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EUSO - Extreme Universe Space Observatory: General assembly and ISS accommodation.

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Abstract. To extend our knowledge on the origin of the highest energy cosmic rays and our understanding of particle interactions for $E>10^{20}$ eV, we need the use of a detector with an effective area many times that of the today operative or planned experiments. The Extreme Universe Space Observatory - EUSO meets this requirement and is the first experiment using the observation from a space-platform of the Earth atmosphere, which behaves like an active detector for these extreme energy primary events. The EUSO telescope images the air fluorescence of the Extensive Air Showers produced by primary particles penetrating the Earth atmosphere as the UV light progresses down through the atmosphere. EUSO will observe this UV fluorescence signal looking downward from the ISS (about 400 km altitude) the dark Earth atmosphere under a 60 degrees full field of view; the fluorescence light will be imaged by a large Fresnel lens optics into a finely segmented focal plane detector. The segmentation and the time resolution adopted will allow reconstructing the shower arrival direction and energy with high precision.

1 Introduction

The scientific importance of the EUSO mission and its impact on the Cosmic Ray (CR) and Neutrino physics has been already described by Scarsi et al. (2000,2001) and Andresen et al. (2000). In this paper we would like to summarise the main characteristics of the EUSO instrument that has to be accommodated as external payload on the European Columbus module of the International Space Station (ISS). The EUSO experiment has been selected by March 2000 by the European Space Agency and it is currently under phase A study (instrument's conceptual study and payload accommodation).

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The EUSO instrument, named "telescope" from now on, has been conceived as a monocular compact telescope, capable of detecting the UV fluorescence light signals (in the wavelength band of 300-400 nm) from EAS (Extensive Air Shower) of Energy > 3×10^{19} eV produced by the primary particles impinging on the earth atmosphere. The telescope will be oriented to the nadir looking to the nocturnal side of the earth. From a distance of ~ 400 km, averaged orbit altitude of the ISS, the EUSO telescope will detect EECR (Extreme Energy Cosmic Ray), high energy Neutrinos, and atmospheric events taking advantage of the vast geometrical factor (~ 500 km^2 sr) obtained with the envisaged telescope configuration and location altitude (space platform) proposed. The telescope design is the outcome of a close synergy between optics, focal surface detector and system electronics that govern the entire system.

Optics of very wide field of view (60°) and large collection area (2.5 m^2) has been designed using Fresnel lens technology.

UV detector has been selected to meet the requirements imposed by the project as pixel size, fast response time and gain as well as limited dimensions and weight.

The detection of the faint fluorescence signals has been accomplished adopting a method based on the single photoncounting and fast timing technique. The EUSO system electronics has been designed making the most of the method adopted.

2 The EUSO telescope assembly

Figure 1 shows an exploded artistic view of the telescope. In the following we briefly describe the characteristics of the main parts of the telescope (optics, focal surface photo-detector and system electronics); a more detailed description can be found in Catalano (2001).

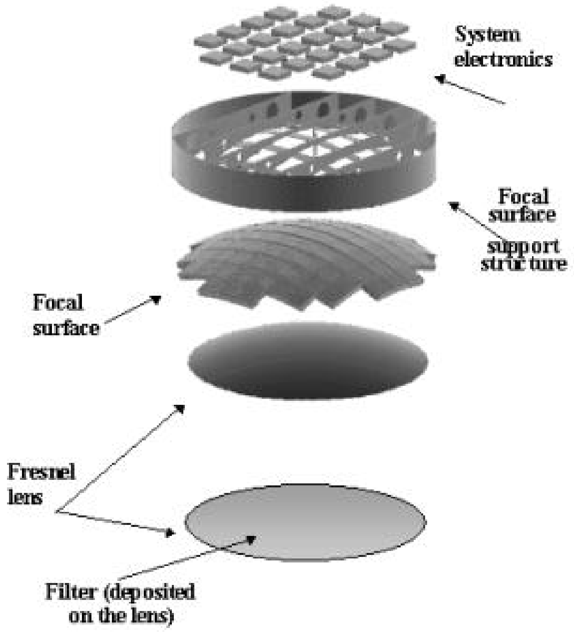

Fig. 1. Exploded artistic view of the EUSO telescope.

2.1 The Optics

Fresnel lenses are the optics elements that, in the configuration shown in figure 2, fulfill the imaging requirements of the EUSO telescope. An angular resolution of 0.1° and a full Field of View of 60° are the operational characteristics of the lens.

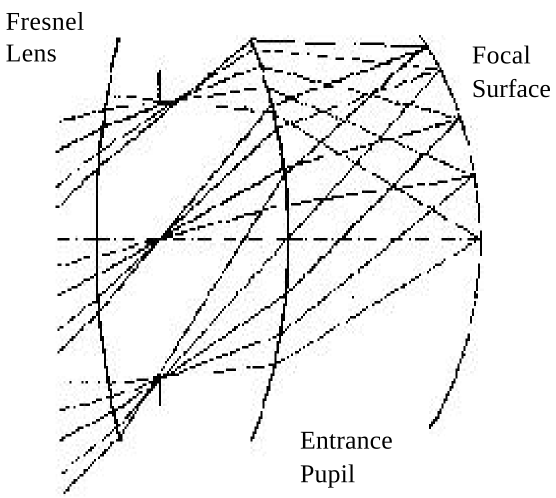

Fig. 2. Ray tracing of doubled curved Fresnel lens focusing the light on the curved focal surface.

To limit the dimension of the focal surface photo-detector, an f number (f/#) close to 1 has been adopted for the lens system. The pixel size at the focal surface, corresponding to the spot size diameter, is determined by the effective focal length and resolution required by the optical system. The required angular resolution θ of ≈0.1° (corresponding to a ground spatial resolution of 0.8 km) yields the pixel diameter at about 5 mm. The total number of pixels, with this configuration, will be of the order of 2 x 10^5. A band-pass filter in the wavelength comprises from 300 to 400 nm is required to prevent light of undesirable wavelengths from reaching the focal surface. A cover mechanism as a shutter or an iris, will be installed on the lens side to protect the optics elements and the focal surface in the diurnal orbit phase, when reflected/diffused light is more effective, and from the pollution produced during the scheduled periodic Shuttle docking on the ISS.

2.2 The Focal Surface Photo-Detector

A couple of commercial multi-anode photomultiplier manufactured by Hamamatsu (1999), series R7600-M64 (M16), meets closely the requirements concerning the pixel size, gain, fast response time and low weight and small dimension. At the end of the phase A study one of them will be adopted for the final design. These devices exhibit a very low cross talk of the order of 2% and good response gain uniformity. The phototube is equipped with a bi-alkali photocatode and an UV transmitting window that assure an average Quantum Efficiency of 20% in the wavelength of interest. A segmented focal surface has been preferred to adapt the detector units to the curved focal surface.

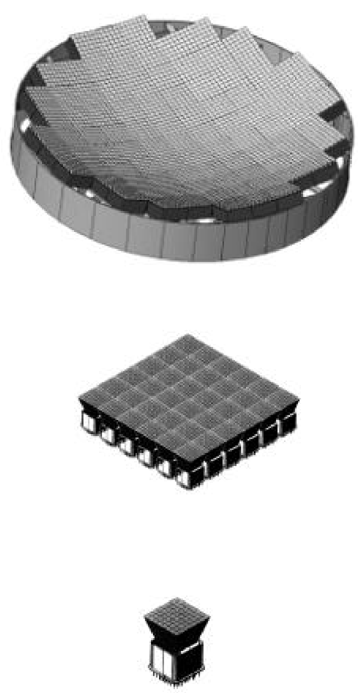

Fig. 3. Schematic representation of photomultiplier + light collector (bottom), macrocell (middle), focal surface photo-detector (top).

The focal surface is constituted by about 100 “macrocells” where as baseline the macrocell is formed by 6x6 multi-anode photomultipliers. The multi-anode photomultiplier is organized in an array of 8x8 (or 4x4) pixels of 2 mm (4mm) size each. Due to the geometrical dead area of the multi-anode photomultiplier of about 50% a suitable light collector system is needed to uniform the collecting area of the focal surface photo-detector. This might be either a lens system, or a system made of a bundle of tapered light pipes, working either by total internal reflection inside plastic pipes or by normal reflection inside empty pipes. The lens could be one-single thick plane-convex hemispherical lens, with the curved surface facing the incident light and whose flat surface is placed in contact with the input window of the multi-anode photomultiplier and coincident with the focal surface of the optics. Exhaustive information on the focal surface detector characteristics can be found in Ameri et al. (2001). A representation of the main components constituting the focal surface photo-detector is shown in figure 3. This representation is far to be the final configuration of the focal surface, but it is useful in the contest to the reader for a better comprehension. A substantial effort is currently in progress to define and improve the most important operational parameters as power consuming, focal surface geometry, light collecting system and the overall geometrical acceptance.

2.3 The System Electronics

The System Electronics is in charge of governing the operations of the telescope. In particular its main functions are:

- Convert the analog signals from the photo-detectors to suitable digital signals;
- Manage the digital signals at level of macrocell, store them in ring memories and provide a macrocell trigger;
- Receive and elaborate the macocell triggers to form a system trigger;

The functions above mentioned are schematically detailed in the block diagram of figure 4: following the scheme from top to bottom, four operational levels can be identified:

PMT-Level: UV photons create a photoelectron that in turn by avalanche multiplication forms an analog pulse at the anode of the photomultiplier.

Pixel Front-End Level: If the analog threshold is exceeded, the fast comparator generates a fast pulse: the pulse is counted by a pixel-level counter and compared with a pre-set value n_thr. If the pre-set counter value is reached within a given GTU (Gate Time Unit) the X,Y lines of the Wired-Ored pixels are marked into the X,Y ring memories, and the pulse counting output is enabled during the remaining GTU. At this stage statistical noise (background) at pixel level is mostly eliminated.

Macrocell-Level: the pulses coming from the enabled pixels are counted at macrocell level, together with the pulses coming from all the other enabled pixels and compared with a pre-set value m_thr. If the pre-set counter value is reached within a given GTU then a macrocell-level trigger is issued lasting until the end of the GTU. At this stage statistical noise at macrocell level is eliminated.

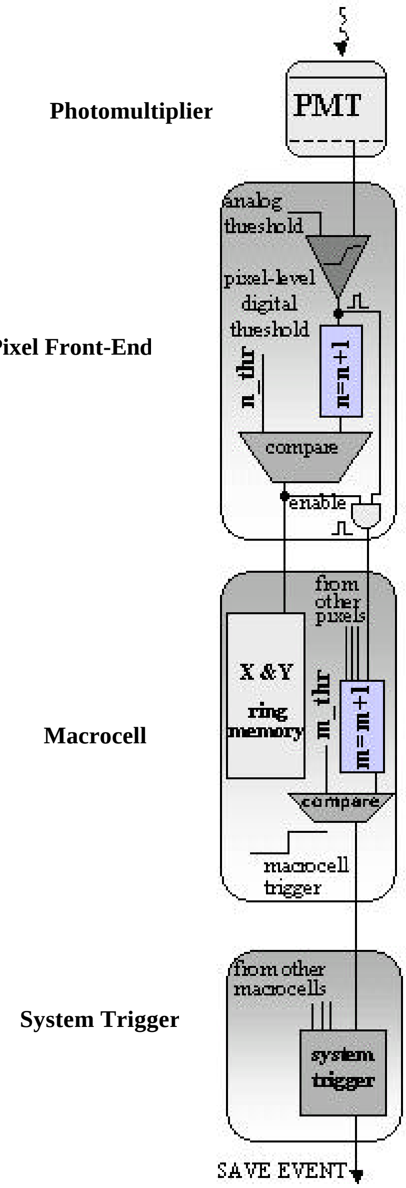

Fig.4. Functional block diagram of the EUSO system electronics.

System Trigger-Level: The system trigger continuously monitors the macrocell-trigger signal activity for valuable patterns (e.g. persistency of activity on one or more macrocells). The system trigger is software re-configurable for maximum flexibility in the trigger operations. If the given software criteria (track length persistency) for a valuable pattern are met, the system trigger issues a Save Event command in order to start the data read-out sequence. The data acquisition goes on for a pre-set time (exposure time) then stops and the relevant memories are downloaded. A more detailed explanation of the EUSO system electronics can be found in Catalano (2001).

4 EUSO accommodation on ISS

Accommodation of EUSO on the ISS is foreseen starting from 2007. Due to the size of the EUSO telescope a dedicated structure is needed to contain the instrument and to interface it directly with the Shuttle Orbiter payload bay. Specific mechanical interface will allow the docking of the telescope on the External Payload Facility of the Columbus module (CEPF) as shown in figure 5.

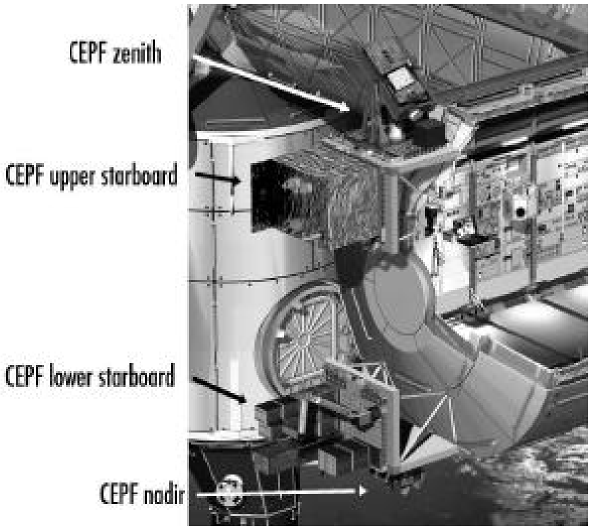

Fig. 5. An artist's impression of the CEPF on a cutaway view of the Columbus module. The four positions are indicated, and typical payloads are shown.

With the aid of the ISS and Shuttle mechanical arms EUSO will be accommodated at the location imposed by the European Space Agency for this category of experiment. The total electrical power available to CEPF payloads is 2.5 kW, with this level of power being available at any one location if desired. EUSO requires half of this power for a total of 1.25 kW. A factor to be considered is the ability to dissipate energy at reasonable temperatures for these types of external payloads. In a similar way to electrical power, data flows to and from CEPF payloads will be available at the Columbus location. The required FOV of EUSO is a 60° acceptance angle, with the axis looking at the Nadir. In this acceptance angle and from the proposed lower starboard CEPF location, no ISS hardware impinges. That is to say that there are no occultations of the field of view, fixed or variable, for the nadir viewing direction.

EUSO requires a minimum duration transportation phase, a staytime of three years, and a minimum time return phase. Figure 6 shows EUSO installed on the Columbus module.

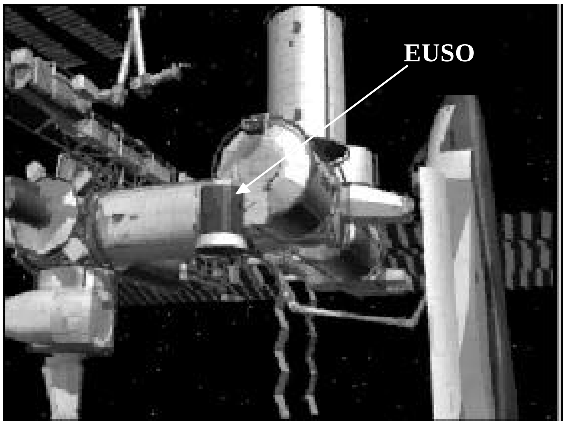

Fig. 6. EUSO on **ISS**.

5 Conclusion

EUSO is surely a challenging project and many efforts have to be done for the completion of the telescope. European Space Agency that currently supports EUSO for the phase A study is in charge for the accommodation and management of the experiment. We expect in the next years a more massive activity on the project aiming to enucleate and resolve the technical critical points that always arise from such a big project like EUSO is. As members of the EUSO team our wish is to bring EUSO on the ISS and make it operative in a short time.

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