KM3NeT

a general introduction

December 17-19, 2019

Town Hall KM3NeT Meeting - Marseille

Mauro Taiuti - **KM3NeT** spokeperson

Outline

- Preamble
- The Detectors
- The Performances
- Conclusions

Motivations & Objectives

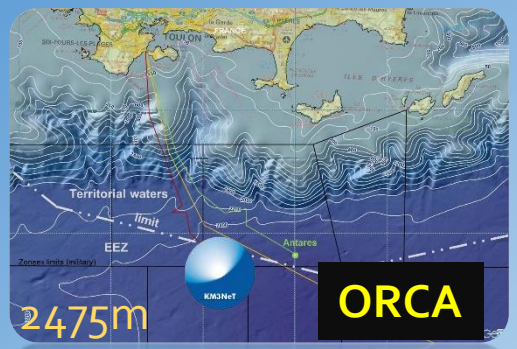
Astroparticle Research with Cosmics In the Abyss

Oscillation Research with Cosmics In the Abyss

- **KM3NeT** is the neutrino research infrastructure in the deep Mediterranean Sea
  - discover and observe high neutrino sources in the Universe

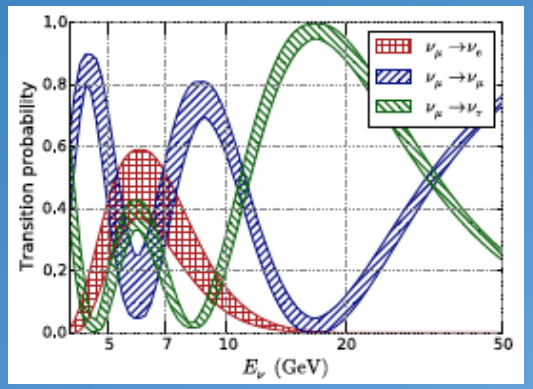
    ARCA (off shore Capo Passero, It @ 3500 m depth)
  - determine neutrino mass hierarchy

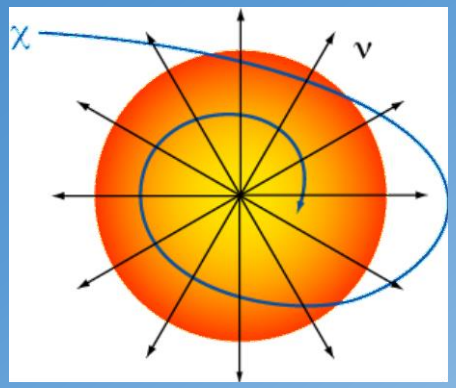
    ORCA (off shore Toulon, Fr @2500 m depth)

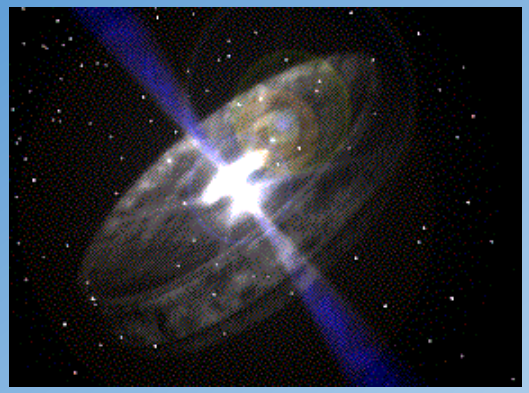


- Same collaboration, same technology, two installation sites

Motivations & Objectives







Low Energy	Medium Energy	High Energy
MeV < E_ν < 100 GeV	10 GeV < E_ν < 1 TeV	E_ν > 1 TeV
ν Oscillations Supernovae	Dark matter Monopoles, Nuclearites	Cosmic ν Origin and production mechanism of HE CR

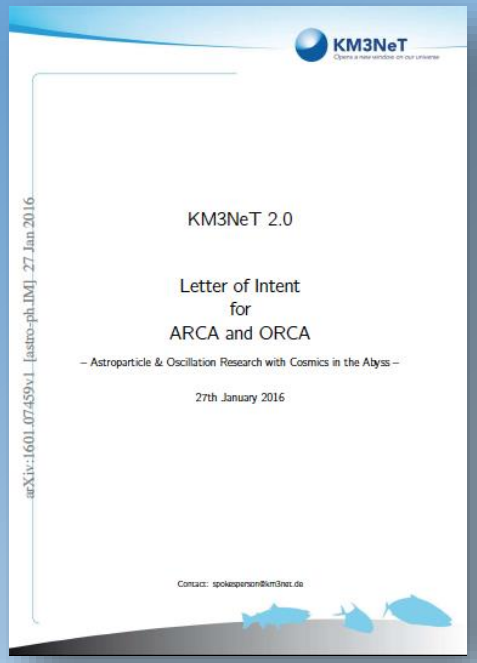
KM3NeT - ORCA — KM3NeT - ARCA

+ oceanography, biology, seismology,…

The Roadmap

KM3NeT selected for the 2016 ESFRI Roadmap

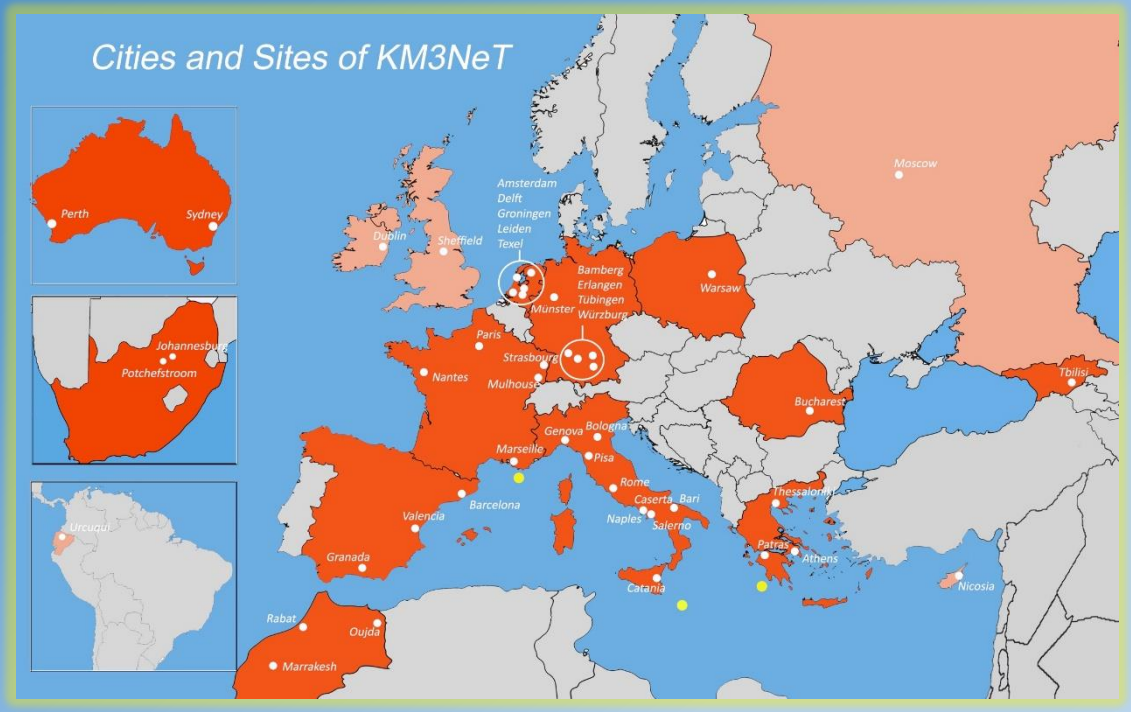
10 March 2016 – Today, at its launch event at the Royal Netherlands Academy of Arts and Sciences in Amsterdam, the European Strategy Forum for Research Infrastructures (ESFRI) announced that KM3NeT 2.0 is selected for the 2016 ESFRI Roadmap for Research Infrastructures. The ESFRI Roadmap identifies new Research Infrastructures of pan-European interest corresponding to the long-term needs of the European research communities. Its mission is to ensure that scientists in



- LoI: *J. Phys. G*, **43** (2016) 084001
- H2020: funds to prepare the ERIC
- Since 2016 **KM3NeT** is back in the ESFRI roadmap
- Since 2018 **KM3NeT** is in the APPEC roadmap
- The process to build the **KM3NeT** ERIC is in progress

The **KM3NeT** Collaboration

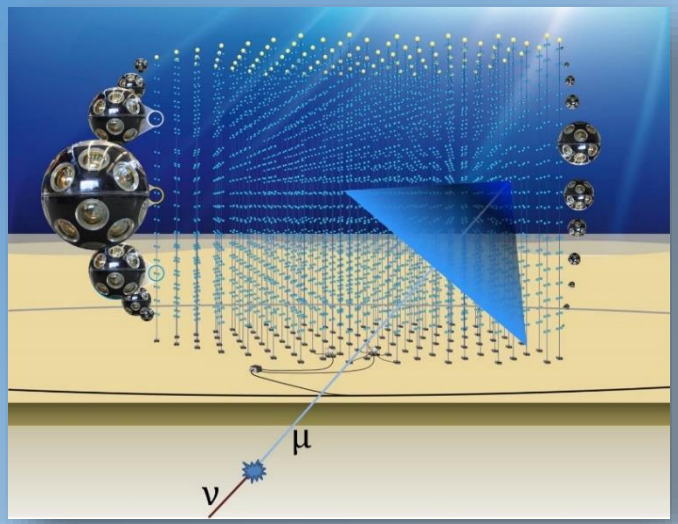
- 15 Countries
- 55 Institutes
- >240 Scientists



The Detectors

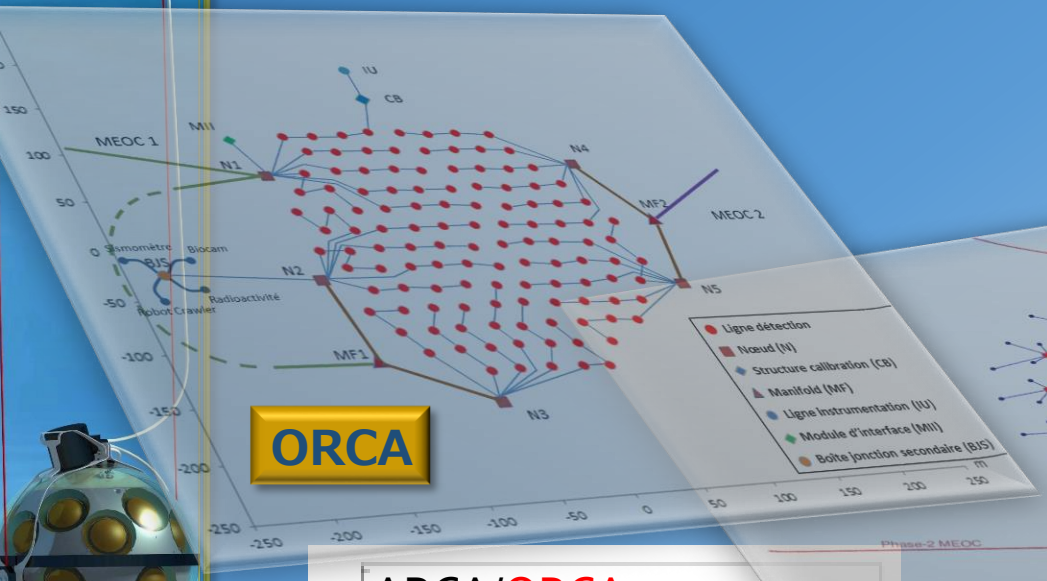
The **KM3NeT** Telescope Design

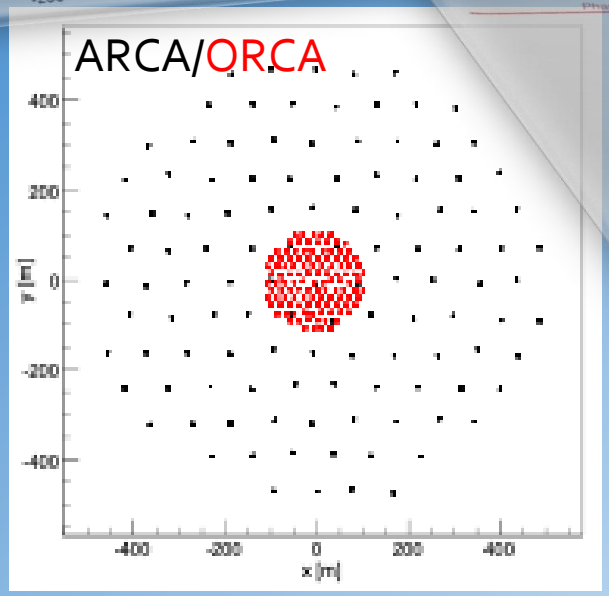
- Detection principle Optical Cherenkov radiation
  - 6 order of magnitude in energy (GeV-PeV)
  - All flavour detection
- A 3D array built with a modular design
- Optical sensor: multi-PMT (DOM)
- Detection units (DU)
  - vertical slender strings host 18 DOMs
- Building blocks of 115 DUs each
- Power and data distributed by a single backbone cable with breakouts at DOMs
- Sea network of submarine cables and Junction Boxes connected to shore via a main e/o cable
- All data to shore



	ARCA	ORCA
Location	Italy	France
DU distance	90 m	23 m
DOM spacing	36 m	9 m
Instrumented mass	2*500 Mton	8 Mton

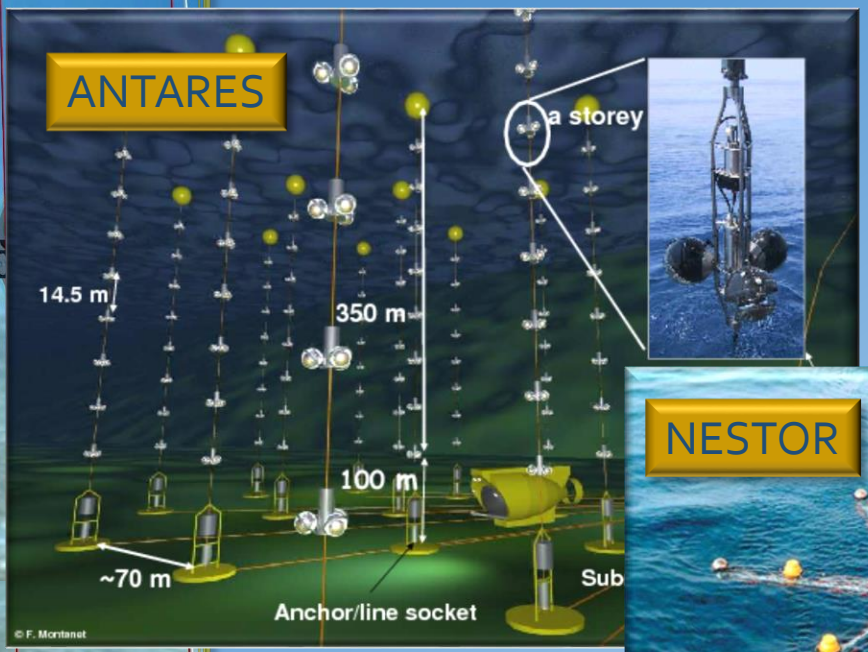
The Seafloor Network

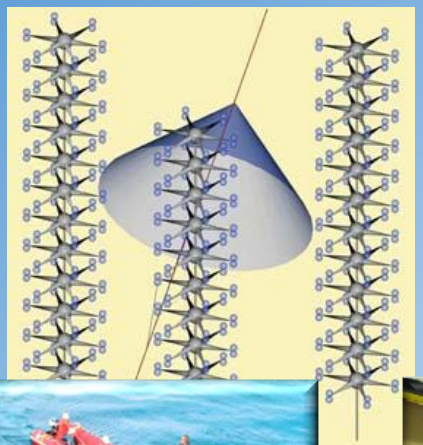


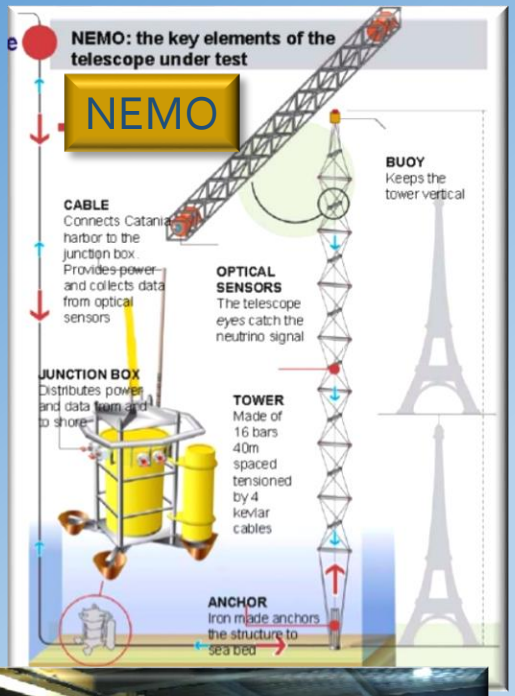


The Optical Sensor

- Basic requirement: a durable, reliable and not-expensive technology
- Several attempts before reaching the final configuration

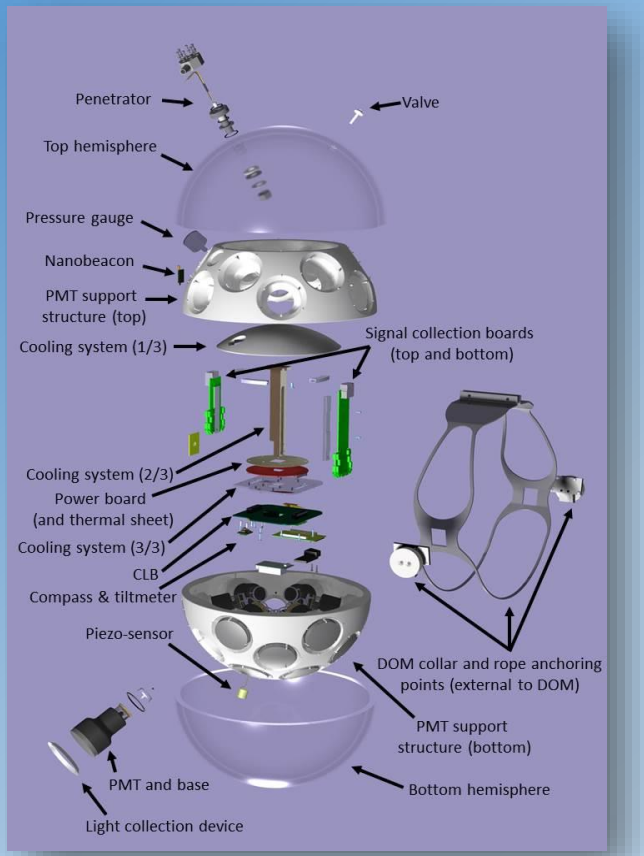






The DOM - Digital Optical Module

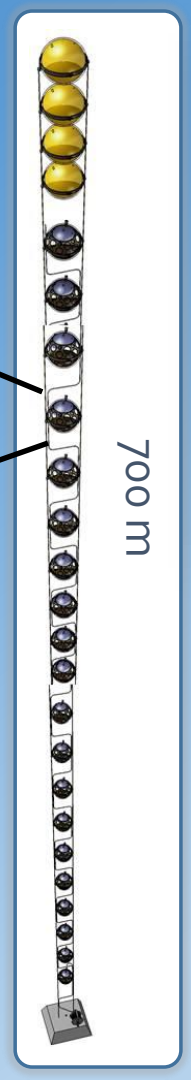
- 31 x 3" PMTs
- LED & acoustic piezo inside
- Tiltmeter/compass
- Gbit/s fibre DWDM
- Hybrid white rabbit



- Digital photon counting
- Directional information
- Wide angle of view
- Improved background rejection
- Compact and cost effective design: 1 DOM equivalent to 3 Antares OMs

The Detection Unit

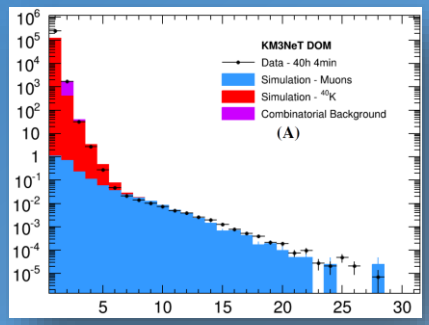
- 18 DOM integrated on vertical slender strings supported by two parallel Dynema ropes



- Strings arranged on the LOM, mounted on the anchor and ready for deployment

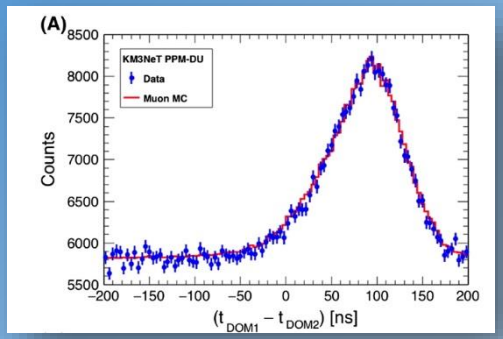
From Validation to Construction

Prototype DOM deployed at Antares site April 2013



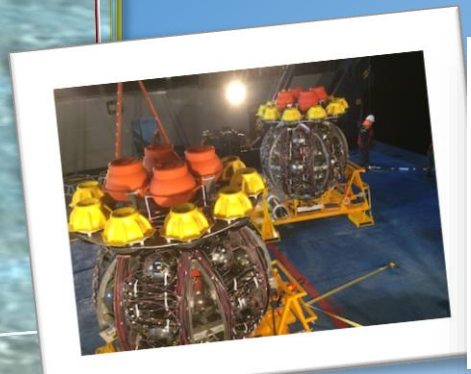
Test of photon counting capabilities and directional sensitivity of DOM
Eur. Phys. J. C (2014) 74:3056

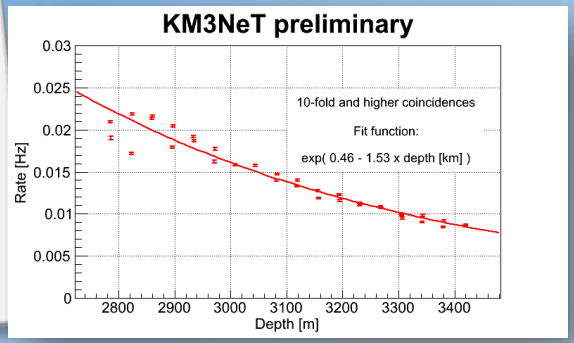
Prototype DU (three DOMs) deployed in Capo Passero May 2014



Test of DU structure functionality
Test of intra-DOM and inter-DOM calibration - *Eur. Phys. J. C (2016) 76:54*

First ARCA DU deployed in Capo Passero December 2015

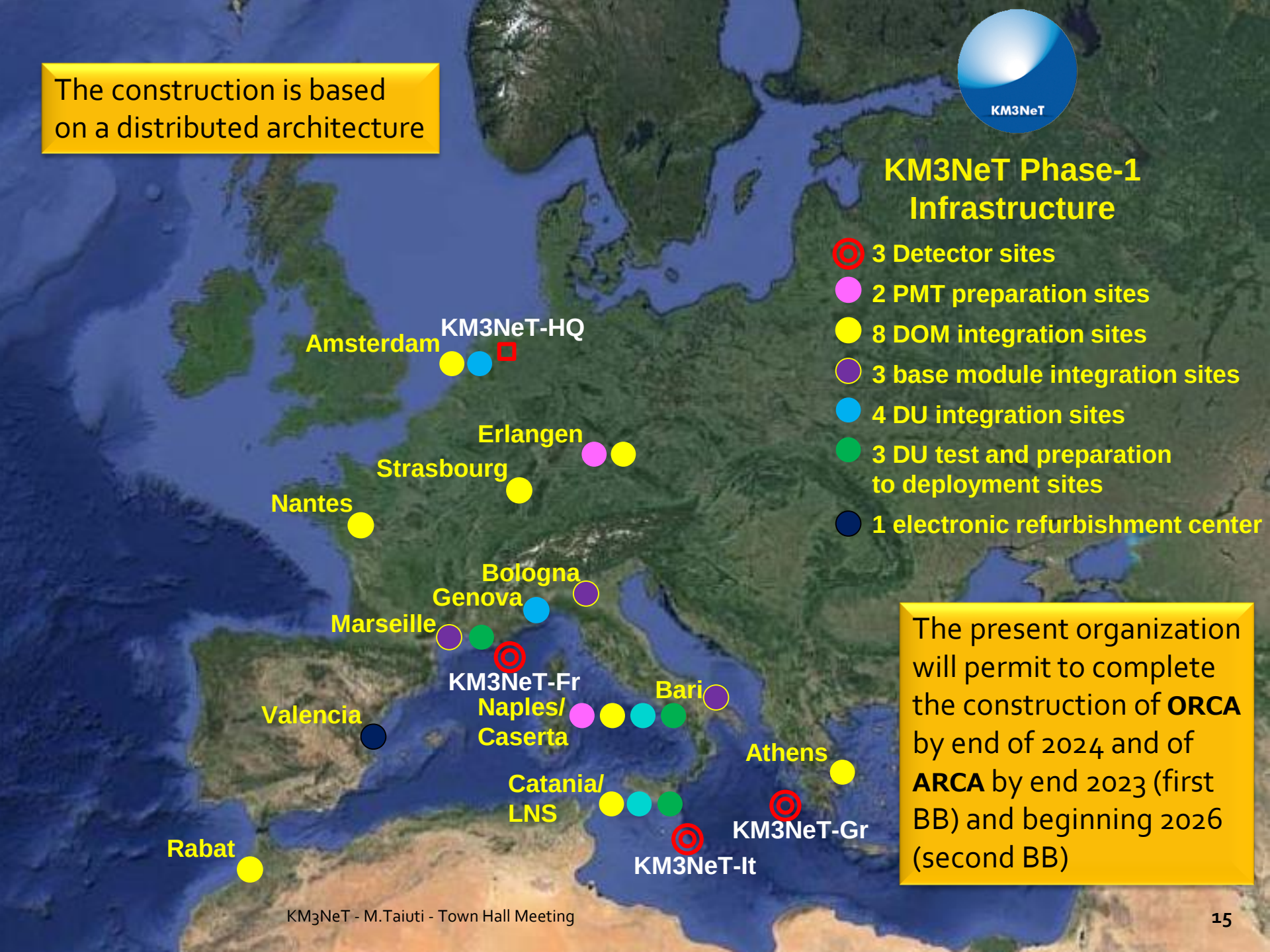




Muon flux dependence on depth
DU calibration
Trigger implementation
Track reconstruction e MC comparison
…

A Phased Approach

PHASE	BLOCKS	PRIMARY DELIVERABLES	FUNDS
1	0.2	Proof of feasibility and first science results 24 **ARCA** + 6 **ORCA** strings	Fully funded
2	2+1	All flavor neutrino physics and astronomy 2 x 115 **ARCA** strings 1 x 115 **ORCA** strings	Funding in progress (presently 1/3 available)
3	6	Neutrino astronomy including Galactic sources	Next step


The construction is based on a distributed architecture
KM3NeT
KM3NeT Phase-1 Infrastructure
3 Detector sites
2 PMT preparation sites
8 DOM integration sites
3 base module integration sites
4 DU integration sites
3 DU test and preparation to deployment sites
1 electronic refurbishment center
Amsterdam
KM3NeT-HQ
Erlangen
Strasbourg
Nantes
Bologna
Genova
Marseille
KM3NeT-Fr
Bari
Valencia
Naples/ Caserta
Athens
Catania/ LNS
KM3NeT-Gr
KM3NeT-It
Rabat
The present organization will permit to complete the construction of ORCA by end of 2024 and of ARCA by end 2023 (first BB) and beginning 2026 (second BB)

Phase 1 - **ARCA**

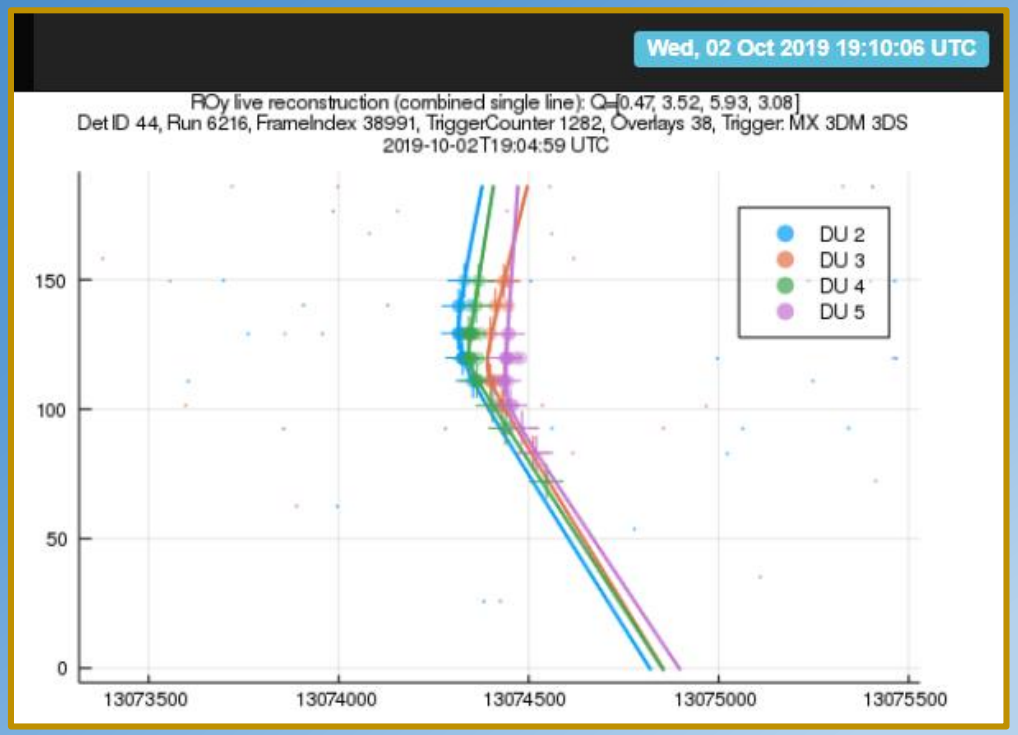
- ARCA-DU1 and ARCA-DU2 deployed December 2015 and May 2016 at Capo Passero, Sicily and worked till April 2017
- ARCA-DU1 operativity resumed in January 2019
- plenty of statistics
- presently the on-shore station is under renovation to host the second cable power supply
- the seafloor network is scheduled to return operative before summer 2020 with 6 DUs connected

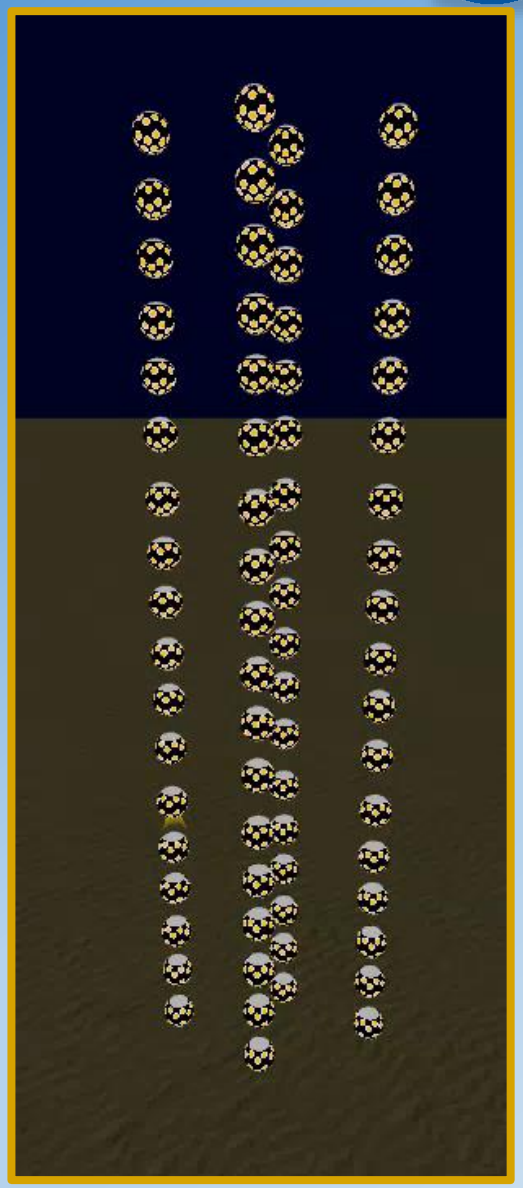
Phase 1 - **ORCA**

- First ORCA DU successfully deployed and connected in September 22, 2017
- Replacement of the cable during two different sea campaigns in October 2018 (12-16 and 22-26)
- Re-installation of the ORCA DU1 in Feb 14-17, 2019
- May 16-17, 2019 two DUs are in operation
- June 29 - July 1, 2019 four DUs in operation
- The deployment of two additional DUs postponed to next year due to bad weather conditions

Phase 1 - ORCA

- 4 DUs fully operative

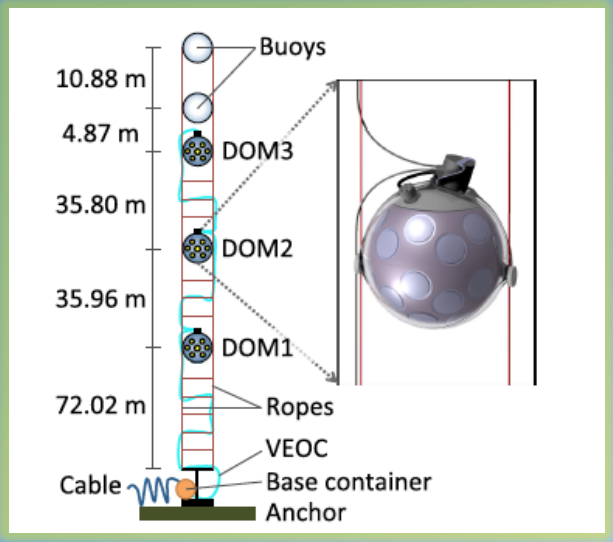


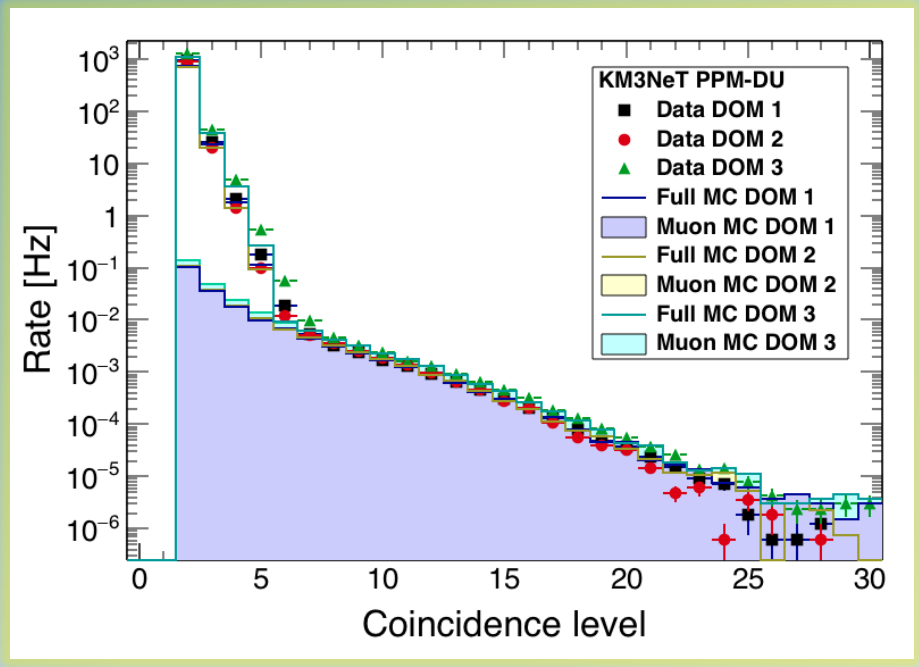


The Performances

DOM Performances

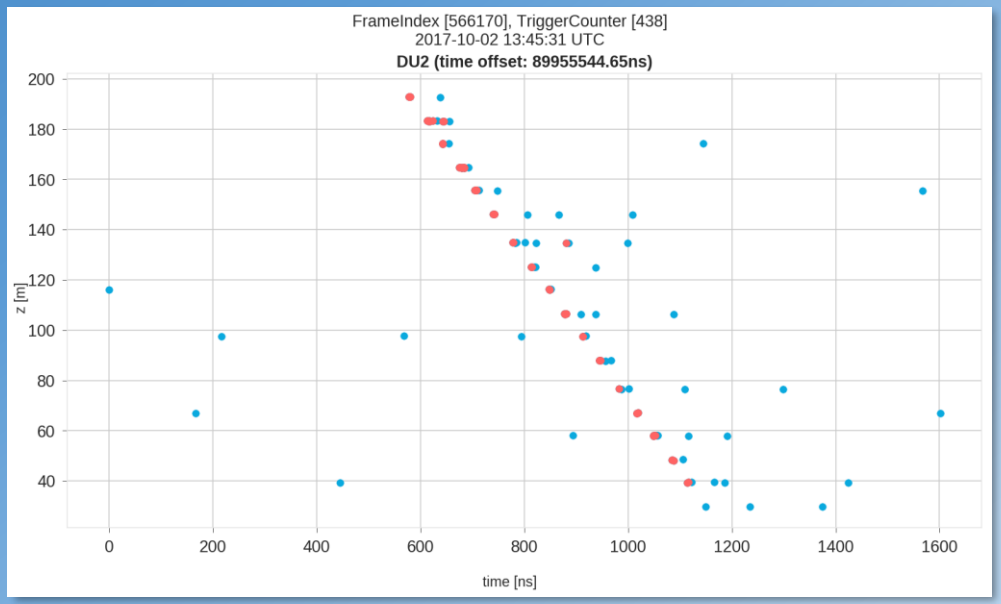
- The module design allows to select the muon events with threshold on multiplicity
- The DOM provides also info on the direction of the detected light

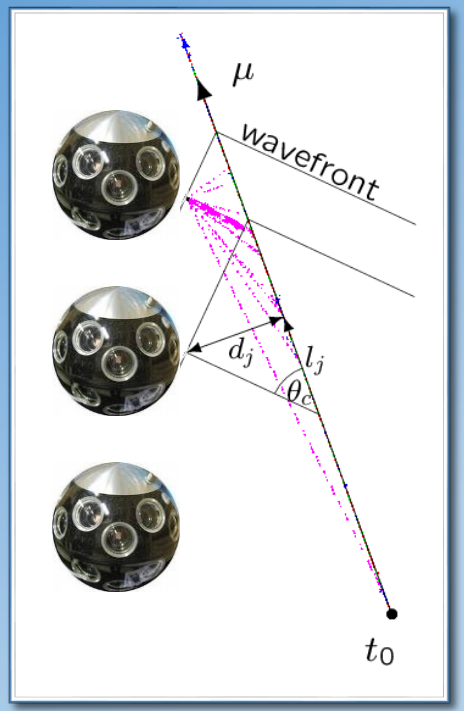




DU Performances

- Events are reconstructed with timing DOM correlation
- Very low ambiental noise



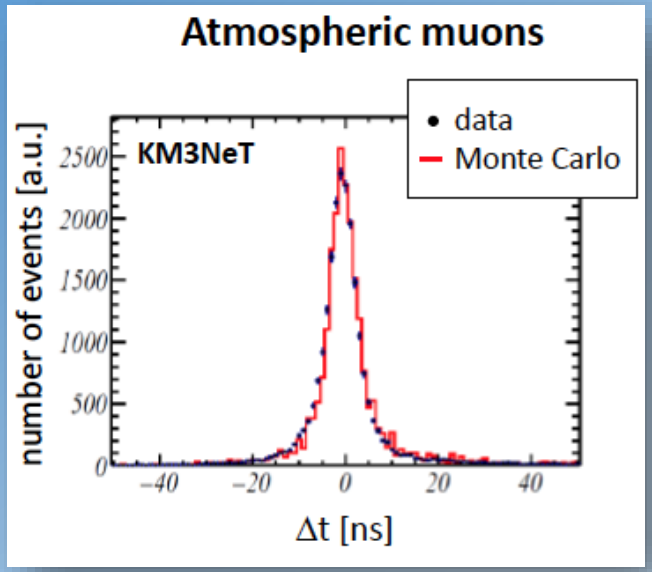


Detector Performances

- **KM3NeT-ARCA** project goals
  - For E_ν >10 TeV track events (muons) ⟶ Median angular resolution <0.2°
  - For E_ν >10 TeV shower events ⟶ Median angular resolution < 2°
- Requirements
  - *Timing* - Relative hit times accuracy ~ 1 ns
  - *Orientation* - PMT orientation accuracy < 3°
  - *Positioning* - DOM position accuracy < 20 cm (corresponding to the distance traveled by Cherenkov photons in 1 ns)

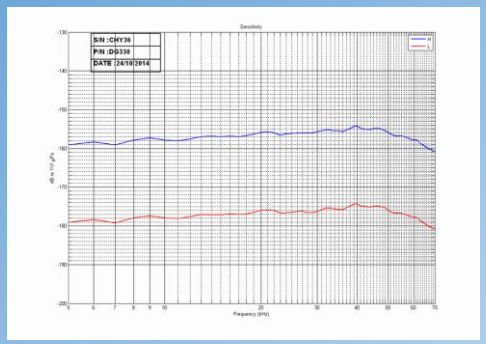
Technical Solutions

- Timing:
  - synchronization based on White Rabbit time distribution protocol
- Orientation:
  - Compass installed in each DOM
- Positioning:
  - Long Base-Line (LBL) of acoustic transmitters (beacons) and receivers, located at known positions as provided by NAAPS (Navigation and Absolute Acoustic Positioning System)
  - An array of digital acoustic receivers (DARs) installed along the detection units (DUs) of the telescope



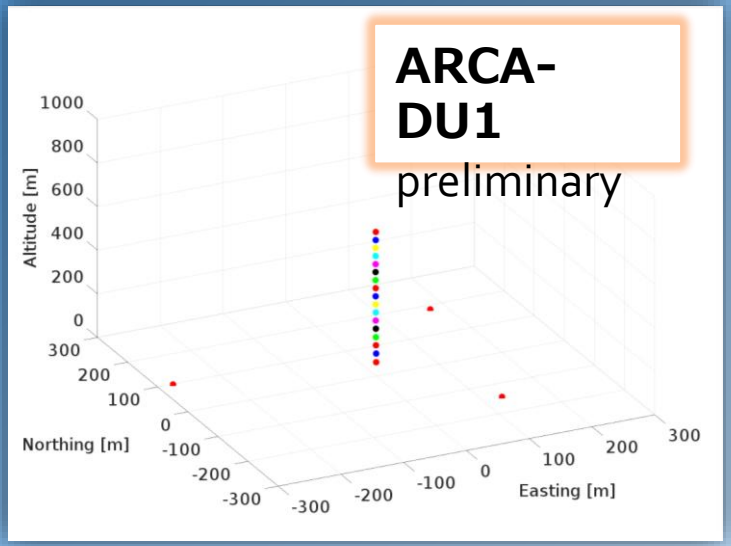
Positioning System

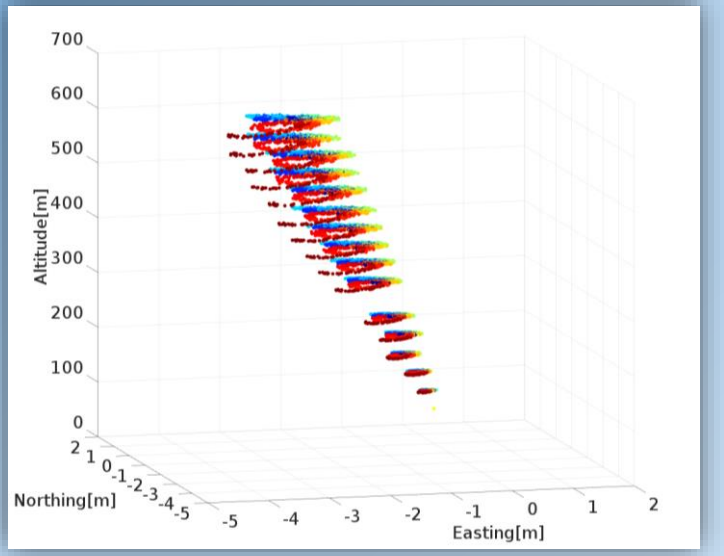
- The movement of the DUs is monitored by means of piezo-electric Digital Acoustic Receivers (DAR) glued to the glass sphere of each KM3NeT Digital Optical Module (DOM)
- Digital hydrophones hosted on the base of the DUs are used to measure the DUs relative distance.



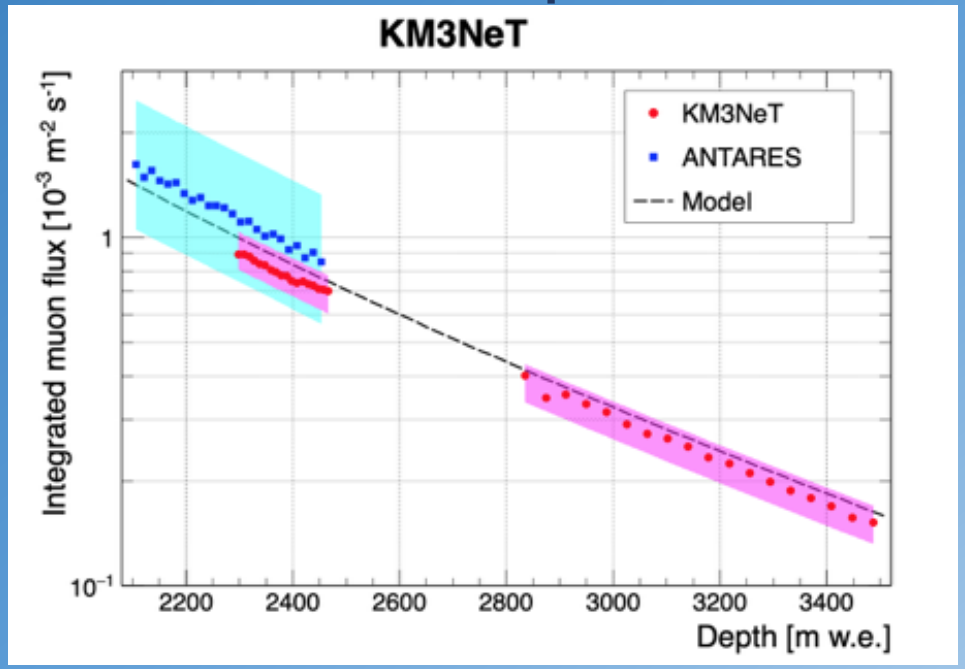
Positioning System

- The DU shape and the DOM position is known at the level of few cm!





ARCA + **ORCA** Muon Flux Depth Dependence



Absolute muon flux

Single DOM A_{eff}=96±4 m²

Integrated atmospheric muon flux measured with the ORCA1 and ARCA2 detectors as a function of depth below the sea level (red points). The systematic errors are displayed as light red shadowed areas. The Bugaev model [1] of the atmospheric muon flux is drawn with a dashed black line, see text for model description. ANTARES data from [2] are included as blue points for comparison (systematic errors are the light blue shadowed area). The depth is expressed in water equivalent (w.e.). Statistical uncertainties are included and smaller than markers.

Summary

- Several lessons learned
- The detectors performances are well under control
- We are confidently proceeding with the integration of the next DUs
- **KM3NeT** is going to become a key infrastructure for neutrino astronomy in the next decade

Thank you!