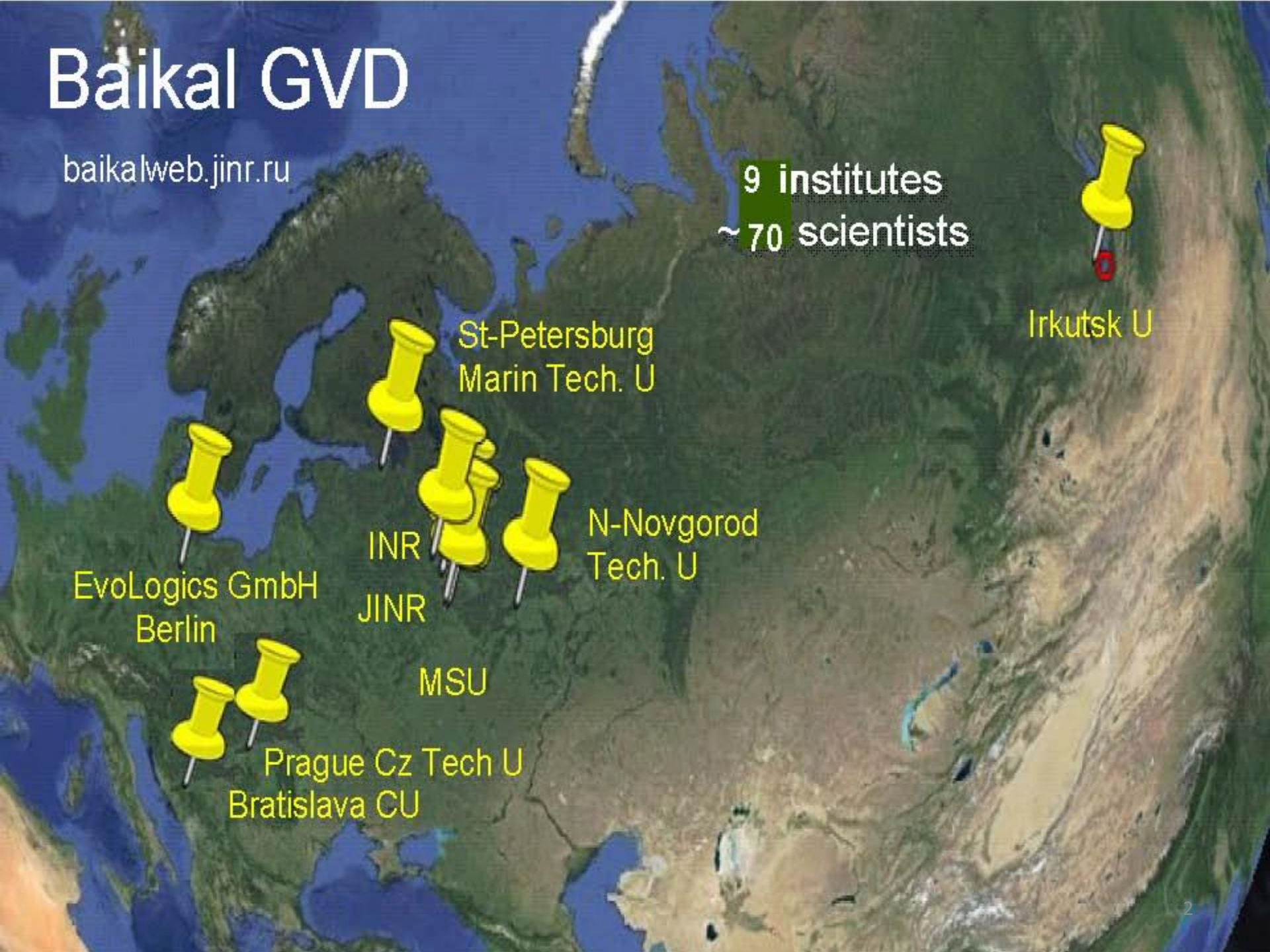
# Baikal-GVD: status and plans

**VLVNT-2018**

*Vladimir Aynutdinov, INR RAS,*
*on behalf of the Baikal collaboration*


Baikal GVD
baikalweb.jinr.ru
9 institutes
~70 scientists
Irkutsk U
St-Petersburg
Marin Tech. U
N-Novgorod
Tech. U
INR
JINR
EvoLogics GmbH
Berlin
MSU
Prague Cz Tech U
Bratislava CU

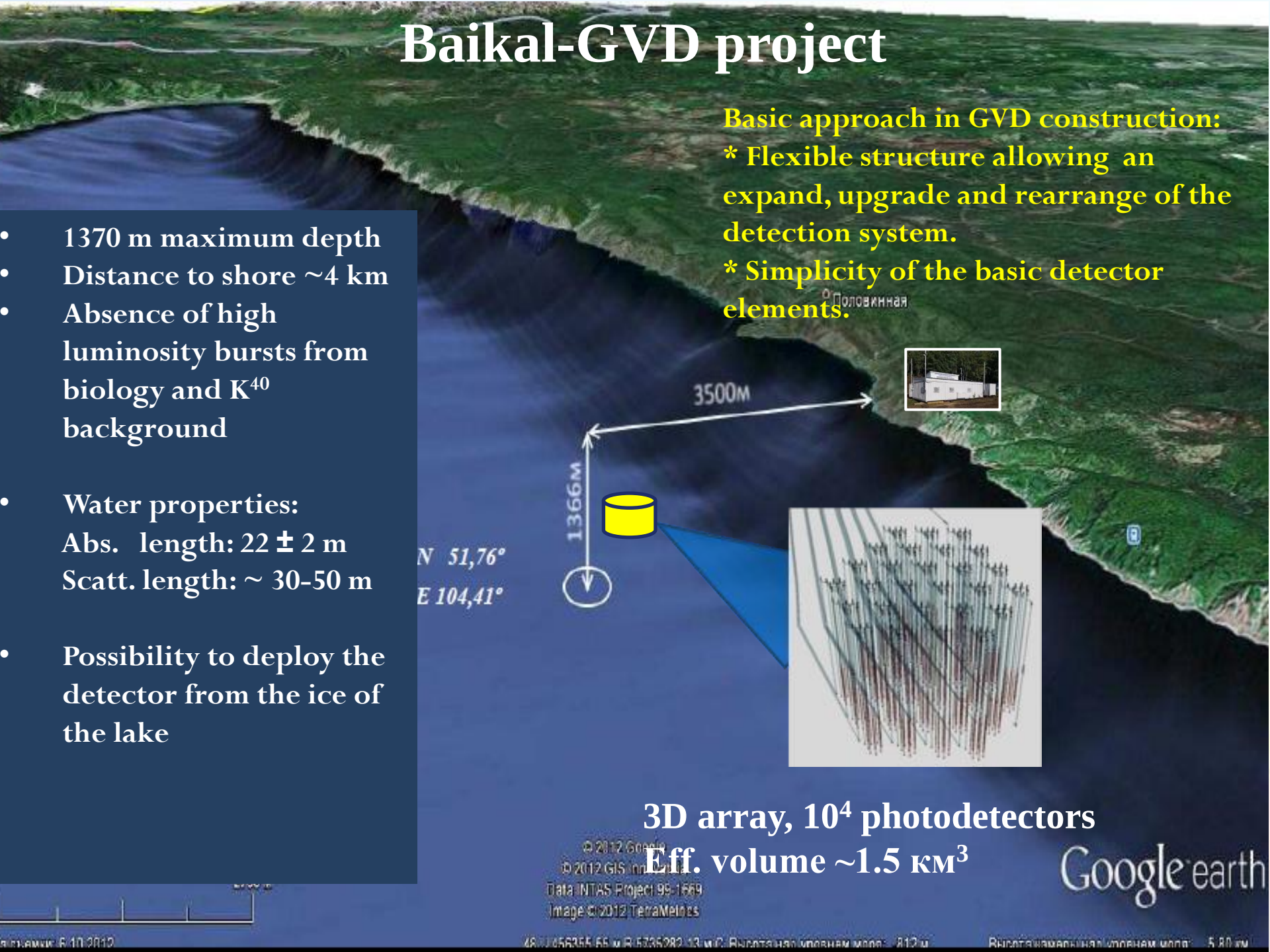
# Baikal-GVD project

- 1370 m maximum depth
- Distance to shore ~4 km
- Absence of high luminosity bursts from biology and $K^{40}$ background

- Water properties:
  Abs. length: 22 ± 2 m
  Scatt. length: ~ 30-50 m

- Possibility to deploy the detector from the ice of the lake

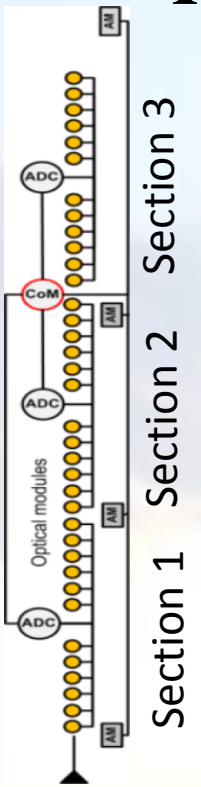
**Basic approach in GVD construction:**
*** Flexible structure allowing an expand, upgrade and rearrange of the detection system.**
*** Simplicity of the basic detector elements.**

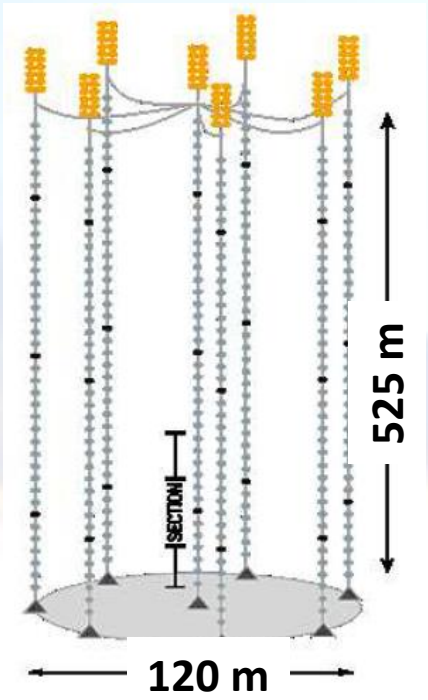



**3D array, $10^4$ photodetectors**
**Eff. volume ~1.5 км$^3$**

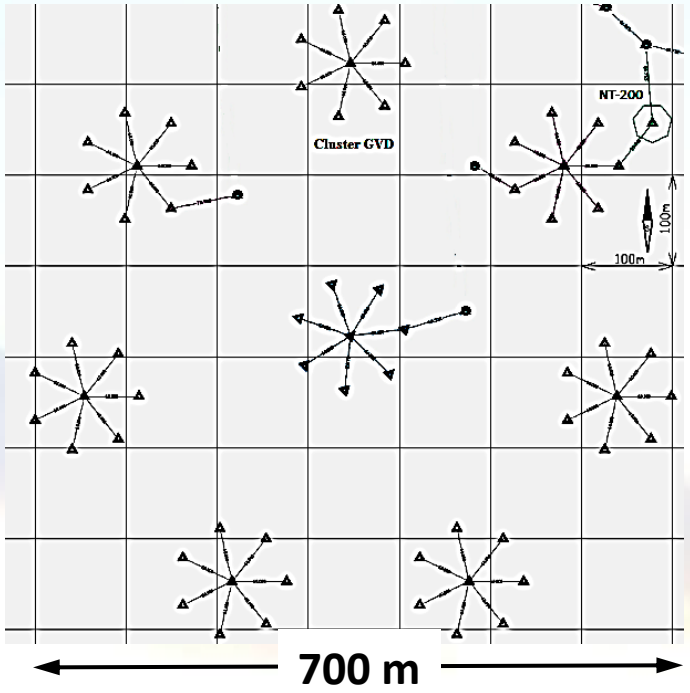
# Baikal-GVD phase 1: GVD-1 (2020-2021)

**Optical module**
PMT: R7081-100
∅=10 inch
QE ≈ 35%




**Cluster:** 8 strings




**GVD-1:** 8 clusters

**String:** 3 Sections×12 OMs&ADC module

| GVD-1 | |
|---|---|
| OMs | 2304 |
| Clusters (8 Strings) | 8 |
| Depths, m | 750 – 1275 |
| Eff. Volume | 0.4 km$^3$ |

| Directional resolution | Energy resolution |
|---|---|
| Cascades: 3.5° – 5.5° | δ(E/Esh) ~ 0.15 |
| Muons: 0.25° - 0.5° | δ(lgE) ~ 0.4 |

# Production of GVD-1 components

**Optical modules**

OM assembling and tests: JINR

Electronics production: SNIIP factory, Moscow

Tests OM electronics: INR RAS

**DAQ modules**

Electronics production: MSU

Assembling and tests: INR RAS

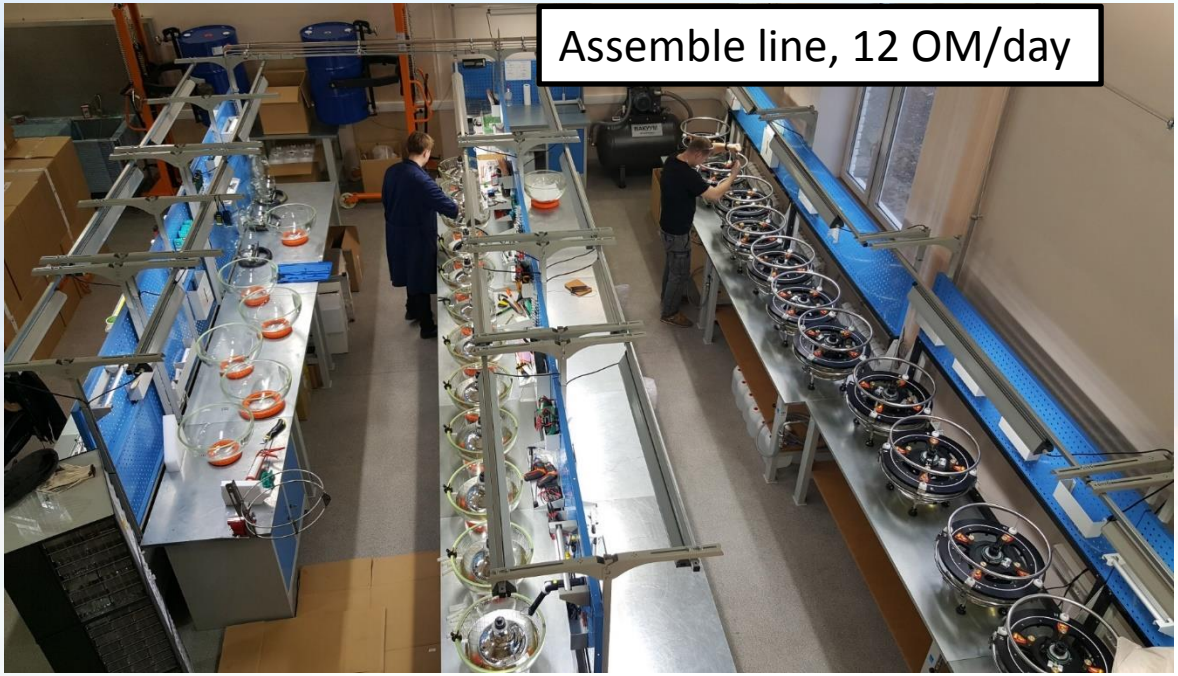
**Cables**

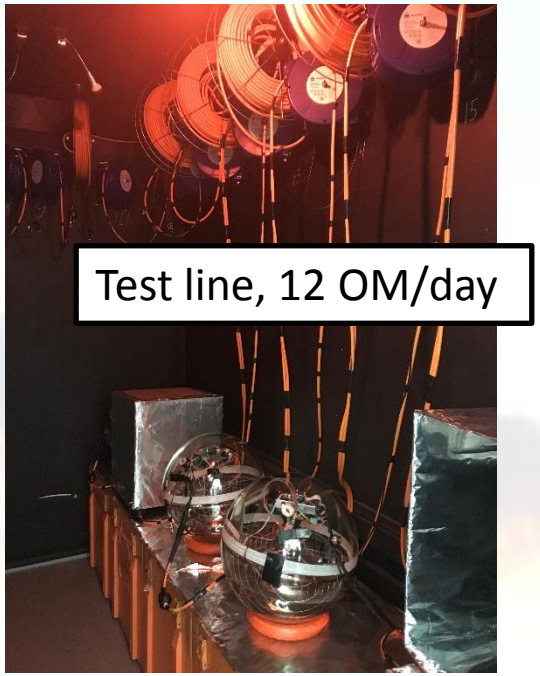
Production: PskovGeocabel factory

Assembling and tests: Irkutsk group.

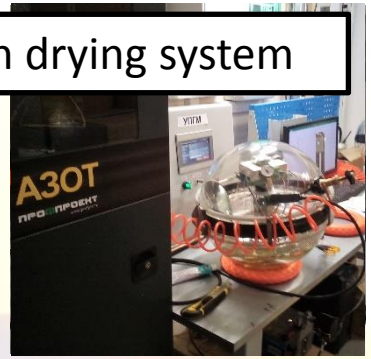
# JINR FACILITIES FOR THE OPTICAL MODULES PRODUCTION

**See talk A. Doroshenko**




**Now we have 450 OMs ready to use: ~1.5 clusters**

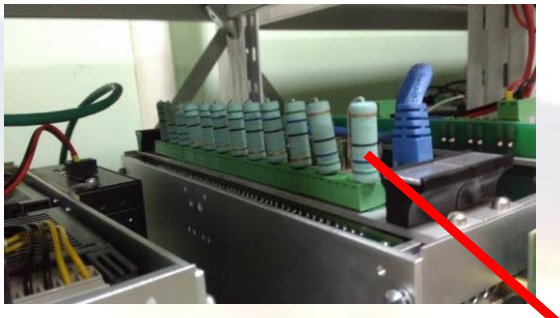


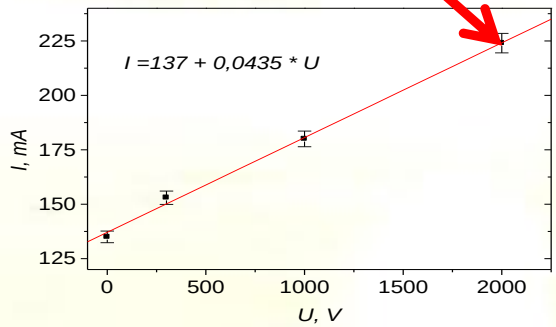

*Equipment allows to assemble and test up to 12 OMs per day*

# INR TEST FACILITIES FOR THE DAQ ELECTRONICS

Facility is designed for long-term tests of all cluster components with full power load.

String electronics:
*3 Section modules and String module (36 ADC channels).*



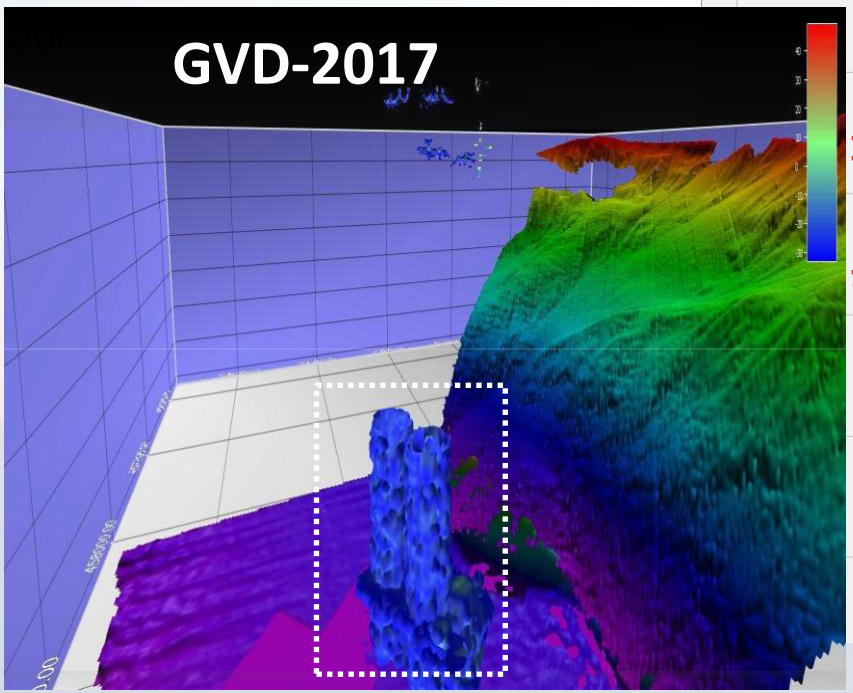


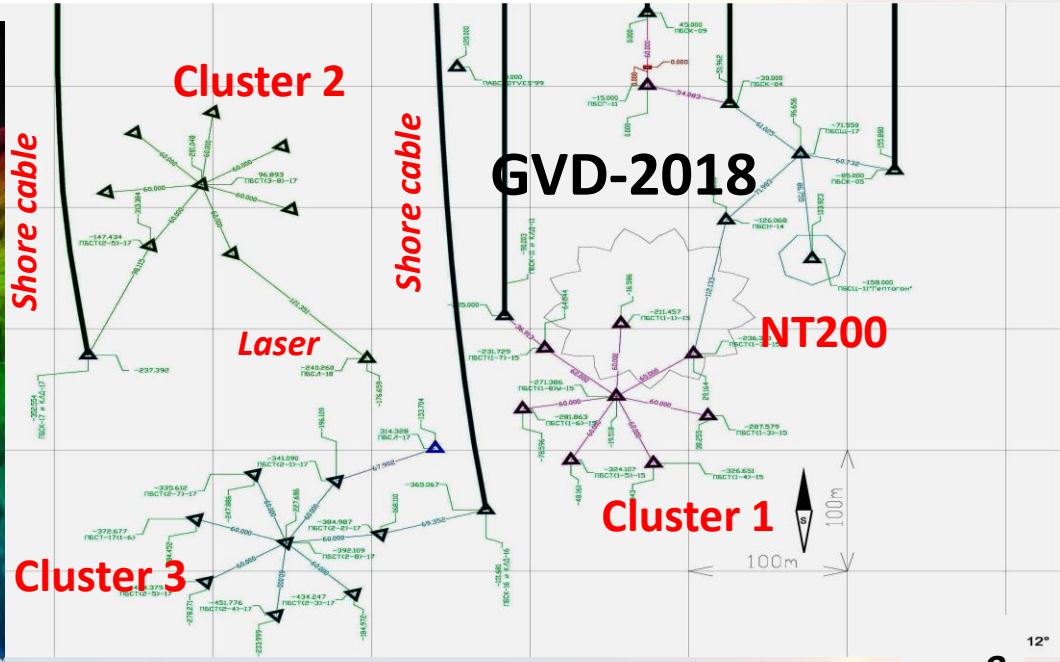

6 strings (216 ADC channels) is under testing now

- Signals on the ADC are simulated by generators with an adjustable frequency.
- Software for data acquisition is the same as for real telescope.

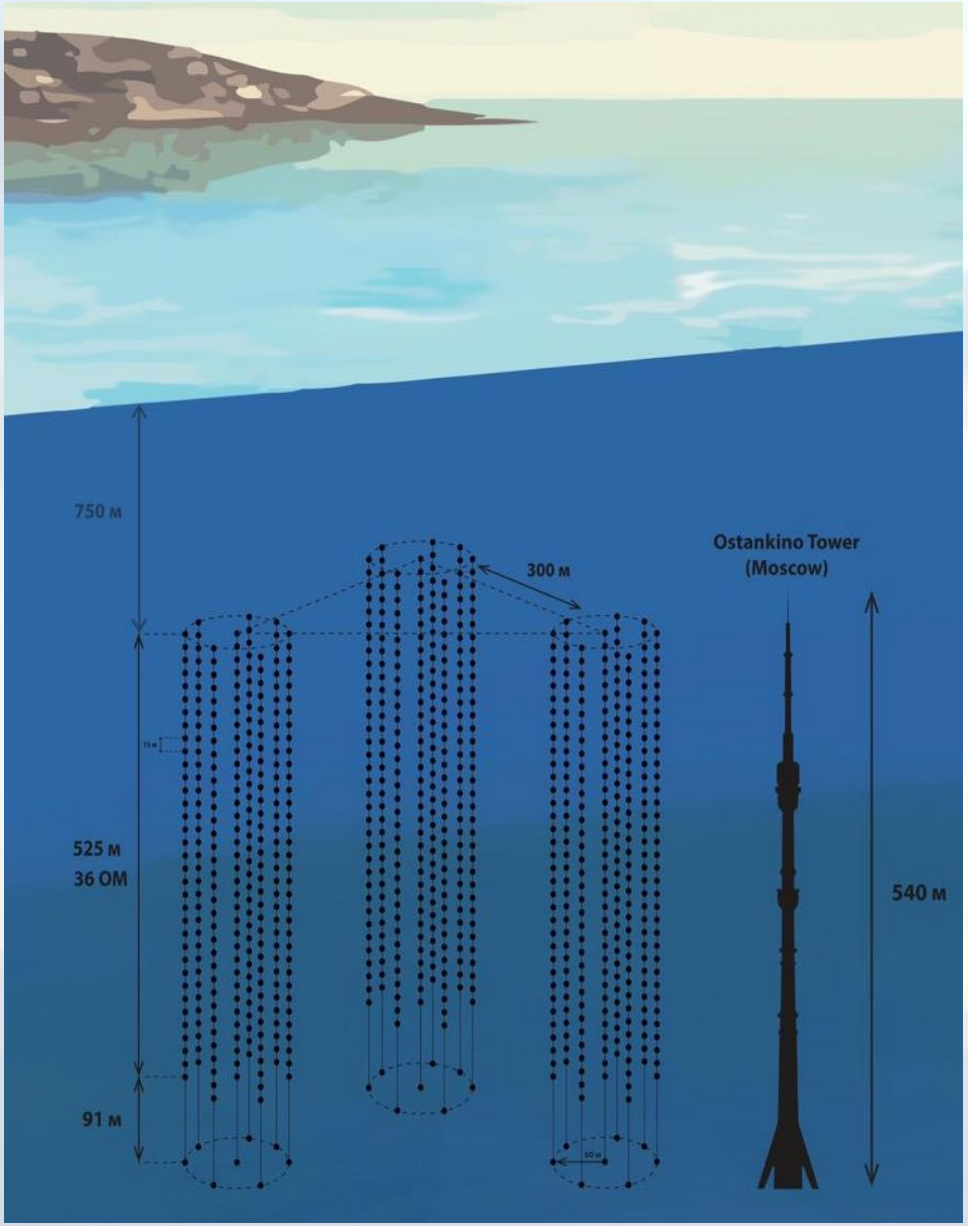
# Stages of deployment of the GVD-1

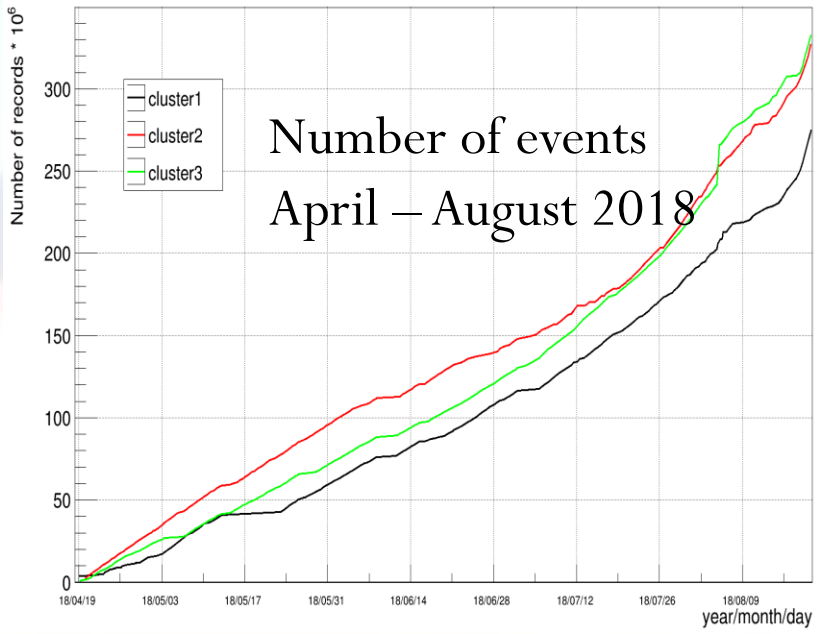
| Configuration | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| The number of OMs | 192 | 288 | 576 | 864 |
| Geometric sizes, m | ∅80×345 | ∅120×525 | 2×∅120×525 | 3×∅120×525 |
| Eff. Vol | 0.03 km$^3$ | 0.05 km$^3$ | 0.1 km$^3$ | 0.15 km$^3$ |



# Status-2018 of Baikal-GVD



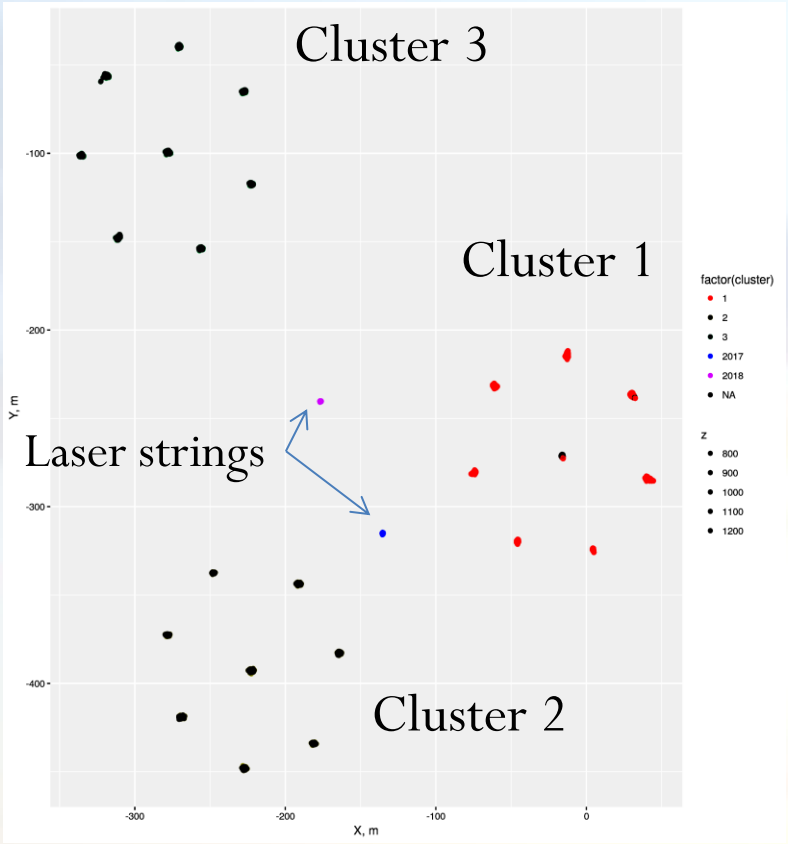




**Data transmission**

- 40 Gb per cluster per day to shore
- 5 Mb/s 40 km radio channel to Baikalsk

# Performance of acoustic positioning system

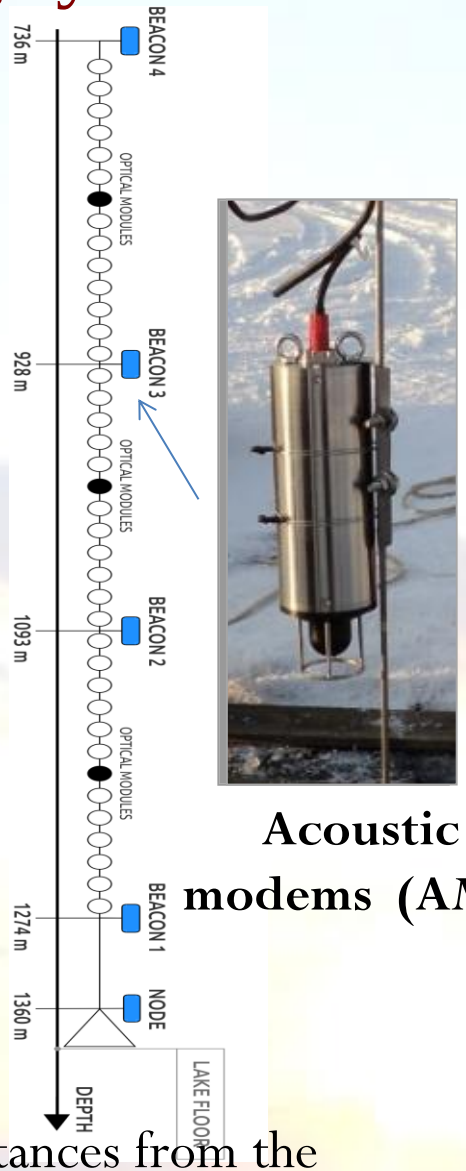
**See talk A Avrorin**




*Measured coordinates of AMs, April-September, X-Y plan*

4 AMs on each string.
1 AM (node) is fixed to the anchor.

OM coordinates are linearly interpolated from AM positions.





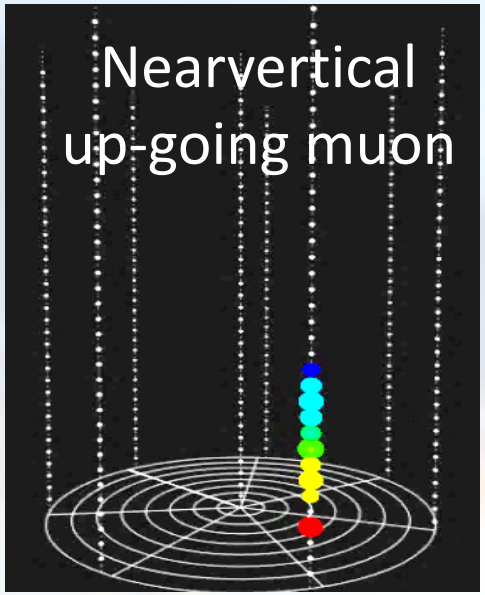

**Acoustic modems (AMs)**

The OM positioning accuracy is 5-20 cm depending on the distances from the OM to the AMs along the string and the deviation of the string from the vertical position.

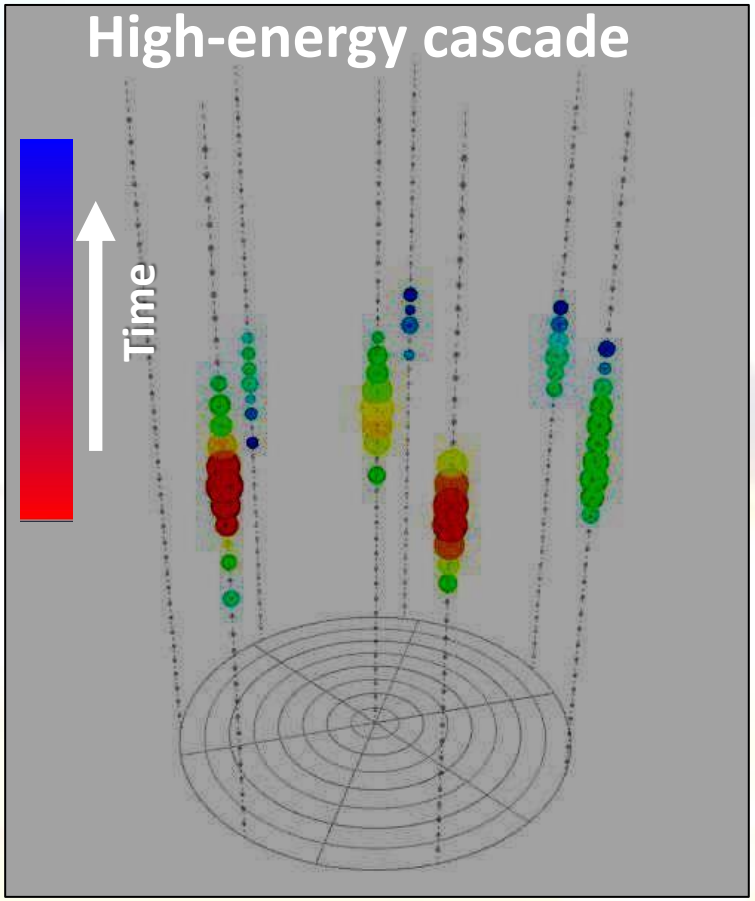
# Detector response

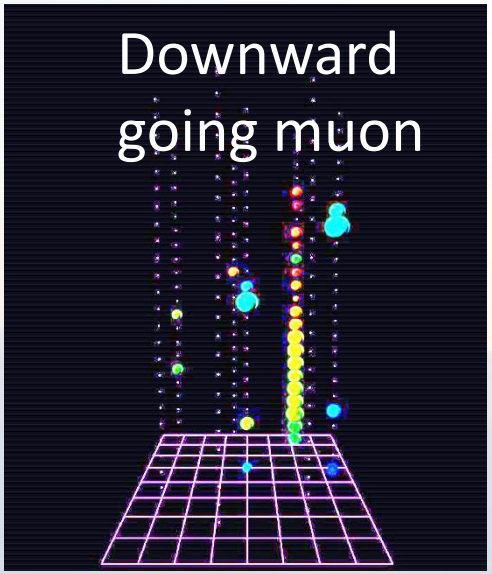
Neutrino signals

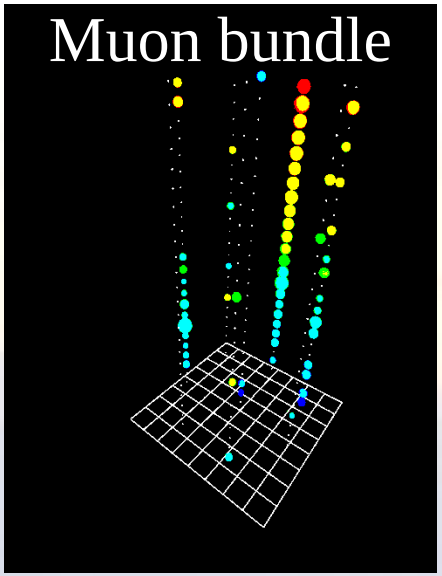
Background







# Search for cascades induced by astrophysical neutrinos

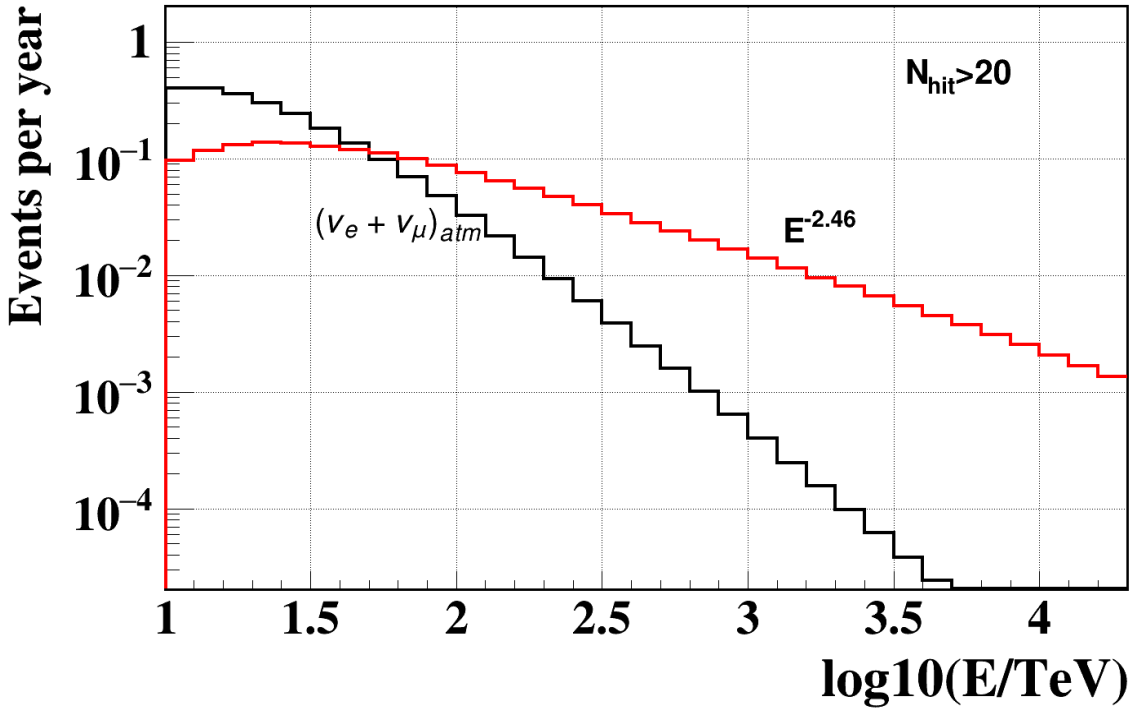
**See talk Zh-A. Dzhilkibaev**

Directional resolution of cascades in water: 3°- 5°

**Cascade selection:**

- Causality cuts (noise rejection);
- Reconstruction of cascade position direction and energy and cuts on quality parameters;
- $N_{hit} > 20$

Expected number of events in GVD Cluster from astrophysical neutrinos for 1 yr.



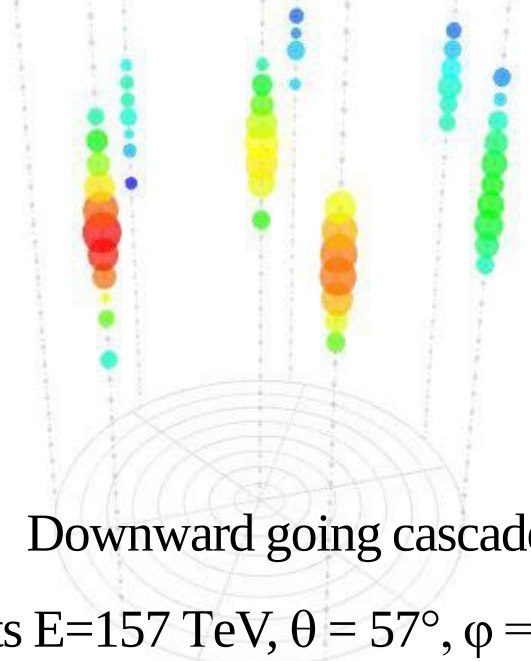

About 0.6 events/year are expected for 1 GVD cluster

# Cascade analysis – 2016

## The first GVD cluster

***PRELIMINARY***

Life time - 182 days (2016)
$6.9 \times 10^8$ accumulated events

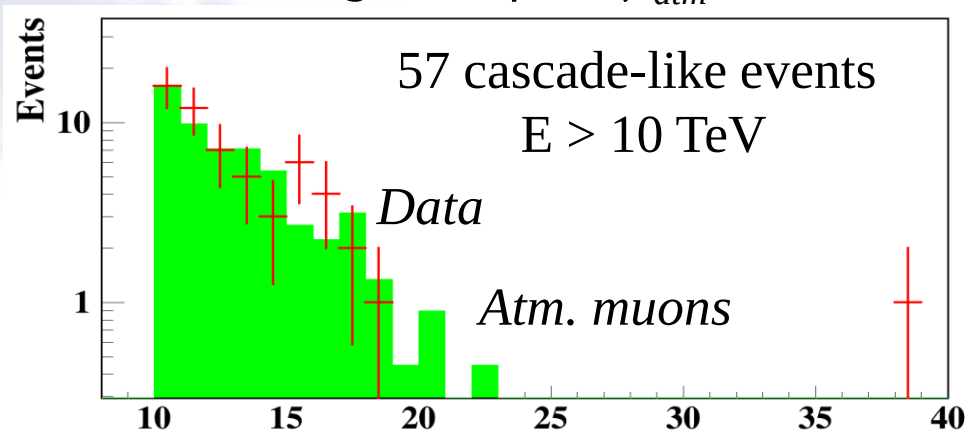


Downward going cascade

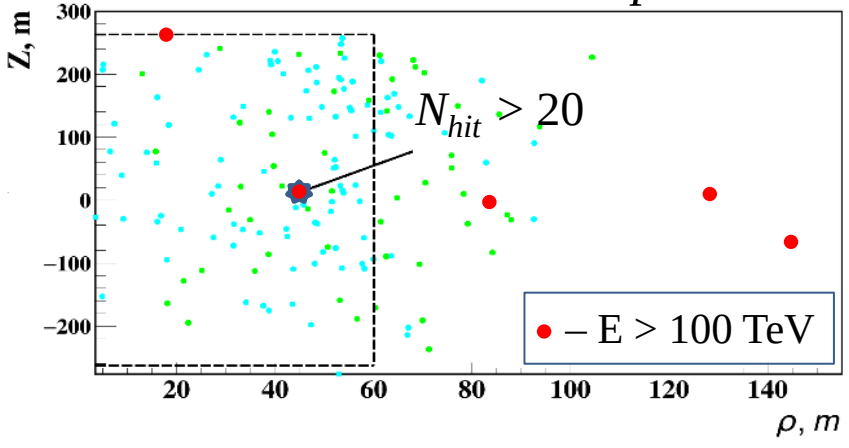
53 hits E=157 TeV, θ = 57°, φ = 249°

**RA=173.4° Dec=13.9 °**
**Equatorial coordinates**

*Distribution of events on multiplicity of the triggered channels ($N_{hit}$) in comparison with background from $\mu_{atm}$*

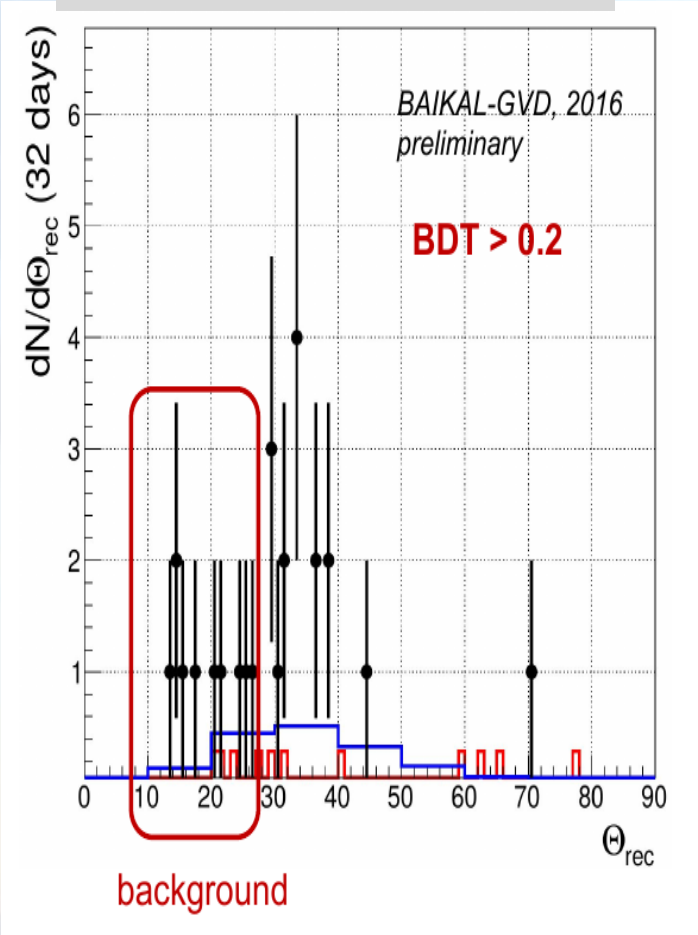



*Reconstructed cascades positions*



# Preliminary muon neutrino flux results

**See talk G. Safronov**



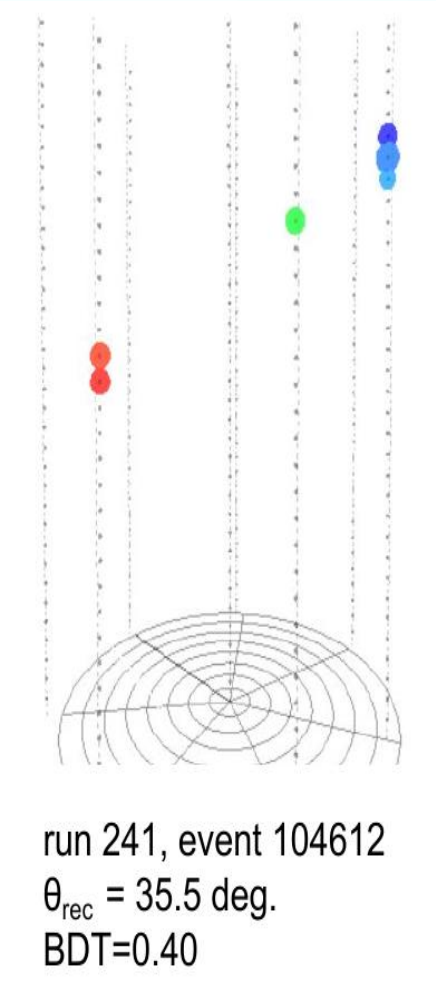

Muon track reconstruction software is implemented

BDT discriminant to reject atmospheric muon background

Three datasets (15, 32, 50 live days) with different data quality and BDT selections:

- Flux results agree with each other within the statistical error
- Conservative flux estimate:

**1 neutrino per ~3 days**



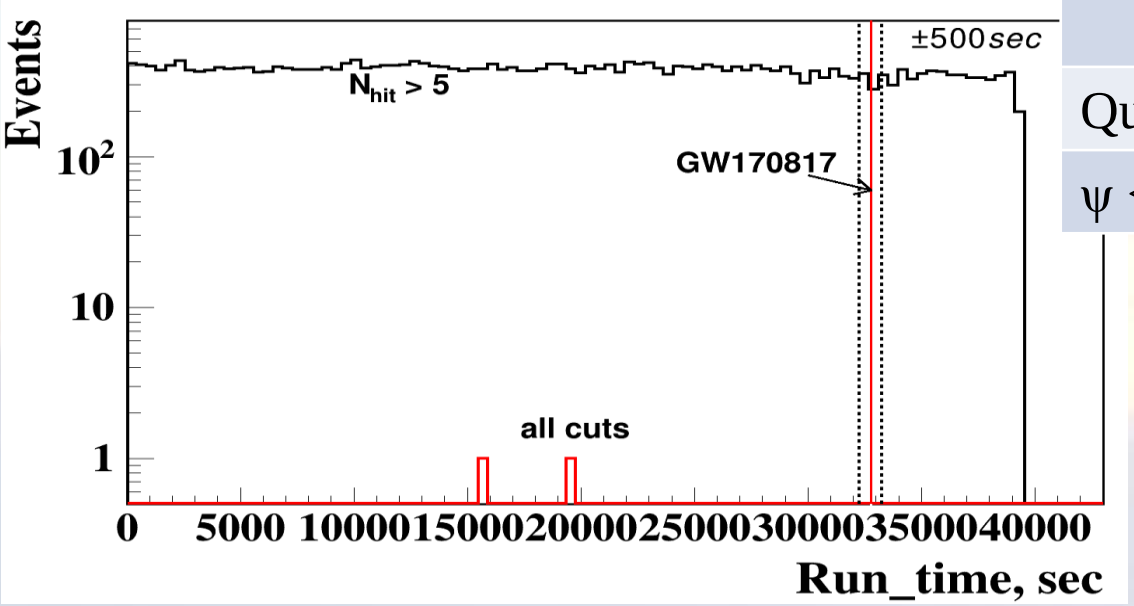

**This work in progress now**
**Procedures to certify good data are being developed**

# Search for neutrinos in coincidence with GW

GW: 17.08.2017, (Advanced LIGO & Advanced VIRGO)
GRB170817A - 1.7 s delay (Fermi-GBM and INTEGRAL)

Cascade mode: search for events in two time-windows
GW ± 500 sec (prompt emission): zenith angle $\theta = 93°$
GW +14 days (delayed emission); $74° < \theta < 150°$

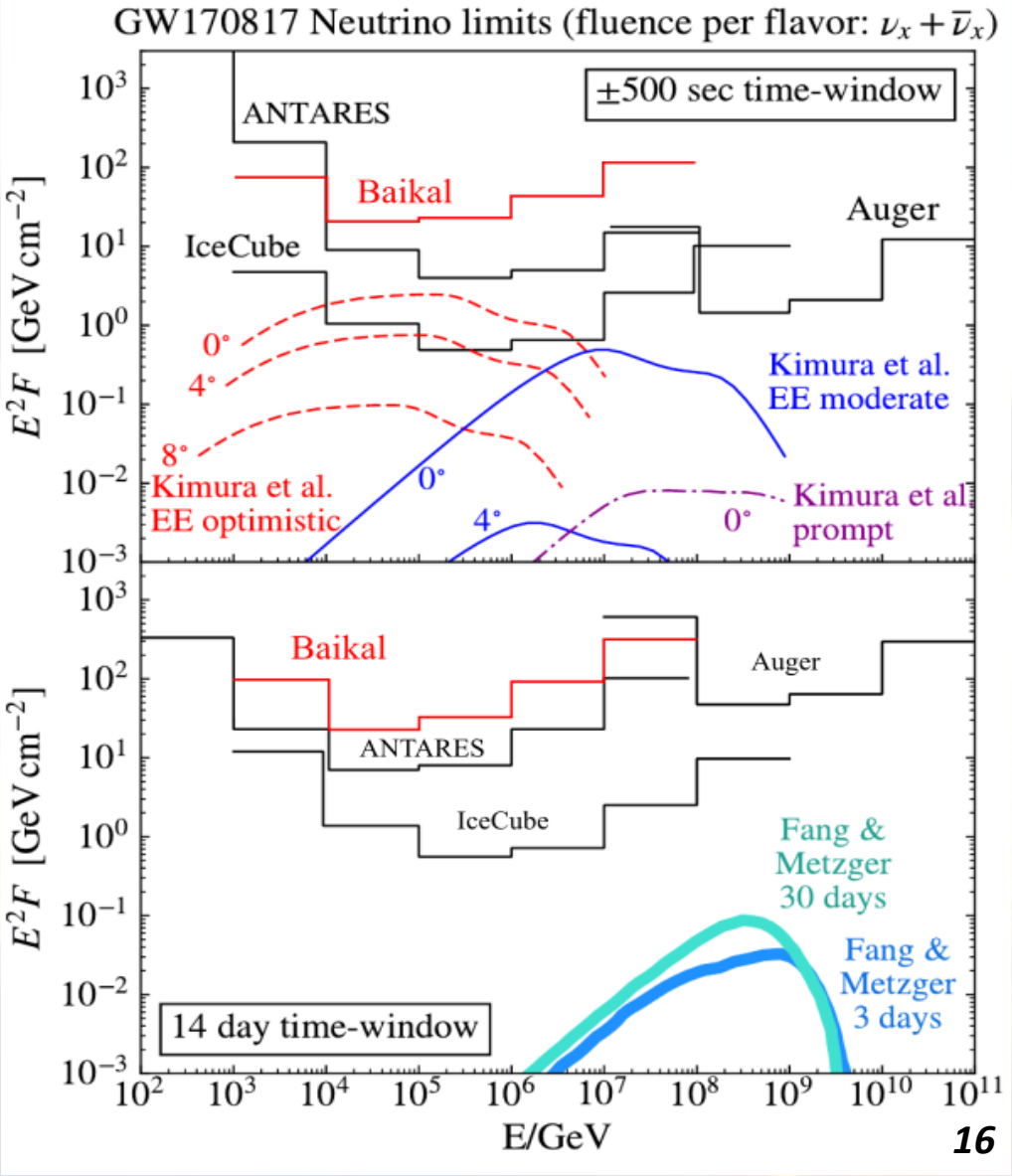
| Cuts | ± 500 s | 14 days |
|---|---|---|
| $N_{hit}$ | > 5 OM<br>**731** | > 7 OM<br>**384116** |
| Quality cuts | **2** | **372** |
| $\psi < 20°$ | **0** | **0** |




No events in the direction to the source wear found

# Upper limits on fluence of neutrinos associated with GW

Assuming $E^{-2}$ spectral behavior and equal fluence in all flavors upper limits at 90% c.l. have been derived on the neutrino fluence.



# GVD plans

## Timeline GVD 1

| Year | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|
| Nb. of clusters | *1* | *2* | *3* | *5* | *7* | *9* |
| Nb. of OMs | *288* | *576* | *864* | *1440* | *2016* | *2592* |

**Main tasks 2019**

- Two clusters deployment
- Reliability increasing.

- Additional facilities for long-term tests of electronics are foreseen.
- Created a conditions for the laying of two shore cables during the season.
- The increasing of manpower during the expedition to Baikal is foreseen.

Completion of equipment preparation for two clusters is planned for December 2018.

# Summary

- Three GVD clusters (864 OMs) is under operation now.
- Experimental data obtained in period 2015 - 2017 were used to search for neutrino events of astrophysical nature.
- Two clusters are expected to be deployed next year.
- Completion of the GVD-1 is expected in 2020-2021.

# Thank you for your attention