



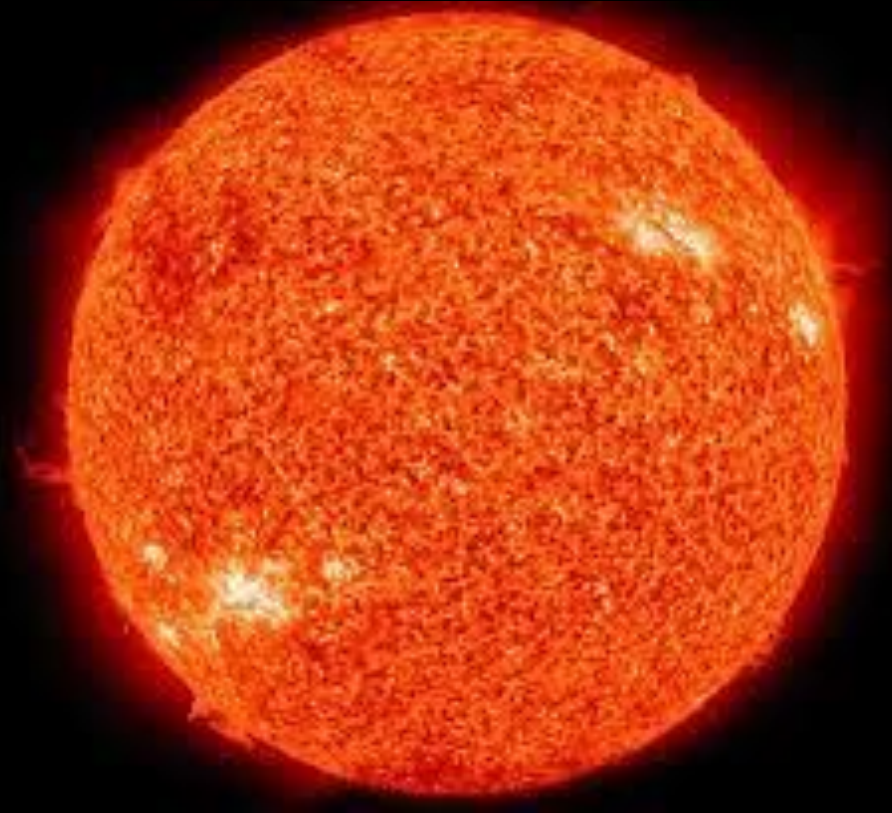
The IceCube Neutrino Observatory: 15 years of achievement

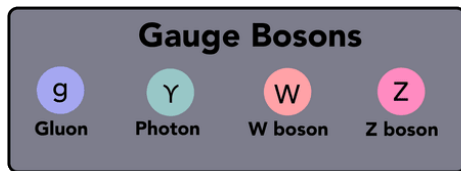
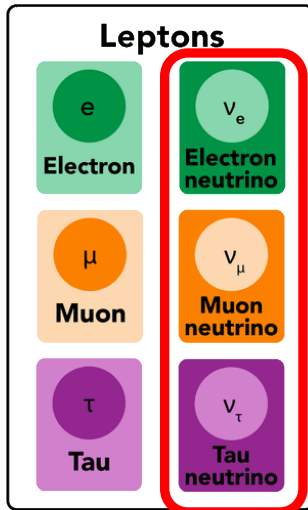
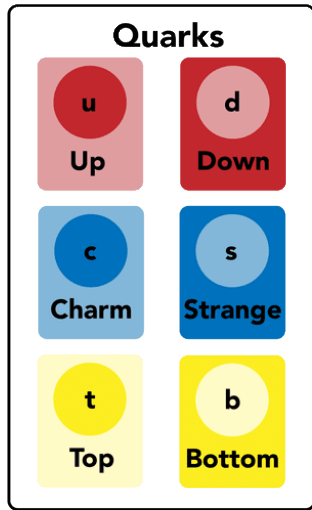
Erin O'Sullivan, Uppsala University

15 year IceCube symposium

Chiba University

“With X-Rays, which penetrate more than ordinary light, you can see inside your hand. With neutrinos, which penetrate much more even than X-rays, you can look inside the Sun” – Ray Davis Jr.



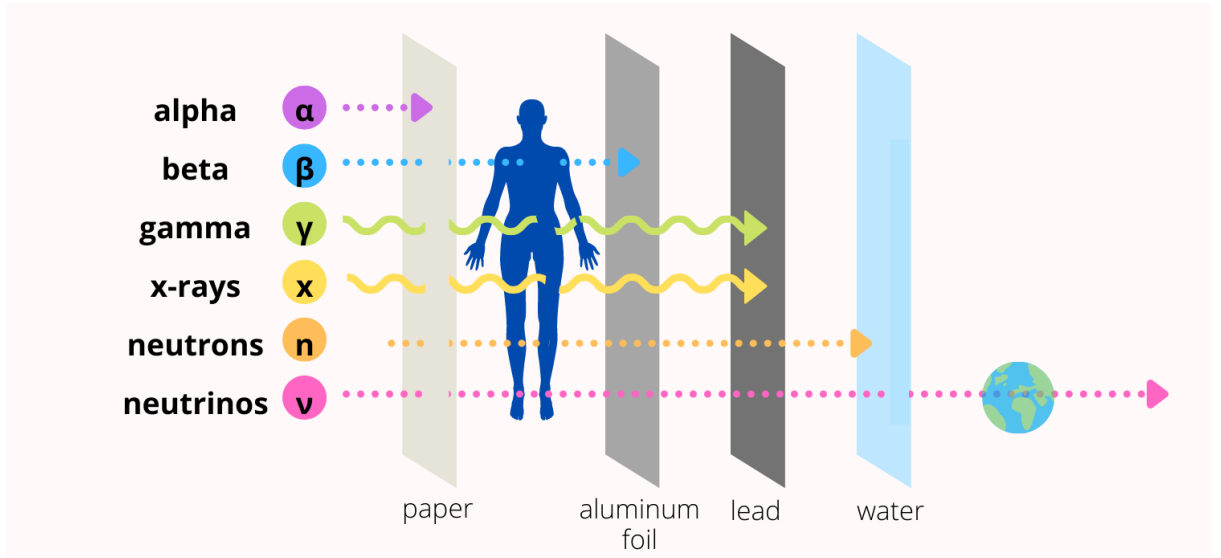


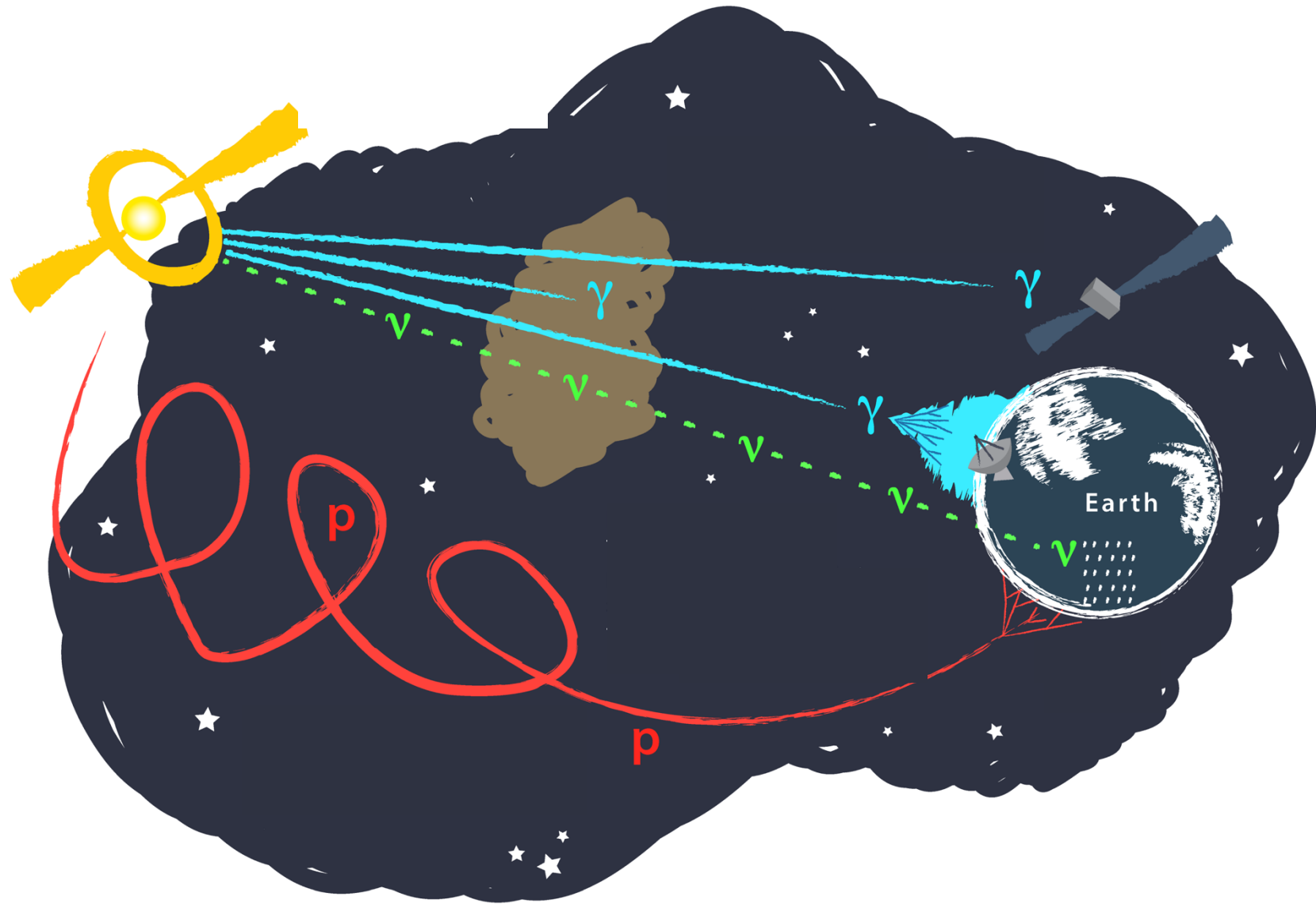
Neutrinos

No charge

Nearly massless

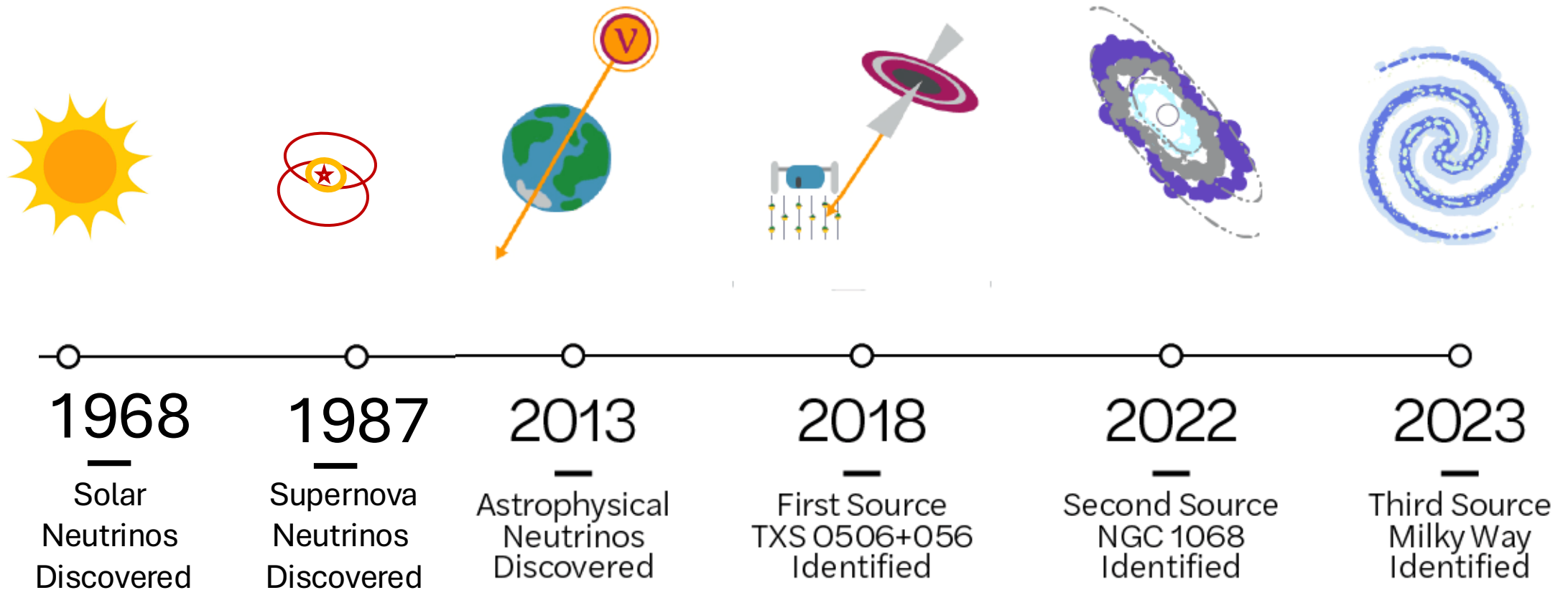
Three “flavours”

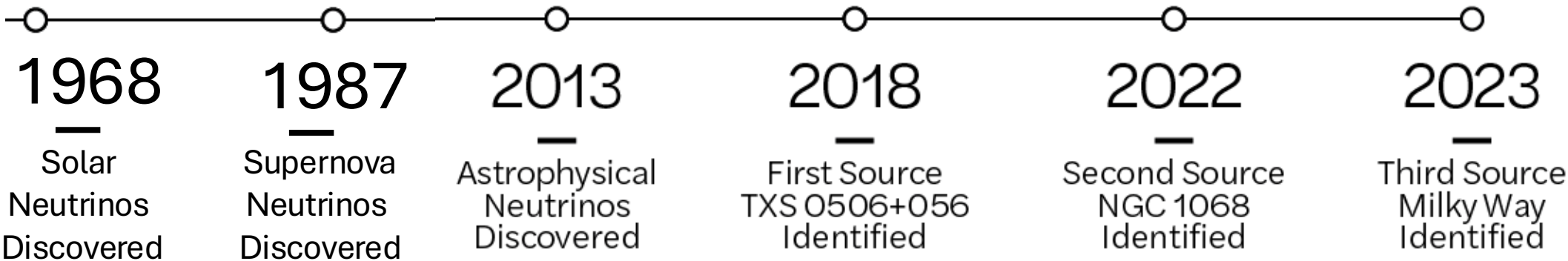
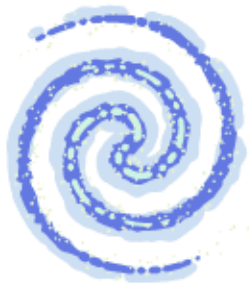
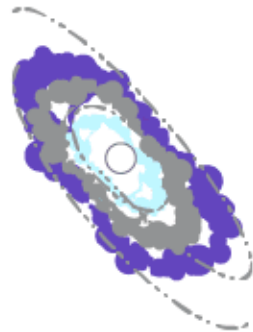
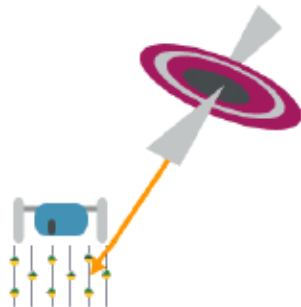
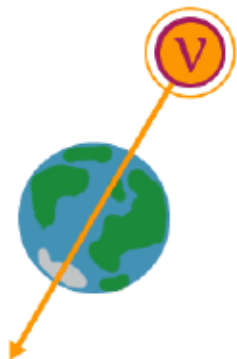
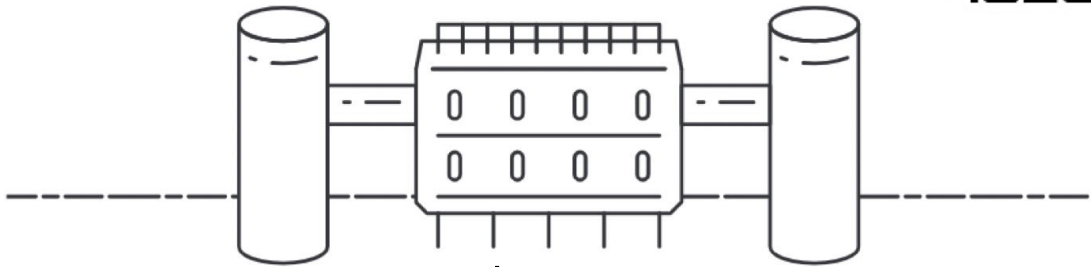


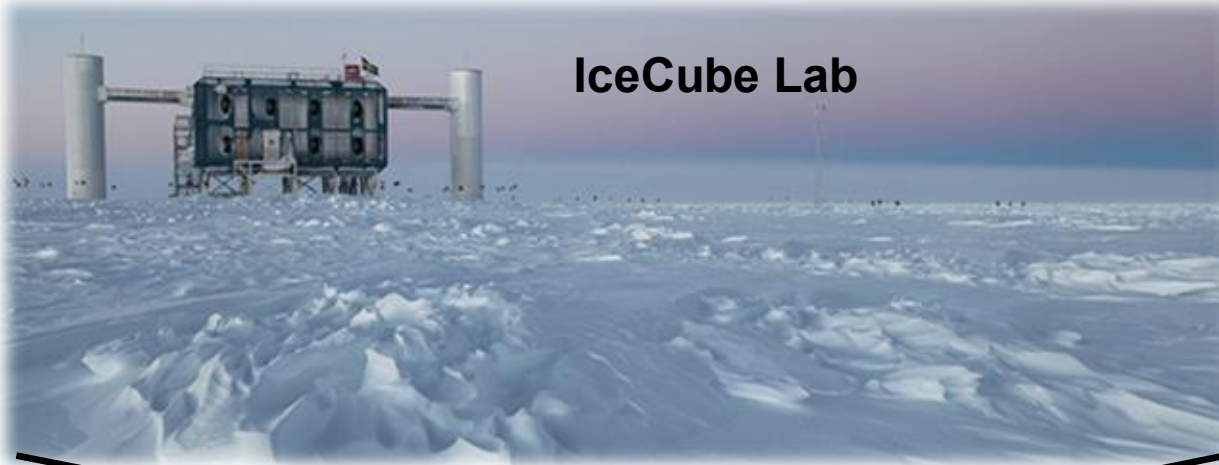


Neutrinos are direct particle messengers from astrophysical environments

A timeline of neutrino astronomy







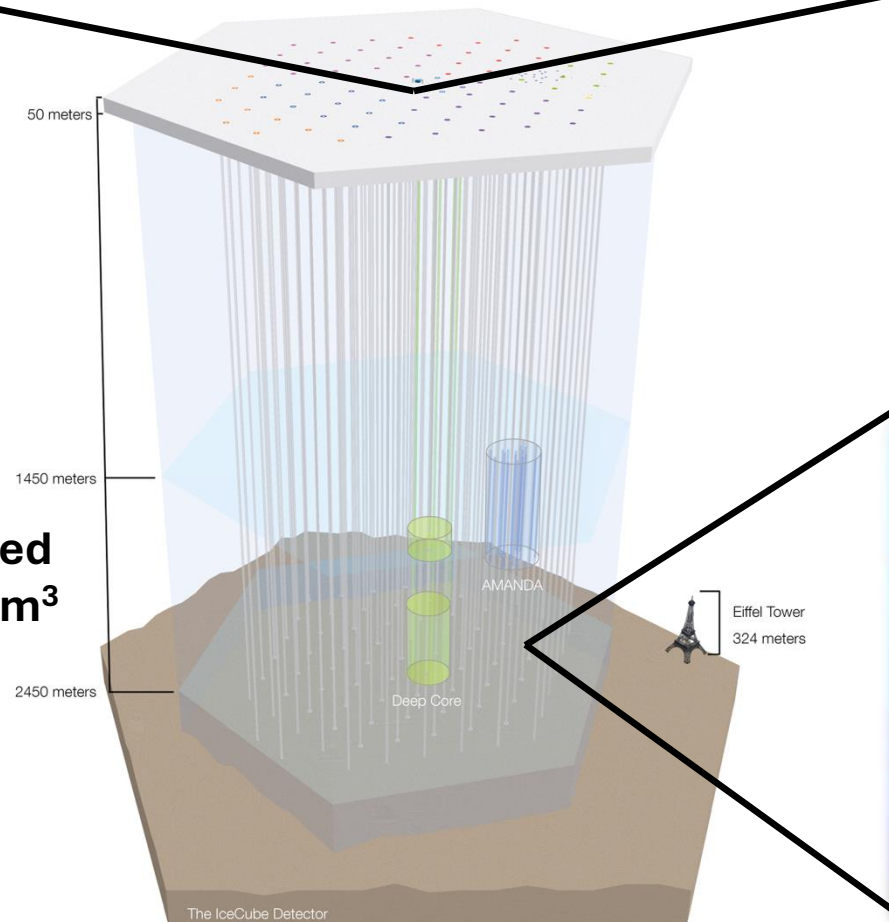
IceCube Lab



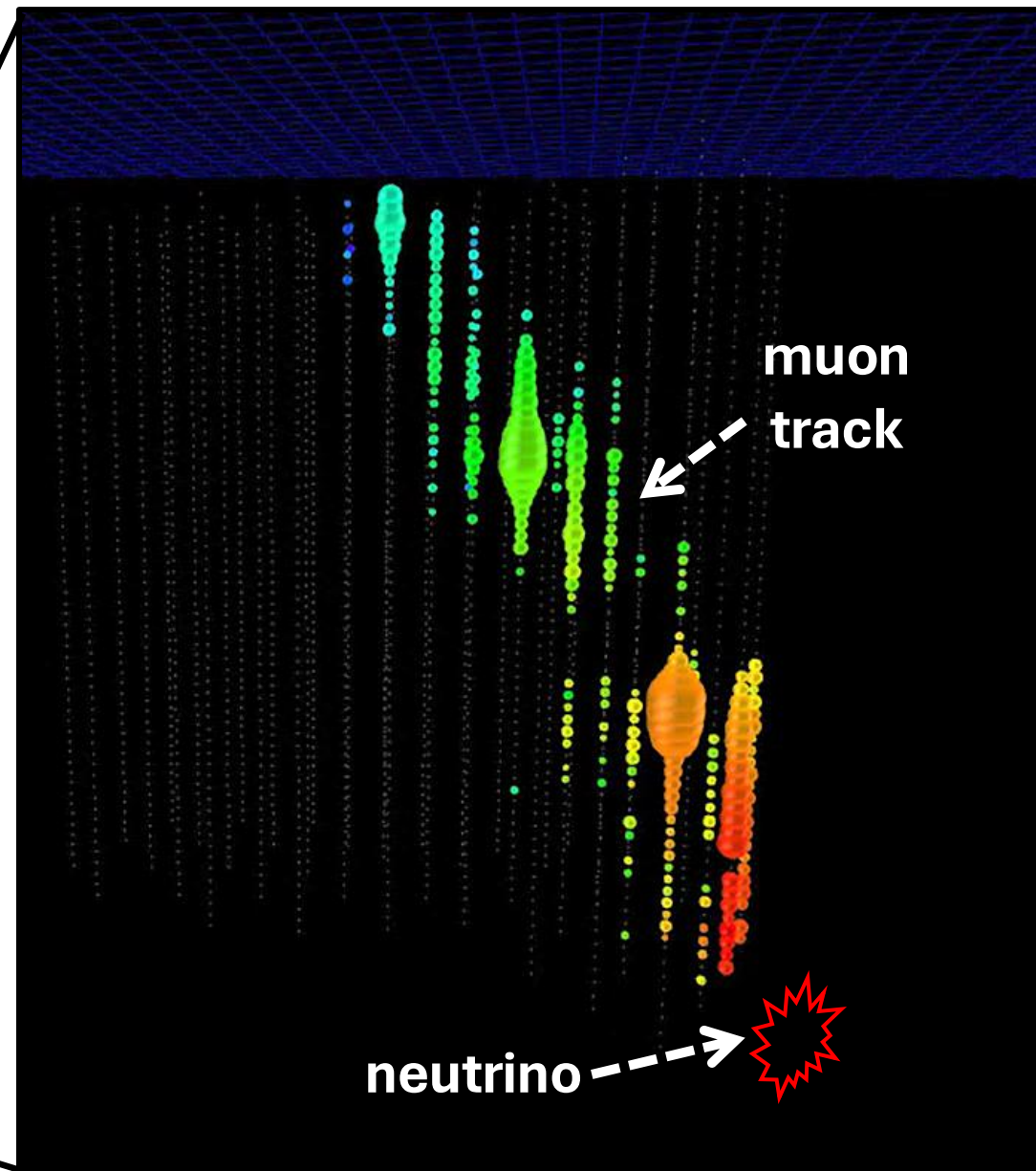
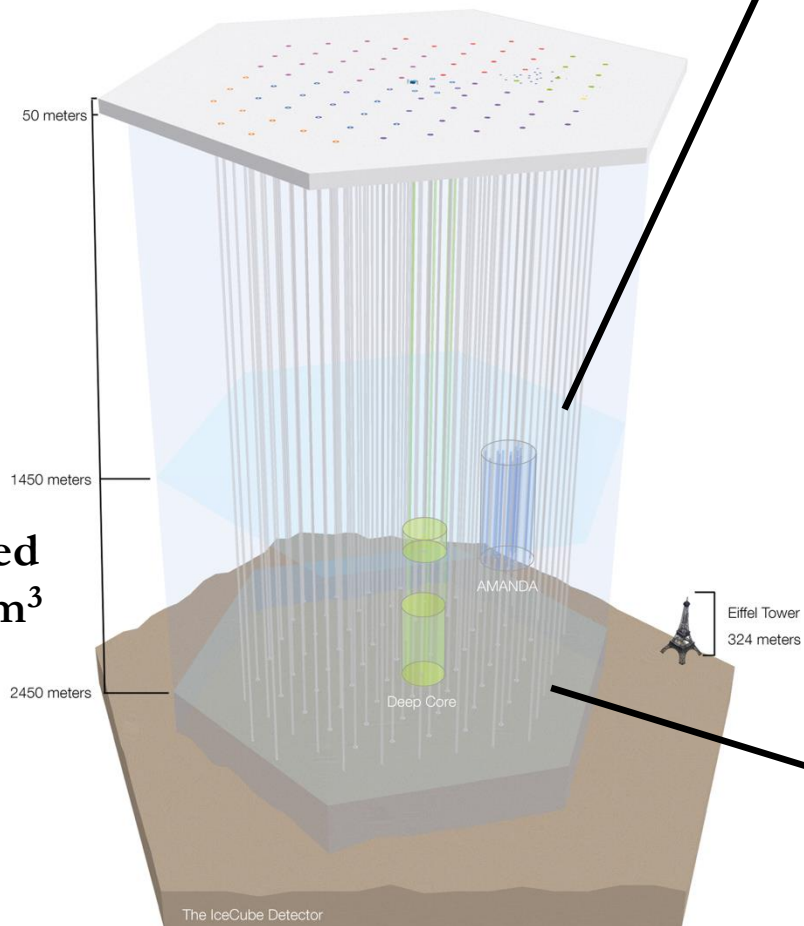
ICECUBE

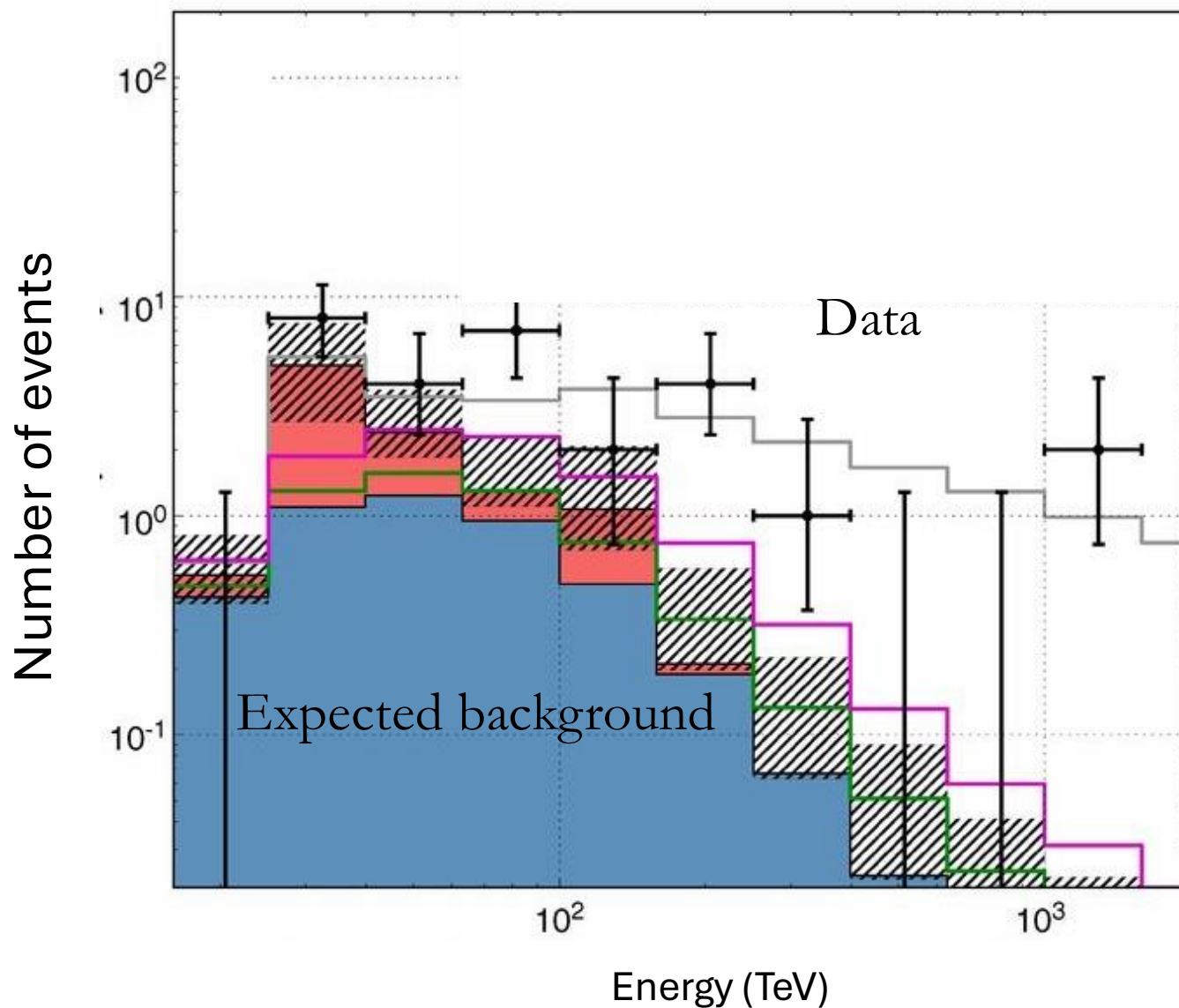
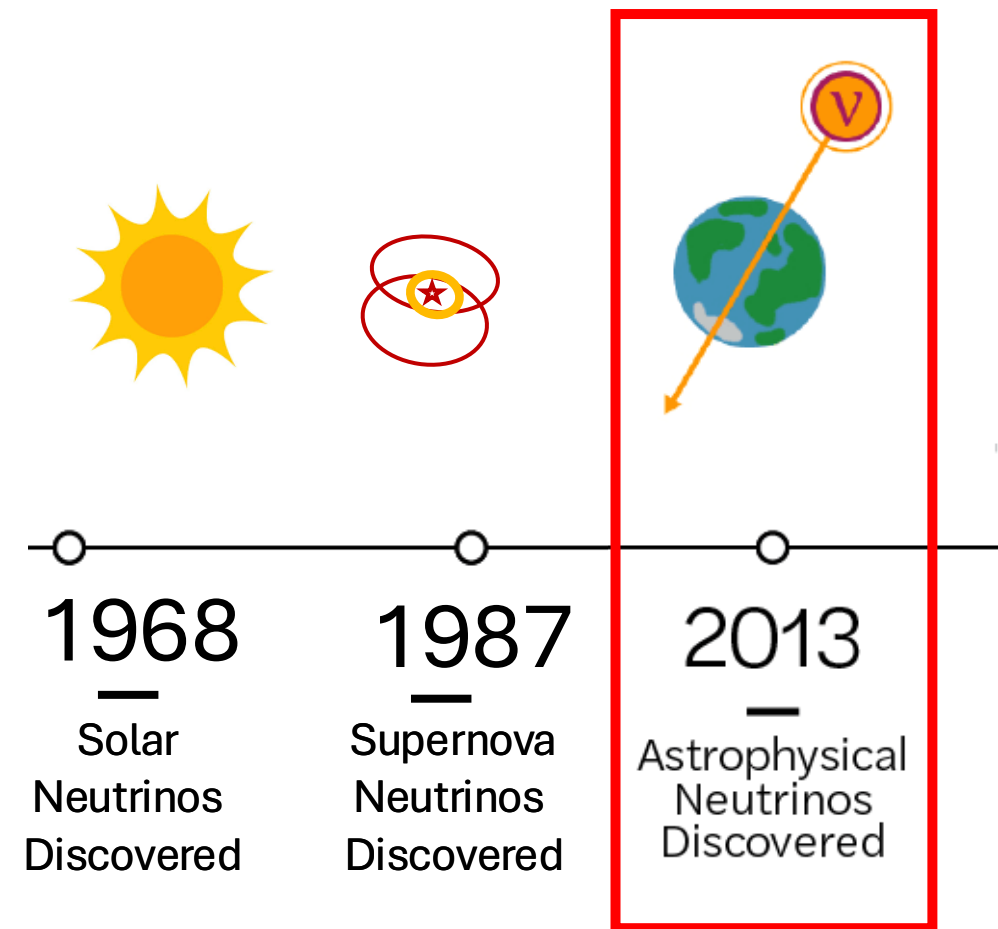
86 Strings, 5160 sensors

**Instrumented
volume: 1 km³**



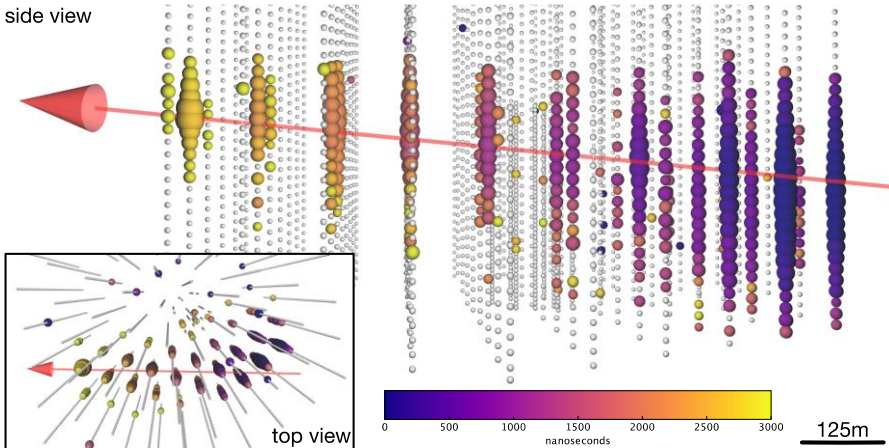
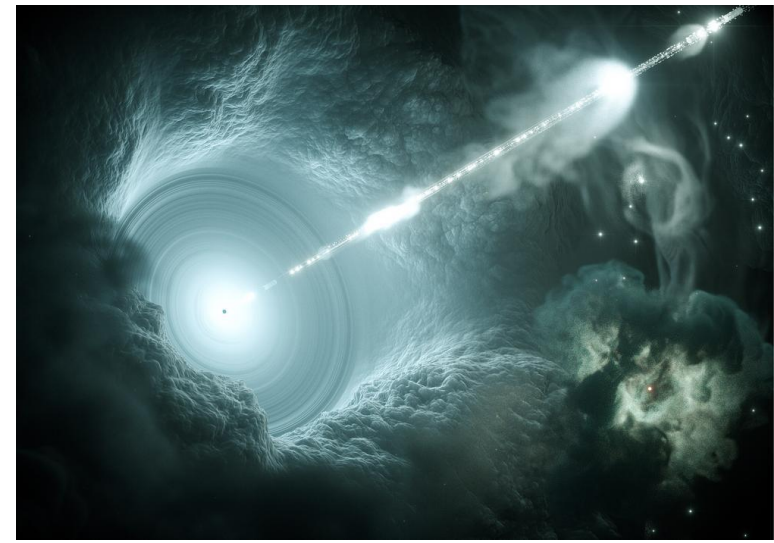
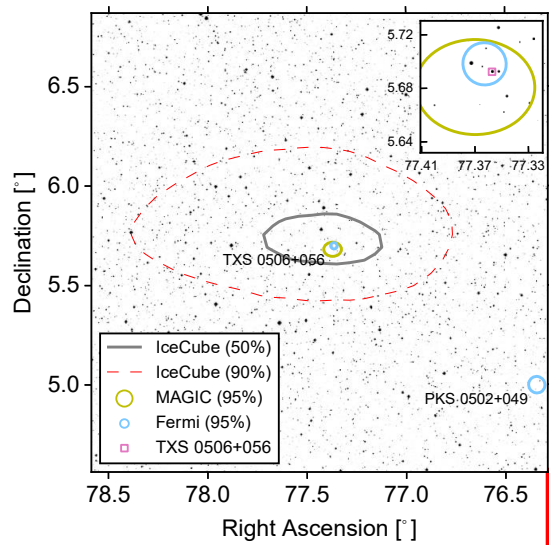
Instrumented
volume: 1 km³



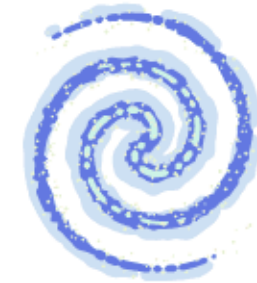
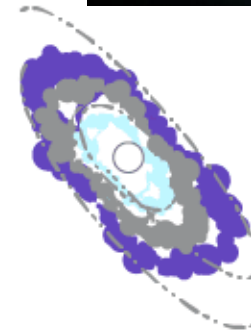
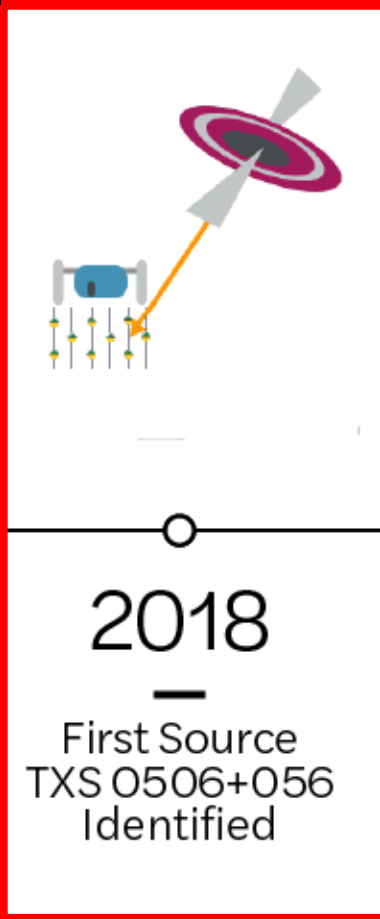


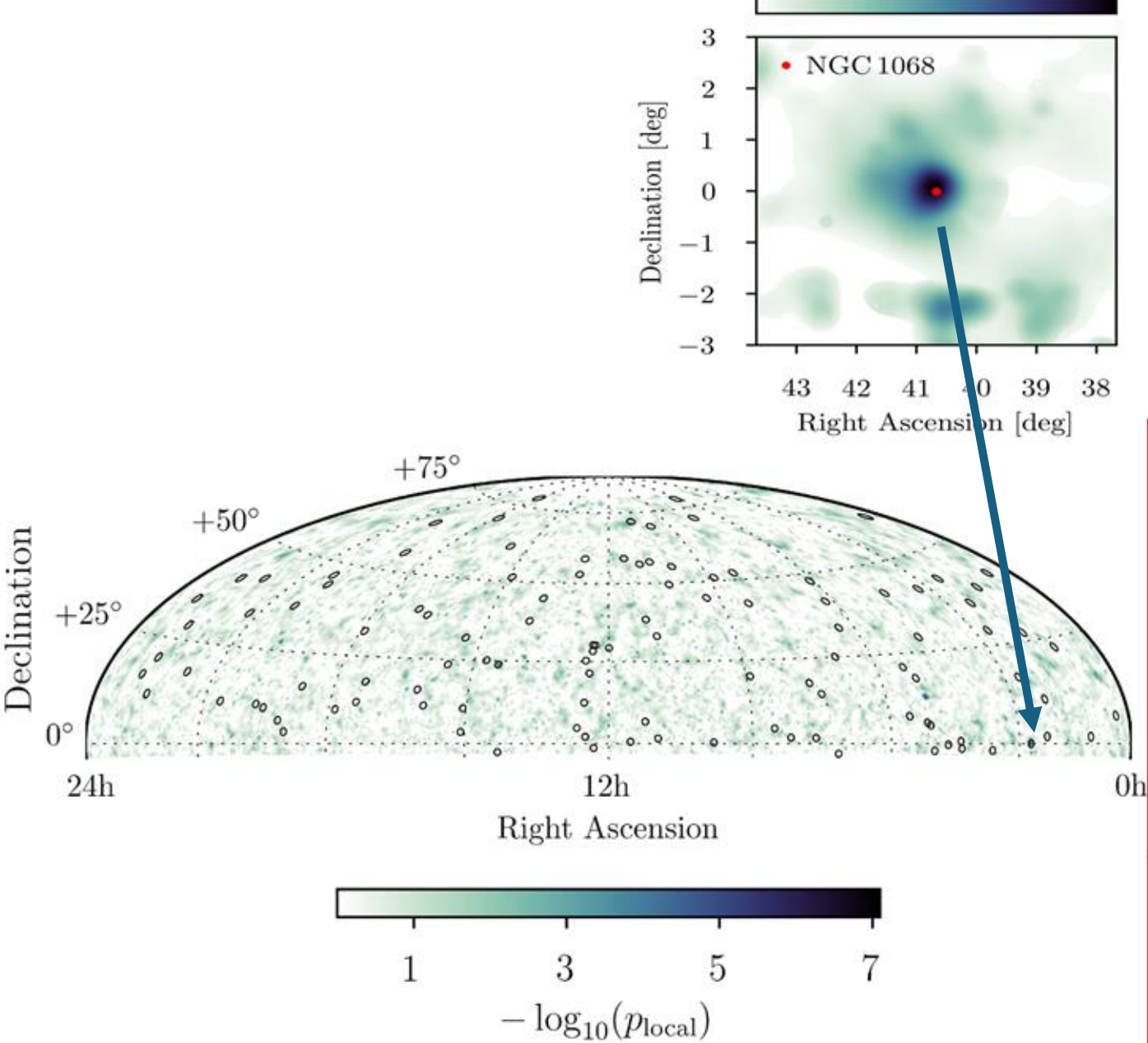
IceCube Collaboration. Science 342, issue 6161 (2013)

(Now detected more than a million neutrinos to date!)



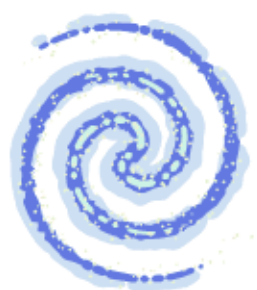
IceCube Collaboration, FERMI-LAT, MAGIC, ASAS-SN, H.E.S.S., INTEGRAL, KANATA, KISO, KAPTEYN, LIVERPOOL TELESCOPE, SUBARU, SWIFT/NUSTAR, VERITAS, VLA/17B-403, Science 361, issue 6398 (2018)





2022

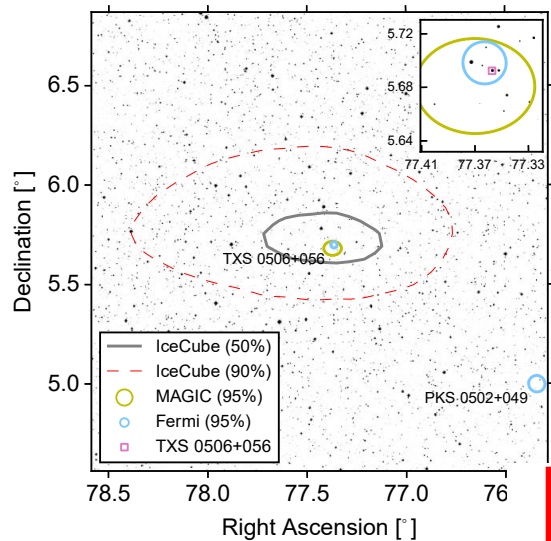
Second Source
NGC 1068
Identified



2023

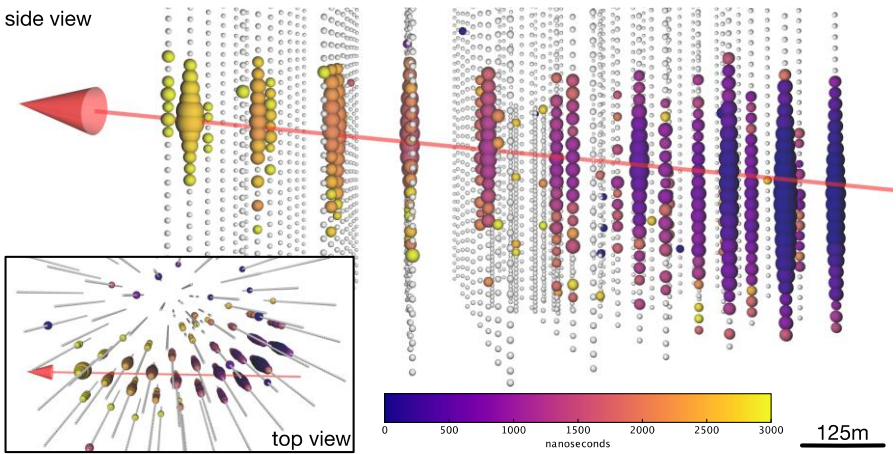
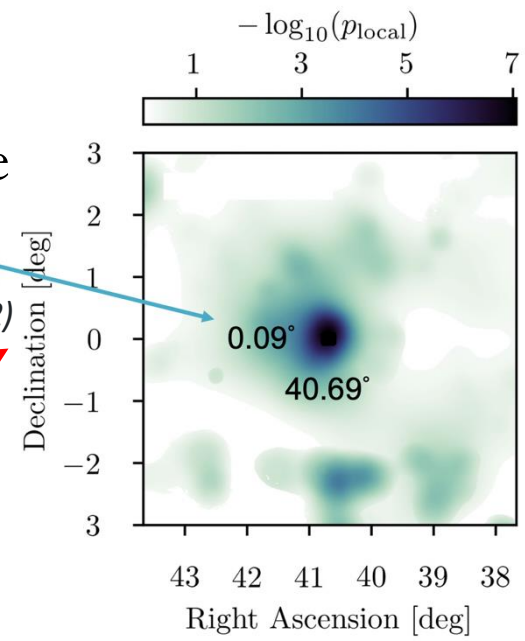
Third Source
Milky Way
Identified

First transient,
multi-messenger
source

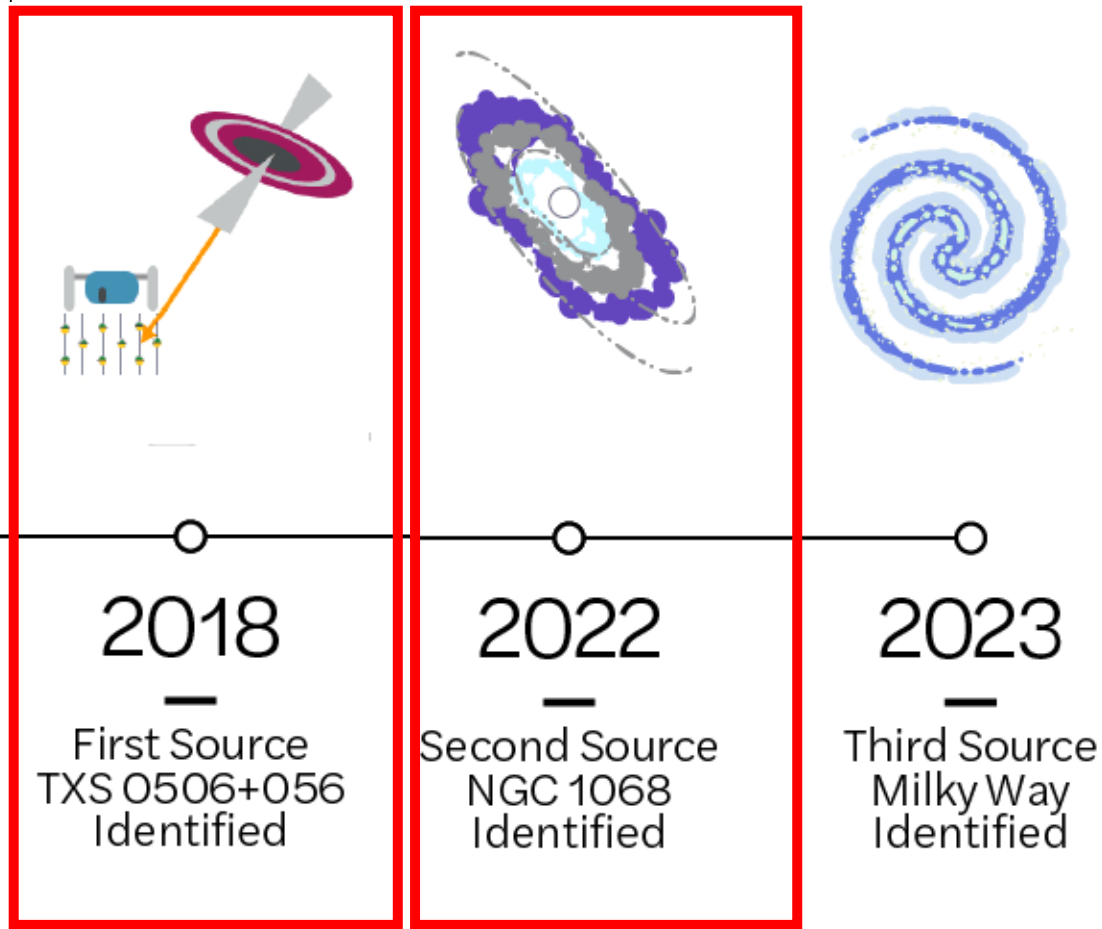


First steady-state source
detected in neutrinos alone

IceCube Collaboration Science 378 (2022)



*IceCube Collaboration, FERMI-LAT, MAGIC, ASAS-SN,
H.E.S.S., INTEGRAL, KANATA, KISO, KAPTEYN, LIVERPOOL
TELESCOPE, SUBARU, SWIFT/NUSTAR, VERITAS, VLA/17B-
403, Science 361, issue 6398 (2018)*

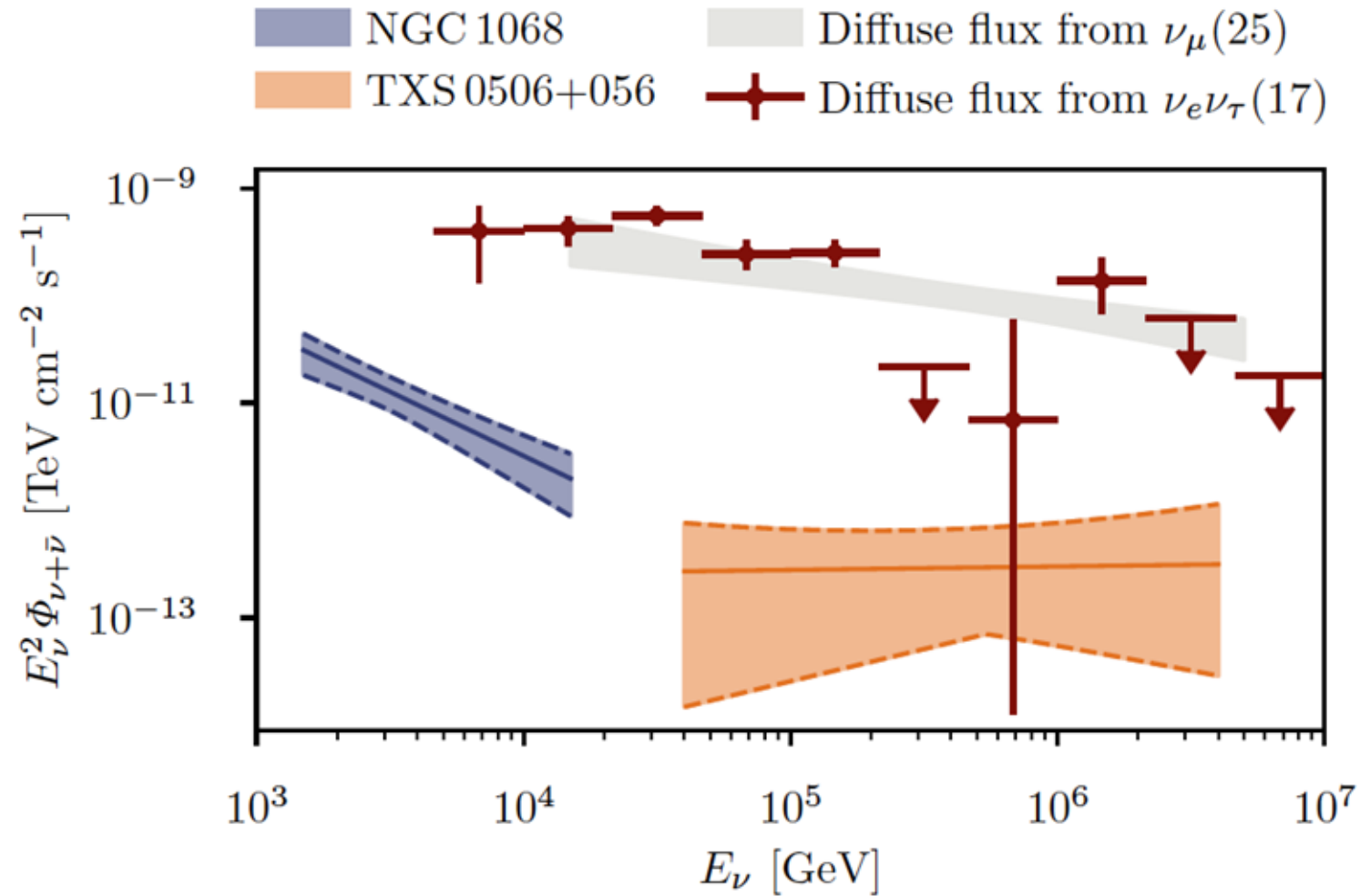


Implications of the two observed sources of HE neutrinos

Active galaxies may contribute to significant fraction of extragalactic neutrino flux.

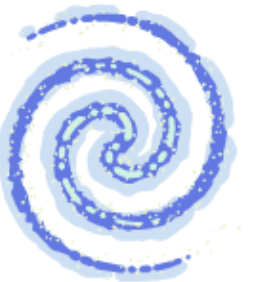
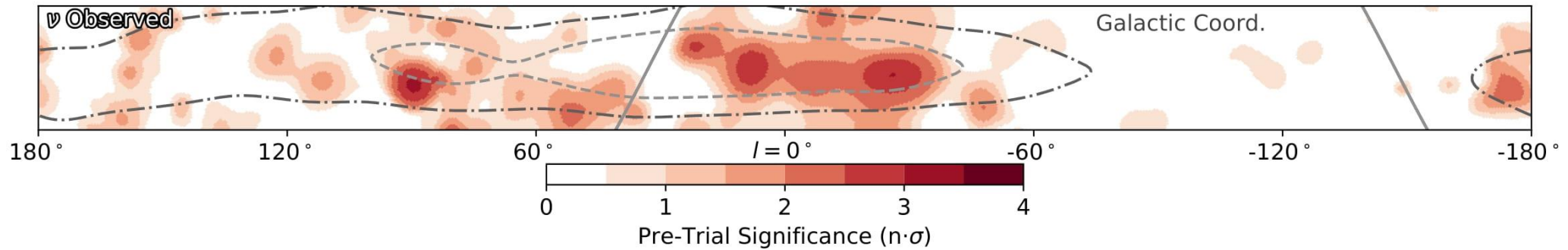
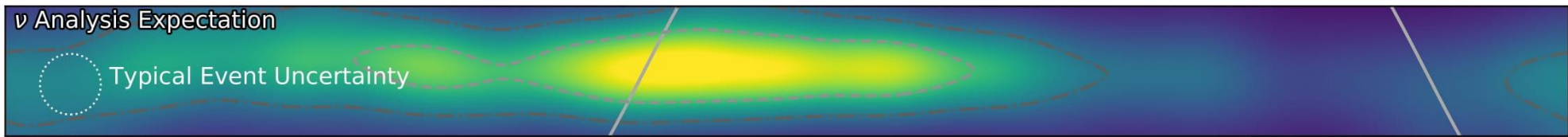
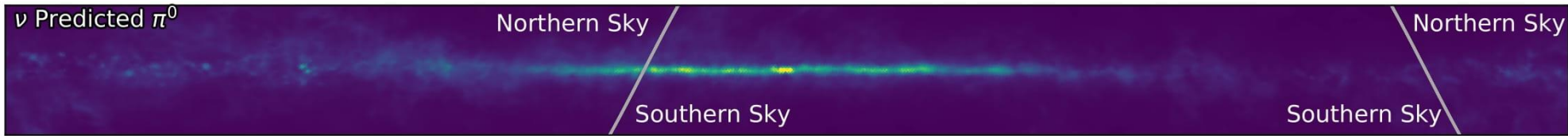
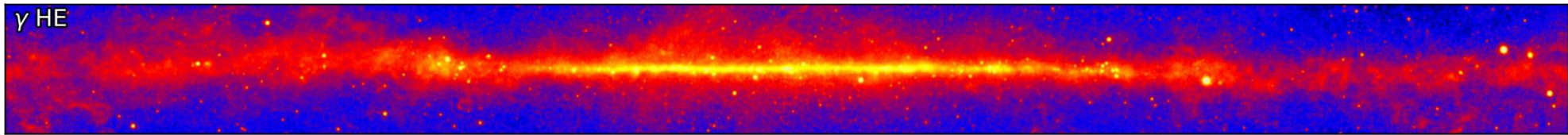
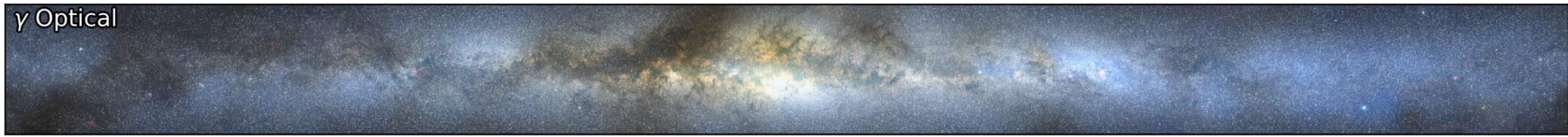
NGC 1068 opaque to high-energy gamma-rays

The properties of neutrino emission from NGC 1068 and TXS 0506+056 are different.



[25] IceCube. ApJ 928, 50 (2020)

[17] IceCube. PRL 125, 121104 (2020)

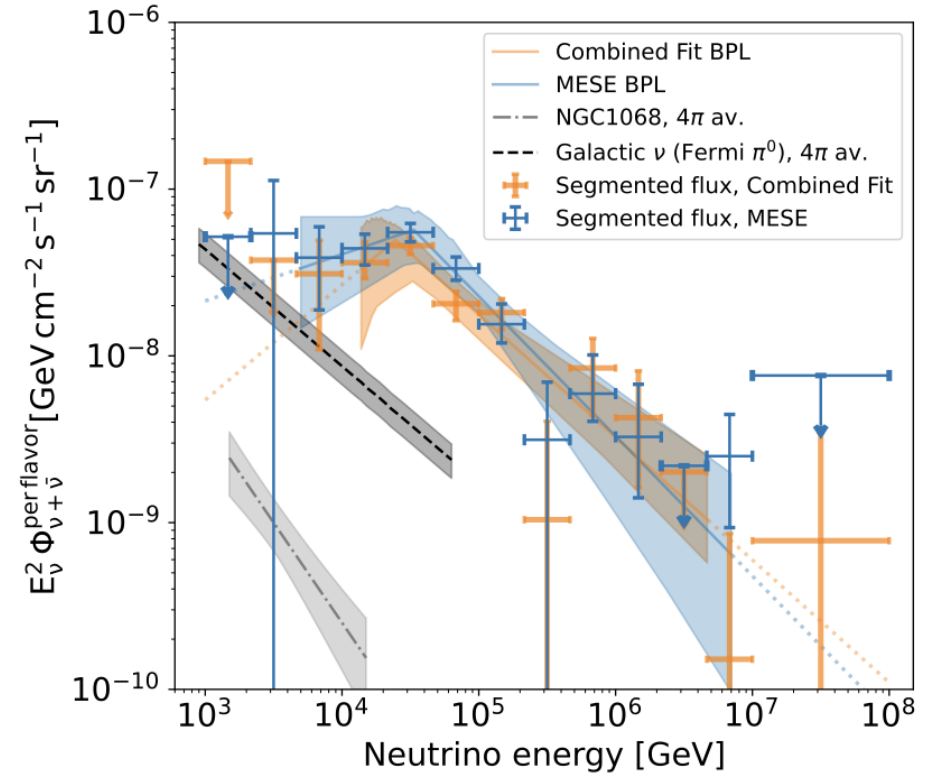
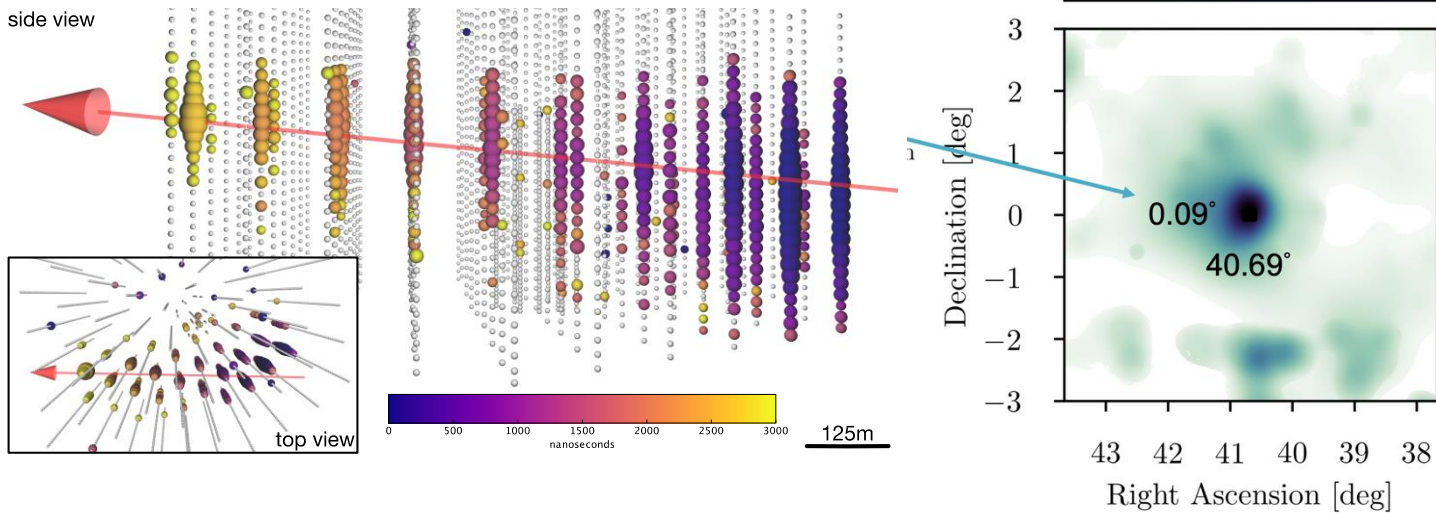


2023

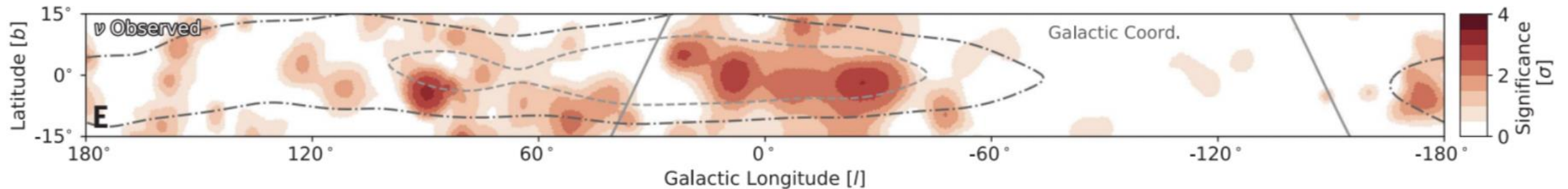
Third Source
Milky Way
Identified

Where are we now with neutrino astronomy?

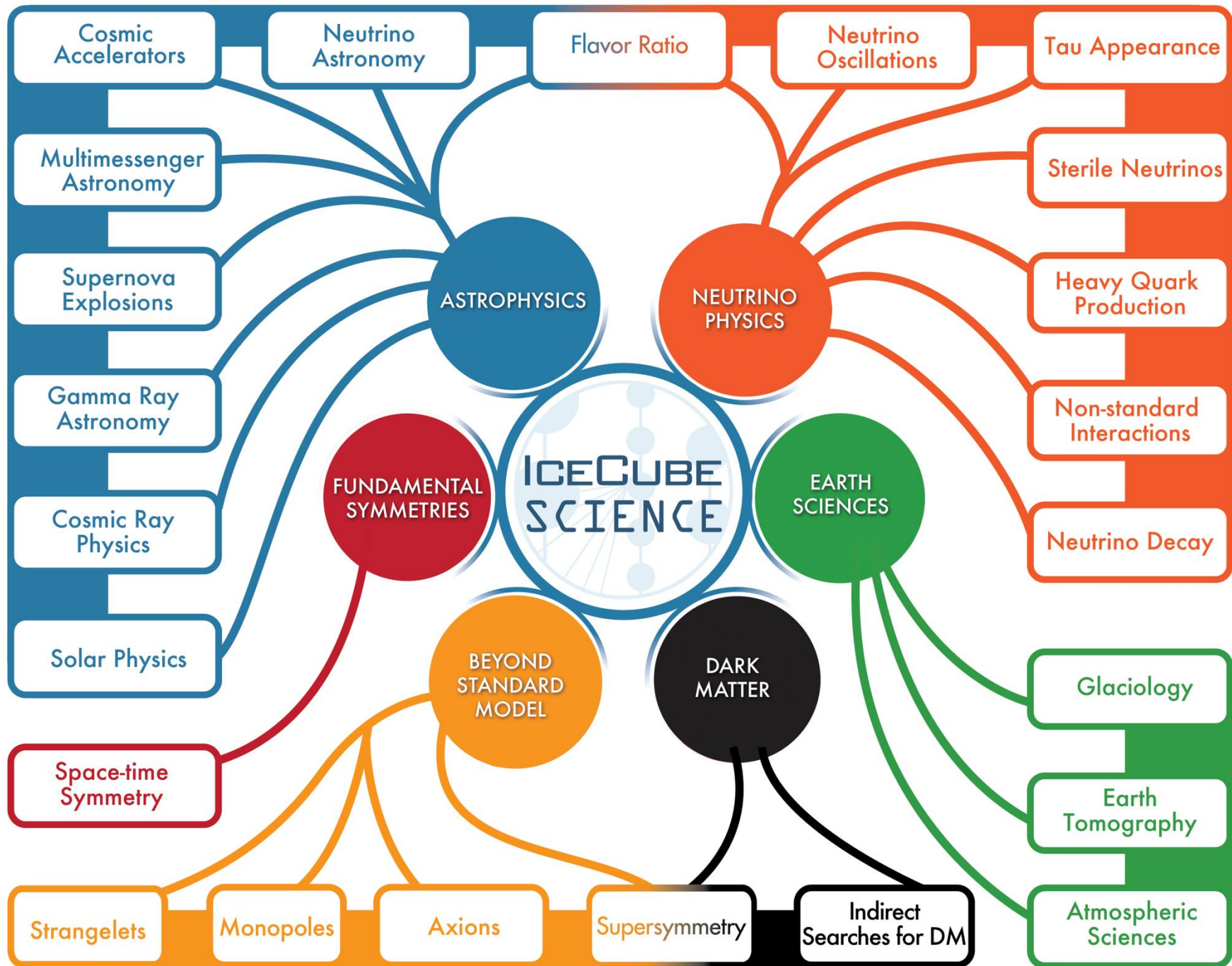
First sources of neutrinos



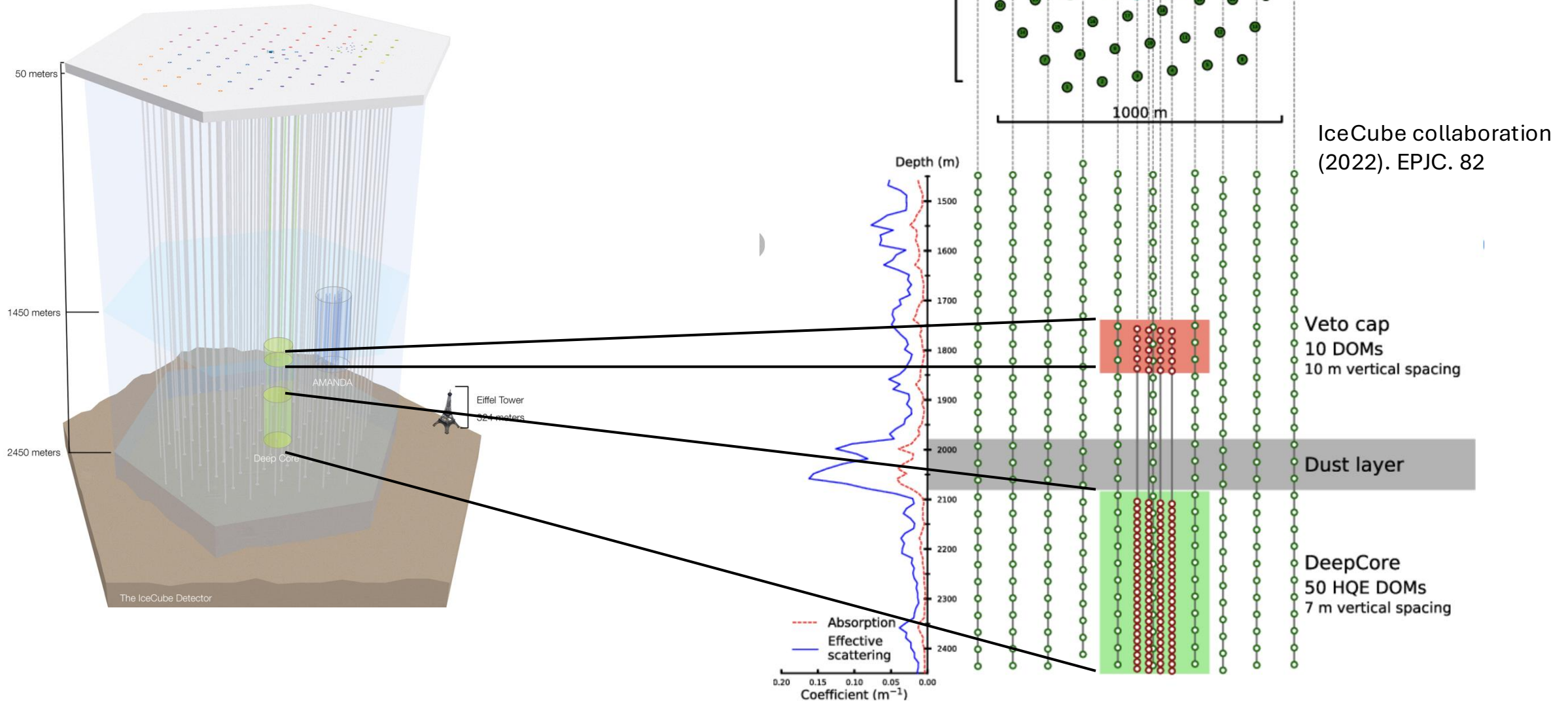
Images of astrophysical systems in neutrinos



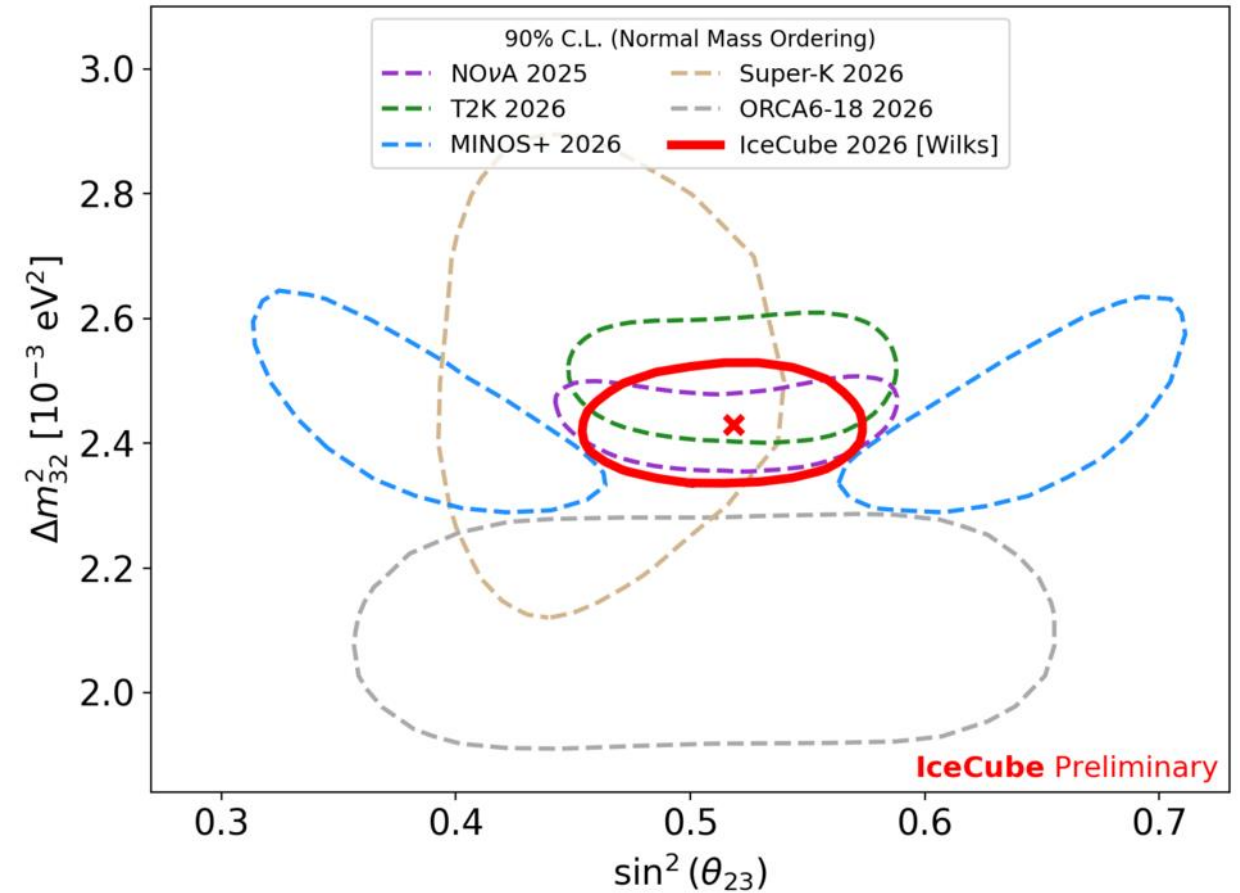
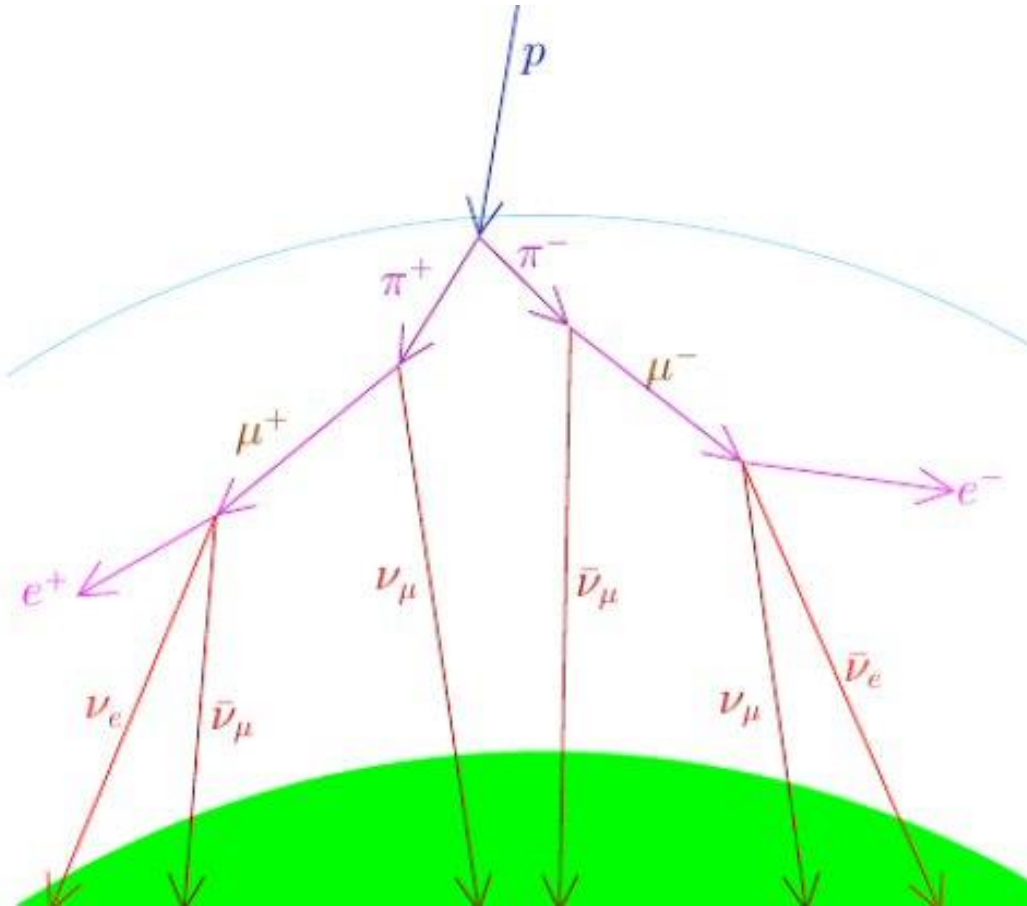
Characterizing astrophysical neutrinos



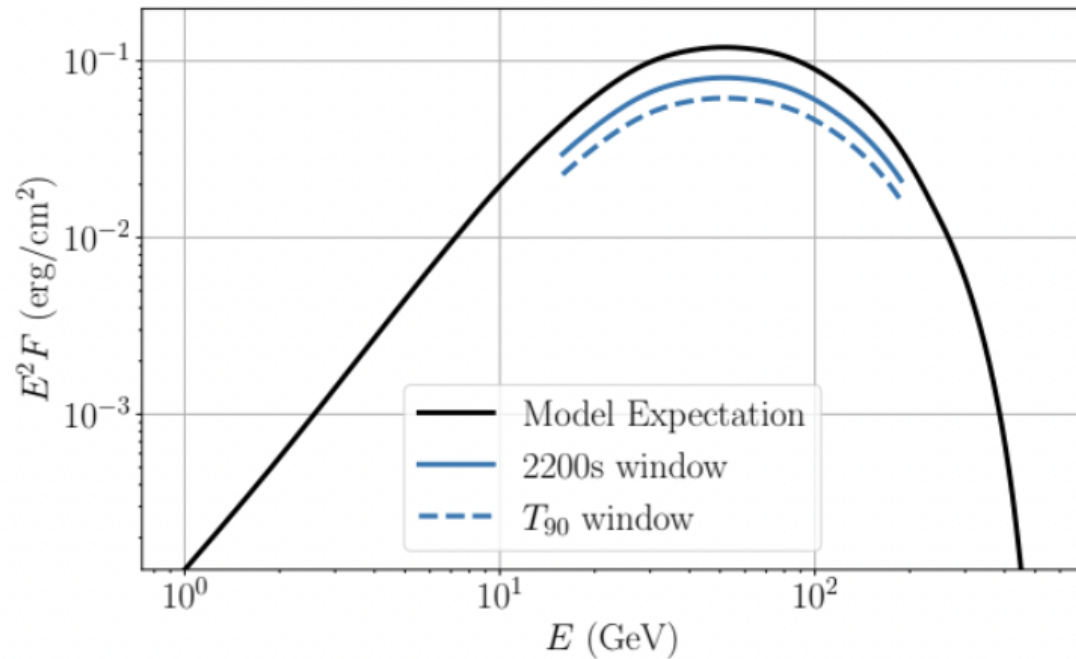
DeepCore: extending energies down to GeV



Measurements of oscillation parameters with atmospheric neutrinos



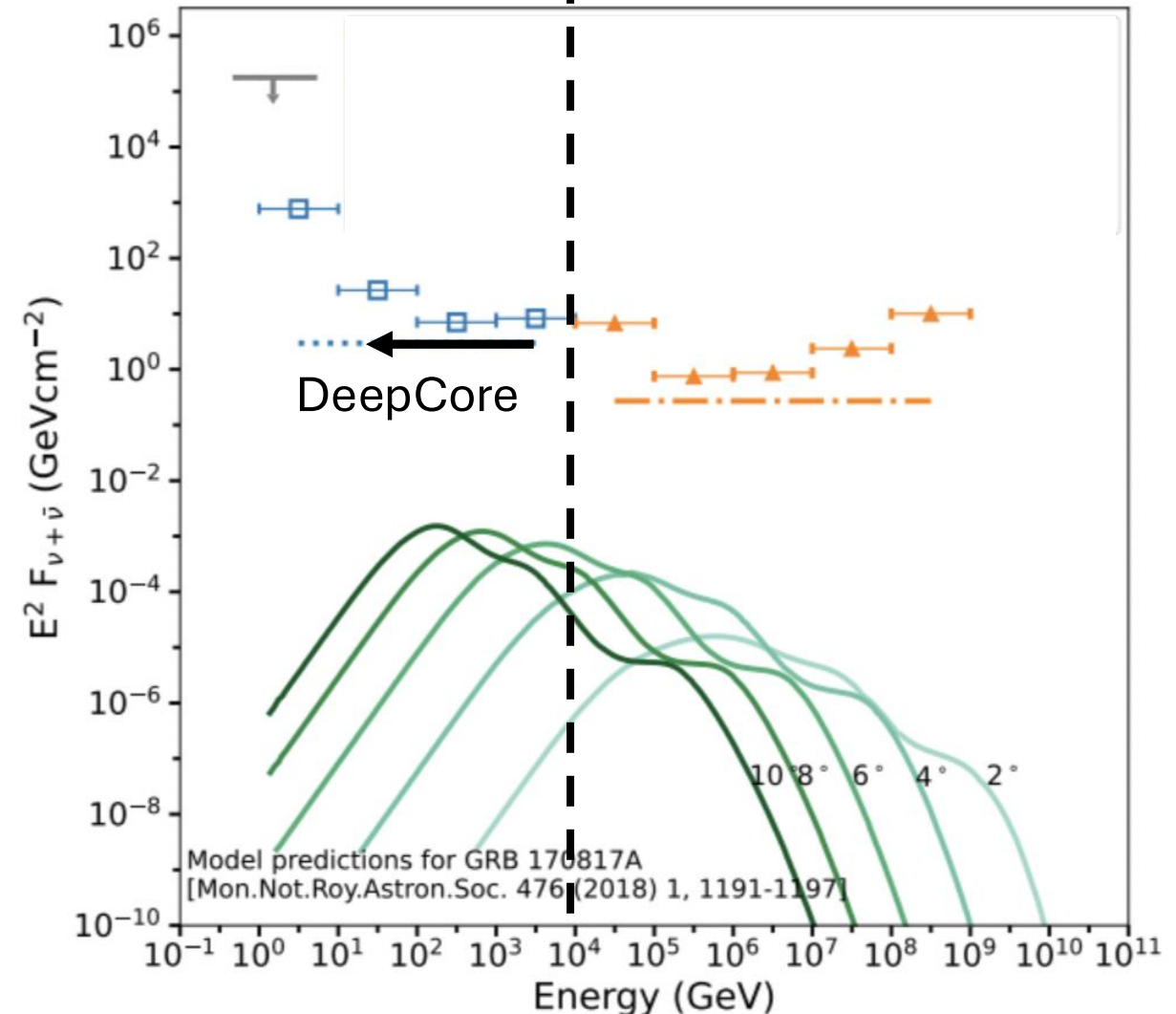
IceCube searches for GeV astrophysical neutrinos



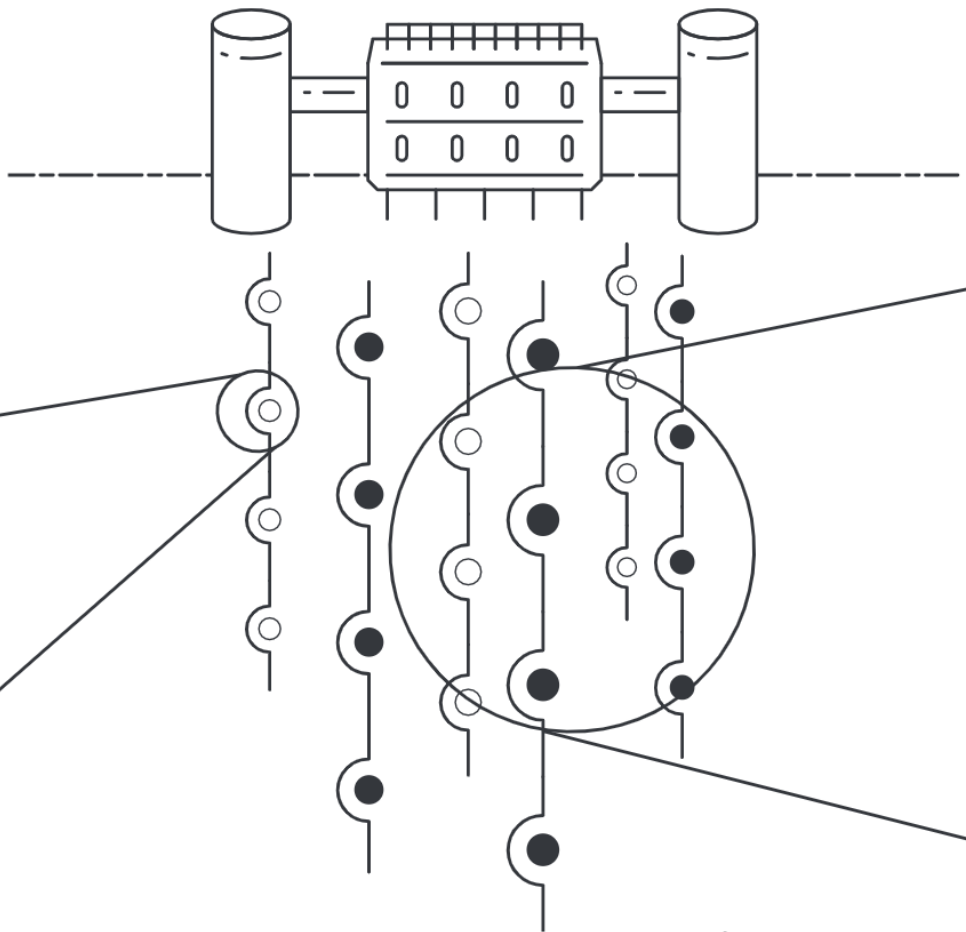
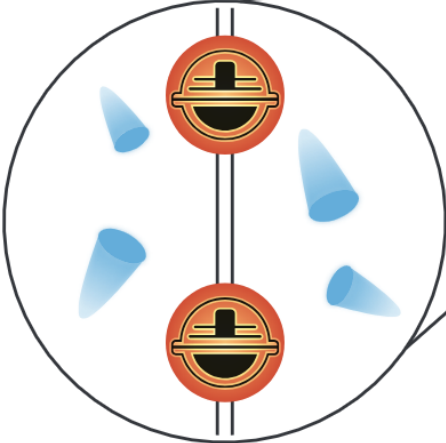
IceCube, ApJ 964 126 (2024)

Example: Limits on
subphotospheric neutrino
emission from GRBs

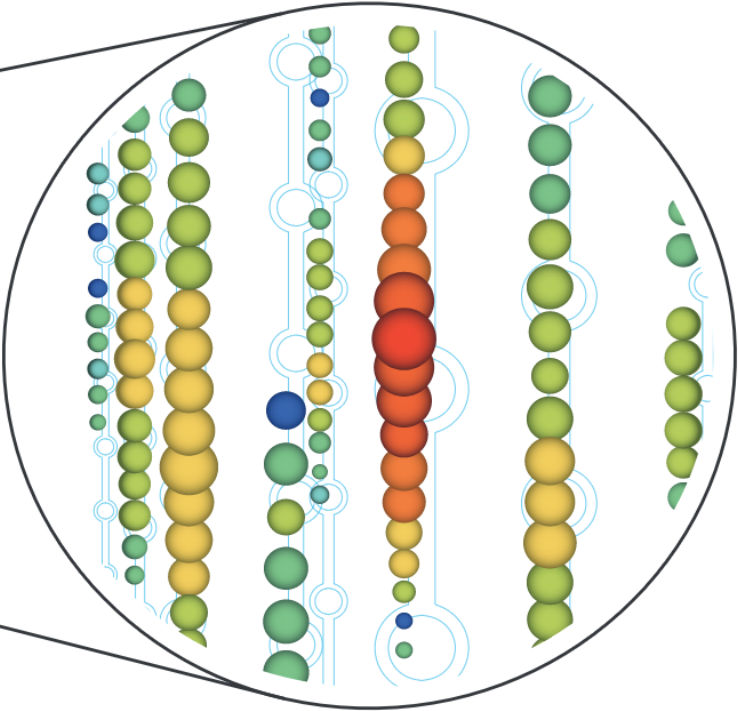
Example: Limits on neutrinos with
gravitational waves



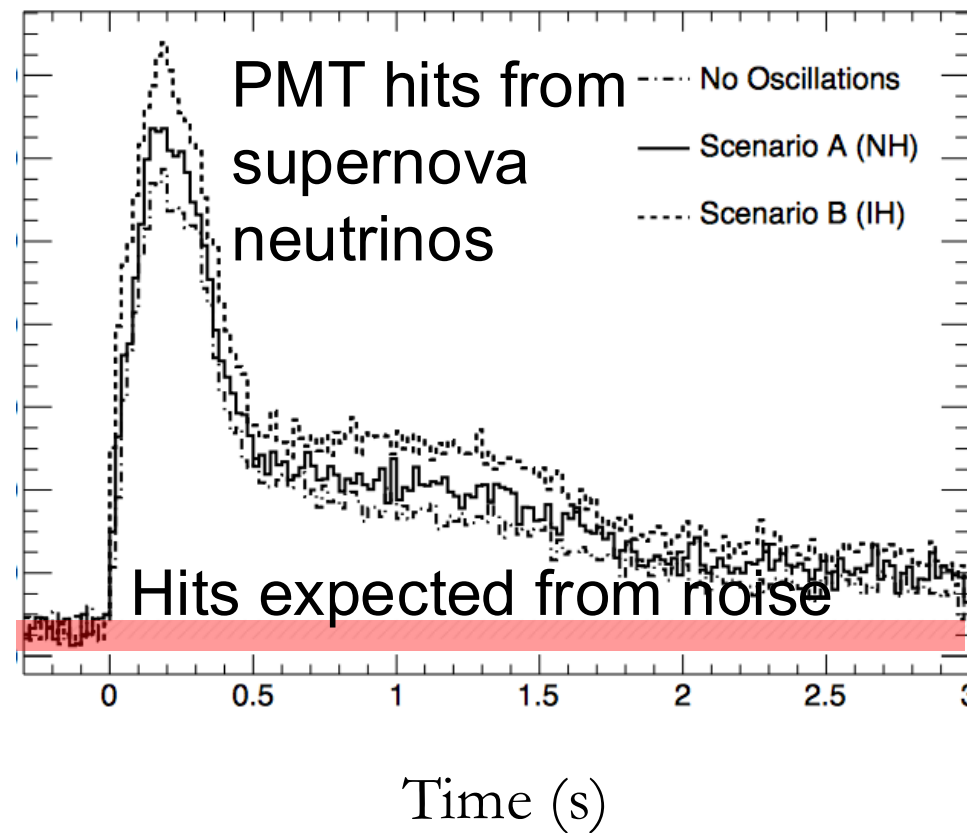
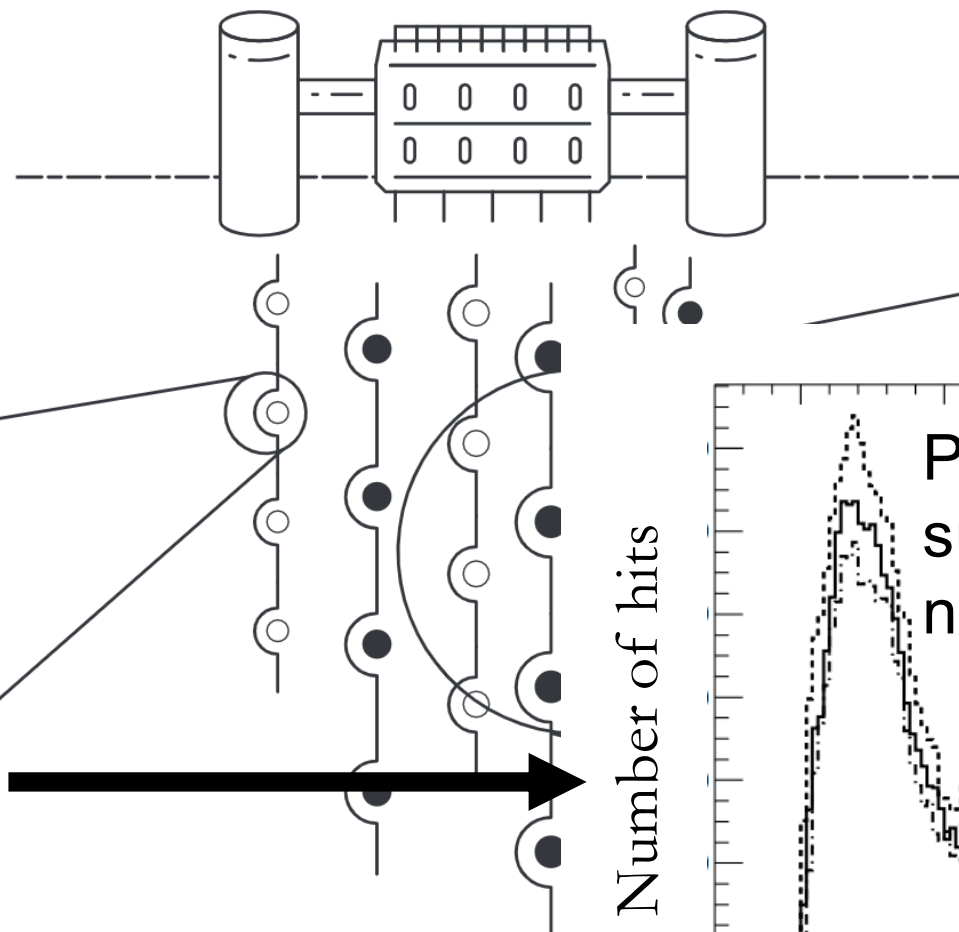
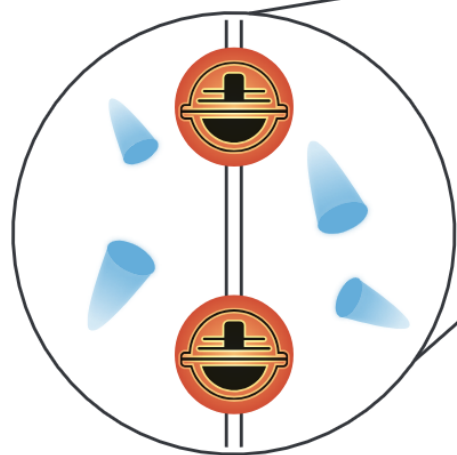
Low energy (MeV)
neutrinos



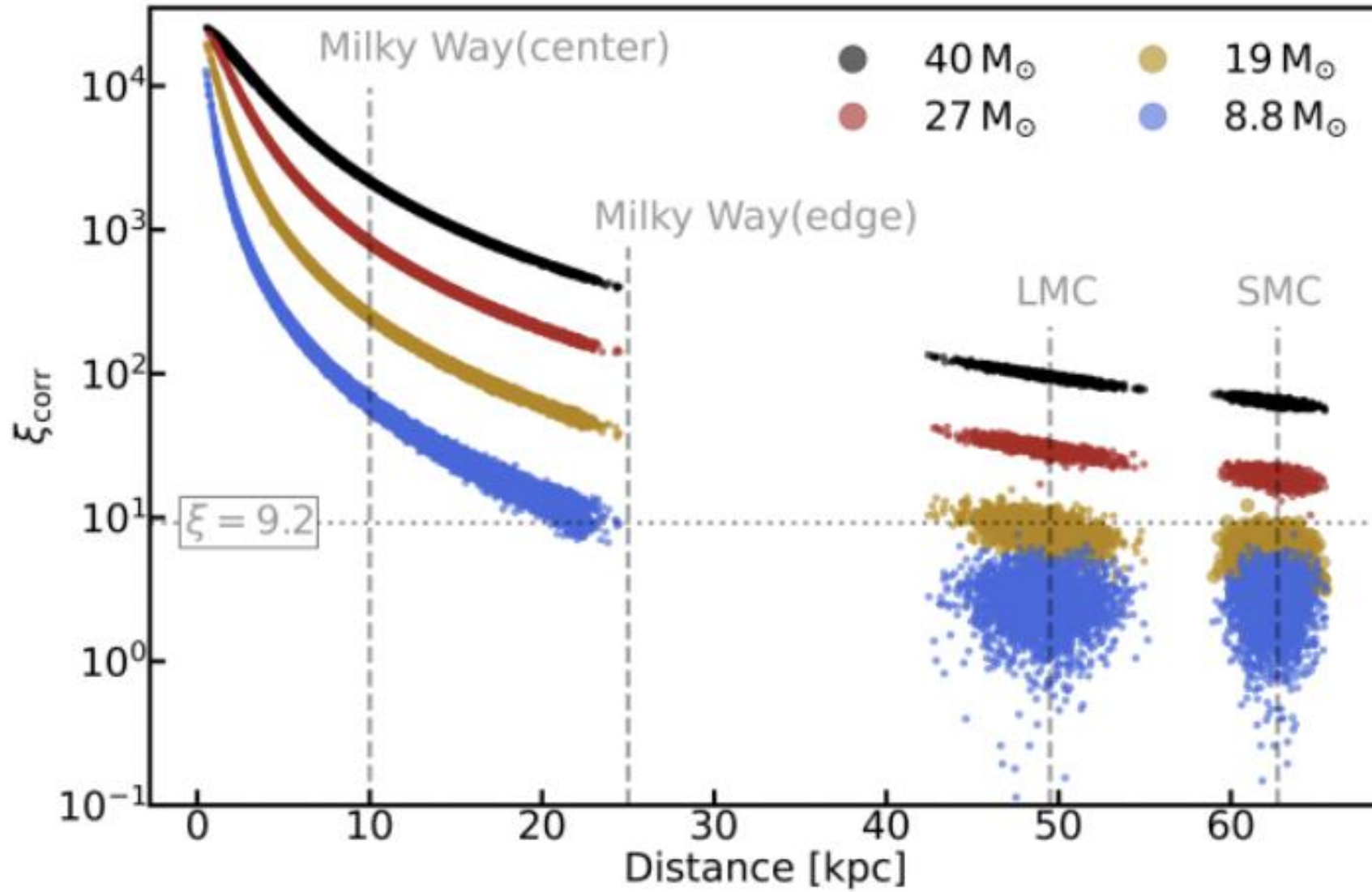
High energy
neutrinos

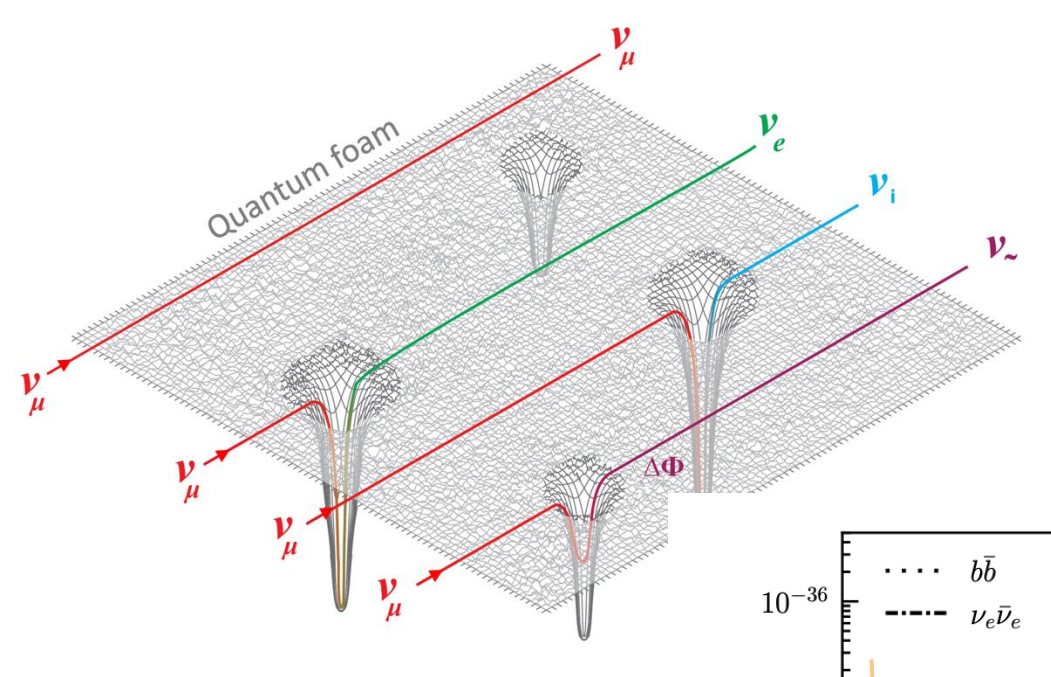


Low energy (MeV)
neutrinos



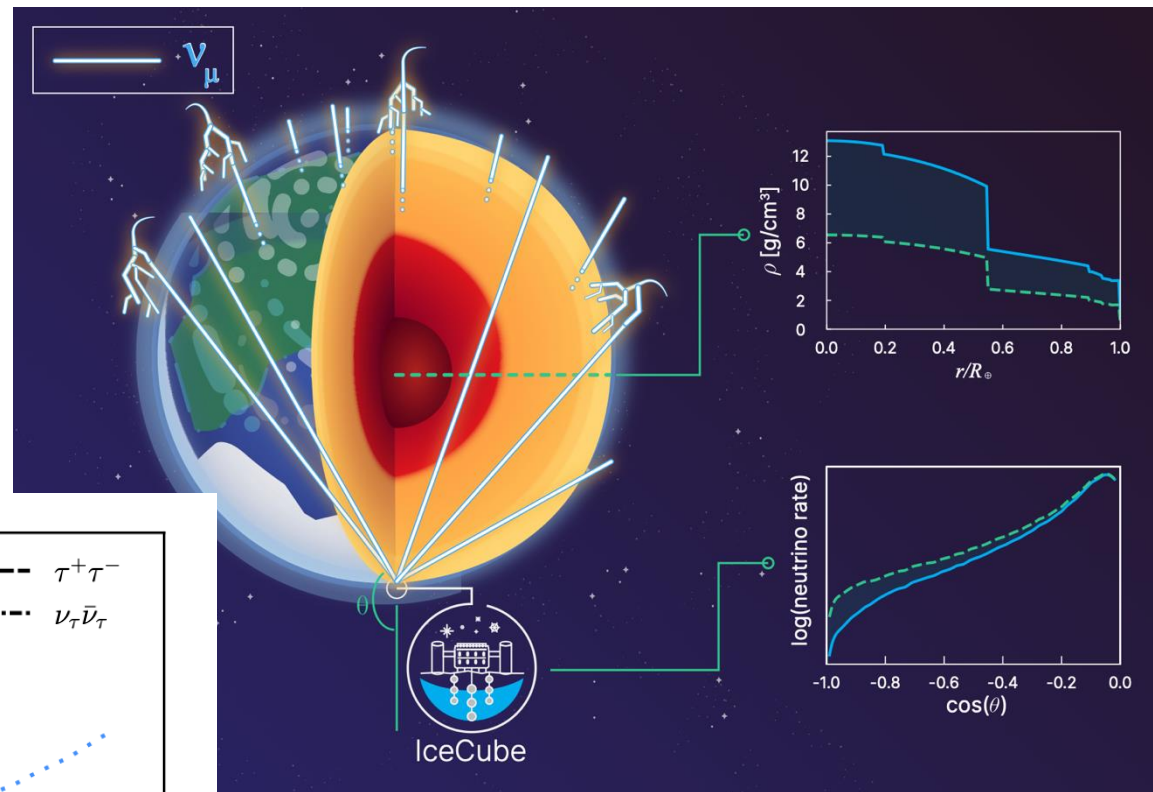
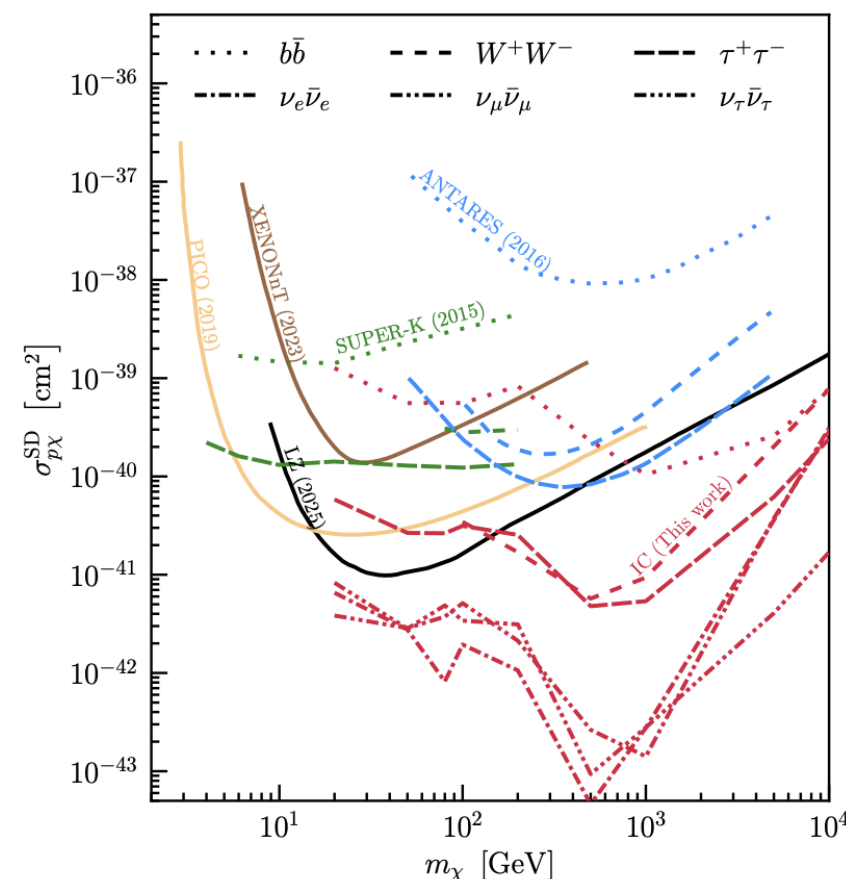
Significance





Quantum decoherence
IceCube, Nature Physics (2024)

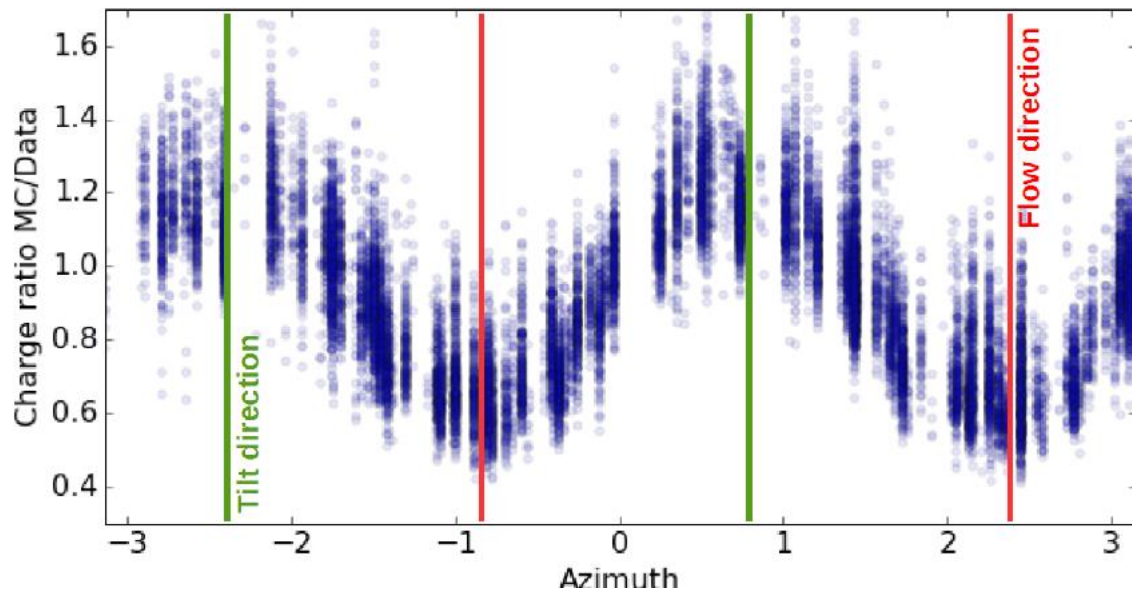
Dark matter limits
IceCube, arXiv 2507.08457



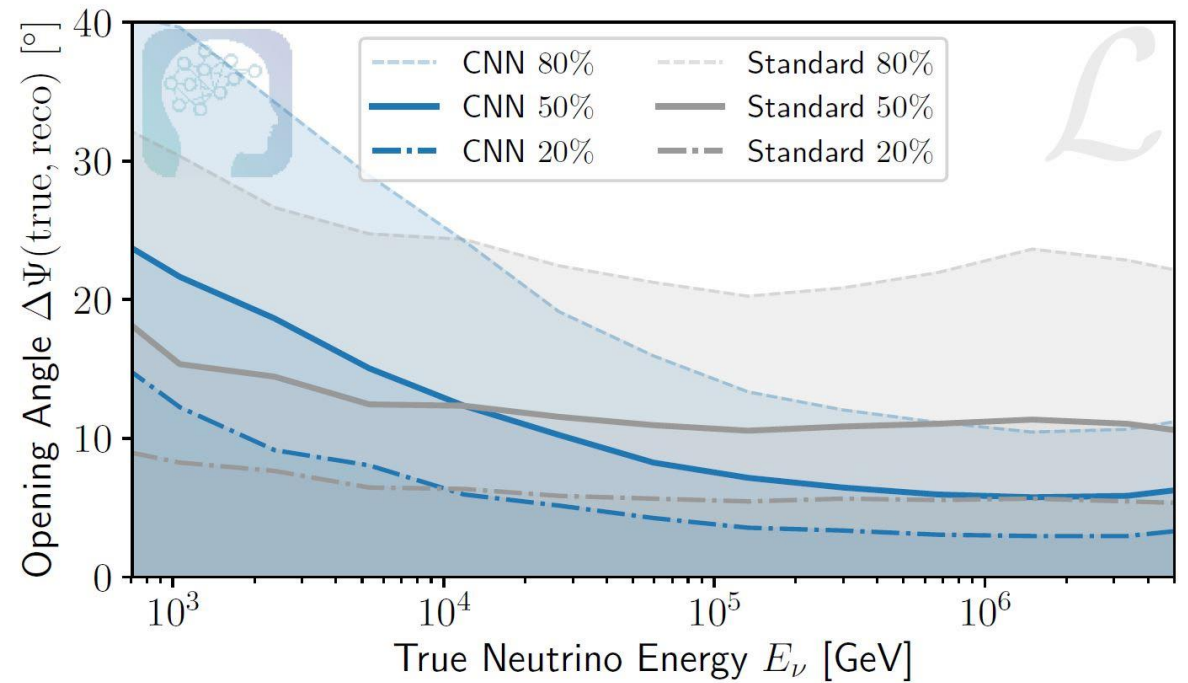
Neutrino tomography of the Earth
IceCube, arXiv 2607.02644

Where are we going?

How to improve 15 years of data



Better understanding of our ice properties



AI methods to improve eg. reconstruction

physicsworld
**BREAKTHROUGH
OF THE YEAR
2013**

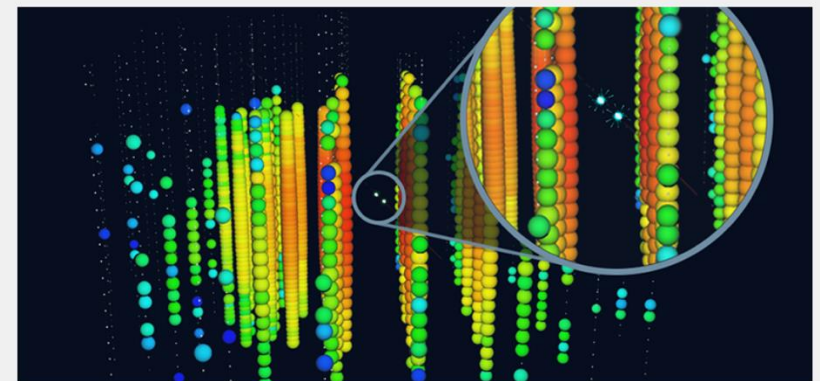


Search for Extremely-High-Energy Neutrinos and First Constraints on the Ultrahigh-Energy Cosmic-Ray Proton Fraction with IceCube

R. Abbasi et al.

PRL Collection of the year

Phys. Rev. Lett. 132, 021001 – Published 11 April, 2024



Observation of Seven Astrophysical Tau Neutrino Candidates with IceCube

IceCube Collaboration

Phys. Rev. Lett. 132, 151001 – Published 11 April, 2024

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