# Cesium calibration and monitoring system of the ATLAS Tile Calorimeter


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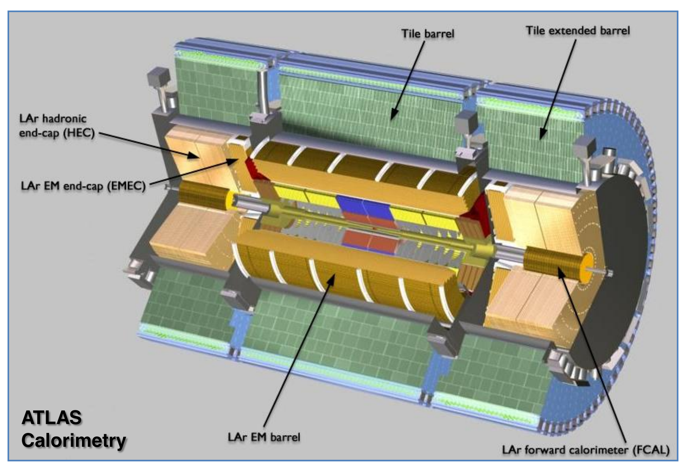
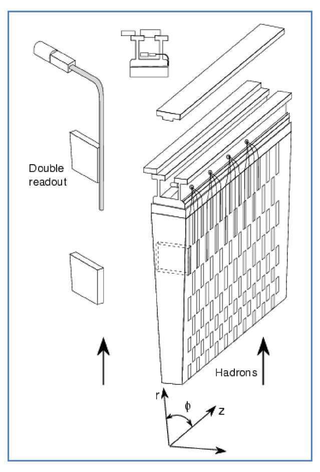
*for Tile Calorimeter collaboration*

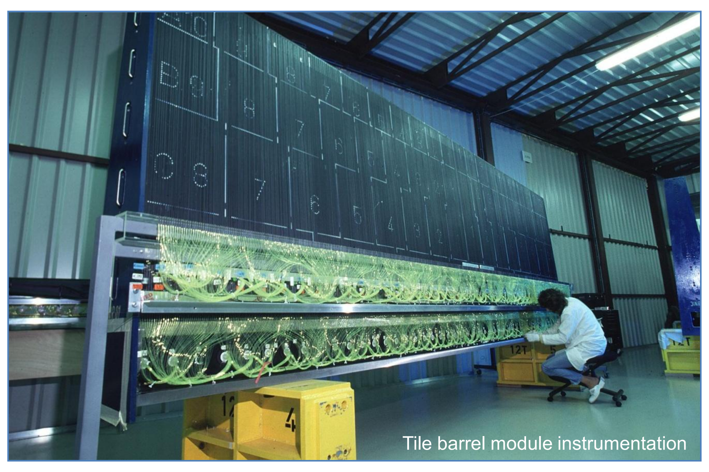

## The ATLAS Tile Calorimeter



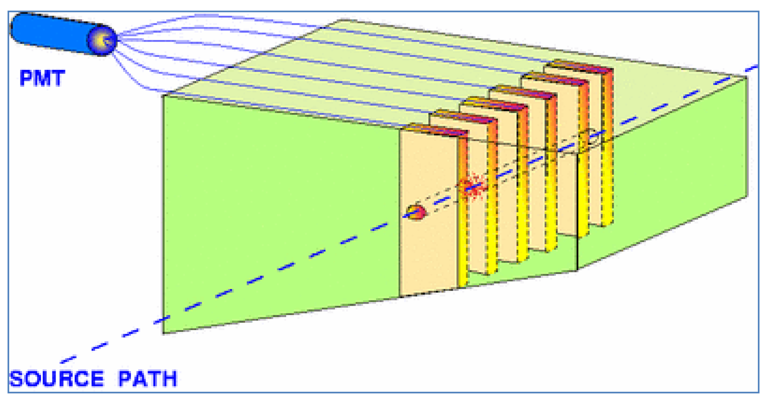

- Sampling hadronic calorimeter
- Steel absorber plates and scintillating tiles
- Three cylindrical sections, Ø9×12m in total
- 10 000 PMT channels
- 64 independent azimuthally oriented modules.
- Projective geometry cells, WLS fiber light collection
- 45 cells per barrel module, 0.1x0.1 ηϕ segmentation
- Each cell read out by a pair of PMTs from two sides.

- Electronics inside module's girder
- Organized in extractable "drawers"
- Shaped bi-gain output signal
- Fast 25ns sampled readout
- Slow integrated current readout
- Analog trigger tower sum output
- Micro-controlled high voltage
- DC-DC switching power supplies



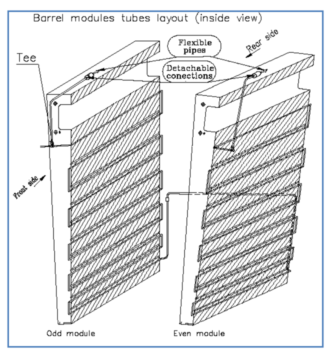



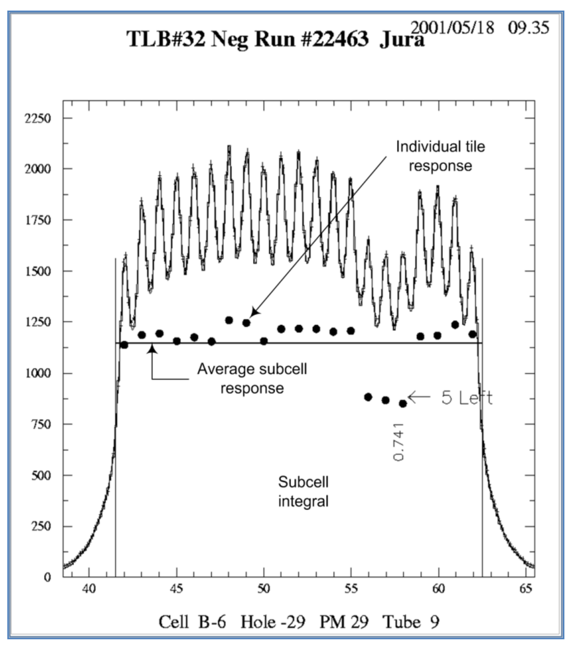

## $^{137}$Cs calibration principles




- Powerful ~10mCi $^{137}$Cs γ-source
- $E_\gamma$=0.662 MeV, $t_{1/2}$=30.2 years
- Dumb-bell capsule driven by liquid flow
- Optical quality test of the scintillators and fibers
- Better than 1% cell response equalization
- Monitoring of every cell over time
- Overall energy calibration


The source, embedded in a capsule, moves with a constant speed ~30 cm/s inside the stainless steel tubes through all the calorimeter volume exiting all the scintillating tiles. The system is composed of three independent parts having closed circuits with three separate sources. The movable source system is the main tool to equalize the calorimeter cells responses and to monitor detector performance over time together with other calibration systems.



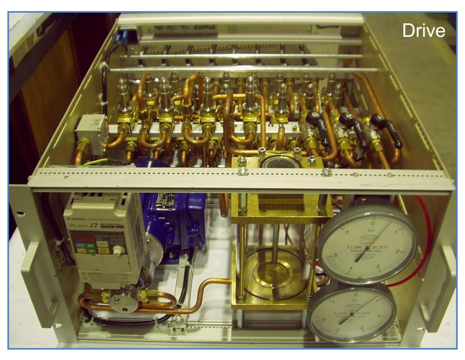



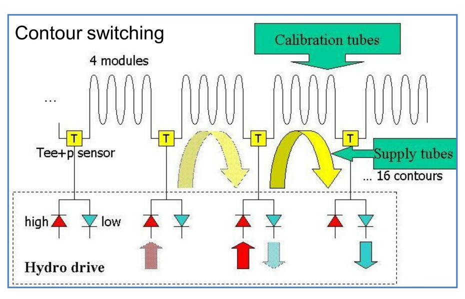

During a cesium scan we acquire the dependency of integrated signal in every channel versus time. Data are read out with the 90Hz frequency via CAN bus. Due to the sampling structure and light gathering scheme we get a number of signals in the shape of peaks. One period of peak structure corresponds to the passage of capsule through one period of TileCal module (iron/scintillator). Signal has maximum when capsule goes through the scintillating tile and minimum when capsule is in an iron plate between 2 tiles. As the source can "see" all the scintillating tiles and readout fibers, an "x-ray" picture of the detector is obtained, that was used for optical quality control and repairs during instrumentation of Tile Calorimeter.

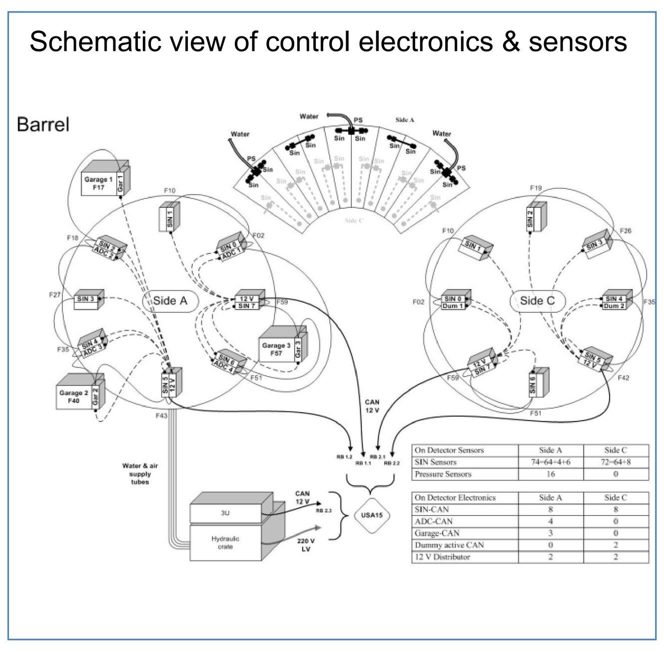
## Source drive & control

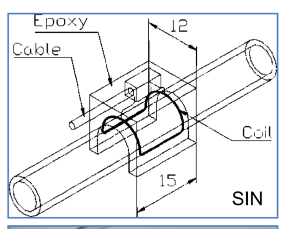
### Hydraulic system

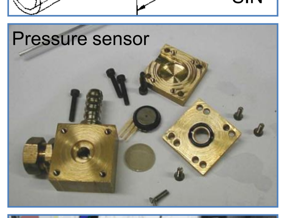
In order to transport the radioactive source in a safe and controllable way along the 10 km of tubes inside the calorimeter, an elaborate source drive and monitoring system are needed. The hydraulic drive, which pumps the liquid to move the source is equipped with electronically operated pump and valves, and placed in the experimental cavern. It is controlled via CAN interface. Calibration tubes sequences in each parts are divided into a number of contours with corresponding number of supply tubes. Contour system requires active control and monitoring of the source position to switch the valves according to the capsule movement. Due to readout limitations, one has to switch from one module to another, this also requires the knowledge of source position

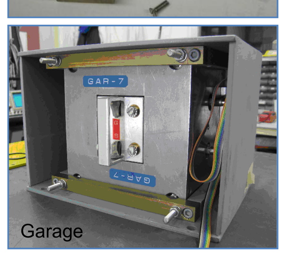



### Control electronics

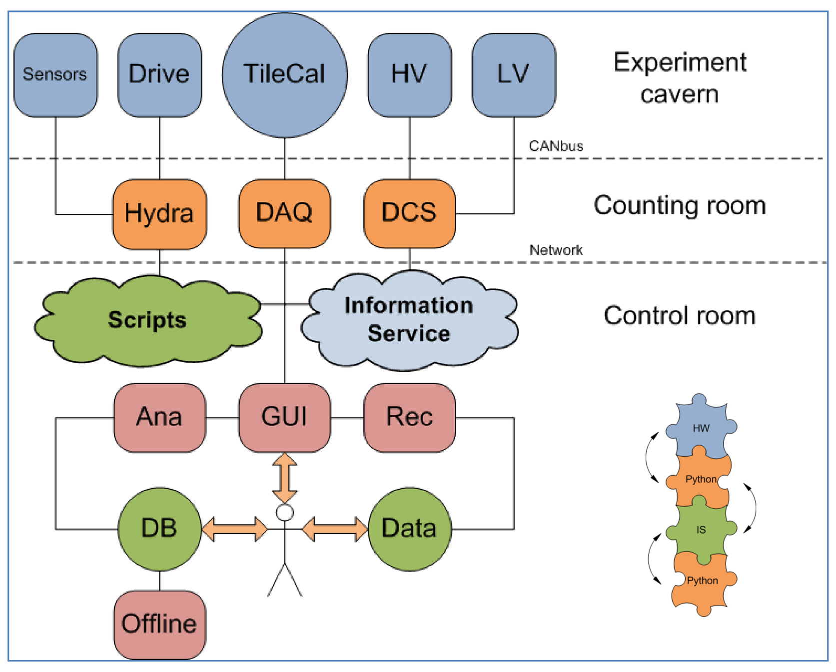
Apart from the font-end electronics itself, about 500 sensors for capsule movement detection and pressure measurement are attached around the calorimeter surface and read out via ~100 electronic boards connected by the CAN bus daisy-chains.

Between the scans the radioactive sources are stored inside the lead containers equipped with Geiger counter, capsule sensor and remotely controllable locks

## Online software

### Distributed software

- Layered architecture
- Remotely controllable hardware in the cavern
- Readout and control processes running inside single board computers in VME crates in the counting room with Linux operating system
- CORBA-based Information Service as inter-process communication of commands and data
- Embedded Python scripting facilities
- Graphical user interface, databases
- Raw and conditions data saved as ROOT trees

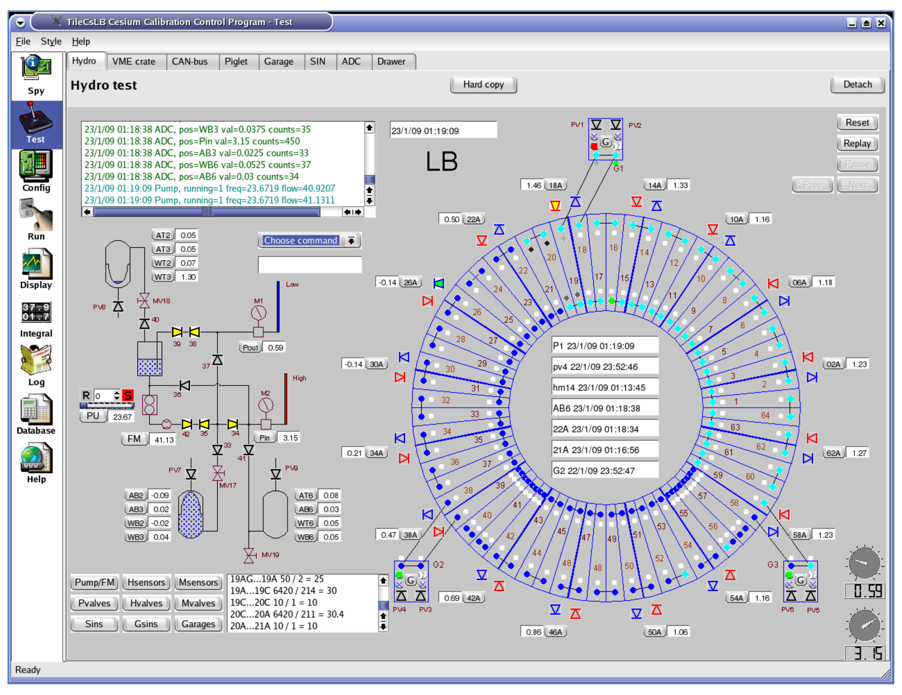



### Python scripting

Scripting facilities for program flow control and configuration add flexibility and ease of use even for non-experts. Embedded Python interpreter with extension library links together hardware objects and their representation inside Information Service to share data between processes running on different computers. Configuration with Python scripts helps complex descriptions of different setups. Standard scripts exist for control process algorithms and run-time behaviour.

### Hardware tests

To cope with system size, number and diversity of components (100 boards of 7 different types) a package of tests has been developed within ATLAS DVS framework



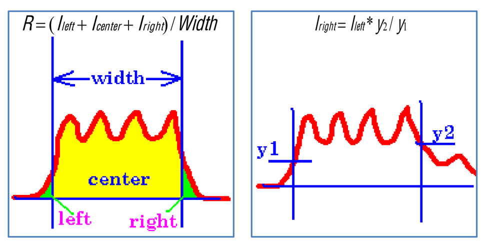

### Multifunctional user interface

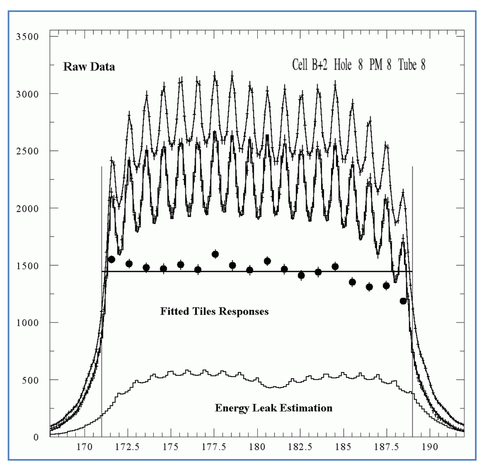
- Qt application running on Linux
- Functional system diagram
- Manipulations down to a single valve
- High level commands and scripts
- Information and status from all the sensors
- Colour coded source path and speed
- Pressure and other variables graphs
- Run information
- Error messages and log files
- History playback in accelerated mode
- Display/operate modes
- Customized for different system setups

## Data analysis & results

### Integral method

Mean period of the peak grid is calculated. Left/right boundaries of the cell are taken as the position of the first/last peak -/+ half of the period. Integral within cell boundaries, as well as integrals below left and right tails, are calculated. If one of the tails has an abnormal shape, the integral under another tail with an appropriate correction is used. 22% leakage from one tile row to another is also taken into account.. Stability of the method ~0.2% in several consecutive runs.



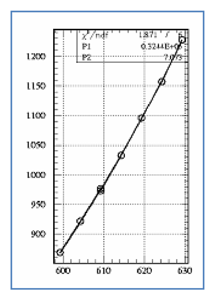

### Amplitude method

It allows to calculate individual tile response. In this method the response is fit by the sum of Gaussian + exp. tails for every tile $F(x) = A(\alpha \times e^{-(x-x_0)^2/2\sigma^2} + (1-\alpha) \times e^{-|x-x_0|/\lambda})$. 22% leakage signal to the next tile row is subtracted before fit. Accuracy of single tile response is about 2%, average cell response is known with 0.3% precision.

### HV equalization

Cesium system is used for initial equalization of cell responses. Signals from all the cells are equalized with an iterative procedure, the desired HV is then calculated from the formula $HV_{new} = HV_{old} \times \left(\frac{Amp_{reference}}{Amp_{measured}}\right)^{1/\beta}$

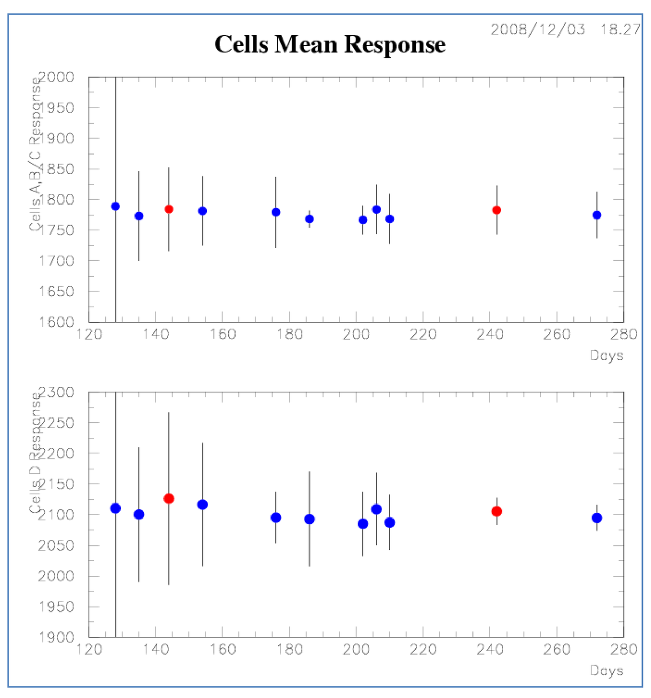
Parameter $\beta$ was measured for every PMT during quality check. Equalization procedure usually stops after 3rd iteration when HV corrections are less than 0.5V.



$Amp = \alpha \times HV^\beta$

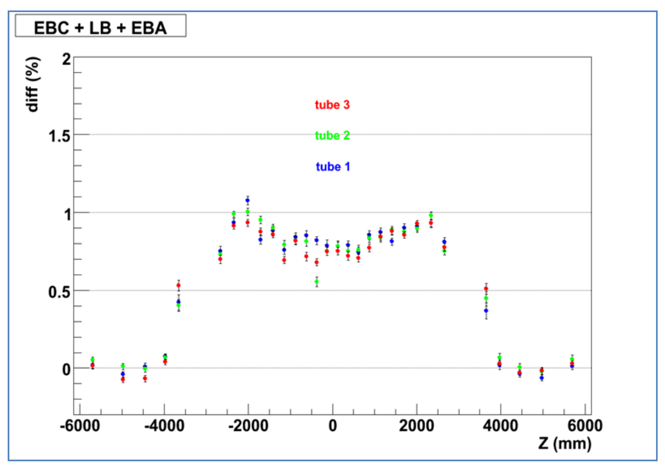
### Calibration constants

The precision of high voltage set up do not require accounting of the smaller scale effects like electronics gain dependence or magnetic field influence. Therefore they are combined altogether into the cesium calibration constant, stored in the database.




### Stability

Preliminary estimations of cell mean responses showed good stability around 0.3% by the end of 2008 year. Initial big RMS is reduced after the end of equalization period in the middle of the year. Further efforts to improve the results are under way




### Magnetic field

An example of good accuracy of the method can be demonstrated by the magnetic field effect visibility.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