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Euso-Balloon: A pathfinder mission for the JEM-EUSO experiment

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ABSTRACT

EUSO-Balloon is a pathfinder mission for JEM-EUSO, the near-UV telescope proposed to be installed on board the ISS in 2017. The main objective of this pathfinder mission is to perform a full scale end-to-end test of all the key technologies and instrumentation of JEM-EUSO detectors and to prove the entire detection chain. EUSO-Balloon will measure the atmospheric and terrestrial UV background components, in different observational modes, fundamental for the development of the simulations. Through a series of flights performed by the French Space Agency CNES, EUSO-Balloon also has the potential to detect Extensive Air Showers (EAS) from above. EUSO-Balloon will be mounted in an unpressurized gondola of a stratospheric balloon. We will describe the instrument and the electronic system which performs instrument control and data management in such a critical environment.

1. Introduction

The Extreme Universe Space Observatory on board the International Space Station's (ISS) Japanese Experiment Module (JEM-EUSO) is a new type of observatory which observes transient luminous phenomena occurring in the Earth's atmosphere [1]. The main objective of JEM-EUSO is to investigate the nature and origin of Ultra High Energy Cosmic Rays, UHECRs ($E > 5 \times 10^{19}$ eV), which constitute the most energetic component of the cosmic radiation. The instrument is planned to be attached to JEM Exposed Facility of ISS during the first half of 2017 for a 3 years long mission.

The JEM-EUSO instrument is a wide-angle refractive telescope in the wavelength of near Ultra Violet (UV) observing fluorescence and Cherenkov photons emitted by air showers created by UHECRs in the Earth's atmosphere. It consists basically of four parts:

- Optics: three high transmittance optical Fresnel lenses (diameter of 2.35 m) focusing the arriving UV photons onto the Focal Surface (FS).
- Focal surface detector: 4936 Multi-Anode Photo-Multiplier Tubes (MAPMTs) of 64 pixels each.
- Electronics: Focal surface electronics, trigger, data acquisition and controls.
- Mechanical structure.

An Atmosphere Monitoring System (Infra Red (IR) camera and Lidar) and a calibration system complete the apparatus.

The mission consortium includes 17 countries and is lead by RIKEN (Japan), in coordination with the Japanese Space Agency (JAXA). EUSO-Balloon is developed by the JEM-EUSO consortium as a demonstrator for technologies and methods featured in the space instrument. The EUSO-Balloon mission has been proposed by a collaboration of three French laboratories (APC, IRAP and LAL) involved in the international JEM-EUSO consortium. The instrument is being built by various institutes of the JEM-EUSO collaboration. Balloon flights will be performed by the balloon division of the French Space Agency CNES. The first flight is scheduled in 2014.

2. Objectives for EUSO-Balloon

EUSO-Balloon (see Fig. 1) is a technology demonstrator for the JEM-EUSO mission, so its main goal is to demonstrate the operation of its crucial components like High Voltage system, trigger, etc. "in (worst) space environment". The instrument can perform measurement of the background, which includes star light, airglow, light from artificial sources, in the near UV region from a float altitude of about 40 km. Since JEM-EUSO is sensitive to the variation of the background sources in this UV range, this

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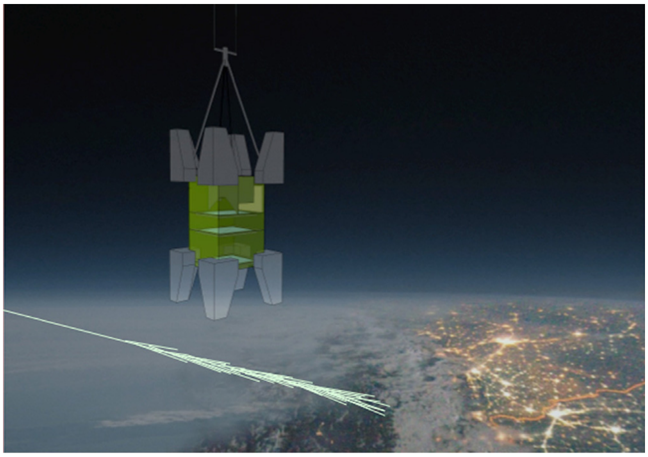

Fig. 1. Concept of the EUSO-Balloon instrument with crash pads.

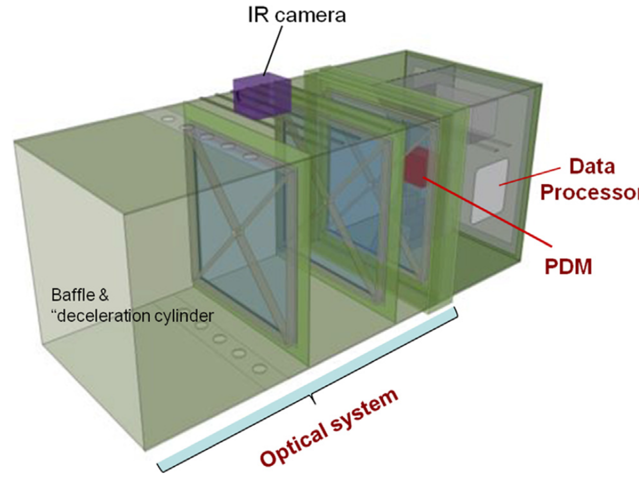

Fig. 2. A schematic view of the EUSO-Balloon telescope.

measurement is an important step for successful operation and optimization of the working mode of the JEM-EUSO mission. Finally EUSO-Balloon will be able to detect for the first time air-showers and laser induced events by looking downward from the edge of space. According to our estimation we expect to get 2–3 events/flight at energy above 10^{18} eV.

3. The EUSO-Balloon instrument

EUSO-Balloon will consist of a Fresnel optics made from 3 PMMA square lenses (UV transmitting Polymethyl-Methacrylate), a focal plane detector made from a single PDM (Photo-Detector Module) and a Data Processor (see Fig. 2).

The balloon-borne instrument points toward the Nadir monitoring a $12^\circ \times 12^\circ$ wide Field Of View (FOV) in a wavelength range between 290 and 430 nm, at a rate of 4×10^5 frames/s. The FOV will be resolved into 2304 pixels. The pixel size in the FOV is $0.25^\circ \times 0.25^\circ$ corresponding to 175 m × 175 m on the ground, for a float level of 40 km. In order to monitor the actual cloud covers, a co-aligned IR camera will observe the FOV of the main instrument [2].

The UV light collected by the optical system is detected by the MAPMTs of the PDM. The PDM is mounted on a translation stage inside the telescope to adjust its position along the *z*-axis. Besides monitoring the UV background, the PDM detects candidate shower events by the first-level trigger implemented in the PDM-board. Data acquired by the PDM are transferred via the PDM-board to the DP component which performs data management and storage, instrument control and commanding.

The telescope is composed of a self-contained, watertight instrument booth containing PDM, electronics, telemetry and an optics module serving as optical bench for the lenses. The structure of both the instrument booth and the optics module is made of 10 mm "Fibrelam" aerospace panels. The total weight of structure, instrument, dedicated electronics, telemetry system and batteries is around 250 kg.

4. Instruments sub-systems

The three main components of the instrument, the Optical System, the PDM and the DP are, in turn, divided into several subsystems. A block diagram of the instrument summarizing the subsystems, and the main sub-assembly items are shown in Fig. 3.

In what follows we will describe the three main components and their sub-assembly items in more detail.

4.1. Optical system

The optical system focuses the incoming UV photon toward a pixel of the detector on the optical focal surface. The FOV of the optics is $12^\circ \times 12^\circ$. A 1 m long baffle defines an Entrance Pupil Diameter, the aperture of the optical system is 1 m × 1 m. The distance between the front surface of the front lens and the focal surface is 1620.7 mm. Each lens has a 1 m^2 square surface, a thickness of 8 mm and a weight of 9.6 kg. The 1st and 3rd lenses are Fresnel lenses, the 2nd lens is a diffractive lens.

4.2. Photo-Detector Module

The PDM is composed of 36 MAPMTs, containing 64 anodes each, equipped with UV filters and their associated electronic chain. A schematic view of the PDM is shown in Fig. 4. On the mechanical structure the MAPMTs are grouped into 9 Elementary Cells (EC) which supply the 14 voltages needed for each MAPMT and collect the signals from their anodes. These signals are transmitted to the SPACIROC ASIC [3] for processing. The output signals of all the ASICs are delivered to the PDM board [4]. The PDM is equipped with two High Voltage Power Supplies (HVPS) (based on a Cockroft–Walton design) providing the necessary voltages to the MAPMT dynodes. To cope with strong light signals (the dynamic scale of the signal ranges from 1 to 10^6), the HVPS are provided with switches that can modify the voltage between the cathode and the first dynode reducing the electron flux reaching the anodes of the MAPMTs.

4.2.1. Photomultipliers and filters

MAPMTs are the photo-detectors that sense the UV photons arriving through the lenses. A color glass filter "SCHOTT BG3", which transmits the UV photons and absorbs the visible light, is glued on each MAPMT. The MAPMTs are manufactured by Hamamatsu and have been developed specifically for the JEM-EUSO mission. The MAPMT has a maximum sensitive area of 23.04 mm × 23.04 mm, a quantum efficiency greater than 35% and a cross talk of about 1%.

4.2.2. ASICs

The ASIC (Spaciroc) has been designed by Omega group at LAL in AMS 0.35 μm SiGe technology. It reads out the MAPMT anode