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Calibration of the L3 BGO calorimeter using an RFQ accelerator

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Abstract

An improved calibration technique based on a radio-frequency-quadrupole (RFQ) accelerator is presented. A high-intensity flux of 17.6 MeV photons, produced by radiative capture of 1.85 MeV protons from the RFQ in a lithium target, is used to calibrate in situ 11 000 crystals of the L3 BGO calorimeter. We present results obtained for the calibration of 1997–1999 L3 data samples. For the first time a calibration precision better than 0.5% is reached for the entire BGO calorimeter. The importance of such a technique is also outlined in view of extensive use of crystal calorimetry at the LHC. © 2001 Elsevier Science B.V. All rights reserved.

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L3 is one of the four experiments operating at the LEP e^+e^- collider at CERN. The L3 electromagnetic calorimeter (ECAL), composed of bismuth germanate (BGO) crystals, is one of the key parts of the detector. BGO crystals of the L3 calorimeter are arranged in two endcaps (each of 1527 crystals) and two half-barrels (7680 crystals combined) [1]. A precision calibration for each crystal is essential to reach the design energy resolution of 1% over the energy range from a few GeV up to 100 GeV.

Prior to the startup of LEP in 1987–88 the barrel of the BGO calorimeter was calibrated using electron beams ranging from 180 MeV to 50 GeV in energy. With approximately 1000 electrons per crystal the achieved precision on the calibration constants was 0.5% [2]. To preserve the energy resolution, a precise calibration in situ is essential. It is needed to follow the change in response with time of each channel, which is due to changes in the crystal itself or in the electronics chain. In L3, the calibration in situ was also essential when the BGO endcaps were installed, in 1991, without any previous test-beam calibration.

The RFQ [3] calibration technique uses a pulsed H^- beam from the RFQ accelerator to bombard

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Table 1
L3 ECAL energy resolution for 70 GeV electrons and photons achieved with this calibration

	Barrel (%)	Endcaps (%)
Intrinsic error	0.8	0.6
Temperature error	0.5	0.5
Calibration error	0.5	0.3
Overall	1.07	0.84

a lithium target installed inside the BGO calorimeter. After focusing and steering, the beam is neutralised to allow it to pass undisturbed through the magnetic field of L3. Radiative capture of protons $p + {}^7_3\mathrm{Li} \rightarrow {}^8_4\mathrm{Be} + \gamma$ produces 17.6 MeV photons that are used to calibrate the calorimeter.

The intrinsic energy resolution of the L3 BGO detector is limited by electromagnetic shower fluctuations and shower leakages through the carbon fibre support structure where BGO crystals reside. This intrinsic resolution is estimated by means of a detailed simulation of the L3 detector. The resulting errors on the energy measurement, for 70 GeV electrons and photons, are 0.8% and 0.6% in the barrel and in the endcaps, respectively. These errors are different due to the different layout of crystals in the two sub-detectors.

From the measured Bhabha energy spectra, and subtracting in quadrature all the known contributions we derive the calibration accuracy, which result in a 0.5% for the barrel and 0.3% for the endcaps. All the relevant contributions to the true energy resolution of the BGO detector are summarised in Table 1. The energy resolution as a function of the electron energy is shown in Fig. 1. The energy dependence of the intrinsic error is well described by a function $A/\sqrt{E}$. The coefficient A is different for the barrel and the endcaps because of the different geometry and amount of material in front of the crystals.

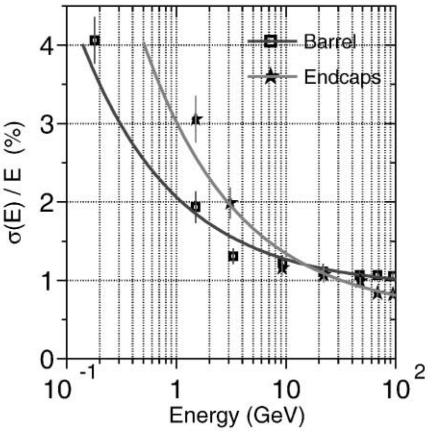

Fig. 1. ECAL energy resolution as a function of the electron energy.

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