GNN Monthly

The Global Neutrino Network

90th Edition

November 29, 2024

Future of GNN

In a ZOOM meeting of the GNN Board on November 22, members of the board discussed the future evolution of the Global Neutrino Network. In the context of a possible RNO-G membership in GNN and the possible future evolution of the GNN beyond the current water/ice optical telescopes, the question came up whether GNN should be open for all kinds of radio-wave neutrino detectors and even beyond. The inclusion of other types of detectors would be in line with our present MoU which speaks about "neutrino telescopes", without further specifying which technology is used. W.r.t. the radio technology this seems logical in the context of astrophysics goals and the perspective of future data combination in the >10 PeV region. There was no specific rejection of the RNO-G membership. Rather, many expressed concerns that an extension beyond underwater/ice Cherenkov telescopes would lead to a certain loss of coherence and of cooperation on methods and details that are specific to the optical technique. Many have found the cooperation on details and "proprietary" information between the experiments a success of GNN. In IceCube & P-ONE, there seems to be a clear preference to extend the GNN perimeter, while the other members feel more reluctant. What everybody wants is to foster and extend is the current level of detailed collaboration between the younger people in the current or emerging working groups. The board had a lively and constructive discussion about the issue which will be continued in a soon following call. The general feeling was that the question of extension should be solved in the next months, but only after careful discussion within the present GNN collaborations (and not only the GNN Board).

News from the Experiments

IceCube

Early November, the first LC-130 Hercules of the summer season has arrived.

Meanwhile, the two new IceCube winterovers, John Baines-Holmes and Ilya Bodo (see above) arrived at the South Pole and are being trained by the previous winterovers Connor and Kalvin.

John Baines-Holmes (left) comes from Brighton, England, and worked as senior software developer, Ilya Bodo (right) comes from Providence, Rhode Island and worked as a software engineer in Boston.

See for more information
https://icecube.wisc.edu/news/collaboration/2024/11/meet-icecubes-2024-2025-winterovers-joe-and-ilya/

While John and Ilya are familiarizing themselves with all processes, more members of the IceCube team have arrived. More about the South Pole activities in the next GNN Monthly edition.

IceCube has admitted two new associate members: George Privon (National Radio Astronomy Observatory) and a group of four people from GOALS (**G**reat **O**bservatories **A**ll-sky **L**IRG **S**urvey) will study Ultra Luminous Infrared Galaxies (using the GOALS catalog). Abhishek Desai, a former postdoc at Univ. Wisconsin is now at NASA Goddard and will conduct searches in neutrino sources.

Last but not least: Just in time for everybody who is still looking for the ultimate picture calendar for 2025: **The new IceCube calendar!**
https://icecube.wisc.edu/news/outreach/2024/11/download-icecubes-2025-calendar/

KM3NeT

Antoine Kouchner, elected in June as the next chair of the KM3NeT collaboration board, has taken over the baton from Uli Katz and is in office since November 5.

On their recent collaboration meeting, KM3NeT accepted three new members:

- AGH University of Krakow, PI: Artur Ukleja (full member) acoustic neutrino detection and Corsika simulations.
- Université Libre de Bruxelles, PI: Juanan Aguilar (observer) focusing on dark matter detection and neutrino oscialltions.
- INFN /U Padova, PI: Elisa Bernardini (observer), focusing on combined KM3NeT/IceCube analyses, with special emphasis on the realtime part.

Publications

The Baikal GVD Collaboration together with four external authors has submitted a paper *Probing the Galactic neutrino flux at neutrino energies above 200 TeV with the Baikal Gigaton Volume Detector* to Phys.Rev.Lett. (see https://arxiv.org/pdf/2411.05608) The leading author is Sergey Troitsky (INR Moscow).

The authors use a sample of eight cascade events with estimated neutrino energies above 200 TeV, detected by Baikal GVD in six years of operation. They find that the distribution of the arrival directions of these eight cascades suggests an excess of neutrinos from low Galactic latitudes. They find the excess above 200 TeV also in the most recent IceCube public data sets, both of cascades and tracks. The combined significance of GVD and IceCube galactic excesses is 3.6σ.

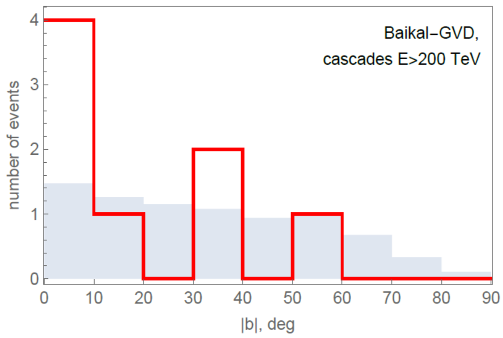
The following table gives the parameters of the eight GVD events:

Event ID	E, TeV	l,°	b,°	r_{50},°	r_{90},°
GVD190517CA	1200	99.9	54.9	2.0	3.0
GVD210117CA	246	168.8	38.8	1.6	3.6
GVD210409CA	263	73.3	−6.1	3.3	6.3
GVD210418CA	224	196.8	−14.6	3.0	5.8
GVD221112CA	380	61.0	−4.7	2.9	7.7
GVD230518CA	214	199.0	4.7	2.3	4.7
GVD231006CA	245	76.9	5.3	2.3	5.1
GVD230611CA	479	15.2	36.2	2.6	5.2

List of Baikal-GVD cascades with reconstructed neutrino energies E ≥ 200 TeV, observed in 2018–2023 observational seasons. Presented are energies E, Galactic coordinates (l, b), 50% CL and 90% CL accuracies of the determination of the arrival direction, r_{50} and r_{90}, respectively.

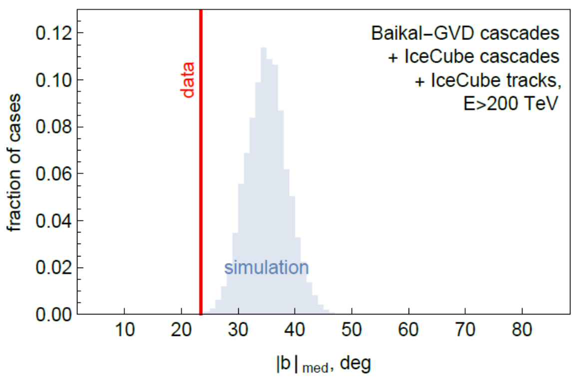
The next figure gives the observed (red line) and expected (assuming no galactic contribution, shaded histogram) distribution of the galactic latitude |b| for Baikal-GVD cascades with E ≥ 200 TeV. For the eight

GVD events, $|b|_{med}$ = 10.4°, while the value expected for no galactic contribution is $\langle|b|_{med}\rangle$ = 31.4°, which indicates the presence of the Galactic excess in the data. This gives a p-value of the rejection of the hypothesis of the absence of the Galactic excess, p = 1.4×10^{-2}. Since the study does not have any trials, this value should be treated as the post-trial value. For Gaussian statistics, it would correspond to 2.5σ.



Observed (red line) and expected (shaded histogram) distribution of |b| for Baikal-GVD cascades with E ≥ 200 TeV.

The authors then also consider published IceCube data, using cascades and tracks, both with E> 200 TeV. Applying the same procedure to the IceCube HESE data set, they find a similar Galactic excess, with an observed $|b|_{med}$ = 12.4°, compared to an expected value for no galactic contribution of $\langle|b|_{med}\rangle$ = 31.9°. The p-value for this excess is p = $8.7\cdot10^{-3}$ (2.6σ). For tracks taken from the ICECAT catalogue, the corresponding numbers are $|b|_{med}$ = 24.7°, $\langle|b|_{med}\rangle$ = 36.0°, and p = $1.8\cdot10^{-3}$ (3.1σ). See the comparison data – simulation for all three samples combined in the next figure and the numbers separately for all samples in the following table.



Distribution (shaded histogram) of the median $|b|_{med}$ in simulated combined sets of Baikal-GVD cascades, IceCube cascades and IceCube tracks with E ≥ 200 TeV. The observed value of $|b|_{med}$ is shown by the vertical red line.

Sample	$\|b\|_{med}$ observed	$\langle\|b\|_{med}\rangle$ expected	p
Baikal-GVD cascades	10.4°	31.4°	$1.4\cdot10^{-2}$ (2.5σ)
IceCube cascades	12.4°	31.9°	$8.7\cdot10^{-3}$ (2.6σ)
combined cascades	12.4°	31.5°	$1.7\cdot10^{-3}$ (3.1σ)
IceCube tracks	24.7°	36.0°	$1.8\cdot10^{-3}$ (3.1σ)
all cascades+tracks	23.4°	35.0°	$3.4\cdot10^{-4}$ (3.6σ)

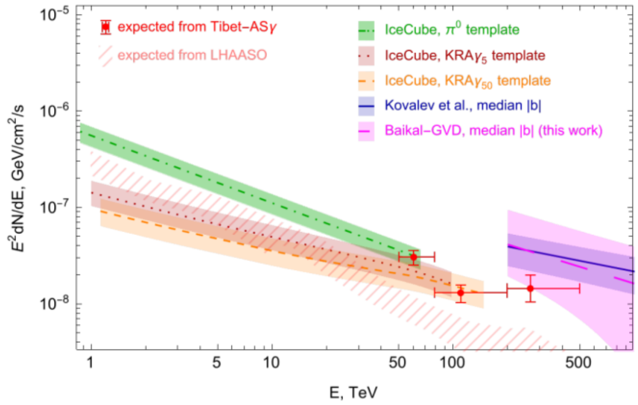
Results of the search for the Galactic component

The next table gives the Galactic neutrino fluxes between 200 TeV and 1 PeV predicted for 3 spectral templates used in the IceCube Galactic Plane analysis (Science 380, adc9818 (2023), arXiv:2307.04427 [astro-ph.HE]). One can see a dramatic difference between template predictions and our model-independent results above 200 TeV: previously used spectral templates under-predict the Galactic neutrino flux at these energies.

	Flux	Fraction
Predicted by templates:		
KRAγ_5	0.34	–
KRAγ_{50}	0.78	–
π^0	0.077	–
Templates normalized to IceCube [18]:		
KRAγ_5	$0.19^{+0.06}_{-0.05}$	$0.044^{+0.016}_{-0.014}$
KRAγ_{50}	$0.29^{+0.10}_{-0.09}$	$0.067^{+0.026}_{-0.024}$
π^0	$0.37^{+0.09}_{-0.08}$	$0.086^{+0.026}_{-0.025}$
Estimated in Ref. [16]:		
IceCube tracks	1.3 ± 0.5	0.28 ± 0.09
Estimated in the present work:		
Baikal-GVD cascades	$3.7^{+4.3}_{-2.8}$	$0.49^{+0.51}_{-0.24}$
IceCube cascades	$1.0^{+1.2}_{-0.6}$	$0.26^{+0.30}_{-0.12}$
IceCube tracks	$1.7^{+0.9}_{-0.7}$	$0.34^{+0.17}_{-0.12}$

Integral fluxes (in units of 10^{-13} cm^{-2} s^{-1}) of Galactic neutrinos with 200 TeV < E < 1 PeV and the Galactic fractions in the total astrophysical flux (per flavor) of neutrinos at these energies, obtained in different analyses.

The last figure presents the observed Galactic neutrino flux from Baikal-GVD cascades, estimated in the present work, together with expectations from Tibet-ASγ and LHAASO observations, in the assumption of the common origin of both neutrinos and photons in proton collisions. The difference between two experiments in the gamma-ray fluxes at high energies may be related to different masks imposed to cut point sources of high-energy emission.



Estimated full-sky spectra of Galactic neutrinos obtained in the present and in some of preceding studies, together with those expected from observations of diffuse Galactic gamma rays.

The Galactic neutrino flux agrees with the expectations from the gamma-ray diffuse Milky-Way emission observed by Tibet-ASγ, though a direct comparison requires model-dependent assumptions. The neutrino flux is higher than similar expectations from LHAASO observations. According to the authors, this may indicate that the neutrino emission is not purely diffuse, and some part of it comes from localized, point-like or extended, sources, masked in the LHAASO analysis. The Cygnus region, with a cluster of three events in the GVD neutrino sky map, may host some of them.

The KM3NeT Collaboration has submitted a paper *gSeaGen code by KM3NeT: an efficient tool to propagate muons simulated with CORSIKA* to the Journal Computer Physics Communications (posted at *https://arxiv.org/pdf/2410.24115*). The corresponding author is Piotr Kalaczynski, Nicolaus Copernicus Astronomical Center, Warsaw.

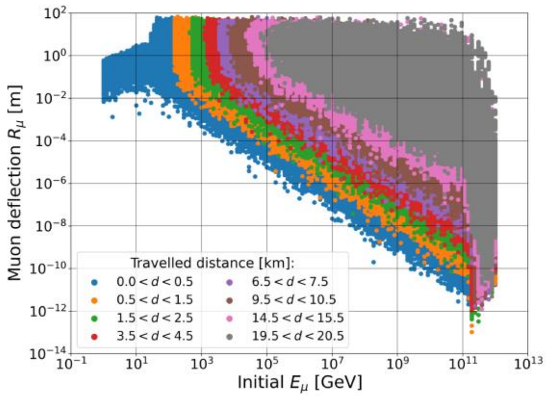
The KM3NeT Collaboration has tackled a common challenge faced by the astroparticle physics community, namely adapting the experiment-specific simulation software to work with the CORSIKA air shower simulation output. The proposed solution is an extension of the open-source code gSeaGen, allowing for the transport of muons generated by

CORSIKA to a detector of any size at an arbitrary depth. The gSeaGen code was not only extended in terms of functionalities but also underwent a thorough redesign of the muon propagation routine, resulting in a more accurate and efficient simulation. Direct readout of CORSIKA output has been implemented, as well as the possibility to either directly convert it to a different data format or to perform propagation of simulated atmospheric muons to a specified detector. The user of gSeaGen can control how the propagation is carried out and what information is deemed worth saving. The muon propagation routine includes many optimizations, which boost both the accuracy of the muon transport and the speed of the code. Options facilitating the reuse of generated showers have been added. These developments were made with simulations of the KM3NeT neutrino telescopes primarily in mind but other underground, -water, or -ice experiments may profit from them as well. The efforts towards a more efficient and complete treatment of CORSIKA air shower simulations continue. The features foreseen in the future include, but are not limited to:

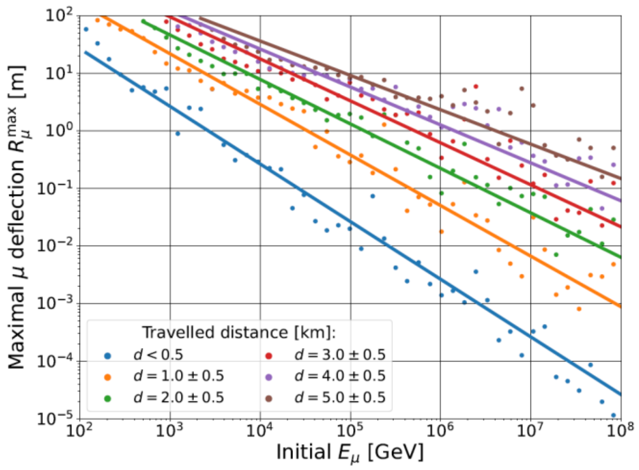
- propagation of neutrinos together with muons,
- upgrade to a newer version of PROPOSAL
- adding the KM3NeT data format as one of the possible output format choices.

The authors would welcome user feedback. It should preferably be expressed via issues in the official GitLab repository.

Adequately to the subject, the paper is rather technical and hard to be discussed beyond what is written above. Below, I extracted just two figures from the appendix of the paper which I found quite illustrative. They show how strongly a muon is deflected as a function of energy and of traveled distance.



Lateral deflection of muons R_μ as a function of their initial energy E_μ and distance d travelled in seawater.



Maximal lateral muon deflections fitted as a function of Eμ. The fitting function is $R(E_\mu) = 10^{(a_d \cdot \log10(E_\mu)+b_d)}$.

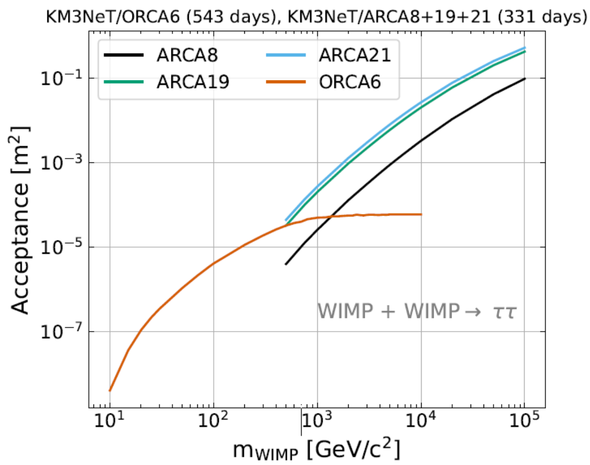
The KM3NeT Collaboration has submitted a paper *First Searches for Dark Matter with the KM3NeT Neutrino Telescopes* to JCAP (see *https://arxiv.org/pdf/2411.10092*). Corresponding authors are M. Gutiérrez (U.Granada) and A. Saina (IFIC Valencia).

In this work, searches for dark matter annihilations in the Galactic Centre and the Sun with data samples taken with the first configurations of ORCA and ARCA are presented. No significant excess over the expected background was found in either of the two analyses. Form ARCA data, limits on the velocity-averaged self-annihilation cross section of dark matter particles are computed for five different primary annihilation channels in the Galactic Centre. For the Sun, limits on the spin-dependent and spin-independent scattering cross sections of dark matter with nucleons are given for three annihilation channels, using ORCA data.

Here are the analyzed periods, the effective life time (arguably much less than 4532 days for ANTARES) and the number of selected events:

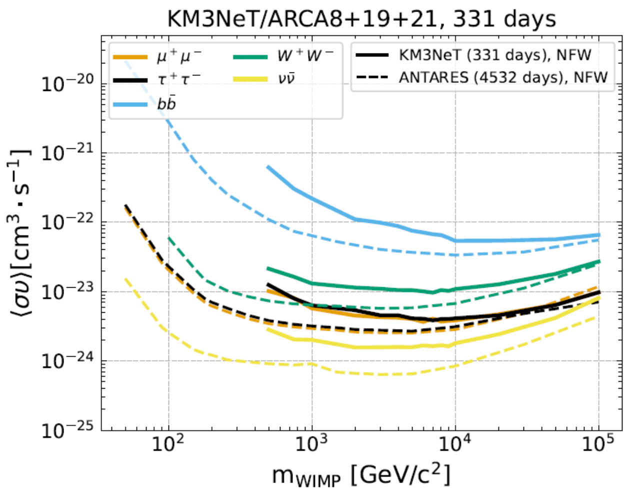
Config.	Period	nb days	nb events
ARCA8	26.09.2021 - 01.06.2022	210	647
ARCA19	10.06.2022 - 12.09.2022	52	517
ARCA21	22.09.2022 - 19.12.2022	69	1044
ORCA6	26.01.2020 - 18.11.2021	543	2366

The next figure shows, as an example, the signal acceptance as a function of the dark matter mass for WIMP particles annihilating into $\tau^+\tau^-$ in the Galactic Centre (ARCA acceptances) and in the Sun (ORCA acceptance).



Signal acceptance as a function of the dark matter mass for WIMP particles annihilating into $\tau^+\tau^-$ in the Galactic Centre (ARCA acceptances) and in the Sun (ORCA acceptance).

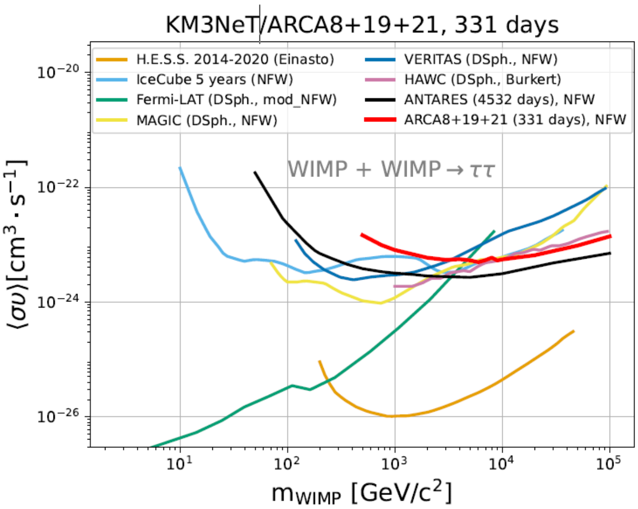
The following shows the 90% CL upper limits on the thermally-averaged WIMP annihilation cross section, $\langle\sigma_\upsilon\rangle$, as a function of the WIMP mass for each of the five annihilation channels, obtained with the ARCA8-21 data set, compared to ANTARES results.



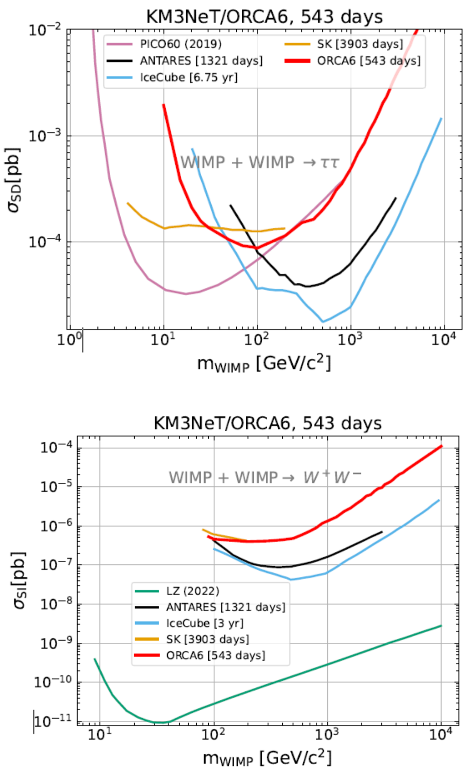
90% CL upper limits on the thermally-averaged WIMP annihilation cross section, $\langle\sigma_\upsilon\rangle$, as a function of the WIMP mass for each of the five annihilation channels, obtained with the ARCA8-21 data set (full lines) and with the ANTARES 4532-day data set (dashed lines).

These results are compared to those from other experiments in the next figure.

From the ORCA data, looking for excesses from the Sun, limits on the spin-dependent and spin-independent scattering cross sections of dark matter with nucleons are obtained for ττ and W+W-annihilation channels, see as an example the second-next figures.



90% CL upper limits on the thermally-averaged WIMP annihilation cross section, ⟨σ$_\upsilon$⟩, as a function of the WIMP mass for the $\tau^+\tau^-$ annihilation channel obtained with the ARCA8-21 data set along with results obtained by other experiments (see the paper for comments on the figure)



90% CL upper limits on the spin-dependent WIMP-nucleon cross section as a function of the WIMP mass for the $\tau^+\tau^-$ (top) and for the spin-independent WIMP-nucleon cross section as a function of the WIMP mass for the W^+W^- (bottom) annihilation channels.

Summing up: The two telescopes, still in their construction phase, are already setting competitive limits on the dark matter coupling to the Standard Model. WIMP-nucleon cross section limits obtained with ORCA6 are surpassing their predecessor, ANTARES, at low WIMP masses, owing to the higher density of detector components and lower energy threshold. The annihilation cross section limits obtained with one year of lifetime with ARCA8-21 are comparable, although less stringent, to those obtained with the full ANTARES data set, due to improved light detection technology and event reconstruction and selection methods. Follow-up searches with currently deployed and future larger detector configurations will push the boundary of dark matter searches with neutrino telescopes.

Impressum
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