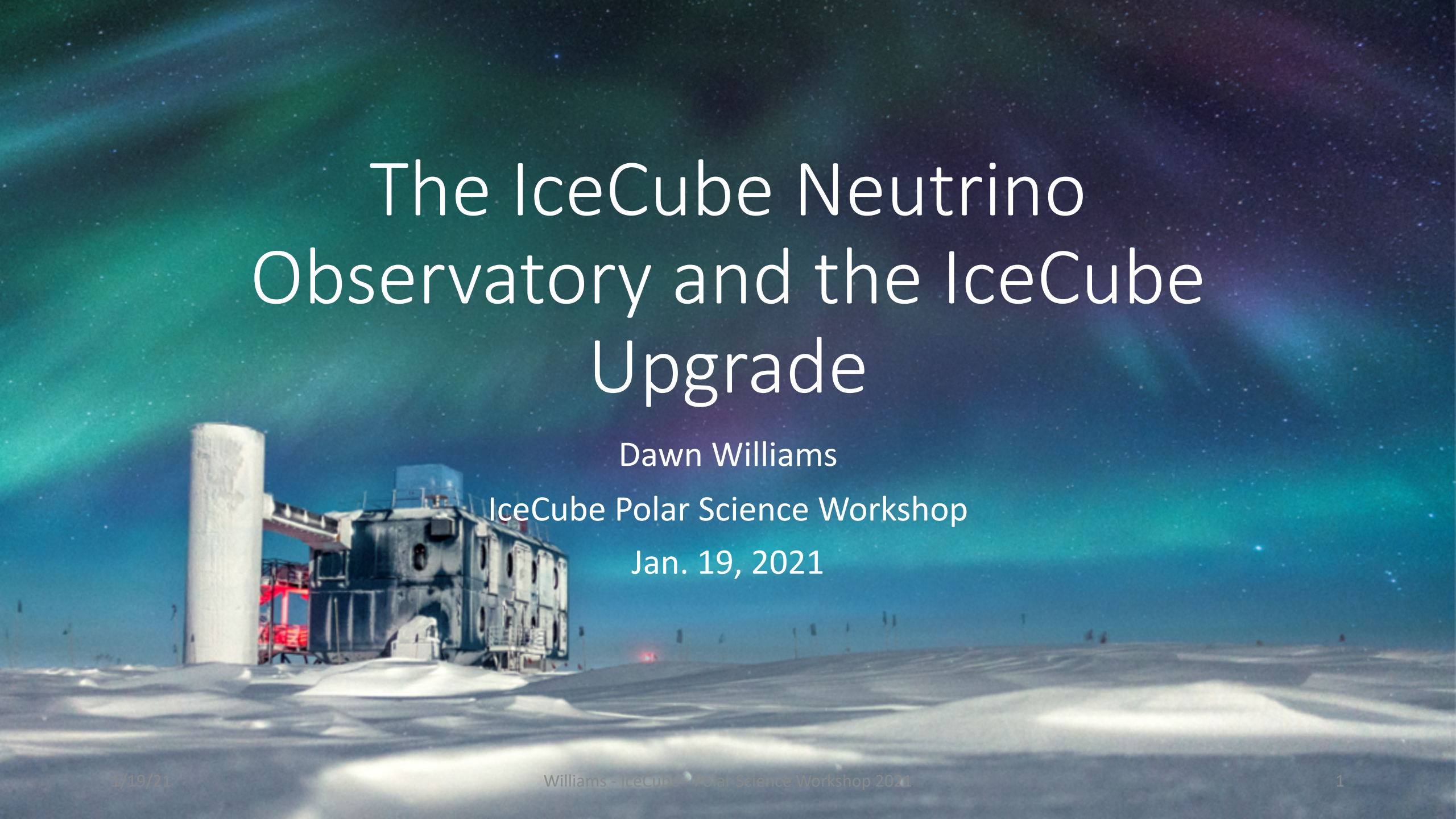




The IceCube Neutrino Observatory and the IceCube Upgrade

Dawn Williams

IceCube Polar Science Workshop

Jan. 19, 2021

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FUNDING AGENCIES

Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen
(FWO-Vlaanderen)

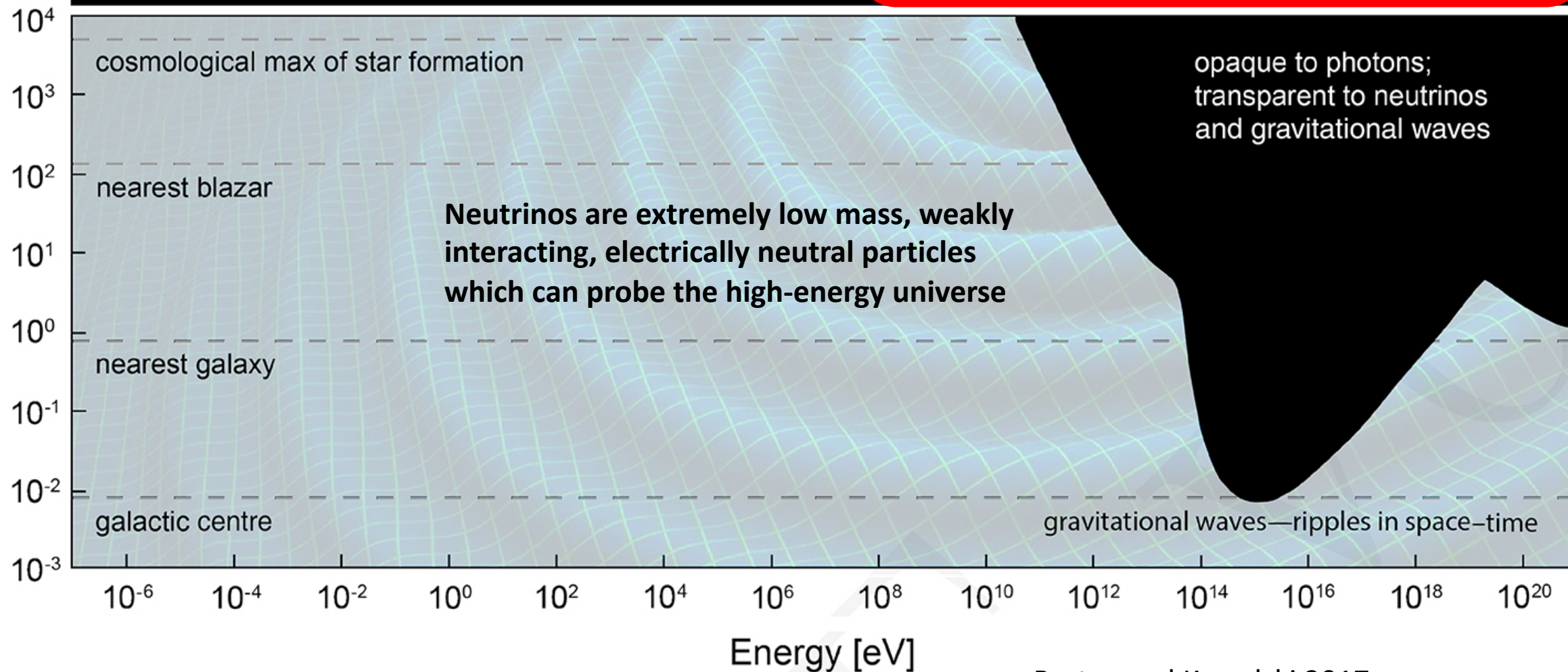
Federal Ministry of Education and Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)

Japan Society for the Promotion of Science (JSPS)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat

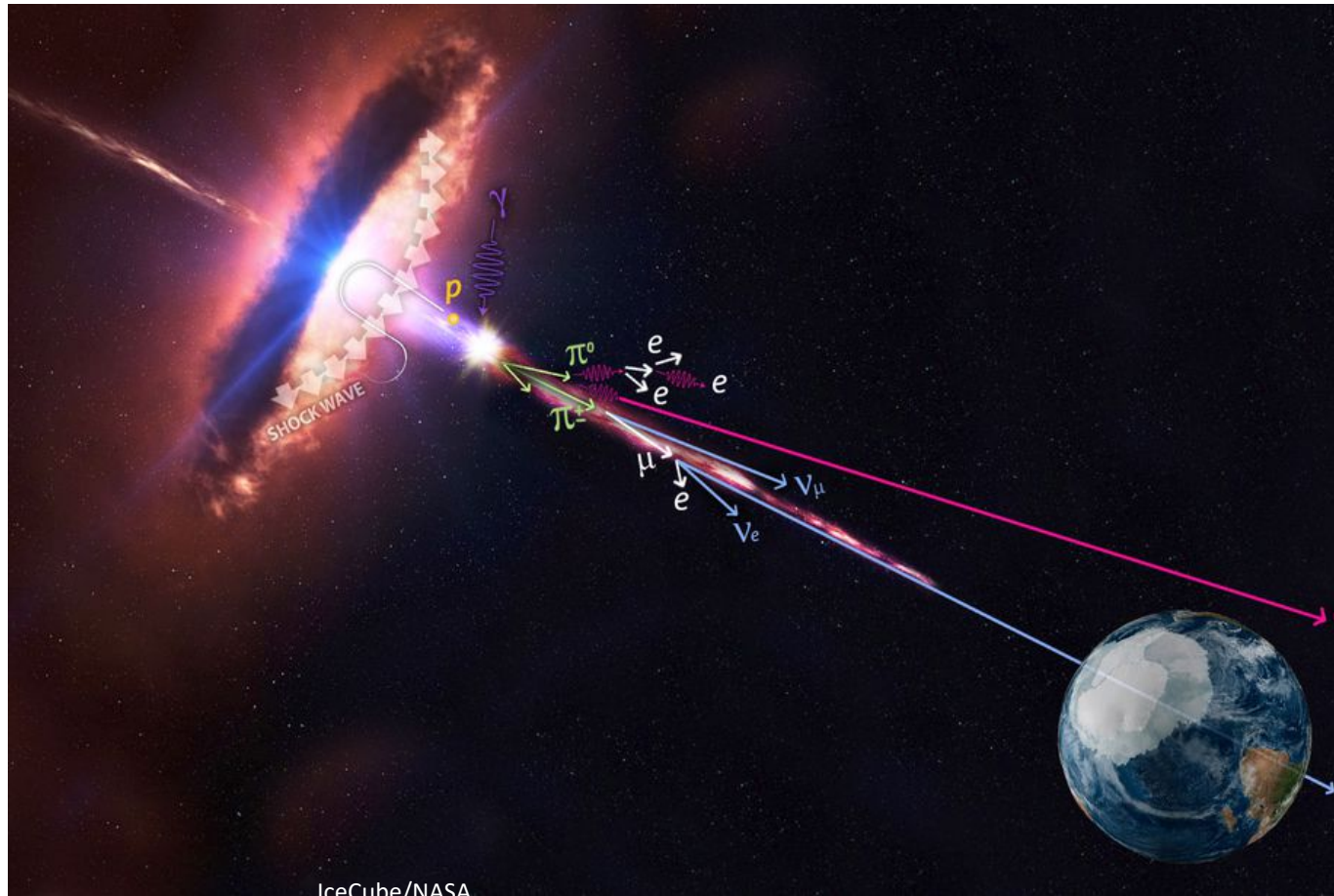
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)



icecube.wisc.edu

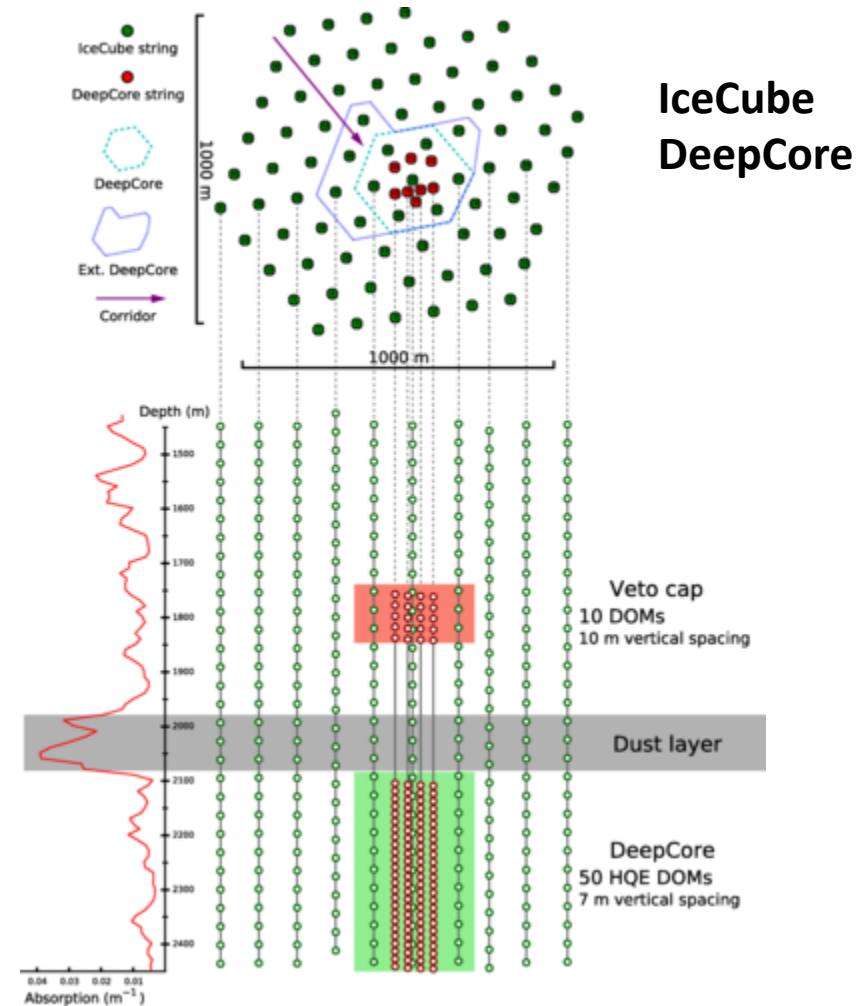
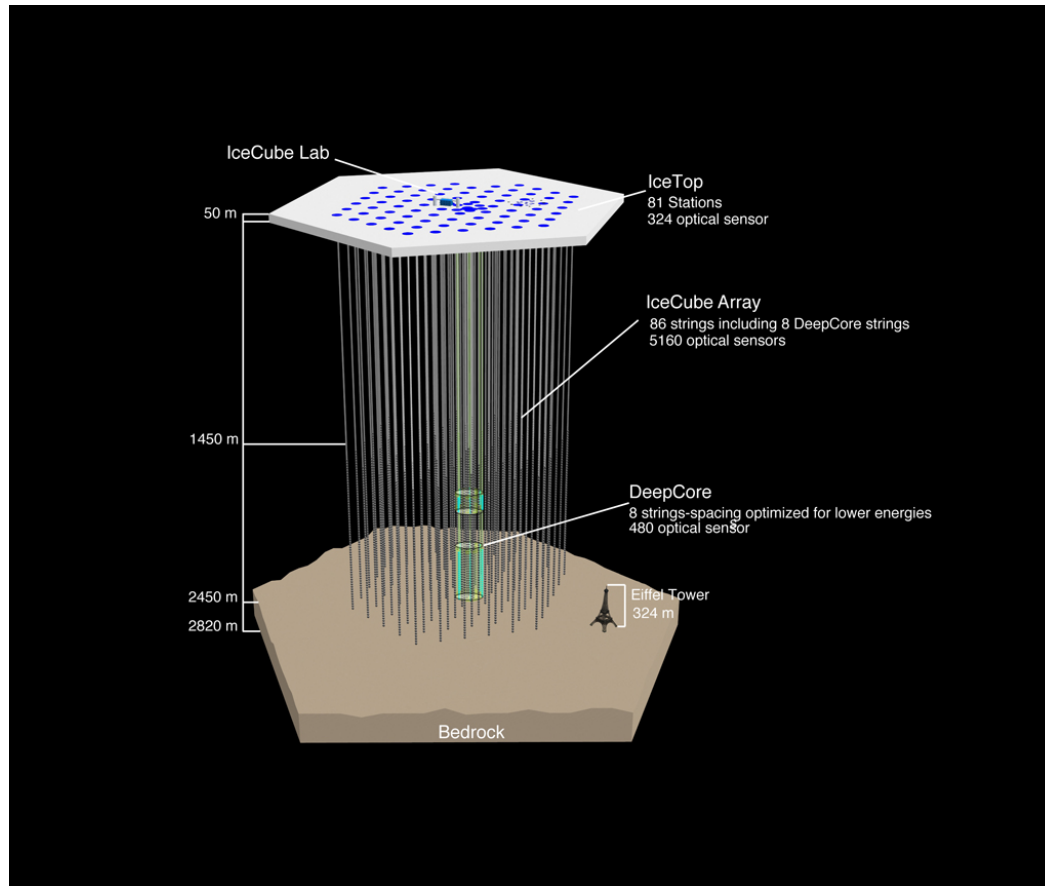


Cosmic accelerators as neutrino sources

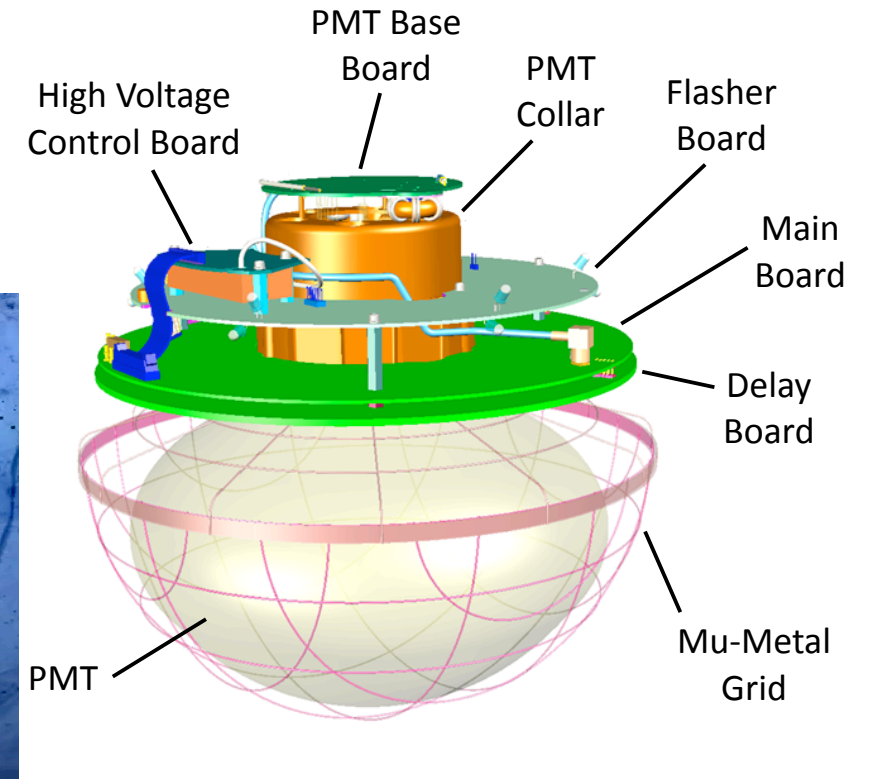
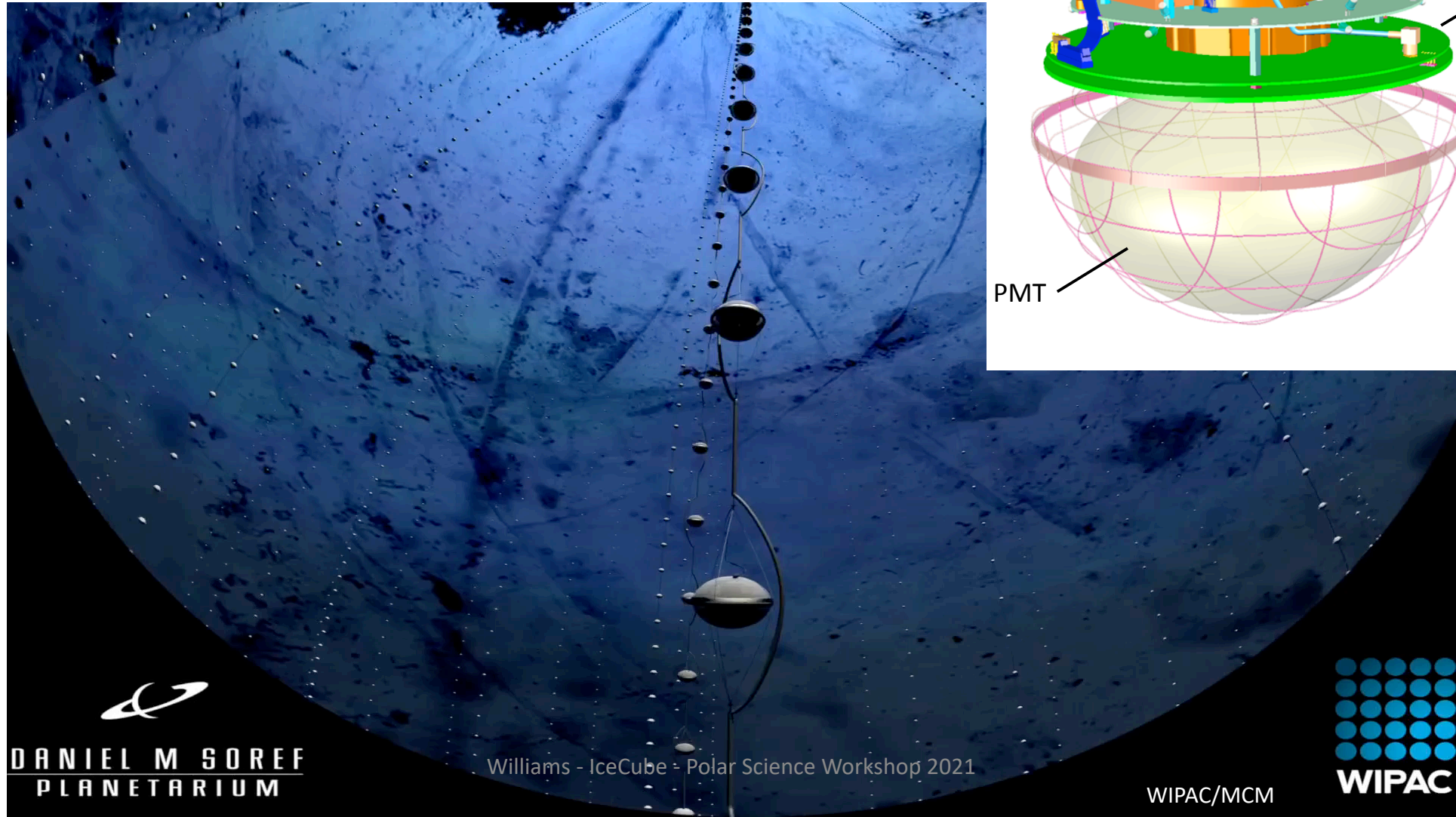


Due to the large distances/low fluxes involved, a very large detector is required to detect high energy neutrinos from cosmic accelerators

The IceCube Neutrino Observatory

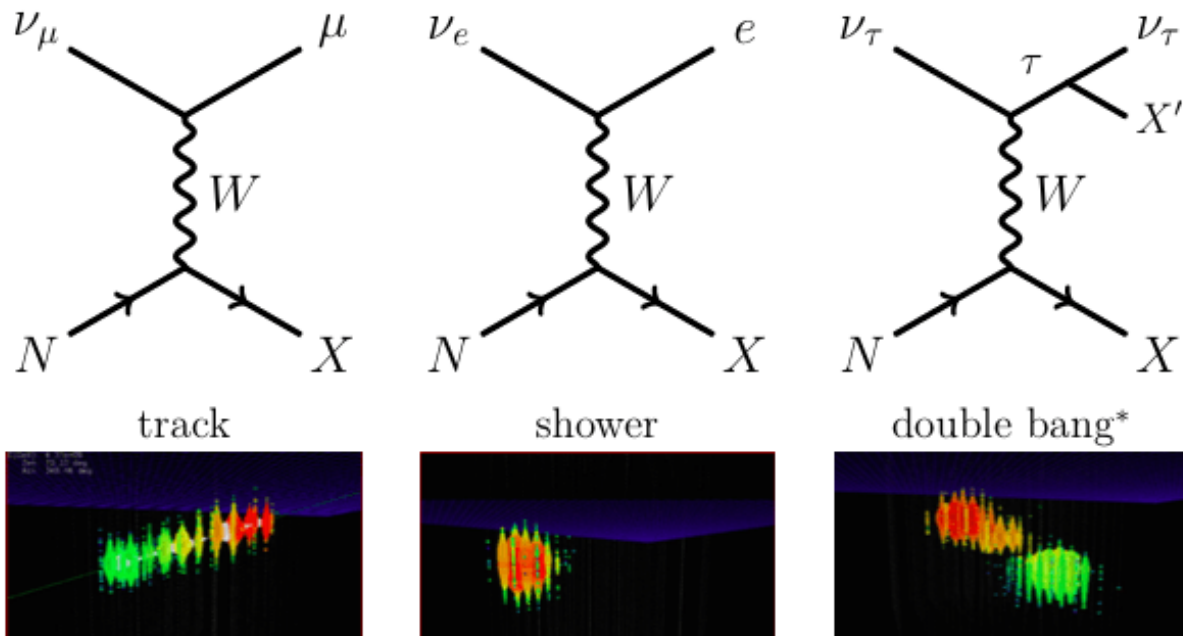


Inside the IceCube DOM

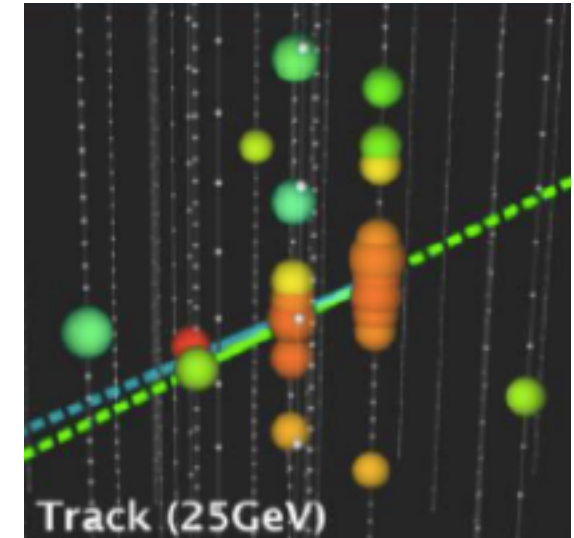


Neutrino Signatures in IceCube

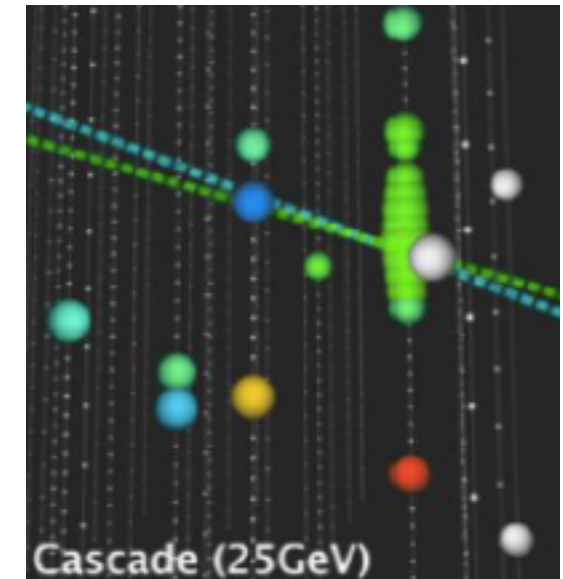
~100 TeV – PeV neutrinos in IceCube



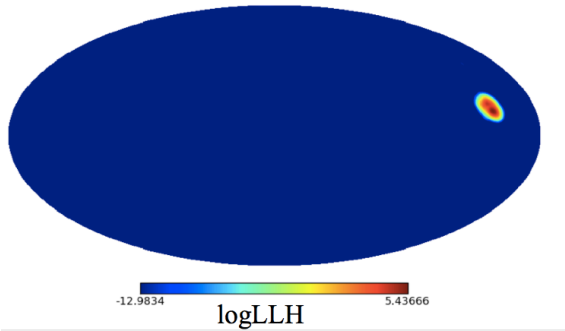
A shower (cascade) is also observed for all flavor neutral current events, and for taus too low in energy to produce a resolved double cascade



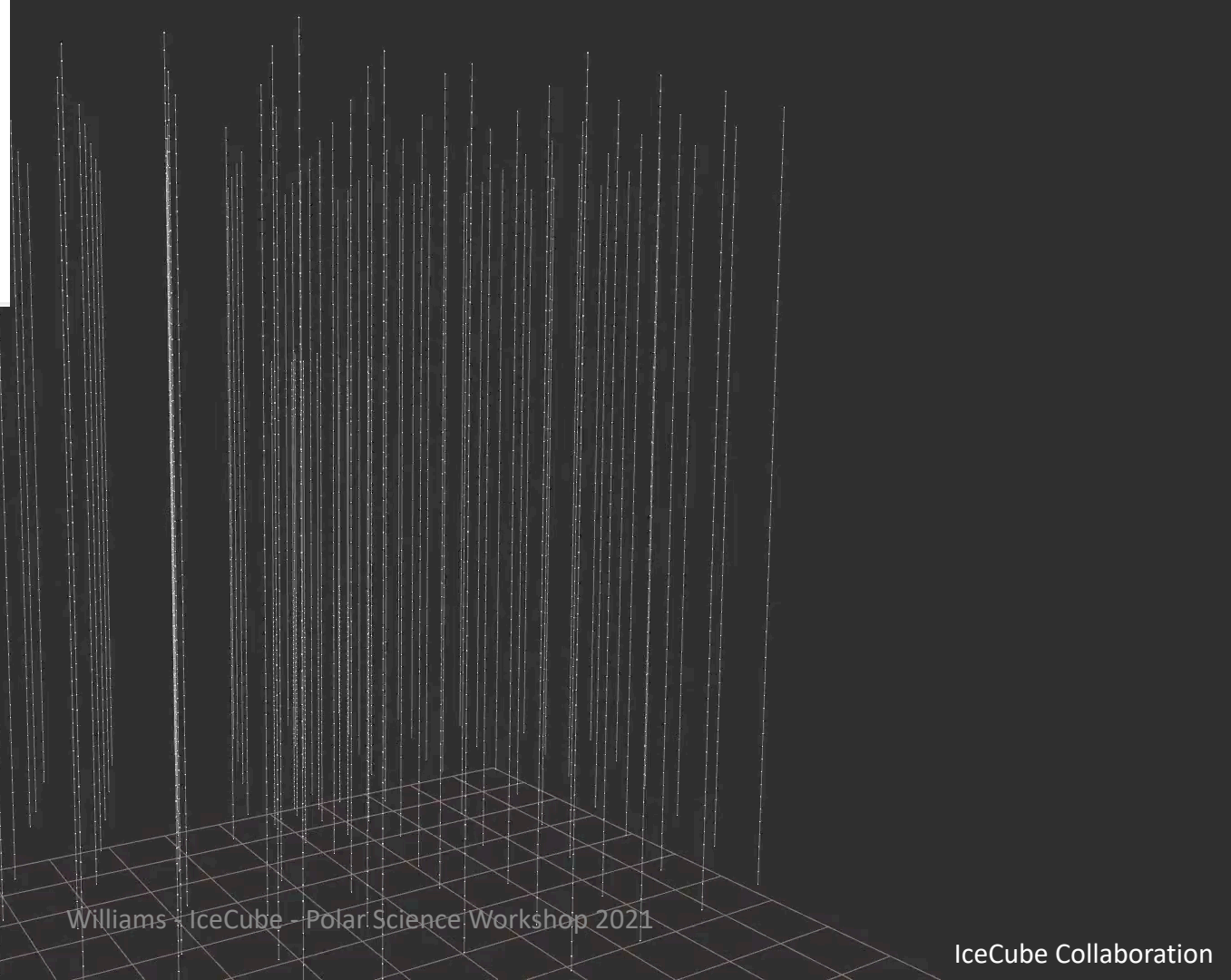
GeV neutrinos in IceCube DeepCore



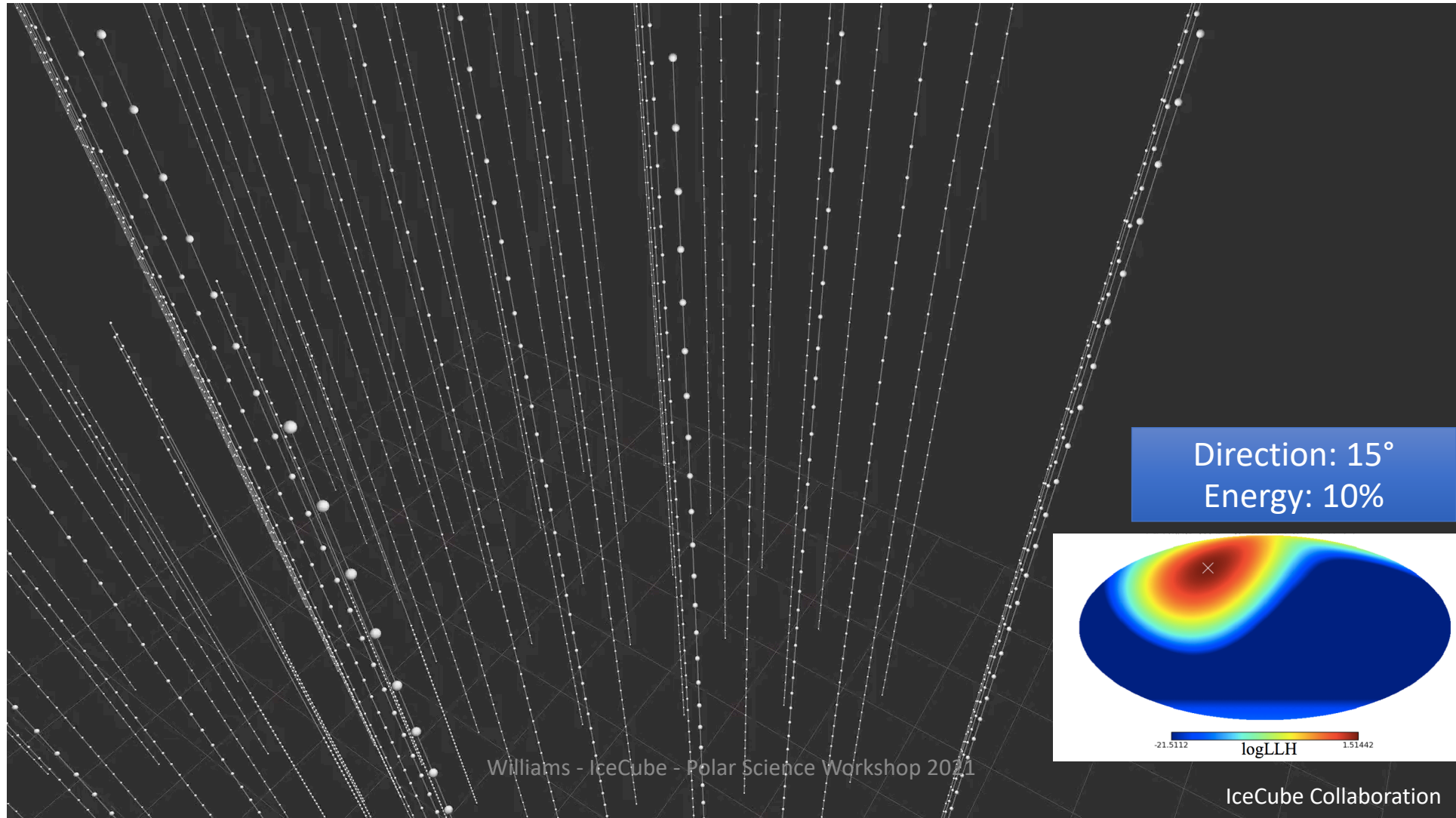
Neutrino Signatures in IceCube: Tracks



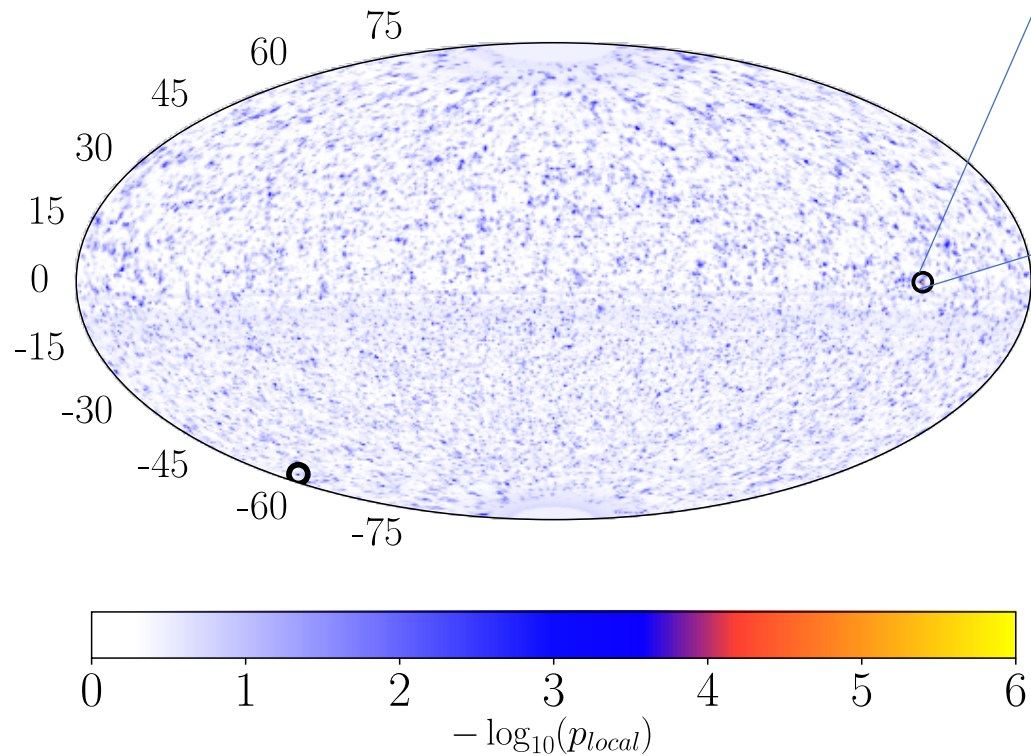
Direction: $>0.2^\circ$
Energy: factor of 2



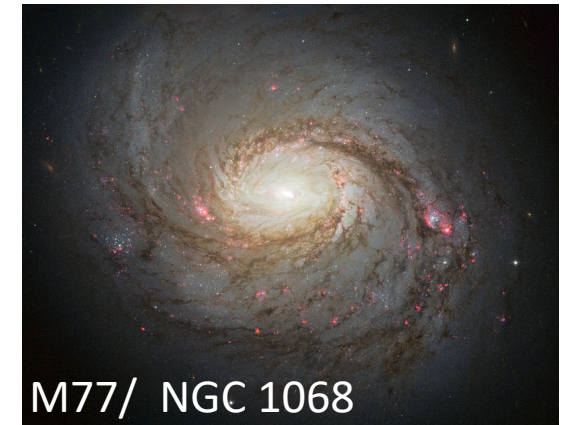
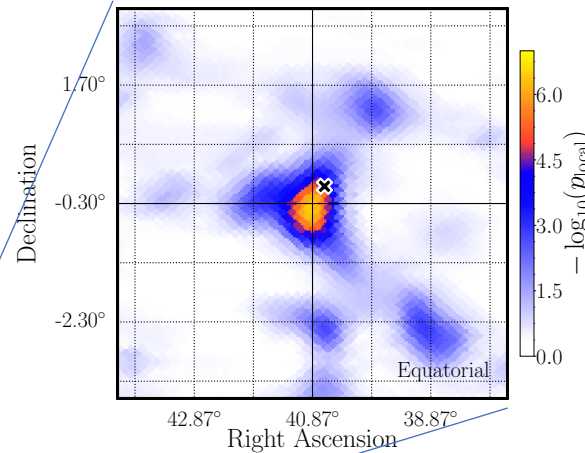
Neutrino Signatures in IceCube: Cascades



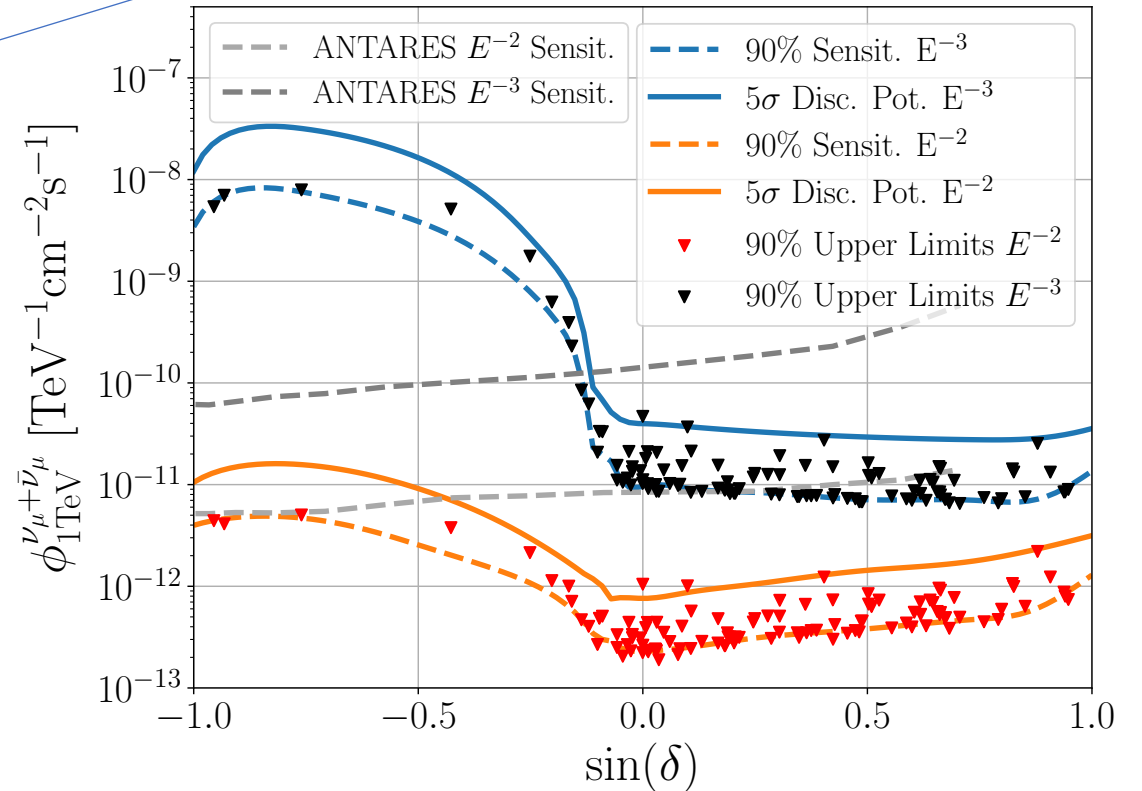
The High Energy Neutrino Sky



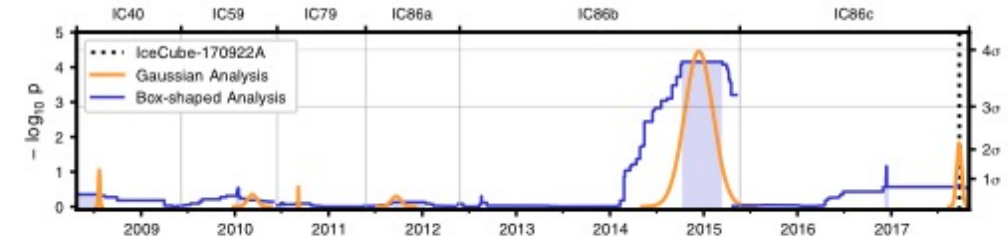
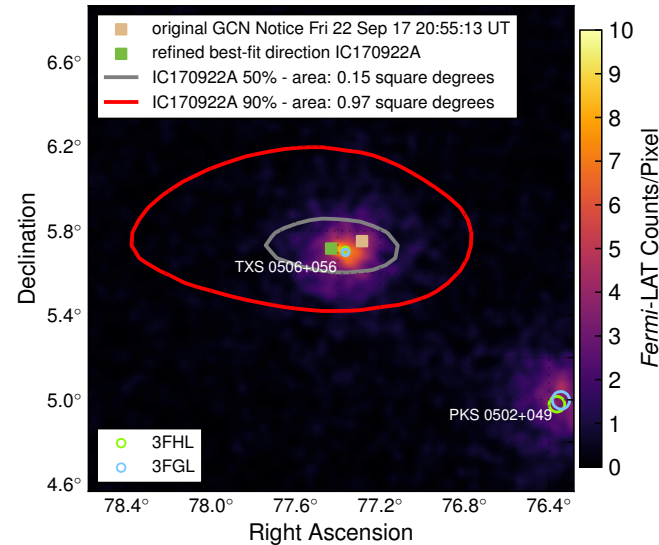
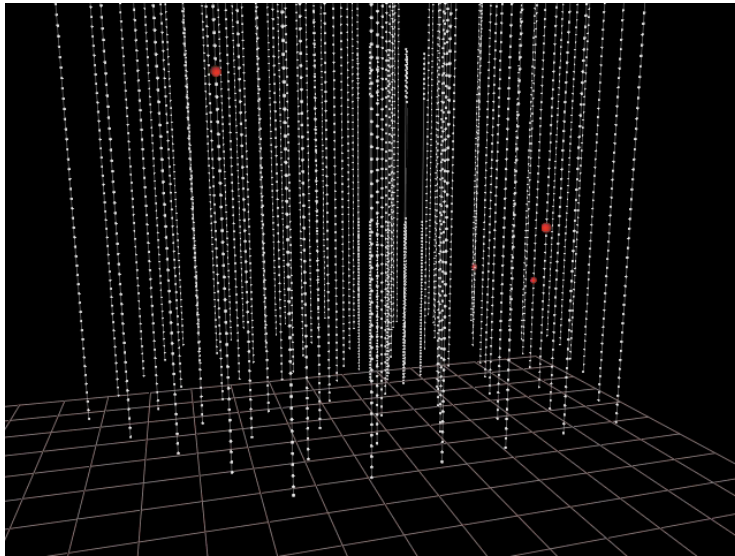
Excess at the coordinates of NGC 1068



NASA, ESA & A. van der Hoeven



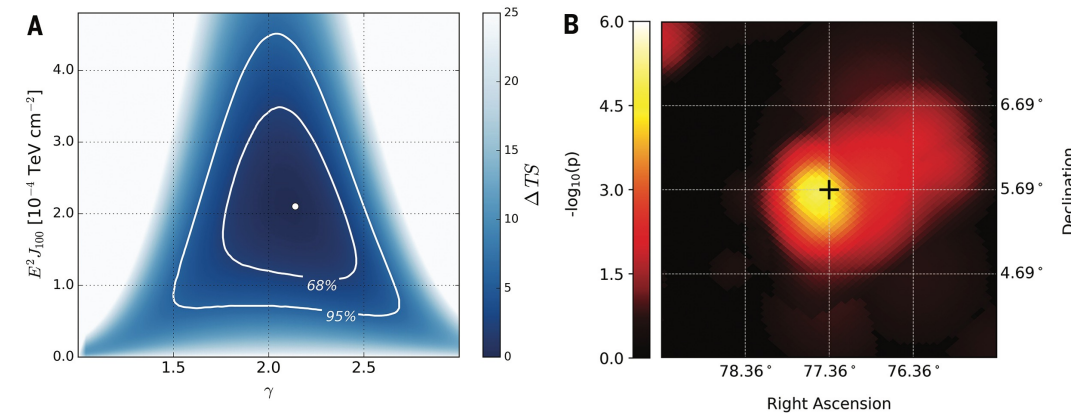
IceCube Science: Multi-messenger Astronomy



Neutrino event IceCube-170922A seen in coincidence with gamma ray flaring blazar TXS 0506+056 on Sep. 22, 2017

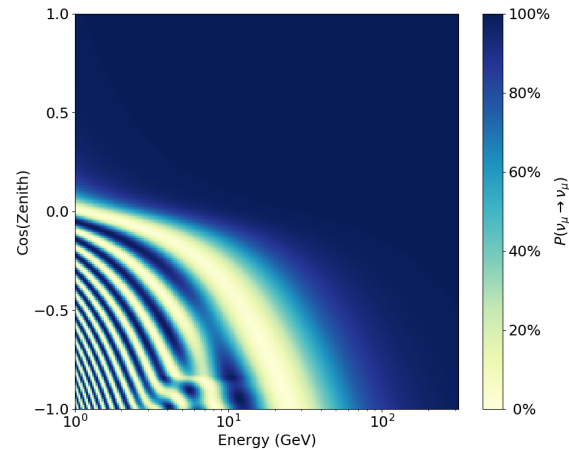
Rapid follow-up by electromagnetic telescopes

Neutrino flare found in IceCube archival data between September 2014 and March 2015

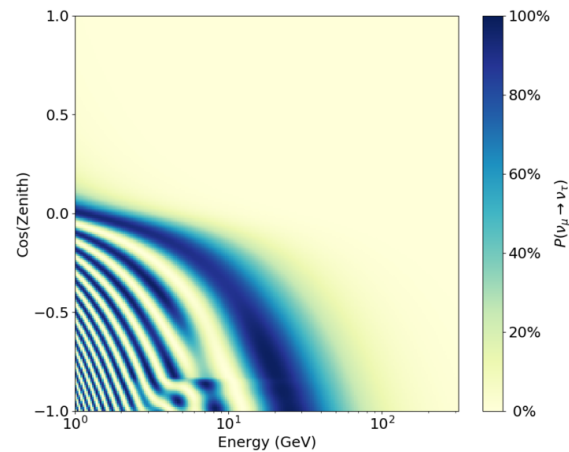


Science 13 Jul 2018: Vol. 361, Issue 6398
IceCube, Fermi, MAGIC and 13 additional collaborations
IceCube coll., *Science* 13 Jul 2018: Vol. 361, Issue 6398

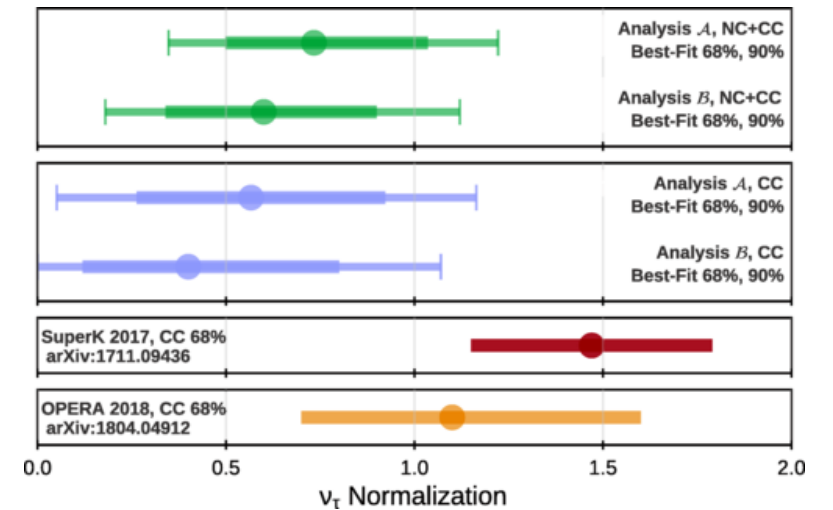
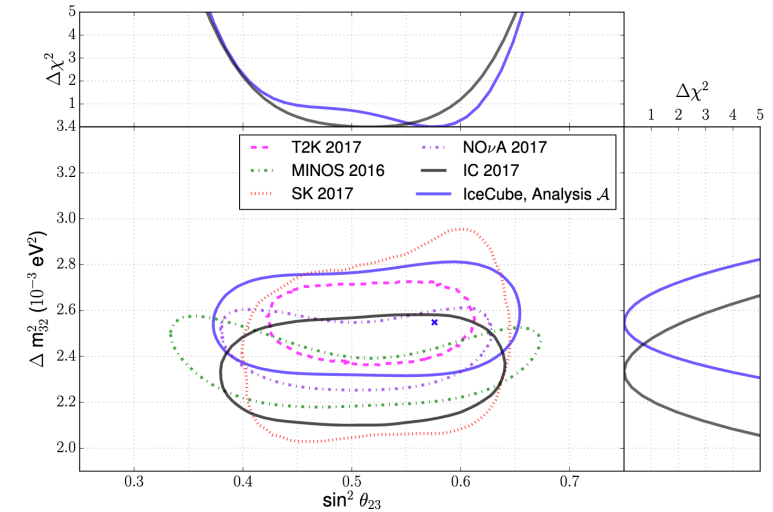
IceCube Science: Neutrino Oscillation Physics



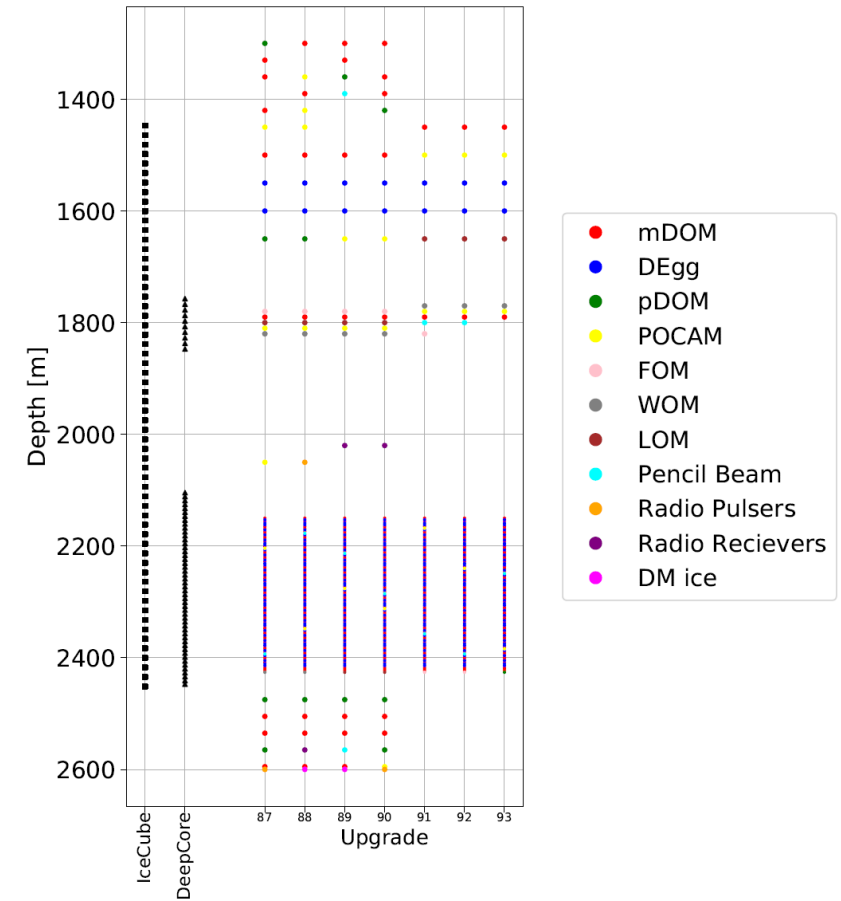
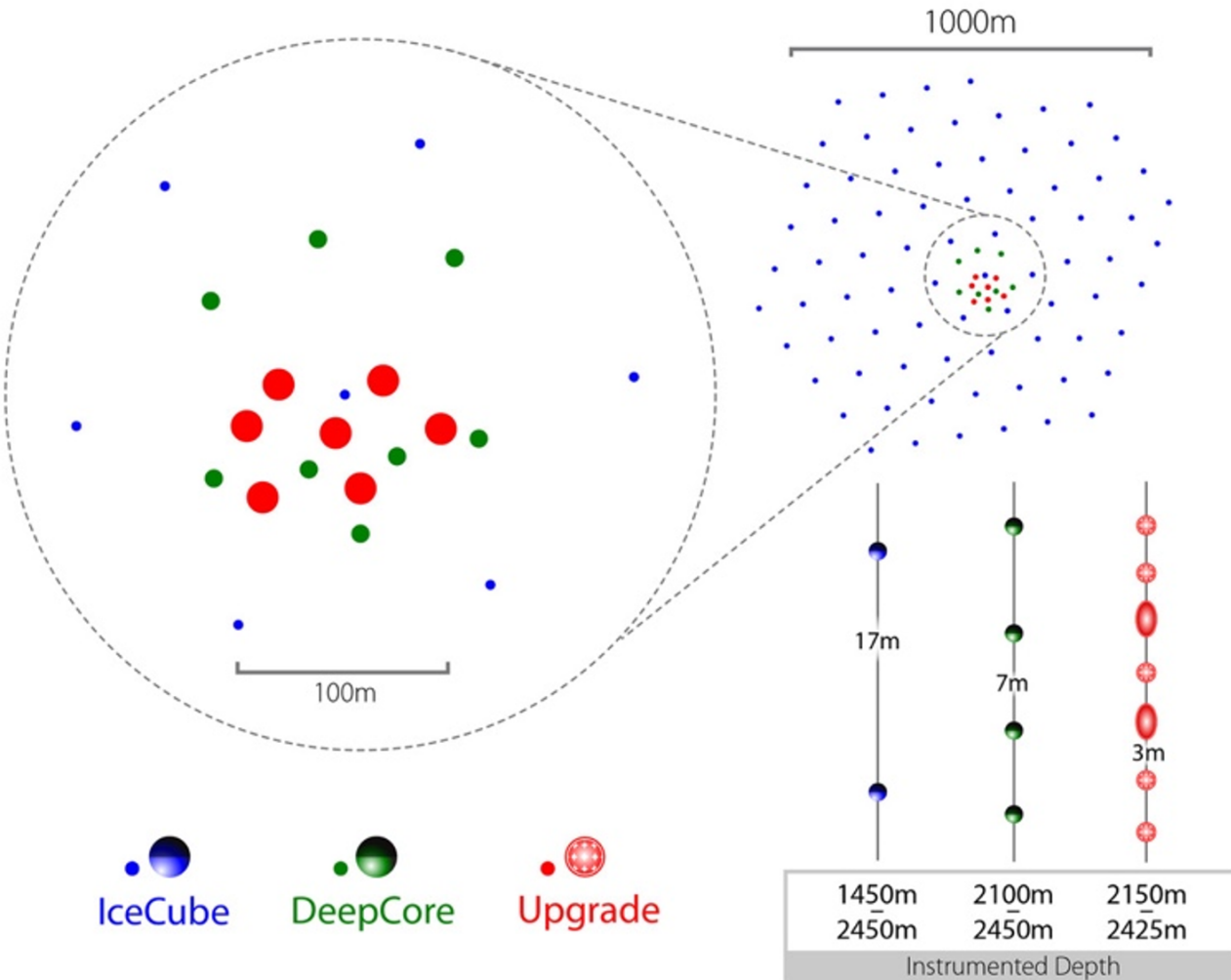
Muon neutrino disappearance



Tau neutrino appearance



The IceCube Upgrade



7 new strings scheduled for deployment in 2022/23
Currently schedule is under review due to impact of COVID

- **Atmospheric ν_τ appearance**
- **Precise calibration of IceCube optical properties and DOM response**
- **Recalibration of high energy neutrino data**

Upgrade sensors and calibration



D-egg



mDOM

Increased photocathode area and more uniform directional sensitivity compared to IceCube DOM

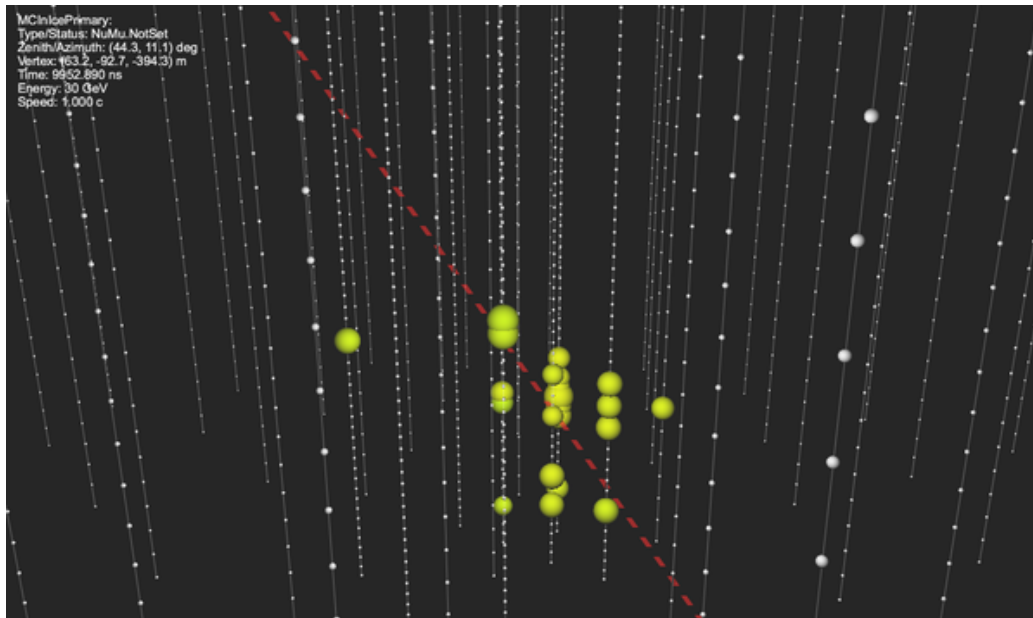
LED flashers and cameras included in each module

A smaller number of additional R&D photosensor designs will be deployed

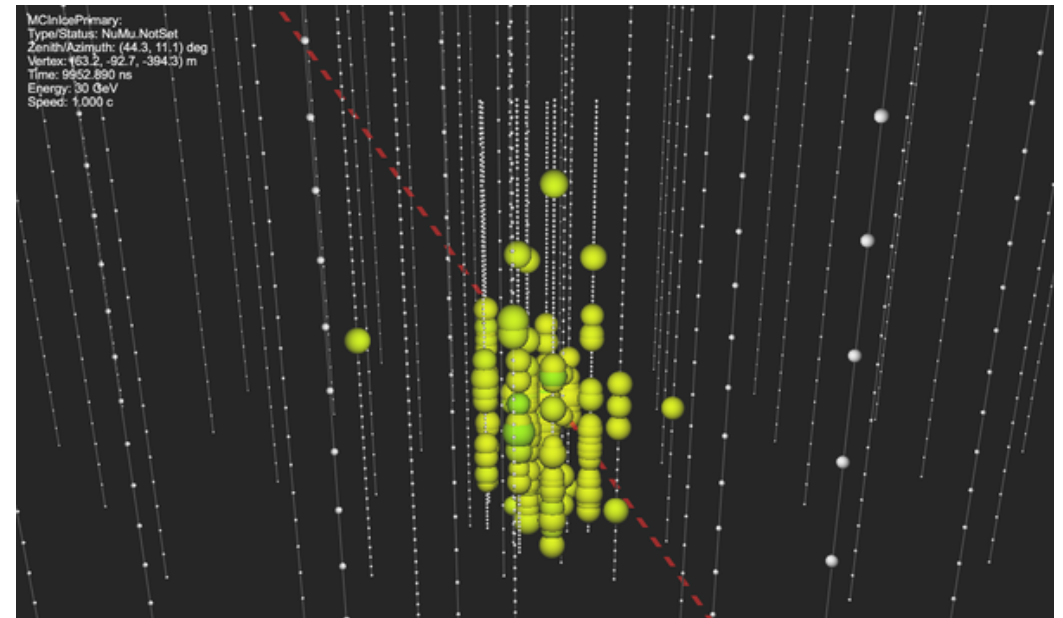
Calibration devices including acoustic sensors, beamed and isotropic light sources, additional cameras, radio calibration, with major emphasis on improving knowledge of the ice – baselines within 1 optical scattering length will be available in the upgrade for the first time

Low energy neutrinos in the IceCube Upgrade

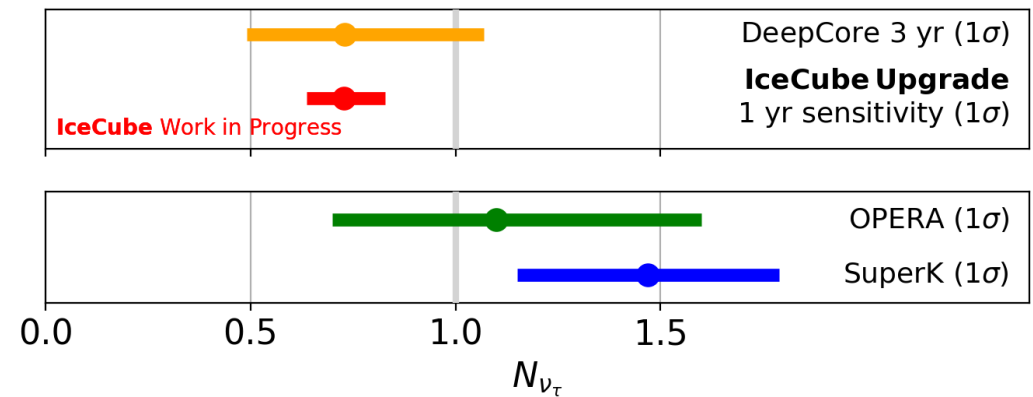
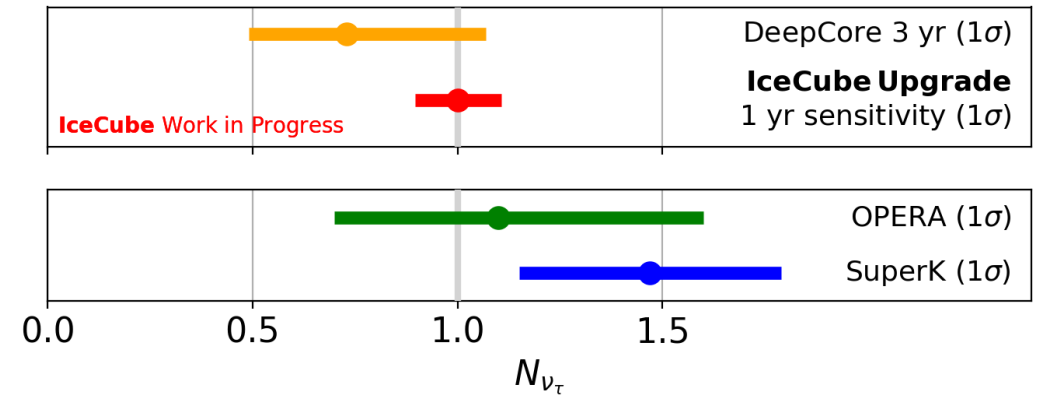
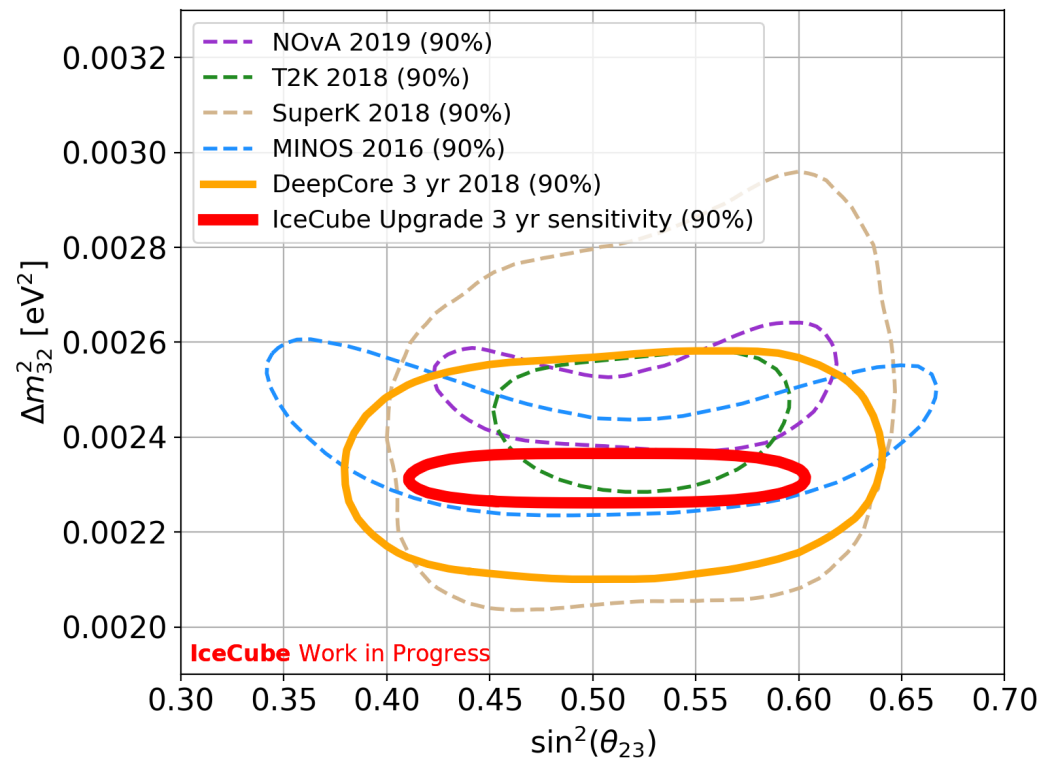
30 GeV, IceCube DeepCore



30 GeV, IceCube Upgrade

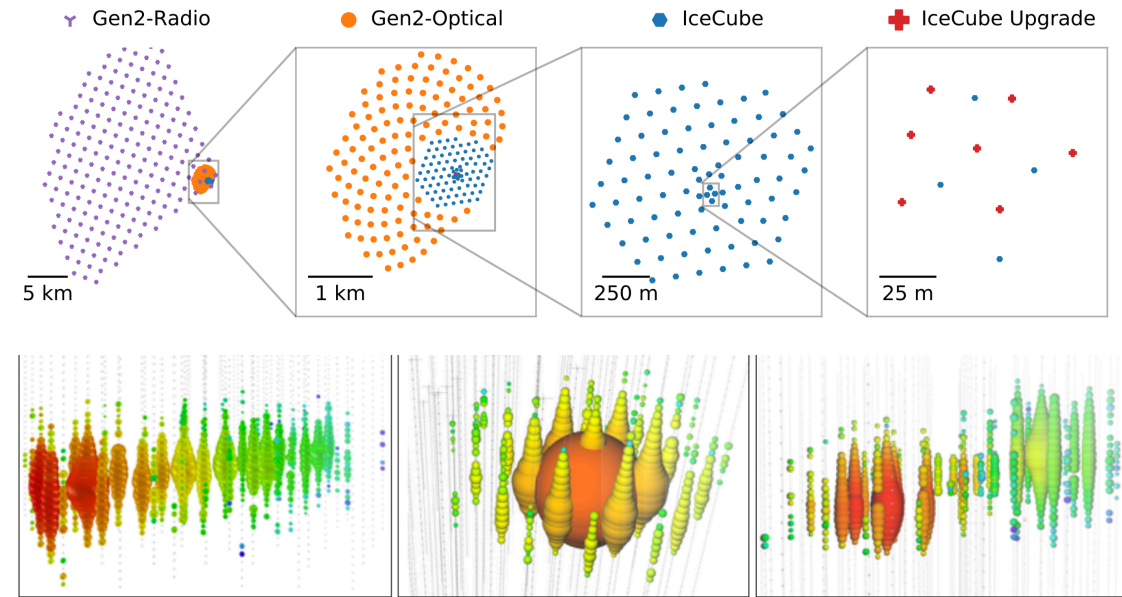
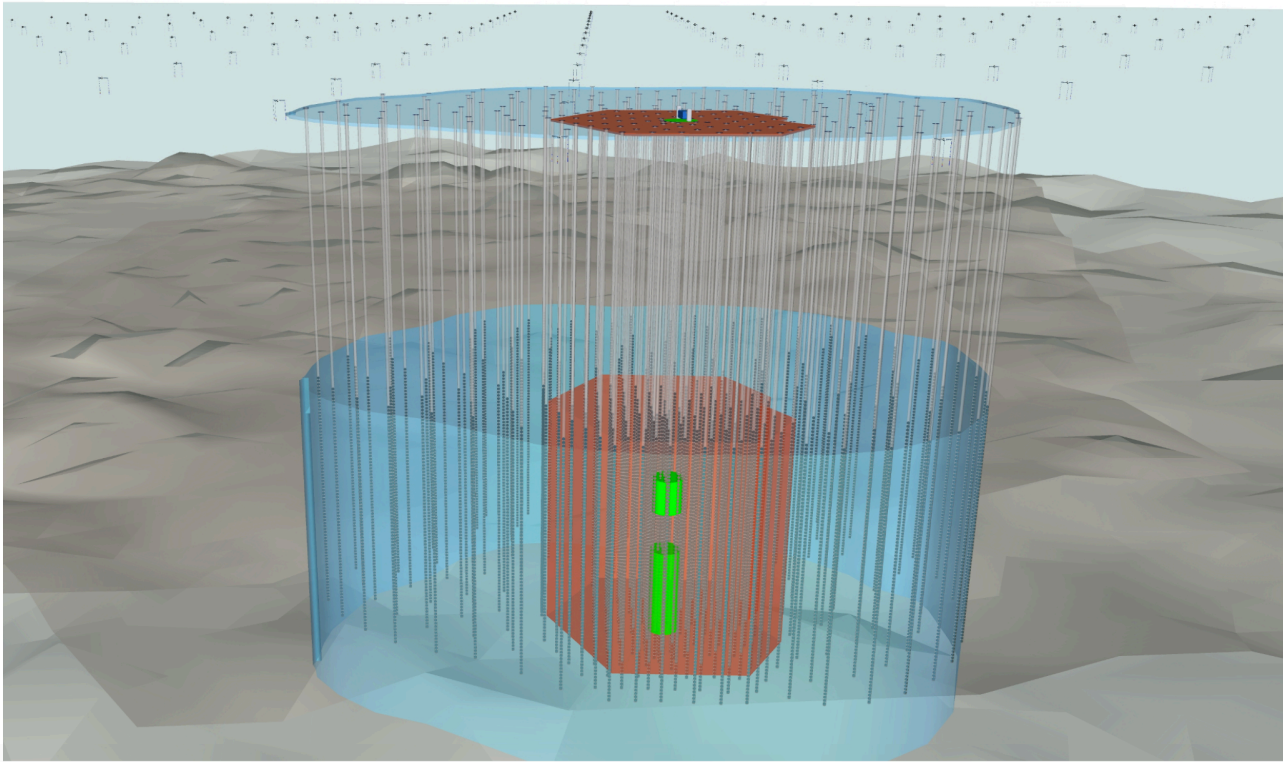


Upgrade sensitivity to neutrino oscillation



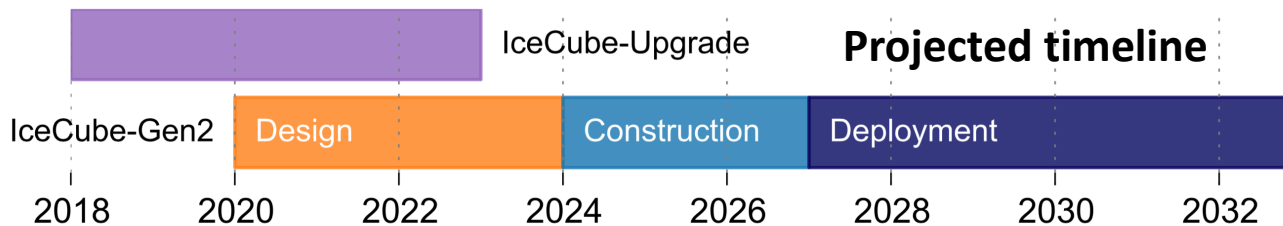
IceCube Coll., ICRC 2019

IceCube-Gen2



IceCube-Gen2 is designed to...

- 1. Resolve the high-energy neutrino sky from TeV to EeV energies**
- 2. Investigate cosmic particle acceleration through multi-messenger observations**
- 3. Reveal the sources and propagation of the highest energy particles in the universe**
- 4. Probe fundamental physics with high-energy neutrinos**



<https://arxiv.org/abs/2008.04323>

1/19/21

Williams - IceCube - Polar Science Workshop 2021

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Summary

- The IceCube Neutrino Observatory has detected high energy cosmic neutrinos and published very sensitive neutrino oscillation studies, in addition to many other physics topics
- The IceCube Upgrade is underway, and will greatly improve sensitivity to low energy neutrinos and improve our knowledge of the ice
- Planning is underway for next generation neutrino telescope, IceCube-Gen2