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NESTOR: Deep Underwater Neutrino Astronomy

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Abstract

NESTOR[2] is the first step toward the construction of a neutrino telescope using the depth of the sea both as a shield against atmospheric muons and as detector material. The experiment is based on the detection of Cerenkov radiation produced by neutrino muons using 12" photomultiplier tubes. 168 PMTs will be arranged in 12 floors separated by 20 m each and with a radius of 16 m.

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1. – Neutrino Astronomy

It is a well known fact that every time the sky has been observed with new instruments, from the first telescope down to high energy gamma rays, new phenomena have been discovered. In this respect, the neutrino is probably the ideal probe to study celestial phenomena. Its low cross section for interaction with matter allows it to escape almost undisturbed the region of creation. Moreover a neutrino can traverse very high distances without scattering, and therefore remembering the original direction. This is a better situation than for any other probe, including high energy gammas, that interact with the 3 K background. In other words, the neutrino allows to look at greater distances in the universe than any other probe.

Of course, this same advantage is balanced by the necessity to have a detector with very high mass, to compensate for the low cross section of neutrinos. The only kind of technology that allows to build a detector with a mass of the order of one cubic Kilometer at a cost not too unreasonable is the use of sea water as a detector and of Cerenkov light to detect the neutrino originated muons. Since the angular spread of muon production by neutrinos is of the order of 1°, the expected accuracy is very reasonable.

2 – The Location

The choice of the location for a deep underwater experiment is not an easy one. It is necessary to find a deep and wide underwater plateau not too far from the shore and from a reasonable place that can accommodation and support. One such place is a 3800 m deep plateau 13 nautical miles from the town of Methoni in the south of the Peloponnesos. The somewhat larger town of Pylos is located 8 Km to the north of Methoni. Pylos looks into the bay of Navarino, which is a very wide and very protected harbour, ideal for low depth tests.

3 – The Detector

The detector (see Fig. 1) consists of 12 planes separated by a distance of 20 m. Each plane is made up of a semirigid six arm star, each arm 16 m long. At the tip of the arms, as well as in the center of the star, is mounted a pair of glass spheres containing one 15" PMT each, one looking up and one looking down. The PMT signal will be digitized at a rate of 300 MHz by a flash ADC and a multifibre optical cable will relay to the shore station all of the information, including the shape of the signal. This will help in the identification of muon bundle events. The threshold for muon detection is of a few GeV and the angular resolution of the order of 1°. The sensitive area as a function of muon energy and angular reconstruction accuracy is shown in Fig. 2.

The goals of the experiment include:

- Diffuse AGN background measurement. The expected rates for the NESTOR tower are shown in Fig. 3.
- Neutralino detection from the center of the earth or of the sun.
- High energy neutrino interactions
- Neutrino oscillations
- and, of course, the unexpected.

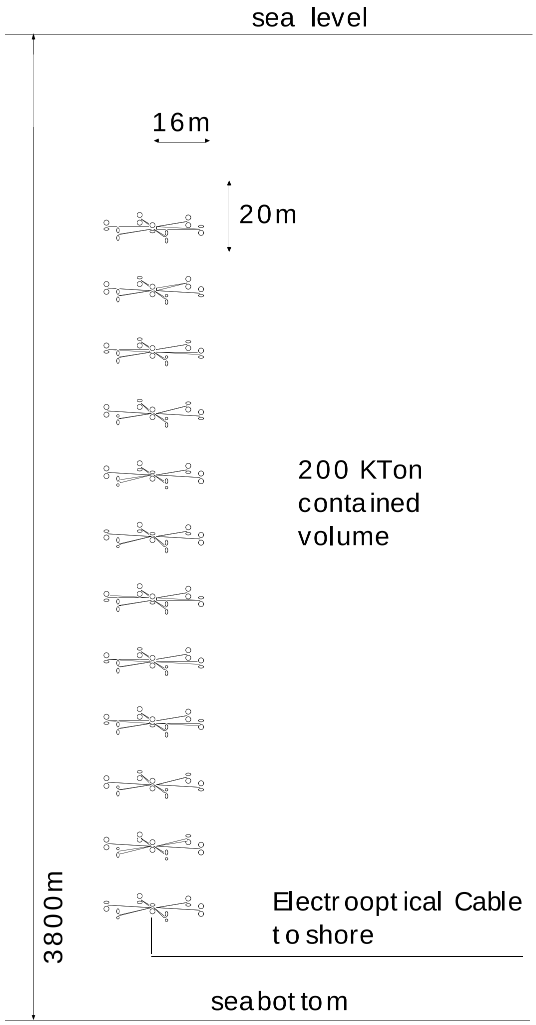

Fig.1 – Schematic diagram of the NESTOR tower.

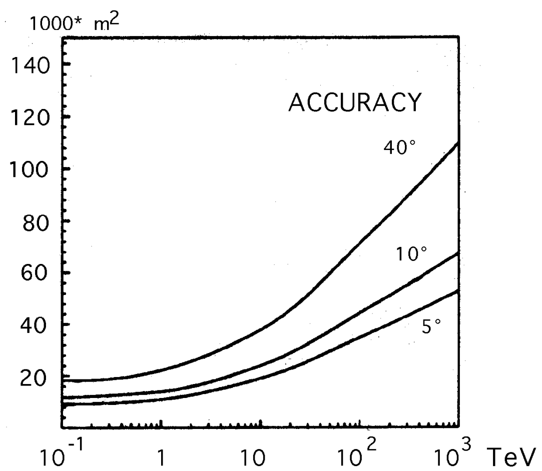

Fig.2 – NESTOR sensitive area as a function of muon energy and reconstruction accuracy.

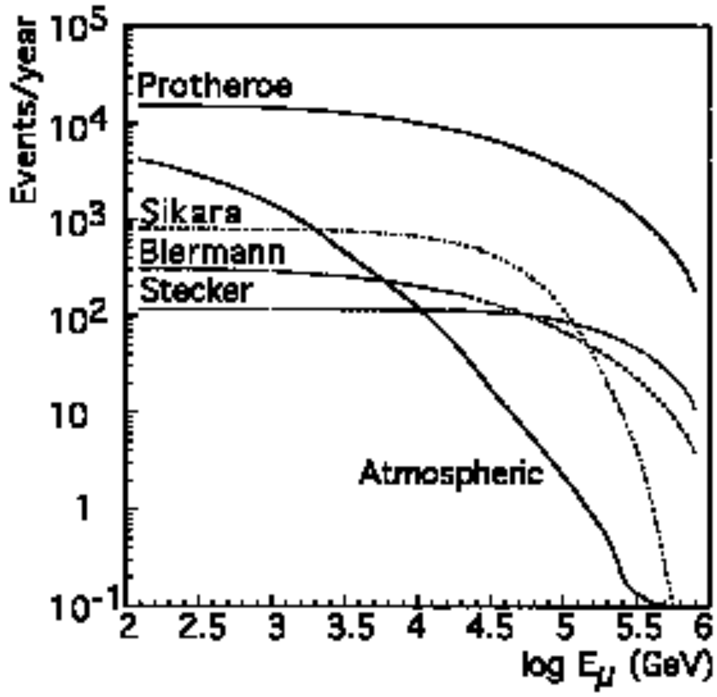

Fig.3 – Expected event rates for the diffused AGN background for a NESTOR tower.

4. – Status

Atmospheric muon fluxes in the NESTOR location have been measured in 1991 by a Russian – Greek expedition, and found in accord with predictions. Water parameters at the NESTOR site have also been measured in that occasion, and the sea bottom has been mapped with high accuracy.

Additional measurements have been performed in April 1996. The background rate from K^{40} decay has been found to be of the order of 50 KHz, and some bioluminescence signals have been detected. Mechanical tests on the method of deployment of the apparatus have started and are going to continue in the summer. Tests with the final electronics and optical cables are planned for autumn 1996.

5. – The Electronics

The NESTOR electronic system has been designedby the Italian group to give the experiment maximum flexibility and reliability, minimising the amount of data reduction to be done underwater.

For each of the 12 floors a titanium sphere, 1 m in diameter, located in the center of the star, will contain the electronic boards for digitisation, transmission and slow controls.

The PMT signals will be digitised by 300 MHz flash ADCs with a double slope conversion system to maximise the dynamic range. The digitised data, together with the Slow Controls data, will be transmitted to shore using one single mode optical fibers per plane at 400

Mbit/s. This will guarantee a maximum singles rate of 150 KHz per PMT. To increase the reliability of the system the fiber from each plane will carry both its own stream of data and the stream from the adjacent plane, using two different lasers at slightly different wavelengths in the third window (about 1500 nm). Moreover, the same fiber will also carry in the opposite direction, from shore to water, the light from a third laser working in the second window (1300 nm). This channel will carry timing signals from shore to all of the planes, allowing to synchronise all the PMTs of the experiment.

6. – Slow Controls and Reliability

The Slow Controls system will serve two purposes:

– Measure and transmit to shore a set of environmental data like temperatures, pressure, salinity, sea current speed, etc.
– Perform housekeeping tasks and execute commands sent from shore, like checking voltages, turning on/off power to the PMTs, etc.

The system will be built around a micro controller of the SH series by Hitachi.

Although this is a relatively simple system, its design is complicated by the very serious problem of high reliability requirements, which also affects the rest of the electronics system.

The process of deployment and recovery of the NESTOR apparatus is not a trivial one. Although it is necessary to foresee the possibility to recover and redeploy for maintenance, the process will be very expensive. Therefore the reliability of the system must be very high, and the MTBF (Medium Time Between Failures) of the order of at least a couple of years. This means that the reliability of the single components must be much higher.

This kind of problem has not traditionally been faced by the high energy physics community, and it leads to lots of complications.

First of all, you should use for your electronics military grade devices. But even apart from the price, which is high, mil style components are never certified over 30000 hours MTBF, roughly three years. Moreover, many companies are not making military components any more (e. g. Motorola) due to the shrinkage of the market. Finally, components certified for military performance tend to be old. Nobody from a high energy lab will accept this limitation.

There is another set of components that would better agree with the requirements of a large underwater experiment: the space grade. But in this case cost and delivery times rise by at least a factor of 10. Moreover we do not really need all of the specifications a space vessel requires. In the case of NESTOR, the temperature is kept at 14°C by the sea, and the vibrations are well under control, even during deployment.

The conclusion is that we shall have to learn the techniques of reliability and transfer them to our laboratories if we want to build underwater experiments for the prices we are used to. This will be by itself a major enterprise, but we will be forced to do it if we do not want our experiments to become giant 4 Km elevators.

7. – Future Plans

We plan for the summer–autumn period 1996 to work on the deployment technique of one and two stars, and to deploy PMTs connected to the final electronics and read out through a fiber optic link.

We expect to be ready to deploy at least two fully implemented planes by the spring of 1997, and to be thus able to reconstruct muon events, proving definitively the feasibility of the NESTOR apparatus.

References

1] The present NESTOR Collaboration is the following:
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2] For a full description of the experiment and more detailed reports of the detector refer to : 2nd and 3rd NESTOR International Workshop, edited by L.K. Resvanis, 1992, 1993