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CALICE scintillator hadron calorimeter prototype commissioning and calibration*

J CVACH
Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague, Czech Republic
E-mail: cvach@fzu.cz

Abstract. First experience with construction and positron beam tests of a scintillator tile hadron calorimeter are discussed.

Keywords. Calorimeter; photodector; calibration.

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1. Introduction

The calorimeter for experiments at the future ILC must be realized as a dense and hermetic sampling calorimeter with a very high granularity where one can efficiently separate contributions of different particles in a jet and use the best suited detector to measure their four-momenta. The goal is to reach the jet energy resolution of $\sigma/E \sim 0.3/\sqrt{E}$. The success of this approach will originate much more from the high segmentation (both lateral and longitudinal) than from the stochastic and constant terms in the energy resolution which can be moderate. One possible realization of the calorimeter is proposed for the LDC detector and described in [1]. In this contribution we concentrate on the progress in the prototype development of the scintillator-steel hadron calorimeter (HCAL) with silicon photomultipliers (SiPMs) – multi-pixel avalanche photodiode detectors operated in the Geiger mode [2]. There are several novel features in this calorimeter. The tile size is as small as $3 \times 3 \times 0.5$ cm^3. The high granularity is suited for the semi-digital readout option. The scintillation light is collected by a WLS fibre inside a tile and brought to a SiPM mounted in a tile corner, therefore no fibres are routed outside the tile.

*Participating Institutes are DESY (FLC) Hamburg, ITEP, LPI, MEPHI Moscow, Institute of Physics AS CR, IPNP of Charles University, Prague within the CALICE Collaboration.

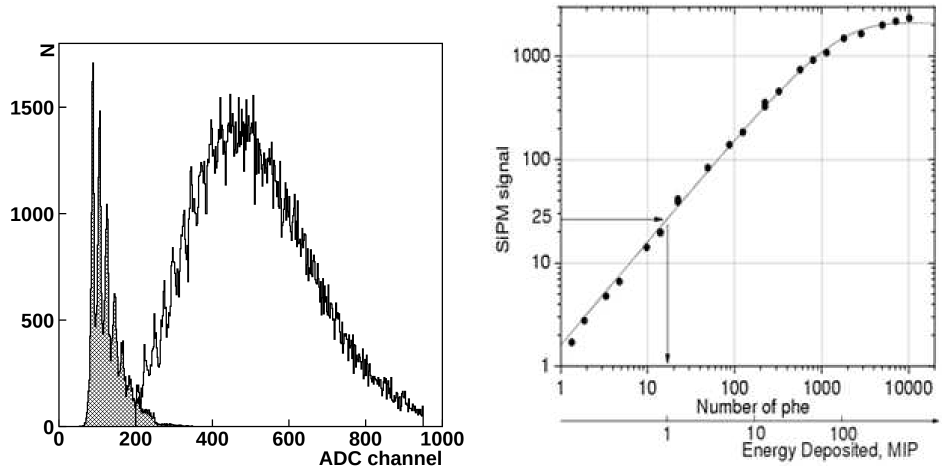

Figure 1. (Left) SiPM response to the low intensity light (shaded histogram) and to one MIP; (right) average response to larger number of MIPs.

SiPMs have several advantages: low bias voltage ∼ 50 V, high gain of 10^6 and they are nonsensitive to the magnetic field.

2. The HCAL prototype and its calibration

The prototype size is $1 \times 1 \times 1$ m^3. The sampling structure consists of 2 cm thick stainless steel plates with 0.9 cm gaps into which scintillator tiles held on PCBs are inserted. In total 38 planes will be built. Each plane contains 216 tiles, sizes ranging from 3×3 to 12×12 cm^2. The SiPM signal is brought by cables to the front-end electronics attached to the same side of each plane. It uses twelve 18 channel ASIC chips which allow individual SiPMs bias voltage adjustment, global gain settings and signal shaping, track&hold and multiplexing [3]. Other details of the prototype can be found in this proceedings [4].

Continuous calibration of the calorimeter is necessary because SiPMs are sensitive to the temperature and bias voltage changes and they are nonlinear in response to the amount of detected light. There are several ways to monitor the calorimeter response: cosmics, beam particles or a dedicated calibration and monitoring system using short UV LED pulses brought to each tile. We shall concentrate on the latter approach.

The advantage of LED light is that it can be easily tuned by width and intensity of the electrical pulse. We have chosen the width of the pulse which is ∼10 ns close to the width of the light pulse produced by shower and the intensity in range up to 100 minimum ionizing particles (MIPs) to cover the dynamic range of the shower in tile. Very good resolution of SiPMs and linearity at low light intensities enables to resolve single photon peaks and provide a unique opportunity to calibrate SiPM gain by a fit with a linear combination of Gaussians (see figure 1(left) – shaded histogram). In this figure the SiPM response to a MIP is superimposed to illustrate

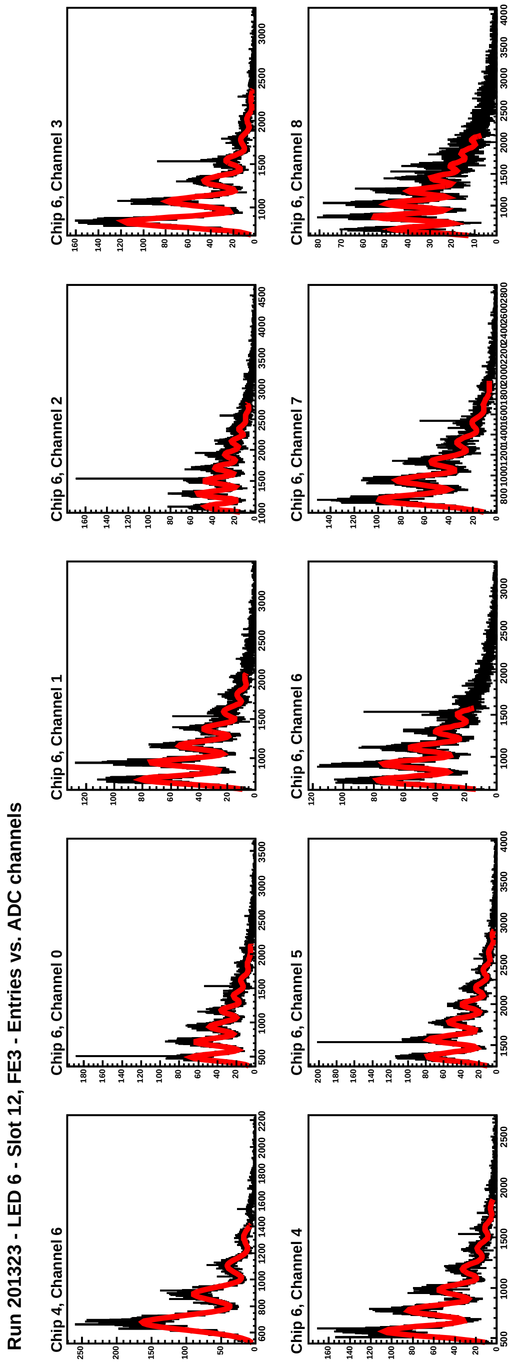

Figure 2. Response of 10 SiPMs to the low intensity light from LED.

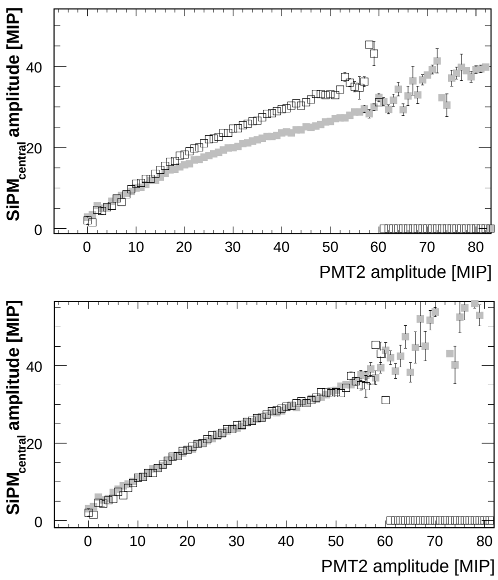

Figure 3. Dependence of SiPM amplitude on the number of MIPs. The shaded circles are data and the open squares are MC prediction. In the lower figure, data are corrected for the SiPM nonlinearity.

that at the typical bias voltage settings of ∼50 V a MIP corresponds in average to 20 photoelectrons [5].

In figure 1(right) the SiPM response to the LED light is shown in the full range of light intensity calibrated already in photoelectrons (MIPs). The position of 1 MIP in the right figure is denoted by a vertical arrow and corresponds to the maximum non-shaded histogram in the left figure. The SiPM nonlinearity at high signals is due to pixelization of the photodiode. The curve is used for the correction of the SiPM signal.

As an illustration that the calibration system works in its complexity, figure 2 shows the response of 10 SiPMs to the light from the same LED. The light is carried by a clear fibre from LED to the scintillator tile, collected by WLS and routed to SiPM in the tile corner. Eventual fluctuations of LED light are monitored by a PIN diode. The different average number of photoelectrons in different SiPMs is mainly due to combination of variations in the SiPMs gains, quality of the optical light transfer from LED to SiPM and surface inhomogeneity of LED. Special investigations were carried on to minimize all spreads. We finally reached a spread of a factor 2 between the dimmest to the brightest.

3. Test results

Tests with first fully equipped planes were done with cosmics and positron DESY beam of energy 2–6 GeV. The aim was to test the detector as a whole including the data acquisition system and specifically its sensitivity to temperature variations and

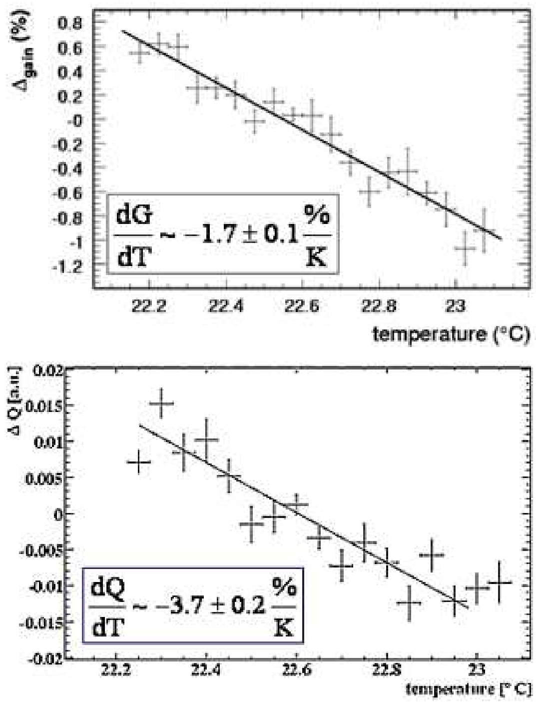

Figure 4. Dependence of relative change of gain (upper) and collected charge (lower) of SiPM on temperature. The number in the box gives the slope of the straight line fit.

corresponding correction, test the calibration procedure, studies of the uniformity over the plane surface and comparison with Monte Carlo simulation [6].

In figure 3 the signal from one tile (3×3 cm^2) in HCAL is plotted from measurement of a shower produced by 5 GeV positron beam in a $5X_0$ lead target placed in front of a HCAL plane. The reference number of MIPs was obtained from the signal in a scintillator (5×5 cm^2) placed between the target and the HCAL plane. Its light was measured by a photomultiplier PMT2. The data are compared to simulation using GEANT3 program. In the upper part of figure 3 data points at large MIP values are below the MC points. After introducing the correction for the SiPMs inefficiency (see figure 1(right) the data in figure 3(lower) are properly corrected and agree with the MC points.

As mentioned in §2 SiPMs are sensitive to temperature and bias voltage changes. The monitoring system provides measurements of these corrections continuously. In figure 4 the temperature dependence of the SiPM relative gain (upper) and relative collected charge (lower) is plotted from two-week long cosmics run. The data points are averaged over 50 SiPMs and fitted by a straight line. The number in the box gives value of the slope of the straight line fit and is in agreement with previous measurements carried out in MEPHI.

4. Outlook

The HCAL prototype will undergo in summer/autumn 2006 tests in the beam of $e/\mu/\pi/p$ of 6–200 GeV at CERN North area beam-line H6. The broad program includes establishing of operation and calibration of more than 8000 SiPMs, measurement of hadron energy resolution, tuning of clustering algorithm and comparison of existing MC models to data in calorimeter with unprecedented granularity. The combined tests of Si–W ECal and tail catcher with muon tracker are envisaged.

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References

[1] TESLA TDR, DESY 2001-011 (2001)
[2] G Bondarenko *et al*, *Nucl. Instrum. Methods* **A442**, 187 (2000)
[3] J Fleury, *These proceedings*
[4] F Sefkow, *These proceedings*
[5] V Andreev *et al*, *Nucl. Instrum. Methods* **A540**, 368 (2005)
[6] E Garutti, *Proceedings of CALOR06*, Chicago, June 2006