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Environmental stress screening of the CMS ECAL Barrel VFE and LVR cards

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In preparation for the operation at HL-LHC the electronics of the Electromagnetic calorimeter Barrel must be replaced. 12240 new very front end (VFE) cards will amplify and digitize signals of 62100 lead-tungstate crystals instrumented with avalanche photodiodes. 2448 low voltage regulator cards provide power for the VFE and digital interface cards. Reliable operation of these cards with failure rates as low as 0.5% at the end-of-life, after ˜20 years, is targeted, requiring environmental stress screening (ESS). We present the implementation of the hardware and software components of the custom developed ESS system, highlighting its modularity, configurability, flexibility, and scalability.

Summary (500 words)

In preparation for its operation at CERNs High Luminosity Lage Hadron Collider the Compact Muon Solenoid (CMS) experiment [1] is undergoing an extensive upgrade program. The Electromagnetic calorimeter Barrel (EB) [2] of CMS is made of 61200 lead-tungstate crystals read out by avalanche photodiodes. Its readout electronics are arranged into readout towers (RTs) of 5x5 channels, comprising five very front end (VFE) cards, one digital interface card (FE) and one low voltage regulator card (LVR) conditioning the power of one tower. The entire on-detector and off-detector electronics, comprising 12240 VFE, 2448 FE and 2448 LVR cards, will be replaced [3].
ECAL is a single layer detector. Missing readout channels degrade the energy resolution and missing towers may allow photons or electrons to remain unidentified. Extracting an ECAL module for repair requires several months and is not foreseen for the operation period of ˜20 years. Consequently, we aim at excellent quality and reliability targeting <0.5% of failing readout channels at end-of-life. This will be achieved and assured among others by Environmental Stress Screening (ESS) of all cards prior to their installation into EB.
We built a dedicated ESS system for performing thermal cycling between ambient temperature and ˜70oC on VFE and LVR cards simultaneously. This approach assures a proper powering of the VFE cards and the correct load for the LVR cards. The system design is modular. Twelve identical boxes host 9 RTs each, enabling simultaneous testing of 540 VFE and 60 LVR cards. Thermal cycling is achieved by powering the electronics on and off together with fans controlling the exchange of air between the box and the ambient. Additional fans inside the box create a homogeneous air temperature within ˜5oC inside the box. Fan speeds and thus temperatures are controlled by STM32 Arm Cortex®-M microcontrollers. Monitoring of temperature is obtained by reading existing temperature sensors on the VFE and LVR cards using Keithley DAQ6510 equipped with Keithley 7701 multiplexing cards. Power is provided by programmable TDK Lambda power supplies.
The software for monitoring and control of the ESS system is built in a highly modular, configurable, and scalable way using public Python libraries (pyVisa, pySerial, Python-can, Python-snep7, RPyC, PyQt, PyMySQL). It comprises multiple servers with data/information subscription services and clients for monitoring/operation/control of the system and includes the graphical user interface and database interface. All test data will be stored in an SQL database.

A Siemens programable logic controller monitors temperatures inside all boxes using independent PT1000 sensors and provides safety interlocks to the power supplies in case of overtemperature, enabling safe unattended operation of the system.

We will use the system to measure the failure rate of eight RTs versus time for several months with a minimum of 200 power cycles. This measurement provides the reliability of the cards and allows to estimate the aging

period, Ta, required to eliminate cards with early failures.
During production of VFE and LVR cards we use the system to screen all of them for one Ta.

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