VLVnT - 2015 : Very Large Volume Neutrino Telescope

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University "La Sapienza", Physics Department

Book of Abstracts

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3+N flavor neutrino propgation with NuSQuIDS

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We introduce the SQuIDS framework, which was designed to solve quantum mechanical evolution in the density matrix formalism in an efficient way. A specialization of this package for neutrino propagation, called ν-SQuIDS, is showcased. Finally, we show how this new propagation scheme is being integrated into the IceCube MC software to add flexibility for analyzers.

Parallel Session F / 26

A Precision Optical Calibration Module for IceCube-Gen2

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We present here a new idea of an in-situ self-calibrated isotropic light source for the future IceCube-Gen2 neutrino detector called the Precision Optical CAlibration Module (POCAM). IceCube-Gen2 will be a matrix of light sensors buried deep in the ice at the geographical South Pole. The timing, the location and the amount of Cherenkov light deposited by the secondary charged particles are used to reconstruct the properties of the incident neutrinos. This calculation relies on a detailed detector model that includes the response of optical modules to the Cherenkov light, as well as the optical properties of the detector medium - the natural Antarctic ice. To understand these properties, both natural and artificial light sources are already used for calibration. New calibration devices are being developed in order to improve the precision of these measurements and reduce systematic errors for the determination of the neutrino mass ordering with the Precision IceCube Next Generation Upgrade (PINGU). The POCAM's concept is based on the principle of an inverted integrating sphere. The main components are LEDs emitting light at several wavelengths and solid-state light sensors e.g. calibrated photodiode or silicon photomultipliers to control the emitted light intensity. We will report on the current status of the POCAM R&D.

Parallel Session D / 84

A Surface Array to Study Astrophysical Neutrinos with IceCube-Gen2

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Motivated by the discovery of high-energy astrophysical neutrinos with IceCube, we study the prospects for improved measurements of neutrinos of astrophysical origin with a surface detector array combined with IceCube or a next generation neutrino detector at the South Pole. The background

in astrophysical neutrino searches is reduced by tagging muons and neutrinos of atmospheric origin through the detection of the accompanying air shower. We discuss the ways in which a surface array can help study the features of the astrophysical neutrino flux and consider a few physics cases that motivate such an array. We will present the various approaches used to understand the capabilities of surface arrays. The prospects of a surface array for studying the cosmic ray flux will be briefly discussed.

Parallel session A / 110

A Wavelength-shifting Optical Module (WOM) for in-ice Neutrino Detectors

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A Wavelength-shifting Optical Module (WOM) for in-ice Neutrino Detectors

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We report the development status of a single-photon sensor that employs wavelength-shifting and light-guiding techniques to maximize the collection area while minimizing the dark noise rate. The sensor is tailored towards application in ice-Cherenkov neutrino detectors using inert and cold, low-radioactivity and UV transparent ice as a detection medium, such as IceCube-Gen2 or MICA. The goal is to decrease the energy threshold as well as to increase the energy resolution and the vetoing capability of the neutrino telescope, when compared to a setup with optical sensors similar to those used in IceCube. The proposed sensor captures photons with wavelengths between 250nm and 400nm.

These photons are re-emitted with wavelengths above 400nm by a wavelength shifter coating applied to a 90mm diameter polymer tube. This tube guides the light towards a small-diameter PMT via total internal reflection. By scaling the results from smaller laboratory prototypes, the total efficiency of the proposed detector for a Cherenkov spectrum is estimated to exceed that of a standard IceCube optical module by a factor of 2 or more. The status of the prototype development and the performance of its main components will be discussed.

Parallel Session C / 72

A compact array calibrator to study the feasibility of the acoustic neutrino detection

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Underwater acoustic detection of ultra-high-energy neutrinos was proposed long time ago since a short bipolar pressure pulse with 'pancake' directivity is produced and propagated when this particle interacts with a nucleus in water. The idea is to build a telescope that consists of thousands of acoustic sensors deployed in deep-sea that will monitor hundreds of cubic kilometres of water looking for these signals and discriminating it from the acoustic noise. To study the feasibility of the technique it is critical to have a calibrator able to mimic the neutrino 'signature' that could be operated from a vessel. Due to the properties of the signal, axial-symmetry very directive short bipolar signal and the constraints of operating at Sea, the development of such a calibrator is very challenging. In this paper, we present the test results of the first compact array calibrator prototype that validated the possibility of using the acoustic parametric technique for this aim and describe the new design composed of an array of piezo ceramic tube transducers emitting in axial direction and new specific electronics adapted to the transducers to feed it more efficiently.

Parallel Session G / 40

A study on implementing a multithreaded version of the SIRENE detector simulation software for high energy neutrinos

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Aim of this work is the development of a multithreaded version of the SIRENE detector simulation software for high energy neutrinos. This approach allows utilization of multiple CPU cores and GPUs, leading to a potentially significant decrease in the required execution time compared to the sequential code. We are making use of MPI, OpenMP frameworks for the production of multithreaded code running on the CPU and CUDA framework to leverage the processing power implicating the GPU. SIRENE implements different geometries for a neutrino detector and different configurations and characteristics of photo-multiplier tubes (PMTs) inside the optical modules of the detector through a library of C++ classes. This could be considered a massive statistical analysis of photo-electrons.Each event consists of a number of particles (tracks) in the detectable area, each track represents the different energy, direction and time of arrival of each particle. Energy loss is calculated in steps. For each step the probability of reaching an optical module is calculated and for each of these modules the number of photo-electrons that give a hit is calculated for each of the PMTs inside.

Accordingly, MPI could be used for the parallelization of the events since they are independent of each other and there is no data exchange between them whatsoever. This permits computations to be trivially spread over several processing nodes. OpenMP could be used to parallelize the tracks, which, in the original sequential code, is the largest external loop containing computations for each particle. It could be implemented by enlisting one thread per track capable of creating sub-threads as needed, according to the inner loops and the available system resources. The most critical part of the sequential code is the loop referring to the energy loss and involving the final calculation which

needs to be transformed in order to allow parallel execution of the loop.In-between, certain parts of SIRENE could be executed using CUDA. The coordinate system must be defined such that the track direction is pointed along the z–axis and the position of the module is located in the x–y plane. The rotation of the coordinate system is expressed as a 3×3 matrix and is used on every module, making this part ideal for acceleration via GPU. Furthermore, Poisson distribution is employed to calculate the arrival times of photo-electrons on a module and polynomial interpolation is repeatedly used during the computation of the number of photo-electrons that hit a PMT. In both cases, there is a choice of either applying straight parallelization to the existing sequential algorithm, or, if this approach does not offer acceptable results in terms of suitability and speed, look into alternate parallel versions of those algorithms. It is also possible to take advantage of fast hardware implementations of arithmetic functions such as hardware linear interpolation on the GPU.

Parallel Session J / **86**

AMON: Transition to Real-Time Operations

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The Astrophysical Multimessenger Observatory Network (AMON) will link the world's leading high-energy neutrino, cosmic-ray, gamma-ray and gravitational wave observatories by performing real-time coincidence searches for multimessenger sources from observatory subthreshold data streams. The resulting coincidences will be distributed to interested parties in the form of electronic alerts for real-time follow-up observation. We present the AMON science case, design elements, current partner observatories, project status, and a preliminary look at an ongoing archival analysis. AMON is an open network seeking new triggering and follow-up observatories, as well as collaborators interested in the scientific goals of AMON. The prototype of the AMON server has been online since summer 2014 and processing archival data, and we have recently deployed two redundant high-uptime servers and are ready to start issuing alerts.

Plenary Session 2 / **3**

ANTARES results

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The ANTARES experiment has been running in its final configuration since 2008. It is the largest neutrino telescope in the Northern hemisphere. After the discovery of a cosmic neutrino diffuse flux by the IceCube detector, the search for its origin has become a key mission in high-energy astrophysics.
The ANTARES sensitivity is large enough to constrain the origin of the IceCube excess from regions extended up to 0.2 sr in the Southern sky. Assuming different spectral indexes for the energy spectrum of neutrino emitters, the Southern sky and in particular central regions of our Galaxy are studied searching for point-like objects, for extended regions of emission, and for signal from transient objects selected through multimessenger observations. The results of the unblended analyses are presented.
ANTARES provides results on atmospheric neutrinos, on the searches for rare particles (such as magnetic monopoles and nuclearites in the cosmic radiation), multimessenger studies of the sky in combination with different experiments, and Earth and Sea science. Of particular note are the

searches for Dark Matter: the limits obtained for the spin-dependent WIMP-nucleon cross section overcome that of existing direct-detection experiments.

Plenary session 6 / **15**

ANTARES/IceCube multimessenger projects

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Neutrino astronomy is driven by the quest for the origin of cosmic rays.
Powerful acceleration engines are needed to produce cosmic rays at the upper end of the observed energy spectrum. Neutrinos would be created in subsequent interactions of these particles in conjunction with photons in a wide range of wave lengths. Gravitational waves might as well be produced by the same sources which yield neutrino signals.
Both Antares and IceCube have carried out various searches for space-time correlations between neutrino signals and observations from either highest energetic cosmic rays, gamma rays or gravitational waves. Further, both collaborations have put in place online alert systems, which trigger observations of optical telescopes and gamma-ray satellites, following the detection of a peculiar neutrino pattern.
The talk will give an overview over such multimessenger projects.

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APIF's view

Plenary session 6 / **18**

APPEC's view

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Parallel Session C / **60**

Acoustic neutrino detection investigations within ANTARES and prospects for KM3NeT

Author: R. Lahmann[1]

[1] _

The acoustic neutrino detection technique is a promising approach for future large-scale detectors with the aim of measuring the small expected flux of cosmogenic neutrinos at energies exceeding 100 PeV. It suggests itself to investigate this technique in the context of underwater Cherenkov neutrino telescopes, in particular KM3NeT, because acoustic sensors are present by design to allow for the calibration of the positions of the optical sensors. For the future, the KM3NeT detector in the

Mediterranean Sea will provide an ideal infrastructure for a dedicated array of acoustic sensors. A particular advantage of such an array would be its interdisciplinary character as it could be used not only for acoustic neutrino detection, but also for purposes of marine science.
In this presentation results from the acoustic array AMADEUS of the ANTARES detector will be discussed with respect to the potential and implications for acoustic neutrino detection with KM3NeT and beyond.

Parallel Session D / 78

An expected performance of "Dubna" neutrino telescope for search for high-energy astrophysical neutrinos by detection of high-energy cascades

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Currently the next-generation km3-scale neutrino telescope Baikal-GVD is under construction in Lake Baikal. It will have modular structure and consist of functionally independent sub-arrays – clusters of strings of optical modules. The first cluster of Baikal-GVD christened "Dubna" was deployed and commissioned in April 2015 in Lake Baikal. We discuss the expected performance of the "Dubna" array for detection of secondary cascades generated by the high-energy neutrinos in water.

Parallel Session G / 27

Application of Data Mining Techniuqes in Atmospheric Neutrino Analyses with IceCube

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The selection of event candidates by using machine algorithms has become an important analysis tool. Data mining, however, goes beyond the simple training and application of a learning algorithm. It also incorporates finding a good reprensation of the data in less dimensions without losing relevant information, as well as a thorough validation of the results throughout the entire analysis. A data mining based event selection chain has been developed for the measurement of the atmospheric muon neutrino spectrum with IceCube in the 59-string configuration. It yielded a high statistics and high purity sample of neutrino candidates, while rejecting 99.9999% of the incoming background muons. Since then the analysis chain could be applied in analyses of the atmospheric muon neutrino spectrum using IceCube in the 79- and 86-string configuration with only minor changes. The setup of the analysis chain will be presented and the results will be discussed in the scope of atmospheric neutrino analyses.

Parallel Session F / 57

Aspects of the optical system relevant for the KM3NeT timing calibration

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The construction of the KM3NeT neutrino telescope in the abyss of the Mediterranean Sea has started. Installation of in total 30 vertical detection units, each supporting 18 optical modules with 31 photomultipliers is foreseen in the first construction phase of the telescope. The KM3NeT timing calibration uses the optical system to send and fan-out an onshore clock signal, derived from a GPS receiver, to all the offshore digital optical modules. The data acquisition system inside the optical modules use this clock signal to time-stamp the light pulses detected by the photomultiplier tubes. The delay between the GPS clock on shore and the clock in each optical module is measured with sub-nanosecond precision using a White Rabbit based timing calibration system. Different aspects of the optical system are of influence on the delay between the onshore clock and the clock in each optical module. These aspects of the optical system need to be quantified and taken into account during the measurement of the delay between the onshore clock and the clock in each optical module. The aspects of the optical system relevant for the timing calibration and the quantification of their effect will be presented.

Parallel Session H / 81

Atmospheric Flux Uncertainties and the Neutrino Mass Hierarchy

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Next generation atmospheric low-energy neutrino detectors, will be able to measure neutrinos with energies of a few GeV. In this energy range the primary signal below the horizon is neutrino secondaries from cosmic ray interactions in the atmosphere. The measured event rate will depend on the neutrino mass hierarchy, allowing determination of the Neutrino mass hierarchy to a significance level of about 3.5 sigma within a 5-year period, mostly limited by systematic uncertainties. We present here the impact of atmospheric neutrino flux systematic uncertainties on the determination of the neutrino mass hierarchy. This work was performed using simulation data from the low-energy extension to the IceCube detector located at the geographic south pole, PINGU, and is relevant to a wide range of other experiments.

Parallel Session I / 108

Baikal-GVD deployment procedures

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Currently the next-generation km3-scale neutrino telescope Baikal-GVD is under construction in Lake Baikal. Assembling of Gigaton Volume Detector (GVD) is highly dependent on an ice cover on Lake Baikal. This cover, used as stable platform, gives a lot of benefits for GVD deployment, but makes a strict timeline constraints. So, assembling procedures are tuned to minimize deployment time and man-hours. Discussion of these procedures is the matter of this presentation.

Plenary Session 2 / 4

Baikal/GVD: results, status and plans

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The future next-generation neutrino telescope Baikal-GVD will be km^3-scale array aimed at detection of astrophysical neutrino fluxes. It will have modular structure and consist of functionally independent sub-arrays – clusters of strings of optical modules. The prototyping phase of the project has been concluded in 2015 with deployment of the first cluster of Baikal-GVD in Lake Baikal. We discuss a current status and perspectives of Baikal-GVD project.

Parallel Session B / 109

CORSIKA Modifications for Faster Background Generation

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CORSIKA is a simulation program for extensive air showers initiated by high energy cosmic particles. These air showers create the majority of the muons and neutrinos that neutrino telescopes detect and are considered a background signature in searches for astrophysical neutrinos. This contribution will discuss changes to CORSIKA which allow for faster high energy background simulation. The theory, implementation, application, and performance of these modifications will be presented.

Parallel Session F / 74

Calibration Methods and Tools for KM3NeT

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The detector of the KM3NeT telescope composed of several thousands digital optical modules is in the process of its realization in the Mediterranean Sea. Each optical module contains 31 3-inch pre-calibrated photomultipliers. Readout of the optical modules and other detector components is synchronized at the level of sub-nanoseconds. The position of the module is measured by acoustic piezo detectors inside the module and external acoustic emitters, installed on the bottom of the sea. The orientation of the module is obtained with an internal attitude and heading reference system chip. Detector calibration, i.e. timing, positioning and sea-water properties, is overviewed in this talk and discussed in detail in this conference. Results of the procedure applied to the first detector unit ready for installation in the deep sea will be shown.

Parallel Session J / 104

Capabilities of IceCube's Gamma-Ray, Optical and X-Ray Follow-Up Programs

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The IceCube Neutrino Observatory is a 1 km³ detector for Cherenkov light in the ice at the South Pole. Although the presence of a diffuse astrophysical neutrino flux has been confirmed, its origin has yet to be resolved.

Given the current constraints on continuous point source searches, transient and variable objects emerge as promising, detectable source candidates. IceCube boosts the sensitivity to these types of sources by alerting third-party observatories of neutrino events clustered in space and time, as well as astrophysical neutrino candidates.

This talk will showcase the different neutrino-triggered multi-messenger programs in IceCube along with their results and prospects.

Parallel Session C / **88**

Characterisation and testing of the KM3NeT acoustic positioning system

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In underwater neutrino telescopes, the search of point-like sources through the Cherenkov detection technique requires a precise knowledge of the positions of thousands of optical sensors, spread in a volume of a few cubic kilometres. In KM3NeT the optical sensors are hosted in 700 m high semi-rigid structures, called detection units, which move under the effects of underwater currents. These movements are continuously monitored through an underwater positioning system based on acoustic emitters and receivers. In this work, the tests performed on the key elements of the positioning system are presented. In particular, the time calibration measurements made with the acoustic data acquisition system are demonstrated. Finally, the performance of the KM3NeT acoustic positioning system is evaluated in relation to the results obtained by the positioning system, developed in the framework of the SMO project for the NEMO Phase-II detection unit prototype.

Parallel Session F / **91**

Characterization benches for the KM3NeT DOMs

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As has been demonstrated by the first generation of neutrino telescopes Antares and IceCube, precise knowledge of the photon detection efficiency of optical modules is of fundamental importance for the understanding of the instrument and accurate event reconstruction. Dedicated test benches have been developped to measure all related quantities for the Digital Optical Modules of the KM3NeT neutrino telescope being currently deployed in the Mediterranean see. The first bench is a black box with robotic arm equiped with calibrated single photon source or laser which enable a precise mapping of the detection efficiency of arbitrary incident angle photons as well as a precise measurement of the time delays induced by the photodetection chain. These measurement can be incorporated and compared to full GEANT MonteCarlo simulations of the optical modules. The second bench is a 2mx2m water tank equiped with muon hodoscopes on top and bottom. It enables to study and measure the angular dependence of the DOM's detection efficiency of the Cherenkov light produced in water by relativistic muons reproducing in situ detection conditions. We will describe thes two benches and present their first results and status.

Parallel Session E / **59**

Characterization of the electro-optical transceivers in the KM3NeT optical network

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KM3NeT is a future research infrastructure hosting a network of neutrino telescopes in the abyss of the Mediterranean Sea. The whole data transport over an optical network is based on the Dense Wavelength Division Multiplexing technique with optical channels spaced 50 GHz apart and a bit rate of 1.25Gbps. Over the telescope life time, precise temperature control of the laser is required to maintain stability of the central frequency, complying with the ITU-T G.694.1 recommendations of the International Telecommunication Union. We will report on the characterisation of the tuneable features of the electro-optical transceivers required to compensate for the expected wavelength drift due to aging factors. Preliminary results will be showed.

Parallel Session J / **97**

Correlation between the UHECRs measured by the Pierre Auger Observatory and Telescope Array and neutrino candidate events from IceCube

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Placeholder. The actual abstract will be submitted later.

Parallel Session E / **30**

Data acquisition system of the Baikal-GVD

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The objective of the Baikal-GVD project is the construction of a km3-scale neutrino telescope in Lake Baikal. The first GVD-cluster with 192 optical modules has been deployed and commissioned in April 2015. The data acquisition system (DAQ) of the detector takes care of the digitization of the photo-multiplier tube signals, data transmission, filtering and storage. The design and the implementation of the data acquisition system are discussed.

Parallel Session I / **87**

Deep subsea data transmission : wet mateable hybrid connectors based on dry inserts

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PowerSea is a spin-off company based on research done by the french CNRS on the wet-mateable underwater connectors.

The reliability and the cost of subsea connections are a key issue for deep sea projects.

The company has already developed a wet-mate connector adapted to marine renewable energies, featuring a high power (24 kV-300A on 3 phases) and a cost adapted to the return of investment of this new market.

Our target is now to offer a deep sea (down to 4000 meter depth) hybrid wet-mate connector dedicated to the scientific market, including a high versatility design. Our goals are reducing the price of 50% compared to the competition, while ensuring a high data rate (up to 24 single-mode fibres) and improved reliability. In the meantime we want to allow bespoke designs to fit any specific demand.

The presentation will introduce the company and give the key points of the connector development, including qualification time table, installation procedures, connector specifications, and reliability targets.

Parallel Session I / **32**

Design and Mass Production of the Optical Modules for KM3NeT-Italia project

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The KM3NeT European project aims to construct a large volume underwater neutrino telescope in the depths of the Mediterranean Sea. Thanks to a dedicated funding by the Italian Ministry of

Education, University and Research (MIUR) in its first phase, referred as KM3NeT-Italia, an 8-towers detector is under construction.
The detection element of the telescope, the optical module, is composed by a 13-inch high-pressure glass-vessel that contains a single 10-inch photomultiplier, optically and mechanically coupled by means of a transparent silicone gel. A mu-metal cage surrounds the photomultiplier to shield it against the Earth's magnetic field. The power supply system, the front-end electronic module and a LED-system designed for underwater calibrations are also hosted into the glass sphere, together with a manometer to check the vacuum inside the vessel.
The whole optical module design, as well as each single component, was chosen after an intense R&D work on photomultipliers, high voltage supply circuit, optical gel and mechanical supports.
Before the production phase, 750 of the selected 10-inch R7081 Hamamatsu photomultipliers have been thoroughly characterized by means of dedicated test-benches.
Following a well-established production procedure, over 700 optical modules were assembled at the INFN-LNS production site located at the Harbour of Catania, and their functionality tested from electrical and mechanical point of view by using properly test-benches and a hyperbaric chamber.
The proposed talk deals with the definitive design of the whole optical module, describing its main components, the main results obtained from the massive photomultipliers measurements, and the foremost phases of the mass production procedure.
In November 2014 a first tower of 14 storeys equipped with 84 optical modules was deployed in the Mediterranean Sea site, at a depth of over 3500 meter.

Parallel Session F / 41

Development and performances of a high statistic PMT test facility

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Since almost a century photomultipliers have been the main sensors for photon detection in nuclear and astro-particle physics experiments.
In recent years the search for cosmic neutrinos gave birth to enormous size experiments (Kamiokande, Super-Kamiokande, etc.) and even kilometric scale experiments as ICECUBE, Antares, and the future KM3NeT.
A very large volume neutrino telescope requires several hundreds of thousands photomultipliers. The performance of the telescope strictly depends on the performance of each PMT. For this reason it is mandatory to measure the characteristics of each single sensor.
To characterize a single PMT normally requires more than 8 hours. This means that it is not feasible to measure the parameters of each PMT of a neutrino telescope without a system able to test more than one PMT simultaneously.
For this application we have designed, developed and realized a system able to measure the main characteristics of 62 photomultipliers simultaneously. Two measurement sessions per day are possible. In this work we describe the design constraints and how they have been satisfied. Finally, we show the performance of the system and the first results coming from the test of few thousand tested PMTs.

Parallel Session E / 23

Digital and analog electronics for an autonomous, deep-sea, Gamma Ray Burst Neutrino prototype detector.

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GRBNeT is a Gamma Ray Burst Neutrino Telescope made of autonomously operated arrays of deep-sea light detectors, anchored to the sea-bed without any cabled connection to the shore. This paper presents the digital and analog electronics that we have designed and developed for the GRBNeT prototype. We describe the requirements for these electronics and present their design and functionality. We will present low-power analog electronics for the PMTs utilized in the GRBNeT prototype and the FPGA based digital system for data gathering and storage. We conclude with preliminary performance measurements of the electronics systems for the GRBNeT prototype.

Parallel session A / 111

ET Enterprises

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ET Enterprises

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Recent demands for photomultipliers as a result of large scale telescope projects has pushed the performance requirements and boundaries in their design and development. The need for improved timing characteristics, low afterpulse, enhanced QE and compact design are essential to meet the performance needs of the next generation telescopes.

ET Enterprises has a long history in the design and development of photomultipliers which has been further enhanced with the experience of a sister company called ADIT based in the USA who also manufacturer PMTs. A recent acquisition of a glass company called Plowden and Thomson has provided ET Enterprises glass supply security and expertise in ultra low background glass and glass blowing.

This presentation will introduce and cover photomultiplier developments with 11” dia , compact 3” dia and high QE . In addition to photomultipliers ET Enterprises has new designs for high voltage bases to enhance detector performance. These are high efficiency and are ideal for large scale photomultiplier deployment and remote applications that need to operate on batteries or solar power

Parallel Session G / 63

Enabling Grid Computing resources within the KM3NeT computing model

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KM3NeT is a future European deep-sea research infrastructure hosting a new generation neutrino telescope with a volume of several cubic kilometres that -located at the bottom of the Mediterranean Sea - will open a new window on the universe. International collaborative scientific experiments, like KM3NeT, are generating datasets which are increasing exponentially in both complexity and volume, making their analysis, archival, and sharing one of the grand challenges of the 21st century. These experiments, in their majority, adopt computing models consisting of different Tiers with several computing centres and providing a specific set of services for the different steps of data processing such as detector calibration, simulation and data filtering, reconstruction and analysis. The computing requirements are extremely demanding and, usually, span from serial to multi-parallel or GPU-optimized jobs. The collaborative nature of these experiments demands very frequent WAN data transfers and data sharing among individuals and groups. In order to support the aforementioned demanding computing requirements we enabled Grid Computing resources, operated by the European Grid Infrastructure (EGI), within the KM3NeT computing model. In this study we describe our advances in this field and the method for the KM3NeT users to utilize the EGI computing resources. We are using the Jpp, Corsika, KM3 and Mupage software packages as the use case.

Parallel Session B / 25

Energy reconstruction of high energy muon and neutrino events in KM3NeT

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KM3NeT will be a European deep-sea infrastructure of neutrino telescopes covering a volume of several cubic kilometers at the Mediterranean Sea aiming to search for high energy neutrinos from galactic and extragalactic sources. This analysis focuses on muon neutrinos and muons coming from charged-current interactions. In large water Cherenkov detectors the reconstructed muon is used to approximate the neutrino direction and energy, thus providing information on the astrophysical neutrino source. Muon energy estimation is also critical for the differentiation of neutrinos originating from astrophysical sources from neutrinos generated in the atmosphere which constitute the detector irreducible background. We describe a method to determine the muon and neutrino energy employing a Neural Network. An energy resolution of approximately 0.27 has been achieved for muons at the TeV range.

Plenary session 1 / 1

Extragalactic Neutrino Sources and their Multi-Messenger Constraints

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Extragalactic sources are believed to dominate the ultra-high energy cosmic ray (CR) spectrum beyond the CR “knee”. These sources are also expected to produce very high-energy neutrinos via interactions with gas and radiation during acceleration and emission of CRs or during CR propagation over cosmic distances. I will focus in my talk on extragalactic source candidates of the TeV-PeV neutrino flux recently observed by the IceCube Cherenkov telescope. There are various interesting multi-messenger relations to gamma-rays and cosmic rays. The TeV-PeV gamma-rays produced in

hadronic interactions are not directly accessible by extragalactic gamma-ray astronomy due to interactions with cosmic radiation backgrounds. Nevertheless, the isotropic sub-TeV gamma-ray background observed by Fermi-LAT contains indirect information from secondary emission produced in electromagnetic cascades and constrains hadronic emission scenarios. Interestingly, the overall energy density of the observed neutrino flux is close to a theoretical limit for neutrino production in the sources of ultra-high energy cosmic rays and might indicate a common origin of these phenomena. I will discuss various constraints and implications of these multi-messenger relations for proposed source candidates.

Parallel Session C / **70**

Fiber optic hydrophones for acoustic neutrino detection

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Acoustic detection may provide way to observe ultra-high energy cosmic neutrinos, i.e. energies above 10^{18} eV, and their extra-galactic sources [1, 2].
The expected flux of cosmic neutrinos with ultra-high energy is low, so that large scale neutrino telescopes are needed for this emerging field of astroparticle physics. Using the acoustic signals induced by a neutrino interaction in water has the advantage that sound can travel for many kilometers with only small attenuation in the relevant frequency range. A hydrophone network that uses the deep sea as a detection medium may therefore be the solution to detect the ultra-high energy neutrinos. It has been advocated that fiber optic hydrophone technology is a promising means to establish a sensitive, cost-effective and large scale sensor network [3]. In this technology several hydrophone sensors are integrated on a optical fiber. The sensors transform the acoustic pressure in to strain in the fiber. Subsequently, this strain causes a wavelength shift of the light that travels through the fiber and that is sensed using an interrogator. Hydrophones based on optical fibers, provide the required sensitivity to detect the small signals from neutrinos. At the same time, optical fibers form a cost-effective and straightforward way for the installation of a large scale network.
In this talk we present an update of the research and development of the fiber hydrophone technology. Recent progress at TNO has led to a new and improved hydrophone sensor. Measurements to characterize the sensor and to show its performance have been carried out and will be presented. In addition the performance of the interrogator is discussed and measurements are shown, leading to an overall performance prediction of the technology.
[1] G. A. Askaryan. Acoustic recording of neutrinos. Zemlia i Vselennaia, 1:13–16, 1979.
[2] J. G. Learned. Acoustic radiation by charged atomic particles in liquids: An analysis. Phys. Rev. D, 19:3293–3307, June 1979.
[3] E. J. Buis et al. Fibre laser hydrophones for cosmic ray particle detection. Journal of Instrumentation, 9(03):C03051, 2014

Parallel Session J / **43**

Follow-up of high-energy neutrinos detected by the ANTARES telescope

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The ANTARES telescope is well suited to detect neutrinos produced in astrophysical transient sources as it can observe a full hemisphere of the sky with a duty cycle close to unity. Potential neutrino sources are gamma-ray bursts, core-collapse supernovae and flaring active galactic nuclei. To enhance the sensitivity of ANTARES to such sources, a detection method based on follow-up observations from the neutrino direction has been developed. This program, denoted as TAToO, includes a network of robotic optical telescopes (TAROT, Zadko and MASTER) and the Swift-XRT telescope, which are triggered when an "interesting" neutrino is detected by ANTARES.
A follow-up of special events, such as neutrino doublets in time/space coincidence or single neutrino having a very high energy or in the specific directions of local galaxies, significantly improves the perspective for the detection of transient sources. As images can be taken within 20 seconds after the neutrino trigger and as observations are also made up to two months after the alert, the search for fast transient sources such as gamma-ray burst afterglows or slowly rising sources such as core-collapse supernovae becomes possible.
The analysis of early and long follow-up observations has been performed and the results covering optical and X-ray data will be presented.

Plenary Session 3 / **102**

From DeepCore to PINGU

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Very large volume neutrino telescopes observe atmospheric neutrinos over a wide energy range (GeV to TeV), after they travel distances as large as the Earth's diameter. DeepCore, the low energy extension of IceCube, has started making meaningful measurements of the neutrino oscillation parameters θ_{23} and $|\Delta m^2_{32}|$ by analyzing this flux. PINGU, a proposed extension to lower DeepCore's detection threshold, aims to use the same neutrino flux to further increase the precision with which these parameters are known, and eventually determine the sign of Δm^2_{32}, also referred to as the neutrino mass ordering. The transition from the currently running DeepCore to the proposed PINGU, as well as their latest results, are discussed in this talk.

Plenary session 5 / **14**

Future very-high-energy gamma-rays detection projects at ground

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Several projects planned or proposed can significantly expand our knowledge of the high-energy Universe. Construction of the Cherenkov telescope array CTA is going to start in October, and other detectors are planned which will use the reconstruction of extensive air showers. This talk

describes the physics potential of this exploration, with particular attention to possible discoveries on fundamental physics and to multimessenger astrophysics.

Parallel Session I / **37**

GRBNeT - A Prototype Autonomous Neutrino Detector

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GRBNeT is a project aiming at the detection of ultra-high energy neutrinos, for example neutrinos originating from Gamma Ray Bursts. The goal is to design, construct and test-deploy a prototype unit of an autonomous (data/energy-wise) neutrino detector.
Being autonomous is crucial since for the detection of ultra-high energy neutrinos a very large volume of water is required. Large scale facilities such as IceCube and KM3Net are designed to be more sensitive to galactic and diffuse flux neutrinos rather than extragalactic ultra high energy neutrinos. However, their sensitivity to such neutrinos could be increased by placing around and at larger distances detectors such as the one of the GRBNeT project. This extension would increase the volume of neutrino telescopes to several cubic kilometres. In addition to that, as no cable connection to the shore is required, GRBNeT detection units cost significantly less to regular detection units and can become a cost effective extension of large scale facilities.
For the GRBNeT prototype unit ultra low power electronics have been developed. Also extended simulations are being made concerning the high energy neutrinos form GRBs and Atmospheric Muon Background.

Plenary Session 3 / **6**

Global neutrino oscillation analysis: status of unknown parameters, and future systematic challenges for ORCA and PINGU

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We present the status of three-neutrino oscillations from a global data analysis, including a partial 2015 update, with emphasis on the unknown parameters: CP phase, θ_{23} octant, mass hierarchy. We also discuss the unprecedented challenges set by (non)parametric systematic uncertainties in hierarchy-sensitive experiments characterized by very high statistics, such as ORCA and PINGU.

Plenary session 5 / **13**

Ground-based gamma-ray astronomy: Investigating the sky at photon energies between ~20 GeV and 100 TeV

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Since about a decade, ground-based gamma-ray telescopes are key instruments to investigate the high-energy universe at photon energies above ~100 GeV. Mainly devoted to searching for and characterizing cosmic particle acceleration and transport, the instruments HESS, MAGIC, VERITAS and HAWC have so far discovered more than 100 Galactic and extragalactic sources of very-high-energy (VHE) gamma rays. The observations complement measurements performed with the Fermi-LAT instrument at lower energies, and in many cases provide good energy overlap with the latter, especially after recent upgrades of the ground-based instruments which in some cases enable observations down to energies of a few tens of GeV.

Meanwhile, gamma-ray astronomy is a matured branch of science which starts to enter an era of precision measurements on the high-energy emission of objects such as supernova remnants, pulsars and their nebulae, binary systems, stellar clusters and active galactic nuclei. With HESS, a deep-exposure survey of the Milky Way has been finished recently, resulting in the first systematic catalog of Galactic VHE gamma-ray sources. Furthermore, the large number of VHE gamma-ray sources enables population studies to investigate the properties of source classes such as VHE-emitting supernova remnants and pulsar wind nebulae. Besides that, questions of fundamental physics are addressed by e.g. searching for dark matter, placing constraints on the star formation rate in the early universe, or testing for an energy dependence of light speed.

The talk will review the recent progress in VHE gamma-ray observations with HESS, MAGIC, VERITAS, and HAWC.

Parallel session A / 46

Hamamatsu PMTs Latest Developmental Status

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[1] *Hamamatsu*

Hamamatsu has been providing various types of vacuum photon detectors in many fields for many years. We will show the latest developmental status for our PMTs.

Plenary session 1 / 2

High energy neutrinos: validations, inferences, prospects

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IceCube has changed the rules of the game and it continues to progress. Remarkably, the observations are compatible with the known neutrino oscillations. Moreover, the topologies of the events have been used to probe exotic physics. Still, we need independent confirmations; the connections of IceCube's neutrinos with astronomical/astrophysical facts heavily rely on speculations–excepting special cases, such as GRB; the amount of prompt events is not known precisely; double bang and/or Glashow resonance events are still to be seen. The situation is rapidly evolving; we should consider expectations but profiting of the new facts and of the new questions in order to reassess the case for high energy neutrino telescopes.

Parallel Session G / 36

IceCube Simulation Production and the Transition to IceProd2

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IceCube's simulation production relies largely on dynamic, heterogeneous resources spread around the world. Datasets consist of many thousands of job workflow subsets running in parallel as directed
acyclic graphs (DAGs) and using varying resources. IceProd is a set of python daemons which process job workflow and maintain configuration and status information on jobs before, during, and after processing. IceProd manages a complex workflow of DAGs to distribute jobs across all computing grids and optimize resource usage. IceProd2 is a new version of IceProd with substantial increases in security, reliability, scalability, and ease of use. It is undergoing testing and will be deployed this fall.

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IceCube results

Parallel Session D / **67**

IceCube results from low-energy point source searches in the southern hemisphere

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Due to the overwhelming background of atmospheric muons, traditional IceCube point source searches in the Southern Hemisphere are sensitive only at neutrino energies above 100 TeV. We will report on a new approach, which focuses on events starting inside the instrumented volume of the IceCube detector. By utilizing different veto techniques we are able to significantly reduce the energy threshold and can now for the first time explore the entire Southern Hemisphere at neutrino energies as low as 100 GeV. Results from one year of data taken with the completed IceCube detector in 2011/12 will be presented.

Parallel Session D / **95**

IceCube results from pointlike source searches using 6 years of through-going muon data

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The IceCube Neutrino Observatory located at the geographic South Pole was designed to study and discover high energy neutrinos coming from both galactic and extragalactic astrophysical sources. Track-like events induced by charged-current

muon-neutrino interactions close to the IceCube detector give an angular resolution better than 1° above TeV energies.
We present here the results of searches for pointlike astrophysical neutrino sources on the full sky using 6 years of detector livetime, of which three years use the complete IceCube detector.
Within 2000 days of detector livetime, IceCube is sensitive to a steady flux substantially below $E^2\,\partial\phi\,/\,\partial E = 10^{-12}\mathrm{TeV\,cm^{-2}\,s^{-1}}$ in the northern hemisphere for neutrino energies above 10~TeV.

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IceCube-Gen2 project status and plans.

Plenary Session 2 / 100

IceCube-Gen2: The Science, the Detector, Drilling, and Logistics

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New groups from the astroparticle physics community have joined an enlarged IceCube Collaboration to pursue construction of a next-generation very large volume neutrino telescope at the South Pole site. This new collaboration, called the IceCube-Gen2 collaboration, hopes to bring forth an instrument that will further push the recently expanded frontiers of knowledge in the field of neutrino astrophysics to cover new territory. The instrument, based on proven engineering and operational experience gained in constructing and running the IceCube Neutrino Observatory, will nevertheless utilize new techniques to effect transformative change in the field. This presentation will describe the scientific mission to understand the sources of high energy neutrinos, probing all the way to the highest energies with new technologies, and will describe the conceptual-level designs under evaluation. Technical aspects such as advances in photodetection and detection via RF sensors are then covered along with associated electronics. Drilling and logistics make up a significant portion of the total project: new designs and strategies for large scale drilling and construction activities in an environment different from that of the IceCube construction merit close attention. The presentation concludes with project-level concerns such as cost, schedule, and the mobilization of large financial and human resources across the globe.

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IceCube/PINGU: status and plans

Parallel Session F / 62

Impact of DM-Ice17 Muon Data on IceCube Reconstructions

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DM-Ice17 is a NaI(Tl) experiment deployed directly below the IceCube Neutrino Observatory in the South Pole ice. It is comprised of two detectors, each containing a 5.5" diameter, 6" tall cylindrical scintillator. Muons are identified in DM-Ice17 by their event topology in the scintillator, and a high portion of tagged muons are coincident with events in IceCube. A study of these coincident events has shown that co-deployment of scintillators with Cherenkov detectors can improve low energy track reconstruction. Knowing that the direct path of the muon passes through the volume of the DM-Ice17 crystal lowers IceCube misreconstruction rates and provides a new metric for reconstruction quality. We present the status of the DM-Ice17/IceCube muon coincidence study and the status of the reconstruction improvements.

Parallel Session D / 38

Indirect detection of Dark Matter with the ANTARES Neutrino Telescope

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One of the main objectives of the ANTARES neutrino telescope is the search for neutrinos produced in self-annihilation of Dark Matter (DM) particles. The analysis for different sources of DM (Sun, Galactic Center, Earth, ...) or DM models (SUSY, Secluded) will be described and the results presented. The specific advantages of neutrino telescopes in general and of ANTARES in particular will be explained. As an example, the indirect search for Dark Matter towards the Sun performed by neutrino telescopes currently leads to more stringent limits on the spin-dependent WIMP-nucleon cross section with respect to existing direct detection experiments.

Parallel Session J / 42

Joint search for High Energy neutrinos and gravitational waves with the Antares neutrino telescope and the LIGO-Virgo gravitational waves interferometers

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Cataclysmic cosmic events can be plausible sources of both gravitational waves (GW) and high energy neutrinos (HEN), alternative cosmic messengers carrying information from the innermost regions of the astrophysical engines. Possible sources include long and short gamma-ray bursts (GRBs) but also low-luminosity or choked GRBs, with no or low gamma-ray emissions.
The ANTARES Neutrino Telescope can determine accurately the time and direction of high energy neutrino events, and the Virgo/LIGO network of gravitational wave interferometers can provide timing/directional information for gravitational wave bursts. Combining these informations through GW+HEN coincidences provides a novel way of constraining the processes at play in the sources, and also enables to improve the sensitivity of both channels relying on the independence of backgrounds of each experiment.
We will describe the joint GW+HEN searches performed using data taken with the ANTARES telescope both in 2007 (while Antares was half its final size) and in 2009-2010 (with the full Antares detector) combined with data from the Virgo/LIGO interferometers during the VSR1/S5 and VSR2-3/S6 (with improved sensitivities) science runs. The 2007 search has allowed to place the first upper limits on the density of joint GW+HEN emitters, and the 2009-2010 analysis will allow a significant improvement in sensitivity.

Parallel Session E / 106

KM3NeT Digital Optical Module Electronics

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KM3NeT is a European research facility that is being built in the Mediterranean Sea and that will house a neutrino telescope of cubic kilometer scale. Cherenkov light from neutrino induced secondary particles will be detected by an array of optical modules consisting in high pressure resistant glass vessels with photomultipliers inside, called Digital Optical Modules. This vessel is composed of 31 small 3 inch Photomultipliers distributed around the glass sphere, which collects the Cherenkov light and transform it into electronic signals. The electronic signals are discretized and time stamped by 31 Time to Digital Converter channels embedded on a Field Programmable Gate Array. Once acquired, they are sent on-shore by the White Rabbit protocol, that also allows 1-ns syncronization with the on-shore station, for their final treatment by the Data Acquisition System. In the present article it is described in detail all the Digital Optical Module electronics.

Parallel Session E / 64

KM3NeT Neutrino Telescope 1-ns resolution Time To Digital Converters

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The KM3NeT collaboration aims the construction of a multi-km3 high-energy neutrino telescope in the Mediterranean sea consisting of thousands of glass spheres, each of them containing 31 photomultiplier of small photocathode area. The main digitization system is composed by 31 Time to Digital Converter channels with 1-ns resolution embedded in a Field Programmable Gate Array. An architecture with low resources occupancy has been chosen allowing the implementation of other instrumentation, communication and synchronization systems on the same device. The 4-Oversampling technique with two high frequency clocks working in opposed phases has been used together with an asymmetric FIFO memory. In the present article the architecture and the first results obtained with the Time to Digital Converters are presented.

Plenary Session 2 / 53

KM3NeT-ARCA project status and plans

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The discovery of a diffuse flux by the IceCube collaboration of extra-terrestrial origin from not identified sources requires a next generation neutrino telescopes with full sky coverage and good angular resolution.
The KM3NeT Collaboration aims at building a research infrastructure in the depths of the Mediterranean Sea hosting a several cubic kilometre neutrino telescope.

KM3NeT, in its intermediate stage, will comprise two detectors with different granularity of the arrays of optical modules: KM3NeT/ARCA at the KM3NeT-It site of two building blocks dedicated to high-energy neutrino astronomy and KM3NeT/ORCA, a single building block located at the KM3NeT-Fr site offshore Toulon (France) dedicated to the study of neutrino mass hierarchy (covered by another presentation).
The latitude of KM3NeT/ARCA will allow for a wide coverage of the observable sky including the region of the galactic centre. Thanks to the favorable characteristics of sea water the direction of neutrinos will be measured with excellent angular resolution also for cascade events.
The technologically innovative component of the detector, the status of construction and the first results from prototypes of the KM3NeT/ARCA detector will be presented as well as its capability to discover neutrinos.

Parallel Session D / 93

KM3NeT/ARCA sensitivity and discovery potential for neutrino point-like sources

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KM3NeT is a large research infrastructure with a network of deep-sea neutrino telescopes in the abyss of the Mediterranean Sea. Of these, the KM3NeT/ARCA detector, installed in the KM3NeT-It node of the network, is optimised for studying high-energy neutrinos of cosmic origin. Thanks to its geographical location in the Northern hemisphere, KM3NeT/ARCA can observe most of the Galactic Plane, including the Galactic Centre. Under the hypothesis of hadronic mechanisms acting inside transparent sources, models for galactic neutrino sources are well constrained by TeV gamma-ray observations. Sensitivities to galactic sources such as the supernova remnant RXJ1713.7-3946 and the pulsar wind nebula Vela X are presented as well as sensitivities to a generic point source with an E^{-2} spectrum, which represents an approximation for the spectrum of extragalactic candidate neutrino sources. Analysis methods and results are discussed both for the track and cascade channels.

Plenary Session 3 / 7

KM3NeT/ORCA: status and plans

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Neutrinos created in interactions of Cosmic Rays with the atmosphere have already for a long time been exploited for measurements of several of the parameters characterizing neutrino oscillations. At low energies, around a few GeV, matter effects from the transition through the Earth are expected to imprint a distinct but also subtle signature on the oscillation pattern specific to the ordering of the neutrino masses which is still unknown.
KM3NeT/ORCA (Oscillations Research with Cosmics in the Abyss), a densely instrumented building block of the upcoming KM3NeT neutrino telescope, will be dedicated to measuring this signature in the Mediterranean Sea. The multi-PMT optical modules can take advantage of the excellent optical properties of deep seawater. An overview will be given how the challenges of accurate particle

reconstruction, flavour identification and background rejection are mastered and how external uncertainties e.g. from the atmospheric flux and oscillation parameters are handled.
An outlook will be provided for the potential of KM3NeT/ORCA to determine the neutrino mass hierarchy and also for the new precision on several of the neutrino oscillation parameters which can be achieved in this measurement.

Parallel Session I / 75

Km3Net Italia Seafloor Network

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The KM3NeT European project aims to construct a large volume underwater neutrino telescope in the depths of the Mediterranean Sea. INFN and KM3NeT collaboration, thanks to a dedicated funding of 21.000.000 (PON 2007-2013), are committed to building and deploying the Phase 1 of the telescope, composed of a network of detection units: 8 towers, equipped with single PMT optical modules, and 24 strings, equipped with multi-PMT optical modules.
All the towers and strings are connected to the main electro optical cable by using a network of junction boxes and electro optical interlink cables. Each junction box is a passive node able to provide all the necessary power to the detection units and to guarantee the data transmission between the detector and the on-shore control station.
The Km3NeT Italia project foresees the realization and installation of the first part of the deep sea network, composed of three junction boxes, one for the towers and two for the strings.
In July 2015, two junction boxes have been deployed and connected to the new cable termination frame installed during the same sea campaign. The third and last one will be installed in November 2015.
The status of the deep sea network are presented in this contribution together with technical details of the project.

Parallel session A / 105

Latest improvements of the Hamamatsu MPPCs

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In the year 2014 a new generation of low cross-talk MPPCs has been introduced. Due to further improvements in the manufacturing processes, it is now possible to commercially offer MPPCs, which combine low cross-talk and low after pulse features with a significantly increased photo-detection efficiency (PDE). Besides the capability to manufacture large sized MPPC arrays with high element fill factor, we are now able to modify the metal film quenching resistor according to the customer's requirements. In addition, new high UV sensitive MPPCs are fabricable by applying special coating technologies.

Plenary session 1 / 20

Latest results from Fermi-LAT and the impact on neutrino observations

I will present some of the most recent results from the Fermi gamma-ray space telescope with emphasis on the latest catalogs (e.g. 3FGL, 3LAC and 2FHL) and on the class of blazars.
I will also discuss the contribution of blazars to the extragalactic gamma-ray, VHE and the neutrino background. These results are based on Fermi detected sources, Monte Carlo simulations and on a new large sample of multi-frequency selected HSP-blazars, a type of AGN known to be VHE gamma-ray emitter that has been proposed as a possible source of neutrinos.

Parallel Session E / 90

Live Monitoring and Quasi-Online Event Reconstruction for KM3NeT

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KM3NeT is a new generation neutrino telescope in the abyss of the Mediterranean Sea. It will instrument a volume of several cubic kilometres of sea water in its final configuration. Currently, the project is in its first phase with the aim of constructing and installing 31 detection units up to 700m in height, each equipped with 18 digital optical modules. The optical modules are equipped with 31 3-inch photomultipliers to detect the Cherenkov light of charged secondary particles produced in high-energy neutrino interactions. This contribution describes a live detector monitoring system, which enables real-time parameter control and a reconstruction of events soon after the data acquisition. It also allows a rapid response to or provision of external alarms of multi-messenger campaigns. The data acquisition system of KM3NeT provides pre-filtered data in event form, as well as general detector status messages. The events will be processed almost in real-time - with a delay in the range of minutes - using fast reconstruction mechanisms. This allows for high-level monitoring of the detector status using derived distributions, such as time and charge distributions and event rates. The resulting data is displayed on a web page using a dedicated, flexible web service. The same service also displays low-level monitoring data such as trigger rates, PMT hit rates and the general status of the optical modules.

Plenary Session 4 / 12

Long Baseline Neutrino Oscillations Experiments

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Some of the most precise measurements of neutrino oscillation parameters have been made using accelerator based muon neutrino beams. By studying how the flavour composition of a beam of muon neutrinos changes and they become electron and tau neutrinos, one can not only measure several mixing angles of the PMNS matrix, but also their mass differences squared. After a short introduction into the phenomenology of neutrino oscillations at accelerators, the presentation will summarise the current status of the field and give an outlook of how future facilities will allow to determine the neutrino mass hierarchy and CP violation in the neutrino sector.

Low Energy neutrino physics with underground detectors

Parallel Session F / 24

Measurement of light scattering in deep sea

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The deep-sea neutrino telescope in the Mediterranean Sea, being prepared by the KM3NET collaboration, will contain thousands of optical sensors to readout. The accurate knowledge of the optical properties of deep-sea water is of great importance for the neutrino event reconstruction process. In this study we describe our progress in designing an experimental setup and studying a method to measure the parameters describing the absorption and scattering characteristics of deep-sea water. Three PMTs will be used to measure in situ the scattered light emitted from six laser diode in three different wavelengths covering the Cherenkov radiation spectrum. The technique for the evaluation of the parameters is based on Monte Carlo simulations and our results show that we are able to determine these parameters with satisfying precision.

Parallel Session H / 33

Measurement of the Atmospheric Muon Neutrino Energy Spectrum with IceCube in the 79- and 86-Ctring Configuration

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IceCube is a neutrino telescope with an instrumented volume of one cubic kilometer. A total of 5160 Digital Optical Modules (DOMs) is deployed on 86 strings forming a three dimensional detector array. Although primarily designed for the detection of neutrinos from astrophysical sources, the detector can be used for spectral measurements of atmospheric neutrinos. These spectral measurements are hindered by a dominant background from atmospheric muons. State of the art techniques from machine learning and data mining are required to select a highly pure sample of atmospheric neutrino candidates. The energy spectrum of muon neutrinos is obtained from energy dependent input variables by utilzing regularized unfolding. The results obtained using IceCube in the 79- and 86-string configuration will be presented.

Parallel Session F / 35

Measuring the optical properties of the IceCube drill holes

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The IceCube Neutrino Observatory deployed 5160 digital optical modules (DOMs) in a cubic kilometer of deep ice below the South Pole that record the Cherenkov light of passing charged particles. A good understanding of the ice is crucial to the quality of calibration and event reconstruction. While the optical properties of the undisturbed ice are reasonably well understood, the properties of the refrozen drill holes still pose a challenge. A new data-acquisition and analysis approach using light originating from LEDs within one DOM detected by the photomultiplier of the same DOM will be described. This method allows us to explore the scattering length as a function of azimuthal angle in the immediate vicinity of the considered DOMs.

Parallel Session F / 101

Moon shadow observation with ANTARES and KM3NeT neutrino telescope

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The ANTARES detector is the largest neutrino telescope currently in operation in the North Hemisphere, while KM3NeT
is a future new generation neutrino telescope with a volume of a cubic-kilometres that will be located at the bottom of the Mediterranean Sea.
The point-like neutrino search is one of the main goal of the neutrino telescopes, therefore the evaluation of the pointing performance is crucial.
This measure can be performed exploiting the absorption of cosmic rays by the Moon that lead to a deficit in the atmospheric muon flux, the so-called Moon shadow effect.
The results of the ANTARES analysis (2007-2012) and KM3NeT simulation will be presented. The six years ANTARES analysis presents a 3.1σ significance of the Moon shadowing, while the KM3NeT simulation shows that a 12.5σ significance can be reached in one year.

Parallel session A / 71

Multi-PMT Optical Module Designs for IceCube-Gen2

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IceCube-Gen2 is the planned next generation neutrino telescope at the South Pole incorporating a high-energy array for neutrino astronomy and a dense array (PINGU) aimed at the determination of the neutrino mass hierarchy. The contribution presents alternatives to IceCube-Gen2's single-PMT baseline design which are currently being developed. These designs feature up to 24 smaller photomultipliers or use glass and gel with enhanced UV transparency to increase the number of detected photons and provide additional information like directionality. Thereby, they have the potential to significantly enhance the performance of IceCube-Gen2.

Parallel Session E / 94

NANET3: THE ON-SHORE READOUT AND SLOW-CONTROL BOARD FOR THE KM3NET-IT UNDERWATER NEUTRINO TELESCOPE

Authors: Alessandro Lonardo[1] ; Andrea Biagioni[1] ; Carlo Alessandro Nicolau[2] ; Davide Rossetti[3] ; Elena Pastorelli[1] ; Fabrizio Ameli[1] ; Francesca Lo Cicero[1] ; Francesco Simeone[1] ; Francesco Simula[1] ; Gianluca Lamanna[4] ; Laura Tosoratto[1] ; Luca Pontisso[5] ; Michele Martinelli[1] ; Ottorino Frezza[1] ; Pier Stanislao Paolucci[1] ; Piero Vicini[1] ; Roberto Ammendola[1]

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The KM3Net-Italia underwater neutrino detection unit, the tower, consists of 14 floors.
Each floor supports 6 Optical Modules containing front-end electronics needed to digitize the PMT signal, format and transmit the data and 2 hydrophones used to reconstruct in real-time the position of Optical Modules, for a maximum tower throughput of more than 600 MB/s. All floor data are collected by the Floor Control Module (FCM) board and transmitted by optical
bidirectional virtual point-to-point connection to the on-shore laboratory. Each FCM needs an on-shore communication endpoint counterpart. In this contribution we present NaNet3, an on-shore readout board based on Altera Stratix V GX FPGA able to manage multiple FCM data channels with a capability of 800 Mbps each. The design represents a NaNet customization for the KM3NeT-Italia experiment, adding support in its I/O interface for a synchronous link protocol with deterministic latency at physical level and for a Time Division Multiplexing protocol at data level.

Parallel Session D / 34

Neutrino fluxes from the Galactic plane and the ANTARES limits

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The existence of cosmic neutrinos has been reported by the IceCube Collaboration. Though this measurement is consistent with an isotropic neutrino flux, a sub-dominant galactic component coming from extended region such as the Galactic Plane/Ridge cannot be excluded.

The ANTARES detector, located in the Mediterranean Sea, is currently the largest and longest operated under-water neutrino telescope; its effective area and good exposure to the Southern Sky allow to constrain an enhanced muon neutrino emission from extended sources such as the Galactic Plane. ANTARES data from 2007 to 2013 have been analysed and upper limits on the neutrino production from the central region of our galaxy have been set.

Parallel Session H / 45

Neutrino oscillation mass spectrometry with megaton neutrino detectors

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Neutrinos have favorable properties for measuring the elemental composition deep inside the earth's interior. First, they propagate a long distance almost undisturbed through the earth due to their weak interactions with matter. Secondly, neutrino oscillations in matter are sensitive to the electron density of the medium traversed by them, rather than the nucleus density. Using our knowledge about the earth's nucleus density distribution inferred from seismic observations, we can measure the average atomic mass ratio Z/A of the earth's core. There is a little uncertainty in densities of the earth's core, but our knowledge of its main light element is still not fixed. With the advent of the new-generation megaton neutrino detectors, neutrino oscillation mass spectrometry will allow us to constrain directly the light elements in the earth's outer core. We report the detail of this novel technique and the sensitivity study.

Plenary Session 4 / **11**

Neutrino-Nucleus Interactions in the few-GeV region

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New and more precise measurements of neutrino cross sections have renewed the interest in a better understanding of electroweak interactions on nucleons and nuclei. This effort is crucial to achieve the precision goals of the neutrino oscillation program, making new discoveries, like the CP violation in the leptonic sector, possible. We review the recent progress in the physics of neutrino cross sections, putting emphasis on the open questions that arise in the comparison with new experimental data. We present some details about the theoretical development in the description of (anti)neutrino-induced quasielastic scattering and the role of multi-nucleon quasielastic-like mechanisms. We cover not only pion production in nucleons and nuclei but also other inelastic channels including strangeness production and photon emission.

Parallel Session H / **49**

Neutrino-nucleon cross-sections at energies of Megaton-scale detectors

Author: Askhat Gazizov[1]

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We present an updated set of (anti)neutrino-nucleon charged and neutral current scattering cross-sections with an emphasis on intermediate energies between ~ 3 GeV and ~ 100 GeV. These cross-sections can be used for reconstruction and analysis of events in the future PINGU, ORCA and

Hyper-Kamiokande experiments and for detector parameters optimization. Dynamic effects due to the finite masses of secondary leptons and target mass corrections in deep inelastic scatterings are taken into account. The DIS calculations are based on the ABM11 set of QCD NNLO parton distribution functions. The sensitivity of the cross-sections to different theoretical parameters and to extrapolations of the nucleon structure functions to small x and Q^2 are discussed. Agreement within the errors of the present calculations with various experimental data is demonstrated. Our results are compared with calculations of other authors.

Plenary session 1 / **0**

Opening speeches, Greetings from local authorities

16

Opportunities within ASTERICS

Plenary session 5 / **103**

Opportunities within ASTERICS

Author: Rob van der Meer[1]

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ASTERICS (Astronomy ESFRI and Research Infrastructure Cluster) brings together astronomers and astroparticle physicists of 22 institutes in Europe to help Europe's world-leading observatories work together to find common solutions to their Big Data challenges, their interoperability and scheduling, and their data access, searching for cross-cutting solutions with mutual and wide-ranging benefit to all concerned.

ASTERICS is a four year project, funded through the European Union's Horizon 2020 Framework programme. The facilities supported by ASTERICS include SKA (Square Kilometre Array), CTA (Cherenkov Telescope Array), KM3NeT (Kilometre cubed Neutrino Telescope), E-ELT (European Extremely Large Telescope).

ASTERICS aims to open up multi messenger astronomy to all scientists and the public through the Virtual Observatory and the citizen science work.

I will draw a picture of the landscape in which ASTERICS operates and the possible interaction with the Very Large Volume Neutrino Telescope community. Attention will be given to emerging opportunities for the Neutrino community and how these can be recognised or created.

Plenary Session 4 / **10**

Phenomenology of atmospheric neutrinos

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The detection of astrophysical neutrinos, certainly a break-through result, introduced new experimental challenges and fundamental questions about acceleration mechanisms of cosmic rays. On one hand IceCube succeeded in finding an unambiguous proof for the existence of a diffuse astrophysical neutrino flux, on the other hand the precise determination of its spectral index and normalization requires a better knowledge about the atmospheric background at hundreds of TeV and PeV energies. Atmospheric neutrinos in this energy range originate mostly from decays of heavy-flavor mesons, which production in the phase-space relevant for the particle cascade is uncertain. Modernized versions of hadronic interaction models are a key ingredient for high-precision flux predictions. Due to the emphasis on new-physics discoveries, the detectors at the LHC are optimized for measuring particles with high transverse momenta. The insight into the very forward phase-space relevant for prompt lepton production in atmospheric cascades is mainly limited by detector acceptance and not so much by the collision energy. In this talk I will recap the general phenomenology of atmospheric leptons, linking recent progress in flux predictions with particle physics at colliders, in particular the LHC.

Parallel Session D / 73

Predicted sensitivity of the KM3NeT/ARCA detector to a diffuse flux of cosmic neutrinos

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The KM3NeT Collaboration has started the construction of a research infrastructure hosting a network of underwater neutrino observatories in the Mediterranean Sea. Two telescopes based on the same technology are being built: KM3NeT/ORCA to measure the neutrino mass hierarchy and to study atmospheric neutrino oscillations and KM3NeT/ARCA to detect high-energy cosmic neutrinos both in diffuse and point source mode. The excellent angular resolution of the ARCA detector, with an instrumented volume of about one Gton, will allow for an unprecedented exploration of the neutrino sky searching for neutrinos coming from defined sources or sky regions, like the Galactic Plane and the Fermi Bubbles. It will also look for diffuse high energy neutrino fluxes following the indication provided by the IceCube signal.

This contribution will report on the sensitivity of the KM3neT telescope with particular attention to the region of the Galactic Plane. Comparison with theoretical expectations are also discussed.

Parallel Session E / 99

Present and Future of the IceCube DAQ and Online Systems

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The IceCube Detector Operations group continues to improve reliability and add new functionality to the data acquisition (DAQ) and online system as the science of IceCube expands. Following a

brief overview of the baseline design which has been running for nearly a decade and highlights of the operational performance of the implementation, this presentation will go on to describe a recent major enhancement to the DAQ, hit-spooling, its implementation, and discuss current uses of the new capabilities. Finally, plans for significant re-architecting of the low-level readout subsystem of the DAQ based on deep-buffer concept of hit-spooling will be discussed.

Parallel Session H / 22

Present theoretical uncertainties on charm hadroproduction in QCD and prompt neutrino fluxes

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Prompt lepton fluxes are basic backgrounds in the search of high-energy neutrinos of astrophysical origin, performed by means of full-size neutrino telescopes located at Earth, under ice or under water.
Predictions for these fluxes are provided on the basis of up-to-date theoretical results for charm hadroproduction in perturbative QCD, together with a comprehensive discussion of the various sources of theoretical uncertainty affecting their computation, and a quantitative estimate of each uncertainty contribution.

Parallel Session C / 66

Proposal for a Giant Radio Array for Neutrino Detection

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High-energy neutrino astronomy will probe the working of the most violent phenomena in the Universe. The GRAND (Giant Radio Array for Neutrino Detection) project consists of an array of 200 000 radio antennas deployed over a total area of 200 000 km2 in a mountainous site. The array aims at detecting high energy neutrinos (E>10^16 eV) via the measurement of air showers induced by the decay in the atmosphere of tau leptons produced by the interaction of the cosmic neutrinos under the Earth surface. Our objective with GRAND is to reach a neutrino sensitivity of 2x10^-11 GeV/cm^2/s/sr above 3x10^16 eV. This sensitivity ensures the detection of cosmogenic neutrinos even in the most pessimistic source models of ultrahigh energy cosmic rays (UHECRs), and about a 100 events per year are expected for the standard source models. GRAND would also probe the neutrino signals produced at the potential sources of UHECRs.

We show how our preliminary array layout should allow us to reach our sensitivity goals, and estimate the associated experimental characteristics for high-energy neutrino detection. We assess the possibility to adapt GRAND to other astrophysical radio measurements (the study of the Epoch of Reionization for example). In particular, such a detector would constitute the largest observatory on ground for UHECR detection. We discuss in this token the technological options for the detector and the steps to be taken to achieve the GRAND project.

Plenary Session 2 / **83**

Results from IceCube

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Data from the IceCube Neutrino Observatory has revealed the existence of a flux of high energy neutrinos of extraterrestrial origin, which is observed in a number of analyses spanning different energy ranges, fields of view, and neutrino flavors. The current data are consistent with an isotropic, equal-flavor flux described by a simple power law spectrum, but deviations from this simple model cannot yet be constrained with high precision. The existing observations in this area will be reviewed, along with recent results on dark matter searches and observations of cosmic rays.

Parallel Session D / **50**

Search for point-like neutrino sources over the Southern Sky with the ANTARES and IceCube neutrino telescopes

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A search for cosmic neutrino point-like sources using the ANTARES and IceCube neutrino telescopes over the Southern Hemisphere is presented. The ANTARES data was collected between January 2007 and December 2012, whereas the IceCube data ranges from April 2008 to May 2011. Clusters of muon neutrinos over the diffusely distributed background have been looked for by means of an unbinned maximum likelihood maximisation. This method is used to search for an excess of events over the whole Southern Hemisphere assuming an E−2 source spectrum. A search over a pre-selected list of candidate sources has also been carried out for different source assumptions: spectral indices of 2.0 and 2.5, and energy cutoffs of 1 PeV, 300 TeV and 100 TeV. No significant excess over the expected background has been found, and upper limits for the candidate sources are presented compared to the individual experiments.

Parallel Session D / **89**

Search for spacial and temporal collective effects in the ANTARES neutrino telescope data.

Authors: Alexis Coleiro[1] ; Rodrigo Gracia[2]

Co-authors: Antoine David Kouchner [3] ; Bruny Baret [4]

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No transient or steady significant signal having been found so far from individual source, we investigate potential collective effects in the spacial or temporal domains in Antares data samples.
On the one hand, we use a two point correlation analysis to look for inhomogeneities in the arrival directions of the high energy muon neutrino candidates detected by the ANTARES neutrino telescope. This approach is complementary to a point source likelihood-based search, which is mainly sensitive to one bright point like source and not to collective effects. We present the results of a search based on this two-point correlation method performed on ANTARES 2007-2012 data, providing constraints on models of a population of point sources too faint to be detected by the likelihood-based method.
On the other hand, a time dependent analysis based on the ANTARES data is carried out with the aim of detecting high energy neutrinos temporally connected with bursts in the electromagnetic spectrum of objects located close to the Galactic center.
This approach, more sensitive than a time-integrated analysis, requires neither prior on the burst timing structure nor on the electromagnetic emission. Therefore, it provides an effective way for looking for neutrino emission of astrophysical sources potentially absorbed in X-ray and gamma-rays.
The timing information of ANTARES events in the Galactic center region is also used together with the X-ray light curve of SgrA* and the time information of the IceCube High Energy Starting Events (HESE) in this region, to evaluate possible correlations in time.

Parallel Session J / **44**

Searches of time-dependent neutrino sources using five years of data of the ANTARES telescope

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ANTARES is currently the largest neutrino telescope operating in the Northern Hemisphere, aiming at the detection of high-energy neutrinos from astrophysical sources. Such observations would provide important clues about the processes at work in those sources, and possibly help solve the puzzle of very high-energy cosmic rays. By design, neutrino telescopes constantly monitor at least one complete hemisphere of the sky and are thus well set to detect neutrinos produced in transient astrophysical sources. The flux of high-energy neutrinos from transient sources is expected to be lower than the one expected from steady sources, but the background originating from interactions of charged cosmic rays in the Earth's atmosphere can be drastically reduced by requiring a directional and temporal coincidence of the astrophysical phenomenon detected by a satellite. Time-dependent point-source searches have been applied to a list of gamma-ray bursts, blazars and x-ray binaries outbursts detected by satellites such as Fermi or Swift using five years of ANTARES data (2008-2012).

Parallel Session D / **28**

THE GALACTIC DIFFUSE NEUTRINO EMISSION: A NEW COMPREHENSIVE SCENARIO

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The IceCube collaboration recently released the results of an updated measurement of the astrophysical neutrino flux based on four years of observation. The origin of this emission is still unknown due to the large uncertainties related to the poor angular resolution of shower-like events. While the present results are consistent with a isotropic flux a recent maximum-likelihood analysis of combined IceCube neutrino samples reported a larger and softer spectrum for the neutrinos coming from the South hemisphere with respect to those coming from the North hemisphere. This result suggests the presence of a significant component of diffuse galactic neutrinos in the reported samples of events. The galaxy is known to be a guaranteed source of a diffuse neutrino emission due to the interaction of the hadron component of the galactic cosmic-ray with the interstellar gas. Although conventional models predict a very low flux, here we present a new comprehensive scenario of Galactic cosmic-ray transport with a radially-dependent diffusion coefficient predicting a significantly larger emission. This model has been already proposed to solve several long standing anomalies of Galactic gamma-ray astronomy as those found by Fermi-LAT above 10 GeV and by Milagro and HESS above the TeV. We show as the predictions of our phenomenological model differs from those of the standard scenario with a uniform diffusion coefficient. Moreover, considering different portions of the Galactic plane, we show what are the current constraints on Galactic neutrino modeling from IceCube and ANTARES observations and how the construction of the new KM3NeT/ARCA observatory can be crucial to disentangle the scenarios recently proposed.

Parallel Session C / 79

The ARIANNA Hexagonal Radio Array performance and prospects

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Detection of neutrinos in the EeV range by observation of radio pulses from the Askaryan effect is proposed by several collaborations. The ARIANNA collaboration is one of them. ARIANNA investigates the possibility to use the unique conditions of the Ross Ice-shelf. The site is isolated with very low levels of anthropogenic radio noise. Reflection of radio signals on the mirror-like ice-sea interface increases the efficiency and angular range covered. The antennas can be installed just below the snow surface and are not limited by e.g. a requirement from a narrow hole. Surface installation makes fast and simple installation possible. The ARIANNA design comprizes a large array of 1236 independent detection stations installed in an area of 36 km* 36 km. The design and the large number of stations provides for a comparatively low threshold.
To develop and verify the design the smaller Hexagonal Radio Array (HRA) has been built. The last stations were deployed in the 2015-2016 Antarctic summer season. The operational experience and first results will be described as well as the future perspective.

Parallel Session C / 98

The Askaryan Radio Array: Status and new results.

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The observation of cosmic neutrinos can offer insights into the sources of
highest energy cosmic rays and energetic process that are involved to generate them.

IceCube has reported neutrinos with energies beyond 10^{15} eV.
Much larger detection volumes are needed to fully explore the energy region
beyond 10 or 100 PeV.
The Askaryan Radio Array (ARA) is designed to use the Askaryan effect, the emission of radio waves from neutrino-induced cascades in the South Pole ice, to detect neutrino interactions at very high energies.
Currently 3 ARA stations are deployed in the ice of which two have been taking data since the beginning of the year 2013. In this talk I will describe calibration strategies and data reduction to distinguish the rare radio signals from backgrounds.
Using data from only two stations over a short exposure time of 10 months, a neutrino flux limit of $3{\cdot}10^{-6}$GeV/(cm2 s sr) is obtained at an energy of 10^{18}eV, which offers promise for the full ARA detector.

Parallel Session F / 92

The Calibration Units of the KM3NeT Neutrino Telescope

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KM3NeT is a network of deep-sea neutrino telescopes to be deployed in the Mediterranean Sea, that will perform neutrino astronomy and oscillation studies. It consists of three-dimensional arrays of thousands of optical modules that detect the Cherenkov light induced by charged particles resulting from the interaction of a neutrino with the surrounding medium.

The performance of the neutrino telescope relies on the precise timing and positioning calibration of the detector elements. The exact location of optical modules (which is affected by sea currents) can be monitored through an acoustic positioning system, while external light sources are used to achieve the required sub-nanosecond time resolution and to measure water optical properties. Other environmental conditions which
may affect light and sound transmission, such as water temperature and salinity, must also be continuously monitored.

For these purposes, KM3NeT foresees the deployment of several dedicated Calibration Units (CUs), whose base will host the detector calibration devices (Laser beacon, acoustic emitter and hydrophone). A few of these CUs will additionally be equipped with an Instrumentation Unit with a semi-autonomous and recoverable inductive line supporting the
environmental monitoring instruments. This contribution describes the technical design and construction of the first Calibration Unit, to be deployed on the French site as part of KM3NeT Phase 1, as well as the purpose and characteristics of the different instruments that it will support.

Parallel Session E / 56

The Control Unit of KM3NeT Data Acquisition

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KM3NeT is a future research infrastructure hosting a new generation neutrino telescope located at the bottom of the deep seas of the Mediterranean. With the KM3NeT telescope, scientists will search

for cosmic neutrinos to study highly energetic objects in the Universe. A new initiative is to extend the research facility with a neutrino detector dedicated to measure the properties of the high-energy neutrino particles themselves. Control of the KM3NeT data acquisition processes is handled by the KM3NeT Control Unit, which has been designed maximising the detector live time, with specified data-taking campaigns. The Control Unit features software programs with different roles, following the philosophy of having no single point of failure. While all programs are interconnected, each one is also able to work alone for most of the time in case other services are unavailable. By means of the Local Authentication Provider, all services can share login and user interface session information, thus providing a single but modular infrastructure. A Master Control Program coordinates all actions in the Control Unit. All services run on the Common Language Runtime which ensures portability, flexibility and automatic memory management. Each service has an embedded Web server, providing a user interface as well as programmatic access to data and functions. Data to and from detector components for monitoring and management purposes are transmitted using a custom designed protocol. The Control Unit is interfaced to one or more Message Dispatchers to control the data acquisition chain and to route data streams to the Data Base. We will report on the details of the design and implementation of the KM3NeT data acquisition Control Unit.

Parallel session A / 65

The KM3NeT Digital Optical Module

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KM3NeT is a European deep-sea multidisciplinary research infrastructure in the Mediterranean Sea. It will host a km3-scale neutrino telescope and dedicated instruments for long-term and continuous measurements for Earth and Sea sciences.
The KM3NeT neutrino telescope is a 3-dimensional array of Digital Optical Modules, suspended in the sea by means of vertical string structures, called Detection Units, supported by two pre-stretched Dyneema ropes, anchored to the seabed and kept taut with a system of buoys.
The Digital Optical Module represents the active part of the neutrino telescope. It is composed by a 17-inch, 14 mm thick borosilicate glass (Vitrovex) spheric vessel housing 31 photomultiplier tubes with 3-inch photocathode diameter and the associated front-end and readout electronics.
The technical solution adopted for the KM3NeT optical modules is characterized by an innovative design, considering that existing neutrino telescopes, like Baikal, IceCube and ANTARES, all use large photomultipliers, typically with a diameter of 8" or 10". It offers several advantages: higher sensitive surface (1260 cm^2), weaker sensitivity to Earth's magnetic fields, better distinction between single-photon and multi-photon events (photon counting) and directional information with an almost isotropic field of view.
In this contribution the design and the performances of the KM3NeT Digital Optical Modules are discussed, with a particular focus on enabling technologies and integration procedure.

Parallel Session E / 80

The KM3NeT-IT Tower data acquisition and data transport electronics

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The KM3NeT European project has entered the production stage of a large volume neutrino telescope that will be deployed at about 100 km off the Sicily coast. The forthcoming installation includes 24 strings, equipped with multi-PMT optical modules, and 8 towers. The KM3NeT tower design is based on the NEMO Phase-2 prototype tower, deployed in March 2013. In order to optimize production costs, power consumption, usability and to simplify calibration procedures, the whole electronics chain has been re-engineered and partially redesigned by taking advantage of the previously gained experience and technological progress. The aim of this contribution is to give a description of electronics, including front-end, data transport and clock distribution systems, and data acquisition, of the KM3NeT towers.

Parallel Session F / 47

The LED Beacons prototype system the for time calibration of the KM3NeT-IT Towers

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The first implementation of the KM3NeT-IT neutrino telescope foresees the installation of 24 Strings, equipped with multi-PMTs Digital Optical Modules, and 8 Towers. The Tower's optical module (OM) is composed by a 10'' photomultiplier tube (PMT) enclosed in a 13'' pressure resistant glass sphere that contains also the electronics boards for power supply and data acquisition; some OMs host a LED source, emitting at a wavelength of 470 nm. 6 optical modules are arranged in a 8m long "floor"; 14 floors make up a "tower", a three-dimensional flexible structure, with a total height of about 400 meters. Given the large dimension of the detection units, the time calibration of the structure is a critical issue for the experiment. The idea behind this work is to exploit the LED sources mounted in the OMs to develop a complementary system for the determination, on shore and before the Tower deployment, of time delays, aiming at the characterizations of the time response of the different elements of the detector. During the assembling of the first tower, a set of measurements has been carried out using a Hamamatsu multi-pixel photon counter as light sensor and an Agilent TDC for computing time differences. The test set-up and the measurement procedure are described, together with preliminary results of the calibration system. Lesson learnt is quite encouraging: uncertainties of the order of hundreds of ps are reached with very few cautions taken during the short calibration session, with large room for improvement available, making this system feasible and effective for the KM3NeT-IT experiment.

Parallel Session I / 85

The MEUST deep sea infrastructure in the Toulon site

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The MEUST (Mediterranean Eurocentre for Underwater Sciences and Technologies) is a permanent deep sea cabled infrastructure currently being deployed off shore of Toulon, France. MEUST is shared between the neutrino physics and astro-physics communities in the context of the European KM3NeT project, and the Environmental Science communities as the West-Ligurian site of the EMSO European network of submarine observatories. The MEUST submarine network has a modular and

extendable topology which will allow hosting up to 120 neutrino detection units and to instrument a seafloor area with sea science sensors.
The MEUST terrestrial base is located in La Seyne sur Mer near Toulon, where a new building is planned to host the technical activities, including a control room of the infrastructure. The MEUST submarine site has been selected after intensive characterization campaigns conducted in the past years leading to the choice of the site located ~40km offshore of Toulon at a depth of 2500m and 15km west of the Antares site. The full MEUST submarine network has up to 6 nodes connected to the shore by two Main Electro Optical Cables (MEOC). The MEOCs are standard telecommunication cables with optical fibres for data transfer and one electrical conductor for power transfer. The nodes are equipped each with 8 wet mate-able connectors allowing to connect at least 20 neutrino detection units (daisy chained by 4) and a set of environmental instruments, with some redundancy. The power transfer is performed in HV AC with sea return, as for Antares, and provides a usable power of ~10kW on each node (~1kW/connector). A dedicated control/command system controls the power and optical systems. The data transfer uses Dense Wavelength Division Multiplexing (DWDM). The proposed talk will focus on the design and the status of the infrastructure with the first lessons learnt from the ongoing deployments.

Parallel Session G / 55

The Relational Database System of KM3NeT

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KM3NeT is a new generation neutrino telescope in the Mediterranean Sea. For the operation of the telescope a relational database is designed and implemented for several purposes, like the centralised management of accounts, the storage of all documentation on components and on the status of the detector, of the slow control and calibration data. It also contains information useful during the construction and the data acquisition phases. It means that the database is not conceived as a simple container but it plays an active role during the whole life of the experiment. Highlights in the database schema and management are discussed along with design choices that have impact on performances. In most cases, the database is not accessed directly by applications, but they go via a custom designed Web application server. It provides connection pooling and can be used to cache responses to frequently accessed information. It also allows serving and receiving data in several formats. For large data streams, binary encoding and columnar storage are used to boost performance in data access. Other issues like database connection reliability over wide area networks and fault tolerance will be discussed.

Parallel Session B / 82

The Run-by-Run Monte Carlo simulation for the ANTARES experiment

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The data acquisition conditions in a marine environment are not stable and constant in time. Some biological and physical phenomena follow a seasonal evolution producing a periodical change of the rates registered in a neutrino telescope. Also variations in the sea current velocity affects the measured baseline value and the burst fraction on short time scales.

Monte Carlo simulations of the detector response to the passage of charged particles in proximity of the telescope should reproduce the conditions of the medium and of the acquisition setup as reliably as possible. An efficient way to account for the variations of the optical background to the Cherenkov light due to physics signals is to extract related information directly from the data runs. A Run-by-Run procedure has been developed to follow the time evolution of data acquisition. A description of the methodology will be given in the talk, together with some examples of the agreement between data and Monte Carlo expectations.

Parallel Session E / 58

The Trigger and Data Acquisition System for the KM3NeT neutrino telescope

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KM3NeT is a large research infrastructure in the Mediterranean Sea that includes a network of deep-sea neutrino telescopes. The telescopes consist of vertical detection units carrying optical modules, whose separation is optimised according to the different ranges of neutrino energy that shall be explored. Two building blocks, each one made of 115 detection units, will be deployed at the KM3NeT-IT site, about 100 km from Capo Passero, Italy, to search for high-energy neutrino sources (ARCA); another building block will be installed at the KM3NeT-Fr site, about 40 km from Toulon, France, to study the hierarchy of neutrino masses (ORCA). The modular design of the KM3NeT allows for a progressive implementation and data taking even with an incomplete detector. The same scalable design is used for the Trigger and Data Acquisition Systems (TriDAS). In order to reduce the complexity of the hardware inside the optical modules, the "all data to shore" concept is adopted. This means that the throughput is dominated by the optical background due to the decay of $^{40}\mathbf{K}$ dissolved in the sea water and to the bursts of bioluminescence, about 3 orders of magnitude larger than the physics signal, ranging from ~20 Gbps to several hundreds Gbps, according to the number of detection units. In addition, information from the acoustic positioning system of the detection units must be transmitted. As a consequence of the detector construction, the on-shore DAQ infrastructure must be expanded to handle an increasing data-rate and implement an efficient fast data filtering for both the optical and acoustic channels. In this contribution, the Trigger and Data Acquisition System designed for the Phase 1 of KM3NeT and its future expansion are presented. The network infrastructure, the shore computing resources and the developed applications for handling, filtering and monitoring the optical and acoustic data-streams are described.

Parallel Session E / 76

The Trigger and Data Acquisition System for the KM3NeT-Italia towers

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KM3NeT-Italia is an INFN project supported with Italian PON fundings for building the core of the Italian node of the KM3NeT neutrino telescope.
The detector, made of 700 10" optical modules (OMs) lodged along 8 vertical structures called {\em towers}, will be deployed starting from fall 2015 at the KM3NeT-It site, about 100 km off Capo Passero, Italy, 3500 m deep.
The {\em all data to shore} approach is used to reduce the complexity of the submarine detector, demanding for an on-line trigger integrated in the data acquisition system running in the shore station, called {\em TriDAS}.
Due to the large optical background in the sea from ^{40}K decays and bioluminescence, the throughput from the underwater detector can range up to 30 Gbps. This puts strong constraints on the design and performances of the TriDAS and of the related network infrastructure.
In this contribution the technology behind the implementation of the TriDAS infrastructure is reviewed, focusing on the relationship between the various components and their performances. The modular design of the TriDAS, which allows for its scalability up to a larger detector than the 8-tower configuration is also discussed.

Parallel session A / 61

The VSIPMT project

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The VSiPMT (Vacuum Silicon PhotoMultiplier Tube) is an innovative design for a revolutionary hybrid photodetector.
The idea, born with the purpose to use a SiPM for large detection volumes, consists in replacing the classical dynode chain with a SiPM.
In this configuration, we match the large sensitive area of a photocathode with the performances of the SiPM technology,
which therefore acts like an electron detector and so like a current amplifier.
The excellent photon counting capability, fast response, low power consumption and great stability are among the most attractive features of the
VSiPMT. We now present the results of a full characterization of the VSiPMT industrial prototypes with their pro and contra and the preliminary tests we are
performing to improve the VSiPMT features and the progress in the realization of a 2-inches and 3-inches VSiPMT prototype

Parallel session A / 48

The effects of Earth's magnetic field on 3-inch diameter photomultipliers used in KM3NeT neutrino telescope.

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Photomultipliers are widely used in astroparticle physics detectors to measure Cherenkov light in media like water or ice.
KM3NeT neutrino telescope will be the largest underwater neutrino telescope and will be located in the abyss of the Mediterranean Sea.
The detection principle is based on the measurement of the Cherenkov light induced by relativistic charged particles emerging from an interaction of a neutrino
inthe vicinity of the detector.
In neutrino telescopes the key element of the detector is the optical module and for KM3NeT it consists of 31 PMTs stored inside a transparent pressure-resistant glass sphere of 17-inch that serves as mechanical protection while ensuring good light transmission.
The signal from each PMT is digitized and the whole digital optical module (DOM) has a vision of about 4π. DOMs are in assembly phase in Netherland, Italy and Germany laboratories.
Since the PMTs installed into an underwater neutrino telescope can change their orientation because of movements of the detector structure due to sea currents, the influence of Earth's magnetic field has been investigated.
The magnetic field can affect the performances of PMTs through to the deflections in the trajectories of the photoelectrons drifting from photocathode to first dynode.
Depending on the orientation of the PMT relative to the Earth's magnetic field, trajectories of secondary electrons in the dynode chains can also be affected.
Influences of magnetic field on the trajectories of photoelectrons drifting towards first dynode affect timing properties and even the energy of photoelectron shitting the first dynode with influences on gain.
Magnetic shielding by means of mu-metal cage is used to reduce magnetic effects and to make the response of the PMT sufficiently orientation independent.
In order to quantify the effect on magnetic filed, we compared measurements on variation of gain, transit time spread and detection efficiency for 3-inch PMTs in shielded and unshielded condition at several PMT inclinations.
Data shows that variations are sufficiently low especially for timing proprieties so DOM can be assembled without a magnetic shielding.

Parallel session A / 29

The optical module of the Baikal-GVD

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The Baikal-GVD neutrino telescope in Lake Baikal is intended for studying astrophysical neutrino fluxes by recording the Cherenkov radiation of the secondary muons and showers generated in neutrino interactions. The first stage of Baikal-GVD will be equipped with about 2300 optical modules. Each of these optical modules consists of a large area photomultiplier R7081-100 made by Hamamatsu Photonics and its associated electronics housed in a pressure resistant glass sphere. We describe the design of the optical module, the front-end electronics and the laboratory characterization and calibration before deployment.

Parallel Session J / **77**

The search for TeV gamma-rays associated with IceCube's high-energy neutrinos using VERITAS

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The origins of the flux of high-energy astrophysical neutrinos observed by the IceCube Neutrino Observatory continue to elude us. These neutrinos most likely originate in hadronic interactions taking place in or near the sources of cosmic-ray acceleration, causing associated gamma-ray production. We use the VERITAS Imaging Air Cherenkov Telescope to search for these gamma rays from the directions of IceCube neutrinos. VERITAS, with its 3.5 degree diameter field of view, is well-suited for followup observations of the muon neutrino events, which have typical reconstruction uncertainty of less than 1 degree. We will report on these observations and discuss the progress in implementing prompt followup of these exciting events.

Parallel Session F / **31**

Time and amplitude calibration of the Baikal-GVD neutrino telescope

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The first stage of the Baikal-GVD neutrino telescope will be composed of more than two thousand light sensors, Optical Modules (OMs), installed deep underwater in Lake Baikal. We describe developed calibration methods which use OM LEDs, atmospheric muons and discuss the performance of these methods.

Parallel Session G / **21**

Using IKAROS as a data transfer and management utility within the KM3NeT computing model

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International collaborative scientific experiments are generating datasets which are increasing exponentially in both complexity and volume, making their analysis, archival, and sharing one of the grand challenges of the 21st century. These experiments, in their majority, adopt computing models

consisting of different Tiers (each Tier is made up of several computing centres and provides a specific set of services) and for the different steps of data processing (simulation, filtering, calibration, reconstruction and analysis) several software packages are utilized. The computing requirements are extremely demanding and, usually, span from serial to multi-parallel or GPU-optimized jobs. The collaborative nature of these experiments demands very frequent WAN data transfers and data sharing among individuals and groups. Typically, such a computing model utilizes several different computing infrastructures like: Grids, Clouds, HPCs, Data Centers and Local computing Clusters.

IKAROS is a framework that enables us to create scalable storage formations on-demand and helps us address several limitations which the current file systems face when dealing with very large scale infrastructures. It enables us to create ad-hoc nearby storage formations and can use a huge number of I/O nodes in order to increase the available bandwidth (I/O and network). IKAROS unifies remote and local access in the overall data flow, by permitting direct access to each I/O node. In this way we can handle the overall data flow at the network layer, limiting in this way the interaction with the operating system. This approach enables us to virtually connect, at the users level, the several different computing facilities used (Grids, Clouds, HPCs, Data Centers, Local computing Clusters and personal storage devices), on-demand, based on the needs, by using well known standards and protocols, like HTTP.

Parallel Session B / 69

Using the JPP software package in KM3NeT reconstruction algorithms

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KM3NeT is a future research infrastructure with a neutrino telescope in the abyss of the Mediterranean Sea. In KM3NeT, the open source JPP software package is primarily used in the data acquisition, offline triggering and calibration of the data send to shore. The available extensive set of JPP methods has been succesfully used for the development of fast, robust and detailed reconstruction algorithms for KM3NeT. We will demonstrate this with the results of a hit clustering algorithm and the multidimensional interpolation of photon probability density functions for two event reconstruction methods: one aiming at fast muon reconstruction, the other at high-energy shower reconstruction. The resulting reconstruction resolution will be presented.

Plenary session 6 / 19

Workshop closure

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Parallel Session H / 54

gSeaGen: a GENIE-based code for neutrino telescope

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The gSeaGen code simulates neutrino-induced events detectable by an underwater neutrino detector. The code is an application based on GENIE (Generates Events for Neutrino Interaction Experiments), a set of libraries developed with the purpose to have a "canonical" Monte Carlo for neutrino interaction physics. The gSeaGen code is able to generate events induced by all neutrino flavours, taking into account topological differences between track-type and shower-like events. The neutrino interaction is simulated taking into account the density and the composition of the media surrounding the detector. The main features of gSeaGen will be presented together with some examples of its application within ANTARES and KM3NeT.