ANTARES: status report

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The ANTARES collaboration aims at the construction of a large underwater neutrino telescope to be deployed in the Mediterranean Sea by 2500 m depth, 40 km off the coast, near Toulon (France). The detector consists in a 3-D array of photo-multiplier tubes to detect the Čerenkov light emitted in sea water by muons produced by the charged interaction of neutrinos in the surrounding matter. The R&D phase of the project comes to a conclusion with the deployments of a subset of a vertical string (December 2002) and of a line equipped with instrumentation for environmental monitoring (February 2003), and with the submarine connections of both lines to the already installed electro-optical cable (March 2003). In this contribution, after a description of the detector, we will go through the main steps leading to the first operation of the detector. Results from the 100 day operation will also be presented.

1. THE ANTARES NEUTRINO TELESCOPE

The goal of the European collaboration ANTARES [1] is the construction of a submarine detector dedicated to the study of high-energy neutrinos (E $\geq$ 10 GeV). The aimed research domains are the search for galactic or extra-galactic neutrino sources, the search for dark matter and the study of neutrino oscillations.

Neutrinos will be detected through their interaction in the matter surrounding the detector, producing muons radiating Cerenkov light while propagating in the sea water. The photons illuminate a 3-D array of light sensors with timing capabilities allowing the reconstruction of the muon path.

In the ANTARES detector, the light sensors are the optical modules (OM) [2]: a pressure resistant glass sphere housing an hemi-spherical photomutiplier (10” diameter), its base and a pulsed LED for timing monitoring. The OM’s, looking downwards at 45°, are mounted in triplet on a titanium frame, which supports also a cylindrical titanium container (LCM) housing the local electronics. This ensemble composes a storey. A chain of 25 storeys, linked by cables 14.5 metre long cable, and ended at the bottom by an anchor, 100 metres below the lower storey, and at the top by a submersed buoy, compose a line. The total height of such a line is about 450 m. On top of the mechanical function, the cables set up the optical and electrical connections between storeys.

The ANTARES detector will consist of 12 such lines, separated by 70 m, arranged in an octagonal geometry. All the lines are connected from the anchors to a junction box, which in turn is connected to the shore station by mean of an electro-optical cable (40 km long).

The equipment of some storeys is completed with hydrophones – for line shape reconstruction and positioning purposes – and pulsed light sources (LED beacons) – for timing calibration purposes.

The selected site is in the Mediterranean Sea (42°50’N, 6°10’E), in front of Toulon (France), at a depth of 2500 m.

The choices for the geometrical parameters of the lines have been guided by the results of the measurements performed on water transparency [3], sedimentation [4], water current and optical background [5]. As the variations of these water properties will influence the performances of the detector, a special line equipped with instruments measuring the environmental parameters will be part of the ANTARES detector. Furthermore, this instrumented line will be a facility for long-term observations in oceanography, sea biology, seismology…

2. THE PROTOTYPE LINES

Before launching the mass production of the lines elements, the collaboration ANTARES has decided to build and to deploy two prototypes of the final lines.

2.1 *The Pre-production Sector Line (PSL)*

In the ANTARES lines, the minimal functional unit, in terms of power supply and data transmission, is a set of 5 consecutive storeys (sector). Hence, the minimal layout for a prototype line is composed of an anchor, a buoy and a sector (PSL).

2.2 *The Mini-Instrumentation Line (MIL)*

The MIL is equipped with the minimal set of instruments necessary to record the variations of the environmental parameters:

- Current profiler, to measure the current velocity and direction along the water column, over a height of 120 m.
- Sound velocimeter, to measure the essential parameter needed for acoustic measurement and line shape reconstruction
- Transmissiometer, to follow the variations of the water optical properties.
- Acoustic transceiver for the positioning of the line.
- Conductivity and temperature probes.

In addition, the devices for the timing calibration of the detection lines, i.e. laser and LED beacons, are also implemented.

3. THE SETTING-UP

3.1 *Lines integration and preparation*

Given the very poor accessibility of the detector when installed, special care must be taken during the assembly of the lines. In order to reach a high level of reliability, procedures have been elaborated to describe extensively the mounting operations and the tests to be performed at each step of the assembly. The integration of the prototype lines was an opportunity to review, and to improve, these procedures.

The last step for a sector is the timing calibration, performed in a dedicated dark room. This facility is equipped with a laser source and a network of optical fibres used to send synchronously light pulses to the OM's. The measurements performed have confirmed the capability of the system to be calibrated in order to obtain a time resolution of 1.5 ns, and an accuracy on the synchronisation between channels smaller than 1 ns.

3.2 *Sea operations*

Prior to obtain the first data, a series of complex and delicate marine operations has been realised.

In October 2001, the 40 km long main electro-optical cable (MEOC) has been deployed between the ANTARES site and the shore station. The 9th of December 2002, the junction box was installed and connected to the MEOC. Then, in December 2002 and February 2003, the two prototype lines were deployed and positioned on sea bed within a few meters with respect to their nominal positions. At last, in two dives, the 16th and 17th of March 2003, the Nautile, a manned submarine from IFREMER, established the interconnections between both lines and the junction box.

This sequence of successful sea operations has been perfected with the recovery of the 2 lines in May and July 2003.

3.3 *Data acquisition system*

The analogue signal of the PMT's is locally (i.e. in the LCM) discriminated, time stamped and the charge is converted by an ASIC called the ARS*. In this full custom chip is also implemented a pipe-line

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* ARS : Analogue Ring Sampler.

memory used to keep data waiting for high level trigger. Furthermore, in case of large signals or complex shape, the ARS acts as a flash ADC (up to 1 GHz sampling). In order to reduce the dead time, each PMT is connected to 2 ARS's, active alternately.

In each LCM, the data acquisition, the data flow and the slow control messages are controlled by a RISC microprocessor. It has an Ethernet port coupled to an optical transceiver. Each LCM behaves like an Ethernet node, exchanging information in accordance with the TCP/IP protocol. Indeed, the full detector can be viewed as an Ethernet network, using standard communication technologies developed for high speed optical transmission.

The remaining part of the data treatment (counting, filtering, event building, etc…), is done at the shore station by a farm of PC's. They also provide the remote control and the monitoring of the junction box and of the lines.

4. RESULTS

In about 100 days of running time, a large amount of data (~ 130 Gb) has been recorded. From these data, optical modules counting rates and line behaviour can be extracted.

4.1 *Line movements*

The tiltmeters and the compass situated in each LCM give the inclination of the storey with respect to the vertical and the orientation with respect to the magnetic North. The main conclusions from these measurements are:

- In average, the line is close to the vertical.
- The maximum tilt observed is 1°.
- The storeys rotate coherently: the line reacts as a solid (Figure 1).

4.2 *Counting rates*

A failure in the clock transmission has not allowed the data taking at nanosecond precision level. Nevertheless, the counting rates of OM's give relevant information on the optical background. Figure 2. illustrates the behaviour of the counting

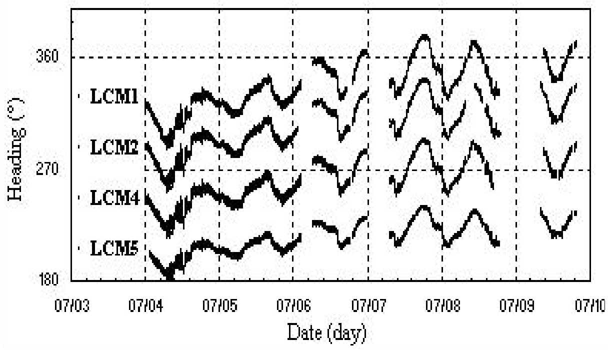

Figure 1. Time evolution of the orientation of the storeys. For the clarity of the plot, for each LCM an arbitrary offset has been added to true heading values.

rates on the 3 OM's of a storey. It shows large and short-lived peaks, due to bioluminescent living species, over a base line coming from -decay of K^{40} and from bacteria[5]. In this example the level of the base line is close to 60 kHz. Indeed it varies slowly (time constant of several hours) but strongly, and can reach values around 200 kHz. Correlations with the sea currents have been observed.

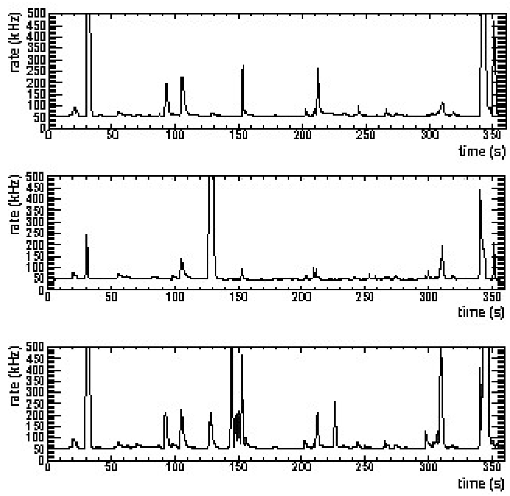

Figure 2. Time evolution over a 5 min window of the counting rate of the 3 OM's of one storey. In this example, the continuous optical background (bacteria + radioactivity from K^{40}) is around 60 kHz. One sees also high peaks, sometimes correlated between the 3 OM's, due to bioluminescence bursts.

5. CONCLUSIONS

With the successful deployments, submarine connections and recoveries of these two lines, ANTARES has passed a major turning point.

Both prototype lines have proved to be operational in real data taking conditions: the data acquisition system has demonstrated its capability to cope with high rates of events, and the remote control of the lines was fully functional.

The observed failures need only minor modifications which do not call into question the general design of the detector.

For the coming months, the objectives of Antares are the re-deployment of the PSL with a new electro-mechanical cable, the deployment of an improved instrumentation line and the launching of the mass production of the lines elements.

The completion of the detector with 12 lines is scheduled for 2007.

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