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KM3NeT highlights

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Abstract

The KM3NeT Collaboration aims at the discovery and subsequent observation of high-energy neutrino sources in the Universe and at the determination of the neutrino mass hierarchy. The KM3NeT technologies, current status and expected performances are reported. The ARCA detector is described and its perspectives for detection of high energy neutrinos signals from different candidate sources are discussed. The ORCA detector and its expected significance for the mass hierarchy determination by means of the measurement of passing through Earth atmospheric neutrinos are also presented.

Keywords: neutrino telescope, high energy astronomy and mass hierarchy

1. Introduction

High energy neutrinos are expected to shed light on the violent Universe providing information on astrophysical distant objects in which hadronic interactions take places [1, 2]. Their detection in association with specific sources will clarify the still unknown origin of cosmic rays. In this framework several projects were developed in the last decades. The recent discovery of a cosmic neutrino flux reported by the IceCube collaboration [3, 4] initiated de facto the era of neutrino astronomy. However, most of the questions raised about the origin of the observed neutrino cosmic flux remain unsolved. Many hypotheses on the sources of these cosmic neutrinos have been proposed including galactic (SNR, PWN, Galactic halo, Galactic center, Fermi Bubbles, ...) and extragalactic sources (AGN, GRB, Starburst galaxies, diffuse flux), but also Dark Matter and other exotic explanations [5]. As a consequence of this discovery the physics case for the construction of a km^3-scale neutrino telescope in the Northern Hemisphere is strongly enforced. Indeed, a telescope installed in the depths of the Mediterranean Sea has a field of view of about 87% of the Galactic Plane including the Galactic Centre (marginally accessible from IceCube) thus allowing a full coverage of the sky. Moreover, the much better angular resolution achievable in deep sea water w.r.t. ice, i.e. about an order of magnitude both for tracks and cascade events, has a strong impact on the potential discovery of a neutrino telescope and eventually increases the chance of identification of point-like sources. A telescope in the Mediterranean Sea, due to its favorable latitude and the Earth rotation, has a field of view of about 87% of the Galactic Plane. Recently, the physics case of KM3NeT has been extended to the determination of the Neutrino Mass Hierarchy (NMH) via the measurement of atmospheric neutrinos in a Mton scale deep sea Cherenkov detector at GeV energy. In this frame a feasibility study aiming at the NMH measurement, the so-called ORCA experiment, using the same technology of KM3NeT but a different, much denser, displacement of the optical sensor is underway. Indeed, after the measurement of θ_{13} the disentangling between so-called normal and inverse neutrino mass ordering is become one of the hottest topic in neutrino physics.

This enlargement of KM3NeT physics case lead to a common multi-site infrastructure, namely the Capo Passero site (Italy), KM3NeT-It, dedicated to the high energy neutrino astronomy, ARCA, and the Toulon site (France), KM3NeT-Fr, dedicated to the NMH, ORCA. The KM3NeT Letter on Intent recently published [6]

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includes the proposal of a Gton scale telescope for high energy astronomy and a Mton detector for a NMH measurement.

2. Detector technology

The goal of the KM3NeT technology is to instrument, at minimal cost and maximal reliability, the largest possible volume of sea water with a three dimensional grid of light sensors. Due to the complexity of the technological challenges related to construction, installation and operation of a detector in the depths of the sea (2500m - 3500 m), the path towards a km^3 underwater neutrino telescope proceeds stage by stage.

The basic element of the detector is the optical sensor, so-called Digital Optical Module (DOM) made of 31 3-inch PMTs hosted with their read-out electronics within a 17-inch pressure-resistant glass spheres.

Figure 1: *The KM3NeT Digital Optical Module*

This design offers several advantages compared to previous designs based on a single large area PMT: larger photo-cathode area per optical module, digital photon counting, directional information, wider field of view and reduced aging effects. The optical module also incorporates an acoustic sensor and a compass used for position and orientation calibration. A photo of an optical module is shown in fig.2.

Each tube is surrounded by a reflector that effectively increases the collection efficiency per PMT by about 27%. The lower hemisphere of each DOM contains 19 PMTs, downward-looking, whereas the other 12 PMTs in the upper hemisphere are up-looking. The optical contact between the PMTs and the glass sphere is assured by an optical gel. The front-end electronics amplify the PMT signals and transform them into digital time-over-threshold information that is fed into the readout via optical fibres. All PMT signals above an adjustable threshold (typically the equivalent of 0.3 photo-electrons) are sent to shore, where event candidates are selected by online filters running on a computer farm. The DOM contains three calibration sensors: a LED nano-beacon for time calibration, a compass and tilt-meter for orientation calibration and an acoustic piezo sensor, glued to the inner surface, for position calibration. The DOMs are hosted in flexible strings, 18 DOMs for each string. One end of the string is anchored to the sea floor and the other end is kept close to vertical by the pull of a buoy. The DU is a slender structure consisting of two parallel Dyneema© ropes to which the DOMs are attached via a titanium collar. Attached to the ropes is the vertical electro-optical cable, a pressure balanced, oil-filled, plastic tube that contains two copper wires and 18 optical fibres for the power and data transmission. At each DOM two power conductors and a single fibre are branched out via the breakout box Fig. 2 left. For the deployment, a detection unit is wound around a spherical frame with diameter of about 2.2 m (Launcher of Optical Modules, LOM), which is posed on the seabed. The DU then unfurls with a rotating upwards movement. At the end of operation the LOM reaches the sea surface, where it is collected for reuse. A picture of the LOM ready for the deployment is shown in Fig. 2.

A collection of strings forms a KM3NeT building block. A building block comprises a total of about 115 strings. Although the technology is the same the spacing between DOMs and DUs is defined according to the physics goals to be addresses, i.e. the energy region of interest of ARCA and ORCA respectively.

A sea floor network assure power distribution and communication. The strings are connected to junction boxes via interlink cables running along the seabed. A main electro-optical cable provides the connection between the deep sea infrastructure and the shore station. The readout of the detector is based on the all-data-to-shore concept while a trigger system is implemented on shore. On site, the shore station is equipped to provide power, computing and a high-bandwidth internet connection to the central data repository. Since the concept of strings is modular by design, the construction and operation of the research infrastructure allow for a phased implementation.

The key technologies of the telescope have been val-