The IceCube Upgrade

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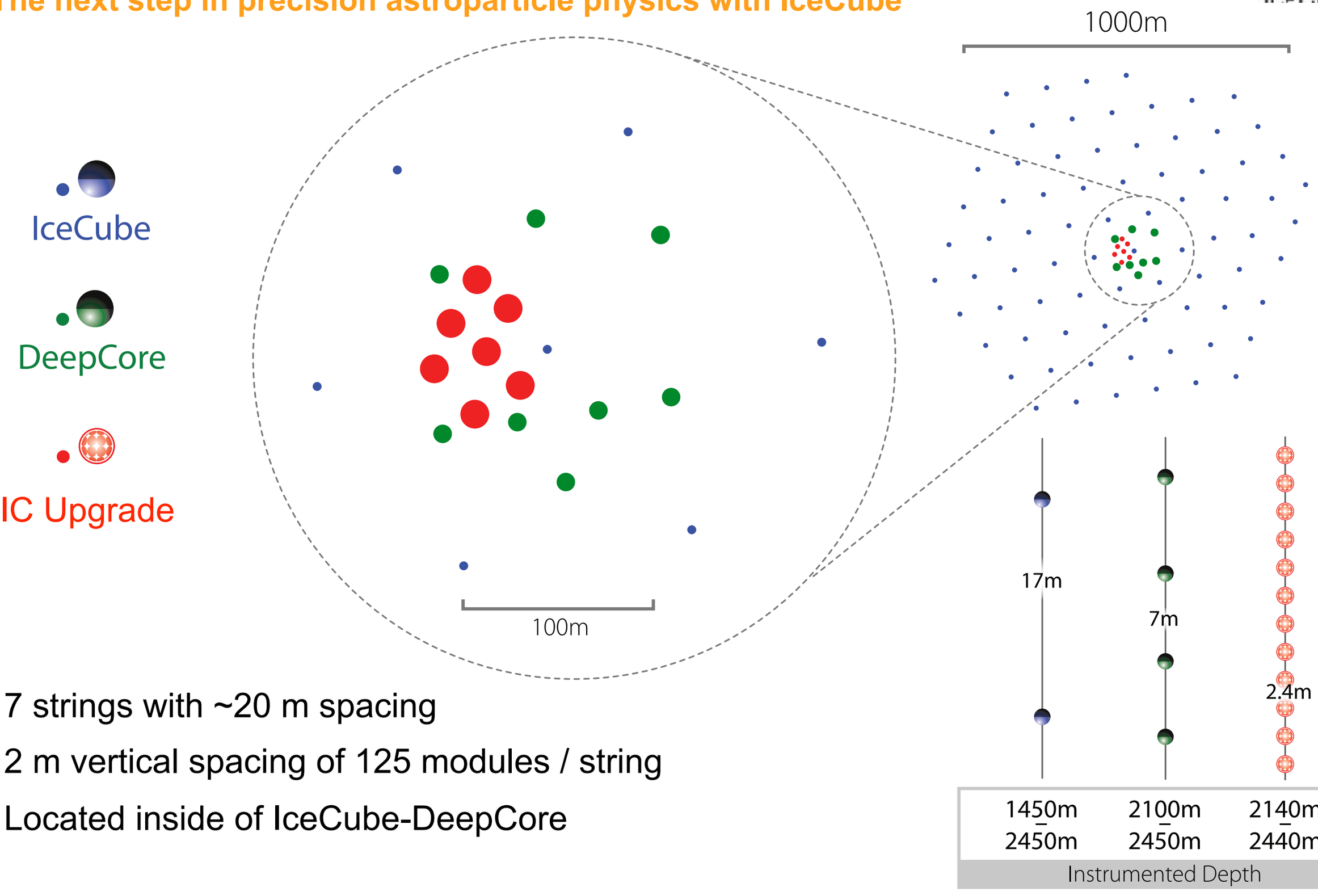
DESY & Humboldt-University
Zeuthen-Meeting in Mainz
September 2018

South Pole 2009

The IceCube Upgrade

The next step in precision astroparticle physics with IceCube

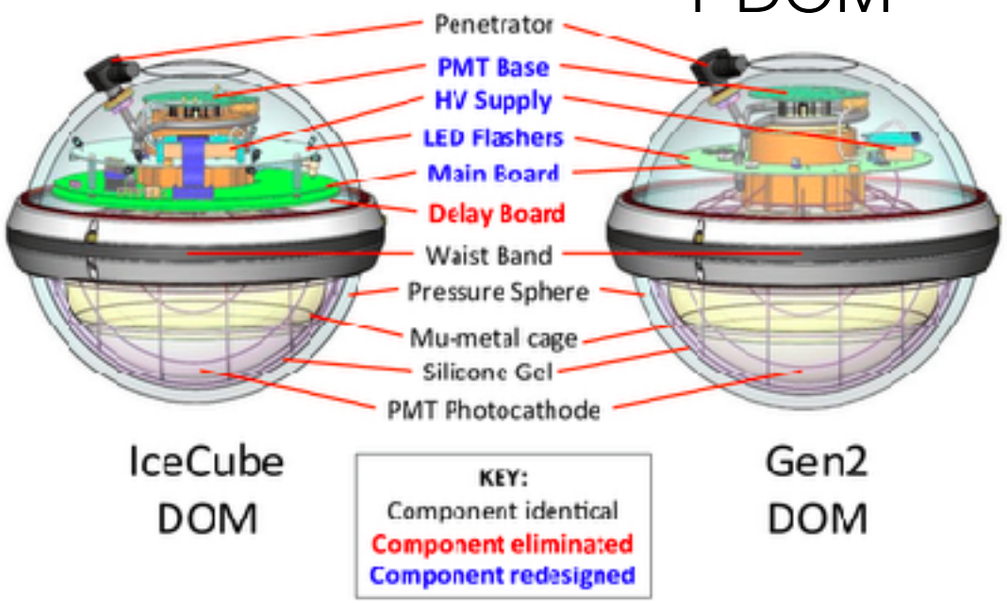


- 7 strings with ~20 m spacing
- 2 m vertical spacing of 125 modules / string
- Located inside of IceCube-DeepCore

The IceCube Upgrade - Sensors

R&D towards a new generation of optical modules

PDOM



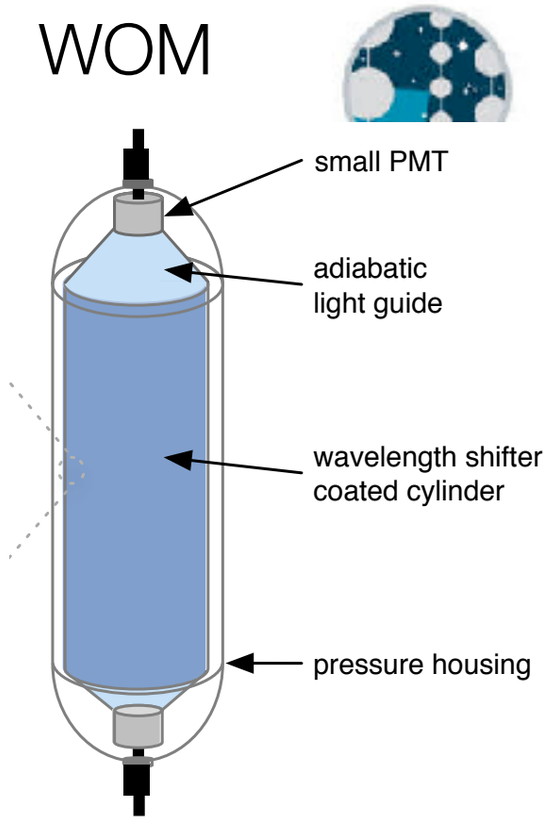
D-Egg

30 cm

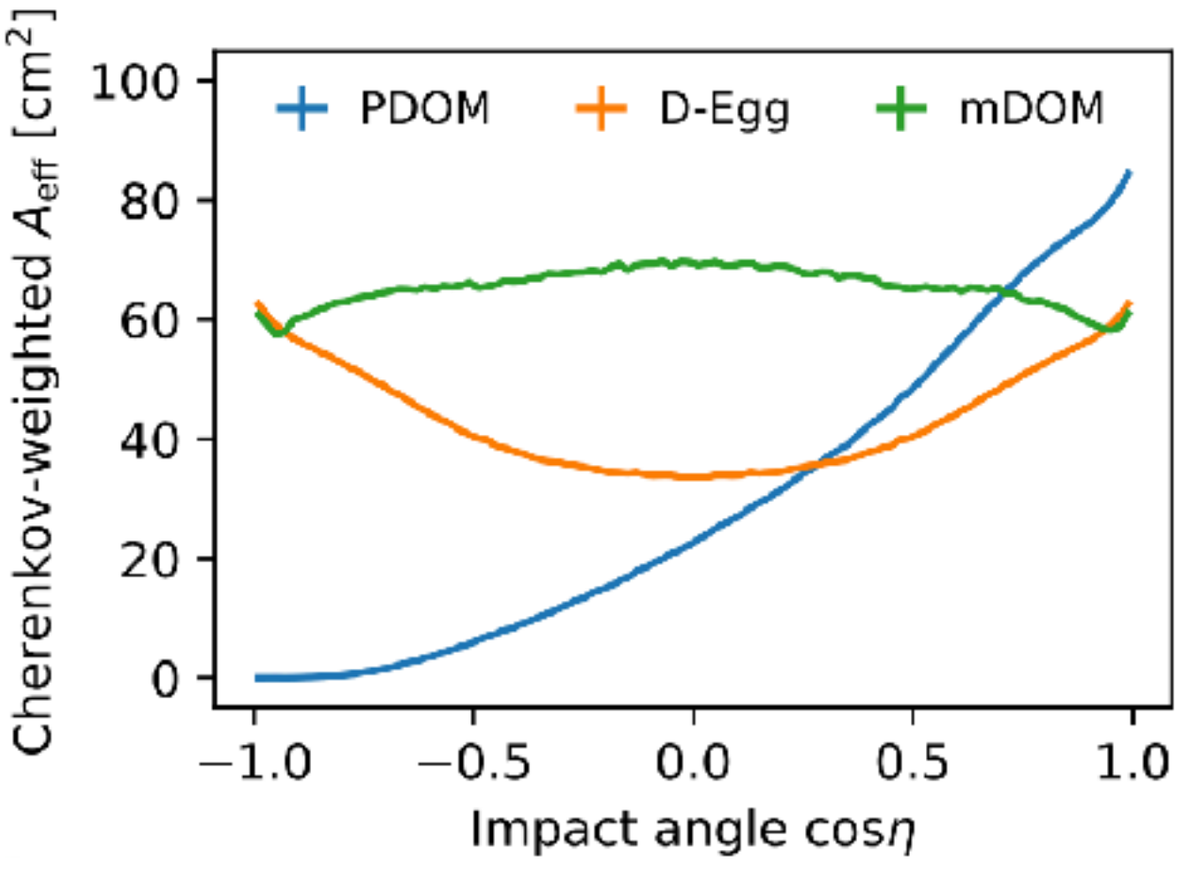
mDOM

36 cm

WOM



11 cm



New sensor designs will incorporate one or more of the following:

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

The IceCube Upgrade - Sensors

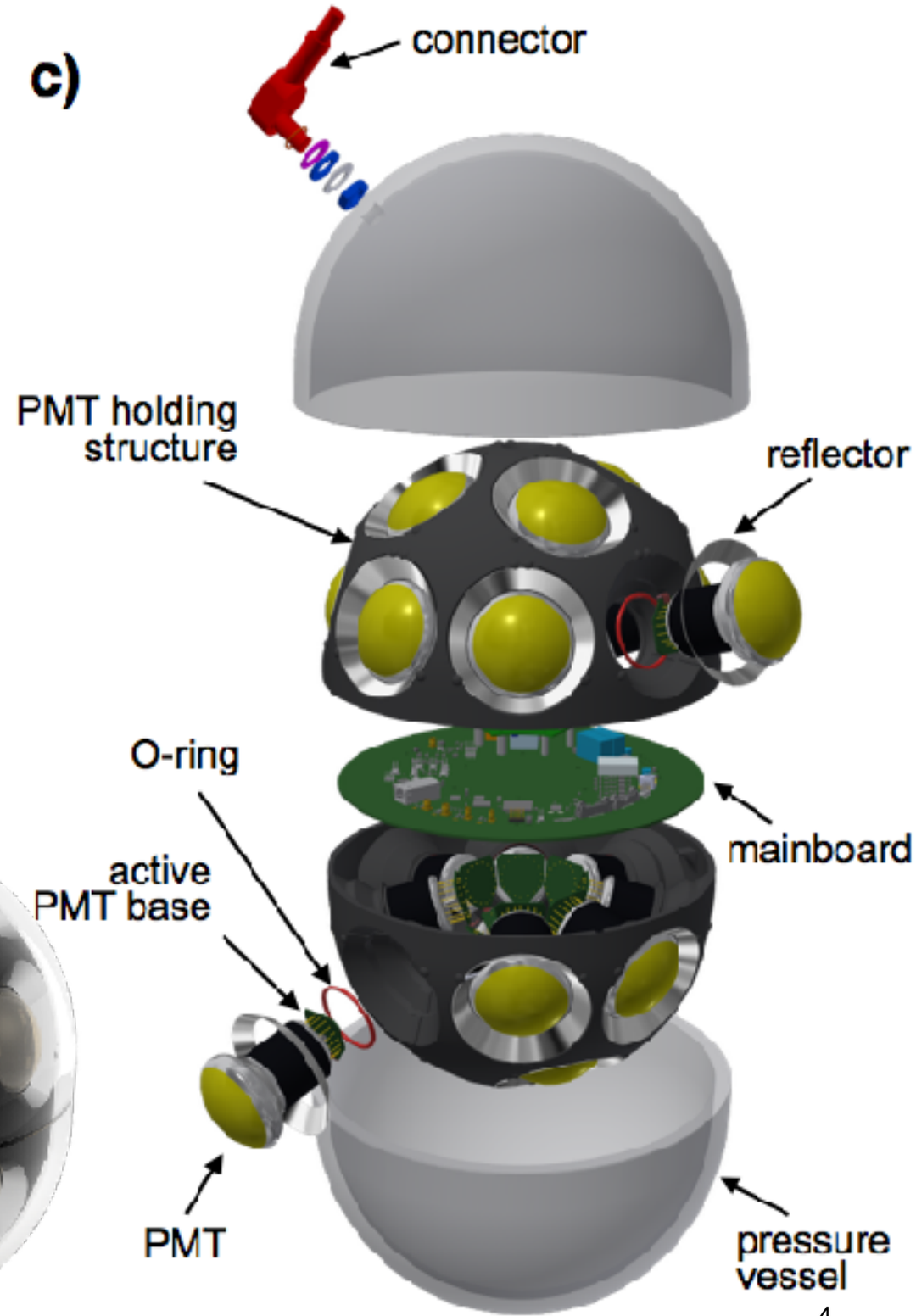
mDOM: multi-PMT DOM

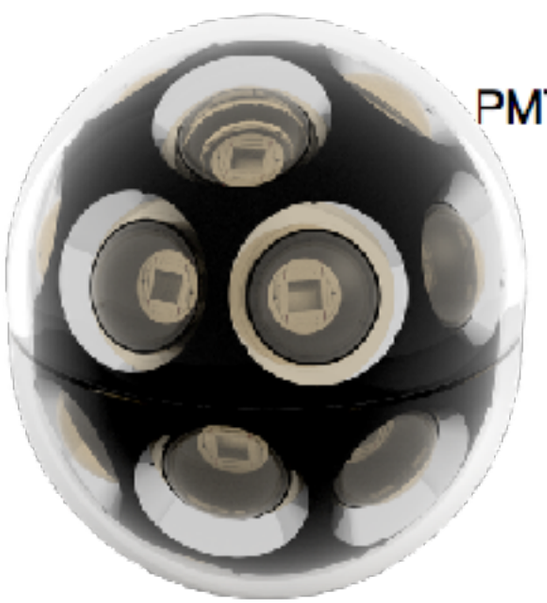
4 of 7 strings equipped with mDOMs

- Adapted from KM3NeT mDOM
- Smaller diameter: 14 inch
- 24 × 3-inch PMTs
- New electronics for cold conditions, reduced power, full waveforms

Features

- Doubled effective area rel. IceCube DOM
- Uniform 4π sr effective area
- Local coincidences (e.g. bkg. suppression)
- Directional sensitivity
- Improved photon counting





The IceCube Upgrade - Calibration

Deployment of new devices at better distances

Integrated devices

- LED flashers
- Acoustic sensors
- Optical cameras

Stand-alone light sources

- Precision Optical Calibration Module (POCAM)
- “Movable” sub-ns pulsed LEDs with small opening angle

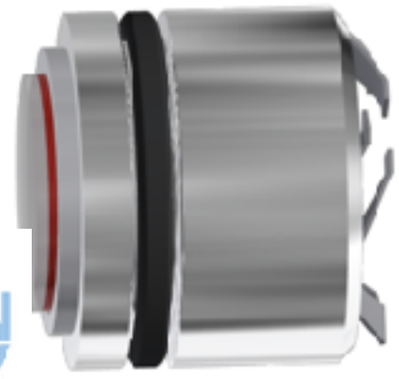
Reduce primary systematic uncertainties

- Better calibration of new and existing sensors
- Improved knowledge of glacial ice

POCAM[3]

TECHNISCHE UNIVERSITÄT MÜNCHEN

Piezo-module[1]



RWTH AACHEN UNIVERSITY

CCD[2]

[1] https://doi.org/10.1051/epjconf/201713506003

[2] https://doi.org/10.22323/1.301.1040

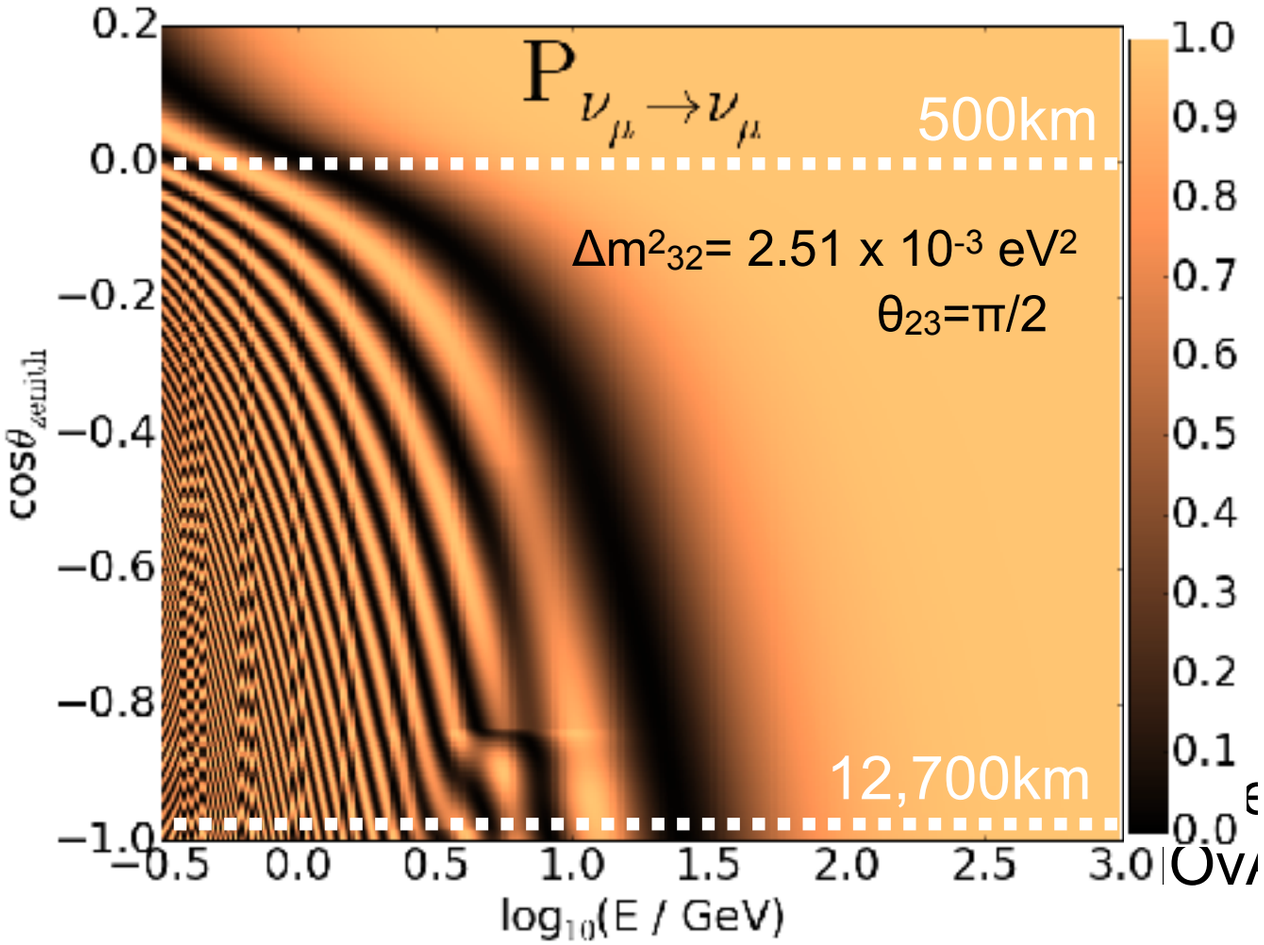
[3] https://doi.org/10.22323/1.301.0934

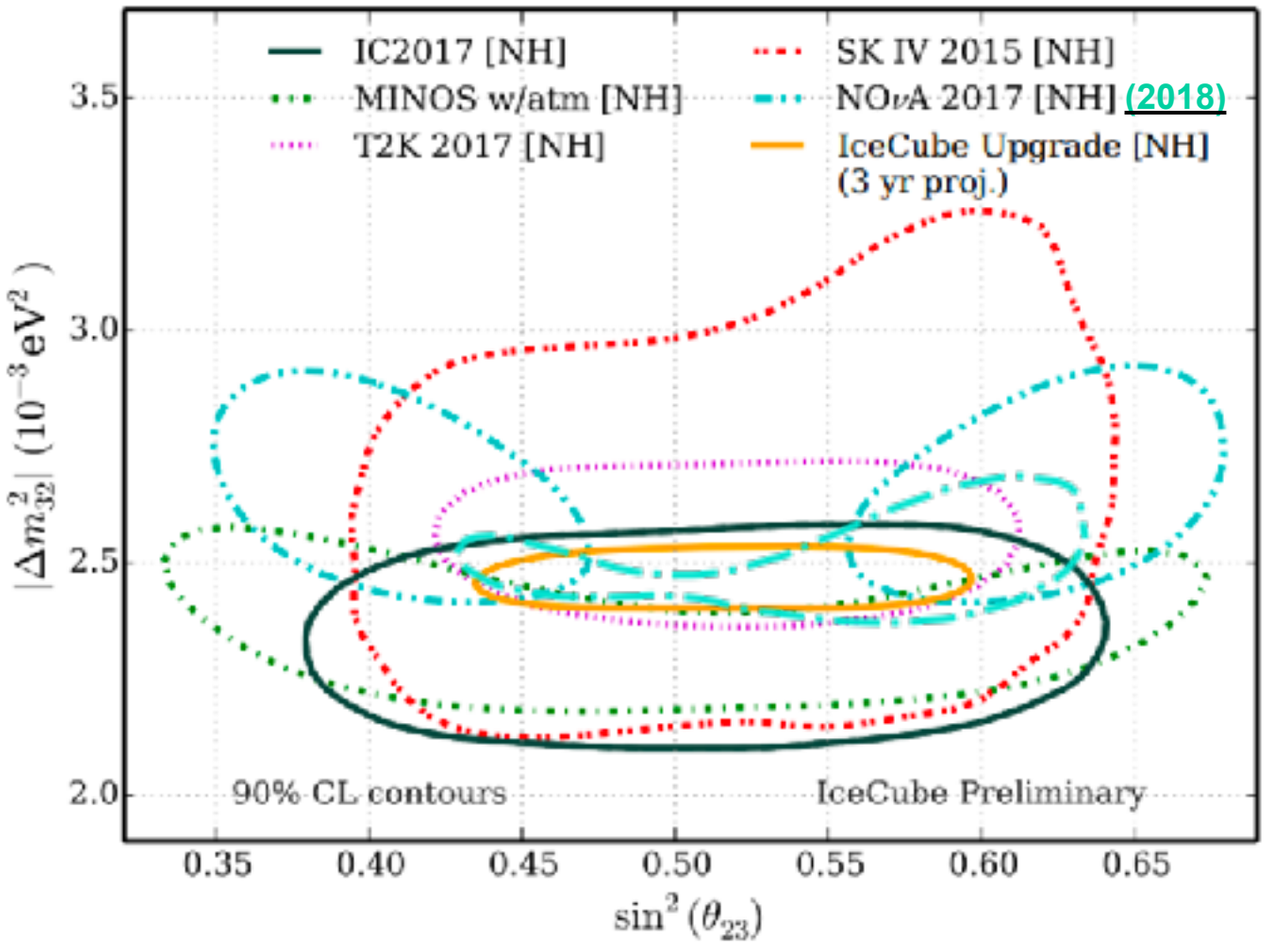
The IceCube Upgrade - Science

Precision atmospheric oscillation measurements

Similar physics program to DeepCore, just better!

- Oscillations, non-standard interactions, sterile neutrinos, dark matter…





- Enable atmos. mixing param. measurements with precision competitive with projected final T2K/NOvA results, but different systematics and energy range

The IceCube Upgrade - Science

Precision atmospheric oscillation measurements

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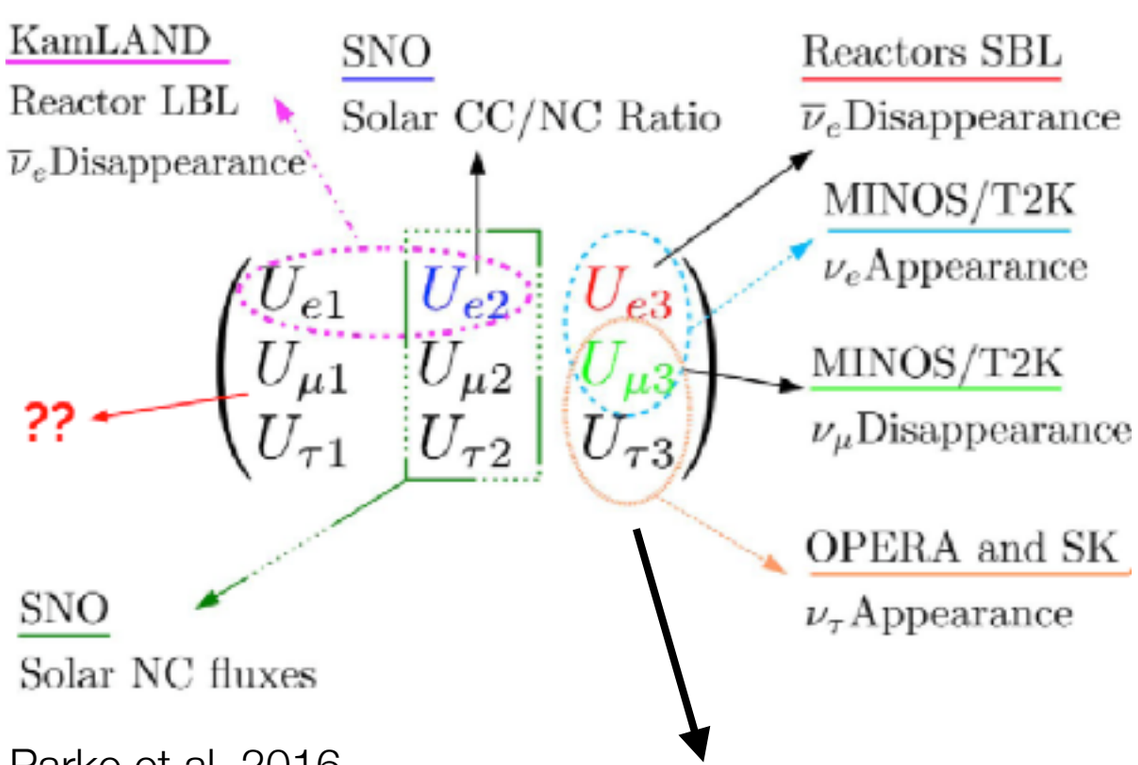
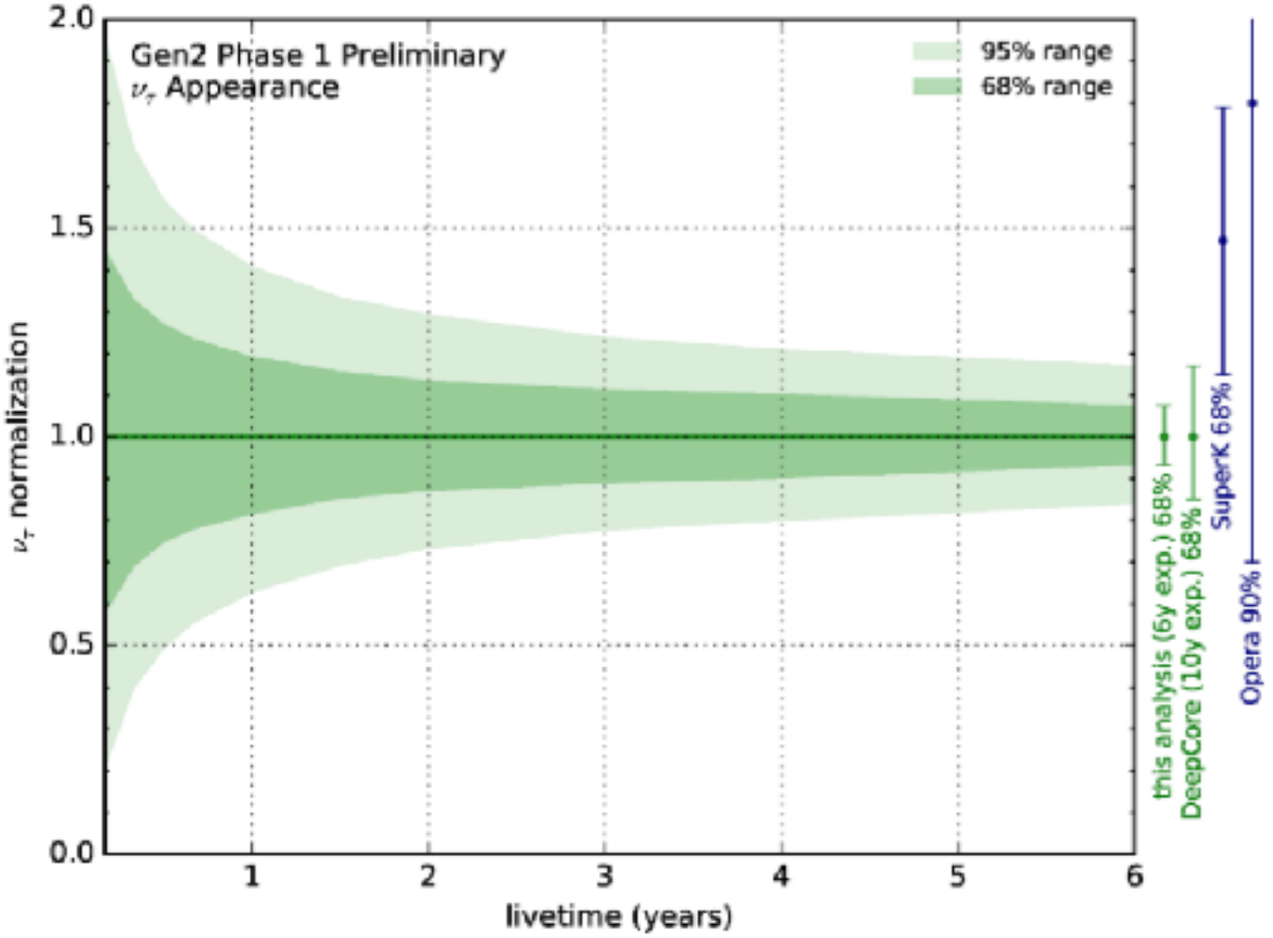


Parke et al. 2016

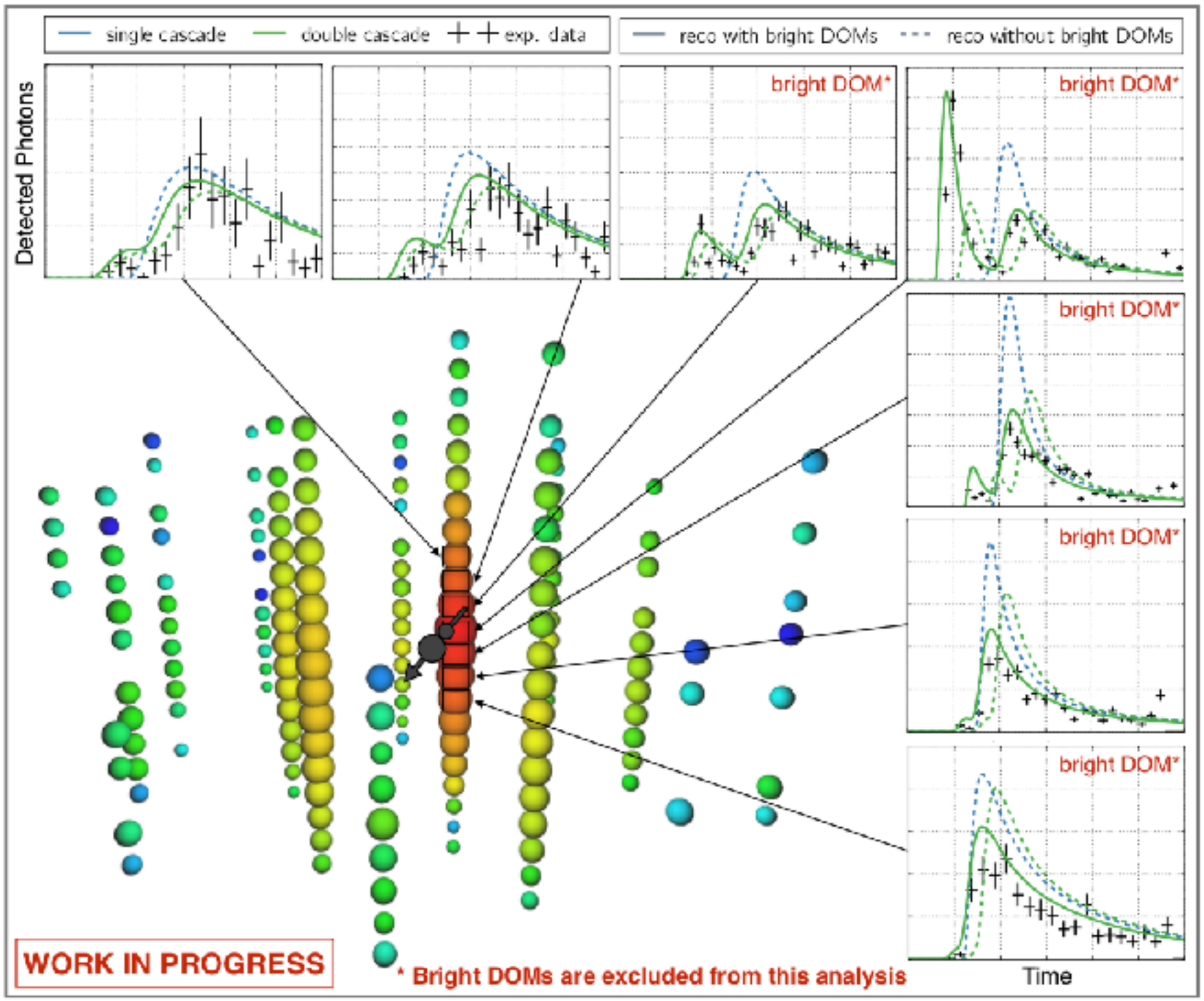


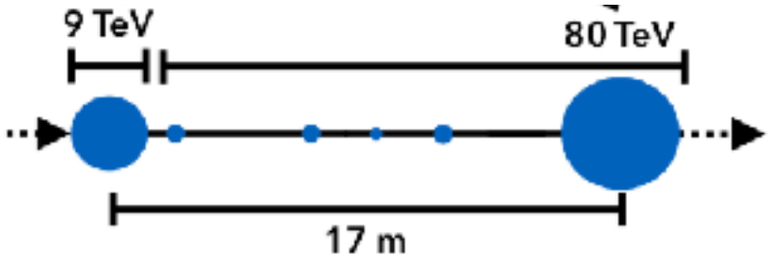
poorest constrained element
targeted directly with IC Upgrade

- World best constraints on tau appearance / Unitarity triangle

Recap: High-Energy Tau Neutrino Candidate

One of two events in the HESE 7.5 year identified by tau neutrino search





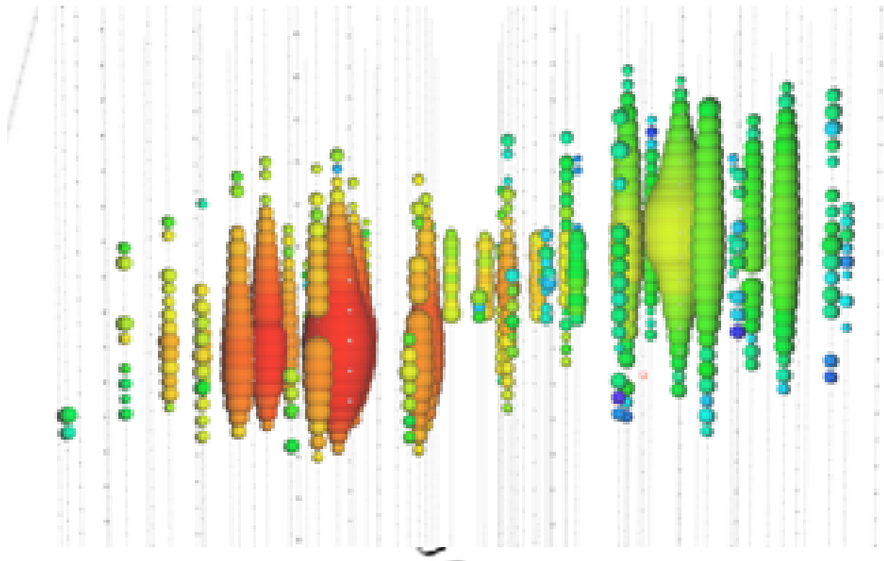
- observed light arrival pattern clearly favors double cascade hypothesis

Stachurska et al, Neutrino 2018

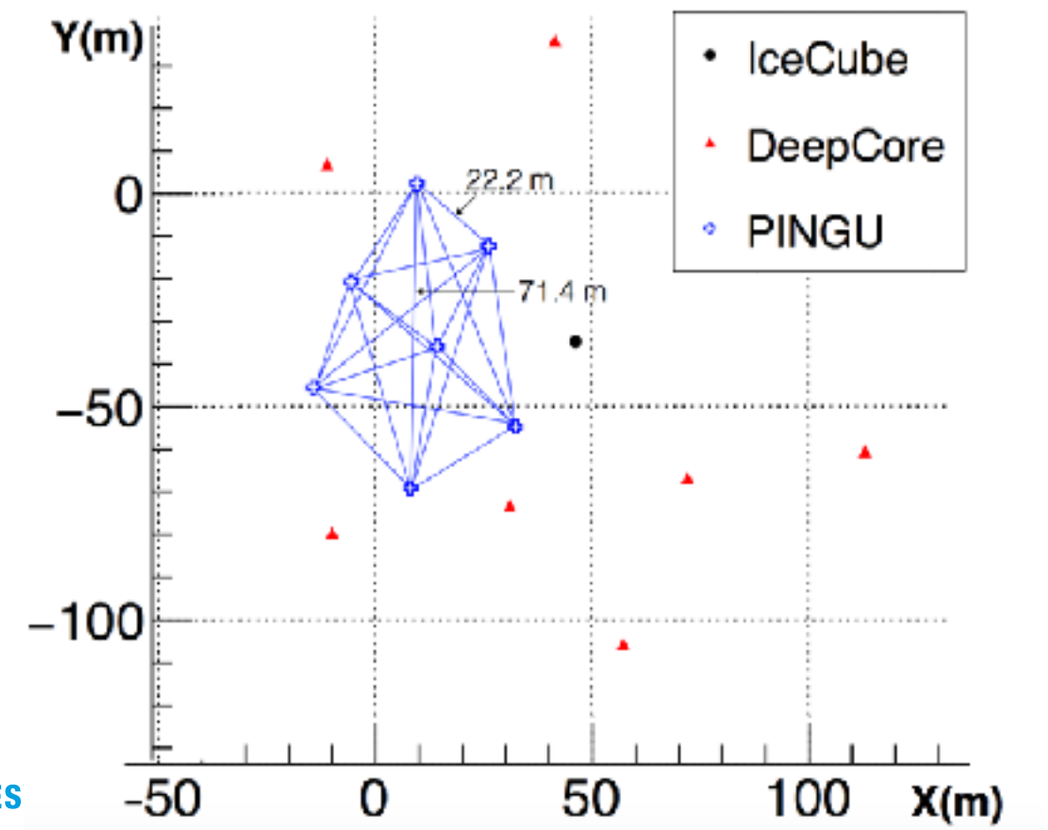
The IceCube Upgrade - Science

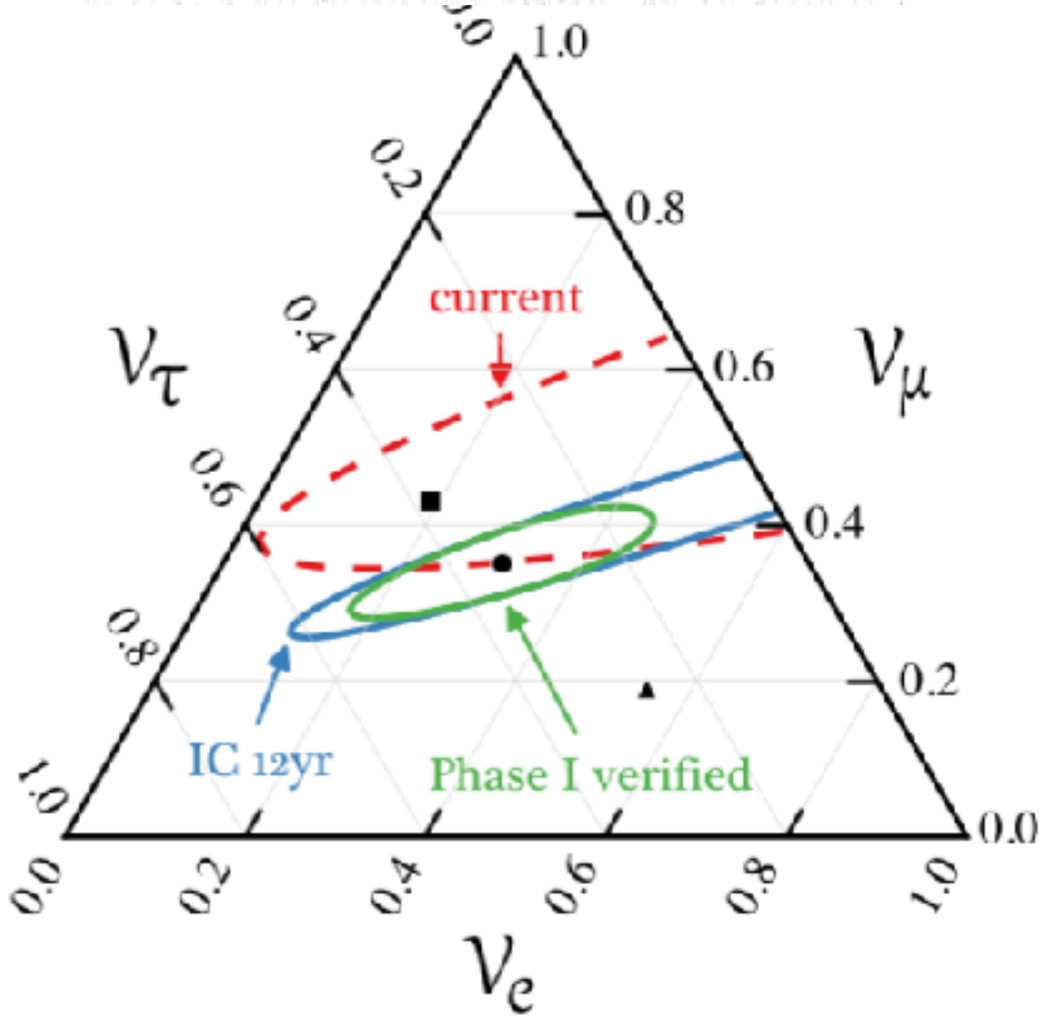
New calibration devices inside IceCube enhance HE science

- better control of systematics
- applicable to all IceCube data



IceCube Upgrade permits to generate double cascades with baselines of ~20 m

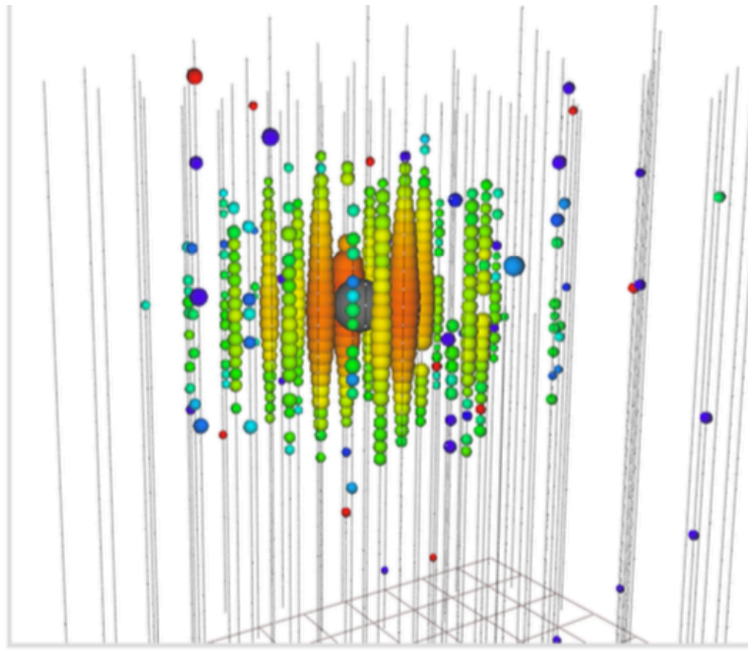


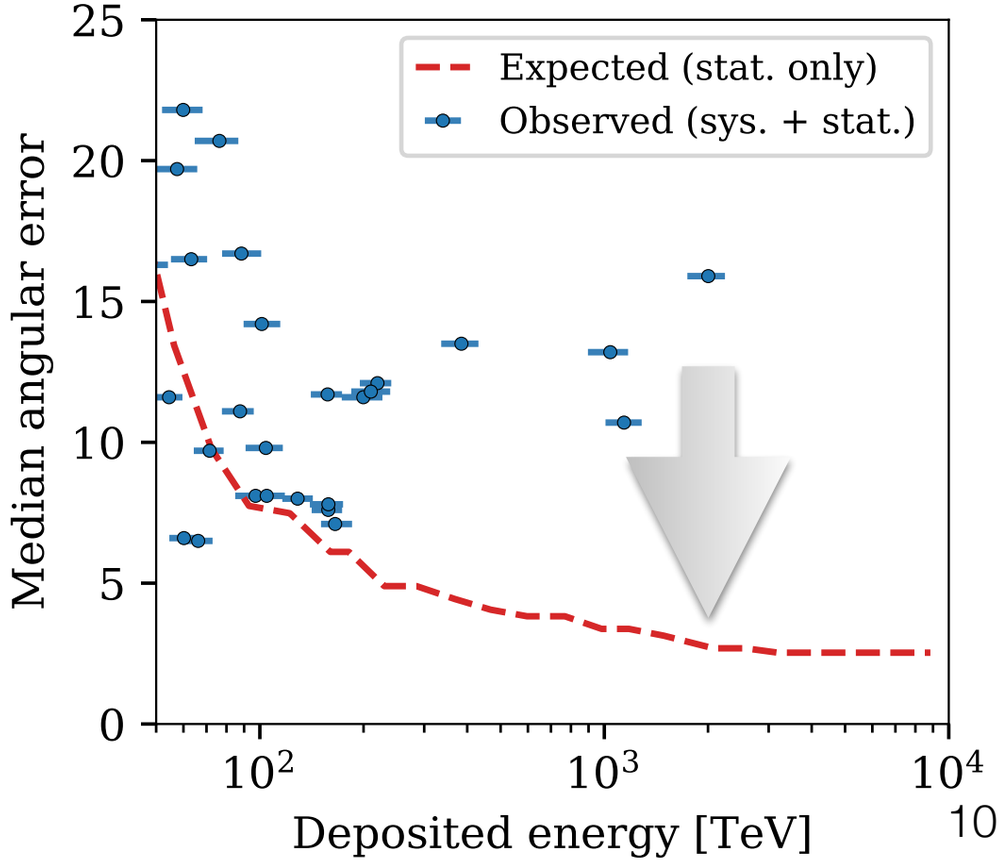


The IceCube Upgrade - Science

New calibration devices inside IceCube enhance HE science

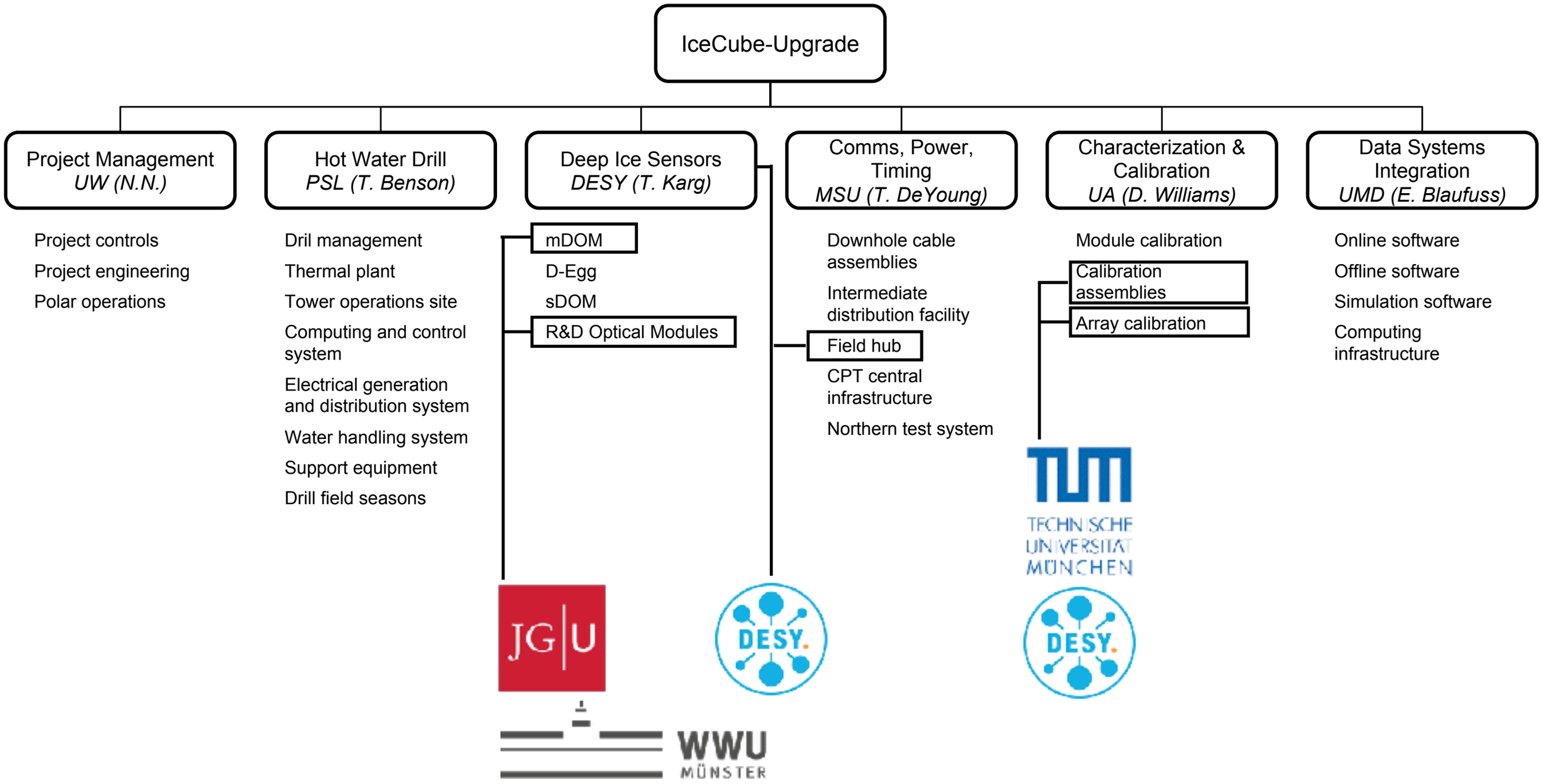
- better control of systematics
- applicable to all IceCube data
- improved reconstruction





IceCube Upgrade Project Organisation

Work Breakdown Structure



Funding

and major budget items

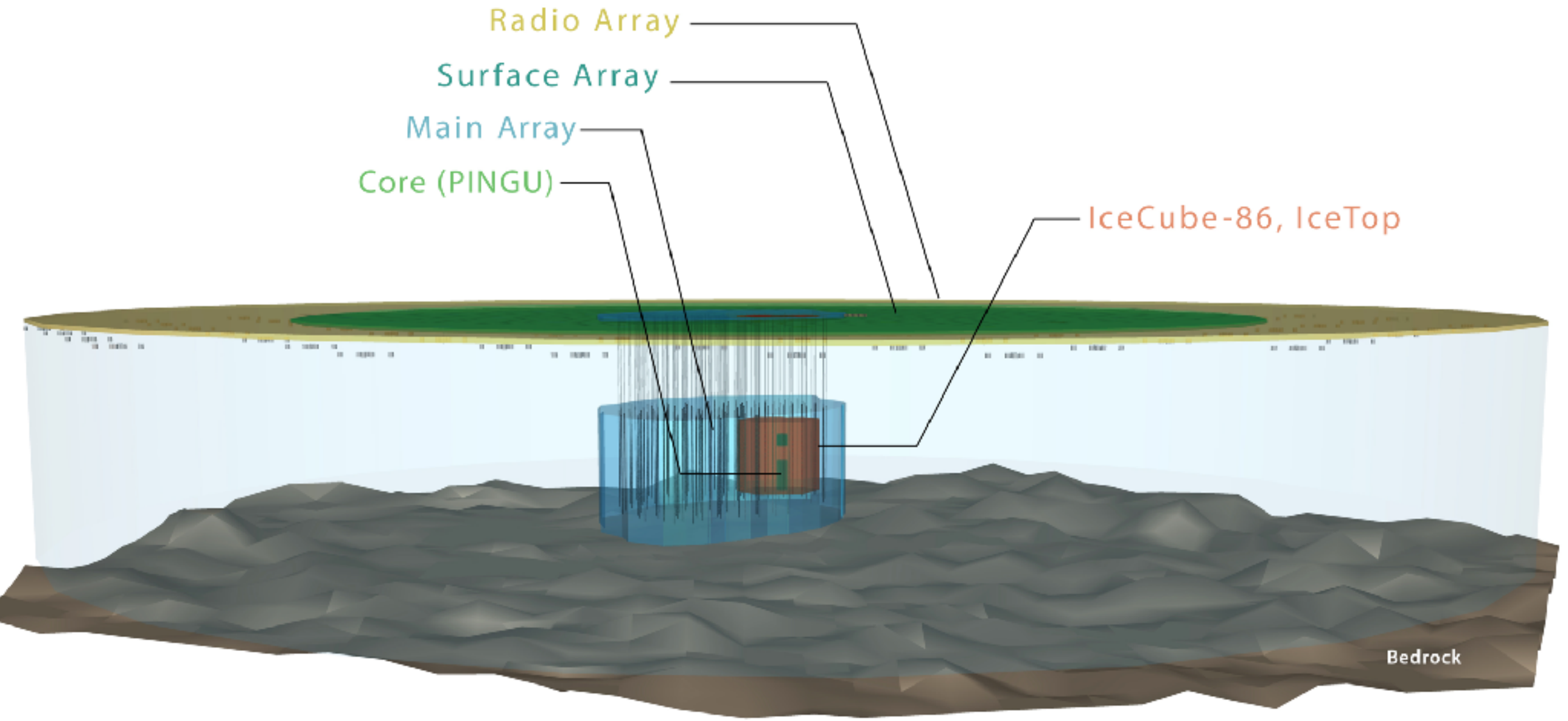
NSF	23 M	Drill
Japan	2.4 M$	d-Egg
Germany	5.3 M$	mDOM
MSU	3.4 M$	mDOM

1 string capital equipment (from proposal):
sensors: 1.2 m$
cable: 260 k$

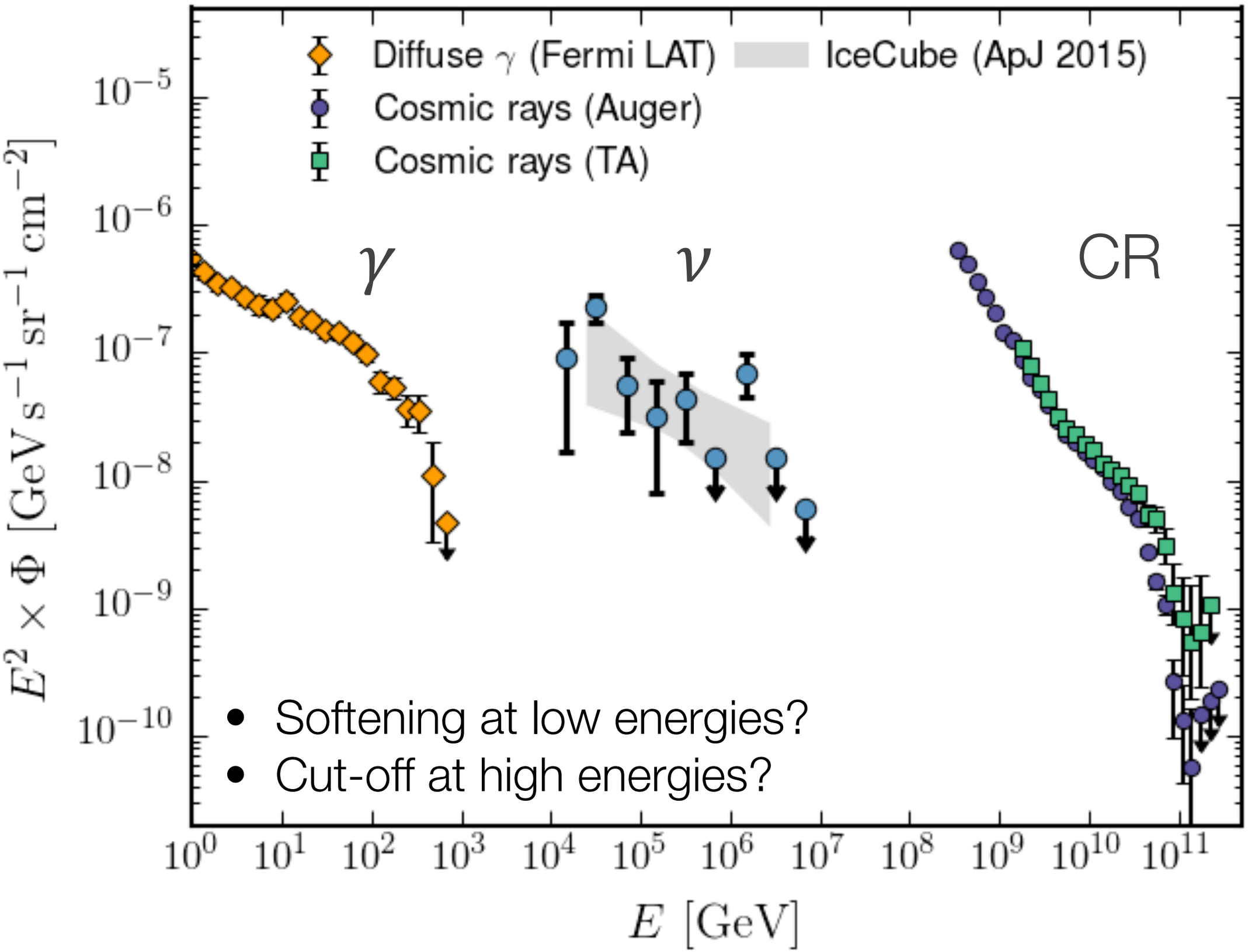
- Start-up funding was approved this month, full NSF funds after technical review in spring 2019
- NSF requests to add 15% contingency while staying in budget => reduce string instrumentation in case of no extra funding

IceCube-Gen2 Facility

A wide band neutrino observatory (MeV – EeV) using several detection technologies – optical, radio, and surface veto – to maximize the science

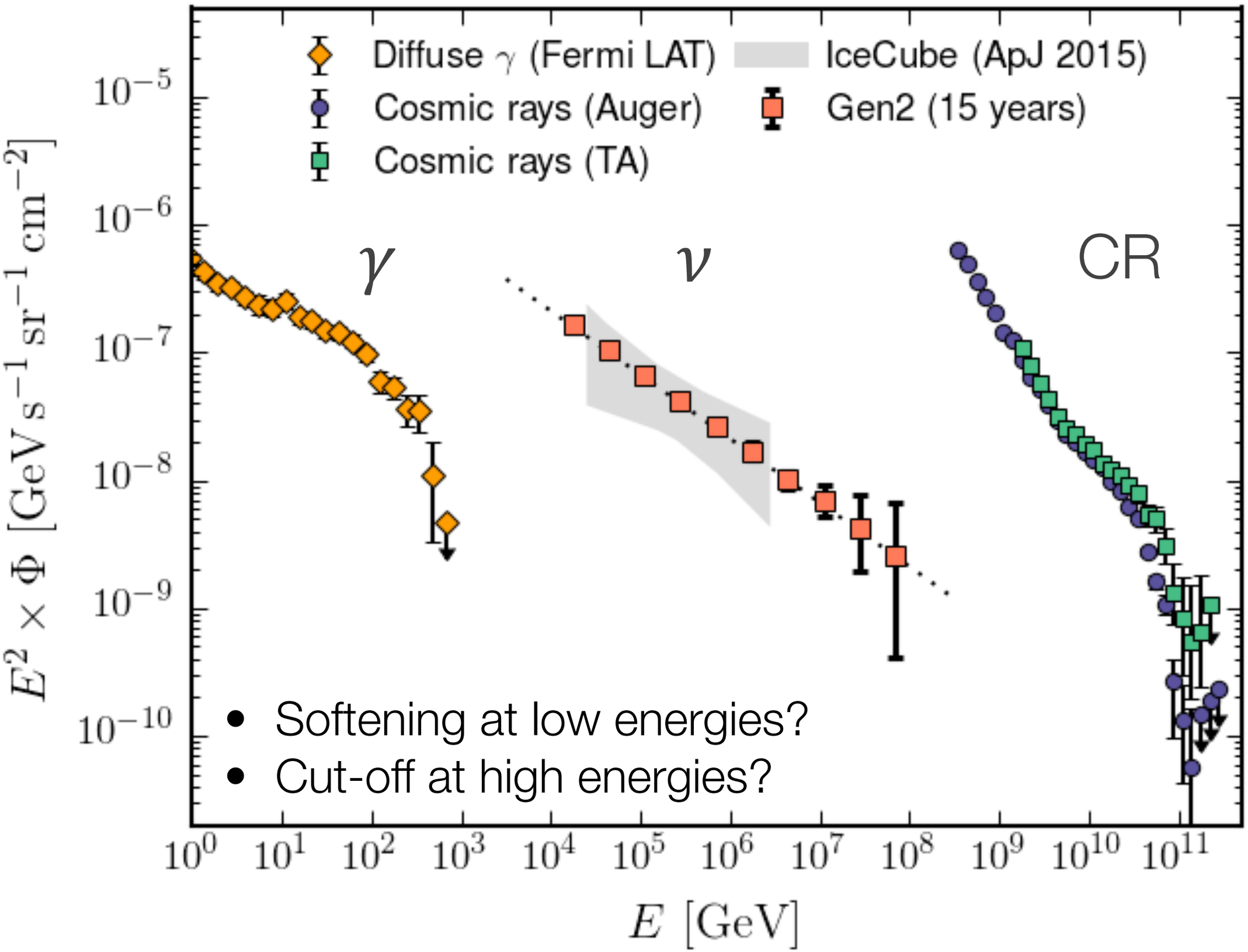


Gen2 example: The cosmic neutrino spectrum



- Softening at low energies?
- Cut-off at high energies?

Gen2 example: The cosmic neutrino spectrum



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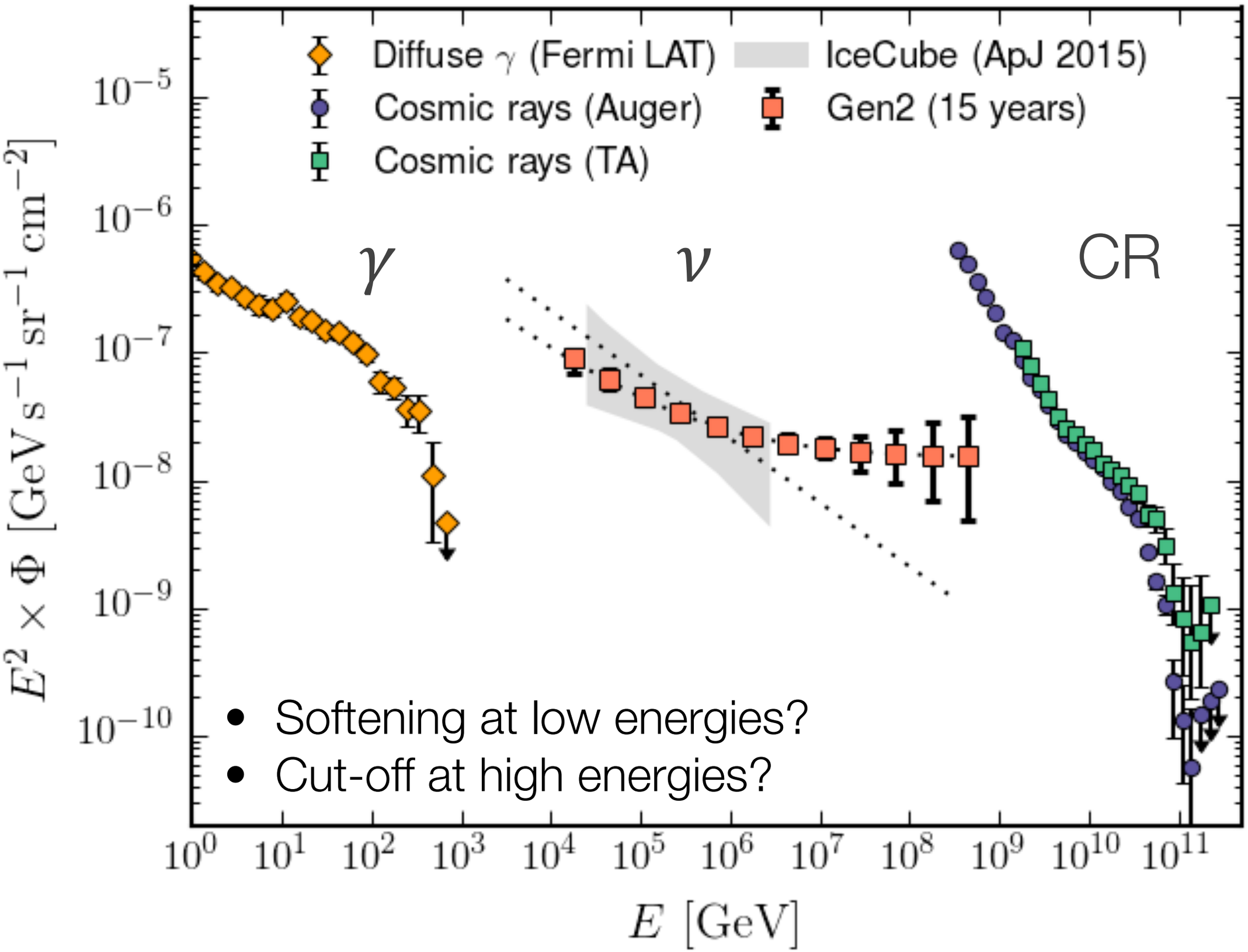
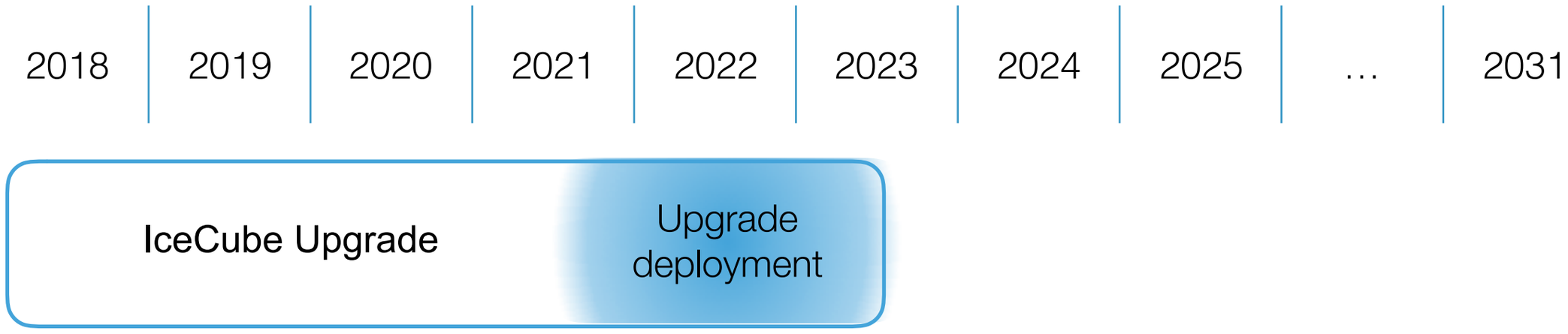


Timeline


2018
2019
2020
2021
2022
2023
2024
2025
…
2031
IceCube Upgrade
Upgrade deployment


R&D
Design & Approval
Production
Deployment

Conclusions

IceCube Upgrade / Gen2 Phase-I

- IceCube Upgrade: an IceCube infill array now approved
- New sensors and calibration devices, incorporating lessons learned from a decade of IceCube efforts
- Enhance IceCube's scientific of capabilities at both high and low energy
- New drill and new generation of sensors:
  An essential step towards IceCube-Gen2