Irradiation effect on the response of the scintillators in the ATLAS Tile Calorimeter

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"Instrumentation as enabler of Science"

Outline

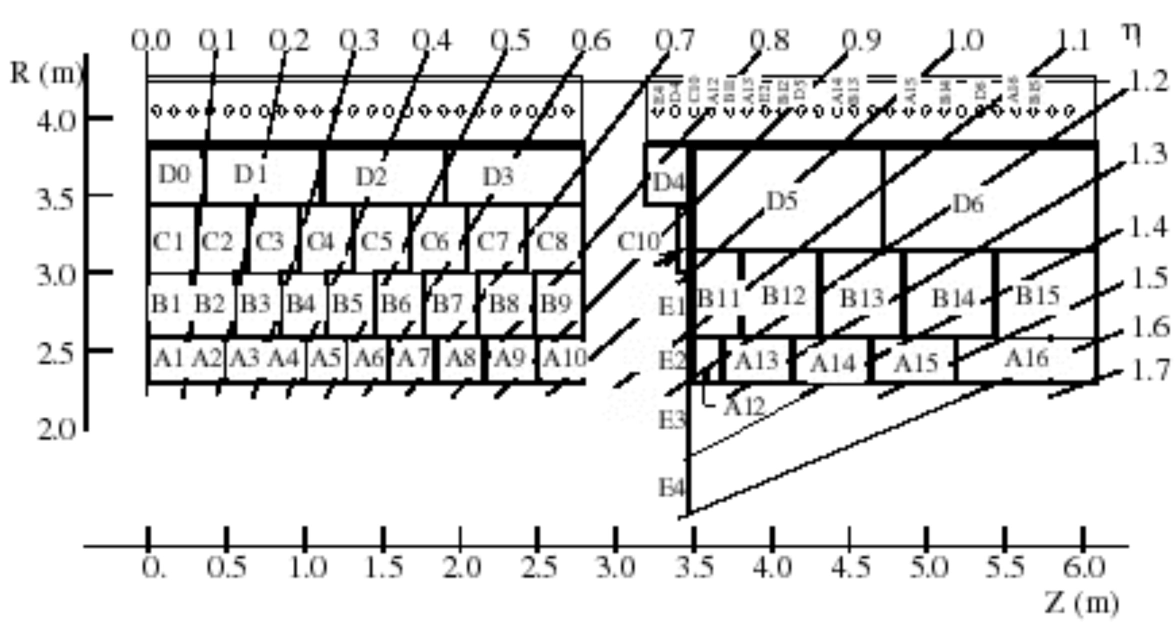
- The ATLAS hadronic calorimeter: TileCal
- Calibration/monitoring of the Tile Calorimeter
  - The Cesium system
  - The Minimum Bias system
  - The Laser system
- Study of the scintillators irradiation
- Conclusions

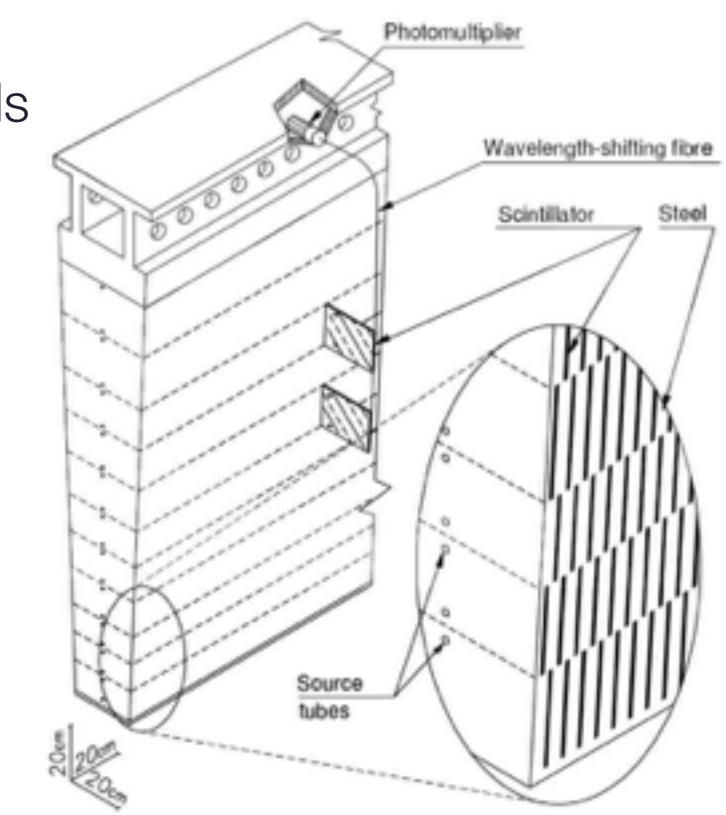
The Tile Calorimeter: overview

- The Tile Calorimeter is the central hadronic calorimeter of the ATLAS experiment
- It is a sampling calorimeter made of steel plates (absorber) and scintillating tiles (active material)
- It provides accurate energy measurements of isolated hadrons, taus and jets
- Calorimeter performance:
    - high data quality efficiency (over 99.6% during 2012)
    - high data acquisition efficiency (over 99.5% during 2012)
- Activities during Long Shutdown 1 aim to ensure high performance, high quality, robust operation during Run II (starting early 2015)

The Tile Calorimeter: structure and readout

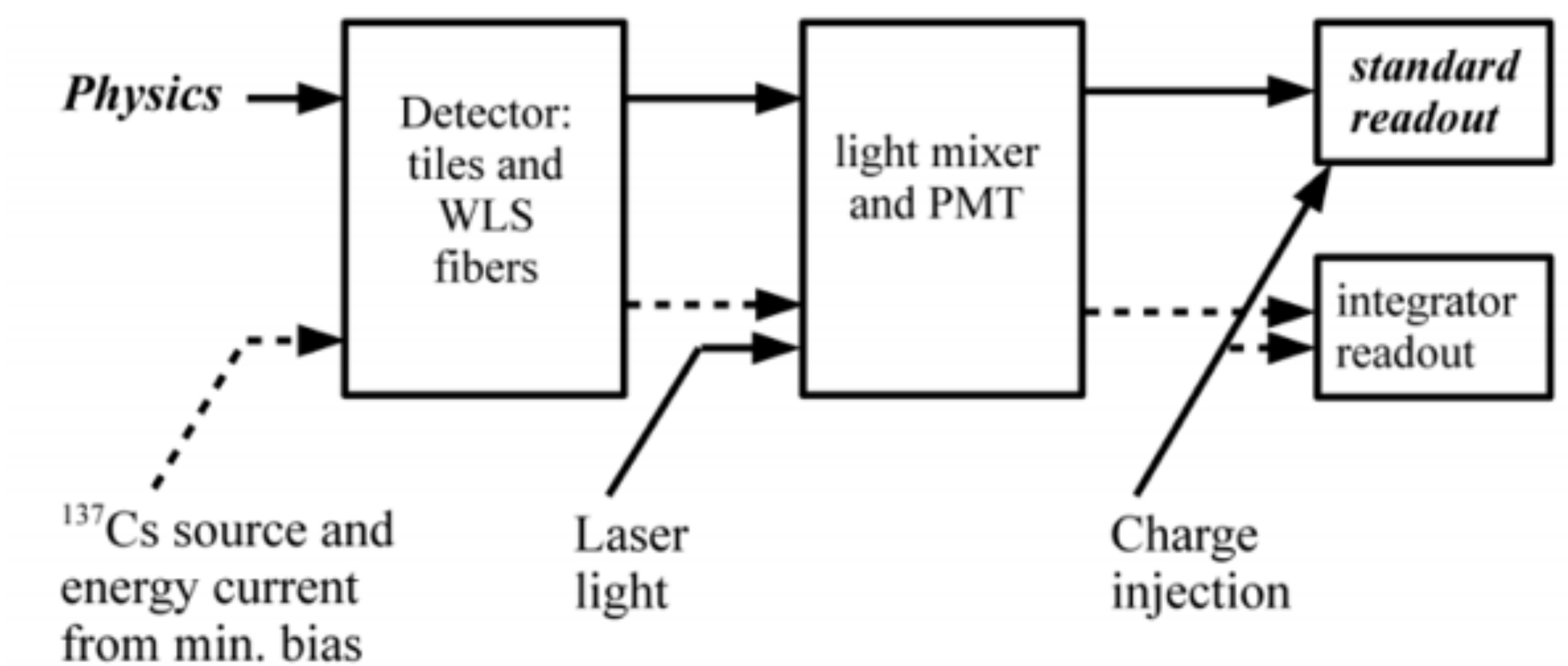
- It consists of three cylinders, covering the most central region $|\eta|<1.7$
- Total thickness of 7.4 λ_{int} at $\eta=0$, total length 12 m, diameter 8.5 m, weight 2900 tons
- Each TileCal cylinder is segmented in 64 modules along the azimuthal coordinate (granularity: $\Delta\phi\sim0.1$)
- Radially, each **module** is segmented into three layers called A, BC and D. The $\Delta\eta$ segmentation is 0.1 in the first two radial layers and 0.2 in the third one
- Light produced in the scintillating tiles is transmitted by wavelength shifting fibers which are grouped in "channels" readout by PMTs (Hamamatsu R7877)
- Each calorimeter **cell** is readout by two PMTs except for special cells which have single readout (9852 PMTs in total)





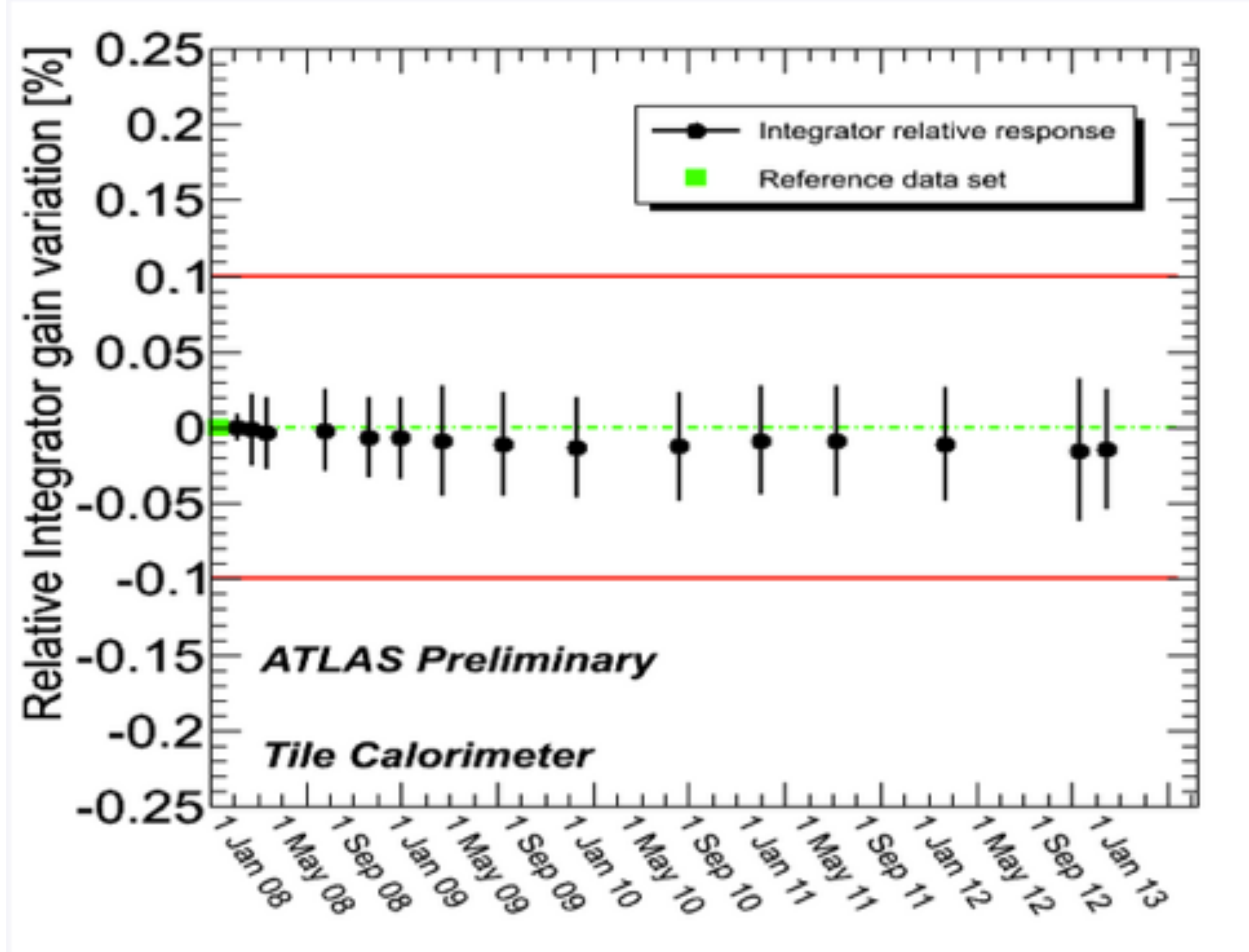
The Tile Calorimeter: calibration systems

- Four dedicated calibration systems for monitoring and calibrating the readout circuit as well as the PMTs and the optics
  - **Cesium system**: stability of the scintillators and inter-calibration of the calorimeter cells
  - **Minimum bias system**: stability of the scintillators and monitoring of the ATLAS instantaneous luminosity
  - **Laser system**: linearity and stability of the PMT response
  - **Charge injection system**: linearity and stability of the readout electronics
  - Only the first three systems will be considered in this presentation



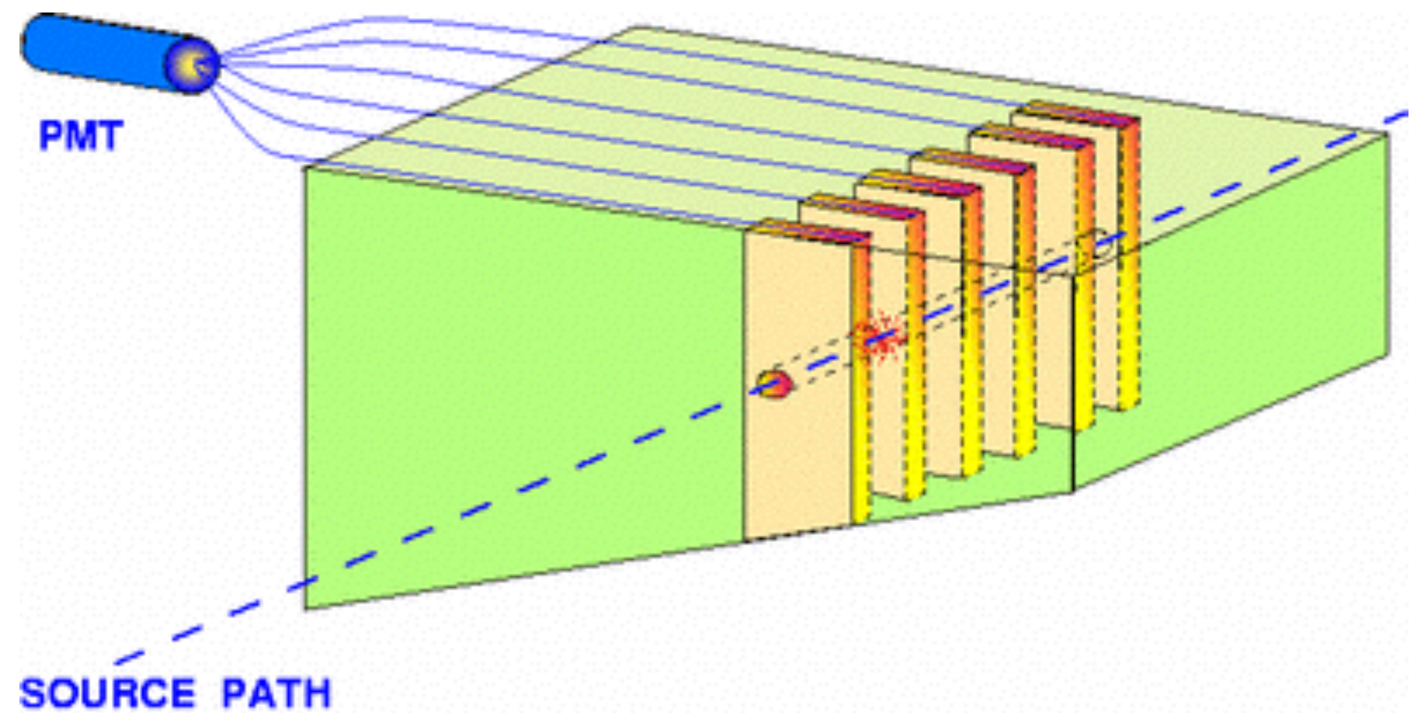
The Tile Calorimeter: the Minimum Bias system

- A signal integrator is printed on an electronic board plugged after every PMT
  - It provides readout for Cs calibration
  - It integrates the response to the continuous minimum bias proton-proton signals (soft parton interactions) over time, allowing
    - to monitor the response of all calorimeter cells during data-taking
    - to monitor the instantaneous ATLAS luminosity
- A 12-bit ADC card digitises the integrator output
- The integrator gain can be varied (six different gains can be configured depending on the instantaneous luminosity)
- Average gain stability better than 0.1%



The Tile Calorimeter: the Cesium system

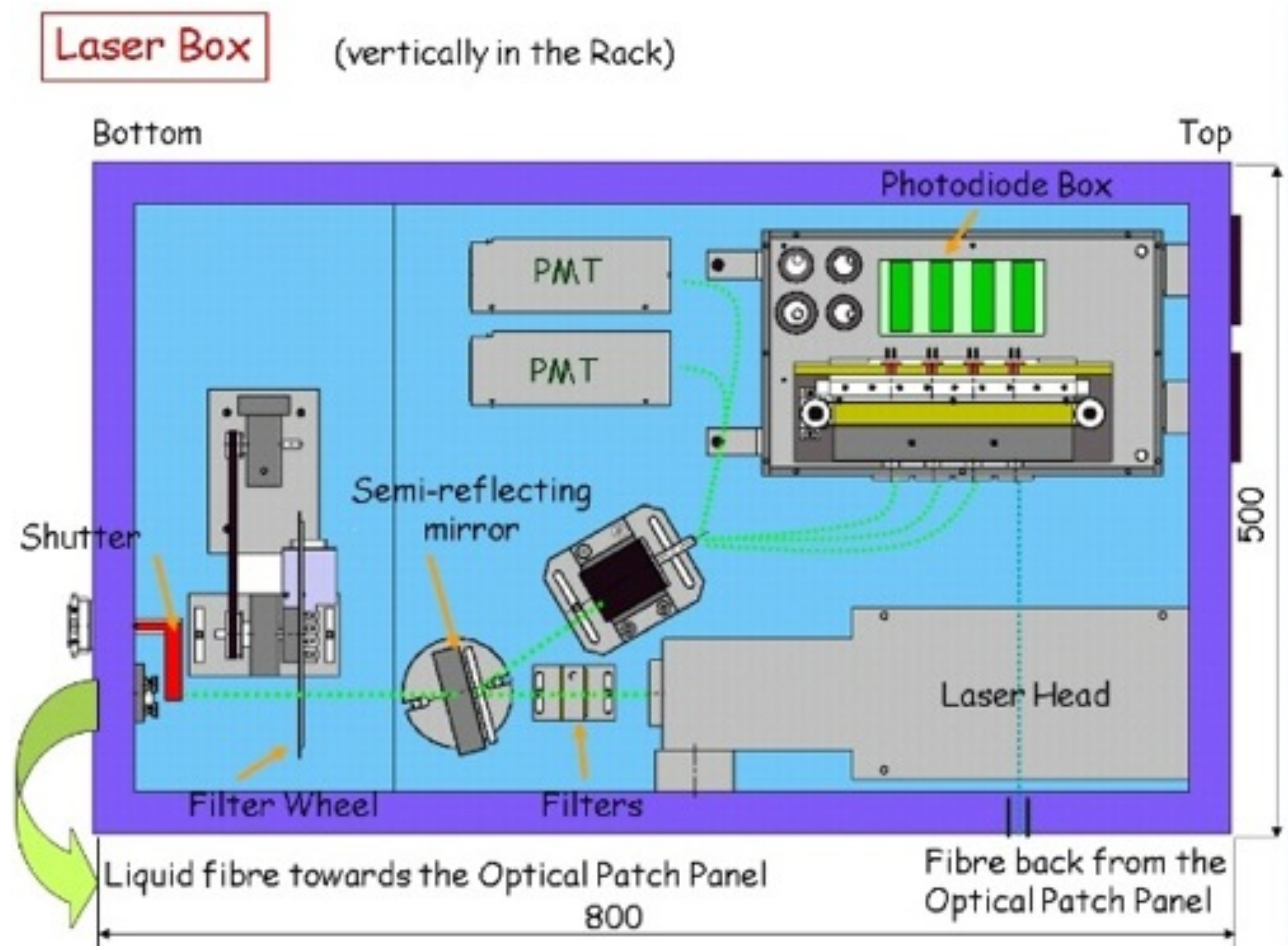
- A ^{137}Cs radioactive γ source is driven through the tiles using hydraulic system
- The integrator system measures the currents of every PMT
- Cs scans performed every one or two months during technical stops (full scan takes several hours)



- Cs calibration allows to equalise the channels response to a level of precision of 0.3%

The Tile Calorimeter: the Laser system

- Laser system allows the monitoring of the PMT response stability between 2 Cs scans
- Laser light with λ=523 nm, pulse width ~5-8 ns
- Intensity monitored by 4 photodiodes
  - Photodiodes response monitored using an α source
  - Set of filters to cover a large range of the PMTs response
- Light splitting system to send laser pulse to all 9852 PMTs simultaneously



Study of the scintillators irradiation: overview of the method

- A method for estimating the effect of irradiation on the TileCal scintillators has been developed, exploiting three different calibration systems:
  - Minimum bias (MB) and laser for direct evaluation of the effect
  - Cs as a cross check (see later)

- This study only includes the cells in the Extended Barrels, since they are those more exposed to irradiation

- The method:
  - Minimum bias and Cesium currents are sensitive to both PMT gain variation and scintillator irradiation
  - Response to laser is sensitive only to PMT gain variation
    - not affected by the ageing of the scintillators
  - Irradiation effect on scintillators is obtained by subtracting the gain variation measured by laser to the total variation seen by Cesium or MB (MB is chosen because more data are available)

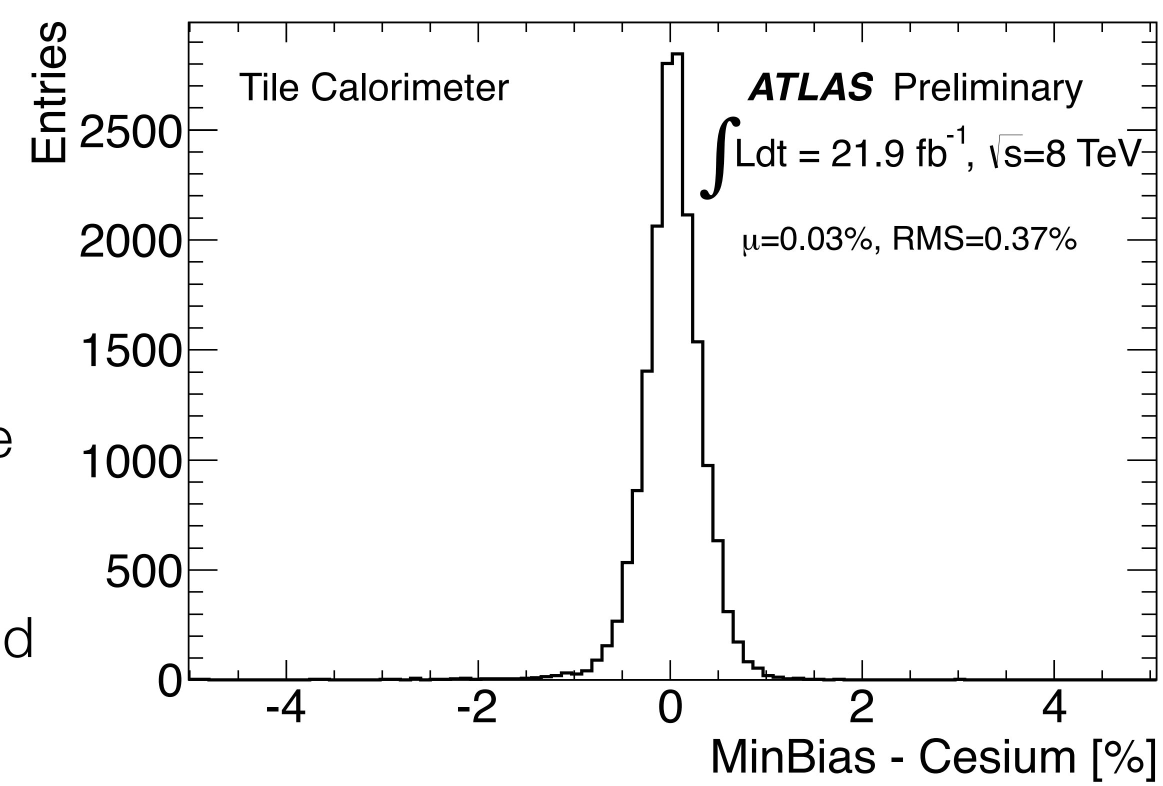
Study of the scintillators irradiation: overview of the method

- The study has been performed using MB data collected in a 7 months period in 2012, corresponding to a total integrated luminosity of ~22 fb^{-1}
- We choose one reference channel (each cell has two channels) to normalise both laser and MB response (a cell in the outer layer of the calorimeter is chosen since rather protected from irradiation)
  - The ratio $Channel_{probe}/Channel_{ref}$ doesn't depend on the variation of luminosity
- The relative response variation of the probe channel with respect to the reference channel is computed with the following relation for both MB and laser data:

$$Variation = \frac{[channel_{probe}/channel_{ref}]_{run_i}}{[channel_{probe}/channel_{ref}]_{run_0}} - 1$$

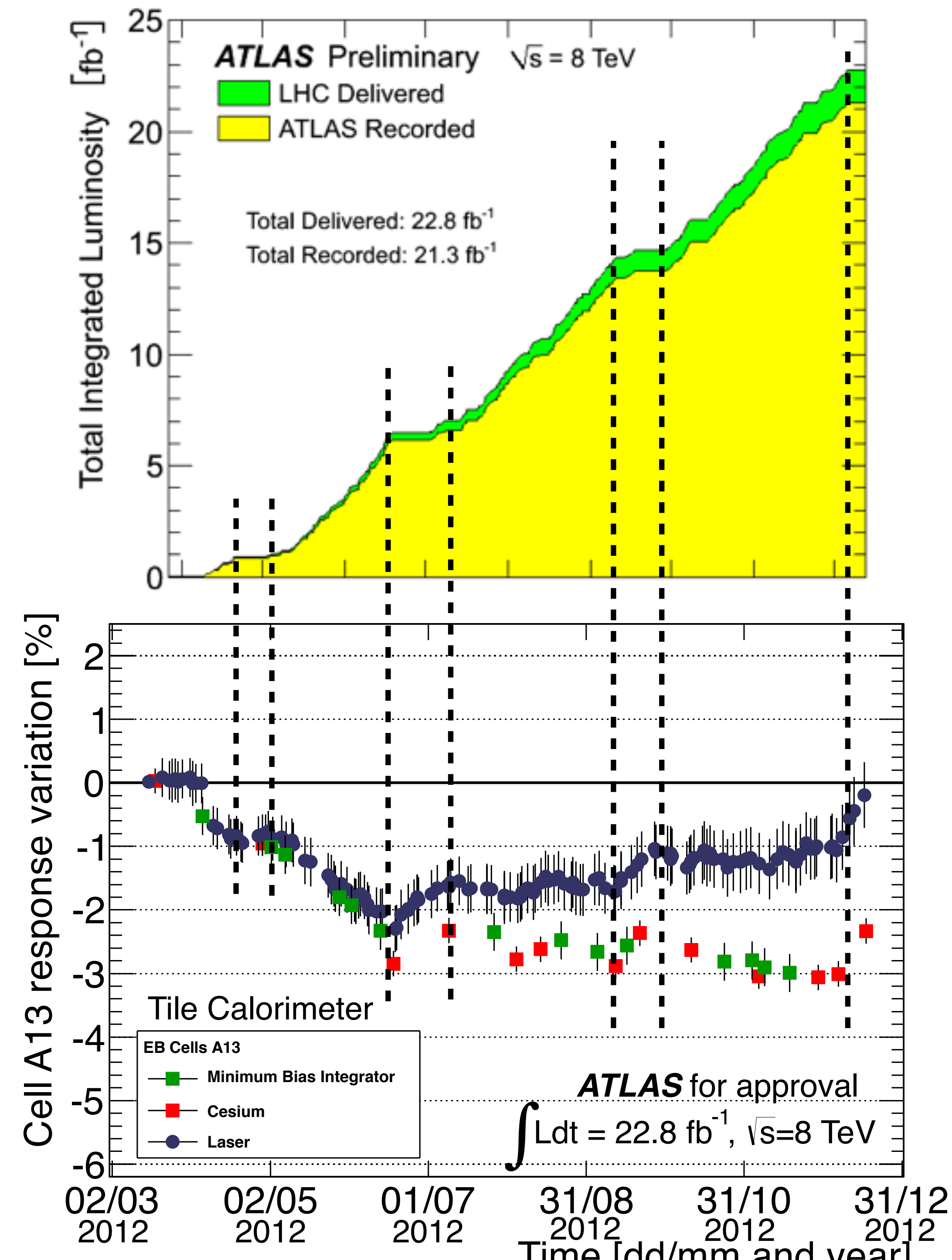
where run_0 is the first MB or laser data taking period in chronological order

- Cross check
  - Cs and MB systems sensitive to the same effects
  - Relative response variation should be similar for the two systems
  - Less than 2% of the events considered show a difference between MB and Cs variations > 1% (and are discarded from the analysis)



Study of the scintillators irradiation: variation of a very irradiated cell

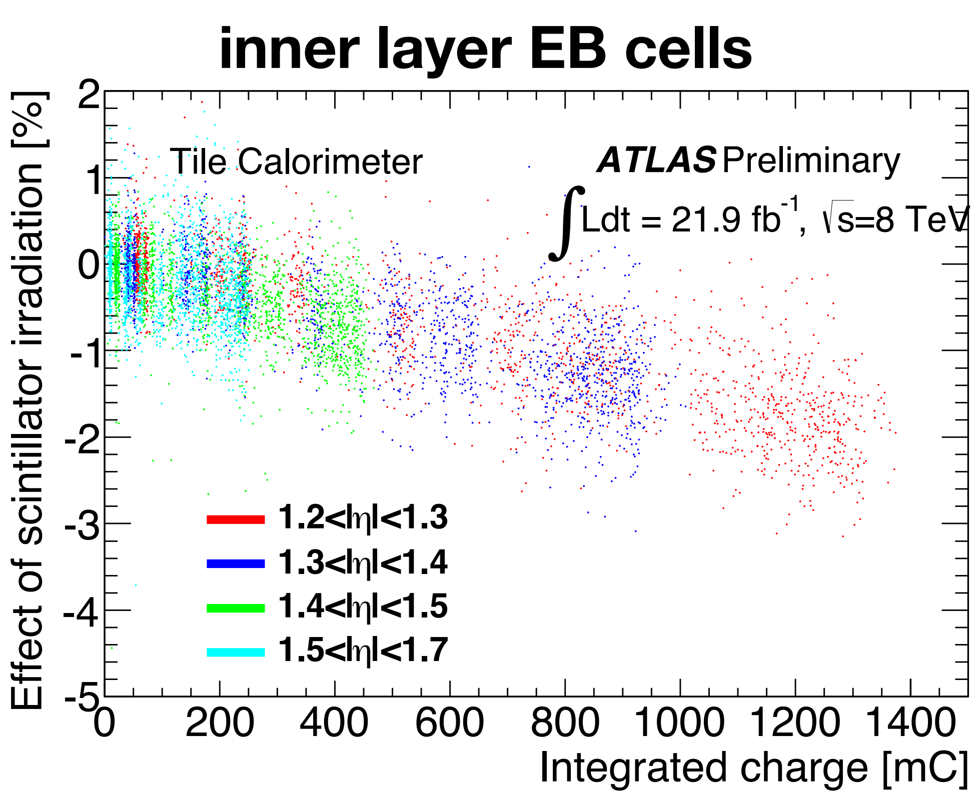
- The variation of the response to minimum bias, Cesium and laser for cells in the inner layer of the Extended Barrel (EB), covering the region $1.2 < |\eta| < 1.3$, as a function of the time
- The variation versus time for the response of the 3 systems is normalised to the first Cesium scan (before the start of collisions data taking)
- As already observed in 2011 the down-drifts of the PMT gains (seen by Laser) coincide with the collision periods, while up-drifts are observed during machine development periods and at the end of the proton data-taking
- The difference between MB (Cs) and laser is interpreted as the effect of irradiation on the scintillators (2% loss of response for these cells)

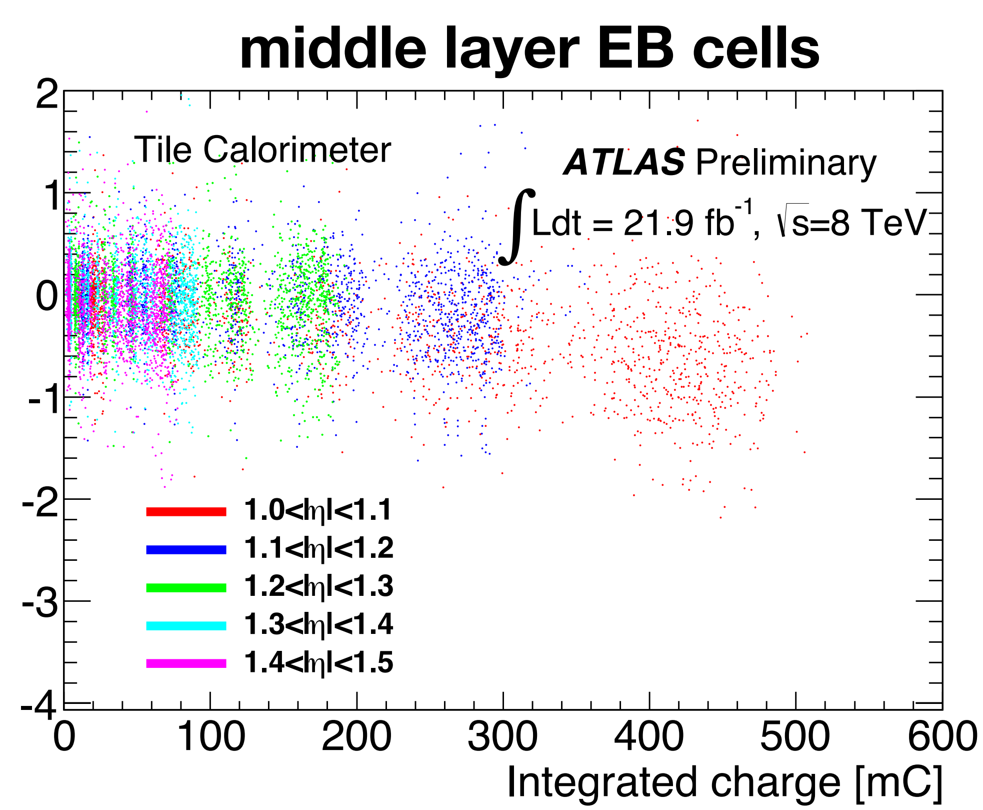


Study of the scintillators irradiation: results

- The relative variation of the response to minimum bias currents, after the subtraction of the laser component, as a function of the integrated charge, defined as $Q_{int} \propto \int L(t)dt$ for each cell, allows to compare the irradiation effect on the same scale for all cells independently from their position on the calorimeter

- Inner layer EB cells collect more integrated charge (up to ~1400 mC) with respect to middle layer cells (up to ~500 mC)



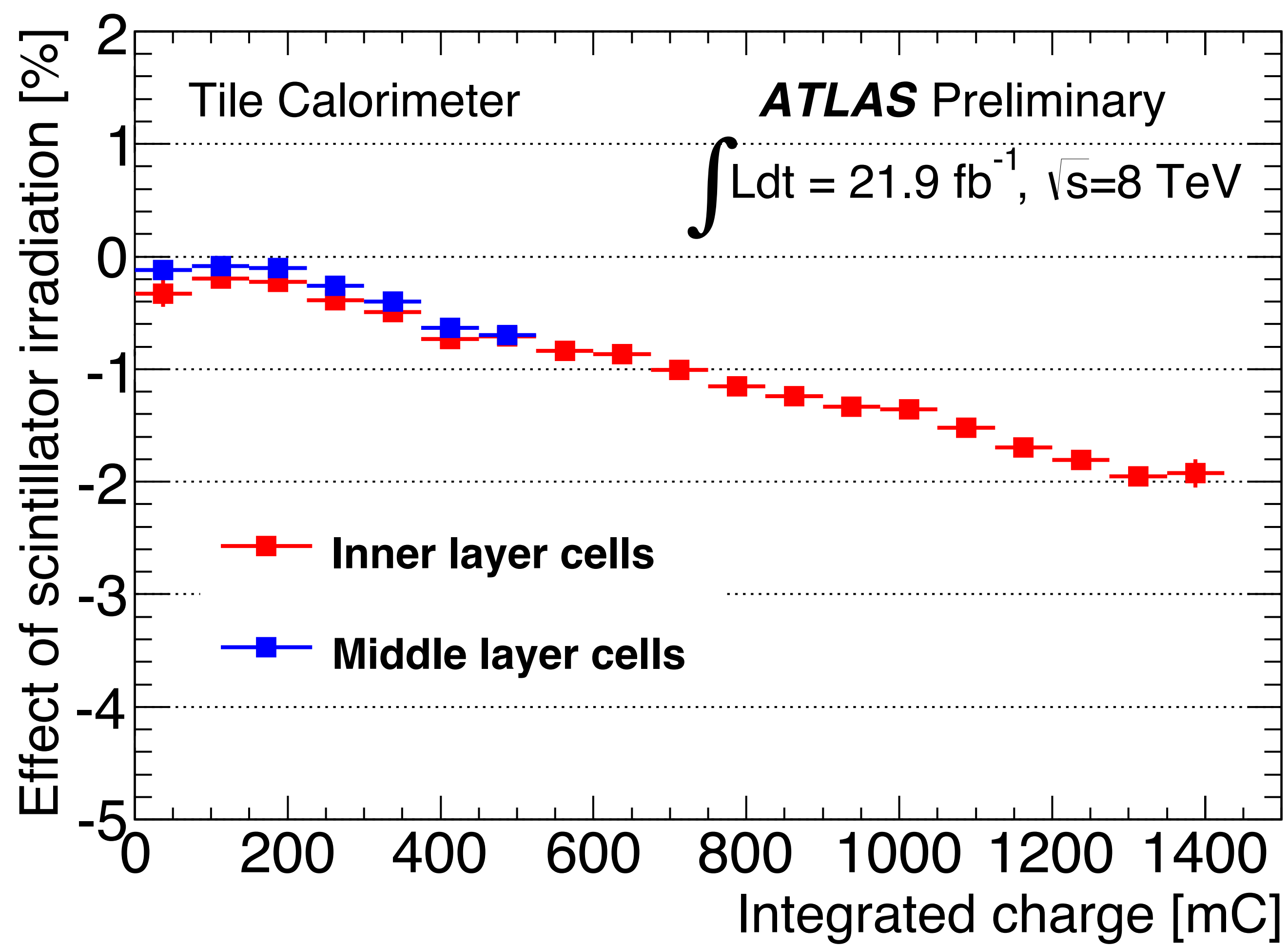


Study of the scintillators irradiation: results

- A loss of response as a function of the integrated charge is observed, which is interpreted as the effect of the irradiation damage on the scintillators

- The two types of cells show the same behaviour as a function of the integrated charge

- The loss of response is maximum (~2%) for the inner layer cell with $1.2 < |\eta| < 1.3$

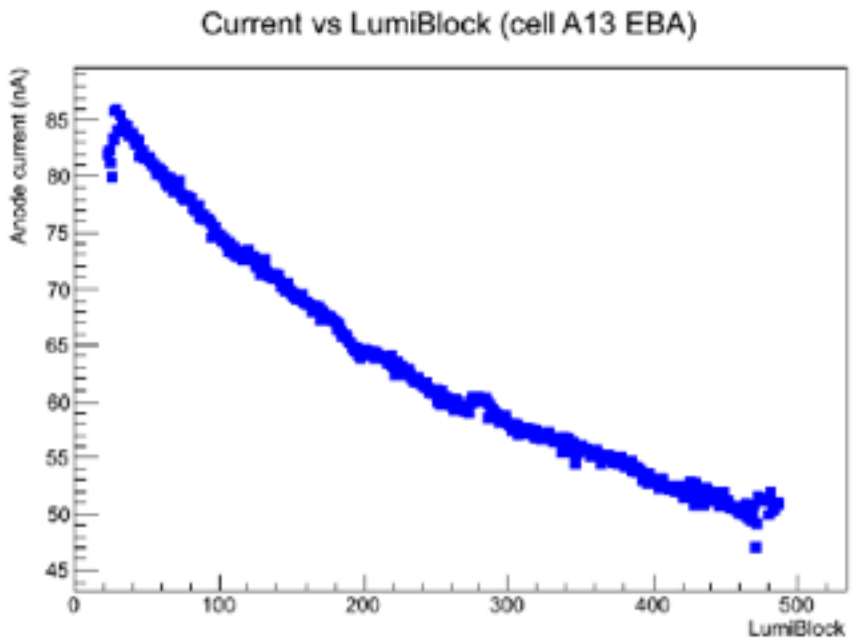


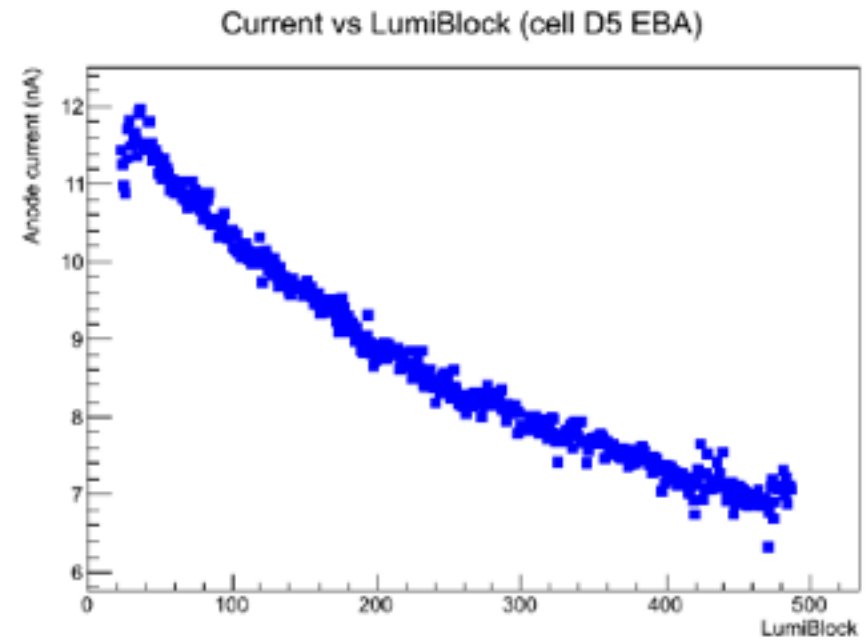
Conclusions

- An overview of the ATLAS Tile Calorimeter and three of its calibration systems has been presented
- A method for estimating the effect of the irradiation on the calorimeter scintillators, based on the combined use of different calibration systems, has been described
- The combination of the Cs, laser and minimum bias calibration systems allowed to compare the evolution of a very irradiated cell with that of the ATLAS integrated luminosity in 2012
- The results obtained for TileCal cells in the Extended Barrels, using 2012 data, have been showed
- A loss of ~2% in the channel response has been detected as the maximum irradiation effect on a very exposed cell

Backup slides

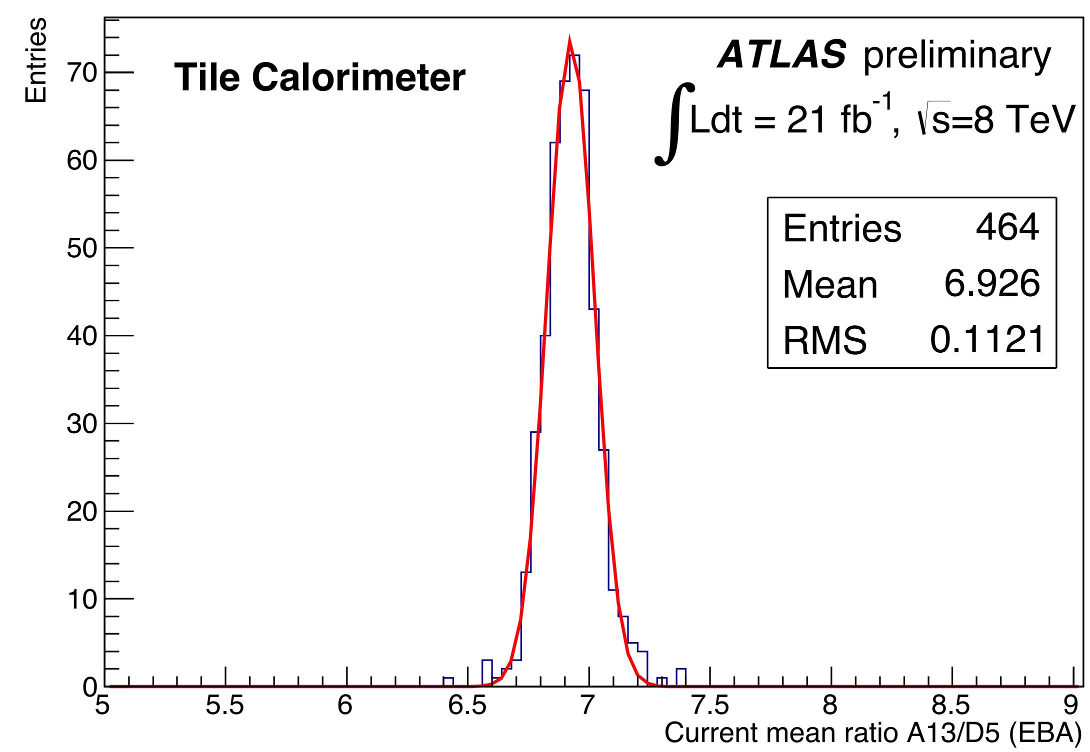
Study of the scintillators irradiation: evaluation of the response variation





- For each LumiBlock (~1 minute) the channel response is averaged over the number of measurements in that LumiBlock

- The distribution of the ratios between the currents of a channel and the reference one for each minimum bias run is constructed, each point of the distribution corresponding to the average over one LumiBlock, and then fitted with a Gaussian function

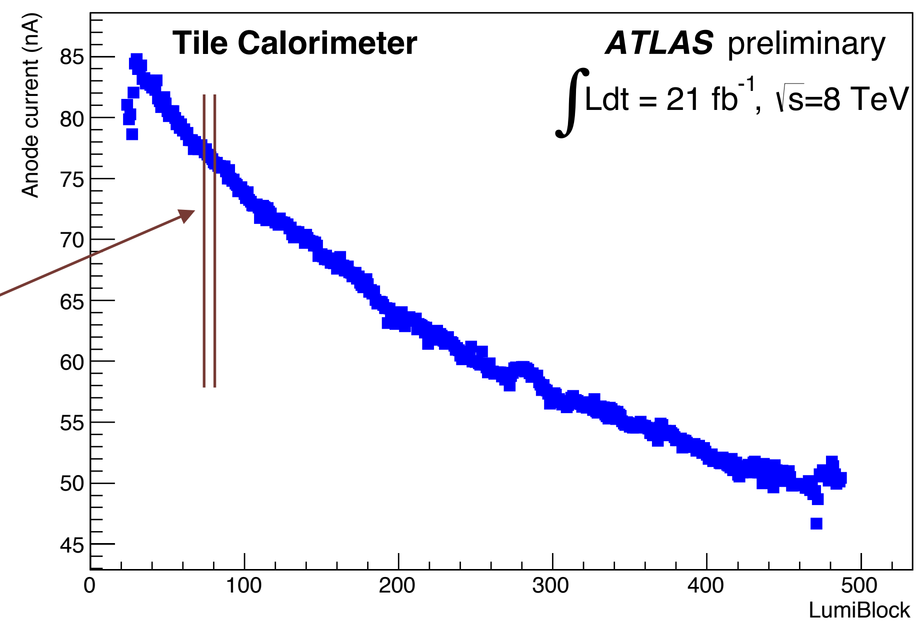


Study of the scintillators irradiation: getting the integrated charge

- For each channel *i*: $I_i(t) = a_i * L(t)$,
  where $I_i(t)$ is the anode current, a_i a constant factor which depends on the cell size and position and $L(t)$ the instantaneous luminosity

- $a_i = I_i(t) / L(t)$ and the constant factors are computed using a single MB run, averaging on 10 successive lumiblocks

10 lumiblocks



- The total integrated charge up to a given run is therefore given by:

$$Q_i(run) = \alpha_i \int_{run0}^{run} L(t)dt$$