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Calibration of the electromagnetic calorimeter of CMS

A. Massironi(*) for the CMS Collaboration
Università di Milano-Bicocca and INFN - Piazza della Scienza 3, Milano, Italy

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Summary. — The electromagnetic calorimeter (ECAL) of the CMS experiment, that will take data at LHC, has been designed to get an excellent energy resolution, essential to search for diphotonic resonances. ECAL is made of lead tungstate crystals whose individual response, that depends on several contributions, affects the resolution of the whole detector. Hence, a channel-to-channel intercalibration is required to get the goal performances. The calibration of the detector at the start-up and the *in situ* calibration strategies are reported.

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1. – Introduction

The Compact Muon Solenoid (CMS) [1,2] is one of the two general-purpose detectors installed at the CERN LHC. Its main physics goals are the observation of the Higgs boson and the search for new physics phenomena. For a mass below $150\,\text{GeV}/c^2$, the Higgs decay in two photons is a promising signature for the discovery. In this mass range, the Higgs width is very narrow and the signal lies above an irreducible background: this leads to the choice of a high-resolution electromagnetic calorimeter.

The electromagnetic calorimeter (ECAL) [3] of the CMS, located within a 3.8 T superconducting solenoid, is a hermetic homogeneous calorimeter comprised of lead tungstate ($PbWO_4$) crystals and a lead-silicon preshower. The $PbWO_4$ has high density ($8.3\,\text{g/cm}^3$) and short radiation length (0.89 cm) allowing a compact design of the calorimeter, while its small Moliere radius (2 cm) guarantees a high granularity.

2. – Commissioning

An excellent energy resolution is essential for different physics analyses to be performed. The stochastic and electronic noise contributions to the energy resolution of ECAL have been measured with known energy electron beams and demonstrated to be

(*) E-mail: Andrea.Massironi@mib.infn.it

within the design requirements of the detector. The main contribution to the overall ECAL energy resolution is therefore due to the channels response uniformity. The calibration procedures are designed to determine the coefficients that equalize the crystals responses to a reference signal. Specific pre-calibration operations were designed and carried out during the commissioning phase of ECAL, to provide an acceptable detector performance at the start-up of LHC operation.

One-fourth of the supermodules was exposed to electron test beams [4]. A $90\,\mathrm{GeV}/c$ and a $120\,\mathrm{GeV}/c$ electron beam were used and a comparison between the coefficients measured for one supermodule at one-month interval showed a 0.3% accuracy in the calibration.

The most precise determination of the pre-calibration coefficients for the whole ECAL barrel is provided by a campaign of measurements performed with cosmic-ray muons. Cosmic-ray muons, that traverse the crystals along their length and whose direction is approximately aligned to the crystal axis, were selected so that the same amount of energy was released in each crystal. After assembly and before installation in CMS, all 36 supermodules were exposed, in turn, to cosmic-ray muons for a period of about one week, on a cosmic-ray stand hosting one supermodule at a time. A 2% accuracy has been obtained.

While preparing colliding beams, the LHC delivered several splash events to CMS by colliding the beam in the collimators located 150 m away from the CMS interaction point, producing a muon flux which reached the cavern and traversed horizontally the CMS detector. The test of the local uniformity in the corresponding energy deposition allowed to validate and improve ECAL endcap intercalibrations [5].

A rapid and precise calibration of the CMS electromagnetic calorimeter can be performed *in situ* through online selection of neutral mesons (π^0 and η), exploiting the meson mass constraint on the energy of the two photons from $\pi^0/\eta \to \gamma\gamma$ decay. Another technique with the very first data is the use of the invariance around beam axis of the energy flow in minimum bias events (ϕ-symmetry). The absolute energy scale of the calorimeter will be obtained exploiting electron decay of Z-boson and its invariant-mass constraint.

During LHC operation, once the CMS tracker is well aligned, the intercalibration of different crystals will be performed by comparing the momentum and energy of isolated electrons [6]. About $5\,\mathrm{fb}^{-1}$ of integrated luminosity is required to gain the goal precision.

3. – Conclusions

Calibration performed during the commissioning phase of the detector provides an acceptable performance of the electromagnetic calorimeter of the CMS experiment for startup physics, while the ultimate calibration accuracy to get an excellent energy resolution will be achieved in situ by exploiting several independent procedures.

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