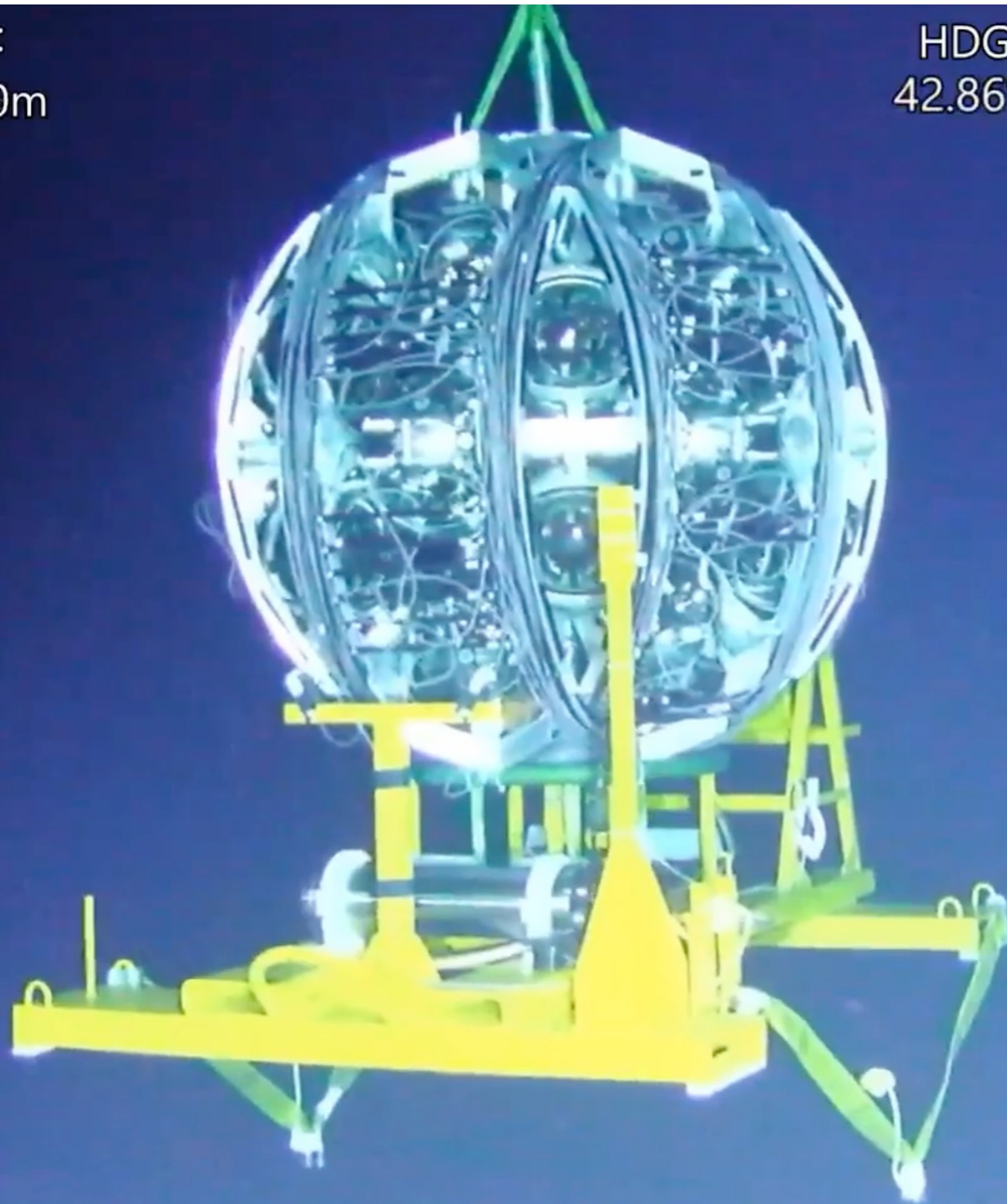




Depth:  
3451.00m

HDG:  
42.86°



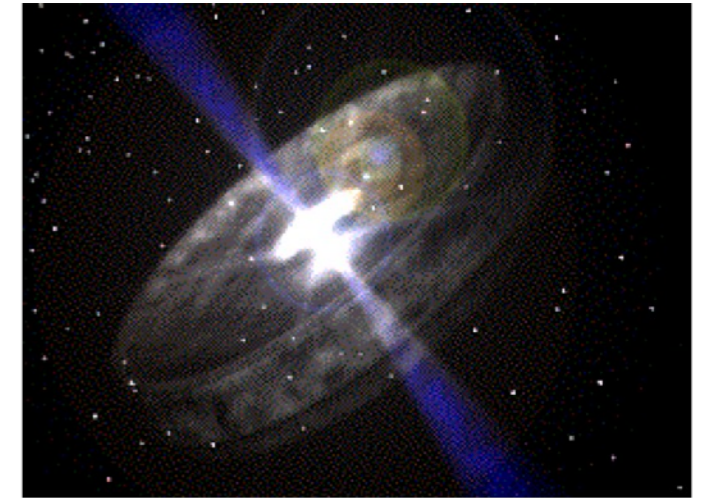
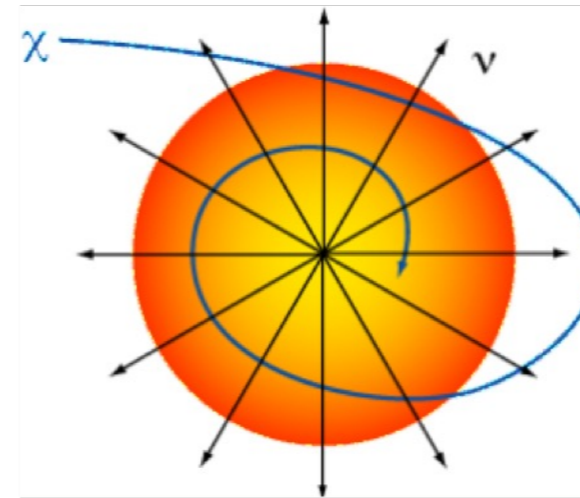
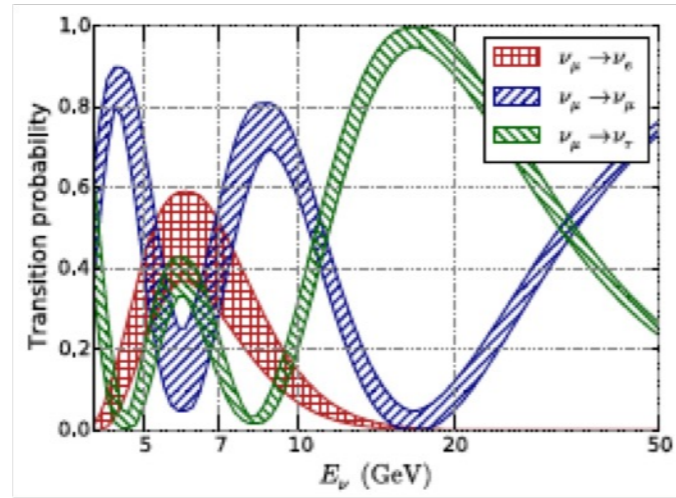
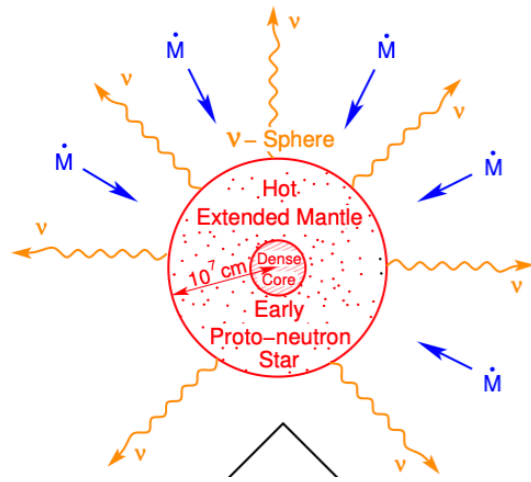
# KM3NeT/ARCA Seafloor Network Infrastructure



Simone Biagi *on behalf of the KM3NeT Collaboration*  
INFN — LNS



# The physics case



Super Novae explosion  
MeV

Neutrino oscillation  
GeV

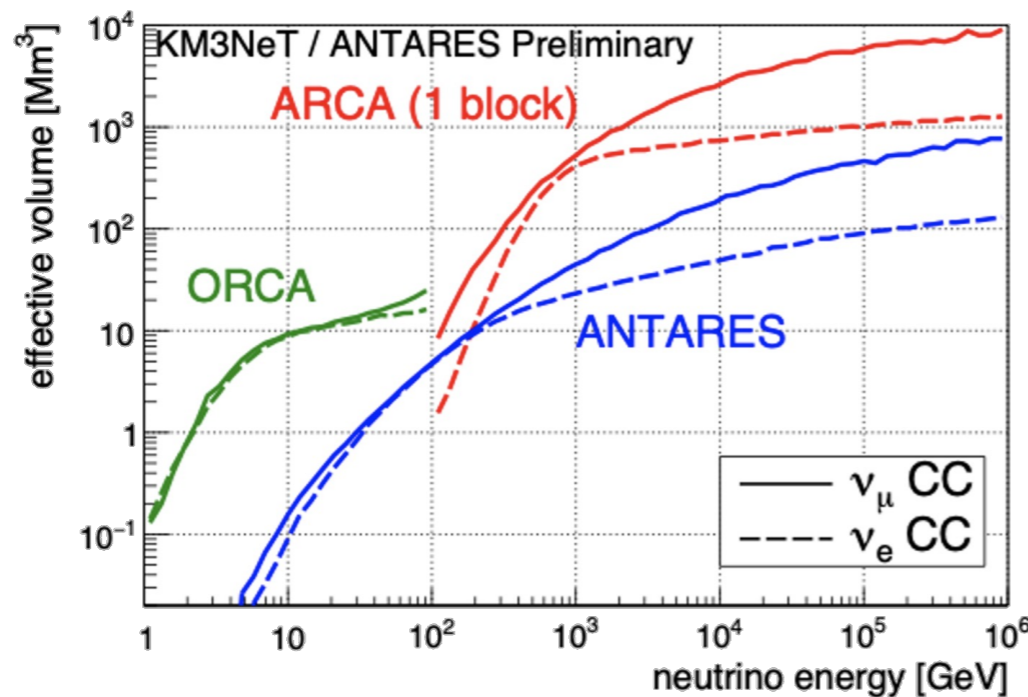
Dark Matter  
TeV

HE neutrinos  
Multi-messenger program  
PeV

ORCA

ARCA

ARCA



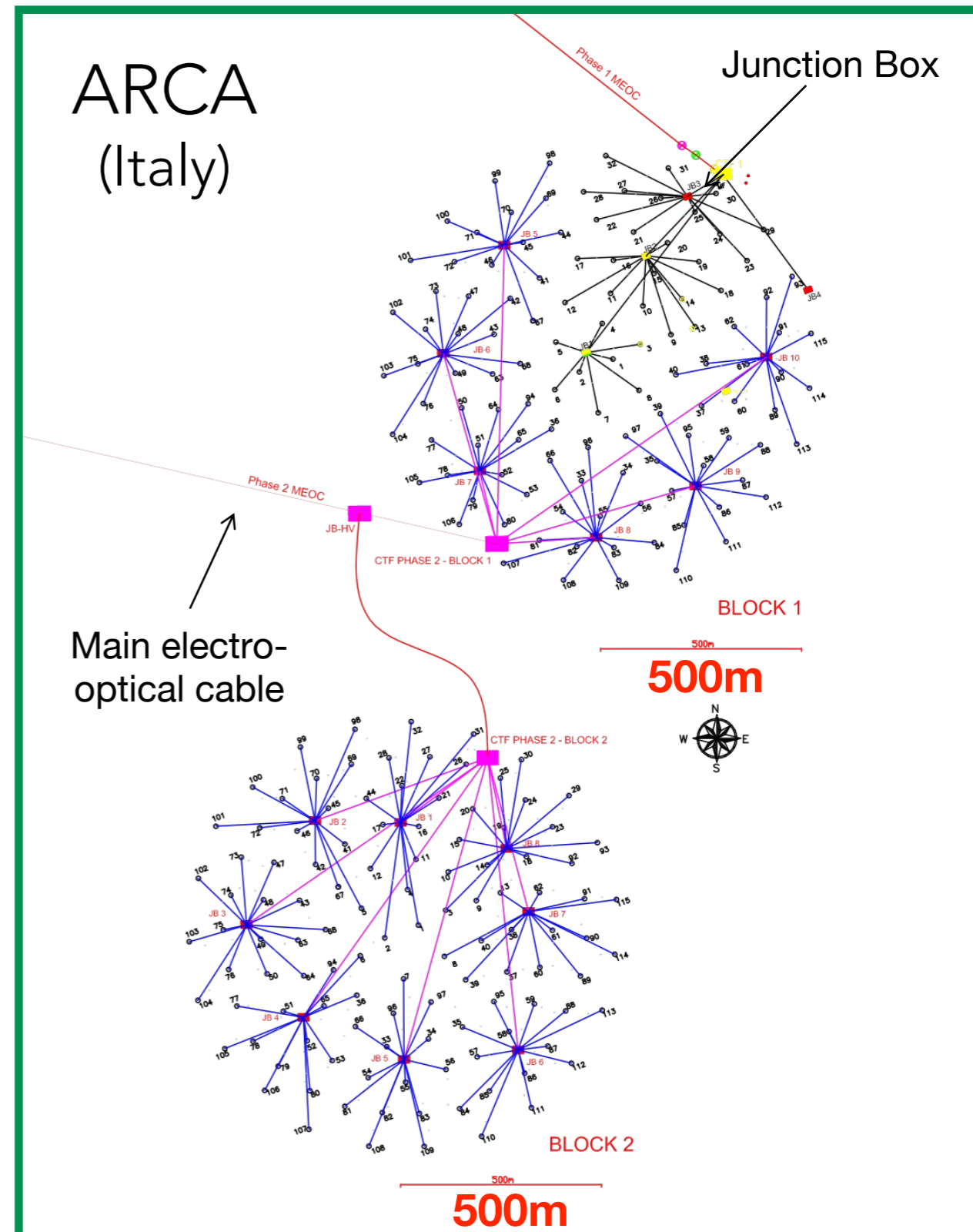
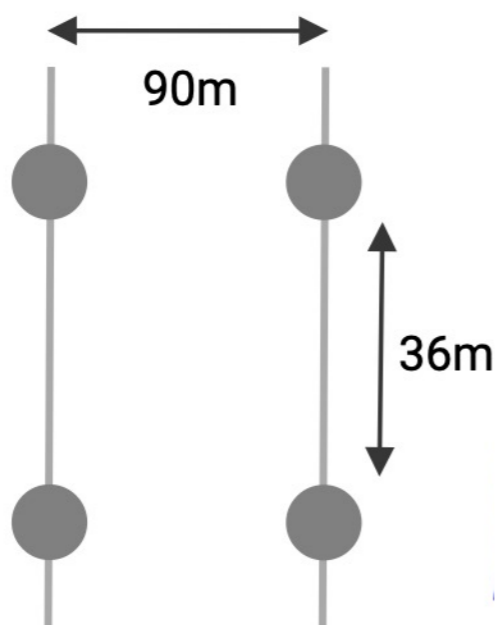
➤ Friday 27<sup>th</sup>, h 09:30: R. Coniglione, Status and perspectives of KM3NeT

Neutrino Energy from **MeV** to **PeV**

# The neutrino telescopes of KM3NeT

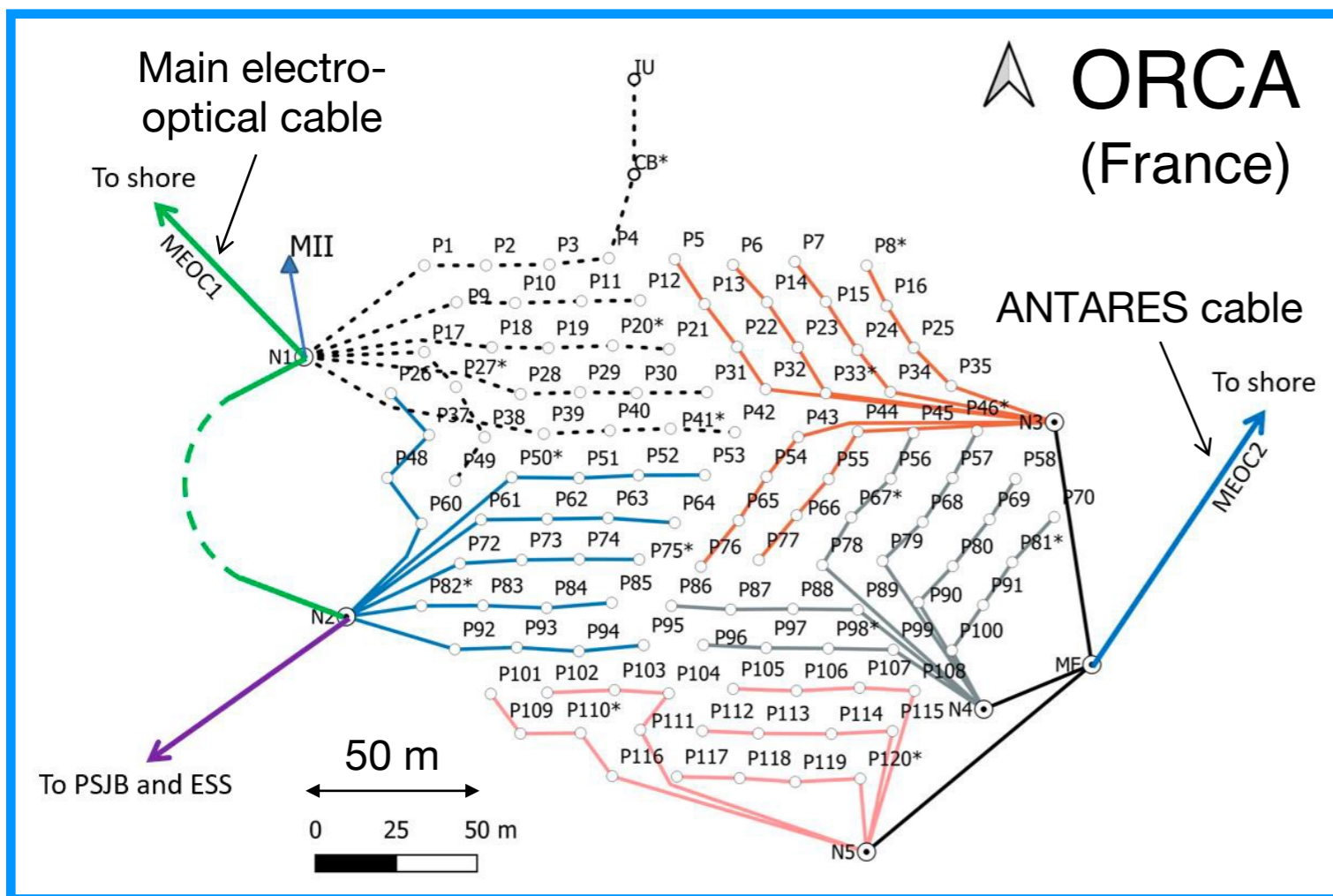
## ARCA: Astroparticle Research with Cosmics in the Abyss

- 2 Building Blocks
- 115 Detection Units each, interspacing  $\sim 90$  m
- 18 Digital Optical Modules (DOM) per DU, inter-DOM spacing 36 m
- Total active volume  $1 \text{ km}^3$ ,  $\approx 500$  Mton/block
- 3500 m depth, SE the Sicilian coasts
- 2 Main Electro-Optical Cables (MEOC) for connection to shore of a network of 9+8 junction boxes and inter-link cables

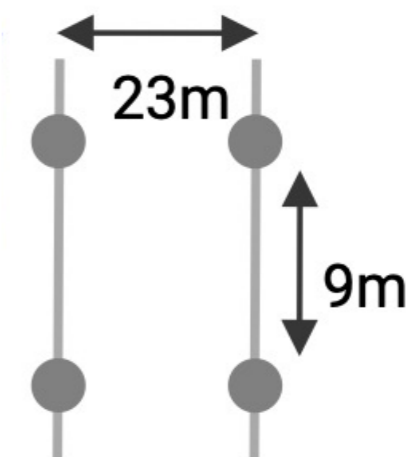


# The neutrino telescopes of KM3NeT

## ORCA: Oscillation Research with Cosmics in the Abyss

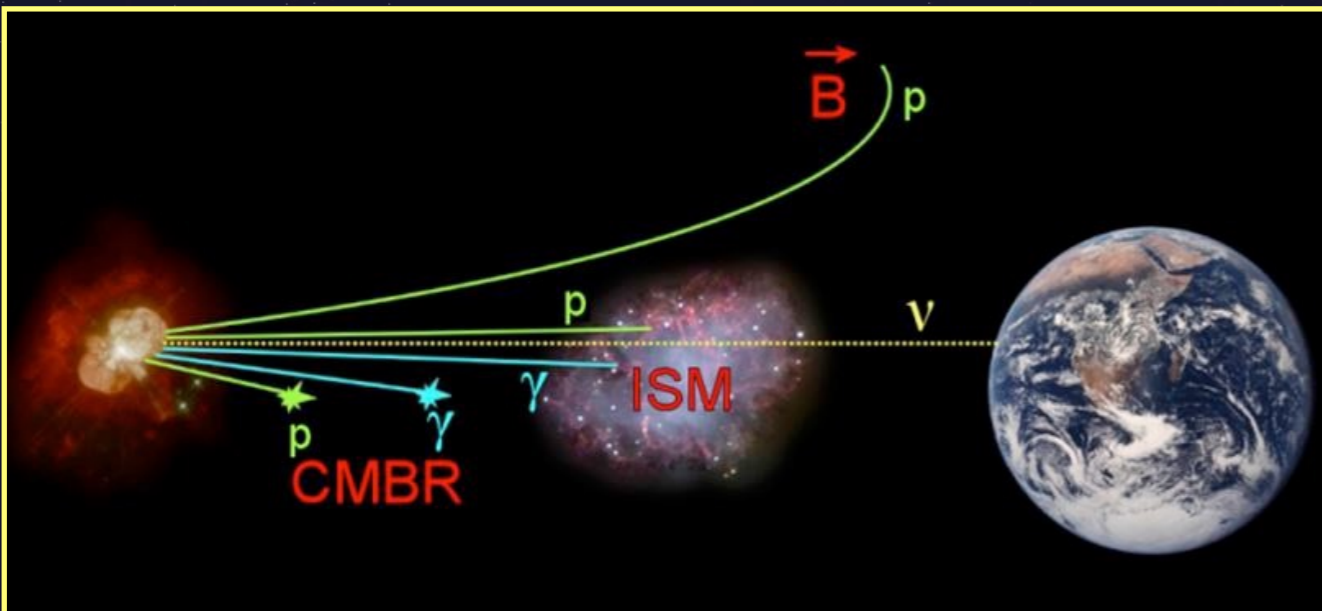


- 1 Building Block
- 115 Detection Units (DU), interspacing  $\sim 20$  m
- 18 Digital Optical Modules (DOM) per DU, inter-DOM spacing 9 m
- Active volume  $\approx 7$  Mton
- 2500 m depth, close to Toulon
- It will reuse the ANTARES main cable



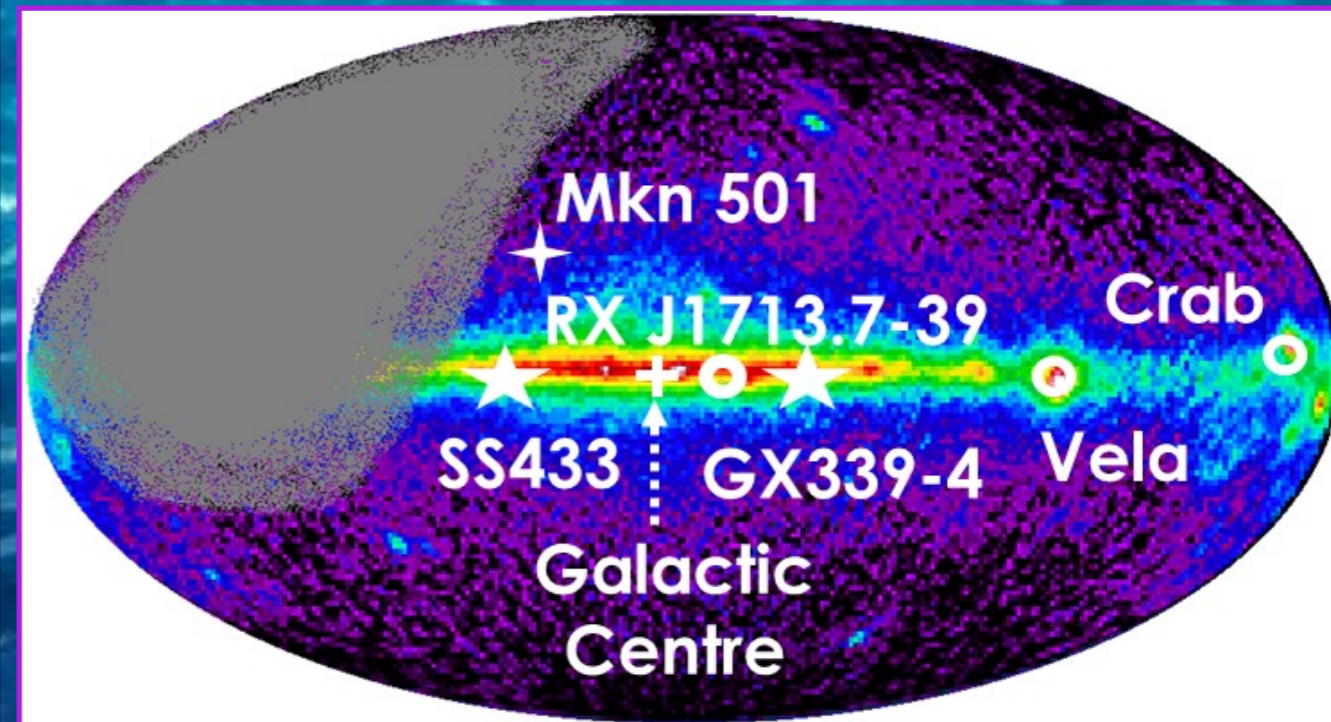
❖ NB: This talk is focused on ARCA infrastructure only!

# Neutrino Astrophysics in the Mediterranean Sea



- Origin of Cosmic Rays
- Neutral messengers point back to their sources
  - Neutrons are short-lived, photons are likely to interact  $\Rightarrow$  Neutrinos as cosmic probe
- Neutrinos are produced at sources via hadronic interactions
  - Cosmic diffuse flux
  - Point-like sources
  - Multi-messenger approach

- Detection principle: large volume of transparent medium instrumented with PMTs
- Located in the Northern Hemisphere
  - Complementary to IceCube
  - Southern sky sources, “Milky-Way optimised”
- Medium: Deep Sea Water
  - Very small light scattering = good angular resolution
  - Natural background ( $^{40}\text{K}$  and bioluminescence) taken into account.



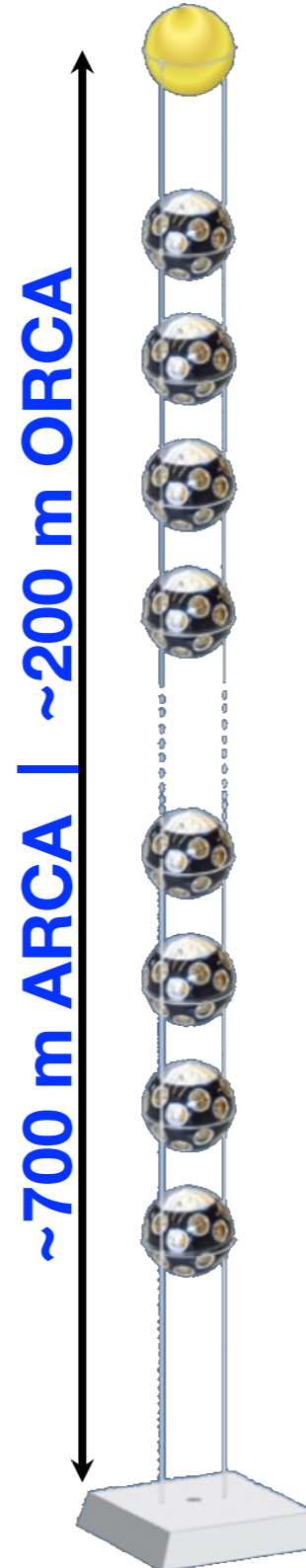
# KM3NeT Technology in a nutshell

## Digital Optical Module

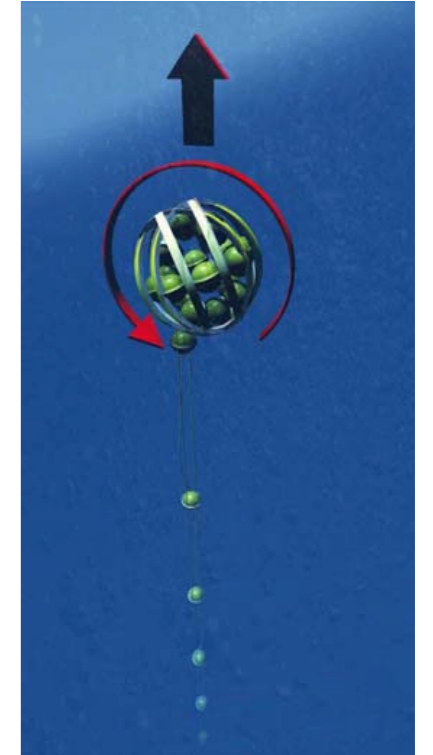
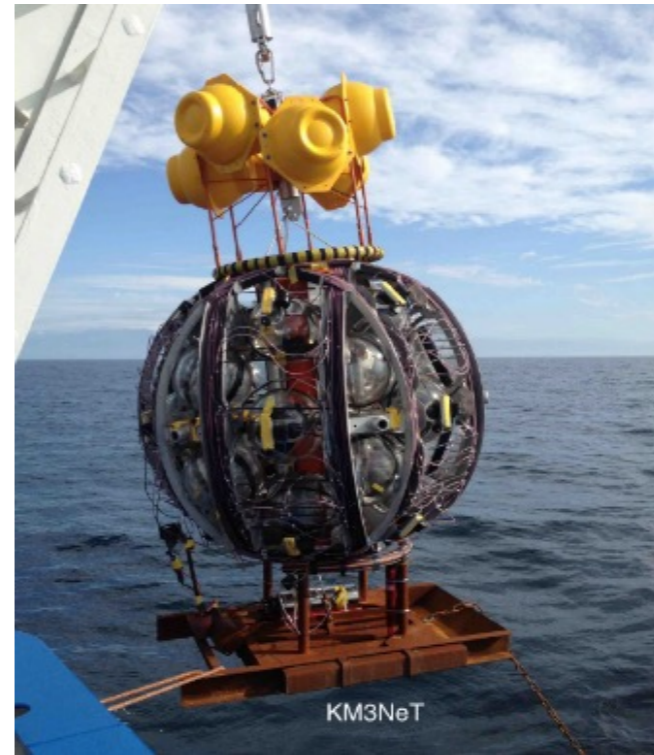


- DOM: 31 x 3" PMTs
- Digital photon counting
- Directional information
- Wide acceptance angle
- All data to shore
- Gbit/s on optical fiber
- Custom White Rabbit
- 18 DOMs / String

## Detection Unit (string)

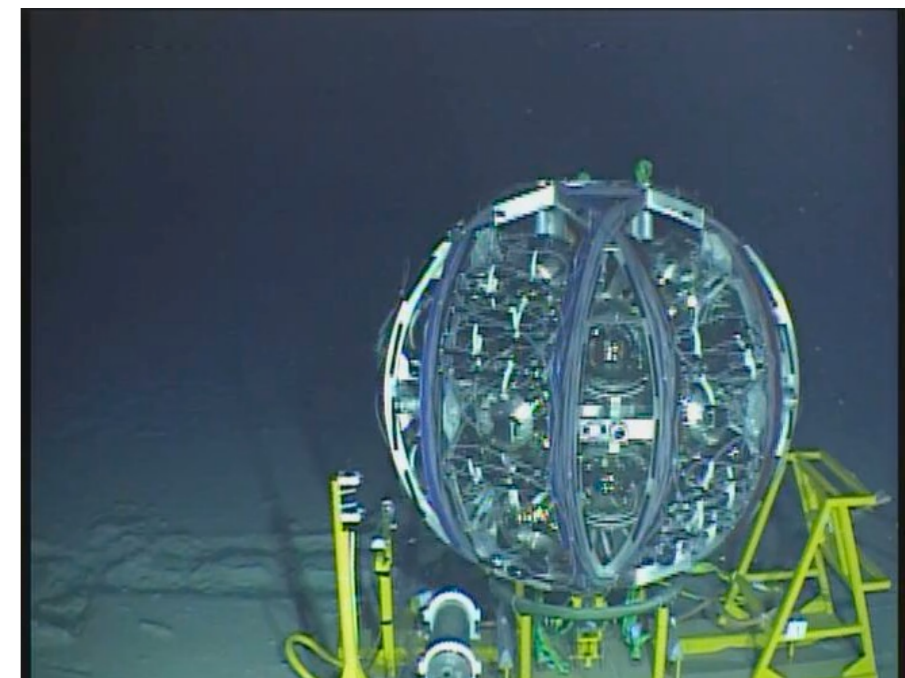


- Unfurling by autonomous ROV
- Rapid deployment
- Multiple strings in one sea campaign

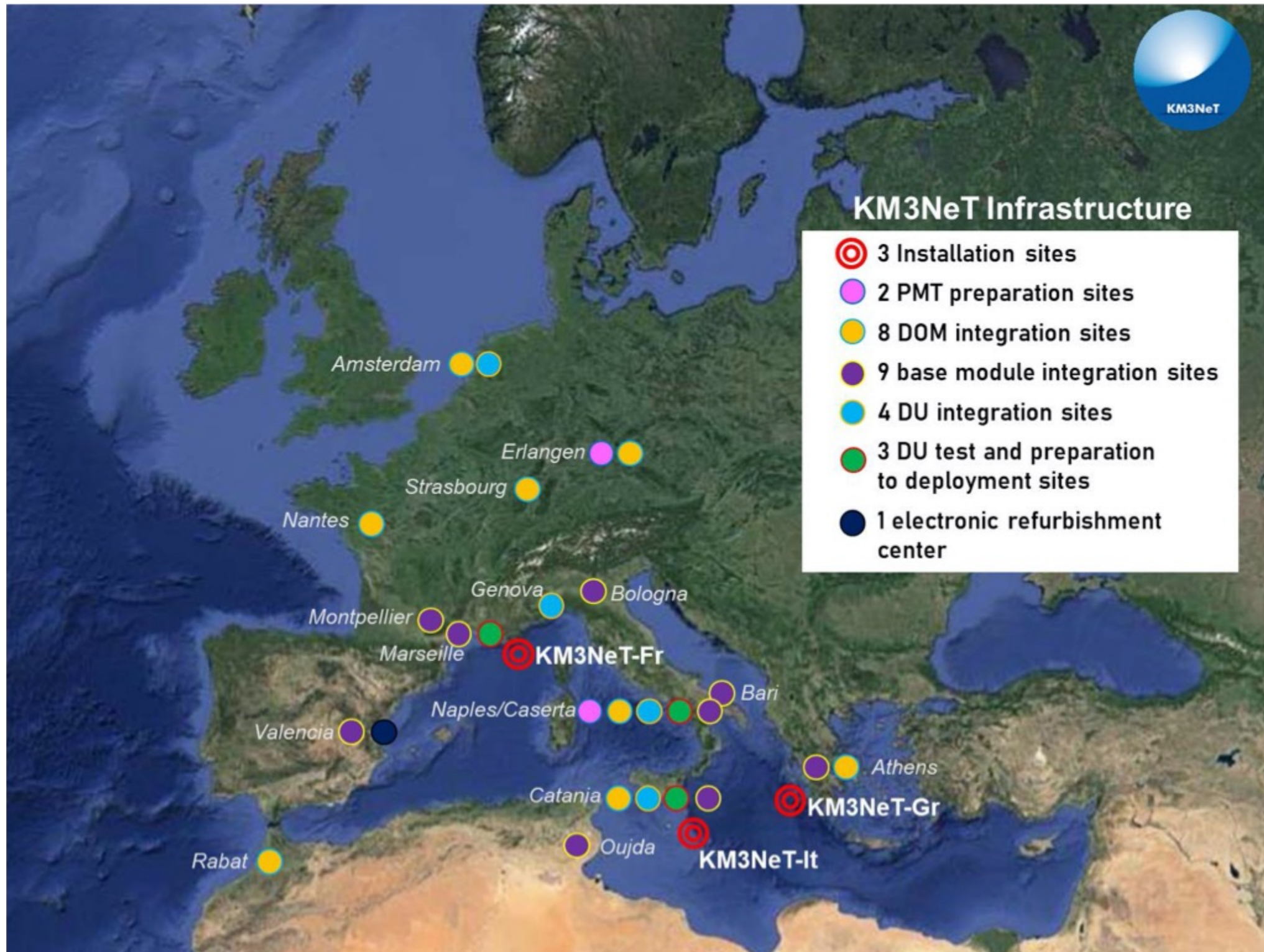


DOM: JINST 17 (2022) P07038

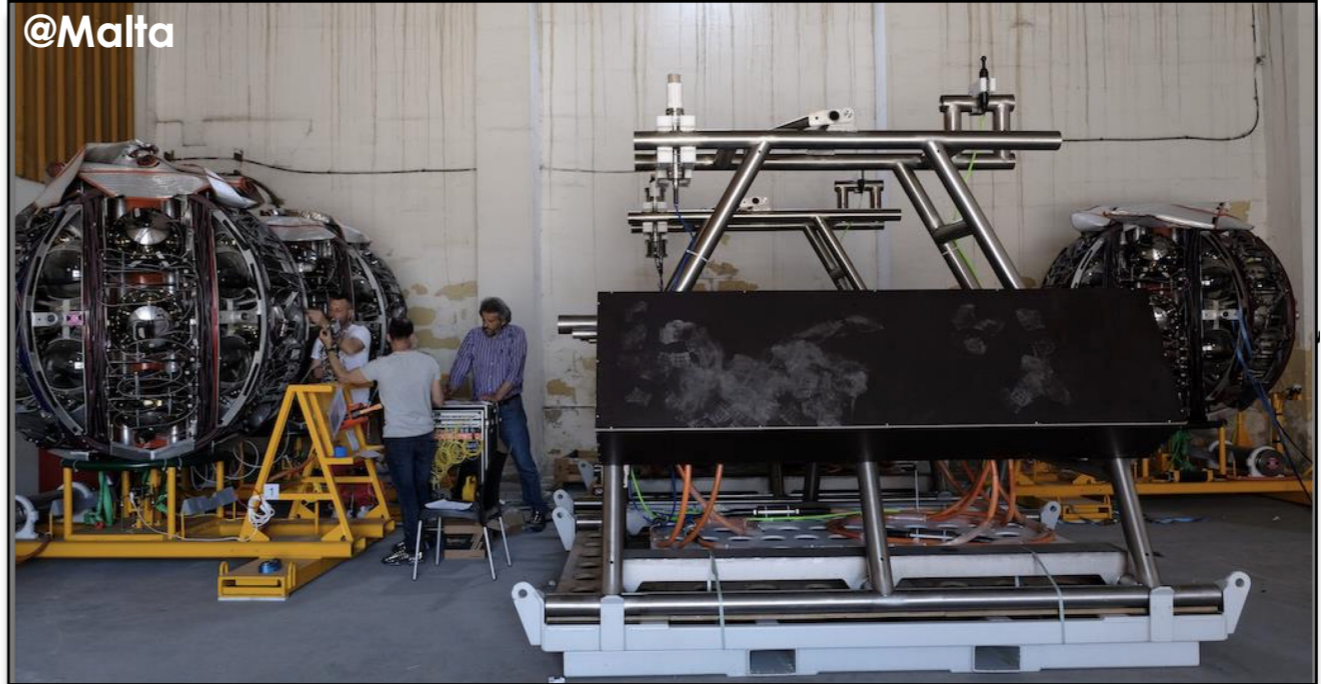
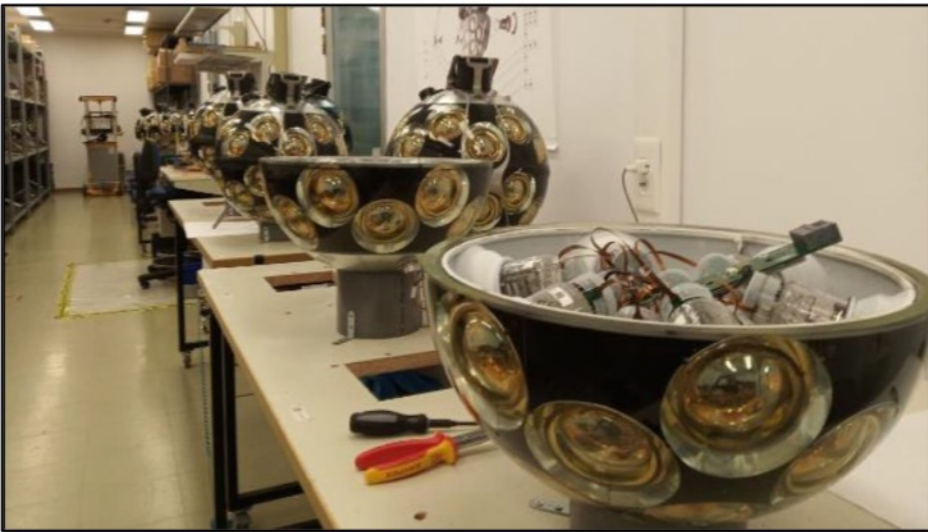
Unfurl: JINST 15 (2020) P11027



# Detector construction



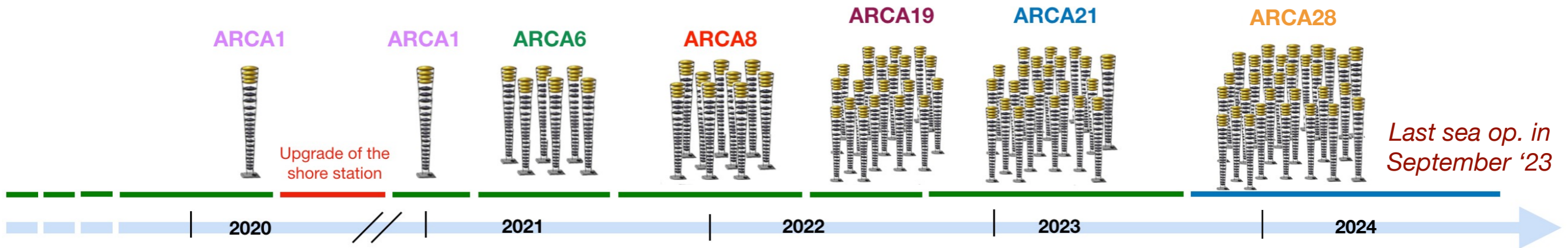
# Detector construction: a collaborative effort!





# ARCA: Construction Phase

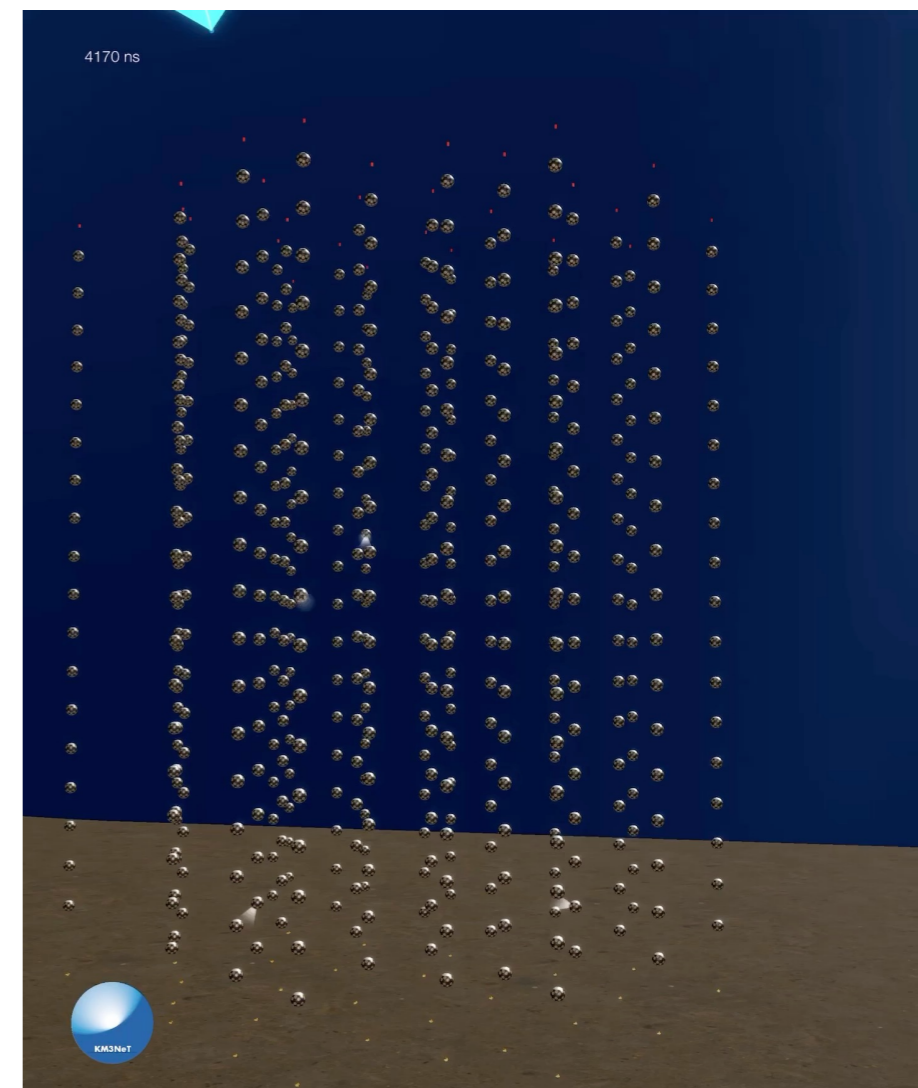
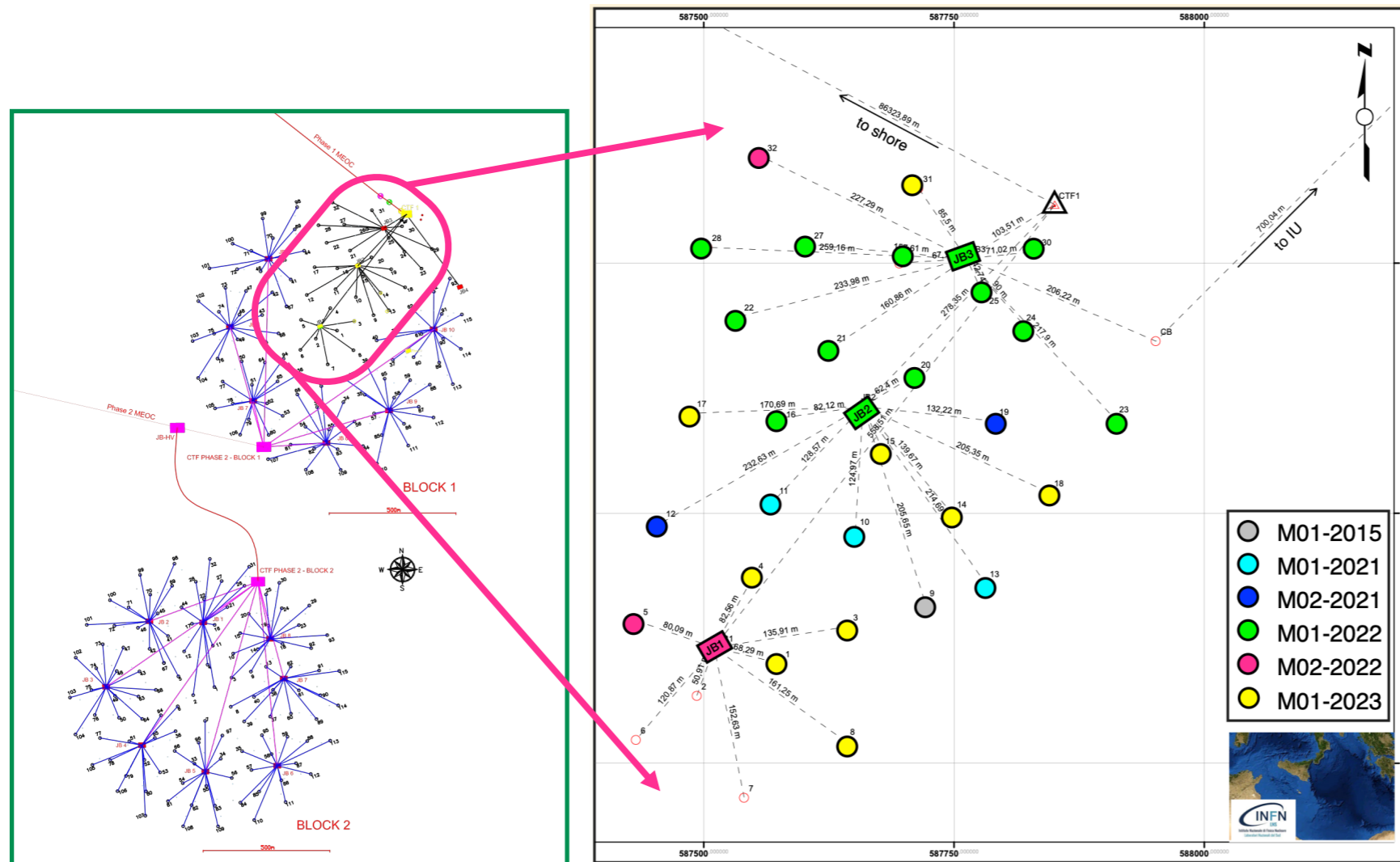
Typically, 1-2 sea campaign per year



First DU deployed in December 2015.

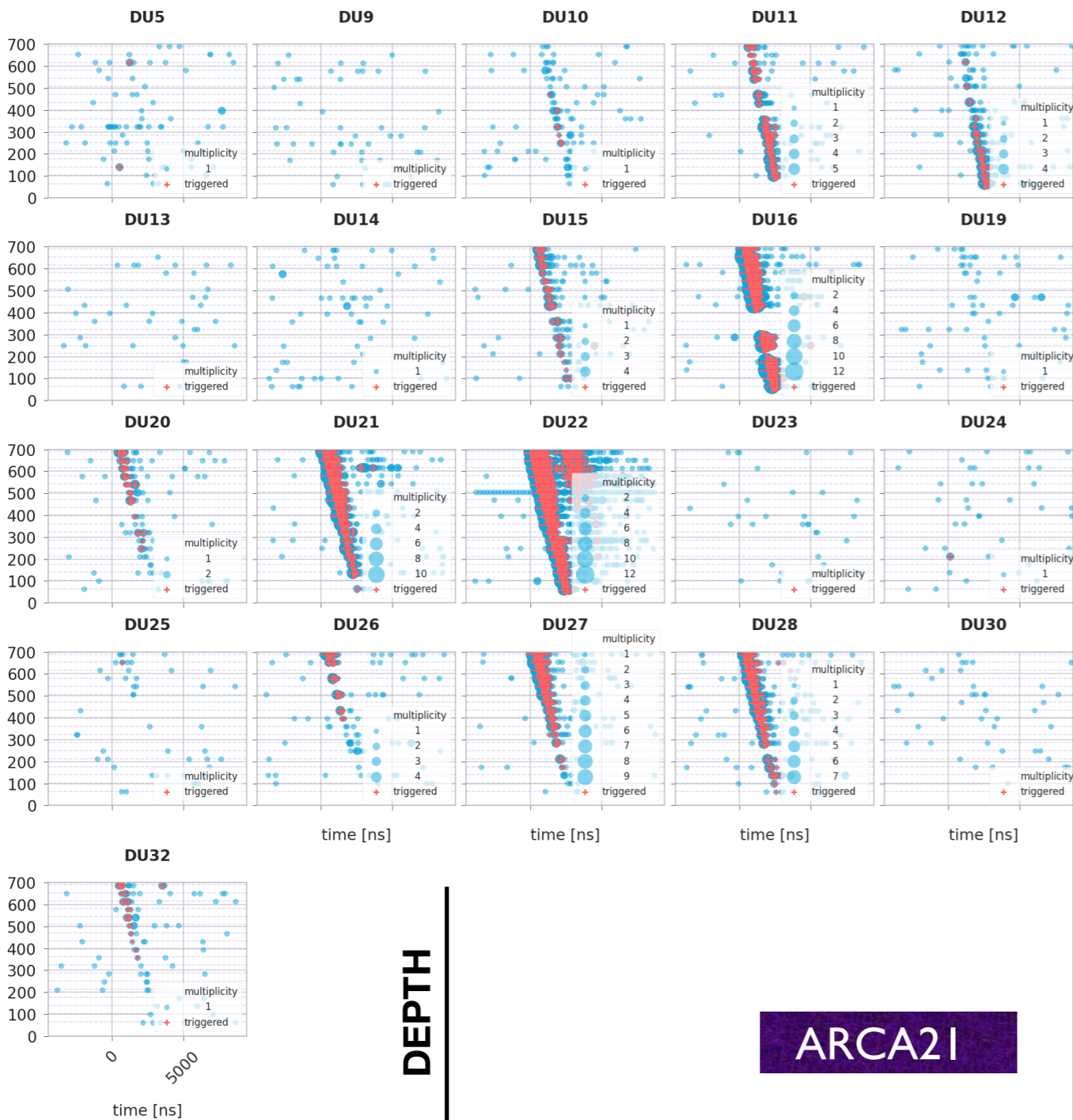
Then, some issues in the electrical network, solved in 2020.

Phase-1 completed



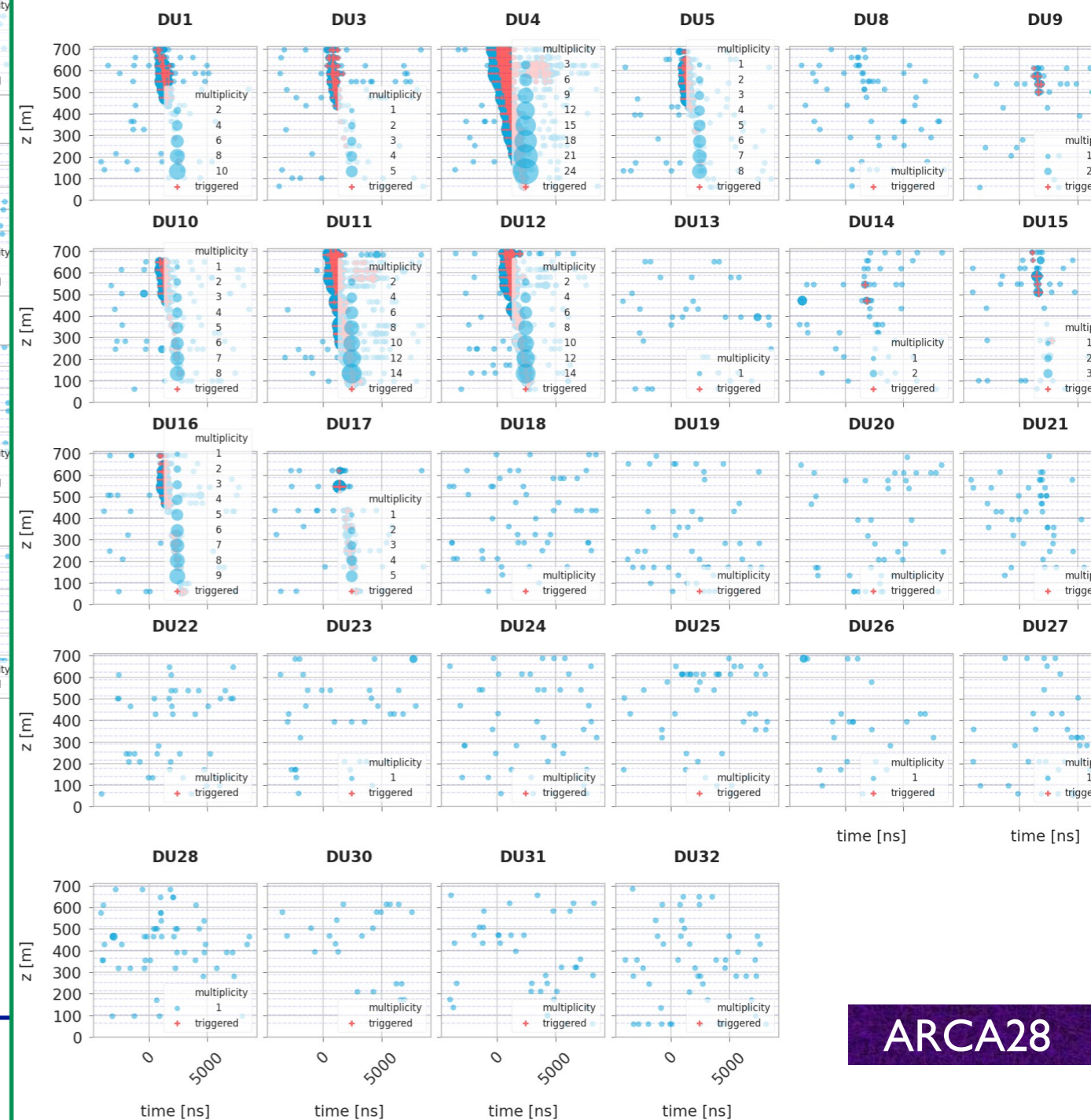
# Selected triggered events

z-t-Plot for DetID-133 Run 14457, FrameIndex 105168, TriggerCounter 2766, Overlays 894, Trigger: MX 3DM 3DS  
2023-01-19 08:55:16 UTC



*From the online monitoring*

z-t-Plot for DetID-160 Run 18575, FrameIndex 48218, TriggerCounter 1562, Overlays 499, Trigger: MX 3DM 3DS  
2023-10-02 04:20:21 UTC



# Location of ARCA

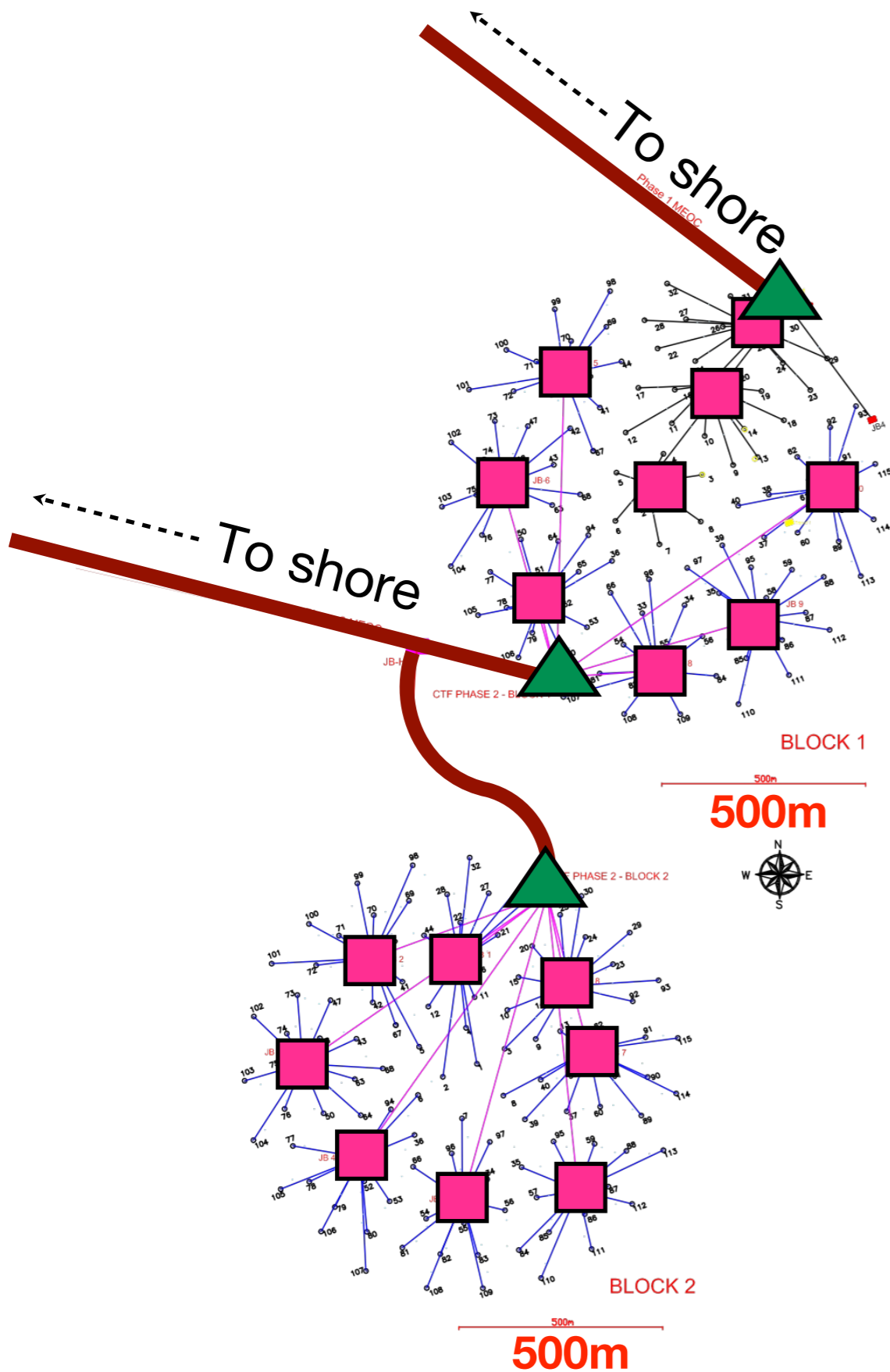


Onshore station:  
Portopalo di Capo Passero  
the Southwest point of Sicily

- Offshore site is ~92 km from the coast of Portopalo
- Water depth 3500 m
- Expected lifetime 20 years  
>> No maintenance offshore



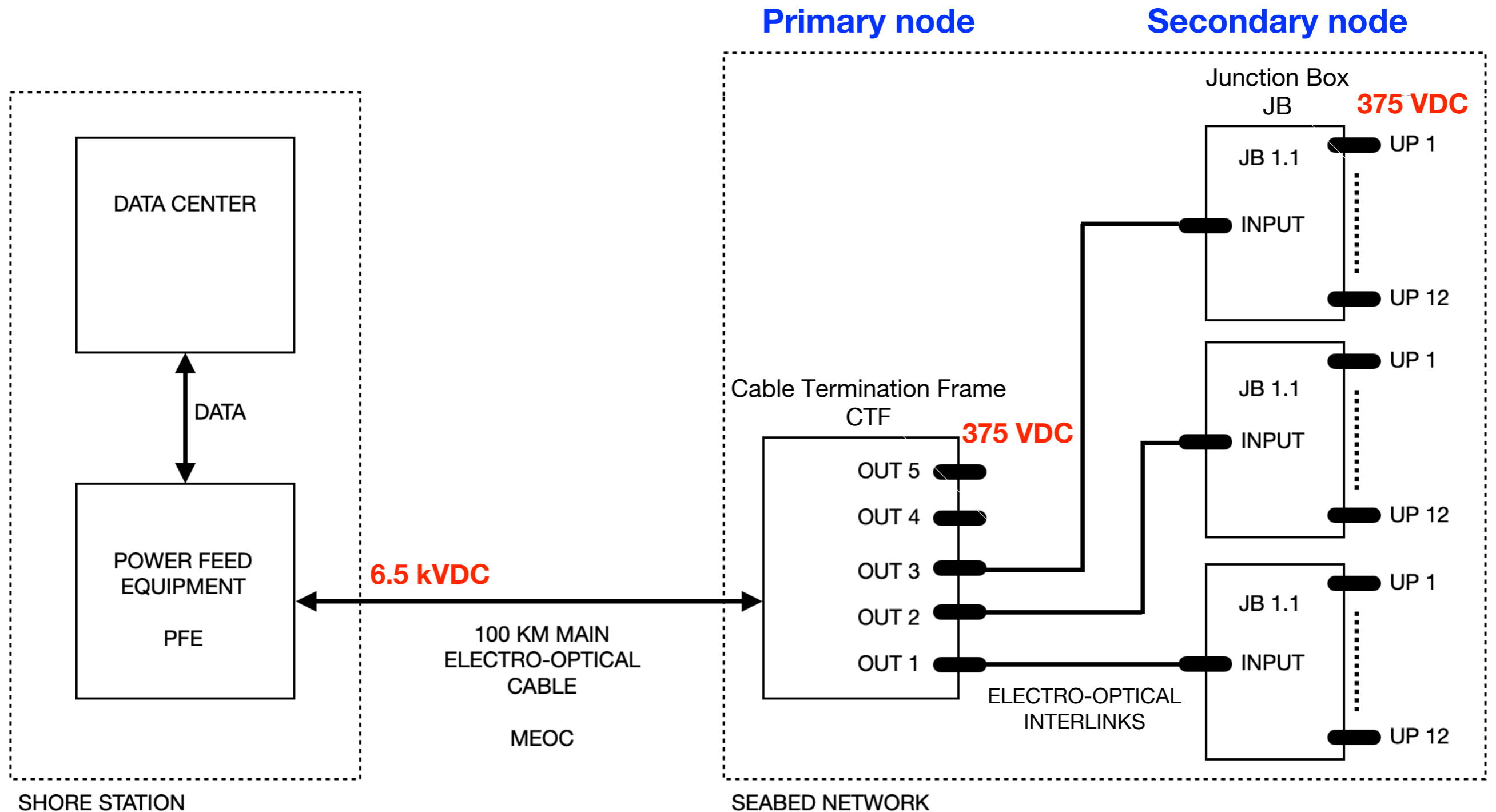
# The elements of the infrastructure



- 2 Main Electro-Optical Cables (MEOC)
- 3 Cable Termination Frames (CTF)
- 9 + 8 Junction Boxes (JB)
- A network of Interlink cables
  - ◆ JB to CTF
  - ◆ DU to JB

# ARCA Seafloor network block diagram

## ARCA-Phase 1 completed

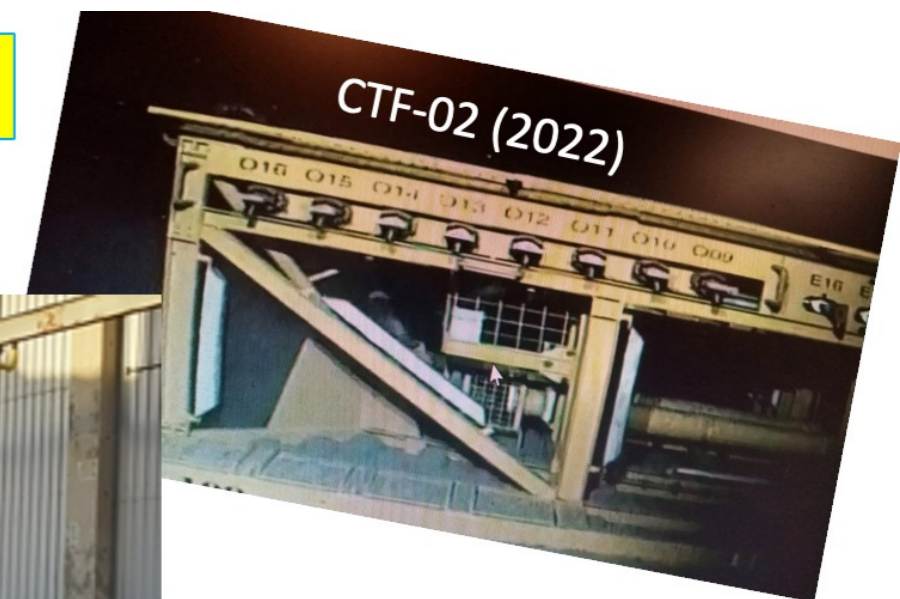


# Seafloor network

- Main Electro-Optical Cable 1: DC power sea-return: “Standard” DC Solution
- Main Electro-Optical Cable 2: DC power 2 conductors
- Star-like power and optical distribution system in deep-sea:
  - Cable Termination -> Junction Boxes -> “Science nodes”



25 year operation no maintenance



# Capo Passero submarine infrastructure

The ARCA Shore lab at Capo Passero has direct 10Gbit connection to the EU optical network infrastructure for research



**ARCA - PHASE 1** cable (2007):  
100 km-long electro-optical cable  
20 fibers, 1 conductor (DC)

Cable Termination Frame (CTF-01):

- 1 MVC, 10 kW
- 20 fibers
- 5 e.o. ROV mate hybrid ports

**ARCA - PHASE 2** Cable (2022):  
100 km-long electro-optical cable  
48 fibers (44 for science, 4 controls), 2 conductors (DCFO)

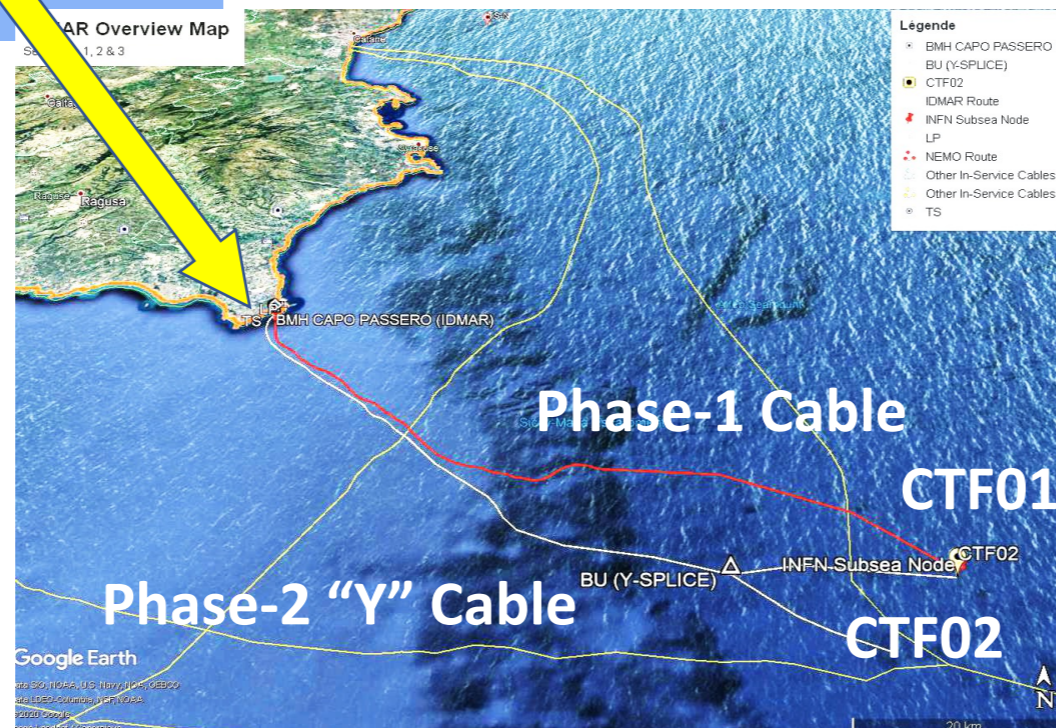
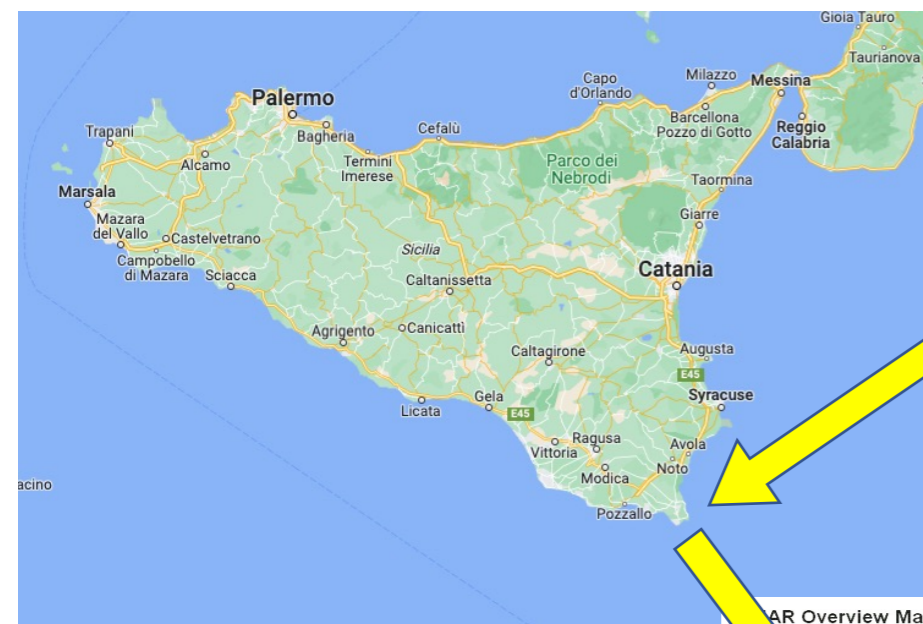
Cable Termination Frame (CTF-02):

- 4 MVCs, 40 kW
- 22 fibers
- 16 e. and 16 o. ROV mate ports

CTF-03 will have 24 fibers and 4 MVCs

\* MVC = Medium Voltage Converter

\* ROV = Remotely Operated Vehicle



# ARCA infrastructure for 2<sup>nd</sup> Building Block

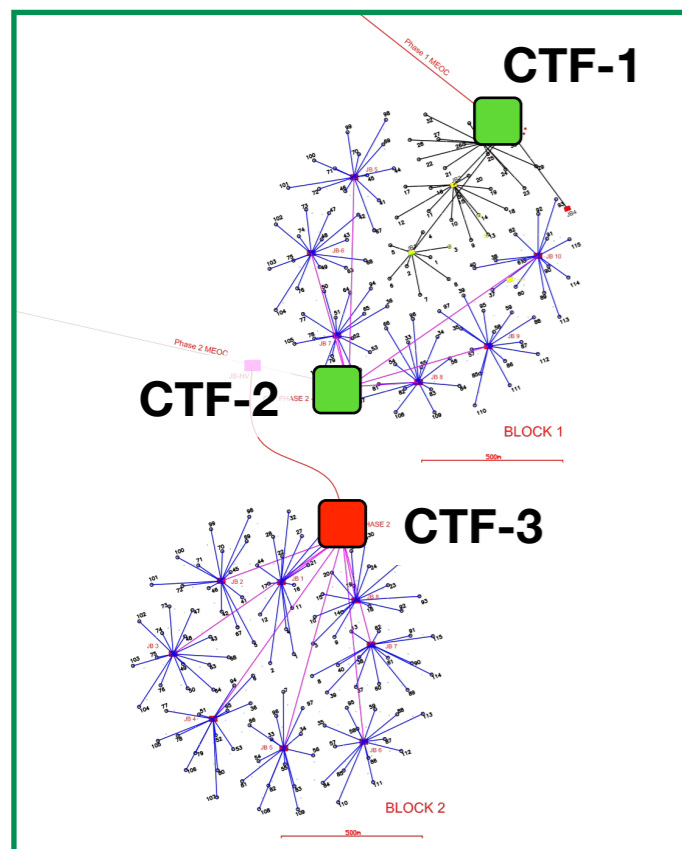
Cable lay  
**2020**



Shore installation  
**2021**



CTF installation  
**2022**

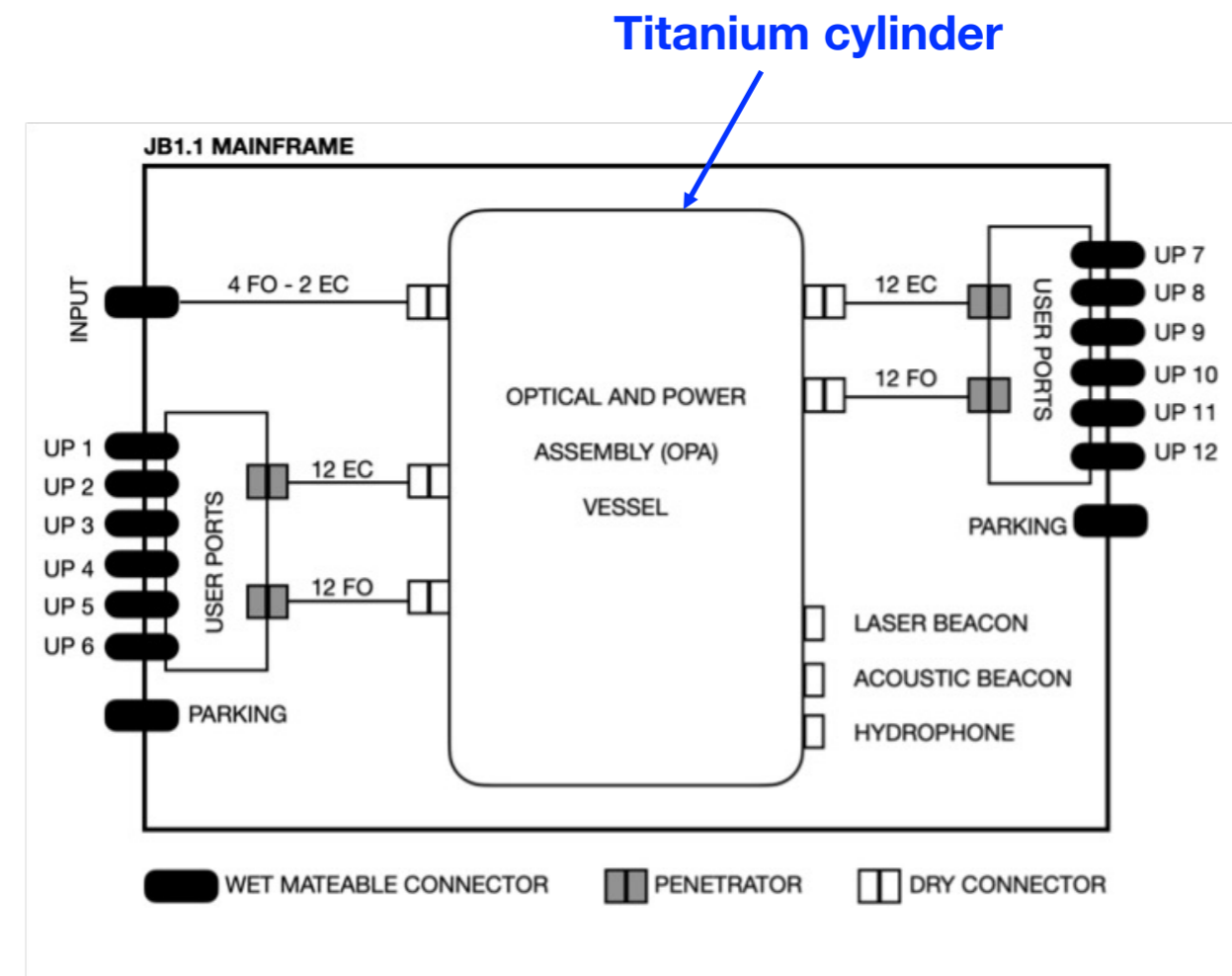


With two main cables, it is possible to connect the full ARCA detector (2 building blocks)  
PNRR is funding the construction and installation of the CTF-3, to power the second block



# The Junction Box

- Technology developed together with external companies, from oil&gas
- Electronics intrinsically redundant, every component is duplicated in case of breaking
- Boards and components produced with military/space standard
- This junction box meets the requirement of a 20-year lifetime at 3500m sea depth
- With a reliable infrastructure, DU mass production can start



# JB electronics core



# Full pressure test in hyperbaric chamber



# Functional tests via I/O ports

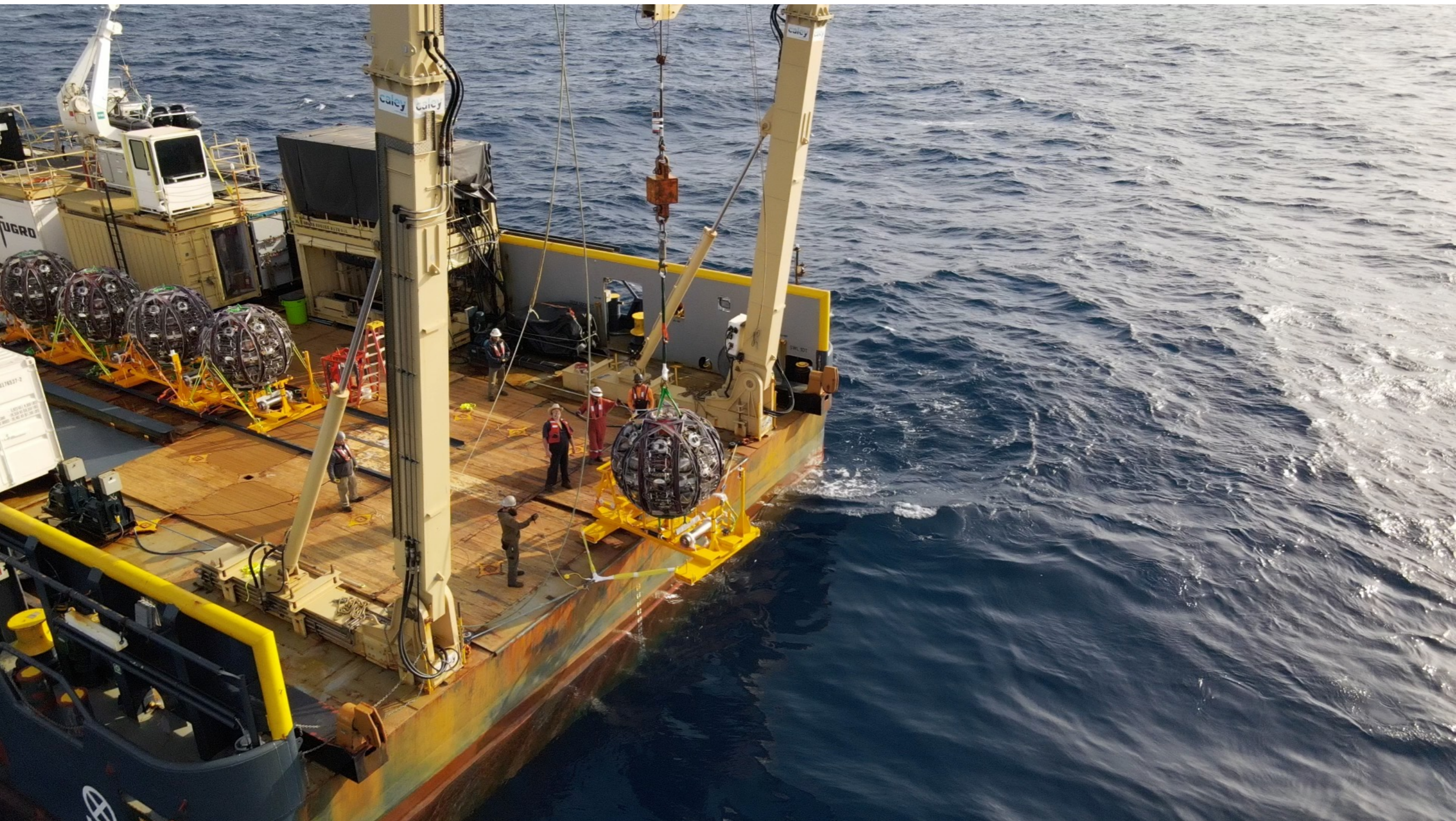


# Summary

- KM3NeT is active and taking data!
- The submarine network infrastructure developed in cooperation with companies active in Oil&Gas.
- Main requirement: zero maintenance for 20 years.
- Military/space standards for critical electrical components.
- ARCA (ORCA) currently in 28 (18) line configuration.
- Detector mass production ongoing. Production rate will increase in the next years
- Interesting physics results in the next (few) years!

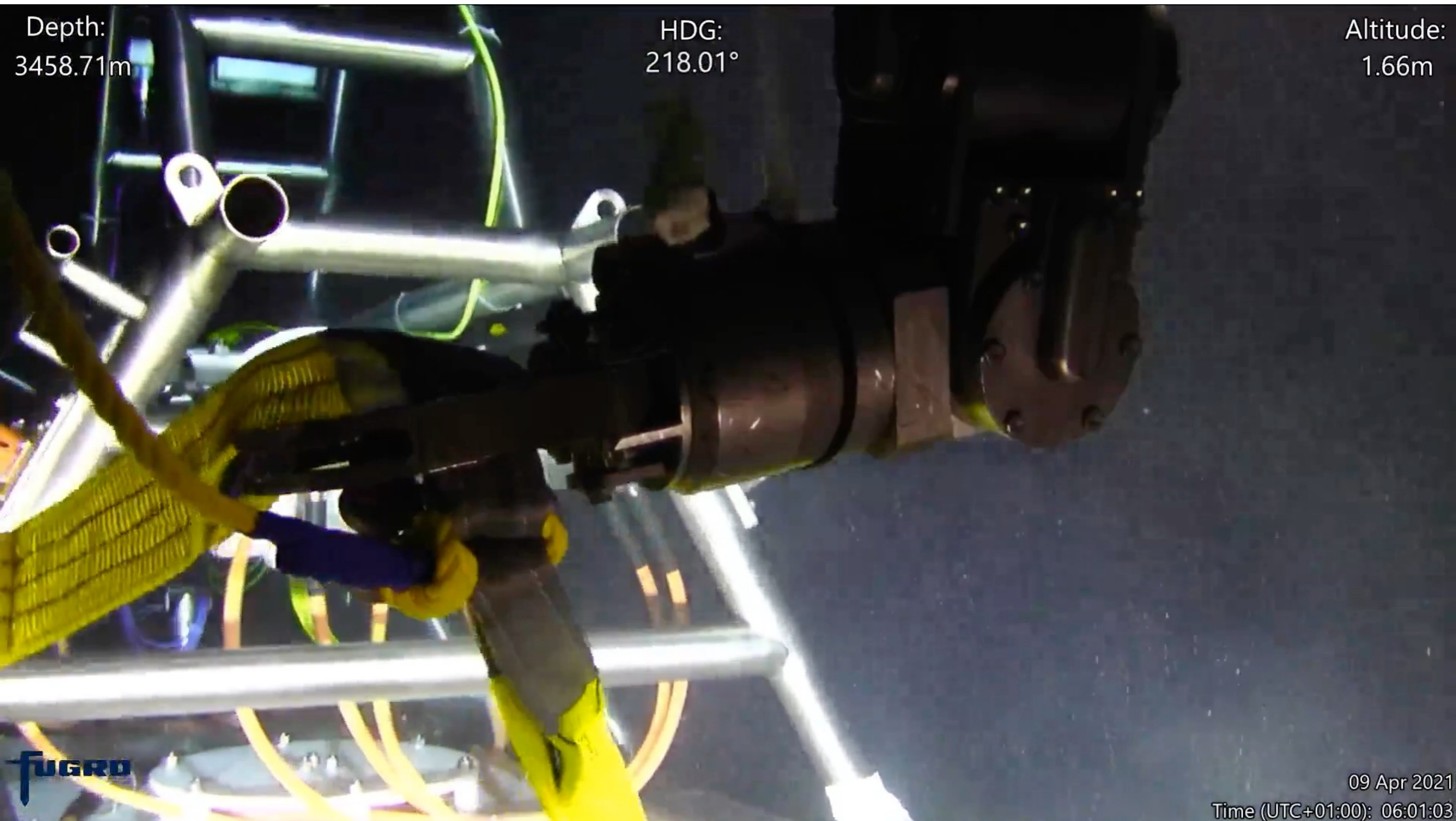


# Detection Unit deployment



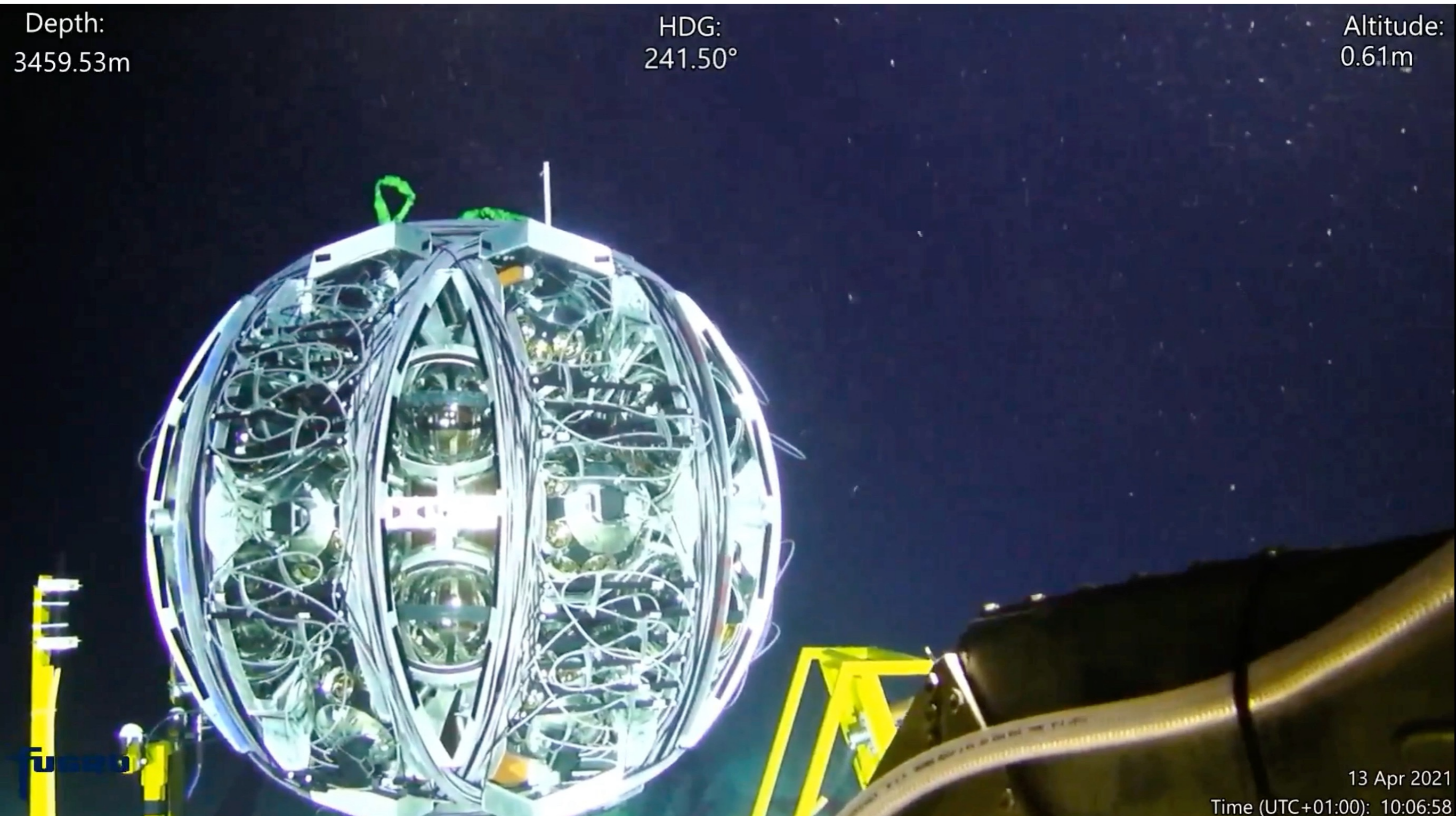
Deployments: **launcher module (LOM) with anchor**, lower to sea floor, connect, test, unfurl, retrieve LOM

# Junction Box touchdown (4x)



Deployments: launcher module (LOM) with anchor, **lower to sea floor**, connect, test, unfurl, retrieve LOM

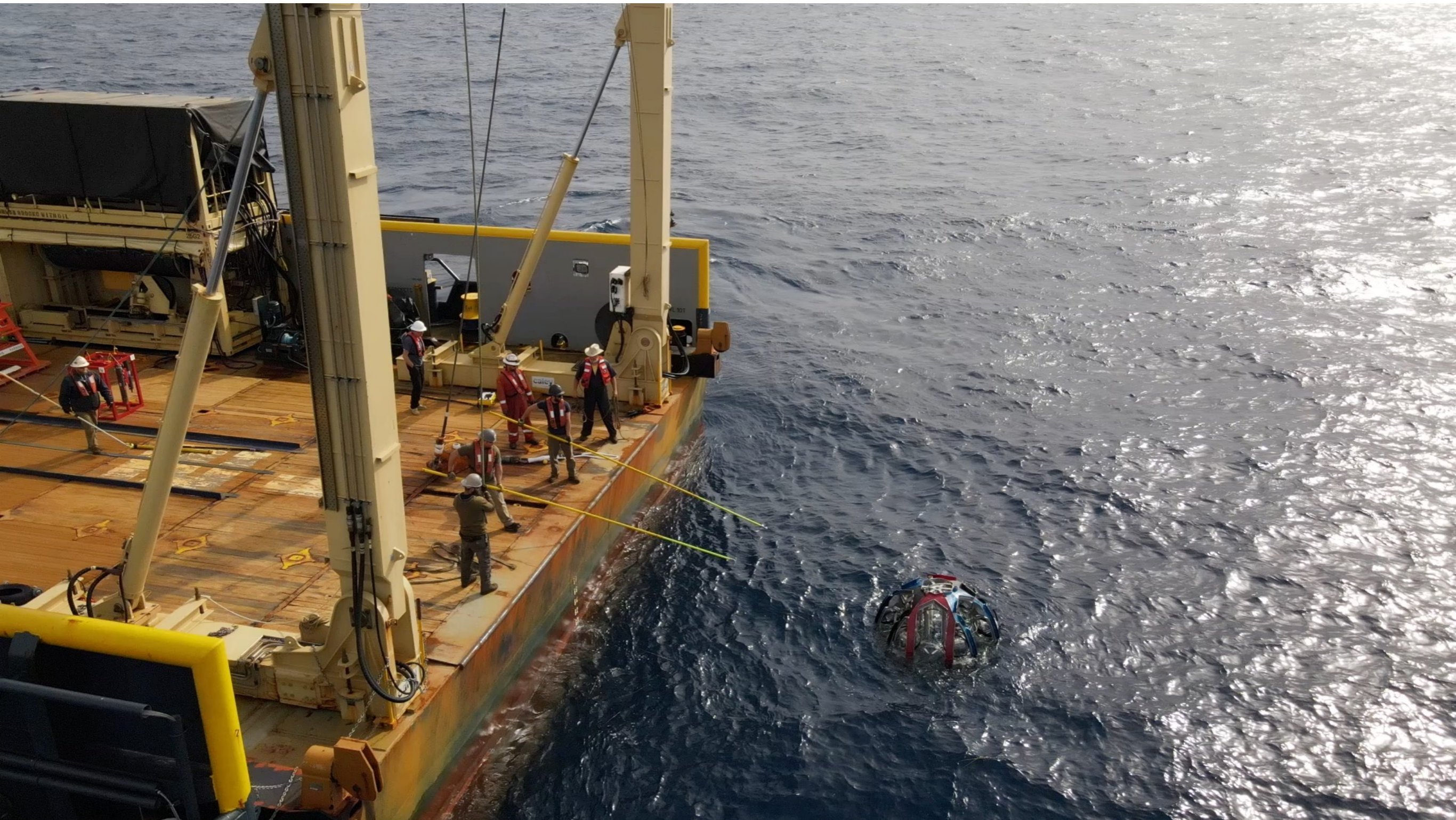
# Detection Unit unfurling, triggered by ROV



Deployments: launcher module (LOM) with anchor, lower to sea floor, connect, test, **unfurl**, retrieve LOM



# LOM recovery (after unfurling)



Deployments: launcher module (LOM) with anchor, lower to sea floor, connect, test, unfurl, **retrieve LOM**

# Junction Box deployment



Deployment during nighttime. We work 24h 7/7 offshore!