GNN Monthly
The Global Neutrino Network
96th Edition
June/July, 11/7/2025
https://www.globalneutrinonetwork.org/

New chairs of the GNN board

White smoke from the Sistine chapel: *Habemus papam*? Yes, however not just one, but two! Paschal Coyle (CPPM Marseille) and Claudio Kopper (ECAP Erlangen) received the same number of votes (3:3) from the six GNN collaborations and will work as co-chairs of GNN for the next two years. Paschal, former spokesperson of the KM3NeT Collaboration, is member of Antares and KM3NeT, Claudio is member of IceCube, KM3NeT, RNO-G and P-ONE.

Paschal Coyle (left) and Claudio Kopper (right)

Thanks for the other three who stood as candidates for the election and congratulations to Paschal and Claudio. I am sure you will you will give GNN a new boost and make it useful for the community. Good luck for you, and thank you to Greg Sullivan, who in 2023/24 maneuvered GNN through difficult waters!

KM3NeT

AISBL: Five funding agencies have signed the statutes for an Association Internationale Sans But Lucratif (AISBL) for KM3NeT. An AISBL is a legal entity under Belgian law for international organizations.
See https://www.km3net.org/km3net-aisbl-is-born/

IPPOG: KM3NeT will join IPPOG, the International Particle Physics Outreach Group (https://ippog.org/)

Collaboration Meeting: Last week of June, KM3NeT met in Caen, France, for its summer Collaboration Meeting, hosted by LPC Caen and Caen University.

The KM3NeT Collaboration welcomed the following new members: Princeton University, with a team coordinated by Christopher Tully (full member). In addition, Technical University of Munich (team coordinated by Philipp Eller), Norwegian University of Science and Technology (team coordinated by Foteini Oikonomou) and Universidade Estadual Paulista in Brasil (team coordinated by Marcio Eduardo da Silva Alves) joined as observers.

Baikal-GVD

The GVD collaboration has hold a spring collaboration meeting on June 3-6 in Dubna. Advances in track-like event analysis have been reported. The collaboration works on a diffuse flux measurement (see the publication section at the end of the newsletter) and a point source search, with the track-like event sample from data taking seasons 2019-2023. Preliminary results of the latter are expected at the ICRC conference.

Group photo of a part of the almost 60 participants of the GVD meeting.

IceCube

Good news for IceCube-Gen2 in Germany: The project successfully passed a prioritization process for the German Research Infrastructure Roadmap. 32 submitted projects underwent a complex evaluation process involving numerous renowned international experts. The most promising projects were announced in the form of a shortlist, which will be updated regularly in the future. A total of nine projects, including IceCube-Gen2, passed the process and were selected for the shortlist. Inclusion in the shortlist is explicitly not linked to a funding commitment, but it is an important signal that the projects are being prioritized from a research policy perspective and that they represent a potentially significant contribution to the performance of the German science system. The outcome of the prioritization process has been released at July 8.

Last DESY DOMs to South Pole: End of June, the last mDOMs for the IceCube upgrade produced in DESY have started their staged travel to the South Pole (a first batch has left in August 2024).

These are two good news which should be celebrated with a nice picture: another great view of the IceCube drill camp at the South Pole, with a beautiful, clear sky and an aurora:

RNO-G

Anna Nelles reports: This season field-season (May to August) RNG-O focuses on drilling. After a very successful drill season in the beginning of the installation of RNO-G, the drill has been an item of worry for the past years. Lab testing of a mechanical drill, reaching a depth of 100 m, can only be done to a certain extent and does not emulate the -30 °C, blowing winds and snow situation that the team faces at Summit, which lead to clogged generators and frost build-up. Oddly enough, an unexpected issue has also been in the past that it was too warm, with ice melting on the motor and creating moisture. An issue clearly caused by much warmer temperatures than typical at Summit and potentially leading to the drill getting stuck in the ice. After taking a season off last year to spend on drilling upgrades and improvements, the drill has been performing much better. At the time of writing this report, the team is close to finishing the holes for the fourth new RNO-G station (3 holes per station). Since the holes stay open, they will simply be instrumented next season. So, we are expecting RNO-G to grow significantly in 2026.

The remainder of one drilled hole: a mountain of ice chips outside of the tent

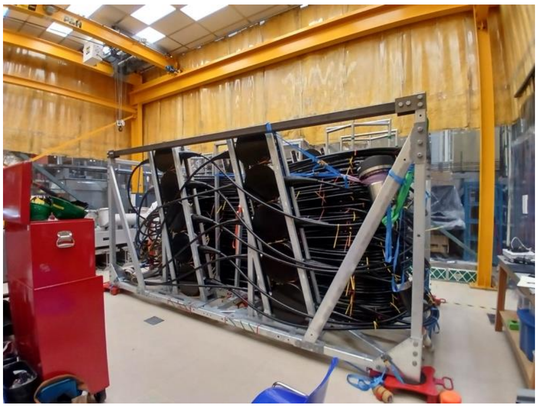
Raising of the drilling tent at Summit.

Next to the drilling effort, calibration and maintenance will take place. RNO-G tries every year to gain a better understanding of the ice. In particular the interaction of the ice of the boreholes and the antennas has now been studied to better detail. To simulate antennas and their response to electromagnetic fields, complex simulations solving Maxwell's equations on a grid of finite elements are performed. In typical industrially used scenarios, antennas are embedded in a smooth homogeneous medium, which is far from the truth in a real-life RNO-G situation, so simulations with complex media and boundaries have a much worse fidelity and strongly depend on getting the ice parameters correct. Every calibration effort brings us one step closer to being able to produce high fidelity neutrino simulations, which will allow more sensitive triggering algorithms. Furthermore, RNO-G will perform the regular maintenance work of raising solar panels, upgrading some electronics, and inspecting the wind turbines. While the performance of the turbines has been much better this winter, RNO-G was unfortunately still not ready to take data during the dark months, but the opportunities to catch transients during the winter are too promising to not keep going.

P-ONE

P-ONE came together at the end of June (23-27) for the Collaboration meeting hosted at Simon Fraser University in Vancouver. Over 60 collaborators were joined by members from TRIUMF and from our key industry partner MacArtney.

The collaboration meeting coincided with the arrival of the backbone cable of P-ONE-1 at the cleanroom facilities at TRIUMF. The cable was expertly craned in front of the cleanroom and is now ready for final integration of all detector components (see pictures below). This is a key milestone for P-ONE, as all crucial detector components are now ready for integration and thorough final testing at TRIUMF. This exciting integration of the first detector line will happen during this summer.



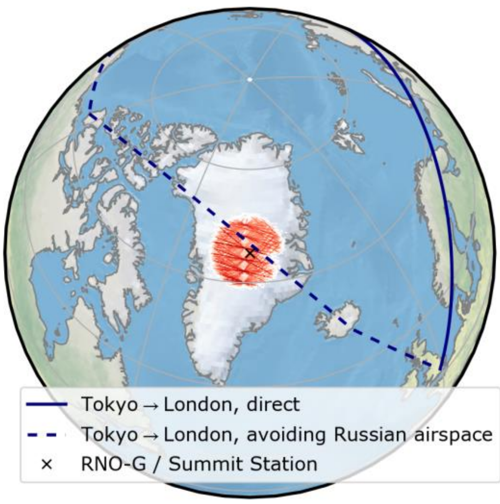
Publications

The P-ONE collaboration has submitted a paper *Prototype acoustic positioning system for the Pacific Ocean Neutrino Experiment* to JINST (posted at https://arxiv.org/abs/2504.13323)
which I did not include in the April edition. The corresponding authors are Felix Henningsen and Dilraj Ghuman (Simon Fraser University, Canada).

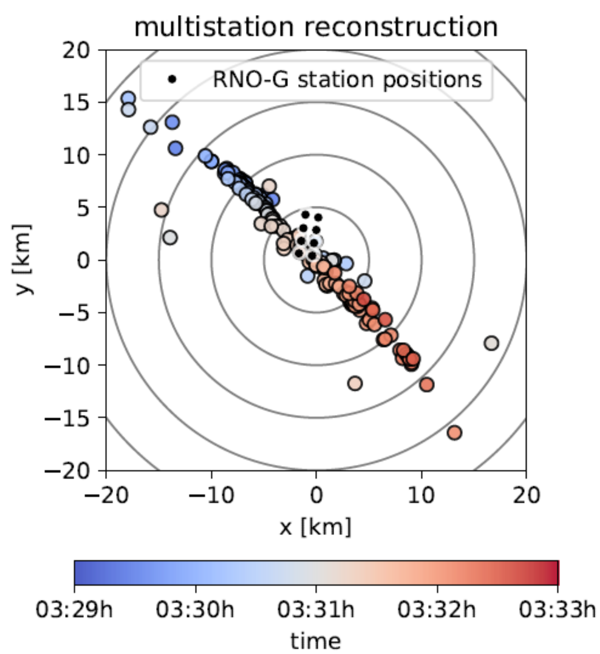
They present design and initial performance characterization of the prototype acoustic positioning system intended for the P-ONE. It comprises novel piezo-acoustic receivers with dedicated filtering- and amplification electronics installed in P-ONE instruments and is complemented by a commercial system comprised of cabled and autonomous acoustic pingers for sub-sea installation. They performed an in-depth characterization of the acoustic receiver electronics and their acoustic sensitivity when integrated into P-ONE pressure housings. These show absolute sensitivities of up to -125 dB re $V^2/\mu Pa^2$ in a frequency range of 10 – 40 kHz. They furthermore conducted a positioning measurement campaign in the ocean by deploying three autonomous acoustic pingers on the seafloor, as well as a cabled acoustic interrogator and a P-ONE prototype module deployed from a ship. Using a simple peak-finding detection algorithm, they observe high accuracy (< 30 cm) in tracking the ships movement at distances of up to 1600 m, which is sufficient for positioning detectors in a cubic-kilometer detector and which can be further improved with more involved detection algorithms. The tracking accuracy is further confirmed by independent ranging of the commercial system and closely follows the ship's drift in the wind measured by GPS. The absolute positioning shows the same tracking accuracy with its absolute precision only limited by the large uncertainties of the deployed pinger positions on the seafloor.

The RNO-G collaboration has submitted a paper *Radio emission from airplanes as observed with RNO-G* to JINST (posted at https://arxiv.org/pdf/2506.17522). The corresponding author is Steffen Hallmann (ECAP and DESY).

The paper describes how intentional and unintentional radio emission from airplanes is recorded with RNO-G. The authors characterize the received signals and define a procedure to extract a clean set of impulsive signals.



Location of Summit Station in Greenland with approximate flight paths between Japan and Europe. The colormap (white to red) indicates the density of aircraft locations seen by a receiver up to ~350 km around Summit Station.



Reconstructed aircraft position for a C17 flight without transmitted position. Time is color-coded.

The signals selected in this analysis will be used in a forthcoming comprehensive instrument calibration for RNO-G that solves for the precise antenna positions, residual instrumental delays, and the ice profile at the same time. Aircraft signals will also allow to repeat the calibration each year and monitor the instrument performance over time. The presented data-set already allowed to probe the realized timing resolution of RNO-G, which shows a spread of 270 ns, which matches expectations due to the drift of the local oscillator. The authors discuss the impact of these signals on the ability to detect neutrinos with RNO-G.

The IceCube collaboration has submitted a paper *GollumFit: An IceCube Open-Source Framework for Binned-Likelihood Neutrino Telescope Analyses* to Computer Physics Communications (posted at https://arxiv.org/pdf/2506.04491). Significant contributions to this paper came from the University of Texas at Arlington, the Massachusetts Institute of Technology, and Harvard University.

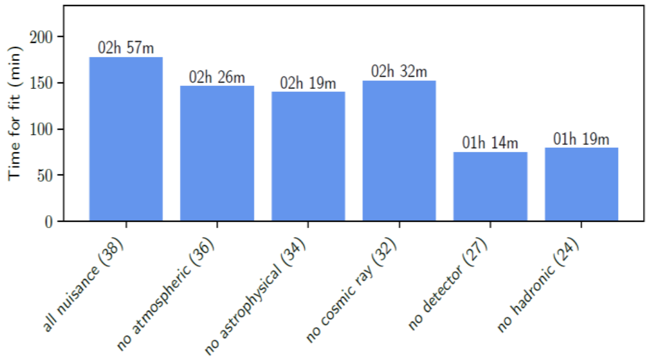
*GollumFi*t incorporates model parameters common to any neutrino telescope and also model parameters specific to the IceCube Neutrino Observatory. The authors provide a high-level overview of its key features and how the code is organized. *GollumFit* addresses the need to quickly optimize a high-dimensional likelihood over a large and particular set of model parameters. It also contains auxiliary helper features that aid in computation speed. The authors discuss the performance of the fitting in a typical analysis scenario, highlighting the ability to fit over tens of nuisance parameters. They then present some examples showing how to use the package for likelihood minimization tasks. The code was released here: https://github.com/icecube/GollumFit/tree/main .

It is essentially impossible to compress the information of that paper to a one-page summary. Just as appetizers, I show the table with the nuisance parameters included in the study, as e.g. the atmospheric density and meson energy loss, ρ_{atm} and $\sigma_{K\text{-}Air}$, the K, π, p and n (10 in total) parameters describing the hadronic yield etc. etc. – see the paper for the explanation of all parameters.

The fit procedure is applied to a large Monte-Carlo set defined in the paper. The figure shows a plot of the time taken for a fit (with identical seed nuisance parameters) to converge. Different bars are for different sets of nuisance parameters turned off.

Parameter	`GollumFit` Variable	Weighting Method
Common to all neutrino telescopes		
convNorm	convNorm	scale factor
ρ_{atm}	zenithCorrection	gradient
$\sigma_{\text{K-Air}}$	kaonLosses	gradient
K^+_{158G}	hadronicHEkp	gradient
K^-_{158G}	hadronicHEkm	gradient
π^+_{20T}	hadronicVHE1pip	gradient
π^-_{20T}	hadronicVHE1pim	gradient
K^+_{2P}	hadronicVHE3kp	gradient
K^-_{2P}	hadronicVHE3km	gradient
π^+_{2P}	hadronicVHE3pip	gradient
π^-_{2P}	hadronicVHE3pim	gradient
p_{2P}	hadronicVHE3p	gradient
n_{2P}	hadronicVHE3n	gradient
GSF_1	cosmicRay1	gradient
GSF_2	cosmicRay2	gradient
GSF_3	cosmicRay3	gradient
GSF_4	cosmicRay4	gradient
GSF_5	cosmicRay5	gradient
GSF_6	cosmicRay6	gradient
$\Phi^{\text{HE}}/10^{-18}\text{GeV}^{-1}\text{sr}^{-1}\text{s}^{-1}\text{cm}^{-2}$	astroNorm	scale factor
$\Delta\gamma_1^{\text{HE}}$	astroDeltaGamma	power law formula
$\Delta\gamma_2^{\text{HE}}$	astroDeltaGammaSec	power law formula
$\log_{10}(E^{\text{HE}}_{\text{break}}/\text{GeV})$	astroPivot	power law formula
promptNorm	promptNorm	scale factor
$\nu/\bar{\nu}$	NeutrinoAntineutrinoRatio	scale factor
ν Att	nuxs	spline
$\bar{\nu}$ Att	nubarxs	spline
IceCube-specific Monte Carlo parameters		
DOM eff	domEfficiency	spline
Hole Ice	holeiceForward	spline
Ice A_0	icegrad0	gradient
Ice A_1	icegrad1	gradient
Ice A_2	icegrad2	gradient
Ice A_3	icegrad3	gradient
Ice A_4	icegrad4	gradient
Ice Phs_1	icegrad5	gradient
Ice Phs_2	icegrad6	gradient
Ice Phs_3	icegrad7	gradient
Ice Phs_4	icegrad8	gradient

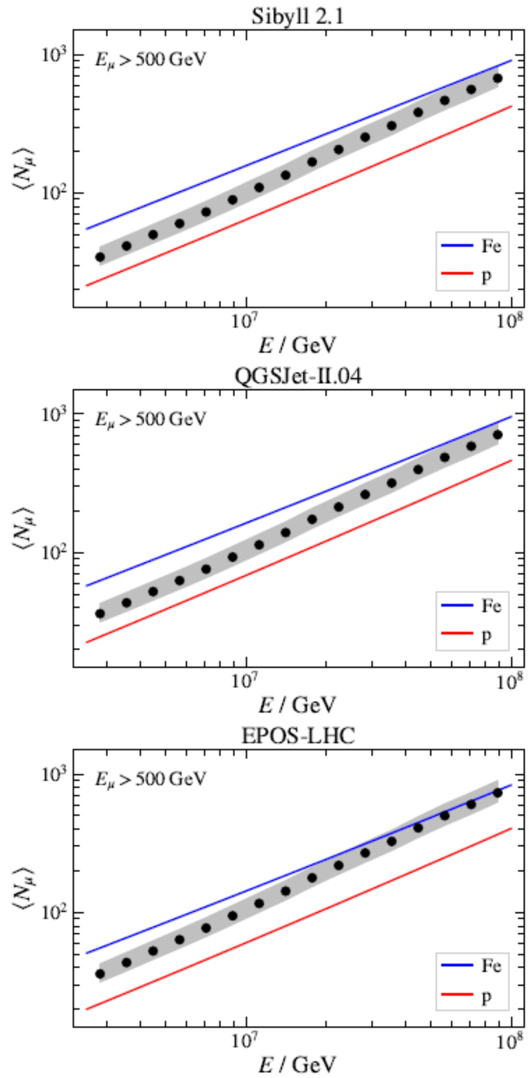
Caption for the table previous page: Table of included nuisance parameters. Shown are their conventional name, the variable name in GollumFit, and the method that is used to account for it in reweighting (see section 3.1 of the paper). A distinction is made between parameters describing a general neutrino telescope and parameters that are specific to IceCube. For a general description of the nuisance parameters, see section 2.2 of the paper. The reweighting method describes exactly how the event weight depends on the nuisance parameter. This can be a gradient, spline, or analytical formula, describing the variation of the weight as a function of the nuisance parameter.



Plot of the time taken for a fit (with identical seed nuisance parameters) to converge. Different bars are for different sets of nuisance parameters turned off. The number of remaining nuisance parameters fitted over is given in the parenthesis. This was performed using 814847 Monte Carlo events, after the FastMC procedure, using a value k = 0.25 (k is a factor responsible for compression, again: see the paper for definition).

The IceCube collaboration has submitted a paper *Measurement of the mean number of muons with energies above 500 GeV in air showers detected with the IceCube Neutrino Observatory* to Phys.Rev. D (posted at https://arxiv.org/pdf/2506.19241). The leading author of this work is Stef Verpoest (Bartol Research Institute, Newark).

The paper focuses on near-vertical air showers initiated by cosmic rays with primary energies between 2.5 and 100 PeV. It uses events detected in coincidence between air showers recorded by IceTop and bundles of high-energy muons ("TeV muons") producing tracks in IceCube. Results are obtained assuming the hadronic interaction models Sibyll 2.1, QGSJet-II.04, and EPOS-LHC. The measured number of TeV muons is found to be in agreement with predictions from air-shower simulations – see the next figure.



Average number of muons with energy greater than 500 GeV in near-vertical air showers as a function of the primary cosmic-ray energy obtained using the hadronic interaction models Sibyll 2.1, QGSJet-II.04, and EPOS-LHC. The shaded region indicates the systematic uncertainty, statistical uncertainties are not visible. The muon number expected from proton and iron simulations performed with the corresponding hadronic models are shown for comparison.

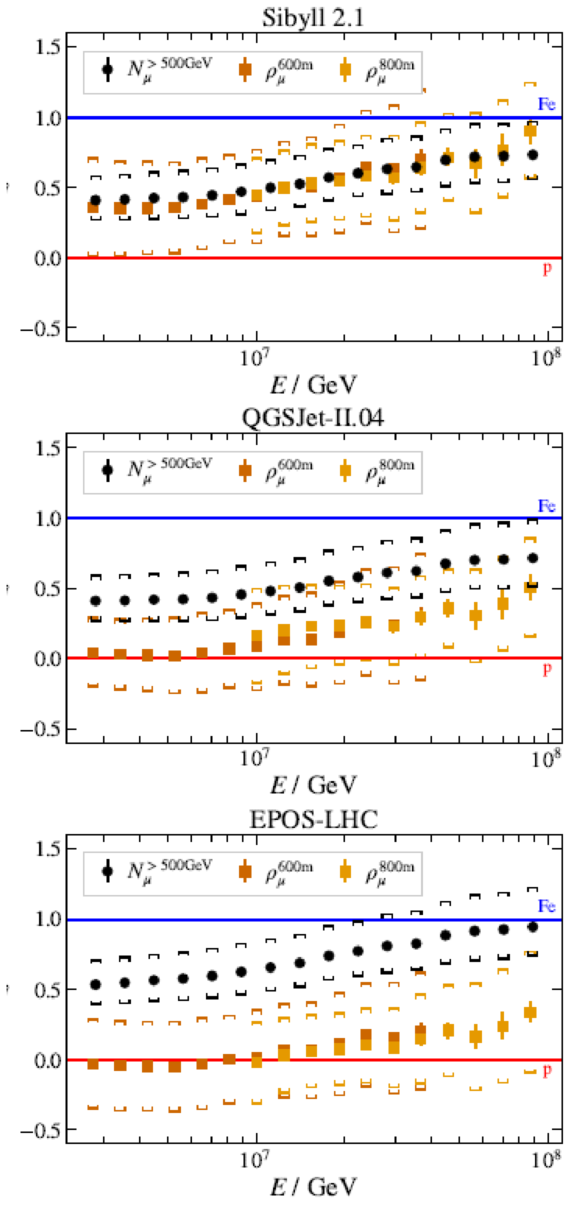
The results have also been compared to a measurement of low-energy muons by IceTop, indicating an inconsistency between the predictions for low- and high-energy muons in simulations based on the EPOS-LHC model.

In that analysis, the density ρ_μ of muons at the surface was determined at lateral distances of 600 and 800 m from the shower axis. These are mainly low-energy muons detected in the IceTop tanks, with a threshold of several 100 MeV, commonly referred to as GeV muons. The GeV muon density analysis covers the primary energy range used in the TeV muon analysis presented in this work, and uses the same zenith range (cos θ > 0.95) and hadronic interaction models. The results of the GeV muon density analysis and the TeV muon multiplicity analysis are shown together in terms of z-values in the next figure, with z defined as

$$z = \frac{\ln\langle N_\mu \rangle - \ln\langle N_\mu \rangle_{\mathrm{p}}}{\ln\langle N_\mu \rangle_{\mathrm{Fe}} - \ln\langle N_\mu \rangle_{\mathrm{p}}}$$

If the simulations consistently describe the experimental data, the two results should be consistent, as they are measures of the same primary cosmic-ray flux arriving at Earth. This is the case for the Sibyll 2.1 results, where one observes excellent agreement over the entire energy range. The increased production of low-energy muons in the post-LHC models QGSJet-II.04 and EPOS-LHC results in the GeV muon measurement being closer to expectations for lighter primaries. The tension with the TeV muon result is strongest for EPOS LHC, where the z-values obtained from the GeV and TeV muon measurements are outside each other's uncertainty bands over nearly the entire energy range. The authors note that there are also preliminary indications for inconsistencies related to the slope of the lateral charge distribution observed in IceTop, most prominently for Sibyll 2.1 simulations.

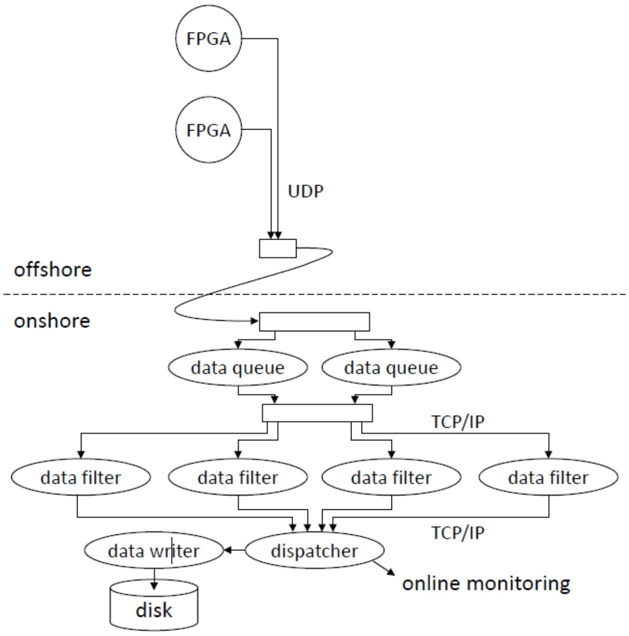
More precise combined measurements of the low- and high-energy muon content of air showers will be important toward resolving the well-known *Muon Puzzle*, as they probe the muon energy spectrum, which differs between hadronic interaction models.



Comparison between the TeV muon data obtained in this work (N_μ, black), and the density of GeV muons measured with IceTop at different lateral distances (ρ_μ, shades of orange), represented as z-values.

The KM3NeT collaboration has submitted a paper *The Online Data Filter for the KM3NeT Neutrino Telescopes* to NIM A *(posted at https://arxiv.org/pdf/2506.05881).* Main author of the paper is Maarten de Jong (Nikhef/Leiden University).

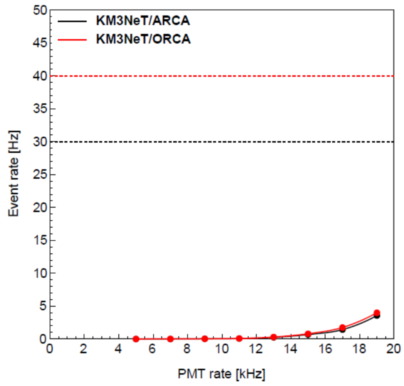
In KM3NeT, the analogue pulses from the photo-sensors are digitized offshore and all digital data are sent to shore where they are processed in real time using a farm of commodity servers and custom software, see the next figure.



The paper describes the design and performance of the software that is used to filter the data. The background is suppressed by optimization of the causality relations. All telescope data within a time window around the detected events are recorded and archived for offline analyses. In addition, summary data, Supernova and calibration data are recorded. Following an external alert, unfiltered or partially filtered data can be recorded which can recover up to several minutes of history.

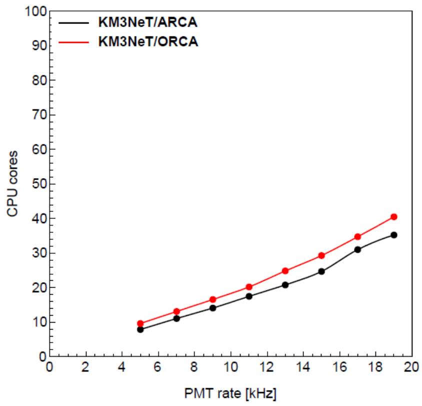
The performance of the data filter is evaluated in terms of its *purity, capacity* and *efficiency*. The *purity* is measured by a comparison of the event rate caused by muons produced by cosmic ray interactions in the Earth's atmosphere with the event rate caused by the background from decays of radioactive elements in the sea water and bioluminescence. The *capacity* is measured by the minimal number of servers that is needed to sustain the rate of incoming data. The *efficiency* is measured by the effective volumes of the sensor arrays. As an example, the results on purity (event rates for signal and background) and capacity are shown in the next figures.

The signal is simulated by generating muons at the depth of the detector according to parametrizations of the observed spectra. The expected event rate for one building block of ARCA and ORCA is found to be 30±5 Hz and 40±5 Hz, respectively. The quoted uncertainty covers the uncertainties about the incident flux, the PMT characteristics and the optical properties of the sea water. The background is simulated by generating hits with random times. The times of consecutive hits follow an exponential probability distribution according to a given rate. The two-fold coincidence rate due to genuine coincidences from decays of radioactive elements in the sea water is set to 500 Hz and the singles rate is varied from 5 kHz to 20 kHz. The upper limit corresponds to the high-rate veto that is implemented in the FPGA. The simulations of the background are also used to determine the minimal number of CPU cores needed to sustain the rate of incoming data.



The rate of events as a function of the singles rate of the PMTs for one building block of ARCA and ORCA.

As can be seen from the figure, the rate of events due to background is very small at the nominal rate of the PMTs. The impurity of the data filter is then also very small (< 1%). At the maximal data taking rate of a PMT, the event rate is a few Hz. The corresponding impurity is then about 10%.



The required number of CPU cores as a function of the singles rate of the PMTs for one building block of ARCA and ORCA.

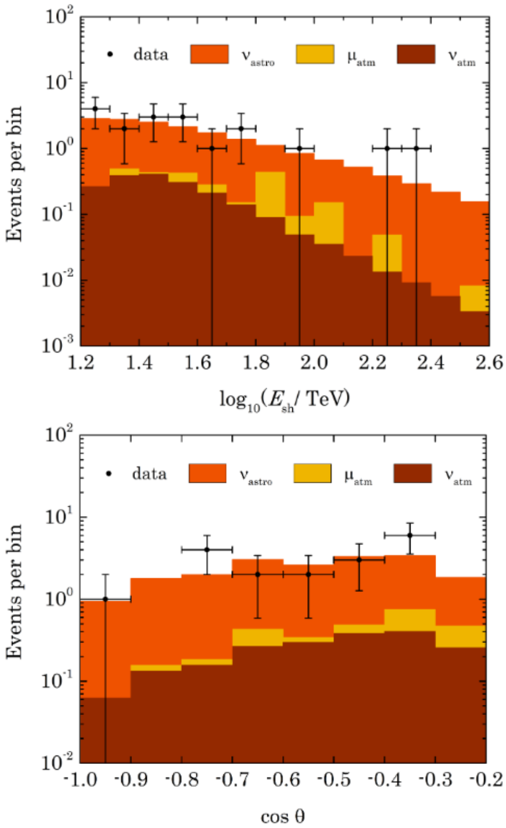
The maximal data rate amounts to about 10 Mb/s and 2.5 Mb/s for ARCA and ORCA, respectively. These values correspond to a worst-case-scenario. The total data rate complies nonetheless with the specifications.

The Baikal Collaboration has submitted a paper *Measurement of the diffuse astrophysical neutrino flux over six seasons using cascade events from the Baikal-GVD expanding telescope* to PRL (posted at https://arxiv.org/pdf/2507.01893). The main contributions to the paper come from Zhan-Arys Djilkibaev and Olga Suvorova (INR Moscow).

In 2022, Baikal-GVD reported its first observation of the diffuse astrophysical neutrino flux at that time with a 3 σ significance, based on data collected between April 2018 and March 2022 (4 years). This paper presents an updated and improved analysis of the diffuse astrophysical neutrino flux which incorporates two more years of data (up to March 2024). For the first time with Baikal-GVD, a statistical significance greater than 5σ is reached, allowing for a more accurate characterization of the observed diffuse flux and a comparison to IceCube results.

The telescope operated with 3 clusters during April 2018–March 2019, 5 clusters in April 2019–March 2020, 7 cluster in April 2020–March 2021, 8 clusters in April 2021–March 2022, and 10 clusters in April 2022–early 2023. From April 2023 to March 2024, the configuration included 11 complete clusters and one incomplete cluster. This analysis treats individual clusters as independent setups. A sample of 5.49×10^{10} events was collected by the basic trigger of the telescope. After applying noise hit suppression procedures, cascade reconstruction and cuts on reconstruction quality parameters, a sample of 12077 cascades with reconstructed energy E_{sh} > 15 TeV and OM hit multiplicity N_{hit} >11 was selected. Restricting the analysis to upward-going directions allows for effective suppression of the atmospheric muon background, thus improving the neutrino sample purity and enabling the extension of the analysis towards lower energies. An additional cut on the zenith angle cos θ < -0.25 is passed by 25 events. The fraction of background events from atmospheric muons and neutrinos in the sample selected with these cuts is expected at a level of 20%. Finally, after applying additional cuts which suppress events from atmospheric muons and atmospheric muon neutrinos, 18 events have been selected, while 2.8±1 atmospheric background events are expected (1.9

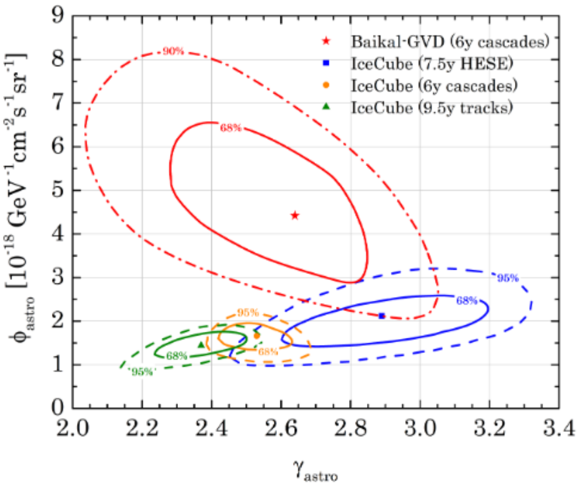
from atmospheric conventional and prompt neutrinos and 0.9 events from mis-reconstructed atmospheric muons). See than energy and zenith angle distributions in the next figure.



Reconstructed cascade energy (top panel) and zenith (bottom panel) distributions obtained in the upward-going cascade analysis. Black points are experimental data, with statistical uncertainties. The stacked colored bands show the expected contribution from background atmospheric neutrinos (brown) and atmospheric muons (yellow), as well as from the best fit astrophysical neutrino flux obtained in this work (red).

The significance of the excess over the expected number of atmospheric background events was estimated as 5.1σ. The cascade energy distribution has been fitted with a single power-law model for the astrophysical flux and MC- based templates for the atmospheric backgrounds, taking into account major sources of detector and water related systematic uncertainties.

The measured value of the spectral index of astrophysical neutrinos is $\gamma_{astro} = 2.64\ (+0.09-0.11)$, and the per-flavor flux normalization for each neutrino flavor at E_0 = 100 TeV is $\phi_{astro} = 4.42\ (+2.31-1.29) \times 10^{-18}\ GeV^{-1}\ cm^{-2}\ s^{-1}\ sr^{-1}$, both consistent with the earlier version of the Baikal-GVD analysis, but with an apparently higher flux normalization compared to that obtained in IceCube analyses, see the next figure.



The best fit parameters (red star) and the contours at 68% confidence region (red solid curve) and 90% (red dot-dashed) for the single power law hypothesis obtained in the upward-going cascade analysis of the Baikal-GVD data. Other best fits and the confidence level contours of the 68% (solid) and 95% (dashed) are shown for IceCube analyses based on high-energy starting events (blue), track-like events (green) and cascade-like events (orange).

The results of Baikal-GVD is not easily compatible with IceCube results, and also not with ANTARES limits on the flux, shown in https://arxiv.org/pdf/2407.00328. So, it will be interesting to see the future KM3NeT results on this issue, as well as GVD results based on track-like events.

A bit too late for a review in this edition of GNN Monthly are the following two IceCube publications:

[2507.03989] A Search for Millimeter-Bright Blazars as Astrophysical Neutrino Sources
and
[2507.07275] All-sky neutrino point-source search with IceCube combined track and cascade data

(see the August edition!)

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