KM3NeT Status and Prospects

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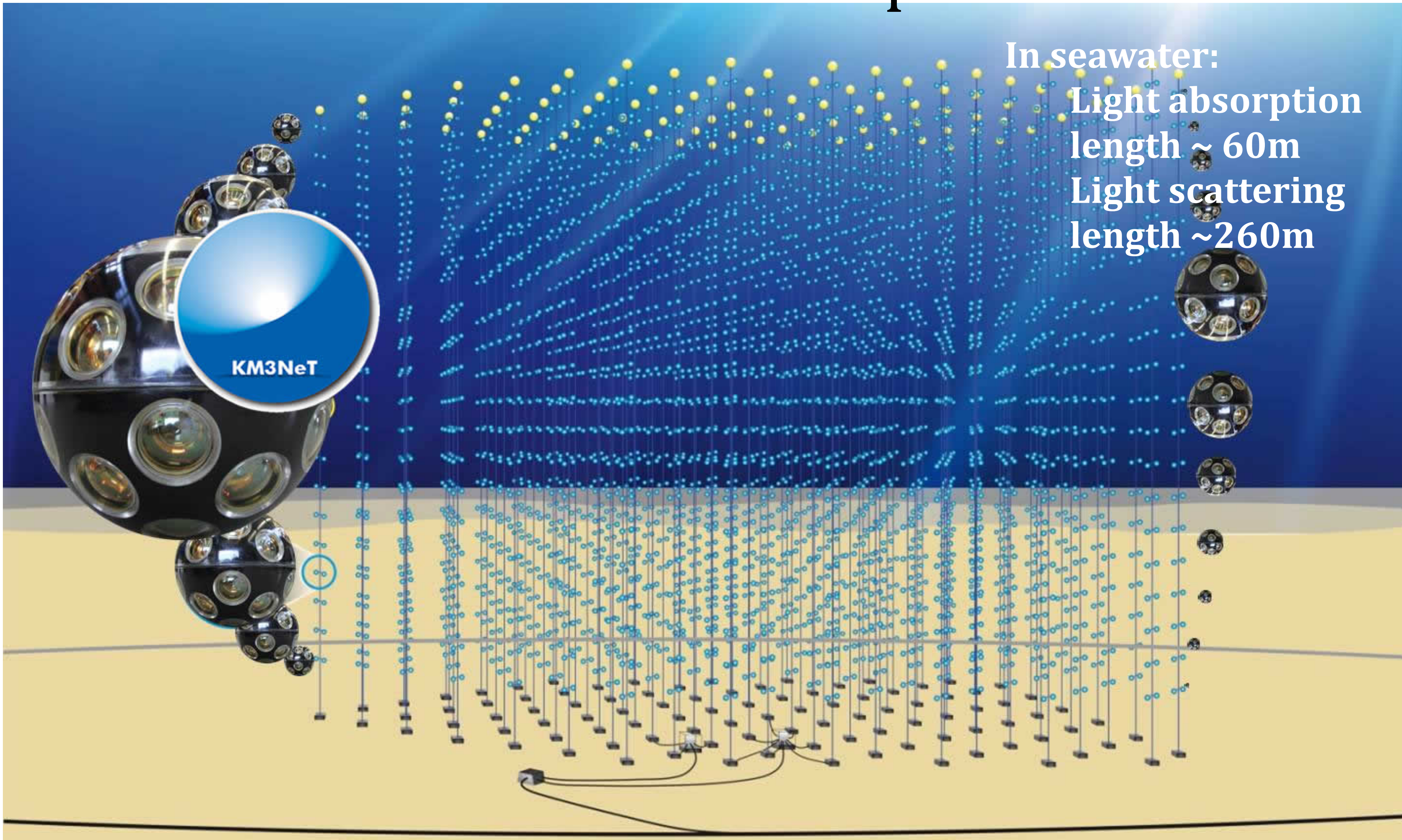
On behalf of the KM3NeT Collaboration

NNN 2018

Neutrino Telescopes

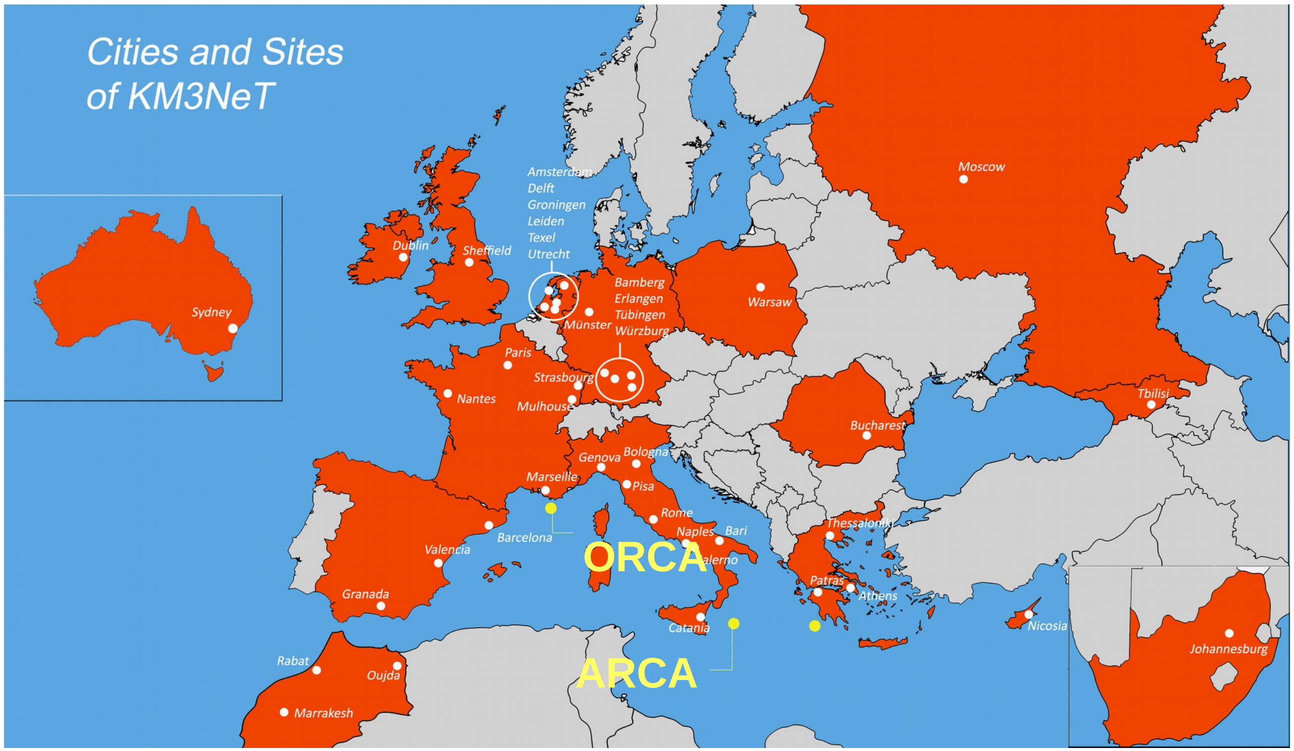


Basic principle: look for Cherenkov tracks in large instrumented volume
Similar to other Cherenkov detectors, but on a much larger scale

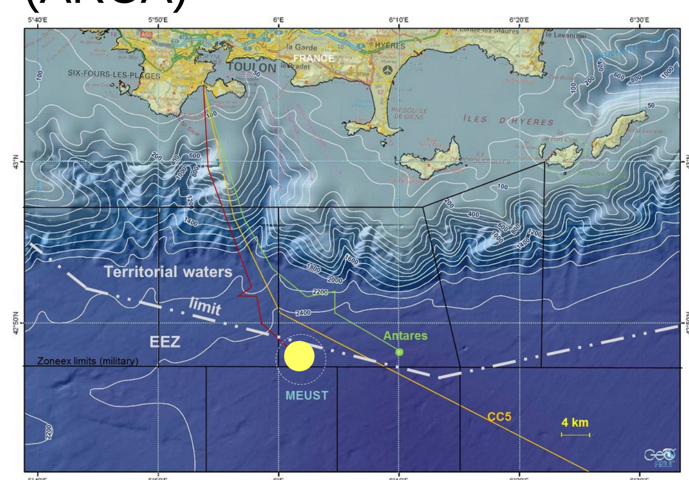
KM3NeT

The KM3NeT Experiment

km³ Neutrino **T**elescope



Astroparticle Research with Cosmics in the Abyss (ARCA)



Oscillation Research with Cosmics in the Abyss (ORCA)

Two sites:

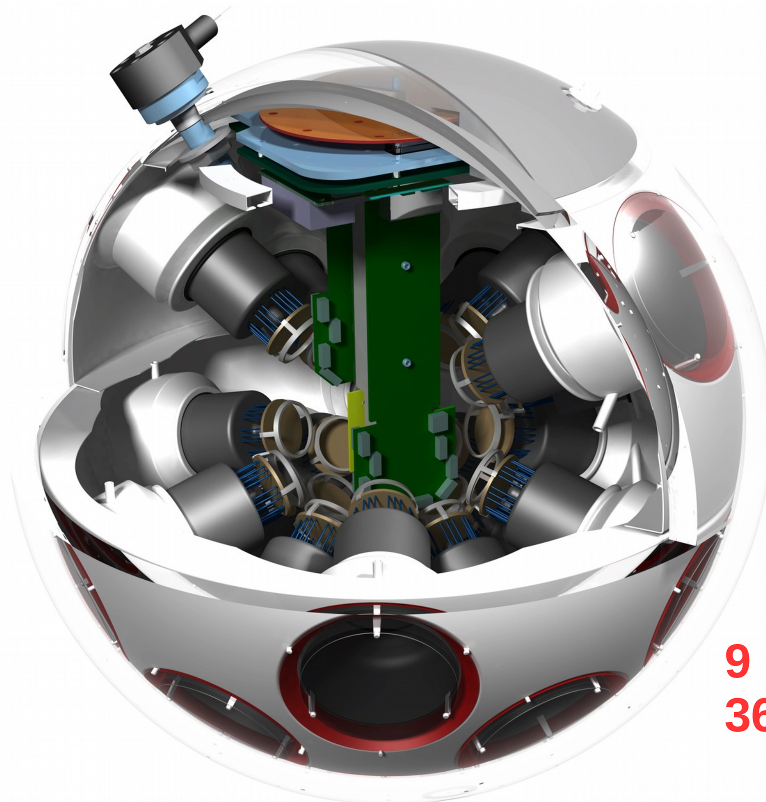
ARCA – High energy

ORCA – Low Energy

Same technology and collaboration

The Digital Optical Module

- 17” diameter
- 31 x 3” PMTs per module
- Used for both ARCA and ORCA – same line design and detection units, different spacing

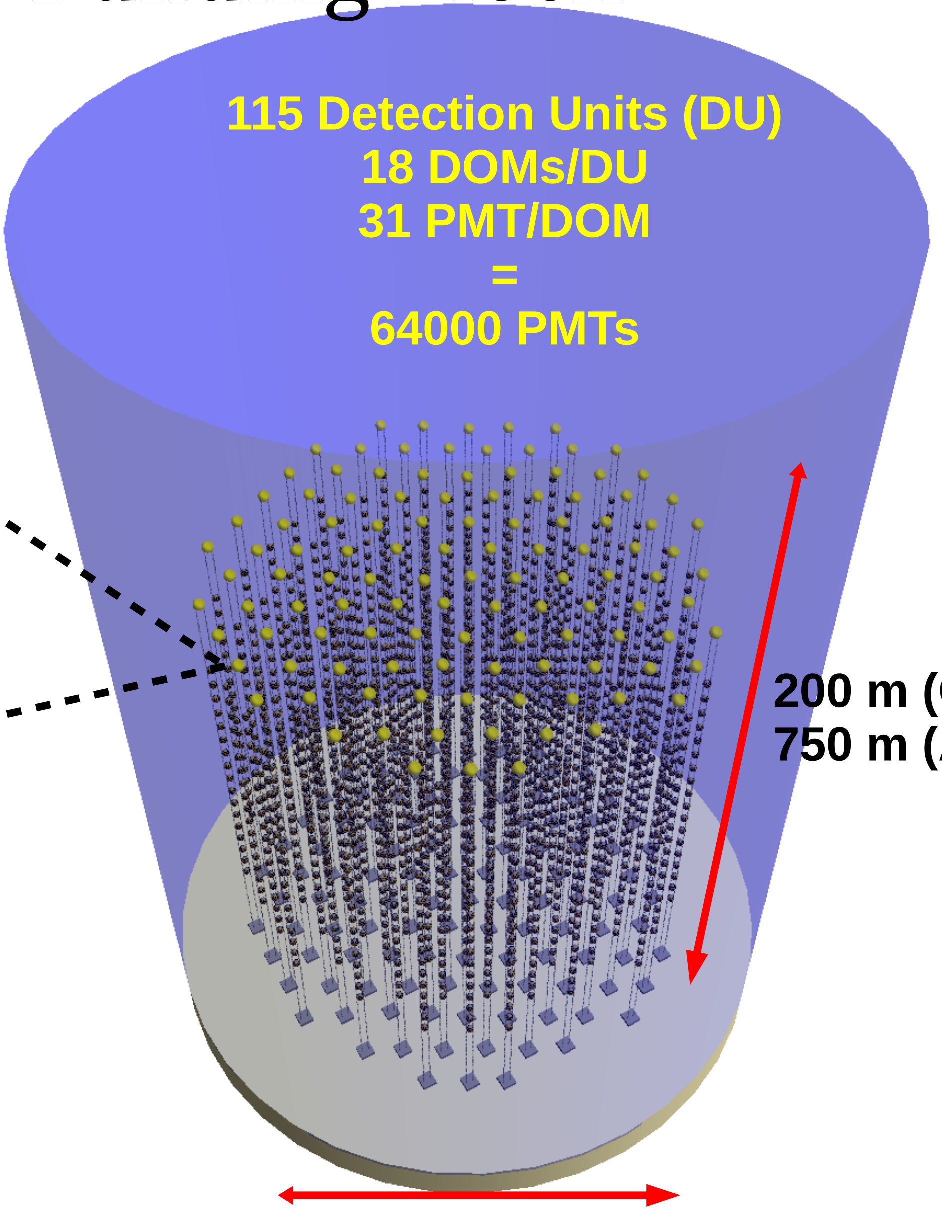


This design allows for:

- Uniform angular coverage – and therefore direction reconstruction
- Digital photon counting

The KM3NeT Building Block

Digital Optical Module (DOM)



ORCA looks at lower energies (10s of GeV):

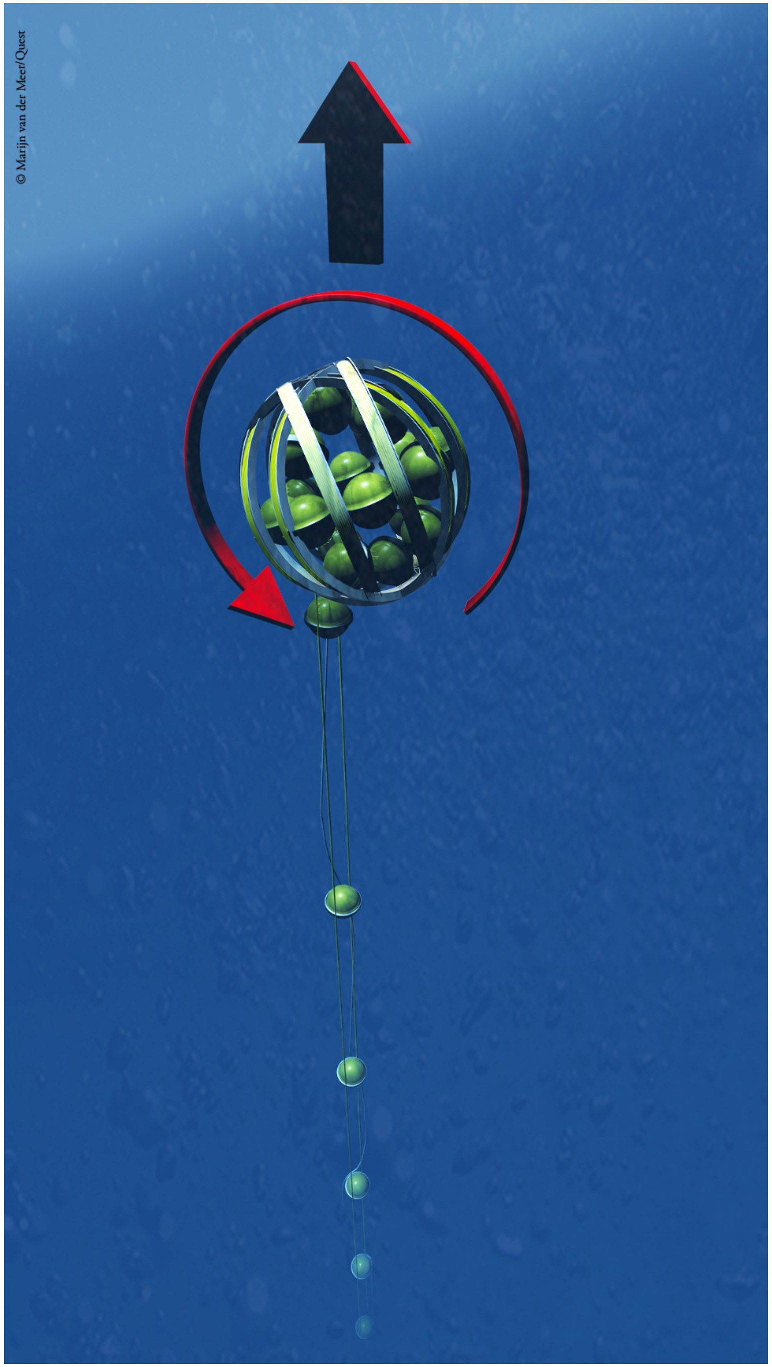
- 8 Mton instrumented
- Densely instrumented (23m spacing between lines)

ARCA looks at high energy neutrinos:

- 2 building blocks
- 2 x 500 Mton instrumented

Depth: 2435 m

Deployment



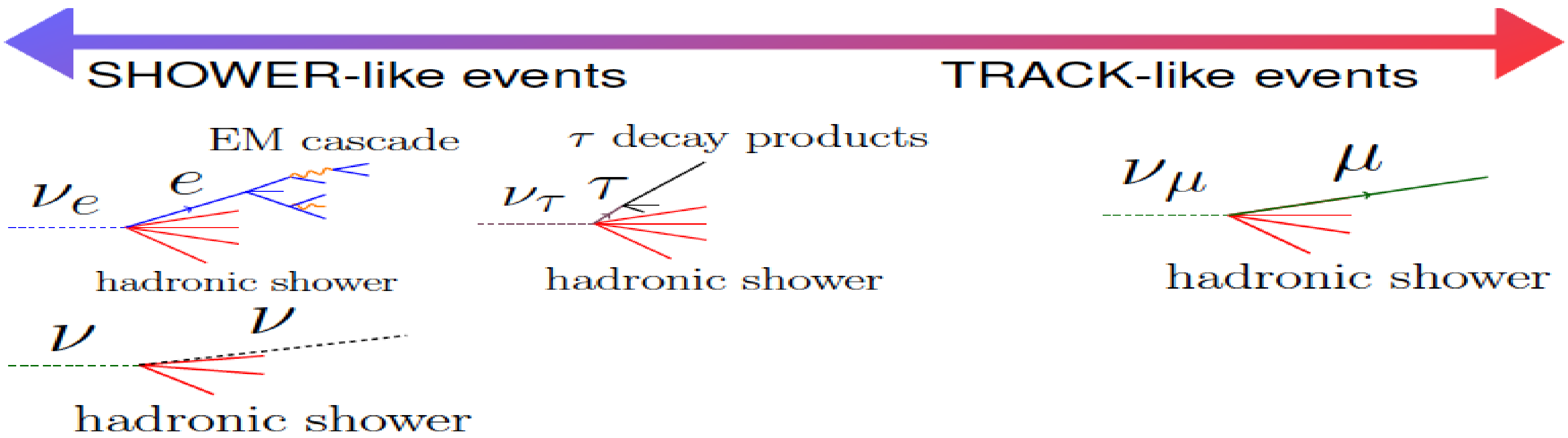
Rapid deployment possible

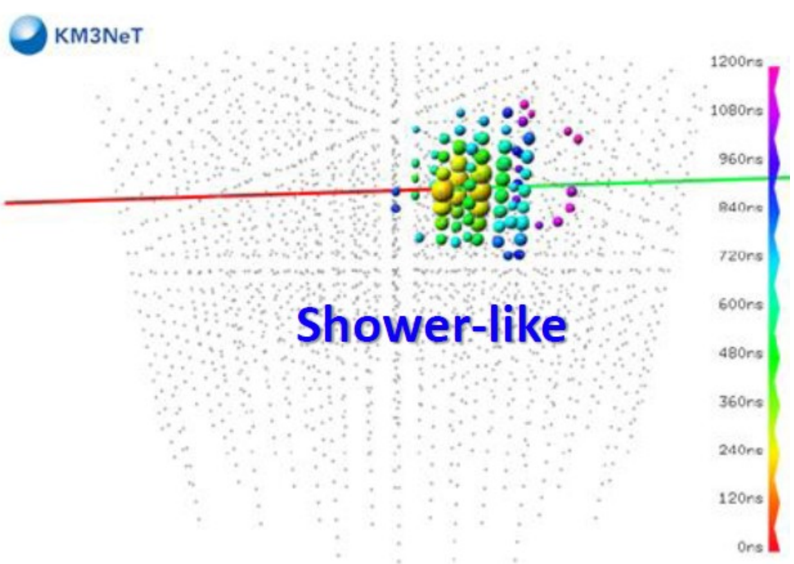
- Autonomous unfurling for each string
- Acoustic signalling

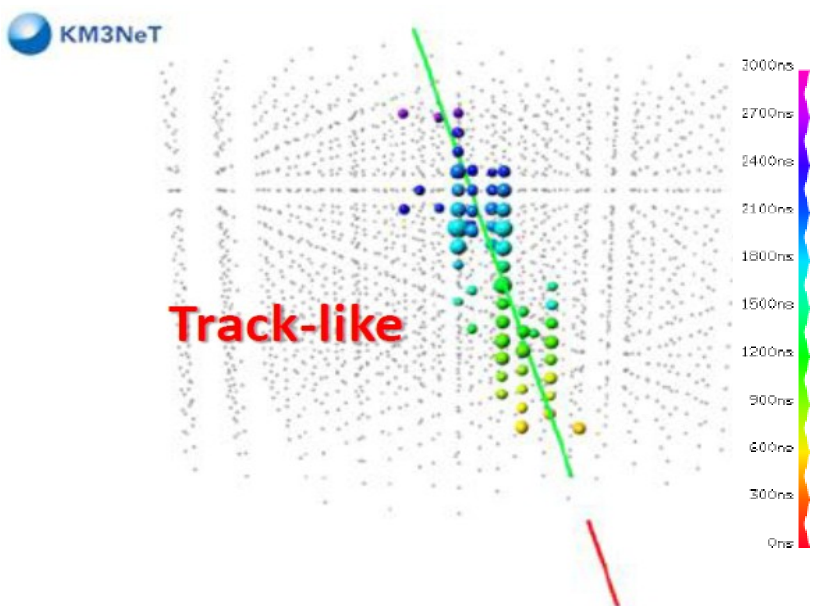
Can deploy multiple strings per sea operation

KM3NeT

Neutrino Signal







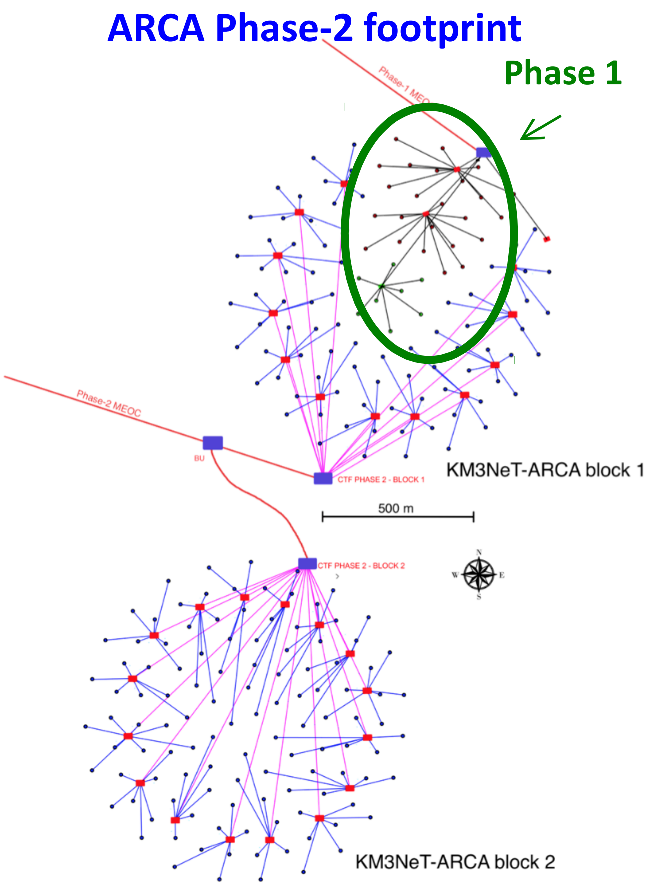
ARCA Current Status

3 strings deployed late 2015 / early 2016

- 2 ran successfully for data taking until April 2017, due to a power fault

Currently working on improvements to seabed network

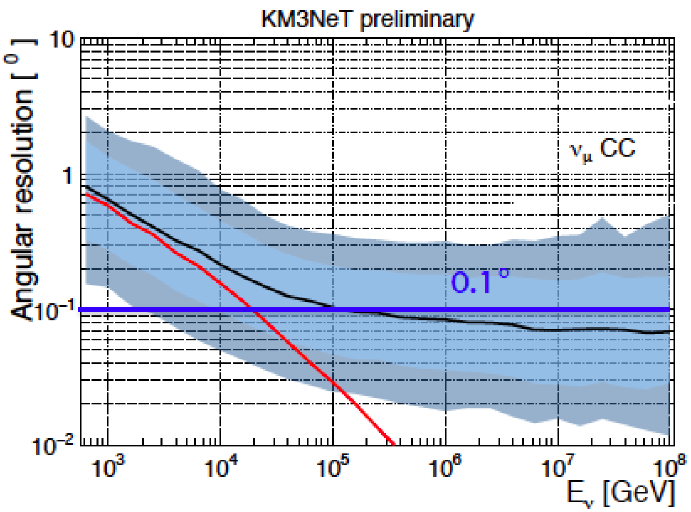
String deployment planned to resume by mid-2019



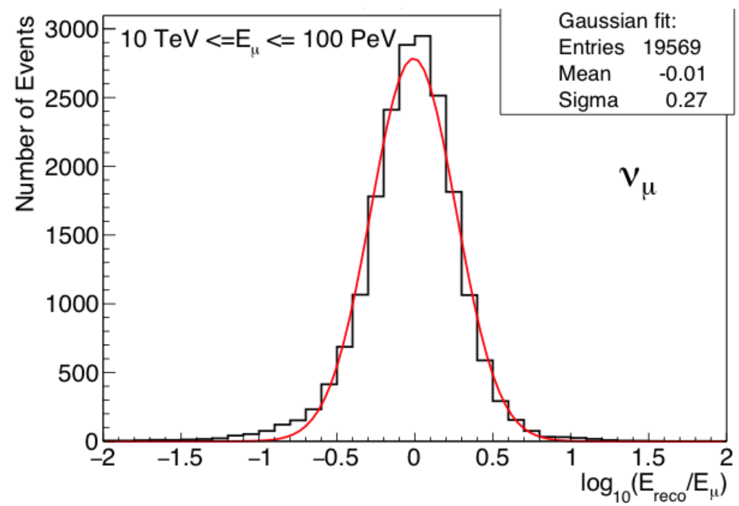
Phase 1 – 24 strings
Phase 2 – full ARCA deployment

Angular Resolution

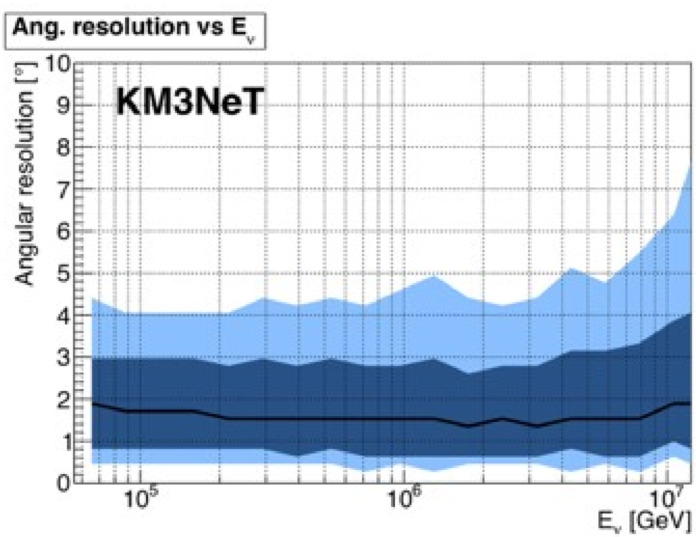
Energy Resolution

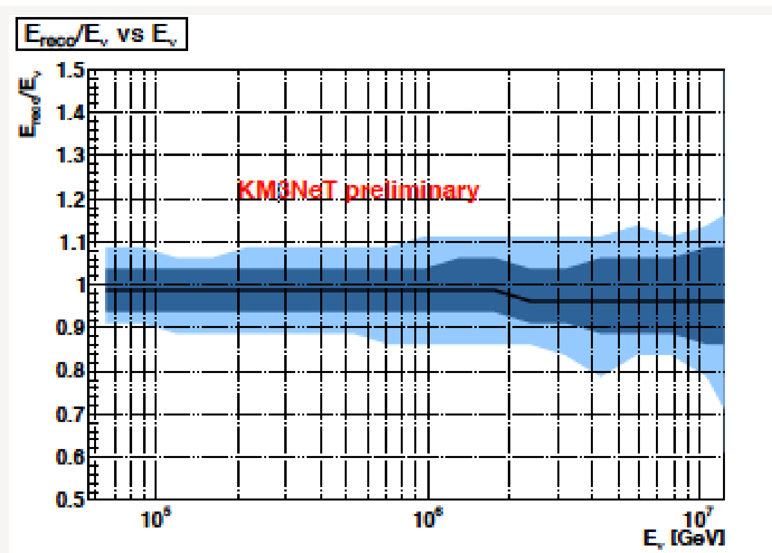


Tracks



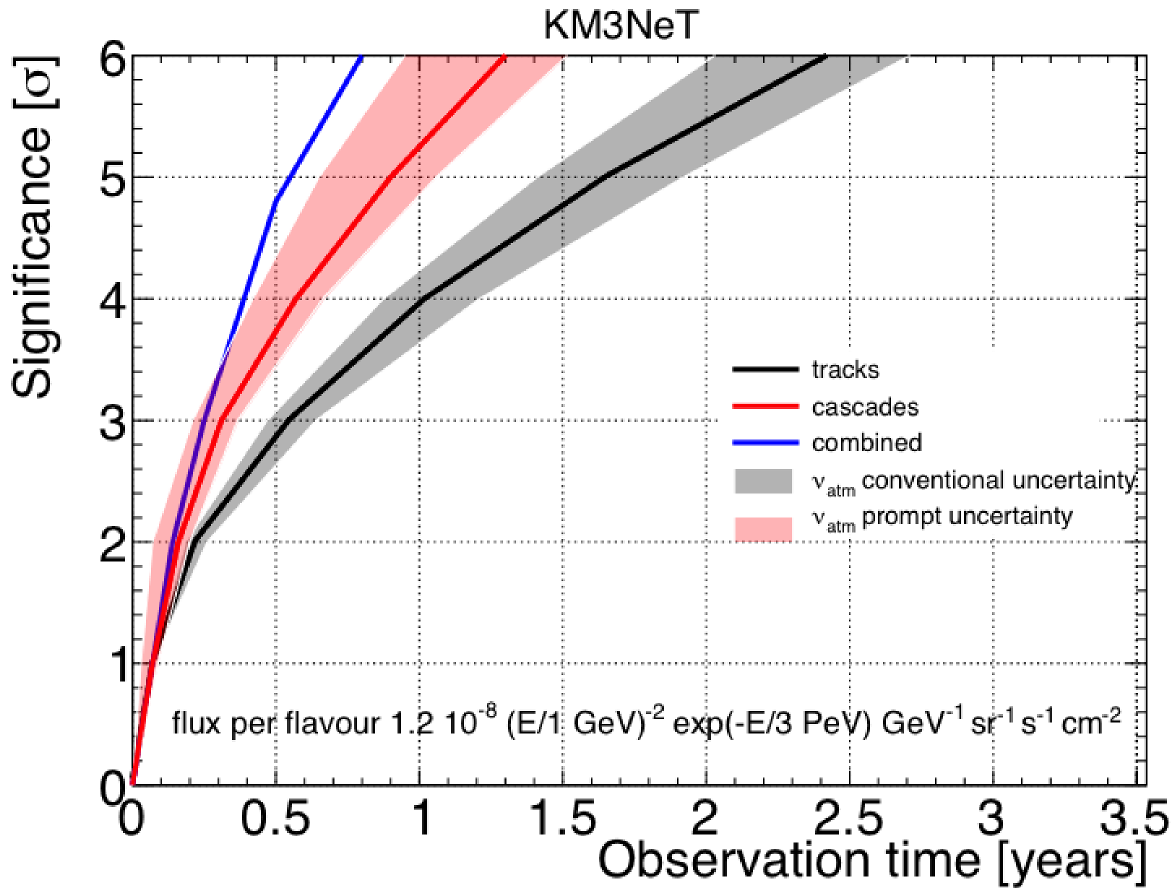
Showers





Diffuse Flux Sensitivity

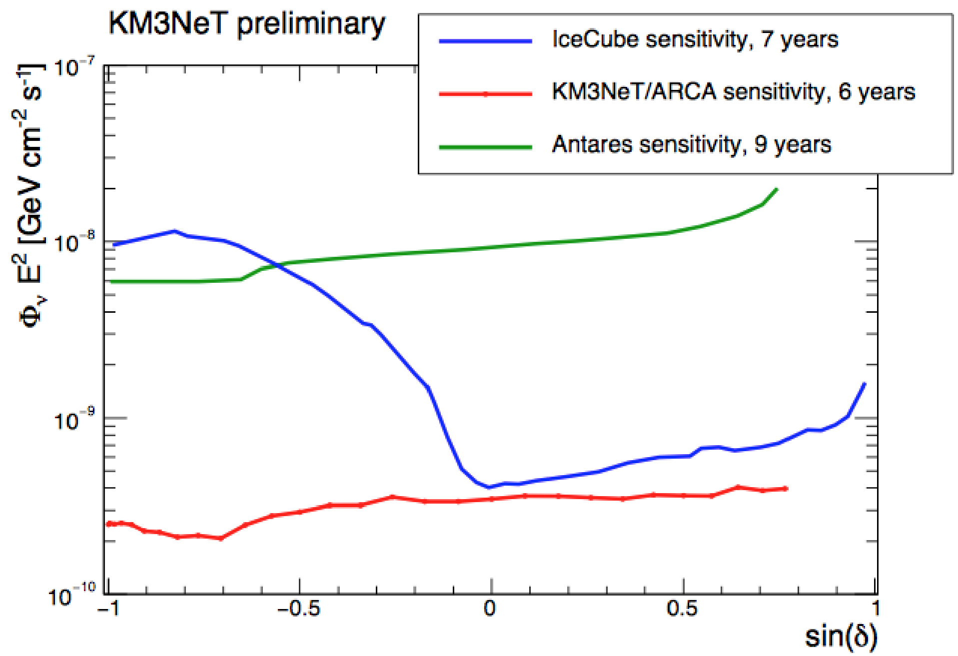
$$\Phi(E) = 1.2 \cdot 10^{-8} (E / 1\ \text{GeV})^{-2} \exp(-E / 3\ \text{PeV})\ \text{GeV}^{-1}\ \text{cm}^{-2}\ \text{s}^{-1}\ \text{sr}^{-1}$$

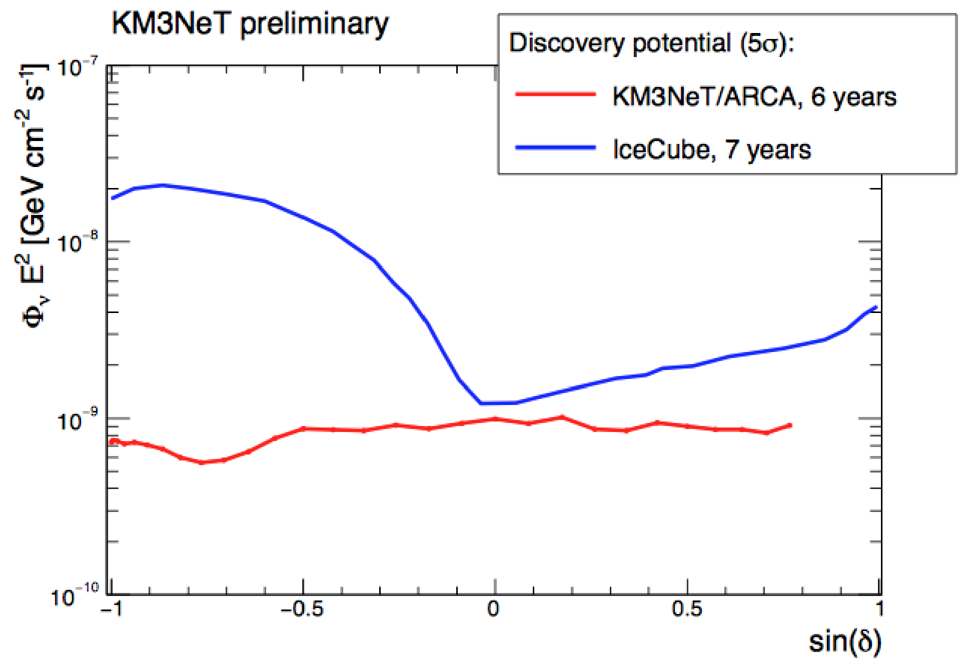


Potential 5σ discovery in 6 months of ARCA running.

Source Searches

Visibility of Galactic Plane + Galactic Center





Good angular resolution in water will help with source identification.

ORCA Current Status

First ORCA string deployed in fall of 2017

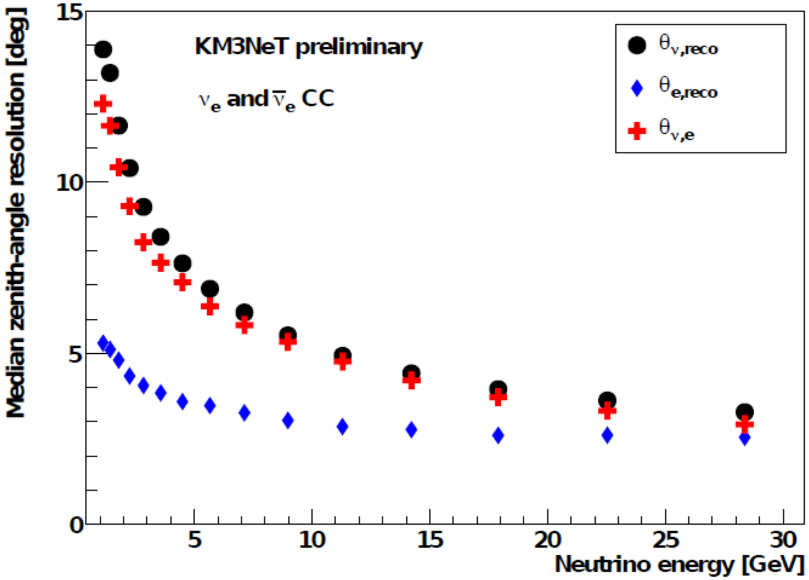
- Successful datataking until Dec 2017

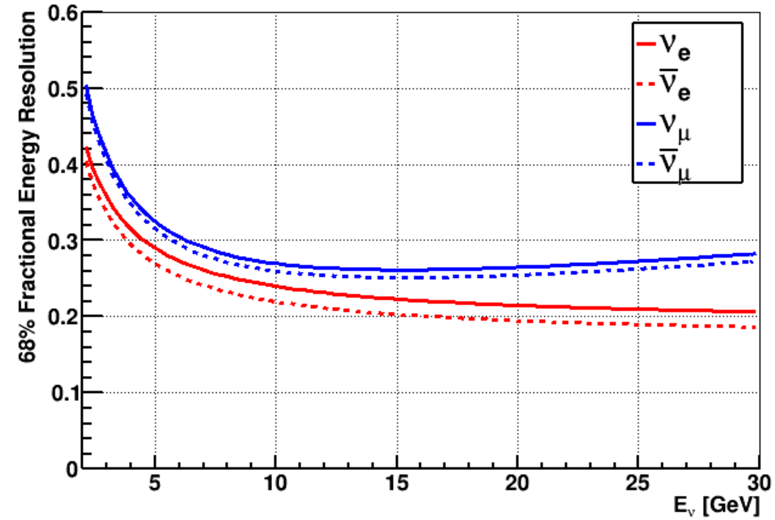
Due to issues with the deep sea cables, the string was recovered to be redeployed after cable replacement

Deep sea cable replacement successfully completed at the end of Oct 2018

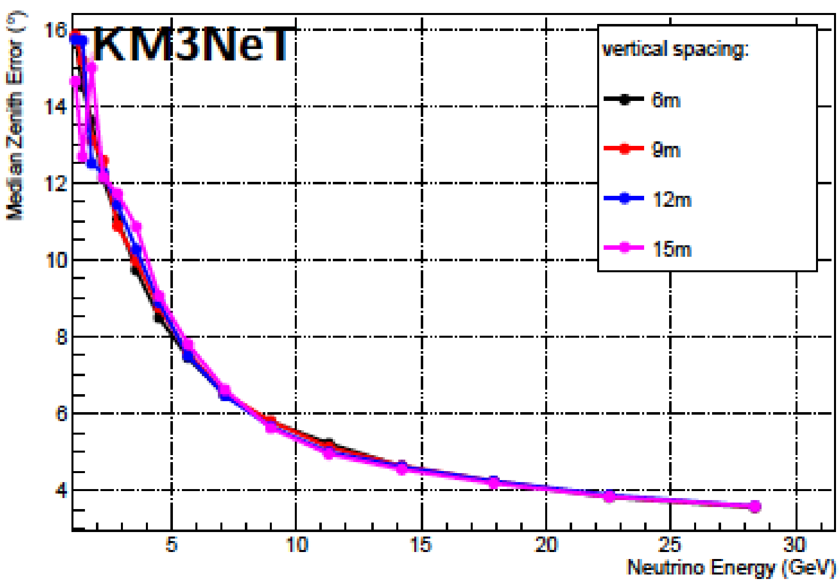
- 5 ORCA DUs are planned to be deployed this year, starting November

Showers



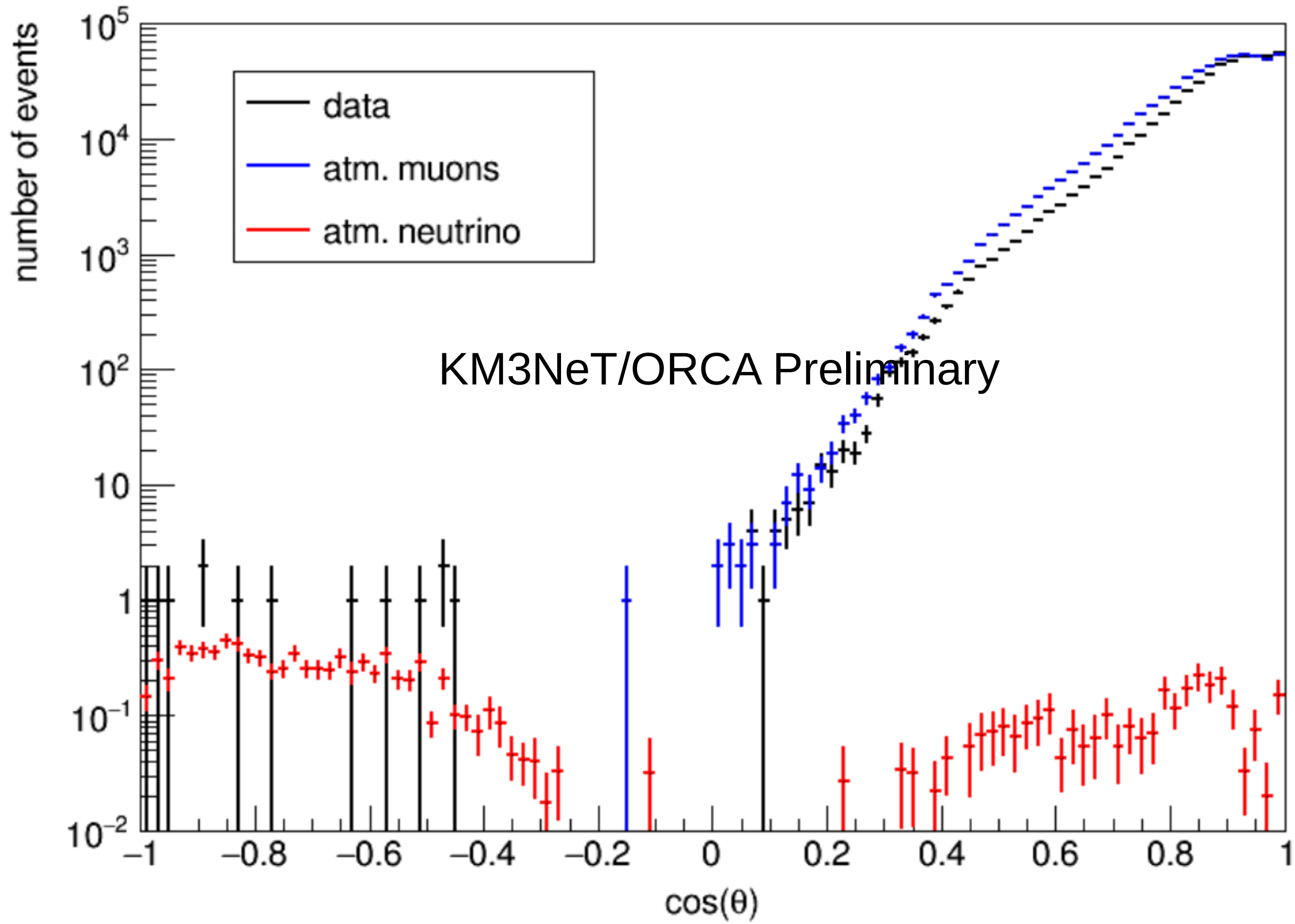


Tracks

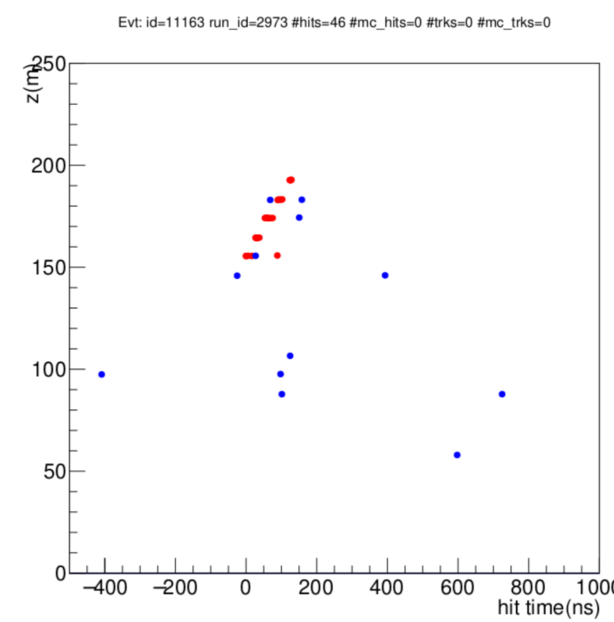


- ~30% energy resolution in region of interest for ORCA
- Median zenith angle resolution of 5° at 10GeV

Observations from first ORCA Detection Unit



Number of upgoing events:
Atm. Nu: 8.33
Atm. Mu: ~1
Events observed: 13



Data from ORCA single DU
82 days of live time

ORCA Physics Goals

Primary goal: Measuring the neutrino mass hierarchy

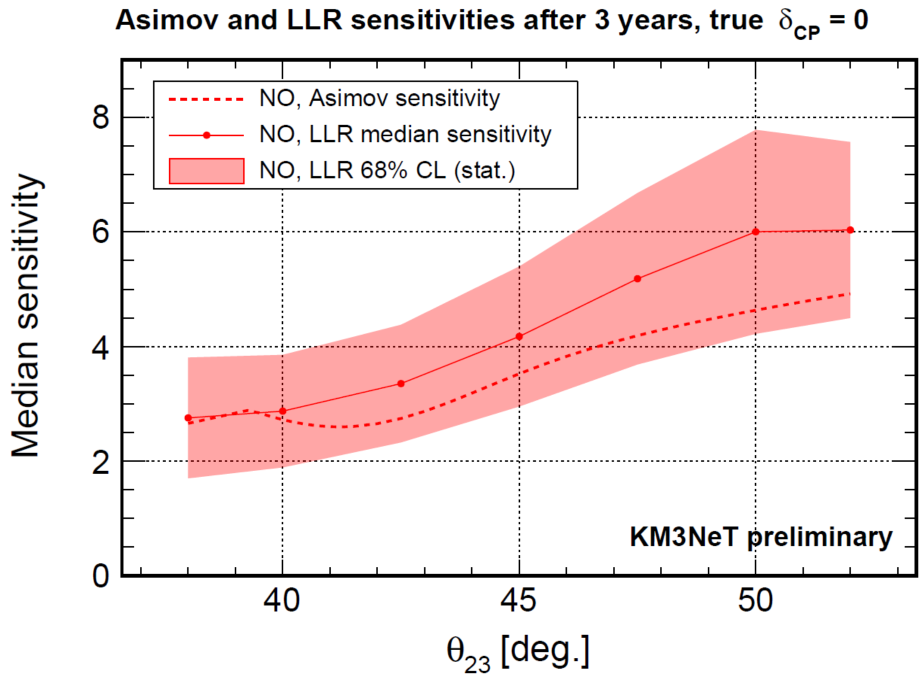
Other potential physics avenues:

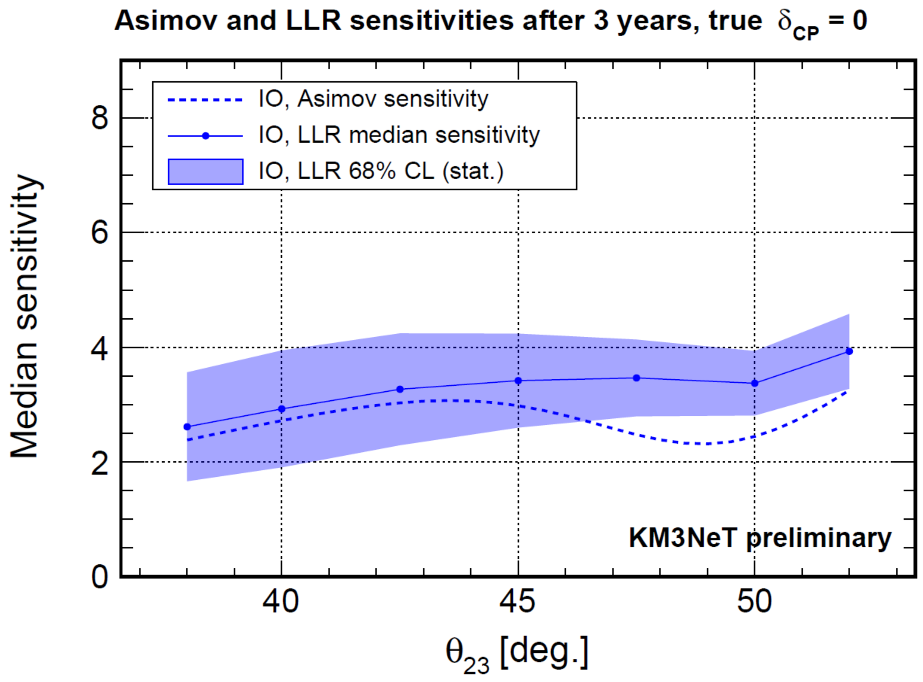
- ν_τ appearance to test PMNS unitarity
- Neutrino tomography of the Earth's core
- Further constraints on neutrino oscillation measurements
- Sterile neutrino searches

Predicted Sensitivities for NMH

Worst case: ~3σ in 3 years

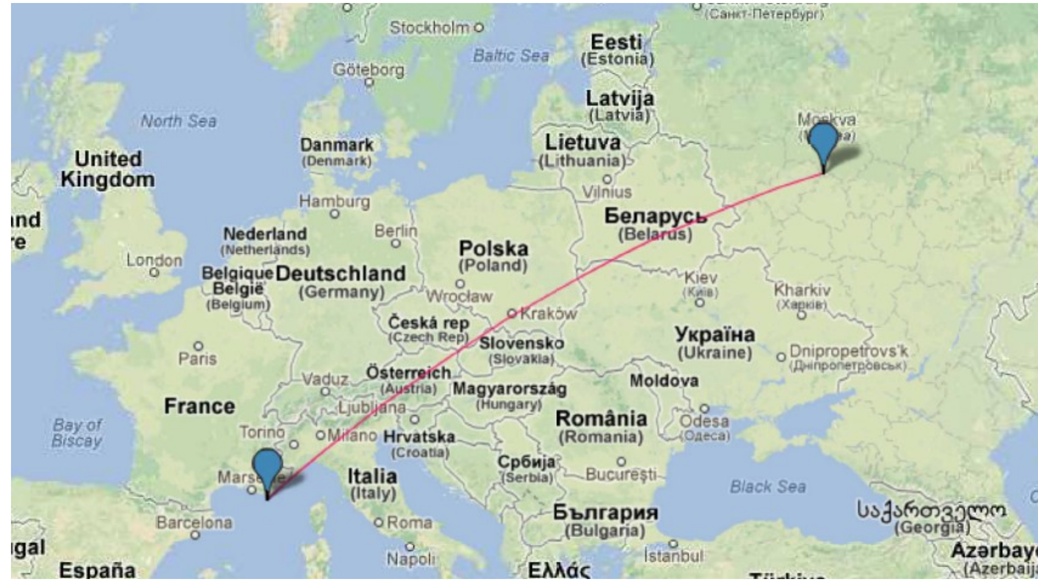
Best case: > 5 σ in 3 years – if NH & we are in upper octant of θ_{23}

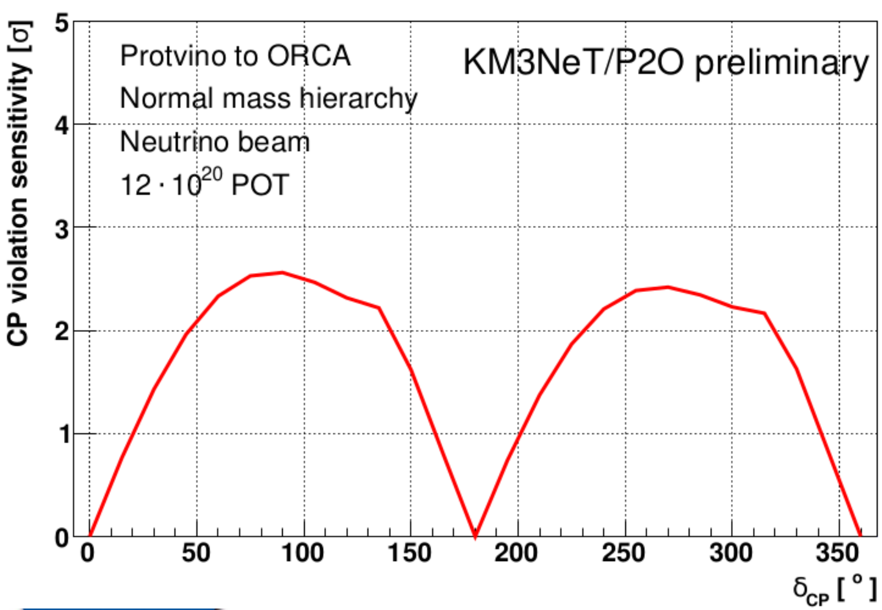




P2O: Protvino-to-ORCA

- 2588 km baseline
- Beam inclination of 11.7
- First oscillation maximum at 5.1 GeV





Projected δ_{CP} sensitivity:

2.5σ in 3 years at 450 kW
(15 years at 90 kW)

δ_{CP} precision of ~20 – 40° in 3 years of running

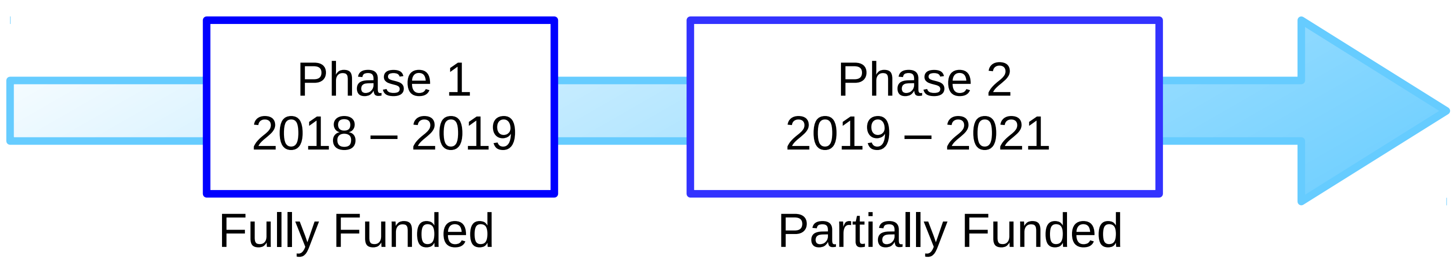
Timeline and Summary

KM3NeT construction and deployment has started

- Multiple ORCA strings on track to be operational by end of 2018
- ARCA construction to recommence 2019

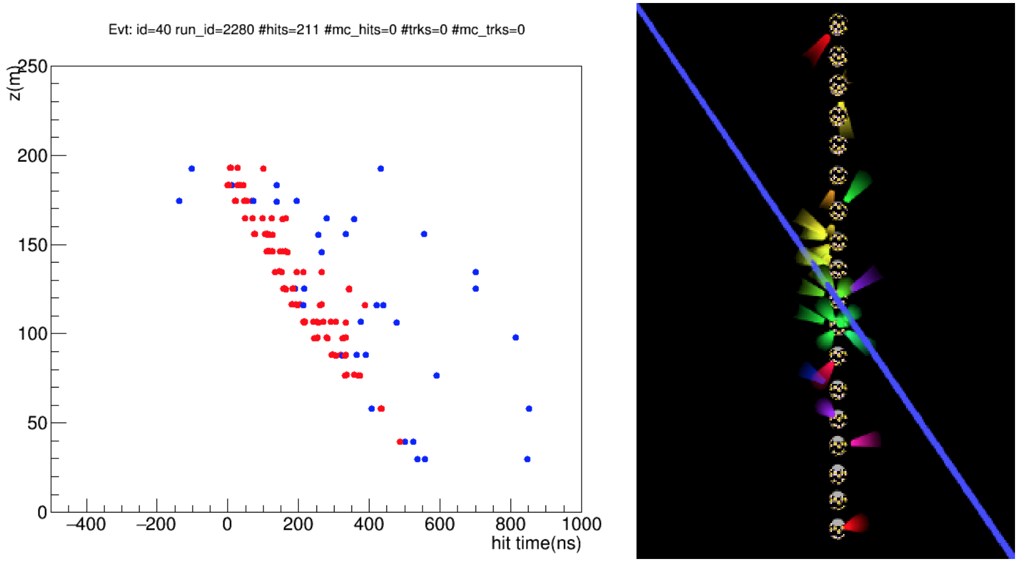
Main goal:

- determine the neutrino mass hierarchy (ORCA)
- Astrophysical neutrino identification (ARCA)

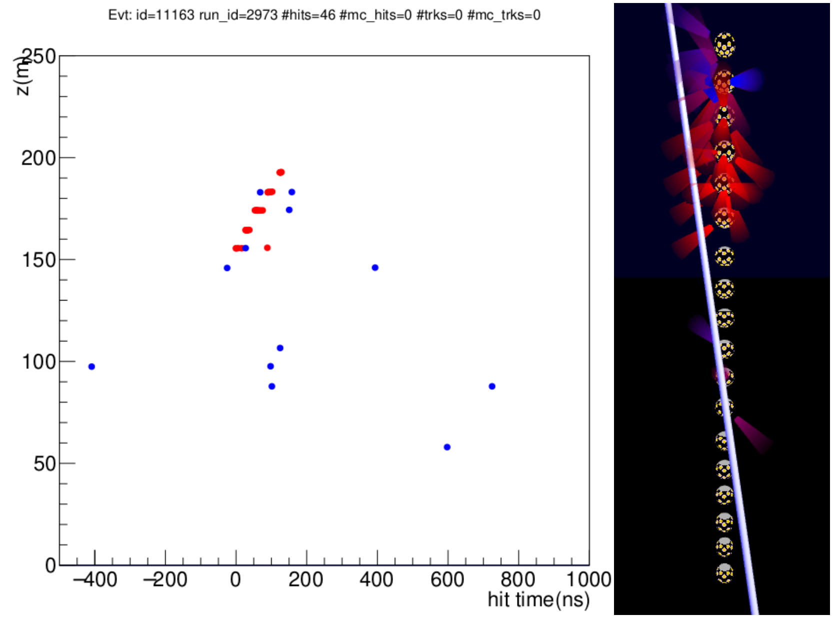


Backup

First Observed Data

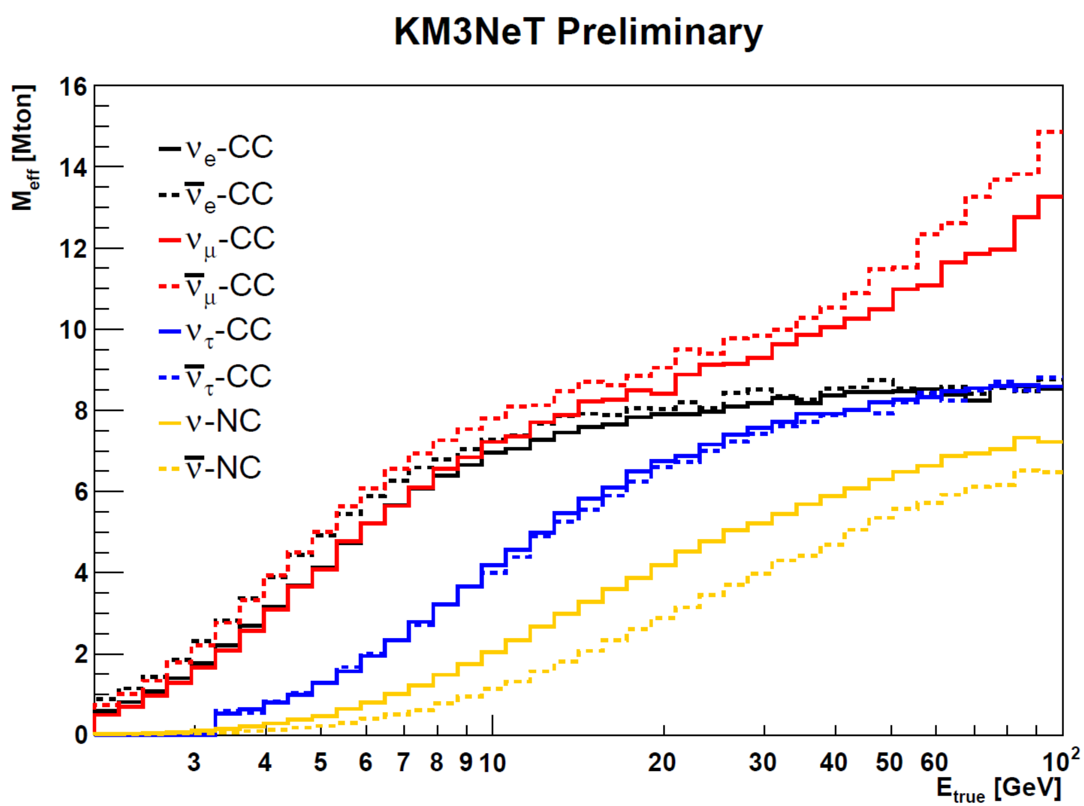


Muon bundle



Typical neutrino
candidate event

ORCA Effective Mass



Effective mass after triggering, background rejection and containment cuts

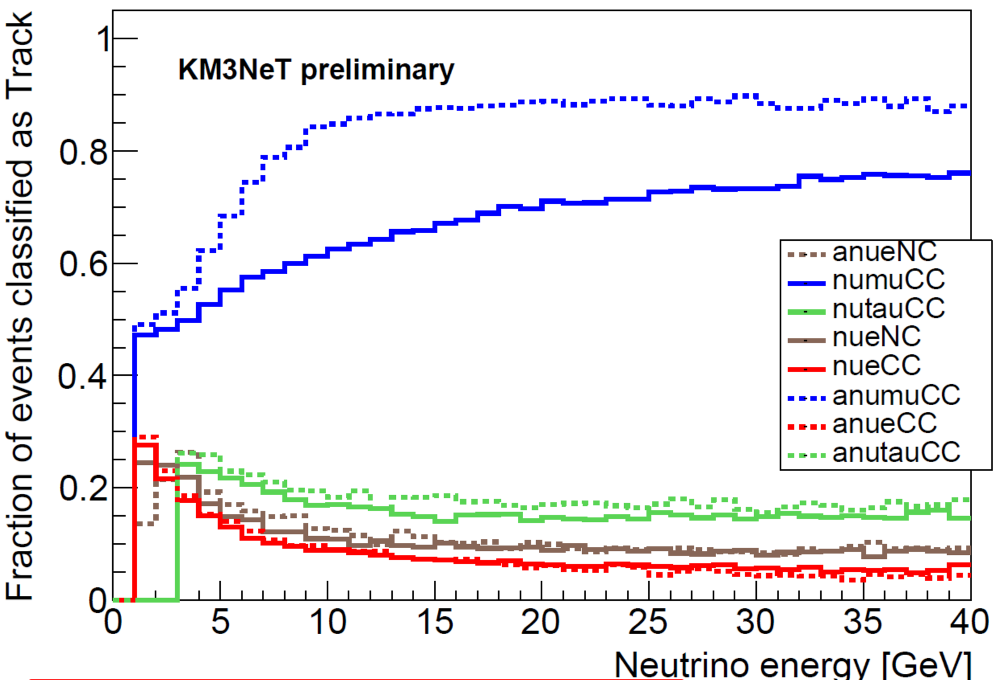
- Threshold dependent on DOM spacing

channel	events/y	channel	events/y
ν_e CC	14700	ν_τ CC	2900
$\bar{\nu}_e$ CC	5700	$\bar{\nu}_\tau$ CC	1300
ν_μ CC	21300	ν NC	5300
$\bar{\nu}_\mu$ CC	9900	$\bar{\nu}$ NC	1500

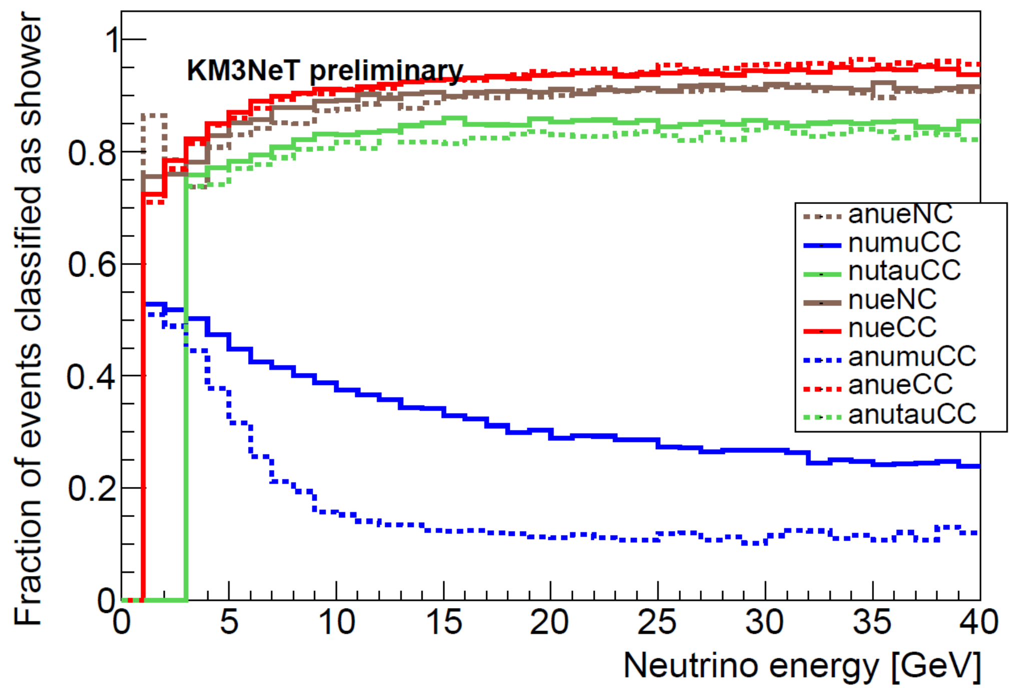
Particle ID at ORCA

Random decision forest technique to both identify atmospheric muons and perform track-shower separation

Classified as Track



Classified as shower (9m Spacing)



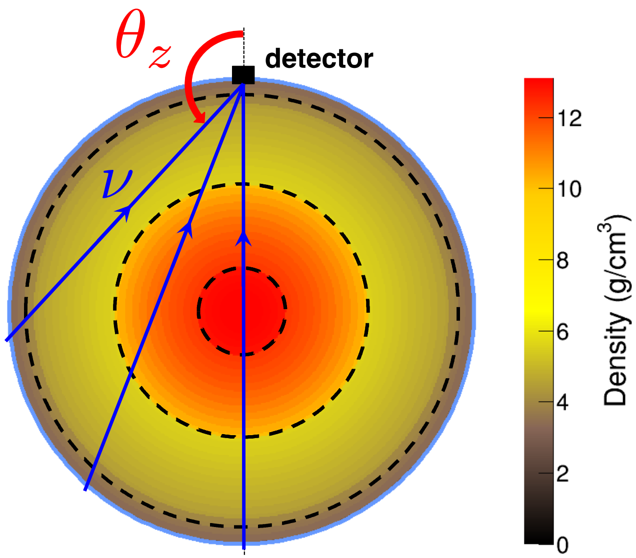
At 10 GeV:
90% correct ID for ν_e CC
70% correct ID for ν_μ CC

Able to suppress atmospheric muon background and noise to the 3% level

- Still preserves 95% of the neutrino signal

Deep-learning based efforts currently underway as well

Atmospheric Neutrinos

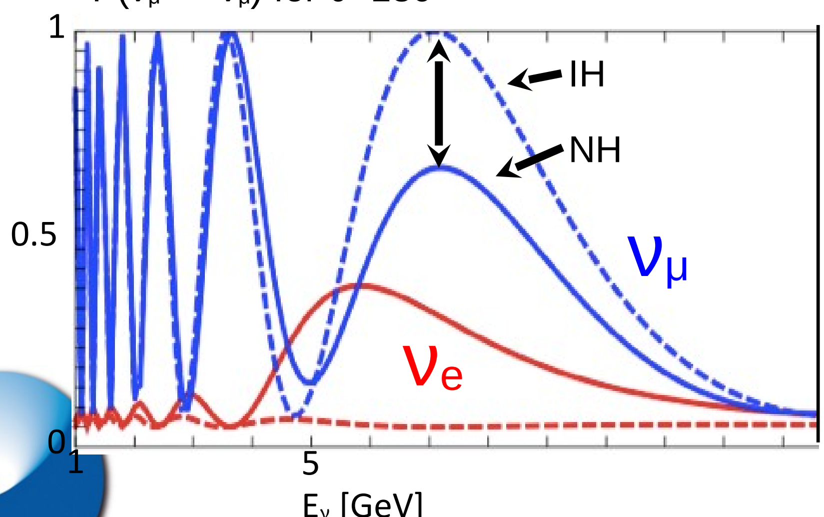


Atmospheric flux gives known ν_e and ν_μ composition
Wide range of zenith angles and neutrino energies

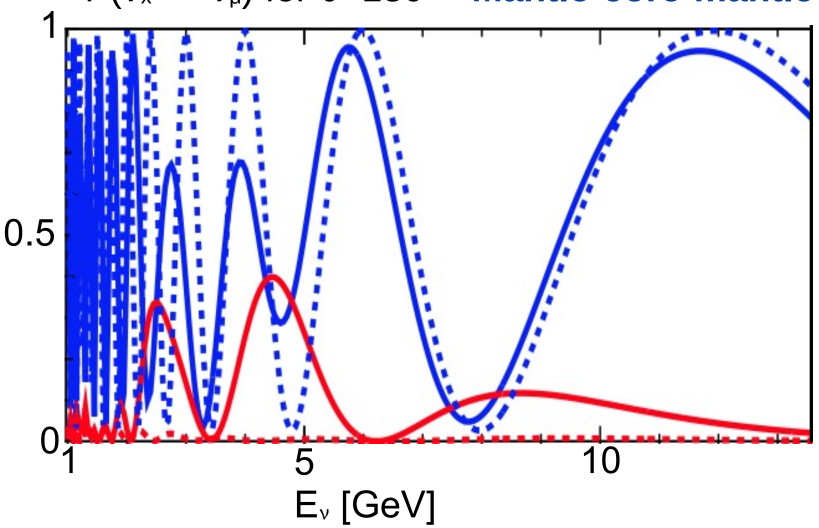
Matter effects in the earth distort the neutrino oscillation pattern

- Maximum difference between IH/NH occurs at θ = 130 E_ν = 7 GeV

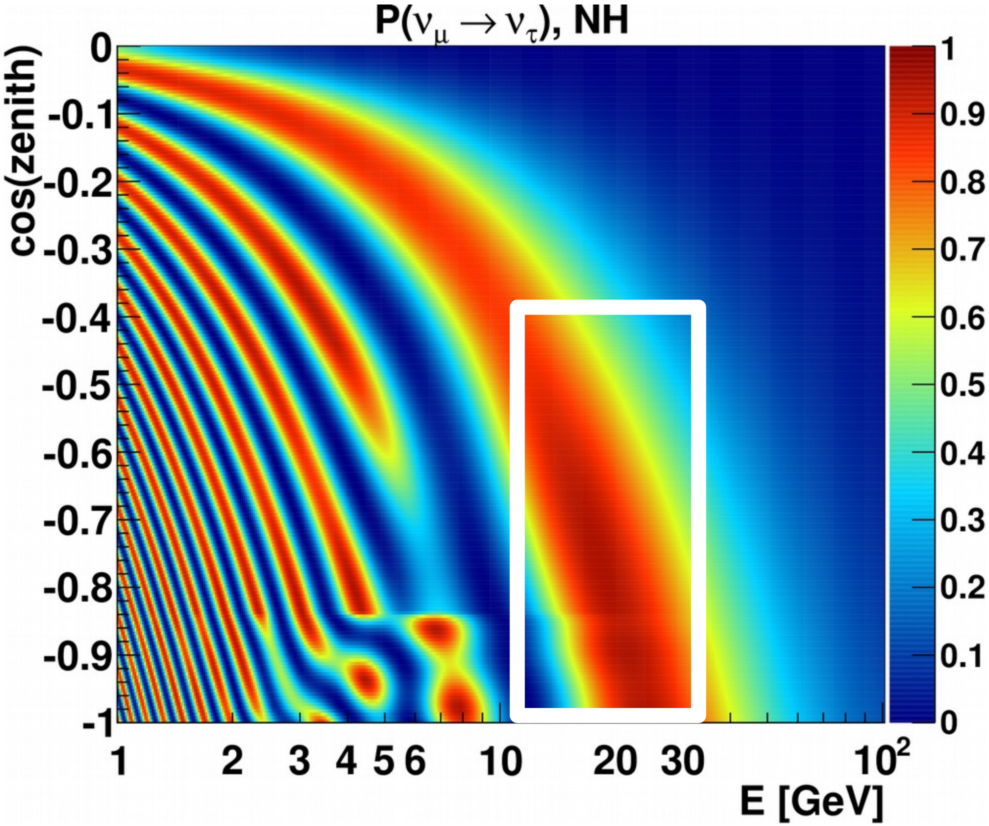
P($\nu_\mu \rightarrow \nu_\mu$) for θ=130º



P($\nu_x \rightarrow \nu_\mu$) for θ=180º - **Mantle-core-mantle**

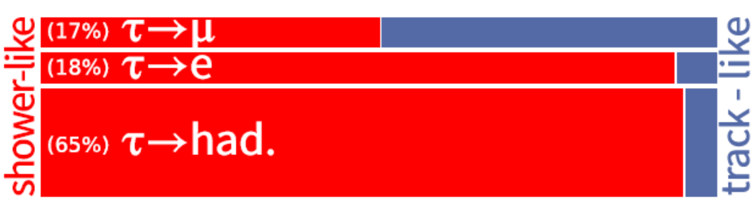


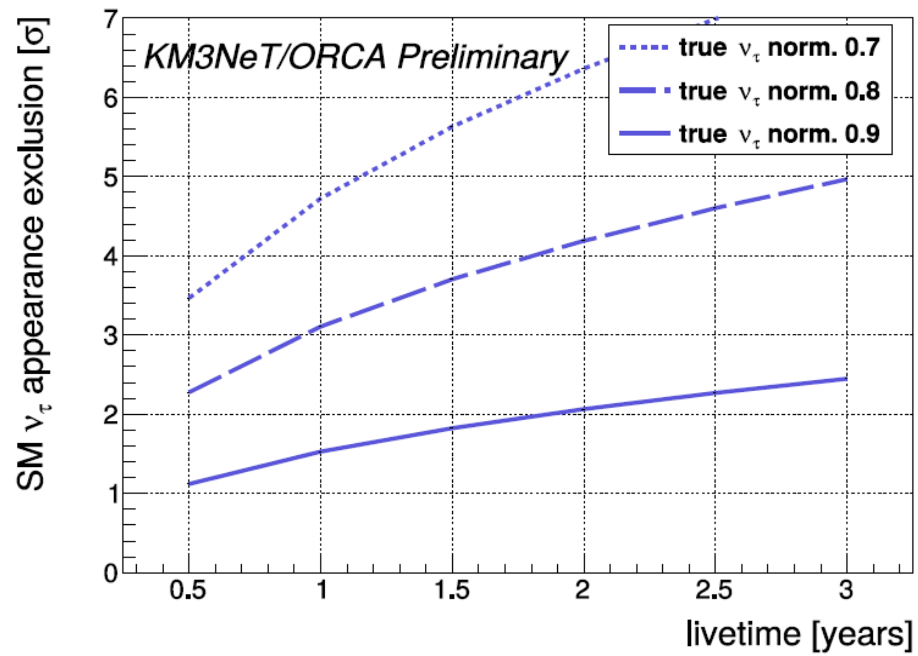
τ Neutrino Appearance



Look for ν_τ appearance to test PMNS unitarity/BSM theories

- ~3k ν_τ CC events expected per year with full ORCA





Rate constrained within ~10% in one year

Neutrino Tomography

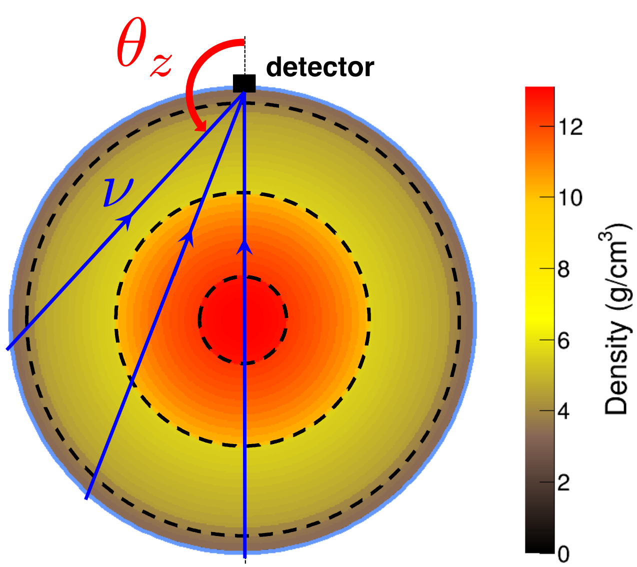
Because of matter effects, ORCA is sensitive to the electron density

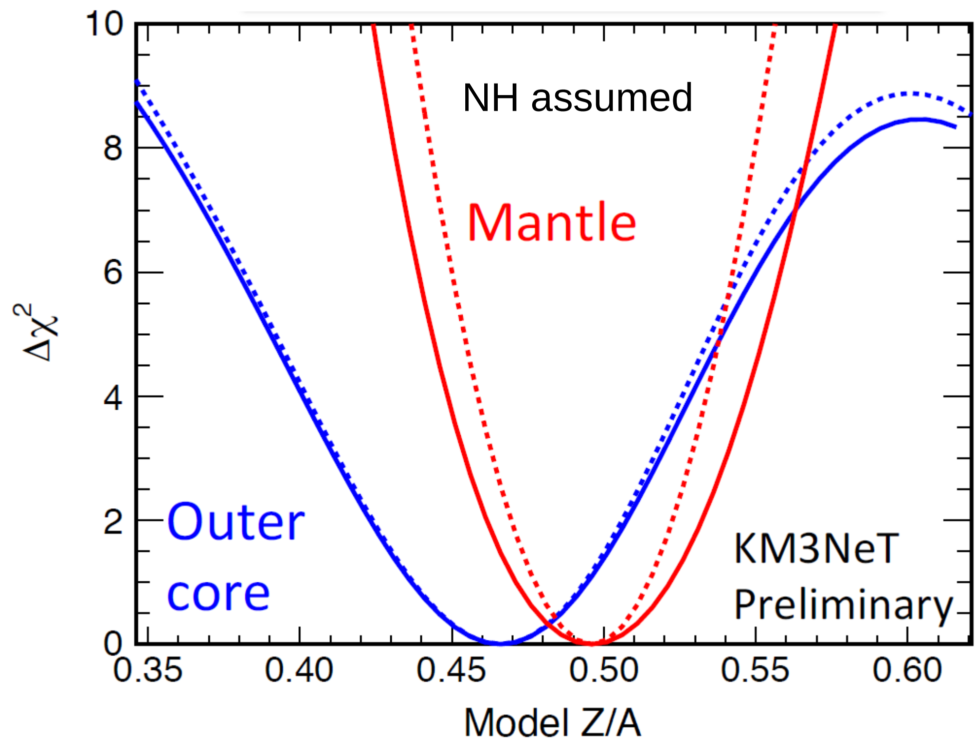
- Compare with geophysics, which measures ρ_M

1σ uncertainty after 10 years (NH)

6% core

5% mantle





- PREM model basis for rho
- Uniform Z/A rescaling in layer