GNN Monthly
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https://www.globalneutrinonetwork.org/

New from the projects

KM3NeT

Second node of ORCA installed 13 August 2025. The submarine network of ORCA comprises two long-distance electro-optical cables for communication between the detector and the control station on the shore and a set of submarine *nodes*, each designed for the connection of up to 24 detection units.

Installation of the node on the ship deck

The installation of a node is a complex operation, executed through close collaboration between ship crews, ROV operators and dedicated KM3NeT teams on board and in the control station. First, the end of the submarine cable was recovered from the seafloor to the deck of the cable ship, where two cable joints were made to connect the node to the cable. Several tests were conducted with the node still on the deck to ensure that the connection was fully functional. Then the deployment of the node started with the cables laid back – to avoid damage the deployment required carefully coordinating the movements of the ship and the lift lowering the node. Finally, the node safely landed on its target position at 2500 m depth within an accuracy of a few meters. Now it is ready for connection of detection units. Four are already deployed. Up to six more will be deployed in the fall.

Deployment of the ROV

The campaign was executed with a cable ship of *Orange Marine* equipped with a work-class ROV for assisting with inspections and operations on the sea bottom, with the support of a vessel of *Foselev Marine*. The ROV used was a novel vehicle which can be operated either in flying mode or in crawler mode. It was the first time that the KM3NeT crew used this ROV.

IceCube

Here is one of the last Antarctic-Night photos for this year:

The station with it's red lights and the power plant exhaust blocking the moon.

Still its night, but summer is coming, as winterover Ilya Bodo demonstrates with the following photo:

With the Sun on its way up, a small amount of light can now be seen on the horizon.

IceCube started its "Voices of IceCube" initiative (https://icecube.wisc.edu/outreach/voices-of-icecube/). The project features blog-style posts highlighting the individuals behind the science. It also provides science communication experience for early career scientists who conduct the interviews and write the posts. The project is inspired by the popular blog "Humans of New York," which has been successfully applied to several scientific collaborations through projects like "Humans of LIGO" or "Faces of DUNE" among other efforts.

RNO-G

RNO-G concluded its field season with all 8 stations maintained and operating as they should. 12 holes (4 x 3) are waiting to be filled with instrumentation next year. A large number of calibration measurements have been obtained. The collaboration will meet in the fall in Maryland to set the goals for next year.

The picture shows members in the annual Moskus Charity run (http://www.runningofthemoskus.org/) all over Greenland and at Summit Station. Nat and Nils from RNO-G (2nd and 3rd from left on the picture below) helped with getting the largest turn-out ever for this community engagement event.

Baikal-GVD

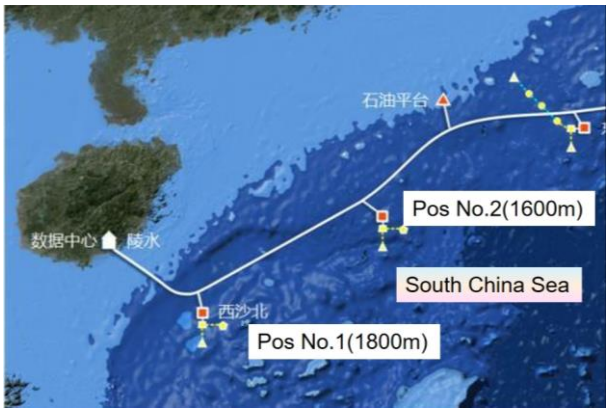
The summer expedition at the shore station of the Baikal Neutrino Detector is coming to an end. The work was primarily aimed at preparing machinery and ice equipment for the winter expedition and the deployment of the next clusters. Work has been completed to update the power supply system of the shore infrastructure. A workshop was built and put into operation. It will serve for the instant repair of ice-cutting equipment for laying cable lines and for ice transport vehicles. Also, excavation work has been carried out to prepare for the expansion of residential and technical coastal infrastructure.

Tractor for the ice-cutting machine

The new workshop

Progress at other sites: HUNT

The HUNT collaboration is focusing on the preparation of a small array (presumably 7 strings with 8 OMs each) which is planned to be deployed in the South China Sea in the next half year.



A partner of HUNT has laid a submarine cable in the South China Sea – a project called Deepsea Network China. This cable can provide several kW power and a large-capacity optical fiber network for data transmission. The prototype array would be deployed in position No.1 or No.2 (see the picture) and would be directly connected to the submarine cable. Right now, the assembly of 60 OMs in the laboratory is almost completed.

GNN Dissertation Prize

Luc Cerisy (Aix-Marseille Université/CNRS Marseille) won the 2024 GNN Dissertation Prize for his thesis "*First tau neutrino appearance, non-unitary mixing and absolute orientation measurements in KM3NeT*" which was one of ten submitted theses.

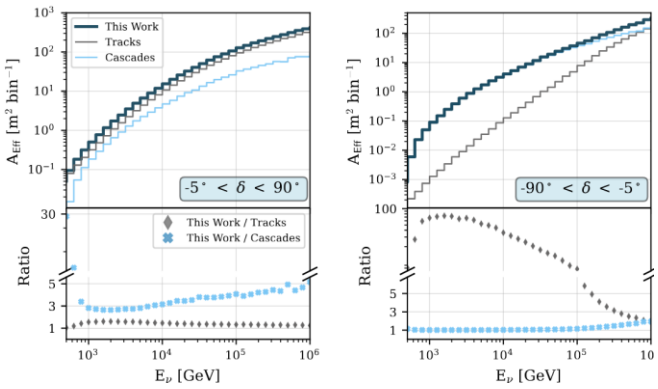
Congratulations, Luc!

Publications

The *IceCube Collaboration* has submitted several papers in July and August and posted the ICRC reports at https://arxiv.org/abs/2507.08666 (IceCube) and https://arxiv.org/abs/2507.08667 (IceCube-Gen2).

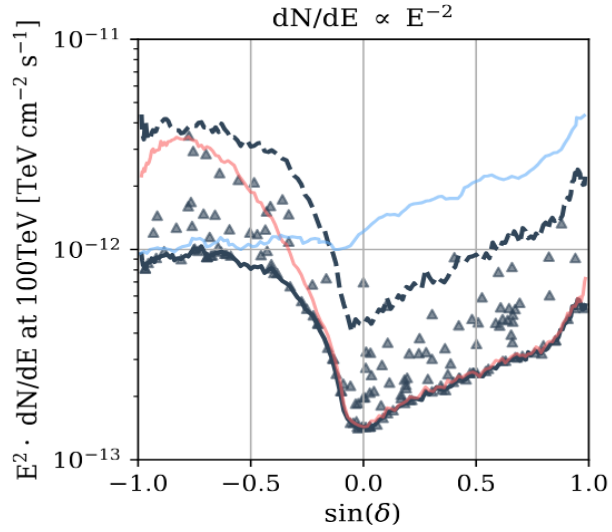
The paper *All-sky neutrino point-source search with IceCube combined track and cascade data* is posted at https://arxiv.org/abs/2507.07275 and has been submitted to ApJ. Leading author is Riya Shah from Drexel University, Philadelphia.

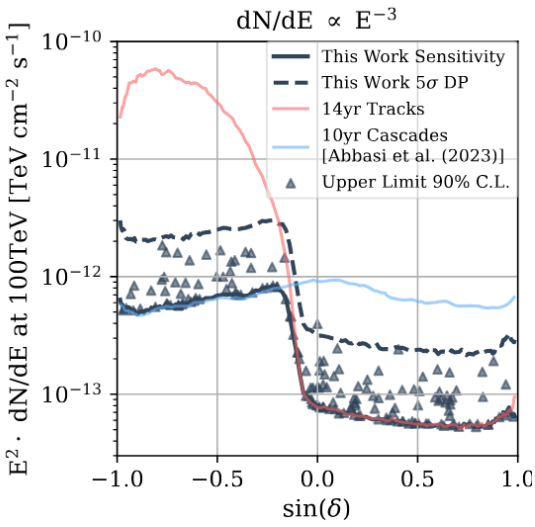
The paper presents an event-level simultaneous maximum likelihood analysis of tracks and cascades using IceCube data collected from 2008 to 2022 to search the whole sky for neutrino sources and, using a source catalog, for coincidence of neutrino emission with gamma-ray emission. This is the first simulta--neous fit of different detection channels to conduct a time-integrated all-sky scan with IceCube.



***Effective Area Comparison**. The effective area in m^2 (averaged over solid angle) of all-flavor neutrinos per energy bin for tracks (this work), cascades (Abbasi et al. 2023), and the combined sample (this work). Effective areas are averaged over solid angle in the declination range of −5◦ to 90◦ for the northern sky (left) and in the range of −90◦ to −5◦ for the* southern sky (right). *Each decade in energy contains 10 bins. The ratio of the combined sample effective area to each component effective area is shown for each sky.*

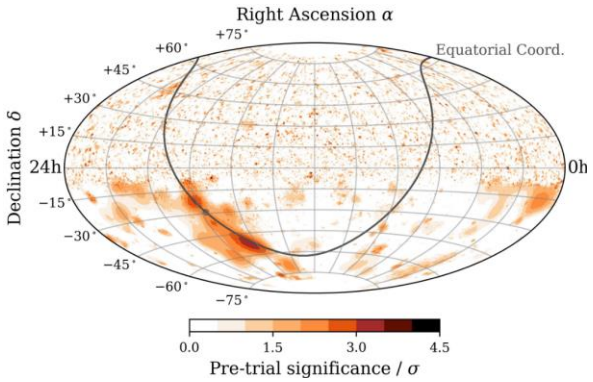
Combining all-sky tracks (with superior pointing-power and sensitivity in the northern sky) with all-sky cascades (with good energy-resolution and sensitivity in the southern sky), this is the most sensitive point source search to date by IceCube which targets the entire sky. The most significant point in the *northern* sky aligns with NGC 1068, which shows a 3.5σ excess over background after accounting for trials (compared to 4.2σ in https://arxiv.org/abs/2211.09972 - which used a different source list, less data and a different reconstruction method). The most significant point in the *southern* sky does not align with any source in the catalog and is not significant after accounting for trials.





***Source List Sensitivity, 5σ Discovery Potential and Upper Limits.** 90% C.L. median sensitivity to sources emitting an E^{-2} spectrum (top) and E^{-3} spectrum (bottom) as a function of source declination for cascades and tracks individually and for combined tracks and cascades. The 90% C.L. upper-limits for the source catalog sources are shown assuming an E^{-2} spectrum (top) and E^{-3} spectrum (bottom). For sources with the best-fit number of signal event = 0, the 90% C.L. median sensitivity is used instead of the upper limit. The 5σ discovery potential (DP) for combined tracks and cascades is also shown. dN/dE is the per-flavor number of neutrinos (N) per neutrino energy (E) per area per time.*

Eight sources in the catalog have a pre-trial p-value ≤ 0.01. These sources are NGC 1068, PKS 1424+240, PMN J1650-5044, GB6 J1542+6129, TXS 0506+056, G343.1-2.3, PMN J1603-4904, and MGRO J2019+37. The full pre-trial significance skymap for combined tracks and cascades is shown in the next figure.

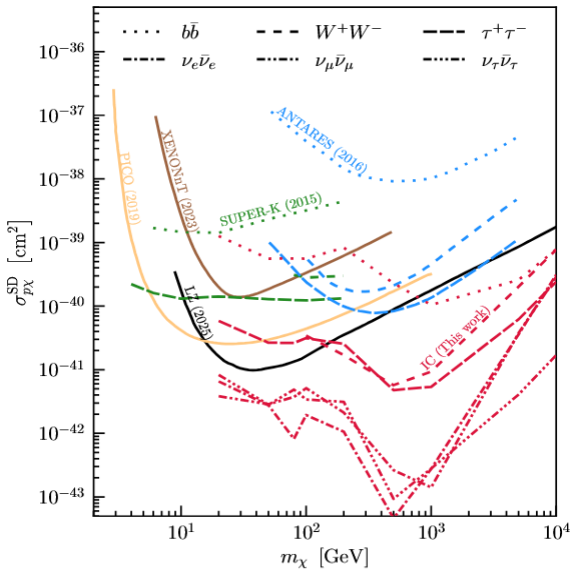


***Combined Tracks and Cascades Skymap.** Best-fit pre-trial significance all-sky Aitoff projection map using combined cascades and tracks as a function of direction in equatorial coordinates (J2000 equinox). The solid gray line denotes the galactic plane with the dot representing the galactic center. The hottest northern spot matches the hottest northern spot seen in the tracks skymap. The hottest southern spot is not the hottest southern spot in either component skymaps.*

A search for the single most significant Gaussian flare at the locations of NGC 1068, PKS 1424+240, and the southern highest significance point shows results consistent with expectations for steady emission. Notably, this is the first time that a flare shorter than four years has been excluded as being responsible for NGC 1068's emergence as a neutrino source.

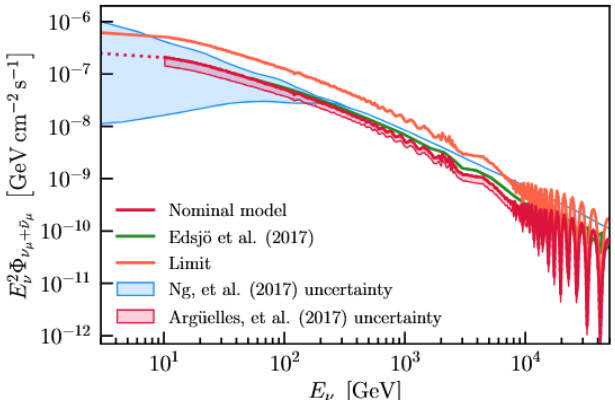
The paper *Search for High-Energy Neutrinos From the Sun Using Ten Years of IceCube Data* has been submitted to Phys.Rev.Lett. and is posted at https://arxiv.org/abs/2507.08457. The main contributions come from J. Lazar (Université catholique de Louvain), Q. R. Liu (University of Wisconsin) and I. Martínez-Soler (Harvard University).

The paper presents the results of a search for high-energy neutrinos produced by the annihilation of dark matter particles trapped in the Sun. Using 9.3 and 10.4 years of data from DeepCore and IceCube, and observing no excess of neutrinos from the direction of the Sun, the world-best limits for spin-dependent interactions between dark matter and Standard Model particles for dark matter masses from tens of GeV to tens of TeV are established (see the figure below).



Limits on the spin-dependent DM-proton cross section from this analysis, compared to existing limits on this cross section from other experiments. Direct detection experiments are shown with solid lines, indirect detection experiments with line styles corresponding to the annihilation channel. This analysis achieves world-leading limits for most annihilation channels for WIMPs above 200 GeV.

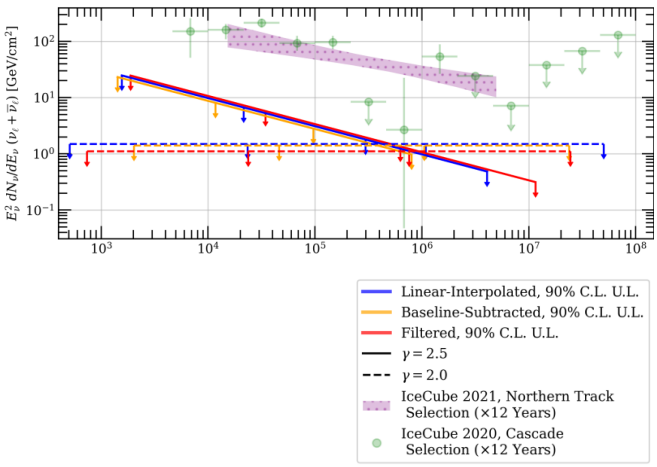
Additionally, constraints on the neutrino background produced by interactions of cosmic rays with the solar atmosphere are derived – see the figure below.



Comparison of solar atmospheric fluxes. The "nominal model" (see the paper for definition) is shown as a thick red line. This model had to be extrapolated beyond the limits of the initial calculation between 1 GeV and 10 GeV. This was done using a quartic spline, and the result is shown as a dashed red line. The uncertainty region from a recent work of Argüelles et al. is shown as the shaded red region. The uncertainty region from Ng et al. results from uncertainties on the impact of the solar magnetic field on the primary cosmic-ray flux. The coral line shows the limit set by this analysis at 2.48 times the nominal model.

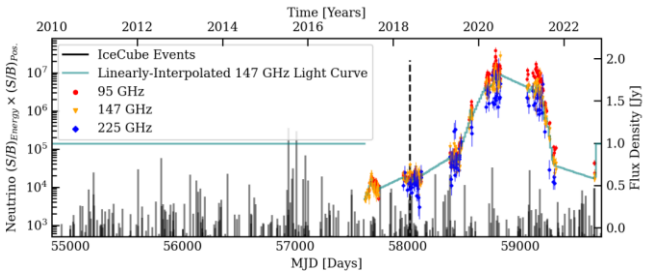
The paper *A Search for Millimeter-Bright Blazars as Astrophysical Neutrino Sources* has been posted at https://arxiv.org/abs/2507.03989 and is submitted to ApJ. Leading author is Alina Kochocki (Michigan State University).

Jets of blazars are considered as likely sites of high-energy cosmic-ray acceleration. In the case when leptonic and hadronic particle injection occur jointly, a temporal correlation between synchrotron radiation and neutrino production is expected. Here, a first catalog of millimeter (mm) wavelength blazar light curves from the Atacama Cosmology Telescope is used to search for a time-dependent correlation with twelve years of muon neutrino events from IceCube. Such mm emission is known to trace activity of the bright jet base, which is often self-absorbed at lower frequencies and potentially gamma-ray opaque. In this paper, an analysis of the population, as well as analyses of individual, selected sources is performed. No significant signal from the stacked population is observed, see the next figure.



Upper limits on the contributions of the stacked population of ACT blazars to the observed high-energy diffuse neutrino flux. Here, upper limits from the three stacked analyses performed are shown, assuming neutrino spectra of indices 2.0 and 2.5. Note that the upper limits for the linearly-interpolated and baseline-subtracted models for a spectral index of 2.0 are nearly overlapping. The flux intensity represents the cumulative flux from the stacked population, corrected to represent a complete set of sources. 90% sensitive energy ranges are shown. The purple butterfly band is taken from a 2020 IceCube measurement of the all-sky diffuse tau and electron flux and is shown for comparison. Similarly, green data points are taken from an analysis of track-like events originating from the northern hemisphere (2022). All pictured fluxes represent a single-flavor flux including both neutrinos and antineutrinos.

The results suggest that the majority of mm-bright blazars are neutrino dim. In general, it is possible that many blazars have lighter, leptonic jets, or that only selected blazars provide exceptional conditions for neutrino production. TXS 0506+056 is found as the most significant, individual source, however, without correlation to GHZ radio data (see e.g. next figure).



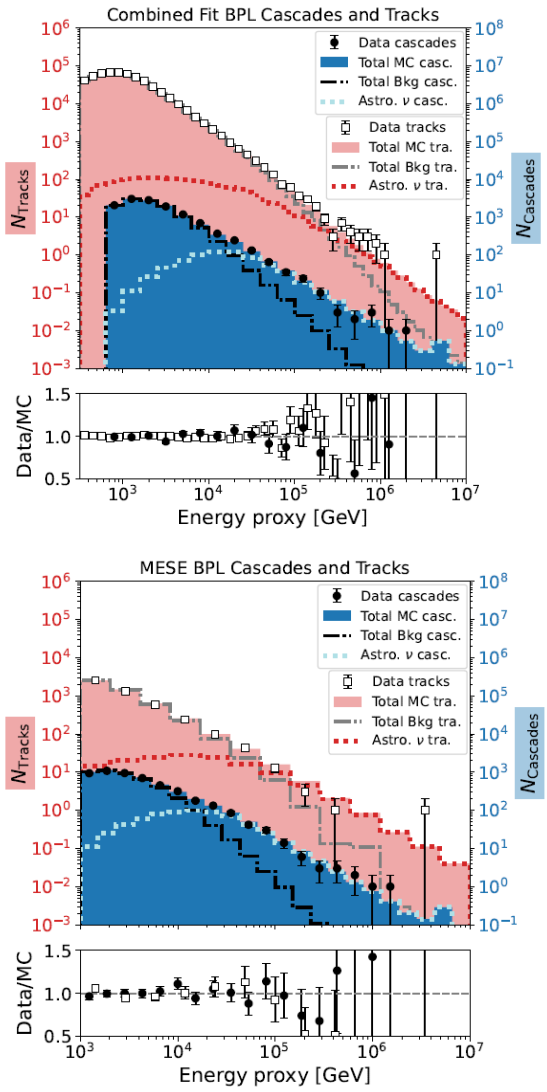
Events contributing to the TXS 0506+056 excess. Shown are neutrino events weighted with energy and spatial as a function of time for events within 1.5 degrees of TXS 0506+056. Also shown are the 95, 147 and 225 GHz data and the linearly-interpolated 147 GHz light curve. The alert event, IC-170922A, is indicated with a dashed line. There is not an obvious correlation between the mm flux density flare from 2019 to 2021 and any neutrino activity.

The paper states a possible conflict between this analysis and analyses of IceCube data performed by non-IceCube authors (Plavin et al. 2020; Plavin et al. 2021; Hovatta et al. 2021; Plavin et al. 2023): "*The increased IceCube data lifetime and the improved analysis methods of this work utilize event observables (reconstructed energy, direction and time) to provide a maximally sensitive search. As these millimeter wavelengths are generally accepted as a preferred tracer of radio–mm synchrotron activity from the blazar core, it is more likely that radio–mm blazar emission is not an important tracer of neutrino production.*"

The next IceCube paper *Evidence for a Spectral Break or Curvature in the Spectrum of Astrophysical Neutrinos from 5 TeV–10 PeV* has been submitted to PRL (posted at https://arxiv.org/pdf/2507.22233) and, in a longer version with more details to Phys.Rev.D (titled *Improved measurements of the TeV- PeV extragalactic neutrino spectrum from joint analyses of IceCube tracks and cascades*). Main contributions come from Aswathi Balagopal V. (UW Madison/Bartol Delaware), Vedant Basu (U. Utah), Erik Ganster (RWTH Aachen), and Richard Naab (DESY).

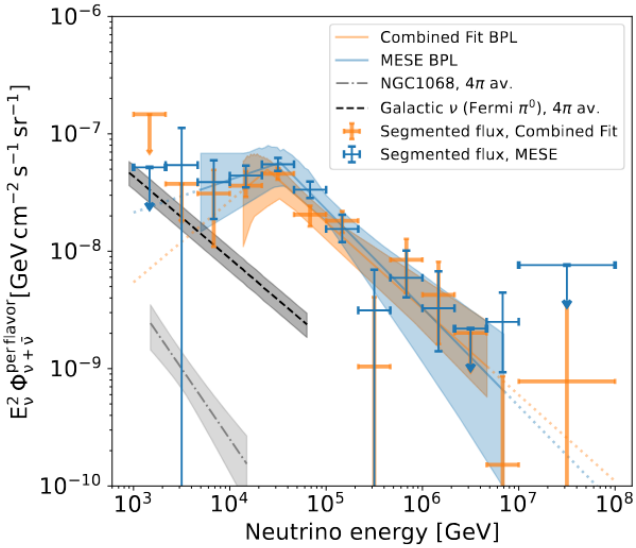
The paper reports improved measurements of the all flavor astrophysical neutrino spectrum with IceCube by combining complementary neutrino samples in two independent analyses. The first analysis, referred to as the "Combined Fit" (CF), is based on the combination of existing data samples: tracks (focused on the Northern sky, where ~ 60% events are through-going tracks), and the latest all-sky contained cascades sample. The second analysis expands the pioneering concept of high-energy starting events (HESE) to lower energies of a few TeV by selecting "Medium Energy Starting Events" (MESE). The MESE events are classified as starting tracks and starting cascades to account for their different backgrounds and uncertainties.

The next figure gives basic information on the two samples.



Energy distribution of cascade- and track-identified events used in the CF and MESE analyses: Contributions from astrophysical neutrinos, assuming the best-fit broken power-law spectrum, total background (atmospheric neutrinos and muons) along with the total contributions compared to data for CF on the top (8.5 years of tracks and 10 years of cascades) and MESE on the bottom (11.4 years). Note the different scales for tracks (left axis) and cascades (right axis). Here, energy proxy represents the reconstructed energy for the given event type which is different for cascades, MESE tracks, and CF tracks. Hence these energy proxies are not directly comparable.

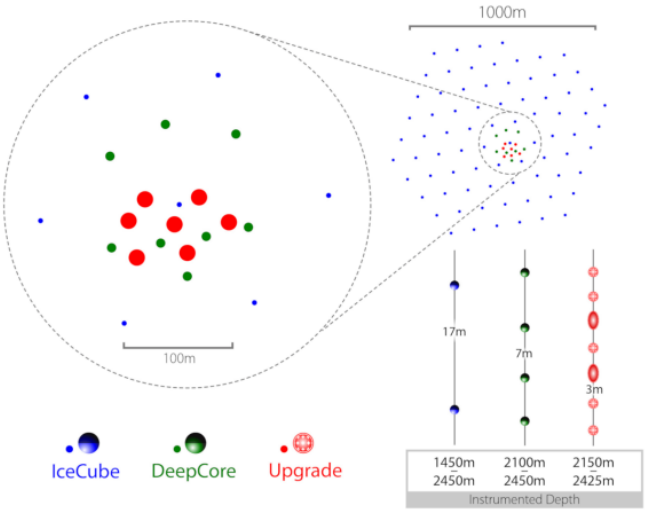
Both analyses show evidence of a harder spectrum at energies below ~30 TeV compared to higher energies where the spectrum is well characterized by a power law. The spectrum is better described by a log parabola or a broken power law, the latter being the preferred model. Both, however, reject a single power law over an energy range 5 TeV-10 PeV with a significance > 4σ, providing new constraints on properties of cosmic neutrino sources.



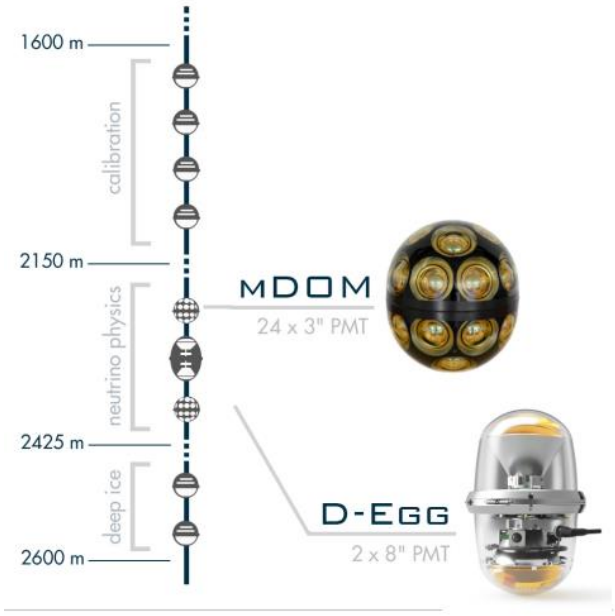
Segmented Flux: The fit to the astrophysical flux normalization assuming an E^{-2} spectrum is shown in each segment. Orange markers and shaded regions represent CF while MESE is shown in blue. The shaded regions show the 68% uncertainties and sensitive energy ranges for each analysis obtained from profile likelihood scans of the four parameters of the BPL model. The flux from NGC 1068 and the galactic plane measured with IceCube lie at much lower scales.

A paper *The LED calibration systems for the mDOM and D-Egg sensor modules of the IceCube Upgrade: Design, production, testing and use in module calibration* has been submitted to JINST and is posted at https://arxiv.org/pdf/2508.03822. This is a truly collaborative work, with Martin Rongen (ECAP Erlangen) as the main editor.

The IceCube Upgrade, to be deployed during the 2025/26 Antarctic summer season, will consist of seven new strings of photosensors, densely embedded near the bottom center of the existing array. Aside from investigating neutrino oscillations, a primary goal is the improvement of the calibration of the optical properties of the instrumented ice. These will be applied to the entire archive of IceCube data, improving the angular and energy resolution of the detected neutrino events. For this purpose, the Upgrade strings include a host of new calibration devices. Aside from dedicated calibration modules, several thousand LED flashers have been incorporated into the photosensor modules.



IceCube upgrade: red dots indicate the positions of the 7 Upgrade strings.



The subdivision of the vertical geometry into a shallow calibration region, the depth dedicated to neutrino (oscillation) physics as well as an exploratory deep-ice region below the depth instrumented by IceCube.

The paper describes design, production, and testing of these LED flashers before their integration into the sensor modules as well as the use of the LED flashers during lab testing of assembled sensor modules. The next two pictures show the two DOM versions and explain the positions of the LEDs.

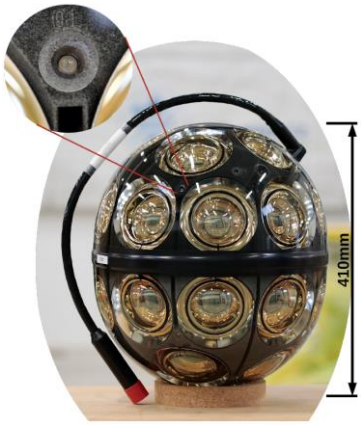
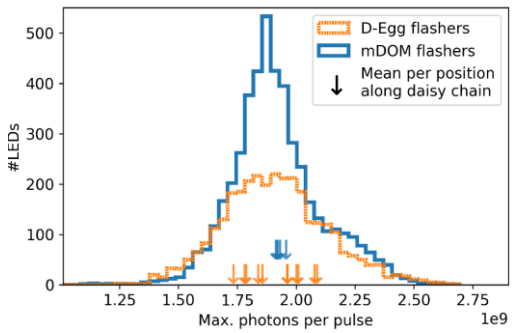


Photo of an assembled mDOM. One flasher daisy chain is integrated into the black support structure of each hemisphere. Eight LEDs point outward at elevation angles of 29◦, and two LEDs point vertically upward/downward. The LEDs are separated by small glass windows from the optical gel, which glues the support structure into the glass pressure.

CAD rendering of an assembled D-Egg. The annular PCB comprising the LED calibration system can be seen resting in the optical gel gluing the lower PMT to the glass pressure vessel.

The table summarizes the design specifications of the LED system, the picture shows the distributions of measured maximum photon yields for all LEDs.

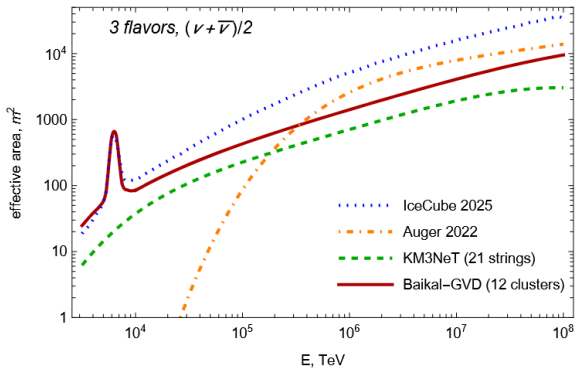
Requirement	Description
Operational temperature	Meet specifications between -30°C (accounting for module self-heating) and +27°C.
Brightness range	$5 \cdot 10^6$ to 10^9 photons per pulse.
Emission spectrum	Central value of 405 ± 10 nm with a FWHM below 30 nm.
Angular distribution	Approximately Gaussian in each degree of freedom with standard deviations not exceeding 15 degrees.
Time profile	FWHM ≤ 7 ns for dim settings and ≤10 ns at maximum brightness.
Accuracy of emission axis	Each LED axis shall be aligned within a 5-degree solid angle tolerance of its nominal design direction.
Controllability of brightness	The LED intensity shall be configurable to within ±50% of any target value in its dynamic range.
Consistency of brightness	The per pulse output of each LED shall be consistent to within 10% standard deviation for a duration of 30 minutes.



Histograms of measured maximum photon yields for all D-Egg and mDOM LEDs. The arrows indicate the mean maximum photon count per individual LED position. The D-Egg LEDs feature a position dependence due to layout differences. This is not the case for the mDOM flashers, which are all produced equally, but their distribution is bimodal due to LED characteristics.

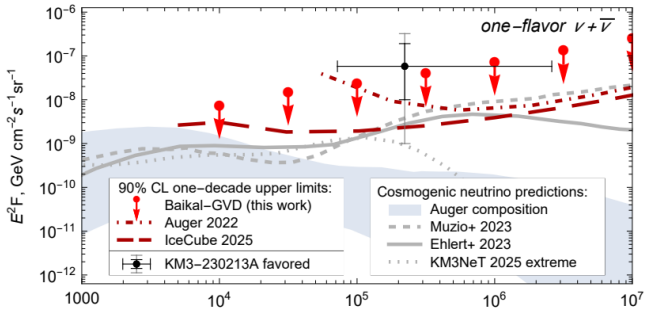
The Baikal GVD collaboration has submitted a paper *Constraints on the diffuse flux of multi-PeV astrophysical neutrinos obtained with the Baikal Gigaton Volume Detector* to Phys. Rev. D (posted at https://arxiv.org/abs/2507.05769) Leading authors are Zhan Djilkibaev and Sergei Troitsky (INR Moscow).

Various theoretical models predict cosmic neutrinos with multi-PeV energies. The recent detection of a $\sim 10^{17}$ eV neutrino with KM3NeT suggests that these energetic neutrinos may be in reach for underwater detectors. The analysis is based on cascade-like events, using many-year data taken with the growing detector, including those taken with the 12-cluster configuration. The next figure compares the effective areas of IceCube, Auger, KM3NeT in its 21-string version and Baikal-GVD in its 12-cluster version.



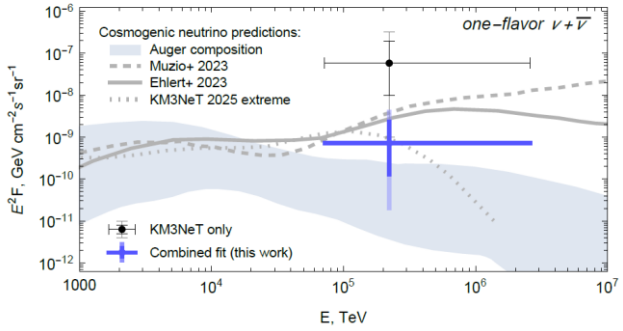
Effective areas of Baikal-GVD (cascades, 2023 configuration, full red line, this work), KM3NeT (ARCA bright track selection, 2023 configuration, dashed green line), Auger (2022 analysis) dot-dashed orange line), and IceCube (2025 analysis, dotted blue line) for the detection of very high energy neutrinos (exposure-weighted full-sky average, three flavors, average over neutrino and antineutrino).

The Baikal data taken with the growing detector between 2018 and 2023 as used in this analysis correspond to ~ 2 years of the present configuration of the detector. No event above $10^{15.5}$ eV is found, resulting in the upper limits on the flux of astrophysical neutrinos with energies ($10^{15.5}$ – 10^{20}) eV shown in the figure.



Very high energy diffuse neutrino fluxes. Red arrows: upper limits from Baikal-GVD cascades (this work). The other limits are from Auger and IceCube, while the black point with error bars is the value favored by the observation of KM3-230213A event (68% confidence limit). For comparison, some of the predictions of the cosmogenic neutrino flux are shown (see the paper for details).

The paper finally discusses the astrophysical implications of these results and constrain several cosmogenic neutrino scenarios using a combination of Baikal-GVD, KM3NeT, IceCube and Auger data – see the figure.



Very high energy diffuse neutrino fluxes per one flavor, sum of neutrinos and antineutrinos (assuming isotropic flux and flavor equipartition). The blue cross represents the result of the combined fit of four experiments (darker – 90% CL in energy, 68% CL in flux; lighter – 95% CL in flux). Other notations are the same as in the previous figure.

Impressum
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