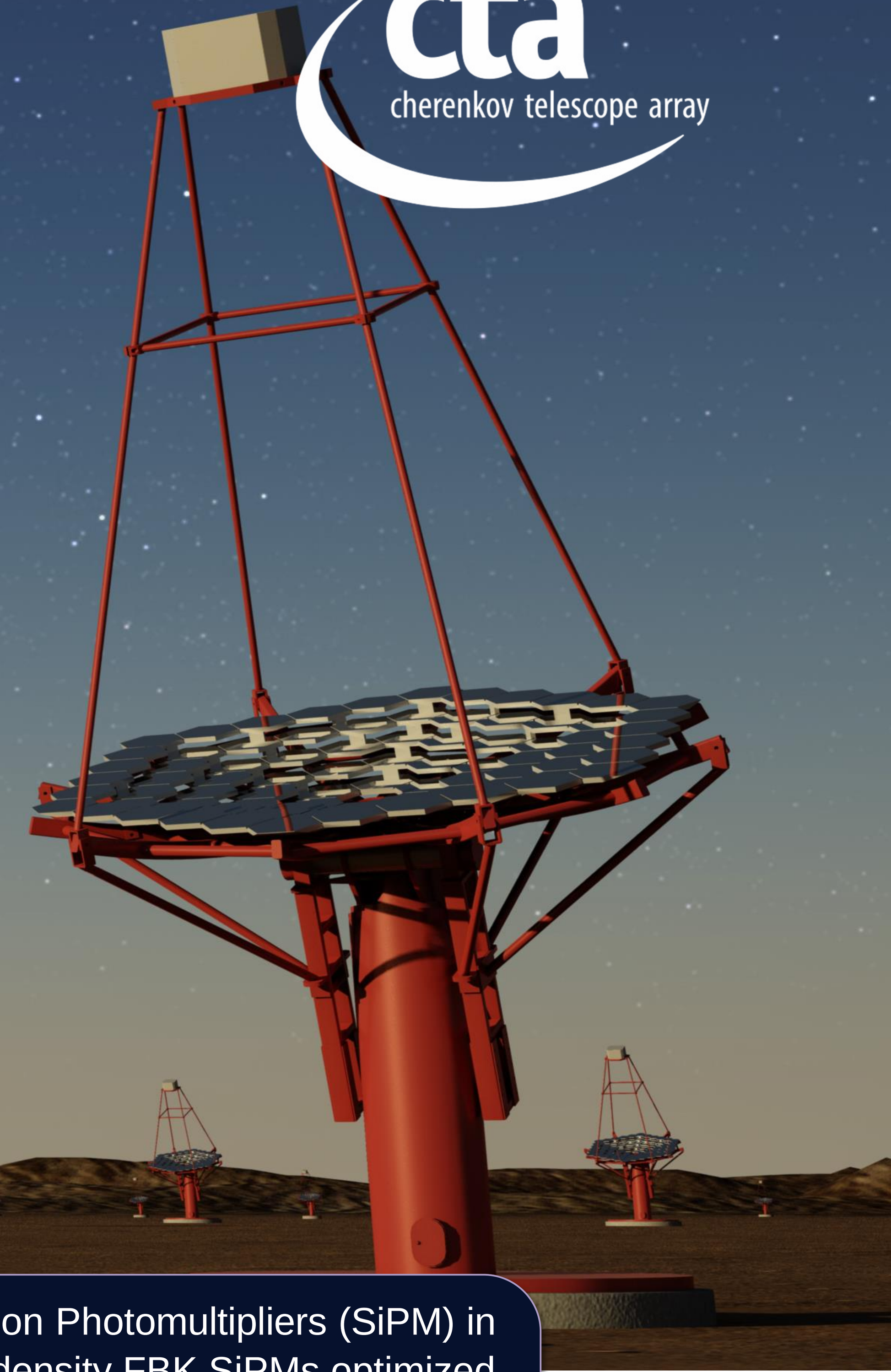
Readout chain validation of INFN modules for the CTA-pSCT camera



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ABSTRACT The Italian Institute of Nuclear Physics (INFN) is currently involved in the R&D for the integration of Fondazione Bruno Kessler (FBK) Silicon Photomultipliers (SiPM) in the focal plane camera for the prototype of the Schwarzschild-Couder Telescope (pSCT) as a part of the Cherenkov Telescope Array (CTA) experiment. High density FBK SiPMs optimized for the detection of Near Ultraviolet Cherenkov light (NUV-HD) will be used to equip the camera, coupled to the TARGET-7 readout electronics. A first production of 9 INFN modules is being tested and will be installed on the focal plane of the pSCT camera. Each module consists of 64 6 mm x 6 mm pixels, based on 40 um x 40 um microcells, arranged in 16-pixel matrices. The front-end electronics is based on the TARGET-7 ASIC, a 16-channel chip for sampling and digitization of the signal. Here we report measurements of the performances of the complete readout chain, including results regarding homogeneity in terms of gain and signal-to-noise ratio.

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1. The SiPM-based module for pSCT

The Schwarzschild–Couder Telescope prototype for the Cherenkov Telescope Array observatory is currently under construction at the VERITAS site in Arizona (Fig. 1). It will provide compensation of optical aberrations, along with high angular resolution, high background rejection and a wide FoV. A section of the pSCT focal plane will be equipped with 9 INFN optical modules made of 64 6 X 6 mm^2 FBK NUV–HD3 SiPMs [1]. The INFN modules integrated on the camera are shown in Fig. 2.

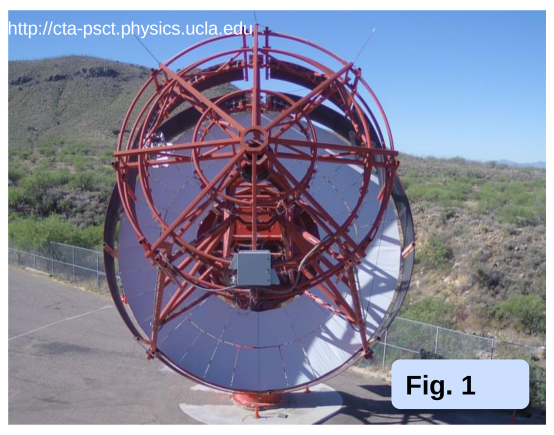

Fig. 1

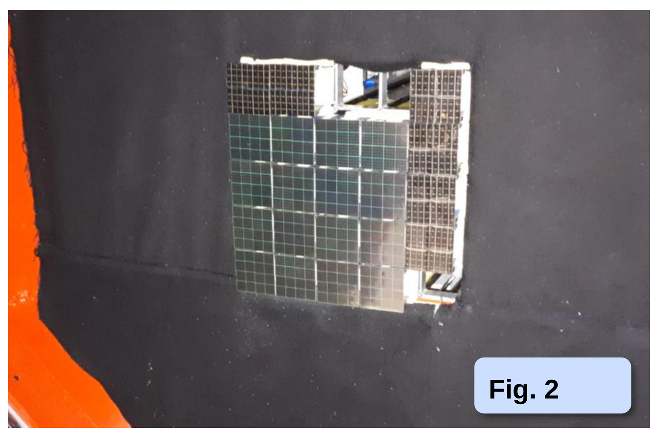
Fig. 2

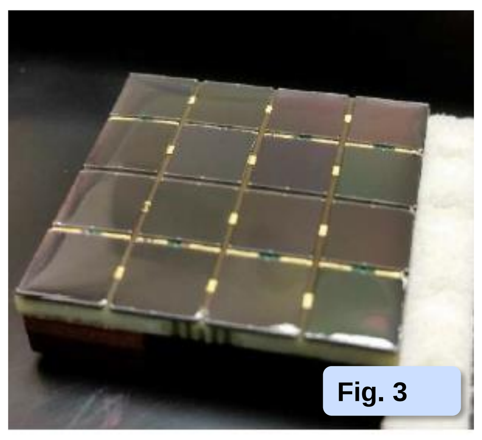
Fig. 3

Pixels are arranged in 4 X 4 matrices, as shown in Fig. 3. Extensive tests have been conducted on the focal plane SiPMs. Details about SiPM's electrical characterization and mechanical structure are reported in [2,3].

2. FBK NUV-HD3 matrix's characterization

A full characterization of more than 50 4 X 4 SiPMs matrices has been conducted in order verify the response uniformity in terms of gain and Signal-to-Noise Ratio (SNR) and choose the ones with which to equip the camera. For these tests, an *ad hoc* 16-channel amplifier was developed [4]. Each matrix, coupled with the electronics, was placed in a dark box and illuminated with a laser emitting at 380 nm. The matrix was biased between 31 V and 36 V, corresponding to an overvoltage from 4 to 9 V. We acquired signals from the 16 channels simultaneously using a DAQ system consisting of a CAEN V792 QDC to obtain the charge of the signal. The integration time was set to 30 ns.

The corresponding charge distribution expressed in ADC channel units at 32 V is shown in Fig. 4 for one of the 16 channels of the matrix L18. The quantization down to the single photoelectron can be observed. Charge distributions for the 16 channels were fitted with a multi-gaussian function in order to extract the parameters needed to evaluate gain and SNR.

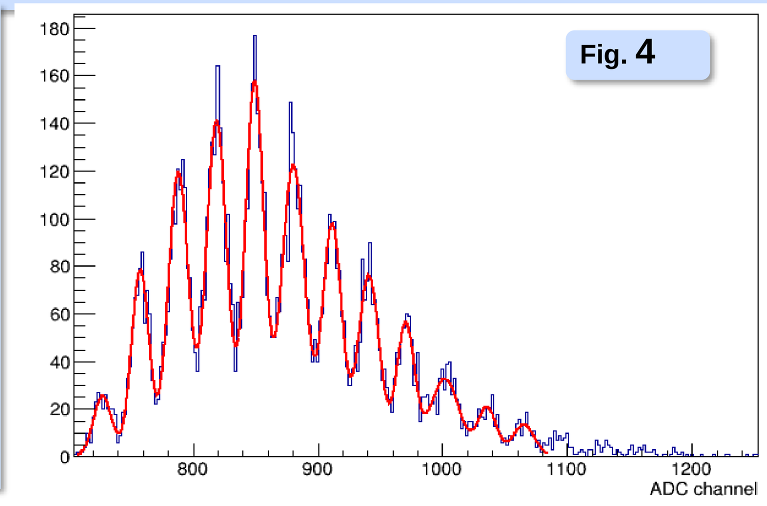

Fig. 4

3. Noise studies on the FEE and the readout chain

The front-end electronics is based on the TARGET-7 ASIC, a 16-channel chip which was specifically developed to sample and digitize the signal produced by SiPM matrices [5]. This chip allows the full waveform to be recorded with a sampling rate of 1 Gsample/second, with an analogue ring buffer of 16384 capacitors, divided in 512 blocks of 32 capacitors. The TARGET ASIC is based on an analogue sampling memory technology which consists of a circular buffer of switched capacitors used in turn to record the signal waveform. Each TARGET module hosts 4 chips, allowing the digitization of 64 SiPMs' signal to be performed.

Before testing the complete readout chain, tests on the TARGET modules were conducted with 4 matrices coupled to the FEE but with no voltage provided in order to study the pedestal for each capacitor. Waveforms were acquired using the external trigger in order to cover the entire buffer. The pedestal was evaluated in terms of mean and sigma for each of the 16k capacitors in the buffer. The noise distribution after the pedestal subtraction for one channel of one of the modules is reported in Fig. 5, with σ = 2.86 ADC channels.

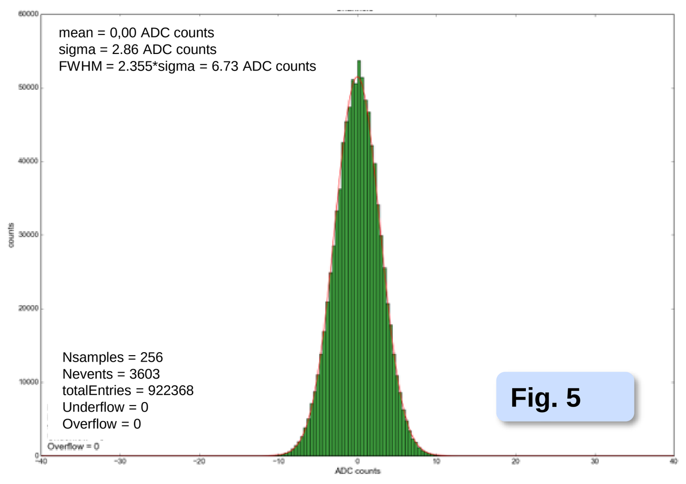

Fig. 5

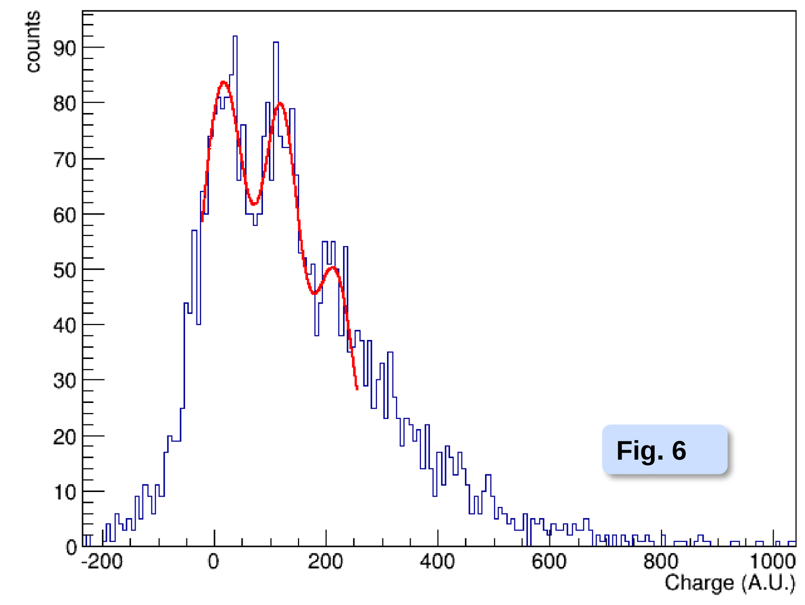

Fig. 6

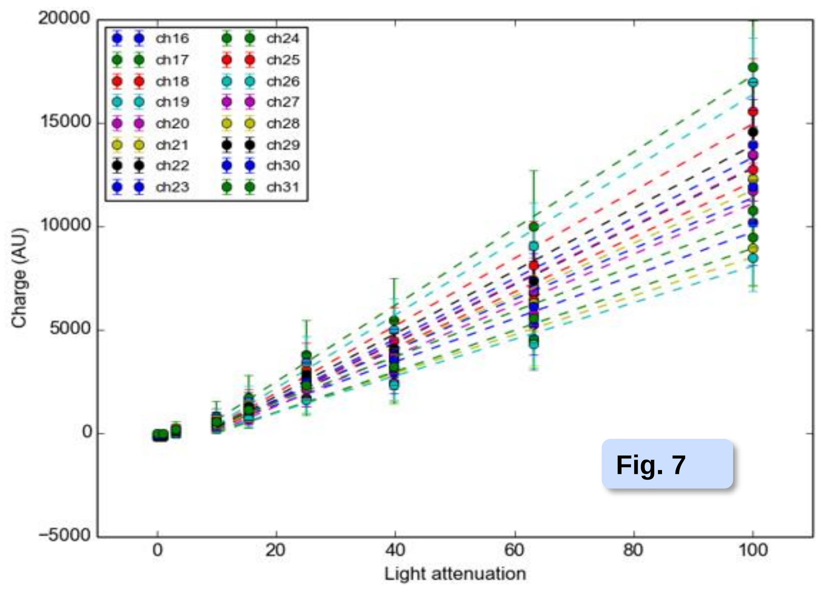

Fig. 7

After the pedestal acquisitions, matrices were biased and illuminated with a NUV laser, varying its intensity by means of specific filters in order to cover the full range of the TARGET 7 Analog-to-Digital Converter and verify its linearity. About 3500 waveforms from 64 channels were acquired simultaneously, and for each channel the charge spectrum on the peak was evaluated, with an integration time of 16 ns, as shown in Fig. 6 for a low laser intensity. The maximum amplitude distribution at different light intensities was evaluated and its mean is reported in Fig. 7 as a function of the light intensity percentage. The linear trend confirms the linearity of the ADC, but low intensity light measurements deviate from it because of their non gaussian distribution, which is Poisson-like, as shown in Fig. 6. Finally the internal trigger of the ASIC was tested, performing two types of scans, the threshold and the amplitude scan. During the threshold scan, the light intensity was kept fixed at high value and the threshold was varied between 0 and 3500 (A.U.), counting the number of events generated, as reported in Fig. 8; then the amplitude scan was performed varying the light intensity and keeping the threshold value fixed so that all trigger groups would have almost 100% efficiency. The results of this last scan are reported in Fig. 9.

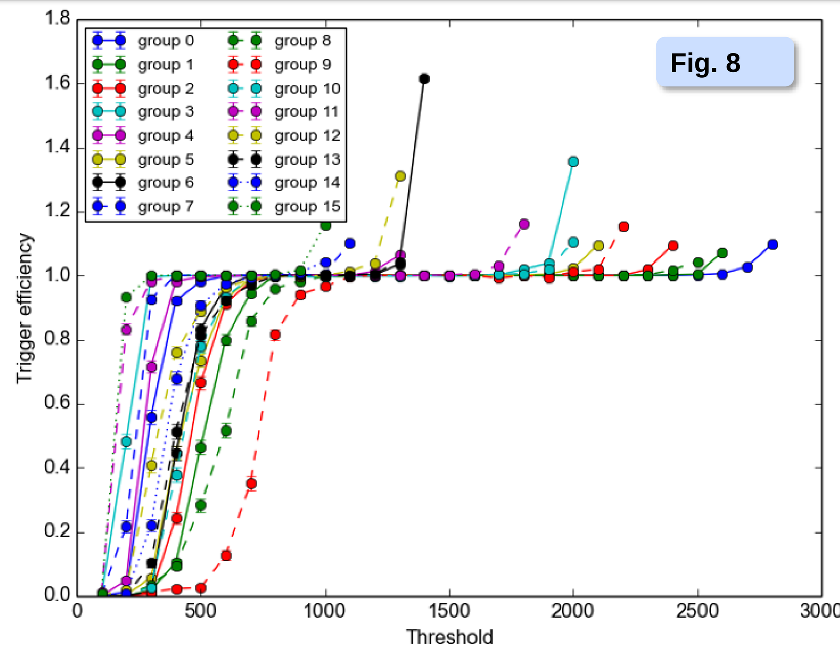

Fig. 8

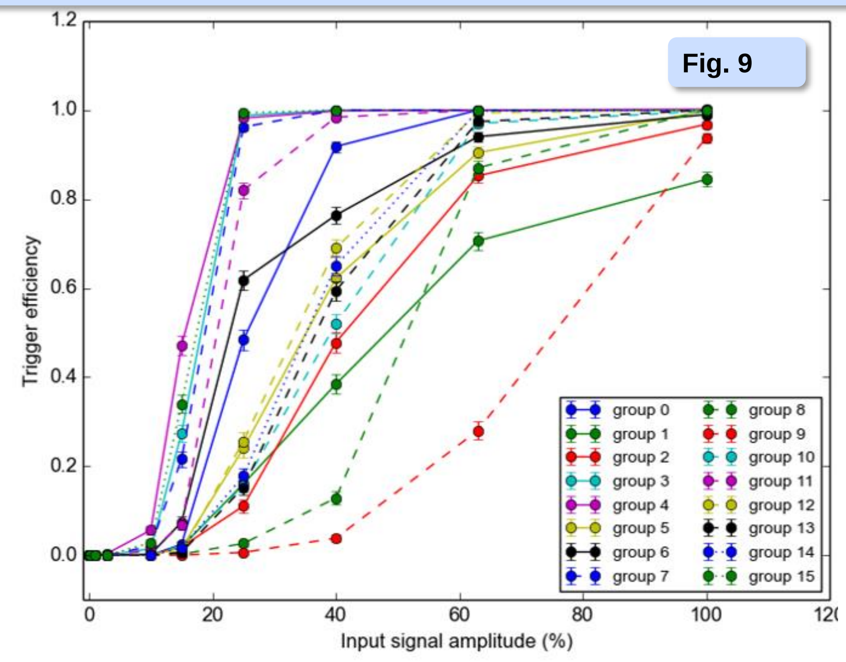

Fig. 9

4. Conclusions

The measurements here reported for one of the modules tested were repeated on each of the 9 modules in order to validate them or identify major issues that needed to be fixed. Among the 64*9=576 channels of the FEE tested, 4 channels were found to be damaged, which corresponds to less than 1% of the total number of channels tested.
Six of the modules tested have already been installed on the camera, which is now being installed in Arizona, while the remaining three will soon be integrated.

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