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THE FIRST RESULTS OF TUNKA-13 EAS CHERENKOV LIGHT EXPERIMENT

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ABSTRACT

The new experiment is developed to get more precise primary energy spectrum and estimate possible changes of primary mass composition in the "knee" region. The new 13 detectors array has started operation last year at Tunka Valley (680 m above see level) 50 km to the west from Lake Baikal. Every detector contains one QUASAR-370 phototube (370 mm diameter). The detectors arrange the square net $240 \times 240\,\mathrm{m}^2$. The trigger (coincidence of 4 detectors from 13 ones) counting rate at clear moonless nights was about 1-2 Hz. The energy threshold of EAS recorded was about 300 TeV.

The preliminary differencial energy spectrum, obtained for the first 120 h of clean moonless nights of recording is presented. The samples of individual lateral distribution functions are demonstrated.

1 Introduction

The classic knee of the cosmic ray energy spectrum near 3000 TeV energy was discovered about 40 years ago with the Moscow University installation [1]. The spectrum was derived from the frequency of EAS (extensive air showers of cosmic rays) containing various numbers of charged particles. The knee in the spectrum was confirmed later by similar methods in many other laboratories world wide.

The recording of Cherenkov light from showers gives the possibility to use the atmosphere of Earth as a calorimeter and so the energy spectrum is less distorted than that, obtained by the old means of recording only the particles from EAS which reach the ground. Besides, the primary nuclei with different atomic numbers generate showers with different lateral distribution functions (LDF) of Cherenkov light. The LDF can hence give information about the chemical composition of primary cosmic rays.

There are theoretical works suggesting different models of cosmic rays origin and propagation through space. Some of them give a smooth change of spectrum exponent and chemical composition, some gives a dramatically sharp change of them, finally some propose the second sharp change of differential spectrum after the first one, which can only be found with high resolution Cherenkov light experiment.

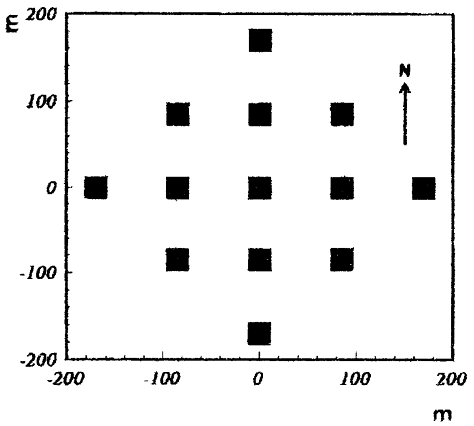

Figure 1: Plan of TUNKA array

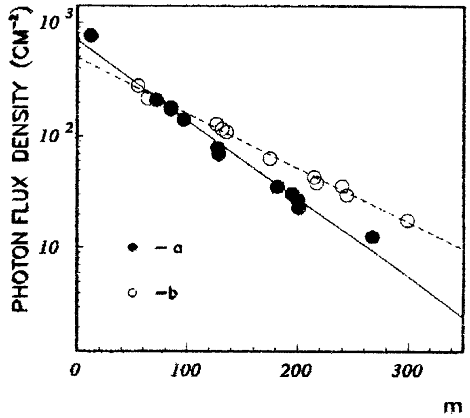

Figure 2: Individual lateral distribution function for 2 events: (a)- E=8300, $\theta = 4^0$, $R_0 = 62$m; (b)- E=9400, $\theta = 10^0$, $R_0 = 89$m.

2 Experimental array

The array is located in Tunka Valley, 50 km to the west from the south-west end of Lake Baikal (51.49 N, 103.04 E), at 680m above the sea-level. The array comprises 13 *QUASAR-370* phototubes with 37cm photocathode diameter [2], set up in a square of 240 m side (Fig.1).

To decrease the constant background current at the PMT output we use 5 multiplying dynodes of the PMT only. The full gain of the phototube is thus about 10^4, and this low gain is compensated by a low noise electronic preamplifier connected directly to the 6th dynode of the PMT.

All the detector apparatus is situated at a container 65x75x90 cm^3. The container cover can be opened and closed distantly from the center point. The container has a circle plexiglass window of 50 cm diameter with a special heater to prevent the dew and hoar frost falling out.

Signals from preamplifier come via the coaxial cable to the central electronic station. It consists of amplifiers, CF discriminators, 12-digits TDC with steps 0.3 - 0.5 ns, 13-digits ADC (with time gate 100ns) and trigger system. Trigger condition is any 4 hits among all the detectors inside the 1 microsecond gate.

To get the very wide range of amplitude measurements we use two ADCs with 10 times different steps for every detector. The hardware threshold is about 100 *ph.e.* The upper limit of amplitude measurement linearity is more than 50000 *ph.e*

3 Calibration

TDC steps calibration has been made 1 - 2 times per month and it has shown full stability of TDC steps during all the winter season. The apparatus delay for every channel was controlled with measuring of time difference between the central end every other detector for recorded events (Δt). We reasonably assume that Δt distribution maximums corresponds to the vertical events.

Absolute amplitude calibration is based upon the method of measuring of number of photoelectrons (*N ph.e.)* produced by the standard flash of light diod. (*N ph.e.)* is estimated from the measured standard deviation of every detector response distribution. This sort of calibration is made every night. The uncertainety in coefficient of recalculation from (*N ph.e.)* to the number of Cherenkov light photons (different for different sample of detector) yeilds the

30% uncertinty in absolute calibration till now. We plan to reduce the uncertainty to 10% with getting more accurate counting of individual detector character to the next winter season.

The accurate relative calibration of detectors is made with the comparing of the response distributions of all the detectors for recorded events. The preliminary computer simulation of the array response has shown that the detector response integral spectrum has to be the same for high enough amplitudes for every detector. Typical statistical accuracy of this calibration is about 5%. The simultaneous change of all the spectra is treated as an adequate change of relative atmospheric transparency *(R.A.T.)*. *R.A.T.* coefficient is assumed to be 1.0 for the night with the best transparency. The transparency coefficient is taken into account during the processing of events. Only the recording time with relative atmospheric transparency coefficient more than 0.8 has been taken into account. Such fine weather recording time collected last winter was about 120 h.

4 Reconstruction of events

The main parameters the program reconstructs are zenith and azimuth angles of the shower axis, shower core location on the surface, EAS energy and individual lateral distribution function slope parameter R_0.

The arrival direction of shower was obtained assuming the spherical shape of the shower front. The accuracy of space angle is less than 0.5 deg.

The program for reconstructing EAS core and energy is based upon the results of previous experiments at Samarkhand [3] and Yakutsk [4]. It was obtained at that works, that lateral distribution function (LDF) can be approximated with expression: $Q = Q_{100} * exp((100 - R)/R_0)$, Q_{100} is the photon density at a fixed distance 100 m from the core. Like at our previous work [5] we use this approximation as a test function and treat the parameter R_0 as an independent veriable during the minimization of functional. As a result of minimization we get 3 independent parameters - x,y,R_0 - at each event and one dependent of them being a photon density at a fixed distance from the core - Q_{100}. To derive the primary energy we use the relation between Q_{100} and E_0 simulated for the energy region 100-10000 TeV [6]: $E_0 = 74 * Q_{100}^{0.95}$ TeV, where Q_{100} is measured in photons per cm^2 (for 300-800 nm spectral range).

The preliminary computer simulation of the array response yields the error of EAS core location less than 10m, the relative accuracy of energy better than 10%, and the accuracy of LDF slope parameter R_0 about 2 m for EAS with energy more than 3 PeV with core locations inside the array geometry frame.

5 The first experimental results

Fig. 2 presents two samples of processed events with energy about 10 PeV one to have the steepest LDF and the other - the most flat LDF for that energy. It is seen that relatively steep individual function deflects a little from the pure exponential form at distances more tham 250 m from the core and closer than 50 m to the core.

To obtain the energy spectrum we use the events with zenith angles less than 25 deg and core location inside the square 240×240 m^2. Spectrum for the first 120 h is presented at fig. 3 together with the spectra of some other installations. The spectrum containes about 61000 events with energy more than 400 TeV and about 1200 events with energy above 5 PeV.

Left three points demonstrate the growth of the effective recording area with the energy. The energy, when the effective area becomes equal to total geometry area of the array is about 400 TeV. From this energy and to the energy 4 PeV the spectrum can be approximated with the unique slope $\gamma = -2.60 \mp 0.02$. It is unambiguously seen that the slope becomes much higher at energies above 5 PeV.

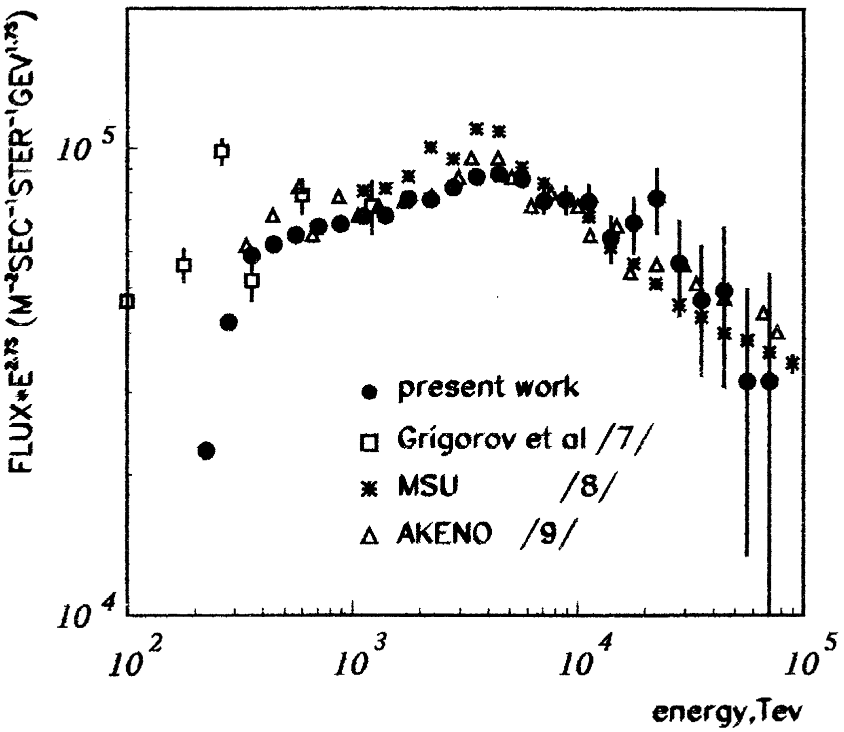

Figure 3: Differential energy spectrum of primary cosmic rays

The existance of any points deflecting from reqular spectrum at energies above 10 PeV is still uncertain. We hope to solve this problem with collecting more ststistics in one or two years.

Acknowlegements

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References

1. Kulikov,G.V.,Khristiansen,G.B., *JETP*, **35**, 635 (1958)
2. Bagduev,R.I. *et al.*, *Proc. Int. Conference on Trends in Astroparticle Physics* Aachen, 132 (1994)
3. Aliev,N. *et al.*, *Proc.19th ICRC* La Jolla **7** 107 (1985)
4. Efimov,N.N. *et al.*, *Proc.Sov.CRC* Alma-Ata, **1** 17 (1989)
5. Bryanski,S.V. *et al.*, *Proc.24th ICRC* Roma, **2** 724 (1995)
6. Anokhina,A.M. *et al.*, *Proc.23th ICRC* Calgary, **4** 227 (1993)
7. Grigorov,N.L., *High Energy Particles at Cosmic Rays* , "Nauka", Moscow(1973)
8. Fomin,Yu.A. *et al.*, *Proc.22nd ICRC* Dublin, **2** 85 (1991)
9. Nagano,M. *et al.*, *J. Phys. G* , **10** 1295(1984)