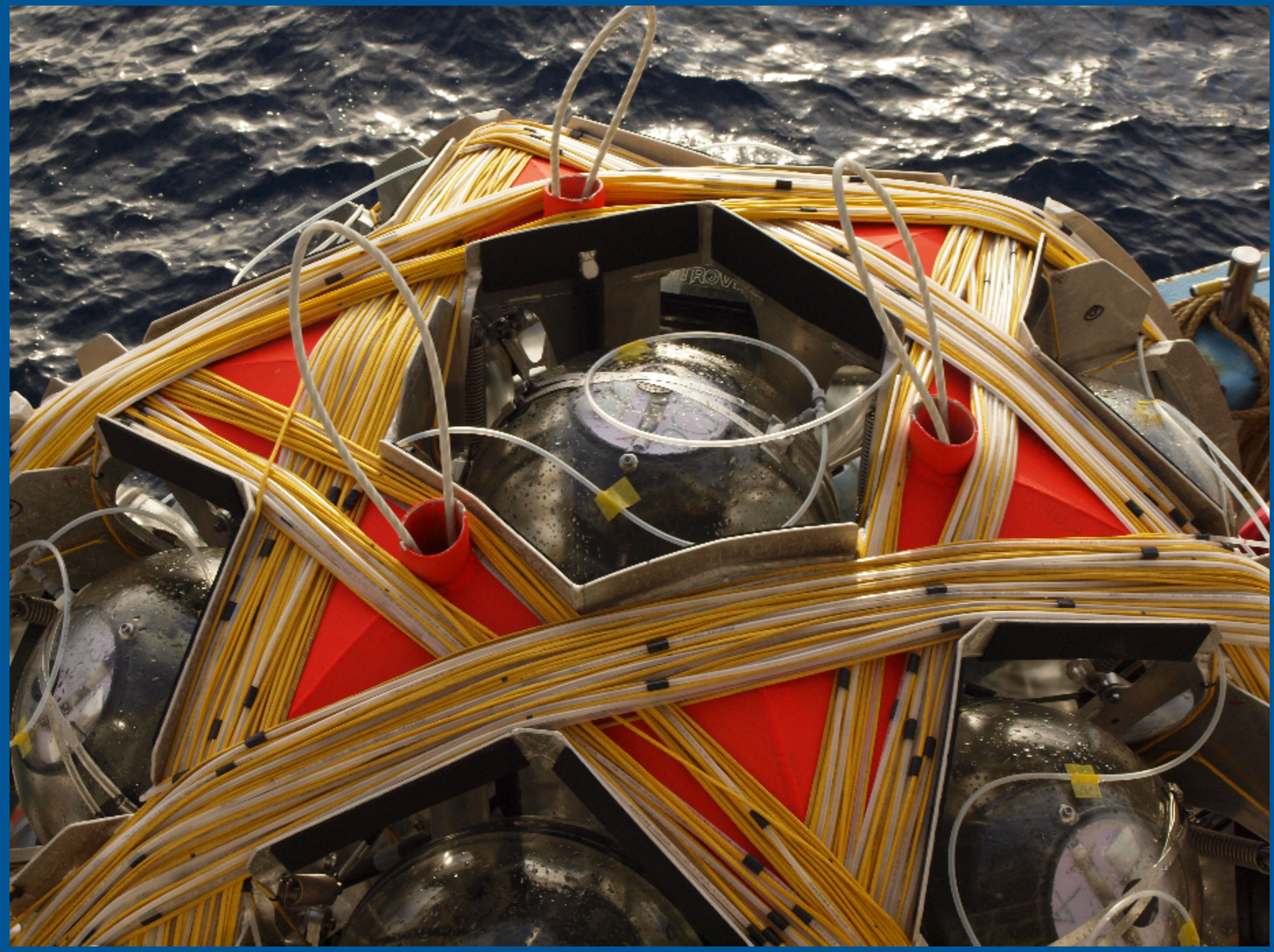
XX International Workshop on Neutrino Telescopes

Venezia 23-27 Ottobre 2023

STATUS AND PERSPECTIVES OF KM3NET

ROSA CONIGLIONE ON BEHALF OF THE KM3NET COLLABORATION
INFN - LABORATORI NAZIONALI DEL SUD (ITALY)



INFN Istituto Nazionale di Fisica Nucleare

KM3NeT

KM3NeT is a research infrastructure hosting two neutrino detectors in the Mediterranean Sea

- KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss)
  - observation of high energy (GeV ÷ PeV) neutrino sources 👉 a telescope offshore Capo Passero (Sicily-Italy) is in construction at a depth of 3500m

- KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss)
  - determination of the neutrino mass hierarchy 👉 a detector offshore Toulon (France) able to detect neutrinos of tens of GeV is in construction at a depth of 2500m

1 collaboration 1 technology 👉 2 detectors

THE HIGH ENERGY NEUTRINO DETECTORS

P-ONE
R&D phase

KM3NeT/ORCA
In construction (14%)
8Mton

ANTARES
(dismantled)
0.01 km³

KM3NeT/ARCA
In construction (12%)
1km³

Baikal-GVD
In construction
1km³

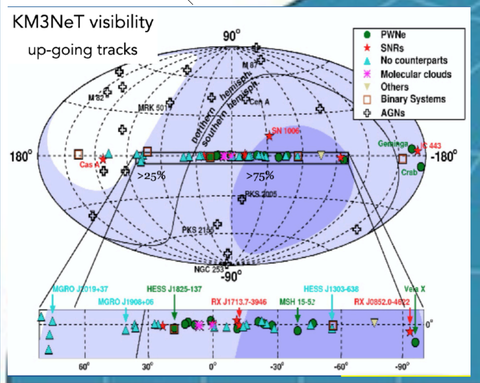
R&D phase
TRIDENT
~8 km³

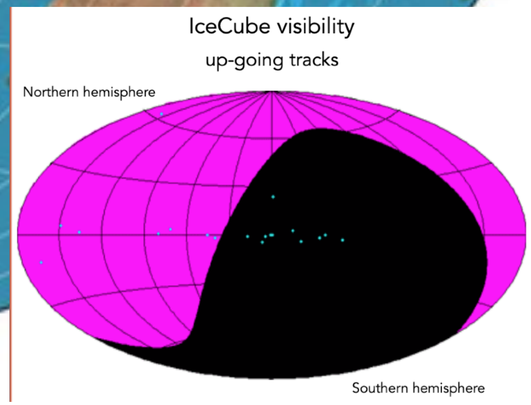
IceCube-Gen2
Planned
~8 km³

IceCube
1 km³

In China also:

- HUNT ~30 km³ in Lake Baikal or the South China Sea http://hunt.ihep.ac.cn/
- NEON ~1 km³ in the South China Sea https://pos.sissa.it/444/1017/pdf

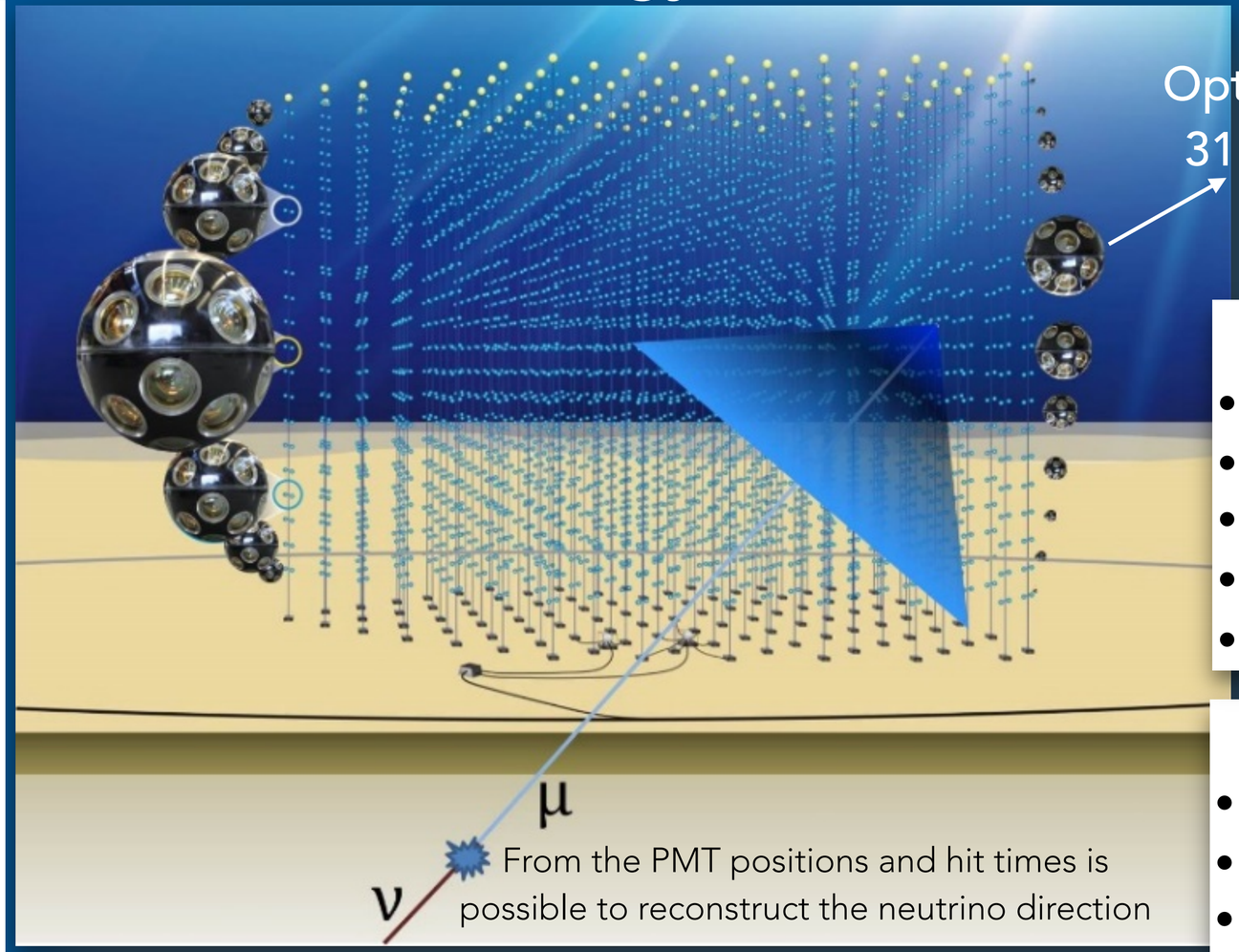




Aitoff Projection

THE KM3NET DETECTORS

Same technology for the two detectors

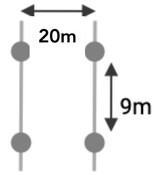


Optical sensor (DOM)
31 PMTs of 3 inches

From the PMT positions and hit times is possible to reconstruct the neutrino direction

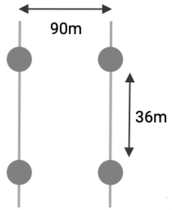
Detection Unit (DU)

ORCA



- Depth ~2500 m
- One block of 115 Detection Units
- Average distance between Detection Units ~20 m
- Average vertical distance between DOMs ~9 m
- **≈8 Mton**

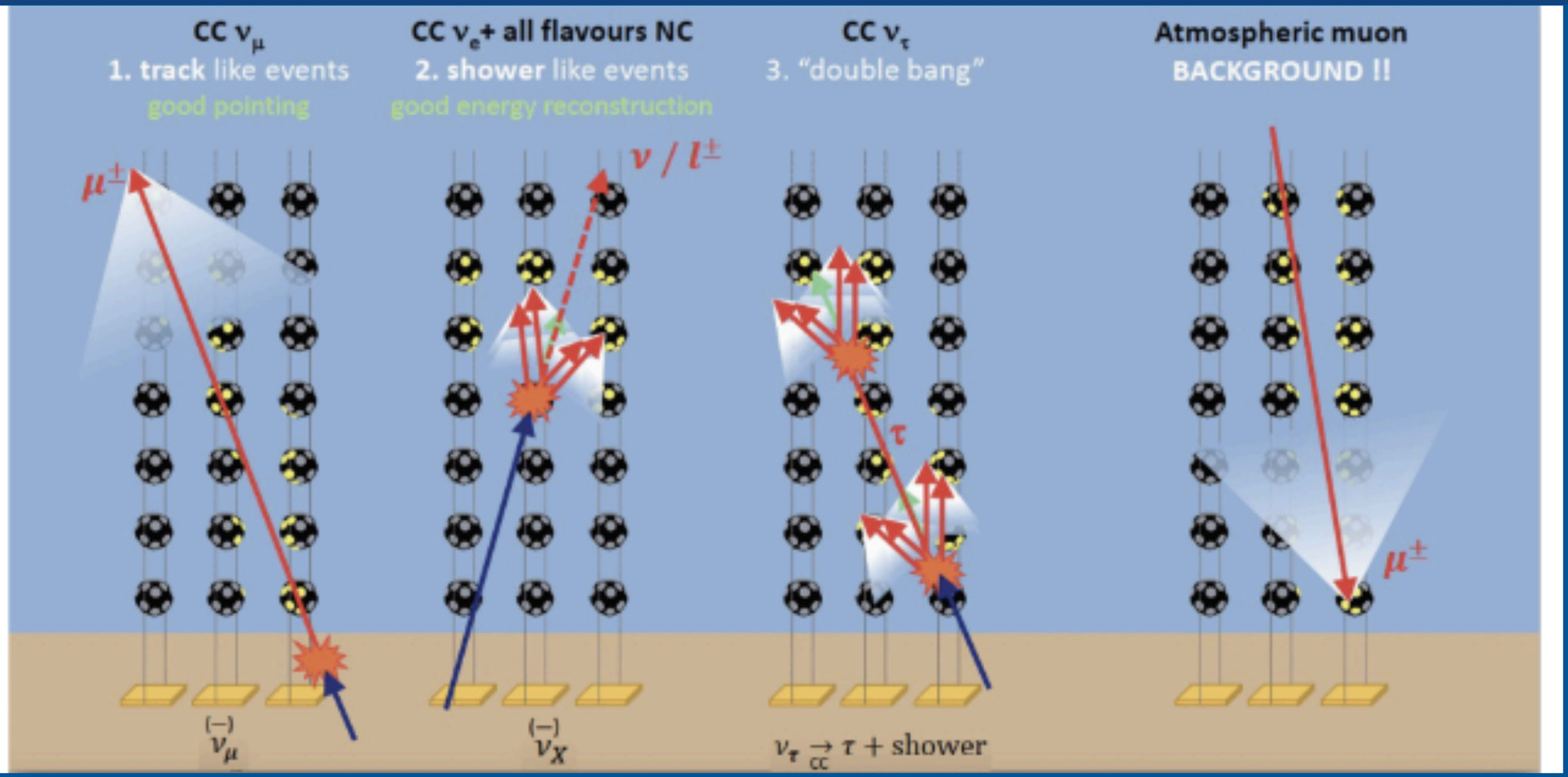
ARCA



- Depth ~3500 m
- Two blocks of 115 Detection Units each
- Average distance between Detection Units ~90 m
- Vertical distance between DOMs ~36 m
- **Volume (0.5 × 2) km³**

Detectors in construction

DETECTION PRINCIPLE

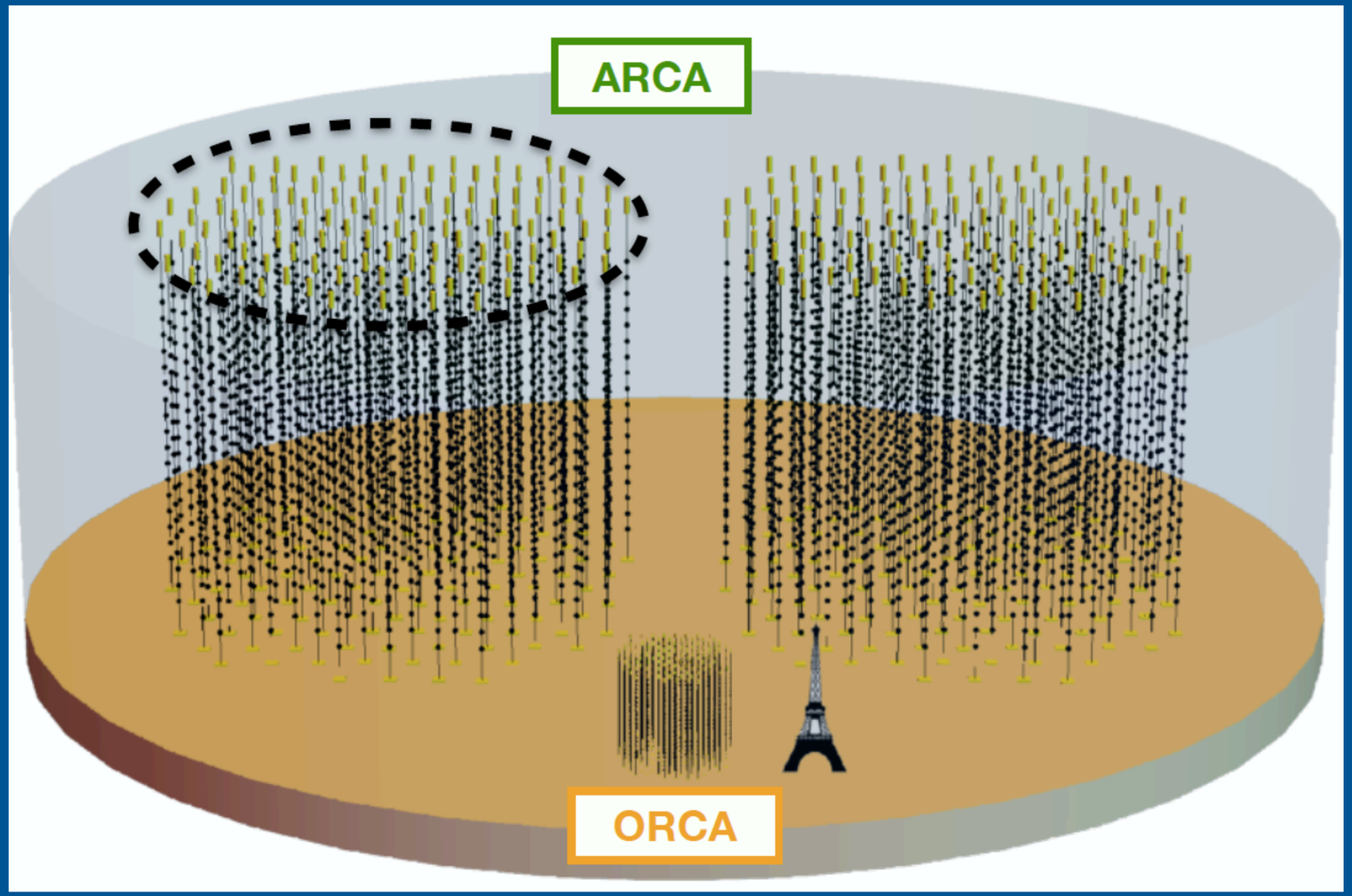


Tracks 👉 @E_ν>100 TeV Ang. res. below 0.1° - Energy res. ~ factor 2

Shower 👉 @E_ν>100 TeV Ang. res. below 2° - Energy res. ~6%

ICRC2023 PoS 1075

THE KM3NET DETECTORS



1 Building Block (BB) 👉115 Detection Units

ARCA 2 BB

ORCA 1BB

Difference in the spatial distance of optical sensors

THE TECHNOLOGY

The basic elements:

- Optical sensors 👉 DOMs (Digital Optical Module)
- Strings 👉 DU (Detection Unit)
- Seafloor network 👉 Electro-optical cables and JBs (Junction Boxes)

The Digital Optical Module

DOM

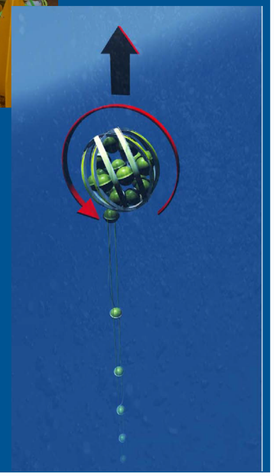
It is a 17” glass sphere containing:

- 31 3” PMTs (photocathode aerea ≃ 3 × 10” PMTs)
- LED and Piezo
- Front-end electronics -> FPGA

Video of the DOM integration

The Detection Unit

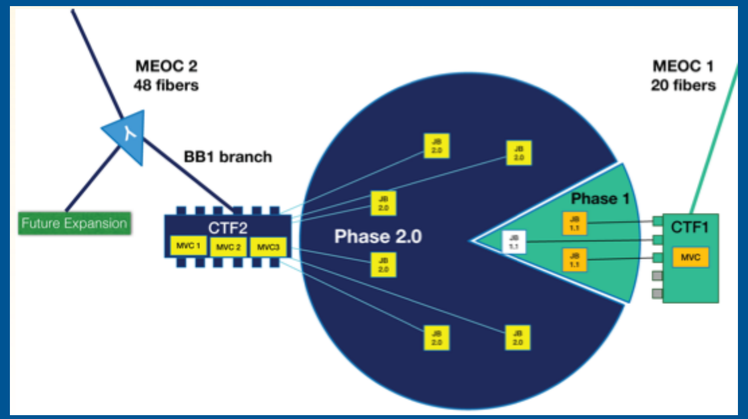
18 DOMs in a DU

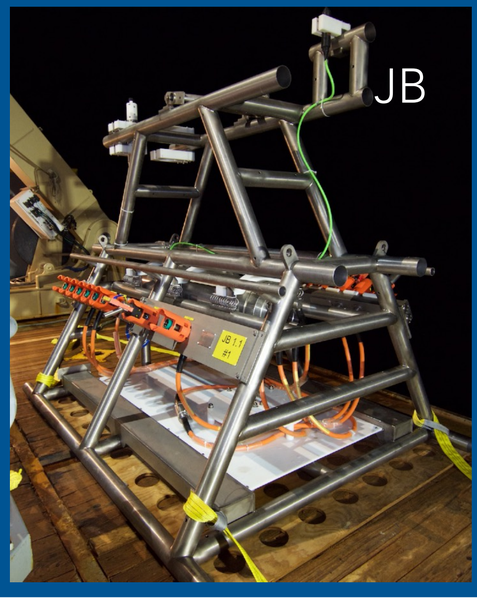


DU

Video of a DU integration

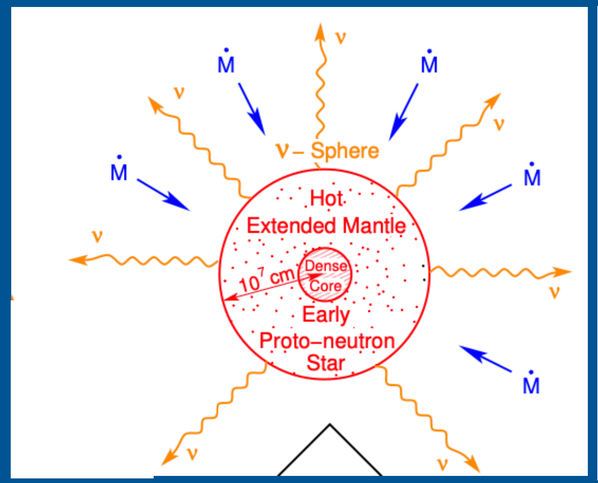
Sea floor network: JB+IL+CTF

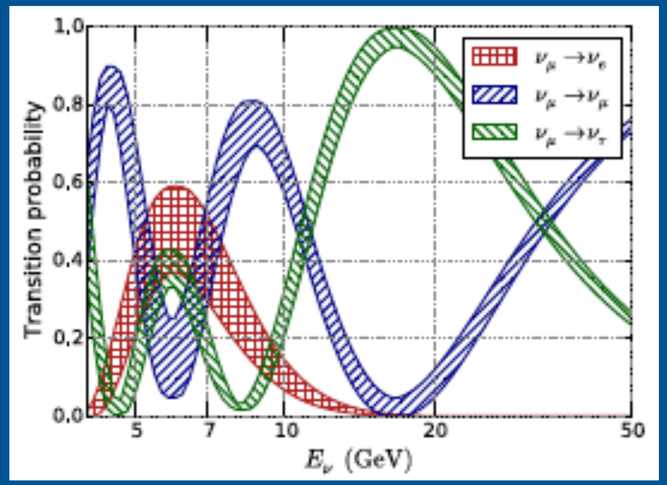


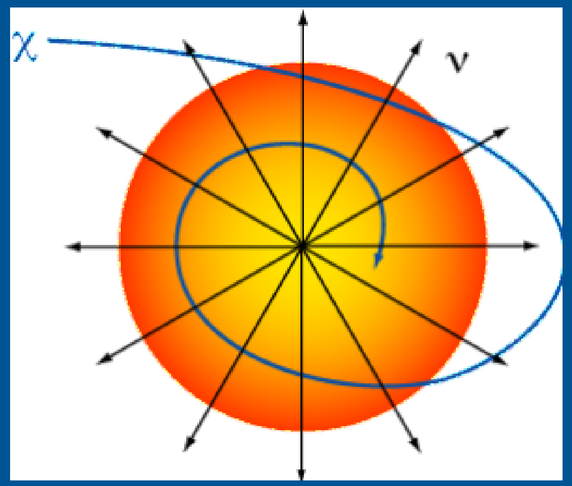


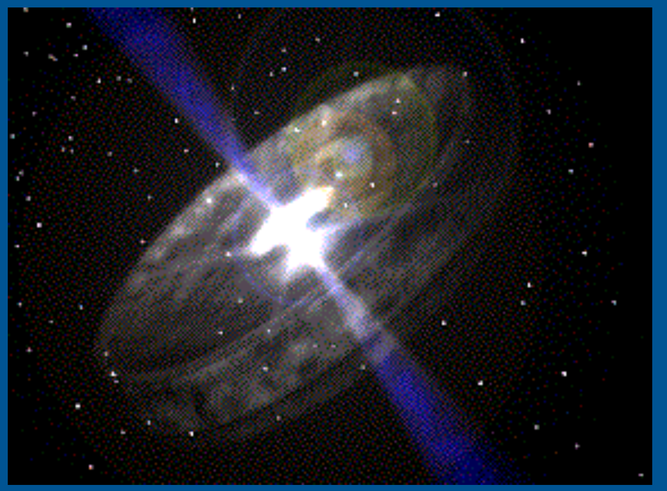
See S. Biagi talk

THE PHYSICS







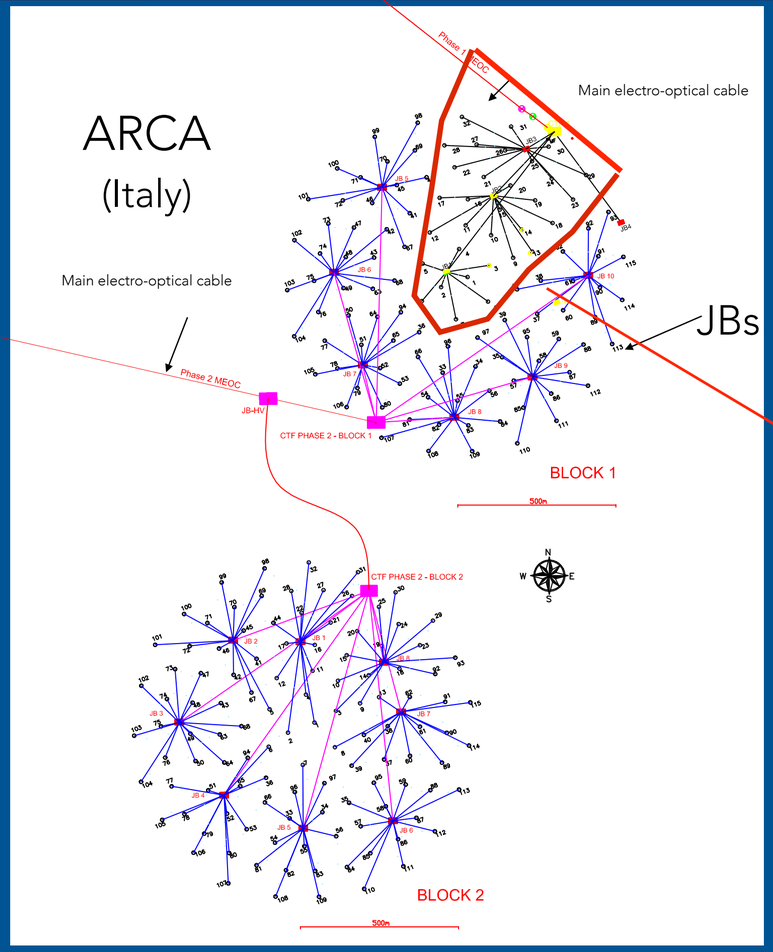


Supernova explosions | Neutrino oscillation | Dark Matter | HE neutrinos
Multi-messenger program

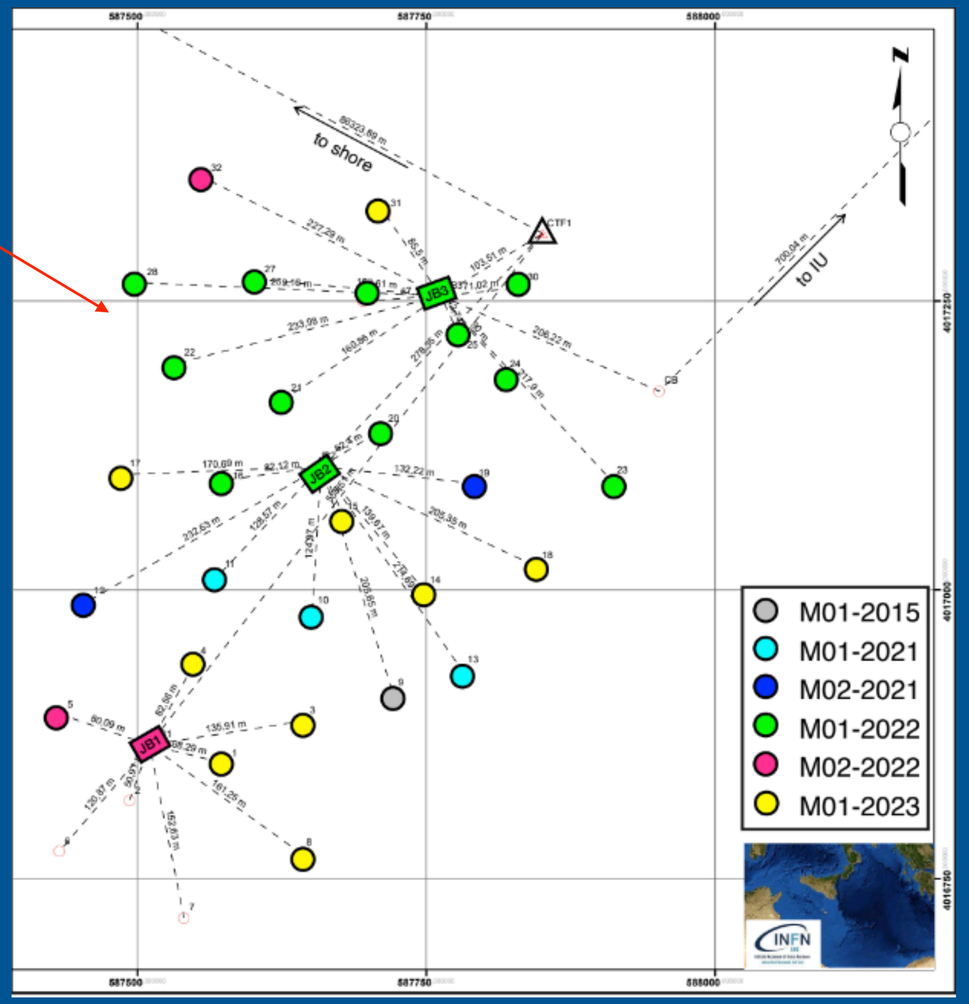
From MeV … …. to PeV

ORCA & ARCA

THE KM3NET/ARCA STATUS



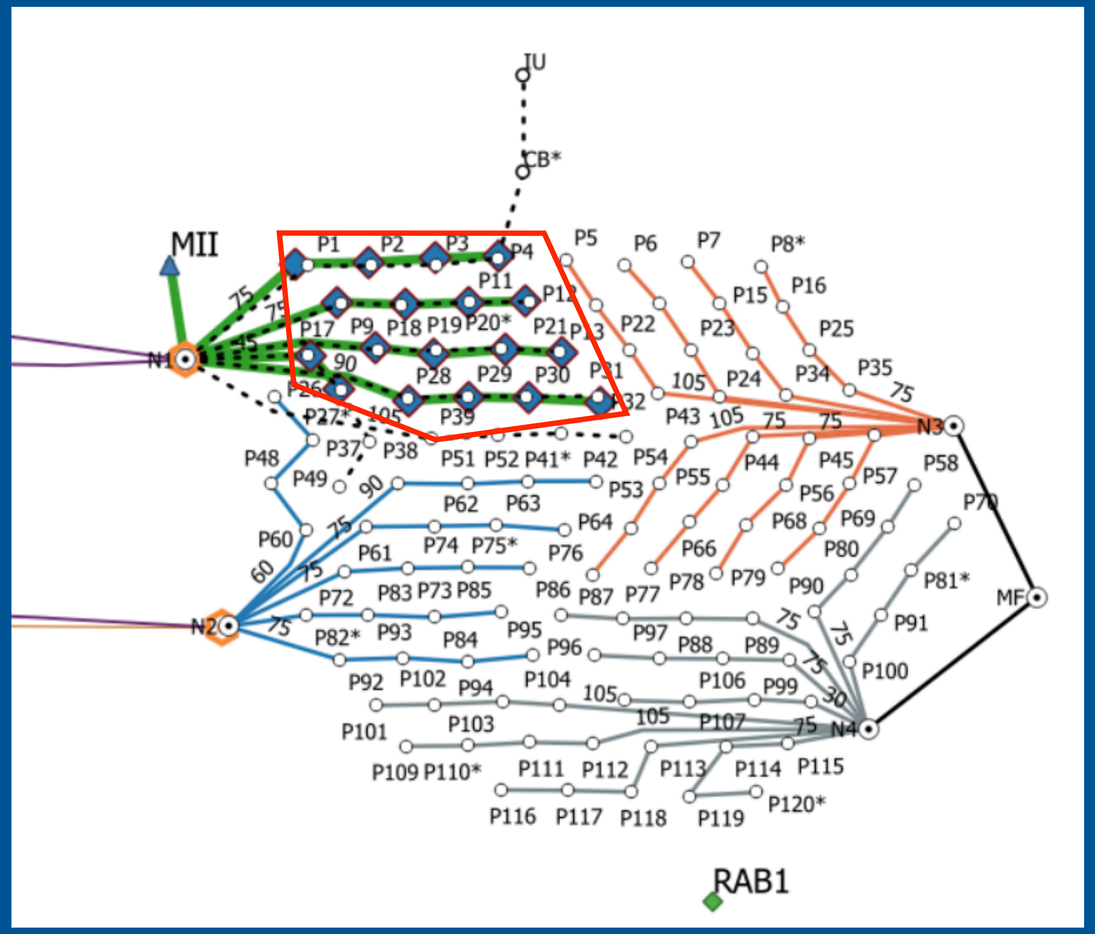
Current status 28 DUs deployed
+ 3 JB



1-2 sea campaigns per year.
The last one in
September 2023 👉 recovered 2 DUs
not working and deployed 9 DUs
Data taking on-going

THE KM3NET/ORCA STATUS

Current status 18 DUs deployed
16 DUs taking data



Many sea campaigns/year

Next campaigns

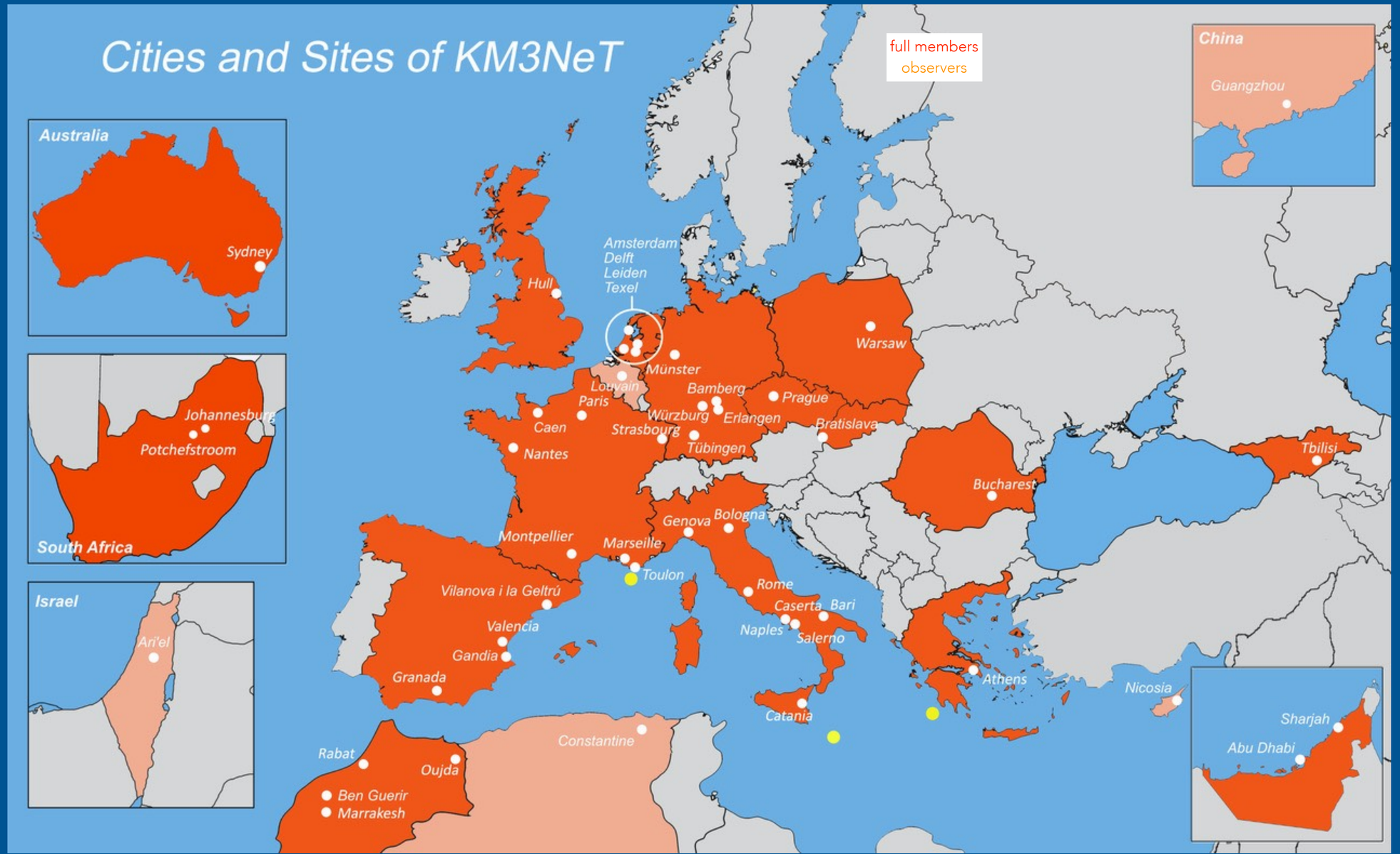
- November 2023 sea campaign 👉 Replace the two not working DUs and add 4 DUs 👉 22 DUs
- December 2023 sea campaign 👉 + 2 DUs 👉 24 DUs

For the end of 2023 completion of first node 👉 24 DUs

THE KM3NET COLLABORATION

60 institutes in 20 countries

Harvard University (USA) just joined



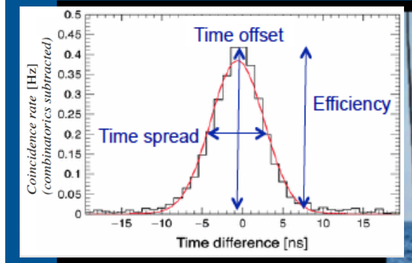
DETECTOR CALIBRATIONS

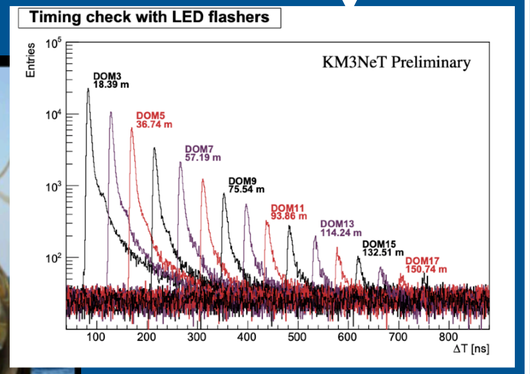
See G. Riccobene talk

Time calibration

Time offsets:

- Intra DOM PMT time offset 👉 K40
- Inter DOM time offset 👉 LED beacon
- Inter Line time offset 👉 White Rabbit based + laser beacon





ICRC2023 PoS 1067

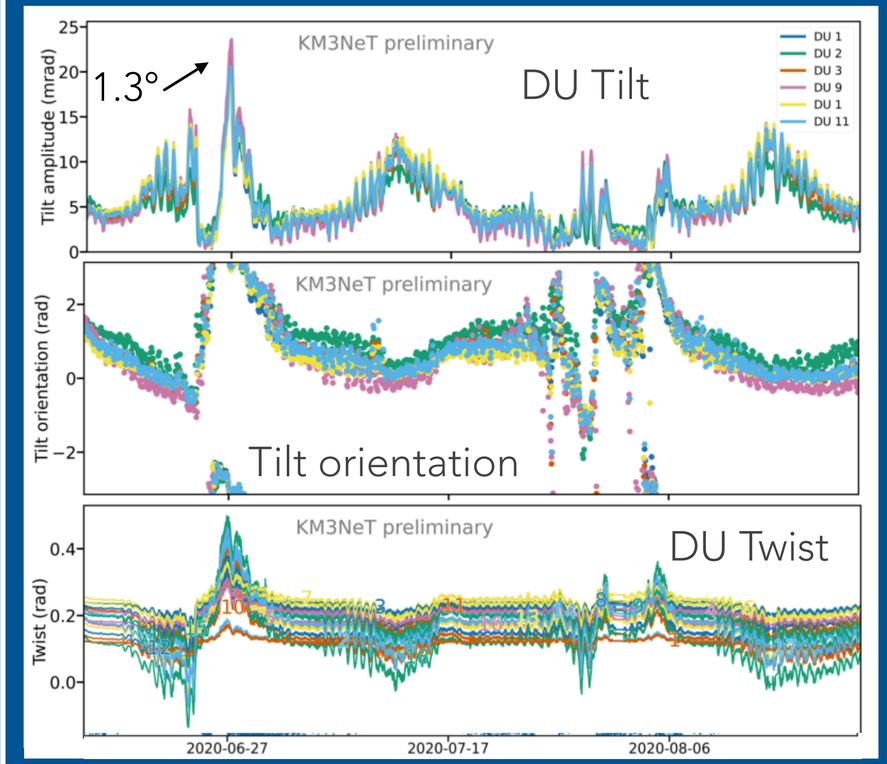
From ^{40}K also PMT efficiency and time spread

Positioning

Based on the acoustic positioning system

Receivers are located in each DOM (Piezo-electric acoustic sensors)
Emitters are located in autonomous tripod and JB and some DUs (Beacon)

ORCA 4 months — A measurement each 10 minutes

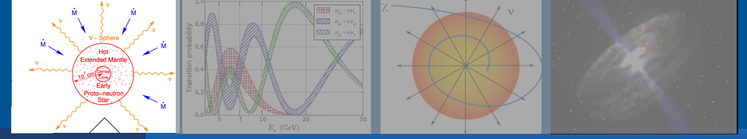


Dynamic positioning taken into account in the event reconstruction

DU Twist with compasses

ICRC2023 PoS 1033

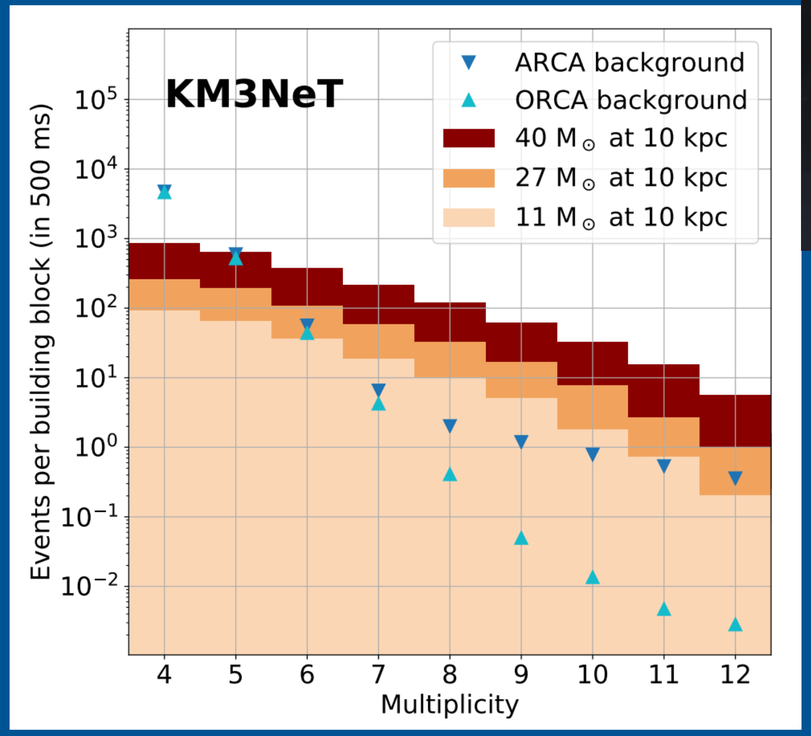
Time, position and orientation verified also with atmospheric muons ICRC2023 PoS 218



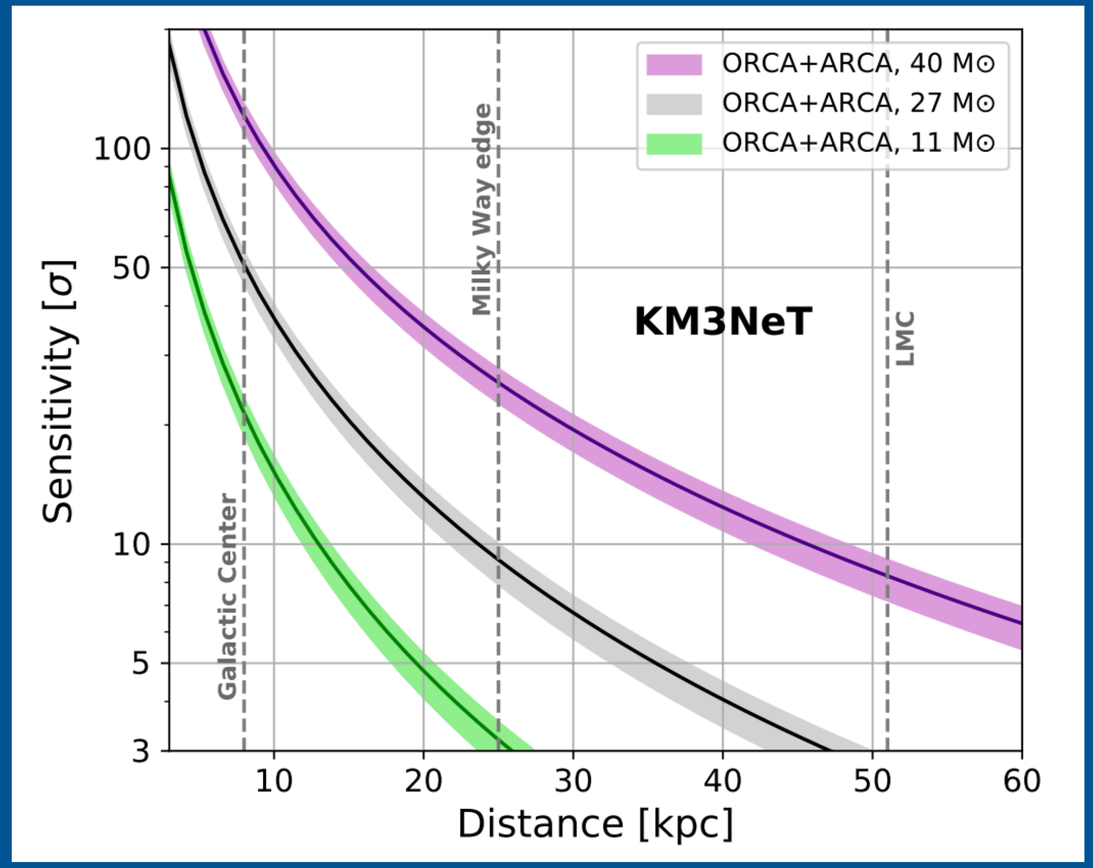
SUPERNOVA EXPLOSION

Eur. Phys. J. C 81, 445 (2021)

PMT multiplicity plot



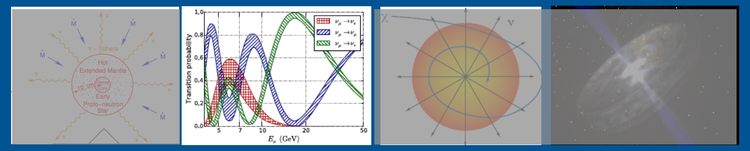
ARCA230+ORCA115



>5σ for ARCA+ORCA for 27$M_\odot$ at a distance <35kpc

Prediction for
ARCA29+ORCA18
@ICRC2023 PoS 1406

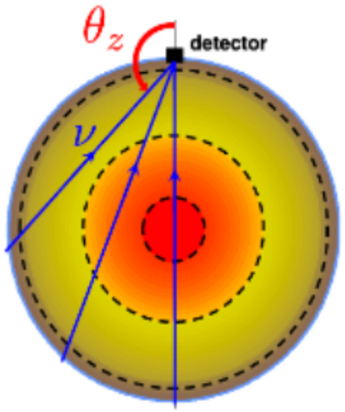
An on-line alert system for CCSN already implemented
Integrated in SNEWS



NEUTRINO OSCILLATION WITH ORCA

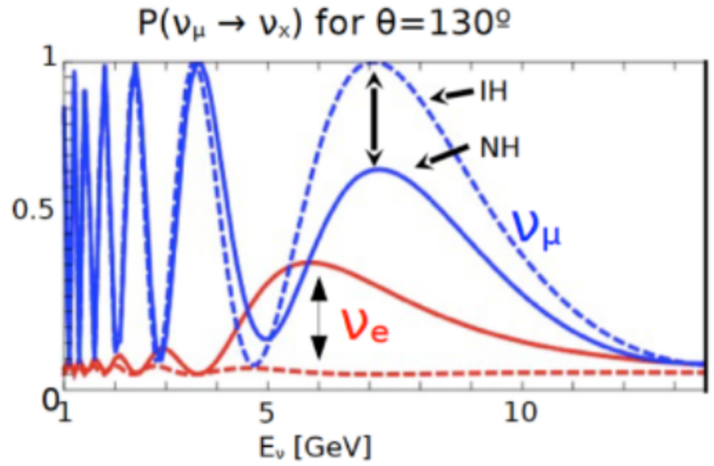
ICRC2023 PoS 996

Baseline from 50 to 12800 km

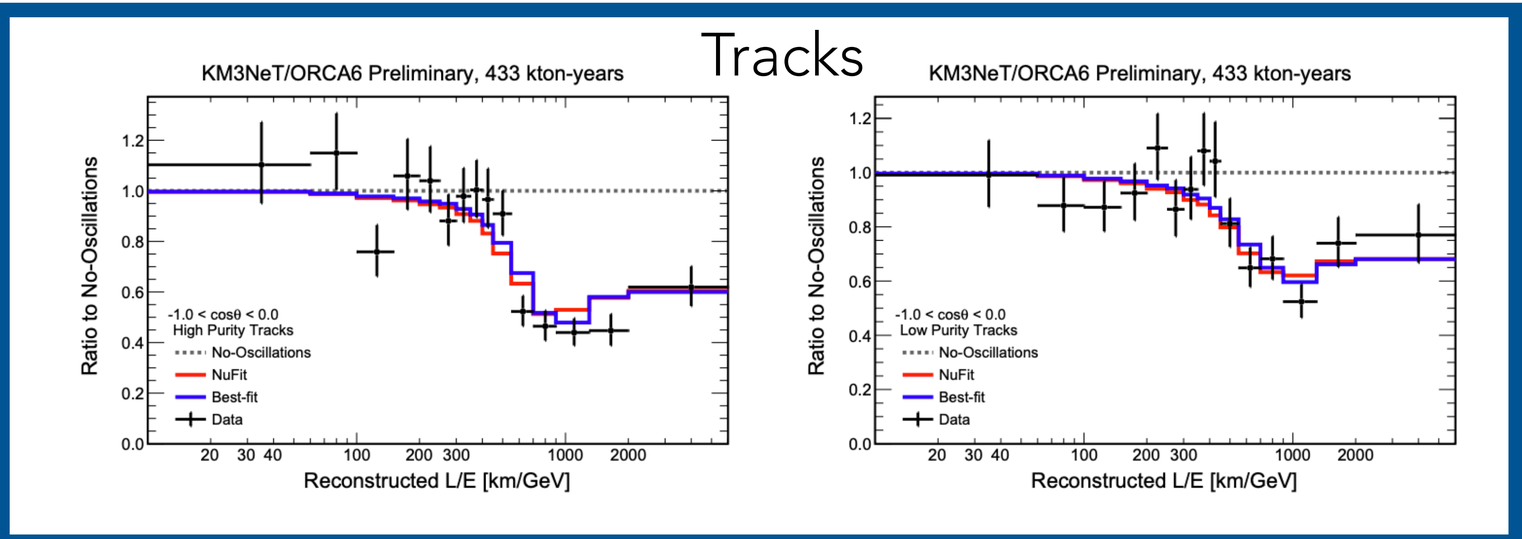


Neutrino Mass Ordering measuring atmospheric neutrinos crossing the Earth

Energy range of interest 5-15 GeV

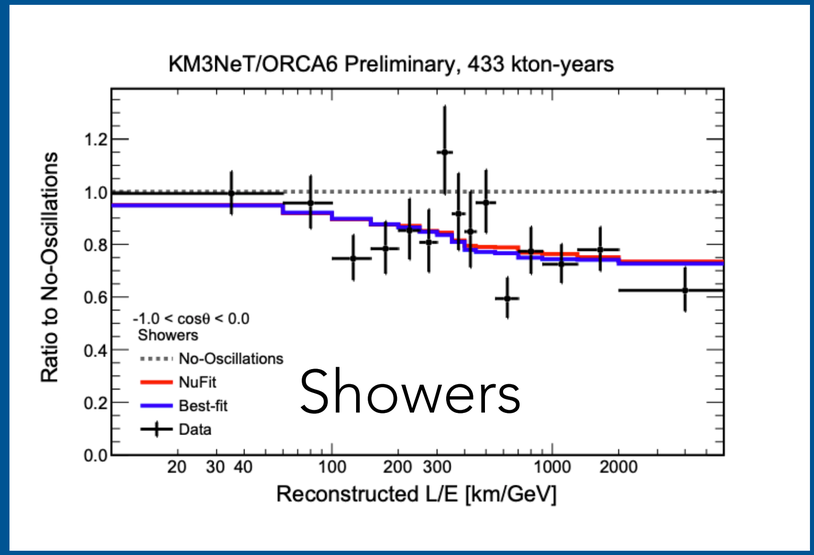


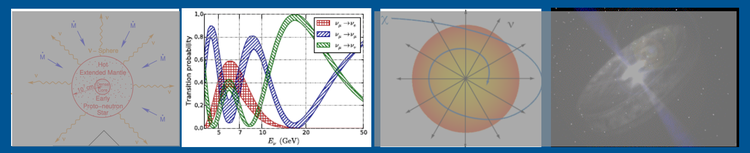
Tracks



ORCA6 data

Oscillation clearly seen both in track and shower events

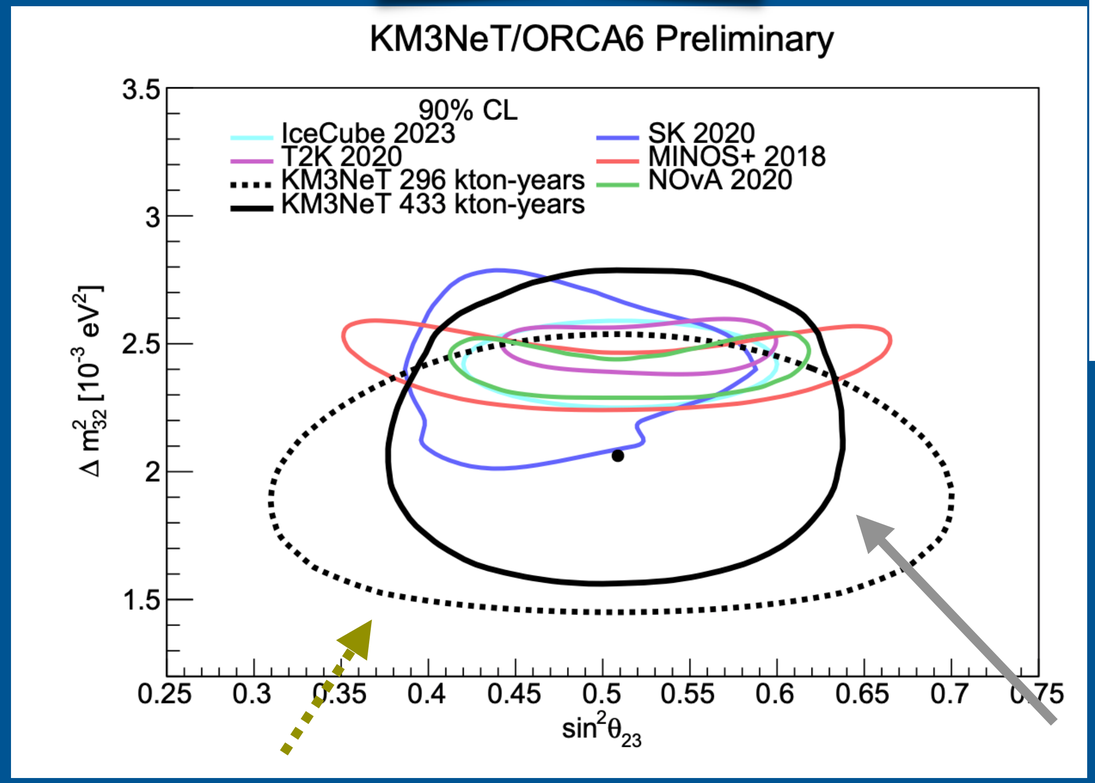


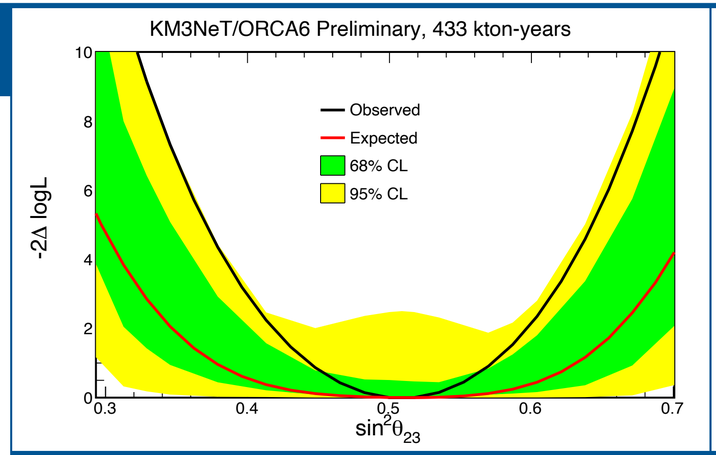


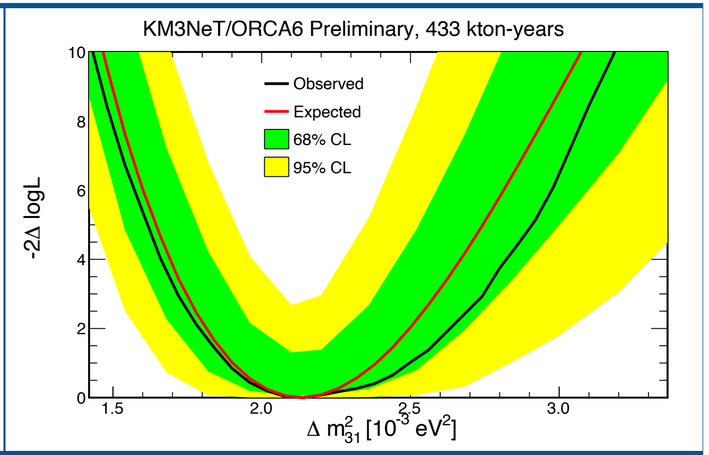
NEUTRINO OSCILLATION WITH ORCA

ICRC2023 PoS 996

Δm^2_{32} vs $\sin^2\theta_{23}$







ORCA6 DUs 354days

ORCA 6 DUs 510days

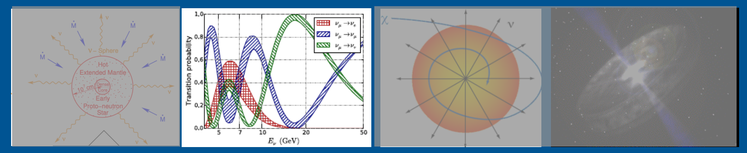
With respect to Neutrino 2022 conference

👇

Increased event sample of a factor 5:

- Better selection track/shower 👉 ICRC2023 PoS 1191
- Added showers
- Livetime + 40%

KM3NeT/ORCA competitive

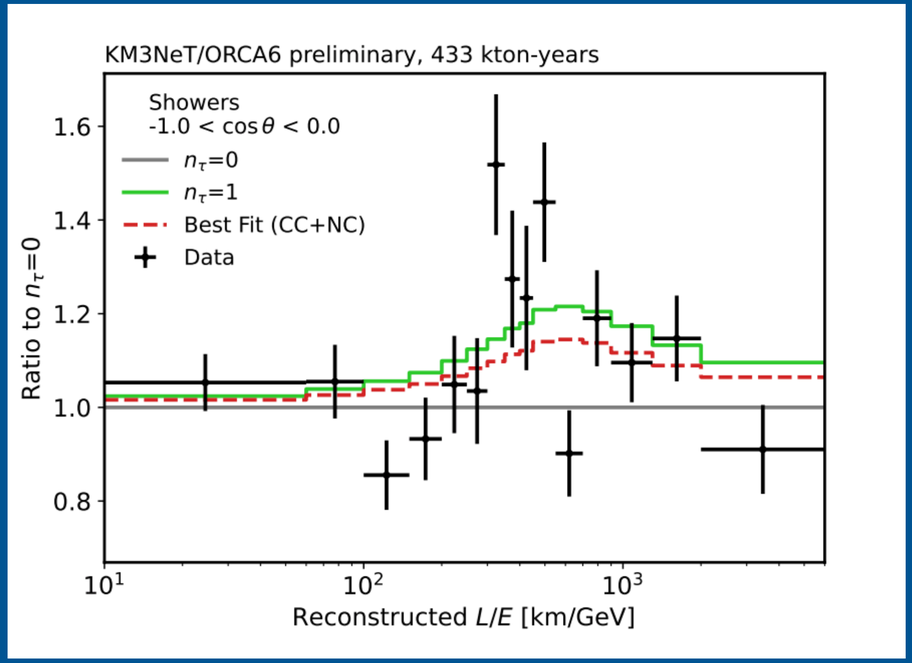


NEUTRINO OSCILLATION WITH ORCA

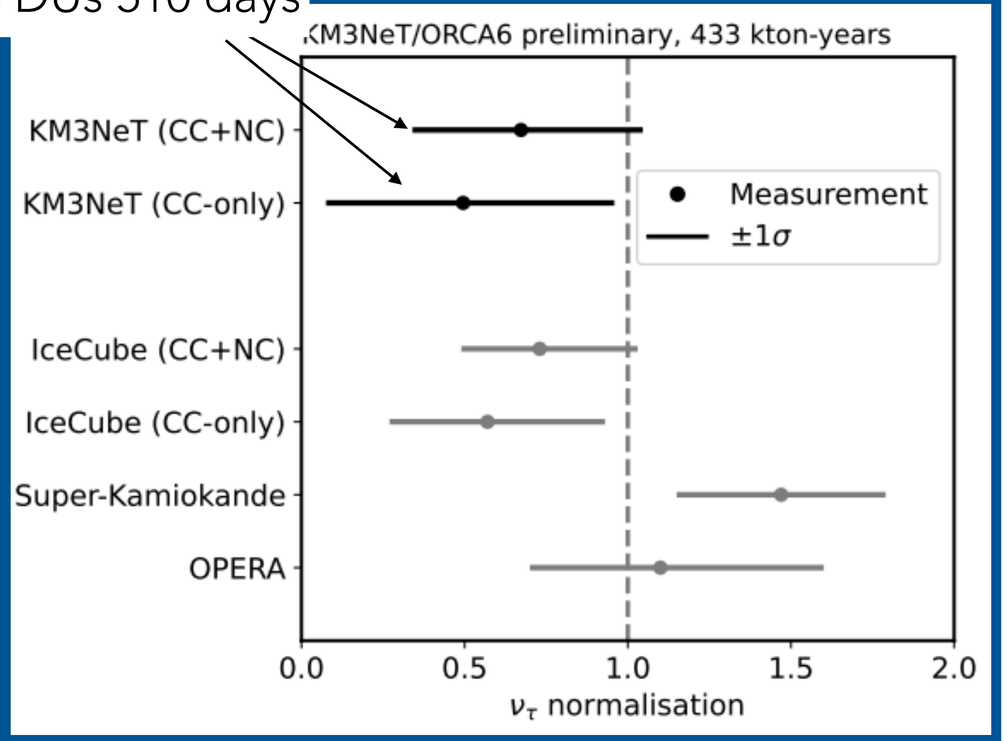
ICRC2023 PoS 1107

ν_τ appearance

ν_μ -> ν_τ 👉 search for a statistical excess of shower-like events



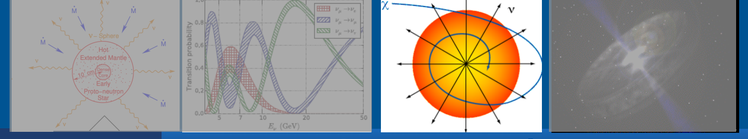
ORCA6 DUs 510 days



Also competitive results in:

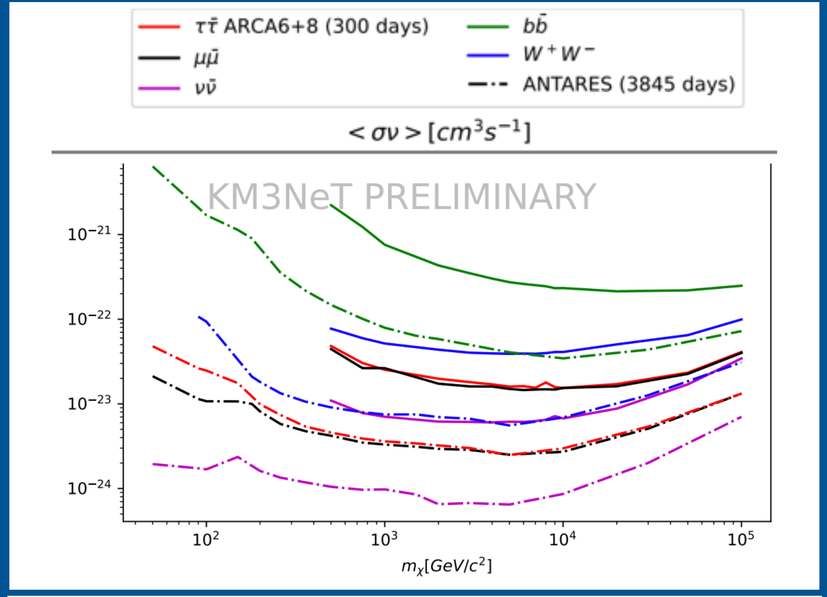
- Non standard interactions 👉 ICRC2023 PoS 998
- Neutrino decay 👉 ICRC2023 PoS 997
- Lorentz invariance violation 👉 ICRC2023 PoS 1086

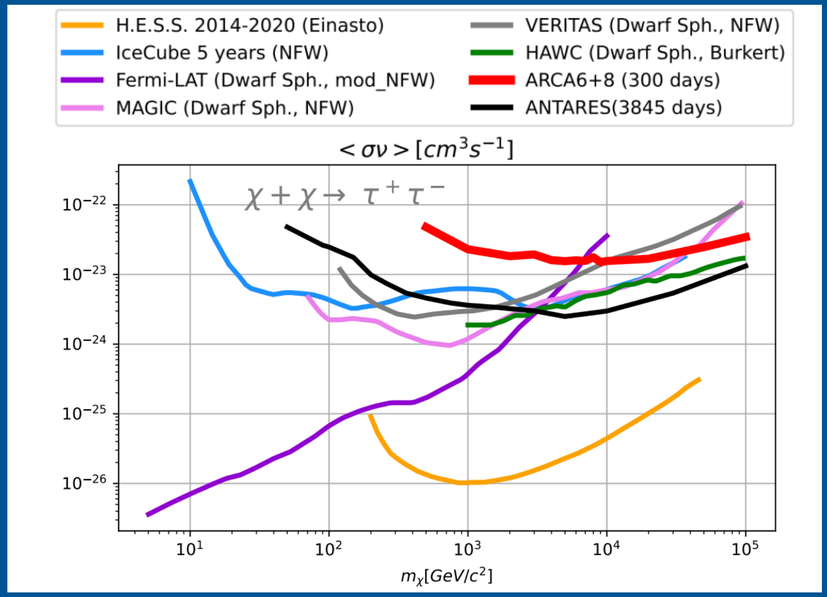
DARK MATTER



From the Galactic Center

ARCA6 & ARCA8 analyzed ICRC2023 PoS 1377

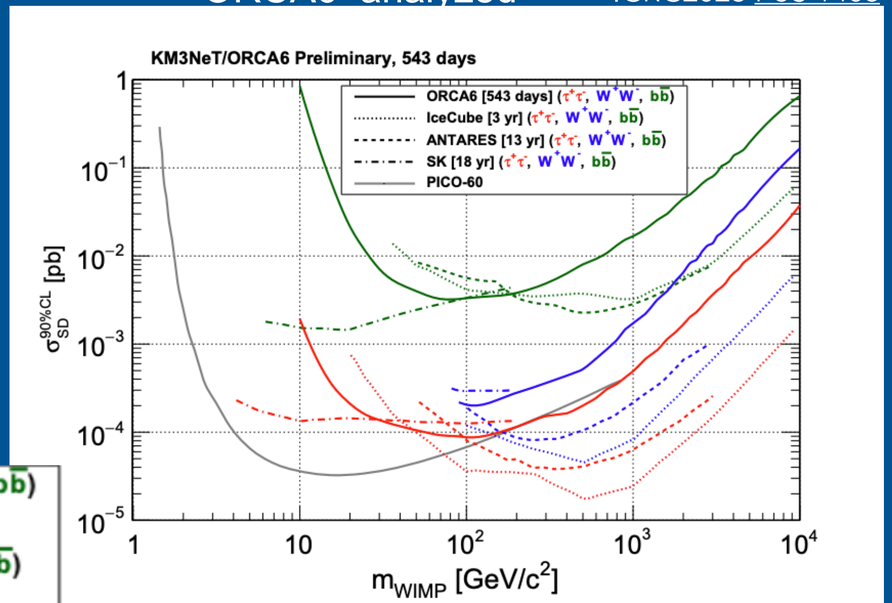


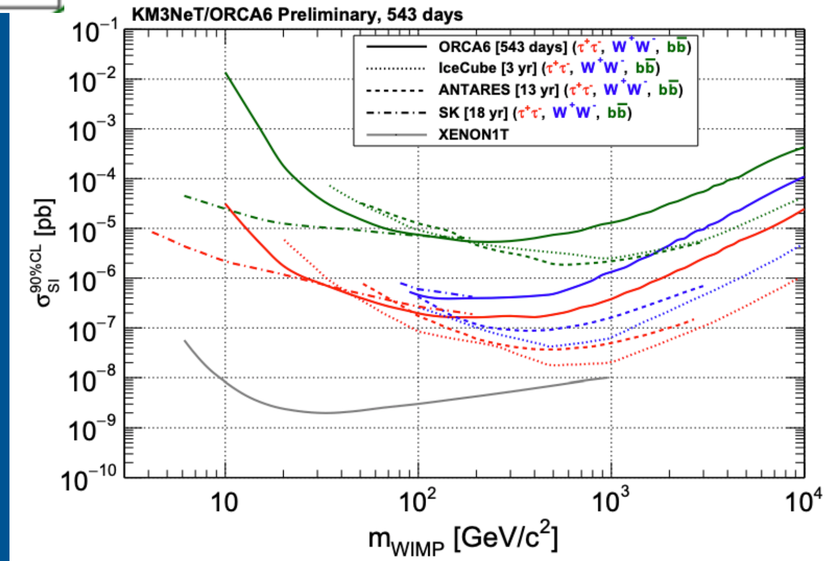


KM3NeT quickly reaching the ANTARES limits

From the sun

ORCA6 analyzed ICRC2023 PoS 1406

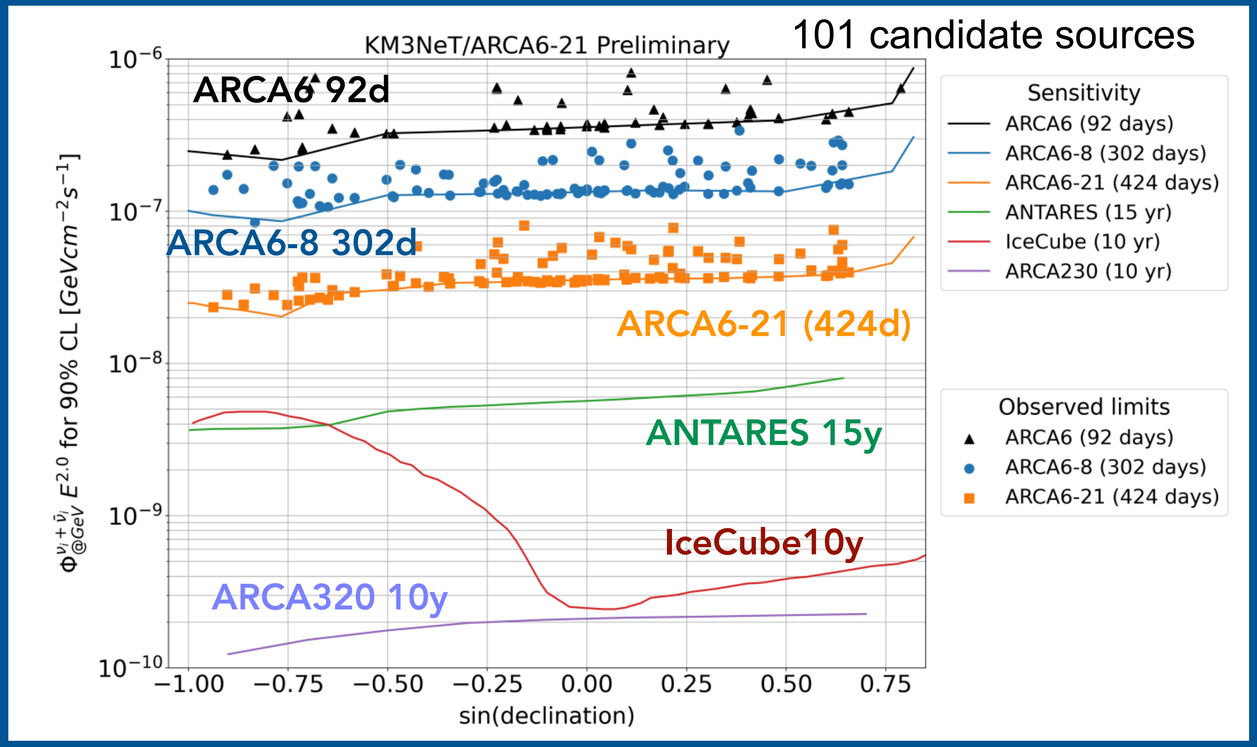




SEARCH FOR POINT-LIKE SOURCES

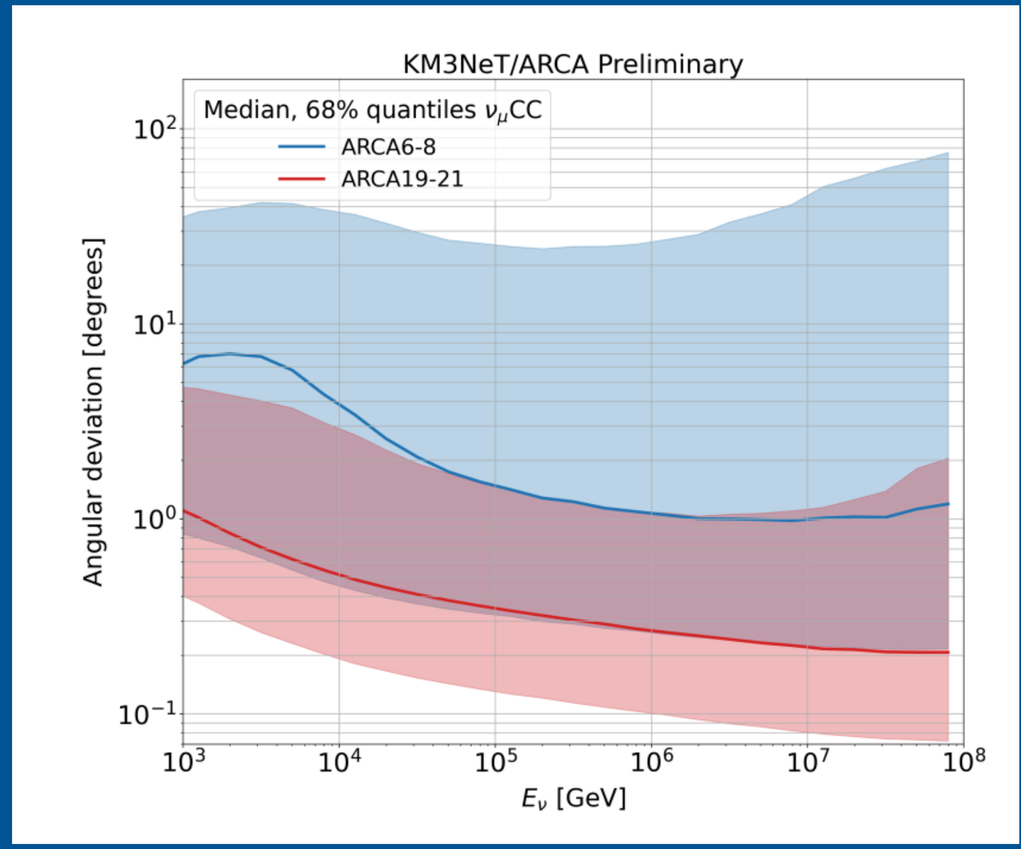
ICRC2023 PoS1018

ARCA6 & ARCA8 & ARCA19 fully analyzed
ARCA21 partially analyzed (until December 2022)



Large improvement in sensitivity is expected. For the next year:
+ 9 months of unprocessed ARCA21 data
+ extended detector (ARCA28 from sept 2023)

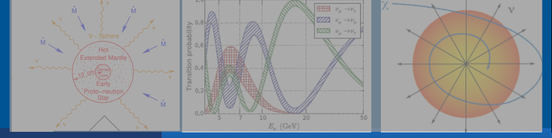
Angular resolution



KM3NeT upper limits are quickly reaching the ANTARES 15yr limits

Improvements also in angular resolution

First results also for joined ARCA-ANTARES point-like searches
ICRC2023 PoS1147
See M. Sanguineti talk



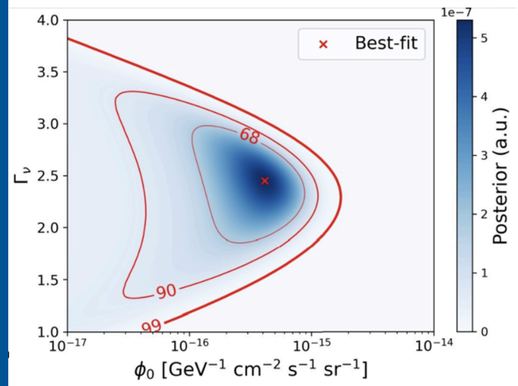
DIFFUSE FROM THE GALACTIC PLANE

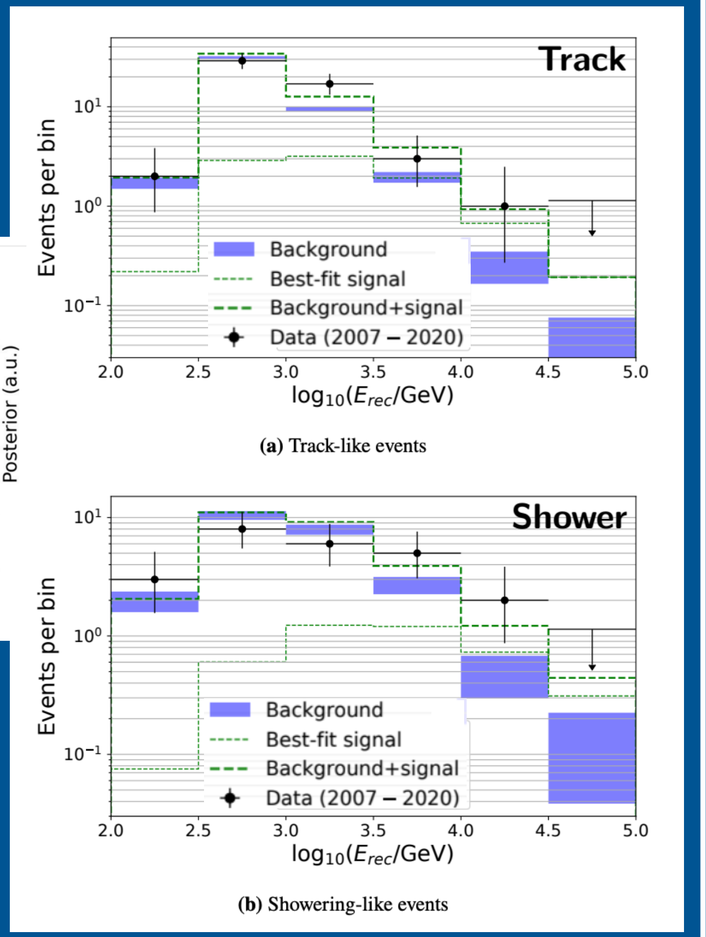
ANTARES 2007-2020 data

Phys. Lett. B 841 (2023), p. 137951

2σ excess in tracks and showers → hint for Galactic signal

ICRC2023 PoS 1103





See talk of C. Poirè for an overview on ANTARES results

For E_ν>1 TeV

21 track events observed -> 11.7±0.6 back. expected

13 shower events observed -> (11.2±0.9 back. expected

ARCA6 & ARCA8 & ARCA19 fully analyzed

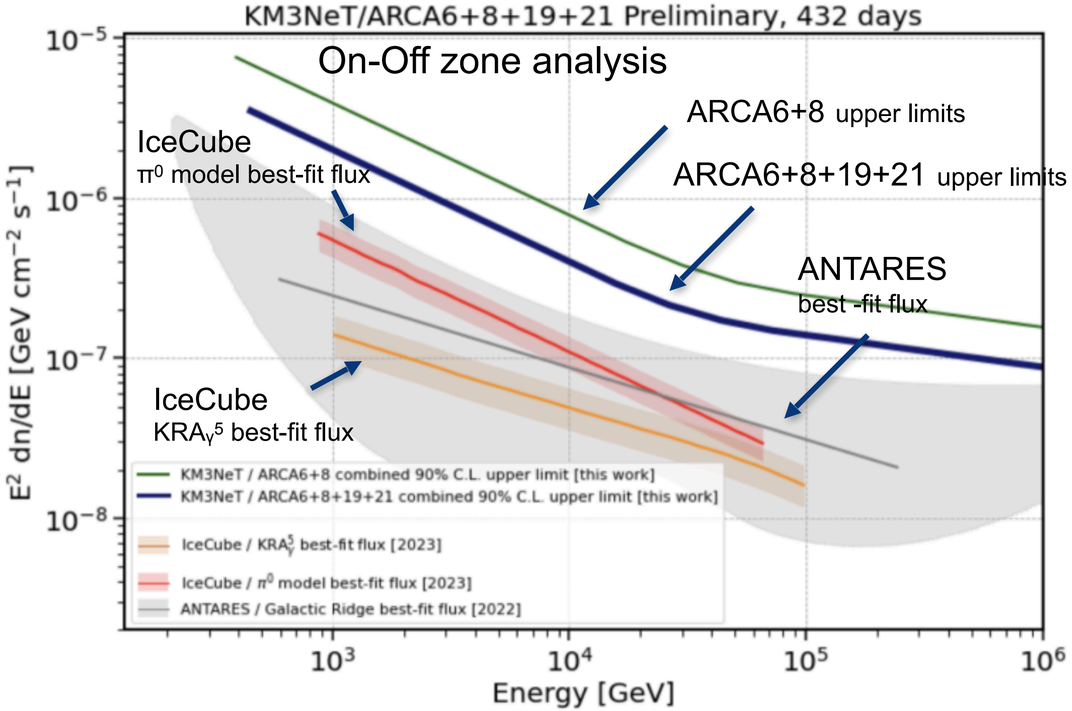
ARCA21 partially analyzed (until December 2022)

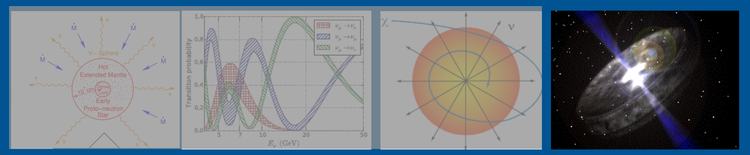
ICRC2023 PoS 1190

KM3NeT

|l| < 31° and |b| < 5° for KM3NeT/ARCA6-8 and

|l| < 31° and |b| < 4° for KM3NeT/ARCA19-21



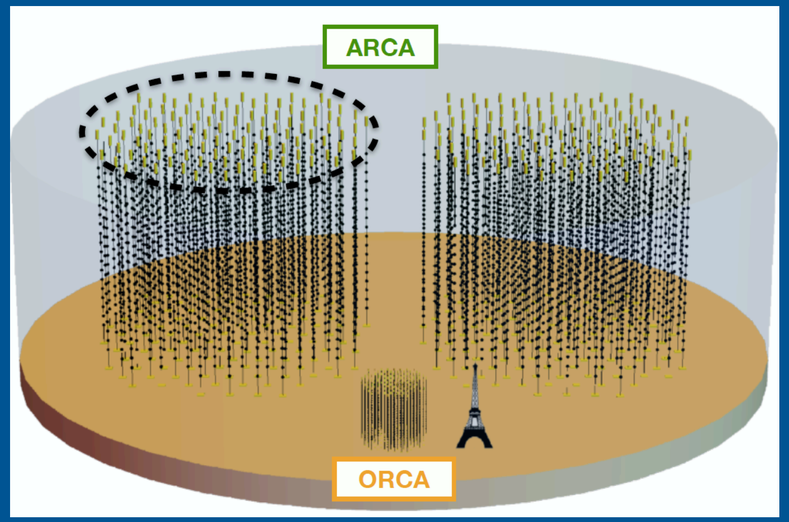


MULTI-MESSENGER PROGRAM

oS(ICRC2023)1125

ICRC2023 PoS 1125 ICRC2023 PoS 1521

A dedicated software is installed at the shore stations for Real-Time Analysis (RTA)



Sending alerts

Send neutrino alert to external communities

Receiving alerts

Receive alert from external communities - on-line analysis and follows ups

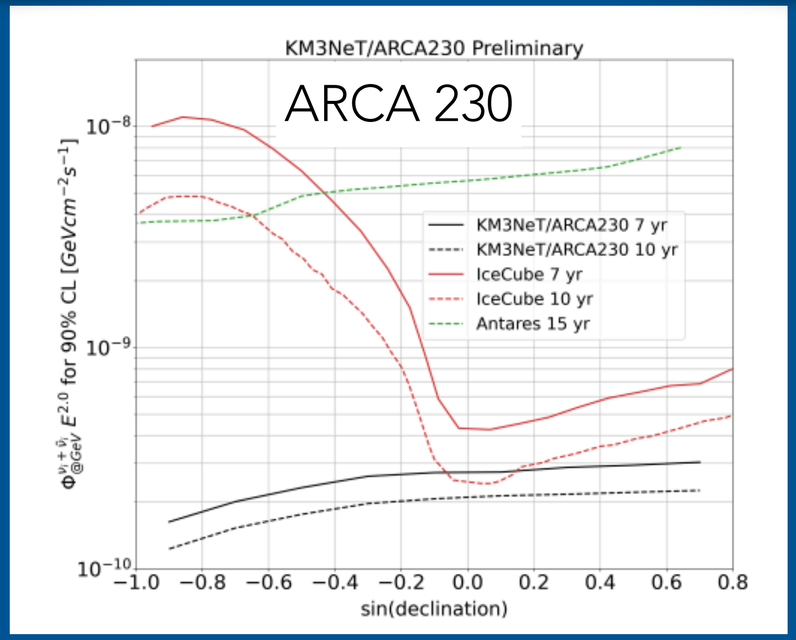
Receiving alert system operative 👉 RTA platform already active from November 2022 in ARCA and in ORCA detectors 👉 No significant excess found in any of the observed alerts

Sending alert system on going 👉 High-energy neutrino alerts will be sent in real-time by end of 2024.

KM3NET PERSPECTIVES

doS(ICRC2023)1125

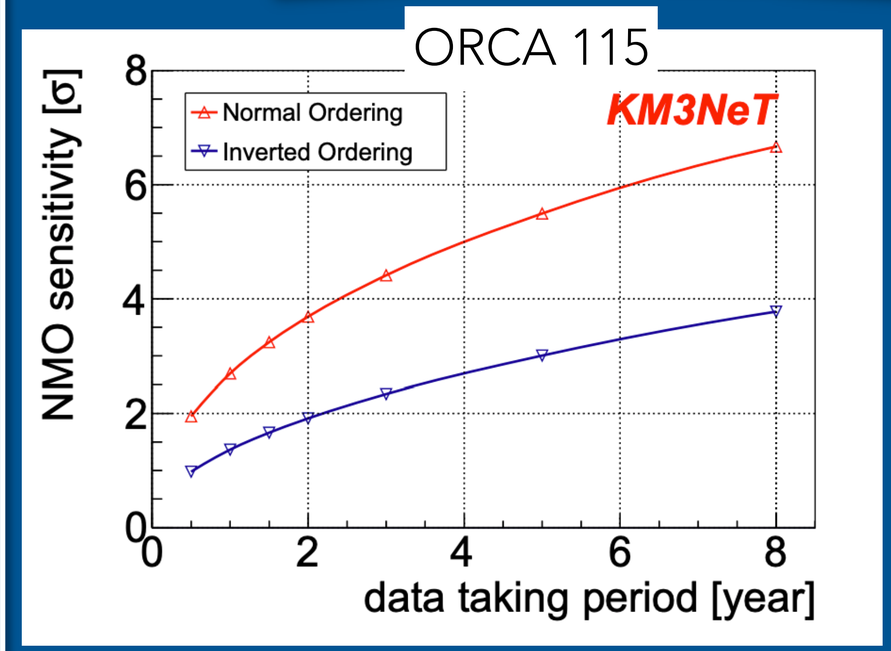
ARCA - Sensitivity for point-like searches



ICRC2023 PoS 1075

ORCA - Neutrino mass ordering

Eur. Phys. J. C 82, 26 (2022)



With ORCA6 Normal Ordering preferred at 1σ level

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029

- ANTARES decommissioning
- ARCA28DUs ORCA 24DUs
- ORCA completion
- ARCA completion

MULTI-DISCIPLINARY SCIENCE AT ARCA SITE

oS(ICRC2023)1125

Real-time marine data harvesting in Capo Passero

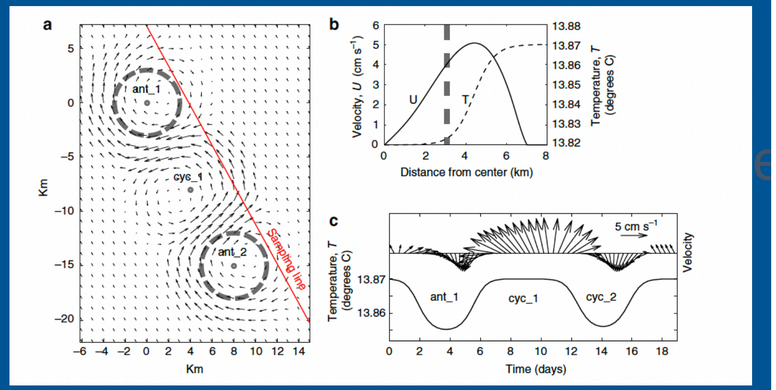
nature COMMUNICATIONS

ARTICLE

Received 17 Aug 2011 | Accepted 11 Apr 2012 | Published xx xxx 2012

DOI: 10.1038/ncomms1836

Abyssal undular vortices in the Eastern Mediterranean basin



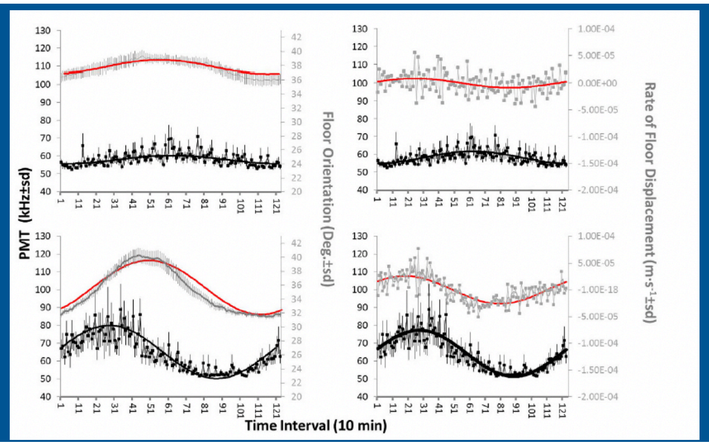
SCIENTIFIC REPORTS

OPEN

Inertial bioluminescence rhythms at the Capo Passero (KM3NeT-Italia) site, Central Mediterranean Sea

Received: 10 October 2016
Accepted: 13 February 2017
Published: 23 March 2017

J. Aguzzi[1], E. Fanelli[2], T. Ciuffardi[2], A. Schirone[2], J. Craig[3] & KM3NeT-Italia/NEMO Collaboration[†]

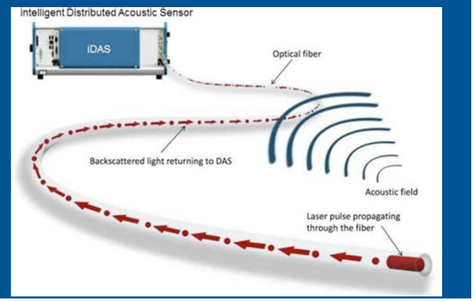


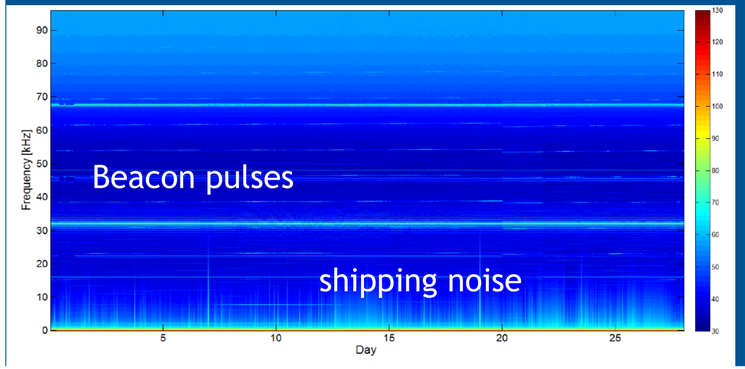
FOCUS ERC

Geo-INQUIRE

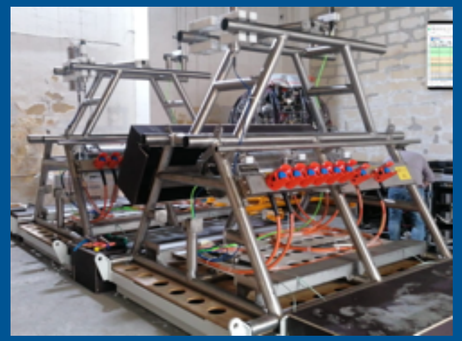
Optical time domain reflectometry (BOTDR and DAS)

Geophysics and Volcanology
Marine hazards real time alert
Surveillance
Marine Spatial Planning





Hydrophone data stream real-time:
Anthropogenic (shipping, airguns, …) noise monitoring
Presence of Cetaceans
Geophysical noise monitoring
Wind/rain (noise) monitoring offshore

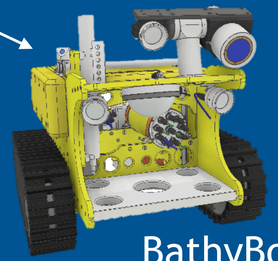


MULTI-DISCIPLINARY SCIENCE AT ORCA SITE

oSt(ICRC2023)1125

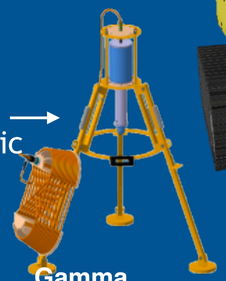
Instrumentation for marine science

Temperature, salinity,
Oxygen measurements
camera

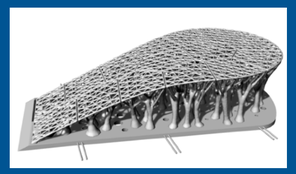


BathyBot

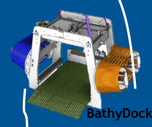
Mesurement of K40 and radionuclide Anthropogenic and not



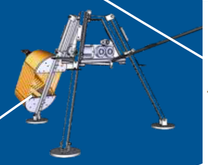
Gamma Spectrometer



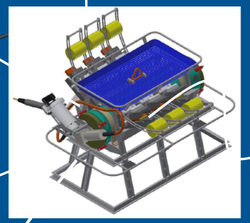
BathyReef



BathyDock



Biocamera



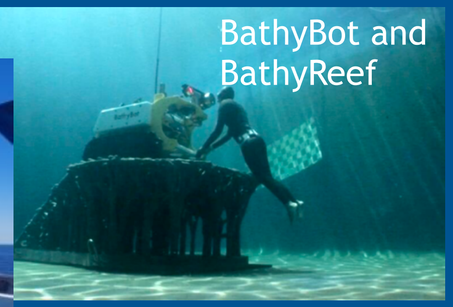
BJS

Seismograph

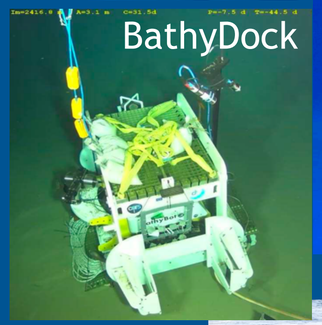
preBJS

Towards
Junction Box2

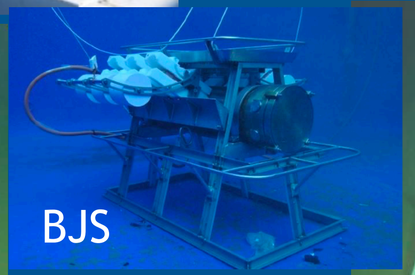
preBJS



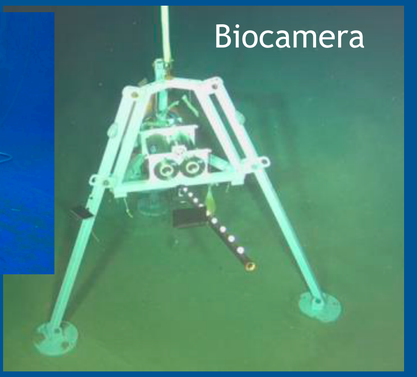
BathyBot and BathyReef



BathyDock

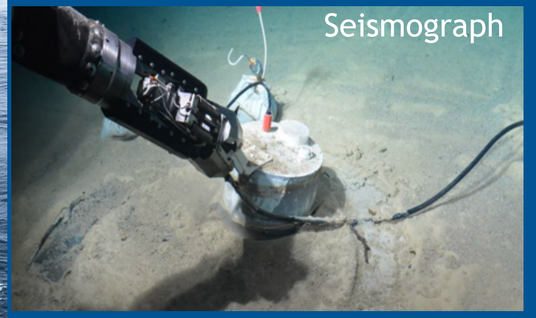


BJS



Biocamera

Gamma spectro



Seismograph

SUMMARY

KM3NeT under construction 👉 present status: ARCA 28 DUs (12% of full detector) and ORCA 18 DUs (14% of the full detector) … next week ORCA22

First results presented at ICRC2023 👉 about 40 contributions (https://arxiv.org/abs/2309.05016)

KM3NeT upper limits are rapidly approaching the ANTARES limits
Online multi-messenger analysis framework for KM3NeT in progress and already operative

👇

Exciting results expected in a few years especially in the exploration of the southern sky

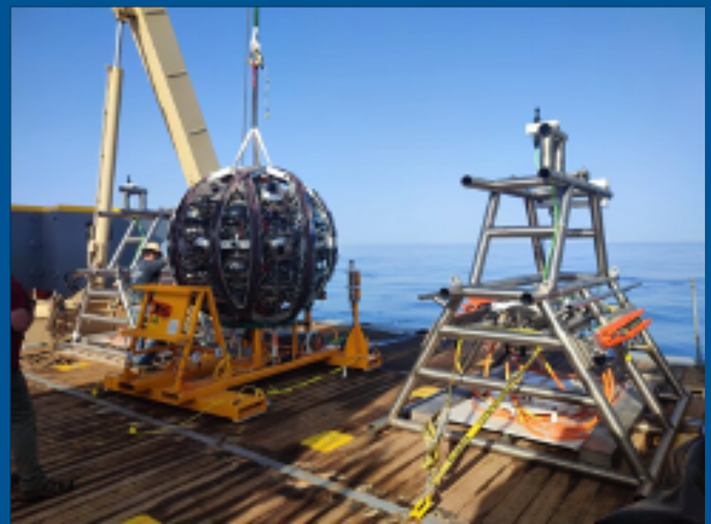
Promising results also in the neutrino oscillation 👉 KM3NeT/ORCA in the race for mass hierarchy

We are building two underwater laboratories 👉 unique multidisciplinary opportunities

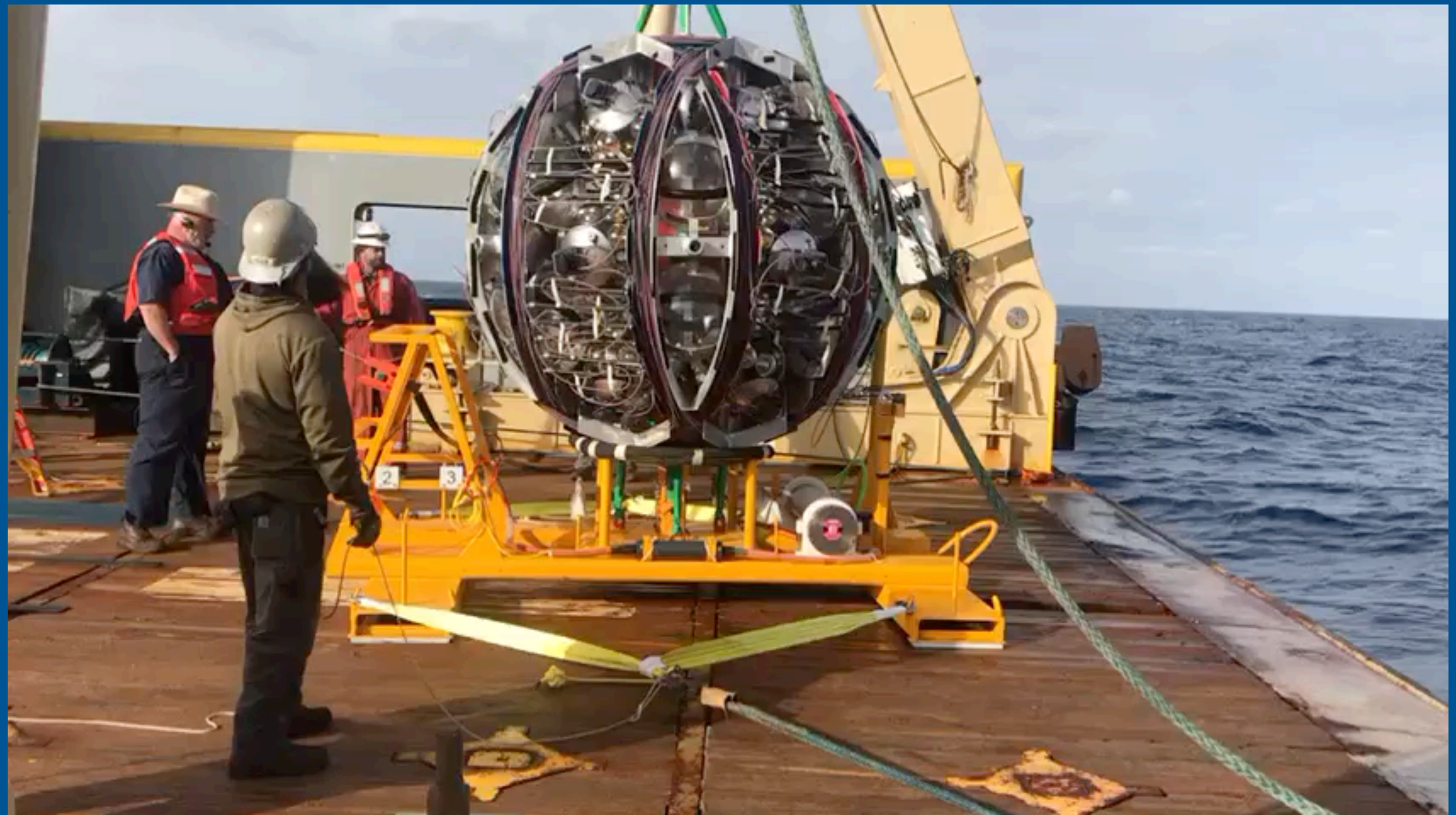
STAY tuned and .. join us!

DU DEPLOYMENT

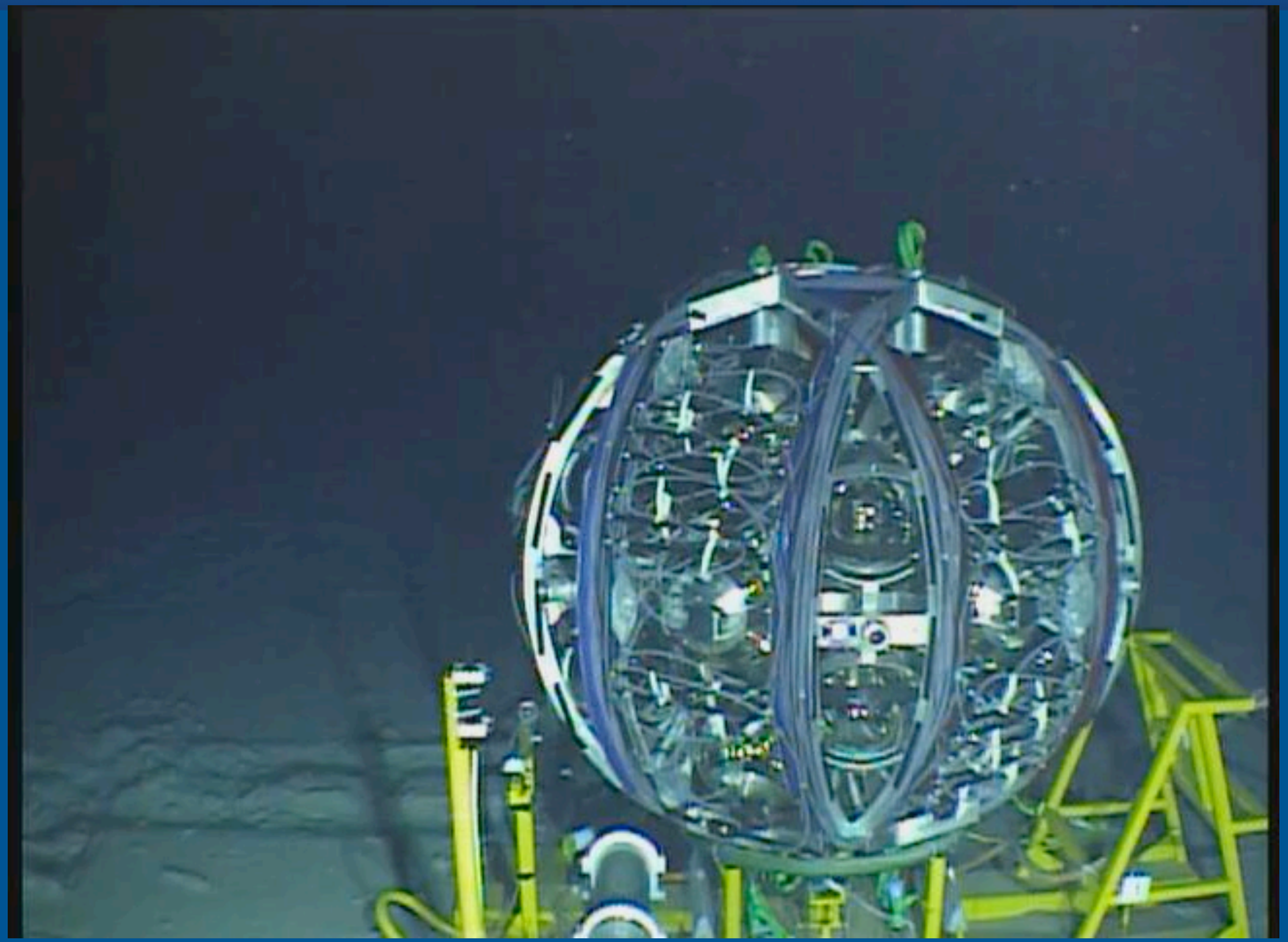
June 2022 sea campign:
11 DUs and 2 JBs + recovery of TJB



Deployment DU



MOVIE: THE UNROLLING



THE INTEGRATION

DOM integration

Base Module integration

THE INTEGRATION

DOI # if your paper already has one
Name and Surname of the primary author -> Rosa Coniglione
Name and Surname of co-authors
Eventual identifiers of the author and co-authors (eg.: Orcid #, ISNI, GND, etc.) -> https://orcid.org/0000-0002-8289-5447
Affiliation of primary author and co-authors and respective role (eg.: researcher, supervisor, project manager, etc.) -> Istituto di fisica Nucleare - Laboratori Nazionali del Sud
Eventual Organization (eg.: project name, collaboration, etc.) -> for the KM3NeT collaboration
Key-word and topic of your presentation (eg.: “cross section”, “Neutrino Properties” etc. according to the topics of the Workshop) -> Neutrino telescopes, Neutrino properties, Neutrinos from cosmos
Funds (if your work has been funded, please indicate the name of the funder and the grant #)
Identifier of the work, if the case (eg.: ARK, arVix, DOI, ISBN, etc.)
Related work, if the case (eg.: derived from, is cited by, it cites, is referenced by, etc. and relevant identifier, string of reference, etc.)
Publishing information: (eg.: Journal - with title and ISSN; Imprint – book title and ISBN)