SPB2 and Mini-EUSO

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SPB2 and Mini-EUSO are part of the JEM-EUSO International Program (Joint Experiment Missions for Extreme Universe Space Observatory), a mission concept devoted to the observation and study from space of the cosmic rays at the highest energies. The main scientific objectives, the instrumentation and the observational principle of JEM-EUSO have been described in detail in previous reports.

SPB2

SPB2 (Super Pressure Balloon 2) is the project for a long duration balloon flight of the JEM-EUSO Collaboration. Following previous balloon flights (EUSO-Balloon in 2014 and EUSO-SPB1 in 2017), and taking advantage of the related technological development, this is a second generation stratospheric balloon instrument devoted to the detection of Ultra High Energy Cosmic Rays (UHECRs, $E > 1$ EeV) via the fluorescence technique and of Very High Energy (VHE, $E > 10$ PeV) neutrinos via Cherenkov emission. SPB2 is a pathfinder mission for space instruments like the proposed Probe Of Extreme Multi-Messenger Astrophysics (POEMMA). The purpose of such a space-based observatory is to measure UHECRs and UHE neutrinos with high statistics and uniform exposure. SPB2 is designed with two mirror Schmidt telescopes, each optimized for their respective observational goals. A scheme of the layout of the instrument is given in Fig.**??**.

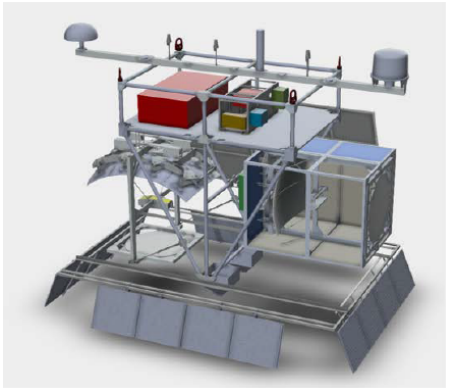

Figure 1: *Layout of the SPB2 instrument, showing the two telescopes (Fluorescence and Cherenkov) and the arrangement in the gondola of the Payload.*

The Fluorescence Telescope looks at the nadir to measure the fluorescence emission from UHECRs, while the Cherenkov Telescope is optimised for fast signals (10 ns) and points near the Earths limb. This allows for the measurement of Cherenkov light from Extensive Air Showers caused by Earth skimming VHE neutrinos if pointed slightly below the limb or from UHECRs if

observing slightly above. The expected launch date of SPB2 is Spring 2023 from Wanaka, NZ with target duration of up to 100 days. Such a flight would provide thousands of VHECR Cherenkov signals in addition to tens of UHECR fluorescence tracks. Neither of these kinds of events have been observed from either orbital or suborbital altitudes before, making SPB2 crucial to move forward towards a space based instrument. It will also enhance the understanding of potential background signals for both detection techniques. SPB2 has been approved in 2019 by the "Commissione Scientifica Nazionale II of INFN and, in 2020, by the Italian Space Agency, ASI. Agreements between INFN and ASI have been successively established. The Italian group (Bari, Catania, LNF, Napoli, Roma 2 Tor Vergata, Torino) has the full responsibility of the development of the Data Processor (DP) and CPU of the Fluorescence Telescope (FT) and of the overall Data system architecture of both telescopes. It is also developing the trigger algorithms, the on-board software and is studying a possible implementation of part of the FT Focal Surface with Silicon Photomultipliers (SiPMs). The LNF group is working in collaboration with the Roma 2 group on the development of SiPMs configurations. During the year 2021, despite the yet present Covid-19 pandemic, most of the work of the Italian group has been carried out to design and test the first prototypes of the DP, of the data flow system, of the on-board software and on the different trigger configurations, in view of the next phases of assembly and integration in Europe (mostly in France) and in the USA that will take place in 2022.

Mini-EUSO

Mini-EUSO, approved by the Russian Space Agency Roscosmos (under the name "UV-Atmosphere") and by the Italian Space Agency, ASI, has been conceived to study and measure the UV emissions from Earth and to perform studies of atmospheric phenomena, observation of meteors, strange quark matter search and space debris tracking. Launched in August 2019 to the Russian Module of the International Space Station (ISS), its main goal is to map the Earth in the UV spectrum from space. The instrument and its functionalities have been described in previous LNF Reports. Mini-EUSO is in operation and taking data since October 2019. Several astronauts, including the Italian ESA astronaut Luca Parmitano during the mission "Beyond", have operated the instrument in successive observation sessions. Part of the data is directly transmitted to ground by telemetry, while a bigger set of data (about 25 TBytes stored in 50 USB sticks) is physically brought to Earth during some of the astronauts' returning missions.

Mini-EUSO maps the Earth in the UV range ($290 - 430$ nm) with a spatial resolution of ~ 6 km and three different temporal resolutions of 2.5 μs, 320 μs, and 41 ms, respectively. Data carried down to Earth from the ISS allowed to perform the first analyses showing that Mini-EUSO observes different Earth emissions depending on the surface visible, e.g., ground, sea, or clouds as well as slow transients such as meteors (thousands of events have been identified in the data with absolute magnitude lower than +5). At shorter times scales, several hundreds of lightings (among them 17 elves) have been detected and at much shorter time scales, many anthropogenic flashes presumably related to airport lights or other flashing tower lights have been acquired. Thanks to the Mini-EUSO capability to record consecutive events, this class of events is clearly identified as they repeat themselves periodically and their location can be easily recognized thanks to the continuous data taking in slow mode (41 ms time frames).

In the preparation of the mission and of the flight instrument, the LNF group has played a key role, through the Mechanical Design and Construction Service (SPCM), responsible of the design, test, prototyping and production of all the mechanical structures and containers and of the overall Focal Surface of the Engineering/Qualification and Flight Model of Mini-EUSO. The LNF group is now participating to the quicklook control of the mission and to the analysis work that

has been carried out all over the 2021.

References

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