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THE INTEGRATION OF THE DETECTION UNITS OF KM3NET IN GENOVA

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Abstract

The KM3NeT experiment (1) for the detection of high energy cosmic neutrinos is being built in two sites of the Mediterranean Sea: Capo Passero in Sicily and Toulon in the French coast. The full detection system includes 3 building blocks of Detection Units (DU) (2), each block of 115 DUs. The DU accommodates up to 18 digital optical modules (DOMs) (3). In this note we describe the facility to integrate the DOMs to the vertical cable of the line (VEOC) as realized in our ground floor laboratory of the INFN Institute in Genova.

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1 The Facility

The choice of the integration space in our Department has been selected on the basis of the following basic conditions:

- Minimal available surface 30 m² , accessible to vehicles of medium size (max height 3.8 m),
- Illumination with LED lamps,
- Availability of compressed air and evacuation system for vacuum pump exhaust,
- Hoisting system to maneuver items up to 1000 kg,

Given these conditions, we were obliged to use part of the 'Sala Grandi Montaggi' located at the ground floor of the Institute. Figure 1 represents the configuration used for the integration of the line.

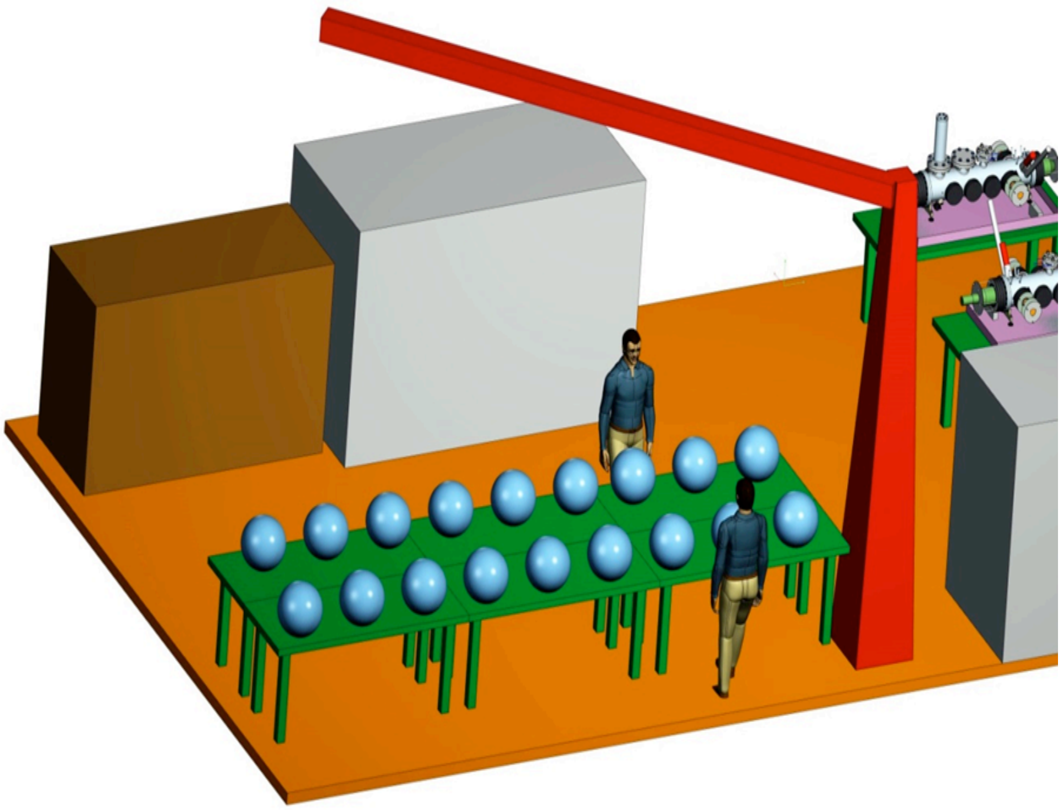

FIG. 1: the Detection Units integration room in Genova : the brown box is the transportation box, the gray is the dark room, integration tables are green, hoisting system in red.

It includes:

- A wooden box to receive and send back the DOMs and the VEOC of 2.5x1.0x1.5m,
- A box with removable cover of 3.8x1.5x2.2 m , light tight as a dark box for test and calibration of the integrated DU,

 6 tables, 0.6x1.8x1.2 m, to position the 18 DOM + VEOC for integration,
 An arm hoist, 5 m long, 4 m high, 1000 kg max lifting weight, rotation of 90°,

The facility is equipped with the instrumentation needed during integration. In particular, various items from the company FITEL for fiber splicing: a fiber fusion slicer mod. S178AVER2, a precision fiber cut mod. S326A, fiber holders etc. and an universal Bare Fiber Terminator mod. BFT1 from Thorlab.

To measure optical signal attenuation we have an Optical Laser Source mod. OLS-6 and an Optical Power Meter mod. OLP-6 from ACTERNA and an Optical Channel Checker C-Band PC SC from VIAVI.

The data acquisition system (DAQ) to read out the full DU when assembled and during the tests in the dark box includes: a GPS mod. XLi 1U from MICROSEMI - SYMMETRICOM and accessories, 3 Withe Rabbit Switches with 18 ports from SevenSolutions, a DELL switch mod. S3124F, a test box provided by NIKHEF which includes add&drops, an 80 channel DWDM Multiplexer and various optical transceivers SFP from Tallgrass.

2 The Dark Box

At the end of the integration the full line is tested in the same conditions as during operation except for the deep sea environment. To do this, the light tight dark box, contains the full string positioned in the support used for transportation. In these conditions the DOMs are powered at the nominal voltage values while the signals are provided by the Cherenkov light produced by the atmospheric muons interacting in the glass of the sphere. These signals are similar to the ones produced by the muons in deep water and can be used to check the functionality of the full line and to preliminary determine infra-DOM time calibration constants.

The box was realized as shown in figure 2. The lateral panels are made in compressed chipboard, internally painted with opaque black paint, while the supporting structure consist in steel bars. The box is divided into two parts: the base, 0.8 m high, and the cover. This subdivision was defined to allow to the displacement of the string outside and inside the box and considering the hoist height. A metallic patch panel in the center of the base provides the access to the internal volume of the box by the optical and electrical signals.

It is not easy to guarantee light tightness in a box of large volume like ours. In order to minimize the risk of light entry inside the box , the fixing of the cover to the base, detailed in figure 3, in addition to various lever locks, was realized using a 2mm black neoprene layer and protecting with black silicon all the splits between the panels and the fixation screws.

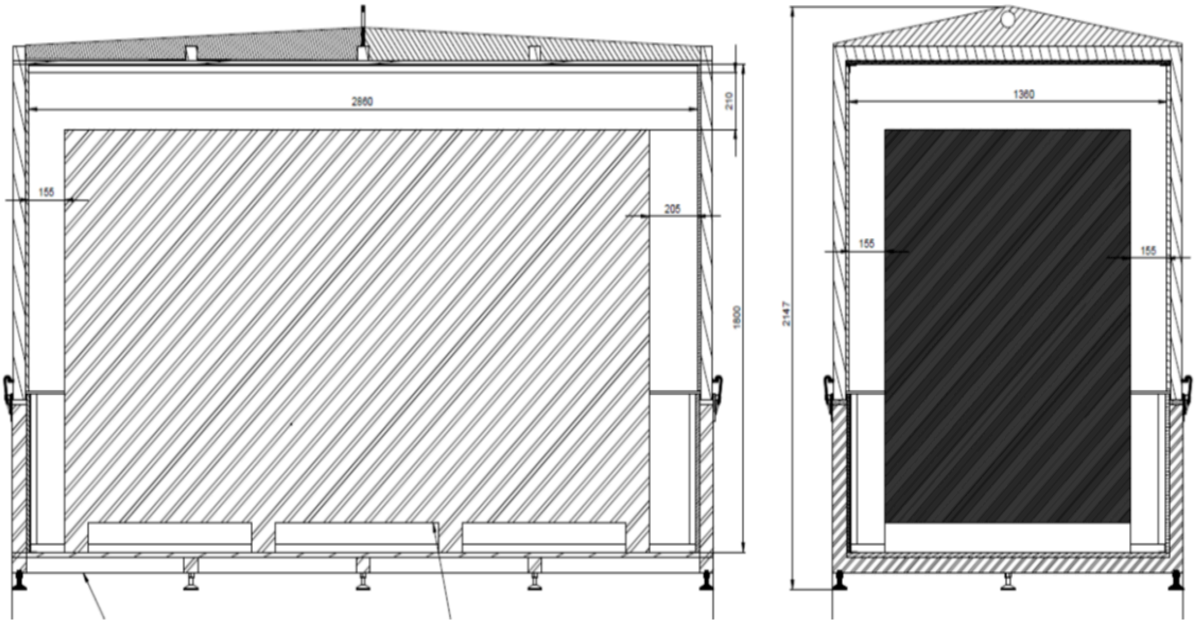

FIG. 2: the dark box.

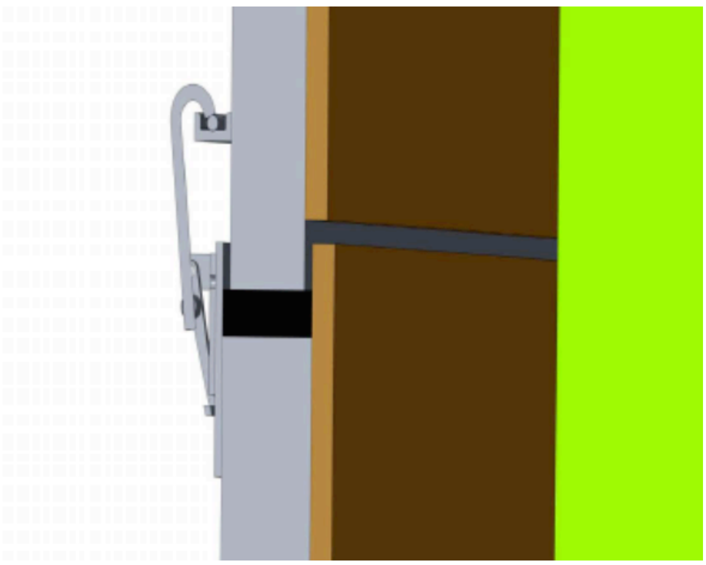

FIG. 3: the locking system of the base to the cap of the dark box.

The light tightness of the box was measured with a 10” Hamamatsu R7081-20 PMT positioned in the center of the box and monitoring its counting rate above 0.3 pe threshold. The measure was performed during night interchanging runs of 1’ duration where all neon tubes in the room were switched on to equivalent runs where all the possible light sources were minimized . The results, shown in figure 4, show that the counting rate is independent from the external illumination conditions (luce spenta, luce accesa) indicating that the dark box is really ‘dark’.

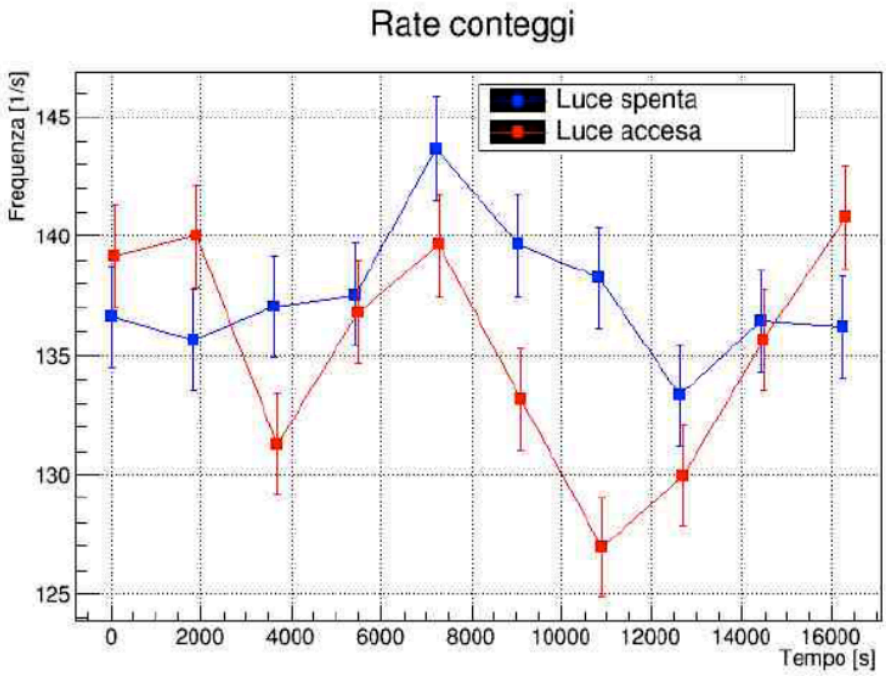

FIG. 4: the noise rate of an Hamamatsu R7081-20 PMT in our dark box with different external light conditions (blue: light off, red: light on).

3 The Illumination in the integration room

The space were integration will take place is presently illuminated by neon tubes in the ceiling, roughly at 5 m height. However, as reported in the manual (4), during DU integration one should avoid the use of neon tubes in favor of LED light lamps. This was stated on the basis of a series of measurements performed on naked PMTs by the integration group of Naples and reported in (5). In this work one can read that 6 naked PMTs, the same model as in the DOM, kept in a dark box for 6 weeks show a dark noise rate of 200 Hz each. The same PMTs exposed to a neon lamp light for 2 hours, took one week to stabilize at the same dark count rates, while when the LED light was used the stabilization occurred in much less than one day, around 4h.

In our conditions the PMT are not naked but housed inside a glass sphere, the DOM, which in principle could operate like a filter for the emission spectrum.

To verify that the influence of the neon light vs LED light is the same as observed in naked PMTs, we have measured the dark count rate on a DOM housed in the center of the dark box and illuminated for 2’ with a LED lamp (2000 lumen) and, after stabilization, with a neon LAMP (5200 lumen). The counting rate as a function of time is illustrated in figure 5.

The counting rate measured after the LED illumination was multiplied by a factor 2.5 to take into account the different intensities of the two lamps. The data show that the dark current contribution decreases more rapidly after LED illumination with respect to the neon lamp, similar to the behavior shown by the naked PMTs.

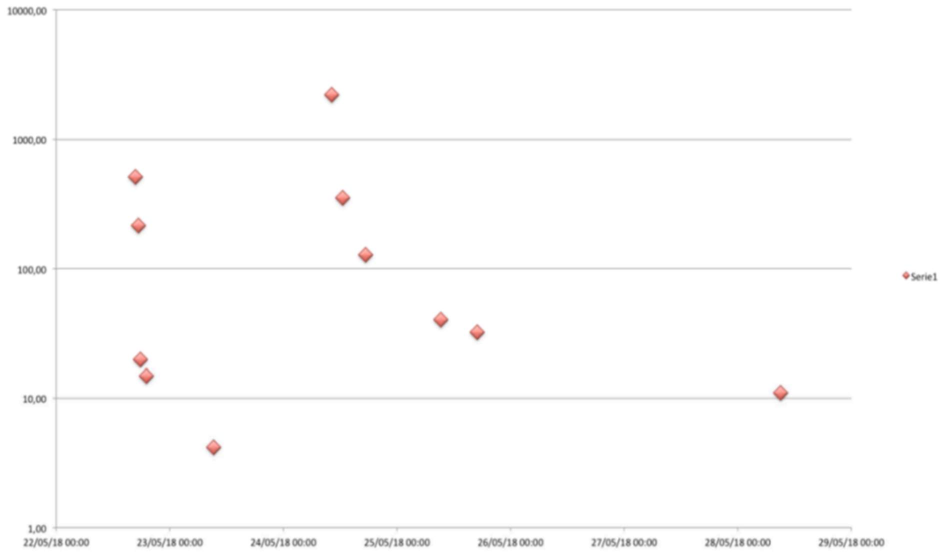

FIG. 5: the counting rate in the DOM after illumination with an LED lamp (left) and a neon lamp (right).

The configuration of the measurement is illustrated figure 6**,** left. During this operation, the DOM was maneuvered using the system illustrated in figure 6, right.

FIG. 6: set-up to measure the effect of illumination (left), the system to hold the DOM (right).

The system is very simple, it exploits the clearance between the titanium collar used to fix the DOM into the ropes of the line and the DOM glass sphere surface. In the clearance a small rope is inserted manually while a carabiner is used to fix it to the hoist hook. The weight of the DOM as measured in this condition resulted 30 kg.

4 The oil filling system

During integration each DOM must be connected to the vertical electro optical cable (VEOC) through a plastic tubing connecting its penetrator cap to the open top part of the break out box (BOB) in the VEOC. The tubing contains the optical fibre and the electrical conductors while the open portion of the BOB houses the plastic reel to wind the fibre after splicing. When the connection is completed, the BOB is sealed and the empty volume is filled with mineral oil, the one chosen by the collaboration being MIDEL 7131.

The procedure includes various steps:

- make the vacuum in the tube and in the BOB,
- fill with oil the empty space,
- repeat the operation two times: de-gassing and refill with oil,
- use compressed air at 2-3 atm to finally reshape the BOB.

To perform this operation we have realized a tubing system, almost the same as the one realized for the integration at NIKHEF. It includes a low vacuum pump, a vacuum buffer of 10 litres, a set of transparent vessels rated for both vacuum and pressure up to 5 atm and various hydraulic components. The block diagram is illustrated in figure 7.

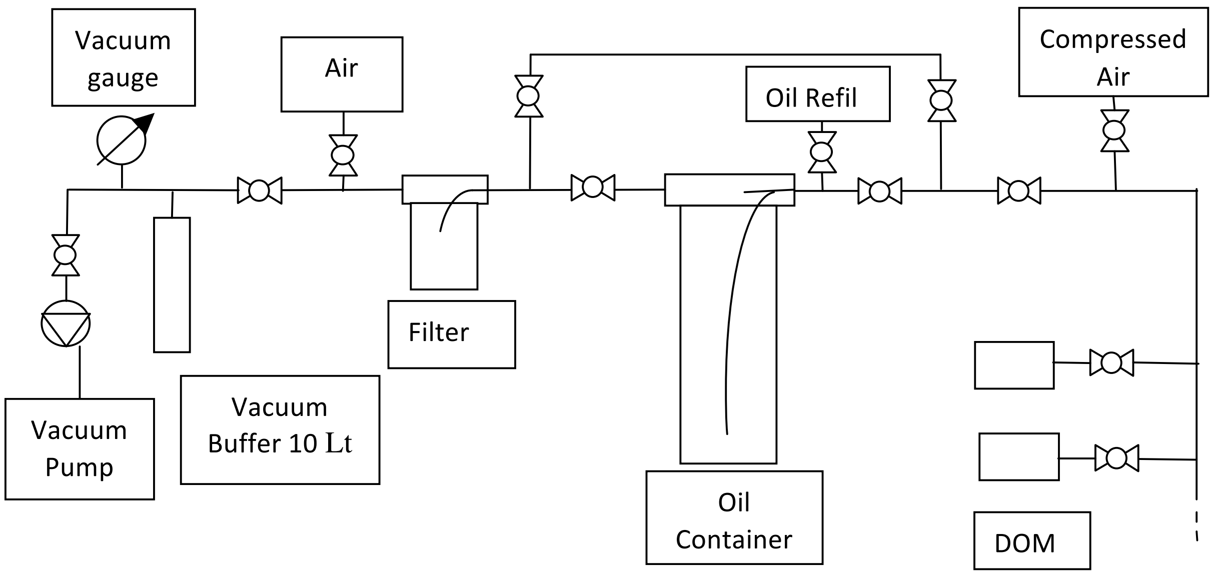

FIG. 7: a sketch of the oil filling system.

A picture showing how the system is installed is illustrated in figure 8: pumping system and vacuum buffer (left), the tubing (right). The system was proven to be vacuum tight for more than a day, well sufficiently for our purposes.

FIG. 8: the low vacuum pump, the vessel for vacuum buffer and the compressed air (left); the oil filling system (right).

5. Conclusions

This note describes the integration facility realized in the 'Sala Grandi Montaggi' of the INFN Institute in Genova. The facility is realized in order to integrate the Detection Units of the KM3NeT underwater detector, in particular the connection of the Digital Optical Modules to the Vertical lector-optical cable.

The availability of a dark box able to contain the full line will allow to perform calibration tests on the full line after integration, before shipping. Details on the integration process will be given in a additional report.

6 References

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(3) EPJ Web of Conferences 116, 01002 (2016).

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(5) "Characterisation of the Hamamatsu photomultipliers for the KM3NeT Neutrino Telescope", Journal of Instrumentation, Volume 13, May 2018.