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Status of the Baikal-GVD project

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ABSTRACT

The construction of a km^3-scale neutrino telescope – the Gigaton Volume Detector (GVD) in Lake Baikal – is the central goal of the Baikal collaboration. During the R&D phase of the GVD project in 2008–2010 years the basic elements of GVD – new optical modules, FADC readout units, underwater communications and trigger systems – have been developed, produced and tested in situ by long-term operating prototype strings in Lake Baikal. The prototyping phase of the GVD project has been started in April 2011 with the installation of a three string array (prototype cluster) which comprises all basic elements and systems of the GVD-telescope in Lake Baikal. We describe configuration and technical design of the GVD, present selected results obtained during 2008–2010 with prototype strings, and describe configuration and design of the 2011 prototype cluster.

1. Introduction

The Baikal collaboration follows since several years a R&D program for a Gigaton Volume Detector (GVD) in Lake Baikal. GVD will be a kilometer-scale high-energy neutrino observatory [1,2]. The main scientific goal of GVD is to map the high-energy neutrino sky in the Southern Hemisphere including the region of the galactic center. Other topics include the indirect search for dark matter by searching for neutrinos produced in WIMP annihilation in the Sun or in the center of the Earth. GVD will also search for exotic particles like magnetic monopoles, supersymmetric Q-balls or nuclearites.

The GVD detector will be located in the southern basin of Lake Baikal close to the NT200+ telescope [3,4]. The geographical coordinates of the detector site are 51°50′N and 104°20′E. Since the slope of the shore bottom relief is rather steep, the telescope can be arranged comparatively nearly to shore at distances of 4–5 km. The depth of the lake is about 1400 m at this place. The light propagation in the Baikal water is characterized by an absorption length of 20–25 m and a scattering length of 30–50 m. The water luminescence is low at the detector site. The rate of light pulses from K^{40}-decays is negligible.

The first generation Baikal Neutrino Telescope NT200 is operating in Lake Baikal since April 1998 [5–8]. NT200 consists

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of eight 72 m long strings, each with 24 pairwise arranged optical modules (OMs). Each OM contains a 37-cm diameter hybrid photodetector QUASAR-370, developed specially for this project [9]. The upgraded Baikal telescope NT200+ [3] was commissioned in April 2005, and consists of a central part (the former, densely instrumented NT200 telescope) and three additional external strings. The construction of NT200+ was a first step towards a km^3-scale neutrino telescope. The important km^3-milestones were the construction and installation of prototype strings in 2009–2010 [1,10] and a prototype GVD cluster, comprising three strings, in 2011. The basic goals of the prototype array installation are investigation and in situ test of basic elements of the future detector. In this paper we review the R&D activities towards a km^3-scale Baikal telescope.

2. GVD design

In this section we will discuss basic principles of the GVD design and the results of optimization of the GVD configuration.

The basic approach designing the Baikal-GVD is the same as for the NT200 design. This approach provides a relatively flexible structure, which allows for a future expansion of the instrumented volume as well as a rearrangement of the main building blocks (clusters), to adapt to requirements of new scientific goals, if necessary.

GVD will consist of strings of optical modules (OMs) (see, Fig. 1). Each string will include a chain of OMs spaced uniformly at depths 900–1250 m. A conventional string structure is optimal for telescope deployment from the natural ice platform of Lake Baikal. For interstring communication and connection to shore, strings will be grouped in clusters. Each cluster will be controlled by the cluster DAQ center placed near the water surface. The DAQ of the cluster has a flexible structure, which allows forming clusters with different number of strings and optical modules. The present version of the DAQ relates to an eight-string cluster with 24 optical modules on each string.

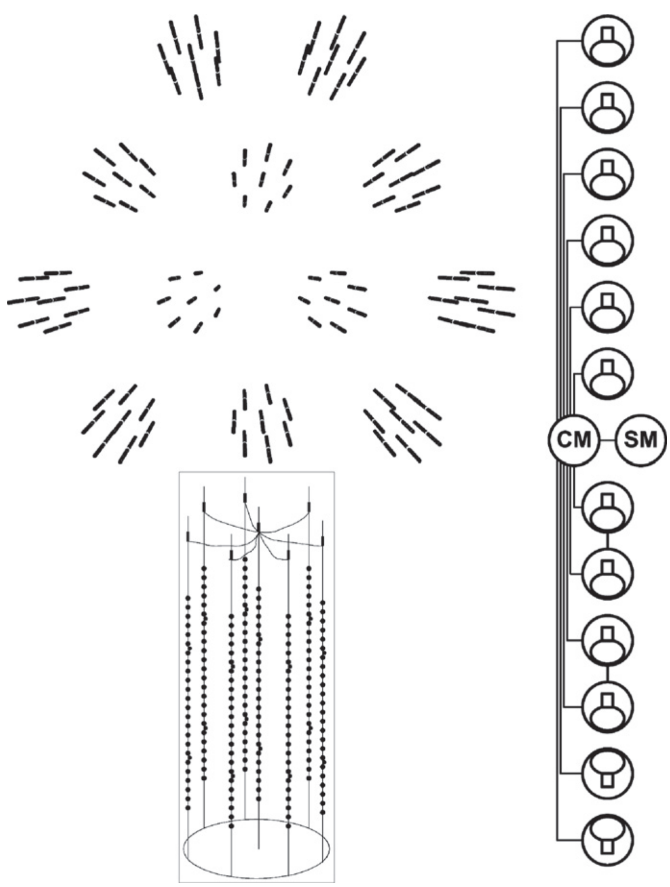

Fig. 1. GVD design: GVD top view (12 clusters); schematic view of cluster (eight strings with two sections each); and a section of OMs (12 OMs with PMTs R7081HQE).

2.1. Optical module

The optical module is the basic element of the future GVD neutrino telescope. Each OM (see, Fig. 2) contains a photomultiplier tube (PMT), which detects the Cherenkov light produced by relativistic charged particles passing through the water. The information from the ensemble of OMs allows reconstruction of event topology and energy. After testing different options the photomultiplier Hamamatsu R7081HQE was selected as a light sensor. This PMT has a hemispherical photocathode with 10 in. diameter and quantum efficiency up to 35%. The functional scheme of the optical module electronics is presented in detail in [2].

Besides the PMT, an OM comprises a high voltage power supply unit (HV), a fast two-channel preamplifier, and a controller. The HV unit (Traco Power SHV 12–2.0 K 1000 P) provides the power for the phototube divider (18 MΩ resistance) in the range from 0 up to 2 kV. The tube gains have been adjusted to about 10^7. This gain is provided by divider voltages between 1250 and 1650 V, depending on the individual tube. An additional signal amplification by a factor of 10 is provided by the first channel of the preamplifier. This gain value results in single photoelectron pulse amplitudes of 30–40 mV in average. This corresponds to a spectrometric channel linearity range up to about 100 photoelectrons. The second preamplifier output with factor 20 is intended for PMT noise monitoring. For time and amplitude calibration of the measuring channel, two LEDs are installed in the optical module. The dominant wavelength of the LED is 445 nm, the LED pulse has a width of about 5 ns (FWHM). The possibility of independent regulation of the LED light intensity and low cross talk between LED channels ($<1\%$) allow to directly measure the linearity range of the spectrometric channel.

The OM controller is intended for HV regulation and monitoring, for PMT noise measurements, and for time and amplitude calibration. The OM controller is designed on the basis of the

Fig. 2. GVD optical module.