UHECR Study on Satellites in TUS/KLYPVE Experiments

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Abstract

The TUS/KLYPVE space experiments have been proposed to study the energy spectrum, composition and arrival direction of the Ultra High Energy Cosmic Rays (UHECR) by detection from the space satellites of the atmosphere fluorescence and Cherenkov light produced by UHECR initiated Extensive Atmosphere Showers (EAS).

The TUS set up is a prototype of the KLYPVE. The aim of the TUS experiment is to detect a dozen of UHECR events in the energy region of the GZK cutoff, to measure the light background, to test the atmosphere control methods, to study a stability of the optic materials, of PMTs, and of DAQ in the space environment.

1. Introduction

Among many important astrophysical problems the nature, energy spectrum and the sources of UHECR are of paramount importance [1]. It is likely that the Galactic Center can be a source of the cosmic rays with energies 10^{18}

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eV [2]. The change of the UHECR energy spectrum at $3-5\cdot10^{18}$ eV may be explained by their extragalactic origin. For extragalactic protons with energies above $5\cdot10^{19}$ eV the GZK cutoff is expected due to interaction with the background relic photons. The measured unexpected flux of UHECR with energies above 10^{20} eV is stimulating different theoretical speculations[1]. However, the existent experimental data are poor in statistics and methodical accuracy. A new more precise and conclusive data are needed for clarifying of the UHECR phenomena. At present a few of high energy astrophysical experiments have been proposed, including experiments in space [3].

The TUS/KLYPVE task is an experimental study of the UHECR by their fluorescent and Cherenkov light excited by EAS in the atmosphere. This light will be detected by the space telescopes flying at the altitudes of 400-600 kms. There are two main parts of these detectors: a modular Fresnel mirror and a matrix of PMTs with DAQ electronics in its focal plane. The EAS image will be recorded as a time evolution of the track "firing" various PMT pixels of the photoreceiver. The UHECR primary parameters: energy, mass and arrival direction can be reconstructed from the registered information. For the accurate measurements of those parameters a condition of the atmosphere in the telescope field of view has to be known. A special control device for atmosphere monitoring is a part of the TUS/KLYPVE telescopes.

2. Status of the TUS construction

Accomodated on the Russian "Resurs" space platform the TUS detector with 1.4 m^2 Fresnel mirror and 16x16 PMTs will be a prototype of the 10 times larger forthcoming KLYPVE detector. At the present time R&D of Fresnel mirror fabrication is in progress. The first sample of the press-form for the mirror module production is shown in Fig.1 (left panel). The different rings of the Fresnel mirror have parabolic shape of the different focal distances to provide coincident focal points. The deviations of measured and theoretical focal distances lead to increasing of the mirror focal spot. The spot size expected in the fabricated mirror as function of the incident light beam angle is shown in Fig.2 (right panel).

The telescope photoreceiver is designed as an orthogonal network of pixels. The pixel is a circular PMT with a square window light guide. The choice of the PMT is a compromise between a good time resolution, high sensitivity in the fluorescence wavelength band 310-420 nm, stable performance in the presence of high light noise, fast recovering after exposing to the scattered day atmosphere light, and slow aging. The Hamamatsu PMT type R 1463P with a multialcali cathode and linear dynode system was selected.

Pixels are organized in clusters: 16 pixels in line is a cluster having a common HV supply, a FADC channel, a FIFO memory. Data are acquisited from every pixel in the cluster with the help of multiplexer. Triggering and DAQ are

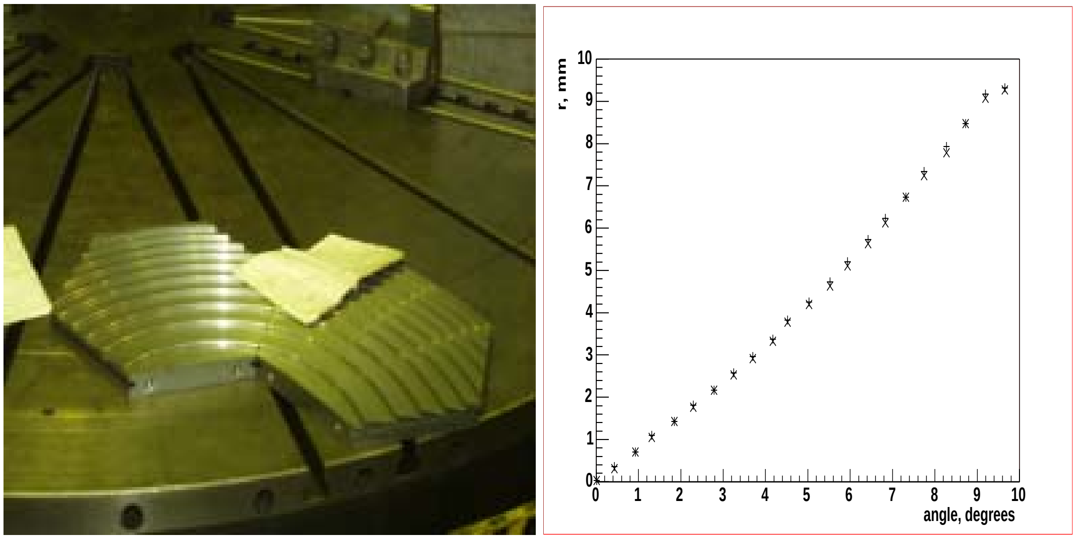

Fig. 1. Left - press-forms for production of Fresnel mirror modules. Right - focal spot size dependence of the incident light angle.

common for the whole retina of pixels. The UHECR signal finding algorithm operates in two trigger levels with sampling time interval $t_s = 0.8\mu s$. On board data processing makes an additional separation of real UHECR events.

The prototype of the TUS telescope is being tested at Cerra La Negra mountains in Mexico. The mountain TUS prototype will allow to observe the EAS tracks at distances 25-100 km from the detector. The atmosphere monitoring in the telescope field of view will be provided by a special control device. The joint EUSO/TUS test is supposed for study the fluorescent EAS radiation in air with the accelerator beams at CERN and/or JINR. It is important for the calibration of both detectors.

3. The UHECR event simulation.

The UHECR events were simulated with aim of testing the efficency of the selection system and estimating of the measurement accuracy. Development of EAS initiated by primary UHECR particles was considered in frame of the CORSIKA/QGSJET model. Special package of EUSO/TUS event simulation program SLAST was elaborated. The first results are presented in Fig. 3.

The energy threshold taking into account the detector efficiency is estimated to be $\cong 10^{20}$ eV for the TUS telescope and 10^{19} eV for KLYPVE. The errors in primary energy, direction angles and position of the EAS maximum for the KLYPVE telescope for energies $E \geq 30 EeV$: $\sigma E/E \leq 30\%$; $\sigma\vartheta, \sigma\phi \leq 5^o$, $\sigma X_{max} \leq 100$ g/cm^2.

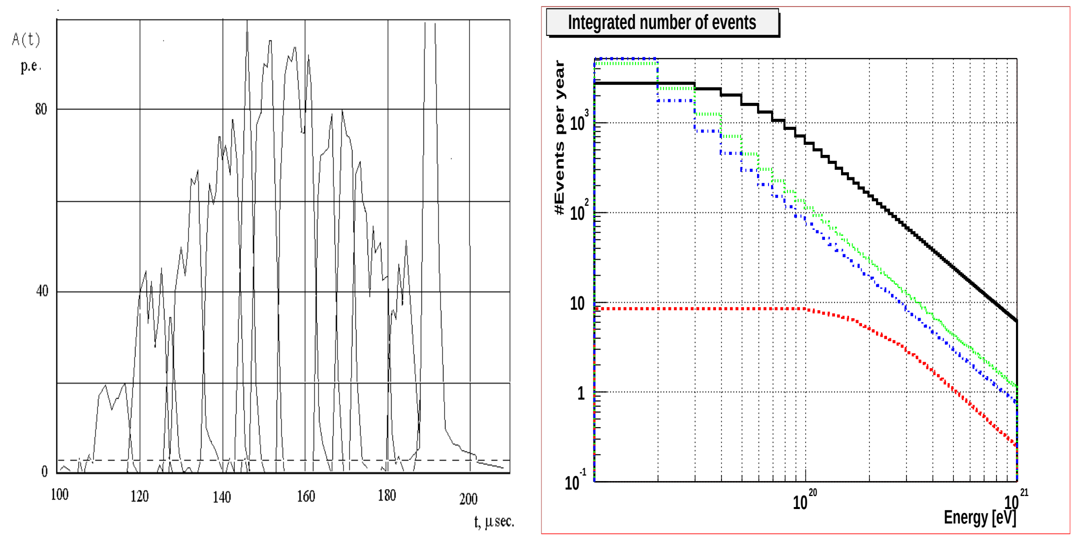

Fig. 2. Left - MC simulated EAS profile in KLYPVE for $10^{20}eV$, right - expected integrated number of events for EUSO (solid line), AUGER (dotted assuming 100% efficiency), KLYPVE (dot-dashed), and TUS dashed) experiments based on AGASA data.

4. Conclusion

In 2004 year the R&D phase of the TUS project has to be finished. It includes design, the protoype construction and its mountain tests in taking data at energies $10^{18}eV - 10^{19}eV$. The TUS mission is planned for 2005-2006 with the aim of measuring events in the most interesting $10^{20}eV$ energy region. Another aim of the TUS experiment, as the KLYPVE telescope prototype, is to study the light background, to test the atmosphere control methods and stability of the detector in space environment.

The KLYPVE project will take 4-5 years. We believe that independent operation on the ISS orbit (since 2008-2009) of the EUSO and the KLYPVE detectors will be of particular interest and importance.

5. References

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