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A Multi-Level Triggering System for the Mini-EUSO UV Telescope

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Mini-EUSO is a telescope and detector designed by the JEM-EUSO Collaboration to observe the UV emission of the Earth from the vantage point of the International Space Station (ISS) in an Earth orbit of around 400 Km. The main goal of the mission is to map the Earth in the UV, thus increasing the technological readiness level of future EUSO experiments and to lay the basis for the detection of Extreme Energy Cosmic Rays from space.
This article introduces the motivation behind the Mini-EUSO multi-level trigger idea, details the readout hardware chain and reports test results on the trigger logic.

Summary

The Mini-EUSO instrument is an experiment by the JEM-EUSO Collaboration and approved by both, the Russian (Roscosmos) and Italian (ASI) space agencies. This telescope will be launched to the Zvezda module of the ISS, where it will look down to the Earth from a nadir-facing, UV-transparent window.
Mini-EUSO aims to be a pathfinder mission for a future space-based detector aiming to detect the fluorescence and Cherenkov light produced by Extreme Energy Cosmic Rays (EECR) atmospheric showers. The scientific goal is thus an unprecedented high-resolution UV map of the Earth (5 Km and 2.5 us respectively), collecting night-time data. Such observations are crucial for the understanding of the detection threshold of EECRs from space, in addition to estimating the duty cycle of future experiments. The same detector is also able to catch a variety of both, atmospheric and terrestrial phenomena, such as transient luminous events (TLEs), meteors, space debris, bioluminescence and anthropogenic lights. The variation of these events require a six orders of magnitude dynamic range, motivating a multi-level trigger system including given constraints on the duty cycle and data storage.
From a system level view, this detector is made up of three main sub-systems: the Fresnel-based optical system, the Photo Detector Module (PDM) and the readout electronics. The optical system consists of 2 double sided Fresnel lenses with a diameter of 25 cm allowing for a compact system with a large aperture. The lenses focus the light onto the focal surface, where it is detected by an array of 36 multi-anode photomultiplier tubes (MAPMTs) with UV filters, called PDM. Each MAPMT consists of 64 pixels, resulting in a 2304 pixels readout. Signals are pre amplified and converted to digital by the SPACIROC3 ASIC, before being passed to the data processing unit for data handling and storage.
The Mini-EUSO trigger logic is implemented inside the FPGA of a custom PCB, called Zynq Board (the PDM readout core). This trigger logic consists of two levels, working with different time resolution thus to capture categories of events on short timescales (e.g. showers), but also to provide continuous imaging on slower timescales as Mini-EUSO orbits around the Earth (e.g. lightnings). In order to achieve this efficiently, 3 different types of data are stored with different time resolution while the trigger rate is kept below 1 Hertz.
Prior to the implementation of the trigger algorithm in hardware, the logic has been extensively tested using both simulated data (using the EUSO Simulation and Analysis Framework software, ESAF) and data taken at TurLab, a laboratory equipped with a rotating tank and located in a dark environment, with a series of different light configurations to reproduce the UV emission of the Earth. After those steps, the trigger algorithm has been integrated in the Zynq Board FPGA and tested with a hardware-synthetized artificial data generator,

that allows standalone testing. Further trials involved the complete readout chain, stimulated using a pulse generator.

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