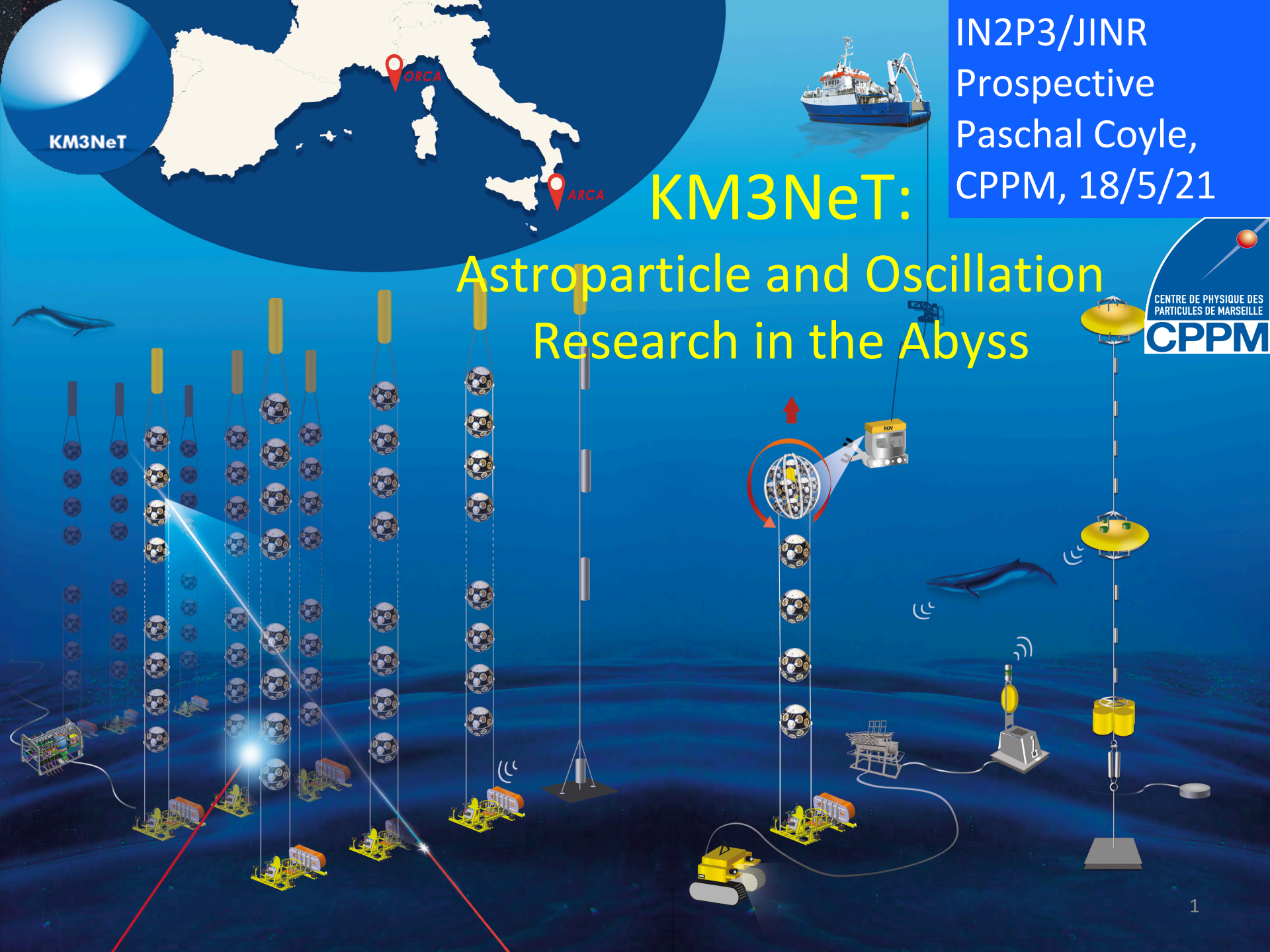


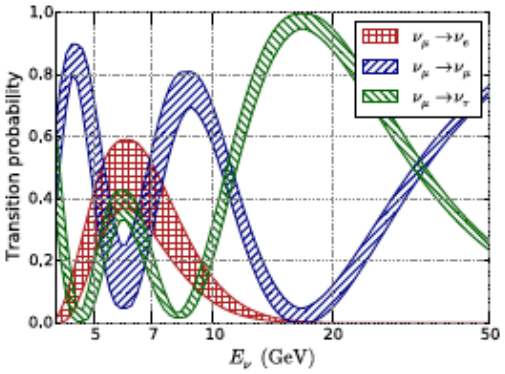
KM3NeT:

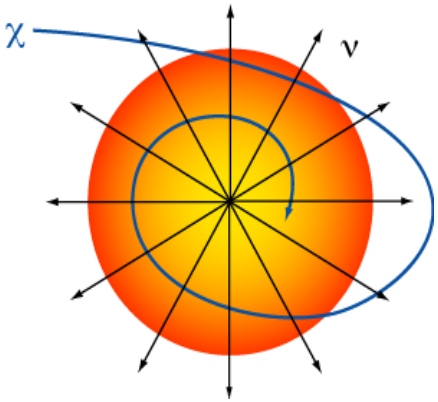
Astroparticle and Oscillation Research in the Abyss

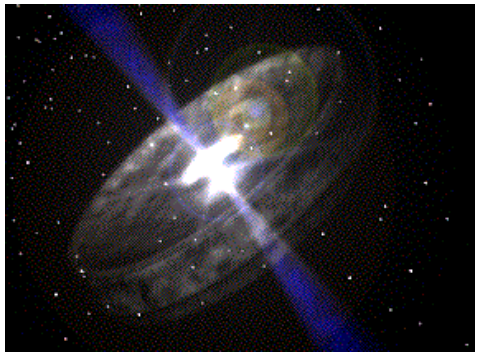
IN2P3/JINR Prospective
Paschal Coyle, CPPM, 18/5/21

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM

Neutrino telescopes: science scope



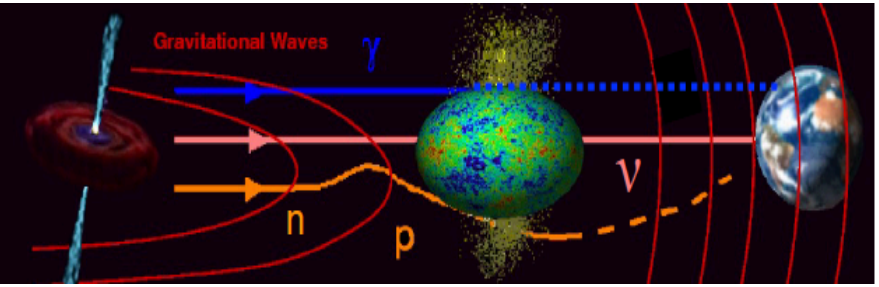


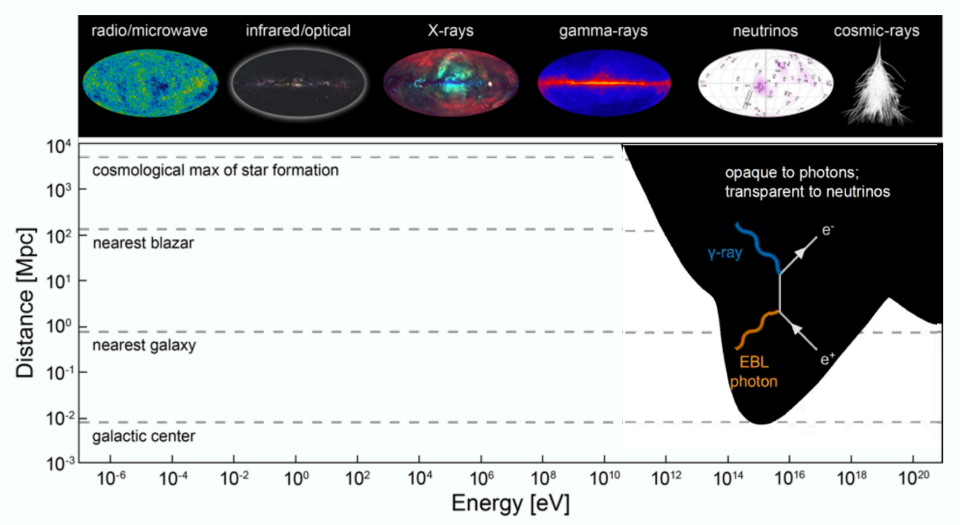


Low Energy	Medium Energy	High Energy
MeV < E_ν < 100 GeV	10 GeV < E_ν < 1 TeV	E_ν > 1 TeV
ν Oscillations ν Mass hierarchy Supernova Solar flares,…	Dark matter search Monopoles, nuclearites,…	ν from extra-terrestrial sources Origin and production mechanism of HE CR

+ oceanography, biology, seismology,…

Neutrinos: cosmic messengers





Neutrinos: neutral, stable, weakly interacting

not absorbed by background light/CMB ➔ access to cosmological distances

not absorbed by matter ➔ access to dense environments

not deviated by magnetic fields ➔ astronomy over full energy range

‘Smoking gun’ signature for hadronic processes

Correlated in time/direction with electromagnetic and gravitational waves

New window of observation on the Universe

Neutrino Telescope around the World

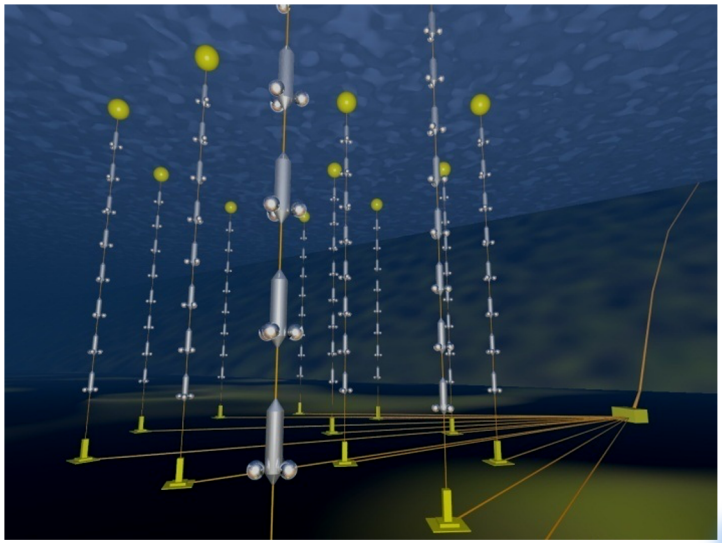
ANTARES & KM3NeT

BAIKAL & GVD

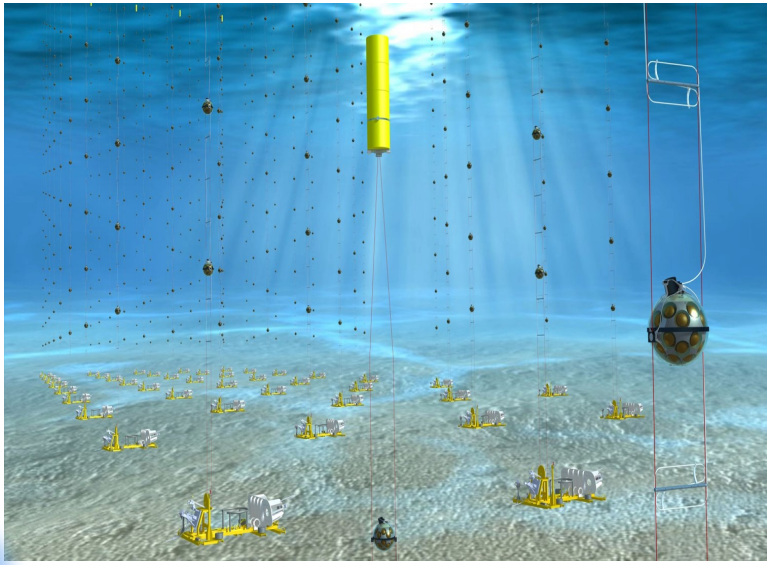
IceCube

ANTARES->KM3NeT

12 lines, 900 OMs



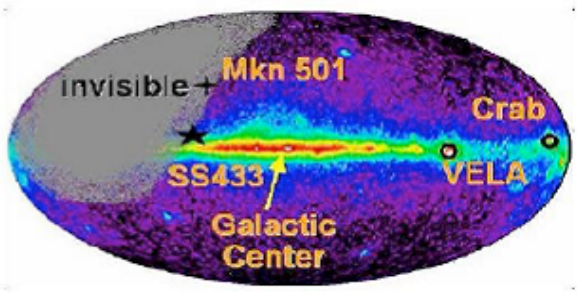
3 Building Blocks (3*115 lines, ~6000 OMs)



Completed 2008
Decommissioning 2022

KM3NeT Strengths

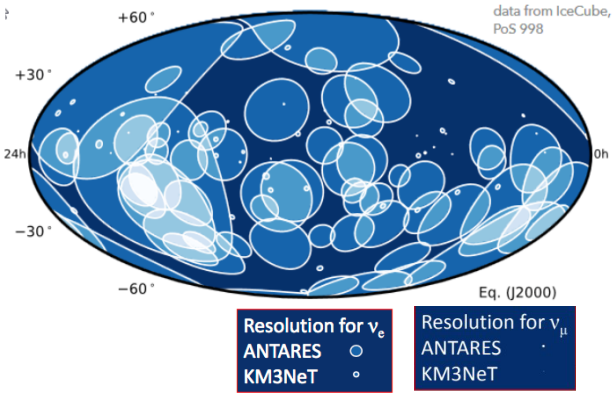
Mediterranean Sea



Location: good view of galaxy centre

-> optimize for galactic sources

-> 10-100 TeV (not PeV)



Angular resolution: Sea water less scattering than Ice

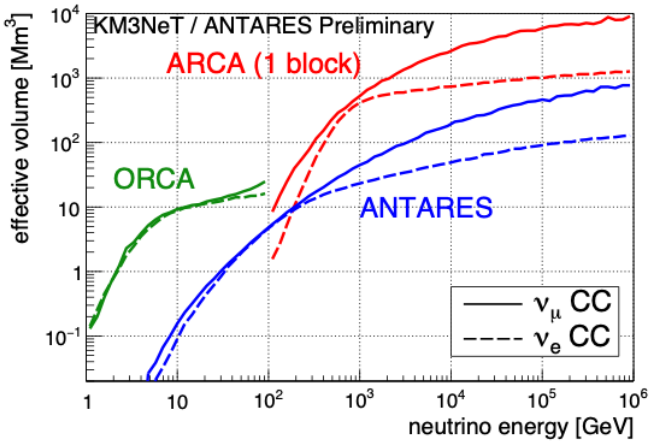
-> better chance to pin point sources

-> multi-flavour astronomy (nu_e, nu_mu, nu_tau)

Large effective volume

-> orders of magnitude better than ANTARES

-> Bit better than IceCube



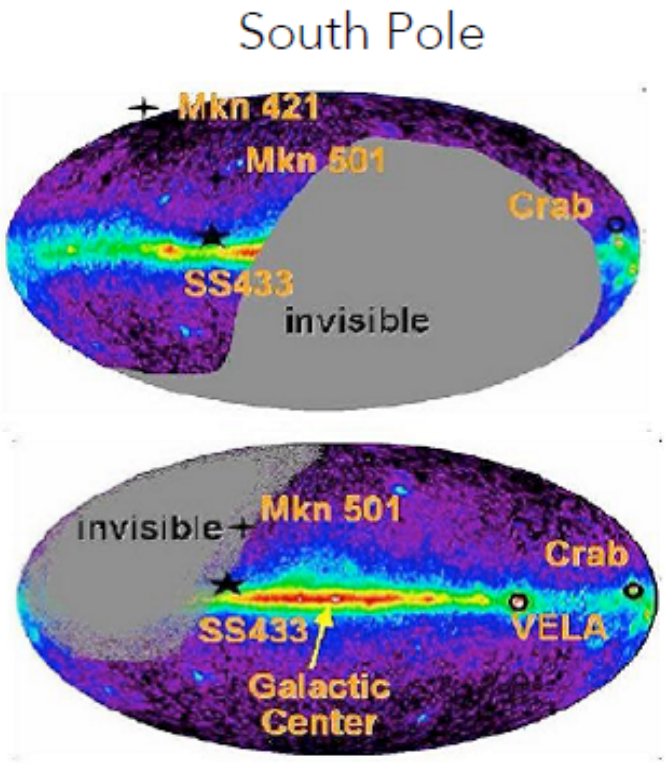
Full Energy range

-> 3 GeV-> 1 TeV : ORCA

-> 1 TeV->PeV : ARCA

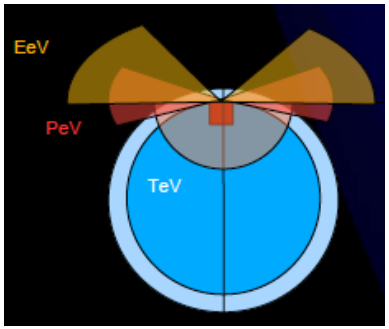
-> neutrino oscillations with atmospheric neutrinos

Location, Location, Location

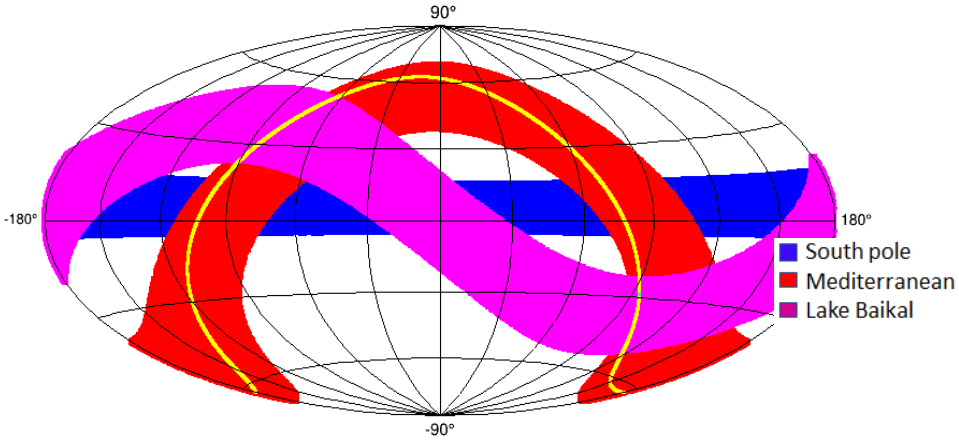


Galactic sources expected at
1-10 TeV energies.

At highest energies, neutrinos
don't pass the Earth:
horizontal tracks are golden channel.



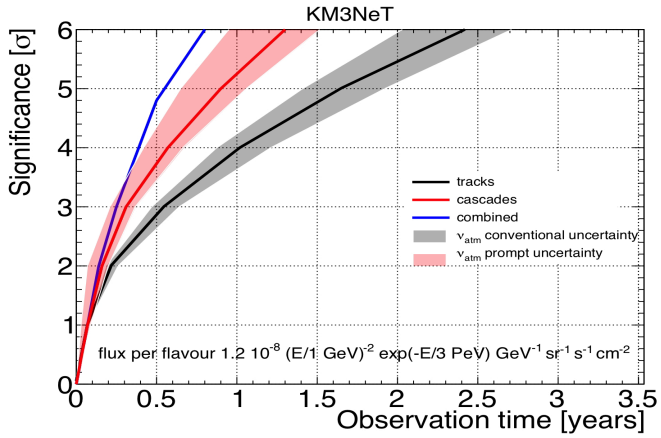
Field of view with horizontal tracks (PeV)



Instantaneous field of view complementary.

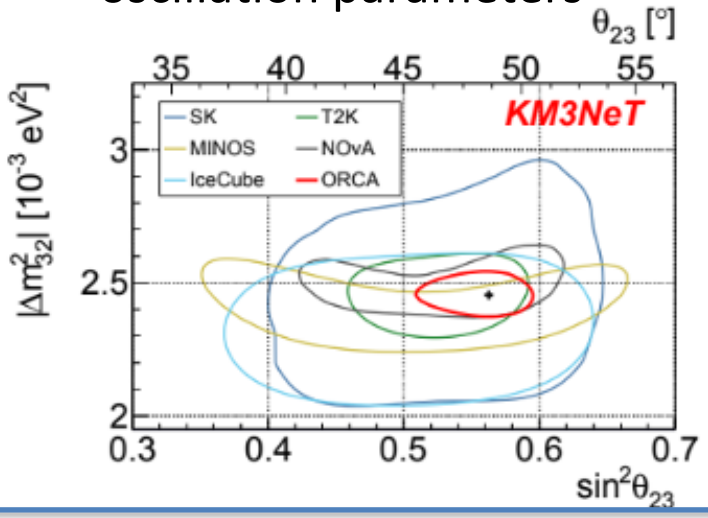
Key KM3NeT science goals

Investigation of the diffuse high energy neutrino flux signal



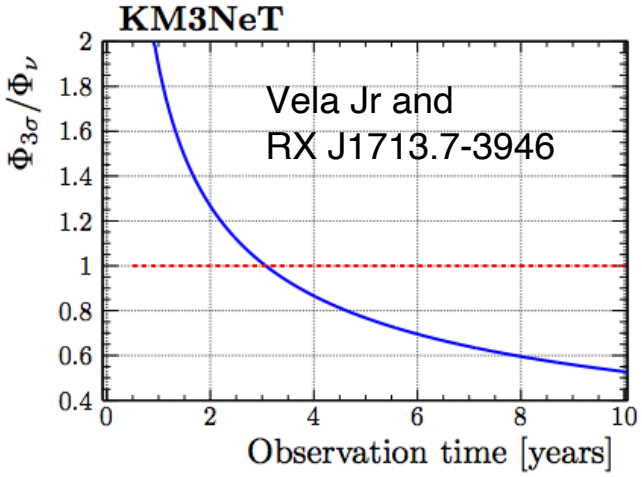
http://dx.doi.org/10.1088/0954-3899/43/8/084001

Measurement of neutrino oscillation parameters

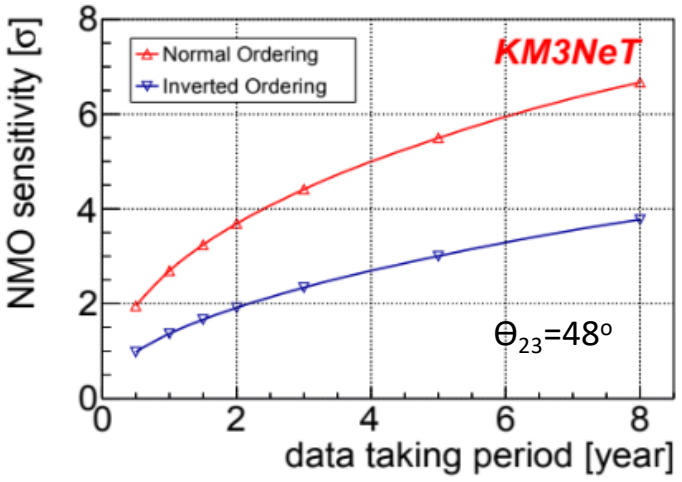


https://arxiv.org/abs/2103.09885

Identification of astrophysical neutrino sources



Neutrino mass ordering

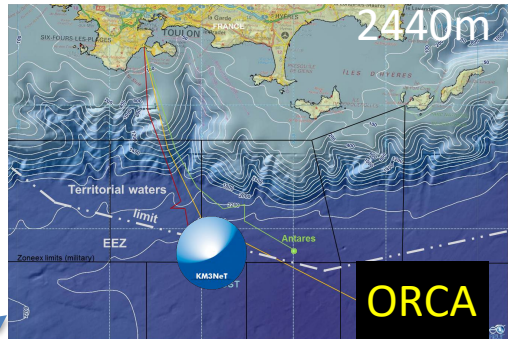


KM3NeT

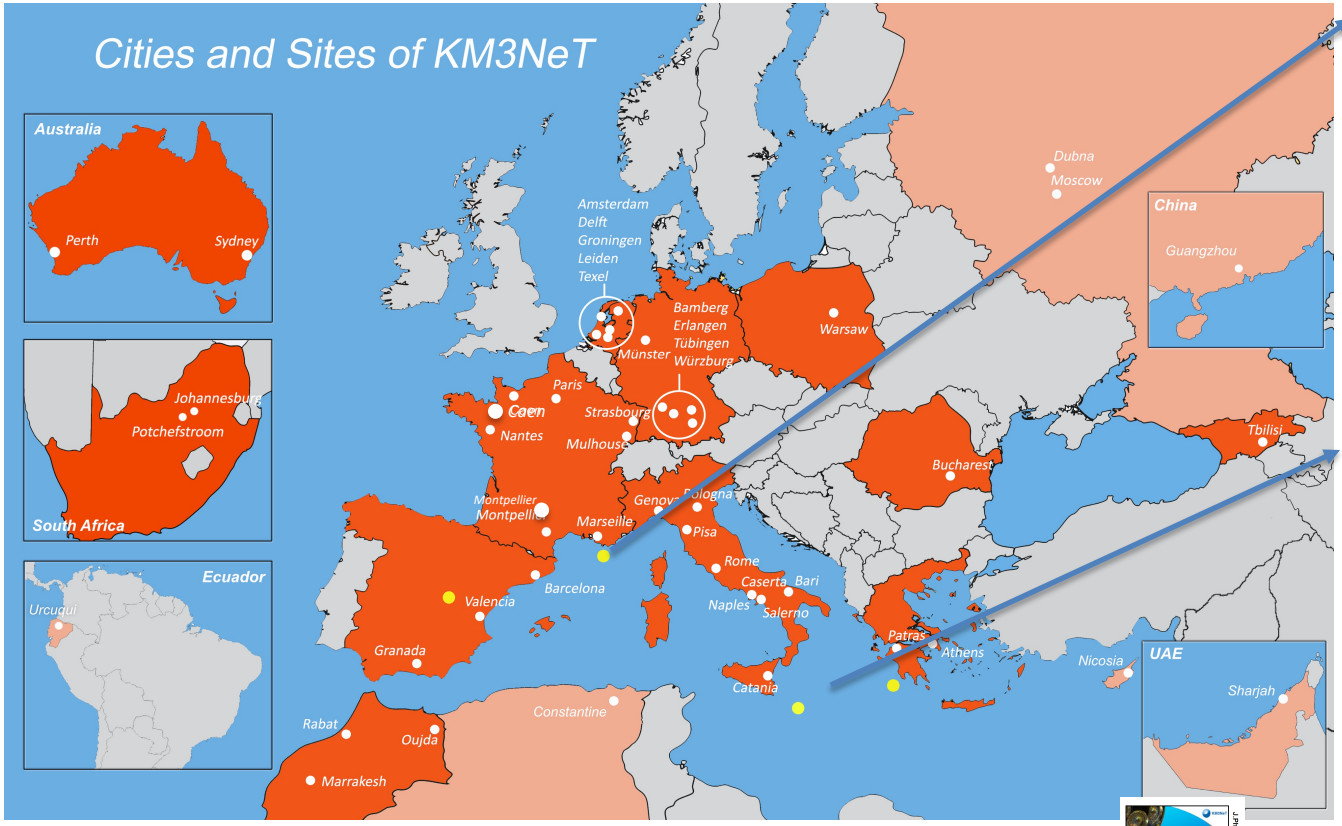
Multi-site, deep-sea infrastructure

Selected by ESFRI roadmap

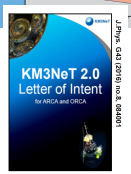
Single collaboration, Single technology



Oscillation **R**esearch with **C**osmics In the **A**byss



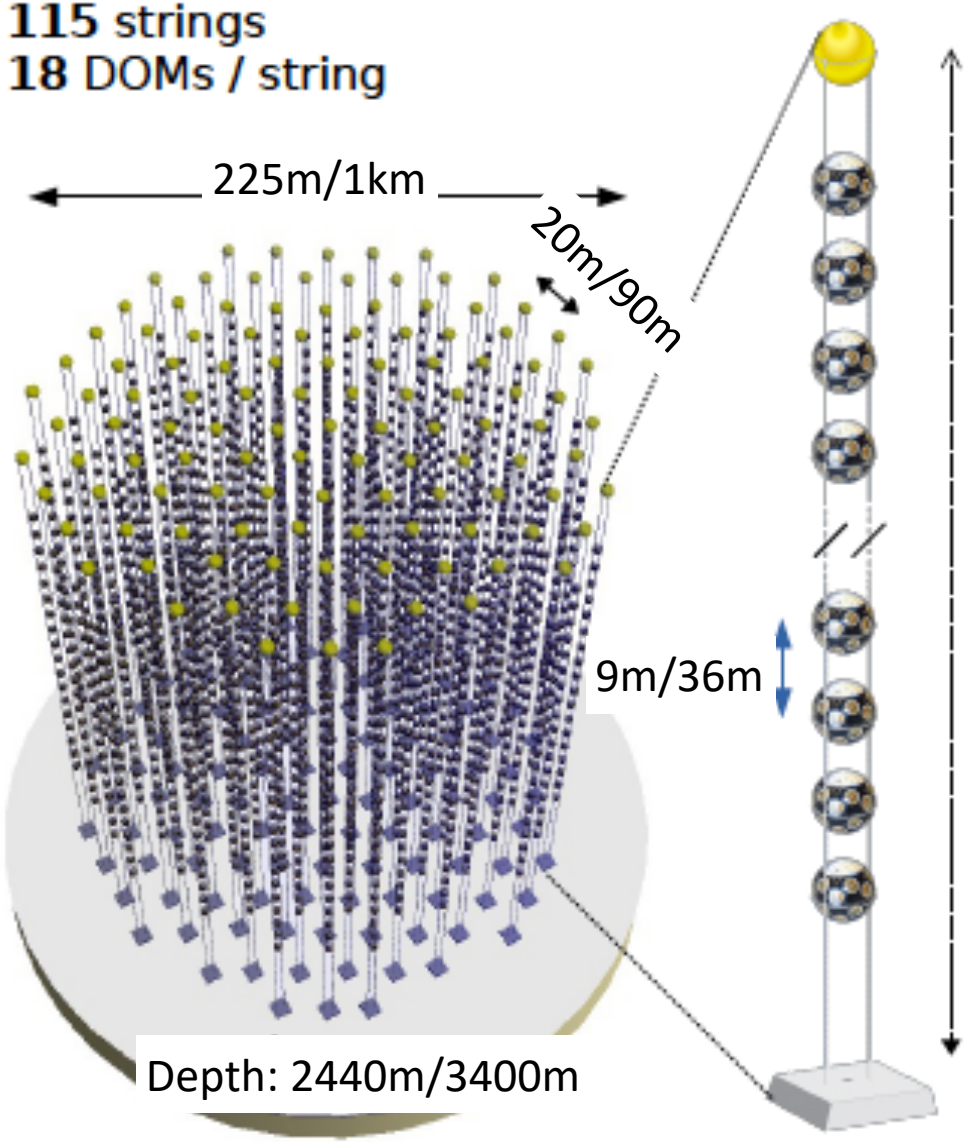
Astroparticle **R**esearch with **C**osmics In the **A**byss

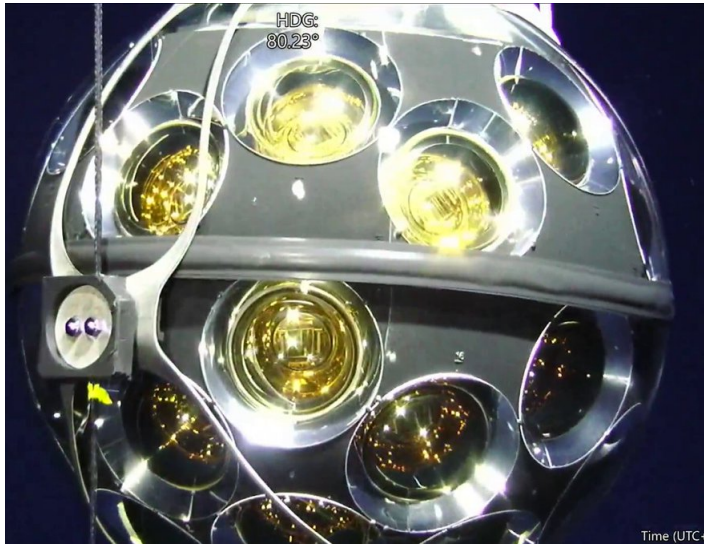


KM3NeT 2.0: Letter of Intent
http://dx.doi.org/10.1088/0954-3899/43/8/084001
J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001

Connection nodes of
european multidisciplinary seafloor & water column observatory
emso

KM3NeT Building Block



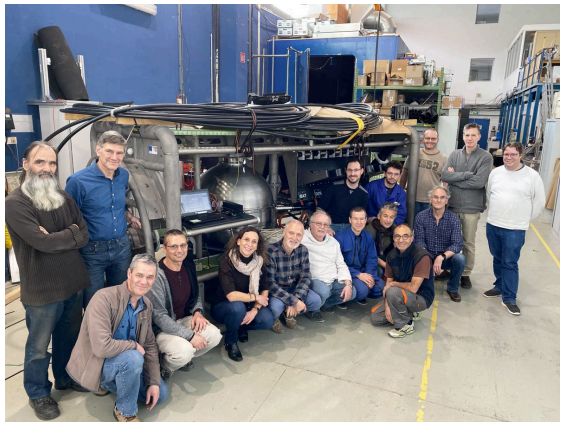


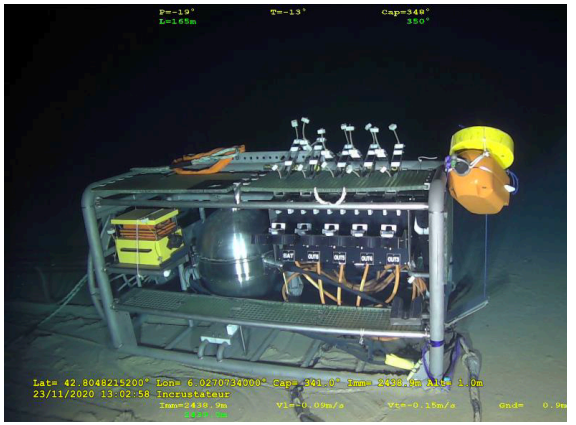
- 31 x 3” PMTs
- Gbit/s on optical fibre
- Hybrid White Rabbit
- LED flasher & acoustic piezo
- Tiltmeter/compass

Instrumented mass	7 Mton	500	2 Mton

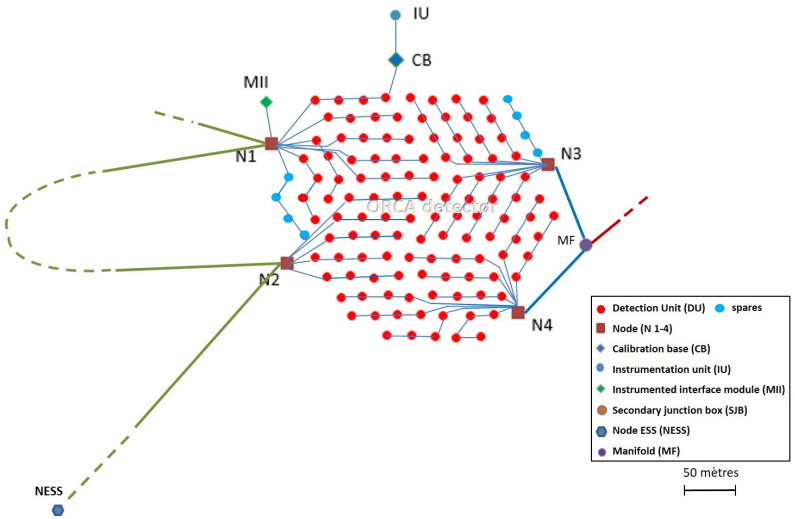
ORCA: Connection second junction box

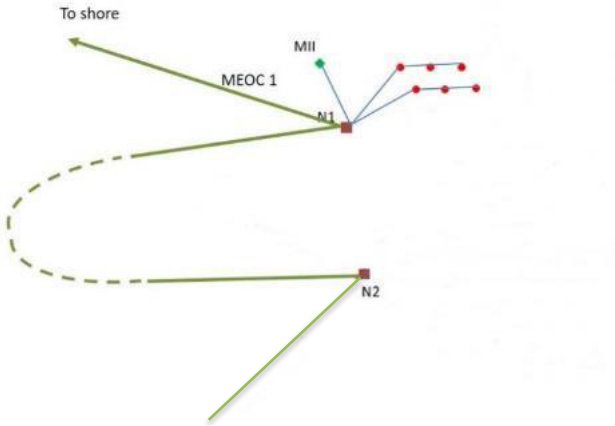
16-24 Oct 2020: Successful connection of Junction Box 2 to ORCA
https://www.km3net.org/sea-operation-in-times-of-corona/





Preliminary DUs connection scheme 2021-02-09

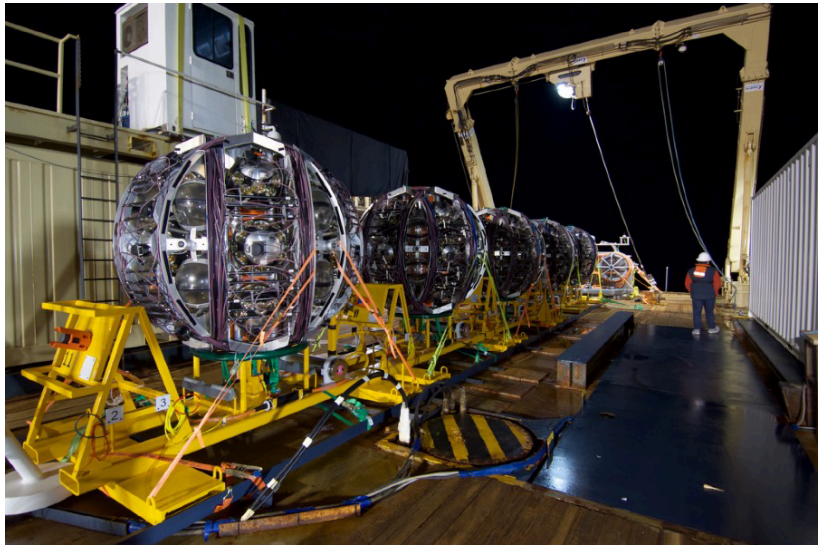


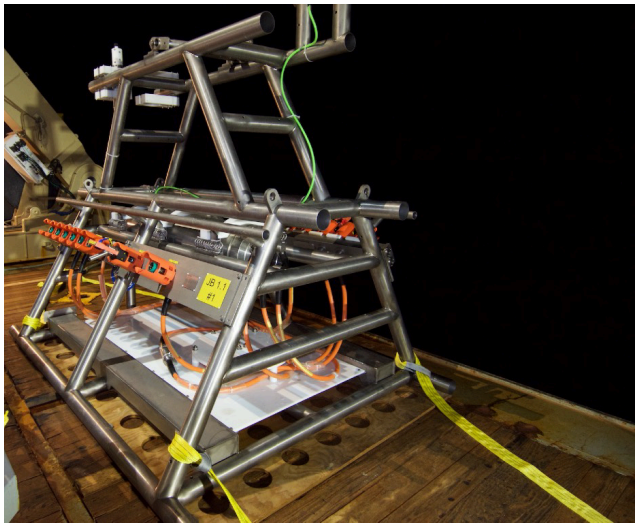


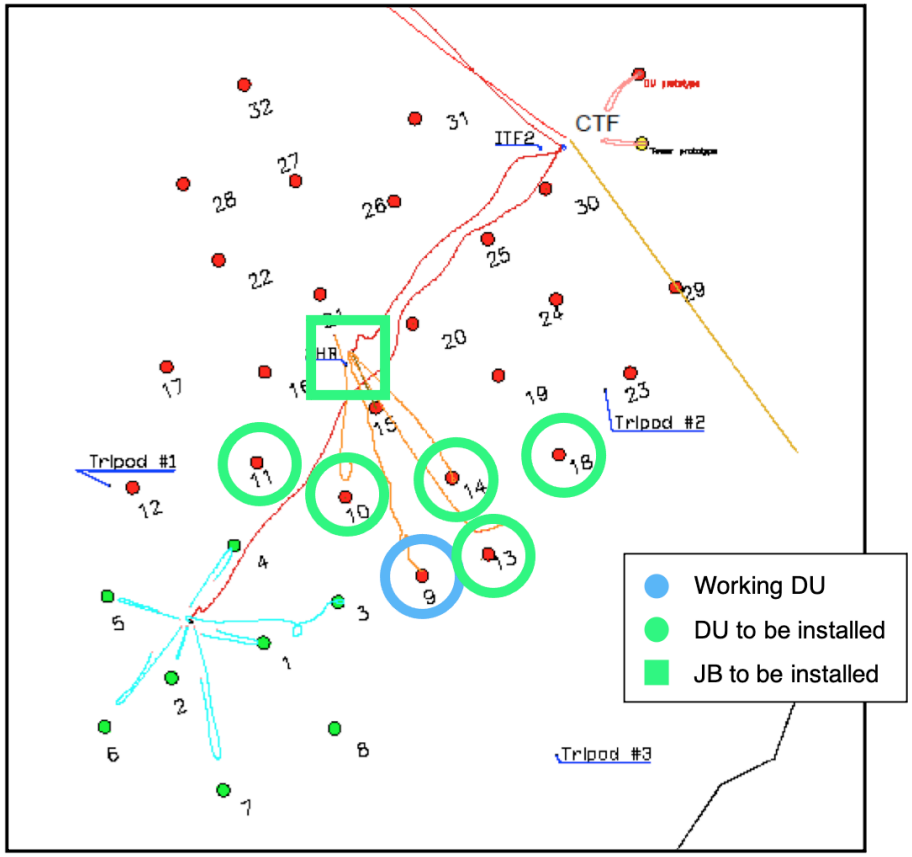
Can now connect upto 52 DUs

ARCA: Connection JB and 5 DUs

8-17 April 2021: Deployment of 1st Junction Box
Connection of +5 new DUs



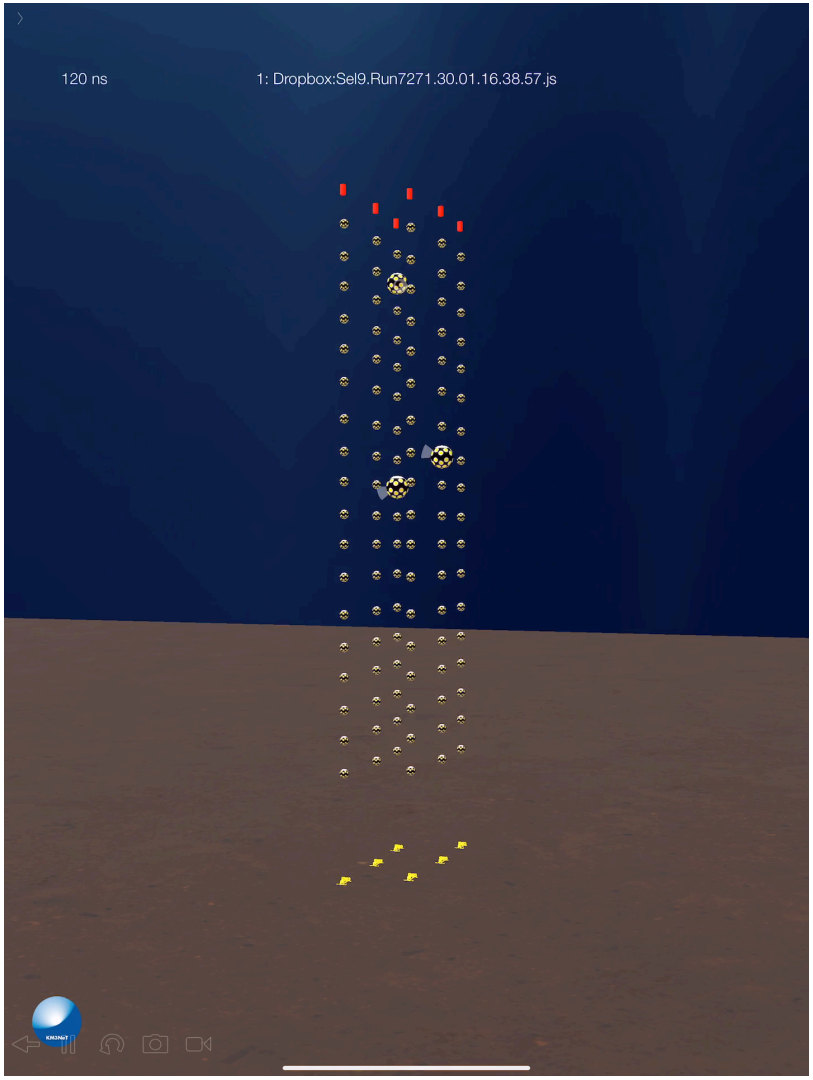




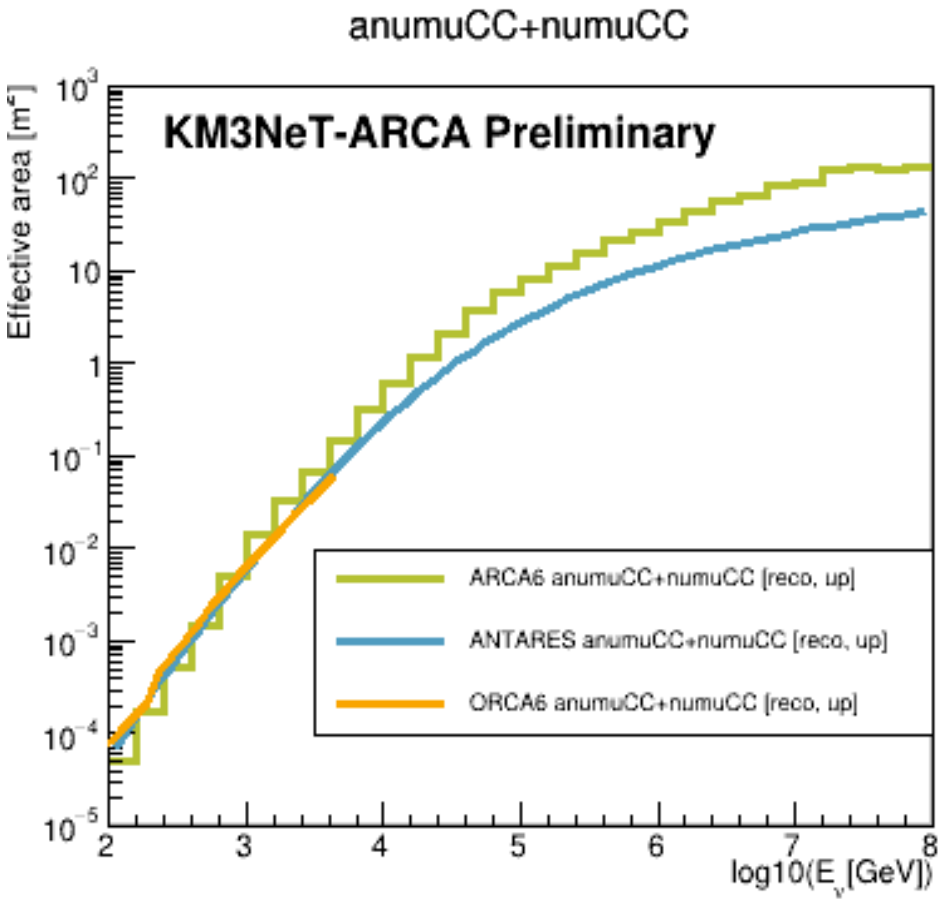
12 KM3NeT Detection Units now operational

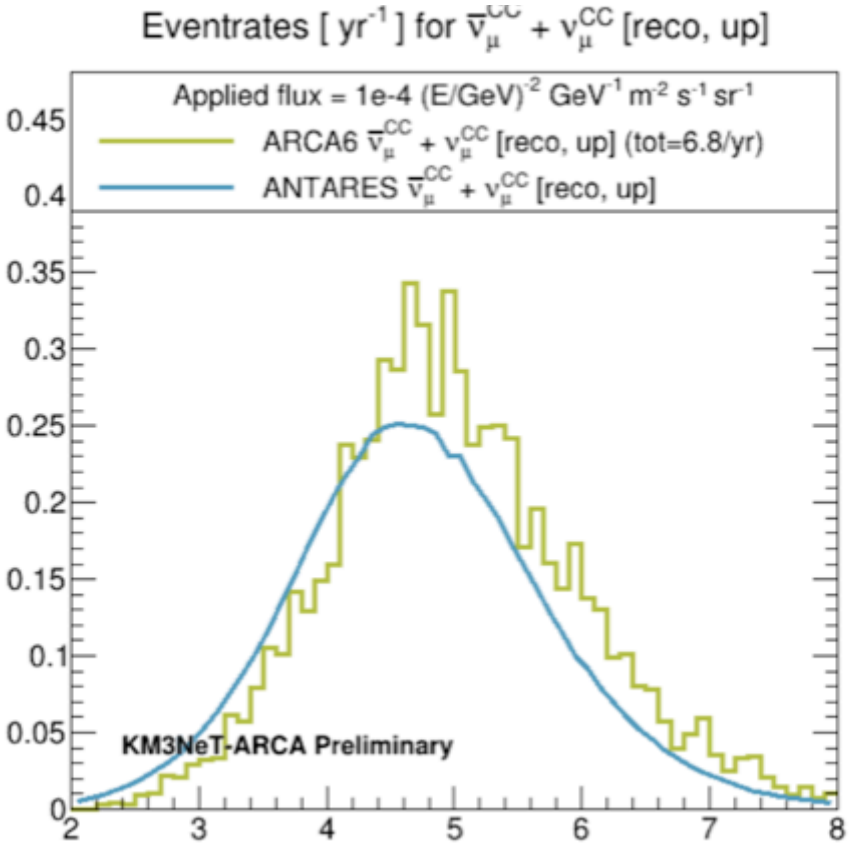
Downgoing muons from cosmic ray showers in ARCA6

Upgoing muons from atmospheric neutrinos In ORCA6



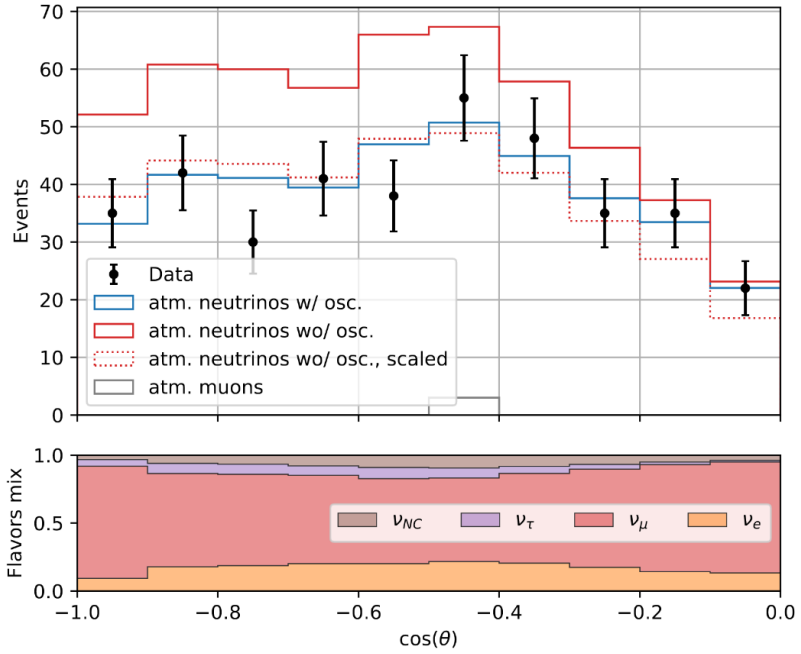
ARCA6+ORCA6 vs ANTARES



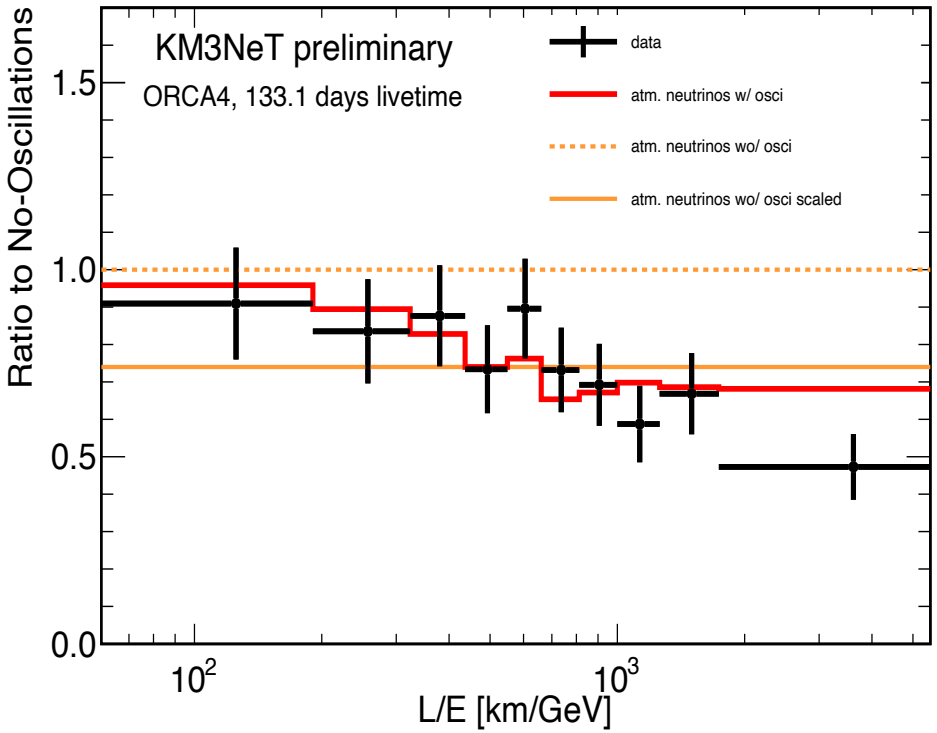


ORCA4 neutrino oscillations (tracks only)

Cos (zenith)



Normalised to non-oscillated

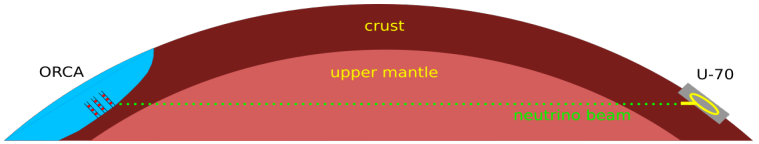


Oscillation favoured at ~2.5σ
(flux normalisation free)

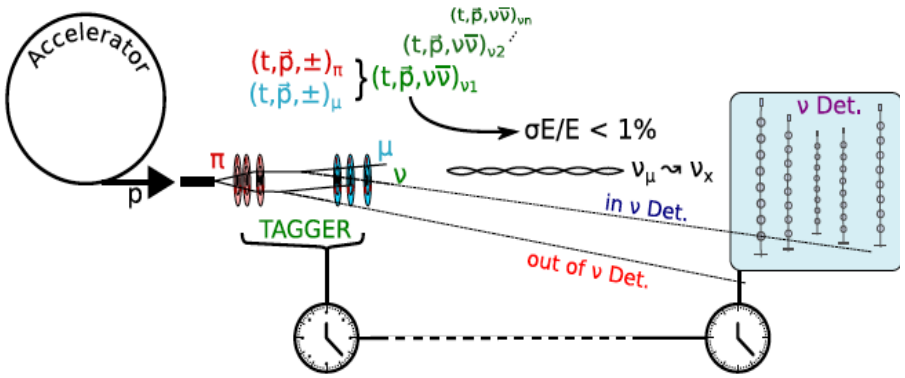
x10 more data with ORCA6 - unblinding in time for ICRC

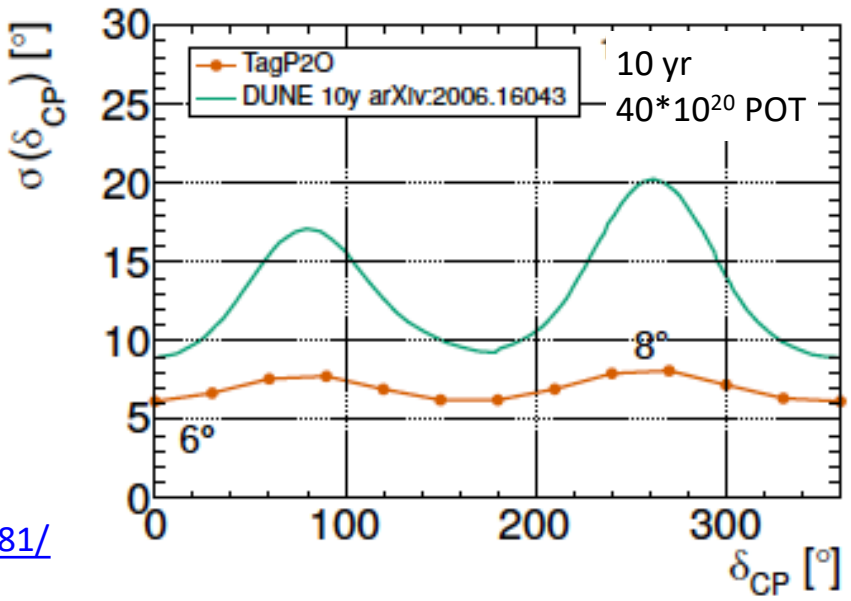
Tagged Protvino to ORCA (TagP2O)

A. V. Akindinov et al.,
"Letter of Interest for a Neutrino Beam from Protvino to KM3NeT/ORCA"
https://arxiv.org/abs/1902.06083



- Neutrino Beam from Protvino to ORCA
- Baseline 2590 km
- First oscillation maximum 5.1 GeV
- Sensitivity to mass hierarchy and CPV
- LoI published: arXiv:1902.06083
- Huge detector -> relax beam power
- New idea - ν tagging at source:





Mathieu Perrin-Terrin@NuTel2021
https://agenda.infn.it/event/24250/contributions/130081/

GNN
The Global Neutrino Network

Web site hosted by JINR

https://www.globalneutrinonetwork.org/

Cooperation ANTARES, GVD-Baikal, IceCube, KM3NeT

Develop coherent long term strategy

Political representation of the neutrino astronomy field

Organise biannual VLVnT Conference/MANTS symposia (VLVnT 2018@JINR)

Oversees combination of results

Neutrino alert network coordination

Annual Dissertation Prize

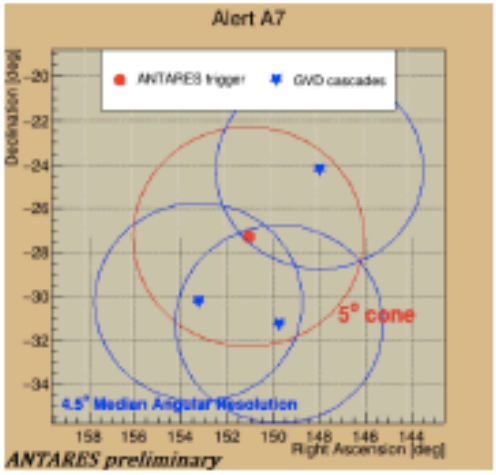
Monthly newsletter

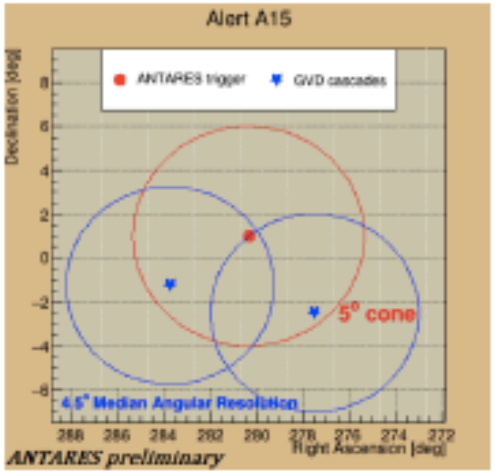
Latest monthly newsletter here:
https://dlnp.jinr.ru/en/science-news/gnn-news/actual-edition

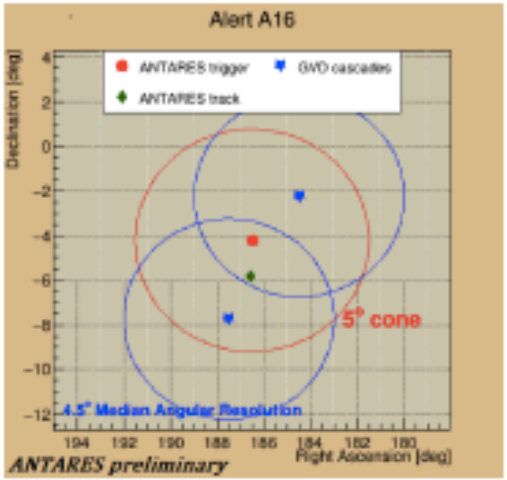
GVD Baikal follow-up of ANTARES alerts

31 ANTARES alerts sent to GVD Baikal, 28 followed up:
Search within ±500s, ±1hour, ±1 day within 5 degree
(cascade median resolution 4.5 degrees)

=> For 3 alerts multiplets of cascades reconstructed within ±1day







5 GVD clusters running during that period
Background events/cluster/day ranging from 0.02-0.05

No additional showers seen in ANTARES for that same direction within ±1 day
Still searching for additional tracks

Summary

Outstanding scientific program

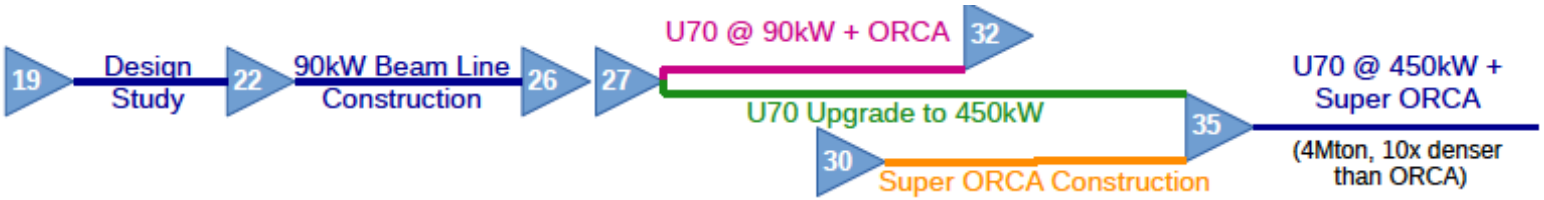
Both GVD and KM3NeT coming online now

Excellent prospects for:

- sharing technology (fibres, white rabbit, PMTs, …)
- analysis methods (event reconstruction, machine learning, ….)
- multi-messenger alerts (e.g. MASTER robotic telescope followups)
- data

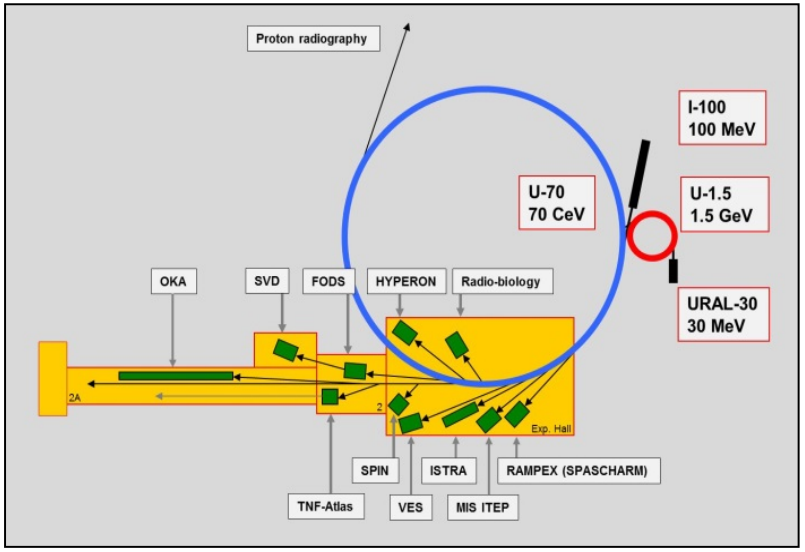
Co-operations started, helped by GNN

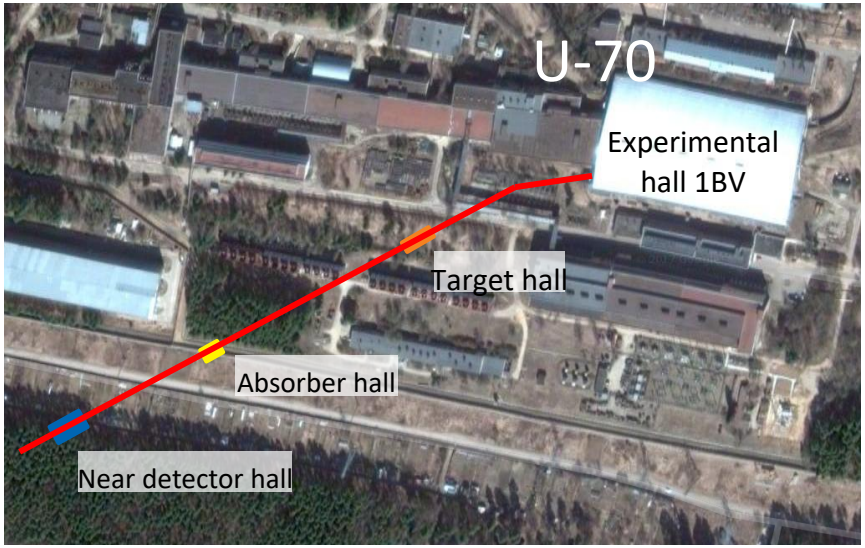
Tagged Protvino to ORCA – the ultimate LBL neutrino experiment

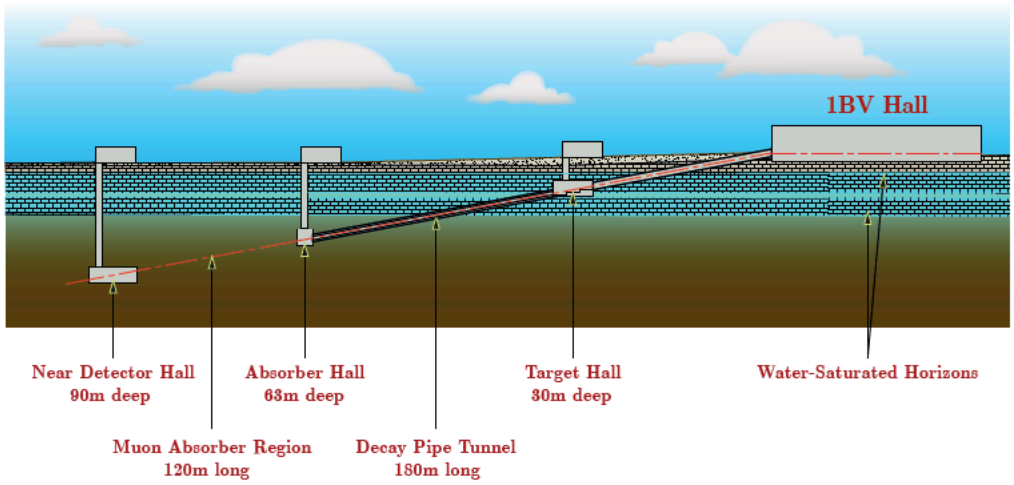


BACKUP

Proposed Protvino beamline



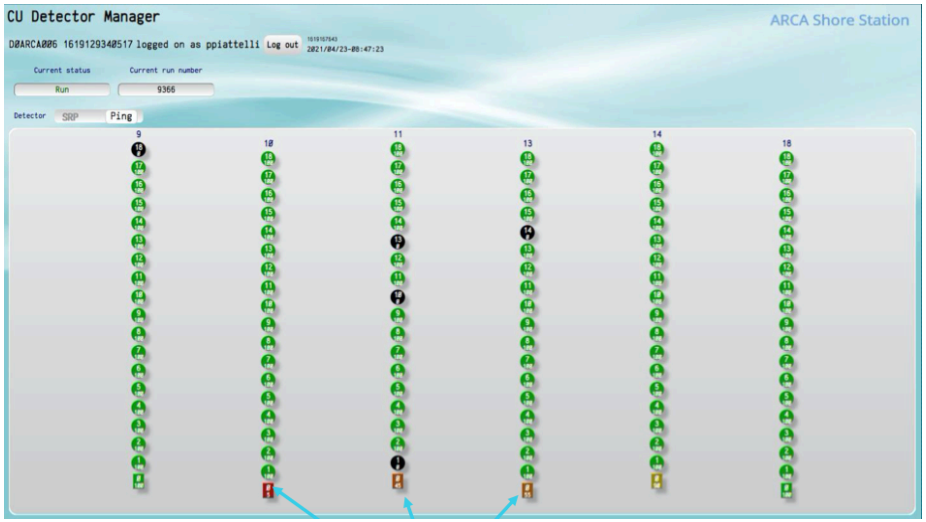


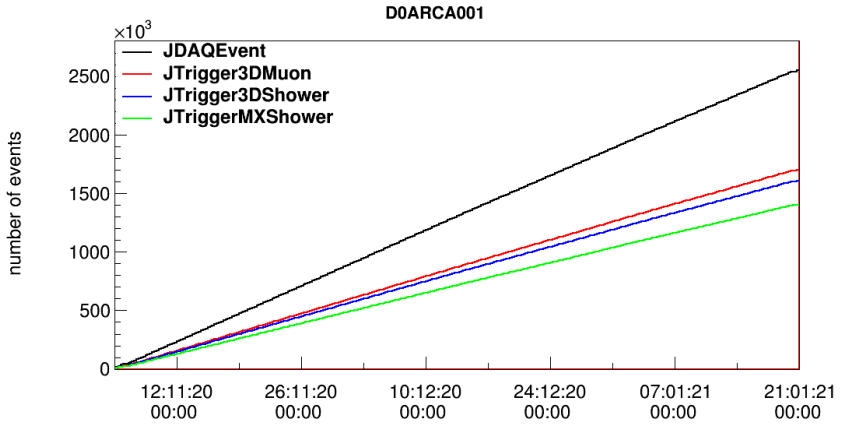


A. Zaitsev, VLVnT 2018
Anatoly Sokolov

Data Taking

ARCA

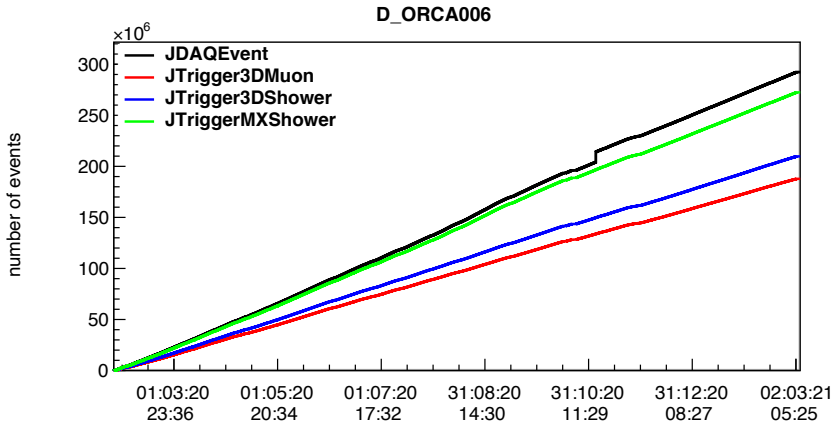




Data taking efficiency: 98.1%

1st DU: 5 years in the sea

ORCA

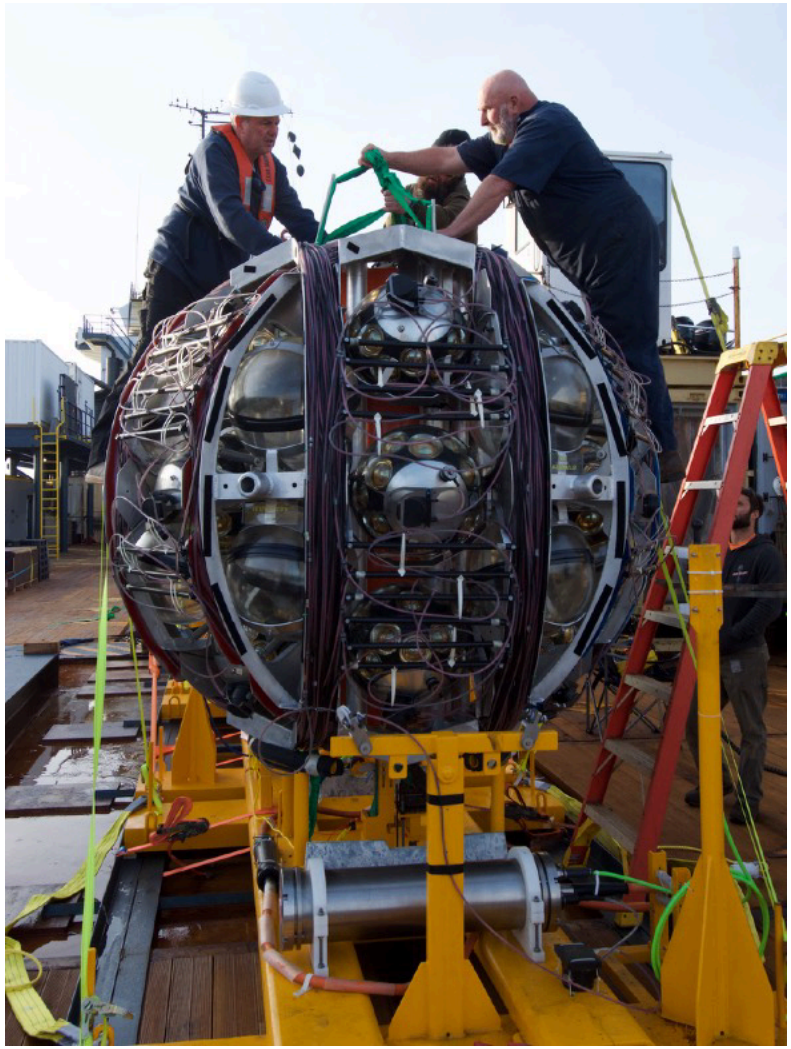


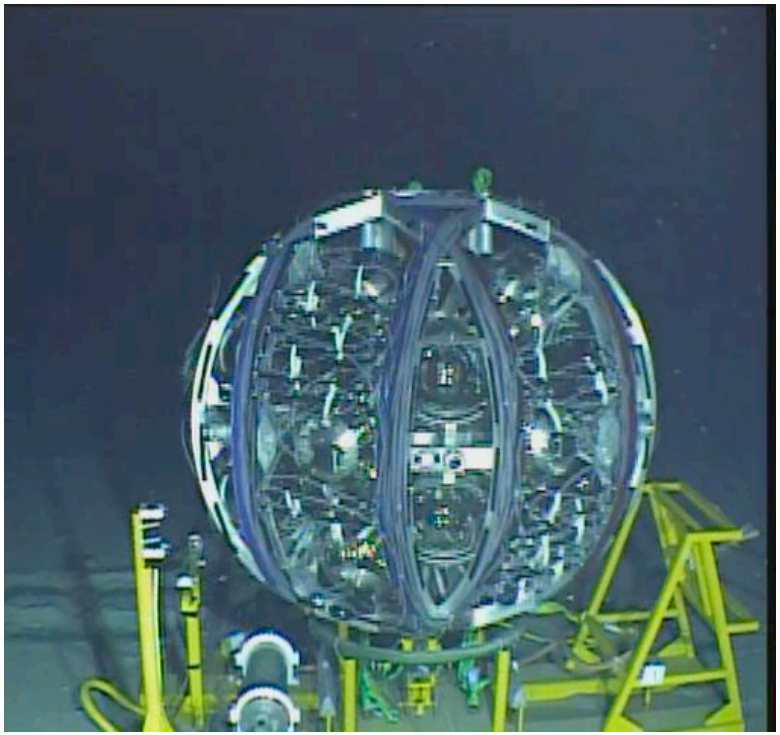
Data taking efficiency: 98.8%

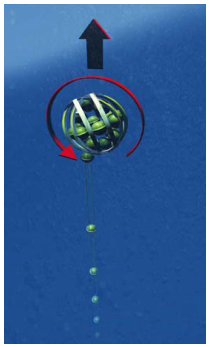
6 DUs operating for over 1 year

KM3NeT Deployment

Deployment Vehicle

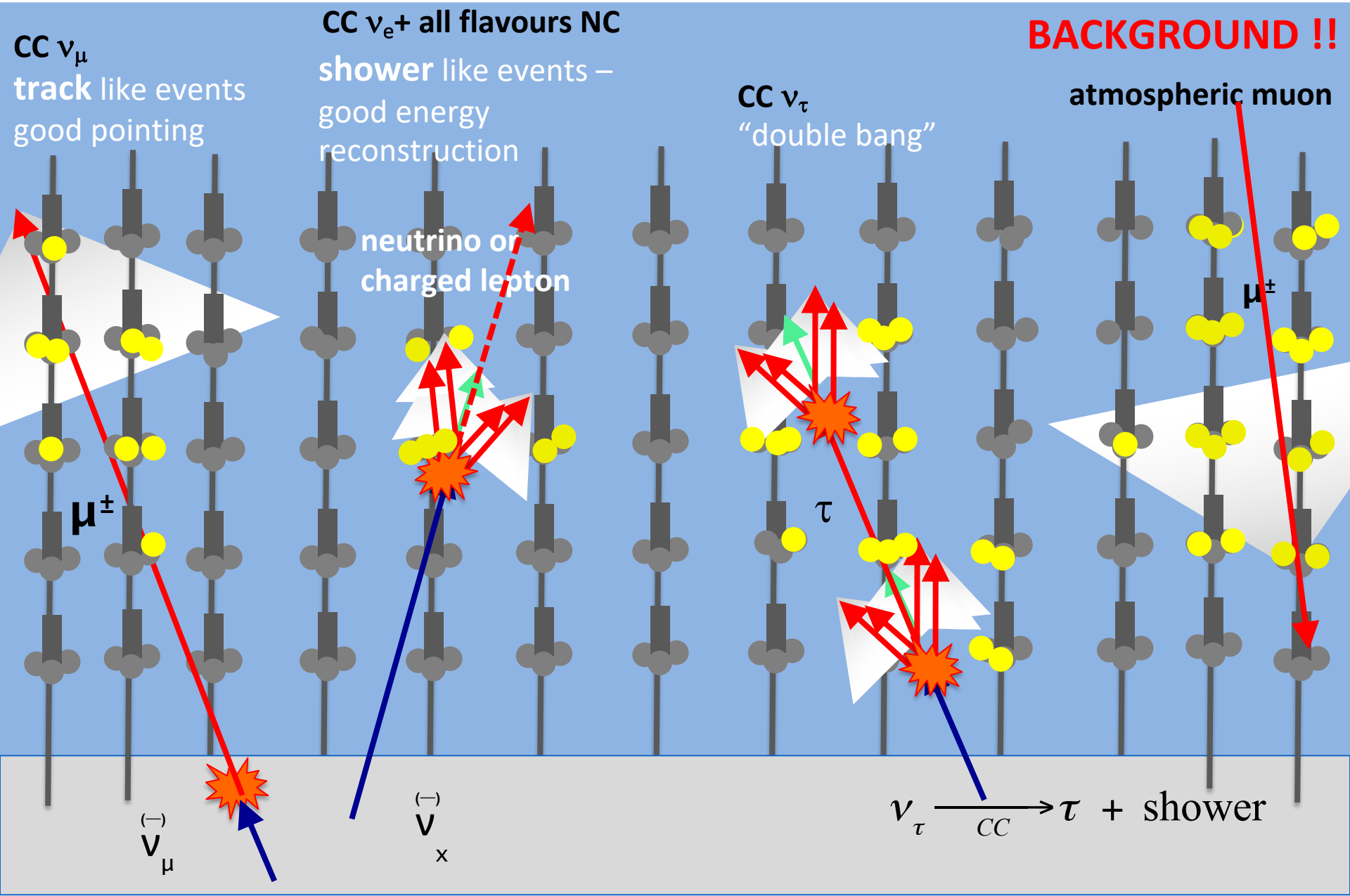






- Rapid deployment
- Multiple strings/sea campaign
- Autonomous/ROV unfurling
- Reuseable

Event Topologies



Seafloor Infrastructures