IceCube Gen2 – Science case

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Picture credit: Martin Wolf

IceCube: > 350 authors. 14 countries. 58 institutions.
Gen2: 1 additional country. 6 additional institutions.
THE ICECUBE COLLABORATION
AUSTRALIA
University of Adelaide
BELGIUM
UCLouvain
Université libre de Bruxelles
Universiteit Gent
Vrije Universiteit Brussel
CANADA
Queen's University
University of Alberta–Edmonton
DENMARK
University of Copenhagen
GERMANY
Deutsches Elektronen-Synchrotron
ECAP, Universität Erlangen-Nürnberg
Humboldt–Universität zu Berlin
Karlsruhe Institute of Technology
Ruhr-Universität Bochum
RWTH Aachen University
Technische Universität Dortmund
Technische Universität München
Universität Mainz
Universität Wuppertal
Westfälische Wilhelms-Universität Münster
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Pennsylvania State University
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Southern University and A&M College
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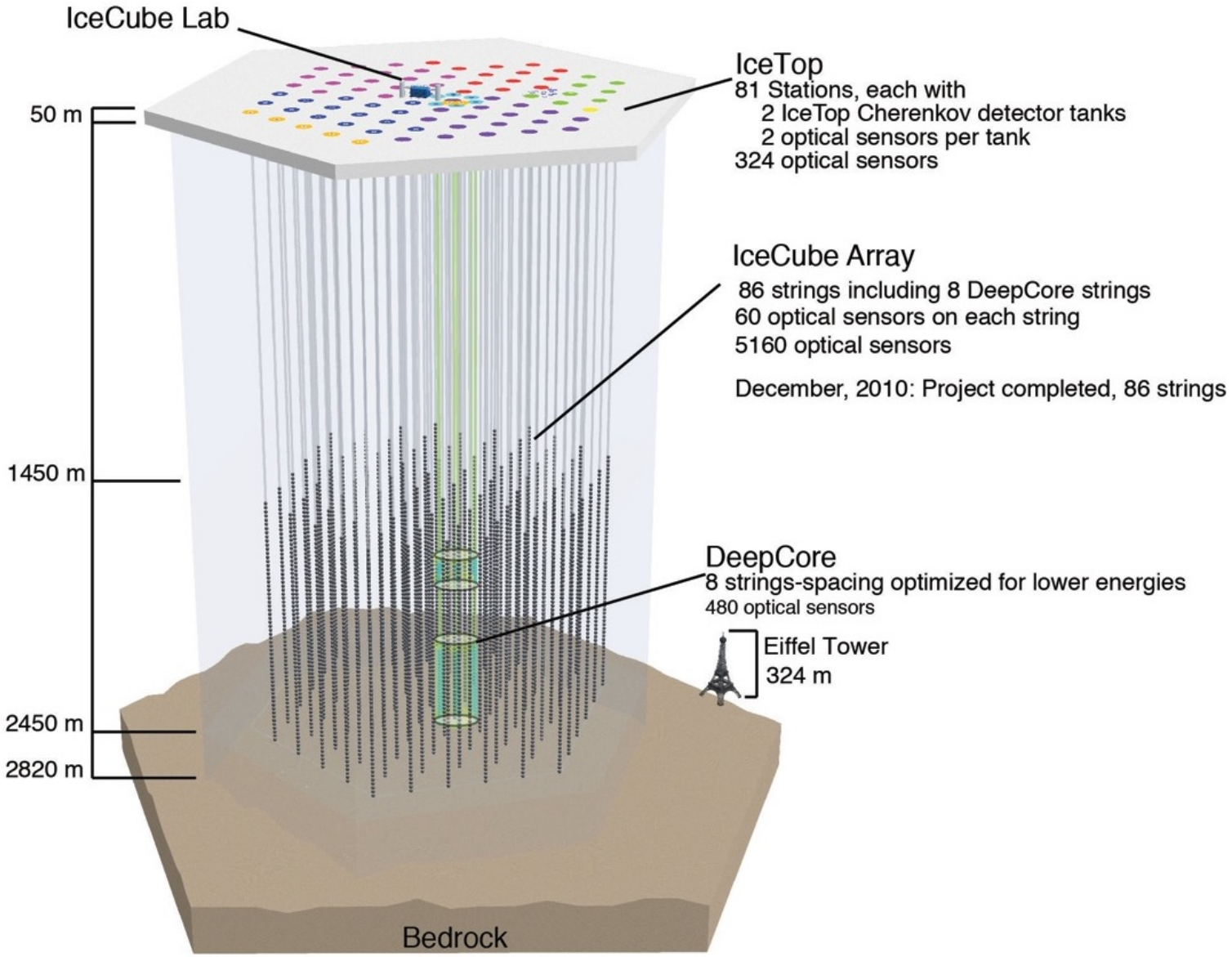
University of Alabama
University of Alaska Anchorage
University of California, Berkeley
University of California, Irvine
University of Delaware
University of Kansas
University of Maryland
University of Nevada, Las Vegas
University of Rochester
University of Texas at Arlington
University of Utah
University of Wisconsin–Madison
University of Wisconsin–River Falls
Yale University
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 NEUTRINO OBSERVATORY
icecube.wisc.edu



IceCube. A multi-component detector:

"IceCube" km^3 E_ν > TeV

"IceTop" km^2 air shower array

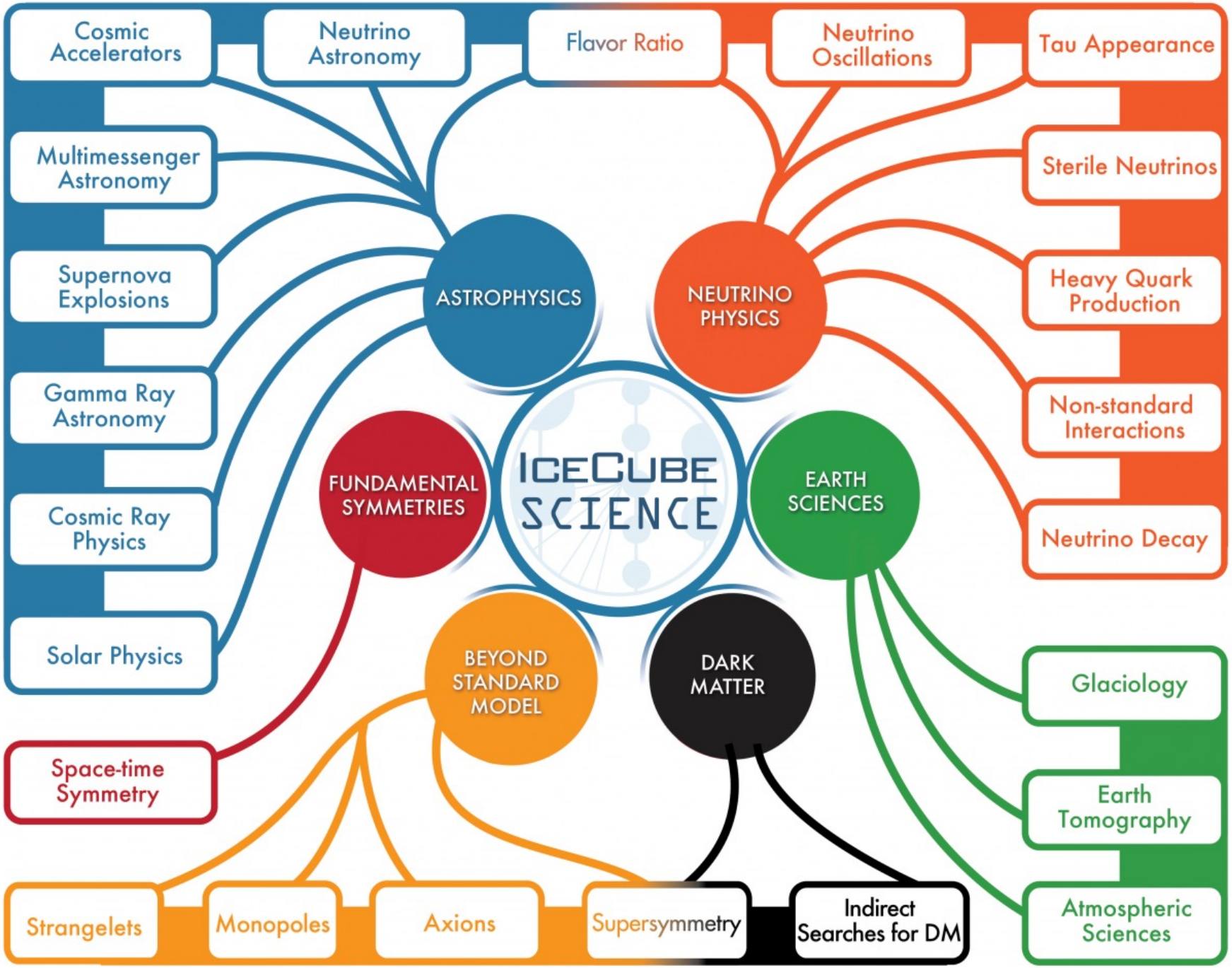
"DeepCore" E_ν >10 GeV

"Upgrade" E_ν > 1 GeV ('25/'26)

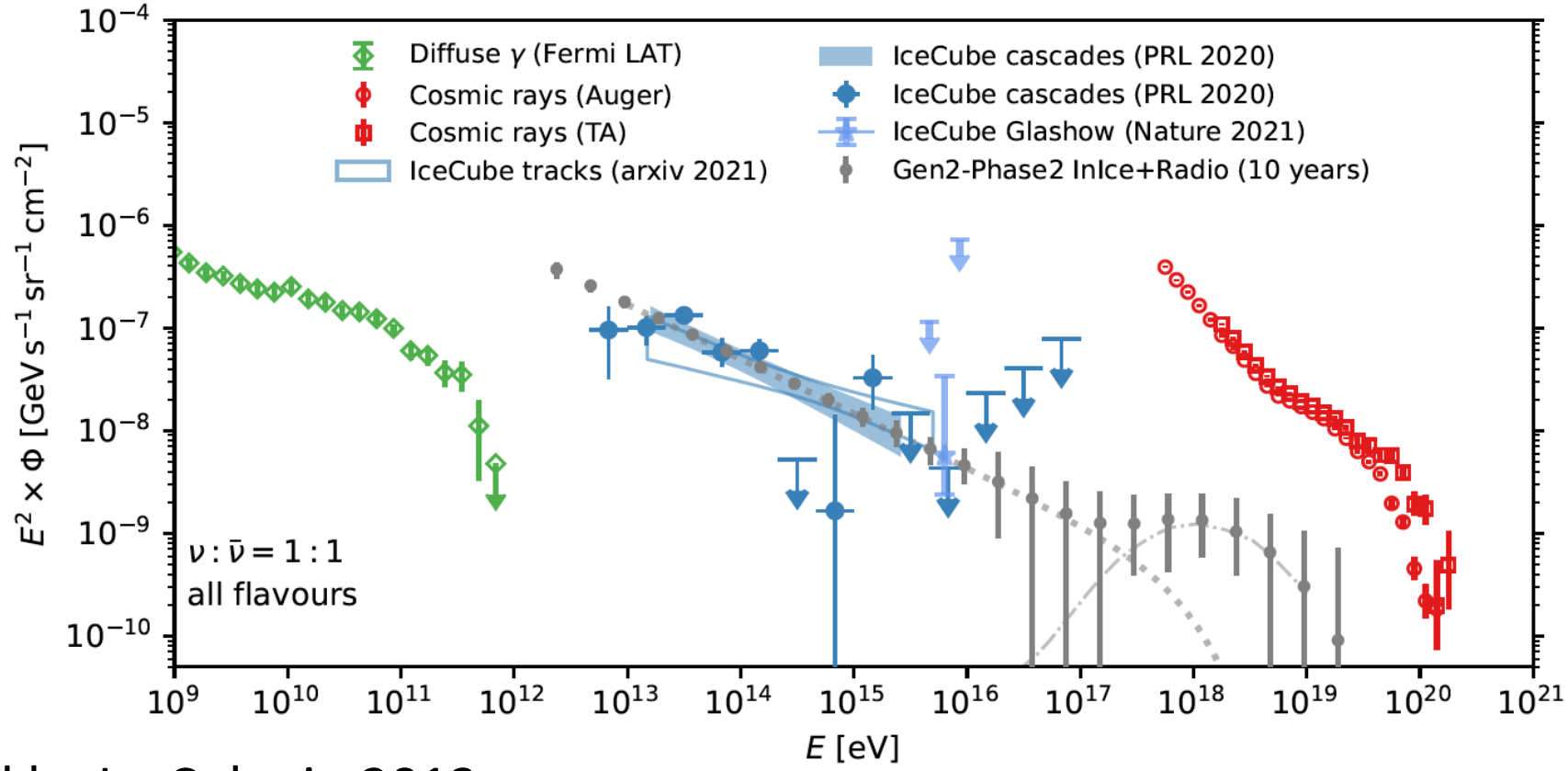
Full configuration operation: May 2011

4π sr survey
(Best sensitivity in the northern sky)

Sensitive to all neutrino flavors


Cosmic Accelerators
Neutrino Astronomy
Flavor Ratio
Neutrino Oscillations
Tau Appearance
Multimessenger Astronomy
Sterile Neutrinos
Supernova Explosions
ASTROPHYSICS
NEUTRINO PHYSICS
Heavy Quark Production
Gamma Ray Astronomy
Non-standard Interactions
FUNDAMENTAL SYMMETRIES
ICECUBE SCIENCE
EARTH SCIENCES
Cosmic Ray Physics
Neutrino Decay
Solar Physics
BEYOND STANDARD MODEL
DARK MATTER
Glaciology
Space-time Symmetry
Earth Tomography
Strangelets
Monopoles
Axions
Supersymmetry
Indirect Searches for DM
Atmospheric Sciences

All-sky flux of extragalactic neutrinos



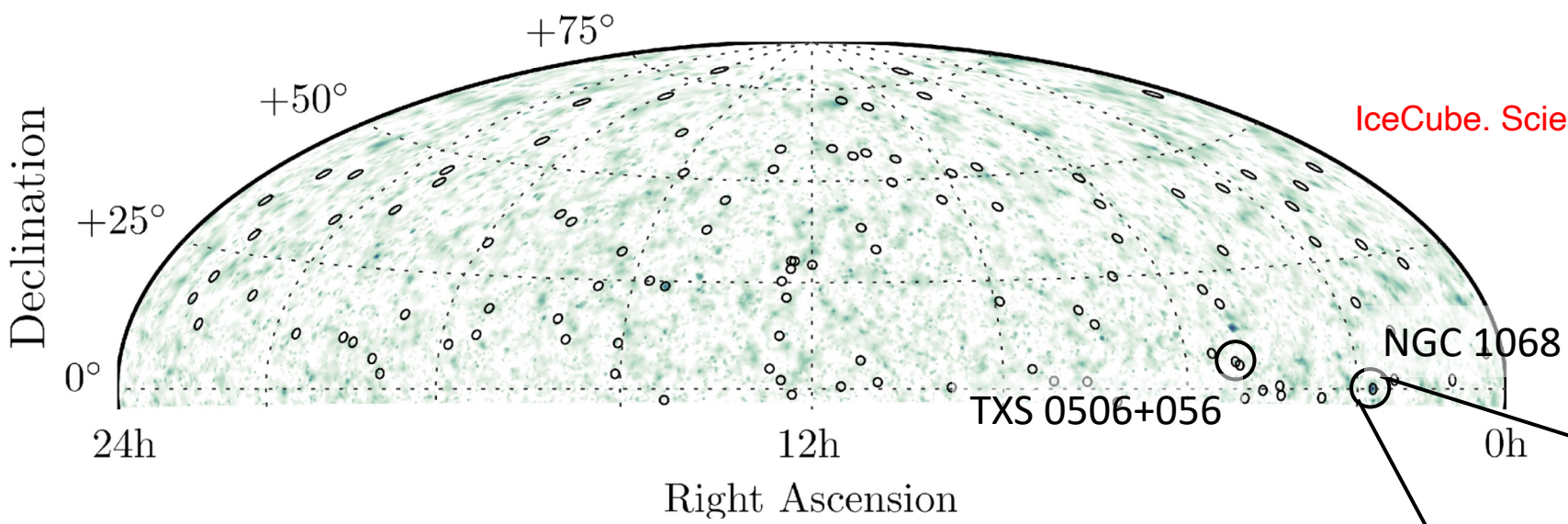
Discovered by IceCube in 2013

Now observed with many methods from ~5 TeV to ~5 PeV

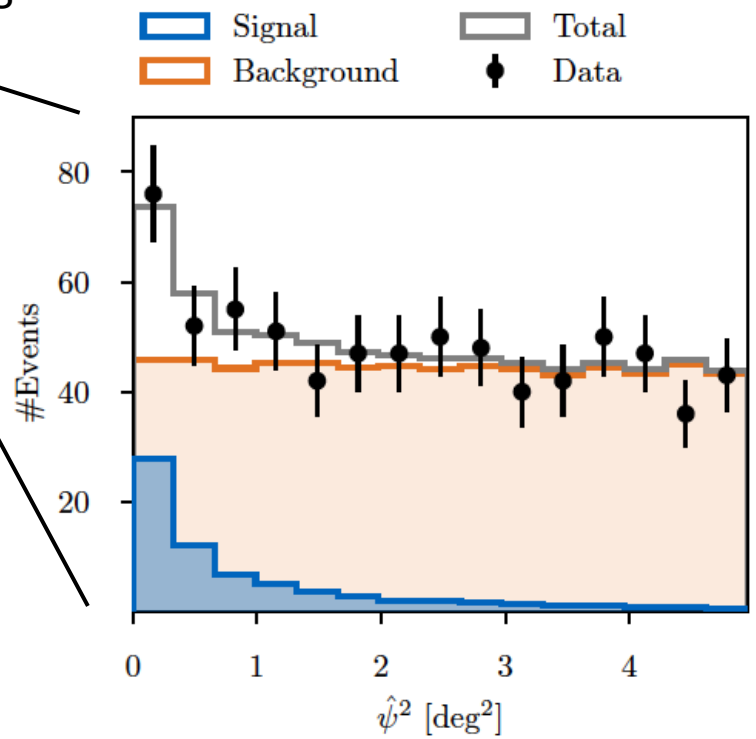
<u>We need a new detector to increase statistics and extend observations to higher energies</u>

Extension of the flux to >10 PeV ? Cosmogenic (GZK) neutrinos ?

Evidence for neutrino emission from the nearby active galaxy NGC 1068



IceCube. Science (2022)



Improved data processing

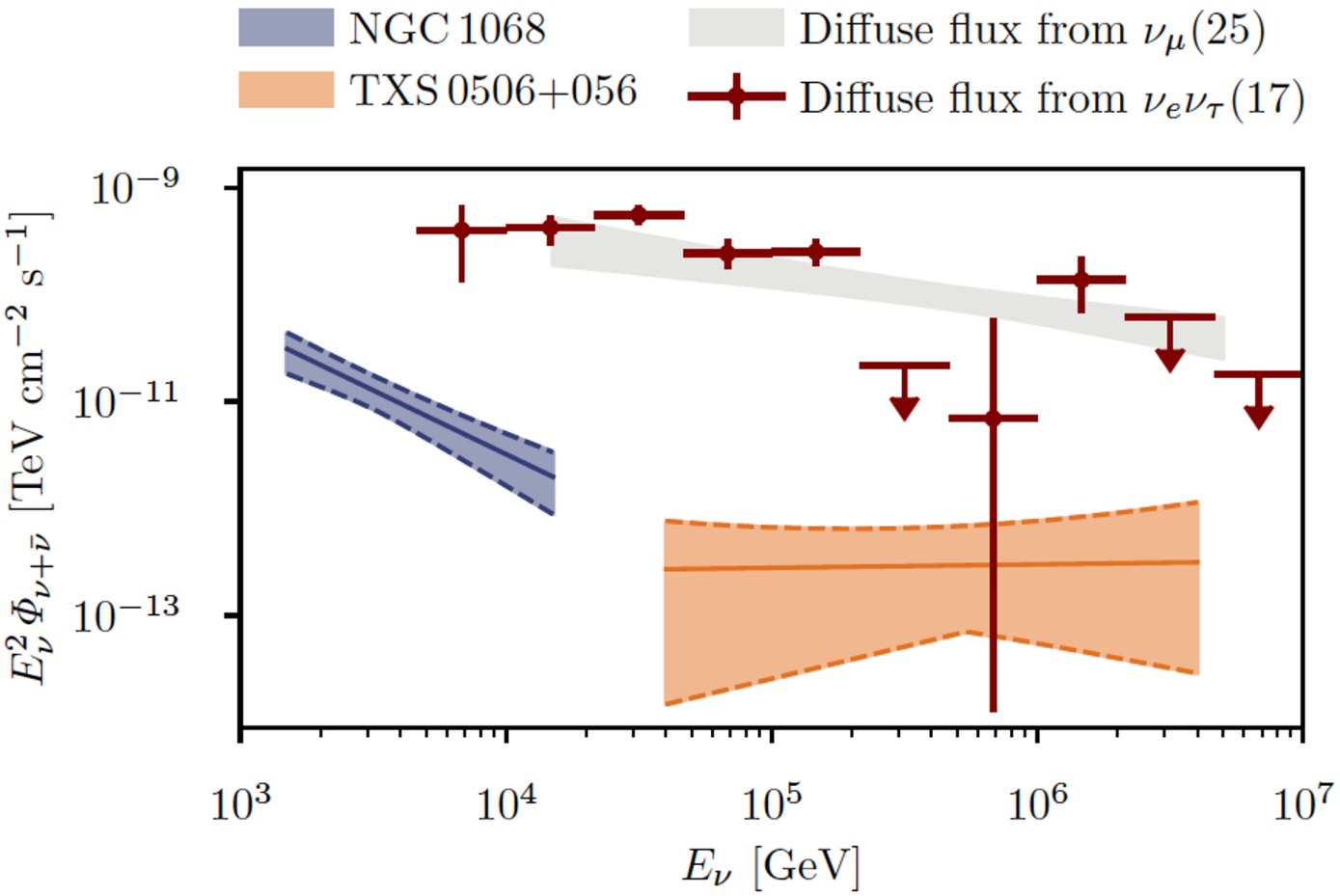
At the location of NGC 1068:

79^{+22}_{-20} neutrinos

Spectral index: -3.2 ± 0.2

Post-trial significance 4.2 σ

Evidence for neutrino emission from the nearby active galaxy NGC 1068



NGC 1068, TXS 0506+056 are ~1% of extragalactic flux.
NGC 1068 is steady – a benchmark source

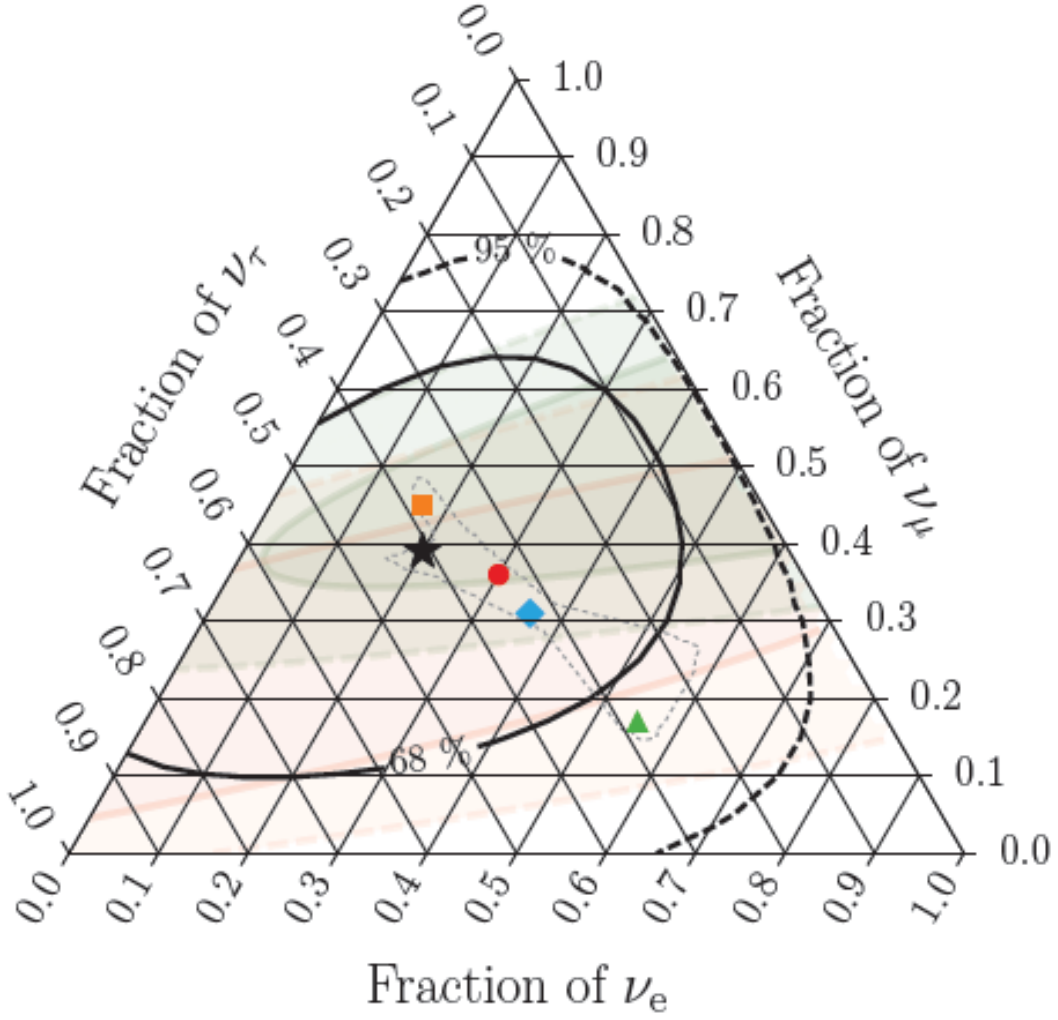
<u>We need more neutrinos</u> to identify the sources

For the brightest astrophysical sources:

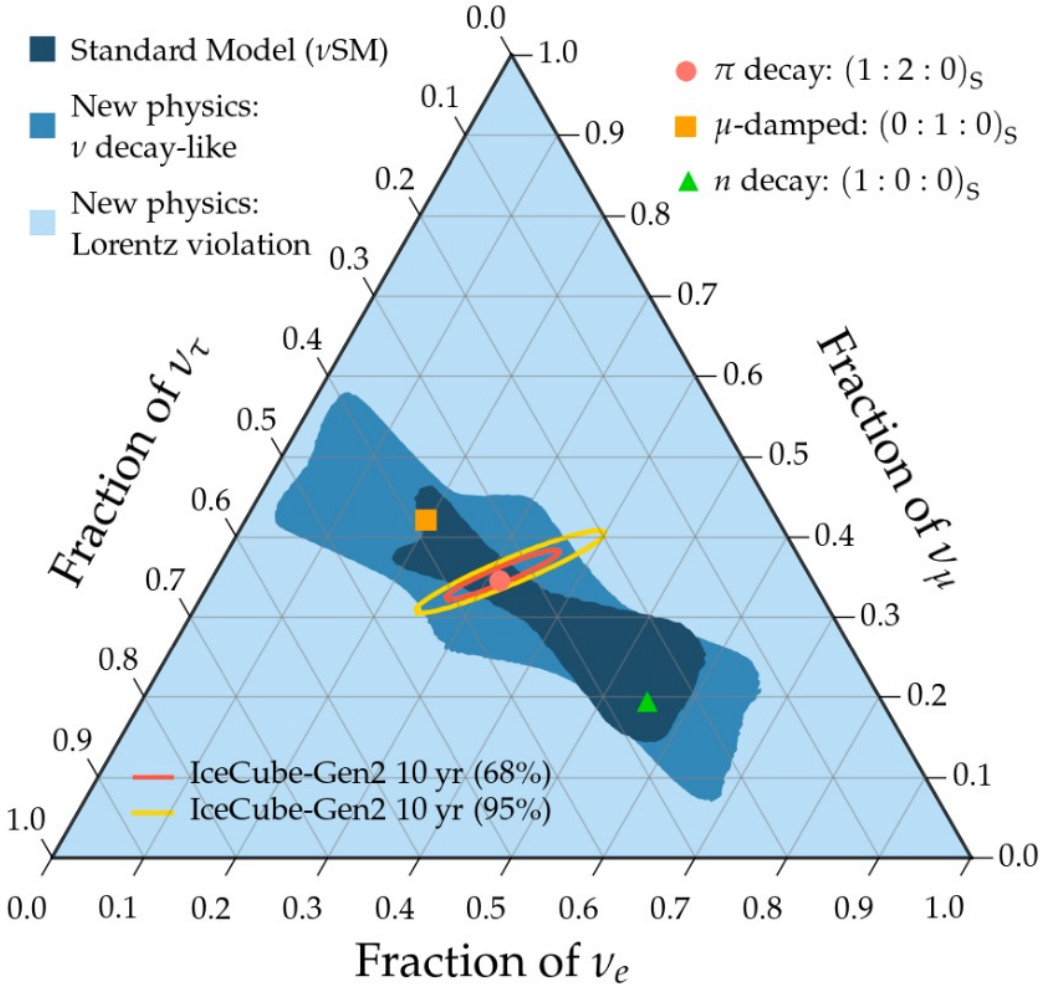
$$N(>f) \propto f^{-3/2}$$

With 5x better sensitivity than IceCube
<u>we expect 10 to 12 times more sources in Gen2</u>

Probing fundamental physics – flavor physics over cosmic baselines



IceCube. EPJC (2022)



IceCube Gen2. J.Phys.G (2021)

Conclusions

IceCube-Gen2 builds on the success of IceCube.

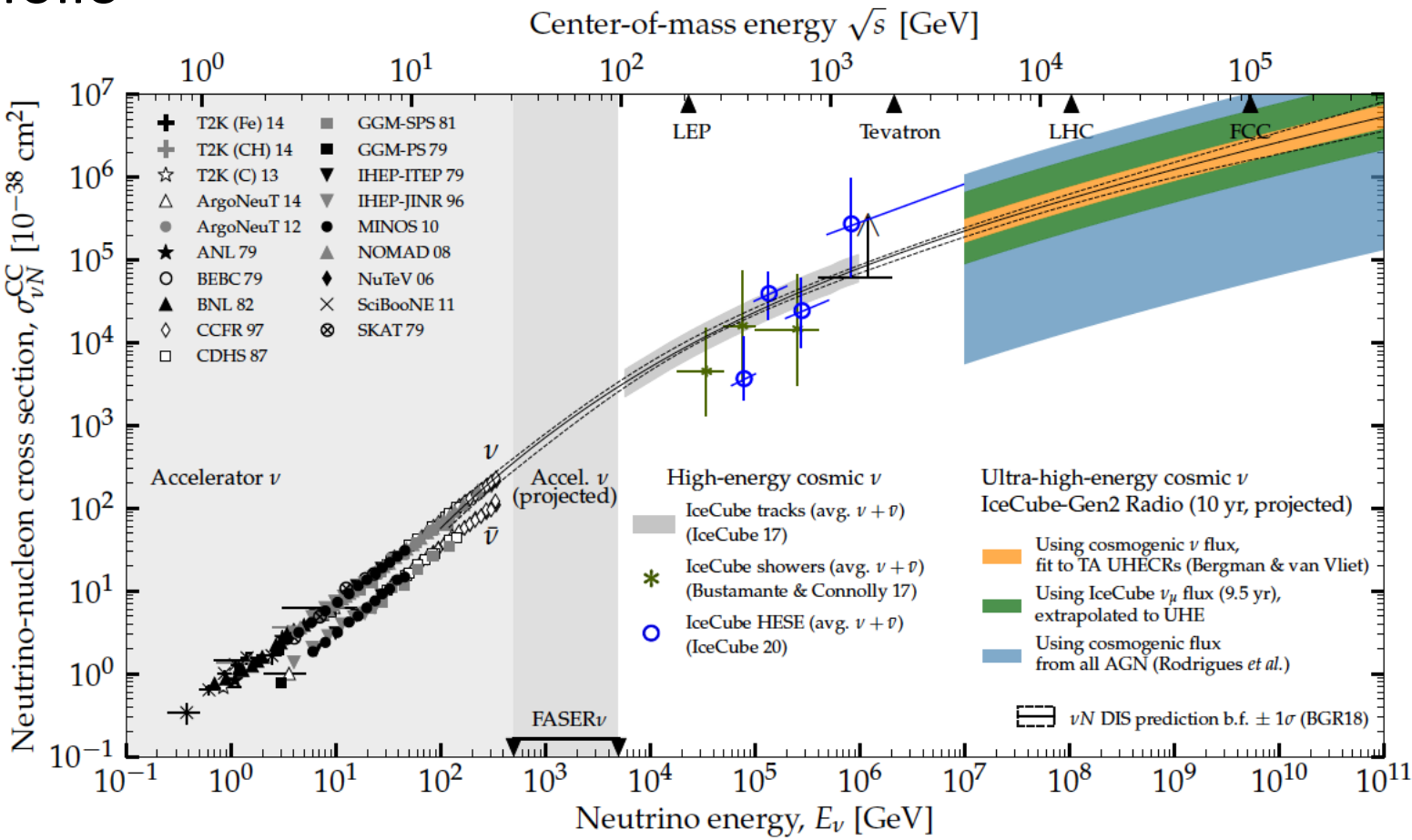
IceCube-Gen2 science portfolio is very broad

Sources of the extragalactic flux

Extend observations beyond 10^{18} eV

Search for galactic Pevatrons

Physics Beyond the standard model

Neutrino-matter cross-section

Many, many more topics …