First results of the ANTARES neutrino telescope

J.D. Zornoza for the ANTARES collaboration
IFIC, Ed. Institutos de Investigacion, AC22085, CP46071, Valencia, Spain
E-mail: zornoza@ific.uv.es

Abstract.
The ANTARES neutrino telescope was completed in May 2008 with the installation of its twelfth detector line. The main goal of the experiment is the detection of high-energy neutrinos from extraterrestrial sources. Other searches, like neutralinos, are also possible. Since the connection of the first lines, the detector ANTARES has been providing data smoothly, enabling physics analyses. In this talk we describe the status of the operation of the telescope and its first results.

1. Introduction
Neutrino astronomy is an important tool to complement our knowledge of the universe at high energies. Up to now, most of the information about the cosmos comes from photons and cosmic rays. However, these “traditional” probes have significant drawbacks. On the one hand, they interact with radiation (infrared and cosmic microwave backgrounds) and matter, so their range is limited, in particular at high energies (the mean free range path is $\sim$10 kpc for PeV photons and $\sim$1 Mpc for ZeV protons). Moreover, cosmic rays are also deflected by galactic and extragalactic magnetic fields. On the other hand, neutrinos are neutral and only interact weakly, which means they are a unique probe to study the high-energy universe.

Neutrinos have been predicted in several astrophysical scenarios [1] and could help to explain the origin of cosmic rays. Moreover, they could also be the key to discriminate about the origin of the TeV gamma rays detected from several sources. In some of these sources, the observed gamma rays can be explained by leptonic mechanisms (where no neutrinos are produced) or from neutral pions produced by collisions of accelerated hadrons. In the latter case, neutrinos are expected.

The scientific goals of neutrino astronomy also include the search for dark matter. In particular, if neutralinos are the favored candidate to explain dark matter, they would accumulate in massive objects like the Sun or the Galactic Centre and annihilate. Among the indirect products of these annihilations, there would be neutrinos. This indirect detection is complementary to direct searches, since it would correspond to neutralinos with large masses (above several tens of GeV). Other studies like oscillations or monopoles are also possible.

2. Detector installation and operation
The ANTARES detector consists of a tri-dimensional array of about 900 photomultipliers (encapsulated in glass spheres called optical modules), distributed along 12 lines anchored at 2475 m in the Mediterranean Sea. It is located at (42° 48’N, 6° 10’E) at 40 km from the French city of Toulon. High energy neutrinos interacting with the water or rock near the detector can
produce relativistic muons which would induce the emission of Cherenkov light. The information of the position and time of the hits of this Cherenkov light in the photomultipliers allow the reconstruction of muon track. Above ≈10 TeV, the muon and neutrino trajectory are almost collinear.

The first detector line of ANTARES was installed in 2006. By the beginning of 2007, five lines were connected and providing data smoothly. The rest of the lines were installed in the following months, the detector being completed in May 2008 [2].

Several calibration systems are necessary in order to ensure the expected angular resolution (better than 0.3 degrees for neutrino energy above ≈10 TeV. First, the time calibration is performed by a high-precision clock which sends a common signal to the front-end electronics in the optical modules. This system is complemented by a set of blue LED beacons which allow to calculate the relative time offsets due to the photomultiplier transit times and the front-end electronics. This system allows a relative time calibration better than 1 ns. Second, an acoustic position system comprised by a set of hydrophones along the lines and in the surroundings of the detector allows to know the position of the optical modules with a precision of 20 cm.

There are two kinds of background in ANTARES. The so-called “optical background” refers to the light produced by the decay of potassium-40 and bioluminescence. The background from potassium-40, which yields a constant rate, is due to the Cherenkov emission induced by the relativistic electrons produced in its decay. There is also a constant contribution from bacteria and other microscopic organisms. In addition to this, there are bursts of bioluminescent produced by macroscopic organisms in the sea.

The other kind of background is produced by cosmic rays. The dominant source of this “physical background” is due to the atmospheric muons interacting with the Earth’s atmosphere. There is a second source of physical background which are the atmospheric neutrinos also produced in the cosmic rays interactions in the atmosphere. These neutrinos can traverse the Earth so they are also present when only up-going events are selected and cluster search methods have been developed to look for accumulations.

3. First results
The technical success of ANTARES has made possible the detection of millions of down-going atmospheric muons and hundreds of neutrino candidates in the first months of operation. In figure 3 (left), the distribution of the zenith angles of these data is shown, together with the Monte Carlo predictions. The sky-map with the equatorial coordinates of the upgoing neutrino candidates is shown in figure 3 (right).

![Figure 1](image-url)
Figure 2. Neutrino flux upper limits at 90% C.L. obtained by ANTARES with data of 2007, compared with the results from other experiments (IceCube, AMANDA, SuperKamiokande and MACRO). The sensitivity of ANTARES for one year with twelve lines is also shown (solid line). The source spectrum assumed in these results is $E^{-2}$.

The first analysis looking for point sources was made using 2007 data. As mentioned before, five lines were already deployed and connected. The expected angular resolution with this configuration and the selection cuts applied is better than 0.5 degrees (above 10 TeV). The active time corresponding to this selection criteria was 140 days. An cluster search method called “Expectation-Maximization” [3] was used in order to look for accumulation in the sky [4]. Two strategies were followed: a search within a list of 25 potential neutrino sources and a scan in the whole visible sky of ANTARES. None of these searches found any excess above the background. The corresponding flux upper limits are shown in figure 2. These limits are competitive with those set by previous multi-year experiments looking at the Southern Hemisphere.

4. Conclusions
The ANTARES collaboration completed in May 2008 the installation of the largest submarine neutrino telescope. Its final configuration comprises ~900 photomultipliers, but data taking has been taking place since the connection of the first line in 2006. The operation of the detector is successful and has allowed the first physics analysis. With the data corresponding to 2007, when five of the twelve lines were connected, the first search for point sources has been made. With these data, corresponding to 140 active days, flux limits for 25 candidate sources have been set, competitive with the results from other multi-year experiments looking at the Southern Hemisphere.

References
[1] Halzen F and Hooper D, Rep. Prog. Phys. 65 (2002) 1025.
[2] Carr J, for the ANTARES collaboration, J. Phys. Conf. Ser. 136 (2008) 022047.
[3] Aguilar J A and Hernandez-Rey J J, Astrop. Phys. 29 (2008), 117.
[4] Aguilar J A et al. (ANTARES collaboration) Search for cosmic neutrino point sources with the 5-line ANTARES telescope, Submitted to Journal of Physics G, preprint arXiv:0909.1262.