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Technical Notes

Characterization of a DAQ system for the readout of a SiPM based shashlik calorimeter

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ABSTRACT

Silicon PhotoMultipliers (SiPMs) are a recently developed type of silicon photodetector characterized by high gain and insensitivity to magnetic fields, which make them a suitable detector for the next generation high energy and space physics experiments. This paper presents the performance of a readout system for SiPMs based on the MAROC3 ASIC. The ASIC consists of 64 channels working in parallel, each one with a variable gain pre-amplifier, a tunable slow shaper with a sample & hold circuit for the analog readout and a tunable fast shaper for the digital one. In the tests described in this paper, only the analog part of the ASIC has been used. A frontend board based on the MAROC3 ASIC has been tested at CERN coupled to a scintillator-lead shashlik calorimeter, readout with 36 large area SiPMs. The performance of the system has been characterized in terms of linearity and energy resolution on the CERN PS-T9 and SPS-H2 beamlines, using different configurations of the ASIC parameters.

1. Introduction

Silicon PhotoMultipliers (SiPMs) consist of a matrix of small passively quenched silicon avalanche photodiodes operated in limited Geiger-mode (GM-APDs) and readout in parallel from a common output node. Each pixel (with a typical size in the 20–100 μm range) gives the same current response when hit by a photon; hence the total output signal is proportional (for moderate fluxes) to the number of hit pixels. More details on SiPMs can be found in Refs. [1,2]. The main advantages of the SiPMs with respect to the photomultiplier tubes (PMTs) are the low bias voltage (~50 V), the small dimensions, the simple readout and the insensitivity to magnetic fields. On the other hand, SiPMs can be affected by radiation, suffer a high temperature dependent dark noise and their dynamic range is limited by the number of available pixels.

In recent years, SiPMs have been used by a large variety of experiments with a rapidly increasing number of channels: among them, the readout system developed for the electromagnetic and hadron calorimeters of the CALICE collaboration [3], the near detector system of the T2K experiment [4] and the scintillating fiber tracker of the PEBS (Positron Electron Balloon Spectrometer) experiment [5] have to be mentioned. These experiments, characterized by thousands of active channels, use specifically developed ASICs (Application Specific Integrated Circuits) to deal with the large number of SiPMs and to optimize the power consumption/dissipation. This paper presents the performance of the MAROC3 (Multi Anode ReadOut Chip) ASIC for the readout of an array of 36 SiPMs connected to a shashlik electromagnetic calorimeter. Originally developed for the readout of multianode photomultiplier tubes (MAPMTs), this ASIC can be used also for the readout of SiPMs [6], as proven in Ref. [7] using a matrix of SiPMs coupled to LYSO (Lutetium-Yttrium OxyorthoSilicate [8]) crystals. The calorimeter and the MAROC3 readout system have been tested both in a test bench in the laboratory and on the beam at CERN on the PS and SPS extracted beamlines. All the tests have been performed in the framework of the FACTOR/TWICE collaboration, a R&D project started in 2007 and funded by the Italian Institute of Nuclear Physics (INFN). The main goals of the project are as follows:

- the development and optimization of the SiPM technology in collaboration with FBK-irst;
- the test of the performance of these devices for the readout of fiber calorimeters and scintillators in high energy and space physics experiments.

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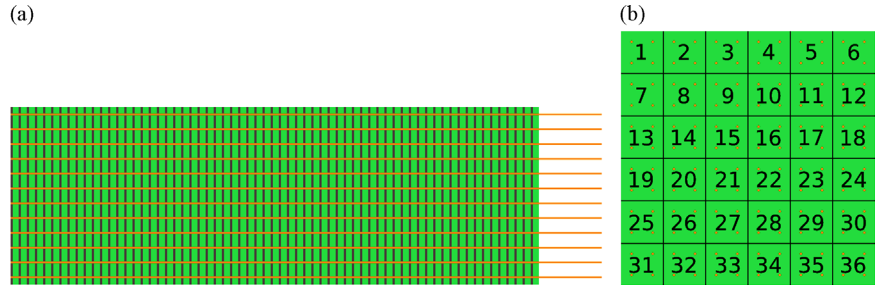

Fig. 1. Lateral (a) and frontal (b) sketches of the calorimeter with the lead and the scintillator tiles and the WLS fibers. The readout channel number is also indicated.

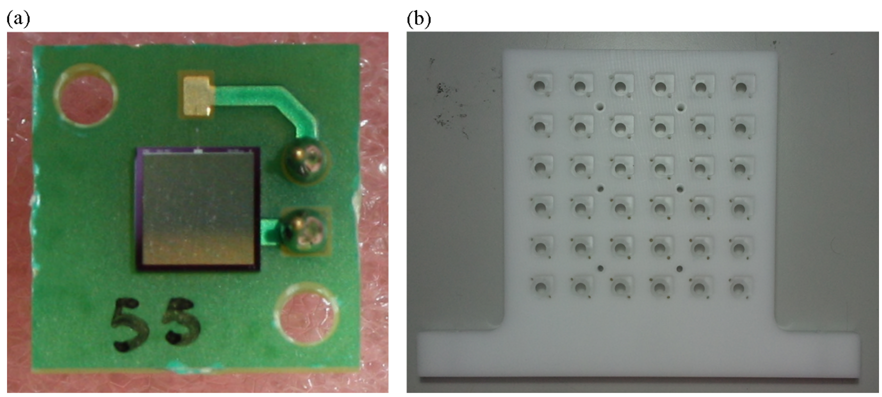

Fig. 2. Picture of the 16 mm^2 SiPM bonded on the FR-4 PCB (a) and of the SiPM holder (b).

The second section of this paper is devoted to the description of the shashlik calorimeter, while the third one describes the MAROC3 ASIC and the laboratory tests performed on the DAQ system. The fourth and fifth sections present the results obtained on the beamtests performed at CERN on the T9 and H2 beamlines with two different DAQ systems, comparing the results themselves in terms of linearity and energy resolution.

2. The shashlik calorimeter

The shashlik calorimeter used for the MAROC3 tests consists of 65 4 mm thick tiles of plastic scintillator and 65 1.5 mm thick tiles of zinc-coated lead, for a total of ~18 radiation lengths; 130 μm thick Tyvek [9] sheets have been used as inter-tile material to enhance the light output. Each tile has an area of 11.5×11.5 cm^2 and the light readout is performed using 144 1.2 mm WLS (WaveLength Shifter) fibers (Saint-Gobain BCF-92 [10]). The sensitive part of the calorimeter is contained in a 1 cm thick aluminum vessel which covers the top and bottom parts of the tiles. A sketch of the calorimeter is presented in Fig. 1.

The WLS fibers cross the whole calorimeter, so that each fiber collects the light of all the scintillator tiles. According to Fig. 1, the fibers are placed in a 12×12 matrix of 1 cm spaced holes in the scintillator and lead tiles; they are then grouped and glued in bundles of four fibers each using 36 plastic holders, and plugged into a support designed to hold an array of SiPMs. The calorimeter is read out using 36 SiPMs manufactured by FBK-irst with a sensitive area of 16 mm^2 with 6400 50×50 μm^2 pixels. The SiPMs have a squared geometry and are glued onto a FR-4 PCB that has a twofold purpose: an electric one, providing the bias and the readout connectors, and a mechanical one, providing the coupling to the calorimeter fiber holder (Fig. 2b); a picture of the device is presented in Fig. 2a, while its main features are reported in Table 1.

Table 1
FBK-irst SiPM specifications: the breakdown (BD) voltage is an indicative value while the PDE (Photo Detection Efficiency) is evaluated at 500 nm.

Breakdown voltage	Time resolution	Gain	PDE (4 V ΔV)	Temperature coefficient ($\Delta V_{BD}/\Delta°T$)
~30 V	80–250 ps [11,12]	~10^6 [13]	~25% [13]	65 mV/°C [13]

A custom interface board has been developed to couple the SiPMs to the MAROC3 frontend board. This board is directly plugged on the SiPMs pins and provides also nine independent lines for the SiPMs bias. The calorimeter is also equipped with a LED monitoring system used during the run to correct the gain variations of the SiPMs, essentially due to the temperature variations. A few pictures of the calorimeter system are presented in Fig. 3.

A slightly modified version of the calorimeter with 16 readout channels readout by a standard charge integrating ADC and without Tyvek sheets as inter-tile material had been previously tested in 2009 and 2010; more details can be found in Ref. [14].

3. The MAROC3 frontend board

The MAROC3 board used for the calorimeter readout is based on the third revision of the MAROC chip, a 64 channel ASIC designed in AMS SiGe 0.35 μm technology; the chip has an effective area of 4×4 mm^2, is powered with a 3.5 V bias and has a power consumption of 350 mW [15,16]. The 64 channels work in parallel and each of them consists of (Fig. 4a) the folowing:

- a pre-amplifier with a variable gain up to $4\times$, adjustable with a 8 bit resolution (the $1\times$ gain corresponds to 64);