

# KM3NET

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R. Coniglione

LNS-INFN

# La sigla KM3NeT

Resp. Nazionale G. Cuttone

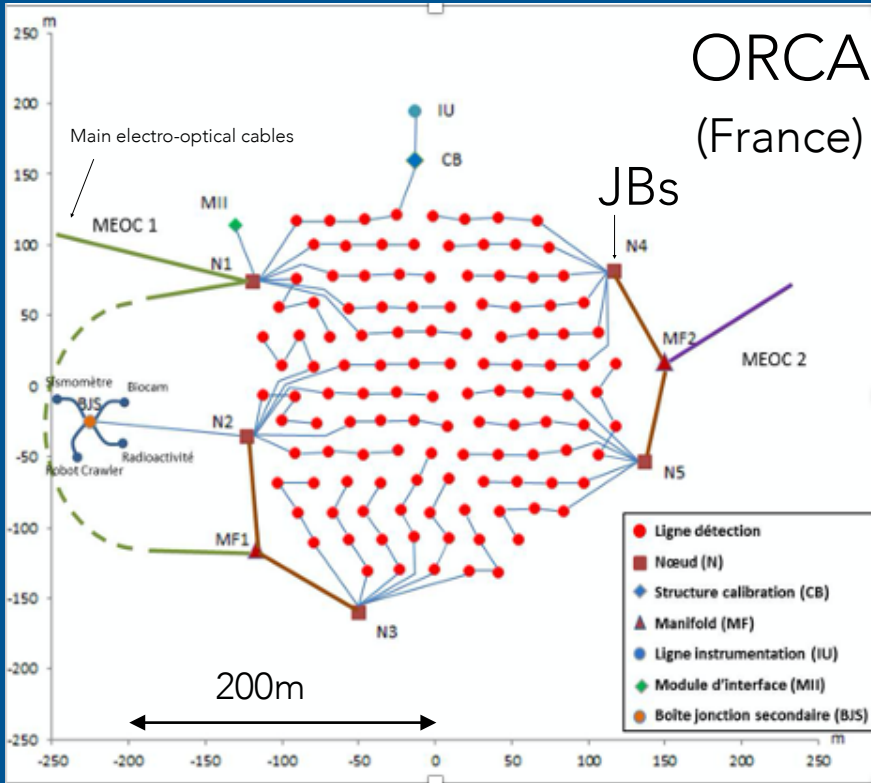
La sigla KM3NeT comprende:

- Attività **KM3NeT**
  - ARCA
    - Rivelazione di neutrini di alta energia ( $>1$  TeV) da sorgenti cosmiche - rivelatore in costruzione a Capo Passero
  - ORCA
    - Rivelazione di neutrini atmosferici per lo studio delle proprietà fondamentali del neutrino ( $E < 100$  GeV) - rivelatore al largo delle coste di Tolone in costruzione
- Attività **ANTARES**
  - Piccolo rivelatore per la neutrino astronomia che ha preso dati per più di 13 anni ed è stato smantellato nel 2022 🙌 si stanno completando le analisi dei dati



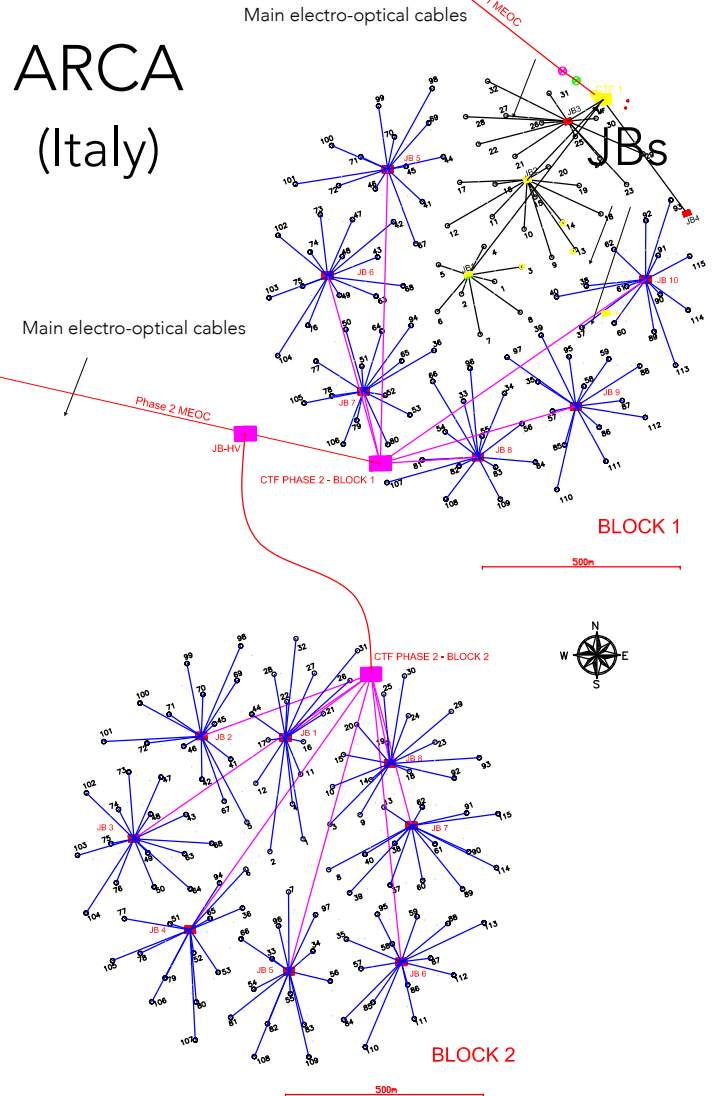
# THE DETECTORS

3



**ORCA is composed of 1 building block of 115 DUs** with 20 m DU interspacing and 9m inter DOM spacing (7 Mton)

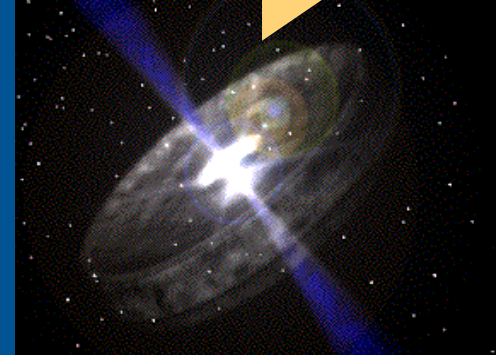
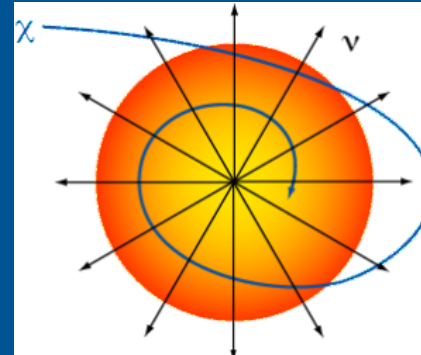
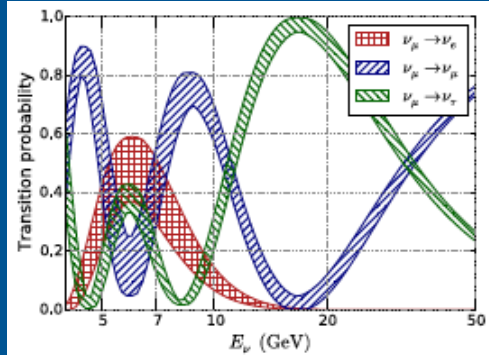
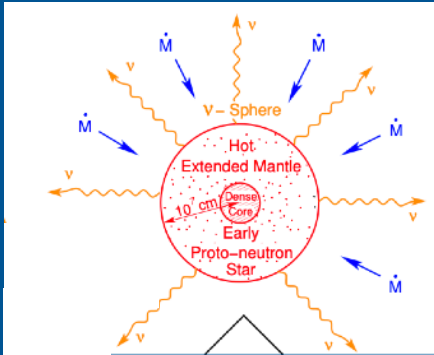
## ARCA (Italy)



**ARCA is composed of 2 building blocks of 115 DUs** each with 90 m DU interspacing and 36m inter DOM spacing (0.5 km<sup>3</sup>=500Mton/block)

# THE PHYSICS

Neutrino Energy from MeV to PeV



Super Novae explosion  
MeV

Neutrino oscillation  
GeV

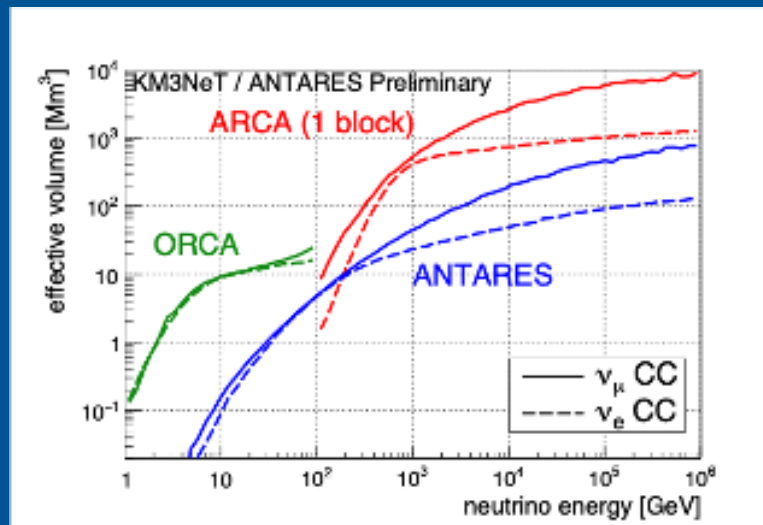
Dark Matter  
TeV

HE neutrinos  
Multi-messenger program  
PeV

ARCA + ORCA

ORCA

ARCA



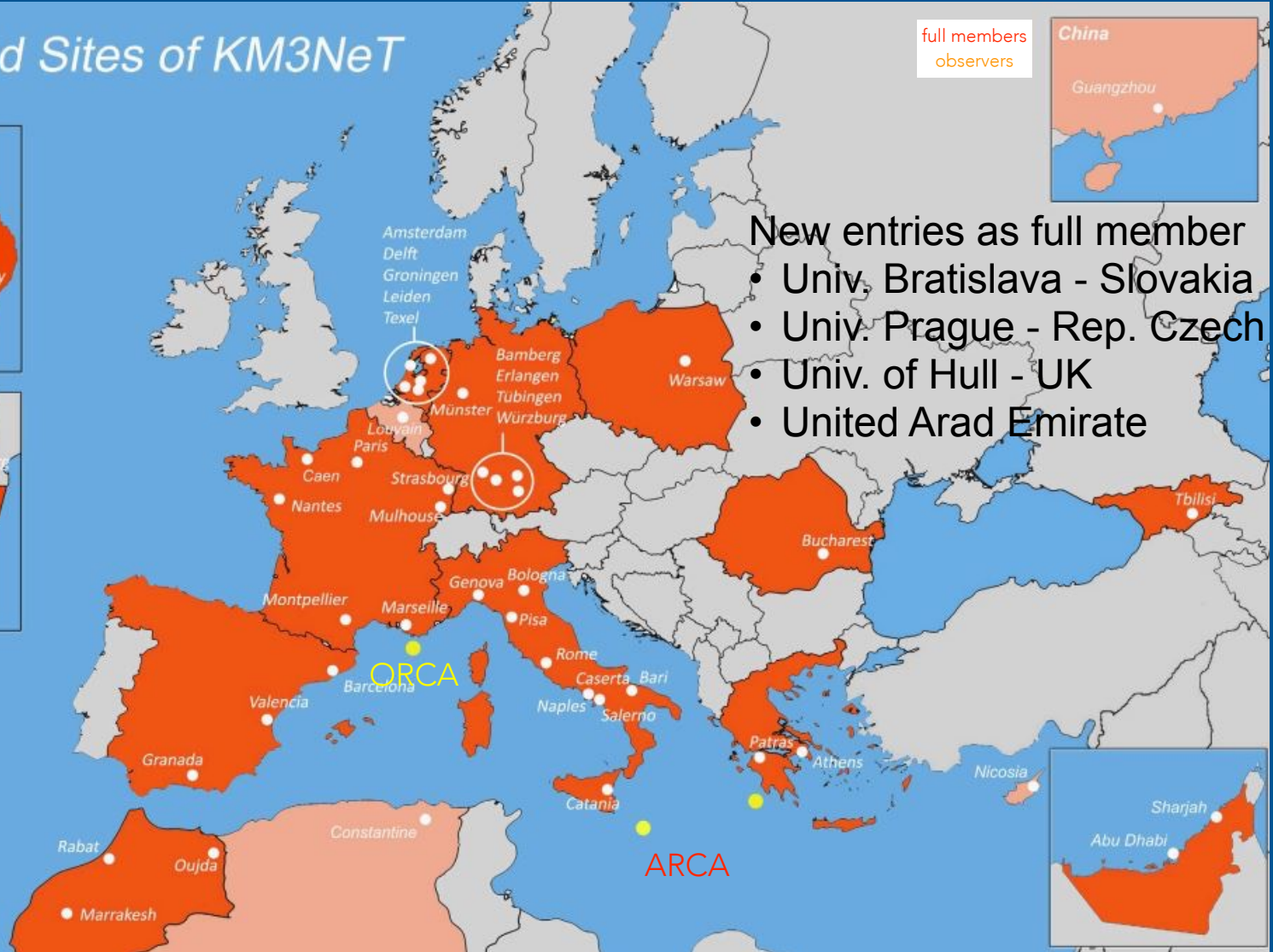


# THE KM3NET COLLABORATION

5

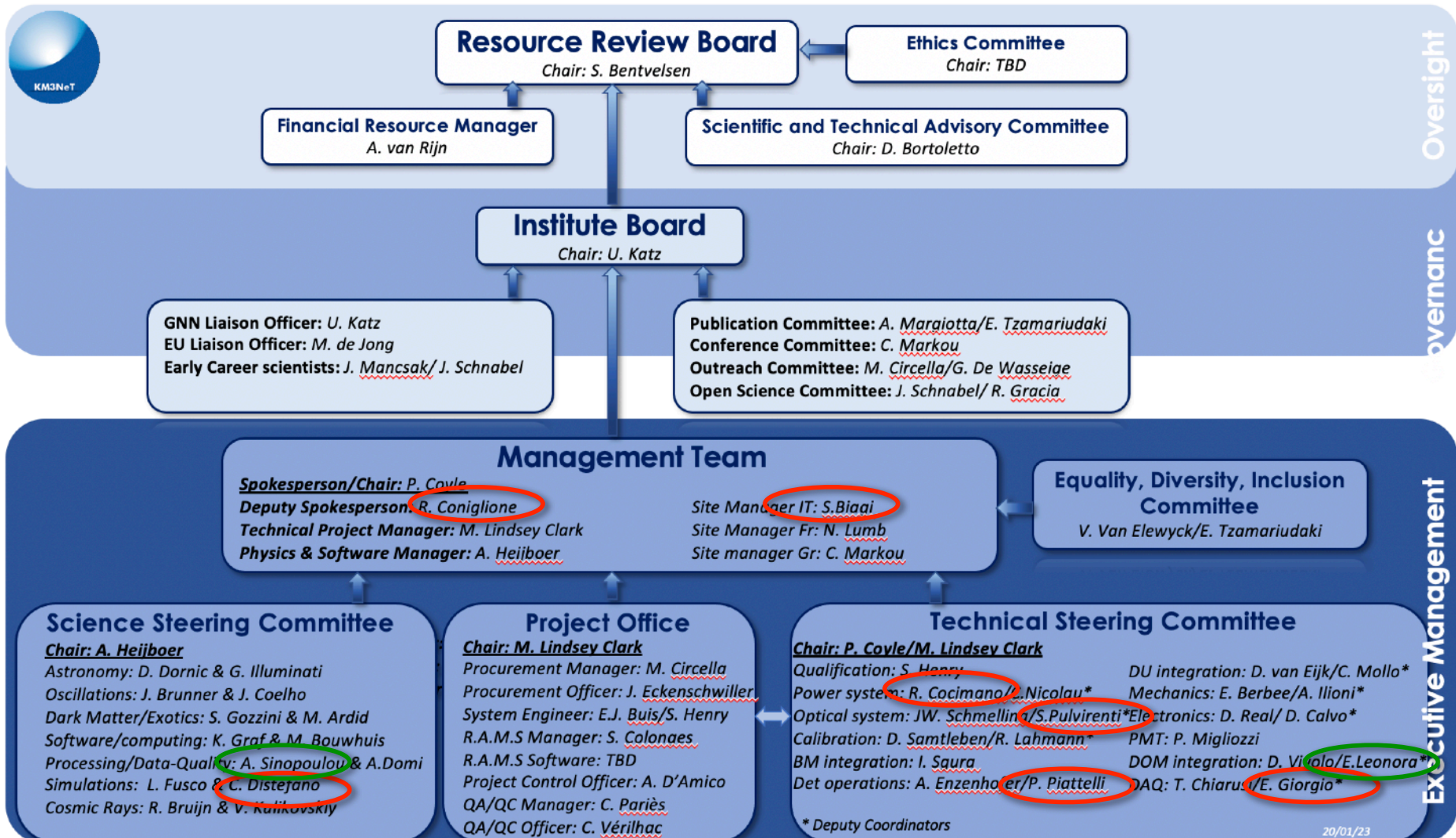
60 institutes in 20 countries

## Cities and Sites of KM3NeT



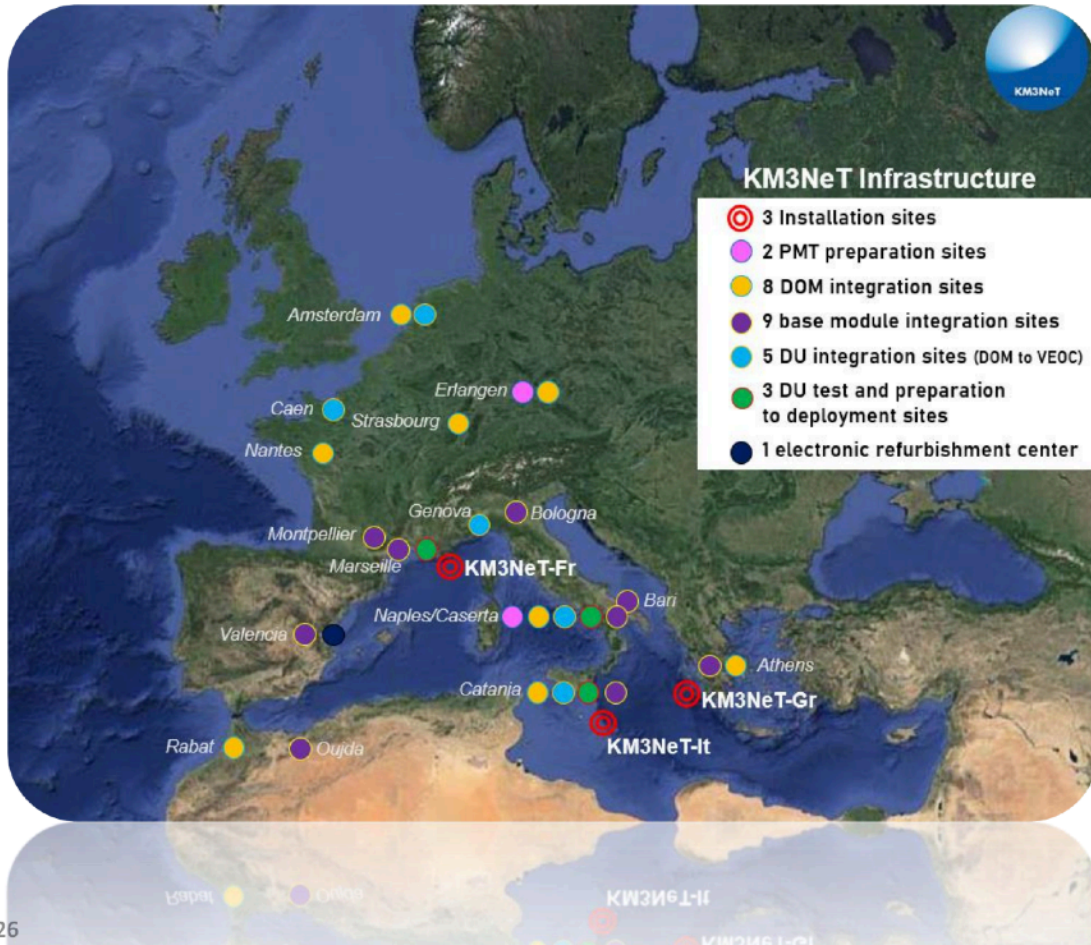
- New entries as full member
- Univ. Bratislava - Slovakia
  - Univ. Prague - Rep. Czech
  - Univ. of Hull - UK
  - United Arab Emirates

# KM3NeT Organigramma





# THE DETECTOR CONSTRUCTION



## DOMs

- 8 integration sites
- **1105 DOMs integrated**
- WWRS DOMs to start soon

## BMs

- 8 integration sites
- **60 BMs integrated**
- 4 currently on bench

## DUs

- 6 integration sites (Welcome to Caen!)
- **48 DUs integrated**
- 18 currently on bench
- 39 deployed



## @ LNS

BM integration site (resp. G. Larosa)

DU integration site (resp. P. Sapienza)

## @ Sezione Catania

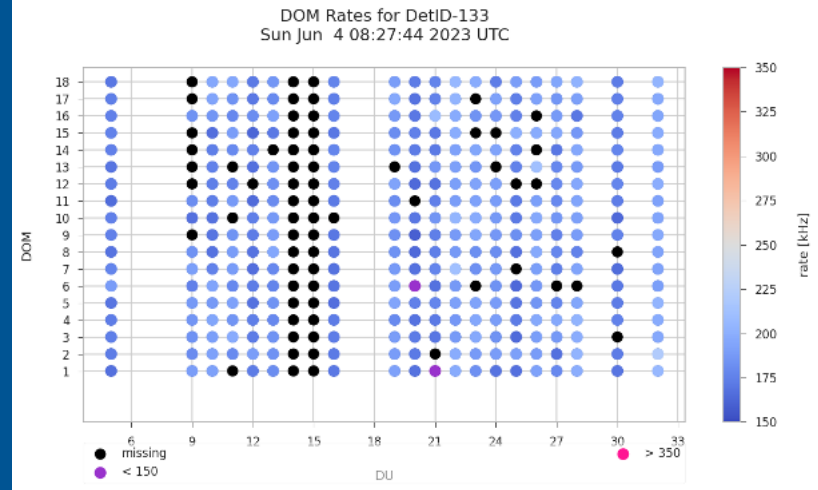
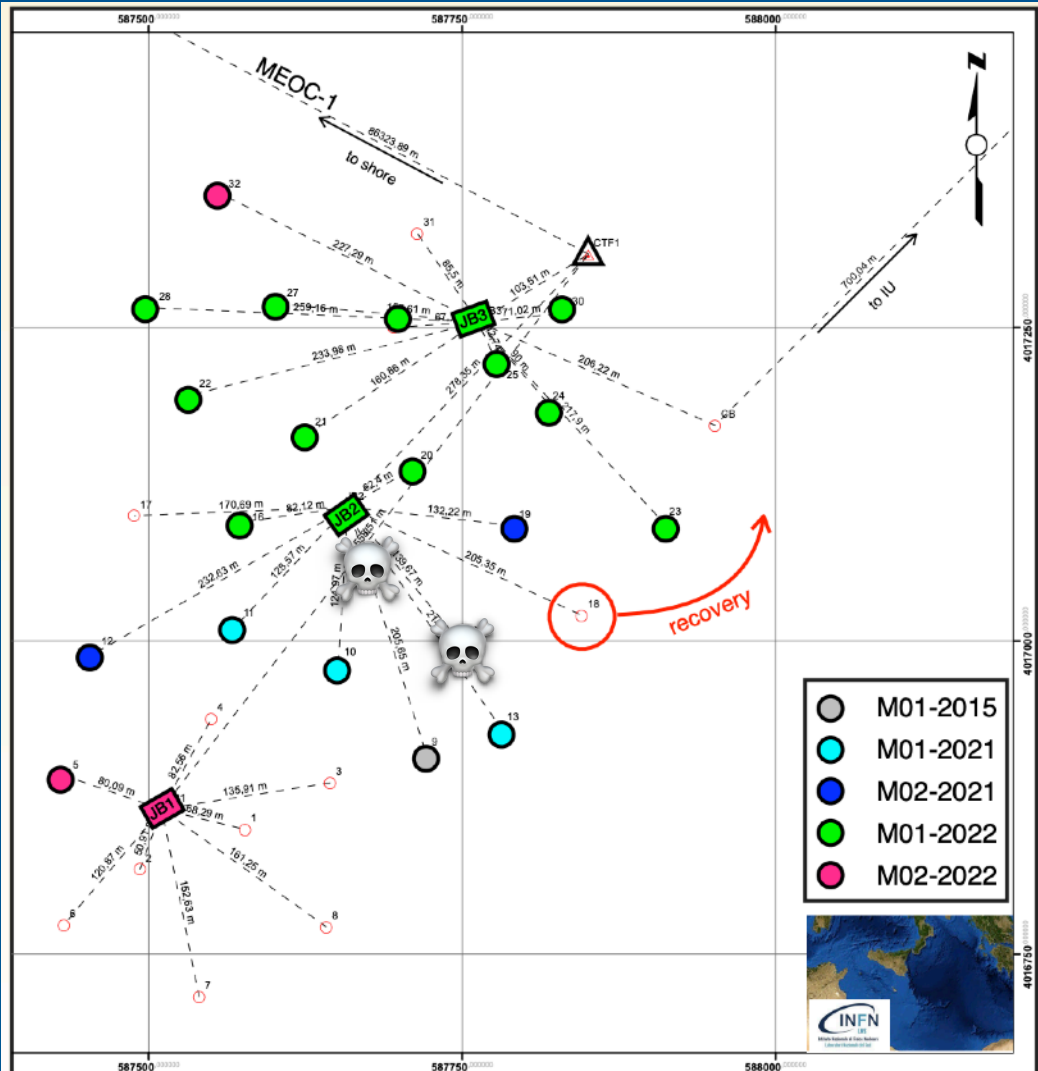
DOM integration site (resp. E. Leonora)

New integration sites in Italy in the next years (PNRR)

- Genova - DU integration process 2 and 3
- Salerno - DOM integration
- Sezione Catania - new laboratory DOM integration to double production
- Caserta - enlargement of the laboratory
- Bari - BM integration

# ARCA STATUS

Settembre 2022 Successful deployment of 2 DUs + 1 JBs (recovery fo DU18)  
 21 DUs now in water 👉 19 in operation

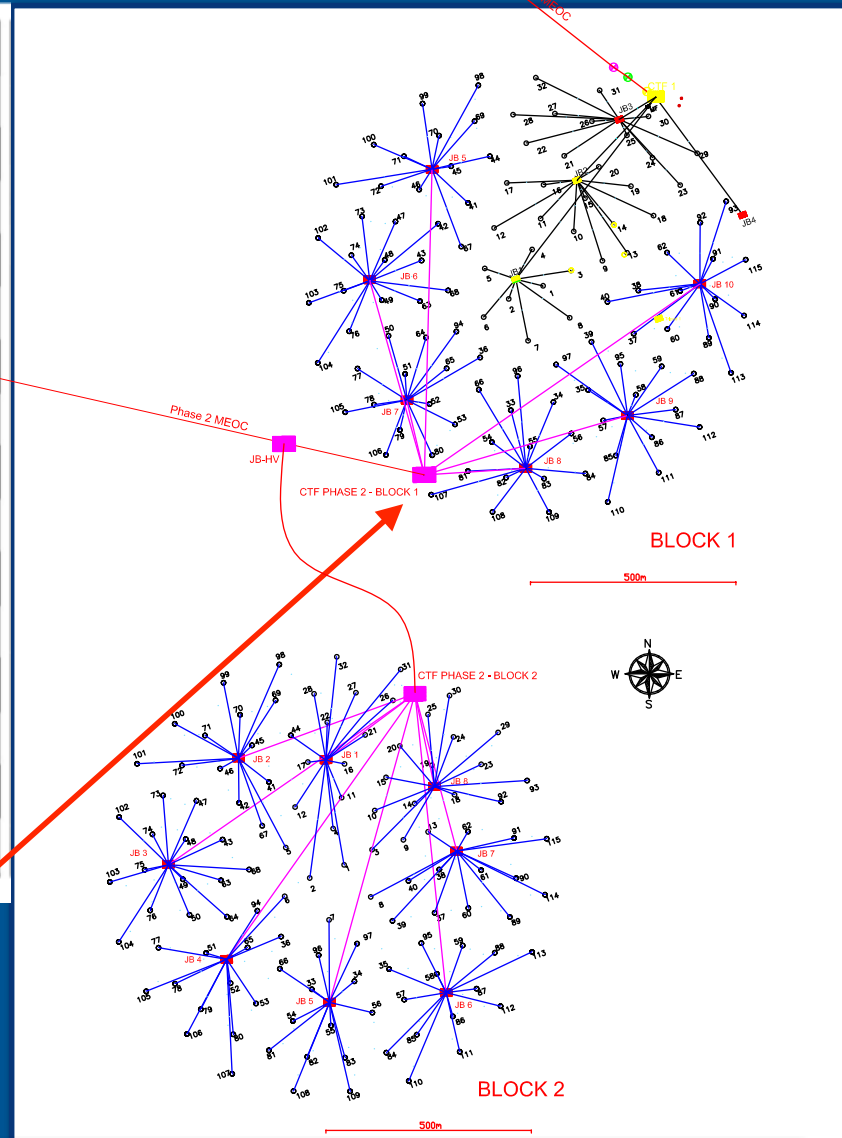
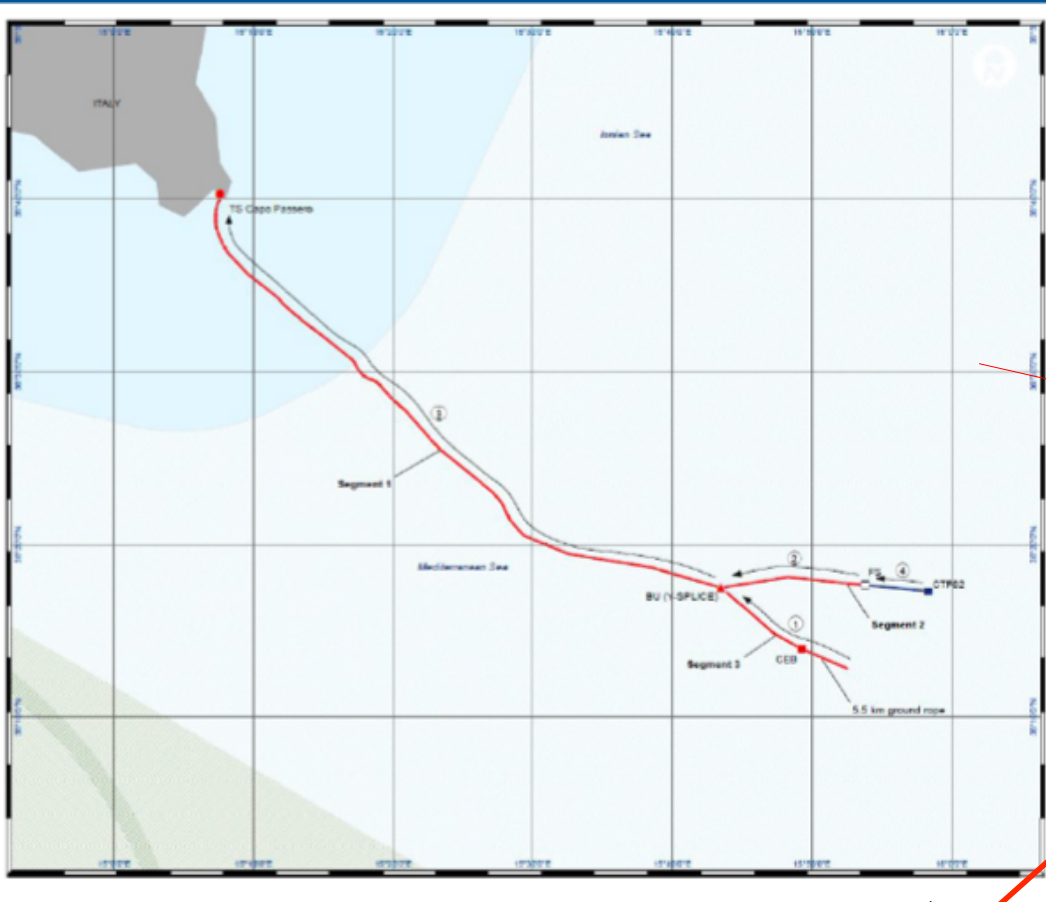


September 2022 -> deployed 2 DU + JB1 recovered DU18

20/04/23: Lost DU14 (Deployed in April 2021)  
 19/05/23: Lost DU15 (Deployed in September 2021)

# ARCA: SECOND BRANCH STATUS

9



All in site:

- New cable
- New CTF deployed in November 2022

Sea floor infrastructure ready for the connection and feeding of the first block

# ARCA NEXT SEA CAMPAIGN

## Next sea campaign Settembre 2023

Canceled the sea campaign of spring 2023

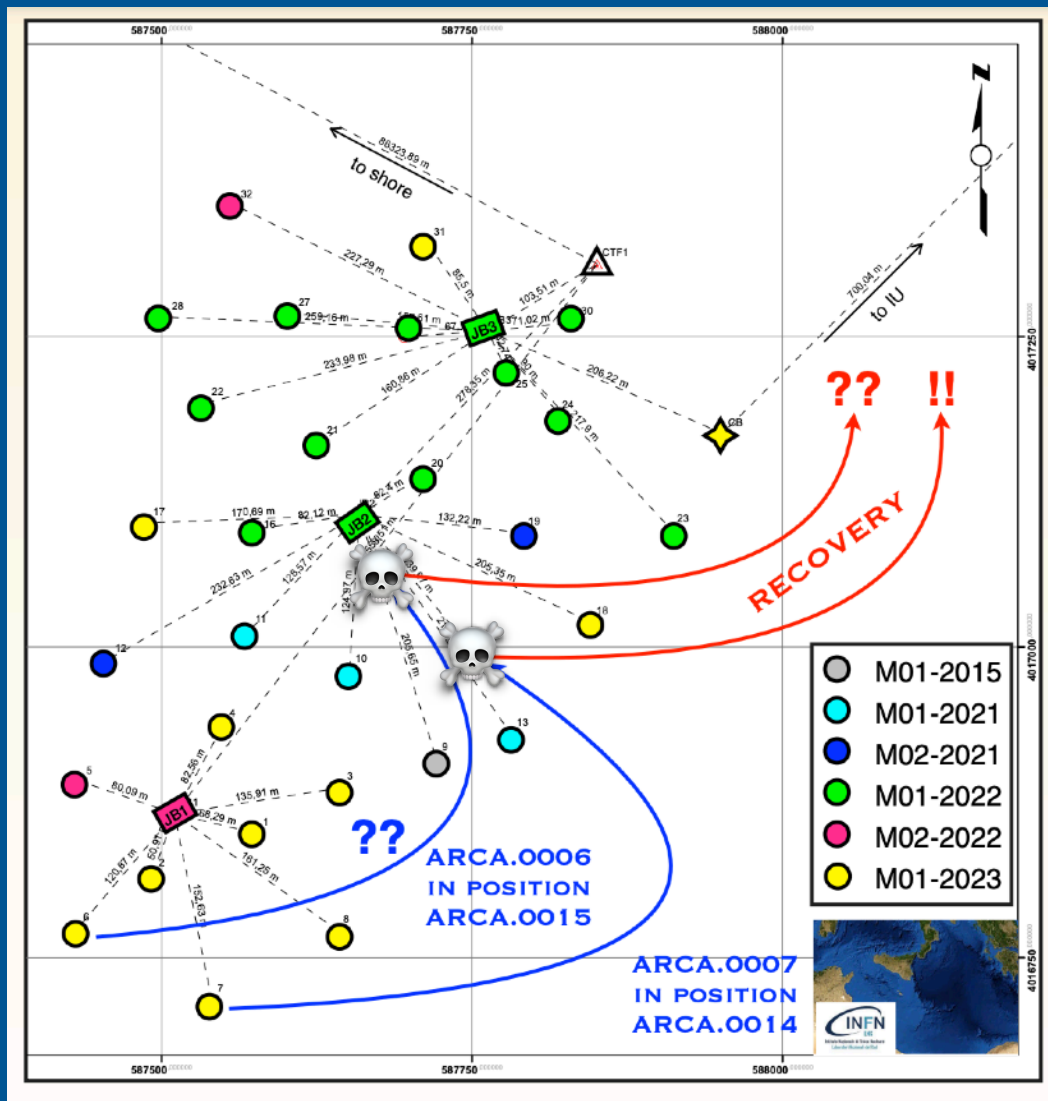
Not easy to find a vessel in the Med Sea in this historical period. A Turkish vessel was found. Unfortunately, due to earthquake, the Turkish vessel availability window moved to September.



Deploying of 10 DUs  
Recovery of DU14  
Recovery of DU15 (?)



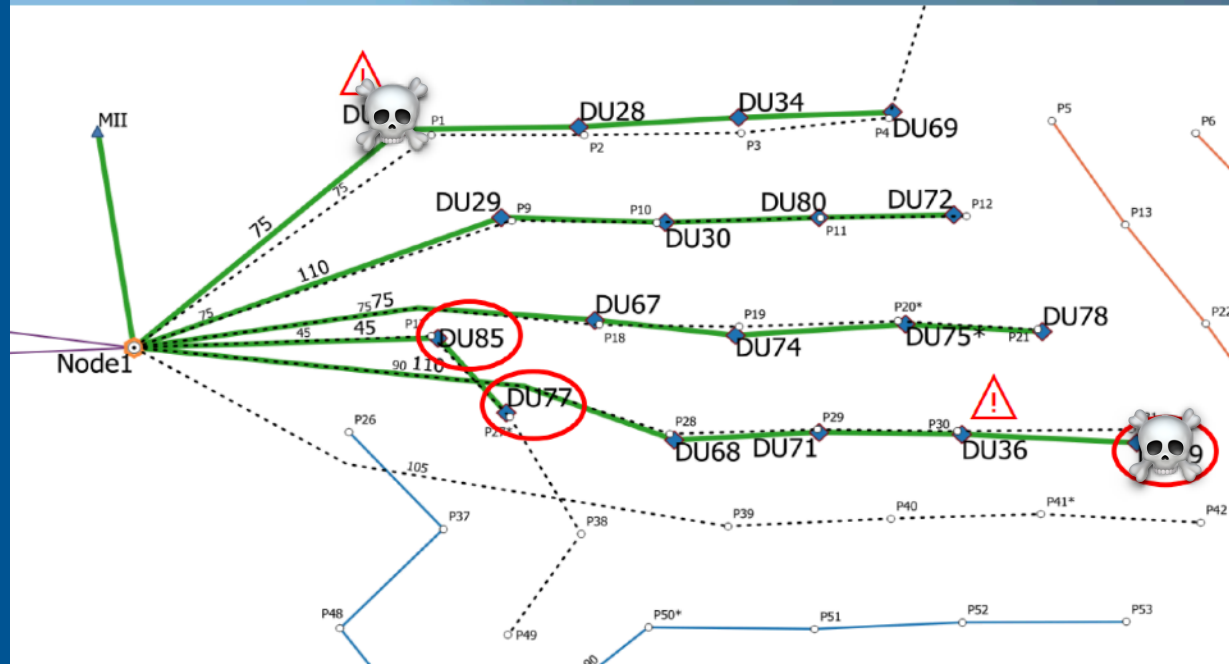
For the end of 2023  
ARCA with 29 DUs



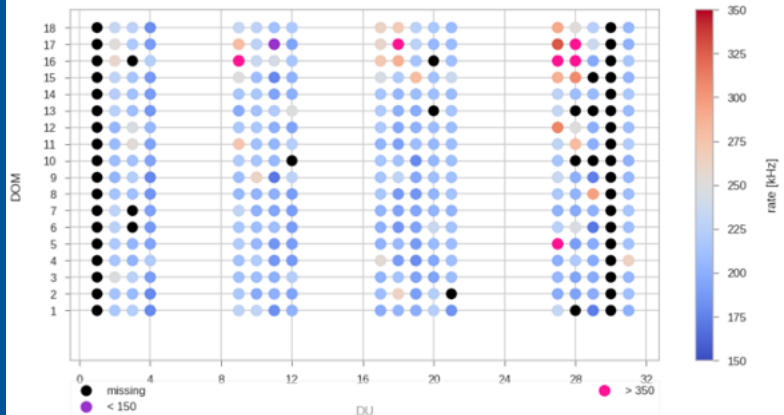


# ORCA STATUS

11



DOM Rates for DetID-148  
Sun Jun 4 08:25:48 2023 UTC

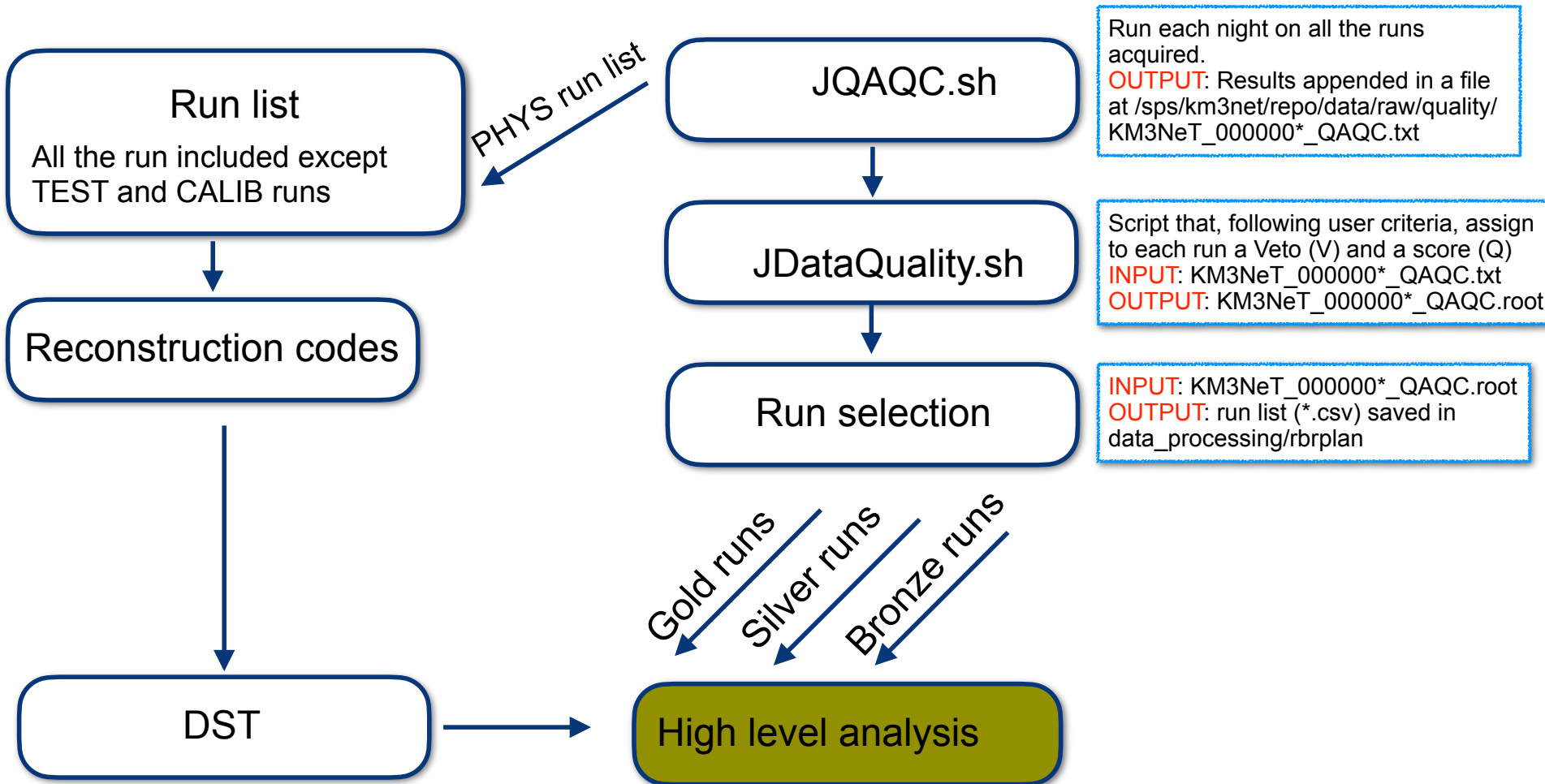


18 DU deployed 16 taking data

2 DU not working

# ARCA: DATA COLLECTED AND ANALYZED

# Data Quality work flow



- **INPUTS:** aonet files (one for each run)
- **OUTPUT:** aonet files (one file)

# ARCA: DATA COLLECTED AND ANALYZED

14

	<i>Starting date</i>	<i>Ending date</i>	<i>From calendar (days)</i>	<i>Live time analyzed (days)</i>	<i>%</i>
<b>ARCA6</b>	<b>12 may 2021</b>	<b>10 sept 2021</b>	<b>121</b>	<b>101.5</b>	<b>84</b>
<b>ARCA8</b>	<b>26 sept 2021</b>	<b>1 june 2022</b>	<b>248</b>	<b>210.5</b>	<b>85</b>
<b>ARCA19</b>	<b>13 july 2022</b>	<b>7 sept 2022</b>	<b>56</b>	<b>53</b>	<b>96</b>
<b>ARCA21</b>	<b>22 sept 2022</b>	<b>10 june 2023</b>	<b>261</b>	<b>216.7</b>	<b>83</b>

ARCA6 & ARCA8 fully analyzed 🙌 results to be presented at ICRC2023

ARCA19 & ARCA21 partially analyzed (ARCA21 till December 2022) 🙌 results to be presented at ICRC2023

# RESULTS

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## ICRC 2023 Nagoya Japan 26July-3August

	<i>Number of contribution</i>
<i>Astronomy</i>	<b>16</b>
<i>Cosmic Rays</i>	<b>5</b>
<i>Dark Matter</i>	<b>3</b>
<i>Neutrino oscillation</i>	<b>8</b>
<i>DAQ</i>	<b>1</b>
<i>Electronics</i>	<b>1</b>
<i>Calibration</i>	<b>4</b>
<i>Outreach</i>	<b>1</b>

More than 40 contributions  
1 general talk ANTARES/KM3NeT  
8 talks in parallel sessions  
32 posters

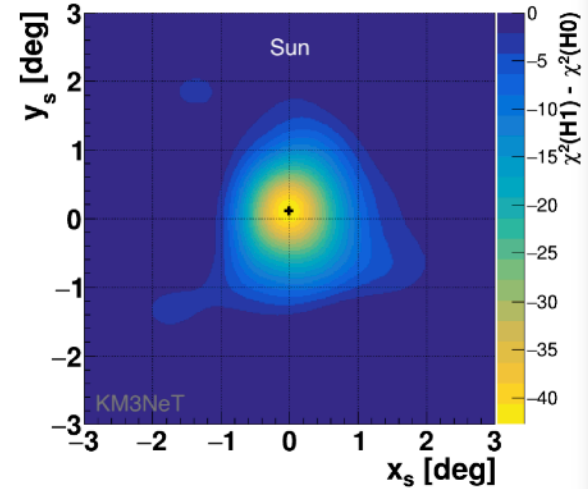
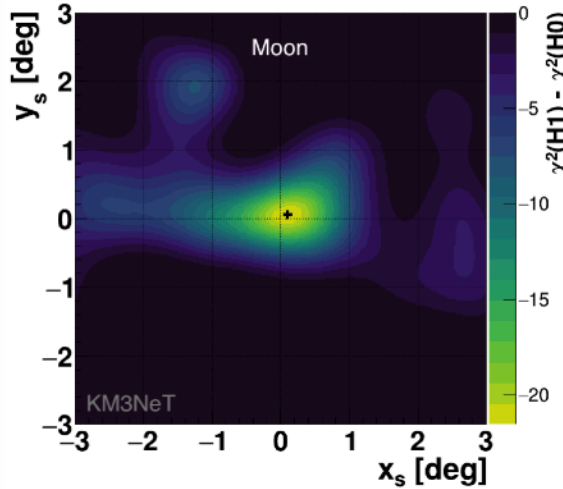
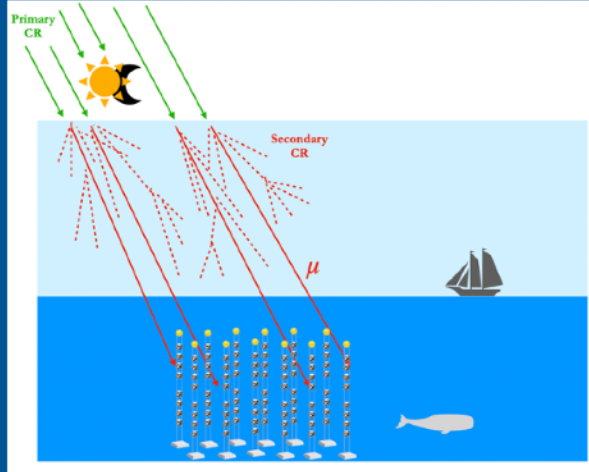
Jul 18, 2023

Proceedings Deadline (Preliminary)

# RESULTS: CALIBRATION

16

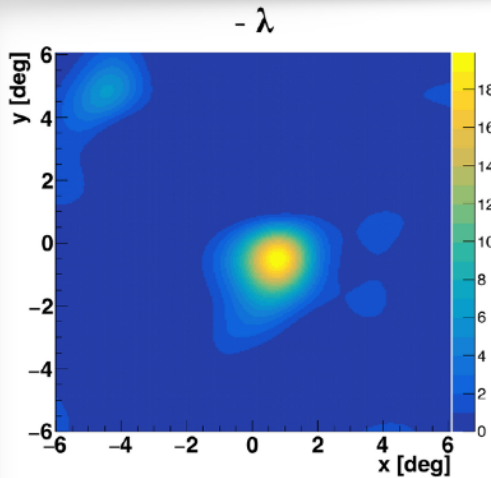
EPJ C 83 (2023) 344 ORCA6 - 500 days



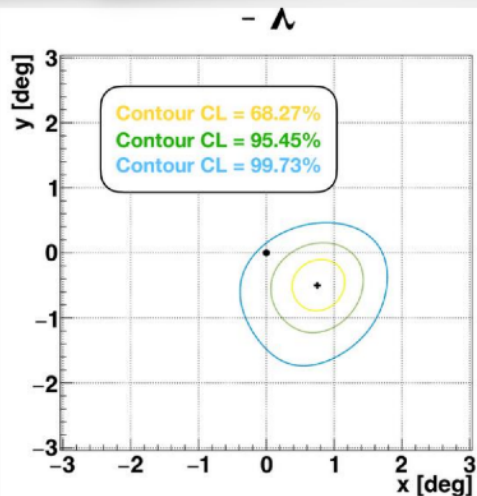
4.2  $\sigma$  - res.  $0.49 \pm 0.15^\circ$

6.2  $\sigma$  - res.  $0.65 \pm 0.13^\circ$

MC  $0.53^\circ$



Events: 697995



Preliminary

Sun+Moon with ARCA 19+21  
Result compatible with perfect  
orientation only at  $3\sigma$  level. Not  
constraining better than  $\sim 0.5^\circ$

Analysis on going to extend the  
statistics



# DETECTOR CALIBRATION

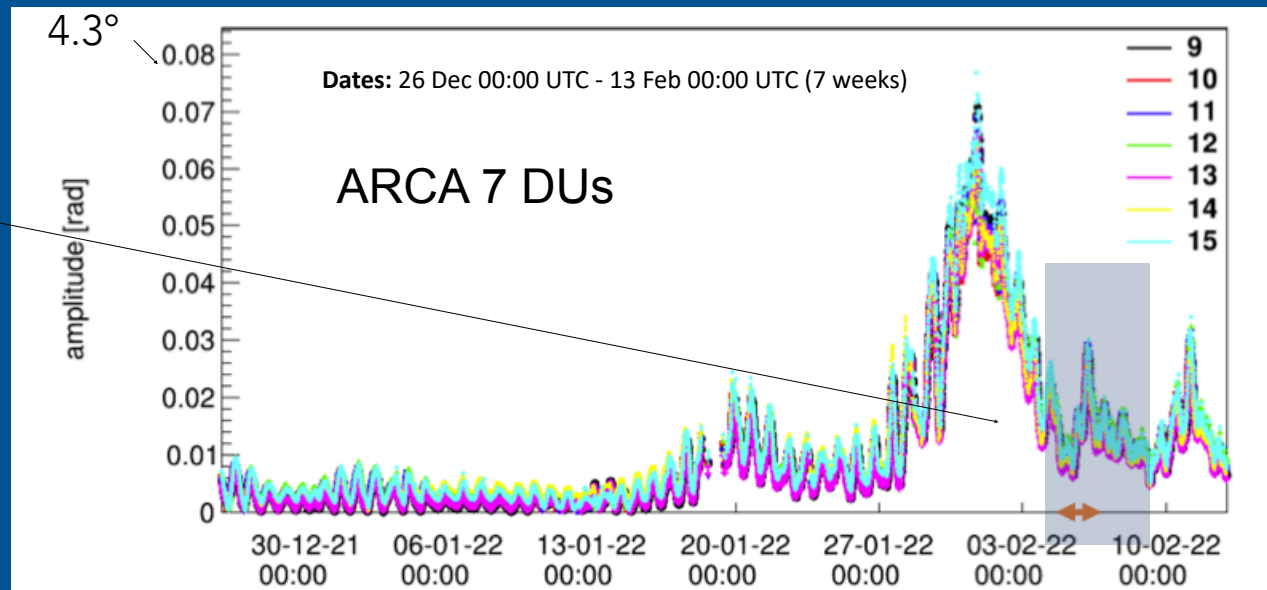
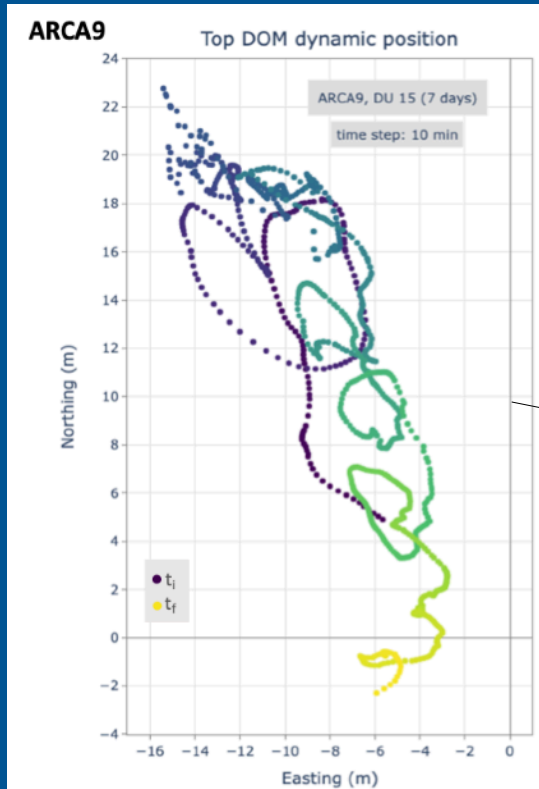
17

## Position

Based on acoustic beacon and piezo

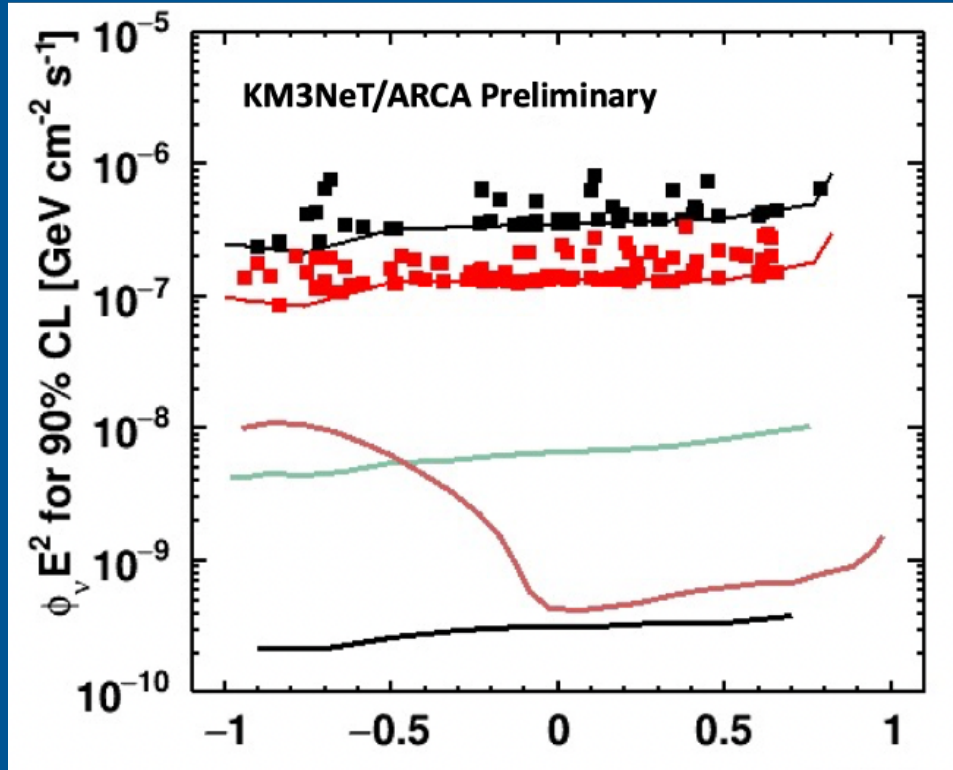
~28 m max displacement of the topmost DOM

Tilt amplitude

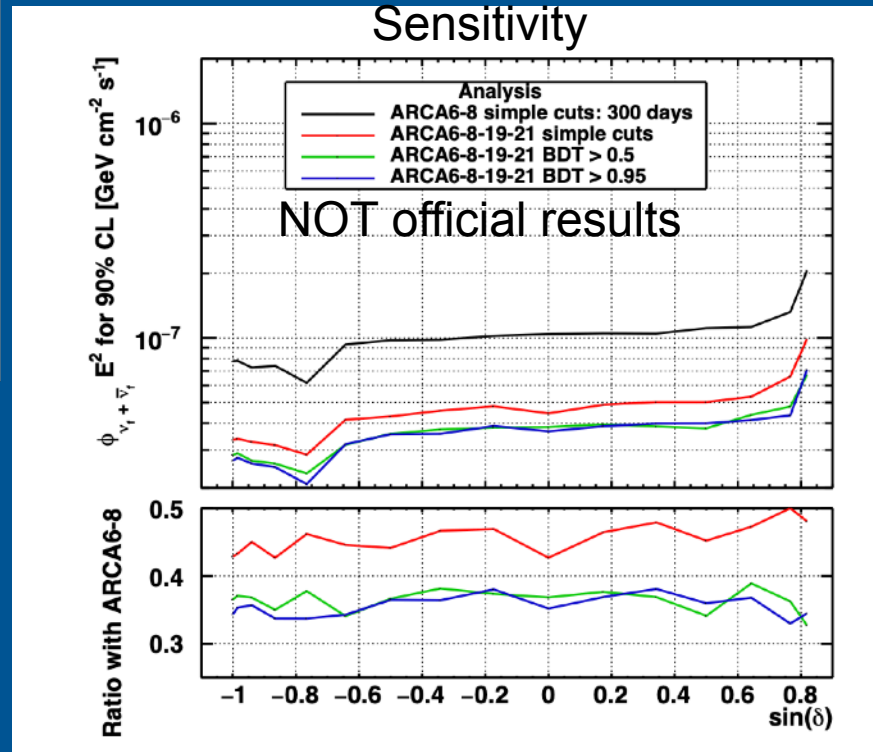


Dynamic positioning applied to the data

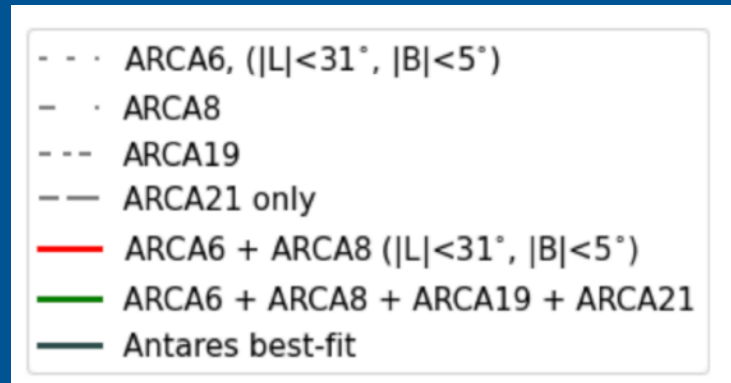
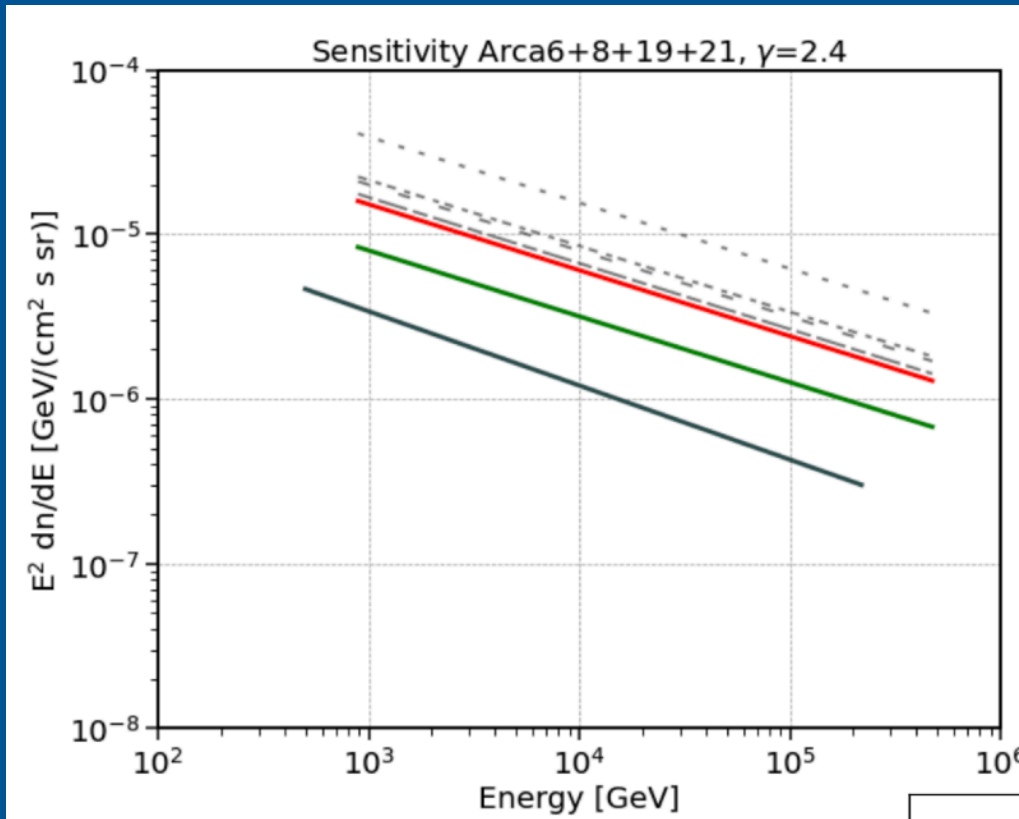
## Search for point like sources



- KM3NeT/ARCA6 (92 days) source limits
- KM3NeT/ARCA6 (92 days) sensitivity
- KM3NeT/ARCA6-8 (~300 days) source limits
- KM3NeT/ARCA6-8 (~300 days) sensitivity
- ANTARES (13yr) sensitivity
- IceCube (7yr) sensitivity
- KM3NeT/ARCA230 (7yr) sensitivity



## Diffuse from the galactic plane

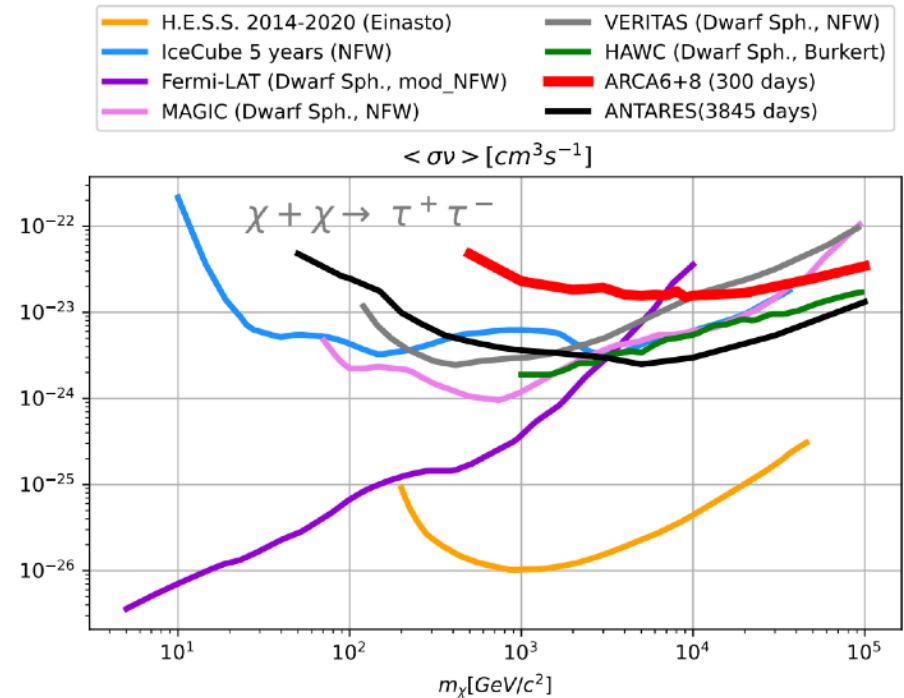
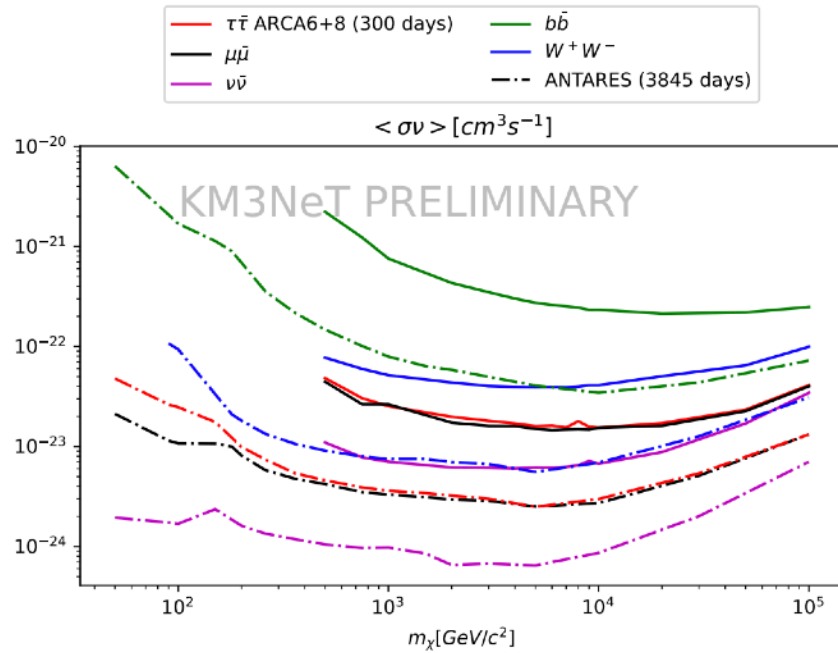


Data unblinding just done

# RESULTS: DARK MATTER

20

## Dark matter searches from the Galactic Plane



# RESULTS: ASTRONOMY - ON LINE

21

- Online follow up on real-time alerts and send results into the world (ATELs, etc) active.
- Ready for new Ligo/Virgo O4 run

## KM3NeT Shifter Tools home page

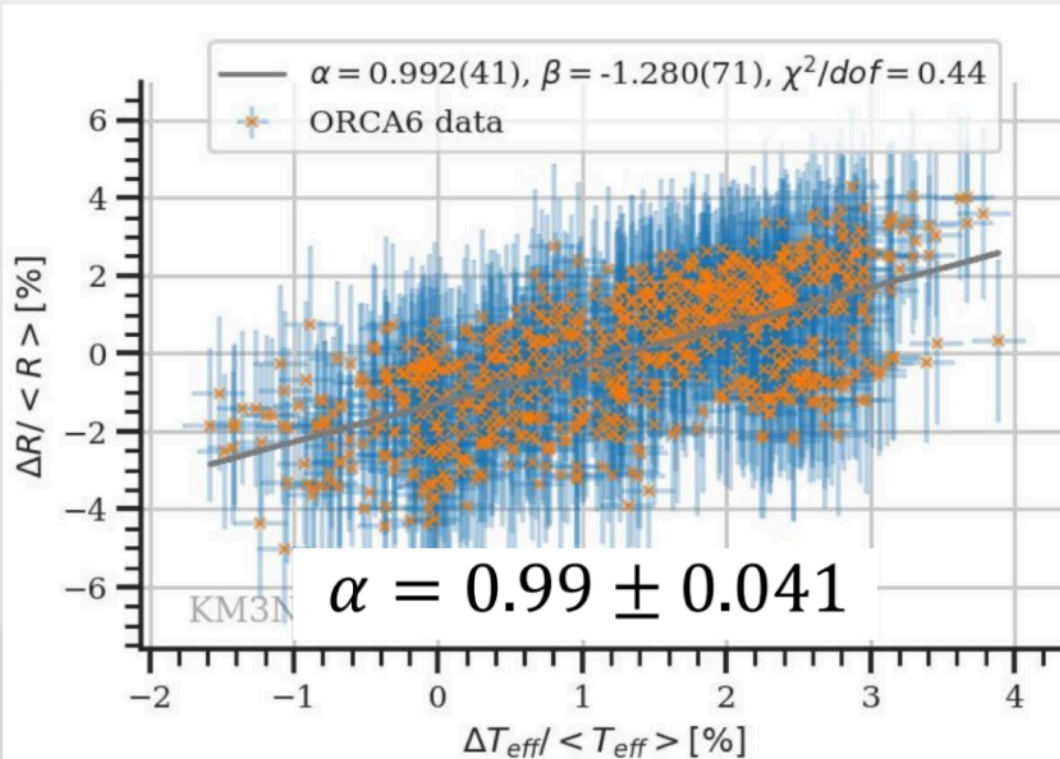
Alert	Type	Time	Status	Energy	Duration	GCN	Details	Analysis
<b>new</b> 709944284	GRB	2023-07-01 22:44:39	Selected	115.74	43.02	GCN_n	Details	Analysis
<b>new</b> 709864601	GRB	2023-07-01 00:38:36	Selected	254.8	72.91	GCN_n	Details	Analysis
S230630bq	GW	2023-06-30 23:45:32	Selected	-	-	GCN_n Link	Details	Analysis
<b>new</b> S230630am	GW	2023-06-30 12:58:06	Selected	-	-	GCN_n Link	Details	Analysis
<b>new</b> S230628ax	GW	2023-06-28 23:12:00	Selected	-	-	GCN_n Link	Details	Analysis
<b>new</b> 1177054	GRB	2023-06-28 22:29:56	Selected	171.8486	-11.464	GCN_n	Details	Analysis
<b>new</b> 709676556	GRB	2023-06-28 20:22:31	Selected	175.02	12.29	GCN_n	Details	Analysis
<b>new</b> 709666599	GRB	2023-06-28 17:38:34	Selected	300.97	35.6	GCN_n	Details	Analysis
<b>new</b> 709623341	GRB	2023-06-28 05:35:36	Selected	131.19	-12.54	GCN_n	Details	Analysis
<b>new</b> 709608965	GRB	2023-06-28 01:38:00	Selected	351.77	-43.8499	GCN_n	Details	Analysis
<b>new</b> S230627c	GW	2023-06-27 01:53:37	Selected	-	-	GCN_n Link	Details	Analysis
<b>new</b> 709482627	GRB	2023-06-25 18:30:22	Selected	146.38	0.09	GCN_n	Details	Analysis
<b>new</b> 709410255	GRB	2023-06-25 18:24:10	Selected	321.2	-18.66	GCN_n	Details	Analysis
<b>new</b> S230624ax	GW	2023-06-24 12:14:46	Selected	-	-	GCN_n Link	Details	Analysis
<b>new</b> S230624av	GW	2023-06-24 11:31:03	Selected	-	-	GCN_n Link	Details	Analysis

Alert	Analysis	Results	Plot
<a href="#">S230531f</a> Burst FAR=1/13.6d	MeV [0, 2s]	z-score=0.56	
	ORCA ±500 s	$N_{ON}=0, N_{BKG}=4.23e-3$	
	ARCA ±500 s	$N_{ON}=0, N_{BKG}=2.78e-3$	
	ORCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=9.22e-2$	
	ARCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=6.11e-2$	
<a href="#">S230601bf</a> BBH (>99%) FAR=1.7e-15 Hz	MeV [0, 2s]	z-score=1.47	
	ORCA ±500 s	$N_{ON}=0, N_{BKG}=2.38e-3$	
	ORCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=3.51e-2$	
	ARCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=2.22e-2$	
<a href="#">S230602ap</a> Burst FAR=1.48e-6 Hz	MeV [0, 2s]	z-score=0.49	
	ORCA ±500 s	$N_{ON}=0, N_{BKG}=2.33e-3$	
	ARCA ±500 s	$N_{ON}=0, N_{BKG}=2.48e-3$	
	ORCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=3.43e-2$	
	ARCA [-500s, +6h]	$N_{ON}=0, N_{BKG}=1.82e-2$	

# RESULTS: COSMIC RAY

22

Correlation between muon rate  
and temperature of the atmosphere



$$\frac{\Delta R(t)}{\langle R \rangle} = \alpha \times \frac{\Delta T_{eff}(t)}{\langle T_{eff} \rangle} + \beta$$
$$\alpha = 0.99 \pm 0.041$$

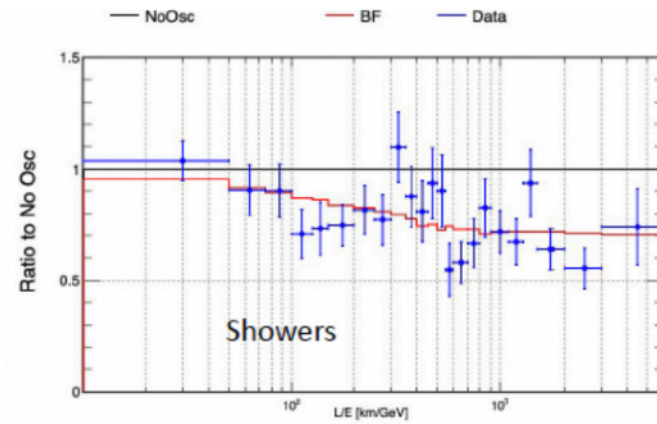
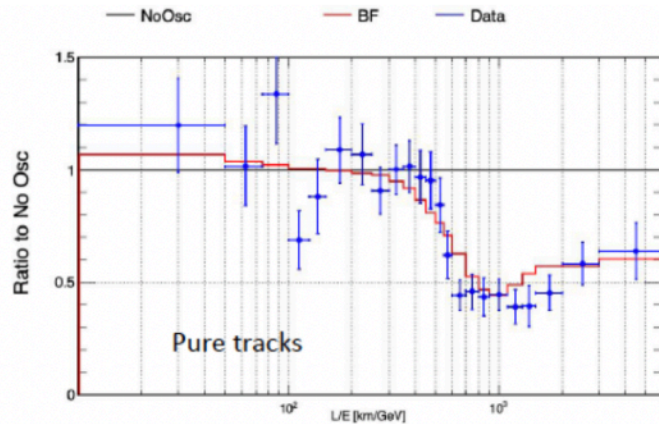
Expected:  $\alpha = 0.9$

$$T_{eff} = \frac{\int d\chi T(\chi) \left[ \int dE_0 \int d\theta P_\mu(E_0, \theta, \chi) A_{eff}(E_0, \theta) \right]}{\int d\chi \left[ \int dE_0 \int d\theta P_\mu(E_0, \theta, \chi) A_{eff}(E_0, \theta) \right]}$$

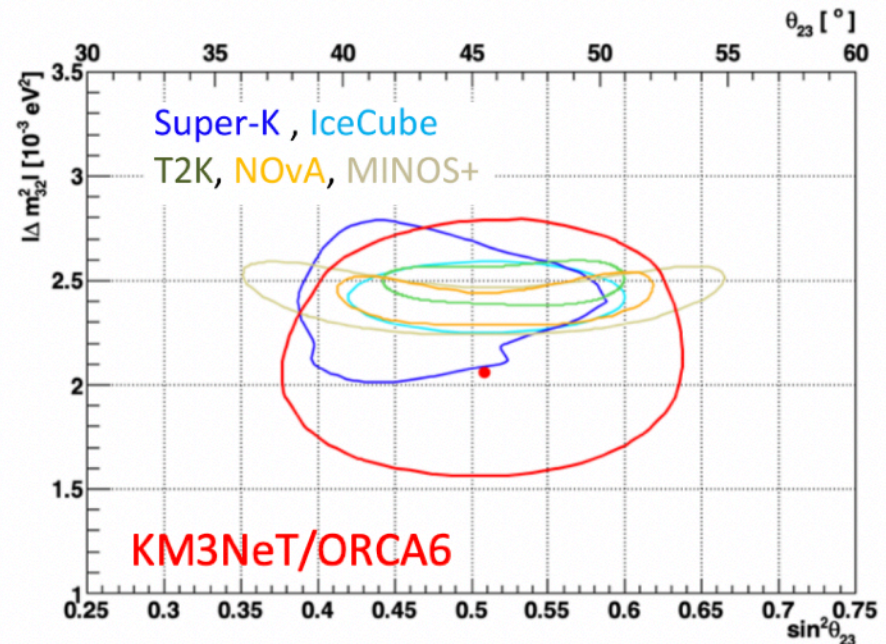


# RESULTS: OSCILLATION

23



- Increased event sample by factor of 5: better selection, add showers, lifetime +40%
- First time we see oscillations in showers
- **1 sigma preference for Normal Ordering**
- Also competitive results on:
  - Tau appearance
  - Non standard interactions
  - neutrino decay
  - Lorentz invariance violation



- PUBLISHED

- Nanobeacon: A time calibration device for KM3NeT neutrino telescope - NIMA [10.1016/j.nima.2022.167132](https://doi.org/10.1016/j.nima.2022.167132)
- The KM3NeT multi-PMT optical module - JINST <https://iopscience.iop.org/article/10.1088/1748-0221/17/07/P07038>
- KM3NeT broadcast Optical Data Transport System - JINST <https://iopscience.iop.org/article/10.1088/1748-0221/18/02/T02001>
- First observation of the cosmic ray shadow of the Moon and the Sun with KM3NeT/ORCA - EPJC <https://doi.org/10.1140/epjc/s10052-023-11401-5>
- Probing invisible neutrino decay with KM3NeT/ORCA - JHEP [https://doi.org/10.1007/JHEP04\(2023\)090](https://doi.org/10.1007/JHEP04(2023)090)

- TO BE PUBLISHED SOON (under review of the collaboration)

- KM3NeT CLB Embedded Software
- Prospects for combined analyses of hadronic emission from  $\gamma$ -ray sources in the Milky Way with CTA and KM3NeT
- Searches for neutrino counterparts from gravitational waves from the run O3 with KM3NeT

KM3NeT @ LNS

# Nuove attività in corso ai LNS

- KM3NeT4RR 🖱 WP a responsabilità LNS:
  - WP1 - Management
  - WP2 - On shore infrastructures (P. Piattelli) - tenders on going
  - WP5 - Sea Floor Network (S. Biagi) - tenders on going
  - WP7 - Implementation of multi messenger liasons (R. C.) - [post docs at INAF and Universities almost all hired + 3 PhDs - first meeting in Bologna 24/5/2023](#)
- At LNS 🖱 1 project manager + 2 tecnologi (+2 su ITINERIS) + 8 tecnici
- First deadlines:
  - [tenders to be assigned before the end of 2023](#)
  - [People hired](#)
- INFRADEV2: EU project started 1st of January 2023
  - WP2 - Legal Entity (P. Sapienza)
  - WP3 - Accelerating implementation - [a post doc for RAM software analysis](#) (R = reliability, A = Availability, M = Maintainability) ([Bologna](#))
  - WP5 - Sustainability and socio-economic impact - [a post doc for socio-economic impact study \(LNS\)](#)
- PRIN 🖱 ALICA - Atmospheric Leptons In Cherenkov Arrays
  - PI Matteo Sanguineti Genova
  - At LNS 🖱 66k€ - 1 year post-doc
  - [Project not yet started](#)

# Attività in corso ai LNS

- Definizione Campagne marine
- Upgrade stazione di terra Capo Passero
- Espansione rete di fondo (JB + interlink cables)
- Integrazione DU
- Integrazione BM
- Procurement
- Detector and infrastructure operation
- PNRR tenders and governance 🙌 new project manager (S. Ciancio)

# LNS e KM3NeT

Tutti i LNS contribuiscono alla riuscita di KM3NeT ed in particolare

- Amministrazione
- Servizio fondi esterni
- Reparto di elettronica e rivelatori
- Reparto infrastrutture marine
- Divisione tecnica
- Divisione acceleratori



# RICHIESTE 2024

## Richieste straordinarie 2023

Quasi esaurito il budget di missioni 2022

29/06/23			
Attività	Dettaglio	Richiesta (k€)	Note
Missione a Malta per finalizzazione processo 6 per campagna marina Settembre	6 persone per 4 gg	9,00	circa 1.5 k€ a persona
Missioni Capo Passero preparazione	20 persone *1gg	3,20	1 giorno di missione a Capo Passero 0,160k€
Missione sulla nave per campagna marina di Settembre deployment 10 DU	3 persone per 10 gg	9,00	0,3 k€ al giorno incluso di viaggio
Attivity on shore per campagna marina Settembre- Capo Passero	10 persone per 10-12 gg (2 viaggi)	24,00	diaria 50euro/giorno+albergo 120 euro a notte + viaggio
Collaboration Meeting	6 persone per 5 giorni (Parigi)	12,00	2K€ a persona
Missioni per contatti con ditte e per costruzione (Caserta)	3 persone per 5 missioni	22,50	1,5k€ a persona
ALCATEL installazione e collaudo PFE (Capo Passero)	3 persone per 4 gg	3,00	1k€/persona
<b>Totale</b>		<b>82,70</b>	

Si richiedono circa  $82.7 - 8 = 74,7k€$

## Richieste 2024

<b>Capitolo</b>		<b>Keuro</b>
<b>Missioni</b>	<b>Totale</b>	<b>182,15</b>
<b>Consumo</b>	<b>Totale</b>	<b>45,00</b>
<b>Altro consumo</b>	<b>Common Funds</b>	<b>520,17</b>
<b>Trasporti</b>	<b>Totale</b>	<b>39,00</b>
<b>GRAN Totale</b>		<b>786,32</b>
<b>Totale senza CF</b>		<b>266,15</b>

Richieste  
2023

155

55

466+150=616

47

Capitolo		Keuro
<b>Missioni</b>	meeting collaborazione 1/3 FTE x 1.5k€ x2	19,31
	meeting steering committee 3 persone x 1 meeting	4,20
	gruppi di lavoro e workshop tematici	19,20
	2 campagne marine 2 persone in nave e 12 persone nella stazione di terra	41,20
	contatti ditte - estero (MacArtney DK )	45,00
	contatti ditte - Italia (Elmacom, MBE )	27,36
	coordinamento tecnico (Klaus Leismuller)	3,76
	viaggi tecnici PNRR per contatti ditte e attività di coordinamento pNRR	5,82
	Missioni Caserta per training e integrazione DU WWRS	6,30
	attività installazione, manutenzione a Capo Passero	10,00
	presentazioni km3net a conferenze Italia	7,35
	presentazioni km3net a conferenze estero	26,88
<b>Missioni</b>	<b>Totale</b>	<b>182,15</b>



<b>Consumo</b>	Materiale consumo integrazione stringhe e Base Module - Calcolato come 1k€ per il numero totale di DU da integrare -> 1 k€ *20	20,00
	Materiale consumo per Capo Passero - Cavetterie - etichette e placche	7,00
	Materiale consumo acustica - reburbishemnt beacon, pacchi batterie, gel	8,00
	Materiale consumo ottica e potenza - riparazione strumenti di misura	10,00
<b>Consumo</b>	<b>Totale</b>	<b>45,00</b>
<b>Altro consumo</b>	<b>Common Funds</b>	<b>520,17</b>
<b>Trasporti</b>		
	Trasporto elettronica dai LNS a McArtney (Danimarca)	20,00
	Trasporto strumentazione da LNS a Porto Catania	4,00
	Movimentazione al porto di Catania	15,00
<b>Trasporti</b>	<b>Totale</b>	<b>39,00</b>
<b>GRAN Totale</b>		<b>786,32</b>
<b>Totale senza CF</b>		<b>266,15</b>

## FTE 2024 - Preliminari

NOME	FTE KM3 2024	FTE fondi esterni	FTE Totali	Fondi Esterni Note
Biagi Simone	80	0	80	
Calì Michele	100			
Cherubini Silvio	50		50	
Cocimano Rosanna	100	0	100	
Coniglione Rosa	83	17	100	KMINFRADEV2
Cuttone Giacomo	56	4	60	KMINFRADEV2
Di Mauro Letizia Stella		100	100	CIR01_00018 (IPANEMA)
Distefano Carla	70		70	
Ferrara Giovanna		10	10	KM3NeT4RR Università CT
Giorgio Emidio	70		70	
Larosa Giuseppina	100		100	
Musumeci Mario	50		50	
Orlando Angelo	100		100	
Piattelli Paolo	63	17	80	KMINFRADEV2
Pulvirenti Sara	100		100	
Riccobene Giorgio	80	0	80	
Santonocito Domenico	20		20	
Sapienza Piera	53	17	70	KMINFRADEV2
Viola Salvo	60	0	60	
Zito Daniele		100	100	PNRR- KM3NeT4RR
Valsecchi Veronica	50		50	
Didac Diego i Tortosa	100		100	
Dino Franciotti	50		50	
Bonanno Danilo		100	100	PNRR ITINERIS da confermare
Sanfilippo Simone		100	100	ITINERIS da confermare
Daniele Paesani		100	100	KM3NeT4RR
<b>Totale</b>	<b>14,35</b>	<b>5,65</b>	<b>20</b>	
<b>Totale KM3+fondi esterni</b>	<b>20</b>			



100% in KM3NeT

In 2023

<b>13,5</b>	<b>2</b>	<b>15,5</b>
<b>15,5</b>		