A DEEP SEA STATION FOR MEASUREMENT OF ACOUSTIC NOISE AT THE NEMO TEST-SITE

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Abstract

The strong interest in neutrino astronomy expressed by the scientific community is leading to the construction of Čerenkov neutrino detectors, installed in deep seawater or ice, having instrumented volumes of km^3 scale. The INFN NEMO (NEutrino Mediterranean Observatory) collaboration, aims at the construction of a km^3 detector in the deep Mediterranean Sea. In this framework NEMO is installing a *Test Site* facility at 2000 m depth, at $\sim$ 25 km offshore the port of Catania (Sicily). The facility will be used to test a prototype module of the future km^3 detector. The collaboration is also studying the possibility to use the thermo-acoustic technique to detect UHE neutrino fluxes. One of the major sources of uncertainty in the reliability of this technique is, presently, the lack of knowledge of the acoustic noise at large depth. For this reason NEMO has developed a station for the measurement of acoustic background, that will be installed at the *Test Site*. The station is equipped with 4 large bandwidth hydrophones (1 Hz $\div$ 50 kHz) whose data, digitized underwater, will be transmitted to shore through optical fibres. The station will be also used, in collaboration with CIBRA, for research on marine mammals.

1. UNDERWATER/ICE NEUTRINO TELESCOPES

The cosmic ray community expects that the future km^3 Čerenkov neutrino telescopes, will detect high energy neutrinos from both Galactic (Super Nova Remnants, microQuasars) and extragalactic (Active Galactic Nuclei, Gamma Ray Burst,...) sources [1]. In the next years the first neutrino telescope will be installed in the South Pole (ICECUBE [2]). Due to the scientific request of full coverage of the sky, another neutrino telescope is planned to be soon installed in the Mediterranean Sea (ANTARES-NEMO-NESTOR [3]). Čerenkov neutrino telescopes detectors are arrays of photomultipliers, having large collection area (the used PMTs have typically diameters between 8 and 15 inches), designed to detect Čerenkov light produced by charged leptons (in particular muons) generated in neutrino interactions. The reconstruction of muon track allows the identification of the neutrino direction and energy. In recent years this technique has been successfully tested by the AMANDA [4] and BAIKAL [5] collaborations, that have demonstrated the possibility to reconstruct TeV neutrinos. Several reconstruction algorithms and simulation codes have been developed and are under test to enhance the capabilities of muon identification and background rejection with Čerenkov light technique [6], enhancing the expected discovery possibility of such detectors. On the other hand, in seawater and ice light is absorbed in relatively short distances, about 100 m: therefore, the mean distance between PMTs must be in this range. The main consequence is that, for an affordable km^3 telescope, composed of $\sim$ 5000 PMTs, the detection effective area is not larger than a few km^2. This detection area, is suitable to measure the expected astrophysical neutrino fluxes in the range 100 GeV $\leq E_\nu \leq$ 10 PeV, but could not be enough to detect UHE neutrinos, whose flux is expected to follow the power law $\frac{dN_\nu}{dE_\nu} \propto E_\nu^{-2}$.

2. ACOUSTIC DETECTION OF UHE NEUTRINOS

In order to detect faint UHE neutrino fluxes a different detection technique has been suggested [7]. At this large energies neutrino interactions produce showers which release, in a time of $\sim 10^{-7}$ sec, a macroscopic amount of energy in a small region of water. Ionization and sudden heating of water produce a bipolar pressure pulse which expands radially from the shower core and perpendicularly to the shower axis [8,9]. The pulse amplitude scales linearly with the deposited energy density [10]. The expected maximum wave amplitude, calculated with thermo-acoustic models, for a 10 PeV e.m. shower is ~ 10 μPa at a distance of ~ 1 km from the shower core [11]. The wave peak frequency is estimated to be in the range of ten kHz. The acoustic technique could be extremely fruitful because the sound absorption length is, in this frequency range, of the order of km. A pioneering work in this field has been recently conducted using military arrays of hydrophones [12]. Moreover acoustic (or radio) detectors could also be extremely interesting to test the results obtained with Čerenkov light telescopes, using a different detection technique and different sensors to detect the same physical phenomena. The possibility to deploy an acoustic detector in deep sea with a large receiving bandwidth (1 Hz $\div$ 50 kHz) opens also a plethora of interdisciplinary follow-ups in marine biology (cetology, fisheries,), oceanography, acoustic data transmission.

3. ACOUSTIC NOISE IN DEEP SEA

The knowledge of acoustic background is fundamental in order to carry out a feasibility study for an underwater acoustic neutrino detector.

Noise in the sea have different origins: biological (fishes, marine mammals, crustaceans), mechanical (wind and surface waves, molecular thermal vibrations) and due to human activities (navigation, fishing, military operations, oceanographical instrumentation, oil exploration) [13].

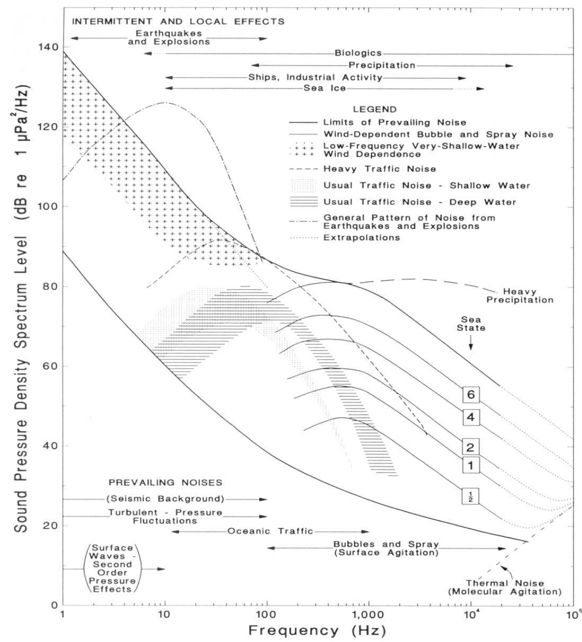

Figure 1: Spectrum of noise pressure density level in the sea.

Biological and human noises could reach very high pressure level, but they are, generally, produced by local and intermittent sources. In the frequency range of interest, noise is, in average, mainly due to surface agitation (see figure 1) and to navigation that, in the Mediterranean Sea, can be assumed as constant acoustic background [14]. At present, only few measurements of acoustic noise have been carried out at depth larger than 2000 m, where acoustic detectors should be presumably located. At these large depths it is expected that surface noise should be strongly reduced, due to the change of sound refraction index with depth. On the other hand, it is not clear the value of sound emissions generated by cetaceans, that can immerse down to thousand meters depth [15]. In order to measure the level of acoustic noise in deep Mediterranean Sea, NEMO has developed a station that will be installed at the Catania *Test Site*.

4. NEMO *PHASE ONE*

During year 2001 the NEMO collaboration has installed a 28 km long electro-optical cable that

Figure 2: The laboratory built by INFN-LNS at the port of Catania. The laboratory is the shore termination of the submarine cable, equipped with 10 optical fibres and 6 electrical conductors, deployed at 2000 m depth.

will permit data transmission from instrumentation moored at 2000 m depth to a shore laboratory, built by INFN-LNS at the port of Catania, Sicily (see figure 2). The LNS facility will be used as a *Test Site* to test new detectors, materials and technical underwater solutions and, finally, to install the NEMO *phase one*, i.e. a prototypal *module* of the future km^3 neutrino telescope. The present project foresees the installation of two *towers* (semirigid structures of 750 m height and 20 m $\times$ 20 m base) holding $\sim$ 100 PMTs, and three *junction boxes* for underwater connections. The collaboration is going to equip the deep sea cable termination with electro-optical connectors suitable for underwater operations with ROV (Remotely Operated Veihicles). At the same time the collaboration will install at the *Test Site* an underwater station for the measurement of acoustic background.

5. THE TEST SITE ACOUSTIC STATION

The apparatus is composed by 4 low noise hydrophones TC-4037 manufactured by *RESON*, specially tested for NEMO at 250 bar pressure. TC-4037 are omnidirectional and they have a receiving sensitivity of -173$\pm$3 dB re 1V/μPa (measured using differential preamp with +20 dB gain) which is linear over a wide range of frequencies: 1 Hz $\div$ 50 kHz. The four detectors, installed in an ERGAL housing, are displaced at the vertexes of a tetragonal fiberglass structure (side $\sim$ 1m). The analog signals are brought, through electric lines galvanically insulated, to two stereo ADCs *Crystal* CS5396, synchronised on the same clock. Each CS5396 samples the signals at a rate of 96 kHz with a resolution of 24 bits: the nominal dynamic range of the ADC is 120 dB. The digital outputs of the two ADCs (each one containing the data of 2 hydrophones, in electric audio protocol SPDIF) feed in to two fiber optic data transmitter manufactured by *Elcomtech*. The data throughput of the transmitter is $\sim$ 14 Mbit/sec, well compatible with the ADC output and the maximum transmitting distance is 80 km (λ =1550 nm). The digitization and data transmission electronics is hosted in a pressure resistant glass spherical housing, 17 inches diameter, manufactured by *Nautilus* (figure 3). The housing is equipped with an electro-optical connector holding 2 optical contacts (for data transmission to shore) and 2 electrical contacts (for power supply from shore). In the shore laboratory data are reconverted into SPDIF protocol by two fiber optic receiver and, then, acquired using PCI audio boards *RME DIGI96-8 PAD* (96 kHz, 24 bit resolution). The data acquisition has been tested: hydrophone data have been acquired, in air, using a calibrated 15 kHz acoustic source. The present receiving sensitivity is estimated to be $\sim$ 5000 μPa (noise floor) for each channel. The optical connections have been tested, using the present 56 km long optical fibres short-cut of the *Test Site*.

6. CONCLUSIONS

When deployed, the station will permit a constant on-line monitoring of acoustic noise in deep sea in a wide range of frequencies. This will allow to evaluate daily and seasonal variations in the received noise levels and to produce a detailed modelisation of acoustic background at large depth. Despite the achieved resolution, the

Figure 3: Half of the glass spherical housing which contains the digitization and data transmission electronics. In the picture are visible two (four, in total) connectors and cables used for connections with the hydrophones, and the e.o. connector (mounted in the lower sphere pole) that will permit data transmission to the shore.

detection of rare UHE neutrinos interactions is expected to be not affordable. On the side of marine biology applications the station will be extremely useful to identify and track cetaceans in a range of several tens of km.

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