering the pseudorapidity range up to $|\eta| < 1.7$. Every barrel is divided into 64 segments in ϕ. Wavelength-shifting optical fibers gather signal from groups of tiles (readout cells) and transfer it to photomultipliers (PMTs) for conversion to electrical signal [2].

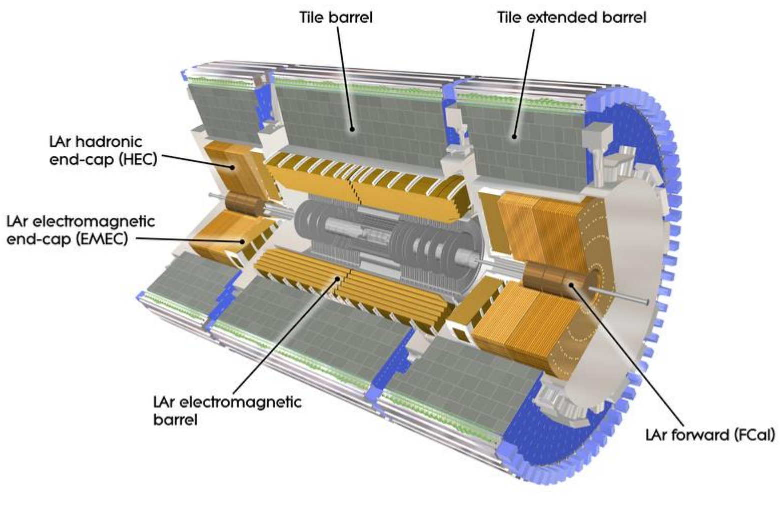

Figure 1: Configuration of the ATLAS TileCal (grey), with four read-out partitions encircling the liquid argon electromagnetic calorimeter.

The PMTs are used as photo-detectors. The Detector Control System (DCS) in the ATLAS detector is in charge of making sure that the electronics and infrastructure are running safely. TileCal DCS constantly checks hardware parameters including voltages and temperatures. With sensors positioned in various places as shown in Figure 2, including power supplies and monitoring boards, the TileCal DCS monitors the temperature of the FE electronics [3].

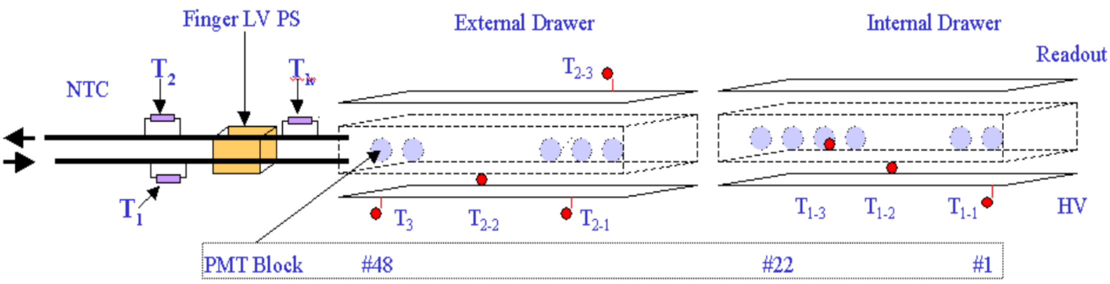

Figure 2: The locations of the cooling pipe and drawer temperature probes. The HV system cards are located at the bottom of the drawer and the readout electronics are located at the top. The temperature sensors for cooling water entering and leaving are T1 and T2, respectively. Red dots represents the temperature probes in the drawer. T_{1-1} and T_{2-1} are probes of the internal and exterior HV opto board, respectively. T_{1-2} and T_{2-2} are probes inside and outside the drawer. T_{1-3} is the probe for PMT block 22. T_{2-3} is the card's interface probe. T_3 is the HV micro card probe

The DCS and the HV distribution system allow voltages between 550 and 950 V to be applied to the PMTs. A change in the HV supply affects the gain of the PMT. When the PMT is affected by temperature or other factors, readout electronics produces readings that are highly inaccurate.

2. Temperature monitoring in TileCal

The PMT is a multipurpose tool with incredibly high sensitivity and ultra-fast response. The temperature monitoring has a precision of 0.1 ℃. The PMT gain changes by 0.2% for every 1 ℃ change in temperature. The temperature was kept within 0.2 ℃, during Run 1 and 2. It is imperative to closely monitor the temperature in the TileCal and promptly detect any tiny variations above 0.5 ℃ every day. High voltage delivered to PMTs affects their gain, as per equation 1.

$$G \propto HV^{\beta} \tag{1}$$

where G is the PMT gain, HV is the high voltage and β is the parameter determined experimentally ~ 7. The TileCal drawers need to stay at a consistent temperature for a number of reasons, such as: calibration of the TileCal modules; stability of the electronics and gain stability of the PMTs; and assessment of PMT test bench properties at a specific temperature. The TileCal uses the Leakless Cooling System (LCS) to maintain the uniformity of the temperature along the drawers. The LCS is a water cooling, functioning below an atmospheric pressure to prevent leakage [3].

3. Tile-in-One web platform

The Tile-in-One (TiO) web platform, part of the TileCal Collaboration, enables users to access shared data and services, as well as computing resources. TiO consists of independent web tools called plugins that assess data quality and conditions for TileCal. The platform aims to combine data analysis by the TileCal community and simplifies platform maintenance by allowing users to write source code directly on the web. Plugins are accessed through a main server hosted at https://tio.cern.ch. The platform features a reverse proxy (Nginx) and separate virtual machines on the OpenStack instance at CERN. New plugins are developed using Bootstrap 4 and Bottle frameworks, and source code is hosted on CERN's GitLab instance and managed using Git. Each plugin has a defined person or group in charge [4].

4. Temperature data plugin

The connection between the front-end, back-end, and templating for the visualization of the temperature probes of the HV system and the readout electrical side of the drawer is summed up in Figure 4.1.

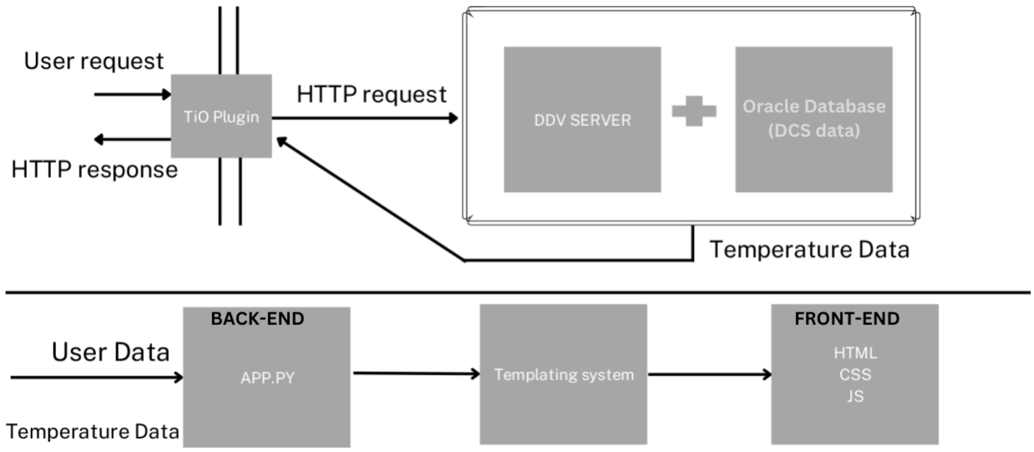

Figure 3: A summary of the process followed in order to use the DDV server to retrieve data from the Oracle database. The temperature data is managed on the back-end by the Python script (app.py), and templating system uses JS, CSS and HTML before sending it to the user (front-end).

A user has options which probe want to visualise. The temperature data for probe 2 is displayed in figure 5. The ability of the plugin to extract, analyse, and visualise temperature data is successful. The minimum and maximum temperatures of the particular probe are used to map colors. The detector's drawers for each module in each division are represented by polygons. The code begins by applying a grey fill color to every polygon on the page. A grey polygon indicates that either a module is off or an array is empty.

The temperature profile shown in the graph is impressively typical across different modules, with very little variation that stays well within the permitted bounds. The minor changes recorded in the temperature readings consistently keeping within the acceptable range suggest a high level

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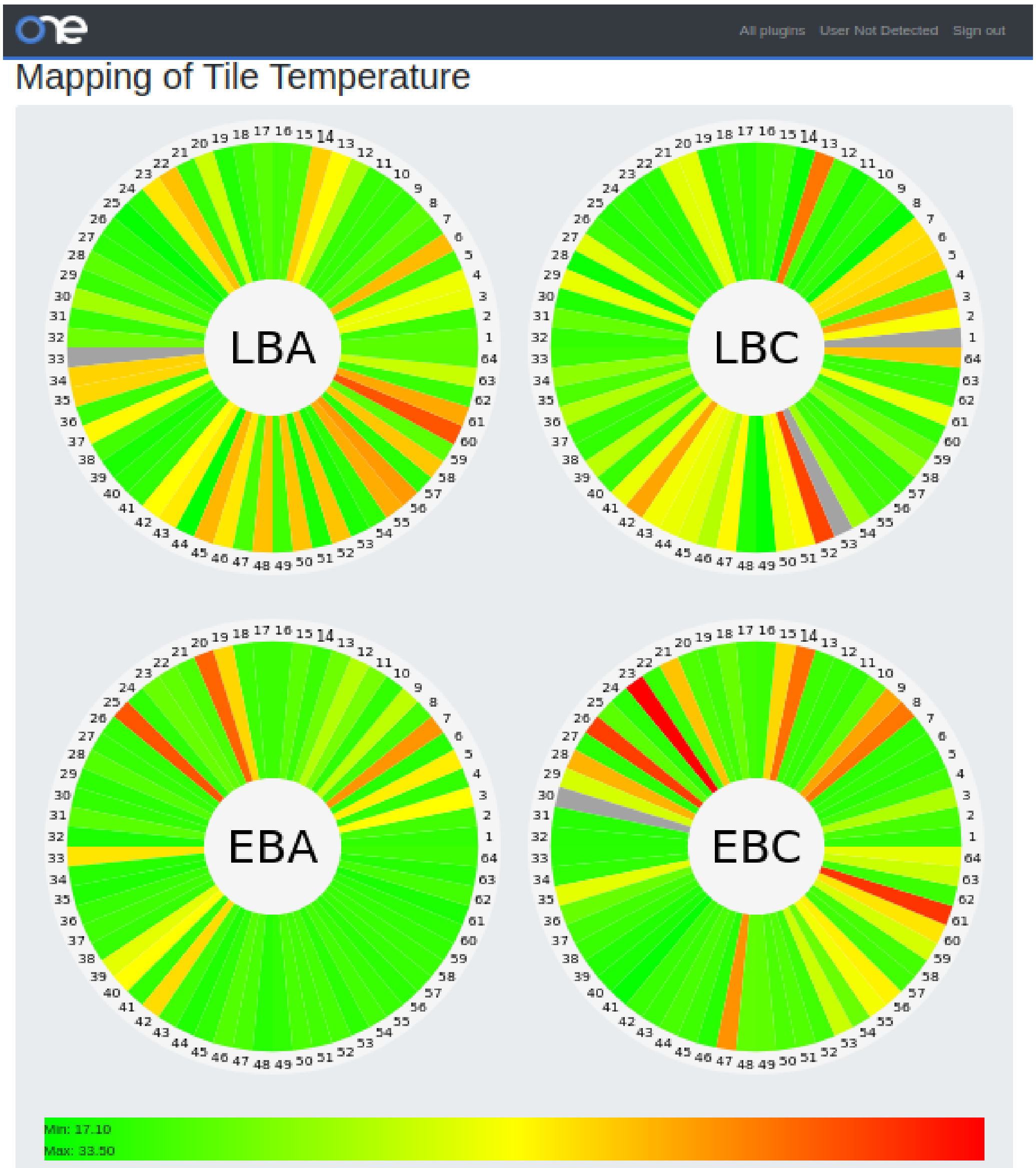

Figure 4: a picture of all four partitions obtained between October 18 and 22, 2023, from `https://tio-dev.cern.ch/detector/temperature/2`. The probe 2 has a minimum temperature of 17.10 °C and a maximum temperature of 33.50 °C.

of precision and control over the thermal conditions within each module. This precision is very important since it guarantees that the PMT gain won't change, which keeps sensitive detection processes stable and reliable. Analysing the historical data confirms the stability pattern and demonstrates a reliable history of temperature maintenance within the designated range during different operational cycles. A user can also have option to either visualise one module with all the probes or one probe in the drawers. Figure 6 only shows all seven temperature probes for long barrel module. This helps to see the variation between the minimum and maximum temperature data.

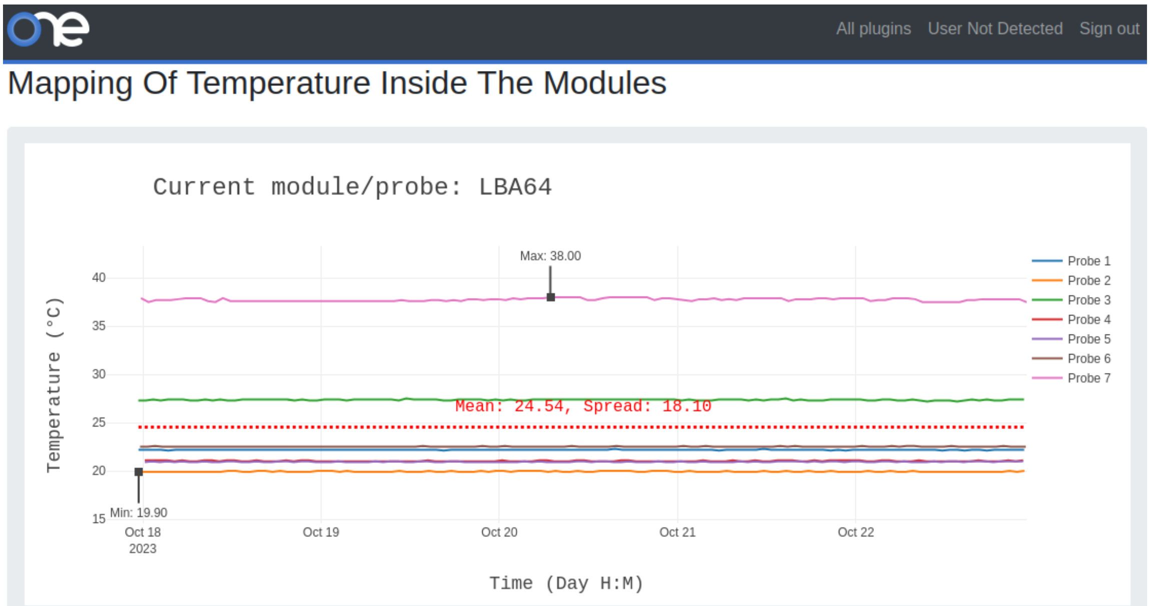

Figure 5: A screen grab of the LBA 41 partition obtained from https://tio-dev.cern.ch/detector/temperature/lba/41.

5. Summary

The findings presented in this research demonstrate the viability of developing a temperature plugin that is user-friendly, intuitive, and incorporates modern technology. The outcomes are in line with run 3, which maintains a temperature of 0.2 ℃. This temperature variation demonstrates that the gain varies by no more than 0.5%. The findings indicate that in order to ensure the electronics' stability and the PMTs' stability, TileCal drawers are kept at a steady temperature The PMT gain cannot alter as a result of these temperature variations. Finding the probe in the HV system and the readout electronic side where the temperature increases or lowers too much over time is the main task at hand.

References

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[4] Y. Smirnov and J. Smieško, *Tile-in-one: an integrated system for data quality and condition assessment for the atlas tile calorimeter*, in *EPJ Web of Conferences*, vol. 245, p. 01010, EDP Sciences, 2020.