ISCRA-2025

The 5th International Symposium on
Cosmic Rays and Astrophysics

Expansion Possibilities of the Baikal-GVD Neutrino Telescope

Vladimir Aynutdinov, Baikal-GVD Collaboration

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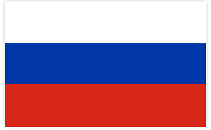
Baikal-GVD Collaboration




- Institute for Nuclear Research of the Russian Academy of Sciences, Russia
- Joint Institute for Nuclear Research, Russia
- Irkutsk State University, Russia
- Skobeltsyn Research Institute of Nuclear Physics, Russia
- St. Petersburg State Marine Technical University, Russia
- National Research Nuclear University MEPHI, Russia
- P.N. Lebedev Physical Institute, Russia
- Comenius University, Slovakia
- Czech Technical University in Prague, Czech Republic
- Institute of Nuclear Physics ME RK, Kazakhstan

Prospects for the development of the Baikal project

2028: 6 000 OM, ~1 km^3
Completing Baikal-GVD deployment

Investigation of the diffuse fluxes of astrophysical neutrinos.

2029 – 2040: ~15 000 OM, ~10 km^3
Advanced Neutrino Telescope GVD+

Research of properties and sources of astrophysical neutrino

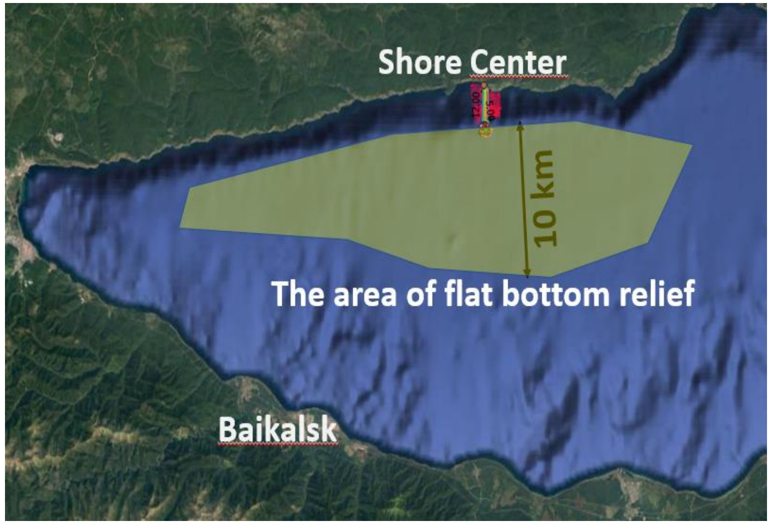
The scientific goals

- Identifying the sources of high-energy neutrinos // Galactic, Extragalactic, Cosmogenic.
- Comprehensive study of galactic (PeVatron) and extragalactic objects in the energy range of hundreds of TeV and above, based on data from GVD+, LHAASO, and TAIGA.
- The energy spectrum and flavor composition of cosmic neutrinos.
- Exploring fundamental physics with high-energy neutrinos.

Strategy of GVD+ development

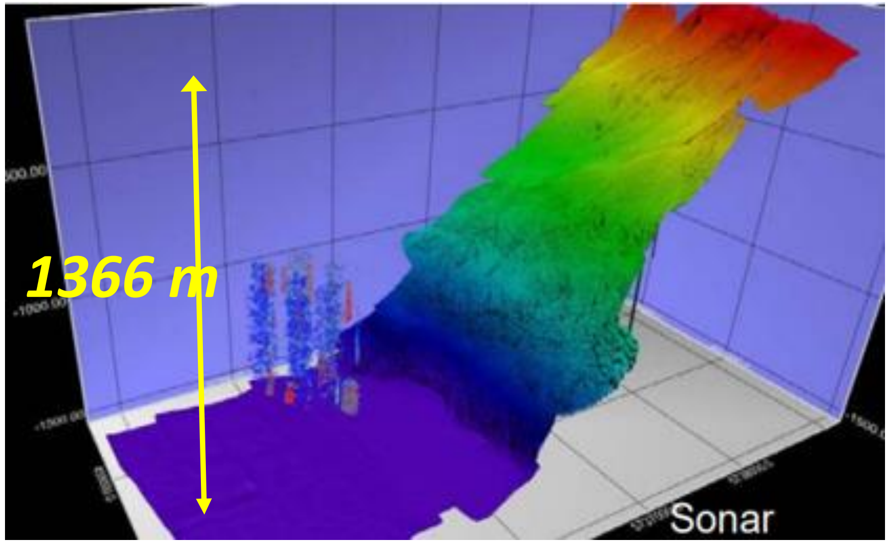
- Increasing the efficiency of neutrino detection in the energy range of 0.1 – 1000 PeV by enlarging the detecting volume of the telescope.
- Formation of a dense core of the telescope for studying neutrinos in the energy range of 1-100 TeV // Baikal-GVD may be rearranged.
- Development of a new system of registration and data acquisition, providing improved measurement accuracy, trigger performance and the possibility of registration of slow particles (Rubakov monopole), supernovae, search for dark matter particles.

Site



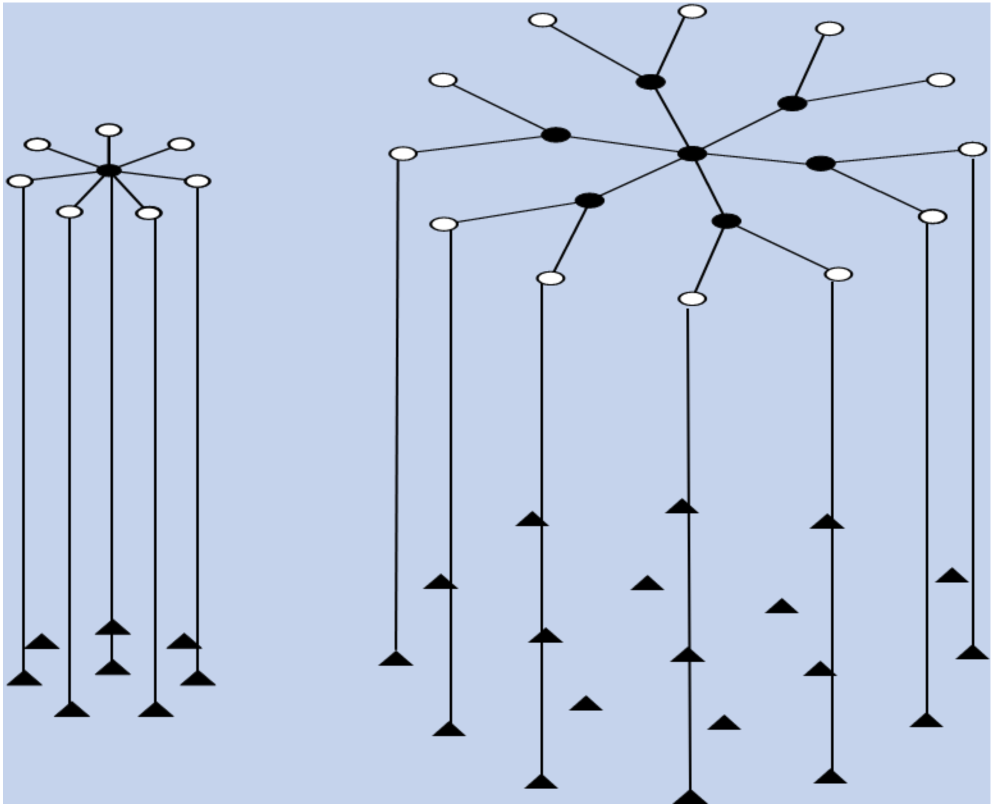
Site properties

- 51°46’ N 104°24’ E
- Depth of the lake is 1366 m.
- Distance to shore 4…10 km.
- The flat bottom relief allows to place new telescope near the Shore.



GVD+ cluster configuration (to be optimized)

Baikal-GVD cluster
- 8 strings, 60 m
- 288 OMs.
- 120 m diameter.



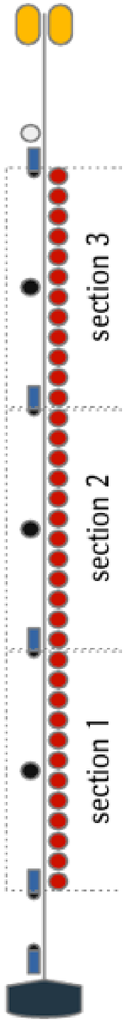
GVD+ cluster
- 19 strings, ~ 100 m
- About 500 OMs
- About 400 m diameter.

1. Increasing the cluster size : ~ 10.
2. Improving the efficiency of track event detections (the condition for track reconstruction is 6 hit at 3 strings).

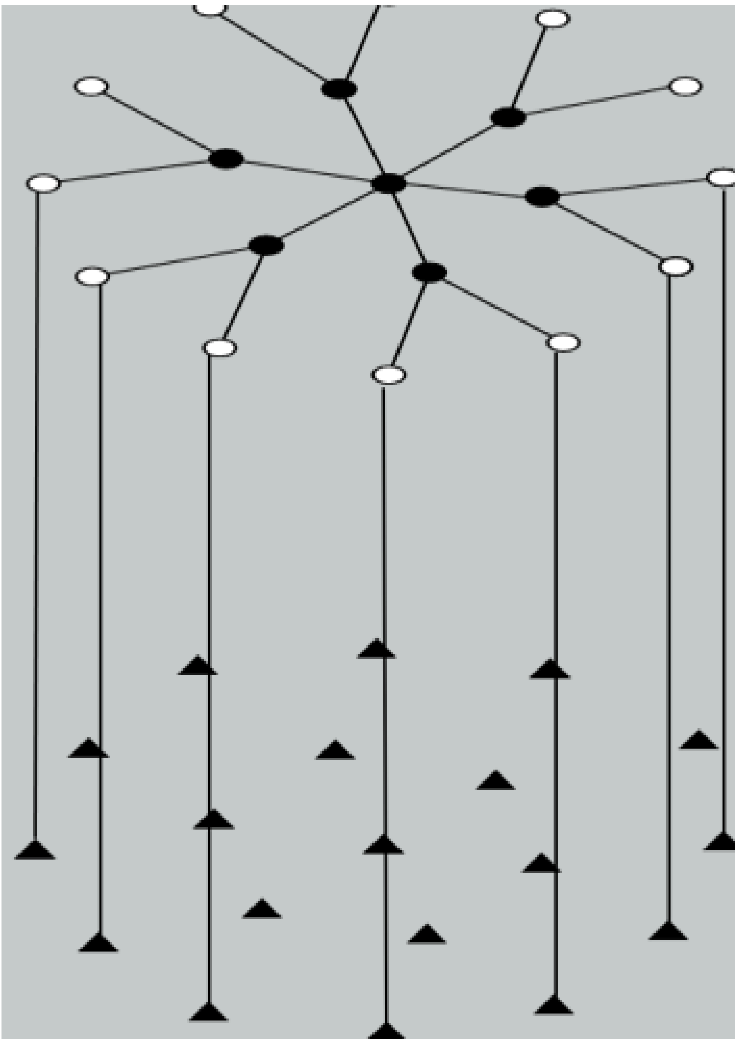
GVD+ data acquisition system

Hybrid data acquisition system (DAQ)
All communications, except for the connection with OMs, are made using fiber-optic hybrid cables

Parameters
1. The width of the data channel: 1 Gb/s.
2. Time binding of channels to World time: < 1 ns.
3. Waveform measurement (200 MHz).
4. Two types of trigger conditions:
   - "Fast" trigger: muons, cascades.
   - "Slow" trigger, supernova, monopole, …



Coax cables to OMs

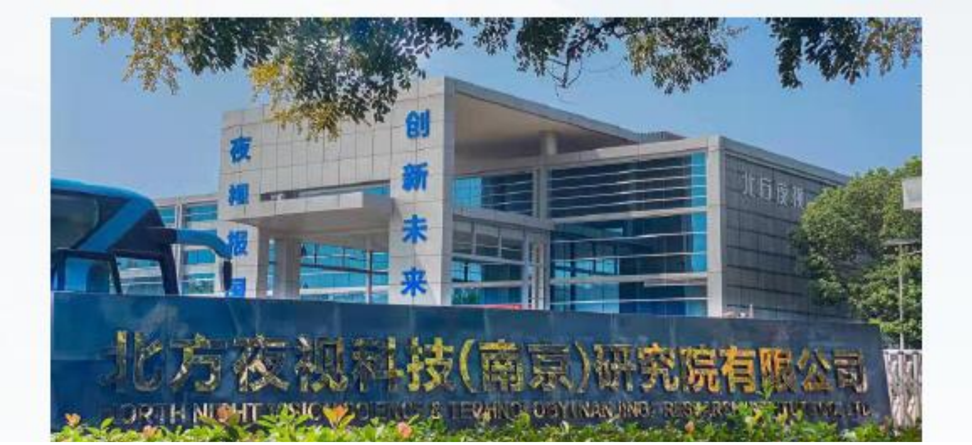


Hybrid cables to sections and strings

Photomultiplier Tube

There are currently available three versions of PMT for purchase:

N6082, D = 8”, N6203, D = 20”, NEW PMT D = 14”



North Night Vision Science & Technology (Nanjing) Research Institute Co. Ltd

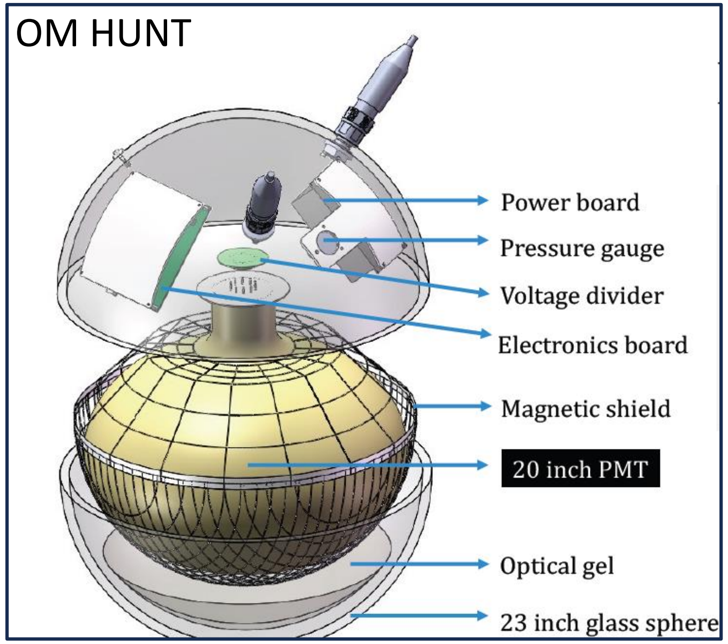
NNVT has organized mass production of the N6082 and N6203 PMT (PandaX, *JUNO, LHAASO*)

Optical module (OM)

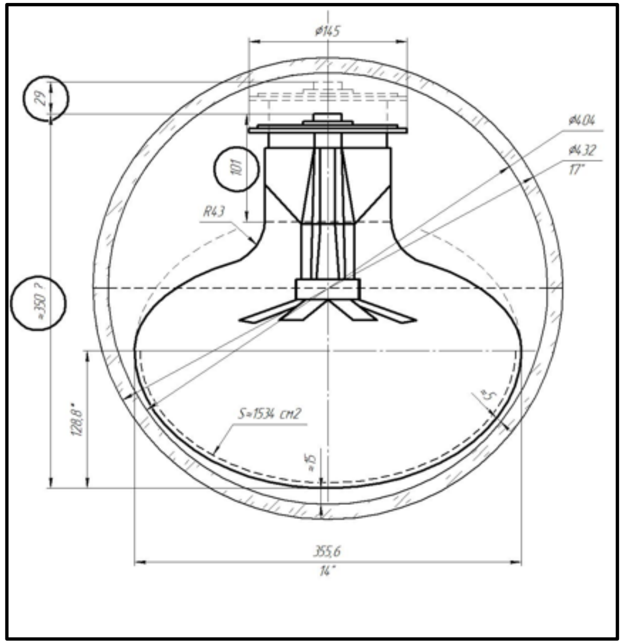
Basic technical demands

1. The maximum possible area of the photocathode for recording weak light fluxes.
2. High time resolution to ensure track reconstruction accuracy on the level $0.2^{\circ}....0.3^{\circ}$.
3. Adaptability in terms of mass production (manufacturing complexity), deployment from the ice cover (installation speed) and operation (power consumption).

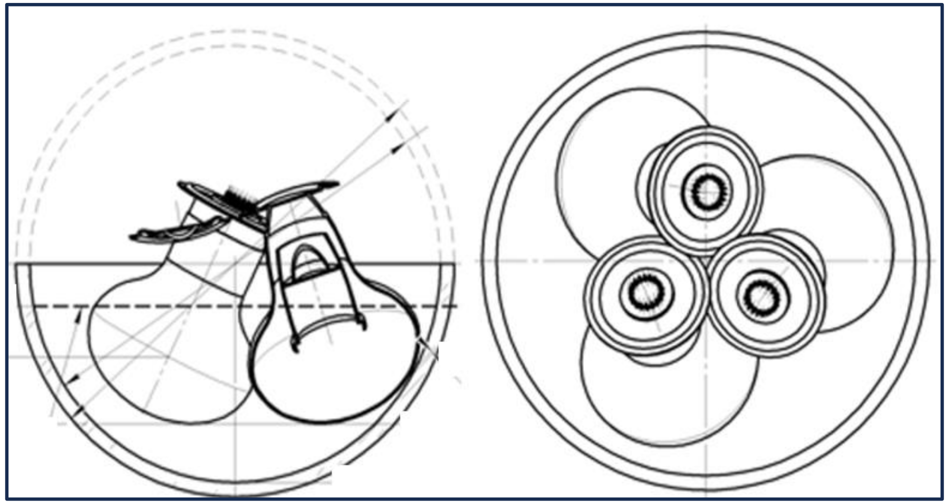
OM construction



Version OM #1:
One PMT 20” - N6203
Glass sphere 23”,
TTS < 6 нс.

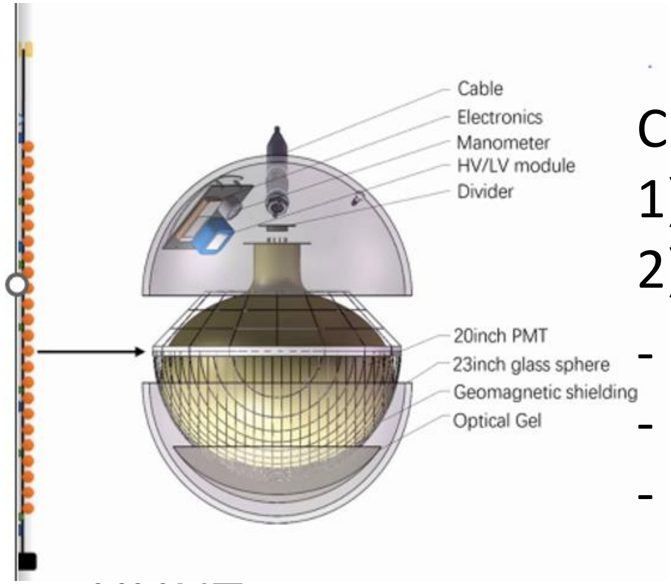


Version OM #2:
One PMT 14” - NEW
Glass sphere 17”
TTS < 3…4 нс.



Version OM #3:
Three PMTs 8” - N6082
Glass sphere 20”- 23
TTS < 2 нс.

Experimental base



Experimental cluster Baikal-GVD

Cluster structure:
1) 2 strings, 72 OM, GVD+ prototype (10” PMT)
2) 2 strings, 24+12 DOM, HUNT prototype (20” PMT)

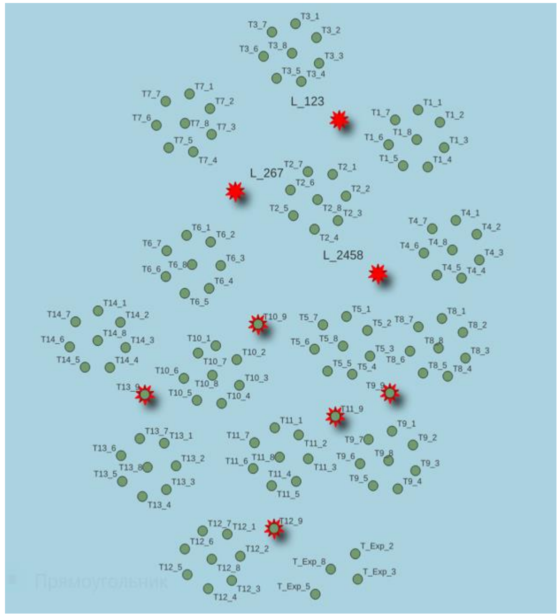
- FO hybrid underwater cable communications.
- NEW control electronics for FO DAQ.
- NEW low consumption OM electronics.

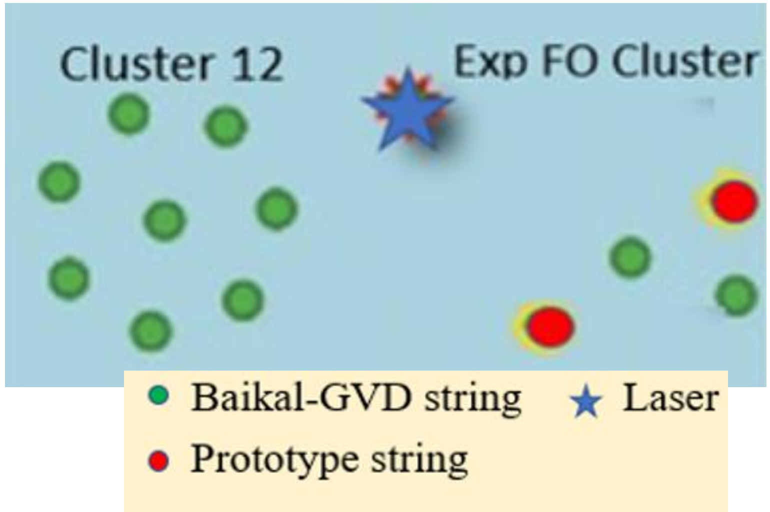
HUNT prototype
24 DOMs

Objectives

- Study 20” PMT operation;
- Investigation of new modes of detector operation (slow trigger).
- Estimation basic DAQ parameters: max count rate, time reference accuracy, width of data transmission channels.
- Long term in-situ tests new electronics and cables.

Baikal-GVD 2025





Production base

Electronics	Cables	Deployment Tools	Shields

JINR Optical Module production line // 12 OM/day

The most significant scientific and technical developments

- New OM and fiber-optic electronics : INR - JINR – MSU
- Positioning system : JINR-LATENA-INFRAD
- Laser calibration system: INR – “Alex Lab ST”
- Disc ice cutting machine D1200 : NSTU – INR
- Cable line immersion monitoring Technology: IGU

The production base can be adapted to solve the problems of expanding the neutrino telescope

Manpower and telescope deployment

Baikal-GVD

Advanced telescope deployment technologies ensure the installation of up to 20 -25 Baikal-GVD strings per season (taking into account repairing work).

GVD+

$\sim$10 km^3; $\sim$ 30 clusters;
$\sim$10 years of telescope deployment

The telescope deployment team needs to be doubled.

Expansion of the team

- Attracting new participants to the Baikal collaboration (2024 – MEPhI, 2025 – LPI RAS, …)
- Cooperation with other projects (HUNT).

Time schedule - preliminary

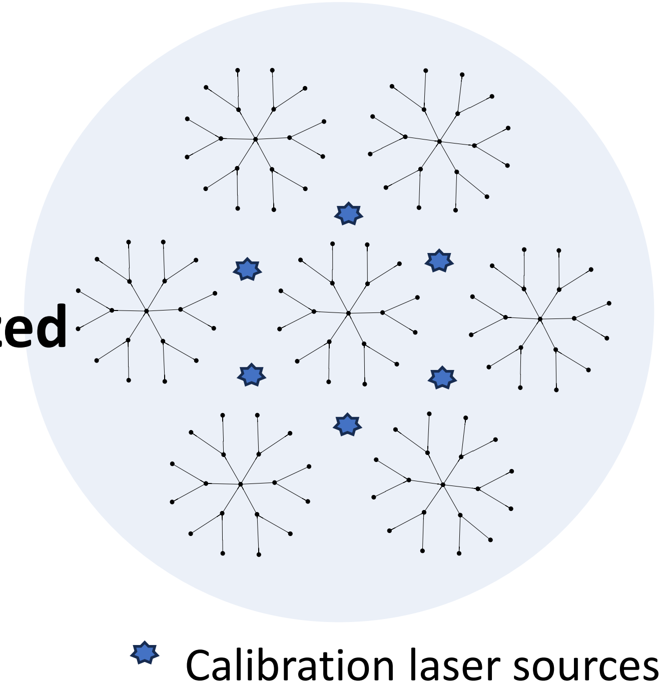
Time	2026-2028	2029-2031	2032-2040
Scope	R&D	1^{st} Cluster Blok	2^{nd}, 3^{rd}, 4^{th} Cluster Blok
Plan	Prototype cluster	2 km3	8 km3

Cluster Block

7 clusters

V ~ 2 km3

To be optimized



R&D – development and long term in-situ tests.

- New optical module.
- FO DAQ.
- New FO cable communications.

Conclusion

1. GVD+ conceptual design is expected in 2026, after the telescope configuration has been simulated and optimized.
2. Completion of the R&D is expected in 2028. The result will be the commissioning of a prototype GVD+ cluster.
3. R&D completion is planned to coincide with the completion of the Baikal-GVD deployment, which will ensure continuity of the production process.
4. As a result of the first stage of GVD+ implementation (2029-2031), it is planned to create a block of clusters 2 km3 scale.

Thank you for attention!