



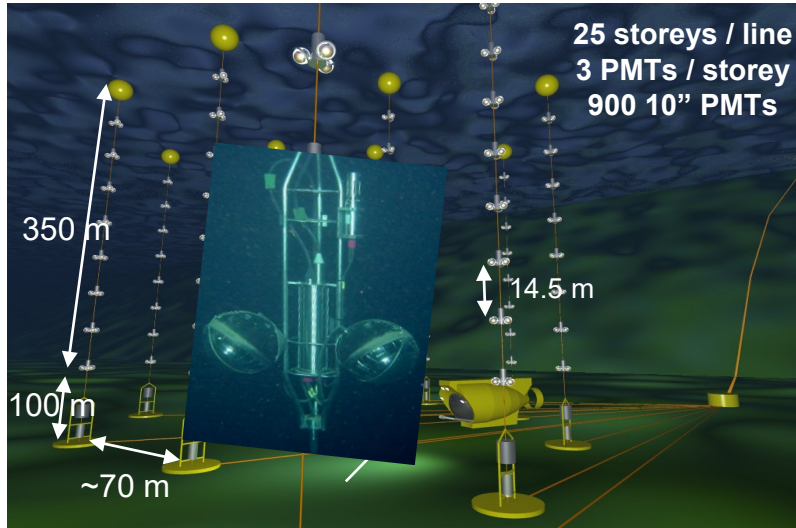
# Status and prospects of KM3NeT

Marco Circella, INFN Bari  
on behalf of the  
KM3NeT Collaboration



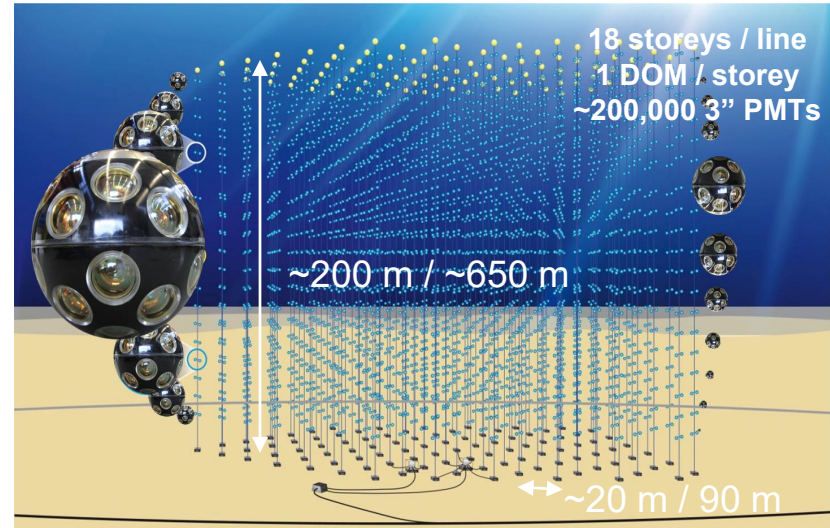
# KM3NeT: the new-generation neutrino telescope in the Mediterranean Sea

ANTARES: complete since 2008



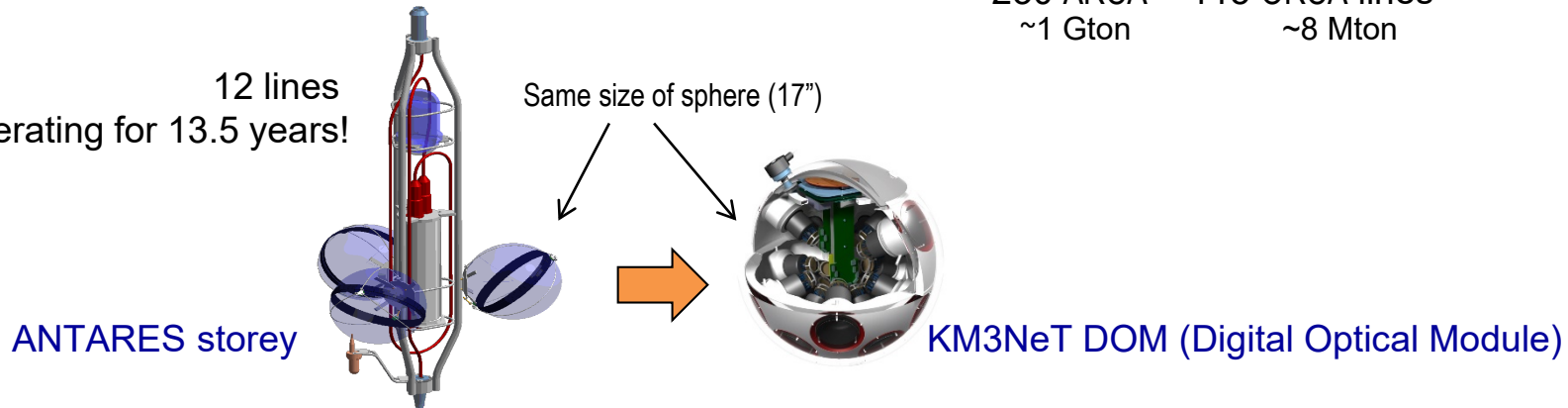
~10 Mton

KM3NeT: under construction



230 ARCA + 115 ORCA lines  
~1 Gton      ~8 Mton

12 lines  
First line operating for 13.5 years!

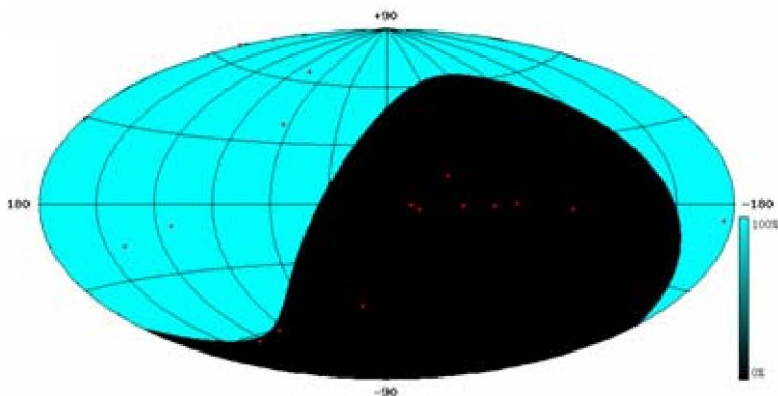




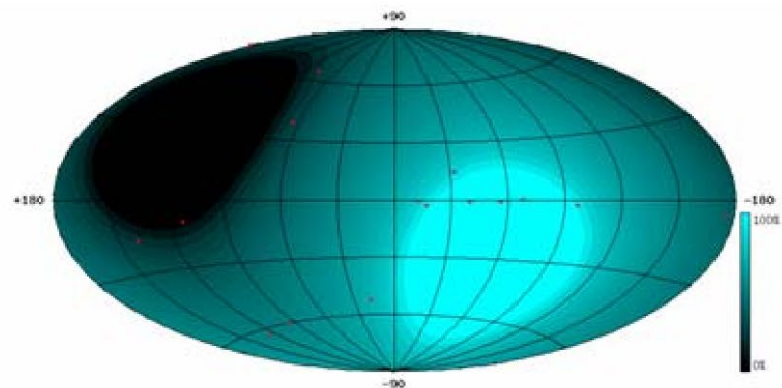
# Why the Mediterranean Sea?

- Good optical properties of sea water (low scattering) => optimal pointing accuracy
- Ideal location to look at the Southern sky (including Galactic Centre) through upward-going neutrinos

In fact: fields of view from South Pole and from the Mediterranean sea are complementary



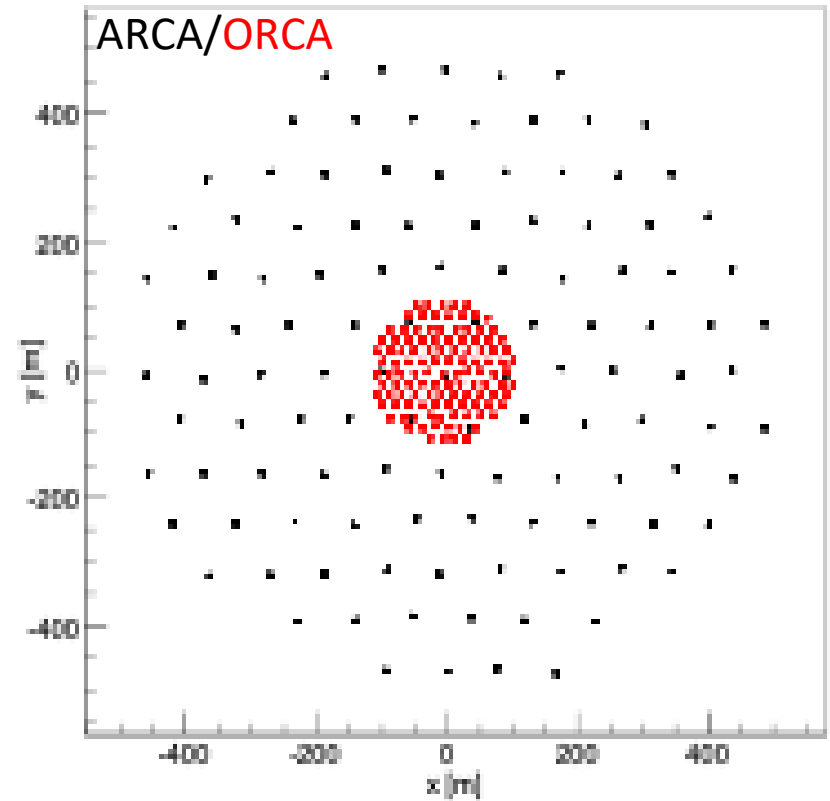
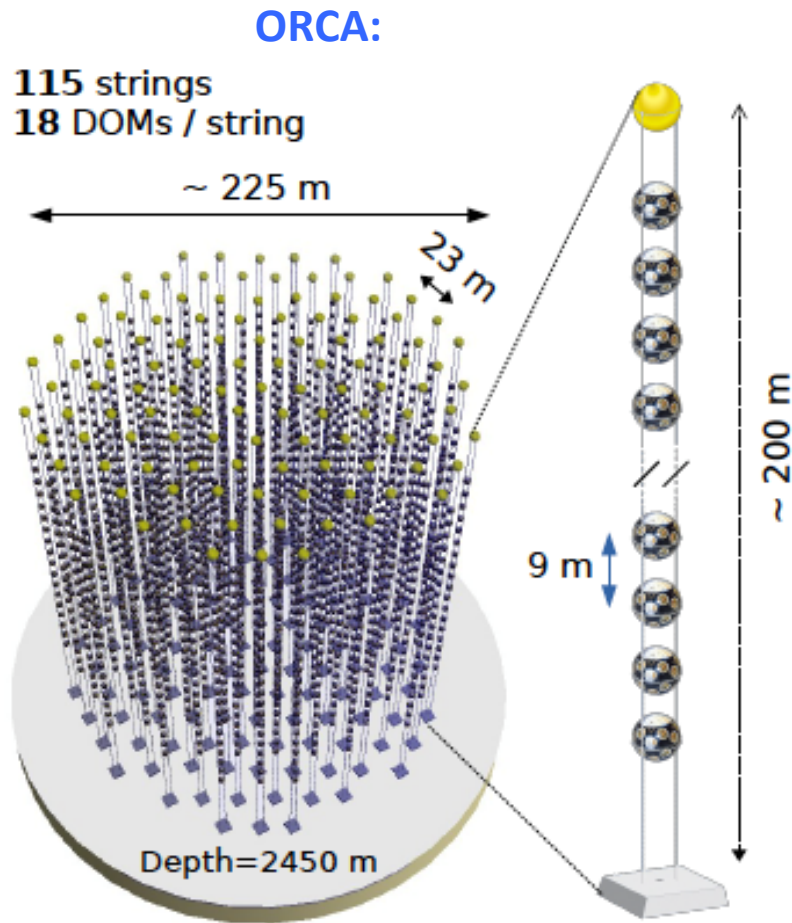
View from South Pole (up-going neutrinos)



View from Mediterranean Sea (up-going neutrinos)



# KM3NeT “Building Blocks”



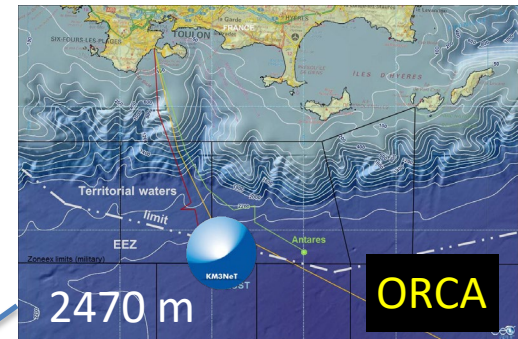
- ~8 Mton instrumented
- 31 PMTs / DOM
- Total: 64k\*3" PMTs

	ORCA	ARCA
String spacing	23 m	90 m
OM spacing	9 m	36 m
Instrumented mass	8 Mton	500*2 Mton

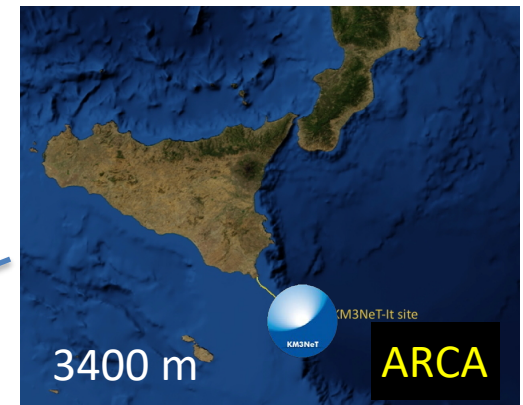


# KM3NeT

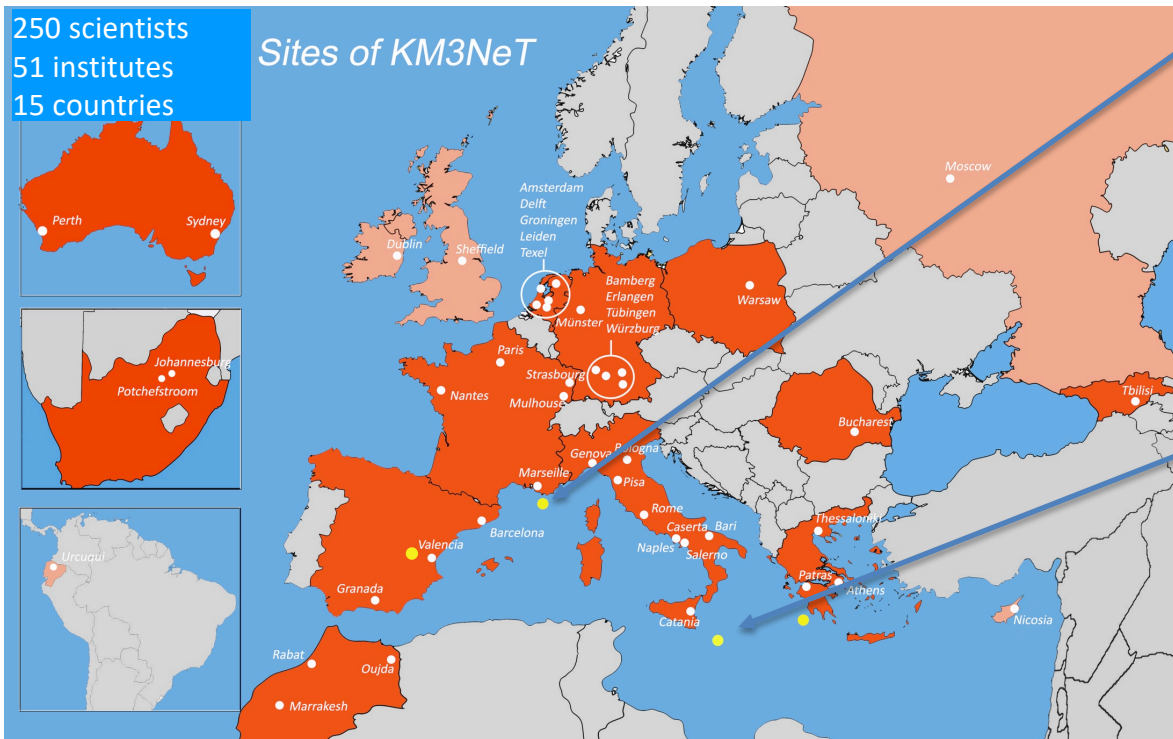
- Multi-site, deep-sea infrastructure
- Single collaboration, single technology
- Two outstanding physics cases: neutrino oscillations and neutrino-astronomy



Oscillation Research with Cosmics In the Abyss



Astroparticle Research with Cosmics In the Abyss



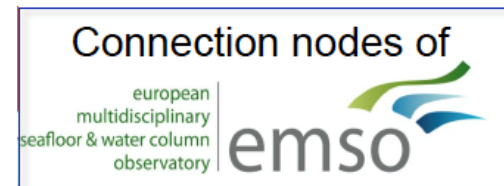
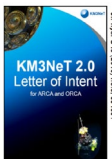
Maps not in same scale!

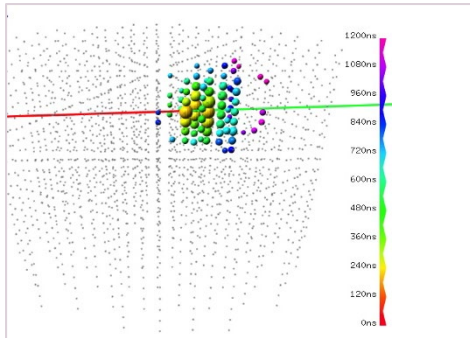
[KM3NeT 2.0: Letter of Intent](http://dx.doi.org/10.1088/0954-3899/43/8/084001)

<http://dx.doi.org/10.1088/0954-3899/43/8/084001>

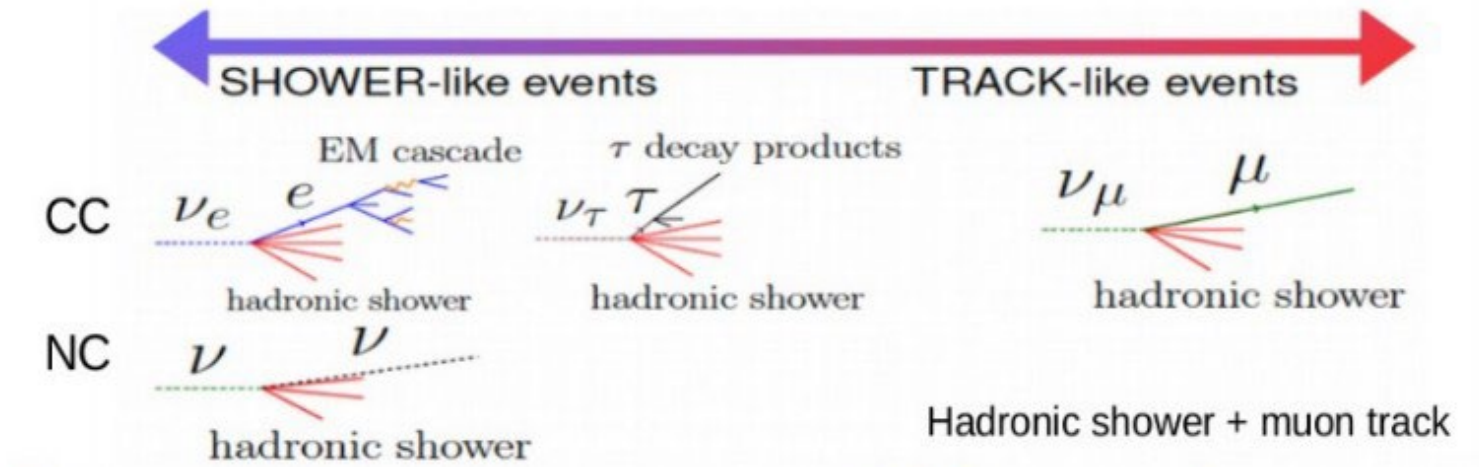
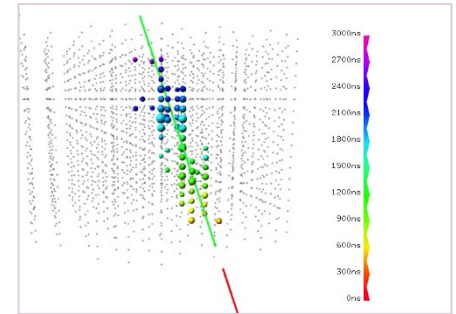
J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001

Marco Circella, KM3NeT, TeVPA, Sydney, 3 Dec. 2019





# Event Topologies in KM3NeT



Angular resolution  $10^\circ/1^\circ$   
at 100 TeV for ice/water

Energy resolution  $\sim 5\%$

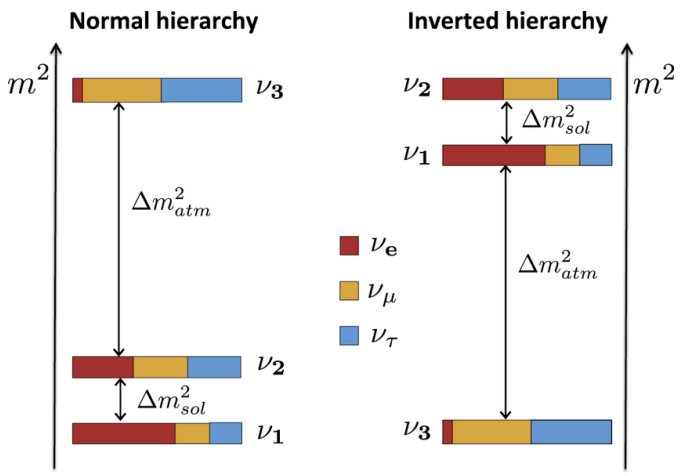
80% of all neutrino interactions

Angular resolution  $0.5^\circ/0.1^\circ$   
at 100 TeV for ice/water

dE/dx resolution factor 2-3

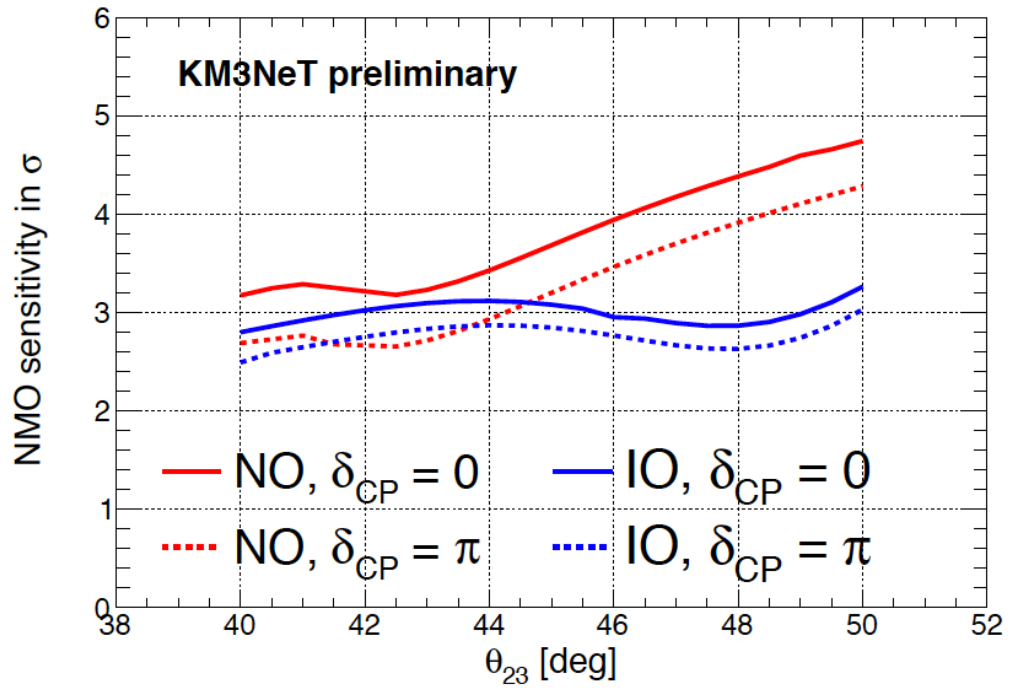
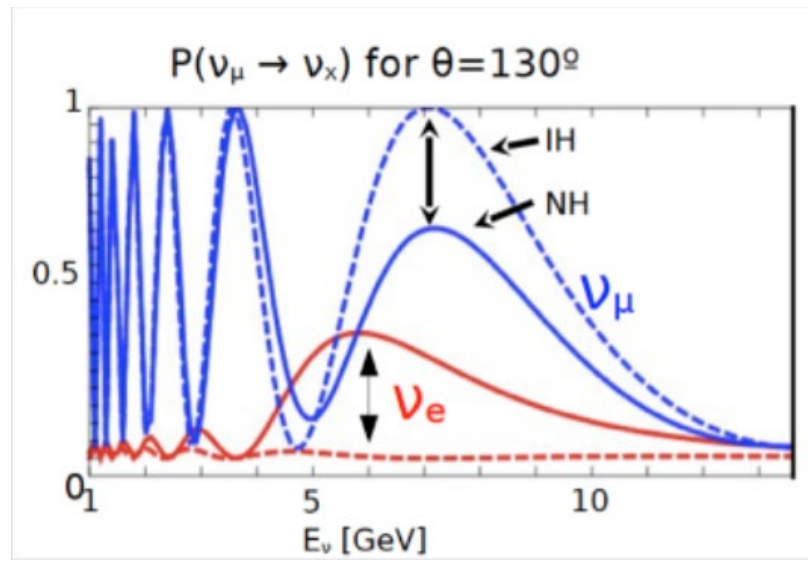


# Neutrino oscillation studies with KM3NeT/ORCA



## Systematics

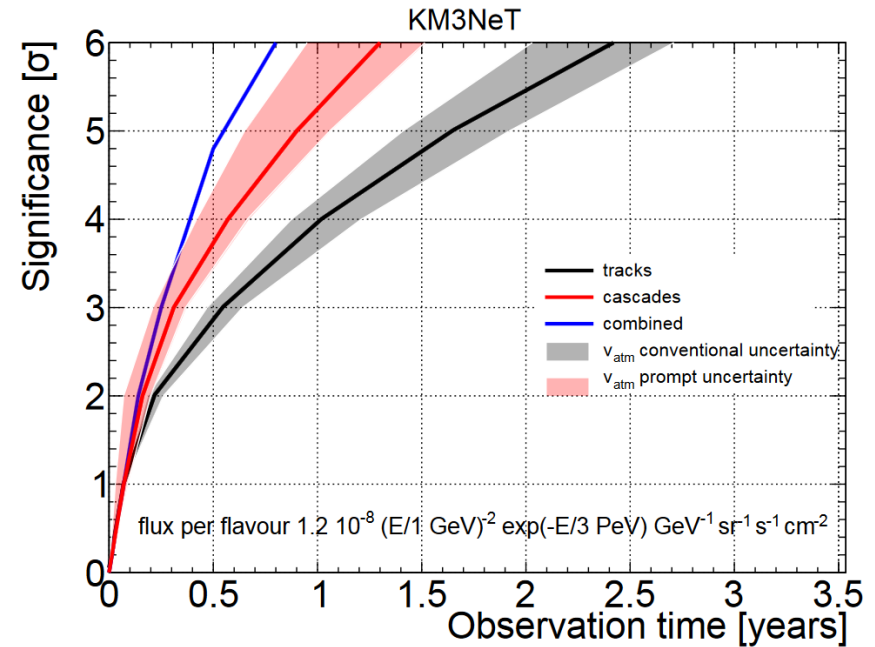
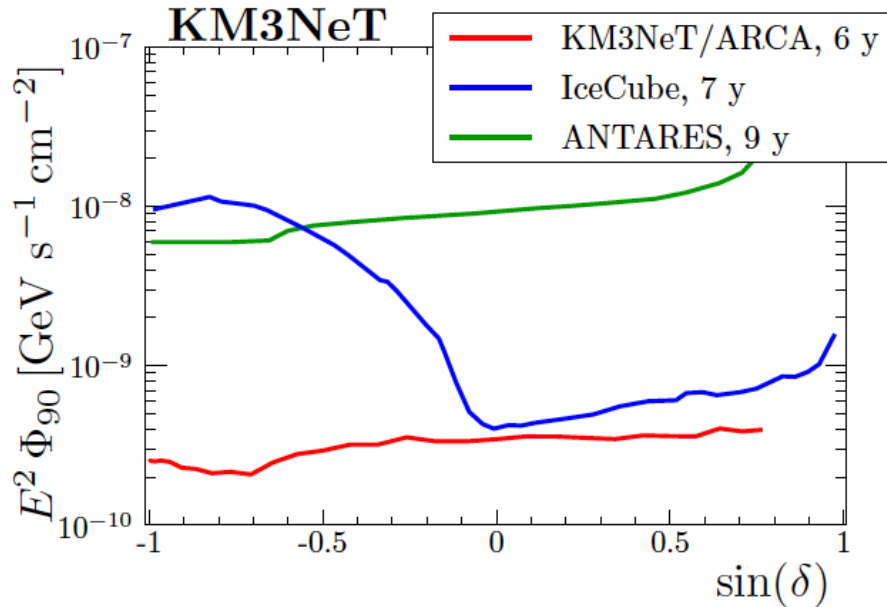
- Neutrino oscillation parameters
- Atmospheric neutrino flux parameters



$\geq 3\sigma$  in 3 years  
 $> 4\sigma$  in 3 years for NO and large  $\theta_{23}$



# Neutrino-astronomy with KM3NeT/ARCA



## Localized sources:

- 1 order of magnitude improvement compared to IceCube for Southern sky
- Sensitivity improved by a factor  $>30$  w.r.t. ANTARES

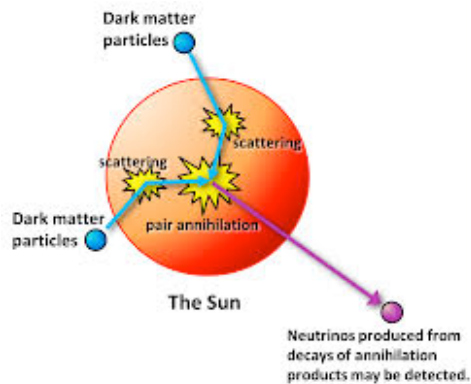
## Diffuse flux:

- $5\sigma$  in  $\sim 0.5$  year for the full detector (230 DUs)
- $5\sigma \sim 1$  year for one-block detector (115 DUs)



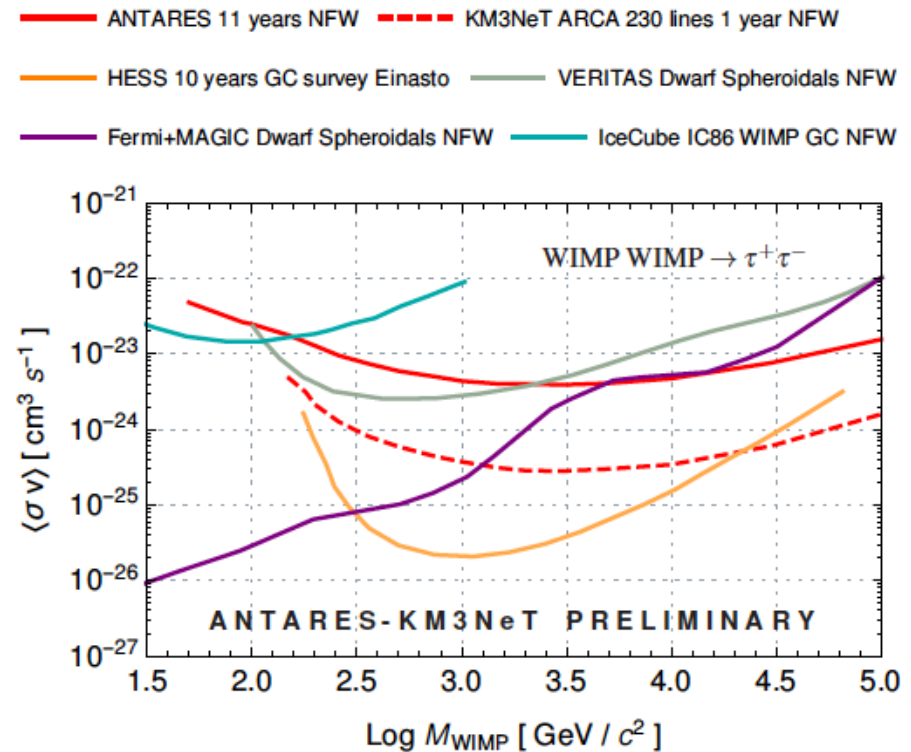
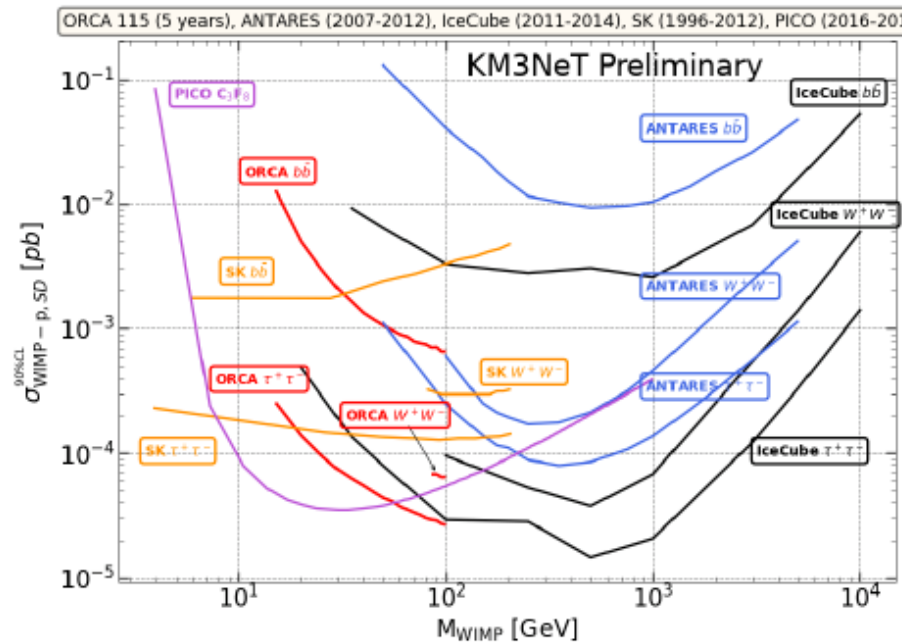


# Dark Matter



Galactic Centre: ARCA230

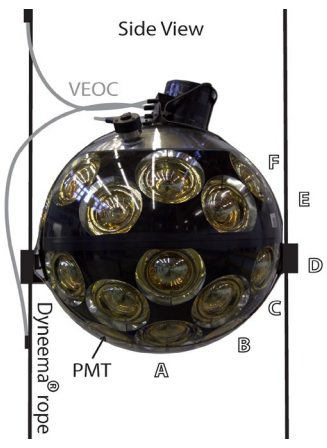
Sun: ORCA115



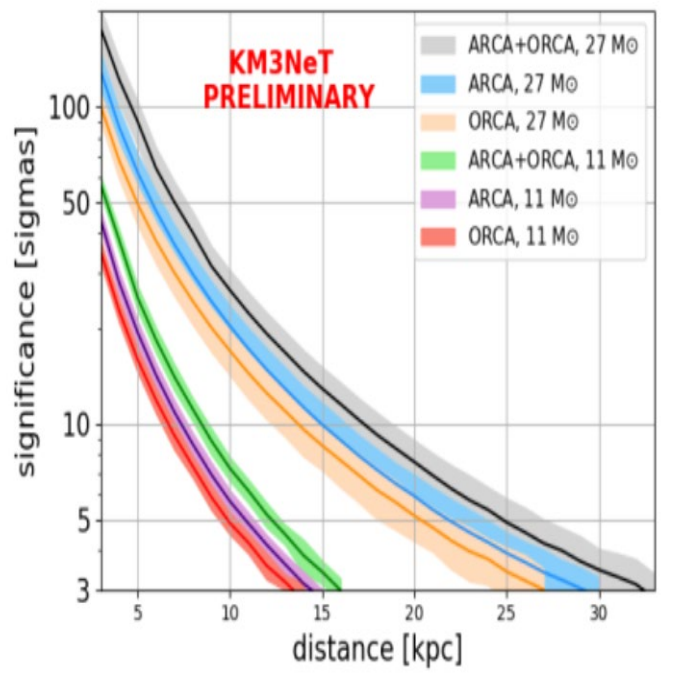
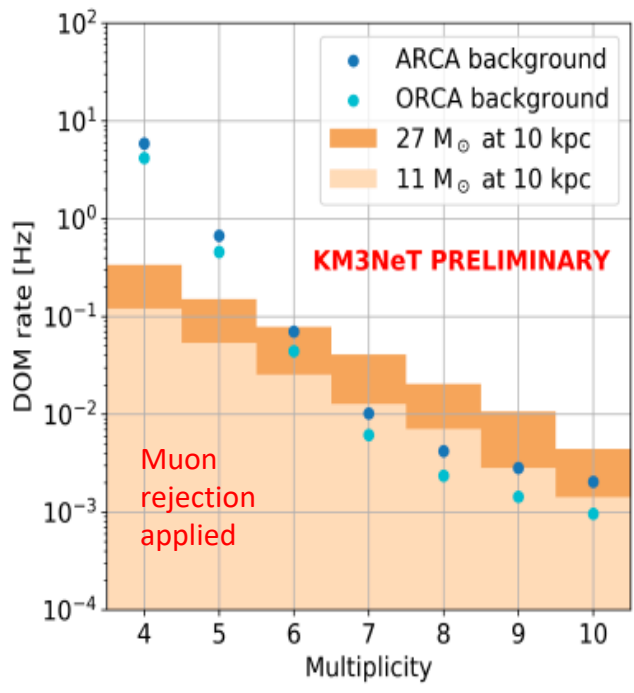


# Core Collapse SuperNovae (CCSN)

Increase of the DOM rates due to many MeV neutrinos from the collapse



Each single DOM can act as a detector



>5 $\sigma$  for ARCA+ORCA for 27M $\odot$  at a distance <25kpc

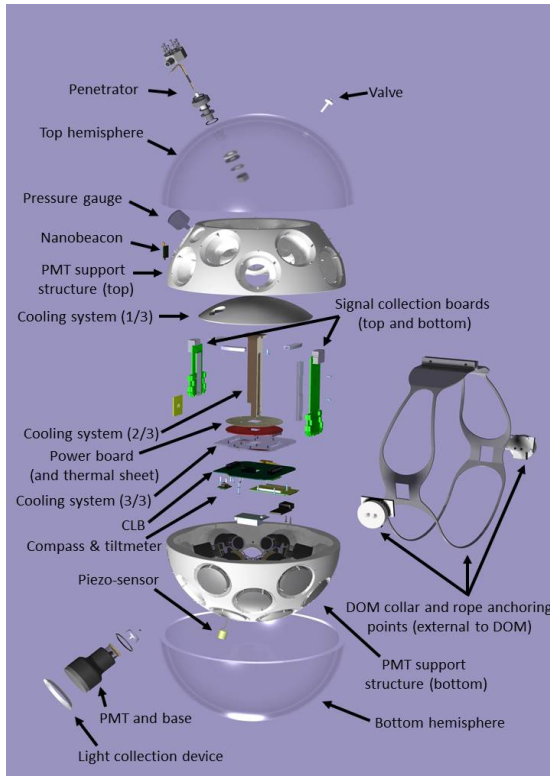
ARCA 230 DU + ORCA 115 DU		
Threshold	11 M $\odot$	27 M $\odot$
1 / 14 days	12.5 kpc	23 kpc



# KM3NeT Technology

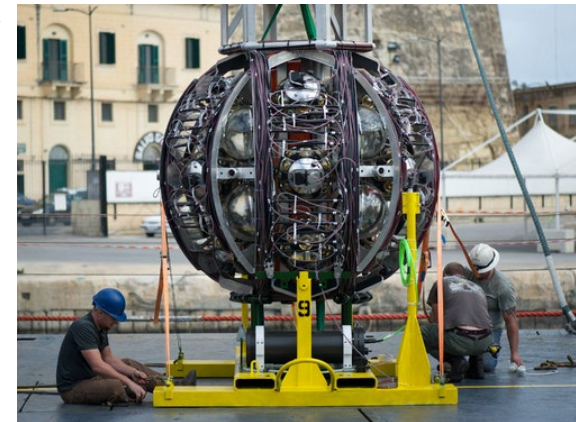
## Detection Unit

### Digital Optical Module

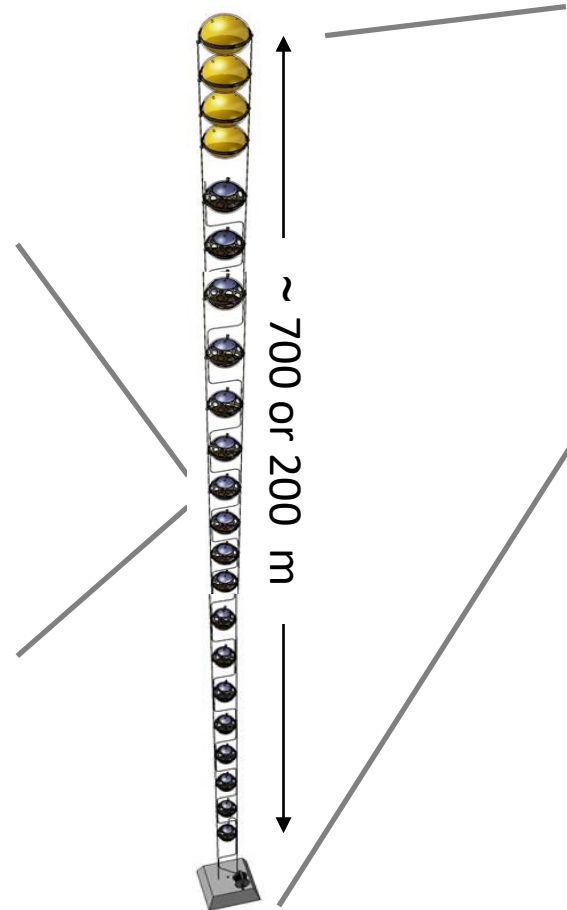


- 31 x 3" PMTs
- Gbit/s on optical fibre
- Hybrid White Rabbit
- LED flasher & acoustic piezo
- Tiltmeter/compass

## Deployment Vehicle



- Rapid deployment
- Multiple DUs/sea campaign
- Autonomous/ROV unfurling
- Reuseable

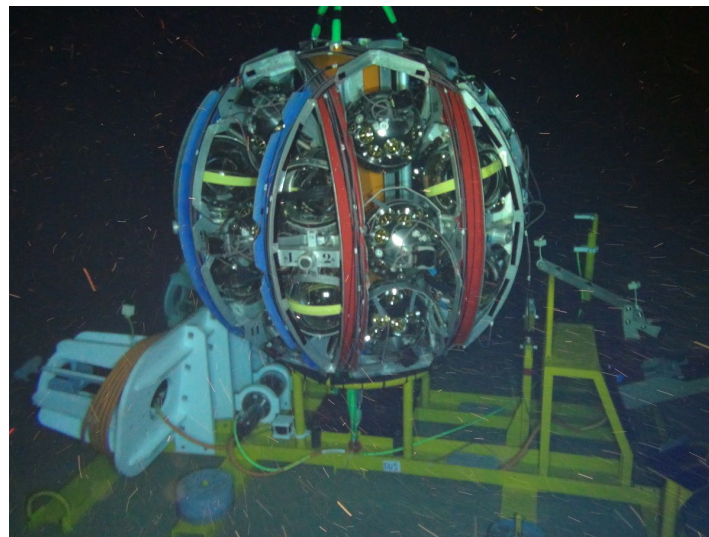


- 2 dyneema ropes
- Oil-filled PE hose backbone
- Low drag
- Low cost



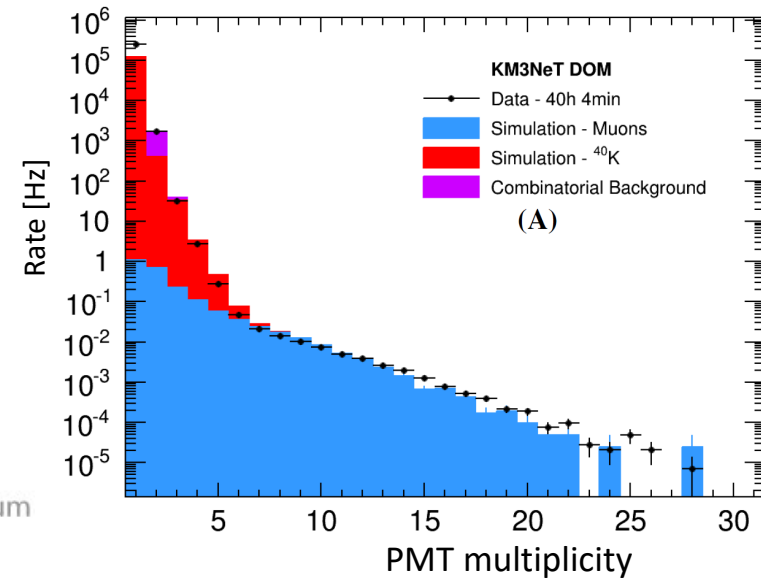
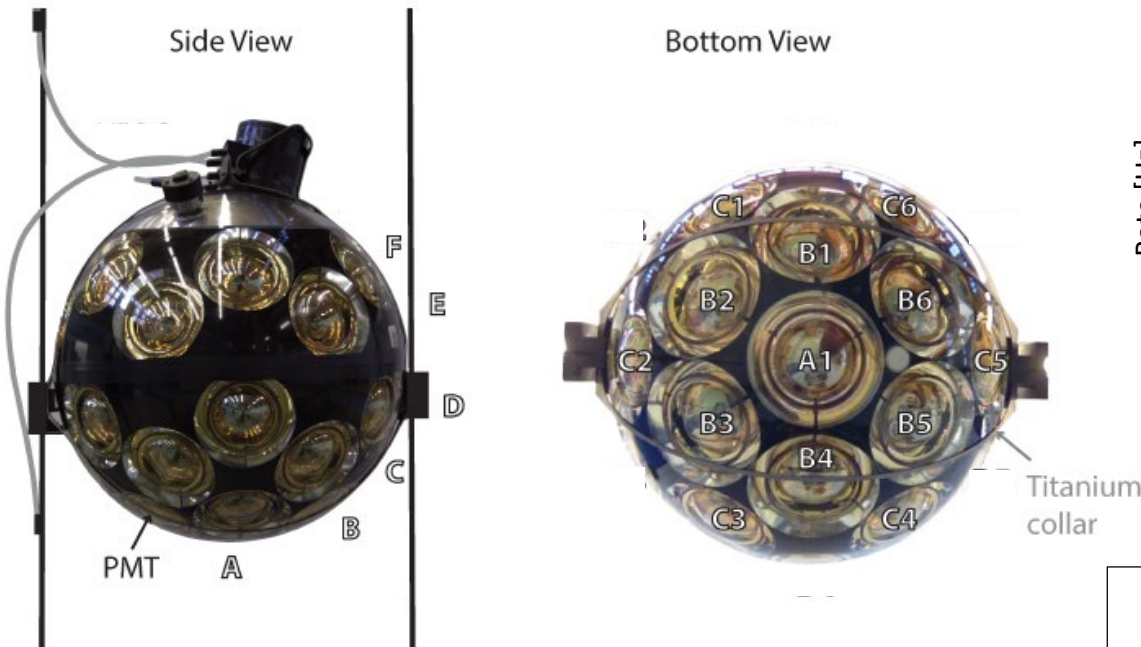
# ORCA 1st DU connection (22 Sept 2017)

Check the movie on: <https://youtu.be/dMjN93H7Nvo> !





# More on the KM3NeT DOM

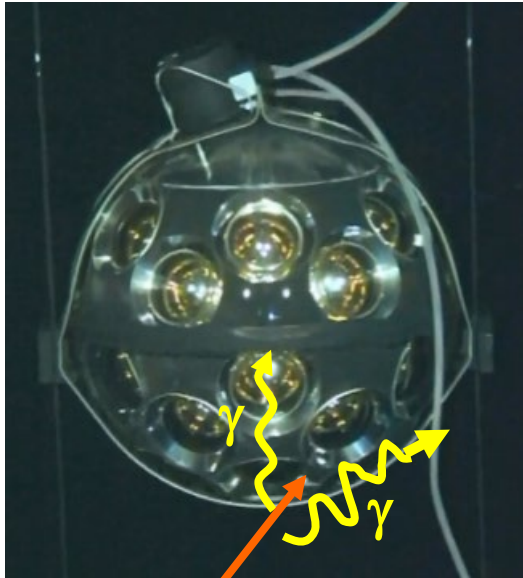


Digital photon counting capabilities  
and directional sensitivity  
*Eur. Phys. J. C (2014) 74:3056*

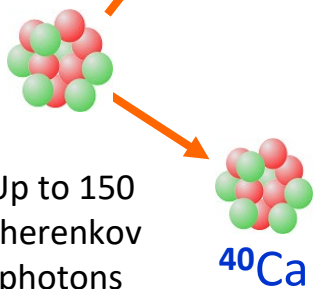
- Photocathode area equivalent to 3 x 10" PMT
- DAQ, front-end electronics and calibration devices included
- Digital photon counting
- $\sim 4\pi$  angular acceptance
- improved optical-background rejection
- directional information => good event reconstruction



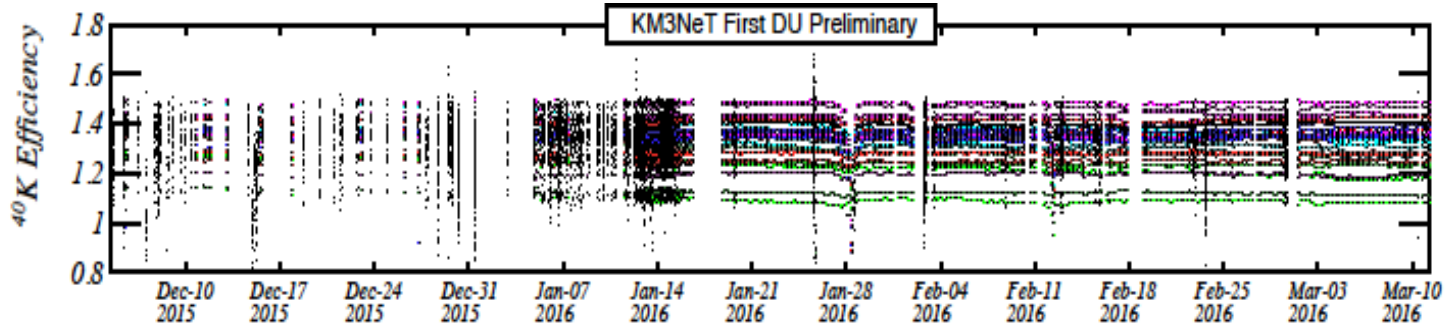
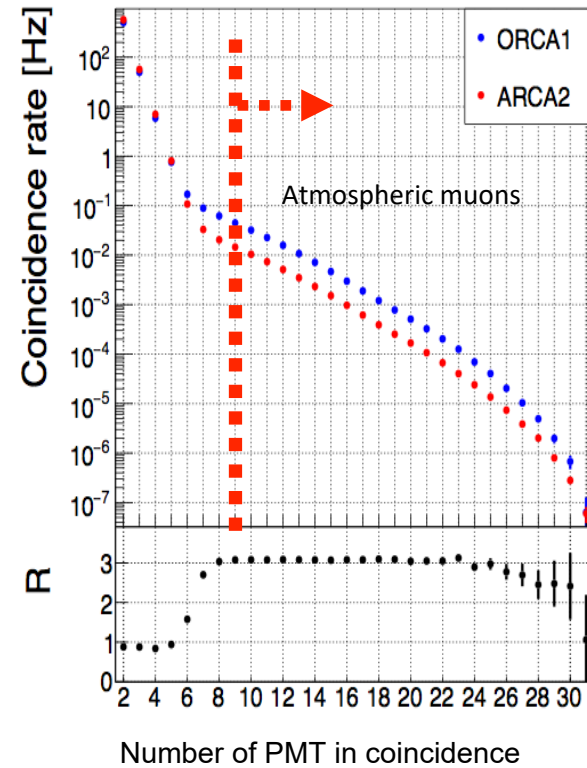
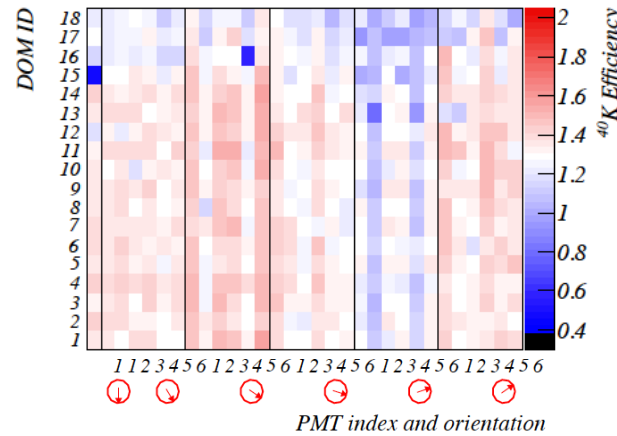
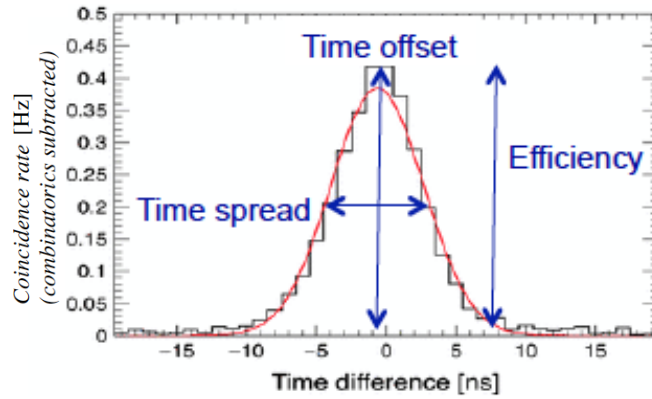
# $^{40}\text{K}$ : Inter-PMT Calibration



$^{40}\text{K}$   $e^-$  ( $\beta$  decay)



Up to 150 Cherenkov photons per decay; stable  $^{40}\text{K}$  concentration



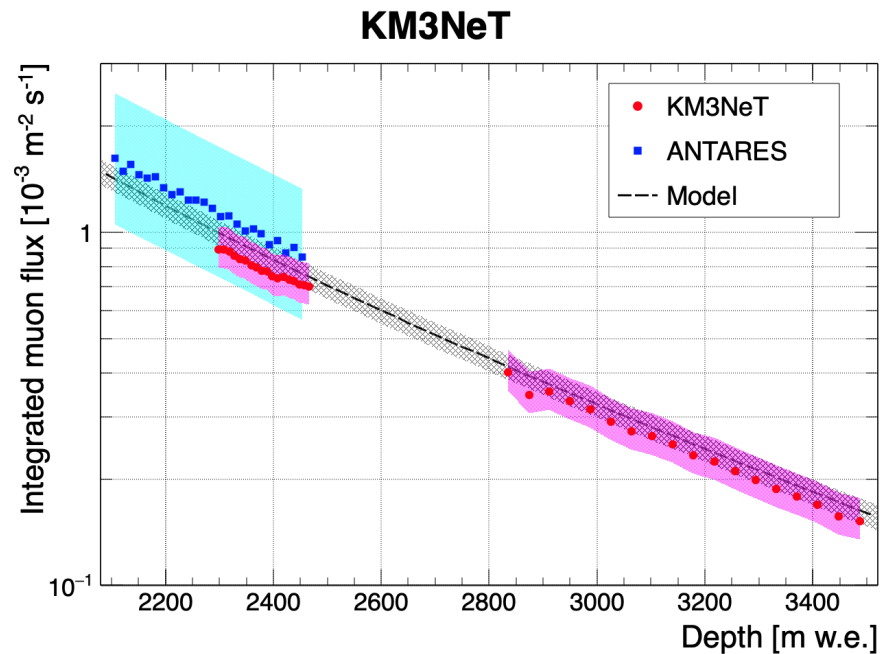
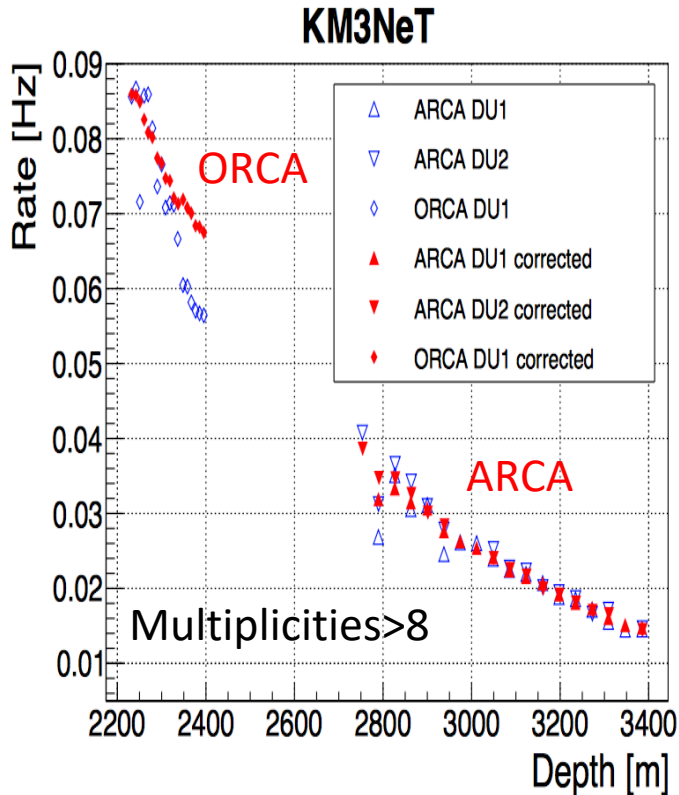
Knowledge of efficiencies vs zenith - important for NMH measurement in ORCA Run date



# KM3NeT – muon depth dependence

2 DUs of ARCA (Dec 23<sup>rd</sup> 2016 - Mar 2<sup>nd</sup> 2017)  
and 1 DU of ORCA (Nov 9<sup>th</sup> 2017 – Dec 13<sup>th</sup> 2017)

Muon flux as a function of depth compared  
to Bugaev model (Bugaev et al, Phys. Rev. D 58 1998 054001)

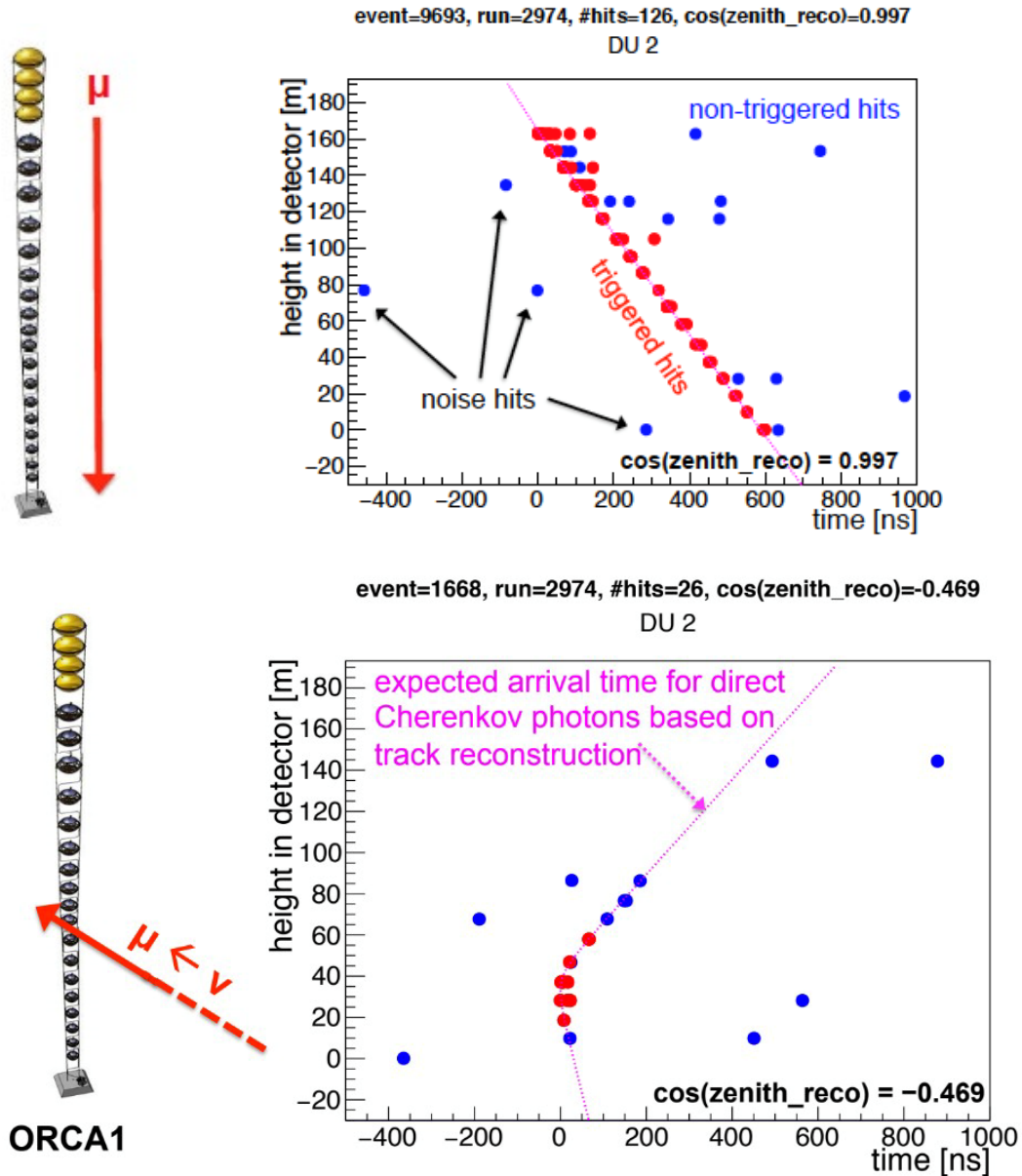


<https://arxiv.org/pdf/1906.02704.pdf>

PMT detection efficiency calibration verified



# ORCA1: first muons and neutrinos







# KM3NeT detectors – neutrino selection

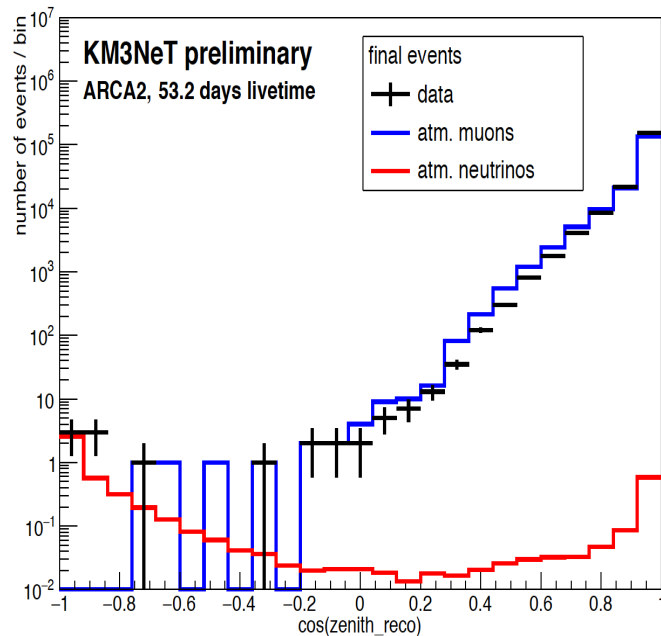
## Up-going atmospheric neutrino selection

ARCA2 = 2 DUs @ ARCA SITE

Dec 23<sup>rd</sup> 2016 - Mar 2<sup>nd</sup> 2017

$E_{th} \sim 100$  GeV

trigger rate  $\mu_{atm} \sim 0.2$  Hz ;  $\nu_{atm} \sim 1$ /day



DATA:  $\sim 6$  neutrinos  $\cos(\theta_{rec}) < -0.8$

MC:  $\mu_{atm} 0 + \nu_{atm} 3.3$

Good Data-MC agreement

Detecting neutrinos with 1-2 DUs

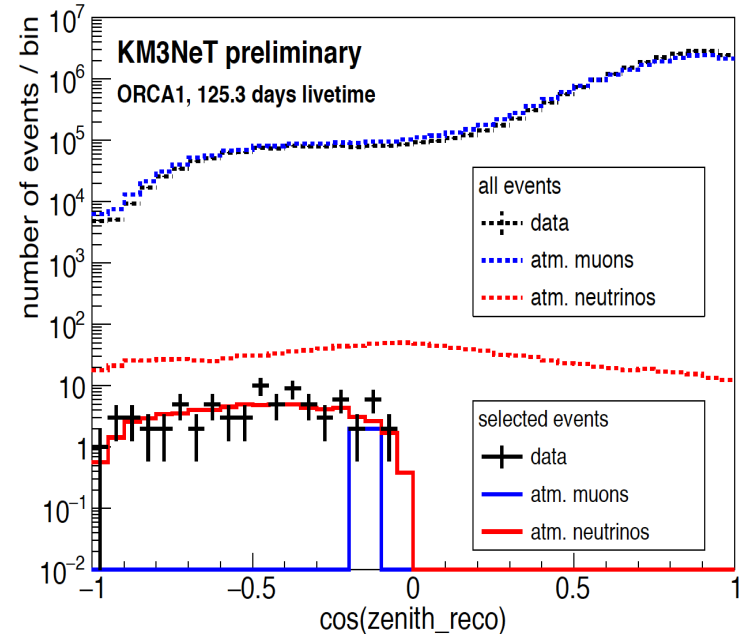
ORCA1 = 1 DU @ ORCA SITE

Sep 28<sup>th</sup> 2017 – Dec 13<sup>th</sup> 2017

Mar 13<sup>th</sup> 2019 – May 15<sup>th</sup> 2019

$E_{th} \sim$  few GeV

trigger rate  $\mu_{atm} \sim 2$  Hz ;  $\nu_{atm} \sim 10$ /day



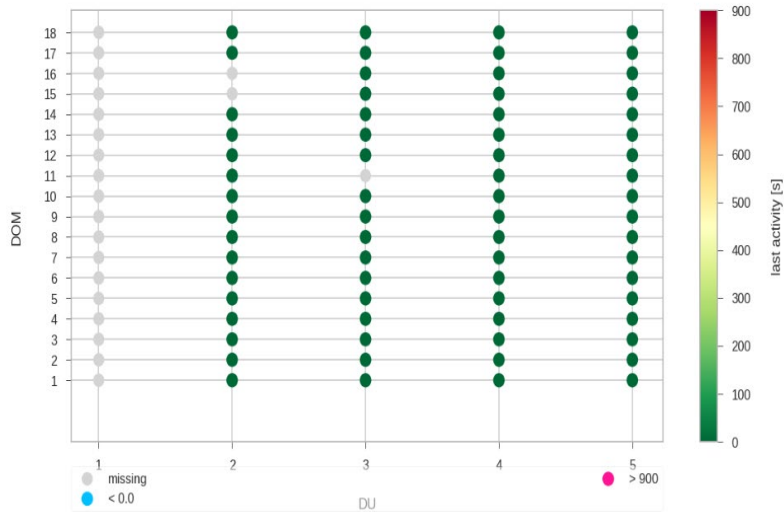
DATA:  $\sim 77$  neutrinos  $\cos(\theta_{rec}) < 0$

MC:  $\mu_{atm} 4 + \nu_{atm} 67.5$



# KM3NeT status

DOM Activity for DetID-44 - via Summary Slices  
Mon Jul 22 23:59:50 2019 UTC

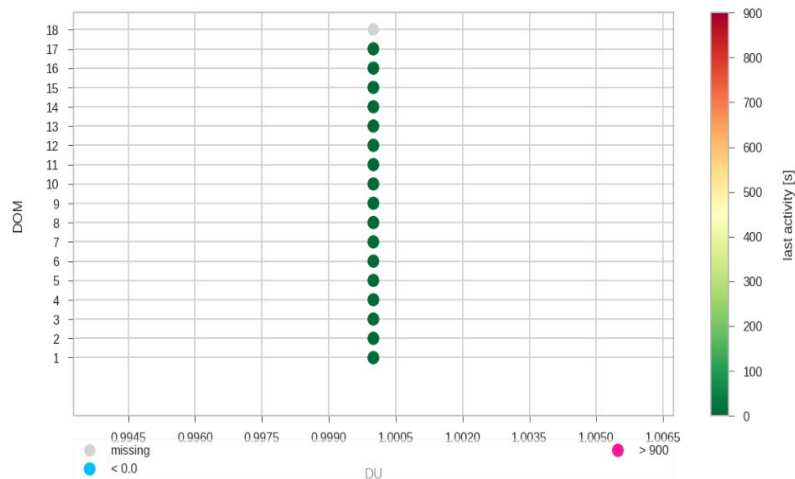


4 DUs @ ORCA site

Installed this year

(2 more waiting to be deployed)

DOM Activity for DetID-42 - via Summary Slices  
Tue Jul 23 04:39:58 2019 UTC



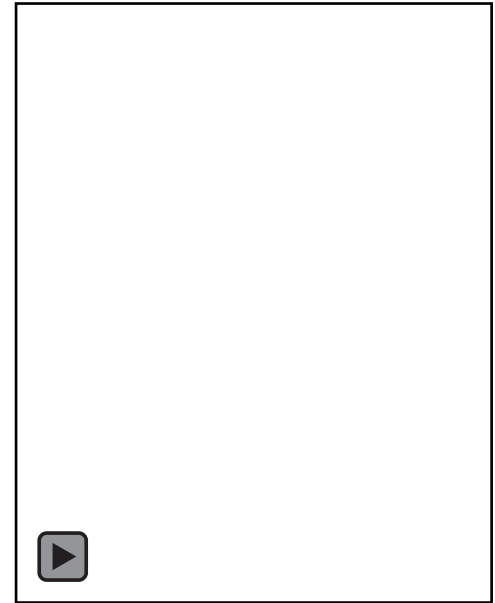
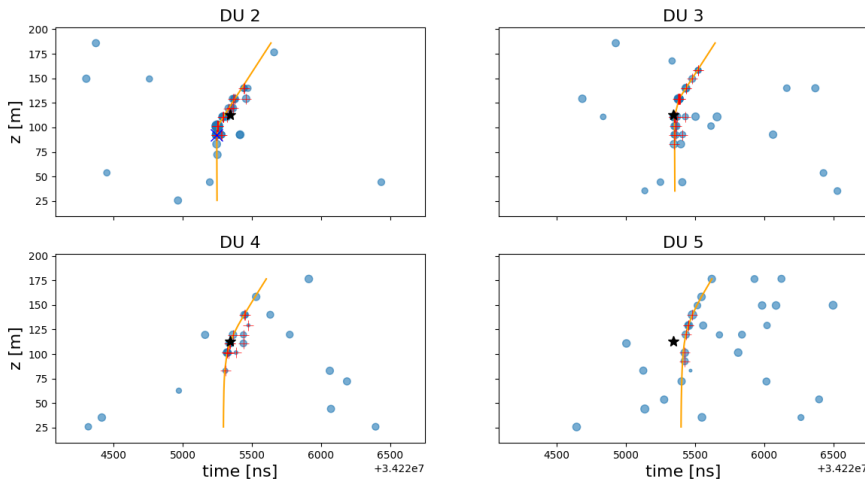
1 DU @ ARCA site

Since 4 years

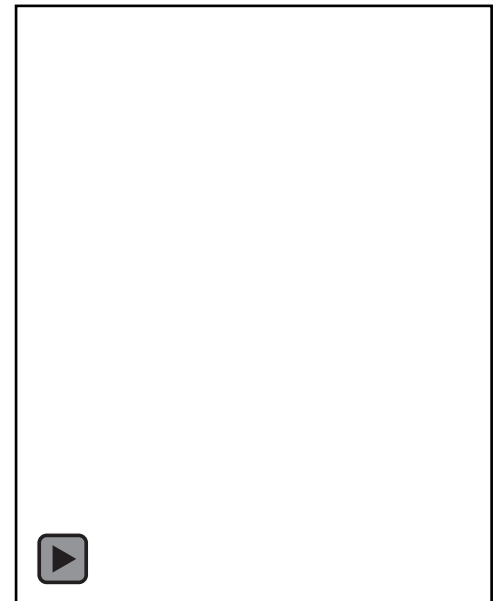
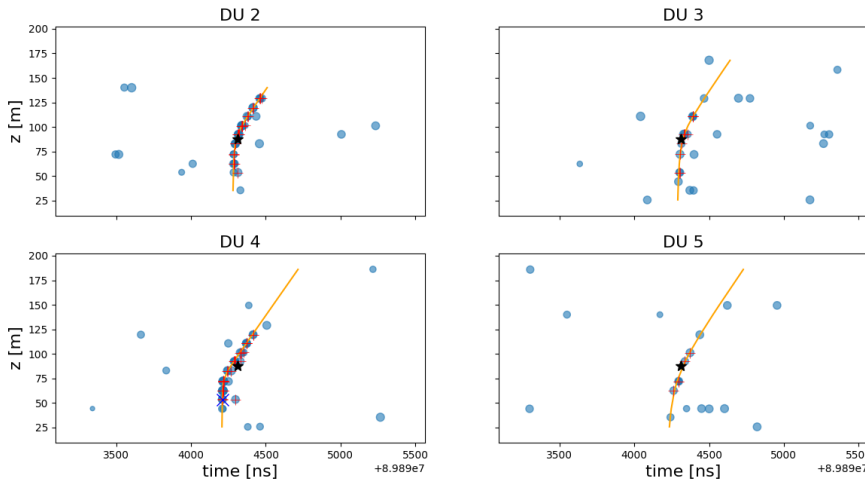


# ORCA4: neutrino events

Det 44 Run 6182 Frame Index 199530  
Trigger: 3d\_muon 3d\_shower mx\_shower  
Fri, 27 Sep 2019 11:32:33 +0000 (GMT) + 0 nsec



Det 44 Run 6573 Frame Index 96526  
Trigger: 3d\_muon 3d\_shower mx\_shower  
Mon, 28 Oct 2019 20:40:52 +0000 (GMT) + 0 nsec

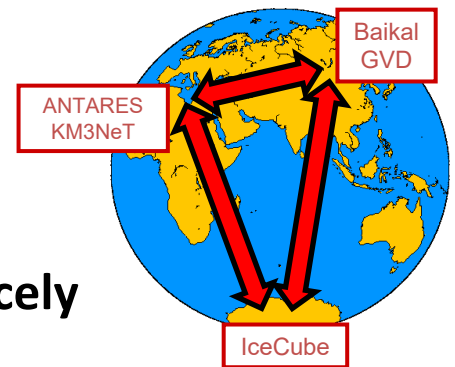




# Conclusions - outlook

- KM3NeT has developed the technology for a new-generation under-sea neutrino-telescope
- The Mediterranean Sea is a very convenient installation site
- Two outstanding physics cases
  - ARCA will study the cosmic neutrino flux (all channels)
  - ORCA will determine neutrino mass ordering
- Synergies are in place:
  - The Collaboration is growing
  - KM3NeT is part of the Global Neutrino Network (GNN)
  - Getting prepared to multi-messenger investigation of the cosmos
  - First GCN circular released recently (#26249, after LIGO/Virgo S191110af GW event)
- **The first detection units of both ARCA and ORCA work nicely**
- **Construction of the two detectors is ongoing!**

**GNN**  
The GLOBAL NEUTRINO NETWORK





# Thank you!

If you want to know more:

e-mail: [marco.circella@ba.infn.it](mailto:marco.circella@ba.infn.it)

web: <http://www.km3net.org>