Integrator based read-out in Tile Calorimeter of the ATLAS experiment

Garoé González

On behalf of ATLAS Tile Calorimeter group

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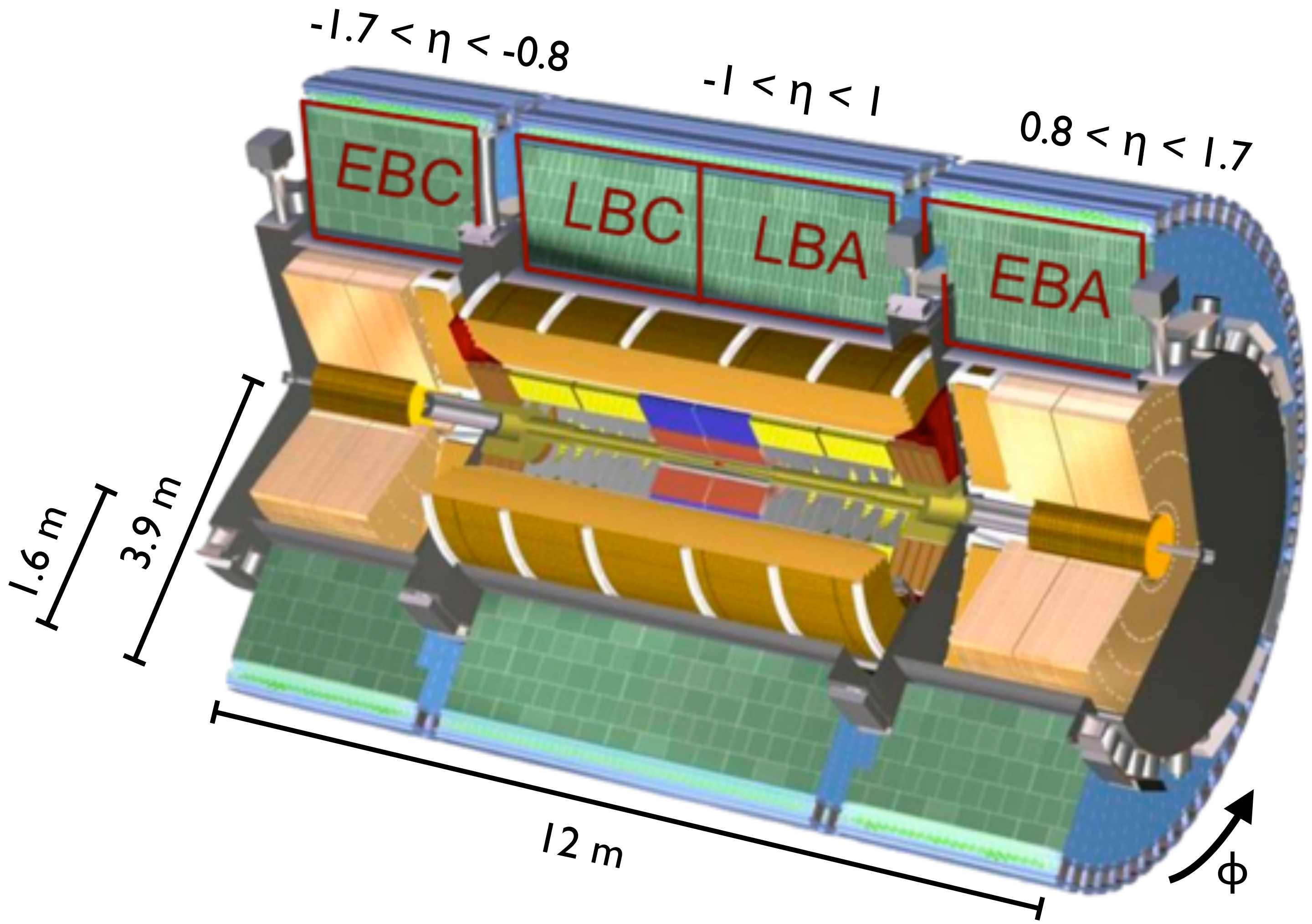
Tile Calorimeter

Tile Calorimeter is the hadronic calorimeter of the ATLAS experiment. It uses scintillator as active material and steel as absorber. It provides accurate energy and position measurements of electrons, photons, isolated hadrons, taus and jets.



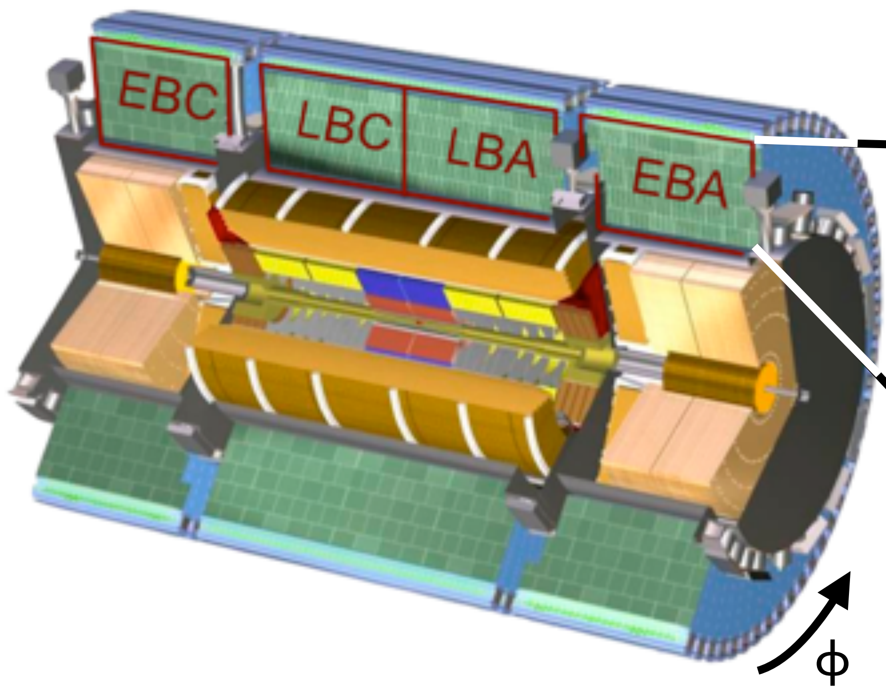
Design goals

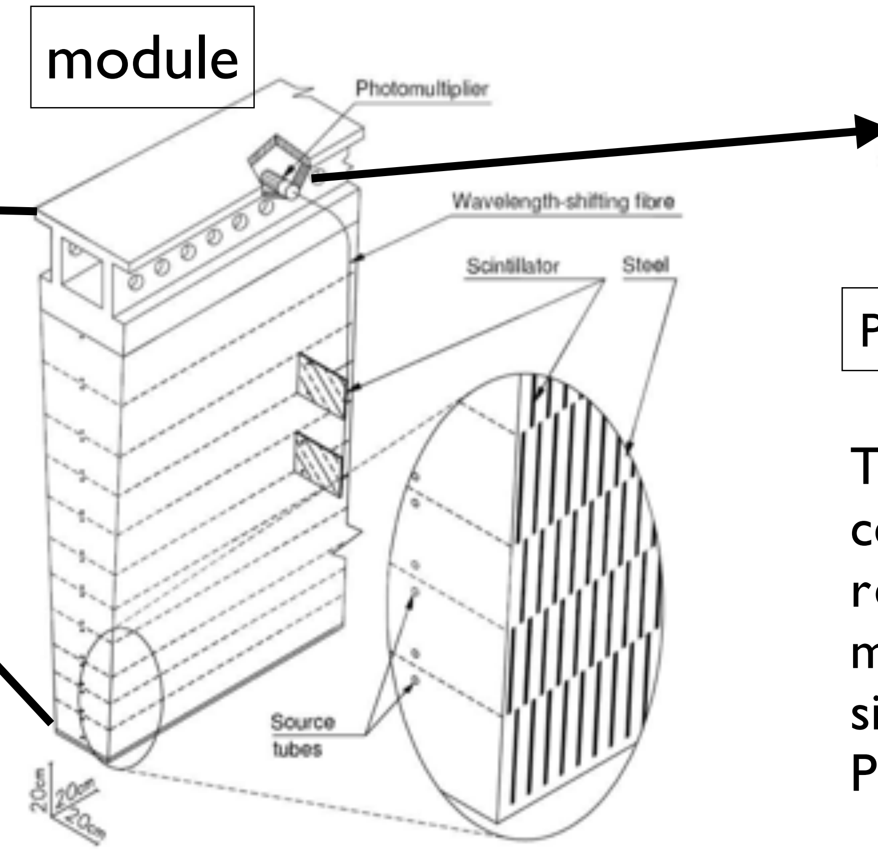
- Energy resolution of $\sigma/E = 50\%/\sqrt{E(\mathrm{GeV})} \oplus 3\%$ which provides sensitivity measurements of physics processes at the TeV scale.
- Systematic uncertainty on the jet energy scale of 1% for precise top quark mass measurements.
- A response linearity within 2 % up to about 4 TeV which is crucial for observing new physics.

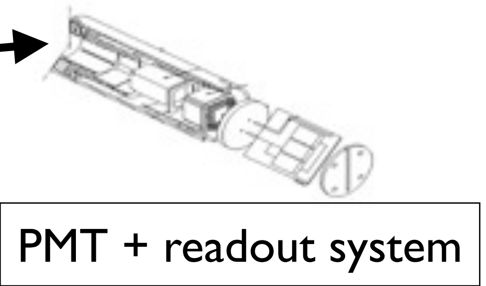
Granularity

- The cylinders are segmented into 64 wedges (modules) in ϕ, corresponding to a $\Delta\phi$ granularity of ~0.1 rad.
- 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.

Tile Calorimeter







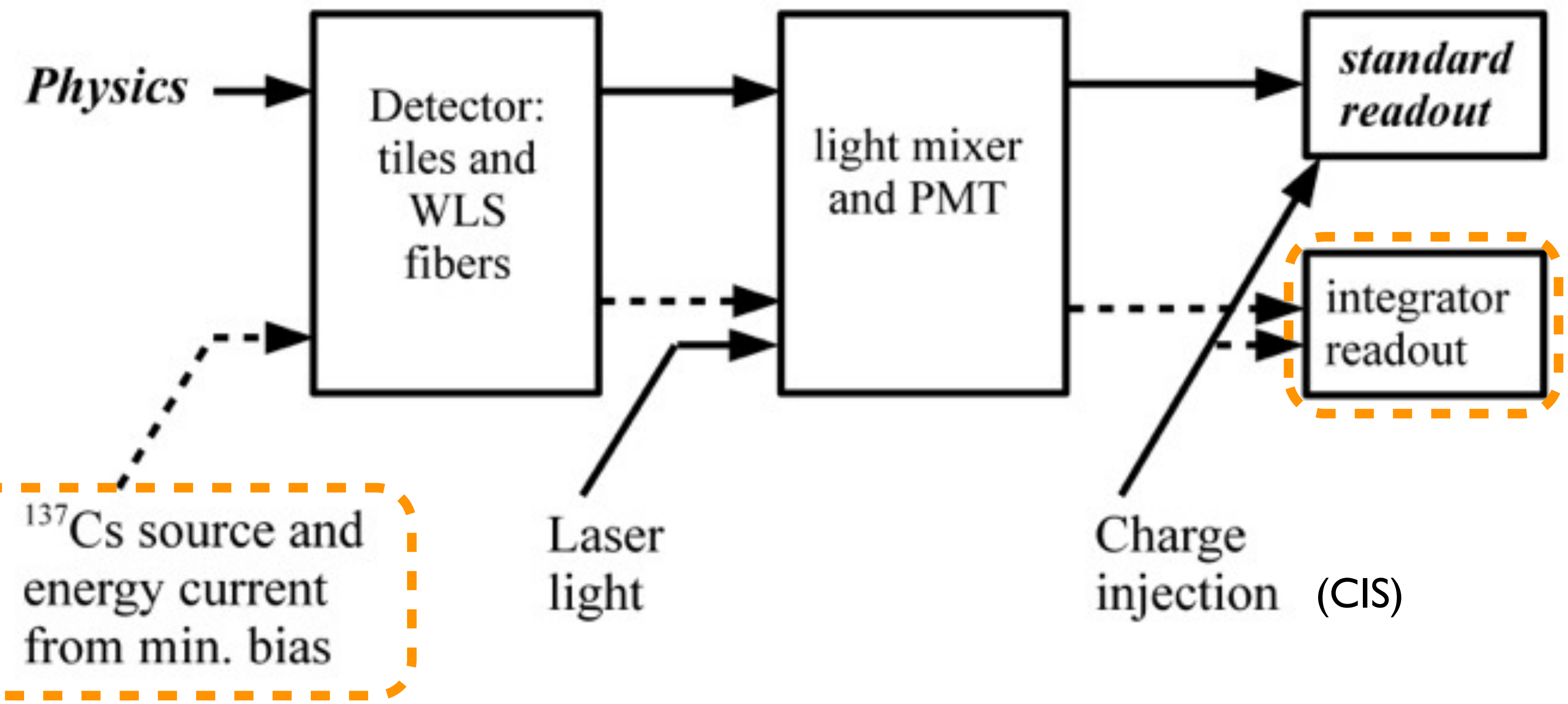
The fibers from a cell (~50 fibers/PMT) reach the optical mixer. After that, the signal is read by the PMT.

The readout architecture divides the detector in **four partitions**, there are two Long Barrels (LB) and two External Barrels (EB). Dividing the detector perpendicular through the interaction point we have the A and C sides.

In the outer radius of each module a "drawer" contains all readout electronics with 45 PMTs in LB and 32 in EB types.

Total channels ~10 k

Calibration of Tile Calorimeter.



Calibration of the initial part of the signal readout path.

Monitoring PMTs gains.

Calibration of the front-end electronic gains.

Integrator

- Functionalities of the integrator:
  - To perform **Cs calibration run** (for calibration of TileCal cells and normalization of PMT gains).
  - To measure anode current induced by **Minimum Bias (MB) proton-proton interaction** (signal coming from inelastic collisions) for continuously monitoring variations of the calorimeter response over long term.
  - To use MB signal for monitoring of relative luminosity.

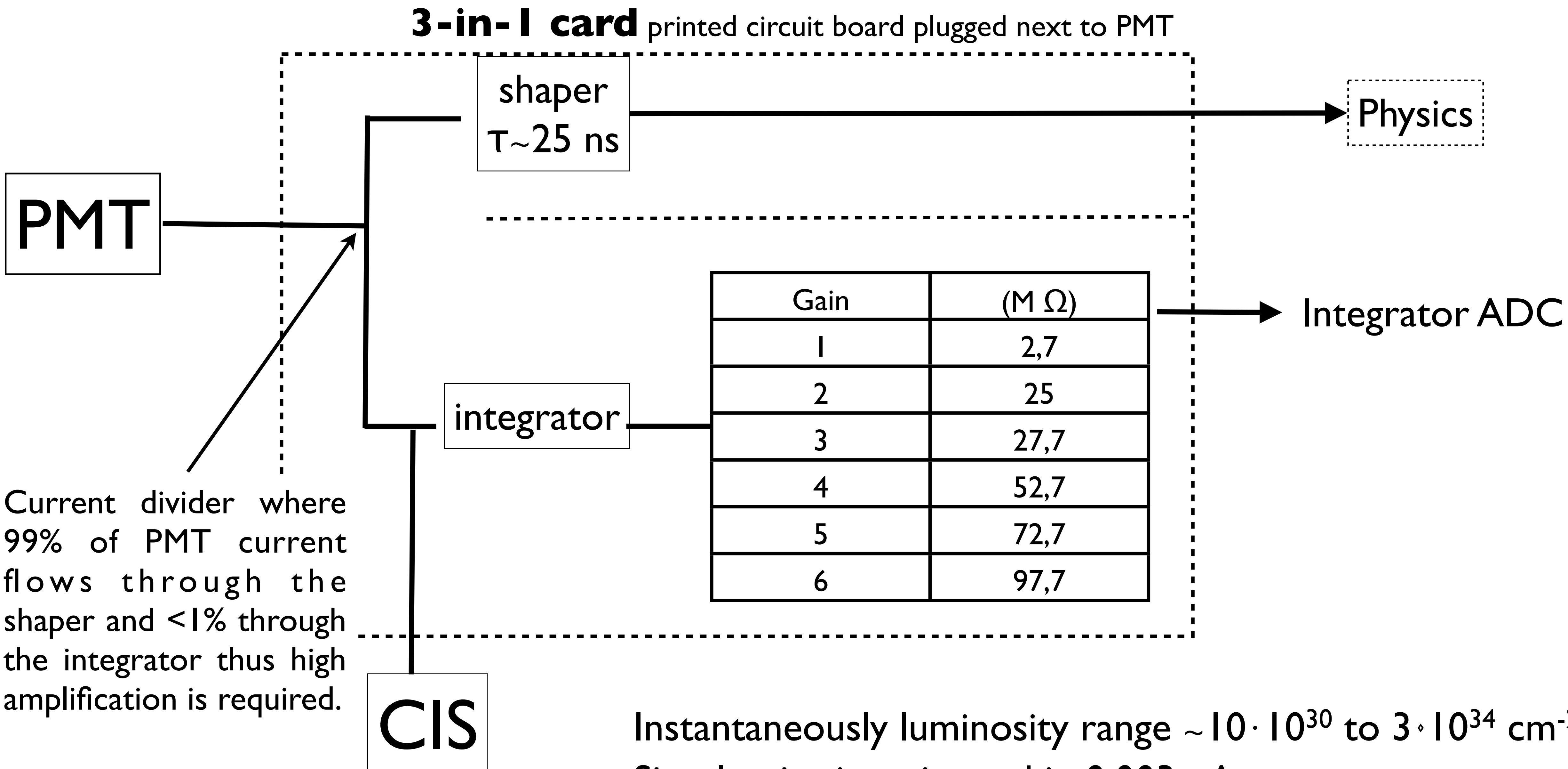
PMT signal → Integrator (τ =10 - 20 ms) → 12 bit ADC

- Cs source radiates with a frequency of ~10^6 gammas/s.
- MB signal, constant source with variable frequency ~(0.04 - 40)·10^4 hits/(s· channel) depending on luminosity.

- Integrating times (τ) were defined from expected frequency and amplitude.
- Six different resistors define τ and the gain of the integrator.

- Incoming signal 0 - 5 V.
- 12 bits = 4095 ADC.
- Six resistors together with ADC give a sensitive integrated PMT current range of 0.01 nA - 1.4 μA.

Integrator electronics

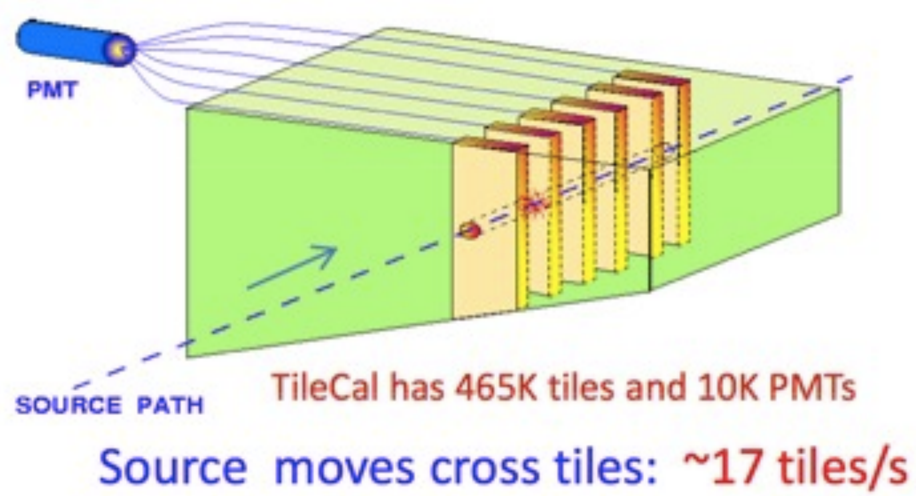


Gain	(M Ω)
1	2,7
2	25
3	27,7
4	52,7
5	72,7
6	97,7

Instantaneously luminosity range ~$10 \cdot 10^{30}$ to $3 \cdot 10^{34}$ $cm^{-2}s^{-1}$.
Signal noise is estimated in 0.003 nA.

Non-linearity of the system over all dynamic range <1 %.

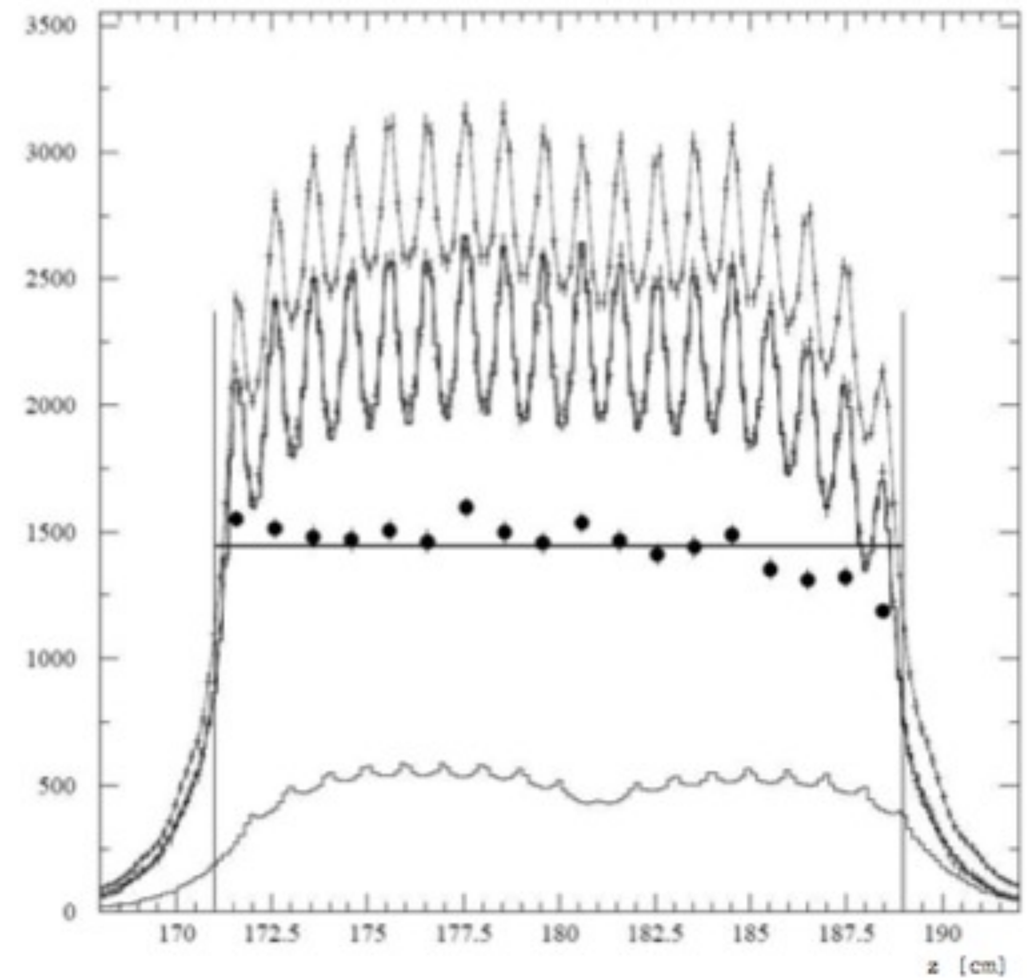
Calibration with ^{137}Cs γ-source.



A Cs radioactive γ-source is moved through each scintillator tile by a hydraulic system.

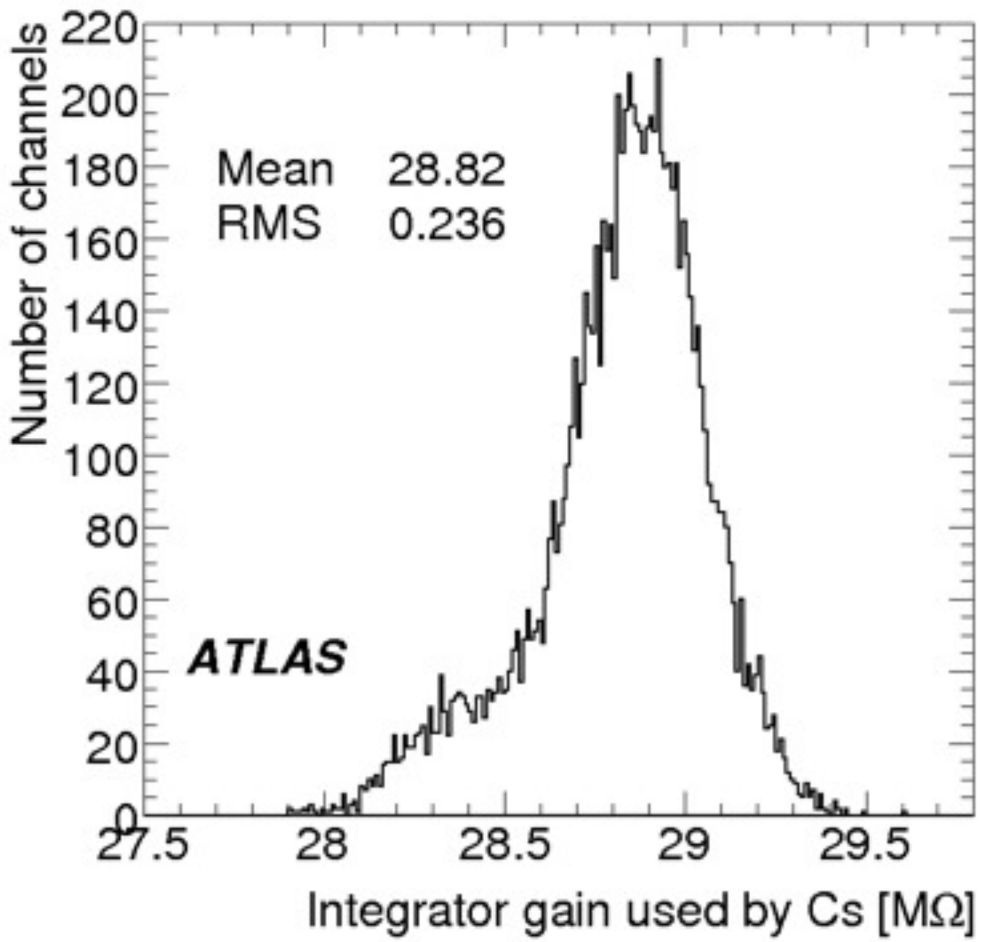
The integrator system measures the current with the response of single PMTs.

After a calibration with Cs source the channels are equalized to a chosen level with a precision of 0.5 %.

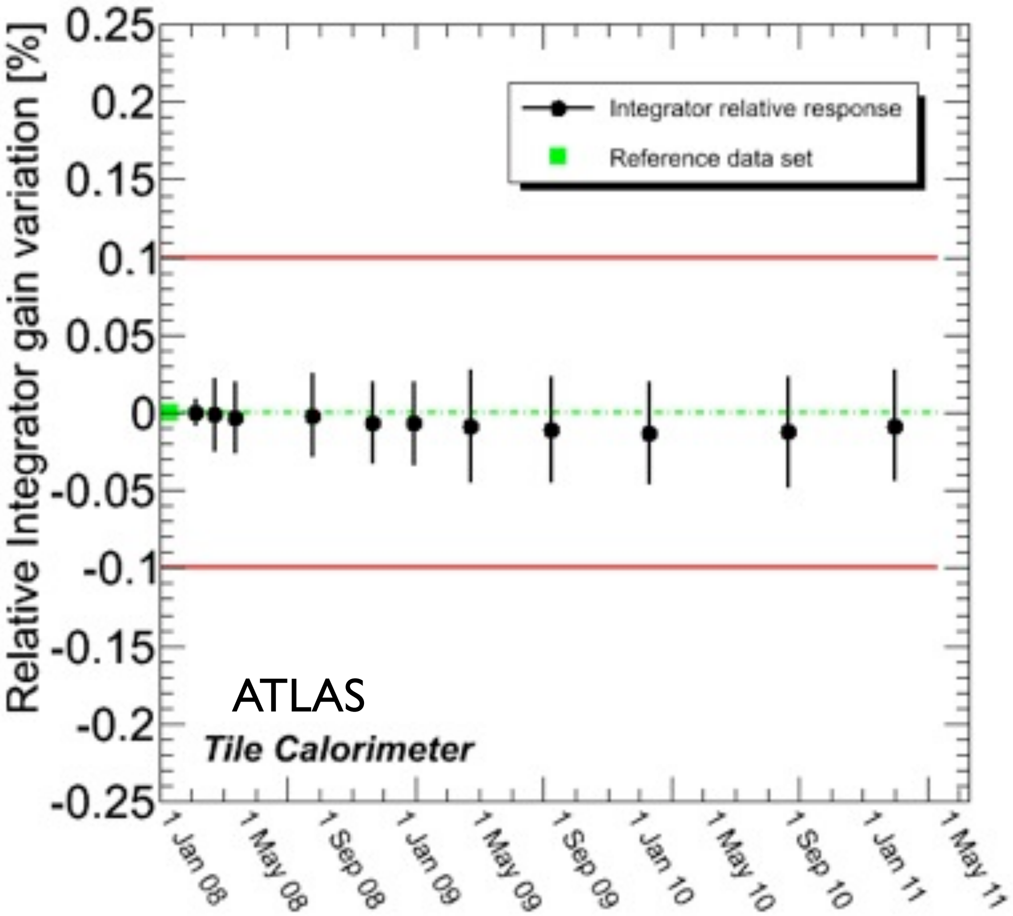


The Cs-source signal measured in one PMT as a function of the source position. The signal (middle curve) is obtained by subtracting the estimate leakage (bottom curve) from raw data (top curve). The individual tile amplitudes (full circles) are obtained by fitting the signal by a sum of pulse shape functions for individual tiles.

Gains and stability of the integrator system



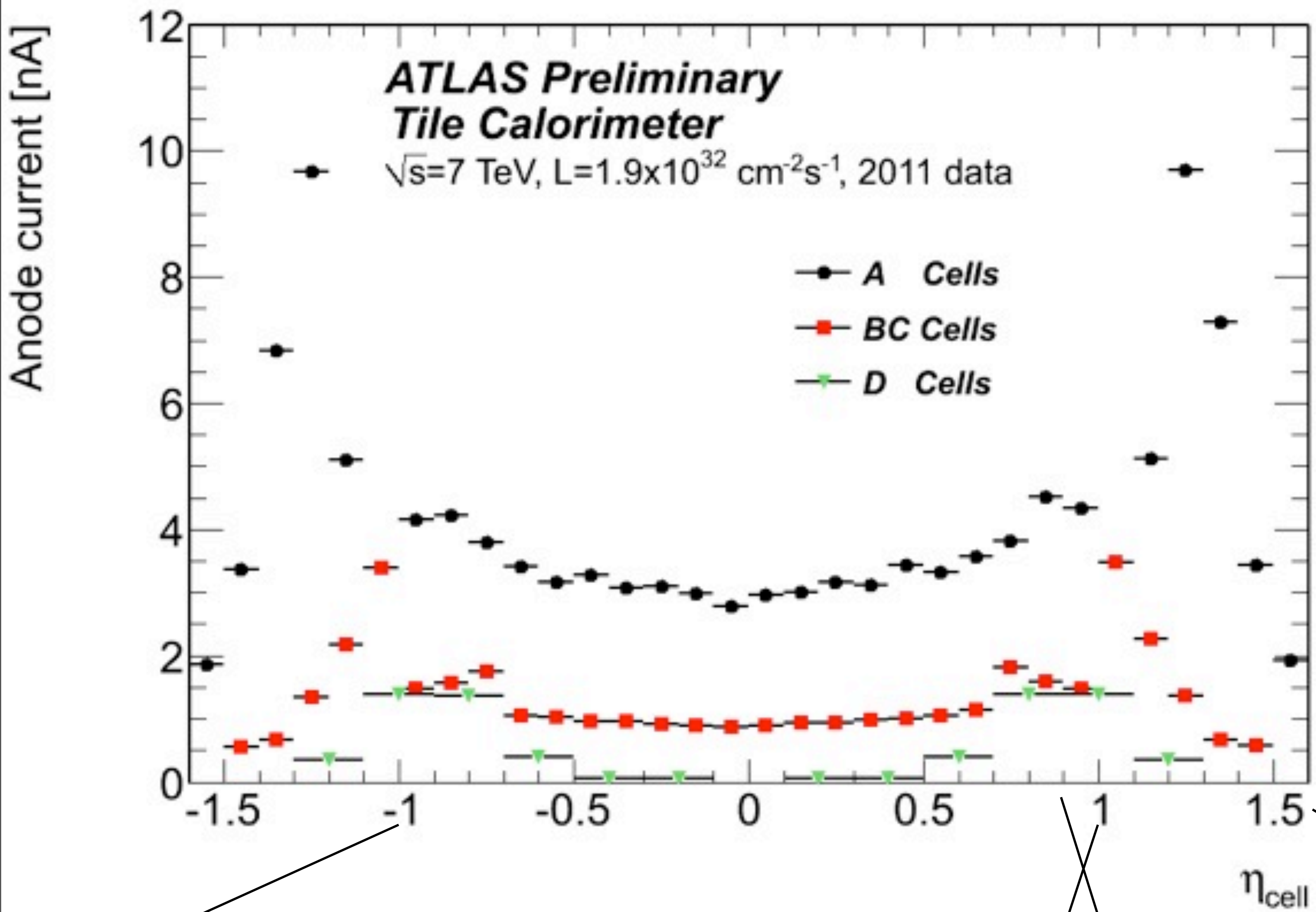
The gain variation is about 1%. The left tail is produced because 16% of the ADC cards come from different production batch.



Relative variation of the integrator gain used by Cs calibration system using 95 % of TileCal channels. Data are taken twice a year during special calibration runs.

The error bars represent the standard deviation from the mean of the relative variation. The Stability of individual channels, represented by the error bars is better than 0.05%. Stability of the average is better than 0.02%.

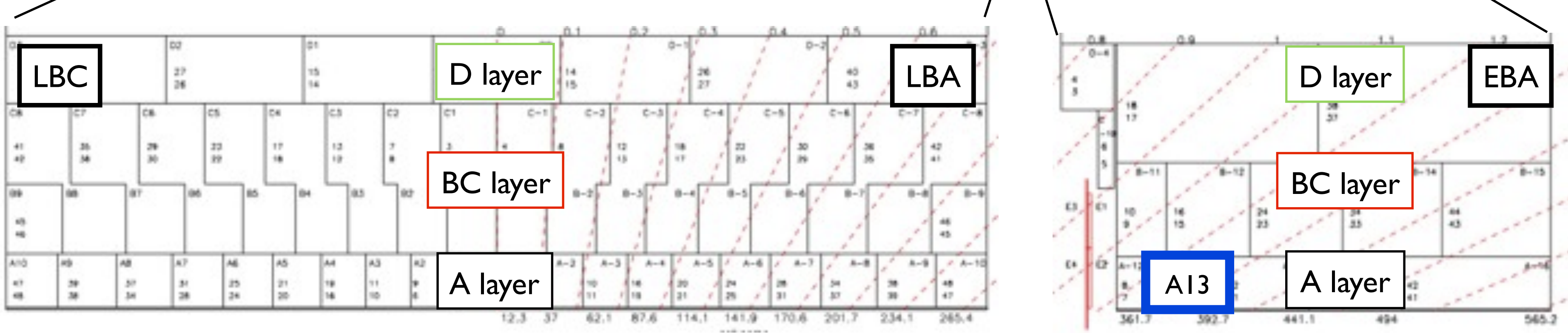
Minbias signal



$$I\,(nA) = [V(ADC) - Pedestal]/[Gain\,(M\Omega) \cdot (Cs\ Constant)]$$

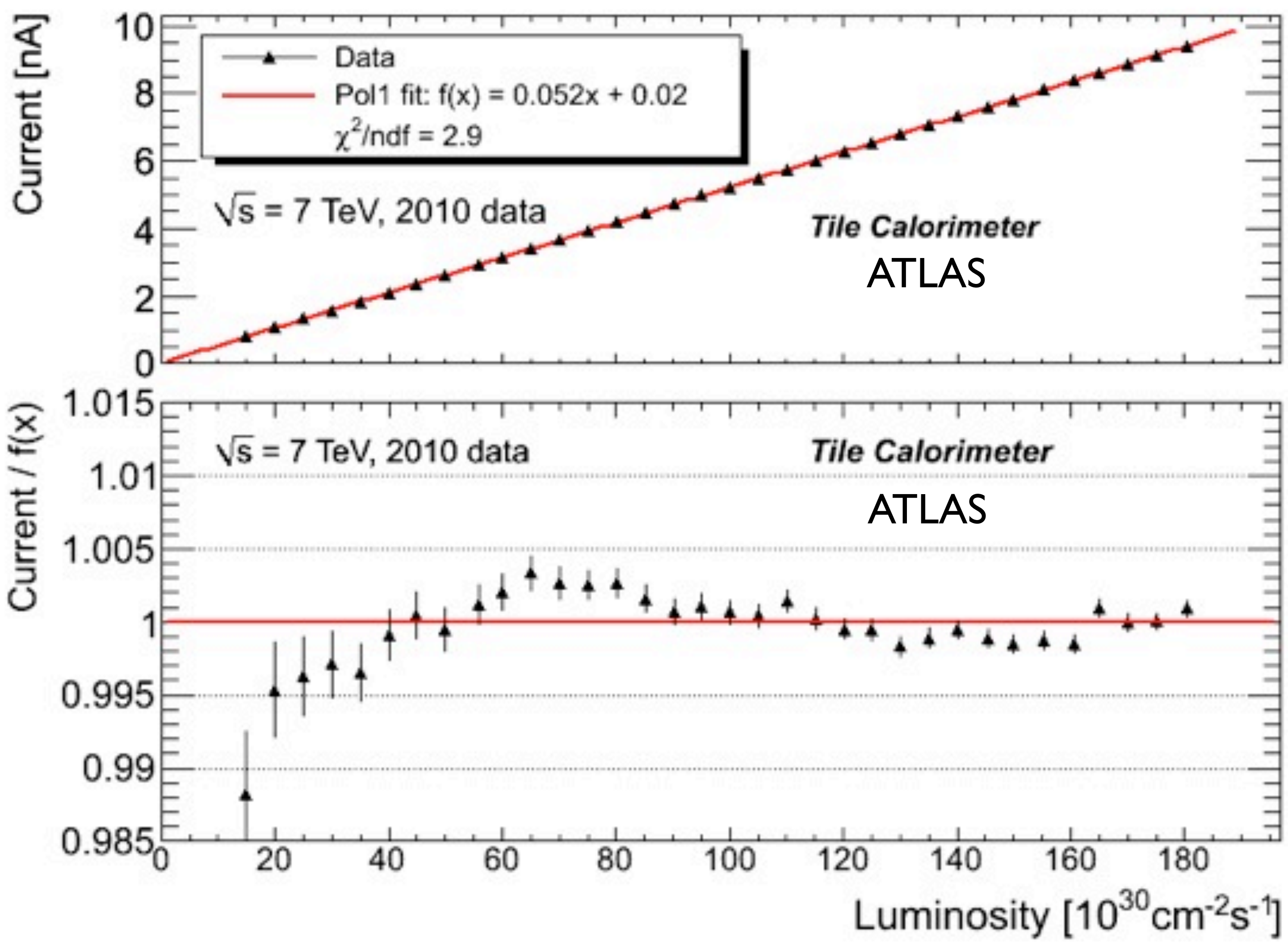
Average of anode current of a cell type is shown as a function of η for three TileCal layers using data collected in 2011.

A13 cell type at |η|=1.3 is the one with the highest MB signal response thus is the one used as a luminosity measurement system.



- Collision point

Anode current of A13 cells vs ATLAS online instantaneously luminosity, based on forward LUCID detector



An average anode current for A13 cell of the TileCal is shown as a function of the instant luminosity on full data sample taken in 2010. The errors on the current are the quadratic sum of the statistical and systematic errors. The red lines are obtained from the linear fit of the data points.

A13 is the cell with the highest response during collisions.

Relatively high X^2/ndf can be explained by the fact that to no errors were put on luminosity.

Five runs were used to cover full range of 2010 data.

MB signal of 2010 data and ATLAS online luminosity are compatible within 0.5%.

Conclusion

- Charge integrator applied in calorimetry particle physics has been designed and successfully used to calibrate with Cs system Tile Calorimeter and to measure MB signal.

- Cs calibration provides a precision to single cells of 0.5 %.

- CIS calibration shows an average stability of gains better than 0.01 % after 41 months.

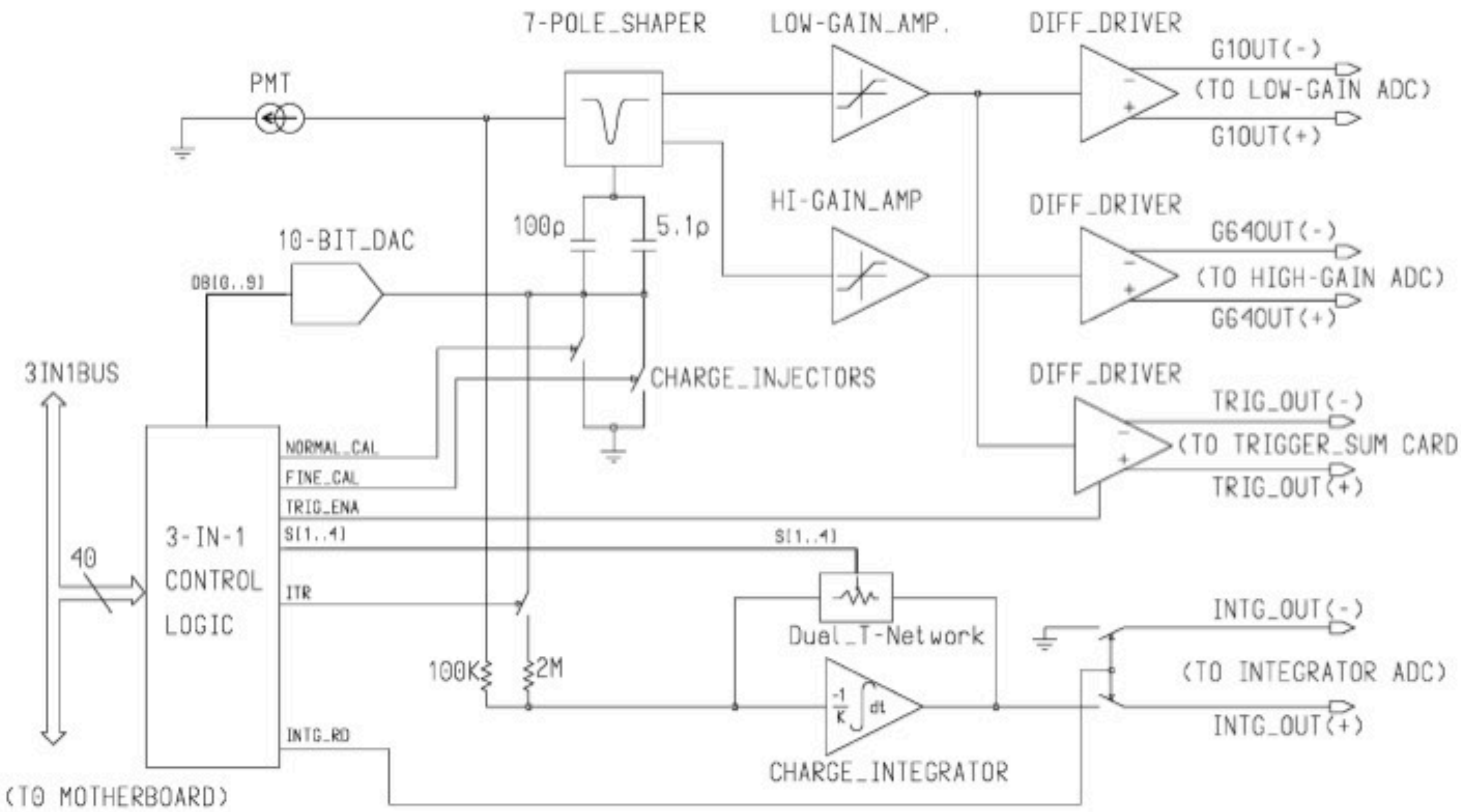
- High linearity between integrated MB signal and luminosity make the system one luminosity monitor of ATLAS.

Plans:

- Integrator is the only system able to monitor the response of all calorimeter cells during data-taking thus a dedicated automatic framework which will enclose all analysis is under construction.

Back slides

3-in-1 circuit



Integrator circuit