Status report on NEMO

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Abstract. The latest results of the R&D activities for the realisation of a km$^3$ Cherenkov neutrino detector, carried out by the NEMO collaboration, are described. A long-term survey of a 3500 m deep site close to the coast of Sicily has shown that it is optimal for the installation of the detector. A complete feasibility study, that considers all the components of the detector as well as its deployment, has been carried out demonstrating that technological solutions exist for the realization of an underwater km$^3$ detector. The realization of a technological demonstrator of the apparatus (the NEMO Phase 1 project) is under way.

High energy neutrinos may easily escape even from thick astrophysical sources, they are hardly absorbed during their propagation through the Universe and are not deflected by cosmic magnetic fields. They are therefore the ideal candidate particle to point back at the sources of high-energy cosmic rays and give information on the acceleration processes that occur in galactic and extragalactic sources. The recent observation of a number of TeV gamma sources in the galactic environments [1] strengthens the hypothesis that the observation of neutrino fluxes may not be far away. However, the expected neutrino fluxes demand for the construction of km$^3$-scale detectors. The only viable solution nowadays is to build a large array of light sensors in a natural transparent medium, such as water or ice. So far, small scale detectors have been implemented or are under construction [2-5], demonstrating that the technique of the Cherenkov detection of neutrino induced muons in deep waters or ice can be applied.

Since 1998 the NEMO collaboration has undertaken a R&D program for the construction of an underwater km$^3$ telescope for high energy neutrino astronomy. In fact, the Mediterranean Sea seems to be an ideal location for detector installation. From such latitudes the observation of the southern part of the sky, that includes the galactic center which is not accessible to IceCube [6], is possible.

The NEMO collaboration research program focuses on the selection and characterization of a deep see site in the Mediterranean, the accomplishment of a technological survey to investigate the project feasibility and the realization of prototypes to validate the technological solutions.

A careful selection of the site is the first step towards the installation of a km$^3$ neutrino telescope. Many sea campaigns, aiming at measuring and monitoring for long time the water properties such as the light transmission properties, the optical background noise, the sedimentation and the biological activity, the water current and the environmental properties (salinity, temperature) have been performed in many sites close to the Italian coasts. A site at about 80 km off the SE coast of Sicily, in the Ionian Sea at a depth of 3500 m near the southernmost cape of Sicily (Capo Passero) has been selected as suitable to host a km$^3$ telescope. The results of these sea campaigns are described in [7]. The design of a large underwater neutrino telescope should be a compromise between detector performance, technical feasibility and construction and maintenance costs. The possibility of reconfiguration, which is one of the advantages of an underwater detector, has also to be considered.
Taking into account these specifications a study of the technical feasibility has been carried out in close contact with leading companies in the field of deep sea operations. As a result, a general layout of the apparatus was defined, which consists of a square array of structures called “towers”, connected each other by means of a network of submarine cables and junction boxes. The connection to the shore for power feeding and data transmission is assured by a single electro-optical cable.

In order to investigate the detector performance, extensive computer simulations were performed. Simulations are based on the ANTARES simulation package [8], modified for a km$^3$ detector. In figure 1 the detector sensitivity to E$^{-2}$ muon neutrino flux from a point like source with declination $\delta = -60^\circ$ is reported as a function of the years of data taking. The sensitivity is calculated, as described in ref [9], for a detector made of 81 towers 140 m spaced arranged in a square array. Each tower is equipped, as described in the following, with 72 10” diameter PMTs. The environmental parameters of the Capo Passero site with an absorption length of about 70 m at $\lambda = 440$ nm and 30kHz of optical background rate have been considered. The NEMO sensitivity, reported in figure 1, is obtained for a search bin of 0.3 degree. For comparison the sensitivity for the IceCube detector [6], obtained for a search bin of 1 degree, is also shown.

The validation of all the technical solutions proposed and a prototyping activity is the program of the NEMO Phase 1 and Phase 2 projects.

The NEMO Phase 1 is under realization at the underwater test site of the Laboratori Nazionali del Sud (LNS) of INFN. This site is located at 2000 m depth at a distance of about 25 km offshore Catania. When it will be completed the NEMO Phase 1 apparatus will host one instrumented tower connected by an underwater cable to a junction box, in order to reproduce the two typical main components foreseen for the full km$^3$ apparatus.

An innovative design has been used for the junction box: pressure-resistant steel vessels containing the electronics are inserted inside a corrosion-resistant fiberglass container filled with mineral oil. This solution decouples the two problems of pressure and corrosion resistance and will allow to build components which are well suited to work in the severe conditions of high-depth salt water, but with a significant cost decrease if compared to more standard titanium containers.

The tower consists of a flexible three-dimensional semi-rigid structure composed by a sequence of bars, which host the optical modules and the instrumentation, interlinked by a system of ropes and anchored on the seabed. The structure is kept vertical by an appropriate buoyancy on the top. In the layout proposed for the km$^3$, each tower will consists of a sequence of 15 m long bars spaced vertically by 40 m, with the lowermost one placed at about 150 m above the sea bottom. For the first prototype tower of NEMO Phase 1 the number of bars will be limited to 4. Each bar will host two optical modules at each end, one down looking and one horizontally looking. Such modules consist of pressure-resistant glass spheres containing a large (10”) hemispheric photomultiplier and its front-end electronics. In its working position, each storey will be arranged perpendicularly with respect to the adjacent ones. Simulations of the unfurling of a 16 storey tower as well as its static behavior under realistic sea current conditions, indicate that the whole tower is a rather stable structure which can assure a safe operational condition of a NEMO tower based km$^3$ detector.

The data communication system exploits a standard, synchronous telecommunication protocol (SDH). A Dense Wavelength Division Multiplexing (DWDM) system has been designed to allow high-bandwidth point-to-point bidirectional communication between the shore and each single storey.
of the towers, with a reasonable number of optical fibers. This system has been successfully tested in July 2005 and certified, after a transmission over 100 km cable length, by ISCTI (Istituto Superiore delle Comunicazioni e delle Tecnologie dell’Informazione).

The towers will also feature: a redundant positioning system, which includes compasses, inclinometers and acoustic triangulation devices; a timing calibration system, which can illuminate the optical modules with calibration pulses delivered on a dedicated network of optical fibers; several environmental sensors.

A sea campaign was conducted on January 2005 to install, on the deep sea ends of the 28 km electro-optical cable, two titanium termination frames with electro optical connectors. The installed connectors permit to plug and unplug underwater instrumentation by means of a Remotely Operated Vehicle (ROV). During the sea operation two experimental devices were installed. A prototype station equipped with four hydrophones for acoustic background measurements in deep underwater environment [10] and the SN1 seismic monitoring station of the INGV (Istituto Nazionale di Geofisica e Vulcanologia) [11]. The two stations are fully operational and they are in data taking continuously since then. This operation has allowed to validate the technique of underwater connection by means of a ROV. Figure 2 is a snapshot of one of the connection operations performed, showing the ROV arm (top left in the figure) while plugging the underwater connector. The completion of the NEMO Phase 1 is foreseen in may 2006 with the deployment and connection of the junction box and the four storey tower.

In order to validate the studied technologies at the depth of 3500 m and perform a long term site survey in Capo Passero, the NEMO Phase 2 has been already started. A 100 km electro-optical cable will be laid in 2006 to connect the deep sea infrastructures at 3500 m depth to a shore station. A complete 16 storey NEMO tower will be deployed and connected in 2007.

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