Dark Matter search in the Galactic Center with the KM3NeT ARCA detector

At IRN Terascale
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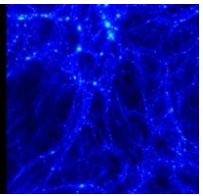
MultiDark
Multimessenger Approach for Dark Matter Detection



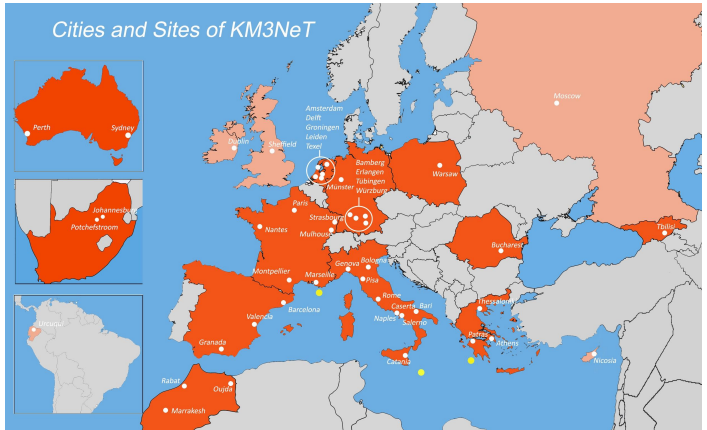
What is KM3NeT?

KM3NeT is the successor to ANTARES and consists of two separate detectors:

- ARCA: Astroparticle Research with Cosmics in the Abyss
  - Main goal: Study high-energy astrophysical neutrinos, both diffuse fluxes and sources

- ORCA: Oscillation Research with Cosmics in the Abyss
  - Main goal: Study neutrino properties, mass ordering, oscillations and non-standard interations

Both detectors are suitable for Dark Matter searches

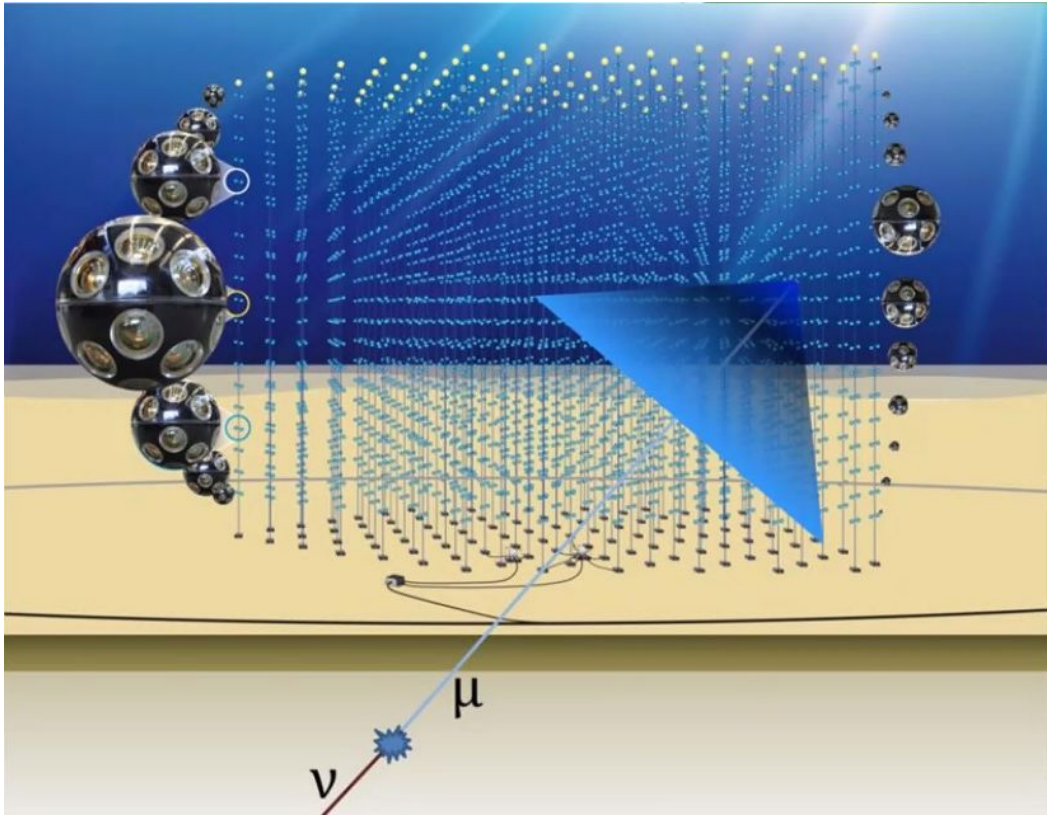


Detection Principle

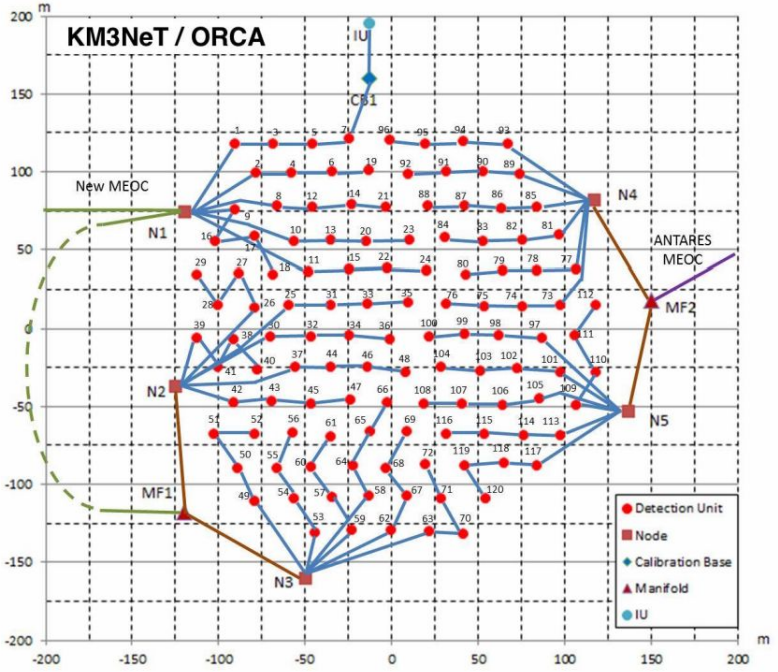
KM3NeT is a Cherenkov detector:

- A neutrino produces a secondary
  particle near or inside our detector

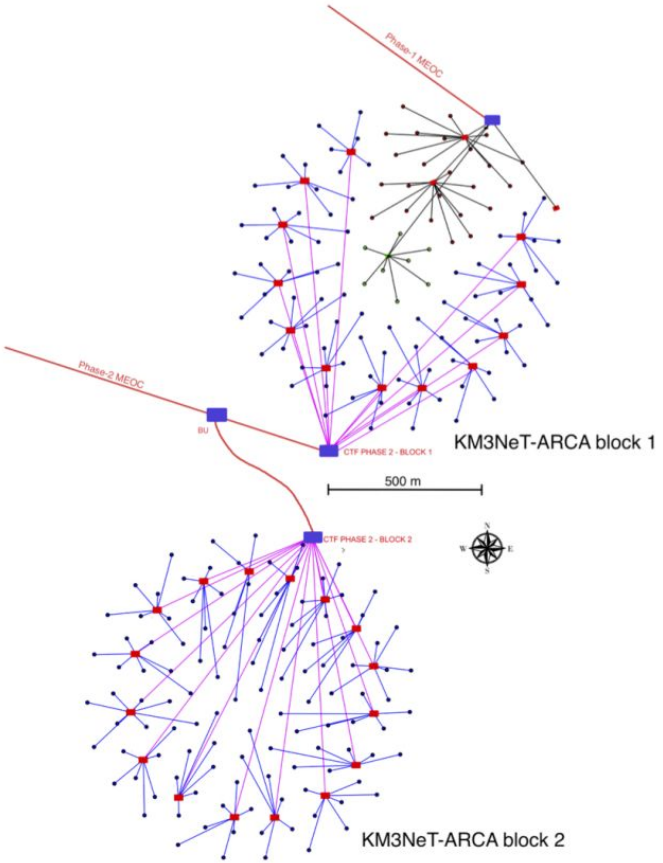
- The particle moves through our detector exceeding the speed of light creating a Cherenkov cone



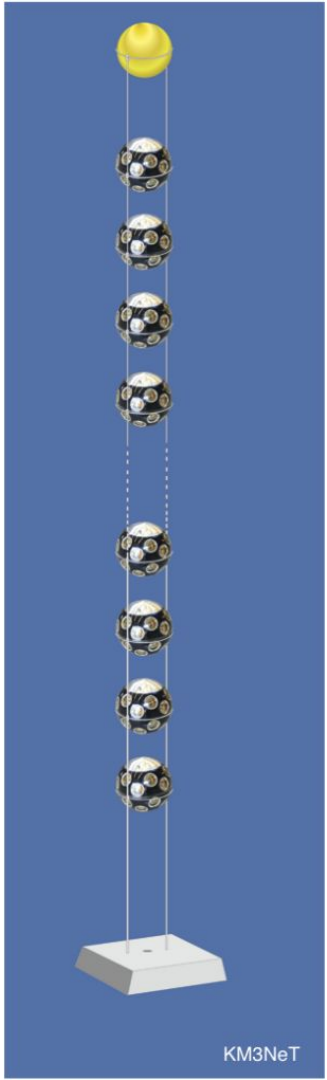
The Detectors



ORCA consists of 1 block of 115 lines with a horizontal spacing of 20m and a vertical spacing of 9m

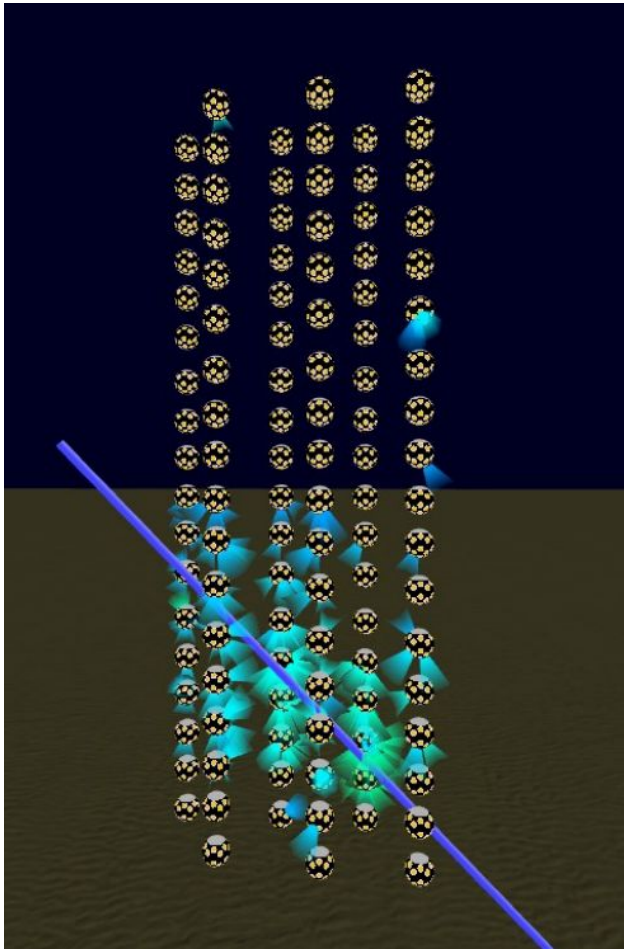


ARCA consists of 2 blocks of 115 lines with a horizontal spacing of 90m and a vertical spacing of 36m



KM3NeT: Current Status

- ARCA: 6 lines currently deployed and taking data
  - 5 more to be deployed in September
- ORCA: 6 lines currently deployed and taking data
  - 7 more to be deployed in September



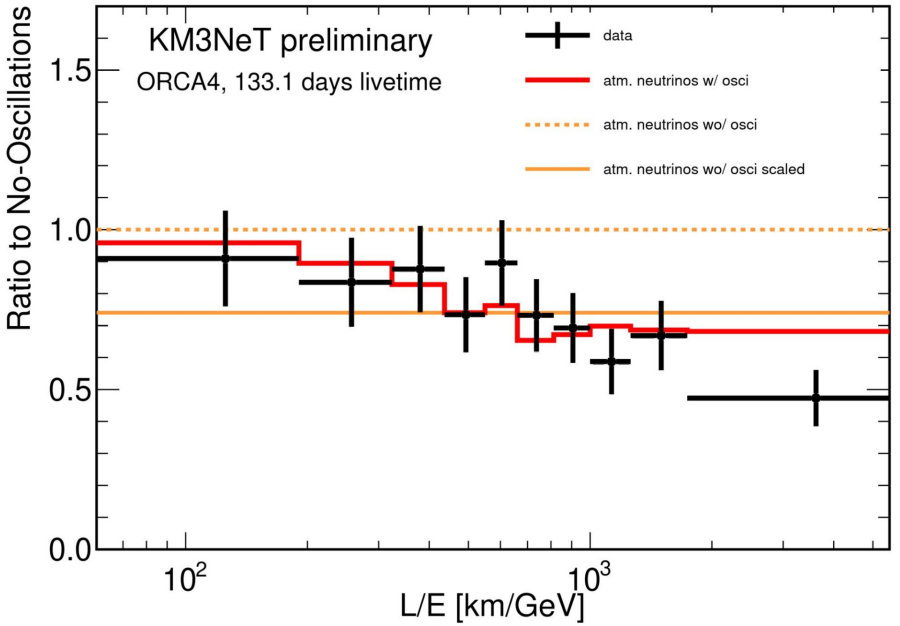
ORCA4 Neutrino Oscillations

Oscillations are favoured at ~2.5**σ** in a first preliminary measurement with a small fraction of our detector:

- Low statistics
- Low energy and direction resolution due to detector size
- No distinction between tracks and cascades

We are very close to measuring neutrino oscillations!

Binning adjusted for similar stats. uncert. per bin



Valentin Pestel, Zineb Aly, Lodewijk Nauta (KM3NeT collaboration), *Analysis of the first KM3NeT-ORCA data*, VLVNT2021

Dark Matter: Indirect Detection

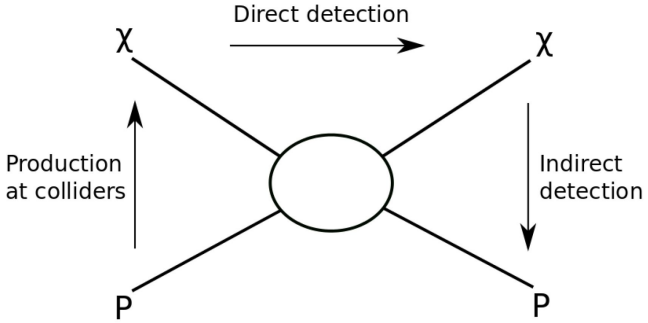
In KM3NeT we look for dark matter through indirect detection:

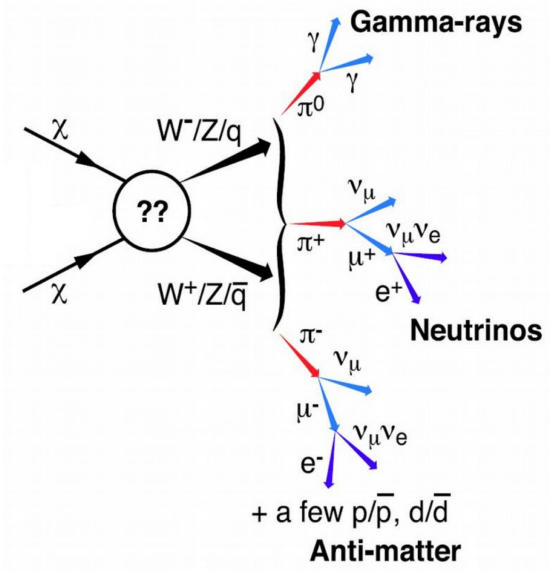
- Two dark matter particles annihilate to standard model particles
- A dark matter particle decays to standard model particles
- Observe neutrinos produced in this process

There are several different annihilation channels:

- W-bosons
- Quarks
- Muons, Taus
- Neutrinos

The neutrino flux produced through these channels is the signal we try to observe





Dark Matter: Indirect Detection

Neutrino telescopes have several advantages:

- Good sensitivity to annihilation cross section for large dark matter masses
- ANTARES and KM3NeT are well positioned to observe the Galactic Centre
- Very low background background for searches for dark matter in the Sun
- Sensitive to candidates directly coupled to neutrinos

Galactic Centre WIMPs with ARCA

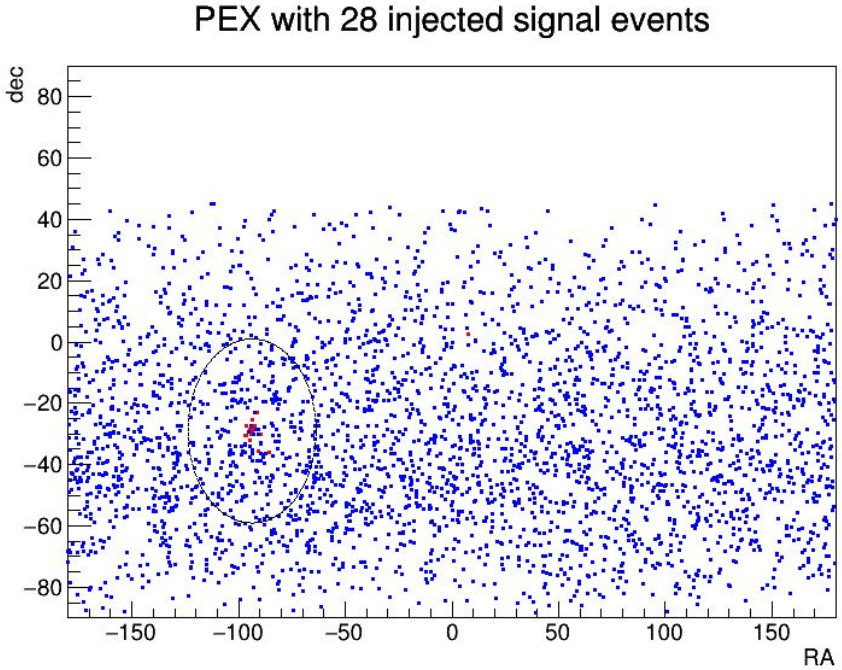
To determine the sensitivity of ARCA to dark matter from the Galactic Centre three ingredients are required:

- The integrated J-factor: the shape of our source
- The acceptance is given by integrating the effective area of our detector over the neutrino flux
- The number of distinguishable signal events

$$\langle \sigma v \rangle = \frac{4\pi}{J_{int}} \frac{n_{sig}}{Acc \cdot livetime} M_{\chi}^{2}$$

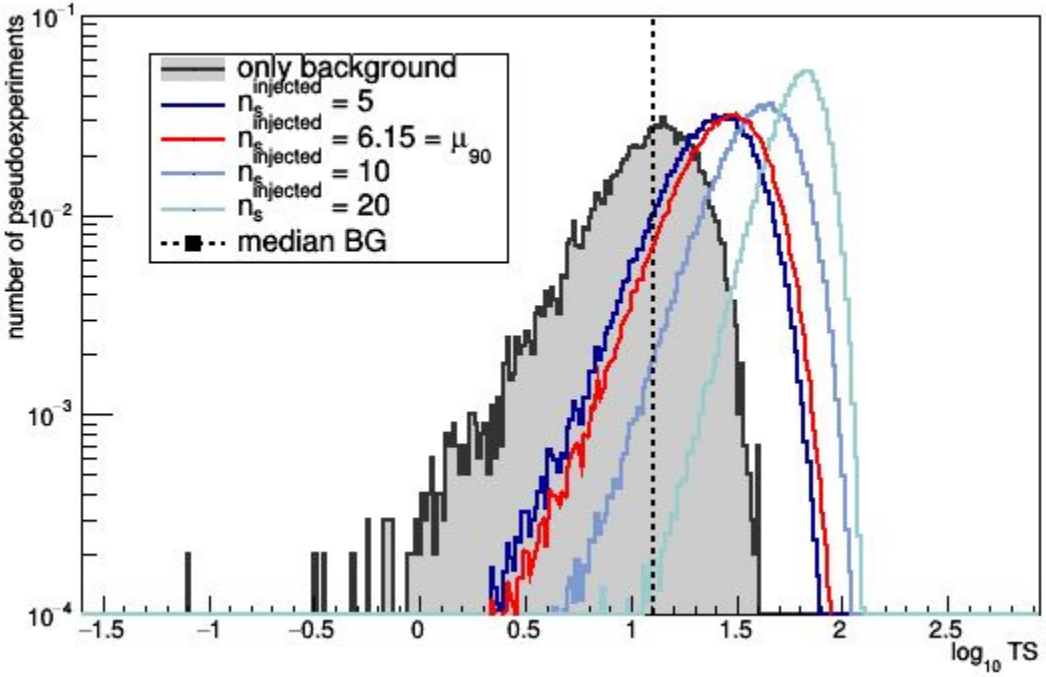
Galactic Center WIMPs with ARCA

We need to determine the number of signal events we can distinguish from the background. We create pseudo-experiments to achieve this.



- We create a skymap of background
- We inject a specific number of signal events between 1 and 30
- Use a minimizer to find the number of signal events
- Potential to use an anomaly-detection ML algorithm

Galactic Center WIMPs with ARCA

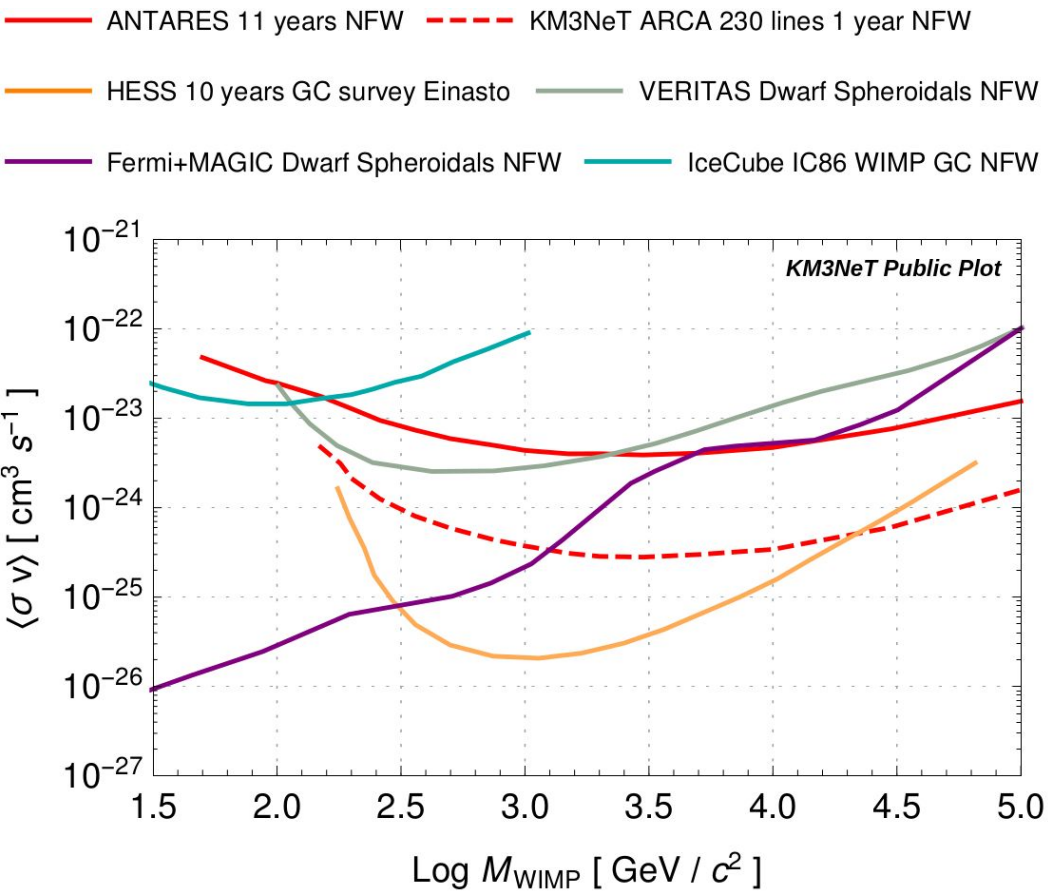


$$TS = \frac{\mathcal{L}(n_s)}{\mathcal{L}(0)}$$

A test statistic is created as the ratio between the likelihood of finding a number of signal events and finding only background.

We find the minimum number of signal events we can distinguish with a 90% confidence level when 90% of the TS distribution is larger than the median of the background.

Dark Matter: Sensitivities



The ARCA detector with 230 lines with a live time of 1 year is set to outperform its predecessor by an order of magnitude with a much shorter live time

Conclusion

- The KM3NeT ARCA and ORCA detectors are under construction with more lines being deployed this year
- Data taking is ongoing with the present configuration of the detectors
- Neutrino oscillations are observed with the present limited layout of the ORCA detector
- The sensitivity to dark matter of KM3NeT ARCA detector is an order of magnitude better than current neutrino telescopes, especially for very large dark matter masses