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SiPM arrays test for the pSCT camera proposed for the CTA Observatory

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Summary. — Arrays of 16 pixels of the Near UltraViolet High-Density third-generation (NUV-HD3) Silicon Photomultipiers (SiPMs) produced by Fondazione Bruno Kessler (FBK) in collaboration with Istituto Nazionale di Fisica Nucleare (INFN) have been assembled and characterised to equip the prototype Schwarzschild-Couder Medium-Sized Telescope (pSCT) camera proposed for the Cherenkov Telescope Array (CTA) Observatory. Each camera module is composed by four 16-pixel optical units coupled with a 64-channel front-end electronics module. The prototype camera has been equipped with 24 of 177 modules and is currently taking data at the Very Energetic Radiation Imaging Telescope Array System (VERITAS) Arizona, since January 2019. Nine of the 24 modules mount FBK NUV-HD SiPMs. Latest results on their characterisation and performance will be shown. pSCT was able to detect its first light soon after the inauguration, in January 2019. A dedicated campaign for the Crab Nebula observation conducted in January 2020 led to the Crab detection. Results of this detection will be shown.

1. – Prototype of the Schwarzschild-Couder Telescope (pSCT)

Fondazione Bruno Kessler (FBK) in collaboration with Istituto Nazionale di Fisica Nucleare (INFN) has developed sensors with the Near UltraViolet High Density technology (NUV-HD), focusing on Cherenkov applications [1]. The Cherenkov Telescope Array (CTA) will be the next-generation ground-based Observatory of Imaging Atmospheric Cherenkov Telescopes (IACTs) for gamma-ray astronomy at very high energies. Three classes of telescopes with different mirror size will be developed, the large, the medium and the small sized telescopes, covering an energy range from 20 GeV to 300 TeV. The prototype of the Schwarzschild-Couder Telescope (pSCT) is a dual mirror version of the

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Medium-Sized Telescope and it has been installed at the Fred Lawrence Whipple Observatory (FLWO) in Arizona, proposed for the CTA Observatory. The two mirrors of the pSCT are 9.7 m and 5.4 m in diameter, compensating optical aberrations and focusing the light on a compact high-resolution imaging camera based on Silicon Photomultipiers (SiPMs). The design of the telescope will reduce the point spread function (PSF) and improve angular resolution and background discrimination compared to the single mirror configuration.

The front-end electronics of the pSCT camera [2] is based on TeV Array Readout with GSa/s sampling and Event Trigger-7 (TARGET) Application Specific Integrated Circuits (ASIC) front-end electronics (FEE) [3]. The camera focal plane will be composed by 177 modules, divided into 9 backplanes that monitor the data acquisition for each camera sector. Each module will consist of 64 pixels arranged over 4 Photo Detection Units (PDU), composed by 16 pixels, for a total of 11328 pixels in the camera. A first sector of the pSCT camera, for a total of 25 modules, was equipped both with NUV-HD3 SiPMs matrices produced by FBK [1] in collaboration with INFN and Hamamatsu S12642 MPPCs ones. NUV-HD3 SiPM matrices were tested in INFN laboratories in terms of gain, signal-to-noise ratio (SNR) and dark count rate (DCR), studying their response to fast and low-intensity light signals [4].

2. – NUV-HD3 matrices SiPMs characterisation/validation

The setup consisted of a laser emitting at 380 nm that illuminates $6 \times 6\,\text{mm}^2$ matrices. The charge signal of the 16 sensors was measured by a DAQ (CAEN V792 QDC), over a time window of 50 ns. The SiPM signals were amplified using a 16-channel FEE, developed to shape the input signal to match the QDC dynamic range [5]. The matrices were characterised covering the voltage range 31–36 V.

An example of a fitted charge distribution for one channel of one HD3 matrix biased at 33 V under beam laser is shown in fig. 1. Plots in figs. 2 show the average values of gain, SNR and DCR as a function of over-voltage (OV) obtained from the test of 50 HD3 matrices. Thanks to the uniformity in terms of gain and DCR, 36 matrices were chosen to equip the camera. The gain and DCR per over-voltage unit were estimated by the

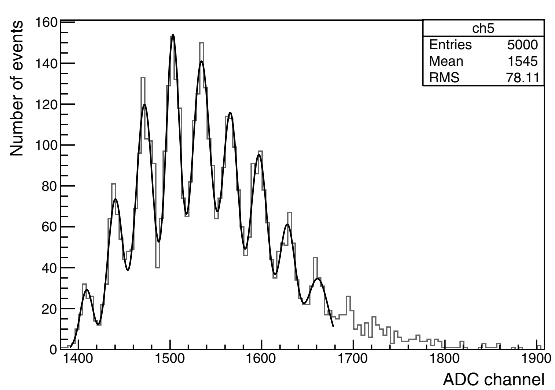

Fig. 1. – Integrated charge distribution of one $6 \times 6\,\text{mm}^2$ channel in a matrix. A multi-Gaussian fit is superimposed on data.

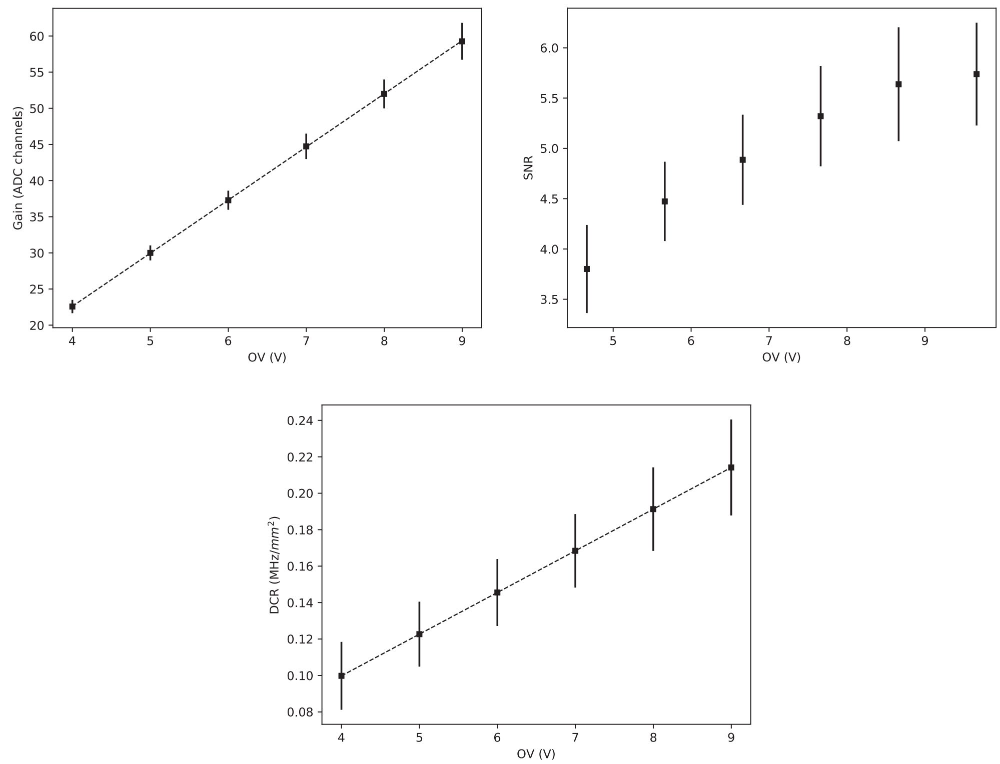

Fig. 2. – Gain mean (top left), SNR mean (top right) and DCR mean (bottom center) over all the pixel tested for the HD3-4 sensors as a function of the over voltage applied.

slope of the best fit line. The DCR was calculated for each channel using the following formula:

$$\mathrm{DCR} = \frac{N_{tot} - N_0}{N_{tot} \cdot \Delta t}, \tag{1}$$

where N_{tot} is the total number of events acquired during the integration window, N_0 is the number of pedestal events (*i.e.*, no photon signal) and Δt is the integration time. The SNR for each channel is obtained using the following relation:

$$SNR_i = \frac{\mu_i - \mu_0}{\sigma_0} \tag{2}$$

where μ_i and μ_0 are the signal and the noise mean value, respectively, and σ_0 is the standard deviation of the noise.

3. – First lights and Crab Nebula detection

Data taking of the pSCT is actually ongoing and the first lights were measured on January 23, 2019 [6]. Also 48 runs were performed in order to detect the Crab Nebula from January 18 to February 26, 2020, including 22.81 hours acquired pointing the source

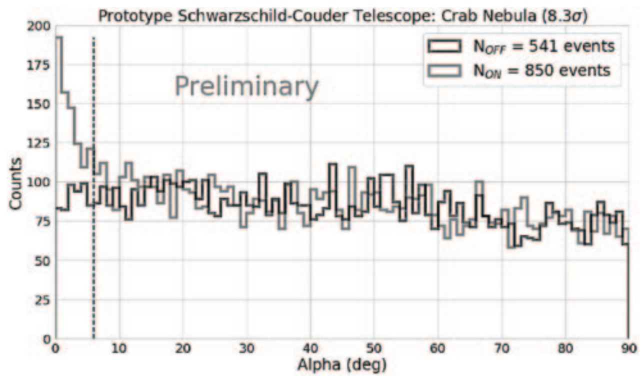

Fig. 3. – Histogram of counts as a function of α that is the angular distance between the Crab Nebula position and the direction of the photon reconstructed. The orange histogram is for 22.81 hours of ON source observations, blue is for 19.15 hour of OFF source observations. The vertical dotted line is a cut applied at 6° [7].

(ON runs) and 19.15 hours pointing a dark part of the sky (OFF runs). The counts as a function of the angular distance between the Crab Nebula position and the direction of the photon reconstructed event, α, are shown in fig. 3. A peak at 0° confirms an excess of counts in correspondence of the Crab Nebula. Considering a cut at 6°, the significance calculated is equal to 8.3σ [7].

4. – Conclusion and future perspectives

NUV-HD3 matrices proved to have a good and uniform performance, and actually are installed on the pSCT camera. An upgrade of the pSCT camera is foreseen in order to equip the full camera with FBK sensors and an upgraded electronics. This upgrade will include the employment of the SiPM Multichannel Asic for high-Resolution Cherenkov Telescopes (SMART) for the signal pre-amplification and of the TARGET-C and T5TEA ASICs for the waveform digitization and trigger formation.

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REFERENCES

[1] Piemonte C. *et al.*, *IEEE Trans. Electron Devices*, **63** (2016) 1111.
[2] Otte N. *et al.*, *PoS (ICRC2015)* (2016) 1023.
[3] Tibaldo L. *et al.*, *PoS (ICRC2015)* (2016) 932.
[4] Adams C. *et al.*, *Nucl. Instrum. Methods Phys. Res., A*, **982** (2020) 164486.
[5] Ambrosi G. *et al.*, *PoS*, **ICRC2015** (2016) 992.
[6] `https://www.cta-observatory.org/sct-first-light/`.
[7] Adams C. B. *et al.*, *Astropart. Phys.*, **128** (2021) 102562, arXiv:2012.08448.