Photo: Martin Wolf

IceCube Results and the path to Upgrade and Gen2

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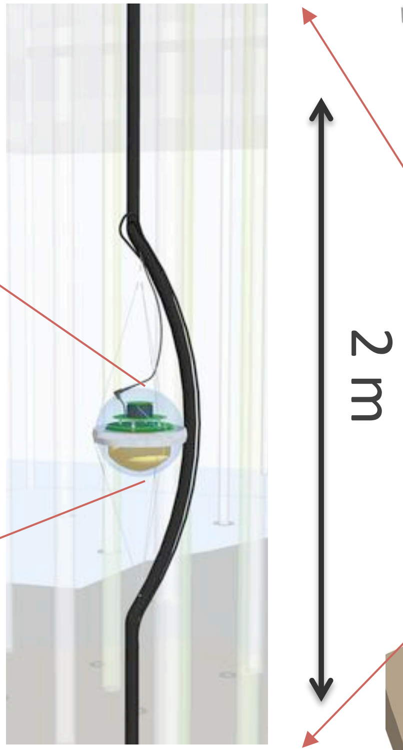
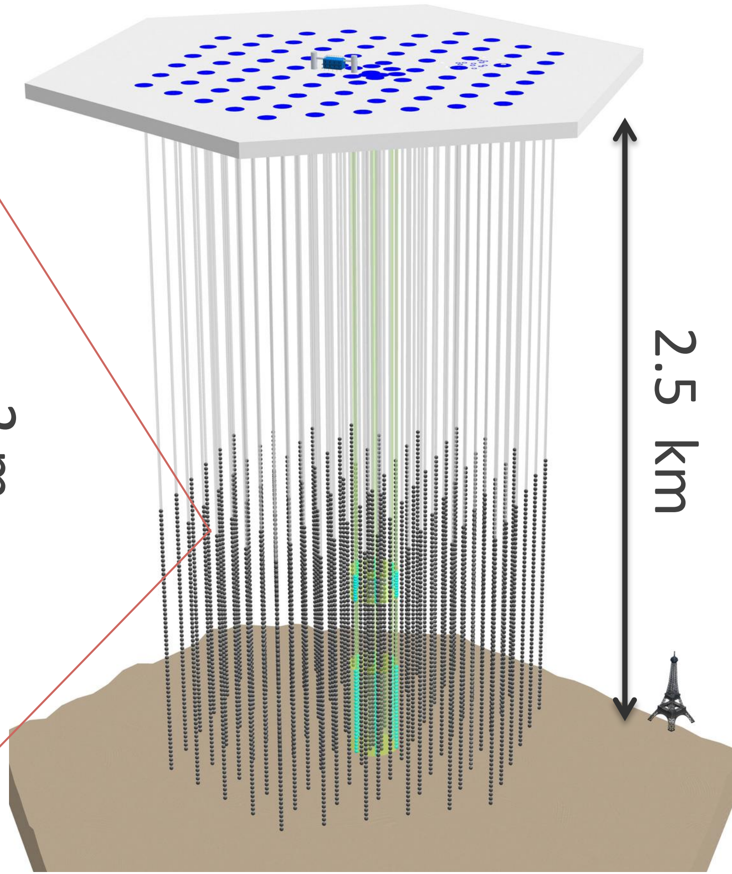
IceCube Neutrino Observatory

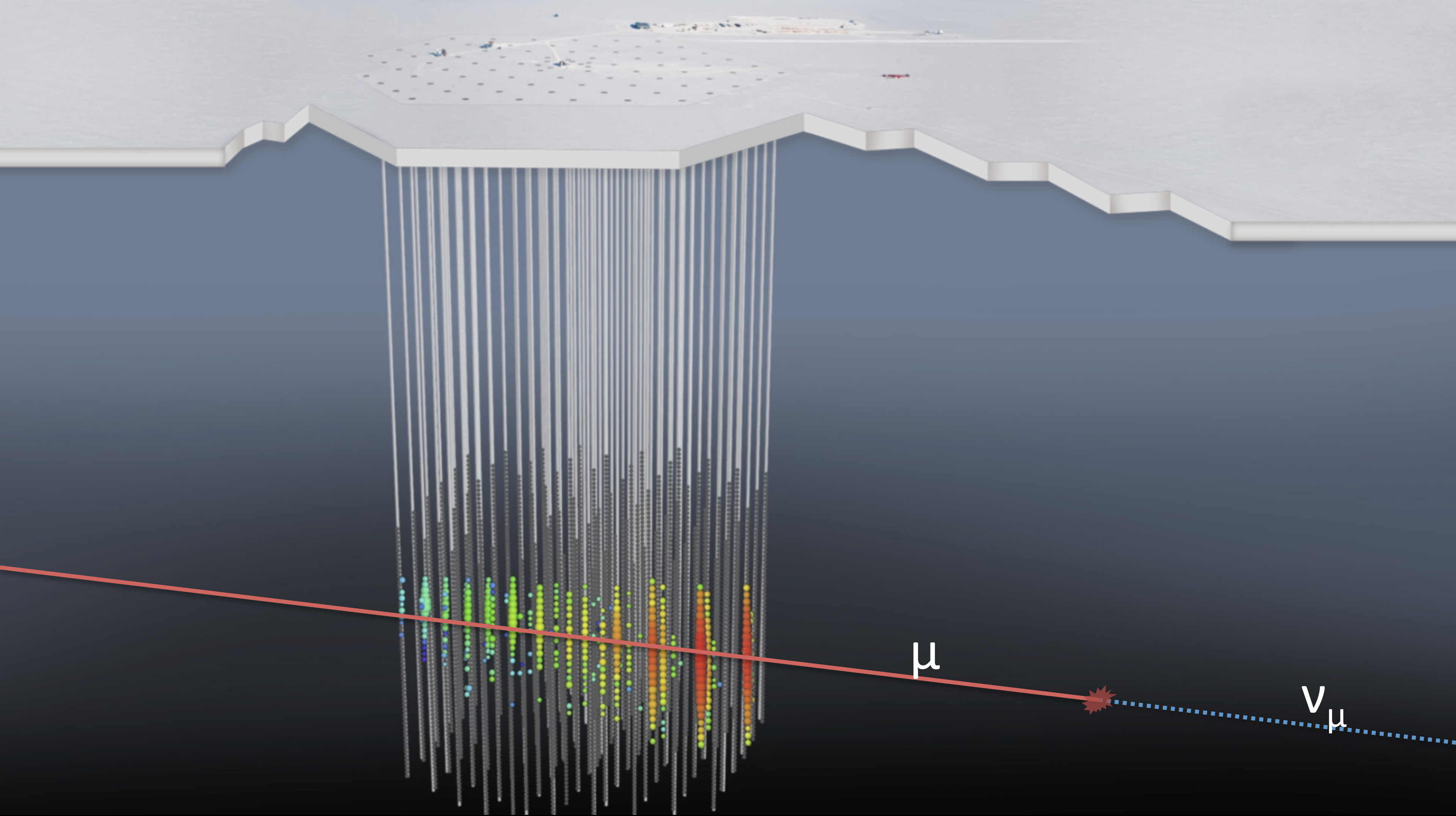
DOM: Digital Optical Module

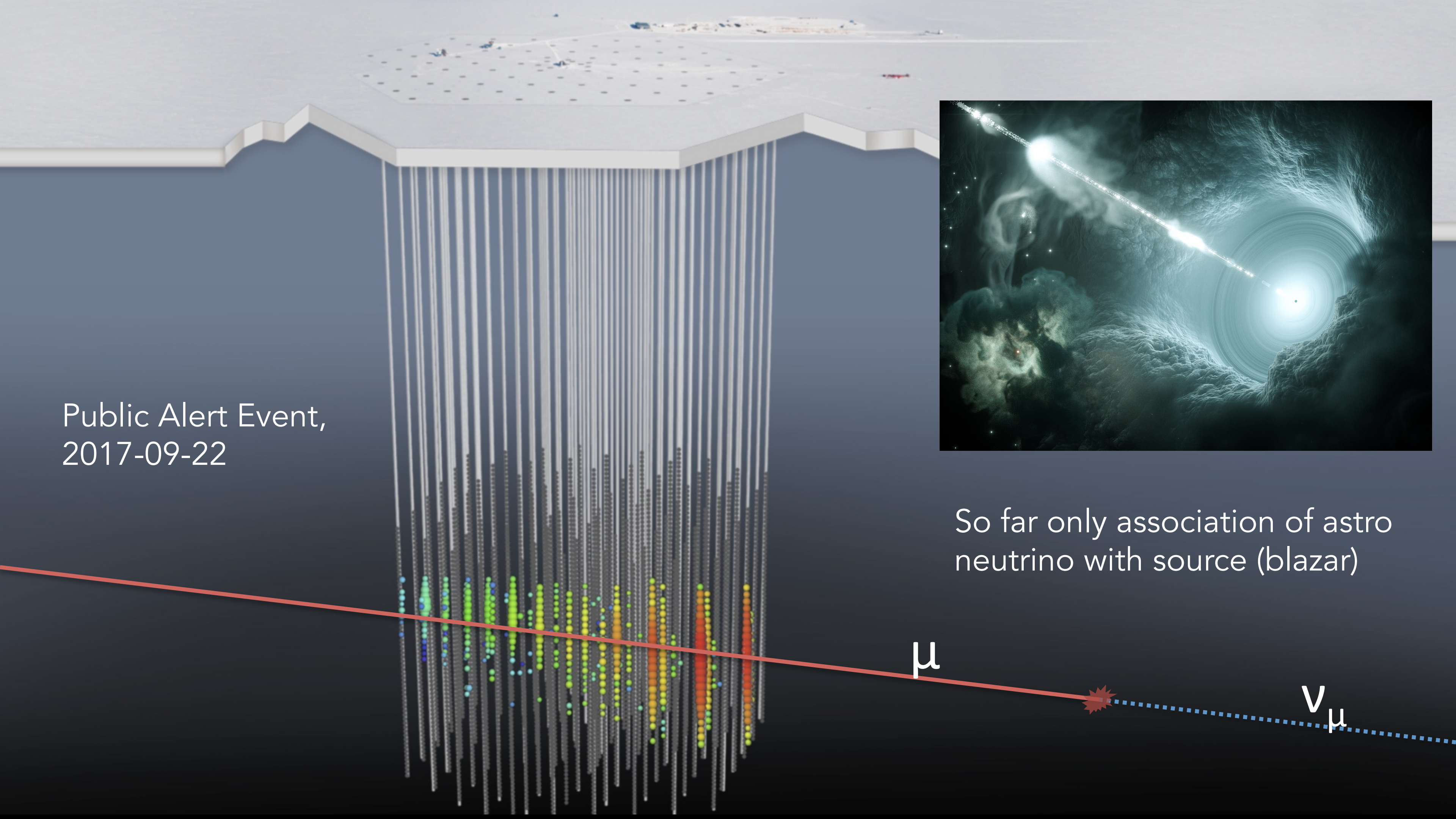
10″ PMT Hamamatsu





5160 DOMs spread over 1 km^3 = 1 Gigaton instrumented volume

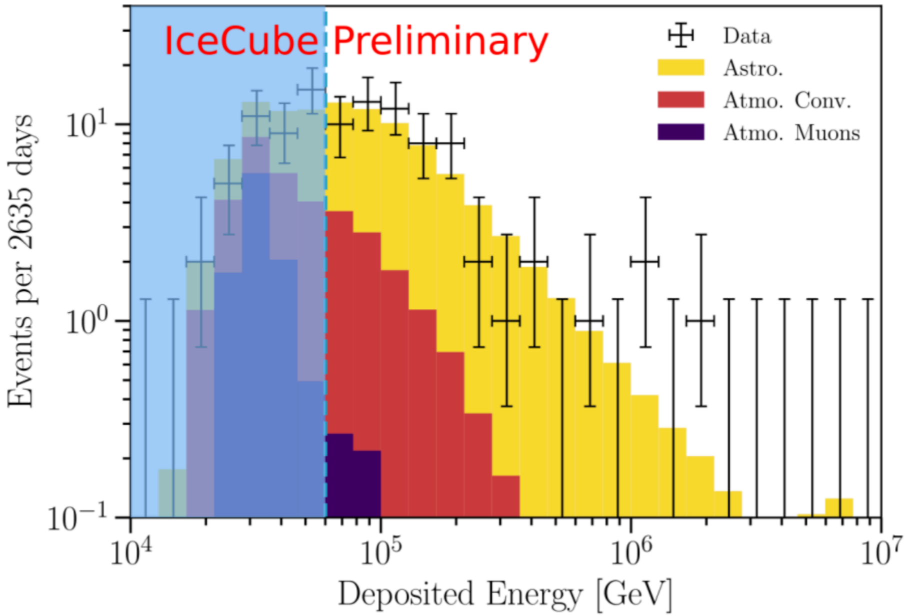

μ
ν μ

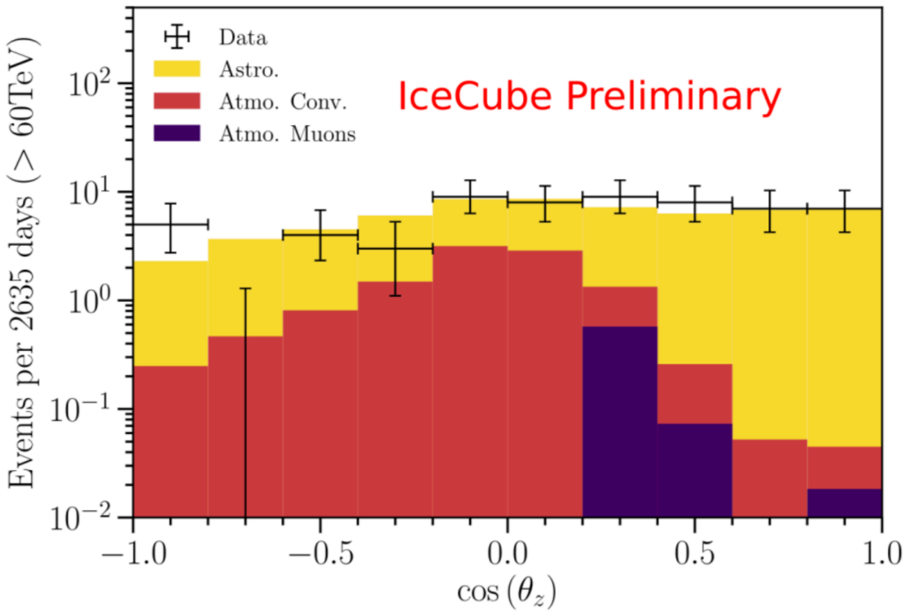

Public Alert Event,
2017-09-22
So far only association of astro
neutrino with source (blazar)
μ
ν_μ

HESE: High-Energy Starting Events

Starting Events – the channel where IceCube discovered in 2013 the high-energy (>100 TeV) astrophysical neutrino flux

Low statistics but high purity sample





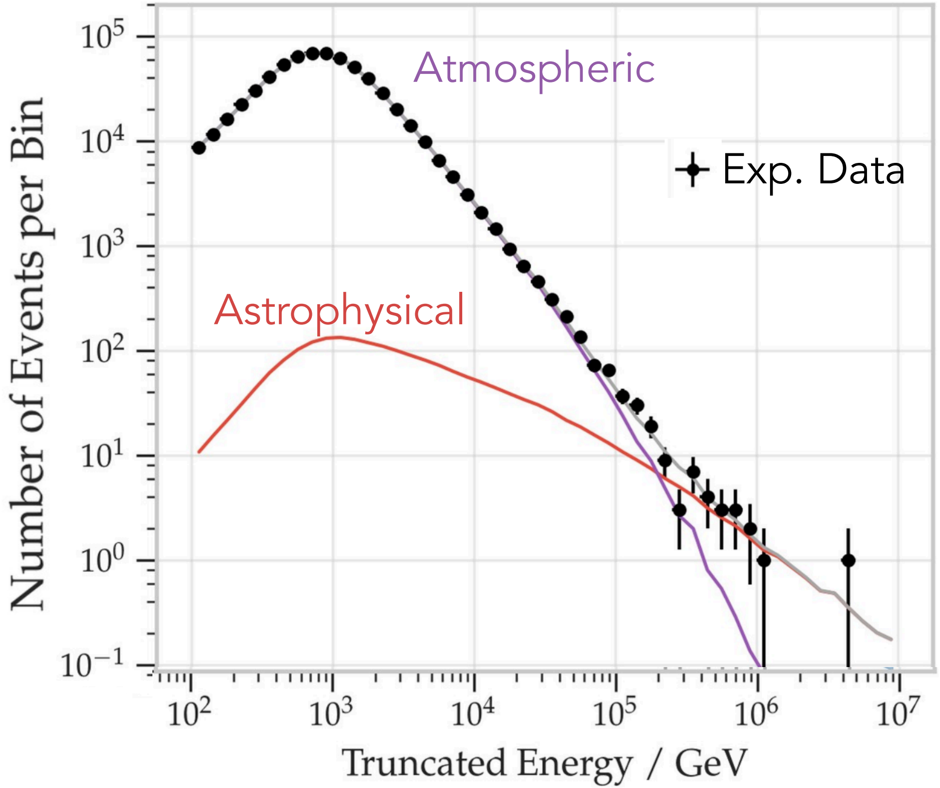
Most recent Starting Event Analysis with 7.5 years data (ICRC 2019)

Up-going Muon Neutrino Events

Complementary event selection

High-statistics (650 000 events) but dominated by background atmospheric neutrinos

Most recent analysis with 9.5 years data (ICRC 2019)



Best-fit astrophysical flux:

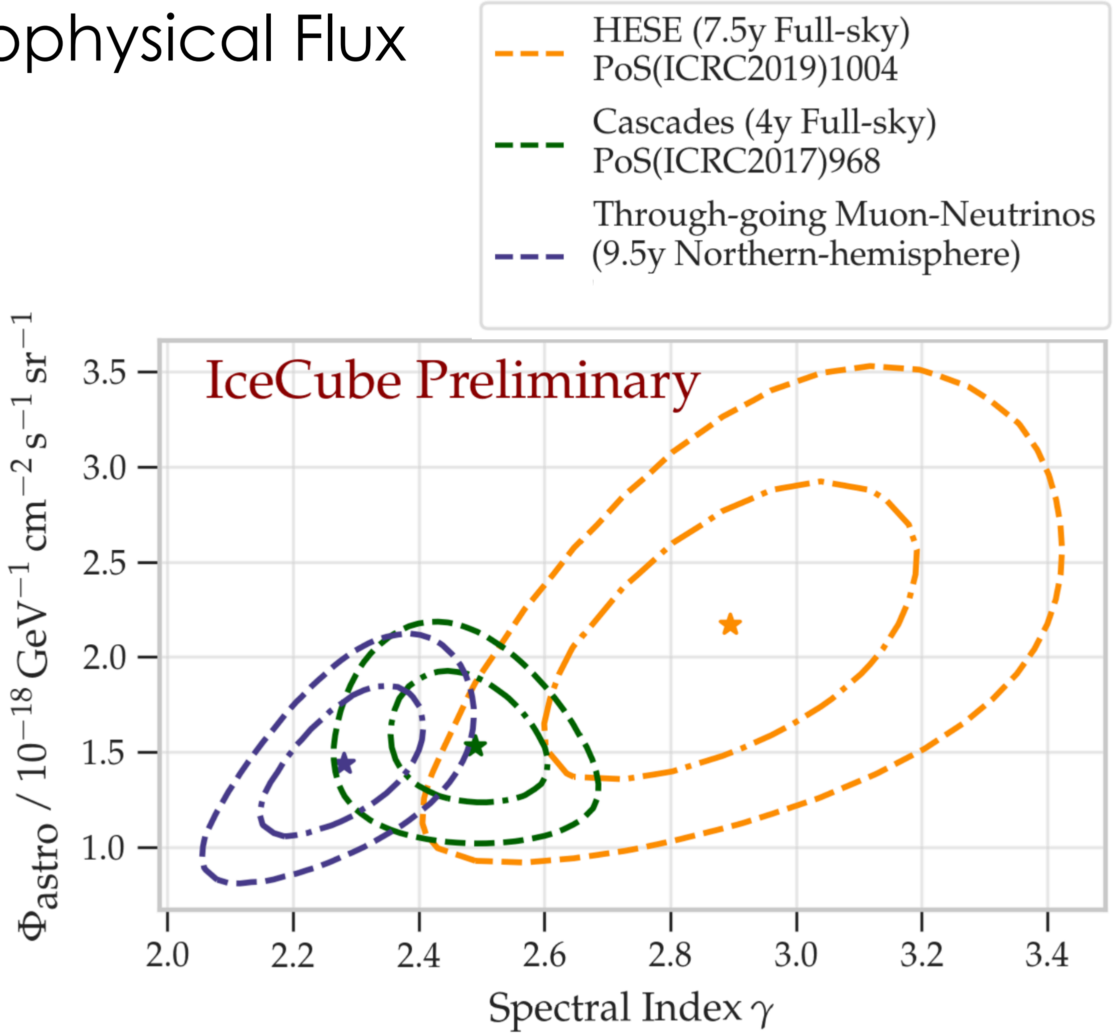
$$\frac{d\phi_{\nu+\bar{\nu}}}{dE} = (1.44^{+0.25}_{-0.24}) \left(\frac{E}{100\,\mathrm{TeV}}\right)^{-2.28^{+0.08}_{-0.09}} \cdot 10^{-18}\,\mathrm{GeV^{-1}cm^{-2}s^{-1}sr^{-1}}$$

Next: Global Fit for Astrophysical Flux

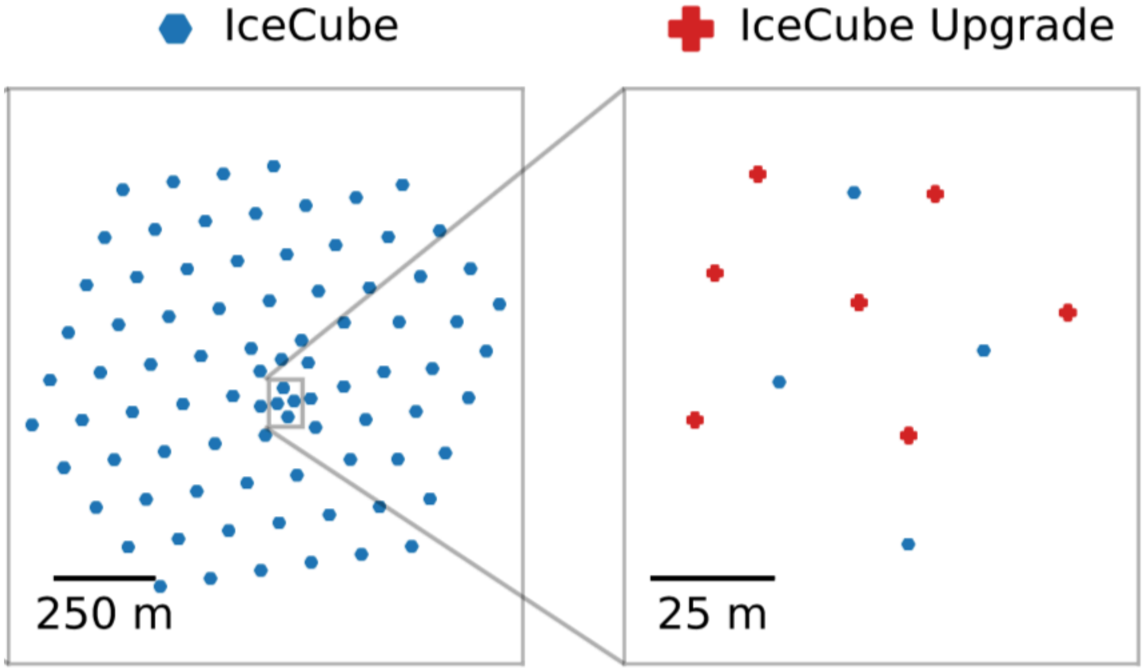
Some tension in best-fit flux and energy spectrum between the analyses.

Want to know if this is:

- real change in spectrum (different energy ranges)
- change due to different parts of sky (galactic?)
- still unknown systematic uncertainty

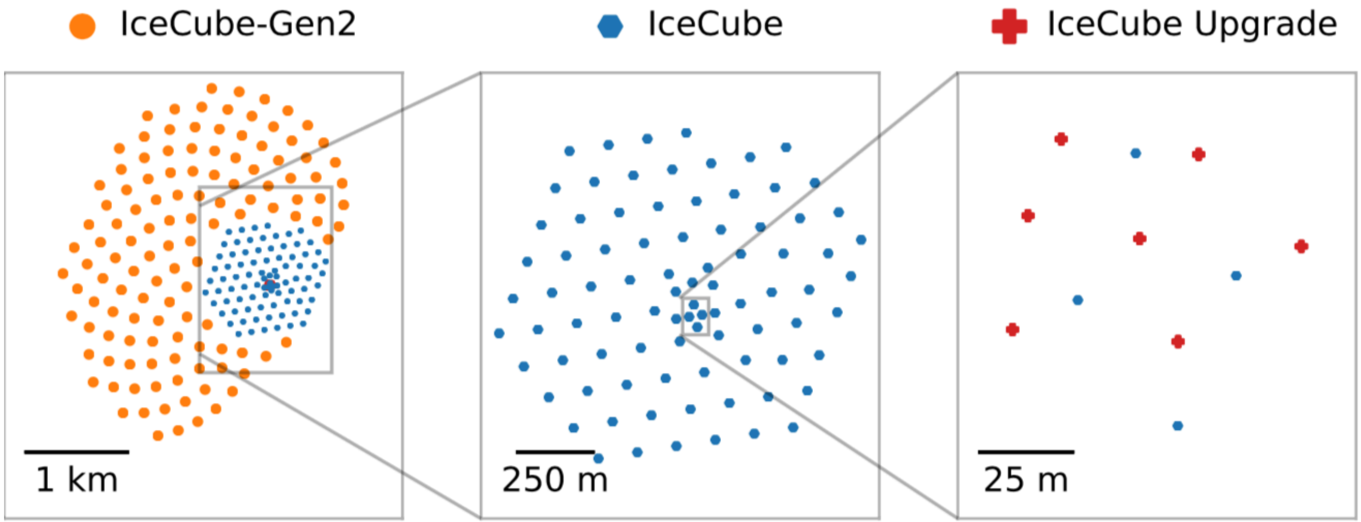


IceCube Future

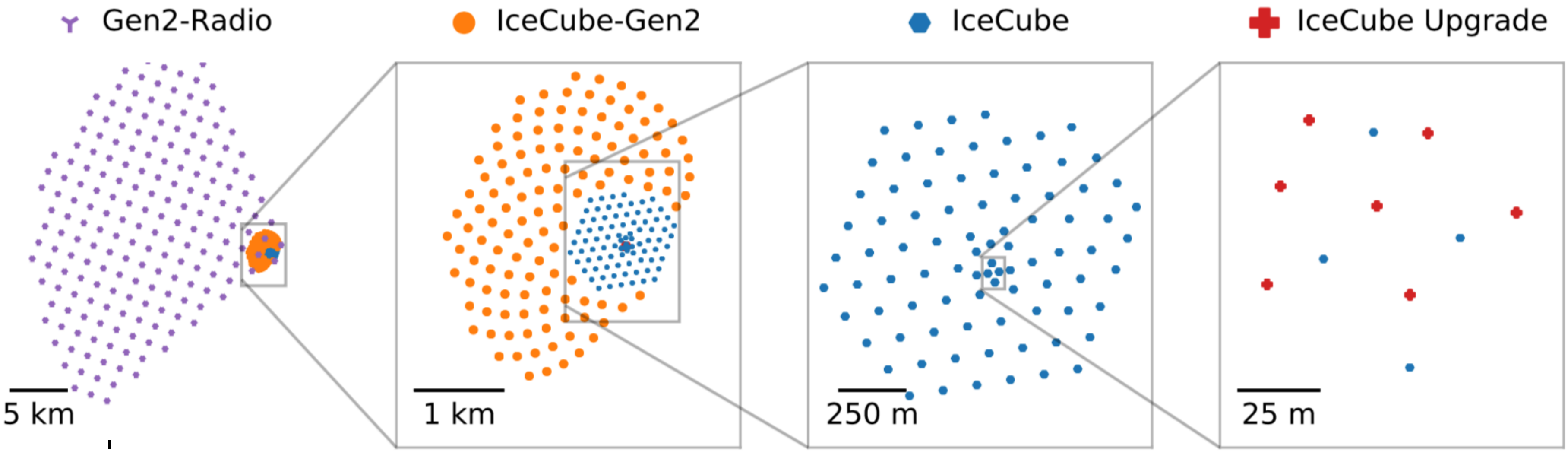


2019 - 2023

IceCube Future



IceCube Future



2033

2011

2023

(First years of data-taking with full detector)

Radio: see next talk

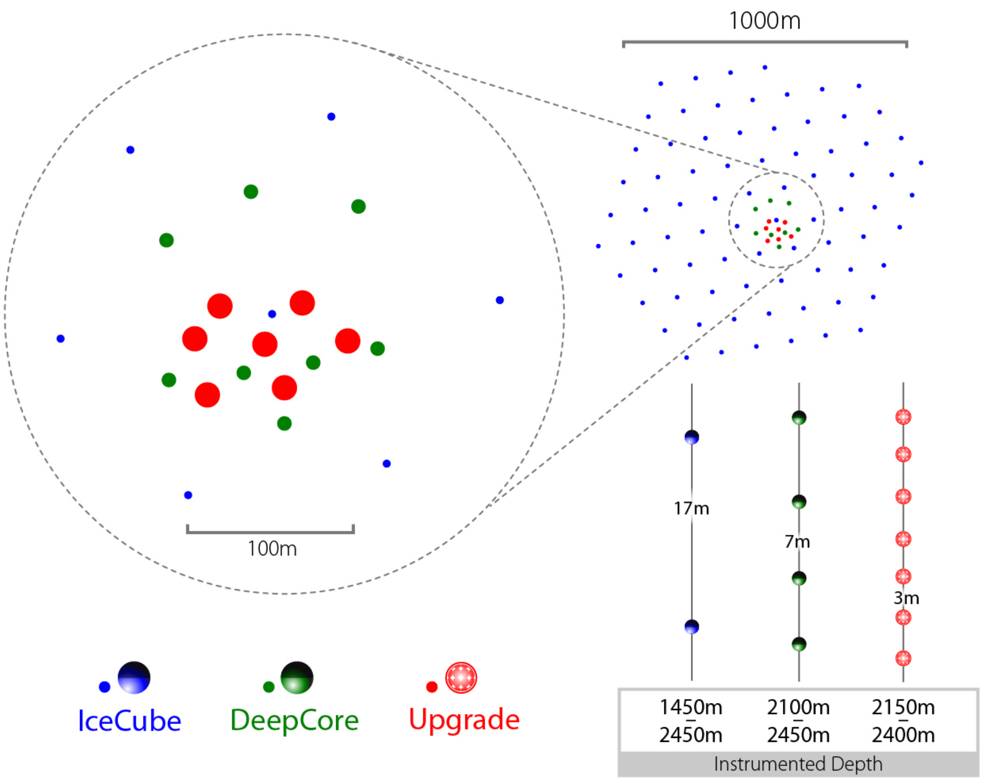
IceCube Upgrade

Next phase in precision astroparticle physics with IceCube

- 7 new strings with 20 m spacing
- 3 m vertical spacing, 90 DOMs / string

Main goals:

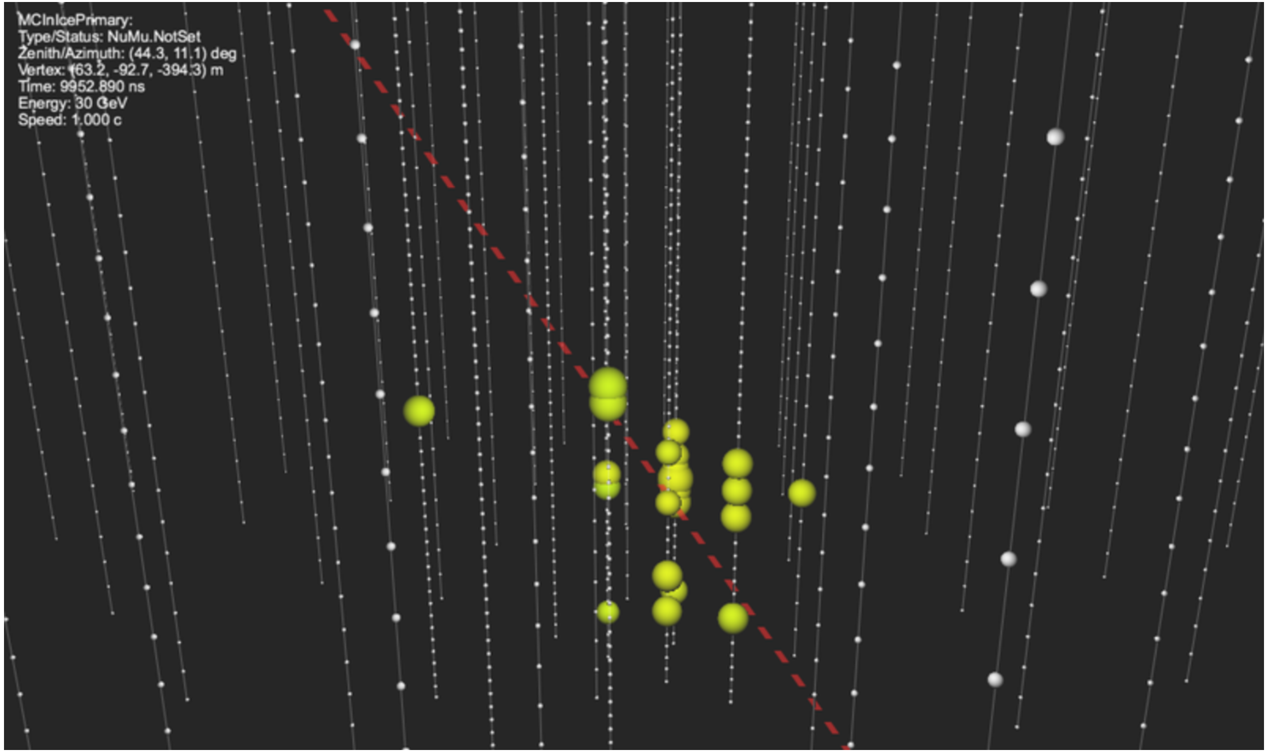
- Neutrino oscillation physics
- Re-calibration of IceCube data at all energies using new calibration devices
- R&D for IceCube-Gen2



More Cherenkov light:

30 GeV muon neutrino interacting in:

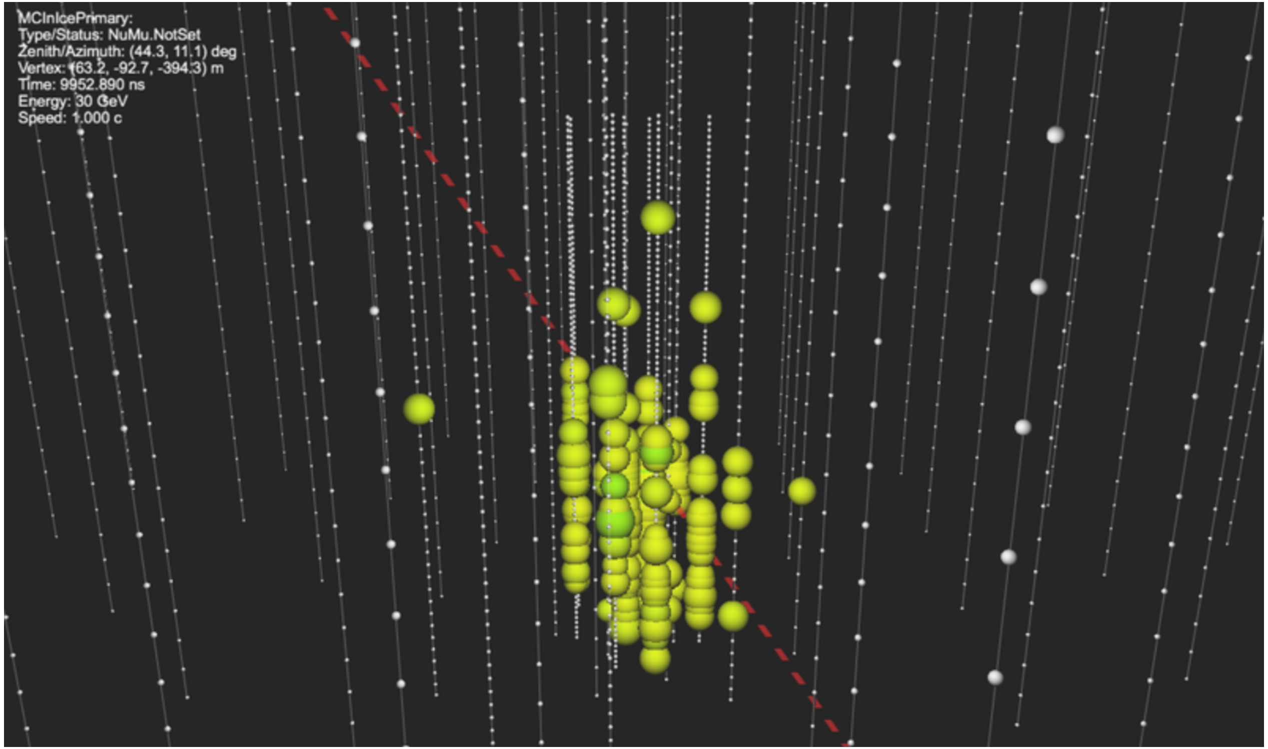
DeepCore



More Cherenkov light:

30 GeV muon neutrino interacting in:

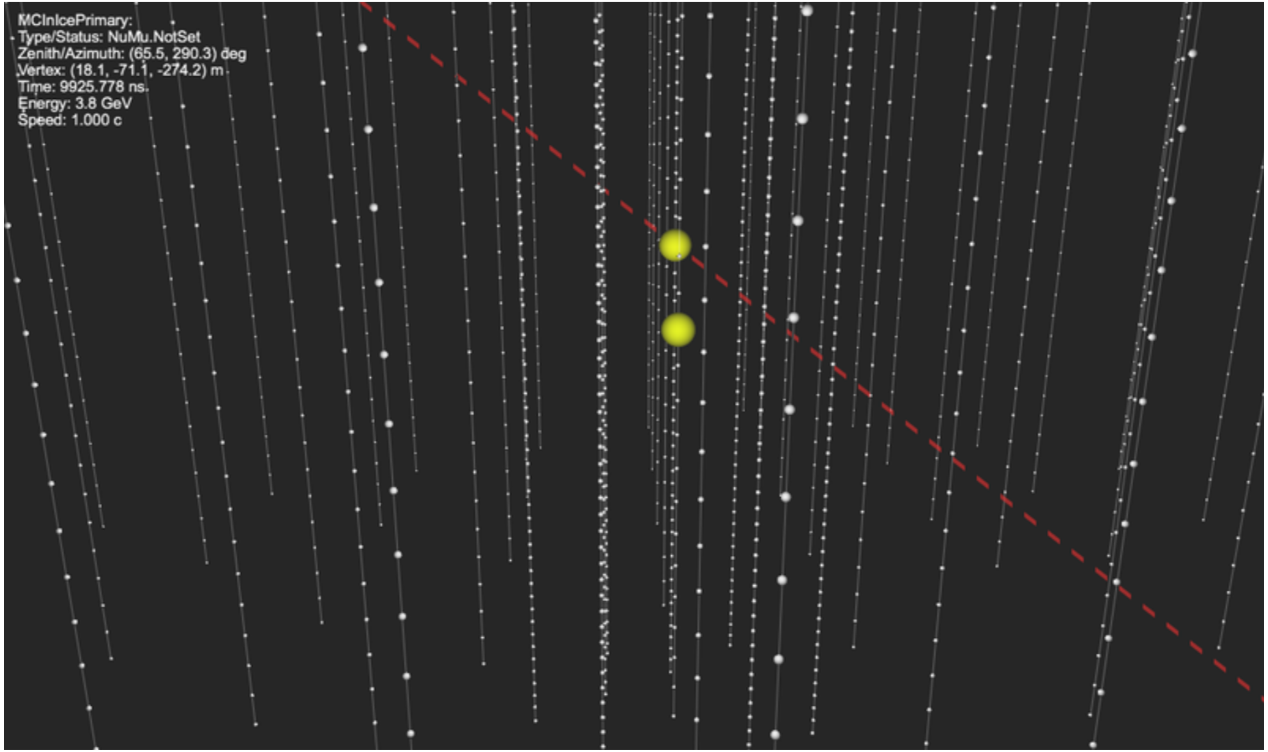
the <u>Upgrade</u>



More Cherenkov light:

3.8 GeV
muon neutrino

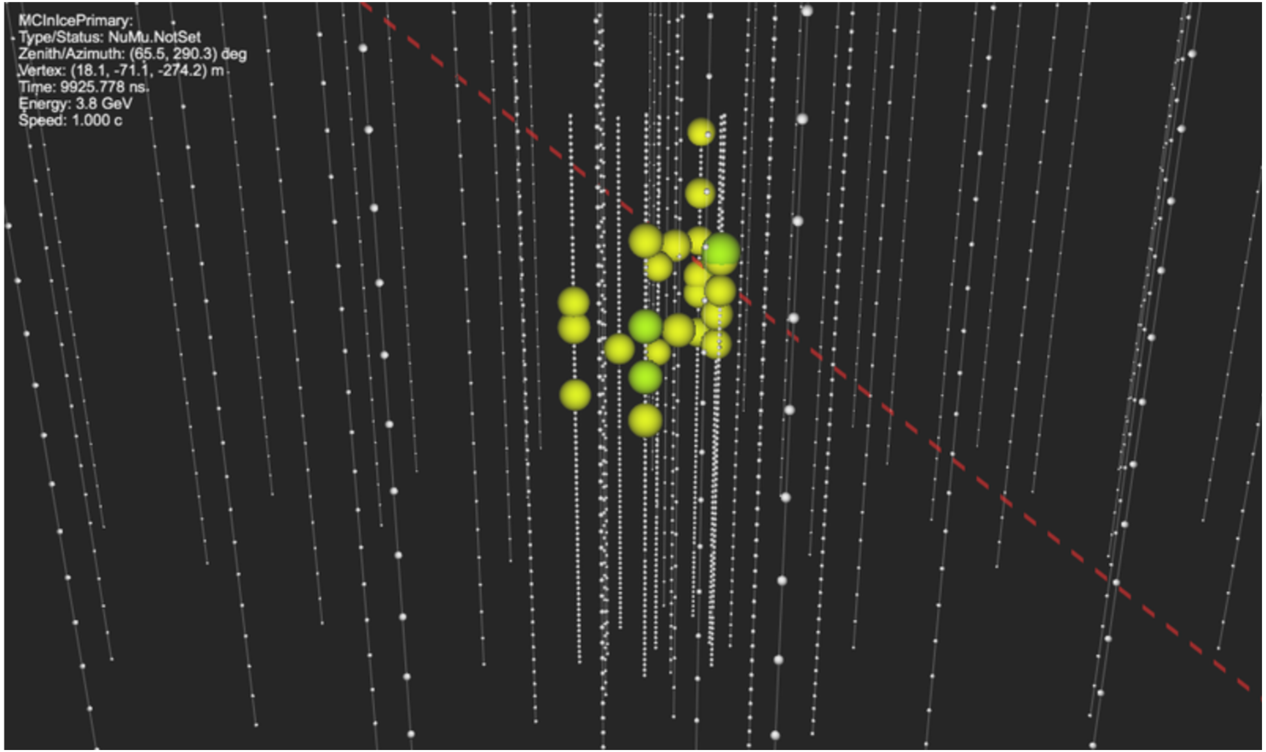
below trigger threshold for DeepCore



More Cherenkov light:

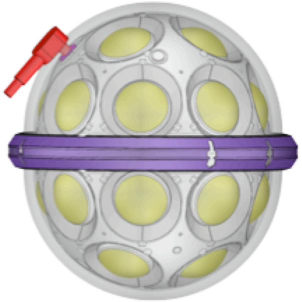
3.8 GeV
muon neutrino

well above threshold and reconstructable with the <u>Upgrade</u>



New Generation of Optical Modules

mDOM
(403 modules)

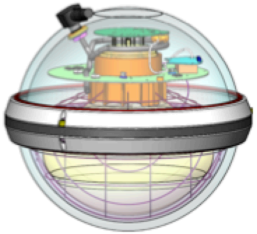


36 cm

D-Egg
(277 modules)

30 cm

PDOM
(14 modules)



33 cm

New sensor designs feature one or more of the following qualities:

- Upgraded electronics
- Smaller diameter
- Increased UV sensitivity
- Larger and/or pixelated effective area

New Calibration Devices

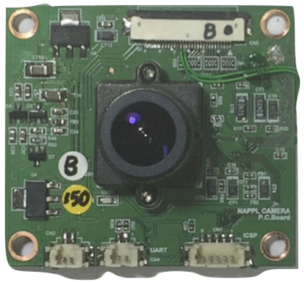
Integrated into all optical modules:
- LED flashers
- Optical cameras

Stand-alone devices:
- Precision Optical Calibration Module
  Steerable sub-ns pulsed LEDs

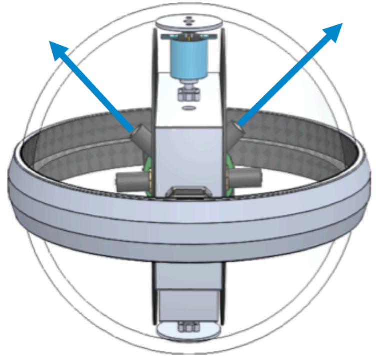
Reduce main systematic uncertainties:
Glacial ice optical properties

Benefits low <u>and</u> high energies

Can reprocess archival data too



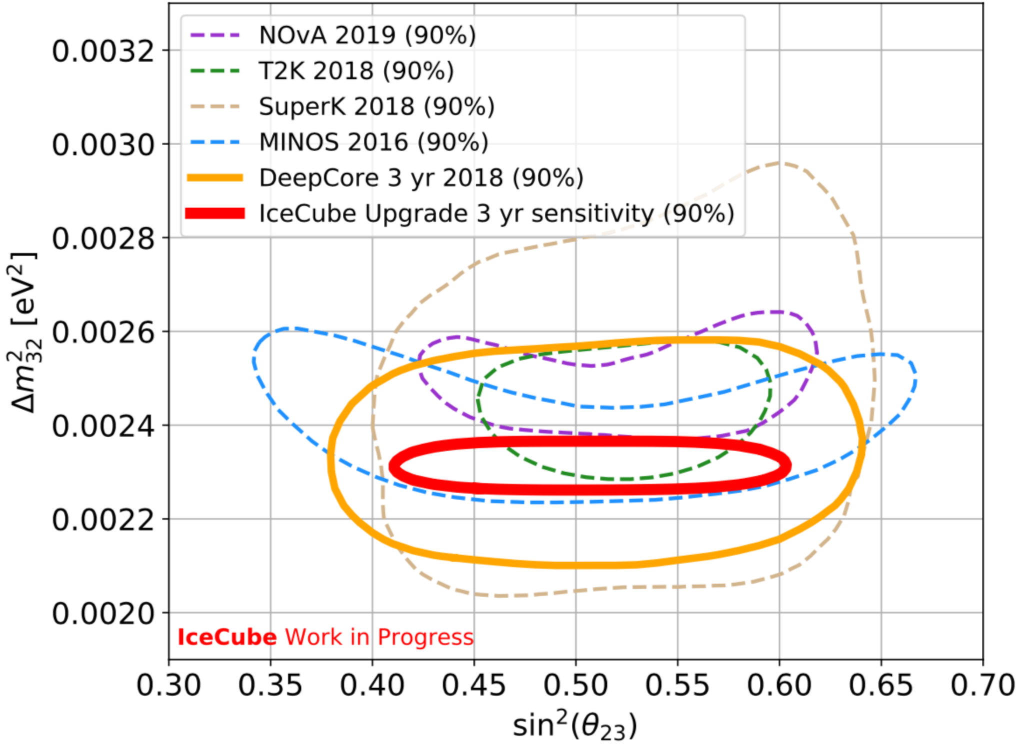
in-module camera



pencil beam

POCAM

Precision ν_μ disappearance measurement



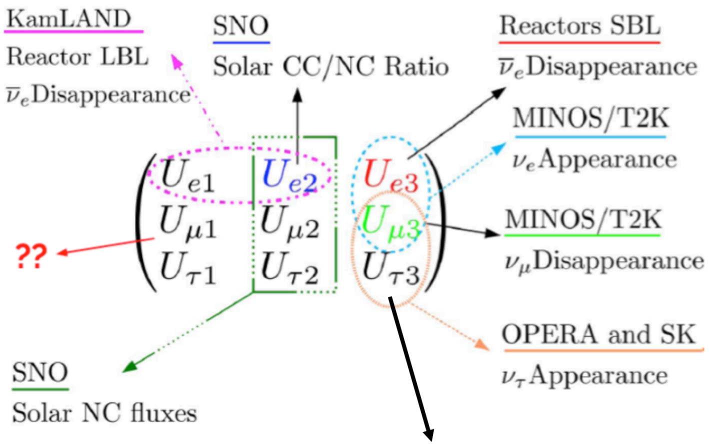
Measurements of $\sin^2 \theta_{23}$ (incl. octant) and Δm^2_{32}

Comparable with results from other neutrino oscillation experiments

Different systematics and different L/E will probed by IceCube-Upgrade

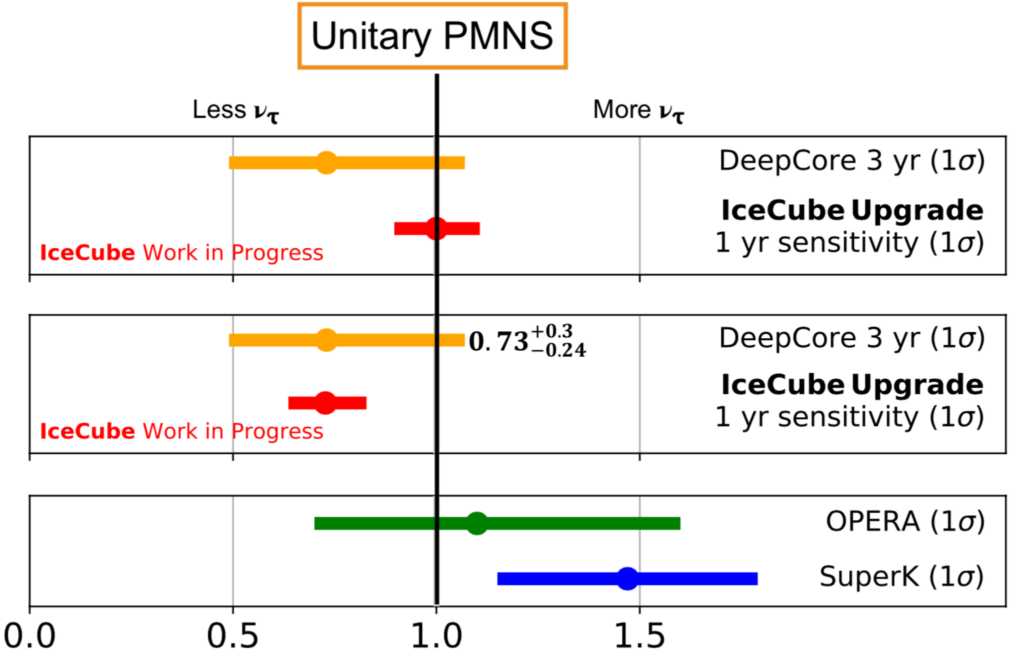
Also: sensitivity to mass ordering via combined fit with JUNO data.

Precision ν_τ appearance measurement: Testing unitarity of PMNS matrix



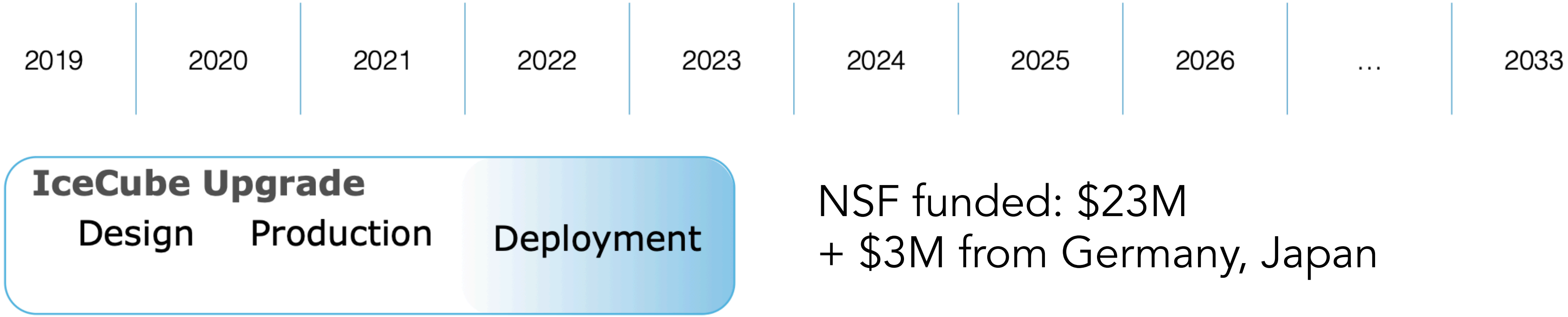
Parke et al. 2016

least constrained element targeted directly with IC Upgrade



Can achieve 10% ν_τ appearance precision after 1 year of data taking

Status and Timeline



NSF funded: $23M
+ $3M from Germany, Japan

Status and Timeline

2019	2020	2021	2022	2023	2024	2025	2026	...	2033

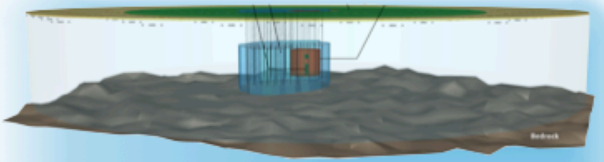
IceCube Upgrade

Design — Production — Deployment

NSF funded: $23M
+ $3M from Germany, Japan

IceCube-Gen2

R&D — Design & Approval — Production — Deployment



IceCube Gen2: Next Generation Neutrino Astronomy

Characterization
of the cosmic neutrino flux,
up to ultrahigh energies

Multimessenger astronomy:
complementary messenger
to photons, probing higher
energy range