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The wide-aperture gamma-ray telescope TAIGA-HiSCORE in the Tunka Valley: Design, composition and commissioning

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ABSTRACT

The new TAIGA-HiSCORE non-imaging Cherenkov array aims to detect air showers induced by gamma rays above 30 TeV and to study cosmic rays above 100 TeV. TAIGA-HiSCORE is made of integrating air Cherenkov detector stations with a wide field of view (0.6 sr), placed at a distance of about 100 m. They cover an area of initially ~0.25 km^2 (prototype array), and of ~5 km^2 at the final phase of the experiment. Each station includes 4 PMTs with 20 or 25 cm diameter, equipped with light guides shaped as Winstone cones. We describe the design, specifications of the read-out, DAQ and control and monitoring systems of the array. The present 28 detector stations of the TAIGA-HiSCORE engineering setup are in operation since September 2015.

1. Introduction

The γ-ray detection beyond 10 TeV is extremely important for the search for the most energetic Galactic accelerators. The energy spectra of most known γ-ray sources only reach up to few tens of TeV and to 80 TeV from the Crab Nebula. Uncovering spectral shape of the γ-ray sources up to few 100 TeV could answer the question whether some of these objects are cosmic ray Pevatrons, i.e. Galactic PeV accelerators [1]. Due to the typical powerlaw shape of the energy spectra of cosmic γ-ray sources, large effective detection areas are needed in order to access higher energies.

The TAIGA-HiSCORE array is part of the gamma-ray observatory TAIGA (Tunka Advanced Instrument for cosmic ray physics and

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Gamma Astronomy). The TAIGA is currently under construction in the Tunka valley, about 50 km from Lake Baikal in Siberia, Russia [2]. The key advantage of the TAIGA will be the hybrid detection of EAS Cherenkov radiation by the wide-angle detector stations of the TAIGA-HiSCORE array and by the Imaging Air Cherenkov Telescopes of the TAIGA-IACT array [3]. TAIGA comprises also the Tunka-133 array and will furthermore host up a net of surface and underground stations for measuring the muon component of air showers.

The principle of the TAIGA-HiSCORE detector follows the idea [4]: the detector stations measure the light amplitudes and full time development of the air shower ligth front up to distances of several hundred meters from the shower core.

2. Design of the gamma-ray telescope TAIGA-HiSCORE

Currently TAIGA-HiSCORE array is composed of 28 detector stations distributed in a regular grid over a surface area of 0.25 km^2 with an inter-station spacing of about 106 m (see Fig. 1).

The optical stations was deployed in 2014 on the same site in the Tunka Valley ($\varphi = 51°48'47.5''$N, $\lambda = 103°04'16.3''$E, $h = 675$ m a.s.l.) where the Tunka-133 installation is located [5]. All stations are tilt into the southern direction by up to 25° to increase the accessible night sky area for study γ-quanta fluxes from the first test objective – Crab nebula.

3. Optical station

Optical Station is a metal box (size of $1 \times 1 \times 1$ m^3) with remotely-operated lid to protect against sunlight, atmospheric precipitations and dust (see Fig. 2).

This metal box contains the optical station controller, high voltage power supply unit (HV), heaters for the plexiglass input windows, photomultipliers with voltage dividers and preamplifiers. Each optical station contains four large area photomultipliers with 20 or 25 cm diameter, namely EMI ET9352KB, or Hamamatsu R5912 and R7081. Each PMT has a Winston cone (made of ten segments of ALANOD 4300UP foil with reflectivity 80%) with 0.4 m diameter and 30° viewing angle (field of view of ~0.6 sr). Plexiglass is used on top to protect the PMTs against dust and humidity. So a total station light collection area is 0.5 m^2. We use the six-stage divider of PMT that has a nominal gain of 10^4 at 1.4 kV supply. The fast pulse preamplifiers for anode and dynode sygnals are designed on base of the ultrahigh speed current feedback amplifier AD8009 chip.

Average PMT anode current due to night sky background light (NSB) is ~80 ± 30 μA depending on the detector operating mode and the weather conditions. Shower counting rate is ~10 Hz by station trigger threshold ~200 photoelectrons. Since the average quantum efficiency is ~0.1 for the optical station, the Cherenkov light detection threshold per station is ~0.3 photons/cm^2.

4. Electronics of the array

The electronics of the array for functional purpose consists of three parts: data acquisition (DAQ) system, slow control system and monitoring system. The basic electronics components, their interrelationship and location shown in Fig. 3.

The Heating Controller maintains a stable temperature DAQ into the Electronics Box.

4.1. Slow control system

The main elements of the slow control system Fig. 4 are the three controllers each on the basis 16-Bit Flash Microcontroller PIC24FJ64GA004I-PT. This controllers (HV Controller, Measurement Controller and Power Load Controller) are connected in single board. This controllers board is located directly in the optical station and connected to the MOXA NPort5150A converter via RS-485 bus. An 8-Port Gigabit L2 Managed Switch TL-SG3210 with 2 SFP Slots and the Moxa NPort5150A Serial Ethernet Converter are placed in the Electronics Box, with special temperature control (see Fig. 3).

The slow control system is designed to:

- control lid position of the station;
- control heating of the input plexiglass windows;
- monitoring load currents of the lid motor and heating;
- control HV power supply of PMTs;
- monitoring HV and PMT anode currents;
- auto turn-off by overcurrent;
- auto turn-off by time of the end of the night.

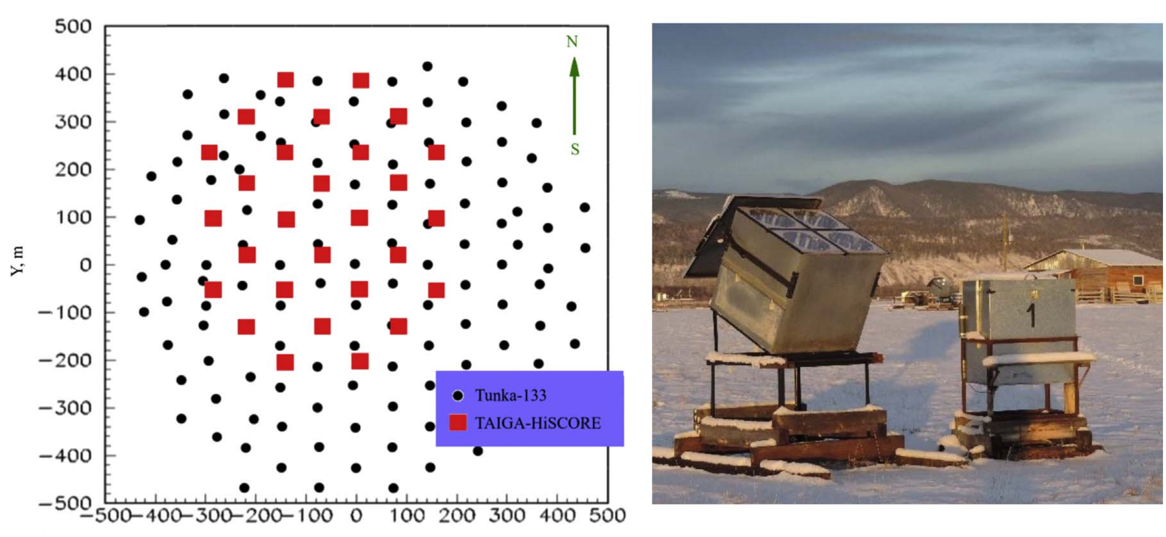

Fig. 1. Station layout of the TAIGA-HiSCORE array. Left: Location of the 28 optical stations (square) in the inner part of Tunka-133 Cherenkov light detectors (circles). Right: Photo of the optical station and its electronic box. In the background – the central DAQ building.

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