Baikal-GVD project

1. Goals of the experiment:

1a. Give a short description of the goals of the experiment - limited to ½ page.

The Baikal-GVD neutrino telescope will study the most violent processes in the Universe, which accelerate charged particles to highest energies, far beyond the reach of laboratory experiments on Earth. These processes must be accompanied by the emission of neutrinos. The large detection volume, combined with high angular and energy resolution and moderate background conditions in fresh lake water allows for an efficient study of the diffuse neutrino flux and of neutrinos from individual astrophysical objects, be they steady or transient. Multi-messenger methods will be used to relate our findings with those of classical astronomers and with X-ray or gamma-ray observations. A high-energy diffuse astrophysical neutrino flux has been observed recently by IceCube, using track-like and cascade-like events. GVD-I will have a detection volume for cascades of about 0.4 km3, which is approximately the same as the fiducial volume of IceCube for this detection mode. That guarantees the detection of astrophysical neutrinos during the GVD's first years of operation. We will scrutinize the IceCube result and study in detail the energy spectrum, the global anisotropy and the neutrino flavor composition of the diffuse neutrino flux. This flux must have been formed by neutrino emission of the entire set of Galactic and extragalactic sources during the period from remote cosmological epochs to the present day. Extragalactic sources make a major contribution to this flux. The neutrinos produced by the interaction of cosmic rays with interstellar matter and, in the case of ultra-high-energy cosmic rays, with electromagnetic radiation from a wide energy range including the cosmic microwave background, do also contribute to the diffuse flux. The high angular resolution of GVD for track-like or cascade-like events (~0.25° for muon tracks and ~2° for cascades, respectively) provides a high capability for identifying point-like cosmic-ray accelerators.

1b. Explain what the project adds to the international scenario: limited to ½ page.

The construction of a large infrastructure is the only way to perform high-energy neutrino astronomy with the necessary sensitivity. Worldwide, three neutrino telescopes are in operation or under construction: IceCube at the South Pole, KM3NeT in the Mediterranean Sea and GVD in Lake Baikal.

IceCube is not adequate to search for sources close to the Galactic center due to its geographical location. Moreover, it has a moderate angular resolution, which limits its capabilities to identify point sources. KM3NeT does not suffer from these limitations, but since high-energy neutrino events are rare, more effective volume is a key for discovery, irrespective whether it is, e.g., a third KM3NeT block in Greece or GVD in Lake Baikal. This makes KM3NeT and GVD, in a sense, "additive". Also, the different systematics (sea water and fresh water, shallow vs. deep depth, configuration of detectors) make KM3NeT and GVD complementary. Another important aspect is the vulnerability to single point failures. IceCube has the least vulnerability (each DOM independently connected to the surface), Baikal the second least (with each of the 8 clusters of Phase-1 with its own shore cable), while KM3NeT has one shore cable for a full block of 115 strings. Therefore, for GVD the danger to miss neutrinos from a transient event (e.g. a gamma ray burst) is potentially smaller.

By now, the only operating one in full scale is IceCube at the South Pole, while the construction of telescopes of similar size on the Northern hemisphere is underway (GVD in Lake Baikal and KM3NeT in the Mediterranean Sea). ANTARES, GVD, KM3NeT and IceCube have joined their efforts within GNN, the Global Neutrino Network, with the common goal of several cubic kilometers of instrumented volume at both the Northern and the Southern hemisphere. The total volume at the Northern hemisphere will be shared between KM3NeT and GVD. GNN serves as a platform to coordinate the scientific and strategic program of the community.

Baikal-GVD, together with other members of GNN, will be an essential node in the global network of multi-messenger instruments in astronomy, including other research infrastructures (ELT, CTA, SKA et. al.).

2. Contributions of the JINR group:

2a. Give an itemized list of the specific contributions of the JINR group in hardware (including use of JINR computing resources for the project), software development and physics analyses - limited to 1 page.

JINR participates practically in all construction steps of the detector and, in fact, in all software stuff. Main items are:

- Assembly, test and parameters measurement of the main detection units of the telescope – optical modules (OM). JINR is the only structure where this elements are prepared;
- facility for testing and calibration OMs;
- Preparing elements of basic construction of the detector;
- Computing and data taking shore part of the DAQ system;
- Clusters synchronization on the base WR (WhiteRabbit) system;
- System of worldwide time synchronization of the telescope;
- All network structure, access and security service at the site;
- Remote control and monitoring of the detector systems;
- On-line software support and development;
- Data analysis frame support and development;
- Data transfer from the site, collecting raw data, support data bank in JINR. JINR is data center of the Baikal-GVD project;
- Simulation software support and development;
- Primary data analysis, data monitoring;
- MC production, support of MC data bank;
- Reconstruction of track events, events selection.

2b. Give a list of the responsibilities of JINR group members within the management structure of the collaboration, if any, giving the name of the JINR member, the managerial role and the appointment period.

I. Belolaptikov, B. Shaibonov, A. Doroshenko, D. Petukhov are permanent members of the Baikal collaboration committee.

I. Shaibonov is responsible person for data analysis framework support and development.

K. Konischev is responsible person for MC bank and raw data transfer.

E. Pliskovskiy and D. Petukhov are responsible persons for on-line software and data acquisition.

K. Korobchenko is responsible person for optical modules assembling.

I. Belolaptikov is acting head of the winter expedition on the Baikal Lake.

3. Plans

Give a short description limited to ½ page of the JINR group plans (in data taking, analysis, detector R&D, upgrade activities…) till the end of the currently approved project.

The JINR group shares leadership with INR RAS team on the project. That is why our team has to participate, make commitment to all stages of the Baikal-GVD project. Our plans coincide with plans of the collaboration to assemble elements of the detector and deploy two cluster, consisting 288 optical modules, per year.

Main plans to succeed with responsibilities that was engaged (see 2a) for the Dubna team.

Next list presents plans out of described items above:

- To improve reliability of experimental setup, create a full-scale testing facility. The facility will allows run detector equipment for long-time test in a whole architecture (cluster).
- Above item make as to optimize the optical modules production line for rate up to 900 OM per year to prepare one additional cluster for long-time testing.
- Extend computing resources in JINR for disk space and computing power for analysis and MC.

More detailed description of the activities is presented at the written project (PAC-NP in January 2018).

4. Publications: List the papers published in 2016, 2017 and 2018 in the refereed literature (no conference proceedings) in which the JINR group had a major contribution (e.g. author of the analysis, promoter of the experiment, corresponding author, realization of a key equipment etc.). Give title of paper, reference and describe in 1-2 sentences the JINR contribution. Mention the total number of papers published by the project in the same time period.

The Baikal is collaboration with less than 60 signatures of the papers. Therefore, each of Baikal papers is result of every member of the collaboration.

JINR group is involved in all stages of the experiment: setup assembly and commissioning, modeling, data taking, calibrations, analysis, publication.

A.Avrorin et al, (Baikal collaboration), "Search for high-energy neutrinos from GW170817 with Baikal-GVD neutrino telescope", Pis'ma v ZhETF(2018) (in press)

A.Avrorin et al, (Baikal collaboration), "Baikal-GVD – neutrino telescope of the next generation", Bulletin of the Russian Academy of Sciences, 2018 (in press)

A.Avrorin et al, (Baikal collaboration), "Dark matter constraints from an observation of dSphs and the LMC with the Baikal NT200", JETP Vol. 152 (7) (2017)

A.Avrorin et al, (Baikal collaboration), "The optical module of Baikal-GVD", Phys.Part.Nucl.Lett. 13 (2016) no.6

A.Avrorin et al, (Baikal collaboration), "Neutrino signal at Baikal from dark matter in the Galactic Center", Phys.Part.Nucl. 47 (2016) no.6

A.Avrorin et al, (Baikal collaboration), "A search for neutrino signal from dark matter annihilation in the center of the Milky Way with Baikal NT200", Astropart.Phys. 81 (2016) 12

5. PhD theses: List the PhD theses completed within the last 3 years, or expected to be completed within 2019, by JINR students within the project, giving the student name, thesis title and graduation year.

2016: PhD thesis by Sheifler A.A. "Optical module of the Baikal deep underwater neutrino telescope Baikal-GVD (development and testing of the detecting system)"

2019: I. Belolaptikov, PhD thesis, in preparation

6. Talks:

6a. List the invited plenary talks given by members of the JINR group in 2016, 2017 and 2018 at international conferences, workshops…: give name and date of the Conference, title of talk and speaker name.

New Trends in High-Energy Physics, 24-30 September 2018, " Baikal GVD experiment: Present status and perspectives", R. R. Dvornický

ISAAP-Baikal Summer School, 12-21 July 2018, "The Next Generation Neutrino Telescope in Lake BAIKAL", B. Shaibonov

The 11th traditional International School on Nuclear Physics, 14 – 18 May 2018, "GVD: deep underwater neutrino telescope", K. Konishchev

MANTS-2017, 7-8 October 2017, "Muon reconstruction in the first cluster of Baikal-GVD", G. Safronov

MANTS-2017, 7-8 October 2017, "Calibration in Baikal-GVD", B. Shaibonov

VI Annual conference of Young Scientists and Specialists, 12-19 June 2017, Alushta, "Baikal GVD experiment", R. R. Dvornický

International Session-Conference of the Nuclear Physics Section of the Physical Sciences Department of the RAS (NPS PSD RAS), «Physics of Fundamental Interactions», 12-15 April 2016, "Status of the Baikal Neutrino Experiment", B. Shaibonov

6b. Give a similar list for parallel talks.

VLVnT-2018, 2 - 4 October 2018, "GVD optical module and other mechanics: experience and progress ", A. Doroshenko

VLVnT-2018, 2 - 4 October 2018, "GVD: results of track reconstruction", G. Safronov

VLVnT-2018, 2 - 4 October 2018, "Optical activity in lake Baikal: GVD results", R. Dvornický

VLVnT-2018, 2 - 4 October 2018, "Data processing and quality monitoring of Baikal – GVD", E.Khramov

VII International Pontecorvo Neutrino Physics School, August 20 - September 1, 2017, "Simulation of high energy neutrino events for Baikal GVD telescope", R. Dvornický

7. Group size, composition and budget.

7a. Present in a Table the list of JINR personnel involved in the project, including name, status (e.g. PI, researcher, post-doc, student, engineer, technician…) and FTE. Mention the total number of people in the collaboration.

Baikal is a international collaboration that includes about 60 scientists from Russia, Germany, Czech Republic, Slovakia and JINR.

JINR group human resources are:

Name	Category	Responsibilities	Time that each participant will give to the work under the Project in relation to its FTE
V. Brudanin	Head of department, project co-leader	Administrative work, general affairs	0.2
P. Antonov	Engineer	Networking, system administrator	0.3
I. Belolaptikov	Project leader	Administrative work, detector building, MC, data analysis, reconstruction	1.0
E. Sushenok	Junior researcher	MC production, data analysis	1.0
A. Doroshenko	Engineer	OM production, detector building	0.5
R. Dvornicky	Researcher	MC, calibration, detector building, data analysis	1.0
K. Golubkov	Engineer	OM calibration, detector network system, synchronization	0.5
N. Gorshkov	Engineer	OM production and testing, detector building	1.0
E. Khramov	Senior Researcher	Data analysis	0.3
M. Kolbin	Engineer	OM production and testing, detector building	1.0
K. Konishchev	Researcher	MC production, detector building	1.0
A. Korobchenko	Junior researcher	Monopole system developer, OM production and testing, detector building	1.0
M. Kruglov	Engineer	OM production and testing, detector building	1.0
M. Milenin	Engineer	Hardware detector constructions	0.5
V. Nazari	Researcher	MC production, data analysis	1.0
T. Orazgali	Engineer	Data analysis, calibration	1.0
A. Panfilov	Engineer	Hardware detector constructions, detector building	0.5
D. Petukhov	Engineer	On-line software development, remote detector control	0.5
E. Pliskovsky	Researcher	On-line software development, remote detector control, calibration	1.0
V. Rushay	Engineer	Data analysis, detector	1.0

		building	
G. Safronov	Senior Researcher	Analysis, reconstruction	0.5
B. Shaybonov	Senior Researcher	Data analysis, calibration, reconstruction, detector building	1.0
S. Sinegovski	Senior Researcher	MC analysis	0.3
A. Svistunov	Engineer	OM production and testing, detector building	1.0
Total FTE (Engineers): 8.8, Total FTE (Scientific staff): 8.3, Total FTE: 17.1			

In JINR the Baikal-GVD project is conducted under scientific theme "Non-Accelerator Neutrino Physics and Astrophysics", thus all common resources of the theme are used.

7b. Indicate the expected changes in the group size, if any, till the end of the currently approved project.

The scientific core of the JINR team of the project will be stable and includes: I. Belolaptikov, A. Doroshenko, K. Konischev, A. Korobchenko, E. Pliskovskiy and B. Shaibonov. A wide list of responsibilities require more man power, especially on analysis and MC. Partially the request is covered by people from another projects inside theme 1100.

7c. Present the JINR group budget from 2018 till the end of the currently approved project in a Table specifying the main budget items (equipment, computing, salaries, common funds, travel…)

The Baikal-GVD project is a part of the scientific theme 1100 “Non-accelerator neutrino physics and astrophysics” at JINR.

Baikal-GVD-only requested resources are reflected into the forms No.26 and No.29 of the written project (PAC-NP, January 2018) - duplicated on the next pages.

Schedule proposal and resources required for the implementation of the Project BAIKAL-GVD

Expenditures, resources, financing sources			Cost of parts (US$), resources needs	Proposals of the Laboratory on the distribution of finances and resources		
				1st year	2nd year	3rd year
Main parts and equipment	1. Underwater optical module elements		8430K	2810K	2810K	2810K
	2. Underwater connectors		2100K	700K	700K	700K
	3. Elements of underwater electronic system of control and data acquisition		1950K	650K	650K	650K
	4. Elements of underwater cable communications		1500K	500K	500K	500K
	5. Elements of the acoustic positioning system		2400K	800K	800K	800K
	6. Infrastructure development and vehicles		2400K	800K	800K	800K
	7. Electro-optical cable and deployment tool		1800K	600K	600K	600K
	Total		**20580K**	**6860K**	**6860K**	**6860K**
Resources	Standard hour	JINR workshop	6000	2000	2000	2000
		DLNP workshop	3300	1100	1100	1100
Financial sources	Budgetary	Budget spending	**18000K**	**6000K**	**6000K**	**6000K**
	ources Externals	Contribution from collaboration(s); Grants; Sponsors; Contracts; Other sources	**3000K**	**1000K**	**1000K**	**1000K**

Estimate of expenditures for the project BAIKAL-GVD, Deep underwater muon and neutrino detector on Lake Baikal

#	Designation for outlays	Full cost	1st year	2nd year	3rd year
	Direct expenses for the project				
1.	Networking	30.0K US$	10.0	10.0	10.0
2	DLNP workshop	3300 h.	1100	1100	1100
3.	JINR workshop	6000 h.	2000	2000	2000
4.	Materials	14280.0K US$	4760.0	4760.0	4760.0
5.	Equipment	6300.0K US$	2100.0	2100.0	2100.0
6.	R&D on a contract base	210.0K US$	70.0	70.0	70.0
7.	Travel expenses	180.0K US$	60.0	60.0	60.0
	Total	**21000.0K US$**	**7000.0K$**	**7000.0K$**	**7000.0K$**
	Including budget spending JINR	**18000.0K$**	**6000.0k$**	**6000.0K$**	**6000.0K$**

7d. Indicate the use of JINR computing resources for the group and for the project if any.

Baikal group file server in DLNP, DLNP cluster, LIT sub cluster (about 100 cores, HybriLIT, Git).