

ATLAS tile calorimeter cesium calibration control and analysis software

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Abstract. An online control system to calibrate and monitor ATLAS Barrel hadronic calorimeter (TileCal) with a movable radioactive source, driven by liquid flow, is described. To read out and control the system an online software has been developed, using ATLAS TDAQ components like DVS (Diagnostic and Verification System) to verify the hardware before running, IS (Information Server) for data and status exchange between networked computers, and other components like DDC (DCS to DAQ Connection), to connect to PVSS-based slow control systems of Tile Calorimeter, high voltage and low voltage. A system of scripting facilities, based on Python language, is used to handle all the calibration and monitoring processes from hardware perspective to final data storage, including various abnormal situations. A QT based graphical user interface to display the status of the calibration system during the cesium source scan is described. The software for analysis of the detector response, using online data, is discussed. Performance of the system and first experience from the ATLAS pit are presented.

Introduction

The ATLAS[1] TileCal[2] sampling calorimeter, shown on fig.1, is constructed of steel plates (absorber) and scintillating plastic tiles (active material). It is designed as one barrel and two extended barrel parts. All the three sections have a cylindrical structure divided in ϕ by 64 wedge modules.

Within modules, the light from tiles is collected by PMTs via fibers as shown at fig.2. The module is divided into a number of cells corresponding to the projective geometry. Front-end electronics are located inside module's girder and organized in extractable "drawers" [3].

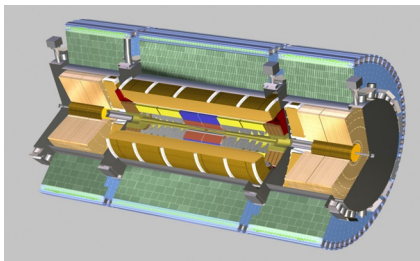


Figure 1. ATLAS calorimetry layout. Tile calorimeter shown in green

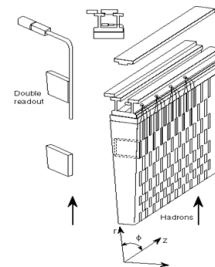


Figure 2. Tile cell geometry and readout

To calibrate and monitor the TileCal, a powerful (~ 10 mCi) ^{137}Cs γ -source is used. While the source drifts (fig.3) through the detector calibration tubes by a flow of liquid, integrated PMT currents from front-end electronics are read out. The use of a γ -source allows to test the scintillators and fibers optical quality (fig.4), equalize the response of all the cells with the precision of better than 1%, to monitor each cell over the time and to provide the overall energy calibration.

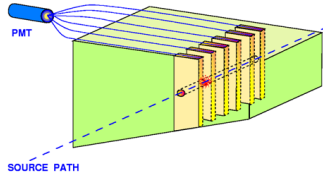


Figure 3. The principle of calibration by moving source

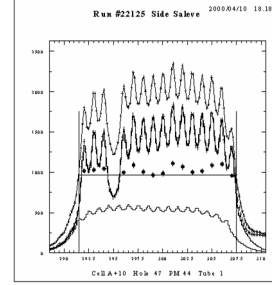


Figure 4. PMT response

In order to transport the radioactive source in a safe and controllable way along the 10 km of tubes inside the calorimeter, an elaborate source drive and monitoring system are needed[4, 5]. The readout of integrated PMT currents is performed using special ADC inside the "drawer" via the CAN bus, as a separate "slow" calibration data path with respect to the "fast" physics events data taking.

Apart from the front-end electronics of the calorimeter itself, a large number of sensors, to control the source movement, is located around the calorimeter and read out by electronic boards, located around the calorimeter and read out via CAN bus, as shown at fig.5. The hydraulic drive, which pumps the liquid to move the source, with electronically operated pump and valves is placed in the experimental cavern, and is controlled via CAN interface too.

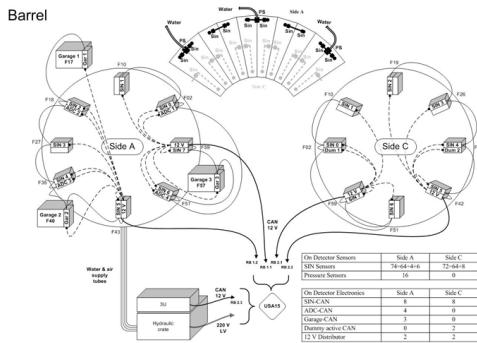


Figure 5. Electronics layout

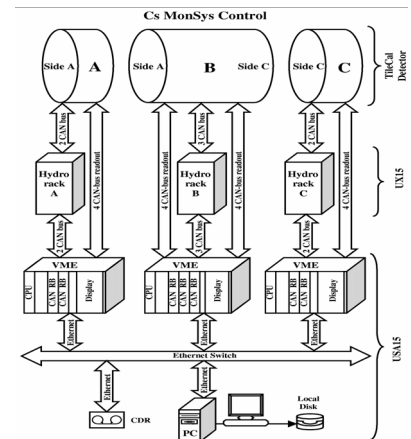


Figure 6. Control and readout scheme

A number of CAN branches are read out by custom-made boards, called "Readout buffer"(RB) located in the same VME crate, used by main DAQ, and are controlled by single board computers running Linux operating system (see fig.6).

1. Software requirements

Given the system described above, an intelligent online software is required to perform the task of source movement and detector response analysis. It should be able to:

- Control and operate the hydraulic equipment, electronics and run the Cs source through the whole Tile calorimeter sensitive volume
- Read out the integrated current of the PMTs, while the source capsule moves with the designed speed, performing readout switch when capsule passes from one module to another
- Be capable to correct/adjust the run conditions according to current system status and acquired on-line analysis information
- Visualize results of online analysis, location of the capsule, and the physical conditions of the run
- Store raw and reconstructed online and offline data
- Communicate with other subsystems, detector control system and calibration databases
- Monitor status of the hardware components, performing routine tests and internal calibration

2. Electronics tests

To visualize the size of the cesium system, consider around 10000 PMT channels in 256 front-end electronics drawers, more than 500 source control sensors which are read out by 100 boards of 7 different types. They are distributed over several hundred meters and connected via a number of different types of interfaces.

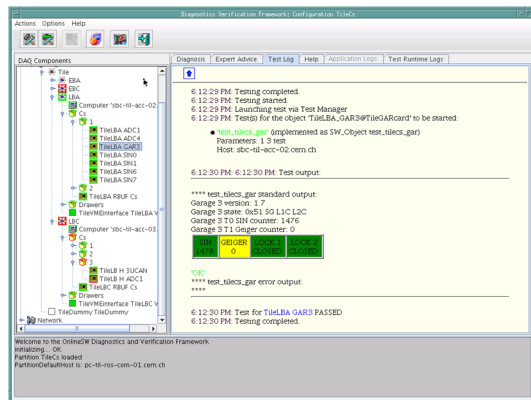


Figure 7. Example of DVS session

To cope with system size, diversity and complexity of components, a set of tests has been developed with the help of ATLAS DVS framework[6], which allows to describe a hierarchy of components and their tests, to be executed in a sequential or parallel way, depending on the need.

Electronic components and their corresponding tests are described in a configuration database, which is also used by the main data acquisition system of ATLAS.

Tests can be executed either from the command line or from the GUI, an example screenshot of which is shown on fig.7. Test results are provided in either text or HTML format.

It is possible to start several tests in parallel, this is specified as an attribute in the test description, thus shortening the testing time. The GUI relieves

the burden of manual test start, all needed parameters for the test are described in the configuration database, and test is started on the required computer.

User can also specify the level of complexity of tests and put some masks, to select only specific type of tests to be executed. The output and error streams of the tests can be consulted via user interface.

Expert system approach is foreseen, using test results, to perform other tests. An advice how to fix the problem, or which test to perform in order to clarify the situation, is presented to the operator. HTML-based help system is available to provide documentation about tests and further steps in case of failure.

The time to perform the standard set of quick functionality tests is less than a minute for all the control part of the cesium system, and several minutes for the front-end electronics.

Regular execution of these tests ensures that all the hardware is ready for the cesium scan to be performed.

3. Software architecture

The architecture of the Cesium calibration online software, shown on fig.8, can be described as a set of readout and control processes, running inside single board computers in the counting room, which are controlled and share the data via information service (IS)[7], and use embedded Python scripting facilities for program logics. At the second level there are data analysis and data recorder processes, they run in the control room computers and communicate with the operator via graphical user interface, log files and databases.

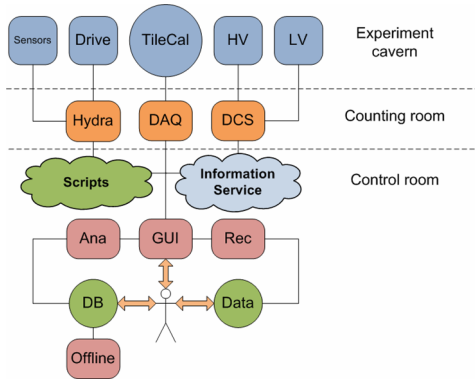


Figure 8. Online software architecture

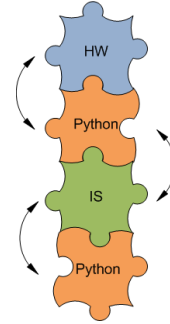


Figure 9. HW-Python-IS linkage

A scripting facility is used to facilitate the configuration and to add flexibility to program logic, so it can be changed without program recompilation. An embedded Python interpreter with extension library links together hardware objects and their representation inside information service to share data between processes on different computers.

Configuration with Python scripts helps complex descriptions of different setups. A package of standard scripts for control process algorithms and runtime behavior has been written.

A set of Cs specific extension classes for Python has been developed, to link together hardware component and its information service representation, as displayed at fig.9.

Python "hardware" object interacts with the hardware and updates the IS information, which can be seen by other processes, like GUI. Objects of Python "info" classes, subscribed to the update, will receive new state, each time the original object is updated. This allows to easily exchange information between Python scripts running at different computers, interconnected by Ethernet network.

A hierarchy of information service classes describes Cs specific hardware and software objects. Many useful IS features, like list and monitor utilities, auto-generated C++ and Java bindings, facilitate software development and help program debugging.

The IS server history mechanism makes easy-to-use the evolution of the various parameters and the automatic backup of information server data helps crash recovery.

The fact that the cesium calibration system is naturally divided in three independent parts, one barrel and two extended barrels, both logically and physically, allows us to run all systems in parallel, using the partitioning mechanism provided by TDAQ software framework, thus shortening the time of the full detector scan.

4. Processes

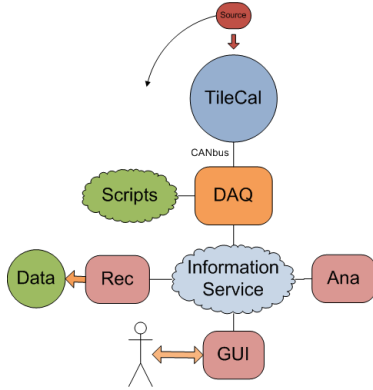


Figure 10. DAQ process

TDAQ is used to retrieve and send high voltage and other important information, like temperatures, power supply status. Run status and location of radioactive sources are provided for global experiment operators like SLIMOS (shift leader in matter of safety).

The recorder process reads the raw data from the IS and store them to the disk file, which is later on copied to the tape archive.

The analysis task perform the online express analysis of the PMT responses from the raw data received via the information service, publishes a set of histograms and other kind of plots for the operator to quickly assess the quality of the current run, so decisions can be made in time, if one need to pass the module again.

5. GUI

The shifter normally interacts with the cesium calibration system via graphical user interface (GUI).

This QT-based application displays the online status of the cesium calibration system using the information provided by control, readout and analysis processes, via the IS subscriptions.

It allows to operate with a single element of the system (single valve e.g.), as well as to send high level commands, and fire script execution.

Using the same application, user can view the global status of the run, the analysis summary, and the very detailed information about the source position, system pressure, valves states and pump settings.

Fig.11 shows the panel with the detailed information during the hydraulic system test of the source movement, including diagnostic messages, valves status, sensor activation state and timing, source garages state, pressure readings, etc.

The heart of the system is the Hydra process, which controls the hydraulic drive and source capsule sensors via CANbus. It moves the source, reacts to current source position to switch drive contours accordingly, and provides information for other processes. Hydra receives commands from GUI or other control processes, uses scripts and manual commands to change current configuration and control logic.

The DAQ process (fig.10) reads out PMT responses and controls the front-end electronics via CANbus, switches front-end module readout based on current source position. Provides data to the analysis and recording processes via IS.

To fulfill the task of a safe and controlled operation, an interface to detector control system (DCS) is required. The DDC package[8] of ATLAS

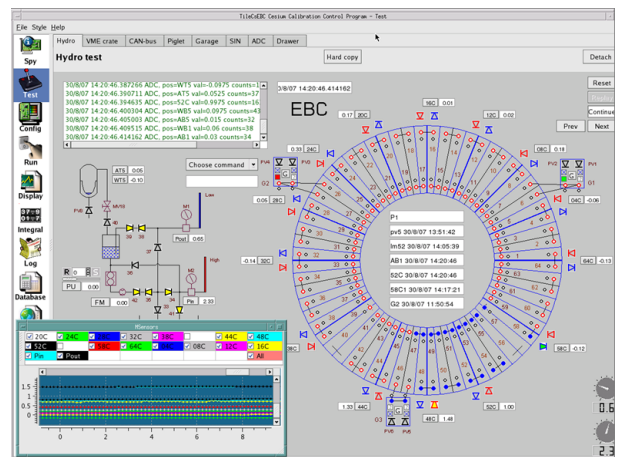


Figure 11. QT user interface

Color is used to provide more information visually, for example the number of times the source passed the sensor is encoded as different color and the time when source activated the sensor is encoded as a shade of grey, so one can see the direction and speed of source travel.

The history mechanism of information server provides the possibility of important playback feature: full story of the cesium scan or test run can be replayed in accelerated mode, to visualize the events sequence for debugging or close examination.

6. Data analysis

Almost all TileCal modules are different, so sophisticated analysis software is required to achieve calibration with required precision. The raw data, taken during the run, are saved to a file in a form of ROOT trees, thus providing an easy access and visualization, using standard set of high energy physics analysis tools.

At fig.12 an example of real data obtained at ATLAS test bench is presented.

Analysis can be initiated during the run as soon as a set of data from one calorimeter module is available. The response of every cell is calculated and results are used in iterative equalization procedure, to set up the required high voltage for individual PMTs.

Global data quality flag from analysis process might be taken into account by control process, to send capsule back to a particular module changing run parameters, interrupt or even terminate the run.

Run processing and its results are visualized in the GUI. Results are stored in the database for the later use by reconstruction software and offline analysis.

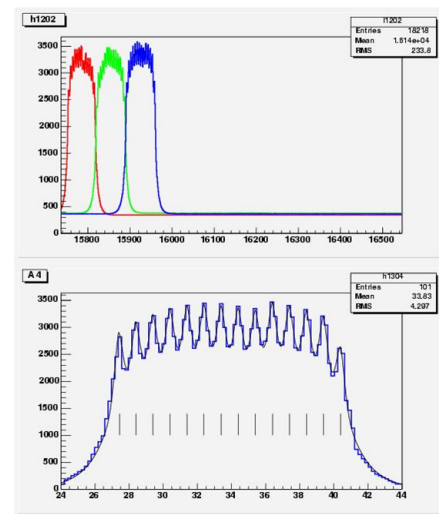


Figure 12. PMT response vs. time during source scan. The tube (top) and tile (bottom) structures are clearly visible

7. Operation, results and performance

A good example of the complexity of the operations can be given by the cesium scan run scenario:

- Preparation
 - FE electronics functionality tests: pressure sensors, SINS, garage sensors, 3U-crates etc.
 - Safety checks: locate the source, air pressure leak test
 - Functionality of the equipment: hydraulic drive, garage locks etc.
 - Control of liquid flow: pump, air pressure, detector local pressures etc.
 - Water filling: fill detector calibration tubes, in a special sequence, with liquid from the storage tanks
- Cs RUN
 - Run the source capsule at a desired speed, keeping an eye on its current position with SIN sensors and detector response
 - Collect PMT responses and store it along with the online analysis of the correctness of the information
 - Adjust the source movement, data readout and online analysis modes according to the current run conditions (situation)

- Post run tasks

- Water draining: pump out and store the liquid in tanks, check detector local pressures for the rest of the liquid
- Safety checks: garages, source location, source blocking

In order to facilitate the description of configuration and control logic for these operation procedures, required for the functioning of the cesium calibration system, the scripting facilities are used, which provide a way for easy algorithm and sequence encoding by non-experts in programming, going from the operation sketch on paper to the working script, without program recompilation.

A set of scripts for standard operational steps, like water filling, run preparation, source location, has been organized in a Python package.

The Cesium calibration system is installed in the ATLAS experiment cavern, commissioning is ongoing. Regular electronics tests verified the integrity and stability of the components. Dummy source runs allowed to check system functionality and operational logic before introducing the radioactive source to the still busy environment of experiment installation.

The nature of the cesium calibration system, which collects data via slow path, does not put special requirements for the data acquisition system, compared to the one, used in the normal data taking. Data flow rate relatively small, 20 KB/s with 90Hz trigger frequency.

But the full Tile Calorimeter barrel scan is relatively long operation, should take about 8 hours and produce around 300 MBs of raw data. Several runs per year are planned, after initial series of runs for optical quality verification, primary equalization and calibration efforts.

8. Conclusions

A system to calibrate and monitor ATLAS Tile Calorimeter with a movable radioactive source, driven by liquid flow, has been installed in the ATLAS pit.

Online software has been developed, using ATLAS TDAQ components for database, information exchange, electronics tests, communication with detector control systems, etc.

Scripting facilities allowed for quick prototyping and modification flexibility by non-experts.

GUI provided operator with clear status and control, and history mechanism for post-run problem analysis.

Data analysis software produces online response.

Good performance has been achieved for data taking and online analysis, to cope with the task at the speed of source travel.

Authors wish to thank all Tile collaboration and ATLAS TDAQ group.

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