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News from the ANTARES underwater neutrino telescope

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Abstract

The ANTARES telescope is a device of 0.1 km^2 size to detect high energy neutrinos. It is located in the Mediterranean Sea at a depth of 2500 m. It consists of a three-dimensional matrix of optical modules (OM) containing photomultiplier tubes. As of September 2006 two complete lines and an instrumentation line, called MILOM, are deployed and fully operational for data taking. Three additional lines have been connected by the end of January 2007 allowing the first up-going muon track reconstruction. At the beginning of 2008, the full Antares telescope will be operational with 12 lines. All technical aspects are under control from the mechanical architecture to the constant improvement of the "all-data-to-shore" concept. This talk will focus on the photon signal processing that allows to reconstruct the neutrino track. After a first review of the line architecture, we will present the signal processing and transport from the OM detector to the on-shore storage. During the R&D phases, the ANTARES collaboration has developed new concepts in terms of detector integration, front-end electronics architecture, cables, DAQ hardware architecture and software management. Finally, preliminary results of the performance of the detector will be shown.

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Keywords: Neutrino; Muon; Photomultiplier; Optical module; ASIC; Frontend electronic; DAQ; Network; Real-time; Hardware; Software

1. Introduction

The ANTARES collaboration is deploying an undersea neutrino telescope at a site located 40 km south of Toulon (France) at a depth of 2500 m. It consists of an array of optical modules. When completed, it will allow sky coverage of 3.5π sr, with 1.5π sr overlap with the AMANDA neutrino telescope. The scientific aims are the exploration of high-energy phenomena in astrophysical objects, the study of topological defects in the universe, and the search for neutrinos produced in the annihilation processes of neutralinos captured at the center of the Earth or in the Sun.

The ANTARES neutrino telescope uses the detection of upward-going muons as a signature of muon neutrino interactions in the matter (the Earth) below the detector. Muons emit Cherenkov light as they pass through the sea water medium. The light detected by 900 optical modules (OMs) housing photomultiplier tubes (PMTs) oriented at an angle of 45° below the horizontal plane allows the reconstruction of the incoming track. The OMs are distributed along 12 detection lines; each line consists of 25 storeys with three OMs per storey and a titanium container housing the local electronics. To reconstruct the muon track and energy deposition and hence the parent neutrino direction and energy, it is necessary to measure the arrival time and charge of the photons detected by the PMT. An ASIC called ARS1 processes the analogue PMT signals and digitizes them. The position is given by an acoustic system and a system of compasses and tiltmeters along the lines. They are read out with a slow-control system.

All digital information coming from the 12 detection lines is transmitted to the shore via a DAQ system consisting of a network of 300 processors connected via a single electro-optical cable. The on-shore processors filter the data to select physical events from the background noise (Fig. 1). The different components of this system are described below.

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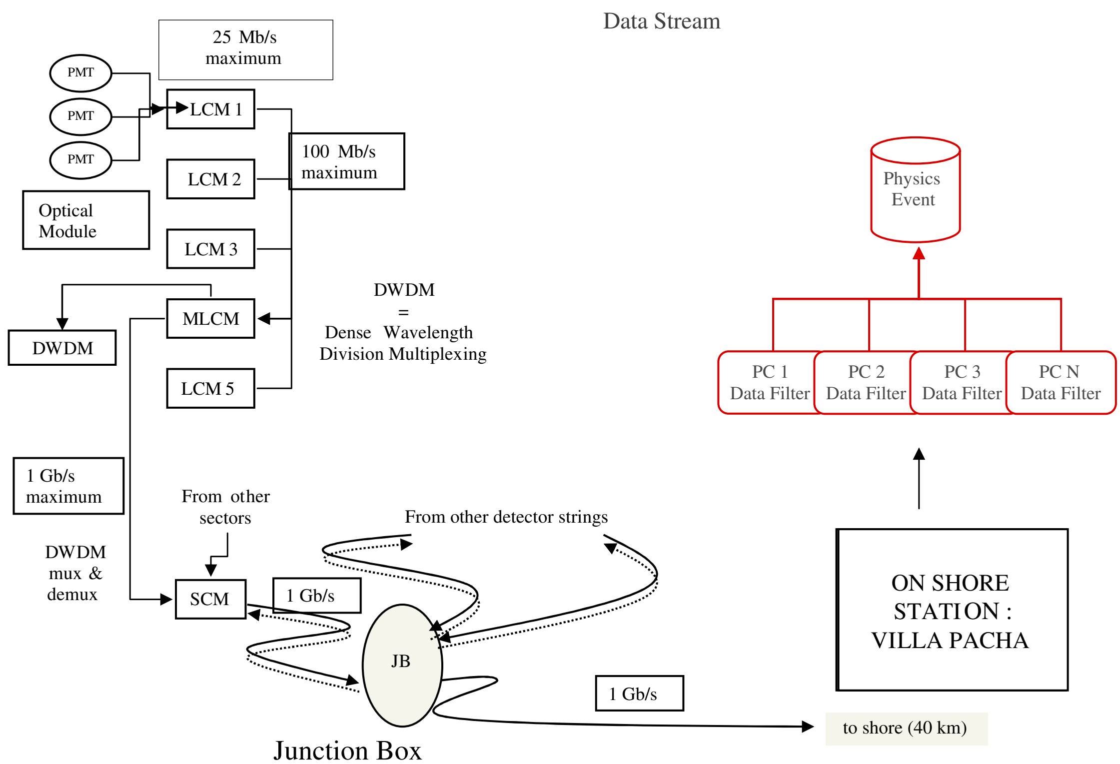

Fig. 1. Scheme of the Data Stream illustrating the all-data-to-shore concept.

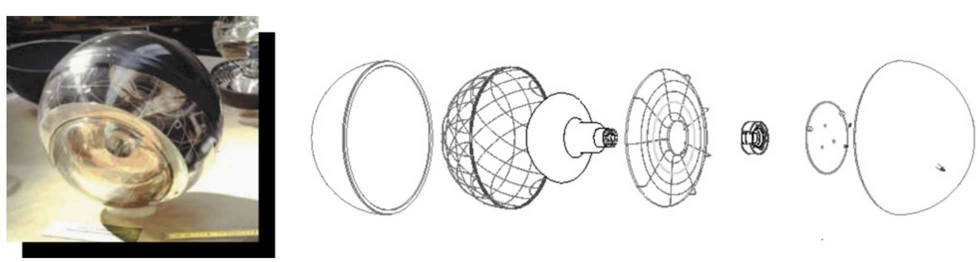

Fig. 2. Picture (left) and blow-up (right) of an Optical Module.

2. Optical module

The detection of high-energy neutrinos together with the expected background sources imposes particular constraints on the design of the optical module. It must optimize the light detection. It must withstand the pressure up to a depth of 2400 m and also different environmental conditions like corrosion, vibration, exposure to sunlight, etc. 1000 optical modules, consisting of a PMT from Hamamatsu (selected after a dedicated R&D phase) and its electronics, a glass sphere, a magnetic shielding and optical gel, have been produced at Saclay [1] (see Fig. 2). The gain of each PMT is about 5×10^7. This means that a single photoelectron produces 45 mV in a 50 Ω output resistance.

3. Front-end electronics

An ARS circuit (Fig. 3) is connected to the output of each OM. It records all the pulses coming from the PMT. Because of the detector size and the length of the optical link to the shore, electric signals cannot be transmitted analogically: the ARS processes the analogue PMT signals and digitizes them.

The circuit operation is based on two principles:

(1) Discrimination between single photoelectrons (SPE), when the OM is hit by one photon, and complex ("waveform") signals, when the OM signal is different from the one for a single photoelectron.
(2) Measurement of the charge and the arrival time of the event; also, for "waveform" event types, the ARS samples the signal at high speed and digitizes it in up to four channels. Two channels are dedicated to anode and clock signals, the remaining two help to record the anode signal reduced by a factor of five and also to store the signal of dynode 12 of the PMT.