Description and preliminary test results of a detector prototype for the TUS space fluorescence observatory

Abstract

We discuss a general scheme of the optics and electronics read out as well as preliminary test results of a detector prototype for the space fluorescence telescope TUS (FD-TUS). The mirror of this prototype is coupled to an 8 by 8 pixel camera. Each of the 64 pixels is read by one PMT of 13 mm diameter (Hamamatsu model R1463) . The optics design is a multi-hexagonal segmented telescope with focal distance of 1.5m and 2 square meter area. The optics design is optimized to have a light collection efficiency greater then 50% for all the pixel positions. The fluorescence detector is being tested at the high mountain site Sierra La Negra near Puebla City in Mexico (600g/cm2). The FD-TUS will observe EAS tracks at energies of about 1 EeV at distances 25-50km,and zenith angles greater than 45 degree with direction tracks perpendicular to the FD axis.

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1. Introduction.

TUS (Tracking Ultra-violet Set up) mission (Abrashkin et al, 2006) is now planned for operation at the Small Space Apparatus (SSA) separated from the main Foton-4 satellite, due to be launched in 2009-2010. SSA is a new platform being designed for operation with space instruments having mass 50-100 Kg, power consumption of 60-100 Wt at the orbits of 500-400 km heights. The platform will be oriented in space due to a scientific task. In transportation mode SSA is placed above the Foton-4 body so that the TUS mirror could be accommodated in full size of 1.8 m diameter.

As a second option, a new variant of a mirror constructcio is now under construction and testing at the Sierra Negra Site (4550m asl). The mirror consumes 19 hexagonal segments of 20 cm side Fig. 1b. Segments are regular spherical mirrors with 4 slightly different curvature radii. All of them are focusing light to one focal point.. The photo receiver operates in the range ψ=0-5^o. One can see that in both options the efficiency decreases with angle ψ and at ψ=5^o it is of about 50% but at small angles the first option has better resolution.

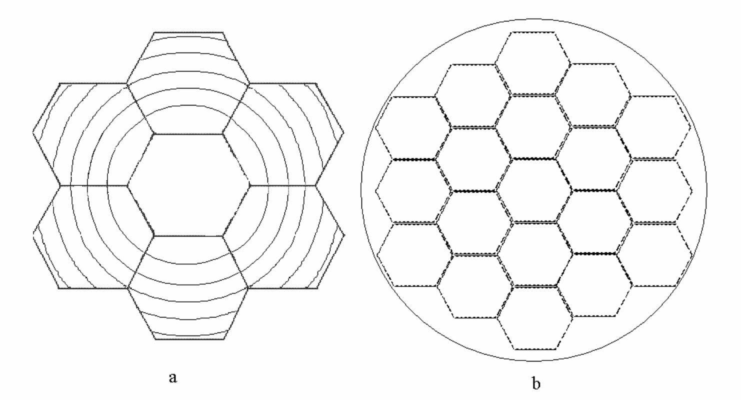

Fig 1. The TUS mirror- concentrator: a. First option, segmented Fresnel mirror, b.Second option segmented spherical mirror.

Electronics of the TUS mountain detector prototype

As in the TUS receiver the photomultiplier tube (PMT) of Hamamatsu type R1463 was selected as an UV sensor. At the entrance window and UV filter are mounted. The filter cuts the light with wavelength >400 nm. Quantum efficiency of the cathode is 20% in the range of wavelength 300-400 nm. Signals from each 16 PM tubes are coming to the multiplexer and then to 10 bits ADC (Fig2). Four cards are controlling the 64 channels of the pixel camera (Fig 3).The TUS mountain prototype electronics has been updated, for study of different types of UV events: EAS, TLE, meteors and sub-relativistic dust grains Khrenov and Stulov, 2006.

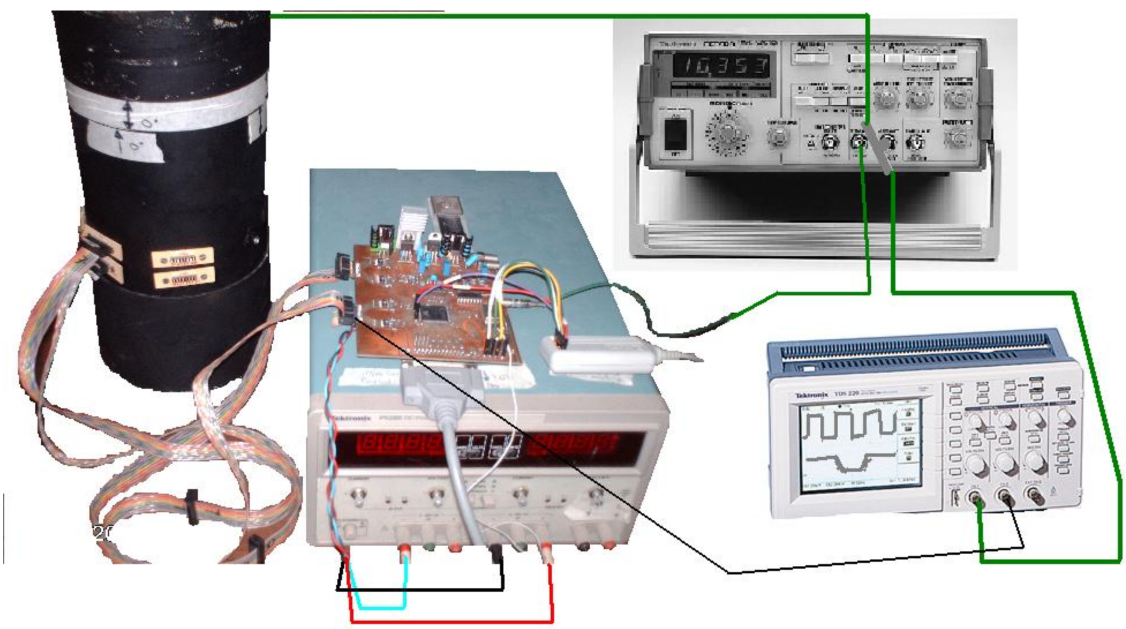

Fig 2. Laboratory test of the readout electronics for 16 channels.

The main feature of the electronics is the use of FPGA (of XILINX type) for digital analysis of the signals after ADC (digital oscilloscope method). Several digital oscilloscopes are used with different time samples for several tasks. Digital integration is used for selection and registration of various event types with a value of integration time determined by the experimental task.

Simulation of the UHECR event registration was improved includding the increased area of the mirror- concentrator, its focusing parameters, light collection efficiency by light guides, losses of light in reflection at the mirror surface and light guide surfaces. Efficiency of event selection for zenith angles in the range 50^{o} -90^{o} and primary EAS energies 1-10 EeV was tried in simulation of electronics operation.

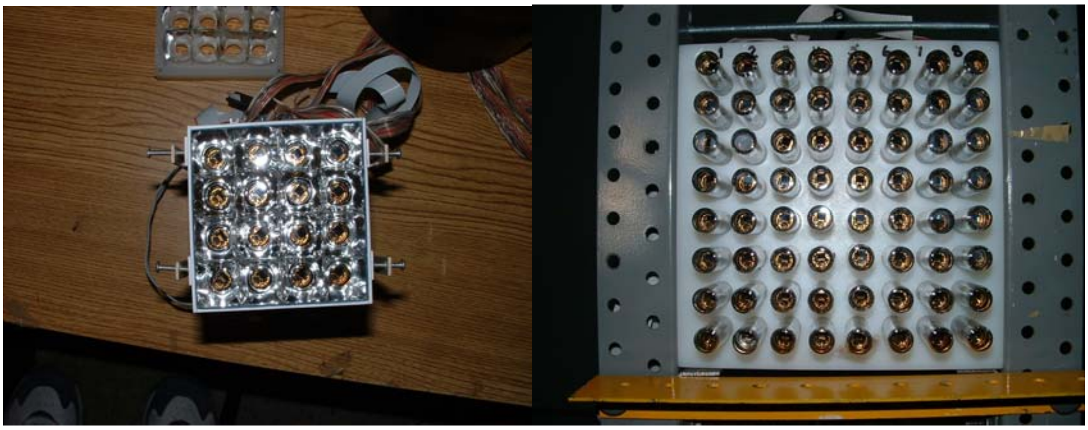

Fig 3 The TUS photo receiver prototypes: 4x4=16 and 8x8=64 PM tubes.
They are being tested in the Puebla University (Mexico) and they will operate in a mexican mountain.

Mountain detectors of the TUS type in Mexico.

At Cerra La Negra at the altitude of 4.5 km the fluorescence detector of the TUS type is being prepared for operation. The mirror- concentrator is a sum of segments presented in Fig.2b but number of segment could be extended until 37 and the mirror area could reach 3.8 m^{2}. At focal distance ~1.5 m from the mirror plane the photo receiver of pixels with size 1.5 cm will cover FOV of the detector. Today the pixel number is 64 but could be enlarged later to 256 pixels. Design of this detector is very close to the TUS detector, one of the construction differences is that mirror segments are made as glass mirror (not the carbon plastic as in TUS). Comparatively large mirror area allows to look in near horizontal direction for EAS tracks at distances 20-50 km. At altitude 4.5 km due to high atmosphere transparency in horizontal direction more than 30% of EAS beam light would reach the detector. EAS of energies in the range 1-10 EeV will be registered with their position of cascade maximum inside of FOV at distances 20-50 km. The area of the atmosphere where the EAS could be registered in the range of those distances is ~200-250 km^{2}. For estimated average EAS energy threshold of 1 EeV, the rate of EAS is expected to be ~1 events per hour for EAS zenith angles >60^{o}. For those zenith angles position of EAS maximum is above the horizon. The main problem in this experiment is an achievement of satisfactory accuracy in the directional measurements in axial plane of the detector. Measurements of EAS angular velocity in several pixels will be used for determination of the angle in axial plane. Energy spectrum in the range of 1-10 EeV is interesting as in this range the change of spectrum exponent is observed in several experiments which may indicate a change in cosmic rays origin from Galactic to extragalactic.

The same detector looking upward (elevation angle ~45^{o}) could register micro meteors and sub-relativistic dust grains producing signals at altitudes in the atmosphere of 90-120 km. In this direction the transparency of the atmosphere for detector at the altitude 4.5 km is excellent (80% of beam light coming to the detector) and the efficient area of the atmosphere for those observations is ~1000 km^{2}. The expected range of kinetic energies of micro meteors and sub-relativistic grains in the mountain experiment is discussed in Khrenov and Stulov, 2006. This kind of experiment in the mountains will help for planning observation of the same objects by the TUS space detector at much larger area in the atmosphere.

Conclusion.

A many- purpose detector TUS prototype is being prepared for testing at Sierra Negra site before the launching in 2009-2010 of the TUS telescope. It will give space-time images of the objects radiating UV light in the wavelength range 300-400 nm. The mirror- concentrator of area 2 m^2 – 3.8 m^2 will be used for measuring very faint signals. The detector will measure images (64-256 pixels) with a lateral resolution in the atmosphere 1-2 km and time resolution depending on the origin of radiation source: for UHECR event resolution is ~1 μs, for TLE or sub-relativistic dust grains- resolution is of 16-256 μs and for micro meteors- 4 ms.

References.

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2. Khrenov B.A. and Stulov V.P., Detection of meteors and sub-relativistic dust grains by the fluorescence detectors of ultra high energy cosmic rays. Advances in Space Research, 37 (2006) 1868-1875.