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Report on the Asterics projects CORELib and ROAst

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In this talk will be introduced the Asteriscs program and presented the status of two Asterics projects: COREllib and ROAst.

CORELib (Cosmic Ray Event Library) is a collection of simulations based on CORSIKA featuring a common set of physical parameters in order to achieve a common high statistics production. Will be discussed the pilot production, the framework used to achieve this productions and finally the productions on going.

The ROOT analysis framework is one of the most used software for the analysis and indeed it is the "de facto" standard for high-energy physics. The goal of ROAst (ROot extension for Astronomy) is to extend the ROOT capabilities adding packages and tools for astrophysical research.
In this talk will be showed the present status of the library, the requirements and will be gathered suggestions for the future development of the library.

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The new CLBv4 for the KM3NeT neutrino telescope

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The KM3NeT collaboration aims at the construction of a multi-km3 high-energy neutrino telescope in the Mediterranean Sea consisting of thousands of glass spheres, the so called Digital Optical Module (DOM), each of them containing 31 photomultipliers of small photocathode area for the detection of the Cherenkov light induced by charged particles produced by the interaction of neutrinos with matter inside or in the vicinity of the KM3NeT detector. The signal acquired by each photomultiplier is sent the Time to Digital Converter (TDC) which is part of a Central Logic Board (CLB) based on the Kintex 7 FPGA. The TDC resolution is 1 ns and the White Rabbit technology is used to guarantee time synchronization at the level of 1 ns between each DOM. The new CLB has been routing to reduce the noise and to improve the clocks stability. Relative time calibration between photomultipliers is crucial to achieve an optimal performance. Due to the high volume to be covered by KM3NeT, a cost reduction of the different systems is a priority. To this end, a very low price time calibration device, the so called Nanobeacon, has been designed and developed. Also additional peripheral devices are connected to the CLB, in order to keep track of both, the environmental conditions (temperature, humidity and pressure), the DOM orientation (yaw, pitch, roll) and its position

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The multi-PMT optical module for the IceCube-Upgrade

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Following the first observation of an astrophysical high-energy neutrino flux with the IceCube Neutrino Observatory in 2013, planning for an upgrade of the detector are progressing, which will expand the capabilities of the detector at low neutrino energies and allow to determine IceCube detector systematics with significantly improved precision. A substantial contribution to the improved performance is anticipated to be achieved by the application of advanced optical module technology. The multi-PMT optical module (mDOM) consists of 24 3-inch PMTs which provide, amongst others, a large photo-effective area, sensitivity to the incident direction of the photon and local coincidences within a module. After an introduction, the contribution presents the current status of the mDOM development with emphasis on the technology challenges and investigated solutions.

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Oscillation Physics with Deepcore and the IceCube Upgrade

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The IceCube neutrino observitory is a cubic km neutrino telescope located at the South Pole. DeepCore is an infill array of the IceCube Neutrino Observatory and enables observations of atmospheric neutrinos
with energies as low as 5 GeV. Atmospheric neutrinos from 5-50 GeV allow for a broad range of particle physics, from measuring standard neutrino oscillations to probing BSM physics. In this talk I will discuss the recent oscillation results from IceCube/DeepCore and go over the future prospects of oscillation physics achievable with the IceCube upgrade.

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Neutrino astrophysics and IceCube

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Cosmic rays and neutrinos are intimately related. And though TeV-PeV astrophysical neutrinos have been observed, their sources and their relation to potential sources of cosmic rays remain largely unknown. IceCube has conducted numerous searches for potential neutrino sources. This talk is an overview that complements other presentations at this conference.

I will describe the characteristics of the observed diffuse neutrino spectrum. I will showcase specific studies of potential neutrino sources of both galactic and extragalactic nature. I will review the multi-messenger aspect of the field, especially in relation to the search for electromagnetic counterparts to neutrino sources. Finally, I will describe real-time activities that enable the multi-messenger studies including a brief discussion of TXS 0506+056.

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D-Egg: The next-generation optical module for the deep in-ice neutrino detector

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The next-generation optical module for such detector extension is expected to have improved detection efficiency for Cherenkov photons over the current IceCube optical module.
Furthermore, it is also anticipated that additional information possibly provided by new sensors, such as positions of the Cherenkov photons at each optical sensors, will lead to advances in event reconstructions.
The Dual optical sensors in an Ellipsoid Glass for Gen2 (D-Egg) is one of the optical modules being developed for the IceCube-upgrade and the IceCube -Gen2 projects.
About 250 D-Eggs are planned to be deployed in the IceCube-upgrade array.
D-Egg has two 8-inch high-QE PMTs facing downwards and upwards, which are coupled to a highly UV-transparent glass vessel.
It has been designed to have an improved capability of detecting Cherenkov photons in all directions.

In this contribution, expected performances of the D-Egg as well as the status of the prototype module development are presented.

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Recent highlights from very-high-energy gamma-ray instruments

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The very-high-energy gamma-ray sky grows ever more populated, with over 200 sources. The current-generation imaging atmospheric Cherenkov telescope arrays, VERITAS, H.E.S.S. and MAGIC, have collected over a decade of observations covering an energy range from tens of GeV to tens of TeV, while HAWC has collected several years of survey observations in the TeV to 100 TeV energy range. These datasets play a key role in studies of astrophysical particle acceleration as well as fundamental physics studies such as the search for astrophysical dark matter. This talk covers a variety of recent highlights from the current-generation instruments, including the recent detection of the blazar TXS 0509+056 as a TeV-emitter. Future prospects with the next-generation instruments are also discussed.

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LHAASO Status and Perspectives

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Cherenkov water detector NEVOD as a facility for calibration of various OMs

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NEVOD is the first in the world Cherenkov water detector (CWD) at the Earth's surface
equipped with a spatial lattice of quasi-spherical measuring modules for the investigations of all basic components of cosmic rays including neutrinos. A large dynamic diapason and close location of quasispherical modules allows use this detector as a Cherenkov water calorimeter for cascade shower investigations and measurements of the energy deposit of muon bundles. On the top and the bottom of the water reservoir, the calibration telescope system (CTS) consisting of scintillation counters (40 ones, on the top and 40 on the bottom) are placed. Around the water reservoir, the coordinate-tracking detector DECOR consisting of modules of streamer tubes is placed. CTS and DECOR allow calibrate measuring modules by Cherenkov light from muons with known trajectories. This possibility for calibration of new optical modules of IceCube, KM3Net and GVD in the CWD NEVOD is considered.

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The blazar TXS 0506+056 as possible neutrino counterpart

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On September 22, 2017, the IceCube Neutrino Observatory observed for the first time ever an extremely high-energy neutrino IceCube-170922A in spatial and temporal coincidence with a gamma-ray flaring blazar, TXS 0506+056. Following the original IceCube alert, the source has been observed by several telescopes in a broad wavelength band. Most notably the Fermi Large Area Telescope has reported an increase of the source's gamma-ray flux by a factor of ~6 compared to its average state. This triggered deep observations by MAGIC leading to the first detection of the source in very high-energy gamma-rays.

These detections motivated an archival search that identified additional IceCube events and multi-messenger data have been analyzed to better understand the physics and time-evolution of the object.

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Dark matter searches with IceCube

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The nature of dark matter remains one of the most enduring unsolved questions in modern cosmology. In order to decipher the mystery of dark matter and understand its properties different experimental avenues are explored. Indirect searches make use of the annihilation or decay products of dark matter as traces to prove its existence. This strategy is complementary of direct detection as different regions of the astrophysical parameter space are tested. Also, unlike direct detection experiments, indirect searches don\t require specialized experiments and existing astro-particle facilities can be used to search for signatures of dark matter. Among the decay and annihilation products, neutrinos offer a unique way to search for dark matter since their low cross-section makes them capable of escaping from environments in which gamma-rays are absorbed, like for example the Sun or the Earth. The IceCube neutrino telescope is not only an excellent astro-particle detector, it also has a lively program on dark matter searches with very competitive and complementary results to direct detection limits. In this talk, I will review the latest results of IceCube regarding the indirect search of dark matter with neutrinos.

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A Cherenkov Telescope Ring for Monitoring and Follow-Up Observations

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The new era of multi-messenger astronomy and the vast discovery potential of future detectors mandate already now the development of capabilities for continuous all-sky observations in the photon channel. For the very high energy gamma-ray regime, this could efficiently be achieved with a globe-spanning network of medium sized imaging air Cherenkov telescopes. In this talk, we present the motivation for such an effort, as well as ideas for resource-efficient implementation.

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Galactic neutrinos

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I review possible Galactic neutrino sources and the resulting signatures. In particular, I discuss options leading to neutrino arrival directions which are extended over a much larger solid angle than the Galactic plane. Finally, I argue that the photons accompanying the Galactic neutrino signal are already seen in the Fermi-LAT data.

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Recent results from the ANTARES neutrino telescope

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ANTARES, the largest underwater neutrino telescope, has been continuously operating since 2007 in the Mediterranean Sea. The transparency of the water allows for a very good angular resolution in the reconstruction of neutrino events of all flavors. This results in an unmatched sensitivity for neutrino source searches, in a large fraction of the Southern Sky at TeV energies. As a consequence, ANTARES provides valuable constraints on the origin of the cosmic neutrino flux discovered by the IceCube Collaboration.

Based on an all-flavor dataset spanning nine years of operation of the detector, we will present the latest results of ANTARES searches for neutrino point sources, and for diffuse neutrino emission from the entire sky as well as from several interesting regions such as the Galactic Plane and the Fermi bubbles. Several results, which will be presented, have been obtained through a joint analysis with the IceCube Collaboration.

An overview of the rich multi-messenger program of ANTARES will be given, with e.g. optical and X-ray follow-up observations of promising neutrino candidates, and searches for neutrinos in coincidence with interesting transient astrophysical events such as Gamma-Ray Burst triggers, Fast Radio Bursts and the gravitational wave signals recently discovered by LIGO-Virgo. Follow-up searches of IceCube alerts will also be covered.

ANTARES is also sensitive to more exotic phenomena, such as magnetic monopoles. Of particular relevance are the strong constraints on the dark matter arising from the search of neutrinos from potential WIMP annihilation in massive objects like the Sun and the Galactic Center.

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Prospectes on CCSN neutrino detection with KM3NeT

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Core Collapse Supernovae (CCSN) are explosive phenomena that may occur at the end of the life of massive stars, releasing over 99% of the energy through emission of neutrinos with energies on the 10 MeV scale. While the explosion mechanics is not fully understood, neutrinos are believed to play an important role in it. The only detection as of today, marking the beginning of extrasolar neutrino astronomy, are the 24 neutrinos from supernova SN1987A. The observation of the next Galactic CCSN will provide an unprecedented potential for the study of these phenomena, and lead to important breakthroughs across the fields of astrophysics, nuclear and particle physics.

For a Galactic CCSN, the KM3NeT ORCA and ARCA detectors in the Mediterranean will observe a significant number of neutrinos via the detection of Cherenkov light, mostly induced from inverse beta decay interactions over a large instrumented seawater volume. The selection of photons in coincidence between the 31 photomultipliers of the KM3NeT optical modules allows to separate the signal from the optical background sources (K40 decays, bioluminescence and atmospheric muons).

The KM3NeT sensitivity for the detection of a Galactic CCSN and the potential to resolve the neutrino time profile have been estimated exploiting detailed MC simulations covering the event generation and the detector response. The directional information of the 31 PMTs, covering a large angular range on the sky, is also used to study the capability of the KM3NeT optical modules to infer the direction of the source. Specific criteria are proposed for the online triggering and the participation in the SNEWS global alert network.

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KM3NeT Acquisition Control

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The multi-site nature of the KM3NeT collaboration has influenced the development and evolution of its Acquisition Control software. It is flexible and portable to the extent that the same programs are used in data-taking shore station of neutrino telescopes as well as in the test and qualification sites for performance and quality assessment of detector components at different stages of the integration. In shore stations of neutrino telescopes, the main goal of the Acquisition Control is to maximize the livetime of the controlled detector, whereas in testing sites common tasks are aimed at quickly and efficiently gaining information on the behavior of single photomultipliers, Digital Optical Modules and Detection Units. Flexibility is obtained through high modularity and tight integration with the central database system. On the other hand, the software architecture can be defined as \"maximally disconnected\" to ensure that no \"single point of failure\" exists and that each software service can continue to operate in the temporary absence of others. The most recent development is Dynamic Resource Provisioning and Failover (DRP-F), to automatically cope with the possible event of a hardware failure of one or more data taking servers or network elements just before or during a transient neutrino burst: if the number of damaged units is not too large (typically failures of one or two units), the system automatically switches, within a few seconds, to a downgraded but working configuration to ensure continuity of operation and minimal data loss. DRP-F is now entering the stage of preliminary tests. When deployment is complete, stress tests and failure simulation tests will be performed on a regular basis.

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Search for correlations of high-energy neutrinos and ultra-high-energy cosmic rays

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The IceCube Neutrino Observatory has recently found compelling evidence for a particular blazar producing high-energy neutrinos and PeV cosmic rays, however the sources of cosmic rays above several EeV remain unidentified. It is believed that the same environments that accelerate ultra-high-energy cosmic rays (UHECRs) also produce high-energy neutrinos via hadronic interactions of lower-energy cosmic rays. Two out of three joint analyses of the IceCube Neutrino Observatory, the Pierre Auger Observatory and the Telescope Array yielded hints for a possible directional correlation of high-energy neutrinos and UHECRs. These hints however became less significant with more data. Recently, an improved analysis with an approach complementary to the other analyses has been developed. This analysis searches for neutrino point sources in the vicinity of UHECRs with search windows estimated from deflections by galactic magnetic fields.
We present this new analysis method for searching common hadronic sources, additionally including neutrino data measured by ANTARES in order to increase the sensitivity to possible correlations in the Southern Hemisphere.

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Reconstruction Techniques in IceCube using Convolutional and Generative Neural Networks

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A key challenge to the success of high-energy physics experiments such as IceCube is the reliable and accurate reconstruction of events. In IceCube, further challenges arise as the detector is situated at the geographic South Pole where resources are limited. However, to perform real-time analyses and to issue alerts to telescopes around the world, powerful reconstruction methods are desired. This results in a dilemma as performance is often paired with computational complexity. But even for offline reconstructions, the computational complexity of the most advanced maximum-likelihood-methods can render these intractable and hence limit the physics potential.

Machine learning-based methods might help to alleviate these complications. Deep neural networks can be extremely powerful and their usage is computationally inexpensive once the networks are trained. These characteristics make a deep learning-based approach an excellent candidate for the application in IceCube.

A reconstruction method using convolutional neural networks is presented which can significantly increase the reconstruction accuracy while reducing the runtime in comparison to standard reconstruction methods in IceCube. In addition, first results are discussed for future developments based on generative networks.

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Analysis of high energy starting events with the KM3NeT/ARCA detector

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KM3NeT is a research infrastructure housing the next generation neutrino detectors in the depths of the Mediterranean Sea. The ARCA detector, which is currently under construction, is optimized for searches for neutrinos from astrophysical sources as well as measurements of the diffuse high energy astrophysical flux. The unambiguous detection of neutrinos of extraterrestrial origin by IceCube has led to the first measurement of a high energy astrophysical neutrino flux. The cutting-edge technology used for the design and construction of KM3NeT Digital Optical Modules along with the properties of sea water allow for a measurement of the neutrino direction with an excellent angular resolution for both track and cascade events. Taking advantage of this angular resolution a method to differentiate track and shower events and a method to reject the atmospheric muon background from track-like events were developed and combined to select a sample of high energy starting events. An analysis for the discovery potential of KM3NeT/ARCA for a diffuse astrophysical neutrino flux using these events is presented.

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KM3NeT Technology Transfer

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The status of the construction of the KM3NeT detector components and the experience gained from the detector units deployed underpin the presentation of technological solutions developed or modified by KM3NeT to industry, Institutions and other stakeholders with potential interest. KM3NeT has now entered a phase during which the design of the detector elements is finalized and the methods adopted for testing and for controlling the quality of the different components and the procedures followed are settled. In addition, few KM3NeT Detection Units have been deployed successfully and many more are coming, data have been recorded and are currently analysed. Therefore, the functionality and scalability of the technological solutions developed or modified by KM3NeT is now proven so they are mature to be presented or exposed to relevant technology developers or users.

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Multimessenger Astrophysics with AMON: Current and Future Alerts

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The Astrophysical Multimessenger Observatory Network (AMON) is connecting observatories around the world in order to enable real-time coincidence searches across all four astrophysical messengers: neutrinos, cosmic rays, photons, and gravitational waves. AMON analyses deliberately extend into the \"sub-threshold\" regimes of these experiments, and are conceived so as to enable near real-time alerts, and rapid follow-up observations, in search of associated transient or variable counterparts. AMON's first real-time alerts were commissioned in 2016 with "pass-through" notices of IceCube likely-cosmic (HESE and EHE type) neutrino events, which have been followed up with great interest by the astronomical community.
Given the new dawn of multimessenger astronomy recently realized with the GW 170817A / GRB 170817A and IceCube-170922A events, we are planning to commission multiple multimessenger alert streams, including gravitational wave + gamma-ray and high energy neutrino + gamma-ray coincidence alerts, over the course of the next year. In this talk I will give an overview of the current alert streams and describe the up-coming coincidence alert streams that are currently under development.

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Improving the directional reconstruction of PeV hadronic cascades in IceCube

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Many neutrino interactions measured by the IceCube Neutrino Observatory produce only hadronic showers, which appear as almost point-like light emission due to the large detector spacing (~125m). At PeV energies these showers often saturate the PMTs closest to the interaction vertex - thus the reconstruction has to rely on more diffused photons which requires precise understanding of the optical properties of the Antarctic ice. Muons produced in the hadronic showers carry information about the neutrino direction, and their Cherenkov light arrives earlier than the photons emitted by the electromagnetic component. A new reconstruction method has been developed which explicitly takes into account the muonic component of hadronic showers and is shown to be robust against systematic ice uncertainties. By applying the new reconstruction, the angular resolution of multi-PeV cascade events can be significantly improved.
This will potentially enable follow-up studies of the highest-energy cascade events measured by IceCube.

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IceCube high energy starting events at 7.5 years - new measurements of flux and flavor

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The IceCube Neutrino Observatory at the South Pole, which detects Cherenkov light from charged particles produced in neutrino interactions, firmly established the existence of an astrophysical high-energy neutrino component. In this talk I will present IceCube\s High-Energy Starting Event sample, the updates made and the new results obtained with a livetime of 7 years. I will focus on the new measurement of the flavor composition performed on this sample. We are directly sensitive to each neutrino flavor via the single cascade, track and double cascade event topologies, the latter being the topology produced in tau-neutrino interactions above an energy threshold of ~100 TeV. A measurement of the flavor ratio on Earth can provide important constraints on sources and production mechanisms within the SM, and also constrain various BSM processes.

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Improving the muon track reconstruction of IceCube and IceCube-Gen2

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IceCube is a cubic-kilometer Cherenkov telescope operating at the South Pole. It aims at detecting astrophysical neutrinos and identifying their sources. High-energy muon neutrinos are identified through the muons produced in the interactions with the ice. The muon tracks are reconstructed using a maximum likelihood method, which models the arrival times of Cherenkov photons registered by the photomultipliers. This work aims at improving the muon angular resolution of IceCube and of its planned extension, IceCube-Gen2, in
the sub-degree range. The current muon reconstruction assumes continuous energy loss along the muon track, and does not take into account photomultiplier related effects like prepulses and afterpulses. In the reconstruction scheme presented here, the expected arrival time distribution has been modified in order to parametrize the effect of prepulses and the stochastic muon energy losses.

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Gamma-ray lightcurve correlation searches for IceCube neutrinos from blazar flares

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Blazars have long been considered as accelerator candidates for cosmic rays. In such a scenario, hadronic interactions in their jet would produce neutrinos and gamma-rays. Correlating the astrophysical neutrinos detected by IceCube, a cubic-kilometre neutrino telescope at the South Pole, with the gamma-ray emission from blazars could therefore reveal the origin of cosmic rays. In our method we focus on periods where blazars show an enhanced gamma-ray flux, as measured by Fermi-LAT, thereby reducing the background of the search. We present results for TXS 0506+056, using nearly 10 years of IceCube data and discuss them in the context of other recent analyses on this source. Further we give an outlook on applying this method in a stacked search for the combined emission from a selection of variable Fermi blazars.

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PMT characterization for the multi-PMT Digital Optical Module

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Optical modules are the \"eyes\" of neutrino telescopes, detecting the Cherenkov light from charged particles created in neutrino interactions in the surrounding medium. In the framework of a planned upgrade of the current IceCube Neutrino Observatory as well as a future next-generation neutrino telescope at the South Pole, new optical modules are being developed which are expected to significantly enhance detector sensitivity. One of the concepts is the multi-PMT digital optical module (mDOM). Inside a glass pressure vessel it features 24 PMTs pointing isotropically in all directions.
While the current baseline PMT is the Hamamatsu R12199-02 HA with an entrance window diameter of 80 mm, alternatives, such as the HZC XP 82B20D with an increased window diameter of 88 mm are being investigated
The talk will present the latest characterization results for both PMT models.

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Deconvolution Algorithms in IceCube

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Since the energy of an incident neutrino is inherently unknown, it has to be inferred from energy-dependent quantities, e.g. the energy loss of secondary particles. The production of secondary particles, however, is a stochastic process, which poses certain challenges for the reconstruction of neutrino energy spectra, which is further made difficult by a limited acceptance and smearing effects introduced by the detector. Mathematically, the reconstruction of a neutrino energy spectrum corresponds to an inverse problem, generally described by the Fredholm integral equation of the first kind. Different algorithms for the solution of inverse problems exist and have been applied in measurements of neutrino energy spectra with the IceCube neutrino telescope. This contribution focusses on the technical aspects of the deconvolution algorithms applied in IceCube analyses, mainly in spectral measurements of muon-neutrino energy spectra.

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KM3NeT: Machine Learning

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The KM3NeT Collaboration is building a network of underwater Cherenkov telescopes at two sites in the Mediterranean sea, with the main goal of investigating astrophysical sources of high-energy neutrinos (ARCA) and of determining the neutrino mass hierarchy (ORCA).
Various Machine Learning techniques, such as Random Forests, BDTs, Shallow and Deep Networks are being used for diverse tasks, such as event-type and particle identification, energy/direction estimation, signal/background discrimination, source identification and data analysis, with sound results as well as promising research paths.
The main focus of this presentation is the application of Convolutional Neural Networks to the tasks of neutrino interaction classification, as well as the estimation of energy and direction of the propagating particles. The performances are also compared to those of the standard reconstruction algorithms used in the Collaboration. There is a plan to incorporate the software tools created into the ASTERICS (H2020) products and possibly continue in future projects.

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KM3NeT Acquisition Control

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The multi-site nature of the KM3NeT project has influenced the development and evolution of its acquisition control software so that it doesn't stick to a single detector site or configuration. It is flexible and portable to the extent that the same programs are used in data-taking shore station of neutrino telescopes as well as in testing sites for detector components at different stages of the integration. Flexibility is obtained through high modularity and tight integration with the central database system. On the other hand, the software architecture can be defined as \"maximally disconnected\" to ensure that no \"single point of failure\" exists and that each software service can continue to operate in the temporary absence of others. The most recent development is dynamic resource provisioning and failover, to automatically cope with the possible event of a hardware failure of one or more data taking servers or network elements just before or during a transient neutrino burst: if the number of damaged units is not too large (typically failures of one or two units), the system automatically switches, within a few seconds, to a downgraded but working configuration to ensure continuity of operation and minimal data loss. Dynamic resource provisioning and failover is now entering the stage of preliminary tests.

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The KM3NeT Multi-PMT DOM and Detection Unit

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The KM3NeT Collaboration is constructing new-generation neutrino detectors in the Mediterranean Sea. The main goals are the study of the high-energy neutrino flux (KM3NeT/ARCA, off-shore Capo-Passero, Italy) and the determination of the neutrino mass ordering (KM3NeT/ORCA, off-shore Toulon, France). The basic detection element, the Digital Optical Module (DOM), houses 31 three-inch PMT's inside a 17 inch glass sphere. The aim is to measure photons emitted by products of neutrino interactions in the sea-water with nanosecond precision. The multi-PMT concept yields a factor three increase in photocathode area, compared to a design with a single 10 inch PMT, leading to a significant cost reduction. Moreover, this concept allows for an accurate measurement of the light intensity (photon counting) and offers directional information with an almost isotropic field of view. We will discus these aspects and the enabling technologies, which include 3D-printed support structures, and custom low-powered PMT bases, which provide the HV and digitization of the analog signal. An FPGA based readout system transfers all sub-ns timestamped photon signals to shore via optical fibers. Additionally, the required mechanical and optical/electrical system on which 18 DOMs each are deployed as vertical strings, called detection units, will be discussed.