GNN Monthly
The Global Neutrino Network
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News from the experiments

Baikal-GVD

After the last two seasons with excellent/good ice, this year the ice conditions are very bad. There are lot of ice cracks between the shore and the ice camp as well as around the ice camp. So, it was decided to postpone the deployment of the new shore cable to the next year. Also, only one of two planned clusters will be deployed in this season.

Crossing a crack bridged by planks

Unloading optical modules

Panorama of the emerging ice camp. The red cones mark cracks (something which was unusual in former years).

Deploying the "Chinese string"

A borrowed hovercraft to facilitate operations on ice

The “Chinese string” installed last year was hauled up, modified and deployed again (see the picture first page). A second one is planned to deployed this week. If weather condition allows, the expedition will last up to the first week of April.

IceCube

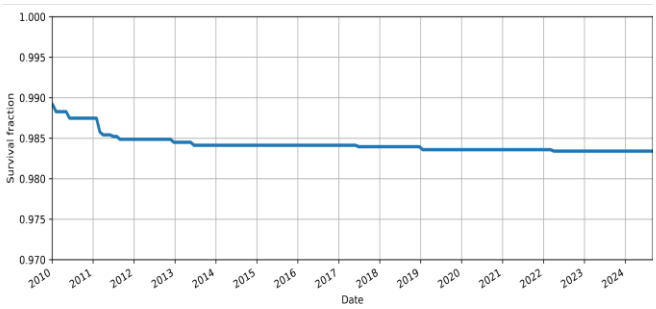
Meanwhile it is already about a month ago that the last summer folks left the station and headed back to McMurdo, then to New Zealand and then home. There have been visitors two weeks later, see the photo.

All three Twin Otters and the Chinese Basler parking outside of the station.

One of the Twin Otters had been at the South Pole most of the summer to support COLDEX (a Science and Technology Center formed in 2021 to explore Antarctica for the oldest possible ice core records), and was also the standing-by support for a South Pole traverse as it returned to McMurdo. The other USAP (United States Antarctic Program) Twin Otter was transiting from McMurdo. The third twin otter was from the Australian Antarctic program. The Basler is owned by China. They came from the Chinese base Zhongshan, on the other side of the continent and – like the Twin Otters – headed home. They stopped at South Pole to refuel.

The IceCube winterovers wearing their fire gear during a fire protection exercise. Fire at the South Pole station would be nightmare.

While preparing a talk, I asked the IceCube coordinator for the South Pole activities, John Kelley (UW Madison), how many of our optical modules survived. He sent me the following figure, which I find so impressing that I cannot resist to include it in this GNN Monthly edition:



The failure rate in the past decade has been exceptio-nally low — only 4 DOMs have died, the most recent was an IceTop DOM in March 2022. So, IceCube is still at about 98.4% operations. Hopefully the failure rate remains at this level for some time!

KM3NeT

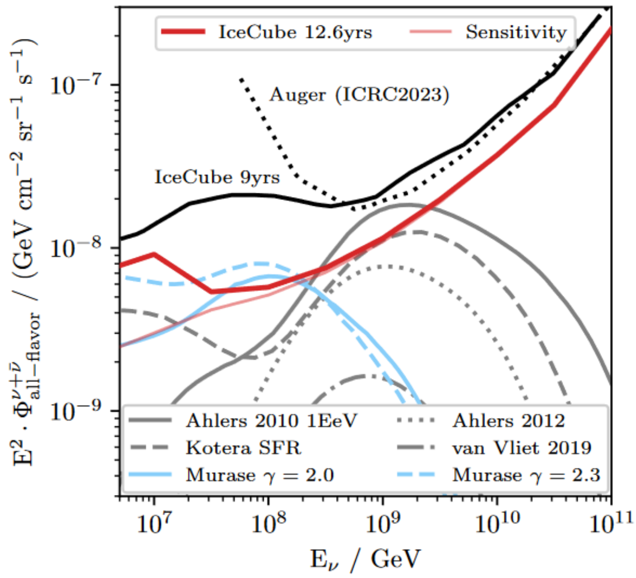
While the 220 PeV event still enjoys press coverage, nothing further spectacular is to be reported. Meanwhile, the KM3NeT Collaboration is organizing the third Town Hall Meeting to present its status and performances, to promote its multi-messenger programs and to initiate/reinforce projects with external collaborators. It will take place in Les Houches, France, from April 13 to 18.

The goal of this meeting is to present the current status, results, and expected outcomes of the KM3NeT project in the field of neutrino astronomy, and to foster collaborations with external partners. See https://indico.cern.ch/event/1459255/ for more details.

Publications

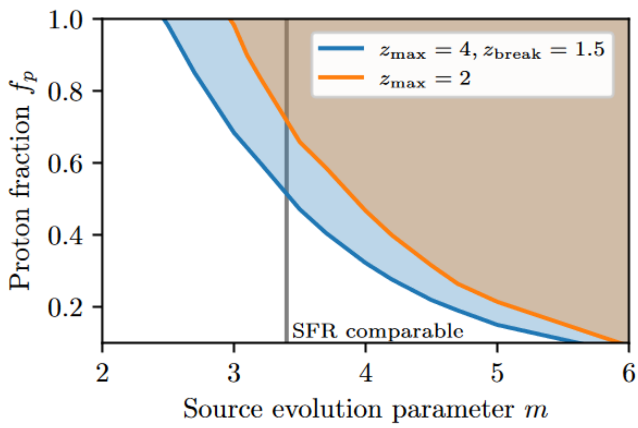
The IceCube collaboration has submitted a paper *A search for extremely-high-energy neutrinos and first constraints on the ultra-high-energy cosmic-ray proton fraction with IceCube* to Phys. Rev. Lett. (posted at https://arxiv.org/pdf/2502.01963). Main authors are Max Meier (Chiba U.) and Brian Clark (U. of Maryland)

The paper presents a search for the diffuse extremely-high-energy neutrino flux using 12.6 years of IceCube data. The non-observation of neutrinos with energies well above 10 PeV constrains the all-flavour neutrino flux at 10^{18} eV to a level of $E^2\Phi_{\nu e+\nu\mu+\nu\tau} \simeq 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}, the most stringent limit to date. Using this data, the proton fraction of ultra-high-energy cosmic rays above $\simeq$ 30 EeV is constrained to be $\lesssim$70 % (at 90 % CL) if the cosmological evolution of the sources is comparable to or stronger than the star formation rate. This result complements direct air-shower measurements by being insensitive to uncertainties associated with hadronic interaction models. It is the first such result to disfavour the "proton-only" hypothesis for UHECRs using neutrino data.



Differential upper limit (90 % CL) on the neutrino flux. The differential limit is compared to the IceCube 9-year result, the limit by Auger, and several cosmogenic neutrino flux models and a UHE astrophysical model (see the paper for more information on the models). The Auger limit is re-scaled to all-flavour, decade-wide bins for comparison.

The next figure shows the constraints on the proton fraction of UHECRs as a function of source evolution parameter m.

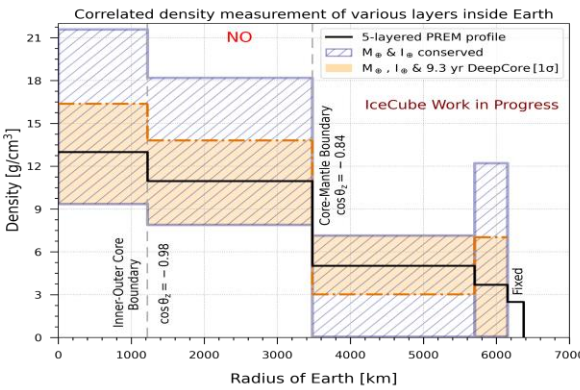


Constraints on the proton fraction (f_p) of UHECRs as a function of source evolution parameter m [in SE = $(1+z)^m$] at 90 % CL based on the non-observation of UHE neutrinos in this study. The excluded region is shown for two source evolution models. SFR stands for star formation rate. Coloured regions are excluded. See the paper for more information.

The IceCube collaboration has submitted a paper *Demonstrating the ability of IceCube DeepCore to probe Earth's interior with atmospheric neutrino oscillations* to the European Physical Journal special (posted at https://arxiv.org/pdf/2502.18995). The authors are Sharmistha Chattopadhyay, Krishnamoorthi J, Anuj Kumar Upadhyay (all from Institute of Physics, Sachivalaya Marg, Sainik School Post, Bhubaneswar India and UW Madison).

Over the past two decades, neutrino oscillation parameters have been measured with a precision of a few percent. Notably, the discovery of a non-zero θ_{13} has created new opportunities to investigate Earth's internal structure through the matter effects that upward-going atmospheric neutrinos experience as they oscillate through the Earth.

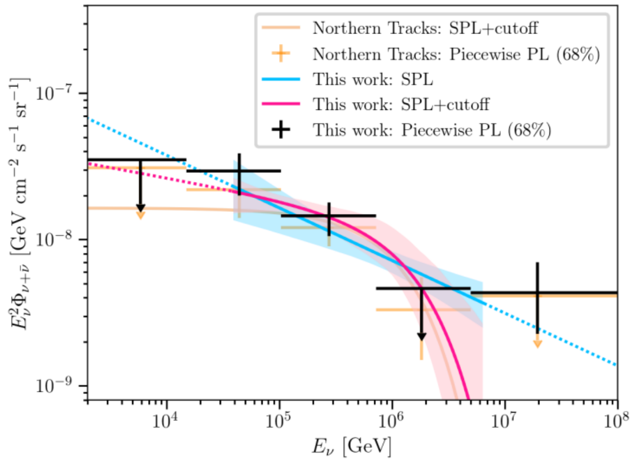
This study, for the first time, focuses on utilizing the high-statistics IceCube DeepCore **simulated** atmospheric neutrino oscillation data, corresponding to 9.3 years of observations, to explore Earth's matter effects and some key features of the PREM profile of Earth. Preliminary sensitivity results are presented for establishing Earth's matter effects, validating the non-homogeneous distribution of Earth's electron density, and measuring the Earth mass. Additionally, the sensitivity for correlated density measurements across different layers is demonstrated, see the figure.



Asimov sensitivity results for correlated density measurements assuming a 5-layered PREM profile. The hatched region represents the band of densities allowed by external constraints from Earth's mass and moment of inertia. The orange region indicates the 1σ uncertainty around the PREM profile, derived using 9.3 years of IceCube DeepCore simulated data, incorporating external constraints on Earth's mass and its moment of inertia.

The IceCube Collaboration has submitted a paper *Probing the PeV Region in the Astrophysical Neutrino Spectrum using ν_μ from the Southern Sky* to Phys. Rev. D (posted https://arxiv.org/pdf/2502.19776). Main authors are Spencer Klein and Yang Lyu (Berkeley).

IceCube has observed a diffuse astrophysical neutrino flux over the energy region from a few TeV to a few PeV. At PeV energies, the spectral shape is not yet well measured due to the low statistics of the data. This analysis probes the gap between 1 PeV and 10 PeV by using high-energy downgoing muon neutrinos. To reject the large atmospheric muon background, two complementary techniques are combined. The first technique selects events with high stochasticity to reject atmospheric muon bundles whose stochastic energy losses are smoothed due to high muon multiplicity. The second technique vetoes atmospheric muons with the IceTop surface array. Using 9 years of data, two neutrino candidate events are found in the signal region, consistent with expectation from background, each with relatively high signal probabilities. A joint maximum likelihood estimation is performed using this sample and an independent 9.5-year sample of tracks to measure the neutrino spectrum. A likelyhood ratio test is done to compare the single power-law (SPL) vs. SPL+cutoff hypothesis; the SPL+cutoff model is not significantly better than the SPL.



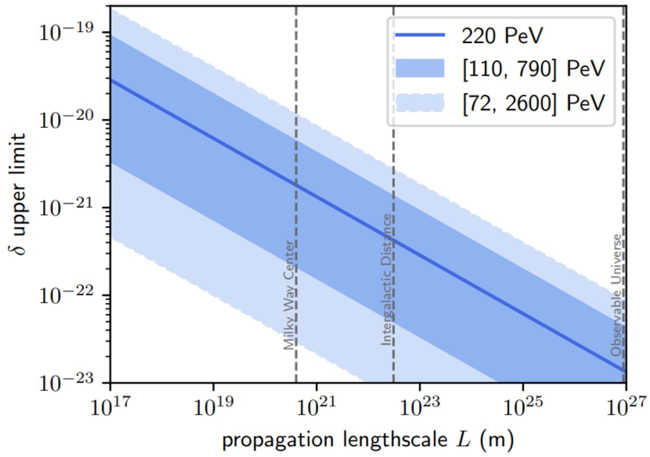
Best-fit per-flavor astrophysical neutrino flux as a function of neutrino energy under various model assumptions. The blue band shows the Single Power Law (SPL) results with ±1σ uncertainties. The left (39 TeV) and right (6.3 PeV) boundaries of the band represent the sensitive energy range for this analysis under the SPL hypothesis. The best-fit SPL+cutoff flux and uncertainty are shown by the pink line and band. Outside the sensitive energy range, flux models are represented by dashed lines. The black crosses represent differential fluxes assuming an E^{-2} spectrum for each bin. Uncertainties are at 68% C.L. and upper limits are at 90% C.L. The yellow crosses and lines represent measurements from the 9.5-year Northern Track paper.

The KM3NeT collaboration has submitted a paper *KM3NeT Constraint on Lorentz-Violating Superluminal Neutrino Velocity* to NATURE Physics (posted at https://arxiv.org/pdf/2502.12070. The corresponding authors are Carlos Argüelles (Harvard), A. Garcia Soto (IFIC Valencia) and A.Y. Wen (Harvard).

Lorentz invariance, together with the geometry of spacetime, implies that no particle can move faster than the speed of light. Recently ARCA has observed a spectacular muon which is indicative of an ultra-high-energy neutrino event, *KM3-230213A,* with an estimated neutrino energy of 220 (+570 −110) PeV (assuming an E^{-2} spectrum). In this work, the lower bound for the neutrino energy (which is the reconstructed muon energy of 120 PeV) is used to derive a limit on the difference between the speed of the neutrino v_ν and the speed of light, c.

Superluminal propagation is characterized by a parameter $\delta \equiv c_\nu{}^2 - 1$, where c_ν is the neutrino speed in units of the speed of light. A superluminal neutrino rapidly loses energy primarily via the process of pair emission of electrons $\nu \rightarrow \nu + e^+ + e^-$. This work assumes that the electron is not also superluminal, which has been independently constrained in other works (see the reference list). The calculation of the decay width $\Gamma = \Gamma(E, \delta)$, where E is the neutrino energy (presented in other references) can be used, for instance, in [1404.7025] Propagation of Superluminal PeV IceCube Neutrinos: A High Energy Spectral Cutoff or New Constraints on Lorentz Invariance Violation to set a limit on δ. It is generally possible to set a limit on δ using any neutrino if we know its energy and propagated distance.

With the assumption is that *KM3-230213A* is likely extragalactic (distance ≥ 1 Mpc), one can set a world-leading constraint on δ. The KM3NeT event leads to the most stringent neutrino-based constraint of superluminal velocity, $\delta < 4 \times 10^{-22}$, see the figure below).



The value of δ scanning over a wide range of L assuming we hold the energy constant at E_{UHE}. The bands correspond to the 68% and 90% confidence intervals in the energy estimation of KM3-230213A. We also indicate in the vertical dashed lines some length scales of interest: the size of the Milky Way, intergalactic distances (1 Mpc), and the size of the observable Universe.

Impressum

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https://www.globalneutrinonetwork.org

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