

# Progress in Baikal neutrino project



*Vladimir Aynutdinov, INR RAS, 20 May 2026, Petrozavodsk .*

# Outline

1. Progress in telescope deployment.
2. Progress in developing the neutrino telescope infrastructure.
3. Progress in data analysis.
4. Progress toward next generation Baikal telescope.



# Baikal-GVD Collaboration



- Institute for Nuclear Research of the Russian Academy of Sciences, Russia
- Joint Institute for Nuclear Research, Russia
- Irkutsk State University, Russia
- Skobeltsyn Institute of Nuclear Physics MSU, Russia
- Nizhny Novgorod State Technical University, Russia
- St. Petersburg State Marine Technical University, Russia
- National Research Nuclear University MEPhI, Russia
- P.N. Lebedev Physical Institute, Russia \*
- Kabardino-Balkarian State University, Russia \*
- Belgorod State University, Russia \*
- Comenius University in Bratislava, Slovakia
- Czech Technical University in Prague, Czech Republic
- Institute of Nuclear Physics ME RK, Kazakhstan
- Astronomy Observatory, Serbia \*
- ITMO University, St. Petersburg, Russia \*

**15 research organizations from 5 countries. ~ 85 researchers.**

\* Joined the Baikal-GVD collaboration in 2025-2026



# Location

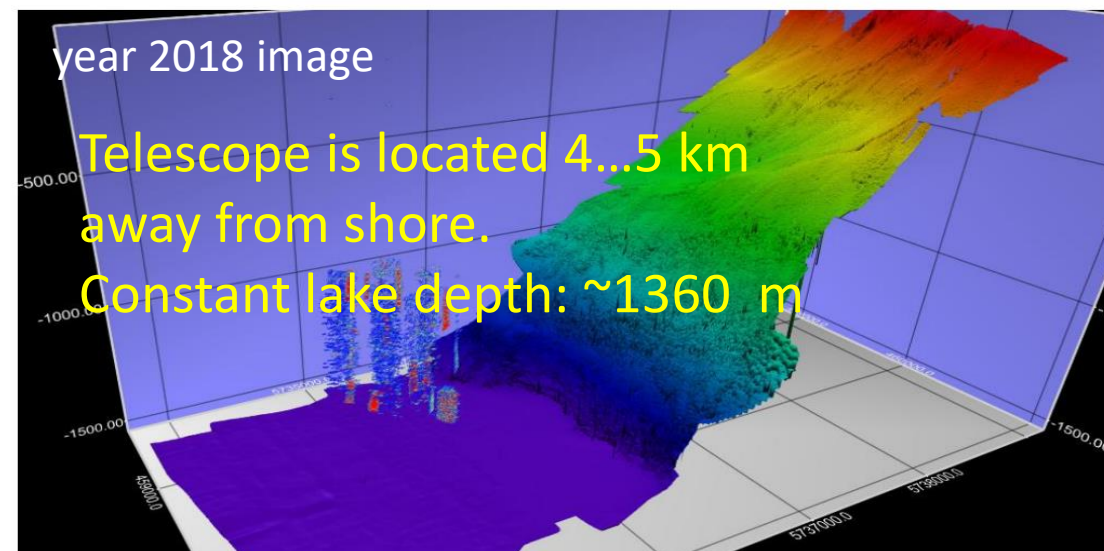
## Site advantages:

- Good water properties, absorption 21 - 23 m.
- Small detector distance to shore.
- Flat lake bottom near the shore.
- Moderate light background: 15–40 kHz (10" PMT).
- Stable ice cover over 7 - 8 weeks (Feb – Apr): detector deployment and maintenance.
- Railway near the site.



The site's location in a national park leads to several restrictions:

- Limited power supply.
- Lack of auto road.
- Difficulties in expanding the site and the coastline.
- Restrictions on building construction.





# Basic components

**String:** Each string carries 36 optical modules (OMs)

- 10-inch Hamamatsu PMT R7081-100
- 15 m vertical spacing
- OM facing lake bottom

## Channel calibration systems

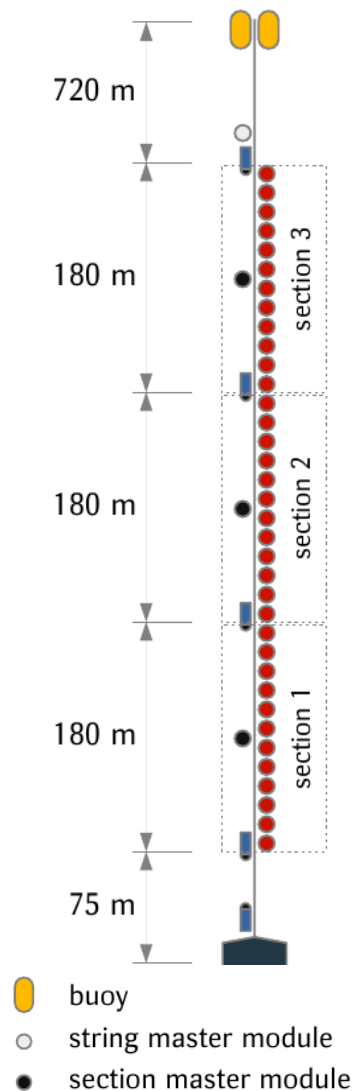
- LED in each OM
  - LED beacons
  - Calibration lasers between clusters
- Time calibration precision  $\sim 2$  ns

## Geometry calibration system

- Acoustic modems on each string
- Compass and accelerometer in each OM
- OM positioning precision  $\sim 20$ cm

## DAQ system

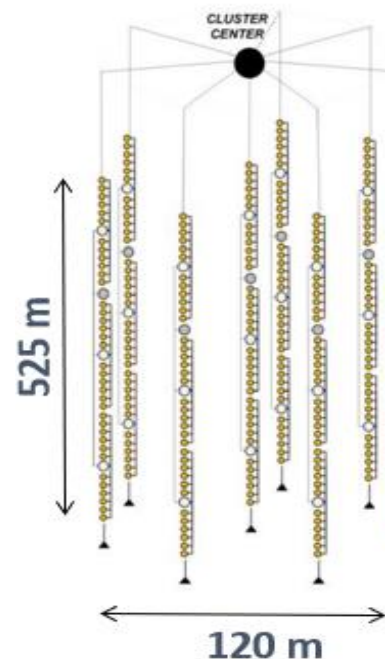
- 3 sections of OMs, 12-ch 200 MHz FADC for each section in separate modules.
- Pulse form measuring, accuracy of front measure  $\sim 1$  ns.



**Optical module (OM):**



10-inch Hamamatsu PMT R7081-100 inside 17" underwater glass sphere.



## Baila-GVD cluster

8 regular strings;  
525 m height is  
instrumented with 36  
optical modules;  
60 m radius.



# Progress in telescope deployment - 2026

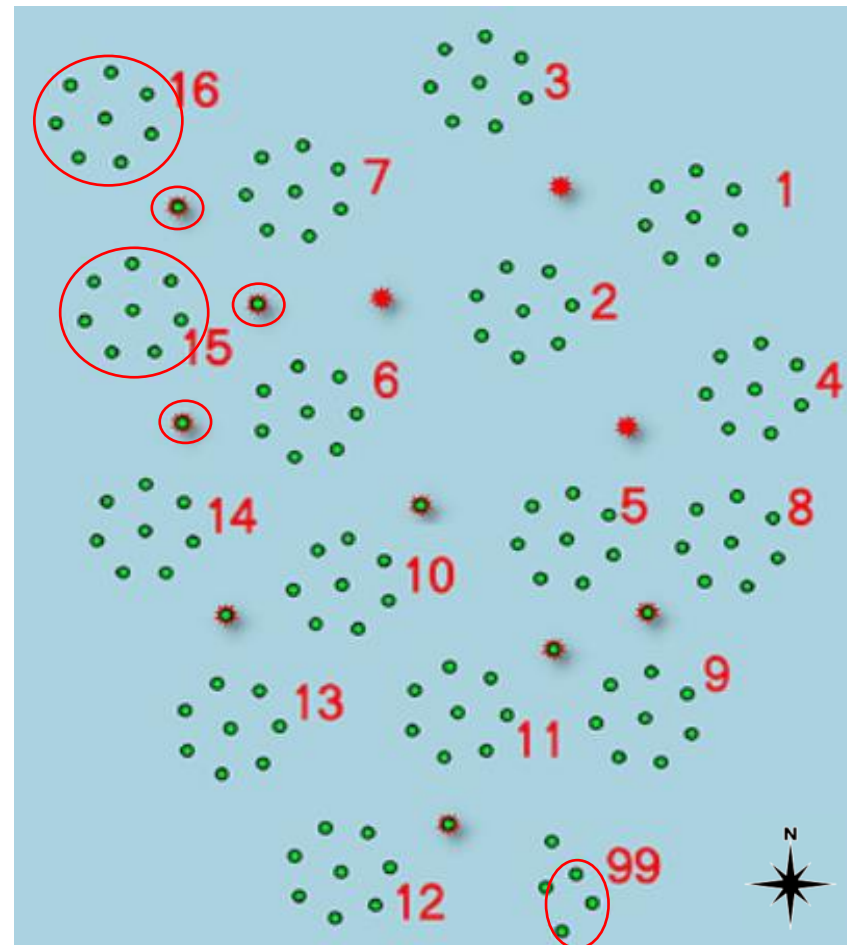


## Expedition 2026

- Good ice conditions;
- Strengthening of the deployment team by young people from MEPHI and MSU.

A significant amount of work was done to telescope deployment:

1. Clusters 15 and 16.
2. 3 inter-cluster strings : C14/9, C15/9, C16/9.
3. The second full-scale HUNT prototype string.
4. Two GVD+ prototype strings.
5. A new technology for laying a bottom cable connecting the clusters to the shore center has been introduced.



**22 new strings were put into operation in total.**

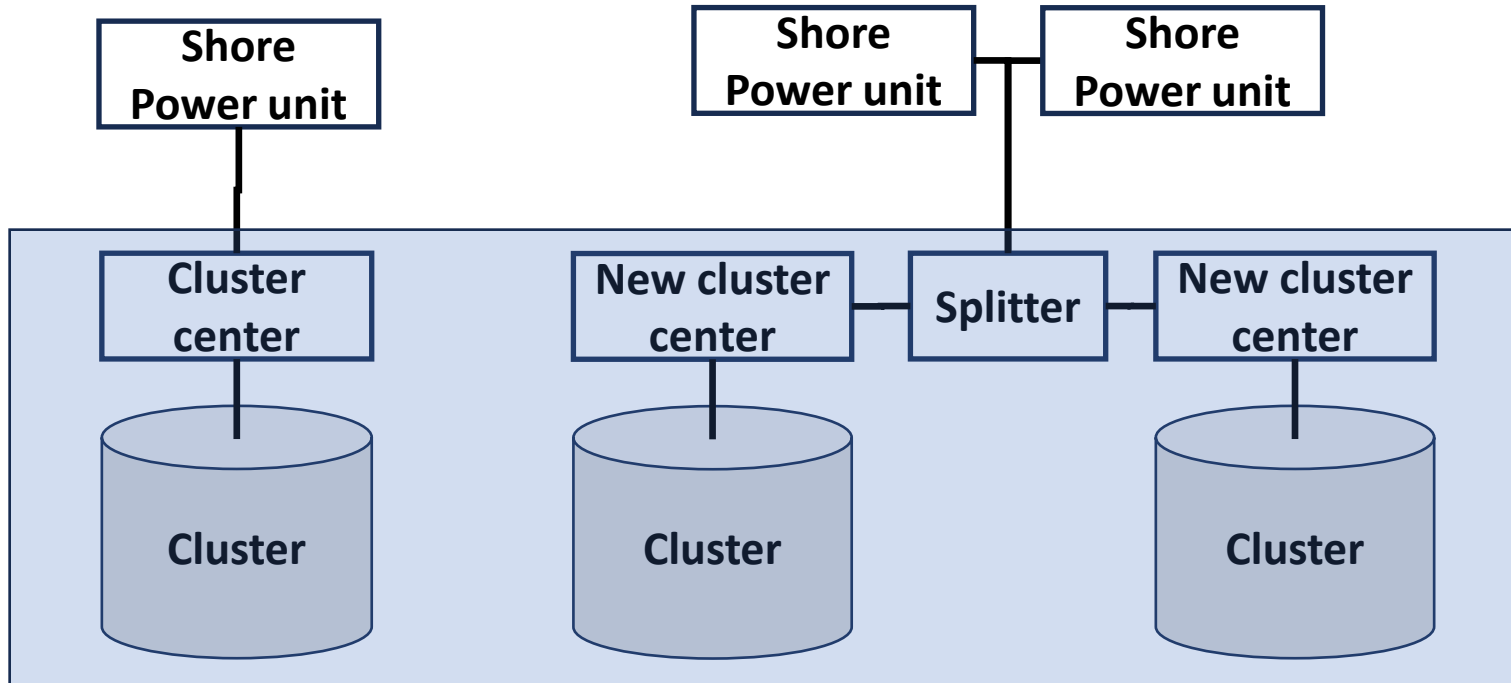


# New technology for bottom cables laying - 2026

The bottom cables connects the shore center to the telescope clusters. Two cables are laid during an expedition under favorable ice conditions. The number of clusters is limited by the number of cables.

*One cluster- one cable*  
*Clusters 1...14*

*Two clusters – one cable*  
*Clusters 15 and 16* **NEW**



New bottom cable for 2 clusters - 4 power lines (2 + 2). Independent shore power unit for each cluster.



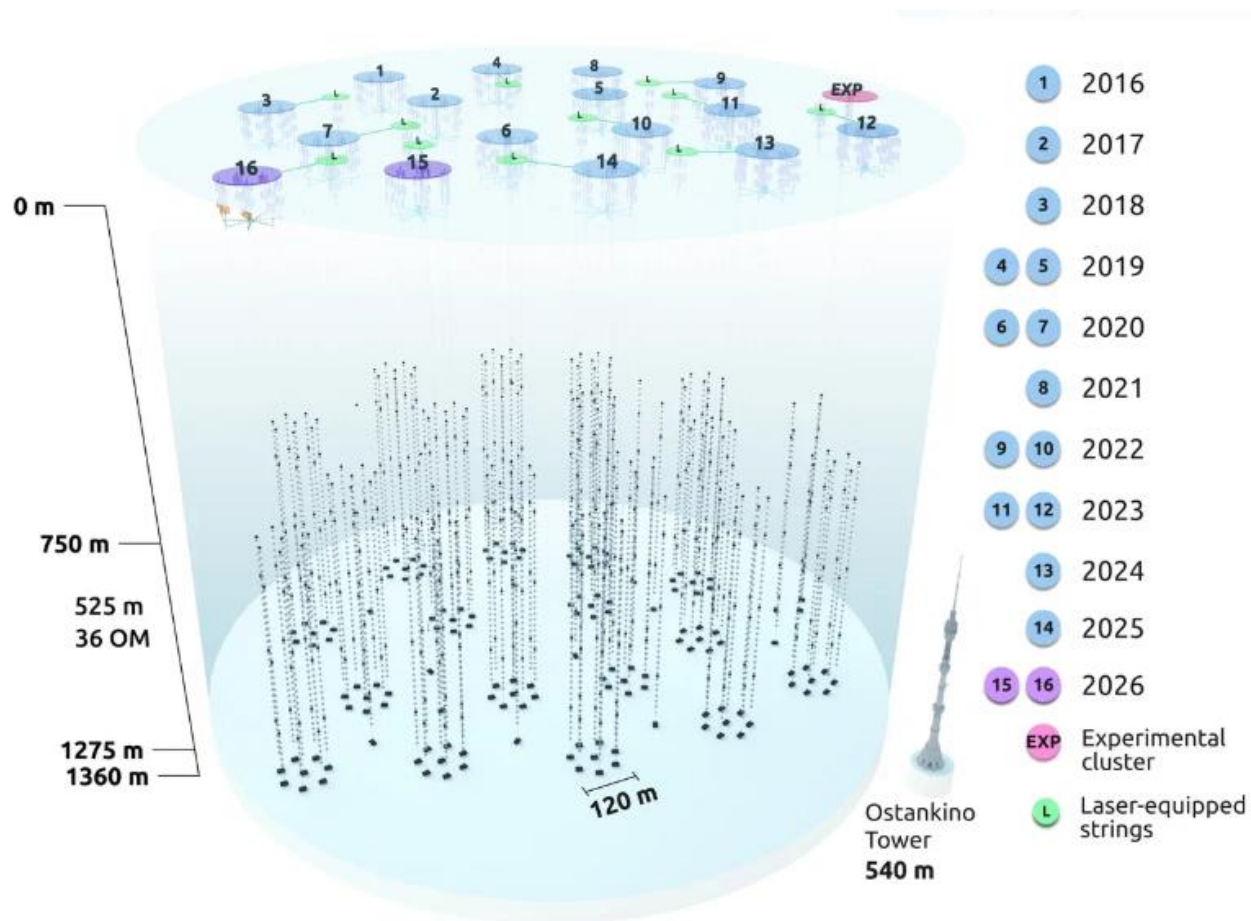
Passive cable splitter

The use of new hybrid fiber-optic cables and the modified cable design allowed to split one bottom cable to two clusters.

The use one bottom cable for two clusters in the future allows to increase the number of strings that can be put into operation during an expedition.



# Detector status - 2026



Basic configuration Baikal-GVD consists of 136 strings arranged into 16 clusters, 4896 OM in total – 684 additional OM in comparison with 2025.

- About 0.8 km<sup>3</sup> of effective volume (cascades, ~ 1 PeV).
- 11 laser stations, 8 stations equipped with OM: inter-cluster strings.
- 5 experimental strings with the optic-fiber DAQ – prototypes GVD+ and HUNT.

Baikal-GVD telescope's deployment (20 clusters) is scheduled to be completed in 2029

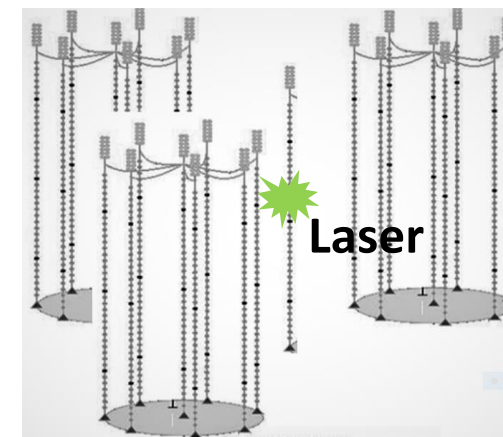


# PMT for full-scale Baikal-GVD: status 2026

The baseline Baikal-GVD configuration comprises 20 clusters with 8 strings each: 5 760 OMs with 10" Hamamatsu PMT R7081-100.

Improved configuration (2022) includes 19 additional inter-cluster with 684 OMs.

- Inter-cluster strings were installed to mount calibration lasers in accordance with the original telescope design.
- Equipping inter-cluster strings with optical modules improves of cascade event reconstruction.



**There are not enough PMTs Hamamatsu 10" to equip the inter-cluster strings.  
There is no possibility of purchasing them.**

## **New PMT production for Baikal neutrino project**

North Night Vision Science & Technology Research Institute (China) designed new PMT optimized for 17" glass sphere: **14" MCP PMT**; New PMT parameters are comparable to PMT R7081.

### **Plan of production:**

**July 2026: pilot samples of new PMTs (10 pcs) for lab tests.**

**September 2026 the first batch: 100 PMTs for in-situ tests.**



N6203  
20-inch MCP-PMT

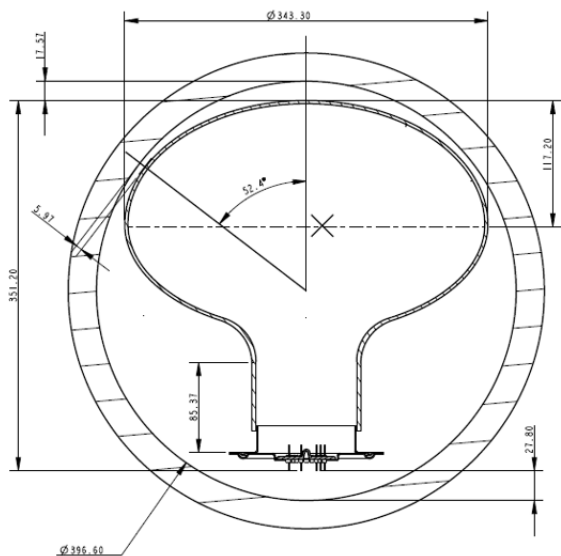
N6082  
8-inch MCP-PMT

N6201  
20-inch MCP-PMT

NNVT provided mass production of the N6082 and N6203 PMT for *JUNO and LHAASO*.



OM with new PMT



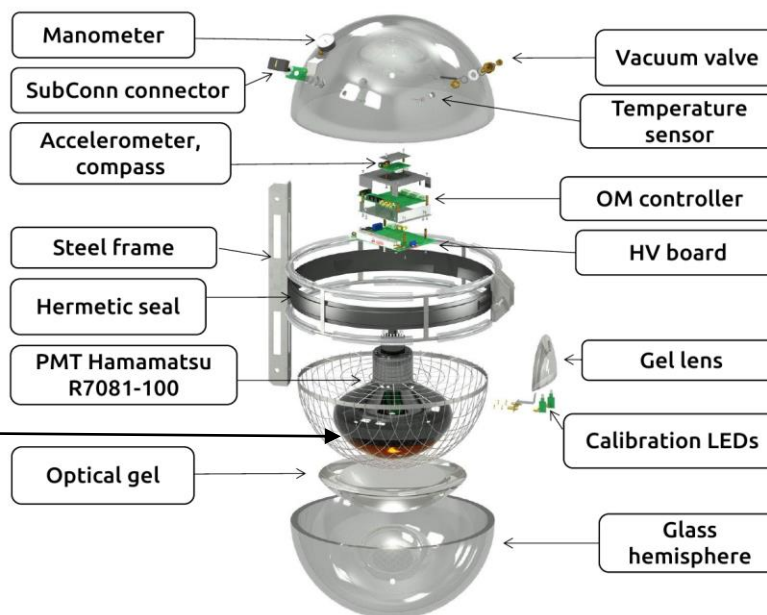
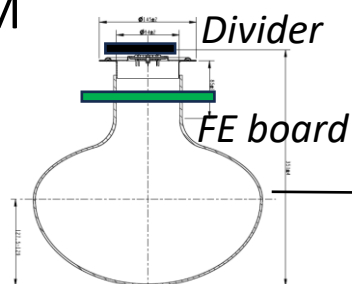
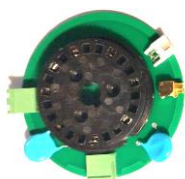
# New optical module

## NEW MCP-PMT

Photocathode diameter 13.5" - the maximum size for a 17" glass sphere. Diameter is limited by the height of the PMT

	10" R7081-100	13.5" NEW PMT
Photocathode square	530 cm <sup>2</sup>	1400 cm <sup>2</sup>
Quantum Efficiency at peak	32%, min	26%, min
Dark Count	16 kHz, max	10 kHz, max
Transit Time Spread (FWHM)	3.4 ns	4 ns, max
P/V (Peak to Valley) Ratio	2.8	3, min

Front-End electronics board of a new design for mounting on PMT bulb and HV divider. Minimal changes to the OM design.



The design of the new OM is fully compatible with the existing Baikal-GVD OM. New OM's sensitivity is approximately twice more.



## Progress in telescope deployment - 2026: summary.

1. The effective volume of the telescope was increased by approximately 15%.
2. A new technology for laying bottom cables has been introduced (one cable for two clusters). The new technology allows to double the speed of detector deployment.
3. A new optical module has been developed for Baikal-GVD, which allows the telescope to be fully configured and deployed.



# Progress in developing the shore infrastructure

*Future Baikal  
Neutrino Center,  
107 km*

*Shore center, 106 km*



In order to expand the base of the experiment in terms of human resource allocation, on the northern shore (106-107 km of the KBZHD) JINR has acquired a site for the construction of the Baikal Neutrino Center, designed to accommodate 80-100 people.

Also, for the storage of the necessary equipment for the deployment of the detector in winter, work is underway to allocate additional land areas adjacent to the JINR and INR sites in use, as well as an additional coastline.

Planned construction on "107 km"





# New means of transportation

**Main goals - minimizing the dependence of deployment and repairing work on the ice conditions of Lake Baikal and delivery by railway.**

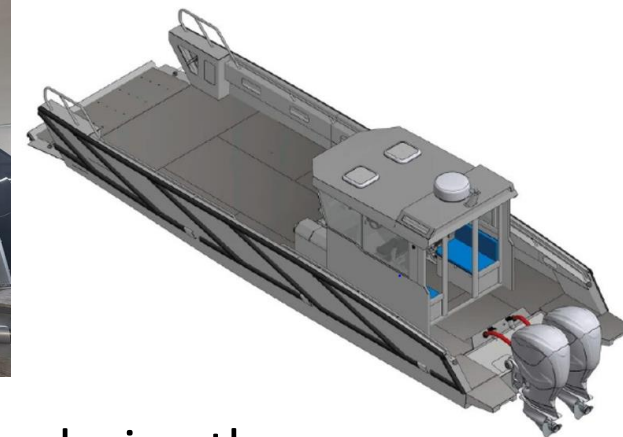
Hovercraft cargo ship.



Safe transportation of people and cargo during the unstable ice cover of the lake. The vessel can accommodate five passengers and a full set of deep-sea modules for one string (40 boxes). The journey from Baikalsk to the telescope takes about 40 minutes on ice.

Deployment teams meeting near the canteen

Cargo ship with ramp.



Transportation of the cargo during the summer.

Cargo capacity of the vessel 3 tons.

One UAZ-"Buchanka" (the main means of transportation on ice) can be transported for repair.





# Progress in data analysis

## Cascade analysis

**$\nu$ -interaction inside detector,  $\sigma_E \sim (0.1...0.3) E$ , angular resolution  $2^\circ - 4^\circ$ .**

**2022.** High-energy neutrino-induced cascade from the direction of TXS 0506+056. *MNRAS* 527 (2024) 8784.

**2023.** Diffuse neutrino flux measurements with the Baikal-GVD neutrino telescope. *Phys. Rev. D* 107, 042005.

**2025.** Search for galactic neutrinos above 200 TeV with Baikal-GVD. *ApJ* 982 (2025) 73 [*arXiv:2411.05608*]

**2025.** Measurement of the diffuse astrophysical neutrino flux over six seasons using cascade events from the Baikal-GVD expanding telescope [*arXiv:2507.01893*] The astrophysical flux is detected with a significance of  $5.1 \sigma$ . The spectrum of astrophysical neutrinos has been measured:  $\gamma_{\text{astro}} = 2.64$ ;  $\phi_{\text{astro}} = 4.42 \text{ GeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$

## Track analysis – the first physical results

**Muon detection,  $\sigma_E \sim 0.3 \log E$ , angular resolution  $0.2^\circ -- 1^\circ$ .**

**2025-2026.** First constraints on point-like astrophysical sources using Baikal-GVD muon neutrino events  
<https://arxiv.org/abs/2603.21261>, sent to the *Astronomy Letters* at 2026.

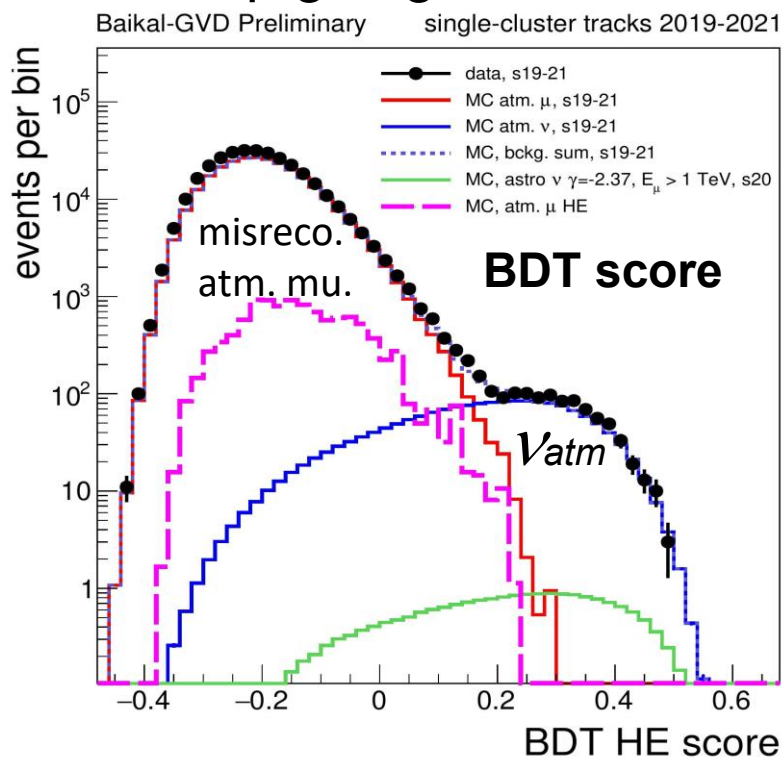


# Diffuse neutrino flux, track mode

The upgoing track rate is dominated by misreconstructed muon bundle.

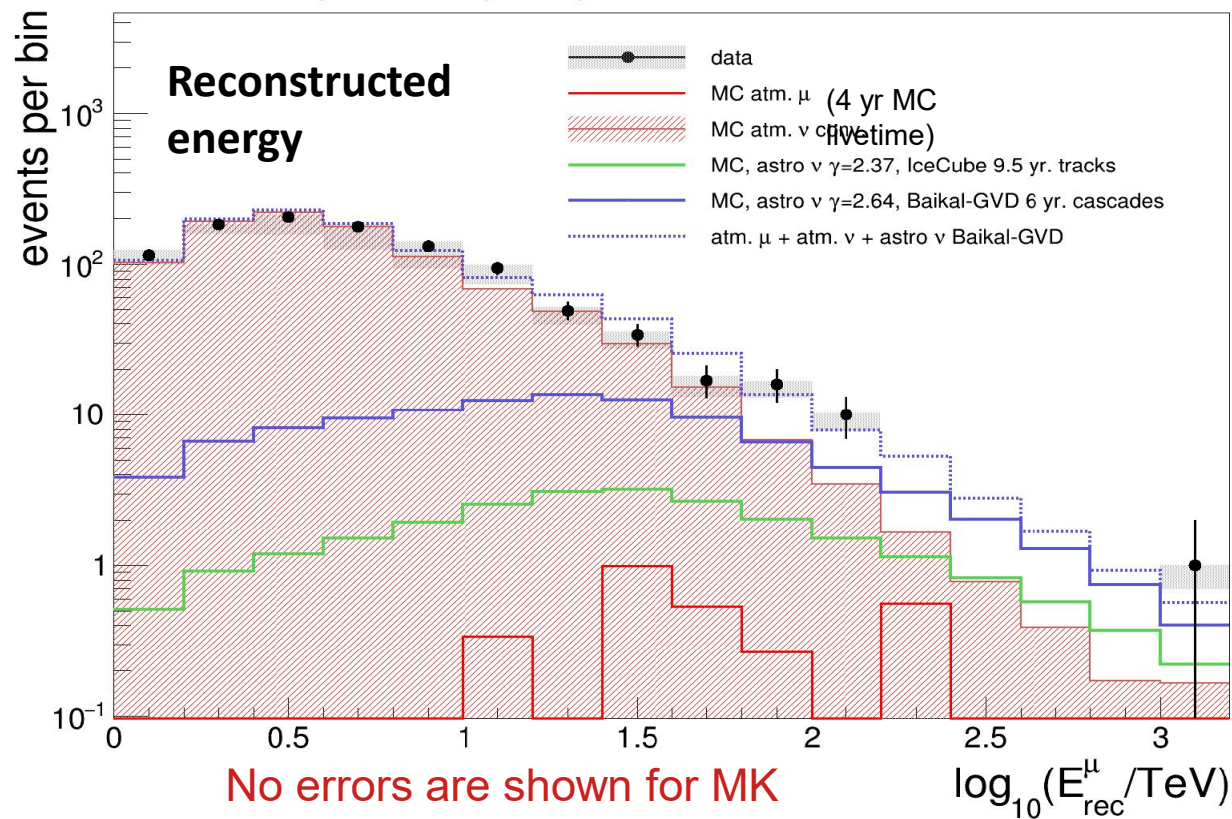
Muon bundles are suppressed with BDT.

## Up going events



[G. Safronov et al, PoS (ICRC2025) 1162]

Energy distribution of neutrino candidates in Apr. 2019 - March 2024

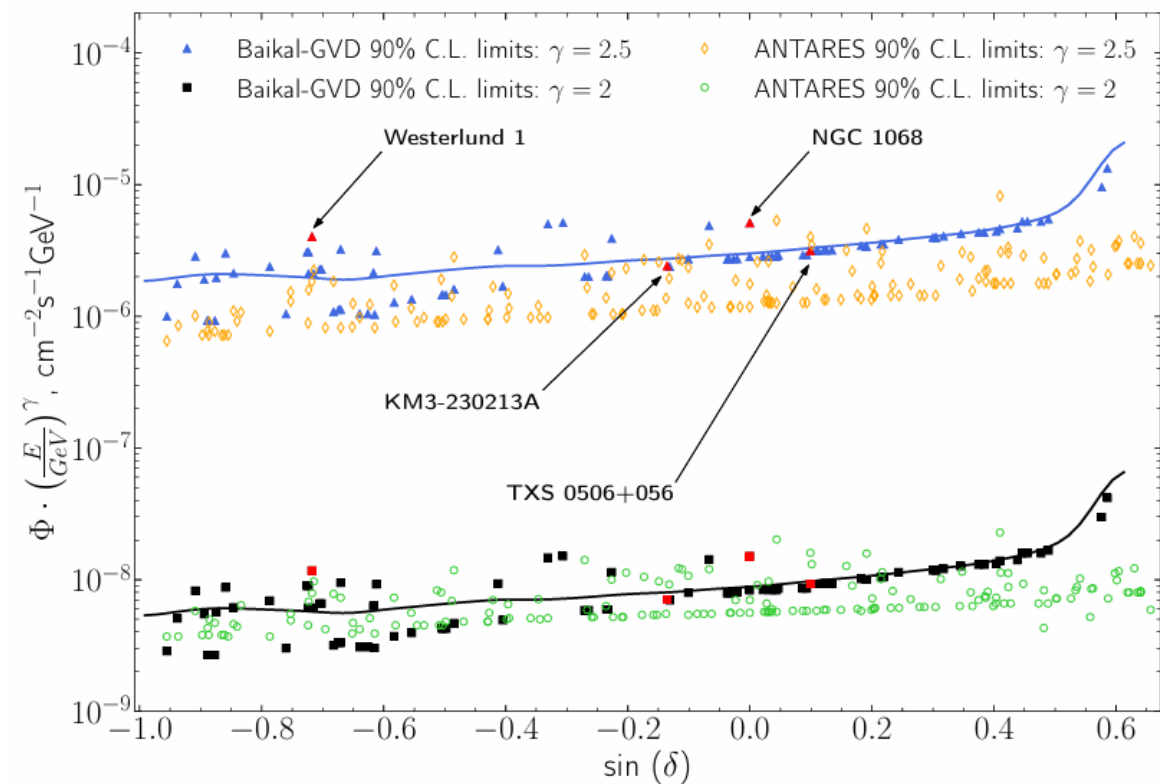


BDT cuts were optimized for power law index  $\gamma=2.37$ .  
 For  $\text{BDT} > 0.26$ ,  $E > 45$  TeV 38 events detected,  
 Background 25 events, significance:  $2.4 \sigma$ .



# Point-like source search with tracks

<https://arxiv.org/abs/2603.21261>,



*Comparison of the Baikal-GVD results (filled squares and triangles) with the ANTARES 15-year limits (empty circles). The attained sensitivity is similar to the ANTARES analysis*

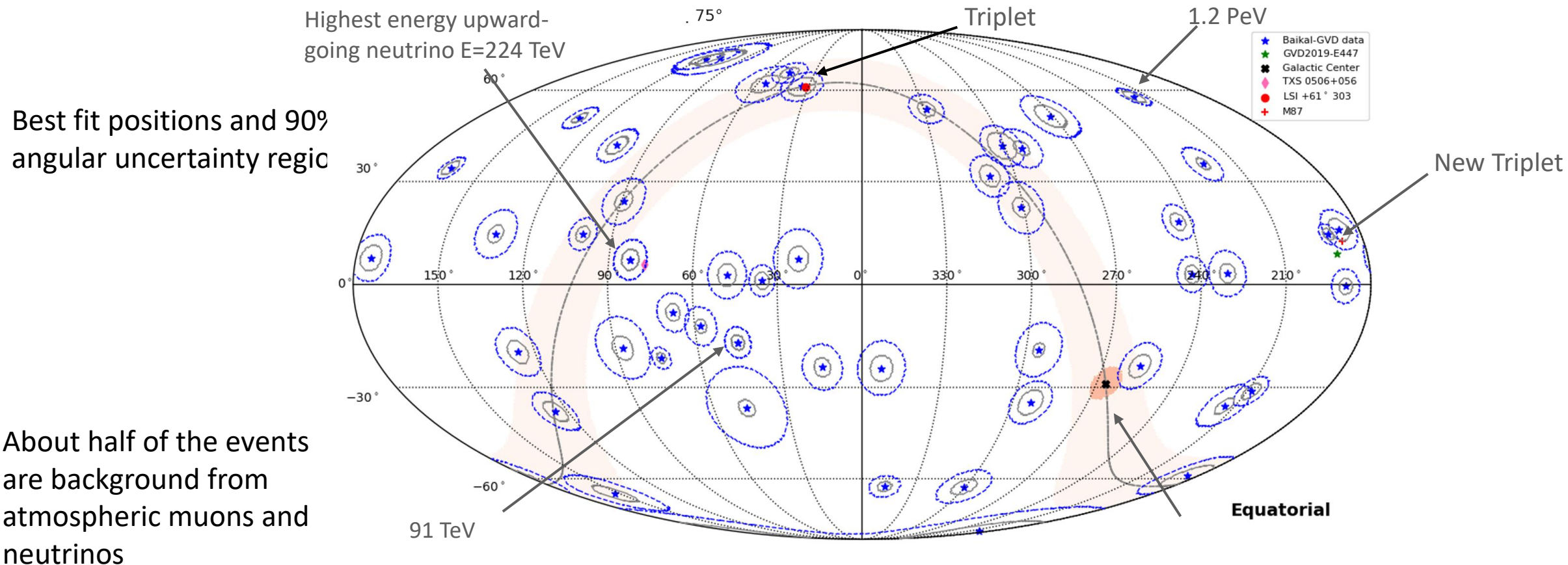
- Guided search over a list of 92 objects at Dec < +38° using a simple cut & count analysis
- 5-year dataset: Apr 2019 - Mar 2024.
- $\chi^2$ -based track reconstruction method, angular resolution  $\sim 0.5^\circ$ .
- The analysis uses 988 upward-going muons - neutrino candidate events,  $E_\mu$  from 100GeV to 1PeV.
- Search in the cone of a  $2^\circ$  around each object.

No significant excess has been found.  
The object with most events in the search cone (3) is Westerlund 1 (bkg=0.98;  $2.7 \sigma$  pre-trial).



# New high-energy cascade sky map

Data from April 2018 to March 2024



Best fit positions and 90% angular uncertainty region

About half of the events are background from atmospheric muons and neutrinos

There is not enough statistics for detailed astrophysical objects studies: an increase in the telescope's volume is required.

# Progress toward next generation Baikal neutrino telescope.

**Conservative approach:**  
started since  
2023

**Two research directions in the development of the next-generation telescope**

**Advantage approach:**  
started since  
end 2025

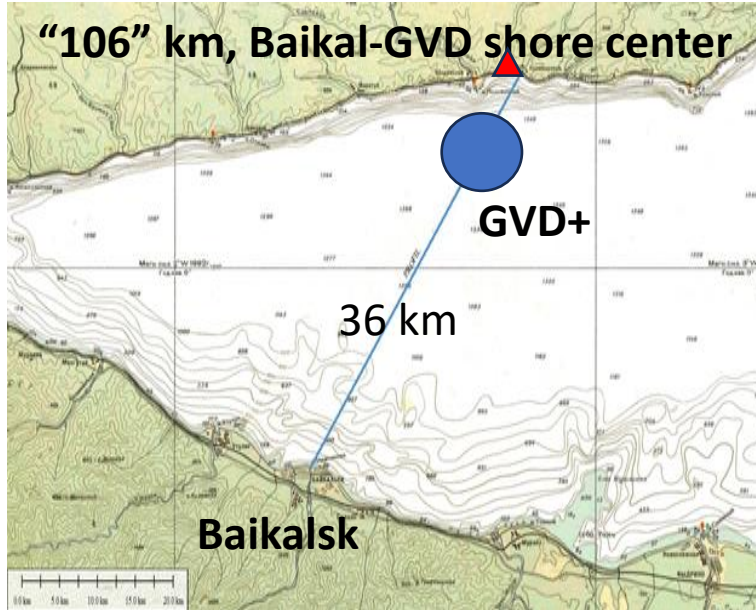
## **GVD+**

- Basically, a Russian project.
- 15 000 optical modules.
- Effective volume  $\sim 8 \text{ km}^3$
- Based on the Baikal-GVD deployment technologies and infrastructure.
- Deployment timeline: 2030 – 2040.

## **Baikal-HUNT**

- Russian-Chinese cooperation.
- 55 000 optical modules.
- Effective volume:  $\sim 30 \text{ km}^3$
- New deployment technologies and infrastructure must be created.
- Deployment timeline: 2030 – 2035.

# GVD+



The design of the next-generation neutrino telescope - GVD+ is based on the following approach:

- Location: near Baikal-GVD, the northern shore of Lake Baikal
- Using the Baikal-GVD deployment and shore infrastructure and technologies.

The development of a next generation neutrino telescope GVD+ began in 2023.

- A high-speed, low-power detection system has been developed.
- Long-term testing of the equipment was carried out in Lake Baikal (experimental strings and cluster).
- The concept of new neutrino telescope has been developed.

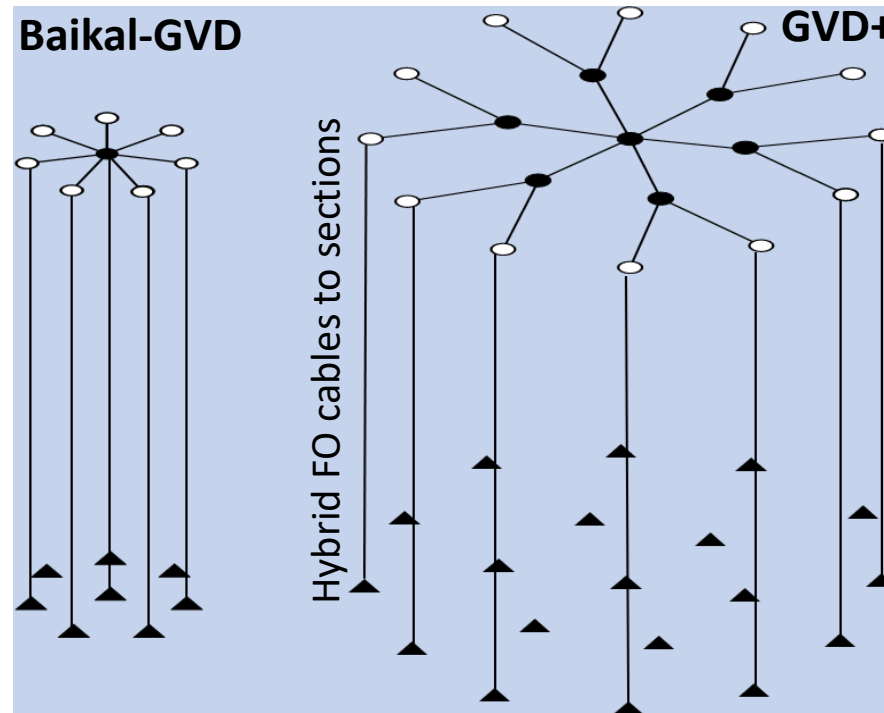
# GVD+ cluster configuration

## Baikal-GVD cluster

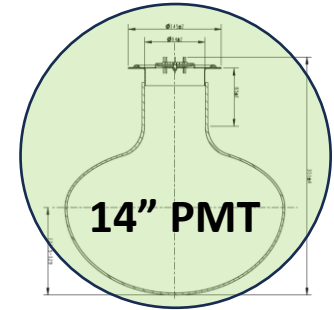
- 8 strings, 60m distance
- 288 OMs with 10" PMT.
- 120 m diameter.

## GVD+ cluster

- 19 strings, ~ 100 m
- About 500 OMs
- About 400 m diameter.



***GVD+ cluster volume increased about 10.***



## Photodetector

- OM with 14 inches PMT in glass sphere 17 inches (same as Baikal-GVD).
- Analog output of OM.
- Small power consumption: 4 Wt/chan (**2 kWt/cluster**).

## Hybrid data acquisition system

All communications, except for the connection with OMs, are made using fiber-optic cables.

The width of the data channel (FO): 1 Gb/s. Time binding of channels to World time: < 1 ns.

Waveform measurement with 5 ns resolution.

# GVD+ time schedule estimation

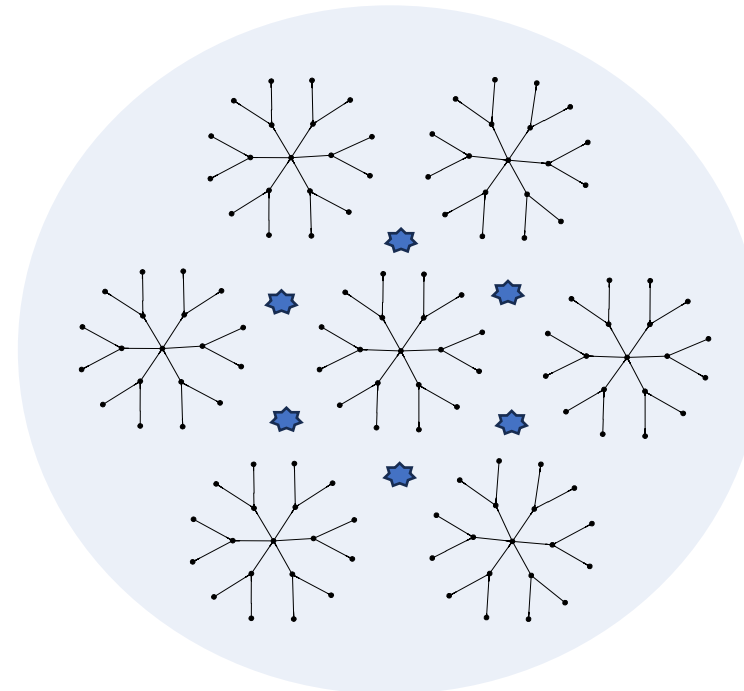
Time	2026-2029	2030-2032	2033-2040
Scope	R&D	1 <sup>st</sup> Cluster Block	2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> Cluster Blocks
Plan	Prototype cluster	~2 km <sup>3</sup>	~8 km <sup>3</sup>

## Cluster Block

7 clusters

$V_{\text{eff}} \sim 2 \text{ km}^3$

Power consumption  $\sim 15 \text{ kWt}$



★ Calibration laser sources

# Russia – China Baikal-HUNT project



LHAASO – a breakthrough in gamma astronomy. LHAASO PeVatrons are guaranteed sources of galactic neutrinos. To detect them, a NT of ~30 km<sup>3</sup> is required

## Cooperation LHAASO-Baikal Proposal for the Next-Generation Neutrino Telescope in Lake Baikal


“The HUNT project in Lake Baikal faces global scientific challenges. Based on LHAASO's scientific breakthroughs, innovative technologies, and Lake Baikal's unique advantages, the initiative demonstrates both scientific necessity and engineering feasibility.”

*Proposal for the Next-Generation Neutrino Telescope in Lake Baikal, signed in Dubna on December 4<sup>th</sup>, 2025*

Proposers:

1. The Institute of High Energy Physics of the Chinese Academy of Sciences

  
Jun Cao  
Director of IHBP

  
Zhen Cao  
Spokesperson of LHAASO  
Academician of the Chinese Academy of Sciences  
and also of the Russian Academy of Sciences

2. The Institute for Nuclear Research of the Russian Academy of Sciences

  
Maxim Libanov  
Director of INR RAS  
Corresponding Member  
of the Russian Academy of Sciences




  
Zhan-Arys Dzhilkibaev  
Spokesperson of Baikal-GVD

3. The Joint Institute for Nuclear Research

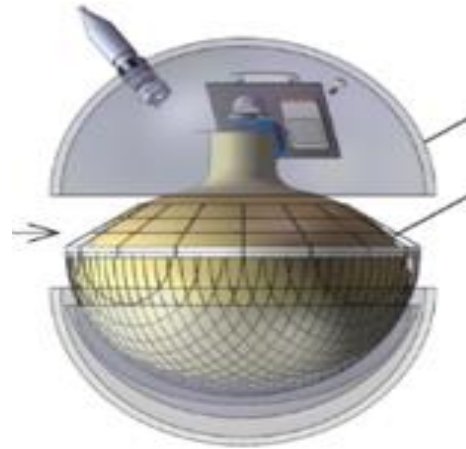
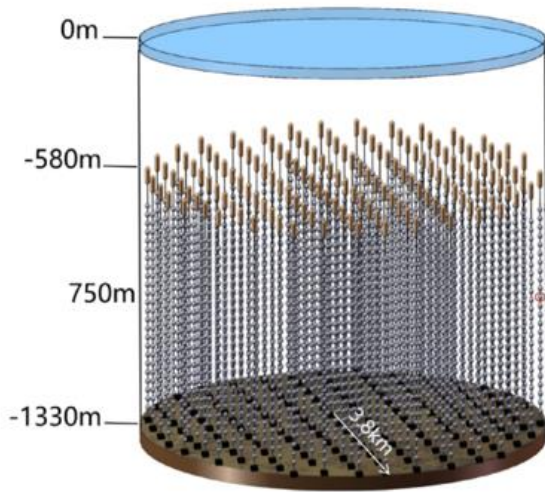
  
Grigory Trubnikov  
Director of JINR  
Academician of the Russian Academy of Sciences



  
Evgeny Yakushev  
Director of DLNP JINR

# B-Hunt specification

*Mingjun Chen // Baikal-GVD Collaboration meeting, JINR, 2025*



## Photodetector

- Optical module with 20-inch PMT;
- Signal digitization inside OM: digital optical module (DOM);
- OM power consumption  $\sim 10$  Wt.

## Configuration

55 296 Optical modules

2304 Strings // 24 OM/String.

144 Clusters // 16 Strings/Cluster

720 m – active string length

Effective volume:  $\sim 30$  km<sup>3</sup>

Angular resolution:  $\sim 0.1^\circ$  (tracks),  $< 3^\circ$  (cascades)

Energy resolution:  $\Delta \log E \sim 0.3$  (tracks),  $\delta E \sim 10-30\%$  (cas.)

# Telescope location

Telescope location determined mainly by necessary electric power and manpower.

## Power consumption:

55 296 Optical modules, 10 Watt per module.

Total power consumption about 600 kW.

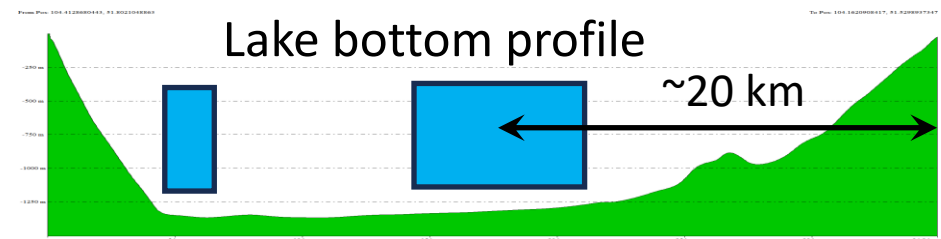
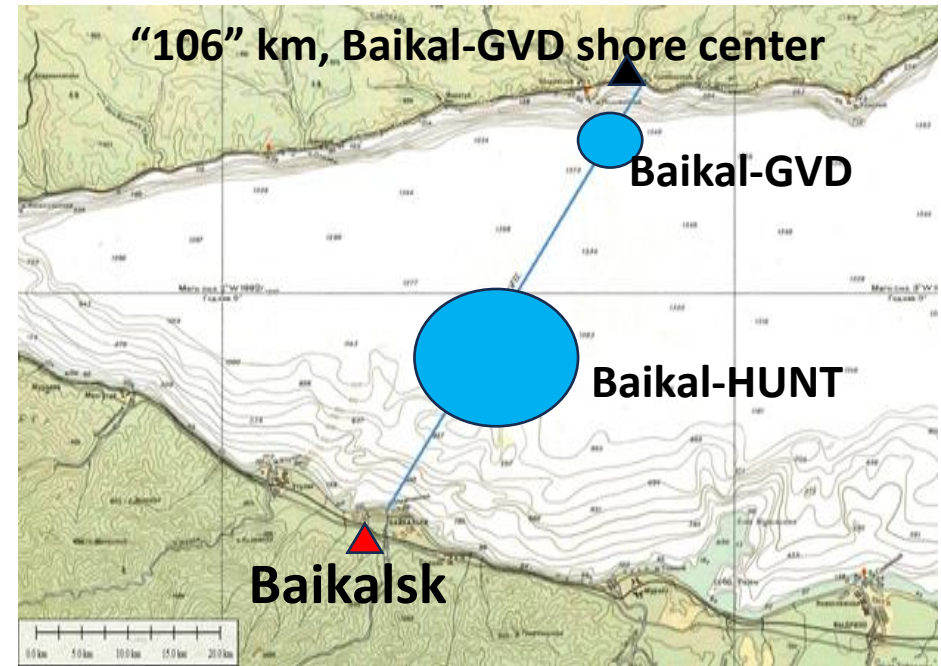
Taking into account cable losses, the required power is 1 MW.

## Manpower

B-HUNT deployment period: 5 years.

144 B-HUNT Clusters: ~30 clusters per season.

Necessary number of staff: about 30 deployment teams (120 installers) plus technical support personnel: ~200 participants of expedition.



The GVD site is inappropriate for BHUNT for both power consumption and staff accommodation. Baikalsk is the optimal location for a telescope shore base. Disadvantage is the increased distance to the shore.

# R&D Baikal-HUNT: 2026 - 2029

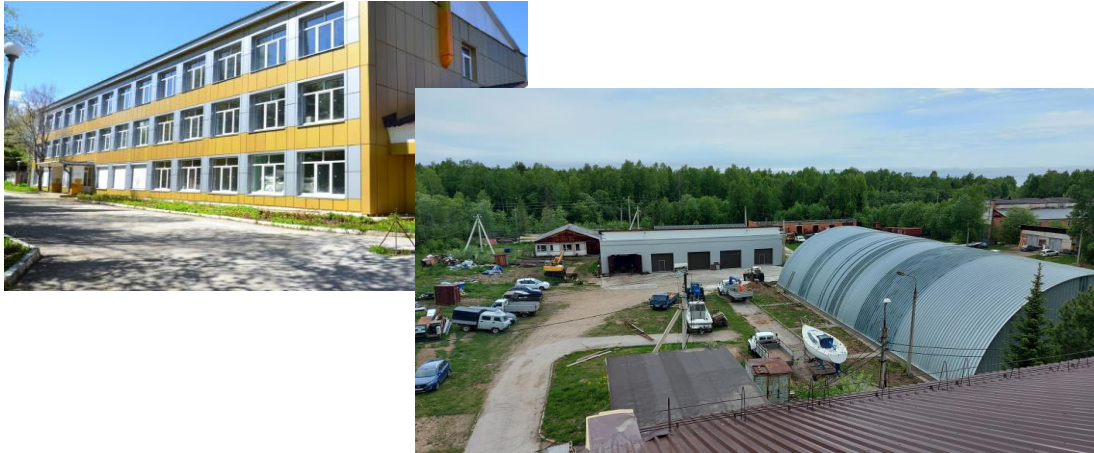
**Due to the relocation of the shore center from the northern shore of Lake Baikal to the southern shore, it is necessary:**

1. Elaboration of the project on creating the necessary infrastructure in Baikalsk for deploying and operating the telescope and its approval.
2. Modernization of bottom cable laying procedure (Increasing the weight of cables).
3. Power supply system modernization (Increasing the length of bottom cables).
4. Deployment of the pilot Baikal–HUNT cluster for performing field testing of all elements of the B-HUNT telescope.

**All these tasks can be solved in parallel.**

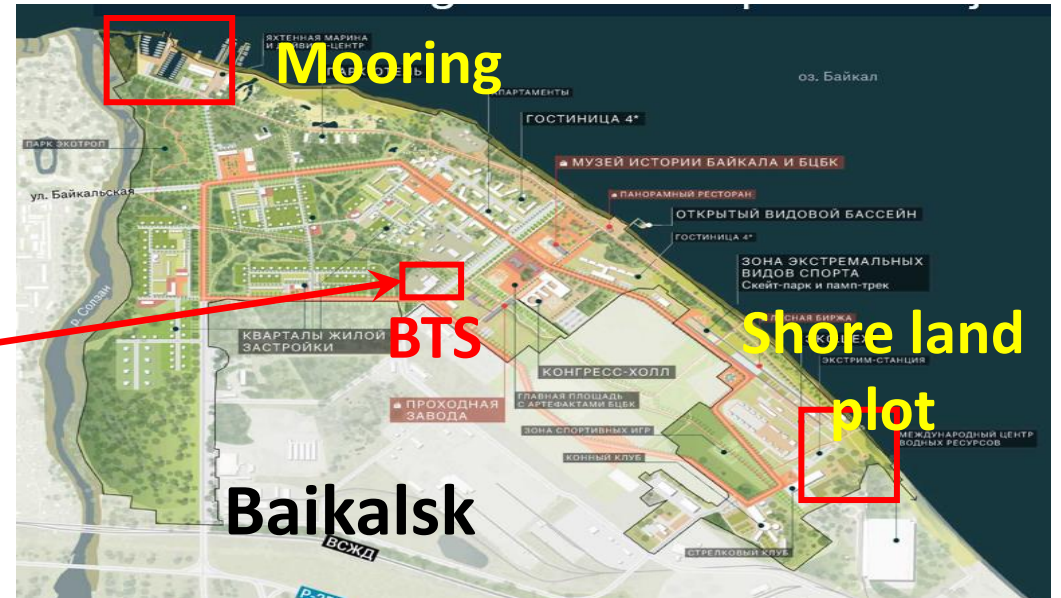
# Development of shore infrastructure in Baikalsk (the southern shore of Lake Baikal)

## Baikal Technical Station (BTS)



Baikalsk technical station is a main storage and technical facility of the Baikal-GVD experiment, workshop for manufacture of mechanical parts of the telescope, transport hub.

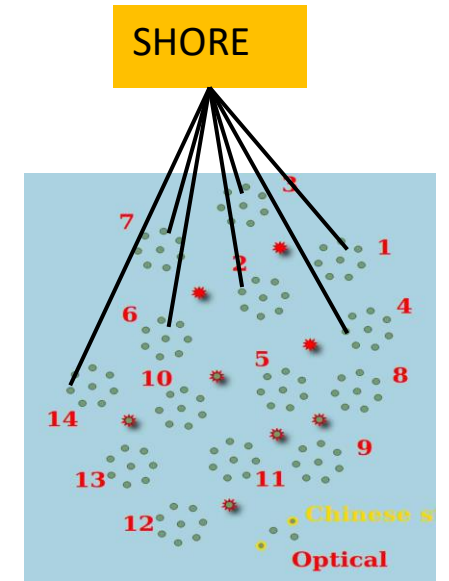
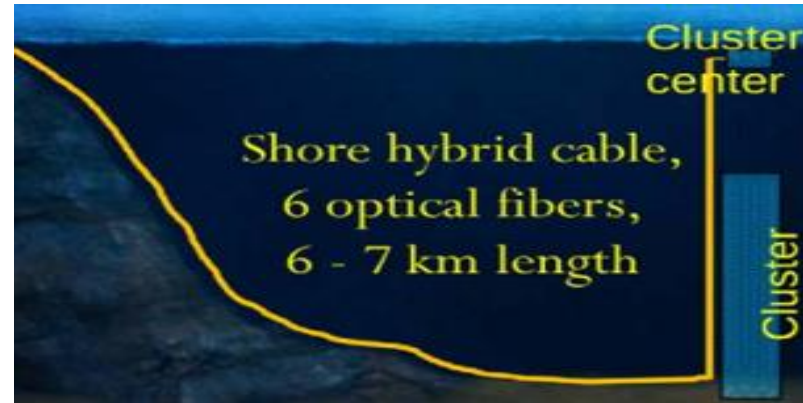
**BUT: There is no access to the shore**



The issue of acquiring a 9.5-hectare plot of land with access to the shore in Baikalsk is currently being resolved. This land plot will allow organize the output of the bottom cables, the locating a power supply system, storage facilities, and a residential complex for personnel.

# Cable laying issues.

## Three basic rules of Baikal-GVD bottom cable laying



1. Cables laying from the ice of the Lake during winter season.
2. Cable lifting to the surface of the lake for connection to equipment from the ice (without deep underwater connections).
3. Individual cable for each cluster (optionally, for two clusters).

### B-HUNT cable system specification:

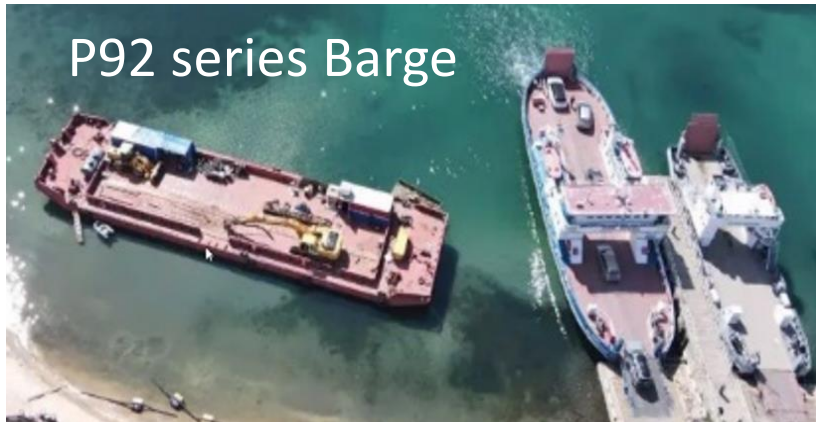
- Length of cables: from 15km up to 25km (one length without connectors). Weight up to 30 tons.
- Number of cables: 144 (one line per one cluster). 29 cable lines per season.

The large weight and the need to install up to 30 cables per season make laying from the ice inappropriate for B-HUNT.

# New technology of B-HUNT cable laying

## Cable laying approach:

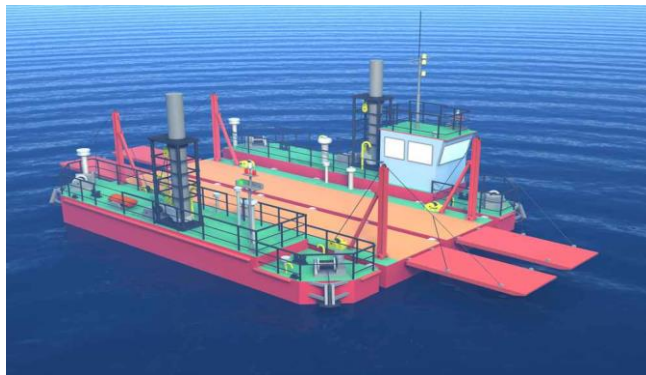
- One cable for one cluster.
- Cable lifted to the lake surface and connected to the equipment (from the ice in winter).
- Laying cables from ships in summer – **NEW technology**



P92 series Barge

Available vessels on Lake Baikal

Hydrotechnical Company "Vostok" in Irkutsk has the necessary experience and technical support to solve the problem of laying cables in Lake Baikal from the ships.



One of the possible options is a modular pontoon-based vessel.

A technical specification is being developed for the preparation of a project for laying underwater cable lines from a ship to Lake Baikal.

A pilot cable laying from a ship is scheduled for 2028-2029.

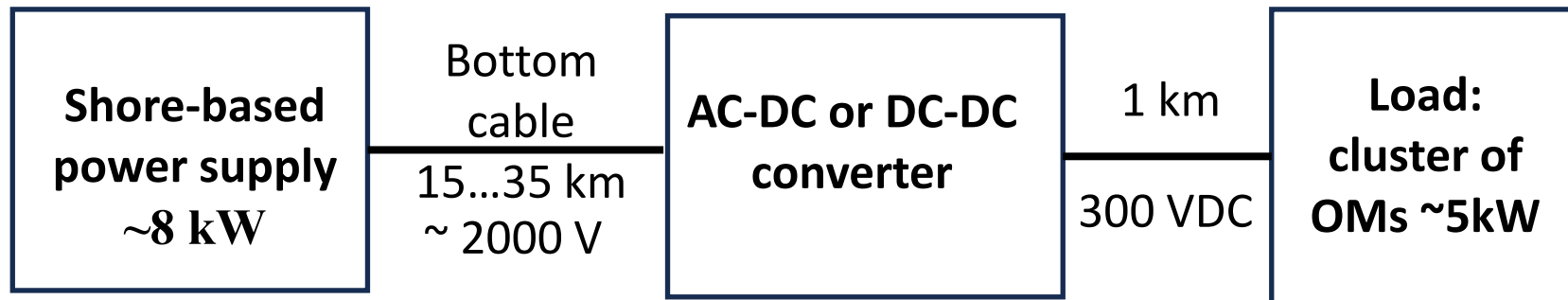
# Power supply system

## Baikal-GVD approach:

- 300 VDC detector supply voltage;
- Bottom cable length up to 8 km;
- Shore supply voltage about 550 VDC.

If length of the cable lines exceeds 10km, the Baikal-GVD approach leads to unacceptable power losses. It is necessary to increase the voltage.

## *Preliminary scheme of power supply for B-HUNT*



## Bottom cable for HV power supply was designed

- 3 Conductive cores,  $D=2.5$  mm ( $R = 3.5$   $\Omega$ /km)
- 12 Optical fibers, 4 pcs in Stainless Steel tube
- Working AC voltage up to 2500 V
- Weight of the cable in the air 1000 kg/km
- A construction length of up to 35 km.

A technical specification for the new power system was developed, and contract for pilot sample was signed.

Laboratory tests of new power system are planned for 2026-2027.

Cable production and power system in-situ tests are planned for 2027 – 2028.

# Pilot B-HUNT cluster

The pilot cluster is planned to be located near the Baikal-GVD and use the existing infrastructure for its deployment and operation.



## Pilot cluster components

- 8 strings×24 DOMs, 30 m vertical spacing.
- 192 DOMs with 20" MCP PMTs.
- Bottom cable of new design.
- New power supply system ~2 kV.

## Purpose

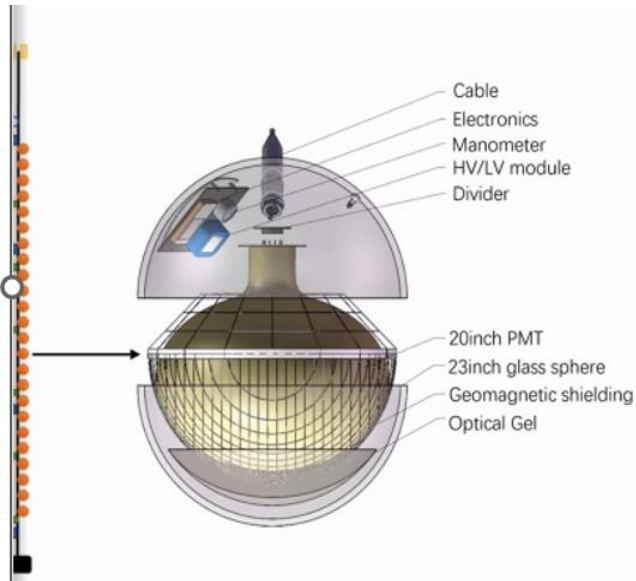
Field tests of all elements of B-HUNT telescope including cable communications, new power system, upgraded systems of detector deploying, DAQ operation.

## HUNT DAQ specification

- Digital OM, power consumption ~10 W per channel.
- Fiber-optical hybrid underwater cable to each DOM.
- FADC 500 MHz, pulse shape measurement.
- Time reference accuracy better 1 ns.
- Hybrid trigger: double coincidences (hardware) and software onshore trigger (for pulse form).
- Synchronization: "White Rabbit" switch on each string.

Completing the deployment of a pilot cluster of 8 strings is planned for 2028-2029.

# The first steps to B-HUNT – experimental cluster Baikal-GVD



Tests of B-HUNT and GVD+ prototype strings with experimental cluster:  
2024 - 2026

HUNT full-scale prototype  
24 DOMs

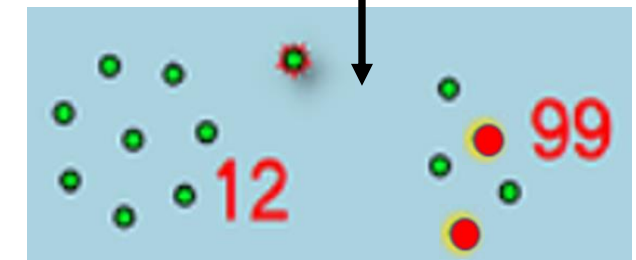
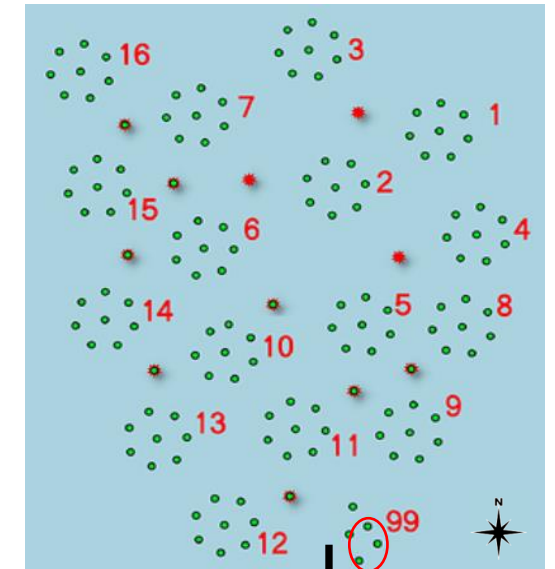
## Configuration 2026

- Three GVD+ prototype strings 36 OMs each, 10" PMTs.
- Two HUNT prototype strings: 24 DOMs and 18 DOMs, 20" PMTs.

## Objectives

- Study 20" PMT operation, comparison 10" and 20" PMTs.
- Investigation basic DAQ parameters.
- Study of reliability, long term in-situ tests of all components.

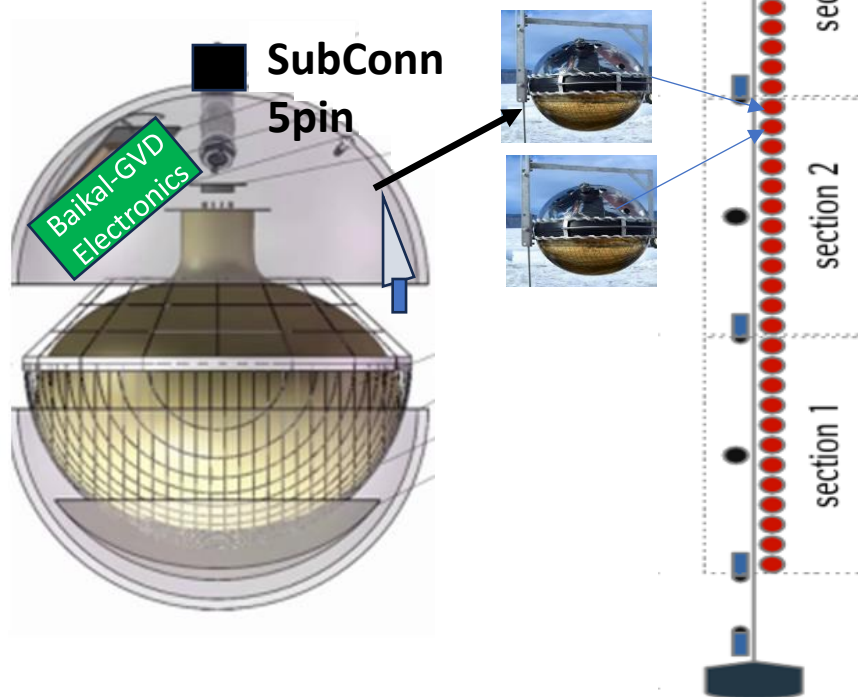
## Baikal-GVD 2026



# Current activity

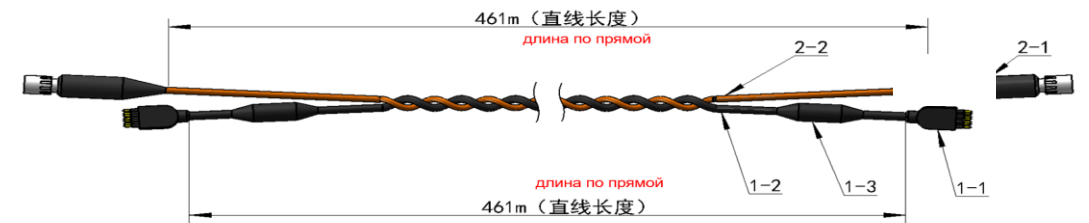
1. It is difficult to compare the characteristics of GVD-OM and HUNT-OM running under different data acquisition systems.

Two 20" HUNT-OMs with GVD FE electronics were installed at GVD string at 2026.



2. Hybrid FO underwater cables is a weak point of the installation – more than 10% cables were leaked.

In 2025, a new type of cable was designed as part of the cooperation between the INR (Russian) and the Chinese company (AQUAT). The development is based on one fiber optical connectors and SubConn power connectors, which have proven to be effective in the telescope.



AQUAT-Y hybrid cable

One GVD-string of the experimental cluster was assembled on AQUAT-Y cables for long term test at 2026.

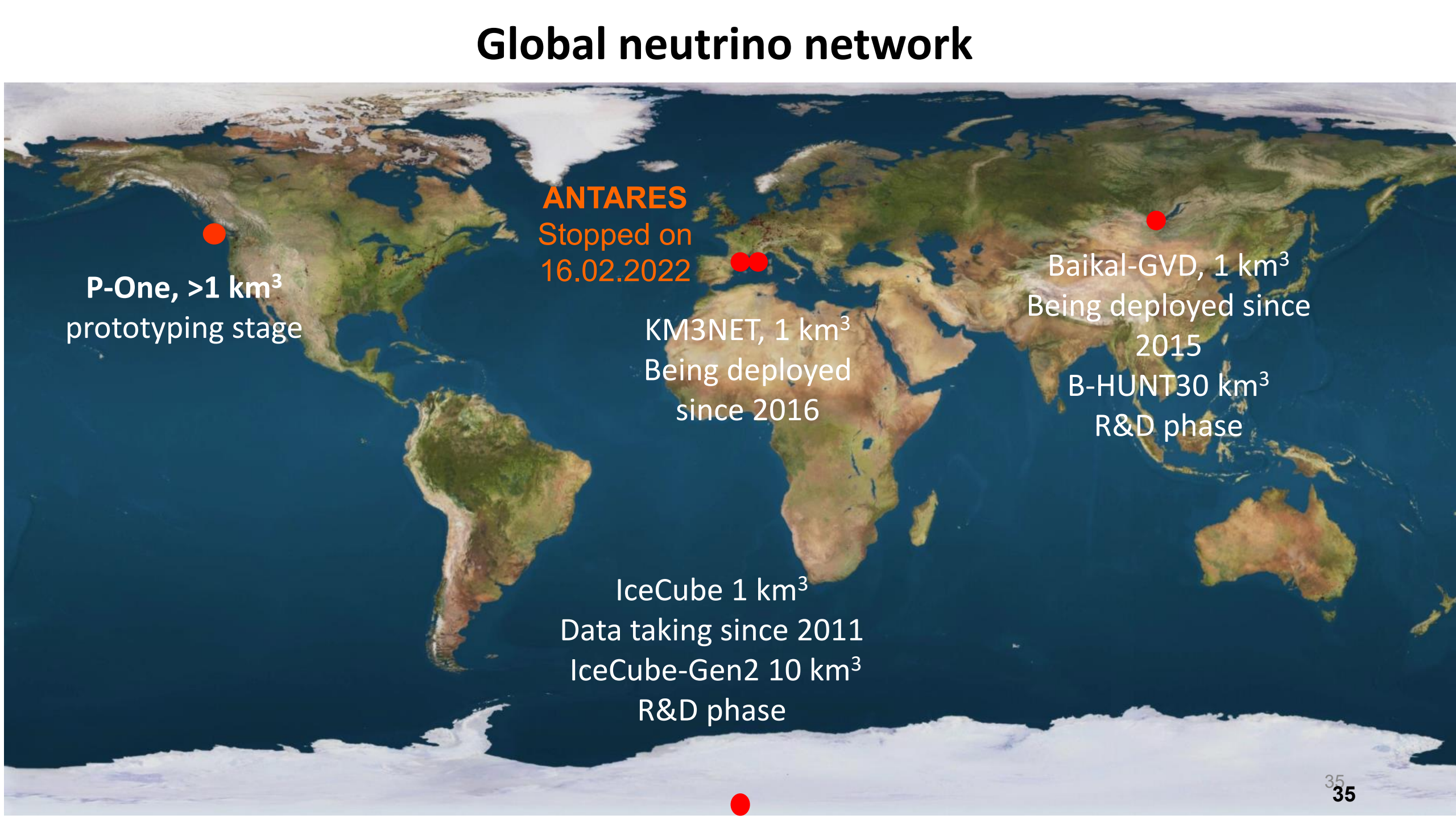
# Conclusion

- The Baikal-GVD deployment is progressing successfully. The necessary conditions have been created to complete the telescope's full deployment in 2029.
- Experimental data is collected and analyzed simultaneously with the telescope's deployment. There has been significant progress in track events analyzing in 2025-2026.
- We are working towards implementing the HUNT project on Lake Baikal. R&D aimed at creating the B-HUNT Technical Project is planned to be carried out in 2026-2030.
- The Baikal-HUNT joint Russian-Chinese experiment, with a volume of  $\sim 30 \text{ km}^3$ , will be a breakthrough experiment in the field of neutrino astronomy and astrophysics, ensuring Russia's leadership in this field for decades to come.

Thank you!

Back up slides

# Global neutrino network



**P-One, >1 km<sup>3</sup>**  
prototyping stage

**ANTARES**  
Stopped on  
16.02.2022

**KM3NET, 1 km<sup>3</sup>**  
Being deployed  
since 2016

**Baikal-GVD, 1 km<sup>3</sup>**  
Being deployed since  
2015

**B-HUNT30 km<sup>3</sup>**  
R&D phase

**IceCube 1 km<sup>3</sup>**  
Data taking since 2011  
**IceCube-Gen2 10 km<sup>3</sup>**  
R&D phase



# All-sky search for HE cascades

Selection requirements:

$(N_{\text{hit}_\mu} = 0, E_{\text{rec}} \geq 70 \text{ TeV})$  or

$(N_{\text{hit}_\mu} = 1, E_{\text{rec}} \geq 100 \text{ TeV})$

$N_{\text{hit}_\mu}$  is number of hits in time interval where hits from muons are expected

Expected:

**14.7** events from atm. muons

**1.0** events from atm. Neutrinos

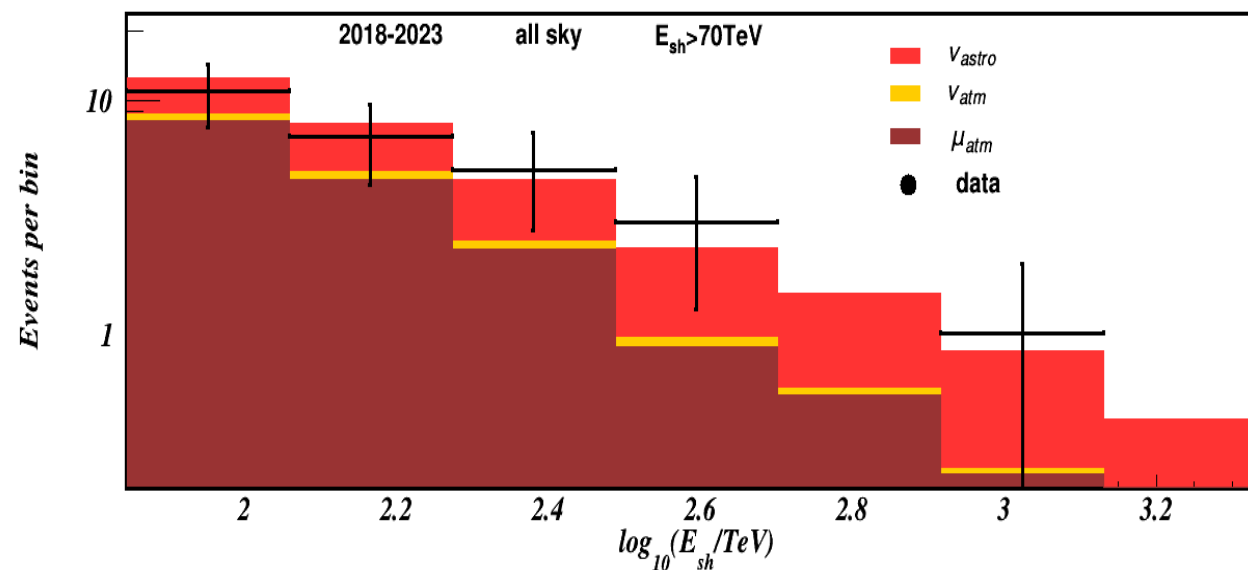
**11.6** events from an astrophysical flux with a spectrum  $E^{-2.58}$  according to Baikal-GVD data.

*Phys.Rev. D107, 042005 (2023)*

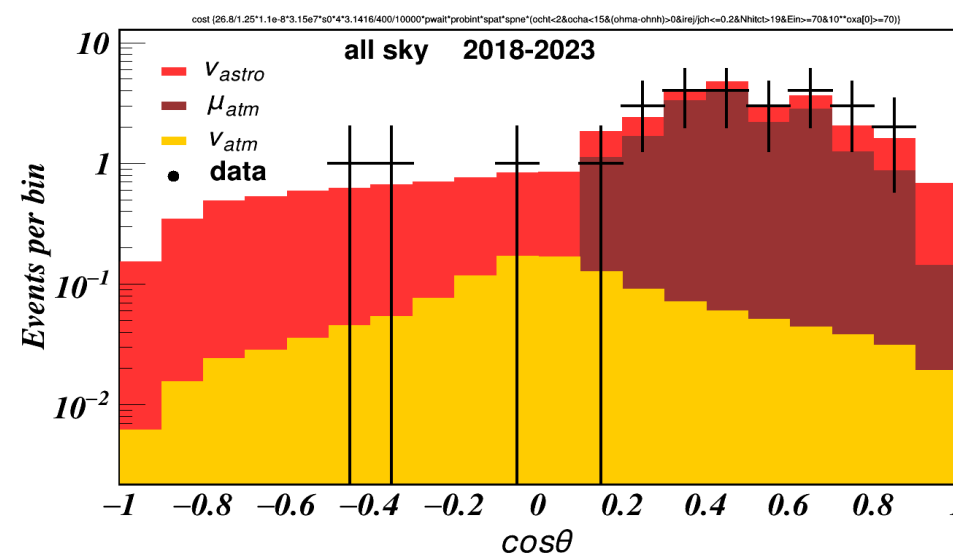
**Found in data: 27 events**

Years	$N_{\text{data}}$	$N_{\text{bg}}$	P-value	Significance (no syst.)
18-21	16	8.2	$2.1 \times 10^{-2}$	$2.3\sigma$
18-23	27	15.7	$3.2 \times 10^{-3}$	<b><math>2.7\sigma</math></b>

Energy distribution (18-23)



Zenith distribution (18-23)





# Upward cascades

## Selection requirements:

$E > 15 \text{ TeV}$  &  $N_{\text{hit}} > 11$  &  $\cos\theta < -0.25$   
+ muon veto

## Expected:

0.9 events from atm. muons

1.9 events from atm. Neutrinos

14.6 events for Baikal-GVD best fit astrophysical flux

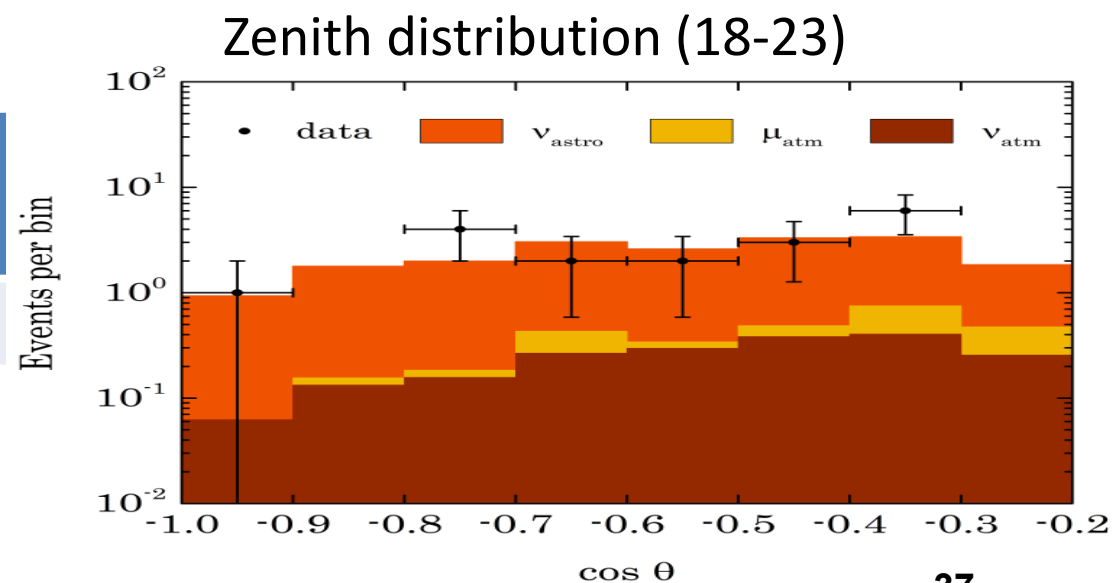
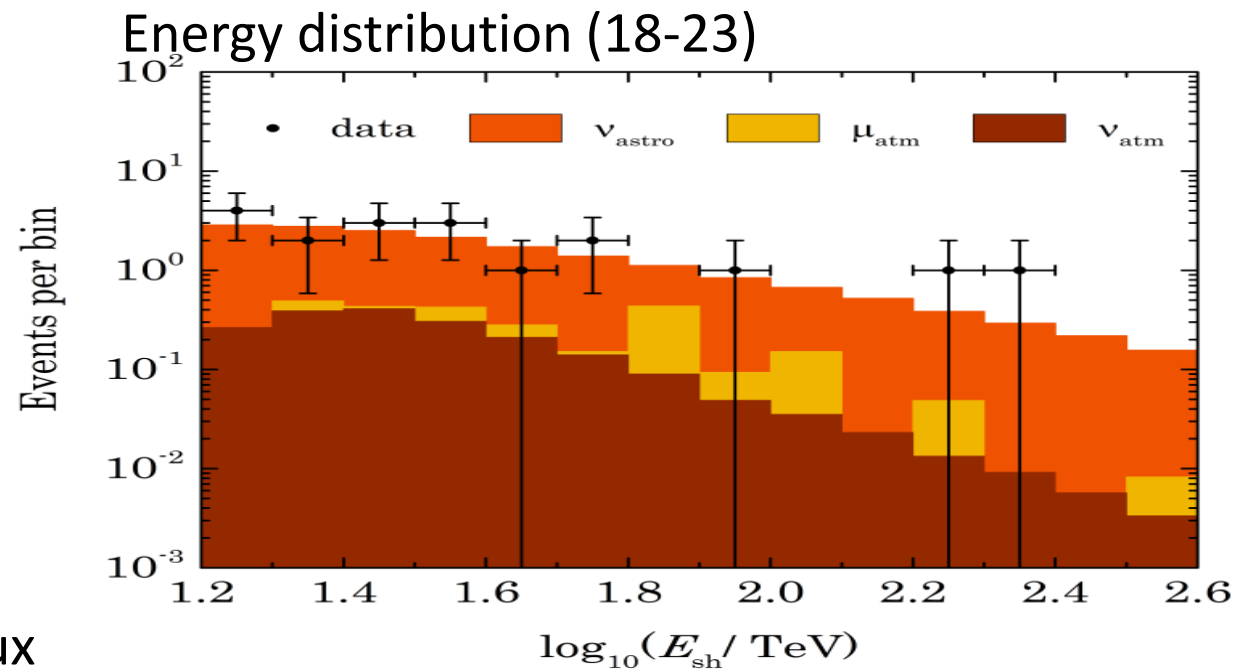
18 events found in data

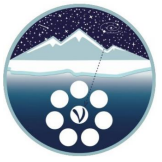
Date	$N_{\text{data}}$	$N_{\text{bg}}$	P-value	Significance (no syst.)	Significance (stat.&syst.)
18-23	18	2.8	$2.15 \times 10^{-10}$	$6.24\sigma$	$5.1\sigma$

Excess over the atmospheric background:  $5.1\sigma$

[arXiv:2507.01893]

<https://doi.org/10.1103/PhysRevD.107.042005>





# Spectrum of astrophysical neutrinos

Single power-law model of isotropic astrophysical flux:

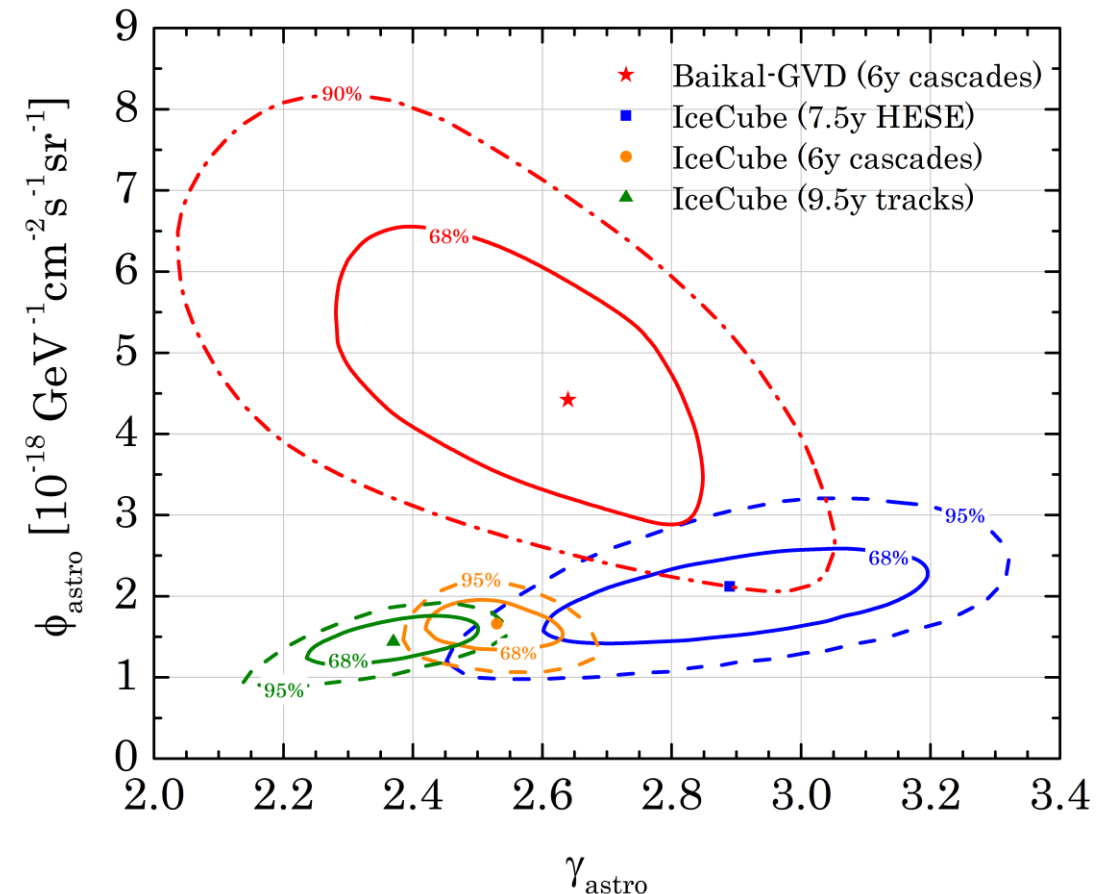
$$\Phi^{\nu+\bar{\nu}} = 3 \times 10^{-18} \phi_{astro} \left( \frac{E}{10^5} \right)^{-\gamma_{astro}} \quad (GeV \text{ cm}^2 \text{ s sr})^{-1}$$

Baikal-GVD best fit parameters:

$$\gamma_{astro} = 2.64$$

$$\phi_{astro} = 4.42, \text{ GeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \text{ per-flavor,} \\ E = 100 \text{ TeV}$$

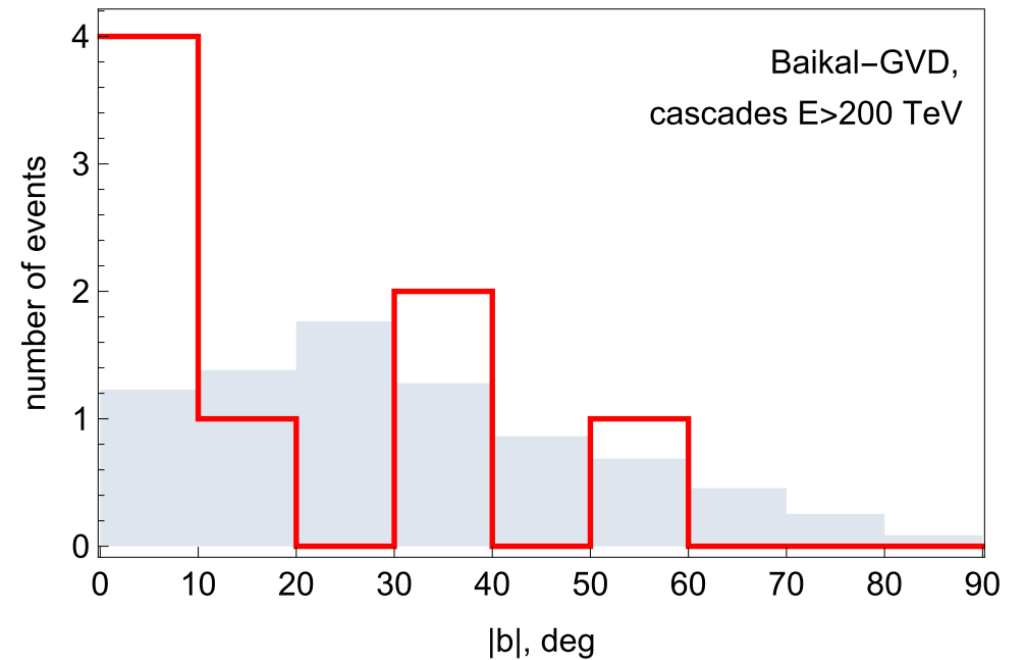
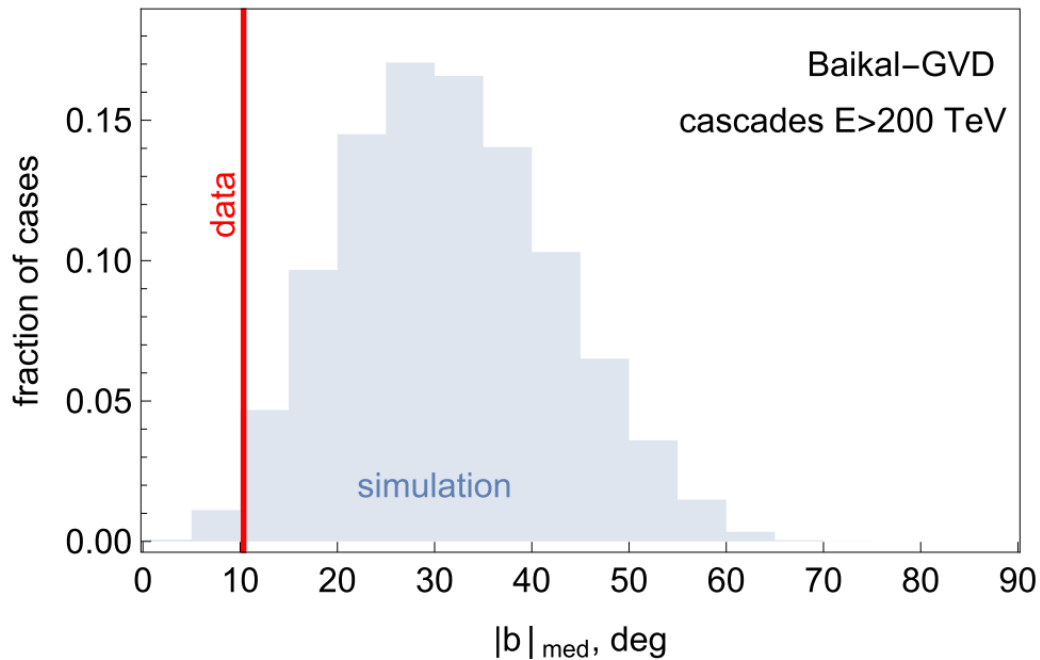
[arXiv:2507.01893v2](https://arxiv.org/abs/2507.01893v2)





# Galactic neutrino flux

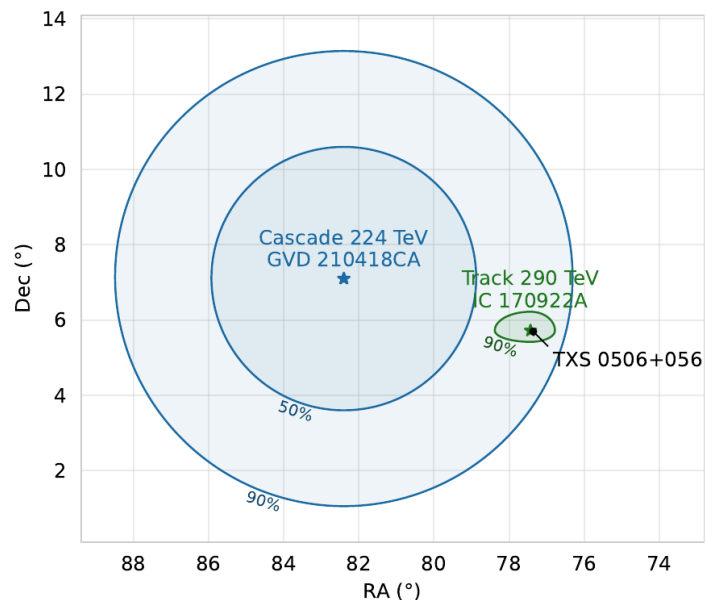
- Analysis inspired by independent analysis of public IC data in [ApJL 940, L41\(2022\)](#)
- Dataset: high-energy cascades April 2018 - March 2024 (6 years)
- Test the Galactic excess for cascades with  $E > 200$  TeV
- Used the sample of 8 events, 64% of astrophysical origin
- Simple model-independent test using median of galactic latitude  $|b|_{\text{med}}$
- Null hypothesis is excluded with a significance of  $2.5\sigma$





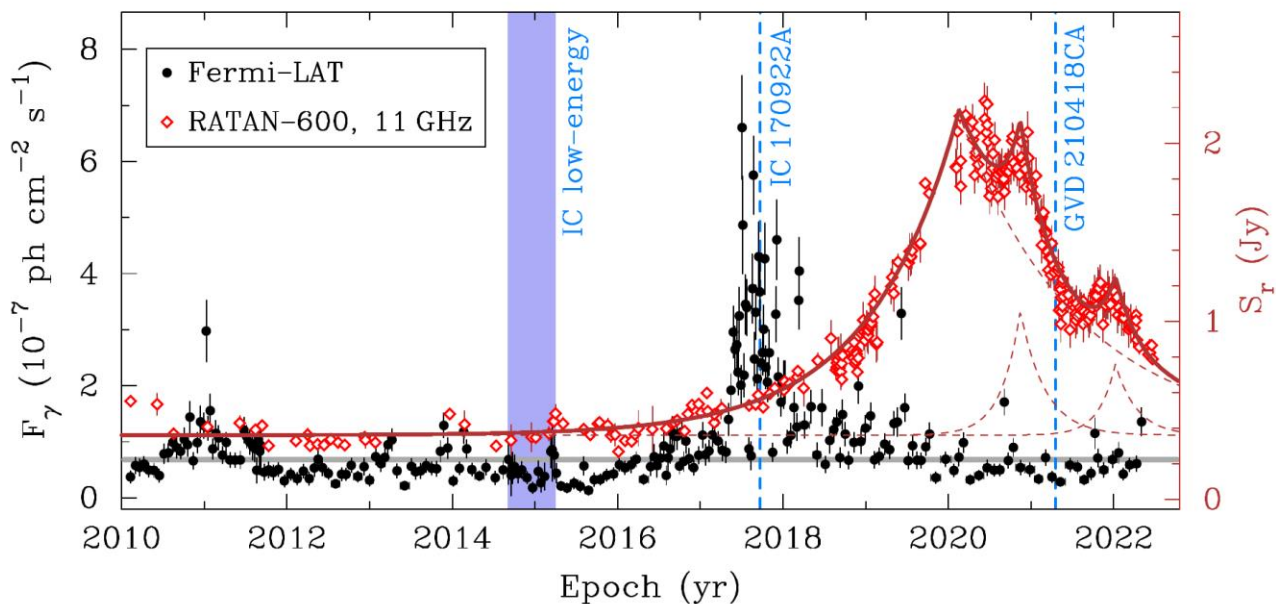
# Cascades: TXS 0506+056 coincidence

[MNRAS 527 (2024) 8784]



Upgoing cascade analysis, highest energy event (18.04.2021):

- 224 TeV, 24 hits
- Neutrino source candidate TXS 0506+056 is within 90% containment circle
- Signalness: 97.1% (probability of astro origin)
- Chance coincidence probability ( $E > 200$  TeV): 0.0074



Analysis of RATAN-600 radiotelescope data (11GHz) showed increased activity

- IC event registered during  $\gamma$  flare
- Baikal event during radio flare
- Consistency with IC observations: 8% or 13% depending on  $\nu$  spectrum assumption