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ANTARES – R&D project for a multipurpose detector

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On behalf of the ANTARES collaboration

Over the last three years, the ANTARES collaboration had an intensive R&D activity for the construction of a deep-sea neutrino telescope. The site, the procedures and the performances of the proposed detector were evaluated. The deployment and the underwater electrical connections were tested successfully at 2400 m depth, in the Mediterranean Sea, near Toulon, in the proposed site for the first phase of the project. This phase consists in the deployment of a detector with an effective area of about 0.1 km^2 by 2002.

1. The ANTARES project

In 1996, a collaboration of particle physicists, astrophysicists and experts in marine technology was formed to build a deep sea neutrino telescope. A first phase of R&D finished in 1999, when the construction of a detector with an effective area of about 0.1 km^2 was approved.

The ANTARES scientific program [1] reflects the interdisciplinary nature of the collaboration. The main motivation comes from neutrino astronomy, since the detection of the cosmic neutrinos would lead to a better understanding of several astrophysical environments, from the supposed accelerators of the UHE cosmic rays, to high density regions, opaques to photons (astrophysical beam-dumps). The neutrinos would result from the charged pions produced by the interaction of accelerated protons with matter (pp) or radiation ($p\gamma$). Candidate sources of high energy neutrinos include X-ray binaries and supernova remnants, active galactic nuclei (AGN) and gamma-ray bursters (GRB).

Dark matter could be detected via high energy neutrinos if supersymmetric neutralinos account for (part of) the missing mass of the universe. Neutralinos would accumulate in the core of heavy bodies such as the earth, the sun or the center of the galaxy and their annihilation would lead to a constant flux of neutrinos, with an angular distribution depending on the neutralino mass.

For the study of the atmospheric neutrinos, ANTARES benefits from an oscillation baseline length of the order of the earth diameter. For the SuperKamiokande oscillation parameters ($\Delta m^2 = 3.5 \cdot 10^{-3}$ eV^2, $\sin^2\theta = 1$) [2], the first dip in the survival probability of the neutrinos crossing the earth occurs at 350 km/GeV, at the maximum of the ANTARES sensitivity.

Long term observations of the deep sea environment will be also pursued, being of particular interest for biologists and sea scientists.

2. Proposed detector

In the first phase of the project, 13 strings carring about 1000 photomultipliers (PMTs) in total will be deployed. The positions of the strings are randomized along a spiral, with a minimal spacing of about 60 m (Figure 1, detector top view).

On one string, the PMTs, housed in pressure resistent glass spheres are clusterized by three in a storey and oriented down-looking at 45° from the vertical. The design ensures a good efficiency for up-going tracks and only a marginal acceptance for the down going ones. In the same time, the overlap in the active solid angle for the PMTs in a cluster allows an event trigger based on local coincidences in a storey.

The spacing of the clusters along the string is of 8 m for the inner four strings, and 16 m for the outer nine. With 41 storeys in the dense strings and 21 on the sparse ones, the instru-

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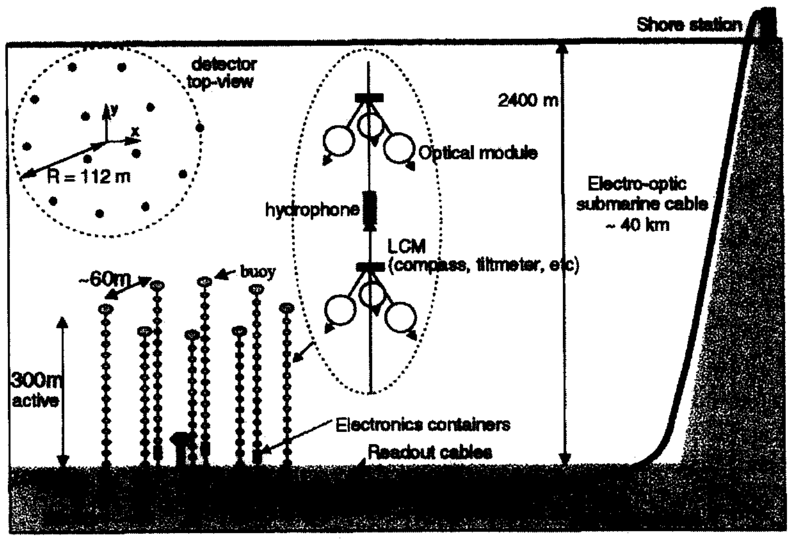

Figure 1. Schematic diagram of the first phase of the ANTARES detector.

mented height of the string is of 320 m. A 100 m of non-instrumented length is foreseen to the bottom of each string. The strings are flexible — the mechanical structure is ensured by an electromechanical cable.

On the same optical module frame, which supports the three optical modules, a special container houses a local control module (LCM), calibration equipment, a compass and a tiltmeter. In order to facilitate the data acquisition, about 6 LCM's are grouped together in a master LCM, which gathers all the information before sending it to the string control module (SCM), located at the bottom of the string. Electrical cables connect all the SCMs to a junction box, which is linked to the shore station by a standard deep sea telecommunications cable.

The off-shore trigger logic will be as simple as possible [1]. A first level trigger requires a coincidence of two of the three OMs serviced by a LCM. The second-level trigger will be based on a combination of first-level triggers. If a second-level trigger occurs, the full detector will be read out. The third level trigger will be made on shore. The first-level rate is estimated to about 150 kHz, and the second level rate to a few kHz. The third level should not pass over 100 Hz, to be recorded for off-line analysis.

In each optical module, an electronic board digitizes the PMT signals before storing them in a pipeline memory, which is read if a second level trigger occurs. A pulse shape discriminator selects single photo-electron pulses (99% of the overall PMT pulses) from more complex signals. In the first case, only the charge and the time information are stored, whereas in the second the full waveform is digitized.

2.1. Positioning

Of special importance for a neutrino telescope is the positioning of the detector. For neutrino source pointing, an absolute orientation with respect to the sky of about 0.2° is necessary. It will be obtained by triangulation of acoustical beacons (one at the bottom of each string) with the surface boat, coupled with DGPS. Supplementary ones will be distributed around the detector in order to have a precise positioning of the outer strings.

The precision of the PMTs relative positioning influences directly the angular resolution on the