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Status of the NEMO project

Paolo Piattelli[a] for the NEMO collaboration
[a]Laboratori Nazionali del Sud, INFN - Via S. Sofia 44, 95123, Catania, ITALY

Activities leading to the realization of a km^3 Cherenkov neutrino detector, carried out by the NEMO collaboration, are described. Long term exploration of a 3500 m deep site in the Mediterranean close to the Sicilian coast has shown that it is optimal for the installation of the detector. A complete feasibility study, which has considered all the components of the detector, as well as its deployment, has been carried out demonstrating that technological solutions exist for the realization of the km^3 detector. The realization of a technological demonstrator (the NEMO Phase 1 project) is under way.

1. INTRODUCTION

The realisation of a km^3 scale detector for astrophysical neutrinos is today considered one of the most important aims of the next decade. Up to now, only smaller scale detectors have been realized or are under way [1–4], demonstrating the feasibility of the technique of Cherenkov detection of the secondary muons in deep waters or ice. However, the realisation of a km^3 scale detector needs further improvement of the technologies by means of appropriate R&D studies.

The Mediterranean Sea offers optimal conditions to locate the telescope and, moreover, it has full complementarity in terms of sky coverage with the ICECUBE detector [5] that is under construction at the South Pole.

The NEMO collaboration was formed in 1998 with the aim of carrying out the necessary R&D for the km^3 neutrino detector [6]. The activity has been mainly focused on the search and characterization of an optimal site for the installation and on the development of a feasibility study of the detector. More recently, the realization of a small-scale technological demonstrator (the NEMO Phase 1 project) has been started.

2. SITE SELECTION AND CHARACTERIZATION

The installation of the km^3 detector needs a complete knowledge of the site's physical and oceanographical characteristics over a long time period. Therefore, the NEMO collaboration has performed, since 1998, a long-term research program to select and characterise an optimal deep-sea site. This activity has demonstrated that the abyssal plateau in the Ionian Sea close to the southernmost cape of the coast of Sicily (Capo Passero) shows excellent characteristics to host the km^3 underwater neutrino detector.

The Capo Passero site is located in a wide abyssal plateau at about 50 km from the Sicilian-Maltese shelf break. A geological survey of the area verified the flatness and the absence of any evidence of recent turbidity events (which occur when sediments of the continental shelf slide down the continental slope and can be of potential danger to the detector). The nature and structure of the seabed was studied in detail, in order to design the mooring structures of the neutrino detector.

Water transparency has been measured *in situ* using a set-up based on a transmissometer (that allows the measure of light absorption and attenuation in nine different wavelengths, 412 to 715 nm) [7]. A series of campaigns to study the seasonal and long-term behaviour of oceanographic and optical properties has been carried out. In Figure 1 we show the absorption and attenuation lengths in the blue region (440 nm) measured at the depths of interest for the telescope (more than 2500 m) in different campaigns. The measured values of the absorption length are about 70 m, close to the one of optically pure water. Seasonal variations are negligible and compatible with the

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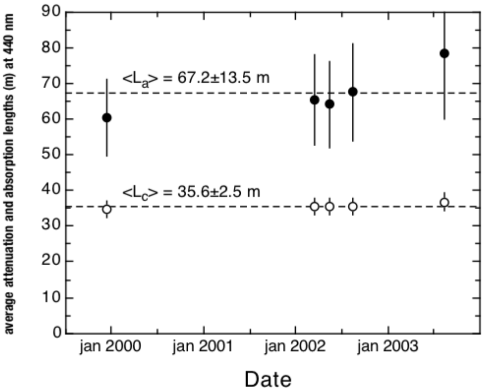

Figure 1. Values of the absorption and attenuation lengths at 440 nm measured during five different campaigns. The reported values are the average in the depth region 2850-3250 m. Dashed lines are the average over the five campaigns.

instrument experimental error.

Another characteristic of the deep-sea water that can have severe impact on the detector performances is the optical background. This background comes from two natural causes: the decay of ^{40}K, which is present in seawater, and the so-called *bioluminescence*, that is, the light produced by biological organisms. Of these two effects the first one shows up as a constant rate background noise on the optical modules, while the second one, when present, may induce large fluctuations in the noise rate. We have measured the optical noise at 3000 m by means of a set-up consisting of two 8" photomultipliers and the associated electronics. An average rate of about 25 kHz has been measured (with a threshold set at 0.3 p.e.), with rare high-rate spikes due to bioluminescence. This results is in agreement with the distribution of bioluminescent bacteria measured in Capo Passero [8], which shows a very low concentration of these bacteria at depths greater than 2500 m.

Deep-sea currents have been continuously monitored in Capo Passero since 1998. The analysis shows that the behaviour in the area is almost homogeneous on the part of the water column that has been monitored (bottom 500 m) with very low average values (around 3 cm/s) and peaks not exceeding 12 cm/s. The downward flux of sediments has also been analysed. The annual average value of material sedimenting at large depth in Capo Passero is about 60 mg m^{-2} day^{-1}, a rather low value as expected for an oligotrophic environment such as the Ionian Plateau [8].

3. PRELIMINARY PROJECT FOR A km^3 DETECTOR

The design of the mechanics and electronics of an underwater telescope should fulfill several specification: it should allow an easy, fast and cost-effective deployment of the whole detector structures (to be completed within ∼5 years); permit the recovery of structures for maintenance; and insure the transmission to/from shore of slow controls and of all PMT signals, possibly without any data filtering. All the elements must be reliable for a time of the order of ten years.

Preliminary computer simulations show that, by filling up a volume of about 1 km^3 with about 6000 optical sensors, one can reach, for muon energies higher than ≈1 TeV, an effective area of the order of 1 km^2. An optimization of the spatial arrangement of these sensors and of the detector architecture must be done in order to achieve the requirements mentioned above.

Following these indications, and taking into account some constraints on the distance between structures (larger than about 120 m) and on their height (smaller than 1 km) suggested by a preliminary feasibility study, we have proposed an architecture composed by a square array of structures, called *towers* [6]. The proposed architecture is modular, in the sense that it is expandable with the addition of extra towers, and configurable with different sea-floor layouts. At present, it should only been considered as a reference for a deeper feasibility study.

The tower that will host the optical modules and the instrumentation is a three-dimensional flexible structure composed of a sequence of storeys (that host the instrumentation) interlinked by a system of cables and anchored on the seabed. The structure is kept vertical by an appropriate buoyancy on the top. The final features of the tower (number of storeys, number of optical modules per storey, distance between the storeys) can be optimized following the results of numerical simulations. However, the modular structure of the tower will permit adjustment of these parameters to the experimental needs. In the preliminary design, we have considered an 18-storey tower, where each storey is made with a 20 m long pipe in glass-reinforced epoxy, hosting four optical modules per storey. In its working position, the spacing between storeys will be 40 m, with each storey rotated around the vertical axis by 90^o with respect to the up and down adjacent ones. One of the advantages of this structure, which represents an alternative solution to the ANTARES string or the NESTOR rigid tower, is that it can be compacted, by piling each storey upon the other, to simplify transport and deployment. The structure is unfurled, reaching its operating configuration only after its deployment on the seabed.

A proposal for the data transmission system, which uses fibre optics transmission with DWDM technology, has also been developed. This system allows the transmission to shore of the full data rate (about 30 kHz for 6000 OM) without any data filtering.

Due to the number of junction boxes needed in a km^3 detector, an alternative design to the standard titanium pressure vessels has been developed, to reduce costs and increase the reliability. The proposed junction box will have a pressure-resistant steel vessel hosted inside an oil-filled fibreglass container, thus decoupling the two problems of pressure and corrosion resistance.

4. NEMO PHASE ONE

The technological solutions proposed for the km^3 detector require an adequate process of validation. For this reason, we have decided to realize a technological demonstrator consisting of a subset of the proposed km^3 detector and including some of its critical elements. This project is called NEMO Phase 1 [6].

The project will be realized at the Underwater Test Site of the Laboratori Nazionali del Sud in Catania, where a 28 km electro-optical cable, reaching a depth of 2000 m, allows the connection of deep-sea intrumentation to a shore station. The NEMO Phase 1 system will be composed of a network of junction boxes (a main one and two secondary), realized following the design outlined above, and two NEMO towers. This will allow for testing of the mechanical characteristics of both, as well as the data transmission and power distribution system of the whole apparatus. The completion of this project is foreseen by the end of 2006.

5. CONCLUSION

The realization of a km^3 telescope for high-energy astrophysical neutrinos is a challenging task and several collaborations in Europe are already working on the realization of first-generation demonstrators. More efforts are needed to develop a project for the km^3 detector. In its five years of activity, the NEMO collaboration has contributed in this direction by performing an intense R&D activity.

An extensive study on a site close to the coast of Sicily has demonstrated that it has optimal characteristics for the telescope installation. A complete study has been performed to analyse all the detector components both in term of their technical feasibility and installation, showing that a detector with effective area over 1 km^2, is realizable at an affordable cost.

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