
# KM3NeT

## (A MULTIDISCIPLINARY OBSERVATORY IN THE ABYSS OF THE MEDITERRANEAN SEA)

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*Cumbayá, Quito, Ecuador*
*29th August 2019*

**PART 1**

INTRODUCTION TO KM3NeT SCIENCE

**PART 2**

THE KM3NeT LAYOUT

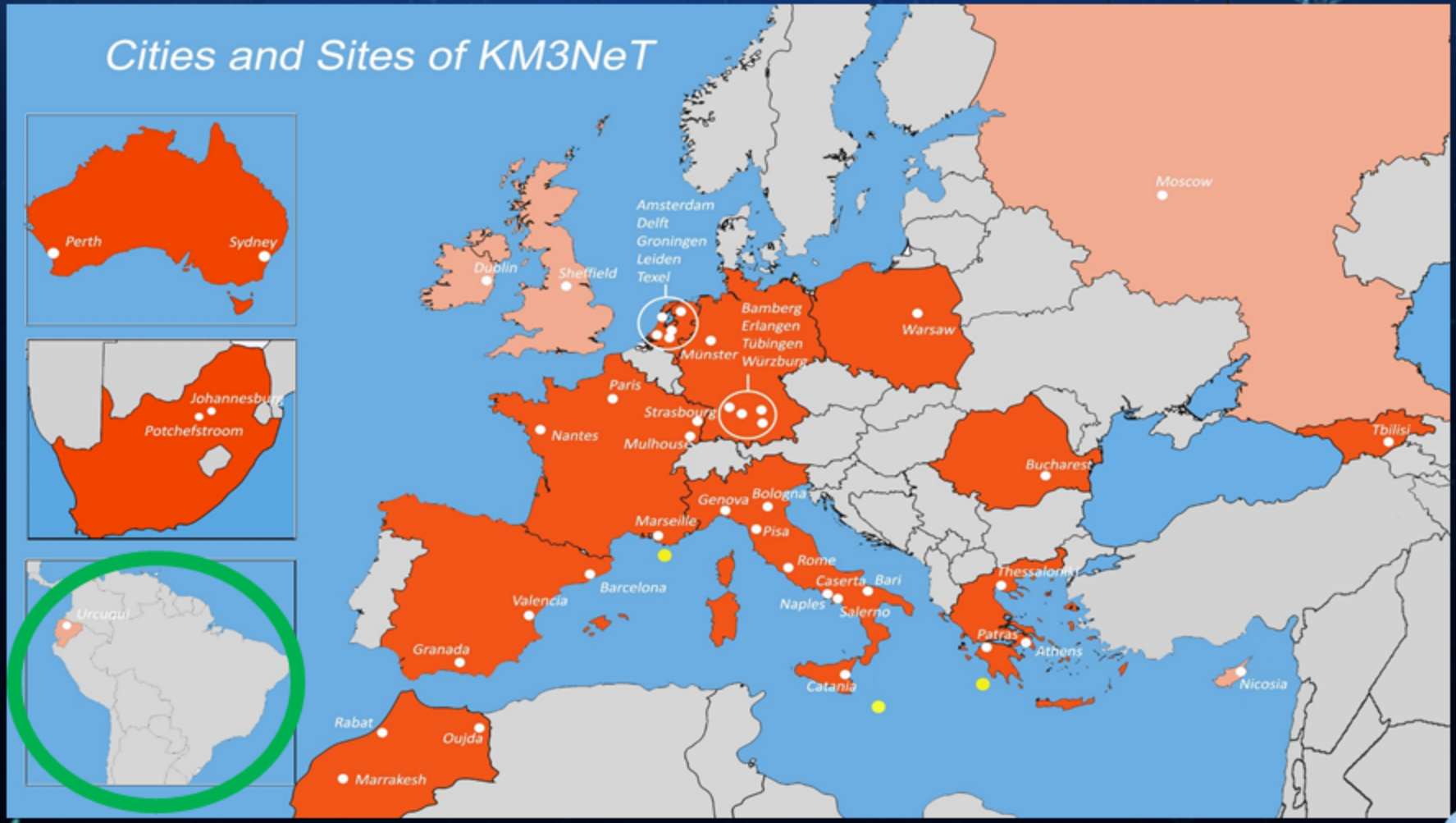
**PART 3**

THE KM3NeT NEUTRINO DETECTOR

# PART 1

# INTRODUCTION TO KM3NeT SCIENCE

# → THE KM3NeT COLLABORATION ←



# → KM3NeT IN ECUADOR (AND AL) ←

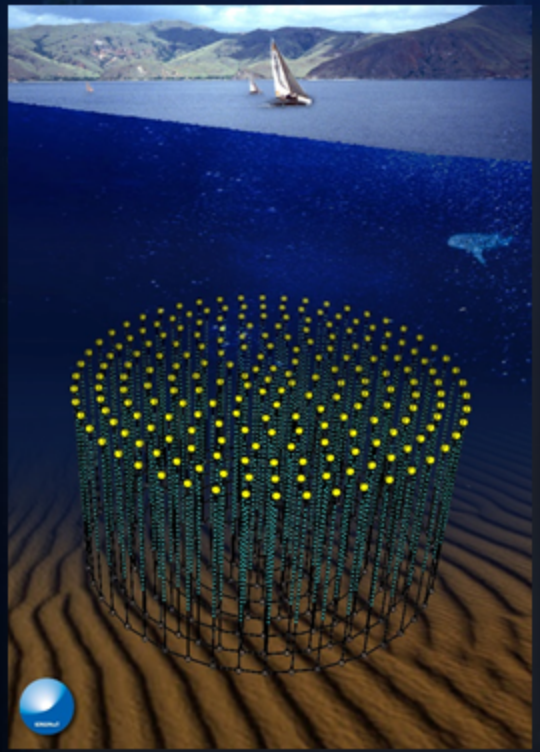


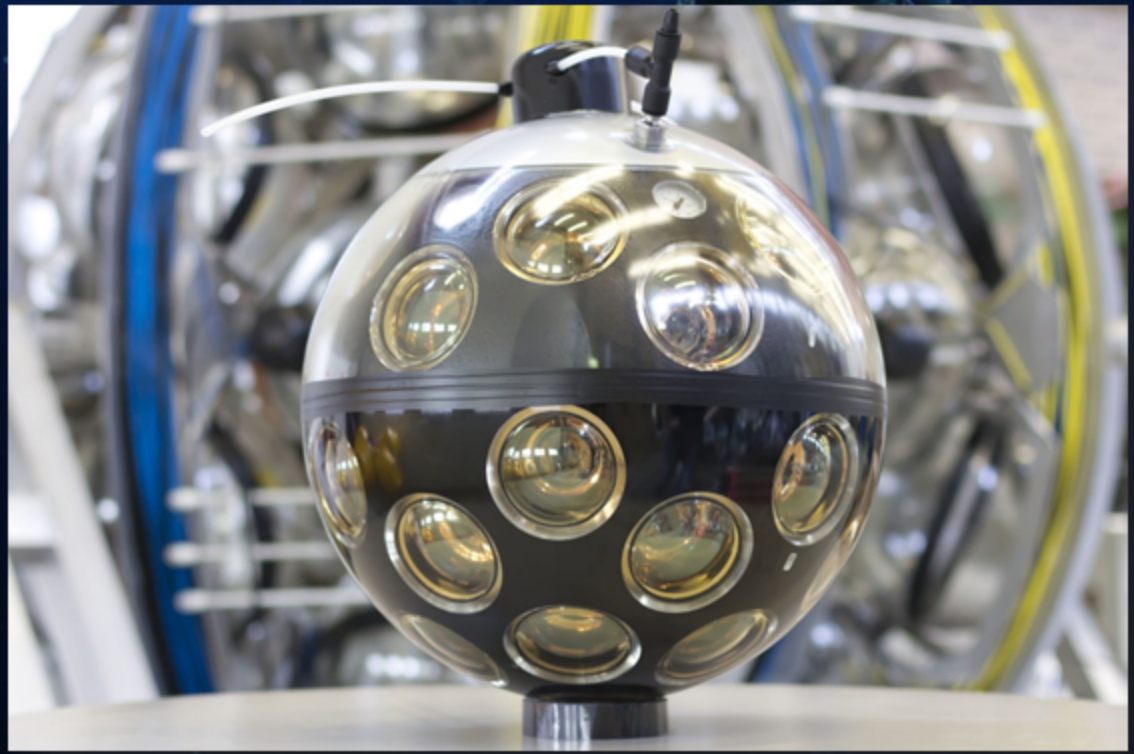
# → KM3NeT IN ECUADOR (AND AL) ←



# → MOTIVATION TO DO KM3NeT ←

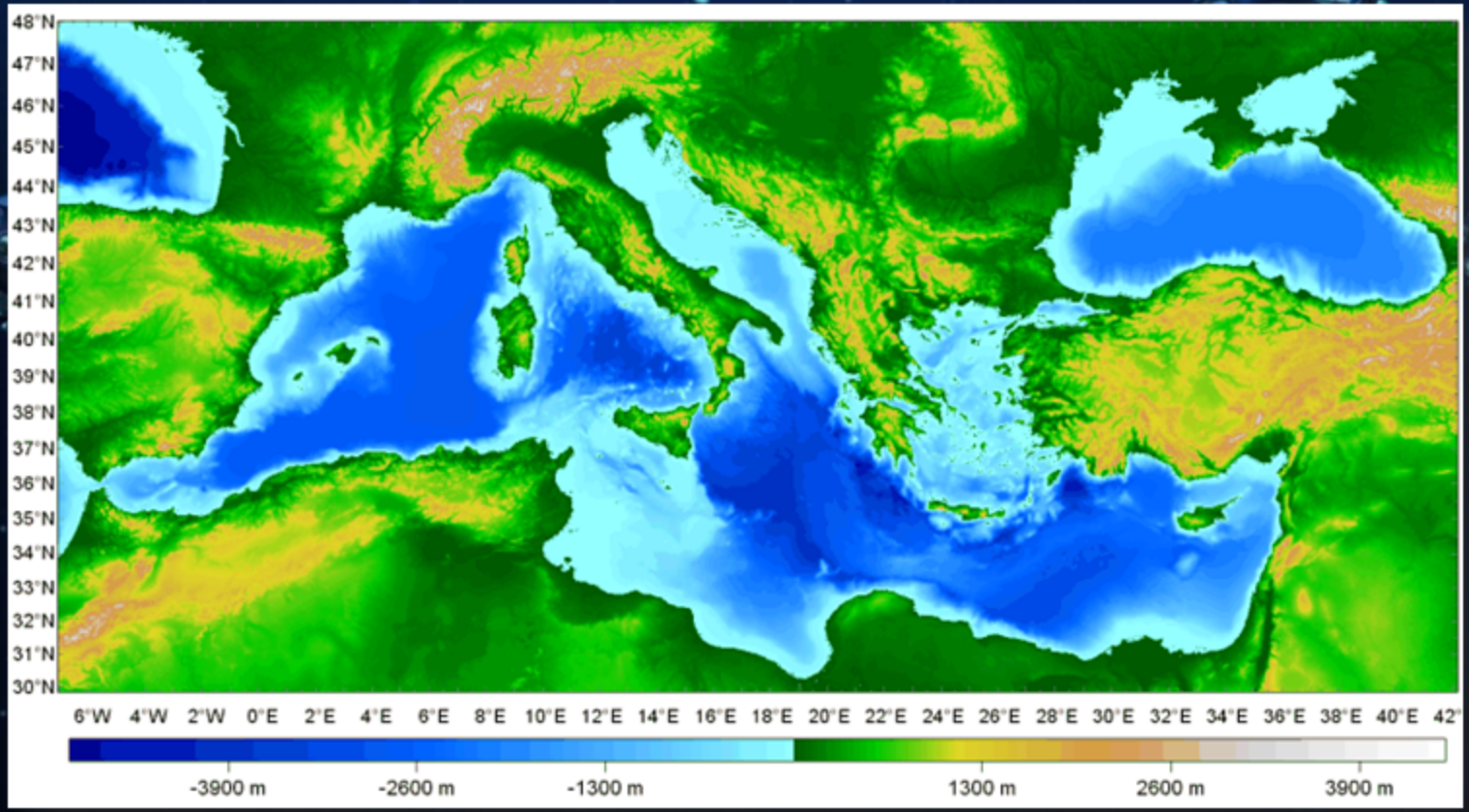
To enhance our knowledge spanning Sea, Earth and Space sciences, looking for new discoveries and technology advance through the construction and operative experience of large-scale deep-sea multidisciplinary infrastructures and advanced detector systems.





# → OBJECTIVE (EARTH AND SEA SCIENCES) ←

- ✓ To guarantee the Mediterranean deep sea as of prime interest for investigations in the fields of marine and earth sciences featured by the permanent connection to the shore.



# → OBJECTIVE (EARTH AND SEA SCIENCES) ←

Such objective is strongly motivated by:

- ✓ Long-term monitoring, since permanent connections (powering and reading out instruments) from the deep sea to the shore are only available via cabled sites, at present in Europe, those of the neutrino telescope pilot projects (e.g., ANTARES).
- ✓ Complementary goals and collaborative activities with an infrastructure hosting **multi-cubic-kilometer neutrino telescopes in several regions of the Mediterranean**.
- ✓ Associated-sciences, infrastructure as a world leading observatory with enormous discovery potential, important node in a global network of deep-sea observatories.

KM3NeT

ESONET NOE

emso ERIC

GMES Observing our planet for a safer world

NEPTUNE Canada Transforming Ocean Science

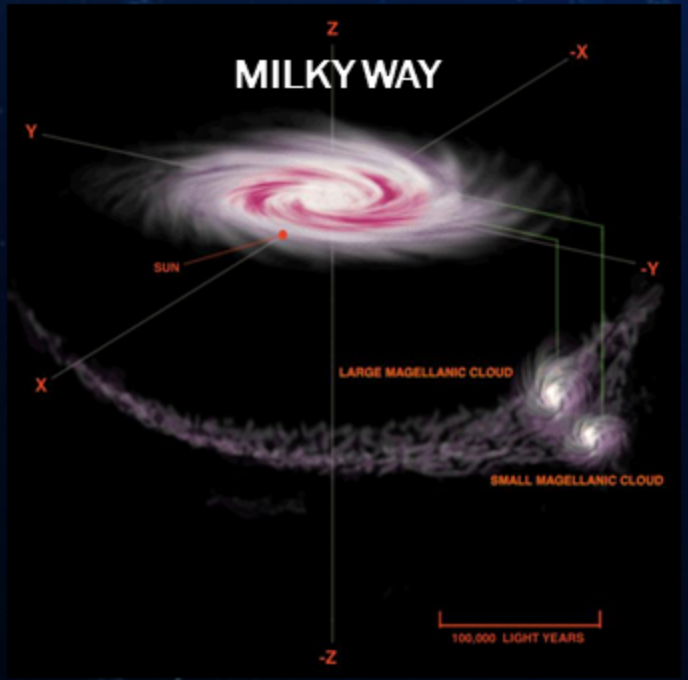
OOI OCEAN OBSERVATORIES INITIATIVE

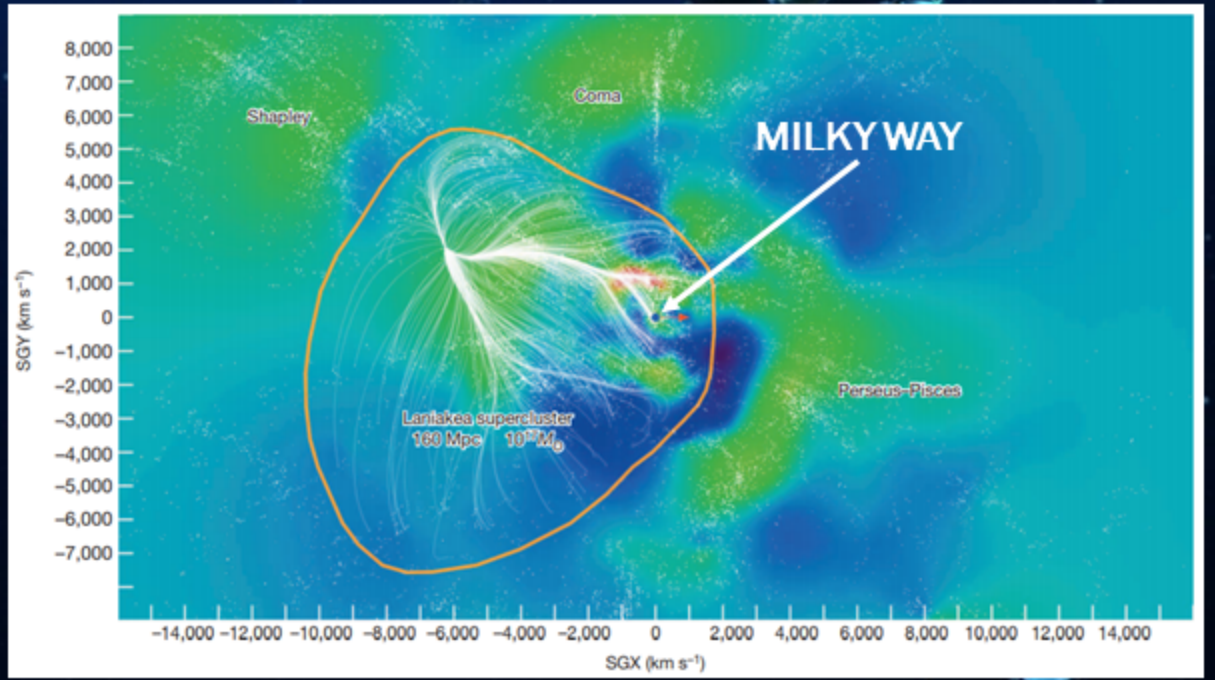
+ DONET Japan

# → OBJECTIVES (SPACE SCIENCES) ←



- ✓ Discovery and subsequent observation of **high-energy neutrino sources** in the Universe.
- ✓ Determination of the **mass hierarchy of neutrinos**.

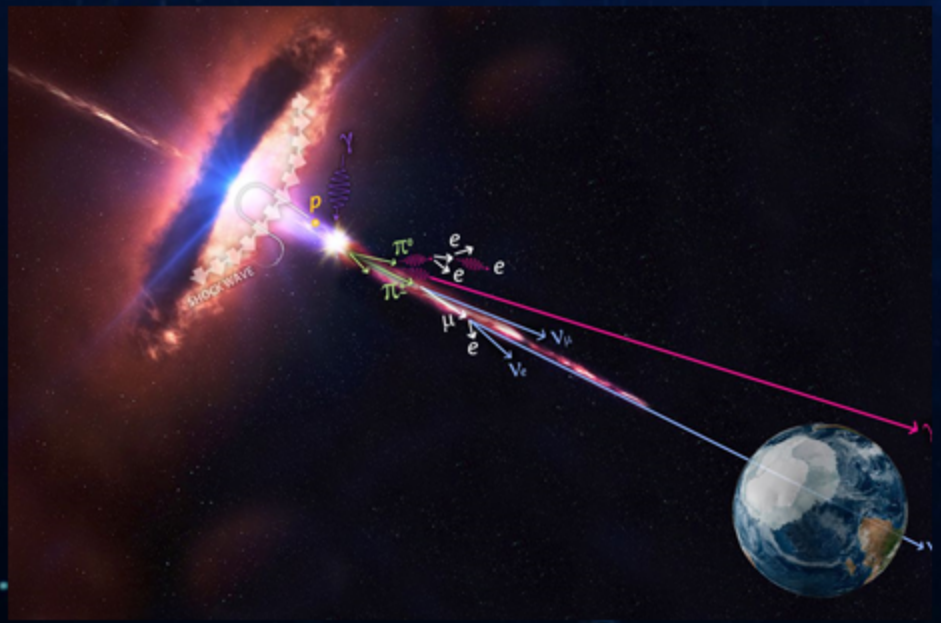


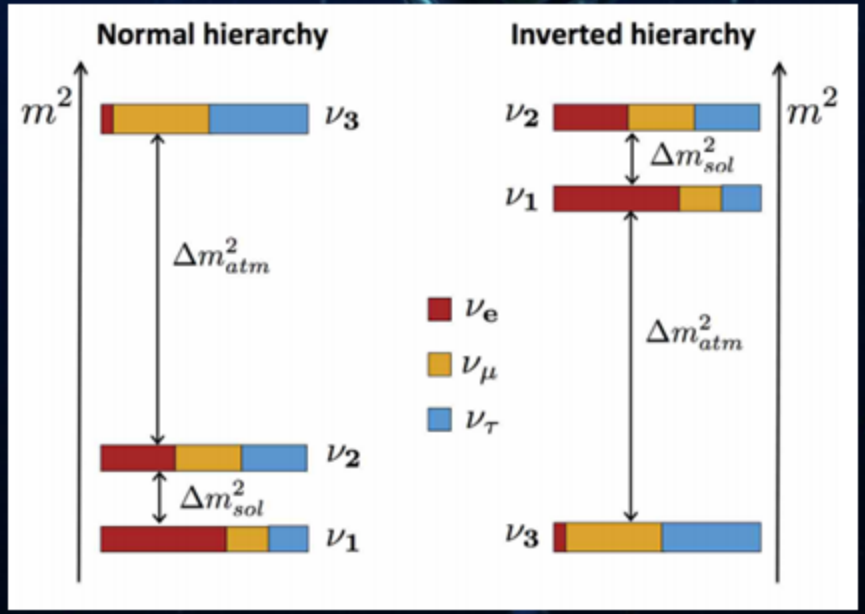



# → OBJECTIVES (SPACE SCIENCES) ←

These objectives are strongly motivated by **two "recent" important discoveries**:

- ✓ The IceCube discovery of high-energy astrophysical neutrino source (TXS0506+056).
- ✓ The sizeable contribution of electron neutrinos to the third neutrino mass eigenstate as reported by Daya Bay, Reno and others.



# → NEUTRINOS ←

**AGNs/GRBs/others?**
$E^{-2}\Phi_\nu^{Earth}$ ~$10^{-8}$ $\nu$ GeV/ cm$^2$s sr
$E_\nu$~ 100 TeV – PeV

**Big Bang**
$\rho\nu$= 330 / cm$^3$
$E_\nu$= 0.0004 eV
(1 MeV = 1.6 x $10^{-13}$J)

**Blazar TXS 0506+056**
*Ev*~100s TeV

**SN1987**
$E_\nu$~MeV

**Sun**
$\nu_e$
$\Phi_\nu^{Earth}$ = 6 x $10^{10}$ $\nu$/ cm$^2$s
$E_\nu$~ 0.1 – 20 MeV

**Atmospheric neutrinos**
$\nu_e, \nu_\mu, \bar{\nu}_e, \bar{\nu}_\mu$
$\Phi_\nu$~1 $\nu$/cm$^2$s
$E_\nu$~0.1– 100 GeV


**Human body**
$\Phi_\nu$= 340 x $10^6$ $\nu$/day


**Nuclear reactors**
$E_\nu$~ few MeV

**Terrestrial radioactivity**
$\Phi_\nu$~ 6 x $10^6$ $\nu$/cm$^2$s

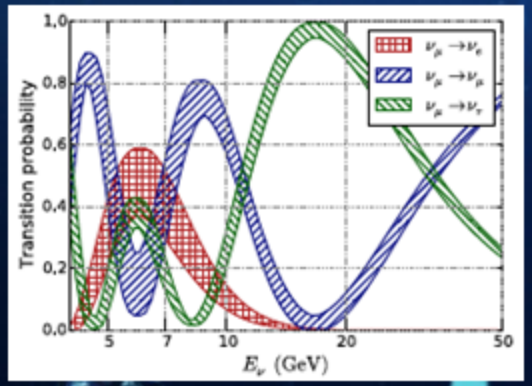
Fermilab

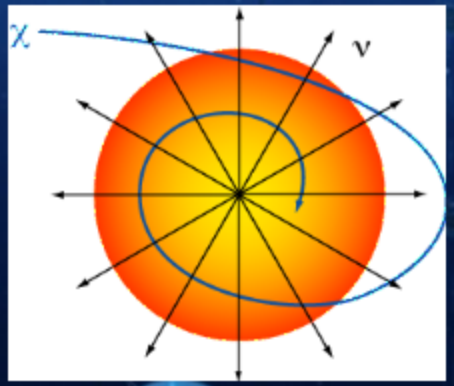
CERN

KEK

**Accelerators**
$E_\nu$ 0.3 – 30 GeV

# → NEUTRINOS ←



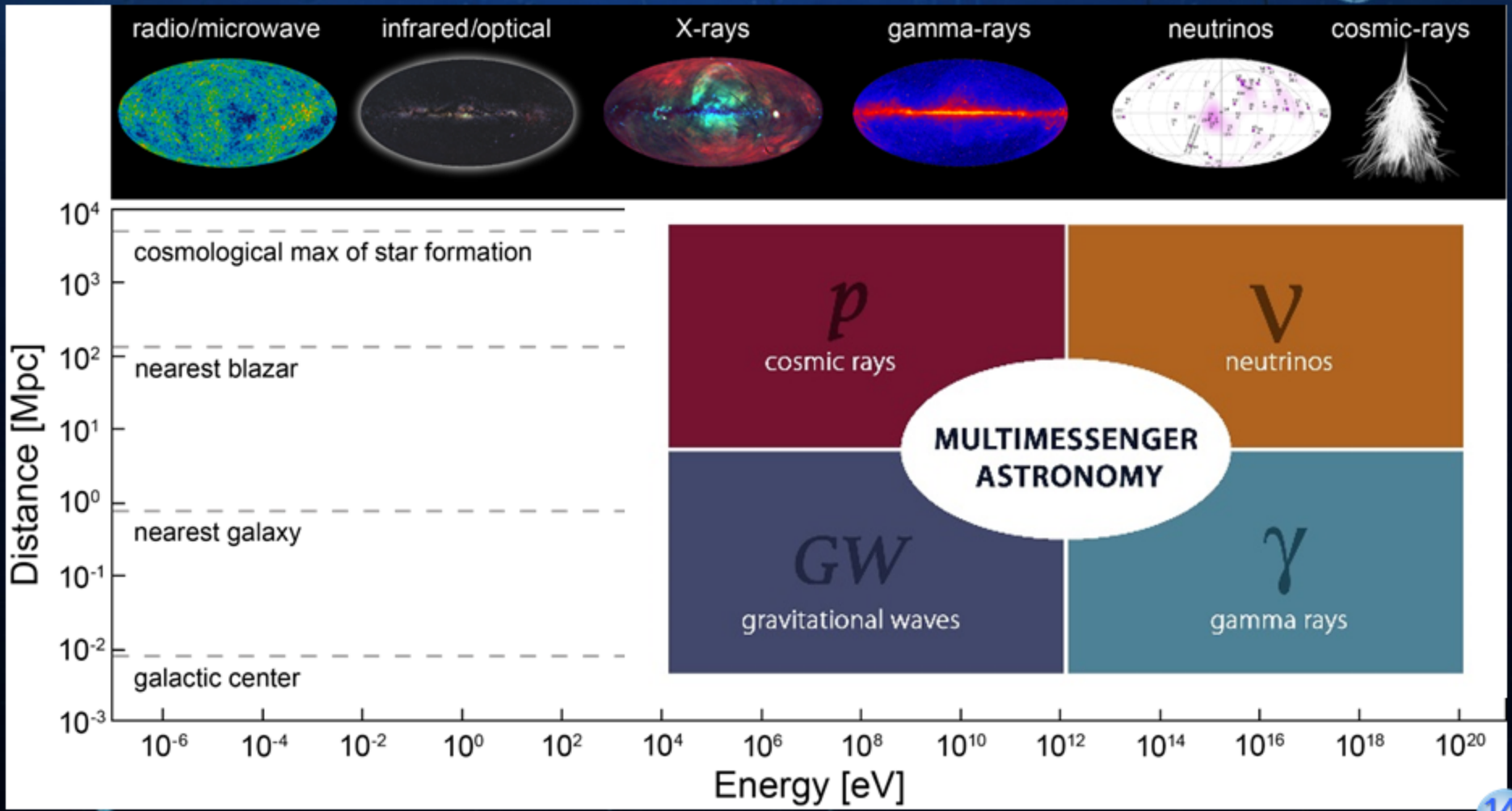




| Low Energy | Medium Energy | High Energy |
|---|---|---|
| (MeV < $E_\nu$ < 100 GeV) | (10 GeV < $E_\nu$ < 1 TeV) | ($E_\nu$ > 1 TeV) |
| ν Oscillations Supernovae | Dark Matter, Monopoles, Nuclearites | Cosmic ν, Origin and production mechanism of HE CR |

KM3NeT-ORCA — KM3NeT-ARCA

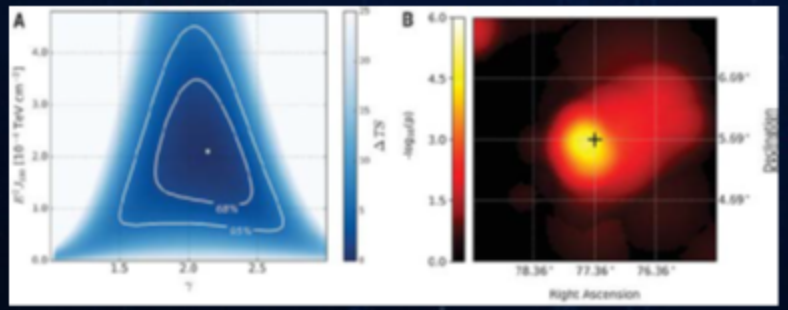
+ **Earth and Sea Science:** environmental sciences, geology and geophysics, marine biology and oceanography ....

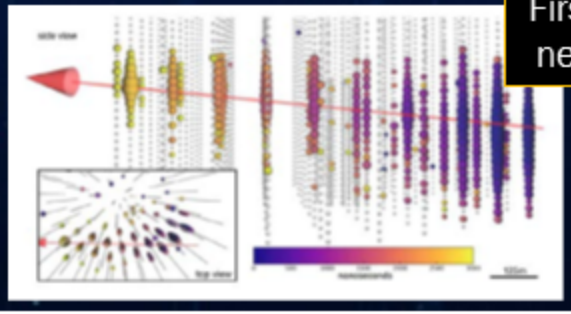
# → WHY NEUTRINOS? (I-ASTRO) ←



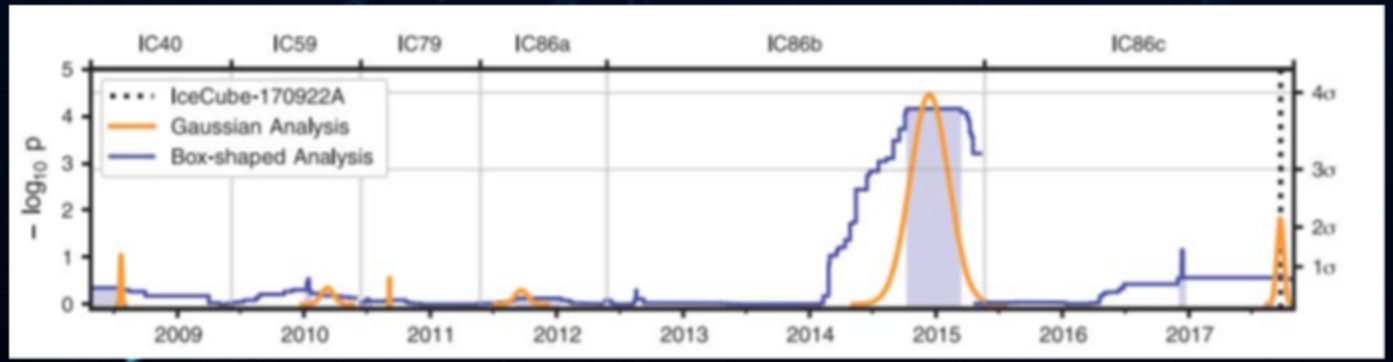
**September 2017:** A EHE alert is sent by IceCube (Ev~290 TeV). Two analyses:

- ✓ IC170922A alert, which triggered positive observation by Fermi, MAGIC and others.
- ✓ Search for additional "neutrino flares" in previous IceCube data: signal of 17±5 over Background.

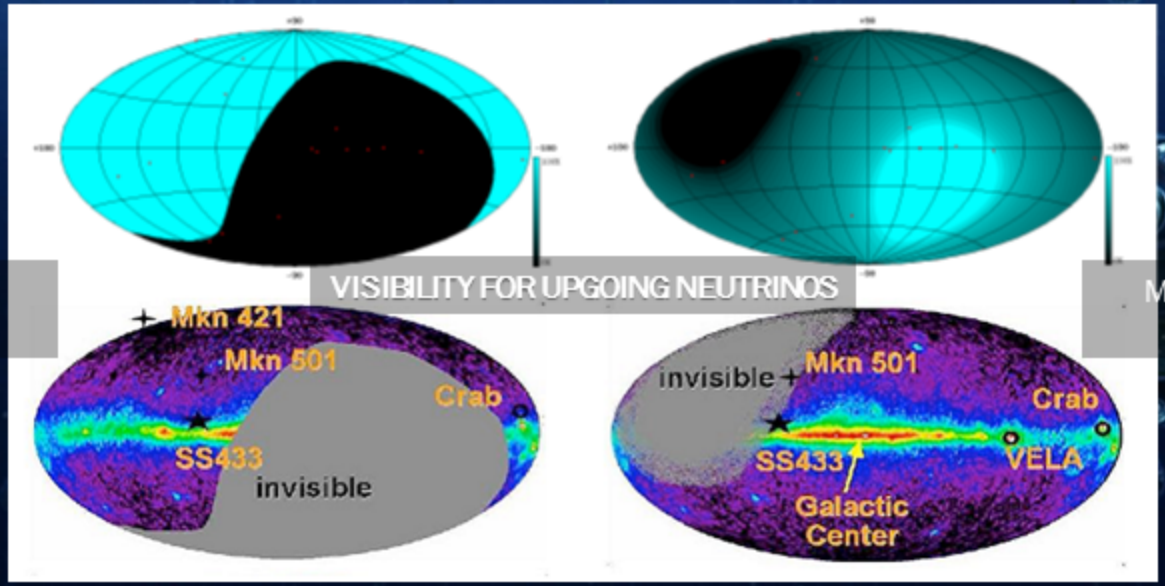


First identification of a (HE) cosmic neutrino source! (TXS 0506+056)




# → WHY NEUTRINOS? (III-ASTRO) ←




South Pole (SH) (AMANDA 1 TeV)

Mediterranean Sea (NH) (ANTARES 1 TeV)

High-energy neutrinos (with IceCube data):

- ✓ Quasi-isotropic dominant component at high energy (E>100TeV) suggests extragalactic origin.
- ✓ Galactic origin component at lower energies.

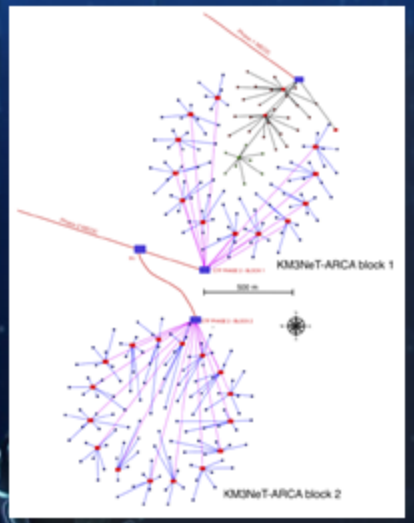
→ **A better angular resolution** is reached in deep-sea water than in ice ←

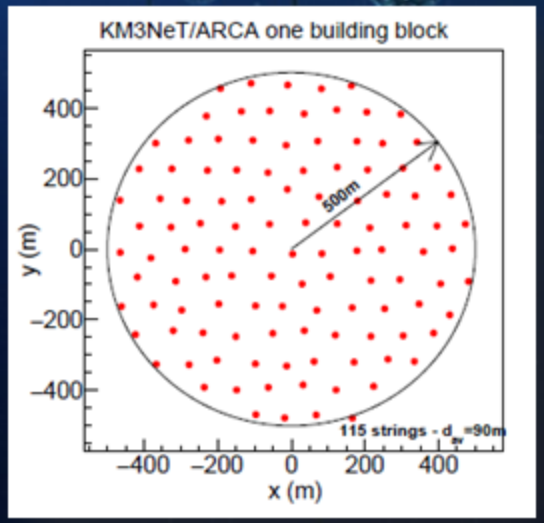
# PART 2

# THE KM3NeT LAYOUT

# → THE KM3NeT LAYOUT (ARCA) ←

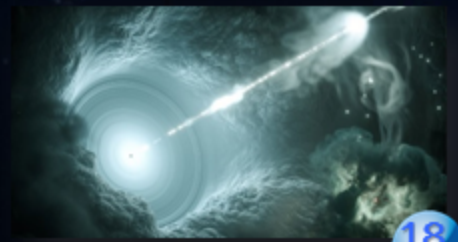


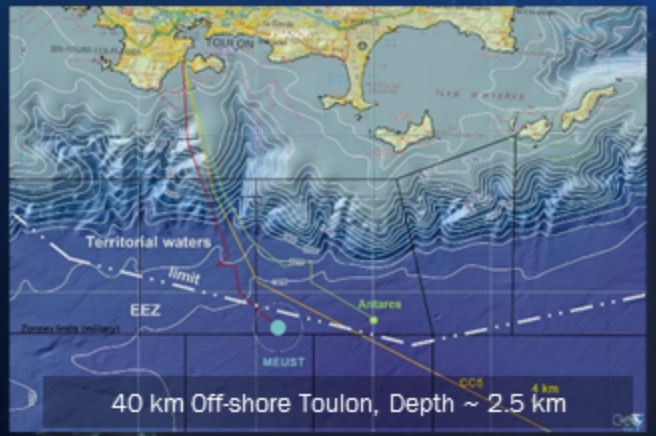



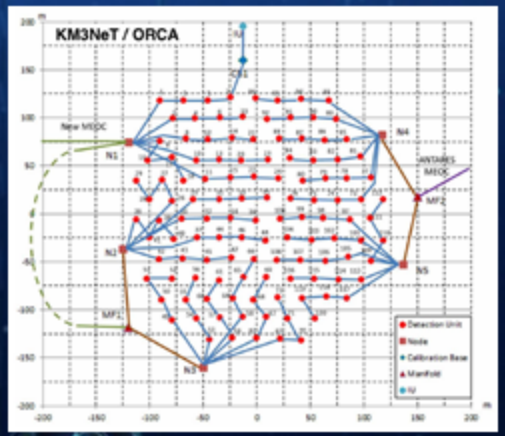

## ARCA (Astroparticle Research with Cosmics in the Abyss)

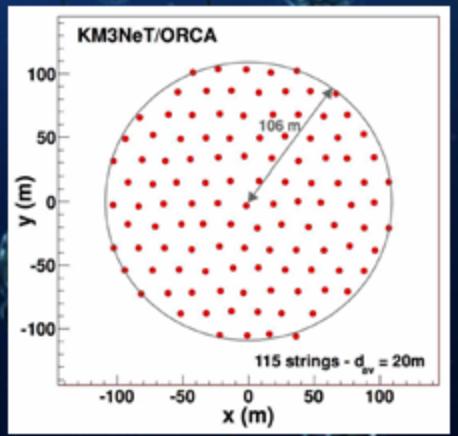
- ✓ High-energy neutrino astronomy and astrophysics (GRB's, AGN's, Blazars, etc.)
- ✓ Multimessenger studies (p, ν, GW, γ) and Cosmic ray physics
- ✓ Particle physics with atmospheric muons and neutrinos
- ✓ Tau neutrinos
- ✓ Dark matter
- ✓ Exotics
- ✓ Violation of Lorentz invariance



# → THE KM3NeT LAYOUT (ORCA) ←

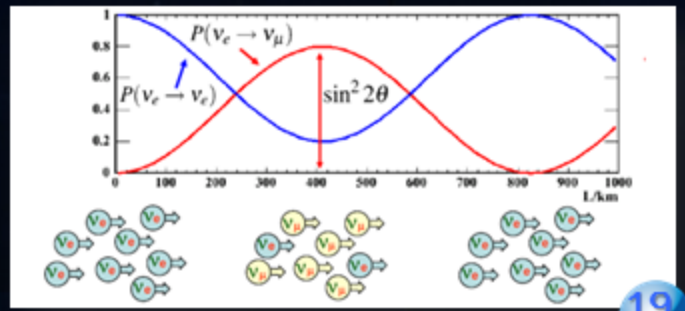



## ORCA (Oscillation Research with Cosmics in the Abyss)

- ✓ Neutrino Mass Hierarchy and Oscillation parameters
- ✓ Tau Appearance
- ✓ Sterile neutrinos and non-standard interactions
- ✓ Dark matter
- ✓ Supernova neutrinos
- ✓ CP violation
- ✓ Tomography with Cosmics



# → THE KM3NeT PHASES ←

## Phase-I:

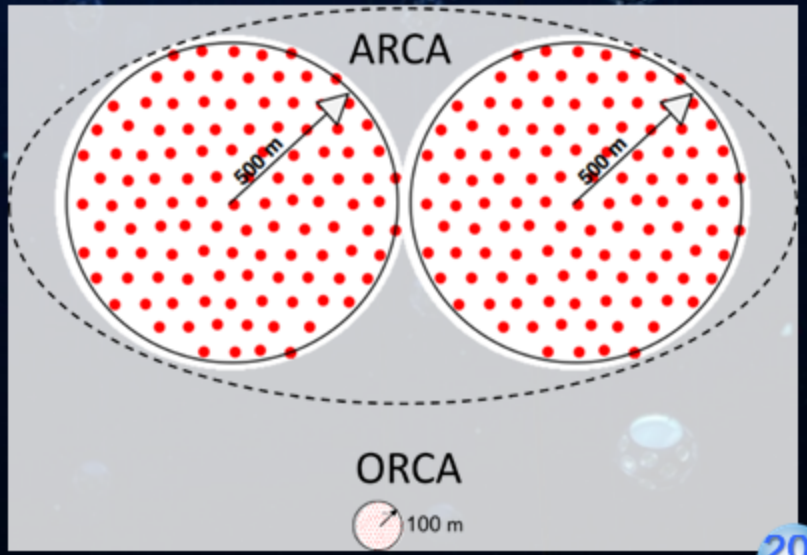
- ✓ Already funded
- ✓ 30 lines or DU's (24 ARCA, 6 ORCA)
- ✓ Proof of feasibility and first science results

## Phase-II (2.0):

| ARCA: | ORCA: |
|---|---|
| Study IC3 Signal | Mass ordering (and DM) |
| 2x115 DU's (=2BB) | 115 DU's (=1BB) |
| Sparce layout | Dense layout |
| DU distance = 90 m | DU distance = 20 m |
| DOM spacing = 36 m | DOM spacing = 9 m |

## Phase-III:

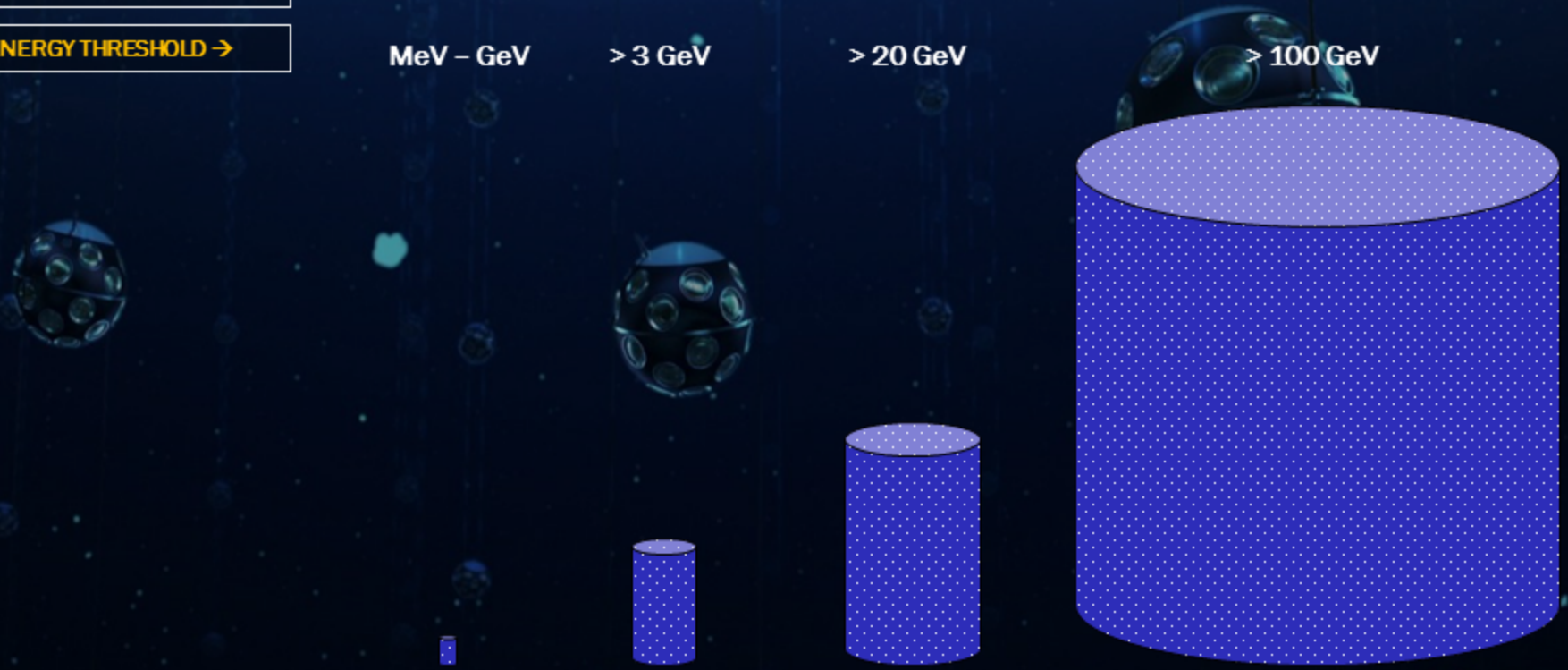
- ✓ 6x115 DU's (ARCA+ORCA) in TOTAL
- ✓ 18 DOM / line; 31 X 3'' PMTs / DOM
- ✓ Neutrino Astronomy including Galactic Sources.



# → THE KM3NeT DETECTOR SIZE ←

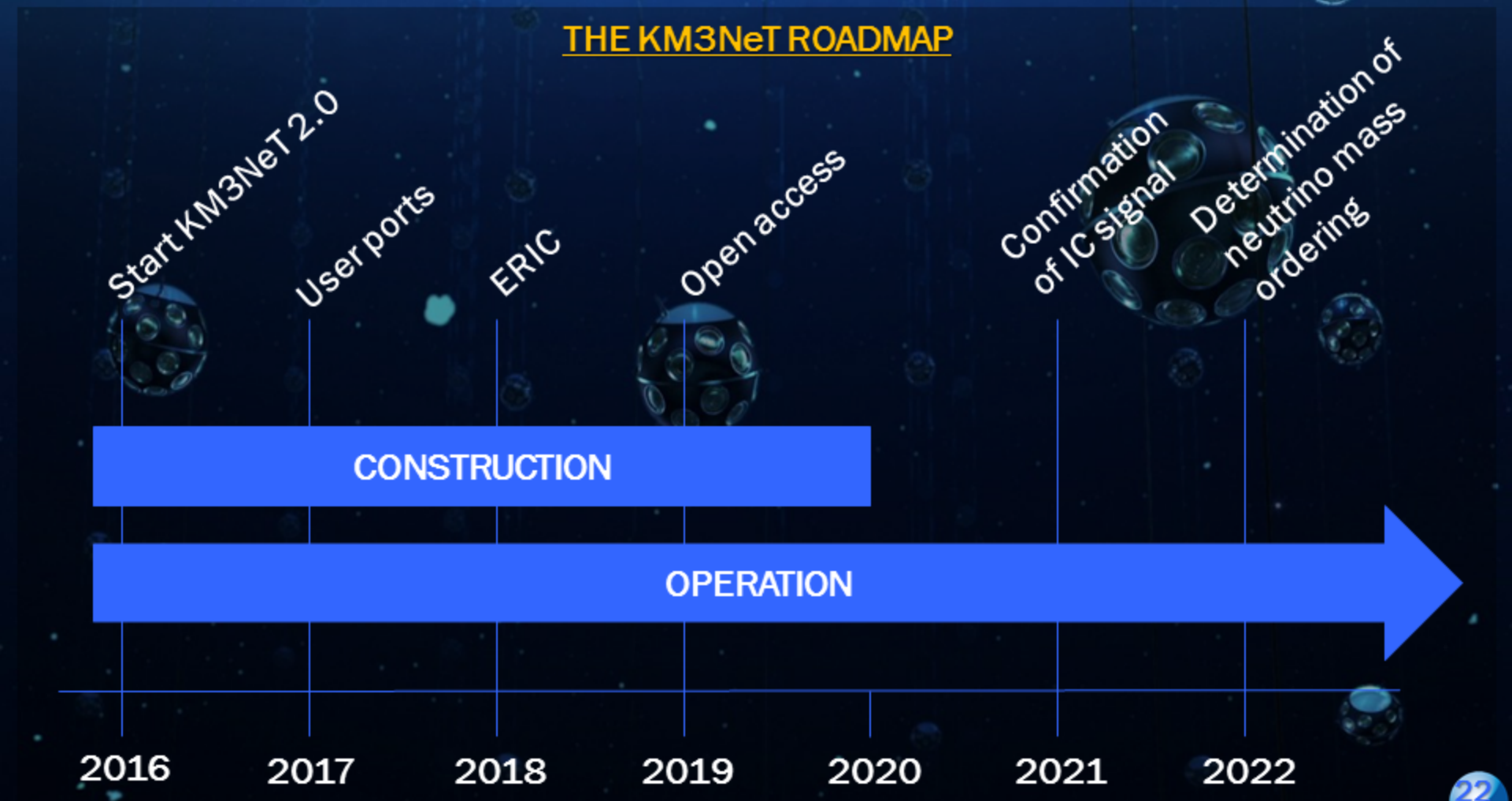


| | | | | |
|---|---|---|---|---|
| INSTRUMENTED VOLUME → | 50 kTon | 8 MTon | 20 MTon | 1 GTon |
| ENERGY THRESHOLD → | MeV – GeV | > 3 GeV | > 20 GeV | > 100 GeV |



| | | | | |
|---|---|---|---|---|
| WATER-BASED CHERENKOV → | Super Kamiokande | ORCA | ANTARES | IceCube, ARCA |

# → KM3NeT TIMELINE ←

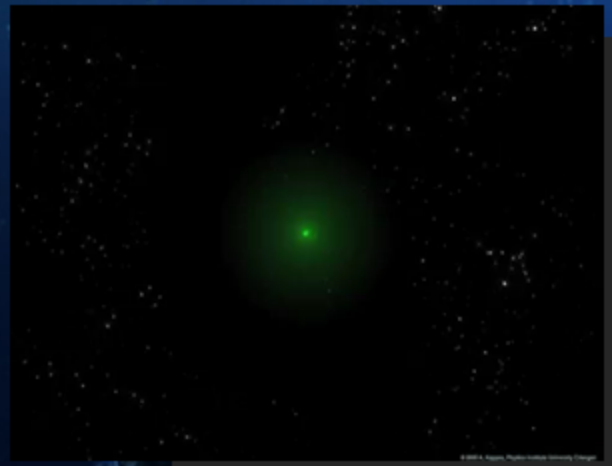


# PART 3

# THE KM3NeT NEUTRINO DETECTOR

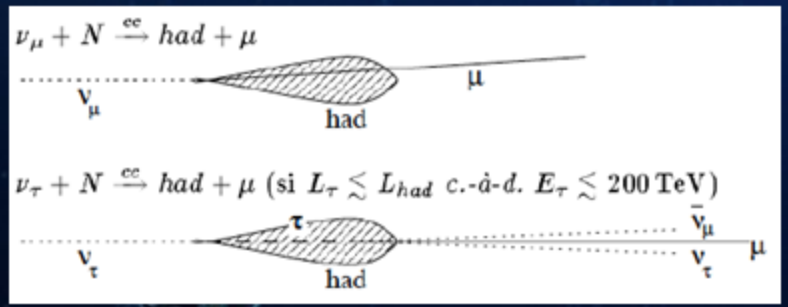
# → NEUTRINO DETECTION PRINCIPLE ←

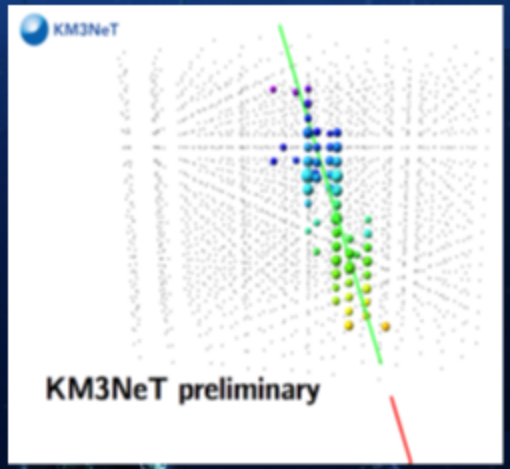




# → EVENT TOPOLOGIES ←

→ **TRACK-LIKE:** contains both a cascade and one track

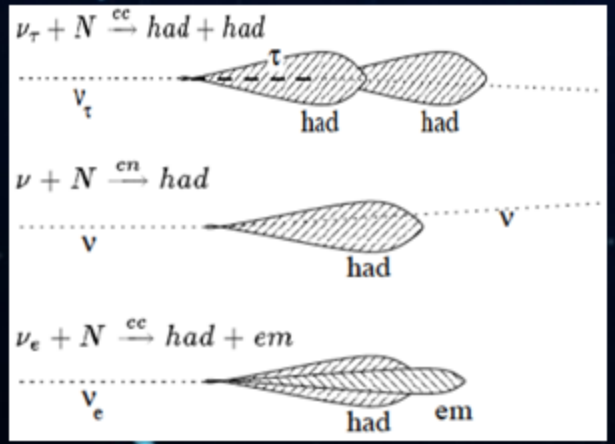


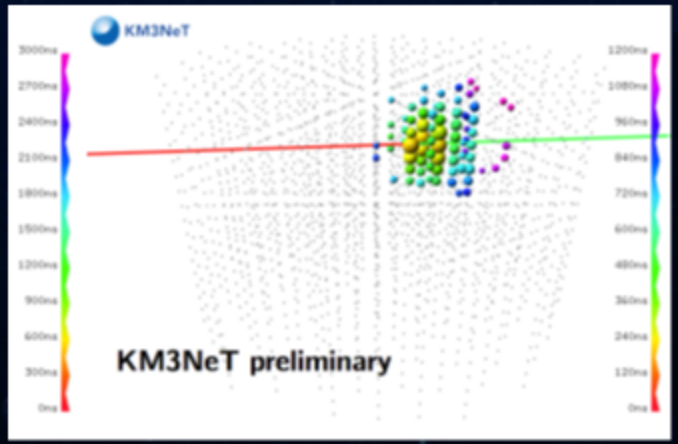




**Muon track from CC muon neutrinos (golden channel for nu astronomy):**

- ✓ Angular resolution 0.5°/0.1° for ice/water.
- ✓ dE/dx resolution factor 2-3.

→ **SHOWER-LIKE:** no track is identified

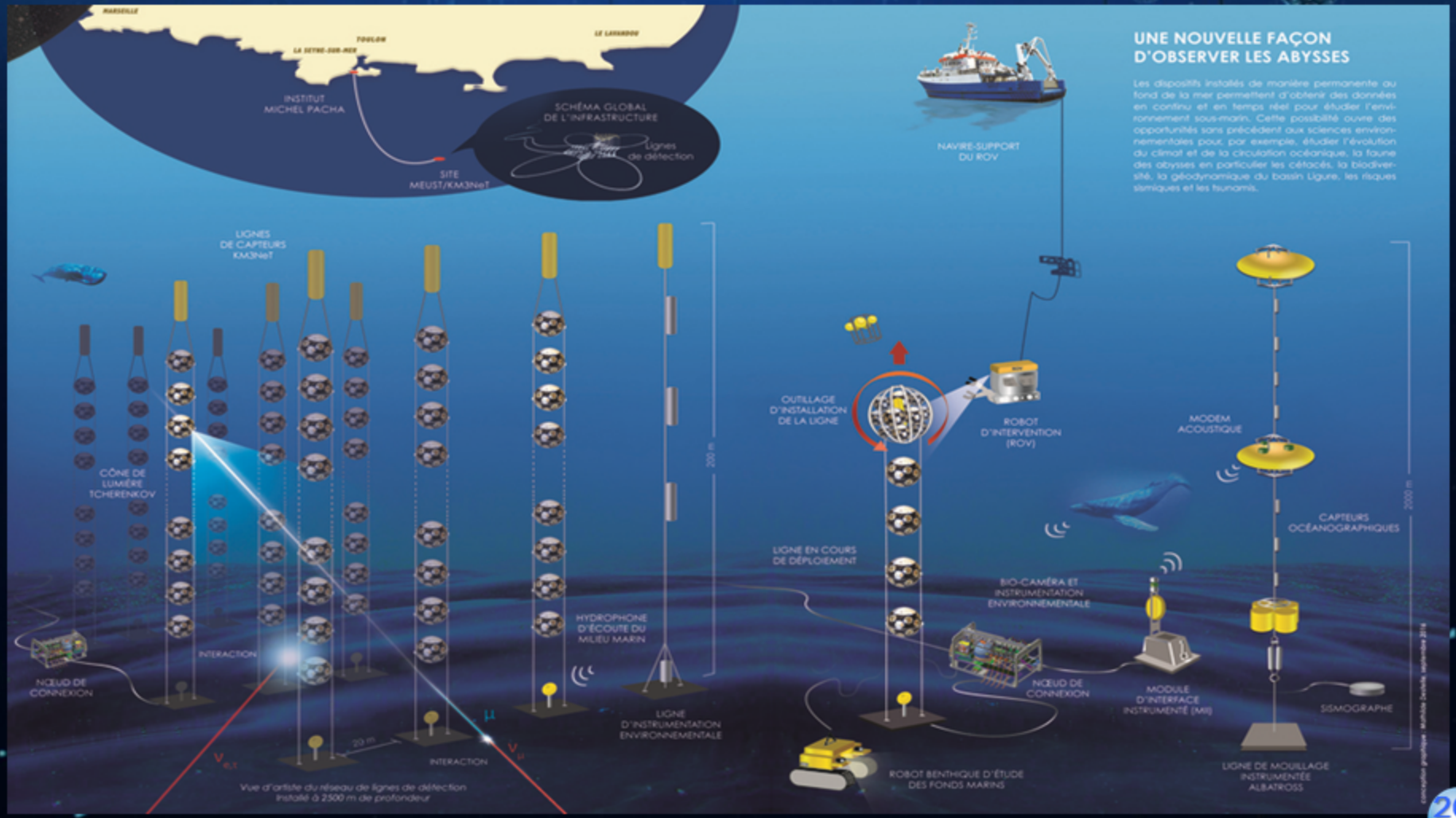



**CC electron/tau and NC all flavour**

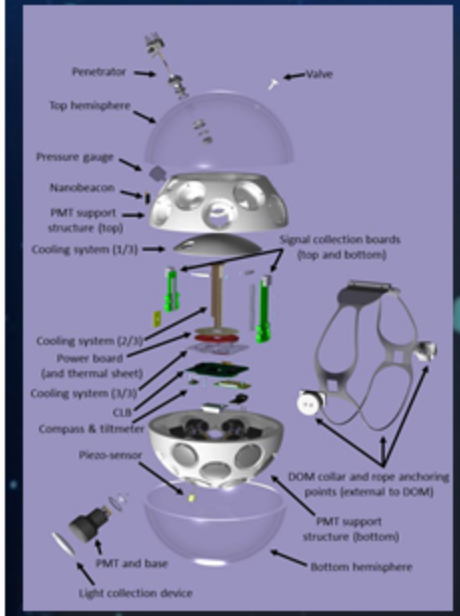
- ✓ 80% of all nu interactions.
- ✓ Angular resolution 10°/1° at 100 TeV for ice/wáter.
- ✓ Energy resolution ~ 10%.

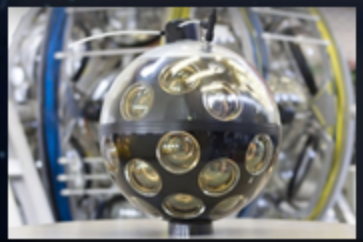
# → THE KM3NeT NEUTRINO DETECTOR ←



# → THE KM3NeT DETECTION UNIT ←

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



→ The DOM, a high pressure resistant glass sphere housing PMTs, acoustic, light devices and associated electronics.

✓ Multi PMT DOMs:
31 X 3" PMTs + expansion cones

✓ Time synchronization:
White rabbit

✓ Optical data transmission:
Base module with DWDM at string anchor

✓ All data to shore concept (optical data transmission):
Filtering/Trigger on shore in computer farm

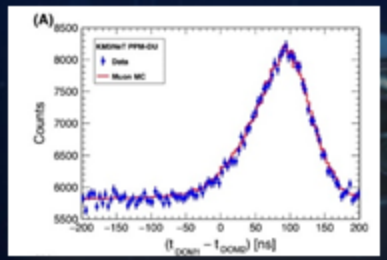
+ nodes for long term high bandwidth connection for Earth and Sea sciences

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

# → FROM VALIDATION TO CONSTRUCTION ←

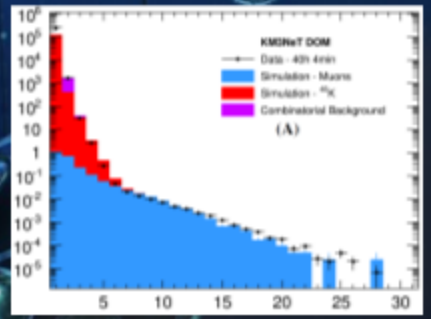


1. Prototype DOM deployed at Antares site April 2013.
2. Prototype DU (three DOMs) deployed in Capo Passero May 2014.

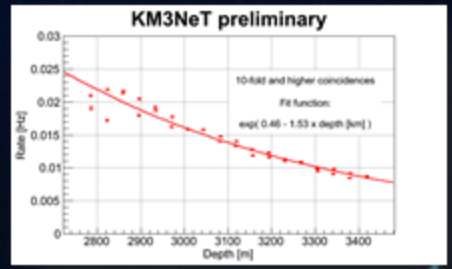



Test of DU structure functionality, Test of intra-DOM and inter-DOM calibration - *Eur. Phys. J. C (2016) 76:54*

3. First ARCA DU deployed in Capo Passero December 2015.

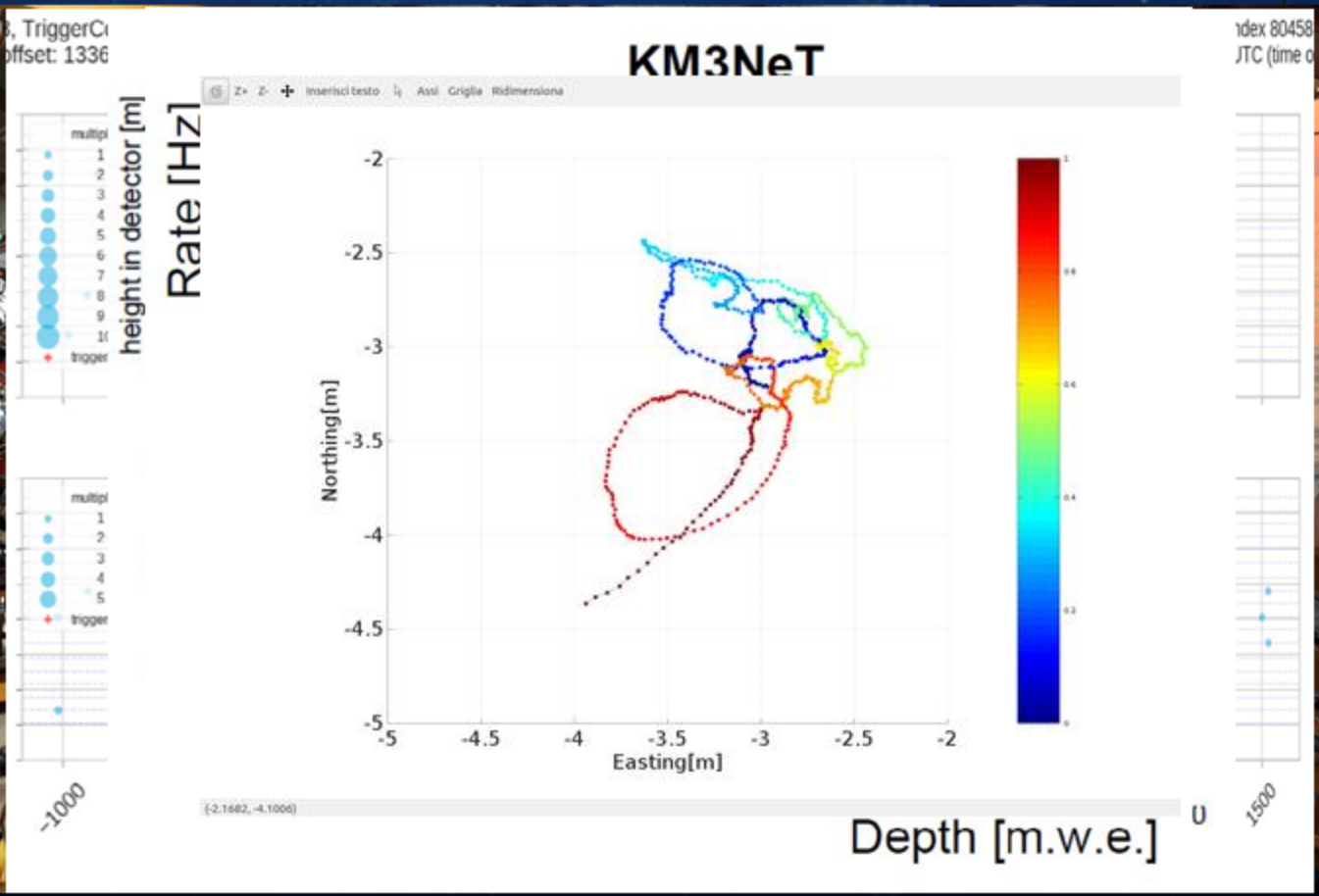


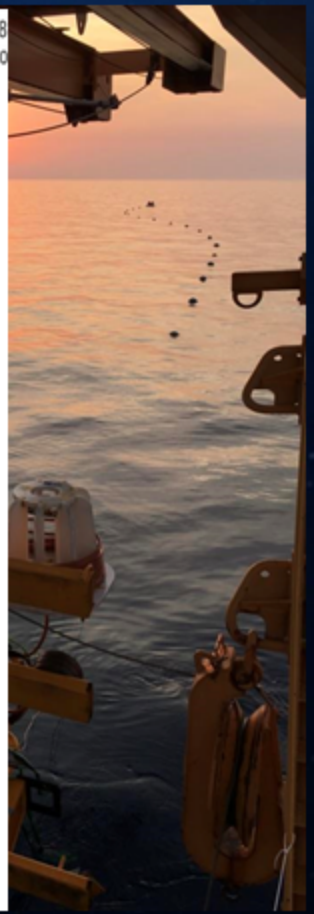

Test of photon counting capabilities and directional sensitivity of DOM. *Eur. Phys. J. C (2014) 74:3056*




Muon flux dependence on depth, DU calibration, Trigger implementation, Track reconstruction + MC comparison ...

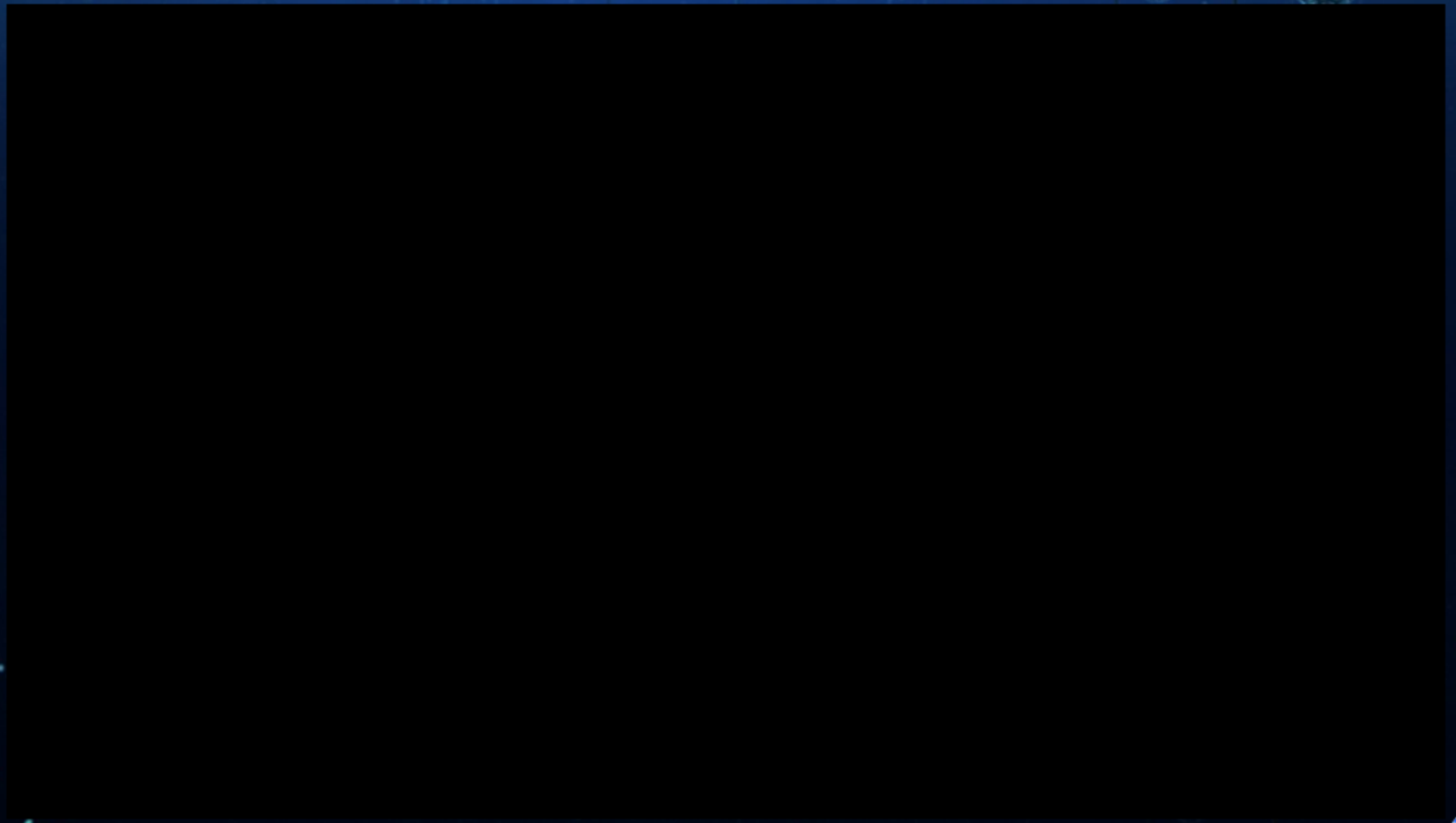
# → KM3NeT ACTUALLY (AUGUST 2019) ←



# → THE KM3NeT NEUTRINO DETECTOR ←






WE WANT YOU!