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NESTOR: an Underwater Neutrino Observatory in the Ionian Sea

NESTOR Collaboration (Presented by L. Trasatti)

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NESTOR: An underwater neutrino observatory in the Ionian sea

NESTOR Collaboration[1], presented by L. Trasatti

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Deep underwater high energy neutrino detection is a very promising field in both elementary particle physics and astrophysics. On one side, the energy range of ground based accelerators cannot be extended much more respect to the present, leaving only astronomical sources for future investigations. In the astrophysics field, neutrinos are the tool to explore further in the universe due to their low interactions. By the same token, the experimental problems for a neutrino detector are enormous. The Cerenkov effect is practically the only poissible tool, because it uses sea water both as shield and as detector. NESTOR is the first step toward a full fledged deep underwater neutrino experiment. While its area, of the order of 10000 m**2, cannot hope to identify all possible celestial sources, it is nevertheless a necessaryy step toward the "Km**3" experiment. The first deployment tests have already been performed,proving the feasibility of the mechanical design, and the electronics is almost completely ready. Additional tests are scheduled for this autumn and next year will see a relevant part of the experiment installed at the bottom of the Ionian sea.

1. NEUTRINOS AND ASTRONOMY

The neutrino is 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 reasonable cost is the use of sea water both as a target and 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 NESTOR SITE

The NESTOR site is probably the best suited for the purpose in the Mediterranean. It is an 8*9 Km^2 plateau at 3800 m depth, 13 nautical miles from the town of Methoni, that can provide accommodation and support. 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, long term tests.

3. PHYSICS GOALS

The goals of the experiment include:
- Diffuse AGN background measurement.
- Neutralino detection from the center of the earth or of the sun.
- High energy neutrino interactions
- Neutrino oscillations
- and, of course, the unexpected.

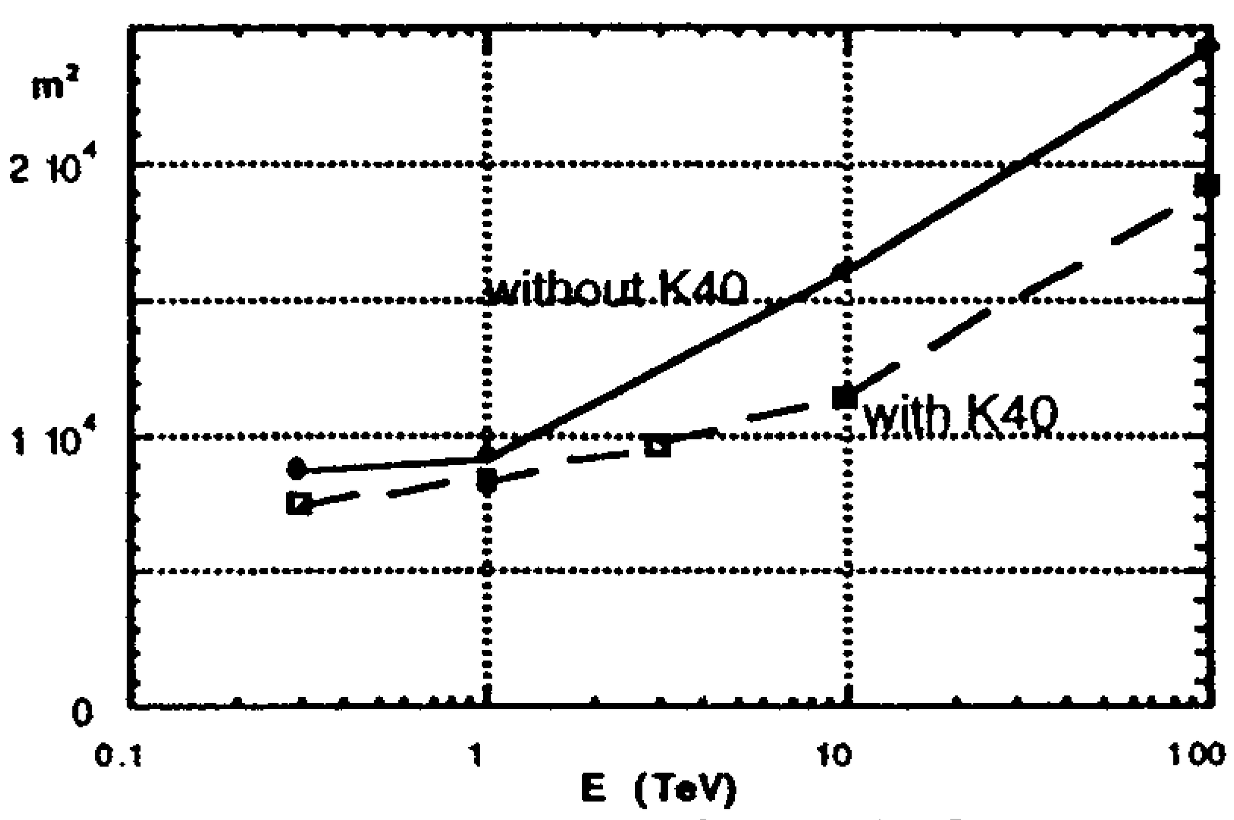

Figure1: Sensitive area of a NESTOR tower

Fig. 1 shows the sensitive area for a NESTOR tower recently recalculated with and without the K40 backgrouind.

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4. THE DETECTOR

The detector (see Fig. 2) 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 Benthos spheres containing one 15" PMT each, one looking up and one looking down. The threshold for muon detection is of a few GeV and the angular resolution of the order of 1°.

At the present moment we have ready two anodyzed Aluminum stars built by the German group and two Titanium stars built by the russian collaboration.

5. THE ELECTRONICS

The NESTOR electronic system has been designed by 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 full information, including the shape of the signal, will be available on shore. This will help in the identification of muon bundle events. The digitized data, together with the Slow Controls data, will be transmitted to shore using one single mode optical fiber 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 carrythe 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.in the opposite direction, from shore to water,

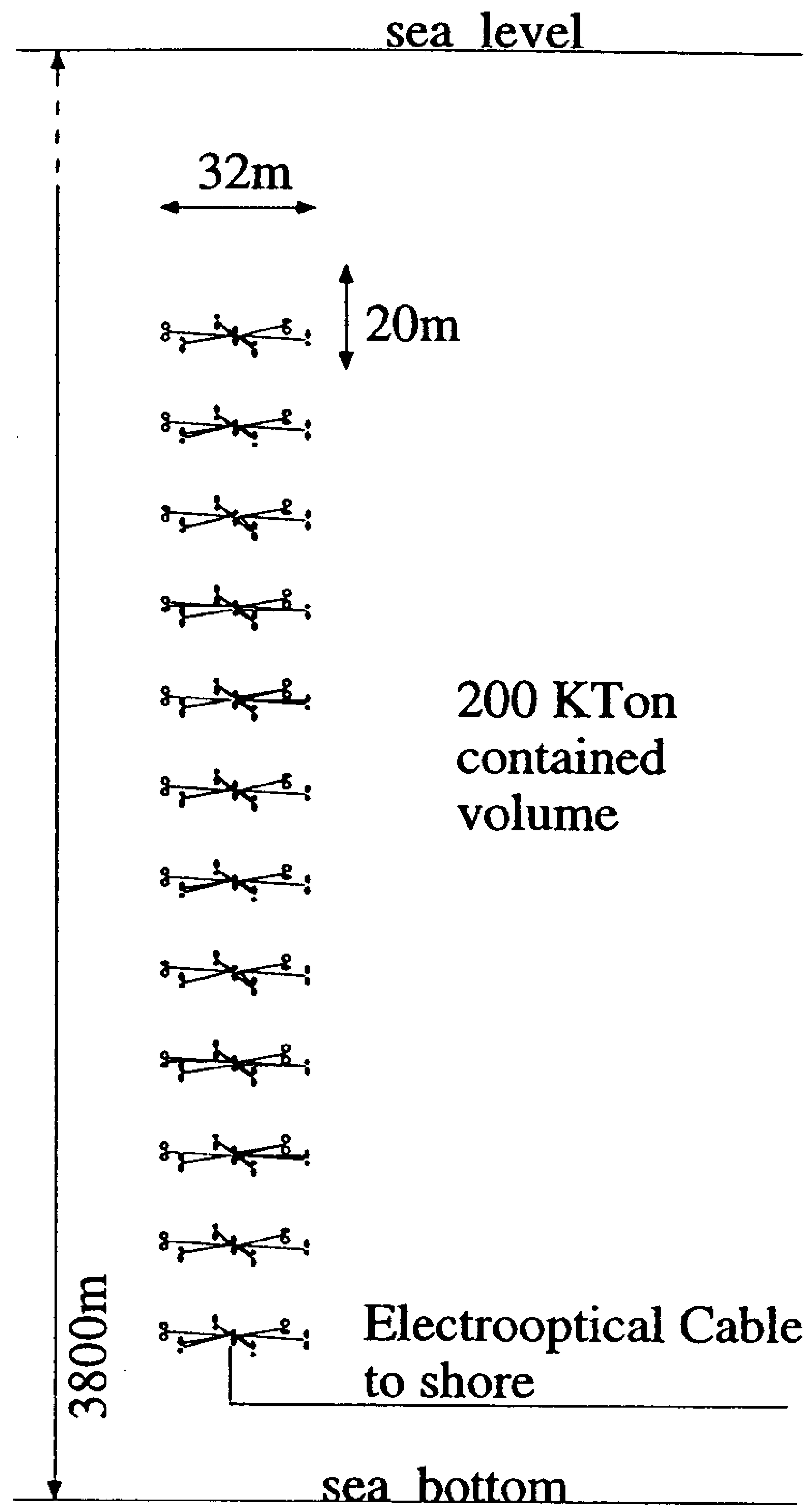

Figure2: Schematic diagram of the NESTOR tower

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, position of the single floors, 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 RISC 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, as was evidentiated by a study on the read out electronics.

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 in 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. 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. In May 1997 two Aluminum floors were deployed and recovered to a depth of 2500 m close to the NESTOR site. Mechanical tests on the method of deployment of the apparatus are going to continue in the summer.

A permanent Test station is going to be built in the bay of Navarino in the Fall 1997 - Spring 1998 period. The Bay Station will be used for long term tests of connectors, galvanic corrosion, electronics, slow controls system, power return via the sea, etc. Although the depth will be only 50 m, a long term test of the components of the apparatus in this conditions will be able to debug most of the system and to add a lot to the general reliability.

In the spring of 1998 the final 30 Km electrooptical cable will be deployed by the ship THALIS of the Greek Telecom.

8. FUTURE PLANS

NESTOR is the first large size step toward the Km3 detector that will be needed for high resolution neutrino astronomy. We expect to be able to deploy the first tower in one or two years and to proceed immediately after to larger size installations.

REFERENCES

[1] The NESTOR Collaboration:
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- Greece:
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  INR
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- Switzerland: Bern Physikalysches Institut