

# The IceCube-Gen2 Project

IceCube 15 year symposium

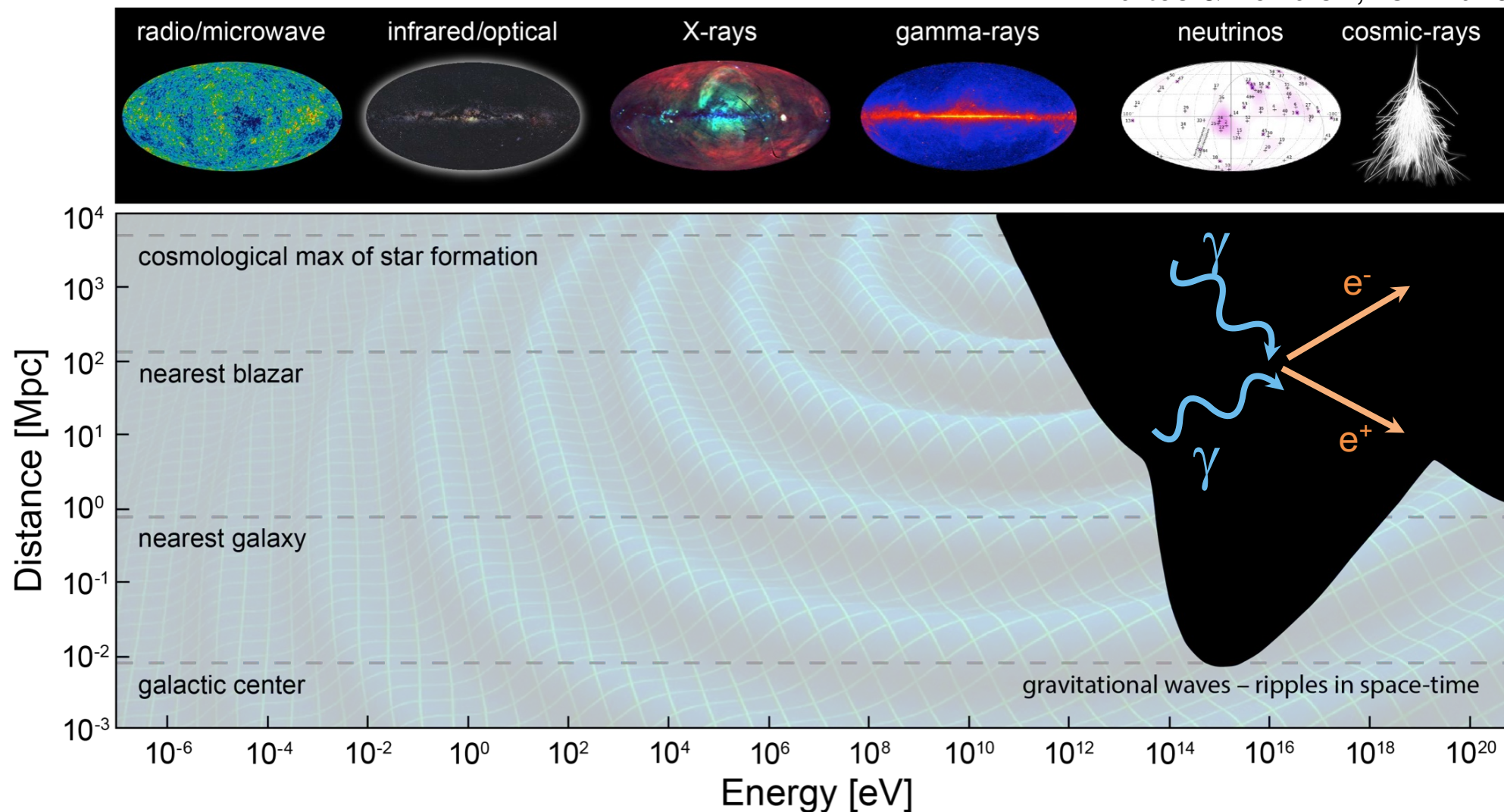
Madison, 16.10.2026

Marek Kowalski  
DESY & Humboldt-University of Berlin



# High energy neutrino astronomy in a nutshell

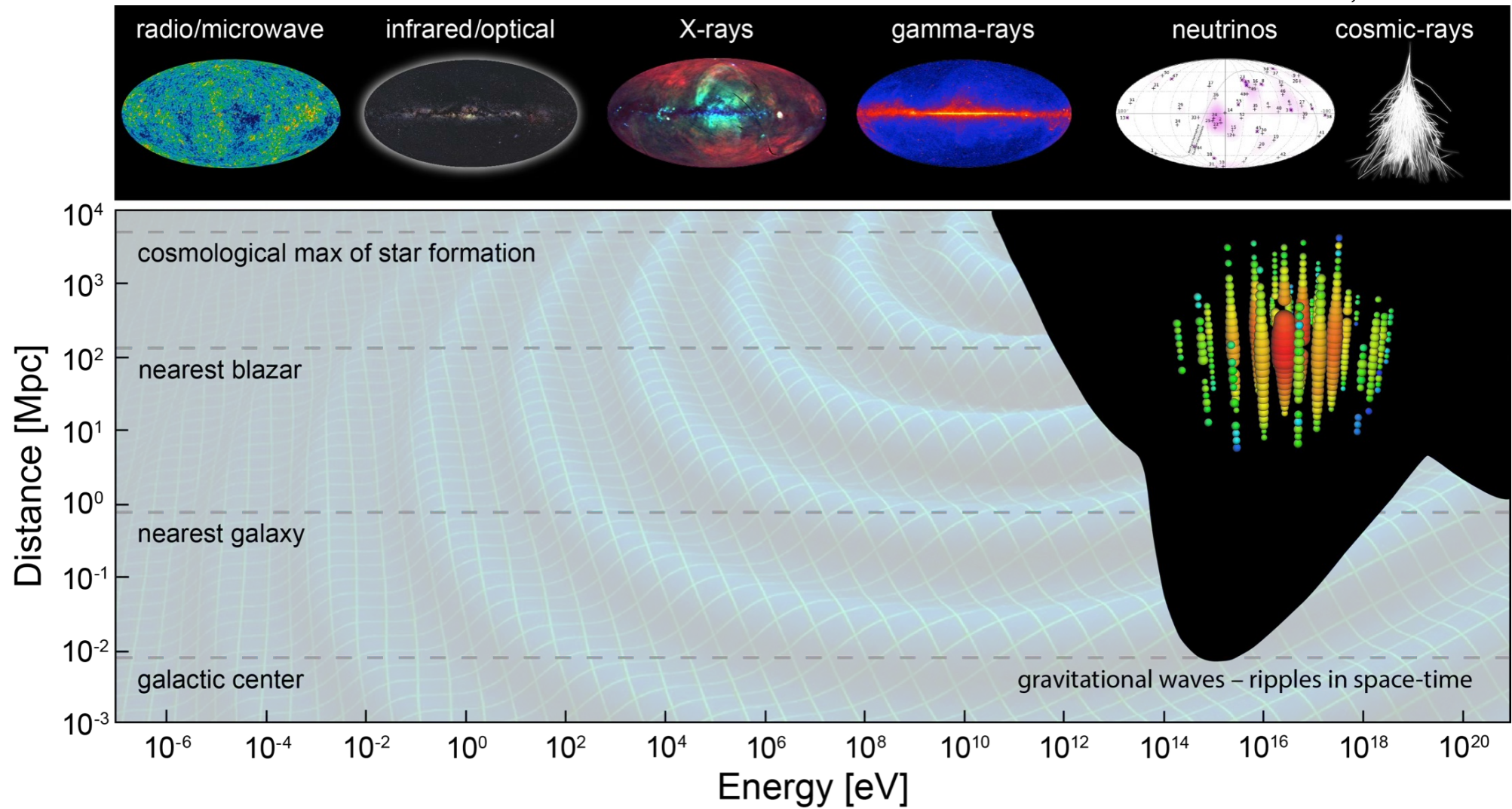
*Bartos & Kowalski, IOP 2018*



**The Universe is opaque to photons for  $\frac{1}{4}$  of the spectrum**

# High energy neutrino astronomy in a nutshell

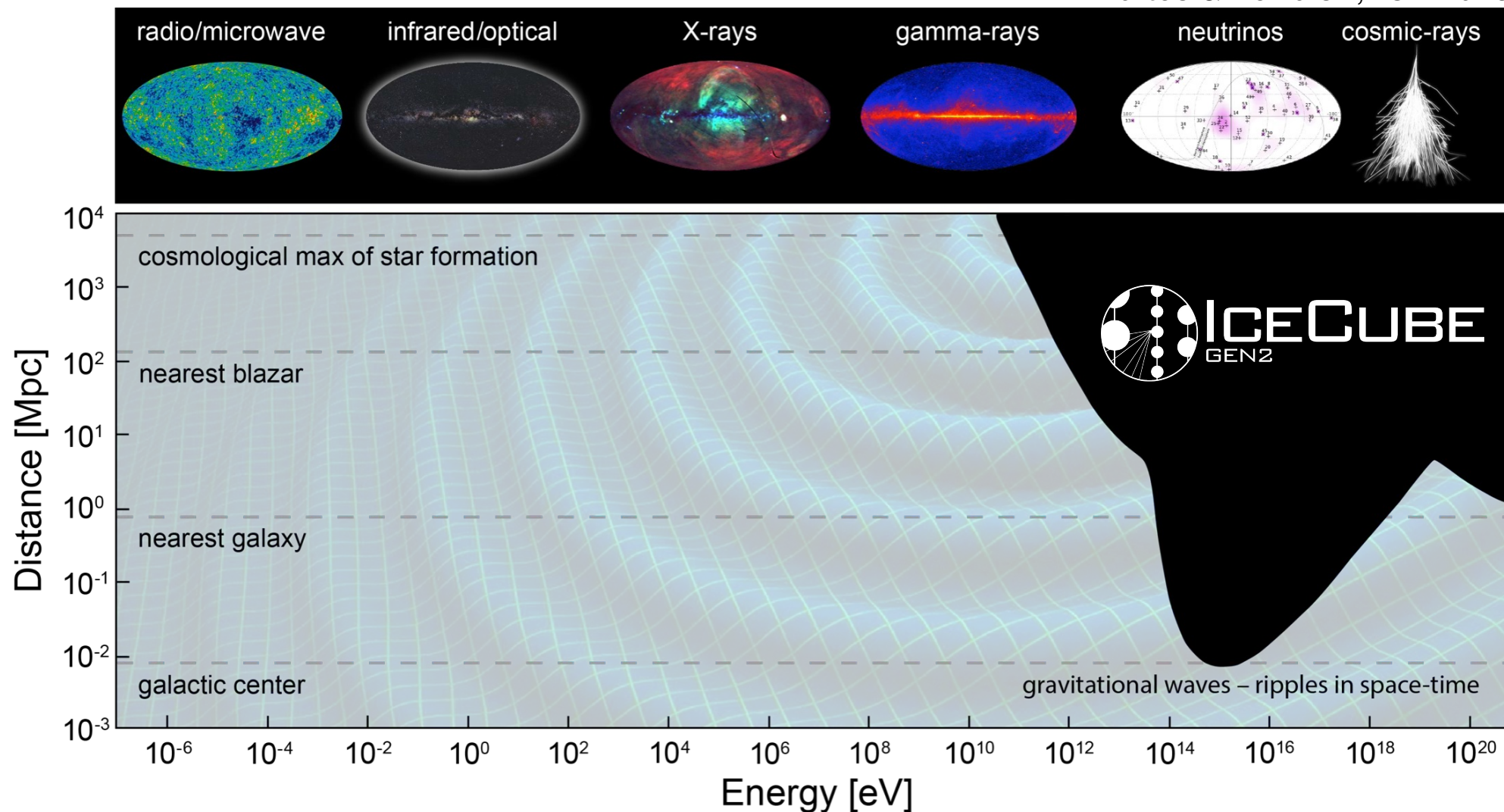
Bartos & Kowalski, IOP 2018



The Universe is opaque to photons for ¼ of the spectrum

# High energy neutrino astronomy in a nutshell

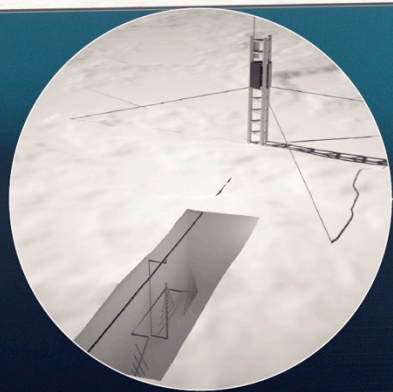
*Bartos & Kowalski, IOP 2018*



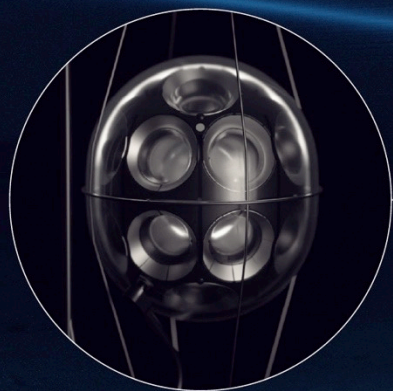
**The Universe is opaque to photons for  $\frac{1}{4}$  of the spectrum**

# ICECUBE

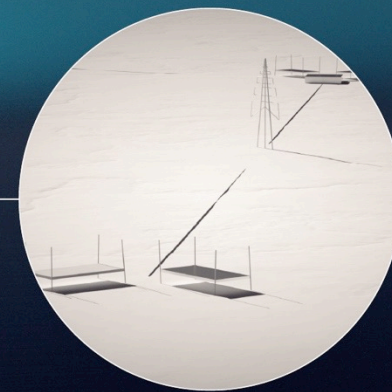
## GEN2



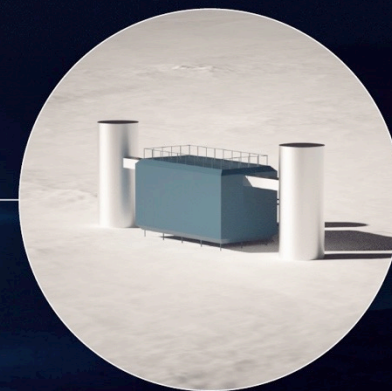
**Radio Array** | Station



**Optical Array** | Sensor



**Surface Array** | Station



**IceCube** | Laboratory

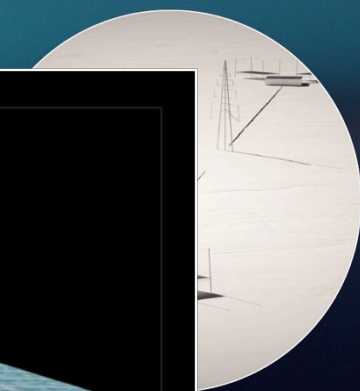
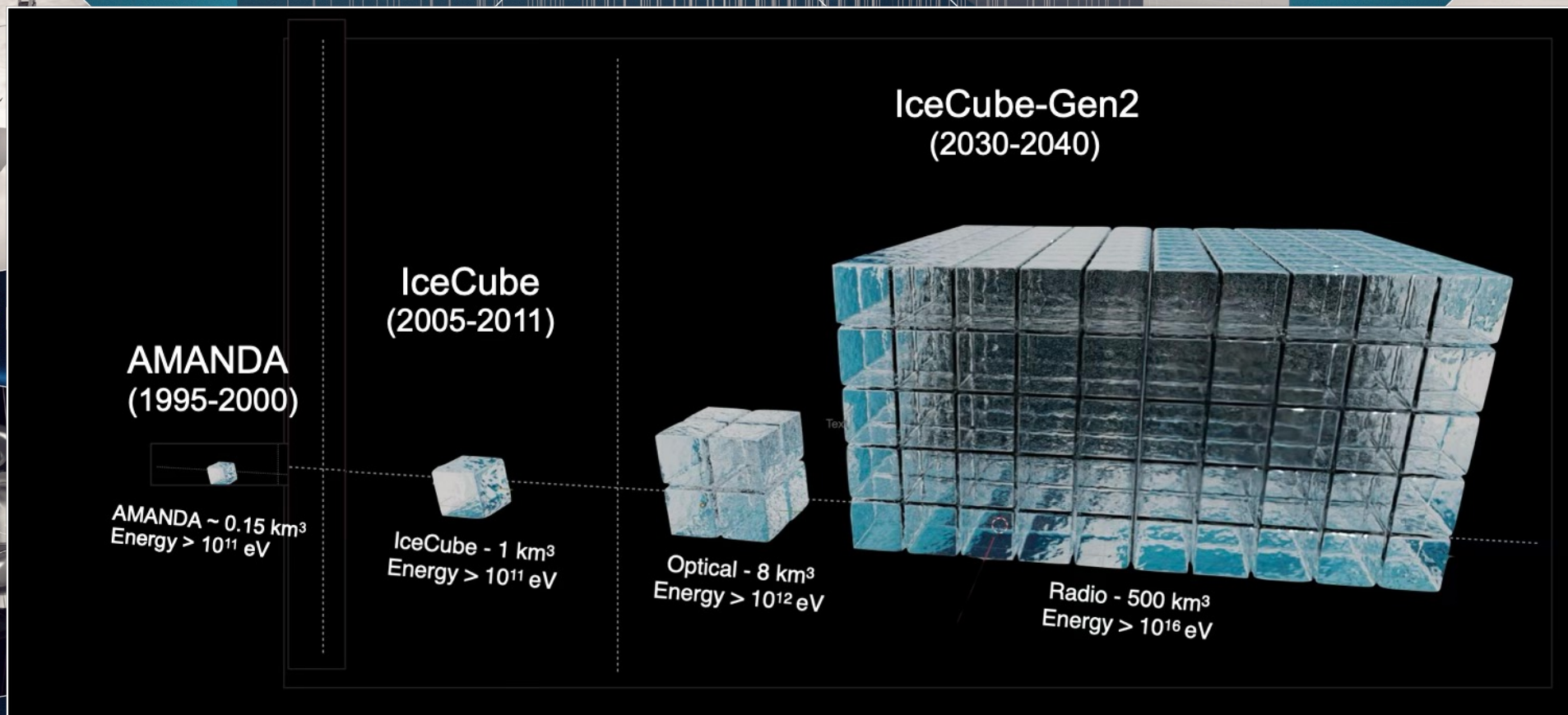
# ICECUBE GEN2



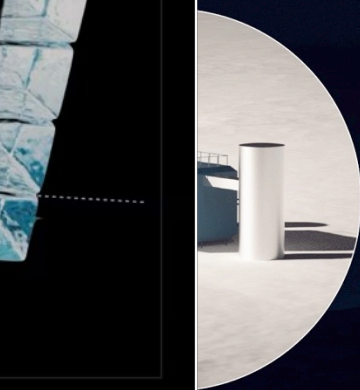
Radio Array



Optical Array | Sensor



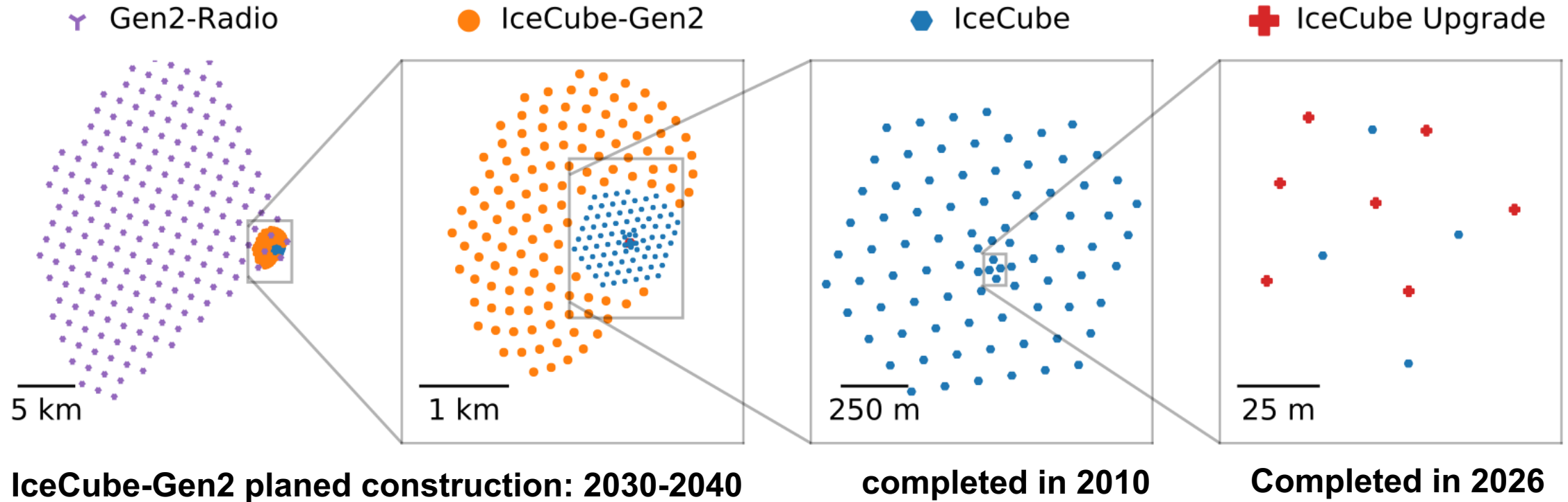
Radio Array | Station



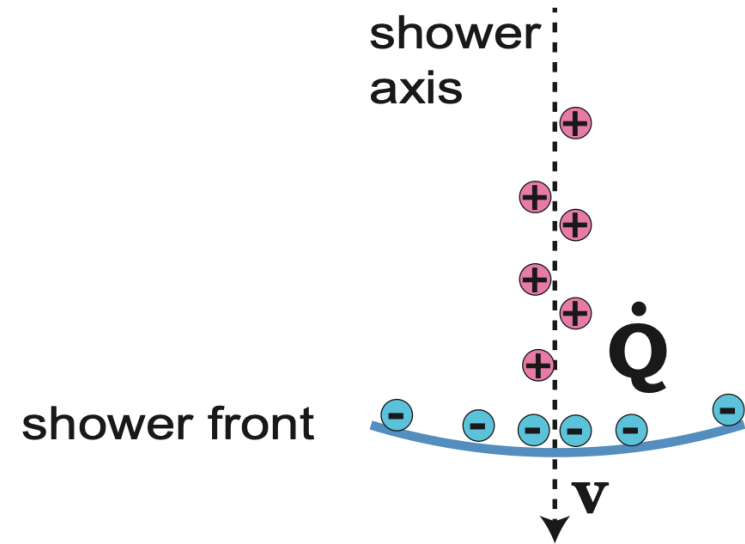
IceCube | Laboratory

# The IceCube Gen2 facility at the South Pole

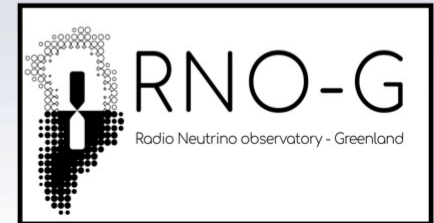
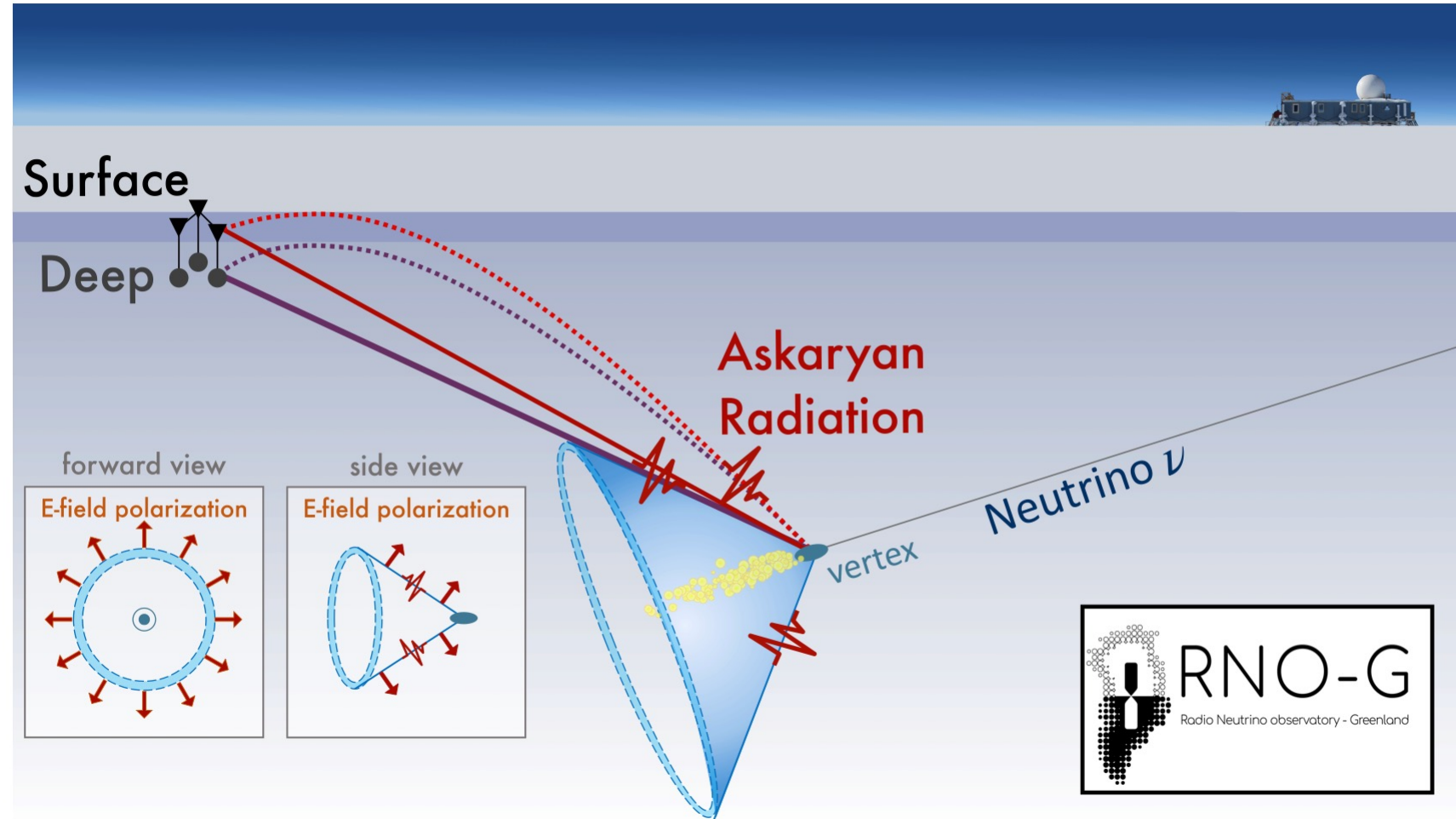
Wide-band observatory: Optimizing scales for leading sensitivity from  $10^9$  to  $10^{20}$  eV



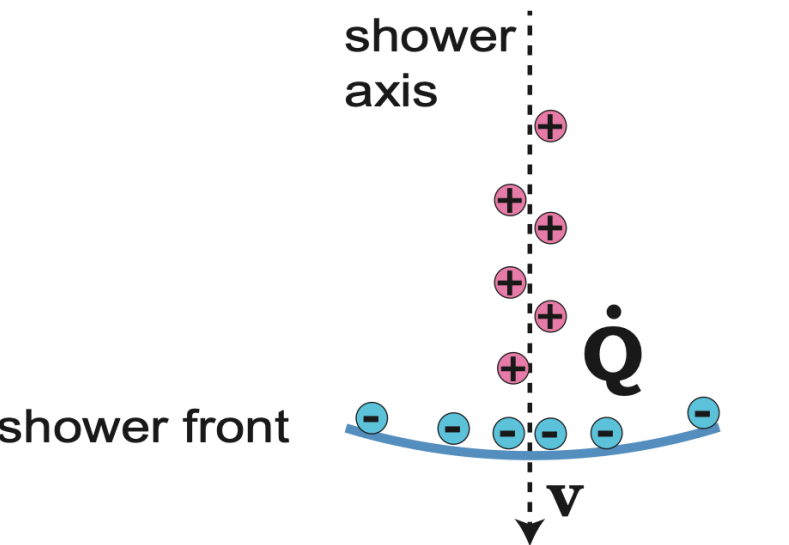
# Radio detection of neutrinos



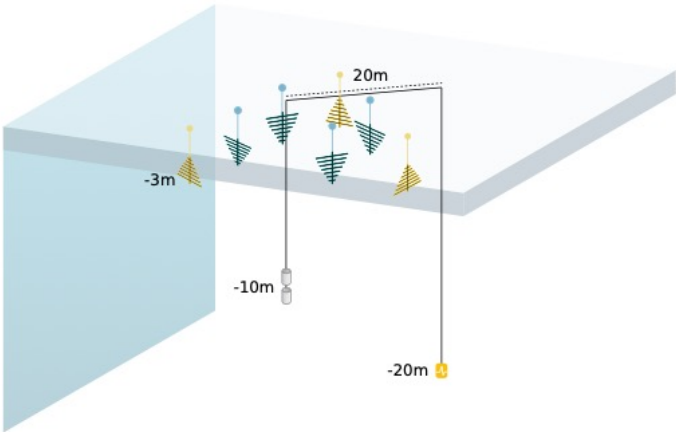
Askaryan emission from  
particle showers in ice,  
dominant @MHz-GHz  
Attenuation length >1km!



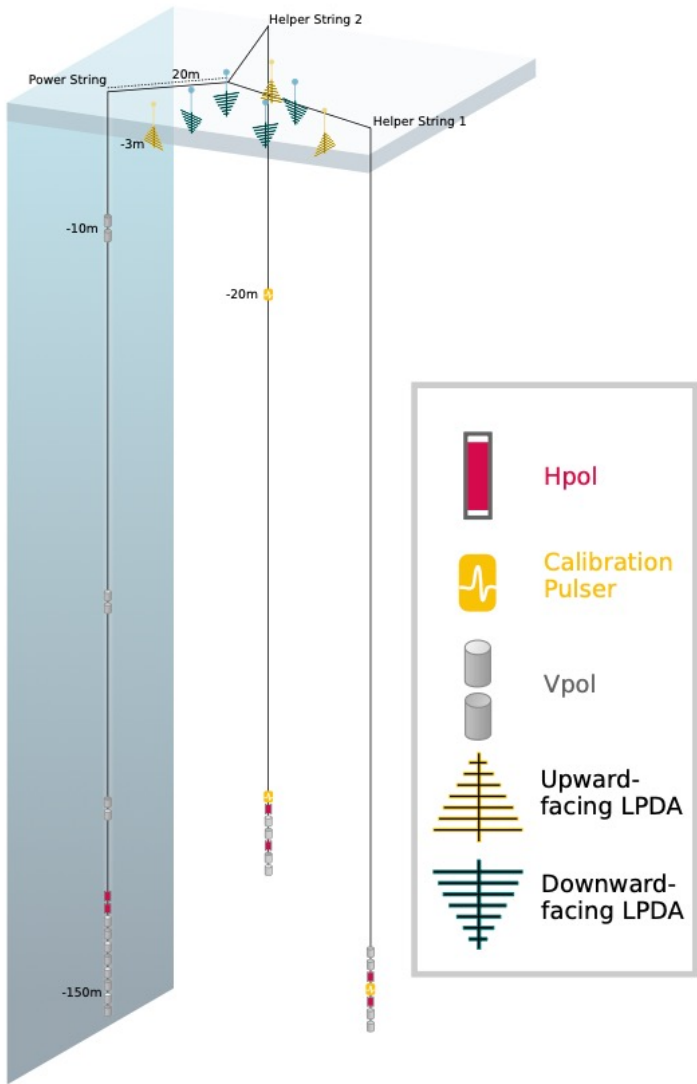
# Radio detection of neutrinos



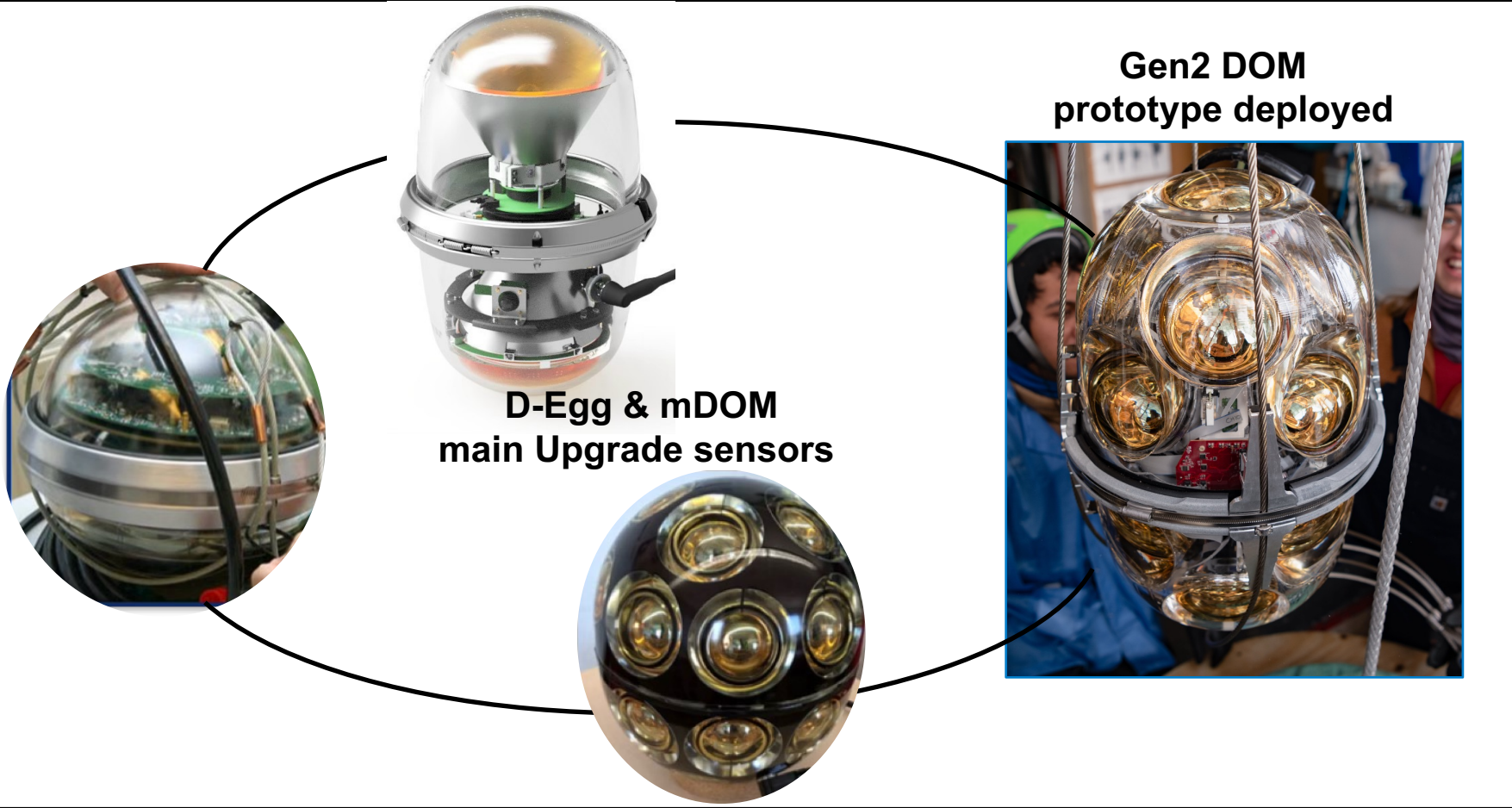
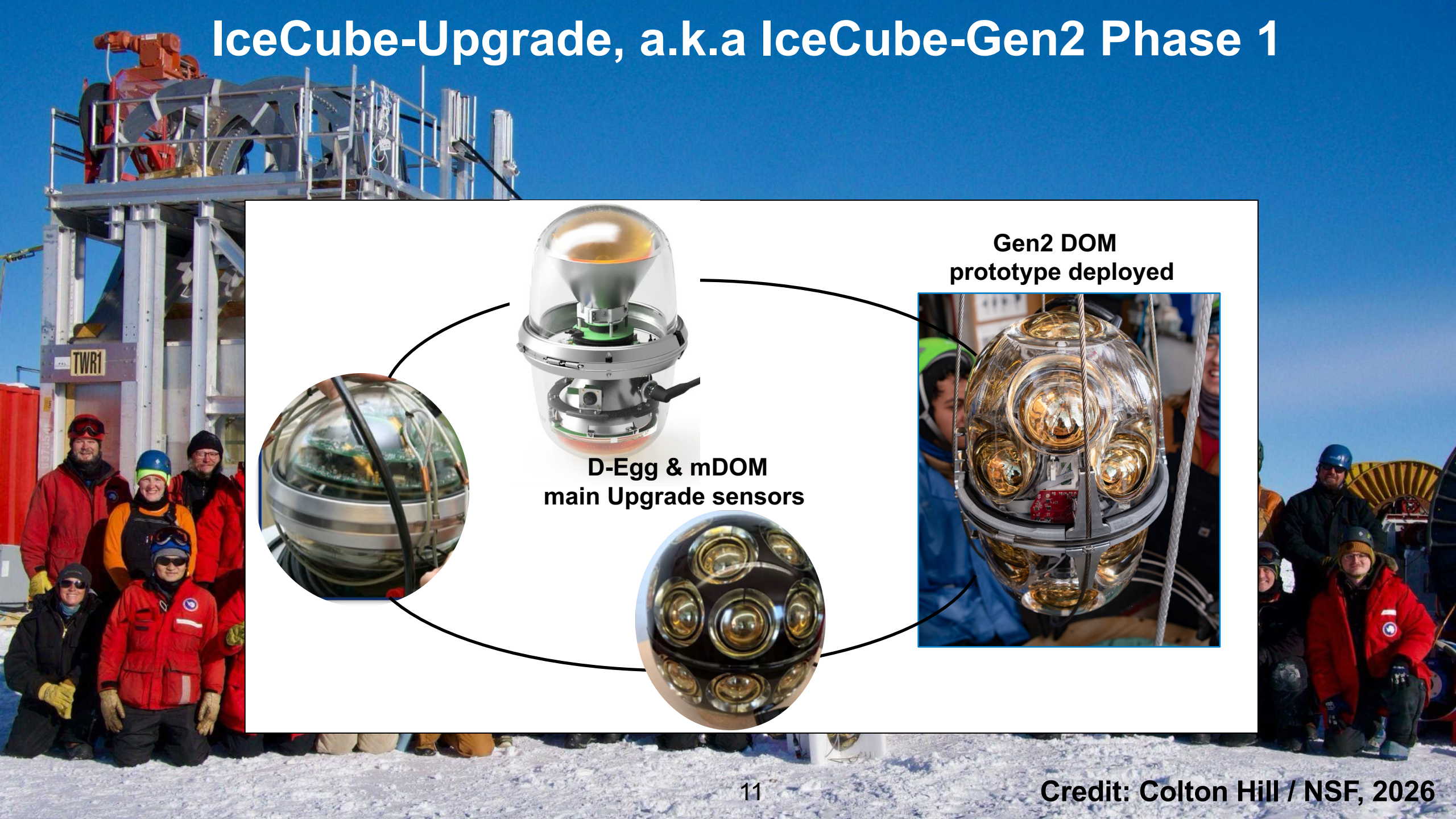
197 surface stations



164 hybrid stations



# IceCube-Upgrade, a.k.a IceCube-Gen2 Phase 1



# Technical Readiness

New technologies verified within IceCube-Upgrade and RNO-G in Greenland.

optical sensors



Prototype Gen2 sensors part of Upgrade

hot-water drilling



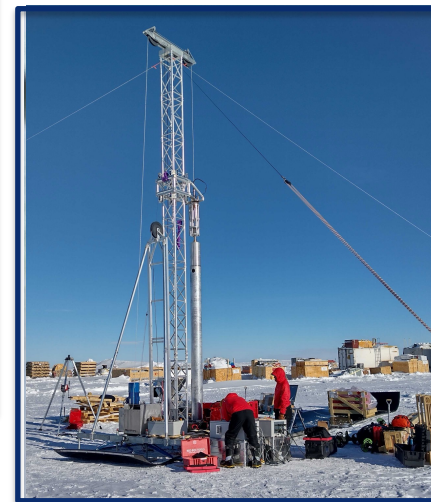
Installation of 6 strings at South Pole in 2026

surface-stations



Next generation surf. stations at South Pole

radio-stations



RNO-G pathfinder installation in Greenland



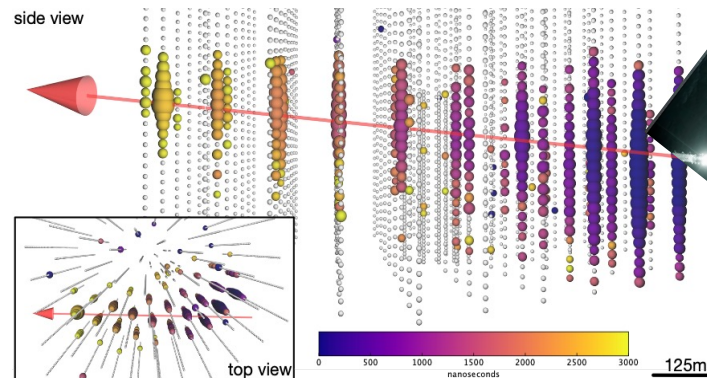
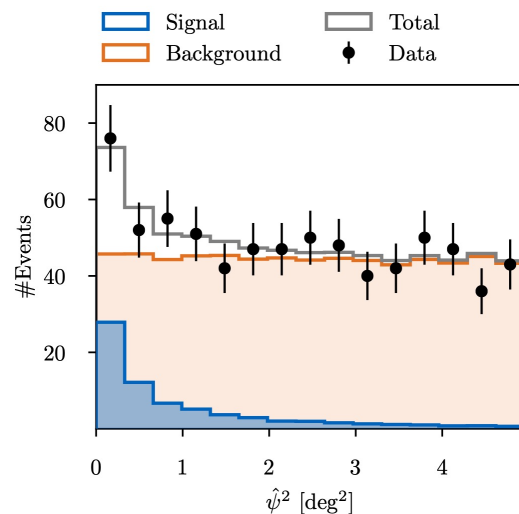
ICECUBE  
GEN2

# Key scientific questions for IceCube-Gen2

## Exploring the new window to the extreme Universe

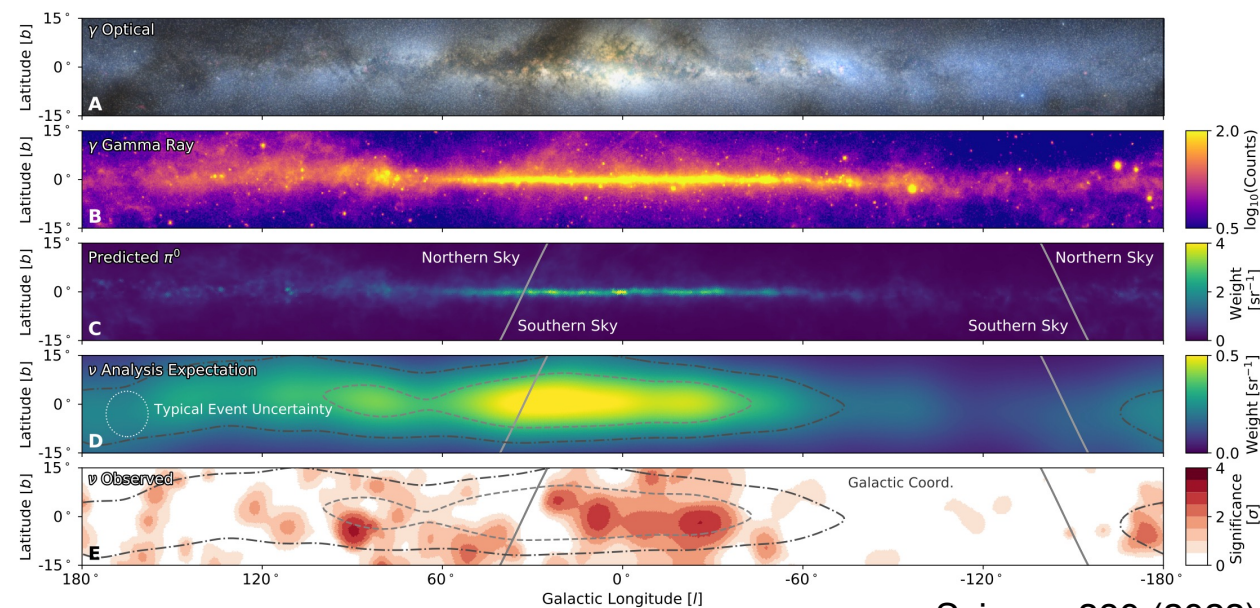


Science 378 (2022)



Science 361 (2018)

- Resolving the high-energy sky from TeV to EeV energies
- Understanding cosmic particle acceleration through multi-messenger observations
- Revealing the sources and propagation of the highest energy particles in the universe
- Probing fundamental physics with high-energy neutrinos

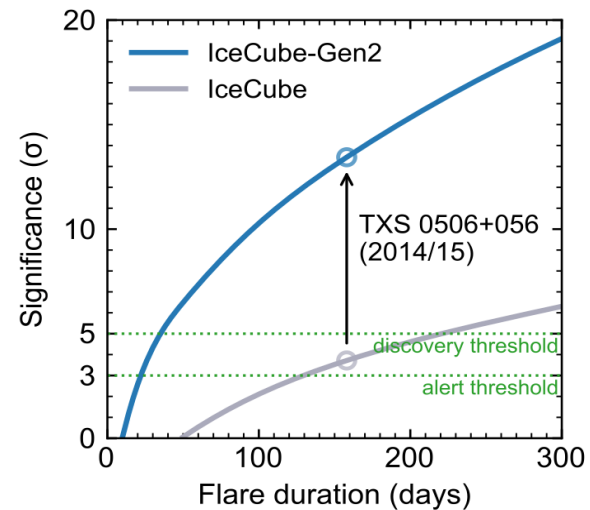
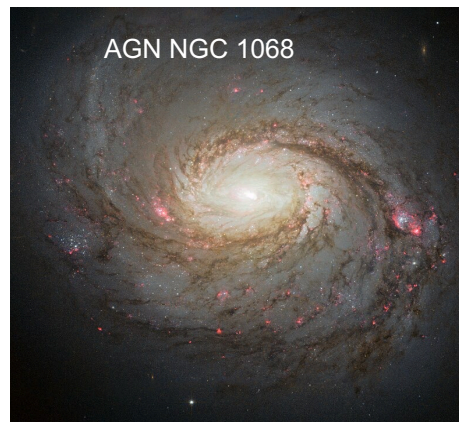
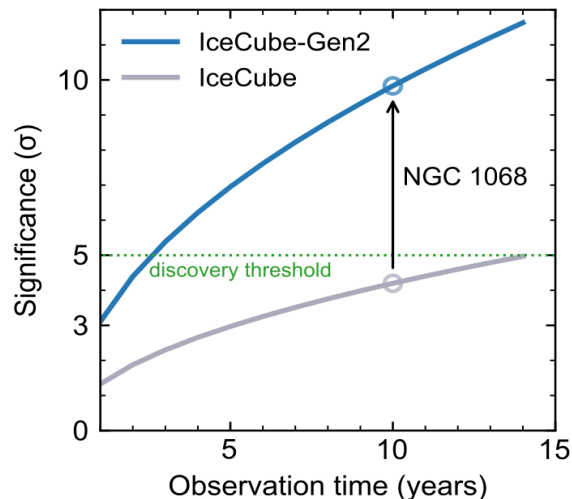


Science 380 (2023)

# Scientific objectives for IceCube-Gen2

## Resolving the high-energy sky from TeV to EeV energies

Sensitivity to point sources, *Technical Design Report 2024*



### IceCube-Gen2 vs IceCube:

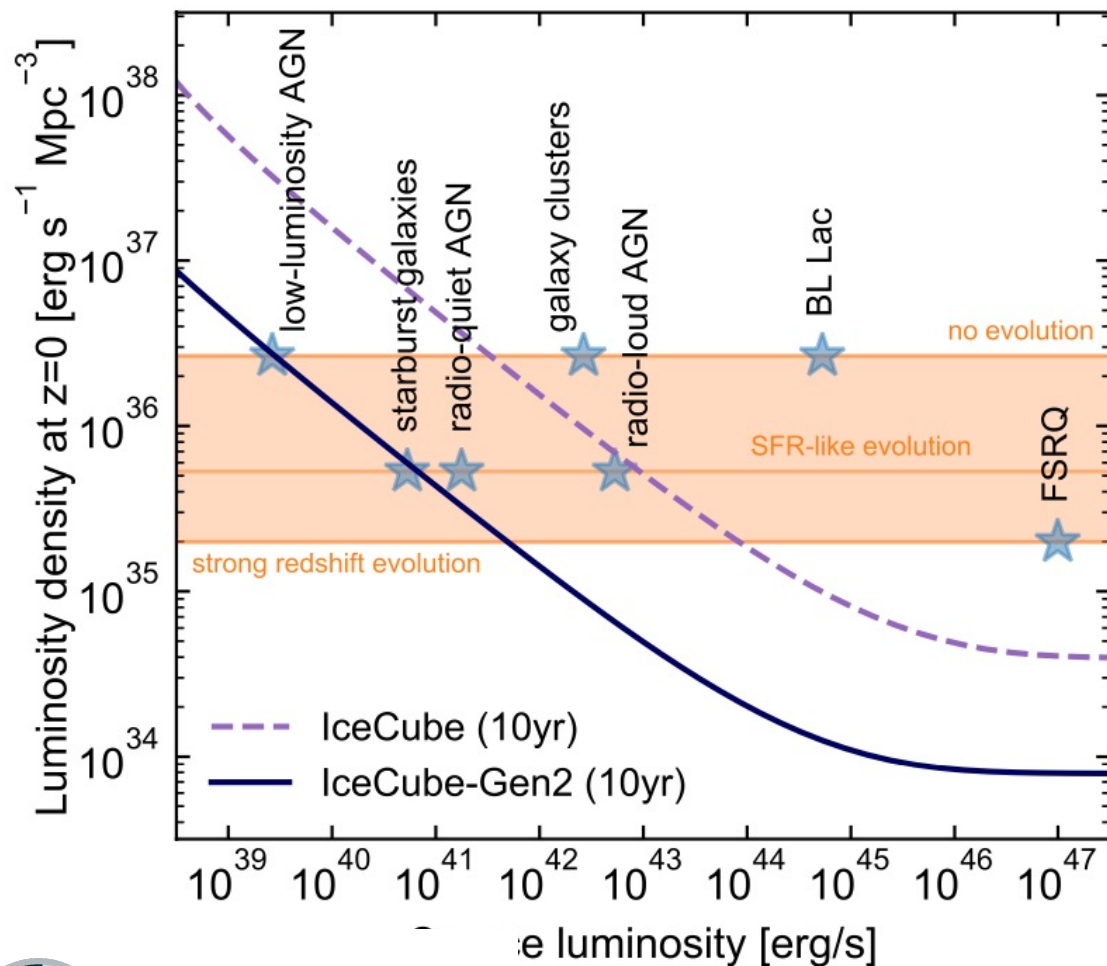
- 5 x point source sensitivity
- 10 x number of sources

**IceCube-Gen2 will probe the leading source classes to produce the diffuse neutrino flux**

# Scientific objectives for IceCube-Gen2

## Resolving the high-energy sky from TeV to EeV energies

Sensitivity to point sources, *Technical Design Report 2024*



### IceCube-Gen2 vs IceCube:

- 5 x point source sensitivity
- 10 x number of sources

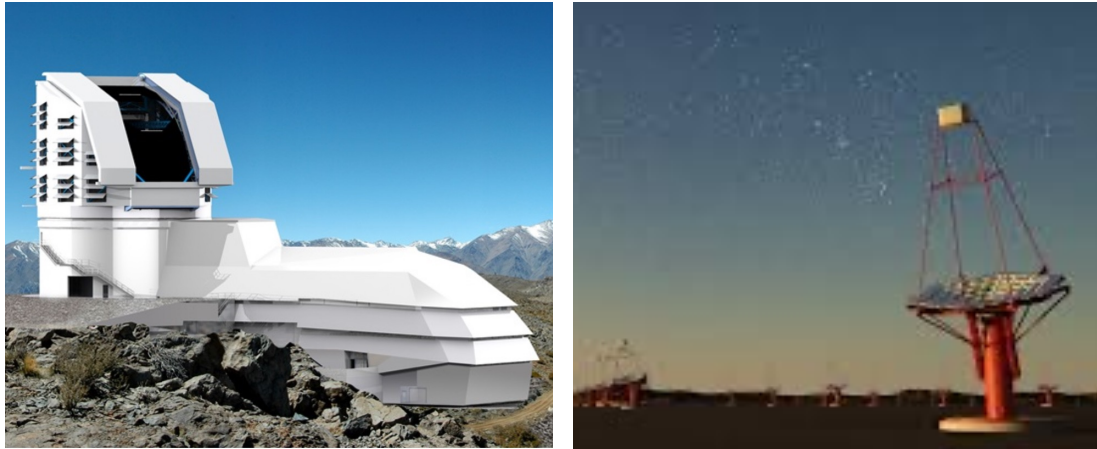
**IceCube-Gen2 will probe the leading source classes to produce the diffuse neutrino flux**



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GEN2

# Scientific objectives for IceCube-Gen2

Understanding cosmic particle acceleration through multimessenger observations

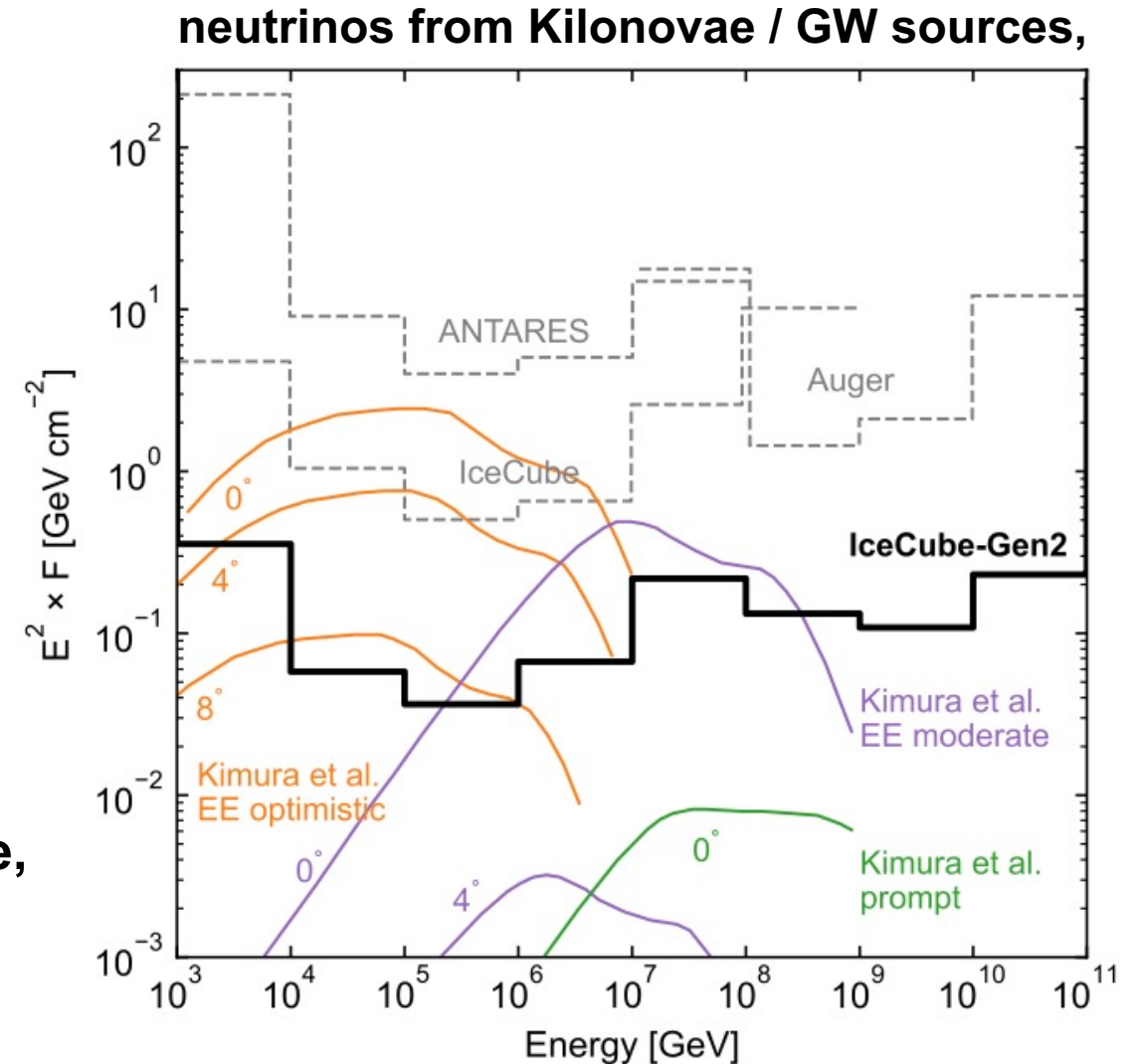


**Significant synergies with LSST / Rubin,  
CTA, SKA, Gravitational Wave detectors,, ....**

**... resulting in huge sensitivity to TDEs, SNe,  
GRBs, Kilonovae, Blazars**



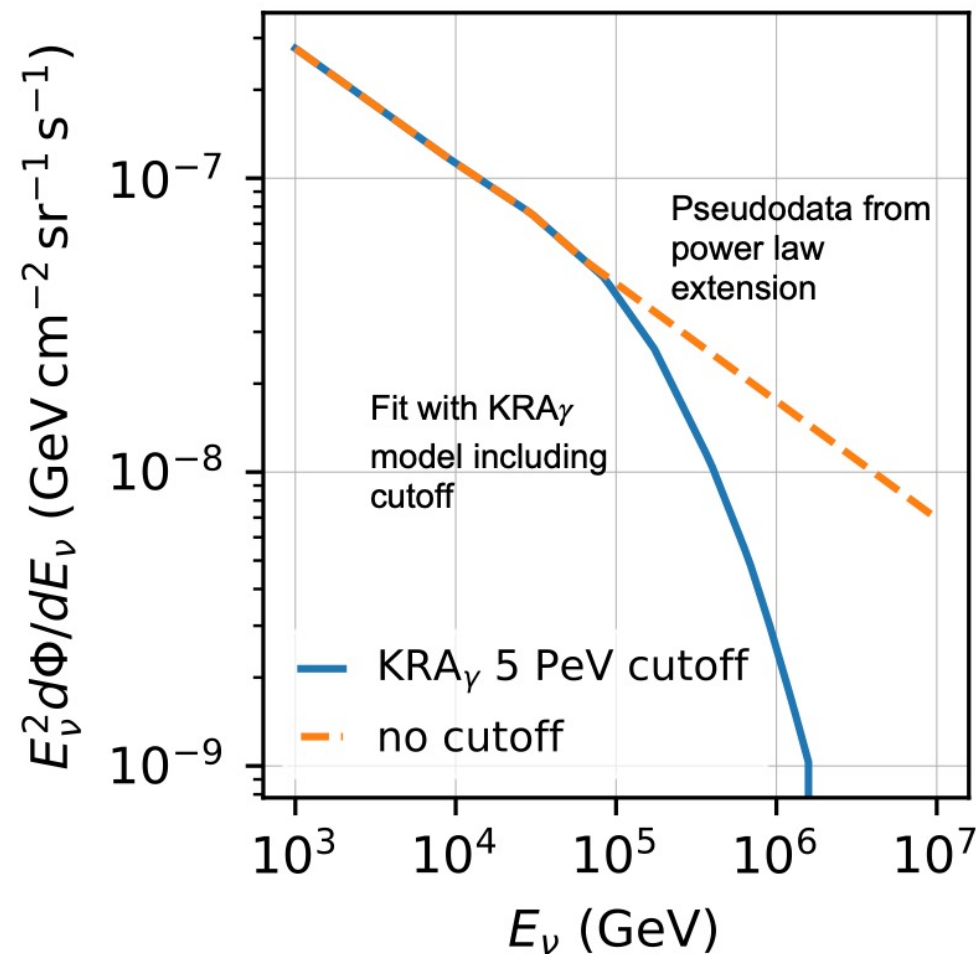
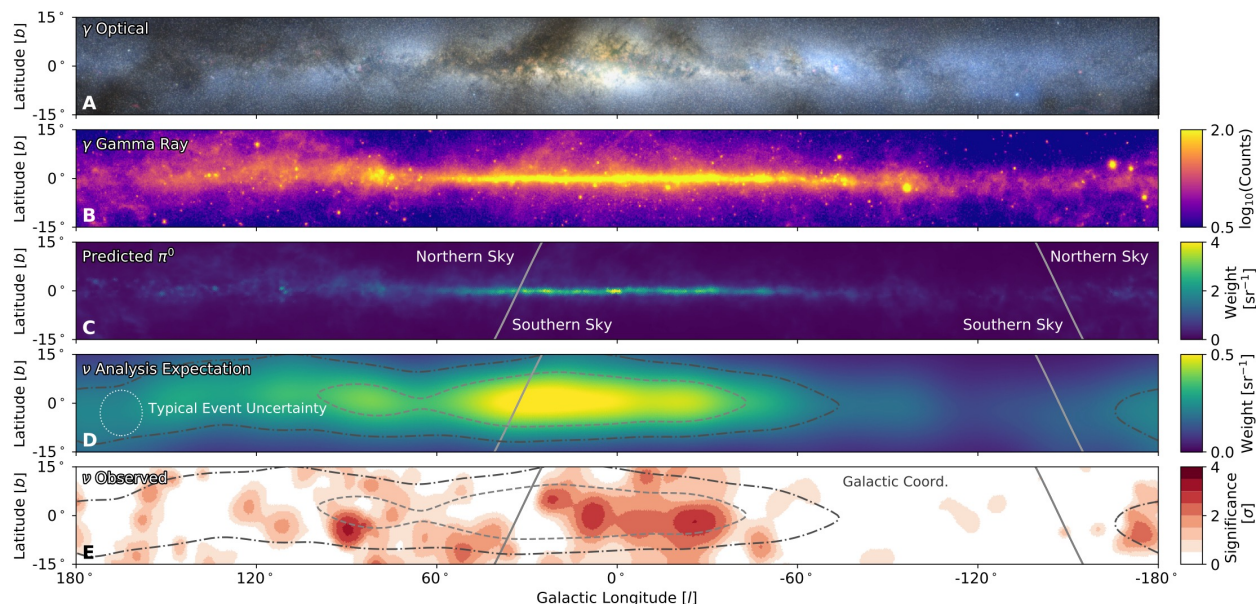
**ICECUBE**  
GEN2



# Scientific objectives for IceCube-Gen2

Revealing sources and propagation of highest energy particles in the Milky Way and the universe.

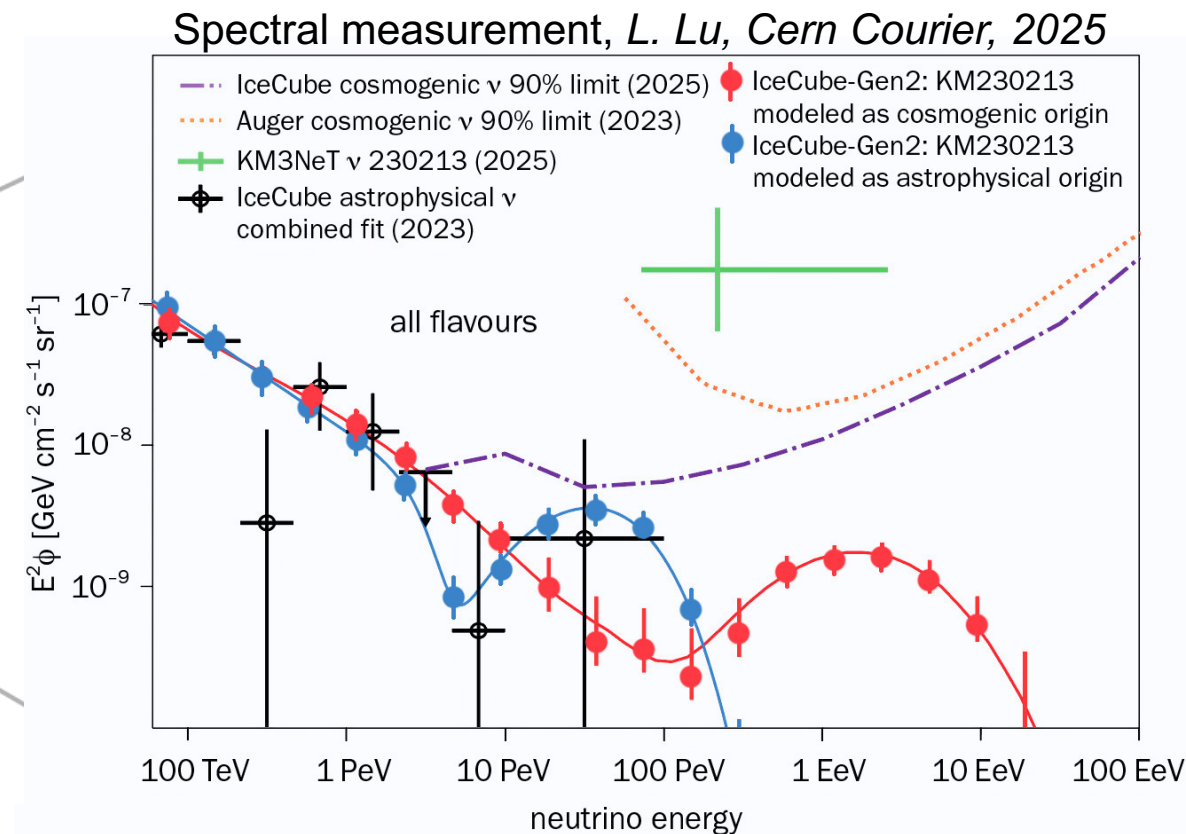
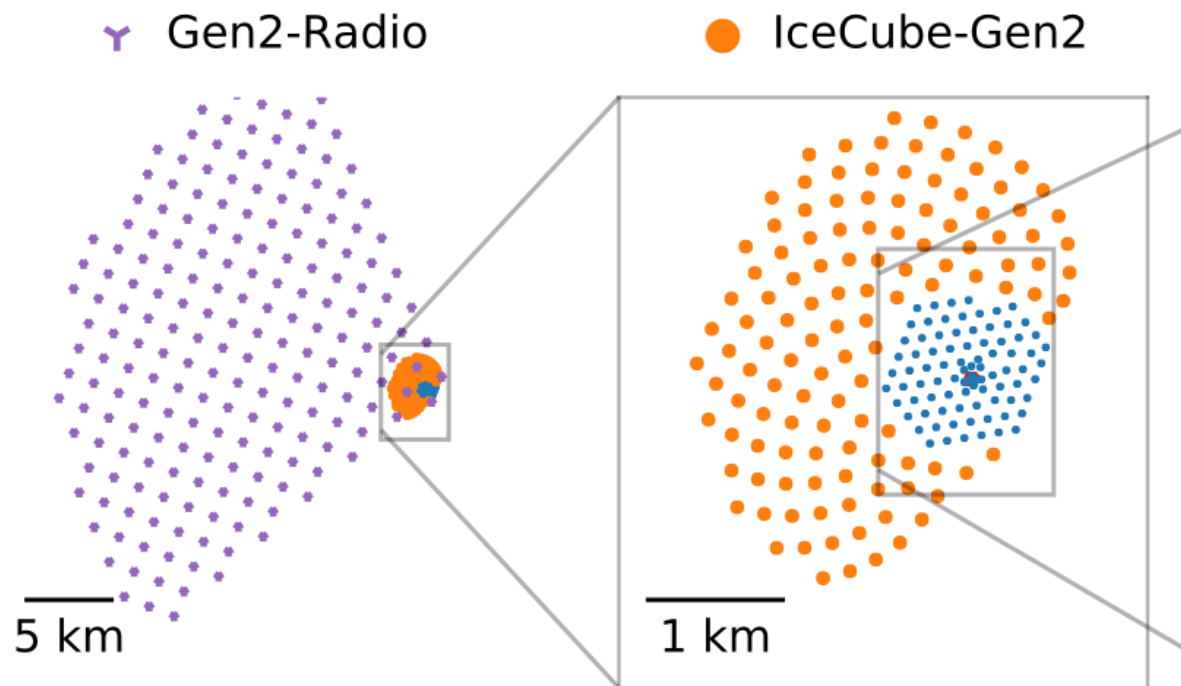
## Our Milky Way in Neutrinos



**Gen2 sensitivity to Gal. Plane:  $11\sigma$  (10 yrs);  
Probe cut-off  $\sim 10$  x faster than IceCube**

# Scientific objectives for IceCube-Gen2

Revealing sources and propagation of highest energy particles in the Milky Way and the universe.



Optical array: **10 x the rate of UHE neutrinos**

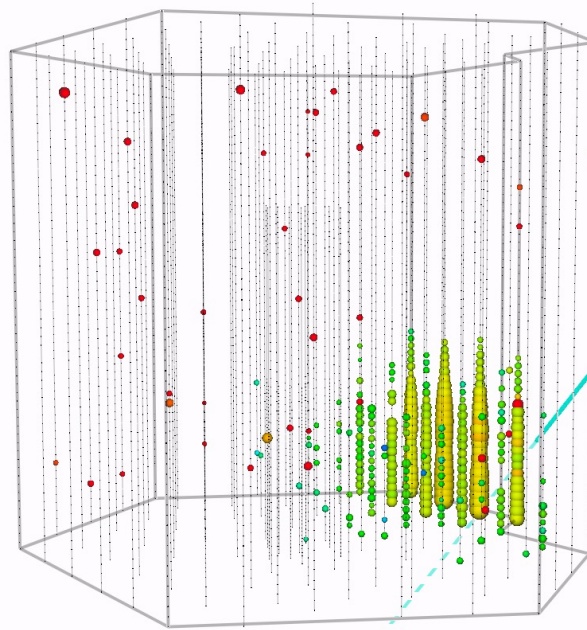
Radio array: **100 x the rate of EHE neutrinos**

E.g. Sensitivity to GZK-Neutrinos, if protons make up more than 10% of cosmic rays

# Scientific objectives for IceCube-Gen2

Revealing sources and propagation of highest energy particles in the Milky Way and the universe.

10 PeV Tau  
Neutrino in  
IceCube-Gen1



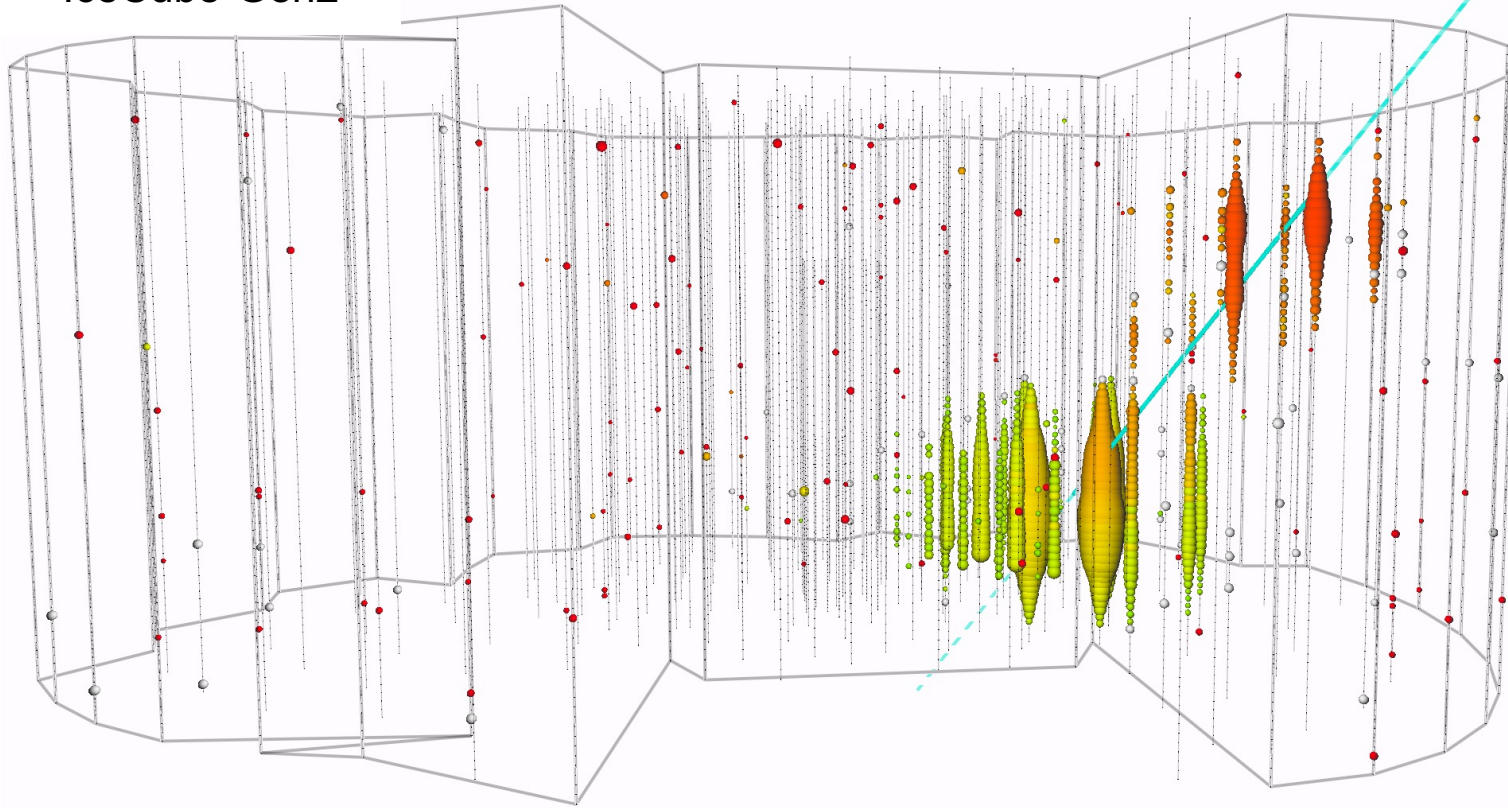
Simulation by Lu Lu

# Scientific objectives for IceCube-Gen2

Revealing sources and propagation of highest energy particles in the Milky Way and the universe.

Interaction:

10 PeV Tau  
Neutrino in  
IceCube-Gen2

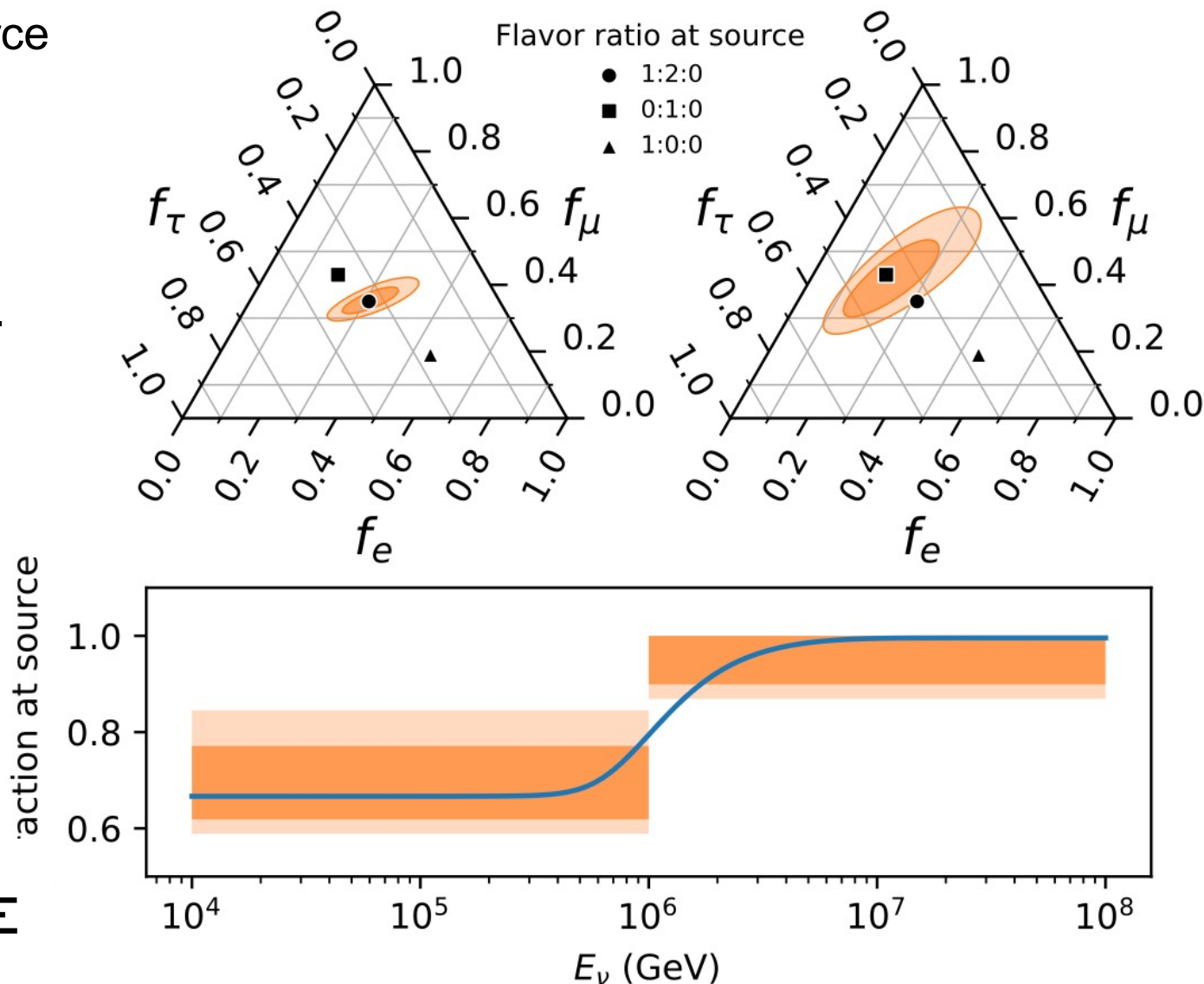


Simulation by Lu Lu

# Scientific objectives for IceCube-Gen2

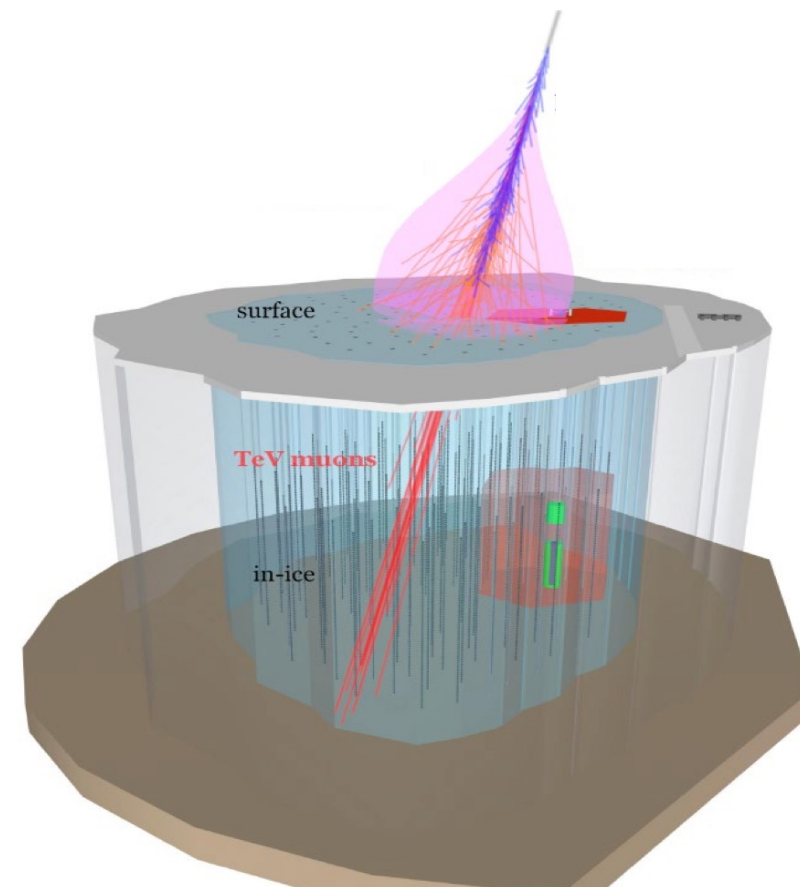
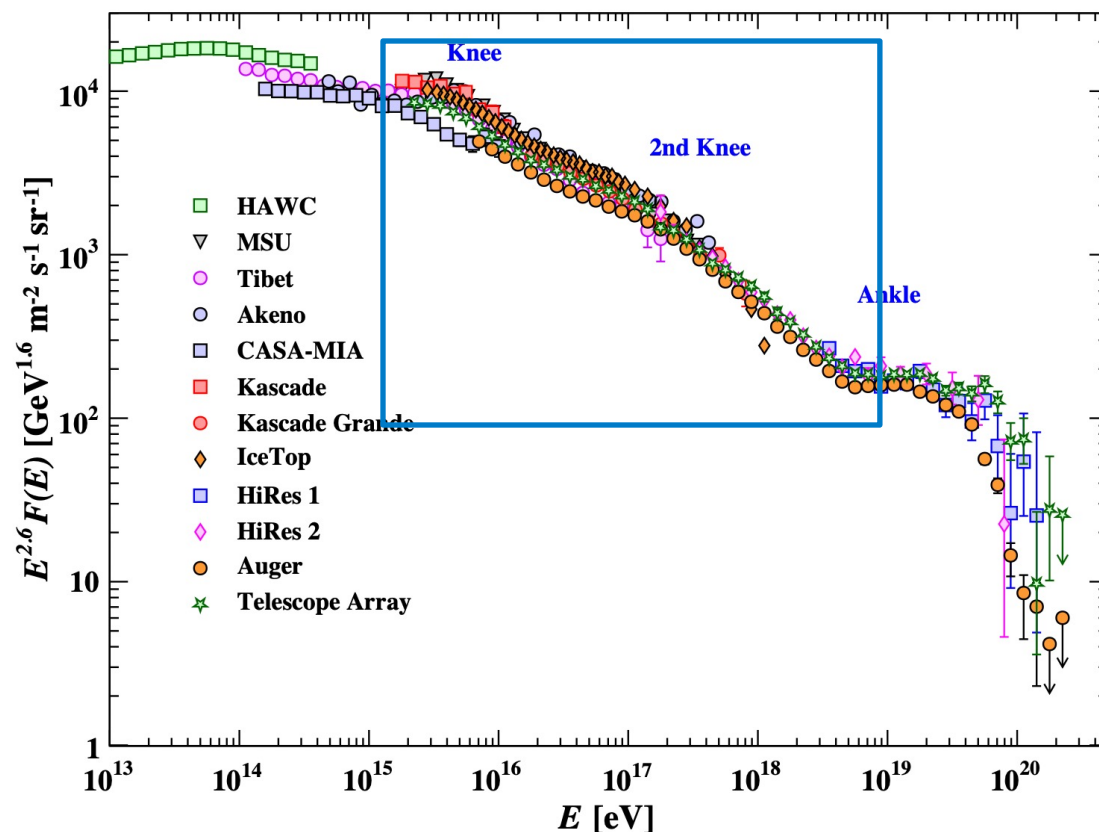
Revealing sources and propagation of highest energy particles in the Milky Way and the universe.

We constrain source environments through neutrino flavor composition changes as a function of energy.



# Scientific objectives for IceCube-Gen2

Revealing sources and propagation of highest energy particles in the Milky Way and the universe.



**30 x coincident cosmic ray rate!**

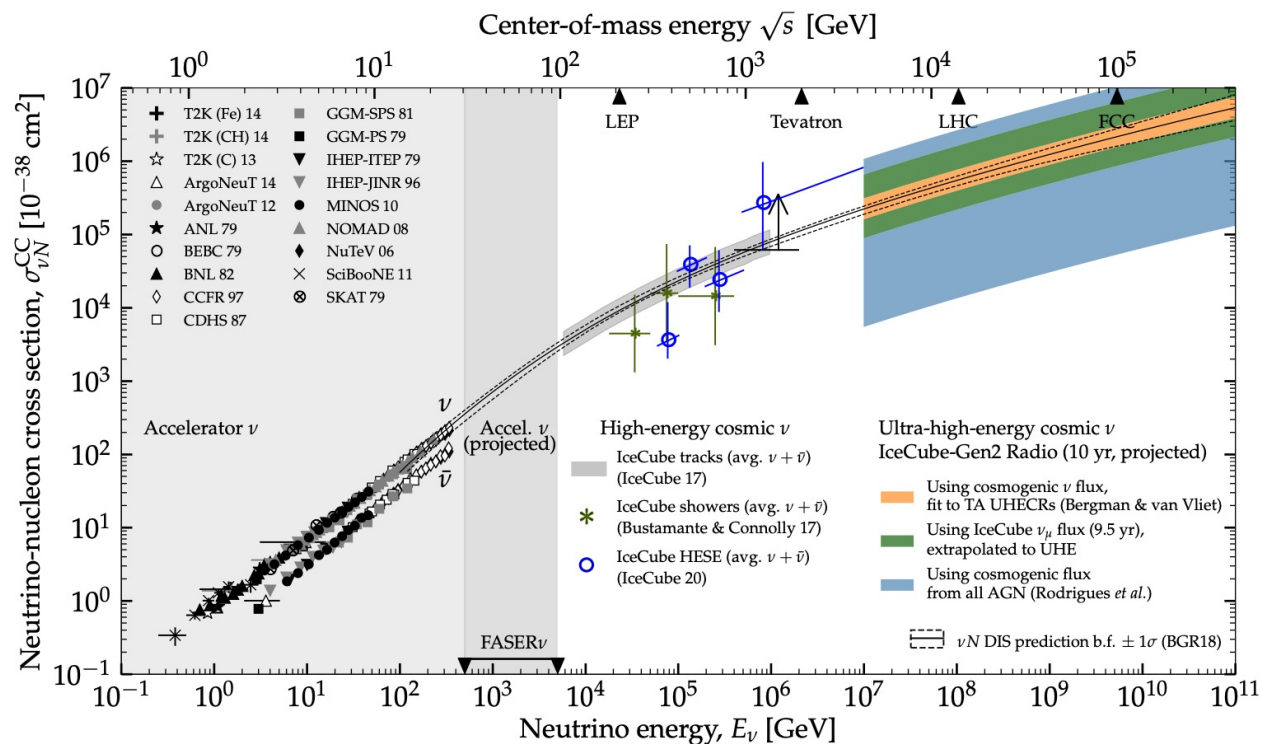
**Uniquely sensitive in the galactic / extragalactic transition region.**



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GEN2

# Scientific objectives for IceCube-Gen2

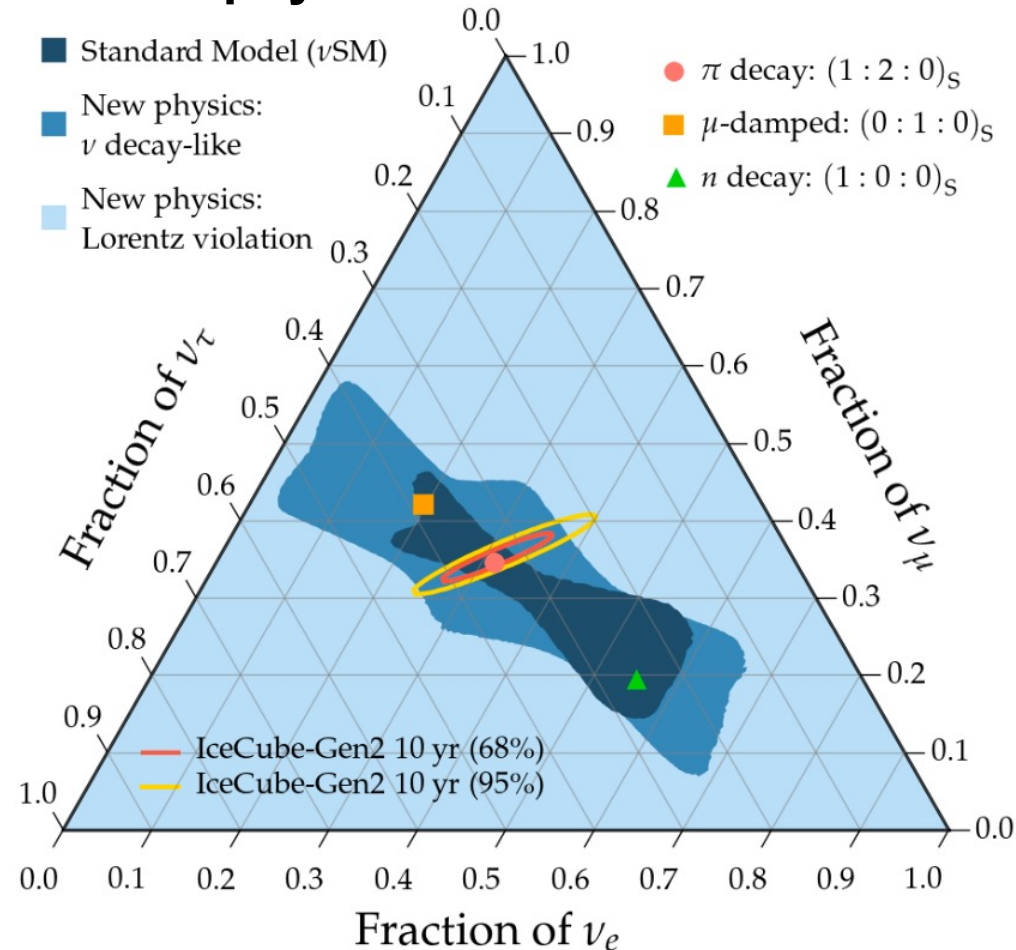
## Probing fundamental physics with high-energy neutrinos



## Neutrino cross-sections @ LHC/FCC energies

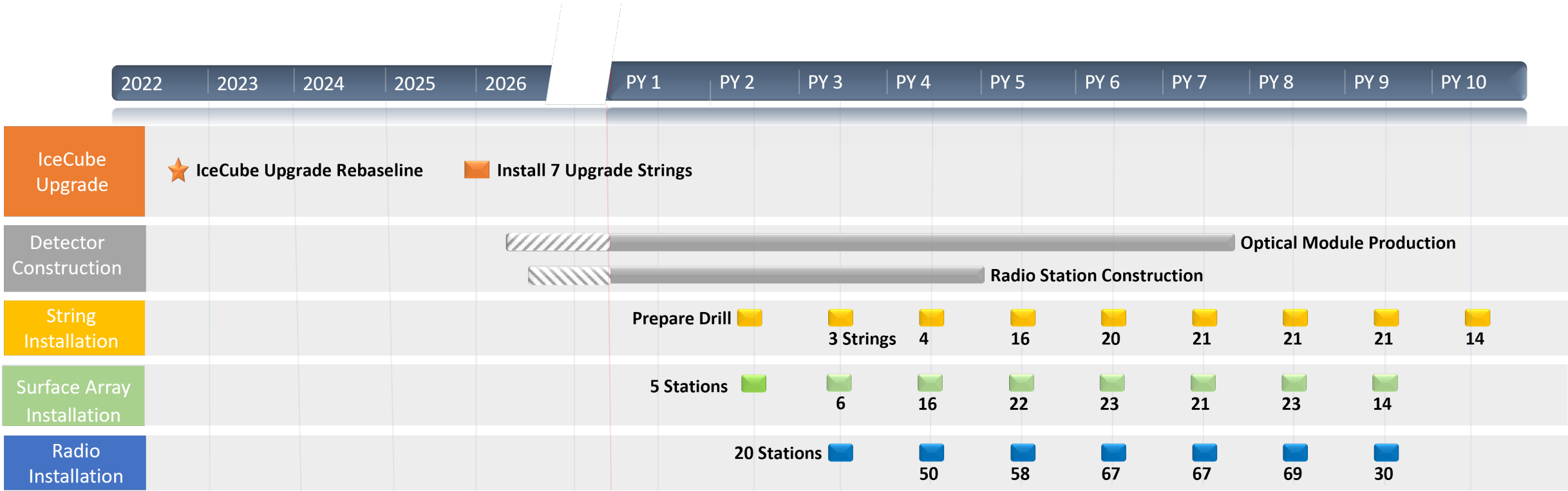
Plots based on Valera *et al.*, Bustamante *et al.*, Song *et al.*

## Flavor physics over cosmic base lines



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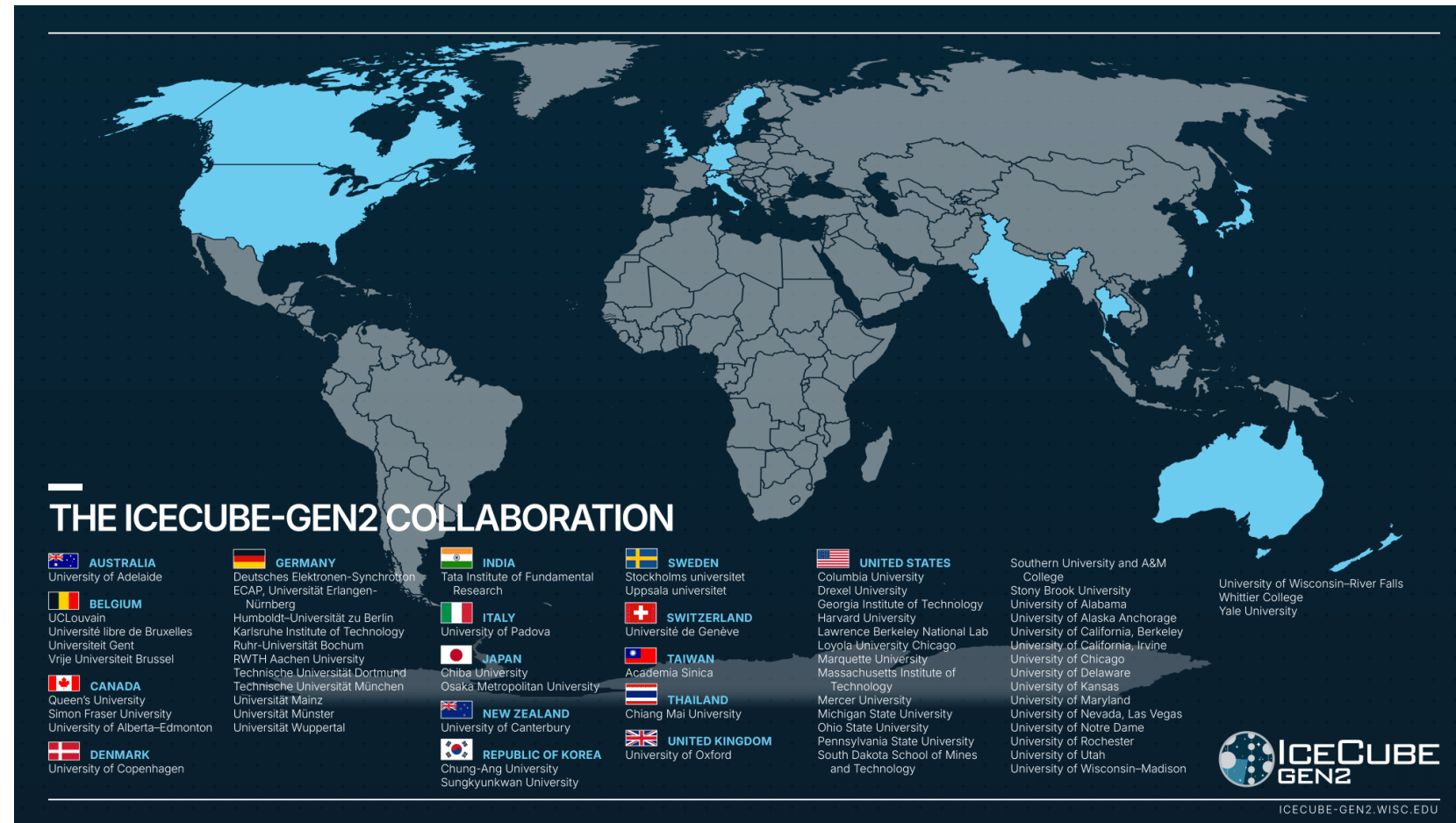
# IceCube-Gen2: Schedule



Initial Technical Design Report public, working on preliminary design. Construction will take ten years, initial data from partial configurations already available after five years

# IceCube-Gen2: Collaboration

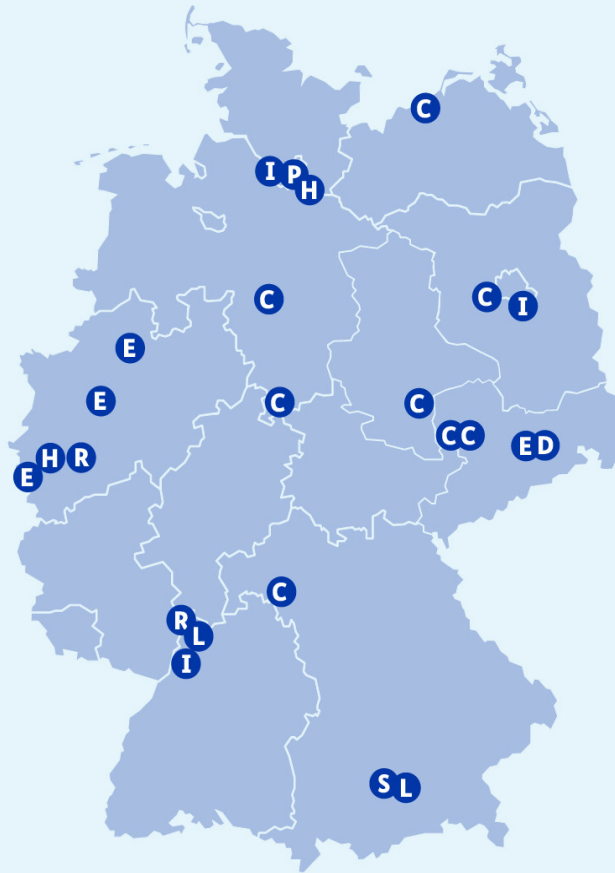
- Internat. collaboration of 400+ scientists from 16 countries
- Endorsements/recommendations from major roadmap processes, e.g. US Decadal Survey on Astronomy and Astrophysics 2020, the Report of the 2023 Particle Physics Project Prioritization Panel (P5 panel), the **Japanese MEXT** roadmap or the European Astroparticle Physics Strategy 2017 - 2026 {APPEC roadmap}, **German BMFTR** roadmap for large scale research infrastructure 2025



# IceCube-Gen2 on the German shortlist for large research infrastructure

## Forschungsinfrastruktur (FIS) Priorisierungsverfahren

- C** **CREATION**, Medizinische Hochschule Hannover, Universitätsmedizin Göttingen, Universitätsklinikum Leipzig, Fraunhofer-Institut für Zelltherapie und Immunologie (Leipzig/Potsdam-Golm/Halle (Saale)/Rostock/Würzburg)
- D** **DALI**, Helmholtz-Zentrum Dresden-Rossendorf e.V.
- E** **Vorphase für das Einstein-Teleskop**, RWTH Aachen, Universität Münster, Ruhr-Universität Bochum, Technische Universität Dresden
- H** **HBS-I**, Forschungszentrum Jülich, Helmholtz-Zentrum Hereon (Geesthacht)
- I** **IceCube-Gen2**, Deutsches Elektronen-Synchrotron (Hamburg/Zeuthen), Karlsruher Institut für Technologie
- L** **LEGEND-1000**, Max-Planck-Institut für Kernphysik (Heidelberg), Technische Universität München
- P** **PETRA IV**, Deutsches Elektronen-Synchrotron (Hamburg)
- R** **RIDLOP**, GESIS - Leibniz-Institut für Sozialwissenschaften (Köln/Mannheim)
- S** **SLICES-DE**, Technische Universität München



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**German proposal: 59 Mio. Euro for construction** (~90 % capital costs)

Additional 15,5 Mio. Euro as in-kind

- Deliverables:
  - 3500 optical sensors
  - A large fraction of the Radio- and surface array

**Review Sep 7.-8.: update on project status, funding needs and establish decision points.**

# Summary

## Subheading, optional

- IceCube's discovery of cosmic neutrinos and evidence for galactic and extragalactic sources has started a new chapter in high energy astrophysics.
- IceCube-Gen2 needed to address the questions raised by 15 years of IceCube.
- Mature design for IceCube-Gen2, many details to be found in our [Technical Design Report](#).
- Large contributions are coming together, so the chances to realize IceCube-Gen2 are better than ever!

