GNN Monthly
The Global Neutrino Network
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https://www.globalneutrinonetwork.org/

News from the experiments

KM3NeT

KM3NeT deployment plans: the next ARCA deployment is scheduled in July, the next ORCA one between May 12 and 22. The window in March could not be used in the end due to adverse weather.

The third KM3NeT Town Hall Meeting took place in the School of Physics of Les Houches, close to Chamonix (France), in front of the Mont Blanc, from 13th to 18th April 2025. It brought together a vibrant community of scientists to exchange ideas, present recent progress, and build new external collaborations in the field of neutrino astronomy. Held in person, the agenda featured plenary sessions in the mornings and interactive working groups in the afternoons, fostering deep discussions between experimentalists and theorists. This meeting structure proved highly effective in encouraging meaningful collaboration and idea-sharing across the astroparticle physics community.

Highlights of the meeting included updates on the status and performance of KM3NeT's ORCA and ARCA detectors, as well as discussions on ultra-high-energy events (among which, of course, KM3-230213A), Galactic neutrino sources and neutrino follow-up strategies. Additionally, poster sessions showcased ongoing analyses and new research directions. With its promising angular resolution, broad energy range and sky-coverage, KM3NeT is positioned at the forefront of the multi-messenger astronomy era. The Town Hall Meeting reinforced the groundwork for exciting future collaborations.

On a lighter note, the event also featured networking sessions on mountain trails, where participants enjoyed scenic trekking routes, and a surprising April snowfall, which added both charm and challenge to the experience – see the pictures below. Thanks to Damien Dornic for organizing the meeting and to Francesco Carenini for providing the text!

IceCube

Erin O'Sullivan (Univ. Uppsala) will start as new spokesperson on May 1st (taking over from Ignacio Taboada). There will be an IceCube Collaboration Meeting in Uppsala from May 12 to May 16. Uppsala has hosted IceCube once before (2011) and AMANDA once as well (1999).

Nothing new at the South Pole. Night is falling. See below another photo of the IceCube Laboratory, this time against a slowly darkening sky.

And here a view of the IceCube Upgrade drill camp generator containers as the snow drift begins to build up around them. You can imagine what the snow drift will look like in almost seven months, when the upgrade operations will be starting…

Baikal photos as usually provided by Bair Shaibonov, JINR Dubna →

Baikal-GVD

The 2025-expedition of Baikal GVD has been finished on March 28. The Baikal-team has deployed the 14th cluster with 8 strings. The additional "outer" string (the ninth) of this cluster will be added next year. Moreover, repair and modernization operations for clusters 1 to 13 have been performed. Last but not least, two "Chinese" strings built by the Institute of High Energy Physics, Beijing, have been deployed (one prototype string and one full-scale string, with 12 and 24 20-inch PMTs, respectively). In parallel with the expansion of GVD, scientists from the Irkutsk State University and the Limnological Institute of the Academy of Sciences conducted a number of experiments on hydrology.

Work on ice ended two weeks earlier than usual due to too warm weather lasting during the winter and the entire expedition. Snowless weather after the ice-formation and sharp day-night temperature changes led to numerous cracks in the ice cover. Due to the lack of snow in the second half of the expedition, the ice was exposed to the bright sun. This, together with the warm weather, strongly changed the ice structure and led to a decrease in its load capacity. Therefore, the camp was folded ahead of schedule. A similar situation is met about once every ten years (hopefully not more frequently in the future, given global warming!). The ice situation prevented the deployment of a 15th cluster and the laying of an additional shore cable. On the positive side, the early departure from the ice gave some more time to reorganize the computing center at shore.

The usual end of the season photo on the ice, this time with a watered crack dividing the crew in two parts.

Part of the crew in front of the century-old shore station.

A dog interested in neutrinos

Three physicists from Beijing working with an Optical Module

Alexander Doroshenko and Igor Belolaptikov

At the shore: spring falls in …

… and in the kitchen: the last pastries are prepared.

P-ONE

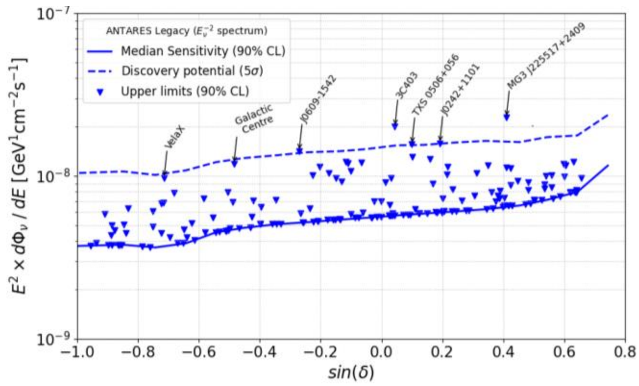
Another Art & Science project initiated by Elisa Resconi: *Radio Amnion: Sonic Transmissions of Care in Oceanic Space*, a multi-year sound art project for water-bodies of the Earth by quantum ecologist Jol Thoms. A radio station broadcasts commissioned compositions by contemporary artists into the Pacific at a depth of 2 km – you may listen to some of the compositions on https://radioamnion.net. The project is funded by the Canadian Council for the Arts. The cooperation will officially kick off on Friday, April 25, in the "Haus der Kunst" in Munich. More on this and on P-ONE in the next GNN Monthly.

Publications

The ANTARES collaboration has submitted an 80-page legacy paper *The ANTARES detector: two decades of neutrino searches in the Mediterranean Sea* to Physics Reports (posted at https://arxiv.org/pdf/2504.09473).

ANTARES was the first neutrino telescope in seawater, operating successfully for more than a decade and a half. The initial challenges and problems related to the operation in the deep sea could be solved, deployment and connection operations became smoother over time; data taking and constant re-calibration of the detector due to the variable environmental conditions were fully automated. A wealth of results on the subject of astroparticle physics, particle physics and multi-messenger astronomy have been obtained, and this despite the relatively modest size of the detector. ANTARES has paved the way to a new generation of larger undersea detectors like KM3NeT.

Readers of GNN Monthly know the ANTARES results, so I show here only one “legacy figure” which gives the final upper flux limits for 169 potential sources.



90% CL upper limits (blue points) on the one-flavor neutrino flux for the 169 potential sources vs. the sinus of the declination δ. The solid line indicates the 90% CL median sensitivity, while the dashed line the 5σ discovery potential assuming a $E^{-2.0}$ ν energy spectrum.

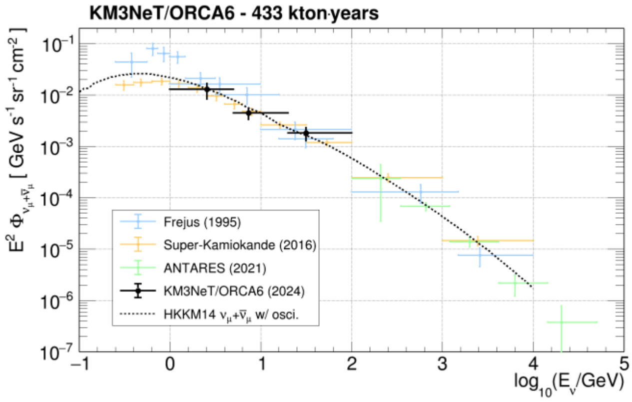
At the end of the dismantling operations in June 2022, all the 885 optical modules were recovered. Some of them were not functioning anymore (the failure rate was on average one OM per month). A few of these have been distributed to different institutions of the collaboration for exposition purposes.

Most of the OM failures were related to the active base or motherboard of the offshore electronics, and not to the phototubes. Many components of the ANTARES detector have been reused after the dismantling. The anchors and buoys are now in use by partners from sea science, the various titanium elements have been recycled to industry and there are several future projects which have expressed interest in reusing either the entire ANTARES optical modules or the 10′′ PMTs, most of which are still in excellent shape.

Recovery of one of the last ANTARES lines in May 2022.

The KM3NeT Collaboration has submitted a paper *Measurement of the atmospheric ν_μ flux with six detection units of KM3NeT/ORCA* to EPJ C (posted at https://arxiv.org/pdf/2504.09119). The corresponding author is D. Stavropoulos (INP Demokritos, Greece).

The paper presents a measurement of the atmo-spheric ν_μ/anti-ν_μ flux with energies of 1–100 GeV, using data taken with the first six detection units of KM3NeT/ORCA (“ORCA6”). The data were collected between Jan. 2020 and Nov. 2021 and correspond to a total exposure of 433 kton·years. Using machine learning classification, 3894 neutrino candidate events have been selected with an atmospheric muon contamination of < 1%. The energy spectrum is derived using an unfolding procedure. The flux measured using the ORCA6 configuration is in agreement with the values measured by other experiments – see the figure next page.



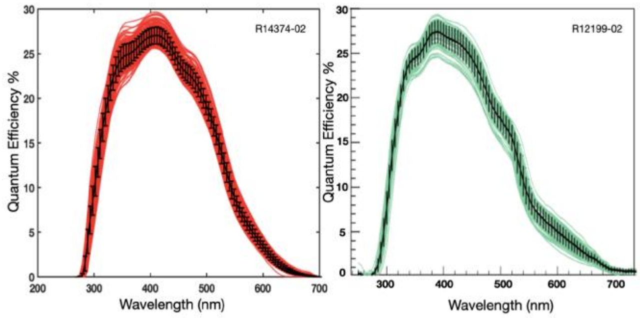
Atmospheric muon neutrino flux measuremen with ORCA6 compared to measurements from other experiments (HKKM14 = Honda et al.).

No new physics (yet), but a nice demonstration what you can do with six strings and 510 days of livetime!

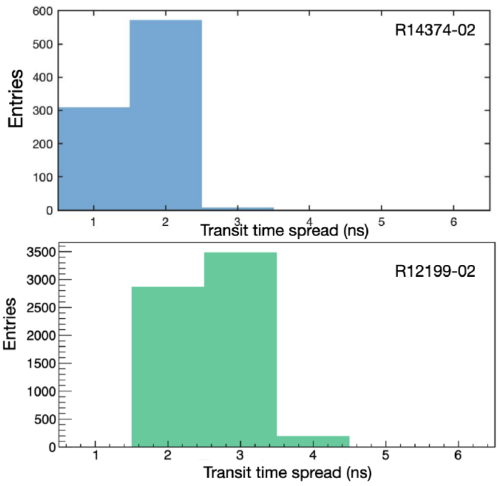
The KM3NeT collaboration has submitted a paper *Evaluation of the upgraded 3-inch Hamamatsu photomultiplier for the KM3NeT Neutrino Telescope* to JINST (posted at https://arxiv.org/pdf/2504.02989). The corresponding author is Andrea Simonelli (INFN Napoli).

The 3-inch Hamamatsu photomultiplier version used for the first Detection Unit was the R12199-02 model. It was later replaced by the improved version R14374-02. A total of 1000 of the new photomultipliers were analyzed to assess their dark count rate, transit time spread, and spurious pulses. A subset of 200 photo-multipliers were further evaluated to determine their quantum efficiency which is an essential parameter for Monte Carlo simulations of the detector response. Results are compared to those of a smaller bunch of R12199-02 measured earlier. The measurements show that the R14374-02 model has better quantum efficiency homogeneity over the photocathode and much better time and afterpulse properties than the R12199-02.

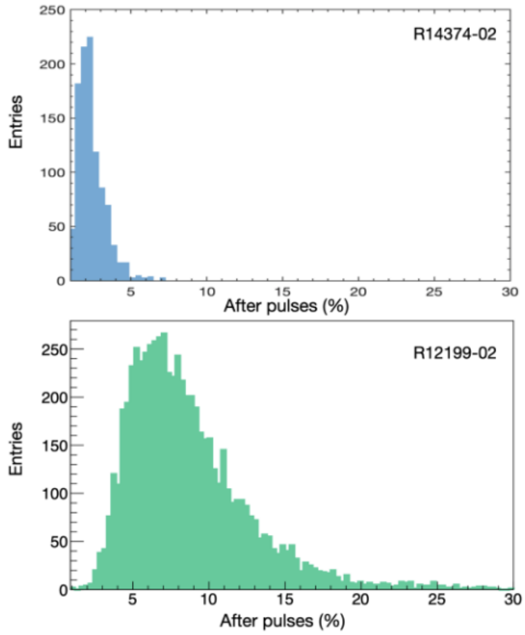
The following figures give a few examples.



Photocathode quantum efficiency measurements as a function of the wavelength for 200 R14374-02 (left) and 46 R12199-02 (right). The improvement (from right to left) is relatively small.



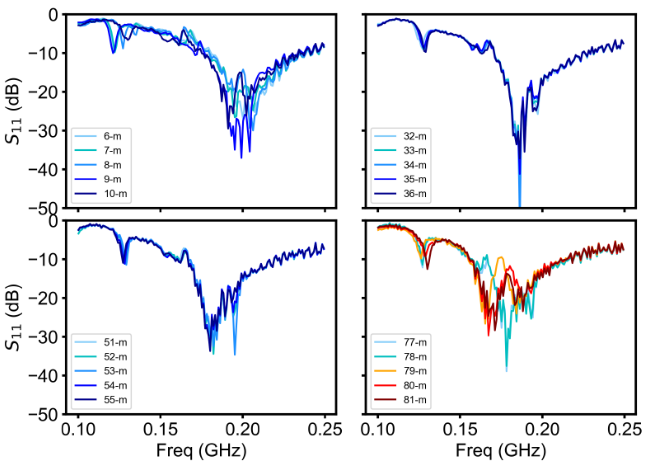
Measured transit time spread for a set of 1000 PMTs R14374-02 (top) and for the R12199-02 model (bottom).



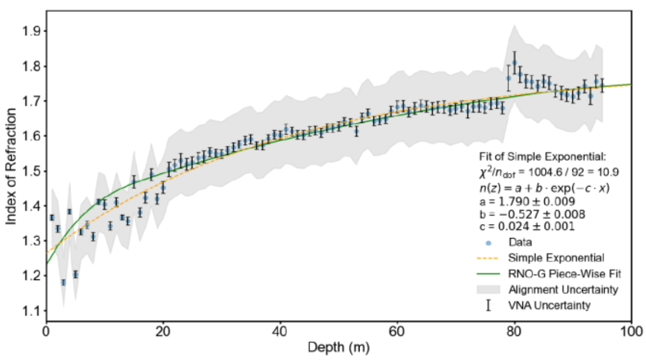
Measured rate of after pulses for a set of 1000 PMTs R14374-02 (top) and for the R12199-02 model (bottom).

The RNO-G Collaboration has submitted a paper *Probing the Firn Refractive Index Profile and Borehole Closure Using Antenna Response* to the Journal of Glaciology (posted https://arxiv.org/pdf/2504.03862). The corresponding author is Curtis McLennan, U. Kansas (USA).

The paper presents a methodology for extracting firn ice properties using S-parameter reflection coefficients ('S11') of antennas lowered into boreholes. S11 is proportional to the natural logarithm of the mismatch between the impedance of an antenna and the impedance of the input/output at the feed (see the paper for the exact definition). The depth-dependent S11 profile can be translated into a refractive index profile, see the following figures.



Measured S11 at various depths in ice. The anomalous response is highlighted, showing the abrupt change in the shape of the resonance. Note the relative constancy of the S11 shape in the depth interval from 32 to 55 m, in contrast to shallower depths and also the depth interval z ≈ 80 m.



Reconstructed index of refraction profile, overlaid with piece-wise exponential fit described in P. Windischhofer: Calibrating the Radio Neutrino Observatory in Greenland. PoS, ARENA2024, 003 (doi: 10.22323/1.470. 0003).

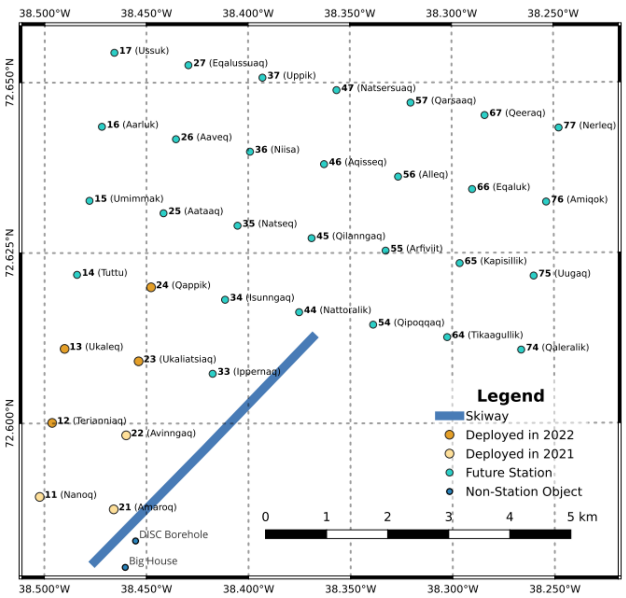
This index of refraction profile is consistent with previous measurements at Summit Station.

Since the response of an antenna deployed into a dry borehole depends on the diameter of the hole, multi-year S11 measurements also permit an estimate of borehole closure, complementary to estimates based on calipers or other dedicated mechanical loggers. The presents first results, based on data taken in August, 2024 from boreholes at Summit Station, Greenland. The estimated borehole closure resolution is ~ 2mm – see the paper for more information!

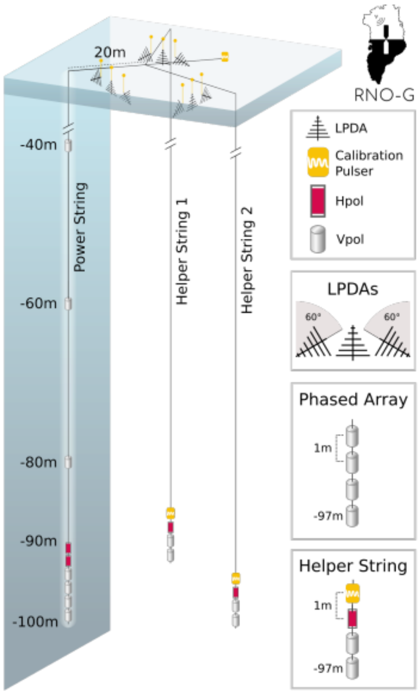
Forgotten in last month's GNN Monthly – The RNO-G instrumentation paper:

The RNO-G Collaboration has posted a paper *Instrument design and performance of the first seven stations of RNO-G* at https://arxiv.org/pdf/2411.12922, submitted to JINST.

The article reports on the design and performance of the first seven stations of RNO-G, which is planned to consist of 35 stations when the first phase of construction is complete. Each RNO-G station comprises 24-antenna receivers installed down to a depth of 100 m.



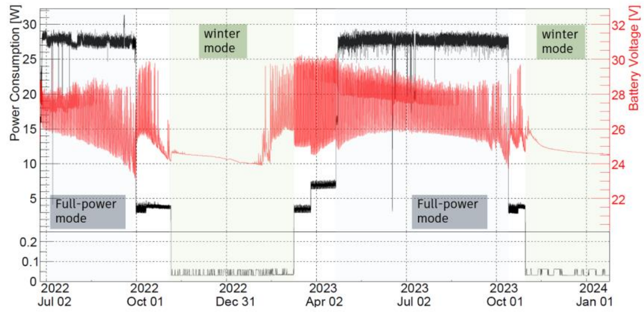
Planned and existing layout of the 35-station array of RNO-G. The first seven stations, the subject of this paper, were deployed in 2021 and 2022. The main building of Summit Station is labeled Big House.



The station construction as installed for the first seven stations of RNO-G, showing the three instrumented boreholes down to 100 m, as well as the antennas in shallow trenches near the surface.

The RNO-G work effort began in earnest in mid-2019, when design and construction of 10 full RNO-G stations of hardware components was initiated, followed by field deployments to Greenland in 2021 and 2022 during which time the initial seven stations were installed and commissioned. After these first field seasons, and affected by the global chip shortage (!), RNO-G paused deployment in 2023 in order to evaluate the instrument performance and design aspects before pushing forward to complete the array. The paper describes these items in detail, starting with an experimental overview including drilling, followed by instrument design, and ending with a review of the initial experiment performance.

As usual for a detector paper, it is impossible to report even a small part of the technical information. Moreover, my own knowledge in radio detection is (still) too rudimentary to pick out the most relevant and to summarize it correctly. So, let me just reproduce a less central figure from the paper, which refers to the solar-power system at one of the RNO-G stations and which also non-experts in radio-detection can understand.



All-year operation of the solar-power system at RNO-G station 23. Shown are both the power consumption (left axis, black) and battery voltage (right axis, red) as function of time. The power consumption shows the different modes of the experiment, including the full-power mode comprising science operations and the low-power winter mode. The transitions between these two modes are also visible, in which the primary DAQ boards are powered-off while keeping the communication links fully on. The battery voltage is determined by the availability of solar power (see Figure 16 in the paper) and the power consumption of the system.

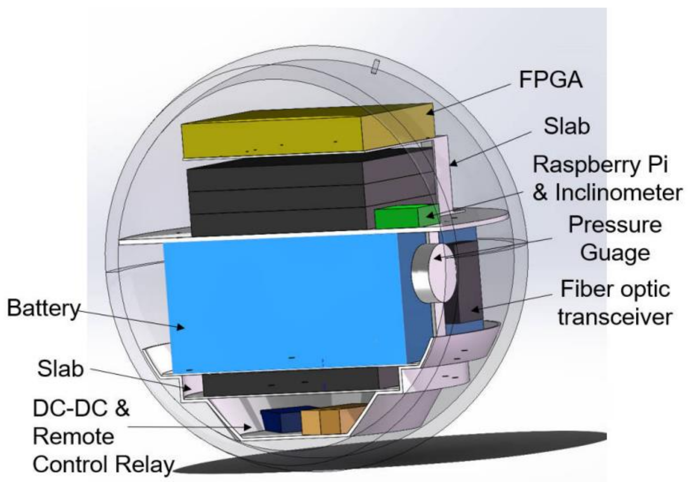
Important lessons have been learned in the first years. New aspects of the RNO-G instrument architecture are currently under test or exist as conceptual design, including the integration of micro wind-turbines, to enable science operation over-winter, and new DAQ systems, so that the instrument can operate with even higher reliability and autonomy. For a large-scale array of distributed stations, it is essential to reduce the need of user intervention for station operations. The collaboration is also improving the design of the above-surface structures that house the solar panels and communications antenna, to reduce yearly maintenance as one better adapts to the high accumulation and snow-drift rates on the Greenland ice sheet. Once the 35-station array is completed, the collaboration is considering several expansion scenarios, such as enhancing the air shower capabilities by adding infill stations or further expanding the array.

Note added (C.S.): The biggest challenge in the moment seems to be the drill. Last summer, most of the time was spent debugging the drill set up, upgrading the electronics and installing newly designed wind turbines. In the end one new full station has been added, and some holes used for calibration purposes have been drilled. Currently, eight RNO-G stations are operational.

The TRIDENT Collaboration has submitted a paper *MuonSLab: A plastic scintillator based detector for muon measurement in the deep ocean* to JINST (posted at https://arxiv.org/pdf/2501.17639). The corresponding author is Hualin Mei from the Shanghai Jiao Tong University.

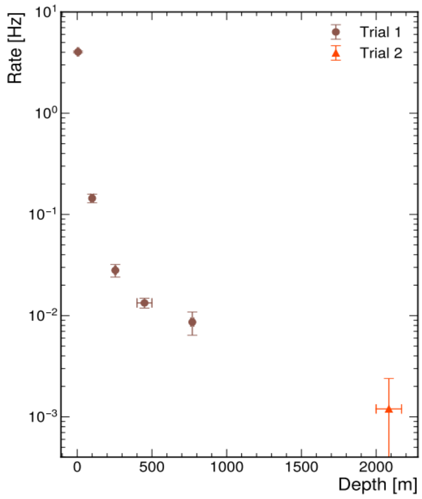
The paper describes a novel device based on plastic scintillators and silicon photomultipliers named MuonSLab, which is designed to measure the muon flux in the deep sea and has the potential to be extended to other atmospheric muon property measurements. It discusses the design of the device and presents results from several muon flux measurements, demonstrating its sensitivity to muon detection and its stability during operations across multiple locations.

All the components are integrated into a spherical glass vessel and a titanium alloy junction box, connected by an oil-filled cable. The 17-inch Vitrovex® glass sphere houses the sensors, electronics and power supply devices, see the next figure.



Glass vessel and key ingredients of MuonSLab.

The figure next column shows the flux vs. depth dependence as measured with MuonSlab.

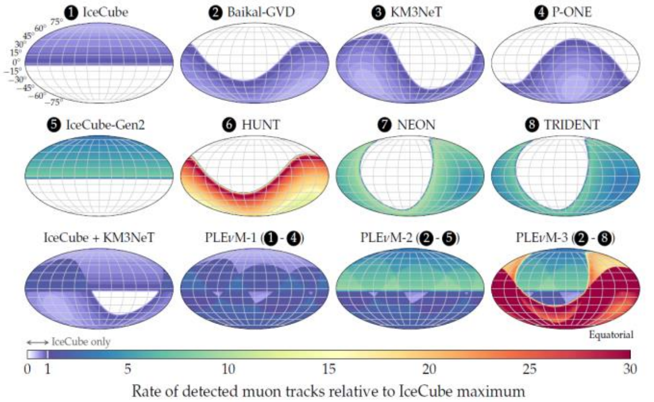


The muon counting rate as a function of depth using data from two sea trials. In the first trial, the detector was paused at several depths, while in the second trial, it was paused only at approximately 2.1 kilometers.

Lisa Schumacher (ECAP Erlangen), Mauricio Bustamante (NBI Copenhagen), Matteo Agostini (UC London), Foteini Oikonomou (U. Trondheim) and Elisa Resconi (TUM Munich) have posted a paper *Beyond first light: global monitoring for high-energy neutrino astronomy* at https://arxiv.org/pdf/2503.07549.

They look to the future and calculate, how the sensitivity to point sources within a joint analysis network (called it Planetary Neutrino Monitoring network – PLEνM) could develop over the next two decades – boldly assuming a scenario for the development of neutrino telescopes worldwide. (they assume PLEνM-1 consisting of IceCube, plus IceCube-sized telescopes KM3NeT, P-ONE, and Baikal-GVD. PLEνM-2 would be the same but with IceCube replaced by IceCube-Gen2. PLEνM-3 adds the three planned Chinese detectors to PLEνM-2.)

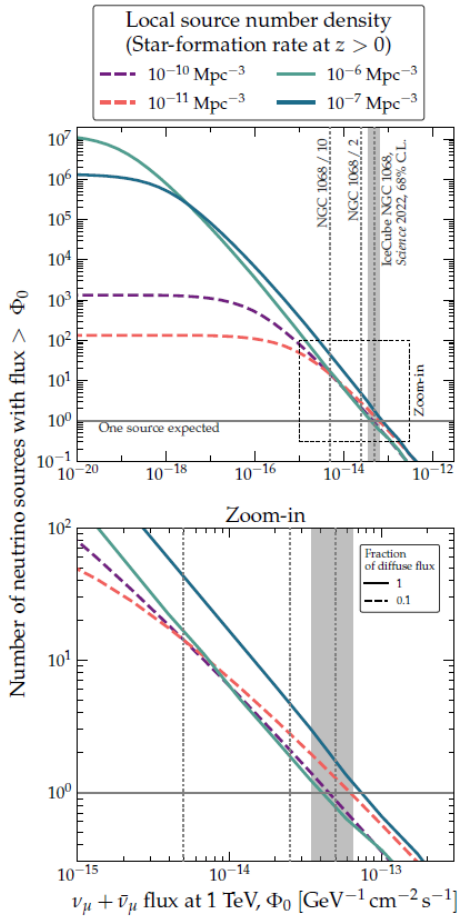
Based on their scenario, they make forecasts for the discovery of steady-state astrophysical sources of high-energy neutrinos. They demonstrate how a combined analysis of global data will expedite source discovery – in some cases, by decades – and enable the detection of fainter sources anywhere in the sky, discovering up to tens of new neutrino sources. A main result is, that PLEνM-1 would be able to detect sources about 40% as bright as NGC 1068 anywhere in the sky with a 5σ significance; PLEνM-3 would be able to do so for sources 10% as bright as NGC 1068.



Expected rate of muon tracks detected in present and future high-energy optical Cherenkov neutrino telescopes. For each detector, the expected event rate is computed, integrated over reconstructed muon energy above 100 GeV and above zenith angles of $\vartheta_z \geq -5°$, with its corresponding effective area. Event rates are computed assuming an illustrative $\propto E_\nu^{-2}$ neutrino energy spectrum, are instantaneous (i.e., not averaged over the rotation of the Earth), and are expressed relative to the maximum event rate achievable in IceCube. For detector combinations, the event rate is the sum of the contribution of its constituent detectors. See the paper for detail.

Based on the above potential to discover single neutrino sources, the authors compute how many sources belonging to an underlying source population one could discover across the sky. The result is shown in the figure next column.

The authors assume a single population of nondescript sources, distributed isotropically, whose number density evolves with redshift, z, following the star-formation rate. They generate the probability distribution functions of populations of neutrino sources with identical luminosities, i.e., standard-candle sources, but located at different redshifts. They normalize the flux per source such that the sum of the fluxes from all the sources matches either 100% or 10% of the diffuse flux measured by IceCube at 10 TeV. The figure shows the results. The authors study four illustrative scenarios of the local source number density (i.e., at z = 0) that ensure that the source population produces, on average, about one source with a flux at least as high as that of NGC 1068.
For each scenario, they compute the all-sky number of sources in the population that emit neutrinos above a certain minimum flux, which they vary. Given that, the figure reveals that PLEvM-1 will be able to detect 2–6 sources, and PLEvM-3 will be able to detect 10–40 sources, depending on the local source density and on the fraction of the diffuse neutrino flux that the source population is responsible for.



Cumulative distribution of the expected number of neutrino sources above a given flux. All sources in a source population emit a soft power-law neutrino spectrum, $\Phi_0 (E_\nu/1\ \mathrm{TeV})^{-3.2}$, similar to that of NGC 1068. Their number density follows the star-formation-rate evolution with the standard-candle flux per source normalized such that they sum up to 100% or 10% of the diffuse flux measured at 10 TeV, i.e., $E_\nu^2 \Phi_{diffuse}|_{10\ \mathrm{TeV}} = 3 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}. The local source number density is chosen such that about one source in the population produces a flux as strong as NGC 1068 or higher, i.e., the number of sources is near the flux of NGC 1068.

Impressum
GNN Monthly is the Monthly Newsletter of the Global Neutrino Network
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