Photo receiver of the orbital ultra high energy cosmic rays detector TUS.

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The TUS space experiment is aimed to study energy spectrum, composition and angular distribution of the Ultra High Energy Cosmic Ray (UHECR) at E ~ 10^{20} eV. The TUS mission is planned for operation at the end of 2011 at the dedicated "Mikhail Lomonosov" satellite. The TUS detector will measure the fluorescence and Cherenkov light radiated by EAS of the UHECR using the optical system - Fresnel mirror-concentrator of 7 modules of ~2 m^2 area in total. A production of the flight model of the photo receiver is in progress. Status of the photo receiver production and tests are presented.

Keywords: UHECR, photo receiver, space experiment

Introduction

The TUS project task is an experimental study of UHECR. 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. 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 and a matrix of PMTs with corresponding DAQ electronics. The SINP MSU (main investigator), JINR and Consortium "Space Regatta" together with several Korean and Mexican Universities are collaborating in the TUS detector preparation. The orbital Ultra High Energy Cosmic Ray (UHECR) detector TUS is at the final stage of its construction and the TUS mission is now planned for operation at the dedicated "Mikhail Lomonosov" satellite shown in Fig.1.

Main TUS parameters are: mass < 60 kg, power consumption ~65 W, data rate 200 Mbytes/day (1 EAS event contains ~80 Kbytes), Field-of-View ±4.5 degree, number of pixels 16x16 (Hamamatsu type R1463 PMT: 13 mm tube diameter, multi-alcali cathode, UV glass window), pixel FOV ~10 mrad, Fresnel mirror area is 1.8 m^2, focal distance 1.5 m.

Photo receiver and electronics consists of 256 PMT pixels with the time resolution 0.8 μ s 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 ~100 μ s (EAS) to 1 ms – 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 [1].

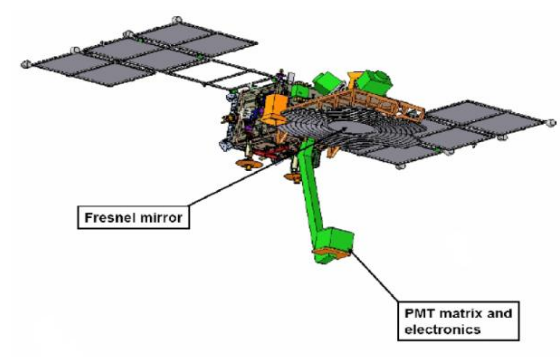

Fig.1. The TUS detector at the "Mikhail Lomonosov" satellite.

In the TUS photo detector box the pinhole camera is added for study of TLE. The pinhole camera consists of multianode PMT and a hole at the focal distance from the PMT cathode. In design of the camera the multianode PMT of JEM-EUSO type is used [2]. The JEM-EUSO UV sensor will be tested in TLE data taking by the pinhole camera.

The TUS photo receiver

One of the main parts of the TUS detector is the photo receiver placed in the focus of the 1.8 m^2 mirror-concentrator. It consists of 256 pixels (Hamamatsu PMT R1463) with the corresponding FE electronics. PMTs are united in the 16 pixel cluster, with common HV supply.

In every cluster FPGA is used for making the first stage selection of useful events and keeping them in preliminary memory. First stage trigger signal analysis carries out in the mother-board, which forms a map of events and produces the final trigger. For UHECR case final trigger, it should be at least three neighbouring pixels sequentially triggered.

After the final trigger mother-board collects data from all clusters. The gain of the cluster PMTs is controlled so that first trigger rate is kept constant. A high uniformity of pixel gain is important in this operation mode. The main demand for the cluster PMT uniformity (in various UV background circumstances) is equal efficiency for detecting UV signal in the whole HV range control. Due to different PMT efficiency for a given voltage, a sufficient uniformity was achieved by preliminary measurements of PMT parameters (gain, anode sensitivity, dark current) and next ranging tubes in groups with similar parameters. Inside one group the tube parameters were adjusted by resistors of the voltage divider. The procedure of PMTs tests, HV adjustments and calibrations are presented as well as photo receiver operation principles and characteristics. The TUS detector has additional scientific objectives: transient luminous events (TLE), relativistic dust grains and micro-meteors. These events develop slower in time and the photo receiver electronics are ready to record them in different temporal scale. The fastest UHECR events are recorded in 256 samples of 0.8 μs each. TLE and relativistic dust grains are recorded in the same number of samples but of longer duration: 256 μs. The slowest events: micro-meteors are recorded in 256 samples of 2 ms.

Description of the PMT qualification setup

The qualification Hamamatsu's R1463 phototube is produced by the hardware and software complex named testbench that was successfully used previously for the PMTs test of the ATLAS Tile Calorimeter in LHC[3,4]. The general view of the testbench is presented in Fig. 2.

The testbench consists of four main parts: "Light Box", "PMT Box", "Electronics Rack" and PC with program in "LabView" environment. "Light Box" provides setting of the direct current mode of light and transfers this light to phototube matrix (5x5 cells). The photomultipliers have been placed to the matrix grid inside "PMT Box" and provided communications with high voltage power supply and digitizer (slow ADC).

One cell (central position) of matrix is used by Hamamatsu S3590-04 photodiode for the optic line calibration. Therefore, maximum 24 PMT's can be tested simultaneously during one run. Electronics in the rack provides readout from PMT's and control of the service modules under LabView application.

Fig.2. The general view of the PMT testbench: left – "Light Box", center – "PMT Box", right – "Electronics Rack".

The main test scheme in DC mode light is shown in Fig.3. The standard deviation of DC light for all optic cells is 2.0±1.7%. Current to voltage (I/V) Converters are the current feedback amplifiers. Type of the slow ADC is XVME-560 of the XYCOM manufacturer.

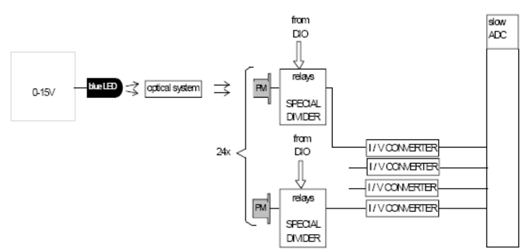

Fig. 3. The main test scheme in DC mode light.

The constant light mode was used at the testbench for the R1463 qualification. The corresponding optical scheme is presented in Fig.4. The blue LED BP280CWB1K-3.6VF-050T of Ledtronics was applied as the constant light source with the 480 nm peak wave lenght.

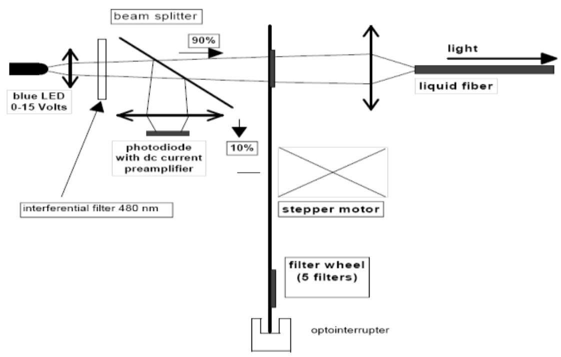

Fig.4. The PMT calibration optical scheme.

Results of measurements

A procedure to HV scan in the gain term was used that is based on the dedicated "GAIN" program. Off-line data analysis included of the linear fit of gain curve (G = a*U + b) and a normalization to the corresponding coefficients of reference phototube VD9778, which placed in the reference position (channel 00) during of the whole test period. The "a" and "b" distributions are shown in Fig.5 that are normalized to the reference PMT .

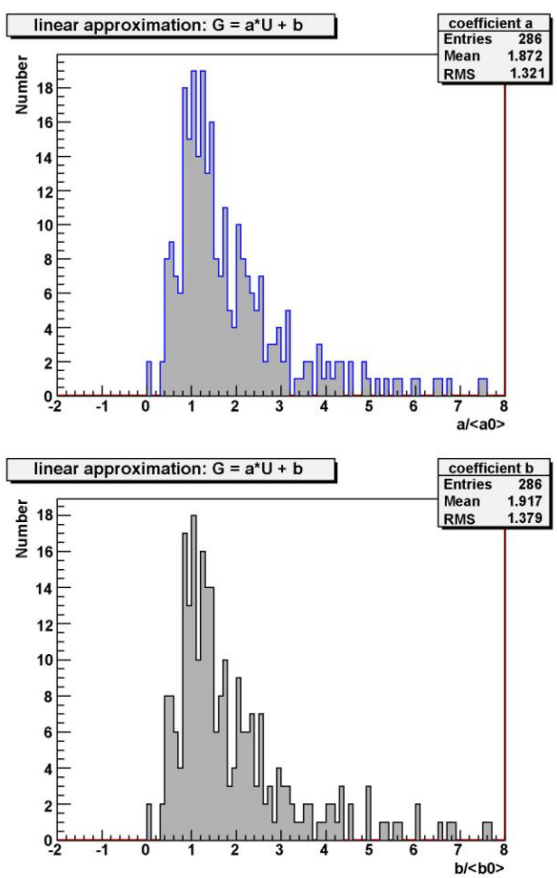

Fig. 5. The "a" and "b" coefficient distribution of linear approximation of the gain curve for each PMT.

Additionally the dark current after a burning period (30 minutes) and photocathode collection efficiency are measured for each PMT's. Distribution of dark currents in HV=900 volts are presented in Fig.6.

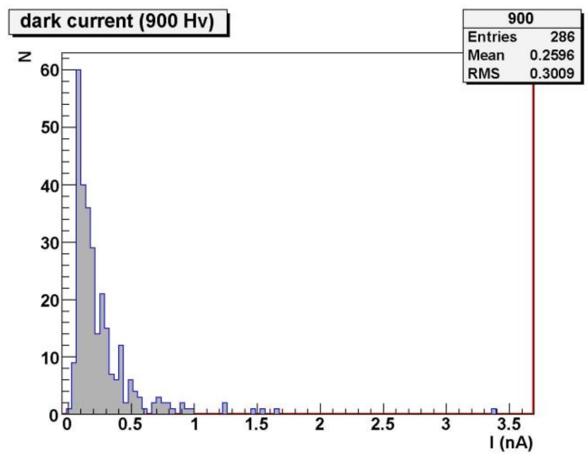

Fig.6. Dark currents of PMT's in HV=900 volts.

Conclusion

The flight TUS photo receiver production is in progress and will be ready soon for integration at the satellite platform. Qualification of 286 PMT's type Hamamatsu R1463 by dynode system gain, dark current, collection efficiency is done. The TUS mission is planned for operation at the end of 2011 at the dedicated "Mikhail Lomonosov" satellite for 3 years of data taking [5].

References

[1] V. Sadovnichi et al, The first results of the "Universitetsky-Tatiana" satellite. Cosmic Research, **45**, (2007) 273-286.

[2] Y. Takahashi and the JEM-EUSO Collaboration, JEM-EUSO mission, 2009, New Journal of Physics, **11**, 065009.

[3] Technical characteristics of the prototype of the TILECAL photomulipliers test-bench. TILECAL-98-148

[4] Characterization of the Hamamatsu 10-stages R5900 photomultipliers at Clermont for the TILE calorimeter. TILECAL-NO-108, 28 April 1997. PCCF-RI-97-5, 1997, 96p.

[5] M.I. Panasyuk et al. TUS Mission. Technological developments in Russia for JEM-EUSO collaboration, this conference, ID 1261.