



XII International Conference on New Frontiers in Physics
10-23 July 2023



UNIVERSITÀ DEGLI STUDI
DI GENOVA



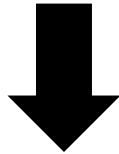
Latest results and outlook of the KM3NeT neutrino telescope

Andrey Romanov^{1,2} on behalf of the KM3NeT Collaboration

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2. INFN – Sezione di Genova

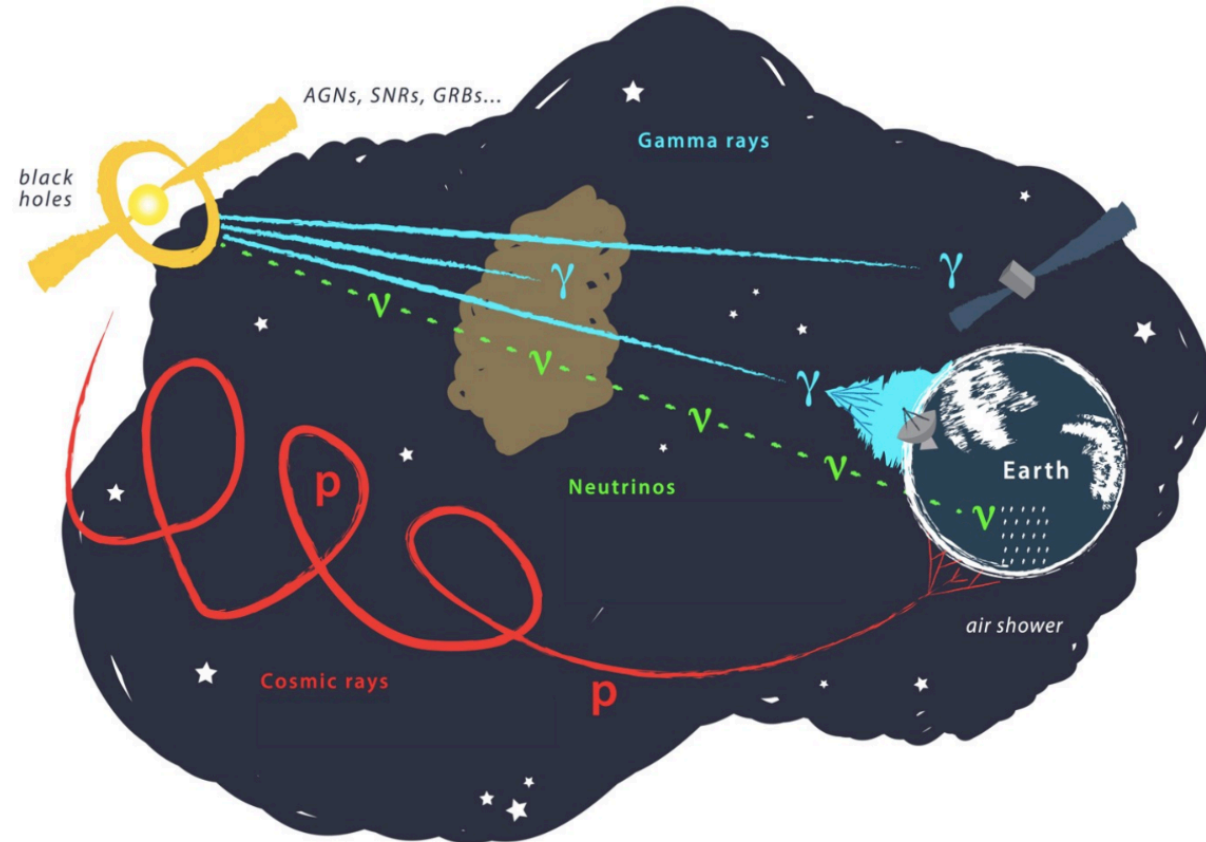
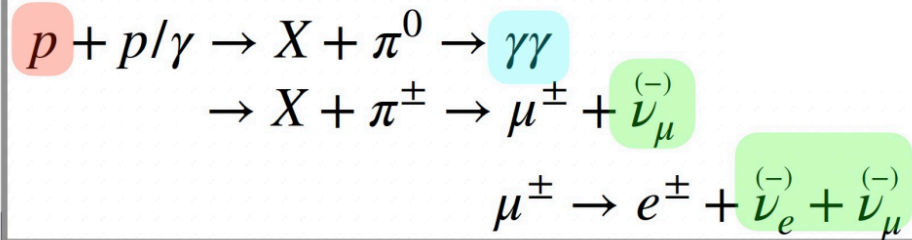
Unique neutrino properties:

- Electrically neutral, stable, and weakly interacting particles.
- **No deflection** in magnetic field (unlike cosmic rays).
- **No absorption** in background light/CMB (unlike gamma-rays).

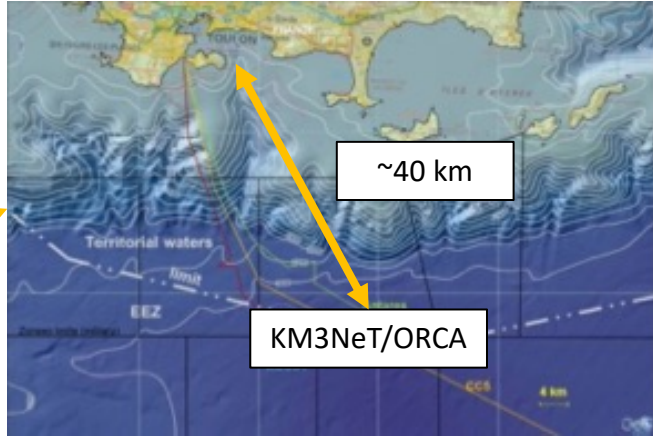
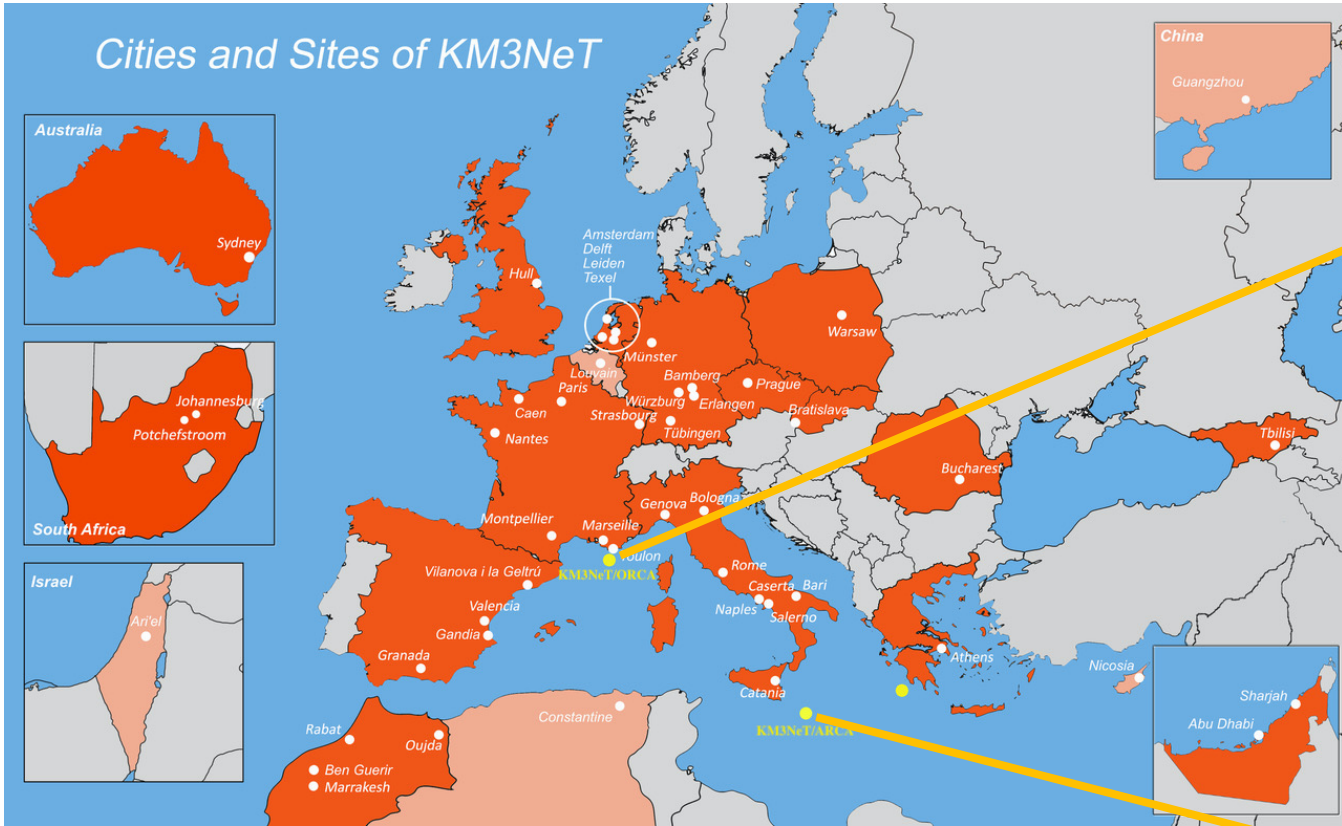


- Access to dense environments
- Access to cosmological distances
- Astronomy over full energy range

“Smoking gun” signature for hadronic processes:

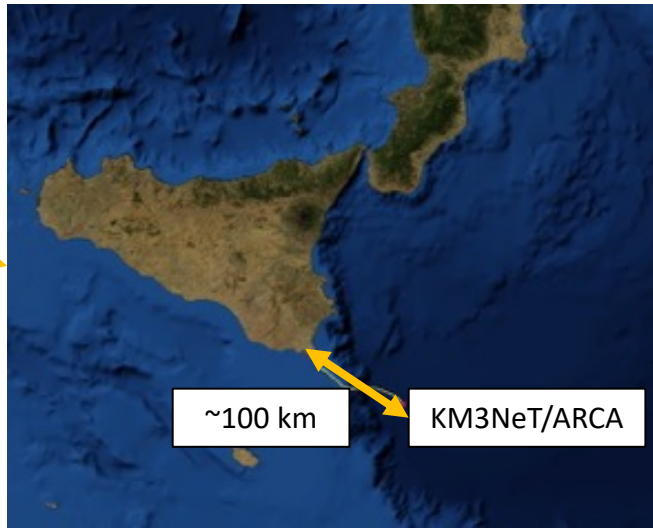


Correlation with electromagnetic and gravitational waves
= Multimessenger approach



Oscillation
Research with
Cosmics in the
Abyss

GeV– TeV neutrinos



Astroparticle
Research with
Cosmics in the
Abyss

> TeV neutrinos

- ~250 members from more than 50 institutes
- Two deep-sea neutrino telescopes
- Single Collaboration and single technology

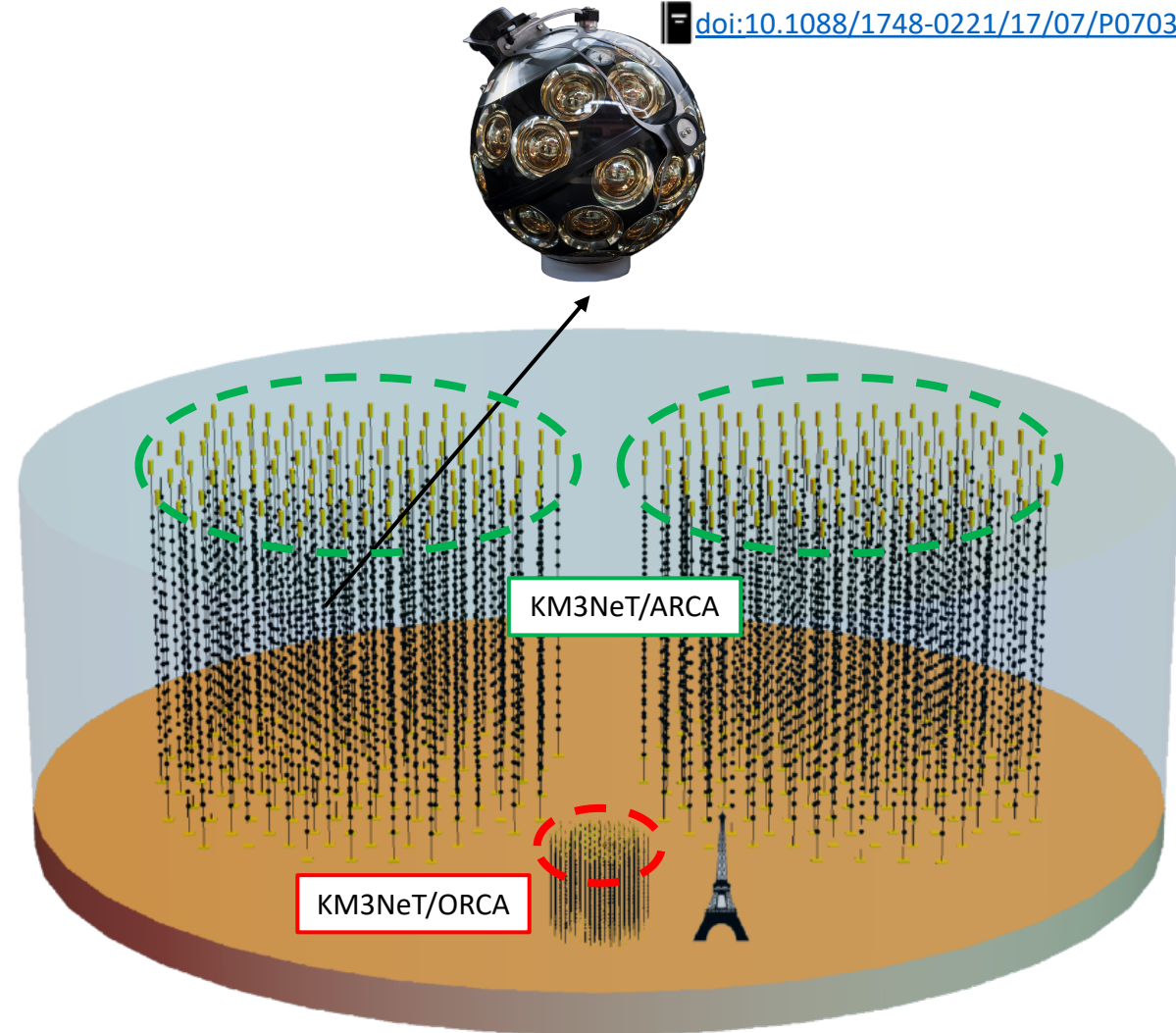
[doi:10.1088/0954-3899/43/8/084001](https://doi.org/10.1088/0954-3899/43/8/084001)

	KM3NeT/ARCA	KM3NeT/ORCA
#PMTs/DOM	31	31
#DOMs/DU	18	18
DOM vertical spacing	36 m	9 m
DU horizontal spacing	80 m	20 m
#DUs	115x2	115
Depth	3450 m	2450 m
Instrumented volume	~1 Gton	~7 Mton
Deployed DUs	21	18

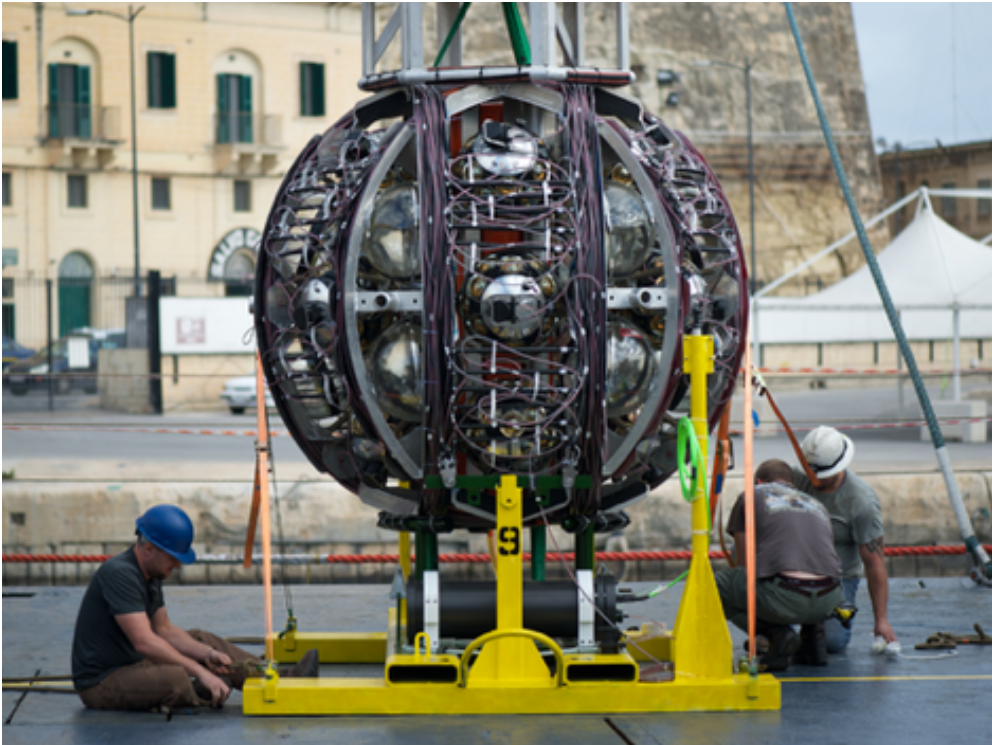
The data taking is already ongoing!

Digital Optical Module (DOM):
multi-PMT (31x3'') pressure-resistant sphere

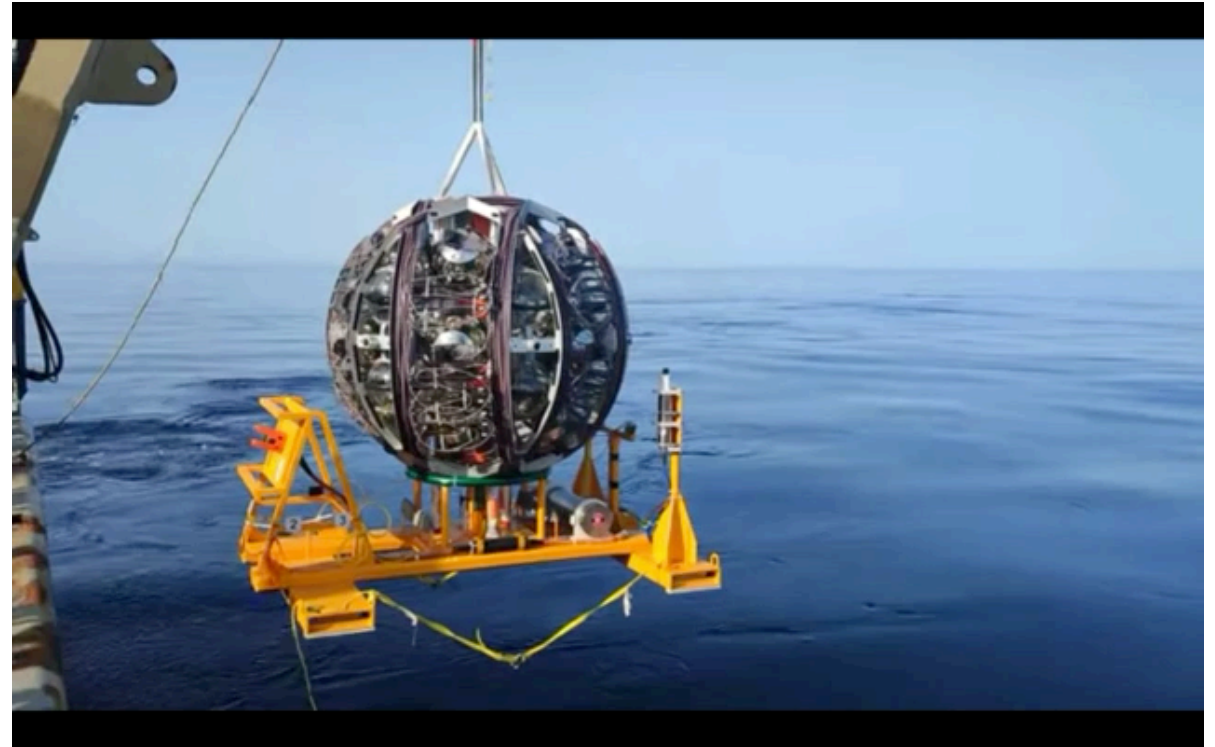
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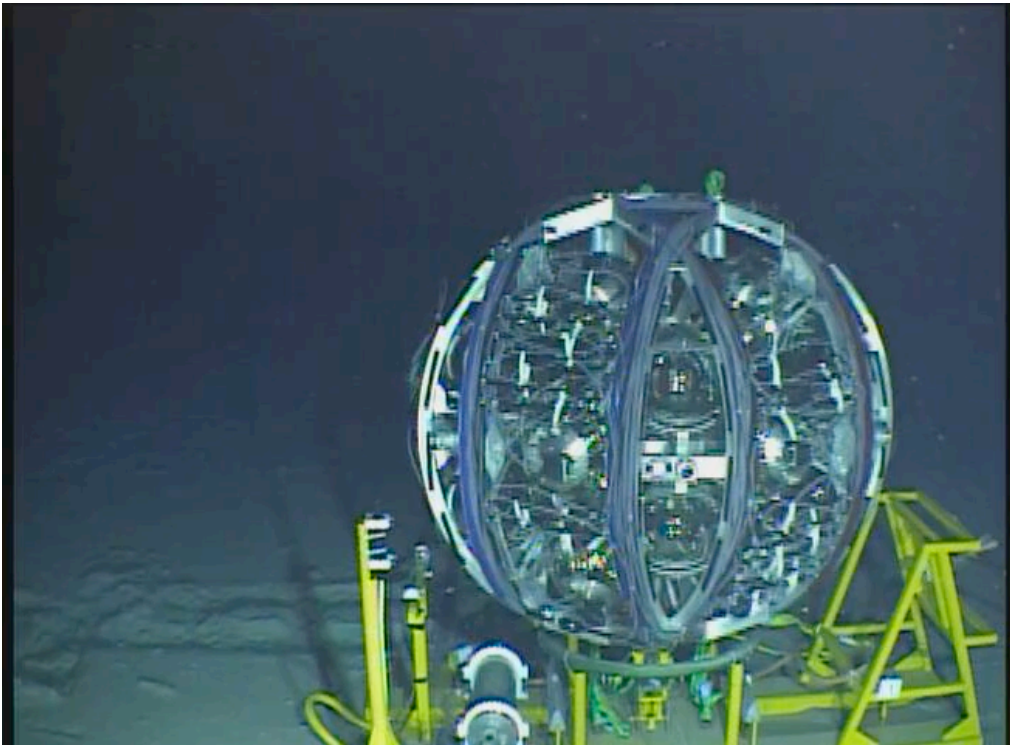
Reusable launcher modules
Multiple DUs per sea campaign



Deployment via ship crane
Sink to the sea floor using an anchor



Autonomous/ROV unfurling



Visual inspection of DOMs with ROV

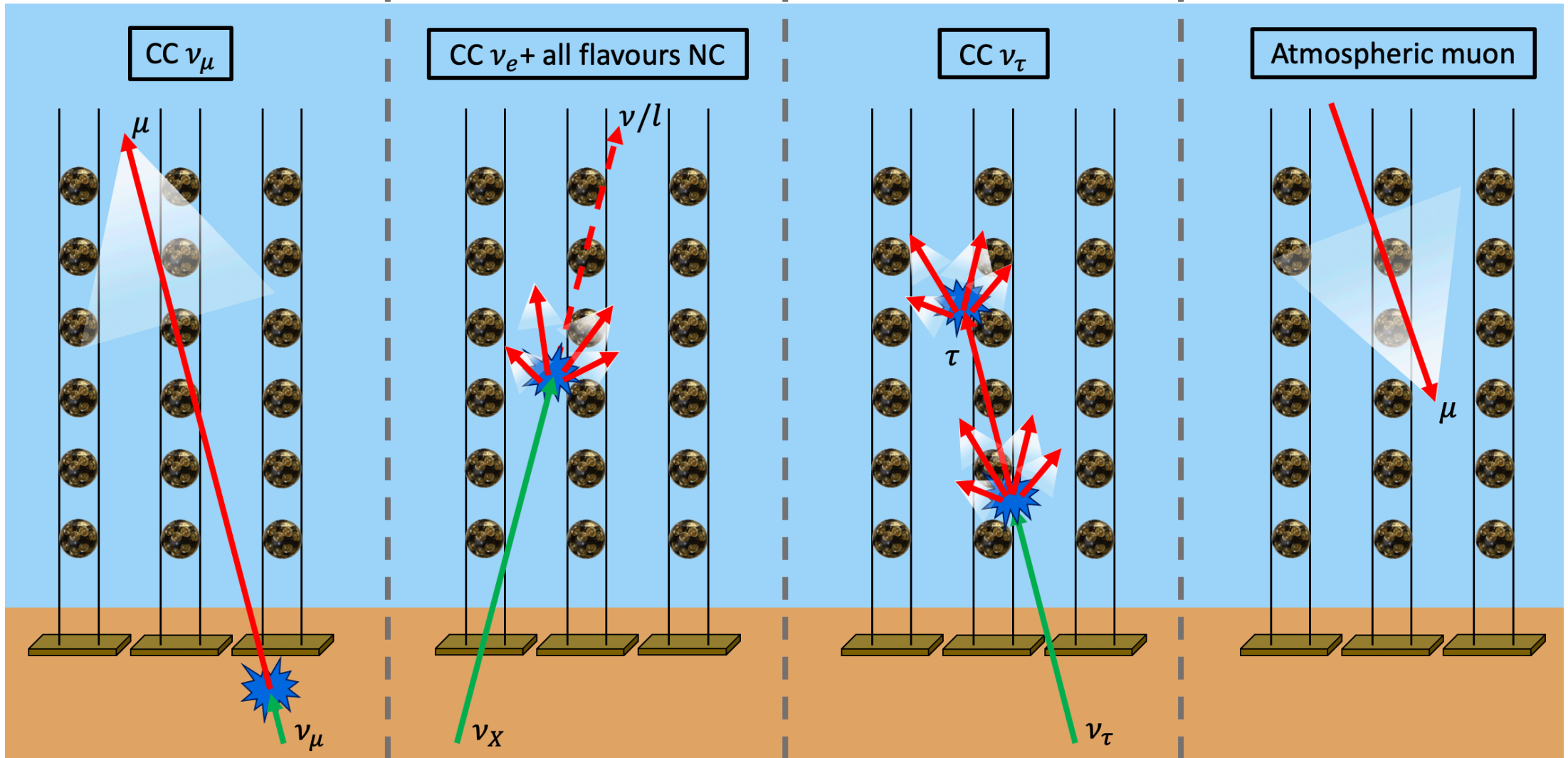


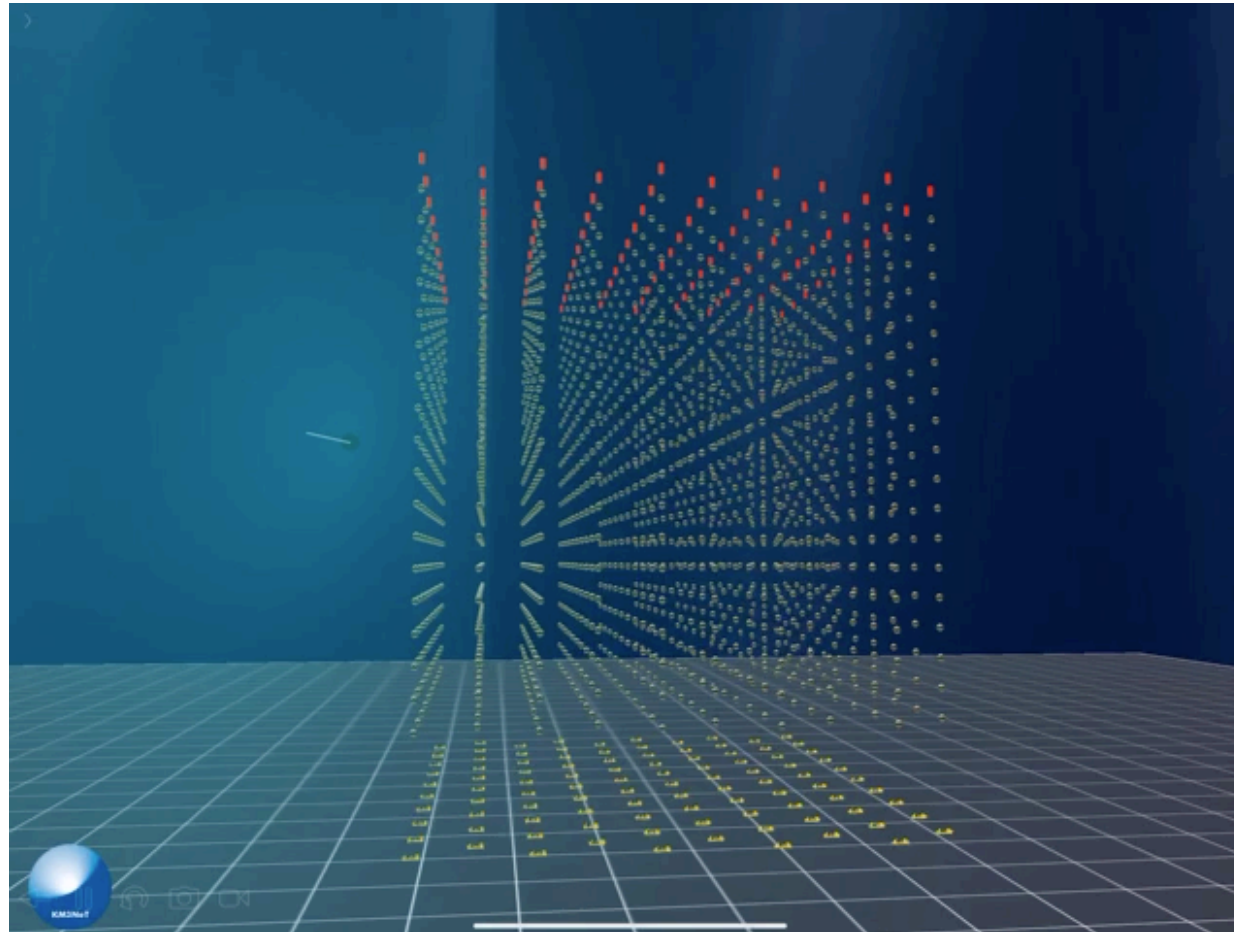
1. Track-like events
Good angular resolution

2. Shower-like events
Good energy resolution

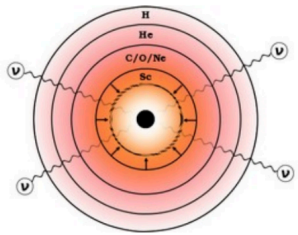
3. "Double bang" events

4. Atmospheric muons
Background for neutrino studies
Signal for CR studies

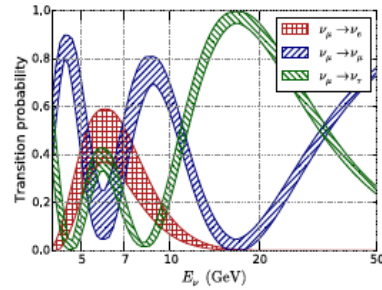




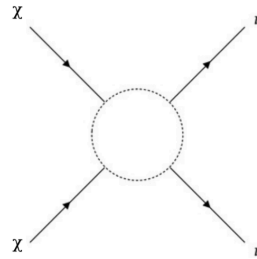
Supernovae
Solar flares



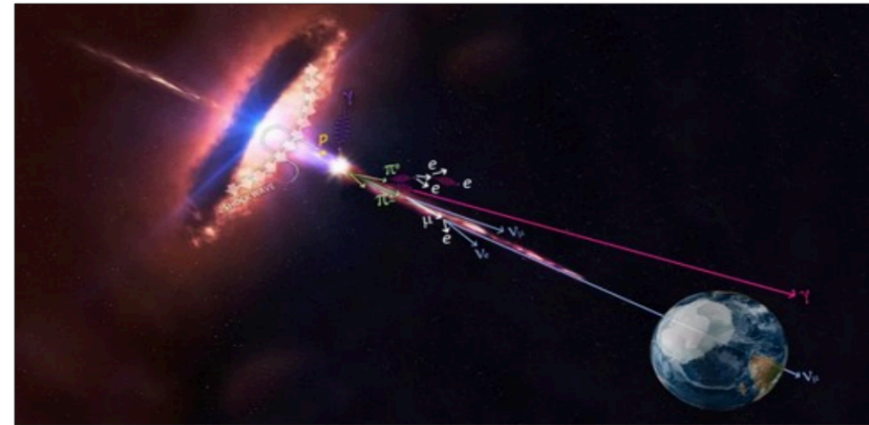
Atmospheric neutrinos
Neutrino oscillations
Mass hierarchy



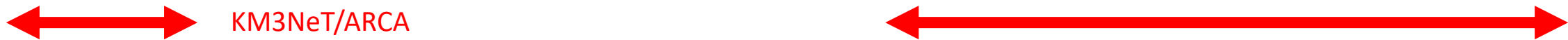
Dark matter
Monopoles, Nuclearites



Cosmic neutrinos
Multi-messenger observations

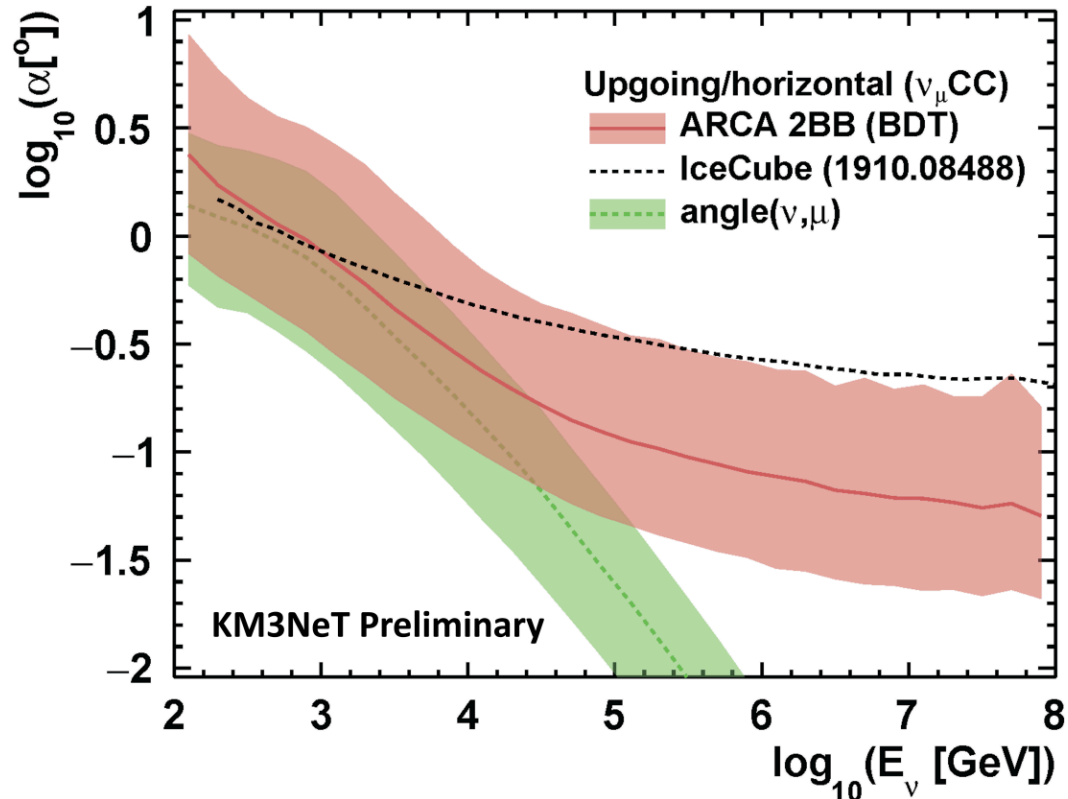


KM3NeT/ORCA



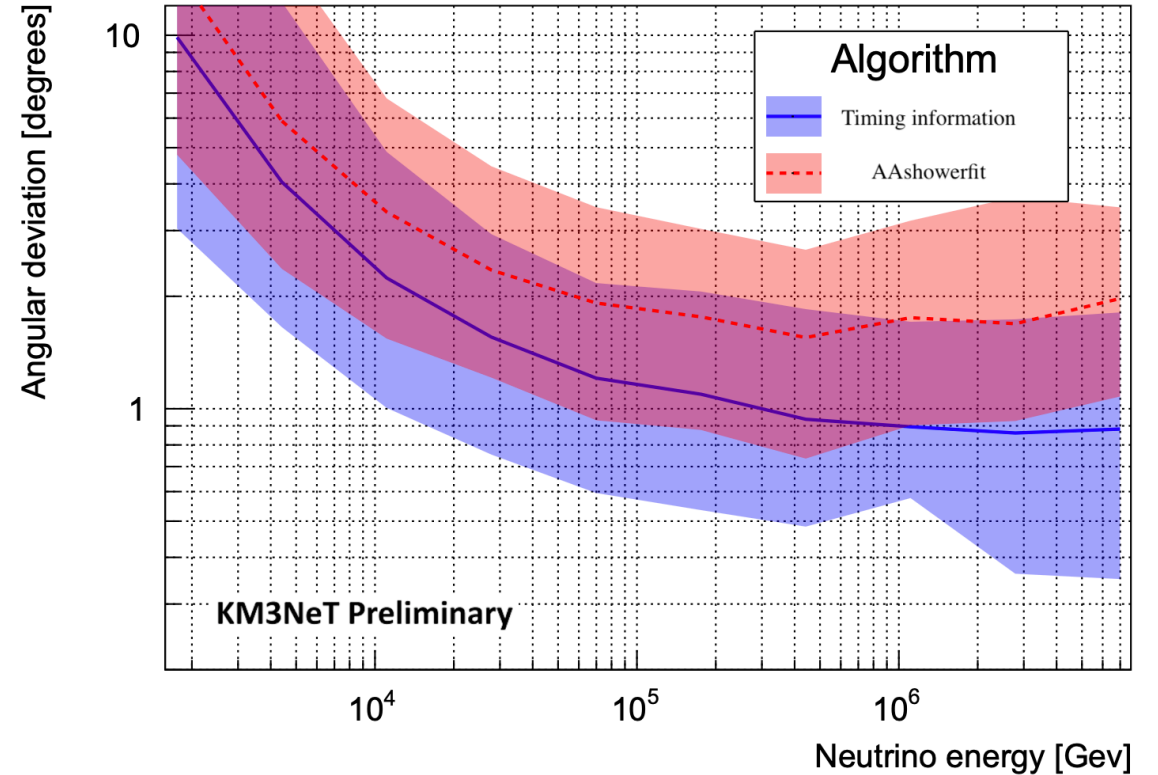
KM3NeT/ARCA

Track-like events



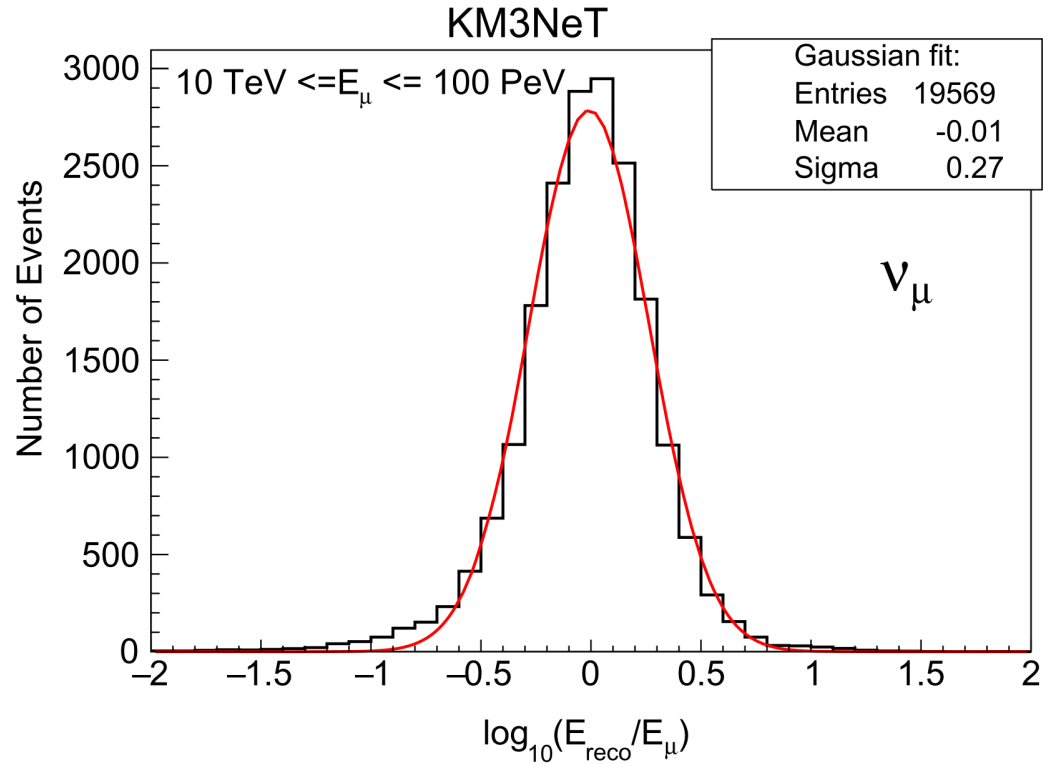
Better than 0.1° for $E > 100$ TeV

Shower-like events



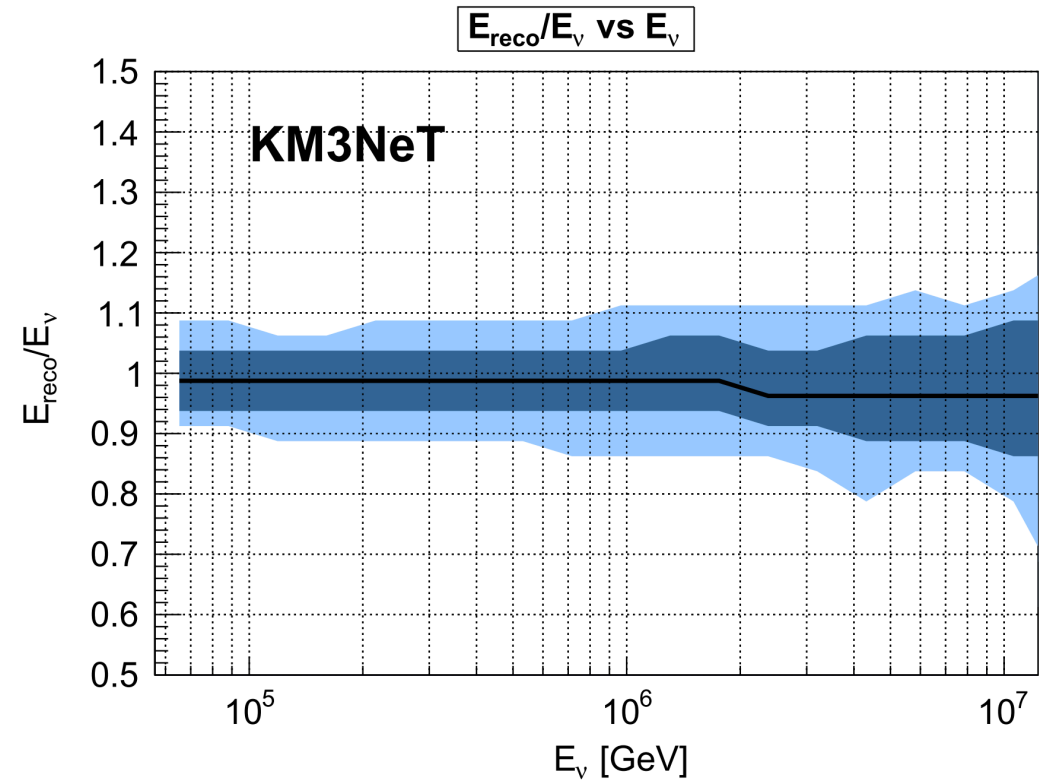
Better than 1° for $E > 30$ TeV

Track-like events



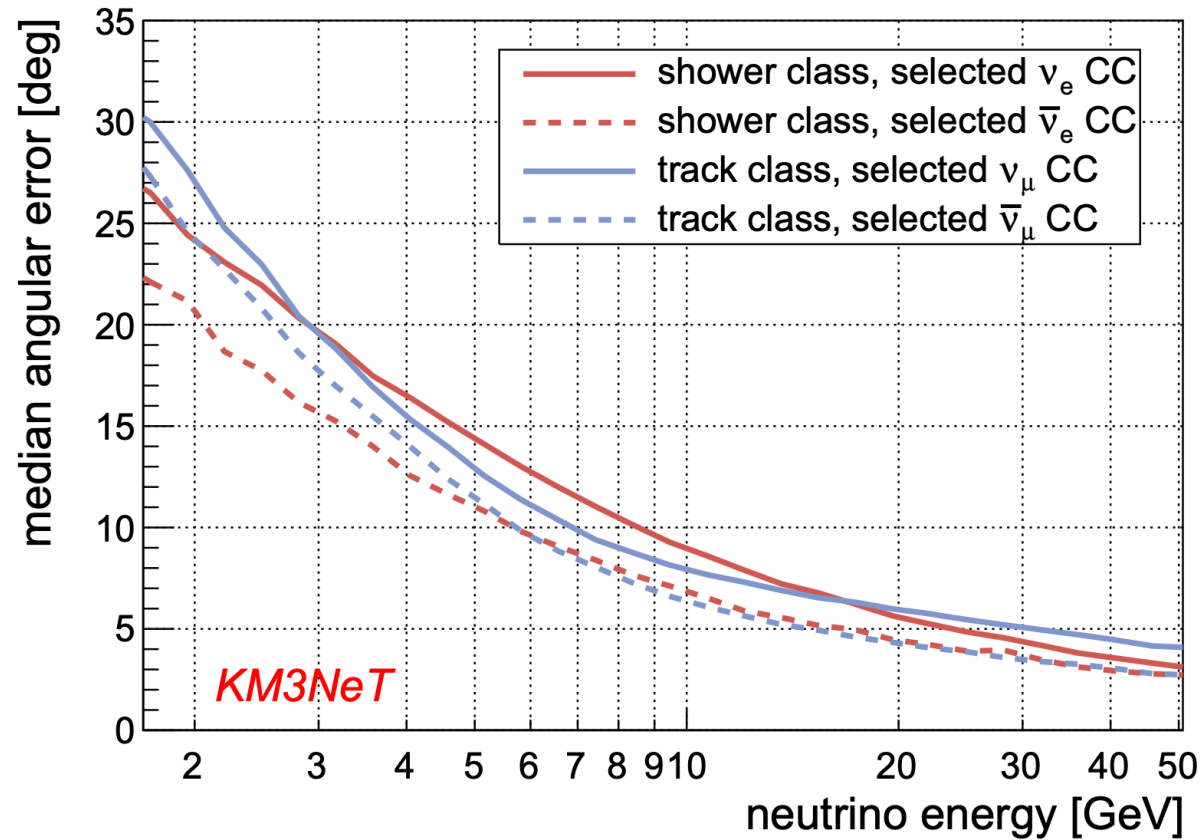
~ 0.27 in $\log_{10}(E_{\text{reco}}/E_{\text{true}})$

Shower-like events



Better than 10%

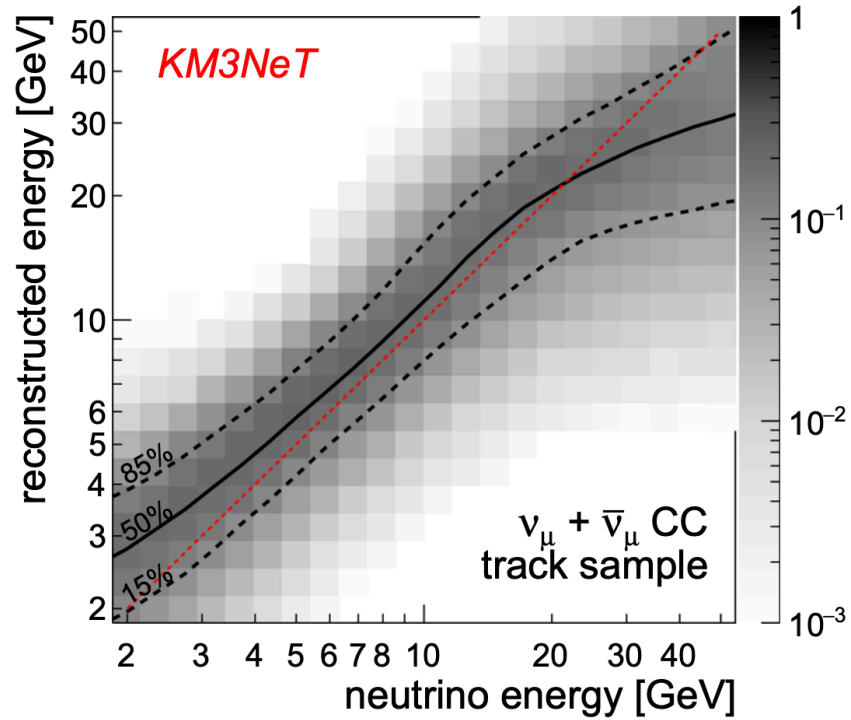
[doi:10.1088/0954-3899/43/8/084001](https://doi.org/10.1088/0954-3899/43/8/084001)



Better than 15° for E>5 GeV

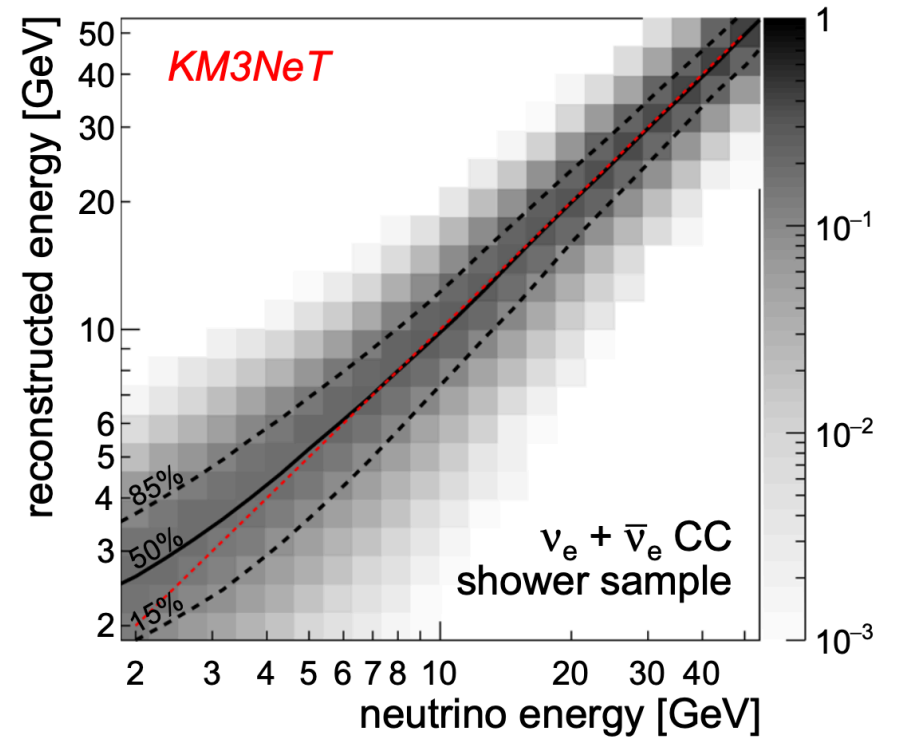
 [Eur. Phys. J. C 82, 26 \(2022\)](#)

Track-like events



$\Delta E/E \approx 35\%$

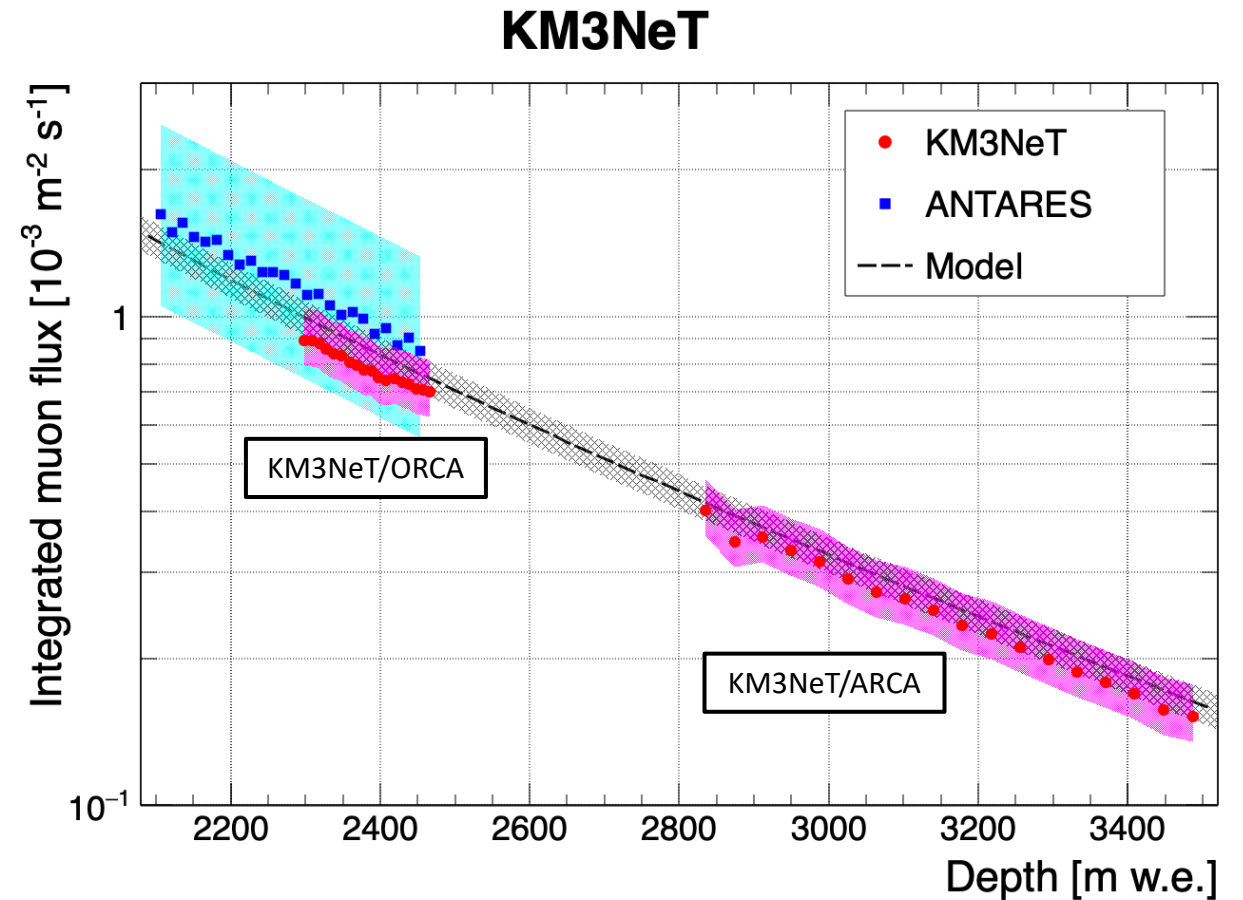
Shower-like events



$\Delta E/E \approx 25\%$

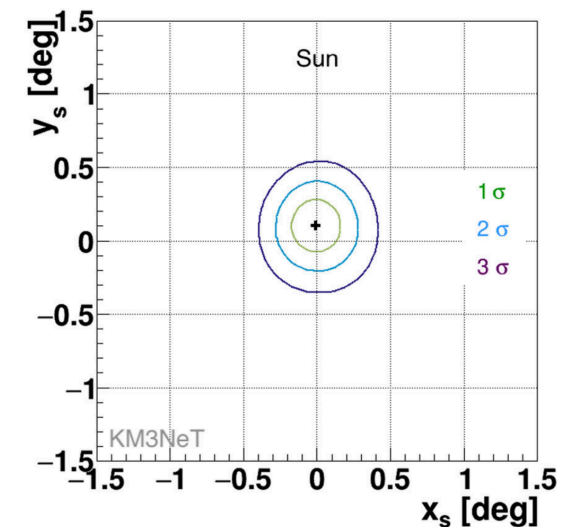
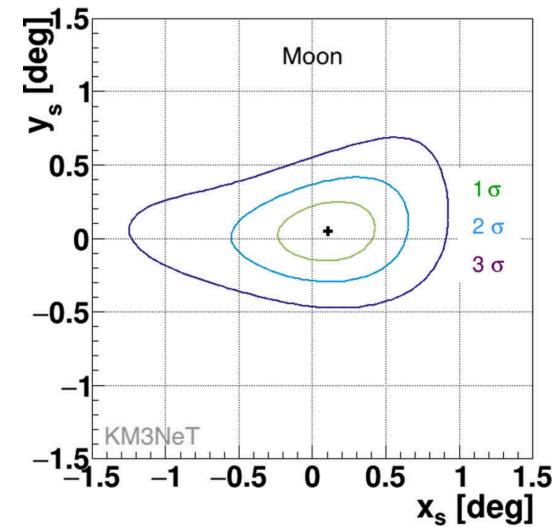
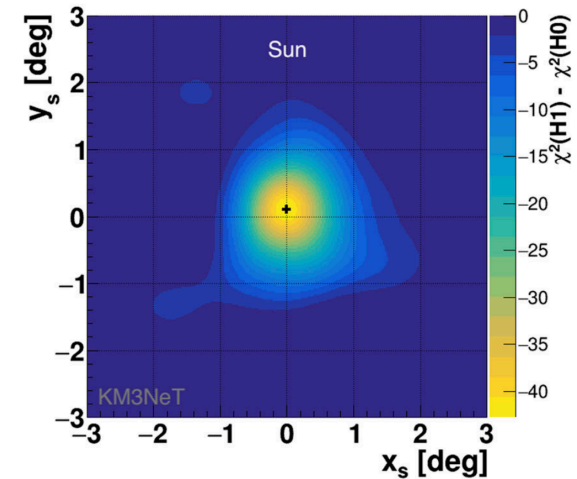
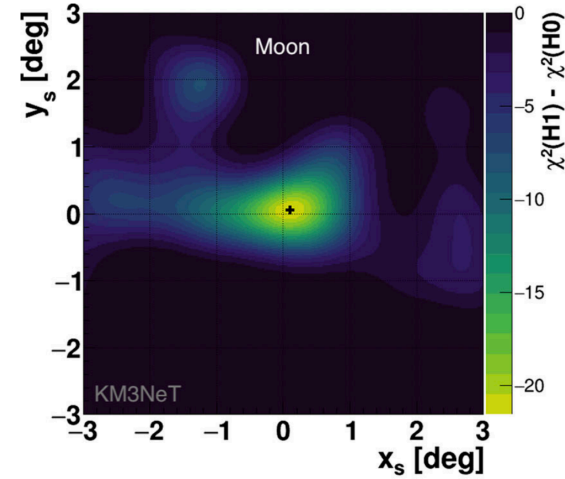
[Eur. Phys. J. C 82, 26 \(2022\)](#)

- Underwater muon flux as a function of depth.
- The KM3NeT/ARCA detector with 2 working DUs (23/12/2016-2/3/2017) and KM3NeT/ORCA with 1 DU (9/11/2017-13/12/2017)
- The flux is compared to the ANTARES result and to [the Bugaev model](#)

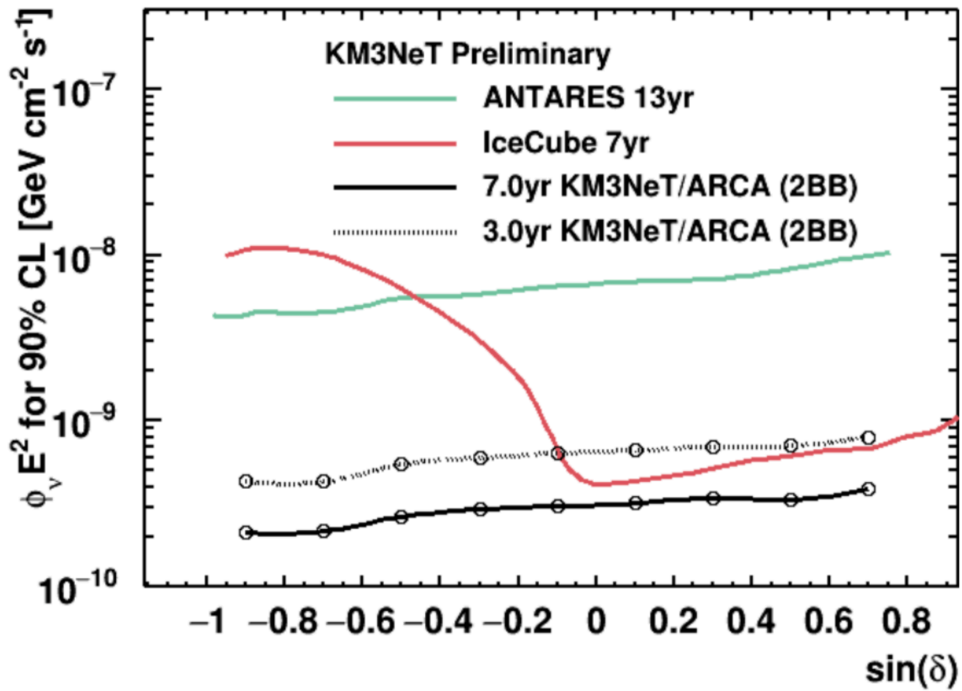


[Eur. Phys. J. C 80 \(2020\) 99](#)

- The shadow is the deficit in atmospheric muon flux induced by the absorption of cosmic rays by the Moon/Sun.
- The KM3NeT/ORCA data taken between February 2020 and November 2021 with 6 DUs
- The shadow detection significance is 4.2σ and 6.2σ for the Moon and Sun, correspondingly.
- The angular resolution values are $\sigma_{res} = 0.49^\circ$ for the Moon and $\sigma_{res} = 0.66^\circ$ for the Sun.
- The pointing accuracy is within the 68% contour.

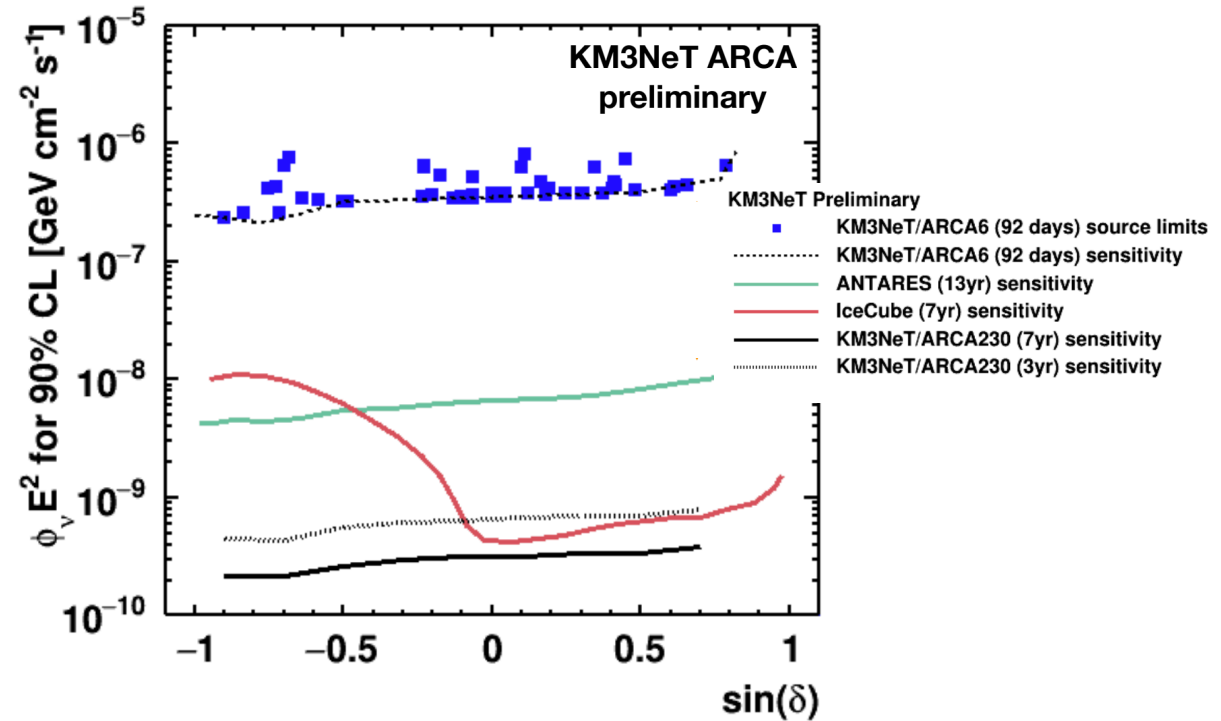


90% CL sensitivity to E^{-2} neutrino flux
Upgoing/horizontal $\nu_\mu + \bar{\nu}_\mu$ tracks



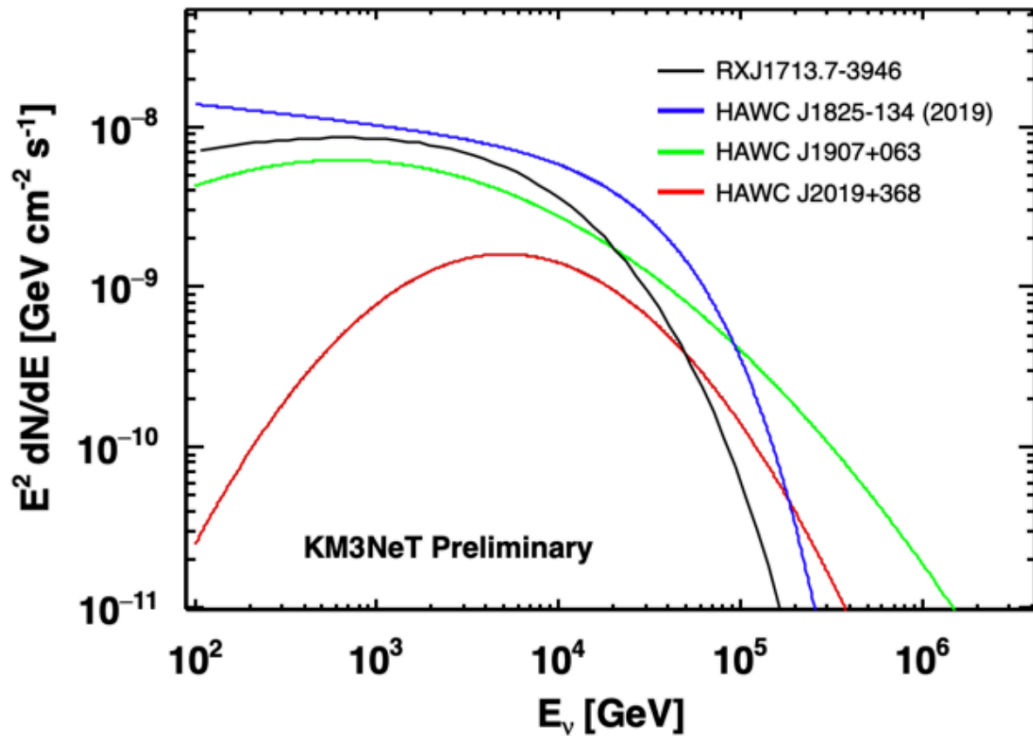
[PoS\(ICRC2021\)1077](#)

Results obtained with the KM3NeT/ARCA
detector with 6 working DUs

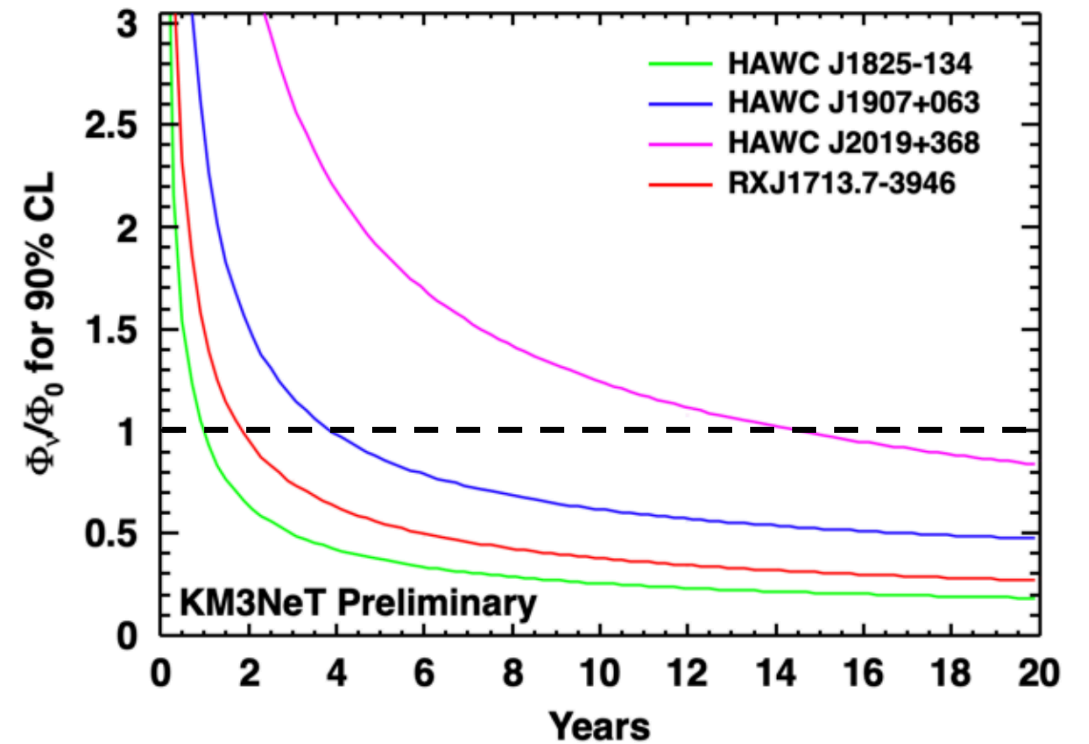


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Expected ν fluxes assuming 100% hadronic emission mechanism

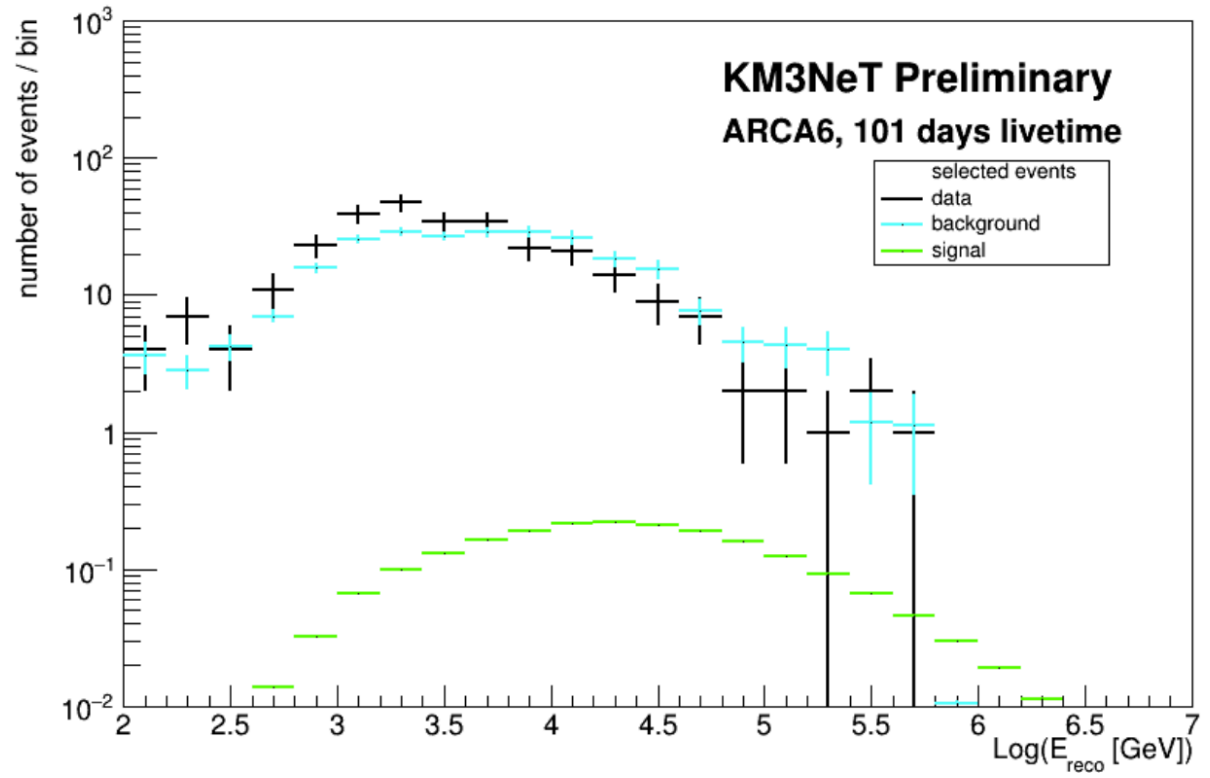


Sensitivity at 90% confidence level (Φ_0 is the expected flux)
 Several extended Galactic sources will be observable in a few years of operation of KM3NeT/ARCA with 2 BB.



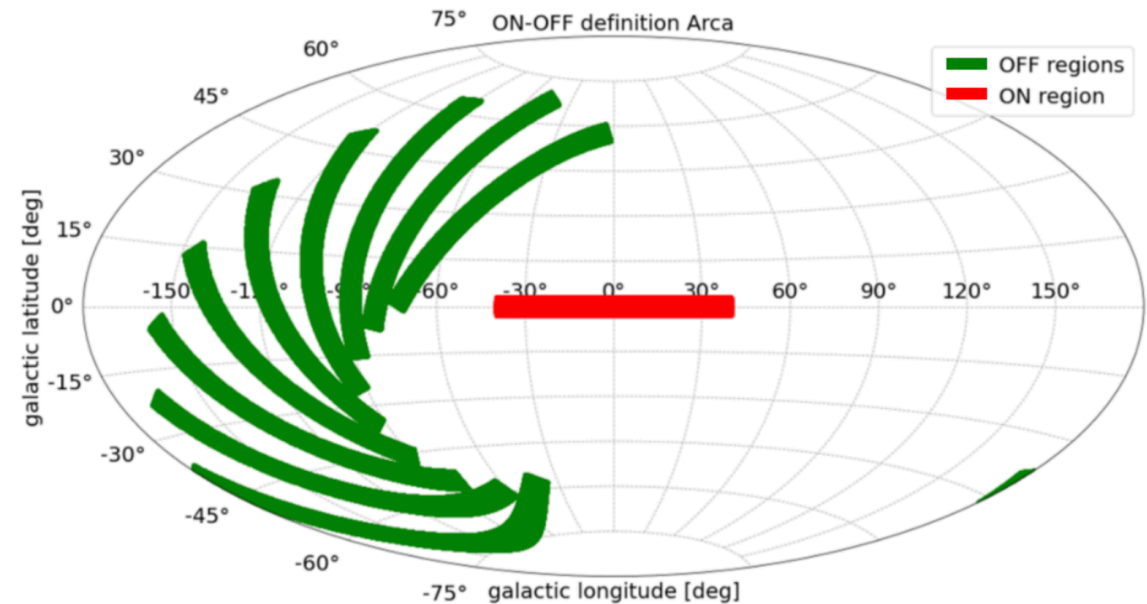
- KM3NeT/ARCA with 6 DUs, lifetime is 101 days
- Simulated signal – $1.44 \times 10^{-18} (E/100 \text{ TeV})^{-2.28}$
([IceCube diffuse flux](#))
- Obtained sensitivity for the corresponding flux:
 $17.3 \times 10^{-18} [\text{GeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}]$

Final energy distribution obtained with the reduced atmospheric muon contamination, keeping a high signal efficiency



[Poster@Neutrino2022](#)

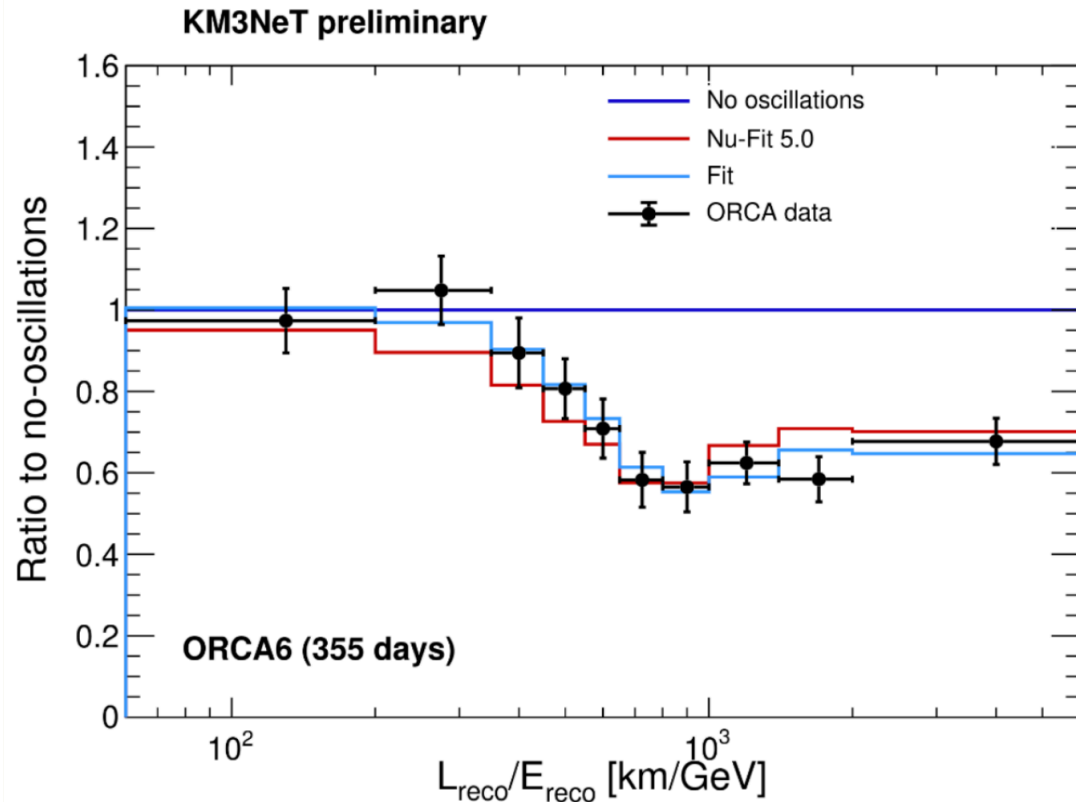
- KM3NeT/ARCA with 6 DUs, lifetime is 101 days
- ON region is the Galactic ridge: $|L_{gal}| < 40^\circ$, $|B_{gal}| < 3^\circ$
- OFF regions are shifted in time avoiding the Fermi bubbles
- The simulated signal within the ON region follows a power-law spectra: $1.2 \times 10^{-8} (E^{-2.4}/1 \text{ GeV}) [\text{GeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}]$
- No statistically significant excess found.
Upper limit: $6.2 \times 10^{-4} [\text{GeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}]$



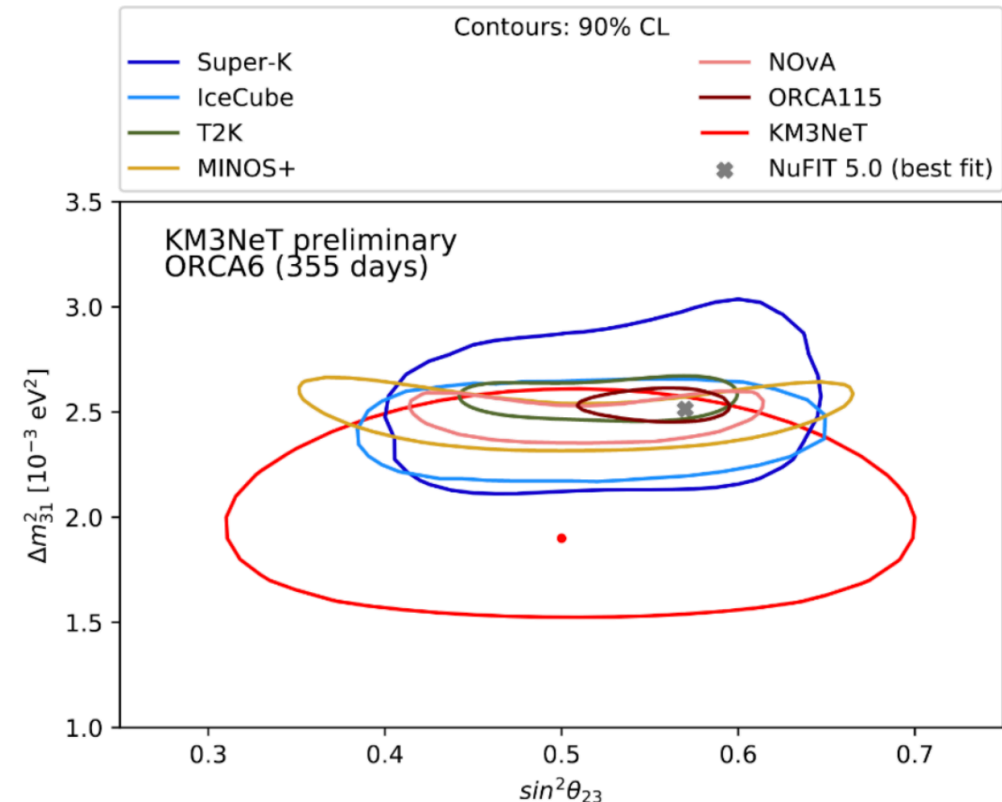
 [Poster@Neutrino2022](#)

- The first KM3NeT/ORCA oscillation results with only 6 DUs!
- **Clear effect of oscillations observed**

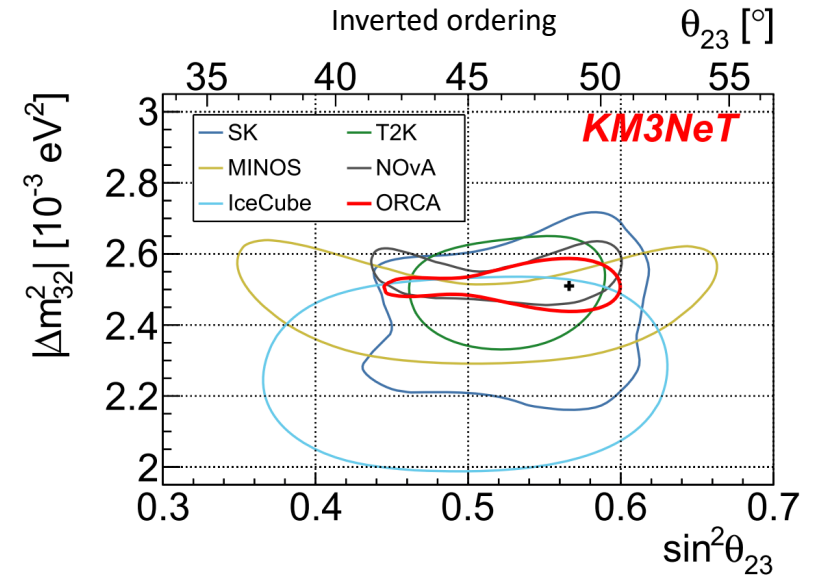
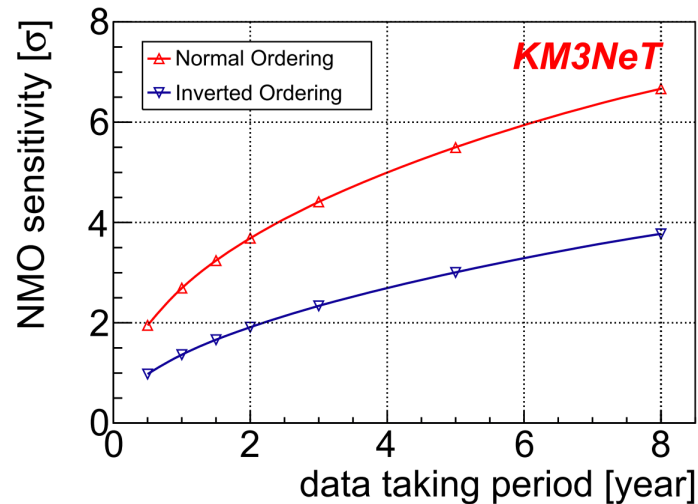
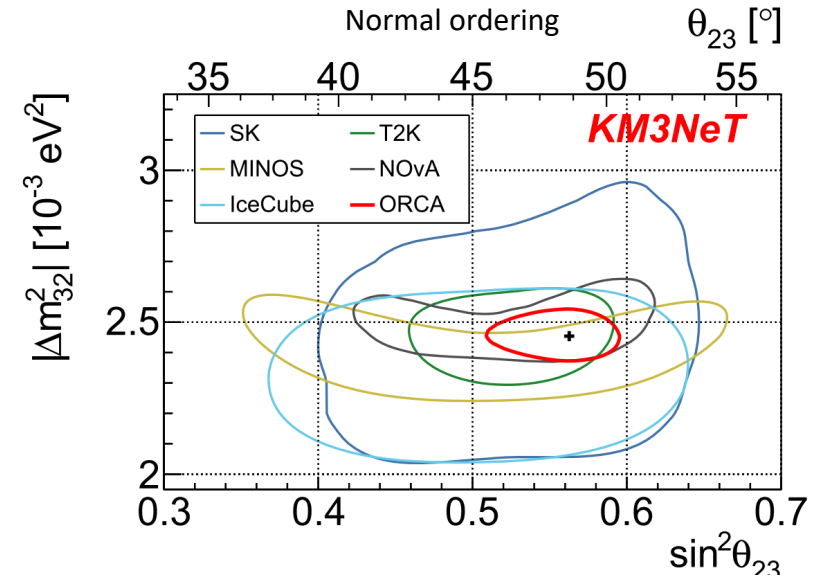
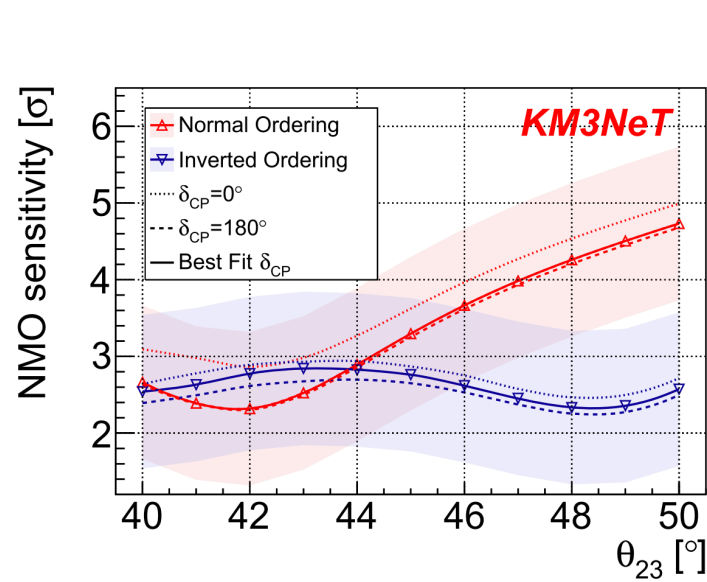
Oscillations preferred with 5.9σ CL over “no oscillations”



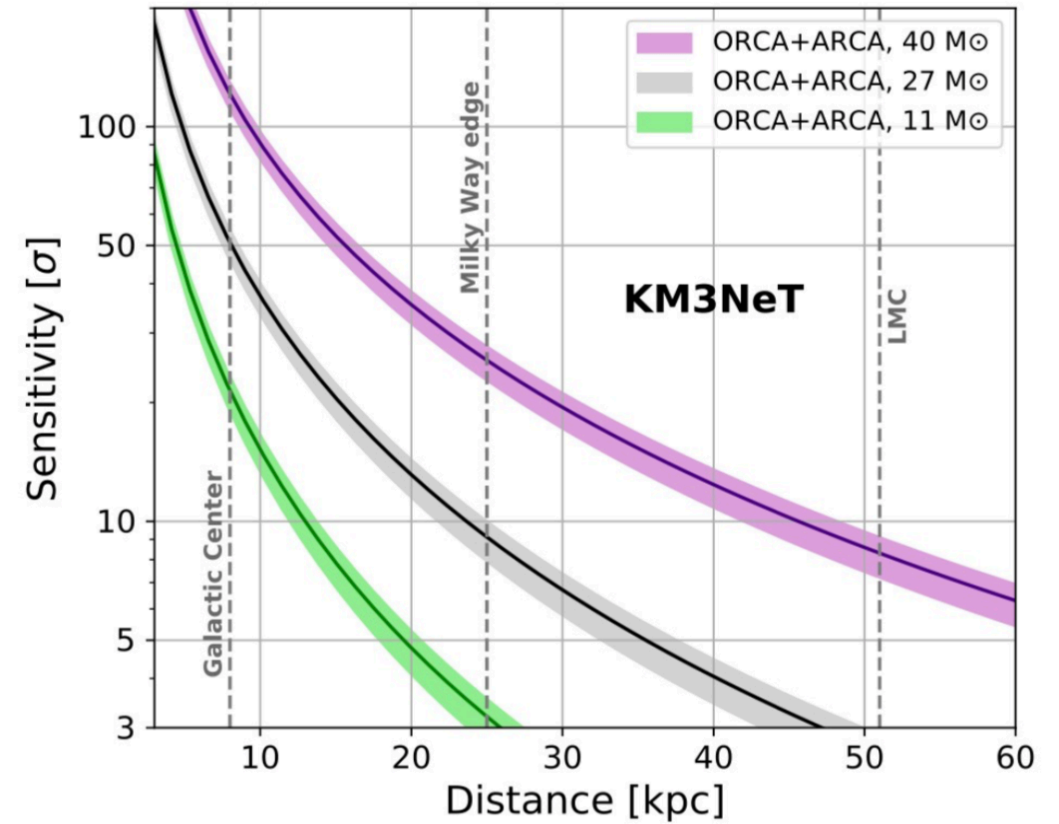
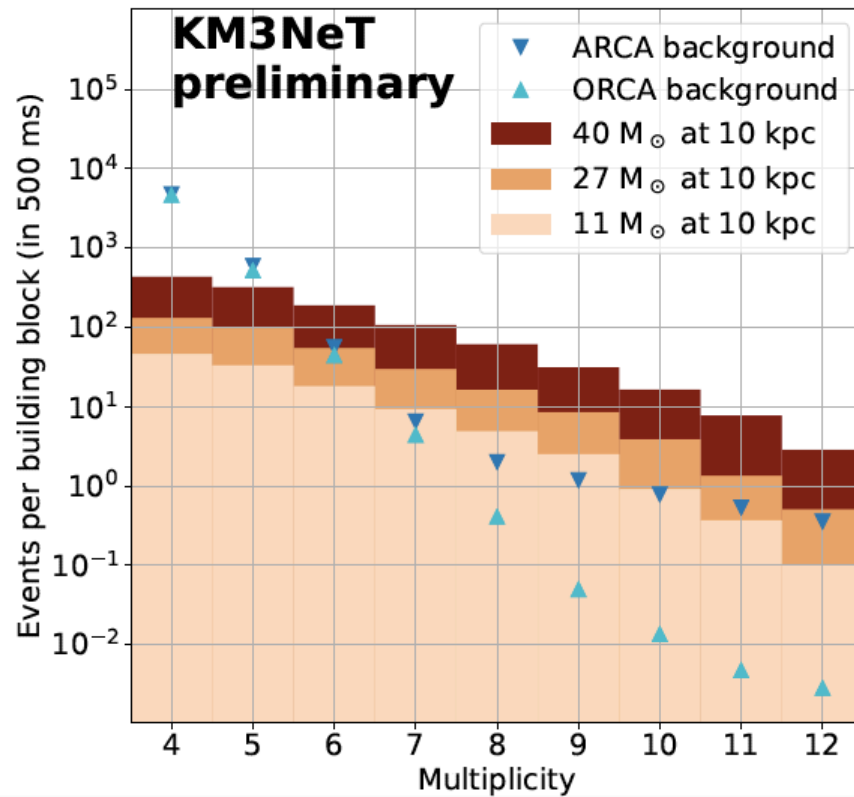
Sensitivity contours at 90% CL



- KM3NeT/ORCA in its full configuration. Three years of data taking
- Sensitivity for neutrino mass ordering at 4.4σ (normal) and 2.3σ (inverted)
- Competitive sensitivity to Δm_{32}^2 and θ_{23}



- Neutrinos with $E < 100$ MeV expected at several stages of core collapse
- Low-energy neutrino detection is based on the coincidences in single DOMs thanks to the multi-PMT DOM configuration



[Eur. Phys. J. C **82**, 26 \(2022\)](#)

- The KM3NeT research infrastructure is being built in the Mediterranean Sea and includes two neutrino telescope: KM3NeT/ORCA (Toulon, France) and KM3NeT/ARCA (Capo Passero, Italy)
- Very broad energy range (MeV – PeV) to explore core-collapse supernovae, neutrino oscillations and astronomy
- To date, 21/230 DUs were deployed in KM3NeT/ARCA and 18/115 DUs in KM3NeT/ORCA
- Several physics results were already achieved and confirmed the expectations
- New exciting results will be presented at the summer conferences, ICRC2023

Stay tuned!