Status report on the ANTARES project

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The ANTARES collaboration is building a large neutrino telescope at a depth of 2500 m in the Mediterranean Sea. This detector will allow the search for high energy cosmic neutrinos from (extra-)galactic sources, for dark matter signatures like neutralinos captured in the Earth or the Sun, and the study of atmospheric neutrinos. The results of a new generation string sector, a junction box and a deep-sea cable deployed in the sea are reviewed. The strings to be deployed in 2005-2007 are under construction.

1. Introduction

Neutrinos are privileged tools to investigate high energy cosmic ray sources, since unlike gammas and protons they are essentially unaffected during their path through galactic or extragalactic distances. Nevertheless the smallness of their weak interaction cross section with matter imposes huge detecting volumes. Large underwater neutrino telescopes based on the detection of the products of either neutral (NC) or charged current (CC) reactions provide a unique way to study very high energy cosmic neutrinos, potentially above the GZK cutoff.

For instance, the signature of the CC reaction of a ν_μ relies on the detection of the Cherenkov light emitted by the secondary μ in the water. Practically, the detector consists of a large 3D PMT array, where the precise knowledge of the time, amplitude and position of the hits allow the reconstruction of the direction and the energy of the muon. This signal can be mimicked by atmospheric neutrinos and muons produced by cosmic rays in the atmosphere. Atmospheric muons are drastically reduced burrying the detector at a large depth under water and selecting only upgoing muons.

2. Antares design

The ANTARES project [1] gathers about 180 physicists, engineers and sea-science experts from 23 institutes of 7 European countries, with the aim of operating a "0.1 km^2" neutrino telescope located 20 km south of the French Porquerolles Island $(42°50'N, 6°10'E)$ at a depth of 2500m.

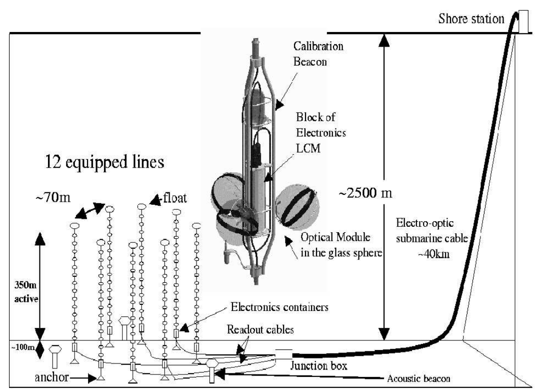

Figure 1. Scheme of the Antares detector with a blow-up of a storey.

The total sky coverage is 3.5π sr, with an instantaneous overlap of 0.5π sr with that of AMANDA, and allows the observation of the Galactic Centre 67% of the day. Intense $R\&D$ programme since 1996 allowed the full characterization of the site, which was found to fulfill the criteria of good water transparency ($\lambda_{abs}(blue) \sim 60m$ [2]), low water current ($\sim 6cm.s^{-1}$) and limited biofouling (less than 1.5% transmission loss for down-looking optical modules in one year [3]).

The detector (Fig 1) consists of 12 lines arranged in an octogonal shape with a spacing about 70m in between lines. 25 storeys are spread over 350m, starting 100m above the anchor at the sea-bed, and a buoy on top ensures that the line is vertical. Lines are deployed individually, and therefore require underwater connection to a junction box with the help of either manned or remote control submarines. The junction box itself is connected to the shore station by a 40 km long electro-optical cable.

The expected performances of such a detector have been estimated by Monte-Carlo simulations. The angular resolution, which is a crucial point for the search of point-like sources, is dominated by the CC kinematics for energies below 10 TeV, and limited above 10 TeV by both the photo multiplier transit time spread and the diffusion of light in water. Its median has a limiting value of 0.2°. The muon energy is obtained from the total amount of emitted light, with a resolution of about a factor 3 for energies above 10 TeV.

The basic detector element is the storey, comprising 3 Optical Modules (OM) [4] housing Photo Multiplier tubes (PM) looking downwards at 45° from the vertical, and the associated electronics in the titanium cylinder of a Local Control Module (LCM). The 900 PM (10" R7081-20 from Hamamatsu) have been fully characterized to work below the photo-electron level, with a mean transit time spread of about 2.7 ns. The PMs are currently being mounted in the OMs. All electronic boards of the LCM have been designed and are at the (pre-)production level. The storeys of one line are chained on a mechanical electro optical cable which carries the power, the 20 MHz common clock, and the Data up to a rate of 1Gb/s.

The DAQ system was foreseen to include up to 4 trigger levels. Data are buffered when the hit amplitude exceeds the level-0 threshold, around 1/4 photo-electron. The resulting rate is about 60 kHz per optical module, coming about equally from ^{40}K activity in the water and bioluminescence. This rate can be reduced by a few orders of magnitude using a local level-1 coincidence between optical modules of the same storey. A further reduction by a level-2 coincidence involving different storeys or lines is not currently implemented in the design. The final reduction by level-3 is done on shore, running matching algorithms on a dedicated PC farm.

3. Latest sea campaigns

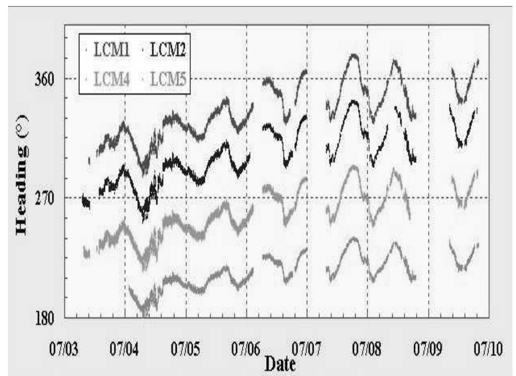

Figure 2. Heading from compass of storeys 1,2,4,5 of the PSL vs time in July 2003. Curves have been offset for clarity.

The tests performed at a depth of 1100m in 1999 with a 'demonstrator string' allowed to validate the reconstruction of muon tracks from hits of 7 PMTs, together with the calibration of the timing and position given with the help of an acoustic positioning system. The last milestone was the validation of the final line design on the final ANTARES site. The choice was to immerse the shortest line element, namely a 'sector' consisting of 5 storeys which will be called here Preproduction Sector Line (PSL). In the meantime, some crucial elements of the final detector were deployed : the main electro-optical cable to the shore drawn from the shore station to the site in October 2001, its end being recovered from the sea-bed in December 2002 to be connected to the final junction box which was then installed under water. The PSL was deployed in 2002 as well, but the connection to the JB occured only in March 2003 when the 'Nautile' submarine became available after his unforeseen campaign on the 'Prestige' in Spain. A 'mini instrumentation line' (MIL) deployed in February 2003 and comprising LED, laser beacons and various probes to measure the water salinity, temperature, sound velicity, sea currents, was connected at the same time. The communication with both lines was established immediately after connection, and the systems were found to be functional and under control from the remote shore station. Large amount of data could be recorded until the recovery of the MIL in May 2003 and of the PSL in July 2003.

Each storey being equiped with a compass, it was possible to monitor the orientation of the line. Figure 2 shows the heading of 4 storeys as a function of time. The observed correlation is linked as well to the current velocity which was evolving from 3 to 8 $cm.s^{-1}$. The tiltmeter showed a maximum of 1° with respect to the vertical, with an average value of 0.2°. The conclusions which can be drawn from these observations are that the line reacts as a solid in the sea current, and that it is essentially vertical.

There was a failure in the fiber transmitting the common clock from the bottom of the line to the storeys, which was traced back after recovery to a collapse of a plastic tube around the fiber. As a result, data from different OMs could not be timed with the required accuracy to allow the reconstruction of muon tracks, and data from the acoustic positioning system couldn't be used either. Nevertheless the counting rates of all OMs were recorded all along the 100 days of running, for instance figure 3 shows the baseline rate and the burst fraction of the 3 OMs of the first storey.

It can be seen that for entire weeks the baseline rate was above 200kHz, and then back to the standard 60kHz. This effect is thought to come from bioluminescence and is somewhat linked to the observed sea currents. It was checked with an autonomous line that it was not an artefact due to drifts of any component of the detector.

A second failure occured on the MIL one month after immersion : a water leak developped in an electronic container, leading to a short circuit in the power supply of the line and a complete loss of communication. The post-recovery analysis

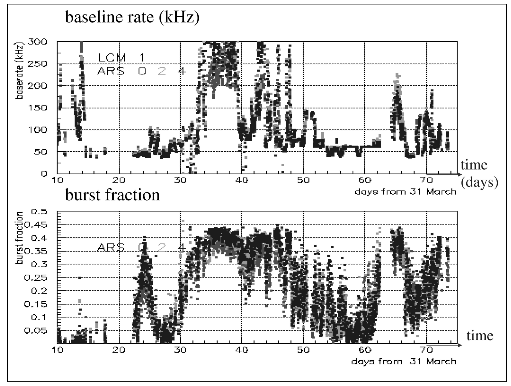

Figure 3. Top : PMT baseline rate averaged over 15 minutes, bottom : fraction of time the rate exceeds the baseline by more than 20%.

pointed to a misunderstanding with the manufacturer, leading to a bad usage of the water-tight connectors.

The design was modified accordindly, so as to avoid such problems in future.

4. Summary and outlook

With the successful deployments, submarine connections, data taking, the PSL and MIL operation allowed to validate the detector design and concepts. The problems encountered are now corrected, and the final cable and junction box are now waiting for the full detector which will be deployed by 2007.

REFERENCES

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