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Characterization of SiPM optical modules for detection of atmospheric shower Cherenkov emission

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Summary. — Silicon Photomultipliers (SiPMs) will be used in the focal planes of part of the telescopes of the Cherenkov Telescope Array (CTA), the next generation of Imaging Air Cherenkov Telescopes (IACT). Optical modules made of 4×4 SiPMs have been developed by Fondazione Bruno Kessler (FBK) and assembled in INFN laboratories, to be integrated on the prototype of a Schwarzschild-Couder Medium-Sized Telescope (SCT) proposed for CTA. As of today, a selection of 36 modules out of 56 working modules is ready for the integration on the telescope camera.

1. – Introduction

Cherenkov Telescope Array (CTA) will be the largest ground-based gamma-ray observatory for very high-energy gamma rays. CTA will be installed in two sites (one in each Hemisphere). It will be equipped with more than 100 telescopes in three different configurations: Large-, Medium- and Small-Sized Telescopes (LST, MST and SST) and will be fully operational by 2025.

2. – SiPM optical modules

The Istituto Nazionale di Fisica Nucleare (INFN) is involved with Fondazione Bruno Kessler (FBK) in the development of SiPM sensors sensitive to near-UV wavelengths, NUV-HD3, for the CTA telescopes. These SiPMs have been integrated in basic optical

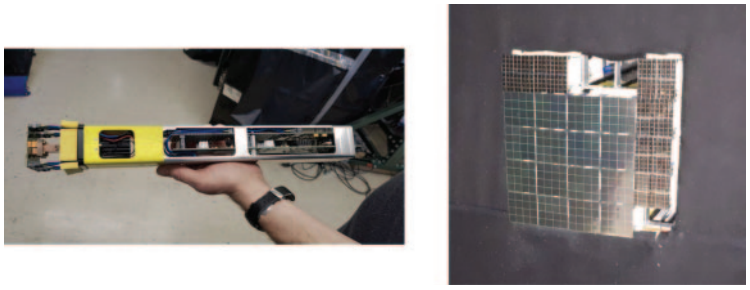

Fig. 1. – Left: single module completely assembled and ready to be installed on the camera. Right: modules assembled on the camera in Madison. The six FBK-INFN modules already installed in the camera are located in the upper and right edge of the camera.

units made of 16 pixels (each one with 6×6 mm^2 area) for a possible upgrade of the camera of the Schwarzschild-Couder Medium-Sized Telescope [1] (SCT) proposed for CTA. Each SiPM represents a single pixel of the entire camera of the telescope. Each unit is tested to check the uniformity of the performance of the SiPMs and coated with UV-transparent epoxy resin for mechanical protection. The uniformity of the SiPMs breakdown voltage value in each unit, the presence of defects in the protective layer and the response of all sensors under laser pulses and in dark conditions have been tested (pedestal, S/N ratio, dark count rate and gain [2]) and the SiPMs have been selected to equip a possible upgrade of the camera of the SCT prototype (pSCT).

3. – Installation on the camera

The optical units have been clustered in groups of four and then coupled with the readout and trigger modules. The mechanical modules have been aligned to be integrated with the camera using a reference frame with a tolerance of 0.1 mm to minimize optical aberration effects. The aligned modules have been integrated on the pSCT telescope camera frame at University Wisconsin-Madison, USA, in March 2018 (fig. 1). A total of 100 units (prototypes included) have been assembled and tested in the INFN laboratories, 56 of them have the right level of performances for the integration on the telescope camera; 36 of them have been selected to build 9 complete modules for SCT. Six modules have been already installed in the pSCT camera together with 16 modules equipped with the main technology based on Hamamatsu SiPMs. The purpose is to test the performances of FBK NUV-HD3 SiPM in standard telescope operations to verify the opportunity to equip a fraction of the SCT telescopes for CTA with NUV-HD3 sensors. In May 2018, the pSCT camera frame was installed on the SCT telescope mechanics in the Fred Lawrence Whipple Observatory (USA) where pSCT is currently taking data for commissioning and calibration of the camera.

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