Study of the EUSO-SPB2 Photodetection Module

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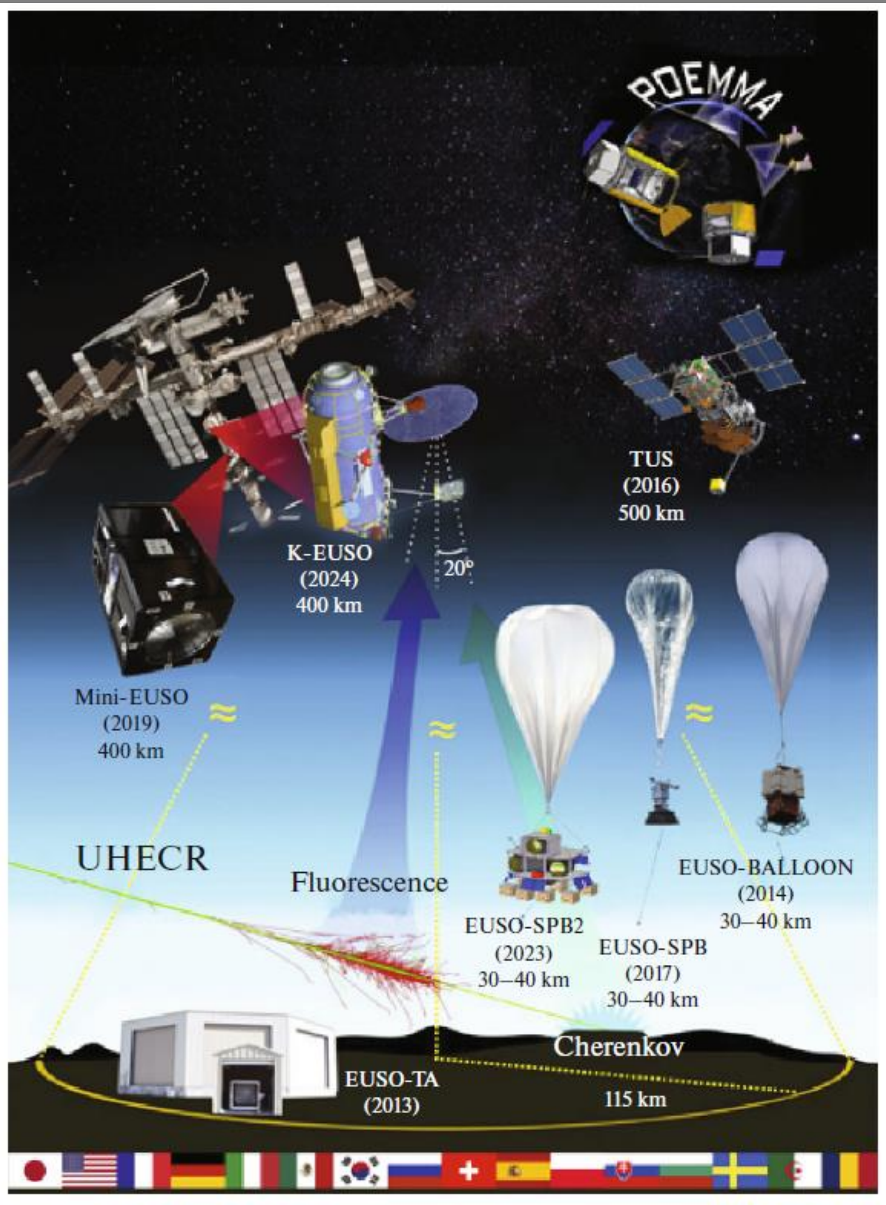
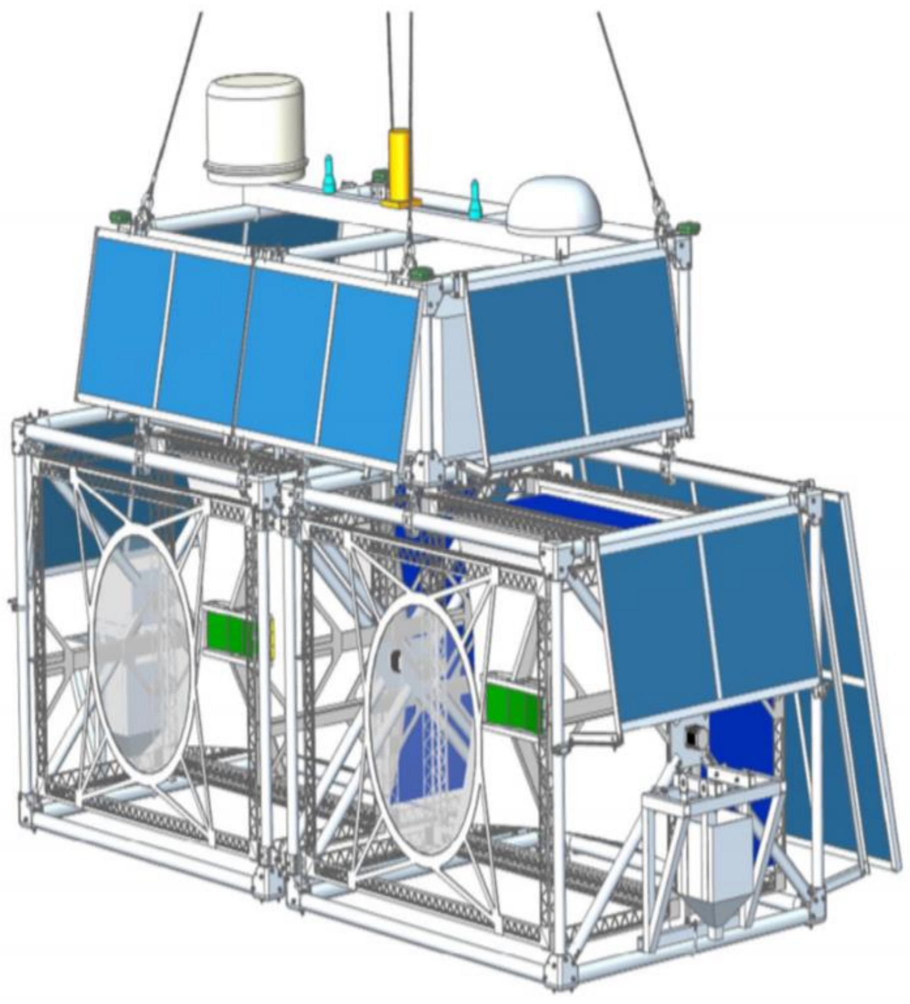
Abstract: **The Extreme Universe Space Observatory Super Pressure Balloon 2 (EUSO-SPB2) is an approved NASA balloon mission that is planned to fly in 2023 from Wanaka, NZ with target duration of up to 100 days. It is a pathfinder for the Probe of Extreme Multi-Messenger Astrophysics (POEMMA), a candidate for an 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 signal and UHECR fluorescence tracks. In this contribution we discuss the calibration with dedicated signal of the photodetection module.**

EUSO-SPB2 main objectives are the detection of Ultra-High Energy Cosmic Rays (UHECR) by measuring fluorescence and Cerenkov light produced by the interaction of the particles with the nuclei of the Earth's atmosphere. EUSO-SPB2 is also a scientific and technical sub-orbital altitude precursor for the Probe of Extreme Energy Multi-Messenger Astrophysics (POEMMA), selected by NASA for an in-depth probe mission concept study in preparation for the next decadal survey. EUSO-SPB2 will be built to view the true horizon of the Earth. Horizontal observations will lead to much larger acceptances for inclined UHECRs, with a distance-dependent energy threshold.



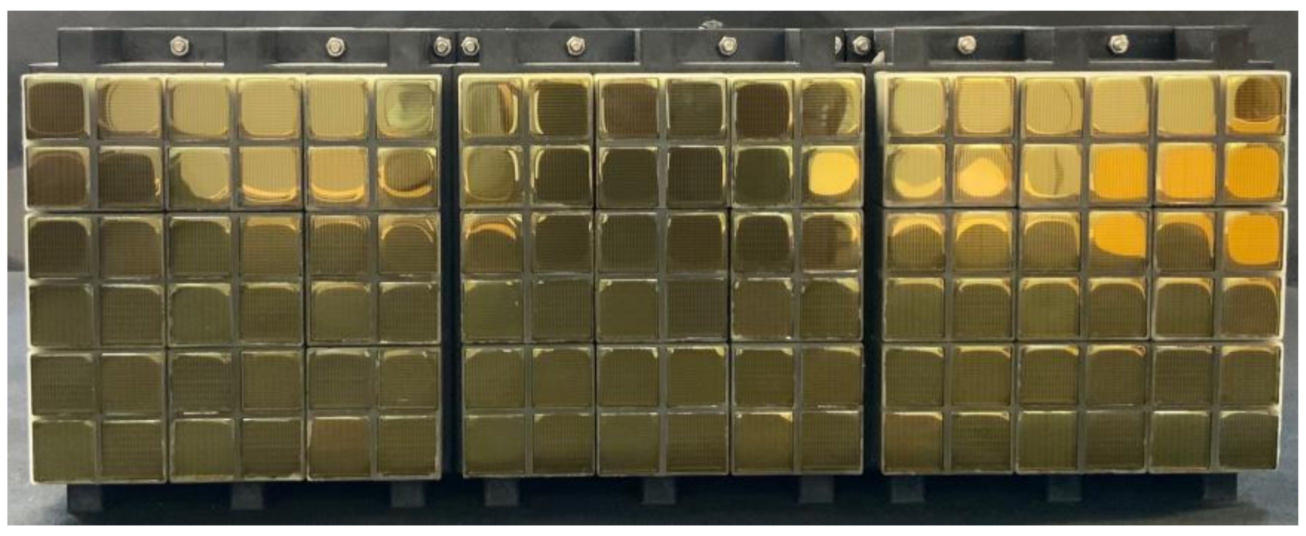
Up: The payloads of the JEM-EUSO program

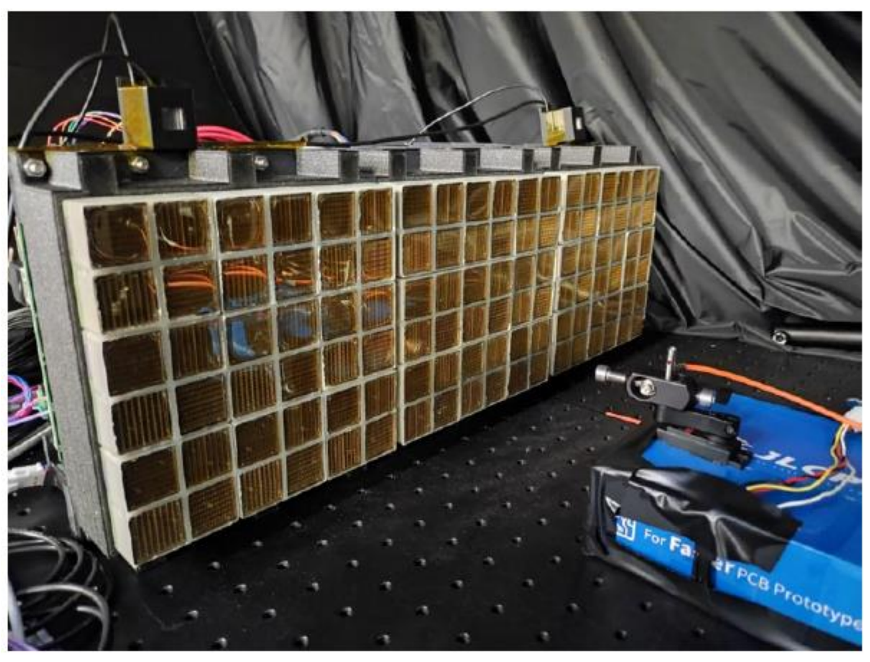
The EUSO-SPB2 Fluorescence Telescope camera has a modular design with 3 Photo Detection Modules (PDM), each consisting of 2034 pixels capable of single photo electron counting in the wavelength bandwidth 290-430 nm and with a time resolution less than 1 µs. The optical system is a Schmidt system consisting 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° x 37°.



Left: The EUSO-SPB2 payload including gondola structure shown in a preliminary configuration, telescopes, solar panels, antennas, and ballast hoppers.

Right: The three Photodetection Module





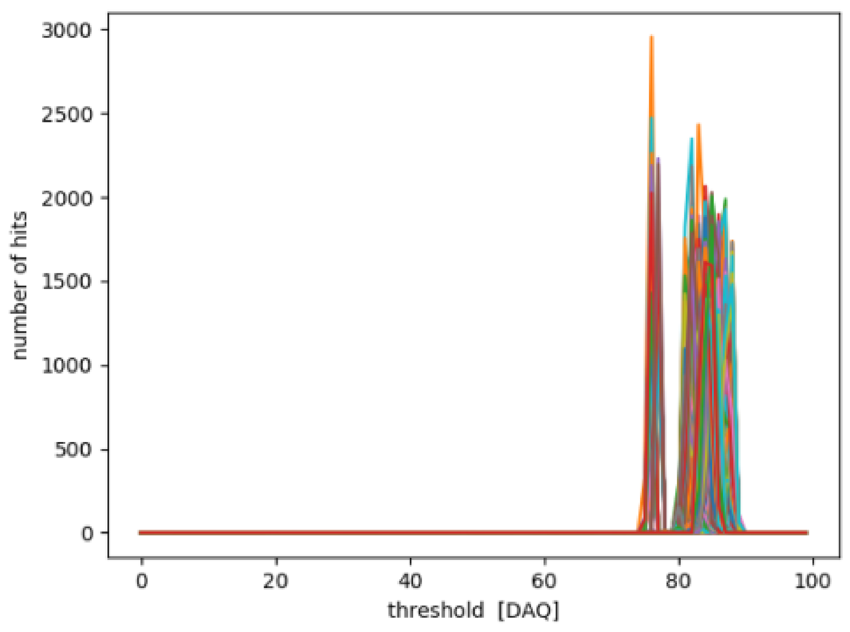
The integration tests have been divided into 3 phases.

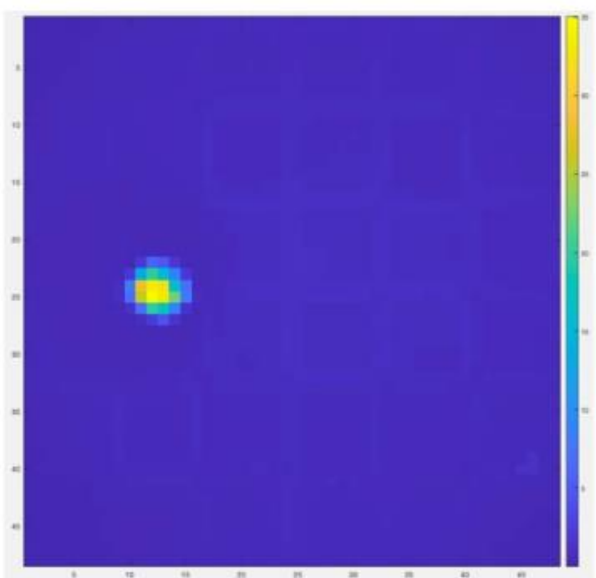
1) Integration of the 3 photodetection modules in the black box of the Laboratory of the Department of Physics at the Naples University
2) Integration of the photodetection modules with the Data Processor in the black box
3) Integration of the entire system in the termo-vacuum chamber at CIRA Laboratory.

All tests have been taken from April to June 2022.

During the flight, EUSO - SPB2 will acquire data in 2 different modes:

- **S-curves** mode: to obtain a measure of the background light before each acquisition and calibrate all pixels of the PMTs;
- **Acquisition Data** mode: after the calibration, data are acquired when a trigger occurs.



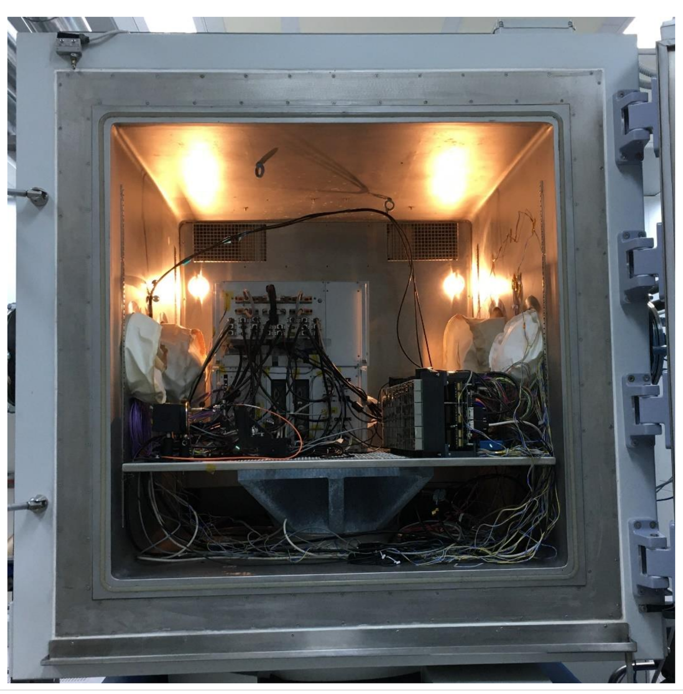


The first phase has been fundamental to define the acquiring sequence of the 3 modules with a standard procedure. A led in continuous mode has been used to evaluate the pixel response with a diffused light to study the behaviour with a background light of the sky. Through the analysis of single S-curves, the threshold with the maximum sensitivity for each pixel has been set.

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 microsec pulse with a 4Hz frequency has been used as external trigger, allowing the improvement of the trigger logic parameters.

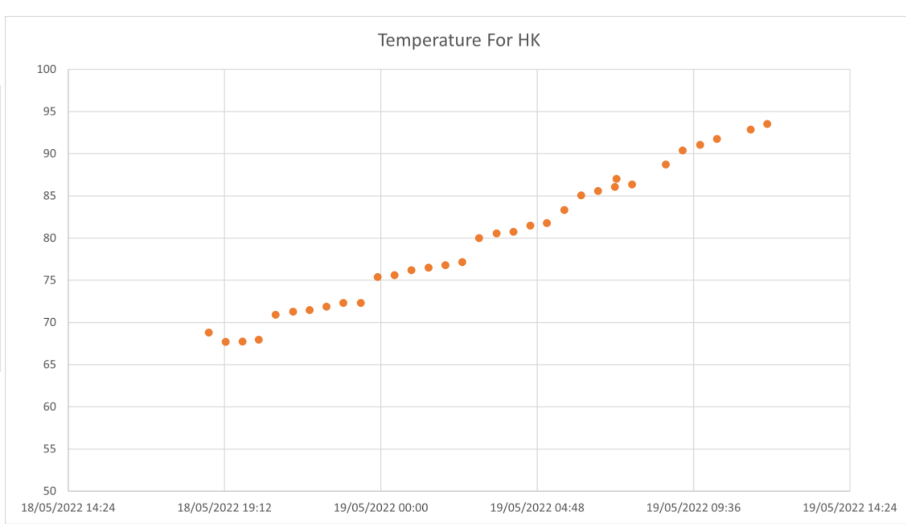
Left: spot on PDM 2 with different acquisition mode and the corresponding signal on single pixels. Acquisition has been taken in the laboratory of the Department of Physics with P = 1 atm and T = 25° C.

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.



COMBINED CHAMBER (Angelantoni UD 1000 C VT)
Temperature: [-75°,+120°C]
Range of U.R.: : 10% -95%
Max EUT Dimensions : 100x100x100 cm^3
Max EUT Weight : 600 Kg
Altitude: up to a 30 Km (~ 1 mbar)

Left up: system in TVAC
Left down: TVAC cycle



During tests, data from all subsystems have been acquired, allowing a precise characterization of the detector behaviour under different pressure and temperature conditions.

Left up: data from the temperature probe site on the detector provided by the housekeeping
Left down: event recorded on detector at P=3 mbar and T= - 15° C