KM3NeT
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Performances and main results of the KM3NeT prototypes

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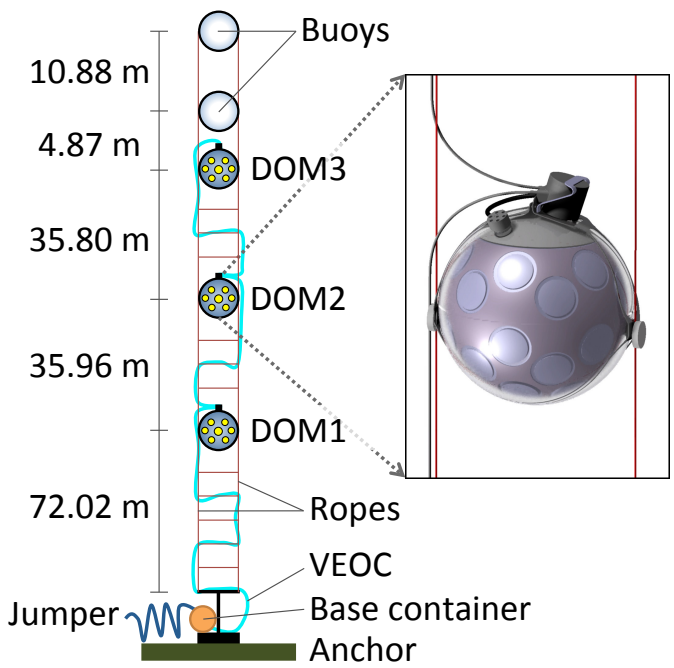


Fig. 1 — Schematic of the PPM-DU (not to scale). Inset: the DOM is kept in place attached to two Dyneema® ropes; the structure is free to oscillate following underwater sea currents.

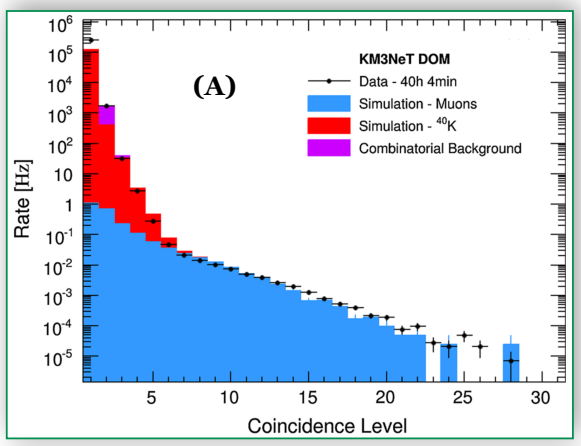
The **KM3NeT** collaboration has started the construction of a multi-site underwater detector to measure and identify neutrino interactions [1]. The basic element of the apparatus is the **Digital Optical Module** (DOM, inset of Fig. 1), a **17" glass sphere** which contains **31 PMTs** of **3" diameter** and the front-end electronics [2, 3, 4]. The DOMs are arranged in vertical lines (**detection units**) kept taut by a system of buoys and anchored on the sea bed. The main results from two prototypes are presented: the prototype DOM (Pre-Production Model DOM, **PPM-DOM**) and the prototype detection unit (Pre-Production Model Detection Unit, **PPM-DU**, Fig. 1).

PPM-DOM

The **prototype DOM** [5] was deployed close to the Toulon coast, attached to the instrumented line of the ANTARES detector [6]; it was operated at a depth of 2375 m since the 16th of April 2013 up to the middle of November 2014.

Using only one DOM, it is possible to select a sample of **atmospheric muons** almost **background free**. Data have been compared with a full **Monte Carlo simulation** that takes into account the atmospheric muon flux [7], the relevant physics processes and the detector response. Fig. 2A shows the event rate as a function of the **coincidence level** (time window of **20 ns**). The signal from atmospheric muons start to dominate above a coincidence size of **seven**.

The potential **directionality** of the DOM is evident in Fig. 2B. A cut is applied at a coincidence level larger than seven. The number of hits detected is shown as a function of the PMT position in terms of zenith angle. Since atmospheric muons come from above, the number of events increases when the zenith angle of the PMTs decreases.



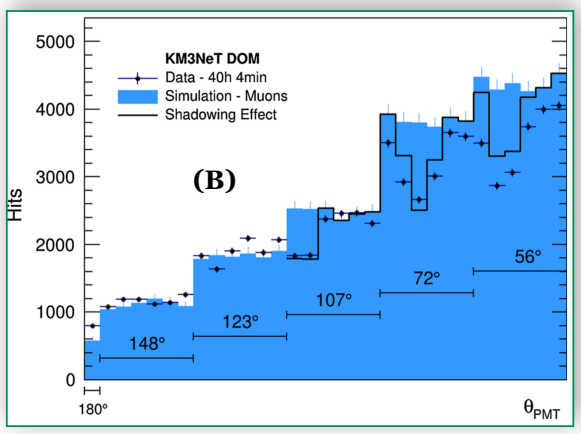


Fig. 2 — (A) Rate of recorded events as a function of the number of hits on PMTs with the signal in coincidence. (B) Number of hits as a function of the zenith position of the PMTs for events with more than seven coincidences.

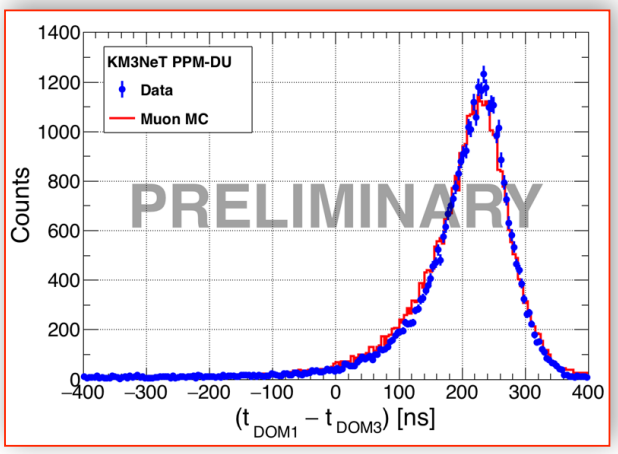


Fig. 3 — Time differences between coincidences of a size larger than 2 on DOM 1 and DOM 3. Events with coincidences in time consistent with a muon signal detected with the three DOMs are selected.

PPM-DU

The **prototype detection unit** was deployed during the night between May 6 and 7 2014 at the site located 80 km offshore Capo Passero, Sicily, at 3457 m depth. A simple **L1 trigger** is defined as two hits in the same DOM with a time difference smaller than **25 ns**. An **L2 trigger** stores physics event grouping all L1 triggers with a time difference smaller than **330 ns** forward in time.

To calculate the **inter-DOM time offsets** (between DOMs) dedicated runs with the **LED nanobeacon** activated are used. The nanobeacon installed in each DOM has a wavelength of **470 nm** and is positioned in the top half of the DOM pointing upwards. The travel time of light in sea water is taken into account in the calibration procedure, assuming a fixed detector position. The time accuracy achieved is of the order of ~**1 ns**. The calibration using nanobeacons was cross checked also with an alternative calibration procedure exploiting the signal from **atmospheric muons** with a good agreement within 2 ns.

A dedicated **Monte Carlo** simulates the expected atmospheric muon flux together with the optical background due to the **^{40}K decay**. Similarly to what is shown for the PPM-DOM in Fig. 2, very good agreement between data and the Monte Carlo simulations is observed.

The distribution of time differences between DOM 1 and DOM 3 when all 3 DOMs are in coincidence is shown in Fig. 3. The requirement of a coincidence in the three DOMs within a time window consistent with the signal from a muon completely removes the optical background.

An algorithm to **reconstruct** the **zenith angle** of the direction of atmospheric muons has been developed. This algorithm uses information on the position of the three DOMs and the time of the local coincidence detection and compares these to the expectation from a muon track.

In Fig. 4A the difference between the **reconstructed** and the **true zenith angle** is plotted using Monte Carlo muon events; a **FWHM** of **7.6 degrees** is achieved. The distribution of cos θ for a data sample with an equivalent livetime of ~550 hours is shown in Fig. 4B demonstrating an excellent agreement with Monte Carlo simulations.

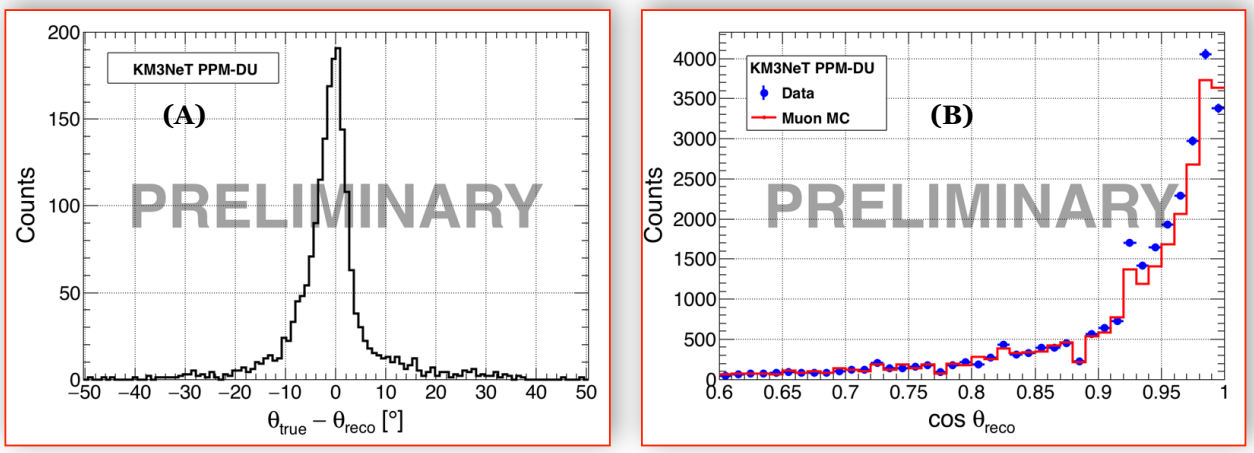


Fig. 4: — (A) Zenith angular resolution of the tracking algorithm obtained with Monte Carlo simulations. (B) Reconstructed cos θ for data and Monte Carlo.

References

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