EUSO-SPB2 and Mini-EUSO

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EUSO-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 (UHECRs, Ultra High Energy Cosmic Rays) above $10^{19}eV$. The main scientific objectives, the instrumentation and the observational principle of JEM-EUSO have been described in detail in previous reports.

EUSO-SPB2

EUSO-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), this is a second generation stratospheric balloon instrument for the detection of Ultra High Energy Cosmic Rays (UHECRs) via the fluorescence technique and of Ultra High Energy (UHE) neutrinos via Cherenkov emission. EUSO-SPB2 is a pathfinder mission for instruments like the proposed space mission 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. EUSO-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.1.

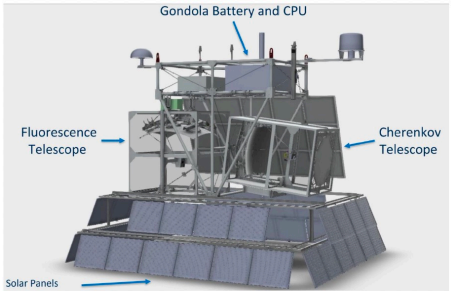

Figure 1: *Rendering of the EUSO-SPB2 instrument, showing the two telescopes (Fluorescence and Cherenkov) and the arrangement in the gondola of the Payload.*

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 UHE neutrinos if pointed slightly below the limb or from UHECRs if observing slightly above. The expected launch date of EUSO-SPB2 is Spring 2023 from Wanaka, NZ with target duration of up to 100 days. Such a flight would provide hundreds of UHECR 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 EUSO-SPB2 crucial to move forward towards a space based instrument. It will also enhance the understanding of potential background signals for both detection techniques. EUSO-SPB2 has been approved - under the name SPB2 - in 2019 by the "Commissione Scientifica Nazionale II of INFN and, in 2020, by the Italian Space Agency, ASI. An agreement for EUSO-SPB2 between ASI and INFN (Convenzione Quadro ASI-INFN-2021-8-Q.0) has been established in 2021 for a duration of five years.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 and trigger algorithms of both telescopes. It is also carrying out a program on R&D of Silicon Photomultipliers (SiPMs) for space by testing several prototypes. The LNF group is working in collaboration with the Roma 2 - Tor Vergata group on the development of different SiPMs configurations. It is also involved in the the management of the Italian Collaboration and in the activities of the Speaker's Office (publications, conferences etc.).

During the year 2022 most of the work of the Italian group has been carried out, in Europe (Italy and France) and USA, to finalise the design of the flight model of the DP and of the data flow system, of the on-board software and on the different trigger configurations. All the instruments (and the software) have been tested, qualified and integrated, and passed the final review by the NASA-CSBF (Columbia Scientific Balloon Facility) to be ready for the shipment to New Zealand.

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. The results so far obtained have shown the good functioning of the instrument and its potentialities in fulfilling the scientific objectives. In particular, several ELVES (Emission of Light and Very low frequency perturbations due to Electromagnetic pulse Sources), a particular class of lightnings, and meteors have been observed, together with other atmospheric phenomena like the TLE's (Transient Luminous Events). Space debris tracking is also in the reach of the observation program. Several UV maps of Earth have been achieved (see References) and further, more detailed processing of images is in progress.
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. During the year 2022, 28 (not consecutive) sessions of data taking have been performed, resulting in more than 130 GBytes of data (engineering and scientific). The LNF group has continued its activity into the quicklook control of the mission and the analysis work.

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