Calibration system of the TUNKA-133 EAS Cherenkov Array

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Abstract: In this paper we present results of a calibration system development for the TUNKA-133 EAS Cherenkov Array. The calibration system is based on light sources developed using high power InGaN/GaN blue LEDs driven by avalanche transistor drivers. The light sources are characterized by ~10^{12} photons per pulse light yield and ~3.5-4ns pulse width (FWHM). Concepts of the TUNKA-133 array calibration systems are discussed.

Keywords: EAS Cherenkov Array, high power InGaN/GaN LEDs, avalanche transistor drivers.

1 Introduction

The TUNKA-133 EAS Cherenkov Array has been installed in the fall of 2009 [1-3]. The main physics goals of the experiment are studies of energy spectrum and mass composition of primary cosmic rays in the energy range of 10^{15}-10^{18} eV.

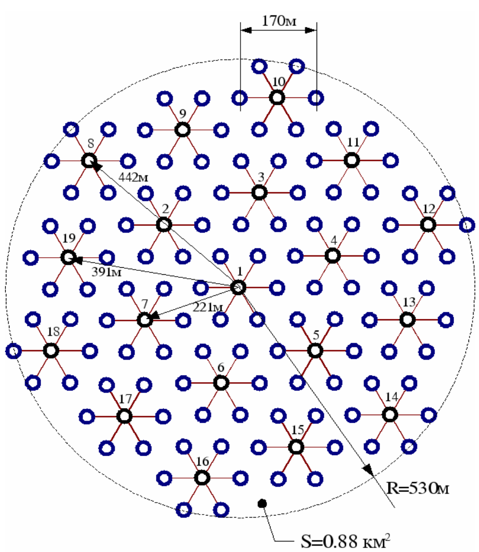

Figure 1. Layout of the TUNKA-133 EAS Cherenkov Array.

The array consists of 133 wide angle optical detectors spread over ~ 1 km^2 geometric area (figure 1) and grouped into 19 clusters with 7 optical detectors in each cluster. 6 optical detectors of each cluster are arranged hexagonally and one detector is in the cluster's center. Each optical detector is equipped with remotely controlled fast LED driver [4] with ultra bright blue GNL-3014BC LED. This LED driver is fixed near optical detector's PMT and used mainly for amplitude calibrations of the optical detectors. The LED driver provides light yield changeable in a wide range of 0-10^9 photons per pulse and pulse width of 3-10 ns.
Time synchronization of the arrays optical detetctors is more complicated experimental task. To solve the problem a dedicated calibration system has been developed.

2 Light sources

The advent of ultra bright InGaN/GaN blue, violet and UV LEDs provides wide opportunities for development of calibration light sources for Cherenkov and scintillator detectors [5-7].
Relatively new high power blue LEDs open new possibilities for design of Cherenkov detectors calibration systems. They are very bright and can withstand up to 1 A DC current. For the TUNKA-133 experiment we have developed powerful nanosecond light source based on high power LED XR7090 produced by Cree Company. The maximum of light emission spectrum of the LED is reached at 450 nm, so called "Royal Blue" LED. To get

high light yield of the light source staying still in a few nanoseconds time domain the LED is driven by specially designed driver (figure 2) using a pair of avalanche transistors ZTX415 switched consecutively. A positive triggering pulse causes consecutive avalanche breakdowns of the transistors which discharge C_2 capacitor (C_2=47 pF) through high power LED providing nanosecond pulses of high light yield. The driver is triggered by a positive pulse withamplitude of ≥ 3 V. The light source is stable over wide range of repetition rate up to 1 MHz, although in the calibration system of the TUNKA experiment the rate is quite low -~5 Hz.

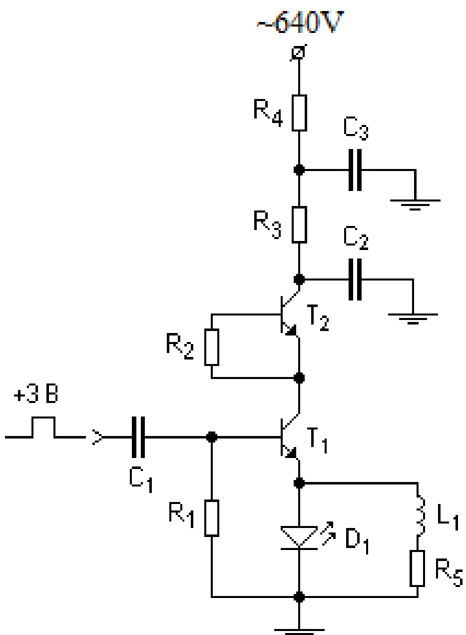

Figure 2: Electrical scheme of the light source.

The light yield of the light source measured by an integrating sphere is ~10^{12} photons per pulse [8].
The light emission kinetics of the light source was measured by time correlated single photon counting technique (TCSPCT) [9] and shown in Fig.3.

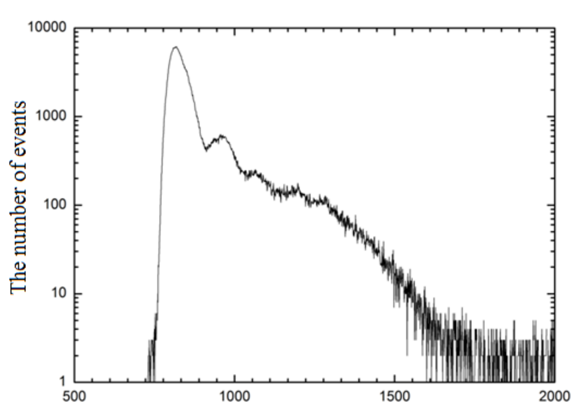

Figure 3: Light emission kinetics of the light source based on XR7090 high power LED.

Fast and slow components of the light emission kinetics are clearly seen. The substantial contribution to the total light yield belongs to the fast component. The width of light pulses of the source is ~3.5 ns (FWHM).
The light source emits photons into 100° full angle. The LED driver enclosed into a metallic box with 40×40×25 mm^3 sizes as it is demonstrated in figure 4. On the right from the light source the XR7090 high power LED is shown.

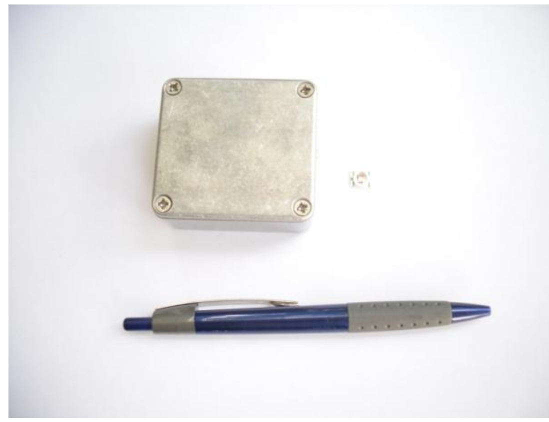

Figure 4: Photograph of the light source.

3 Calibration system

Two approaches have been conceived to make time synchronization of the TUNKA-133 array's optical detectors using above described light source.
The concept of the first approach can be seen in figure 5. In this approach the light source is fixed on a helium balloon or a pilotless helicopter and raised at the height of ~400 m above the array.

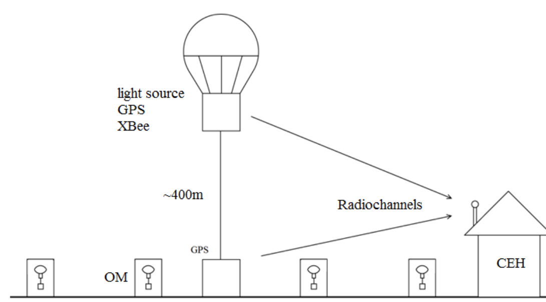

Figure 5: The concept of calibration of the TUNKA-133 array using light source attached to a helium balloon or a pilotless helicopter. Here OM is optical detectors and CEH is the central electronics hut of the array.

In this case one need to use GPS units and XBee radio units to know with good accuracy coordinates of the light source. In this approach it is enough to use only one light source because the light yield of the source and its emission angular distribution allow to illuminate from 400 m height all optical detectors of the array.
Implementation of the approach is hindered by the fact that so far it's unclear with which precision the coordi-

nates of the light source on the balloon or helicopter can be maintained. Another shortcoming of the approach is its price.
Based on the described light source we have developed a system for calibration of the TUNKA-133 array from balloon or helicopter. The scheme of the system is presented in figure 6.

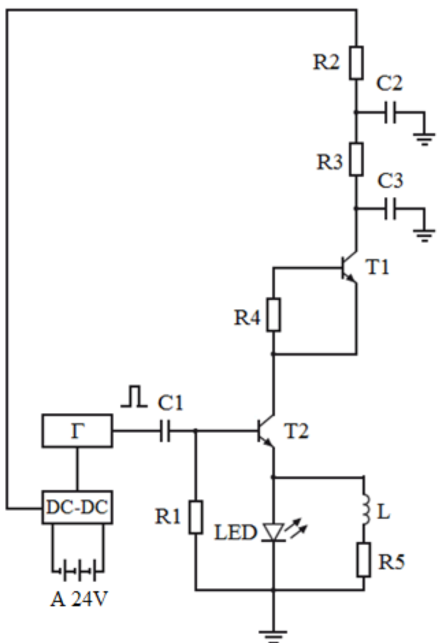

Figure 6: A system to calibrate the TUNKA-133 array from balloon or pilotless helicopter.

The system is equipped with a pulse generator with repetition rate of 5 Hz and power supply with batteries. The total weight of the system should be no more than 1 kg.
The concept of the second approach is explained in figure 7.

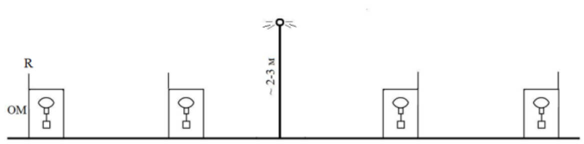

Figure 7: The concept of calibration of the TUNKA-133 array using the light source hoisted on a pole at the height of 2-3 meters above the array. Here OM is optical detectors of the array; R – light reflectors.

In this approach the light source is raised above the array using 2-3 meters long pole. The optical detectors of the array have 50° half angle of angular acceptance [3]. So, in this case there is a necessity to use light reflectors attached to the edge of the optical detectors.
For this calibration system we have developed a complex light source consisting of 4 light sources identical to the one described in section 2 of the paper. All sources are fixed on one plate orthogonally to their neighbors. So, in such geometry the whole source emits photons into 2π angle in azimuth. The drawing of such complex light source is shown in figure 8. All individual sources are triggered simultaneously from one pulse generator. The light sources including cables and all other connections are tuned between themselves in such a way that the accuracy of simultaneousness of the light pulses from all individual light sources is better than 50 ps.

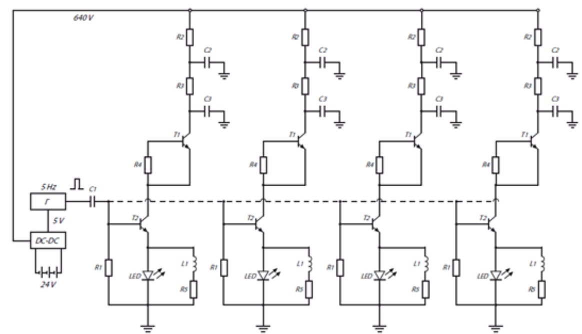

Figure 8: Electrical scheme of a system to calibrate the TUNKA-133 array using a complex light source raised above the TUNKA-133 array at the height of 2-3 m on a pole.

The photograph of a pilot sample of such system is demonstrated in figure 9.

Figure 9: Photograph of the complex light source for calibration of the TUNKA-133 array using the light source hoisted on a pole at the height of 2-3 meters above the array.

4 Conclusion

The calibration system has been developed for the TUNKA-133 EAS Cherenkov Array. The system is based on the light sources using high power InGaN/GaN blue LEDs driven by avalanche transistors drivers. The light sources have ~10^{12} photons per pulse light yields and ~3.5-4 ns pulse width (FWHM). The system is stable, robust, easy in operation and cheap in production.
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