



UNIVERSITY OF THE  
WITWATERSRAND,  
JOHANNESBURG

# Status and physics results of the KM3NeT experiment

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A. Chen

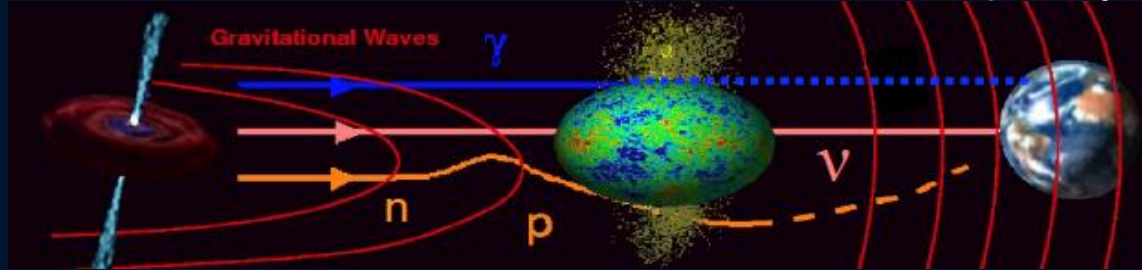
University of the Witwatersrand  
On behalf of the KM3NeT Collaboration



**KM3NeT**

First Pan-African Astro-Particle and Collider Physics Workshop– 21 March 2022

# NEUTRINOS AS COSMIC MESSENGERS



Neutrinos are neutral, stable, weakly interacting

- not absorbed by background light/CMB
- not absorbed by matter
- not deviated by magnetic fields

access to dense environments

access to cosmological distances

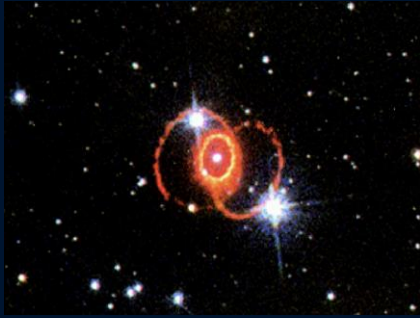
astronomy over full energy range

‘Smoking gun’ signature for hadronic processes

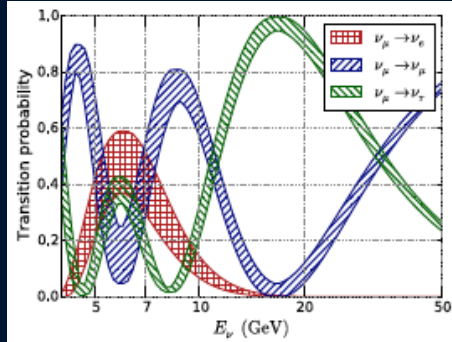
Correlated in time/direction with electromagnetic and gravitational waves

# NEUTRINO ENERGY RANGE

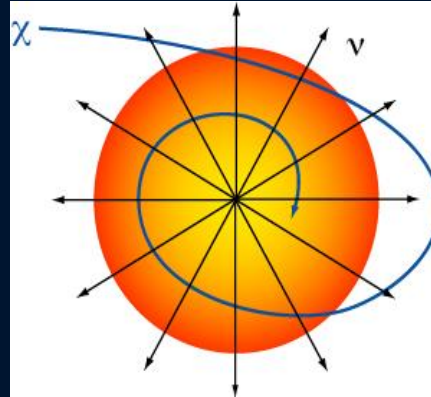
MeV to PeV energies



Supernovae  
Solar flares



Atmospheric  $\nu$   
 $\nu$  oscillations  
 $\nu$  mass ordering  
sterile  $\nu$



Dark matter  
Monopoles,  
Nuclearites,...

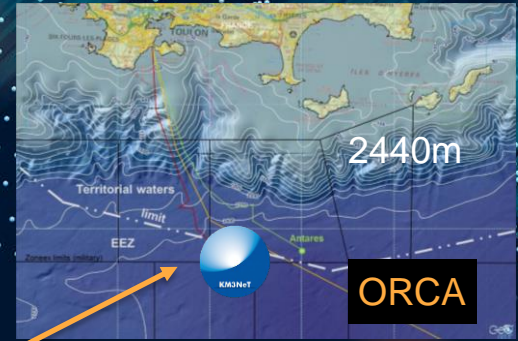
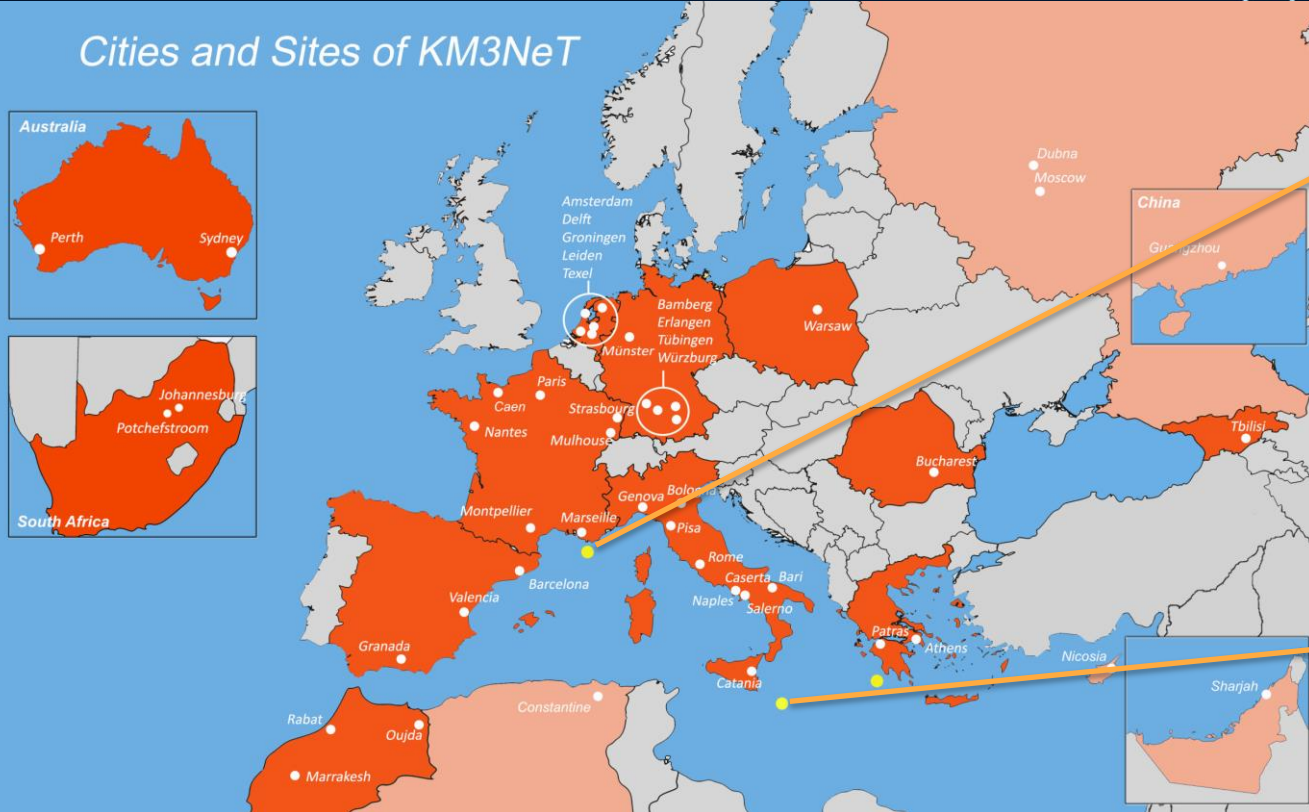


Cosmic  $\nu$   
Production  
mechanism  
of HE CR



# THE KM3NeT EXPERIMENT

## Cities and Sites of KM3NeT



Oscillation Research  
with Cosmics In the Abyss



Astroparticle Research  
with Cosmics In the Abyss

# WHY IN THE MEDITERRANEAN SEA?

Galactic coordinates

0%  
visibility

100%  
visibility

Mediterranean  
~ 43° North

100%  
visibility

0%  
visibility

South Pole

# THE KM3NeT DETECTOR

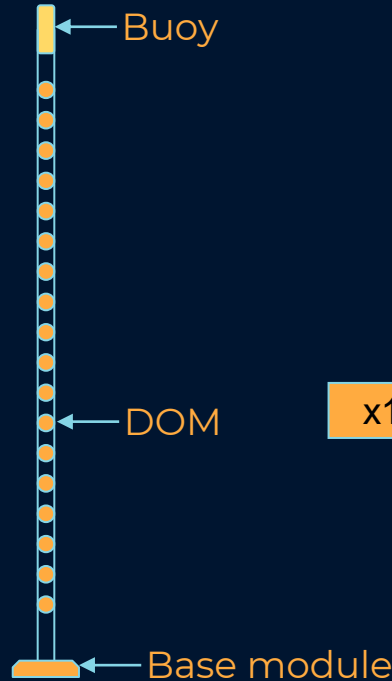
Digital Optical Module (DOM)



- 31x3" PMTs
- ns timing
- ~10 cm spatial positioning

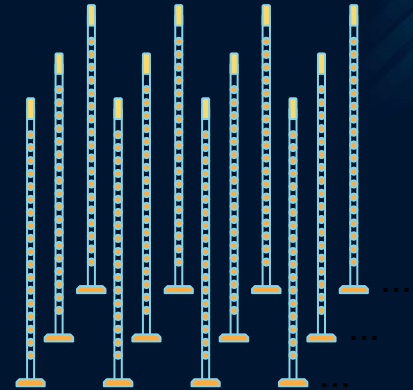
x18

Detection Unit (DU)

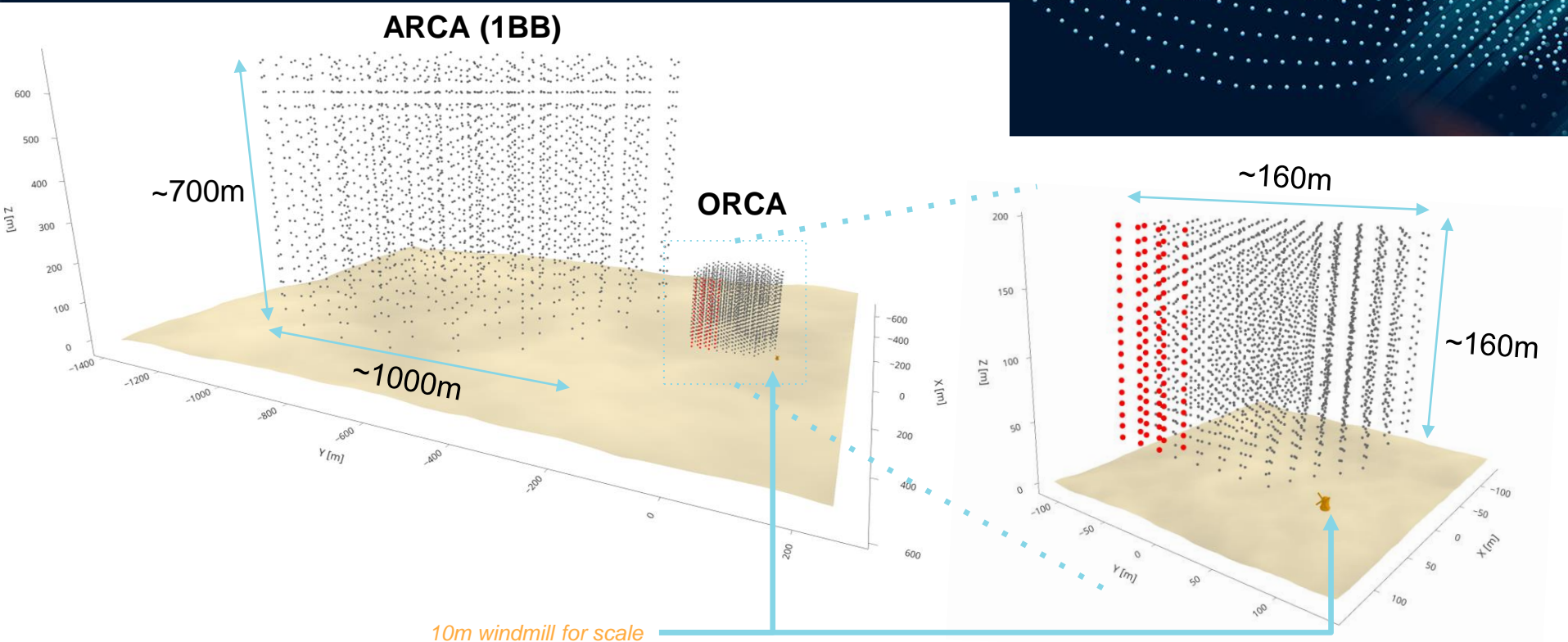


x115

Building Block (BB)

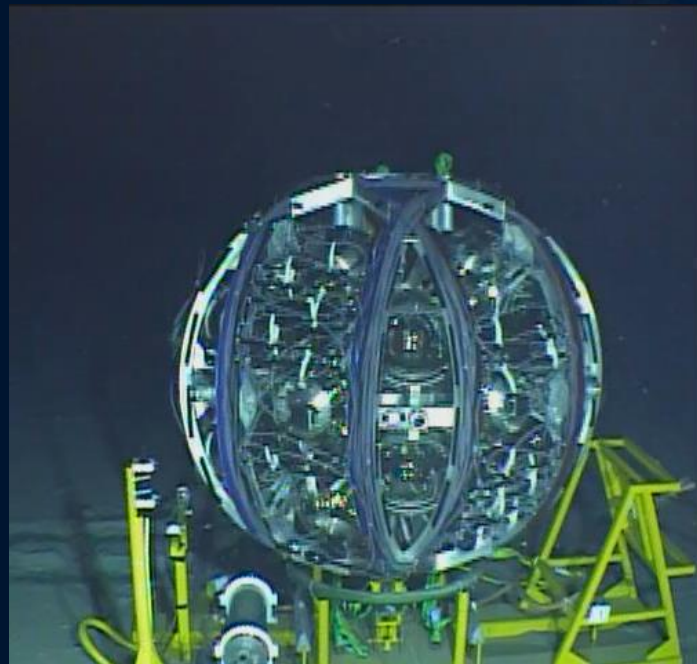
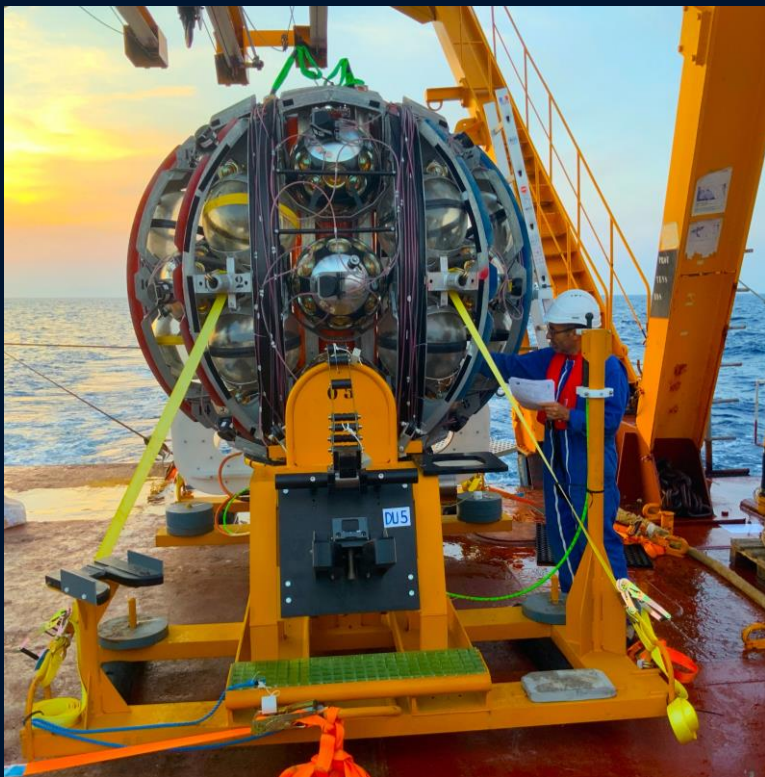


# KM3NeT ARCA & ORCA





# THE DETECTOR CONSTRUCTION





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# THE DETECTOR STATUS

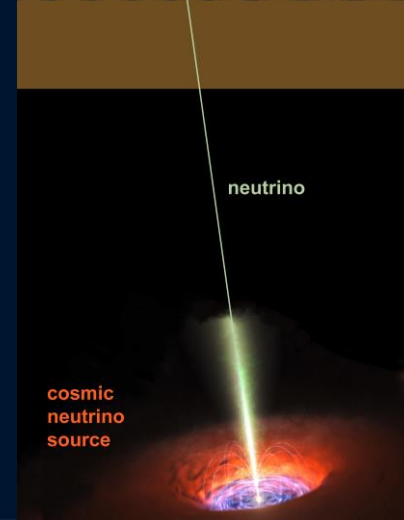
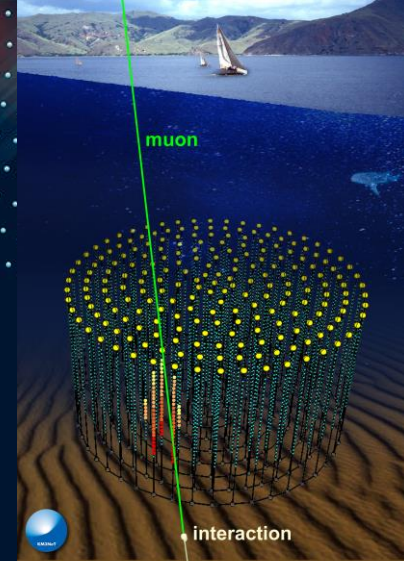
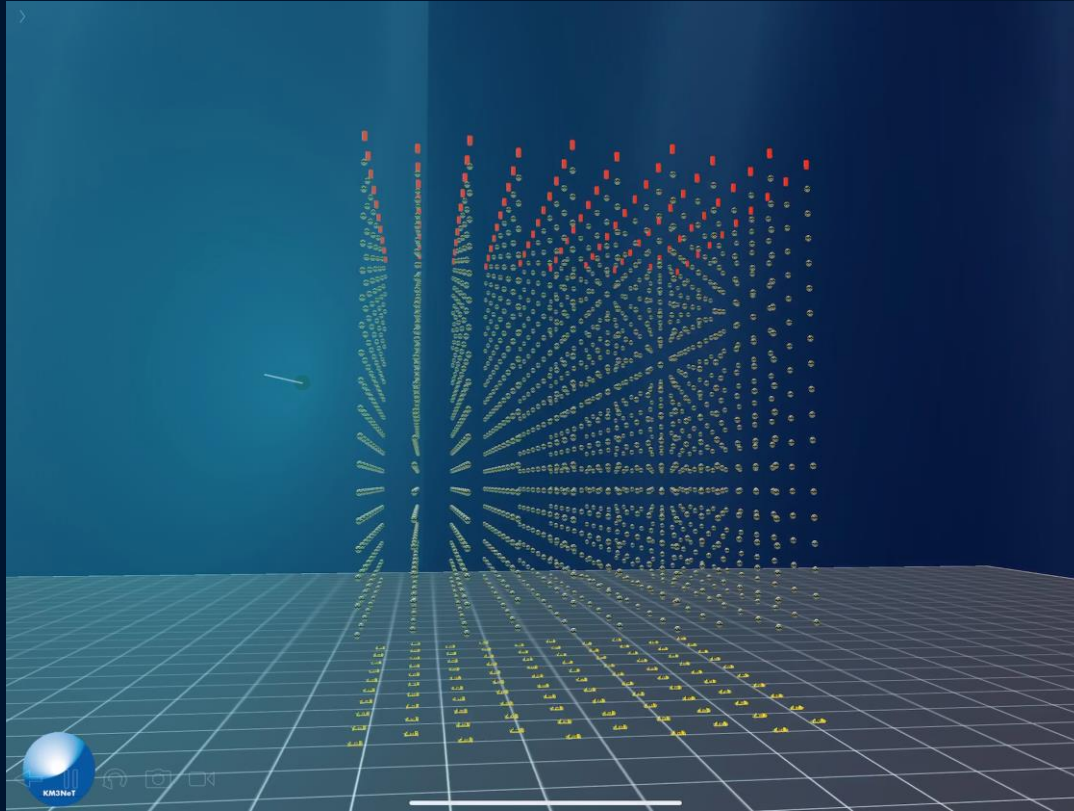
KM3NeT-ARCA

8 DU currently  
deployed

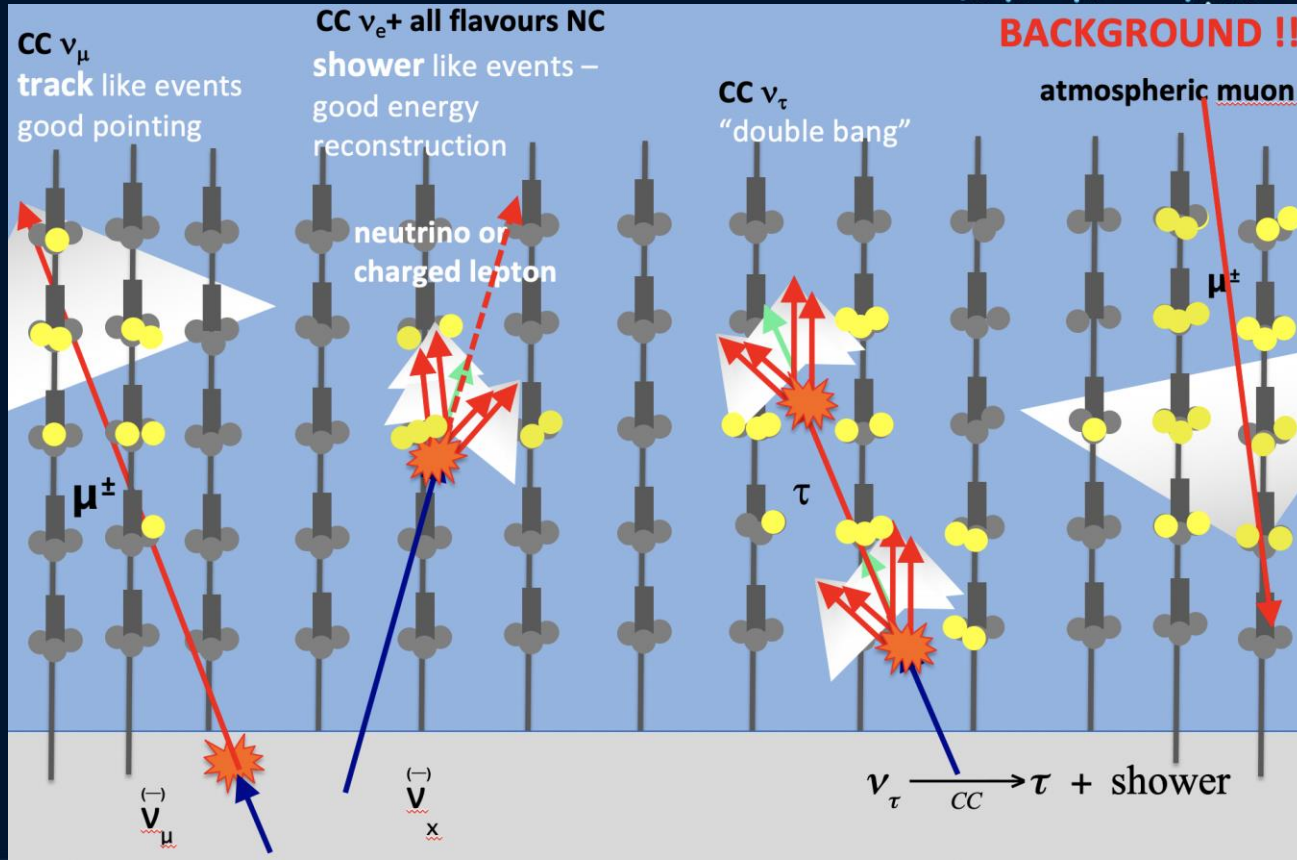
KM3NeT-ORCA

10 DU currently  
deployed

# THE DETECTION PRINCIPLE



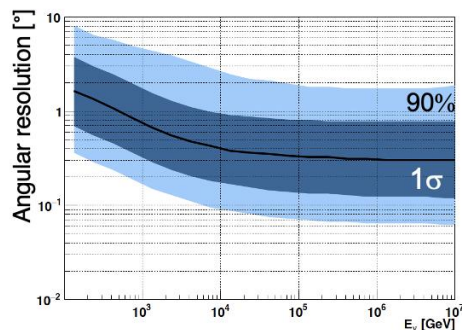
# EVENT TOPOLOGIES



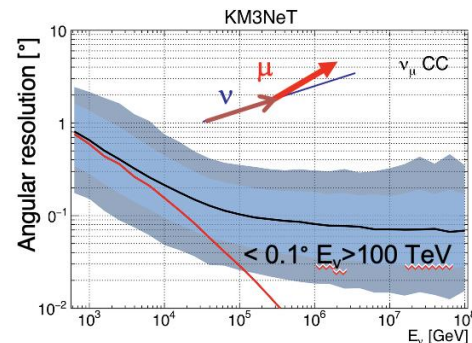


# RESOLUTIONS

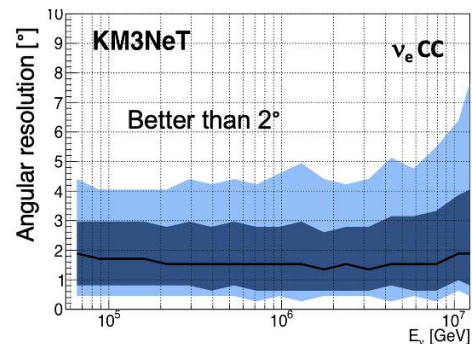
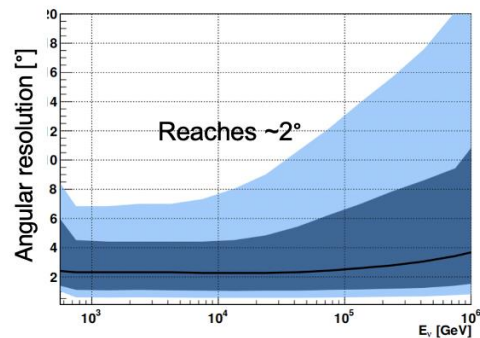
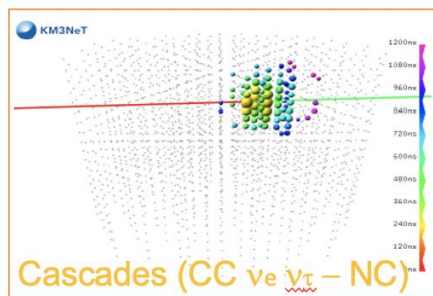
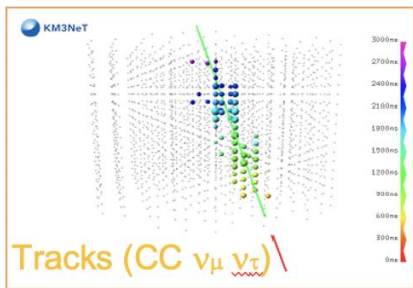
ANTARES



KM3NeT



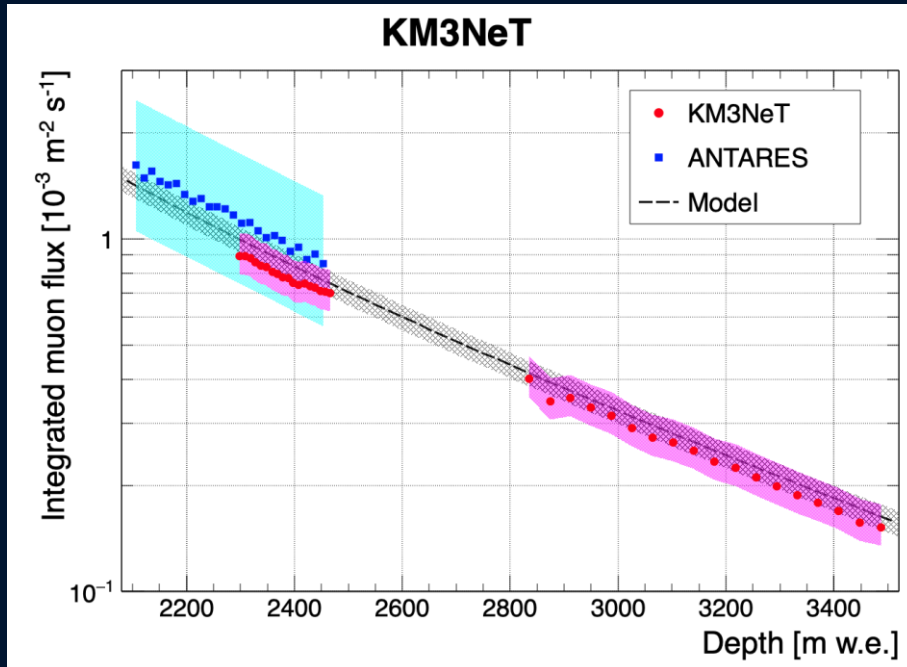
Energy resolution  
~ 30%



Energy resolution  
< 5%

# FIRST RESULTS

## Atmospheric muons



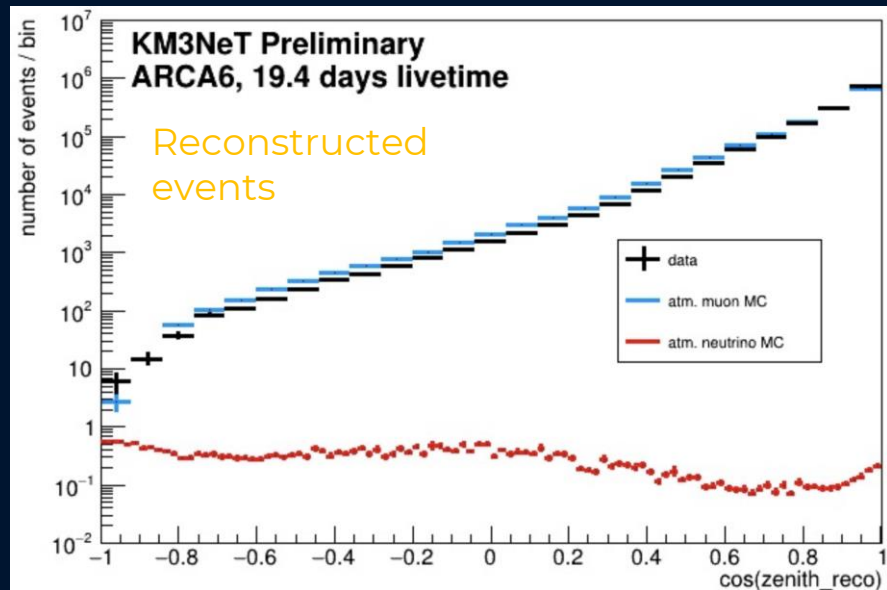
ARCA 2 (23/12/2016-2/3/2017)  
ORCA 1 (9/11/2017-13/12/2017)

Muon flux as function of depth  
compared to Bugaev model  
(Bugaev et al, Phys. Rev. D 58 1998 054001)

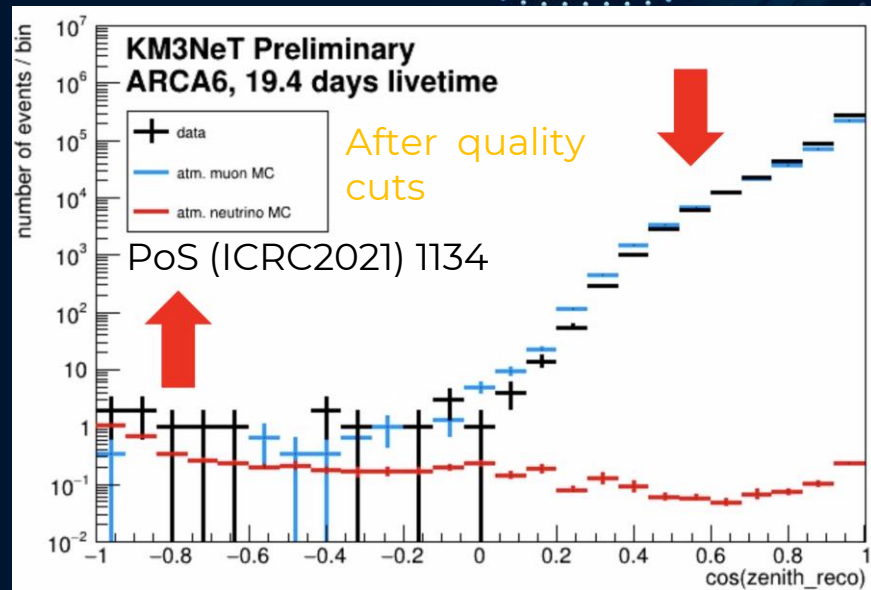
Eur. Phys. J. C 80 (2020) 99

# FIRST RESULTS

## Atmospheric neutrino



Upgoing tracks = neutrino induced events  
Downgoing tracks = dominated by atm muons



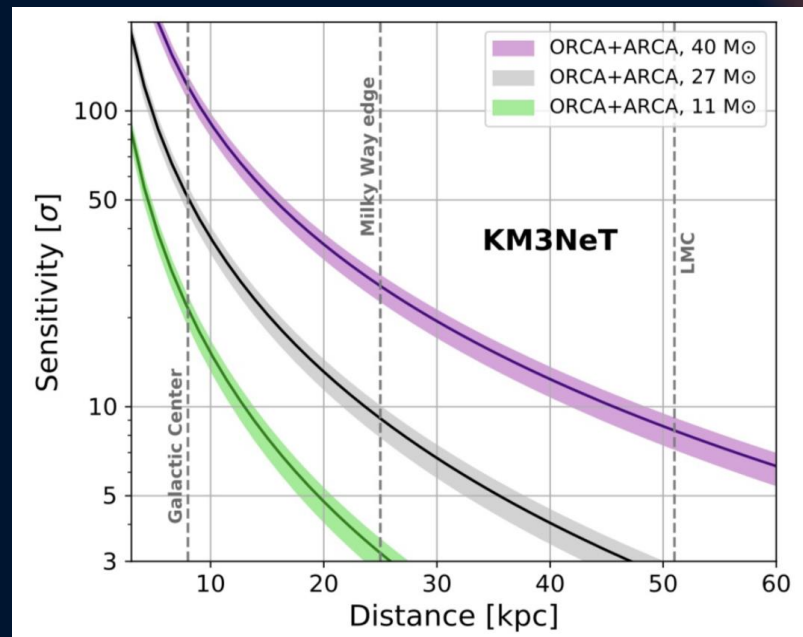
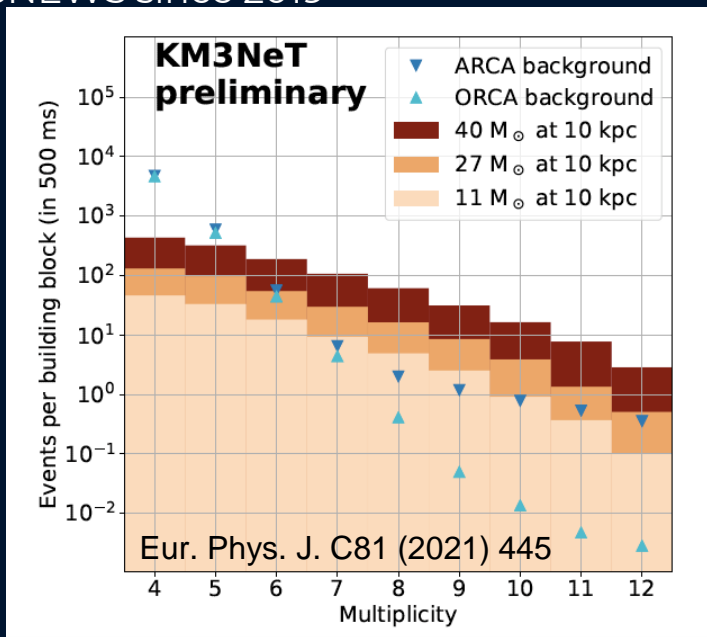
15 up-going tracks > 100 GeV  
MC expectations: 4 atm  $\nu$  + 7 atm  $\mu$



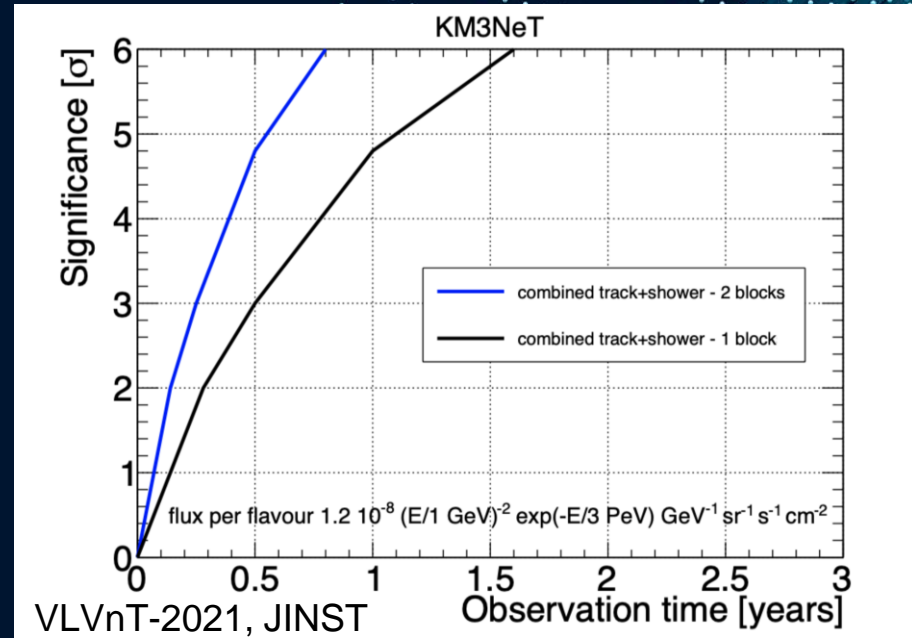
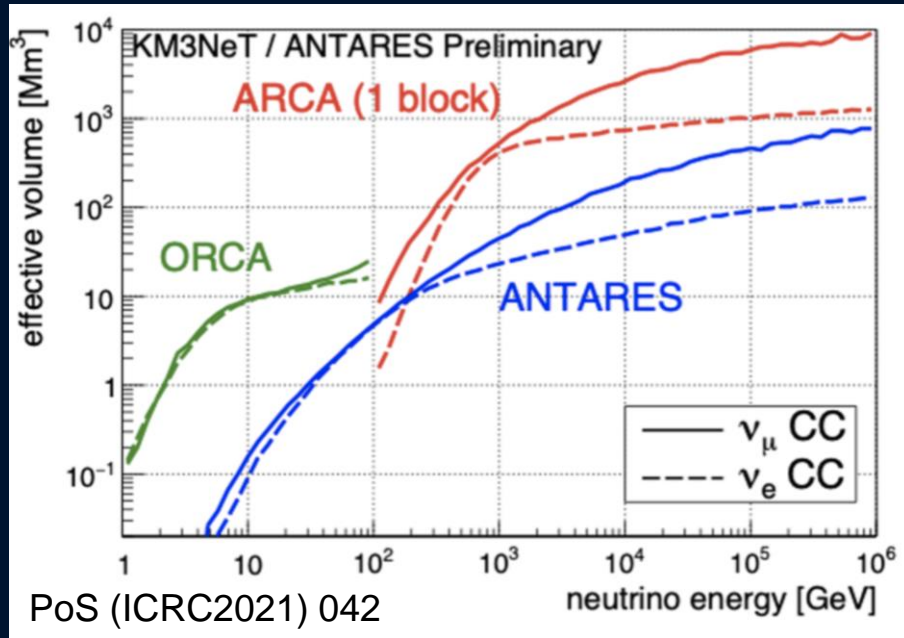
# SUPERNOVA MONITORING

Neutrinos below 100 MeV expected at several stages of the core collapse  
Cherenkov signature detected as a population of coincidences in single DOMs  
Real time alert system is in place within SNEWS since 2019

$5\sigma$  for ARCA+ORCA for  $27M_{\odot}$  at a distance  $\sim 36$  kpc  
 $\sim 60\%$  of the CCSN Galactic population



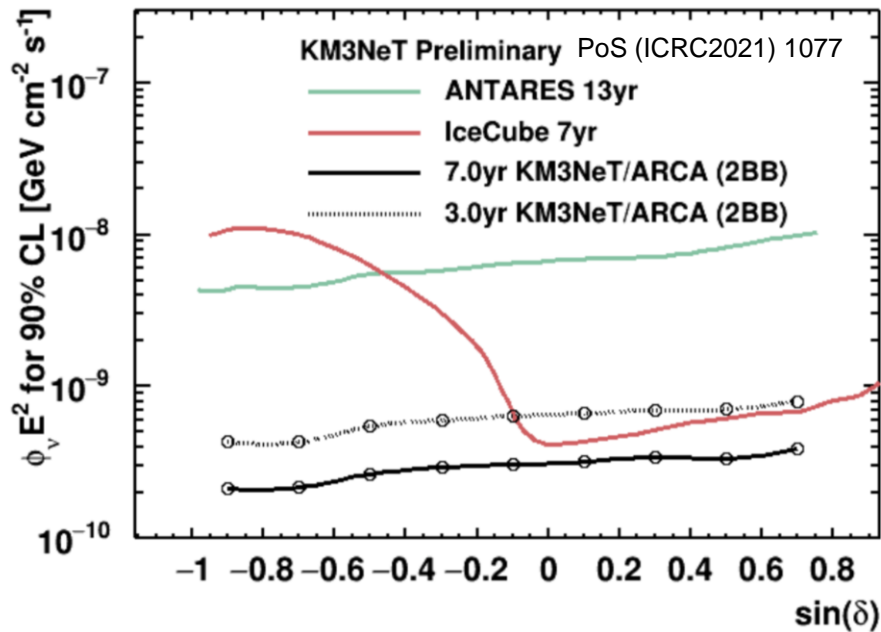
# DIFFUSE COSMIC NEUTRINO



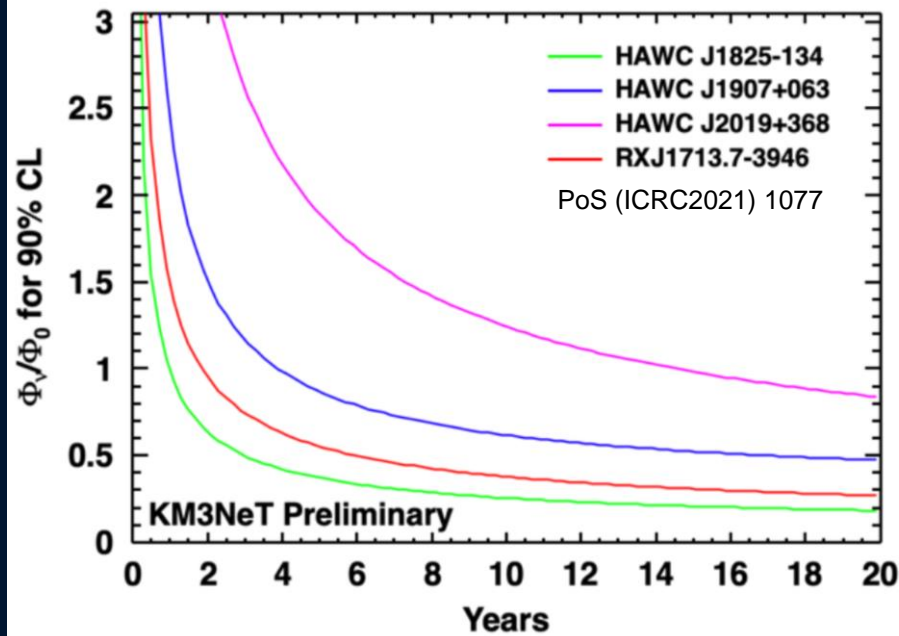
Broad energy coverage of the full detector

$5\sigma$  detection in less than 1 year for 1 BB!

# POINT-LIKE NEUTRINO SOURCES



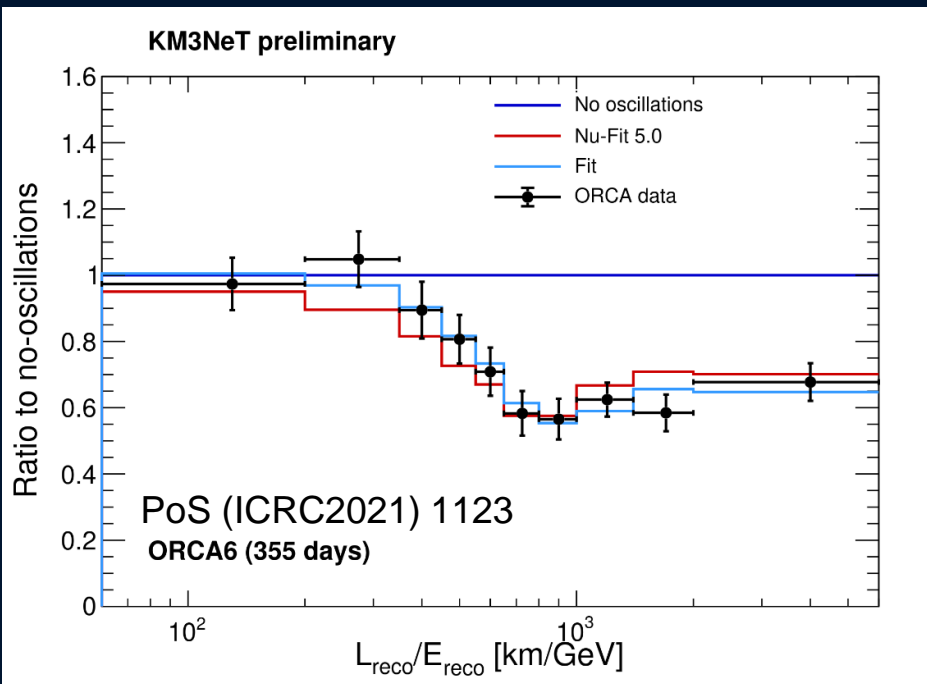
$E^{-2}$  neutrino flux 90% CL sensitivity



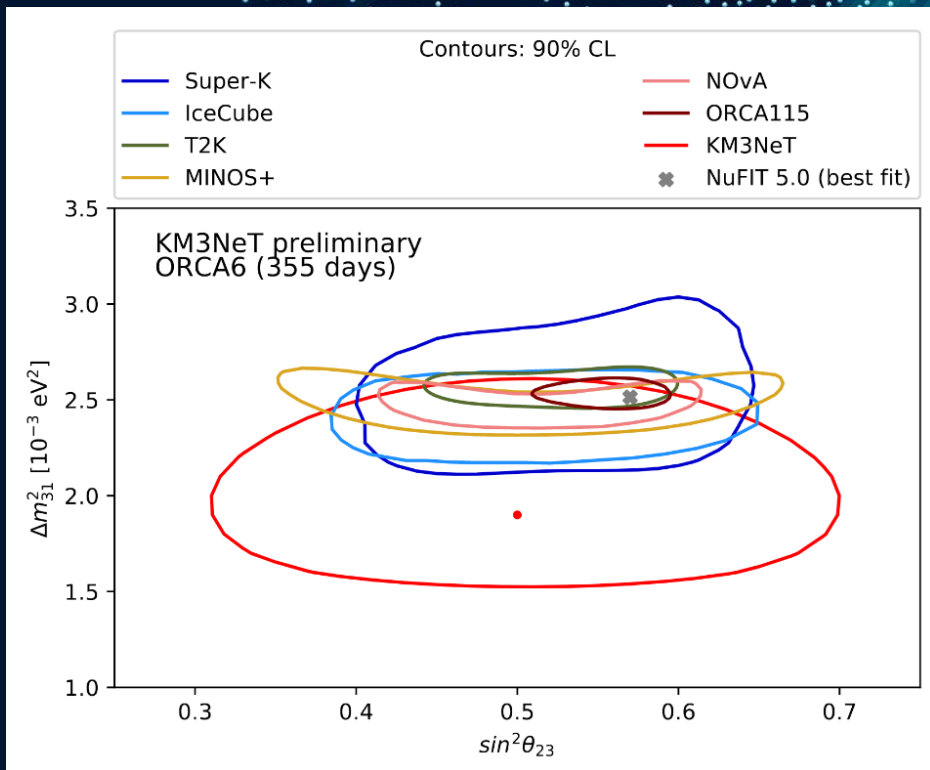
90% CL sensitivity for several candidate sources



# NEUTRINO OSCILLATION

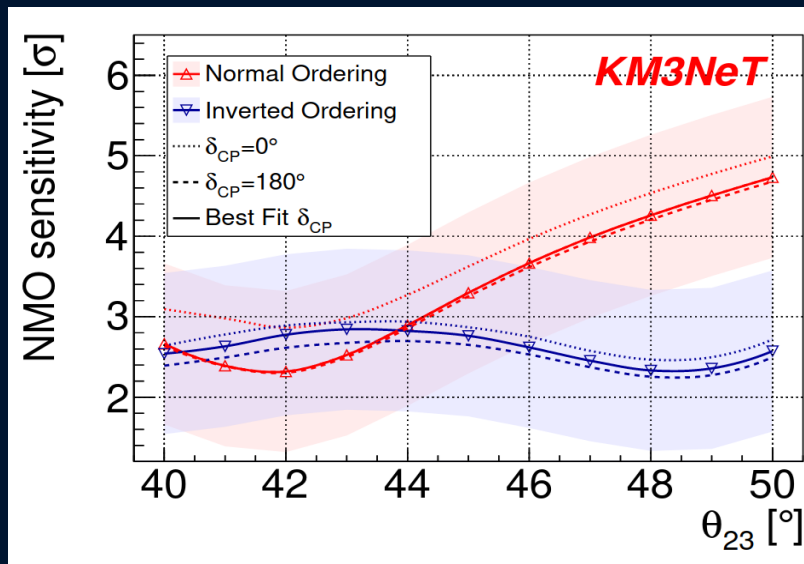


Strong oscillation signal with only 6 DU

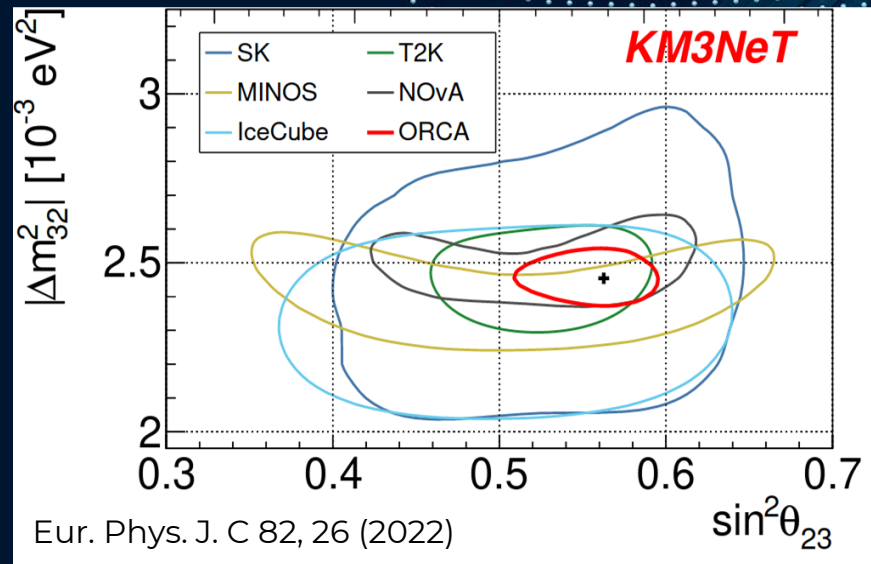


Data has a preference to oscillation of  $5.9\sigma$

# NEUTRINO MASS ORDERING

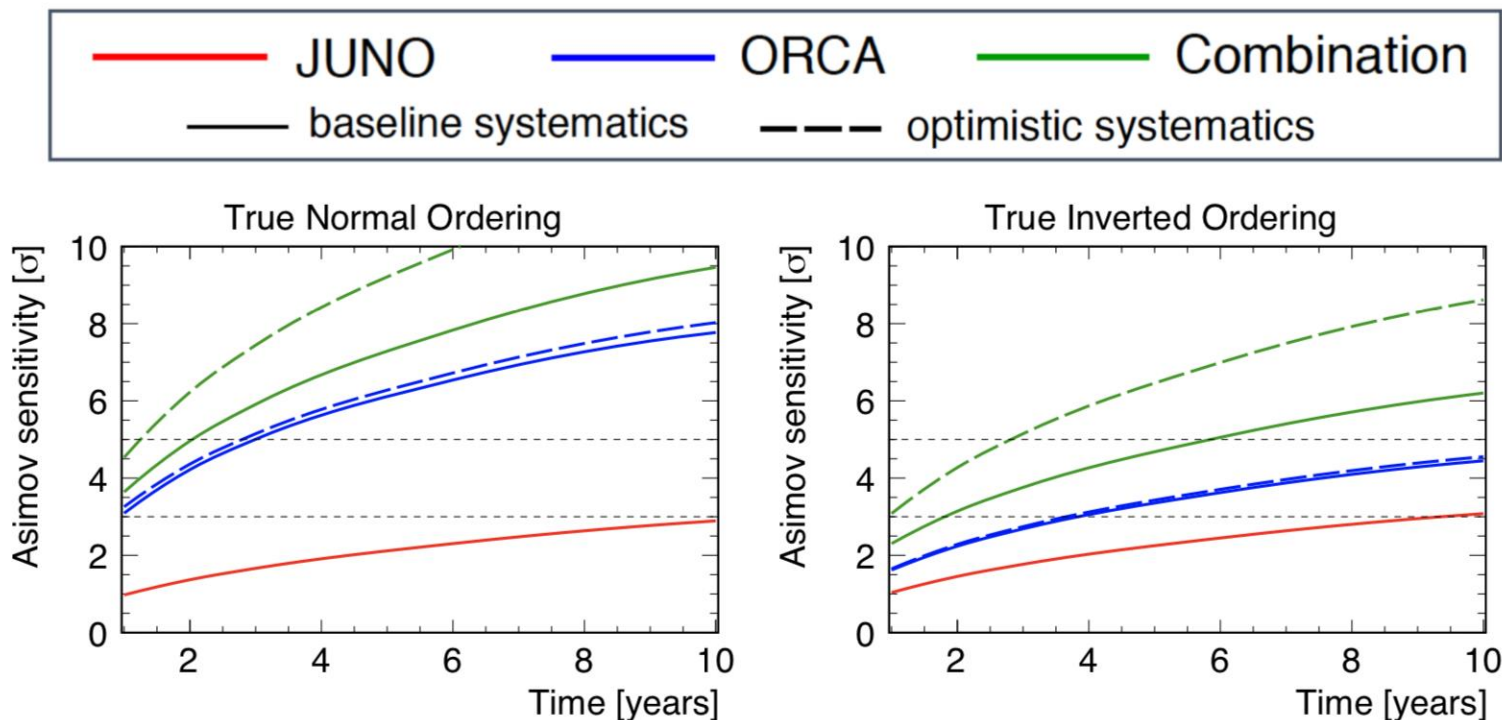


Expected results for 3 years exposure, full detector.



Competitive sensitivity to  $\Delta m^2_{32}$ ,  $\theta_{23}$

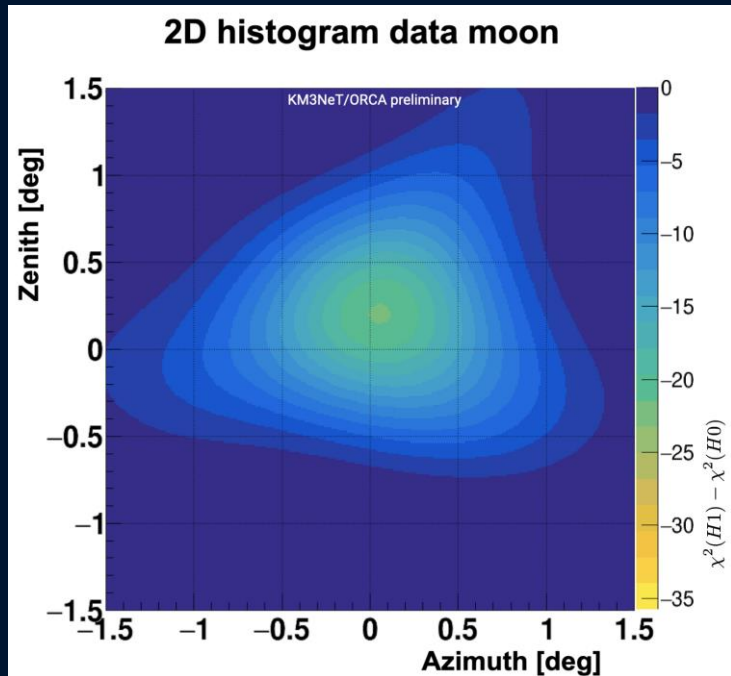
# NMO COMBINED WITH JUNO



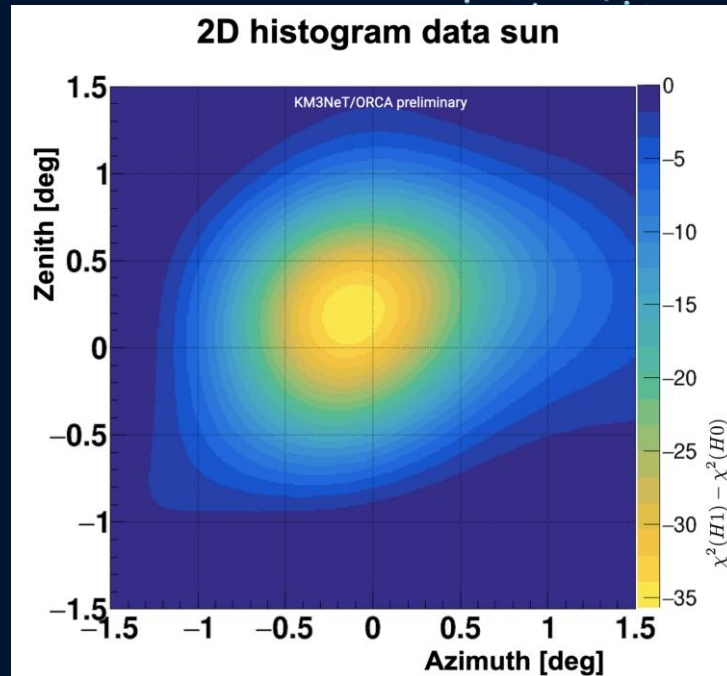
arxiv:2108.06293 accepted for publication in JHEP



# MOON/SUN SHADOW SENSITIVITY



Significance =  $4.4 \sigma$   
Angular resolution =  $0.54^\circ \pm 0.13^\circ$  deg



Significance =  $5.7 \sigma$   
Angular resolution =  $0.59^\circ \pm 0.10^\circ$  deg

KM3NeT  
ORCA  
13 months  
data taking

# CONCLUSIONS

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- KM3NeT Neutrino telescopes will allow neutrino physics and neutrino astronomy from the MeV scale to the PeV scale
- Well established underwater technology and calibration procedures
- First preliminary results confirm expectations
- KM3NeT effective area already larger than ANTARES
- 8 ARCA + 10 ORCA Detection Units have been deployed
- More Detection Units to be deployed this year

STAY TUNED!



Mariam Darjania, Draw me a neutrino contest winner

**THANKS FOR  
YOUR ATTENTION**