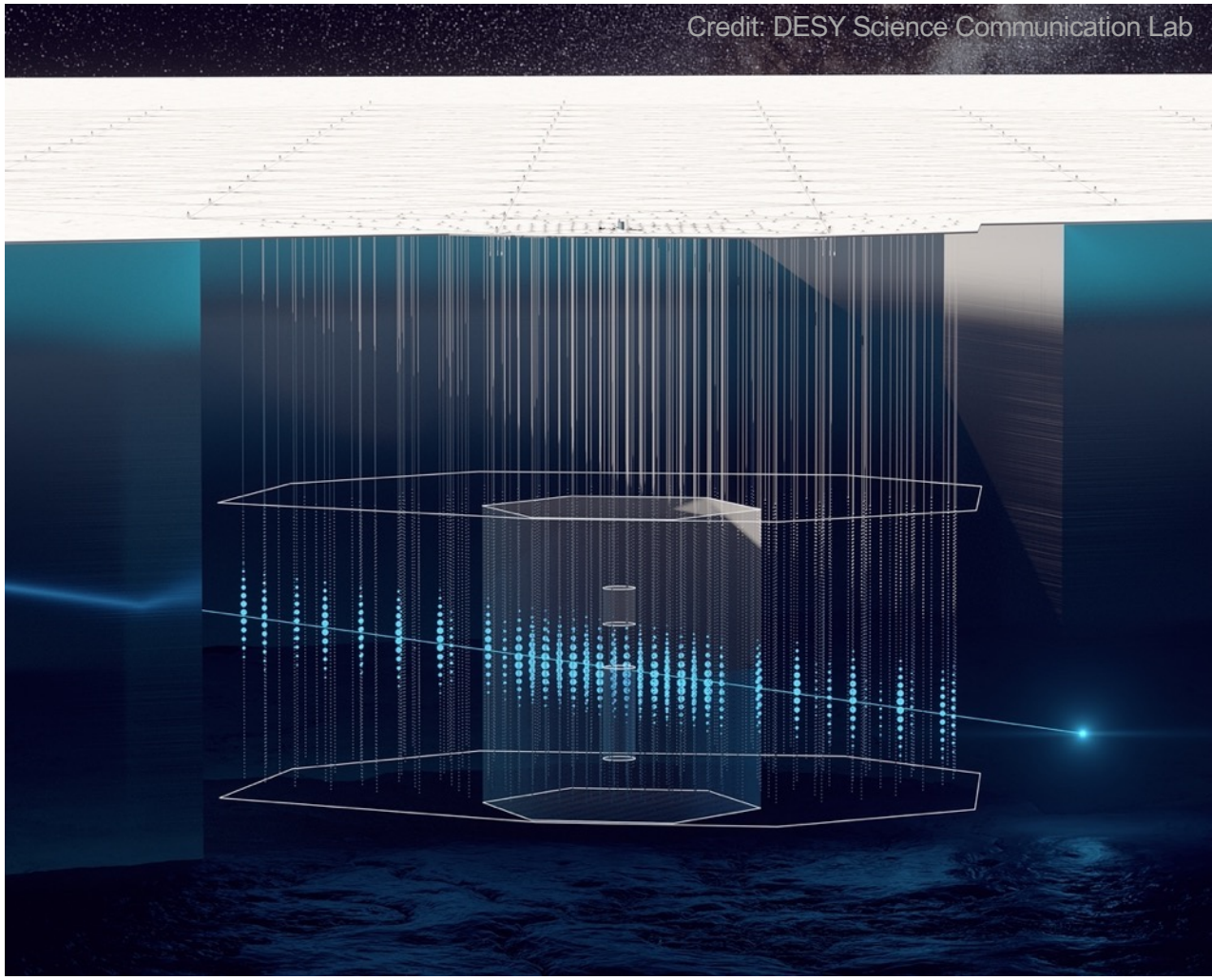
The IceCube-Gen2 Neutrino Observatory

Brian Clark

for the IceCube-Gen2 Collaboration

Michigan State University



Very Large Volume Neutrino Telescopes
May 19th, 2021
"Valencia"

VLVνT VALENCIA 2021

MICHIGAN STATE UNIVERSITY

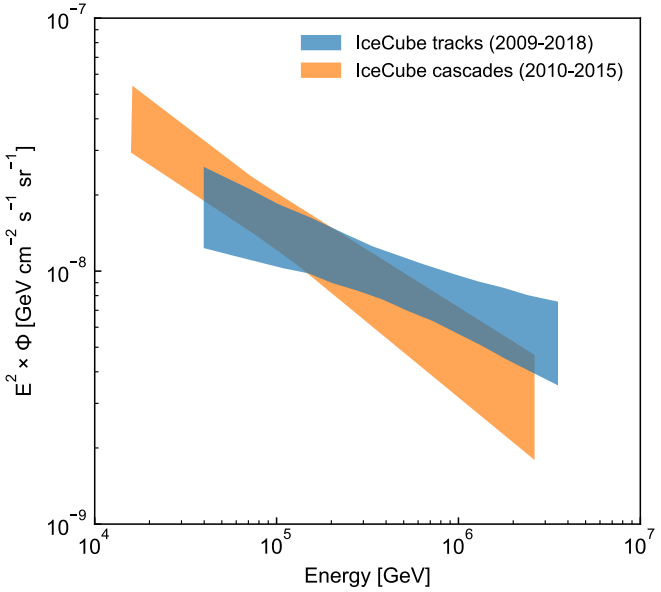
Open Questions

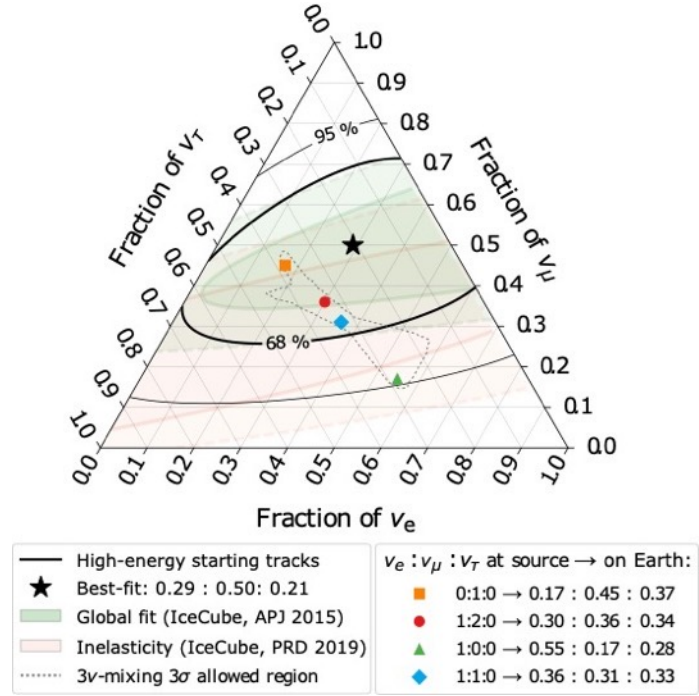
What we know about the flux of high-energy neutrinos:

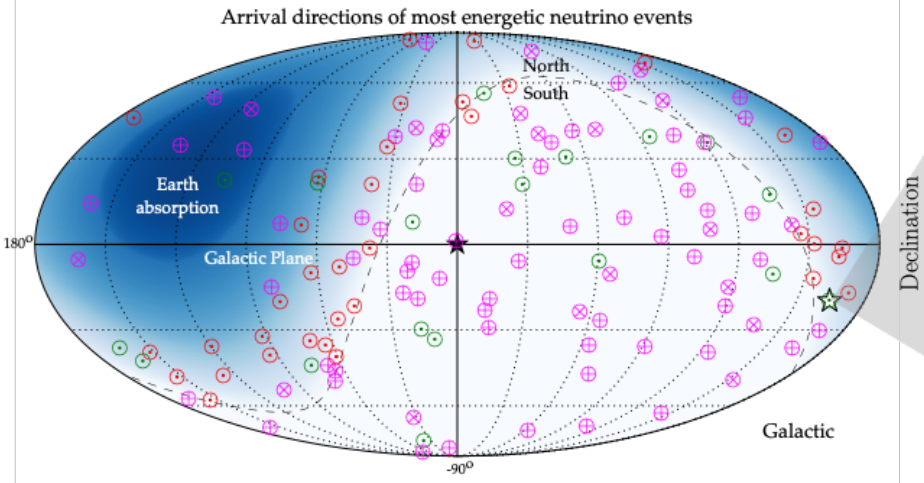
- Roughly power law in shape
- Seemingly flavor democratic
- Isotropic in arrival direction

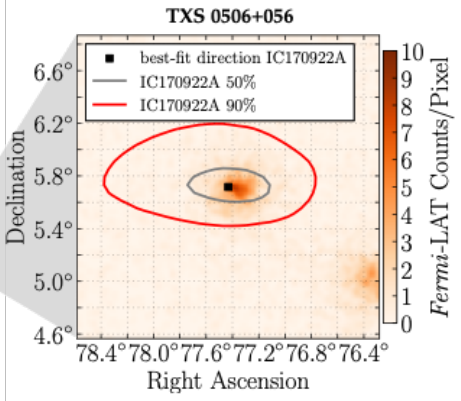
But…

- No definitive sources yet (some tantalizing evidence)
- No UHE neutrinos (>10 PeV)









Driving Goals

A next generation observatory must enable…

- Improved precision on the spectrum and composition of the diffuse flux
- The identification of more point sources
- Better cross-correlations with astronomical catalogs

Which requires…

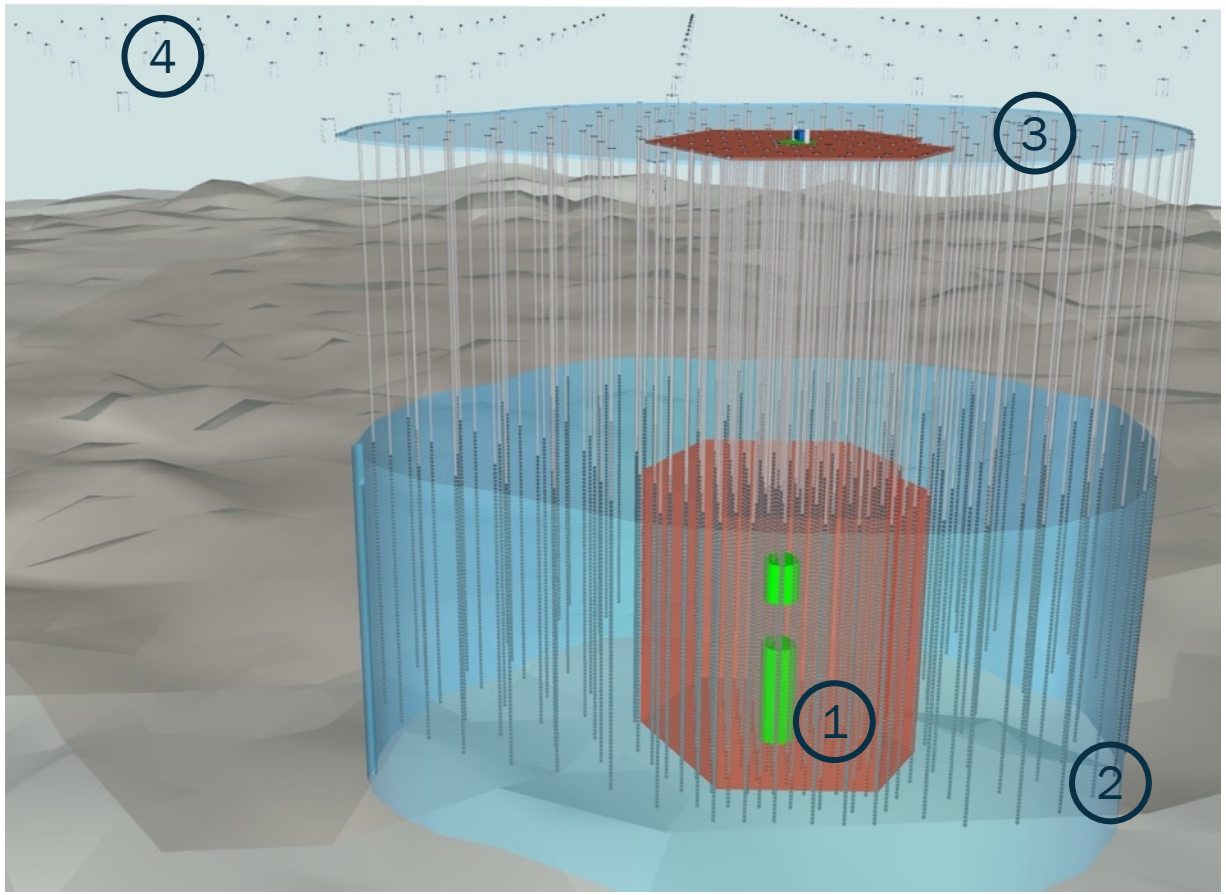
- Higher event rates, over a broader energy range
- Improved angular resolution

The IceCube-Gen2 Facility

A broadband neutrino observatory

Four new elements, leveraging complimentary technologies, to achieve sensitivity to MeV-EeV neutrinos

1. IceCube Upgrade
2. Enlarged deep optical array
3. Surface array extension
4. Shallow radio array




THE ICECUBE COLLABORATION
AUSTRALIA
University of Adelaide
BELGIUM
Université libre de Bruxelles
Universiteit Gent
Vrije Universiteit Brussel
CANADA
SNOLAB
University of Alberta–Edmonton
DENMARK
University of Copenhagen
GERMANY
Deutsches Elektronen-Synchrotron
ECAP, Universität Erlangen-Nürnberg
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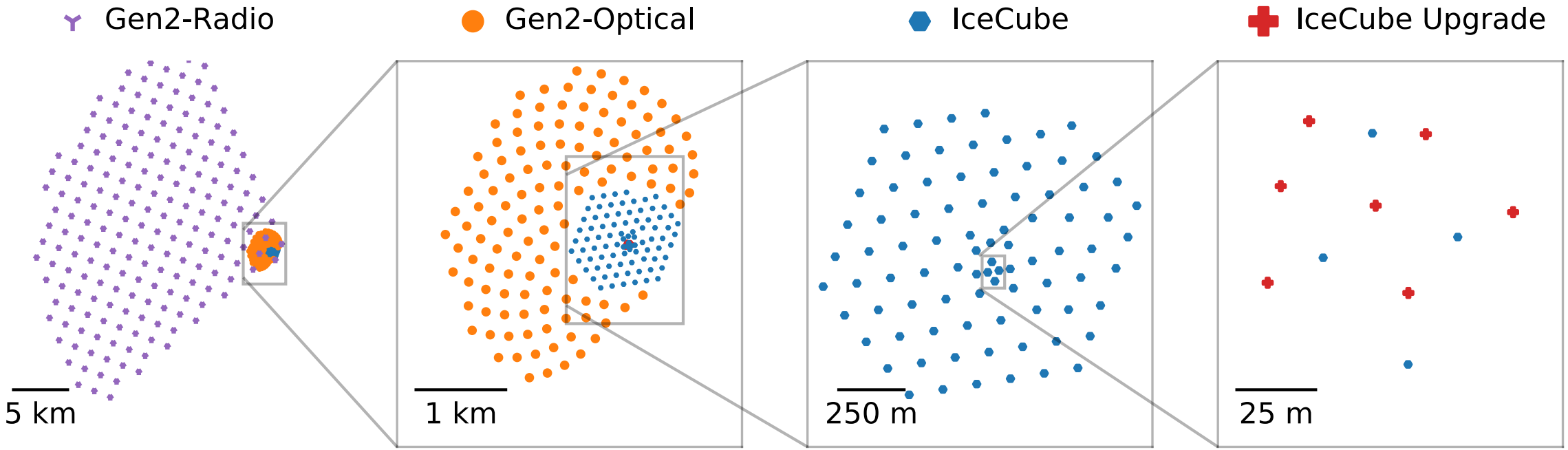
icecube.wisc.edu

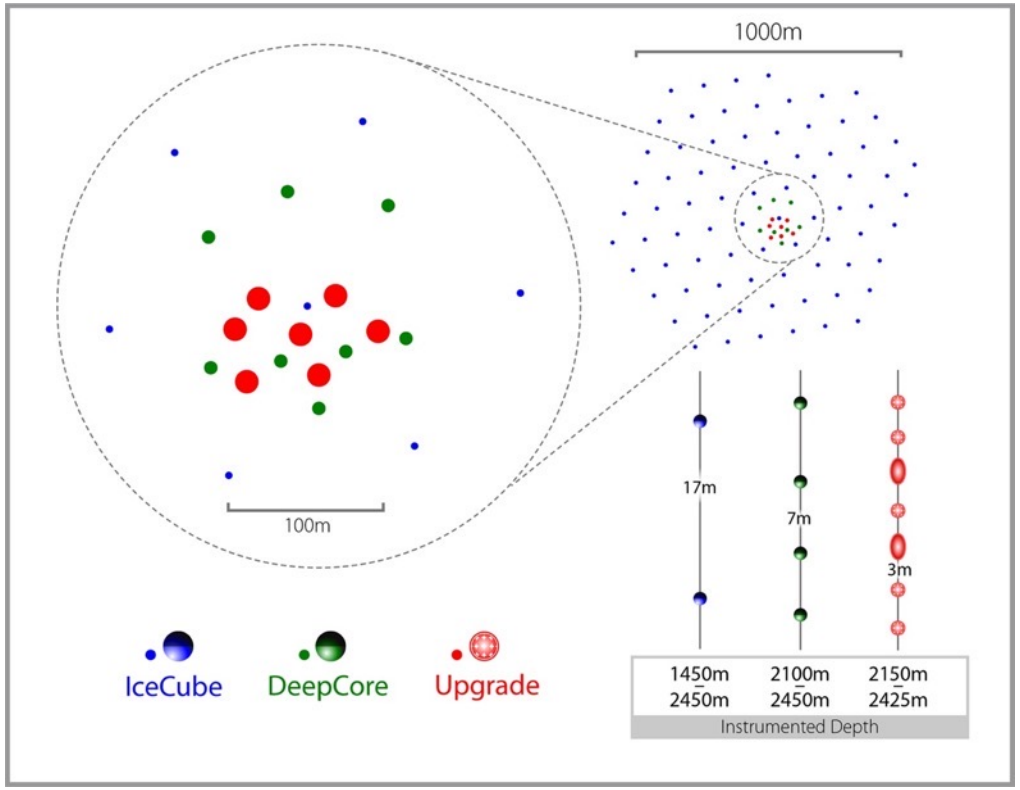
The IceCube-Gen2 Facility



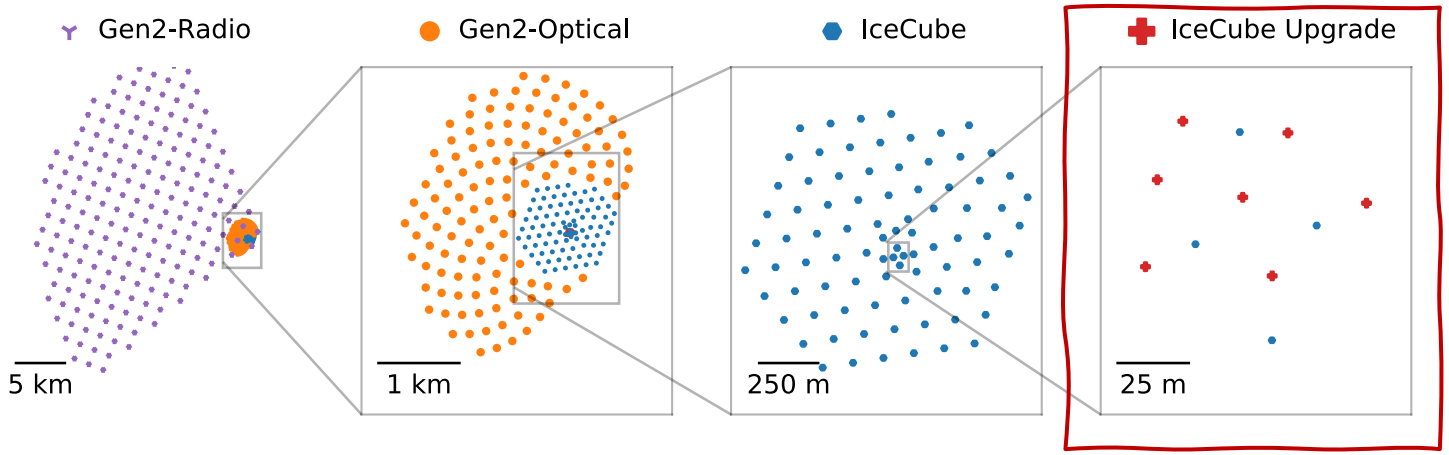
IceCube Upgrade

GeV Neutrinos

- 7 new strings, ~100 sensors/string
- 5 year construction project underway
- Key goals: ice calibration, sensitivity to GeV neutrinos
- R&D Platform: pixelated detectors, wavelength shifting sensors



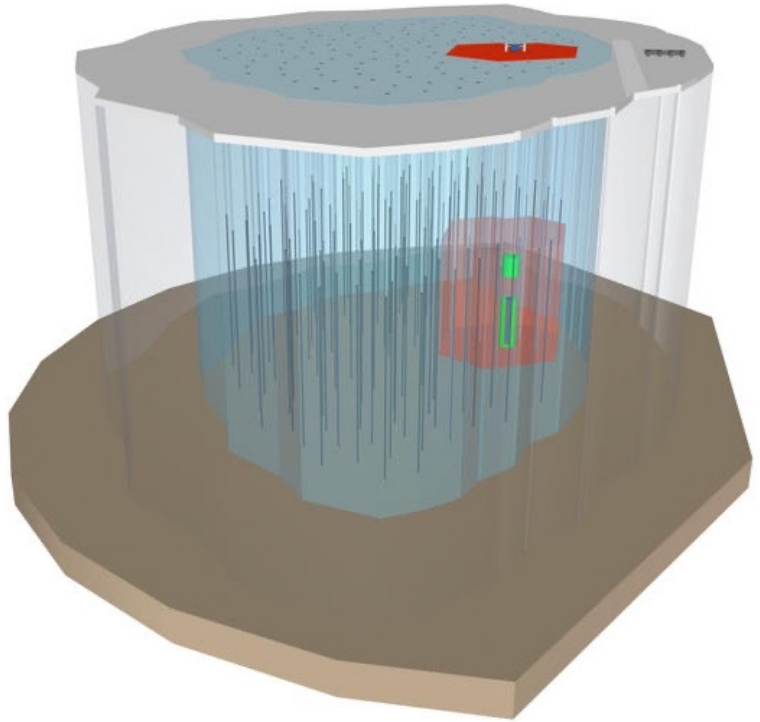
See talk by M. Rongen (94)

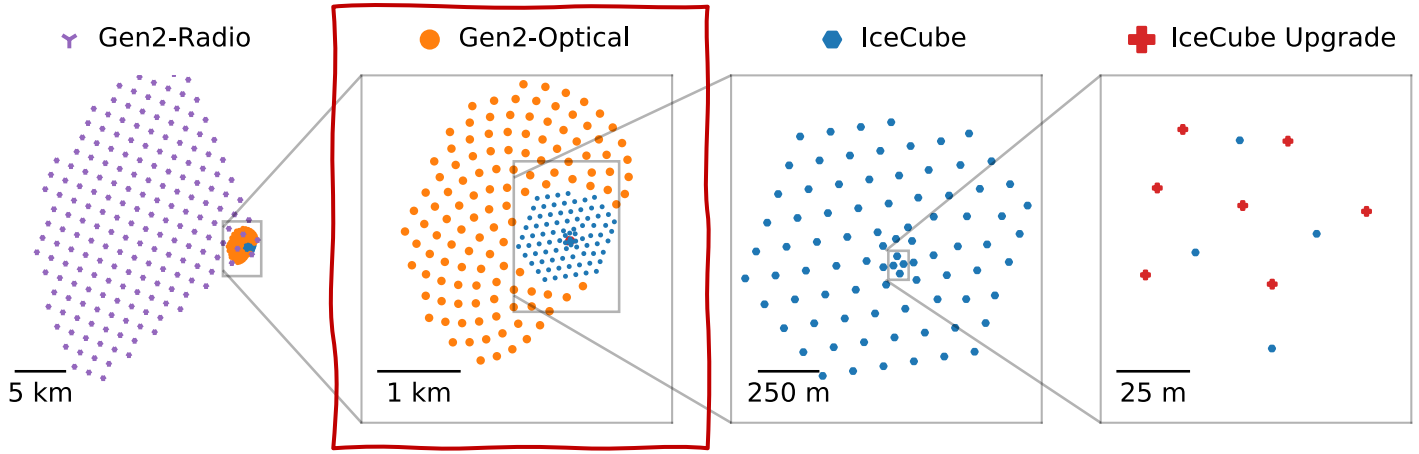


Gen2-Optical

TeV-EeV neutrinos

- Enlarged, 8 km^3 optical array in a "Sunflower" layout
  - 122 strings, 240m lateral spacing
  - 80 OMs/string, 17m vertical spacing
- ~10x the contained volume of IceCube

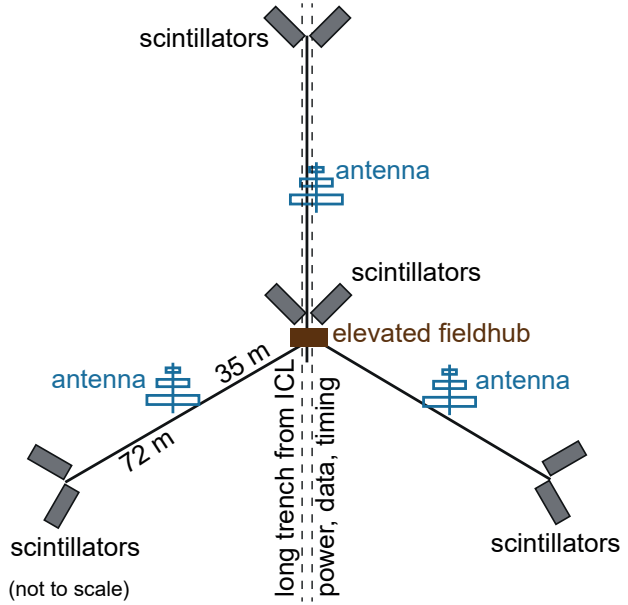


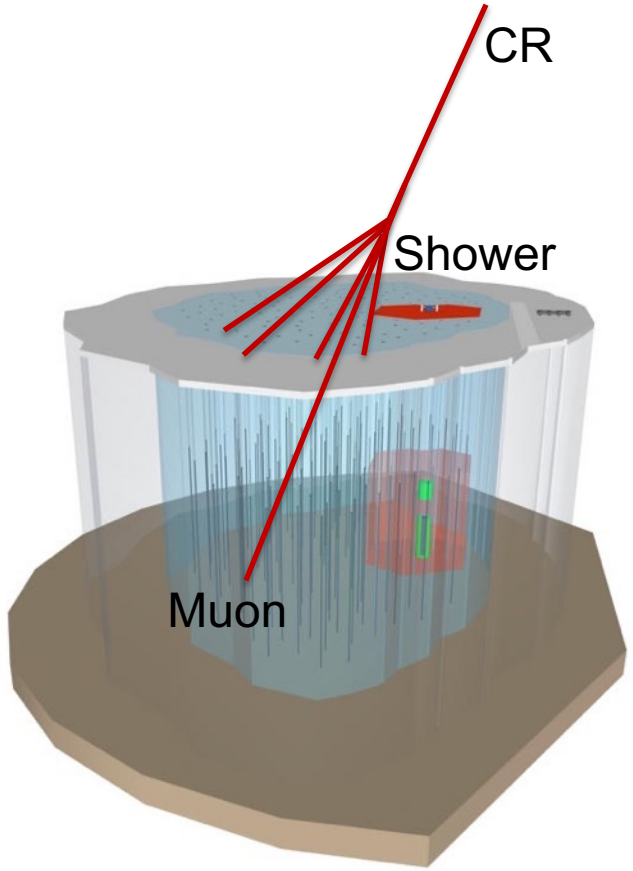


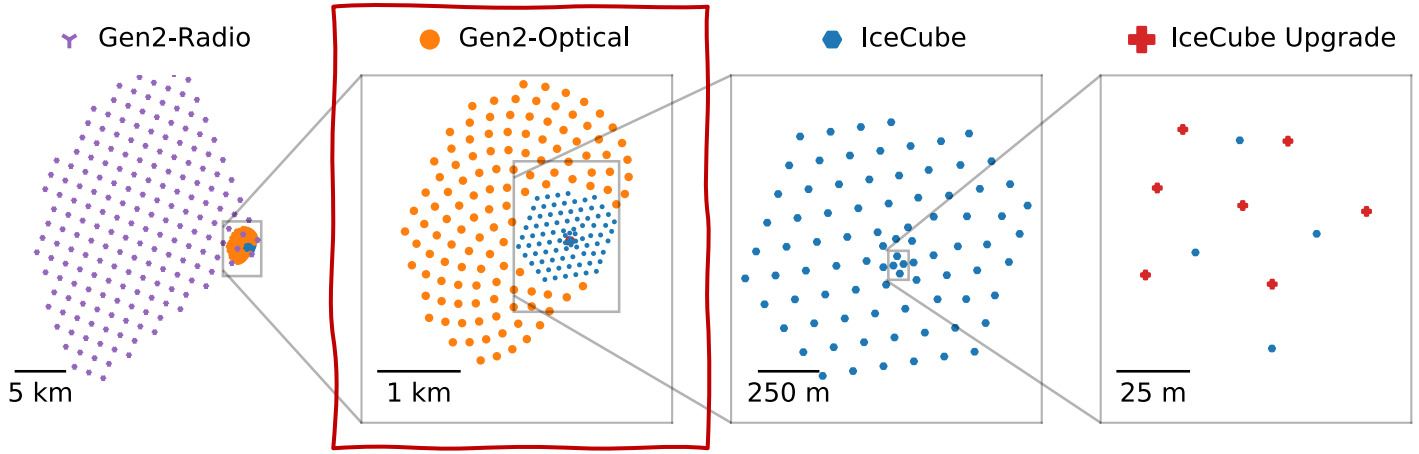
Gen2-Surface

Cosmic rays

- Extension of IceTop, with a station atop each new optical string
- Dual technologies enable separation of muon and electromagnetic shower components
- CR detectors also provide a veto to the in-ice array
  - Gen2: 10 km^{2}sr
  - IceCube: 0.25 km^{2}sr



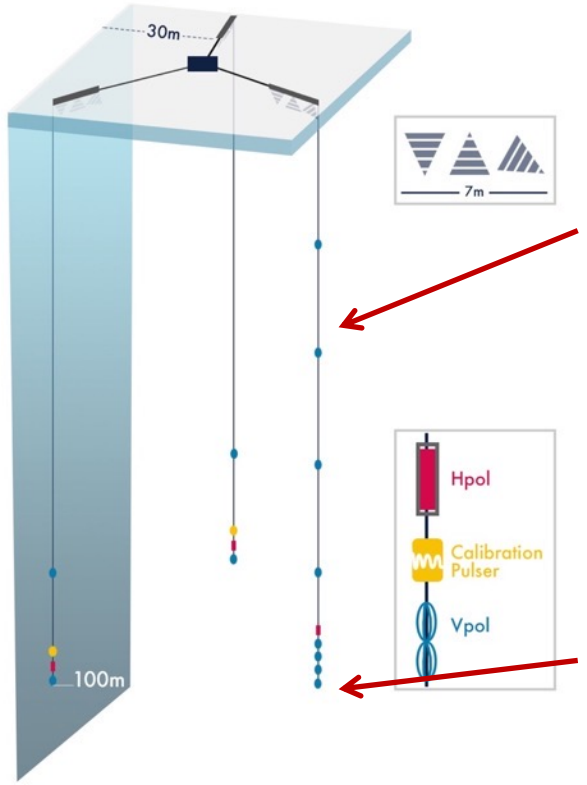




Gen2-Radio

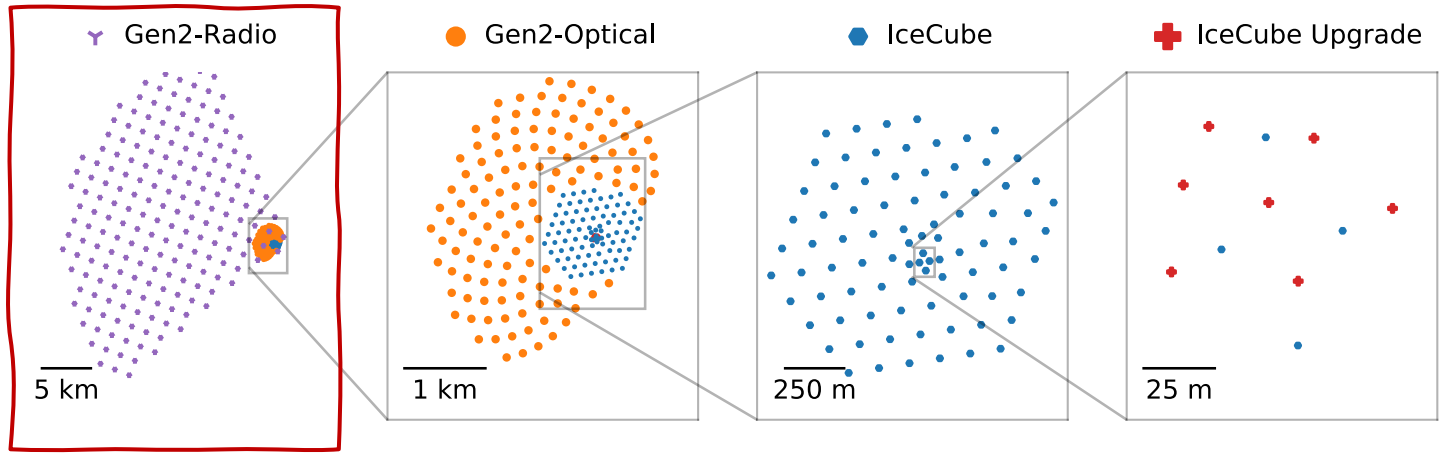
EeV Neutrinos

- $\mathcal{O}(200)$ stations over 500 km^2
- Combination of “deep” and “surface” technology
  - Dipole antennas at ~200m depth (like RICE, ARA)
  - LPDAs at surface (like ARIANNA)
- Final design still being optimized



Auxiliary antennas for reconstruction

Phased-array for low threshold triggering



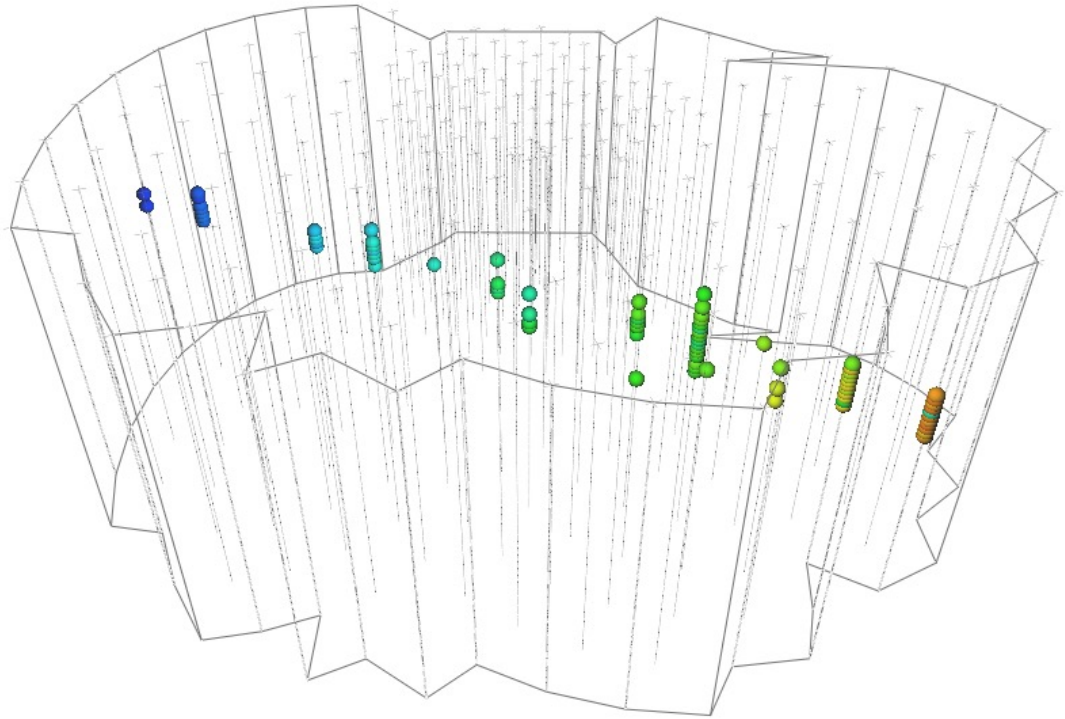
Gen2-Optical Performance

Event Topologies

Like IceCube (and many other telescopes!) two primary detection channels

Tracks

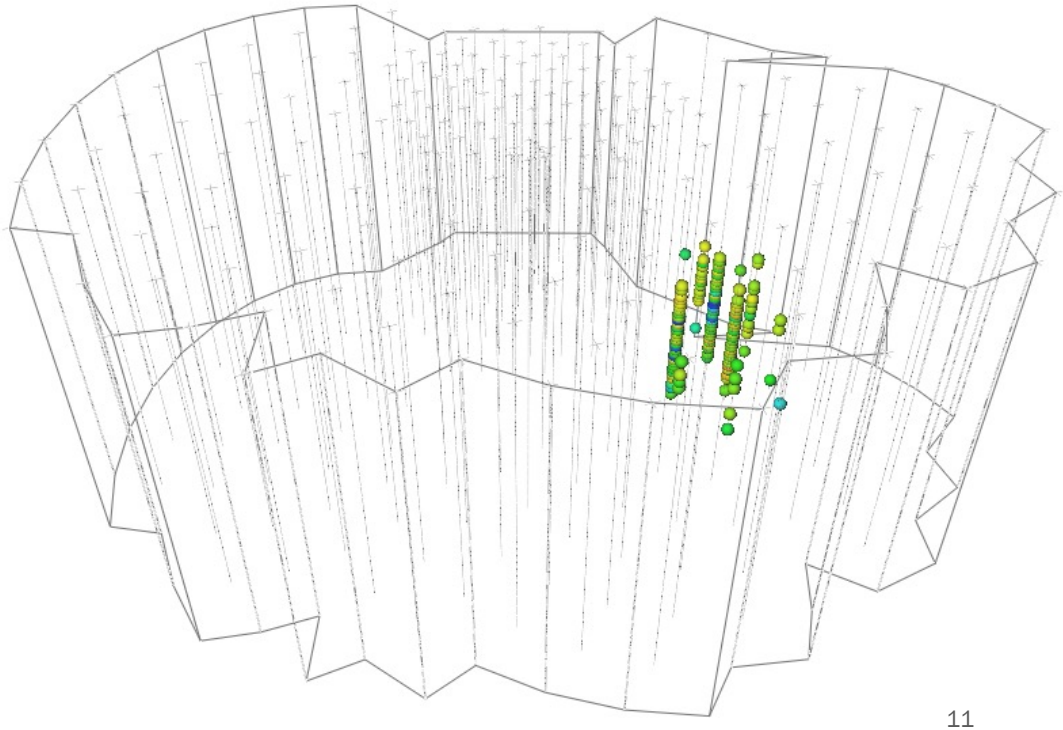
Mostly $\nu_\mu/\bar{\nu}_\mu$ charged current



Cascades

$\nu_e/\bar{\nu}_e$, $\nu_\tau/\bar{\nu}_\tau$ charged current

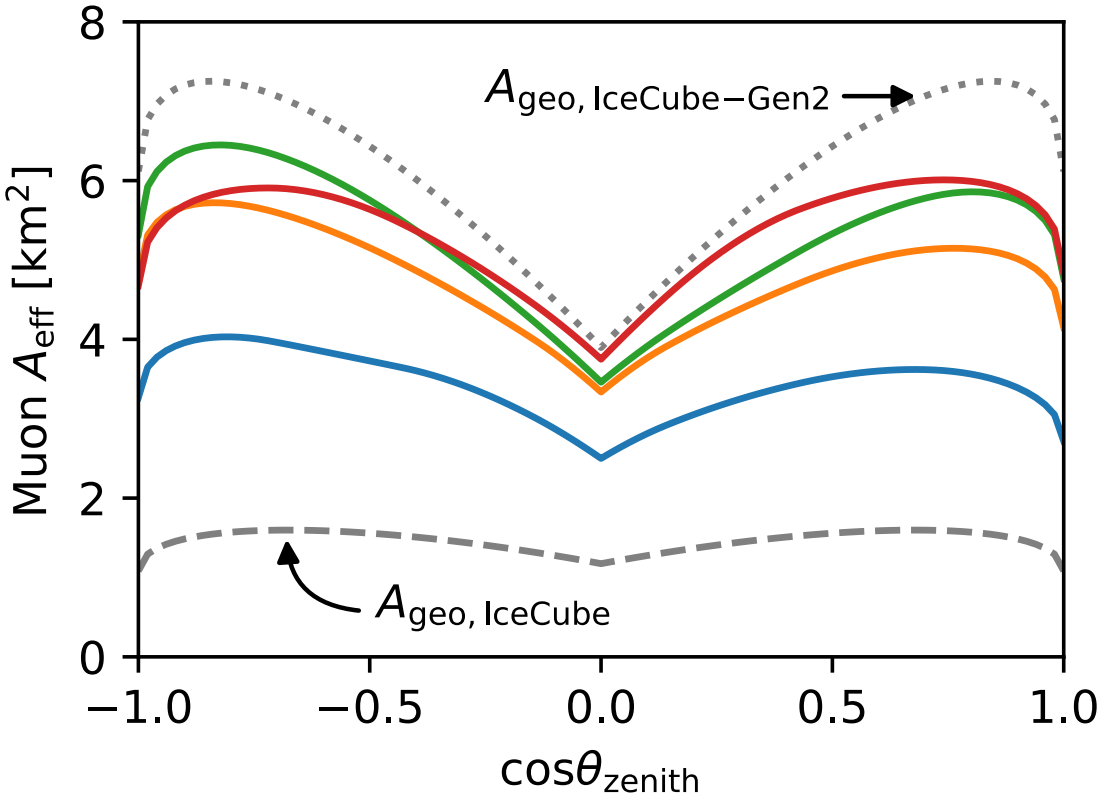
All flavors neutral current

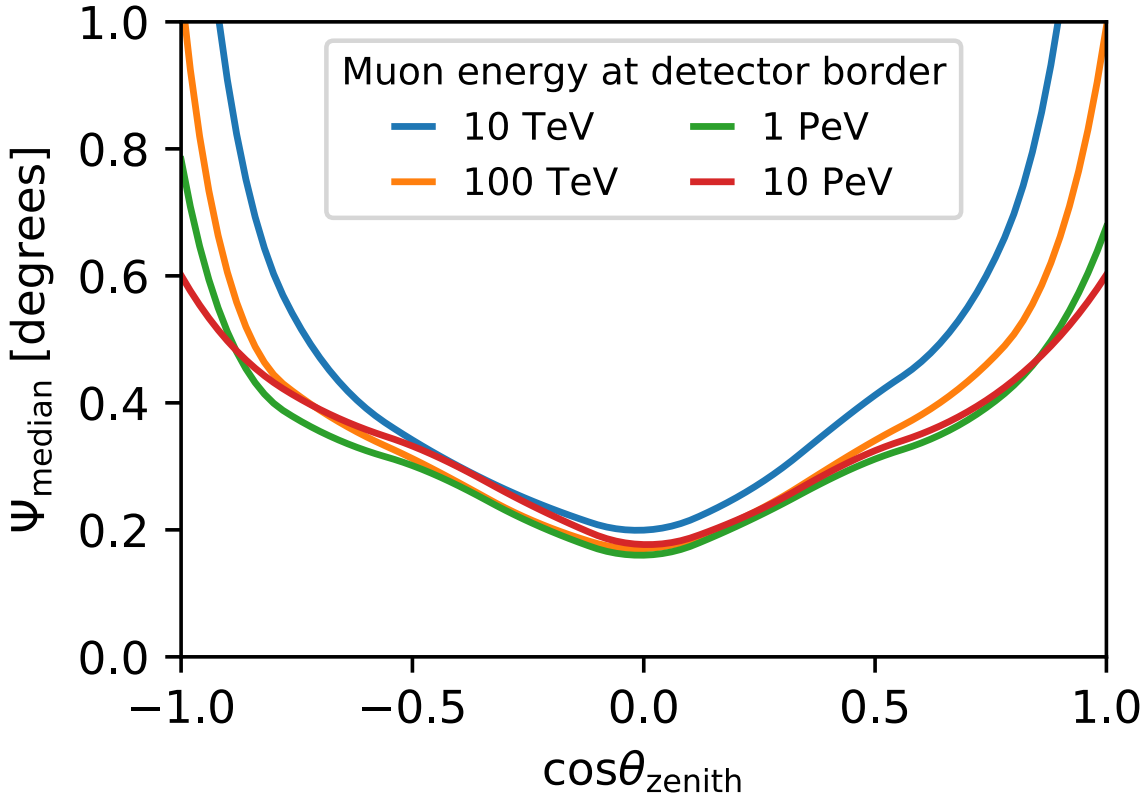


Gen2-Optical Performance

Through-going tracks

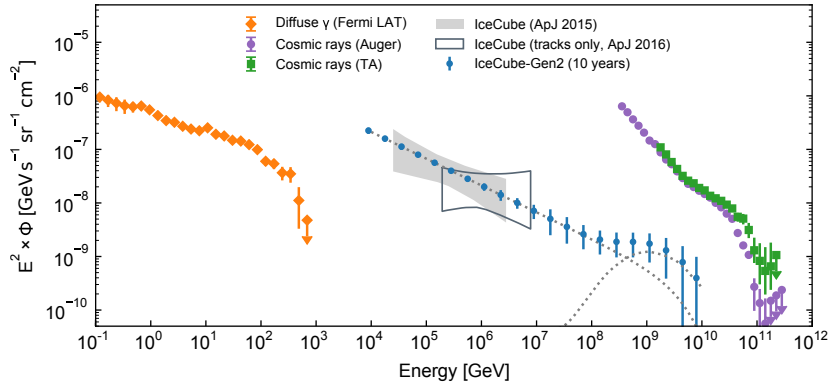
5x the effective area of IceCube
2x improvement in angular resolution



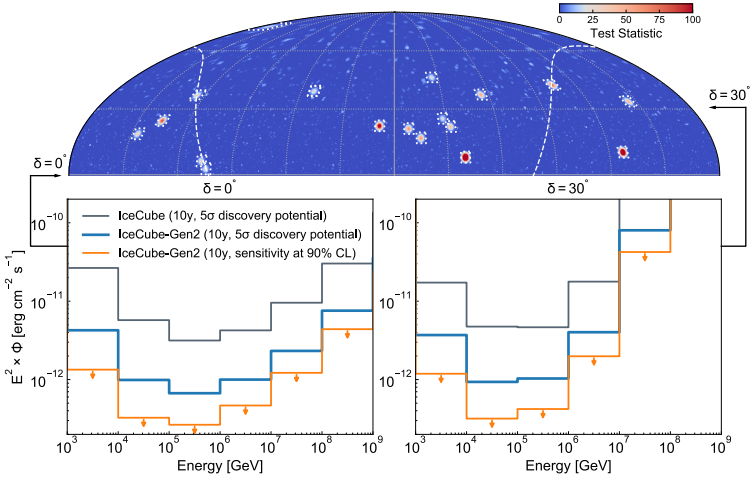


Science

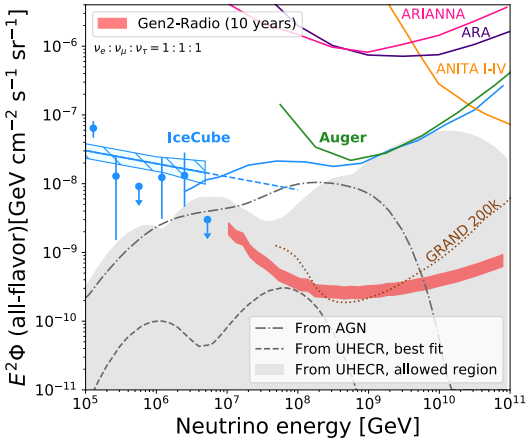
Study Cosmic Particle Acceleration



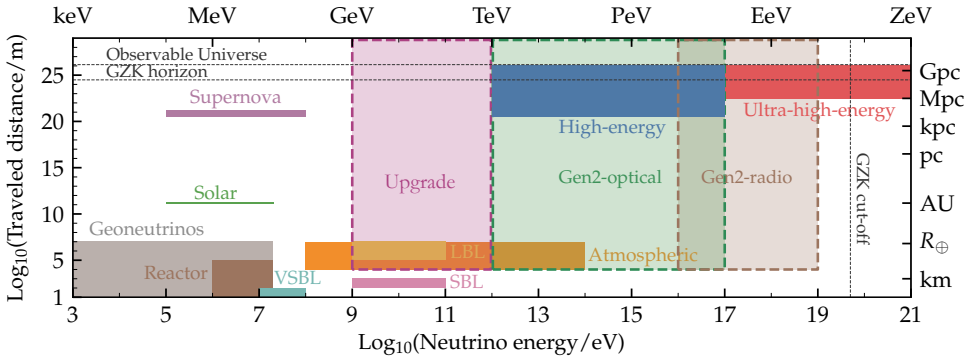
Resolve the TeV-EeV Neutrino Sky



Constrain the Sources and Propagation of Cosmic Rays



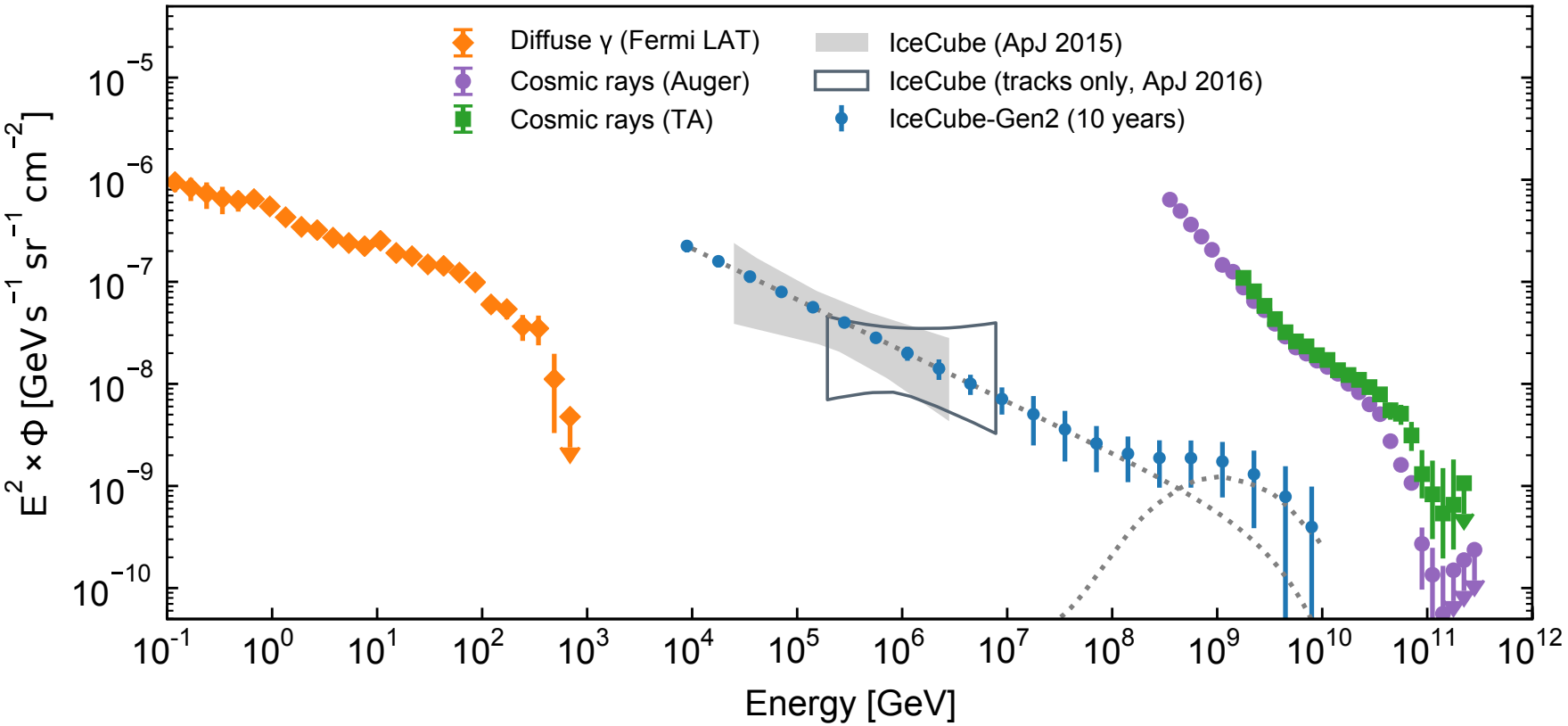
Probe Fundamental Physics on Cosmic Baselines



Cosmic Particle Acceleration

Astrophysical Neutrinos

- Improved and extended measurement of the diffuse flux of neutrinos
- What is the flux at high energies? Is there a cutoff?

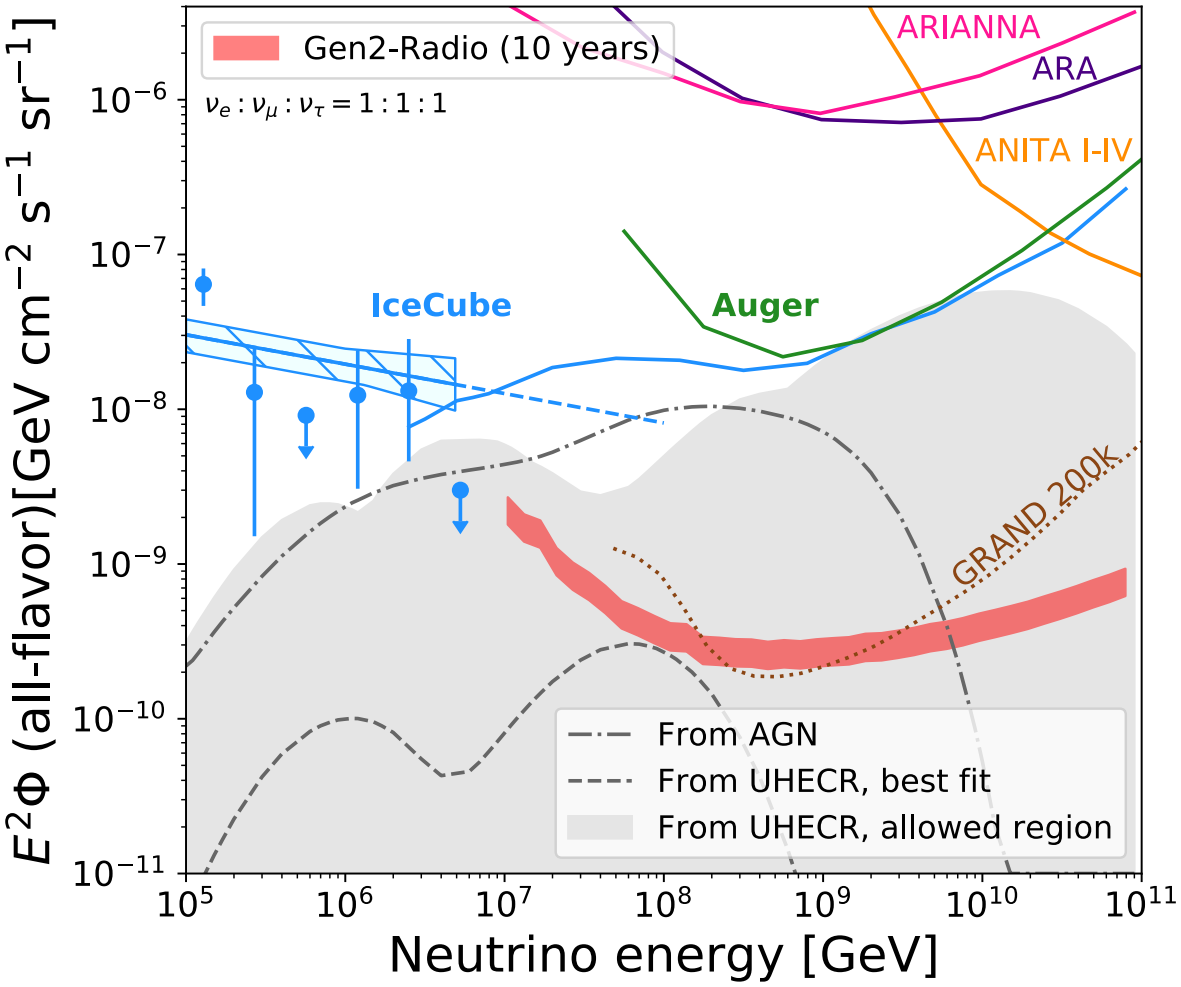


Mock measured spectrum, assuming 10 years of livetime, an $E^{-2.5}$ astrophysical flux, and a mixed-composition cosmogenic flux.

Sources and Propagation of Cosmic Rays

Cosmogenic Neutrinos

- 500 km^2 radio array enables unprecedented sensitivity to UHE neutrinos
- Probes the makeup of cosmic ray primaries, even to very heavy (iron rich) compositions

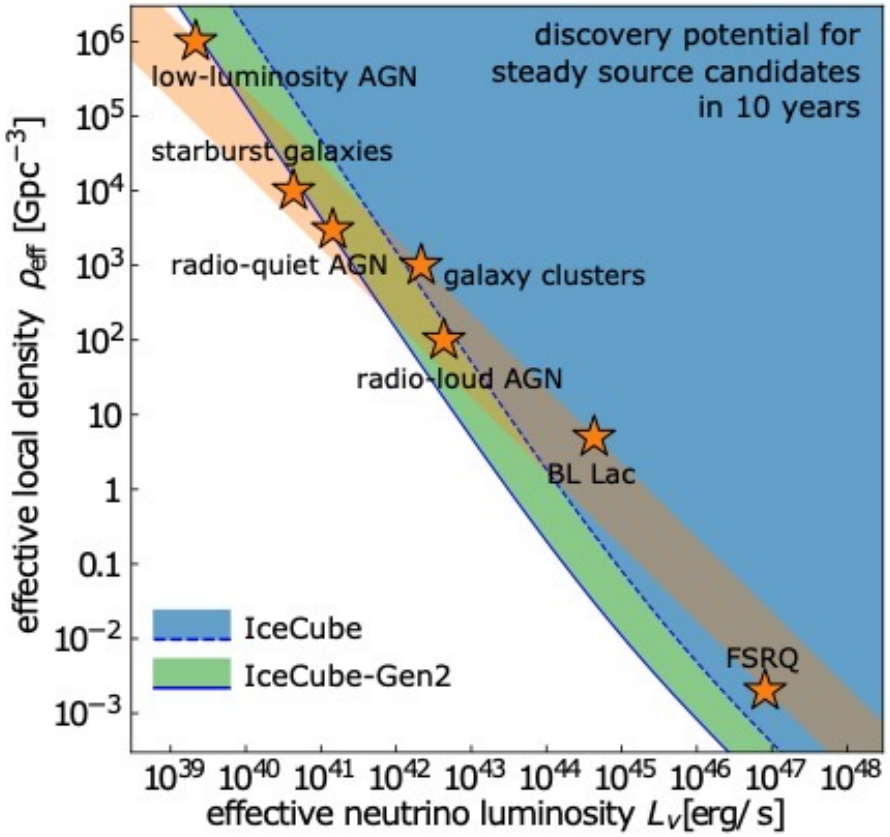


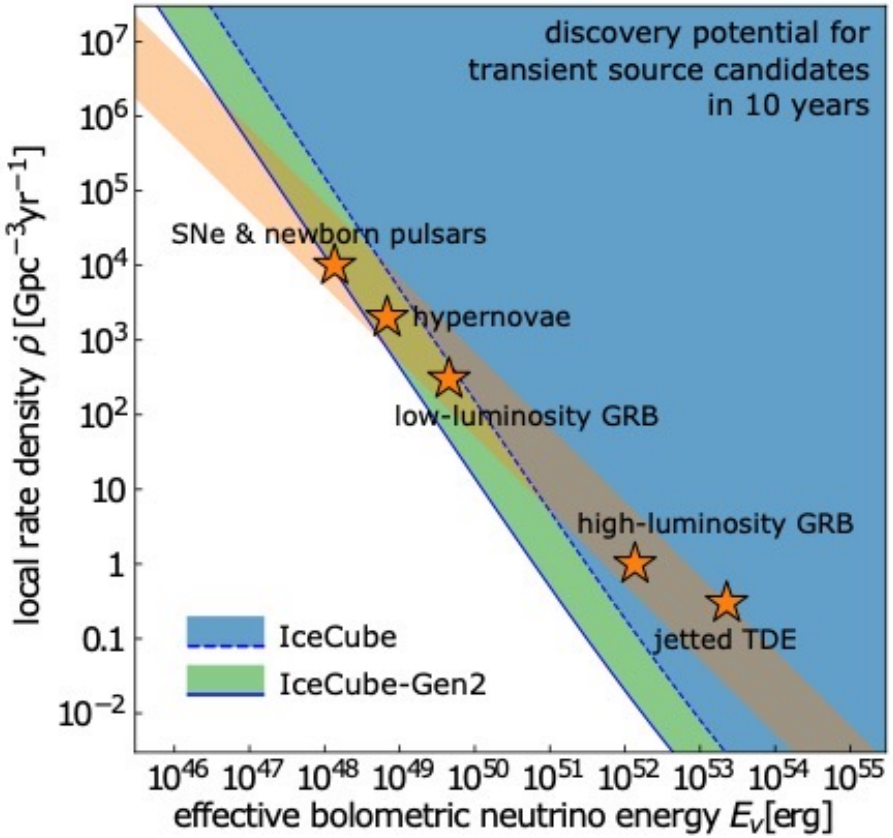
Resolving the Neutrino Sky

Steady Sources

IceCube-Gen2 will be sensitive to sources 5x fainter than IceCube

5x fainter sources ⟶ 11x more sources total

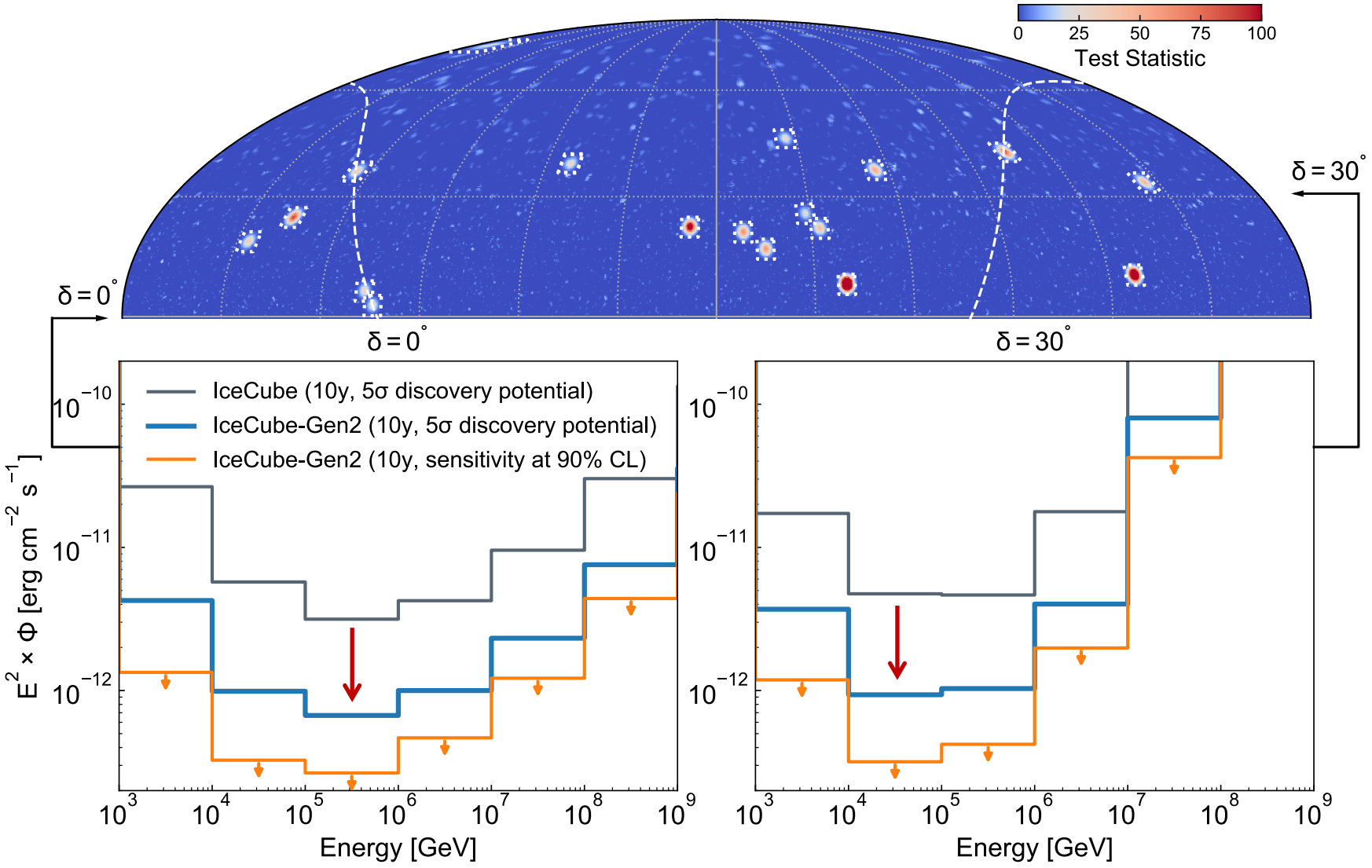




Resolving the Neutrino Sky

Steady Sources

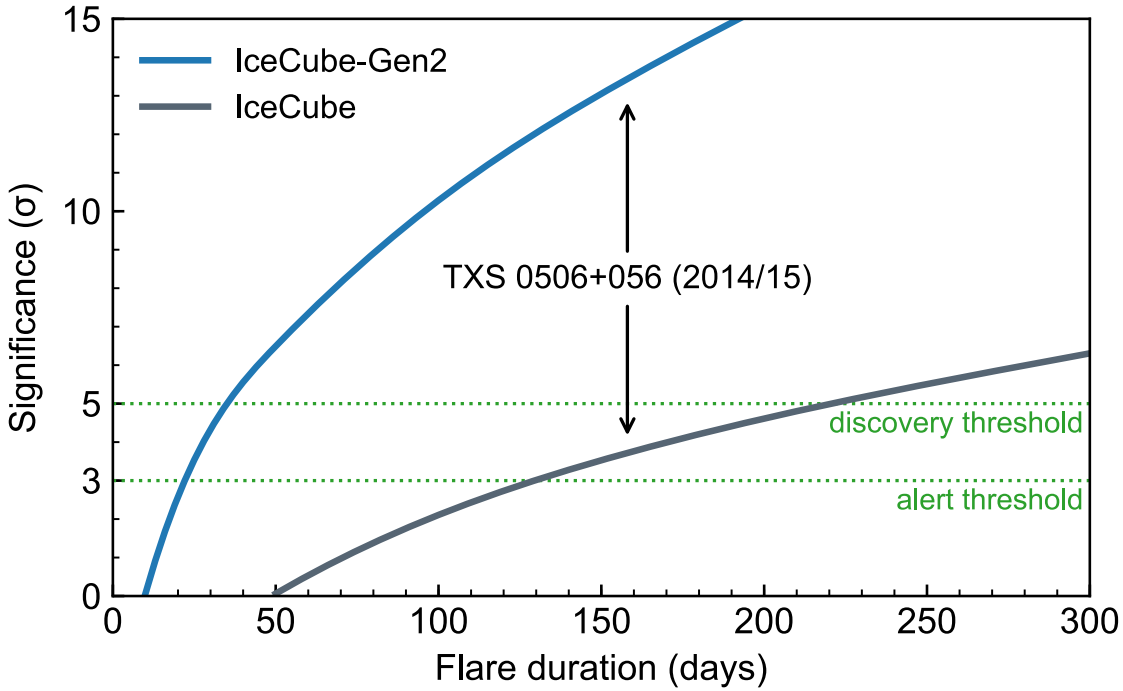
10-year mock TS skymap and differential sensitivities (assuming an E^{-2} spectrum)



Resolving the Neutrino Sky

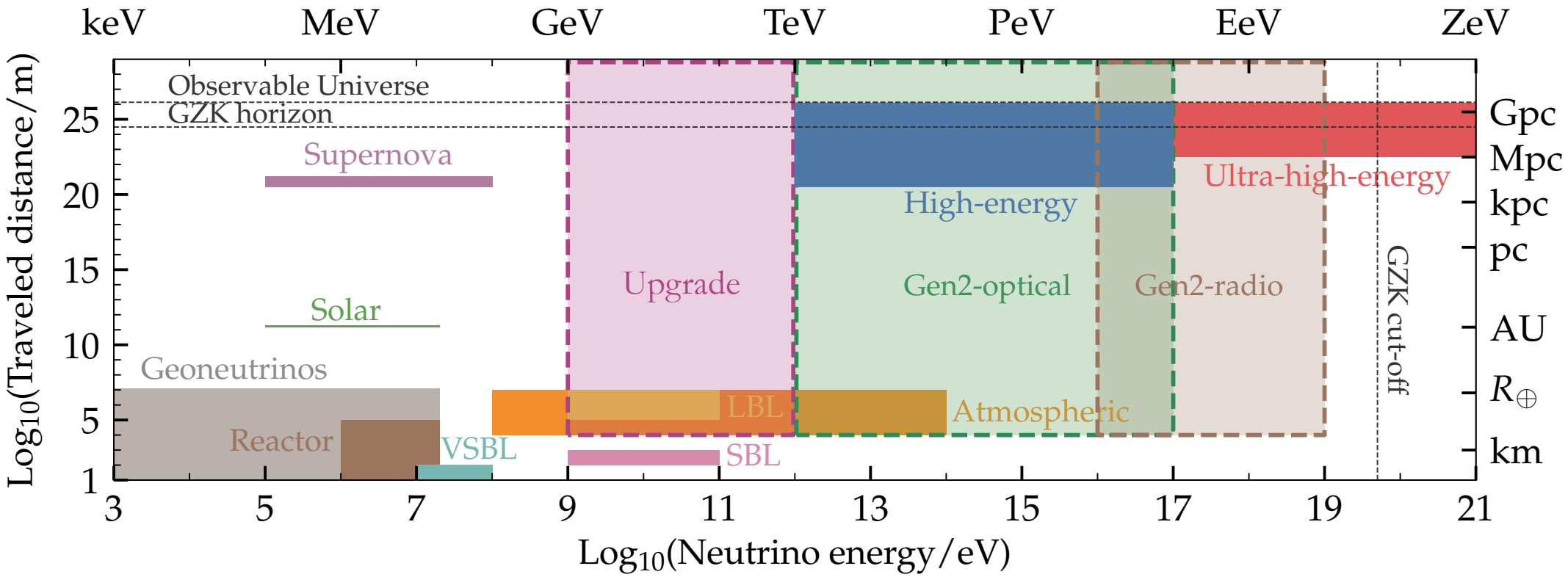
Transients

- IceCube-Gen2 has larger effective areas and improved pointing resolution
- Sensitivity to broad range of accelerators
  - Blazars/AGN flares
  - GRBs
  - Neutron star mergers
- "Hidden" sources
  - A TXS0506+056-like event would be discovered at high significance, *without* a gamma ray counterpart



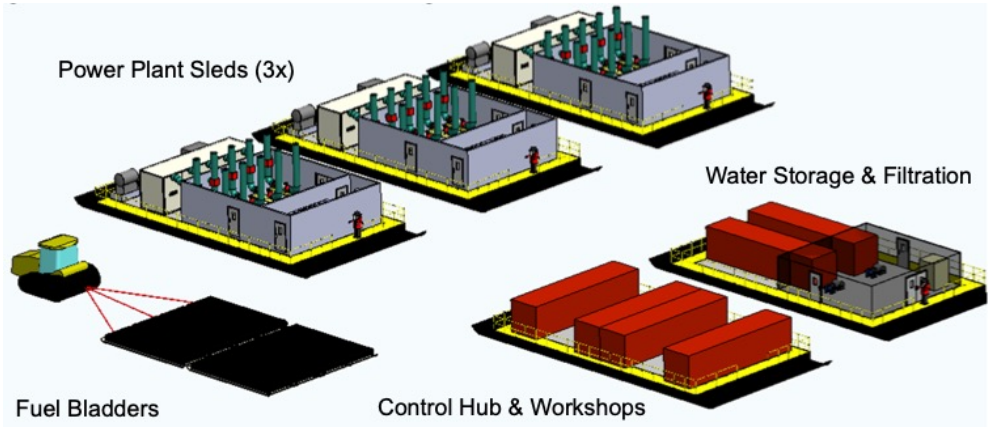
Fundamental Physics

IceCube-Gen2 will probe neutrino propagation over cosmic baselines

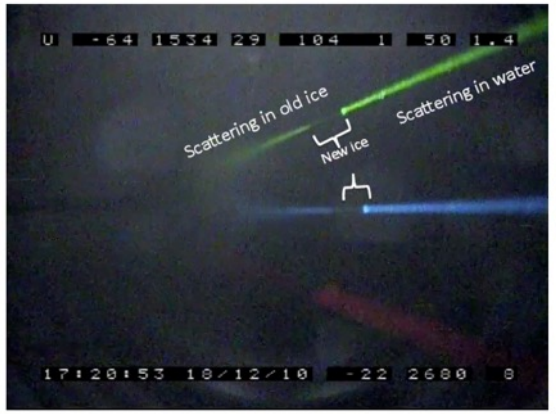


Drilling

- Hot water drill for optical component is modified from IceCube for enhanced performance
  - Large sled modules – delivered by traverse, easy to move
  - “Degassed” holes to reduce bubble column
- Drill for radio component, “BigRAID,” is designed by the British Antarctic Survey
  - ”Dry” drill—removes ice as chips
  - Reach 200m in ~20 hours



Camera looking sideways



Camera looking up, sees “bubble column”

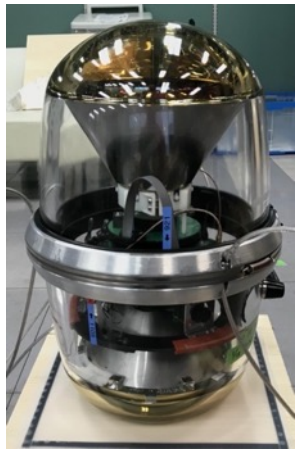
Per Olof Hulth, VLVnT 2013

Technology Development

Optical and Surface

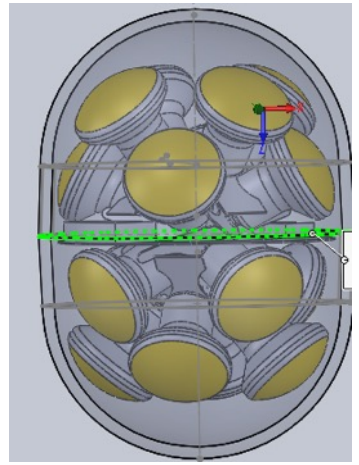
- Gen2 will have pixelated OMs
  - 3x photocathode area ⟶ more photons
  - Directional information per-OM
  - A combined multi-PMT sensor for Gen2 is envisioned
- Surface technology being developed and deployed in the existing IceTop footprint
- Other sensors in development: wavelength shifting modules, etc.

Credit: V. Basu

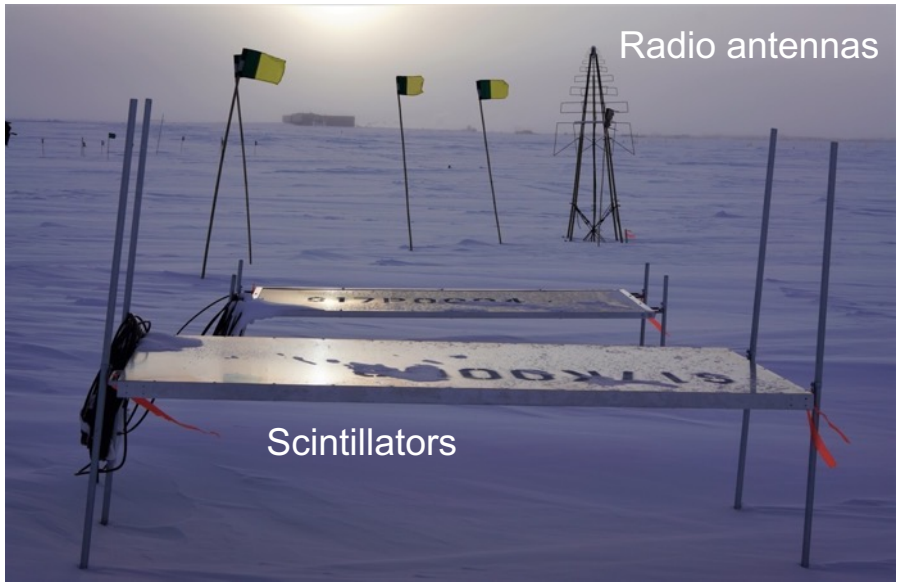


D-Egg

mDOM



Gen2 DOM



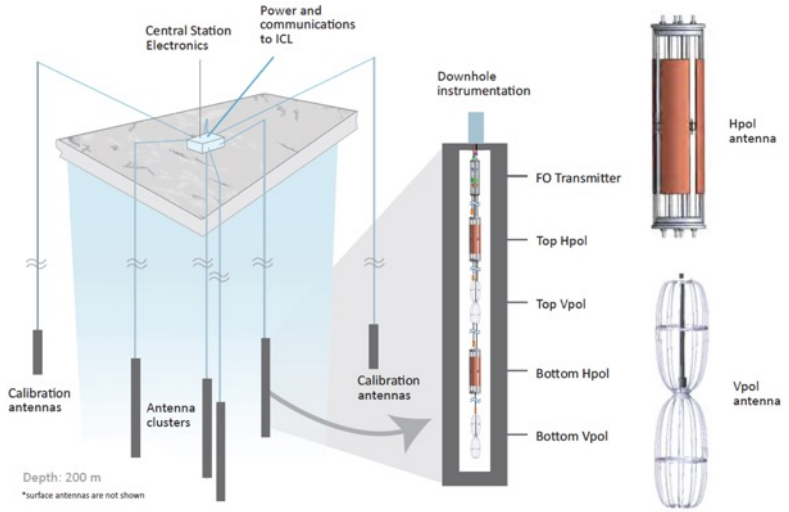
See talks by V. Basu (67),
A. Pollmann (95), J. Kelley (90)

Technology Development

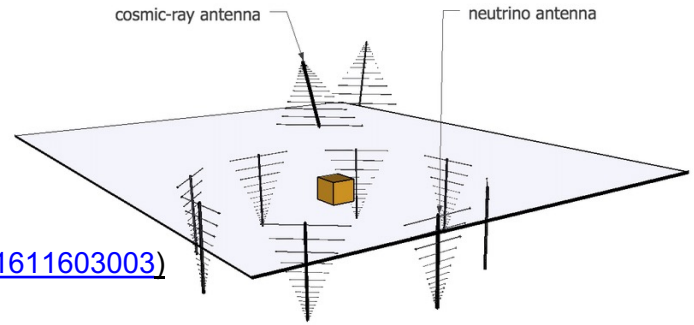
Radio Array

- Radio array builds on heritage from RICE, ARIANNA, and ARA
  - Shallow antennas
  - Deep antennas
  - Autonomous power solutions
  - Phased array triggering
- Some new technology will be tested this summer in RNO-G, e.g. LTE-comms

See talk by A. Vieregg
(this session!)



ARA station and antennas

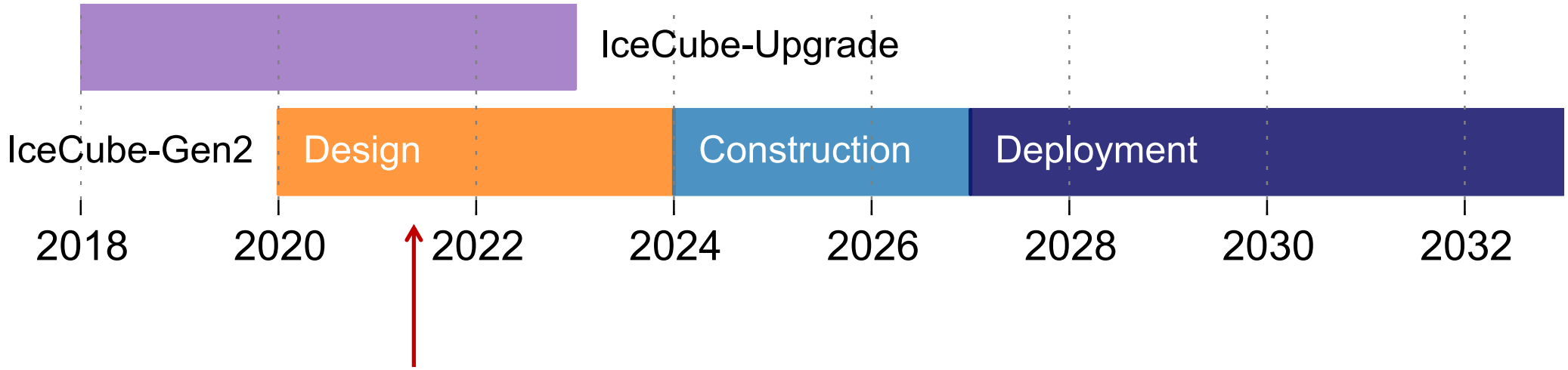


ARIANNA station
(10.1051/epjconf/201611603003)

Wind Generator Prototypes @ ARIANNA
(PoS ICRC 2019 968)

Timeline

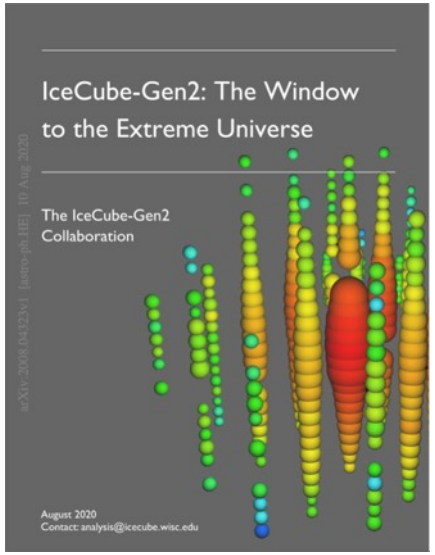
- IceCube Upgrade (“Gen2 Phase 1”) is under construction
- Gen2 design is well underway



We are here.
Radio array has completed first internal design review, with Surface array imminent.

Conclusions

- Gen2 will be a broadband neutrino observatory with unprecedented capabilities
- New detector technologies—pixelated detectors, radio arrays, scintillators, etc.—drive this progress
- Please see recent white paper for more information!



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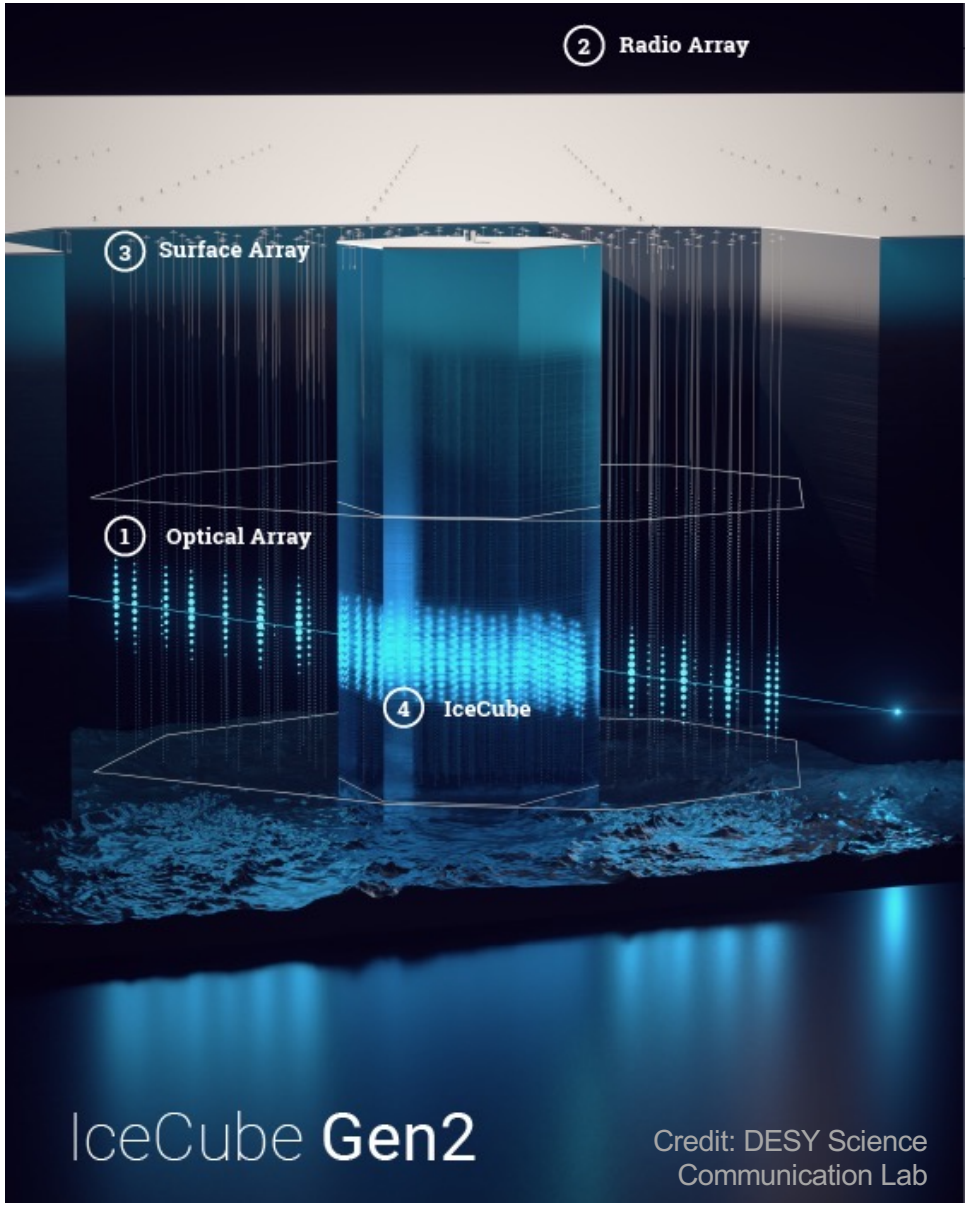
arXiv 2008.04323



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