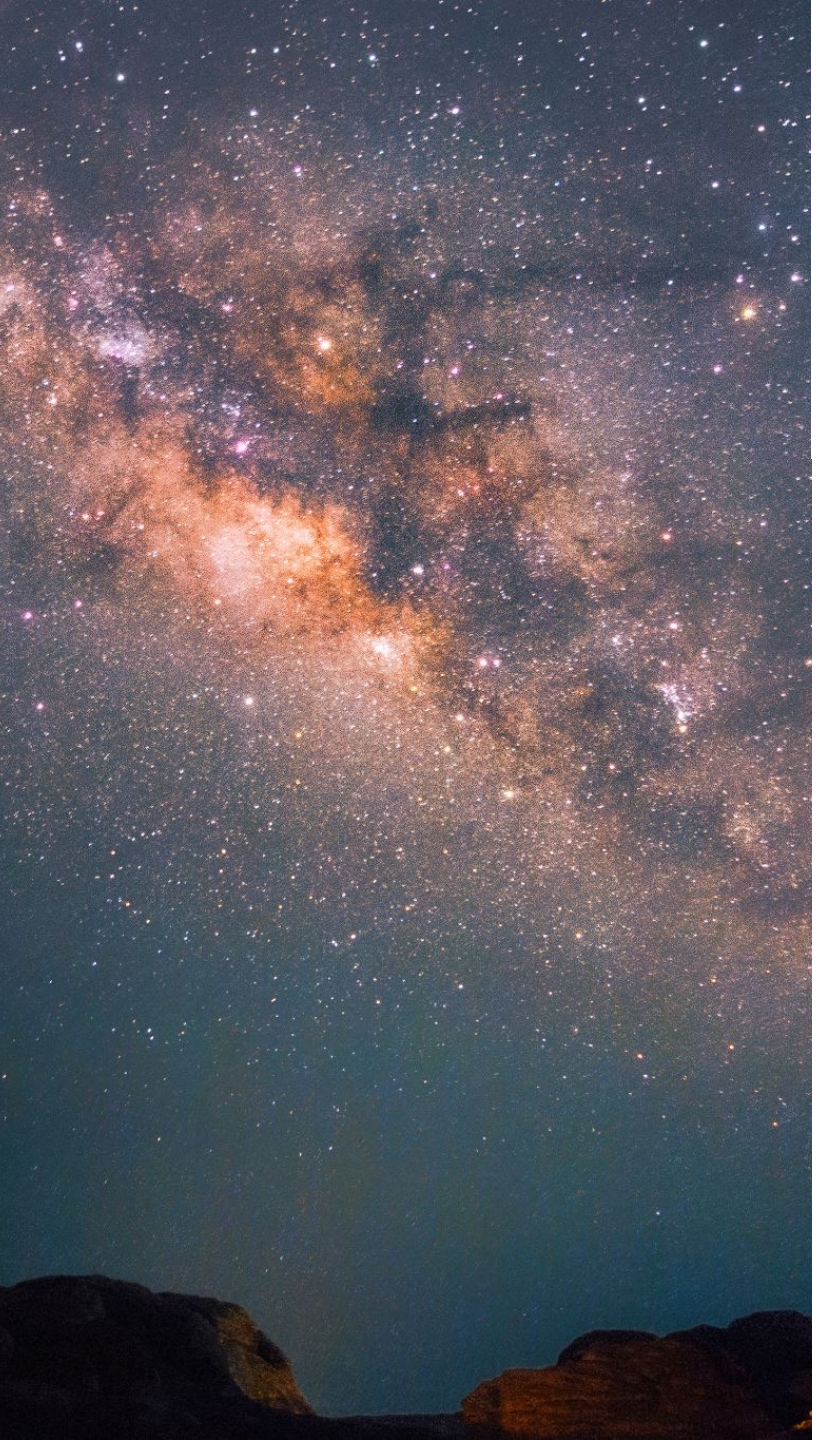


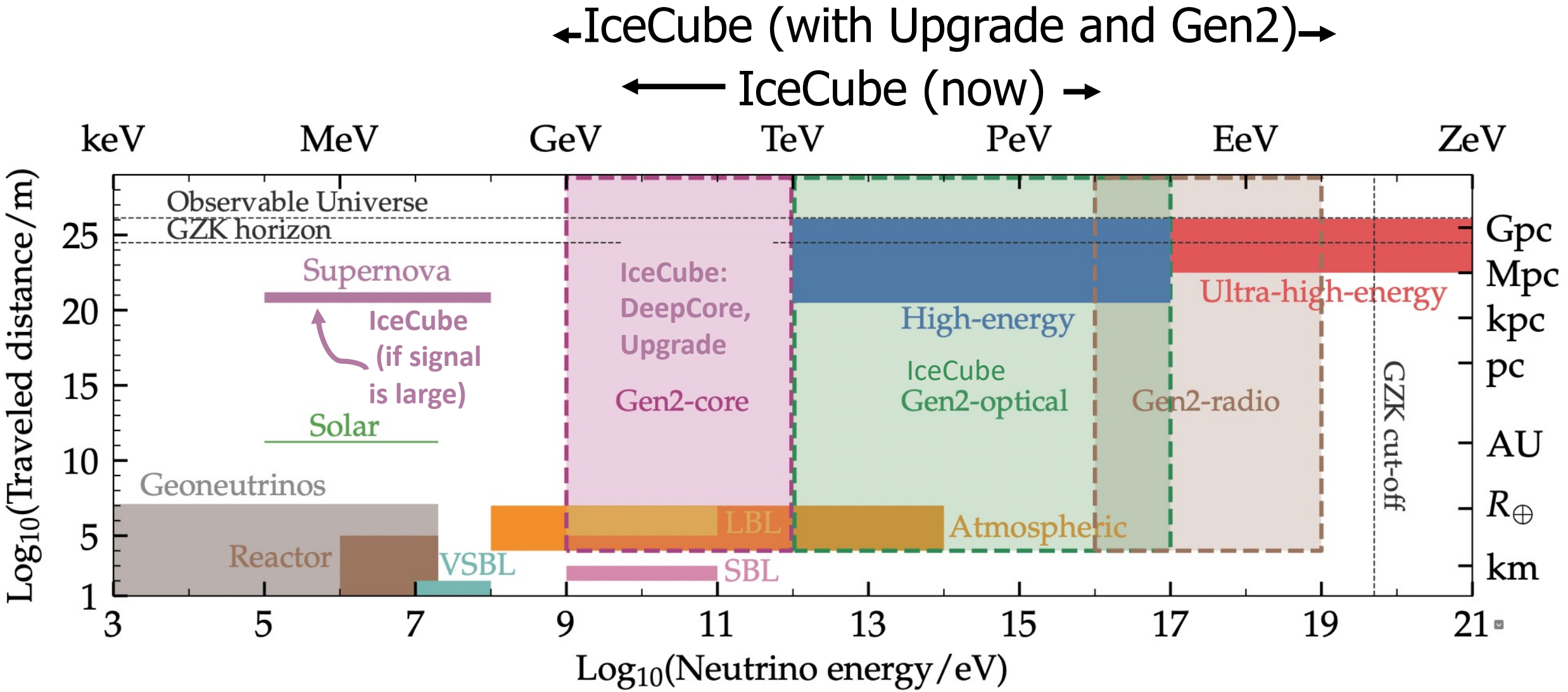
UPPSALA UNIVERSITET

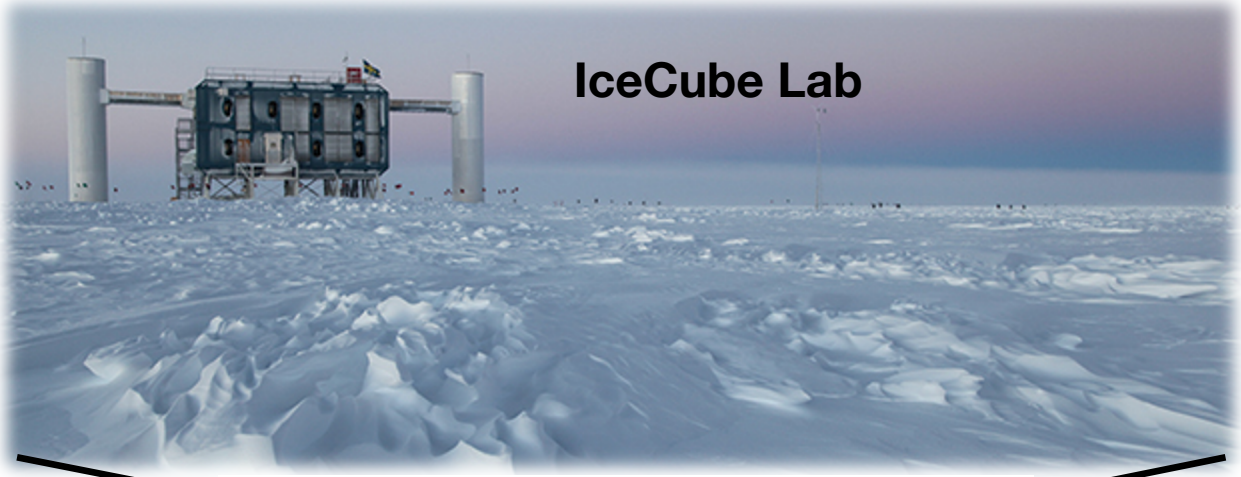
IceCube: From MeV to PeV

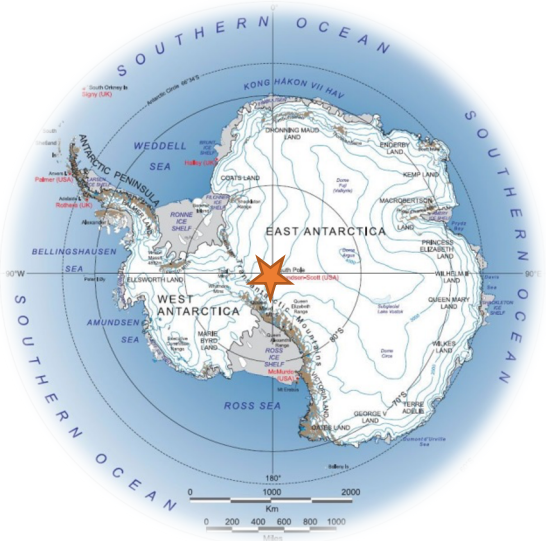
Erin O'Sullivan, on behalf of the IceCube collaboration

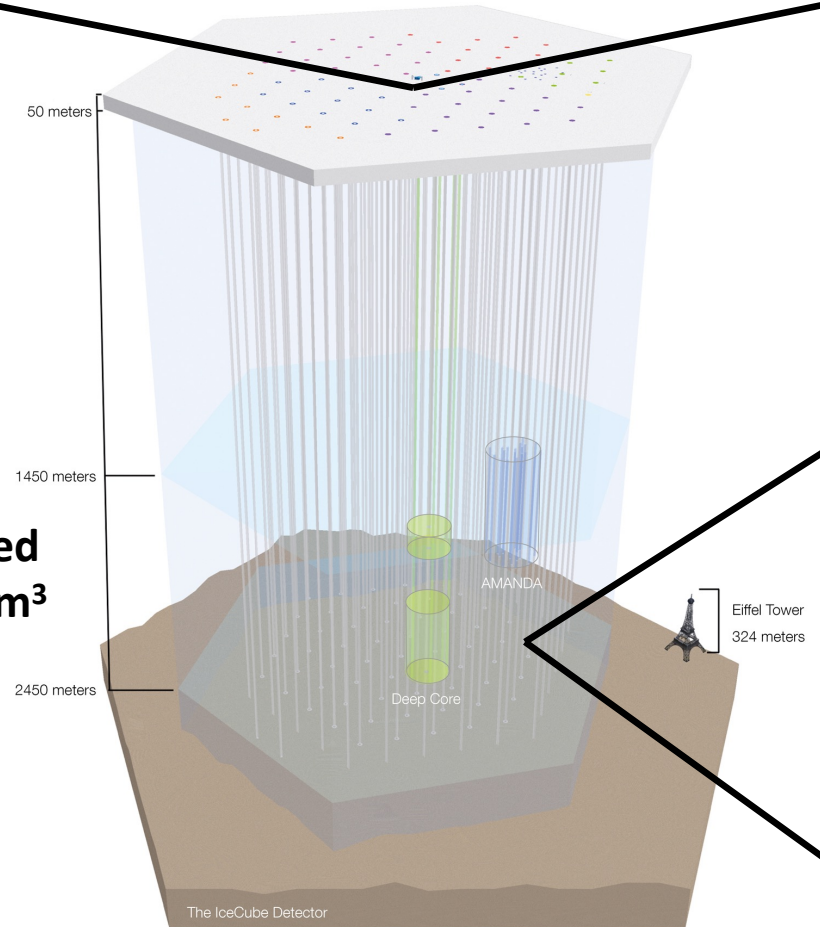
Cosmic Rays and Neutrinos in the Multi-Messenger Era

The energy landscape for IceCube







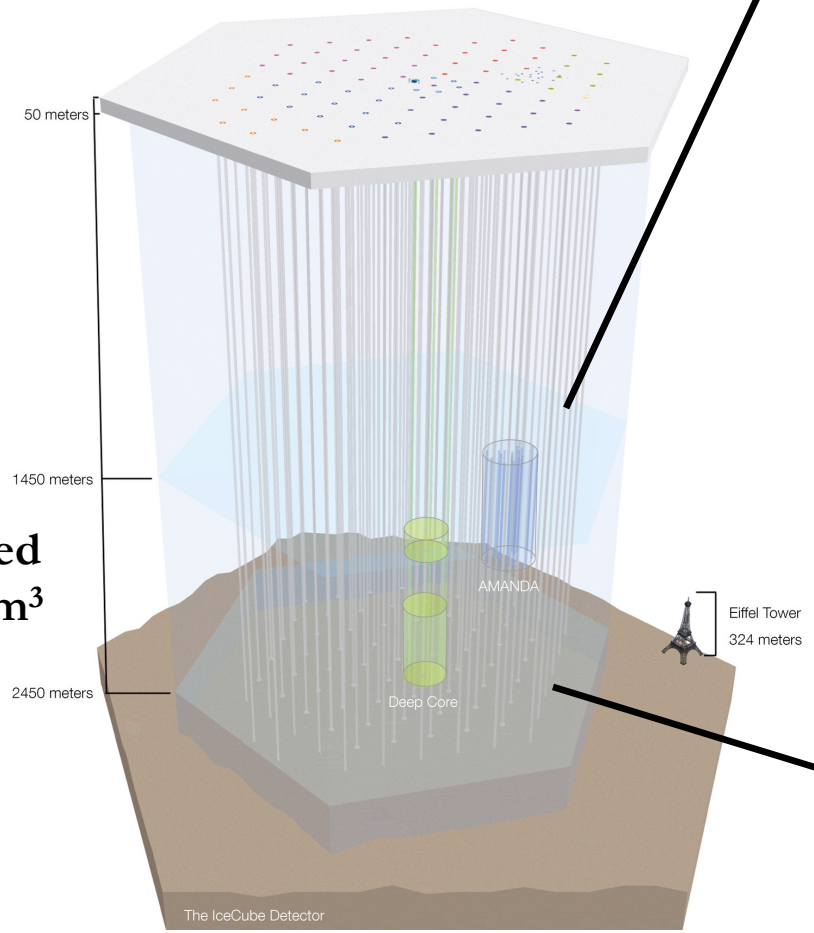


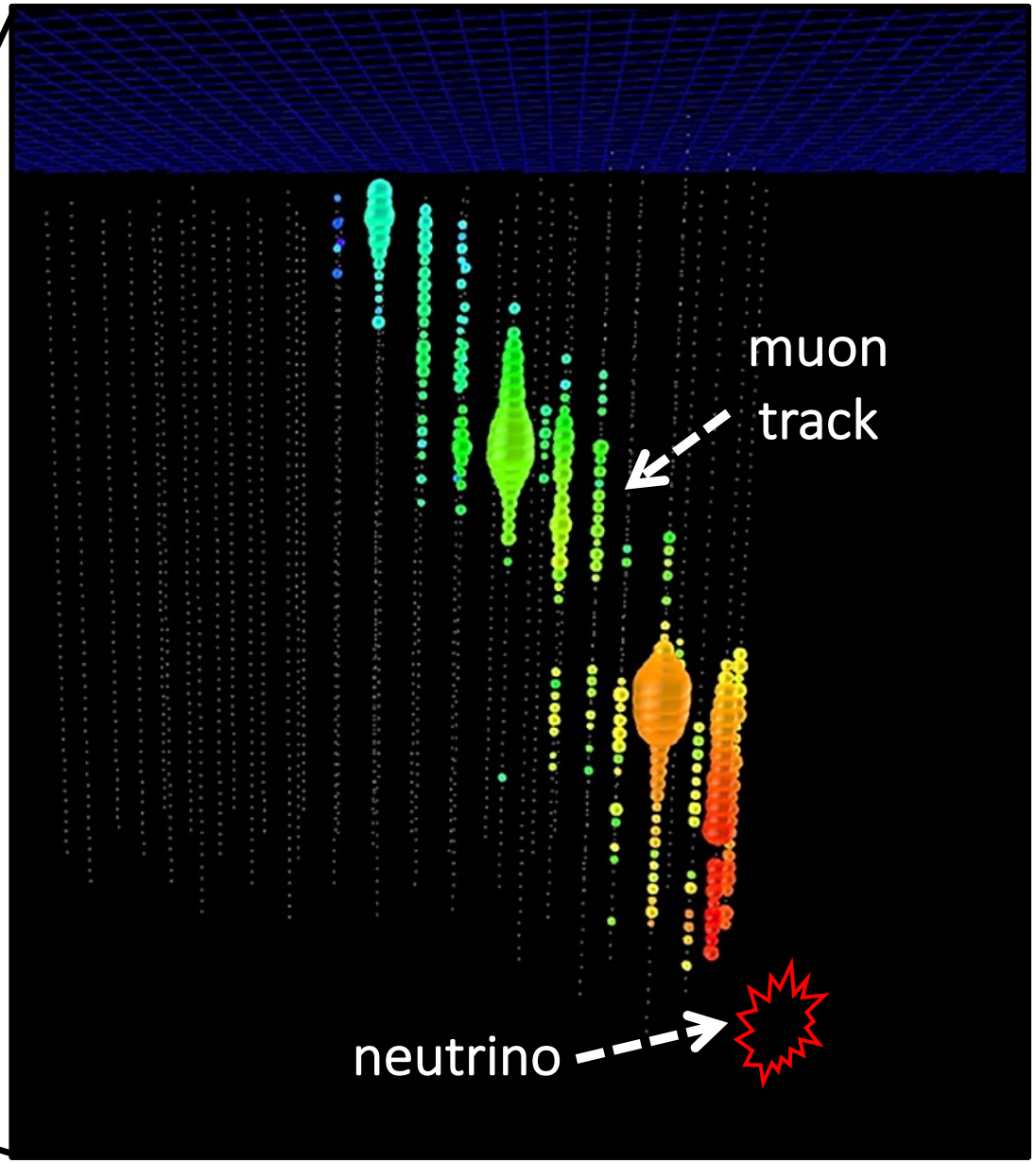
ICECUBE
completed 2011

Instrumented volume: 1 km^3

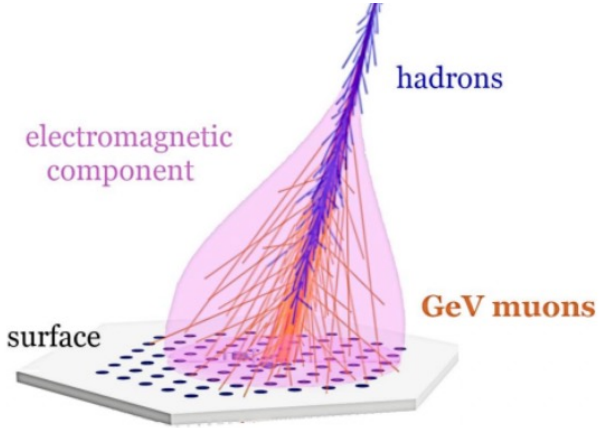
86 Strings

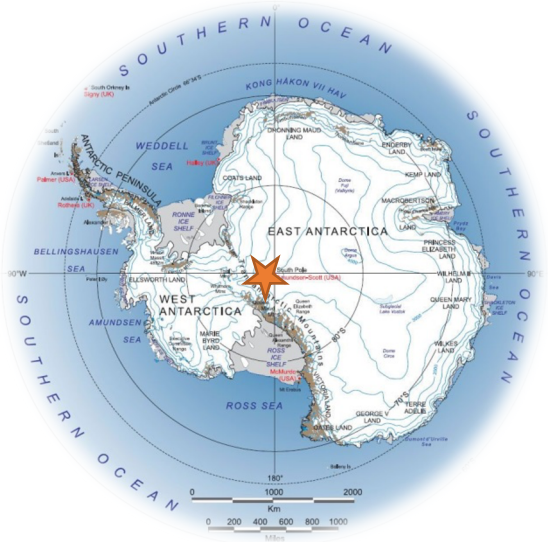
Instrumented volume: 1 km^3

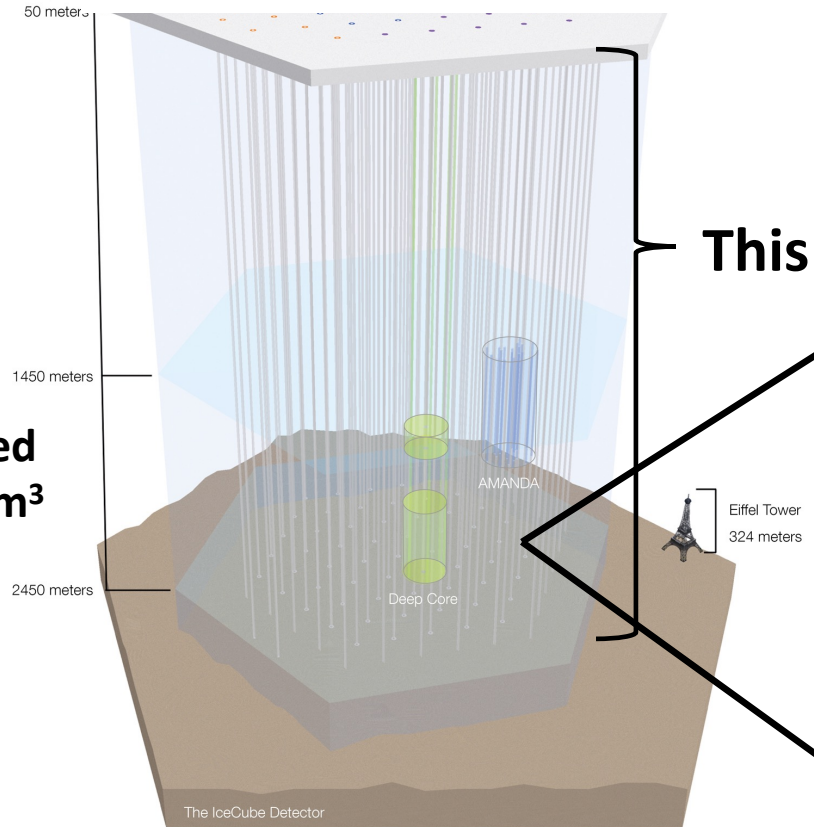




IceTop: cosmic ray measurement (Dennis Soldin on Tuesday)





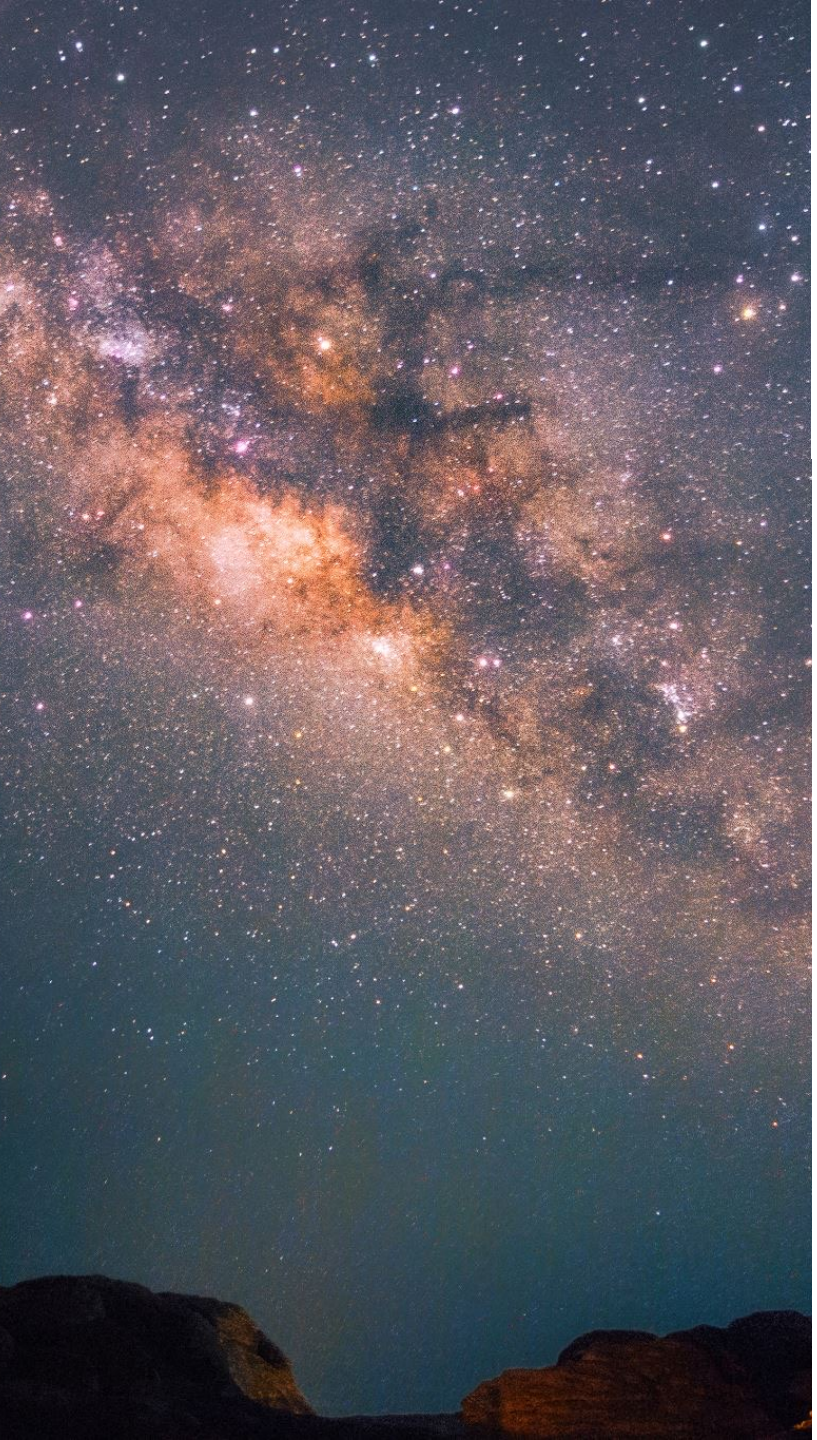


Instrumented volume: 1 km³

This talk

ICECUBE
completed 2011

86 Strings



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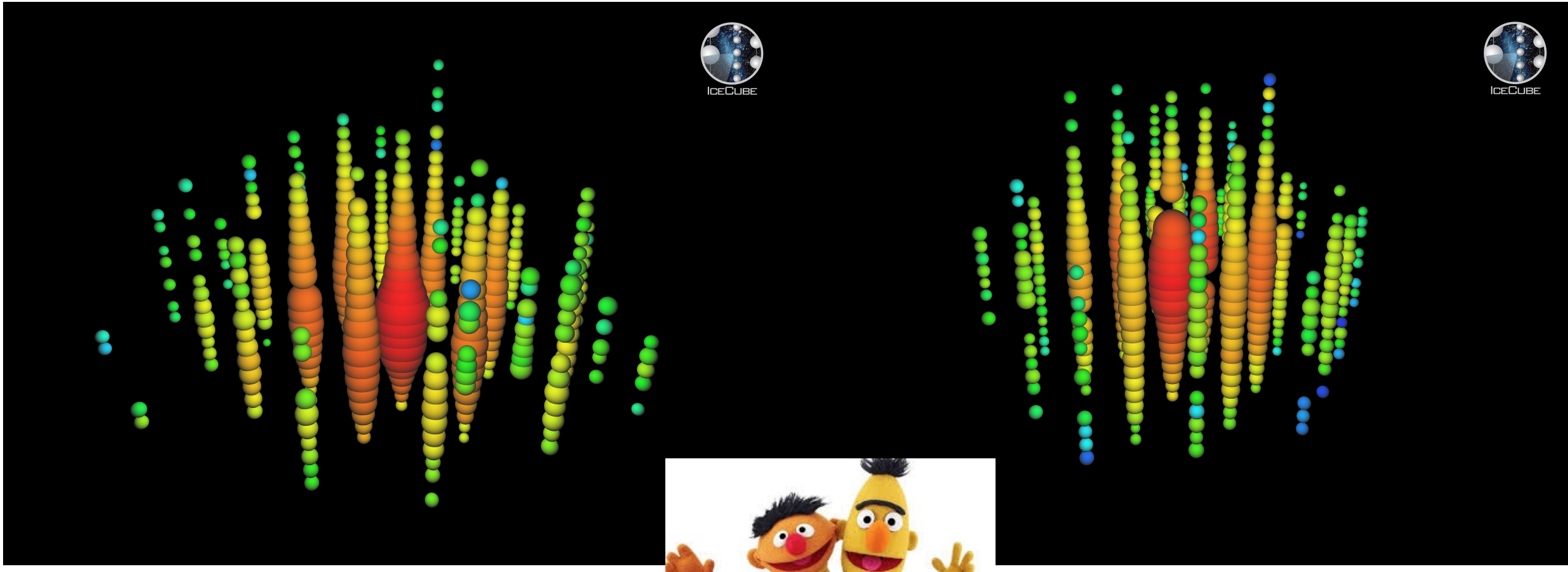
IceCube:
~~From MeV to PeV~~
From PeV to MeV to EeV

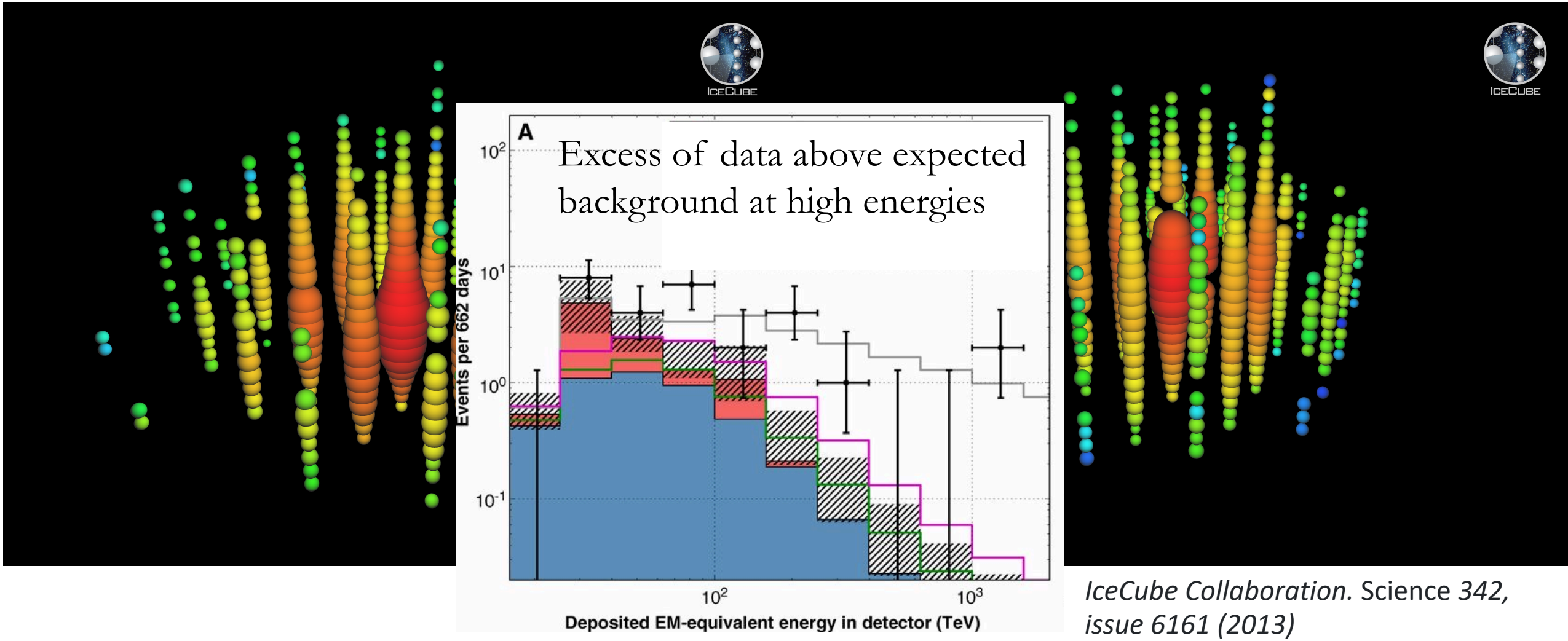
Erin O'Sullivan, on behalf of the IceCube collaboration

Cosmic Rays and Neutrinos in the Multi-Messenger Era

How it started:
the first high energy (PeV) events

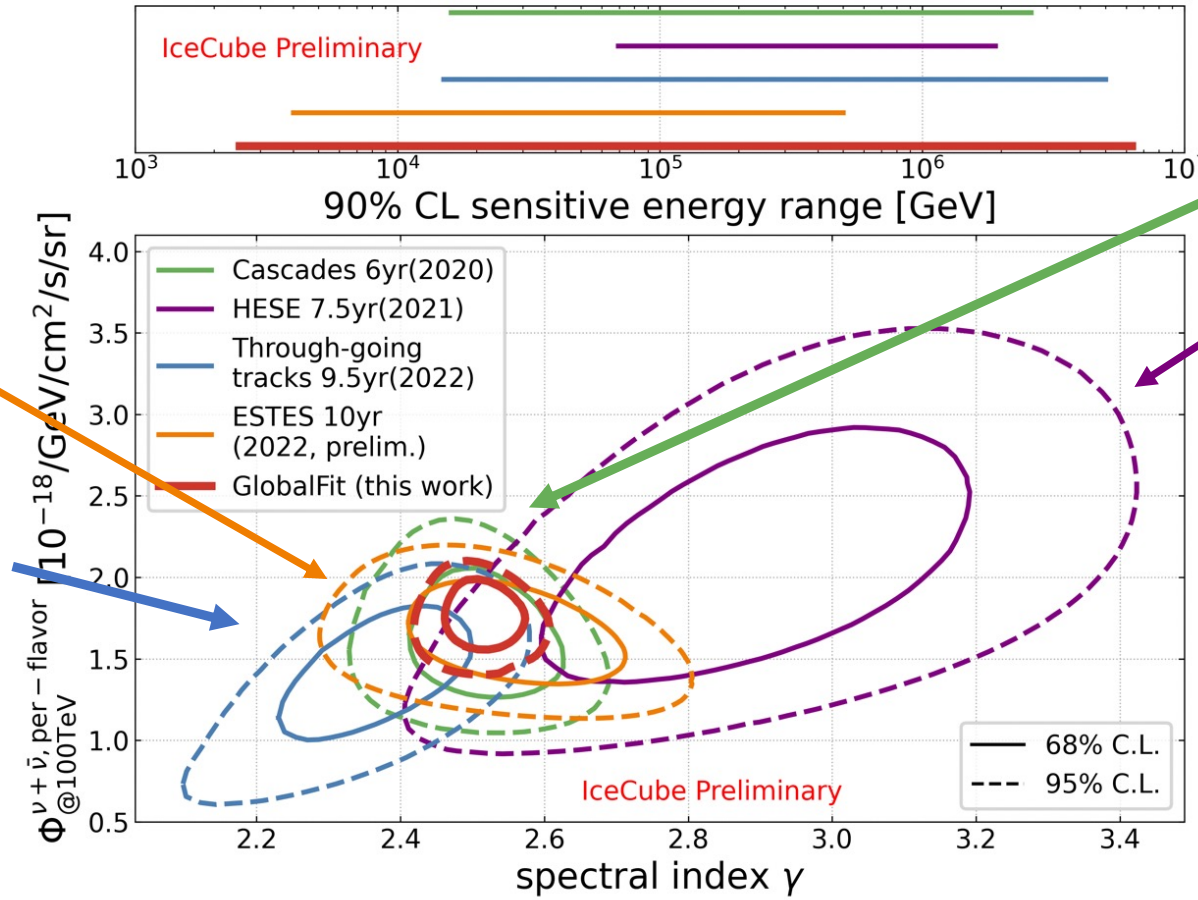


How it started: the first high energy (PeV) events



IceCube Collaboration. Science *342, issue 6161 (2013)*

Characterizing astrophysical neutrinos at different flavours and energies



Lower energy, muon neutrinos

Higher energy, muon neutrinos

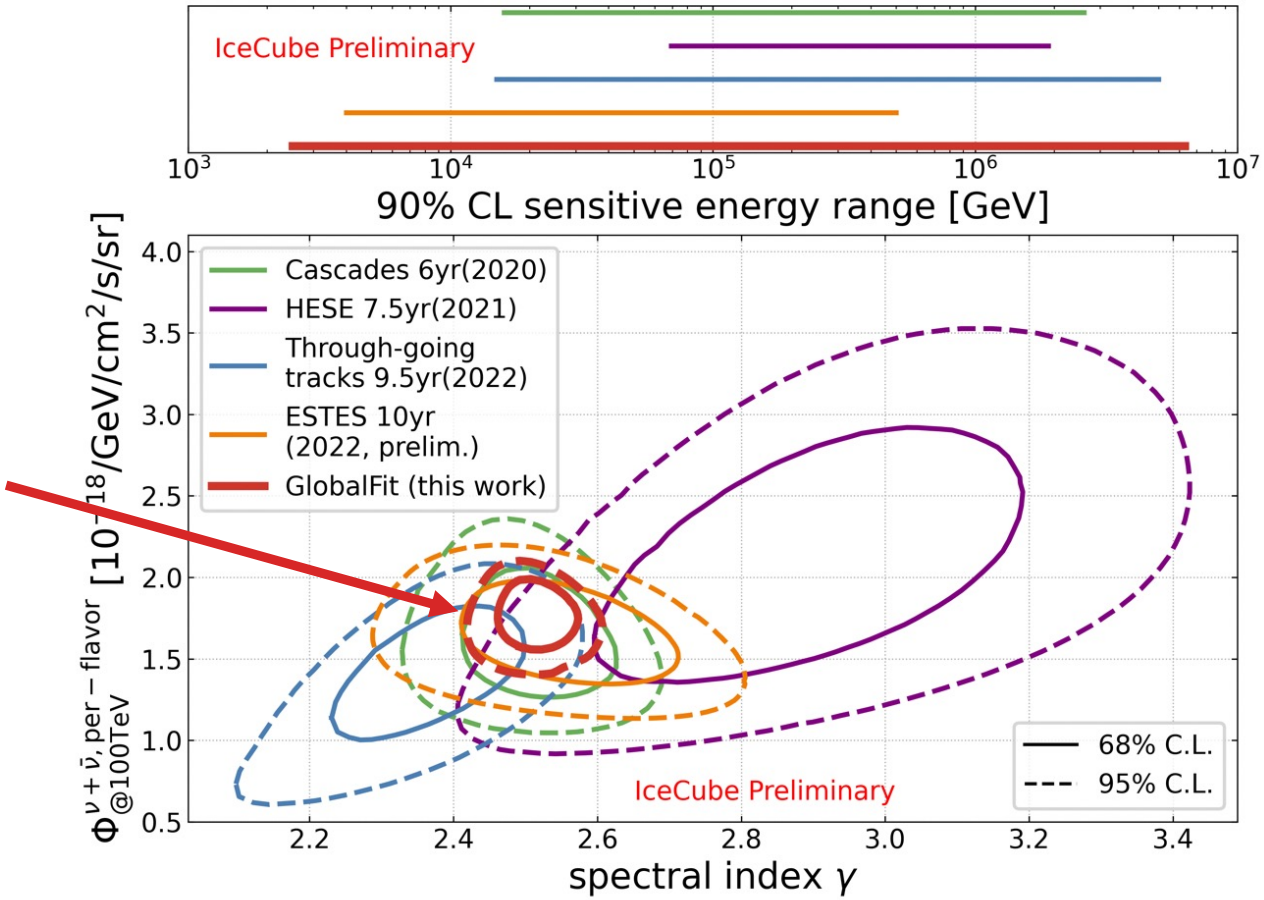
Electrons and tau neutrinos (with some muon neutrinos)

High energy, all flavour

Richard Naab, Erik Ganster, Zelong Zhang (for IceCube) PoS-ICRC2023-1064, [2308.00191](2308.00191)

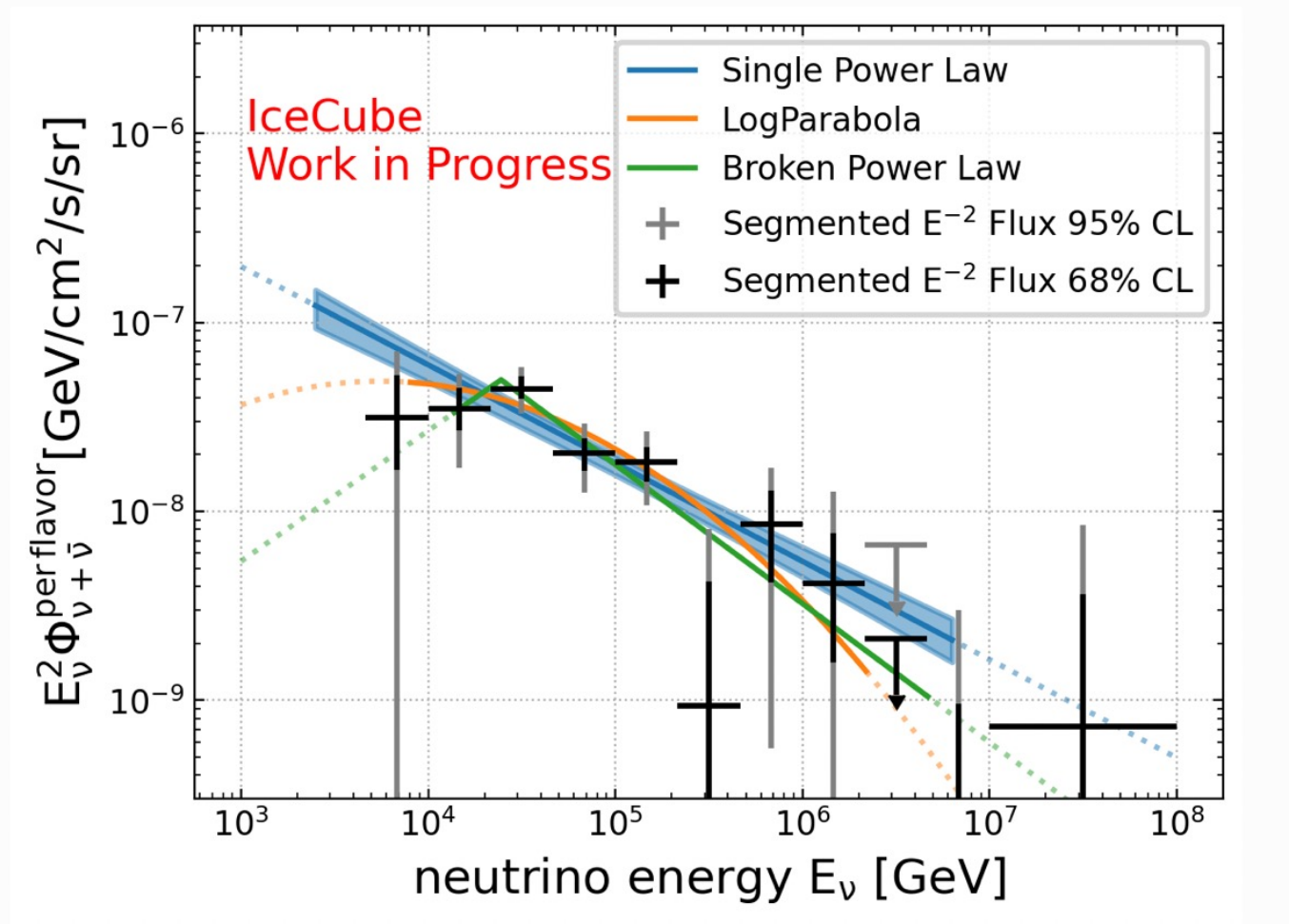
Characterizing astrophysical neutrinos with high precision

Combining data sets for precise measurements



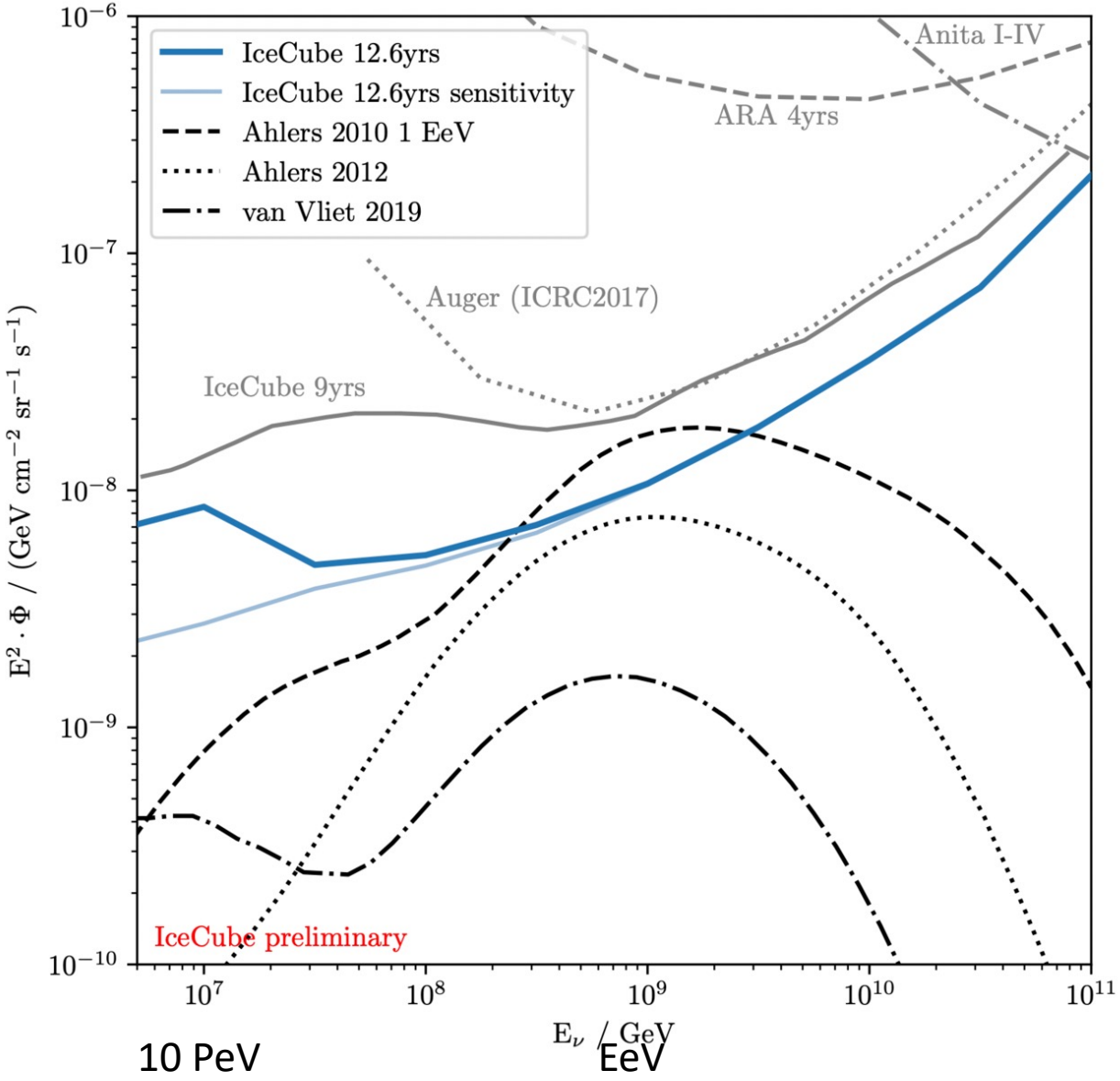
Richard Naab, Erik Ganster, Zelong Zhang (for IceCube) PoS-ICRC2023-1064, [2308.00191](2308.00191)

Characterizing the spectral shape of astrophysical neutrinos



Richard Naab, Erik Ganster, Zelong Zhang (for IceCube) PoS-ICRC2023-1064, [2308.00191](2308.00191)

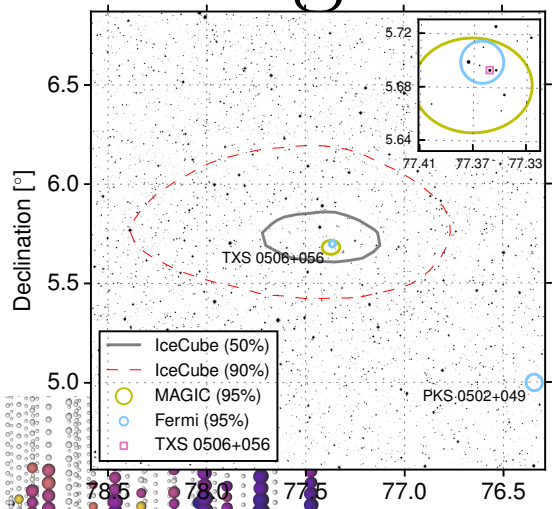
Limits at the highest energies

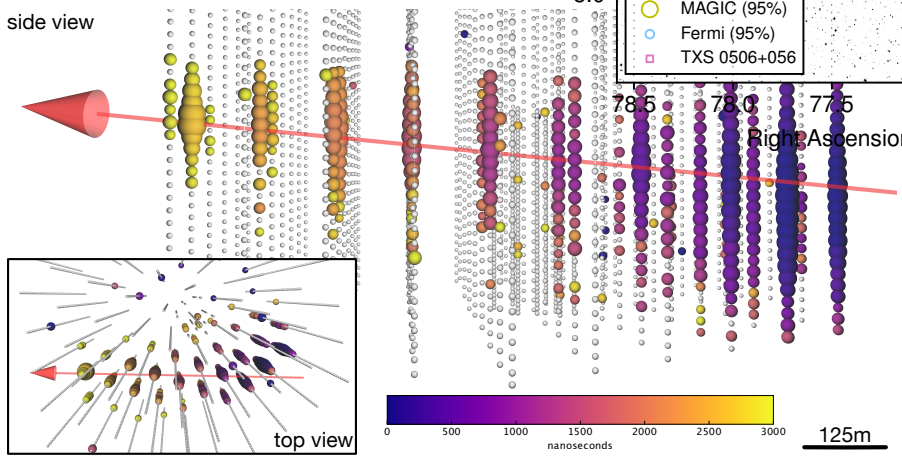


Not seeing higher energy neutrinos also sets competitive limits on EeV neutrinos.

Identifying the sources of high energy neutrinos

2018: First transient, multi-messenger source (See Marcos Santander's real time talk)

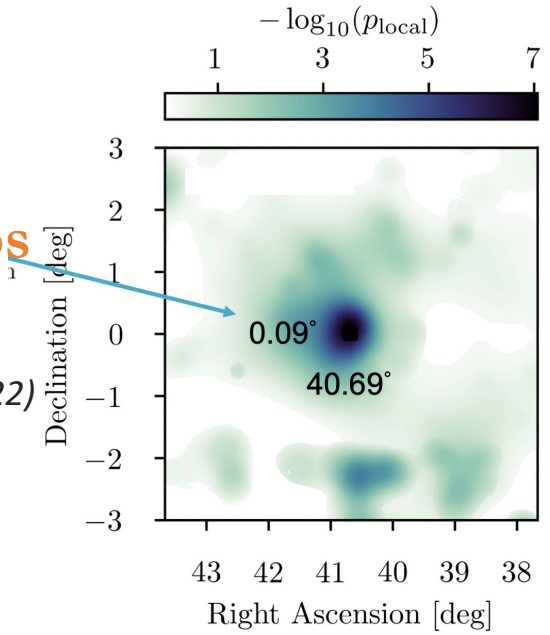




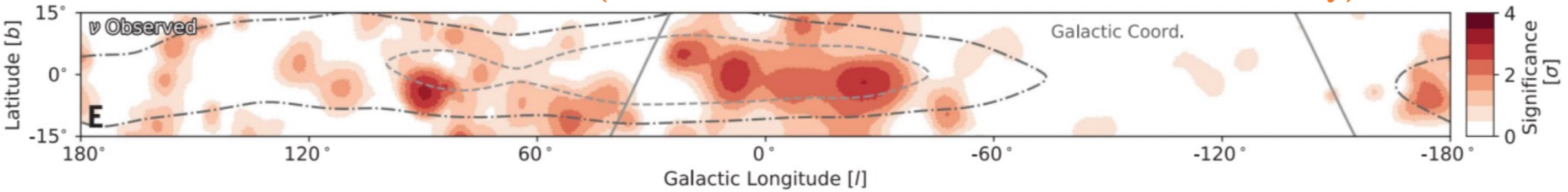
IceCube Collaboration, FERMI-LAT, MAGIC, ASAS-SN, H.E.S.S, INTEGRAL, KANATA, KISO, KAPTEYN, LIVERPOOL TELESCOPE, SUBARU, SWIFT/NUSTAR, VERITAS, VLA/17B-403, Science *361, issue 6398 (2018)*

2022: First steady-state source detected in neutrinos alone

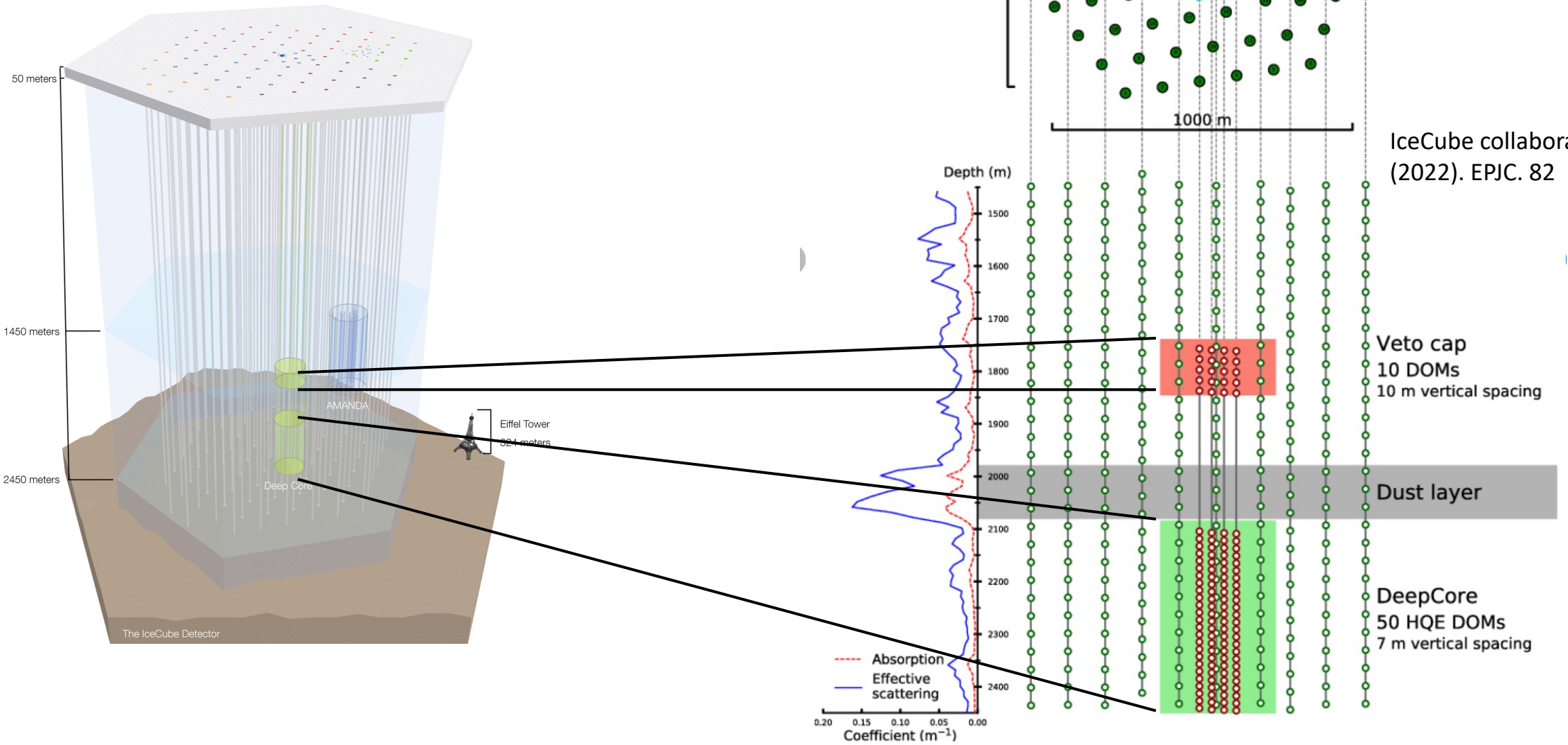
IceCube Collaboration Science *378 (2022)*



2023: First image of the galaxy in high energy neutrinos (See Naoko Kurahashi Neilson's talk today)

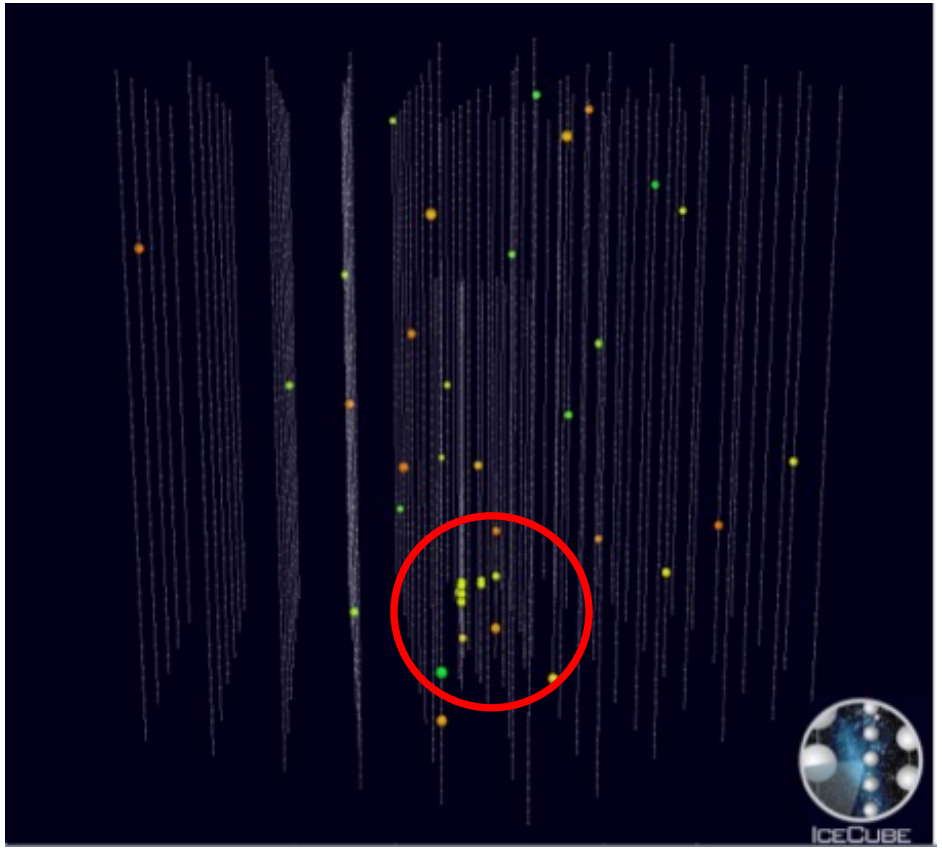


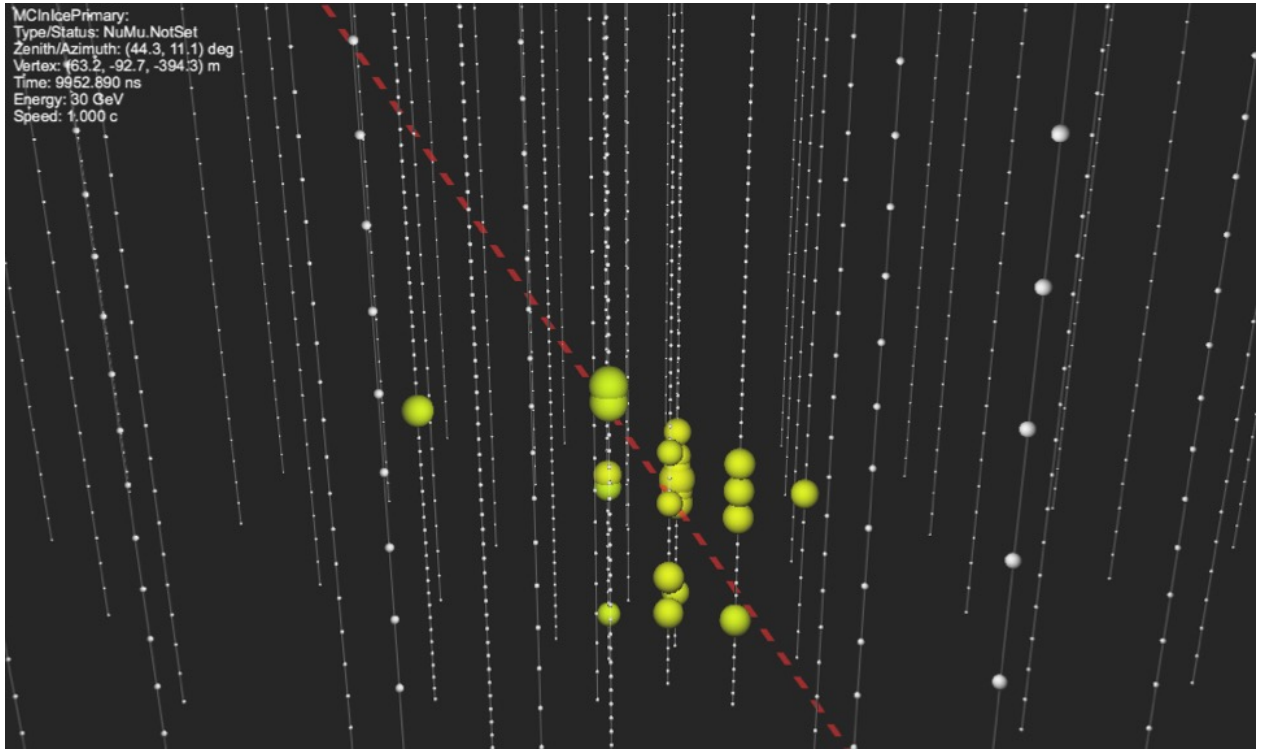
DeepCore: extending energies down to GeV



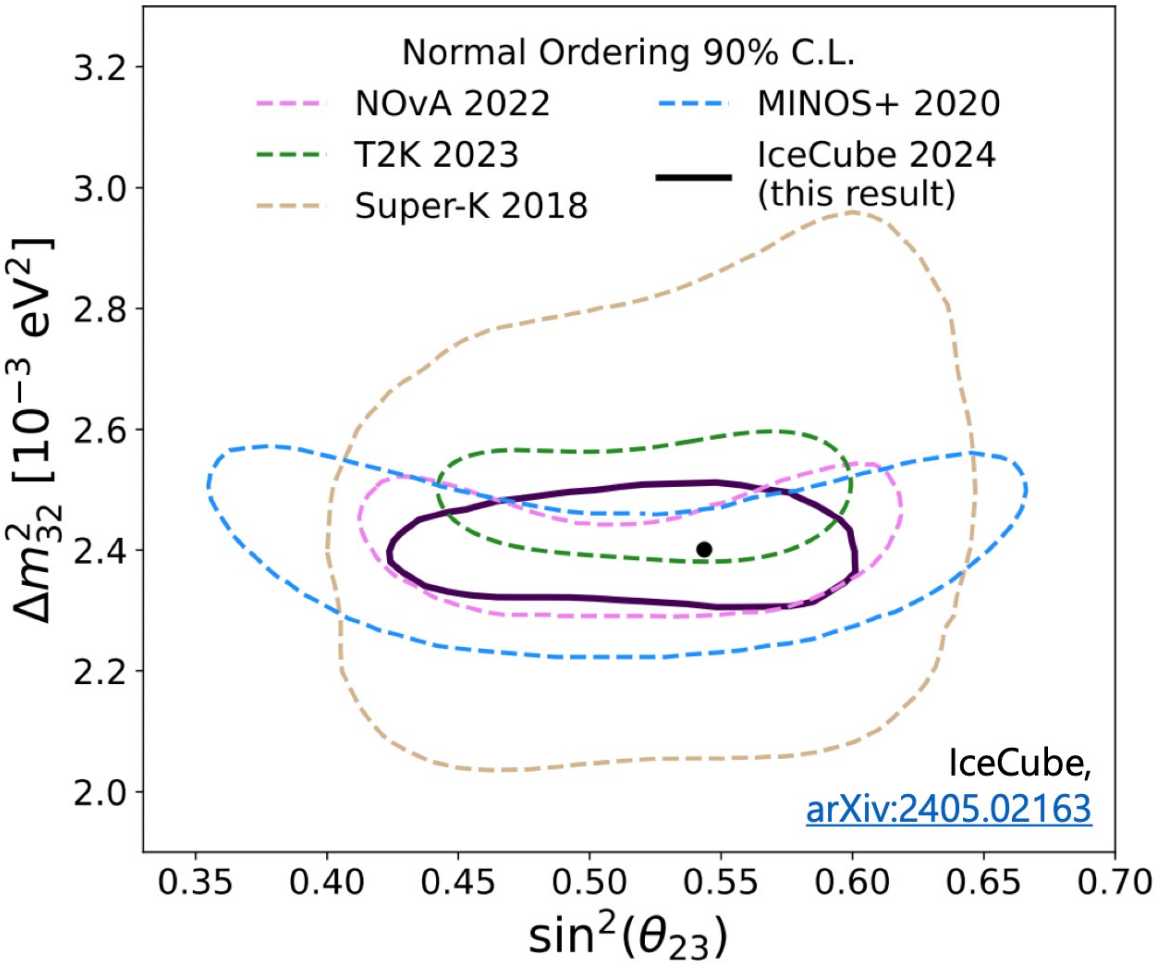
IceCube collaboration (2022). EPJC. 82

What do GeV neutrinos look like in IceCube?

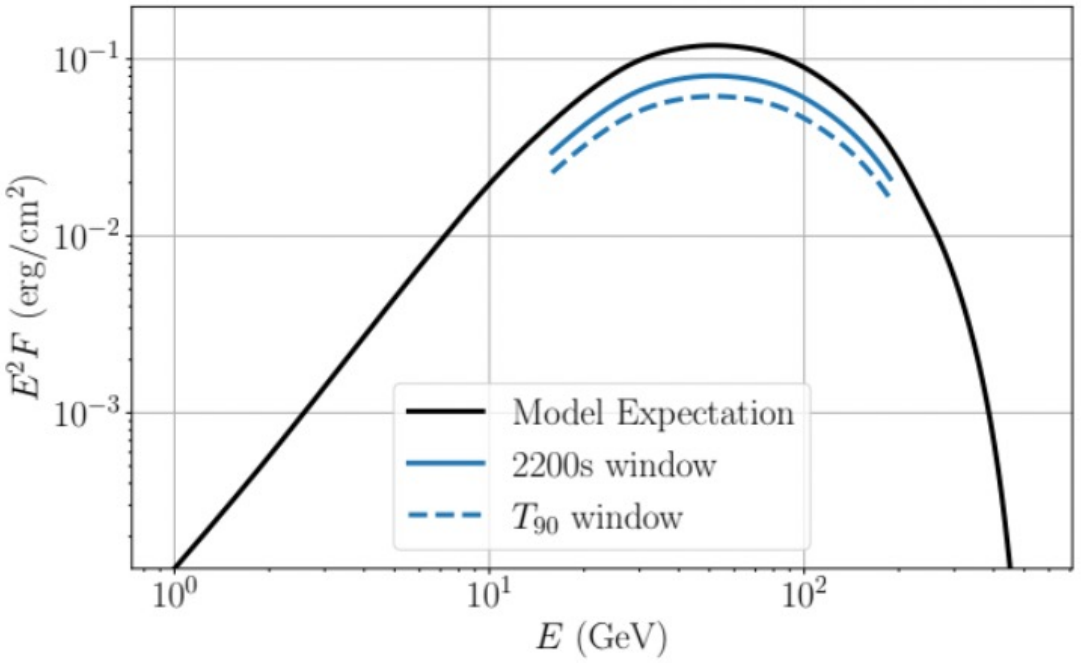




GeV neutrinos: Measurements of oscillation parameters with atmospheric neutrinos



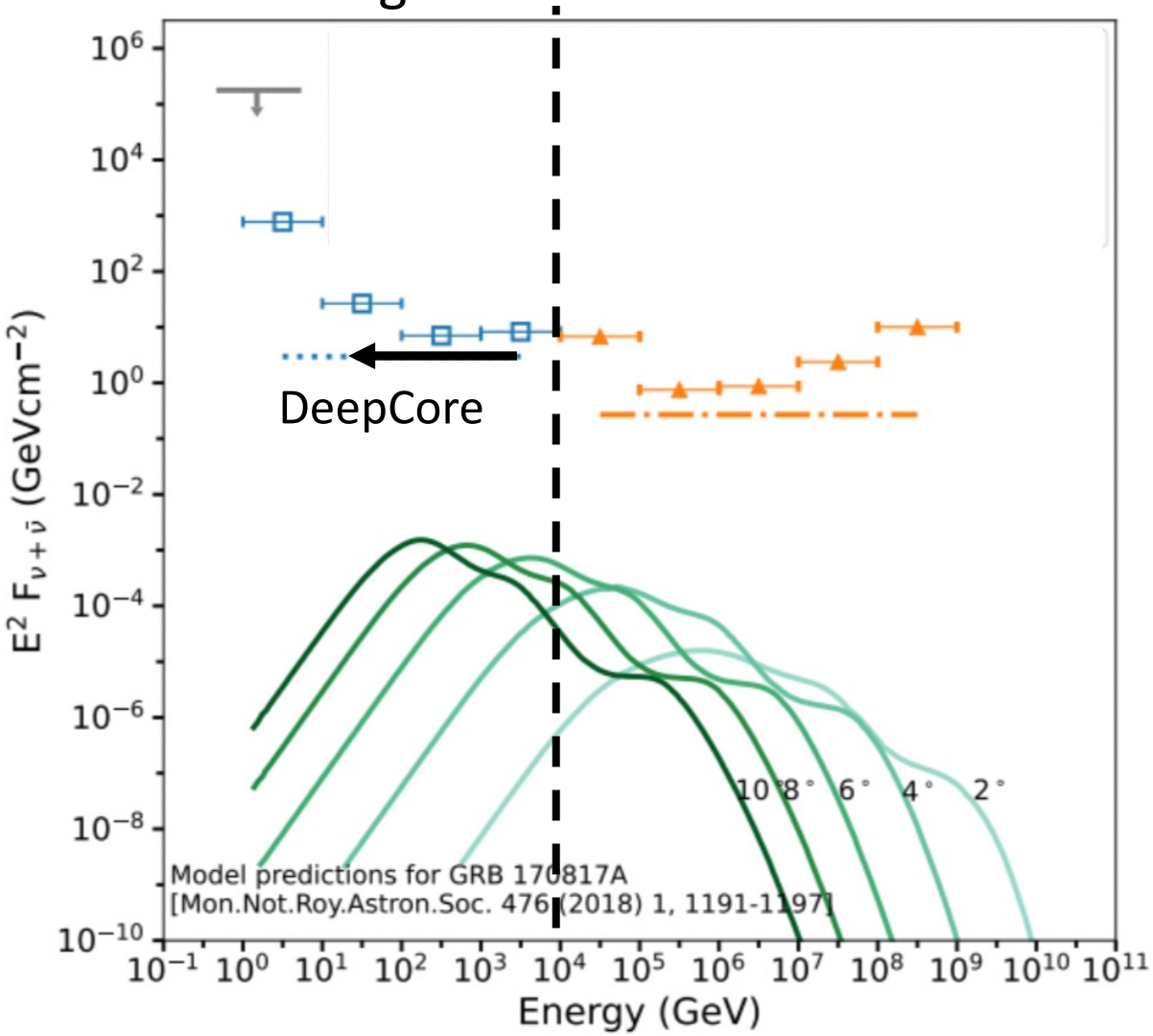
IceCube searches for GeV astrophysical neutrinos

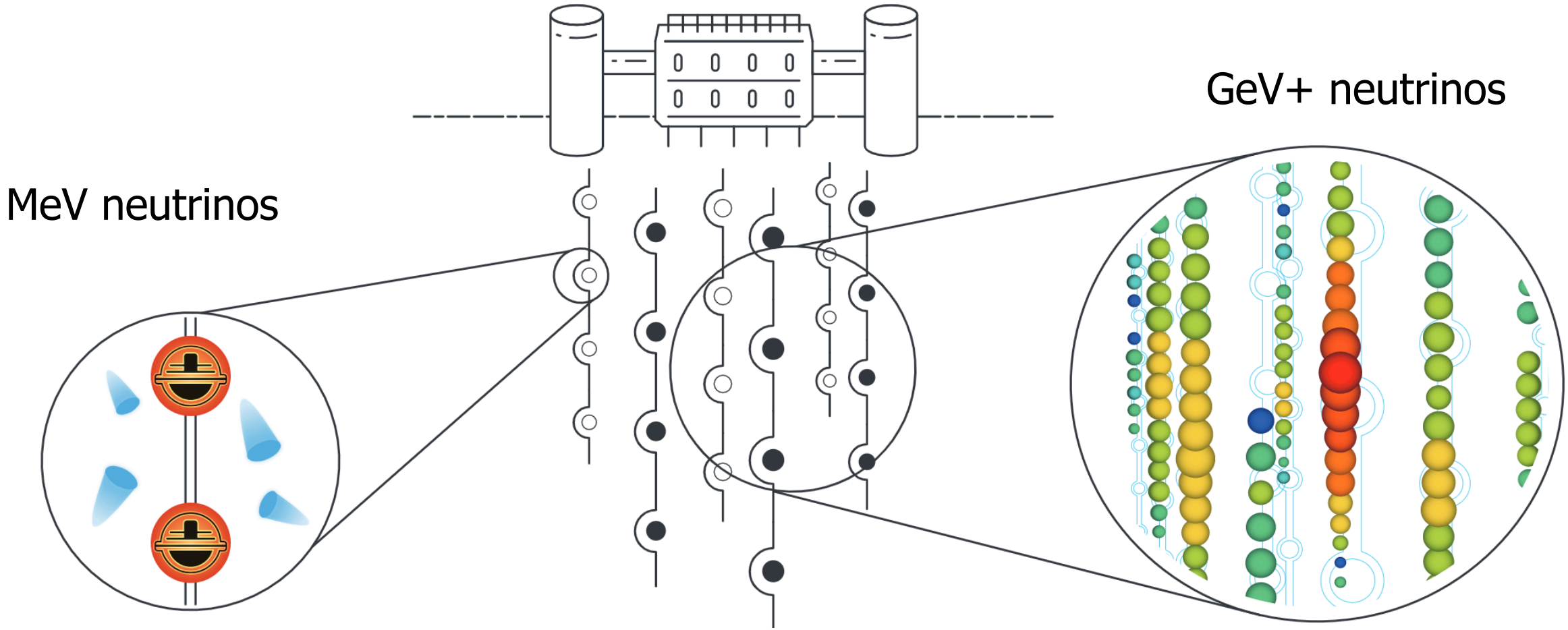


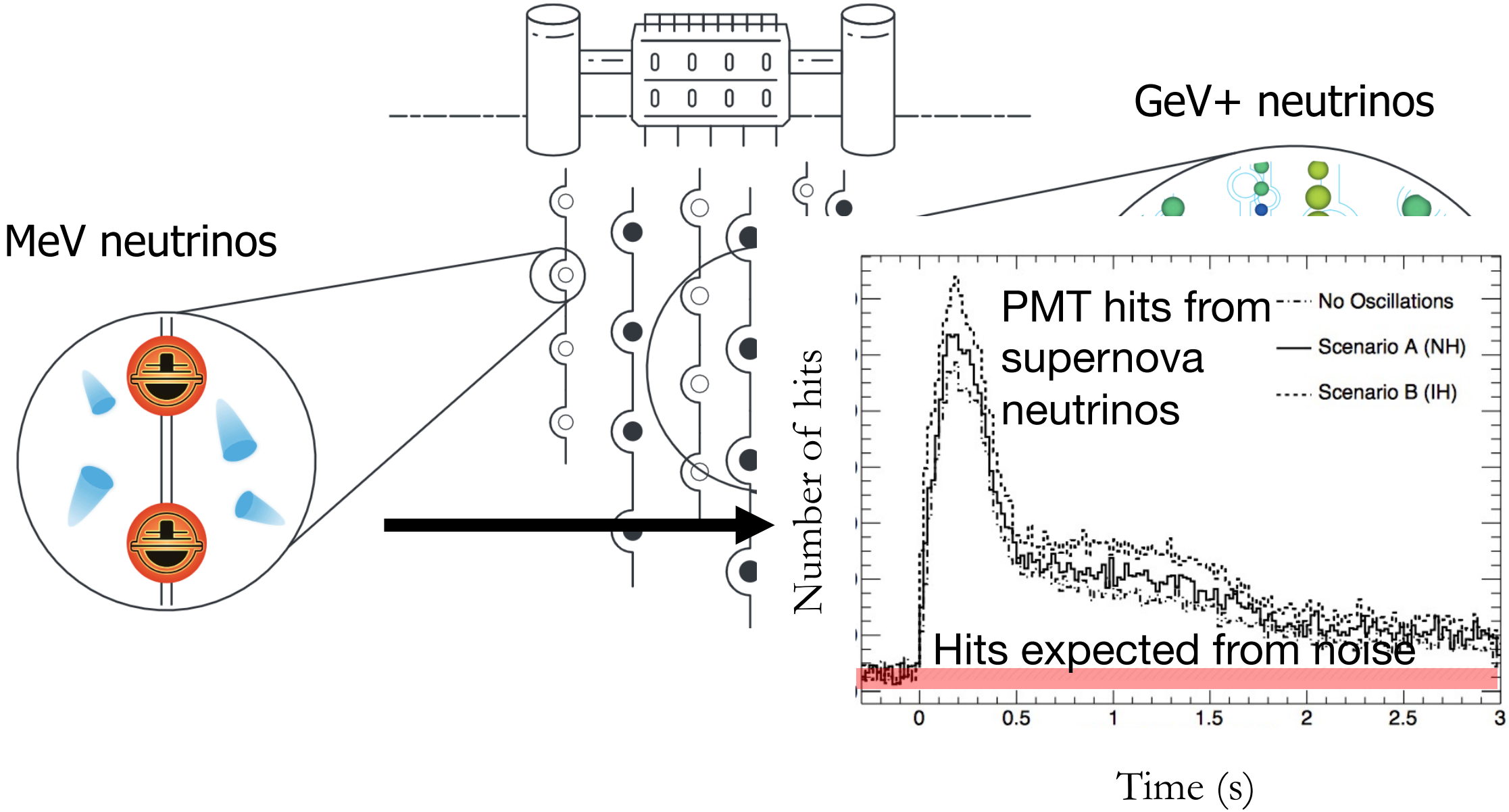
IceCube, ApJ 964 126 (2024)

Example: Limits on subphotospheric neutrino emission from GRBs

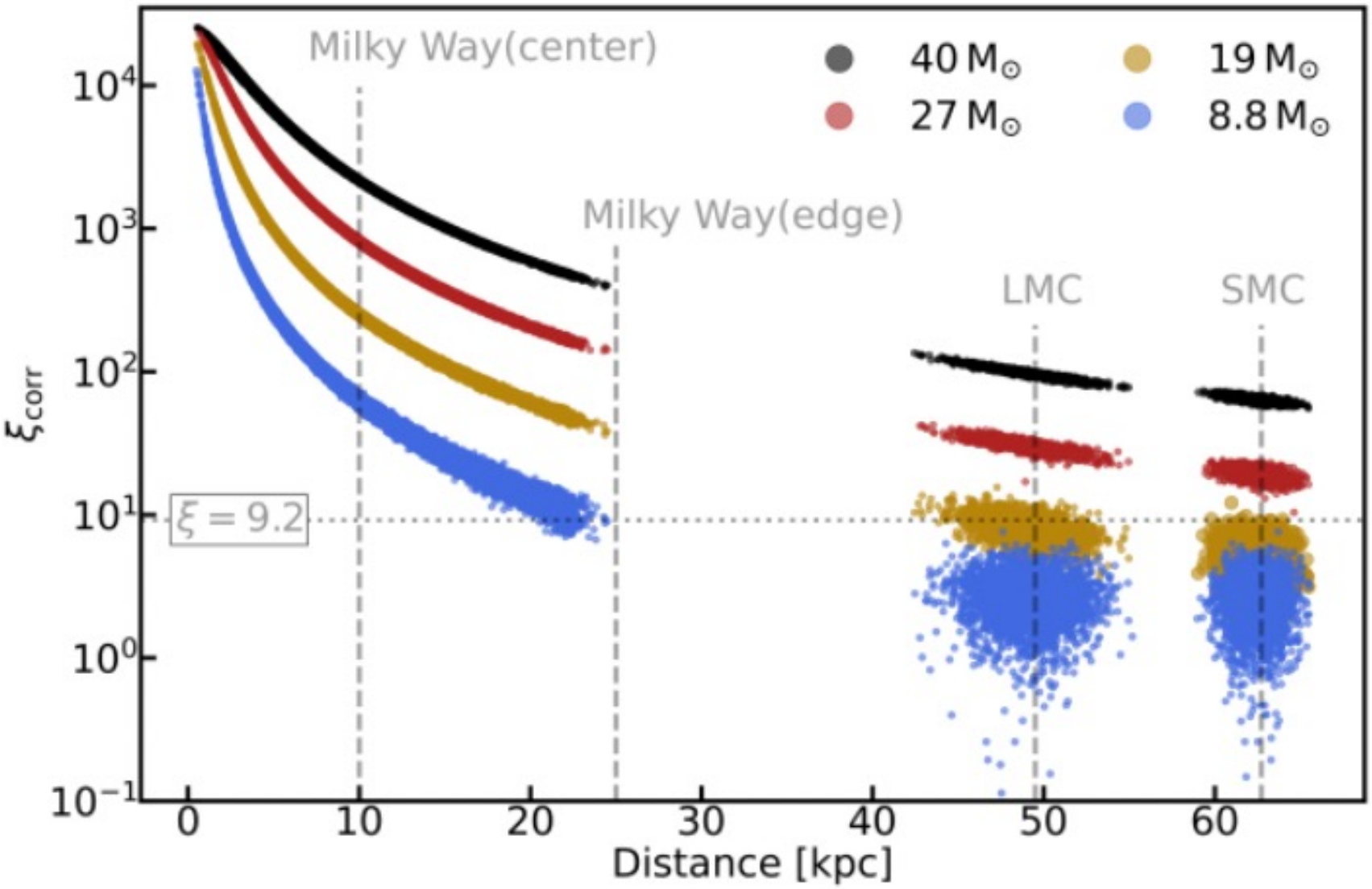
Example: Limits on neutrinos with gravitational waves




GeV+ neutrinos
MeV neutrinos

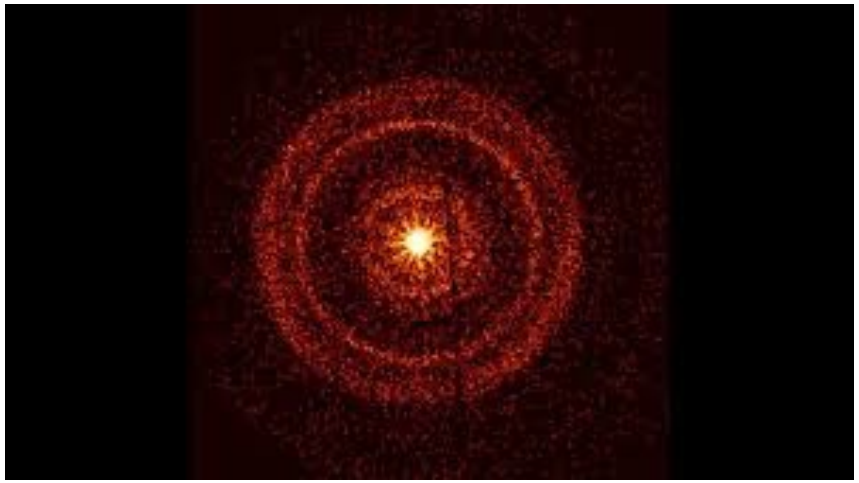

GeV+ neutrinos
MeV neutrinos
PMT hits from supernova neutrinos
No Oscillations
Scenario A (NH)
Scenario B (IH)
Hits expected from noise
Number of hits
0
0.5
1
1.5
2
2.5
3
Time (s)

Significance



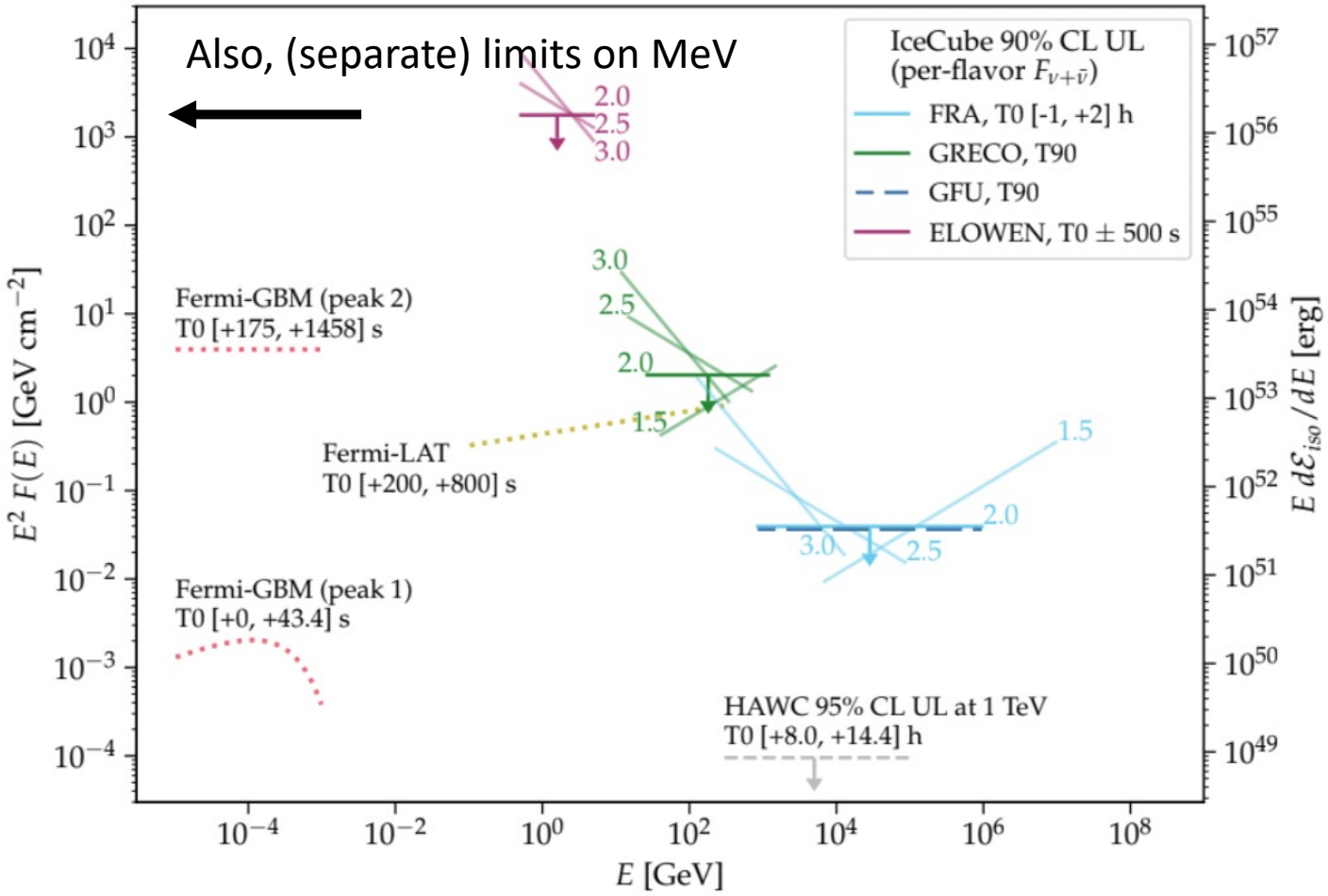
IceCube collaboration, ApJ. 961 (2024) 1, 84

GRB 221009A: From MeV to PeV



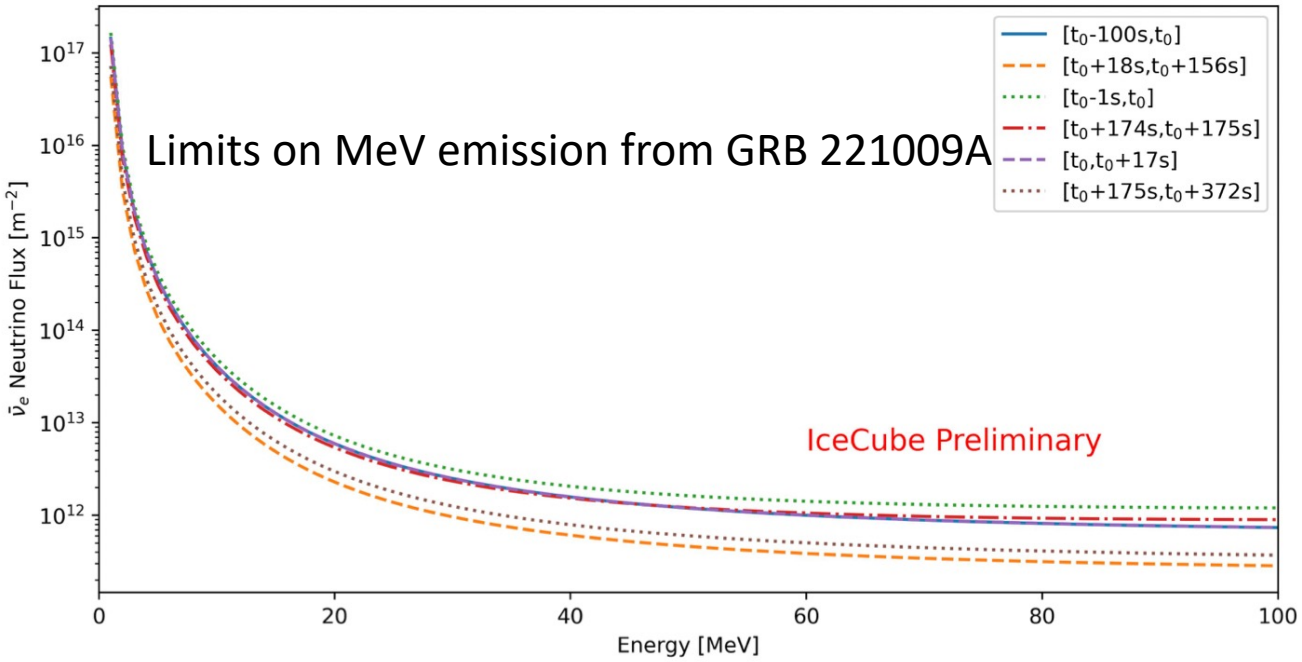
BOAT (brightest of all time) GRB

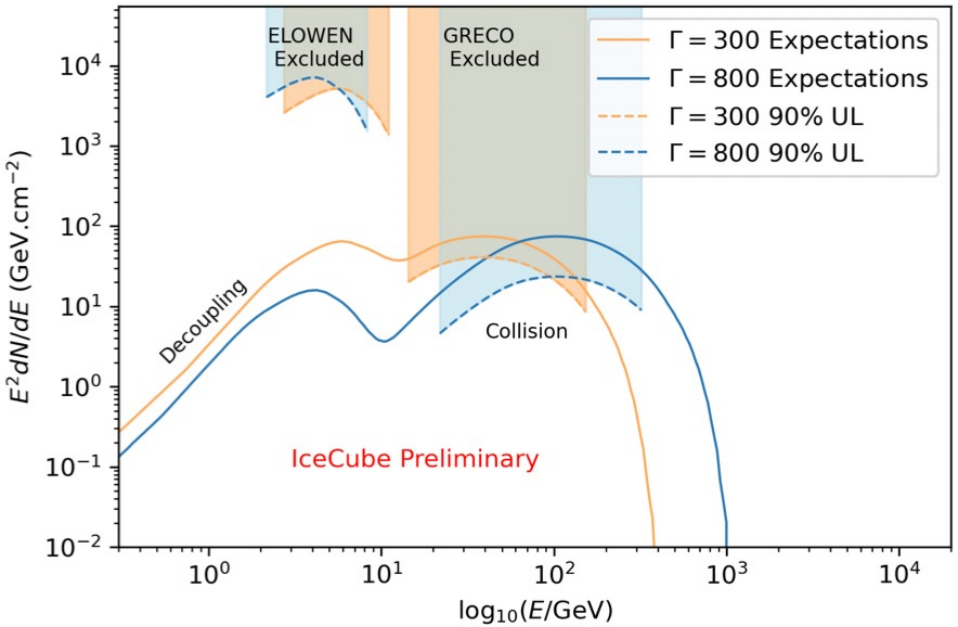
First IceCube analysis that included the entire energy range of the detector



IceCube, ApJL 946 L26 (2023)

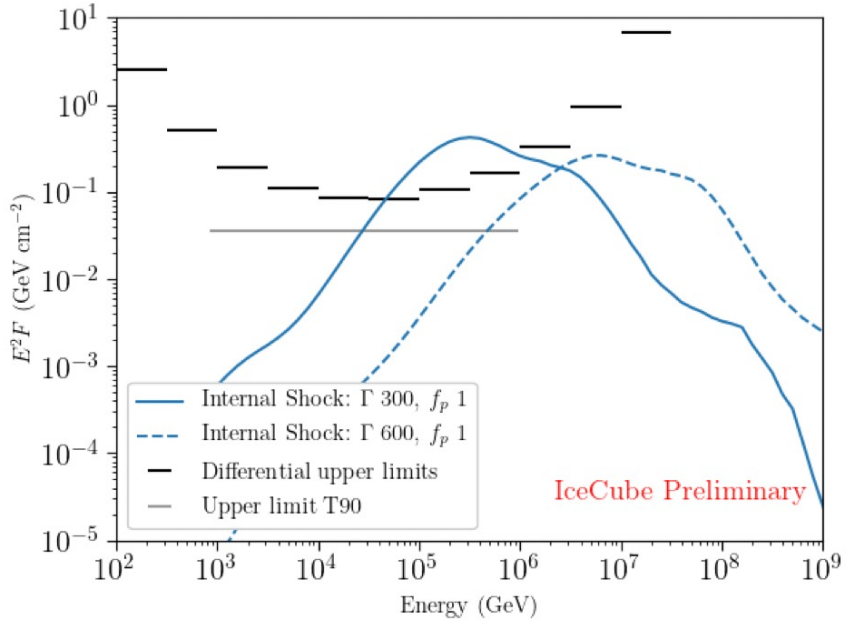
Limits on MeV emission from GRB 221009A





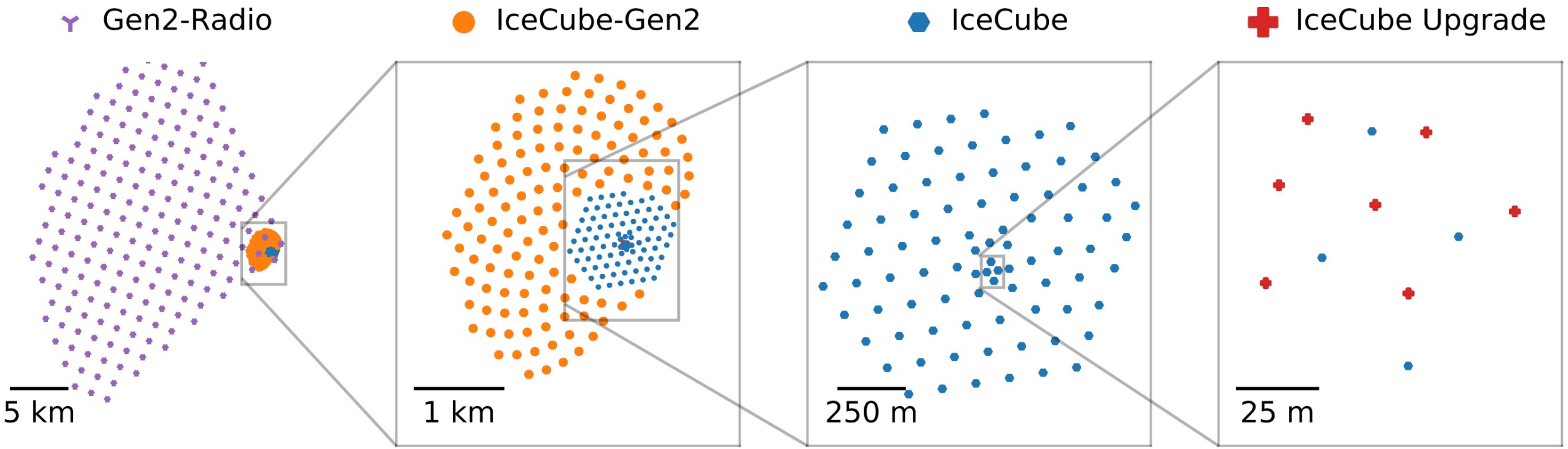
Limits on GeV emission models from GRB 221009A

Limits on TeV+ shock emission models from GRB 221009A



Kruiswijk, Brinson, Procter-Murphy, Thwaites, Nora Valtonen-Mattila, for IceCube PoS-ICRC2023-1511

IceCube, Upgrade, and IceCube-Gen2: A multi-energy (GeV-EeV, and MeV bursts), multi-instrument facility (Optical, radio, surface)

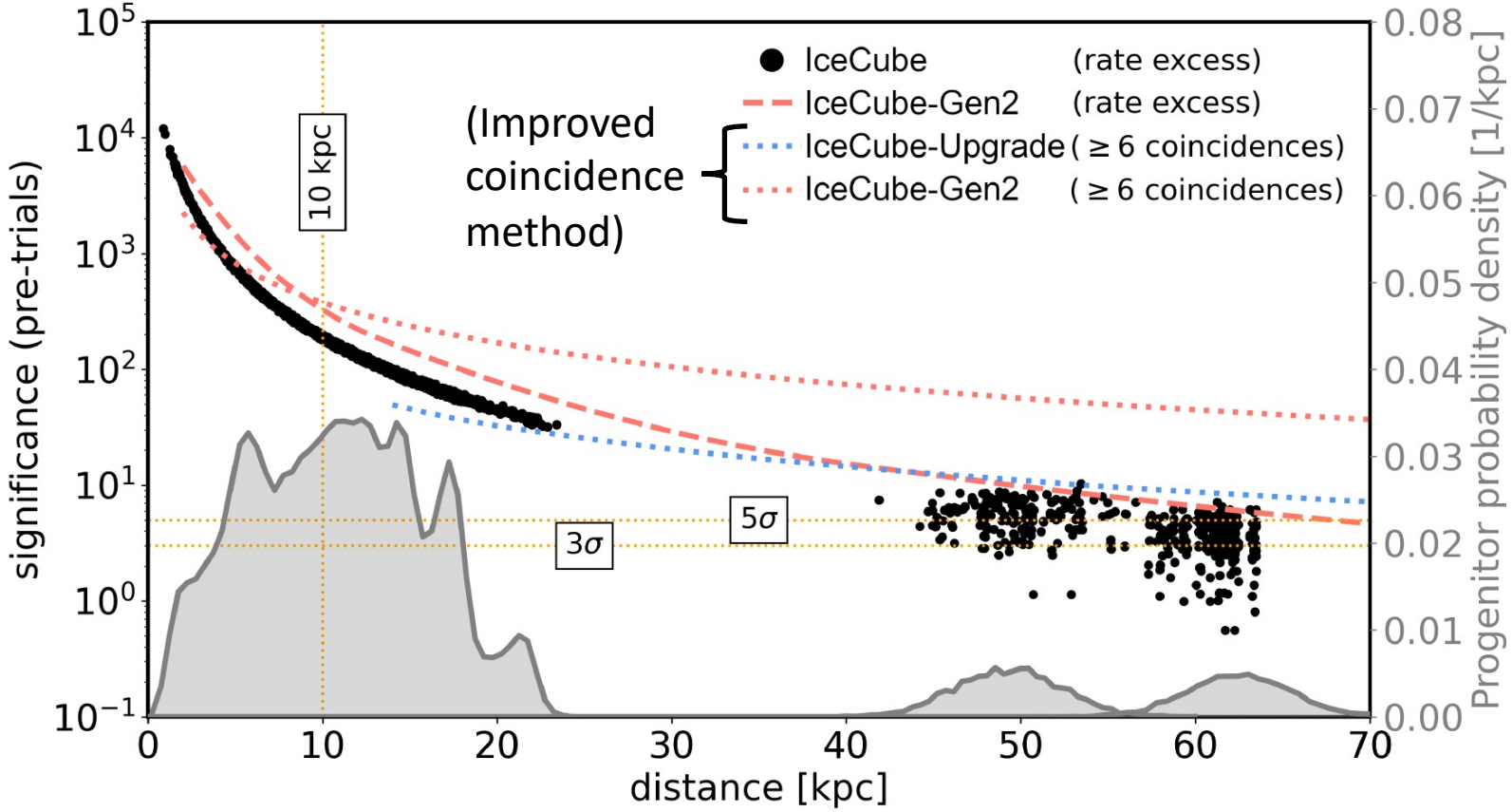


Operating for over 10 years

2025/26

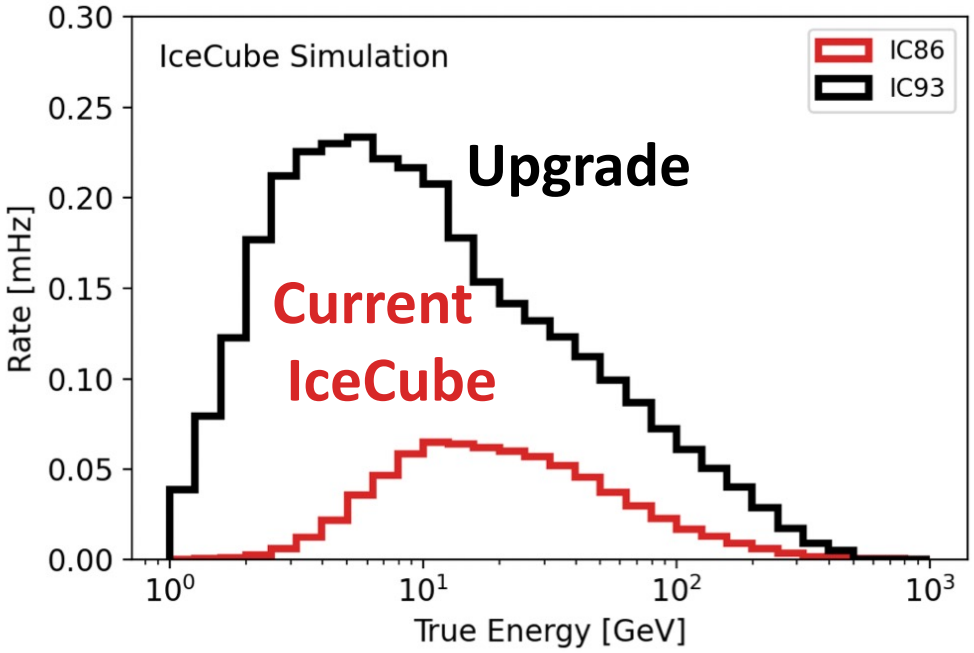
MeV neutrinos in the Upgrade and Gen2

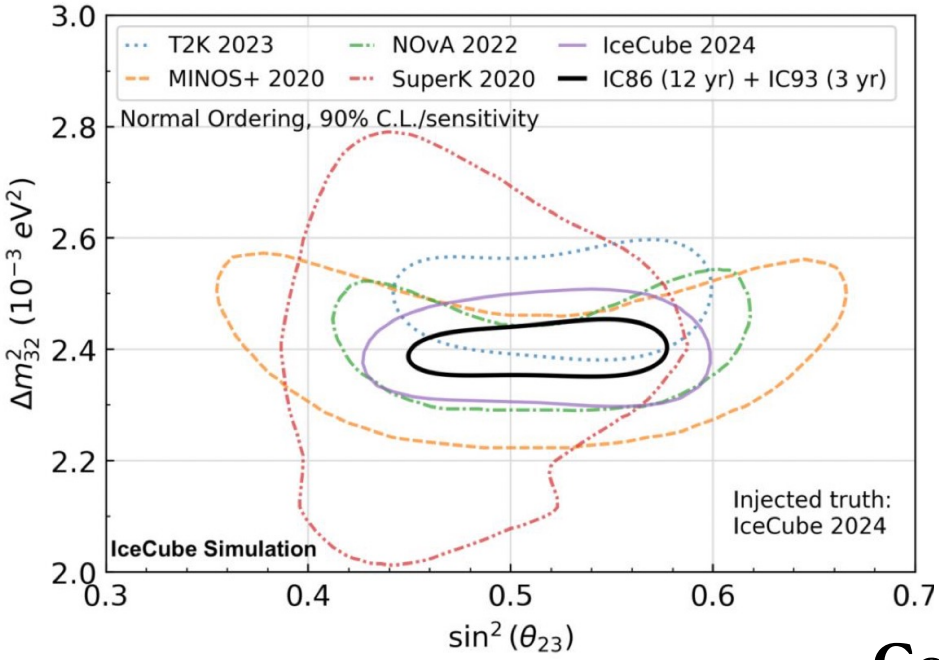
Require coincidences between nearby phototubes to reduce noise



GeV neutrinos in the Upgrade

Enhanced rate of GeV neutrinos will improve astro searches

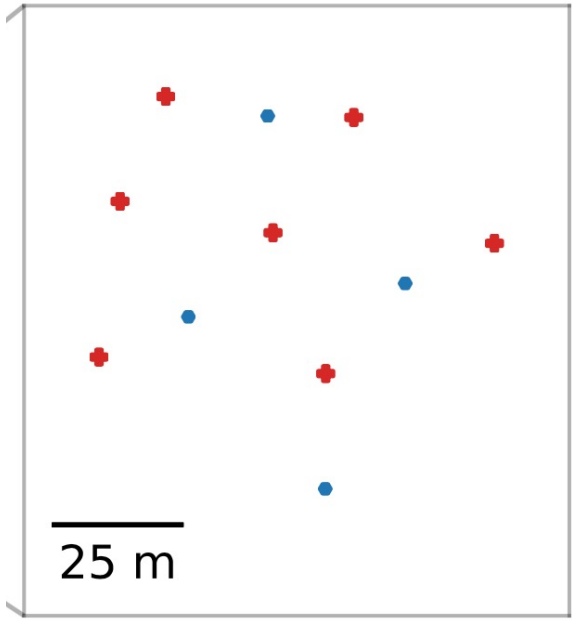




2 Mton volume

Energy threshold of 1 GeV

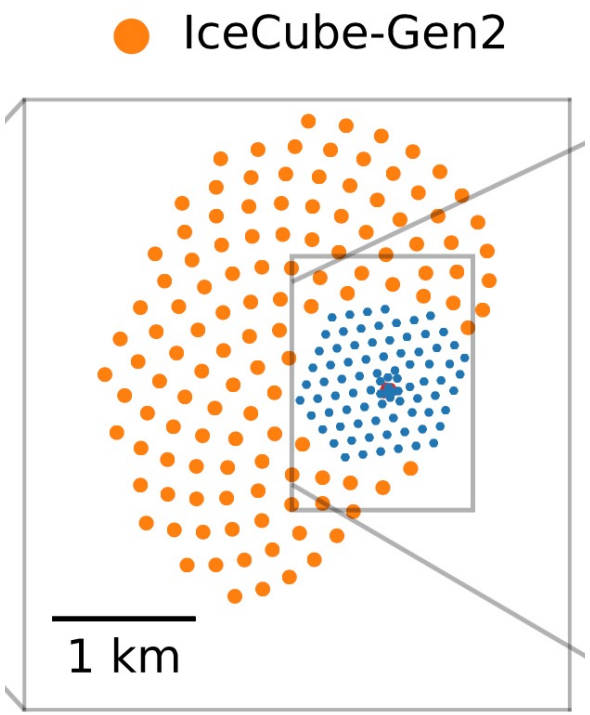
IceCube Upgrade

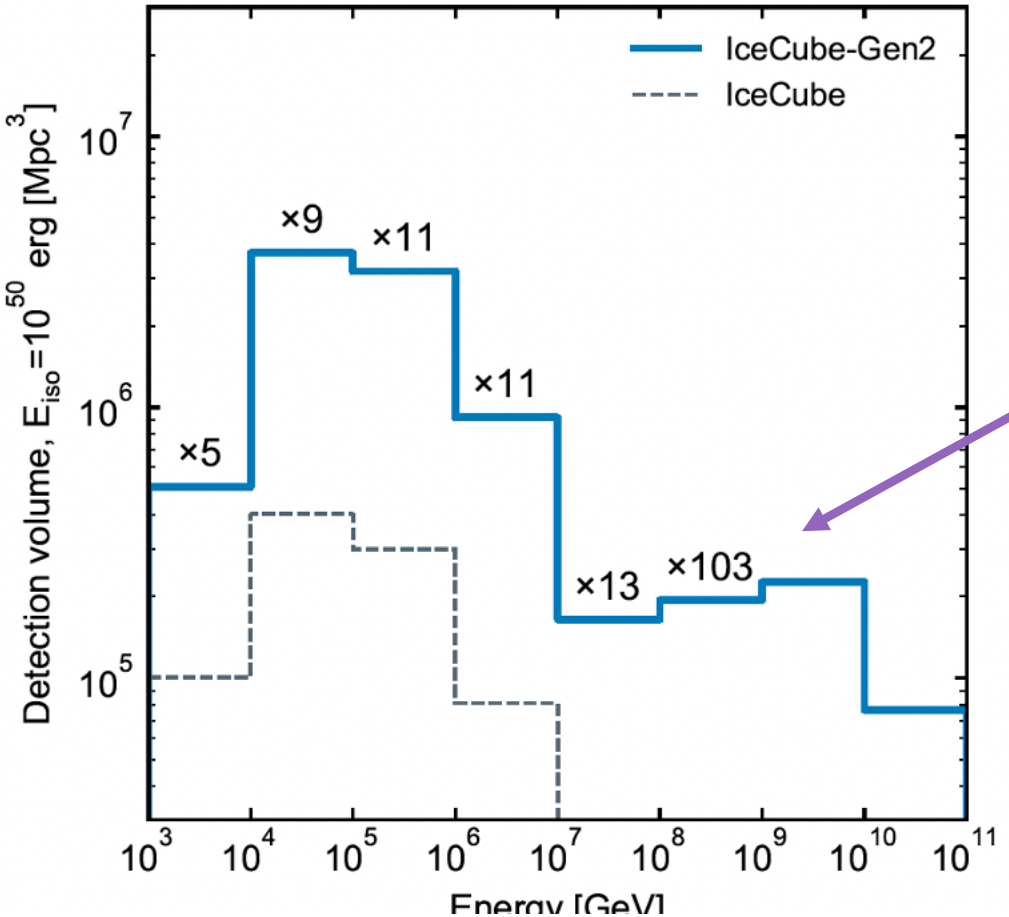


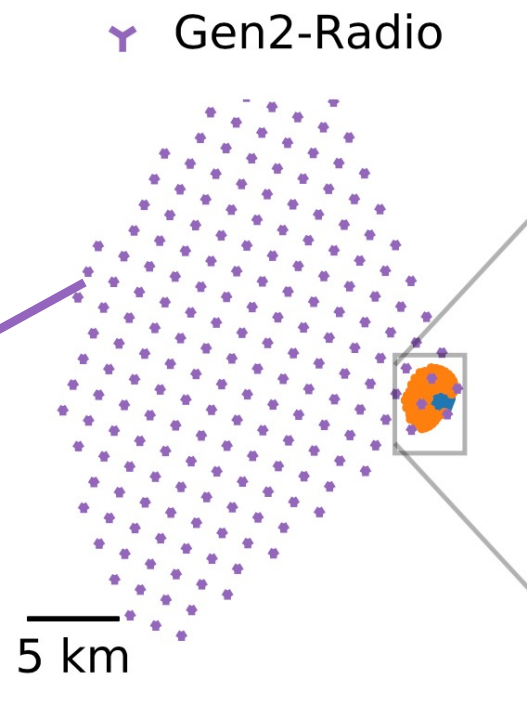
Construction underway

7 new strings in 2025/26

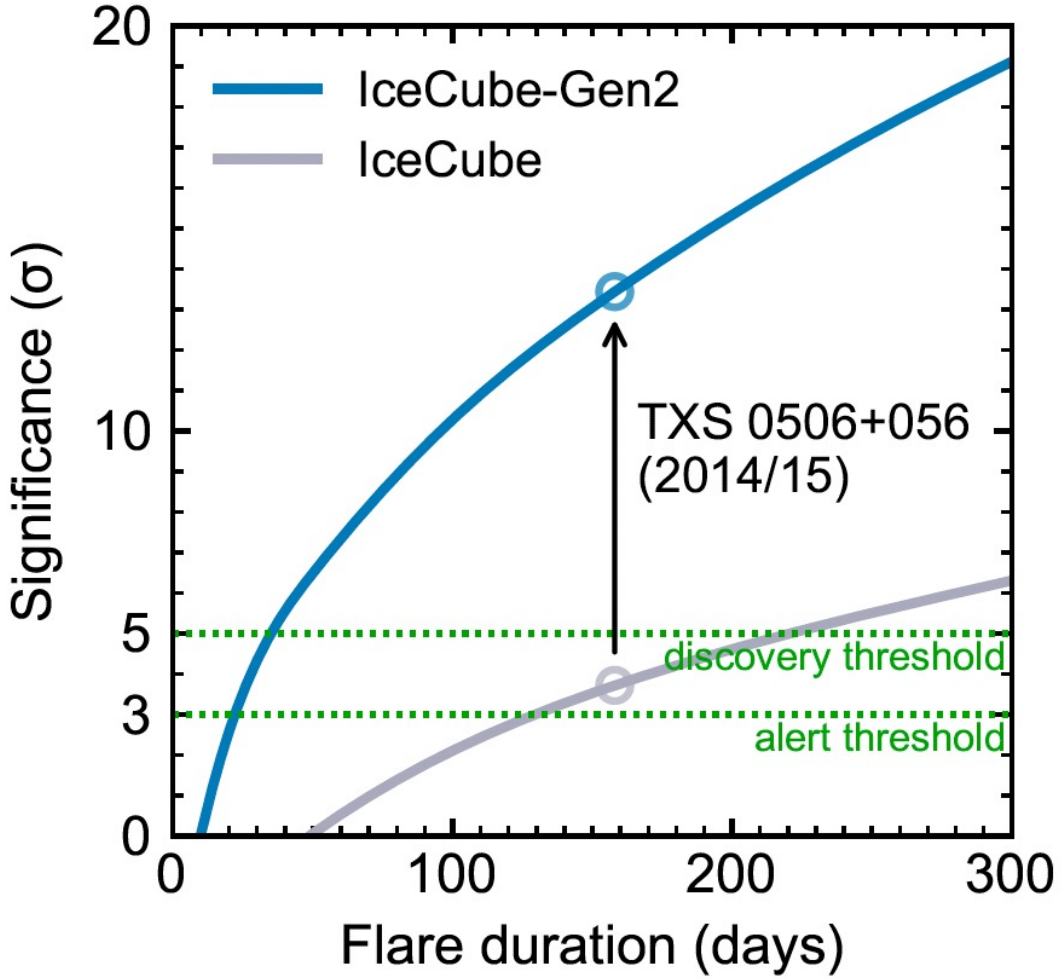
TeV-EeV neutrinos in IceCube-Gen2: More than 10x expanded volume for steady-state sources, plus extension to the highest energies

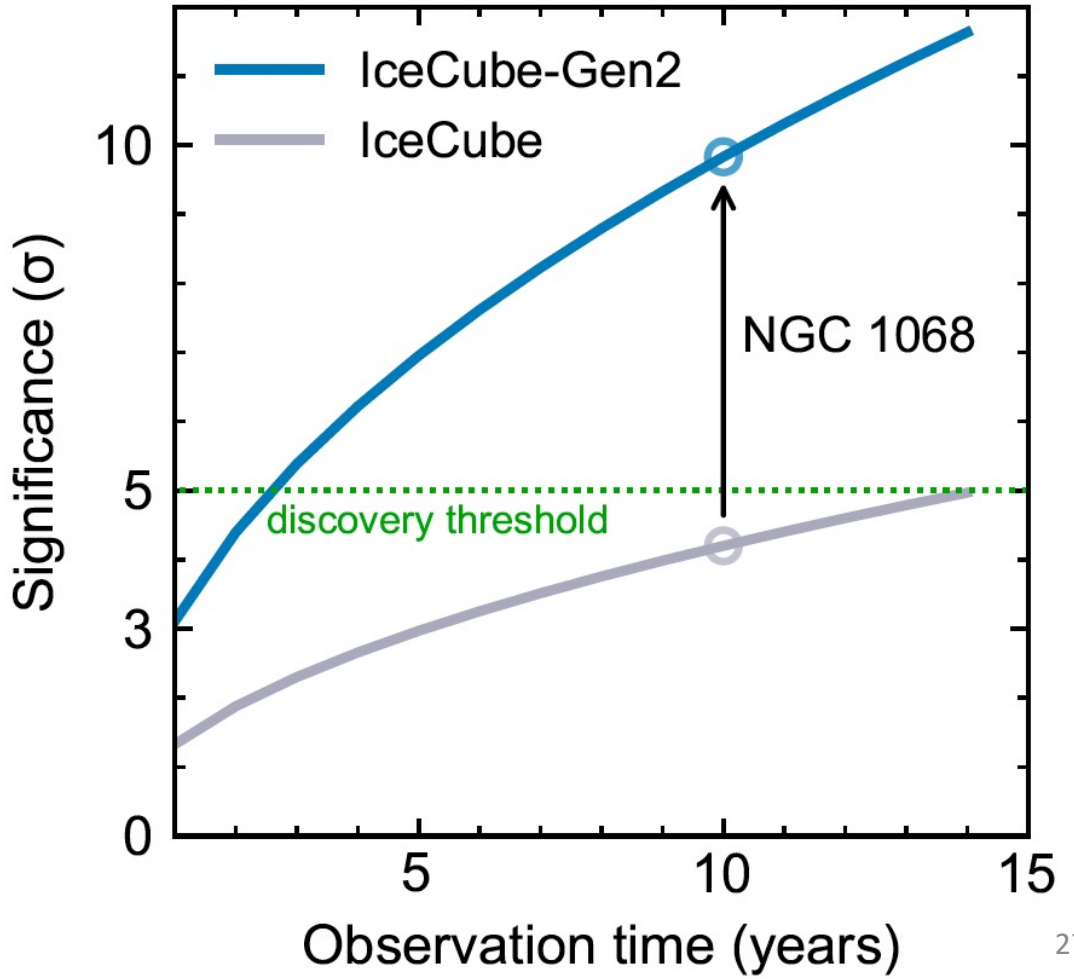




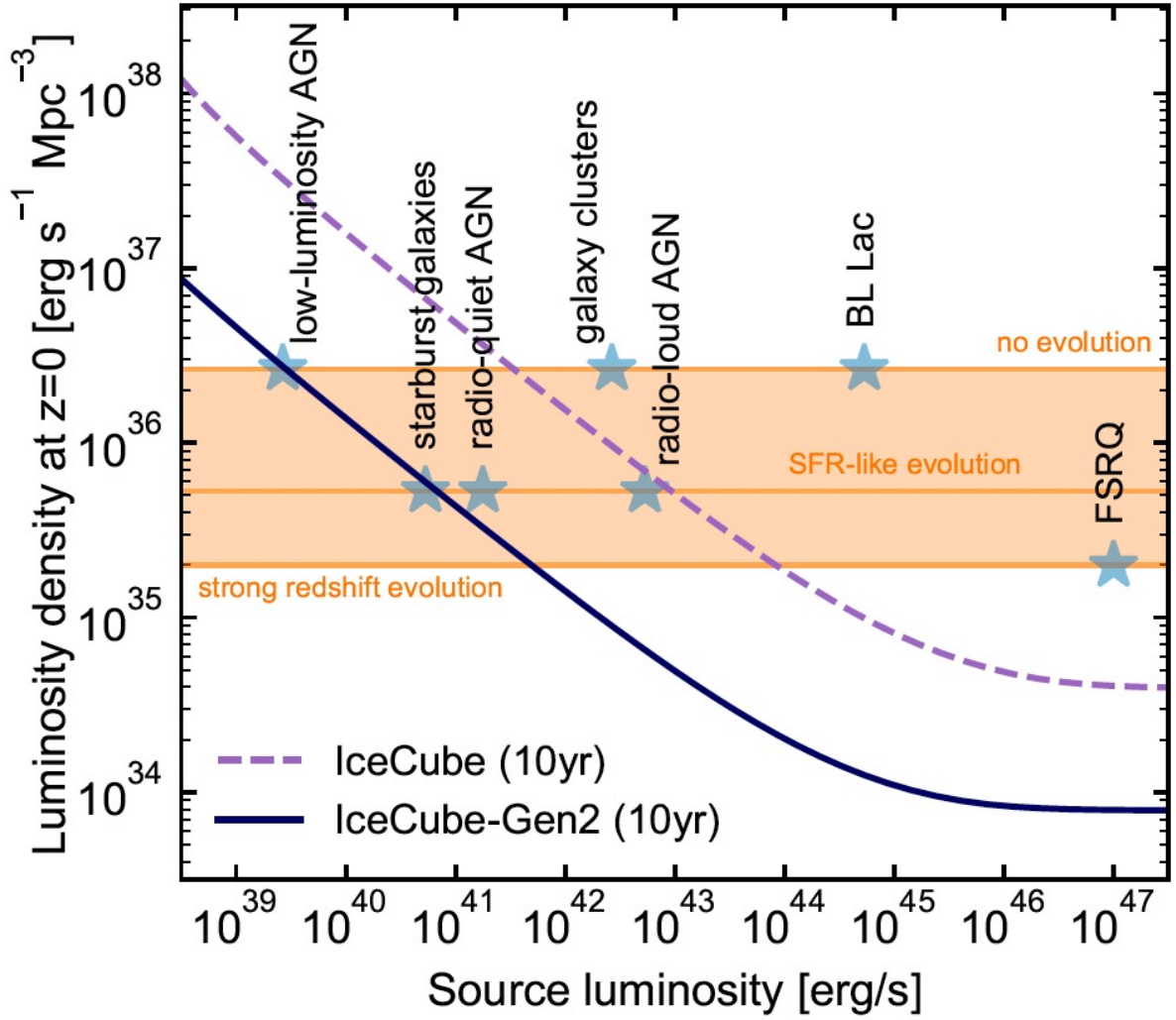


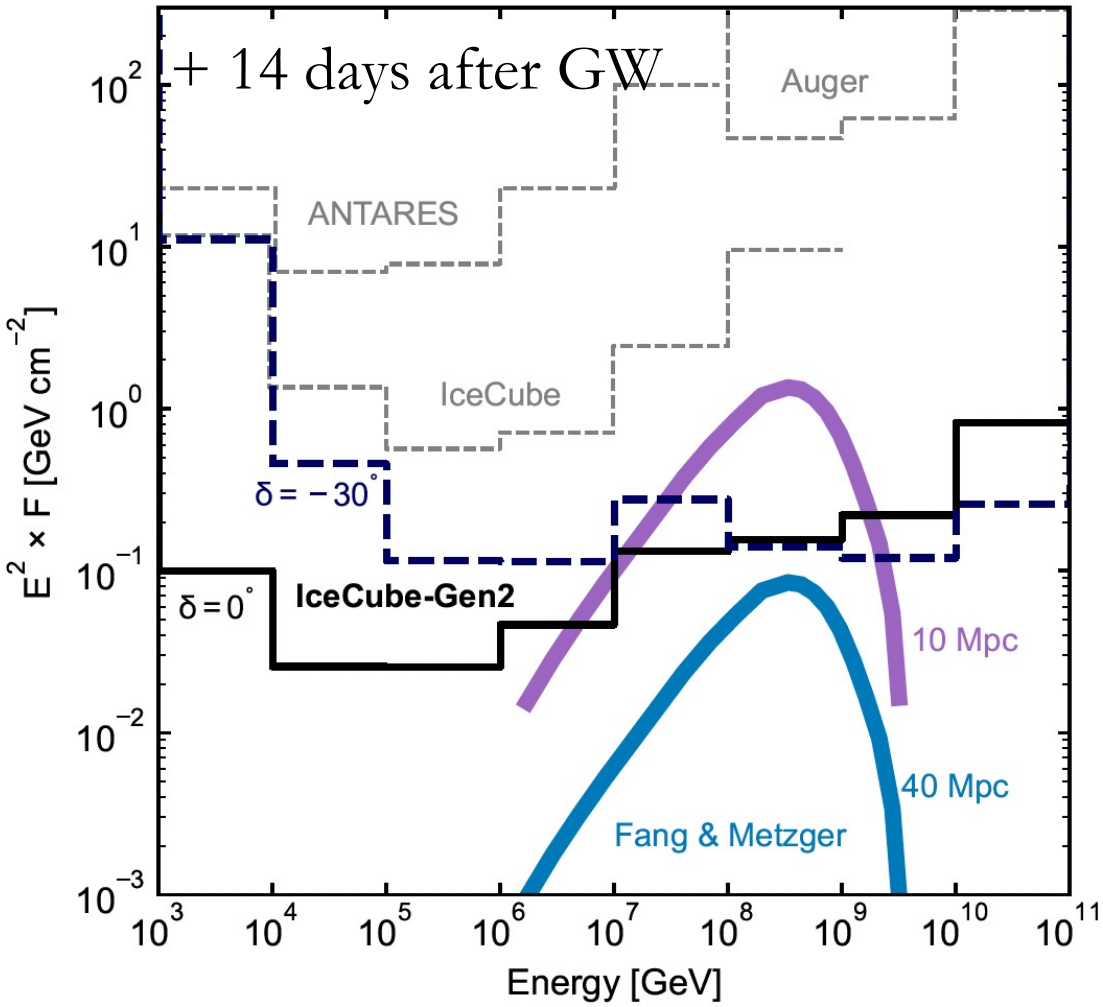
Enabling firmer associations with bright sources





Unlocking the potential to discover new, dimmer source classes





THE ICECUBE COLLABORATION

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Université libre de Bruxelles
Universiteit Gent
Vrije Universiteit Brussel

CANADA
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Simon Fraser University
University of Alberta–Edmonton

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Humboldt–Universität zu Berlin
Karlsruhe Institute of Technology
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RWTH Aachen University
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Mercer University
Michigan State University
Ohio State University
Pennsylvania State University
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Southern University and A&M College
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University of Wisconsin–River Falls
Yale University

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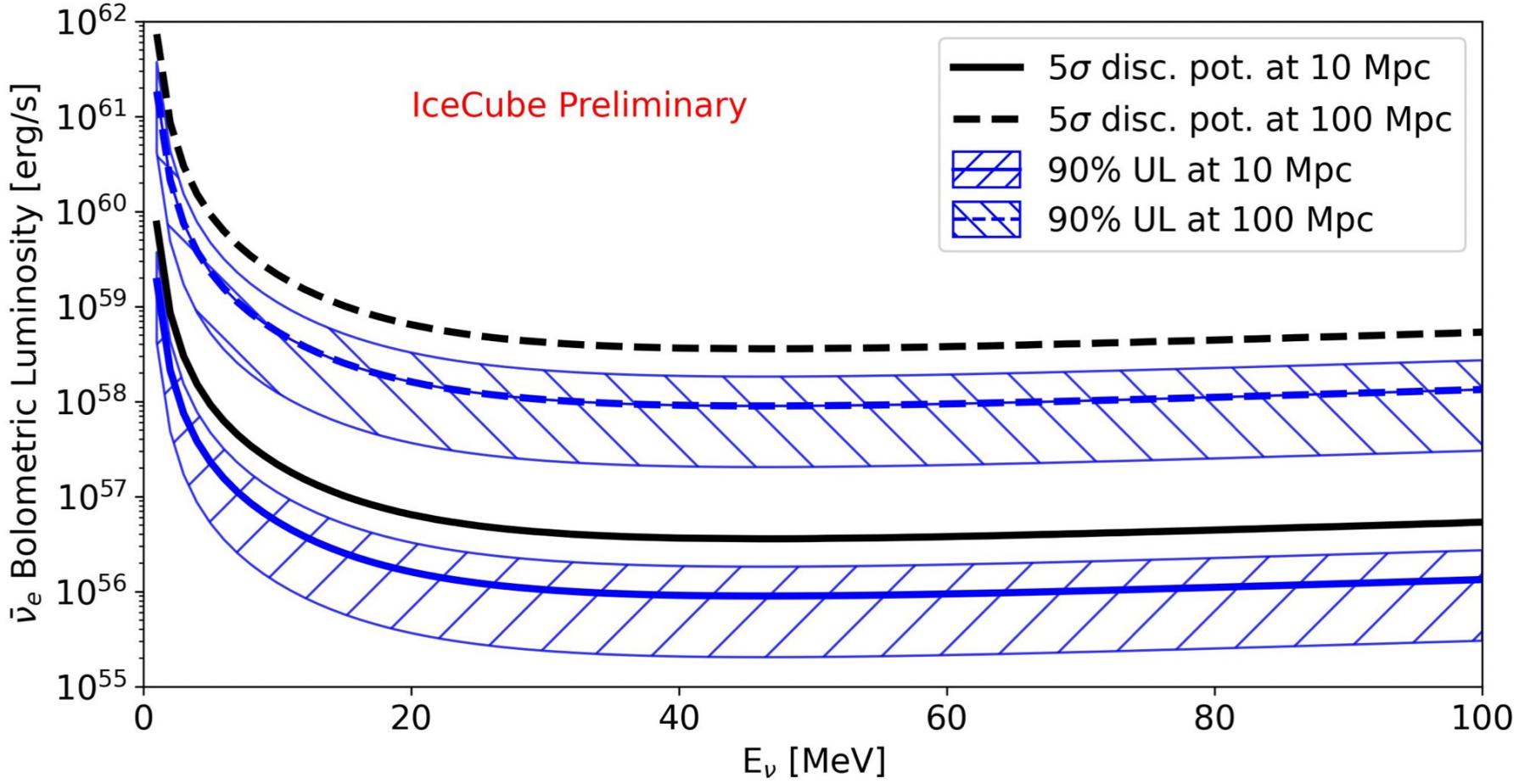
Deutsches Elektronen-Synchrotron (DESY)
Japan Society for the Promotion of Science (JSPS)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

IceCube Neutrino Observatory

icecube.wisc.edu

IceCube is developing methods to set limits on MeV neutrino emission with externally triggered alerts



Nora Valtonen-Mattila (for IceCube) PoS TAUP2023 (2024) 236