Prototype of a Space Fluorescence Detector At Cerro La Negra Mountain Site

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Abstract

The prototype of space fluorescence detector TUS (see V. Alexandrov *et al.*, this conference) is begin prepared for operation at the mountain site Cerro La Negra (atmosphere depth $600g/cm^2$). The fluorescence detector (FD) field of view cover the atmosphere above the EAS array at the Pico de Orizaba site (see O. Martinez *et al.*, this conference), separated from the FD by $\sim 5km$. At night at energies $E_0 > 0.05$EeV both FD and EAS array will operate as an "hybrid detector." The range of atmosphere depths available for observation of EAS tracks by FD in hybrid mode is $200g/cm^2$. FD will also observe EAS tracks at energies of about 1 EeV at distances R=25-50 km, at zenith angles $> 45^0$ (when the atmosphere depth is more than $850g/cm^2$) with direction of tracks perpendicular to the FD axis. The FD design and preliminary data of the FD performance will be presented.

1. Introduction

Ultraviolet scintillation photons are produced by nitrogen molecules excited by the passage of charged particles, mostly electrons and positrons which along with photons form the electromagnetic component of an Extensive Air Shower (EAS). The fluorescence light from the extensive air shower is collected by the mirrors of the telescope which focuses it into a PMT camera where the signal is digitized. The telescope calibration provides the conversion from signal, in ADC units, into the number of incident photons on the telescope aperture. Absolute calibration is achieved by using calibration devices which are linked to an absolute standard calibration. A typical fluorescence telescope include a spherical mirror; UV filters; the camera of photomultipliers: light guides and the read out electronics. An absolute calibration provides the conversion factor from FADC

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Table 1. Parameters.

Telescope		Photomultipliers	
Curvature radius	116 cm	Photocathode Material	Multialkali
Number of elements	19	Photocathode Area	10 mm dia.
Field of view	20 degrees	Window Material	UV glass
Diameter	84 cm	Gain	$1X10^5$
Spot size	1.5 cm	Camera Area	$8X8cm^2$

Fig. 1. Segmented telescope with 19 mirrors (left) and photosensor camera (right).

counts to calculate the number of photons arriving at the front of the mirror. The FADCs counts for each PMT belonging to the camera give us, from the absolute calibration and the geometry, the number of photons produced at each step of the longitudinal profile of the shower. The conversion of fluorescence photons coming from the shower to the number of electromagnetic particles is obtained by fitting the profile to a Gaisser-Hillas function and subsequently the electromagnetic energy E and X_{max} can be evaluated [1].

Light background at moonless nights is expected to be of about 200 to 500 photons/nsm^2sr. The goal is to observe rare physical events like ultrahigh energy cosmic rays in variable light backgrounds with an optical detector. We want to extend the observation time to include full moon night. For this purpose it is necessary to have a light sensor system with a very wide dynamic range and a photo sensor capable to deal with a huge cathode and anode current. The FD design and the laboratory results working with a prototype of 4 by 4 pixel system and a mirror with $0.8m^2$ area will presented in this paper contribution.

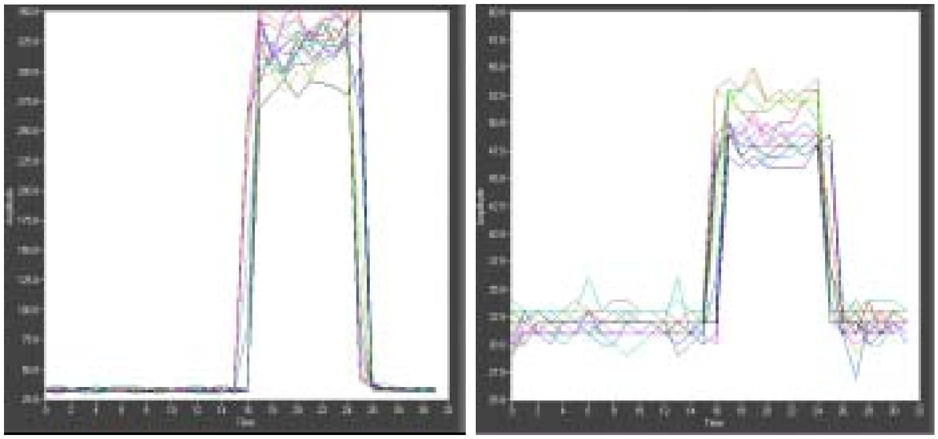

Fig. 2. Example of matching process. The accuracy is around ±5% and the two cases correspond to a factor of de 7 times in the gain of the PMTs.

2. Telescope design and performance

In this section we will discuss a general scheme of the optics and electronics read out of the fluorescence telescope coupled to a 4 by 4 pixel camera. The PMTs are Hamamatsu model R1463 of 13 mm diameter. We will also describe gain matching methods for the PMTs. The measurement of the electronics signal coming from s Xenon flash tube in a fullmoon night will be presented in this section. The photo-receiver camera with 4x4 pixels is located at the focal point of a 0.84 m diameter segmented spherical mirror Figure 1 (see table 1); each pixel consists of a photomultiplier tube (PMT) with a light guide with 2cmX2cm aperture and covered with an UV filter. The light guide is used to avoid light leaks between adjacent photo-catode (see table2). The set of 16 pixels has two higt voltage sources (HV), a common divider with two sets of variable potentiometers, a flash analog to digital converter (FADC), and FIFO memory. The first HV (1-1100 Volts) handles the first 6 dynode of each PMT, in order to keep its performance close to the linear region; the second HV (1-250 Volts) fixes the voltage so that the last stage of the PMT works in the lineal region. The gain of the 16 PMTs is matched using the individual potentiometer described above for each, when all of them are exposed to a common light source. One set of variable resistors will be used to match the slope of the gain variation when the high voltage is increased. Each signal of the PMT is multiplexed and sampled by the FADC with a sampling rate of 40 Mhz. During this time of conversion, the digitalized signal is recorded into a FIFO memory. The 16 lines of PMTs work synchronously. The trigger system works with programmable digital logic (CPLD or FPGA), as well as the control system of the multiplexed signals [2]. The control system will send the digital information from the FIFO memory to the computer.

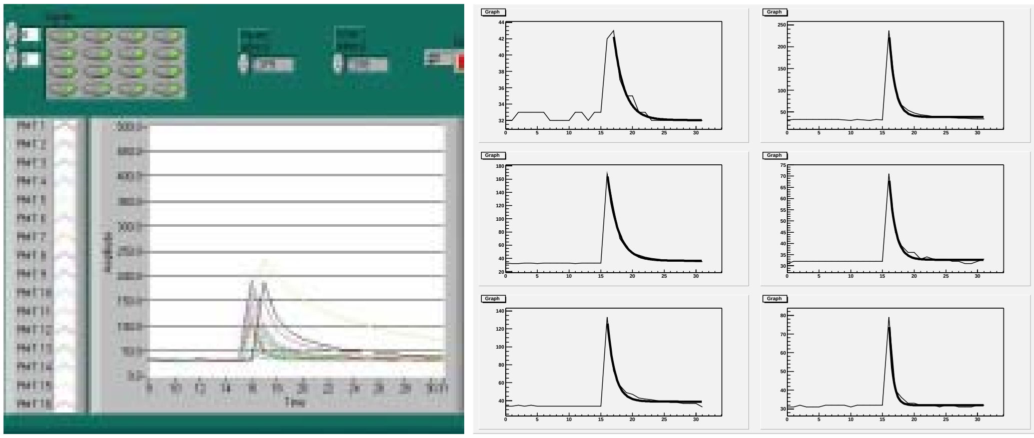

Fig. 3. Measurement of scattered light from a flasher and sky noise as view for the FD read out electronics during a fullmoon night.

The digitalized signals are read out by a dedicated PC. An example of matching process result is presented in Figure 3. The accuracy is around $\pm 5\%$ and the two cases correspond to a factor of 7 times in the gain of the PMTs. As a first stage of operation of the FD, we use in the Campus of the University of Puebla. a simple Xenon flash tube, with a FWHM of us light pulse. Figure 4 shows the scattered light as detected for the FD and displayed in the PC by a LABVIEW program (left) and in a Root program (right). The base line (background) correspond to the sky and electronic noise.

3. Results and Conclusion

We have discussed the general scheme of a photosensitive camera for a fluorescence detector. By using a Flasher to generate scattered light, we have measured the profile signal generated by the FD in the campus of the University of Puebla in a fullmoon night. The multialkali cathode has shown to be able to work in this conditions. We have successfuly integrated the optical system and the electronics systems of the telescope. The authors are very grateful with the technician Saul Aguilar. This work was done with partial support of the CONACyT-G32739-E grant.

References

[1] A. M. Hillas and T. K. Gaisser 1977, Proc. 15th ICRC (Plovdiv), **8**, 353.

[2] B. A. Khrenov for the Kosmotepetl Collaboration 2002, Nucl. Phys. B (Proc. Suppl.) **113**, 115-122.