the EUSO electronics

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Abstract

Euso is an innovative mission for the study of the EECR from space.
In order to detect an EAS in a large night-glow background using 350k photodetector pixels, a complex, fast and very low power-hungry electronic system is required.
In this paper we briefly describe the main features of the front end electronics, of the read-out architecture and of the triggering system.

1. Introduction

The Euso project is the first attempt to implement in a real experiment a truly innovative approach to the study of the Extreme Energy Cosmic Rays (EECR), first proposed by J. Linsley more than 20 years ago [[Linsley(1979)], [Catalano(2001)]].

The idea is conceptually simple. It is well known that extensive air showers (EAS) can be detected by observing the fluorescence light emitted by nitrogen, when this is excited by charged particles. Instead of looking at this UV light from ground, Euso proposes to watch the same signal from above, using a monocular telescope that may be attached at the International Space Station (ISS) in orbit around the earth.

The fluorescence light is produced isotropically and, at any depth in the shower, is proportional to the number of charged particles (mostly electrons). The number of emitted photons is about 4 per charged particle per meter, and it is mostly independent from the altitude, due to the combined effect of density and recombination processes. Besides the fluorescence light, a lot of Cerenkov photons are emitted too. This Cerenkov pulse is collinear to the shower axis and, after having hit the ground, is partially (10%) reflected, thus being detectable by Euso.

Euso will observe the Earth atmosphere at night time by looking down to nadir from the height of the ISS (about 430 Km), covering an active area of about

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150.000 Km^2 with 10% duty cycle*.

A real EAS generated by an EECR has very specific and unique characteristics both in the time development and light intensity; on the detector focal plane it will be seen as a point moving at the speed of light with a peculiar intensity profile that will strongly help to disentagle signals from backgrounds.

The Euso detector is therefore a very fast UV camera composed of an optical system, an array of UV light detectors and an electronic system suitable to trigger on the signals expected from EAS, digitize them and send them to earth using the ISS facilities.

The Euso electronic and triggering system must be able to identify and acquire this fast light profiles efficiently and with very little use of electric power, due to the severe limitations imposed by the ISS energy supply.

Next sections will give a brief description of this crucial part of the detector. For other features of the Euso telescope the reader should refer to the other Euso articles in these Proceedings.

2. The Electronic system

2.1. Requirements

The Euso detector must be able to acquire a light spot moving on the focal surface with high efficiency and speed. The Extensive Air Shower moves in atmosphere at the speed of light. A photodetector pixel sees an area of the order of 1 Km^2, so the light spot remains for just a few μs in one single pixel, taking also into account the optical system PSF which is of the order of one pixel as well. The expected signal amplitude is about 100 photons/μs at maximum; this requires that the electronics must be able to count photons at a rate of 100 MHz.

Euso must be of course self triggering. This is function is very difficult to achieve because of the very high incoherent background coming from the atmosphere night-glow. From measurements we know that the background is 300-400 photons sr^{-1} ns^{-1} m^{-2}, corresponding to a rate of the order of 1 MHz per pixel on the Euso focal plane. The triggering system must be able to identify a track in this huge incoherent background.

Another crucial and very severe constraint is the limited power budget. Euso is expected to be attached to the Columbus module on the ISS and the maximum power available for the Euso instument is 700 W. This strong constraint is of course conflicting with the high speed requirements and a very careful trade off solution must be chosen.

The Euso electronics is composed of 3 main sub-systems:

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*This estimate of the duty cycle is the worst case, assuming that no useful data can be obtained when the moon is present and when the weather conditions are not perfect. Full Montecarlo simulations are on-going to make a more realistic estimate.

- **The Front End ASIC**: it provides with the first two level of triggering system, and contains a set of digital and analog functions for counting the number of photons in a given time interval (called Gate Time Unit, GTU) and measuring the total charge on the last dynode of each PMT and, possibly, on individual pixels.
- **The Macrocell**: it performs the third and final stage of triggering system, and handles data read out.
- **The Main Processing Unit**: it controls the system, prepares data for grounding (zero suppression and data compression) and possibly performs final data filtering.

In the following sections we very briefly describe these elements.

2.2. The Front End electronics

In order to meet the requirements while keeping the electric power consumption within the limit imposed by the ISS, a custom made, spatialized, front end ASIC is mandatory.

Each ASIC will be mounted on a PCB that will be at the same time the multi-anode PMT holder and the electronic connection between MAPMTs and electronics.

This ASIC, that is now under joint development by INFN Genova and ISN Grenoble, will be built using CMOS 0.35 μm technology or biCMOS. It is devoted to the following functions:

- Pre-amplify and shape each MAPMT signal.
- Count the photons in a given GTU with a programmable threshold (first level trigger, see next section)
- Perform a second level trigger (see next section)
- Integrate, store into analog memories and, if needed, convert the analog information into digital data with an external ADC. In the baseline design this operation will be done with the signal taken from the MAPMT last dynode; if possible, also the individual pixels will done in this way.

Both in Grenoble and in Genova, prototypes of the digital and analog sections have been built. It has been proven that it is possible to build a preamplifier and a discriminator that are fast enough to count photon up to 100 MHz and that have a total power consumption below 700 μW/channel, including the base triggering functions. It is clear that all function enhancements will be severely limited by power budget.

2.3. Trigger and Read Out

The trigger logic is of course a very crucial feature of the electronic system, because it must assure that EAS signals corresponding to EECR of energy below 10^{20} eV can be efficiently detected by Euso in the large night-glow background.

In order to simplify and architecture the focal surface has been divided in modules, called Macrocells, that are large enough to contain a large fraction of a shower (of the order of 6x6 MAPMTs, not necessarily squared).

The different trigger levels and their meaning are the following:

- Level 1: The pixel analog signal is sent to a programmable discriminator and the photons giving signal above threshold counted by a digital counter in the front end chip; the counter is active for a GTU and then reset. The GTU duration is of the order of 2.5 μs.
- Level 2: When the number of counts is equal to a digital threshold, the front end ASIC generates a set of logic signals informing the Macrocell of the coordinates of the pixel above threshold and allowing the Macrocell to count photons coming from the pixel.
- Level 3: If more than 2 consequtive GTUs pass Level 2, the Macrocell enters in triggering mode and inform the main processor to start to acquire the track.
- Level 4: A possible filter on the main processor via software; data are zero suppressed and compressed to be sent to ground.

The Macrocells are all independent, so that man-made or atmospheric background cannot blind the whole field of view.

Another specific trigger will be implemented to acquire atmospheric phenomena; in this case the time scale is much slower than the EECR one (ms instead of μs), therefore a dedicated logic is needed.

References

[Linsley(1979)] J. Linsley, Calls for Projects and Ideas in High Energy Astrophysics (1979)

[Catalano(2001)] O. Catalano, Il Nuovo Cimento 24C, n. 3, pag. 445 (2001)