RECENT PROGRESS OF THE ANTARES PROJECT

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The ANTARES collaboration aims to build, deploy and operate a high energy cosmic neutrino detector of large surface under the Mediterranean sea. The ANTARES design for a 0.1 km^2 high energy cosmic neutrino detector is briefly explained and some of the results recently obtained with a demonstrator string immersed at 1100 m are shortly reviewed.

1 Introduction

The interest of the detection and study of high energy neutrinos as cosmic messengers has been extensively discussed in the literature [1]. Neutrino telescopes use the Earth as a shield against atmospheric muons and take advantage of polar ice or sea and lake water as active media for the detection of the Cherenkov light produced by the neutrino-induced muons [2]. At present, two first-generation cosmic neutrino detectors are actually operating [3].

The ANTARES collaboration aims to build a high energy cosmic neutrino detector under the Mediterranean sea. To this end a series of deployments of instrumented strings have been carried out which have led to the measurement of the relevant environmental properties [4]. Subsequently, a suitable site (30 km off the coast of La Seyne sur Mer in Southern France) for the installation of a 0.1 km^2 detector has been selected. Furthermore, a detailed proposal for the construction and deployment of such a detector has been written [5]. In this note, we briefly describe the main features of the ANTARES proposal for a 0.1 km^2 detector and report on the latest progress made by our collaboration.

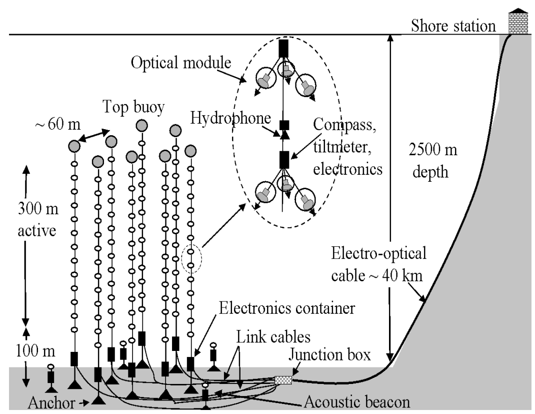

Figure 1. The ANTARES 0.1 km^2 detector concept.

2 The ANTARES detector design

A schematic drawing of the future ANTARES 0.1 km^2 detector is shown in figure 1. The detector consists of a total of 13 strings anchored to the sea bed and with the necessary buoyancy to stay taut. The horizontal separation between strings is around 60 m and their position on the sea bed follows approximately a spiral curve in order to avoid reconstruction ambiguities due to symmetries. The strings are in turn composed of storeys, whose main component are 3 optical modules. There are 30 storeys in each string, one every 12 m, starting 100 m above the sea bed. The optical modules in the storeys are pressure-resistant spheres housing one large-photocathode photomultiplier (PMT) and its associated electronics. Silicon gel is used to hold the PMT inside the optical module and to ensure a good optical coupling between the PMT and the sphere. The PMTs, which point downwards, have their axes making an angle of 45° with respect to the horizontal plane with their projections onto this plane being separated by 120°.

The string also contains several acoustic devices (rangemeters) which together with receivers on the sea bed (transponders) are able to determine accurately the profile of the string and the position of its components. A series of tiltmeters along the string completes the positioning system. A number of light sources along the string and in the optical modules act as well-known optical beacons in order to perform the time calibration of the detector.

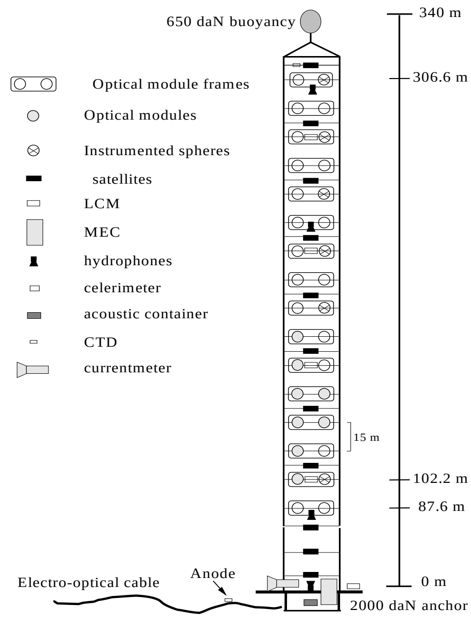

Figure 2. Schematic representation of the ANTARES demonstrator string.

3 Demonstrator string

In November 1999 a demonstrator string was immersed at a depth of around 1100 m in a site situated 37 km off the coast of Marseilles. This site (42° 59 N, 5° 17 E), different from the final ANTARES site, was chosen by virtue of its accesibility to a suitable electro-optical cable. The string (see figure 2) has a total length of 354 m and consists of 16 storeys, separated 14.6 m vertically from each other. Each storey has two 17” Benthos spheres, 1.5 m horizontally apart. Some of the spheres were instrumented: there were seven photomultipliers (six 8” and one 10”) and six tiltmeters. The string also contained another 11 tiltmeters (satellites in the figure), a system for acoustic positioning and some other measuring devices. Although it does not have the final design of the 0.1 km^2-detector string, the demonstrator string had many components in common with it and allowed a wide range of studies, such as the test of the deployment techniques of a full-scale string, the checking of the data retrieval through electro-optical cable, working experience on the positioning systems, recording of down-going muon events, etc.

3.1 Positioning systems

The string contained a total of 17 active tiltmeters (11 in the string spacers and 6 in Benthos spheres) which allowed to deduce the string shape and its movement in space. The string could be reconstructed as a straight line inclined at 2.5° to the vertical and with a negligible twist, headings being stable to within 2° over one week. The tilt of the string was stable to 0.2° over this same period. The reconstruction accuracy of this system alone was better than 10 cm in the horizontal coordinates and $\sim$1 cm in the vertical position.

In addition, an acoustic system of 3 rangemeters along the string and 4 acoustic transponders around its base was also available. The transponders were located on the sea floor at around 200 m from the string anchor. All these devices were able to emit and receive soundwaves (40–60 kHz) and measure their arrival time. A sound velocimeter with an accuracy better than 5 cm/s completed the set-up. Measurements were performed every 5 or 10 seconds. The distance between rangemeters or between transponders could be measured with residuals of the order of 1 cm. The 12 different transponder-rangemeter distances were simultaneously fit, giving residuals of the order of 5 cm, well within specifications.

3.2 Reconstructed events

More than 50000 coincidences in the seven photomultipliers were recorded. These coincidences are due to atmospheric (down-going) single and multiple muon events. Although with the information delivered by just one string the muon tracks cannot be reconstructed in space, a hyperbolic fit to the altitude versus time pattern of the hit PMTs allows the determination of their azimuthal angle.

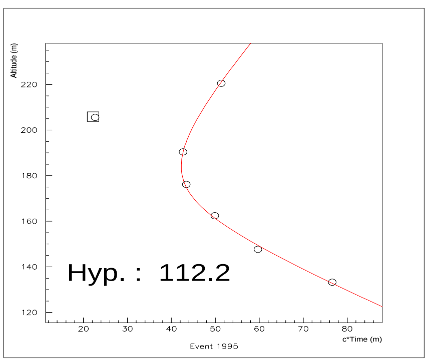

Figure 3. Example of reconstructed down-going muon with its hyperbolic fit superimposed. The boxed hit is due to ^{40}K.

An example of reconstructed track can be seen in figure 3. The value extracted for the azimuthal angle is given in the figure and the corresponding hyperbolic fit is shown superimposed. The hit in a box is most likely due to ^{40}K, identified as such by the reconstruction software and excluded from the fit. The distributions of timing residuals of all reconstructed events ($\sigma \sim 6$ ns) and of the azimuthal angle of the tracks are in agreement with the Monte Carlo expectations.

Conclusions

Important progress has been made by the ANTARES collaboration towards the installation of a cosmic neutrino telescope in the Mediterranean sea. A site with the appropiate characteristics has been selected, a variety of checks of the different components of such a detector have been performed and a proposal for a 0.1 km^2 detector has been put forward. Recently, a full-scale demonstrator string with some of the instrumentation to be employed in the final design has been deployed, operated and recovered. Extensive checks were made with this demonstrator string and very useful experience has been gained. Several tens of thousands atmospheric muon events were recorded and analysed.

The ANTARES collaboration aims to have 13 strings deployed by the end of 2003. This 0.1 km^2 detector will be a major step towards a 1 km^3 detector in the Mediterranean sea.

References

1. See for instance: F.Halzen, Phys. Rep. **333-334** (1-6) (2000) 349; T.K.Gaisser, F.Halzen and T.Stanev, Phys. Rep. **271** (5-6) (1996) 355, Phys. Rep. **258** (1995) 173
2. The idea dates back to the 60's, see: M.A. Markov in proceedings. *Proc.* ICHEP 60, Rochester (1960).
3. See for instance: BAIKAL: V.A. Balkanov, ICRC 99, Salt Lake City, USA, (1999); AMANDA: D.F. Cowen's, these
4. See for instance: P. Amram et al., Astr. Phys. **13** (2000) 127; N. Pallanque-Delabrouille, ICRC 99 *Proc.*, Salt Lake City, USA, (1999).
5. ANTARES proposal, astro-ph/9907432.