EDIT 2011

Excellence in Detectors and Instrumentation Technologies
CERN, Geneva, Switzerland - 31 January - 10 February 2011

Laboratory 1A: Calibration of ATLAS Tile calorimeter barrel module with the use of a movable ^{137}Cs source

Laboratory script

Tutors: A. Karyukhin, S. Solodkov, O. Solovyanov, J. Starchenko, H. Wilkens.

NOTE: Every participant should be in a possession of a personal radioactive dosimeter, provided by the organizers. Record the dosimeter serial number and the accumulated dose before and after the exercise.

Name: Dosimeter N: Dose at start: Dose at end:

1. Introduction

ATLAS is a general-purpose pp-experiment at the Large Hadron Collider (LHC) at CERN. The Tile Hadronic Calorimeter (TileCal) [1] is an essential part of the detector. It contributes to the energy measurements of particles and jets produced in pp interactions as well as to the missing E_t measurements. TileCal together with the Liquid Argon (LAr) calorimeters constitutes the ATLAS calorimeter system.
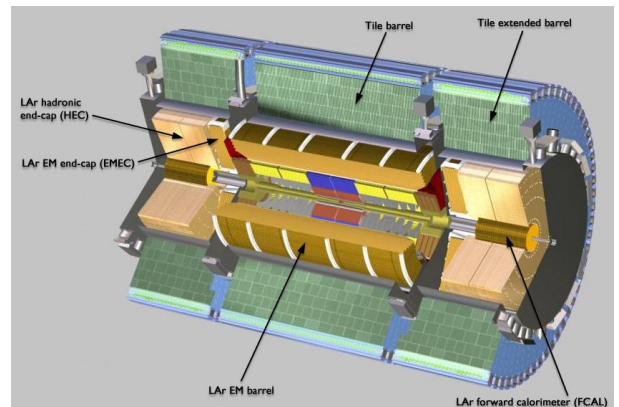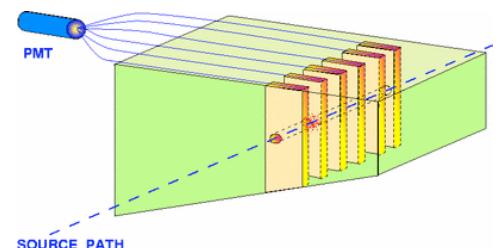

TileCal consists of one barrel (TLB) and two extended barrel (TLE) parts. All the three sections have a cylindrical structure with an inner and outer radius of 2280 and 4230 mm respectively. Inside the TileCal the mechanical structure a LAr Calorimeter cryostat is positioned.
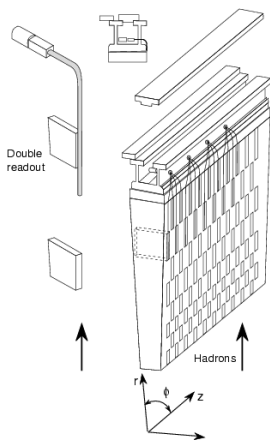
Each of the cylinders is further subdivided into 64 independent azimuthally oriented modules. The scintillating tiles lie in the r-φ plane inside the module and light from tiles is collected by WLS fibres running radially. Readout cells are then defined by grouping together a set of fibers into a photomultiplier (PMT). There are 45 cells in one TLB module and 14 cells in one TLE module.

To calibrate and monitor the TileCal it was proposed [2] to use Cs^{137} γ-source, which moves inside the calorimeter body.

When every scintillating tile is traversed by the Cs^{137} source, a flow of γ particles, with energy E_γ=0.662 MeV induces light emission in the cells tiles. The light is then transported to PMTs by fibers. The value of PMT's current reflects the tiles and fibers optical quality in the cell.

Tile Calorimeter
Cells and Tile Rows

Calibration tubes layout for Tile calorimeter modules.

There are 11 Ø6.0x8.0 mm stainless steel tubes rows in the LB module (left picture) and 12 rows in EB one (right). Every cell is traversed by 2÷6 tubes according to number of tile rows included into the cell. So, the traveling source will irradiate ("illuminate") all the tiles included and will produce a detailed picture of cell response. Total length of the calibration tubes including modules inter-connections and supply ones is around ~4500 meters (LB) and ~2000 meters for each EBs.

While crossing a tile the source radiation penetrates up to 5 adjacent tiles, so the resulting picture is a superposition of a number of tiles (~10). The evaluation of real response of an individual tile becomes a difficult task. It is easier to calculate mean row (and cell) values, so called "integrals" – a nickname for a tile-row mean response.

$$R = (I_{left} + I_{center} + I_{right})\,/\,Width$$

The combination of these mean values over all the tile rows belonging to the cell is a mean cell response. The procedure of the "integral" calculations is a special program which provides the cells mean responses, deviation from the reference ones and HV corrections to be applied to improve the situation.

To determine the electromagnetic scale, few modules were brought to test-beam where they were calibrated using electron, pion and muon beams of well-defined energy, and under different incident angles.

The system main goals and tasks:

- Check and monitor the whole optical path quality of the calorimeter cells from scintillator to PMT with the accuracy better than 1%.
- Be capable to perform an operational adaptation of PMTs high voltage (HV) settings for the best whole calorimeter uniformity and energy range
- Inter-calibrate modules to real particles using calibrated energy source
- Calibrate all the cells in all 64+64+64 modules of all three calorimeter sections

The main principles:

- Use a powerful ^{137}Cs γ-source depositing equal energy to all the cell tiles and by its nature having interaction characteristics alike to "real" particles
- Response value is identified by measurement of the individual PMT integrated current
- The source, embedded in a strong capsule, drifts inside stainless steel calibration tubes with a flow of liquid (water), the tubes pass through all the tiles of each calorimeter modules
- The system is composed of three independent parts (LB, EBA, EBC), having closed source circuits with three separate ^{137}Cs γ-sources.
- Calibration tubes sequences in each part are divided into number of segments (contours) with corresponding number of supply tubes. That helps to keep the applied operational pressure at the minimal level
- All the system operations are controlled remotely
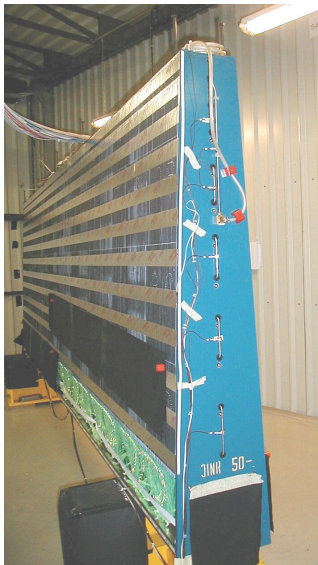
In the pictures one can see a module with installed calibration tubes (left), a real ^{137}Cs γ-source embedded into a capsule and, as an illustration, the way the capsule pass the bent tube section – that explains a dumbbell shape of the capsule.
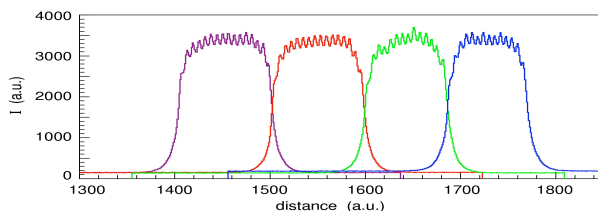
While every cell is traversed by the source, the resulting response picture (top) reflects their whole status and quality of every tile of a selected cell (right). So, that is in a kind of an X-ray photo of the calorimeter.

3
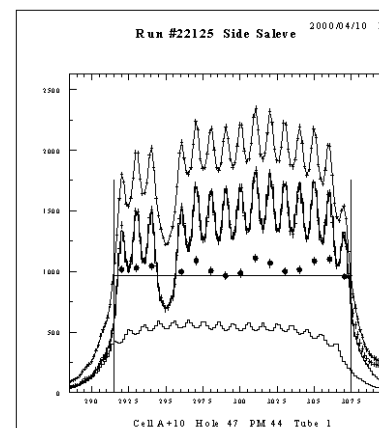
2. Scope of the laboratory

- Presentation of test-bench organization, tasks and performance. Comparison with the full scale (ATLAS) calibration system
- Components of the source calibration system:
  - o pipes, sensors, hydraulics and electronics
- On-line control and data acquisition operations, graphical user interface, safety aspects
- Scans with radioactive source and high voltages optimization
- Analysis of the calibration data

3. Laboratory setup

Cs monitoring system test-bench functionally is an exact replica of the real (big) ATLAS TileCal system scaled to use only two calorimeter modules instead of almost two hundreds.

All the parts of the system: sensors, hardware and electronic equipment [3] as well as the software [4] is the same as used in the ATLAS cavern to run though all three calorimeter subsections.

It consists mainly of the following parts:
- Two TileCal spare modules (LB#65 and EBA#65) used for long stability test
- Storage device (garage) to keep the source safe inside in between the scans
- Hydraulic system to drive the source through one or another module
- Control system to operate the source movements in a safe mode
- DAQ to collect the response data via CAN bus
- Dedicated software program, packages and procedure to fulfill the tasks
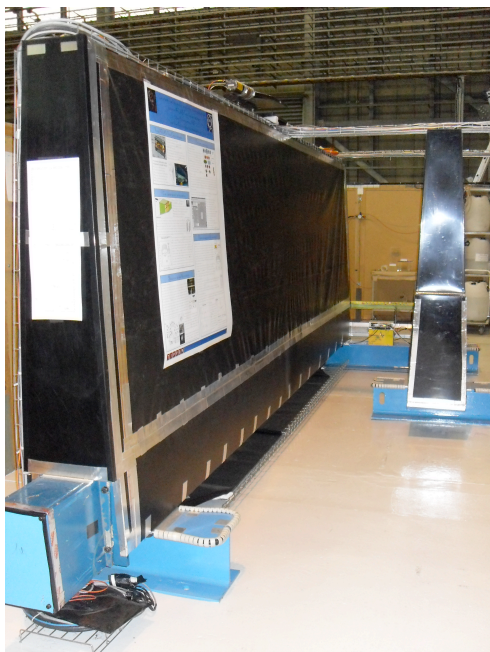
At the left picture there is a general view of both LB and EB modules in the Cs safety zone. The yellow box at the back is the source storage device (garage), containing ~300 MBq ^{137}Cs source behind the ~5 cm of lead shielding.

Picture below presents a simplified schematics of the calibration tubes layout, pumping device (drive), the garage location and source movement detection sensors.

4
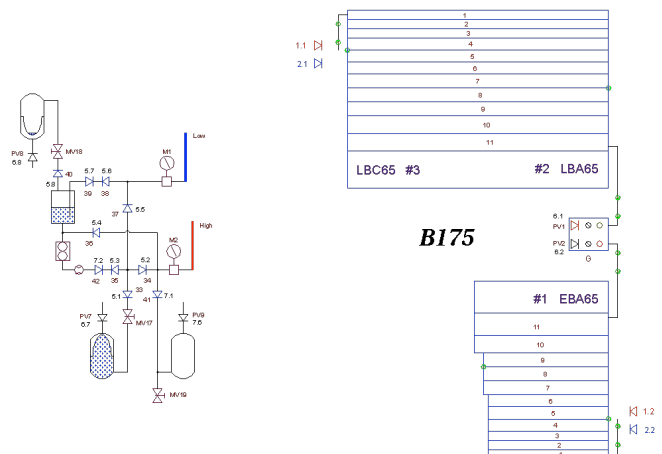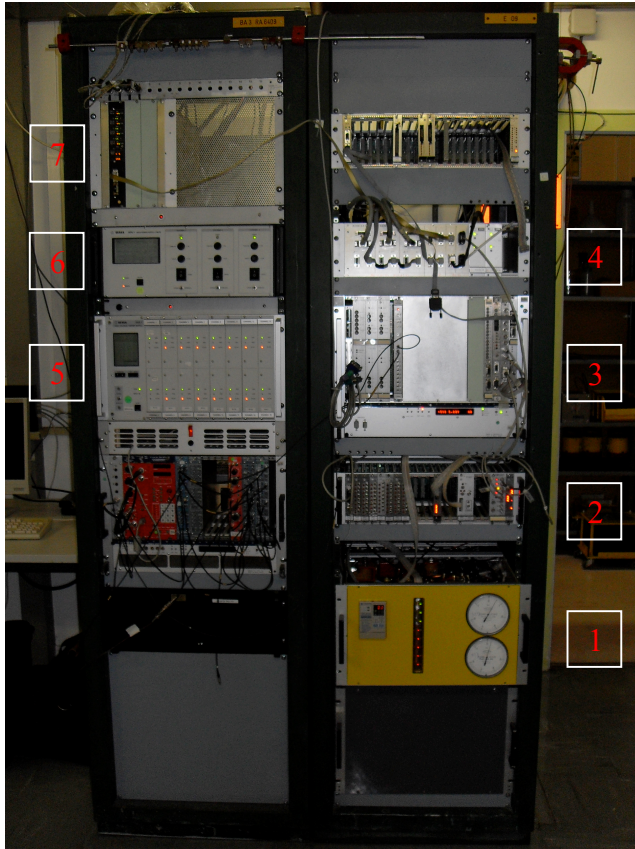
In the left picture there are two racks containing the main system control equipment, placed in the room adjacent to the safety zone.

One can see there:

1. Pumping unit (drive)
2. Pump, electromagnetic valves and sensors control unit (3U crate)
3. On-line CPU and CANbus buffer
4. CAN bus power supply
5. HV power supply
6. LV power supply
7. Auxiliary board for LV control
8. Hidden behind the racks are liquid and gas storage vessels, manual valves patch panel, pressure air control distributing equipment etc.

The procedure of a usual Cs scan consists of the following main steps:

- The test zone is checked and all the doors are safely closed. No person is allowed at the test zone during the scan. Flashing lamps announce that the zone is closed.
- Load and check the software packages responsible for the equipment control, DAQ, data storage and GUI
- Test the communications with module front-end electronics and control units, make sure that the proper responses are received and all the equipment has expected (normal) status.
- The chosen module scan starts when pre-arranged run script is sent to the control process.
- The source movement and data quality might be seen and controlled with GUI screen and on-line display
- After the source passes through the module twice ("forward-backward"), returned to the garage and is safely locked there, the run stops automatically and the data are stored into "csNNNNN.root" file (where NNNNN – is the run number)
- The content of the stored file might be visualized with a qc.sh script located at the same data directory

4. **Measurements**

The aim of the measurements is to equalize the response of the cells of a module – thus to make all the cells responses equal to the same value (related to electromagnetic scale) by tuning the HV settings for each PMT.

We perform three measurements on a half of LB module - LBC. During the run LBA part of the module is scanned too but we will not use it in the analysis.

The first one is done with a completely un-calibrated calorimeter module (HV channels variation ~10%), the second one with ~5% variation (derived from the first set). Then the last set of HV settings is calculated from the results of the second scan and applied to the PMTs, finally equalizing all the responses. A third, final measurement is done with these new settings.

Preparatory steps:

- Make sure that all participants have their personal dosimeters with them
- Make sure that nobody is inside the scan zone, two warning lamps are on and the scan zone doors are closed
- At the control PC open DCS window and check that modules 2 and 3 are ON (all green).
    - See DCS screenshot below for expected correct status
- Open Hydra terminal by clicking corresponding icon at the desktop and then type:
    - `cs`
    - `hydra`
    - `>>> config()`
    - `>>> drive()`
    - `>>> run()`
- Open DAQ terminal by clicking corresponding icon and then:
    - `cs`
    - `daq`   *(this takes time…)*
    - `>>> config()`
    - `>>> prepare(lb)` *(this takes time…)*
    - Wait until configuration is finished
- Open CCCP GUI by clicking the corresponding icon
    - Enter the password provided by tutors
    - Select "Test" from left menu
- Open Main terminal by clicking the corresponding icon and then type:
    - `source ~tilecs/public/setup_cs.sh`
    - `mainlab`
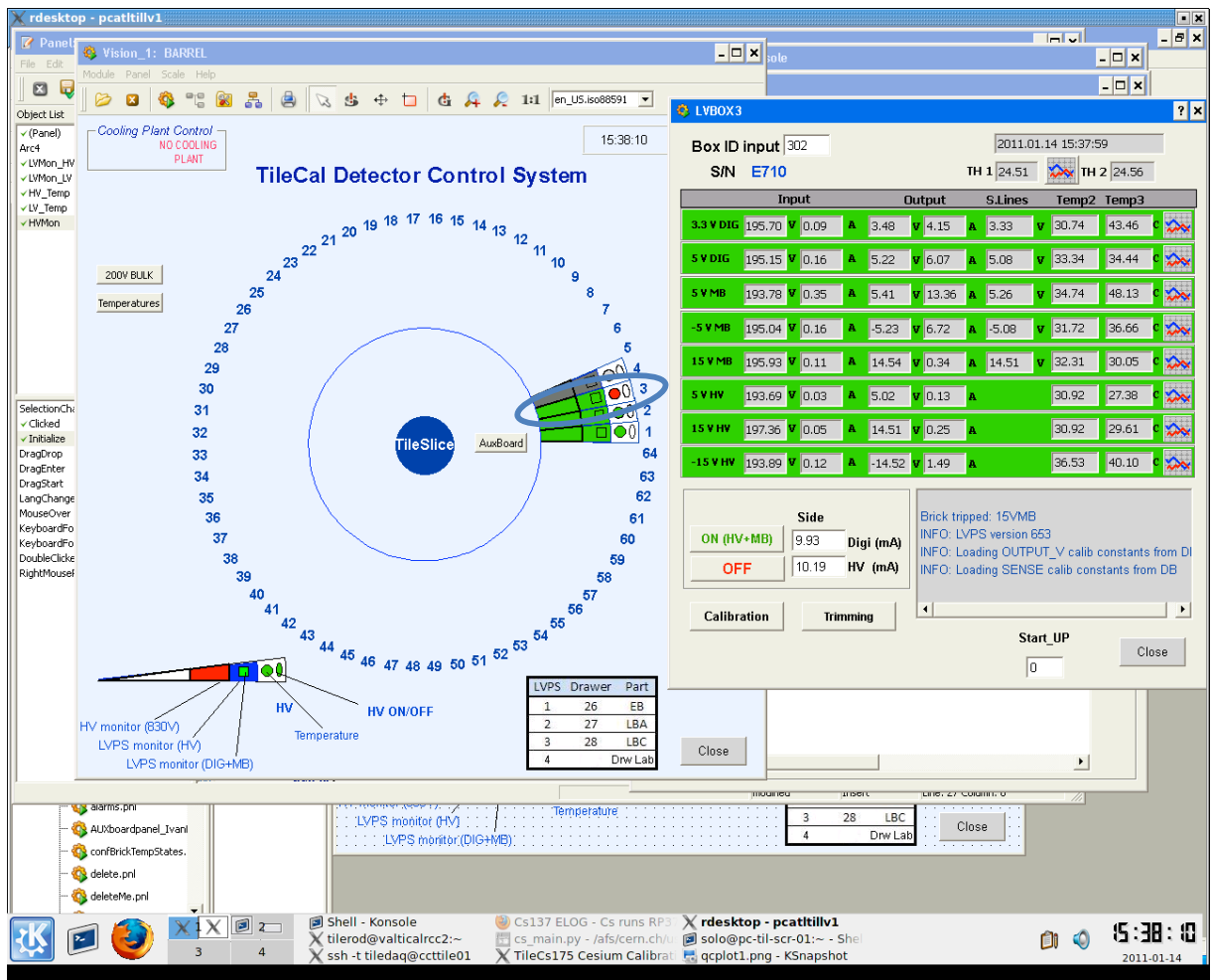
DCS screen. Module 3 inner (HV) and middle (LV) wedges should be green.

4.1 "10%" un-calibrated scan

- Make sure that all preparatory steps from section 4 have been done
- Load 10% randomized HV set, from terminal window:
    - `cd /data/cs/labs/hv/B175`
    - `./loadhv.sh rand10`
- Start the scan from the Main window:
    - `>>> run1b()`
    - The scan will start, and you will follow the progress via the CCCP GUI
    - Click on LBA65 button to see the online plot
    - Wait until the end of scan (~10 minutes)
    - Record run numbers from Main window for further use
- Reconstruct the data:
    - `cd /data/cs/labs`
    - `./produce_int_b175_lab.sh run-number LB rand10`

CCCP Qt-based GUI

4.2 "5%" un-calibrated scan

- Load 5% randomized HV set, from terminal window:
  - `cd /data/cs/labs/hv/B175`
  - `./loadhv.sh rand05`
- Start the scan from the Main window:
  - `>>> runlb()`
  - The scan will start, and you will follow the progress via the CCCP GUI
  - Click on LBA65 button to see the online plot
  - Wait until the end of scan (~10 minutes)
  - Record run numbers for further use
- Reconstruct the data:
  - `cd /data/cs/labs`
  - `./produce_int_b175_lab.sh run-number LB rand05`
  - Note this run number for next measurement (final scan)

Online response vs. time plot (sum of all PMTs)

4.3 Final scan

- Load final HV set, from terminal window:
  - `cd /data/cs/labs/hv/B175`
  - `cp ../../int/csNNNNN/LBA65_NNNNN.hv ./`
  - `cp ../../int/csNNNNN/LBC65_NNNNN.hv ./`
  - `./loadhv.sh NNNNN`
  - where NNNNN is the run number from section 4.2 "5%" non-calibrated scan
- Start the scan from the Main window:
  - `>>> runlb()`
  - The scan will start, and you will follow the progress via the CCCP GUI
  - Click on LBA65 button to see the online plot
  - Wait until the end of scan (~10 minutes)
  - Record run numbers for further use
- Reconstruct the data:
  - `cd /data/cs/labs`
  `./produce_int_b175_lab.sh run-number LB NNNNN`
  Where NNNNN is the run number from measurement 4.2

Measurement	Run number	Mean	RMS
Rand10			
Rand05			
Final			

5. Data analysis

Go to the directory /data/cs/labs/int/summary
Identify ROOT files, obtained during measurements.
Study the distributions of the PMT responses by making histograms of the variable
LBC[64][pmt][12] (integral response), where pmt index is in the range [0-47].

```
Quick example:
1. shell> root integrals_NNNNN.root
2. root> tree = (TTree *)gROOT->FindObject("integrals")
3. root> tree->Draw("LBC[64][][12]","LBC[64][][12]>100")
```

- Get mean value and RMS of the distribution plotted as described in previous paragraph
- Using 3 runs with different HV settings, plot the pmt response vs. HV settings and then fit it with the $I=I_0*(HV/HV_0)^\beta$ function and extract β factors for all PMTs
- Plot a distribution of β factors
- One could use showint.C macro, provided with the laboratory.

6. Questions

- What are the main goals and principles of Cs monitoring system?

- The advantages of the system in comparison with other ones (laser, charge injection)

- The main parts of the system, their tasks and the main parameters

- Achieved accuracy and performance

- Why ^{137}Cs γ - source is particularly good for TileCal (vs other γ - sources or β & α)?

- Potentially dangerous aspects of the system. What are the safety measures that must be taken while working with Cs system?

7. References

[1] Tile Calorimeter Technical Design Report, **CERN/LHCC 96-42**, December 1996.

[2] E. Starchenko *et al*, Cesium monitoring system for ATLAS Tile Hadron Calorimeter, **NIM A 494 (2002) 381-384**

[3] N. Shalanda, A. Karyukhin, Radioactive source control and electronics for the ATLAS tile calorimeter cesium calibration system **, NIM A 508 (2003) 276–286**

[4] O. Solovyanov *et al,* ATLAS tile calorimeter cesium calibration control and analysis software 2008 *J. Phys.: Conf. Ser.* **119** 022012

[5] O. Solovyanov et al, Cesium calibration and monitoring system of the ATLAS Tile Calorimeter, **TIPP2009**