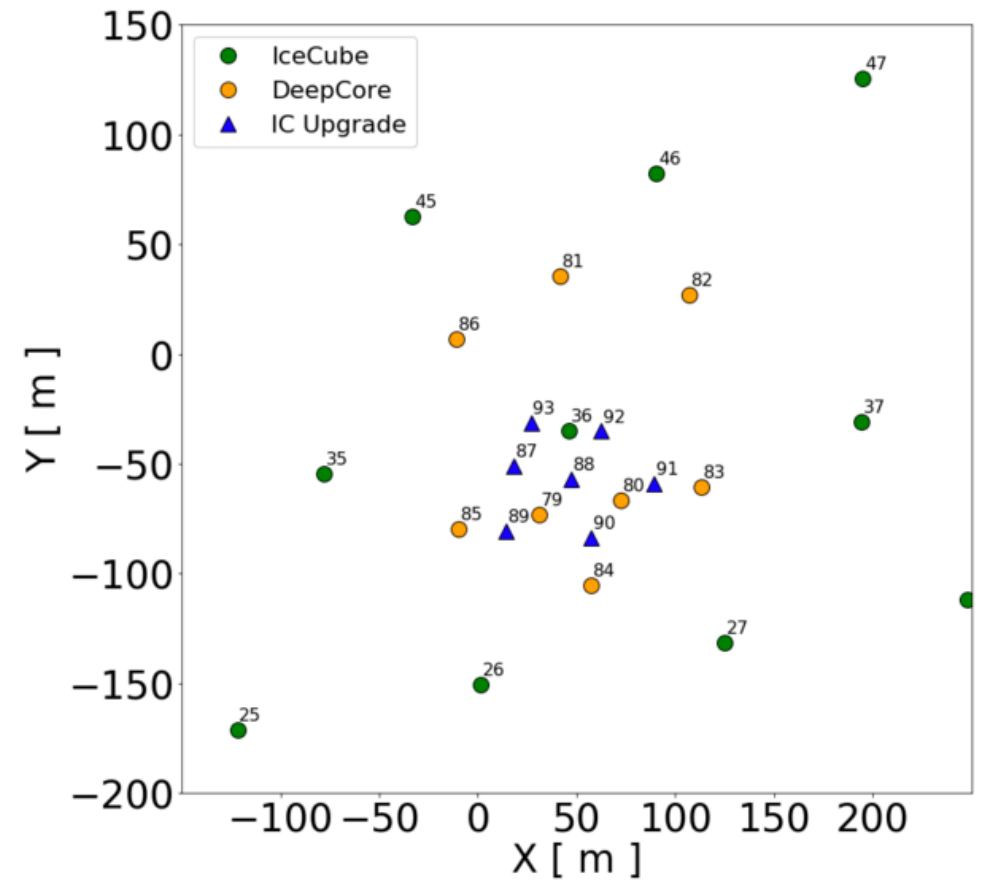


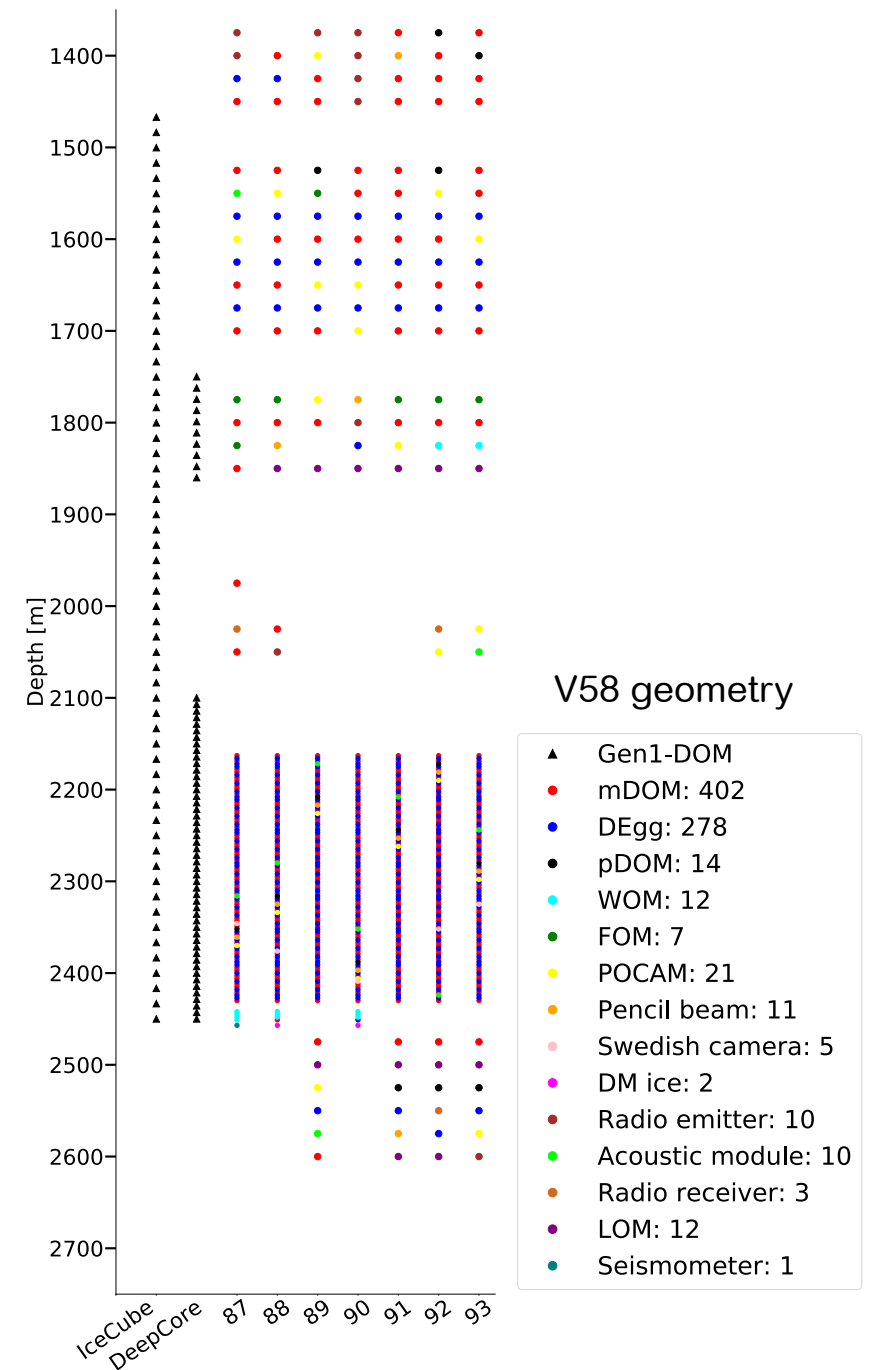
The IceCube Upgrade

- 7 new boreholes in the centre of IceCube DeepCore
- Drilling and installation of all 7 strings in 2025/26
- Goals:
 - Precision neutrino oscillations
 - Improved calibration of IceCube data
 - R&D and logistics training for Gen2



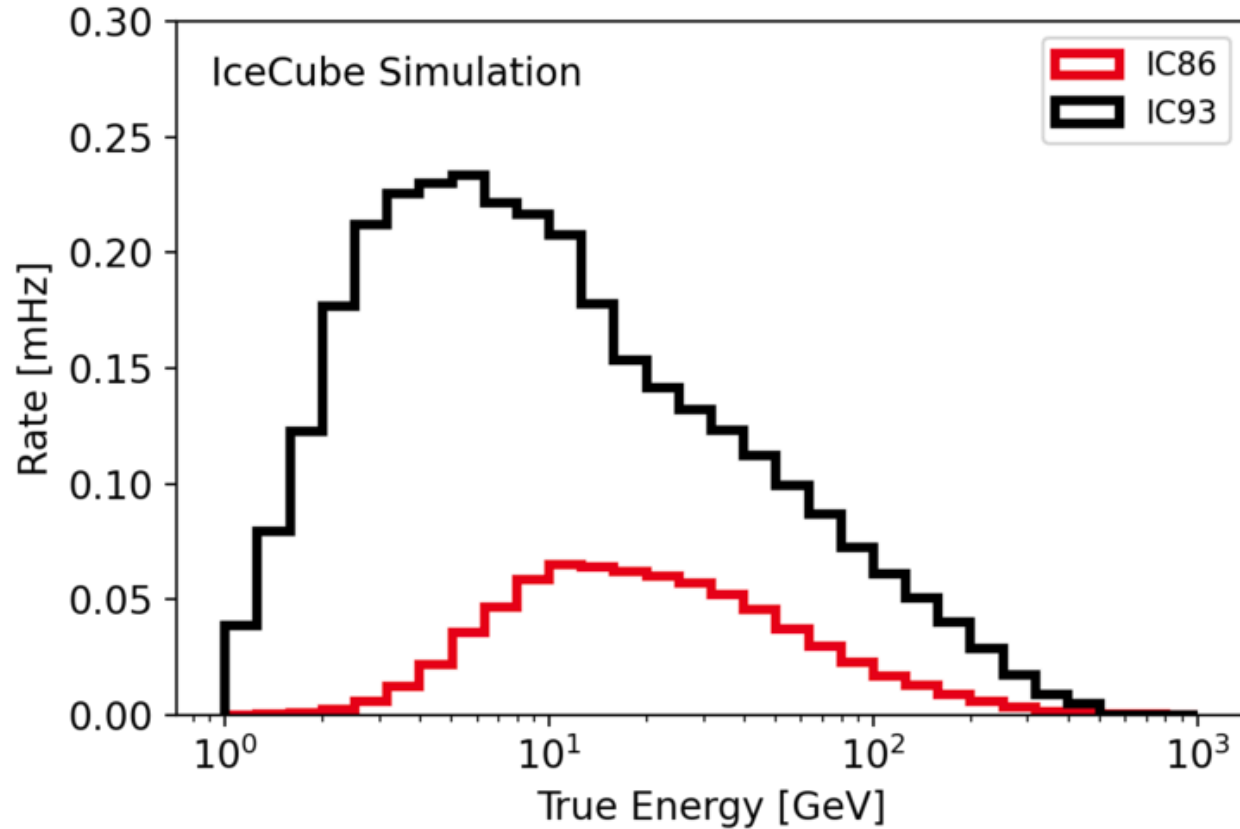
Upgrade instrumentation

- Instrumenting ice from 1350 — 2600 m
 - Extends both above and below existing array
 - Physics region from 2150 — 2450 m with 3m vertical spacing
 - Elsewhere 25 m vertical spacing
 - Calibration, R&D and special devices sprinkled throughout; locations matched to design goals
- 111-116 modules per string
- All devices talk through **ICM** - common DAQ
- Planning for operation **during installation**
 - During string descent
 - During borehole re-freezing period



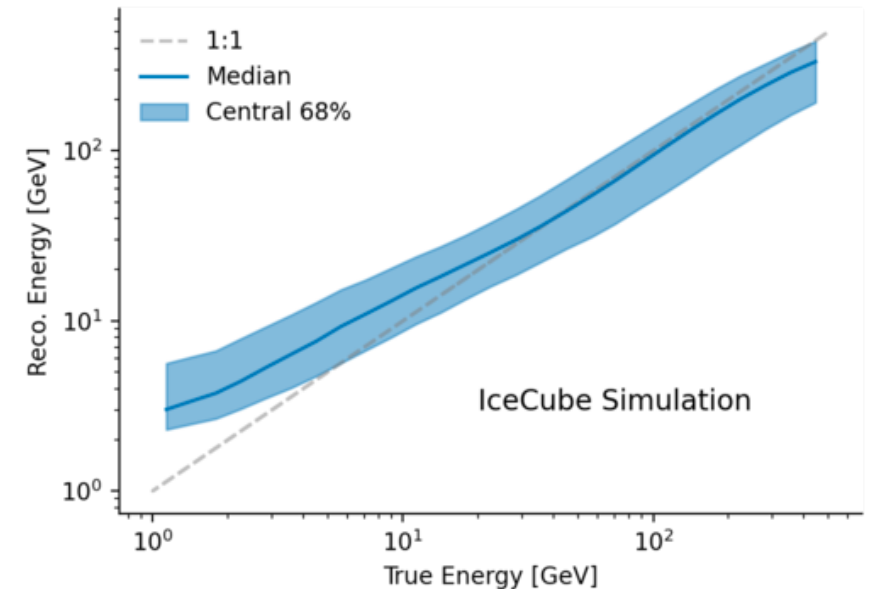
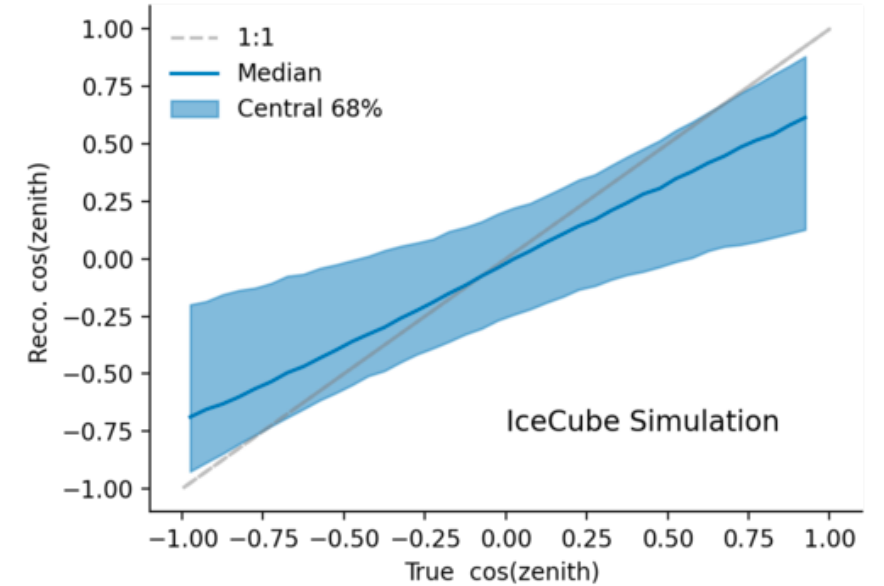
Low energy expected performance

Factor 2-4 higher rates, depending on energy, interaction type...



https://wiki.icecube.wisc.edu/index.php/IceCube_Upgrade_Simulation_2023

GNN reconstruction

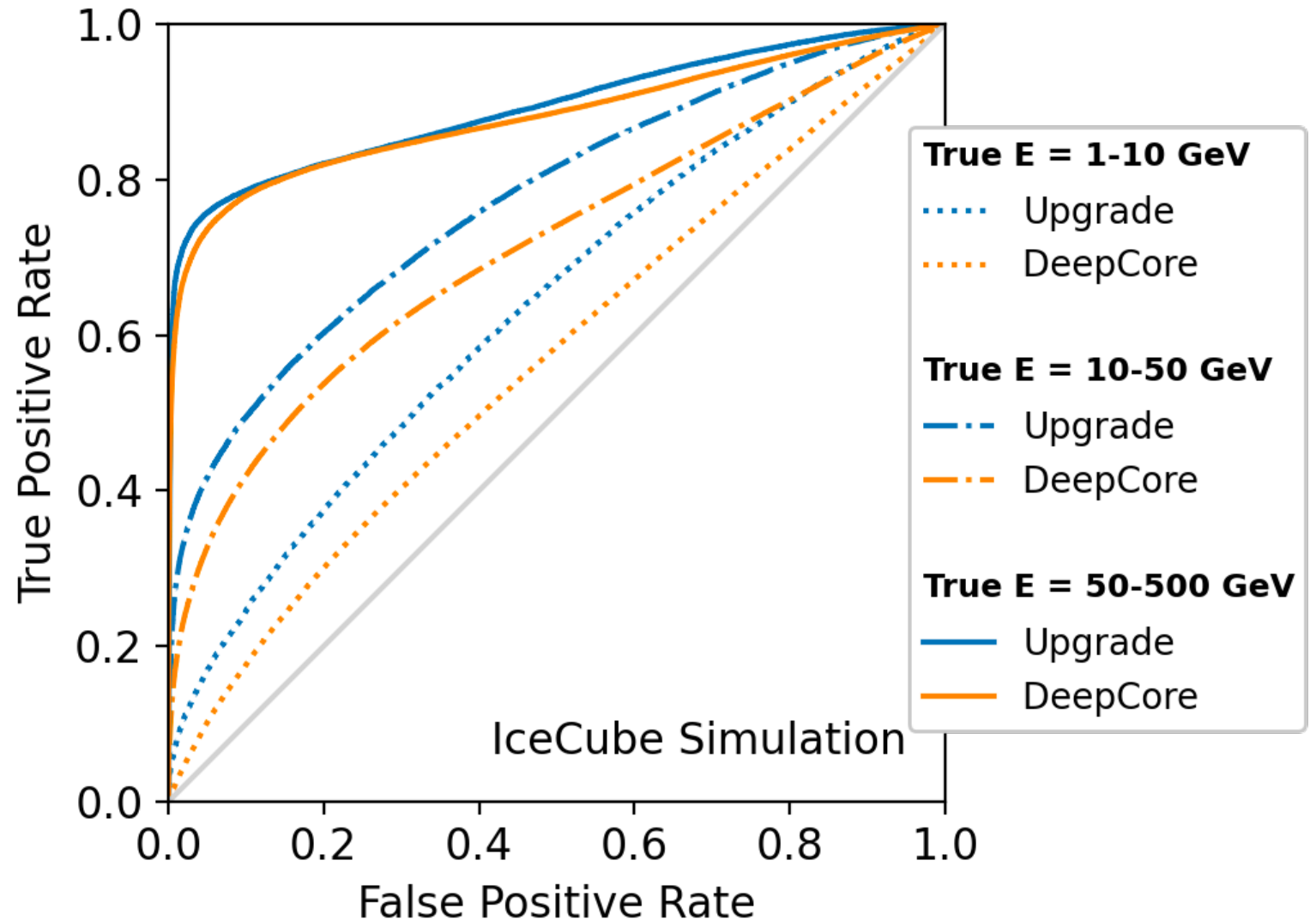


Low energy expected performance

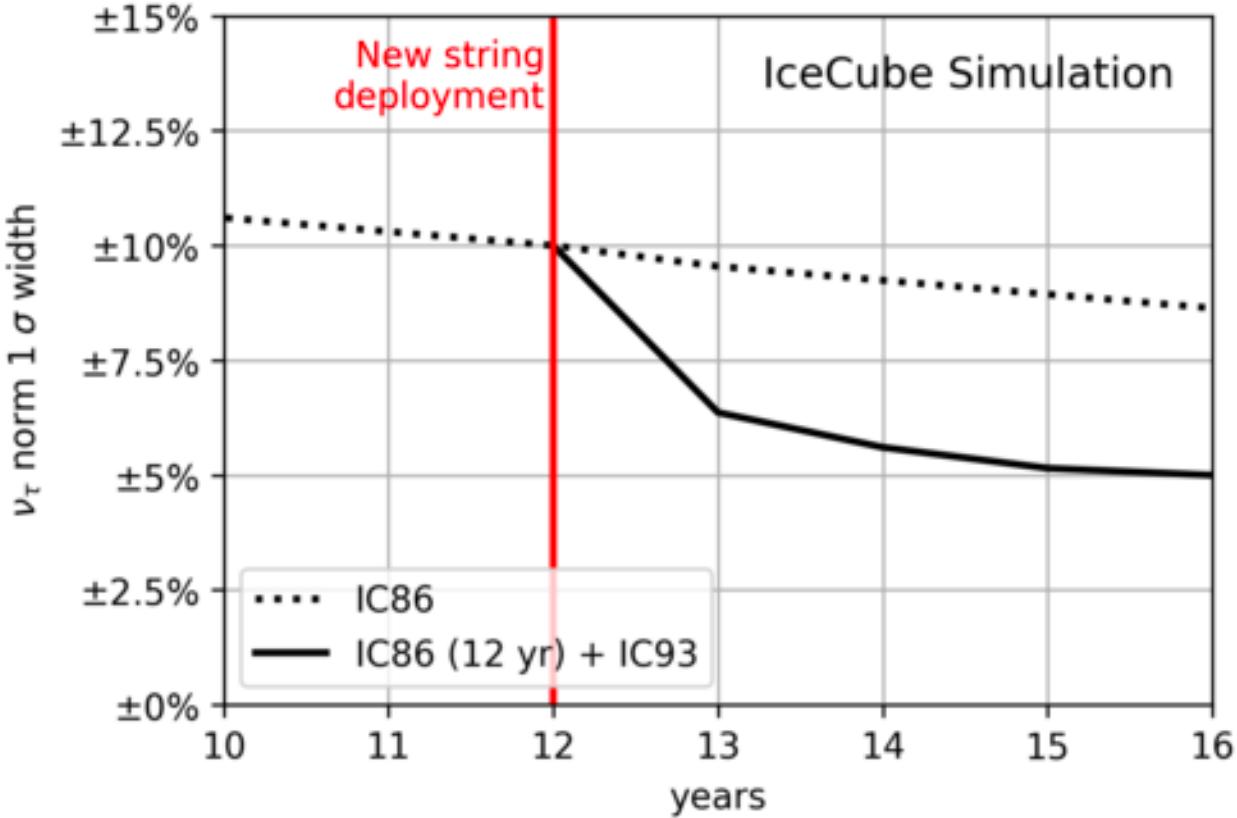
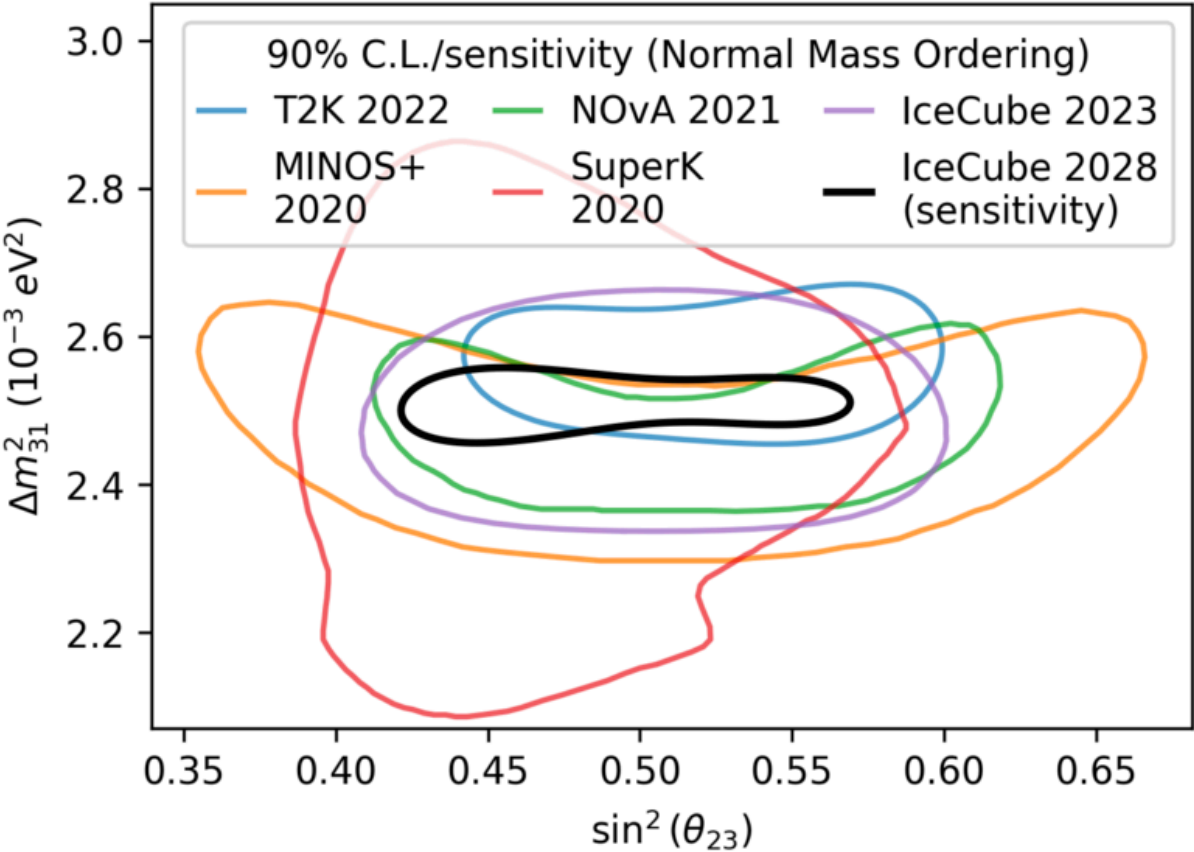
Significant improvement in
“traditional” PID: track vs. cascade

Efforts underway to re-think PID with
new reconstructions:

- Inelasticity
- Neutron echos
- ...



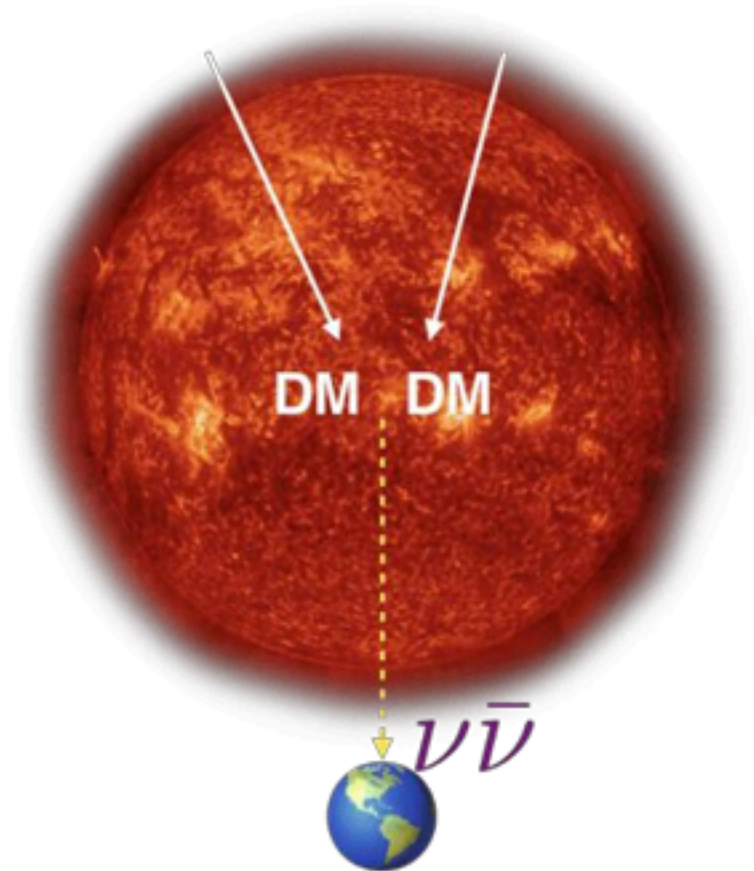
Low energy expected performance



World leading results expected — but competition is fierce!

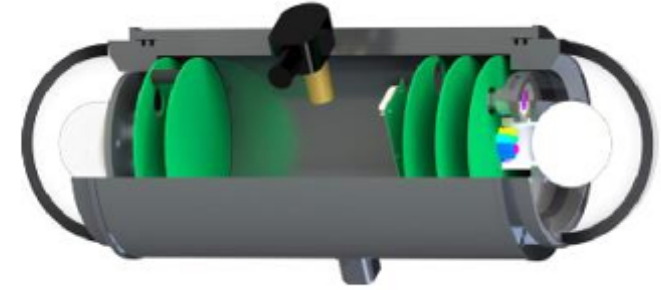
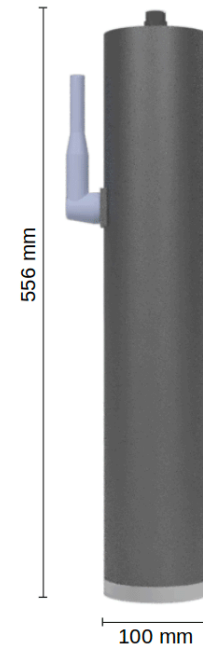
BSM physics - Dark Matter

- Annihilation in the Sun & the Galactic Plane

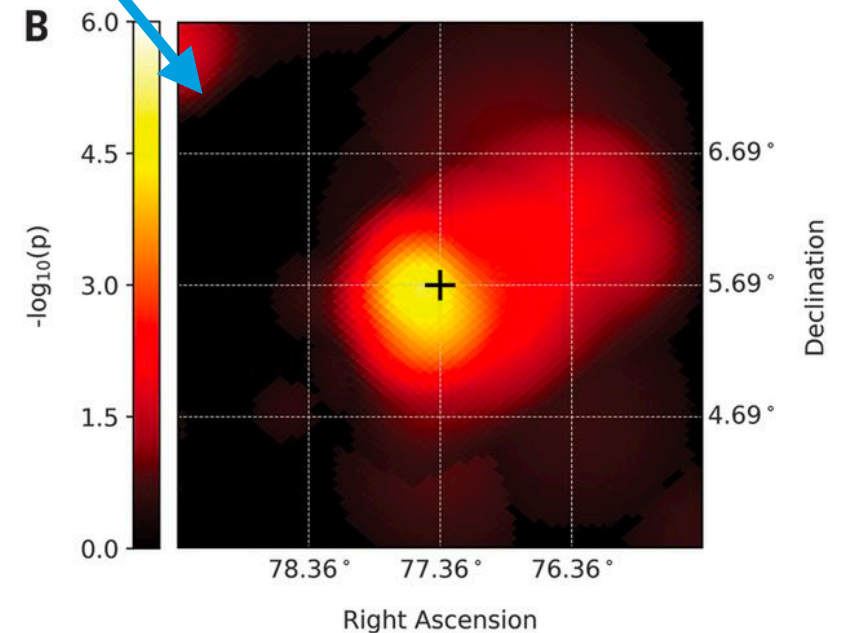


Impact on High Energy Physics with IceCube

- Calibration with the Upgrade is fundamental for improved high energy measurements
- German IceCube groups are well-positioned to play a leading role in these efforts
 - POCAM, Acoustic Module, flasher LEDs, mini-mainboard
- Significant opportunities for experience in detector commissioning, and publications — sense of ownership and visibility for ECS members
- Calibration also offers cross-disciplinary topics with glaciology, earth sciences ...



How will [X] improve with calibration?



Current Status

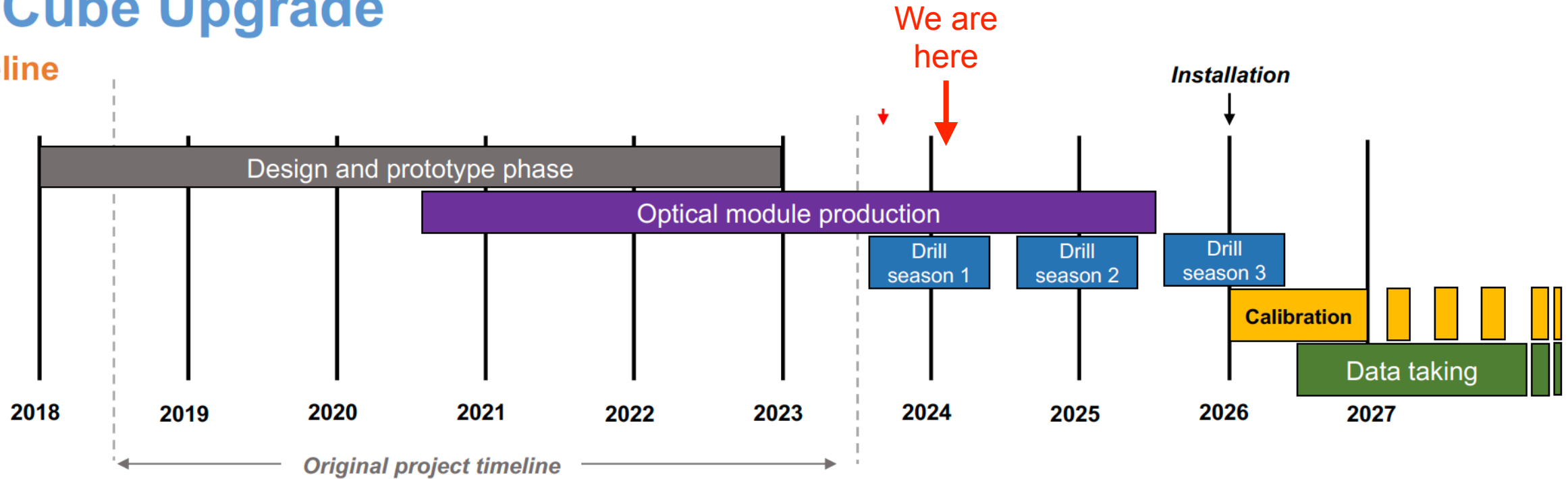
- Critical hardware production and testing is on track
 - Optical modules: DEgg (Japan) and mDOM (Germany, USA)
 - First shipments summer 2024!
 - Almost all calibration and “special device” designs reviewed, production ramping up
- First field season underway at Pole
 - Some unforeseen set-backs but that’s pretty normal for Pole - no critical failures



Figure 3 (left) IFD carrot, (center) hole in the firn, (right) cover for the temporary outfall (Photos: K. Studt/PSL).

IceCube Upgrade

Timeline

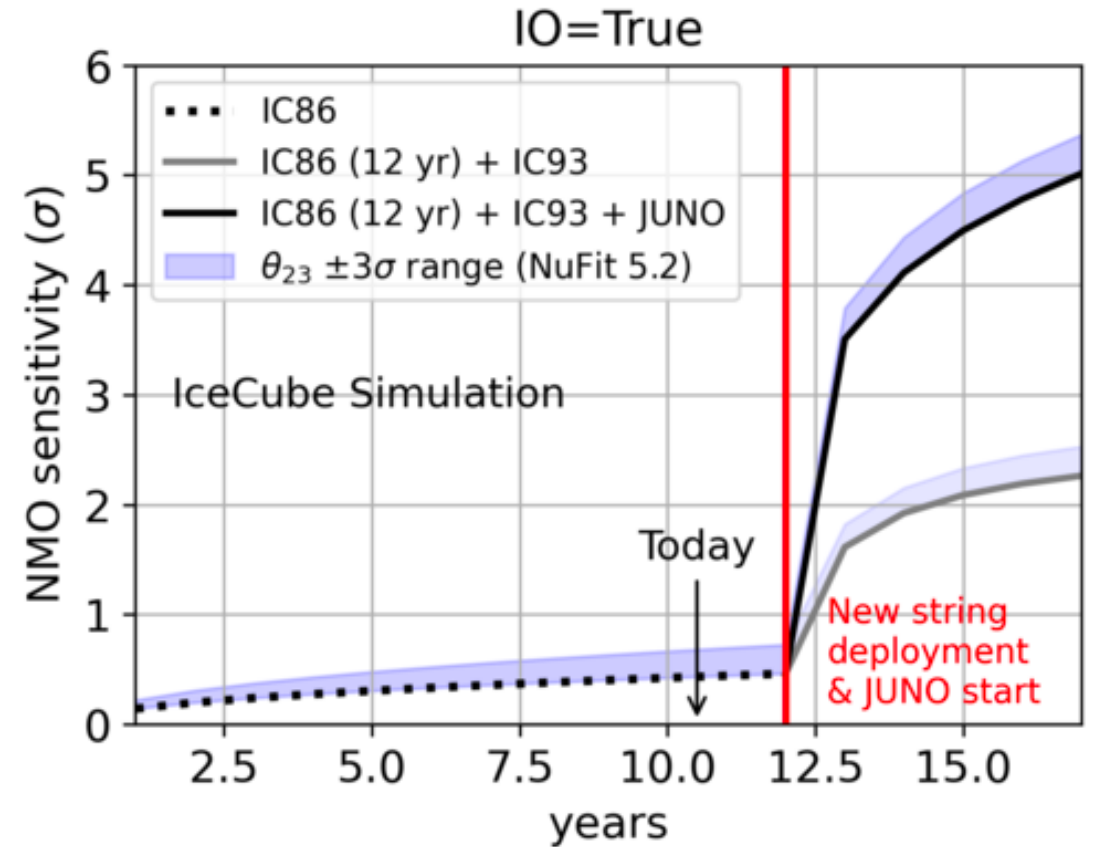
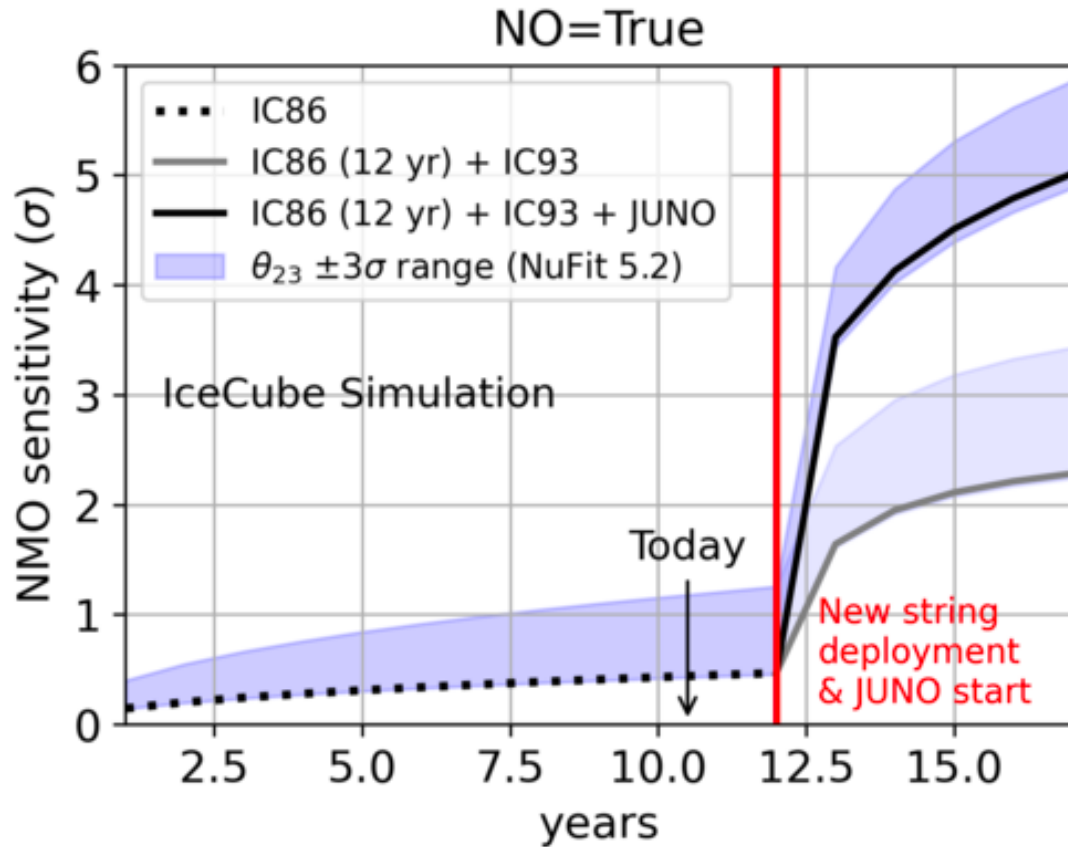


- Originally approved as a 5-year project through NSF mid-scale program
- Delays due to COVID – no access to South Pole (2020-22), electronics supply chain issues
 - More time for (re)design, refining processes and testing (2022)
- Rebaseline approved last year, new deployment set for field season 2025/26

Discussion...

Backups

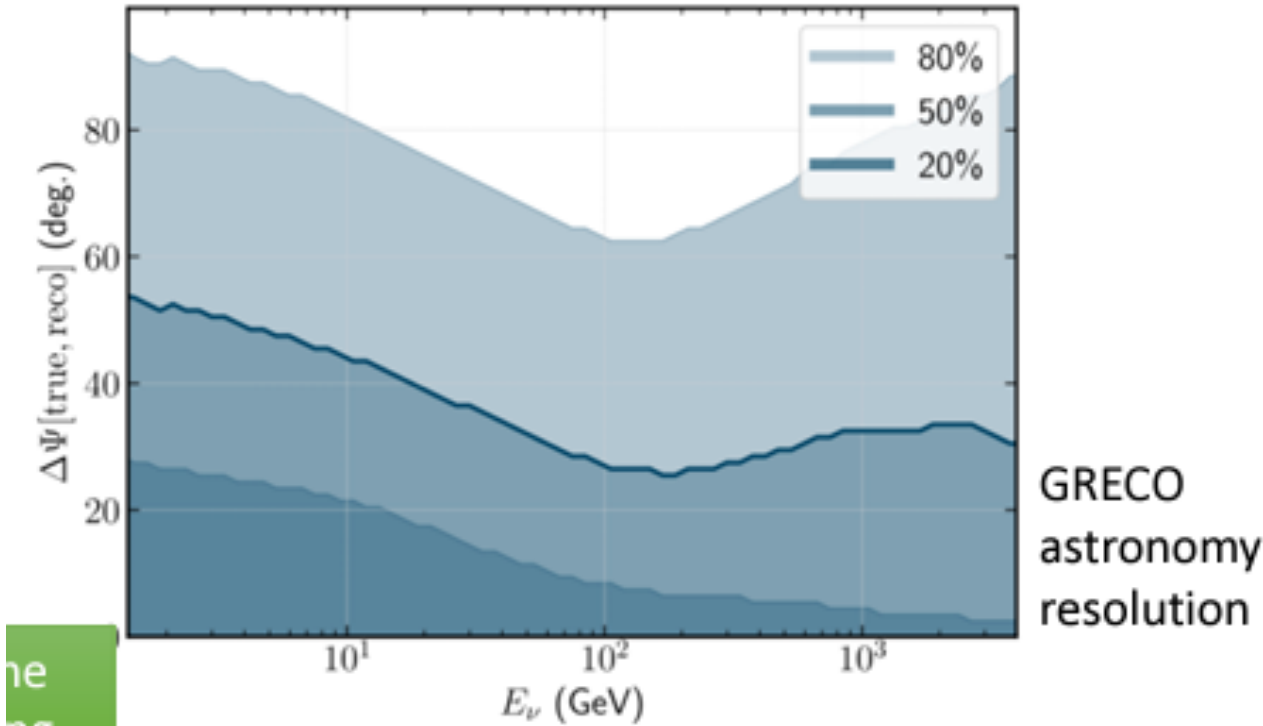
NMO sensitivity



Assumes 8 core JUNO*

Actively exploring synergies with other experiments

Low energy astrophysics



Supernova?