

Upgrade of the ATLAS Tile Calorimeter High Voltage System

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Abstract: The high voltage system of TileCal, the ATLAS central hadron calorimeter, needs to be upgraded for the HL-LHC, in the so called Phase II Upgrade. In the proposed solution for the upgrade, instead of the current location inside the detector, the HV regulation boards are deployed far from the radiation, in a room where there is permanent access for maintenance. This option requires a large number of 100 m long HV cables but removes the requirement of radiation hard boards. HVremote regulation boards have been developed and tested. Preliminary results are presented.

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1. Introduction

The Tile calorimeter (TileCal), central hadron calorimeter of ATLAS [1], is made of steel and plastic scintillator tiles. The light is collected on both sides of the scintillators by wavelength shifting fibres that transport it to two photomultiplier tubes (PMTs). The calorimeter is divided in 4 partitions, each one composed of 64 modules. The PMTs and Front End electronics are mounted in 3m long drawers at the outer radius of the modules.

For operation at the High-Luminosity Large Hadron Collider (HL-LHC), scheduled to start operation in 2026, the ATLAS Phase II upgrade is in progress. The HL-LHC is planned to deliver more than ten times the integrated luminosity of the LHC Runs 1-3 combined. To achieve up to 4000 fb^{-1} integrated luminosity in a reasonable amount of time, an instantaneous luminosity of up to $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ is required. The higher radiation levels due to higher luminosity and the ageing of the TileCal high voltage (HV) system require the development of a new HV system [2].

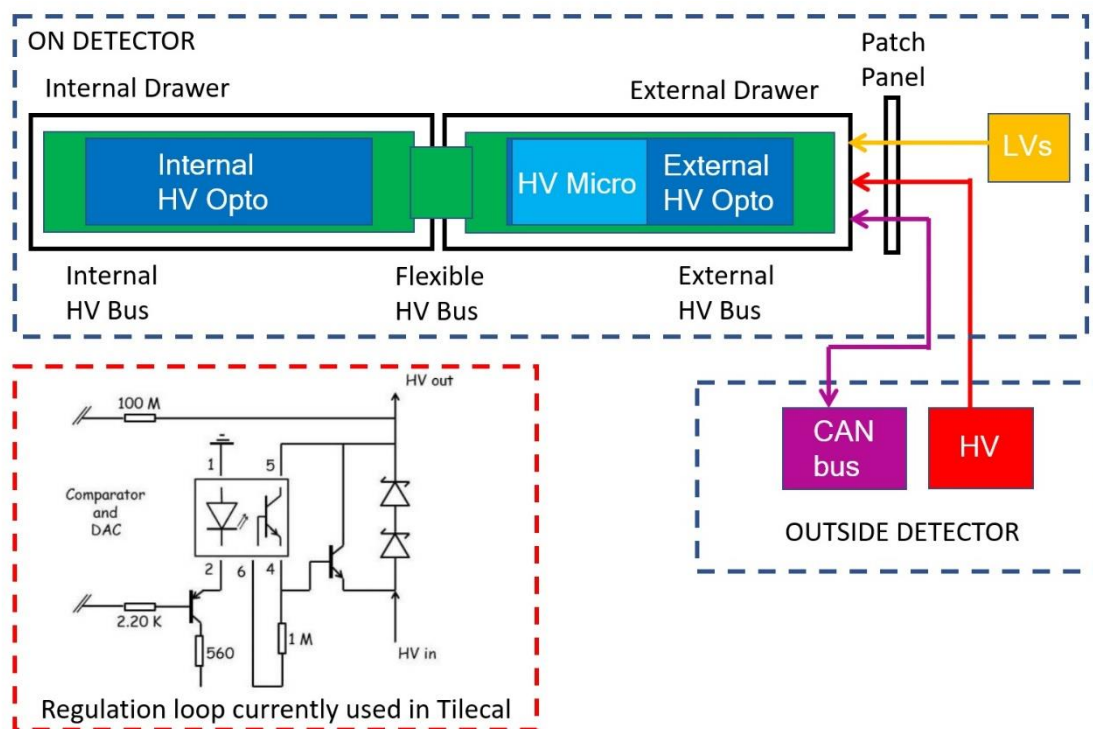


Figure 1 – Current TileCal high voltage system [3]. Bulk power supplies located outside supply one single HV input per module, and regulation boards on detector produce up to 48 individual voltages for the PMTs. The main part of the high voltage regulation loop is shown.

2. High Voltage system design, prototypes and results

The High Voltage system of TileCal after the Phase II upgrade will consist of HVremote boards, located far from the detector in crates that supply the low voltage (LV) and primary HV, connected to the detector by 100 m long cables. The individual voltage upper limit is 950 V and is required to be stable within 0.5 V rms. There will be passive HVbus boards with the purpose of distributing the high voltage to each of the photomultiplier tubes located in mini-drawers inside the girders of the modules.

In the cable system, the worst constraints are the available volume and the maximum diameter of 17 mm for the cables with 32 pairs of wires that will be used for the Extended Barrel modules. Prototypes produced by two companies are being tested.

The HVbus boards are to be used inside the detector as extension of the cables for the connection to the PMTs. They are fully passive (sets of 500 Ω resistors and connectors, only) and the boards have 4 layers to protect the HV tracks in the inner layers. Prototypes are under tests.

The HVremote boards regulate the HV for each individual PMT of TileCal. The number of boards needed for the TileCal operation is 256. There is one input high voltage (-830 or -950 V) for each set of 24 channels and the voltage of each channel will be regulated down individually in a range of the order of 350 V as in the current TileCal design [3]. The final boards are intended to use two primary HV inputs to provide high voltage for 48 channels in the case of the Long Barrel modules or 32 channels in the case of the Extended Barrel ones.

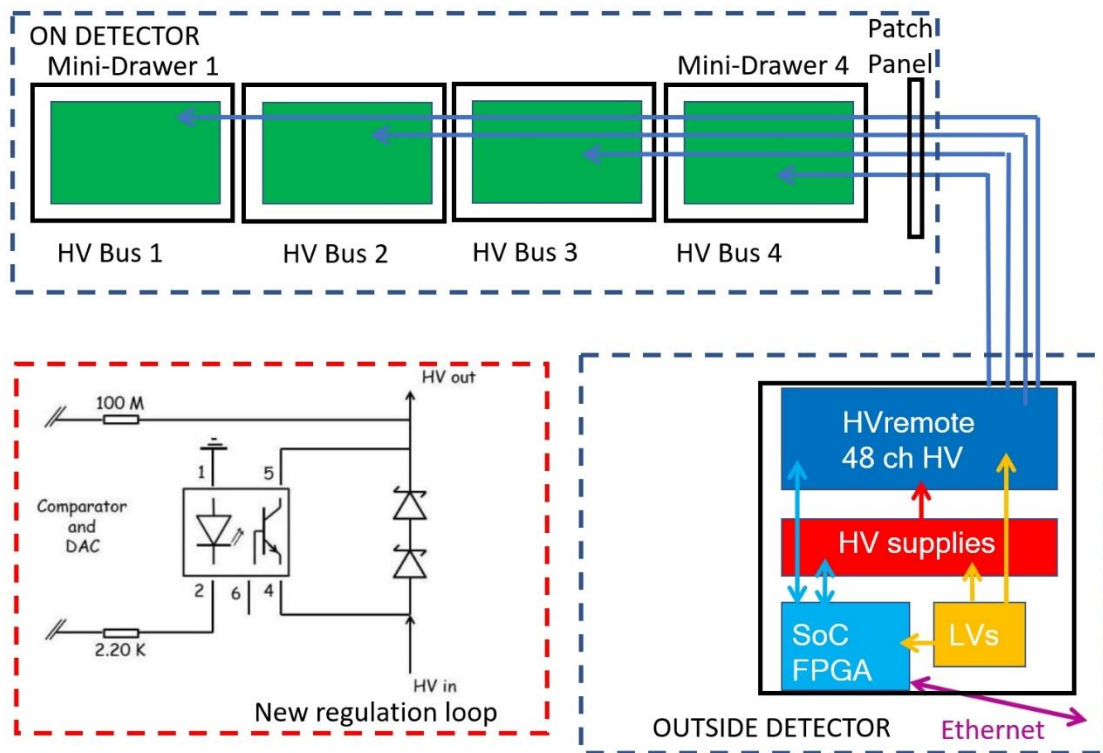


Figure 2 – High voltage for Phase II upgrade. The regulation system is remote, located far from the detector, and a large number of 100 m long cables bring the HV to the detector modules. Inside the detector, the HV is distributed to 4 (3) mini-drawers in the Long Barrel (Extended Barrel) modules. The main part of the new regulation loop is very similar to the current one (seen in Figure 1) with the removal of the transistors.

Relative to the present TileCal HV system, the main functional improvement is the addition of individual on/off control for each individual channel. The operation in the absence of radiation allows the simplification of the regulation loops with the removal of the transistors shown in Figure 1. The new loop is shown in Figure 2. Obsolete components are replaced once alternative components are available. The control and monitoring, that in the current TileCal version are performed with HVmicro boards that communicate with the DCS PCs via CANbus [3], were completely redone. A first set of prototypes, derived from the TileCal boards with 12 channels that are in operation, was used to demonstrate the feasibility of the remote system and to ensure that the performance of the remote system is comparable to the one of the current system [4].

The first generation of HVremote prototype boards with 24 channels is produced and the latest generation is designed with 48 channels. The communication and control are done via Serial Peripheral Interface (SPI) bus through an ethernet interface. The 24 channel prototype boards use Tibbo EM1206 modules as interface. A final version with 48 channels, using a System on Chip (SoC) solution based on Xilinx Zync, is foreseen, even if the first tests will use a Raspberry Pi that is also used to develop part of the control software.

The primary HV is provided by Hamamatsu C12446-12 modules, located in boards in the crates that contain LV/HV supplies and a control board. The crates are currently being designed.

HVremote boards prototypes with 24 channels have been tested in the laboratory. In an environment with small temperature fluctuations and a stable set of channels with HV on, the HV output is quite stable as can be seen in Figure 3. The raw data, acquired every 10 seconds during 5 days with a Schlumberger 7150plus voltmeter, is shown in the top plot, the average voltage per half hour in the middle plot and the temperature at the bottom plot. The correlation between the average voltage and the temperature is very clear, and the rate of change of the output voltage with the temperature is estimated to be in the range 50-100 mV/°C.

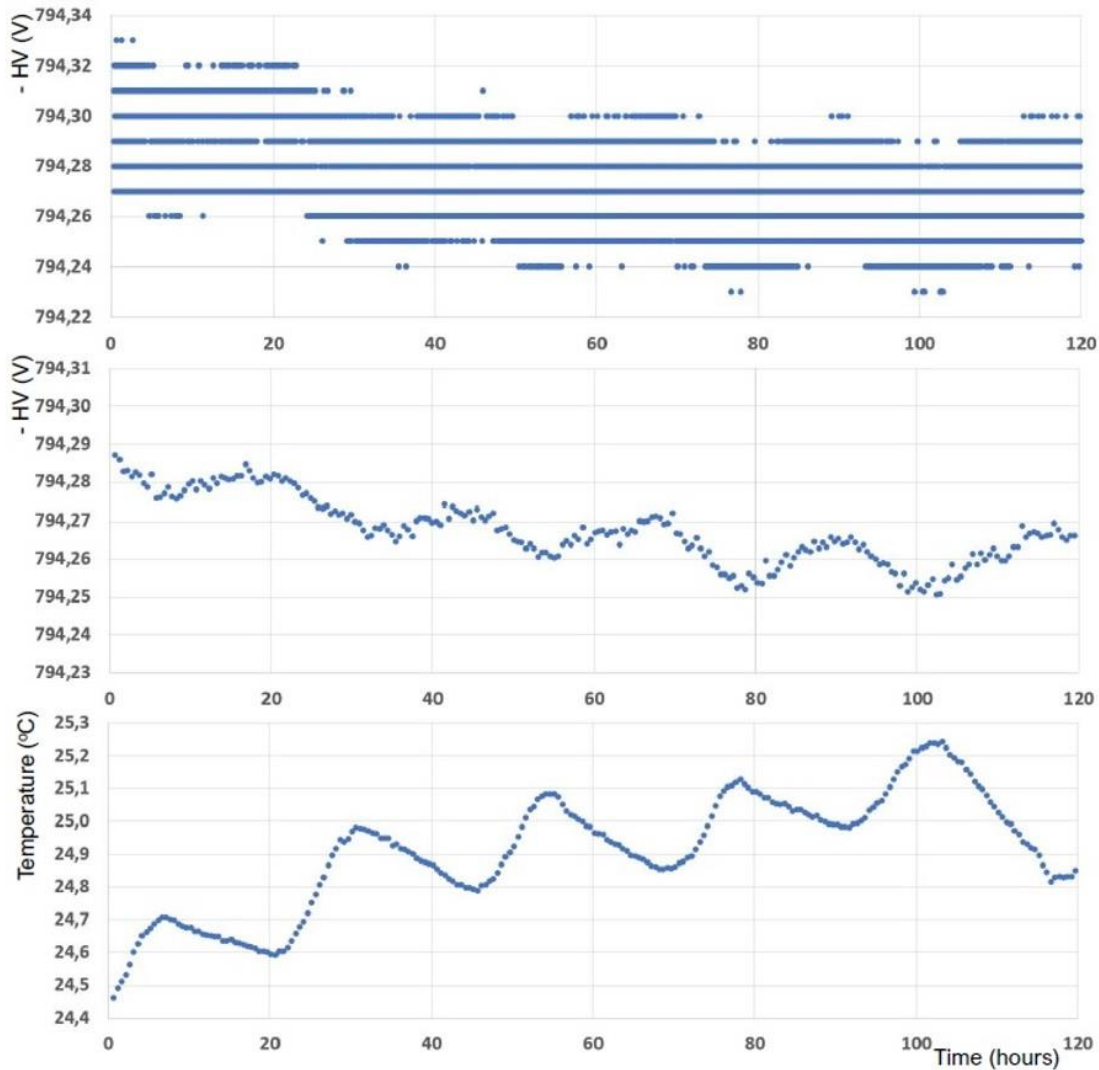


Figure 3 – Output voltage readings for channel 1, raw data at the top plot (readings every 10 seconds) and average voltage per half hour at the middle plot. The average temperature is shown at the bottom plot.

Some problems have been identified in the 24 channel prototypes during the tests, resulting in changes in the design that are being implemented in the last generation of 48 channel prototypes. The individual channels switch on/off mechanism could oscillate in some channels due to dark current variations of the optocoupler phototransistor, but the removal of a transistor in the new design of the 48 channels board is expected to solve it. A problematic series of 1 μF tantalum capacitors have been successfully replaced by ceramic capacitors. After almost 2 months of operation they are working properly.

3. Next steps

New prototype of the HVremote board is in production. The HV supplies boards with high voltage and low voltage supplies have been designed and the production will start soon. These boards will be tested using a Raspberry Pi (Zync SoC with FPGA will come later) and will be introduced in the Demonstrator test at the ATLAS detector [2]. New cable prototypes and connectors will also be tested in the Demonstrator. Design of the crate to house the boards is in progress. A full slice of the high voltage system will be tested in 2020.

Acknowledgements

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