Monitoring the stability of the CMS electromagnetic calorimeter

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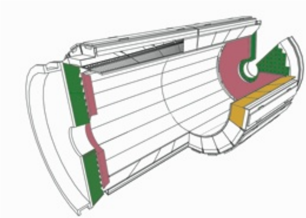
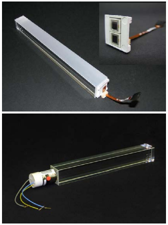
Introduction



- 61200 + 14648 $PbWO_4$ scintillating crystals (roughly $2.2 \times 2.2 \times 26$ cm^3 each) total weight ~ 90 t
- barrel readout via Avalanche Photo Diode (APD)
- endcap readout via Vacuum Photo Triode (VPT)



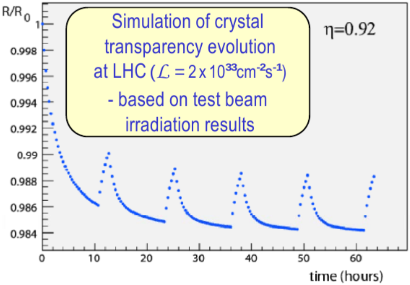
Main sources of variations in the ECAL response:

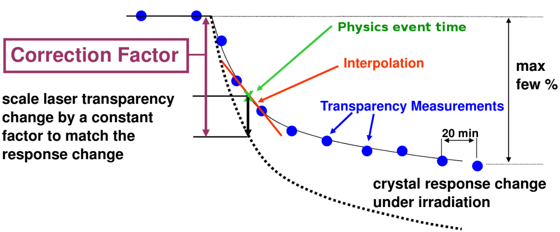
- crystal transparency $\rightarrow$ radiation dose-rate dependence
  from 1-2% @ $\mathcal{L} = 2 \cdot 10^{33}$ cm^{-2} s^{-1} in the barrel
  to $>$ 10% @ $\mathcal{L} = 2 \cdot 10^{34}$ cm^{-2} s^{-1} (nominal) at high η regions in the endcaps
- scintillation process $\rightarrow$ temperature dependence: $\sim -2\%/\ ^\circ$C @ 18 $^\circ$C
- APD gain $\rightarrow$ high voltage dependence: $\sim$ 3%/ V
  temperature dependence: $\sim -2\%/\ ^\circ$C
- Other minor sources of variations: VPT operation in 3.8 T magnetic field, electronics effects

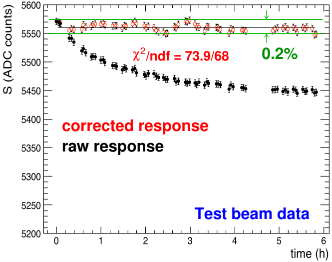
Target performance: resolution of 0.5% at high energies

Transparency variations

- rapid loss and recovery of the optical transmission under irradiation (few hours)
- due to the creation of colour centres which absorb the transmitted light







Requirements and procedures

Requirements for the two main topics addressed in this talk:

- temperature stability better than 0.05(0.1) °C for the barrel (endcap)
- transparency corrections with a precision of 0.2%
  no significant irradiation yet during LHC operation ⇒ laser monitoring stability at the level of 0.2%

Procedures:

- calibration sequence
  - ran continuously during the data taking using the LHC beam abort gap period (3 μs at the end of the each 89 μs of beam cycle, $\mathcal{O}(1\%)$ used)
  - monitor crystal transparency via a laser system, pedestals, electronics stability through a fixed charge injection in the readout chain (Test Pulse)
  - about 20 − 30 min to span the whole ECAL
- on-board electronics gives a continuous readout of parameters such as temperature thermistors, High Voltage, Low Voltage, APD dark currents etc.
- dedicated runs

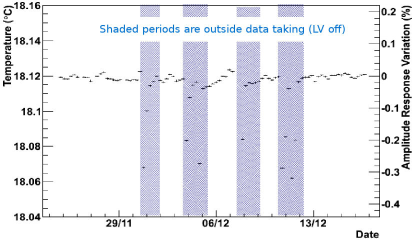
- HV voltage stability, electronics noise and all the other operational requirements are also completely fulfilled, see e.g JINST 5:T03010,2010

Temperature stability

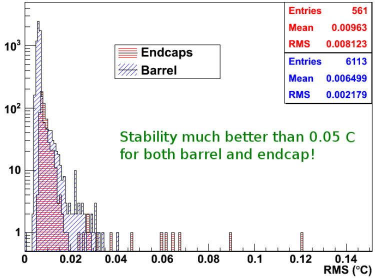
- nominal temperature of 18 °C
- water flow to stabilize the detector temperature
- thermistors with nominal sensitivity of 0.012 °C: on the back of each 5×2 (5×5) matrix of crystals in the barrel (endcap)

- the APD temperature dependence is absorbed into the transparency corrections
- local in-homogeneities are absorbed into the definition of the inter-calibration constants; only the time stability is relevant for the energy resolution.

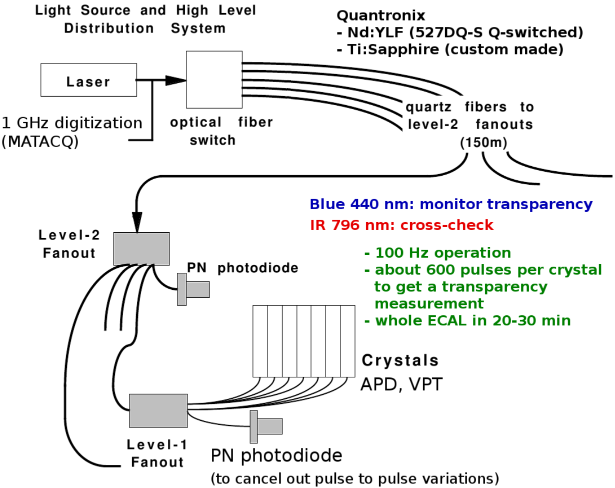
average temperature of the ECAL barrel over one month of data taking



Corresponding tempeature stability measured by each single thermistor for barrel and endcap

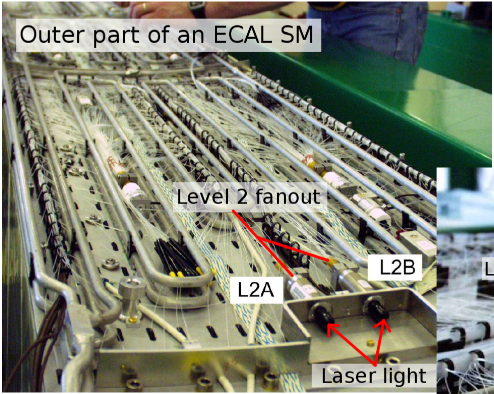


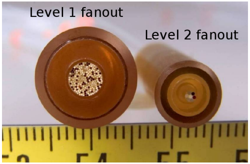
Laser monitoring system

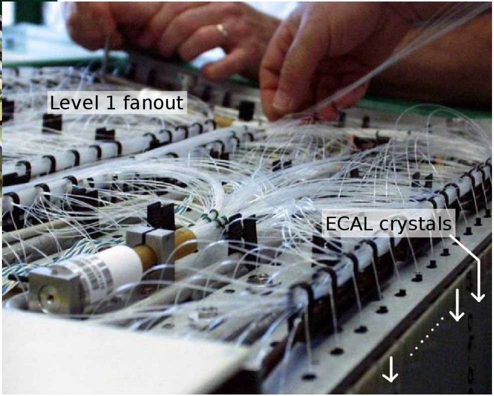


- Spectral contamination: $< 10^{-3}$
- Pulse energy: 1 mJ at the source, dynamic range up to 1.3 TeV equivalent
- Pulse width: < 40 ns FWHM to match the ECAL readout
- Pulse jitter: < 4 ns (24 hours), < 2 ns (30 min).
- Pulse to pulse instability: < 10%

Laser monitoring system

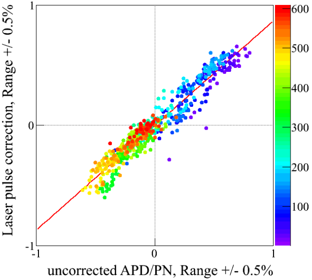




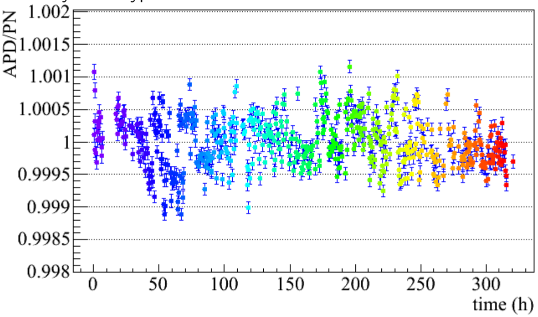


Laser transparency measurement

- PN linearity correction
- correction for the different shaping time of APD (VPT) and PN using the Single Pulse Response of each individual channel of APD (VPT) and PN convoluted with the laser shape from the 1 GHz digitization



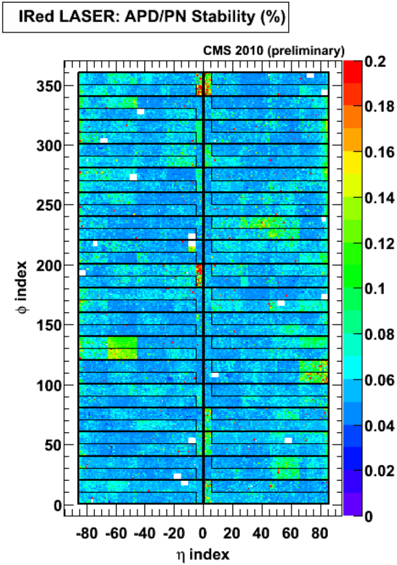
Stability for a typical channel over about 350 h



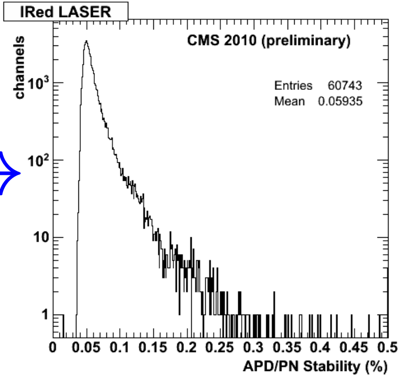
- stability defined as the r.m.s. of the considered quantity

- standard loose quality selections applied
- excellent stability: $< 4 \cdot 10^{-4}$

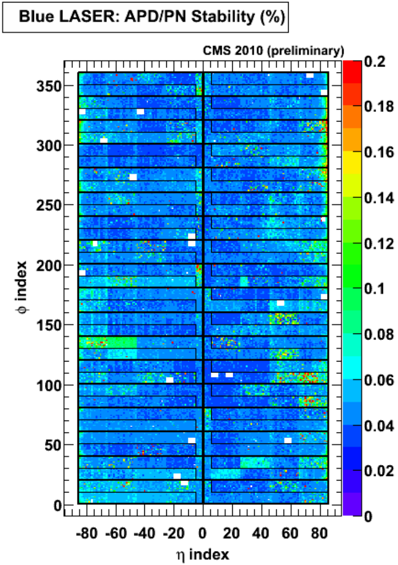
Infra-red laser stability: barrel



- 500 h during 2010 LHC collision data taking
- white spots are dead readout regions



Blue laser stability: barrel



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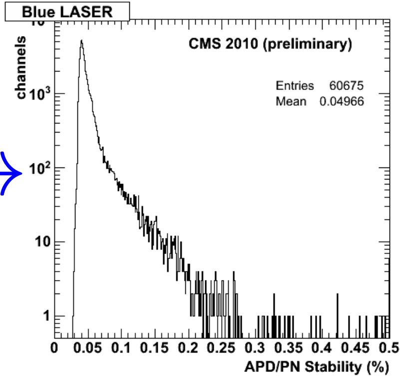
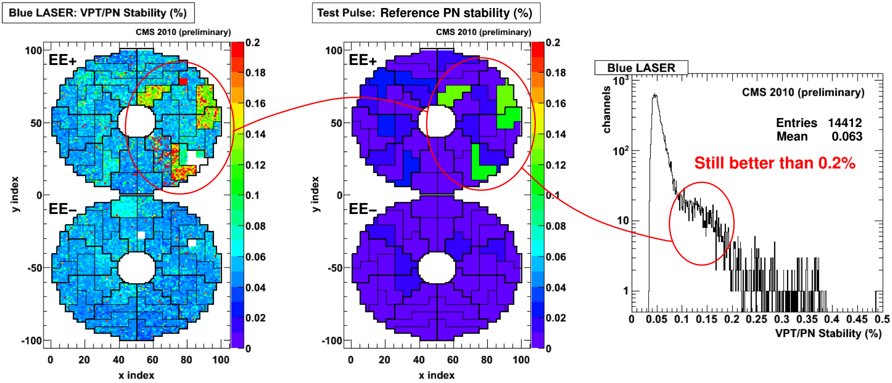


Blue laser stability: endcap



- 350 h during 2010 LHC collision data taking
- white spots are dead readout regions
- VPT/PN for the right half of EE+ is slightly less stable because it had only one active PN instead of the nominal 2 during the period considered here

Conclusions

The system operation is able to meet the stringent requirements imposed by reaching 0.5% resolution at high energies

All the detector parameters have proven to be extremely stable during the CMS operations

The temperature stability of the detector is much better than the requirements

The ECAL laser monitoring system performs very well and has proven to be amazingly stable during the whole period of the first collision data taking