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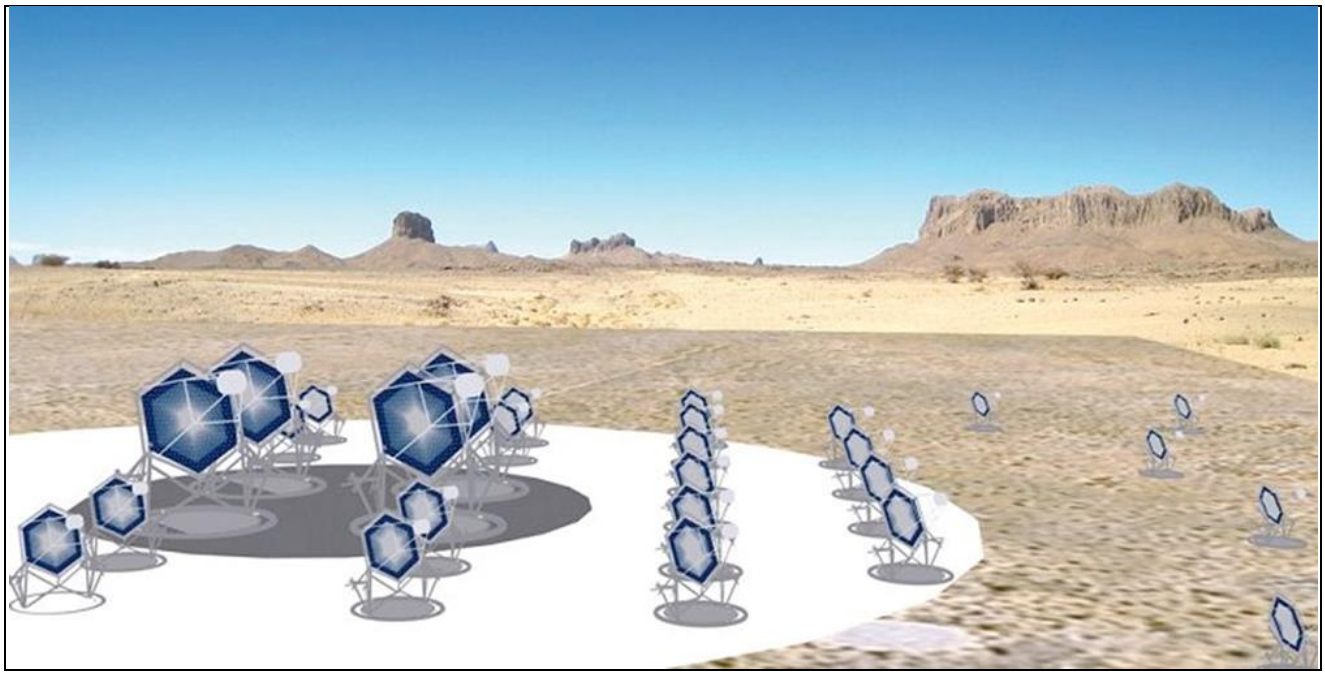
SiPM Interface Systems for the Characterization of Complete PDMs of the ASTRI SST-2M Telescope Camera



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Rapporti interni e tecnici
N. 5/2014

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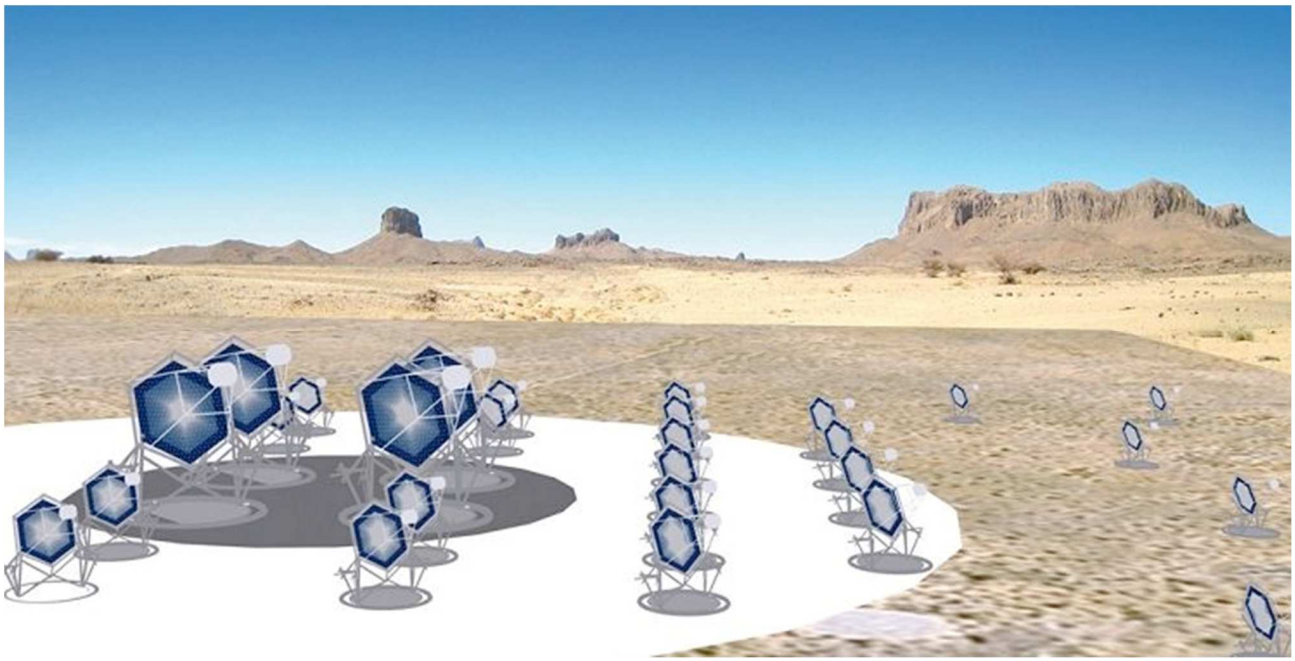
SiPM Interface Systems for the Characterization of Complete PDMs of the ASTRI SST-2M Telescope Camera



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DOCUMENT HISTORY

Version	Date	Modification
1.0	Date	first version
		update

LIST OF ACRONYMS

OACT	Osservatorio Astrofisico di Catania
IFC	Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo
COLD	Catania astrophysical Observatory Laboratory for Detectors
PCB	Printed Circuit Board
SiPM	Silicon Photo-Multiplier
MPPC	Multi Pixel Photon Counter
SST-2M	Small-Size Telescope Dual-Mirror
PDM	Photon Detection Module
ASIC	Application Specific Integrated Circuit
FEE	Front-End Electronics
BEE	Back-End Electronics
FPGA	Field Programmable Gate Array
EASIROC	Extended Analogue Silicon-pm Integrated Read-Out Chip
CITIROC	Cherenkov Imaging Telescope Integrated Read-Out Chip
I/F	Interface

APPLICABLE DOCUMENTS

[AD1]

REFERENCE DOCUMENTS

[R1] Distribuzione delle PDM sul piano focale della camera ASTRI e layout di ogni singola PDM – code: ASTRI-TR-OACT-3200-012.

[R2] Systematic Calibration Procedure for the Temperature Sensors of the SiPM Interface Board – code: ASTRI-TR-OACT-3200-013.

[R3] Reliability Tests of all 37 SiPM Boards of the ASTRI SST-2M Camera through Pulse Height Distribution Measurements – code: ASTRI-TR-OACT-3200-015.

1. INTRODUCTION

This document is intended to report on the SiPM interface systems realized at the COLD laboratory to provide a complete characterization of an entire detection module (PDM) at the focal plane of the ASTRI SST-2M telescope.

In particular, the SiPM interface board, interfacing the MPPC detectors of a PDM with the front-end electronics, and the adapter board, providing a versatile interface between the SiPM output signals and the electronic evaluation board, are henceforth described in detail.

The instrumental apparatus developed at the COLD laboratory has been envisaged to provide a systematic characterization of a complete structural detection unit (PDM) of the ASTRI SST-2M telescope prototype, as well as to achieve a systematic thorough characterization of any solid-state detector.

2. SIPM INTERFACE BOARD

The MPPC detectors are assembled in a PDM module so that each single detector unit is mounted on a small printed circuit board (PCB) of the same dimensions; the monolithic MPPC detector is soldered to the front side of the PCB, while the rear side of the board hosts two multi-pin connectors along with a temperature sensor for gain stabilization. Thereby, the focal plane sensors can be coupled, side by side, onto a bigger PCB to form the complete PDM structural module.

16 monolithic MPPCs are assembled in a single PDM on top of the SiPM interface board, so as to constitute an entire module with equally distributed interspaces.

The complete circuit schematic of the designed I/F board is depicted in Fig. 1. Fig. 2 and Fig. 3 show respectively the top and bottom layers of the realized PCB. On top of the board, 4 soldered monolithic MPPCs are visible.

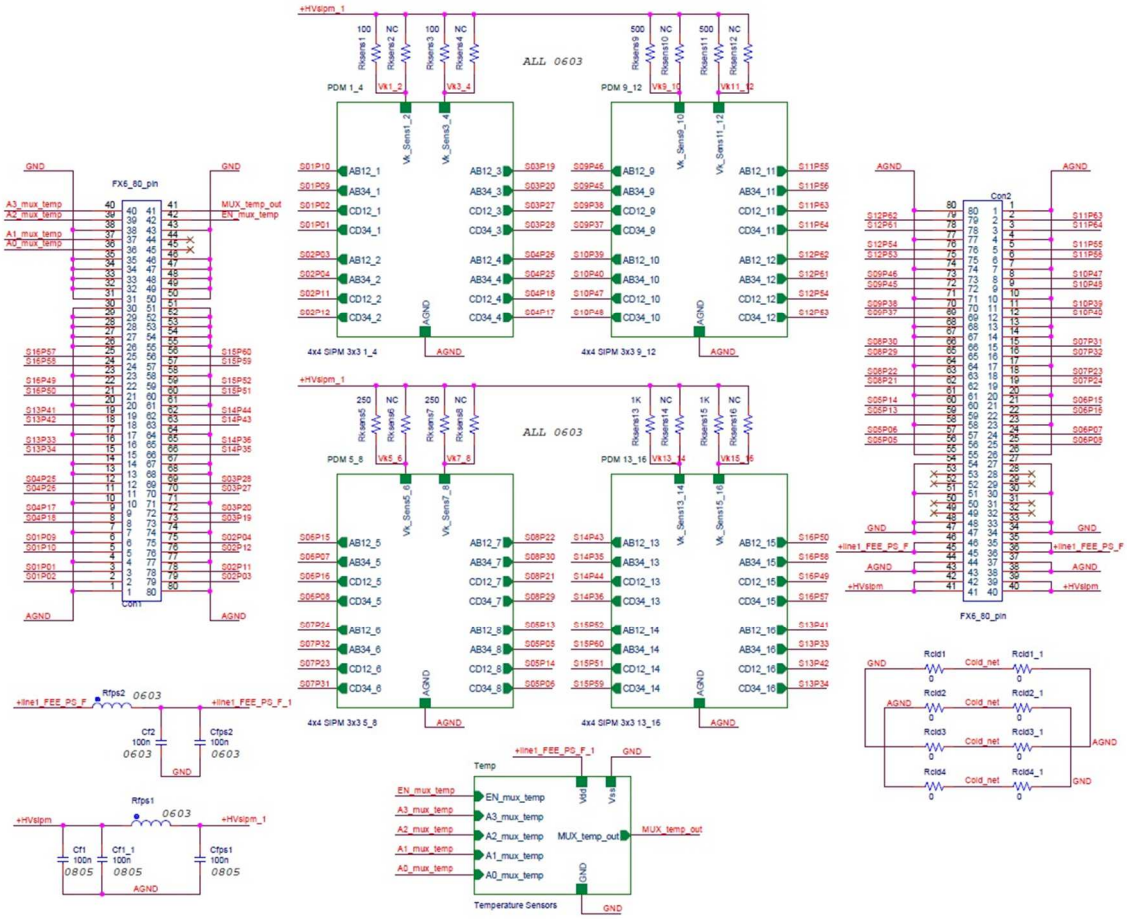

Fig. 1. Complete circuit schematic of the SiPM I/F board.

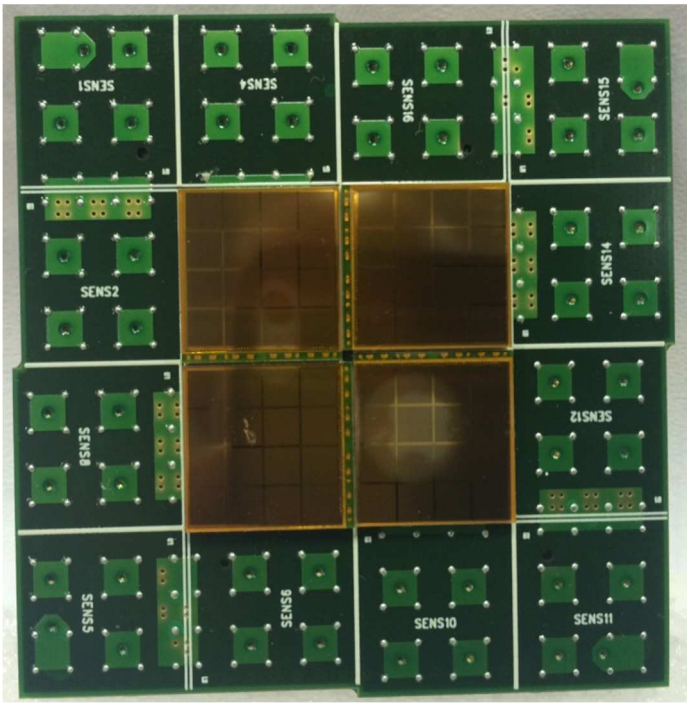

Fig. 2. Top layer of the SiPM interface board, with 4 monolithic MPPCs soldered.

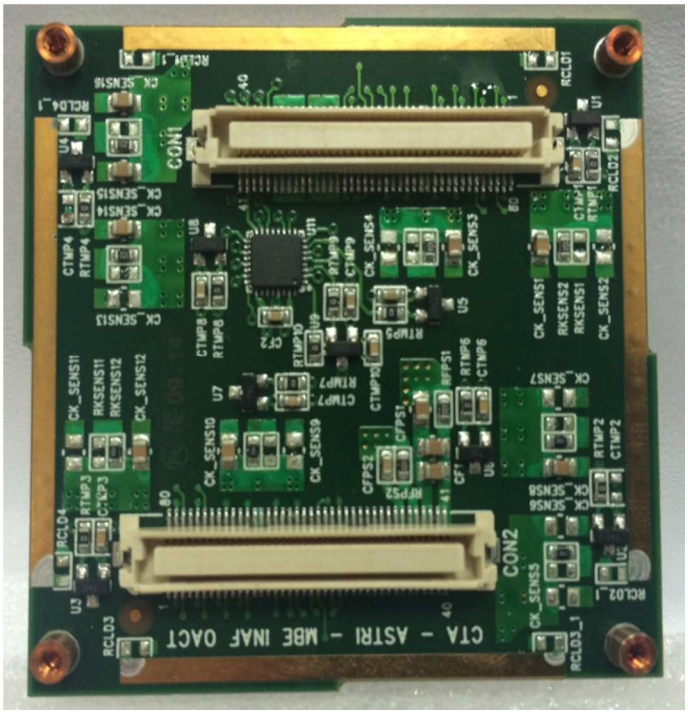

Fig. 3. Bottom layer of the SiPM interface board, with the temperature sensors and analog mux.

On top of the SiPM I/F board, the four anode pins of each basic 3x3mm^2 MPPC are connected together, in order to realize a logical pixel.

All MPPC detectors are mounted so as to perfectly adapt to the mechanical structure of the I/F board, thus covering its entire surface. Each monolithic detector is soldered through an innovative process which allows monitoring of each single pads at the same time. As a result, an accurate placing of the MPPCs on the board is achieved.

The reference position of SiPMs and logical macro-pixels for each single PDM unit is illustrated in Fig. 4.

Each I/F board has in total 10 temperature sensors: 9 LM-60 sensors located on the rear side and 1 LM-94023 sensor located at the center of the front side. Fig. 5 and Fig. 6 depict the bottom layer assembly drawings of the SiPM interface board, where the position of the LM-94023 sensor in the top and that of the 9 LM-60 sensors in the bottom is visible. The two assembly drawings are flipped with each other.

An analog multiplexer located at the center of the bottom layer allows individual selection of the outputs of all 9 LM-60 temperature sensors.

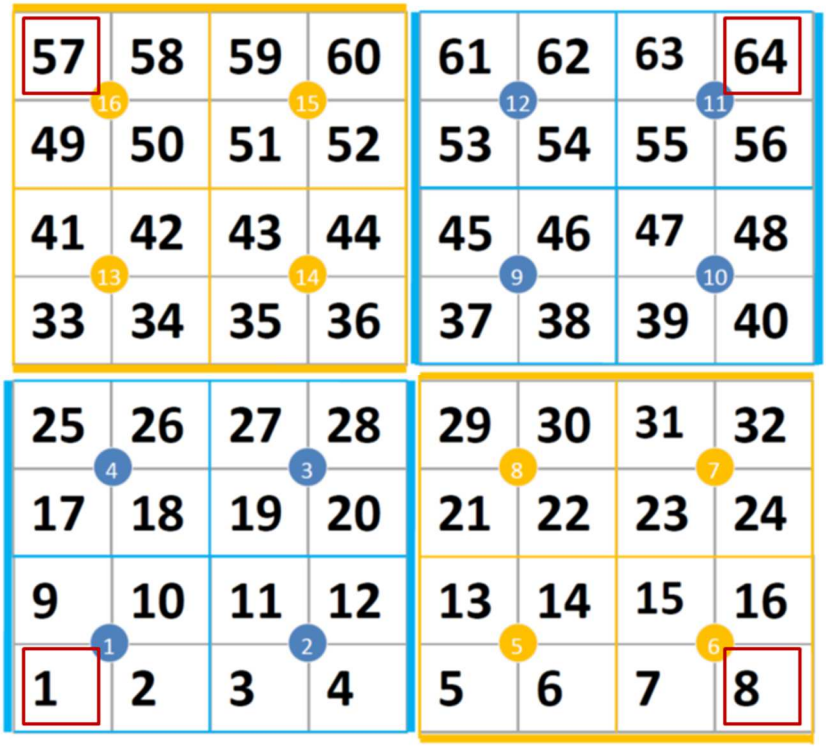

Fig. 4. SiPMs and macro-pixel reference position for each single PDM unit.

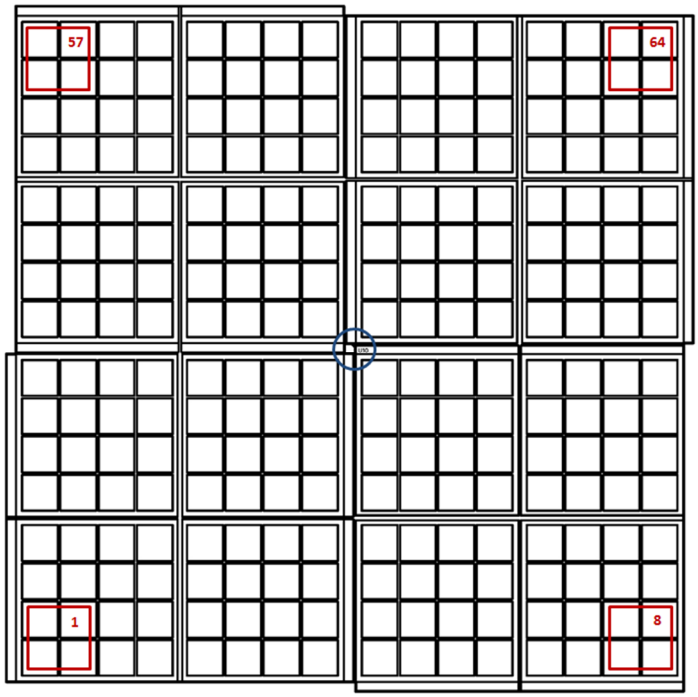

Fig. 5. Top layer assembly drawing of the SiPM interface board, where the central LM-94023 temperature sensor is apparent.

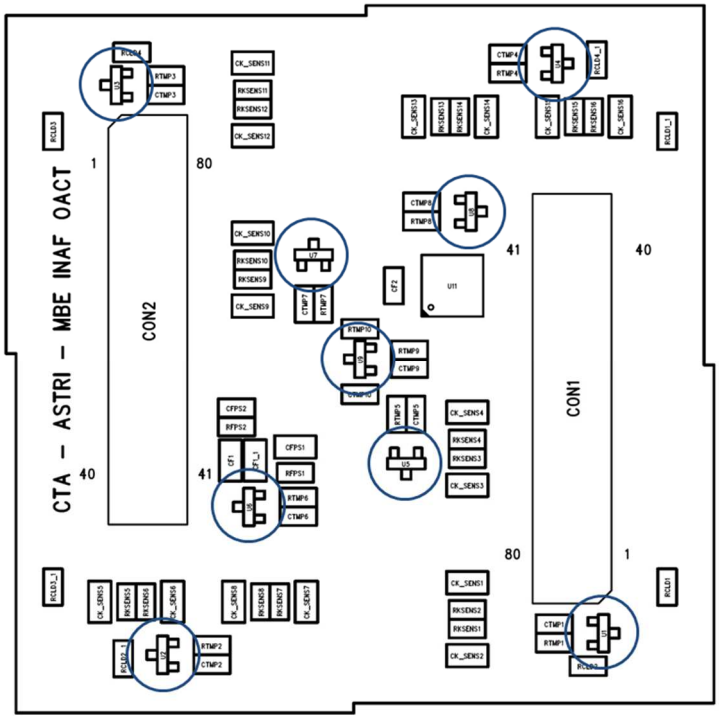

Fig. 6. Bottom layer assembly drawing of the SiPM interface board, showing the position of the 9 temperature sensors.

3. ADAPTER BOARD

EASIROC (Extended Analogue Silicon-photomultiplier Read-Out Chip) is a 32-channel fully analogue front end ASIC produced by OMEGA and dedicated to the gain trimming and read-out of the ASTRI MPPC detectors signals. The EASIROC chip is soldered onto a dedicated evaluation board providing 32 external inputs for the MPPC signals. The EASIROC evaluation board is depicted in Fig. 8.

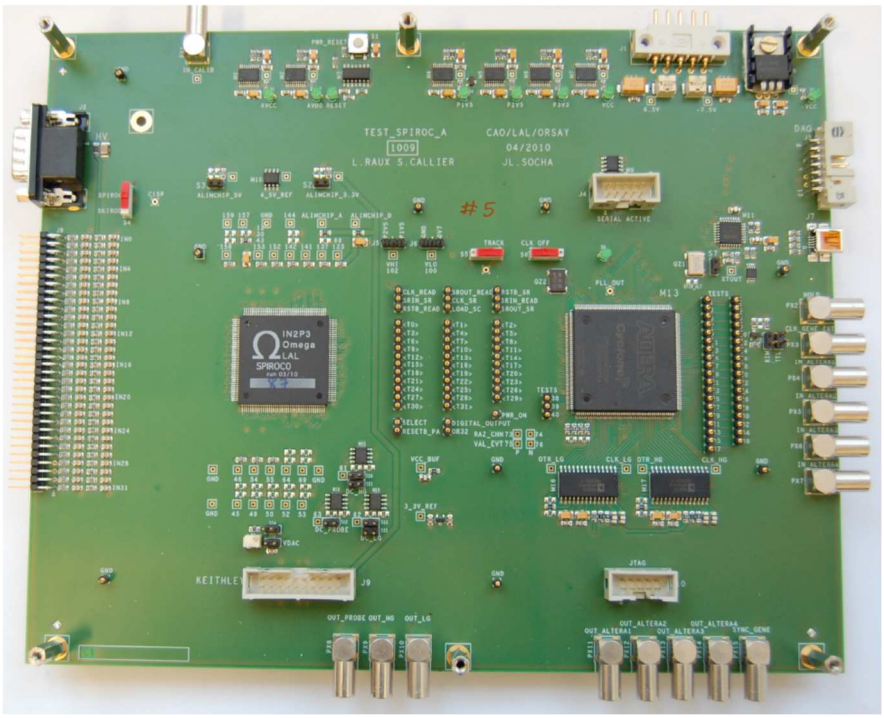

Fig. 7. EASIROC evaluation board (realized by Omega).

To allow a versatile interface between the silicon photomultiplier signals of the logical PDM pixels and the EASIROC evaluation board, an adapter board has been realized at the COLD laboratory, to interface the PCB hosting the PDM camera detectors with the EASIROC evaluation board.

The complete schematic of the adapter board is reported in Fig. 9. The layout of the top and bottom layers of the board is shown in Fig. 9 and Fig. 10, respectively.

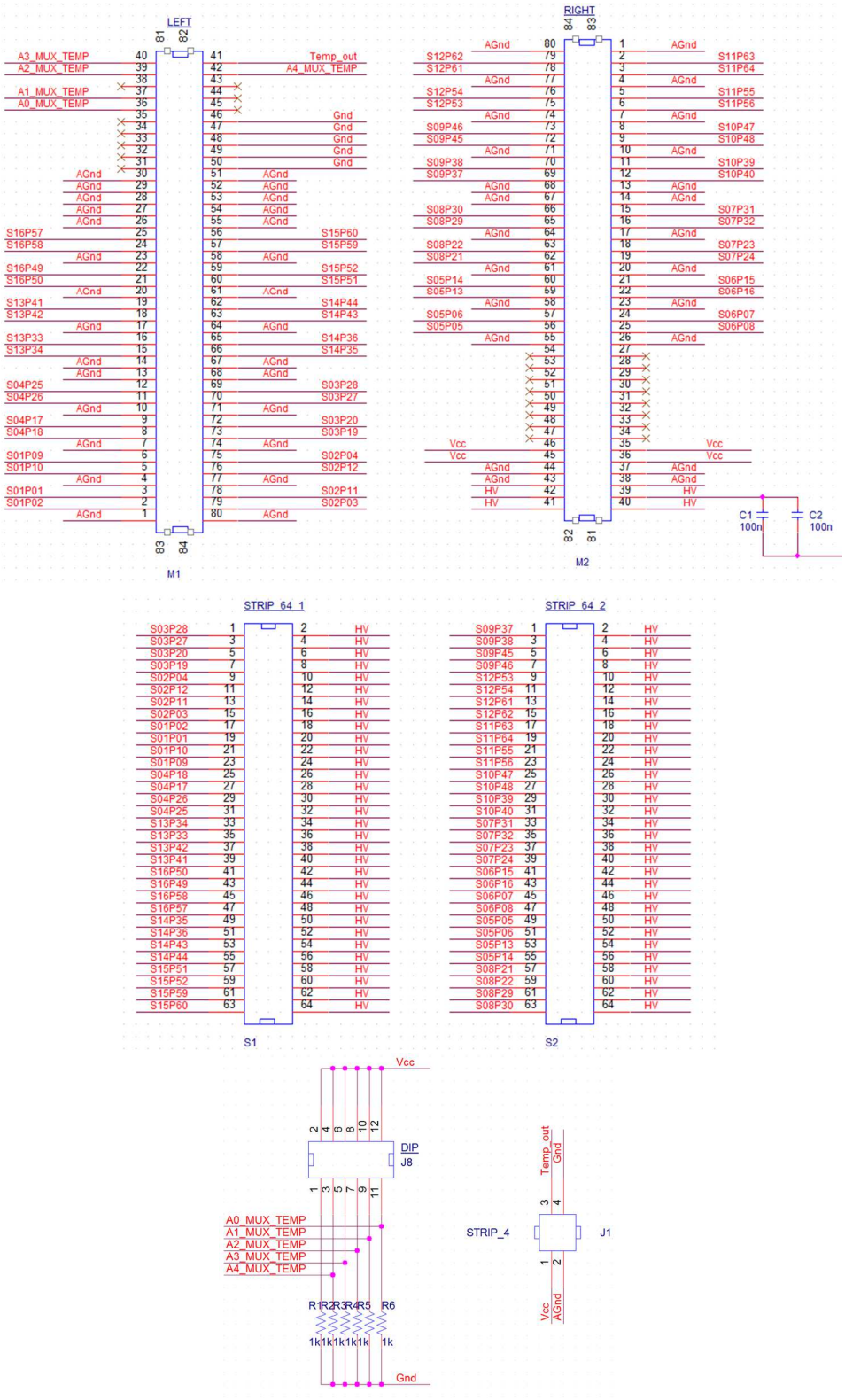

Fig. 8. Complete schematic of the adapter board (connectors, strips and dip-switch).

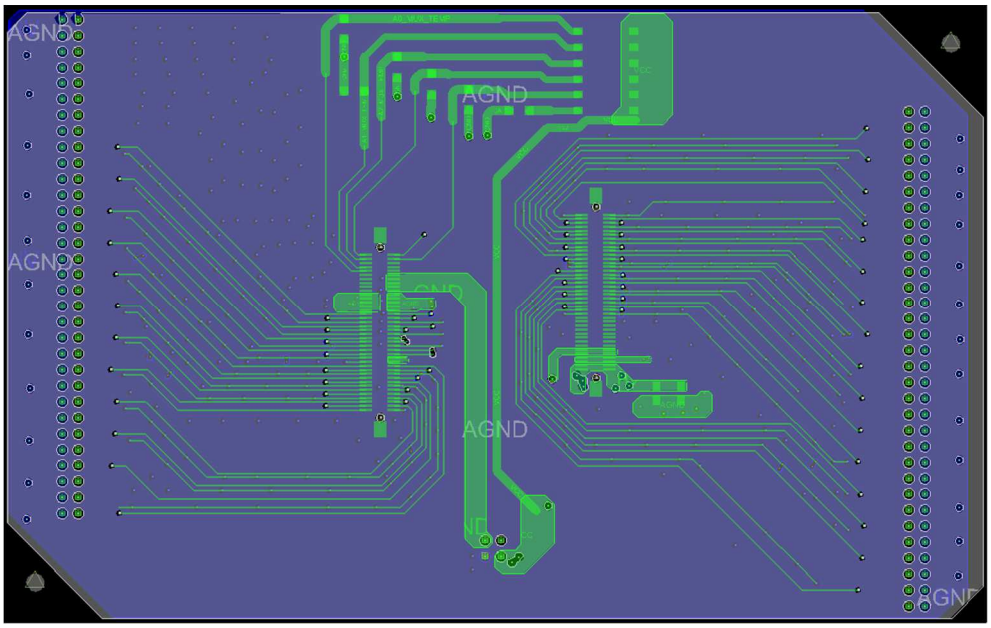

Fig. 9. Top layer layout of the adapter board.

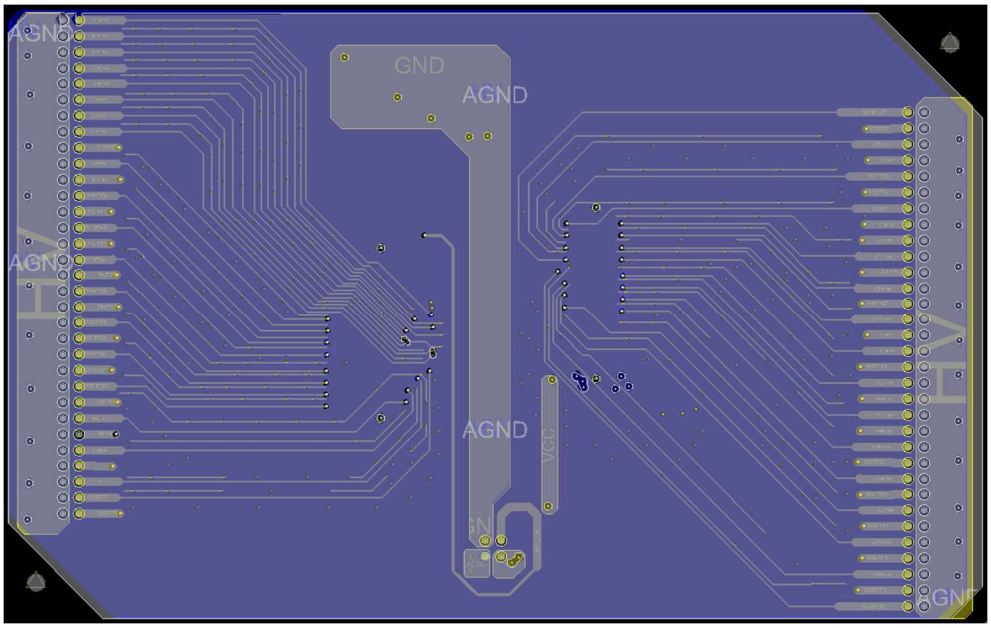

Fig. 10. Bottom layer layout of the adapter board.

The PCB of the realized adapter board are shown in Fig. 11 and in Fig. 12, respectively for the top and bottom side.

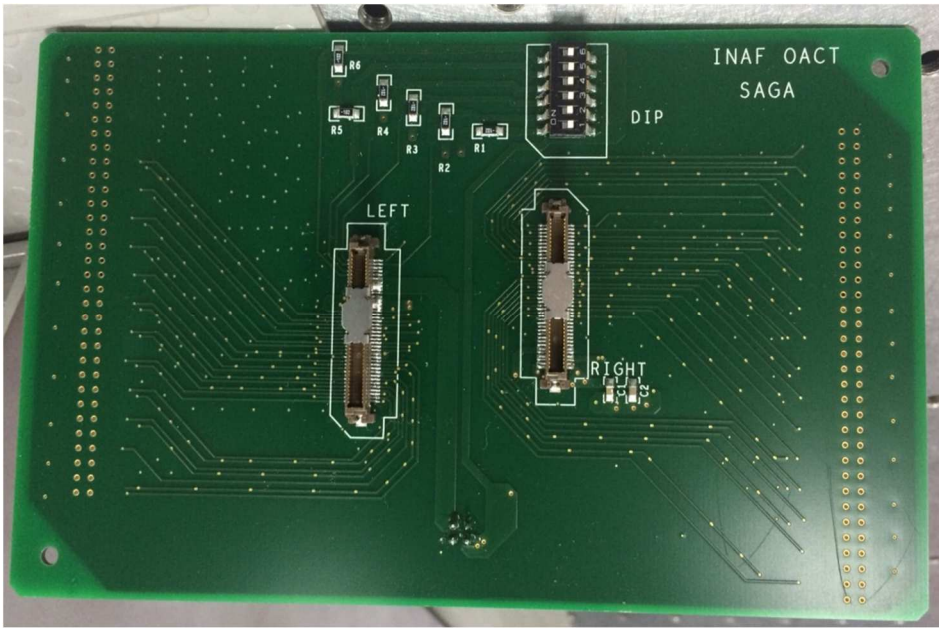

Fig. 11. Top layer printed circuit of the realized adapter board.

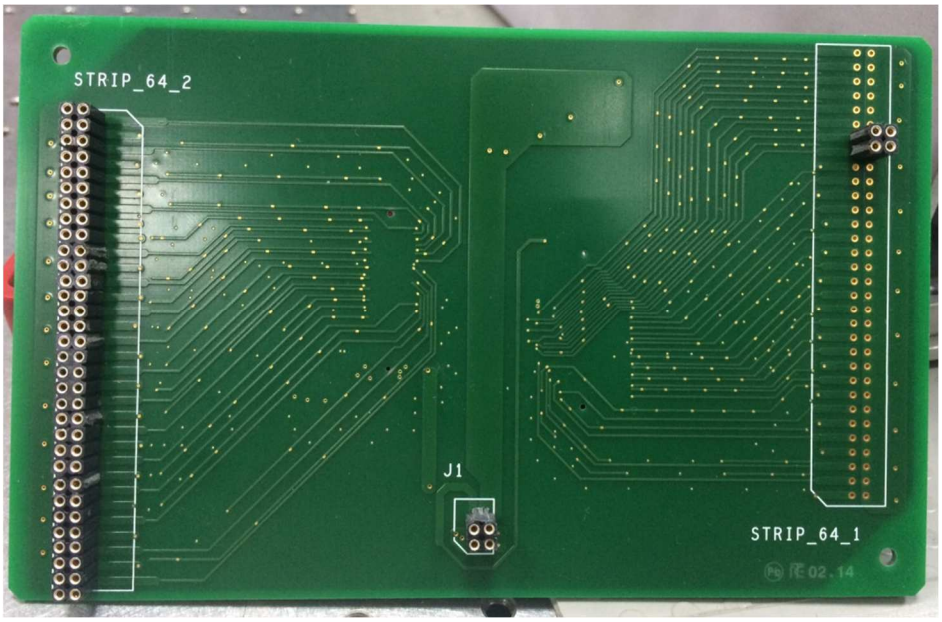

Fig. 12. Bottom layer printed circuit of the realized adapter board.

To allow the SiPM signals to be profitably interfaced with the read-out evaluation board, two Molex multi-pin connectors on the adapter board receive the 64 detector output signals from the PDM board, which are routed towards two 32-pin strip connectors located on the rear side of the adapter board.

As a result, one strip connector at a time can couple 32 output signals from each PDM (half of the available logical pixels) to the EASIROC evaluation board. In this way, each complete PDM can be characterized by simply rotating the position of the adapter board and connecting both strips to the EASIROC board, as shown in Fig. 13.

Fig. 13. SiPM board connection to the EASIROC evaluation board through the strip connectors.

A dip-switch in the bottom layer of the board allows individual selection of the outputs of all 10 temperature sensors, providing the input digital selectors to an analog multiplexer located at the center of the board according to the configuration scheme reported in Table I.

Table I. Configuration table for individual selection of the LM-60 sensors.

SENSOR	SELECTOR
U1	1000
U2	1011
U3	0100
U4	0000
U5	1001
U6	0111
U7	0110
U8	0010
U9	1101
U10	1111

4. MECHANICAL SUPPORT

An additional specific mechanical support has been realized to house the MPPC board; in particular, the black light-tight box shown in Fig. 14 and Fig. 15 (front view and rear view, respectively) prevents any accidental light exposure of the MPPC detectors and allows a thermic regulation by means of a cooling system adopting a Peltier cell.

A light shield is realized on top of the adapter board in order to prevent light penetration through the back of the black-box, and helps to maintain stable the temperature inside the box, avoiding the heat exchange with the outside of the box (see Fig. 16).

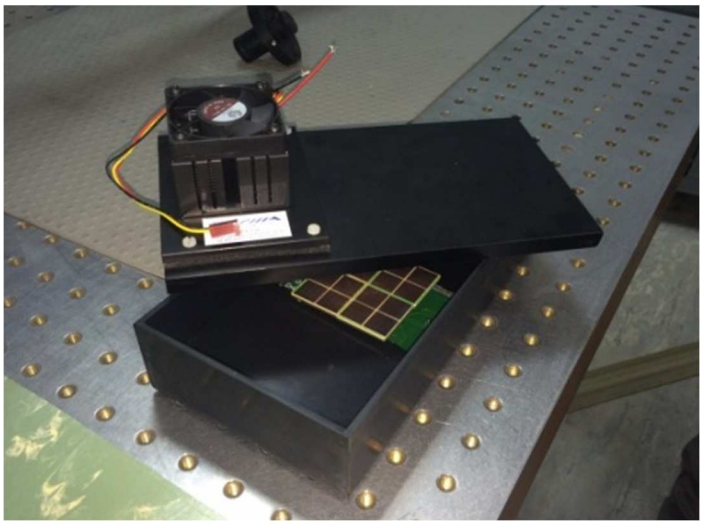

Fig. 14. Front view of the black light-tight box preventing accidental light exposure of the MPPC detectors.

Fig. 15. Rear view of the black light-tight box preventing accidental light exposure of the MPPC detectors.

Fig. 16. Light shield realized on top of the adapter board to prevent light penetration.

The temperature control of the SiPM I/F is obtained through a cooling system designed at the COLD laboratory of INAF-OACT, based on a Peltier cell whose hot side is cooled by a CPU fan. The thermoelectric cooler is shown in Fig. 17. The entire cooling system is thermally calibrated.

The cool side of the Peltier cell is connected to an aluminum foil of sufficient thickness so as to penetrate inside the black box and approach to the inner SiPM interface board, as illustrated in Fig. 18.

The thermic calibration of the system allows to set the desired temperature.

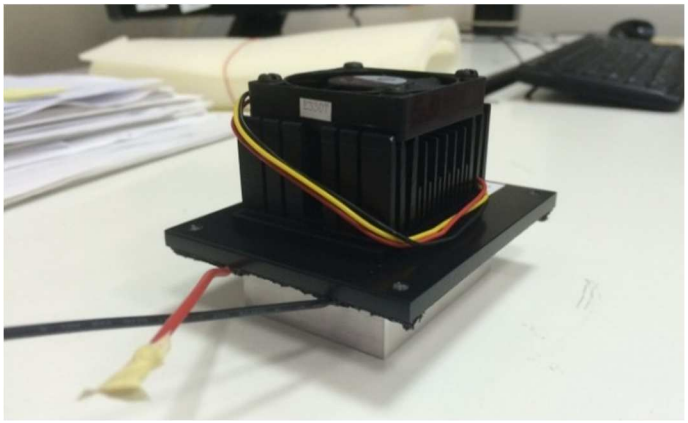

Fig. 17. Thermoelectric cooler based on a Peltier cell.

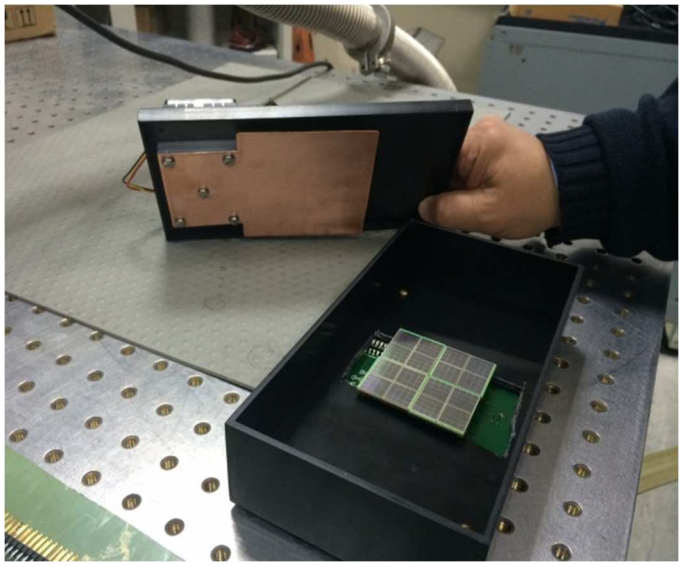

Fig. 18. Black light-tight box housing the adapter and SiPM interface boards, along with related thermoelectric system for temperature control.

5. INTERFACING TESTS

The adapter board guarantees a versatile interface between the SiPM board and the EASIROC read-out electronics, ensuring the realization of several functional tests and measurements for SiPM characterization.

The two multi-pin connectors of the adapter board can host the relevant connectors of the SiPM interface board, in order to analyze a complete PDM unit. Fig. 19 shows the SiPM interface board connected to the top side of the adapter board.

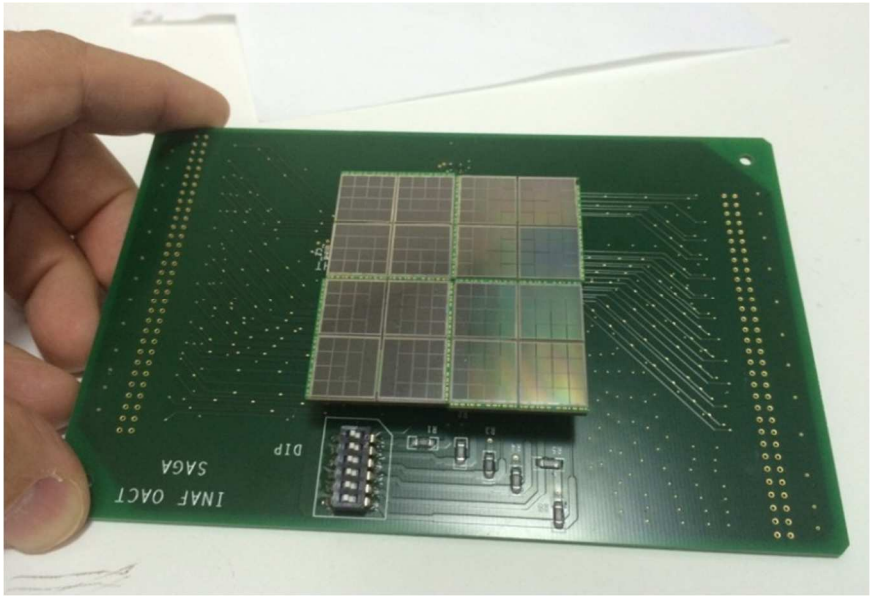

Fig. 19. SiPM interface board connected to the adapter board.

On the other hand, it is also possible to test any solid-state detector by connecting its anode terminal to one of the connector pins of the board, and its cathode terminal to the strip connector, as shown in Fig. 20.

The adapter board also allows a convenient interface with the EASIROC evaluation board, as one strip connector at a time can couple half of the available logical pixels) of each PDM to the EASIROC read-out channels. Thereby, each complete PDM can be characterized by simply rotating the position of the adapter board and connecting both strips to the EASIROC board, as depicted in Fig. 21.

As a result, thanks to the SiPM interface board and the previously analyzed mechanical systems, a complete and systematic electro-optical characterization of SiPM detectors can be achieved. The complete apparatus set-up for SiPM characterization is pictorially reported in Fig. 22.

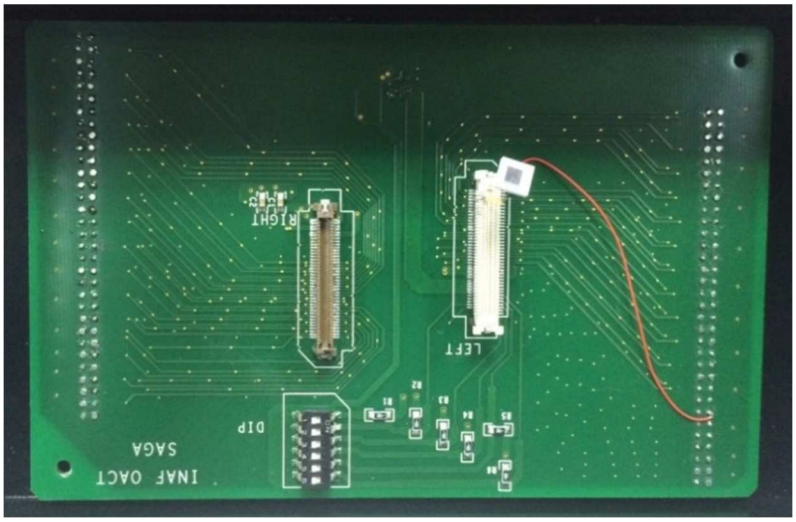

Fig. 20. Test of a SiPM detector through the adapter board.

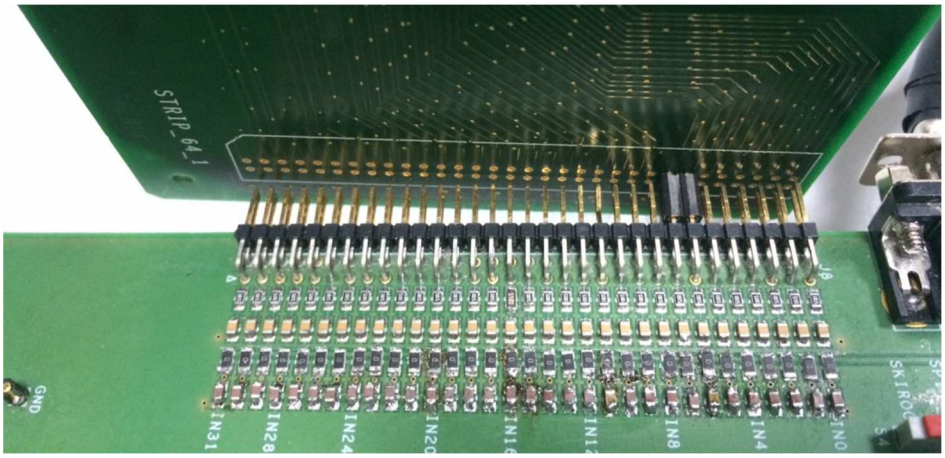

Fig. 21. Connection of the adapter board to the 32-channel EASIROC evaluation board through the strip connectors.

Characterization tests of the MPPC sensors in each PDM through the EASIROC evaluation board as a function of the detectors' operating conditions include dark stairs measurements (performed through the box at the bottom-left of the figure), detectors gain measurements, linearity tests and absolute PDE (Photon Detection Efficiency) measurements (performed through the box at the top-left of the figure, where the circular hole allows interfacing with the integrated sphere). All these sets of tests can be useful for characterizing the detector performance and evaluating its compliance with the ASTRI focal plane requirements.

Fig. 22. Complete experimental apparatus for SiPM characterization.

6. CONTACTS

The team working on the electronic design of the ASTRI camera is composed by people from INAF's Catania Astrophysical Observatory and Palermo IFC. It is also referred to as the Electronics Camera Team.

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