SiPM Detectors Characterization, Production and Testing of the 37 Silicon Photomultipliers Interface Boards for the Camera of the ASTRI SST-2M Telescope Prototype

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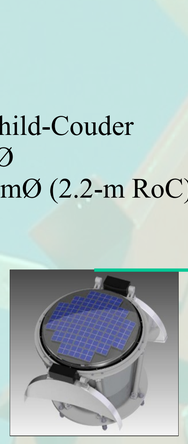
The instrumental set-up developed at the "COLD" Laboratory (Catania Astrophysical Observatory Laboratory for Detectors) of INAF-OACT (Astrophysical Observatory of Catania) aims at providing a systematic characterization of all complete Photon Detection Modules (PDMs), which form the structural units of the ASTRI SST-2M camera at the focal plane.
All the 37 SiPM boards have been successfully produced and their reliability, in terms of design and assembling, has been confirmed through a large set of laboratory measurements.
The 37 SiPM board are ready to be mounted on each PDM front-end electronics.

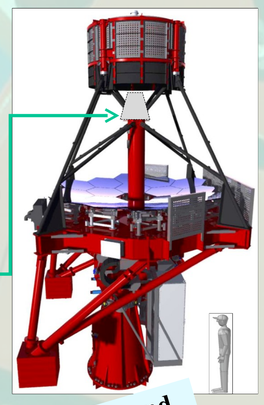
The ASTRI SST-2M Concept

Energy threshold:
- approximately 1TeV

Telescope properties:
- Optical design: Schwarzschild-Couder
- Primary mirror, M1=4.3mØ
- Secondary mirror, M2=1.8mØ (2.2-m RoC)
- M1-M2 distance: 3m
- Effective area: 6.5m2
- F/D1=0.5, F=2.15m

Camera properties:
- Size: 50cm×49cm×56cm
- Total logical pixels: 1984
- Pixel size: 0.17°
- Field of View: 9.6°
- Sensors type: SiPMs



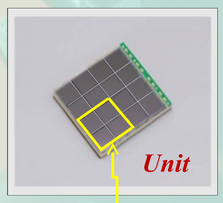


End-to-end prototype

The Telescope Camera Detectors (SiPMs)

- Avalanche Photo-Diodes work in Geiger mode (over breakdown).
- Very fast and sensitive in the 350–700-nm range, making them suitable for the detection of Cherenkov flashes (few ns duration).
- Dark Count Rate (**DCR**) well below the Night Sky Background.
- Critical issues managed by proper bias and thermic compensation.

Hamamatsu S11828-3344M1 Multi-Pixel Photon Counter (MPPC) is the detector unit for the ASTRI SST-2M camera prototype:
a monolithic SiPM array of 4×4 square pixels, 3×3mm in size made up of 3600 cells each.
To match the optical design, the physical pixels are electrically grouped 2×2 in one logical pixel with a sky-projected angular size of 0.17°.



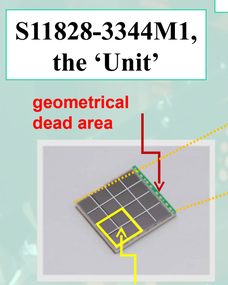
Logical pixel
6.2×6.2mm≡0.17°
(4 channels)

Modularity of the Telescope Camera Design

Photon Detection Module (PDM)

Each PDM works independently of the others

S11828-3344M1, the 'Unit'



Logical pixel
6.2×6.2mm≡0.17°
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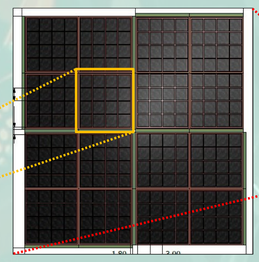
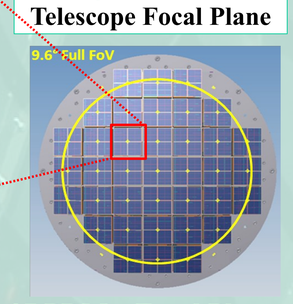


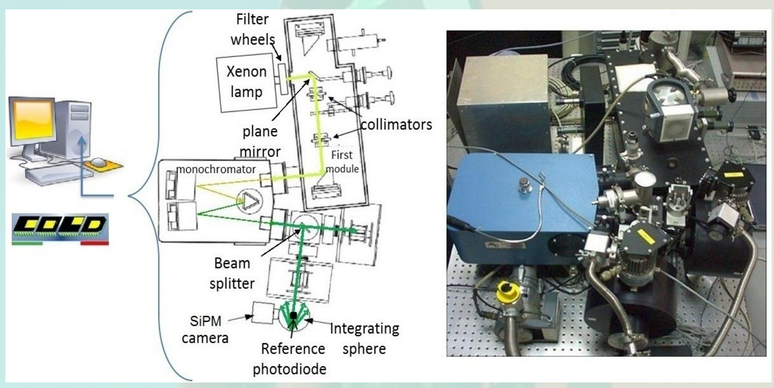
4×4 Units: 1 PDM
56×56mm
(64 channels)

Telescope Focal Plane



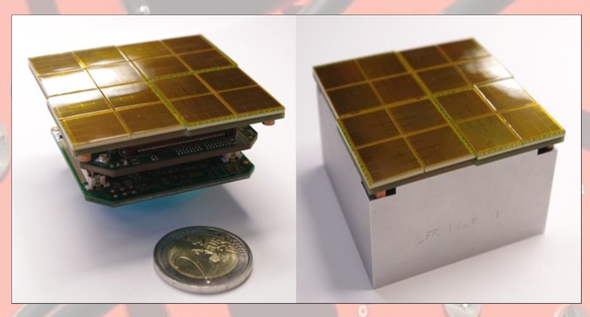
37 PDMs: Focal Plane
560×560mm
(1984 channels)

SiPM Detectors Measurement Apparatus

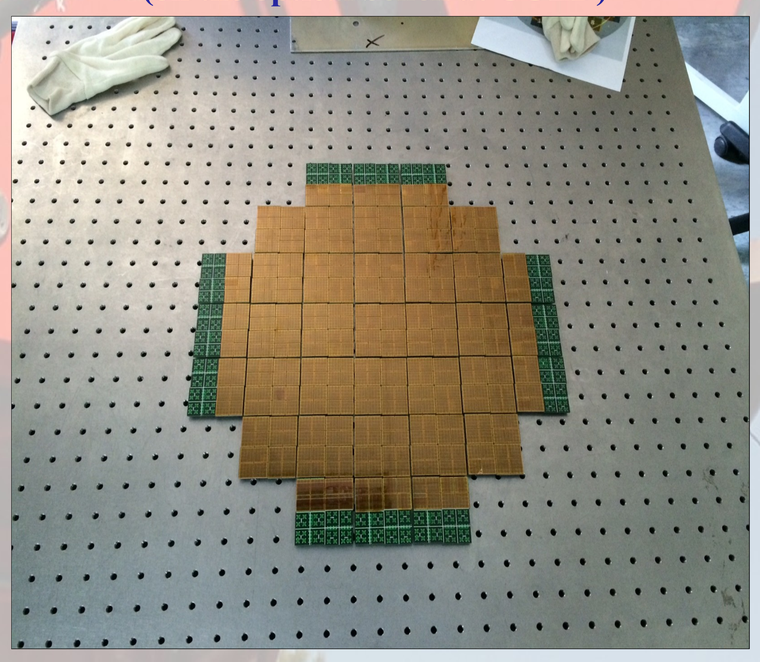


The experimental set-up exploited for the optical characterizations of SiPM detectors is one of the available facilities at the **Catania astrophysical Observatory Laboratory for Detectors (COLD)**.

ASTRI SST-2M PDM Unit
(accomodated in a dedicated aluminum case)

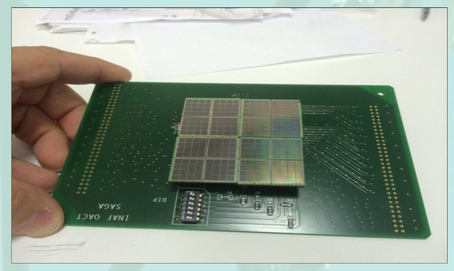


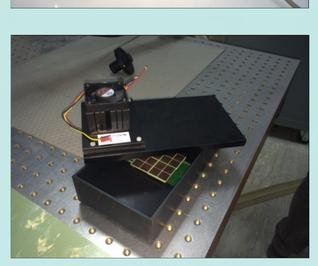
ASTRI SST-2M Focal Plane Composition
(on the optical bench at COLD)



SiPM Detectors Instrumental Set-Up

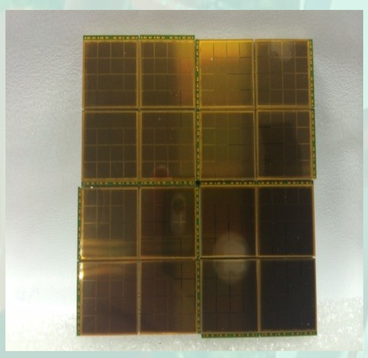
Tests have been performed connecting the SiPM boards with the **EASIROC** front-end evaluation board through a specifically developed adapter board. A dedicated mechanical housing supports the MPPCs and allows to easily control the working temperature.





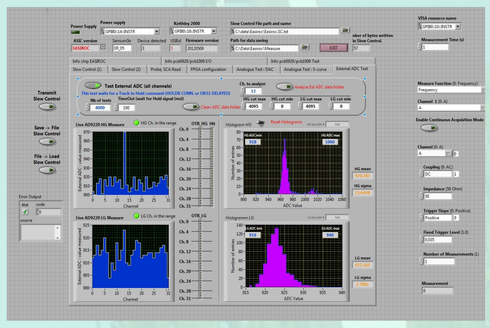
SiPM Interface Board realized at COLD

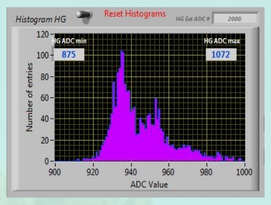
The MPPC detectors are assembled in a PDM unit so that each single monolithic detector device is soldered to the front side of the **SiPM Interface Board**, while the rear side of the board hosts two multi-pin connectors along with 9 temperature sensors for gain stabilization.

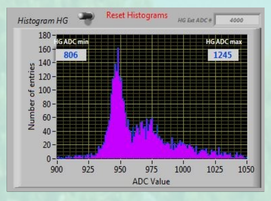


Tests of 37 SiPM Boards with EASIROC

Reliability tests and measurements through pulse height distributions have been performed for the logical pixels of all 37 SiPM boards of the telescope focal plane by means of the EASIROC evaluation board and its related Labview software tool.

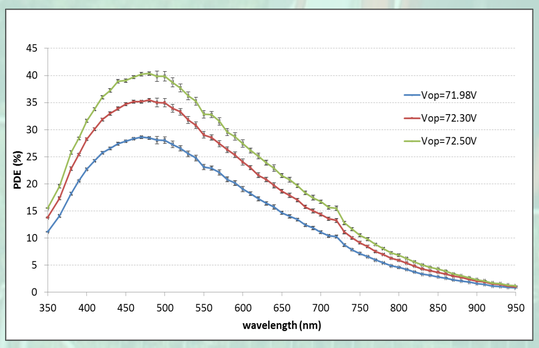






PDE Measurements of the Camera Detectors

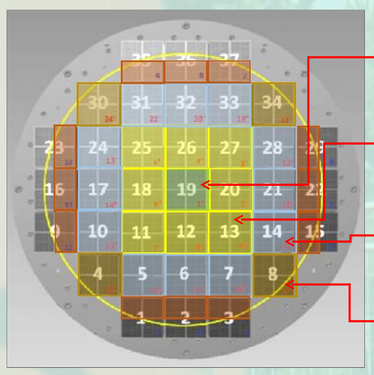
SiPM absolute **Photon Detection Efficiency (PDE)** measurements are carried out based on the photon counting method, by which the pulse rate in monochromatic light conditions are compared to the light level, recorded by a reference NIST-calibrated photodetector.



The figure shows PDE results of the MPPC detector in the 350–950-nm range for different bias conditions.
An **hold-off** time is also applied in order to reduce any extra-charge noise contribution.

SiPM Boards Distribution on the Focal Plane

Based on accurate selection criteria, the quality of all SiPM boards has been evaluated in terms of minimum deviance, ΔV, between the reference voltage of each pixel at which the SiPM gain is constant.

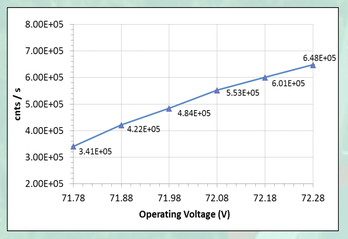


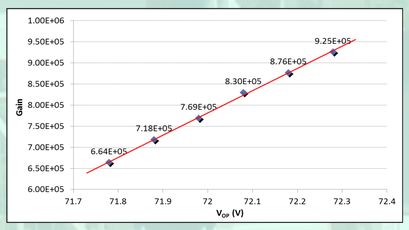
- **ΔV<65mV**
  MPPC in the green PDM
- **65mV<ΔV<70mV**
  MPPCs in the yellow PDMs
- **70mV<ΔV<90mV**
  MPPCs in the grey PDMs
- **ΔV>90mV**
  MPPCs in the orange PDMs

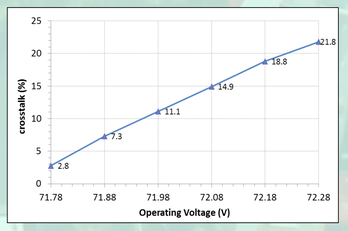
Other Measurements on the Camera Detectors

Gain determination in a range of bias voltage and at a given temperature is accomplished by a pulsed laser. Gain results of the MPPC vs. bias voltage at *T*=25°C are reported at the bottom.

Cross-talk and **DCR** achieved results at *T*=25°C are shown on the right side.







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1 The ASTRI Collaboration → see www.brera.inaf.it/astri/ for full author & affiliation list

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