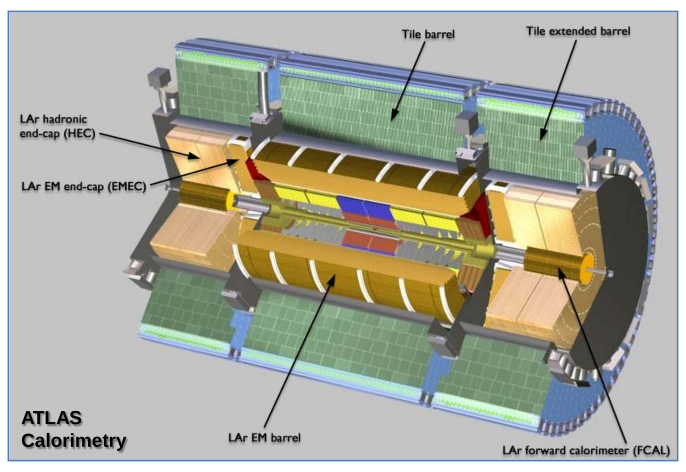
ATLAS Tile Calorimeter calibration and monitoring with a movable ^{137}Cs source

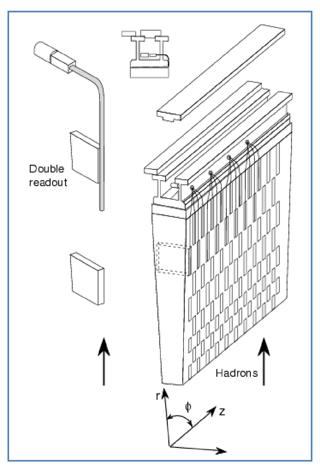
Oleg Solovyanov for Tile Calorimeter collaboration

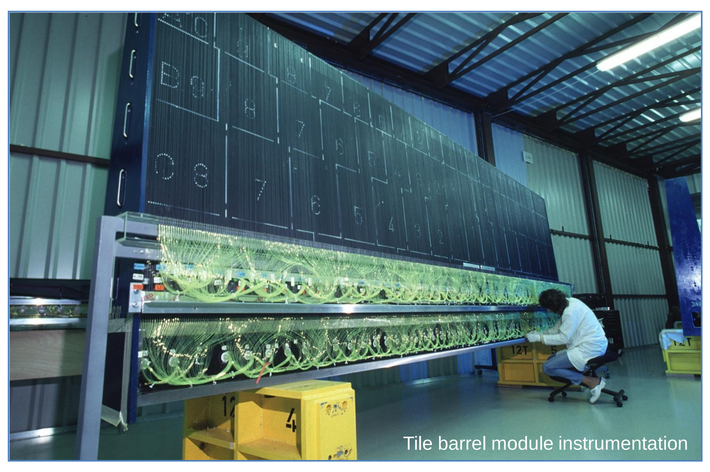
The ATLAS Tile Calorimeter



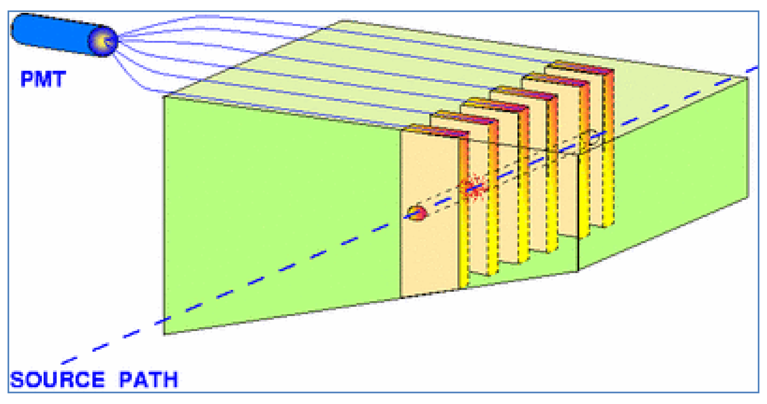
- **Sampling hadronic calorimeter**
- **Steel** absorber plates and **scintillating tiles**
- Three cylindrical sections, Ø9×12m in total
- **10 000 PMT** channels
- 64 independent azimuthally oriented modules.
- **Projective geometry** cells, **WLS fiber** light collection
- 45 cells per barrel module, 0.1x0.1 $\eta\phi$ 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



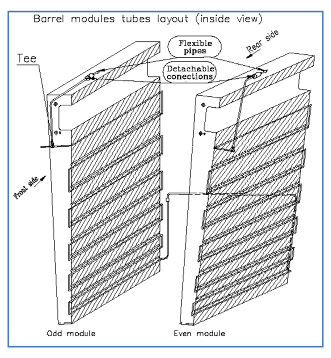


^{137}Cs calibration principles

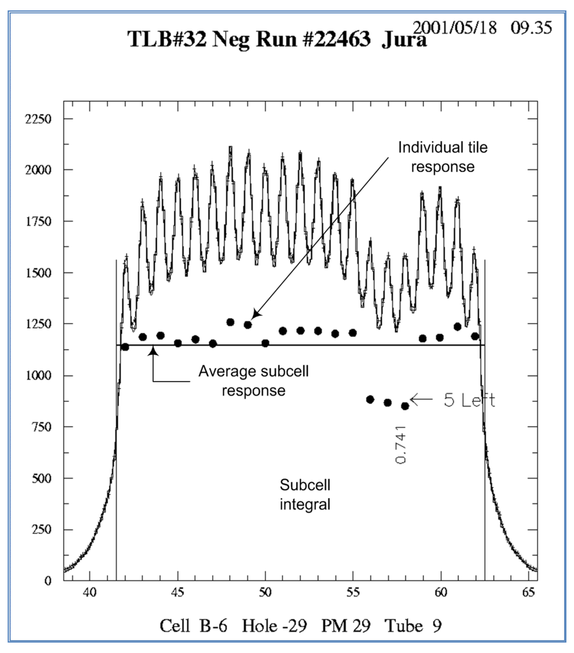


- **Powerful ~10mCi ^{137}Cs γ-source**
- E_γ=0.662 MeV, $t_{1/2}$=30.2 years
- Dumb-bell capsule driven by **liquid flow**
- Optical quality test of the scintillators and fibers
- **Better than 1% cell response equalization**
- Monitoring of every cell over time
- Overall **energy calibration**

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, to transport the energy scale, and to monitor detector performance over time together with other calibration systems.



Several modules were tested with calibrated energy beams of various particles and at the same time the response to the Cs source was measured. Later on all other modules were scanned with the source and the high voltage was set up accordingly, to have the same response as the tested modules, thus **transporting the energy scale** from test-beam measurements to experiment.

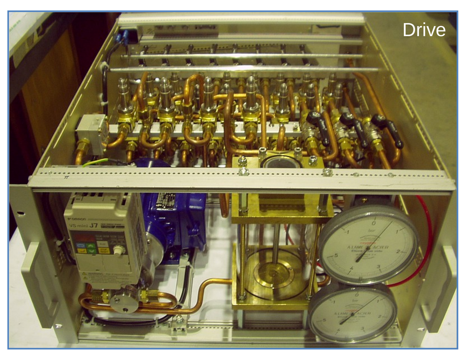


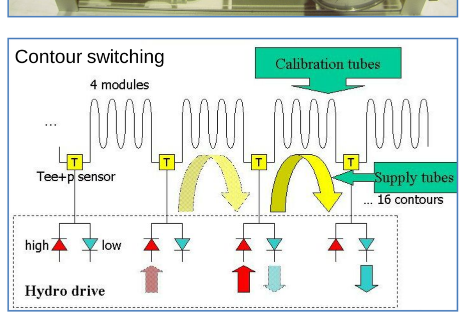
During a **cesium scan** we acquire the dependency of integrated signal in every channel versus time. Data are read out with the 90Hz frequency via **CAN** bus. Due to the sampling structure and light gathering scheme we get a number of signals in the shape of peaks. One period of peak structure corresponds to the passage of capsule through one period of TileCal module (iron/scintillator). Signal has maximum when capsule goes through the scintillating 2 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.

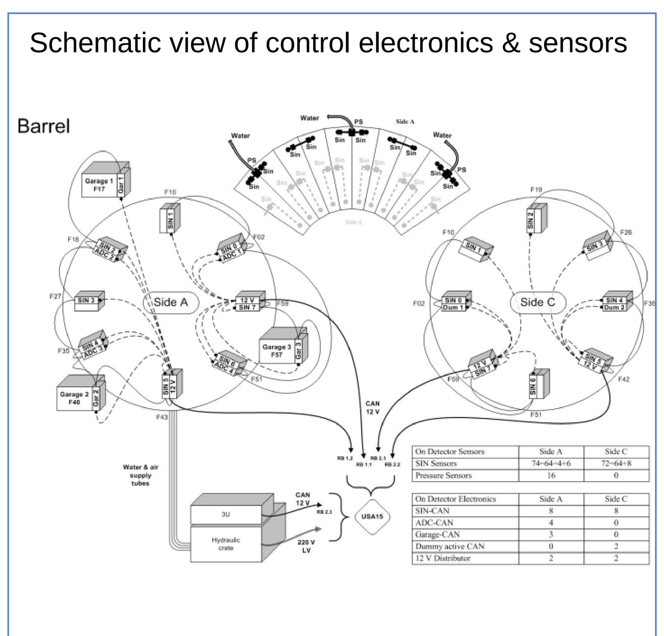
Source drive & control

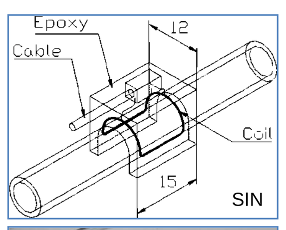
Hydraulic system

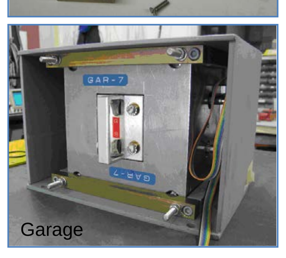
In order to transport the radioactive source in a safe and controllable way along the **10 km of tubes** inside the calorimeter, an elaborate source drive and monitoring system are needed. The hydraulic drive, which pumps the liquid to move the source is equipped with electronically operated pump and 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

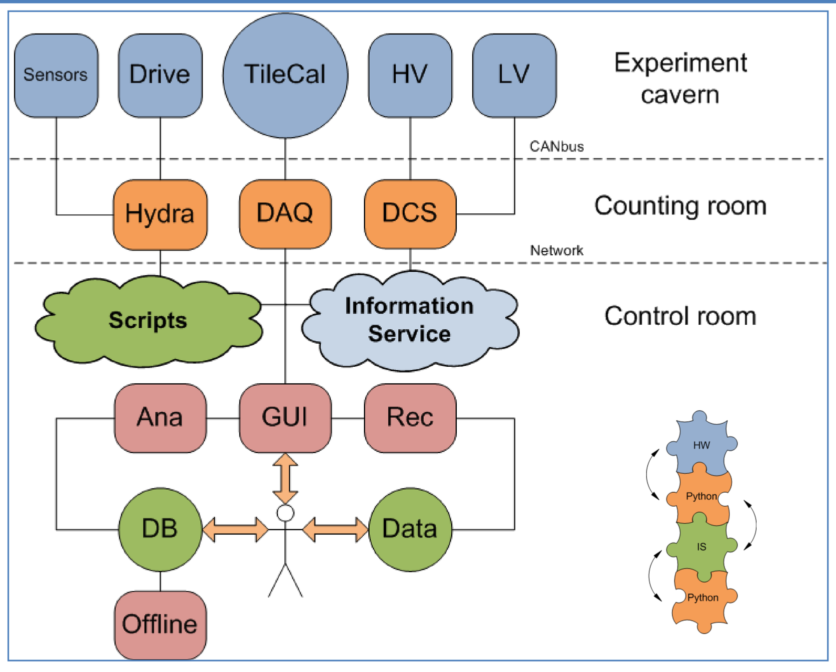
Apart from the font-end electronics itself, about **500 sensors** for capsule movement detection and pressure measurement are attached around the calorimeter surface and read out via ~**100 electronic boards** connected by the CAN bus daisy-chains.

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

Online software

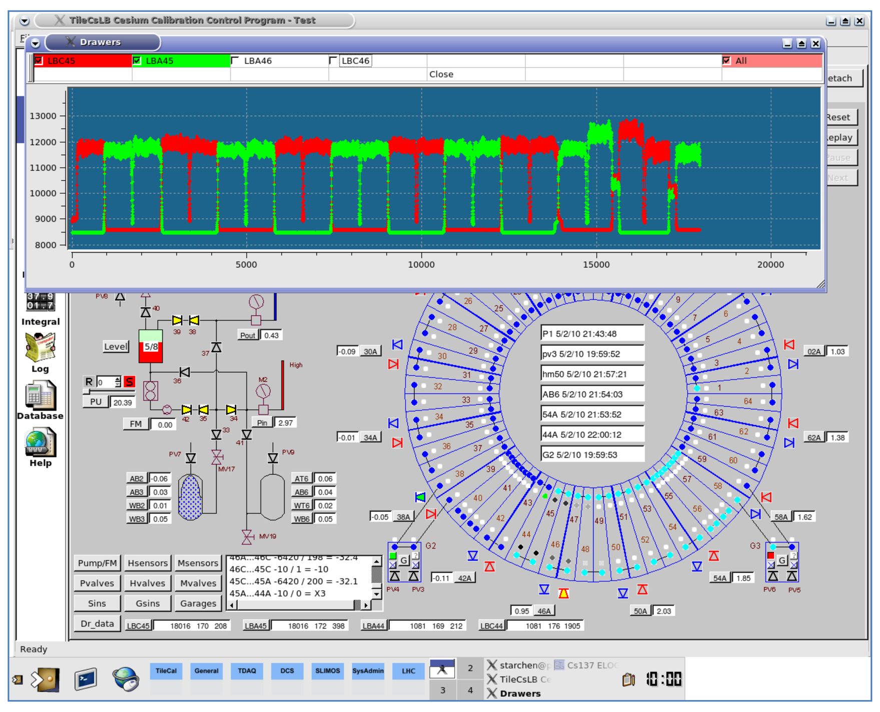
Distributed software

- **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.



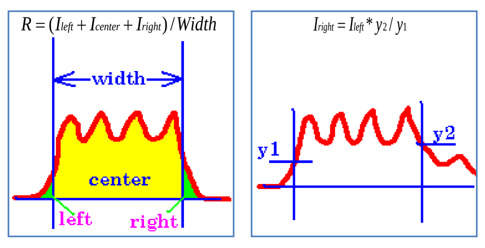
Multifunctional user interface

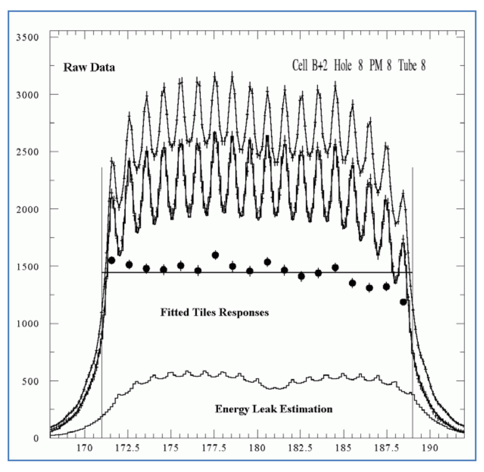
- **Qt** application running on Linux
- Functional system diagram
- Manipulations down to a single valve
- High level commands and scripts
- Information and status from all the sensors
- Colour coded source path and speed
- Pressure and other variables graphs
- Online data monitoring
- Run information
- Error messages and log files
- **History playback** in accelerated mode
- Audible status and alarms

Data analysis & results

Integral method

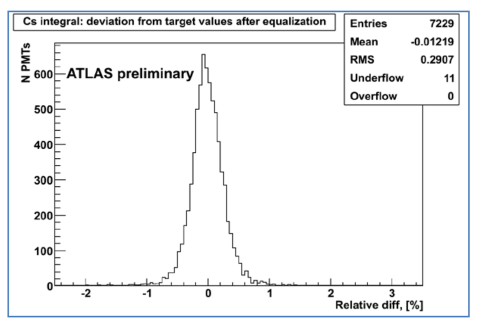
Mean period of the peak grid is calculated. Left/right boundaries of the cell are taken as the position of the first/last peak -/+ half of the period. Integral within cell boundaries, as well as integrals below left and right tails, are calculated. Energy leakage from one tile row to another is also taken into account.. The accuracy of the method is estimated at ~0.2% for the average cell response.





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 $F(x) = A(\alpha \times e^{-(x-x_0)^2/2\sigma^2} + (1-\alpha)\times e^{-|x-x_0|/\lambda})$. The 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

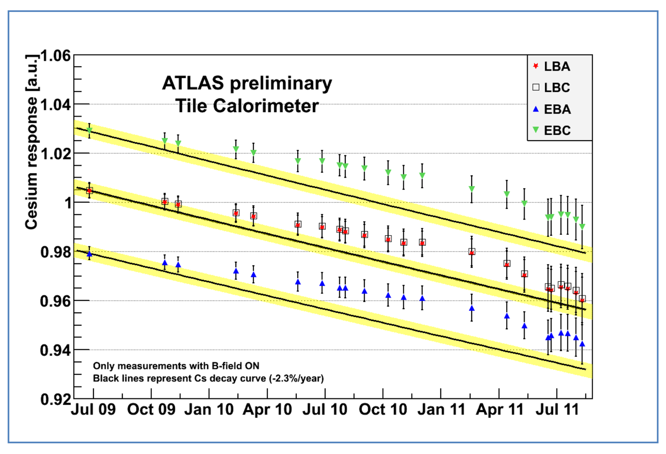
Cs system is used for initial equalization of cell responses. Signals from all the cells are equalized with an iterative procedure, the desired HV is then calculated and set in the hardware. Further small changes in the response are followed with the calibration constants.

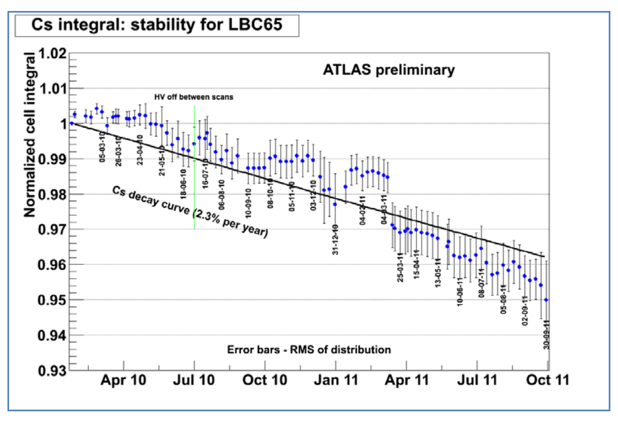
Calibration constants

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 one cesium calibration constant, stored in the database for every channel.

Stability

Monitoring of the Tile calorimeter responses to Cs source over the last two years shows good correspondence to the Cs decay curve, and all the deviations from it can be monitored with the precision better than 0.5%. Periods of beam activity/inactivity are changing the response of the calorimeter, so regular Cs scans, once every 2-3 weeks, are used for timely constants updates.





Long term test

A long term test facility has been created to study the behaviour of Tile Calorimeter spare modules in the absence of the beam. It has the same components as in the pit, but on a smaller scale of two modules, and it is scanned every week with the Cs source. The behaviour of these test modules is the same as the ones in the pit. This facility is also being used for hardware and software developments.

Conclusions

Cs movable source system is an essential tool to calibrate and monitor the response of the Tile calorimeter with time and changing environment. The system is working reliably for three years, providing precision calibration used for real event reconstruction. Future improvements and upgrades of the system are being planned, including more complex analysis of special cases and hardware evolution of the source driving equipment.

Conference on Future Perspectives in High-Energy Physics "Physics in the LHC era"
October 17-21, 2011, TSU, Tbilisi, Georgia

Oleg.Solovyanov@cern.ch