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EUSO-BALLOON
a pathfinder for detecting UHECR's from the edge of space

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Abstract. EUSO-Balloon has been conceived as a pathfinder mission for JEM-EUSO, to perform an end-to-end test of the subsystems and components, and to prove the global detection chain while improving our knowledge of the atmospheric and terrestrial UV background. Through a series of stratospheric balloon flights performed by the French Space Agency CNES, EUSO-BALLOON will serve as an evolutive test-bench for all the key technologies of JEM-EUSO. EUSO-Balloon also has the potential to detect Extensive Air Showers from above, marking a key milestone in the development of UHECR science, and paving the way for any future large scale, space-based UHECR observatory.

1. CONTEXT OF THE MISSION

EUSO-BALLOON is a test-bench for JEM-EUSO, the Extreme Universe Space Observatory on-board the Japanese Experiment Module of the International Space Station (ISS). JEM-EUSO is designed to

Figure 1. Concept of the instrument/gondola with floater/crash pads during a first flight (nadir pointing).

identify the astrophysical origin and nature of the ultra high-energy cosmic rays (UHECRs), the most energetic particles known in the Universe. JEM-EUSO will monitor a gigantic detection volume by looking downward to the Earth's atmosphere from the ISS, observing the UV fluorescence light of UHECR-induced Extensive Air Showers (EAS). The two ton space instrument features Fresnel optics with a large field of view ($\pm 30^\circ$), and a focal detector surface of $\sim$5000 multi-anode photomultipliers – i.e. more than 300 000 pixels. The mission consortium includes 13 countries and is lead by RIKEN (Japan), in coordination with the Japanese space agency (JAXA). A comprehensive description of JEM-EUSO is given by [1] Santangelo (2012).

EUSO-BALLOON is developed by the JEM-EUSO consortium as a demonstrator for the technologies and methods featured in the space instrument. Since the JEM-EUSO's observation of UHECR-induced EAS is based on the detection of an UV light track (fluorescence emission of Nitrogen molecules excited by collisions with shower particles), EUSO-BALLOON is an imaging UV telescope as well. The balloon-borne instrument points towards the Nadir from a float altitude of about 40 km. With its Fresnel Optics and Photo-Detector Module, the instrument monitors a $12 \times 12^\circ$ wide field of view in a wavelength range between 290 and 430 nm, at a rate of 400′000 frames/sec. 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 presently built by various institutes of the entire JEM-EUSO collaboration. Balloon flights will be performed by the balloon division of the French Space Agency CNES, a first flight is scheduled in 2014.

2. OBJECTIVES OF THE BALLOON FLIGHTS

EUSO-BALLOON will serve as an evolutive test-bench for the JEM-EUSO mission as well as any future mission dedicated to the observation of extensive air shower from space. The following objectives shall be attained in a series of balloon flights:

A) Technology demonstrator

EUSO-BALLOON is a full scale end-to-end test of all the key technologies and instrumentation of JEM-EUSO. Particularly, crucial issues that will benefit from the balloon flights include the HV power supplies, the HV switches (HV relays commuting the HV in case a city or a bright atmospheric event comes into the FOV and on a pixel), the Front-End Electronics (including the ASICs and FPGA), the

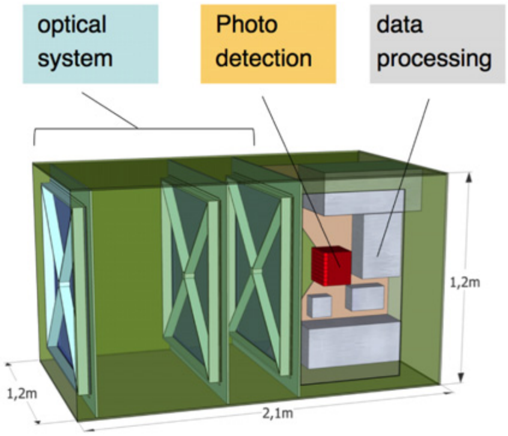

Figure 2. Schematic view of the instrument, its three main subsystems in a watertight telescope envelope.

on-board hardware and software algorithms involved in the triggering and recognition of cosmic-ray initiated air showers.

B) Data acquisition and background study

Although the physics and the detection technique is well established and daily used in ground detectors, the observation of an Extended Air Shower (EAS) from space through the Ultraviolet (UV) light emission has never been performed previously. Observation of EAS from space for the first time will confirm the feasibility of the technique and provide valuable data for all future space-borne UHECR experiments.

Since JEM-EUSO uses the Earth's atmosphere to observe UV (300–400 nm) fluorescence tracks and Cherenkov reflections from EAS, the instrument is sensitive to the variation of the background sources in the UV range. Measuring the background light / airglow in the near UV region is therefore an important goal to successful operation and optimization of the working mode of the JEM-EUSO mission.

The main objectives are thus:

- experimental confirmation of the effective background below 40 km observed with a pixel size on ground representative for JEM-EUSO (175 m in our $+/-6$ deg FoV).
- acquisition of 2.5 microsecond frames of UV signal and background (in a format similar to JEM-EUSO) from a balloon-borne gondola.
- testing of the observational modes and switching algorithms.
- testing/optimization of the trigger algorithms with real observations and changing background.
- testing/optimization of the trigger algorithms with real observations above various ground surfaces.
- testing of the acquisition capability of the camera.

C) Precursor mission

Although a number of background measurements have been performed, even from space, no focusing instruments have been employed so far and, most importantly, spatial resolutions were extremely low, i.e the "pixel size" was much larger. Large localized background signals could have been washed out by the integration over a large surface, and likewise, possible temporal variations on small scales were not known/constrained. It is therefore important to better understand the background in the same conditions as JEM-EUSO will experience.

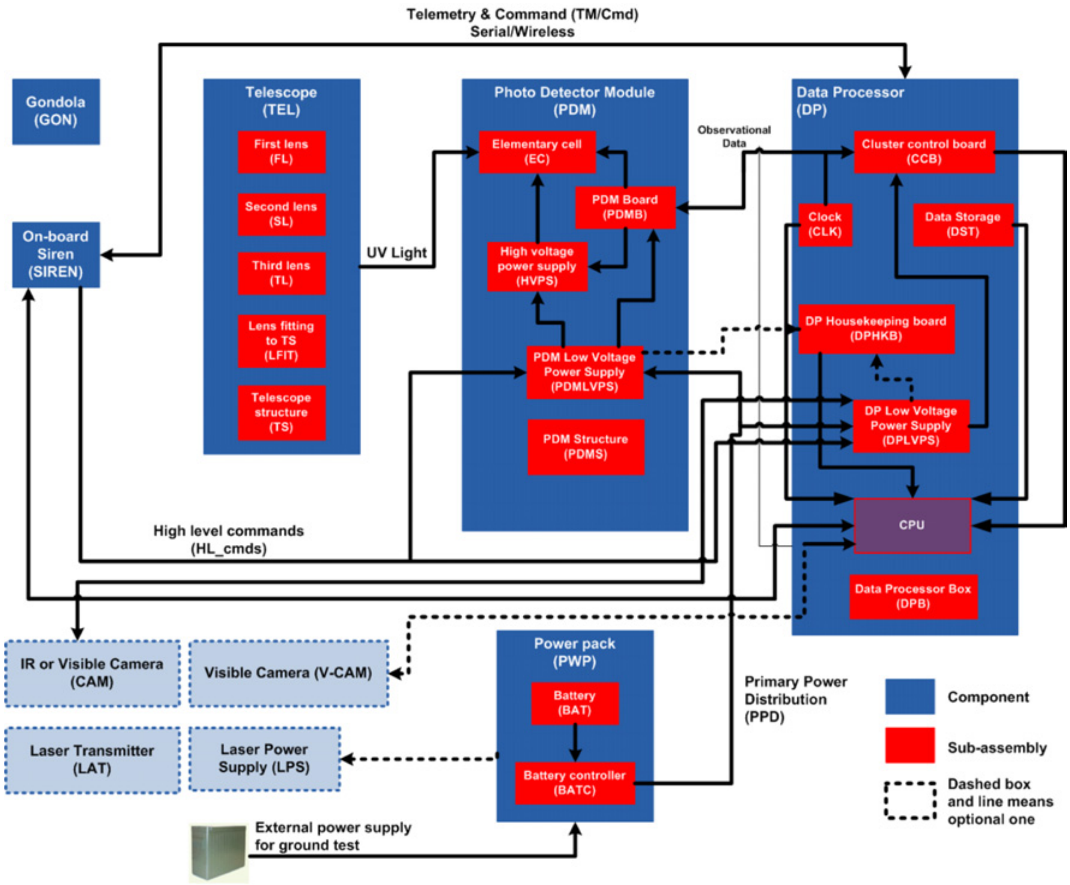

Figure 3. Functional Block Diagram of the EUSO-Balloon Instrument.

- detection of air-showers by looking downward from the edge of space.
- detection of laser induced events from space.

According to our estimation we expect to get 0.2–0.3 events/night(10 h) at $E > 2.1.10^{18}$ eV, this threshold energy arising from the background value measured by [2] Sakaki et al. 2005.

3. PAYLOAD OVERVIEW

EUSO-BALLOON will consist of a focal plane detector made from a single PDM (Photo-Detector Module) and a Fresnel Optics made from 3 PMMA square lenses (UV transmitting polymethyl-methacrylate). The PDM is composed of 36 multi-anode photomultipliers (MAPMT) containing 64 anodes each, with associated ASICS, HV and HV switches. This 15 cm × 15 cm focal plane together with the 100 cm × 100 cm Fresnel lenses provide a field of view of $\pm 6^{\circ}$ that will be resolved into 2304 pixels. Integrating one of the Fresnel lenses as a port-hole window directly into the telescope structure will make the electronics compartment (with its crucial payload elements such as the PDM) entirely water tight without moving parts and will permit offshore recovery (later, possibly long duration balloon flights).

A block diagram of the entire instrument, summarizing all subsystems and components is shown in Fig. 3, while Fig. 4 displays schematic views of the PDM. The UV light collected by the telescope

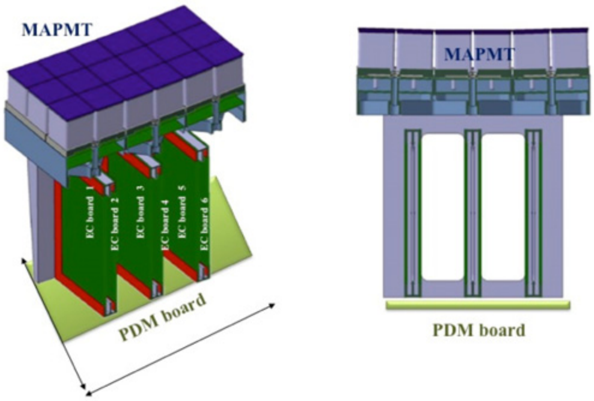

Figure 4. Schematic view of the Photo-Detector Module (PDM) : the MAPMTs are covered with UV filters; four MAPMT's form an Elementary Cell (EC). The PDM includes 9 ECs, 6 EC-boards and a PDM board.

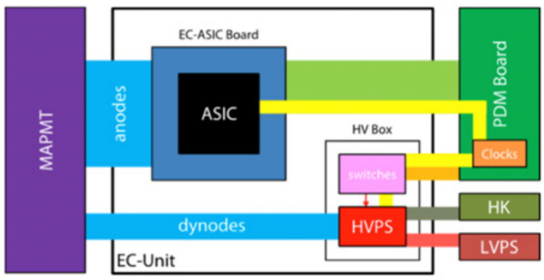

Figure 5. Block diagram of the main PDM components : The PDM board receives the clock from a Cluster Control Board (CCB, not shown here) and distributes it to the PDM electronics.

is focused onto and detected by the PDM. Besides monitoring the UV background, the PDM detects candidate shower events by the first trigger implemented in the PDM-board. In the EUSO Balloon mission a full PDM is implemented to demonstrate the viability of the prototype developed for the JEM-EUSO mission.

Data acquired by the PDM is transferred via the PDM-board to the DP component. The PDM requires a dedicated data transfer interface: the Cluster Control Board (CCB), already developed for the JEM-EUSO mission is therefore utilized in the EUSO Balloon mission. Other components and sub-assembly items are coherently developed based on similar JEM-EUSO components and sub-assemblies.

The basic data processing chain of JEM-EUSO, as shown in Figure 5, is implemented in the EUSO Balloon mission. Data from the CCB are transferred to the CPU, which controls the instrument and interfaces telemetry. The CPU manages a disk for on-board storage and the collection of housekeeping data from a dedicated Housekeeping board. Power supplies complete the DP component. All major elements are implemented according to the requirements of the EUSO Balloon Instrument.

During a first flight the payload will operate in nadir pointing mode, the spin rate will be determined by the natural azimuthal oscillations of the flight train. For later flights, the inclination of the pointing axis will be controlled between 0 and 30° w/r to the nadir and an azimuth motor will provide the possibility to perform revolutions with a spin rate of up to 3 rpm. Performing azimuthal revolutions will simulate a groundspeed comparable to the ∼7 km/s of the space-station, permitting a full scale test of the HV-switches : switching MAPMT voltages on/off within a few microseconds, as artificial and other light sources cross the field of view of the instrument.

Table 1. The EUSO-Balloon collaboration: Responsibilities in the procurement and delivery of the various components of the EUSO Balloon instrument.

Component	Sub-Assembly	Lab / University	Country
Telescope	Fresnel Lenses	RIKEN	Japan
	Lens Fitting	IRAP	France
	Telescope Structure		
PDM	PhotoMultiplier	RIKEN	Japan
	ASIC	LAL	France
	Elementary Cell	LAL/KIT	France / Germany
	HV Power Supply + Switches	NCBJ / APC	Poland France
	PDM Board	EWHA	South Korea
	PDM Low Power Supply	UNAM	Mexico
	PDM Structure	INFN Frascati	Italy
Digital processor	CCB Data Processor	IAAT	Germany
	Main processing unit	INFN Napoli	Italy
	Data Storage		
	Clock Generator		
	House Keeping Board	UNAM	Mexico
	Low Voltage Power Supply	UNAM	Mexico
Battery / Controller	Battery Controller	RIKEN	Japan
	Battery		
IR-CAM	IR Camera	UAH	SPAIN

In order to monitor the actual cloud covers, a co-aligned IR camera will observe the field of view of the main instrument [3]. A possible option to create signal-type events is to use an on-board laser for simulating air-showers within the field of view.

4. PROJECT ORGANIZATION

Since the EUSO-Balloon instrument is identical (PDM, trigger…) or similar (lenses…) to the JEM-EUSO instrument, the relevant institutions and international partners within the JEM-EUSO collaboration contribute to the instrument according to their corresponding tasks and responsibilities in JEM-EUSO, under the management and responsibility of the French team, which acts in coordination with the JEM-EUSO management (Table 1). The French Space Agency CNES is in charge of the EUSO-Balloon project and supervises the instrument deployment.

We acknowledge strong support from the French Space Agency CNES.

References

[1] Santangelo, A., 2012, this conference
[2] Sakaki, N. et al., 2005, Proc. 30th ICRC **5**, p. 965
[3] Rodriguez Frias, M.D., 2012, this conference