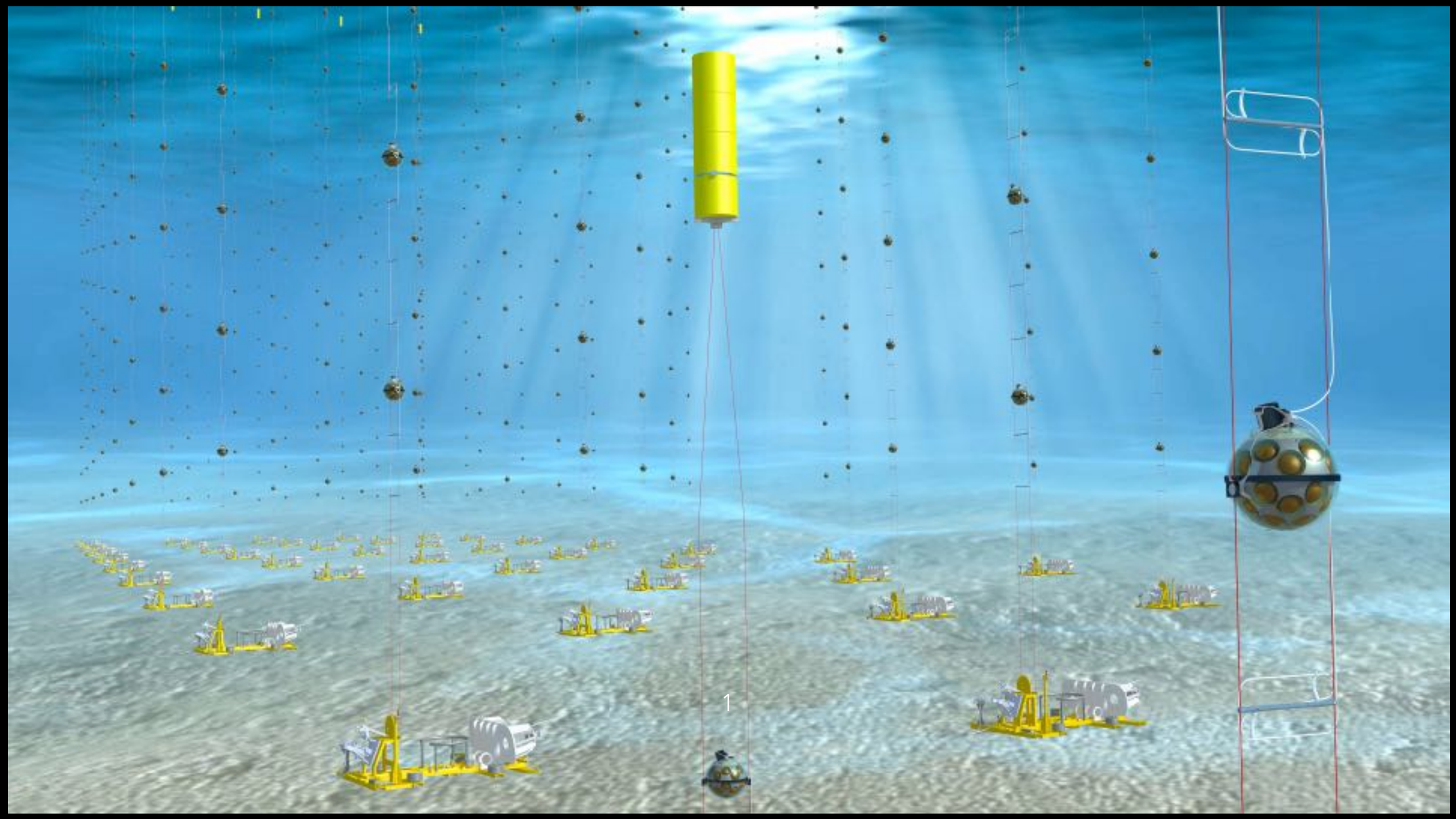
KM3NET/ORCA: PERSPECTIVES AND MULTI-SEARCH POTENTIAL OF AN UNDERWATER NEUTRINO TELESCOPE



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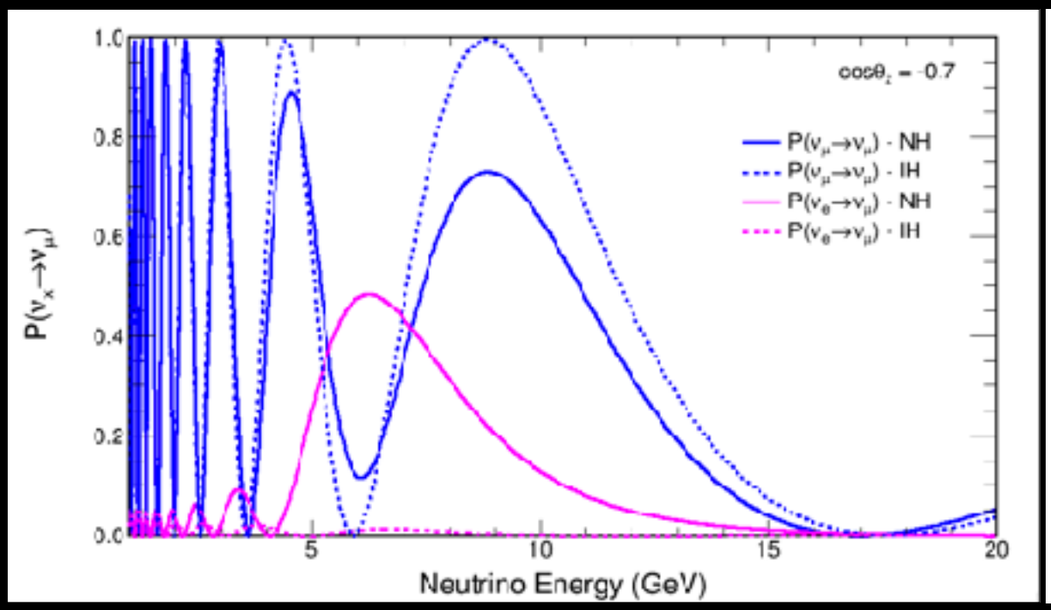
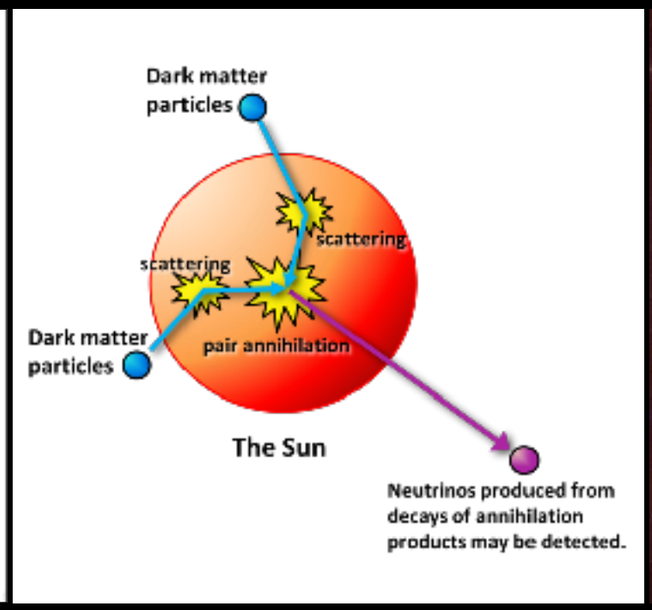
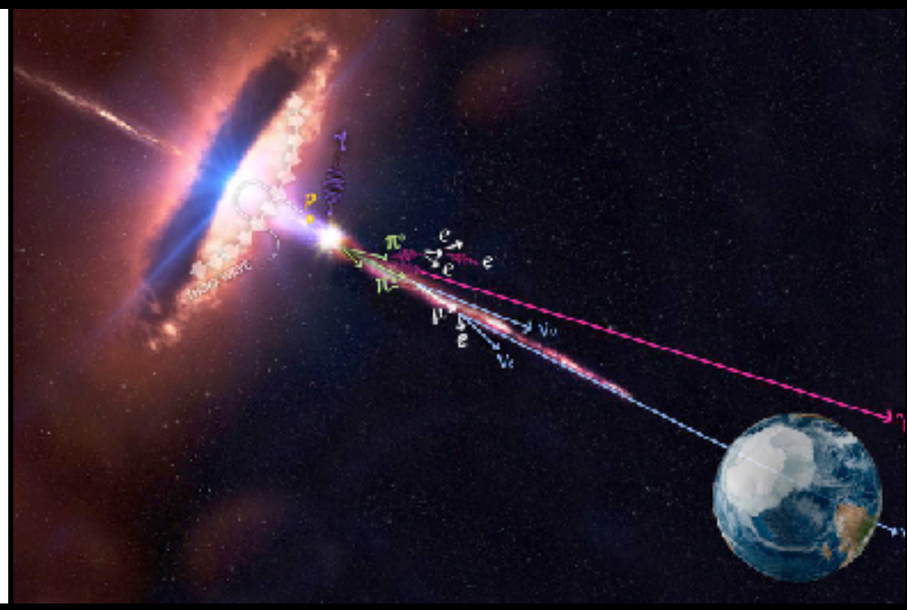
ALBA DOMI - UNIVERSITÀ DEGLI STUDI DI GENOVA, CPPM MARSEILLE

Neutrino Telescopes: Science Scope







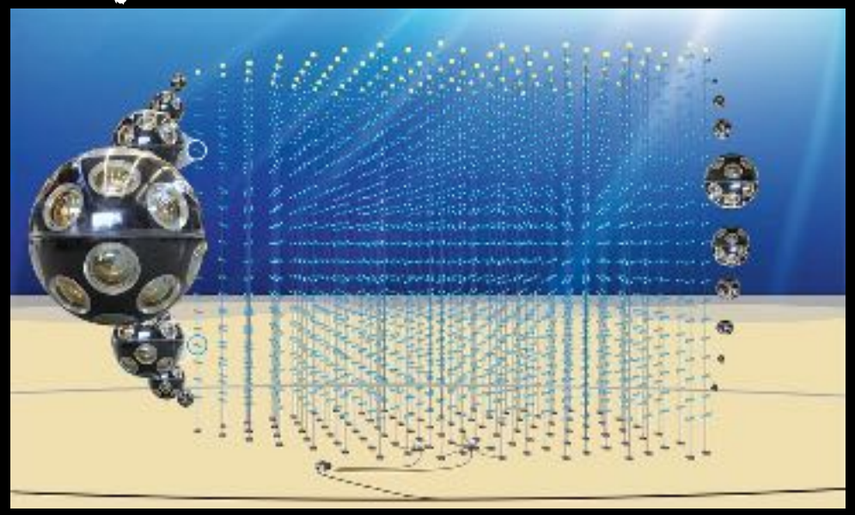
Low Energy:	Intermediate Energy:	High Energy:
MeV < E_ν < 100 GeV	10 GeV < E_ν < 1 TeV	E_ν > 1 TeV
ν oscillations, Supernovae…	Dark Matter search, Monopoles…	ν from extra-terrestrial sources…
KM3NeT/ORCA	KM3NeT/ORCA+ARCA	KM3NeT/ARCA

NEUTRINO TELESCOPES OVERVIEW

Higher Sensitivity to neutrino sources: "precision frontier"

Sensitivity at ≥EeV: "energy frontier"

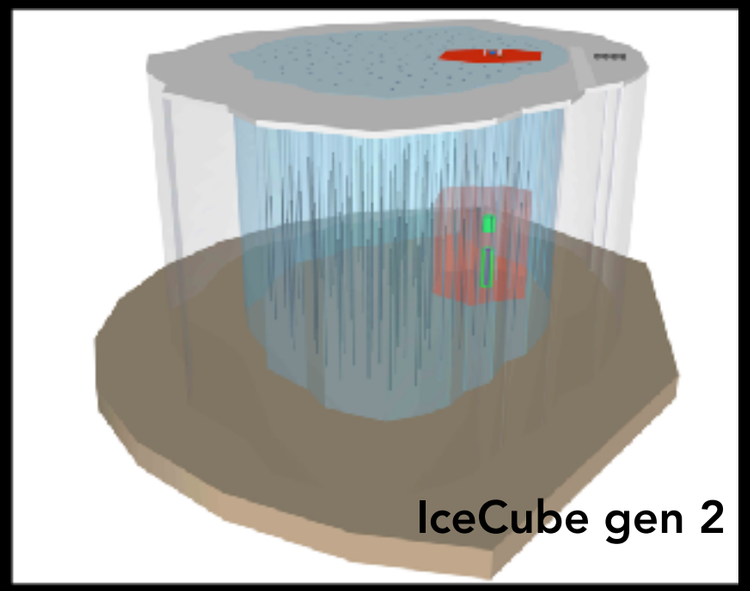
Present neutrino detectors

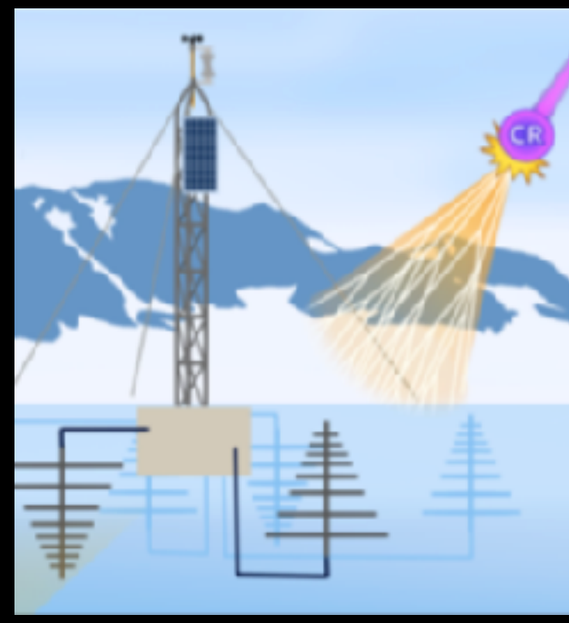


KM3NeT

See Talk of Sergio Navas

Sensitivity at PeV energies: "intensity frontier"





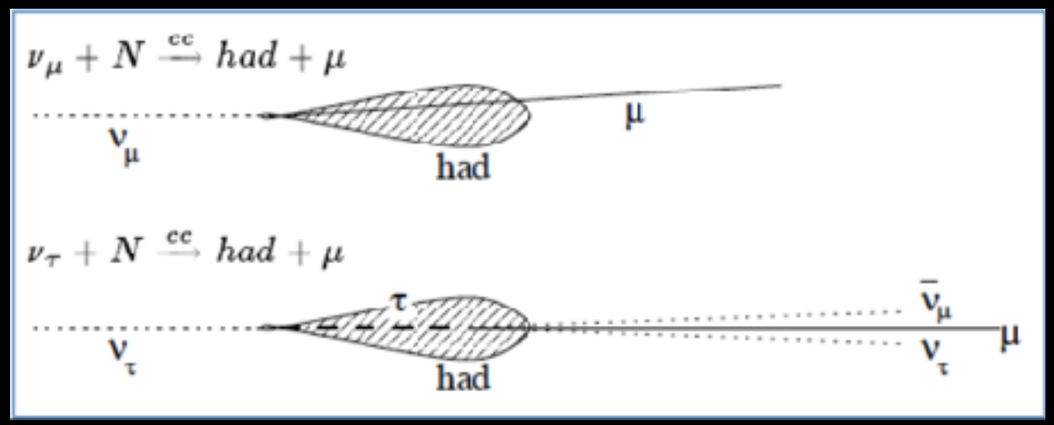
ARA, ARIANNA, EVA, GRAND

Credits: M. Ackerman

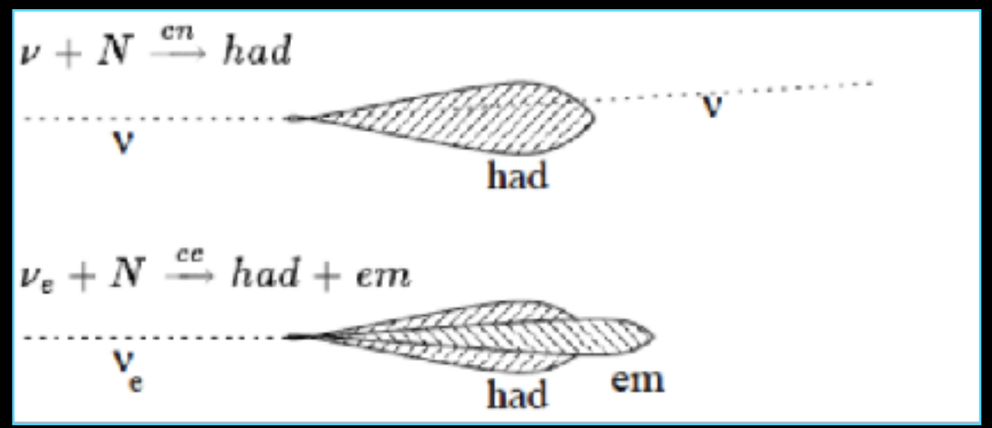
Why KM3NeT?

Event Topologies

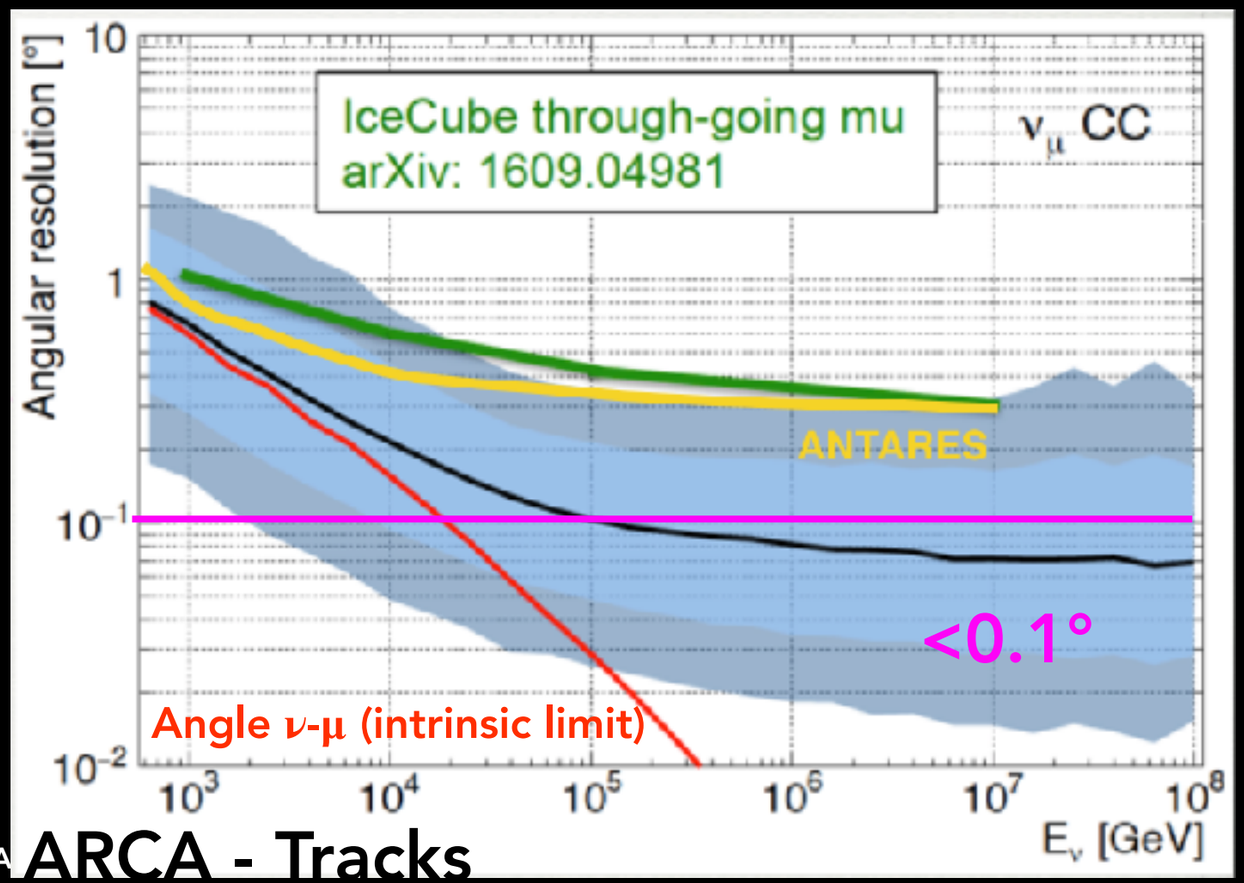
Tracks: ν_μ^{CC}, ν_τ^{CC} ($\tau \to \mu$)



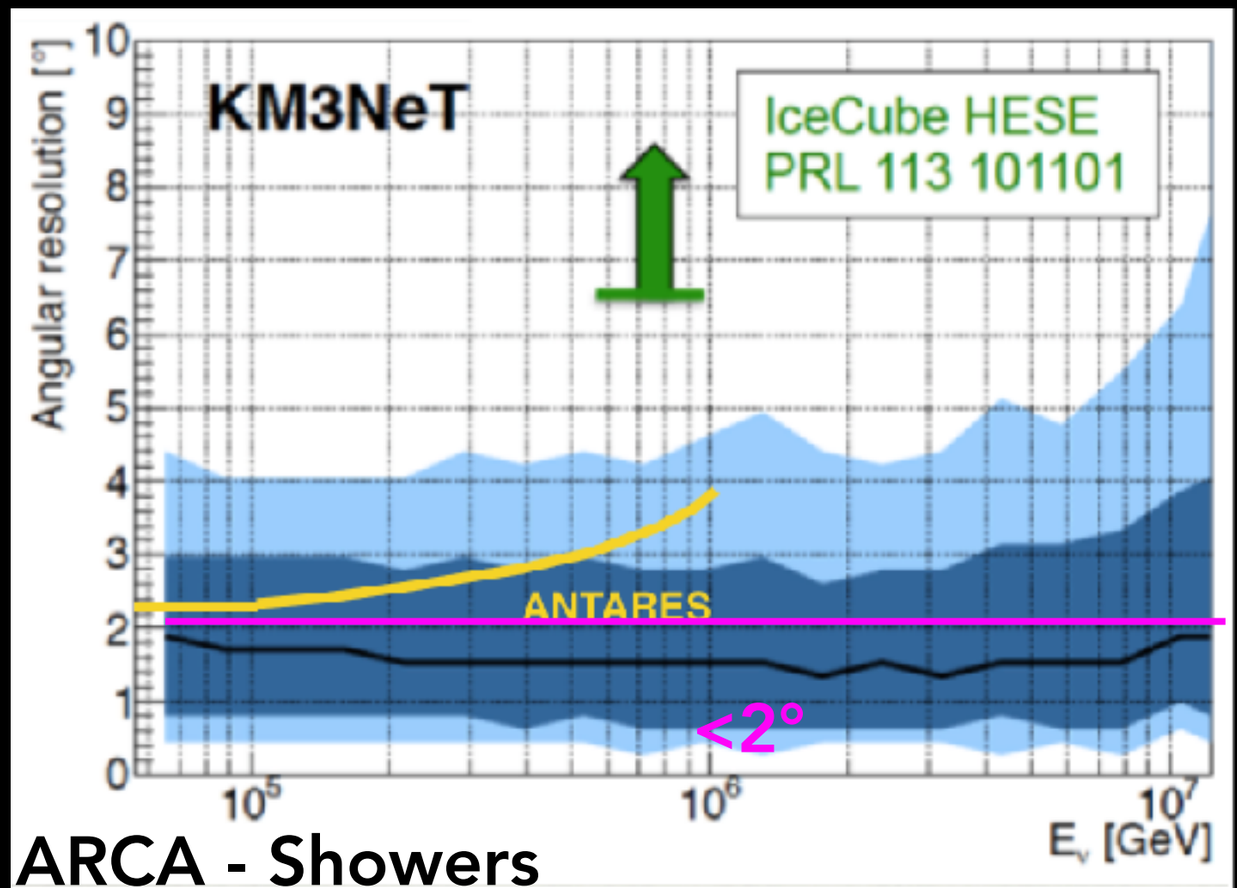
Showers: ν_e^{CC}, ν^{NC}, ν_τ^{CC} ($\tau \to e$)



Angular resolution KM3NeT vs IceCube

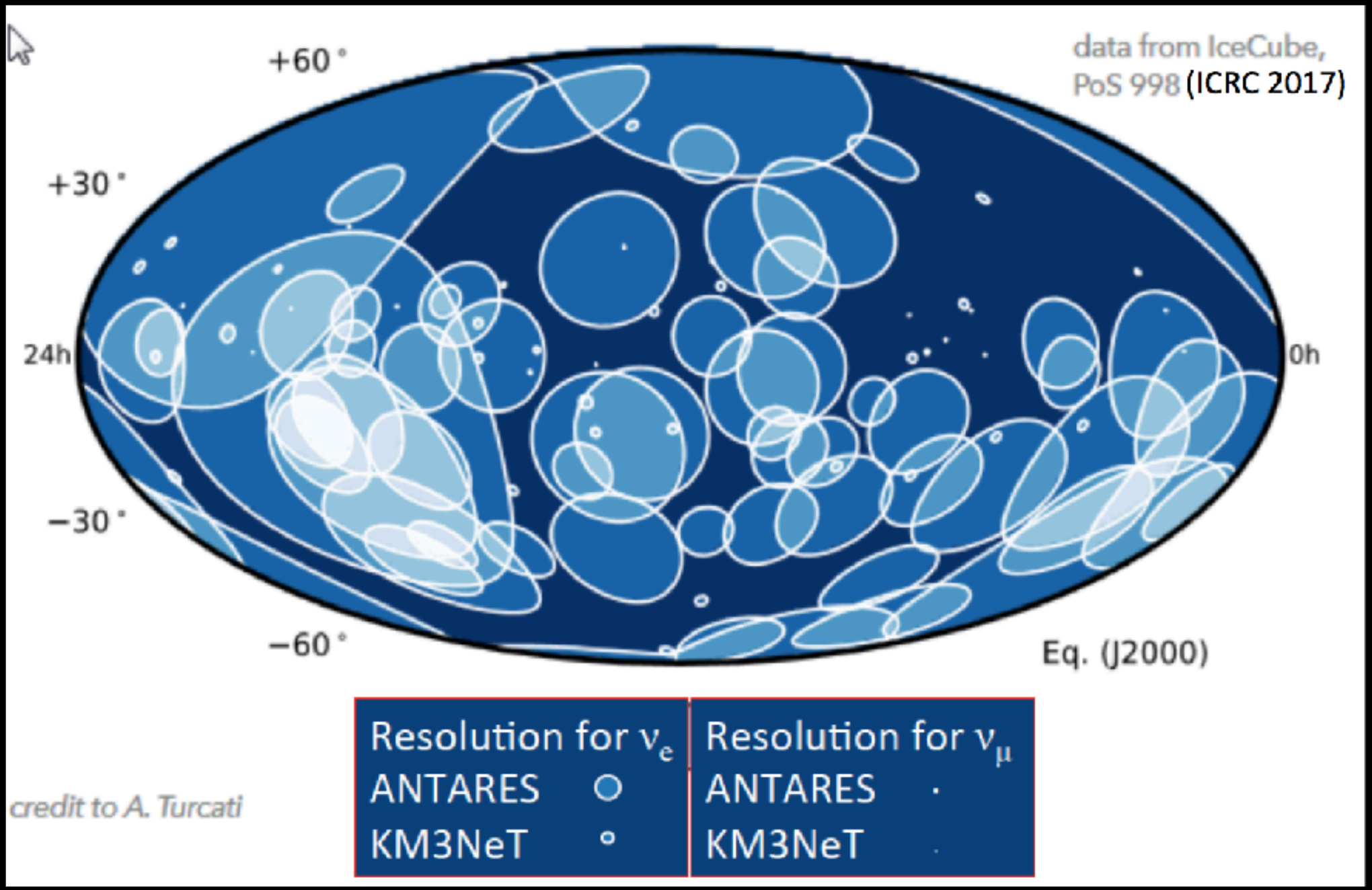


ARCA - Tracks



ARCA - Showers

Why KM3NeT?

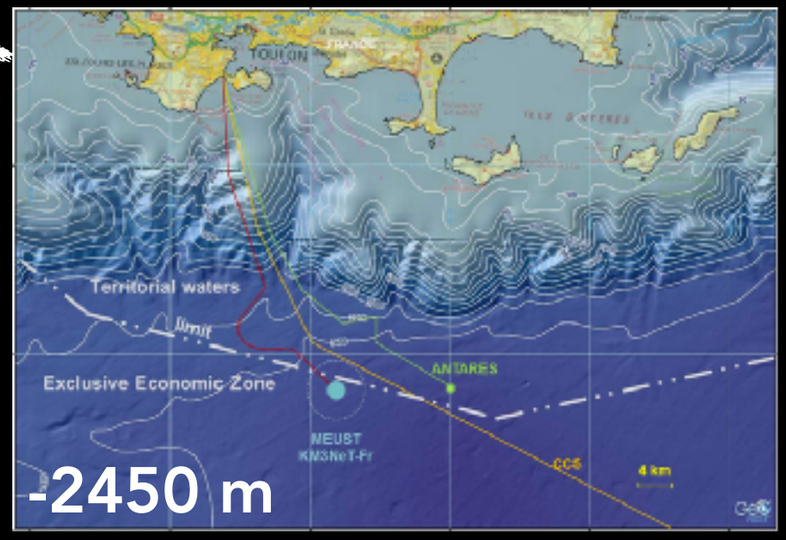

data from IceCube,
PoS 998 (ICRC 2017)
+60°
+30°
24h
0h
−30°
−60°
Eq. (J2000)
Resolution for ν_e
ANTARES
KM3NeT
Resolution for ν_μ
ANTARES
KM3NeT
credit to A. Turcati

KM3NeT COLLABORATION

KM3NET LOI: DOI:10.1088/0954-3899/43/8/084001

ORCA

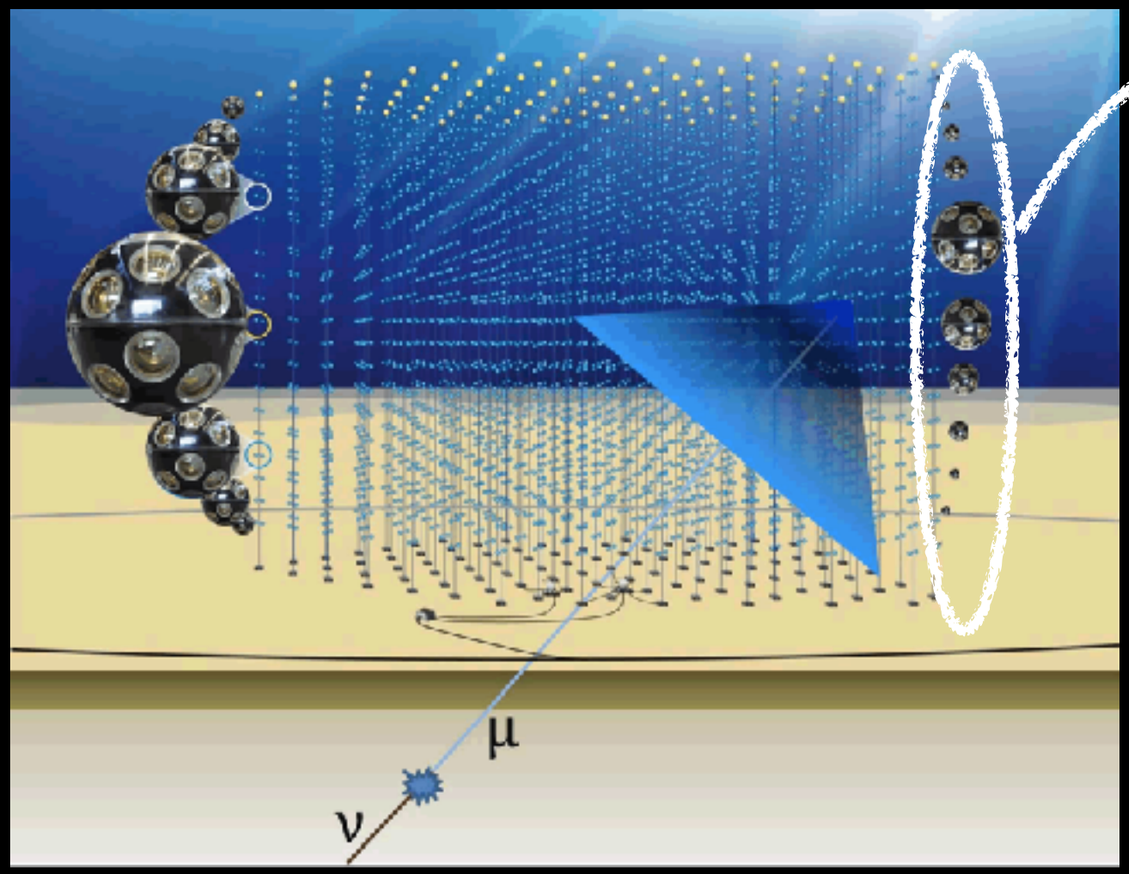
(Oscillation Research with Cosmics in the Abyss)



ARCA

(Astroparticle Research with Cosmics in the Abyss)

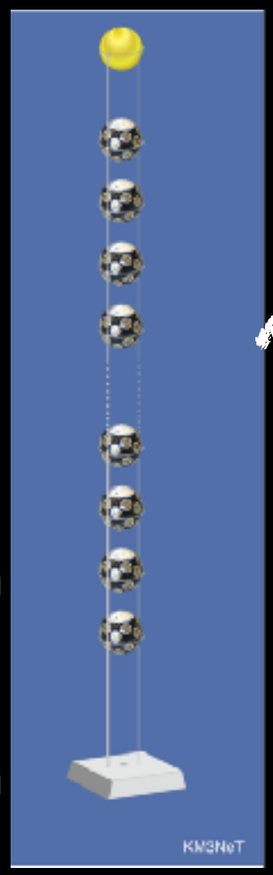
DETECTION TECHNOLOGY



DU:
18
DOMS

ARCA -
h 700 m

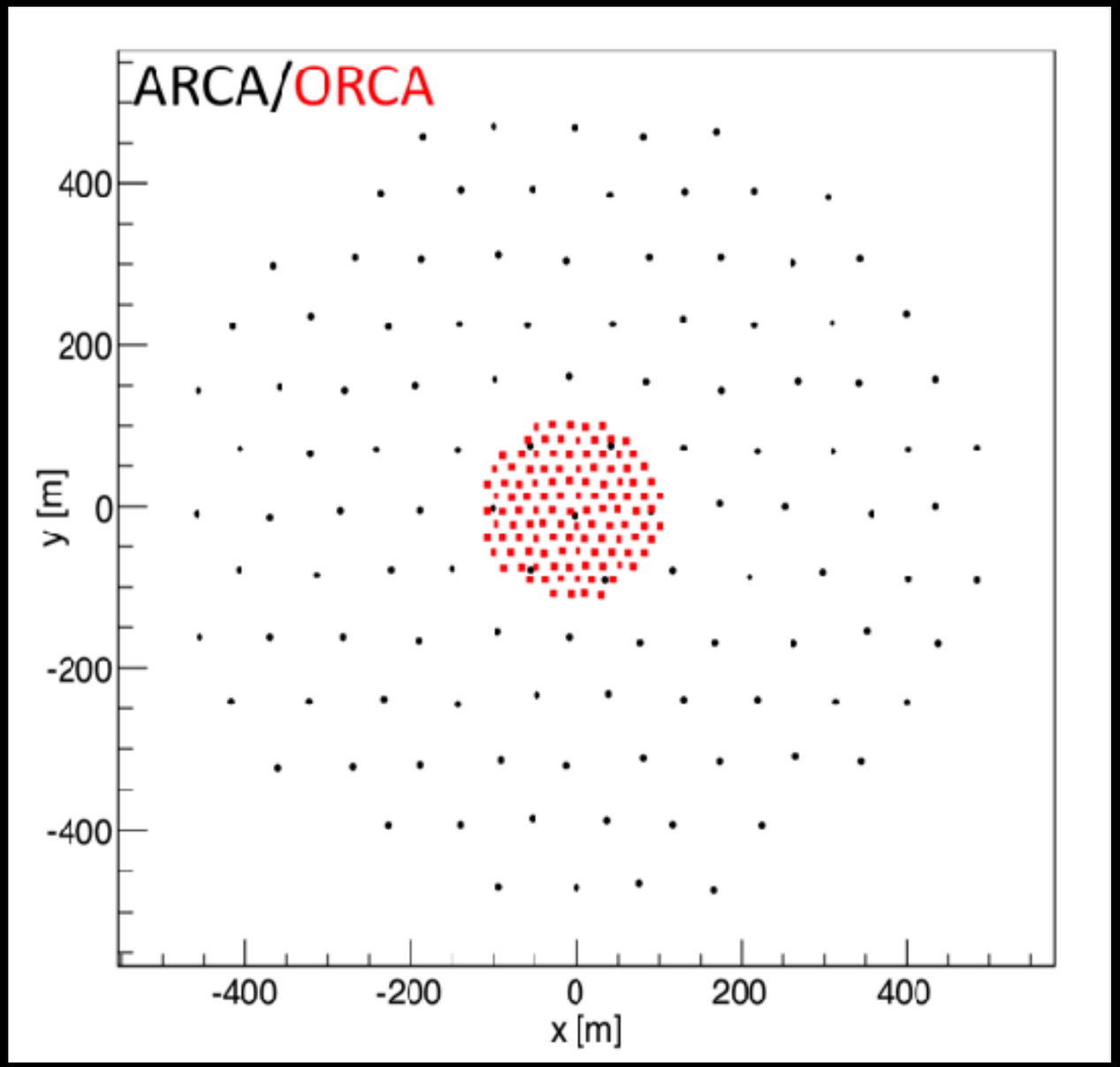
ORCA -
h 200 m



DOM:
31
PMTs

- 3 Building Blocks (BB):
- 115 Detection Units (DUs) per BB
- 18 Digital Optical Modules (DOMs) per DU
- 31 PMTs (3″) per DOM (19↓, 12↑)

ORCA/ARCA DETECTORS



	ORCA	ARCA
String spacing	23 m	90 m
Vertical spacing	9 m	36 m
Depth	2470 m	3500 m
Instrumented mass	1x 8 Mton	2x 0.6 Gton

ORCA:

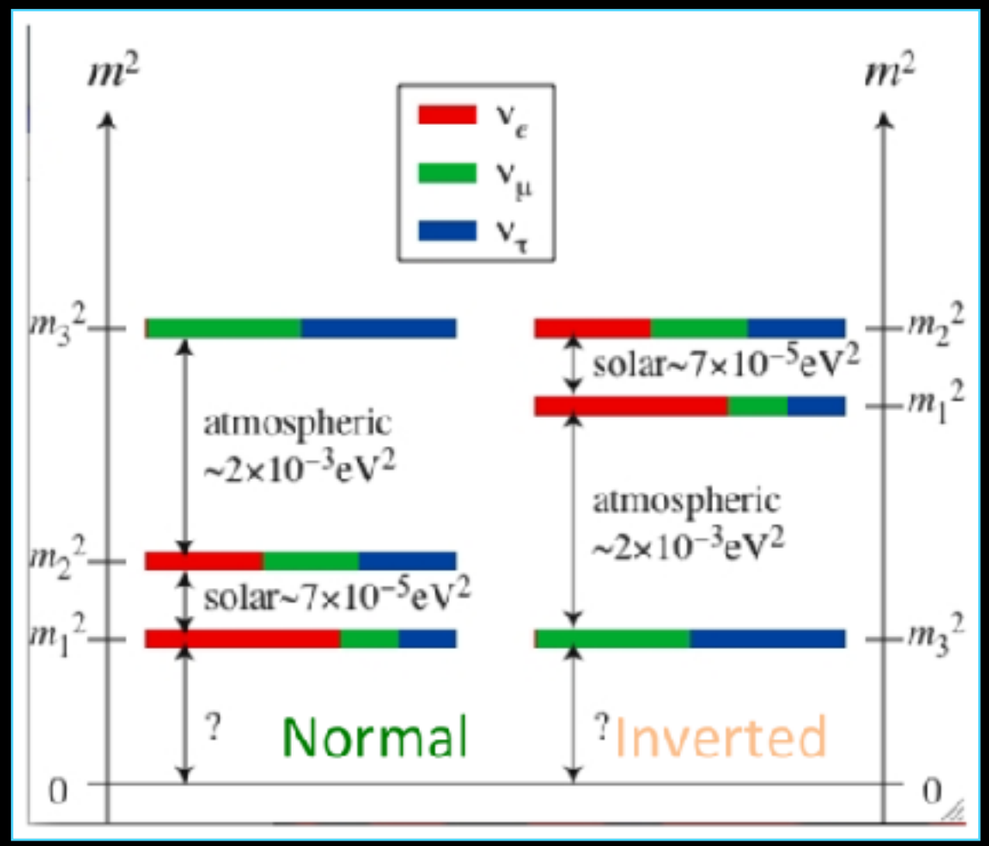
1 DENSE BUILDING BLOCK OPTIMISED FOR INTERMEDIATE ENERGIES (1-100 GEV)

TOTAL OF 64170 PMTS

ARCA:

2 SPARSE BUILDING BLOCKS OPTIMISED FOR HIGH ENERGIES (>1 TEV)

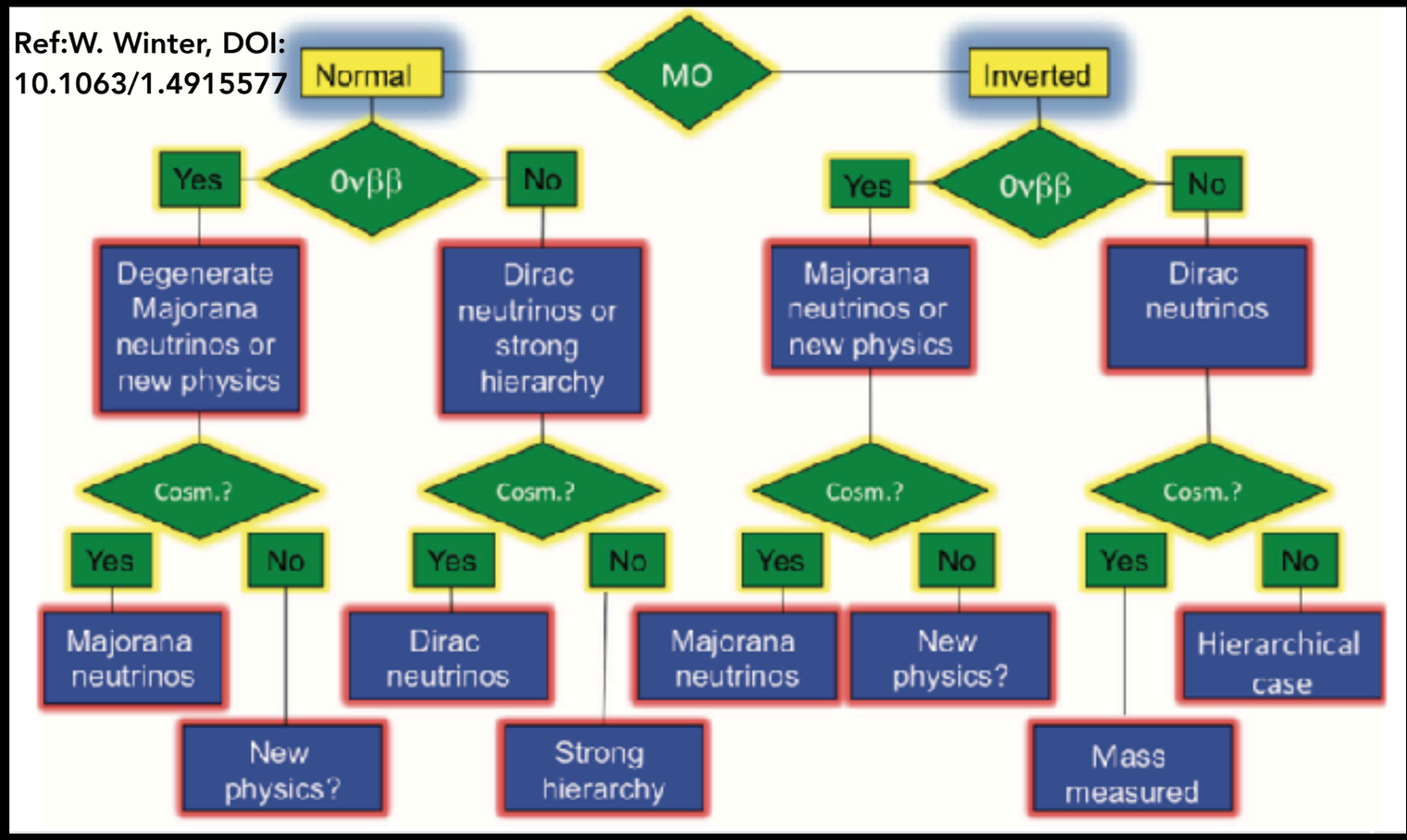
ORCA: Neutrino Mass Ordering



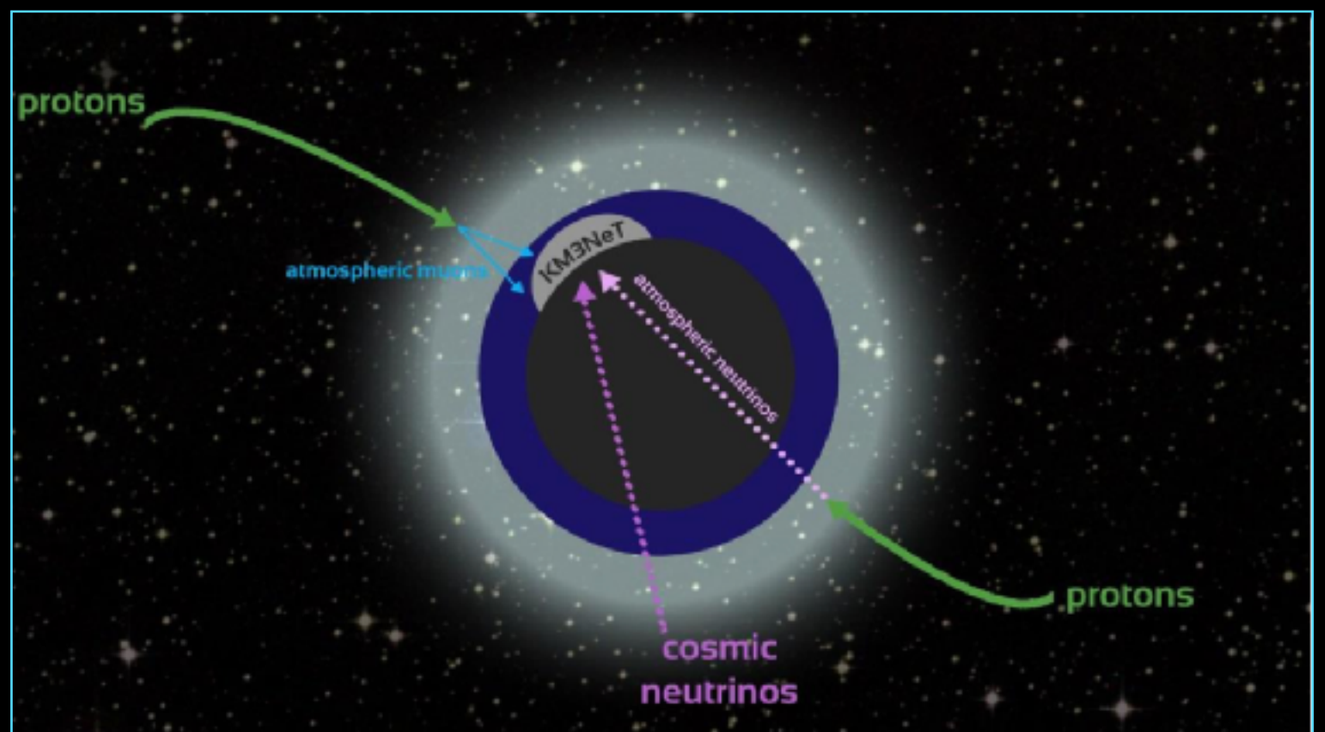
Impact on:

- Magnitude and nature of neutrino mass.
- Distinguish between different theoretical models.
- Impact on $0\nu\beta\beta$ studies.
- Core-collapse supernovae.

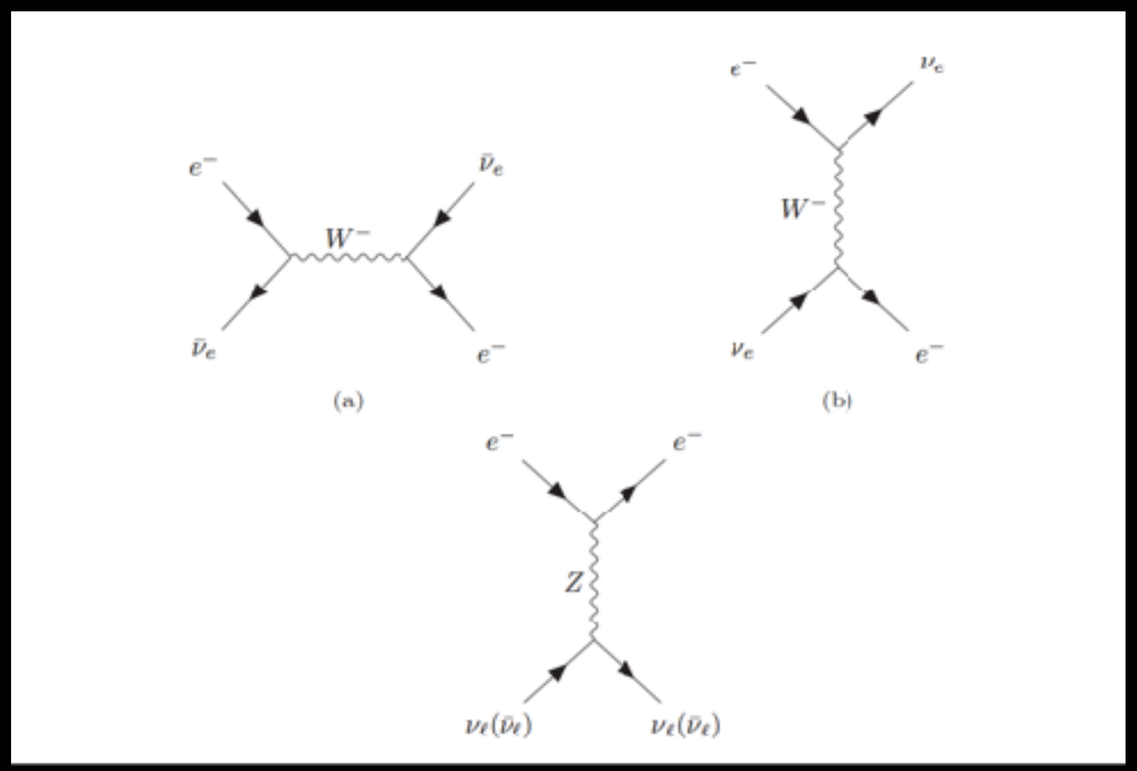
Alba Domi, VHEPU 2018 - Quy Nhon

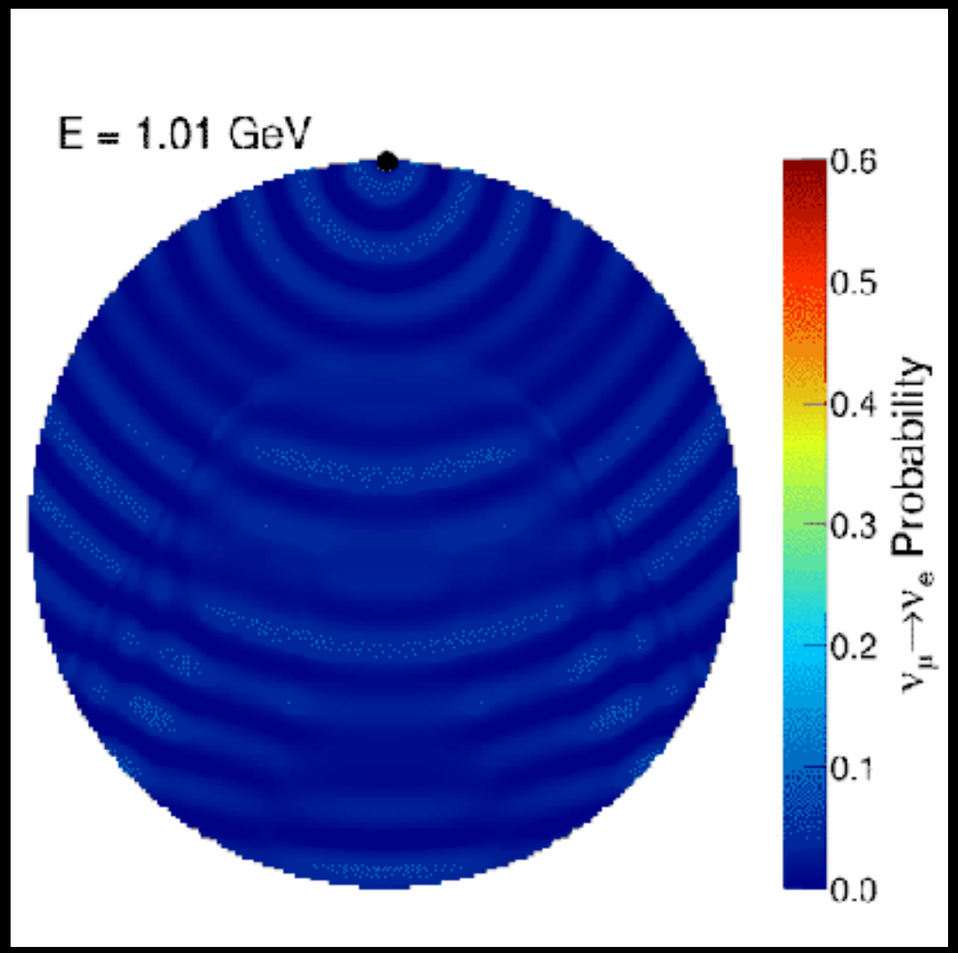


ORCA: Measuring Mass Ordering with Atmospheric Neutrinos



- Free, Natural Beam of known composition (ν_e, ν_μ).
- ν_e interaction with electrons.
- Oscillation pattern distorted by Earth's matter effects: IO ↔ NO difference.



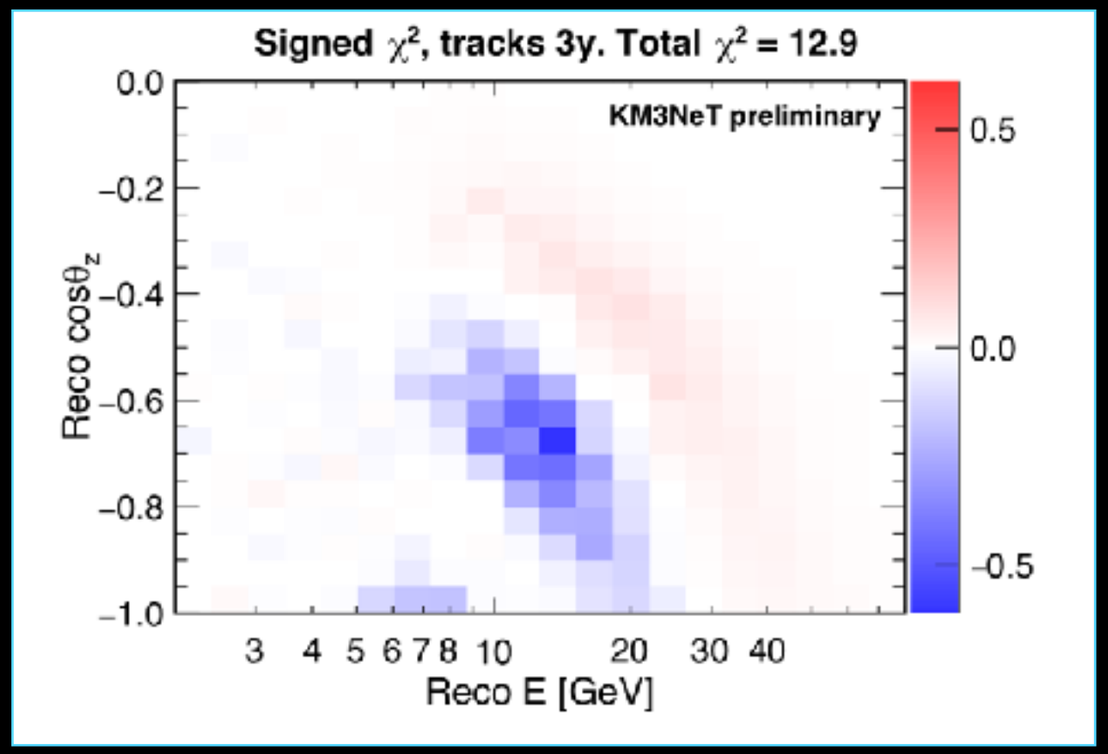


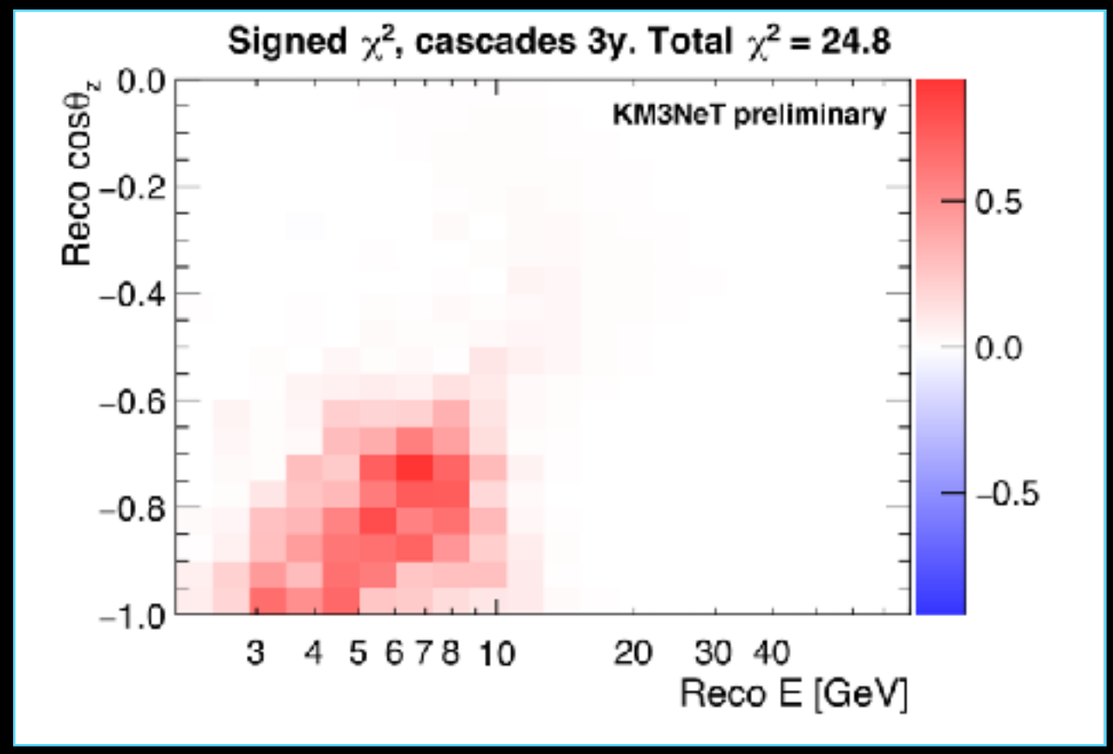
Ref: J. Coelho - http://www.apc.univ-paris7.fr/Downloads/antares/Joao/animations/

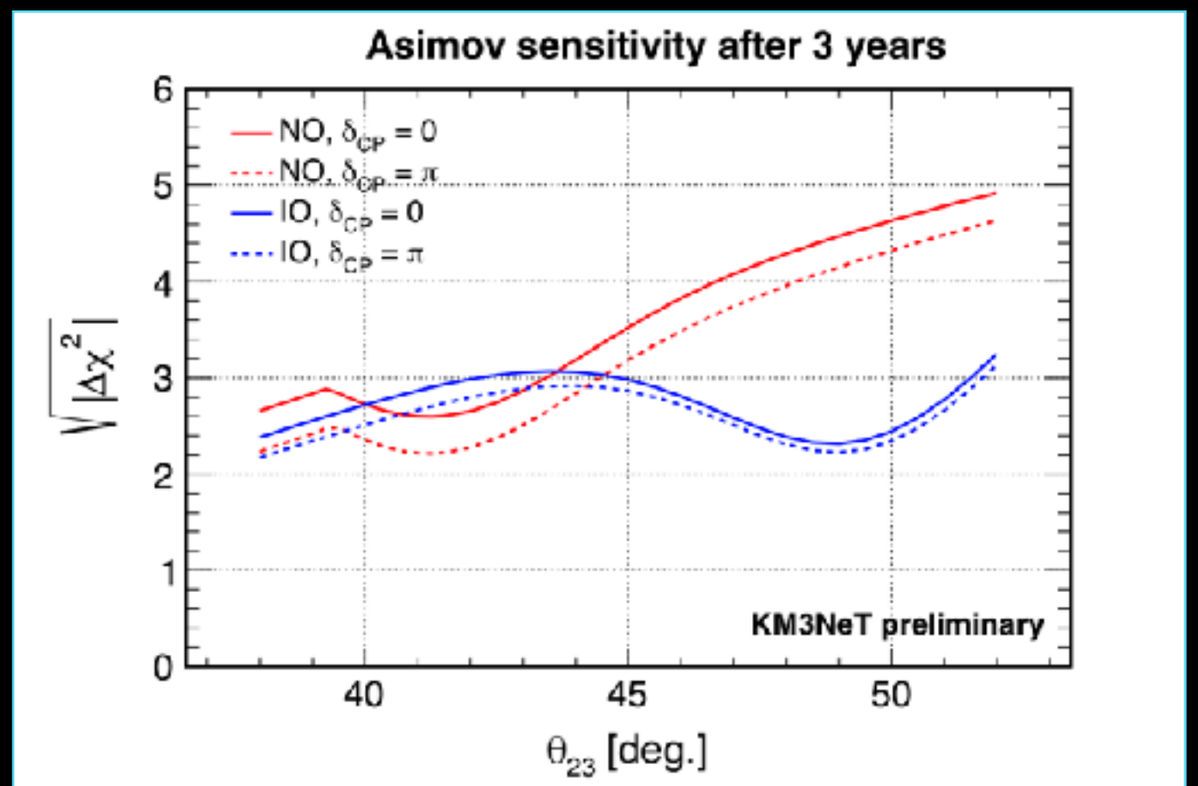
ORCA: Neutrino Mass Ordering

Approach: measure E_ν and θ_ν of upgoing neutrinos.

$\chi^2=(N_{NO}-N_{IO})*|N_{NO}-N_{IO}|/N_{NO}$

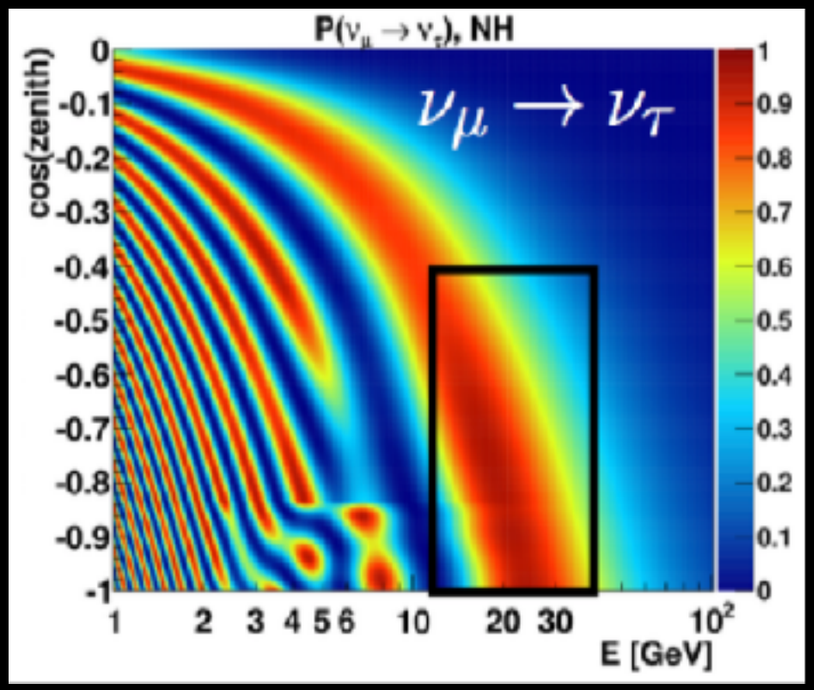




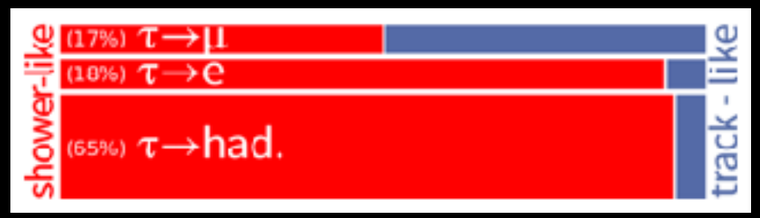


Ref: S. Bourret, L. Quinn: PoS Neutrino 2018

Tau Neutrino Appearance

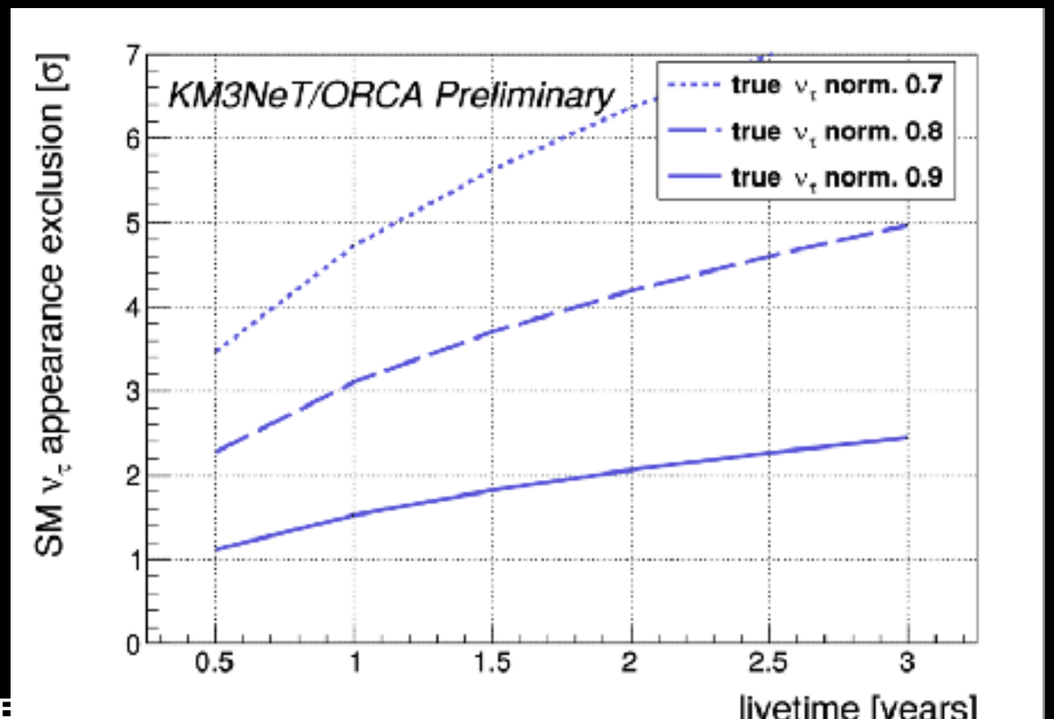


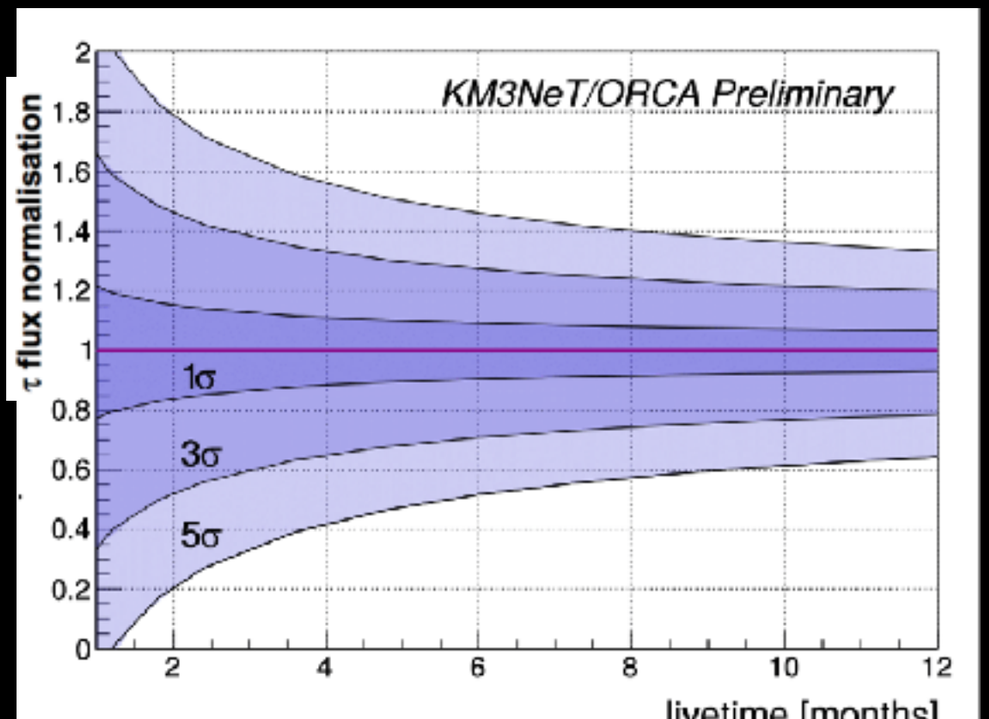
- ν_τ appearance tests unitarity of 3ν mixing matrix and BSM theories.
- 20% deviation from unitarity can be detected with 5σ in 5 years.
- ~3000 ν_τ^{CC} events/year with full ORCA.
- ν_τ events predominantly shower-like.



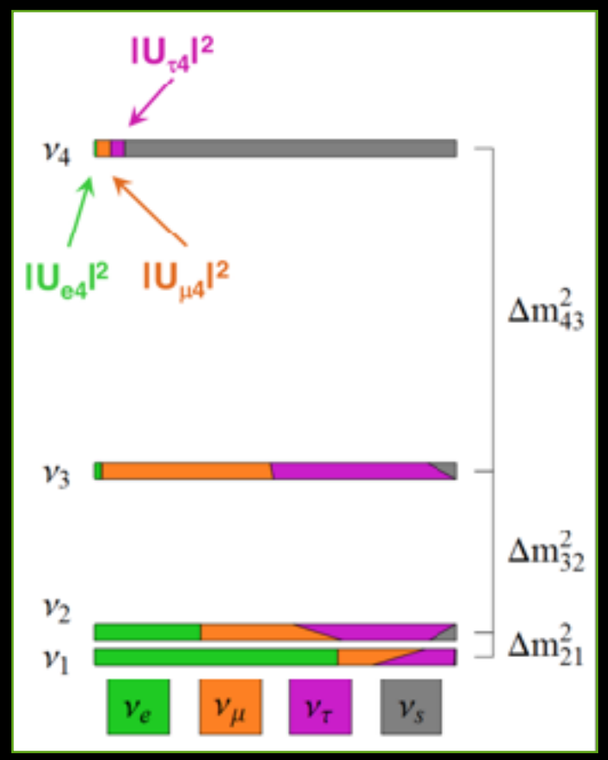
- Confirm exclusion of non-appearance (=0) already with 2 months of data

Ref: S. Hallmann PoS (ICRC 2017) 1025

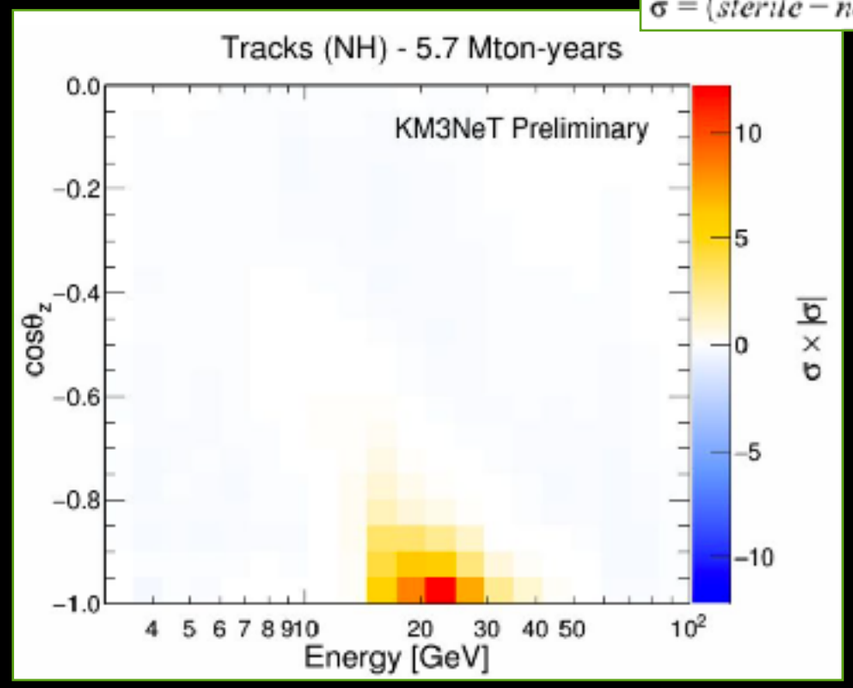


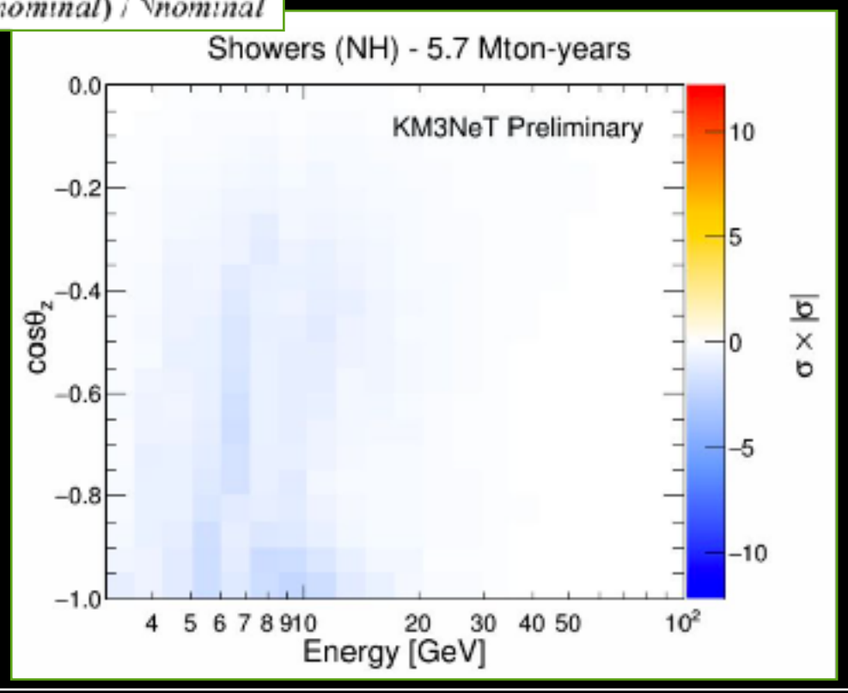


ORCA: STERILE NEUTRINOS

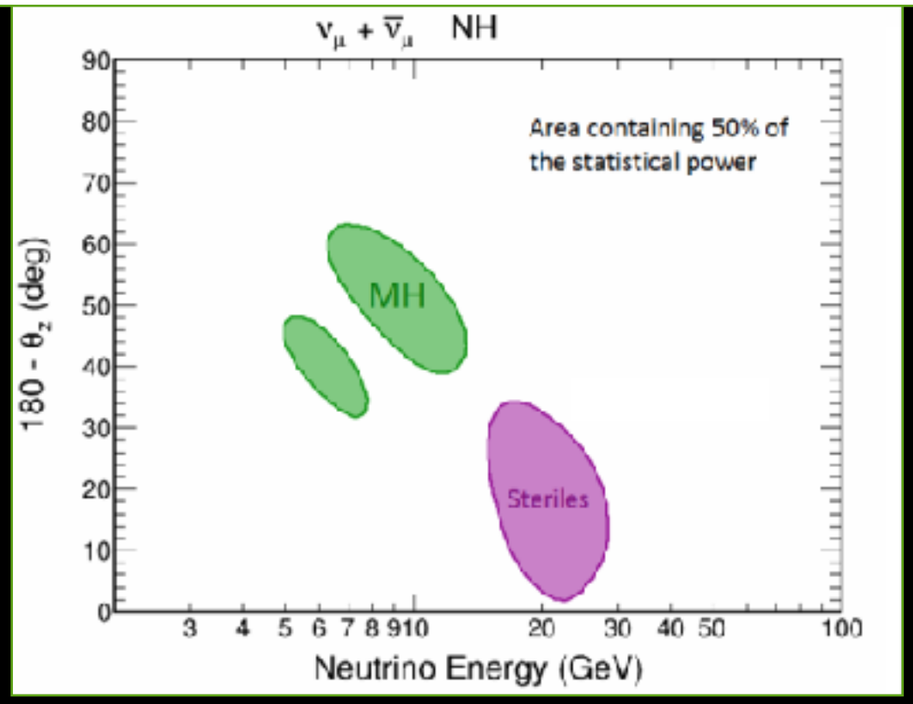


$\sigma = (sterile - nominal) / \sqrt{nominal}$

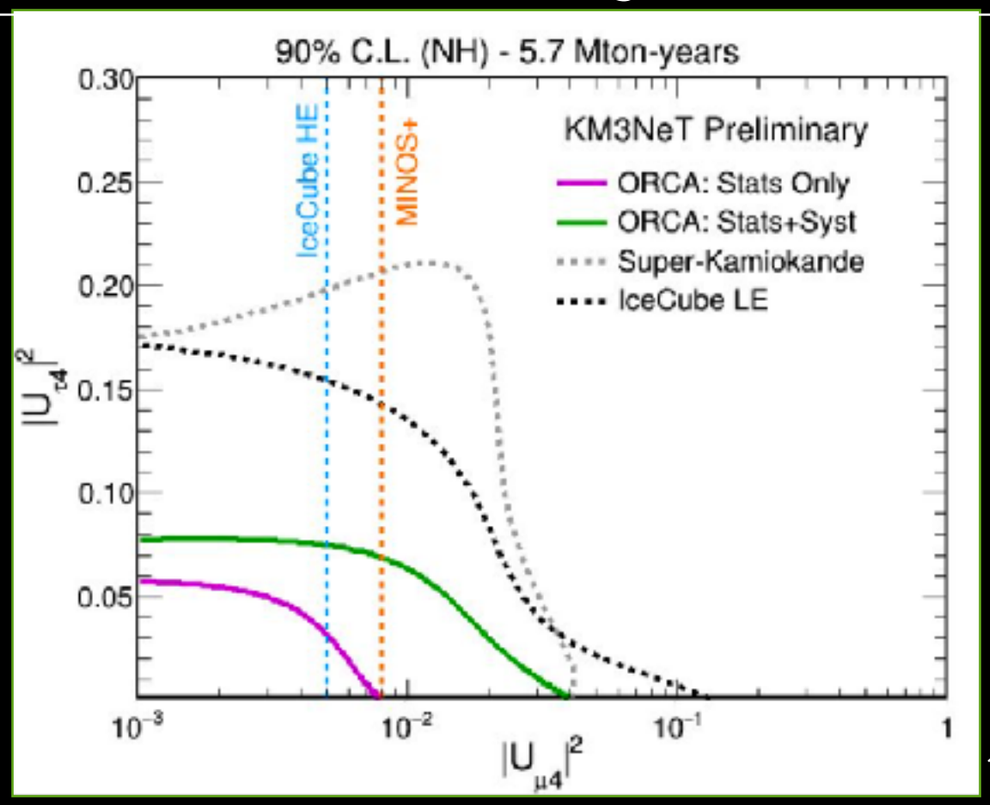




Effects on tracks for both NMH and STERILE NEUTRINO

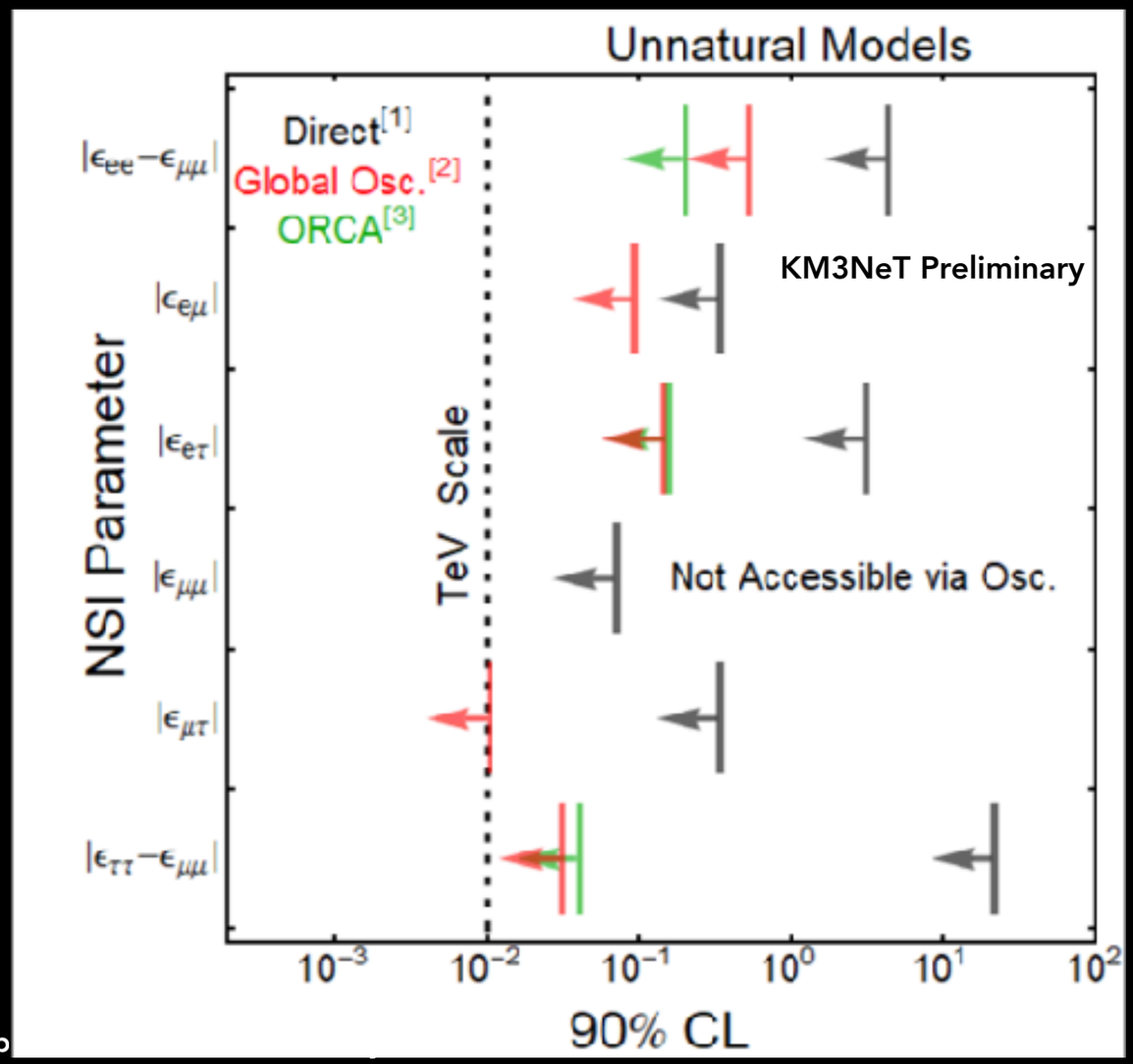


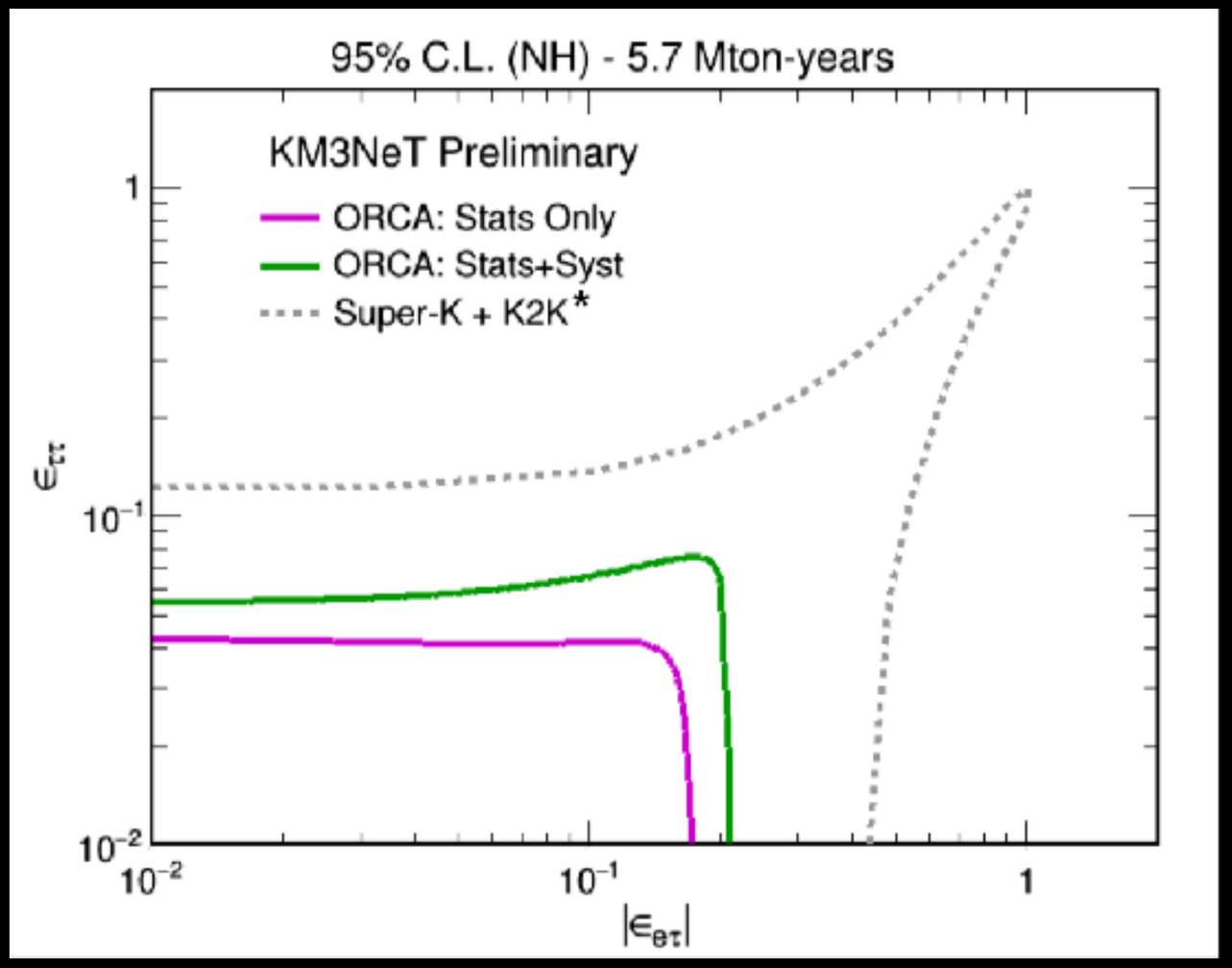
ORCA Sensitivity to 1 sterile neutrino for 1 year of data taking!



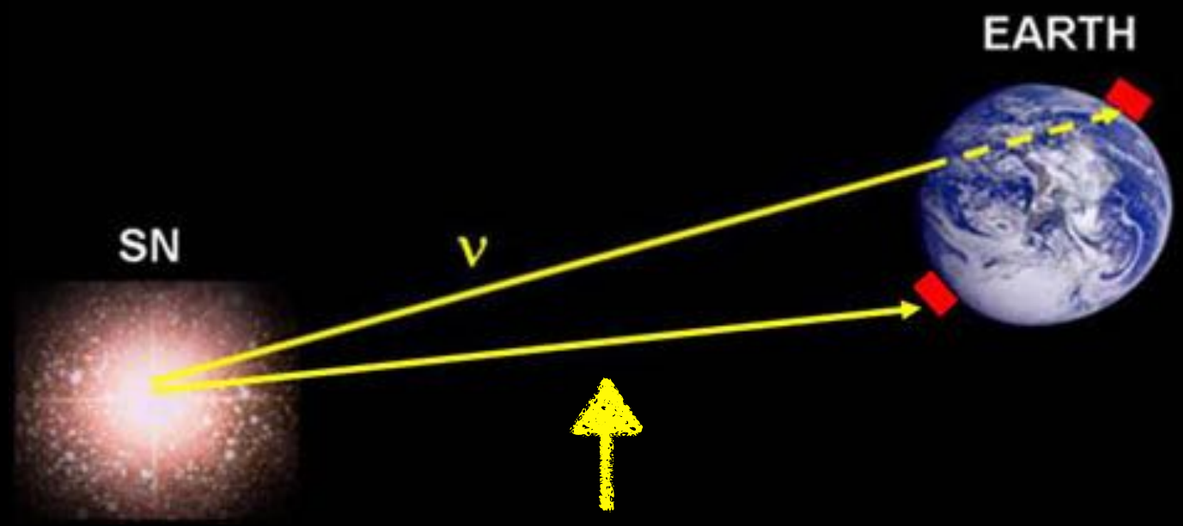
ORCA: Non Standard Interactions (NSI)

- ORCA sensitive to NSI effects of order 10% of the Fermi int.
- Direct bounds are more than 10x larger in some cases.
- ORCA improves over current atmospheric scale bounds.
- Limits competitive with global limits from oscillation.



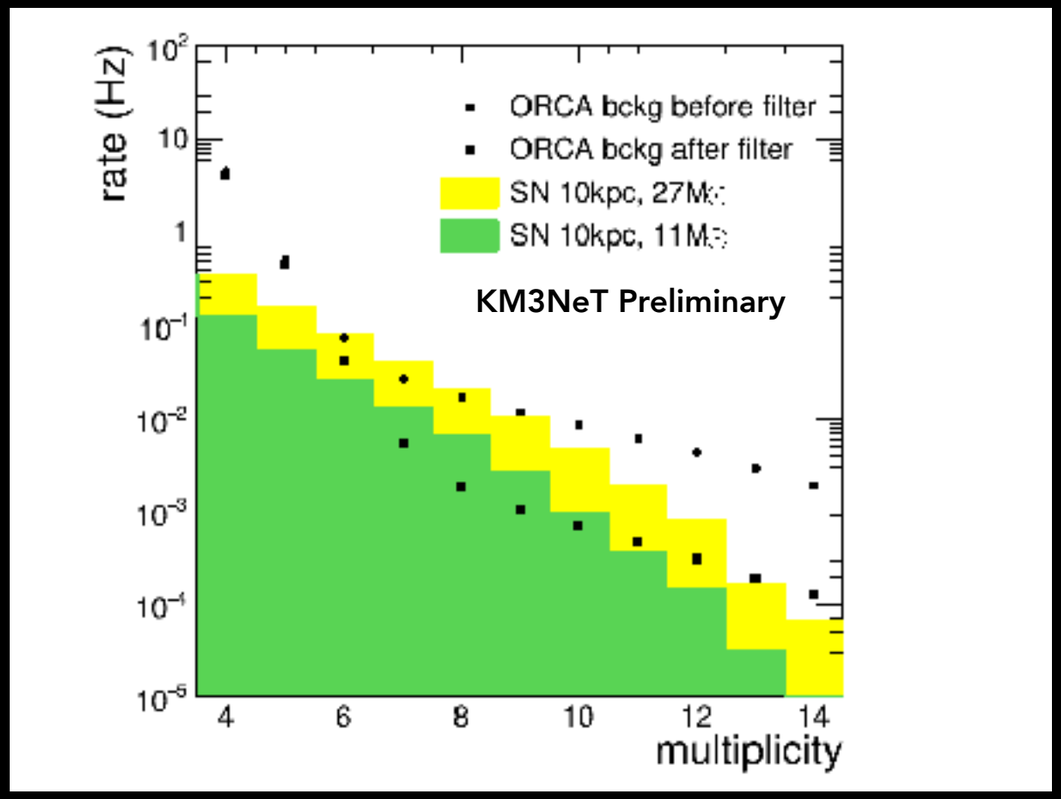


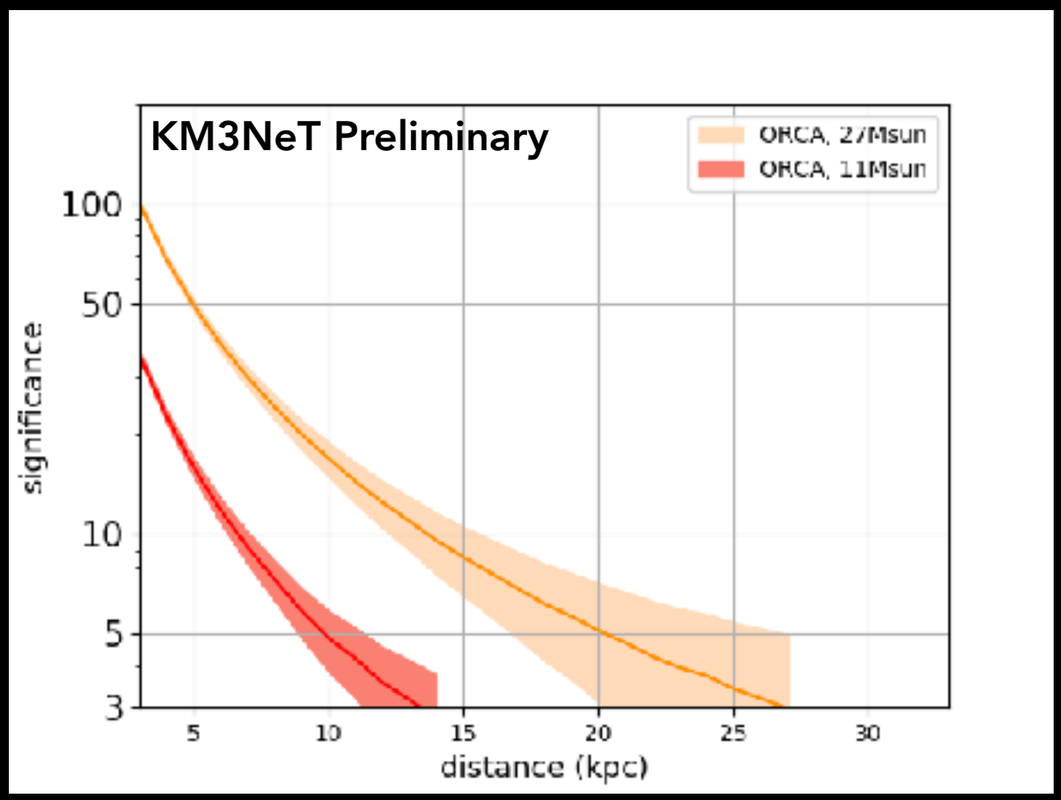
ORCA: SUPERNOVAE



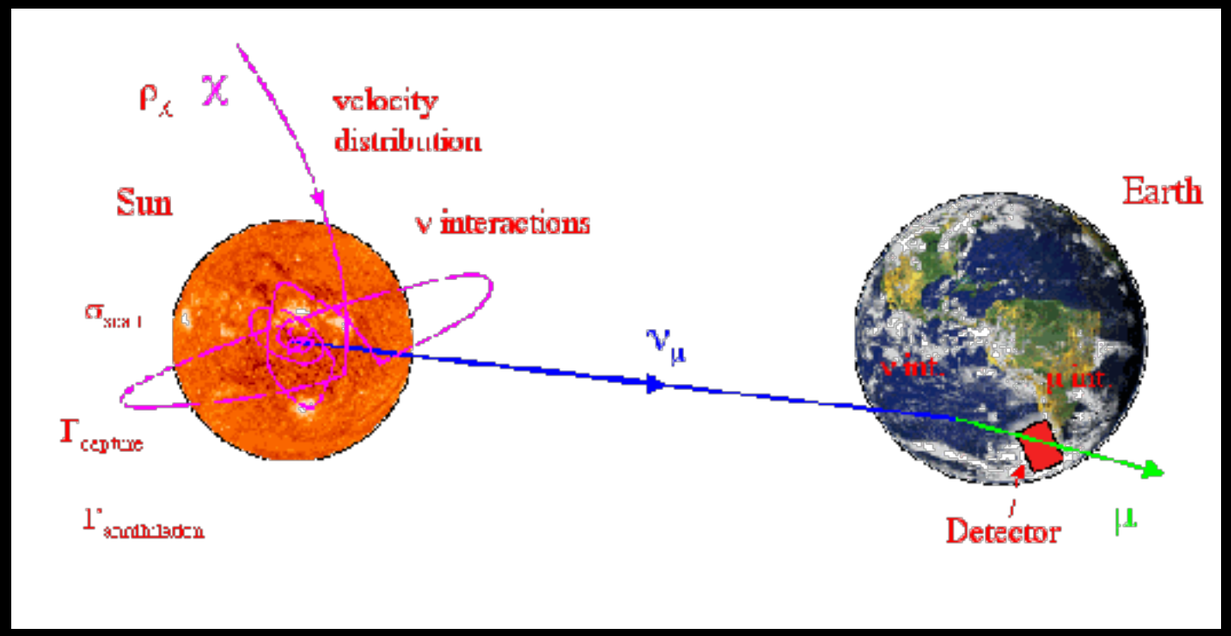
Low energy neutrinos (1-100 MeV)

- Event by event reconstruction impossible due to low energy ν.
- Really high ν flux from SN ➟ overall rise on PMTs counting rate!
- Background from K40, bioluminescence, muons ➟ cuts on PMTs multiplicities in a DOM + filter between different DOMs.



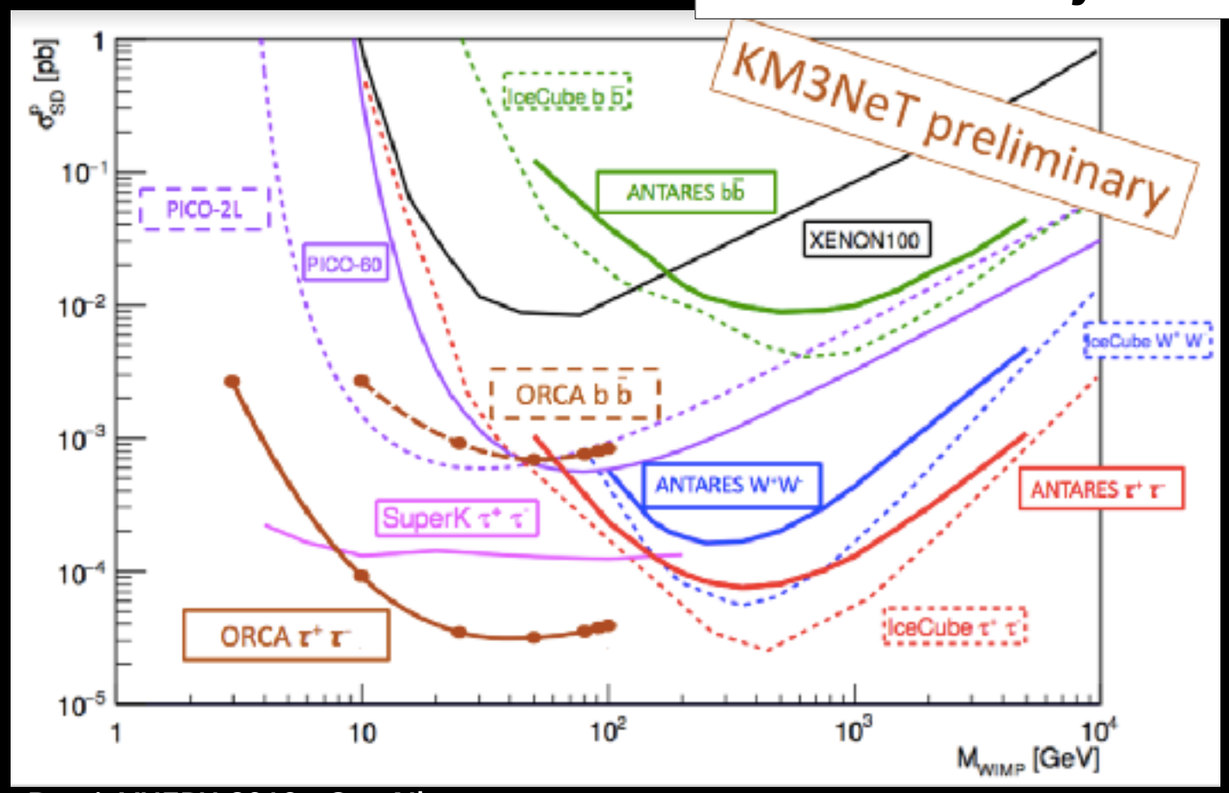


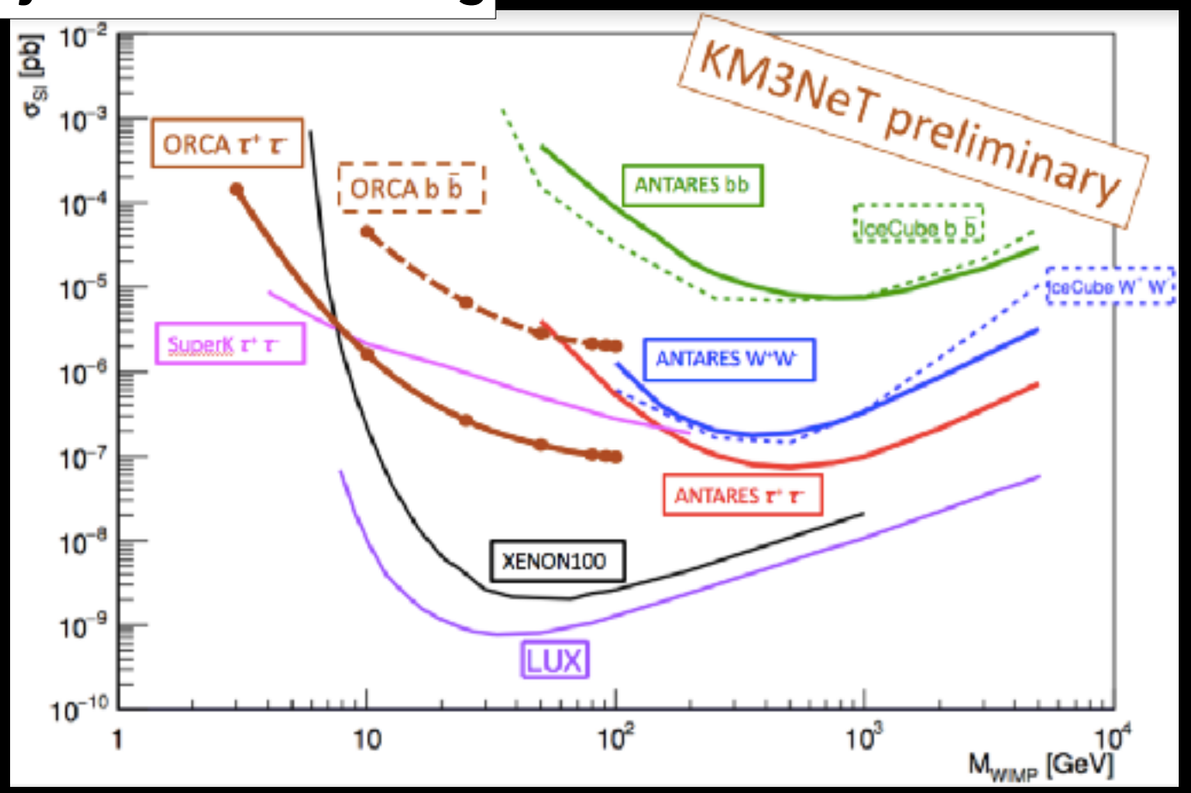
ORCA: DARK MATTER INDIRECT DETECTION



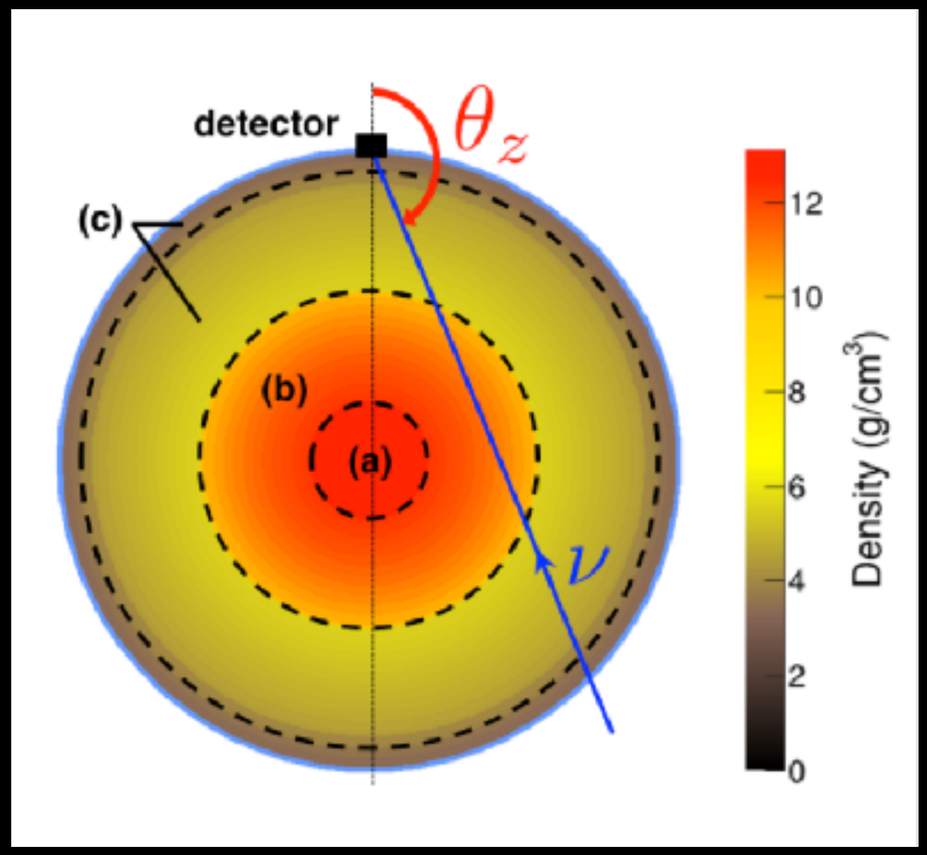
- DM annihilation in the Sun.
- ν production (E > GeV).
- Constrain DM-DM cross section.

ORCA sensitivity after 3 years of data taking



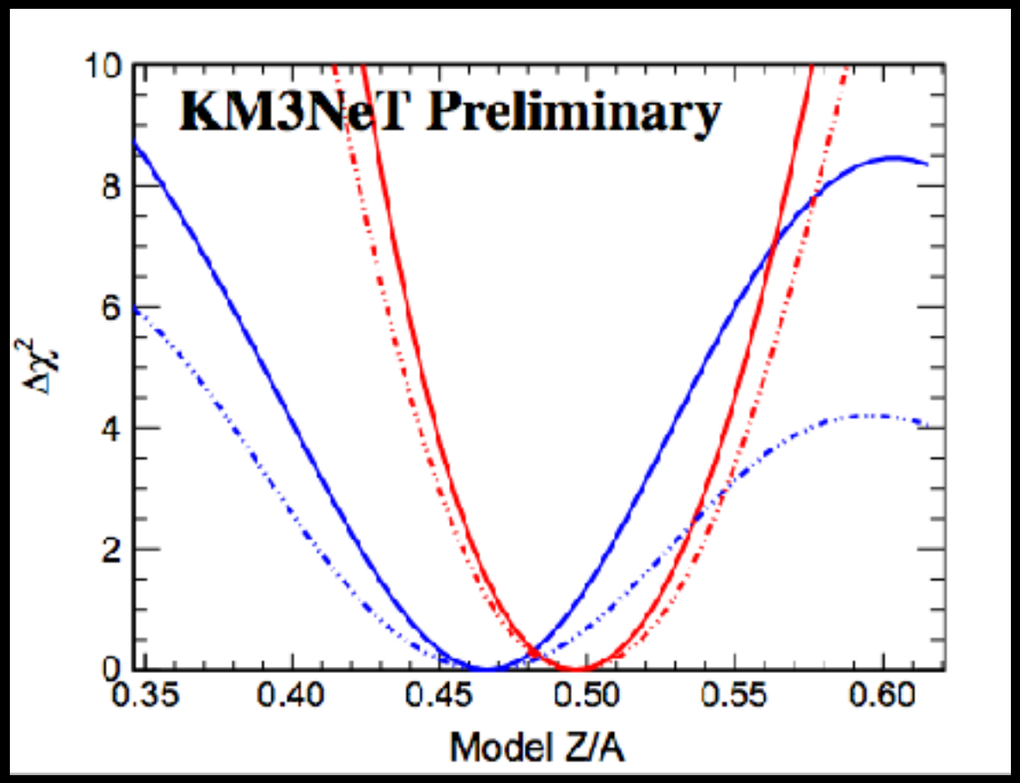


ORCA: EARTH TOMOGRAPHY



- Atmospheric ν crossing the Earth.
- E_ν and θ_ν of upgoing neutrinos also provide tomographic information complementary to the standard geophysics methods.
- ORCA: sensitive to electron density N_e while geophysics measure ρ_m

$$\frac{N_e}{\rho_m} \propto \sum_i w_i \frac{Z_i}{A_i}$$

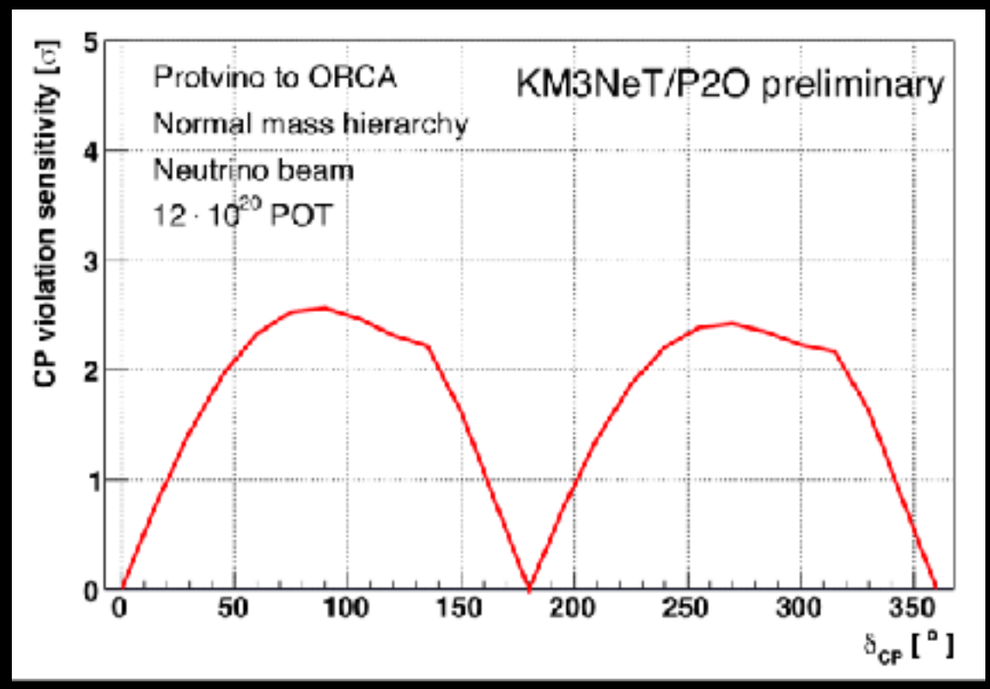


Ref:V. Van Elewyck, S. Bourret, J. Coelho
PoS(ICRC2017)1020

POSSIBLE EXTENSIONS: P2O -> Protvino2ORCA Beam

Protvino U70 proton accelerator:

- 2-7 GeV Neutrino Beam (to be constructed).
- Sensitivity to Mass Ordering at least 5σ after 1 year of beam.
- Sensitivity to measure CP phase.

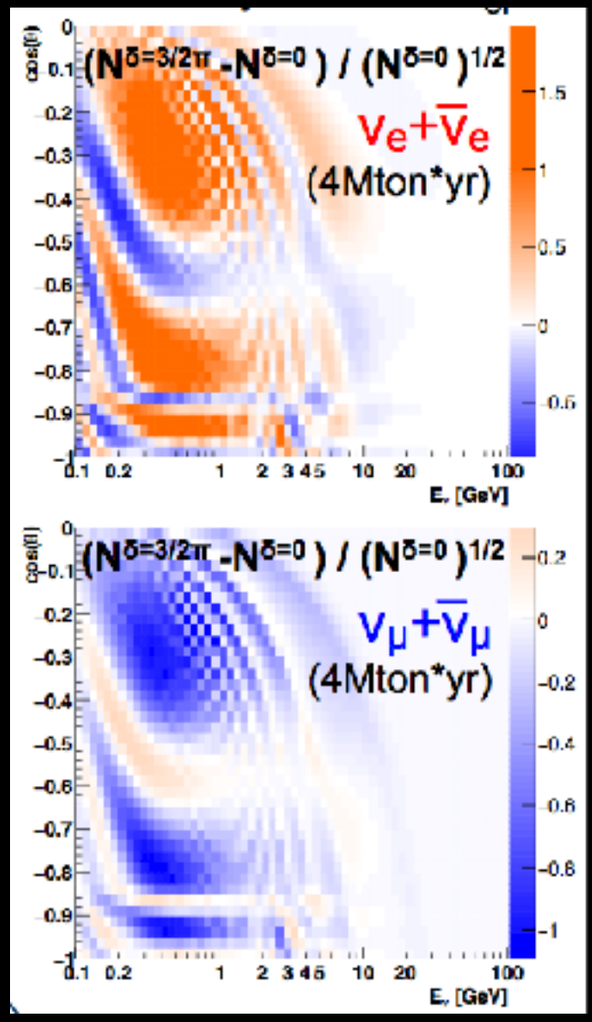


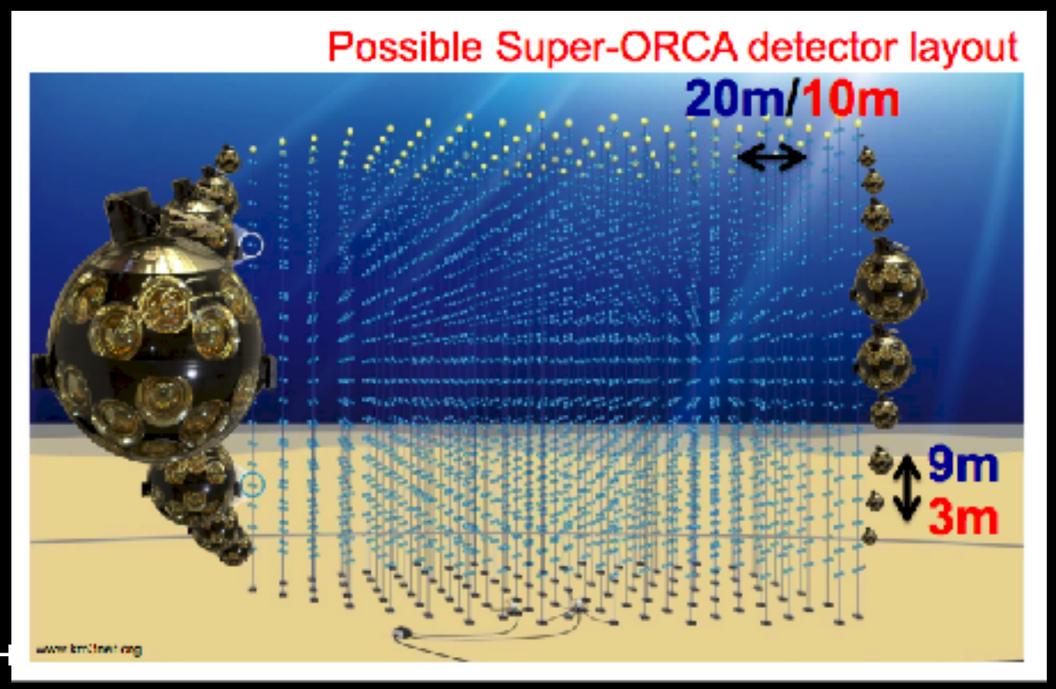
Ref: Brunner, arXiv:1304.6230

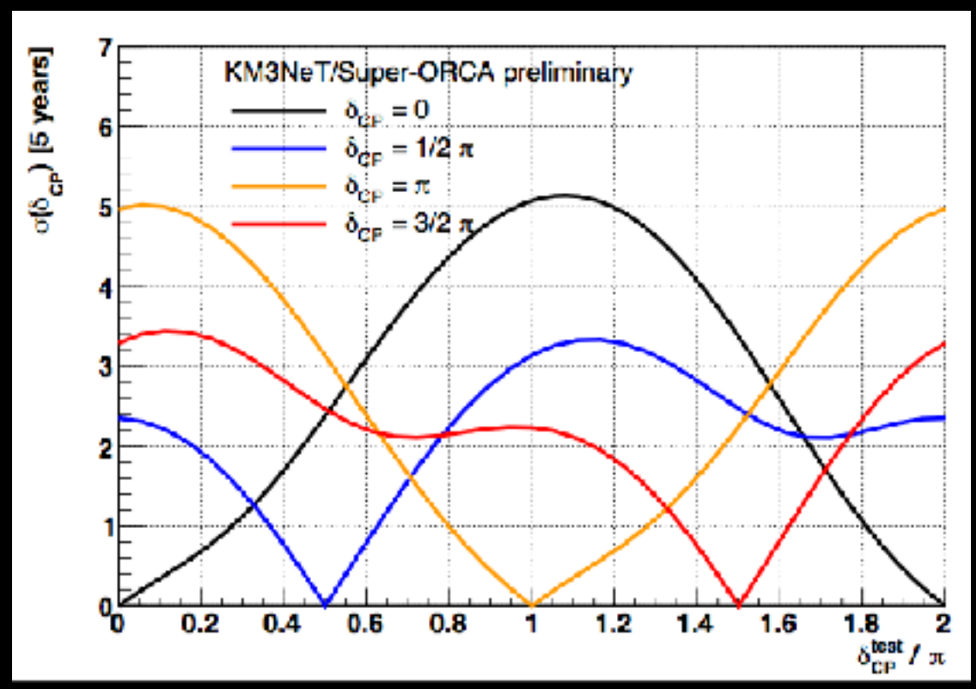
POSSIBLE EXTENSIONS: Super-ORCA

- Task: Measure δ_{CP} with atmospheric neutrinos.
  - Possible with ν energies $\lesssim$3 GeV ➟ below ORCA's energy threshold!
  - Precise flavour identification, better energy and direction resolution needed.
    - ➡ 5-10x denser detector.
    - ➡ Assumed ~115k 3" PMTs/Mton
    - ➡ ~1% density of SuperK

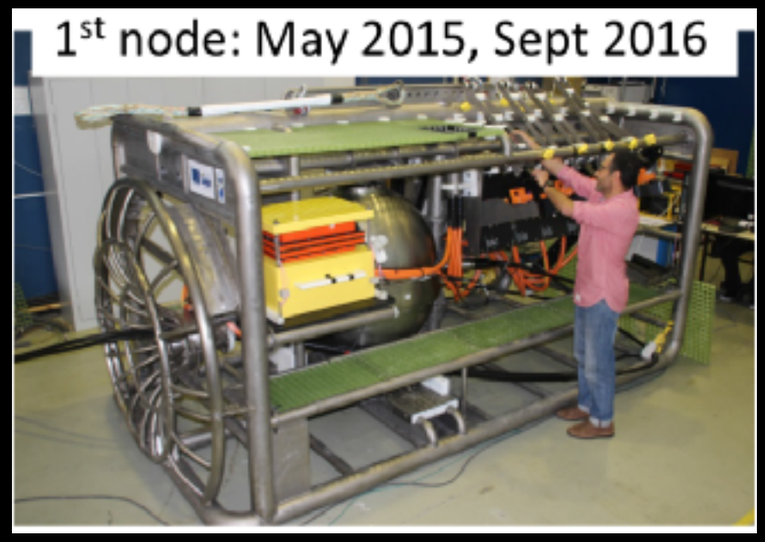
Ref: J. Hofestädt, T. Eberl, M. Bruchner, Neutrino 2018

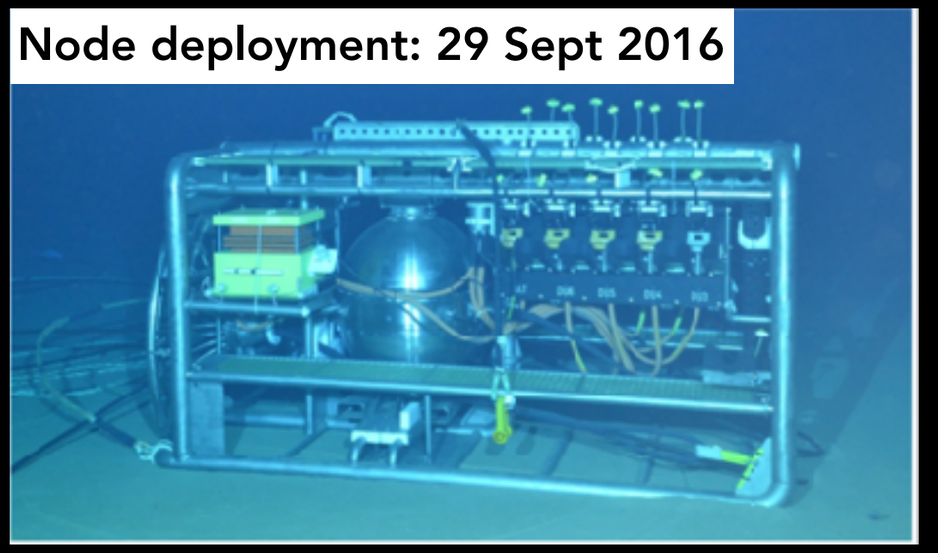






ORCA: CONSTRUCTION STATUS



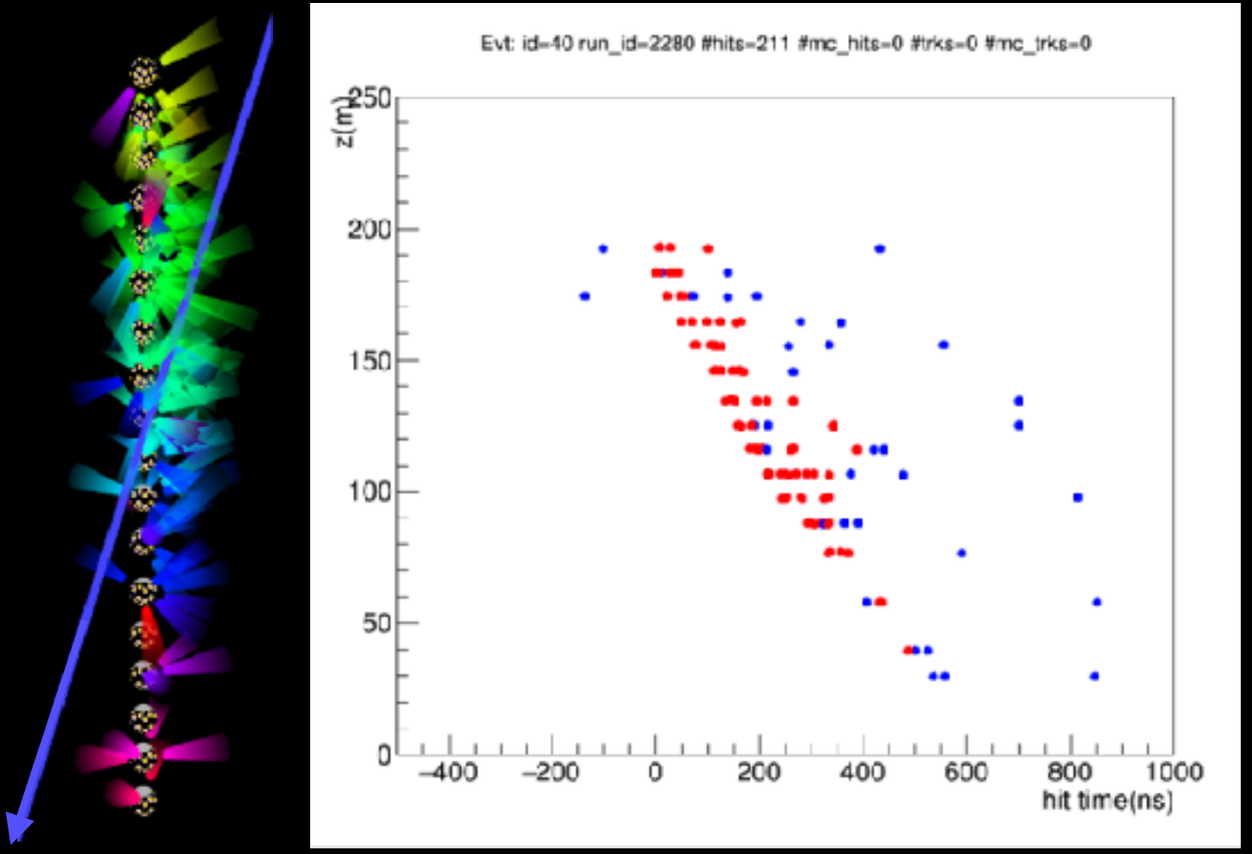


22 September 2017: First ORCA string

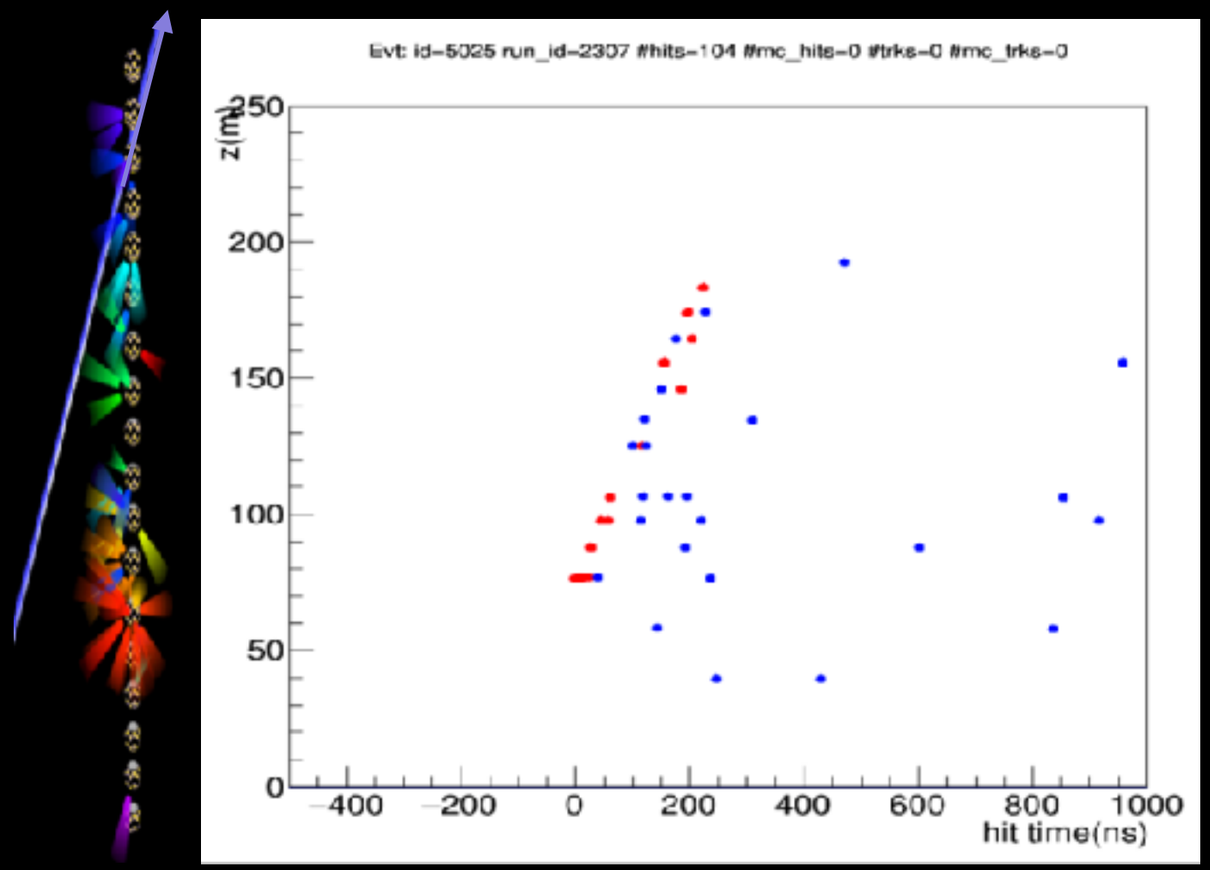
Video: https://tiny.cc/OrcaDeployment

- Data taking currently interrupted: replacement of deep sea part of main cable.
- **Phase 1 (funded):** 7 string array at KM3NeT-France site to demonstrate technology/detection methods in the GeV range ➟ deployment of 4 lines planned after summer 2018!
- **Phase 2:** Deploy 1 building block (115 strings).

ORCA: FIRST EVENTS WITH SINGLE LINE



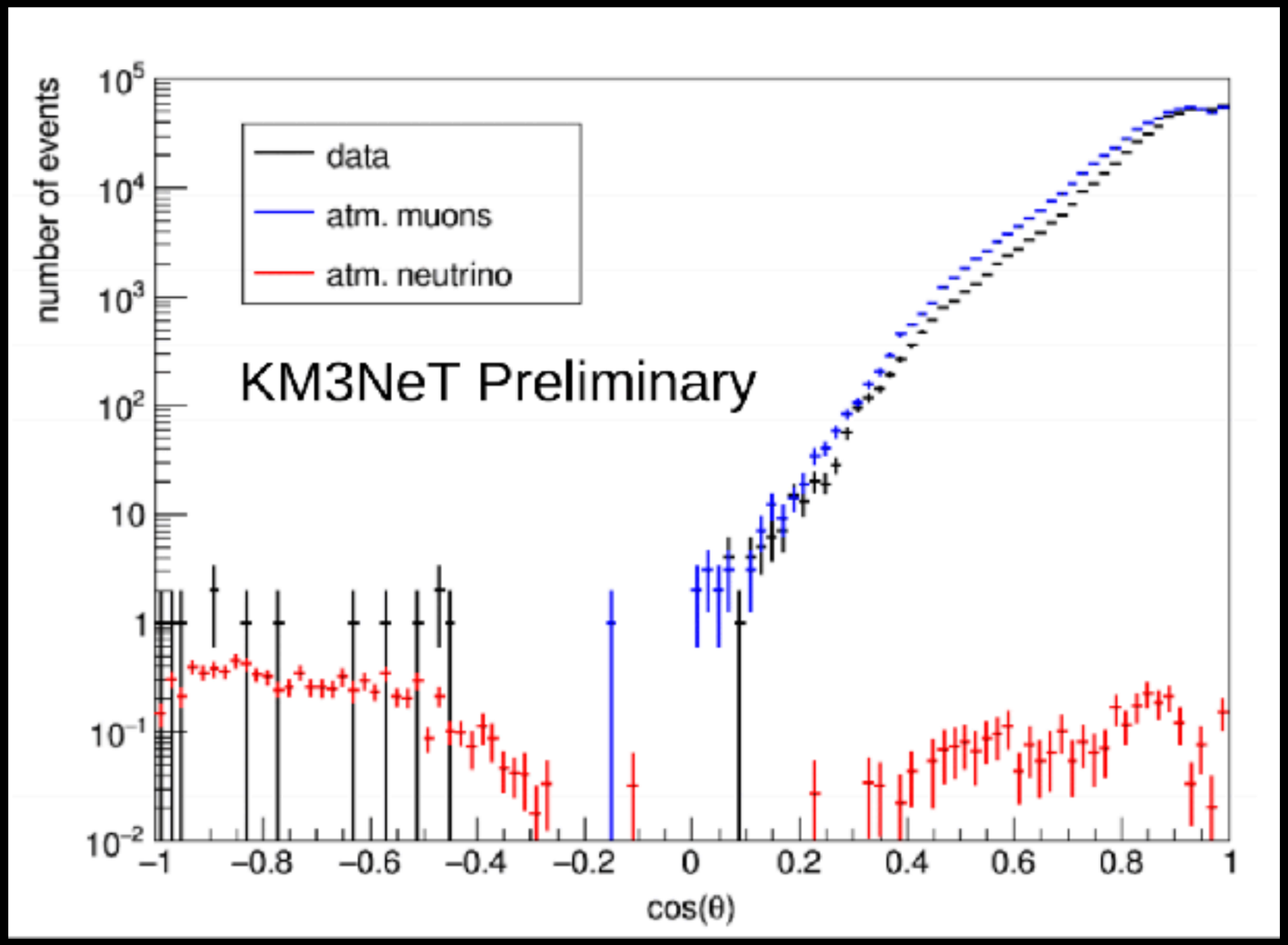
A Muon Bundle



Upward going neutrino

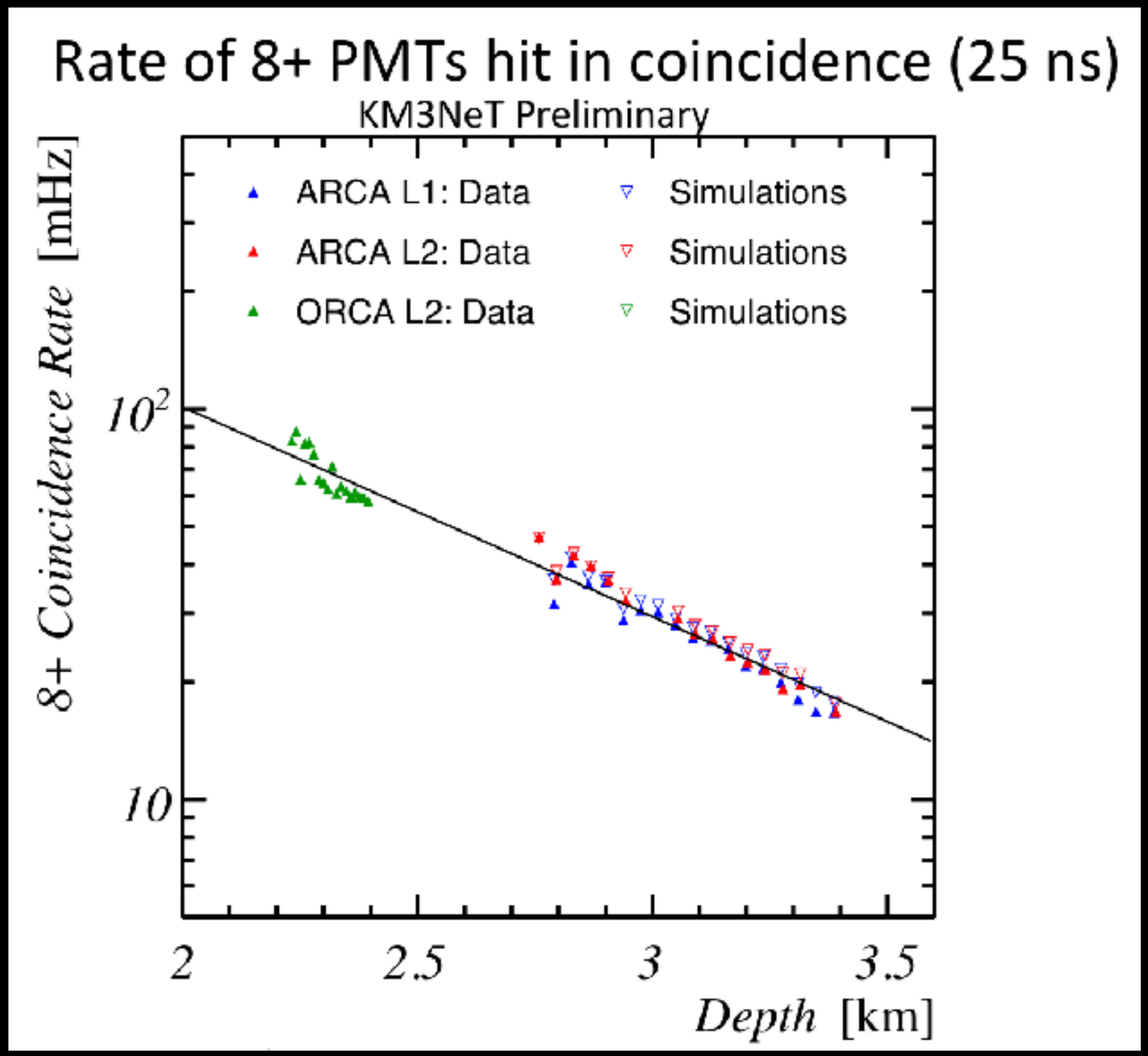
ORCA: FIRST NEUTRINO ANALYSIS

82 days of data taken with first ORCA line!



Events in cos(θ)<0	
observed:	**13**
atm. muon	**1**
atm. neutrino	**8.33**
- νμ	5.44
- νe	1.36
- ντ	0.96
- ν NC	0.57

Atmospheric Muons



- Excellent data-MC agreement.
- Fewer muons seen at larger depths.

SUMMARY

KM3NeT/ORCA intermediate energy neutrino telescope

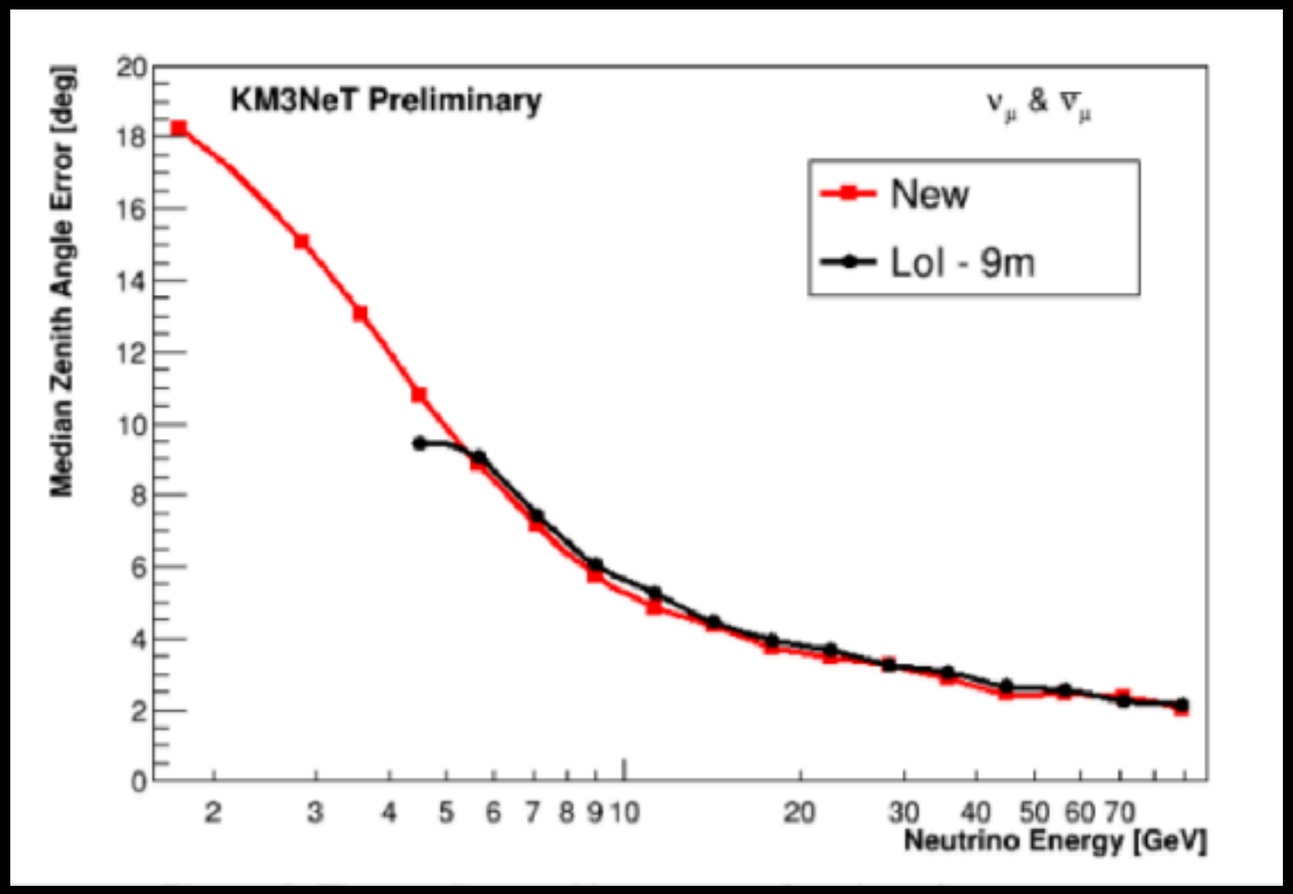
- Main purpose: NMH determination
- Big multi-search potential in other physics topics: sterile neutrinos, NSI, Dark Matter, Supernovae…
- Construction has started

Thank you!!!

Backup slides

Resolution for ORCA

ORCA Tracks reconstruction performance



ORCA Showers reconstruction performance