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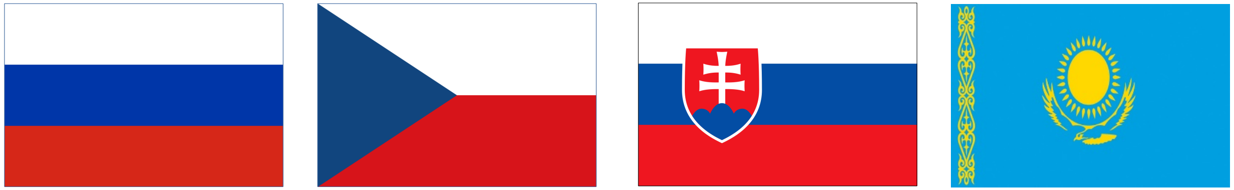
Recent results from Baikal-GVD

Dmitry Zaborov (INR RAS)
for the Baikal-GVD Collaboration

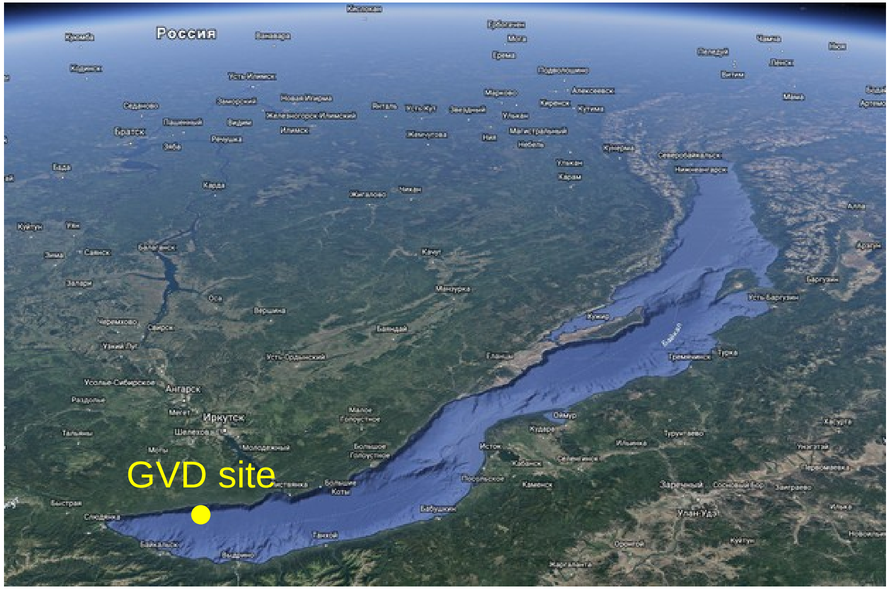
Baikal-GVD collaboration (as of Aug 2025)

11 research institutes from 4 countries, ~70 collaboration members



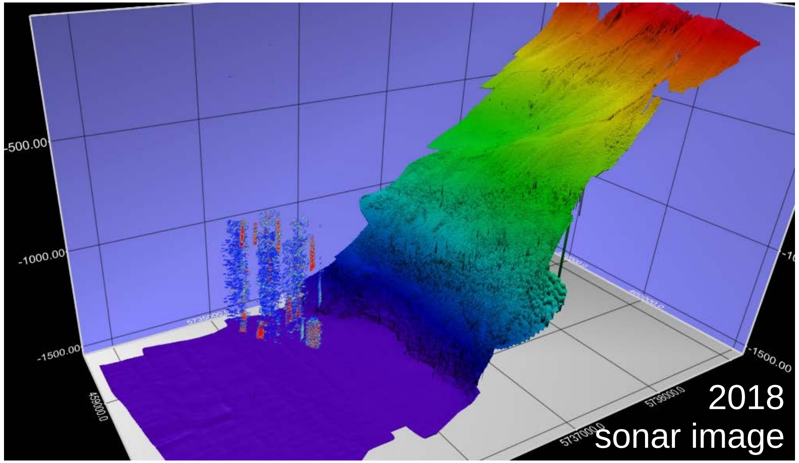
- Institute for Nuclear Research RAS (Moscow)
- Joint Institute for Nuclear Research (Dubna)
- Irkutsk State University (Irkutsk)
- Skobeltsyn Institute for Nuclear Physics MSU (Moscow)
- Nizhny Novgorod State Technical University (Nizhny Novgorod)
- Saint-Petersburg State Marine Technical University (Saint-Petersburg)
- National Research Nuclear University MEPHI, Moscow, Russia
- P.N. Lebedev Physical Institute (Moscow)
- Institute of Experimental and Applied Physics, Czech Technical University (Prague, Czech Republic)
- Comenius University (Bratislava, Slovakia)
- Institute of Nuclear Physics ME RK (Almaty, the Republic of Kazakhstan)

Baikal-GVD site



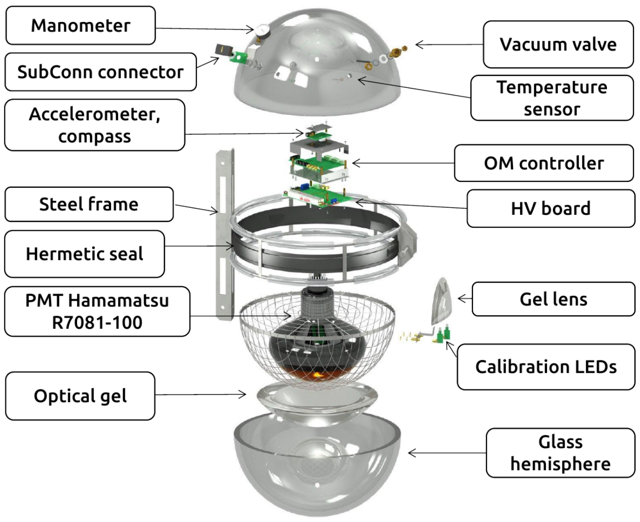
- 51° 46’ N 104° 24’ E
- Southern basin of Lake Baikal
- ~ 4 km away from shore
- Flat area at depths ~ 1360 m
- Stable ice cover for 6–8 weeks in February – April: detector deployment & maintenance

- High water transparency
  - Absorption length: 22 m
  - Scattering length: 30 – 50 m ($L_{eff} \approx 480$ m)
- Moderately low optical background: 15–40 kHz (PMT R7081-100 ∅10”)

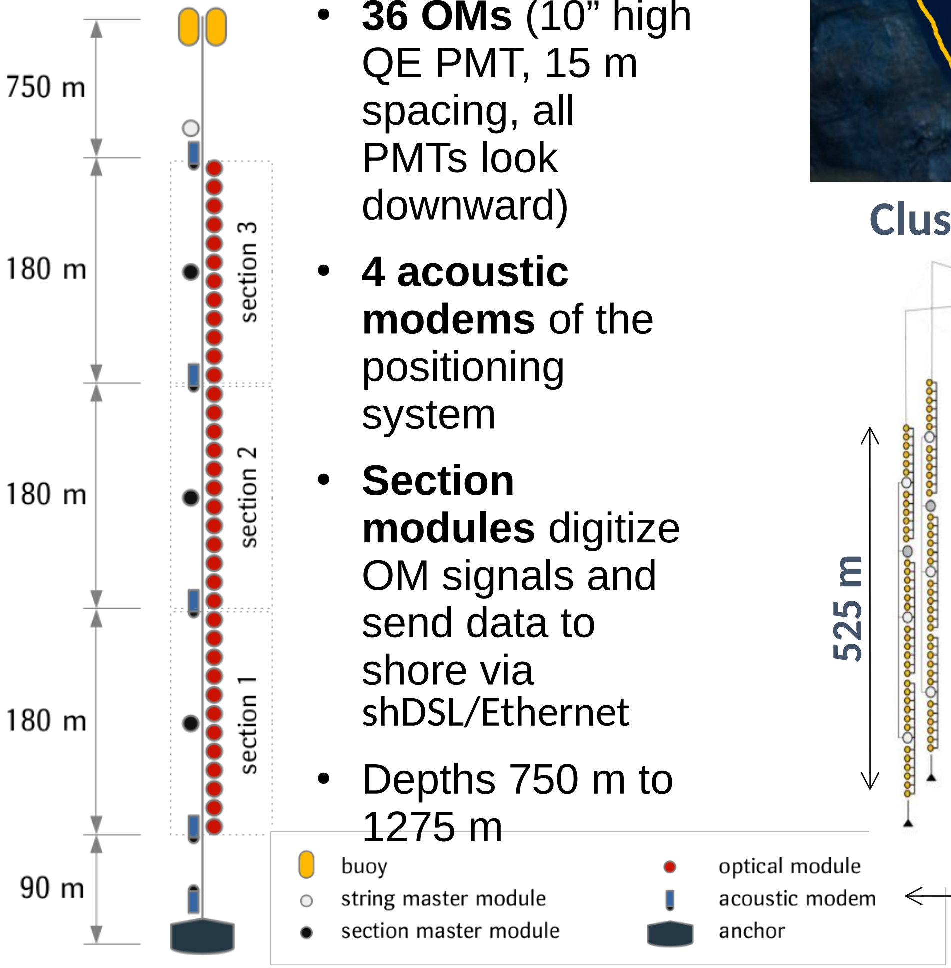


Baikal-GVD technology

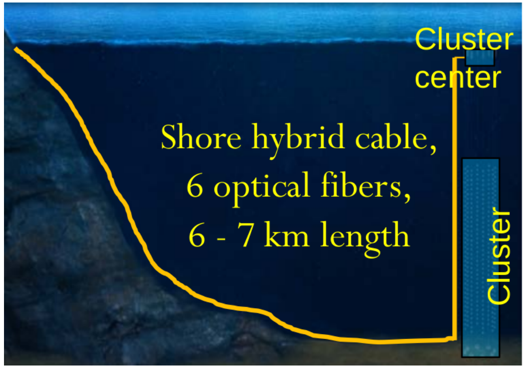
Optical module



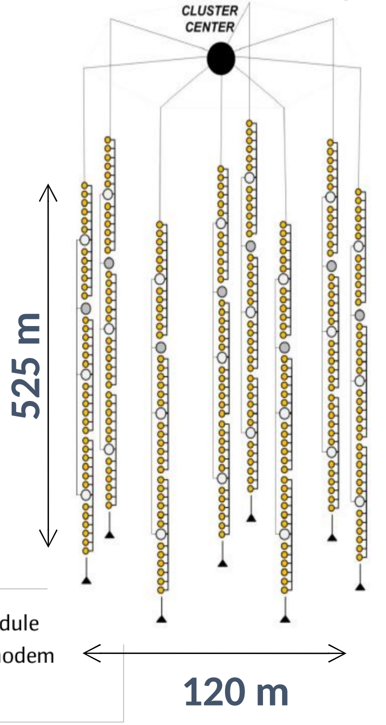
string



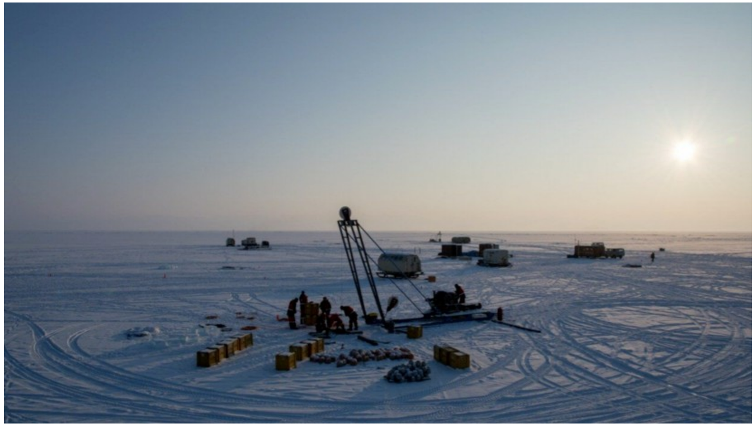
- **36 OMs** (10” high QE PMT, 15 m spacing, all PMTs look downward)
- **4 acoustic modems** of the positioning system
- **Section modules** digitize OM signals and send data to shore via shDSL/Ethernet
- Depths 750 m to 1275 m



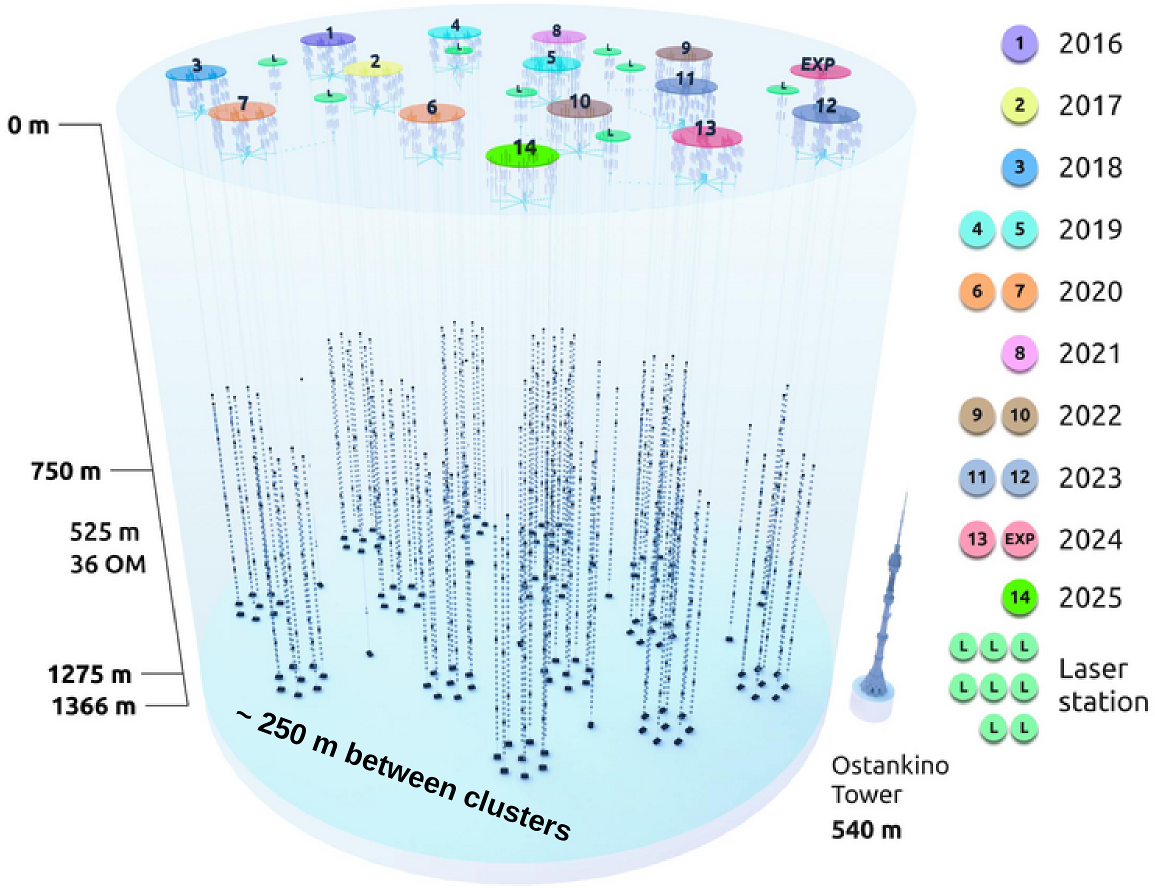
Cluster: 8 strings



Deployment



Baikal-GVD : current status



GVD = Gigaton Volume Detector

Deployment history

Year	Number of clusters	Number of strings	Number of OMs
2016	1	8	288
2017	2	16	576
2018	3	24	864
2019	5	40	1440
2020	7	56	2016
2021	8	64	2304
2022	10	80	2880
2023	12	96	3456
2024	13	114	4104
2025	**14**	**117**	**4212**

14 clusters + 8 laser/inter-cluster strings
+ 4 experimental strings

Eff. volume 2025: **~ 0.7 km^3** (cascades, E ~ 1 PeV)

Plan for 1 km^3 and 6000 OM in ~ 3 yr

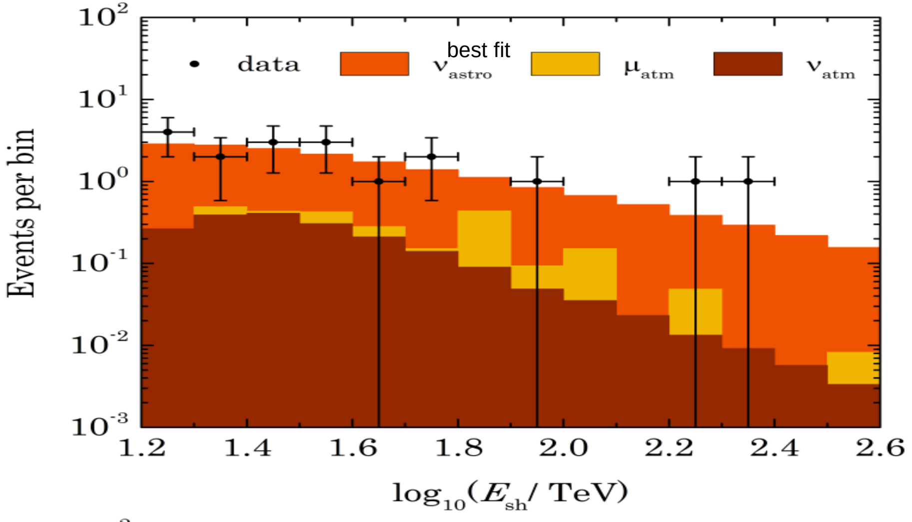
Diffuse flux measurement with upward-going cascades

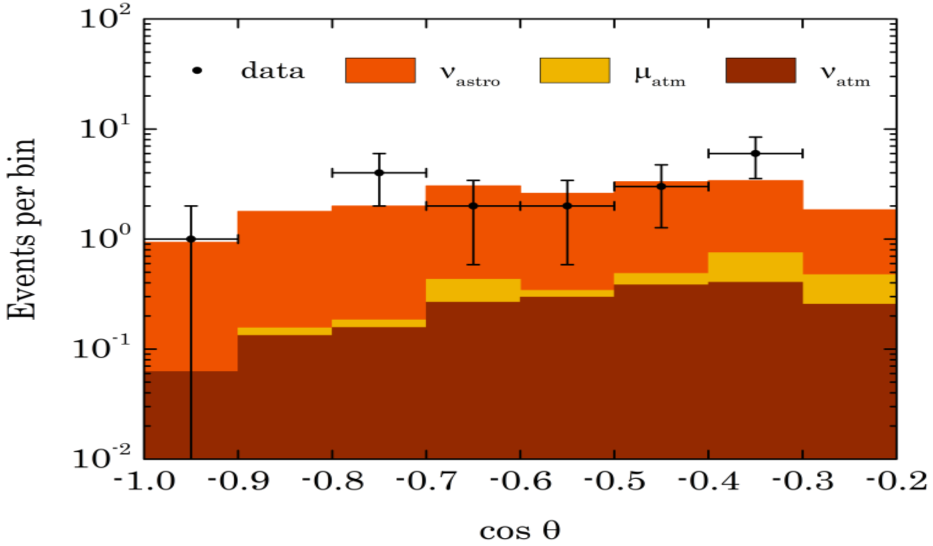
Data from Apr 2018 – March 2024
Event selection:
$E > 15$ TeV & $N_{hit} > 11$ & $\cos\theta_z < -0.25$
& downgoing muon veto cuts

Expected background:
0.9 events from atm. muons
1.9 events from atm. neutrinos

Found in data: 18 events

Astro diffuse flux is observed with
significance 5.1 σ (stat.+syst.)

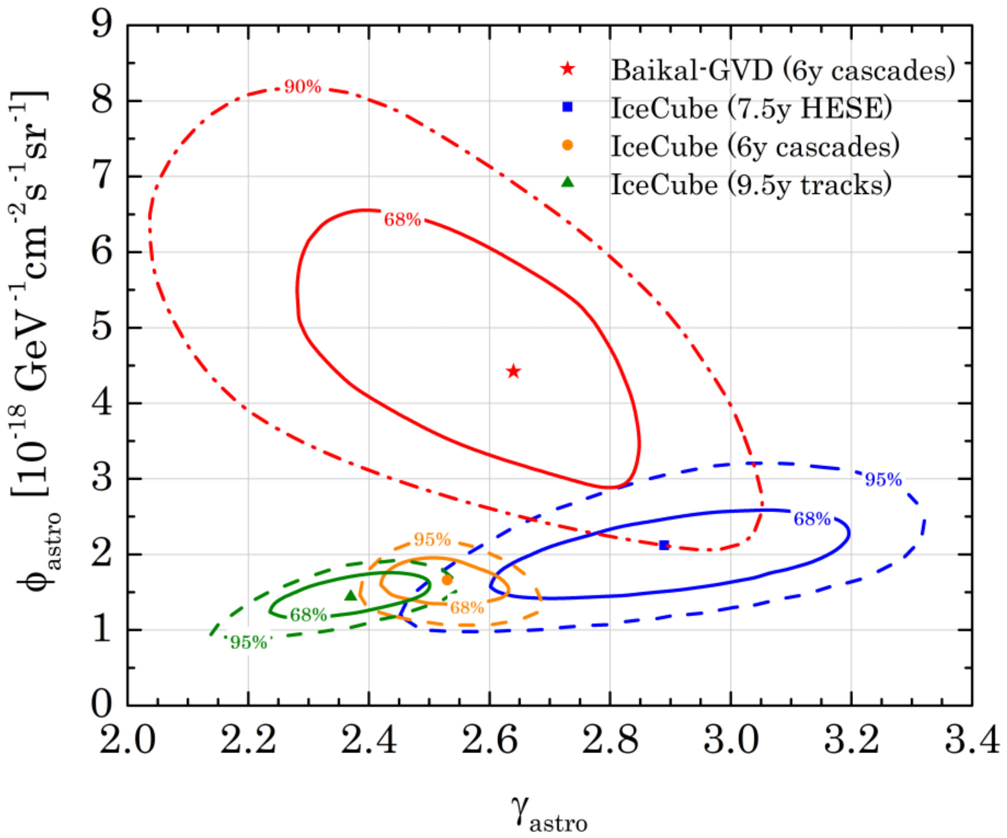


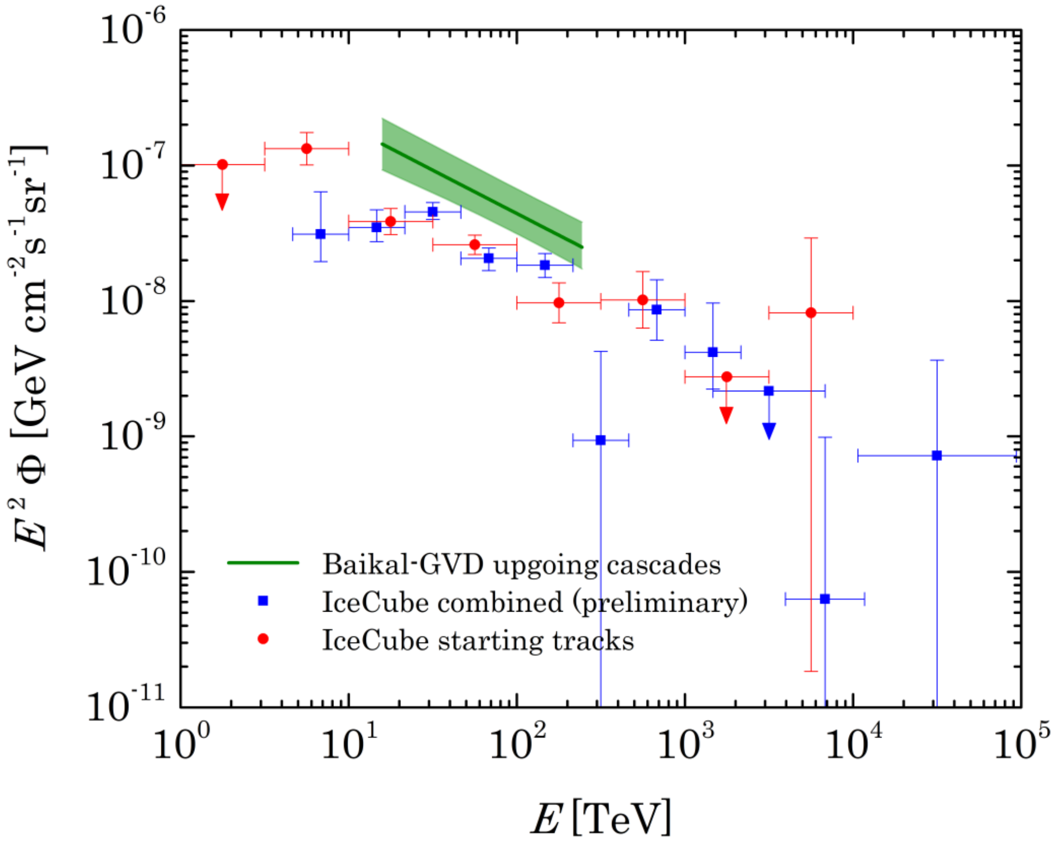


[arXiv:2507.01893]
older version:https://doi.org/10.1103/PhysRevD.107.042005

Diffuse neutrino flux spectrum (upgoing cascades)

[arXiv:2507.01893]





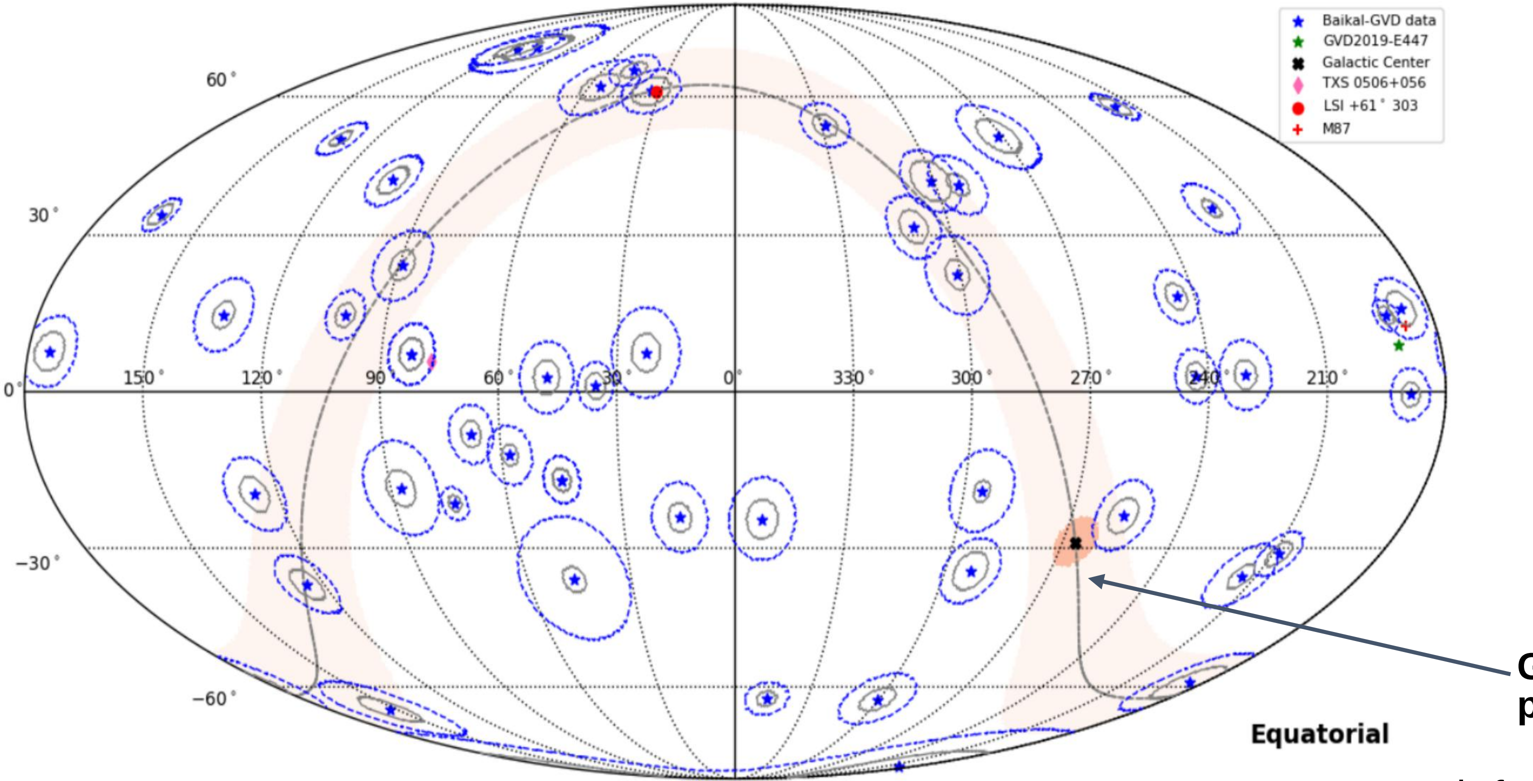
γ = 2.64

ϕ = 4.42 x 10^{-18} GeV^{-1} cm^{-2} s^{-1} sr^{-1} (per-flavor, E_0=100 TeV)

$$\Phi^{\nu+\bar{\nu}}_{astro} = 3\times 10^{-18}\phi_{astro}\left(\frac{E_\nu}{E_0}\right)^{-\gamma_{astro}}$$

Baikal-GVD sky map (cascades only)

Cascade events from the 6-year dataset (Apr 2018 - March 2024)

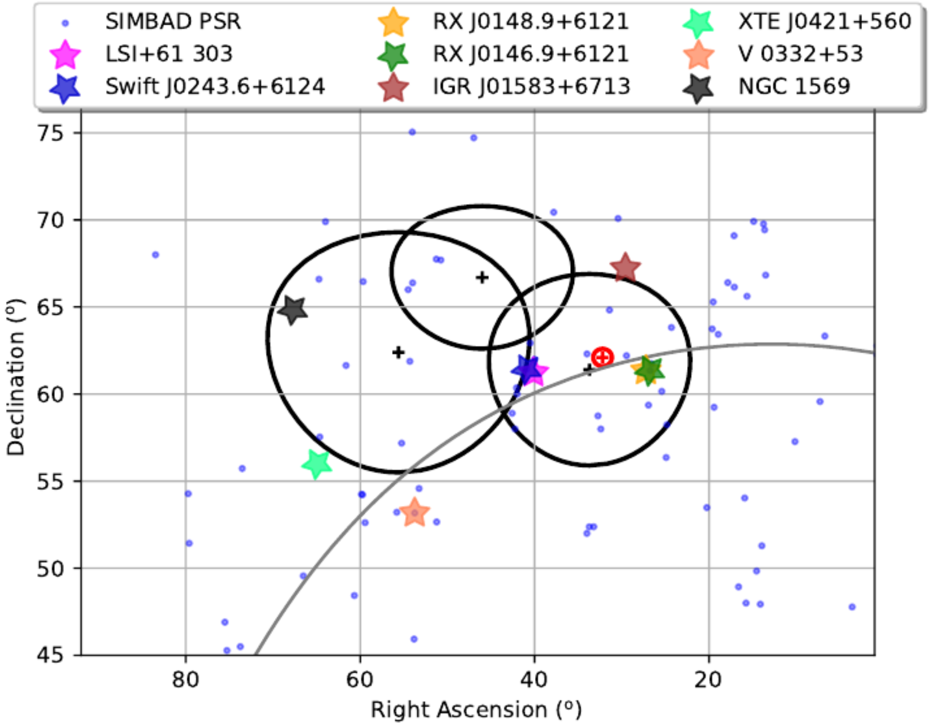


Best fit positions and 50%, 90% angular uncertainty regions

For a search for associations with VLBI blazars using a subset of this sample see *MNRAS 526, 942–951 (2023)*

https://doi.org/10.1093/mnras/stad2641

Event triplet near Galactic plane



Three events close to
the Galactic plane (grey line)

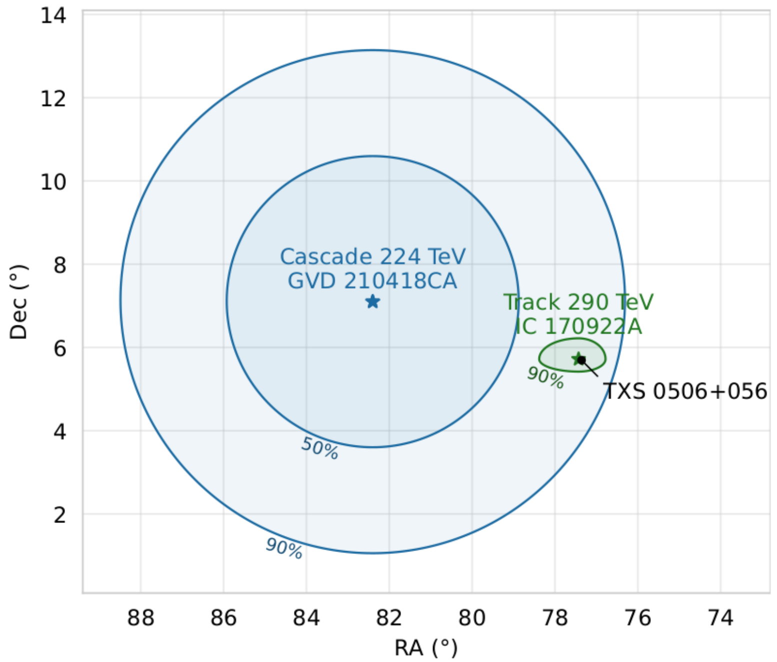
The red plus and circle – IC hotspot
[Aartsen & et al. ApJ, 835,151 (2017)]

LS I +61 303 is a γ-ray microquasar

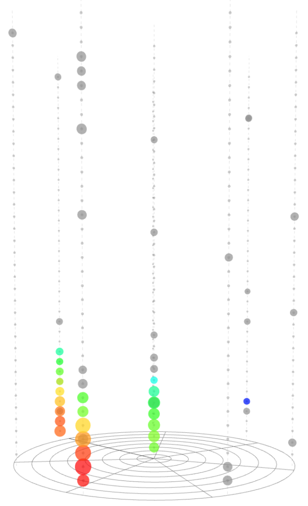
https://doi.org/10.1093/mnras/stad2641

A high energy neutrino from the direction of TXS 0506+056

Analysis of data collected between April 2018 and March 2022 yields a sample of 11 high quality cascade-like neutrino candidate events, one of which lies within 90% error circle from TXS 0506+056



GVD210418CA



MJD = 59322.94855324
Zenith = 115°
RA, Dec = 82.4°, 7.1°
E = 224±75 TeV

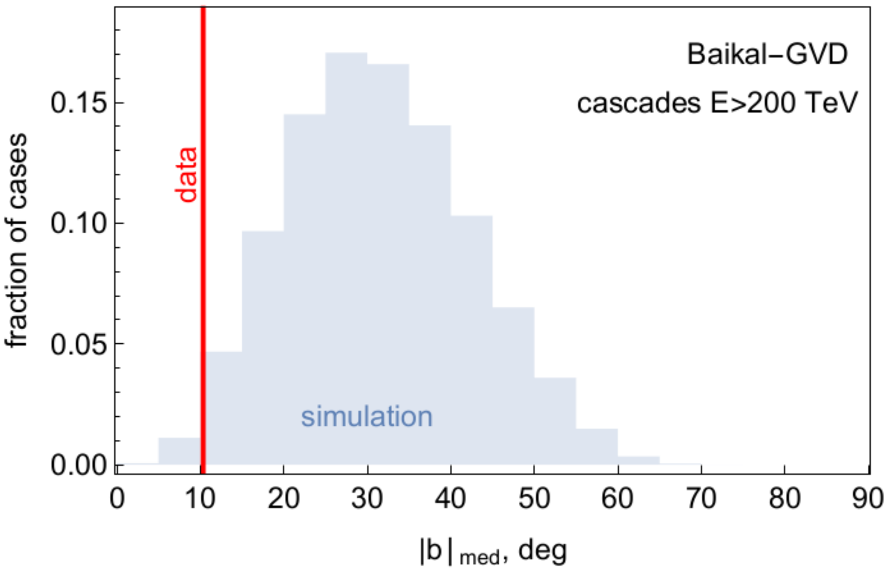
This event is probably of astrophysical origin (signalness = 97%)

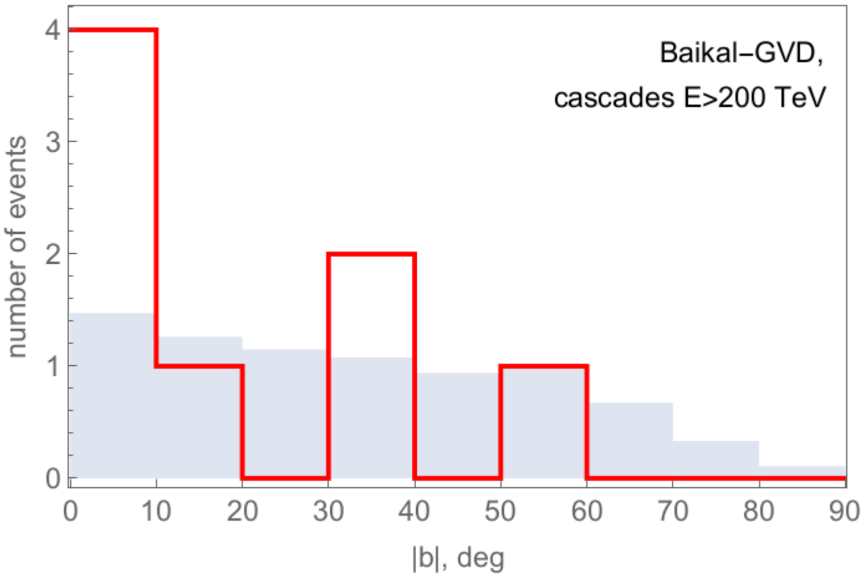
The chance probability for such an association to occur randomly due to the background is p = 0.0074

https://doi.org/10.1093/mnras/stad3653
MNRAS 527 (2024) 8784

Probing Galactic neutrino flux above 200 TeV with Baikal-GVD

– test the Galactic excess at E>200 TeV
– Baikal-GVD cascades Apr 2018–Mar 2024
– simplest, model-independent median |b| test like in *Kovalev et al. [APJL 940 (2022) L41)]*

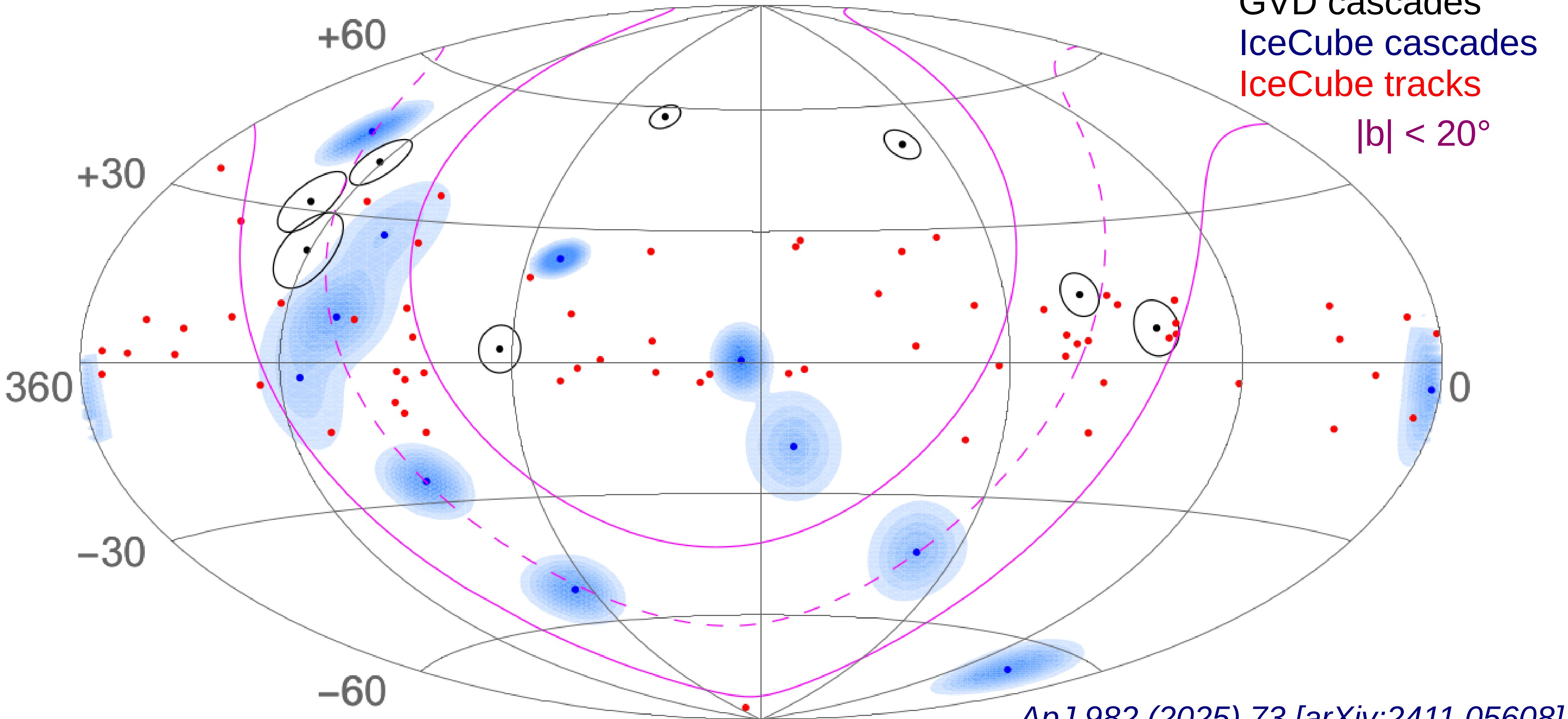




Sample	$\|b\|_{\mathrm{med}}$ observed	$\langle\|b\|_{\mathrm{med}}\rangle$ expected	p
Baikal-GVD cascades	$10.4°$	$31.4°$	$1.4 \cdot 10^{-2}$ (2.5σ)
IceCube cascades	$12.4°$	$31.9°$	$8.7 \cdot 10^{-3}$ (2.6σ)
IceCube tracks	$24.7°$	$36.0°$	$1.8 \cdot 10^{-3}$ (3.1σ)
combined	$23.4°$	$35.0°$	$3.4 \cdot 10^{-4}$ (3.6σ)

ApJ 982 (2025) 73 [arXiv:2411.05608]

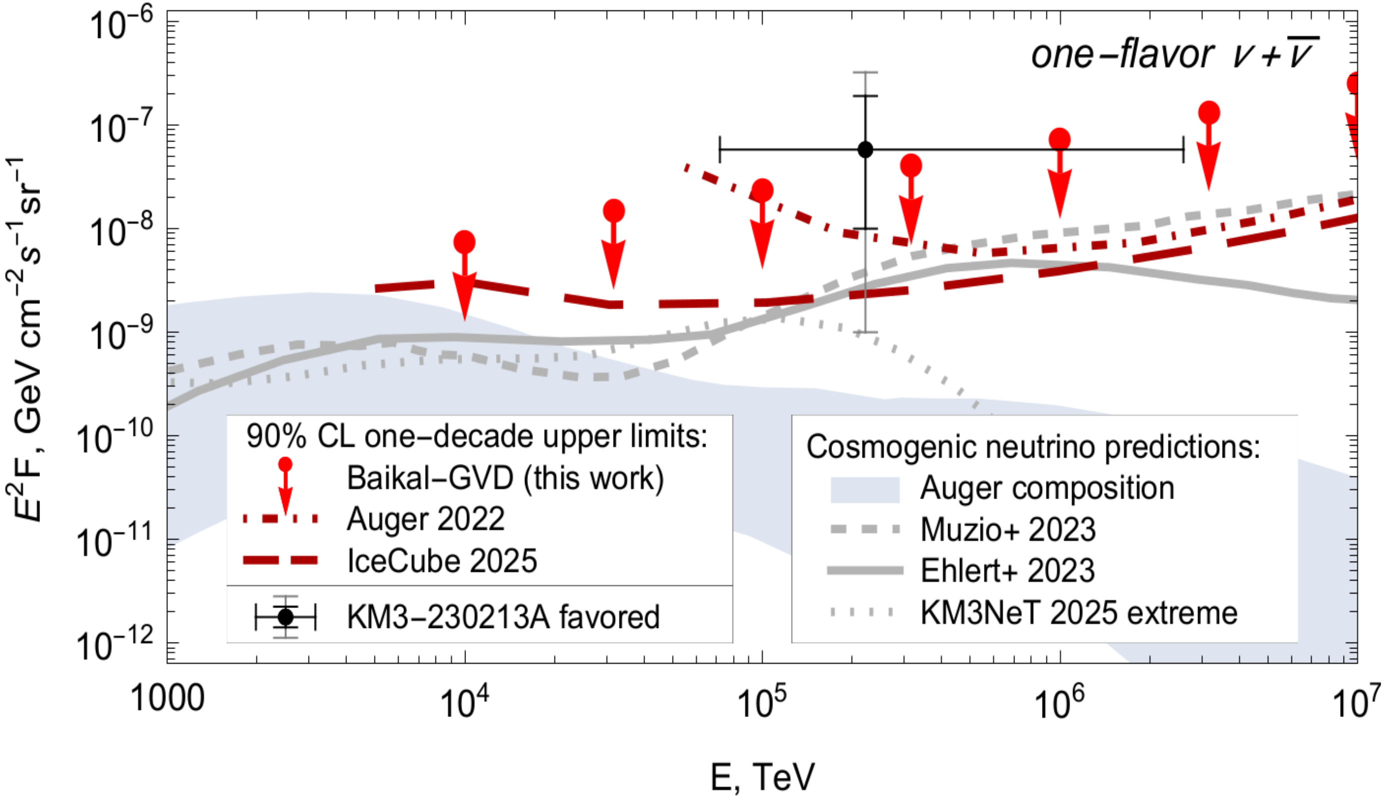
Neutrino sky above 200 TeV

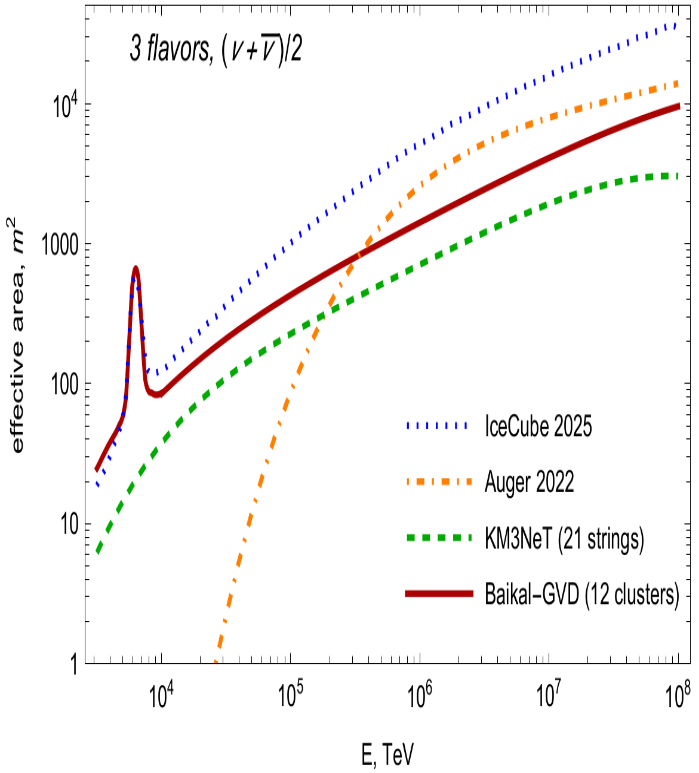


ApJ 982 (2025) 73 [arXiv:2411.05608]

Constraints on multi-PeV neutrinos

Using non-observation of cascade-like events above $10^{3.5}$ TeV

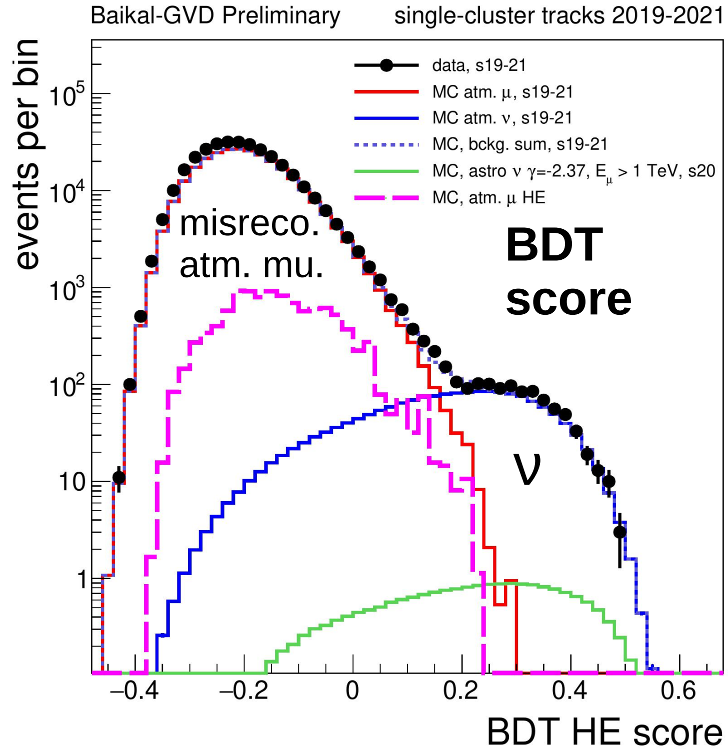


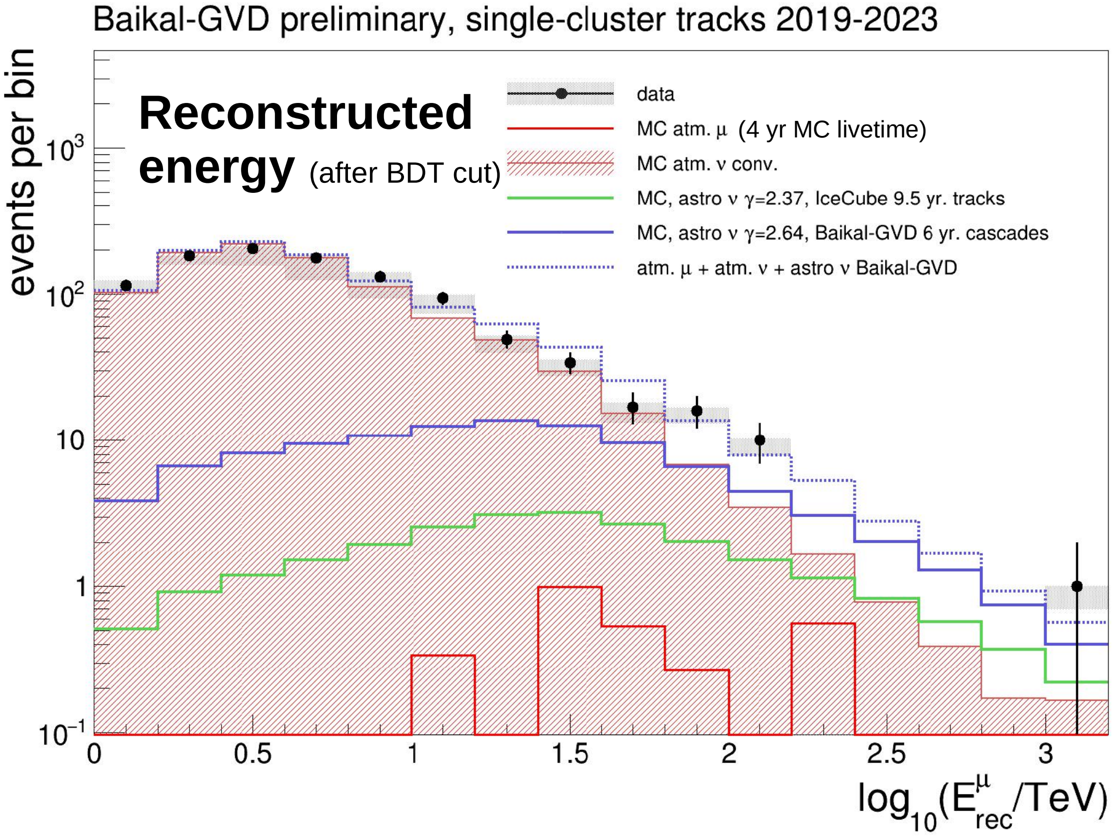


[arXiv:2507.05769]

Towards diffuse flux with tracks (work in progress)

“Upgoing” events only





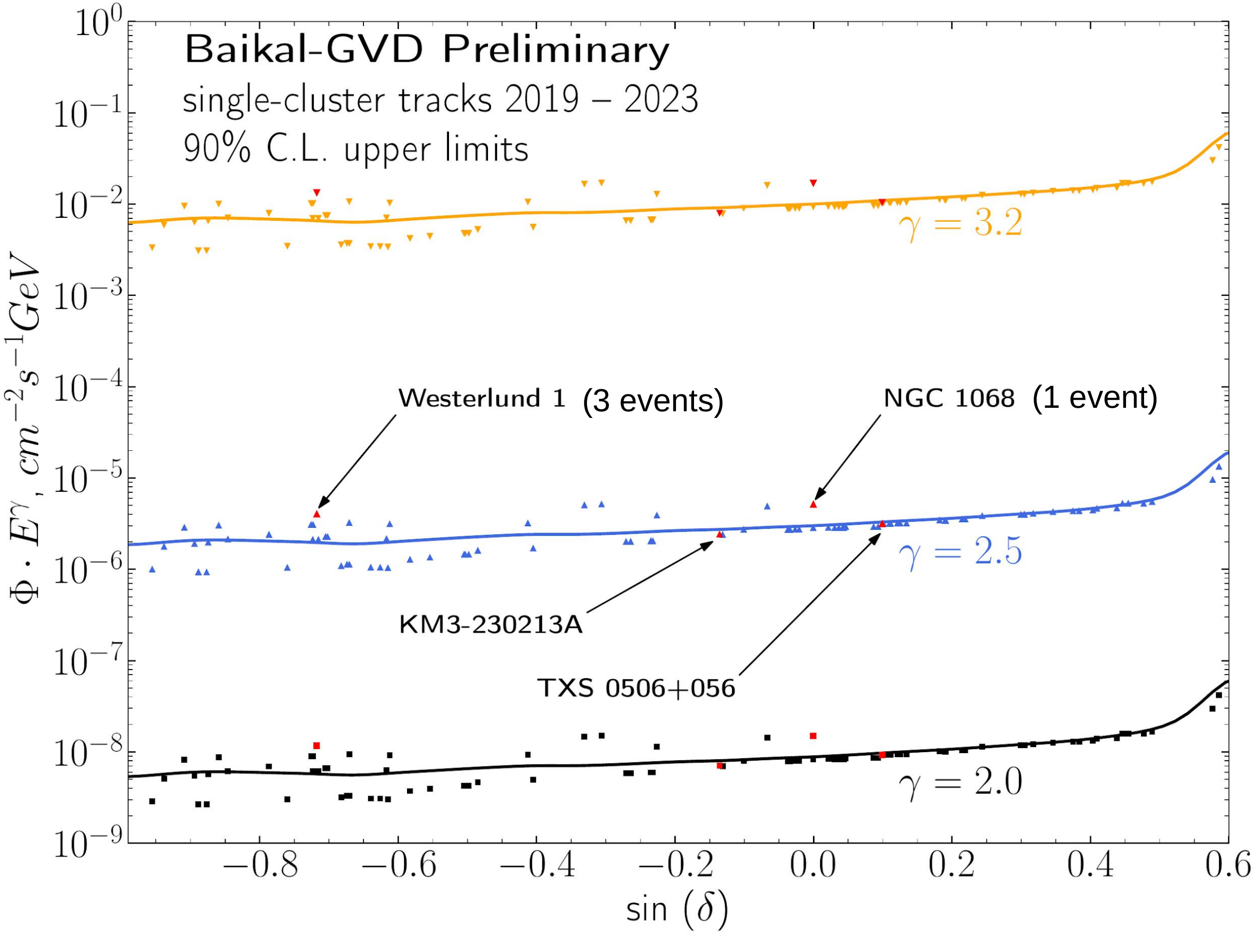
[G. Safronov et al, PoS (ICRC2025) 1162]

$BDT_{HE} > 0.26$, $E^{\mu}_{rec} > 45$ TeV

Error bars for MC not shown

→ 38 events observed while 25 events expected from background

Point-like source search with tracks



Guided search over a list of 112 objects using a simple cut & count analysis

5-year dataset: Apr 2019 - Mar 2024

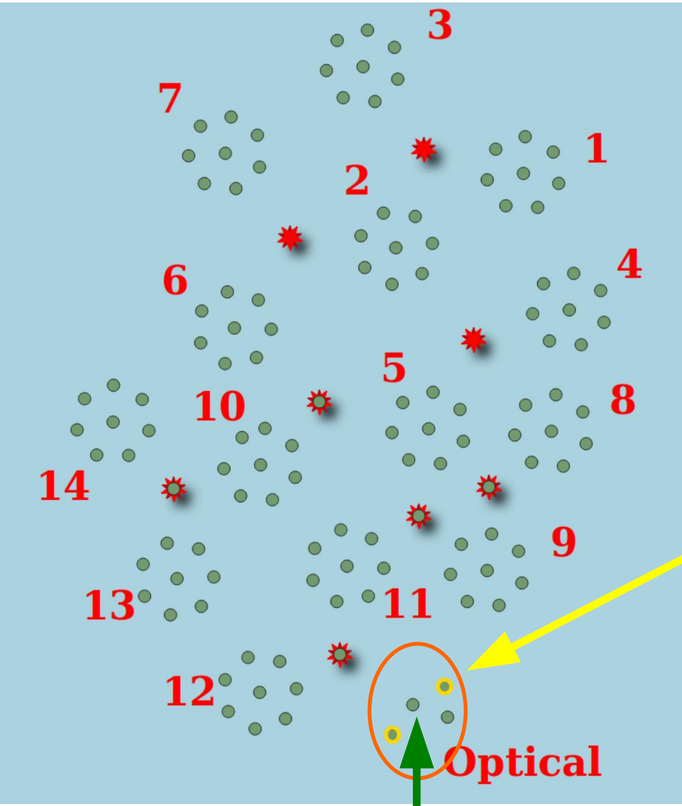
The cuts on BDT and angular distance were optimized for best sensitivity to E^{-2} spectrum

The sensitivity is similar the level of ANTARES 15 yr (and will be further improved)

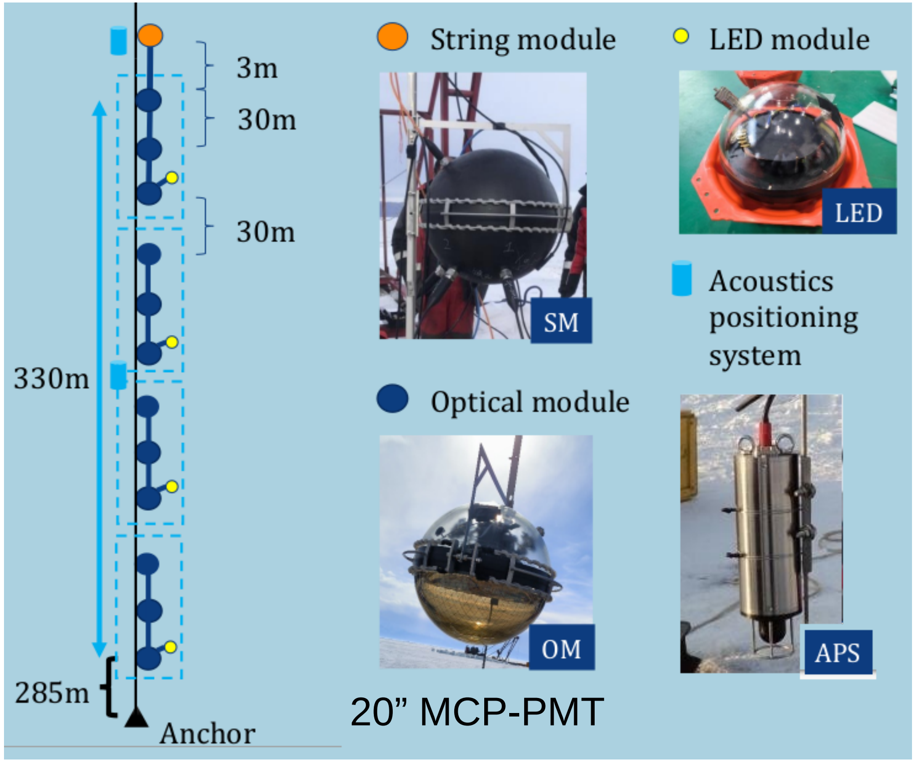
The object with most events in the search cone (3) is Westerlund 1 (bkg=0.3; 2.89 σ pre-trial)

G. Safronov et al, PoS (ICRC2025) 1162

Baikal-GVD as a testbed for next-generation telescopes



Two HUNT prototype strings deployed in 2024 & 2025
36 OMs in total
IHEP (Beijing) & Baikal-GVD joint effort



20” MCP-PMT

2 “experimental” strings using fiber optic technology for data transmission and standard Baikal-GVD OMs

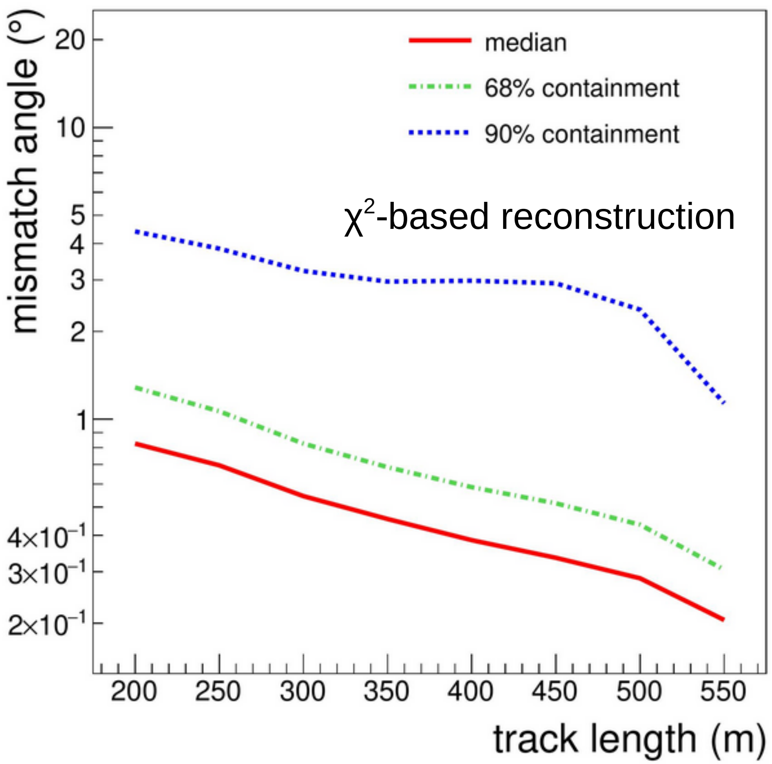
Summary

- Baikal-GVD is a new neutrino telescope under construction in Lake Baikal
  - Volume approaching 0.7 km^3 (cascades, E ~ 1 PeV)
  - Sub-degree angular resolution (tracks)
  - Field of view complementary to IceCube
- The IceCube’s diffuse neutrino flux is confirmed by Baikal-GVD with a 5 σ significance
- Hints of Galactic and extragalactic neutrino sources are accumulating

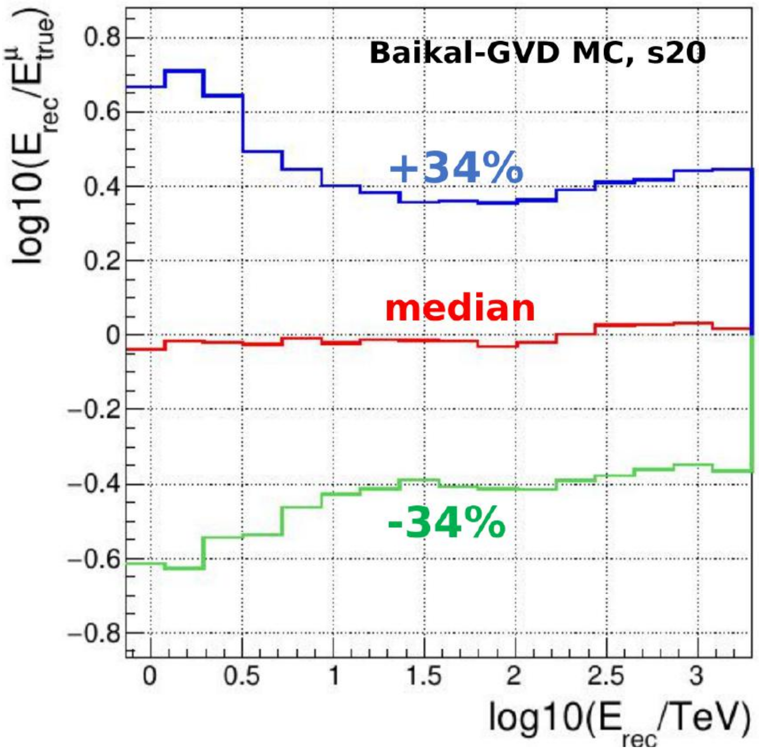
Backup slides

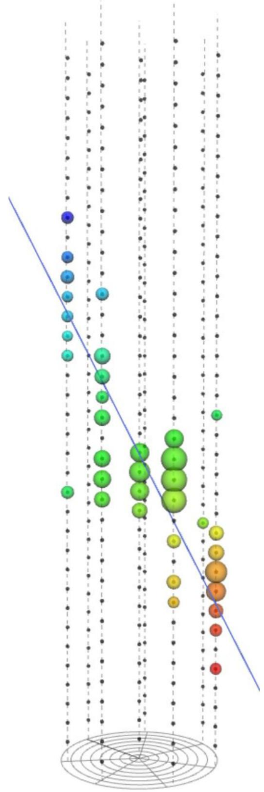
Expected performance for tracks

Angular resolution



Energy resolution



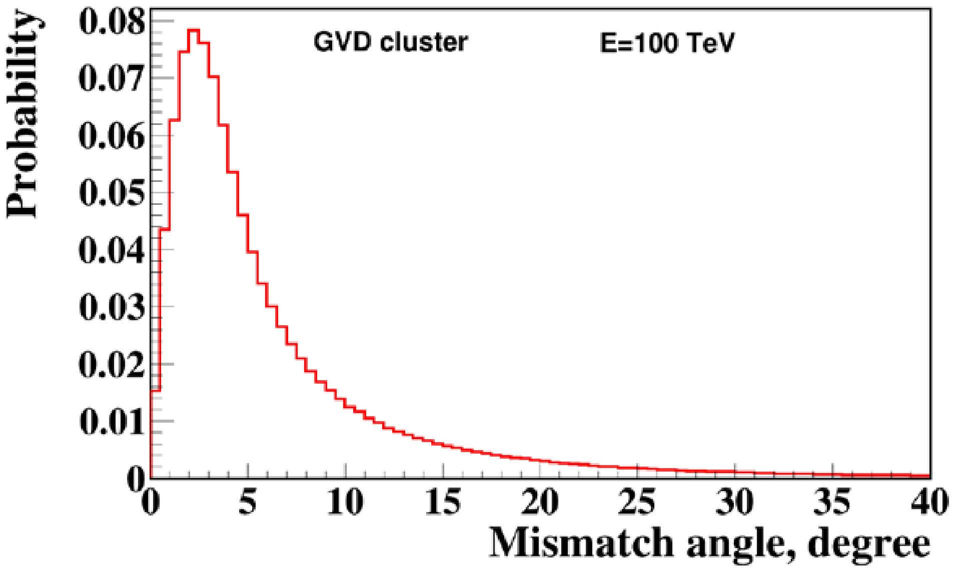


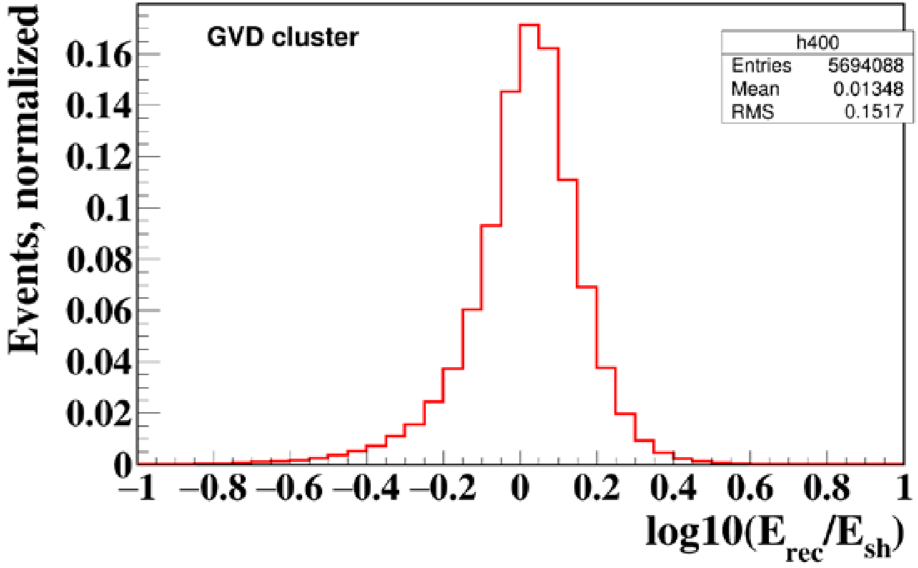
Improvements expected from likelihood-based reconstruction (under development)

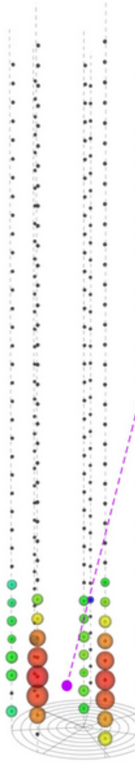
energy resolution ~ factor 2.5 at E > 10 TeV (±34% containment band)

G. Safronov @ ICRC 2025

Cascade analysis performance







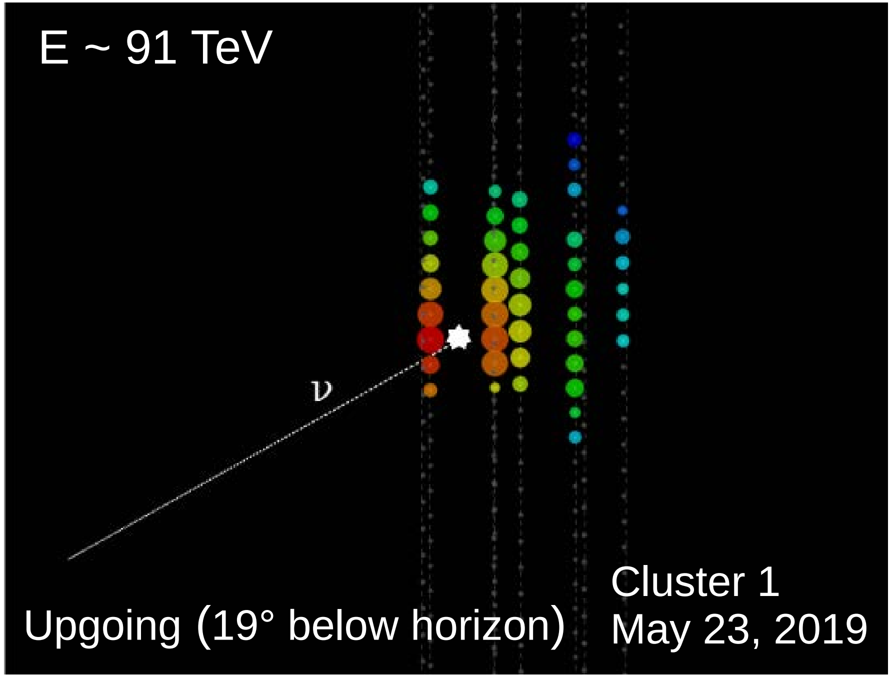
Directional resolution for cascades:
median mismatch angle ~ 4.5°

Energy resolution : δE/E ~ 10 – 30%

Data 20

Upward-going cascade #1

GVD2019_1_114_N

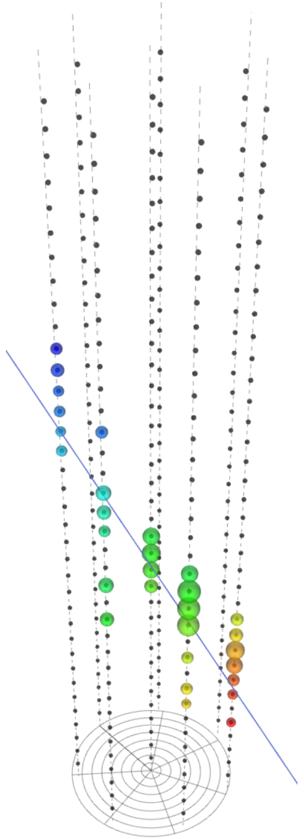


Contained event (50 m off central string)

Excellent candidate for a neutrino event of astrophysical origin

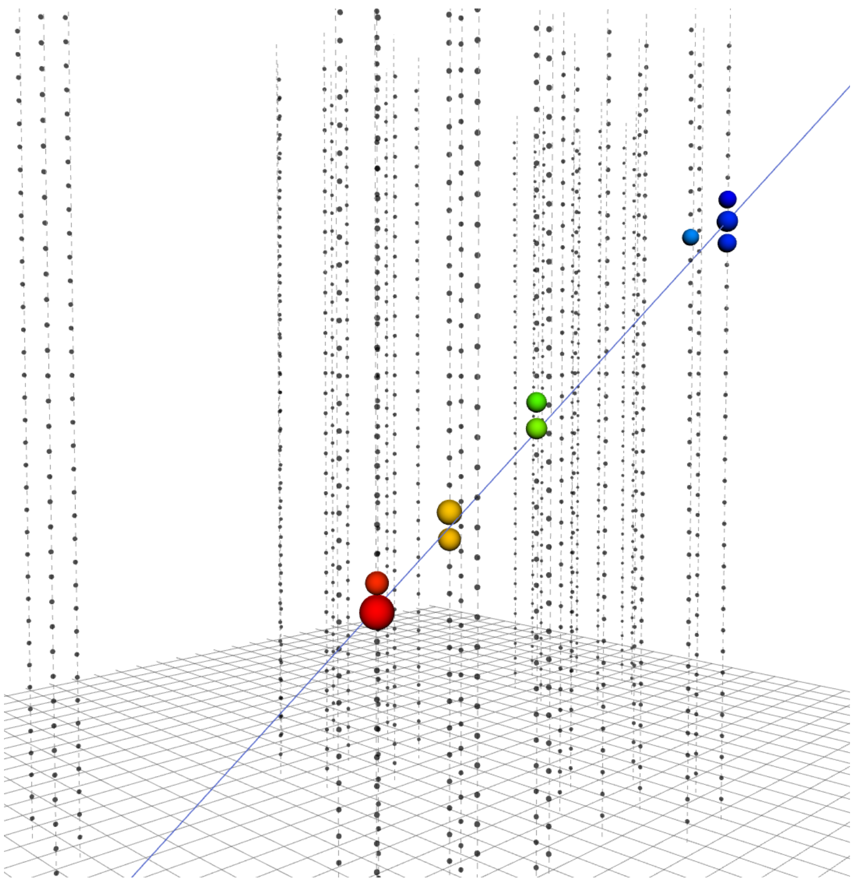
Neutrino candidate events

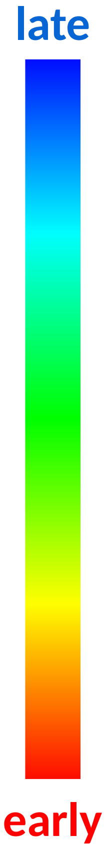
A single cluster event



Energy ~ 100 TeV !

An event seen in two GVD clusters





Expected neutrino rates from individual sources

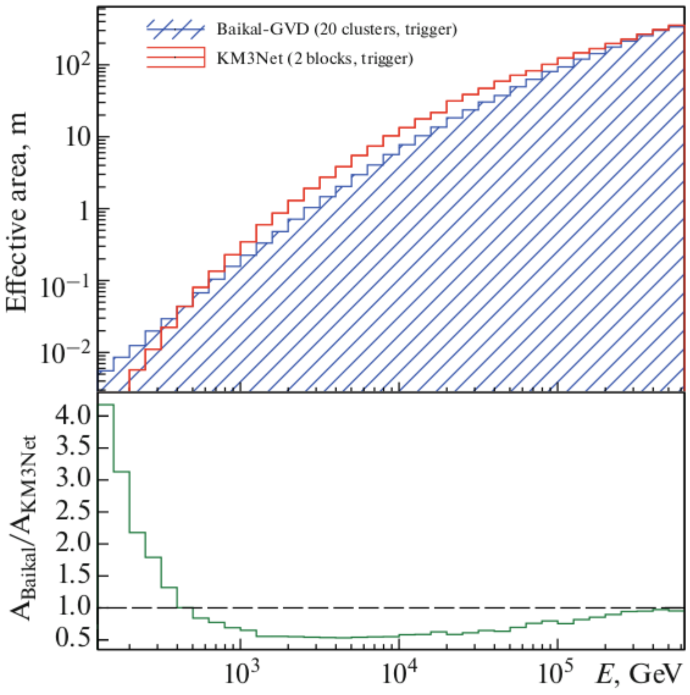


Fig. 2. 20-clustered Baikal-GVD effective area (blue) and 230-string KM3NeT effective area (red) at the trigger level [6].

Table 2. Registration rate (counts/5 years) for KM3NeT/ARCA (ARCA) and Baikal-GVD (Baikal) at trigger (trig) and reconstruction (reco) levels. The first column shows the calculation results from [1]. The second and the third ones show our results for KM3NeT/ARCA and Baikal-GVD. These three columns are for the trigger level, and the fourth column shows the ratio for Baikal-GVD and KM3NeT/ARCA also at the trigger level. The fifth column shows Baikal-reconstruction registration rate, and in the rightmost column Baikal-GVD reconstruction-trigger ratio is presented

Source	ARCA trig [1]	ARCA (trig)	Baikal (trig)	Baikal/ARCA	Baikal (reco)	reco/trig
RX J1713.7-3946	20.0	17.9	11.4	0.64	2.3	0.20
Vela X	40.7	37.2	19.5	0.52	4.88	0.25
Vela Jr	25.6	23.7	13.6	0.58	2.83	0.21
HESS J1614-518 (1)	10.5	9.0	6.1	0.68	1.5	0.25
HESS J1614-518 (2)	9.1	8.4	5.2	0.62	1.2	0.23
Galactic center	7.0	5.5	3.9	0.71	0.93	0.24
MGRO J1908+06 (1)	4.1	3.5	1.6	0.46	0.31	0.19
MGRO J1908+06 (2)	7.1	5.8	3.1	0.54	0.80	0.26
MGRO J1908+06 (3)	8.3	6.7	3.8	0.56	1.0	0.28
NGC 1068	–	52.8	66.4	1.3	3.1	0.05
TXS 0506+056 (1)	–	5.8	3.4	0.59	0.97	0.29
TXS 0506+056 (2)	–	5.0	3.1	0.63	0.96	0.31

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https://doi.org/10.1134/S1547477124700912