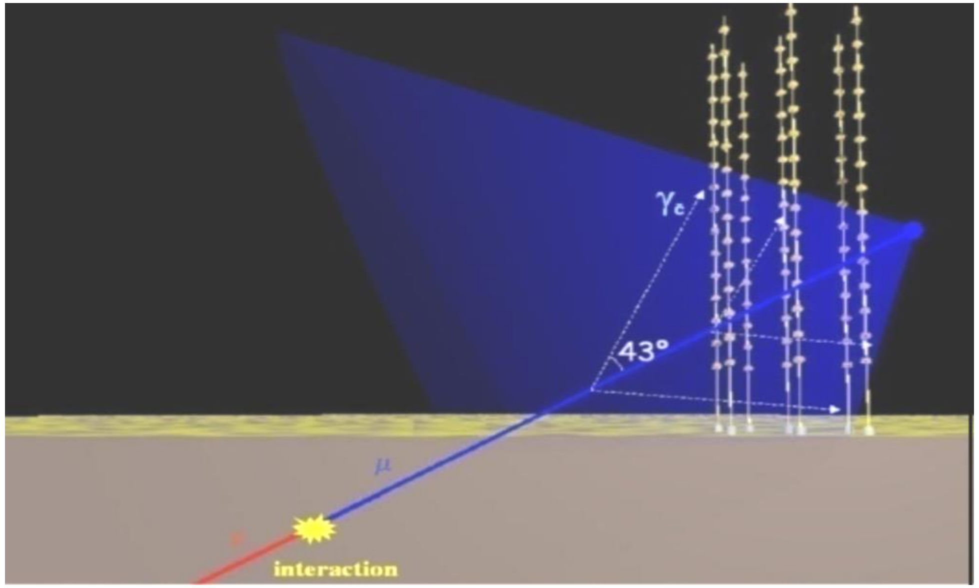
The Baikal-GVD Neutrino Telescope: current status and development prospects

International Symposium on Cosmic Rays and Astrophysics (ISCRA-2023) June 27-29, 2023

Vladimir Aynutdinov for Baikal collaboration



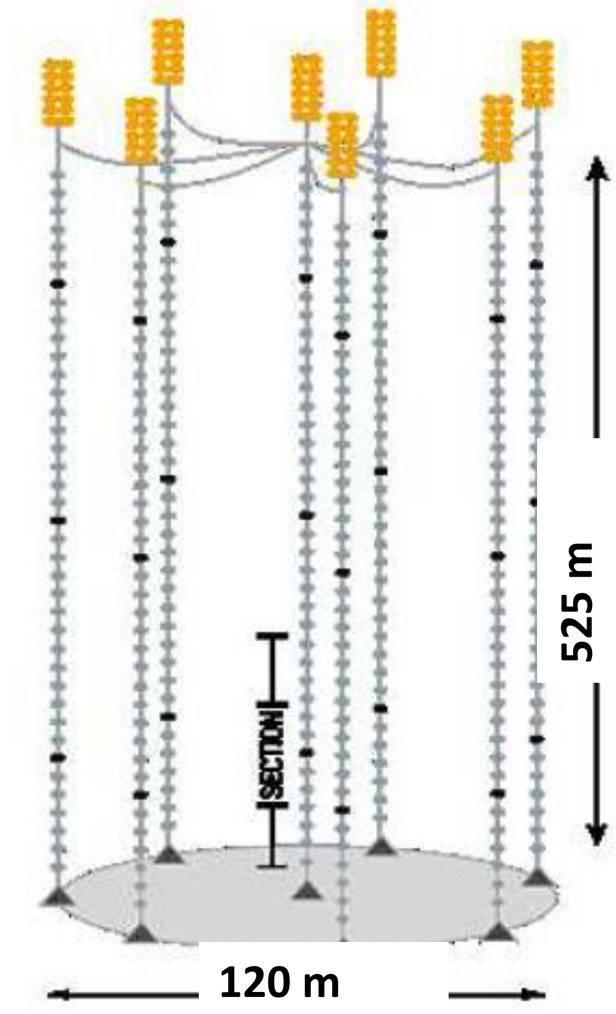
Site properties

- 51°46' N 1046 24' E
- Depth of the lake is 1366 m.
- Distance to shore ~4 km.
- Absence of high luminosity bursts from biology.
- Water properties:
  Abs. length: 22 ± 2 m
  Scatt. length: 60-80 m
- Installing the telescope from the ice significantly simplifies the deployment.

The principle of operation

Registration of Cherenkov radiation generated by neutrino interaction products (muons and cascades) using a 3D array of photodetectors - optical modules.

Baikal-GVD design



GVD cluster

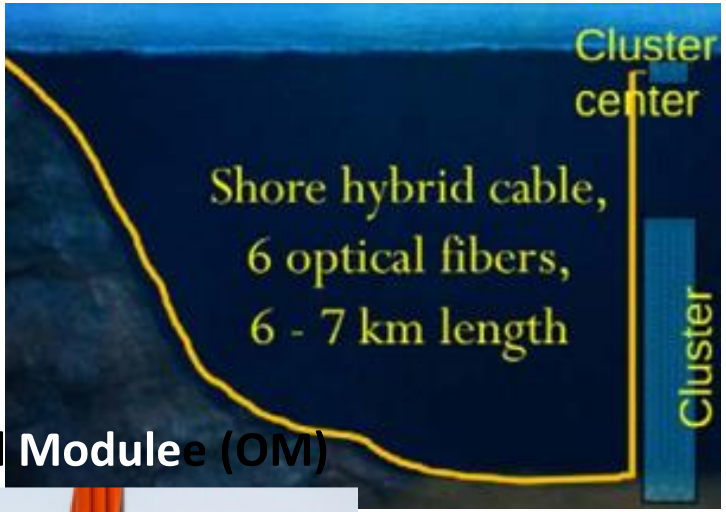
Optical module: one PMT,
Hamamatsu R7081-100,
10 inches, 36% q.e. (in max)
Analog output

String: 3 Sections × 12 OMs,
15 m step between OMs

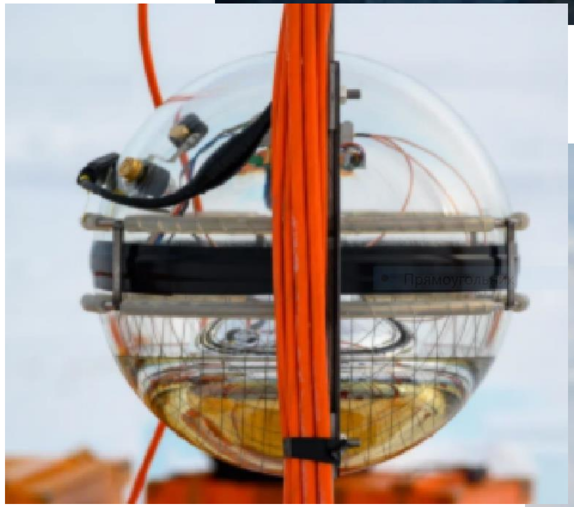
Cluster: 8 strings,
60 m step between strings
Cluster center: 30 m depth.

Connection to shore:
One hybrid fiber-optical cable per cluster,
Cable connects Shore station and Cluster center.

Positioning system: 3 / 4 acoustic modems per string,
Real-time positioning with ~20 cm accuracy



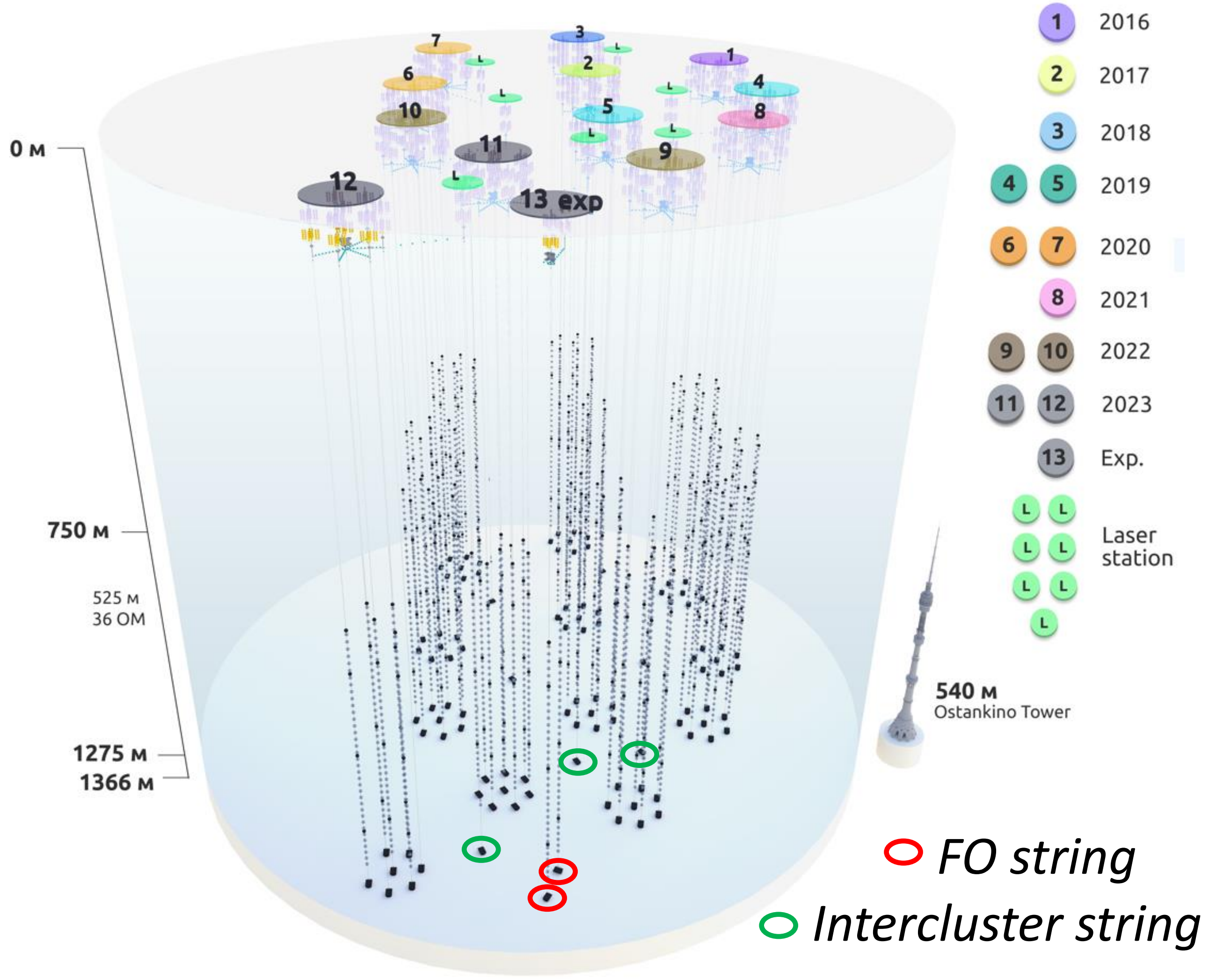
Optical Module (OM)



Acoustic modem

Current status of Baikal-GVD

- Currently, the deployment of the Baikal-GVD neutrino telescope is successfully underway.
  - 12 clusters with 3456 OMs.
  - About **10 astrophysical neutrinos per year**.
- The production and technical base of the Baikal project ensures the deployment of **two clusters annually**.
- GVD has **developed shore infrastructure**: control center, laboratories, workshops, deployment tools, living quarters.
- GVD is **testing ground** for the development the systems for next-generation telescope:
  - 2 strings with fiber-optic DAQ;
  - 3 inter-cluster strings.



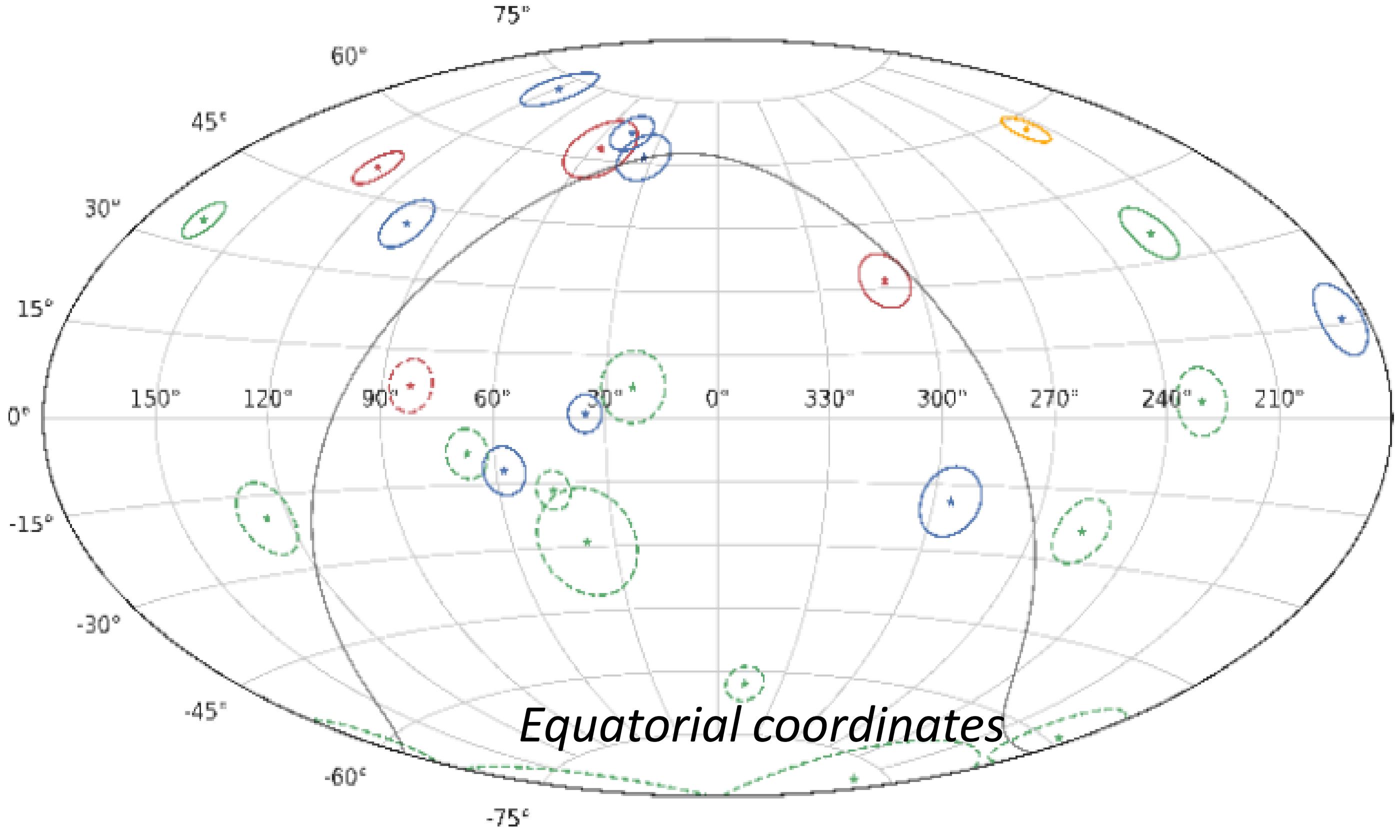
Selected physical results: cascade detection

See report of Zh.-A.M. Dzhilkibaev

Data from 2018-2021, livetime: 13.5 years single-cluster equivalent

16 events: E > 70 TeV (solid ellipses).
Expected background of 8.2 events, 2.22σ
11 up-going cascades with E > 15 TeV
Expected background of 3.2 events, 3.05σ (dashed ellipses). The index of the spectrum of astrophysical neutrinos is 2.6 +/- 0.3.

Experimental estimation: ~1 event per year per cluster (cascade mode) from astrophysical neutrinos:



Arrival directions of high-energy and under-horizon Baikal-GVD neutrino cascades. Phys.Rev. D 107, 042005

Green: < 100 TeV; Blue: 100 TeV … 200 TeV; Red: 200 TeV … 1 PeV; Orange: > 1 PeV.

Prospects for the development of the Baikal project

2025
The project of the Baikal telescope of the next generation
~ 10 km^3

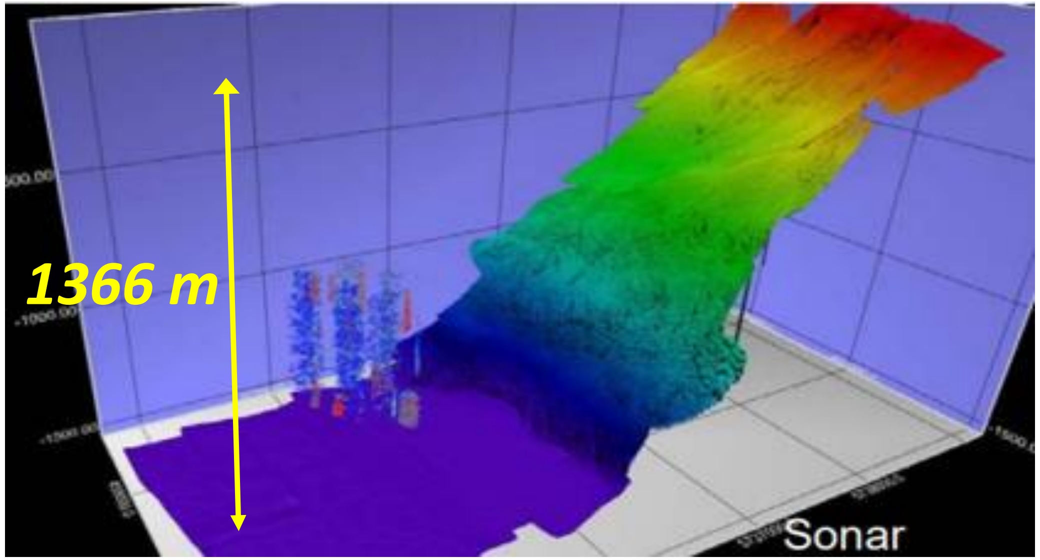
Directed to research of the sources of astrophysical neutrinos.

2027
Increasing the effective volume of the Baikal-GVD telescope:
~ 1 km^3

The largest neutrino telescope in the world at this point in time

Preservation of the production and technical base of the project

Experimental base for next generation telescope design



The next-generation telescope is planned to be placed near Baikal-GVD telescope.

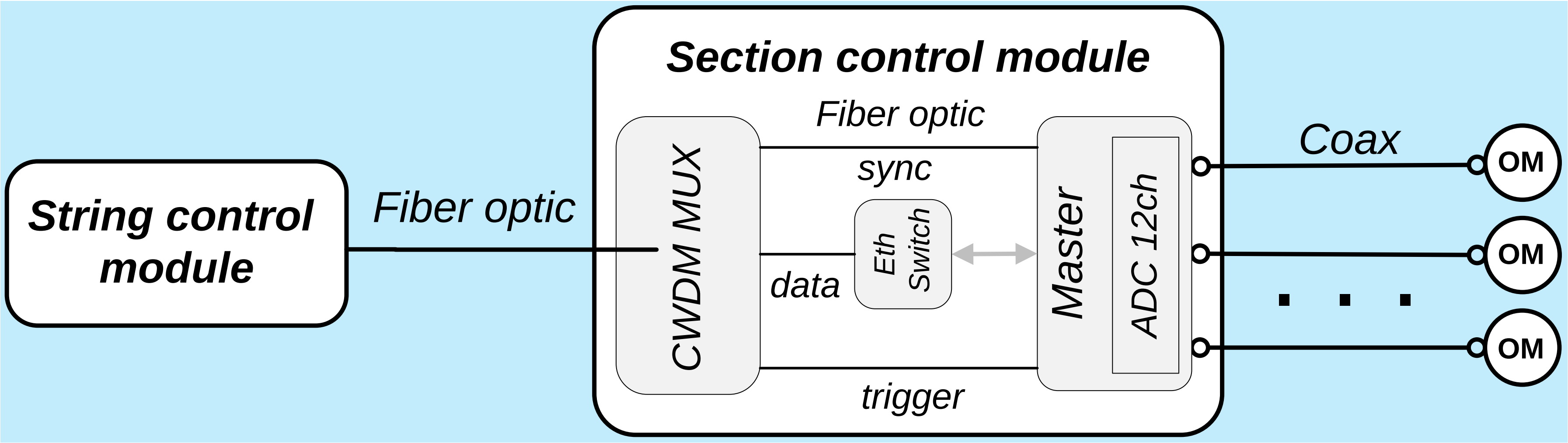
The flat bottom relief allows to place new telescope near the Shore.

Research directions for the development of a new telescope

- Experiments on the implementation of a fiber-optic deep-sea data acquisition system.
- Experimental studies of the characteristics of a detection system with a reduced density of photodetectors.
- Studies of the possibility of increasing the sensitivity of photodetectors.

Fiber-optic DAQ concept

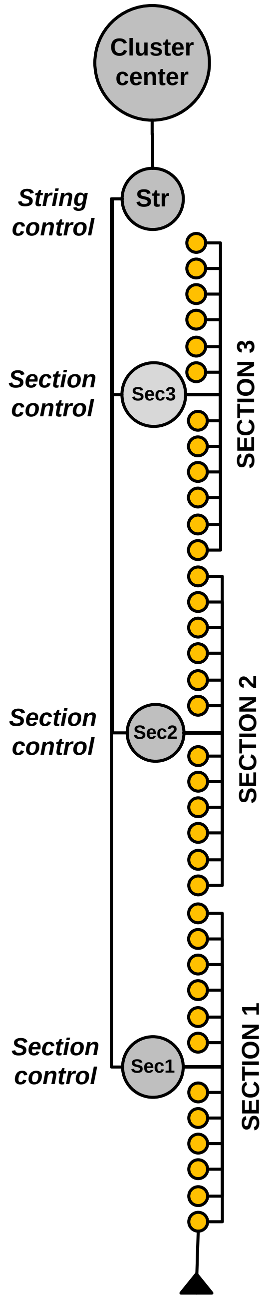
The basic structural units of DAQ: **Section and String**



Main technical features:

- Analog signals from OMs are transmitted via coaxial cables to the control module of the section.
- Data and Trigger are formed by the Master board of the section module and transmitted to the string control module via one optical fiber using CWDM multiplexor together with the Sync.
- Up to 12 OMs can be connected to the section module.
- Up to 8 sections can be connected to the string module.

Fiber optic DAQ: in-situ studies and plans



Experimental string with fiber-optic DAQ

2021 The first FO string: three sections, 36 OMs.
Deep-sea FO cables: “Starlink” (Russia), “DWTEK” (Taiwan).
Negative FO cables operational experience.

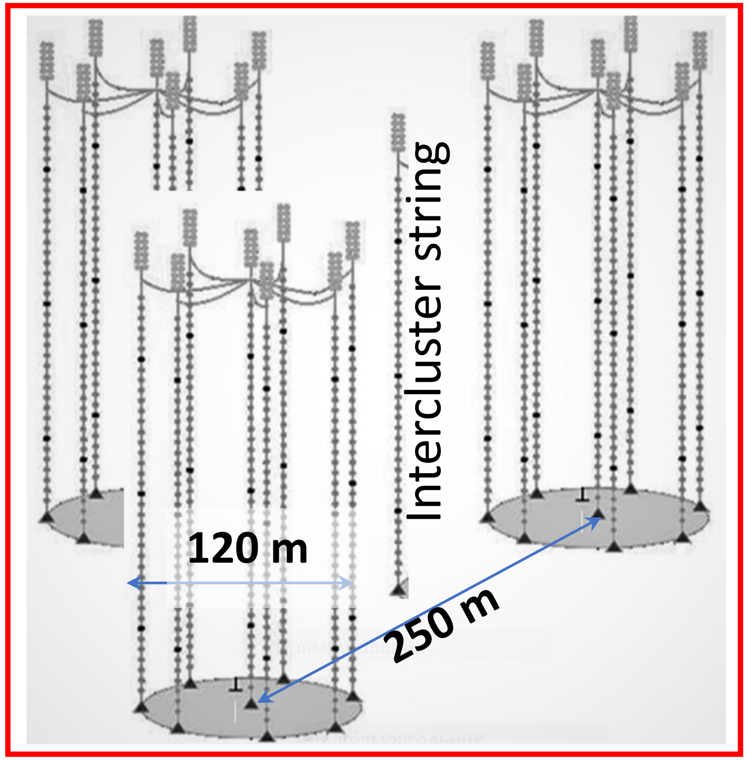
2022 Deployment FO string on the basis “Teledyne” FO cables.
Successful operation 2022 – 2023. But it was the last cable delivery from Europe.

2023 Deployment the second FO string with Chinese Hybrid Optical Cables. Reliable string operation from April 2023 to the present.

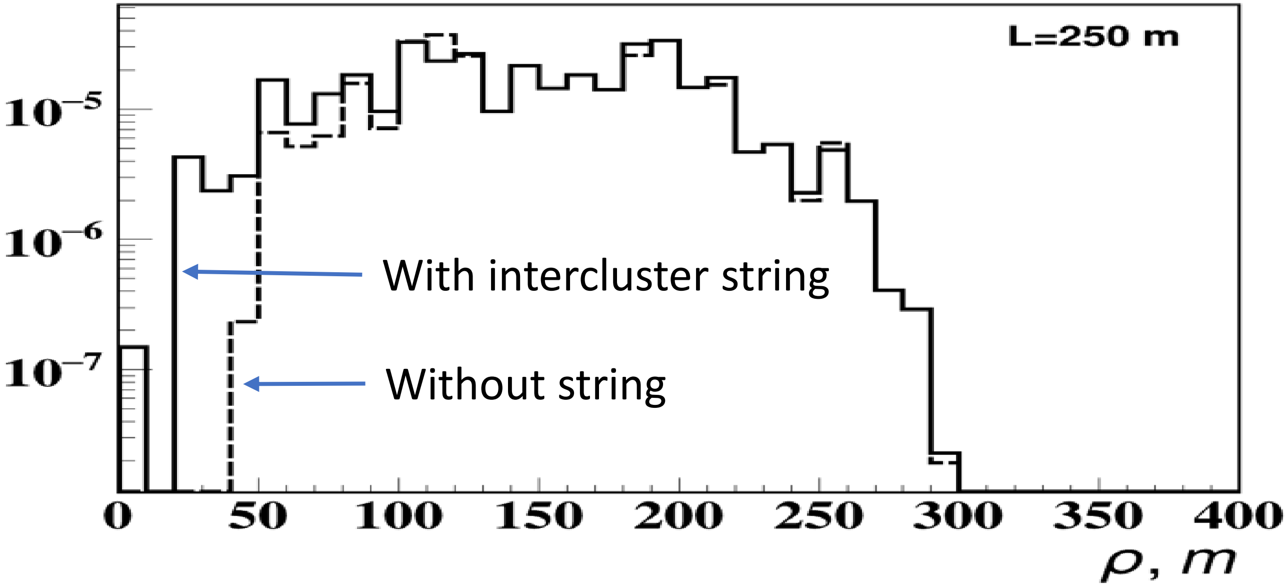
If FO string will be successfully tested during 2023, mass installation of a fiber-optic strings will begin in 2024 and cross-check of the conventional cluster and the FO cluster will be possible by 2025.

Baikal-GVD intercluster strings

2022 The first interclusterl string was installed in the geometric center of clusters #5, #8, #9.

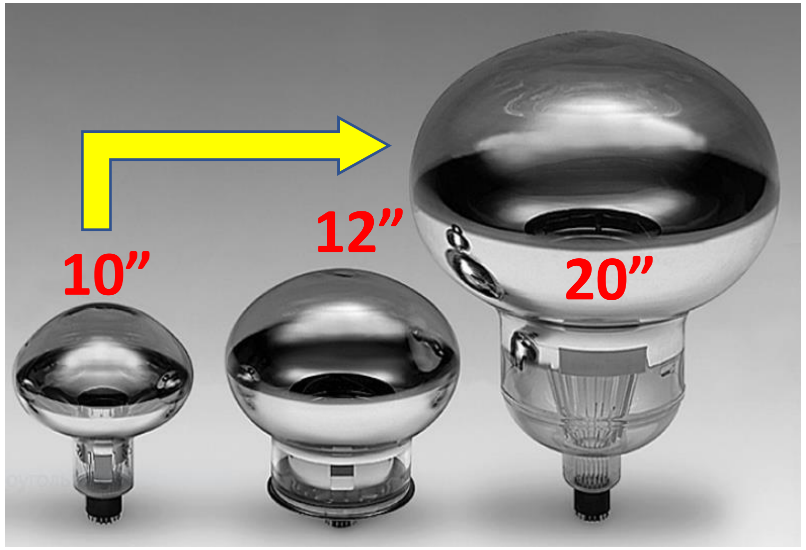


- The possibility to study the detection system with increased distance between the strings: from 80 m up to 200 m.
- Increasing in the number of events in the cascade mode:
  E > 1 TeV: 10% E > 100 TeV: 24%.
- 2023. Two additional intercluster strings were installed.
- It is planned to install intercluster strings between all clusters of Baikal-GVD.



Distribution of events (cascades generated by neutrinos) on distance from intercluster center, E > 1 TeV

Increasing the sensitivity of photodetectors



Increasing the photocathode area

Using multy-PMT OMs

Joint Russian-Chinese project:

Prototype string with 20-inches PMTs in Baikal.

The PMTs, deep-sea housings and prototype electronics will be provided by the Chinese side

2024 – Deployment of a Prototype string in Lake Baikal as part of GVD:

- 12 Digital OMs with 20-inches PMT,
- Fiber optic technology.

Conclusion

- Baikal-GVD is currently the largest neutrino telescope in the Northern Hemisphere and allows studying the diffuse flux of astrophysical neutrinos (~10 events per year).
- The completion of work on the creation of 1 km^3 Baikal-GVD detector is planned in 2027.
- In 2025, it is planned to present a project of a next-generation neutrino telescope aimed at studying the sources of astrophysical neutrinos.
- Currently, experimental studies are being conducted directed to developing a next-generation telescope project.

Thank you !

Back up slides

Production and technical base of the Baikal project

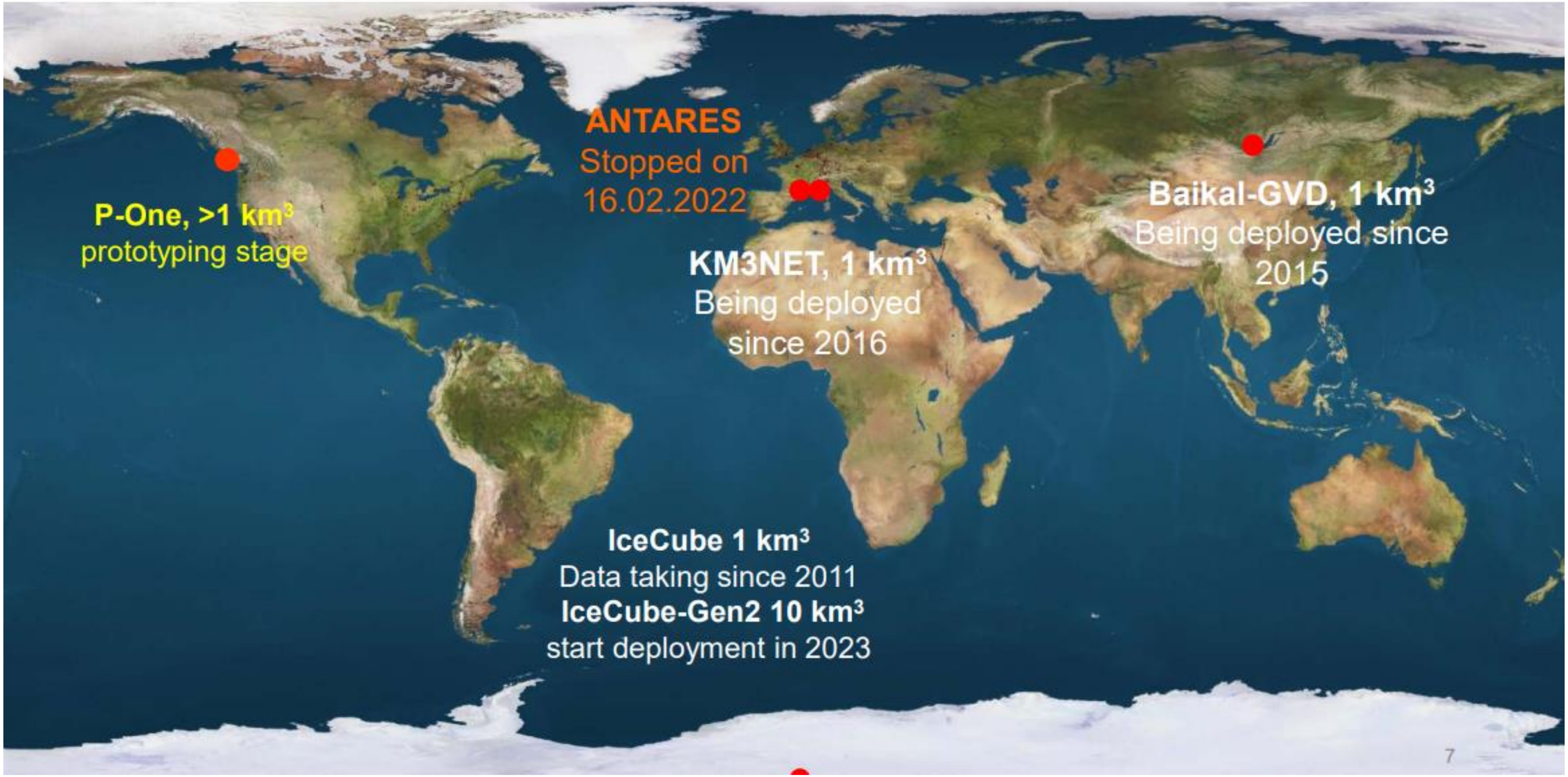
Electronics

Cables

Deployment Tools

PMT shields

Global neutrino network



Baikal-GVD Scientific Advisory Committee online meeting, January 28, 2022

Report and recommendations

The first phase of Baikal-GVD is scheduled to be completed in 2026, with at least 16 clusters and a volume on the cubic kilometer scale. The SAC considers this milestone extremely important. The SAC appreciates the plans toward GVD Phase II which envisages a detector

on the 10 km^3 scale. We note that this is the right time to start serious consideration of such a future detector.

Chair of the Baikal-GVD Scientific Advisory Committee

Valery Rubakov