Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Hardware and first results of TUNKA-HiSCORE

M. Kunnas^{a,*}, M. Brückner^c, N. Budnev^e, M. Bükér^a, O. Chvalaev^e, A. Dyachok^e,
U. Einhaus^a, S. Epimakhov^a, O. Gress^e, D. Hampf^a, D. Horns^a, A. Ivanova^e,
E. Konstantinov^e, E. Korosteleva^d, L. Kuzmichev^d, B. Lubsandorzhev^f, R. Mirgazov^e,
R. Monkhoev^e, R. Nachtigall^a, A. Pakhorukov^e, V. Poleschuk^e, A. Porelli^b, V. Prosin^d,
G.I. Rubtsov^f, G.P. Rowell^g, P.S. Satunin^f, Yu. Semeny^e, D. Spitschan^a, L. Sveshnikova^d,
M. Tluczykont^a, R. Wischnewski^b, A. Zagorodnikov^e

^a Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

^b DESY, Platanenallee 6, 15738 Zeuthen, Germany

^c Institute for Computer Science, Humboldt-University Berlin, Rudower Chaussee 25, 12489 Berlin, Germany

^d Skobeltsyn Institute for Nuclear Physics, Lomonosov Moscow State University, 1 Leninskie gory, 119991 Moscow, Russia

^e Institute of Applied Physics ISU, Irkutsk, Russia

^f Institute for Nuclear Research of the Russian Academy of Sciences 60th October Anniversary st., 7a, 117312 Moscow, Russia

^g University of Adelaide 5005, School of Chemistry & Physics, Australia

ARTICLE INFO

Keywords:

HiSCORE

Astroparticle

Non-imaging Cherenkov experiment

ABSTRACT

As a non-imaging wide-angle Cherenkov air shower detector array with an area of up to 100 km², the HiSCORE (Hundred* Square km Cosmic ORigin Explorer) detector concept allows measurements of gamma rays and cosmic rays in an energy range of 10 TeV up to 1 EeV. In the framework of the Tunka-HiSCORE project we have started measurements with a small prototype array, and planned to build an engineering array (1 km²) on the site of the Tunka experiment in Siberia. The first results and the most important hardware components are presented here.

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1. Tunka-HiSCORE

The Tunka-HiSCORE detector array is a ground-based extensive air shower Cherenkov detector array that samples the air shower light front using the non-imaging technique. With a spacing of about 100–300 m between stations, it is possible to cover a large area with a small number of detectors. For the physics goals, see Ref. [1], for a description of the expected reconstruction performance see Ref. [2]. We are currently working towards an engineering array [5] of 1 km² on the site of the Tunka experiment [3,4].

2. Detector station concept

2.1. Planned station setup

A single detector station consists of four Photomultiplier Tubes (PMTs) of a diameter of 8 in. (20 cm) with six dynodes that yield a nominal gain of 10⁴ at a supply voltage of 1.4 kV.

Each PMT is equipped with a light collector (Winston cone) made up of ALANOD 4300 UP material with a reflectivity of 80%. In the standard configuration, the Winston cones have a half opening angle of 30° and point to the zenith. For a better view of the galactic plane, it is possible to tilt the viewing axis of the stations. The cones increase the light collection area by a factor of four in comparison to pure PMT area, resulting in a total light collection area of 0.5 m² per station. Each cone is composed of ten segments of reflective material, mounted along the optical axis and fixed with plates at the top and bottom of the cone [2].

To acquire the shower data, the high-gain anode channel signals of the PMTs are split and amplified by a custom fast preamplifier. One set of signals is processed by a clipped sum trigger. In this trigger system, each signal is first clipped at an adjustable clipping threshold, then the clipped signals are summed up. If there was an event, the amplitude of the signal is four times the amplitude of a single clipped signal. The threshold for the following trigger should be slightly below this level so that it only sets off if all four channels had a signal that was high enough to be clipped. This behavior greatly reduces noise, especially the noise produced by afterpulses of the PMTs.

The other set of the PMT signals is summed up and sampled via a custom DRS4 chip based board. For the same purpose we also

* Corresponding author. Tel.: +49 15772704242.

E-mail address: maike.kunnas@desy.de (M. Kunnas).

Fig. 1. Concept of a HiSCORE station.

Fig. 2. Comparison between dead-time corrected single station trigger rate (squares) and estimated night sky background spectrum (dots).

sum up and sample the low-gain PMT channels, which are read out at the fifth dynode.

Each event in each station is provided with a time stamp to reconstruct the direction of the shower. For this, the time between stations needs to be synchronised to a nanosecond level (also see Ref. [7]). The system will be based on an improved Tunka time synchronization (based on the carrier frequency of the optical fibers) or on the WhiteRabbit system, a Gbit-ethernet based system developed at CERN for synchronisation of nodes with a spacing of up to 10 km, yielding a resolution of 1 ns with a phase stability of 200 ps.

Different solutions for station to data acquisition center communication (industrial miniPCs) and for slow control are available and being tested.

2.2. Current prototype test setup

The three Tunka-HiSCORE stations built so far have not yet reached the full planned setup. The PMTs used are EMI 9350 KB, also in operation in the Tunka-133 array. In the future, we plan to use ET9352KB or Hamamatsu R (modified with 6 stages) PMTs [5]. The clipped-sum-trigger is not operational yet, thus far we have developed a summator board without clipping, the trigger being provided by one of three possible methods: the Tunka-FADC trigger of the Tunka array, the onboard trigger of the WhiteRabbit system or the trigger of the DRS4 evaluation board which is used for readout. The DRS4 evaluation board [8] was developed by the

Paul Scherrer Institute and features a Domino Ring Sampler (DRS) 4 chip capable of 1024 bin sampling with 0.5–5 Gigasamples per second and a readout rate of up to 500 Hz. The Evaluation board currently used has four channels plus one trigger input, but the DRS4 chip itself is capable of using up to eight channels plus trigger, which is an option considered for the custom DRS4 board which is currently under development.

3. Results from the prototype station measurements

Three prototype stations have been installed in October 2012, and were used for cross-calibration with the Tunka-133 Array (Fig. 1).

Different trigger measurements have been made to test background and minimum trigger threshold (see Fig. 2). Air-shower induced events are the main component of the trigger rate down to a trigger threshold of 70 mV for the chosen station (dashed straight line for reference). Below, the night-sky background is responsible for the sharp increase of the trigger rate (dashed curved line for reference). The saturation of the measured raw trigger rate in the integrated spectrum (to be seen in Ref. [6]) lies at 20 Hz, which gives us an estimation of the dead time of about 50 ms.

4. Outlook

Nine stations have been deployed so far. The Tunka-HiSCORE engineering array will cover an area of about 1 km² with about 60 stations, with the option of further expanding the array size to 10 km² and more. Also, the final layout of the array is being under evaluation, finding the best compromise between sensitivity and the number of stations.

For improvement of the single stations, the use of UV wavelength shifter coating of the PMTs is explored. These shifters turn photons from 300 to 340 nm range to 360 to 400 nm, thus increasing the trigger rate of a station by about two times.

Further analyses of the prototype data are underway (e.g. energy threshold and zenith angle acceptance).

Acknowledgements

This work was supported by the Russian Federation Ministry of Education and Science (G/C 14.518.11.7046, 14.B25.31.0010, 14.14. B37.21.0785, 14.B37.21.1294), the Russian Foundation for Basic Research (Grants 11-02-00409, 13-02-00214, 13-02-12095, 13-02-10001) and by the Helmholtz Association (Grant HRJRG-303) and the Deutsche Forschungsgemeinschaft (Grant TL51-3).

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