IL NUOVO CIMENTO **40 C** (2017) 149
DOI 10.1393/ncc/i2017-17149-7

Colloquia: SciNeGHE 2016

Towards the development of a SiPM-based module for the camera of the Schwarzschild-Couder Telescope prototype of CTA

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received 3 June 2017

Summary. — In recent years, Silicon Photomultipliers (SiPMs) proved to be very performing devices for those applications where high sensitivity to low-intensity light and fast responses are required. The Italian National Institute for Nuclear Physics (INFN) is currently involved in the development of a prototype for a camera based on SiPMs for the Cherenkov Telescope Array (CTA), a new generation of telescopes for ground-based gamma-ray astronomy. Here we present the progress made during the last year in the development and testing of SiPMs suitable for Cherenkov light detection in the Near Ultraviolet (NUV SiPMs). The developed device is a High-Density (HD) NUV SiPM based on a micro cell of $30\,\mu\text{m} \times 30\,\mu\text{m}$ and $6\,\text{mm}\times 6\,\text{mm}$ area produced by the Fondazione Bruno Kessler (FBK). We present the characterization of the NUV-HD SiPMs arranged in a matrix of 4×4 single units, which will be part of the focal plane of the mid-size Schwarzschild-Couder Telescope prototype (pSCT) for CTA. An update on recent tests on the front-end electronics will be given.

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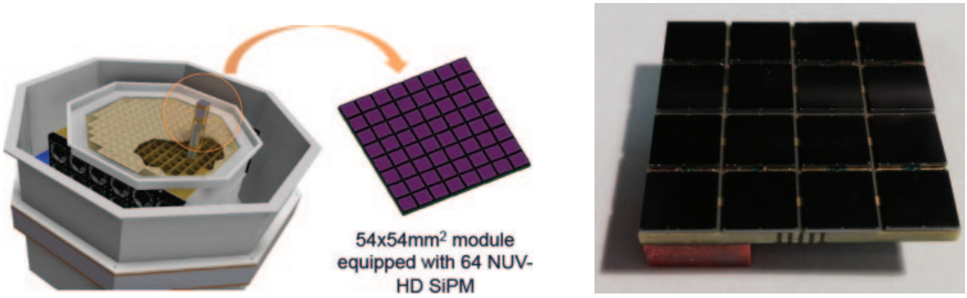

Fig. 1. – Left panel: Schematic view of the focal plane of pSCT. Right panel: 4×4 matrix consisting of four independent quadrants equipped with 16 NUV–HD SiPMs.

1. – The SiPM–based module for pSCT

The mid-size Schwarzschild-Couder Telescope prototype (pSCT) for the CTA observatory is currently under construction and will be operated at the VERITAS site in Arizona at the end of 2017. It will provide high angular resolution, high background rejection and a wide field-of-view (FoV). A section of the pSCT focal plane, for a total of nine modules, will be equipped with 25 matrices made of 64 FBK NUV-HD SiPMs [1] for a total of 1600 SiPMs, as shown in the left panel of fig. 1.

The right panel of fig. 1 displays a 4×4 matrix, which is made by four independent quadrants equipped with 16 SiPMs. The employed devices are based on a micro cell of $30\,\mu\text{m} \times 30\,\mu\text{m}$ and $6\,\text{mm} \times 6\,\text{mm}$ area. More details about the mechanical layout of the SiPM module PCB and the SiPM electrical characterization are given in [2].

2. – Test campaigns for the pSCT

Before the final installation on the pSCT focal plane, we need to perform an extensive test campaign of the 1600 SiPMs. A first set of tests was carried out on a single 4×4 SiPM matrix, in order to verify the response uniformity. For this purpose, we developed an *ad hoc* 16-channels charge amplifier (see the left panel of fig. 2) to reshape the signal [3]. Its electrical scheme is shown in the right panel of fig. 2. The design was optimized in

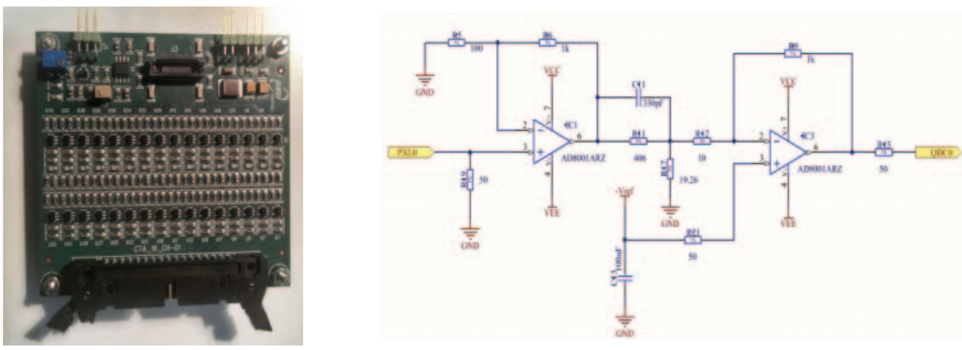

Fig. 2. – Left panel: The 16-channels charge amplifier. Right panel: Electrical scheme of the charge amplifier.

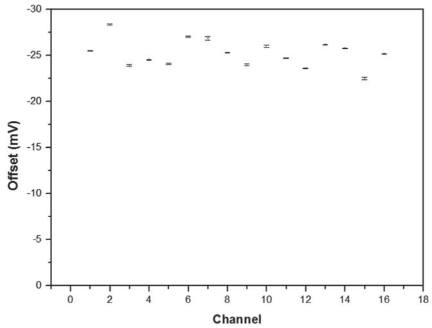

Fig. 3. – Negative offset values of the 16 channels of the charge amplifier.

order to generate a negative signal, which is required by the acquisition system used in the test campaigns. The PCB hosting the charge amplifier was tested in order to determine the negative offset value for each channel. We thus checked the consistency between the 16 channels and obtained a mean value of about -25 mV, as shown in fig. 3.

3. – Preliminary test results

The laboratory tests on the matrix coupled with the electronics were performed in a dark box, using a laser emitting at 380 nm as light source. We first studied the performance of a single channel of the matrix by covering all but one SiPMs with a dark mask. We applied different values of the bias voltage (U_b) between 35 V and 39 V, corresponding to ~ 7 to 11 V of overvoltage. The signal was acquired with an oscilloscope.

The waveforms shown in the left panel of fig. 4 were obtained by inverting the negative signal. This is particularly useful for analysis purposes. A good waveform quantization down to the single photoelectron (p.e.) is evident. The pulse width is $\sim$ 20 ns, as expected from the electronics design, and the small undershoot is due to the Pole-Zero

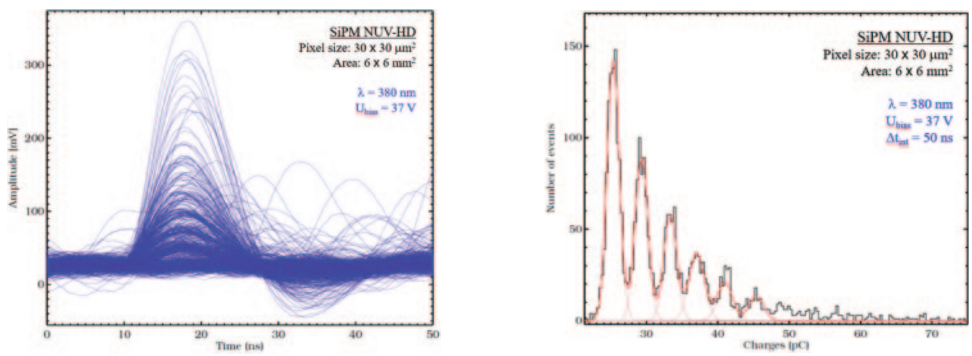

Fig. 4. – Left panel: Waveforms aquired by illuminating the $6{\times}6\,\mathrm{mm}^2$ NUV-HD SiPM with a 380 nm LED, at a bias voltage of 37 V. The quantization of the signal is evident. Right panel: Charge distribution obtained by integrating each waveform for 50 ns starting from the onset of the waveform peaks (at $\sim$ 10 ns). The superimposed red line represents a MultiGaussian fit to six p.e. peaks.

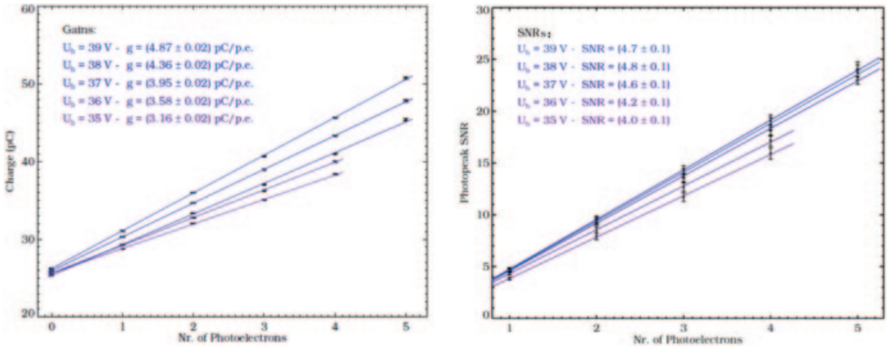

Fig. 5. – Gain (left panel) and SNR (right panel) per photoelectron for five different values of the bias voltage. The linear fit parameters are given in the top left corner of each panel.

cancellation network. We then integrated each waveform for a time window of 50 ns and obtained the charge distribution shown in the right panel of fig. 4. For each value of the bias voltage, the peaks of the charge distribution were fitted with a Multi-Gaussian model in order to obtain the corresponding equivalent charge per p.e., as shown in the left panel of fig. 5. The typical value lies between 3 and 5 pC per photoelectron. The signal-to-noise ratio (SNR) was also evaluated (see the right panel of fig. 5), resulting in a mean value of about 5.

We then removed the dark mask and illuminated the whole array of SiPMs, acquiring all 16 channels at the same time with a DAQ system consisting of a CAEN V792 QDC module. The integration time was set to 100 ns. The left panel of fig. 6 shows the 16 charge distributions of the p.e. peaks expressed in ADC channel units. Each unit

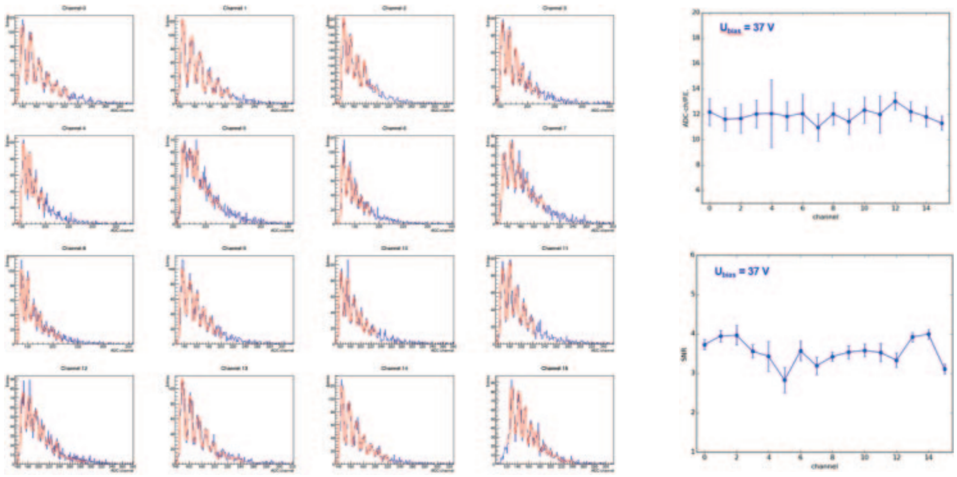

Fig. 6. – Left panels: Charge distribution for each of the 16 channels, expressed in terms of ADC counts. The superimposed red lines represent the MultiGaussian fits to the p.e. peaks. Right panels: Gain (top panel) and SNR (bottom panel) per photoelectron for all 16 channels, showing good uniformity among all SiPMs.

corresponds to a charge of $\sim$ 100 fC, according to the instrument specifications. We derived the gain and the SNR for each channel, as can be seen in the right panels of fig. 6, thus verifying a good uniformity among all SiPMs. Comparing these results with the ones previously obtained with the oscilloscope, we note that the gain ($\sim$ 1.2 pC/p.e.) and the SNR ($\sim$ 3.5) are slightly lower. This effect is probably due to the different length and intrinsic impedance of the cables used in the two acquisition systems. Further checks are currently ongoing, aiming to optimize and calibrate the QDC setup before moving on towards the massive 1600 SiPMs tests.

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We gratefully acknowledge support from agencies and organizations under Funding Agencies at www.cta-observatory.org. EB ackowledges the Italian "Fondo di Sviluppo e Coesione 2007-2013 - APQ Ricerca Regione Puglia - Future In Research".

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