IL NUOVO CIMENTO Vol. 34 C, N. 6 Novembre-Dicembre 2011
DOI 10.1393/ncc/i2011-11071-0

Colloquia: IFAE 2011

Operation and performance of the CMS Electromagnetic Calorimeter during the 2010 run

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(ricevuto il 29 Luglio 2011; pubblicato online il 6 Dicembre 2011)

Summary. — The CMS Electromagnetic Calorimeter (ECAL) is a high resolution, finely grained calorimeter devised to measure photons and electrons at LHC. Built of lead tungstate crystals, it plays a crucial role in the search for new physics as well as in precision measurements in the Standard Model. The status and general performance of the CMS ECAL in proton-proton collisions 2010 run at $\sqrt{s} = 7\,\text{TeV}$ are described. The precision of the inter-channel calibration and absolute energy scale has been verified and improved exploiting *in situ* data. The quality of the offline data reconstruction, from low level quantities to high level objects, has been investigated and improved using known physics processes. Collision data and data/MC comparisons have been used to measure and tune the detector performance.

PACS 29.40.Vj – Calorimeters.

1. – Overview of the CMS electromagnetic calorimeter

The Electromagnetic CALorimeter (ECAL) of the Compact Muon Solenoid (CMS) experiment [1] at the LHC [2] is an hermetic homogeneous calorimeter made of 75848 lead tungstate ($PbWO_4$) scintillating crystals. It consists of a central barrel region (EB) organized in 36 supermodules, each containing 1700 crystals, and two endcaps (EE) of 7324 crystals each. The scintillation light is read out by avalanche photodiodes (APDs) in the barrel and with vacuum phototriodes (VPTs) in the endcaps. Silicon preshower detectors (ES) are installed in front of the ECAL endcaps. The Barrel provides the coverage of pseudorapidity $|\eta| < 1.479$ with the Endcaps extending to $|\eta| = 3.0$. The ES covers $1.653 < |\eta| < 2.6$.

The ECAL energy resolution measured in electron test beams is parametrized by [1]

$$\frac{\sigma(E)}{E} = \frac{2.8\%}{\sqrt{E(GeV)}} \oplus \frac{12\%}{E(GeV)} \oplus 0.3\% \tag{1}$$

for electrons incident on the center of crystals. The three contributions correspond to the stochastic, noise and constant terms. In the environment of CMS, for unconverted photons with energies above 100 GeV, the energy resolution is dominated by the constant term. As a consequence, the performance of the CMS ECAL at the LHC will depend mainly on the quality of its inter-calibration and monitoring. Achieving the design-goal inter-calibration precision of 0.5% in situ will be particularly important for a discovery of the Higgs boson in the decay channel $H \to \gamma\gamma$, one of the primary goals of the LHC physics program.

2. – ECAL status and stability

During the LHC collisions in 2010, the percentage of working channels in the Barrel and in the Endcaps was about 99.3% and 98.9%, respectively [3]. The stability of the entire system is crucial to achieve the target constant term in the energy resolution. Among the different contributions to that are the temperature stability of the crystals and photodetectors and the crystal transparency, which can decrease with radiation. The temperature stability over two months has been measured to be about 0.008 °C and 0.015 °C for the Barrel and the Endcaps, respectively [3]. These values are well within specifications, which allow for maximum variations of 0.05 °C in the Barrel and 0.1 °C in the Endcaps. The light monitoring system itself shows a stability at the 0.03% level, which is much better than what is required to maintain the constant term in the ECAL energy resolution at the level of 0.5%.

3. – ECAL calibration strategy

The ECAL calibration aims at the best estimate of the energy of electrons and photons. The CMS ECAL was pre-calibrated prior to LHC collisions with an overall inter-calibration precision of 0.5%–2% in the Barrel and 5% in the Endcaps [4, 5].

The calibration precision is improved in-situ by using LHC collision data: di-electron resonances such as $J/\psi \to e^+e^-$ and $Z \to e^+e^-$, can be used to monitor and correct the absolute ECAL energy scale. The ECAL energy scale test gives excellent results: the agreement between the Z mass peak in data and MC reaches a precision of 1%(3%) in the Barrel (Endcaps([1])) [6].

In parallel, the inter-calibration has been improved with several methods [7]. The two most important ones for 2010 data taking period, in terms of precision, are:

- The ϕ-symmetry inter-calibration. A fast calibration method, *i.e.* it requires a low amount of statistics ($\sim 10^2\,\text{nb}^{-1}$) and it is based on the invariance around the beam axis of energy flow in minimum bias events; it allows to inter-calibrate crystals in a ring at the same pseudorapidity. Inhomogeneities in the detector material limit the precision of the method to about 1.5%-3% depending on the channel pseudorapidity.

- The π^0 and η calibration. It exploits the mass peak of photon pairs selected as $\pi^0(\eta) \to \gamma\gamma$ candidates; it is useful at the start-up also to investigate the ECAL energy scale.

Figure 1 shows the inter-calibration precision as a function of the crystal η index for these two different methods (ϕ-symmetry, $\pi^0 \to \gamma\gamma$); the combined resulting precision

([1]) The energy scale test of the Endcaps takes into account also the reconstructed energy in the preshower silicon detector.

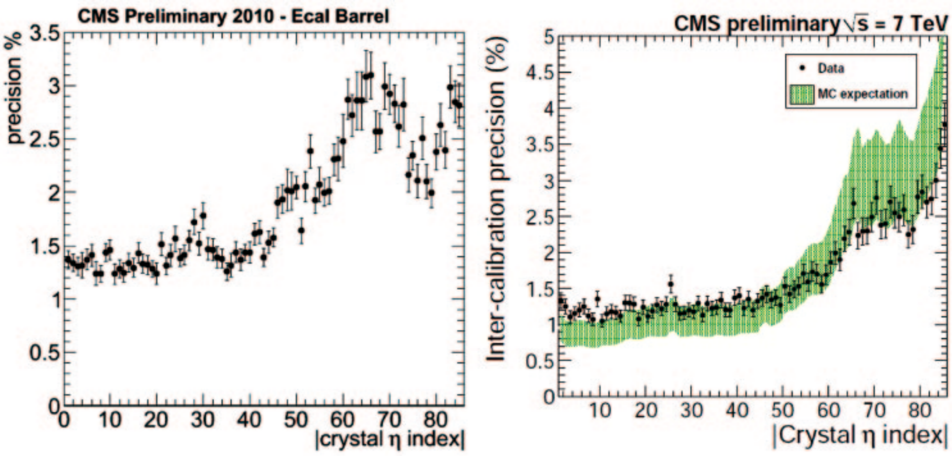

Fig. 1. – Inter-calibration precision as a function of the crystal η index, proportional to the crystal pseudo-rapidity, in the Barrel using two different strategies [7]: ϕ-symmetry (left) and $\pi^0 \to \gamma\gamma$ (right).

ranges from about 3% in the forward barrel, where the tracker material budget limits the statistics of $\pi^0(\eta) \to \gamma\gamma$ candidates, to 0.6% in the central region of the calorimeter, with only $35\,\mathrm{pb}^{-1}$. This accuracy is already close to the 0.5% required for $H \to \gamma\gamma$ discovery.

4. – Conclusions

The CMS ECAL status and performances with the first 2010 proton-proton LHC collisions have been presented. The ECAL stability is found to be well within specifications and is constantly monitored. An average inter-calibration precision of 0.6% in the central barrel region has been achieved and the ECAL energy scale has been tested at the percent level. New in-situ results on the energy scale became available after the conference and substantially confirm these findings.

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