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TUS/KLYPVE Space Telescopes – Simulation Of Performance

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Abstract

We started to simulate the performance of the TUS/KLYPVE telescopes – a space based UHECR detectors measuring the fluorescent and Cherenkov signals from EAS, developed in atmosphere. The optical part of the telescope consists of a segmented Fresnel mirror, focusing light to a grid of PMTs. We studied effects of various atmosphere profiles, parametrizations of the fluorescent light and the atmosphere attenuation models. The electronics and triggering system are simulated. The detector trigger efficiency is also studied as a function of the EAS energy and its arrival direction.

1. Introduction

Recent years are marked by an increasing interest to Ultra High Energy Cosmics Rays (UHECR) Physics and various UHECR detection techniques are proposed both from the ground (like Auger) and from the space (like EUSO and TUS/KLYPVE projects). All these activities are focused on the UHECR enigma found by the AGASA measured, statistically limited flux of UHECR with energies beyond GZK cut-off. It is interesting to note that HiRes experiment working in the same field presents the UHECR's flux compatible with GZK cut-off. One of the goals of currently running and planing experiments is to fix this conflict. The TUS/KLYPVE experiments will consist of the Fresnel mirrors (1.5 meter diameter for TUS, and 3.5 meter diameter for KLYPVE) focusing the fluorescent and Cherenkov light emmited by EAS on a focal plane. The light on the focal plane will be collected by PMTs and stored by the data acquisition system (DAS).

This note presents the current status of our simulation/reconstruction code.

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2. Event simulation

We develop a simulation/reconstruction package of programs for the TUS/ KLYPVE projects. The physics simulation is done with help of the SLAST package (Shower initiated Light Attenuated to the Space Telescope). SLAST is able to generate nuclei or neutrino initiated showers. This is a fast simulator of the shower development according to GIL parametrization of CORSIKA/GQSJET model, production of both fluorescent and Cherenkov light in the atmosphere, and of the attenuation of the light in atmosphere. There are various atmosphere profiles tabulated. Both the atmosphere and Earth are considered spherical. The first interaction point is generated based on nuclei-Air cross-section interpolation for nuclei. The energy distribution of electrons in shower is important for both the fluorescence and the cherenkov light production. We adopted Hillas parametrization [1]. The fluorescent light is produced by charged particles passing in air and exiciting N_2 molecules (2P band) and N_2^- ions (1N band). SLAST adopts parametrization [2] for the integral yield of fluorescent photons. The Cherenkov light is simulated according to the classical theory taking into account the energy distribution of the electrons in the shower. The light absorption and scattering in the atmosphere is taken into account using LOWTRAN7.1 program. We studied the TUS/KLYPVE performance with the help of the SLAST generated showers traced to the space telescope. The TUS efficiency as a function of UHECR energy and zenith angle in Fig. 1. The KLYPVE efficiency is significantly better. Expected statistics of events by TUS (dotted) and KLYPVE (solid) experiments as a function of UHECR energy based on the AGASA data is presented in Fig. 2. We started to reconstruct the EAS parameters (primary energy, arrival direction, altitude of the shower maximum H_{max}) relying on the fluorescent information only. Fig. 3. displays our preliminary results on the relative error in H_{max} determination

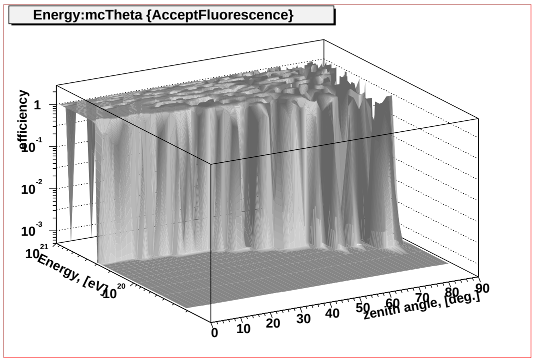

Fig. 1. TUS efficiency as a function of UHECR energy and zenith angle for the proton UHECRs assuming perfect trigger.

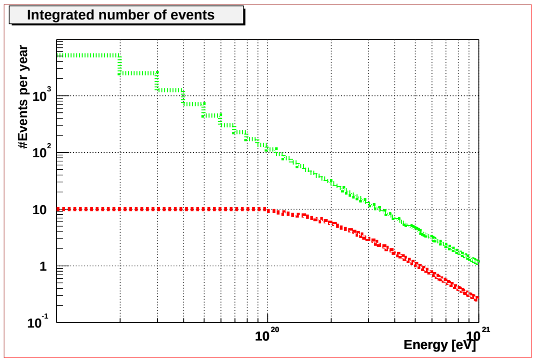

Fig. 2. Expected statistics of events by TUS (dotted) and KLYPVE (solid) experiments as a function of UHECR energy based on the AGASA data.

as a function of UHECR zenith angle.

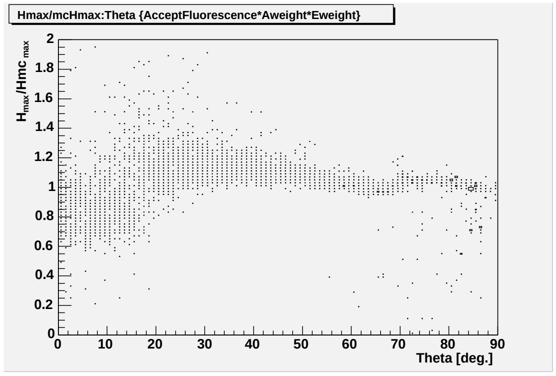

Fig. 3. Relative resolution of the altitude of the shower maximum as a function of UHECR zenith angle.

Perfomance of the electronics designed for the TUS/KLYPVE telescopes ([3,4]) is also simulated. It includes two lines of pixel signal analysis:

- the digital oscilloscope with time sampling t_s ($t_s = 0.8 \mu s$)
- triggering system that gives a command to DAS for the event registration.

The simulation of electronics operation starts with a conversion of the signal at the PM tube cathode (in number of photo electrons) to the signal amplitude at the PMT's anode with $RC = t_s$. We found the fluctuations of a signal sampled over time interval t_s comparable to the fluctuations of a signal at the tube cathode for the EAS energies of interest ($E > 30 EeV$). It confirms that the signal analysis done by the digital oscilloscope in the selected time samples is correct.

The triggering system operates in two modes: a) for selection of the "horizontal" EAS (zenith angles $\vartheta > 60^o$) and b) for selection of the "vertical" EAS ($\vartheta < 60^o$). At the first stage of this analysis, the signals in every sample t_s are compared with the signals in time sample $t_{s'}$, previous in time by time $t_{pr} \cong 100 \mu s$ (which is larger than any expected EAS signal) and the result of subtraction of signals in samples t_s and $t_{s'}$ gives the signal value above the noise level. The digitization is done comparing the signal to the 1-st threshold q_1. The obtained digit values are summed over the time t_{int} which is different for 2 modes of the EAS selection: in mode a integration time is determined by the expected horizontal EAS signal (taken to be $t_{int} = 12 \mu s$), while for the mode b we use $t_{int} = 30 \mu s$. This integrated signal is compared to the 2-d threshold q_2 finalizing the first stage of the trigger. Thresholds q_1 and q_2 determine both: the EAS energy threshold and the background triggerring rate. The background rate (in one pixel) has to be lower than 10 Hz, a limit set by DAS of the telescope. This rate corresponds to the EAS energy threshold $E_{\rm thr}$. In Fig. 4. an example of q_1, q_2 threshold selection is presented for $E_{\mathrm{thr}} = 40\,\mathrm{EeV}$ (probability of signal registration in one pixel at shower maximum is 70%) for zenith angle 75^o.

In mode b the 1-st stage trigger gives the command to DAS. In mode a there is the second stage of triggering- a selection of n neighbor pixels, triggered at the first stage. At the 2-d stage, addresses of pixels, hit at the 1-st stage, are coming to the "map" of pixels. The final trigger in variant a is formed when the number of hit neighbor pixels is larger than threshold n. The rate of accidental triggering and the probability of EAS selection were calculated for the TUS telescope as function of thresholds q_1,q_2, n for various EAS energies and zenith angles. Fig.5 displays the trigger efficiency for two modes a and b as a function of zenith angle θ for UHECR energy 40 EeV.

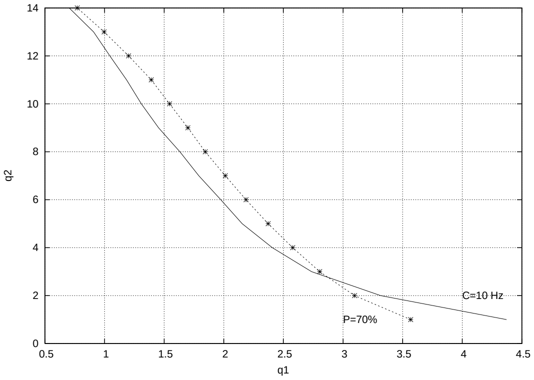

Fig. 4. Rate of accidental triggering (solid curve) and registration probability of 40 EeV EAS (dotted line) as a function of q_1, q_2 (see text).

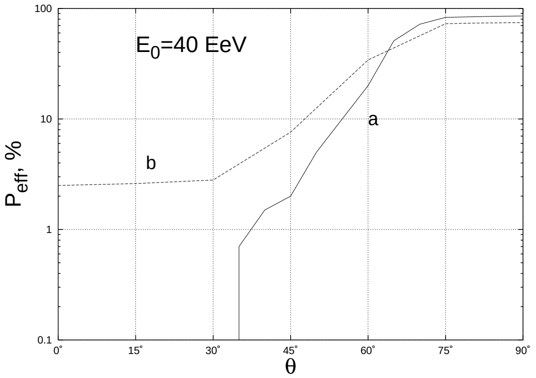

Fig. 5. Trigger efficiency for two modes a and b as a function of UHECR zenith angle.

Let us note that the trigger threshold ($\sim 4.10^{19}$ eV) for the TUS telescope is lower than that required by our reconstruction code ($\sim 10^{20}$ eV).

3. References

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