PROCEEDINGS OF SCIENCE

Study of the EUSO-SPB2 Photodetection Module

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The Extreme Universe Space Observatory Super Pressure Balloon 2 (EUSO-SPB2) is an approved NASA balloon mission that is planned to fly in 2023 from Wanaka, NZ with target duration of up to 100 days. It is a pathfinder for the Probe of Extreme Multi-Messenger Astrophysics (POEMMA), a candidate for a NASA Astrophysics probe-class mission. EUSO-SPB2 will consist of a Cherenkov telescope and a fluorescence telescope. The first is optimized for fast signals and is devoted to estimate the background sources for astrophysical neutrino observations; the second looks at the nadir to measure the fluorescence emission of Ultra High Energy Cosmic Rays (UHECRs). The long-duration flight will provide a large number of VHECR Cherenkov signals and UHECR fluorescence tracks. In this contribution we discuss the calibration with dedicated signal of the photodetection module.

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1. EUSO-SPB2

The Ultra-High Energy Cosmic Rays (UHECRs) are cosmic rays with energy greater than 10^{18} eV. Given the steeply falling energy spectrum, especially above $5 \cdot 10^{19}$ eV, it is important to collect as many events as possible. To obtain a larger exposure and a uniform coverage of the celestial sphere, it is possible to measure the fluorescent radiation of EAS using a UV telescope on-board of a satellite [1]. EUSO-SPB2 is a cosmic ray detector on board of a NASA Super Pressure Balloon that aims to detect the UHECRs by measuring fluorescence and Cherenkov light produced by the interaction of the particles with the nuclei of the Earth's atmosphere [2]. The EUSO-SPB2 Fluorescence Telescope (FT) is composed by an Ultraviolet (UV) camera, mounted at the convex focal surface where the Schmidt optics focuses the light. The EUSO-SPB2 FT camera has a modular design with 3 Photo Detection Modules (PDMs), that are the UV sensitive detectors. Each PDM is composed of a matrix (167×167 mm^2) of 36 multi-anode photo-multipliers tubes (MAPMTs) sensitive to UV light. Each MAPMT has 64 anodes (pixels), resulting in a PDM of 2304 pixels (48x48), capable of single photo electron counting in the wavelength bandwidth 290-430 nm and with a time resolution of about 1 μs. The optical system is a Schmidt system consisting of 6 mirror segments with a diameter of 1 m and an effective focal length of 860 nm. A Schmidt corrector plate at the aperture will be placed providing a field of view of roughly $12° \times 37°$. The EUSO-SPB2 is also a scientific and technical sub-orbital altitude precursor for POEMMA [3].

2. The integration tests on the FT camera

The integration tests have been divided into 3 phases, during the period April 2022 - June 2022. During the first phase the 3 PDMs have been integrated and tested in the black box of the Laboratory of the Department of Physics at the Naples University, Italy. Then, in the same laboratory, the 3 PDMs have been integrated, and tested with the Data Processor and the trigger logic. Finally, the system has been tested into the termo-vacuum chamber at CIRA Laboratory, Capua, Italy. During the flight, EUSO-SPB2 will acquire data in 2 different modes: to obtain a measure of the background light before each acquisition and calibrate all pixels of the PMTs we have the *S-curves mode*; in the *Acquisition Data mode*, data are acquired when a trigger occurs.

2.1 Integration at the INFN/UNINA Laboratory

The first phase has been fundamental to define the acquiring sequence of the 3 modules with a standard procedure. A led in continuous mode has been used to evaluate the pixel response to a diffused light. In Fig. 1 the black box, the PDMs and the led are shown.

The analysis of single S-curves has been done with different spot sizes, and a threshold with the maximum sensitivity for each pixel has been set. After the calibration, a scan on all pixels of the three PDMs has been performed. In Fig. 2 the image of the detected led light by the first module is shown on the left; on the right, in the S-curves the response of the hit pixels is well separated from the background.

During the second phase, the integration with data processor has been fundamental to synchronize the response of the PDMs to the signal. A led with 30 μsec pulse with a 4Hz frequency has been used as external trigger, allowing a fine tuning of the trigger logic parameters.

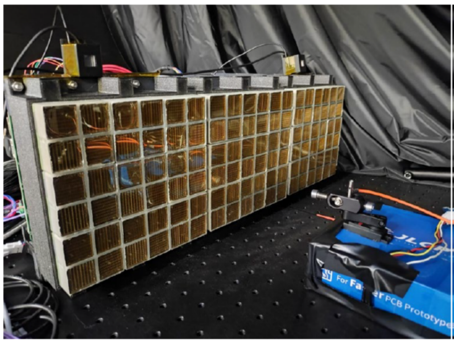

Figure 1: The experimental setup for tests in the laboratory of the University of Naples and INFN Section of Naples.

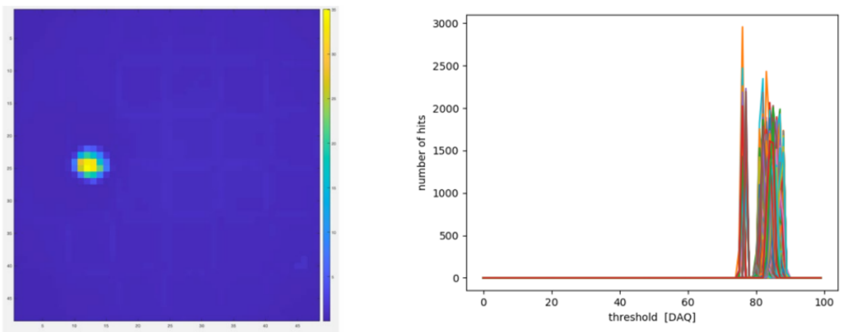

Figure 2: Event taken during the Phase 1.

2.2 CIRA Space Qualification Laboratory

The system has been also tested into the termo-vacuum chamber at the CIRA's Space Qualification Laboratory, Capua. Three different cycles on pressure and temperature have been used to test the instrument behaviour. In Fig. 3, information about pressure and temperature measured during one cycle are reported; these data have been acquired by the chamber probe.

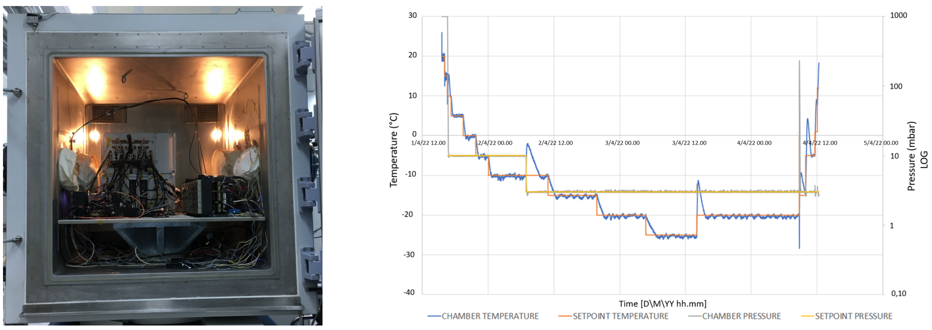

Figure 3: On the right side, the qualification cycle in the termo-vacuum chamber is shown. On the left side, there is a picture of the entire setup contained into the chamber.

During tests, data from all subsystems have been acquired, allowing a precise characterization of the detector behaviour under different pressure and temperature conditions. In Fig. 4 one of the recorded events is shown. It can be clearly seen the shadow of a cable with a very good resolution. Also the housekeeping has provided data; for example, in Fig. 5 the temperature measured on one side of the zynq board is reported.

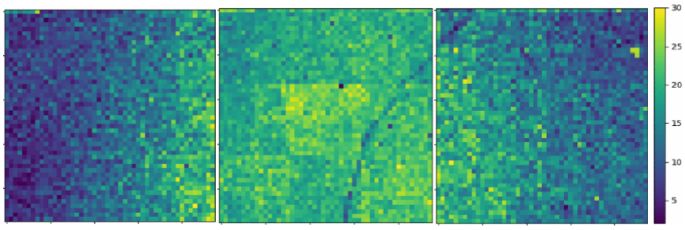

Figure 4: Event recorded on detector at P = 3 mbar and T = - 15 °C.

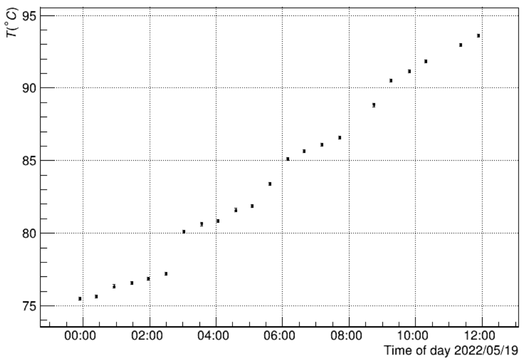

Figure 5: Data from the temperature probe located on the detector and provided by the housekeeping.

3. Conclusions

EUSO-SPB2 will be launched in Spring 2023 from Wanaka, New Zealand. It will take a long duration flight of about 100 days at a nominal altitude of 33 km, with an average observation time per night of about 5 hours. The tests on the photodetection modules and the data processor have been described. Results are in line with expectations.

References

[1] R. Batista et al., *Open Questions in Cosmic-Ray Research at Ultrahigh Energies*, *Front. Astron. Space Sci.*, Sec. High-Energy and Astroparticle Physics, https://doi.org/10.3389/fspas.2019.00023 (2019)

[2] J. Eser, A.V. Olinto, L. Wiencke, *Science and mission status of EUSO-SPB2*, *37th International Cosmic Ray Conference 2021*, https://doi.org/10.22323/1.395.0404 (2021)

[3] A. Olinto et al., *The POEMMA (Probe of Extreme Multi-Messenger Astrophysics) observatory*, *J. Cosmol. Astropart. Phys.*, 06 007 doi:10.1088/1475-7516/2021/06/007 (2021)