GNN Monthly
The Global Neutrino Network
101st Edition
December 31 ,2025
https://www.globalneutrinonetwork.org/

Zoom Meeting of the GNN Board

On Dec. 5, members of the GNN Board connected via Zoom. They agreed on location and date for the next GNN Meeting (formerly called MANTS meeting): Amsterdam, May 25/26 (Monday/Tuesday). This is the week after the IceCube collaboration meeting in Bochum. A preparation committee is going to be formed. Participation will be restricted to members of GNN collaborations, so that information internal to GNN can be freely exchanged. Moreover, the conditions for the next call for the GNN thesis award have been discussed. A call for nominations has been distributed within the collaborations. The deadline for nominations is January 30, 2026.

Towards NMO determination

Before the end of the decade, three emerging experiments will be able to probe the neutrino mass ordering (NMO) on an interesting level. These are JUNO, which started data taking in August 2025, IceCube with the IC-Upgrade under installation at the South Pole right now, and KM3NeT/ORCA, under construction and currently operating with 33 detection units, corresponding to almost 1/3 of its final size. While each of the three experiments can reach a certain significance to measure the NMO, a combined analysis would allow to unambiguously resolve the NMO before the end of the decade. In the spirit of this idea, the 2nd Joint NMO Analysis Workshop was held on the 2nd and 3rd of December 2025 at CPPM, Marseille. Participants from the three collaborations discussed how to prepare for such a future combined analysis. For the atmospheric neutrino experiments KM3Net/ORCA and IceCube-Upgrade, a consistent treatment of the systematic uncertainties in flux, neutrino cross-section and detector systematics is required. Additionally, software frameworks are needed that allow to implement such an analysis. To address this challenge, four working groups have been formed to streamline the work in the corresponding area. The inclusion of JUNO is found to be somewhat easier as only the oscillation parameters are shared between JUNO and the atmospheric experiments. Lively exchanges took place around all these topics with substantial progress in some of them. If you are interested, follow our presentations at the upcoming MANTS (now GNN) meeting or join our next workshop planned in Summer 2026.

(Report: Jürgen Brunner)

The workshop participants (missing: Juan-Pablo Yanez, Teppei Katori and the photographer, Jürgen Brunner)

News from the experiments

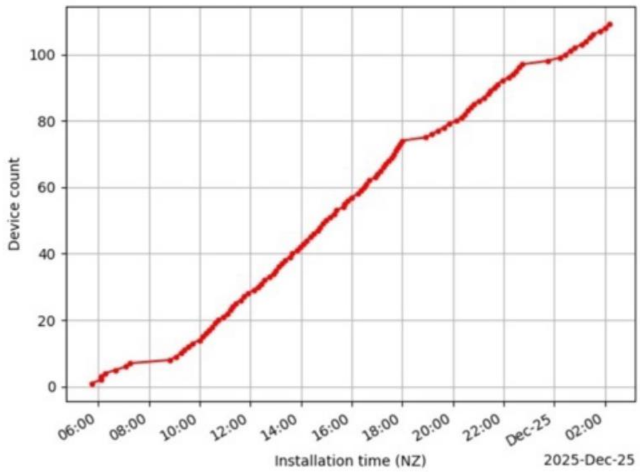
IceCube

Much has happened at the South Pole since the November edition of GNN Monthly was disseminated. In the following, I summarize the news from the last two weeks, following the reports which Albrecht Karle sent to the members of the IceCube collaboration.

A drill readiness review was conducted on December 13. On Dec. 19 all mentioned items were resolved. Drilling of hole 87 (the present IceCube has 86 strings) started in the early morning hours of Dec. 20. The hole was handed over to the installation team at around 02:30 AM on Wednesday, Dec. 24.

Removing the main drill hose after finishing drilling.

Installation for hole 87 began around 03:00h on December 24 and took 26 hours, with the final drop finishing around 05:00h on Dec. 25. This duration was roughly consistent with the time of 24 hours budgeted for the installation of 108 (!!) instruments on the first string – see the next figure.



Logbook snapshot of the installation: device number versus time. The final modules were connected around 2:30 am on December 25, followed by the "drop" which took about 2 hours.

Left: Preparing the first mDOM for deployment (photo: A. Ishihara). Right: the first mDOM going down the hole (photo: A. Karle)

The first D-Egg goes down the hole (photo: A. Ishihara)

By the end of the week, drilling for hole 88 began. Initial commissioning results for string 87 show that all tested devices are communicating. Meanwhile, the IceCube population had reached its maximum of 51 people on the ice.

KM3NeT

The KM3NeT collaboration has decided to complete ORCA with 4 nodes (i.e. junction boxes), with a total of 108 DUs (24 + 3*28). The original design included 115 DUs on 5 nodes. The inter-DU distance will remain the same, so this implies a small downscaling of the detector volume. However, by not having to design a "manifold" for the connection of 3 junction boxes to the second main cable (the rerouted ANTARES cable), but adopt a simpler solution for 2 nodes, one gains time in deploying nodes and DUs and thereby can complete the detector earlier.

Baikal GVD

The Baikal collaboration is in full swing preparing the 2026 expedition. 816 OMs were produced in JINR Dubna and sent to Lake Baikal. The total number of OMs to be used for the 2026 expedition is about 900. 70 modems of the acoustic positioning system are produced and tested for deployment in 2026. Moreover, the electronics modules for 3 clusters are produced and tested in INR Moscow.

One full string with 24 Chinese OMs will be deployed, with a separate readout system. In addition, two Chinese modules have been adapted to the GVD electronics scheme and will be implemented in one of the new standard GVD strings.

A collaboration meeting was held in Dubna at 1.12.2025-5.12.2025.

View of the grand meeting room during the talk of Zhen Cao (IHEP Beijing) about the status of the LHAASO project.

Two new associate members were accepted: the Lebedev Physical Institute of the Russian Academy of Science (Moscow) and the Kabardino-Balkarian State University in Nalchik (North Caucasus)

Publications

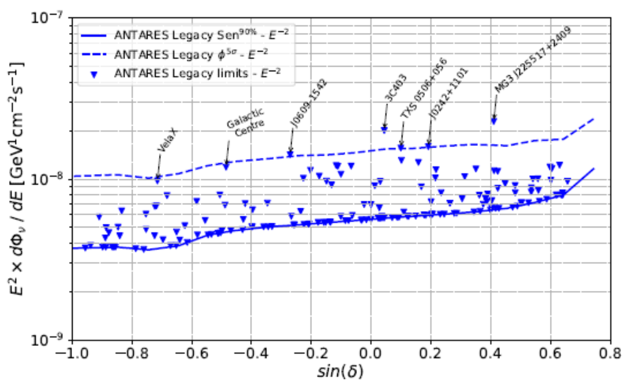
The ANTARES Collaboration has posted a paper *Deep Learning Framework for Enhanced Neutrino Reconstruction of Single-line Events in the ANTARES Telescope* at https://arxiv.org/pdf/2511.16614 (submitted to the journal Machine Learning: Science and Technology). Corresponding authors are Juan Garcia, Salva Ardid and Miquel Ardid (UP València).

The paper presents an "*N*-fit algorithm" designed to improve the reconstruction of neutrino events detected by a single line of ANTARES, usually associated with low energy neutrino events (~ 100 GeV). *N*-fit is a neural network model that relies on deep learning and combines several advanced techniques in machine learning – deep convolutional layers, mixture density output layers, and transfer learning. This framework divides the reconstruction process into two dedicated branches for each neutrino event topology – tracks and showers – composed of sub-models for spatial estimation – direction and position – and energy inference, which later on are combined for event classification. Regarding the direction of single-line events, the *N*-fit algorithm significantly refines the estimation of the zenith angle, and delivers reliable azimuthal angle predictions that were previously unattainable with traditional χ^2-fit methods. Tests on Monte Carlo simulations and data demonstrate a significant reduction in mean and median absolute errors across all reconstructed parameters. *N*-fit modules characterizing track events have already been used in the follow-up analysis of an IceCube neutrino track-like event with a moderate probability of being of astrophysical origin that occurred on December 8, 2021 (https://gcn.gsfc.nasa.gov/gcn/gcn3/31191.gcn3). The authors also note a promising improvement in the low energy range for dark matter WIMP searches towards the Sun. The repertoire and combination of machine learning techniques used in *N*-fit may be adapted to reconstructions in other neutrino telescopes, such as KM3NeT and IceCube, as well as inspiring new applications in other areas of computational physics.

The ANTARES Collaboration has submitted a paper *Search for Steady and Flaring Neutrino Emission from Cosmic Sources Using the Complete ANTARES Data set* to EPJ C (posted at https://arxiv.org/pdf/2511.07239). Corresponding authors are Sergio Alves (IFIC Valencia) and Giulia Illuminati (INFN Bologna).

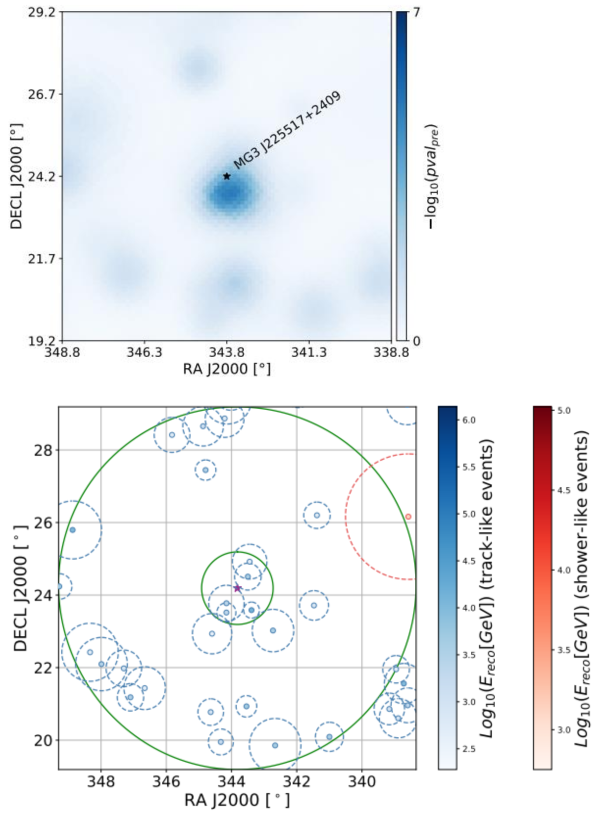
ANTARES has been decommissioned in 2022. This study makes use of data collected over the entire operational period of ANTARES to search for sources of high-energy cosmic neutrinos, considering both steady and flaring emission scenarios.

First, a time-integrated search for high-energy neutrino clustering across the celestial sphere was conducted. The most significant accumulation was found at coordinates (α, δ) = (200.5°, 17.1°) with a post-trial p-value equal to 0.38 (see the next figure).



Upper limits at 90% CL (triangles) on the one-flavor neutrino flux normalization for the investigated astrophysical candidates as a function of the source declination, shown here for an $E^{-2.0}$ energy spectrum. The arrows point to the upper limits corresponding to the sources for which a pre-trial significance over 2.0σ has been obtained. The solid (dashed) line shows the 90% CL median sensitivity (50% 5σ discovery flux) of the analysis.

A dedicated search in the Galactic Plane was also performed for extended sources, yielding no significant excess. Additionally, a list of potential neutrino sources is investigated. The blazar MG3 J225517+2409 is identified as the most significant object, yet the excess remains compatible with background fluctuations (see the next figure).



Top: Pre-trial p-value map around the location of the most significant source MG3 J225517+2409 for an E^{-2} spectrum. Bottom: Distribution of the ANTARES events close to MG3 J225517+2409. The inner (outer) solid green line depicts the one (five) degree distance from the position of the hotspot. The red points denote shower-like events, whereas the blue points indicate track-like events. The dashed circles around the events indicate the angular error estimate. Different tones of red and blue correspond to the values assumed by the energy estimators as shown in the legend.

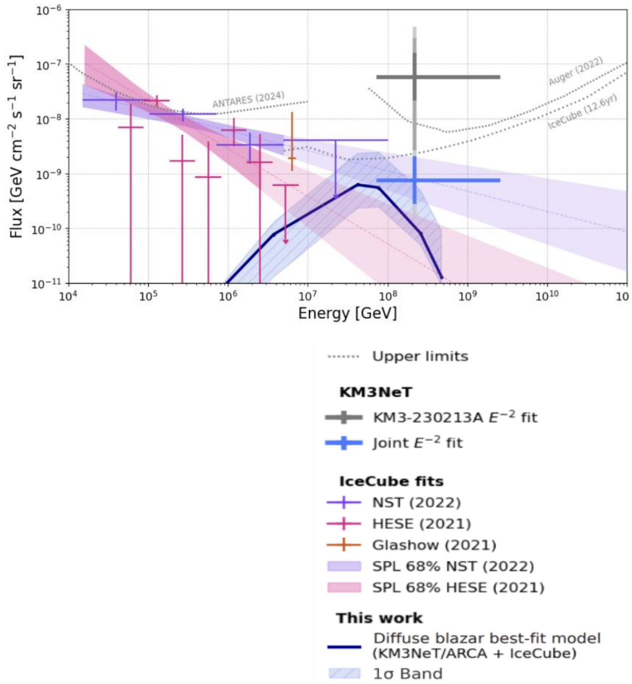
A mild local excess of 2.4 σ is found for the blazar TXS 0506+056. The full sky is also examined for the presence of flaring neutrino emissions. The most significant excess in this case corresponds to a ~4-day flare from the direction (α, δ) = (141.3°, 9.8°), with a post-trial p-value of 0.30. Finally, the directions of sources highlighted in IceCube's time-dependent searches are investigated. Temporal overlaps between ANTARES and IceCube flares are identified for PKS 1502+106 and TXS 0506+056, with an estimated chance probability of about 0.02%, making this observation particularly noteworthy.

The KM3NeT Collaboration has submitted a paper *Blazars as a Potential Origin of the KM3-230213A Event* to JCAP (posted at https://arxiv.org/pdf/2511.13886) Corresponding authors Antonio Ambrosone (INFN and University Napoli) and Meriem Bendahman (INFN Napoli).

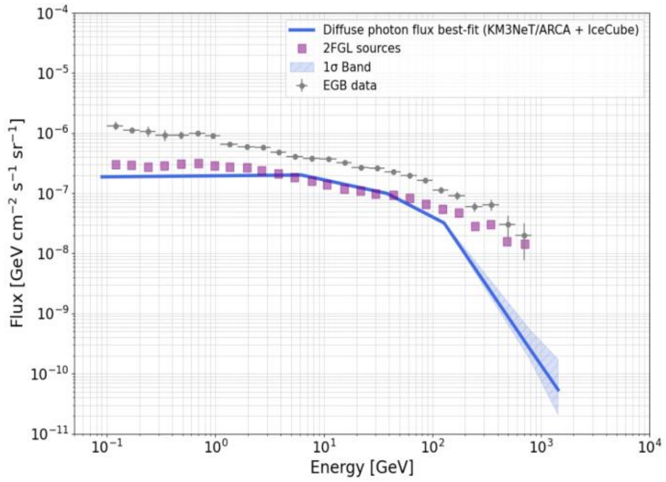
The KM3NeT collaboration has reported the highest-energy neutrino event detected to date, with an estimated energy of ~ 220PeV. In this article, the possibility that this event might have originated from the diffuse neutrino flux produced by blazars is considered. This is theoretically well motivated since blazars are the most luminous objects in the gamma-ray sky. In order to constrain the spectrum of a single blazar, the publicly available *AM3 software* is used. In order to extrapolate this result to the whole blazar population, the luminosity function inferred by the Fermi-LAT collaboration is used. The constraints imposed by the IceCube non-observation and the gamma-ray measurements from Fermi-LAT are also taken into account. Results demonstrate that the diffuse neutrino flux due to blazars is compatible with all constraints and may explain the KM3-230213A event considering a joint fit combining information with the IceCube diffuse flux measurement (see the first of the following figures)

The gamma-ray spectrum deduced from the neutrino spectrum shown in the first figure is compatible with the Second Fermi-LAT (2FGL) resolved source catalogue. Blazars would contribute ~ 42% of the Extra-Galactic Background Radiation (EGB): see the second figure.

In an Appendix, the case of the KM3NeT/ARCA exposure alone is discussed. In this case, the diffuse emission from blazars remains consistent with Fermi-LAT gamma-ray constraints, though it is in tension with the IceCube upper limits at the ~2.5–3 σ level.



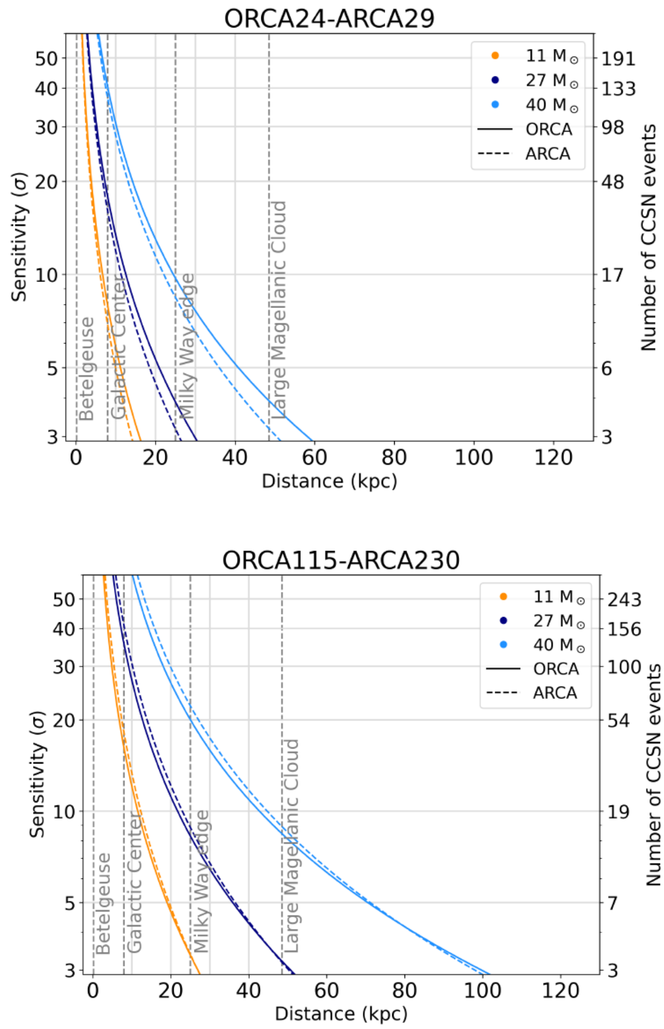
Neutrino diffuse spectral energy distribution for blazars in terms of the energy for a single neutrino flavor. The dark blue solid line represents the best fit, while the shaded region is the 1σ band. The prediction is compared with the KM3-230213A equivalent flux, the joint E^{-2} flux obtained by including IceCube-Extreme High-Energy and Auger non-observations, and the updated IceCube and Auger differential upper limits. For comparison, the diffuse neutrino flux measured by IceCube with several samples and also the ANTARES upper limits are reported. The pink and purple shaded regions represent the IceCube single-power-law (SPL) fits for High-Energy Starting Events (HESE) and Northern Sky Tracks (NST), respectively.



Gamma-ray diffuse spectral energy distribution for blazars as a function of the energy. The solid line represents the best fit while the shaded region the 1σ band. The result is compared with Extra-Galactic Background measurements of Fermi-LAT (EGB) and the 2FGL sources.

The KM3NeT collaboration has submitted a paper *Optimizing the potential of KM3NeT in detecting core-collapse supernovae* to JCAP (posted at https://arxiv.org/pdf/2511.18565) The corresponding authors are Sonia El Hedri and Isabel Goos (both APC Paris).

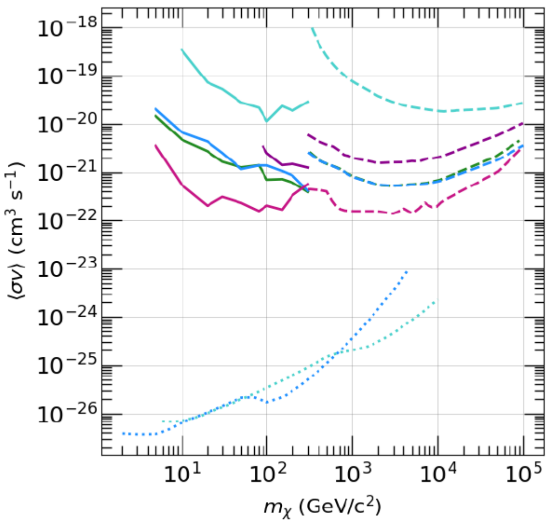
The paper presents a strategy to improve the potential of KM3NeT to detect core-collapse supernovae (CCSN) in our Galaxy or the Large Magellanic Cloud by further exploiting the properties of its optical modules equipped with multiple photomultipliers. As is well known, a supernova burst is expected to produce a sudden hit rate increase in detectors like IceCube and KM3NeT. In this paper, new observables are defined for individual optical modules that exploit the geometry and time distribution of the detected hits, enabling a better discrimination between signal and background signatures. In addition, a thorough investigation of the related systematic uncertainties is presented for the first time. When implemented, this new methodology would allow KM3NeT to probe 46% more Galactic core-collapse supernova candidates than with the previous trigger strategy, reaching the dense Galactic bulge. It is expected that, once completed, KM3NeT will achieve full Galactic sensitivity to core-collapse supernovae – see the following figures. Note, for comparison, that the progenitor of SN 1987A had a mass of 15-20 solar masses.

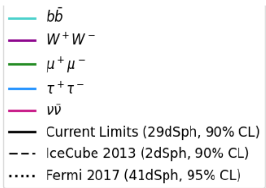


Sensitivity, in units of σ, as a function of the CCSN distance to Earth for the 11 M⊙, 27 M⊙, and 40 M⊙ models already considered in the previous KM3NeT CCSN search. In this figure, the performances of ARCA and ORCA are evaluated separately. The sensitivities for the ORCA24 (solid lines) and ARCA29 (dashed lines) detector configurations are indicated in the top panel, and the projected sensitivities for ORCA115 and ARCA230 are indicated in the bottom panel.

The IceCube Collaboration has submitted a paper *Limits on GeV-scale WIMP Annihilation in Dwarf Spheroidals with IceCube* to Phys.Rev.D (posted at https://arxiv.org/pdf/2511.19385). The main author is Brandon Pries (Michigan State University).

After becoming gravitationally bound in cosmic structures, WIMPs can self-annihilate and produce SM particles including neutrinos, which are observable by detectors like IceCube. This paper presents a search for neutrinos from low-mass (≤ 300 GeV) WIMP annihilation in dwarf spheroidal galaxies with over seven years of IceCube lifetime, i.e. for much lower masses than previous analyses using full IceCube. No statistically significant evidence of neutrinos produced by WIMP annihilation is found, resulting in upper limits on the velocity-averaged annihilation cross section ⟨σv⟩. The strongest upper limits at the 90% confidence level are the order of 10^{-22} cm^3 s^{-1} for WIMP annihilation directly into neutrino-antineutrino pairs. For the least sensitive channel, the corresponding limits are of the order of 10^{-20} cm^3 s^{-1} which is an improvement of over two orders of magnitude over previous IceCube limits from dwarf galaxies at the upper end of IceCube's mass range.



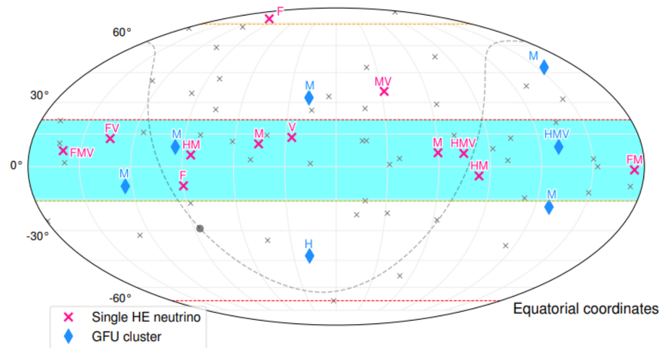


Upper limits at 90% confidence level (solid lines), with comparison to IceCube 2013 and Fermi 2017 results (dashed and dotted lines, respectively.

The IceCube Upgrade, currently being installed, will reach effective area and energy resolution down to O(1 GeV). Together with discoveries of new Dwarf Spheroidals and better characterization of them with surveys like LSST, IceCube will be able to probe additional DM parameter space and set stronger limits in the coming years.

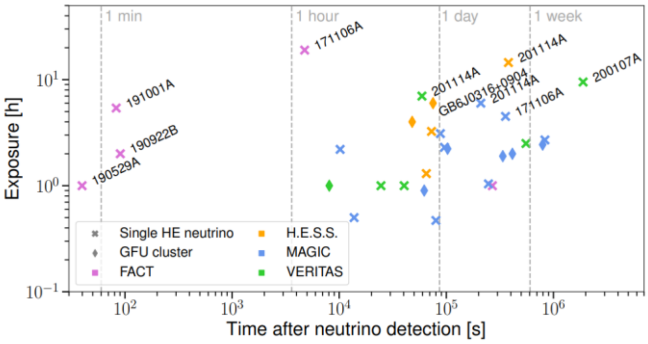
The IceCube collaboration (together with FACT, H.E.S.S., MAGIC, VERITAS and Fermi-LAT collaborations) has submitted a paper *Prompt Searches for Very-High-Energy γ-Ray Counterparts to IceCube Astrophysical Neutrino Alerts* to ApJ (posted at https://arxiv.org/pdf/2512.16562).

FACT, H.E.S.S., MAGIC, and VERITAS are conducting extensive neutrino target-of-opportunity follow-up programs. These programs have two components: follow-up observations of single astrophysical neutrino candidate events (such as IceCube-170922A), and observation of known γ-ray sources after the identification of a cluster of neutrino events by IceCube (GFU alert). The paper presents a comprehensive analysis of follow-up observations of high-energy neutrino events conducted by the four IACTs between September 2017 (after the IceCube-170922A event) and January 2021.



Skymap in equatorial coordinates showing IceCube alert positions in the period from September 2017 to January 2021. Alerts followed up by IACTs are shown in color (according to the alert type), and those not followed up are shown in gray. Letters indicate which IACTs participated in the observations (F - FACT, H - H.E.S.S., M - MAGIC, V - VERITAS). The latitude band between two dashed orange lines and two dashed red lines indicate regions of the sky that are potentially observable at zenith angles less than 45∘ from the northern (FACT, MAGIC, VERITAS) and southern (H.E.S.S.) IACTs, respectively. The light cyan band represents the overlapping visibility window for instruments in both hemispheres around the celestial equator, where the IceCube sensitivity to neutrinos in the ~100 TeV energy range is at its best.

The next figure shows the exposure times vs. the delay time for the follow-up observations.

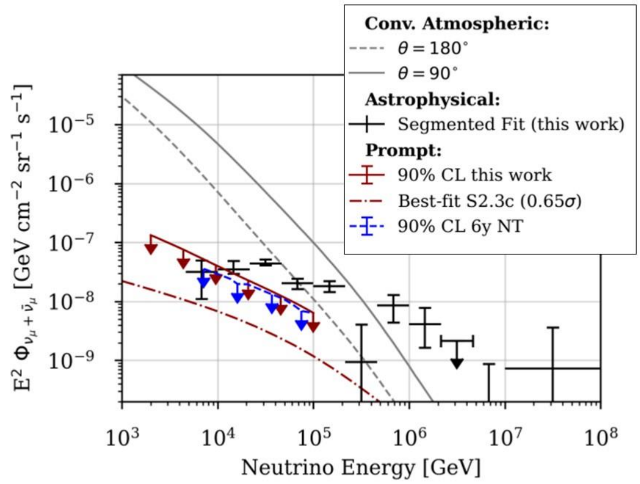


Exposure times plotted against delay times for IACT follow-up observations of neutrino alerts in the period from September 2017 to January 2021. The delay is calculated from the neutrino event arrival time (single events) or the flare threshold-crossing time (clusters) up to the start of the IACT observation. Observations performed with delays of less than 100 s or total exposures longer than 4 hours are labeled by alert names. The marker color represents the IACT performing the observation while the marker type represents the alert type.

The study did not find any association between γ-ray sources and the observed neutrino events. The authors provide a detailed overview of each neutrino event and its potential counterparts. Furthermore, a joint analysis of all IACT data is included, yielding combined upper limits on the VHE γ-ray flux.

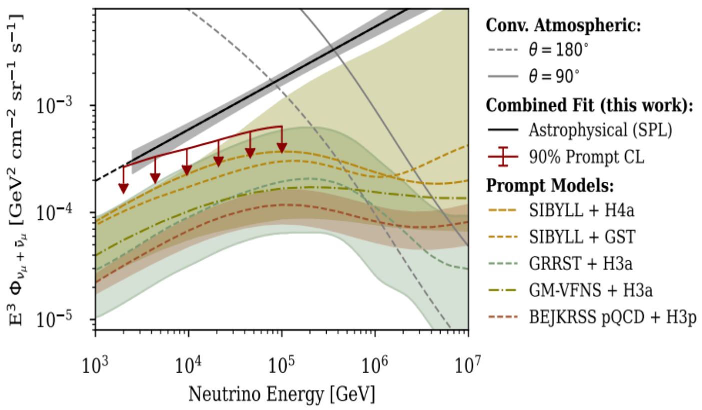
The IceCube collaboration has submitted a paper *Constraining the Prompt Atmospheric Neutrino Flux Combining IceCube's Cascade and Track Samples* to EPJ C (posted at https://arxiv.org/pdf/2512.17760). The main authors are Jakob Böttcher, Philipp Fürst, and Christopher Wiebusch (all RWTH Aachen).

Prompt atmospheric neutrinos may constitute a non-negligible background to the diffuse flux of high-energy astrophysical neutrinos. They dominantly originate from the decay of charmed mesons produced in cosmic-ray-induced air showers. The production rate of charmed mesons in the very forward phase space of hadronic interactions, and consequently, the prompt neutrino flux, remains uncertain. An accurate measurement of this flux would enhance the understanding of fundamental particle physics such as hadronic interactions in high-energy cosmic-ray-induced air showers and the nucleon structure. Furthermore, an experimental characterization of this background flux will improve the precision of astrophysical neutrino flux spectral measurements. In this work, a combined fit of cascade-like and track-like neutrino events in IceCube is performed, with the goal to constrain the prompt atmospheric neutrino flux. Given that the prompt flux is a sub-dominant contribution, treating systematic uncertainties arising from the potential mis-modeling of the conventional and astrophysical neutrino fluxes is critical for its measurement. The analysis yields a non-zero best-fit result, which is, however, consistent with the null hypothesis of no prompt flux within one standard deviation. Consequently, an upper bound is derived, see the following figures.



Limit on the prompt atmospheric neutrino flux (in dark red) compared to the previous 6-year NT-limit (blue dashed line). The limits are given in their respective sensitive energy ranges. The best-fit prompt flux is also shown, the fitted segmented astrophysical flux in black, and the conventional atmospheric neutrino flux as a gray line.

The figure next page relates this limit to model predictions (see the paper for details).



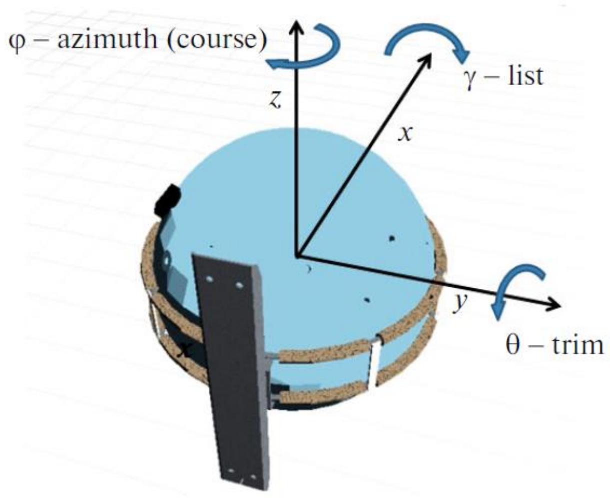
Model predictions for prompt neutrino fluxes. Shown are the models SIBYLL, GRRST, GM-VFNS and BEJKRSS, as dash-dotted and dashed lines. Uncertainties for the latter three are plotted as colored bands in grey-green, olive, and red, respectively. The conventional neutrino flux (Conv.) from vertical zenith direction θ = 180◦ (dashed line) and horizontal zenith direction θ = 90◦ (solid line) direction is shown in grey. Also shown are the results of this analysis as an upper limit on the prompt flux (dark red) and the best-fit single power-law spectrum (SPL) of astrophysical neutrinos (black line).

The Baikal GVD Collaboration has published a paper *Application of an Inertial Positioning System for Estimation of Coordinates and Orientation of Optical Modules of the Baikal-GVD Deep Underwater Neutrino Telescope* in Приборы и Техника Эксперимента (Instrum. Exp. Tech. 68, 453–460 (2025), https://doi.org/10.1134/S0020441225700551). The English version appears to be not "open access", even though the Russian version is, so please contact Dmitry Zaborov (zaborov@inr.ru) if you want to get an author's copy.

Position and orientation of the GVD Optical Modules are determined by two systems: the hydroacoustic positioning system and inertial positioning system.

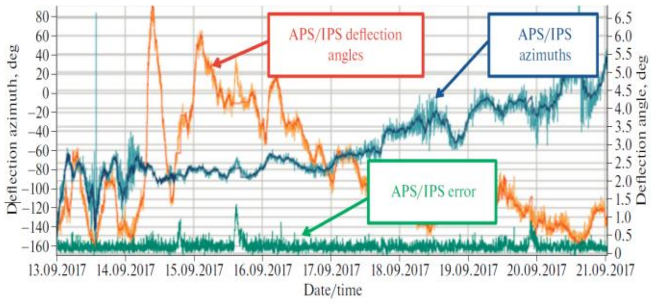
The Hydro-Acoustic Positioning System (APS) consists of four acoustic modems ("beacons") installed along strings. Their transmitters and receivers are directed downwards. Some strings have additional modems installed near the anchor, their receivers and emitters are directed upward, their coordinates are assumed to be constant and are determined from the ice-surface soon after the installation of all the cluster strings

The Inertial Positioning System (IPS) is designed to estimate the spatial orientation and coordinates of the OMs based on data from the spatial orientation sensors (SOS) installed on the OM controller board. The SOS includes a three-axis accelerometer and a three-axis magnetic field sensor, see the next figure.

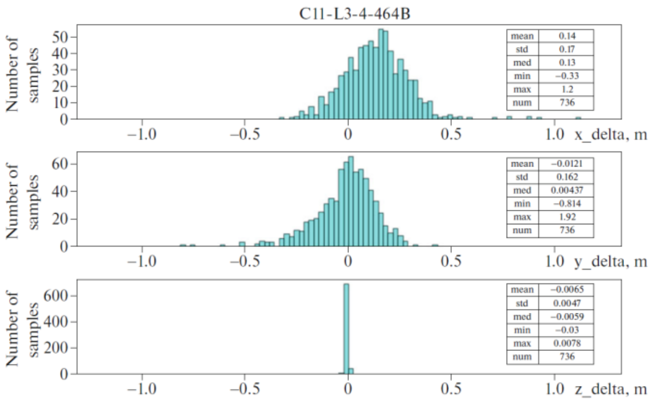


The paper describes in detail how the IPS is calibrated and how not only the orientation but also the position of OMs can be derived from the IPS. The IPS allows obtaining a result with a time interval of 1–2 min, significantly less than the APS time interval of the order of 10 minutes. (With an average beacon speed of 0.5 cm/s, an APS beacon can move more than 3 m from the previous measurement before a new measurement is completed!)

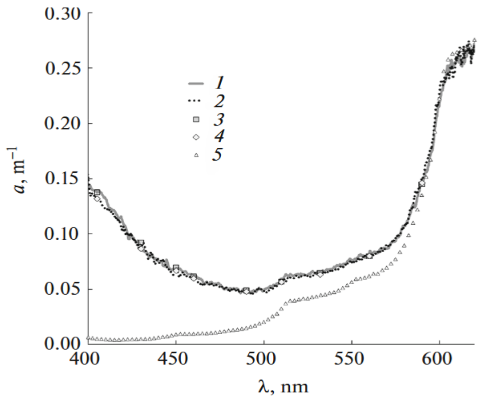
The next two figures demonstrate the agreement between the two systems.



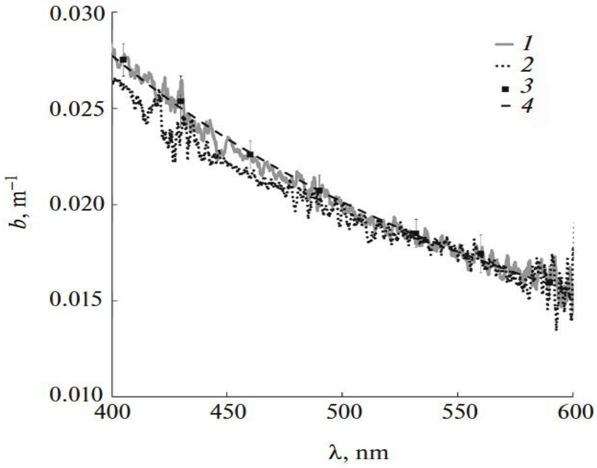
Orientation angles (deviation from vertical, right scale, and azimuth, left scale) of the APS and IPS sections (the IPS data are the light-colored, stronger fluctuating data, the APS data the dark colored data).



Comparison of the coordinate estimation result by APS and IPS.



Absorption spectra (May 11, 2023): algorithm A2, depth 1100 (1) and 1180 m (2); algorithm A1, depth 1100 (3) and 1180 m (4); absorption spectrum of clear water (5).



Scattering spectra (depth is 1100 m): algorithm S2, April 5, 2023, (1) and November 16, 2023, (2); algorithm S1, April 5, 2023 (3); approximation $b(\lambda) = B\lambda^{-\mu}$ of the spectrum of April 5, 2023.

The Baikal GVD collaboration has published a paper *Instruments and Techniques for Long-term Monitoring of Optical Properties of Deep Waters of Lake Baikal* in the Journal Atmospheric and Oceanic Optics, 2025, Vol. 38, No. 5, pp. 609–617. https://link.springer.com/article/10.1134/S1024856025700484?fromPaywallRec=true

The device described in this paper is the successor of the ASP-15 device, described e.g. in https://link.springer.com/article/10.1134/S1024856011020151. The new device was named Baikal-5D. Like ASP-15, it was developed and built at the Applied Physics Institute of Irkutsk State University (API ISU). Baikal-5D is used to measure the inherent optical properties of the deep Baikal water.

Summarizing the technical description of the device and its operation modes is beyond what can be done in GNN Monthly (be it only due to the very detailed drawings of the device). Therefore, I will just reproduce two figures with the results on absorption and scattering length (see the paper for details of the algorithms used).

And finally:

A happy and successful New Year to all of you!

GNN Monthly is the Newsletter of the Global Neutrino Network
https://www.globalneutrinonetwork.org
Editor: Christian Spiering, for the GNN Board
christian.spiering@desy.de