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Laser calibration system of TileCal in ATLAS detector

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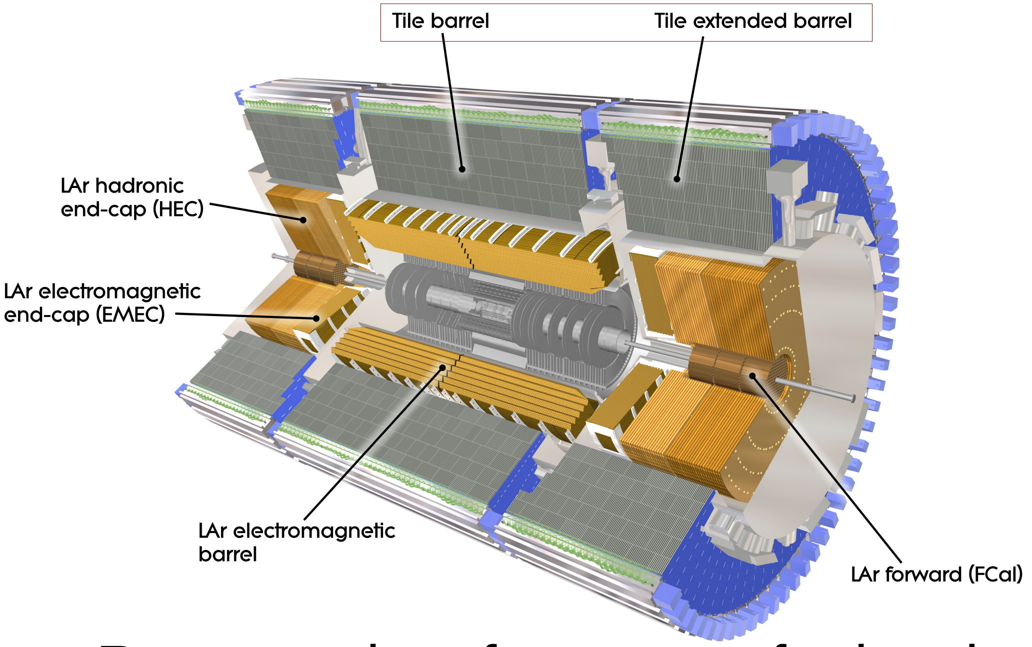
Technology and Instrumentation in Particle Physics 2011

Overview

- Hadronic calorimetry in ATLAS
  - Short presentation of TileCal
  - Systems to set and monitor TileCal energy scale
- Monitoring of TileCal stability
  - Cesium system
  - Laser system
- Results obtained with TileCal Laser system

TileCal : the central hadronic calorimetry in ATLAS

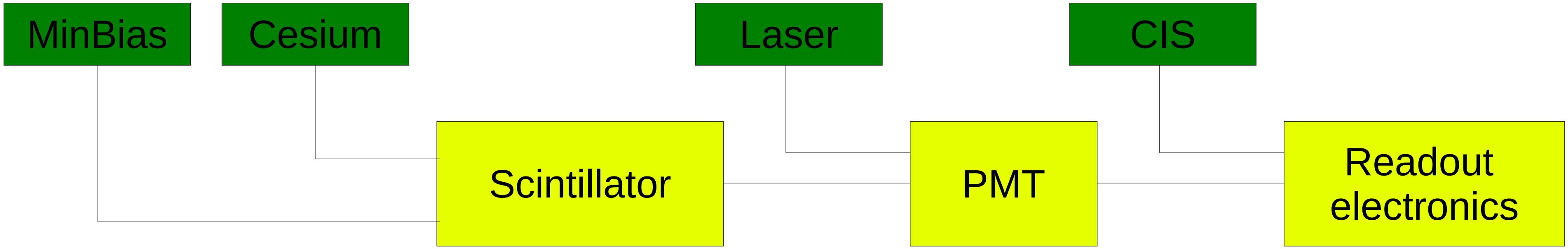


- Sampling calorimeter (plastic scintillator/iron)
- Readout by photomultipliers (PMT Hamamatsu R7877)

- Requested performances for jet physics are :
  - energy linearity for high pT jet and cross-section measurements : 2% up to 4 GeV
  - energy resolution for missing ET and di-jet mass measurements : $\sigma(E)/E = 50\% / \sqrt{E} \oplus 3\%$ $|\eta|<3$
  - η-φ segmentation for reconstruction of di-jet resonance, and jet calibration (weighting techniques) :
    - Segmented radially in 3 layers
    - $\Delta\eta\times\Delta\varphi=0.1\times0.1$ (first 2 radial layers); $\Delta\eta\times\Delta\varphi=0.2\times0.1$ (third layer)

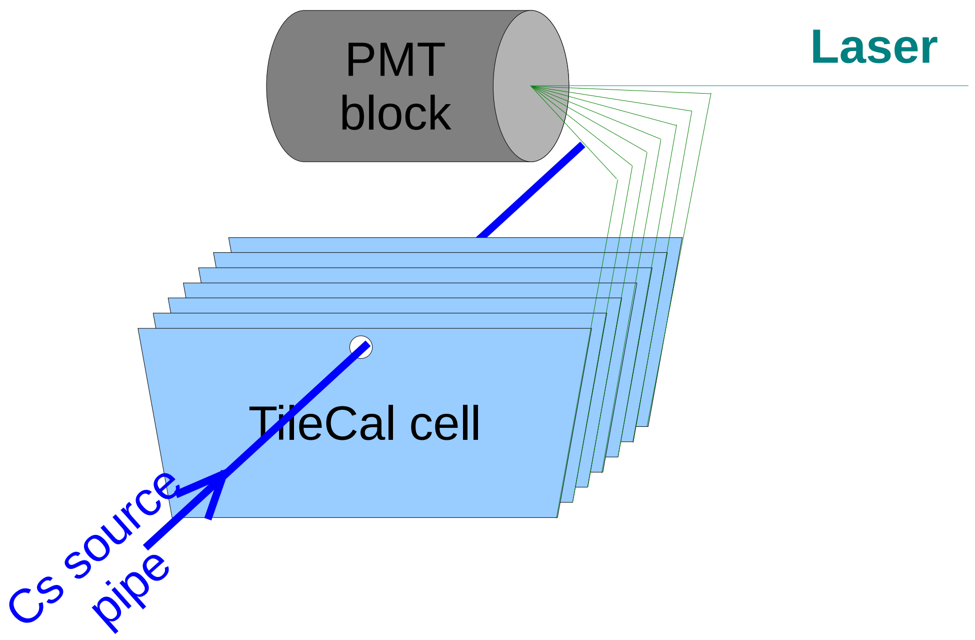
Calibration and monitoring of the energy scale

- Conversion from digital signal to energy made in several steps
  - Charge Injection System (CIS) : ADC counts to pC
  - Test-beam (only for a fraction of the calorimeter) : pC to GeV
  - Cesium source (traveling across all calo) : equalisation of the opttical response and transfer of the TB energy scale to the whole calorimeter
- The calibration is monitored during the periods of data taking
  - CIS : linearity/stability of the readout electronics
  - Laser : linearity/stability of the PMT response
  - Cesium and Minimum Bias (see talk on integrator by G.Gonzalez) : stability of the optical chain (scintillators+fibres+PMT)



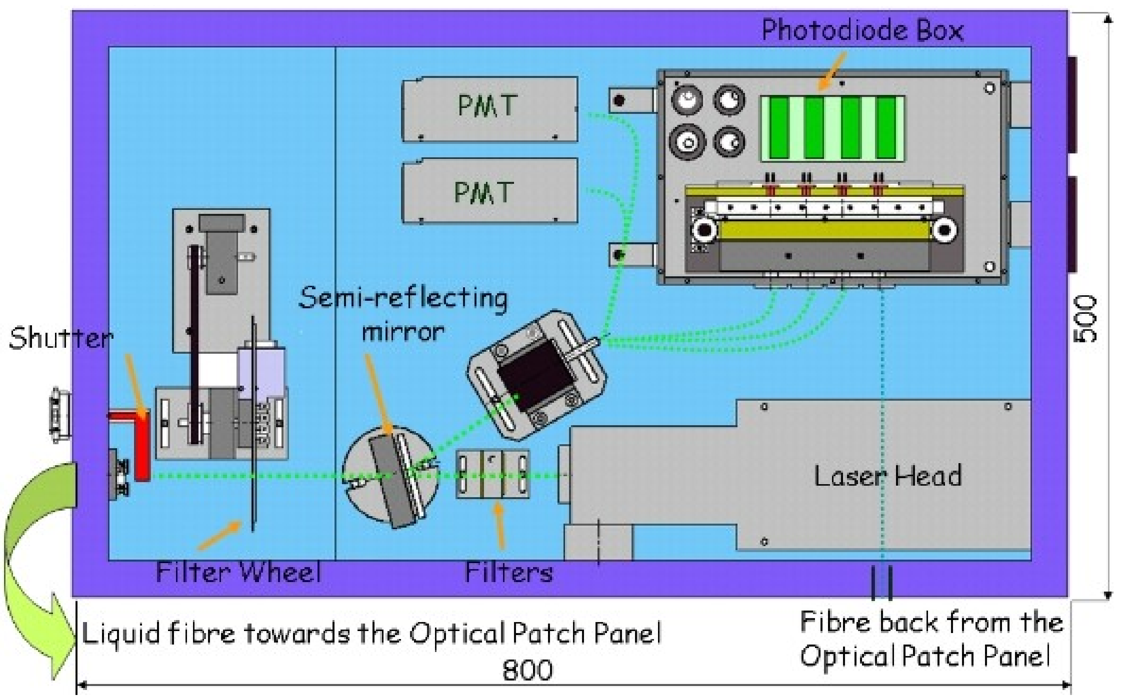
- In this presentation : role of Laser+Cesium

Cesium system



- Cs 137 -source transported by hydraulic system through every scintillator composing TileCal cells.
- Cesium scans taken ~every month during technical stops (full scan takes several hours)

Laser system



- λ=523 nm, pulse width ~5-8 ns
- Pulse to pulse amplitude stability ~2%
- Intensity monitored by 4 photodiodes (stabilised temperature)
- Photodiodes response monitored using an Alpha source.
- Light splitting system to send laser pulse to all ~10 000 PMTs simultaneously

- Set of filters to cover a large range of PMT response
- Laser system used mainly for
  - Timing adjustment of the electronics
  - Recovering linearity for very high energy deposit
  - Monitoring of the PMT response stability between 2 Cs scans

Combined use of Cesium and Laser

- The gain of individual PMT may drift in time (photo-cathode ageing, individual instability of the HV or temperature regulation...)

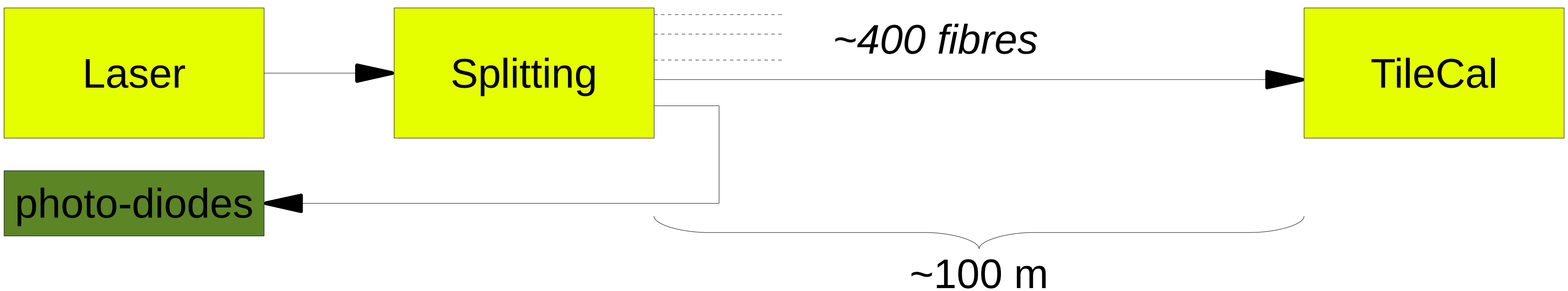
- Cesium and Laser system designed to keep the PMT response stable within ~1%

- Every month (t_0)
  - Cs scan : equalisation of the cells response
  - Reference laser run taken

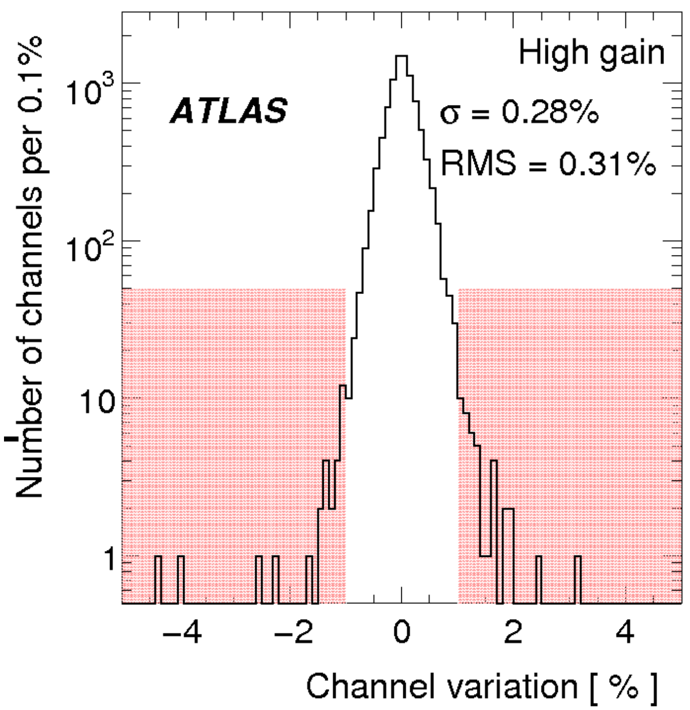
- Every ~3 days (t_i): new laser run taken

- After each new laser run, possibility to correct drifts of the PMTs response
  - $R(t_i) = R(t_0) \times \alpha(\text{laser}, t_i) / \alpha(\text{laser}, t_o)$

Monitoring with laser : direct method



- Response to laser defined for each PMT *k* as :
  - $\alpha(k)$ = Response (PMT *k*) / Response (Photo-diode)
- The response ($\propto$ gain) variation between 2 runs taken at t_0 and t_i is :
  - $(\Delta\alpha/\alpha)_k = [\alpha(k, t_0)-\alpha(k, t_i)] / \alpha(k, t_0)$
- Advantage
  - good precision on response variation (<1%)
- Problems
  - Systematics due to instabilities of the light transmission system not all corrected by photo-diodes (100 m upstream of TileCal). Additional corrections have to be applied.



Monitoring with laser : statistical method

- Gain measurement based on statistical nature of the photo-electrons production and multiplication (see reference below)

$$Gain \propto \frac{Var(q)}{\bar{q}} - \bar{q} \times \frac{Var(I)}{(\bar{I})^2}$$

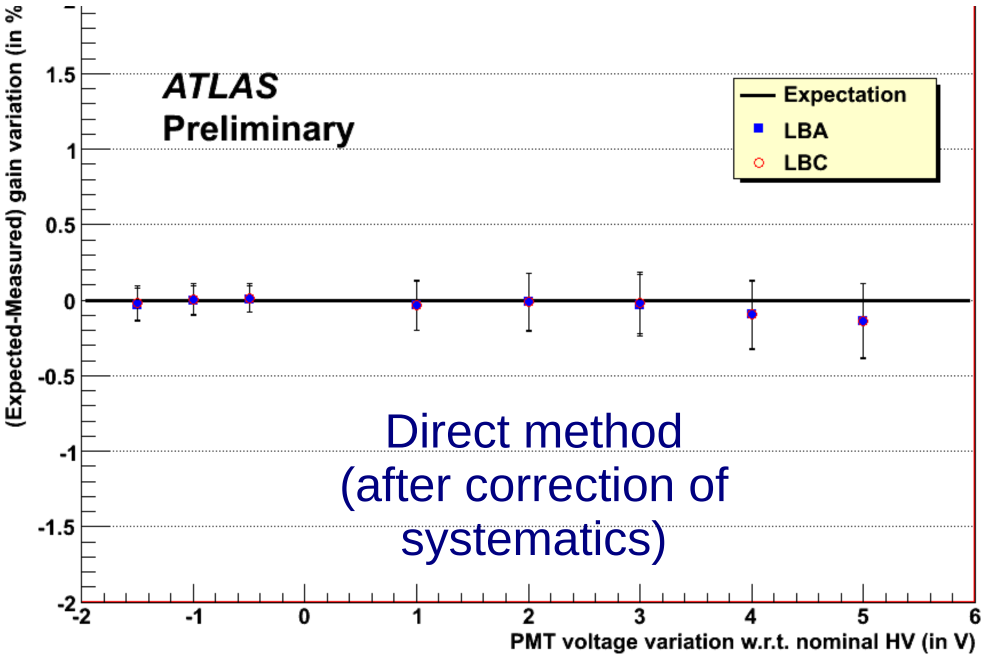
  - $Var(q)$ and $\bar{q}$: variance and mean of the PMT recorded charge
  - $Var(I)/(\bar{I})^2$: factor depending on the light properties (variation of intensity I, coherence state)
- Advantage
  - No need to know precisely the incident light intensity on PMTs (photo-diodes not used).
  - Less dependence to instabilities and ageing of light transfer system
- Problems
  - Precision is limited by the statistical uncertainties. Hard to do better than 1-2% on single PMT gain variation.

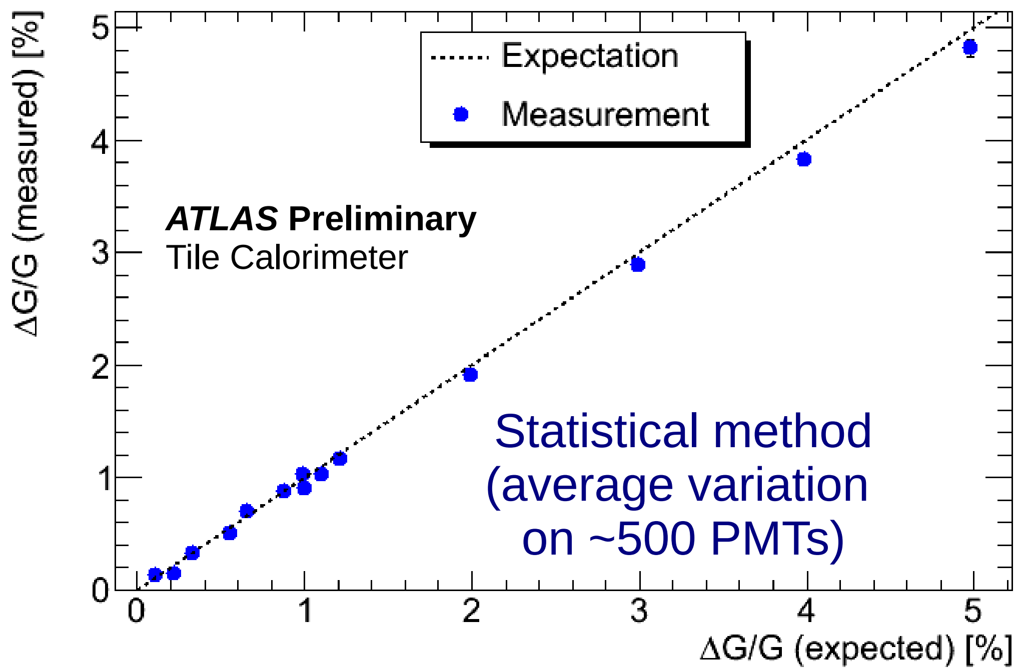
"Degeneracy of light and the optimum accuracy of photoelectric measurements"
JOURNAL OF THE OPTICAL SOCIETY OF AMERICA, VOLUME 64, NUMBER 12 DECEMBER 1974
Jacques Bures

Methods validation & performances

- High Voltage scan on PMTs
- For small HV change, direct relation with the gain variation :

$$\Delta G/G = \beta \times \Delta HV/HV$$ (β such that 1V ≡ ΔG/G~1%)

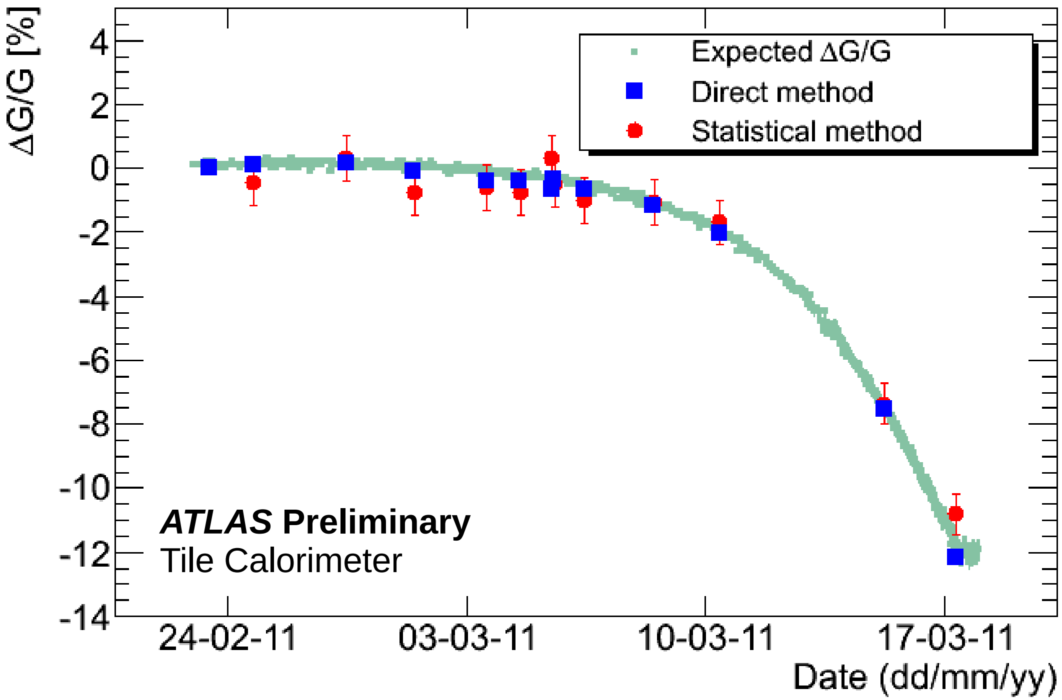




- Both methods sensitive to very small variations of gain
- Measurement follows the expectation down to ~0.2-0,3% (enough for monitoring purposes)

Case of PMT with drifting gain

- Few PMTs may have accidental drift in high voltage
- Can be used to validate the gain monitoring methods
- The HV is measured continuously (Detector Control System)
  - Estimation of the gain variation (wrt reference date) using the relation :



- Gain variation (wrt reference date) using the relation :

$$\frac{G}{G_{ref}} = \left(\frac{HV}{HV_{ref}} \right)^{\beta}$$

- Gain variation measured using both direct and statistical approaches

- Both methods agree with the expected gain variation
- Statistical method has bigger errors, as expected for measurement on single PMT

Conclusions

- To reach the designed performances (energy linearity and resolution) TileCal requires a good monitoring of the energy scale
- Variation along time of TileCal PMT response (gain drift, ...) affects the energy reconstruction
- Two systems used to monitor the optical part of the readout
  - Cesium scan : ~once per month to equalise the PMT response and set it to the right energy scale (from test-beam)
  - Laser runs : ~twice per week, to correct variation of response between 2 Cesium scans
- Two methods developed to monitor the PMTs response with Laser
  - Direct method : very precise but sensitive to instabilities of light transmission chain
  - Statistical method : less precise but less affected by instabilities & ageing fibres
- Both methods give a good measurement of the variation of PMT response (~1% precision). Using 2 methods gives a cross-check helping to make decision whether correcting or not the PMT response
- A lot has been learnt during last years of data taking. Ongoing studies to improve the stability and precision of the system.