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The focal surface of the JEM-EUSO instrument

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Abstract. The Extreme Universe Space Observatory on JEM/EF (JEM-EUSO) is a space mission to study extremely high-energy cosmic rays. The JEM-EUSO instrument is a wide-angle refractive telescope in the near-ultraviolet wavelength region which will be mounted to the International Space Station. Its goal is to measure time-resolved fluorescence images of extensive air showers in the atmosphere. In this paper we describe in detail the main features and technological aspects of the focal surface of the instrument. The JEM-EUSO focal surface is a spherically curved surface, with an area of about 4.5 m^2. The focal surface detector is made of more than 5 000 multi-anode photomultipliers (MAPMTs). Current baseline is Hamamatsu R11265-03-M64. The approach to the focal surface detector is highly modular. Photo-Detector-Modules (PDM) are the basic units that drive the mechanical structure and data acquisition. Each PDM consists of 9 Elementary Cells (ECs). The EC, which is the basic unit of the MAPMT support structure and of the front-end electronics, contains 4 units of MAPMTs. In total, about 1 200 ECs or about 150 PDMs are arranged on the whole of the focal surface of JEM-EUSO.

1 Introduction

The Extreme Universe Space Observatory on JEM/EF (JEM-EUSO) is a space mission to study extremely high-energy cosmic rays (Takahashi et al., 2009). The JEM-EUSO instrument is a wide-angle refractive telescope in the near-ultraviolet wavelength region which will be mounted to the International Space Station. Its goal is to measure time-resolved fluorescence images of extensive air showers in the atmosphere. The focal surface is a spherically curved surface, and its area amounts to about 4.5 m^2.

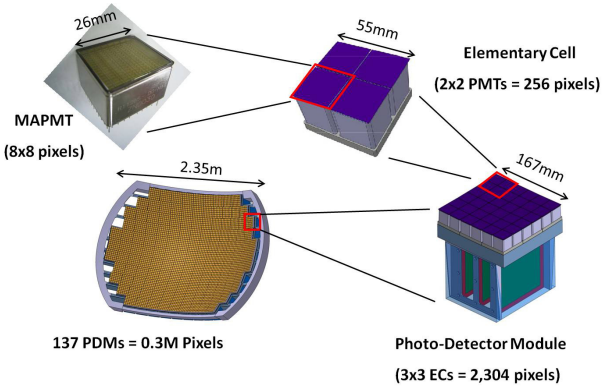

Fig. 1. JEM-EUSO Focal Surface

2 JEM-EUSO Focal Surface

The Focal Surface (FS) of JEM-EUSO has a curved surface of about 2.35 m in diameter, and it is covered with about 5 000 Multi-Anode Photomultipliers Tubes, MAPMTs, (Hamamatsu R11265-M64). It makes $\pm 30°$ FOV and 0.07° angular resolution. The FS detector consists of Photo-Detector Modules (PDM), each of which consists of 9 Elementary Cells (EC) arranged in an array of 3×3. About 1 233 ECs, corresponding to about 137 PDMs, are arranged on the whole FS (Fig. 1).

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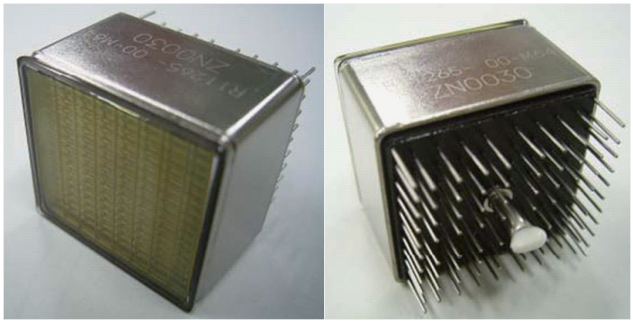

Fig. 2. The MAPMT for the JEM-EUSO photo-detector (R11265-03-M64)

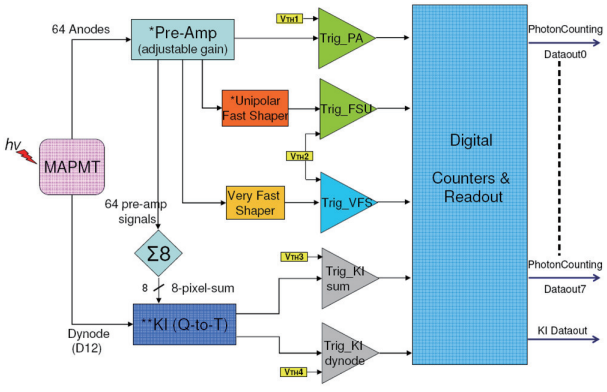

Fig. 3. SPACIROC Block diagram and Layout

3 Photo-detector

JEM-EUSO is a photon-hungry experiment; its expected photon ratio is < 100 photons/μsec/pixel. And its FS detector should have high detection efficiency. The FS detector should have single photon counting capability in the near-ultraviolet wavelength region to avoid the systematic errors, which may be introduced through the gain drift. It should be reliably and stably operational in Space environment for at least 3 or 5 years mission period. For the above reason, MAPMTs with UV-glass entrance window are employed as sensors of the FS detector.

Present baseline choice is the Hamamatsu R11265-03-M64 (see Fig. 2), which was developed by RIKEN in collaboration with Hamamatsu Photonics K.K. It has an ultra-bialkali photo-cathode, which transforms photons into electrons, and amplifies photo-electrons by means of a stack of metal channel dynodes. The signals are taken from the anode which is formatted as an array of 8×8. The photon detection efficiency of this is about 0.3 in the near-ultraviolet wavelength region.

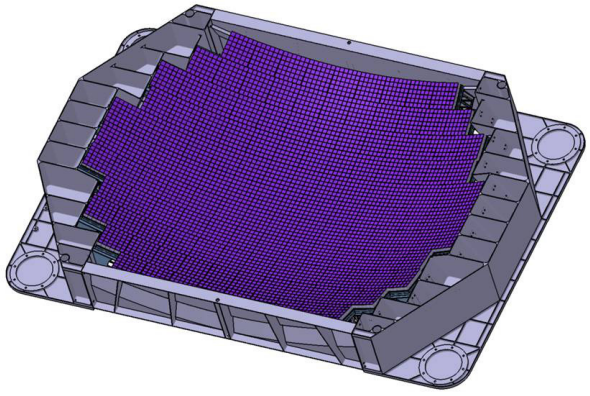

Fig. 4. Focal Surface Assembly

4 Elementary Cell

The Elementary Cell (EC) is the most basic module in the electronics systems of JEM-EUSO. This module will house 4 units of MAPMTs along with its 4 dedicated Front End ASICs. By regrouping 9 ECs, it will form a bigger subsystem which is known as Photo-Detector Module (PDM). The JEM-EUSO Front-End ASIC, named SPACIROC (Ahmad et al., 2010), which stands for Spatial Photomultiplier Array Counting and Integrating ReadOut Chip, is designed for the readout of 64-channel MAPMTs. Its purpose is to perform a counting of the detected photons and a charge to time (Q-to-T) conversion. The basic Scheme of the ASIC is shown in Fig. 3. It has 64 inputs dedicated to each single anode of one MAPMT and 1 input for its last dynode. The photon counting is carried out independently for each one of the 64 channels while the Q-to-T conversion is performed for the sum of 8 channels and the last dynode. The output of the photon counting discriminators and the Q-to-T comparators are then processed by the digital part of the ASIC composed of a set of counters. The first version of this chip (see layout given by Fig. 3) has been developed. The chip dimensions are 4.6 mm $\times$ 4.1 mm (19 mm^2).

5 Focal Surface Mechanical Structure

The FS of JEM-EUSO is composed of a grid of $\sim$5000 MAPMTs arranged in modular support structures, EC and PDM, that cover all the surface to collect the light of the optical system.

The FS is a portion of a sphere of radius 2 785 mm, inserted within an in-plane section 2 650 mm $\times$ 1 900 mm (allowed by the HTV Exposed Pallet dimensions). We have studied the FS geometry and analyzed different PDMs distributions in order to maximize their number within the allocated space. The adopted configuration consists of a total of 137 PDMs lying in 11 rows along the parallels of the

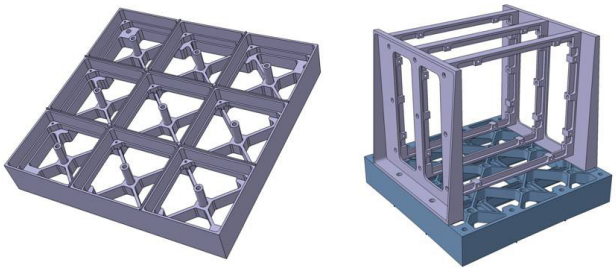

Fig. 5. PDM mechanical structure

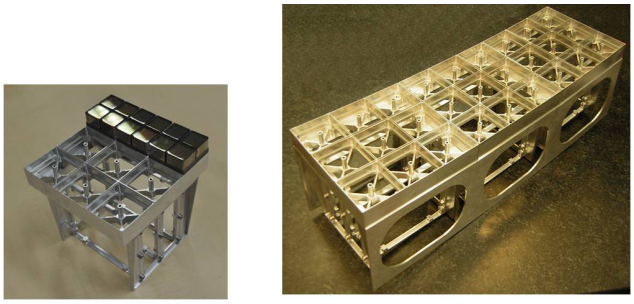

Fig. 6. Prototype of the PDM with 3 ECs and FS sector prototype (3 PDMs)

mentioned sphere, with one PDM located at the center of the FS geometry as shown in Fig. 4. The FS main structure is an assembled structure, composed by 2 head Master Frames, connected by 2 Side Frames and 10 supporting "Ribs" lying along the parallels of the FS sphere. This supports the PDM within the optical positional tolerance of 2.5 mm.

The mechanical structure of a PDM is designed in order to place the 9 ECs on a spherical surface (radius 2 805 mm) in the same way as for the overall geometry. The frame on which the ECs are positioned presents quite a complex shape and s built by machining a single aluminum alloy piece (Fig. 5). This frame, besides allocating the ECs, is rigidly connected to the main FS structure, contributing to the overall rigidity and strength. Each EC base can accommodate MAPMTs and the Front-End electronics board, while the PDM layout is completed by 5 aluminum alloy frames supporting 6 electronic boards: PDM trigger electronics boards, High Voltage board, Power Distribution board. The total mass of each PDM mechanics is 0.624 kg.

Besides design, simulations and FEM studies, real prototypes of the PDM modular structure have been produced. The mechanics of few complete PDMs was realized in aluminum alloy (6 000 Series, Alcoa Mic-6). In particular, a sector of 3 PDMs has been worked out in order to test the assembly procedure on the main structure and to check any possible issue due to curvature (Fig. 6).

6 Conclusions

We have developed a very large area photodetector system for the JEM-EUSO focal surface, based on the Photo Detector Module. We will start to build the full system when the JEM-EUSO mission is started.

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References

Ahmad, S., Barrillon, P., Blin-Bondil, S., Dagoret-Campagne, s., de La Taille, C., Dulucq, F., Kawasaki Y., and Hirokazu, I.: SPACIROC: a rad-hard front-end readout chip for the JEM-EUSO telescope, 2010 JINST 5 C12012, doi: 10.1088/1748-0221/5/12/C12012, 2010.

Takahashi, Y. and the JEM-EUSO Collaboration: New J. Phys., 11, 065009, doi: 10.1088/1367-2630/11/6/065009, 2009.