Implementation of the LED Integrator panel for the Prometeo system in the ATLAS Tile Calorimeter

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Abstract. The high-luminosity upgrade to the LHC (HL-LHC) poses significant issues for the ATLAS detector, including increased radiation exposure to the on-detector electronics and higher pileup from low momentum collisions compromising the operation of the trigger selection system. Almost every electronic component of the Tile Calorimeter (TileCal) will be upgraded during the ATLAS Phase-II Upgrade. During the assembly, installation, and maintenance phases of the new on-detector readout electronics system, its correct functionality must be validated by a portable system. Prometeo (Portable readout module for tile electronics) is an improvement to the MobiDICK system, which was utilised to assess current electronics during the Long Shutdown 1 and 2. To achieve precise calibration of the Tile calorimeter and to be able to measure individual parts of the detector readout chain, a set of calibration systems is used. Signals from the PMTs are conditioned and digitized by readout electronics, and slow readout measures the integrated current from the PMTs in parallel. This slow readout, known as the integrator, is used for light yield cell calibration and LHC luminosity monitoring. An Integrator Panel has been integrated into the Prometeo web interface and we present the current status and test results.

1. Introduction

The Large Hadron Collider (LHC) at CERN will will push the limits of particle physics with its unprecedented high energy and luminosity. The upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC) [1] allows for a plethora of physics studies but provides significant challenges to the detector, trigger, and data acquisition systems in the form of increasing trigger rates and detector occupancy.

The ATLAS Tile Calorimeter (TileCal) is the central hadronic calorimeter section of the ATLAS experiment [3] at the LHC as illustrated in Figure 1 and it is made of steel as passive material and scintillator plates (tiles) as active material [4]. In preparation for the HL-LHC, the TileCal will require new electronics to provide a low-latency, high-frequency and fully digital input for ATLAS trigger system. Therefore Test benches, are being developed to validate the assembly of components into the mini-drawers and their installation into the ATLAS detector.

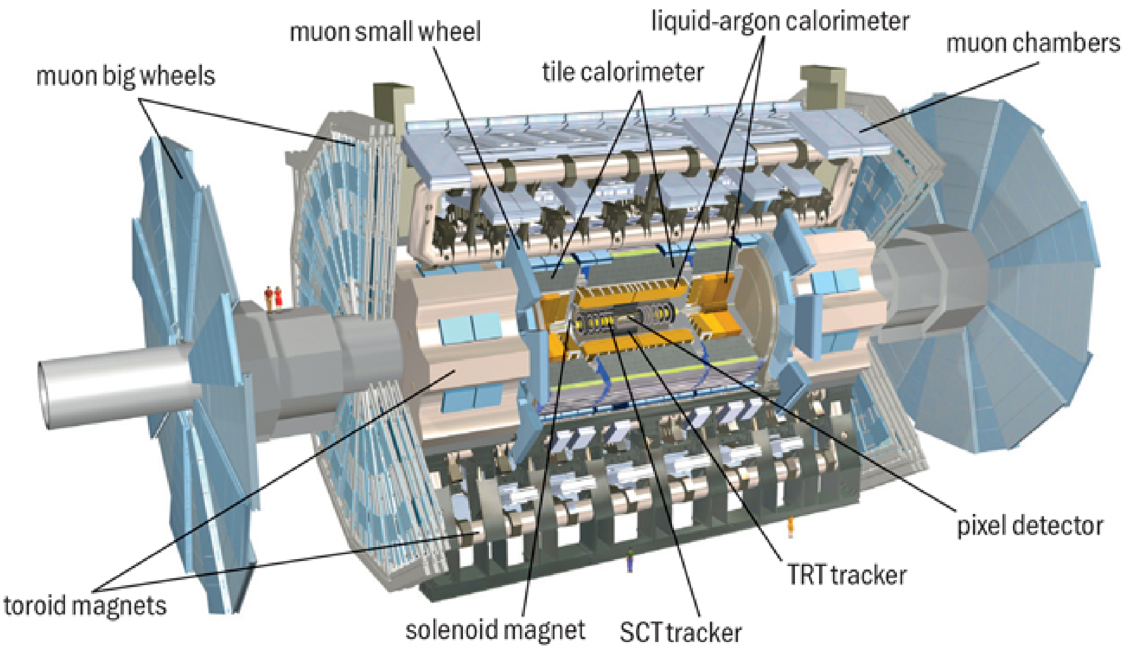

Figure 1: The layout of the ATLAS detector, showing some of the key components. Overall, the detector is 25 m tall and spans some 40 m from end to end. This image was taken from Ref [2] .

A lighter more portable Test station, called the Prometeo will be used to validate the installation (see Section 2) of the mini-drawer into ATLAS and perform the initial quality assurance.

2. Prometeo

The Prometeo is a portable test bench used to certify front-end electronics of the TileCal at the HL-LHC. It is a high-throughput electronic device designed to simultaneously read all all digitised samples from 12 channels at the LHC bunch crossing frequency and evaluate the data quality in real time. electronics. The design inherits features from the presently-used MobiDICK4 test-bench [5]. Prometeo must be able to test, among many other things, the following: connection with mini-drawers (MD), connection with Daughterboard (DB) and MainBoard (MB), Photomultiplier Tubes (PMT) and Charge Injection Linearity. To test the PMT-Blocks' responsiveness to light pulses, an LED system must generate light pulses that simulate physics pulses. The PMT-Block teststand for testing the response of 12 PMT-Blocks to light (corresponding to one mini-drawer).

2.1. Prometeo functions and usage

The PMT-Block teststand shown in Figure 3 is designed to validate the functionality of assembled PMT-Blocks but is not intended to measure PMT properties. The initial step of mini-drawer construction is the production of up to 12 PMT-Blocks, which will be used to populate the mini-drawer. Each PMT-Block includes an active separator and a FENIC card. Once the 12 PMT-Blocks have been built, they are placed and tested on a PMT teststand designed to accommodate 12 PMT-Blocks (Figure 3). The PMT teststand is equipped with its own MB, DB, and High Voltage (HV) distribution board. The portable HV of Prometeo is connected to the HV bus board in order to deliver HV to the 12 PMT-Blocks [6]. The Prometeo LED generates

Figure 2: Light tight box for the phase-2 PMT teststand showing 12 PMT-Blocks on the tray.

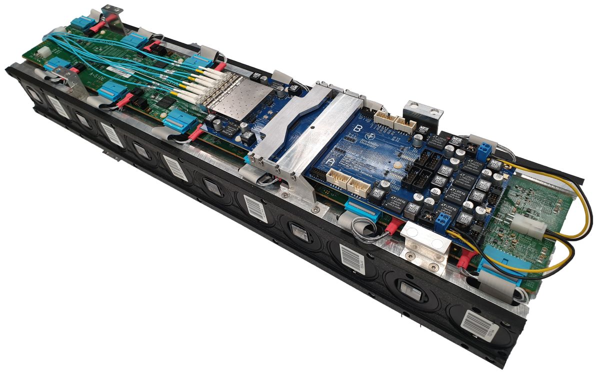

Figure 3: Components of the PMT Block.

light pulses that are transmitted to the PMTs. The portable LV of Prometeo transmits LV to the MB, and readout fibres connect Prometeo to the DB.

Throughout the PMT-Block certification process, LED runs are conducted in low gain, high gain, pedestal, and charge injection modes. In addition to measuring linearity, noise, gains, and data transmission errors in slow and fast readout channels, linearity, noise, and gains are also assessed in slow and fast readout channels.

3. Prometeo Software

The Prometeo web interface as shown in Figure 5 is the software used to execute certification tests and analyse the results. It is accessible via any web browser, including mobile devices, and is platform independent. The system is based on a client-server architecture, with Prometeo acting as a server that communicates via ethernet through a VHDL module that supports IPbus [7]. The client connects via UDP protocol, employing a modular framework with panel plug-ins for various mini-drawer tests. This architecture is client-driven, meaning the client has direct control over the server's functionalities and can modify them on the go.

Through the IPbus protocol, the software communicates with the server to perform read and write operations on a specific memory address or a FIFO memory [7]. The firmware keeps track of the list of registers so that commands, status, data position, sample count, calibration parameters, etc. can be configured.

3.1. IPBus Server

The IPbus software is written in C++, and a Python extension is provided to enhance the scripting capabilities of the end-user, which is frequently employed for developing new tests. Alternately, the user may also use the Java Graphic User Interface (GUI) (Figure 5) to manage test results interactively. The C++ implementation and Python extension can be compiled on any platform, and a Java graphical user interface is compatible with all operating systems. In any event, the core of the software is a collection of algorithms that transform IPbus protocol commands into functions for mini-drawer testing.

The user is able to test communication with the mini-drawer, operate front-end cards, LEDs, and HV power, and store/retrieve data from FIFO or address-specific memory. In addition,

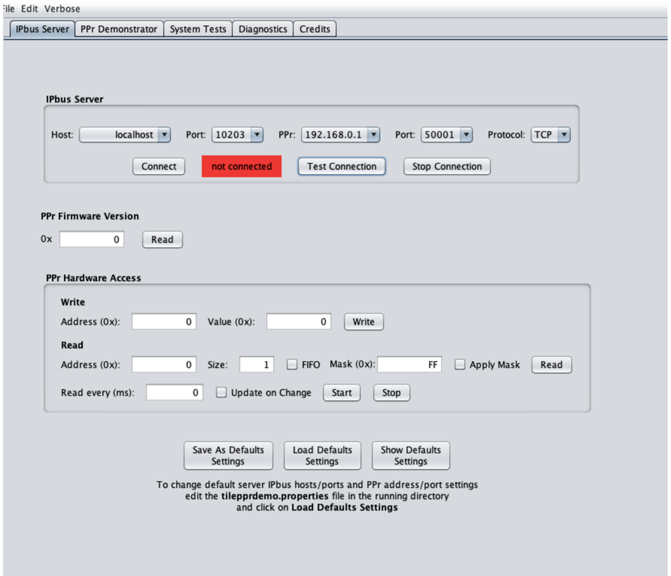

Figure 4: Prometeo Graphic User Interface.

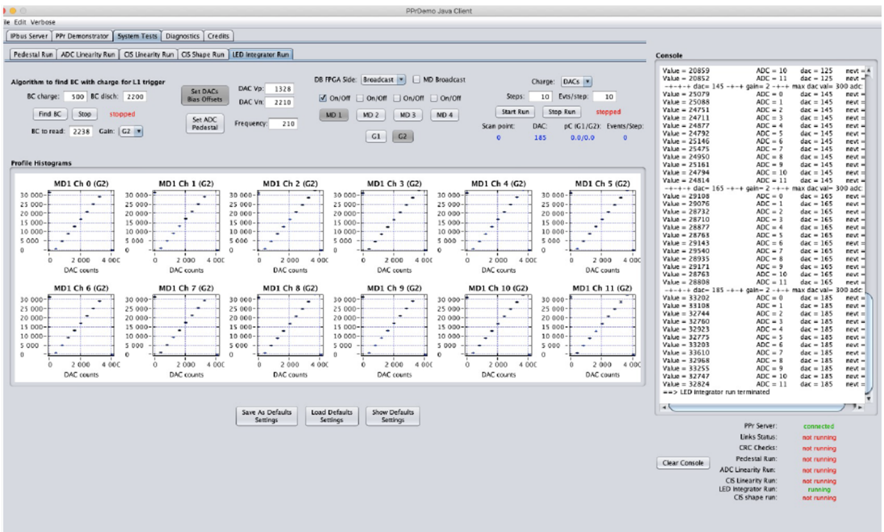

Figure 5: Integrator Panel installed in the Prometeo GUI.

tests for the Integrator for the new system have been rebuilt, and the results are reported in Section 4.1.

4. System Tests

4.1. Integrator

Integrator is printed on a circuit board that is connected to the FENICs card. In addition to the integrator, this board contains a fast digital signal processor for processing collision events of interest in physics, and it delivers a portion of the ATLAS Level 1 Calorimeter trigger signals. A panel for the integrator, as displayed in Figure 5, has been added and tested on the Prometeo GUI. To prevent saturation, the integrator gain can be selected by choosing one of six preconfigured resistors that also specify the integration time. The user can set the frequency,

Figure 6: LED Shape panel installed in the Prometeo GUI.

sample number, mini-drawer to read, gains, and events for each measurement step using this panel.

4.2. LED Shape and LED Linearity

As previously outlined in Section 2.1, one of the submodules for the Prometeo is the LED Driver, which is used to evaluate the functionality of PMT blocks. The LED driver is physically connected to the Compact Processing Module (CPM) and operated from the PC using Prometeo software. A LED Shape panel, as demonstrated in Figure 6, was integrated to and tested on the GUI. This panel uses an LED driver to evaluate the light injection of 12 PMT-Blocks. By adjusting "LED Voltage" from 5 to 30V, the light intensity can be modified.

5. Conclusion

The LHC's Phase II Upgrade will enhance instantaneous luminosity by a factor of 5-10. Electronics will have to endure a substantially higher radiation dose and a greater data throughput need. All TileCal on- and off-detector electronics will be replaced between 2025 and 2027 as part of the HL-Phase LHC's II update .Prometeo is designed to certify the phase-II front-end electronics of TileCal. The test-bench, which can conduct a variety of tests, was motivated by the success of the MobiDICK systems in maintaining the TileCal super-drawers.

Each component of this demonstrator is currently being tested as it is incorporated to the system. Pulses have been measured and integrator, LED shape, and charge-injection tests have been successful. Concurrently with the development of the demonstrator, more tests are developed and evaluated.

Acknowledgments

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References

[1] ATLAS Collaboration 2012 Letter of Intent for the Phase-II Upgrade of the ATLAS Experiment Tech. rep. CERN Geneva draft version for comments URL `https://cds.cern.ch/record/1502664`

[2] Atlas undergoes some delicate gymnastics, howpublished = `https://cerncourier.com/a/atlas-undergoes-some-delicate-gymnastics/`, note = Accessed: 2022-08-30

[3] Aad G *et al.* (ATLAS Collaboration) 2008 *JINST* **3** S08003. 437 p also published by CERN Geneva in 2010 URL `https://cds.cern.ch/record/1129811`

[4] Aad G *et al.* (ATLAS Collaboration) 2010 *Eur. Phys. J. C* **70** 1193–1236. 64 p accepted for publication in EPJC (latest version has minor editorial modifications following requests from EPJC referees) (*Preprint* `1007.5423`) URL `https://cds.cern.ch/record/1282535`

[5] Alves J *et al.* 2013 URL `http://cds.cern.ch/record/1558969`

[6] Adragna P *et al. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **564** 597–607

[7] Bullock D, Carrio F, Hofsajer I, Govender M, Mellado B, Moreno P, Reed R, Ruan X, Sandrock C, Solans C, Suter R, Usai G and Valero A 2014 URL `https://cds.cern.ch/record/1704927`