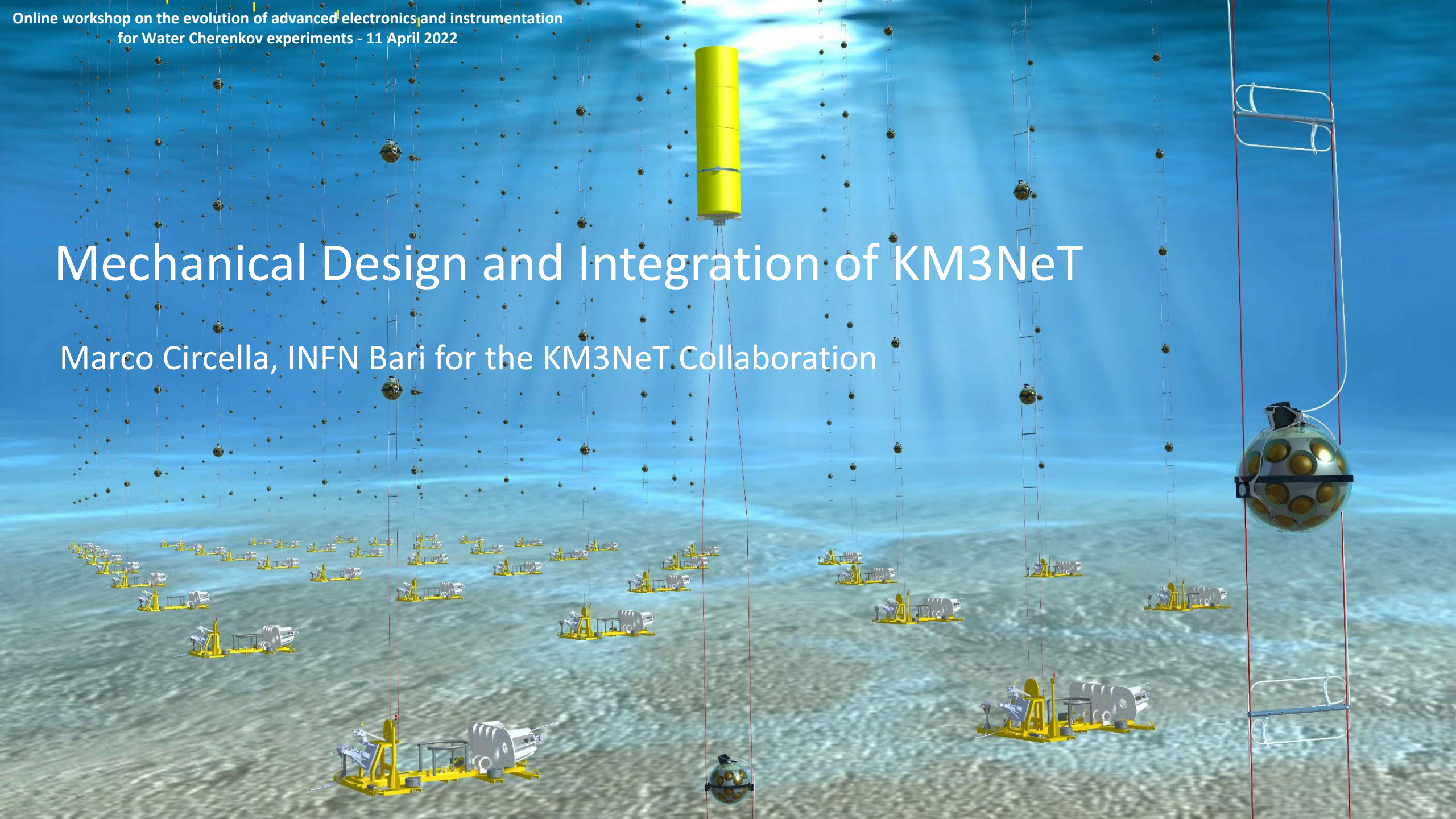
Online workshop on the evolution of advanced electronics and instrumentation
for Water Cherenkov experiments - 11 April 2022

Mechanical Design and Integration of KM3NeT

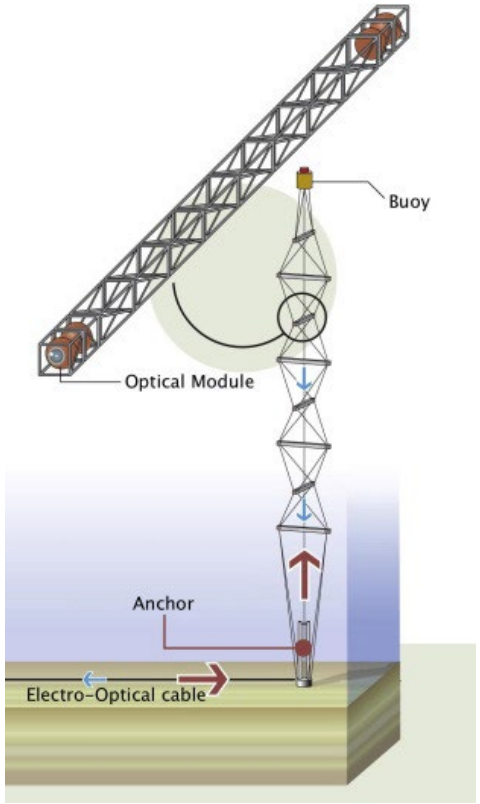
Marco Circella, INFN Bari for the KM3NeT Collaboration



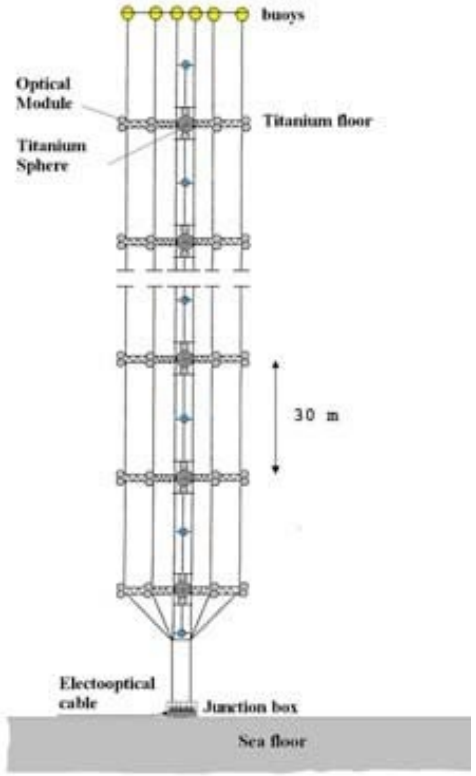
Neutrino astronomy in the Mediterranean: the initiatives

ANTARES – first undersea neutrino telescope ever built – operated from 2006 to 2022
NEMO and **NESTOR** – extensive R&D programs carried out in Italy and Greece
KM3NeT – construction of ARCA and ORCA ongoing

Assembly of one ANTARES 'storey'



A NEMO 'tower'



A NESTOR 'tower'

A KM3NeT 'detection unit' (DU)

Neutrino astronomy in the Mediterranean: the challenges

ANTARES – first undersea neutrino telescope ever built – operated from 2006 to 2022
NEMO and **NESTOR** – extensive R&D programs carried out in Italy and Greece
KM3NeT – construction of ARCA and ORCA ongoing

Assembly of one ANTARES ‘storey’

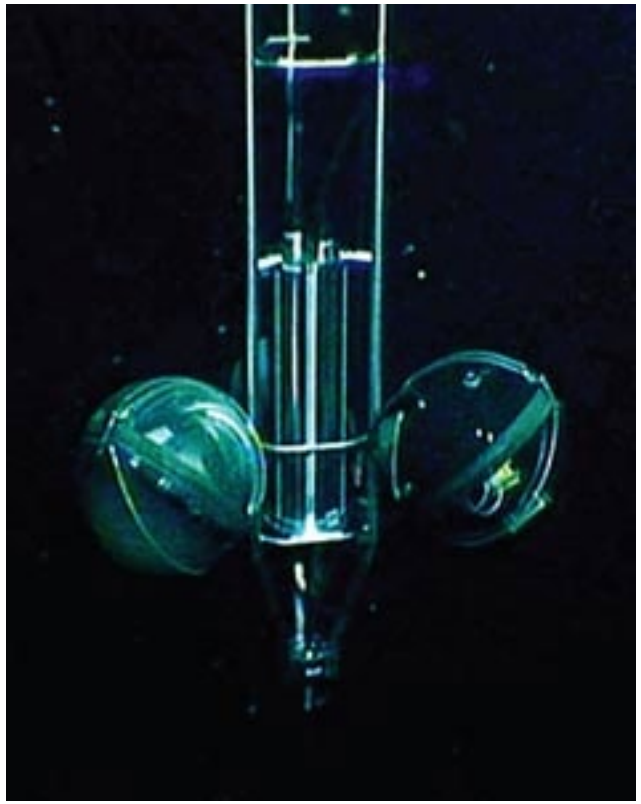
Working in the (deep) sea implies:

- High pressure
- Salted water!
- Sea currents
- Optical background (^{40}K decays and bioluminescence)
- Need to deploy and connect structures on the bottom of the sea

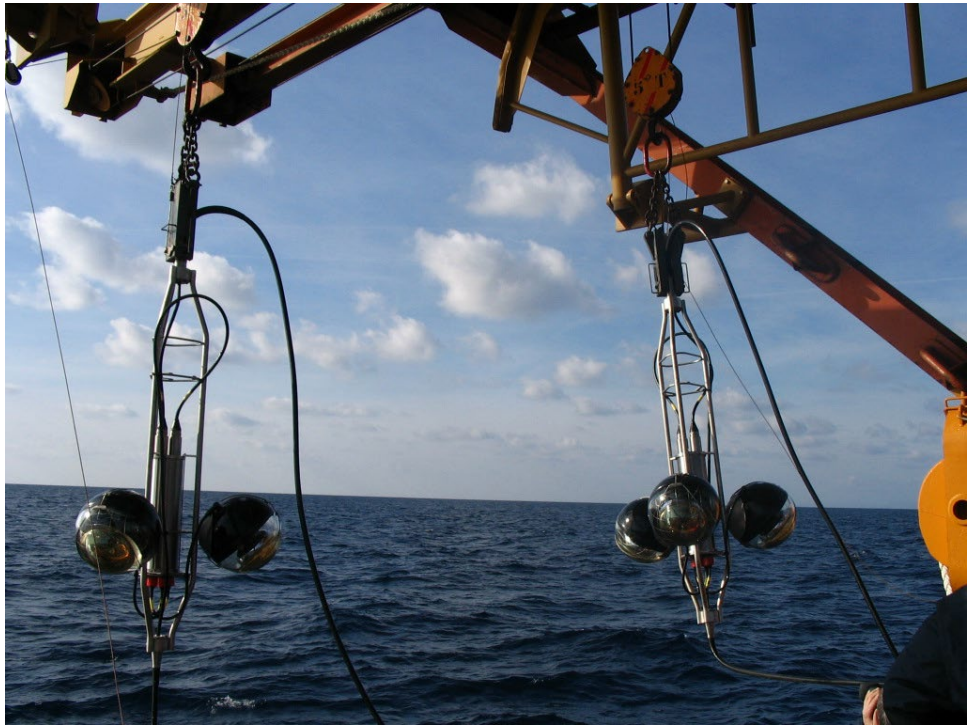
A KM3NeT ‘detection unit’ (DU)

The ANTARES ‘storey’

- Three optical modules (each equipped with a 10" PMT housed in a 17" glass sphere)
- One electronic container
- A frame to keep all things together (including, when applicable, a hydrophone and/or a LED optical beacon)
- An electro-mechanical cable keeps the storeys (up to 25 in a line) together



One ANTARES ‘storey’
(in the deep sea)

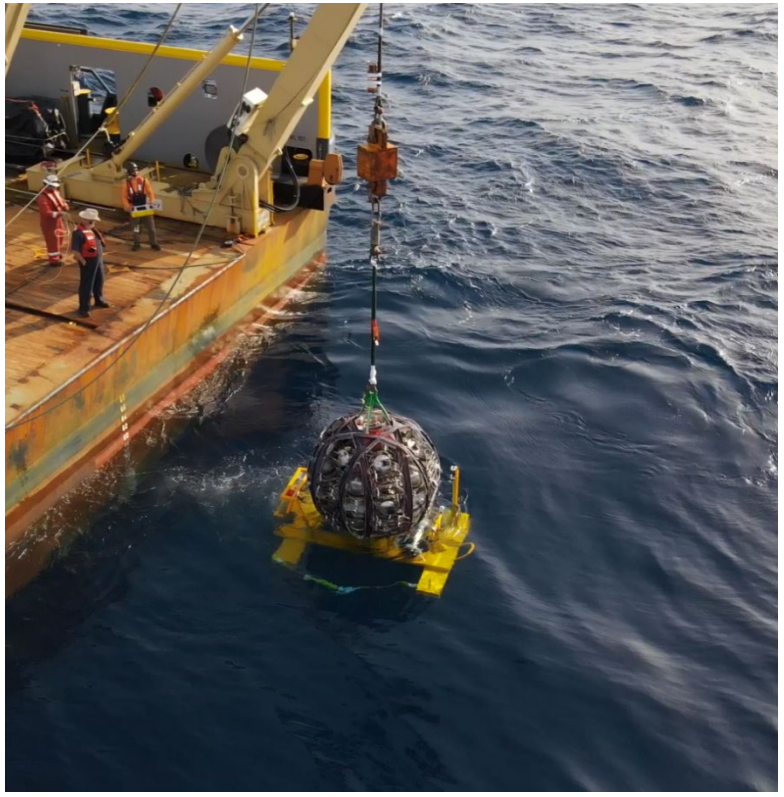


Deployment of one ANTARES line

Principles of KM3NeT design

- Push performance and reliability
- Simplify the mechanics: reduce containers and interfaces
- Go for a lean detection unit structure (foldable!), easy to transport and deploy

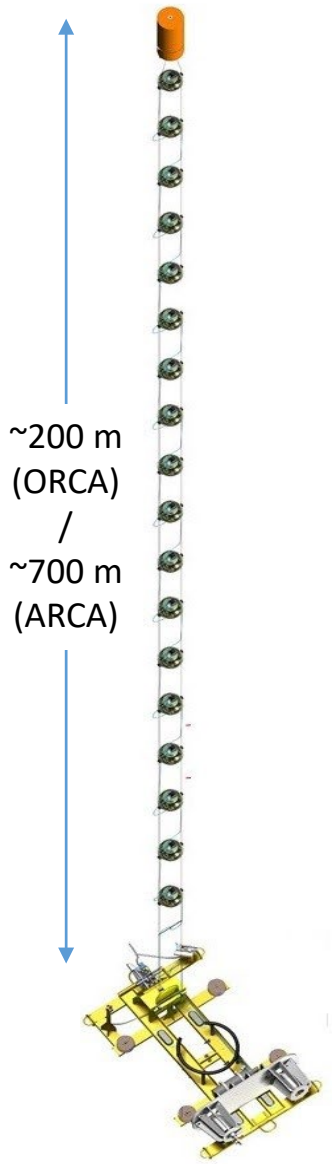
The multi-PMT Digital Optical Module (DOM) of KM3NeT



Deployment of a KM3NeT DU

KM3NeT: ARCA and ORCA

(Astroparticle/Oscillation Research with Cosmics in the Abyss)



Same technology for the two detectors – the main aim of KM3NET is:

- **ARCA**: detection of HE/VHE/UHE/etc. neutrinos from the cosmos
- **ORCA**: detection of «atmospheric neutrinos» with focus on neutrino mass ordering

The main differences in the ARCA and ORCA detectors are due to:

- Different size of the detectors (~9 m inter-DOM and ~20 m inter-DU distances in ORCA vs. ~36 m and ~90 m, resp., in ARCA)
- Different power systems (DC in ARCA vs. AC in ORCA, which is closer to shore)
- Different anchors and underwater connection systems (due to the different vehicles used at sea and the shorter inter-DU distance in ORCA)
- Slightly different optical communication systems (consequently)

The DOM (Digital Optical Module)

A KM3NeT DOM (bottom view)

- 31 3" PMTs (by Hamamatsu)
- a fast LED pulser (for timing calibrations)
- an acoustic piezo-sensor + a compass/tiltmeter (for positioning)
- electronics and DAQ for data taking and communication with the shore station

All components are packed in a 17" pressure-resistant glass sphere (by Nautilus)

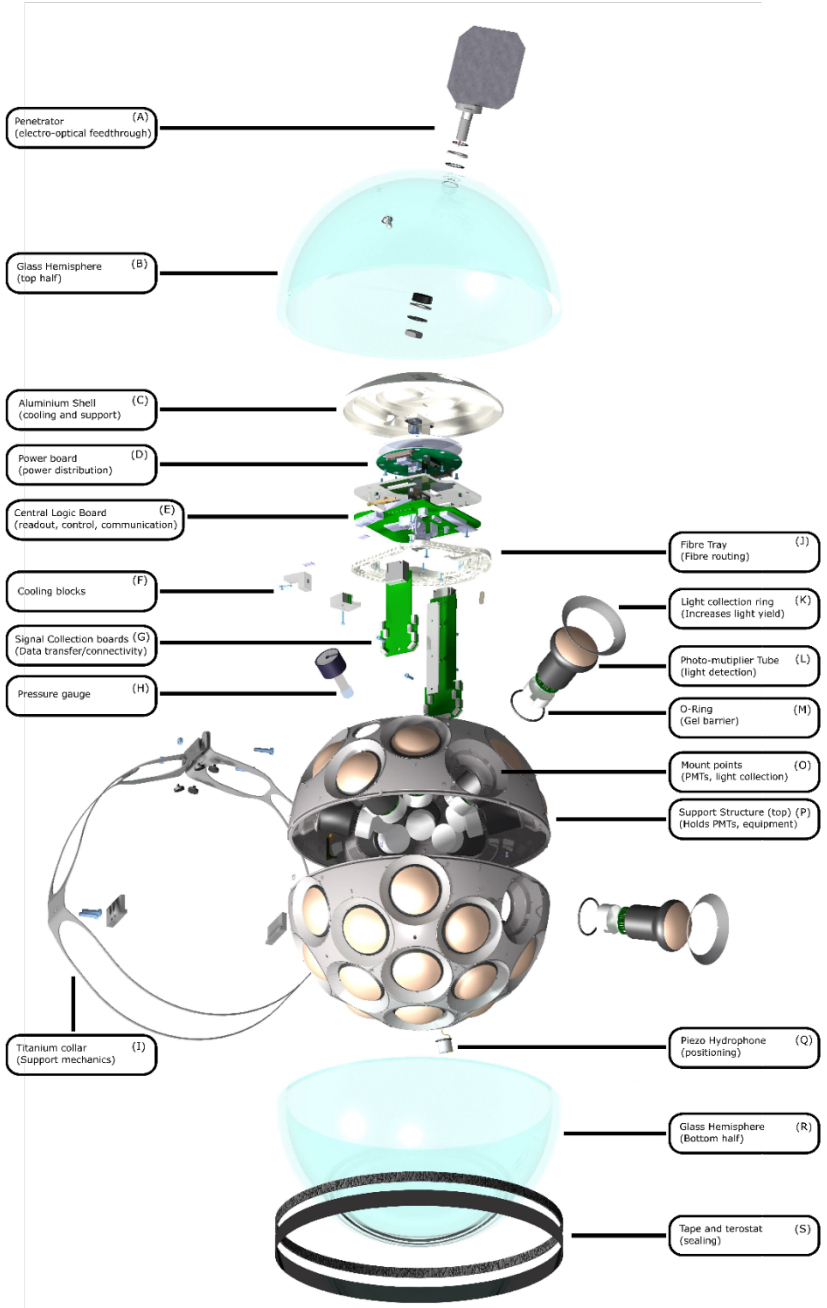
Each DOM requires: electrical power (~7W @12 VDC) and one optical fibre for communication (through a penetrator)

Advantages of the multi-PMT choice:

- large photocathode area
- large angular coverage
- sensitivity to photon direction
- improved photon counting capabilities
- possibility of local triggers
- simplified detector layout

For more details please check: https://inspirehep.net/literature/2054872

The DOM structure and components



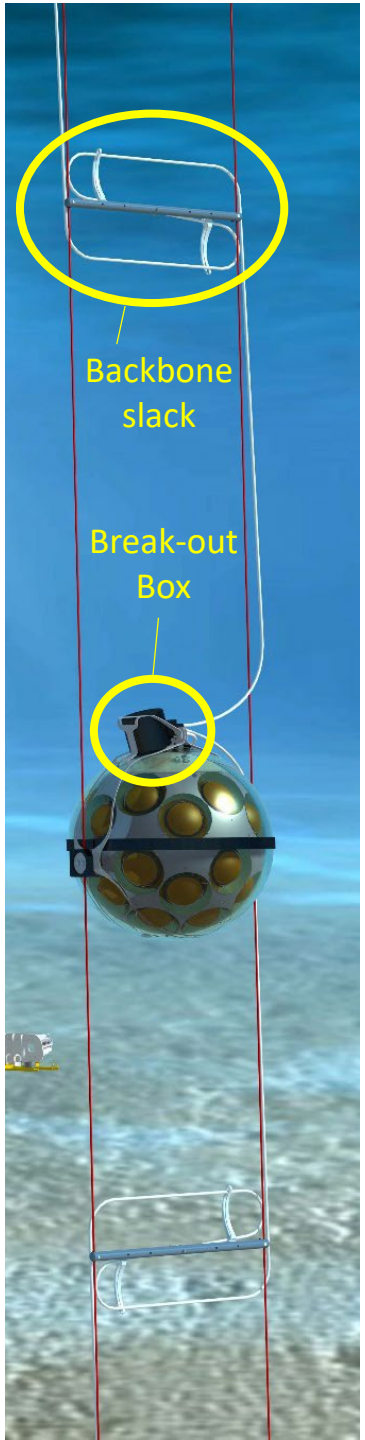
1. Section of a bottom support structure
2. Section of a top support structure
3. Glass hemisphere (bottom)
4. Bottom support structure with PMTs and light collection rings installed
5. Tray for routing of optical fibres
6. Cooling and support mechanics (shell with rod mounted)
7. Power board
8. Central Logic Board
9. (Three) PMTs with base attached and light collection rings
10. Pressure gauge
11. Signal collection boards (2)
12. Nanobeacon (led flasher) on driver board
13. Penetrator flange (left) and penetrator with temporary fibre/cable routing plate (right)
14. Piezo hydrophone
15. Laser transceiver

The DU (Detection Unit)

Slender, yet robust, design:

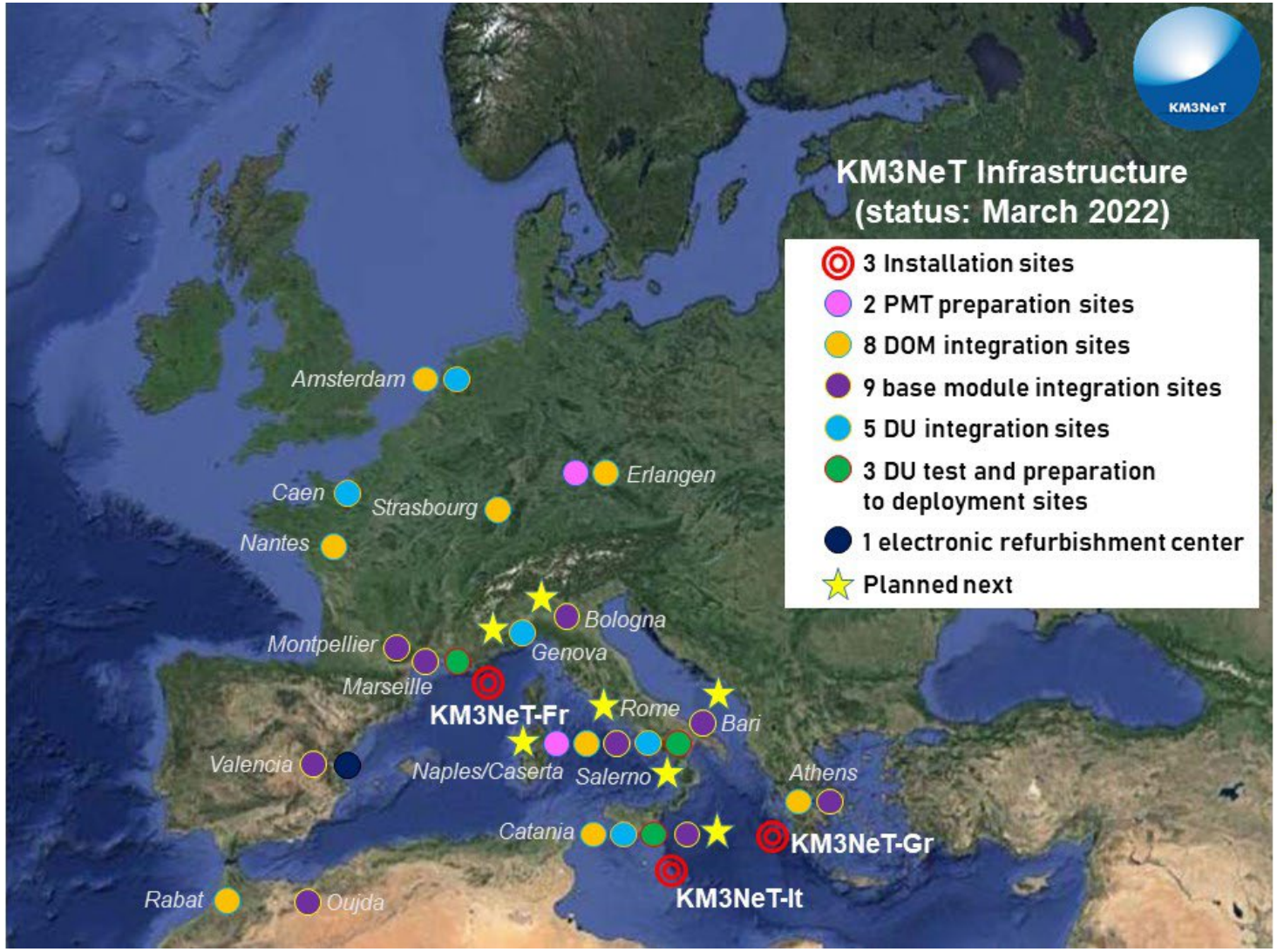
- Two ropes connect the DOMs to an anchor and a top (submersed) buoy
- The DOMs are attached to the ropes by means of a slim titanium ‘collar’
- An electro-optical backbone provides each DOM with power and an optical fibre for data communication (through a break-out box connected to the penetator mounted on the DOM)
- A base module is installed on the anchor to interface the DU with the submarine cabling network

The DU can be packed on a launcher vehicle (spherical, 2 m diameter) placed on the anchor for installation



Rendition of a DOM mounted in a DU

Detector integration organization



On 1st March 2022:

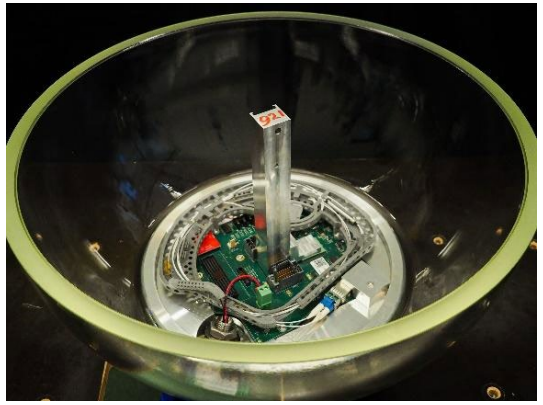
- DOMs: 860 produced, 105 in production
- BM: 45 produced, 5 in production
- DU: 33 produced (19 deployed), 8 in production

Planned next:

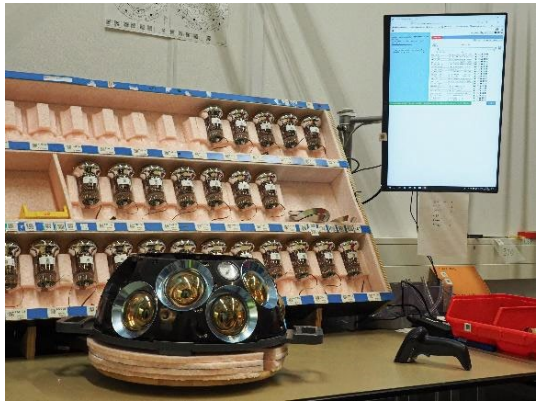
- ☆ New DOM integration site in Salerno
- ☆ New DU integration sites in Bari and Rome
- ☆ Enlargement of integration sites in Bologna, Catania (Sezione and LNS), Genoa and Naples/Caserta

- Organization defined so as to optimize construction schedule and simplify logistics
- Flexible organization: the activities in each site can be adjusted so as to better serve the needs of ARCA and ORCA

Integration and preparation to deployment

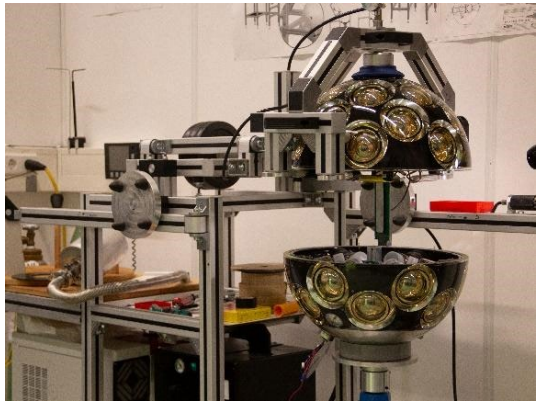


Mounting of DOM electronics

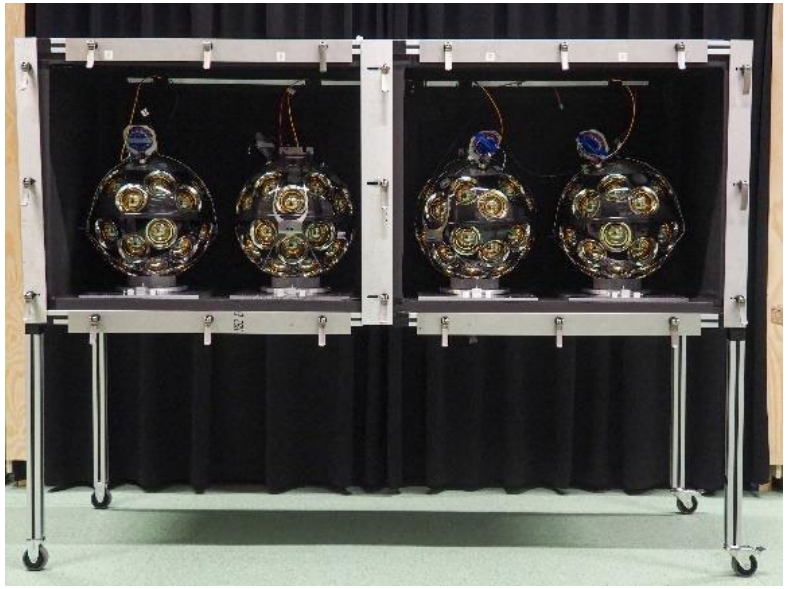


Installing the PMTs on their support structures

Pouring gel into the spheres

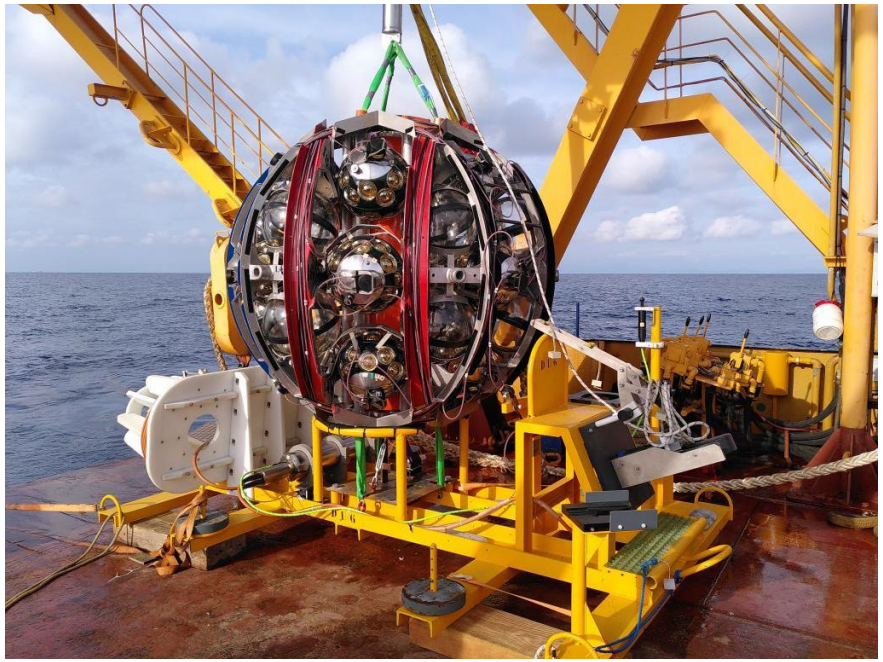


Sealing the sphere



Tests of integrated DOMs

Integration of a base module



A DU ready for deployment

Thank you very much for your attention!

Interested in any further details? Please don't hesitate to contact me:
marco.circella@ba.infn.it

Note: you can please check our Youtube channel for illustration of detector construction!
In particular:

- DOM and DU integration (at Nikhef, Amsterdam): https://www.youtube.com/watch?v=tzxHlLgAahE
- loading of launcher vehicle (for ORCA): https://www.youtube.com/watch?v=TMjEQKshOqw
- integration and installation of first ARCA DUs: https://www.youtube.com/watch?v=tR8jwgG6uzk
- installation of first ORCA DU: https://www.youtube.com/watch?v=dMjN93H7Nvo