KM3NeT/ORCA: status and prospects

M. Perrin-Terrin

KM3NeT ORCA

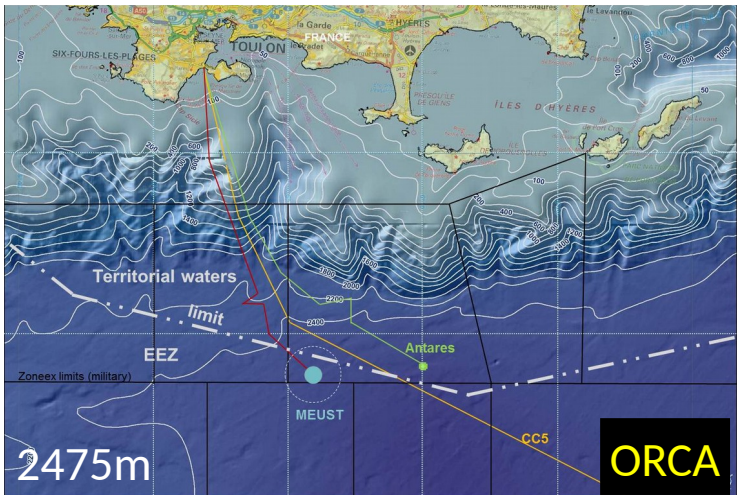
NuFact 2019, Daegu, Korea

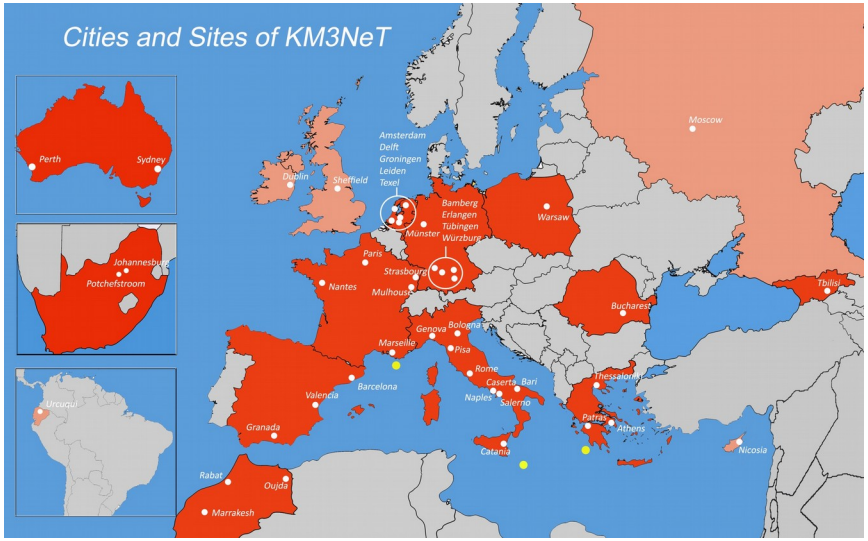
Mathieu PERRIN-TERRIN
on behalf of the KM3NeT Collaboration

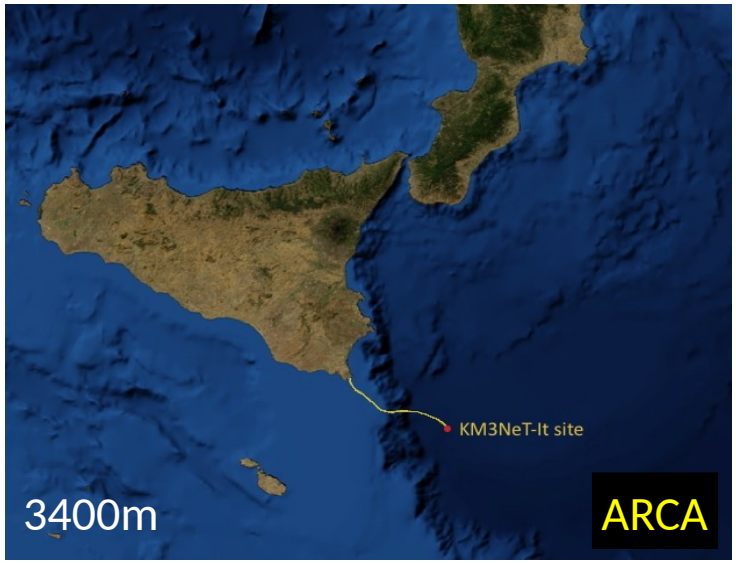
Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France.

The KM3NeT Collaboration

- Two detectors with the same technology:
  - ORCA : neutrino mass hierachy (few GeV)
  - ARCA : neutrino astronomy (TeV-PeV)



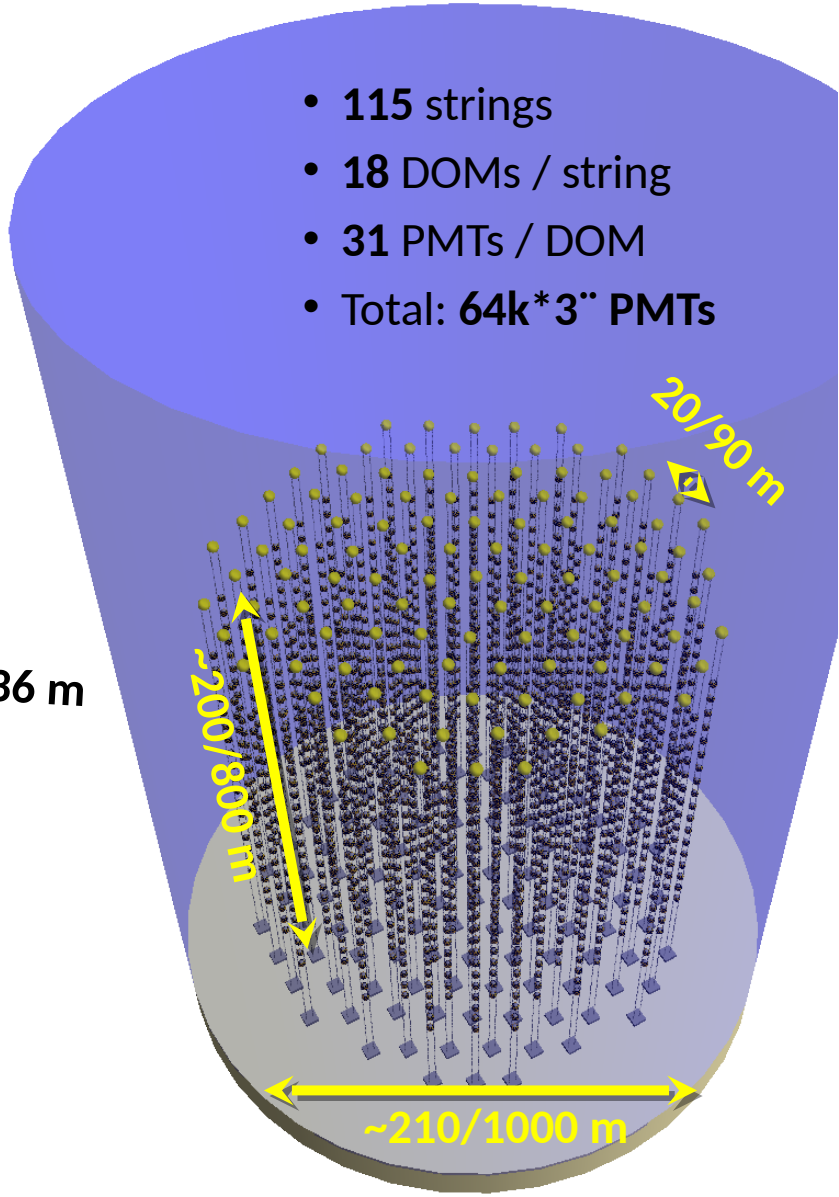




KM3NeT Technology

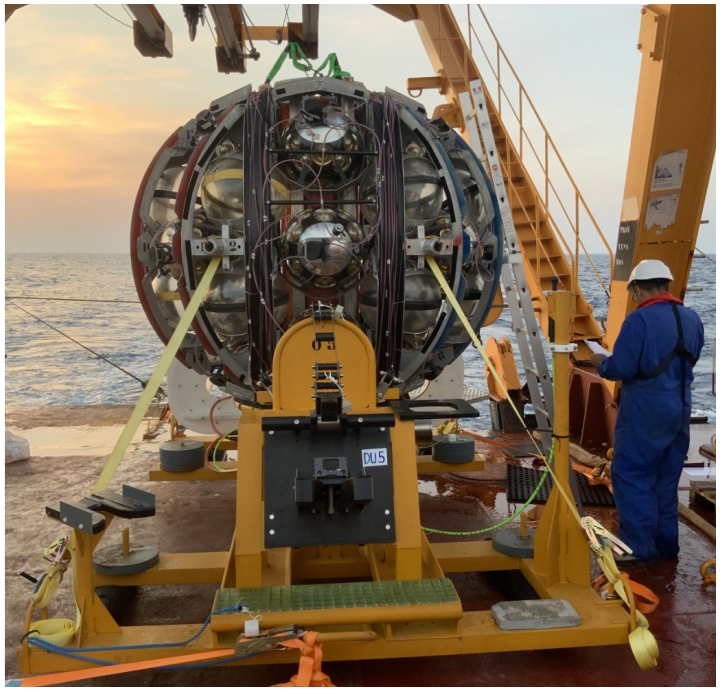
- Digital Optical Module
  - 31 x 3” PMTs / DOM
  - Uniform angular coverage
  - Directional information

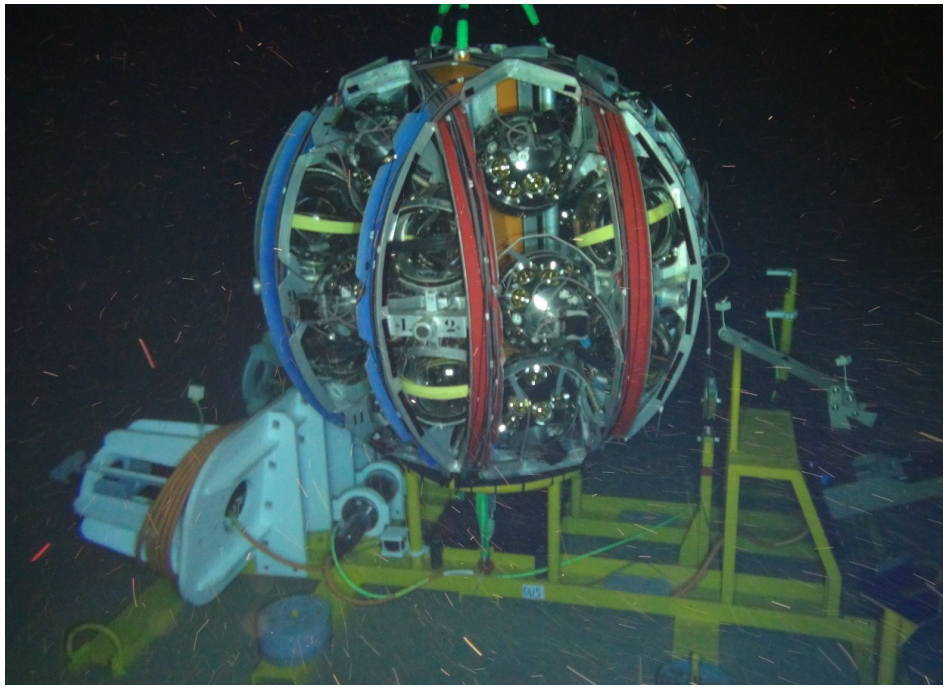
- DOM arranged in lines rolled in a launching vehicule

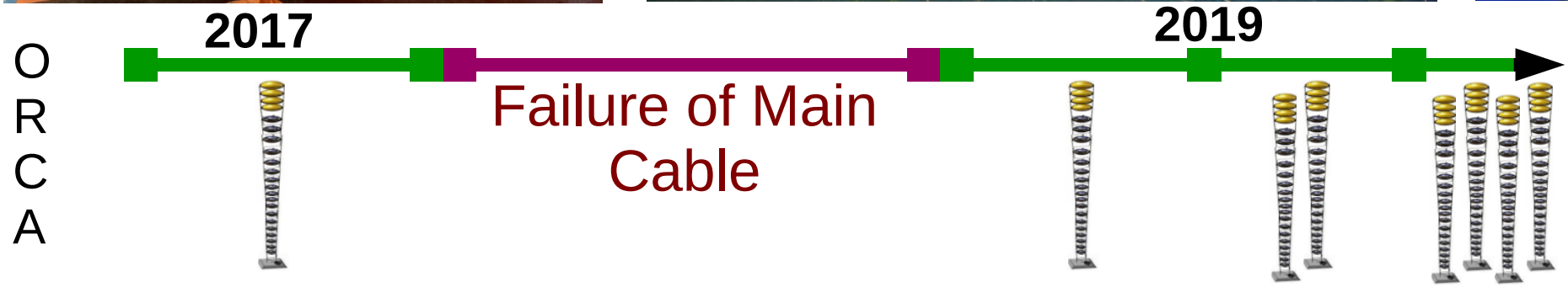


Construction Status

- 4 lines operational at ORCA (2 DU installed in July)
- 1 line operational at ARCA





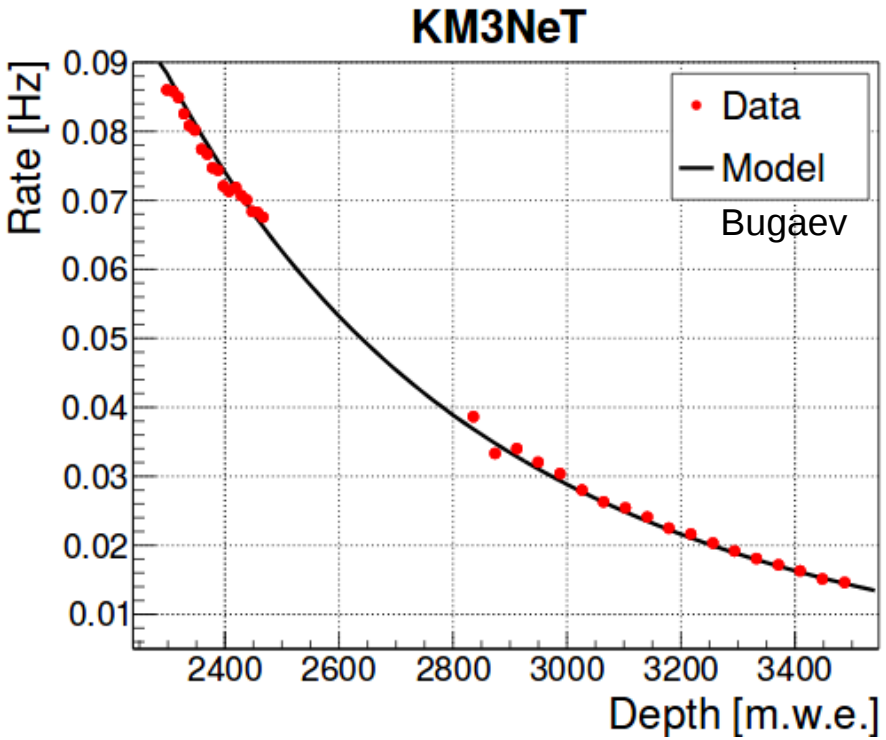


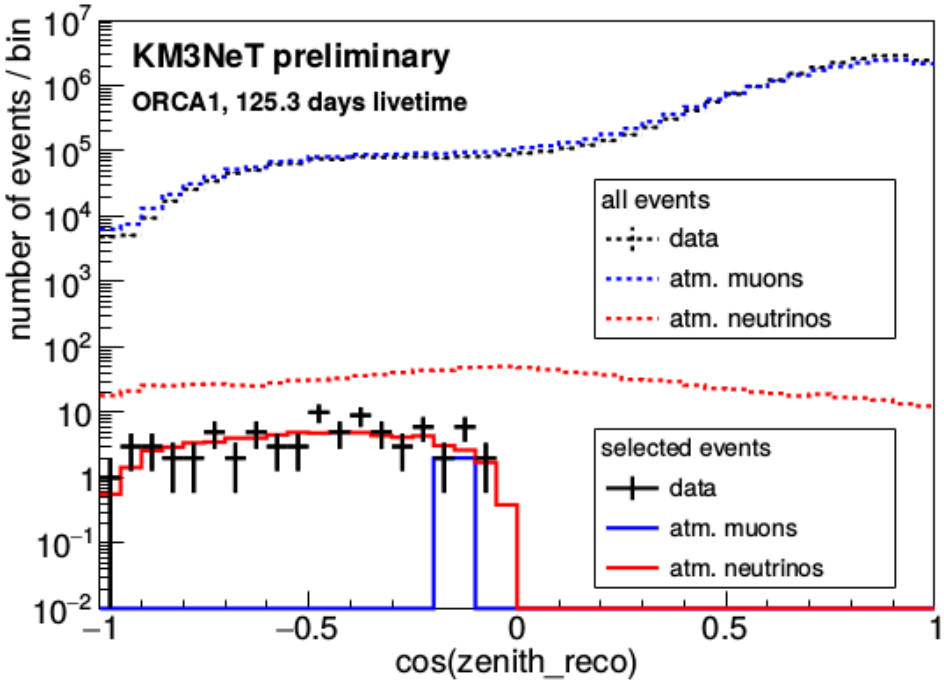
First Results from Data

- Muon Rate Depth Dependance by ARCA and ORCA

  arXiv:1906.02704v1

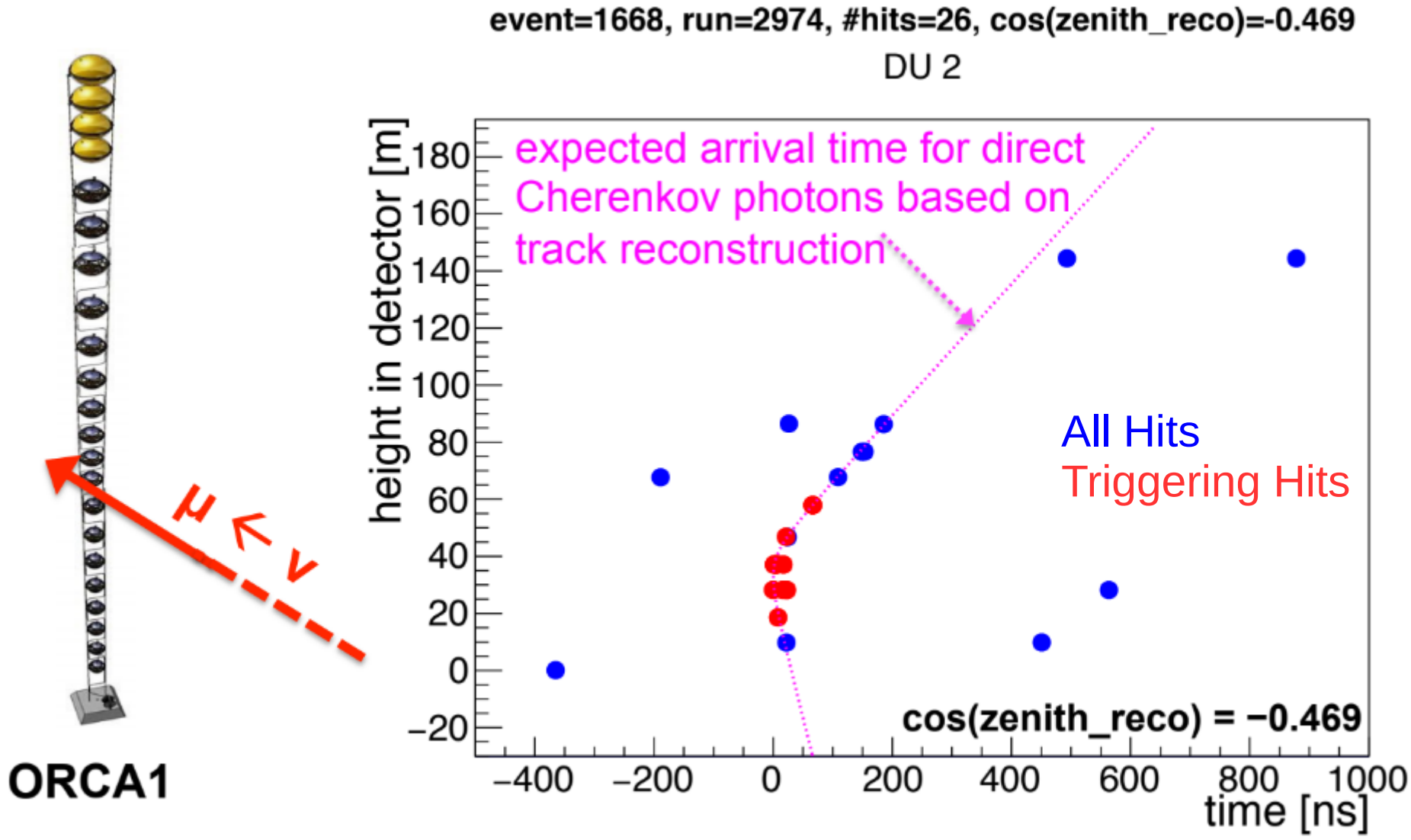
- Neutrinos with 1 ORCA Line
  - 77 upoing candidates observed in 125.3 days
  - Expected: $67.4\ \nu\ +\ 4\ \mu$
  - Good agreement Data/MC





Event Display

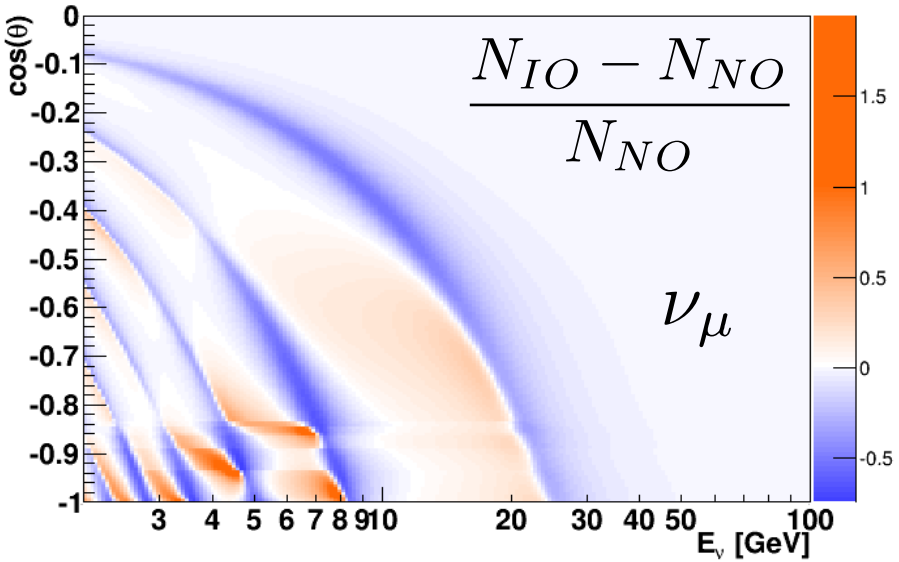
- Up-going neutrino

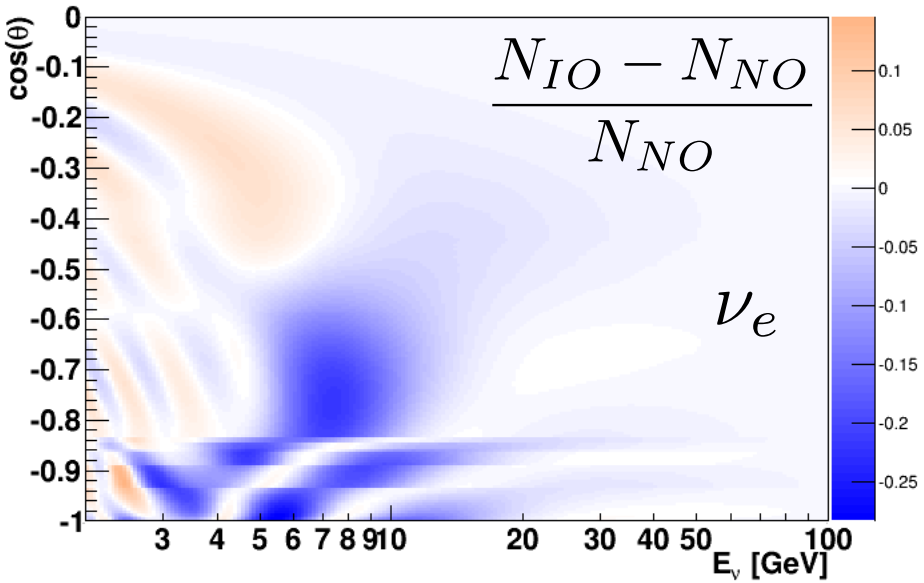


Neutrino Mass Ordering at ORCA

- NMO determined using matter effect
- Event distribution depends on NMO

~63k events / year:
νe CC: 20.4k
νμ CC: 31.2k
ντ CC: 4.2k
NC : 6.8k

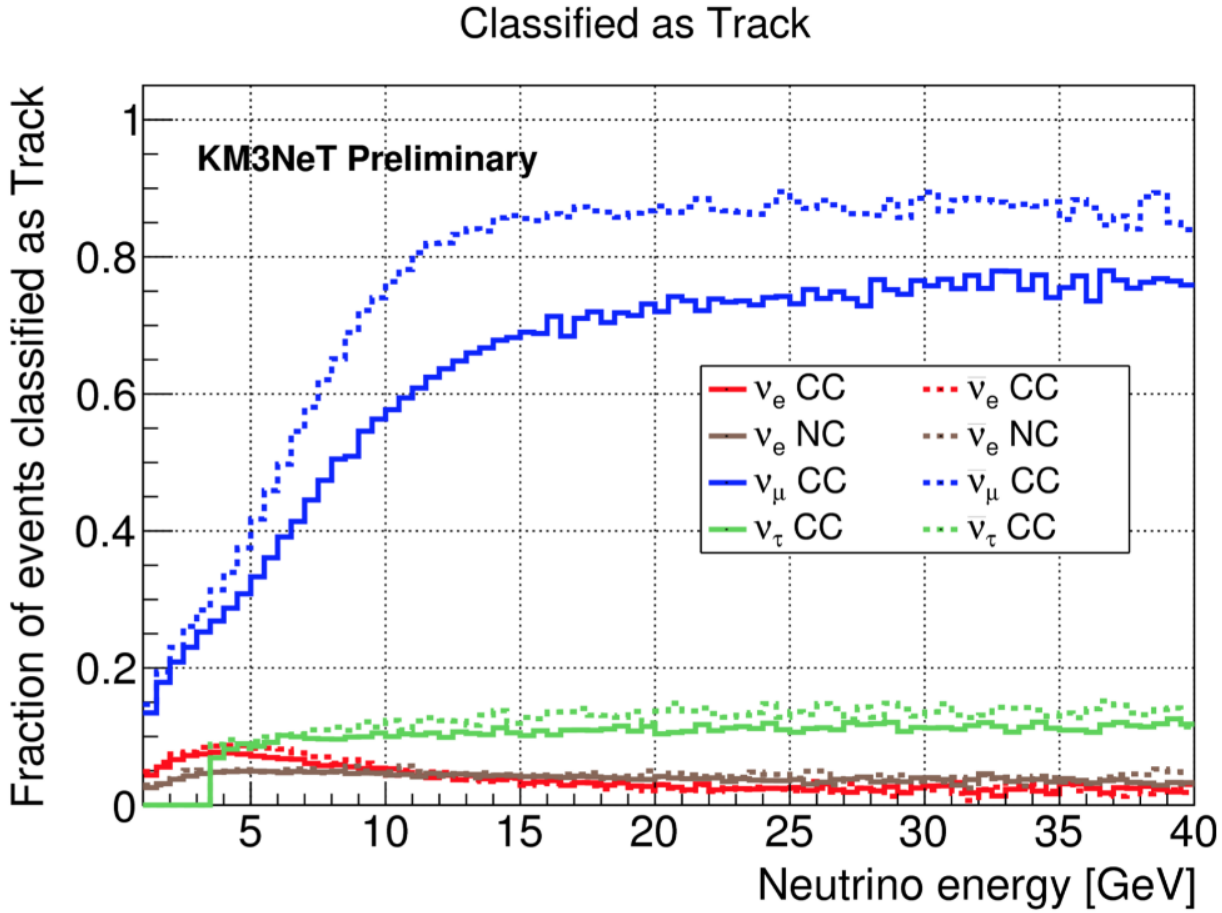




- Asymmetry NO/IO smeared by detector performance (PID, resolution)

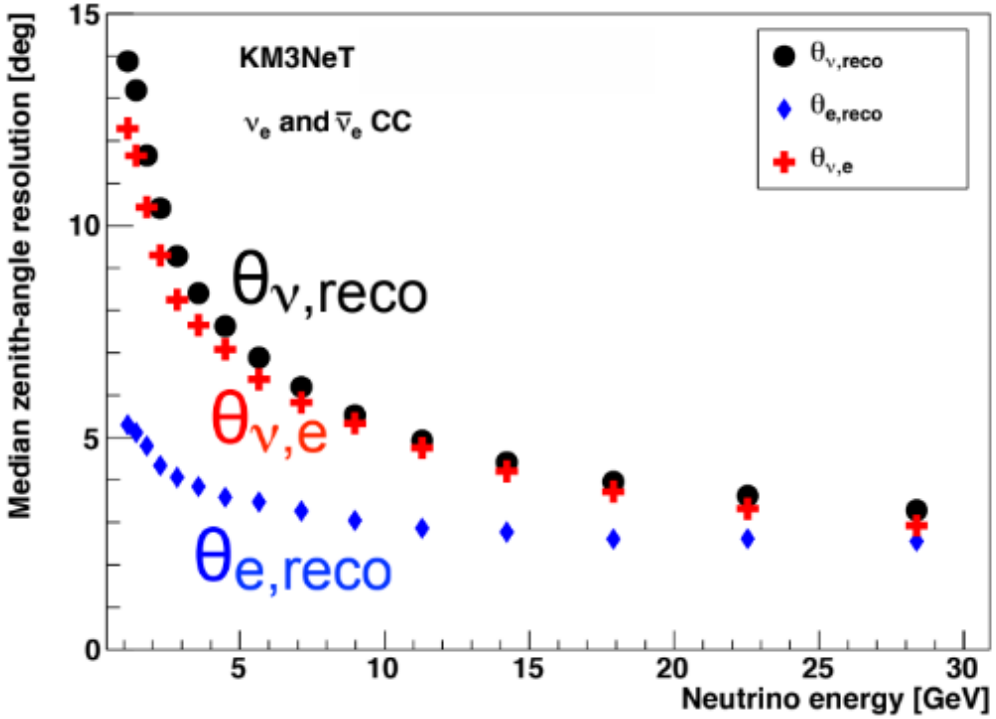
ORCA Expected Performance

- PID: ability to separate track ($\nu_\mu, \nu_\tau \rightarrow \mu$) from shower ($\nu_e, \nu^{NC}, \nu_\tau^{had}$).

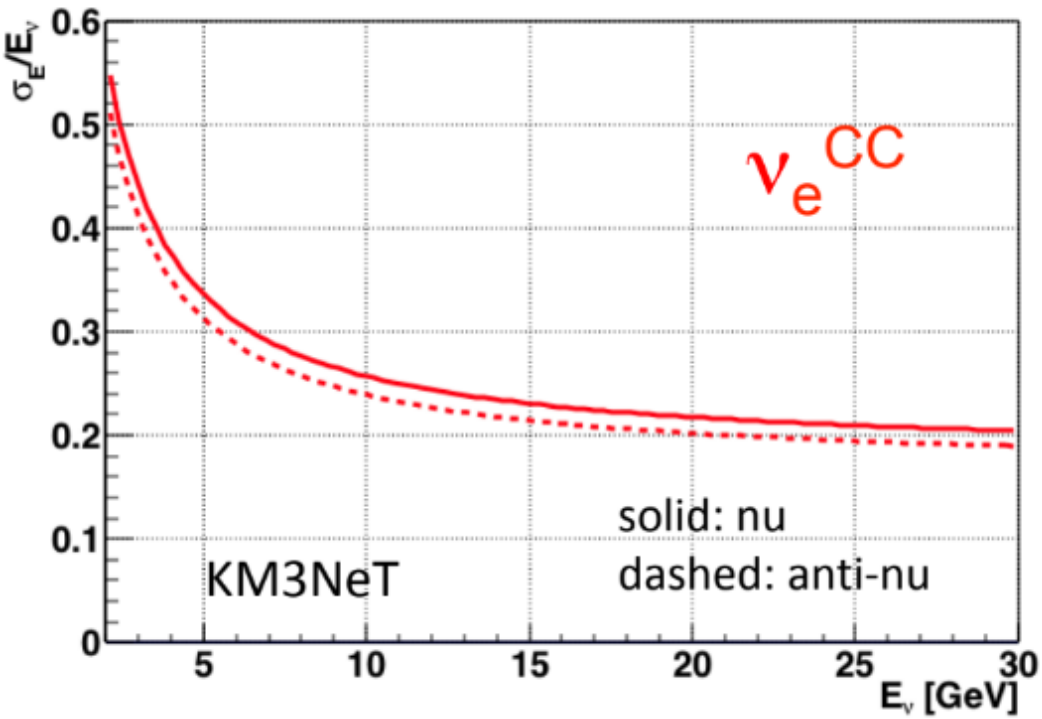


ORCA Expected Performance

- Energy and Angular resolution for Showers (similar for Tracks)



Angular reso. 5° at 10 GeV, dominated by decay kinematics



Energy reso. 25 % at 10 GeV, dominated by light yield fluctuation

NMO Analysis Method

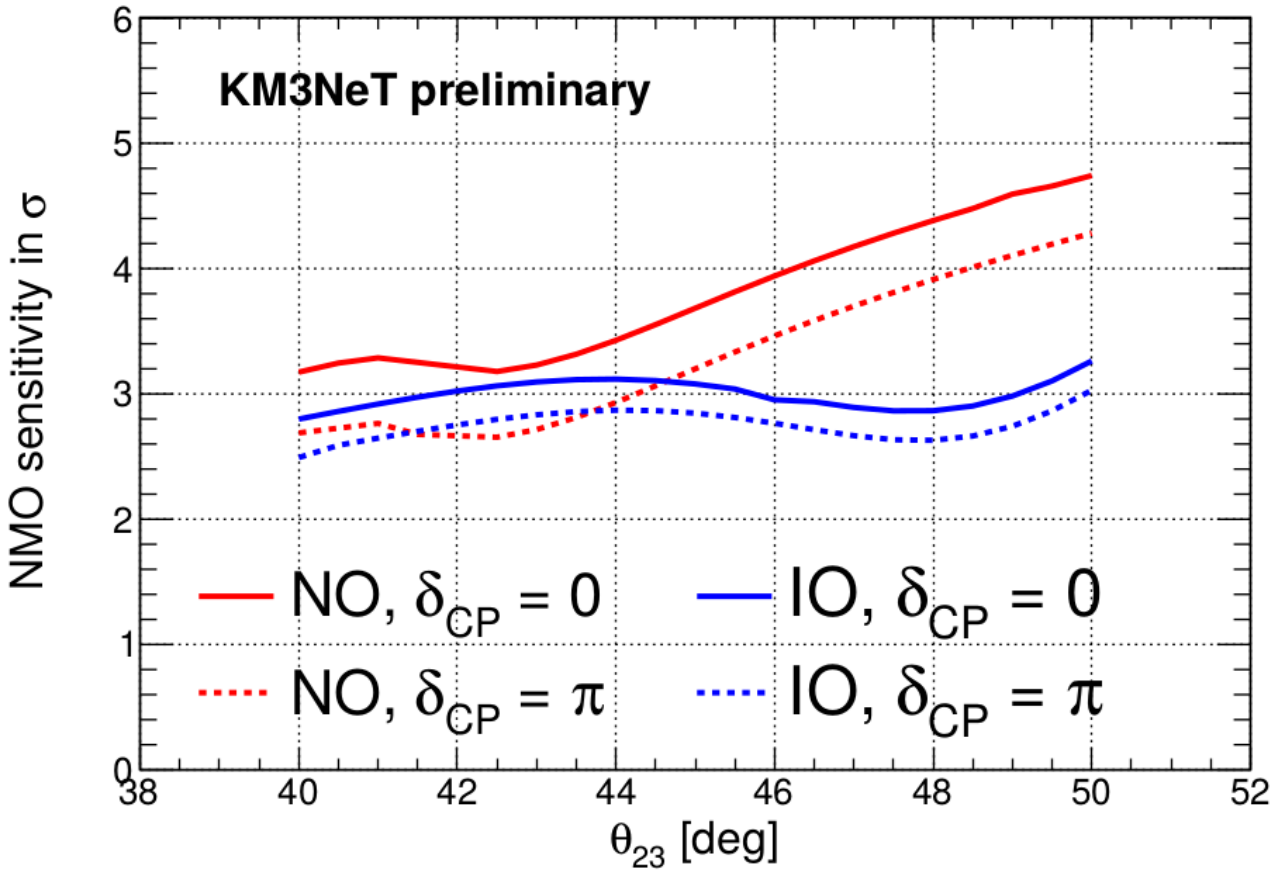
- Fit E-θ event distribution expected for a given NMO with the other NMO
- Data set split in 3 categories track-like, shower-like and mixed
- Fit strategy and systematics :

Δm^2_{21}	fixed to $7.4 \cdot 10^{-5}$ eV^2
$\sin^2\theta_{12}$	fixed to 33.62°
$\sin^2\theta_{13}$	8.54°, 0.15° prior (NO), 8.58°, 0.14° prior (IO)[1]
δ_{CP}	free
flux $\nu_\mu \leftrightarrow \bar{\nu}_\mu$ skew	10% prior
flux $\nu_e \leftrightarrow \bar{\nu}_e$ skew	10% prior
flux $\nu_\mu \leftrightarrow \nu_e$ skew	10% prior

flux E-tilt	free
flux $\cos\theta$-tilt	free
NC cross-sec. norm.	10% prior
norm. track-like	free
norm. shower-like	free
norm. middle sample	free

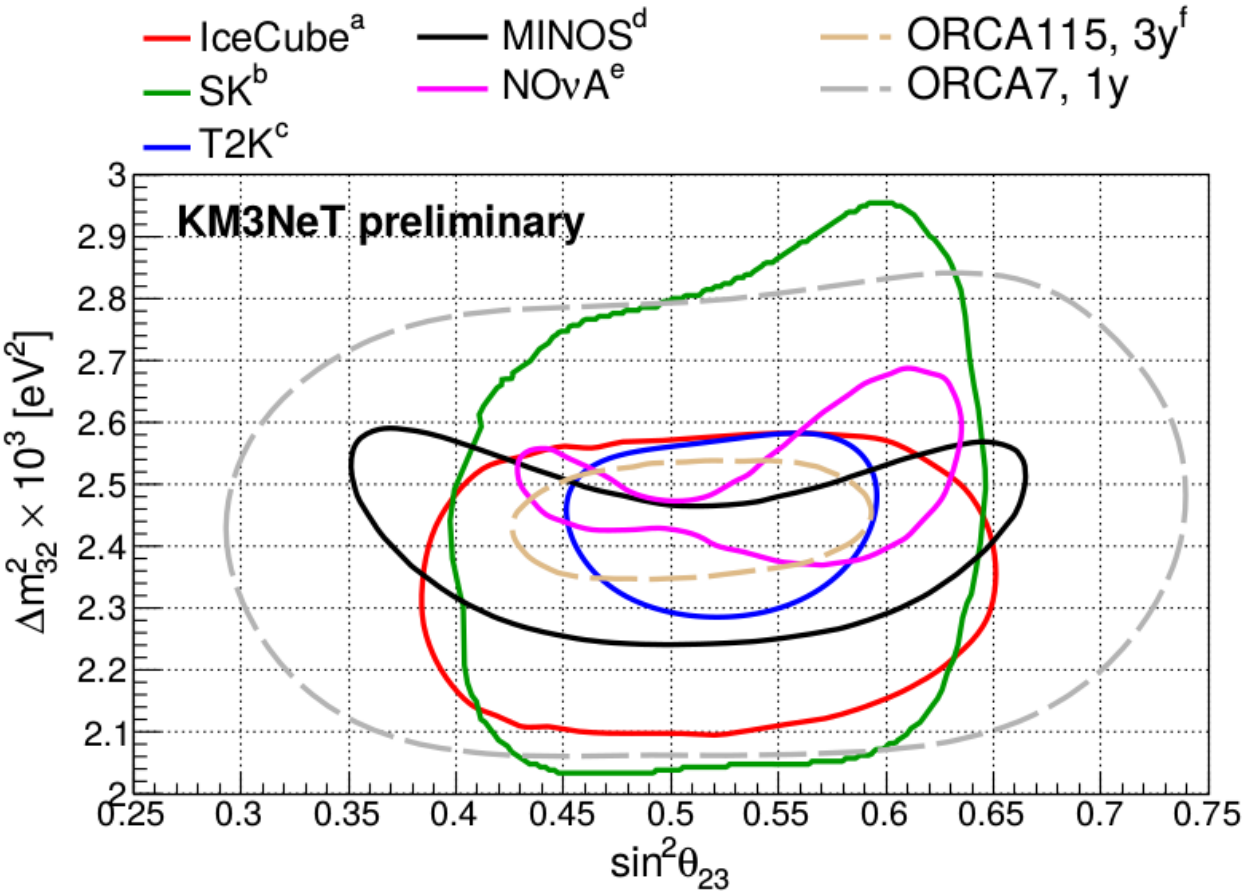
Prospects for NMO

- 3 years of data taking with full ORCA (115 lines)
- Sensitivity > 3σ excepted if NMO=NO and θ_{23} in the second octant



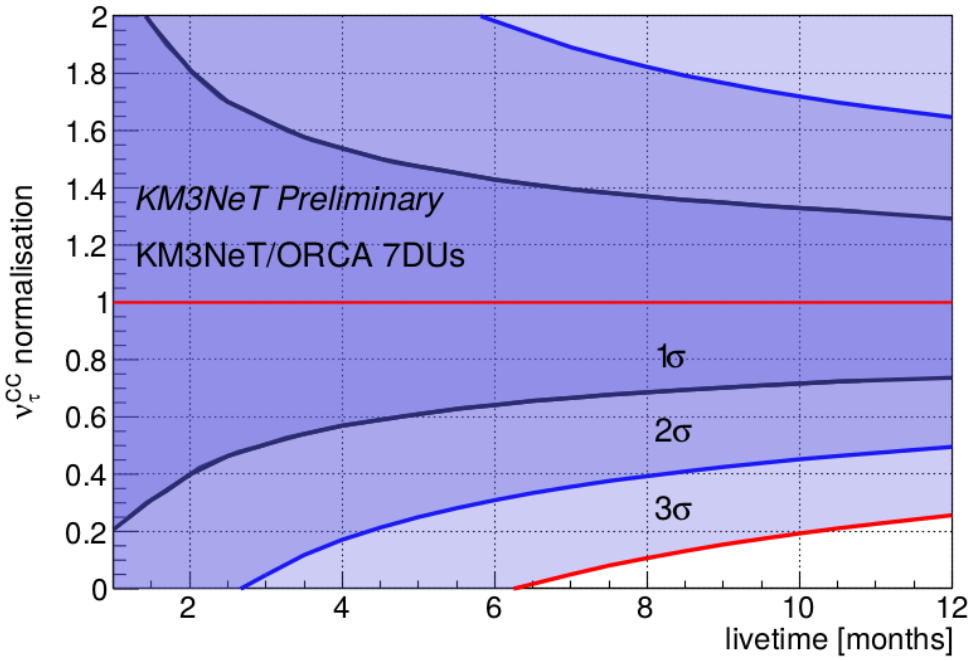
δm^2_{23} and θ_{23} with 7 ORCA Lines

- With 7 lines ORCA starts bringing informations to dermine the oscillation parameters



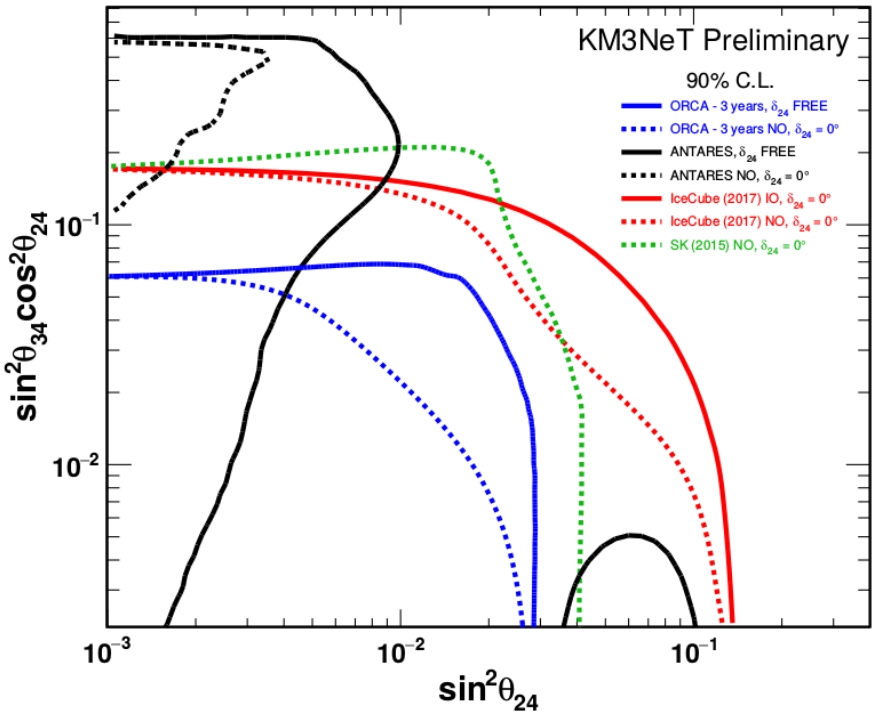
ν_τ appearance with 7 ORCA Lines

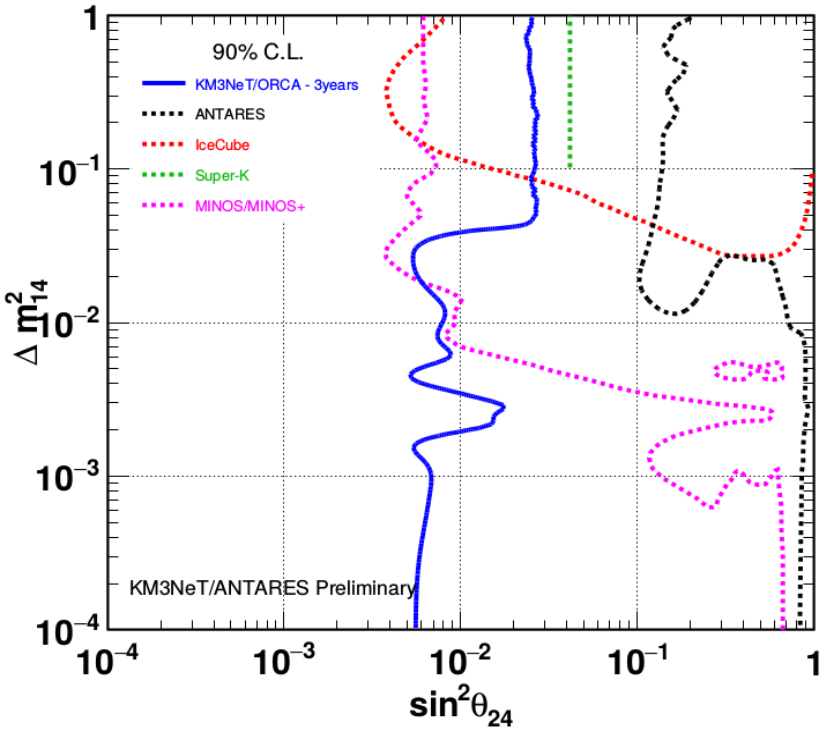
- Most ν_τ are detected as shower and cause an excess of shower at 25GeV where $\nu_\mu \rightarrow \nu_\tau$ is maximal
- ν_τ Norm is essential to probe PMNS unitarity (ie. Normalisation=1)



Sterile Neutrino (3+1)

- Atm. ν sensitive to $|U_{\mu 4}|^2$and $|U_{\tau 4}|^2$ via $\nu_\mu \leftrightarrow \nu_\tau$ osc.
- Limits strongly improves at low Δm^2_{41}



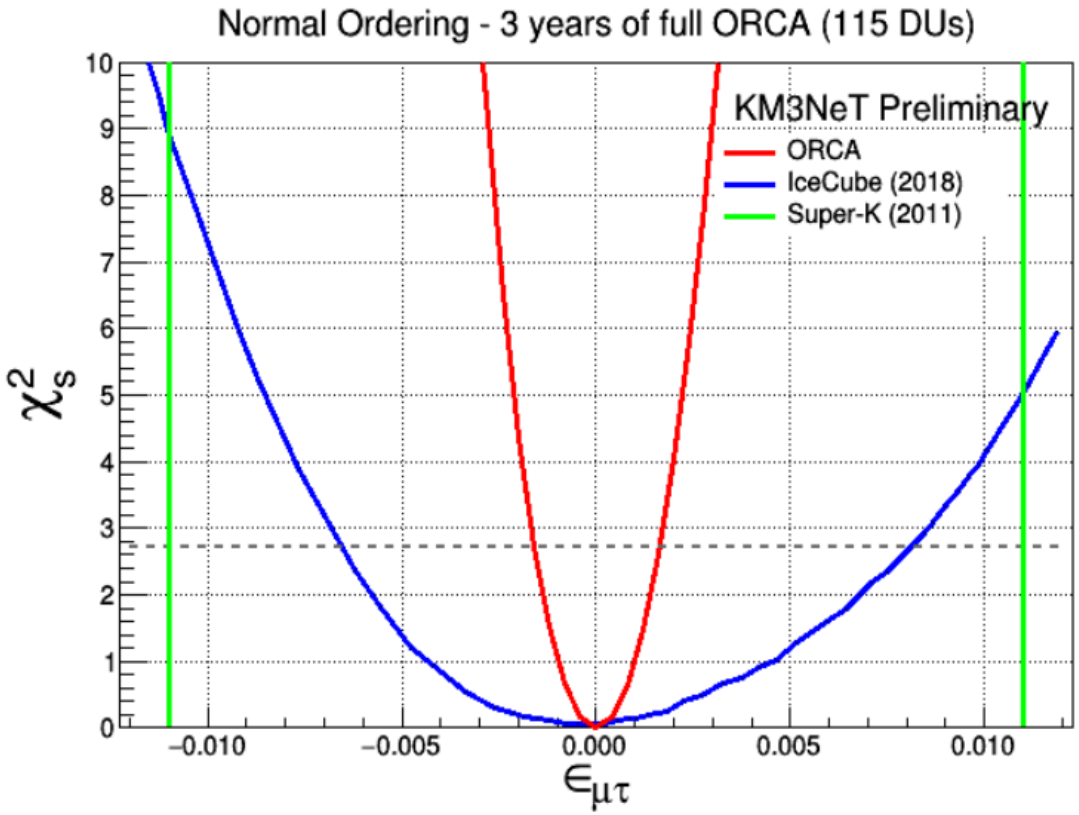


Non Standard Interactions

- Probe Neut. Curr. NSI of ν with Earth matter:

$$H = \frac{1}{2E} U \begin{bmatrix} 0 & 0 & 0 \\ 0 & \Delta m^2_{21} & 0 \\ 0 & 0 & \Delta m^2_{31} \end{bmatrix} U^\dagger +$$

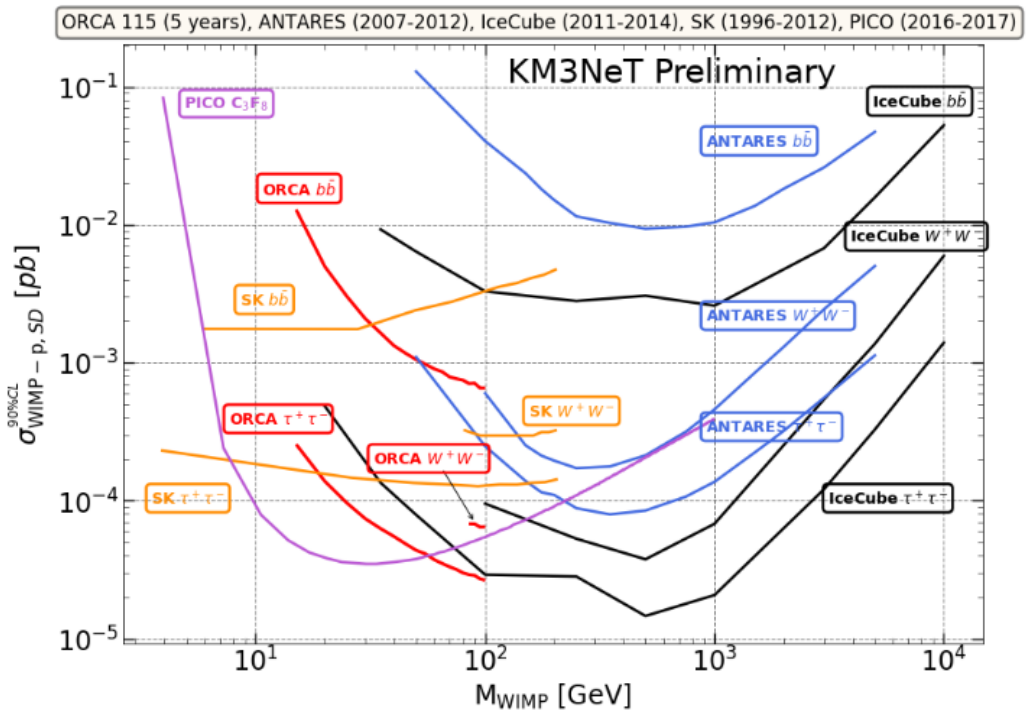
$$+ 2\sqrt{2} G_F N_e(x) \begin{bmatrix} 1+\varepsilon_{ee} & \varepsilon_{e\mu} & \varepsilon_{e\tau} \\ \varepsilon^*_{e\mu} & \varepsilon_{\mu\mu} & \varepsilon_{\mu\tau} \\ \varepsilon^*_{e\tau} & \varepsilon^*_{\mu\tau} & \varepsilon_{\tau\tau} \end{bmatrix}$$



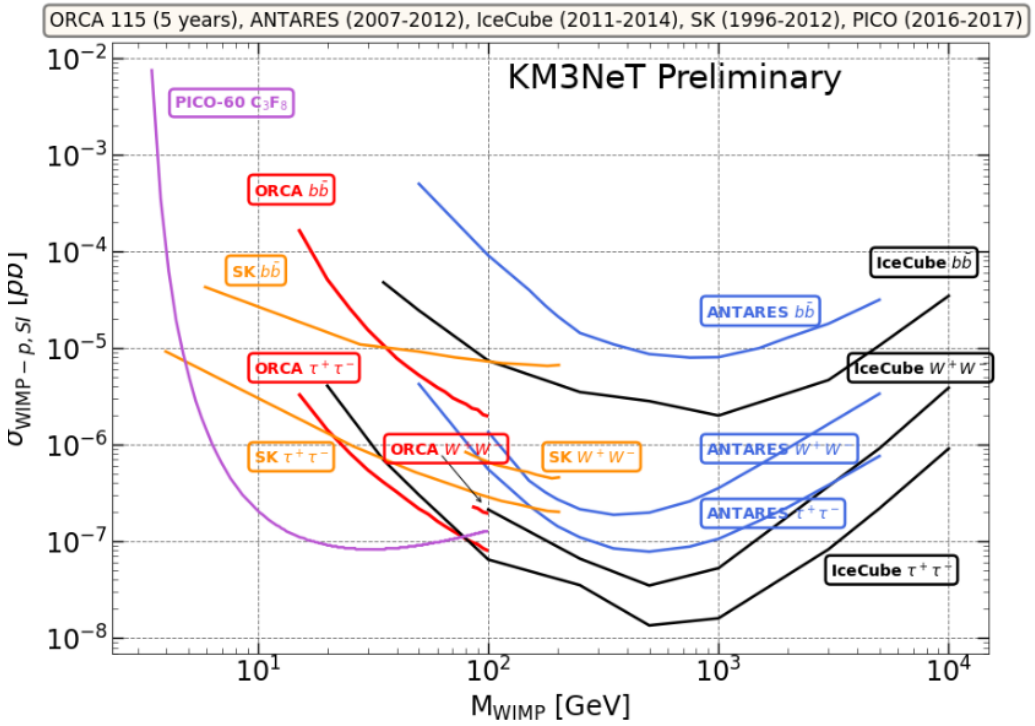
- For 2-flavour hybrid model ORCA will improve current limits by a factor ~4

Dark Matter in the Sun

- WIMP (e.g. neutralino χ) can be captured in the sun
- Produce ν when annihilating via : $\chi\chi \rightarrow \tau\tau, bb, WW$



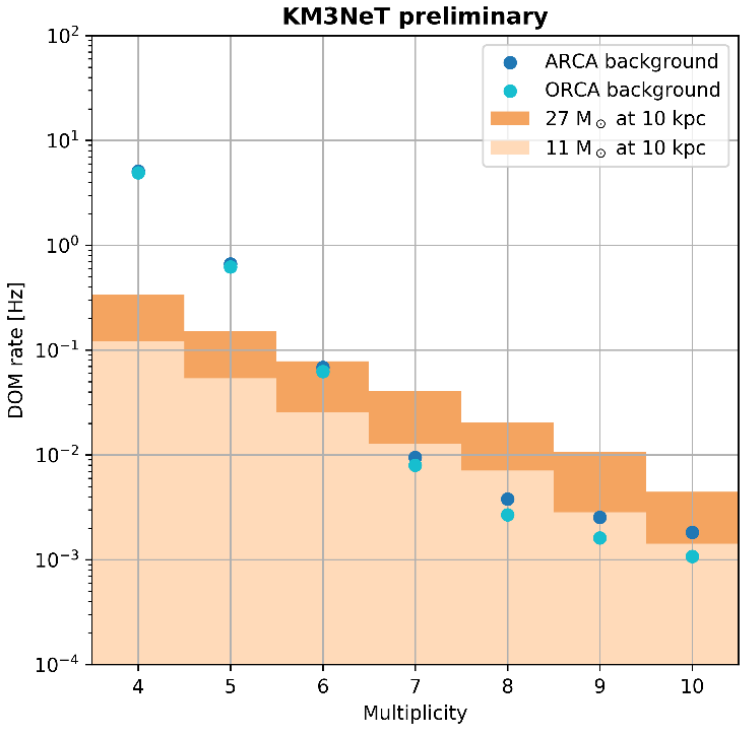
Spin Dependent Capture

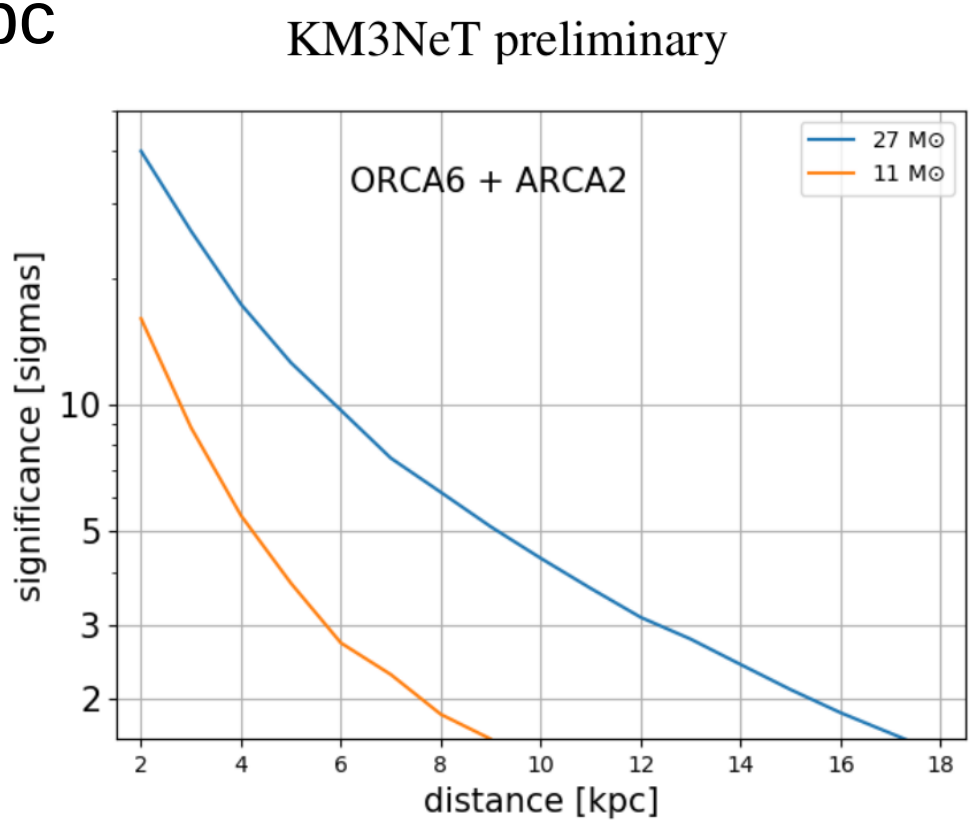


Spin Independent Capture

Supernovae

- A core-collapse supernovae produces a burst of O(MeV) neutrinos lasting O(100)ms
- Burst induces a increase of in-time hits on a DOM
- 5σ discovery with 6 ORCA + 2 ARCA lines for a 11(27)$M_{\odot}$ SN at 4(9) kpc





Possible Upgrade: Protvino to ORCA

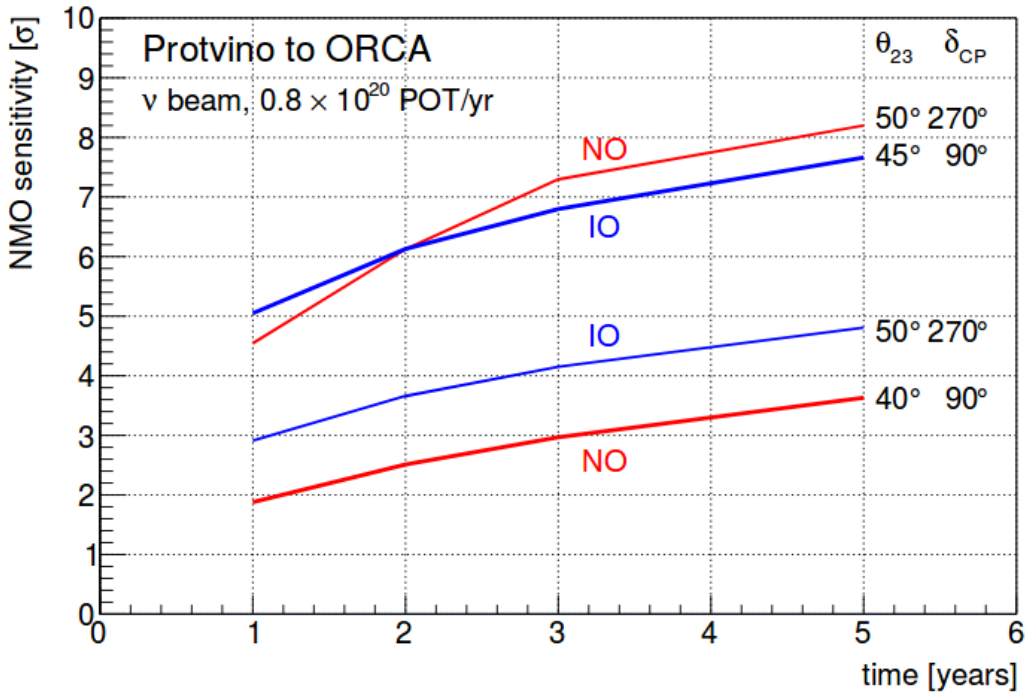
- U70 accelerator complex:
  - Proton at 70GeV, 15kW
  - Beam line to be constructed

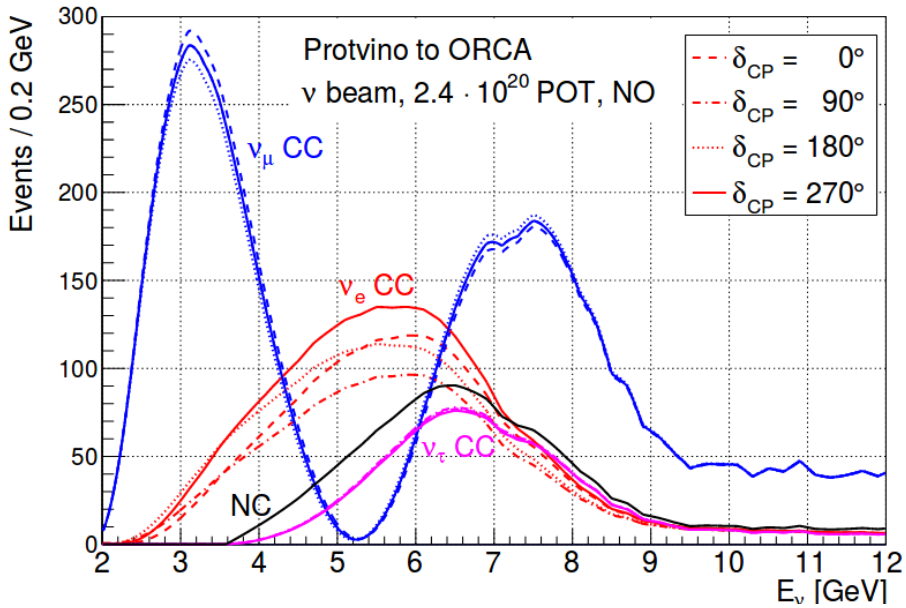
Letter of Interest arXiv:1902.06083

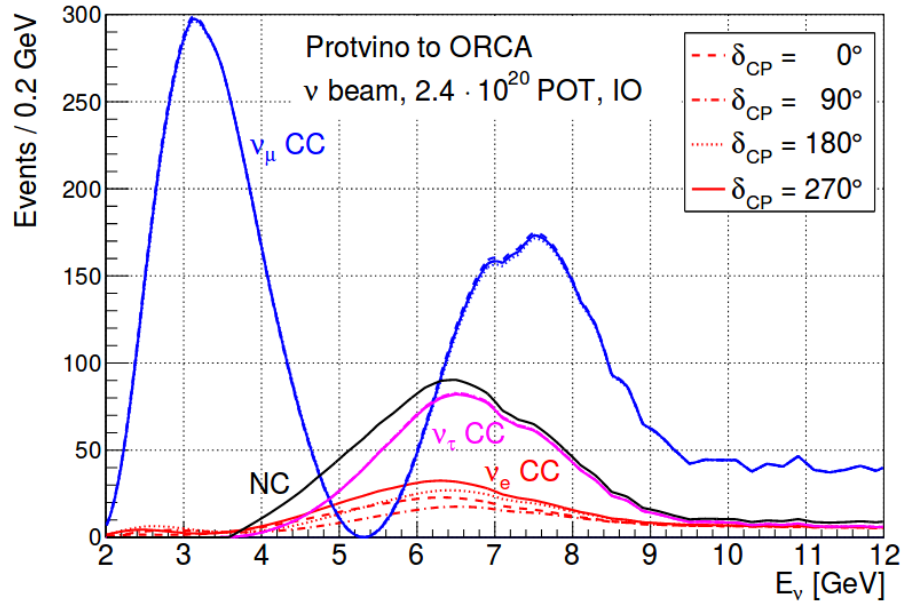
- First Stage : U70 @ 90kW to ORCA
  - Minor accelerator upgrade to reach 90kW (now 15kW)
- Second Stage : U70 @ 450kW to Denser ORCA
  - Major accelerator upgrade (new injector)
  - Super ORCA : 10x denser, 1/2 size

1rst Stage: NMO with P2O

- 3σ determination of the NMO regarless of Ordering or CP phase
- 4000 neutrinos per year !

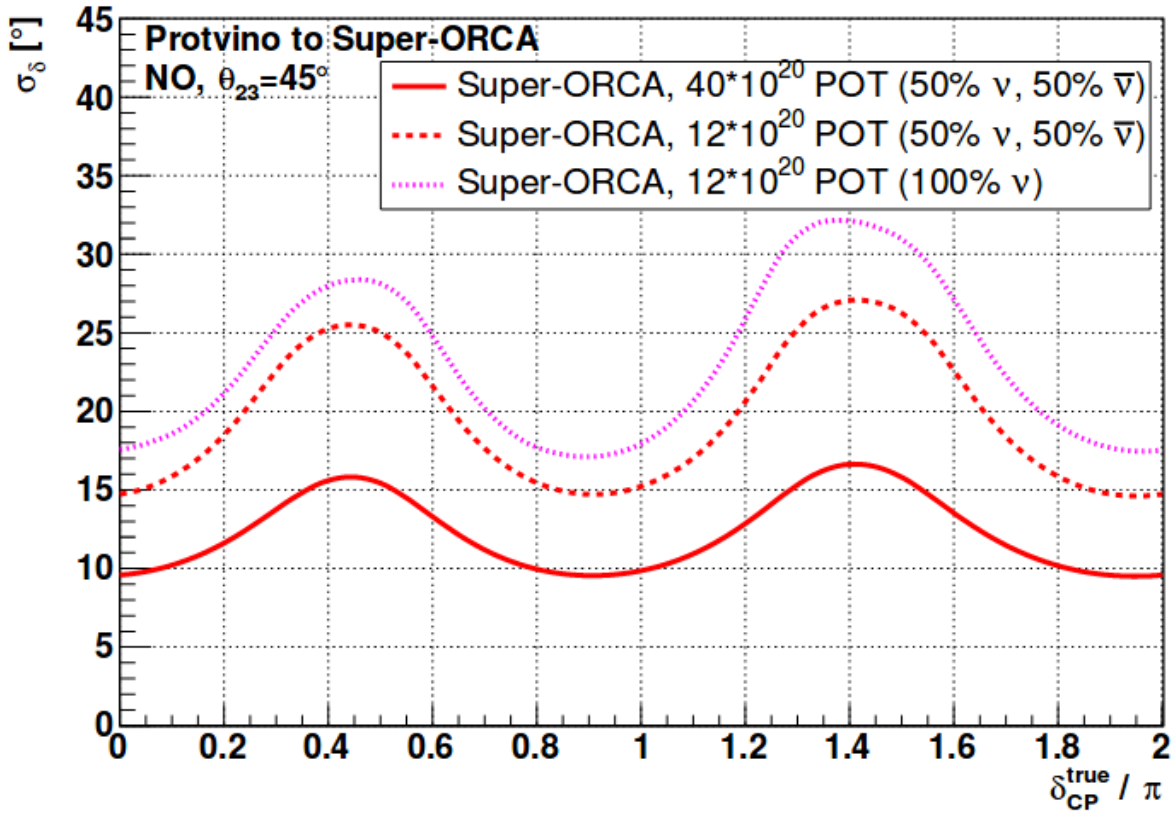






2nd Stage: CP Phase with P2SO

- With a 10x denser detector (Super ORCA) :
  - Lower energies and better PID (Cerenkov ring fuziness)
- Measure CP Phase with 10-16° precision in 10 years



Conclusions

- KM3NeT-ORCA has a rich physics programme
- First detection line operational since 2017
- Data shows a very good quality
- First physics results expected in the coming year
- Upgrade programme being prepared: P2O