First deployment and prototype data of HiSCORE

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Abstract. With the HiSCORE (Hundred*i Square kilometer Cosmic ORigin Explorer) experiment we aim at the exploration of the accelerator sky using indirect air shower observations of cosmic rays from 100 TeV to 1 EeV and gamma rays above 10 TeV to several PeV. In this paper the HiSCORE detector is discribed and the results of the first prototype deployment are shown. Several components are discussed like the photomultiplier tubes, the clip-sum-trigger and the DRS4 based data acquisition. We present data taken with a first prototype station in April 2012 at Tunka.

1. Introduction
The question of the origin and propagation of cosmic rays can be addressed by indirect air shower observations with ground-based experiments. One important aspect in this context is the search for the so far undetected Galactic cosmic ray pevatrons, one of the main goals of the HiSCORE experiment. Details on further physics cases can be found in [1].
2. HiSCORE

2.1. HiSCORE array

The HiSCORE array is a distributed array of detector stations with an inter-station spacing of 150 m and a total area of up to 100 km$^2$. The inter-station distances chosen for the simulated design are motivated by a compromise between the capability of sampling the inner part of the lateral density function (LDF) (up to 120 m radius) and the goal to cover the maximum possible area with a given number of detector stations. Different array designs and spacings are currently being simulated and investigated. Predictions for the sensitivity based on a full simulation are given in [2].

2.2. HiSCORE detector station

The HiSCORE detector consists of a box with four PMTs each equipped with a Winston cone, readout electronics, slow control, environment sensors, data transmission, and a (sub)ns precision clock. In the following some components are explained in detail. Figure 1 shows a schematic of the HiSCORE detector.

![HiSCORE detector station concept](image)

**Figure 1.** Block diagram of the HiSCORE station without station mechanics. Further details are explained in the text.

2.2.1. Station mechanics

The station mechanics consists of a 1 m$^3$ box with a sliding lid mechanism. The readout and control electronics will be partly placed inside the station box. An additional electronics box is also envisaged. Necessary components like the Winston cone (light collector) constructed out of ten segments of reflective foil (ALANOD 4300 UP) are contained in the station box, too. One cone is mounted on each PMT and increases the effective area of a PMT by a factor of four.
2.2.2. Photomultiplier tubes
A six-stage PMT by Electron Tubes (KB 9352) is mounted at the focal plane of each Winston cone. The same PMTs were used in the AIROBICC experiment [3]. The six stages, resulting in a nominal gain of $10^4$, are appropriate for the expected level of night sky brightness (NSB). The PMTs are used with especially developed high voltage dividers by iseg. The divider base generates the high voltage directly at the PMT and is run with a 12 V power supply and 5 V regulation voltage, and provides the anode signal and the signal from the 5th dynode. Using a fast pre-amplifier (x10) results in a total dynamical range of 5 orders of magnitude.

2.2.3. Readout
The PMT signals at the anode (high gain) and the 5th dynode (low gain) are amplified before triggering and readout. The anode signals are clipped and summed, and the sum is discriminated at a level of slightly less than four times the clipping level (figure 2). This clip-sum-trigger suppresses false triggers from random coincidences and strong signals in individual channels, caused by NSB fluctuations or afterpulsing. The anode and the dynode signals from all channels are summed before readout. Alternatively, possibilities for sampling all channels individually are explored. In case of a trigger the next element in the readout chain is a readout board based on the DRS4 chip\(^1\), providing GHz sampling rates. It samples the anode sum and the dynode sum for later event reconstruction, with an inter-station relative time-precision at (sub)ns level. For this purpose White Rabbit is tested.

\[ \text{Figure 2. Clip-sum-trigger logic of HiSCORE from [4].} \]

2.2.4. Slow Control
Central part of the slow control is the Arduino Mega micro controller. Together with a custom built sensor and control shield it regulates the high voltage of the PMTs, checks environment parameters like brightness, humidity, and temperature, opens and closes the lid, and switches

\(^1\) http://drs.web.psi.ch/
the heater on and off. The GuruPlug\(^2\) 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.

3. First prototype measurements

3.1. Laboratory tests

In preparation of the deployment, PMTs were intensively tested and characterized. A test bed was developed, which could cover several measurements. Beside the gain and the relative signal jitter of the PMT, the acceptance of the photocathode surface was analyzed by using different azimuth angles. The acceptance turned out to be inhomogeneous, an aspect to be considered during the deployment and event reconstruction.

3.2. Field tests

In April 2012, the first HiSCORE prototype station was deployed at the Tunka site in Russia [5]. Due to good observational conditions the first data could be taken (example pulse see figure 3). These measurements allowed us to gain experience with detector components and their on-site integration.

The next deployment of five stations at Tunka will start in autumn 2012.

Figure 3. Cherenkov event detected during in April 2012 at Tunka. Channel A and B are Cherenkov pulses detected by HiSCORE PMTs, the Tunka PMT from a nearby Tunka-133 sensor triggering the readout.

3.3. Analysis

The data reconstruction in joint operation with the Tunka-133 array lead to events between 1 and 130 PeV, seen with Tunka-133 and HiSCORE. The reconstructed LDF of one of these events is shown in figure 4. The density measurement provided by the HiSCORE station is compatible with the Tunka measurement. Further analysis of these and future data will allow a full cross-calibration and provides input for our detector simulation. A quantitative analysis of

\(^2\)http://www.globalscaletechnologies.com/
the current data is limited by the poor statistics. In the last observation night, the HiSCORE station triggered by its own, resulting in a significantly higher trigger rate due to the lower energy threshold of the HiSCORE station (8 times more light collection area than a Tunka PMT).

![Image]

**Figure 4.** LDF of the most energetic event seen with HiSCORE and Tunka. Upper curve: integral analysis, lower curve: amplitude analysis. The circles with stars represent HiSCORE, all others Tunka detectors.

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