The MEUST Deep Sea Cabled Observatory

Claude Vallée
Centre de Physique des Particules de Marseille (CPPM)
CNRS-IN2P3 and Aix-Marseille Université, 163 Avenue de Luminy - case 902
F-13288 Marseille cedex-09, France
vallee@cppm.in2p3.fr

On behalf of the MEUST contributors:

M. Ageron, V. Bertin, S. Beurthey, M. Billault, J. Brunner, L. Caillat, A. Cosquer, P. Coyle, J.J. Destelle, D. Dornic, F. Gallo, S. Henry, P. Keller, P. Lamare, J. Laurence, F. Léon, Ch. Lerouvillois, J. Royon, M. Solazzo, D. Tezier, S. Théraube
Centre de Physique des Particules de Marseille
CNRS-IN2P3 and Aix-Marseille Université,
163 Avenue de Luminy - case 902 F-13288 Marseille cedex-09, France

K. Bernardet, C. Gojak, Z. Hafidi, F. Le Moal, Y. Lenault, K. Mahiouz
Division Technique CNRS-INSU
Zone portuaire de Brégaillon, BP330, F-83507 La Seyne cedex, France

D. Lefèvre, C. Tamburini
Mediterranean Institute of Oceanography (MIO)
CNRS UMR 7294 – IRD 235 – Aix-Marseille Université, 163 Avenue de Luminy - case 901
F-13288 Marseille cedex-09, France

Abstract: This paper describes the motivations and main components of MEUST (Mediterranean Eurocentre for Underwater Sciences and Technologies), a permanent deep sea cabled observatory being deployed off shore of Toulon, France.

Keywords: Mediterranean, neutrino astronomy, environmental sciences, cabled deep sea observatory

I. SCIENTIFIC MOTIVATION

MEUST [1] is a second-generation follower of the pioneering ANTARES [2] submarine observatory which has been operated for a decade. It is designed as a shared platform opened to all scientific domains including astronomy, fundamental physics and Environmental and Sea Sciences (ESS). Compared to ANTARES the MEUST submarine network has a modular and extendable topology which will exceed the ANTARES capacities by an order of magnitude in most respects.

The MEUST infrastructure is primarily dimensioned to host a large neutrino detector. Neutrinos are the most elusive and least understood matter components of the present Standard Model of fundamental forces and elementary particles. The abysses offer an attractive medium to study neutrinos of cosmic or atmospheric origin: neutrinos impinging the other side of the Earth produce a faint upwards light flash in deep water when they interact in the Earth crust close to the seabed. An array of optical sensors distributed on the seabed can detect this light flash and reconstruct the neutrino trajectory, while being protected by the water column from the high rate cosmic background impinging the sea surface. The neutrino optical sensors to be connected to MEUST are structured in Detection Units (DU) designed by the European KM3NeT Collaboration [3]. A DU (Fig. 1 left) consists of 18 Digital Optical Modules (DOM), equipped each with 31 photo-multipliers, and linked to each other as a vertical flexible line of several hundred meters laid on the seabed. For MEUST the KM3NeT DUs will be configured as a dense array optimized for measurement of low energy neutrinos (ORCA project [4]): the inter-DOM distance

Fig. 1. Examples of scientific instruments to be connected to MEUST. Left: the 18 DOMs of the first neutrino KM3NeT DU in calibration in the CPPM dark room before integration as a DU; right: the EMSO ESS MII module integrated at the CNRS-INSU Technical Division.

within a DU and the inter-DU distance on the seabed will be ~9m and ~20m, respectively. The detailed measurement of the flux of atmospheric neutrinos after their travel through the Earth will give information on a fundamental but yet

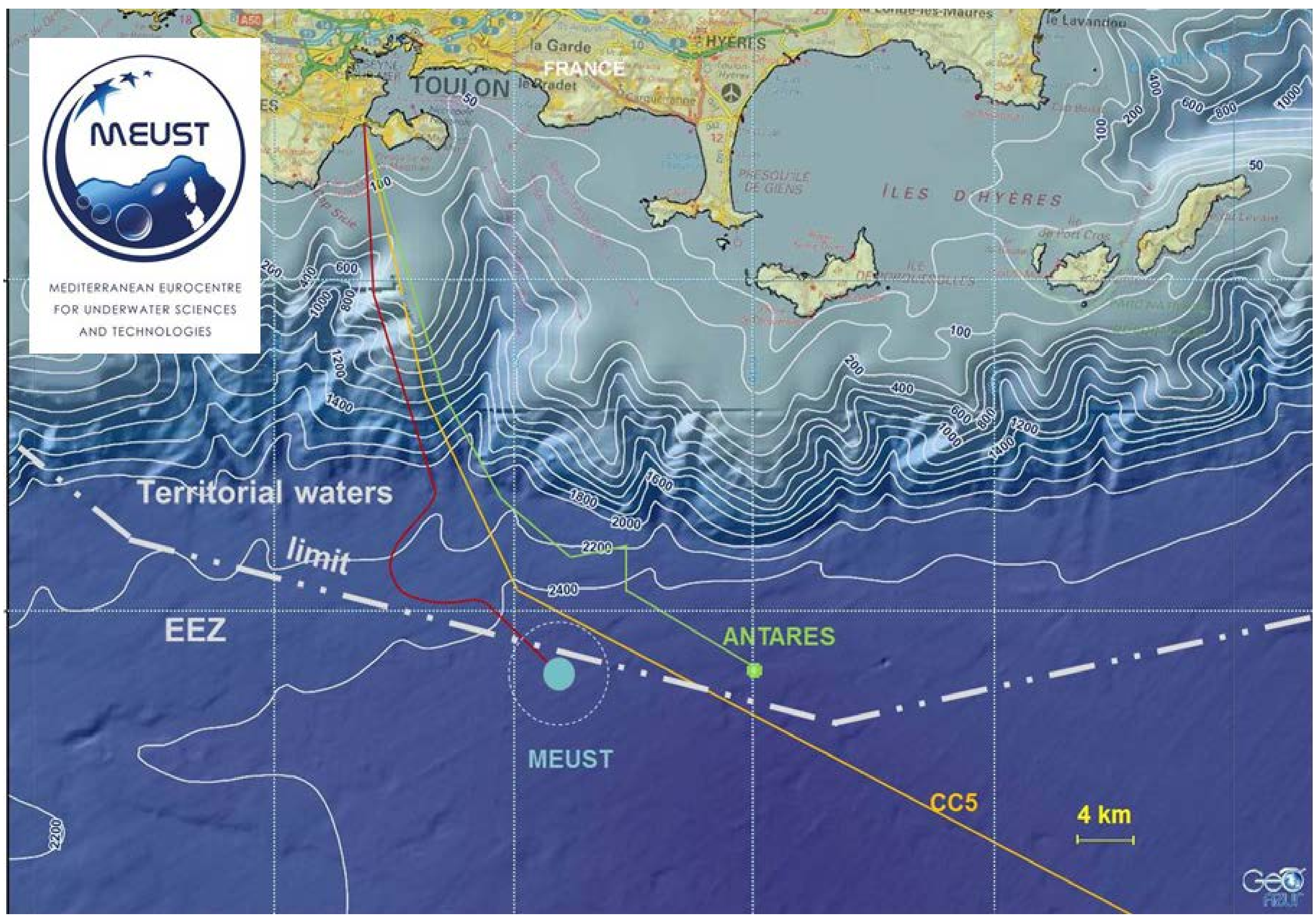

Fig. 2. Geographic location of the MEUST submarine site (blue disk) with the route of the MEUST cable to shore (red line). The CC5 cable (orange line) is an active telecommunication cable to Corsica. The ANTARES location and cable (green dot and line) are also shown.

unknown property of neutrinos: the mass ordering of the 3 neutrino families, referred to as "neutrino mass hierarchy". It may also provide a first tomography of the inner structure of the Earth. In addition the measurement of low energy neutrinos will improve the sensitivity to possible dark matter signals from the cosmos.

The MEUST submarine infrastructure gives the possibility to connect permanent ESS instruments of interest for a broad range of domains including Oceanology, Bio-geochemistry, Biodiversity monitoring and Seismology. The cabled network can host sensors with a high power consumption and collect their data on shore at a high rate in real time. A first set of such instruments is currently being designed within the European EMSO consortium [5], a network of permanent submarine observatories all around European coasts, for which MEUST will be part of the Ligurian site. They include an Interface Instrumented Module (MII, Fig. 1 right) which will be connected to the infrastructure. The MII will host dedicated sensors and provide real time acoustic communication with an autonomous mooring line ("ALBATROS") which will instrument the whole water column on a height of 2000m from the seabed.

II. MEUST SITE

The MEUST terrestrial base is located on the Brégaillon site of the Toulon Bay, where a new building is planned to host the MEUST technical activities, including a control room of the infrastructure. The MEUST submarine site has been selected after intensive characterization campaigns conducted in the past years at several possible locations, in order to find the best compromise between the site intrinsic

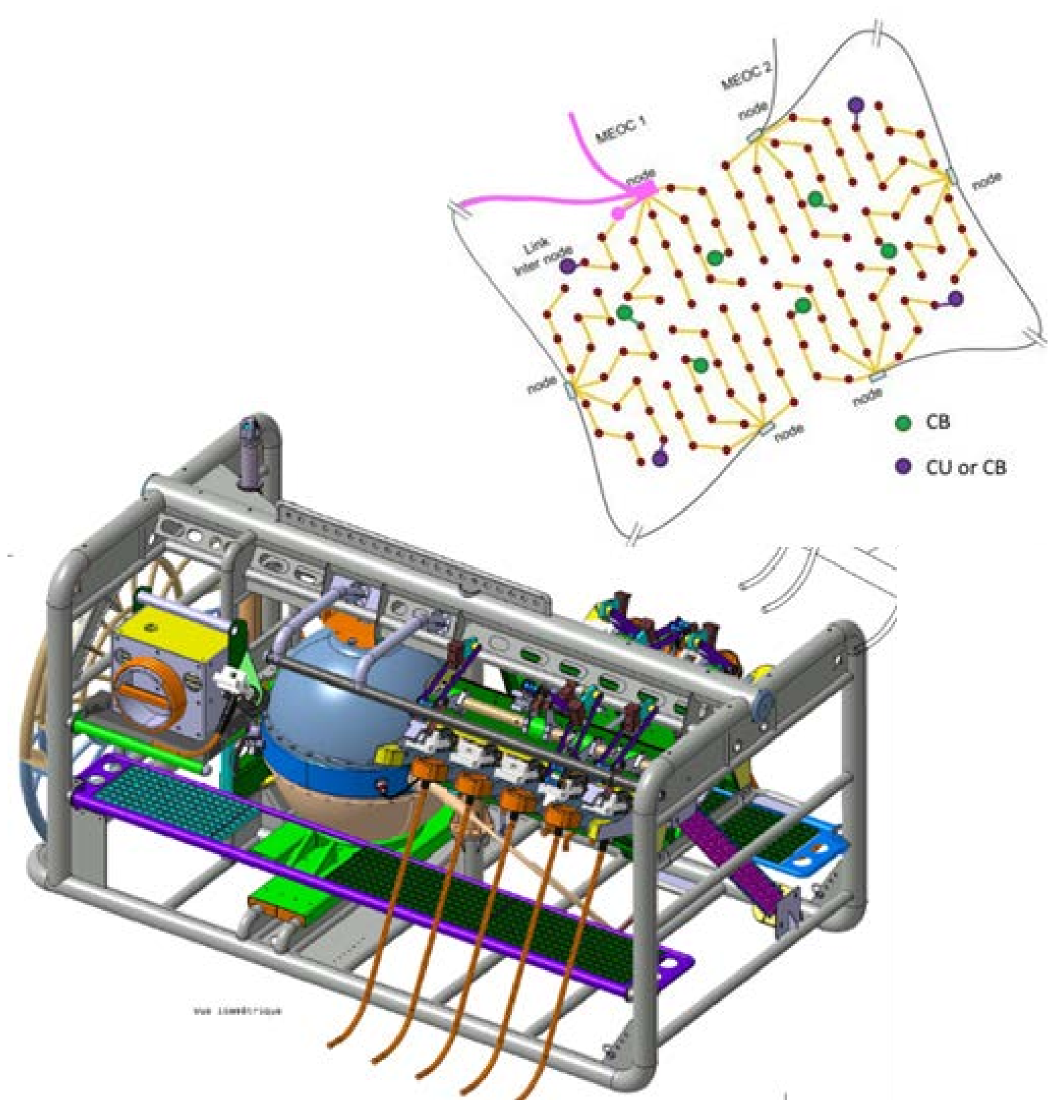

Fig. 3. The MEUST submarine network topology (top) and layout of a MEUST node (bottom). On the top picture the small brown dots correspond to the neutrino DUs and the other ones (CB and CU) to calibration devices. ESS instruments are not shown. The purple items will be deployed until mid-2015.

qualities and external constraints such as existing cables and logistics costs. The MEUST final site (Fig. 2) is located ~40km offshore of Toulon at a depth of 2500m and 15km western of the ANTARES site. A detailed ROV visual and sonar inspection of the whole seabed area expected to host instruments has revealed a very flat sandy area similar to that of ANTARES.

III. SUBMARINE NETWORK TOPOLOGY

The full MEUST submarine network (Fig. 3 top) has a ring topology with 6 nodes connected to the shore by two Main Electro Optical Cables (MEOC). The MEOCs are standard telecommunication cables with optical fibers for data transfer and one electrical conductor for power transfer. The network components (cables and nodes) are designed to allow a staged implementation using standard telecommunication marine deployment techniques and procedures.

The MEUST nodes (Fig. 3 bottom) are equipped each with 8 wet mateable connectors including 6 connectors usable for neutrino DUs only, and 2 multipurpose connectors suitable for both neutrino DUs and ESS instruments. The nominal instrumentation configuration connected to a node involves 20 neutrino DUs chained by 4 (using 5 neutrino-DU connectors) and one set of ESS instruments (using one multipurpose connector). The 2 extra connectors are provisioned as spares in case of failures but may also allow to extend the available instrumentation.

IV. NETWORK FUNCTIONNALITIES

The MEUST infrastructure provides three main systems which are largely independent from each other: the electrical power distribution system, the optical network for data

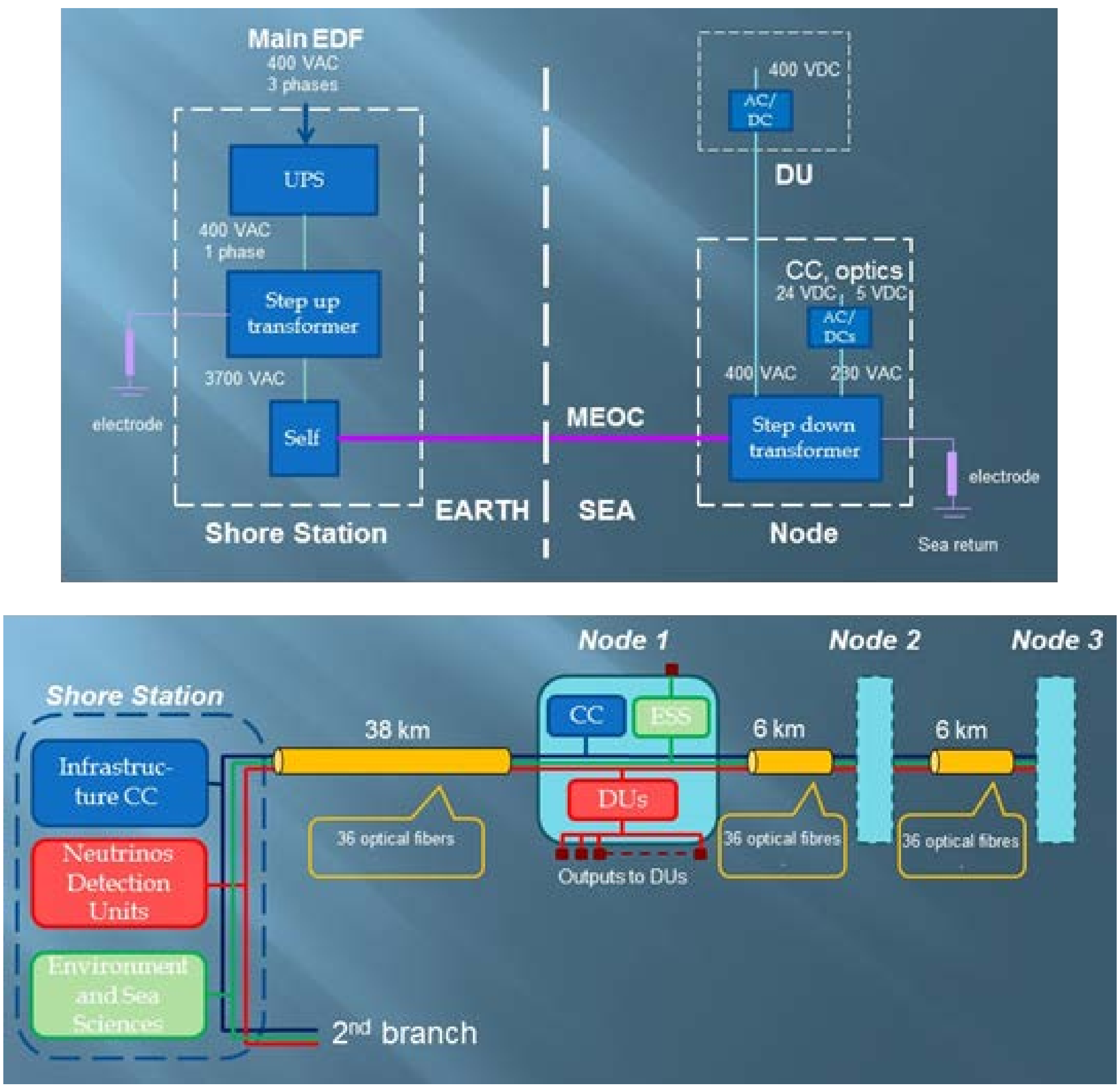

Fig. 4. General schemes of the MEUST electrical power system (top) and of the optical network (bottom).

transfers and control of scientific instruments, and the Control Command for configuration and monitoring of the infrastructure network.

Proximity to the coast of the submarine site allows to perform the power transfer (Fig. 4 top) in High Voltage AC with sea return, as for ANTARES, using robust electrical components with an overall acceptable offshore power loss. Power is transferred as 3700 VAC through the conductor of the MEOC and stepped down to 400 VAC by a transformer in each node. The scientific instruments connected to the nodes must include adequate AC/DCs tailored to their DC current uses. The power system is primarily dimensioned by the neutrino DUs consumption and provides a usable power of ~10kW on each node (~1kW/connector).

The overall philosophy of the optical system is to provide an Ethernet network where scientific instruments communicate directly with the shore as independent Ethernet hubs. The MEUST nodes include only passive optical components and optical amplifiers. The optical network (Fig. 4 bottom) comprises three independent subsystems: the neutrino DU network using 30 MEOC fibers (10/node) to transfer and control the data of the neutrino telescope, the ESS network (2 MEOC fibers), and the Control Command network (2 MEOC fibers). Two extra fibers in the MEOC are reserved as spares. The DU optical fibers are distributed to the 8 node output connectors whereas the ESS fibers are distributed to the 2 multipurpose connectors only (section III). The DU network uses Dense Wavelength Division Multiplexing (DWDM) with a 50GHz spacing and up to 80 wavelengths packed on each MEOC fiber. Each DU DOM acts as an independent Ethernet hub with its own wavelength. A MEOC fiber can therefore transfer the data of 4 DUs (corresponding to 4 x 18 = 72 DOMs), which has guided the design of the DU array topology with 4 DUs chained to 1 node connector (section III). The ESS optical network uses bidirectional CWDM with a wavelength grid of 20nm. This provides the possibility to design optical sub networks with more wavelengths using a denser DWDM grid, in order to serve a complex array of ESS sensors connected to a multipurpose port.

The Control Command manages the power, optical and monitoring systems of the infrastructure. It uses industrial Input-Output modules compatible with Linux for software developments, with a communication based on the Ethernet protocol. All components and optical paths are doubled to provide redundancy in case of failure of individual components.

Fig. 5. The main components of the MEUST infrastructure: the shore power hut (top right); the MEOC under deployment in December 2014 (top left); the first node under final assembly in the CPPM hall (bottom right) with a zoom on the closure or the Junction Box (bottom left).

V. INFRASTRUCTURE COMPONENTS

The components of the MEUST infrastructure have been prototyped and engineered from 2010 to 2015.
A new power hut (Fig. 5 top right) is operational beside that of ANTARES on the Sablettes beach near Toulon, to power the submarine infrastructure and handle the optical signals. The MEUST MEOC #1 (36 optical fibers) is a ~40km long standard telecommunication cable from ALCATEL (reference OALC-7) which has been successfully deployed and connected to the power hut in December 2014 (Fig. 5 top left).
The MEUST first node (Fig. 5 bottom) is under final assembly. Its main active element is a Junction Box made of a titanium sphere containing the electrical step-down transformer, the optical network components and the Control Command devices. The Junction Box is inserted in a titanium frame hosting 2 panels with each 4 output wet mateable hybrid connectors (reference NRH from the Teledyne ODI company). The connector panels include specific connection tools which have been developed in order to be able to use light commercial ROVs to connect the instruments.

VI. DEVELOPMENT PLAN

The first operational part of the MEUST submarine infrastructure is expected to be completed in spring 2015 with deployment and connection to the MEOC of the first MEUST node. This will be followed by deployment and connection of the first KM3NeT neutrino DU (Fig. 1 left) and of the instrumented EMSO module MII (Fig 1 right). A prototype version of the EMSO ALBATROS mooring line (section I) is already in operation with acoustic communication to the surface. It will be recovered, reconfigured and redeployed with communication to the MII once the latter is operational on the seabed.

In the coming years the submarine infrastructure is expected to be extended by 1 or 2 more nodes for connection of a set of ~50 neutrino DUs. These DUs will be configured in the dense ORCA layout (section I) optimized for measurement of low energy neutrinos. A first determination of the neutrinos mass hierarchy is hoped for within the coming decade. The extension of the submarine infrastructure will also allow connection of additional ESS instruments, including an array of hydrophones for monitoring of marine mammals populations, a bio-camera for study of bioluminescent organisms, and transfer to MEUST of the current ESS Secondary Junction Box of ANTARES. Other potential ESS users of the infrastructure are welcome.

For the longer term a patented R&D is being conducted to decrease the submarine connection costs of future devices and instruments. The present ANTARES MEOC (Fig. 2) has also been checked to comply with the MEUST specifications for a possible re-routing to the MEUST site as MEUST MEOC #2, after the ANTARES decommissioning scheduled in 2017. This would more than double the capacity of the MEUST submarine infrastructure for neutrino physics and astronomy as well as for environmental sciences.

ACKNOWLEDGEMENTS

The authors wish to thank E. Heine, S. Mos, J-W. Schmelling, G. Kieft, R. Coccimano, A. Damico and R. Coniglione for their contributions to specific aspects of the design of the MEUST infrastructure. The MEUST development was conducted with the support of CNRS, Aix-Marseille Université, the Town of Marseille and the European Regional Development Fund (ERDF).

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