The JEM-EUSO time synchronization system and EUSO BALLOON Data Processor.

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Abstract. The JEM-EUSO instrument is a wide-angle refractive telescope in near-ultraviolet wavelength region being proposed for attachment to the Japanese Experiment Module onboard ISS. The instrument will study the fluorescence light produced in atmosphere by UHECR of energy E > 5 × 10¹⁹ eV. It consists of high transmittance optical Fresnel lenses with a diameter of 2.5 m, a focal surface covered by 4932 MAPMTs of 64 pixels, front-end readout, trigger and system electronics. The tracks generated by the Extensive Air Showers produced by UHE primaries propagating in the atmosphere, are reconstructed on the focal surface by registering in a cyclic memory, every 2.5 microseconds, the data coming from the 315648 pixels and by selectively retrieving only the interesting ones on the occurrence of a second level trigger. In order to guarantee the correct time alignment of the events and to measure the arrival time of the event with a precision of few microseconds, a clock distribution and time synchronization system for the focal surface electronics has been developed. In this poster we will present the status and the technical solutions adopted so far. We will also discuss the Data Processor of EUSO-BALLOON experiment, the JEM EUSO pathfinder mission, in which a telescope of smaller dimension respect to the one designed for the ISS, will be mounted on board a stratospheric balloon. The main objective of this pathfinder mission, planned for the 2013, is to perform a full scale end-to-end test of all the key technologies and instrumentation of JEM-EUSO detectors. Furthermore EUSO-BALLOON will measure the atmospheric and terrestrial UV background components, in different observational modes, fundamental for the development of the simulations.

1. Introduction

JEM-EUSO (Extreme Universe Space Observatory on Japanese Experiment Module) is a project for a new type of observatory that uses the whole Earth as a detector[1]. The sensor is a super wide-field telescope that detects transient luminous phenomena taking place in the Earth atmosphere caused by particles coming from Space.

The main objective of JEM-EUSO is to investigate the nature and origin of the Extreme Energy Cosmic Rays, EECRs (E > 5 × 10¹⁹ eV), which constitute the most energetic component of the cosmic radiation. [2]

This remote-sensing instrument orbits around the Earth every ~90 minutes on board of the International Space Station at the altitude of 300-400 km. The instrument is planned to be attached to JEM/EF of ISS during the first half of the 2017. It will be launched by H2B rocket and conveyed to ISS by HTV (H-II transfer Vehicle).

The launch in orbit of the JEM-EUSO telescope will be preceded by EUSO-BALLOON a pathfinder balloon mission. The objectives of EUSO-BALLOON are:

1. to perform a full end-to-end test of a JEM-EUSO qualification model consisting of all the main subsystems of the space experiment,
2. to measure the critical atmospheric and terrestrial UV background components,
3. to perform the first detection of air-showers by looking from above the atmosphere.

The first flight is planned for the end of 2013 and will produce useful input for the planning and construction of the JEM-EUSO mission. One or several further flights will allow to adjust trigger criteria and complete the measurement of the background in different conditions.
In the following we shall describe the JEM EUSO time synchronization system specifically designed for the EUSO Balloon mission which is in an advanced stage of development in our laboratories. The system can be considered a subassembly of the Data Processor system of the EUSO Balloon mission therefore we shall present it after a brief description of the JEM EUSO and EUSO BALLOON apparatus.

2. The JEM EUSO apparatus

The instrument consists of high transmittance optical Fresnel lenses with a diameter of 2.5m, a focal surface covered by 4932 MAPMTs of 64 pixels (figure 1), focal surface electronics and system electronics. A LIDAR and an IR camera assembly will also be provided for atmosphere sounding, which is an important complement for the main data analysis.

The fluorescence and Cherenkov photons coming from EAS are converted to electric charge by 64 pixels MAPMTs. The signals from the MAPMT are discriminated from electrical noise and digitalized by a front-end ASIC [3]. The ASIC counts the number of photo-electrons produced in a fixed time window for each pixel. The recorded amount of light is nearly proportional to the shower size at various depths in the atmosphere. By imaging the motion of the streak every few microseconds, it allows to determine the arrival direction of the primary EECR. The integral of light recorded is correlated to the energy of the primary EECR.

Since the total number of pixels in the array is very large (~3×10^5), a multi-level trigger scheme was developed [4]. This trigger scheme relies on the partitioning of the Focal Surface in subsections, named PDM (Photo Detector Module), which are large enough to contain a substantial part of the imaged track under investigation. The general JEM-EUSO trigger philosophy asks for a System Trigger organized into two main trigger-levels.

![Figure 1. JEM EUSO Focal Surface detector](image1)

![Figure 2. Focal Surface electronics hierarchical scheme](image2)

![Figure 3. The EUSO BALLOON apparatus](image3)

The two levels of trigger work on the statistical properties of the incoming photon flux in order to detect the physical events hindered in the background, based on their position and time correlation. In figure 2 a scheme of the FS electronics and trigger flow diagram is reported.

The First-level trigger is implemented in a dedicated board (PDM board) [5]. Each PDM board is connected to 9 pieces of ECs (36 MAPMTs), handling 2304 channels in total. The output from each 8 PDM board is transmitted to one of 21 Cluster Control Boards (CCB) [6], then CCBs in turn transmit pixel information which passed the fine trigger conditions via Intermediate Data Acquisition Board to the main CPU. The data acquisition is based on the same hierarchical architecture designed to reduce the amount of data at each level of trigger. All the signals produced by MAPMTs are registered and stored in cyclic buffer waiting for the trigger signal before being transmitted to the next level for further analysis. The two trigger levels have different latencies in particular the second level trigger has a latency of the order of 10 ms. The data has to be stored for such a long period before being...
rejected of acquired. The apparatus is segmented in various zones and in each of these zones different units process independently different sets of data. In order to correctly assign to an event all its own data sets (distributed in space and time) and in order to keep under control the dead time of the apparatus (at level of PDM) is mandatory to perfectly synchronize the whole system and to tag properly the data sets. The role of management the synchronization of the system is performed by a dedicated board (CLK board) [7].

3. The EUSO-BALLOON apparatus
The EUSO-Balloon apparatus (figure 3) will consist of a single Fresnel Optics made from 3 PMMA square lenses (UV transmitting polymethyl-methacrylate) and a focal plane detector made from a single PDM (Photo-Detector Module, composed of 36 multi-anode photomultipliers containing 64 anodes, with associated ASICS, HV and HV switches) representing 2,304 pixels. The 15 x 15 cm focal plane and the 100 cm x 100 cm Fresnel lenses provide a field of view of ± 6°.

The electronic chain used to readout the focal surface PMTs is a simplified version of the one projected for JEM EUSO. The hierarchical scheme is the same of the one shown in figure 2, but with only one Control Cluster Board and one PDM board. The nine EC units and the relative ASICs are managed by a PDM board which perform the first level trigger. Data are then transferred to the Digital Processor (DP) system where the second level trigger is applied by the Cluster Control Board (CCB) and data are handled by the CPU to be sent to telemetry.

4. The EUSO BALLOON Data Processor
The Data Processor is the sub-system of the EUSO Balloon apparatus which performs data management and storage, instrument control and commanding. More in details, the DP controls the front-end electronics, performs the second level trigger filtering, tags events with arrival time (UTC) and payload position (GPS), manages the Mass Memory for data storage, measures live and dead time of the instrument, provides signals for time synchronization of the event, performs housekeeping monitor, handles interface to tele-commands and to telemetry system.

The DP functionalities are obtained by connecting different specialized items, which form a complex system. The main subassembly items are:

- Control Cluster Board (CCB)
- CPU
- Data storage (DST)
- Housekeeping system (HK)
- Clock Board (CLKB)

![Figure 4. Block diagram of the EUSO BALLOON Data Processor](image)

![Figure 5. Block diagram of the CLK board](image)
• GPS receiver (GPSR)
• Data Processor Power Supply (DP-LVPS)

A block diagram of the DP is shown in figure 4.

5. The Clock board

The clock and time synchronization board (CLK-board) is the part of the data processor devoted to generate and to distribute the system clock and the synchronization signal (GTU clock) to all devices of the Focal Surface electronics and to provide time synchronization of the events. The board has an interface with a GPS receiver which allows to collect, for each event, information on the position of the instrument and the UTC time with a precision of few microseconds. The CLK board receives the level2 trigger signal from the CCB and a busy signal from the CPU. These two signals drive the logic implemented on the board to measure the fraction of live time and dead time of the apparatus. The board receives commands from CPU and transmits/receives data to/from the CPU by using the SpaceWire communication protocol.

The master clock is generated by a 40 MHz Temperature Compensated Crystal Oscillator capable of a frequency stability of +/-1 ppm in the temperature range of -40°C to +85°C. An FPGA Xilinx Virtex5 XC5VLX50T (Industrial grade) is used to implement all the required functionalities of the board. The GTU clock is obtained from the master clock. The system clock signals and the GTU clock signals are sent to the CCB boards. Differential LVDS as output protocol and point-to-point connections are used.

The CLK board has a direct connection with the GPS receiver through a serial port in order to collect data and deliver commands according to the NMEA protocol. The 1PPS pulse generated by the GPS receiver is used in order to synchronize, at level of 1 GTU, the apparatus with the UTC time.

In figure 5 a block diagram of the CLK board with the main interfaces is presented.

A GPS receiver board based on the SiRFstarIII™ 20-channel GPS receiver loaded with a “High altitude” version of the firmware is under developing in our laboratory in Naples and will be soon produced and tested. The correct behavior at high altitude (42 Km) will be verified in a GPS constellation simulator at CNES laboratories of Toulouse.

6. Conclusion

The time synchronization system for the JEM-EUSO project as implemented for the EUSO BALLOON mission has been described in this paper. The system distributes the clock signals to the FS electronics and manages all the signal needed to take correctly aligned in time the data packets produced in different parts of the apparatus at different time. The system, for each event, provides the measurement of the arrival time with a precision of few microseconds, the position of the payload in absolute coordinates, the measurement of the time elapsed since the previous event (live time) as well as the time needed to acquire the previous event (dead time). The system described in this paper is now under development, and it will be completed in laboratory in this year.

References

[1] Takahashi Y 2009 New Journal of Physics, 11 065009
[2] Medina Tanco G A et al. 2012, arXiv:1204.5065 [astro-ph.IM].
[3] Ahmad S et al. 2012, arXiv:1204.5065 [astro-ph.IM].
[4] Catalano O et al., Proc. of the 31st Int. Cosmic Ray Conf., Lodz, Poland (2009).
[5] Park I et al. 2012, arXiv:1204.5065 [astro-ph.IM].
[6] Bayer J et al. 2012, arXiv:1204.5065 [astro-ph.IM].
[7] Osteria G 2012, arXiv:1204.5065 [astro-ph.IM].