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CMS Electromagnetic Calorimeter performance during the 2011 LHC run

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Summary. — The CMS Electromagnetic Calorimeter (ECAL) is a high-resolution, fine-grained calorimeter devised to measure photons and electrons at the LHC. Built of lead tungstate crystals, it plays a crucial role in the search for new physics as well as in precision measurements of the Standard Model. A pre-shower detector composed of sandwiches of lead and silicon strips improves π^0/γ separation in the forward region. The operation and performance of the ECAL during the 2011 run at the LHC, with pp collisions at $\sqrt{s} = 7\,\text{TeV}$ will be reviewed.

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PACS `29.40.-n` – Radiation detectors.

The Electromagnetic Calorimeter (ECAL) of the Compact Muon Solenoid (CMS) experiment [1] at the LHC [2] is an hermetic, homogeneous calorimeter composed by 75848 lead tungstate scintillating crystals. The barrel region (EB) covers the pseudorapidity range $|\eta| < 1.479$, is composed by 36 supermodules, each containing 1700 crystals. The scintillation light is read out by avalanche photodiodes (APDs). The interval $1.479 < |\eta| < 3.0$ is covered by the endcaps (EE) and each of their 7324 crystals is read out by a vacuum phototriode (VPT). The silicon preshower detectors (ES) are installed in front of EE, over the range $1.653 < |\eta| < 2.6$ in order to improve π^0 rejection.

The ECAL energy resolution can be parametrized as the sum of a stochastic, a noise and a constant term. For unconverted photons with energy greater than 100 GeV, the resolution is dominated by the constant term. As a consequence, the ECAL performance relies on the quality of its inter-calibration and monitoring [3]. Since both the APD gain and the light yield depend on the temperature, the ECAL temperature stability is very important. This stability has been measured, between April and October 2011, to be better than 0.05 °C in the EB, and better than 0.1 °C in EE, well within the allowed limits.

The energy of electrons and photons can be written in terms of all the effects that are taken into account for the ECAL calibration as

$$E_{e,\gamma} = F_{e,\gamma}(E_T, \eta) \sum_i G(\text{GeV}/\text{ADC}) \cdot c_i \cdot A_i \cdot S_i, \tag{1}$$

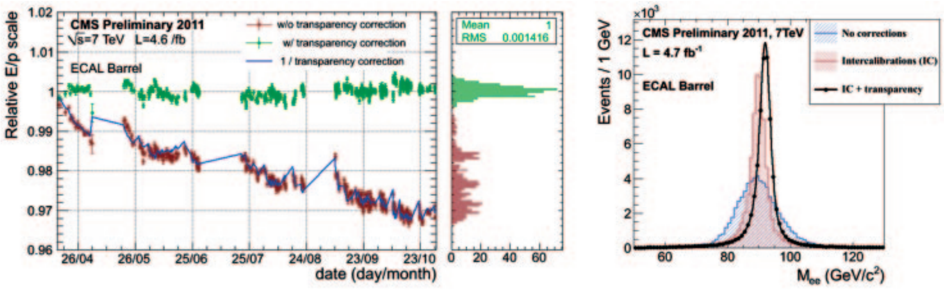

Fig. 1. – Left: Ratio of electron energy E, measured in the ECAL Barrel, to the electron momentum p, measured in the tracker, as a function of time for 2011 data. Right: Z→ee invariant-mass plot for 2011 data, from the reconstruction of di-electron events with both electrons in the ECAL Barrel.

where the sum is over the crystals involved in the local cluster of electromagnetic energy deposits, A_i is the measured ADC amplitude, c_i is the inter-calibration constant, S_i is the correction for response loss, G is the ADC-to-GeV energy scale and $F_{e,\gamma}$ is an additional correction factor which depends on the type of particle and its properties. The detector has been pre-calibrated prior to LHC startup [4], exploiting laboratory measurement of light yield and photodetector gain, beam dumps, test beam and cosmic rays measurements. The obtained results are improved in-situ using LHC collision data combining different methods [3, 5]. The inter-calibration exploits the invariance around the beam axis of the energy flow in minimum bias events, for crystal at the same pseudorapidity, combining the results with the ones obtained using the invariant mass peak of di-photon events from π^0 and η photon decays. In EB, for $|\eta| < 1.0$, precision is about 0.5%, and better than 1% elsewhere. In the EE it is about 2%. Another important aspect is the crystal radiation damage. The consequent loss in transparency has been measured during data taking with different type of lasers to monitor and correct for changes in the crystal effective light yield. In 2011 the loss was up to 5% in EB and 20–30% in EE. The effect of these corrections on the E/p distribution for isolated electrons is shown in fig. 1 (left).

In order to evaluate the ECAL physics performance, the Z→ee invariant mass obtained using electrons in EB with low energy loss through bremsstrahlung is shown in fig. 1 (right). The position of the peak is used to calibrate the absolute energy scale. The global instrumental resolution after preliminary energy calibration of 2011 data is measured to be around 1 GeV in EB.

REFERENCES

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