Components of the HiSCORE detector and prototype test results


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Abstract: The Hundred Square-km Cosmic ORigin Explorer (HiSCORE) experiment is currently in its engineering phase. Different hardware components were developed, tested, and deployed in the Tunka valley (Siberia). In this presentation, first data and measurements will be presented.

Keywords: HiSCORE, Tunka, gamma-astronomy, cosmic rays

1 Introduction
The Hundred Square-km Cosmic ORigin Explorer (HiSCORE) is a new wide-angle non-imaging EAS Cherenkov array designed for multi-TeV gamma-astronomy and cosmic ray studies. It will provide spectrum and composition measurements of cosmic rays in the energy range from 100 TeV to 1 EeV, and gamma-ray observations above 10 TeV [1].

During 2012 three prototype stations have been deployed on the Tunka site in Siberia [2] where an engineering array of up to 1 km² is planned for deployment by 2014.

2 HiSCORE design
HiSCORE is a ground-based array of optical detectors distributed over a large area (up to 100 km²) with an inter-spacing of 100-200 m. The distance between stations chosen for the simulated design are motivated by a compromise between the capability of sampling the inner part (up to 200 m) of the air-shower lateral density function (LDF), and the goal to cover the maximum possible area with a given number of detector stations.

Comparison of different layouts, such us rectangular and graded array, and predictions for sensitivity are discussed [3].

Fig. 1 shows the concept of the HiSCORE detector station.

2.1 Optical station
Each optical station has four hemispherical 8-inch PMT (20 cm photocathode diameter) equipped with light collecting Winston cone (half-opening angle 30°) pointing at zenith resulting in an effective field of view of 0.6 sr, and a total light collection area of 0.5 m² per station. The light collector is a 10-segmented cone with 80%-reflecting material ALANOD 4300 UP. As result light collection area is increased by the factor of 4. Further possibilities of increasing the effective light collection using 12-inch PMTs (30 cm photocathode diameter) [3], and UV wave length shifter for PMTs are explored. Depending on the source location, the sky coverage can be significantly increased by tilting the detector optical axis up [5].

A PMT with nominal gain of 10⁴ is mounted at the focal plane of each Winston cone. The divider base provides the anode and dynode signals. It sets the high voltage directly at the PMT, and operates with a 12 V power supply and 5 V regulation voltage. Using a fast pre-amplifier (x10) results in a total dynamical range of 5 orders of magnitude.

At the moment, prototype stations are equipped with custom Tunka PMTs (EMI 9350), divider bases and pre-amplifiers [2].

Fig. 1: HiSCORE detector station concept.
2.2 Data acquisition system

During the engineering phase of Tunka-HiSCORE two DAQ systems are used in parallel. For the 2012/13 setup (see sect. 3), the standard Tunka DAQ, based on a FADC readout (200 MHz sampling), and a DAQ system based on a GHz sampling DRS4 evaluation board and ns-time synchronization. In future, we plan to use a custom realization of a readout board based on the DRS4 chip, which is currently under development.

Fig. 2: Signal processing and triggering [6].

The trigger board (version 2) is under testing. Anode signals on the trigger board are summed and the sum is discriminated. The next design of trigger board will have clipping as well, when signals of four channels on the trigger board are clipped and summed, and the sum is discriminated at a level of slightly less than four times the clipping level (Fig. 2). This procedure suppresses false triggers from NSB fluctuations or afterpulsing. Different solutions for the discrimination are explored.

Two different systems for slow control (HV regulation, lids opening/closing, heating) are available: Plug PC/Arduino/ISEG(HV) and Tunka controller.

The custom-made high voltage supply by ISEG can be used to power the PMTs. The supply board and trigger board are controlled with an Arduino Mega micro controller. The GuruPlug PC is used as a local station PC interface for the slow control and readout. A central DAQ PC controls the GuruPlug via server/client connection.

Synchronization of events between stations will be done with sub-ns precision. Two different systems are under study, WhiteRabbit (operating since 2012 [7]) and a custom system based on transmitting a frequency over the optical ethernet fiber.

3 Prototype tests

During the 2012/2013 winter season three prototype stations were tested.

Fig. 3 shows a pulse of an air-shower together with triggering of evaluation board and WhiteRabbit synchronization system. The on-board WhiteRabbit FPGA was used to generate a trigger signal with a defined time-over-threshold of 16 ns. Both trigger show excellent timing with sub-ns jitter (the late oscillation for the WR-signal is of no relevance).

We measured the trigger rate of a single station. As can be seen in Fig. 4, cosmic-ray induced air-shower events dominate the dead time corrected trigger rate down to a threshold value of 70 mV for the chosen station. The dashed curve in the air-shower region with slope of 1.6 shown for reference. Below, the sharp rise in trigger rate is due to the night-sky background. For dead time correction, we estimated dead time of 50 ns from the saturation of the measured raw trigger rate (not shown in figure). NSB rate is derived from the pre-pulse analysis of the electronic noise trace in the assumption of harmonic behavior. Background spectrum is approximated by the function $F(>A) = F_0 \cdot (1 - \text{erf}(A/\sqrt{2}\sigma))$. The fit gives electronic response time $T_{eff} = 1/F_0 \approx 19$ ns and NSB fluctuations around zero line $\sigma \approx 11$ mV.

During spring 2013, ultraviolet wave length shifter coating of the PMTs to increase the light yield were explored. Shifters turn UV light into light visible for the PMT. Preliminary tests show that using different UV wave length shifters and the effective plexiglass increase the trigger rate of a single station by factor 2-3.

The future analysis will include time-amplitude calibration, determination of energy threshold and detector zenith angle acceptance. An prototype array of up to 0.1 km² with nine optical stations is planned for deployment in 2013. Joint operation with Tunka array will provide cross calibration measurements and the first physics.
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