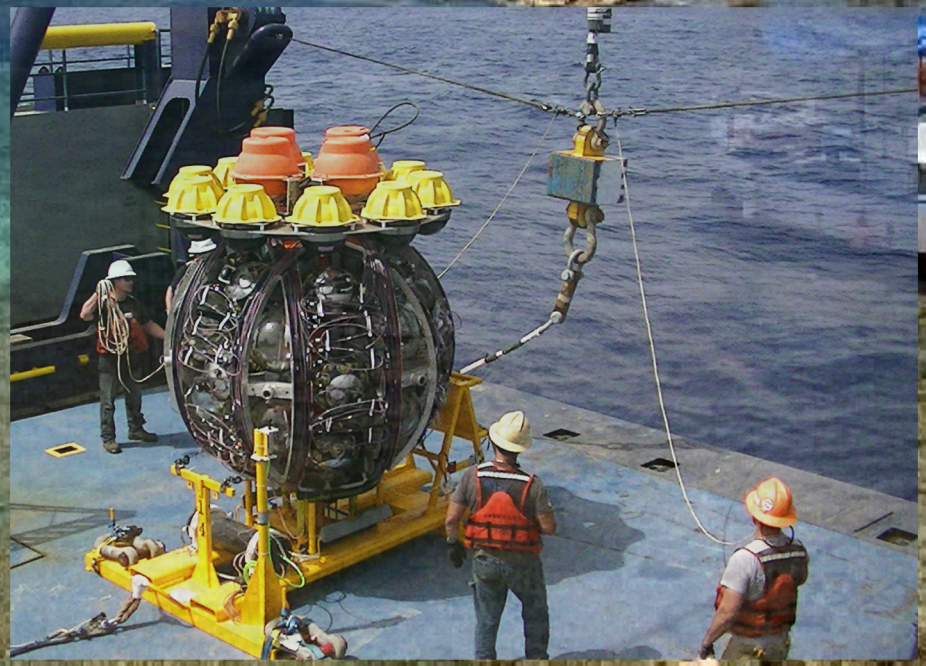
CRIS 2018

Status and development of KM3NeT

Giorgio Riccobene INFN – LNS
On behalf of the KM3NeT Collaboration



The giant-scale detector KM3NeT

KM3NeT will be a distributed reasearch infrastructure

Network of cabled observatories located in deep waters of the Mediterranean Sea.

Centrally managed: common hardware, software, data handling and control

Astronomy: ARCA @ Capo Passero 3500 m wd

2 building blocks (few km among the blocks)

115 Detection Units(DU) / block

18 DOMs (36 m inter-DOM), 90 m inter-DU distance

1 km^3 volume

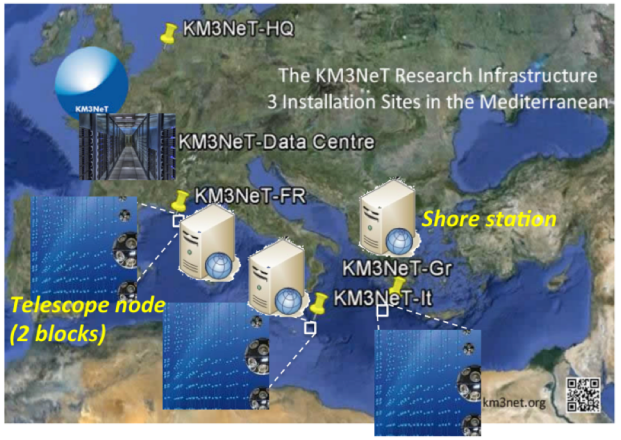
Oscillations and Mass Hierarchy: ORCA @ Toulon 2500 m wd

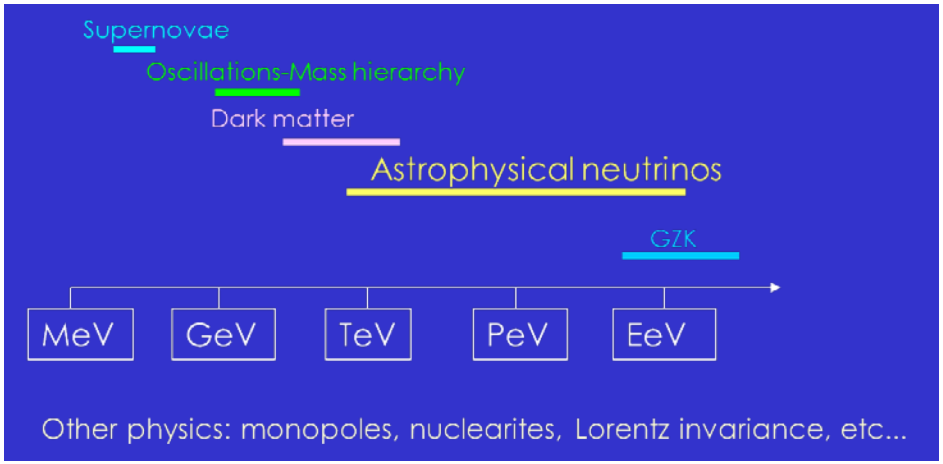
1 building block

115 detection Units

18 DOMs (9 m inter-DOM), 23 m inter-DU distance

8 Mton volume





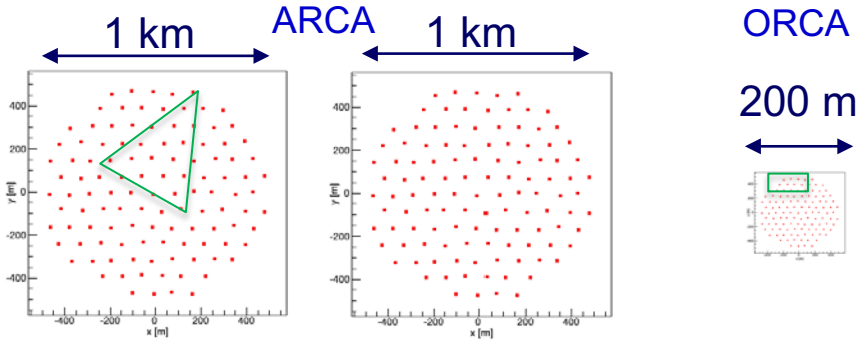
A growing Collaboration !

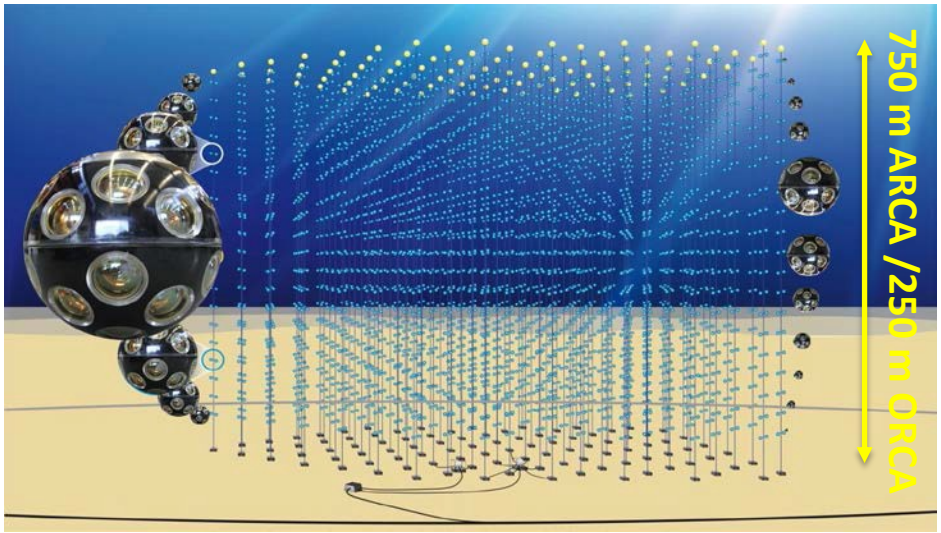
KM3NeT in the Med Sea

Large volume of transparent medium surveyed by photodetector

- Deep Sea water
- Long light absorprion length (70 m)
- Very small light scattering (good angular resolution)
- Natural backgrounds (^{40}K and biolum) can be handled
- Northern terrestrial hemisphere:
- Complementary to IceCube
- Upgoing tracks from southern sky sources. Milky-Way optimized

KM3NeT 2.0 Letter of Intent:
arXiv:1601.07459 and
J.Phys. G43 (2016) 084001



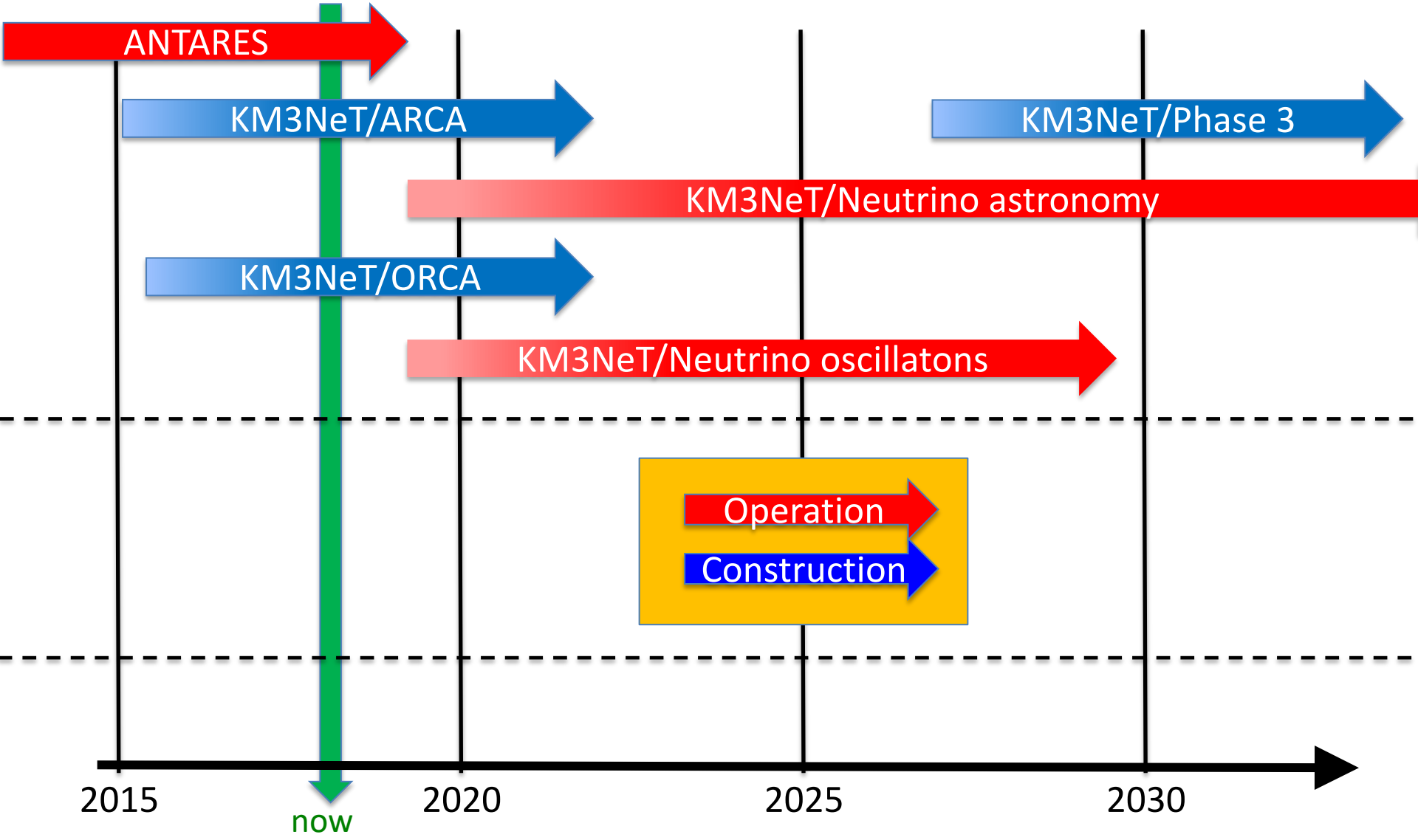


Phase 1: 24 ARCA + 7 ORCA strings

KM3NeT 2.0: 2 ARCA +1 ORCA blocks
~50% funded →2021

Phase 3: 6 ARCA + 1 ORCA blocks

The KM3NeT timeline



KM3NeT: the DOM

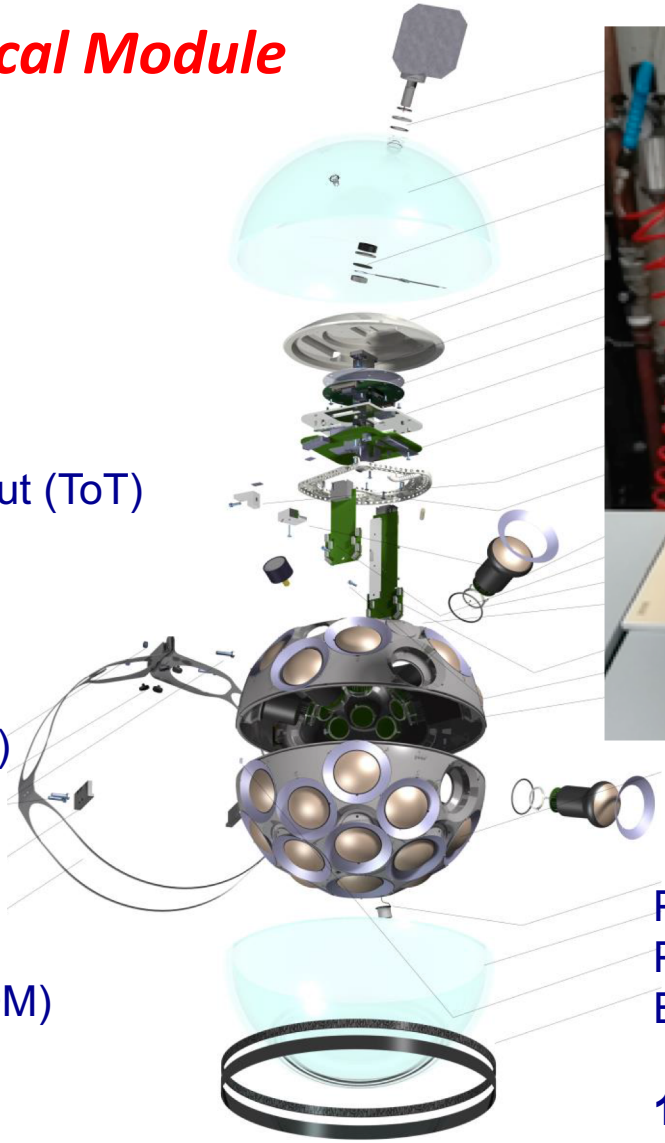
Multi-PMT Digital Optical Module

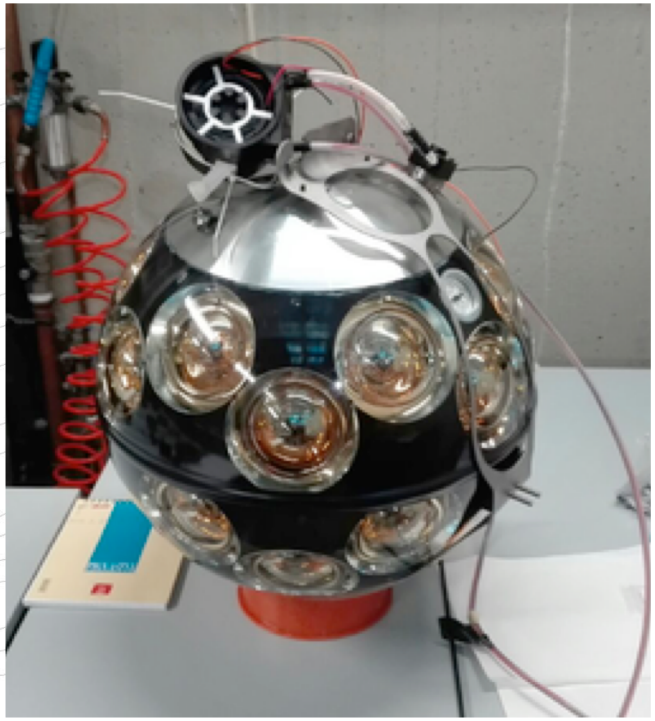
17'' glass housing
e.o. penetrator
3d printed support structure
cooling structure (mushroom)

31 x 3'' PMTs
light collection cone
active base & digital signal readout (ToT)
equalised PMT Gain ($3*10^6$)
Threshold 0.3 s.p.e.

AHRS (tilt, compass)
Digital piezo receiver (positioning)
LED emitter (time calibration)

Central logic board (CLB)
FPGA-based, white rabbit (T_{GPS})
DWDM optical comm (1 color/DOM)
power board
All data to shore



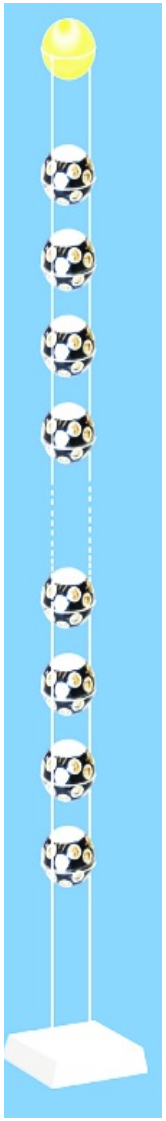


Photon counting
Particle direction reconstuction
Enhanced photocathode area

1DOM = 1 ANTARES Storey

About 100 components per DOM

Detection Unit: vertical slender string with 18 DOMs



String

1 Buoy

2 Dyneema ropes

18 DOMs

Electro-optical backbone:

- Flexible hose 7mm
- Oil-filled
- 18 fibres
- 2 copper wires (375VDC)

DU Base

Anchor with electro-optical ROV mateable connector

Base Module:

- CLB (white rabbit timing)
- Power control board
- Optical amplifier

Hydrophone

LBL beacon

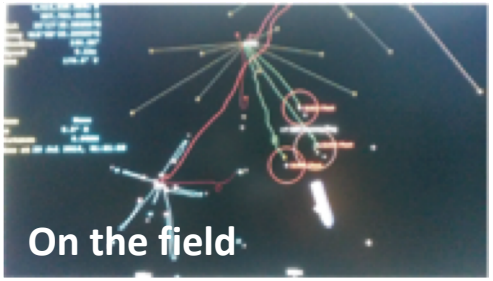
LOM (DU launch only)

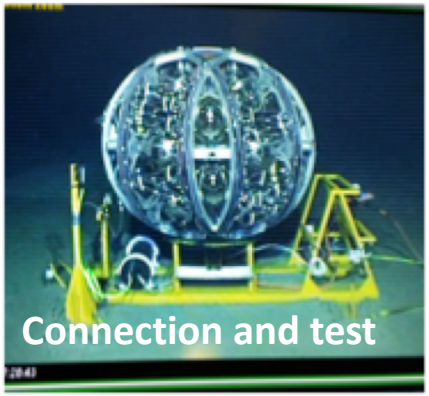
9 (ORCA) /36 (ARCA) m distance between DOMs

36 (ORCA) /72 (ARCA) m anchor-first storey

250 (ORCA) /750 (ARCA) m total height from seabed

Deployment of an ARCA-DU

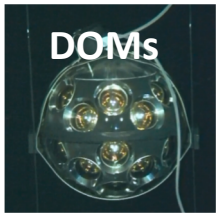


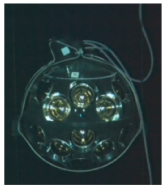


Winch and ROV guides DU landing ±2 m accuracy

Batched deployment: 6 DUs in a single ship operation

Deployment of an ARCA-DU

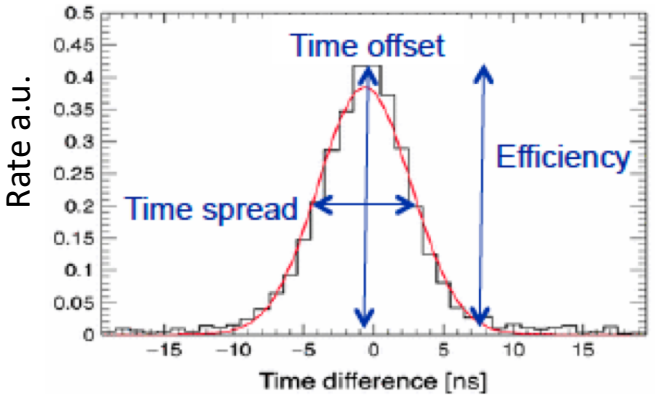




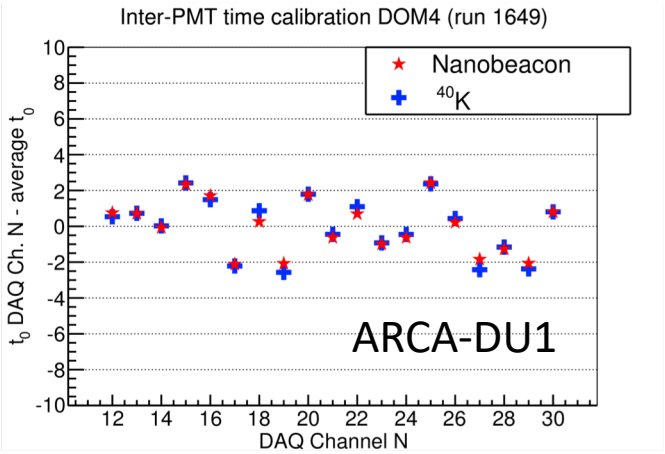
DOM: validation and performances

150 Cherenkov photons per decay
stable ^{40}K concentration

2-fold PMT coincidence in a DOM



L1 trigger
Intra-DOM calibration

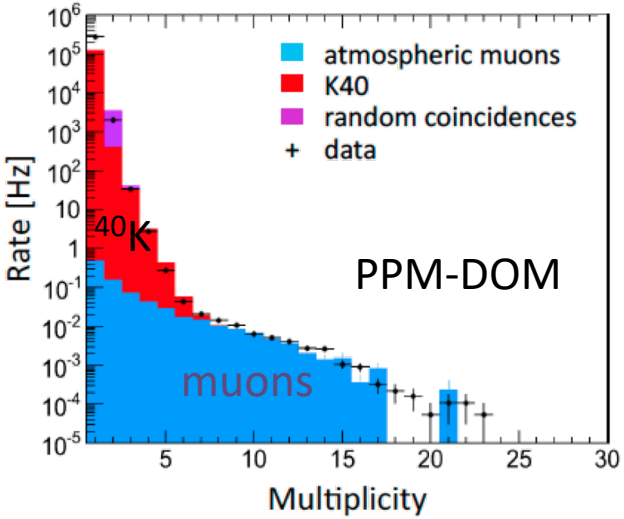


Muon/background separation with the DOM in ANTARES (PPM-DOM)

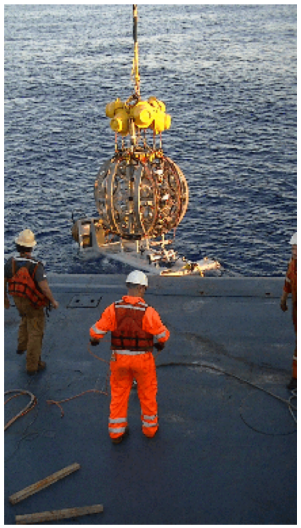
Photon counting + coincidences

N_{coinc}>6 suppress ^{40}K
^{40}K rate: 5kHz

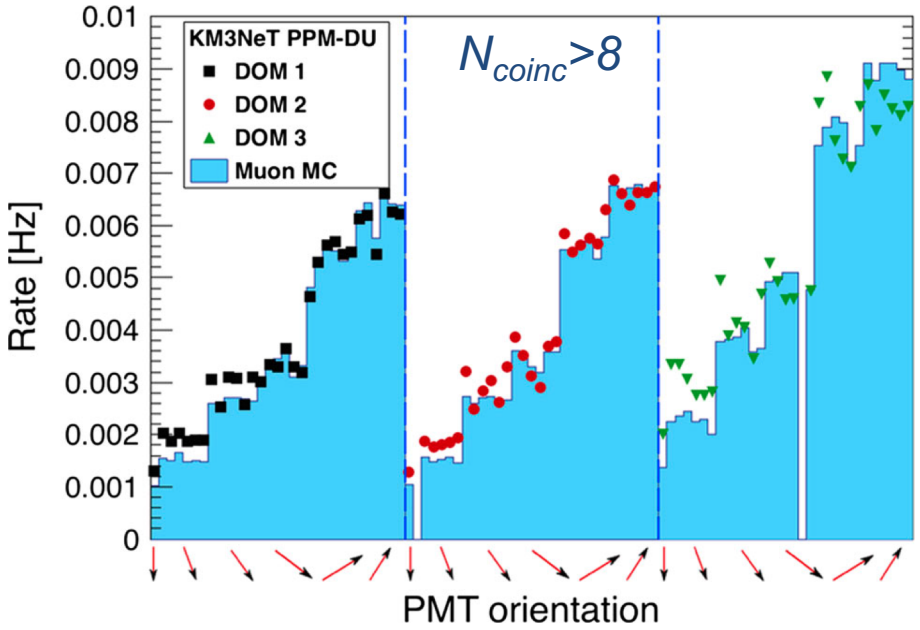
Eur. Phys. J.
C (2014) 74: 3056



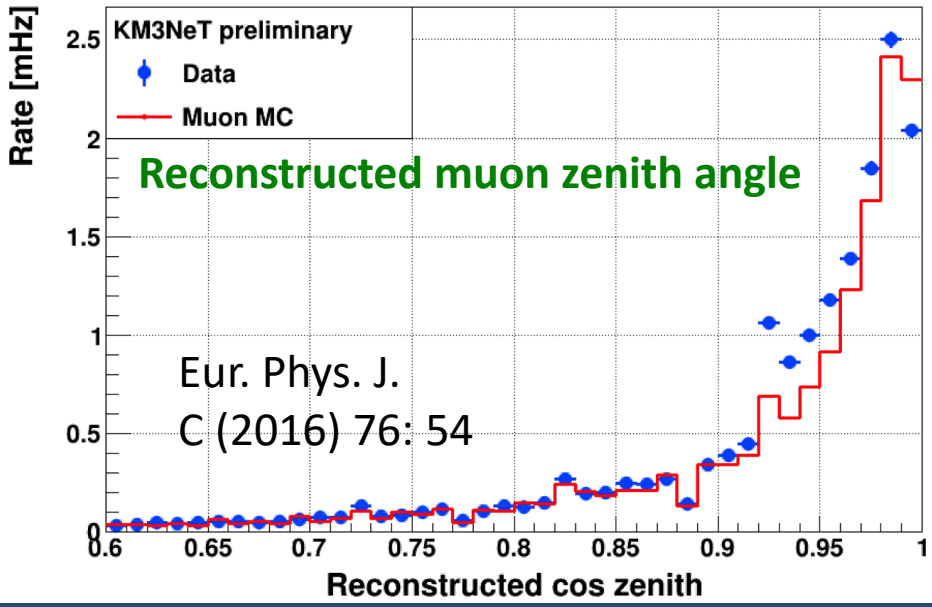
The PPM-DU in Capo Passero



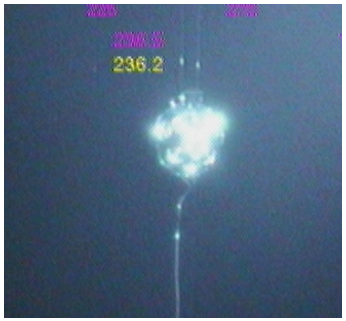
3 Multi PMT DOMs
in a mini DU:
muon track reconstruction



Directionality:
Upper PMTs see Cherenkov light from downgoing muons



Eur. Phys. J.
C (2016) 76: 54



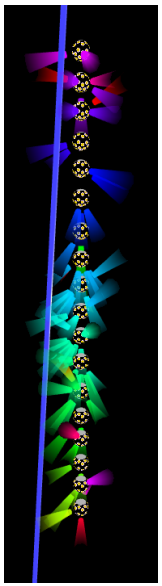
First Results

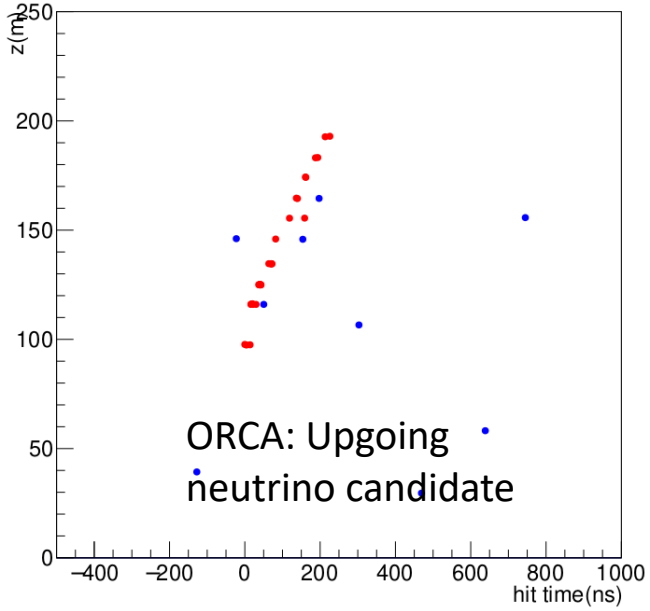
2 full strings in ARCA site
1 full string in ORCA site

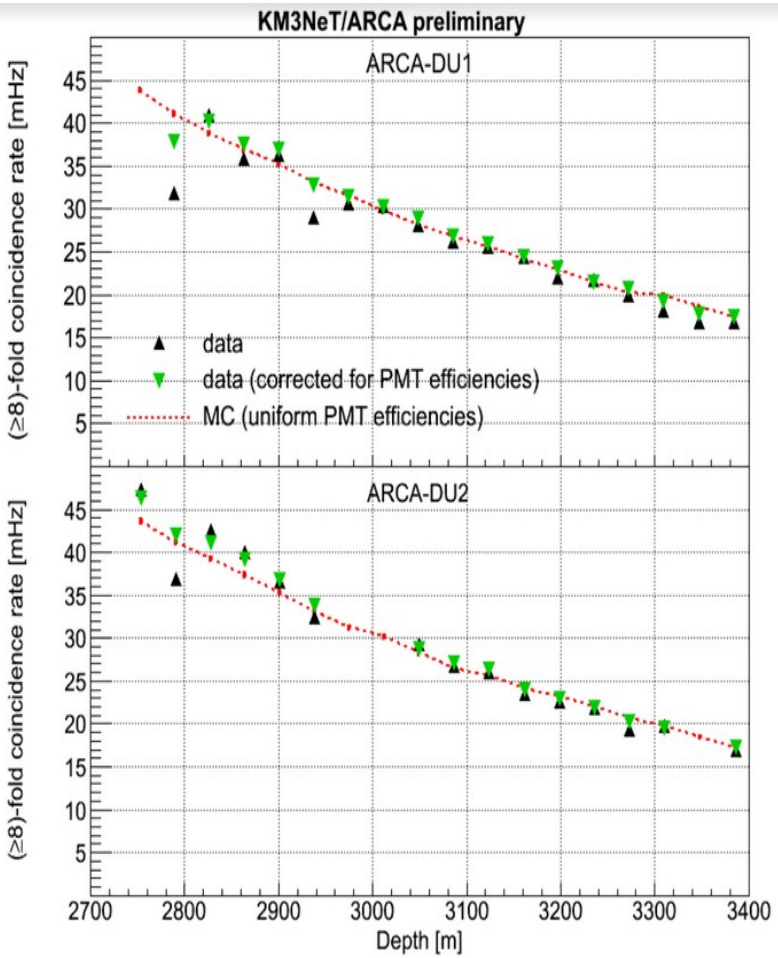
Muon reconstruction

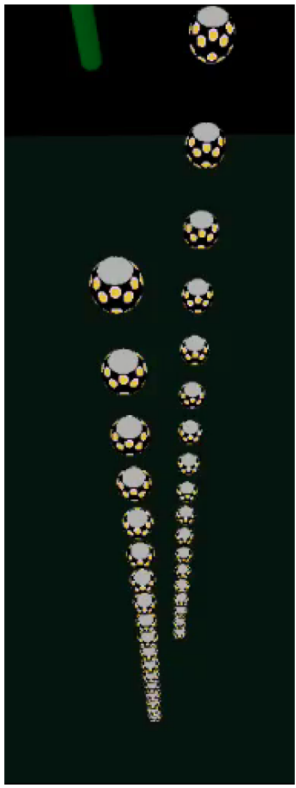
Muons vs depth

Neutrinos



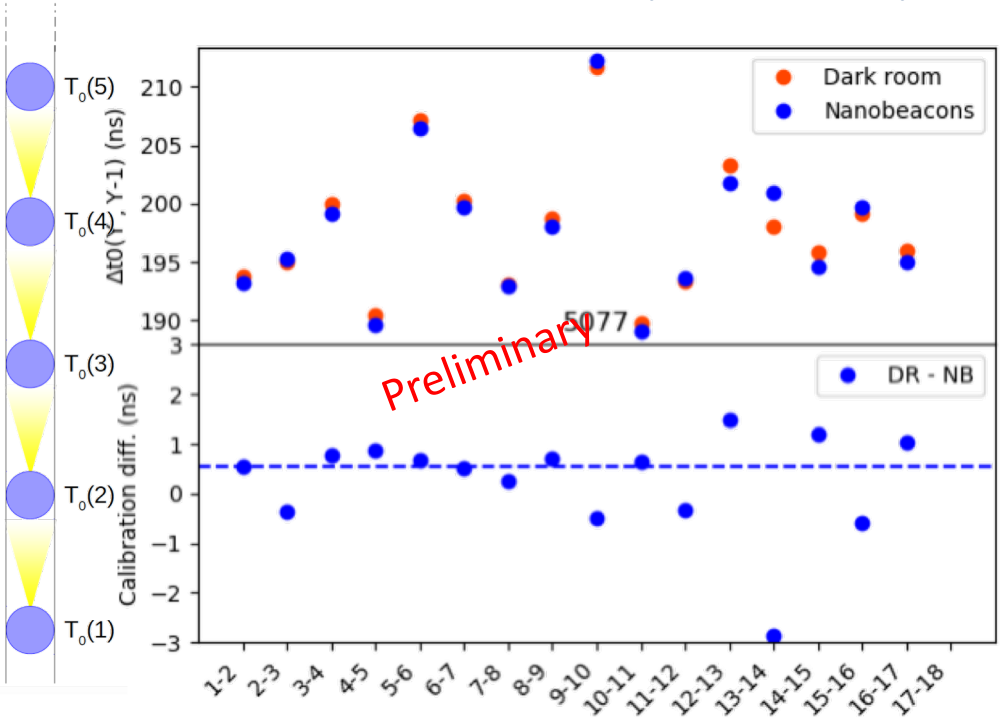


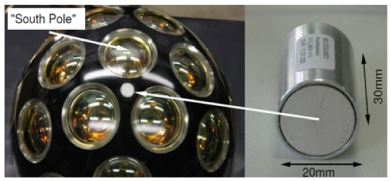




Calibration (Work in progress)

Intra-DU time calibration check (nanobeacon)



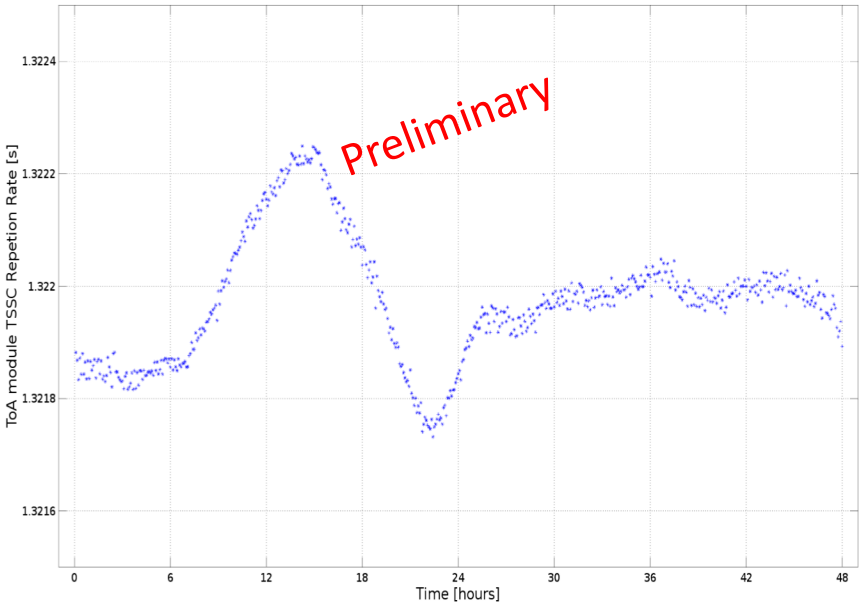


Median values, calculated every 5 minutes

50 μs ~ 8 cm range resolution

In-situ check of time calibration

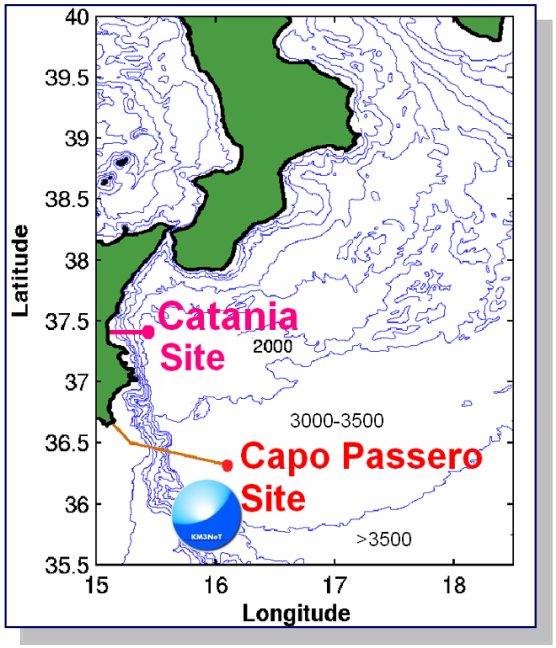
Positioning system

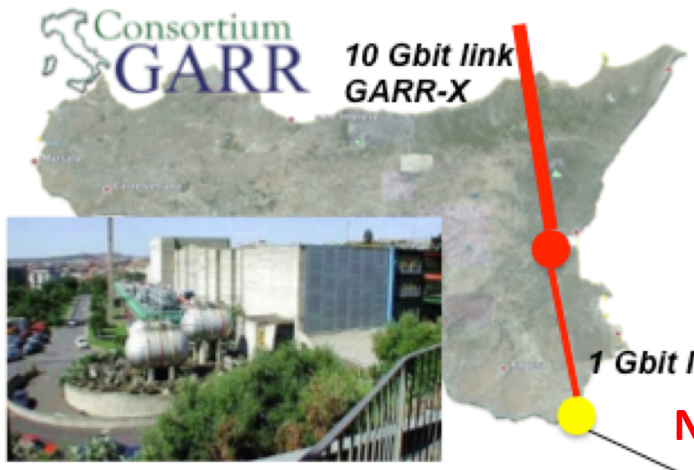


KM3NeT/ARCA: infrastructure

KM3NeT/ARCA Capo Passero Site (plus Earth and Sea science node)

90 km South East offshore Capo Passero, 3450 m depth





The Capo Passero site

- Excellent water optical properties
- Low optical background
- Low and stable deep sea water currents
- Wide and flat abyssal plain

New 10 Gbit from June 28!

The Capo Passero submarine insfrastructure

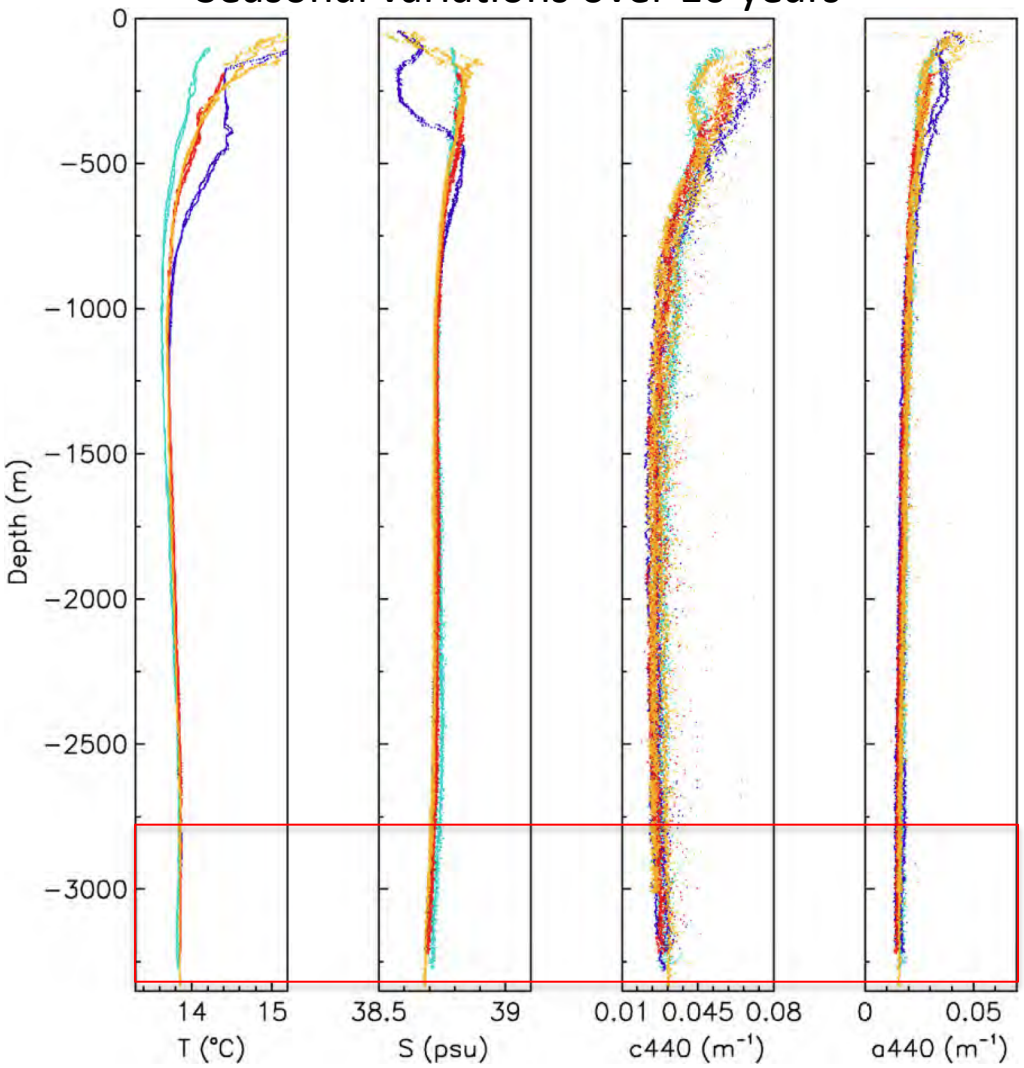
- MEOC: 20 fibres, 80 kW , CTF with 5 outupts (Phase 1)
- 2nd MEOC +CTFs tender in itinere (Phase 2)
- JBs: new tender in itinere for hi-rel JB for Phase 1 and Phase 2 (1st BB)
  reconnection of 2 DUs with a mini-JB in fall 2018

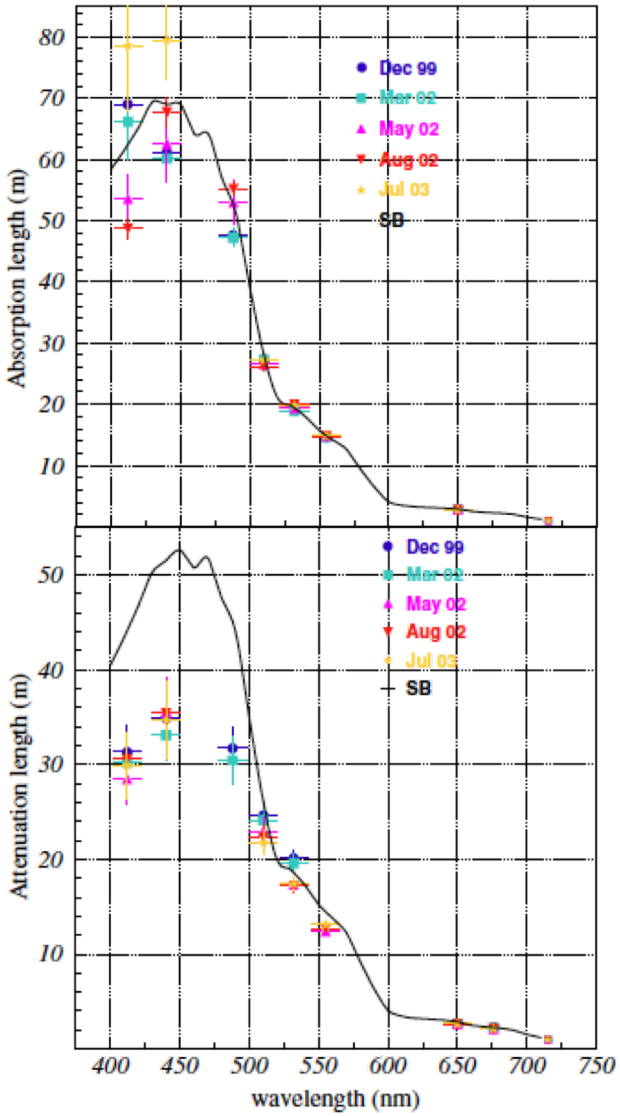
The Capo Passero Shore Lab

- Power Feeding Equipment
- DAQ Centre + Buffer storage
- Guest House
- Welcome to visit !

Capo Passero: Water optical Properties

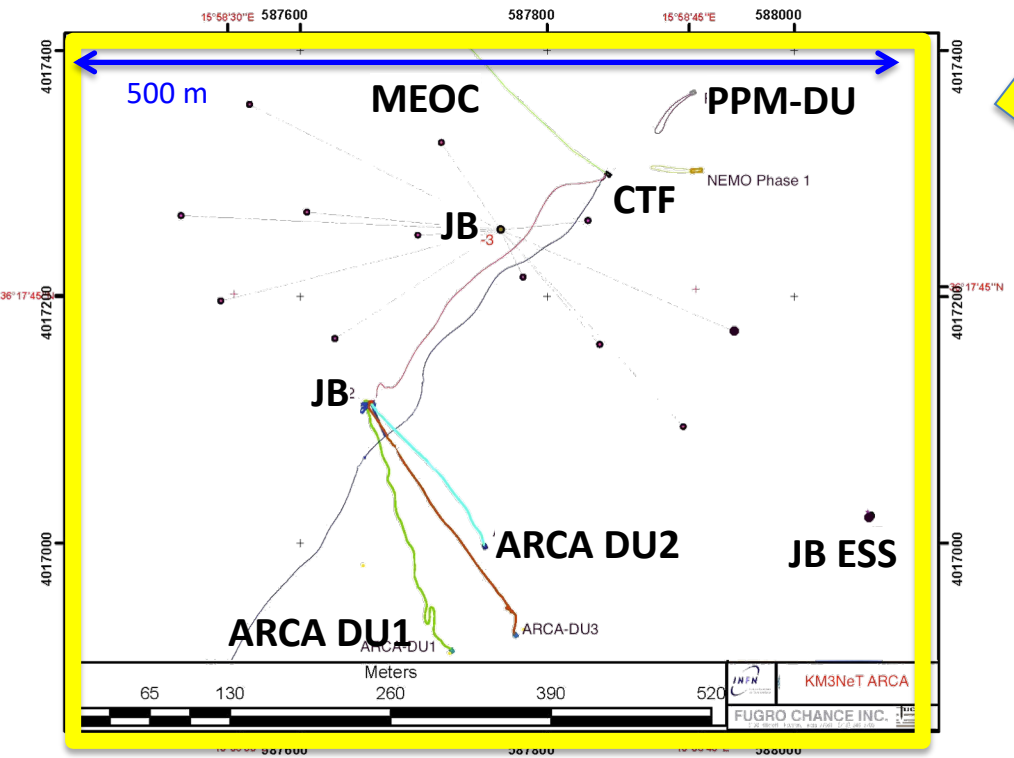
Seasonal variations over 10 years

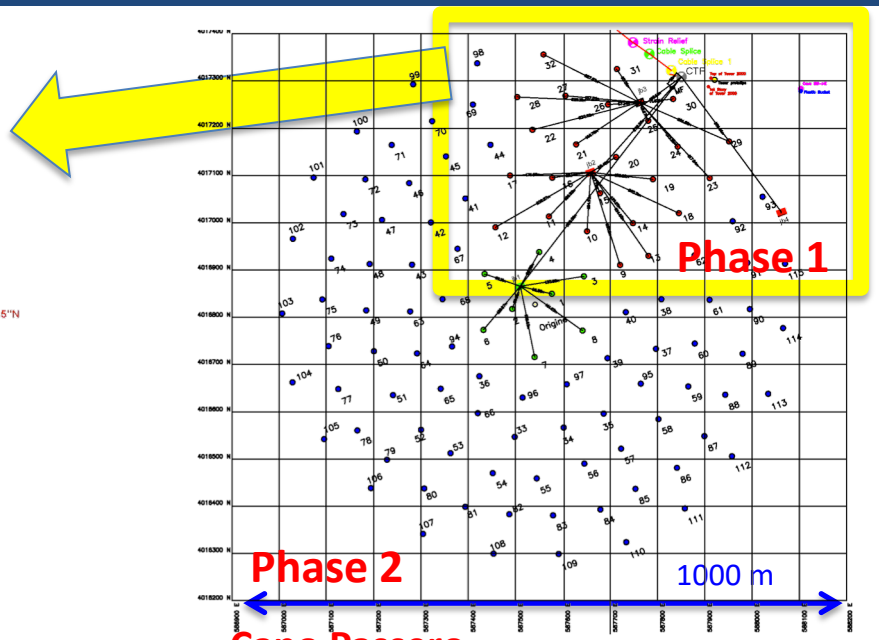




Astroparticle Physics 27 (2007) 1–9

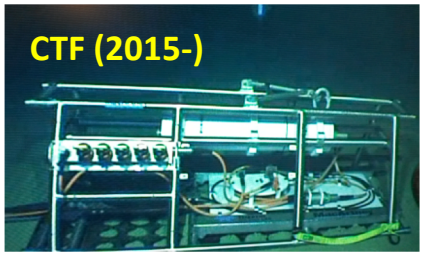
KM3NeT/ARCA: footprint and seabed network

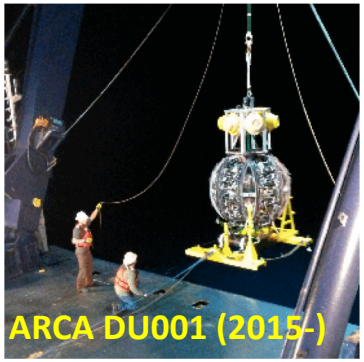


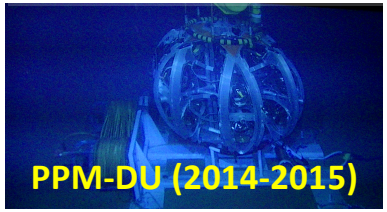


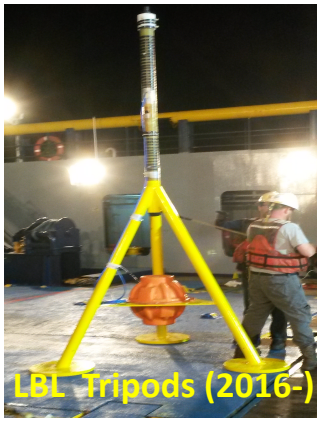
Capo Passero
ARCA Buliding block 1

ARCA Phase 1

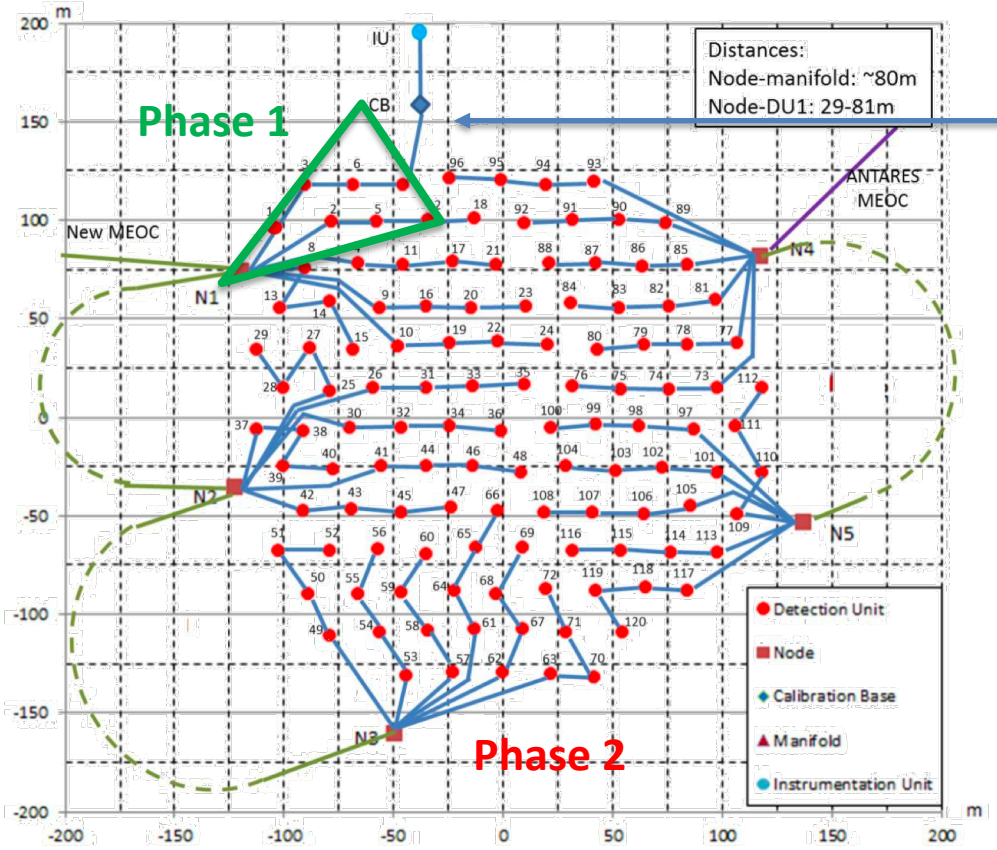


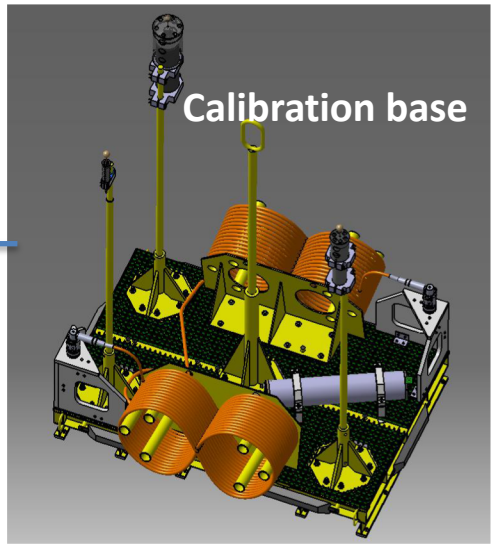


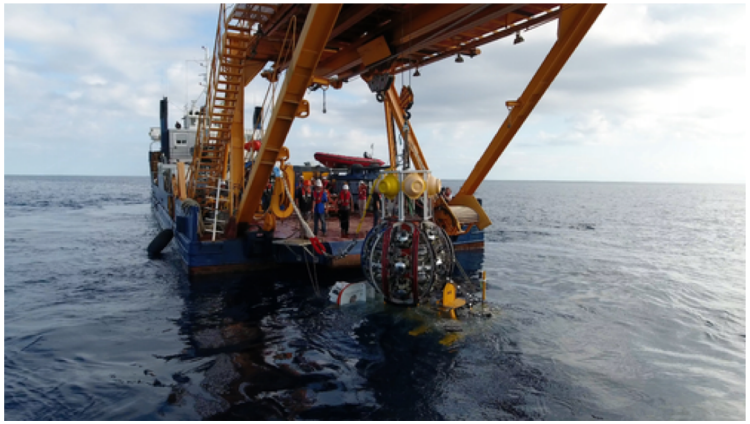




KM3NeT/ORCA: footprint and seabed network

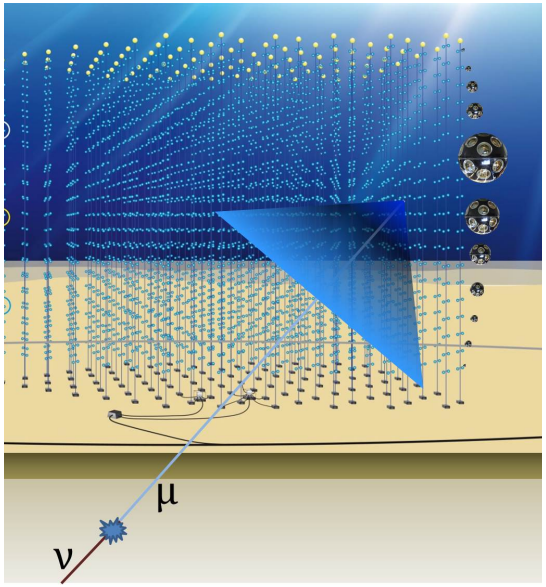




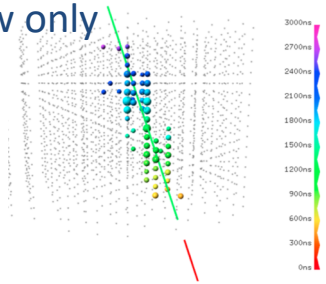


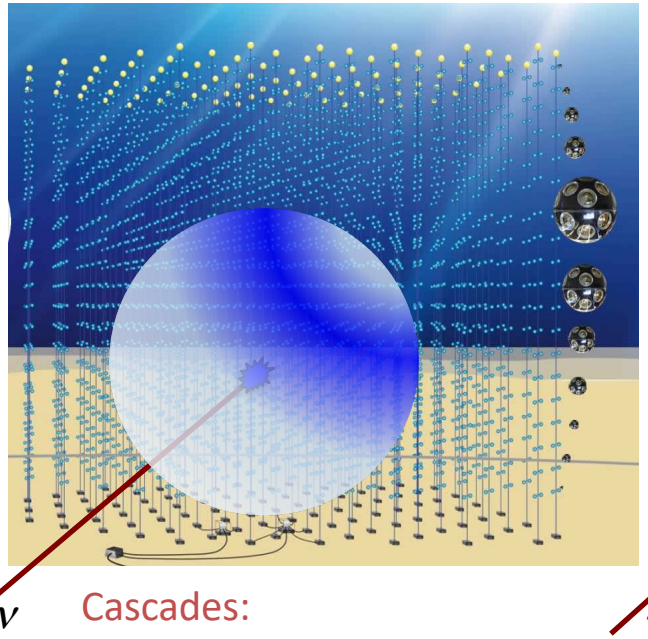
Cable refurbishment and DUs deployment end of summer

Neutrino detection channels

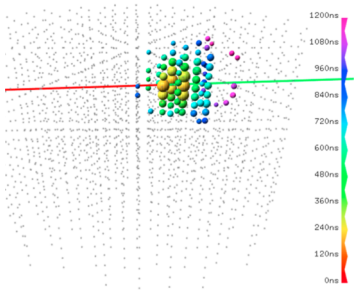


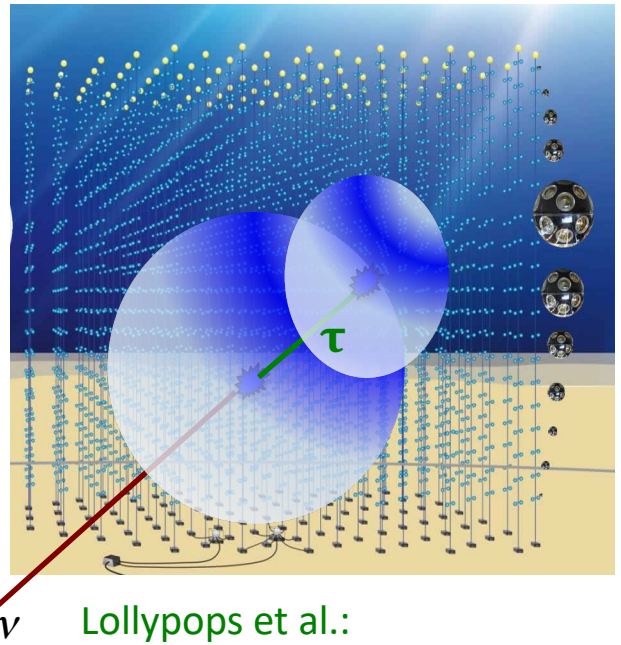
Tracks:
CC muons (and taus)
highest effective area, good angular resolution
High atmospheric muon background: look at events from below only



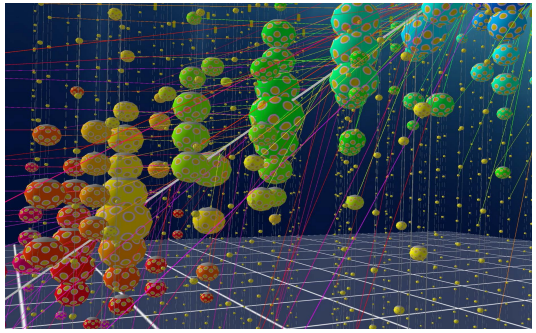


Cascades:
NC, CC electrons and taus
remove atmospheric muon background: studies over 4π.
'Good' energy resolution, worse directional resolution

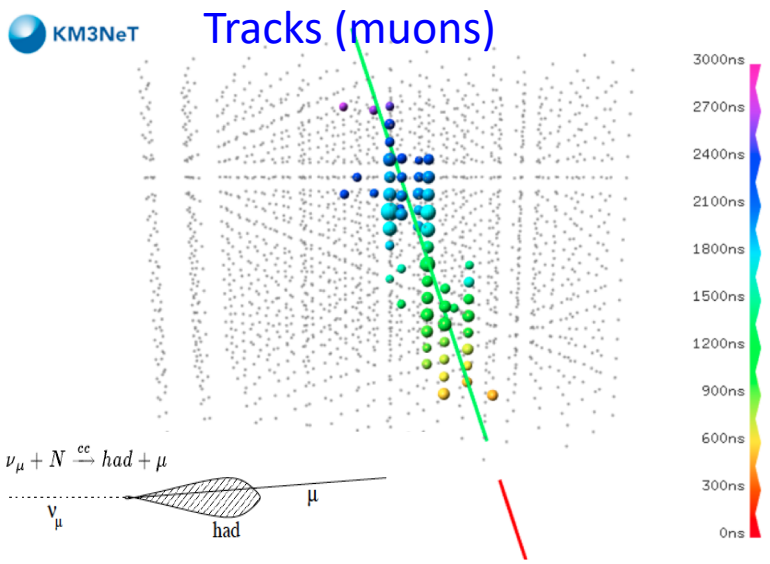


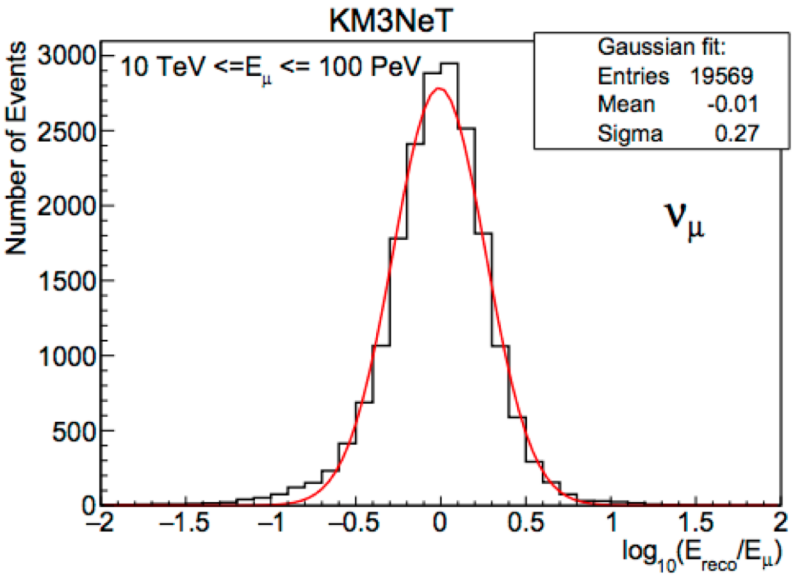


Lollypops et al.:
taus (HE)
Unambiguous topology
at E_{tau}> PeV

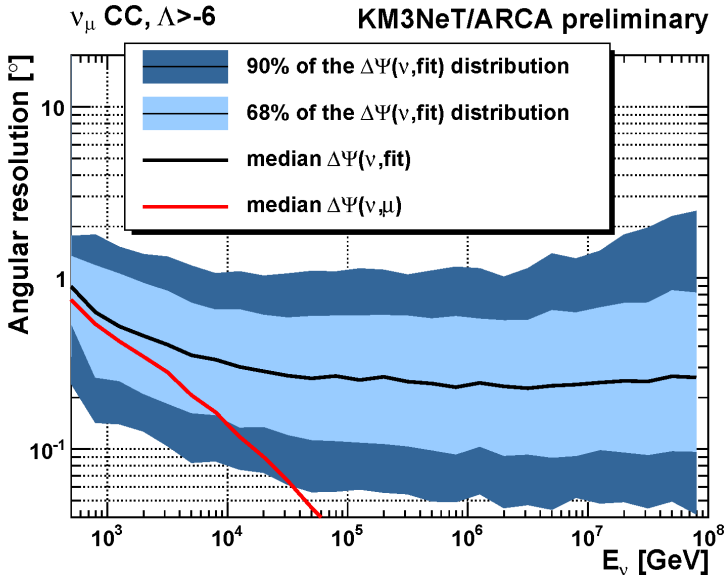


ARCA (Phase 2): Performances





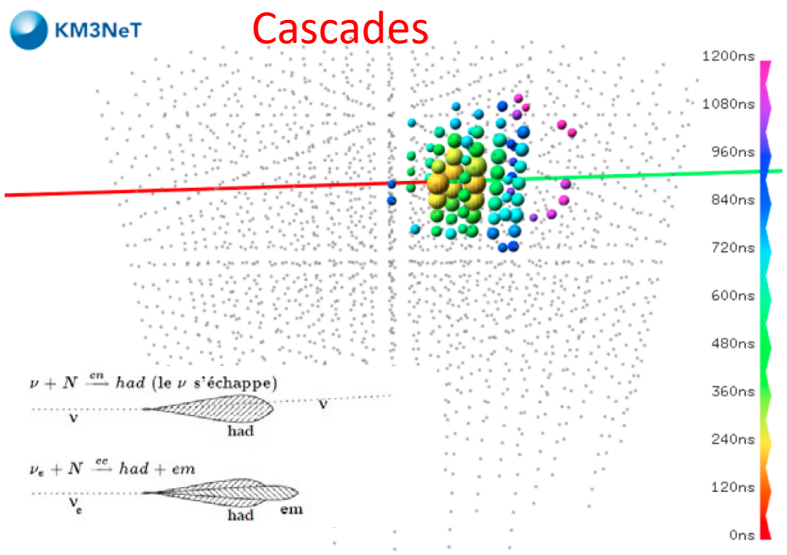
Energy resolution d(log10 E)=0.25-0.3 E_μ> 10 TeV

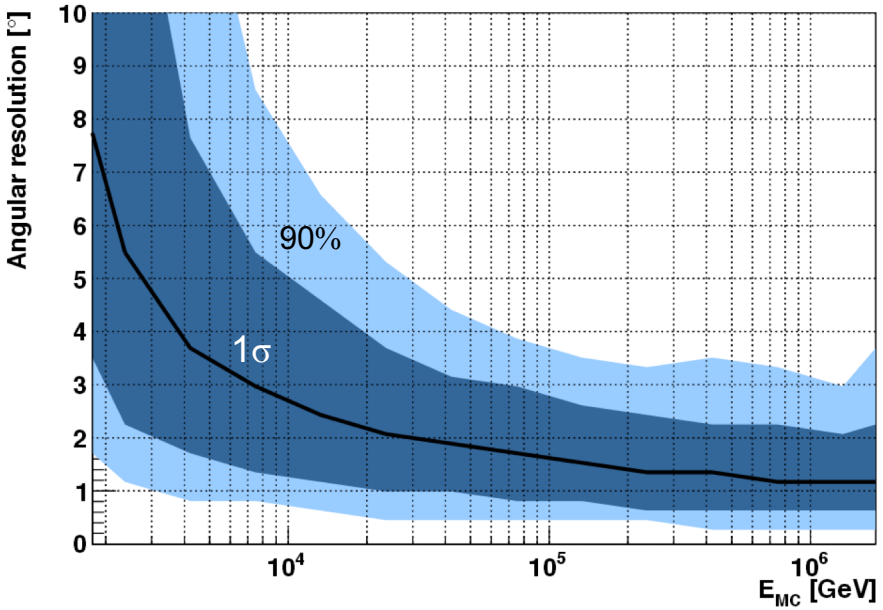


Median angular resolution <0.2° E_ν>10 TeV

Median angular resolution <0.1° E_ν>10^5 GeV

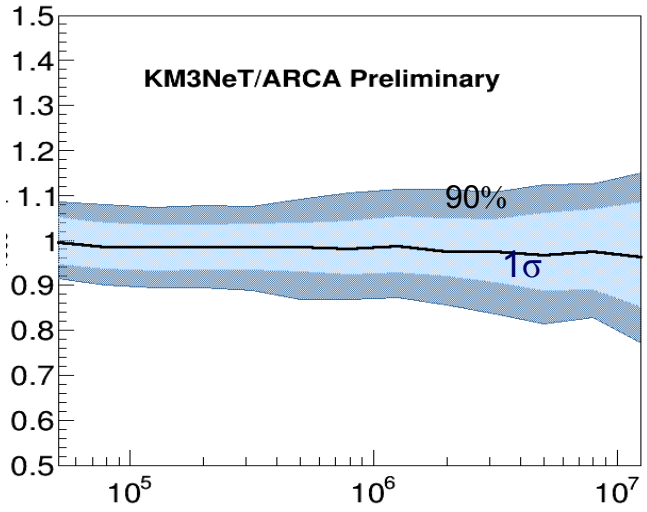
ARCA (Phase 2): Performances

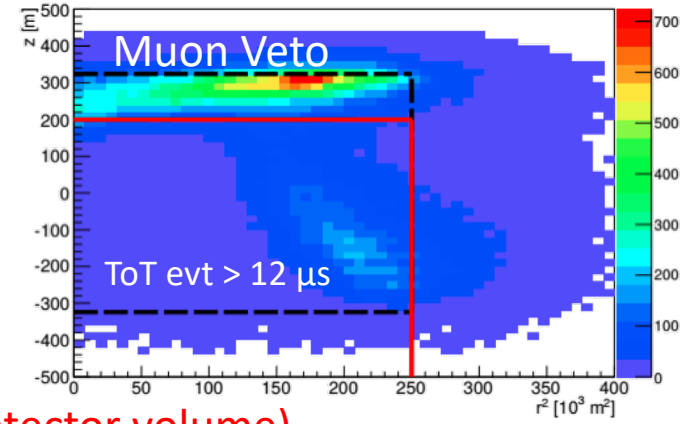




Energy resolution 5-10% $E_\nu > 10^4$ GeV

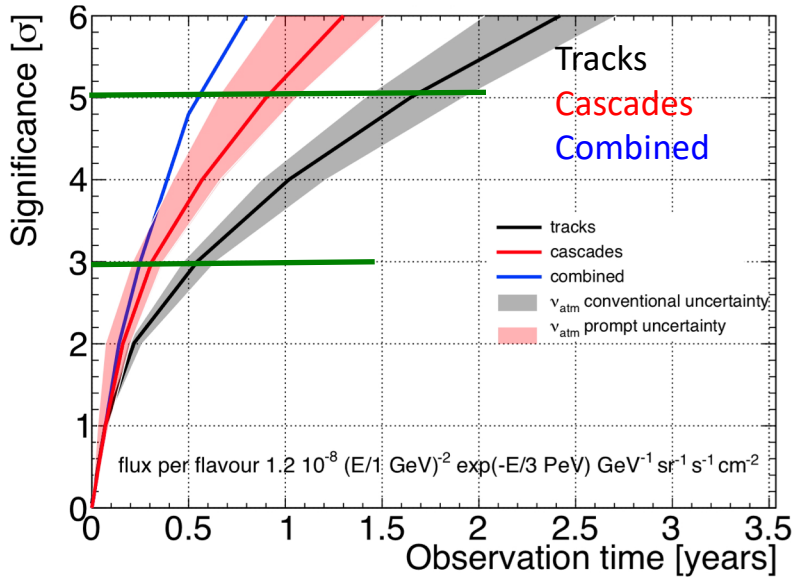
Median angular resolution <2° $E_\nu > 10^5$ GeV





Cascades contained in the detector core (80% of detector volume)

ARCA (Phase 2): Performances



Discovery potential for diffuse flux

Tracks:

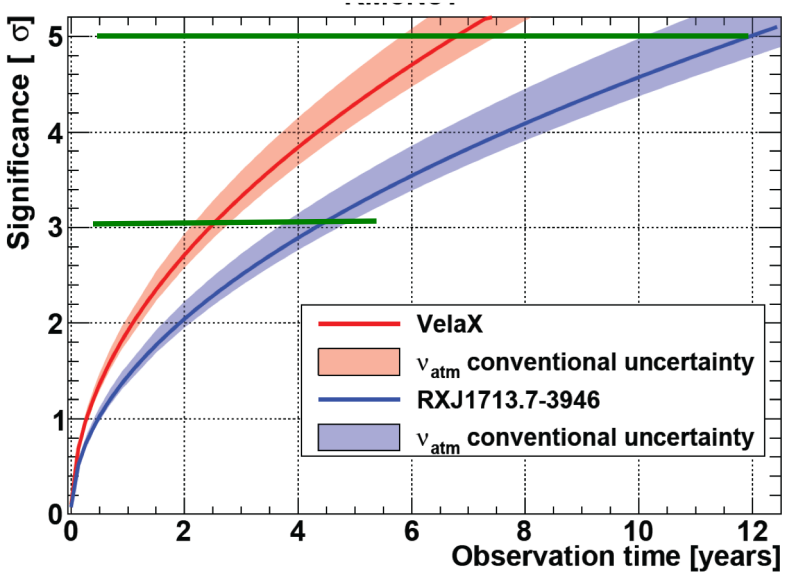
Analysis for up-going events based on maximum likelihood

Pre-cuts on θ_{zen} >80°, reconstruction quality parameter and N_{hit} (proxy for muon energy)

Cascades:

Containment cut on reconstructed vertex to remove atmospheric muons

All sky analysis based on BDT and maximum likelihood



Discovery potential for Galactic Sources

Neutrino spectra inferred from gamma-rays data
for 100% hadronic emission and transparent sources
Source extension and energy cutoff taken in into account

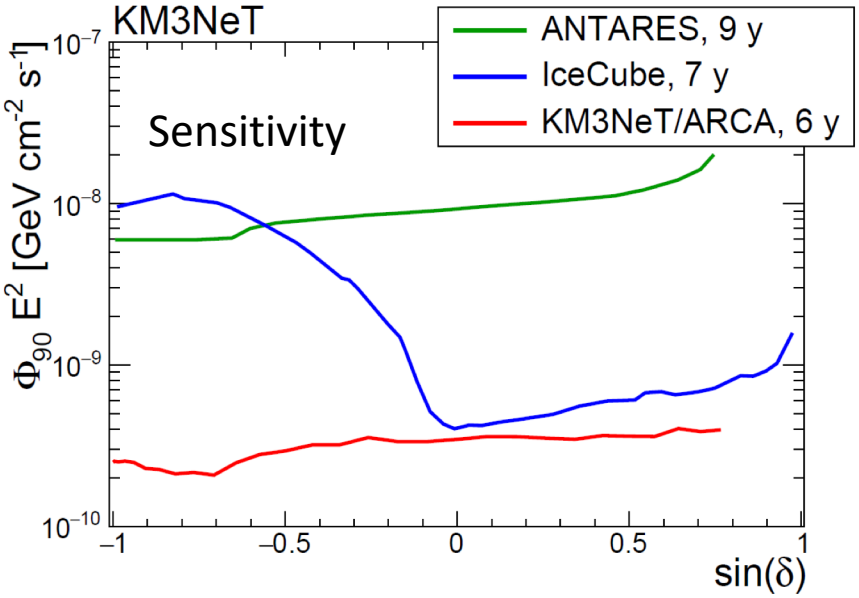
Vela X : 3σ in ~2 years

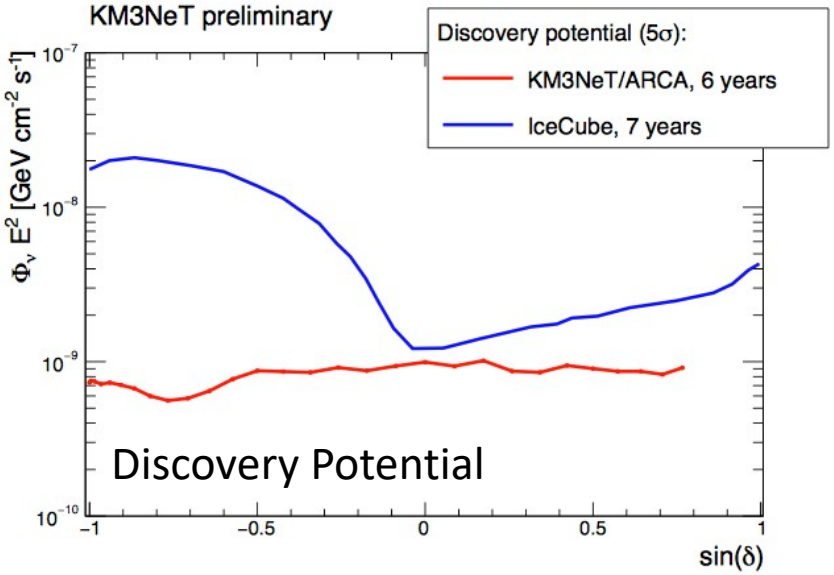
RXJ1713 : 3σ in ~4 years

J.Phys. G43 (2016) 084001

ARCA (Phase 2): Performances

Point like sources (E^{-2} spectrum)

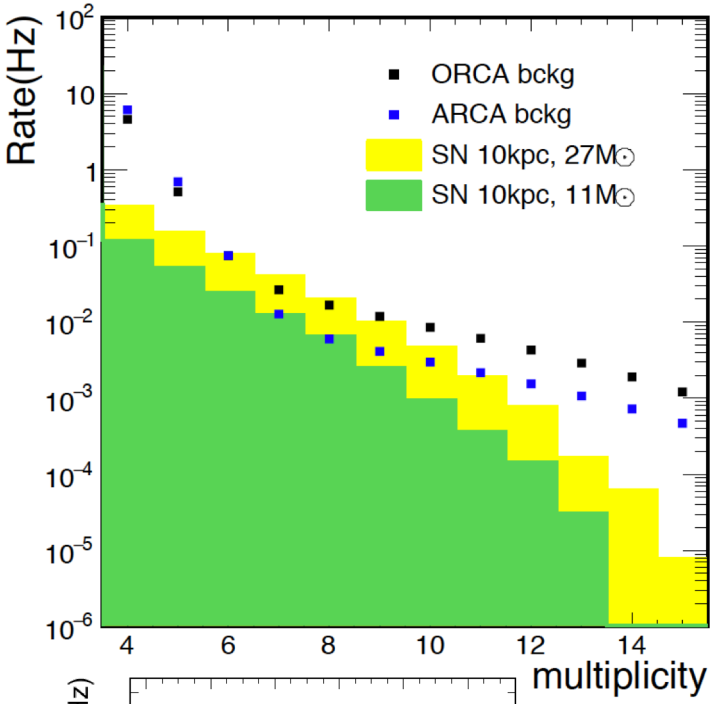


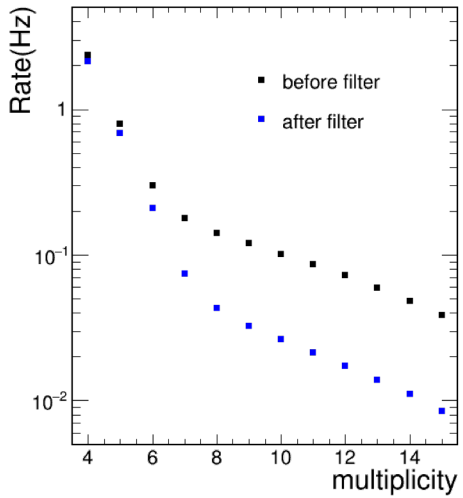


3 years cascades and tracks

Better sensitivity (for equivalent exposure)
and better sky coverage than IceCube

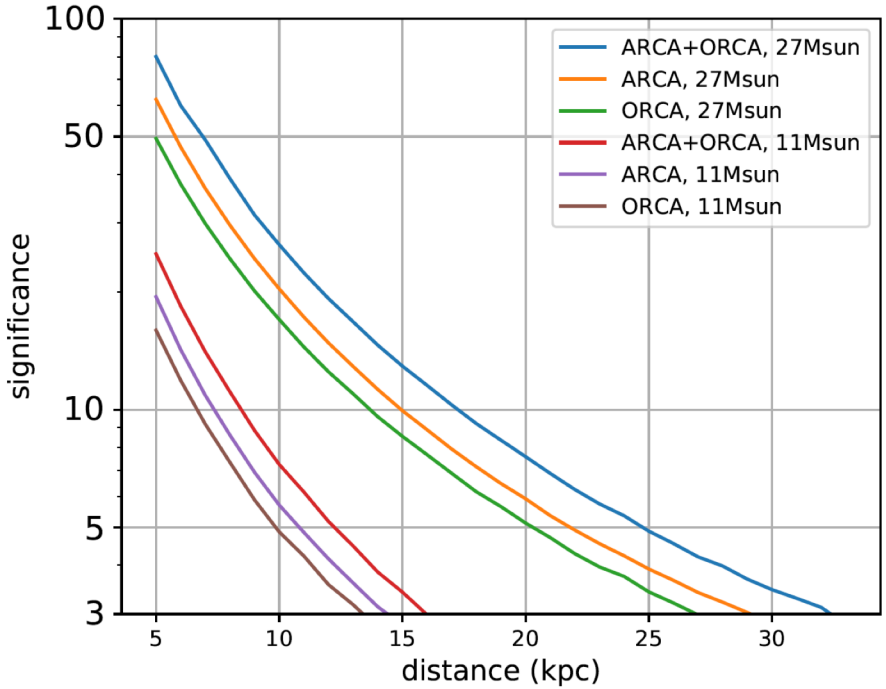
ARCA /ORCA Performances





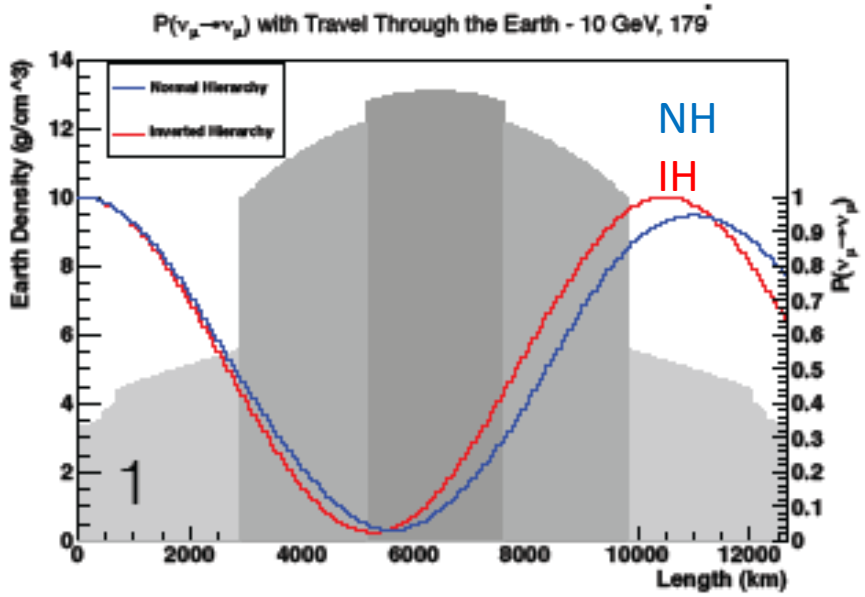
Low Energy Neutrinos from Supernova explosions

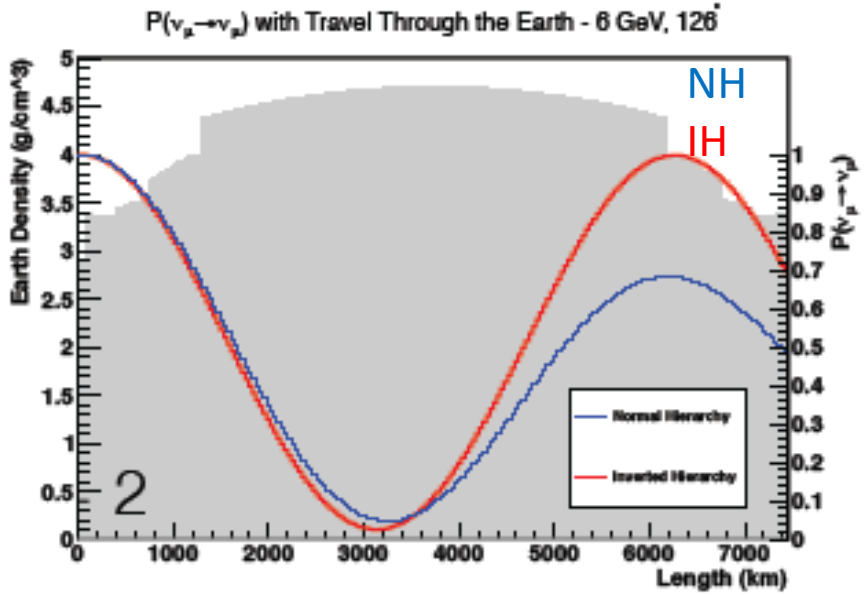
KM3NET PRELIMINARY



Muon veto → bkg reduction

ORCA: NMO from ν oscillations in Earth



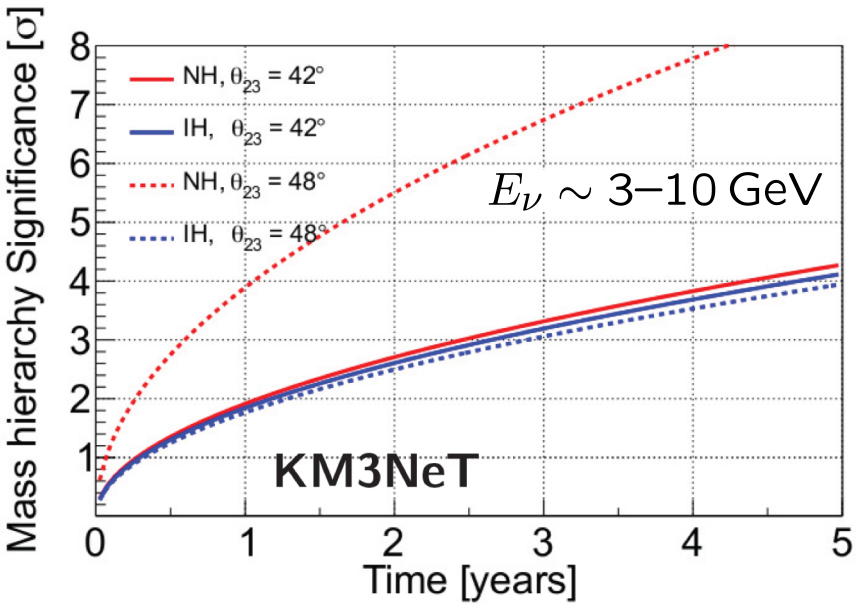


Primary signature: Energy-zenith distribution

Signal measurable since $\sigma(\nu) \approx 2\,\sigma(\text{anti-}\nu)$ and $\Phi(\nu) > \Phi(\text{anti-}\nu)$

Measurement requires

- best possible resolution in energy and zenith
- separation ν_e/ν_μ
- detailed understanding of systematics



- Neutrino beam Protvino-ORCA (P2O)

Earth and Sea Science

Real Time and long term deep sea monitoring

KM3NeT

european multidisciplinary seafloor observatory emso

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

NEWS FEATURE

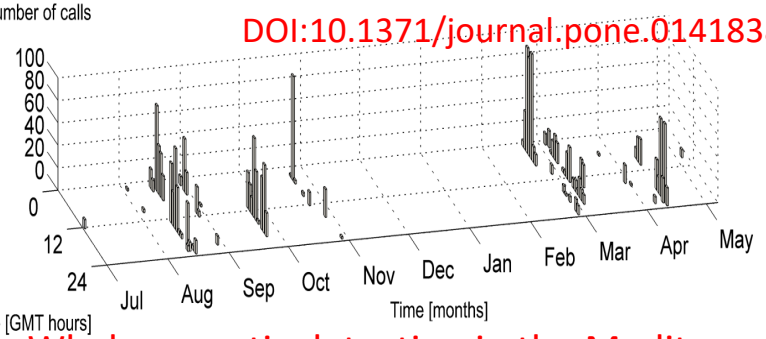
The neutrino and the whale

N. Nosengo, G. Pavan, G. Riccobene

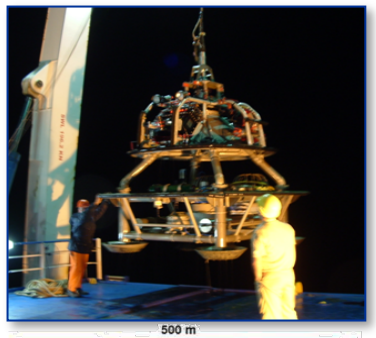
NATURE Vol 462 - 3 December 2009

PLOS One

DOI:10.1371/journal.pone.0141838

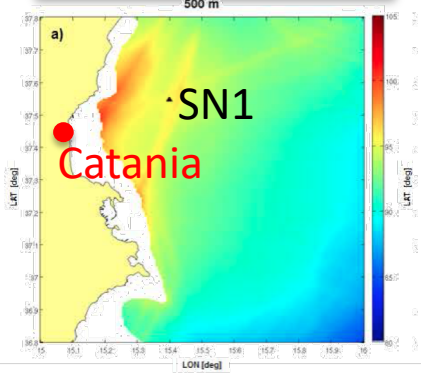


Fin-Whale acoustic detection in the Mediterranean



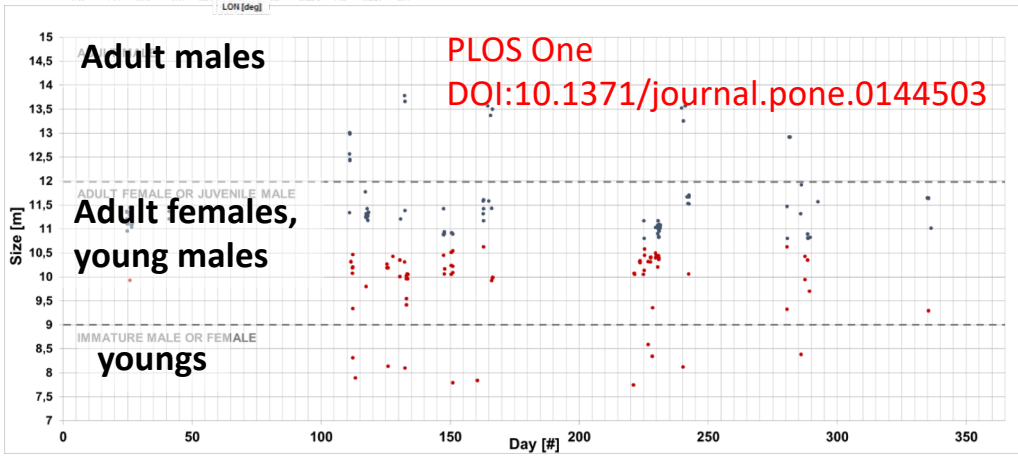
SN1

Geophysic, Volcanology, Oceanography, Tsunamy alert, Sea Noise, Bioacoustics



Acoustic pollution measurement and modelling in the Gulf of Catania (ship noise)

FIRB 2008 - SMO



PLOS One

DOI:10.1371/journal.pone.0144503

Sperm-Whale acoustic detection and population

Conclusions

- High Energy neutrino astronomy era has begun with IceCube
- KM3NeT/ARCA and ORCA: common technology and management
- Two KM3NeT/ARCA units are deployed, several others are under construction. Next operations: recovery of seabed network (hi-rel JBs) and batched deployment of DUs. Phase 1 will reach 0.1 km^3 i Next operations: recovery of seabed network and batched deployment of DUs. Phase 1 will reach 0.1 km^3 within 2020.
- One KM3NeT/ORCA deployed. Next operations: MEOC refurbishment and and batched deployment of DUs (7 DUs within 2018).
- Design of Phase 2 started. Subsea network tenders started.
- KM3NeT/ARCA will complement IceCube and will provide unprecedented sensitivity for neutrino sources
- KM3NeT offers a huge opportunity for Earth and Sea Science