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Test of a multi-PMT digital optical module on the ANTARES site

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Abstract: KM3NeT will be a multi-cubic-kilometer neutrino telescope, to be deployed in the near future in the Mediterranean Sea. The KM3NeT design is based on the previous experience of the ANTARES, NEMO and NESTOR projects, and brings many innovative solutions, amongst which is the concept of a digital multi PMT optical module. We intend to soon test a prototype of such a module at the ANTARES site. We report on the technical aspects of the integration of a multi PMT optical module for evaluation within the operating ANTARES deep-sea infrastructure and discuss the status of the KM3NeT project.

Keywords: Neutrino telescopes, KM3NeT, ANTARES, multi-PMT optical module, background measurements

1 Introduction

Neutrino astronomy, the missing link in reaching the multi-messenger astronomy goal, justifies the efforts to build very large volume neutrino telescopes in both Earth hemispheres. Today there are two such instruments: IceCube, at the South Pole – with an instrumented volume approaching one cubic kilometer - and a smaller one in the Mediterranean Sea, ANTARES. KM3NeT will be the next very large volume neutrino telescope (about 6 km^3) in the Mediterranean Sea, with the main role to search for neutrino point sources in the Southern sky, including the Galactic Plane. The E.U. FP6-funded KM3NeT Design Study has been completed with the publication of a conceptual design report [1] and a technical design report [2]. The E.U. FP7-funded Preparatory Phase will end in February 2012. The next step is the construction and deployment of a prototype of a full size KM3NeT detection unit, with only the two uppermost of the 20 storeys active. KM3NeT will implement various innovative solutions with respect to its predecessors, among them the multi-photomultiplier Digital Optical Module (DOM). We report on our intention to deploy a hybridized optical module which can operate with the existing ANTARES readout system, and discuss the reasons and means to do that.

2 KM3NeT optical modules and layout.

Neutrino telescopes are designed to detect the Cherenkov light emitted by relativistic charged particles (muons) in water or ice. The common choice is to use large photomultipliers (PMTs), each one in its own optical module (OM). As an example, Fig. 1 shows a detail of part of an ANTARES line. Three "storeys" are visible. Each storey is

Figure 1. An image of ANTARES OMs mounted on 3 storeys. The large PMTs are visible inside the glass spheres. The LCMs (the cylinders) are also visible.

made of 3 OMs, each containing a 10” PMT, and a Local Control Module (LCM) housing the electronics.
The KM3NeT structure will be completely different. Each DOM (Digital Optical Module) will house 31 3” PMTs, the calibration instrumentation and all acquisition electronics [3], all inside a 17” pressure glass sphere. Furthermore, the PMT signals will be digitized inside the PMT bases (developed by NIKHEF, Amsterdam) [4, 5]. Fig. 2 shows a prototype of a KM3NeT digital optical module.

Figure 2. View of a KM3NeT prototype DOM.

The multi PMT digital optical modules will be mounted on 6 meter long bars (the equivalent of the ANTARES storeys), as shown in Fig. 3.

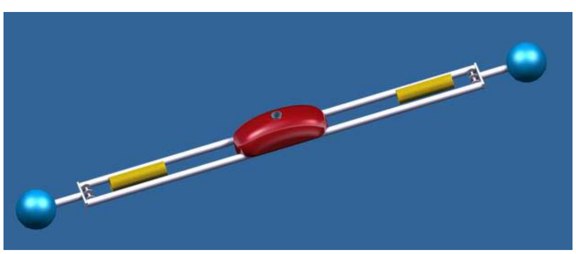

Figure 3. The final design of a KM3NeT bar, supporting 2 DOMs; also showing the central syntactic foam buoyancy device and cable spools.

Each “detector unit” (DU) consists in a flexible tower of 880 m height, made of 20 bars (storeys) with 40 m space between them. Each bar will be oriented perpendicular to its neighbors. Fig. 4 suggests the KM3NeT DU geometry.
The detection units will be grouped in “building blocks”. A building block will represent about one third of the full detector. A possible footprint of such a building block is presented in Fig. 5. This is one of the layouts under investigation, the final choice is due in the near future.

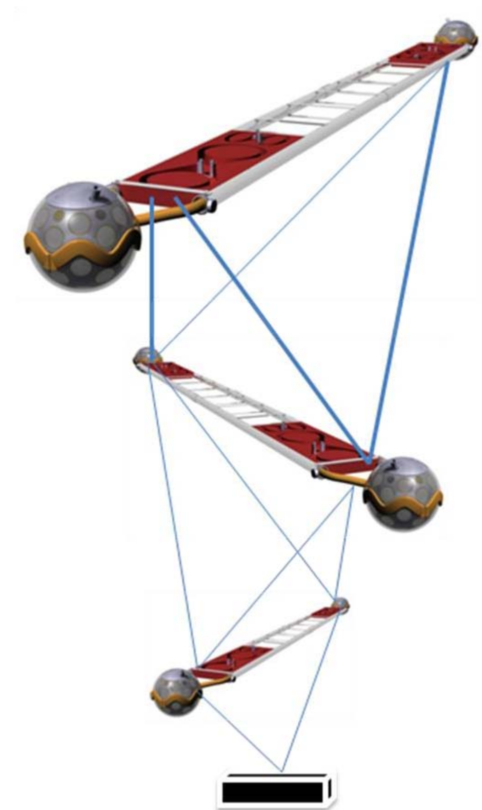

Figure 4. A sketch (not in scale) showing the orthogonal layout of a KM3NeT DU. Only 3 of the 20 storeys (in an intermediate design) are represented.

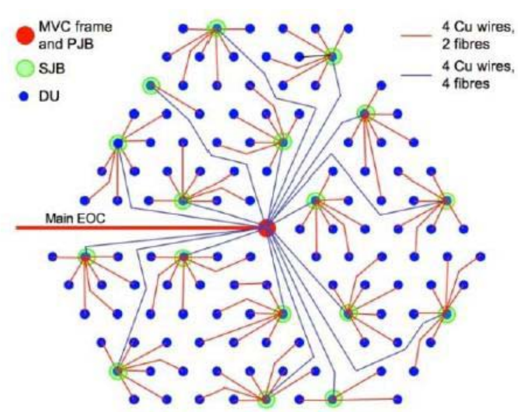

Figure 5. A possible layout of a building block. The primary junction box (PJB) is at the center of the structure, and secondary JBs (SJBs) are distributed in a star geometry. 7 DUs are connected to each SJB. The main electro – optical cable (EOC) connecting the building block to the shore station is also visible.

3 Testing a multi-PMT digital optical module in ANTARES

The task of KM3NeT software development (Monte Carlo simulations, reconstruction algorithms, etc.) needs as crucial input the knowledge of the response of the multi-PMT DOMs to the environmental background (^{40}K radioactivity and bioluminescence). The precursor experiments, ANTARES [6], NEMO [7] and NESTOR [8] used large PMTs, so local background coincidences were seen as large pulse signals. The recovery and redeployment of the ANTARES instrumentation line would offer the opportunity to test a multi – PMT digital optical module in the ANTARES site. The main motivation of this project is to measure the hit coincidence rates as a function of the space angle between the axes of the PMTs. This will be achieved by selecting / deselecting various PMTs inside the hybridized OM through software commands from the shore counting room. It will ease the KM3NeT software development prior the prototype deployment.

The multi-PMT DOM used for this purpose should be a hybridized one. Signals delivered by the PMT bases are already digitized, whereas the ANTARES data acquisition system (DAQ) is conceived to collect analog signals from the OMs and digitize them inside the LCMs, using "Analogue Ring Samplers" (ARS) custom ASICs [9] which sample the PMT pulses in amplitude and produce the digital signal sent to the shore station.

The hybridized DOM contains only eight 3" PMTs, all mounted in the lower hemisphere of the module. The compatibility with the ANTARES DAQ is ensured by a specially designed summing board, developed at ISS, Bucharest. This board has multiple tasks:

- to combine the digital signals from two or more PMTs in the DOM and deliver an "analog" output signal compatible with the ARS input;
- to ensure the "slow control" of the device (to receive commands from the shore station concerning the PMT combination for each run, to transmit information on the acquisition status and control of the PMT high voltage);
- to ensure the power to all components inside the DOM.

Fig. 6 illustrates the principle of the analogue summing process. For simplification, only three PMTs are represented here.

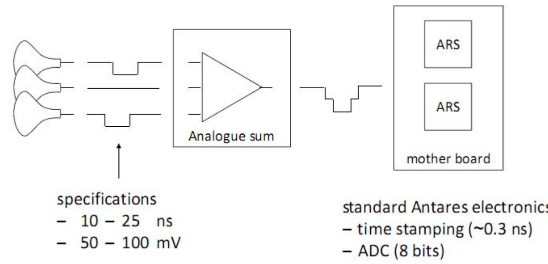

Figure 6. The principle of the analogue summing board.

4. Conclusions

While this paper was being written, various components of the hybrid multi-PMT digital optical module were in the final stage of development and testing. We intend to integrate the device on the ANTARES instrumentation line, to be redeployed on the ANTARES site (2500 m depth, about 40 km South of Toulon, France) later this year. The complexity of the instrumentation line redeployment as well as the time constraints imposed by the sea operations might limit our window of opportunity at the ANTARES site. With this in mind we are considering an alternative integration of the hybrid optical module into an ANTARES line which is being independently prepared for deployment to test the recently deployed deep sea infrastructure at the NEMO site (near Capo Passero, Sicily), later this year.

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