The km^3 Mediterranean Neutrino Observatory - The NEMO.RD Project

C.N. De Marzo for the NEMO Collaboration*

The NEMO.RD Project is a feasibility study of a km^3 underwater telescope for high energy astrophysical neutrinos to be located in the Mediterranean Sea. Results on various issues of this project are presented on: i) Monte Carlo simulation study of the capabilities of various arrays of phototubes in order to determine the detector geometry that can optimize performance and cost; ii) oceanographic survey of various sites in search of the optimal one; iii) feasibility study of mechanics, deployment, connections and maintenance of such a detector. Parameters of a site near Capo Passero, Sicily, where depth, transparency and other water parameters seem optimal are shown.

1. A km^3 detector for ν-Astronomy

The scientific interest in the foundation of the astronomy of the high energy neutrinos has steadily increased in the last years, along with the perspective that these particles could bring information from the deep interior of their astrophysical sources. The observation of tens of TeV γ-ray emitters [1,2] has reinforced the possibility of existence of "beam dump sources", i. e. accelerated proton beams interacting with gas of matter or photons. In the mean time several models concerning neutrino astrophysical production have been proposed, mainly based on the existing fluxes of high energy gamma rays, and the relative calculation of the expected fluxes on the Earth has been produced. Among the possible neutrino sources are active galactic nuclei (AGNs), binaries where a non compact companion transfers matter to the compact one (neutron star or black hole), supernova remnants and γ-ray bursts [3]. The possible future detection of gammas in the 100 TeV range will prove the existence of this physical condition definitively. On the other hand, less optimistic is the limit on neutrino fluxes based on the high energy comic ray measurements [4]. Although a general consensus on the expected astrophysical neutrino fluxes has not been reached yet, it seems clear today that the level of counting rates predicted, even by the most optimistic of the proposed models, asks for detectors with volumes at the km^3 scale. Apparently, the only technique suitable for such a large detector is given by under-water - or under-ice - arrays of phototubes (PMTs) able to detect the Cherenkov light radiated by muon tracks. In these arrays the high energy neutrino signature is an upward going muon. To select muons induced by neutrino interactions, the Earth must be used as a filter. In underwater, and underground detectors as well, one of the main source of background for these events is given by the downward going cosmic ray muons. For this reason a neutrino telescope must be located at depths of order 3000 meters for shielding of the atmospheric muon background. The required overburden of water above the detector will attenuate the downward-going muon flux by about a factor 10^5

*M. Ambriola, R. Bellotti, F. Cafagna, F. Ciacio, M. Circella, C. De Marzo, T. Montaruli: INFN and University, Bari, Italy; D. Falchieri, A. Gabrielli, E. Gandolfi, M. Masetti, C. Vitullo, G. Zanarini: S. Cecchini, G. Giacomelli, A. Margiotta, M. Sioli, M. Spurio: INFN and University, Bologna, Italy; R. Habel, I. Usai: INFN and University, Cagliari, Italy; S. Aiello, G. Burrafato, L. Caponetto, E. Costanzo, D. LoPresti, L. Pappalardo, C. Petta, N. Randazzo, G. V. Russo, O. Troia: INFN and University, Catania, Italy; R. Barnà, V. D'Amico, E. De Domenico, D. De Pasquale, S. Giacobbe, A. Italiano, F. Migliardo, G. Salvato, A. Trafirò, M. Trimarchi: INFN and University, Messina, Italy; F. Ameli, M. Bonori, A. Capone, F. Massa, R. Masullo, E. Salusti, M. Vicini: INFN and University "La Sapienza", Roma, Italy; R. Coniglione, E. Migneco, P. Piattelli, R. Riccobene, P. Sapienza: INFN-Laboratori Nazionali del Sud, Catania, Italy; M. Cordelli, L. Trasatti, V. Valente: INFN-Laboratori Nazionali di Frascati, Italy; E. Accerboni, R. Mosetti: Osservatorio Geofisico Sperimentale di Trieste, Trieste, Italy; M. Astraldi, G. P. Gasparini: Consiglio Nazionale delle Ricerche, IOF-CNR, La Spezia, Italy; A. Ulzega, P. Orrù: CIRCAM, University, Cagliari, Italy.

respect to surface. The remaining rate of background must be managed by the capabilities of the electronics of the apparatus and, in particular, by its time of flight resolution. Last, but not least, with the Cherenkov light technique in water the cost per cubic meter of detector sensible volume is many orders of magnitude less expensive than that of underground electronic detectors, like the Frejus detector or the MACRO at Gran Sasso, for example. This situation makes it possible to build detectors having very large volumes. Moreover, for a survey of the full sky two detectors are needed, one in each hemisphere. So, a neutrino telescope in the Mediterranean Sea results complementary to the Ice Cube at the South Pole [5]. Because in these apparatus neutrinos are detected as upward going muons, the northern telescope will be able to observe the galactic center.

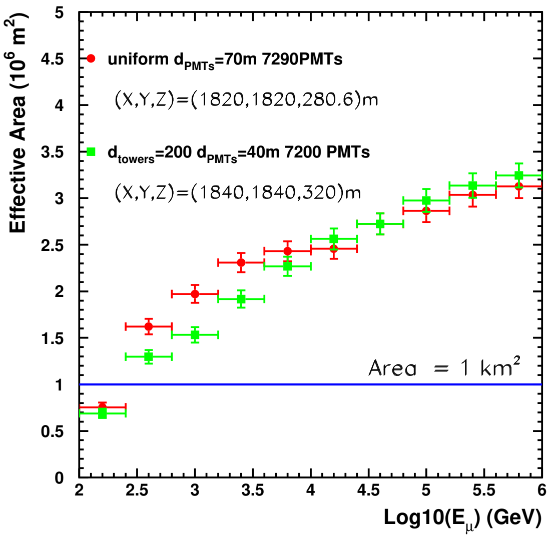

Figure 1. Effective area vs muon energy for 2 PMT arrays: a parallelepiped with distance between PMTs of 70 m; square tower configuration with distance between centers of towers of 200 m and between PMTs in each tower of 40 m. Total numbers of PMTs are indicated for each array. The error bars are due to the Monte Carlo statistics.

NEMO.RD (NEutrino Mediterranean Observatory) is an R&D project for a ν-telescope to be deployed in the best site in the Mediterranean Sea. In order to optimize the physical performance of the neutrino telescope versus the number of PMTs, we have used a "fast" Monte Carlo in which high energy muons can be propagated and the corresponding detector response simulated. The results of this simulation in terms of effective area are shown in figure 1. In order to be fast this code transports muon tracks but not hadronic or electromagnetic showers. A more accurate study will be performed with a full GEANT-based [6] simulation is under development. This will be used for real data analysis more than for detector design. In the simulation code an attenuation length of 55 m has been assumed for the Cherenkov light, as due to absorption only. Scattering of light is not simulated, but this is a reasonable approximation since measurements of the scattering length show that it is ≥ 70 m in the Mediterranean sites surveyed so far and the fraction of backscattered light is quite small.

2. Site characterization for a km^3 ν-telescope

The choice of the ν-telescope location is such an important task that a careful survey of four candidate sites was carried out in order to identify the most suitable one. Careful and extensive measurements were routinely made of deep-sea water optical properties (absorption and diffusion) and of environmental properties: water temperature, biological activity, water current, salinity and sedimentation. The selection of the site where the km^3 detector can be located implies several requirements. The site has to be deep enough to filter out the downgoing atmospheric muon background. At least a 3000 m depth is required in order to reduce the rate of downgoing muons of a factor 10^5. The remaining rate of background must be coped by the detector capabilities. In addition, the distance from the coast should be as short as possible in order to ease data transmission to the on-shore counting room as well as transmission of power and commands to the off-shore detector. For the purpose an electro-optical multi-fiber cable will be used. A length of cable up to 100 km is still suitable for data transmission. The site needs to have good optical underwater properties because the detector effective area is not only directly determined by the extension of the instrumented volume but is also strongly affected by the light transmission in water. Sedimentation and bio-fouling in the selected site must have very low values and the site has to be be "quiet", i.e. the sea current must have low intensity and stable direction.

In search of a site having characteristics as close as possible to the above mentioned requirements, we started a systematic oceonographic survey along the Italian coasts, since July 1998. After having considered a certain number of sites both in the Tyrrhenian and Ionian Sea nearby the Italian coasts, with depth beyond 3000 meters, we concentrated our attention in a region around the point with geographical coordinates: 35° 50′ N, 16° 10′ E in the Ionic Sea, South-East of Capo Passero in Sicily. Up today this seems to be a very good site, with promising values of the characterizing parameters. Its depth is around 3400 m and the average value of the sea current - about 3 cm/s - is almost stable in intensity and direction all over the year. Transmission length, obtained combining the measured absorption and assumed scattering, results close to 60 m at 460 nm. Further survey campaigns will definitively assess the quality of this site. Moreover a direct measurement of the scattering distribution and further measurements of the absorption of light are in program. Dedicated instruments for these measurements have been built and will be used. At present a deep-sea station is in operation at the Capo Passero site, measuring sedimentation and bio-fouling rates, and sea current as well, on a long term period. Data from these instruments will be available in the next future.

3. Study of the km^3 detector mechanics

The study of the NEMO mechanics has been started in collaboration with industries having experience in submarine operations; in particular those operating in oil extraction and transport. In order to minimize the cost of the detector, a structure made of semi-rigid towers holding optical modules (OM) has been chosen against a uniformly spaced arrays of flexible strings or against

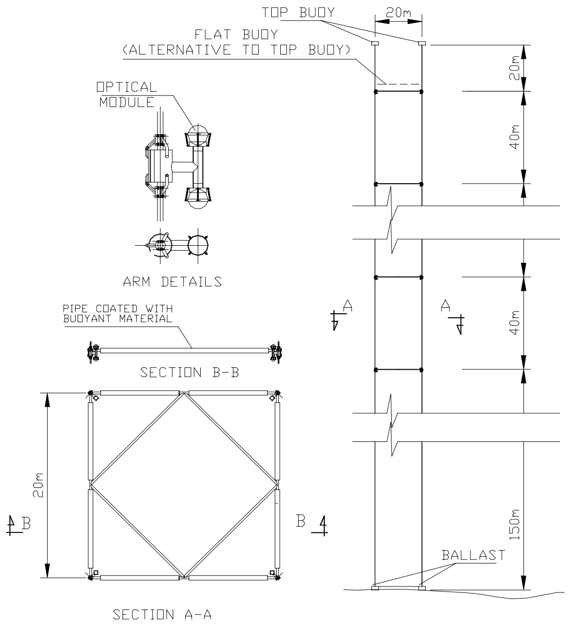

Figure 2. Schematic of the semi-rigid tower for the km^3 Neutrino Telescope.

a structure made of rigid towers. The detector sensible height is assumed to be 300 m, beginning 150 m from the sea floor. These choices have been validated by the simulation code, as mentioned above. In figure 2 a schematic of the tower is shown. It appears that a volume of the order of 1 km^3 can be covered by about 8000 PMTs with good efficiency and pointing capability. In our mechanical study dimensions, materials and deployment procedures of the structures have been carefully considered and determined in order to figure the less costly and more reliable design.

REFERENCES

1. Thompson, D.J., et al., 1995, Ap. J. S, 101, 259.
2. Krennrich, F., et al., 1998, Astr. Phys. 8, 213.
3. Gaisser, T.K., Halzen, F. & Stanev, T., 1995, Phys. Rep. 258, 173
4. Waxman & Bachall, 1999, Phys. Rev. D59, 023002.
5. Halzen, F. for the Amanda Collaboration, 26th ICRC, Salt Lake City, USA, HE 6.3.01.
6. Brun, R., et al, 1987, CERN report DD/EE/84-1.