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Development of a SiPM Cherenkov camera demonstrator for the CTA observatory telescopes

G. AMBROSI(1), E. BISSALDI(3)(4), E. FIANDRINI(2)(1), N. GIGLIETTO(3)(4), F. GIORDANO(3)(4), M. IONICA(1), R. PAOLETTI(5)(6), V. POSTOLACHE(1), D. SIMONE(3) and V. VAGELLI(1)(*)

(1) *INFN, Sezione di Perugia - Perugia, Italy*
(2) *Dipartimento di Fisica e Geologia, Università degli Studi di Perugia - Perugia, Italy*
(3) *INFN, Sezione di Bari - Bari, Italy*
(4) *Dipartimento Interateneo di Fisica, Università e Politecnico di Bari - Bari, Italy*
(5) *INFN, Sezione di Pisa - Pisa, Italy*
(6) *Università degli Studi di Siena - Siena, Italy*

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Summary. — The Cherenkov Telescope Array (CTA) Consortium is developing the new generation of ground observatories for the detection of ultra-high energy gamma rays. The Italian Institute of Nuclear Physics (INFN) is participating to the R&D of a possible solution for the Cherenkov photon cameras based on Silicon Photomultipliers (SiPM) sensitive to UV energies. INFN is developing the concept, mechanics and electronics for SiPM prototype modules intended to equip the focal planes of CTA telescopes. The module design and performances are reviewed here.

The CTA project [1] aims to improve the measurement techniques at ground level of ultra-high energy cosmic gamma rays employed by the current generation of Imaging Air Cherenkov Telescopes (IACTs) to achieve a gain of ~ 10 in the current sensitivities and to extend the energy reach up to 100 TeV. Telescopes of different dimensions and acceptances will be installed in two arrays to be operated from 2025 as an open observatory accessible by the astrophysics scientific community.

Matrices of Silicon Photomultipliers (SiPM) placed in the telescope focal planes might be used to detect and measure the intensity of the Cherenkov light radiated by the atmospheric showers. SiPM sensors sensitive to UV radiation, developed by Fondazione Bruno Kessler (FBK) [2] in collaboration with INFN (NUVHD-SiPM), have been chosen to equip the focal plane of a camera demonstrator.

The devices are based on p^+-n implants and $30 \times 30\,\mu m^2$ microcell area, arranged to achieve a microcell geometrical fill factor of 76%. Devices with $6 \times 6\,mm^2$ active area

(*) E-mail: valerio.vagelli@pg.infn.it

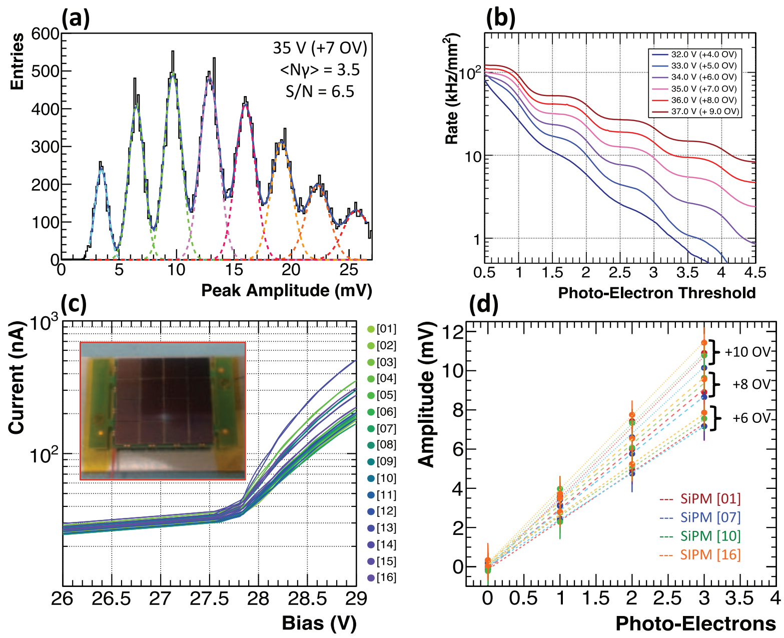

Fig. 1. – (a) Spectrum for the response of a single SiPM to a 407 nm pulsed laser source. (b) Noise event rate as function of the photo-electron threshold measured in dark conditions. (c) Current-Voltage curves for 16 SiPMs of a prototype matrix (in the insert). (d) Gain linearity for 4 SiPMs of a prototype matrix. All the results shown here have been measured at ~ 300 K.

have been selected to assemble a focal plane camera prototype for CTA. The sensors have been characterized with pulsed light sources (fig. 1(a)) and in dark conditions, over a wide range of operating bias voltages and temperatures. They show noise rates well below 100 kHz/mm^2 at room temperature (fig. 1(b)), an optimal noise/background ratio of single-photon resolution and Photo Detection Efficiencies (PDE) better than 40% in the signal spectral region.

Focal plane modules with 54×54 mm^2 area, each divided into 4 matrices composed of 16 SiPM sensors, are being developed in INFN laboratories. Their mechanics and front-end electronics are designed to equip the focal plane of the pSCT telescope [3], a CTA medium-size telescope demonstrator that will be operated in the Veritas telescope site. The 16 SiPMs are arranged uniformly over the matrix area, and each SiPM is readout by wire-bonds at the anodes, while the common matrix bias voltage is provided to the SiPM cathodes. To confirm and qualify the assembly and bonding operations, matrix prototypes are being designed, assembled and tested. A preliminary characterization has confirmed a uniformity better than 10% in the response of the matrix to light signals and in dark conditions (fig. 1(c), fig. 1(d)). Additional tests to validate the module properties and to complete the development of a dedicated front-end electronics are now ongoing.

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