THE ANTARES PROJECT

F. FEINSTEIN, on behalf of the ANTARES collaboration
DAPNIA/SPP, CE Saclay, 91191, GIF SUR YVETTE, France

After a three-year long programme of extensive R&D the ANTARES collaboration has started the design and construction of a large undersea neutrino telescope to be installed in the Mediterranean sea off the coast of Toulon, France.

1 Introduction

ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) is a European collaboration of particle physicists, astrophysicists, oceanologists and sea scientists. It has undertaken to build and operate a high energy neutrino telescope in the Mediterranean sea off the French coast, near Toulon[1].

2 Neutrino astronomy

2.1 A unique messenger from the stars

Due to their weak interaction with matter, neutrinos can escape from regions of the Universe too dense for any other particles to escape. They can also travel distances too big for any other particles to reach us before interacting with the intergalactic medium. Indeed, only through them can one map the sky above 10^{13} eV, where photons interact with ambient infrared photons or with the cosmic microwave background, and below 10^{18} eV, where protons are too scattered by magnetic fields to give us any information on their initial direction. As it happened often when a new observation technique made possible to detect a previously invisible radiation, neutrinos may give us quite a new view of the universe.

2.2 Neutrino sources

Neutrinos may be produced by potential charged cosmic ray accelerators, such as supernova remnants, active galactic nuclei and gamma ray bursters. When interacting with matter or radiation, these charged cosmic rays produce mesons which decay into neutrinos. This would give rise to a diffuse neutrino flux. The most intense point-like sources may also be visible as the angular resolution is of the order of 0.3°. The muon energy can be determined within a factor 2 to 3. The expected number of events ranges from tens to hundreds of events per km^2 per year, depending on the models.

Another source of neutrinos could be the annihilation or the decay of Weakly Interacting Massive Particles (WIMPs) which may have been produced during the Big Bang. WIMPs are a possible explanation for accumulating evidences that the dark matter is mostly non-baryonic and cold. A candidate for WIMPs is the neutralino predicted by Supersymmetry, which is its own antiparticle. Neutralinos may be trapped in the centre of celestial bodies, such as the Earth or the Sun or around the super massive black hole which may lie in the Galactic centre, and produce neutrinos when they annihilate. To go above limits set near existing accelerators, 10^4 to 10^5 m^2.years are needed.

Atmospheric neutrinos produced by the interaction of primary cosmic rays in the upper atmosphere are a background for the above mentioned processes. However, they can be used to study neutrino oscillations. For contained events, the muon track length is related to the parent neutrino energy and the track direction gives the oscillation distance. Three years of statistics with the ANTARES detector should permit to measure the oscillation parameters within the region allowed by the Super-Kamiokande experiment.

2.3 Detection principle

Neutrinos are detected when they undergo a neutral or charged current interaction. Charged current interaction of muon neutrinos is the most promising way of detecting high energy cosmic neutrinos, thanks to the big range of the muon. The detector consists in an array of photomultiplier tubes (PMT) installed in a natural body of water. Upward going muons are the signature of neutrino interactions in the matter surrounding the detector. The muons produces Cherenkov light which is used to reconstruct their direction and energy, related to those of the initial neutrinos. The detector is installed deep enough to be shielded against most of the atmospheric muons, which may fake the signal. The detector is more sensitive as the neutrino energy increases due to several effects. The neutrino cross section increases with energy, as well as the muon range making the effective conversion target more efficient and thicker. The Cherenkov light yield increases with the muon energy, due to secondary particles produced along its path, increasing the effective area of a sparsely equipped detector. Finally, the angle between the muon and the neutrino decreases with energy, thus improving the sensitivity to point-like sources.

3 Detector design

The ANTARES detector will be installed at 2400 m depth, 40 km off the coast of Toulon. It consists of 13 vertical strings, separated by 60 m to 80 m, onto which about 1000 PMTs are installed. The instrumented part of the strings starts 100 m above the sea bed and is 350 m long. The array covers a geometrical surface which is roughly 0.1 km^2 in every direction. The PMTs are housed in pressure resistant glass spheres and shielded from the Earth magnetic field by a mesh of high permeability metal. Ten-inch diameter PMTs from Hamamatsu have been selected. They are grouped in storeys of three, oriented 45° downward (see fig. 1), separated 12 m from each other. An application specific integrated circuit has been developed for the front-end

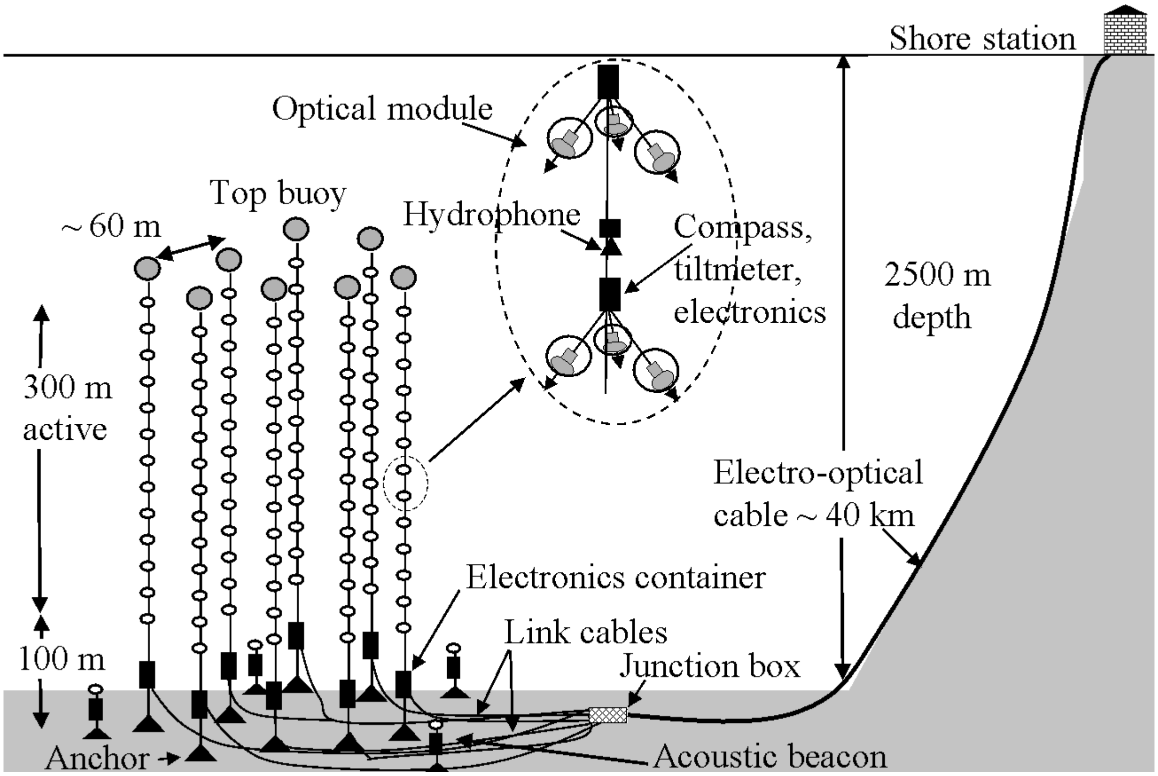

Figure 1: Schematic of part of the detector array; the magnified view shows two storeys and a hydrophone

electronics, the Analogue Ring Sampler (ARS). It captures and stores the PMT signals, and digitizes them upon request from a trigger[2]. Each string is connected to the shore for data and power transmission, via a junction box and an electro-optical cable.

4 Optical properties of the site

Since 1996, the optical properties of the ANTARES site have been extensively surveyed. The optical noise consists of a background of several 10^4 Hz, mainly caused by the decay of ^{40}K, on top of which bioluminescence bursts are superposed[3]. This noise will cause less than 5% dead time. The optical fouling of a glass sphere has been surveyed for eight months. The transmission loss was less than 1.5% for the vertical surface of the sphere. The water transparency was studied using continuous and pulsed light sources. At 470 nm, the absorption is 50 m to 60 m and the effective scattering length is greater than 200 m[4].

5 A prototype string

A prototype string has been constructed to test deployment and recovery procedures, and monitor the mechanical behaviour of the detector when exposed to undersea currents. It consists in 16 storeys, 15 m apart, each holding two glass spheres. The string was equipped with acoustic positioning as well as compasses and tiltmeters. It has been deployed and recovered two times in summer 1998. Since then, 8 optical modules have been installed as well as the electronics needed to transmit the signals to the shore. The string has been deployed and connected to an undersea electro-optical cable on November 30, 1999 at 1200 m depth 30 km of the coast of Marseilles. This site was chosen in order to use an electro-optical cable previously installed for telecommunications between Marseilles and Corsica, lent by the France Télécom company. The string has been operated for several months and recovered in June 2000 [5].

The positioning system consisting of compasses and tiltmeters allowed to monitor the positions of the glass spheres to a precision of about 10 cm in the horizontal and about 1 cm in the vertical. The acoustic system consisted of three hydrophones placed along the string and four acoustic beacons placed on the sea bed about 200 m around the string. From redundant measurements, the precision was estimated to be about 5 cm. The results obtained from the two systems were compatible.

A light source consisting in a pulsed blue LED was installed in each optical module. We checked that it could illuminate other optical modules over the whole 90 m of the string where they were placed. This result gives confidence that a time calibration of the detector *in-situ* will be possible with optical beacons based on similar light sources.

Finally, signals coming from down-going muons shining Cherenkov light on the optical modules were recorded and used to reconstruct the zenith angle of the track. Comparison with Monte Carlo simulations show that the experimental angular distributions can be explained when the multimuons events are taken into account.

The deployment and recovery of the string showed that such a big and fragile equipment could be handled without breaking it. During deployment, two connectors were pulled which prevented us from using one of the optical modules and one of the hydrophones. The design and the deployment procedure of the 0.1 km^2 detector strings will be devised to minimise such risks.

6 Conclusions

The R&D phase of ANTARES has been completed after addressing most of the techniques required to build and operate an undersea detector and successfully deploying and operating a prototype string. A suitable site has been selected and its optical properties characterised. The construction and the deployment of the 0.1 km^2 will be completed in 2003.

In parallel, potential sites for a km^3 undersea detector will be studied and acoustic detection of high energy neutrino interaction will be evaluated.

References

1. see the ANTARES proposal on our web site http://antares.in2p3.fr/antares and also astro-ph/9907432
2. F. Feinstein Proc. of 26th ICRC **Salt Lake City, Utah, USA**, HE6.3.19 (1999)
3. P. Amram et al. Astroparticle Physics **13**, 127-136 (2000)
4. N. Palanque-Delabrouille Proc. of 26th ICRC **Salt Lake City, Utah, USA**, HE6.3.18 (1999)
5. A. Kouchner Proc. of Rencontres de Moriond, 1999