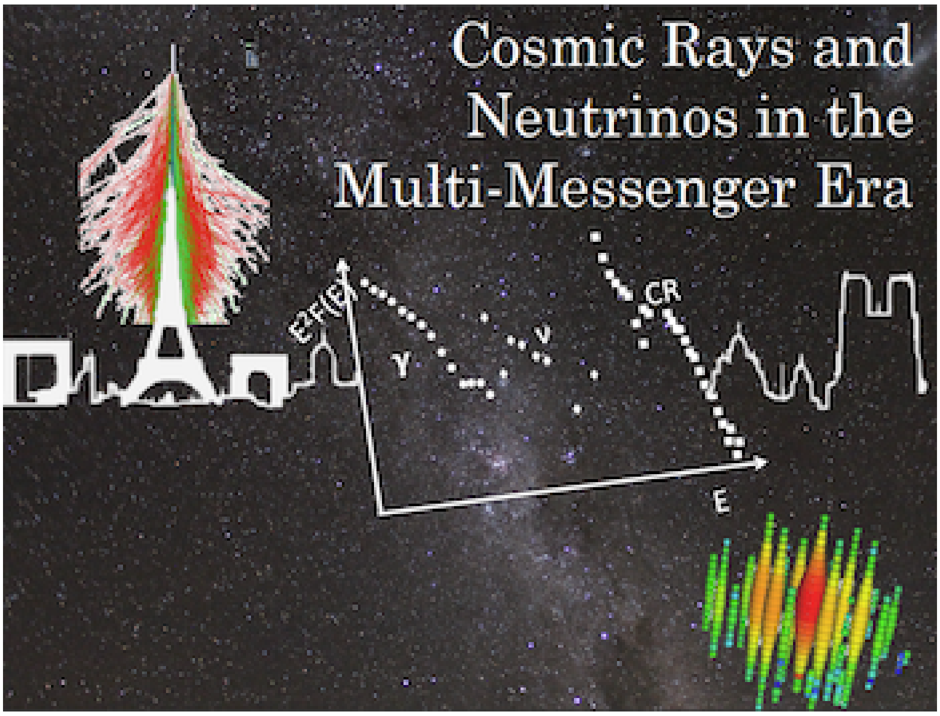
Cosmic Rays and Neutrinos in the Multi-Messenger Era

lundi 7 décembre 2020 - vendredi 11 décembre 2020

IPGP



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Solar WIMP Search with 8 Years of IceCube Data

Auteur: Jeffrey Lazar[None]

Weakly Interacting Massive Particles (WIMPs) are a broad class of dark matter (DM) candidates. Generically, WIMPs can have a non-zero cross section with the Standard Model (SM) particles. This allows WIMPs to scatter off large celestial bodies, and become gravitationally bound. These captured WIMPs can then co-annihilate into SM particles which can be seen by current telescopes. I will present the status of IceCube's most recent search for neutrinos created from WIMP annihilation in the Sun.

Related session:

Particle physics with neutrinos

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The Blazar Hadronic Code Comparison Project

Auteurs: Matteo Cerruti[1]; Michael Kreter[2]; Maria Petropoulou[3]; Annika Rudolph[4]; Foteini Oikonomou[5]; Markus Böttcher[6]; Stavros Dimitrakoudis[7]; Anton Dmytriiev [8]; Shan Gao[4]; Susumu Inoue[9]; Apostolos Mastichiadis[10]; Kohta Murase[11]; Anita Reimer[12]; Xavier Rodrigues[4]; Andreas Zech[13]

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Blazar hadronic models have been developed in the past decades as an alternative to leptonic ones. In hadronic models the gamma-ray emission is associated with synchrotron emission by protons, and/or secondary leptons produced in proton-photon interactions. Together with photons, hadronic emission models predict the emission of neutrinos that are therefore the smoking gun for acceleration of relativistic hadrons in blazar jets. The simulation of proton-photon interactions and all associated radiative processes is a complex numerical task, and different approaches to the problem have been adopted in the literature. So far, no systematic comparison between the different codes has been performed, preventing a clear understanding of the underlying uncertainties in the numerical simulations. To fill this gap, we have undertaken the first comprehensive comparison of blazar hadronic codes, and the first results from this effort will be presented in this contribution.

Related session:

Multi-messenger

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Neutrinos from hadronic X-ray blazar flares

Auteurs: Apostolos Mastichiadis[1]; Maria Petropoulou[2]

[1] *University of Athens*

[2] *Department of Physics, University of Athens*

The detection of a high-energy neutrino from the flaring blazar TXS 0506+056 and the subsequent discovery of a neutrino excess from the same direction have strengthened the hypothesis that blazars are cosmic neutrino sources. The lack, however, of gamma-ray flaring activity during the latter period challenges the standard scenario of correlated gamma-ray and high-energy neutrino emission in blazars. We propose that TeV-PeV neutrinos are produced in coincidence with X-ray flares that are powered by proton synchrotron radiation. In this case, neutrinos are produced by photomeson interactions of protons with their own synchrotron radiation, while MeV to GeV gamma-rays are the result of synchrotron-dominated electromagnetic cascades developed in the source. This "pure hadronic flaring" hypothesis has several interesting consequences. The X-ray flux is a good proxy for the all-flavor neutrino flux, while certain neutrino-rich X-ray flares may be dark in GeV-TeV gamma-rays. Lastly, hadronic X-ray flares are accompanied by an equally bright MeV component that is detectable by proposed missions like e-ASTROGAM and AMEGO. Using the extreme blazar 3HSP J095507.9+355101 as a test bed, we show that the number of muon and antimuon neutrinos

above 100 TeV during hadronic flares can be up to $\sim 3 - 10$ times higher than the expected number in standard leptohadronic models.

Related session:

Multi-messenger

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A marginally fast-cooling proton-synchrotron model for prompt GRB emission

Auteurs: Ioulia Florou[1]; Maria Petropoulou[2]; Apostolos Mastichiadis[3]

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A small fraction of GRBs with available data down to soft X-rays (~0.5 keV) have been shown to feature a spectral break in the low energy part of their prompt emission spectrum. The overall spectral shape is consistent with optically thin synchrotron emission from a population of marginally fast cooling particles. If the radiating particles are electrons, this interpretation implies relatively weak magnetic fields and large emitting regions to limit, respectively, synchrotron and inverse Compton cooling. Both requirements are, however, in tension with the idea of a compact region producing the variable GRB prompt emission. In this work we consider the hadronic scenario and investigate the idea that the prompt emission originates from relativistic protons that radiate synchrotron in the marginally fast cooling regime. We compute the source parameters required for such a scenario to work and investigate how additional processes, namely photohadronic interactions and gamma-gamma pair production, contribute to the overall spectrum. We numerically compute the observed photon spectra and calculate the expected high-energy neutrino emission following the assumptions of this work.

Related session:

Multi-messenger

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The highest-energy gamma rays and multi-messenger astrophysics

Auteur: Kelly Malone[1]

[1] *Los Alamos National Laboratory*

The High Altitude Water Cherenkov (HAWC) Observatory, located in Puebla, Mexico, has observed many sources emitting gamma rays above 100 TeV. These objects appear to come from a wide variety of source classes: pulsar wind nebulae such as the Crab Nebula; unidentified objects such as MGRO J1908+06; and at least one superbubble containing freshly accelerated cosmic rays originating from a star-forming region (the TeV counterpart to the Cygnus Cocoon). In this poster we will show multi-messenger and multi-wavelength observations for selected high-energy gamma-ray sources. The detection of neutrinos from any of them would be a smoking gun that they are PeVatrons and contribute to the knee of the cosmic-ray spectrum.

Related session:

Multi-messenger

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ANTARES - Baikal GVD Alerts Analysis

Auteur: Sergio Alves Garre[1]

Co-auteurs: A.D Avrorin [2]; Federico Versari [3]; M.D. Shlepov [2]; Olga Suvorova [4]; Zhan-Arys M Dzhilkibaev [2]

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ANTARES and Baikal-GVD are both Cherenkov neutrino telescopes located in the Northern Hemisphere. As a consequence, their fields of view overlap allowing for a combined study of the sky. Since December of 2018, Baikal followed up a total of 25 ANTARES alerts, and while no prompt coincidence was found, a cascade mode search showed some events falling within an angular distance of less than 5° for three of these alerts. The 4.5° angular resolution of Baikal-GVD allows for the possibility of these events to be spatially correlated, which makes them of special interest, and therefore, a dedicated analysis was performed to check the possible correlation between ANTARES and Baikal-GVD events.

In this poster we present the final results on the analysis after the addition of the latest ANTARES shower dataset, and the optimization of the search method with a novel Machine Learning Algorithm for background rejection.

Related session:

Searching for neutrinos

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Status of Real-time Multi-Messenger Program of KM3NeT

Auteurs: Damien Dornic[1]; Feifei Huang[1]; Massimiliano Lincetto[2]

[1] *CPPM*

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KM3NeT, consisting of ORCA and ARCA (for Oscillation and Astroparticle Research with Cosmics in the Abyss), is a multi-purpose cubic-kilometer neutrino observatory in construction in the Mediterranean Sea. Although ORCA and ARCA have different primary goals, both detectors can be used to do neutrino astronomy over a very wide energy range, from few GeV to few tens of PeV. Already few detection lines are in operation in both sites. With the growing time domain astronomy, it is more and more crucial to be able to identify neutrinos in real-time. This online neutrino sample will serve to trigger neutrino alerts that will be sent to the astronomy community and to look for time/space coincidence around external electromagnetic and multi-messenger triggers. These real-time searches have the potential to significantly increase the discovery potential of transient cosmic accelerators and in case of poorly localized triggers, such as gravitational waves, to refine the pointing directions. This poster presents the status of KM3NeT's real-time multi-messenger activities, including the online event reconstruction, event classification, alert distribution and the supernova monitoring system.

Related session:

Multi-messenger

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Testing cosmic ray composition models with very large volume neutrino telescopes

Auteurs: Luigi Antonio Fusco[1]; Federico Versari[2]

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The composition in terms of nuclear species of the primary cosmic ray flux is largely uncertain in the knee region and above. The possibility of testing it in the measured flux of atmospheric leptons in very large volume Cherenkov detector such as IceCube and ANTARES has been tested in this contribution. Two possible models of cosmic ray composition have been used to produce pseudo-data sets and it is observed that a 2-sigma level of discrimination between composition fits can be already achieved with the current IceCube data sample, even though in a model-dependent way. Improvements in the energy reconstruction foreseen with the next generation neutrino telescopes, and the combination of their data-sets, is expected to make these instruments more sensitive to the differences between models.

Related session:

CR Knee + Gamma sources + Galactic neutrinos

UHECR / 65

Galactic magnetic field models and UHECR

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Neutrino Production Associated with Late Bumps in Gamma-Ray Bursts and Potential Contribution to Diffuse Flux at IceCube

Auteurs: Gang Guo[1]; Meng-Ru Wu[2]; Yong-Zhong Qian[None]

[1] *Institute of Physics, Academia Sinica, Taiwan*

[2] *Institute of Physics, Academia Sinica*

IceCube has detected many TeV-PeV neutrinos, but their astrophysical origins remain largely unknown. Motivated by the observed late-time X-ray/optical bumps in some gamma-ray bursts (GRBs), we examine the correlation between IceCube neutrinos and GRBs allowing delayed neutrinos about 1 day after the prompt gamma rays. Although we have not found any definitive correlation, up to 10% of the events observed so far at IceCube may have been neutrinos produced by the late-time GRB activities at about 1 day. Assuming a connection between some IceCube events and the late GRB bumps, we show in a model-independent way that GRB sites capable of producing late PeV scale neutrinos should be nonrelativistic or mildly relativistic. We estimate the diffuse neutrino flux from such sources and find that they can possibly account for a few IceCube events. Future observations of high-energy neutrinos and late-time GRB afterglows can further test the above proposed connection.

Related session:

Searching for neutrinos

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Probing Cosmic-Ray Accelerated Light Dark Matter with IceCube

Auteurs: Gang Guo[1]; Meng-Ru Wu[2]; Yue-Lin Sming Tsai[None]

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The direct detection of particle dark matter (DM) through its scattering with nucleons is of fundamental importance to understand the nature of DM. In this work, we propose that the high-energy neutrino detectors like IceCube can be used to uniquely probe the DM-nucleon cross-section for high-energy light DM with energy around PeV, up-scattered by the high-energy cosmic rays. We derive for the first time strong constraints on the DM-nucleon cross-section down to 1E−32 cm^2 at this energy scale for sub-GeV DM candidates. Such independent probe at energy scale far exceeding other existing direct detection experiments can therefore provide useful insights complementary to other searches.

Related session:

Particle physics with neutrinos

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Search for multiple flare neutrino emission with 10 years of IceCube data

Auteur: Francesco Lucarelli[1]

Co-auteur: Teresa Montaruli [2]

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After more than 100 years since their discovery, cosmic rays (CRs) are still one of the most intriguing open questions in astrophysics. Different astrophysical objects, such as black holes in active galaxies, gamma-ray bursts, supernova shocks, etc., have been proposed as sources of high-energy CRs, but any scientific attempt to track back the sites of their production and acceleration is intrinsically limited by the deflection of these charged particles in galactic and intergalactic magnetic fields. Hints of a cosmic accelerator might come from the detection of a flux of high-energy photons or neutrinos that are expected to be produced by the interactions of CRs with the ambient matter and radiation in the vicinity of a potential source. While the photon horizon is limited by electromagnetic interactions, neutrinos weakly interact across the universe and only change flavour due to oscillations, turning out to be excellent messengers to study cosmic accelerators.
After 10 years of operation, IceCube, the largest neutrino telescope ever built, has the first hints of such sources. Recently published investigations of a catalog, comprising 110 known gamma ray emitters, observed a cumulative excess at 3.3σ-level in the time-integrated flux emitted in 10 years by four of these potential sources in the northern sky (declination $\delta \geq -5°$), namely the starburst galaxy NGC 1068 (also reported as the most significant northern spot in a time-integrated all-sky search), the blazar TXS 0506+056 and the BL Lacs PKS 1424+240 and GB6 J1542+6129.
This poster illustrates the methods and the results of a time-dependent follow up of that investigation. A new multiple flare algorithm is developed and firstly applied to this analysis to search for possible multiple flaring emissions from the same direction across 10 years of IceCube data. It turns out that at the location of TXS 0506+056, a well known blazar in the multimessenger sector, this algorithm identifies two notable and independent flares. Moreover, this time-dependent follow-up confirms at a significance of 3σ-level the excess observed in the northern sky by the aforementioned time-integrated search. Four sources are mainly responsible for the time-dependent excess: three (NGC 1068, TXS 0506+056, GB6 J1542+6129) are the same responsible for the time-integrated excess too, and a fourth, M87, is characterised by a clear time-dependent signature with 3 signal-like neutrinos in a 4-minute time window. M87 is also found to be the best individual source in the northern sky with a pre-trial significance of 3.3σ, that becomes 1.7σ post-trial after correcting for the look-elsewhere effect. No interesting results are found in the southern sky, where the sensitivity of IceCube is degraded by the overabundant background of atmospheric muons.

Related session:

Neutrino source observations

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UHE cosmogenic and astrophysical neutrinos

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The Giant Radio Array for Neutrino Detection

Auteur: Simon Chiche[1]

[1] *Institut d'Astrophysique de Paris*

The Giant Radio Array for Neutrino Detection (GRAND) is a project dedicated to the radio detection of ultra-high energy cosmic rays, gamma rays, and neutrinos. It aims at deploying in total 200 000 antennas in about 20 sub-arrays, located in mountainous regions, with a combined area of 200 000 km^2, making it the largest ground detector ever built. The objective is to detect inclined (> 65°) ultra-high-energy particles from the Universe through the air showers these induce either directly (cosmic rays and photons) or indirectly (charged current neutrino interactions in soil). GRAND will detect the radio-emission of air showers in the 50-200 MHz range. Its expected sensitivity of ~10^{-10} $\mathrm{GeVcm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}$ above $5*10^{17}$ eV combined with its sub-degree angular resolution should allow unveiling the unchartered territory of ultra-high energy neutrinos, secondary particles guaranteed to exist as ultra-high-energy cosmic rays have been detected. GRANDProto300, a prototype of 300 antennas, will be deployed by 2021 and will serve as a test bench for the GRAND project. It should already be able to perform multi-messenger astronomy with detection of cosmic rays and gamma rays in the $10^{16.5}$-10^{18} eV energy range. GRANDProto300 aims at tackling two significant challenges: autonomous radio detection of air showers and the reconstruction of inclined air showers parameters.

Related session:

Searching for neutrinos

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Comparison of the measured atmospheric muon rate with Monte Carlo simulations for the first KM3NeT/ARCA and KM3NeT/ORCA Detection Units

Auteur: Piotr Kalaczyński[1]

[1] *NCBJ Warsaw*

Auteur correspondant pkalaczynski@km3net.de

The KM3NeT Collaboration has successfully deployed the first detection units of the next generation undersea neutrino telescope in the Mediterranean Sea in 2016 and 2017 at the two sites in Italy and in France. The sample of data collected between December 2016 and January 2020 has been used to measure the at mospheric muon rate at two different depths under the sea level: 3.5 km with ARCA and 2.5 km with ORCA. A tmospheric muons represent an abundant signal in a neutrino telescope and can be used to test the reliability of the Monte Carlo simulation chain. In this contribution data collected with the f irst detection units of K M3NeT are compared t o Monte Carlo simulations based on MUPAGE and CORSIKA codes. The main features of the simulation and reconstruction chain s are discussed and presented in the poster.

Related session:

Searching for neutrinos

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How to search for multiple messengers - a general framework beyond two messengers

Auteur: Doga Veske[1]

Co-auteurs: Zsuzsa Marka [1]; Imre Bartos [2]; Szabolcs Marka [1]

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[2] *University of Florida*

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Quantification of the significance of a candidate multi-messenger detection of cosmic events is an emerging need in the astrophysics and astronomy communities. All the searches and analyses done so far are on two messenger coincidences. However, with improving sensitivities of the detectors (i.e. upgrades in LIGO/Virgo/KAGRA, IceCube Gen2, KM3NeT, Vera Rubin Observatory, Ultrasat…), more than two messenger coincidences are inevitable. As an example, in December 2019, during the real-time neutrino counterpart follow-up of LIGO/Virgo's gravitational wave (GW) candidates by IceCube, a candidate neutrino was reported by gamma ray coordinates network (GCN) notice. Soon after, HAWC observatory also reported a subthreshold gamma-ray detection which coincided with both the neutrino and the GW candidate. However, due to lack of a statistical treatment for multiple messengers'coincidence, that coincidence's significance could not have been quantified.

In this study we address the optimal multi-messenger search problem. In general for multi-messenger searches, model independent optimal search does not exist. Here we present a general Bayesian method for the optimal model-dependent search, which is scalable to any number and any kind of messengers, and applicable to any model. The method is based on weighting different sub-hypotheses, which describe each messengers'origin (astrophysical or noise) and relation to other messengers, based on the assumed emission rates.

Details including an analysis for a gravitational-wave, neutrino, gamma ray coincidence can be found in the paper https://arxiv.org/abs/2010.04162. The treatment here is was designed to be adoptable by the LLAMA pipeline infrastructure (https://multimessenger.science), which is used for GW+ high energy neutrino searches [1,2] in the advanced gravitational-wave detectors era.

[1] IceCube Collaboration, IceCube Search for Neutrinos Coincident with Compact Binary Mergers from LIGO-Virgo's First Gravitational-wave Transient Catalog, ApJL 898 L10 https://doi.org/10.3847/2041-8213/ab9d24
[2] Azadeh Keivani et. al., Multi-messenger Gravitational-Wave + High-Energy Neutrino Searches with LIGO, Virgo, and IceCube, PoS-ICRC2019-930, https://arxiv.org/abs/1908.04996

Related session:

Multi-messenger

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Mass composition analysis of ultra high energy cosmic rays using the code CONEX

Auteur: Ghazala Lakel[1]

Co-auteurs: Mohamed Cherif TALAI [2]; Reda ATTALLAH [3]

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[2] *Badji Mokhtar University of Annaba, Department of Physics*

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Experiments like the Pierre Auger observatory, the Telescope Array and soon the space telescope JEM-EUSO are investigating ultra-high-energy cosmic rays (UHECRs) in order to determine their identity and their mysterious origin. These experiments are mainly based on indirect and simultaneous measurements of parameters such as the primary energy E_0 and the slant depth of the shower maximum $X_{\max}$. The mass composition of such particles is the keystone of the information needed to solve this relevant problem. Only air-shower simulation can be used to convert $(E_0, X_{\max})$ into a primary mass. In this work, we have performed Monte Carlo simulations of air showers initiated by UHECRs of 10^{18} to 10^{21} eV with the CONEX program in combination with different up-to-date hadronic interaction models. We focused on the slant depth of the shower maximum and the charged particle number $N_{\max}$ as these parameters and their fluctuations are very sensitive to the primary particle mass (identity) and energy. The obtained results are compared to the most recent data from the current experiments.

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UHECR

Art & Science / 84

Instruments in a Sea of Noise.

Donald Fortescue is a professor of art and design at the California College of the Arts in San Francisco. He creates sculptural instrument that engage with the natural world. His research investigates how scientific approaches to knowledge building and investigating with the "hidden"forces and processes that surround us can influence and engage with artistic approaches. For the last 5 years, he has been working in collaboration with leading neutrino researchers and observatories; initially at the South Pole with the IceCube Neutrino Observatory and more recently with KM3NeT in the Mediterranean Sea. Prof. Fortescue will share his research to date and discuss the development of his latest collaborative project with KM3NeT.

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Observations of TDE AT2019fdr coincident with high-energy neutrino IceCube-200530A

Auteur: Simeon Reusch[1]

[1] *DESY*

High-energy neutrinos are considered the smoking gun signature for identifying hadronic acceleration sites. High-energy cosmic rays interact with ambient matter or photon fields to produce charged and neutral pions. Neutral pions decay to gamma rays, but charged pions produce neutrinos in their decay chain. While high-energy gamma rays can also be produced in leptonic processes such as Inverse Compton scattering and Bremsstrahlung, neutrinos are solely produced in hadronic processes.

A flux of high-energy astrophysical neutrinos was first discovered by the IceCube Neutrino observatory in 2013, and there has since been an ongoing search looking for the origins of this flux. A promising strategy to identify the neutrino sources is to search for their electromagnetic counterpart. To increase sensitivity to transient and variable sources, since 2016 the IceCube collaboration has issued real-time high-energy neutrino alerts. In 2017, one neutrino alert (IC170922A) was associated

with the flaring blazar TXS 0506+056. In 2019, a second neutrino alert (IC191001A) was associated with the tidal disruption event (TDE) AT2019dsg.

We perform a systematic search for electromagnetic counterparts by following up all IceCube alerts for which observations with the Zwicky Transient Facility (ZTF) are possible. ZTF is an optical telescope with a unique 47 sq. deg. field of view. So far, we have observed 29% of all 55 IceCube alerts since April 2018. The TDE cited above was found during this search.

Here we report observations of AT2019fdr, a bright nuclear transient in a Narrow-Line Seyfert 1 (NLSy1) galaxy, that we have identified as coincident with high-energy neutrino IceCube-200530A. The transient is most likely a TDE, like AT2019dsg. We performed and analyzed observations of AT2019fdr in the optical (ZTF), UV (Swift) and near infrared (WISE and Palomar P200). The source was not detected in X-Ray (Swift) and Gamma-Ray (Fermi).

Related session:

Multi-messenger

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Observing Millicharge Particles from Cosmic Rays in Neutrino Experiments

Auteur correspondant volodymyr.takhistov@ipmu.jp

Abstract: Millicharge particles with electric charge smaller than the electron, aside posing great theoretical interest, have been also considered as dark matter candidates. I will discuss production of energetic millicharge particles from cosmic accelerators as well as from cosmic rays colliding with the atmosphere. Large neutrino experiments, such as Super-Kamiokande, are particularly well suited to explore them.

Related session:

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Energy reconstruction for the Radio Neutrino Observatory in Greenland

Auteur: Christoph Welling[None]

Astrophysical neutrinos in the energy range above 10PeV can deliver new insights into the origins and physics of ultra-high energy cosmic rays. Because of the low expected flux, to observe them , gigantic detectors with fiducial volumes of several cubic kilometers are necessary. Starting in the coming summer, the Radio Neutrino Observatory in Greenland (RNO-G) will overcome these challenges by detecting radio signals from the particle showers produced by high-energy neutrinos when they interact in the Greenland ice sheet. To cover the large volumes required, RNO-G detector stations are placed over 1km away from each other, so that a neutrino is likely only seen by a single station. Combined with the low signal-to-noise ratios expected for most events, this makes it challenging to infer the neutrino properties from the radio signals.
In this poster, we show the techniques we use to for event reconstruction, particularly how the neutrino energy can be determined from the amplitude, spectrum, and timing of the radio signal.

Related session:

Searching for neutrinos

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Direction Reconstruction for the Radio Neutrino Observatory Greenland (RNO-G)

Auteur: Ilse Plaisier[1]

[1] *DESY Zeuthen*

RNO-G targets neutrino energies above 10 PeV. It uses the detection of the produced radio signals from the particle showers due to highly energetic neutrinos interacting in the ice. Because the attenuation length of the radio signal in ice is large O(1km), a sparse array of stations can be built, implying large effective volumes and sensitivities up to the highest energies. By 2023, 35 stations will be deployed at Summit Station in Greenland. RNO-G will be the rst large-scale implementation of the in-ice radio detection technique.

The radio signal propagates through the ice and will travel to the antennas directly or will reflect from the air-ice boundary. The signal is emitted on a full cone of the Cherenkov angle (56) and falls off quickly for higher frequencies for off-cone angles. The signal arrival direction, the angle with respect to the shower axis (viewing angle) and the polarization of the signal altogether are needed to reconstruct the direction of the incoming neutrino.

To reconstruct the direction of the incoming neutrino, first the vertex position is determined (see 'Energy reconstruction for the Radio Neutrino Observatory in Greenland', Christoph Welling). Next, the reconstructed vertex is used to reconstruct the neutrino direction of the event. A model for the electric field is used and for the reconstructed vertex position the expected response at the antennas are calculated, correcting for hardware responses and propagation effects. The waveforms are fitted in the time-domain and a Chi2 minimization is used to determine values for the neutrino direction and energy.

This poster shows the results for the directional reconstruction for event directions where RNO-G is the most sensitive, and the analysis efficiency for different directions and neutrino energy ranges are shown. An angular resolution of 7.7 degree is achieved.

Related session:

Searching for neutrinos

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A Catalogue of GRBs and their Precursors

Auteur: Paul Coppin[1]

Co-auteurs: Krijn de Vries [2]; Nick van Eijndhoven [1]

[1] *VUB*

[2] *VUB/IIHE*

Auteur correspondant paul.coppin@vub.be

Gamma-Ray Bursts (GRBs) have historically been regarded as one of the prime potential sources of (ultra-high-energy) cosmic rays and astrophysical neutrinos. They can occur following the collapse of a super-massive star or the coalescence of a binary neutron star system. In both cases, a compact object is formed, from which a highly-relativistic jet is subsequently expulsed. In terms of their emitted electromagnetic power, GRBs are unrivalled by any other class of cosmic transients. If hadronic acceleration takes place in GRB jets, a signal could potentially be observed by current neutrino telescopes, such as the IceCube detector.

GRBweb
To enable studies looking for multi-messenger counterparts, we have composed a comprehensive catalogue of GRBs, called GRBweb. This catalogue pools observations by dedicated missions, such as Fermi and Swift, with observations from gamma-ray satellites in the IPN network and follow-up studies reported via GCN circulars. After unifying the data format, a summary table is composed, grouping all available data per GRB. GRBweb is updated on a weekly basis and publicly available at https://icecube.wisc.edu/~grbweb_public. To ensure user friendliness, the web interface also provides examples on how to load the data and information on the data format and resources that were used.

Precursors
While this catalogue houses all information on GRB prompt emission, another phase of particular interest is that of the precursor flashes that precede ∼10% of all GRBs. During the precursor stage, the large density at early times could enhance hadronic interactions with respect to the prompt phase. As a result, GRB neutrinos could predominantly come from the precursor stage. To allow such correlation studies, we composed a precursor catalogue by analysing 11 years of Fermi-GBM data. A Bayesian block algorithm was used to identify statistically significant excesses of gamma radiation before the onset of the prompt emission. A total of 217 GRBs with precursor emission were identified out of 2364 bursts. The temporal properties and light curves of these events can be accessed via GRBweb.

Follow-up studies
In this poster, we present a first application of the presented GRB (precursor) catalogue. By analysing the statistical properties of the precursor sample, we uncovered a novel feature in their temporal characteristics, potentially indicating the existence of two progenitor source classes. Follow-up studies to further investigate this bimodality are encouraged.

Related session:

Multi-messenger

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Timing and pointing to the next Core Collapse Supernova with neutrinos and the participation of KM3NeT

Auteurs: MARTA COLOMER MOLLA[1]; Damien Dornic[2]; Massimiliano Lincetto[3]; Alexis Coleiro[4]; Vladimir Kulikovskiy[5]

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[2] *CPPM*

[3] *Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France*

[4] *APC / Université Paris Diderot*

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Auteur correspondant mcolomer@apc.in2p3.fr

A multi-messenger observation of the next Galactic Core Collapse Supernova (CCSN) will help understanding the different physical phenomena involved in these energetic explosions. Measuring the time of arrival of neutrinos with a good precision is crucial for the identification of the CCSN, the reconstruction of its sky location and thus the rapid identification of an electromagnetic and/or gravitational-wave counterpart. In this contribution, we will discuss the estimation of the time of arrival of the neutrino signal and its uncertainty for the KM3NeT detectors using a model-independent method based on the analysis of the first events of the detected neutrino light curve.

We will also discuss a new approach for the determination of the delay of the arrival times of the neutrino signals between different detectors by combining their experimental light-curves. The time delay between detectors will feed a triangulation algorithm used to determine the localization of the

CCSN. Its performances will be presented for the currently running and nearly coming detectors. This tool can be implemented into SNEWS for a real-time analysis allowing a fast pointing response in case of a CCSN neutrino alert.

Related session:

Multi-messenger

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PKS 1502+106: multi-messenger modeling of a high-energy neutrino source candidate

Auteurs: Xavier Rodrigues[1]; Simone Garrappa[2]; Shan Gao[1]; Vaidehi Paliya[2]; Anna Franckowiak[2]; Walter Winter[2]

[1] *DESY*

[2] *DESY Zeuthen*

Auteur correspondant simone.garrappa@desy.de

In July 2019, the IceCube experiment, located in the South Pole, detected a 300 TeV neutrino from a direction consistent with PKS 1502+106, the fifteenth brightest known gamma-ray blazar detected by Fermi-LAT. Given the large redshift of 1.84, this source must have an extremely high intrinsic luminosity, and it has shown high variability in gamma-rays as well as in other bands during more than a decade of observations. While the source was not undergoing exceptional activity in gamma rays at the time of the detection, it was showing peculiar features in different bands, like a hard X-ray spectrum and an enhanced radio flux. In this work we employ a self-consistent numerical radiation model to explain different activity states of PKS 1502+106, representing 11 years of Fermi-LAT observations. We find two hadronic models that can both describe the multi-wavelength emission: a leptohadronic model with a contribution from photo-hadronic processes and a proton synchrotron model. Both models predict a substantial neutrino flux that is correlated with the gamma-ray and soft X-ray fluxes and are compatible with the detection of a neutrino during the quiescent gamma-ray state similar to the one observed contemporaneous to the IceCube high-energy neutrino.

Related session:

Multi-messenger

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Recalibration of redshift-dependent distances and sources of UHECR

Auteur: Mohamed Lamine Abdelali[1]

Co-auteur: Noureddine Mebarki [2]

[1] *Univerité Frères Mentouri Constantine 1 Algeria*

[2] *Université Frères Mentouri Constantine 1 Algeria*

A new redshift effect was proposed in the literature. In this effect, the photon is red-shifted; additionally to cosmological, gravitational and Doppler effects; by its gravitational radiations due to the gravitational interaction of the photon with cosmic magnetic fields. This effect can have a significant contribution depending on the strength and wide presence of these magnetic fields in the

intergalactic medium. Such contribution affects the precision of our estimation of cosmological redshift which bias consequently our perception of several phenomena in the Universe. For instance, all redshift-dependent distances to extra-galactic objects would be over-estimated. Also, estimations of extra-galactic magnetic fields using Faraday rotations measurements are affected as they are dependent of exact estimation of cosmological redshifts as indicators of distance. In the case of UHECR, a recalibration of redshift-dependent distances to possible sources could make them within the GZK distance and change our perception for potential sources of observed events. The recalibration of extra-galactic magnetic fields could change the estimations of deviations from original primary cosmic rays directions within those magnetic fields. We present here how the estimation of such an effect contributions to astrophysical measurements is crucial to achieve a high precision in models of UHECR potential sources and even for lower energies sources identification studies.

Related session:

UHECR

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The Radar Echo Telescope

Auteurs: Simon De Kockere[1]; Enrique Huesca Santiago[1]; Vesna Lukic[1]; Katharine Mulrey[1]; Cade Sbrocco[2]; Rose Stanley[1]; Dieder Van den Broeck[1]

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The Radar Echo Telescope for Neutrinos (RET-N) project aims to detect astrophysical neutrinos with energies of 10 PeV (10^{16} eV) and above using the radar echo technique. The results of SLAC experiment T-576 show that a high-energy neutrino interacting in a dense medium like ice will create a short-lived plasma with the ability to reflect incoming radio waves. By detecting the reflection of transmitted radio waves, the energy and direction of the neutrino can be reconstructed.

Current neutrino observatories based on the detection of Cherenkov light can efficiently cover a detection volume large enough to detect neutrinos up to an energy of approximately 10 PeV. At higher energies, neutrinos can be detected via the direct radio emission from the neutrino-induced cascade (the Askaryan effect), which typically leads to peak sensitivities around 1 EeV (10^{18} eV), but can also be detected using the radar echo technique, which could potentially cover the full energy range from 10 PeV up to the EeV scale.

RET-N will be preceded by the Radar Echo Telescope for Cosmic Rays (RET-CR) experiment, which will use the radar echo technique to detect in-ice cascades produced when an ultra-high energy cosmic ray shower impacts the ice of a high-elevation ice sheet, producing a dense in-ice cascade similar to a neutrino-induced cascade. Here we present details of detector optimization studies for RET-CR and RET-N, including the feasibility of detecting in-ice particle cascades induced by high energy cosmic rays. We also present the modeling efforts to predict the radar signal from an ultra high energy neutrino or cosmic ray induced particle cascade, and projected sensitivity for both experiments.

Related session:

Searching for neutrinos

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Neutrino follow-up of gravitational-wave events with ANTARES data

Auteur: MARTA COLOMER MOLLA[1]

[1] *APC/IFIC*

Auteur correspondant mcolomer@apc.in2p3.fr

Since 2015, fifty gravitational-wave (GW) signals have been identified and published in two catalogs, marking the growth of the GW astronomy. A single multi-messenger observation from a binary neutron star merger, with an electromagnetic and GW signals detected, has been achieved up to now. Even though compact binary mergers are promising candidates, no neutrino has been yet detected from these sources in coincidence with a GW signal.

The ANTARES neutrino telescope has been taking data for more than twelve years, and it has actively participated in the follow-up of the gravitational-wave triggers. Two analyses are detailed in this poster. First, the results of an all-flavor neutrino follow-up of six binary black hole events observed during O2 data taking period are shown. Second, the first ANTARES results using O3 data are presented, with the follow-up of the two GW candidates identified during O3a for which one of the merging objects follows into the mass gap (it could be a neutron star, a black hole, or an unknown object): GW190814 and GW190426.

Related session:

Multi-messenger

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The Origin of the IceCube Neutrinos: Multimessenger hints from the diffuse gamma-ray flux

Auteurs: Antonio Capanema[1]; Arman Esmaili Taklimi[2]; Pasquale Dario Serpico[3]

[1] *Pontifical Catholic University of Rio de Janeiro*

[2] *IPM (Institute for Studies in Theoretical Physics and Mathematics)*

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Auteur correspondant antoniogalvao@aluno.puc-rio.br

Uncovering the sources of the astrophysical neutrinos observed by IceCube has been one of the most daunting challenges of neutrino astronomy since their discovery in 2013. By taking advantage of the multimessenger nature of these sources, it is possible to extract important information from them. In particular, we expect their production of TeV-PeV neutrinos to be accompanied by a γ-ray byproduct that undergoes electromagnetic cascades as it propagates to the Earth. This results in a GeV-TeV γ-ray flux which is expected to comprise the diffuse extragalactic γ-ray background (EGB) measured by Fermi-LAT. Since most of the EGB intensity has already been attributed to classes of sources that cannot account for the bulk of the IceCube neutrino flux, we are able to set stringent constraints on the spectra of the IceCube neutrino sources. We find that Fermi-LAT excludes any γ-ray-transparent class of sources whose neutrino spectrum extends below $\sim$10 TeV, irrespective of its redshift distribution. The marginally consistent case of a spectral break at 10 TeV requires a modification in our understanding of the EGB sources at energies below a few GeV. To avoid such complications, we are forced to imagine a significant contribution to the IceCube flux coming from objects opaque to high-energy γ-rays. Another way out is the possibility of such neutrinos being produced within the Galactic halo, although this solution seems to be in tension with limits from air shower experiments.

Related session:

Multi-messenger

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Searching for Neutrino Emission from Compact Binary Mergers with IceCube

Auteurs: Raamis Hussain[1]; Alex Pizzuto[1]; Justin Vandenbroucke[None]

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Auteur correspondant rhussain@icecube.wisc.edu

The advent of gravitational wave and neutrino astronomy has led to an exciting era of multi-messenger astronomy. Identifying high-energy neutrino emission from compact binary mergers could shed light on the sources of high-energy neutrino emission as well as particle acceleration mechanisms in these compact binary systems. The LIGO-Virgo Collaboration (LVC) has reported a total of 67 compact binary merger candidates throughout its first three observing runs. We present a search for high-energy neutrino emission from each merger reported by LVC using the IceCube neutrino observatory.

In this work we use an unbinned maximum likelihood method to test for spatial and temporal correlation of IceCube neutrino candidates with the GW candidates reported by LVC. We test for neutrino correlations within a ±500s time window centered around the GW merger time. The test statistic is the log-likelihood ratio weighted by a spatial weight derived from the GW localization uncertainty. A p-value describing the probability that the neutrinos on the sky are consistent with the GW source is computed for each GW candidate independently.

Figure 2 shows the final p value distribution for all of the 67 GW candidates we tested. No statistically significant neutrino correlations are observed and thus we set upper limits on the time-integrated neutrino flux from each GW candidate as well as setting limits on the isotropic equivalent energy, E_{iso} emitted in high-energy neutrinos.

Figure 3 shows our upper limits on E_{iso} as a function of the distance to the GW candidate. We see that the upper limits on E_{iso} follow roughly an r^2 scaling as expected from geometric arguments.

Note that LVC recently published their second GW catalog, GWTC-2, in which they reported 39 events from the first half of the O3 run. This work does not include the new events reported in this catalog and also contains some events that are no longer considered GW candidates in the new catalog. We are currently working on updating our results using the new catalog. Additional analyses searching for neutrino emission are currently in progress. One analysis searches for neutrino emission on longer time scales. There are also two analyses searching for neutrino emission with different data samples, namely cascade type events and lower energy neutrino events. For more details on this analysis, see the published paper in ApJL, DOI: 10.3847/2041-8213/ab9d24

Related session:

Multi-messenger

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Recent results from the Askaryan Radio Array (ARA) experiment

Auteurs: Jorge Torres[None]; Brian Clark[1]; Ming-Yuan Lu[2]

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Neutrinos are unique messengers to the distant, high energy universe. As neutral, weakly interacting particles, neutrinos arrive from cosmic distances (>100 Mpc) unattenuated and undeflected. Because of their low fluxes and low cross sections, neutrinos of ultra-high energies (UHE, >10 PeV) remain undetected. The Askaryan Radio Array (ARA) is an experiment deployed at the South Pole searching for these UHE neutrinos. ARA searches for neutrinos by looking for the burst of radio waves emitted by relativistic particle showers induced by neutrino interactions in the ice. In this poster, we present the latest results in the search for a diffuse flux of neutrinos. This search leverages four years of data from two detector stations. The work represents the best limit set by an in-ice radio neutrino experiment above $\sim$100 PeV.

Related session:

Searching for neutrinos

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Generation of Z bosons in emission processes by neutrinos in early universe

Auteurs: Mihaela Baloi[1]; Cosmin Crucean[2]

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Auteur correspondant mihaela.baloi@e-uvt.ro

Production of Z bosons in emission processes by neutrinos in the expanding de Sitter universe is studied. We use perturbative methods to investigate emission processes that are forbidden in flat space-time electro-weak theory by the energy and momentum conservation. The amplitude and probability for the spontaneous emission of a Z boson by a neutrino or an antineutrino are computed analytically, then we perform a graphical analysis in terms of the expansion parameter. Our results prove that this process is possible only for large expansion conditions of the early Universe. The total probability of the process is analyzed and we explore the physical consequences of our results proving that in the Minkowski limit there is no emission of Z bosons by neutrinos. The limit of large space expansion when the expansion parameter is much more larger than the mass of the Z boson is also obtained and the results prove that in this limit the emission probability increase.

Related session:

Particle physics with neutrinos

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First measurements of track-like events with Baikal-GVD using a chi2-like track fit

Auteurs: Dmitry Zaborov[1]; Grigory Safronov[2]; Baikal-GVD Collaboration[None]

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Baikal Gigaton Volume Detector (Baikal-GVD) is a 1 km^3 neutrino detector currently under construction in lake Baikal, Russia. The detector consists of several thousand optical sensors arranged on vertical strings. The strings are grouped into clusters of 8 strings each. Each cluster can operate as a stand-alone neutrino detector, providing an effective volume of ~ 0.05 km^3. A fast χ^2-based reconstruction algorithm has been developed to reconstruct track-like events observed with Baikal-GVD. The algorithm has been applied to data collected in 2019 from the first five operational detector clusters. Both the downgoing atmospheric muon flux and the upgoing atmospheric neutrino flux are observed. This analysis is limited to single-cluster data, favoring nearly-vertical tracks.

Related session:

Searching for neutrinos

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Preparing to Observe the Next Galactic Supernova with IceCube

Auteur: Spencer Griswold[1]

[1] *University of Rochester*

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The next Galactic supernova will be a once-in-a-lifetime opportunity for multi-messenger astronomy. A core collapse will produce a neutrino burst visible hours to days before electromagnetic radiation from the explosion, so the burst will provide an early warning for optical follow-up and offer valuable insight about the proto-neutron star. Since local supernovae are exceedingly rare, it is critical that neutrino detectors provide prompt alerts after the arrival of a burst. The IceCube Neutrino Observatory is currently the world's largest neutrino detector and is operating with >99% uptime, making it a crucial component of the worldwide network of detectors known as the SuperNova Early Warning System (SNEWS). We will discuss the sensitivity of IceCube to supernovae near the Milky Way and describe the "data challenges" used to ensure the readiness of the detector. We will also discuss the coordination of IceCube alerts with other neutrino detectors in SNEWS.

Related session:

Multi-messenger

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Follow up of the IceCube alerts on the Baikal GVD telescope

Auteur: Viktoriya Dik[1]

Co-auteurs: Olga Suvorova [2]; Mark Shelepov [2]

[1] *Joint Institute for Nuclear Research*

[2] *INR RAS*

Auteur correspondant viktoriya@jinr.ru

High energy neutrino alerts observed by IceCube in Fall 2020, have been performed in fast regime using Baikal-GVD data first time. Search for correlations between alerts and events reconstructed in two modes, track and cascade, for the time windows \pm 1 hour and \pm 12 hours does not indicate statistically significant excess of the number over the expected number of background events. Upper limits on fluences of the neutrino emission are presented for nine directions of the alerts.

Related session:

Multi-messenger

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Gravitational Wave Follow-up with the Super-Kamiokande detector

Auteur: Mathieu Lamoureux[1]

[1] *INFN Padova*

The detection of a common source of gravitational waves (GW) and neutrinos would greatly help in the understanding of the dynamic of such astrophysical objects. It would also permit more prompt EM follow-up, as the coincidence surely improves the pointing to the source. Since 2015, LIGO/Virgo collaboration (LVC) is providing GW alerts, both in realtime (fully public since April 2019 and the beginning of O3 run) and through published catalog, as the latest GWTC-2 published in October 2020.

The Super-Kamiokande detector is a 50-kton water tank instrumented with $\sim$13k photomultipliers and running since 1996, in the Mozumi mine (Japan). It is sensitive to neutrinos with energies ranging from 4.5 MeV to several TeV. For the region above 100 MeV, three subsamples are defined: fully-contained events, partially-contained events and upgoing muons, that are sensitive to various neutrino flavours and energy ranges.

These samples can be used to search for neutrino events in time and spatial coincidence with various external triggers. A new framework has been developed for the follow-up of gravitational wave triggers provided by LVC. Neutrinos are searched for in a 1000 seconds time window centered on alert time.

Such observation can then be used to constrain the neutrino emission from the GW source. Comparing the localisation of the GW with the reconstructed direction of detected SK event allows extracting significance of the potential signal, by comparing the observation to the expected background, taking into account the contributions from the different SK samples.

Even if the observation is not significant, one can compute upper limits on the incoming neutrino flux, for the different flavours to which SK is sensitive. Using the distance estimation provided by LVC, this could be converted to a limit on the total energy emitted in neutrino by the source (assuming isotropic emission).

The results using LIGO/Virgo O3 realtime alerts will be presented, as well as the plans for the study of the full GWTC-2 catalog.

Related session:

Multi-messenger

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Neutrino cross section from TeV to EeV

Auteur: Alfonso Garcia[1]

[1] *NIKHEF*

Neutrino telescopes have the potential to advance our knowledge of both astronomy and particle physics. The interpretation of the measured event rates from these experiments depends on knowledge of the interaction cross section of neutrinos. At high energies, the cross section is dominated by deep inelastic scattering off matter nucleons and scattering on atomic electrons via the Glashow resonance. In this poster we present an overview of the neutrino cross-section models used in the TeV and EeV energy regimes; the former is used to constrain the galactic neutrino flux or BSM scenarios (dark matter, sterile neutrinos, NSI, etc.), while the latter will be explored by a new generation of radio detectors during the next decade.

Related session:

Particle physics with neutrinos

Extragalactic neutrino sources / 107

TDE

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