GNN Monthly
The Global Neutrino Network
68th Edition
November 6, 2022

This will be a pleasant Newsletter with respect to the November news and a very sad Newsletter with respect to the news from mid of October. Within less than two weeks we lost three scientists who left their firm footprints in our field, in the one way or another. I had the sad duty of writing three obituaries and hope to have done justice to each of the three with their own memorable merits and personalities.

The good news, of course, are the IceCube results on NGC 1068, meanwhile known to many GNN readers from the webinar on November 3. The Publication Section of GNN Monthly is dedicated this time only to this beautiful result.

RNO-G Collaboration Meeting in Erlangen

For the second time only, the RNO-G Collaboration got together in person in October 17-21 in Erlangen Here the report of Anna Nelles: We discussed the operation of the 7 existing stations in Greenland and plan for the installation of the next 28 stations. The current stations have successfully operated throughout the winter since 2021. But they had to be switched to a low-power mode that does not allow for data-taking. Going forward, the stations will be equipped with wind-turbines, allowing for year-round science operations. Installation seasons are planned for 2024, 2025, and 2026 with drilling of new stations. Due to hardware procurement issues, 2023 will see a smaller season with hardware upgrades and calibration only.

The collaboration is currently mostly busy with calibrating the instrument and the ice. Several publications about ice properties are close to completion. RNO-G is also getting ready for physics analysis: Discussion topics included real-time capabilities, cosmic ray studies, and trigger optimization.

Overall, it has been a very successful meeting with more than 2/3 of the authors attending in person. RNO-G will continue to meet in-person once a year and once virtually, acknowledging every scientist's responsibility for keeping the travel footprint small.

The meeting was also the first meeting to use the new laboratory building at ECAP -- even before the official inauguration in November -- which provides lots of space and facilities for future experimental ideas in the astroparticle world.

Photo Credit: Cosmin Deaconu, RNO-G Collaboration

KM3NeT Collaboration Meeting

Read the report by Uli Katz, chair of the institute board:

The third KM3NeT Collaboration of the year, 24-28 Oct 2022, was held in presence - with substantial remote participation - at the Enrico Fermi Study and Research Centre located on the site of the Ministry of the Interior close to the centre of Rome. This Centre is located in the same building where Enrico Fermi and a group of young physicists conducted the first experiments on neutron-induced radioactivity, fundamental for the future development of nuclear energy. The KM3NeT members also enjoyed a guided tour through the associated museum dedicated to Fermi's work and legacy.

During the meeting the Management Team (Spokesperson: Paschal Coyle; Deputy: Rosa Coniglione: Physics and Software Manager: Aart Heijboer; Technical Project Manager: Miles Lindsey Clark) have been re-elected with overwhelming majorities. Three institutes have been endorsed as new full Collaboration members: The Technical University of Prague (PI: Ivan Stekl), the Comenius University of Bratislava (PI: Fedor Simkovic) and the Université Mohammed VI Polytechnique in Morocco (PI: Ahmed Ratnani). The application of Yuri Y. Kovalev (on leave of absence from Lebedev Physical Institute Moscow, now Max-Planck Institute for Radio Astronomy Bonn) for the newly created Associated Membership has been strongly supported and is expected to be concluded soon.

Altogether, it was a busy week with lots of new results under discussion and reviewing the great progress achieved towards construction of the detector. The weather shared the good mood and indulged the participants with blue skies and summer-like temperatures.

Publications

On November 4, Science Journal published the IceCube paper *Evidence for neutrino emission from the nearby active galaxy NGC 1068*. The main results had been presented in a webinar on November 3 (see [LIVE] Evidence for neutrino emission from the nearby active galaxy NGC 1068 - YouTube). With a significance of 4.2 σ, they mark the first compelling evidence for a steady point source of high energy neutrinos.

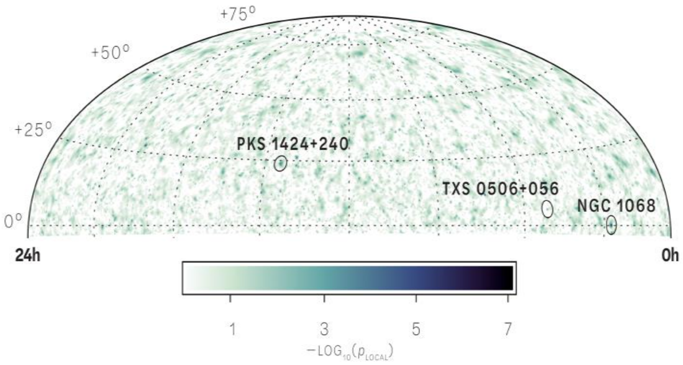
The paper reports from three searches for high energy neutrino emission from astrophysical objects. The data have been taken between 2011 and 2020. Improvements over previous work include new neutrino reconstruction and data calibration methods (see also the last figure below).

The *first search* consists of three discrete scans of the Northern Sky to identify the location of the most significant excess of high-energy neutrino events. It uses three different hypotheses on the spectral index: *a)* as a free parameter and fixed to *b)* 2.0 and *c)* 2.5.

The other two analyses have been done on a list of 110 astronomical objects, all located in the Northern Hemisphere: *one* is the search for the most significant candidate neutrino source in the list, the *second* consists of a binomial test to evaluate the significance of observing an excess of k sources with local p-value below or equal to a certain threshold, with k going from 1 to 110. Similar to the sky scan, the binomial test was also repeated under the three spectral index hypotheses.

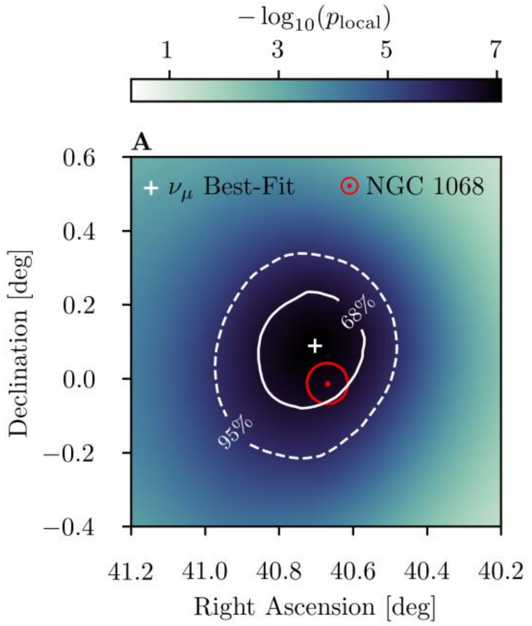
All searches were performed in the Northern Hemisphere from declination -3° to -81°. Declinations < -81° were excluded because low energy events tend to line-up completely with the strings of IceCube, complicating the numerical modeling of the signal and background in the likelihood. Of course, all analysis methods, including the selection of the hypotheses to be tested, were formulated a priori.

The result of the sky-scan (method 1) is shown in the next figure.

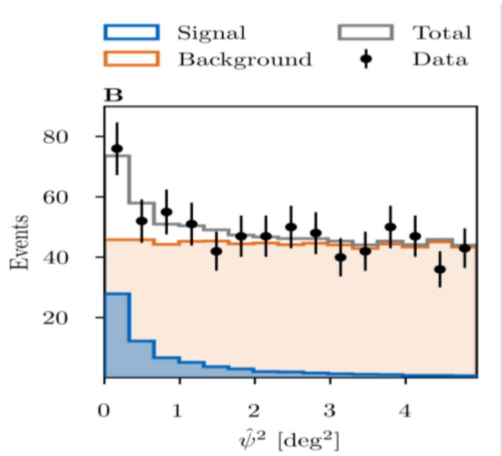


Skymap of the scan for point sources in the Northern Hemisphere. The color scale represents the local p-value obtained from the maximum likelihood analysis evaluated (with the spectral index as free fit parameter) at each location in the sky. The black circles indicate the three most significant objects in the source list search. The circle of NGC 1068 also coincides with the overall hottest spot in the Northern Sky.

In the second of the three searches, the positions of the 110 *a priori* selected gamma-ray sources were analyzed individually for a possible surplus of neutrinos over atmospheric and cosmic background expectations. An excess of 79 (+22,-20) neutrinos associated with NGC 1068 was found, with the mentioned significance of 4.2σ (corrected for all possible trials).

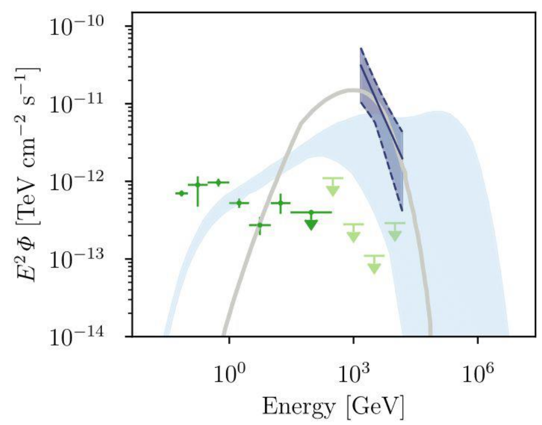


The sky region around the most significant spot in the Northern Hemisphere and NGC 1068. The plot shows a fine scan of the region around the hottest spot. The spot itself is marked by a yellow cross, the red circle shows the position and size of NGC 1068. In addition, the solid and dashed contours show the 68% and 95% confidence regions of the hot spot localization.



Distribution of the squared angular distance between NGC 1068 and the reconstructed event direction. From Monte Carlo one estimates the background (orange) and the signal (blue) assuming the best-fit spectrum at the position of NGC 1068. The superposition of both components is shown in gray and provides an excellent match to the data (black). Note that this representation of the result neglects all the information on the energy and angular uncertainty of the events that is used in the unbinned maximum likelihood approach.

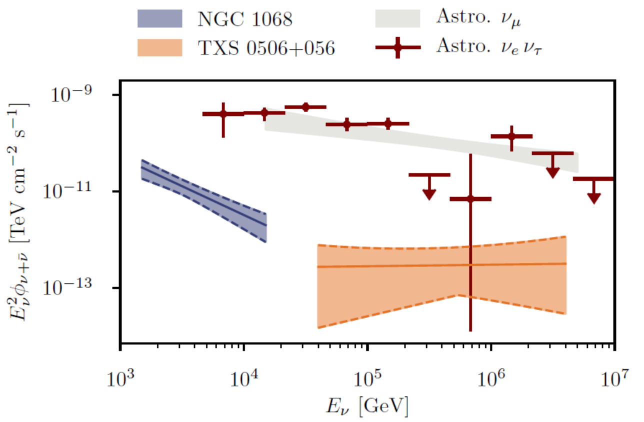
This result is interpreted as direct evidence of TeV neutrino emission from NGC 1068. The inferred flux exceeds the potential TeV gamma-ray flux by at least one order of magnitude, as shown in the next figure, i.e. the source is obscured in gamma rays.



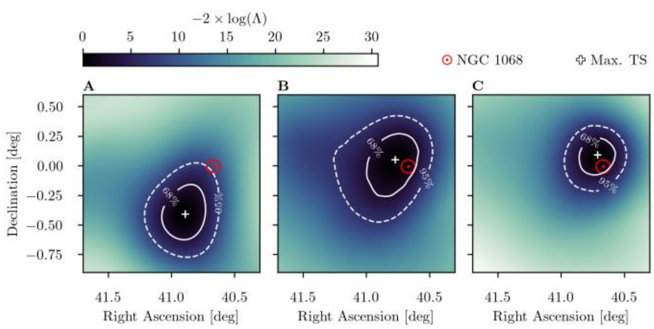
Spectral energy distribution of NGC 1068. Dark and light green error bars refer to gamma-ray data from Fermi-LAT and MAGIC, respectively. The solid, dark blue line shows the best-fit neutrino spectrum, the corresponding blue band covers all power-law neutrino fluxes that are consistent with the data at 95% C.L. It is shown in the energy range between 1.5 TeV and 15 TeV where the flux measurement is well constrained. Fluxes from two NGC 1068 neutrino emission models are shown for comparison (light-blue band: Y. Inoue, D. Khangulyan, A. Doi, APJ Lett. 891, L33 (2020), grey curve: K. Murase, S. S. Kimura, P. Meszaros, PRL 125, 011101 (2020)).

Both AGN core scenarios mentioned in the figure caption predict a significant absorption of gamma-ray photons (different to the TXS 5060+056 case). Note that NGC 1068 was one of the two AGN suggested by R. Silberberg and M. Shapiro at a 1982 DUMAND meeting, including the prediction that "gamma rays from the ergosphere of a black hole are degraded above ~ 1 MeV", while "neutrinos are not thus effected".

The evidence of neutrino emission from NGC 1068 suggests that AGN could make a substantial contribution to the diffuse neutrino flux observed by IceCube. However, the next figure demonstrates that in their respective energy ranges the sources NGC 1068 and TXS 0506+056 contribute no more than ~1% to the overall diffuse flux of astrophysical neutrinos.



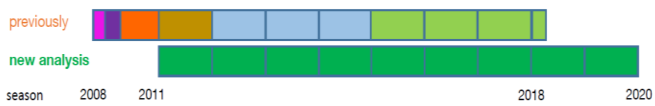
Comparison of point-source fluxes for NGC 1068 and TXS 0506+056 from the present analysis with the IceCube total diffuse astrophysical neutrino flux. Fluxes are given for a single flavor of neutrinos and anti-neutrinos assuming equal flavor ratio. The bands provide coverage at 68% C.L.



Regions around the best-fitting locations using different analysis methods. Left: the best-fitting position and the corresponding test-statistic value from the previous search (Aartsen, et al., PRL. 124, 051103 (2020)). Middle: new methods but with "Pass 1" data (old calibrations + processing.) Right: final result of this analysis. The trial-corrected significance at NGC 1068 is (from left to right): 2.9σ, 3.3σ, 4.2σ.

Actually, I (C.S.) cannot remember any IceCube publication which has been scrutinized like this - even more than the TXS 0506+056 papers. While the basic results from unblinding had been available already in November 2020, the paper was submitted only in November 2021, i.e. one year later. On the one hand a sign for IceCube's careful internal review process, on the other hand a duration which must not become a standard. Formal questions with Science Journal led to another year of delay. It was hard for IceCube members to know about this exciting result and be silent about it for more almost two years.

This significant progress in the search for point sources is based on many people's work and dedication, even during the pandemic period. The data taken with IceCube in the final configuration were fully reprocessed to remove fragmentation and unevenness in the extraction from the data recorded at the South Pole ("pass 2", see next figure):



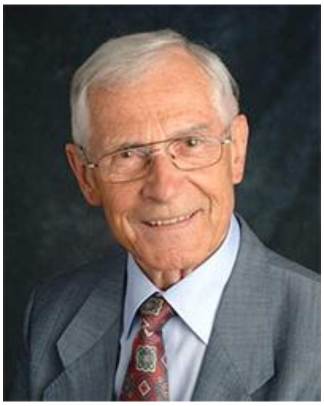
Also, on the simulation side, an enormous effort was made to study the tails of distributions and systematic uncertainties. The result is a uniform and well-modeled sample of 670,000 neutrinos recorded over 3186 days of near-perfect data taking. With the quality achieved in the processing, modeling, and understanding of the neutrino sample, new reconstructions using ML have significantly impacted the accuracy of angular and energy estimates.

Of course, it is challenging to identify individuals without doing injustice to many others. First, this work is based on previous generations of point source searches, most notably that by Teresa Montaruli's group at University Geneva and the results published in PRL 124 (2020). Second, the processing and simulation support team was central in creating the necessary elements for the results reported here.

Those who then made the very last round are Hans Niederhausen at TUM in Munich (now at Michigan State U.), Theo Glauch, Chiara Bellengh, and Tomas Kontrimas – all in the TUM team lead by Elisa Resconi.

Obituaries

Peter K. F. Grieder



Peter K.F. Grieder, 22/11, 1928 – 14/10, 2022

On October 14, Peter K. F. Grieder, one of the early researchers in our field, passed away after a long cancer illness. He was 93 years old and very active until just recently.

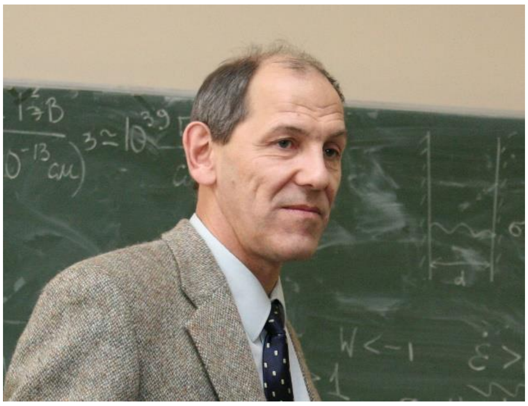
Peter's research activities comprised high energy phenomena, extensive air showers, and neutrino astronomy. In the 1980s, he developed the ASICO air shower simulation program, which then became the basis of the CORSIKA package used across many cosmic rays experiments today. He also was an early member of the DUMAND project in Hawaii, which was the template for the presently existing neutrino telescopes underwater and in ice. Peter was a long-term stalwart of developing underwater/ice high-energy neutrino astronomy, with a substantial impact on DUMAND and NESTOR over decades. Peter's computer simulations contributed to the design and simulation of the experiments leading to high energy neutrino astronomy, only now coming into fruition after a half-century of efforts.

Less known is certainly that the fiber connectors for the DUMAND optical modules have been developed in Switzerland on Peter's initiative, and that they later have been successfully applied for optical data transmission in AMANDA.

Peter obtained his MS degree in physics from the Illinois Institute of Technology in Chicago in 1957. He got his Ph.D. from the University of Bern in 1961, then already working in high energy cosmic ray physics. He then worked on quark hunting experiments at CERN and later on models of high energy hadronic interactions and multiparticle production in conjunction with air showers. In 1968 he was appointed lecturer and, in 1978 full professor at the University of Bern, Switzerland. From 1985 to 1987, he was secretary of the Swiss Physical Society.

Peter was a guest professor at the Institute for Nuclear Studies, University of Tokyo, and later for several years at the University of Hawaii, collaborating on the DUMAND project. Over many years he was an active and enthusiastic supporter of the bi-annual ICRC conferences. He is perhaps most remembered as the author of his books and compilations "Cosmic Rays at Earth" and "Extensive Air Showers". A new edition "Ultrahigh Energy Hadron and Neutrino Astronomy and Astrophysics", is awaiting completion of one chapter. It is hoped that this work can be completed quickly and will stand as Peter's legacy!

Valery Anatolyevich Rubakov



Valery A. Rubakov, 17/02, 1955 - 18/10, 2022

On October 18, Valery Anatolyevich Rubakov, one of the brightest stars of Russian theoretical physics, passed away after a sudden breakdown just before a lecture to be given in Sarow, the former Arzamas-16, close to Nizhni Novogorod. He was only 67 years old.

Members of our Global Neutrino Network will connect Valery's name prominently with his and (independently) Curtis Callan's prediction that a magnetic monopole would induce proton decay, leaving an observable footprint in the form of scintillation or Cherenkov light along its path. He submitted his paper on the catalysis of proton decay to a well-known European journal in 1981, but it was rejected. This was devastating for him, he later said. But he persisted and submitted the paper to the Russian Journal for Experimental and Theoretical Physics Letters. This journal promptly published his work which would make him famous. Today, the effect is generally accepted as the Callan-Rubakov effect. One of the first limits on the flux of these super-heavy particles have been obtained by a single-string detector operated in 1986 in Lake Baikal.

Valery was renowned for his studies of the cosmological effects of gauge interactions and the development of novel ideas of space-time and gravity. Together with his colleague Mikhail Shaposhnikov, he was one of the first to model spacetime and gravity using ideas from brane cosmology. The two conjectured that we live on a four-dimensional brane embedded in a higher-dimensional universe. Ordinary particles are confined in a potential well which is narrow along the additional dimensions, thereby localizing matter to the brane. Another paper of Valery, written together with Shaposhnikov and Vadim Kuzmin, addressed the effect of electroweak non-conservation of baryon and lepton numbers at high temperatures. It is considered fundamental to modern theory about the early universe. Valery is also known as author of a highly-regarded textbook on field theory.

Valery Rubakov was a full member of the Russian Academy of Sciences since 1998 and acted as Head of the Nuclear Physics Section of the Physical Sciences Division of the Academy. In 2015 he was also elected to the American Academy of Arts and Sciences. He received numerous prestigious awards worldwide, the last being the Hamburg Prize for Theoretical Physics which comes with prize money of 137,036 Euros (an allusion to Sommerfeld's fine structure constant), making it one of the highest endowed awards for physics in Germany.

Valery was affiliated with the Institute for Nuclear Research (INR) of the Russian Academy of Sciences in Moscow. He had studied physics at Moscow State University, graduating in 1978. He subsequently began doctoral work at the INR and completed his thesis in 1981. From 1987 to 1994, he acted as INR's Deputy Director for Research. He was also Head of the Department of Particle Physics and Cosmology at the Faculty of Physics of Moscow State University.

Photo: Herz Foundation

The Baikal neutrino project owes Valery Rubakov a lot. In the difficult times of the decay of Soviet Union in early 1990s, his support for the project was indispensable. This support continued on all levels of science and science policy, the last time when he chaired the strategic science review of the Baikal GVD project in January 2022.

Valery Rubakov was a courageous person with a clear inner compass. His passing is particularly sad in these times of Russia's invasion of Ukraine, against which Valery had raised his voice from the very first days. With him, the world loses a great scientist who shaped research in theoretical physics by challenging the known. We also lose a steady supporter of the Baikal project, a sharp-witted, humorous and warmhearted friend.

Igor Mikhailovitch Zheleznykh

Igor Mikhailovitch Zheleznykh, 28/8, 1936 - 25/10, 2022

On October 25, Igor Mikhailovitch Zheleznykh passed away at the age of 86. He was one of the pioneers in neutrino astronomy and was active until recently.

Igor studied physics at the Moscow State University and started to work on atmospheric neutrinos in the late 1950s. Together with his supervisor Moisei Markov, the published first reliable calculations of the flux of atmospheric neutrinos in 1961. Already in 1960, he together with Markov had considered the possibility of creating large-scale underground and underwater detectors for neutrino astronomy – a basis of what we are doing today underwater and in deep ice.

Igor was among the Soviet participants of the DUMAND project, a cooperation which regrettably was terminated in 1980 by the Reagan administration, in the context of the Soviet intervention in Afghanistan. While from then on the INR activities on underwater detectors were focused to Lake Baikal, a small group around Igor started Ocean explorations for a "Soviet DUMAND". In 1989, they cruised in the Mediterranean Sea in order to determine a suitable place for a neutrino telescope. Two years later, together with Greek collaborators, a prototype of a NESTOR floor with ten PMTs was tested from the Soviet Vityaz Vessel. But, with the successful operations at Lake Baikal and with the technical and financial problems of the NESTOR project, these activities were terminated in the following. In the NESTOR context, Igor's group also performed a series of hydro-acoustic measurements (project SADCO), with the aim to explore the possibility of acoustic detection of neutrinos.

One important activity was Igor's work on radio neutrino detection in Antarctica and on neutrino detection with radio telescopes. His group was the first to propose coherent radio waves as an experimental cosmic ray detection technique in 1984. They performed the first experimental studies and laid the initial groundwork for the development of a radio-wave neutrino detectors in ice. Between 1985 and 1990, a pilot experiment ("RAMAND", for Radio wave Antarctic Muon And Neutrino Detector) tested many aspects of neutrino radio detection at the Soviet Vostok station, including critical initial measurements of natural and man-made radio impulse backgrounds in Antarctica. Unfortunately, this nascent effort was terminated in 1991, when the Soviet Union collapsed.

Another project of Igor became known under the name RAMHAND (Radio Astronomical Method of Hadron and Neutrino Detection). In the 1980s, he was among those who proposed to use the Moon as a giant target and ground-based radio telescopes to detect the long-wavelength tail of Cherenkov bursts from neutrino interactions in the lunar regolith. This method has then been applied by several radio telescopes worldwide, leading to flux limits in the 10^{20} eV range.

Over the last two decades, Igor worked on the development of coordinate-sensitive scintillation detectors based on multipixel avalanche photodiodes.

We will remember Igor as a true pioneer, a friendly, open-minded colleague, always optimistic and always full of new ideas.