TUS detector trigger system tests by optical simulator of EAS.

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FOR THE TUS COLLABORATION.

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Abstract: Orbital ultra high energy cosmic ray detector TUS is prepared for launching in 2013 on-board Mikhail Lomonosov satellite. The preflight tests of detector and its systems are ongoing now. The trigger system was tested as well. A special tool (optical simulator of extensive air shower) with rapidly moving laser beam was produced for tests of the TUS photo-detector trigger electronics. These tests produced data that are useful for development of trigger simulation and event reconstruction programs. The optical simulator of extended air shower is presented. The TUS calibration in flight is shortly considered.

Keywords: TUS, EAS, trigger, preflight test

1 Introduction

The TUS project task is an experimental study of UHECR at the energy $E > 7 \cdot 10^{19}$ eV. The fluorescent and Cherenkov radiation of Extensive Air Showers (EAS) generated by UHECR particles will be detected at night side of the Earth atmosphere from the space platform at heights 400-500 km [1, 2]. It will make possible to measure the CR spectrum, composition and arrival directions at $E > 7 \cdot 10^{19}$ eV beyond the GZK energy limit. There are two main parts of this detector: a modular Fresnel mirror (figure 1) and a matrix of PMTs with corresponding DAQ electronics. The SINP MSU, JINR and Consortium "Space Regatta" together with several Korean and Mexican Universities are collaborating in the TUS detector preparation. The TUS mission is now planned for operation at the dedicated Mikhail Lomonosov satellite.

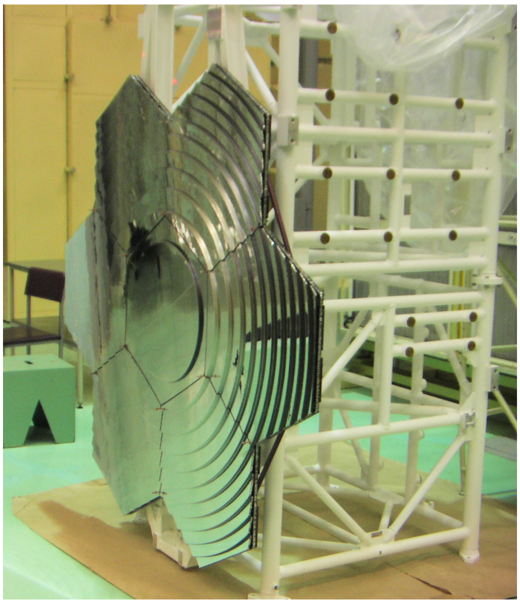

Fig. 1: The TUS detector modular Fresnel mirror

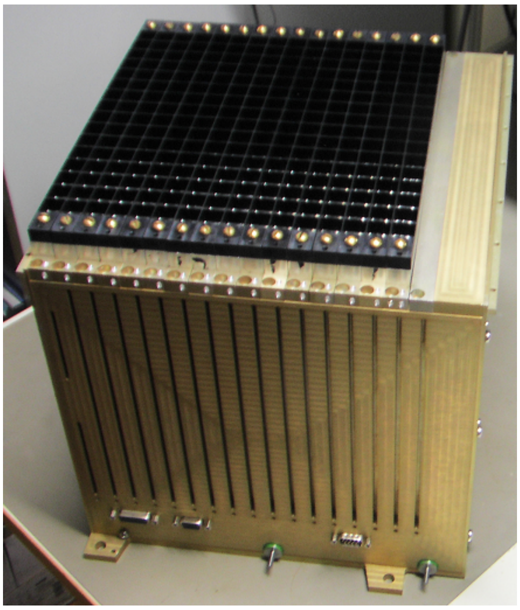

Fig. 2: The TUS photo detector and FE electronics

2 The TUS photo detector

Photo detector and electronics (figure 2) consists of 16 clusters with 16 Hamamatsu type R1463 PMT pixels with the time step t = 0.8 μs and the spatial resolution 5x5 km (for the orbit height of 500 km). The digital integrators allow us to use the same photo detector to study different phenomena in the atmosphere in wide time interval: from 100μs (EAS) to 1-100 ms (transient luminous events, TLE) and up to 1 s (micrometeors). A prototype of such photo detector was tested during 2 years of Universitetsky-Tatiana mission [3].

The UHECR event rate will be exceptionally low $\sim$ a few tens of events per year. The TUS trigger electronics rate is designed for 1-2 triggers per minute and will obviously collect the background events mainly.

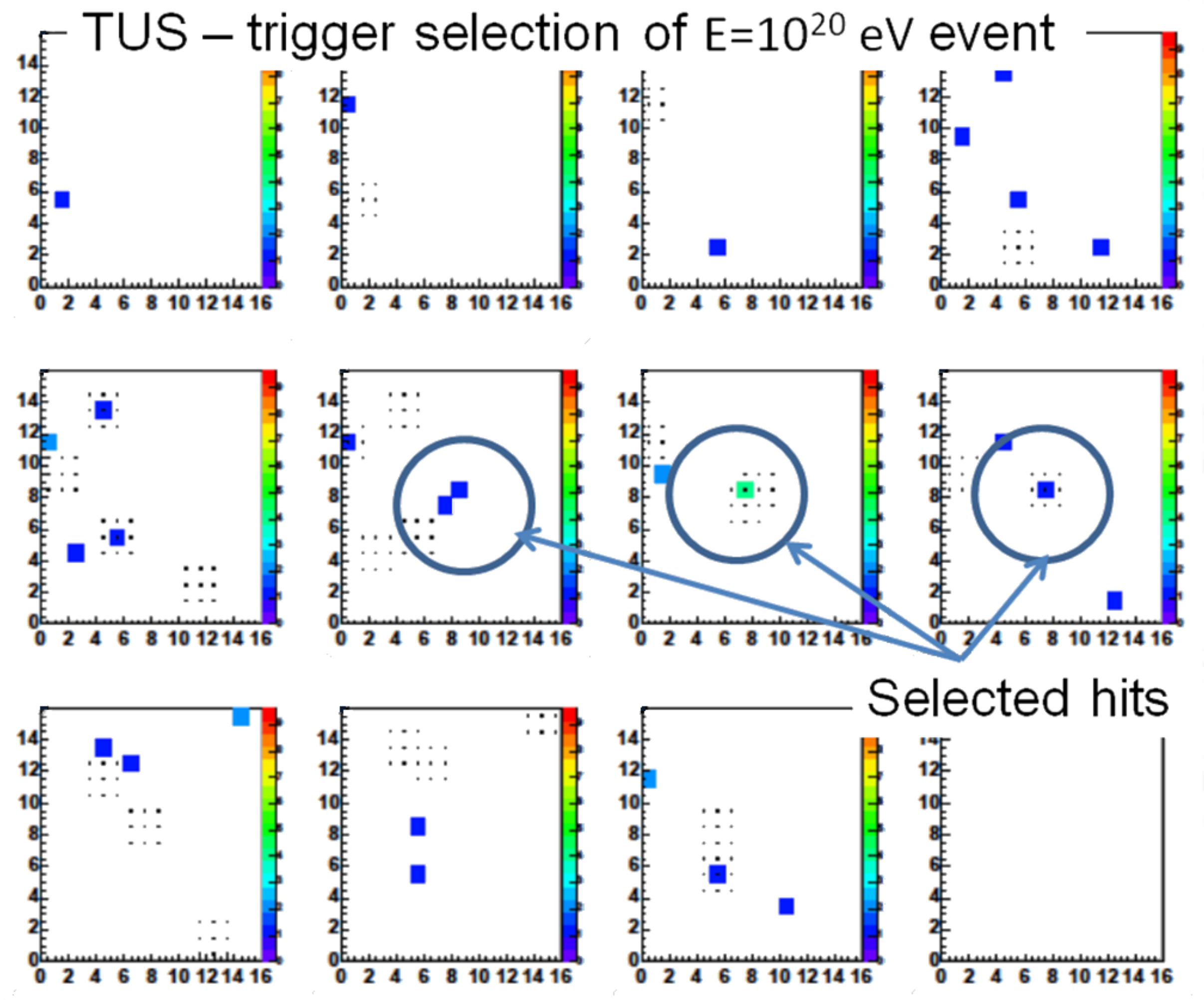

Fig. 3: Schematically presentation of the TUS trigger algorithm.

The TUS trigger algorithm is presented in (figure 3 schematically. It will be operates in two levels. At the 1-st trigger level the PMT currents are integrated for each pixel during 16 time steps of Δt=0.8 μs and the integral signal above a threshold level S_{th} in some pixel is needed for the 1-st trigger level creation. The choice of the S_{th} threshold value is determined by the background light trigger rate and is limited by the speed of the data flow in the TUS acquisition system.

In the 2-nd trigger level, the map of 16x16 hit pixels is considered. The UHECR event candidate is selected by either **n** map repetitions of the same pixel hitted at the 1 level trigger or in **n** map repetitions of neighboring hit pixels. The **n** $\geq$ **3** is needed as was obtained from the TUS trigger simulation program TUSSIM. This situation is shown in the figure 3 as three marked plots with circles: the 2-nd level trigger is formed as a set of 3 time successive 16x16 maps was obtained those have contained hit pixels of the 1-st trigger level.

3 Preflight test of the photo-detector

A special optical simulator of EAS with rapidly moving laser beam was produced for tests of the TUS photo detector and trigger electronics and shown in figure 4.The tool consists of the rotating mirror, light attenuators, blue laser beam and reference PMT. The light beam of 2040PG laser of 405 nm wave length is going through optical attenuators to have a possibility to change a light intensity from 50 photons/μs to the laser maximum value. After attenuators the laser ray is going onto the small rotated mirror. The mirror rotation speed may be changed in the 0-200 Hz interval.

Reflected light spot is moving in a plane that is shown in figure 5 by cyan color and that across the surface of the photo-detector PMT matrix. Speed of the light spot movement depends on the distance between the rotated mirror and the photo detector PMTs and of the mirror rotation speed. Orientation of the plane with a rotating laser beam may be easily changed by the tool orientation as whole to simulate different EAS arrival directions. The independent light source is used to simulate the night atmosphere background radiation on the PMT matrix.

The change of the light beam intensity, speed and axis of the mirror rotation and the intensity background light source gives a possibility to do a simulation of the EAS registration at the different conditions that will be happened during the TUS orbit flight. A special screen with a gap just before the PMT matrix may be used to open and investigate the different parts of the photo-detector. The scheme of the photo detector preflight test with the EAS simulator is shown in figure 5.

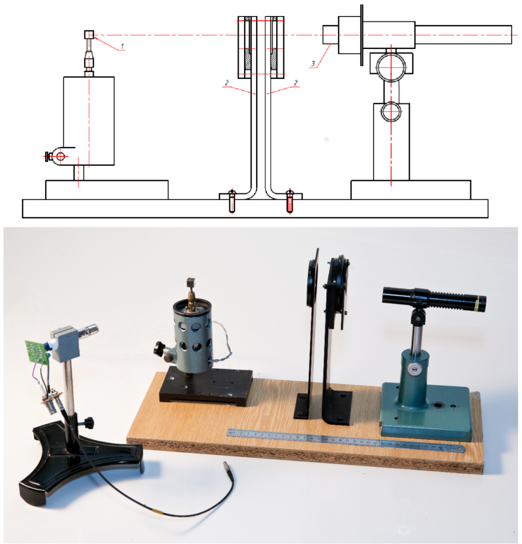

Fig. 4: EAS simulator for the TUS detector trigger system preflight test. 1-rotating mirror, 2-light attenuators, 3-laser. Reference PMT is on the separate support.

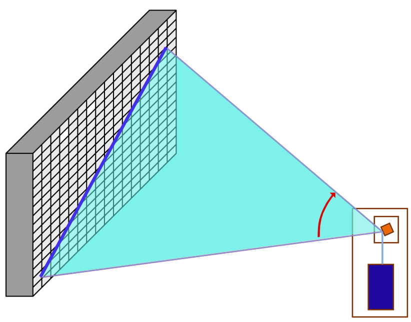

Fig. 5: The scheme of the photo detector preflight test with the EAS simulator.

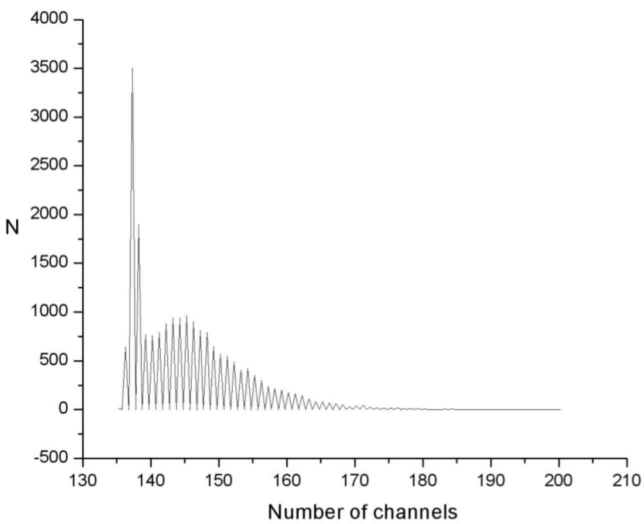

Fig. 6: One photoelectron spectrum of the reference Hamamatsu type R1463 PMT

There are two modes of the EAS preflight tests with a fluorescent radiation simulation: direct laser beam radiation on the photo-detector PMT matrix as shown in figure 5 or radiation on the TUS mirror that will reflect light on the PMT matrix. In the last case light source is located at $\sim$ 15 m from the mirror and there are two possibility also. (1) Moving laser beam is falling upon mirror and then reflected upon the photodetector like in figure 5. The mirror is tested in the case locally. (2) The special lens is used to disperse laser light on the whole or part TUS mirror surface and then focuced on the PMT matrix. In that case mirror may be tested globally.

In the both modes the reference PMT is used that is located nearby of the rotating mirror and illuminated by the laser light together with PMT matrix. The reference PMT is calibrated beforehand. The one photon spectrum of the reference PMT is shown in the figure 6 that was obtained at the HV 1100 V. The dependence between the PMT current and the number of the input photons fallen onto the cathode is measured and known in figure 7. The dependence curves are used as a reference to transform the PMT matrix currents in the number of the input photons what is the goal of the TUS detector calibration.

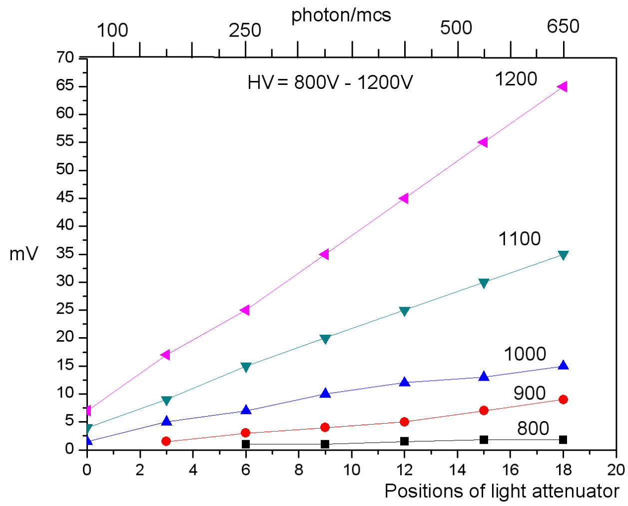

Fig. 7: Results of the reference PMT calibration

4 TUS calibration in flight

The only possibility for the TUS calibration in flight will be the use of the ground based light sources. The question of the net sources creation is rather urgent due to awaiting the satellite launch in a nearing few months. The TUS FoV is $\pm 4.5°$ or $\sim$ 80x80 km^2 at the Earth surface for the 400-500 km orbit altitude. Rather small observable area on the Earth means that light source have to be movable, i.e. located on a car or much better on a plane.

The TUS orbit will be solar-synchronized and the satellite will fly every 24 hours above the equatorial points those are shifted on the $\sim$ 110 km to east in latitude only or even nearer for the other points out of equator. It means that light source on a car is a reasonable solution and obviously on the plane that have to fly above clouds.

The light contact between TUS detector and ground source will be during $\sim$10 sec only. A line of the ground source image on the TUS photo detector will go across the whole PMT matrix with a speed 0.5 sec per the PMT pixel. A special trigger mode has to provide such a calibration.

The ground based light source should provide ∼500 UV photons/μsec/m^2 at the orbit altitude. It seems that HAMAMATSU Xenon flash lamp L7684 (1 J per one flash, 60 Hz repetition rate, 2.9 μsec flash pulse-width and other suitable characteristics) may be used for the TUS calibration in orbit. There were preliminary contacts with the physical groups of the JINR member-states in Kasakhstan, Romania, Ukraine and Vietnam about establishing of such TUS calibration centers.

5 Conclusion

A special optical simulator of extensive air shower with rapidly moving laser beam was produced for tests of the TUS photo-detector trigger electronics. These tests will produce data that will be useful for development of trigger simulation and event reconstruction programs. The TUS apparatus is presently at the general preflight tests at the ISTRA space workshop. As it will be finished the trigger system will be tested. This simulator of extensive air shower will be also used for fluorescent detector of Tunka-133 EAS Chrenkov array trigger tests which is now being developed in SINP MSU and JINR. Investigation of the TUS calibration in flight is in progress.

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