Toward the ANTARES Neutrino Telescope: Results from a Prototype Line

Marco Circella,[1] for the ANTARES Collaboration
(1) Istituto Nazionale di Fisica Nucleare, INFN - Sezione di Bari, via Amendola 173, 70126 Bari, Italy

Abstract

The ANTARES Collaboration is constructing a neutrino telescope to be operated at large depth in the Mediterranean Sea. As a qualification step before the deployment of the full-size detector, the Collaboration has constructed a final-design prototype line, which was successfully deployed in December 2002. In February 2003 a second prototype line equipped with instrumentation for environmental measurements was also deployed. Both lines were put into operation since March 2003, when they were successfully connected to the already deployed ANTARES electro-optical cable. In this contribution we illustrate the major highlights from this prototyping effort: integration of the two lines, calibration in the laboratory, marine and submarine operations, first results from the measurements collected underwater.

1. Introduction - The ANTARES Detector

The ANTARES Collaboration aims at the construction of a neutrino telescope to be operated in the Mediterranean Sea. The selected site is located at about 40 km off the coast of Toulon, France at a depth of 2400 m. The detector will comprise 12 lines equipped with optical modules for reconstruction of physics events and one line instrumented with devices for environmental measurements. The status of the ANTARES project is illustrated in more details elsewhere at this Conference [1].

As a qualification step before the construction of the full-size detector, the Collaboration has built and deployed two prototype lines, one equipped with optical modules and final-design acquisition electronics, the other one equipped with devices for environmental measurements. Both lines were put into operation in March 2003, when they were connected to the shore station through the already installed long-distance electro-optical cable and its junction box, deployed in December 2002. Ref. [1] includes a map of the ANTARES installation site, with the positions of the two protoype lines marked.

The aim of this prototyping effort is manifold: to qualify the detector design and its integration procedures, to assess the reliability of the marine and submarine operations, respectively for deployment/recovery of the lines and for connection to the long-distance electro-optical cable, to monitor the functionality

pp. 1529–1532

of the lines over a prolonged operation period, to complete the characterization of the detector site by means of extended measurements of environmental parameters and of the background pulse rates on the optical modules.

2. The Prototype Lines

The prototype detection line comprises 5 storeys, each equipped with a triplet of optical modules and an electronics container for data acquisition and control. These 5 storeys constitute together the basic functional element of the ANTARES lines, a sector: a full-size line will consist of 5 of such sectors.

The storeys are connected by means of an electro-mechanical cable which carries 21 optical fibres for communications and 9 conductors for power distribution. The lowest storey is at a height of 100 m above the sea bed, the distance between consecutive storeys being of 12 m. The line is anchored to the sea bed and kept vertical and taut by means of a submersed buoy.

The mechanical and electronics solutions implemented for the prototype line are as close as possible to the final design of the full-size lines. In particular, the data communication system exploits the Dense Wavelength Division Multiplexing (DWDM) technique, at 400 GHz spacing. The DWDM solution allows the transmission of data and slow-control commands for the full prototype line to take place over the same optical fibre. This same design will be used for data communications with the future ANTARES lines.

Calibration and monitoring devices have been located on the prototype line as follows: the top and bottom storeys are equipped with hydrophones for acoustic triangulation measurements needed for determining the positions of the optical modules; the second storey from the bottom is equipped with a LED beacon for time calibration purposes; at the anchor of the line are located a sound velocimeter and a pressure sensor as well as an acoustic transceiver for the acoustic triangulation measurements.

The prototype of the instrumentation line is equipped with the following devices: a seismometer, an acoustic transceiver and a hydrophone for acoustic triangulation measurements, a laser and a LED beacons to be used for time calibration of the optical modules of the prototype detection line, a pressure sensor, a sound velocimeter, an acoustic Doppler current profiler, a combined conductivity-temperature-density meter, a deep-sea light transmissometer. These devices are properly located at the anchor of the line and in two detection storeys at heights of 100 and 200 m above the sea bed.

3. Integration of the Prototype Lines - Onshore Calibration

The construction of the two prototype lines has represented a major opportunity to study in detail the procedures necessary for a reliable integration and qualification of the future ANTARES lines. The integration facilities developped for this purpose include a test dark room equipped for a full functional test and onshore calibration of the lines before deployment.

This test room, which can be used for testing a complete sector of a line, is equipped with a flashing system consisting of a laser source and an optical fibre distribution network to deliver optical pulses simultaneously to each optical module. In this way it is possible to check the time alignment of the optical module measurements as well as to measure the time resolution of each channel. A LED system is also provided for flashing the optical modules at the rates expected in the sea from ^{40}K and bioluminescence background as well as for simulating the light signals expected from muon tracks. Therefore it is also possible to check the complete functionality of the line in realistic data taking conditions and to determine its capability in muon detection.

The dark room calibrations confirm a time resolution of about 1.5 ns (essentially established by the transit time spread of the optical modules) when illuminating at the single photoelectron level, and a sub-nanosecond accuracy on the synchronization of the different channels.

4. Marine and Submarine Operations

Surely, one of the most significant successes of this prototyping effort was the validation of the marine and submarine operations for deployment and connection of the prototype lines. The deployment operations followed the procedure tested during a deployment and recovery rehearsal performed in December 2001. The sea conditions on the 21st December 2002 and 12th February 2003 were very quiet and allowed smooth deployment operations for the two prototype lines.

The connection of the lines to the junction box was performed by means of the Nautile manned submersible of the French IFREMER oceanographic research agency during two dives in March 16-17, 2003. During each of these operations, first a 350 m spool of electro-optical interlink cable was deployed from the Nautile service ship l'Atalante and positioned on the sea bed at a short distance from the junction box. Next, Nautile was deployed to plug the wet-mateable connector of the interlink cable to the junction box. It then moved the cable spool toward the line to connect, unwinding the cable on the sea floor. Finally, it plugged the other end of the cable to the base of the line. Therefore, a total of four successful submarine connections were performed to connect the two prototype lines.

The receptacle for the interlink cable is fixed to the dead-weight of the anchor of each line. During the recovery phase, the line will get automatically disconnected from the interlink cable, which will remain on site. Dampers are provided on the line anchor to ensure that the connector is disengaged in safety velocity conditions. In this way, it will be possible to re-use the two immersed cables for connecting future lines.

5. Underwater Measurements

Environmental measurements from the prototype instrumentation line have been performed. The measurements from the compasses and tiltmeters have been used to monitor the movements of the lines. Counting rate measurements from the optical modules are being acquired. A sample of these data is shown for illustration in Fig. 1.

All these data will contribute to further characterize the installation site of the detector, in addition to the extensive site surveys conducted in the past. Furthermore, this experience represents an invaluable validation of the acquisition system and remote control of the lines in real data taking conditions.

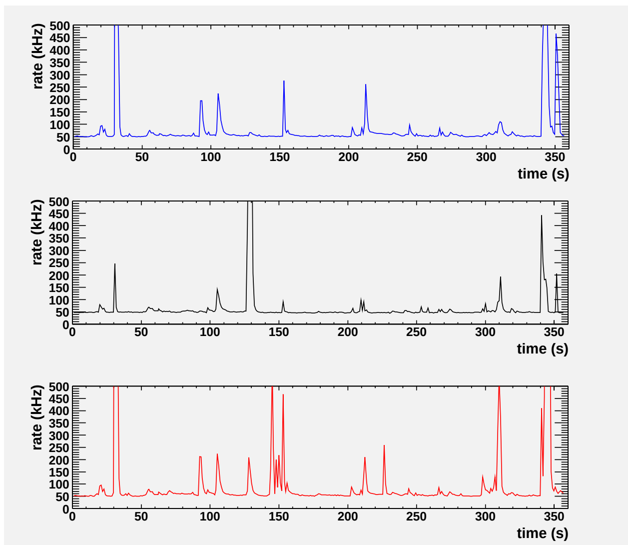

Fig. 1. Counting rate on the three optical modules of one storey of the prototype line, measured in a 360 s time window. Correlated peaks due to bioluminescence bursts may be noticed over a baseline that amounts, in this time window, to about 60 kHz. The threshold level is of 0.3 photoelectrons.

6. Conclusions

The large prototyping effort described in this note is proceeding with very positive results. The integration, the onshore test and calibration of the two lines, the deployment and submarine connection operations have been completely successful. Both lines have proved to be operational in real data taking conditions, and valuable data have been collected so far. By the time that the Conference will take place, both lines will have been recovered and the prototype effort completed with the planned post-recovery inspections. To date, this whole experience constitutes a major validation of the overall design of the detector and its implementation. The deployment of the first ANTARES lines is planned for next year.

7. References

1. Montaruli T. (for the ANTARES Collaboration), *ANTARES Status Report*, talk presented at this Conference