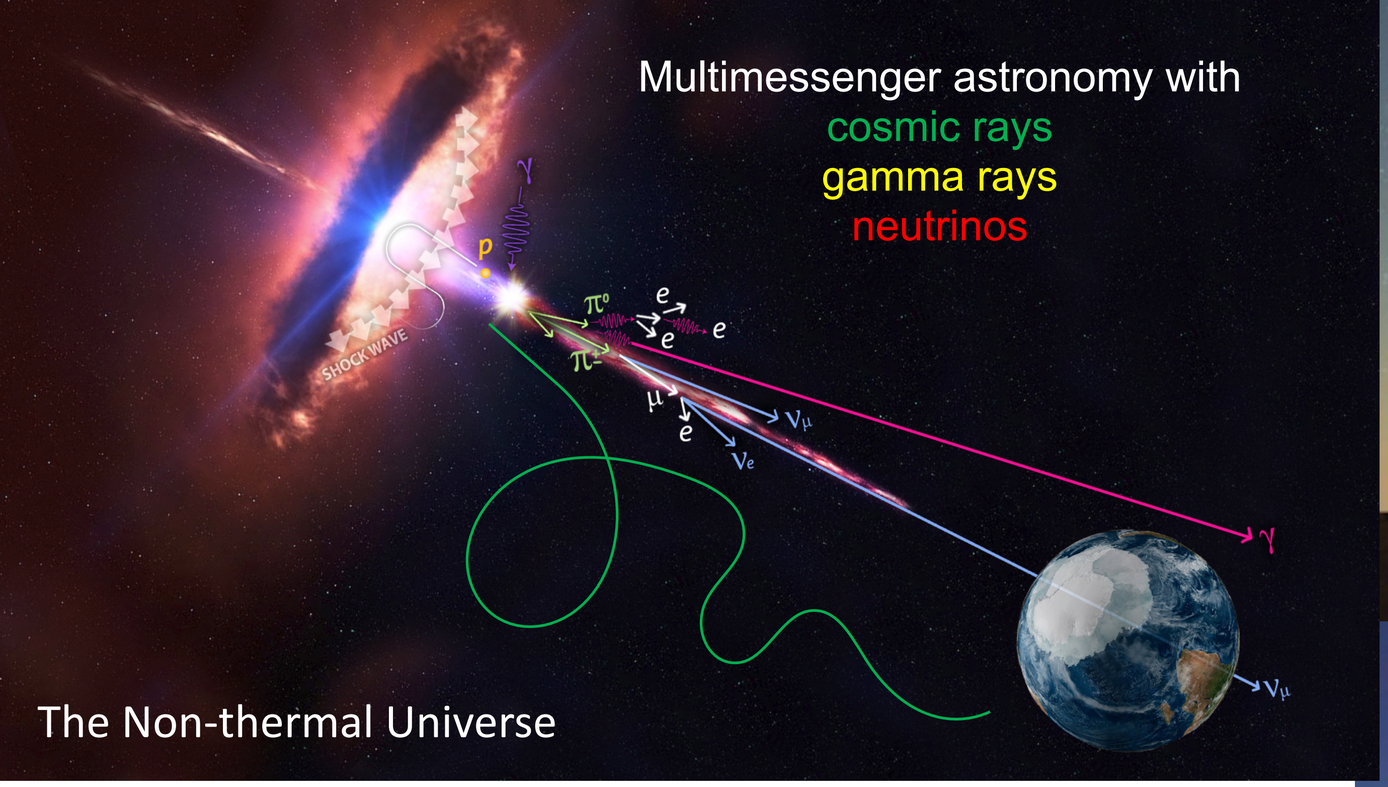
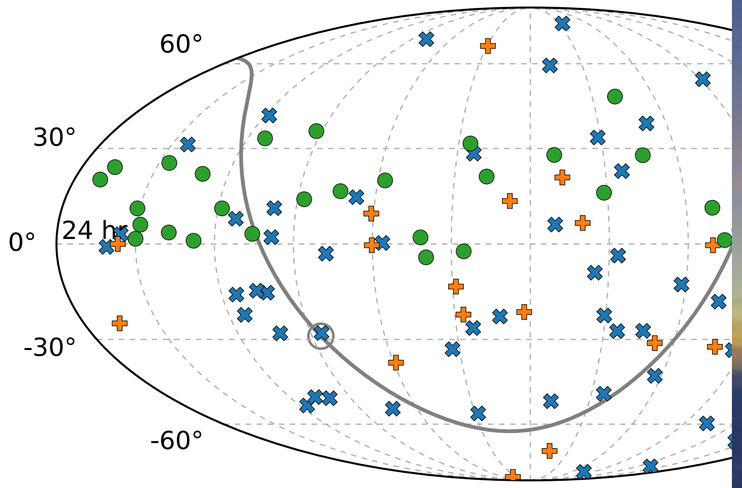

What people may have talked about at UW-Madison around 1990 …
Where do cosmic rays come from?
The ice is totally clear!
If we go deep enough there will be no background!

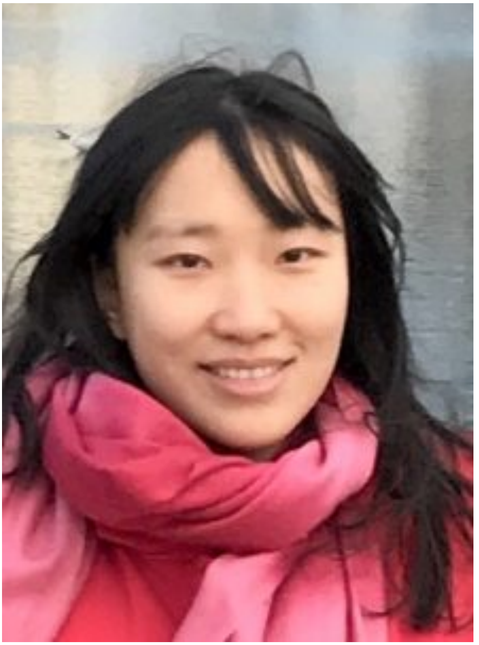


Astro-particle physics at UW Madison

Professors
Ke Fang
Francis Halzen,
Kael Hanson,
Albrecht Karle,
Lu Lu,
Justin Vandenbroucke

Prospective graduate student visit
March, 2023





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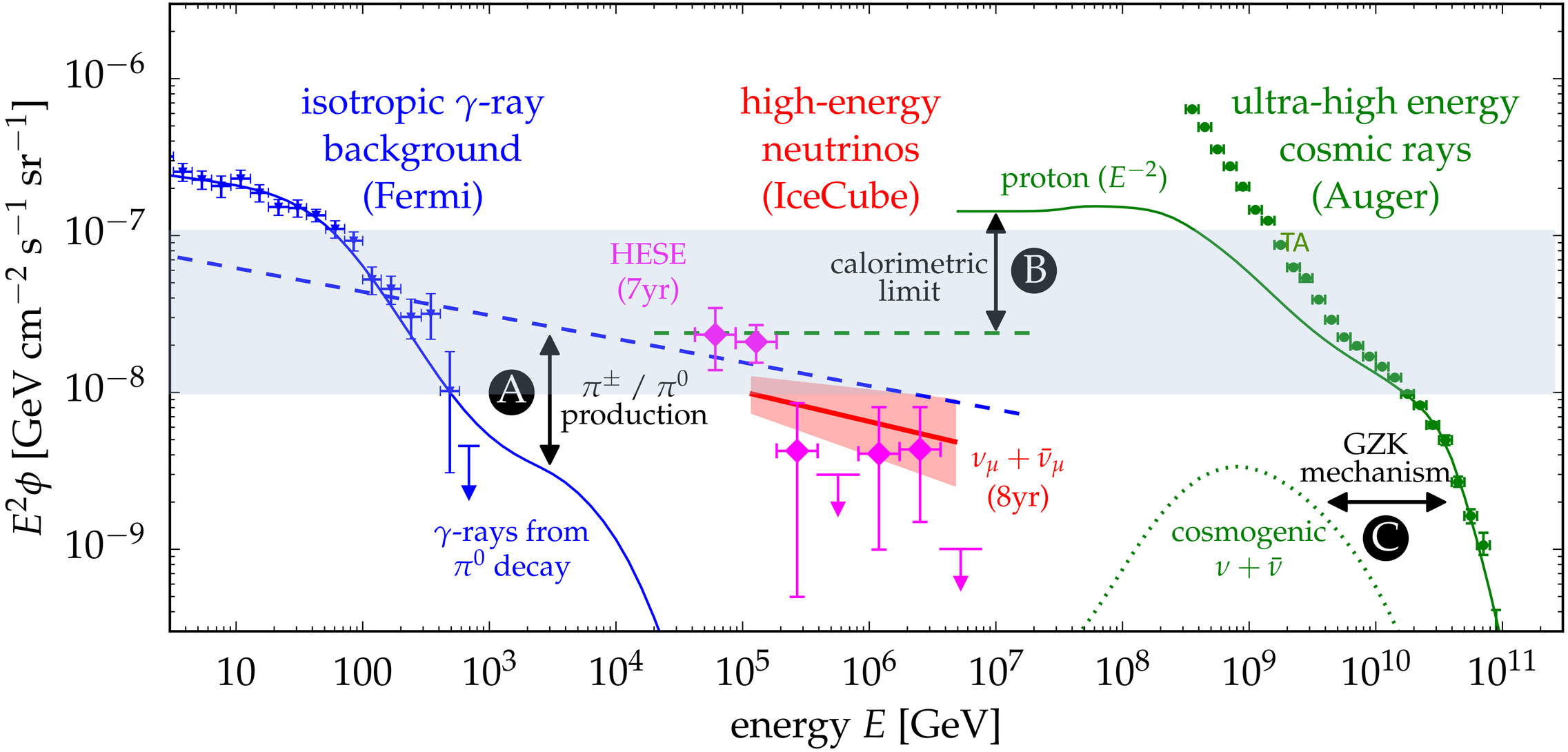
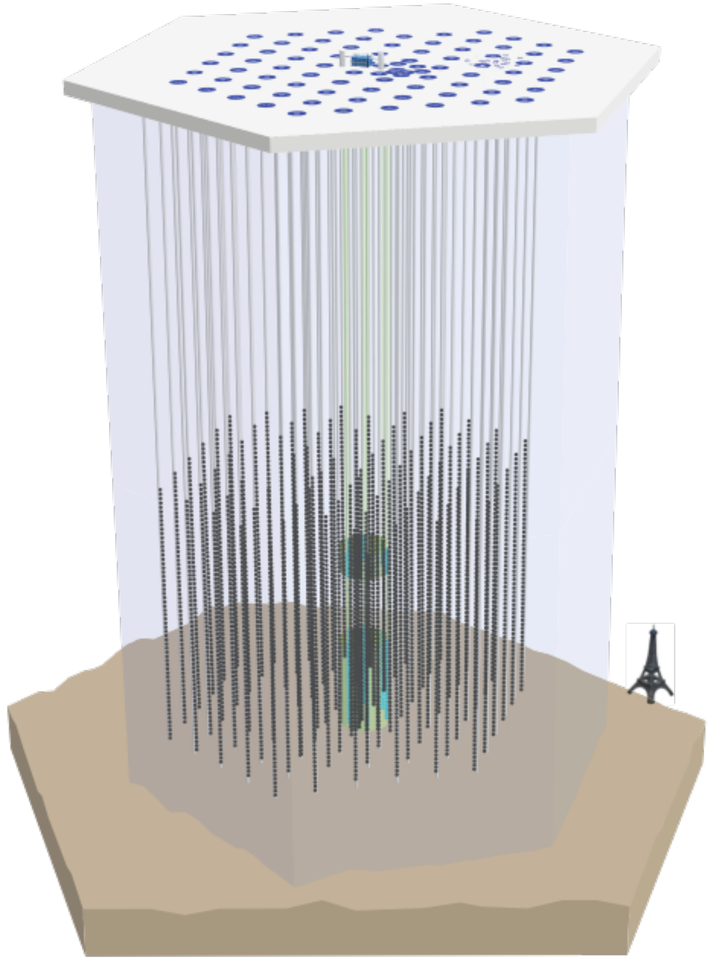
Gamma Rays — Neutrinos — Cosmic Rays

The energy density of neutrinos in the non-thermal Universe is large,
- and is the same as in diffuse gamma rays, and similar to UHE cosmic rays.



The IceCube Neutrino Observatory



IceTop (surface array): 81 stations

IceCube: 86 strings

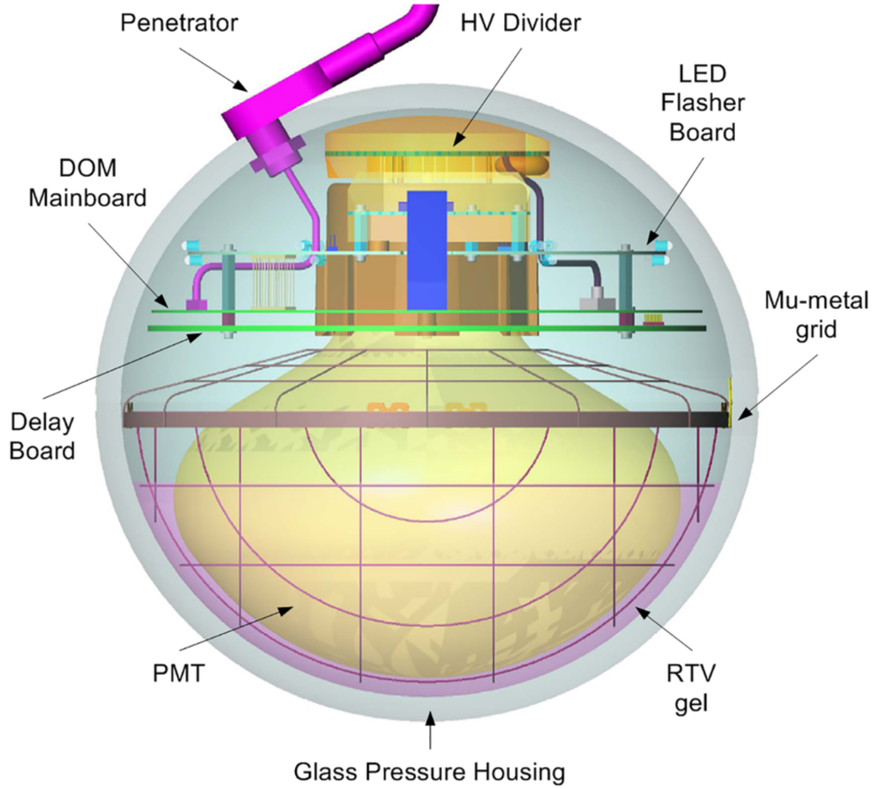
5160 optical sensors over 1 km^3 volume

17 m vertical spacing

125 m horizontal spacing

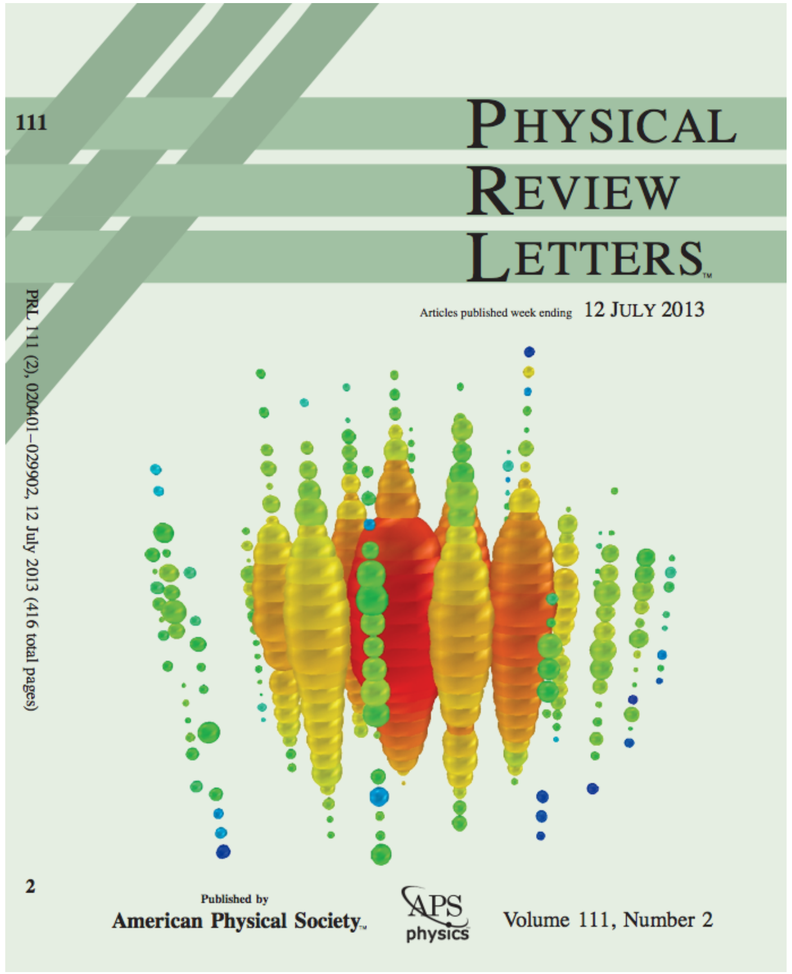
Highly stable operation.

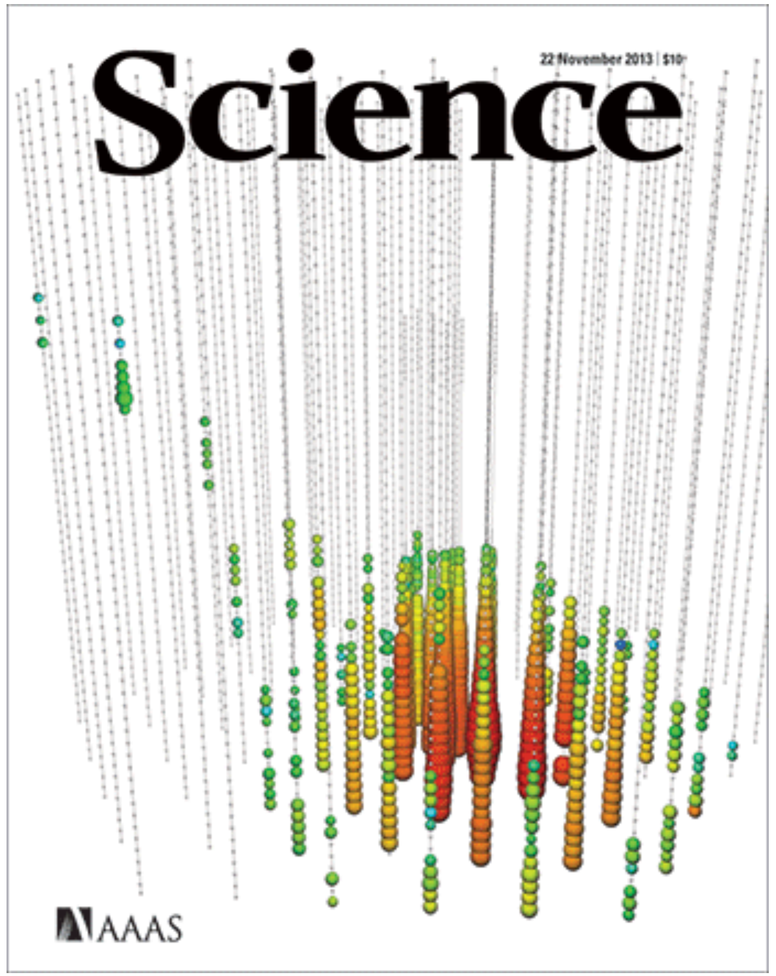
Since 2016: livetime > 99.5%



DeepCore (low energy threshold)

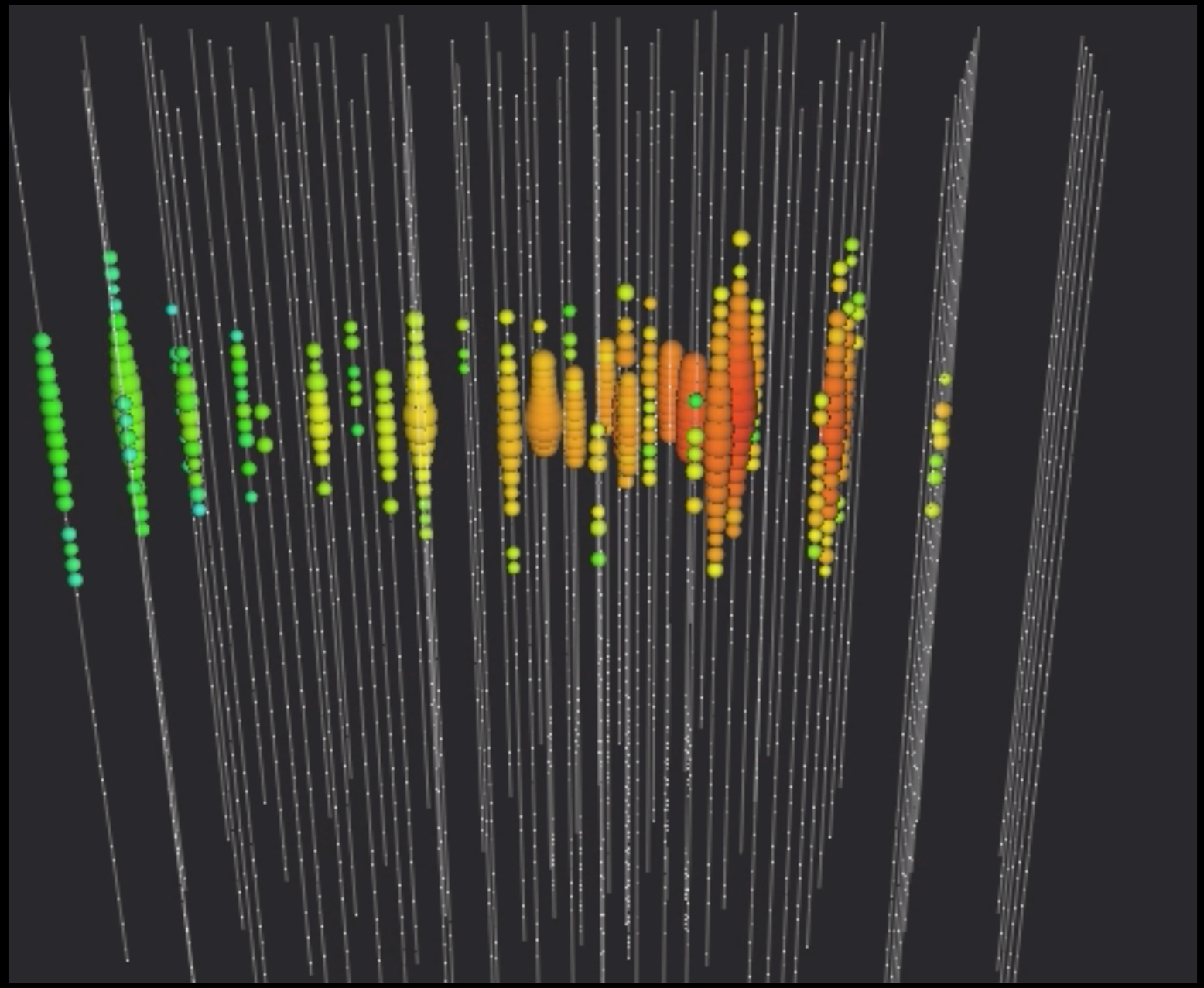
IceCube has discovered high energy (TeV to PeV) astrophysical neutrinos





“Dr. Strangepork”
Starting muon track
Deposited energy: 71 TeV

“Dr. Strangepork”
Starting muon track
Deposited energy: 71 TeV

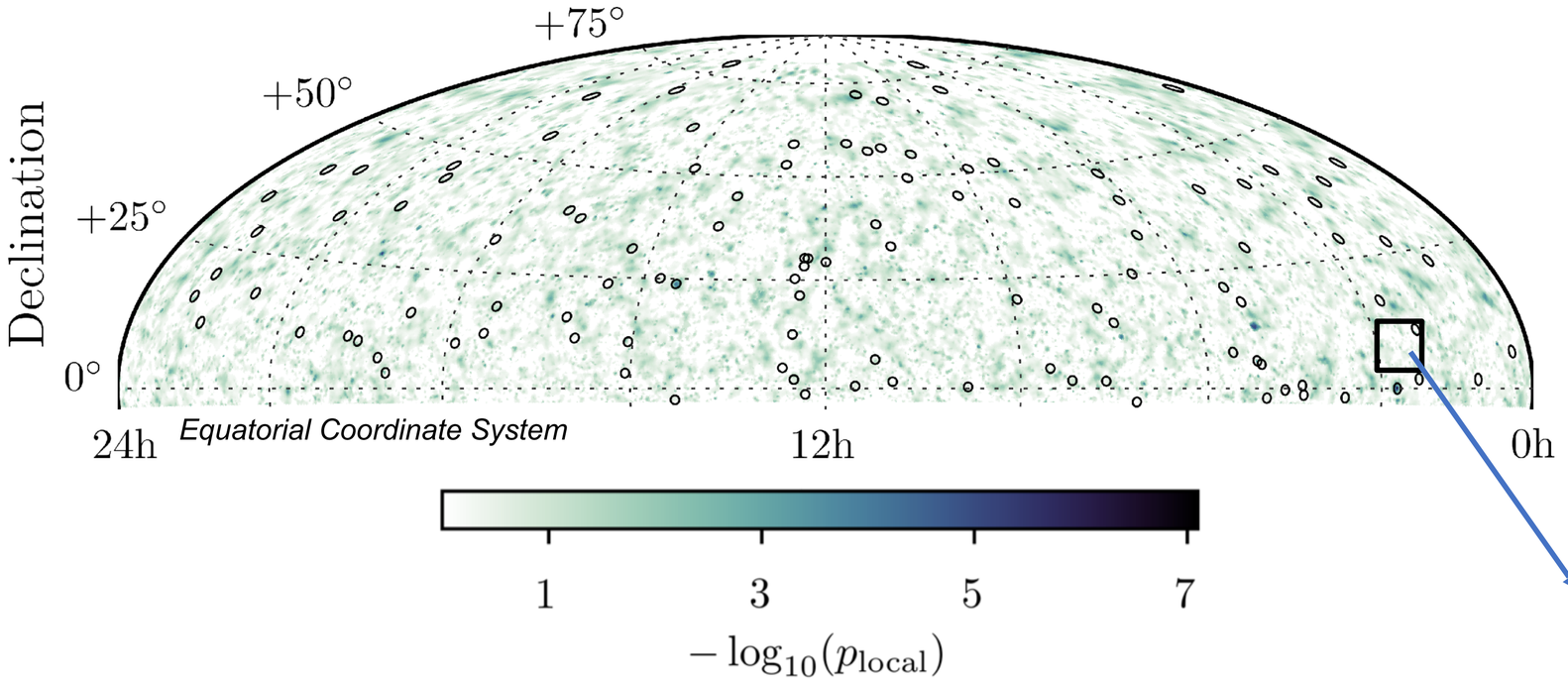


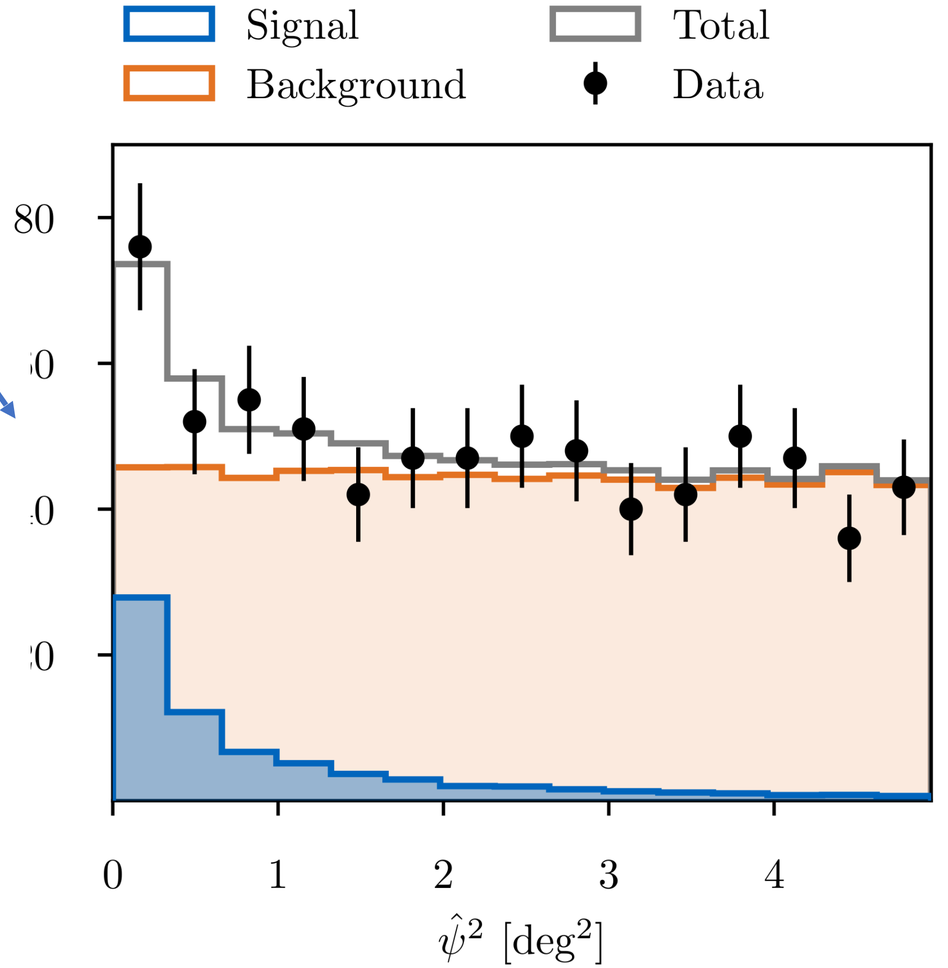
Evidence for neutrino emission from the nearby active galaxy NGC 1068 (M 77)

New!

Science , Nov. 4, 2022

Analysis with improved calibrations



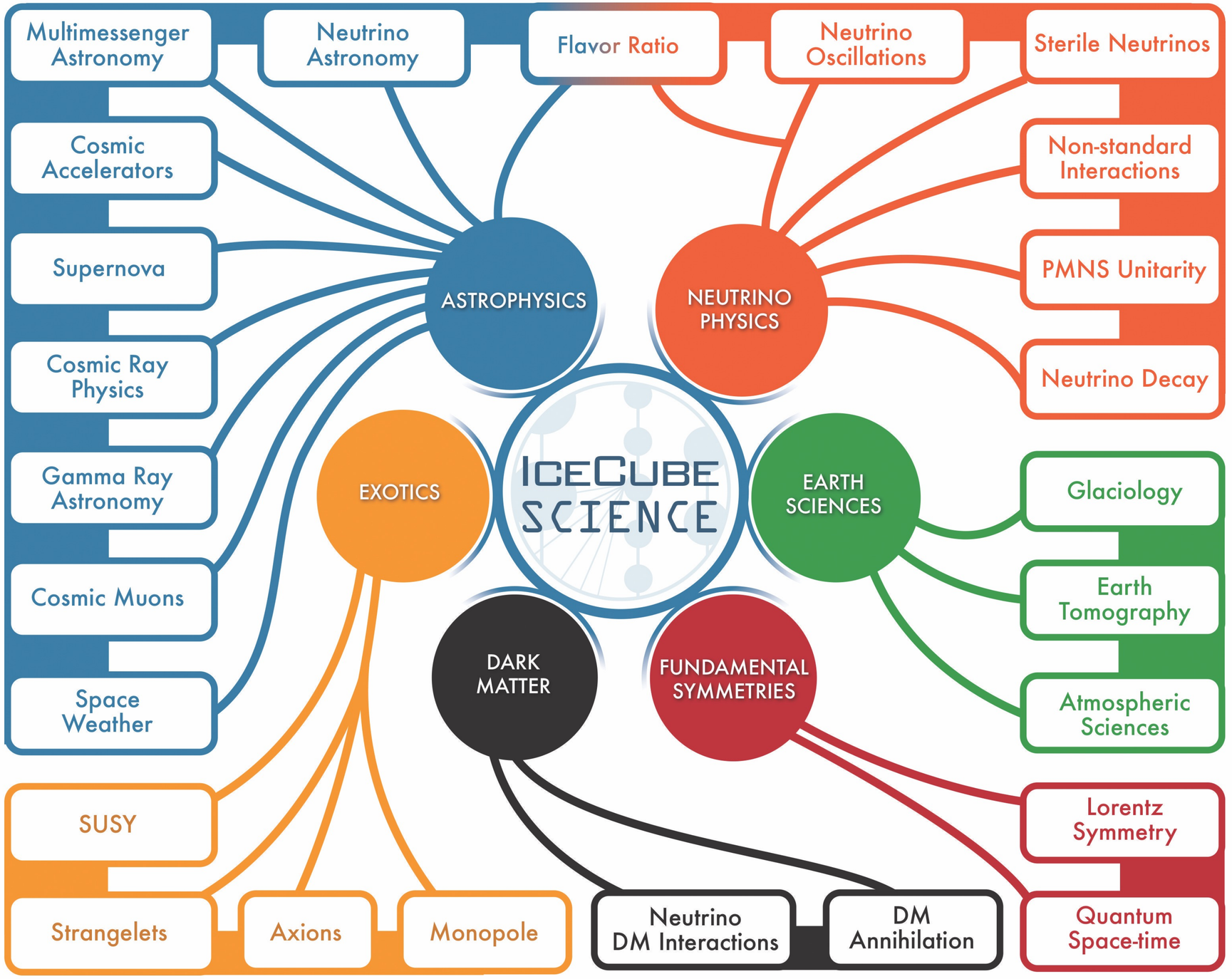


At the NGC 1068 location:

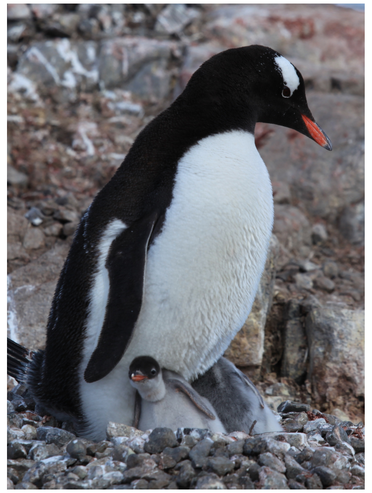
Astrophysical neutrino events = 79 $^{+22}_{-20}$

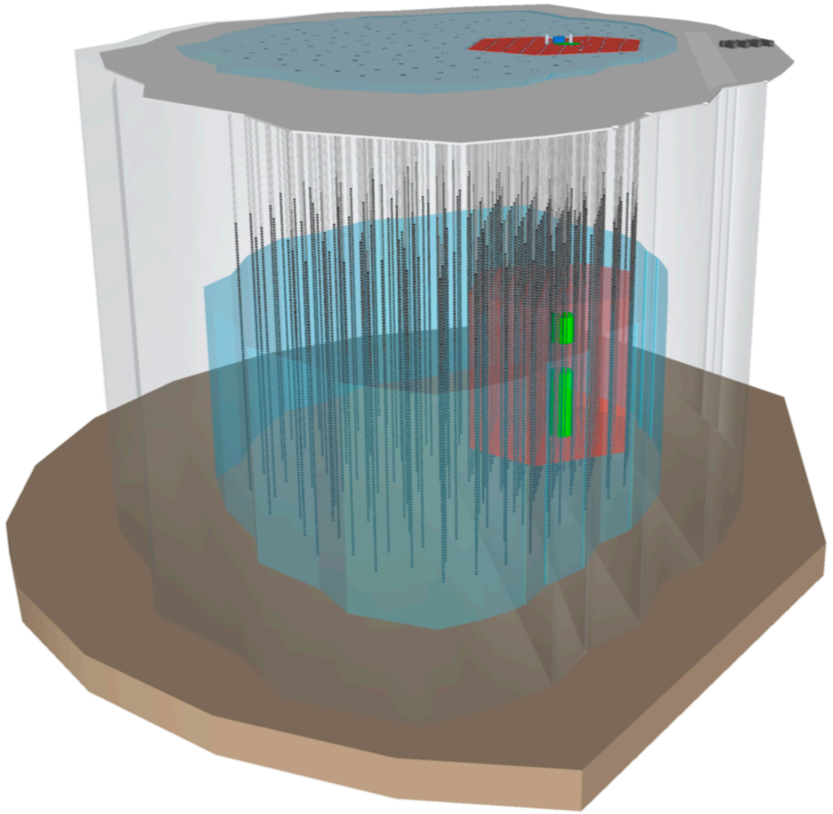
Spectral index = 3.2 ± 0.2

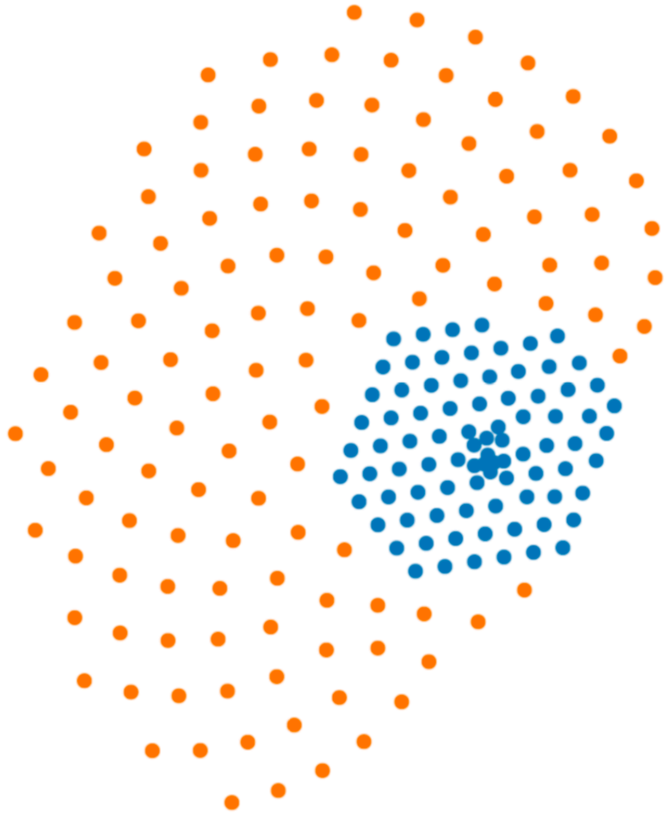
... significance **4.2σ**


ICECUBE SCIENCE
ASTROPHYSICS
NEUTRINO PHYSICS
EXOTICS
EARTH SCIENCES
DARK MATTER
FUNDAMENTAL SYMMETRIES
Multimessenger Astronomy
Neutrino Astronomy
Cosmic Accelerators
Supernova
Cosmic Ray Physics
Gamma Ray Astronomy
Cosmic Muons
Space Weather
Flavor Ratio
Neutrino Oscillations
Sterile Neutrinos
Non-standard Interactions
PMNS Unitarity
Neutrino Decay
Glaciology
Earth Tomography
Atmospheric Sciences
SUSY
Strangelets
Axions
Monopole
Neutrino DM Interactions
DM Annihilation
Lorentz Symmetry
Quantum Space-time

IceCube-Gen2: the next generation

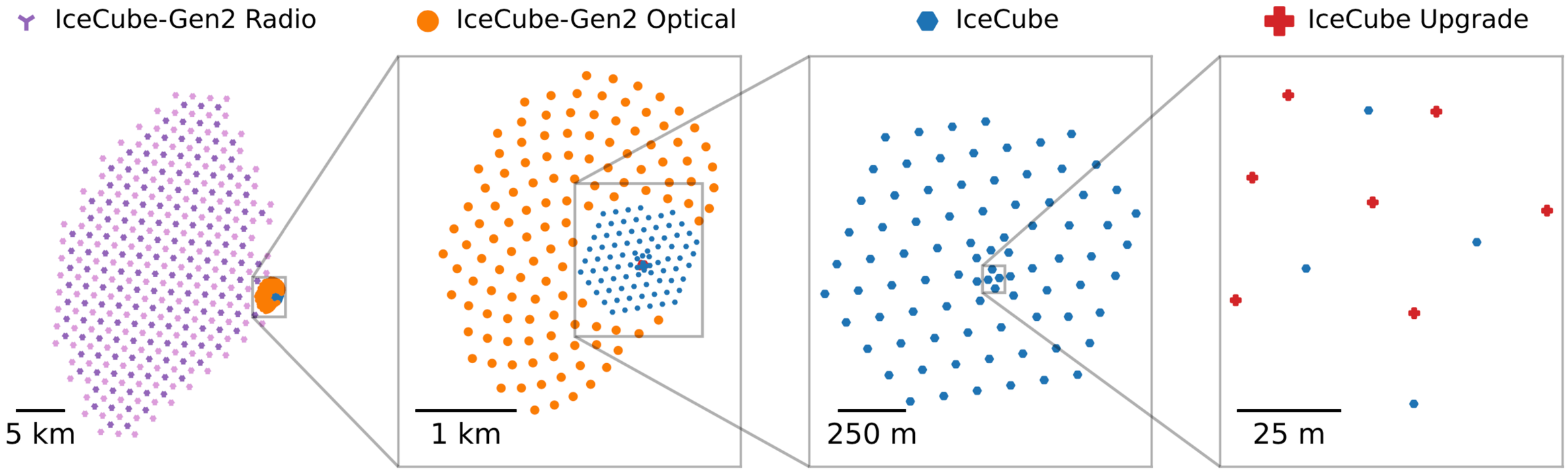






- High energy extension: Instrument 10 km^3 (sparsely) to increase sensitivity to high energy (0.1-10 PeV) muon and cascade events
- Dense inner core for neutrino physics including mass hierarchy —> Funded
- Askaryan Radio Array for 10^{18} eV neutrinos - extensions planned

IceCube and IceCube-Gen2 — scales and energie ranges



>10 PeV **> 5 TeV** **>0.5 TeV** **few GeV**

IceCube Upgrade (a step towards Gen2)

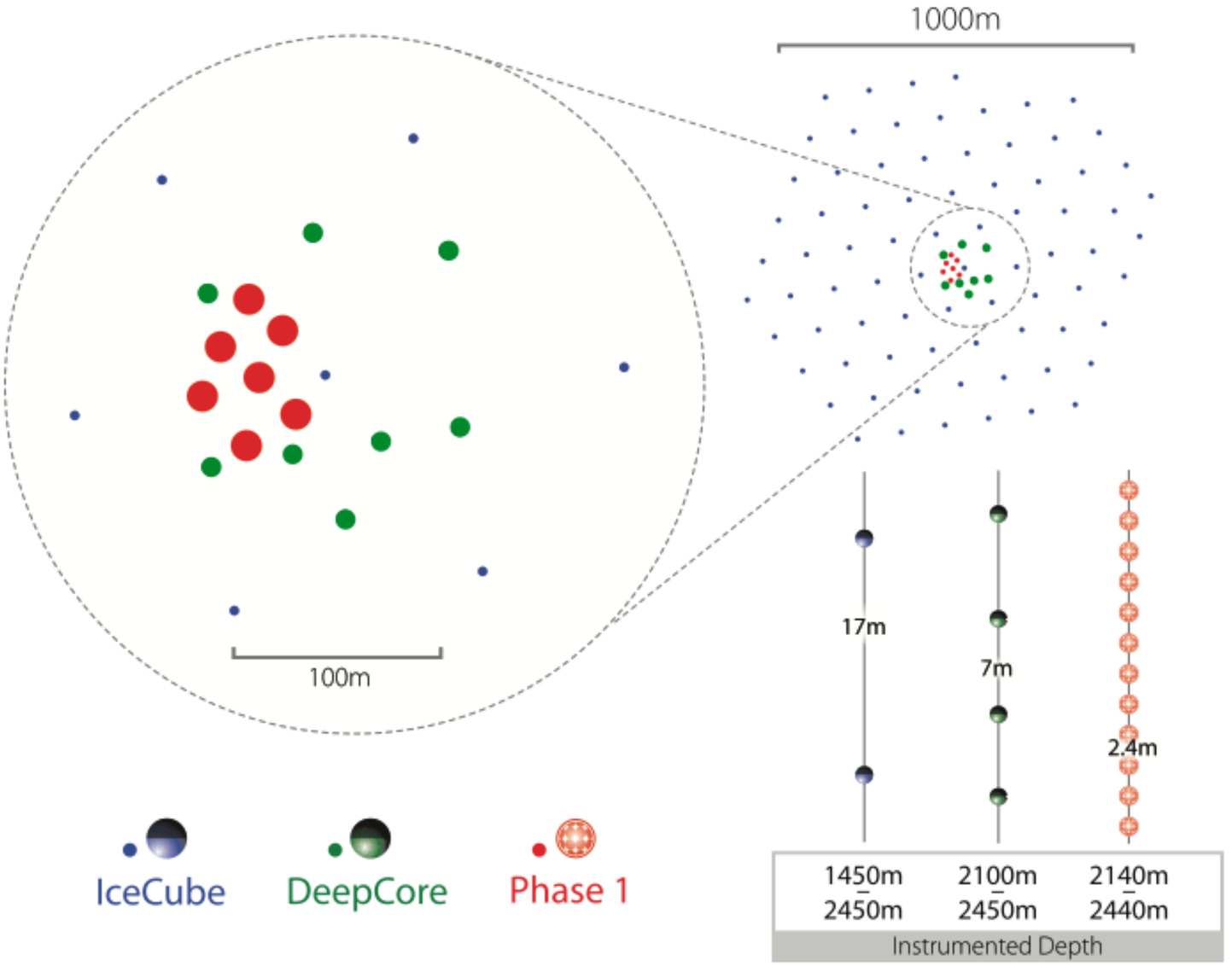
7 strings in center of IceCube, densely instrumented

Installation at South Pole in December 2025

Science goals:

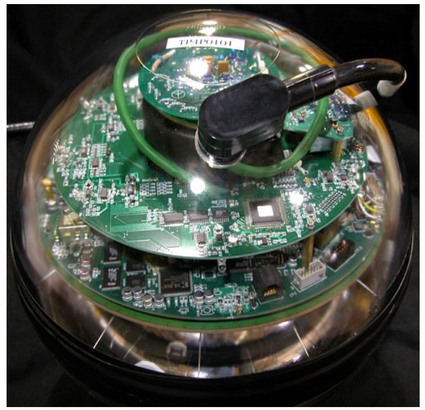
- ν_μ disappearance
- ν_τ appearance
- Precise calibration of IceCube optical properties and DOM response

A big step towards IceCube-Gen2



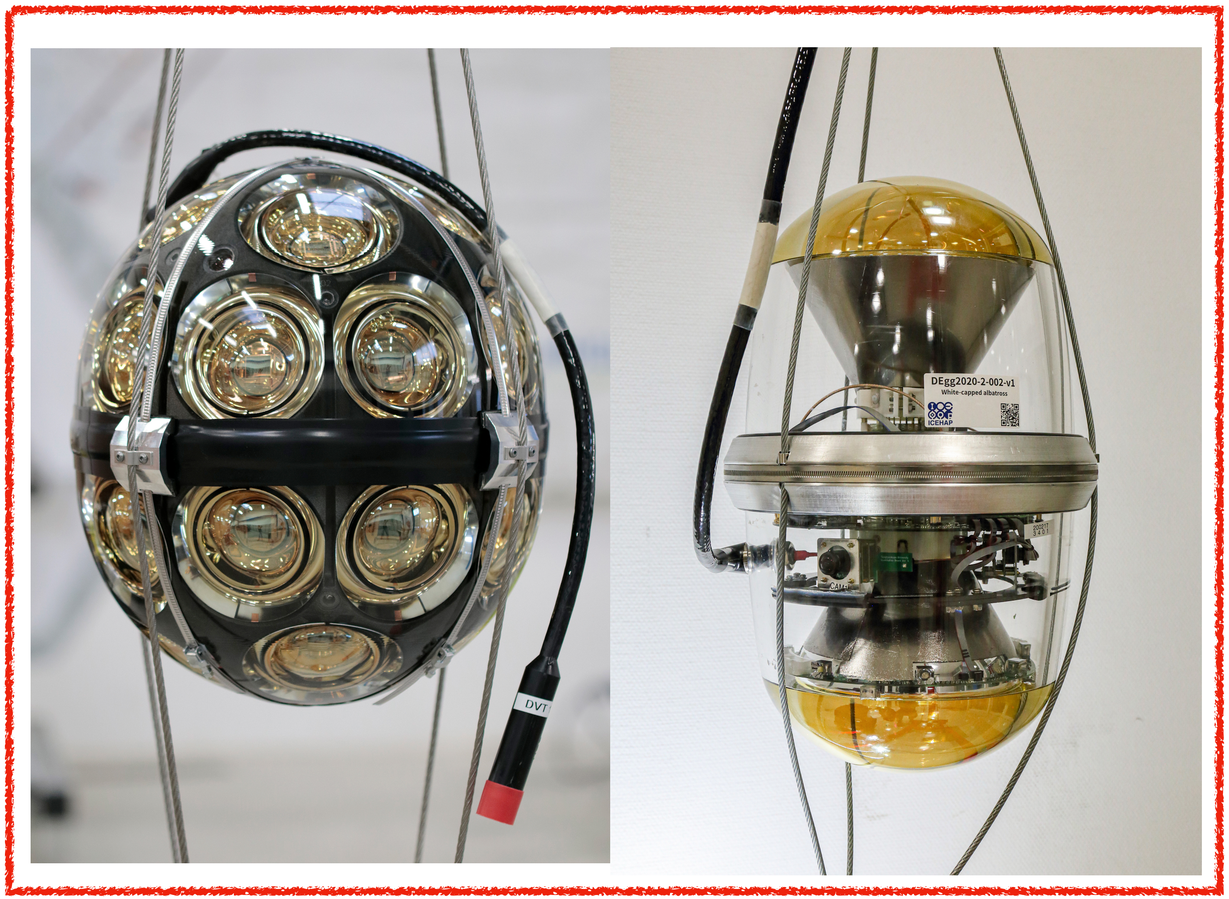
Optical sensor for Gen2

IceCube DOM

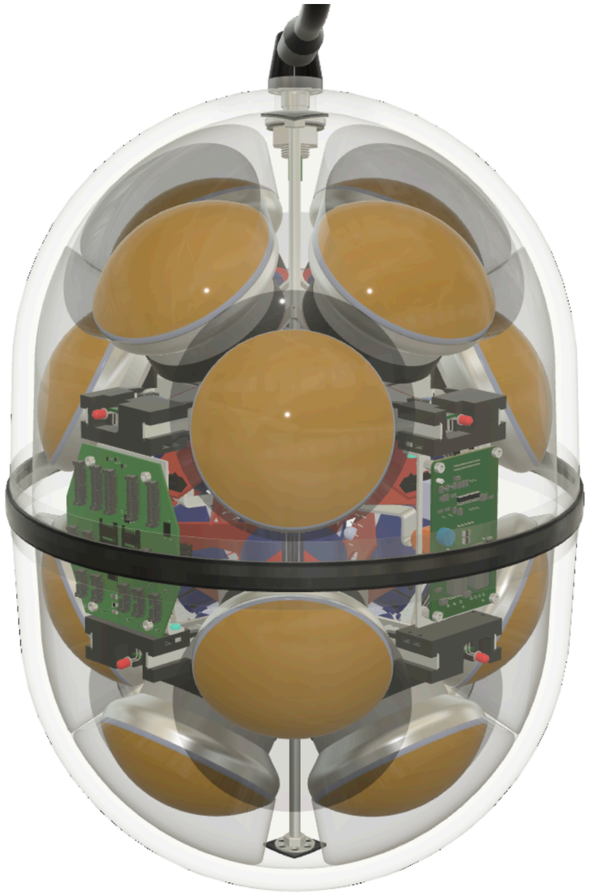


33 cm

Sensors used for IceCube Upgrade



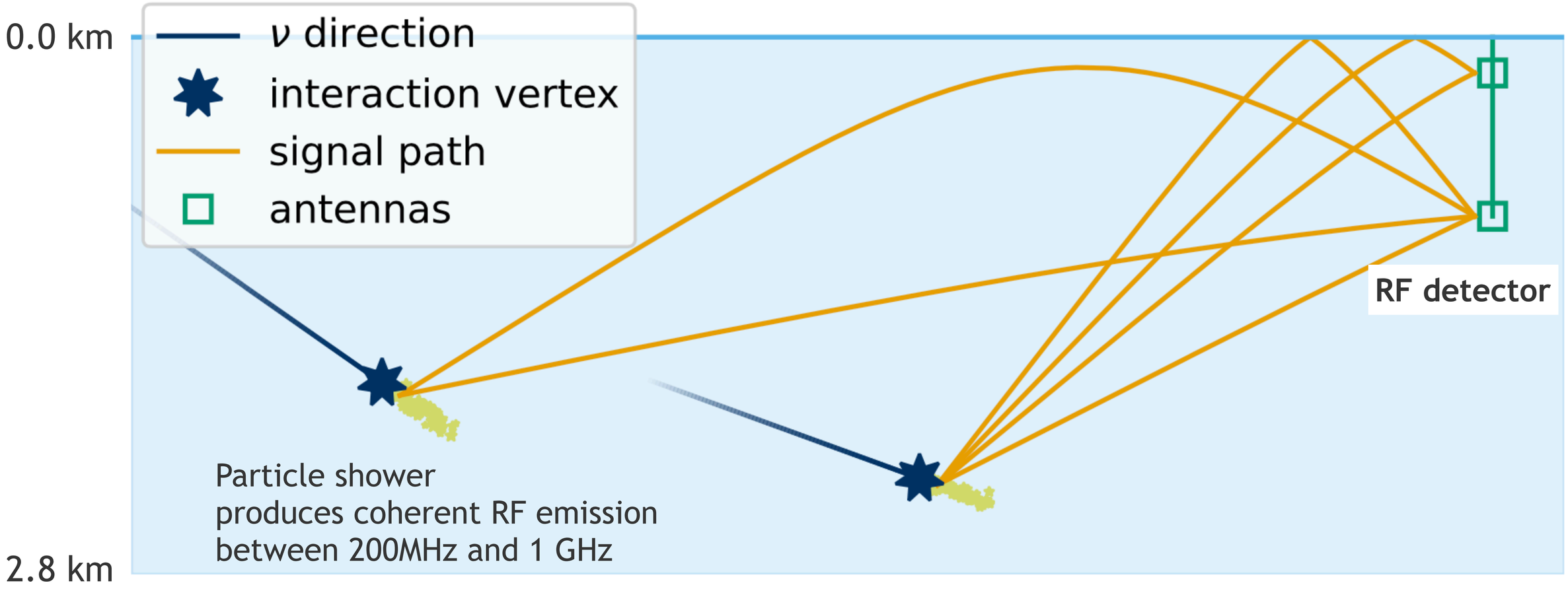
Next generation sensor in development in our lab



THE UNIVERSITY of WISCONSIN MADISON

The IceCube-Gen2: the radio array

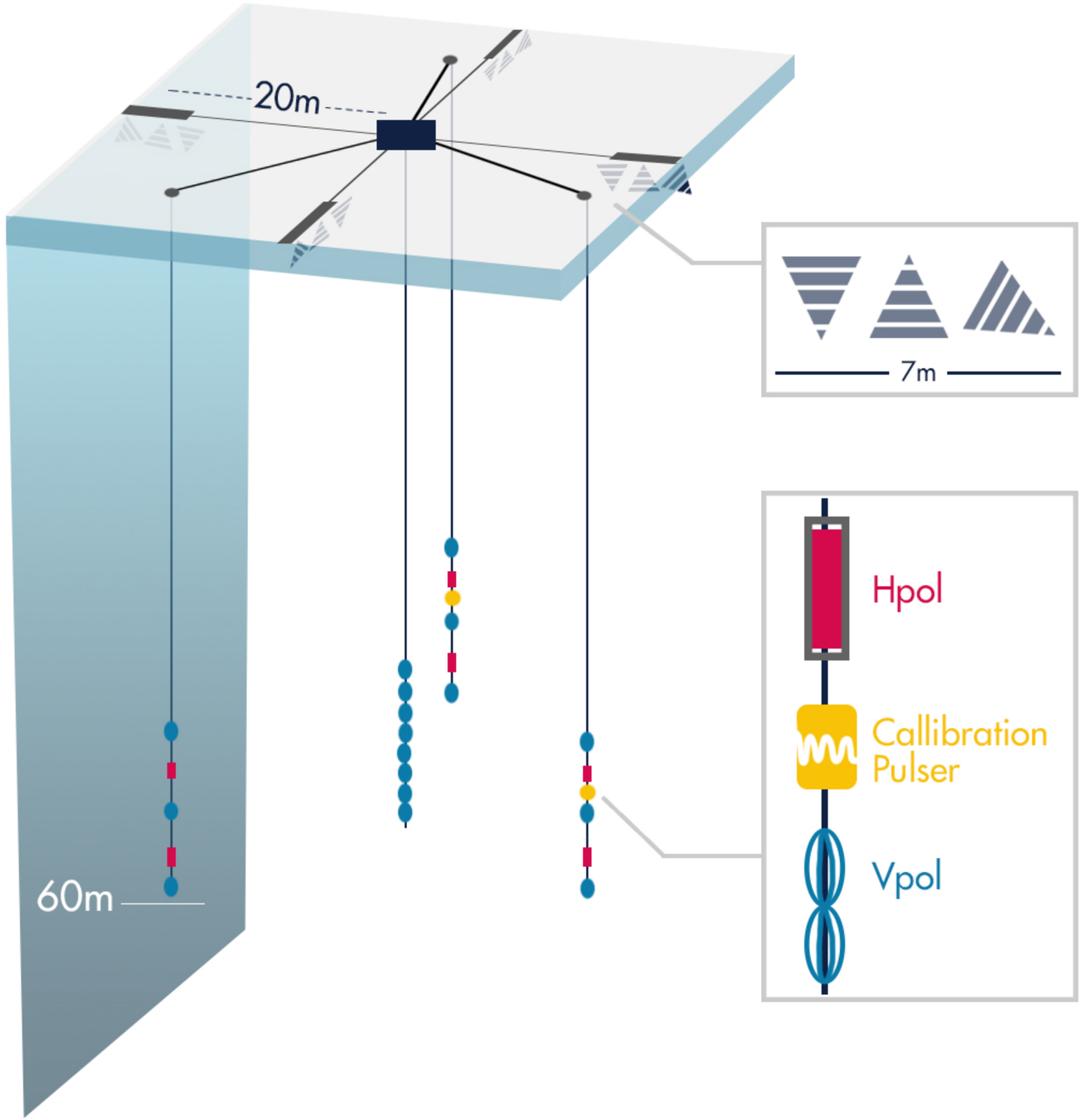
Askaryan Radio Detector array to complement optical detector at energies > 30 PeV



Station design

Result of optimization effort

- Phased array, 8 antennas (trigger at 1.5 sigma)
- 3 outer strings with 5 antennas (reconstruction)
- 12 log periodic antennas at surface (reconstruction and cosmic ray)



ARA: Calibration, an example

Surface pulsers allow to take data from many known locations.

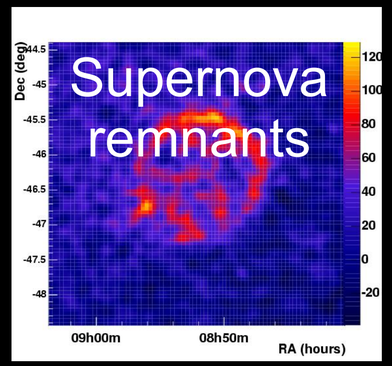
One measurement takes only a few minutes (rate > 100 Hz).

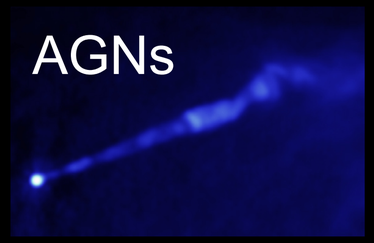
Allows constraining detector geometry and ice model.

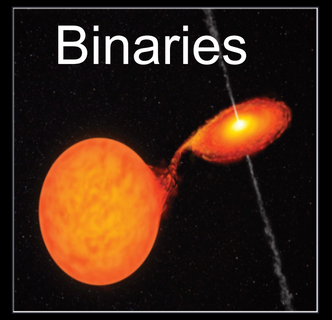
Gamma Astronomy (10 GeV to 100 TeV)

CTA (Justin Vandenbroucke)
HAWC (Ke Fang)

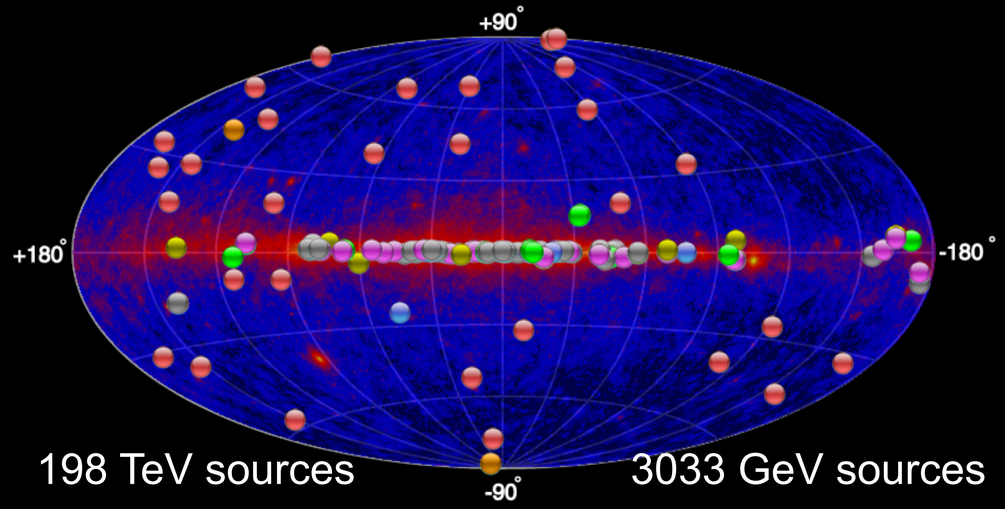
Physics with TeV gamma-ray telescopes





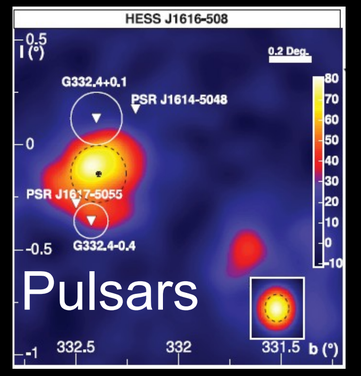


The gamma-ray sky as of 2017

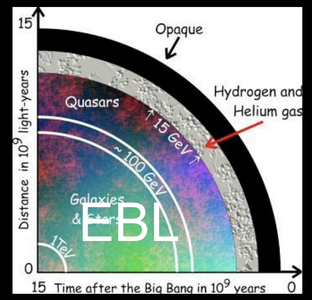


198 TeV sources

3033 GeV sources

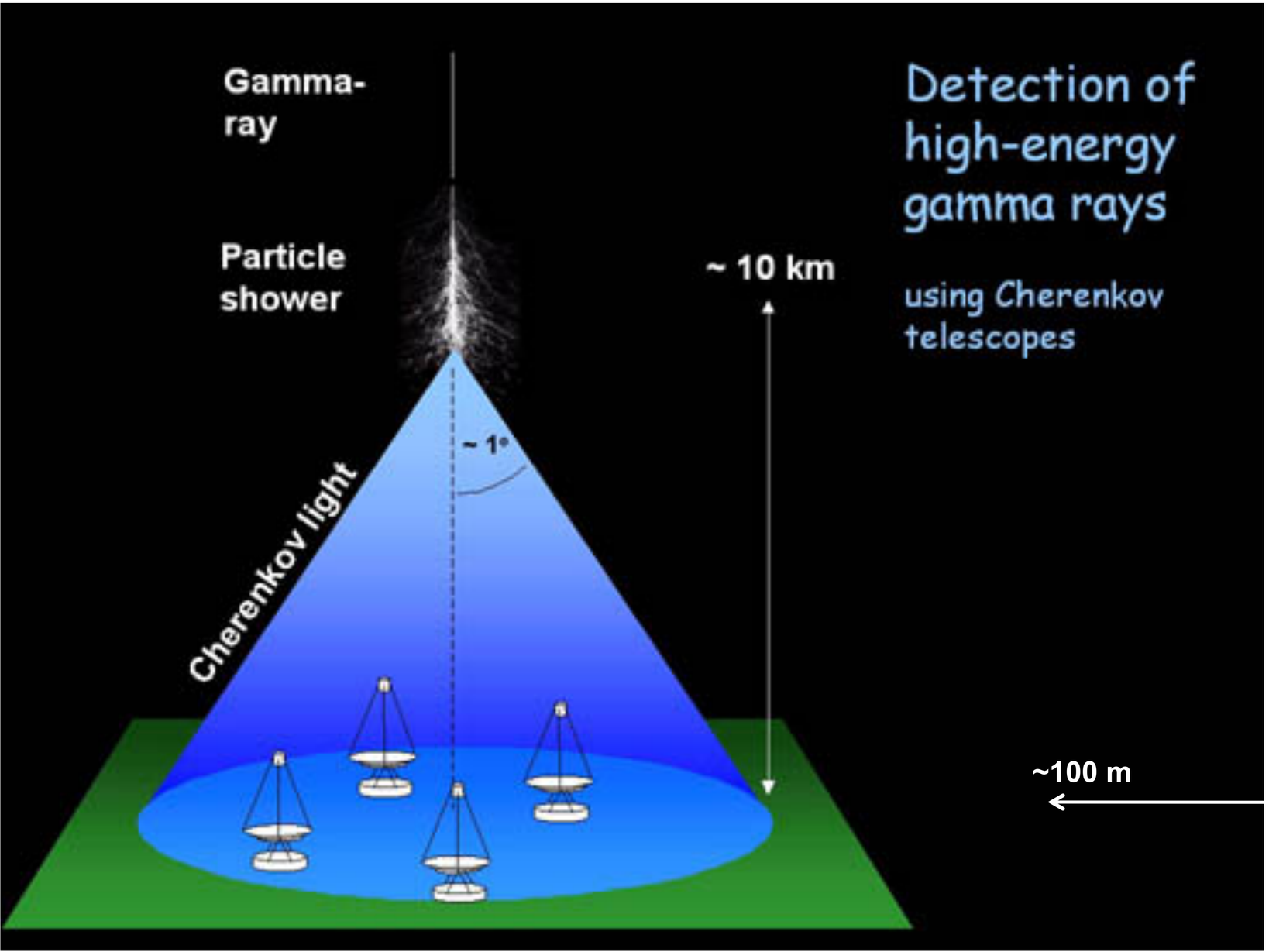


Axions, …

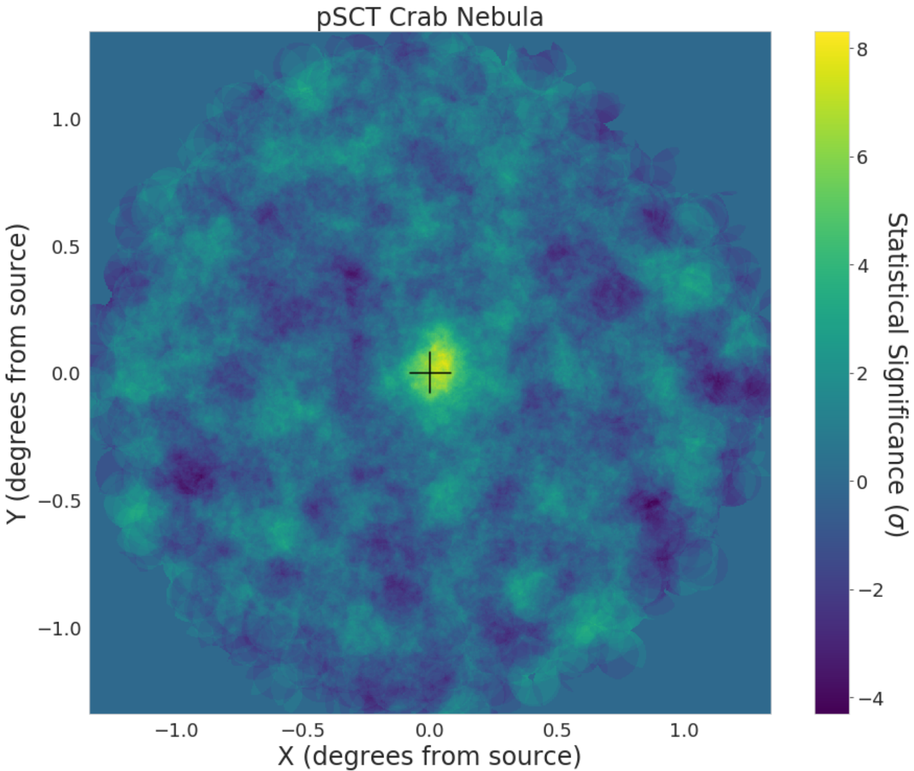


Also neutrino physics: oscillations and mass hierarchy

The atmosphere as a detector



- Optical frequency (blue) light
- Very short (few ns) exposure to limit night sky background
- Cherenkov cone very narrow, ~1°:



Dual-mirror telescope construction in Arizona

http://cta-psct.physics.ucla.edu
live web cam

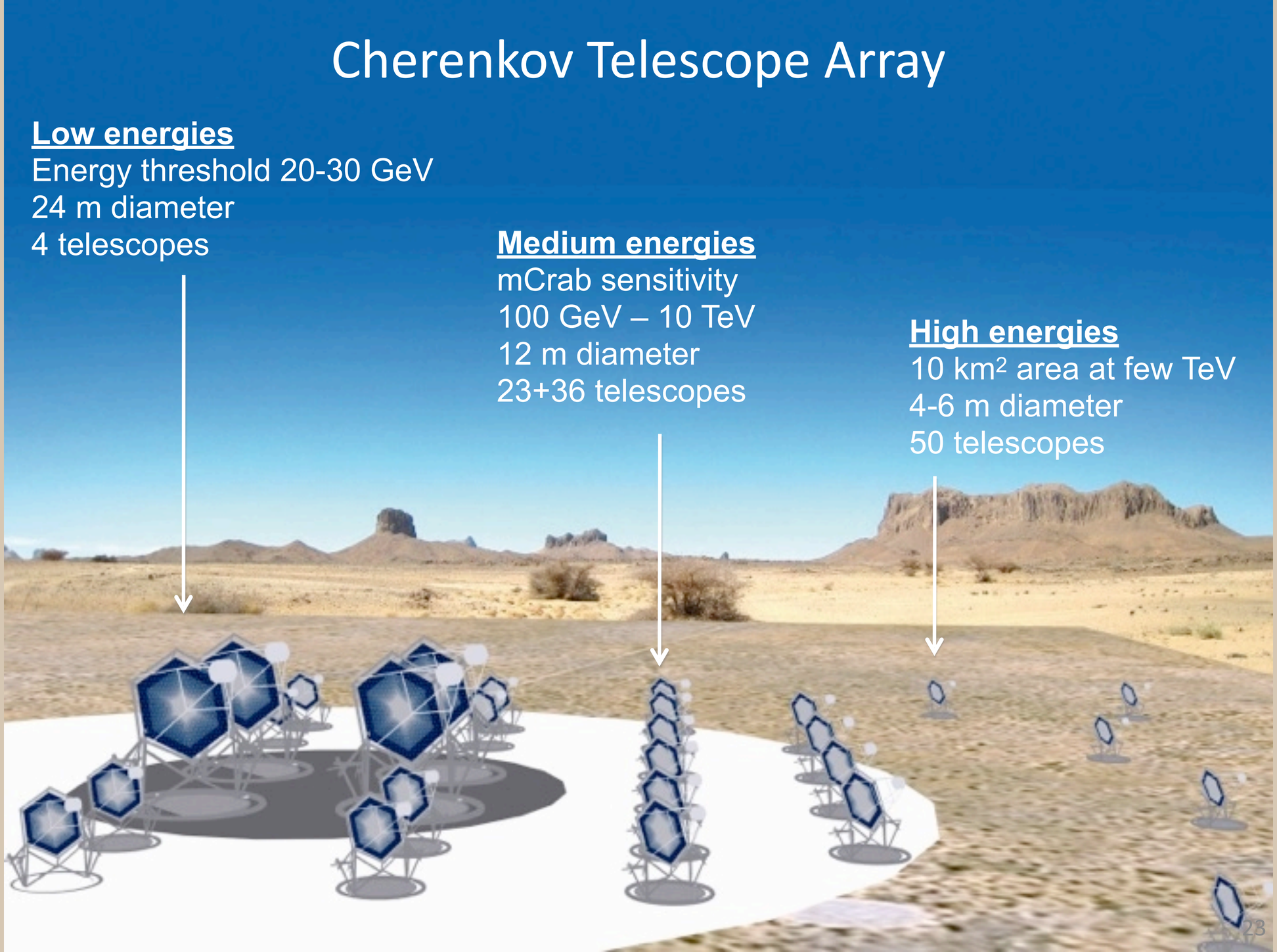
05-18-2017 06:31:51

Cherenkov Telescope Array

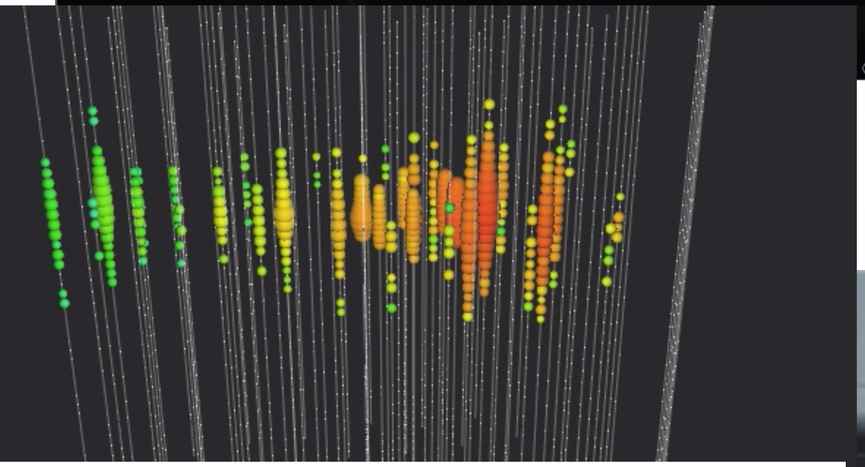
Low energies
Energy threshold 20-30 GeV
24 m diameter
4 telescopes

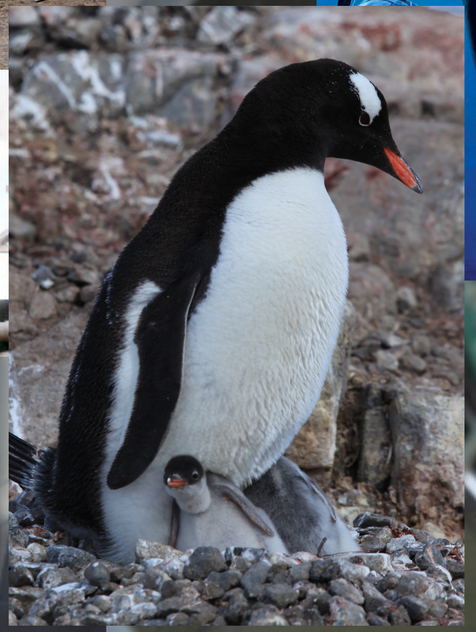
Medium energies
mCrab sensitivity
100 GeV – 10 TeV
12 m diameter
23+36 telescopes

High energies
10 km^2 area at few TeV
4-6 m diameter
50 telescopes

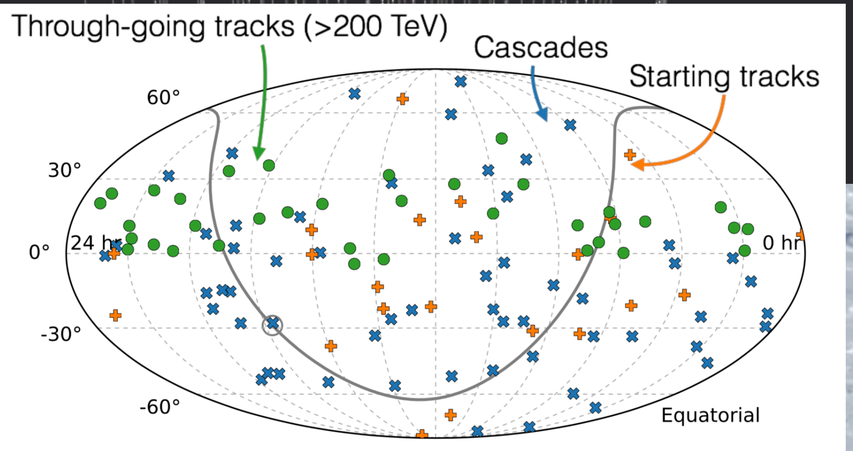



Chasing the ammonia economy p. 120
Time invested matters for mice, rats, and humans pp. 124 & 178
Two spindles are better than one pp. 138 & 189
Science
$15
13 JULY 2018
sciencemag.org
AAAS
NEUTRINOS
FROM A BLAZAR
Multimessenger observations of an astrophysical neutrino source pp. 115, 146, & 147



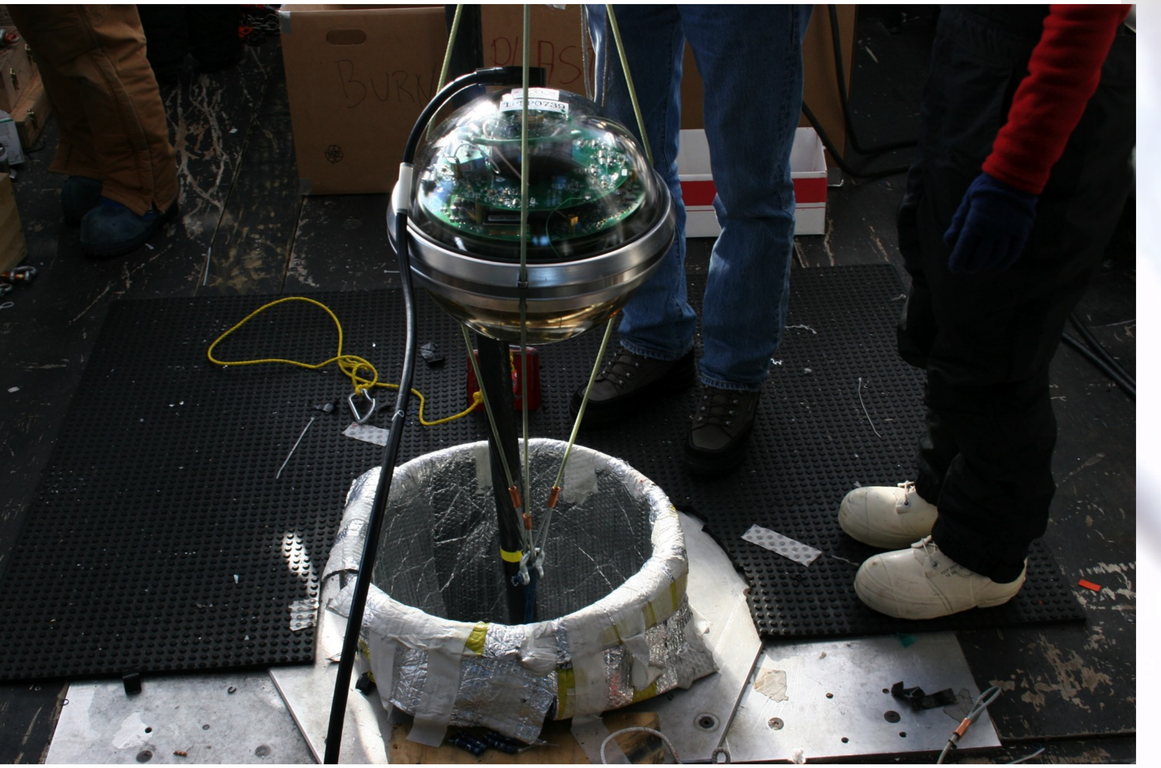


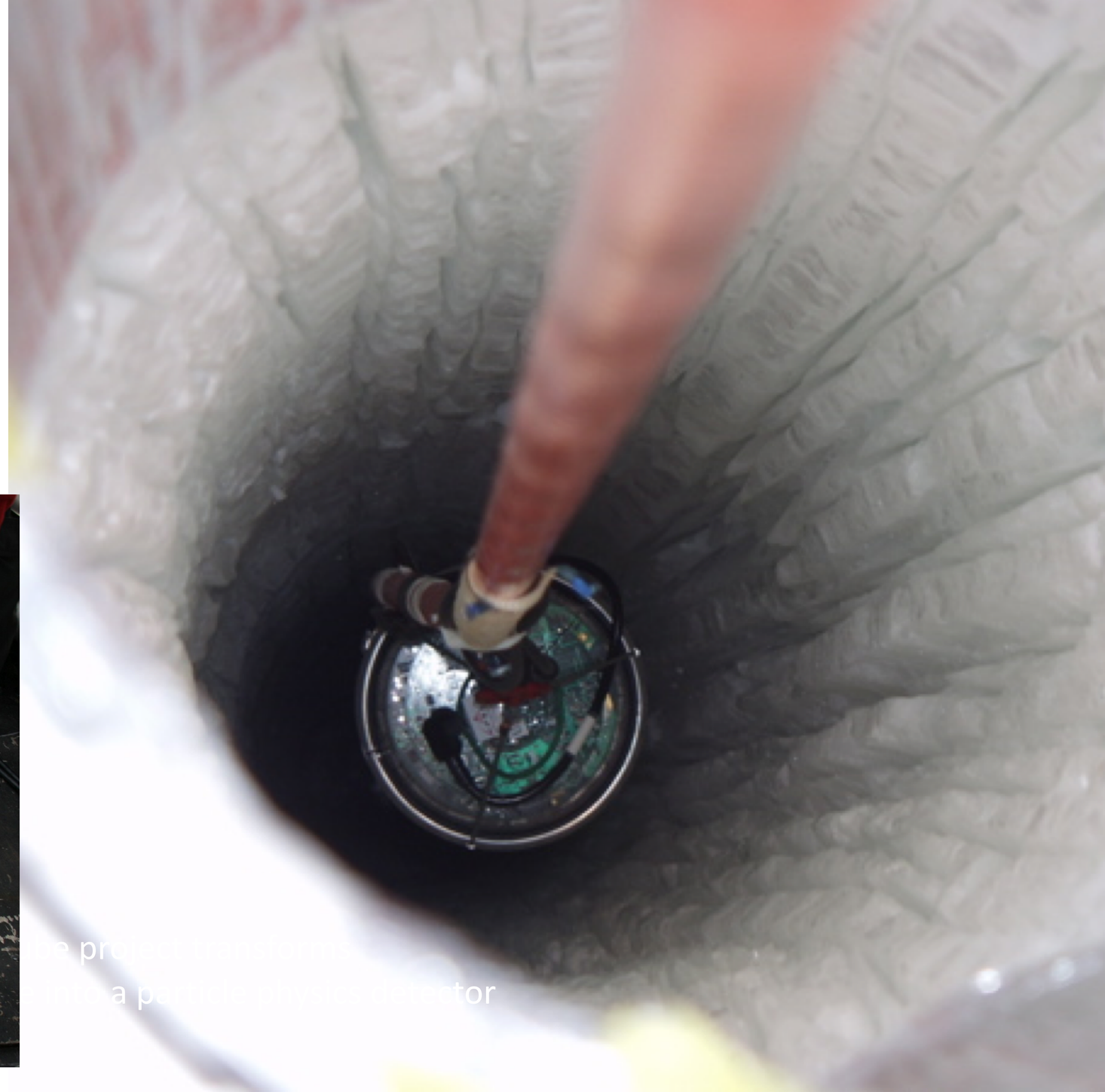

Grad School
is
Awesome!!


Through-going tracks (>200 TeV)
Cascades
Starting tracks
60°
30°
0°
-30°
-60°
24 hr
0 hr
Equatorial

Thanks

The photomultiplier
at installation (bottom) and
its decend (right) into the
2km deep (water filled) hole





IceCube Laboratory