

Baksan large volume scintillation telescope: a current status

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Abstract. A current status of the project of a large volume scintillation telescope at the Baksan neutrino observatory is presented. The main research activities of the BLVST are low-energy neutrino physics, astrophysics and geophysics. To detect geoneutrinos, large-scale new-generation scintillator detectors located at large depths in the regions with a low background level from nuclear reactors are required. The Baksan Neutrino Observatory is geographically located in one of these places. Recently resumed R&D activities are aimed at the creation of new-generation telescope with a target mass of 10 kt at a depth of 4800 m.w.e. A small scale prototype is already under construction.

1. Introduction

A large volume detector filled with liquid scintillator at the Baksan neutrino observatory (BNO) is discussed for long time ([1] – [5]). The main research activities of the BLVST are neutrino geophysics and neutrino astrophysics. At present R&D work aimed at the creation of a new-generation telescope using an extra-pure scintillator of 10 kiloton mass is performed ([6] – [12]).

The list of scientific problems is practically the same for an entire class of such detectors: investigating the solar-neutrino spectrum and seeking neutrinos from CNO reactions; studying the antineutrino flux emitted by daughter products of the decay of uranium and thorium, contained in the Earth's interior (geoneutrinos) and thereby determining the radiogenic component of the heat flux from the Earth; estimating the potassium content in the Earth's interior on the basis of the spectrum of electrons recoiling from neutrino scattering on electrons (similarly to detecting solar neutrinos); testing, via searches for the flux of antineutrinos from the georeactor, the hypothesis that a chain fission reaction proceeds at the center of the Earth; exploring the dynamics of supernova explosions by detecting the neutrino-burst intensity and spectrum;



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seeking an isotropic flux of antineutrinos accumulated in the Universe over billion years in gravitational collapses of massive-star cores and in the formation of neutron stars and black holes;

detecting the total antineutrino flux from all power nuclear reactors that are present on the Earth and studying electron-antineutrino oscillations.

2. Location

Baksan Neutrino Observatory of INR RAS is located in vicinity of mountain Elbrus, in the Baksan valley of Kabardino-Balkaria (Russia). BNO is unique complex of surface and underground experimental facilities [14]. The overburden of underground laboratories reaches 4700 m.w.e., so the BNO has facilities that are among the deepest in the world. Reactor neutrinos are an irremovable background in detecting geoneutrinos. Therefore, the counting rate associated with events induced by nuclear reactors is an important parameter in choosing place for deploying a detector intended for recording geoneutrinos [15]. The geographic position of the BNO makes it possible to suppress substantially the background associated with antineutrino fluxes from operating atomic power plants. The low reactor neutrino background makes this location very promising for geo-neutrino measurements (see table 1).

Table 1. Counting rate for antineutrinos from nuclear reactors and geoneutrinos at the detector locations. R – total reactor neutrino (TNU), R_G – reactor neutrino within geo-neutrino window (TNU), G – geoneutrino (TNU)

	R	R_G	G	R_G/G	Ref.
Baksan	38.24	14.37	52.6	0.3	[9]
Gran Sasso	94.15	35.35	39.8	0.9	[9]
Sudbury	190.74	72.85	49.9	1.4	[9]
Pyhasalmi	72.97	27.61	52.9	0.5	[9]
Hawaii	3.44	1.29	15.3	0.1	[9]
Kamioka	27.79	10.30	31.7	0.3	[9]
Jinping	27.8	6.8	59.4	0.1	[13]

3. Experiment preparation

The choice of a specific liquid scintillator (LS) mixture is an important for the detector performance. Development of a large scintillation detector requires to consider also its cost and safety. A scintillator on the basis of linear alkyl benzene (LAB) has indisputable advantages, such as hypotoxicity, low volatility, and high flash point. Besides, LAB is a low-cost compound produced by the industry in large amounts.

The sample from KINEF refinery (Kirishi, Russia) is examined now, using chromat-mass-spectrometric analysis [16]. Light attenuation length was measured for wavelength of 440 nm, 430 nm, 420 nm (see table 2). Decrease of light attenuation length is the result of interaction of hydrocarbons with oxygen and the formation of primary oxidation products. Blowdown the tank with an inert gas to store LAB after its purification or introduce antioxidants can solve this problem.

An important task for such a detector is to suppress the natural background from natural radioactivity and the radioactive carbon isotope ^{14}C contained in the liquid scintillator. The measurements have been performed with an LAB-based liquid organic scintillator containing 2 g/l of a BPO scintillation addition. Next measurement results was obtained for the sample of

Table 2. Attenuation length for wavelengths of 420, 430 and 440 nm.

	L ₄₄₀ , m	L ₄₃₀ , m	L ₄₂₀ , m
crude LAB	25.6	18.1	14.0
refined LAB	72.5	48.3	39.5
refined LAB after 1 year	25.6	18.1	14.5

LAB from KINEF refinery (Kirishi, Russia): 6.2×10^{-12} g/g for the ^{232}Th and 1.8×10^{-11} g/g for the ^{238}U .

Low concentration of ^{14}C is also of great importance for lowering detection threshold because the background from ^{14}C does not allow lowering the threshold for detecting solar neutrinos below 200 keV and makes it difficult to detect neutrinos from the pp cycle. The measurement of $^{14}\text{C}/^{12}\text{C}$ ratio for the sample of LAB from KINEF refinery have been performed in the low background Laboratory of the Baksan Neutrino Observatory at a depth of 4900 m.w.e., the result is $(3.3 \pm 0.5) \times 10^{-17}$ [17].

4. First prototype

Structurally, the first prototype consists of an external cylindrical tank (Fig.1) and the inner part, including an acrylic sphere and stainless steel construction, to which photodetectors are attached and which provides additional fixation of acrylic sphere (Fig.2). The prototype has about 420 kg of LAB-based scintillator with 2,5-Diphenyloxazole (PPO) and bisMSB admixtures. The scintillator is contained within the acrylic sphere with the inner diameter of 960 mm. The sphere is put into a cylindrical tank filled with water serving for protection from external radioactivity. The diameter and height of the tank are 240 and 280 cm respectively. An array of 20 10-inch Hamamatsu R7081-100 PMTs surrounds the scintillator contained in the acrylic sphere. PMTs are placed at vertices of a regular dodecahedron at about 75 cm distance measured from the sphere center to PMT equators. The PMTs and the acrylic sphere are mounted on a stainless steel supporting structure. PMTs are also to be equipped with conical concentrators in order to increase the amount of gathered light.

5. Conclusion and outlook

Baksan neutrino observatory is attractable place for installing geoneutrino detector (existing infrastructure, high counting rate, low nuclear reactors rate). Large detector installed at BNO will be a part of international detector net for geoneutrinos. Now the work on the development of the detector and creation of its prototypes is performed. The first prototype is now under construction and will be in operation before the end of this year. We plan to construct second prototype with 5 t of liquid scintillator next year.

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References

- [1] Domogatsky G V, Kopeikin V I, Mikaelyan L A, Sinev V V 2005 *Phys.At.Nucl.* **68** 69 (*Preprint hep-ph/0401221*)



Figure 1. External tank from polypropylene.



Figure 2. The acrylic sphere with stainless steel supporting structure.

- [2] Domogatsky G V, Kopeikin V I, Mikaelyan L A, Sinev V V 2006 *Phys.At.Nucl.* **69** 43 (*Preprint hep-ph/0409069*)
- [3] Domogatsky G V, Kopeikin V I, Mikaelyan L A, Sinev V V 2006 *Phys.At.Nucl.* **69** 1894 (*Preprint hep-ph/0411163*)
- [4] Domogatsky G V, Kopeikin V I, Mikaelyan L A, Sinev V V 2007 *Phys.At.Nucl.* **70** 1081 (*Preprint arXiv:0705.1893*)
- [5] Barabanov I R, Novikova G Ya, Sinev V V, Yanovich E A 2009 Research of the natural neutrino fluxes by use of large volume scintillation detector at Baksan. *Preprint arXiv:0908.1466*
- [6] Lubsandorzhev N B, Bezrukov L B, Lubsandorzhev B K et al 2013 *Instruments and Experimental Techniques* **56** 34
- [7] Petkov V B 2016 *Physics of Particles and Nuclei* **47** 975 (*Preprint arXiv:1508.01389*)
- [8] Petkov V B 2016 *Proc. of the International Workshop on Quark Phase Transition in Compact Objects and Multimessenger Astronomy: Neutrino Signals, Supernovae and Gamma-Ray Bursts (Russia, Nizhnij Arkhyz (SAO RAS), Terskol (BNO INR RAS), October, 7 - 14, 2015)* Pyatigorsk: Publishing house Sneg pp 102-106
- [9] Barabanov I R, Bezrukov L B, Veresnikova A V et al 2017 *Phys.At.Nucl.* **80** 446
- [10] Dzaparova I M, Yanin A F, Gorbacheva E A et al 2018 *Physics of Particles and Nuclei* **49** 753
- [11] Yanin A F, Dzaparova I M, Gorbacheva E A et al 2018 *Physics of Particles and Nuclei* **49** 804
- [12] Malyshkin Yu M, Fazliakhmetov A N, Gangapshev A M et al 2020 *NIM A* **951** 162920 (*Preprint arXiv:1909.03229*)
- [13] Linyan Wan, Ghulam Hussain, Zhe Wang and Shaomin Chen 2017 *Phys. Rev. D* **95** 053001
- [14] Kuzminov V V 2012 *Eur. Phys. J. Plus.* **127** 113
- [15] Smirnov O 2019 *Progress in Particle and Nuclear Physics* **109** 103712
- [16] Bakulina N I, Novikova G Ya, Redchin A S et al. 2018 *Chemical industry today* **3** 38 (in Russian)
- [17] Barabanov I R, Bezrukov L B, Veresnikova A V et al 2017 *Phys.At.Nucl.* **80** 1146