GNN Monthly

The Global Neutrino Network 61th Edition March 28, 2022

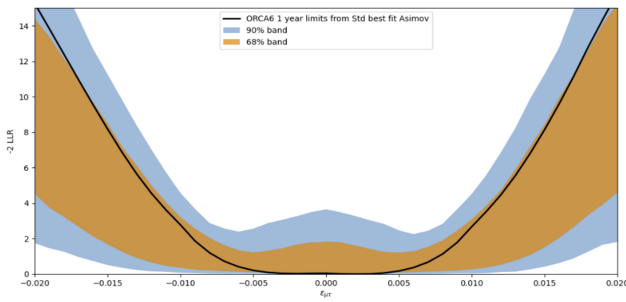
It is a bizarre and depressing feeling to publish a Monthly Newsletter while a brutal war is raging against Ukraine less than 1000 km from here. More than three million people are fleeing, Berlin alone has received about a hundred thousand refugees. Mariupol is in ruins and looks like Berlin after World War II. And no end in sight ... At this moment, my sympathy and solidarity go out to the Ukrainian people and likewise to all my Russian friends who consistently oppose this war.
Christian

News from the GNN partners

KM3NeT

Recent IceCube alerts of high energy neutrinos have led to excitement in the community, due to possible correlations with Blazars and/or other observations. While KM3NeT is still commissioning its online analysis and alert system, several alerts are followed up in offline analyses. Recently, a search was completed around IceCube-211208A, which coincided with a flare of the blazar PKS0735+178 in December of last year. Using both the ARCA and ORCA arrays, KM3NeT searched for coincident neutrinos during a +/- 1 day time-window around the IceCube alert, and also in the full month of December. While no excess of events was found, an Astronomer's Telegram was published, which marks one of the first astronomy results of KM3NeT.

Using the 1-year ORCA dataset that was already used for measuring neutrino oscillations, results have been unblinded that probe so-called non-standard interactions (see the Jan/Feb GNN Monthly for a detailed description along with the ANTARES and IceCube publications). By looking for an anomalous pattern in the distributions of the energy and zenith angle of the detected neutrinos, the analysis probes the parameter $\varepsilon_{\mu\tau}$. The results are fully compatible with the absence of non-standard interactions and the parameter is constrained to be $-0.01 < \varepsilon_{\mu\tau} < 0.01$ at 90 CL (see the figure). For comparison, limits from ANTARES and IceCube are both about $-0.004 < \varepsilon_{\mu\tau} < 0.003$. Projections for the completed ORCA detector indicate that it would surpass this with less than 3 years of data.



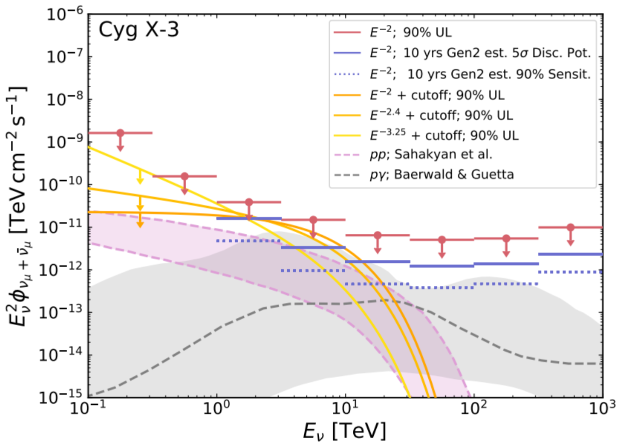
Baikal GVD

On March 18, the deployment of the 9th cluster was completed and that of the 10th cluster started. Meanwhile also the first of the two new cables has been laid.

Publications

The IceCube Collaboration has submitted a paper *Search for High-Energy Neutrino Emission from Galactic X-ray Binaries with IceCube* to *ApJ Letters* (2202.11722.pdf (arxiv.org)). The analysis was made by Ali Kheirandish (Pennsylvania State U.), Qinrui Liu (UW Madison) and Chun Fai Tung (Georgia Inst. of Technology, Atlanta). Galactic X-ray binaries are long-standing candidates for the source of Galactic hadronic cosmic rays and neutrinos. The compact object in these systems can be the site of cosmic-ray acceleration, neutrinos can be produced by interactions of cosmic rays with radiation or gas, in the jet of a micro-quasar, in the stellar wind, or in the atmosphere of the companion star.

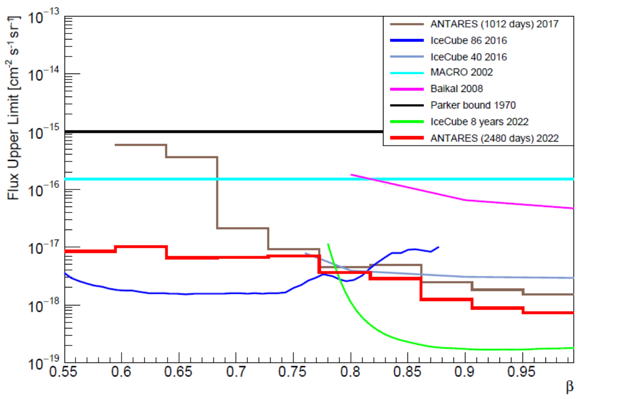
The paper reports the results from three separate analyses, each using 7.5 years of IceCube data. The first searches for periodic neutrino emission from 55 binaries in the Northern Sky with known orbital periods. In the second, the X-ray light curves of 102 binaries across the entire sky are used as templates to search for time-dependent neutrino emission. The third analysis searches for time-integrated emission of neutrinos for a list of 4 notable binaries identified as micro-quasars (Cyg X-3, LS 5039, LS I +61 303, SS 433). In the absence of a significant excess, upper limits are placed on the neutrino flux for each hypothesis and the results compared with theoretical predictions for several binaries.



Cygnus X-3: Current IceCube upper limits (red) and 10-year sensitivity (blue dotted) and discovery potential (blue solid) for IceCube-Gen2. The full yellowish curves denote integral upper limits to pp scenarios assuming different spectral indices and an exponential cutoff. The shaded regions show predictions of pp and pγ scenarios including various uncertainties.

The ANTARES Collaboration has submitted a paper *Search for Magnetic Monopoles with ten years of the ANTARES neutrino telescope* to the *Journal of High Energy Astrophysics* (2202.13786.pdf (arxiv.org)) which is meanwhile accepted https://www.sciencedirect.com/science/article/pii/S2214404822000118?dgcid=author. The analysis has been performed by Jihad Boumaaza from University Rabat (Morocco).

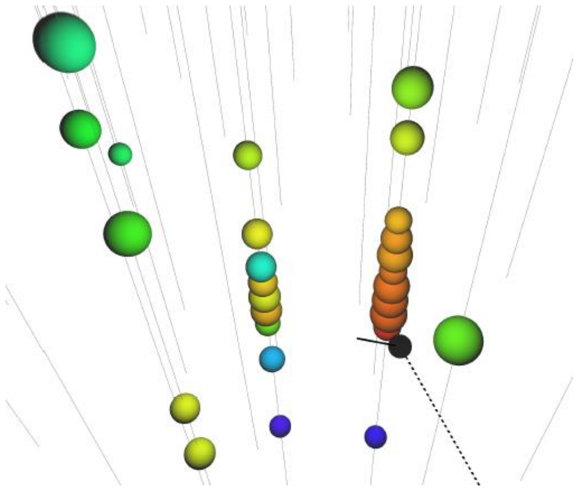
The paper presents the results of a new MM analysis for velocities 0.55000 < v/c < 0.9950, searching for MMs crossing the detector from below. It uses an optimized simulation strategy of MMs based on the KYG model (Kasama, Yang and Goldhaber, 1977), and a larger exposure than previous work. A Model Rejection Factor method, relying on the cuts on observable parameters, such as the number of hits in the detector and the quality of the reconstructed event, has been employed to optimize the sensitivity for each of the 10 intervals of β = v/c. After the analysis of the full data sample (2480 days), no event survived the selection, and upper limits on the flux are set for each of the 10 intervals. The choice of the KYG model for the MM cross-section with matter led to the improvement in the upper limit on the flux for low velocities with respect to previous ANTARES results. An extra cut applied in this region allowed a better background rejection. The upper limits on the fluxes hold for MMs with masses larger than 10^{11} GeV/c^2, due to the requirement to cross the Earth.



ANTARES 90% C.L upper limit on the flux for magnetic monopoles corresponding to 10 years of analyzed data (2480 days, thick red line) compared to: ANTARES previous upper limit on the flux (brown), IceCube (blue and green), MACRO (cyan) and Baikal (magenta), and the theoretical Parker bound (black).

The IceCube Collaboration has submitted a paper *Low Energy Event Reconstruction in IceCube DeepCore* to EPJ C (posted at [2203.02303.pdf (arxiv.org))](2203.02303.pdf (arxiv.org)). The paper is based on the work of many people, the main actual contributors are Philipp Eller (TU Munich), Kayla Leonard (UW Madison), Alexander Trettin (DESY) and Jan Weldert (U. Mainz).

Reconstructed direction and energy of a neutrino interacting in DeepCore are prime ingredients to many analyses. Algorithms to extract this high level information from the detector's raw data have been successfully developed and used for *high energy* events. This work addresses the extraordinary challenges associated with the reconstruction of *low energy* events in the range of a few to hundreds of GeV. The next figure gives an impression of the challenge: note the tiny muon track (black line) which emits the light on which the reconstruction builds.



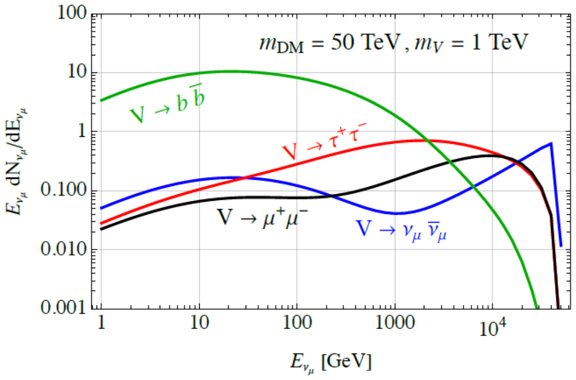
A simulated ν_μ CC interaction with a neutrino energy of 25 GeV inside the DeepCore sub-volume. The outgoing 8 GeV muon is indicated by the black, solid line (dotted line: neutrino path).

The paper presents two separate, state-of-the-art algorithms. One focuses on the fast directional reconstruction of events based on un-scattered light. The second algorithm is a likelihood-based multipurpose reconstruction offering superior resolutions, at the expense of larger computational cost. Naturally the many technical details are difficult to be summarized in this letter, so I have to refer to the paper itself for more information.

The ANTARES Collaboration has submitted a paper *Search for secluded dark matter towards the Galactic Centre with the ANTARES neutrino telescope* to JCAP (posted at 2203.06029.pdf (arxiv.org)). The main authors of this paper are Rebecca Gozzini (IFIC Valencia), Filippo Sala (CNRS Paris) and Cristina Lagunas Gualda (now DESY Zeuthen).

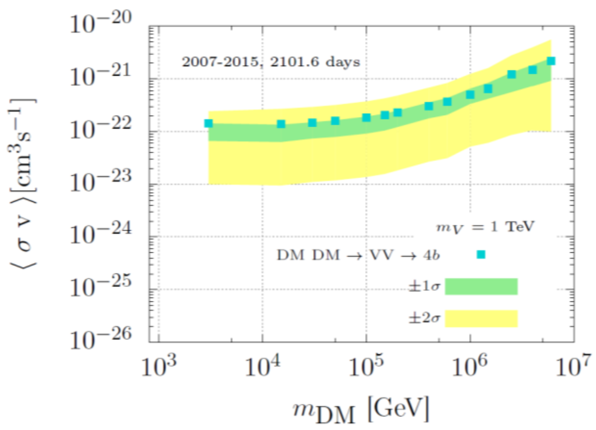
Among the many proposed DM candidates, WIMPs with a mass at the electroweak scale (up to $\mathcal{O}$(10) TeV) have been prime candidates since long. They annihilate to ordinary particles detectable far from their source (indirect detection), are scattered by ordinary matter (direct detection), and can be produced at colliders. The missing evidence for their existence has motivated the exploration of new regions of the DM parameter space, and indeed recent years have seen a growing theoretical interest in DM candidates heavier than 10 TeV. Considerations of unitarity of DM annihilation processes imply the existence of an upper limit on the DM mass. This limit holds if some conditions about the cosmological history of the universe and of DM are respected, and can for example be evaded if the universe was matter dominated between the freeze-out of dark matter interactions and Big Bang nucleosynthesis. This is the domain of the so-called *Secluded DM models*. Here, the DM particle interacts with a mediator particle (let's call it V), which in turn is only feebly interacting with SM particles. In these scenarios, the unitarity bound on the mass of thermal dark matter is avoided and DM masses of 100 TeV and above are allowed. Such models provide large signals in indirect detection searches (because controlled by the dark matter $\leftrightarrow$ mediator interaction) with almost no signal in direct detection and collider experiments (because controlled by the small mediator $\leftrightarrow$ SM coupling).

The present search is performed as a function of three free parameters: the dark matter mass m_{DM}, the mediator mass m_V, and the annihilation channel ($V \rightarrow$ bb, $\mu\mu$, $\tau\tau$, $\nu\nu$ - meaning particle and antiparticle in each case). The next figure shows the energy distribution of the muon neutrinos plus antineutrinos at Earth location, per single annihilation of a pair of DM particles (each with mass of 50 TeV) into two mediators V. The mediator V decays to the SM pair indicated in the legend, after that all (anti)neutrino flavors coming from that specific pair are included and contribute via long-distance oscillations to the muon (anti)neutrinos at Earth location. The mediator mass is assumed to be 1 TeV.



Energy distribution of muon (anti-)neutrinos from various V-decay channels; see text for more information.

The next figure gives an example of the final results. Note that this constitutes the first time that any telescope tested annihilation signals from DM with masses up to the PeV range.



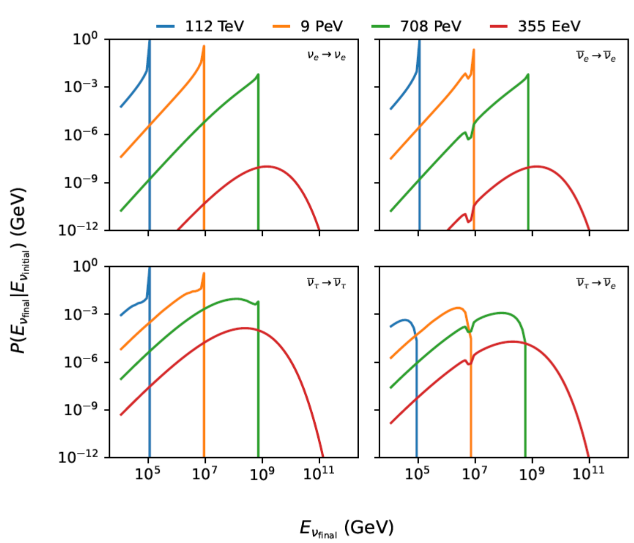
Upper limits at 90% CL on the velocity-averaged DM pair annihilation cross section ⟨σ v⟩ for a mediator mass m_V = 1 TeV, each V decaying into b/anti-b, with 1σ and 2σ containment.

A paper ***toise****: a framework to describe the performance of high-energy neutrino detectors* by J. van Santen (DESY) B. A. Clark (UW Madison) R. Halliday (both UW Madsion) S. Hallmann (DESY) and A. Nelles (DESY/Erlangen) is of interest for all of us planning new neutrino telescopes, optical as well as radio-detectors (2202.11120.pdf (arxiv.org)).

Complete Monte Carlo estimates of detector performances are extremely time consuming, restricting the number of detector configurations considered when designing the instruments. The paper describes a Python-based software framework to forecast the performance of neutrino detectors in the TeV to EeV range, using parametrizations of the detector performance, such as the effective areas, angular and energy resolutions, etc.

toise can be used to forecast the performance of a variety of physics analyses, including sensitivities to diffuse fluxes of neutrinos and sensitivity to both transient and steady state point sources. The parameterized approach allows the user to study the influence of single performance metrics, like the angular resolution, in isolation. The framework is designed to allow for multiple detector components, each with different responses and exposure times, and can be applied to both optical and radio-Cherenkov (Askaryan) neutrino telescopes. The paper describes the mathematical concepts behind **toise** and introduces the reader to its use.

One nice projection of the relevant five-dimension response tensor $D_{f,\,E_\nu,\,\cos(\theta_\nu),\,E_{rec},\,\Delta\Psi}$ (f for each 3 neutrino and anti-neutrino flavors, E_ν the incoming neutrino energy, $\cos(\theta_\nu)$ the zenith angle, E_{rec} the reconstructed energy and ΔΨ the angular reconstruction uncertainty) is shown in the figure below. It gives the probability of observing a neutrino of the given final flavor as a function of final neutrino energy for different $E_{\nu,\,initial}$, at a fixed angle cos θ = - 0.15. The shoulders at lower energy are due to interactions in the Earth, the dip in the upper right panel to the Glashow resonance. The lower left panel illustrates the "τ regeneration" effect, where decays of τ leptons produced in CC ν_τ interactions result in a secondary flux of lower-energy ν_τ (figure based on the calculation of transmission probabilities by Vincent et al. https://iopscience.iop.org/article/10.1088/1475-7516/2017/11/012).



Obituary

Our friend and colleague Thomas K. Gaisser, Martin A. Pomerantz Professor of Physics at the University of Delaware, passed away on Sunday, February 20, 2022, after a short illness. He was 81.

Tom was a pivotal researcher in the field of cosmic-ray physics. Since the late 1970s, he has inspired and contributed to the scientific success of many efforts in cosmic ray, particle astrophysics, and multi-messenger astronomy.

Tom's scientific legacy includes the foundations of the physics of extensive air showers, which have since motivated state-of-the art detectors that study with great precision the properties and origins of cosmic rays, as well as contributions to fundamental questions in particle physics.

He also laid the theoretical foundations for interpreting the physics of the atmospheric "neutrino beam", and his continued passion for the subject contributed to the discovery of neutrino oscillations and to the successes of the present generation of atmospheric neutrino experiments. Other examples of his many contributions include early calculations of the antiproton flux in the atmosphere, which is relevant for the search for new physics; atmospheric muon and neutrino fluxes; early gamma-ray and astrophysical neutrino flux predictions; cosmic-ray air shower physics and hadronic interaction; the Sibyll simulation of cosmic-ray interactions; and the modeling of the cosmic-ray flux.

Tom's far-reaching and innumerable contributions to the field have been internationally recognized, e.g. with the Humboldt Research Award, the O'Ceallaigh Medal, and the Homi Bhabha Medal and Prize. He was also named a Fellow of the American Physical Society in 1984 for "seminal contributions to our current understanding of the nature of the diverse interactions of cosmic rays with very high energies, and of their astrophysics implications." Tom has even been recognized with a valley in Antarctica named after him, Gaisser Valley.

The main reason he is known to every scientist in the field is, of course, his book "Cosmic Rays and Particle Physics", published in 1990 and as a second updated edition in 2016, coauthored with Ralph Engel and Elisa Resconi – a book sitting on the shelves of scientists and students all around the globe.

In the IceCube Collaboration, Tom Gaisser was both a leader and a person everyone could count on. He has served this team in many ways, including as IceCube's spokesperson between 2007 and 2011. He was also the soul of IceTop, IceCube's surface array. Although a theorist, Tom actively participated in all seasons of IceCube construction at the South Pole.

A great scientist and friend has left us. We will always remember his kindness, his encouragement to many young scientists, his reliability and incorruptible judgement, and we will treasure his memory.