

# XX International Workshop on Neutrino Telescopes

Venice, October 23<sup>rd</sup>-27<sup>th</sup> 2023

## Overview of ANTARES, the first Mediterranean Sea telescope

Dr. Chiara Poirè,  
on behalf of the ANTARES collaboration



UNIVERSITÀ DEGLI STUDI DI SALERNO



Dipartimento di  
Fisica E.R. Caianiello



# Physics motivations

Supernovae  
Explosions

Neutrino  
Physics

Dark Matter  
& Exotics searches

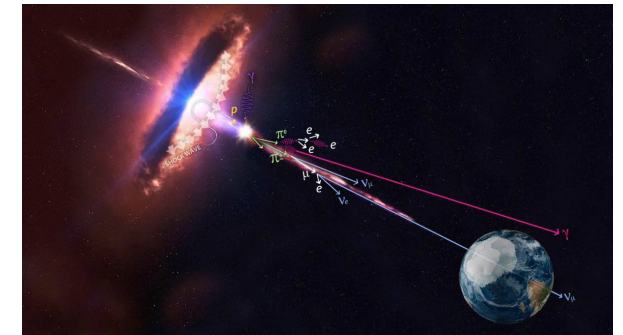
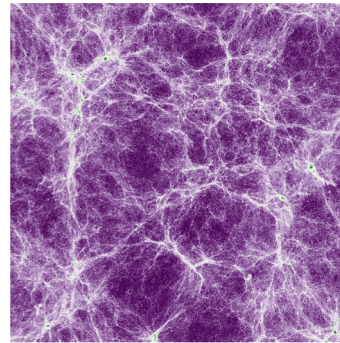
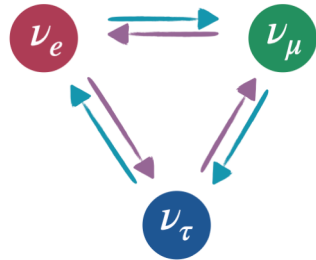
Cosmic neutrinos  
Multi-Messenger program

MeV

GeV

TeV

PeV



ANTARES

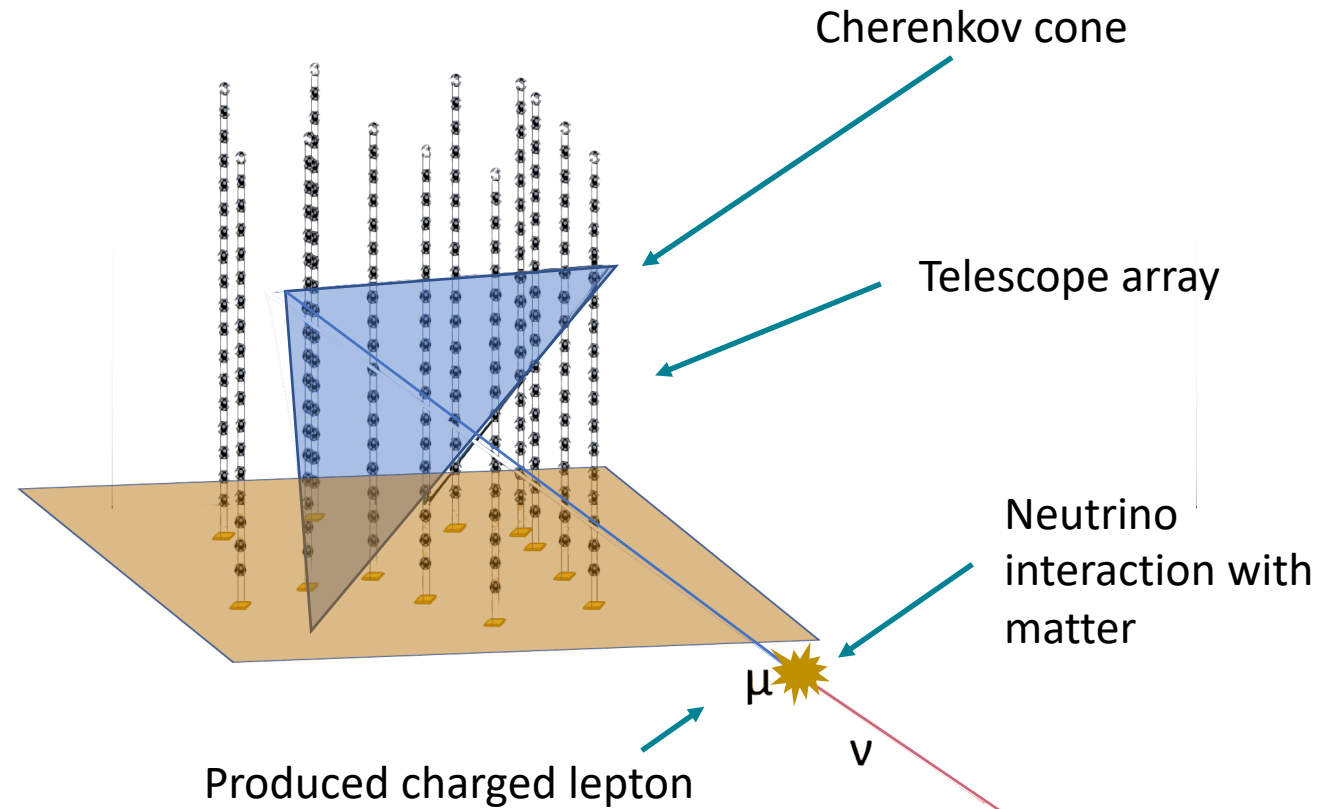
+ Not only physics: Environmental research (Earth & Sea Science).



# Characteristics of neutrino telescopes

Sensitive from few GeV to few PeV

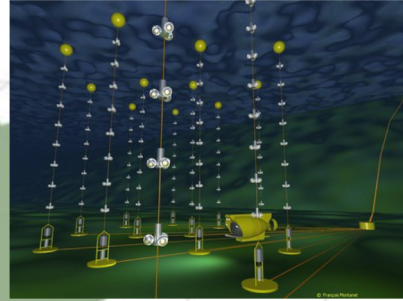
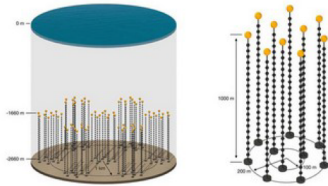
- Large volume: offers a large number of free target nucleons for neutrino interactions.
- Great depth: provides shielding against secondary particle produced by CRs.
- Transparent medium: allows propagation of Cherenkov photons emitted by relativistic charged particles produced by neutrino interactions



Time and position of photons to reconstruct the Cherenkov cone → neutrino incoming direction

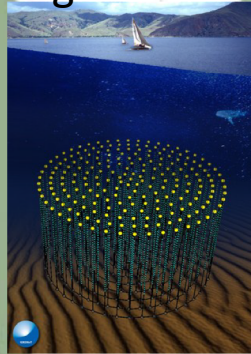
# Neutrino telescopes around the world

P-ONE  
R&D phase



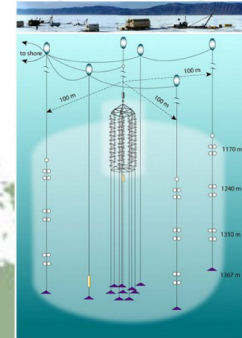
ANTARES , 0.01 km<sup>3</sup>  
2007 – Feb 2022

KM3NeT/ORCA,  
Under construction,  
taking data

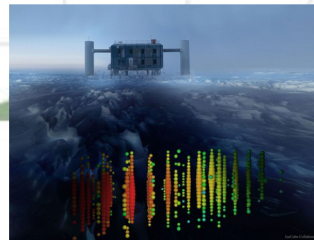


KM3NeT/ARCA,  
Under construction,  
taking data

Baikal/GVD,  
Under construction,  
taking data



IceCube, 1Km<sup>3</sup>



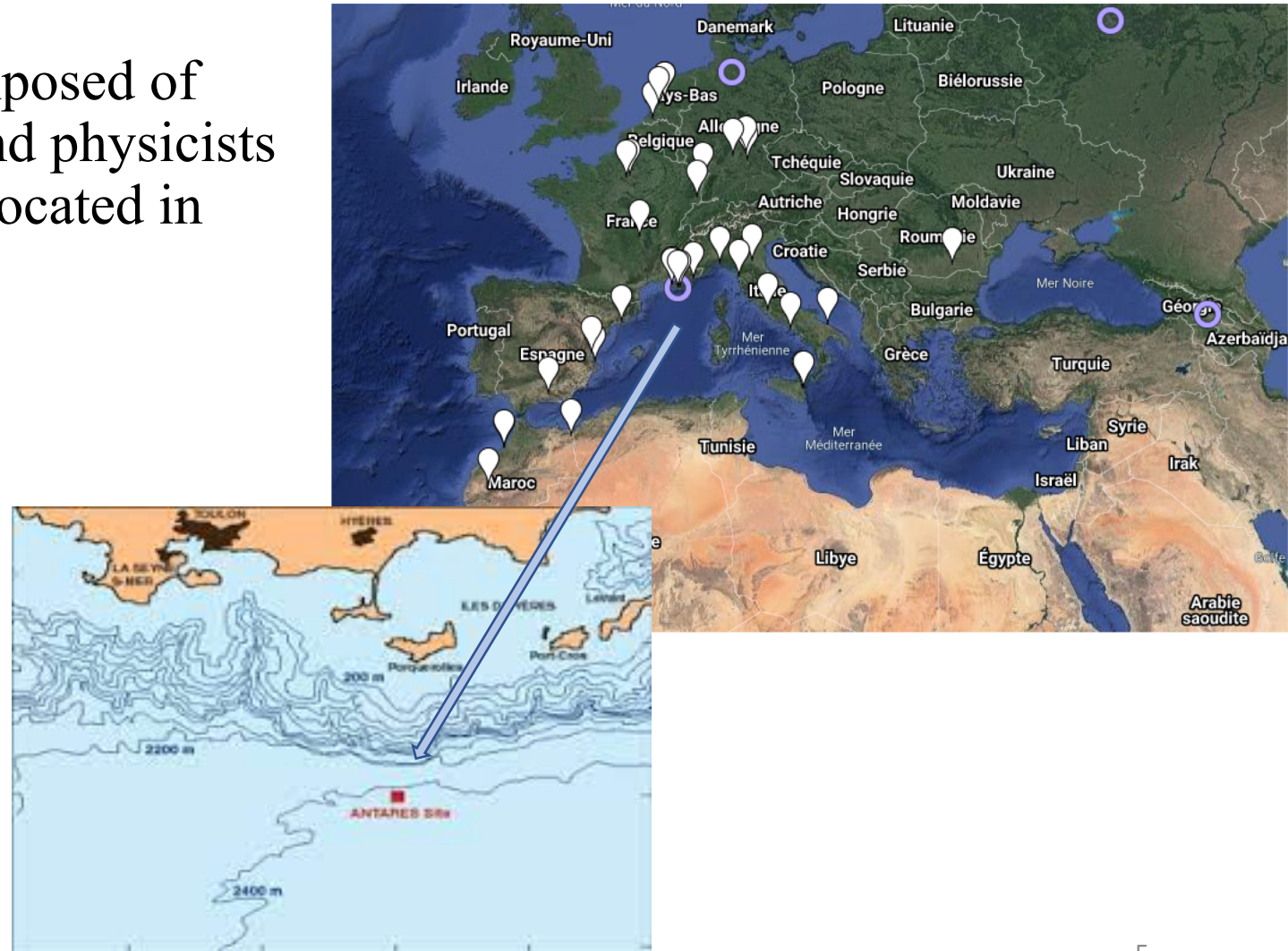
IceCube Gen 2,  
Projected



# The ANTARES Collaboration

The ANTARES collaboration is composed of around 150 engineers, technicians and physicists from different institutes principally located in Europe.

The collaboration was born in 1997.



# The ANTARES neutrino telescope

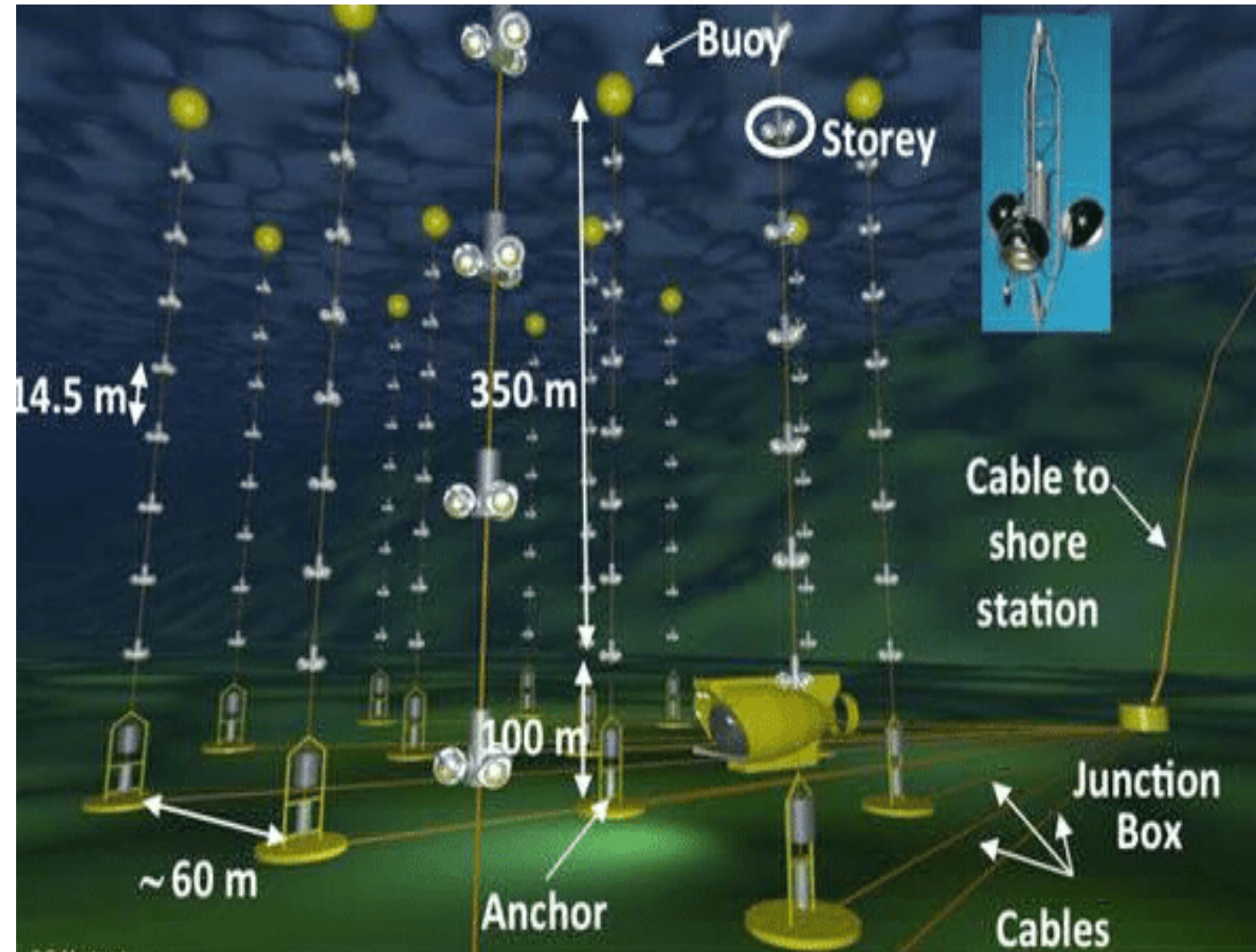
- Toulon, France
- ~2500 m depth
- Data taking: 2007-> February 2022 ♡

Array infrastructure:

- 12 lines
- 25 storeys (3 OM x storey)
- ~900 PMTs
- Volume =  $0.01 \text{ km}^3$

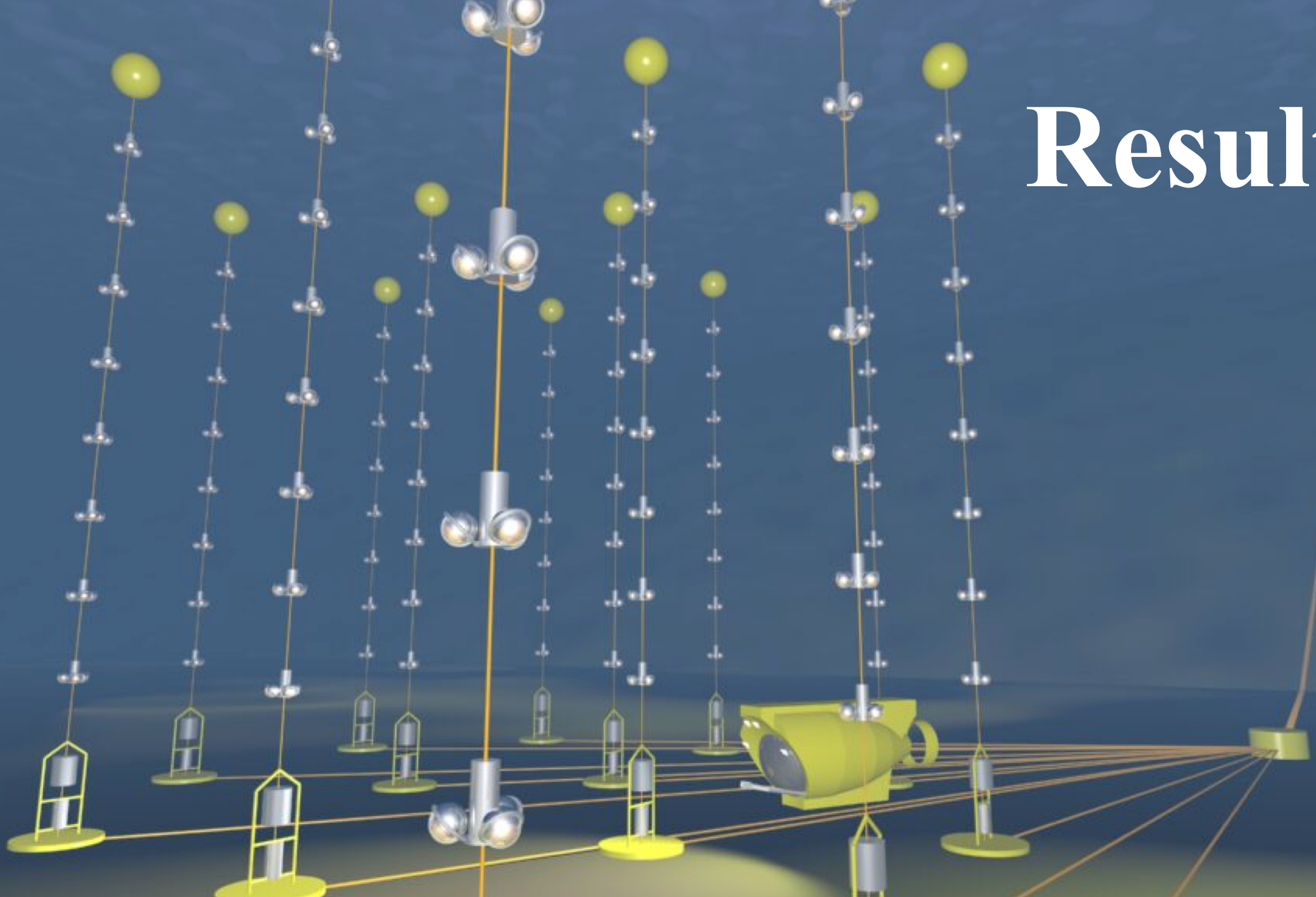
→ > 10000 neutrinos recorded

→ ~100 publications in the field of neutrino physics and astrophysics





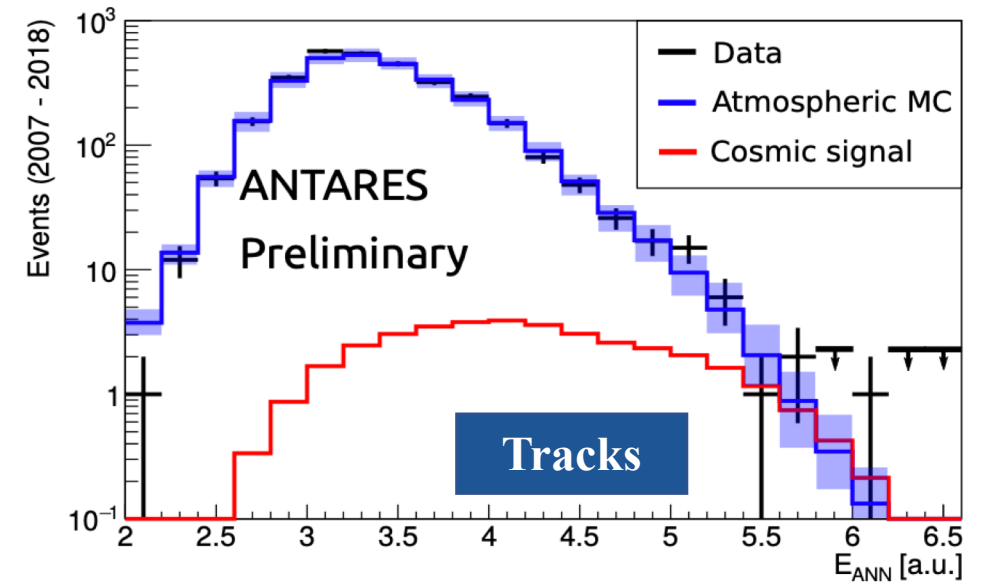
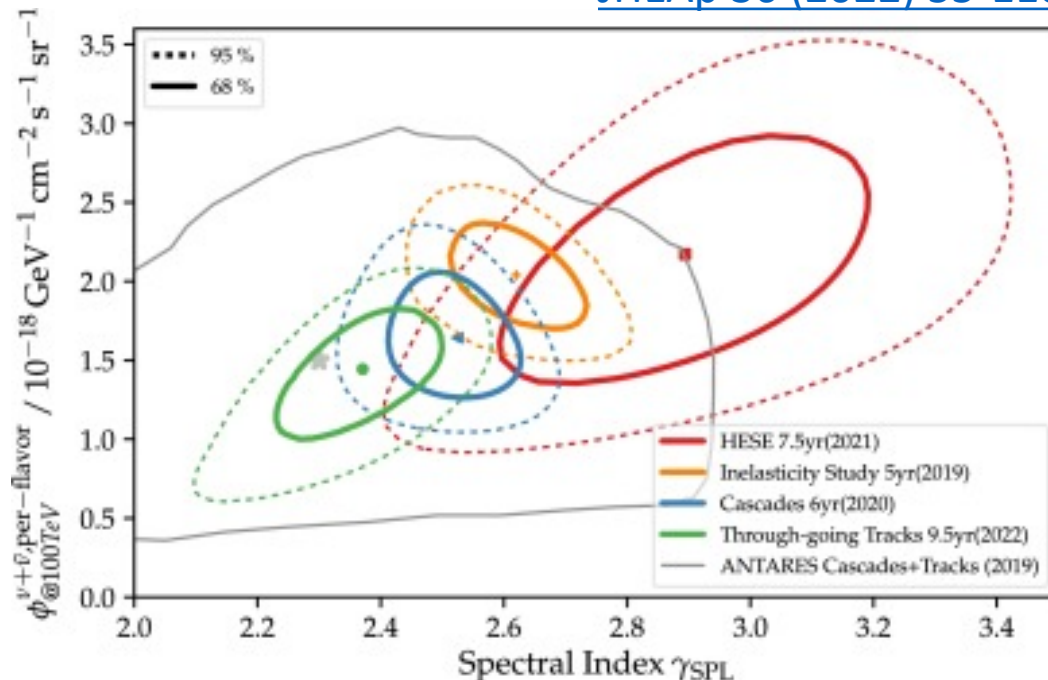
# Results



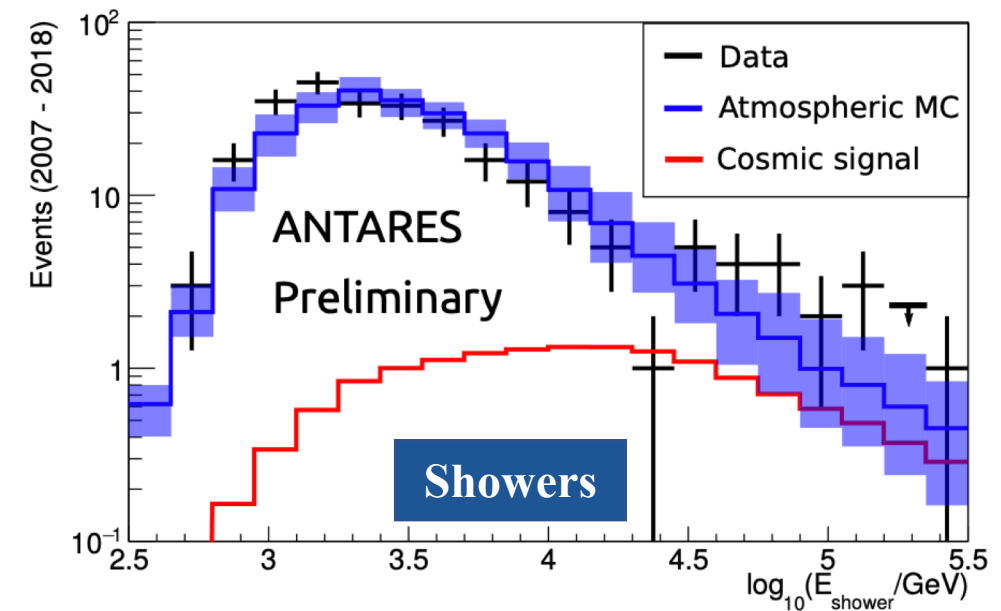
# Cosmic diffuse emission

- IceCube has confirmed the existence of high-energy cosmic neutrinos in 2013
- ANTARES using data from 2007-2018 (3330 days) has observed  $1.8 \sigma$  excess  $\rightarrow$  50 events observed while  $36.1 \pm 8.7$  expected from background (tracks + showers).
- New results are in preparation.

[JHEAp 36 \(2022\) 55-110](#)



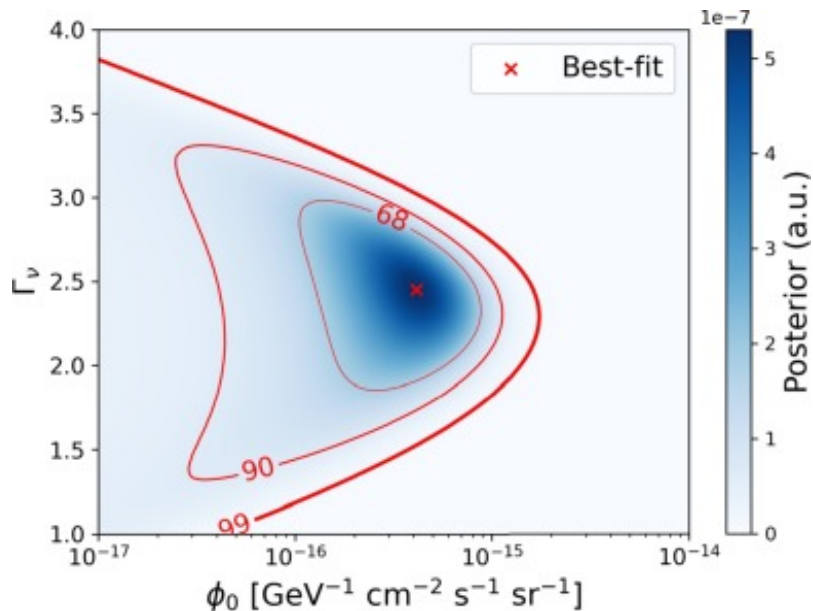
[PoS ICRC2021 \(891\)](#)



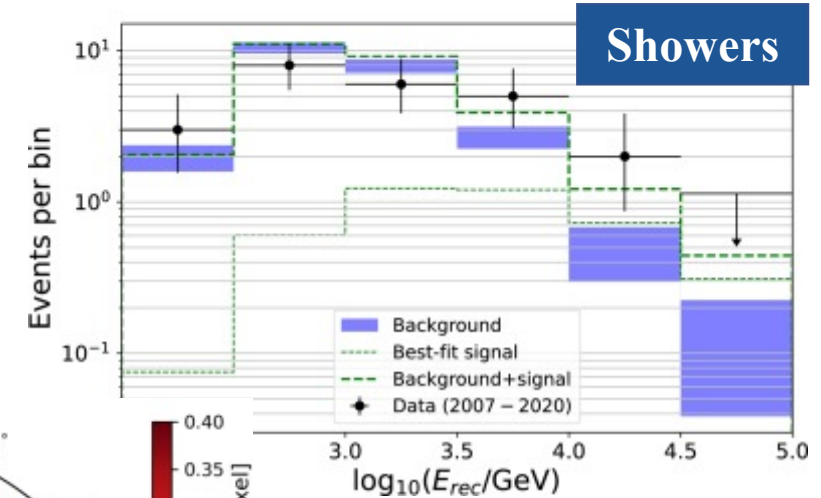
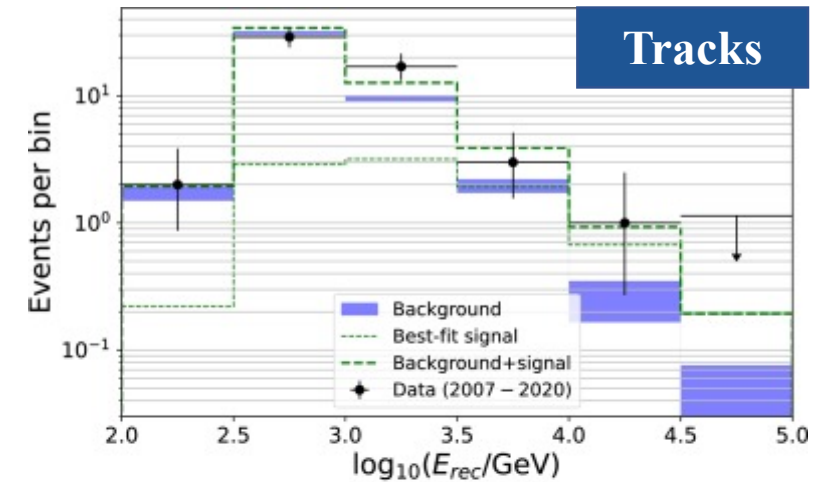
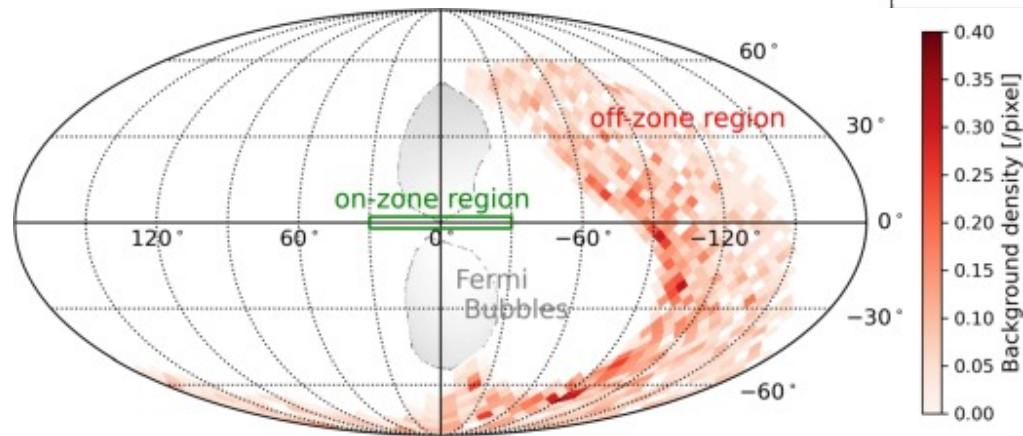


# Galactic diffuse emission

- This year two announcements for Galactic component contributing to the cosmic neutrino diffuse flux: ANTARES ( $\sim 2 \sigma$ ) and IceCube ( $\sim 4.5 \sigma$ ).
- ANTARES ON/OFF analysis at  $E > 1$  TeV detects  $21+13$  track+shower events while  $11.7 \pm 0.6 + 11.2 \pm 0.9$  events are expected  $\rightarrow 2.2+0.2 \sigma$  excess.

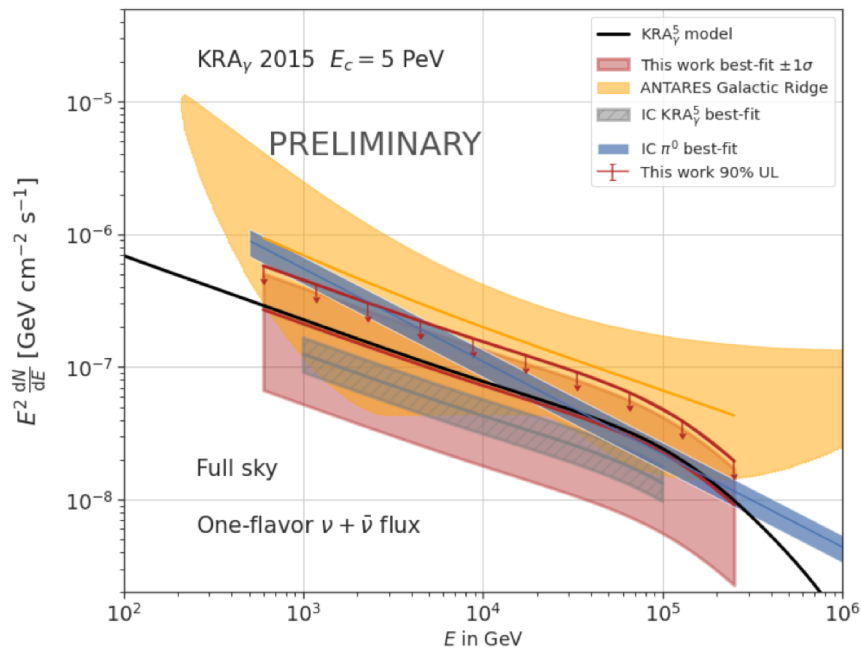


[Phys.Lett.B 841 \(2023\) 137951](#)

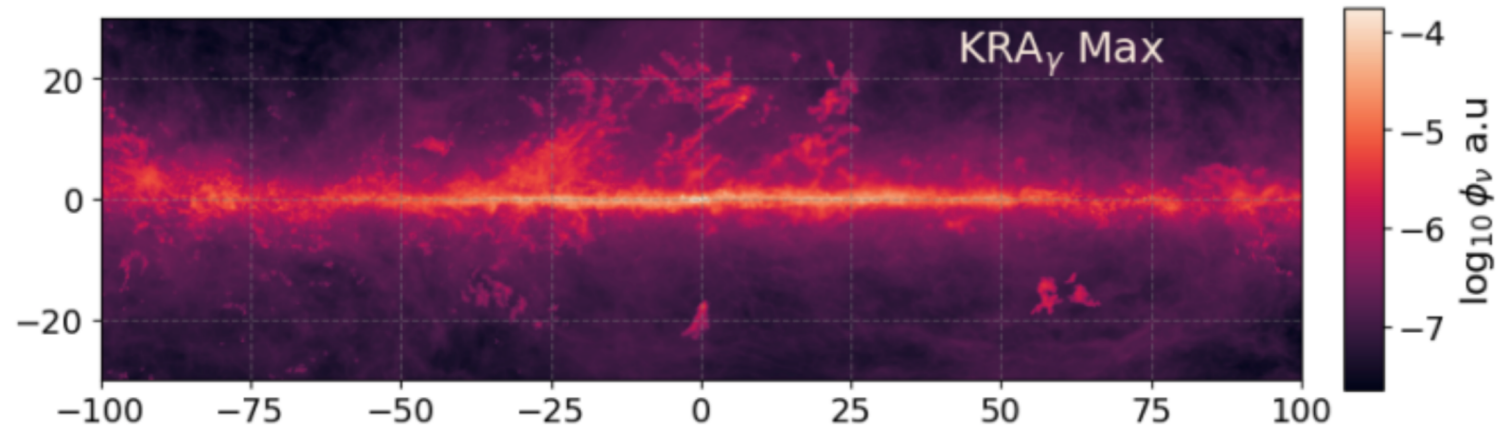


# Galactic diffuse emission

- ANTARES template analysis using the most recent  $\text{KRA}_\gamma$  models shows a 1.5-1.8  $\sigma$  excess.
- This is the same method used by IceCube ( $\sim 4.5 \sigma$ ).



[PoS ICRC 2023 \(1084\)](#)



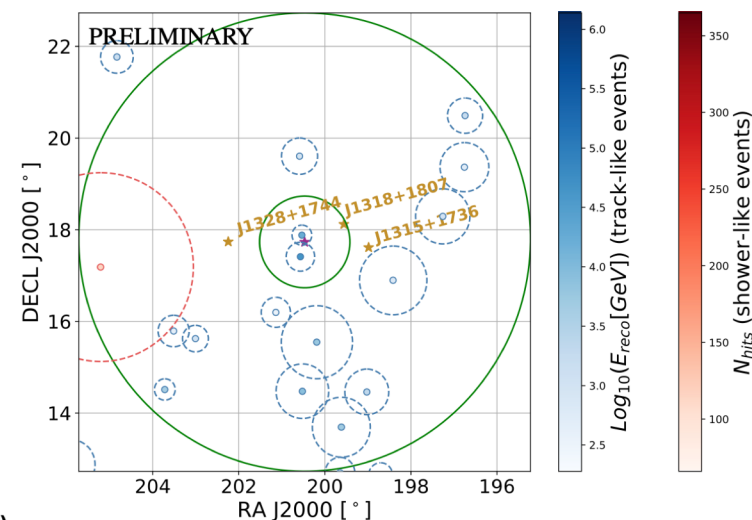
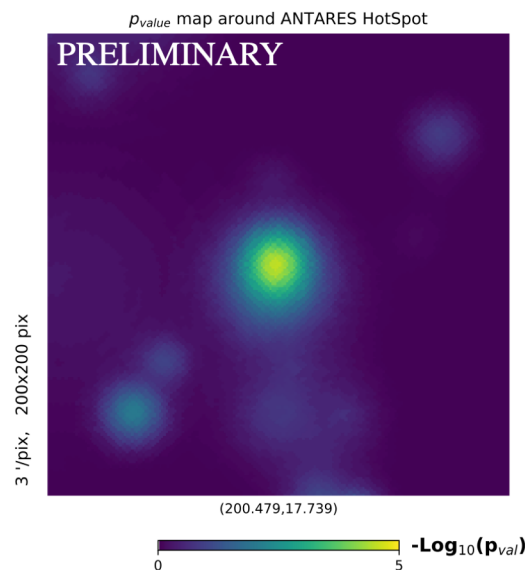
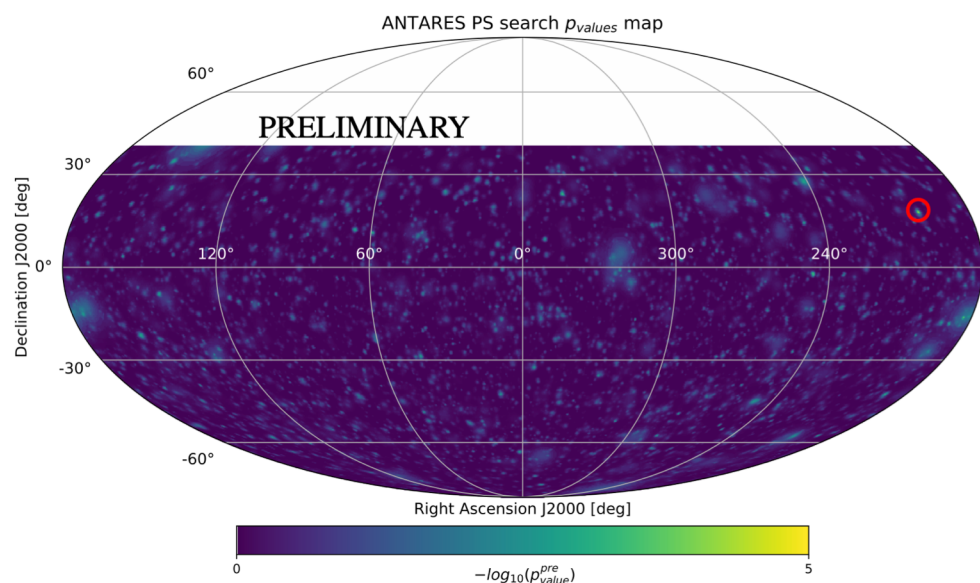


# Search for neutrino sources



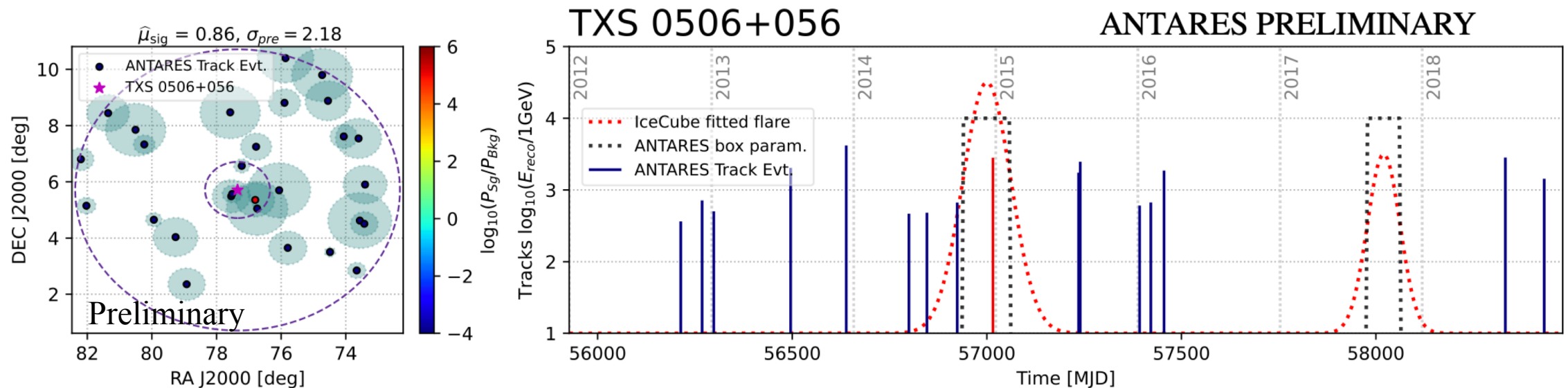
- Several types of searches performed: time-integrated, all-sky search and candidate list search
- All-sky time-integrated search: the most significant spot, (RA, dec) = (200.5, 17.7)°, has a pre(post)-trial significance of 4.0(1.2)  $\sigma$ , with no evident association (closest source is 1° away).
- Candidate list search: 163 sources were tested to reduce the trial factor. No significant excess observed but some sources show interesting upper fluctuations.  
→ Best candidates are **MG3 J225517+2409** and **3C403** with 3.4(1.7)  $\sigma$  pre(post)-trial significance.

[PoS ICRC 2023 \(1128\)](#)



# Time-dependent Source Searches

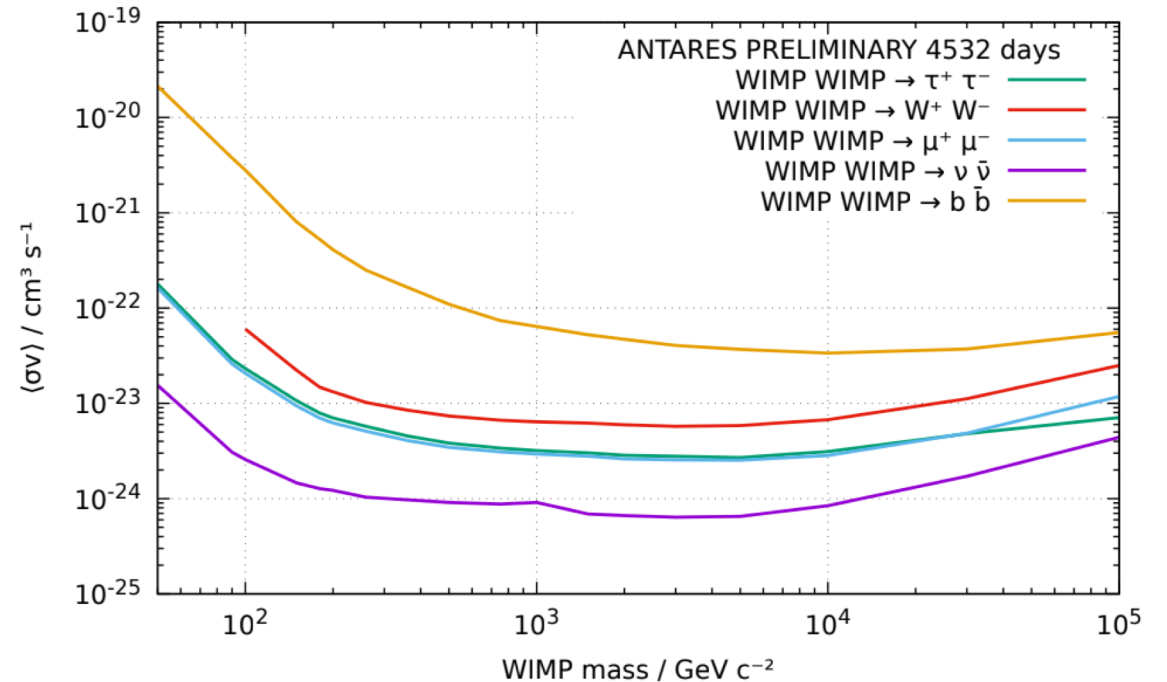
- Time-dependent search: using the temporal information from external observatories
- Tested potential neutrino flares by IceCube [ApJL 920 L45 (2021)] with ANTARES data.
- Out of 36 sources, 4 have fitted signal ( $\sim 2\sigma$  upper-fluctuations).
- TXS 0506+056 has 1 event compatible with the “orphan” neutrino flare (2014-2015). Overall significance comparable to time-integrated search, with 3 times less signal.
- Searches based on Electro-Magnetic observatories ongoing.





# Dark matter searches from Galactic centre

- Limits on  $\langle \sigma v \rangle$  from WIMP annihilation in galactic center
- ANTARES **2007-2022**, 4532 days
- 11850 tracks, 235 showers
- Assuming NFW halo profile with 100% branching ratio for each annihilation channel



[PoS ICRC 2023 \(1375\)](#)



# Other analysis

Full list of publications:

<https://antares.in2p3.fr/publications/>

- Exotic physics: search for magnetic monopoles [[JHEAp 34 \(2022\)](#)], Limits on the nuclearite flux [[JCAP01\(2023\)012](#)]
- Neutrino physics: Neutrino oscillations [[JHEP 06 \(2019\) 113](#)], Non-standard Interactions [[JHEP 07 \(2022\) 048](#)]
- Multi-messenger searches: with HAWC through AMON [[ApJ 944 166 \(2023\)](#)], GRBs [[JCAP03\(2021\)092](#)], GWs [[JCAP04\(2023\)004](#)]
- Catalog analysis [[ApJ 911 48 \(2021\)](#)]
- Combined analyses:
  - Dark matter with IceCube [[Phys. Rev. D 102 \(2020\)](#)]
  - Sources with IceCube [[ApJ 892 92 \(2020\)](#)]
  - Correlations of neutrinos (with IceCube) with UHE Cosmic rays with AUGER [[ApJ 934 164 \(2022\)](#)]
- Multi-disciplinary facility: Sperm whale [[Sci Rep . 2017 Apr 12;7:45517](#)]

# What is next?

- The next generation neutrino telescope KM3NeT is under construction and is already taking data
- KM3NeT has an improved design, with two detectors (ARCA & ORCA) sensitive from MeV to PeV energies.
- Expected to become complete by 2028

ANTARES



KM3NeT

# Conclusions

- ANTARES has taken data from 2007 to early 2022
- More than 100 papers have been published in peer-review journals in the field of neutrino searches
- ANTARES was part of the multi-messenger world collaborating with other experiments
- Final legacy analysis are ongoing and will be finalized in 2024







Thanks for the attention!