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TAIGA experiment –a new instrument for high energy gamma-ray astronomy and cosmic ray studies.

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The gamma-ray observatory TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) is being developed to study gamma rays and fluxes of charged cosmic rays in the energy range of 10ˆ13 eV –10ˆ18 eV. The array will include a network of wide-angle (Field-of-view (FOV) - 0.6 sr) Cherenkov stations and up to 16 Imaging Atmospheric Cherenkov Telescopes (IACTs) with FOV˜10×10 degrees each covering an area of 5 km² and muon detectors with a total area of 2000 mˆ2 distributed over an area of 1 km2. The expected sensitivity of the observatory to search for local sources of gamma-rays in the energy range of 30-200 TeV is about 10-13 erg/cmˆ2 sec. In the paper we give a detailed description of photon detectors developed for the experiment. This paper presents also results of operation of the first 28 wide-angle Cherenkov stations.

Summary

In recent years, ground-based gamma-ray astronomy at very high energies (VHE) became the most dynamically developing field in high-energy astroparticle physics. More than 150 sources of TeV gamma rays have been discovered and studied with Imaging Atmospheric Cherenkov Telescopes (IACTs) of the third generation (HESS, VERITAS, MAGIC). However, gamma rays with energies higher than 80 TeV have not been detected up to now. For an extension to higher energies one needs an array with several square kilometers area.
This talk presents the gamma-ray observatory TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) which addresses crucial questions of gamma-astronomy and of cosmic ray physics. TAIGA is under construction in the Tunka valley, about 50 km from Lake Baikal in Siberia, Russia. The key advantage of TAIGA is the combined detection of air shower Cherenkov radiation by the wide-angle detector stations of the TAIGA-HiSCORE array and the IACTs of the TAIGA-IACT array. The HiSCORE data will allow reconstructing the shower arrival direction with an accuracy of about 0.1 degree, the shower axis within 5-6 m, the shower energy E0 with about10-15% and the shower maximum height Xmax with 20-25 g/cm2. The main task for the IACT array is separating gamma-initiated air showers against the background of charged cosmic rays. Simultaneous measurement of air showers by several of the more densely spaced wide-angle Cherenkov detectors allows increasing the distance between the IACTs up to 1000 m. The HiSCORE and IACT arrays complement each other. This allows constructing a detector with an area of >5 km2 for a price which is about 10 times less than a mere IACT array (like CTA) and to search for super-high energy gamma rays.
TAIGA-HiSCORE is a net of detector stations with spacing 75-200 meters, each equipped with four PMTs with a light-collecting Winston cone of 30o half-opening angle. The principle of HiSCORE is the sampling of the Cherenkov light front of air showers. The detector stations measure the light amplitudes and the arrival time differences over a distance of a few hundred meters. The main DAQ-board is designed on the basis of the DRS-4 chip and the FPGA Xilinx Spartan-6. The accuracy of the time synchronization of detector stations is 0.2 ns and the time step of the PMT waveform digitization 0.5 ns. The energy threshold for gamma-ray detection is ˜30 TeV. The TAIGA-HiSCORE engineering array with 28 detector stations is in operation since September 2015. The full array with 500 detector stations, distributed over an area of 5 km2, is planned to be completed in 2020.
The TAIGA-IACT array will consist of 16 IACTs distributed over an area of 5 km2. Its reflector area will be about 10 m², with a focal length of 4.75 m. The imaging cameras with 547 PMT-based pixels have a total Field of View of 9.72×9.72 degree. Each PMT is equipped with a Winston cone with an entrance size of 30 mm and an exit spot of 15 mm diameter. The entire array of pixels is divided into clusters of 28 PMTs. Each cluster includes an electronic board MAROC, the basic of which is the 64-channel chip ASIC MAROC3.
For additional suppression of the background of charged cosmic rays, TAIGA will be equipped with a muon array. It consists of underground muon detectors with total area of 2000-3000 m2. The first stage of this subarray uses the muon scintillation counters formerly operated as part of EAS-TOP and KASCADE-Grande. This

so-called Tunka-Grande detector with 19 scintillation stations was put in operation in November 2015. Each station has a surface part with 12 scintillation counters (size of each is 80×80×4 cm3) and an underground part with 8 of the same counters. The DAQ of the Tunka-Grande array is rather similar that of the Tunka-133 wide angle Cherenkov array operated since 2009.
Simulations show that gamma rays with energies >100 PeV can be rather effectively identified by the hybrid operation of the TAIGA-Muon array and Tunka-Rex (Tunka Radio extension) which presently consists of 44 antenna stations spaced by 200 m and spread over about 3 km2. Also Tunka-Rex will be extended in the future.

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