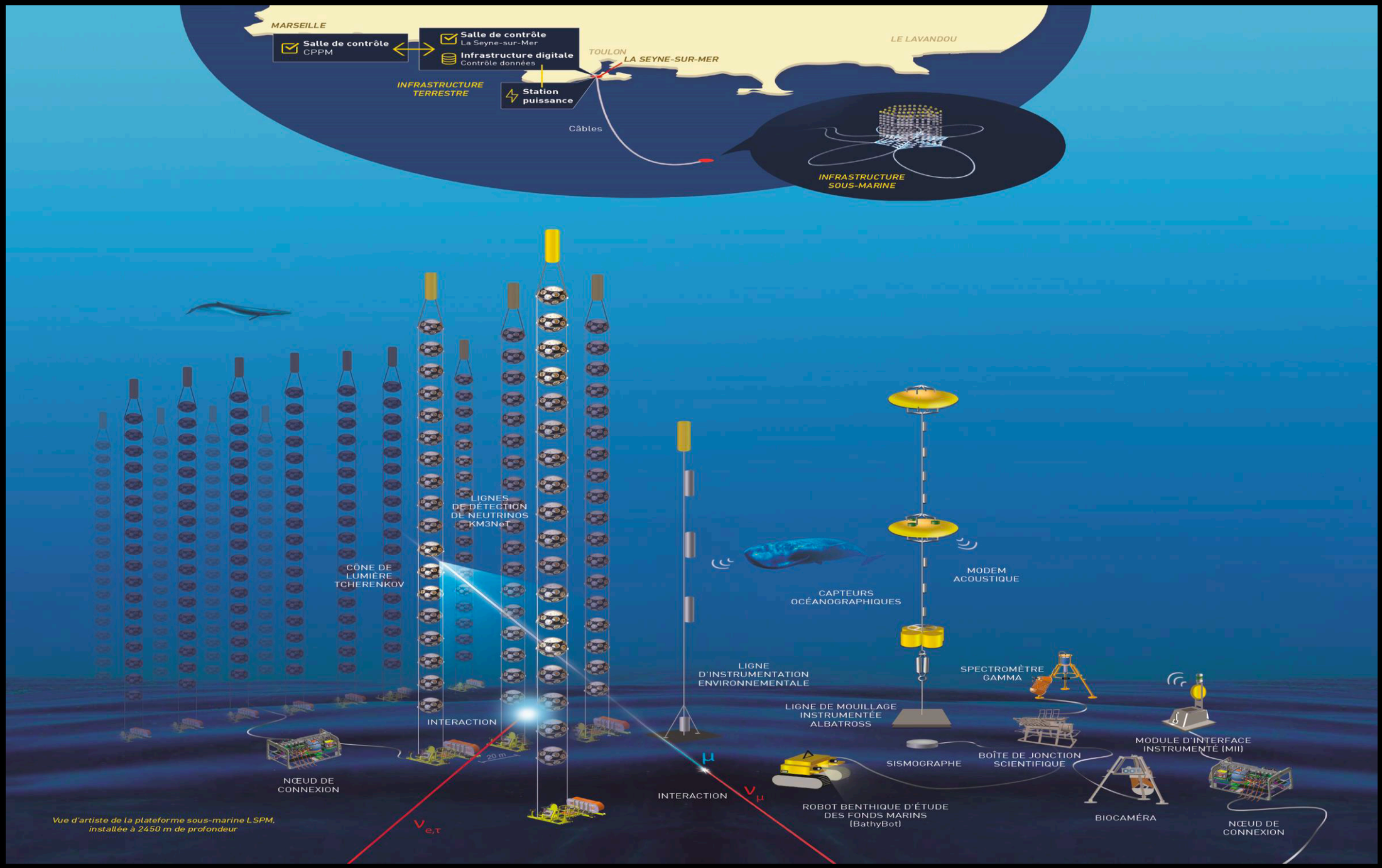
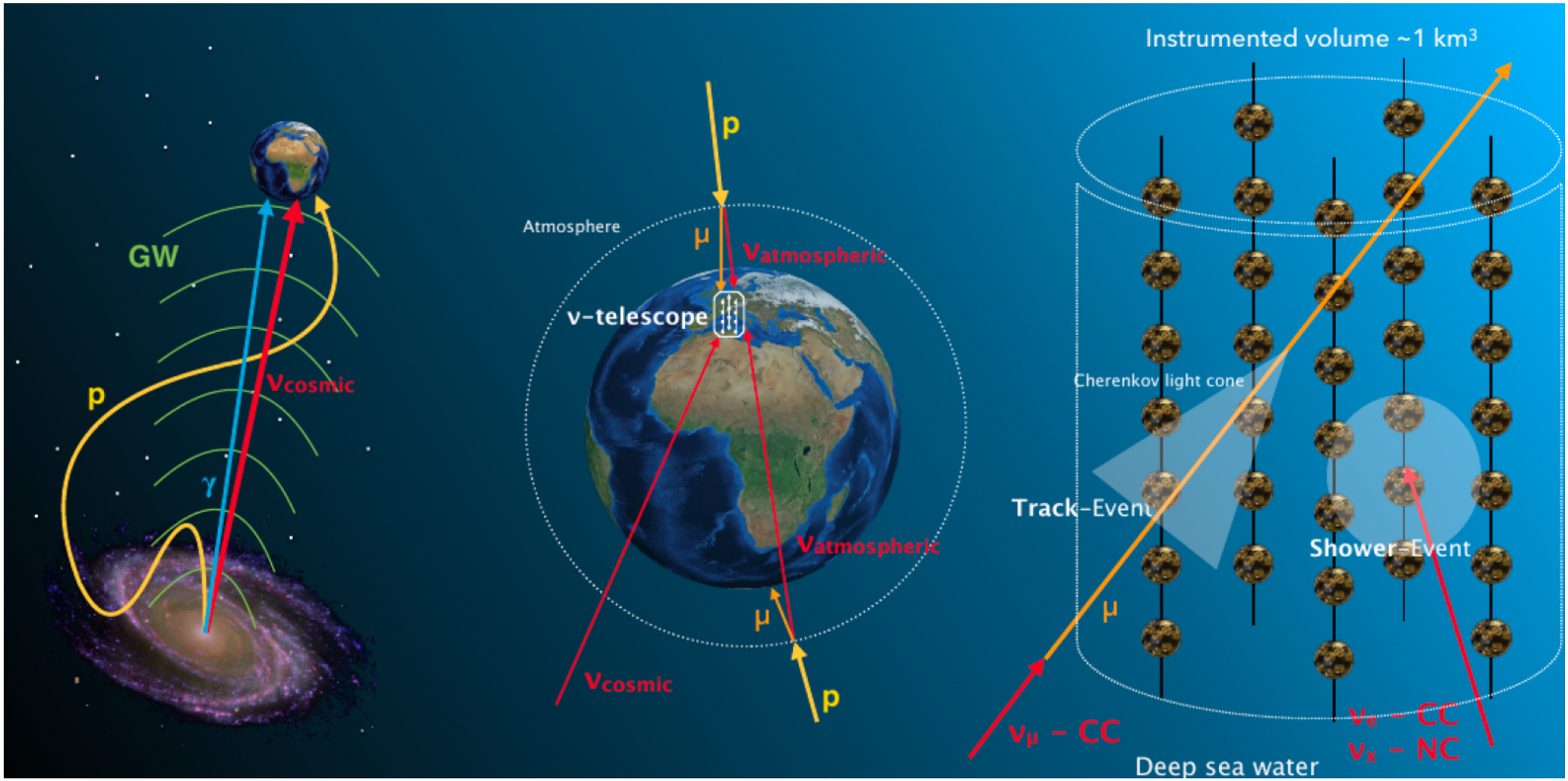
# KM3NeT

## Multi-purpose Mediterranean Sea Neutrino detectors




Damien Dornic - CS-IN2P3 - 02/03/2026

# Neutrino detection in KM3NeT



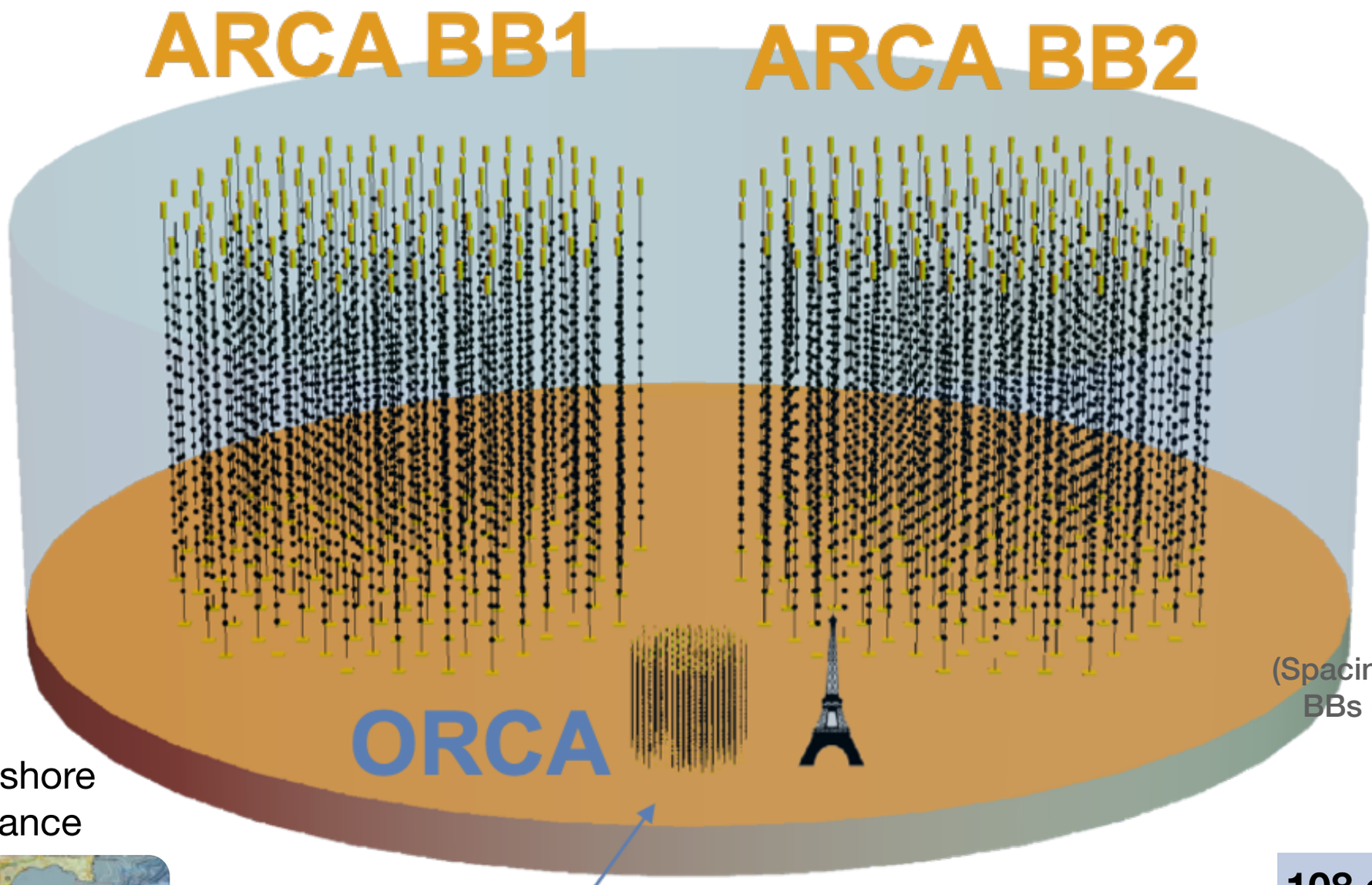
# KM3NeT detector scales

**230 detection units**

**4140 optical modules**

**128340 PMTs**

36m vert. x 90m horiz. spacing TeV - PeV

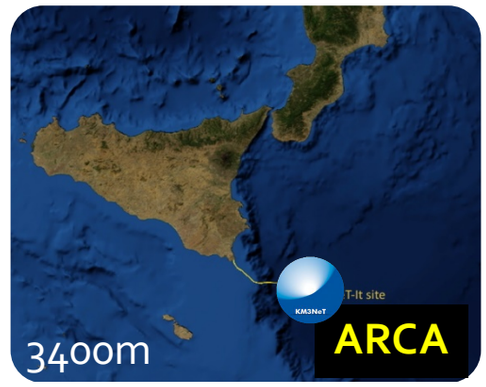



(Spacing between the 2 BBs is not at scale)

9m vert. x 20m horiz. spacing GeV - TeV

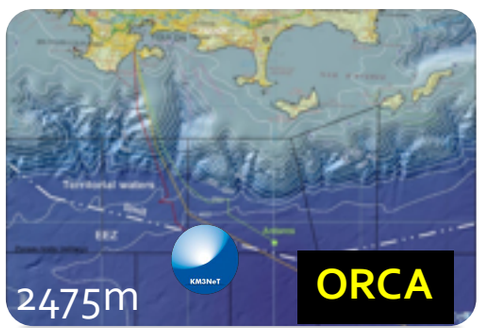
**Astroparticle Research with Cosmics In the Abyss**

ARCA: off shore Capo Passero, Italy




**Oscillation Research with Cosmics In the Abyss**

ORCA: off shore Toulon, France



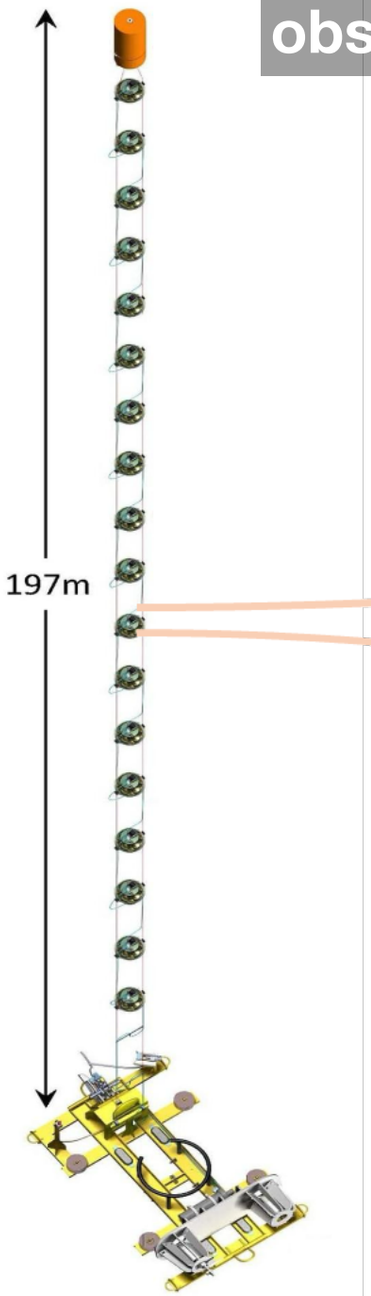

**108 detection units**

**1944 optical modules**

**60264 PMTs**

# KM3NeT Technologies

**The KM3NeT digital optical modules are the eyes of the experiment observing the light around it**




**KM3NeT Digital Optical Modules**

31 PMT assembled in a presure resistant glass sphere

18 DOMs mounted on a mouring line anchored on the sea bed

**Inspired several experiments**

HyperK

IceCube

# KM3NeT Technologies

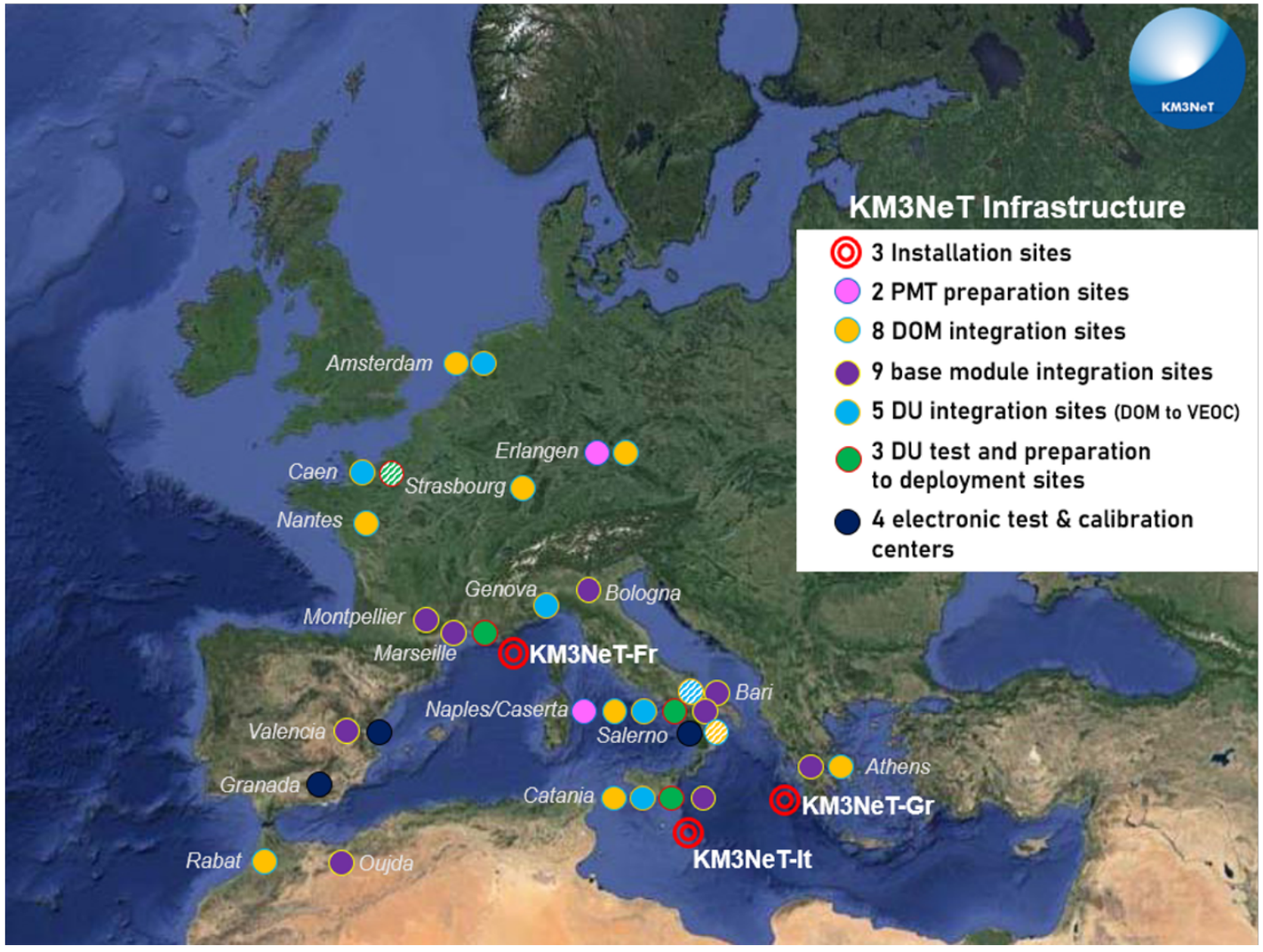
**Deployment**

Line are furled onto a launcher to be deployed

Once at the bottom of the sea, they are unfurled.

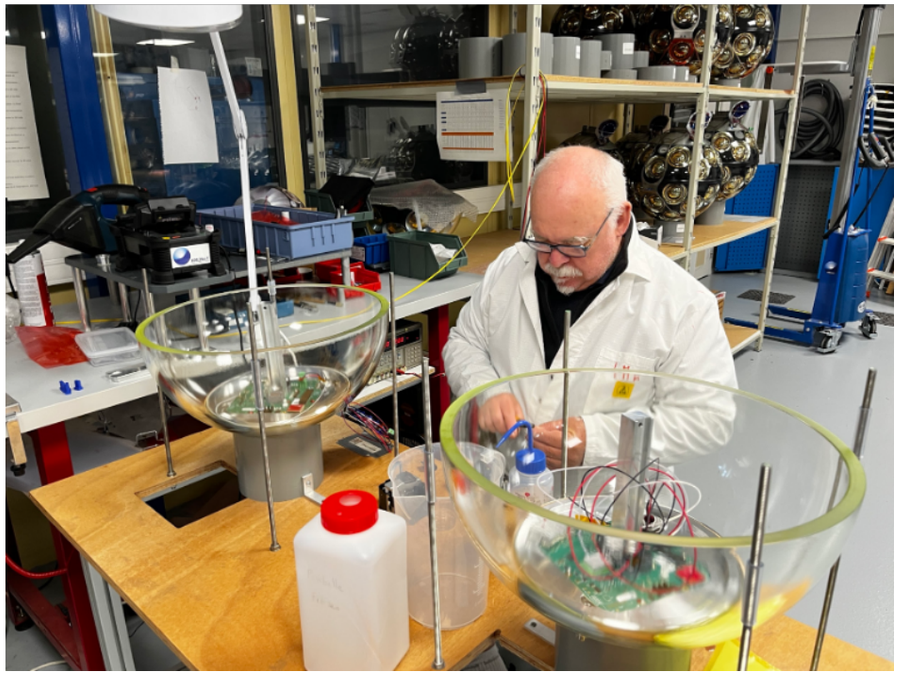
# Status of the construction

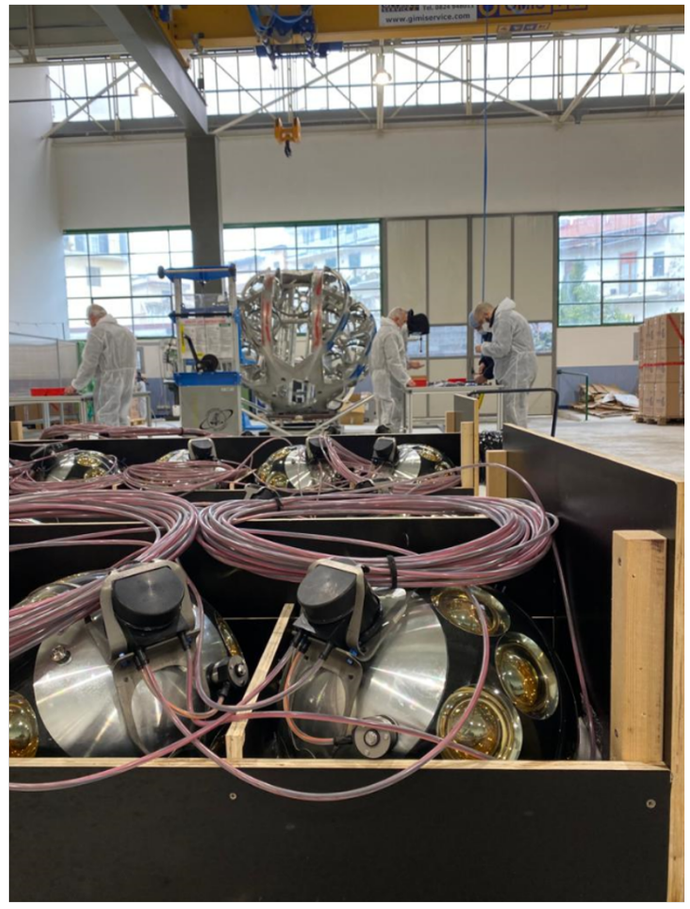
- **Parallel construction of ORCA and ARCA**
- Multiple integration sites across the world: 24 sites on 7 countries
- **~2100 optical modules built**
- **~100 detection units integrated**
- **End of the construction 2030 for ORCA, 2032 for ARCA**



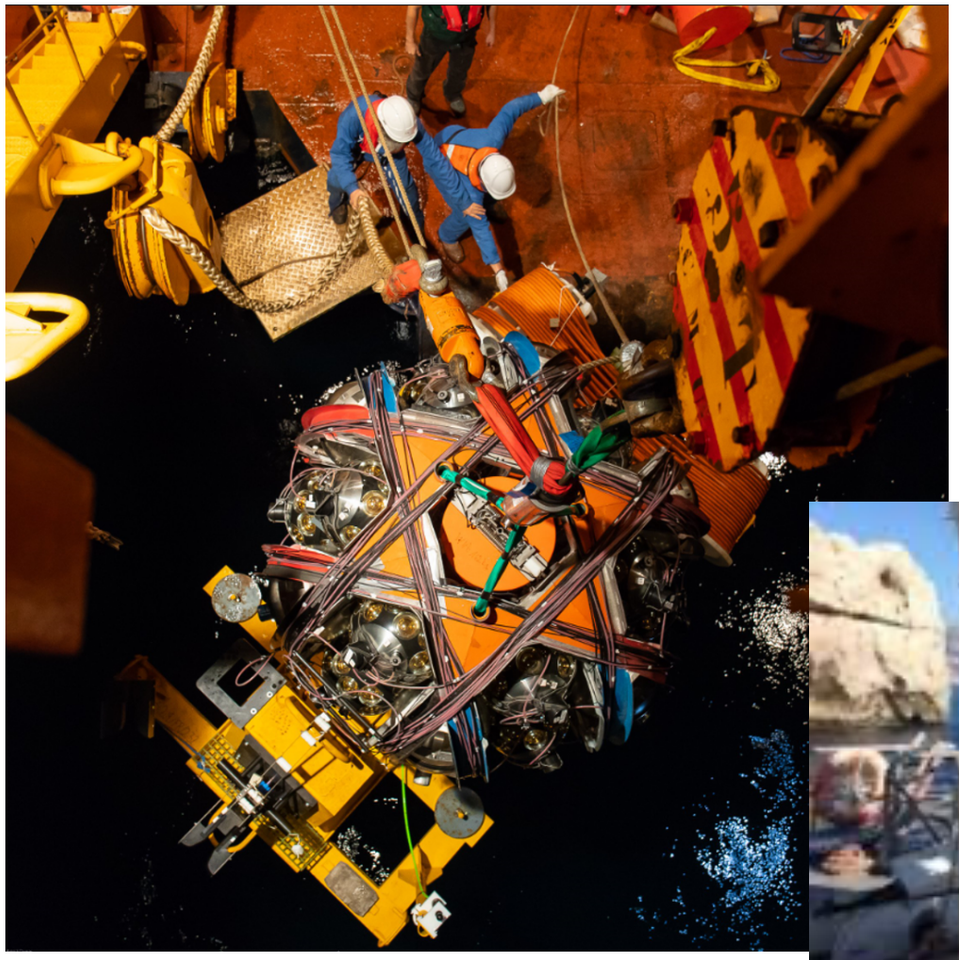

| 27-Jan-26 | ARCA | | ORCA (108) | |
|---|---|---|---|---|
| | quantity | % completed out of total | quantity | % completed out of total |
| **Optical Modules** | 1206 | 33,8% | 864 | 44,4% |
| **Base Modules** | 71 | 35,9% | 47 | 43,5% |
| **Detection Units** | 58 | 29,3% | 36 | 33,3% |

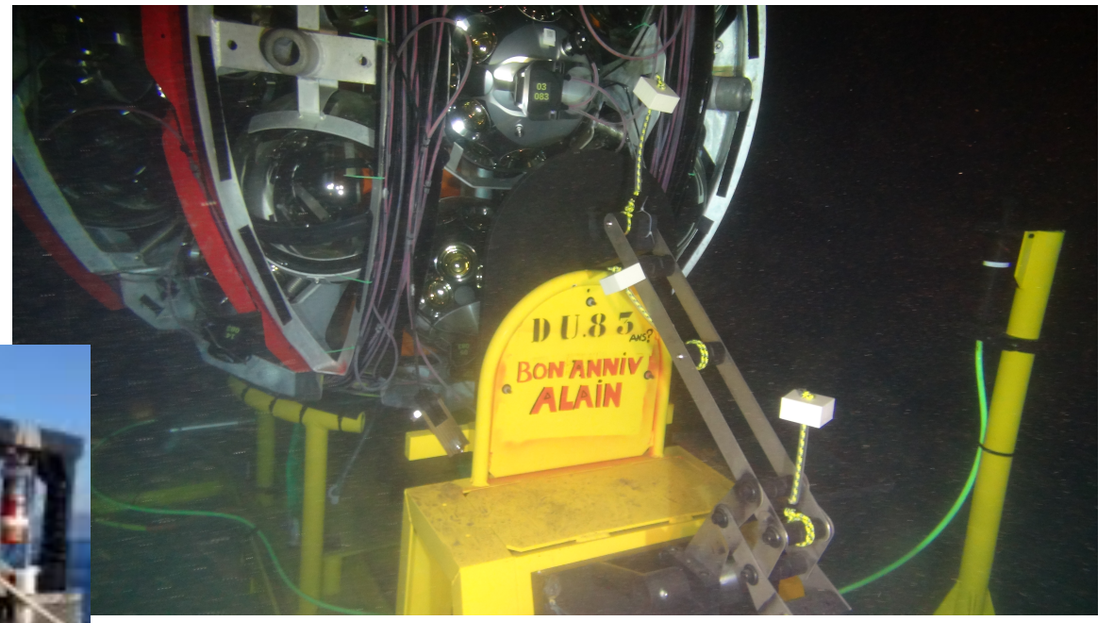
# Some pictures





# Some pictures





# Some key numbers…

## Eléments

- **ORCA:**
  - 108 DUs
  - ~2000DOMs
  - 4 Nodes
- **ARCA:**
  - 230 DUs
  - ~4100 DOMs
  - 17 Nodes
- 200 000 PMT
- ~1Million de composants
- ~300 transports/an

## Coûts

- DU:420k€
  - BM:35k€
  - 1xDOM:13k€
- Node:~850k€
- Transports: ~7k€/DU
- Déploiement: ~40k€/DU

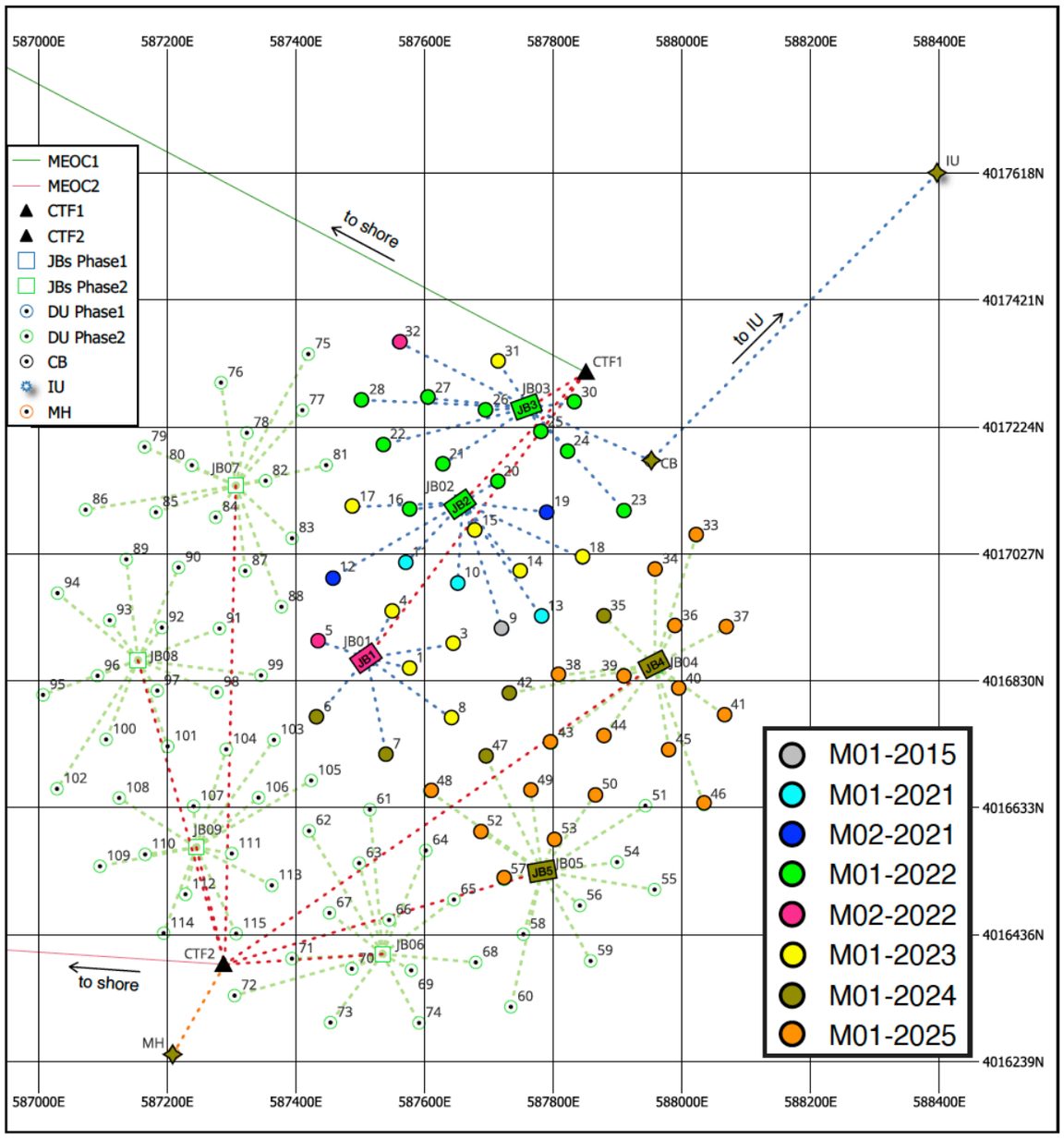
## Durées

- **Durées moyennes d'intégration <u>par site</u>:**
  - 1xBM: ~1 mois
  - 1xDU: ~1 mois
  - 18xDOM: ~1,2 mois
- **Rythmes d'intégration <u>tout sites compris)</u>:**
  - 1xBM: ~0,5 mois
  - 1xDU: ~1 mois
  - 18xDOM: ~1,2 semaines

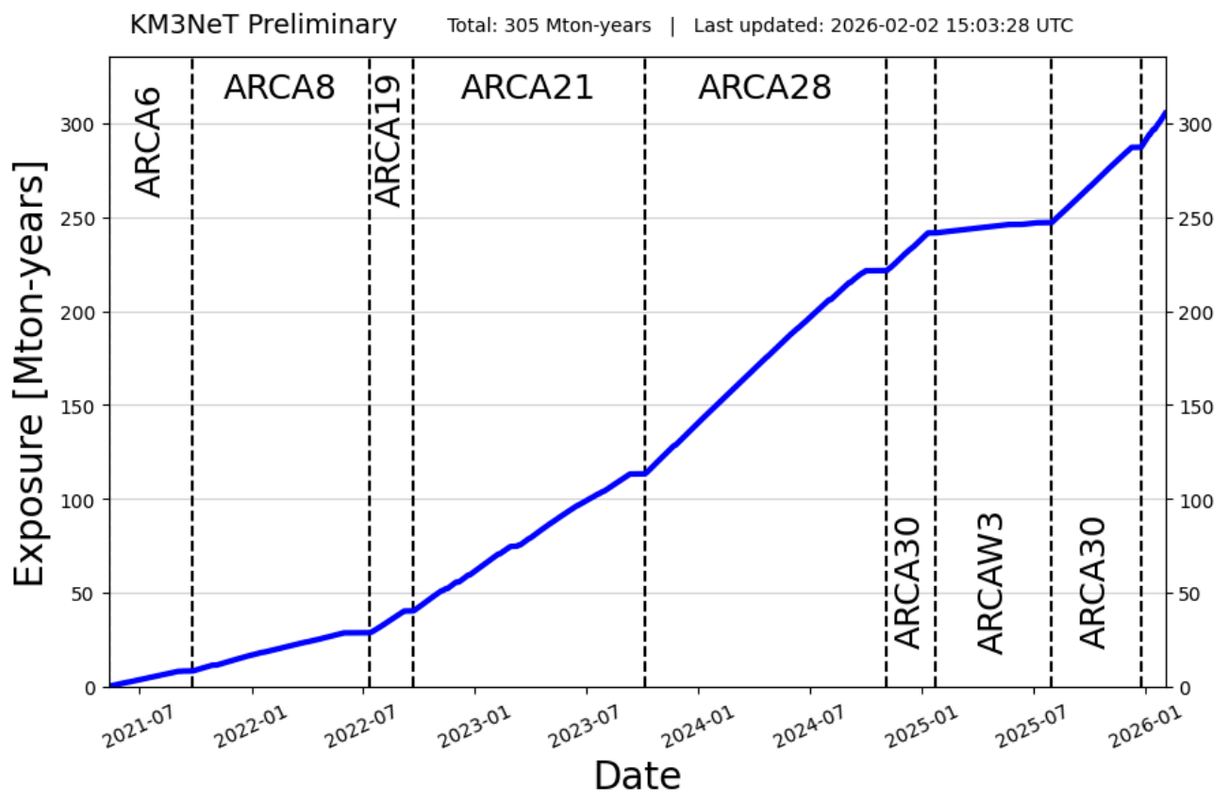
# Current situation of ARCA

## 51 DUs deployed (44 % of the 1st building block)

## + 2 JBs + 14 DUs + 2 replacements DU in Summer 2026




Current layout of the 1st building block




- Stable data-taking efficiency ~90%
- So far, we have presented results of the ARCA6-21 dataset (~130 Mt.yr)
- We are finalizing the calibration and processing of ARCA28/30 dataset

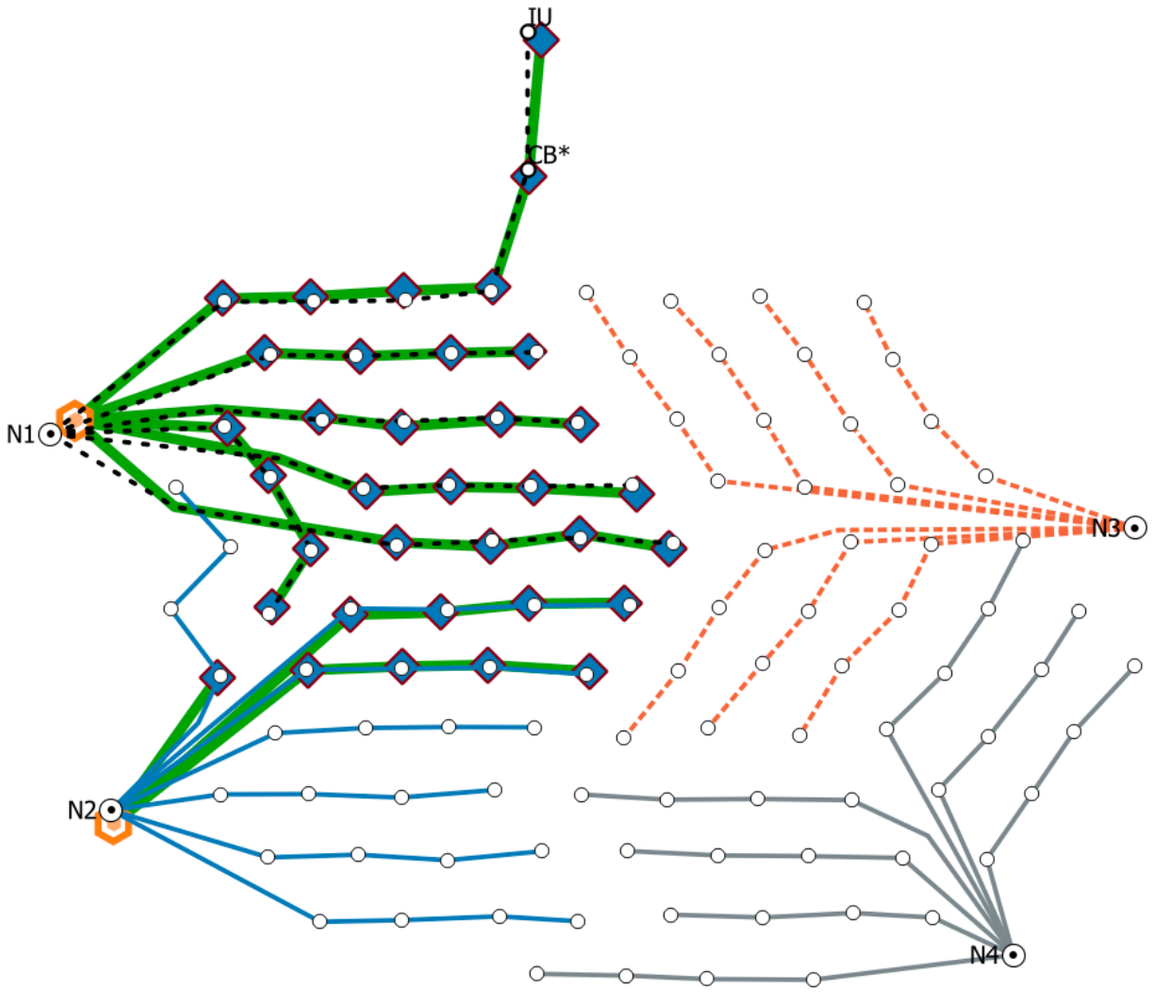
# Current situation of ORCA

**33 DUs deployed (1/4 of the full detector)**

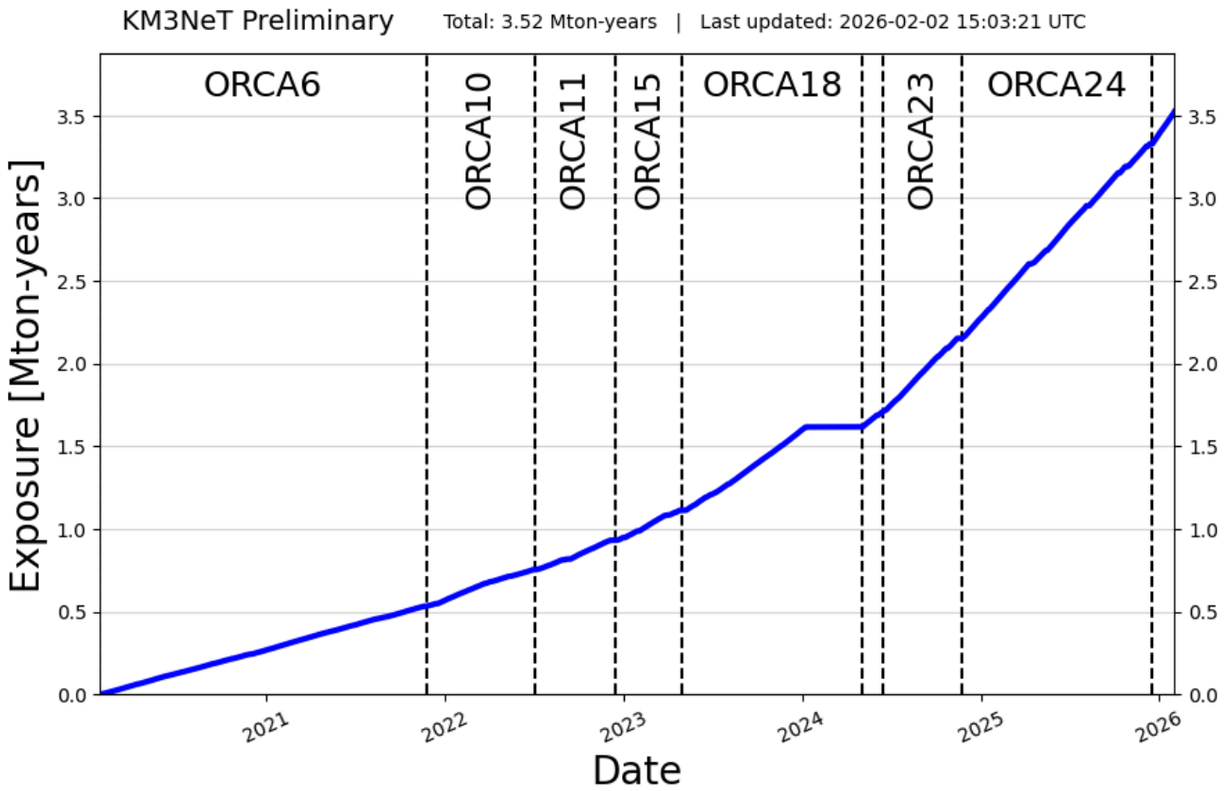
**+ 2 sea science instrumented units**

**6 DUs to be deployed in April 2026**

**6 DUs to be deployed in October 2026**

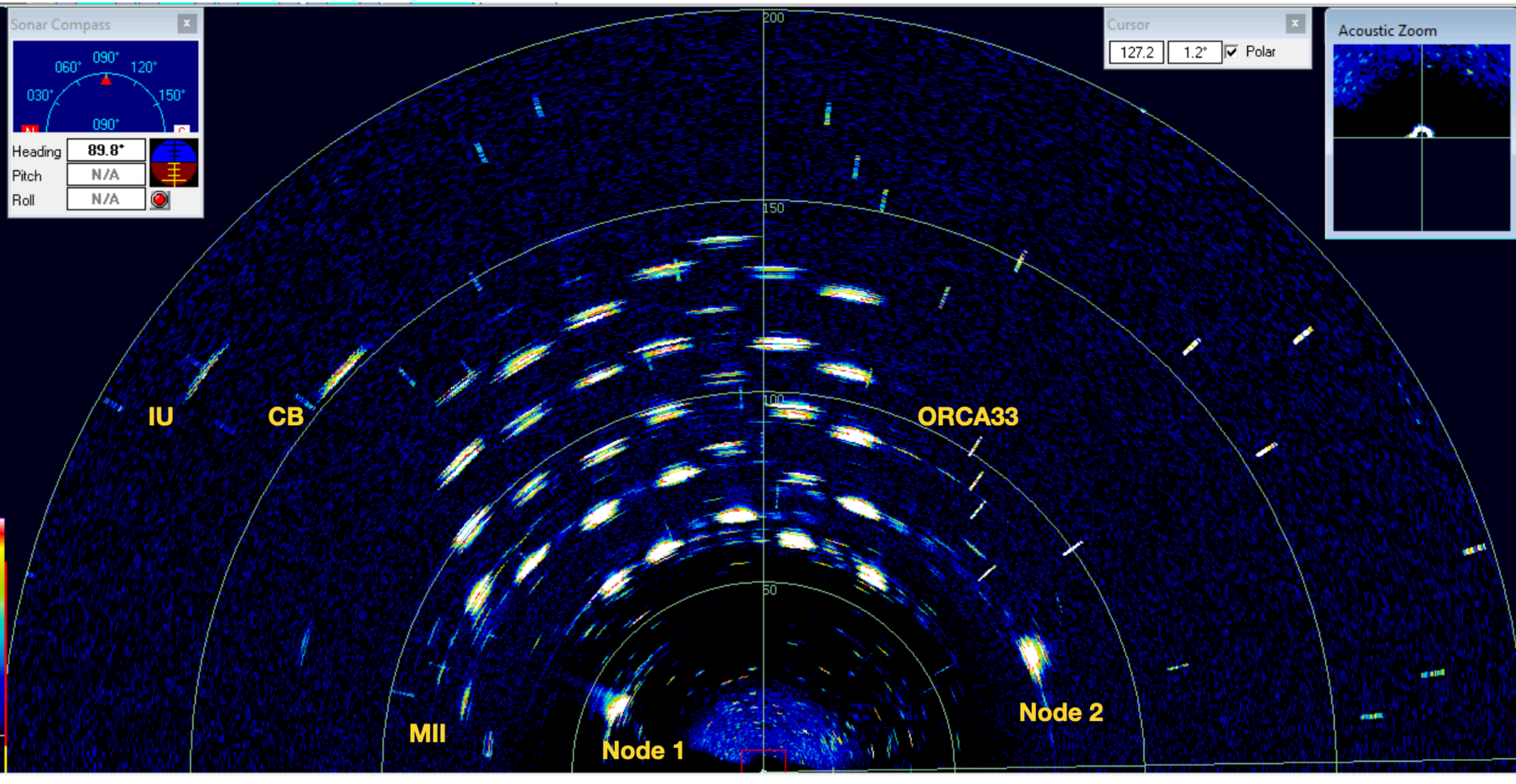



**Current layout (1 building block)**

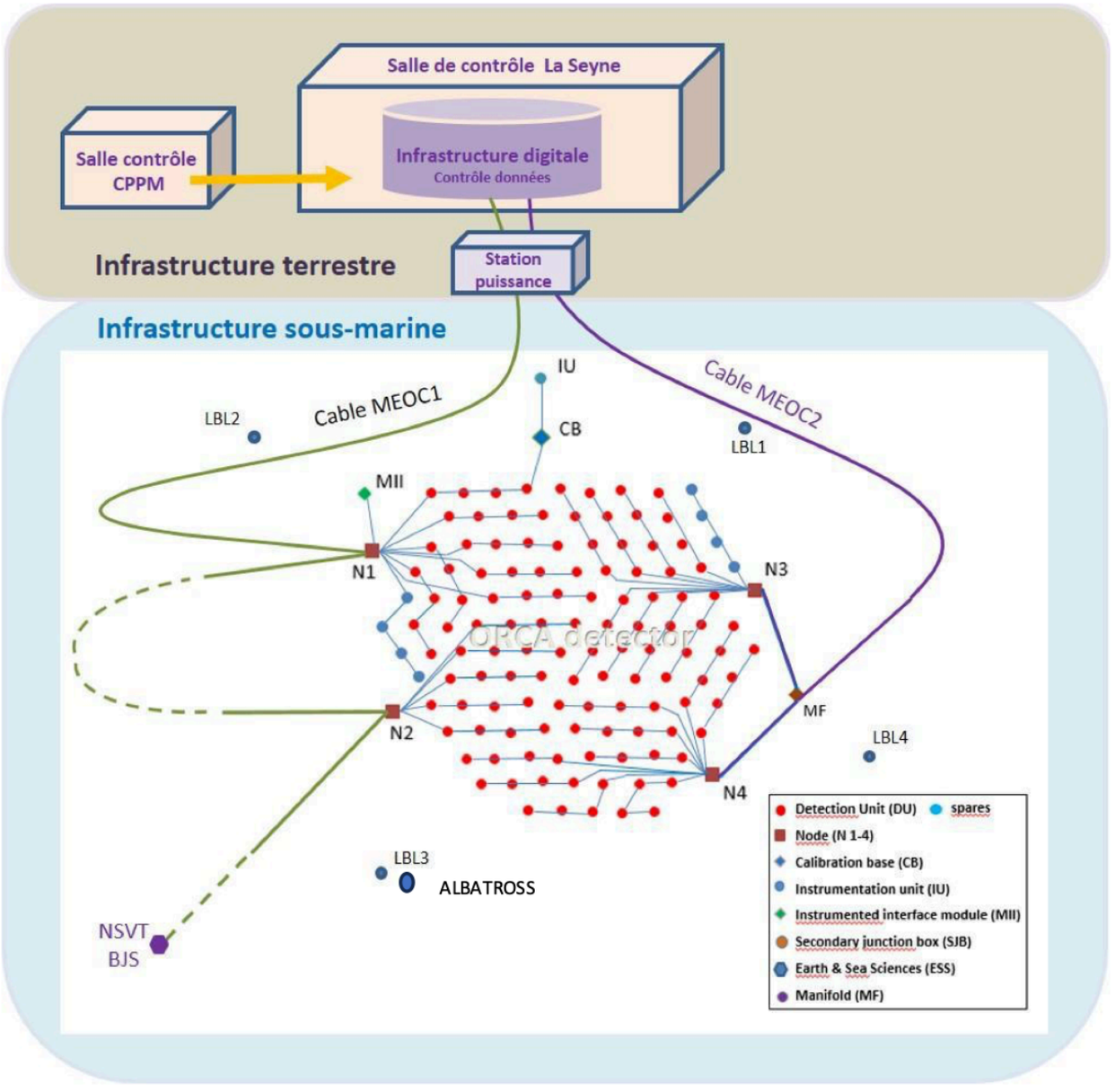



- **Stable data-taking efficiency ~92%**
- **So far, we have presented results of the ORCA6-11 dataset (~715 kt.yr)**
- **We are finalizing the analyses of ORCA15-18 dataset and prepared the ORCA23-24 dataset.**

# Current situation of ORCA



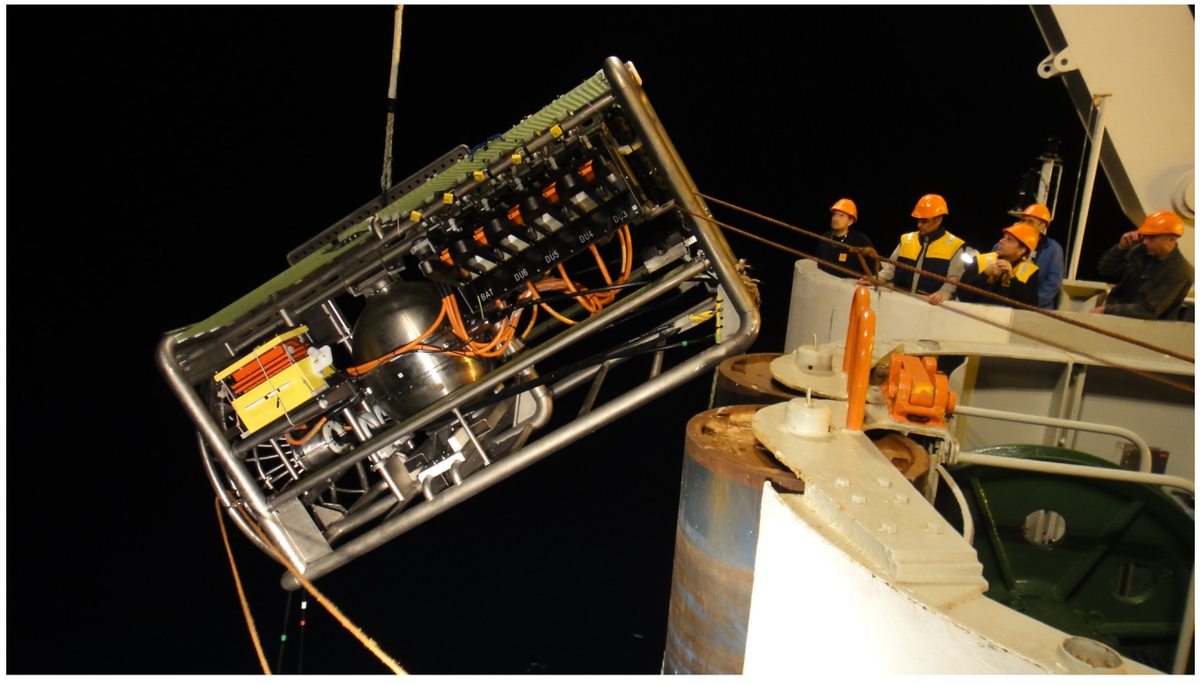
# LSPM: ORCA sea-floor infrastructure




- 1 shore station in La Seyne sur Mer
- 1 power hut (1 /2 Power Feeding Equipments)
- 2 deep-sea cables
- 2 /4 nodes deployed and in operation

- 1 Pre-BJS + 1 BJS
- Earth and Sea Science Equipments

+ strong links with INSU, Ifremer and EMSO



# Calibration

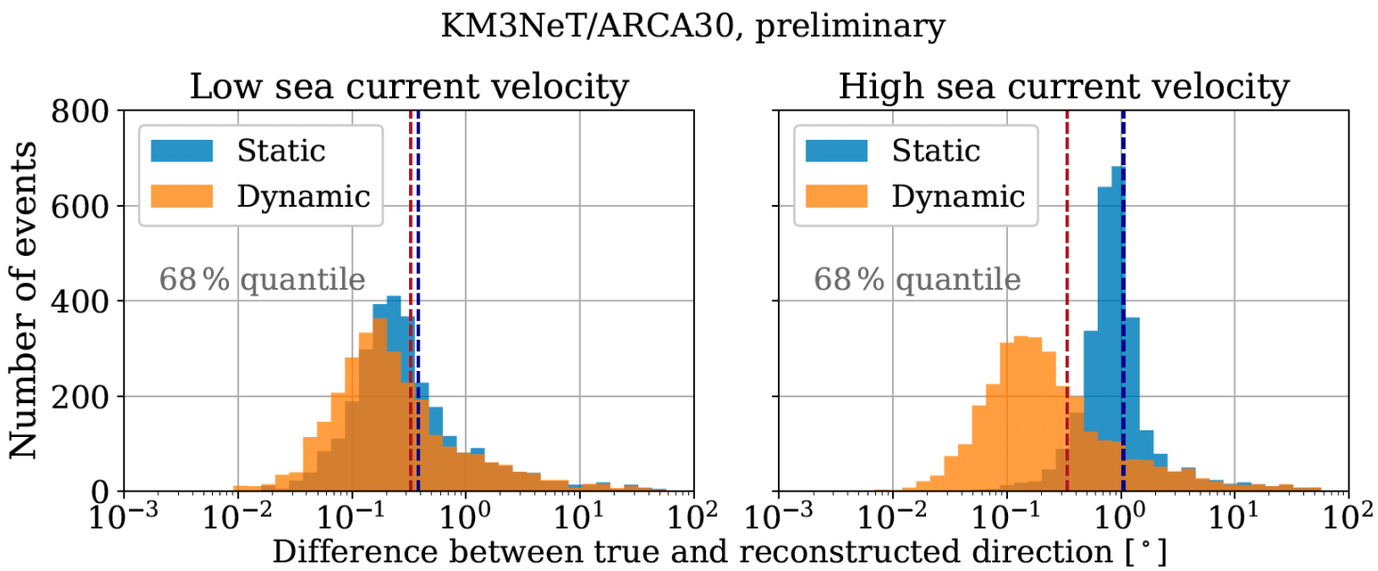
| Quantity | Target |
|---|---|
| Position | < 20 cm |
| Orientation | ~ 5° |
| Timing | < 1 ns |
| PMT response | few % |

**Calibration in time, efficiency and position of the 2 detectors is a very challenging task.**

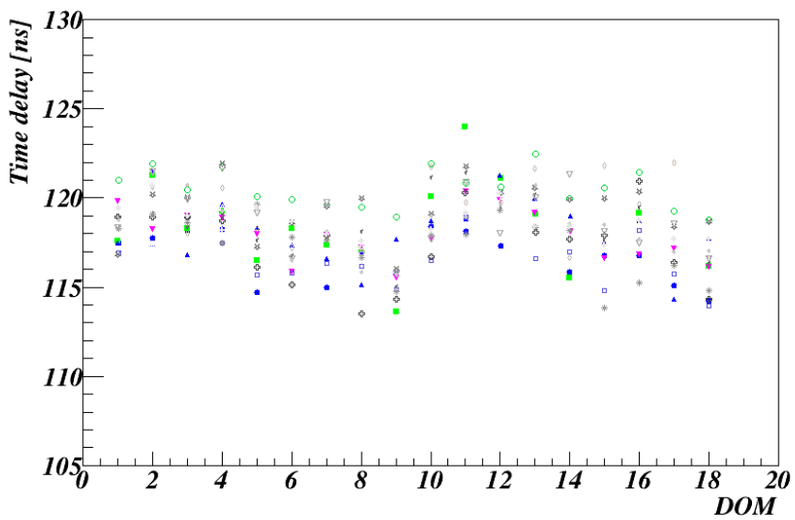
**Calibration is performed in multiple steps:**

- Dark room calibration to get a pre-calibration (with a laser)
- Dynamic orientation and acoustic positioning (acoustic emitters, compass/tilt)
- Inter-DOM and inter-DU time calibration (40K, atmospheric muons, nano beacons, laser)
- PMT gain and efficiencies (40K)
- Absolute pointing (Moon/Sun shadow, external acoustic source)

**Comparison static/dynamical positioning**

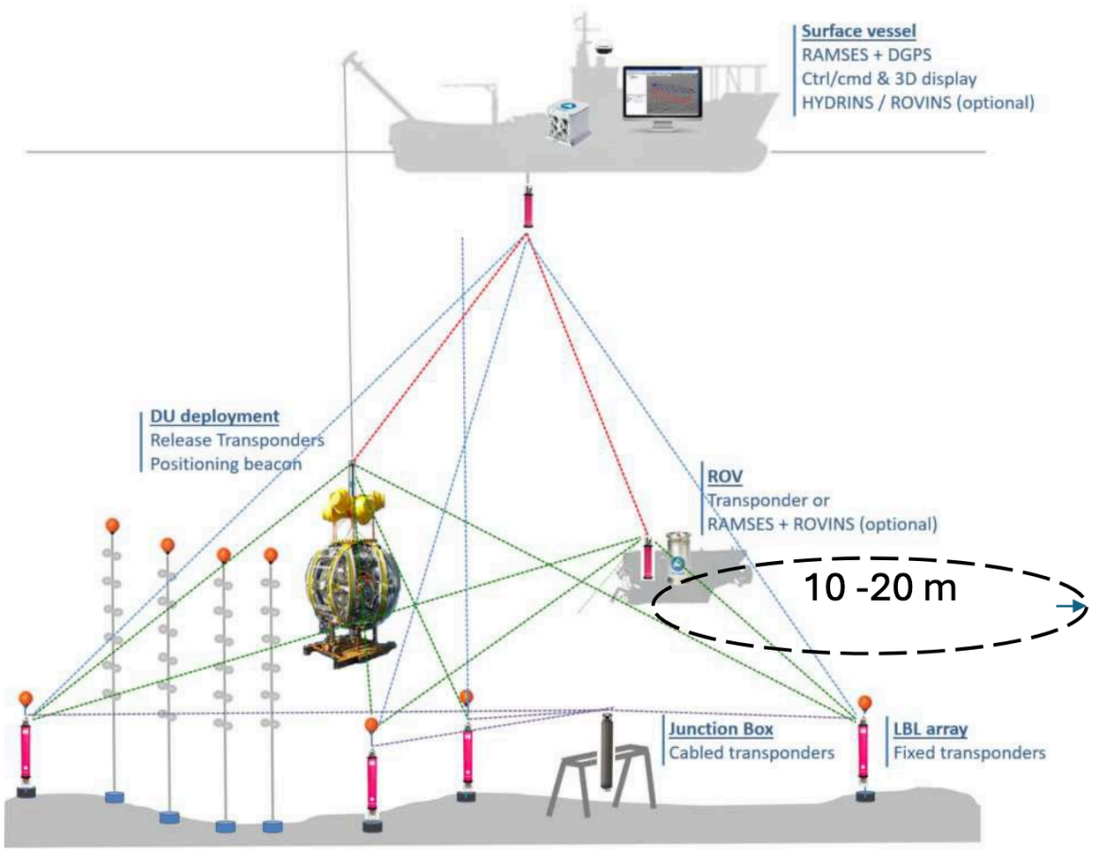



**Time calibration in dark box**



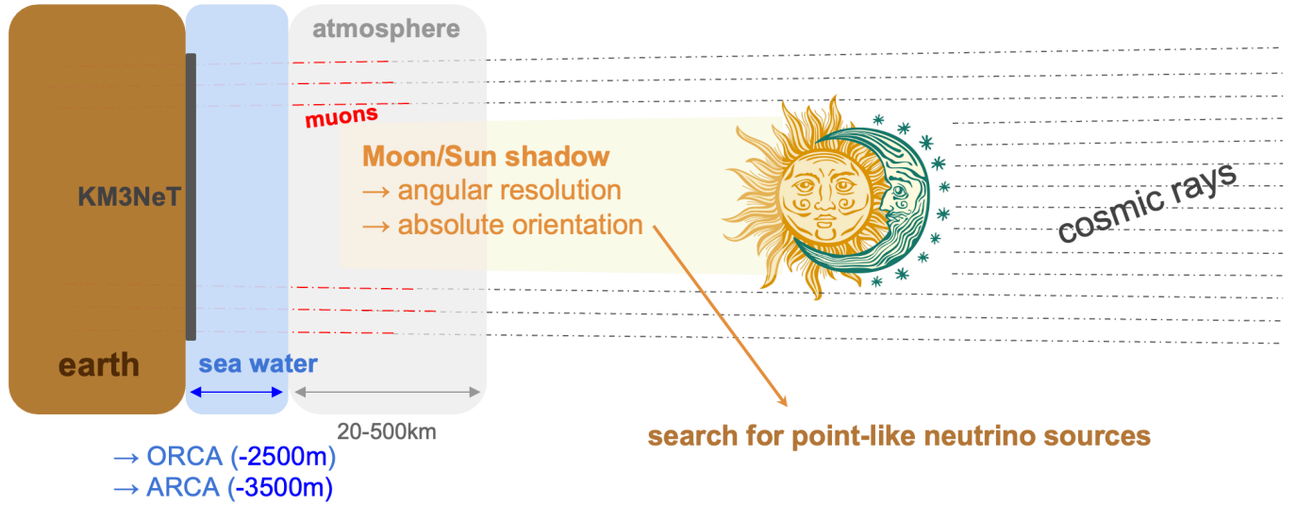
# Absolute pointing calibration

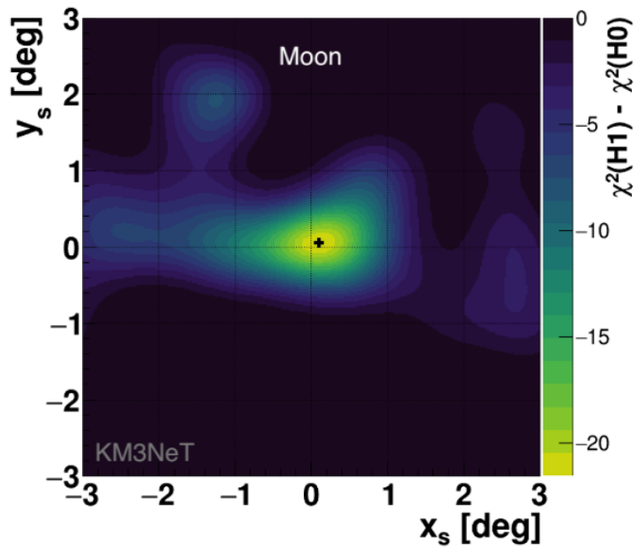
## Box-in method with RoV or vessel

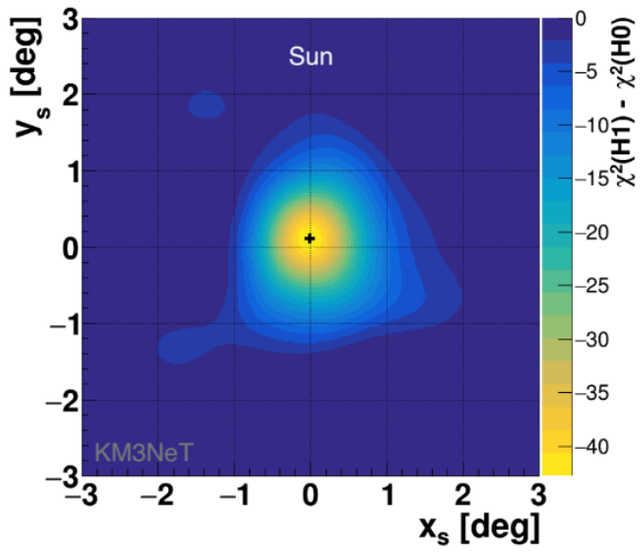



- **Absolute positioning of reference beacons <1m**
- **Standard acoustic positioning calibration procedure**

## Moon/sun shadows



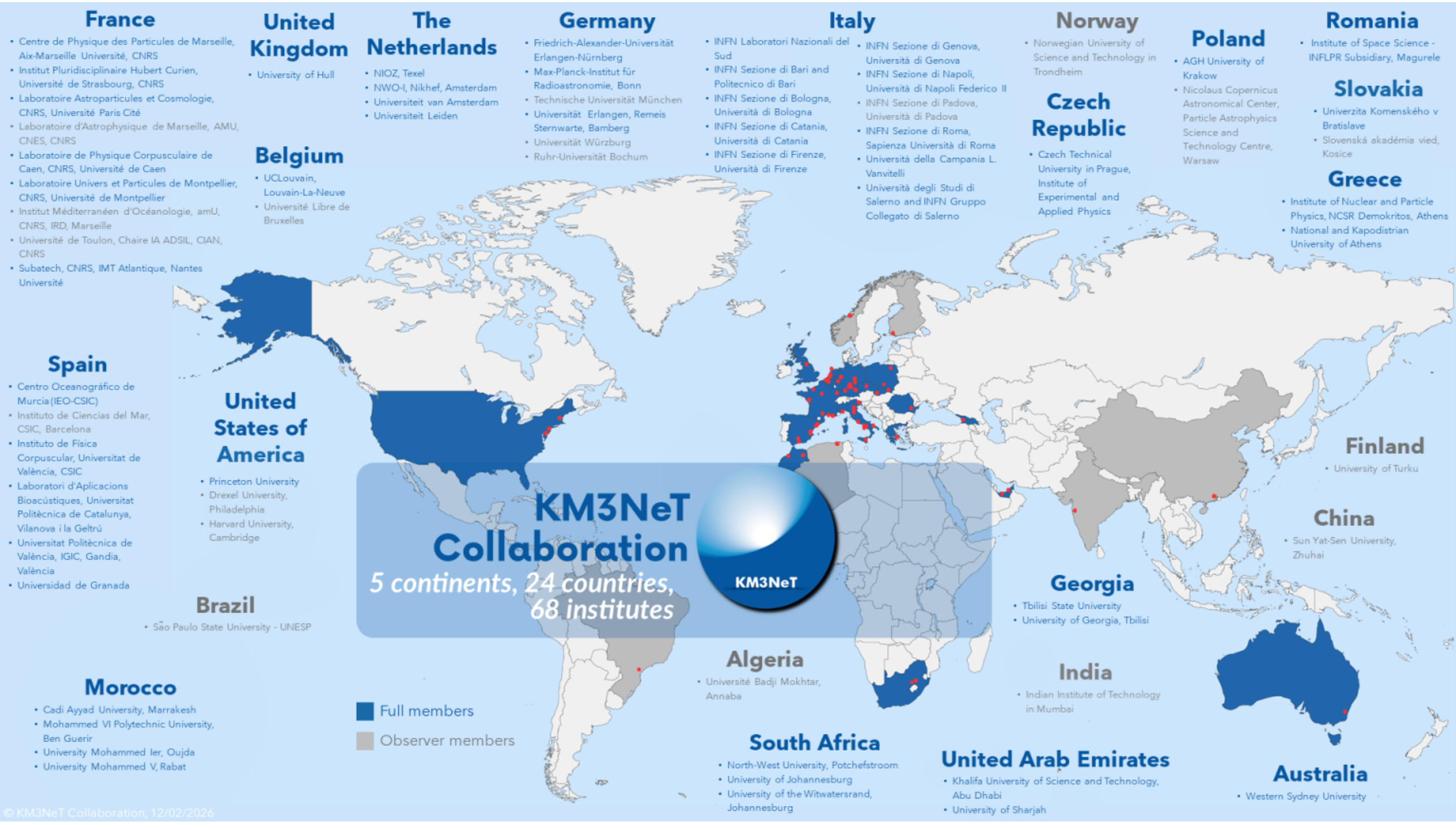




**ORCA6**

| Parameters | Moon 2D | Sun 2D |
|---|---|---|
| $\sigma_{res}$ | $0.49° \pm 0.15°$ | $0.65° \pm 0.13°$ |
| $A$ | $0.71 \pm 0.27$ | $1.31 \pm 0.34$ |
| $\Delta\chi^2_{H1/H0}$ | -21.3 | -43.0 |
| Significance | $4.2\sigma$ | $6.2\sigma$ |
| Events/$deg^2$ | 2892 | 3161 |

# KM3NeT Collaboration



# KM3NeT organigram

## Governance & Oversight

**AISBL Council**
Chair and Director: ***N. Leroy***

**Scientific and Technical Advisory Committee**
**Chair:** *C. Timmermans*

**Institute Board**
**Chair:** *A. Kouchner*

**Publication Committee:** *A. Margiotta, E. Tzamariudaki*
**Conference Committee:** *C. Markou*
**Outreach Committee:** *M. Circella, TBD*
**Open Science Committee:** *J. Schnabel*
**Early Career Scientists:** *A. Bariego Quintana, TBD*

## Executive Management

**AISBL Executive Board**

**AISBL Director:**
*N. Leroy*

***Management Team***

***Spokesperson/Chair:*** *P. de Jong*
***Deputy Spokesperson:*** *D. Dornic*
***Technical Project Manager:*** *A. D'Amico*
***Physics & Software Manager:*** *R. Coniglione*
***Site Manager KM3NeT-Fr:*** *N. Lumb*
***Site Manager KM3NeT-It:*** *R. Cocimano*
***Site Manager KM3NeT-Gr:*** *C. Markou*

**Equality, Diversity, Inclusion Committee**
*V. Van Elewyck, E. Tzamariudaki*

### Science Steering Committee

**Chair: R. Coniglione**
**Astronomy:** *G. Illuminati, M. Lamoureux, A. Marinelli*
**Calibration:** *V. Pestel*
**Cosmic Rays:** *R. Bruijn, A. Romanov*
**Dark Matter/Exotics:** *A. García-Soto, S. Gozzini*
**Oscillations:** *J. Brunner, V. Carretero Cuenca*
**Processing/Data-Quality:** *F. Badaracco, F. Filippini, C. Lastoria*
**Simulations:** *C. Distefano, L. Fusco,*
**Software/computing:** *L. Aphecetche, R. Bruno, J. Schnabel*

### Project Office

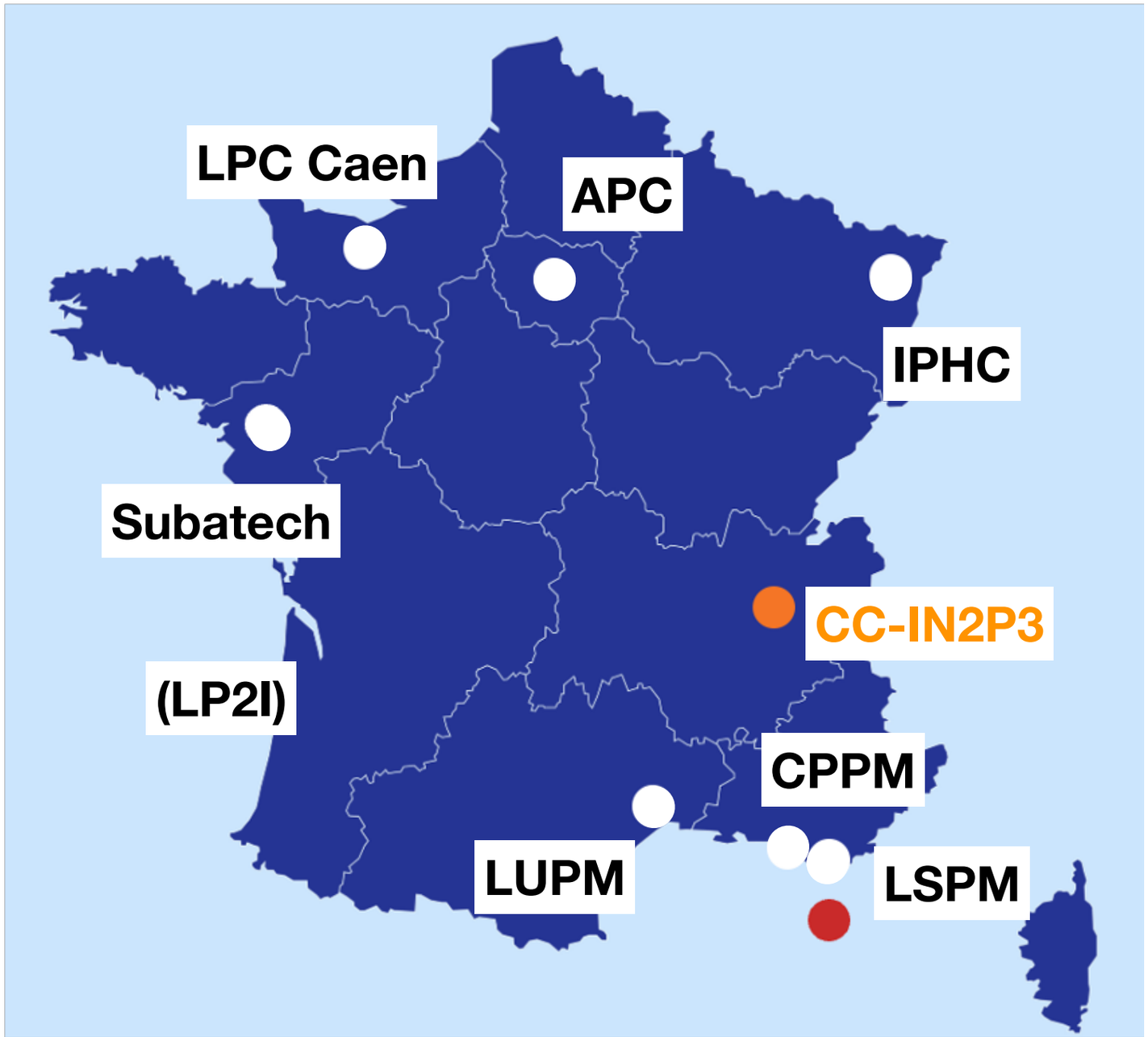
**Chair: A. D'Amico**
**Project Control Officer:** *TBD*
**Procurement Manager:** *M. Circella*
**Procurement Officer:** *S. Lancelin*
**QA/QC Manager:** *C. Vérilhac*
**QA/QC Officer:** *L. Morales Gallegos*
**R.A.M.S Manager:** *S. Colonges*
**R.A.M.S Software:** *TBD*
**System Engineer:** *S. Henry, M. Lindsey Clark*

### Technical Steering Committee

**Chair: P. de Jong/A. D'Amico**
**Calibration Hardware:** *D. Vivolo*
**DAQ:** *E. Giorgio, F. Benfenati*
**Det. operations**: *A. Enzenhöfer, P. Piattelli*
**Electronics**: *D. Calvo, D. Real**
**Mechanics:** *A. Ilioni, E. Berbee**
**Optics:** *J-W. Schmelling, S. Pulvirenti**
**PMT:** *A. Simonelli*
**Power:** *C. Nicolau, D. Bonanno**
**Software/computing:** *L. Aphecetche, R. Bruno, J. Schnabel*
**BM integration:** *I. Sgura*
**DOM integration:** *E. Leonora, C. Poiré*, Y. Roy**
**DU integration:** *A. Marini, C. Mollo*
**DB manager:** *C. Bozza*

**deputy coordinator* **30/01/2026**

# KM3NeT France




**<u>7 Laboratories @ IN2P3:</u>**

**APC, CPPM, IPHC, LPC-Caen, LSPM, LUPM, Subatech (+LP2I)**

**In 2025, 102 persons for 65 ETP**

**~57 scientific persons (34 ETP)**

**~45 technical persons (31 ETP)**

# KM3NeT France responsabilities

| Laboratoire | ETP (S/T) | Technical responsibilities | Scientific responsibilities | Management responsibilities |
|---|---|---|---|---|
| APC | 5.9/3.8 | Mechanics WG convener<br>RAMS Manager<br>System Engineer<br>Calibration Base<br>QA/QC Manager | Astronomy WG convener<br>Oscillation WG convener (former) | ANTARES Spokesperson<br>KM3NeT IB Chair<br>EDI Committee Chair<br>Technical Project Manager (former) |
| CPPM | 3.6/14.2 | Procurement Officer<br>System Engineer<br>Detector Operation Manager ORCA<br>DU Integration WG convener<br>ORCA Marine Operation<br>ORCA seafloor infrastructure<br>ORCA seafloor infrastructure operation<br>ORCA BM integration<br>DU anchor integration<br>Acoustic Positioning<br>ORCA shore station manager<br>Instrument Unit<br>Radioactivity detector<br>MECMA contact person | Oscillation WG convener<br>Astronomy WG convener (former)<br>Online Physics Analysis WG convener | ORCA Site Manager<br>KM3NeT Deputy Spokesperson<br>KM3NeT Spokesperson (former)<br>KM3NeT-Fr Scientific Resp.<br>KM3NeT-Fr Technical Resp.<br>LSPM Director<br>ANTARES Technical Manager<br>CZAR CC-IN2P3 |
| IPHC | 0.8/2.0 | DOM integration | | |
| LPC Caen | 3.0/1.5 | DU integration | Calibration WG convener<br>DPDQ WG convener<br>CR WG convener<br>Software & Computing WG convener (former) | CZAR CC-IN2P3 |
| LUPM | 0.1/1.0 | BM integration | | |
| Subatech | 3.5/3.5 | DOM integration<br>DOM integration WG convener<br>BM integration (until end 2026) | Software & Computing WG convener | |

# Actual funding situation

**For ORCA:**

* **Secured budget for the upgrade of the sea-floor infrastructure (2 nodes + branching unit + upgrade PFE + shore station equipment). CPER NEUMED**
* **Secured budget for 94/108 detection units (CNRS + NWO + INFN)**

**For ARCA:**

* **Secured budget for the upgrade of the sea-floor infrastructure: 12/15 nodes + + shore station equipment**
* **Secured budget for ~150/230 detection units (mostly INFN+regions)**

# Events in KM3NeT

**⟹ Optical background light from 40K decay and bioluminescence [easily rejected thanks to the multi-PMT design] ⟹ calibration + ESS**
**⟹ For physics searches, 3 main event categories are recorded in KM3NeT :**

**Atmospheric muons**

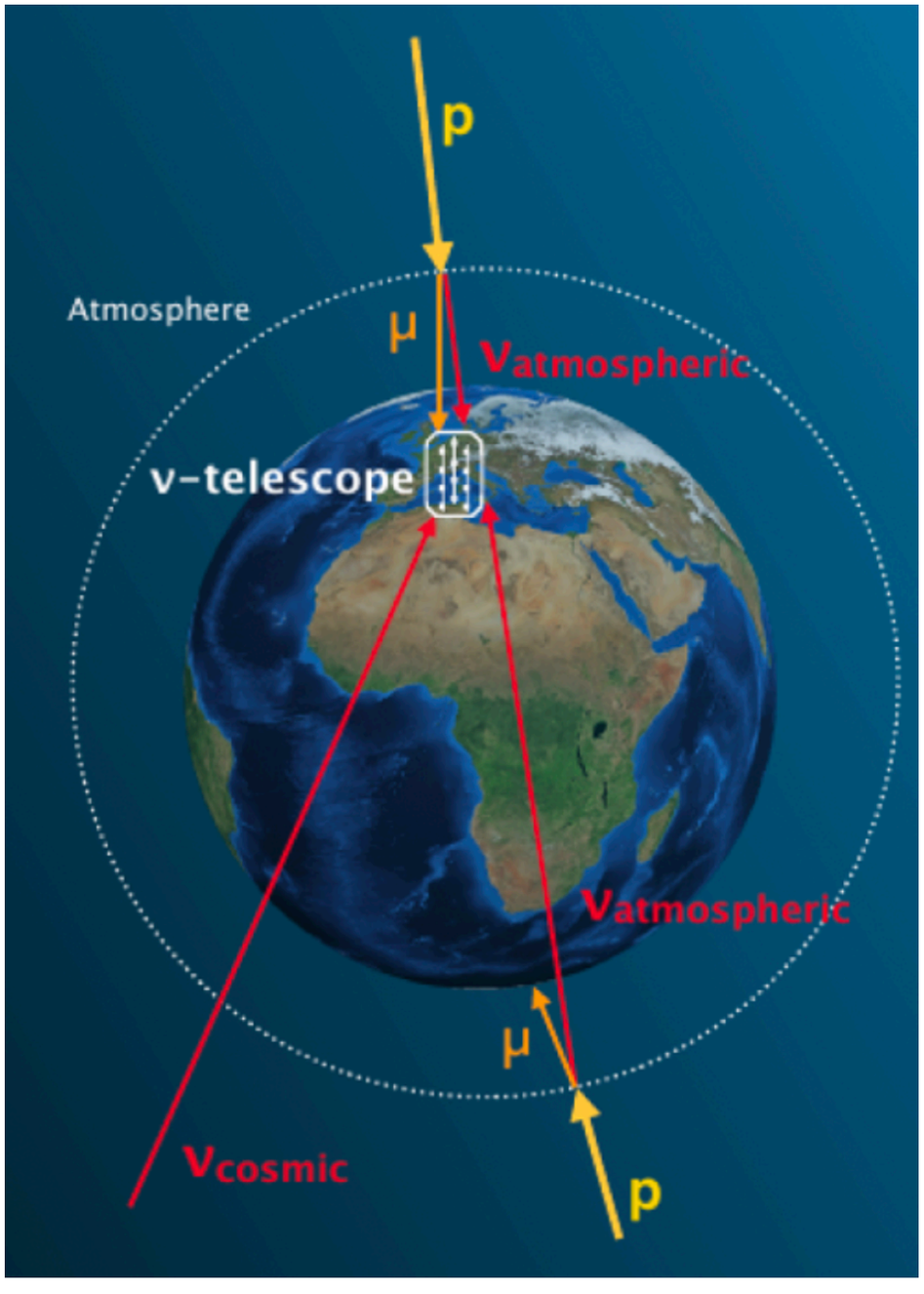
⟹ $\mu_{atm}$ ~ $10^8$ - $10^{10}$ /yr [downgoing]
⟹ Calibration
⟹ Cosmic ray physics

**Atmospheric neutrinos**

⟹ $\nu_{atm}$ ~ $10^5$ - $10^6$ /yr [all-sky]
⟹ Neutrino oscillation
⟹ Beyond standard model

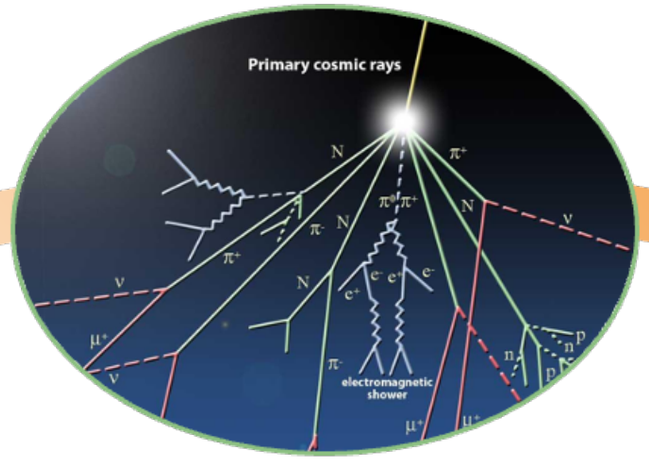
**Cosmic neutrinos**

⟹ $\nu_{cosmic}$ ~ 100 - 500 /yr [all-sky]
⟹ Neutrino astronomy
⟹ Dark matter

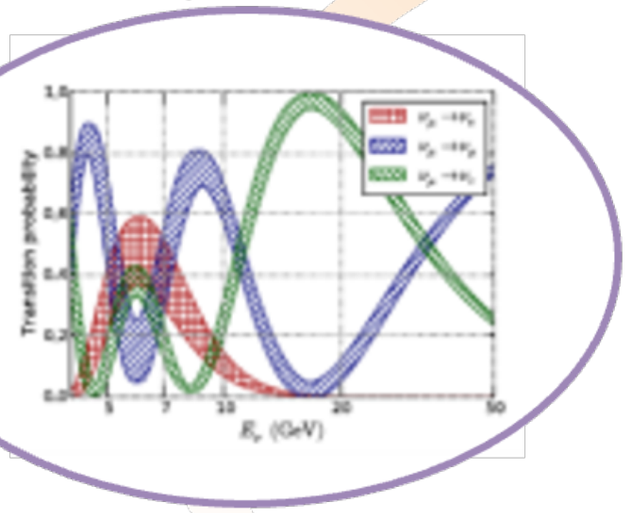


# Science cases with KM3NeT

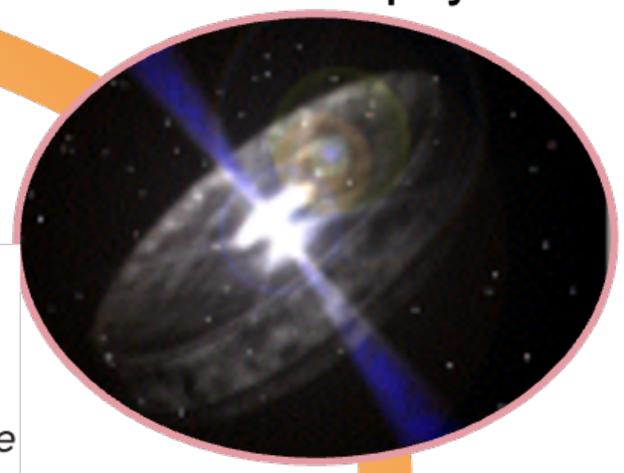
Cosmic Rays




Neutrino Physics



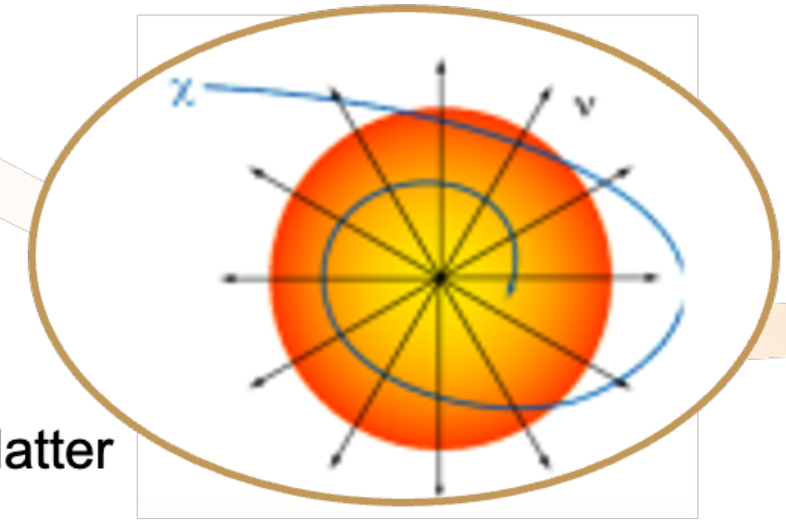
Astrophysics



**KM3NeT**

*Opens a new window on our universe*

Complementarity of ORCA and ARCA on all topics

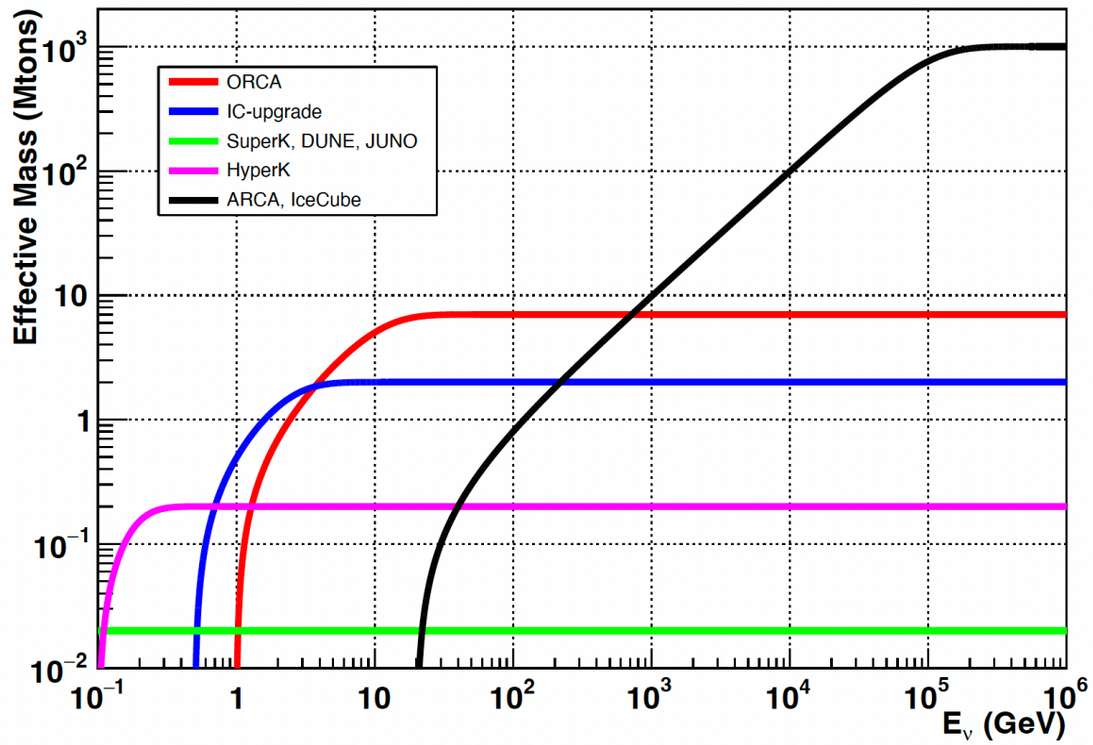



Dark Matter

Earth and Sea

# Combinaison ORCA+ARCA

**One of the main advantage of KM3NeT is the complementarity between ORCA and ARCA to have the best discovery potential in a very large energy range**

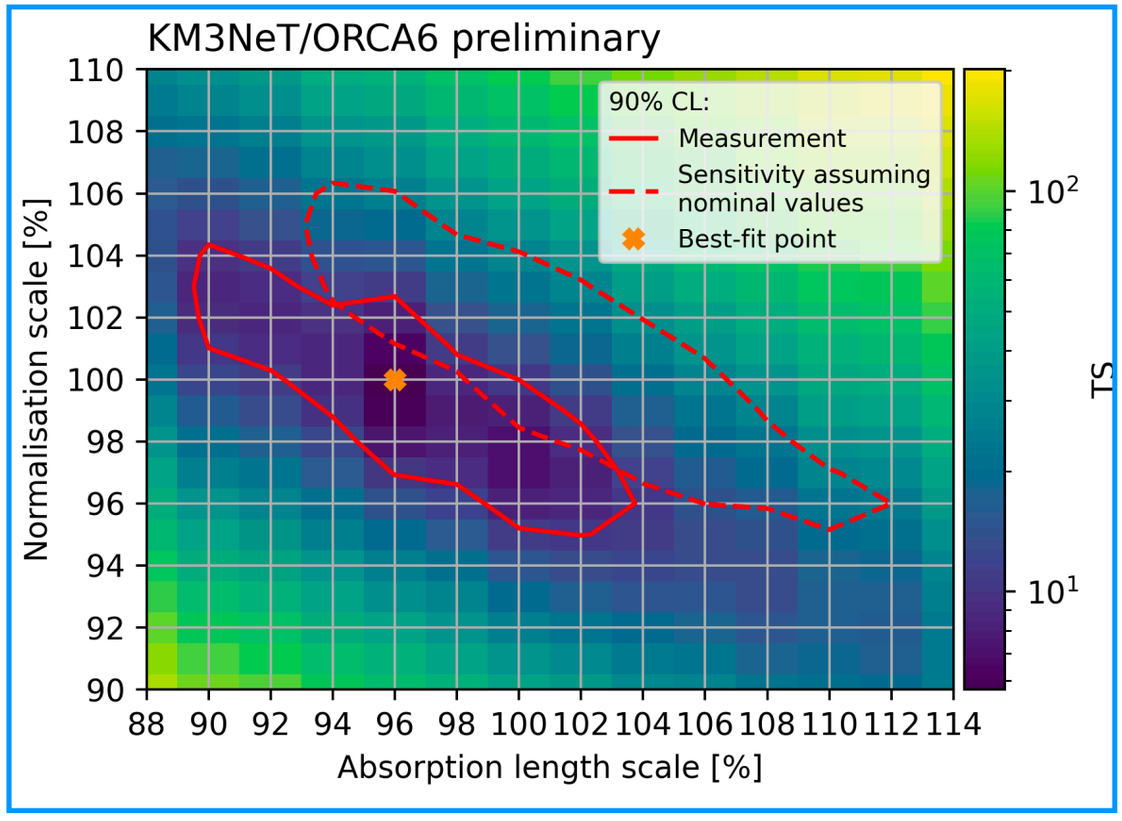


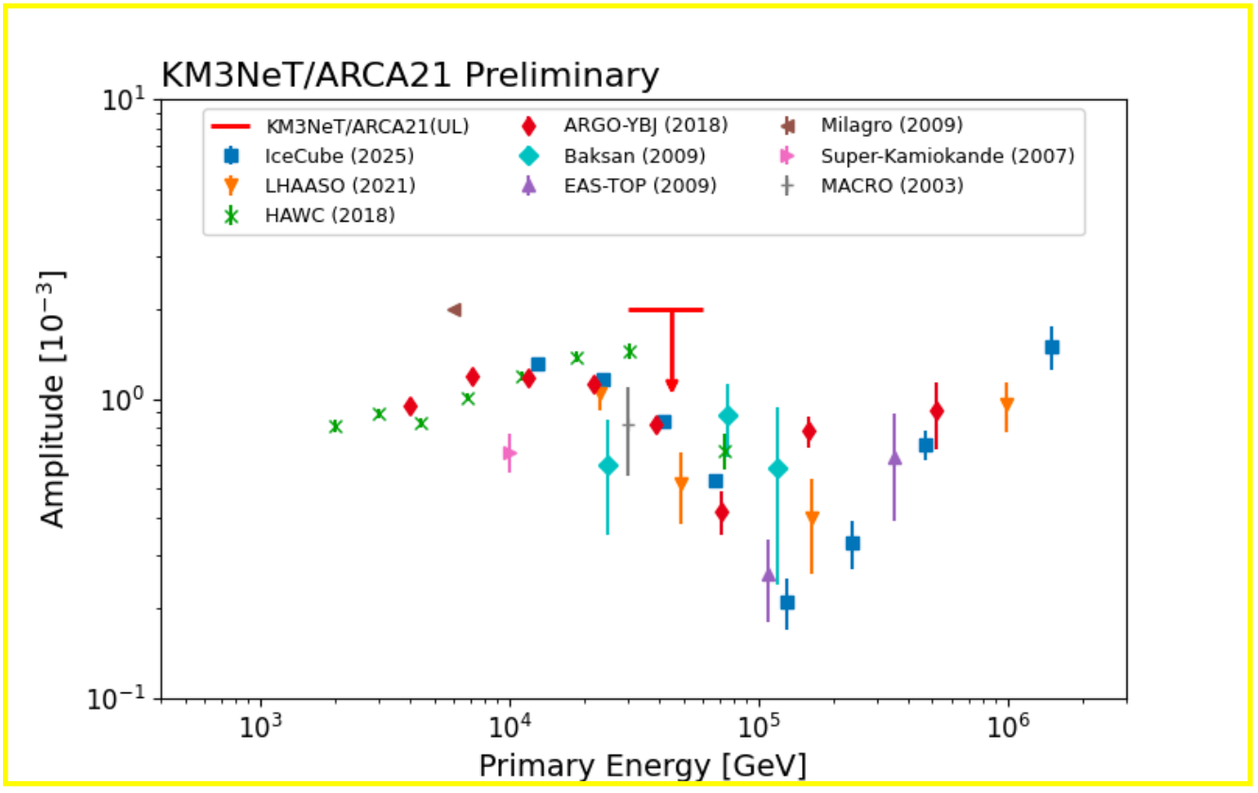

| Scientific Topic | ORCA | ARCA |
|---|---|---|
| Cosmic sources | ★★ | ★★★★ |
| CCSN (Core-Collapse Supernovae) | ★★★ | ★★★ |
| Oscillation parameters | ★★★★ | ★ |
| Mass hierarchy | ★★★★ | ★ |
| Sterile neutrinos | ★★★ | ★★ |
| Beyond the Standard Model (BSM) | ★★ | ★★★ |
| Dark matter | ★★★ | ★★★ |
| Cosmic rays | ★★ | ★★★ |

# Cosmic rays

**Very large atmospheric muon sample:**

- Atmospheric muon parametrization using the Daemon flux data-driven model
- Measure the water properties with stopping muons
- Prompt component in atmospheric muon analysis
- Measurement of the cosmic rays anisotropy
- Seasonal variation of atmospheric muons
- Measurement of the atmospheric neutrino spectrum

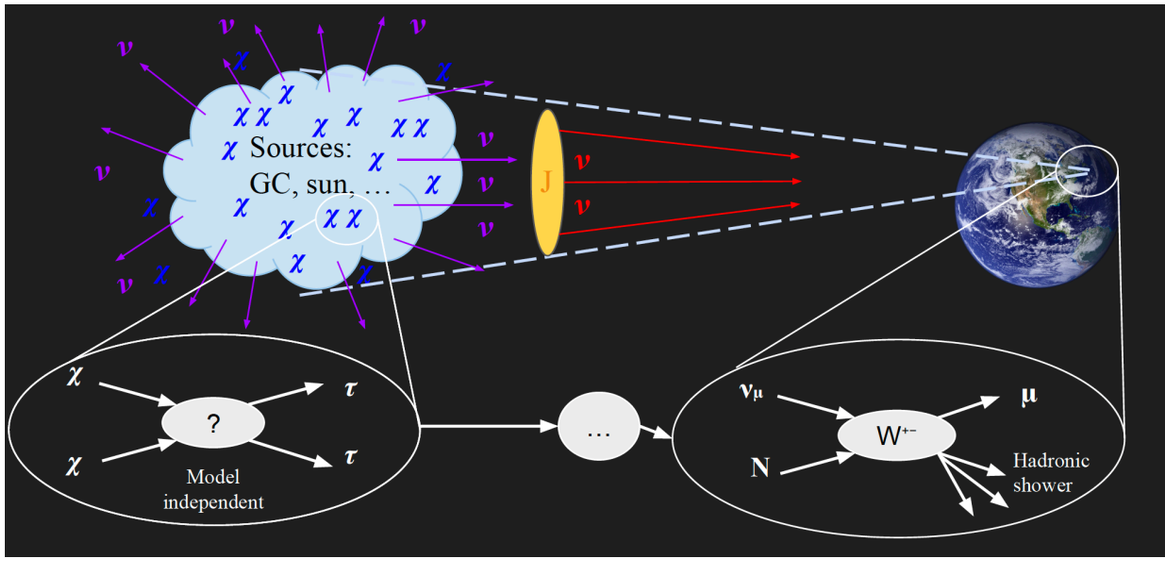


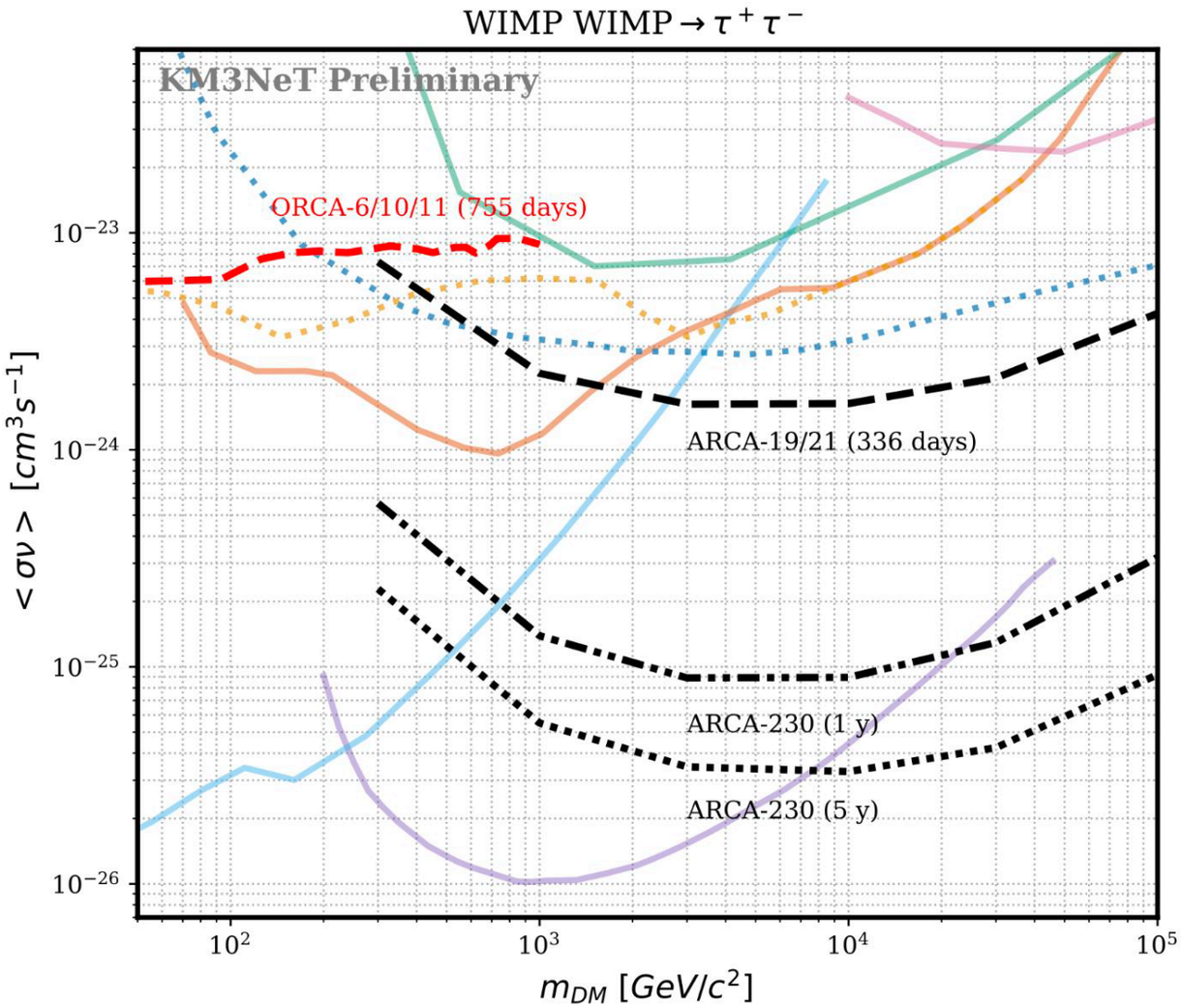



# Dark matter at Galactic Center

**Analysis for WIMP Dark Matter annihilation:**

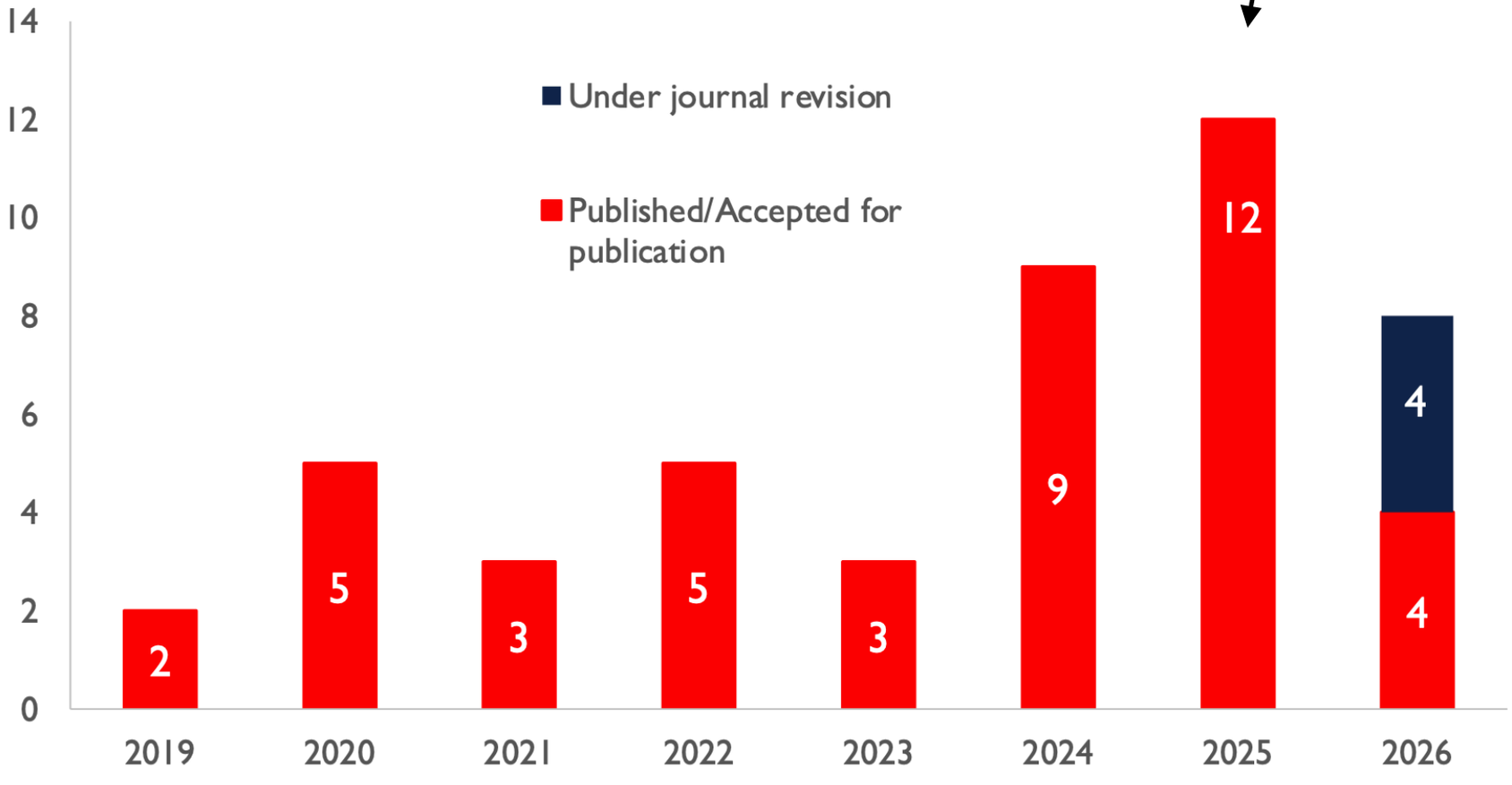
- **Competitive upper limits for ARCA19-21**
- **New sensitivities for ARCA230 (1y and 5 y)**
- **New sensitivities for ORCA6-11**




**Competitive results for the Sun**

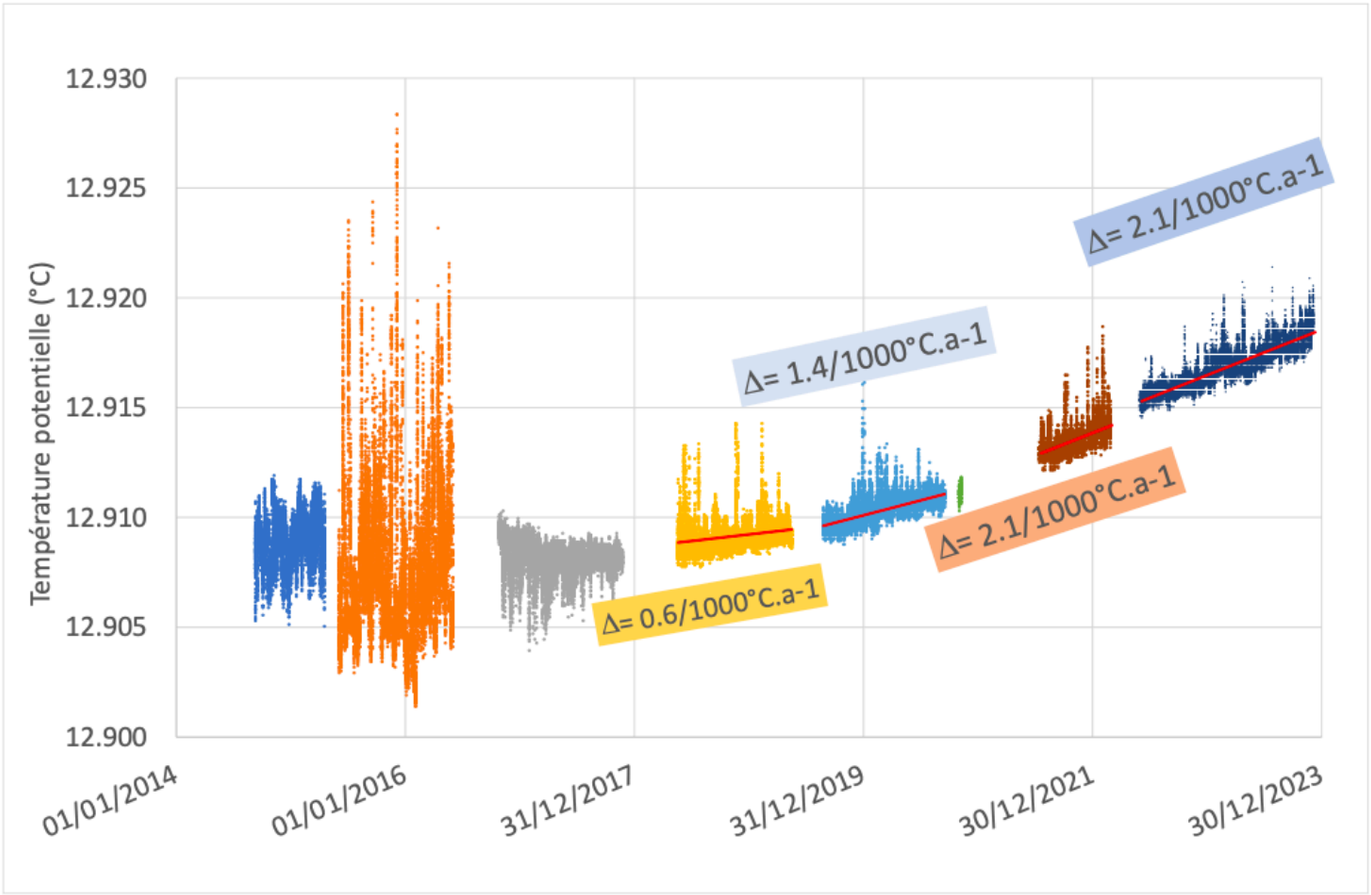
# Publications

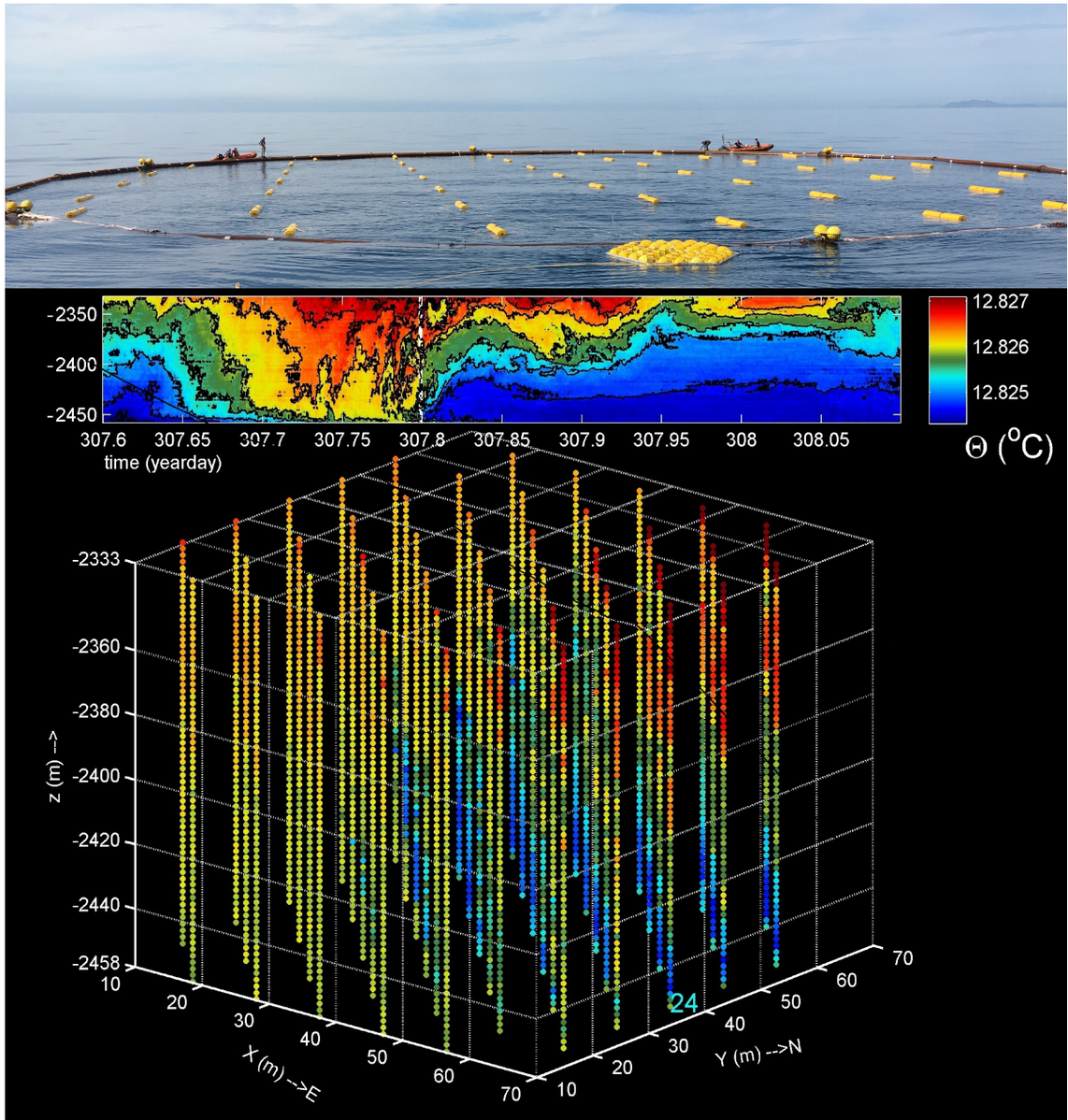


# Earth and Sea Science

**Long-term monitoring of the sea water properties:**

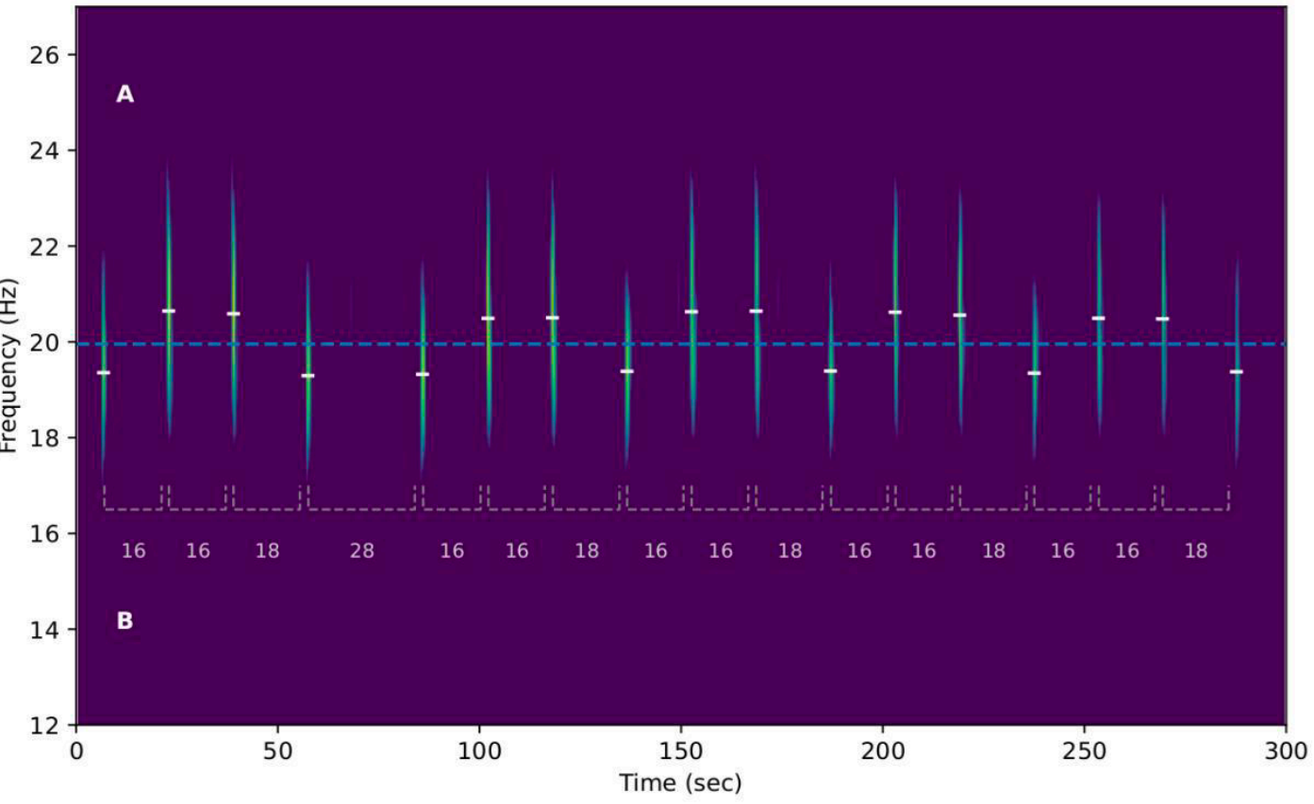
- **M2II (INSU) and IU (CPPM) connected to LSPM**
- **ALBATROSS mooring line (MIO/INSU)**
- **Large array of high precision temperature sensors (NIOZ-Netherlands)**
- **Germanium gamma-ray spectrometer (CPPM)**
- **KM3NeT optical modules**



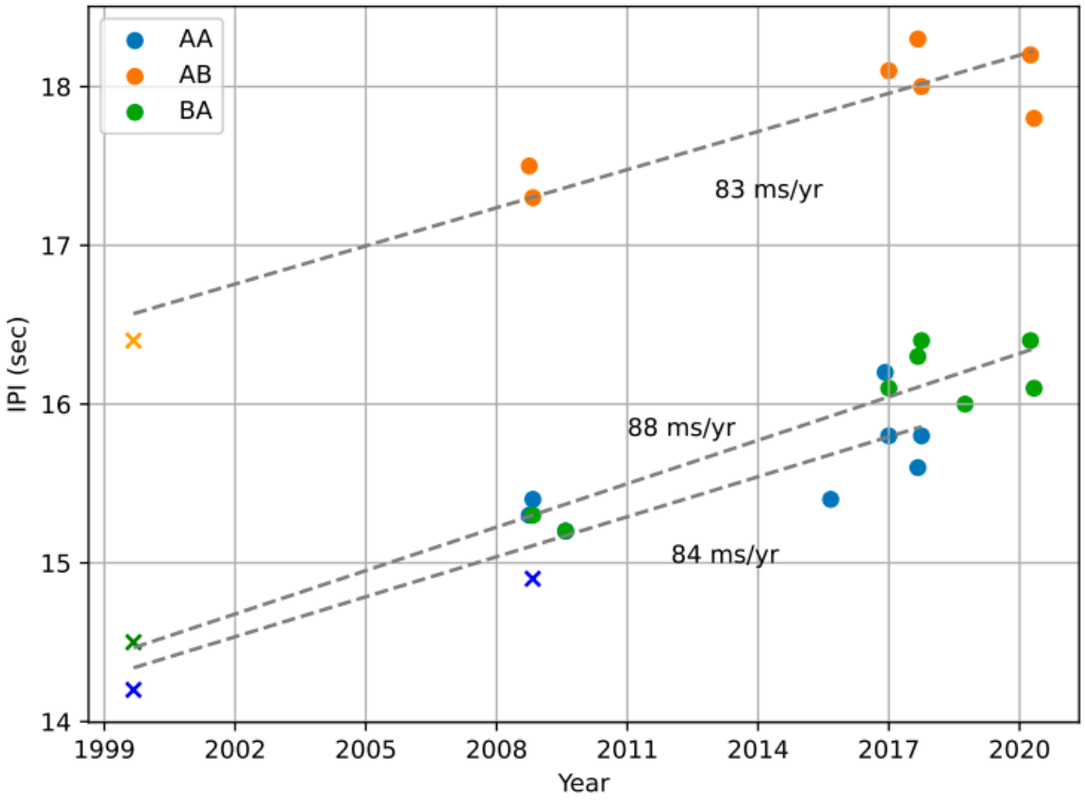



# Earth and Sea Science

- **BathyBot/BathyReef benthic crawler (MIO/INSU) to survey the deep-sea marine life**
- **A stereo biocamera system (IP2I-Lyon) to detect faint bioluminescence animals**
- **The KM3NeT acoustic beacons/piezos to detect and monitor the bio-acoustic signals from Cetaceans**



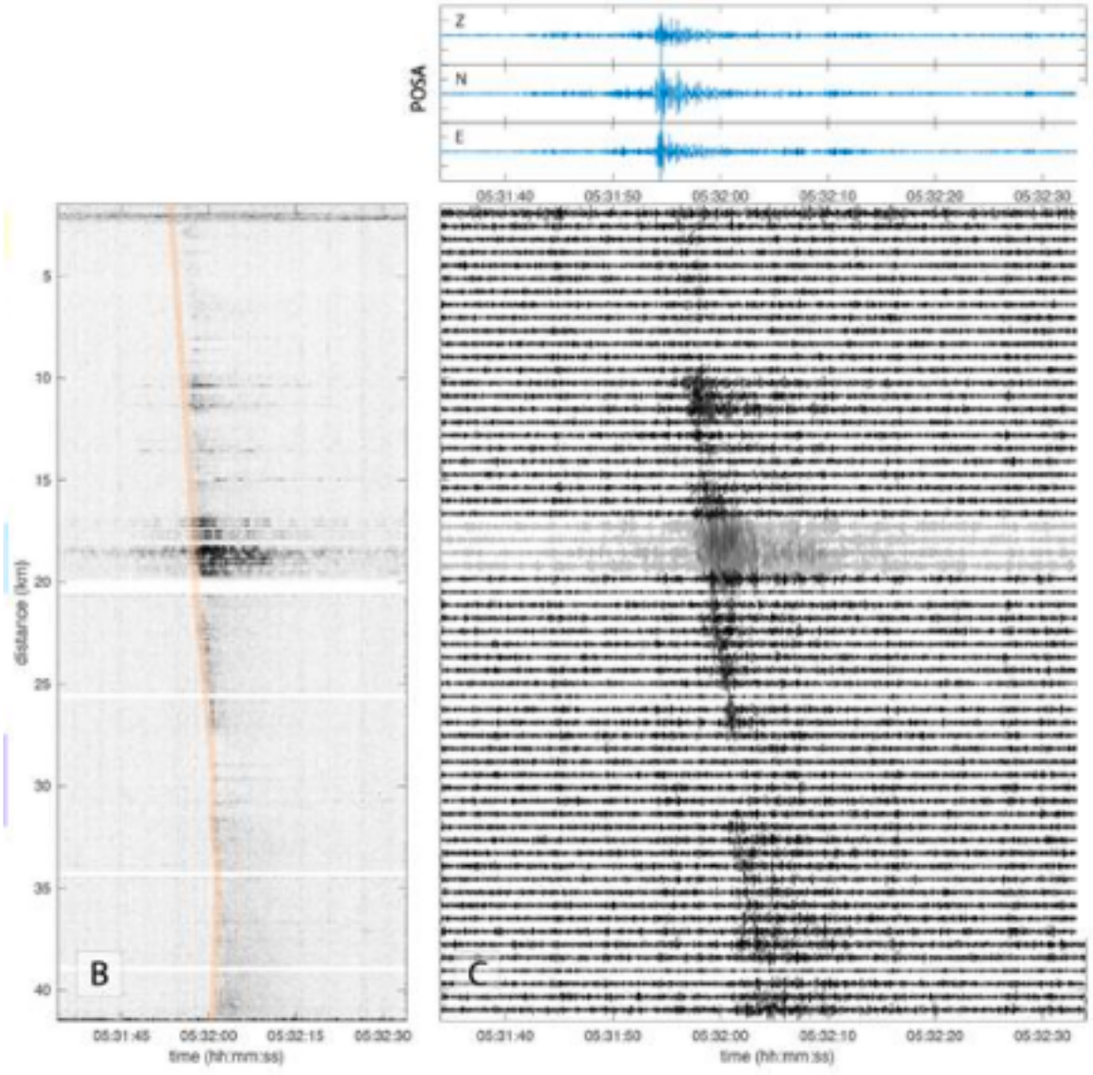

*Spectrum chant sur 20 ans*




*Evolution du chant sur 20 ans*

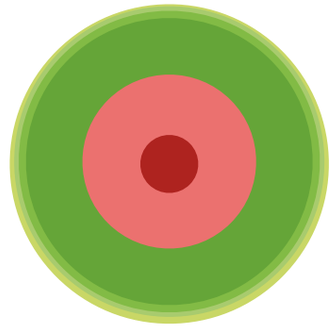
# Earth and Sea Science

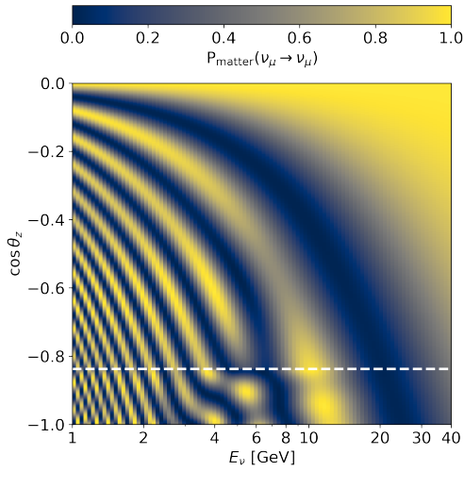
**Distributed Acoustic Sensing (DAS) laser system, tested on the some unused fibres of main electro-optic cable (with Alcatel and GeoAzur-Nice/INSU)**

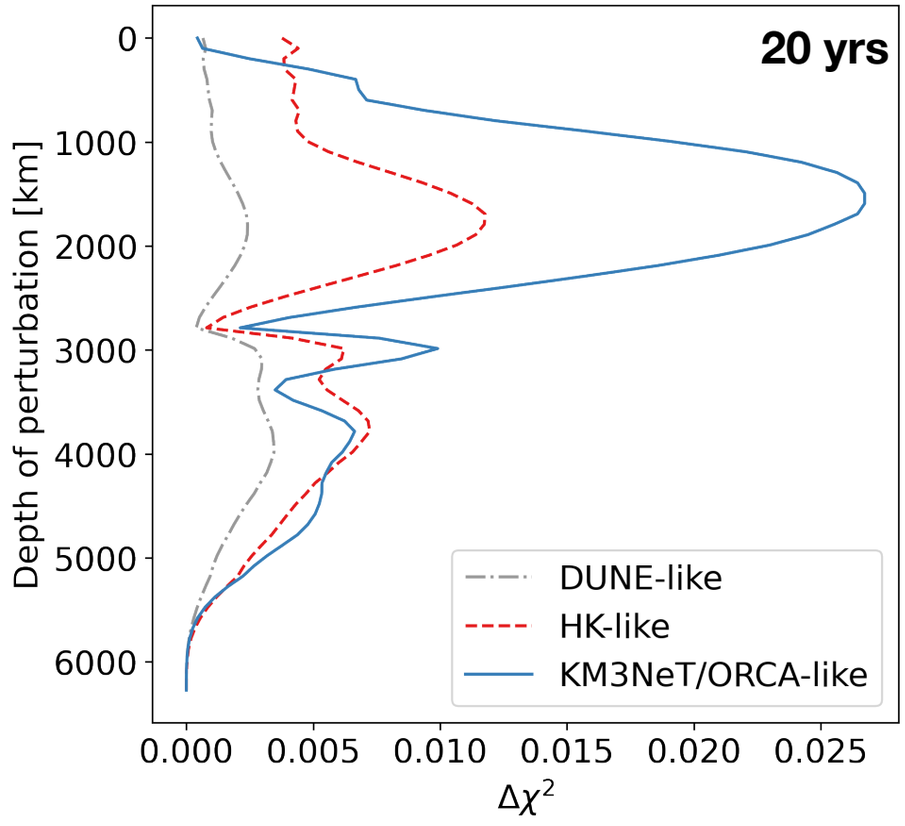



*A Magnitude 1.9 earthquake near Frejus (DAS)*

**Probing the Earth's interior with neutrino oscillation tomography (APC / IPGP / LGL-TPE / Idaho Univ.)**





# Summary

**KM3NeT telescope is currently under construction but already taking data with partial configurations. ARCA: 51 lines, ORCA: 28 lines (completion in 2030-32)**

**Two sites with complementary energy coverages:**

- ORCA from 5 GeV to TeV → optimized for neutrino oscillations but excellent telescope for astronomy
- ARCA from TeV to 100 PeV → optimized for high-energy astrophysical neutrinos

  ⇒ < 0.1° (< 1.5°) for tracks (showers) for $E_\nu$ > 100 TeV
- ARCA+ORCA combined detector for MeV

**First results:**

- With only 5% of the planned exposure, a lot of quite competitive results in oscillation
- KM3-20230213A: first UHE neutrino event
- Diffuse emission and point-source searches: getting close to ANTARES sensitivities
- Multi-messenger online program: started. Soon: sending follow-ups and ν alerts
- Start open science program (public dataset, public alert, transnational access…)
- A lot of diverse ESS studies