IceCube-Gen2 application for the BMBF-FIS prioritization process

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Coordinating institutions: DESY, KIT
Partner institutions in Germany: Bergische Universität Wuppertal, Friedrich-Alexander-Universität Erlangen-Nürnberg, Johannes Gutenberg-Universität Mainz, Ruhr-Universität Bochum, RWTH Aachen University, Technische Universität München, Technische Universität Dortmund, Universität Münster

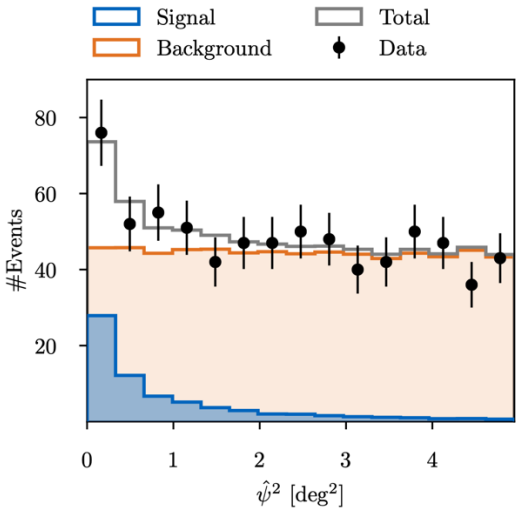
HELMHOLTZ

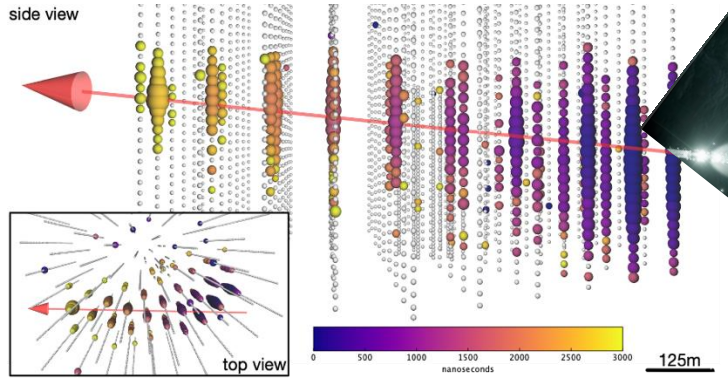
DESY.

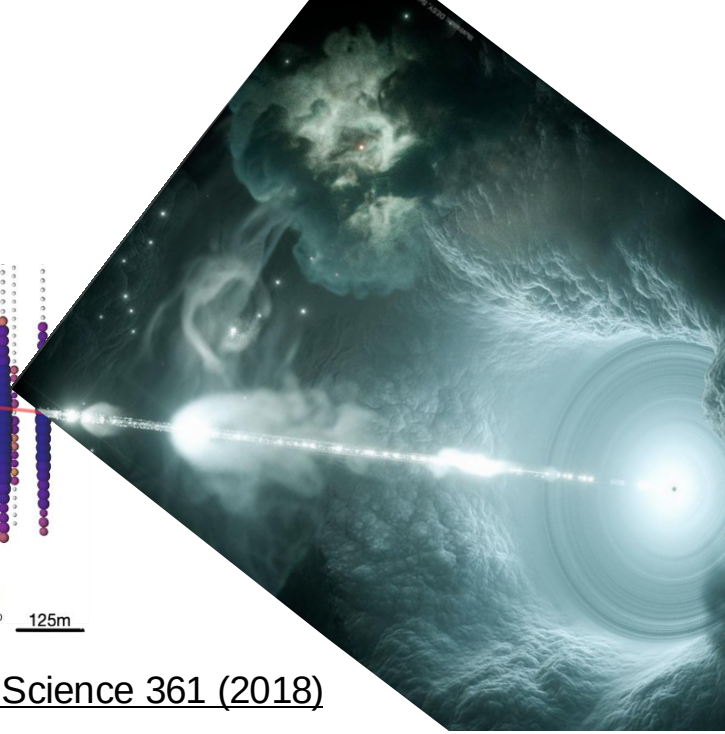
High-energy neutrino astronomy

A new window to the Universe has been opened during the last decade!

Science 378 (2022)

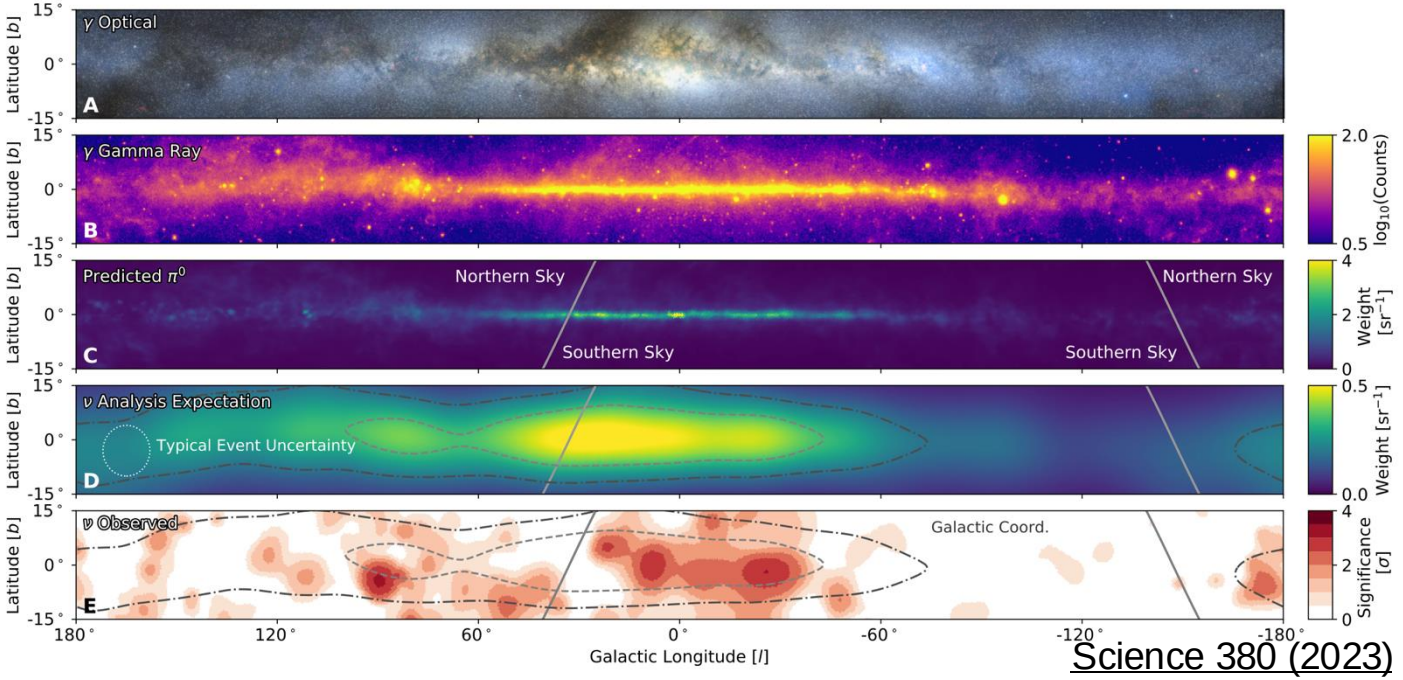






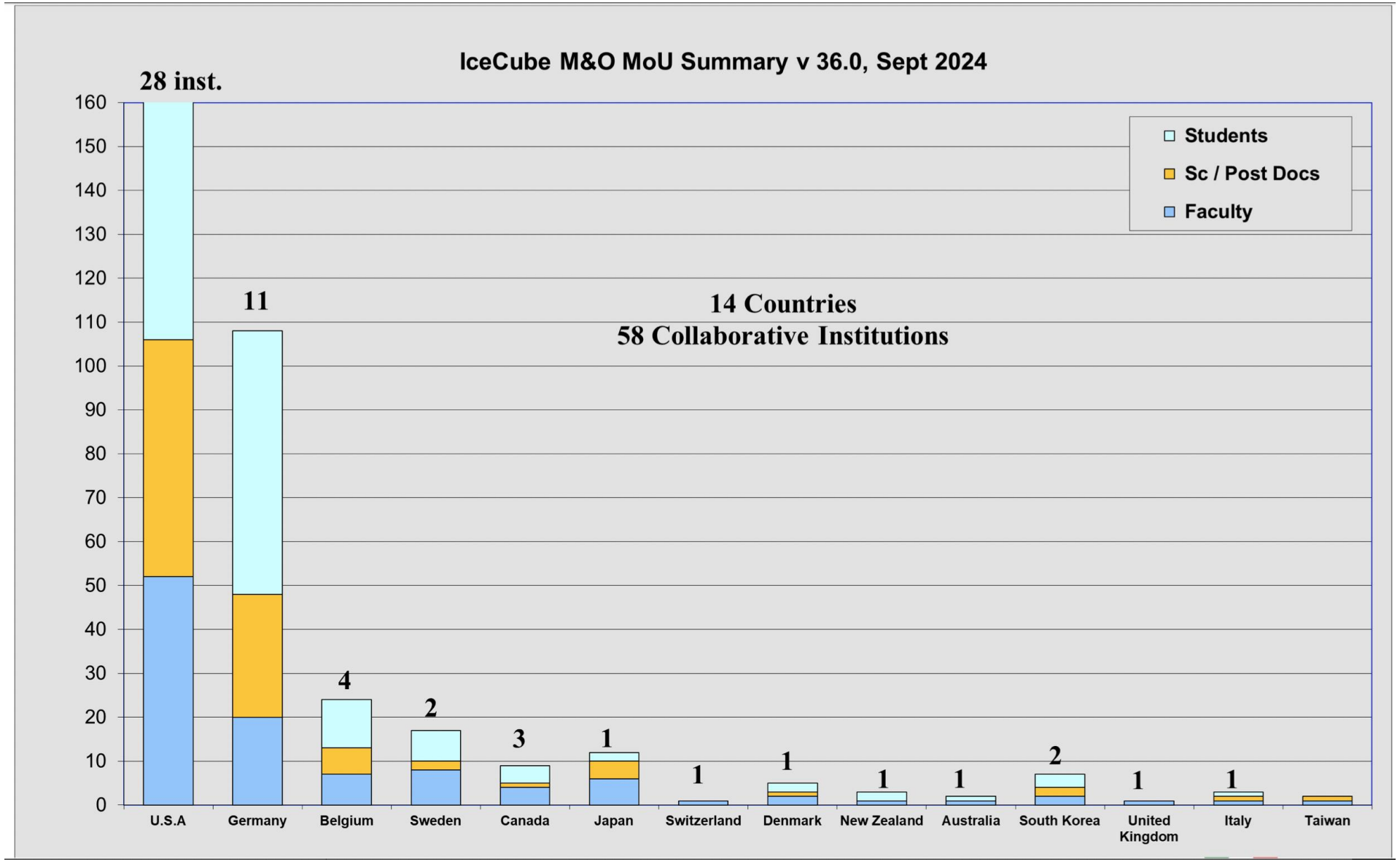
Science 361 (2018)

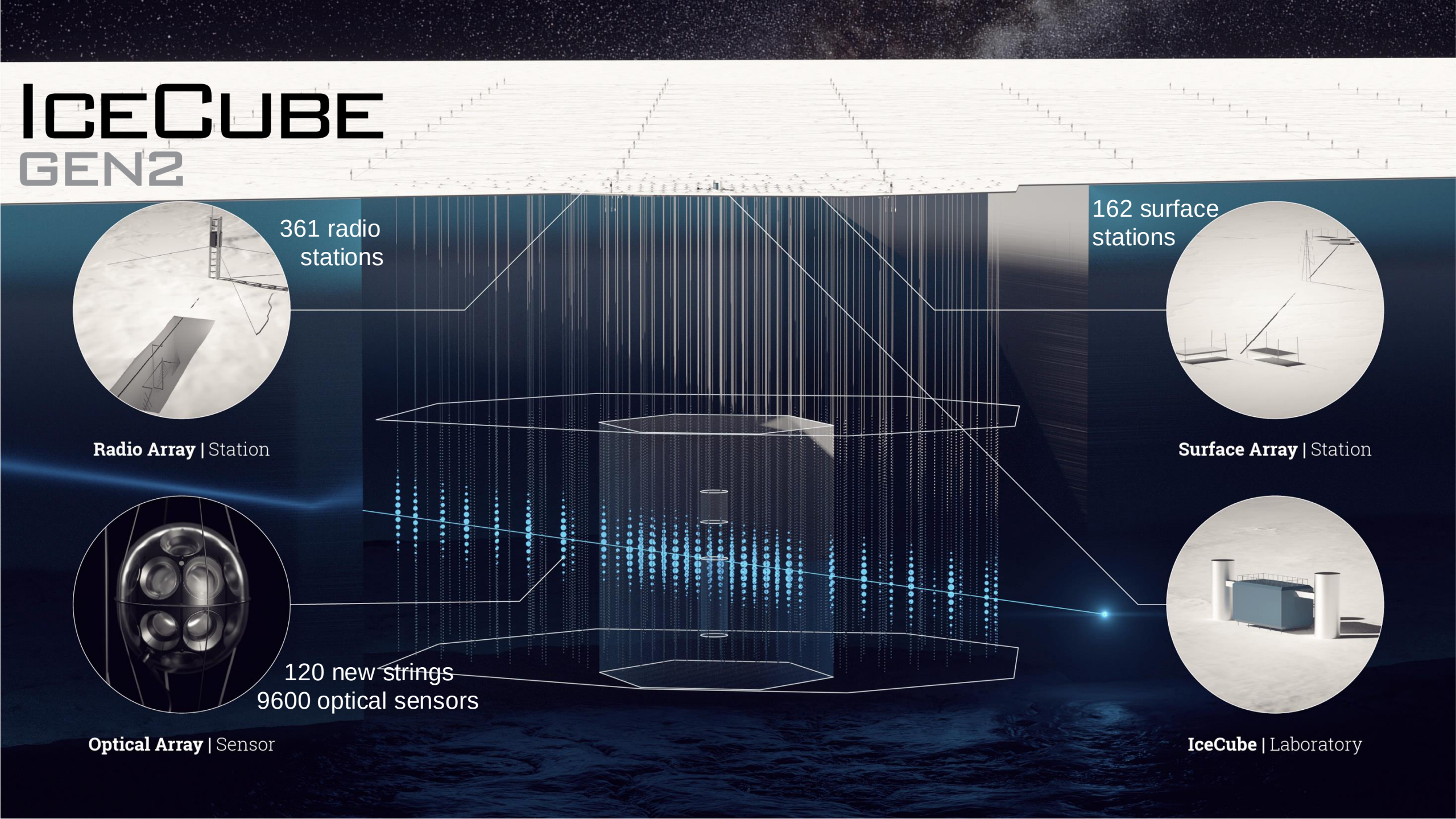
- 9+ sigma evidence for PeV energy cosmic neutrinos
- First point sources observed (NGC1068, TXS 0506+056)
- Evidence for emission from the Galactic plane
- Glashow resonance & tau neutrino events observed
- ....



Science 380 (2023)

German groups are a major part of the IceCube collaboration




ICECUBE
GEN2
361 radio stations
Radio Array | Station
162 surface stations
Surface Array | Station
120 new strings
9600 optical sensors
Optical Array | Sensor
IceCube | Laboratory

IceCube-Gen2 sensitivity

World leading sensitivity from 10^9 to 10^{20} eV

- ~10 (100) times the rate of events at PeV (EeV) compared to IceCube
- ~10 (100) times the number of point sources expected at PeV (EeV) energies
- Flavor sensitivity over full energy range
- Excellent cosmic ray detector

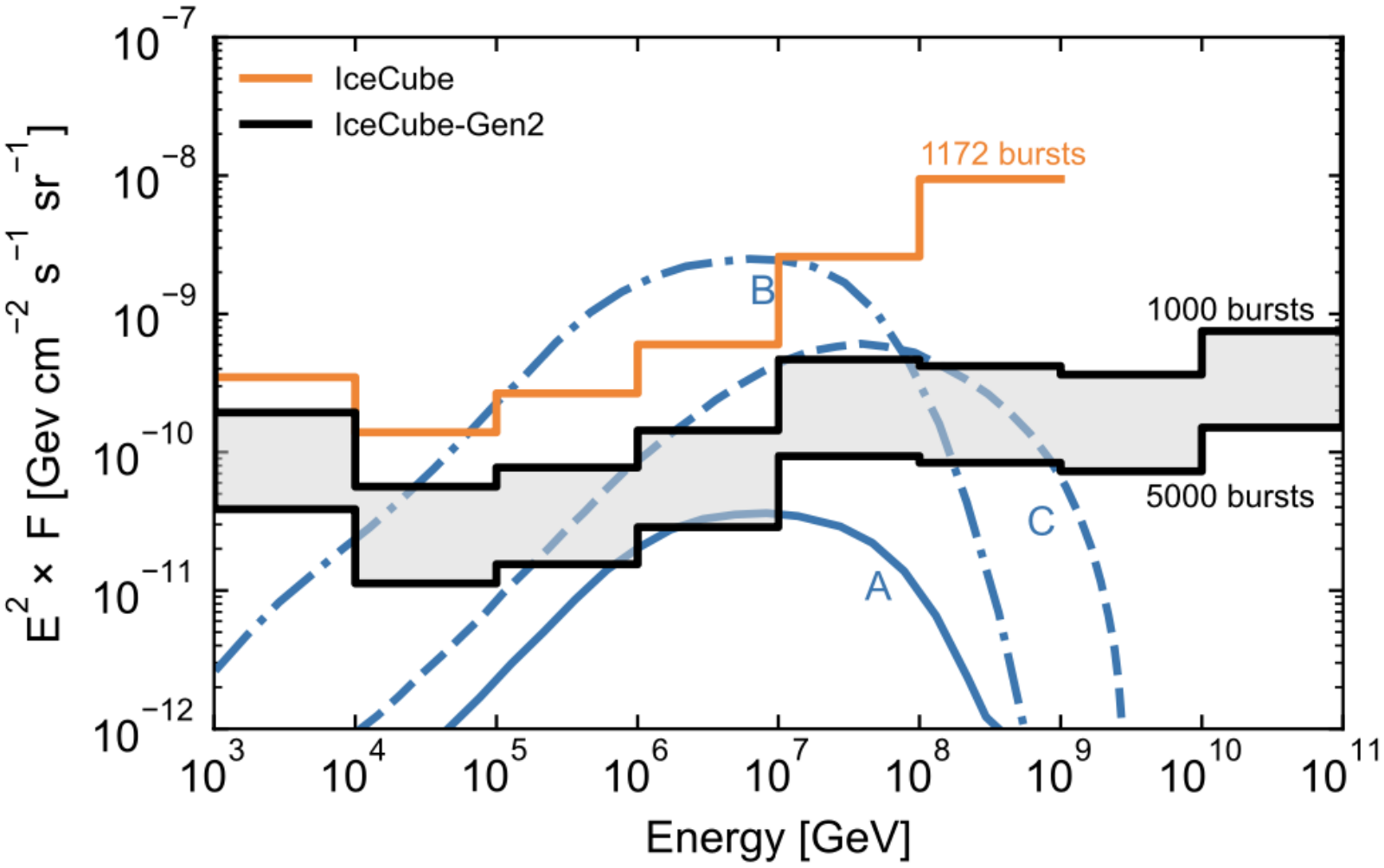
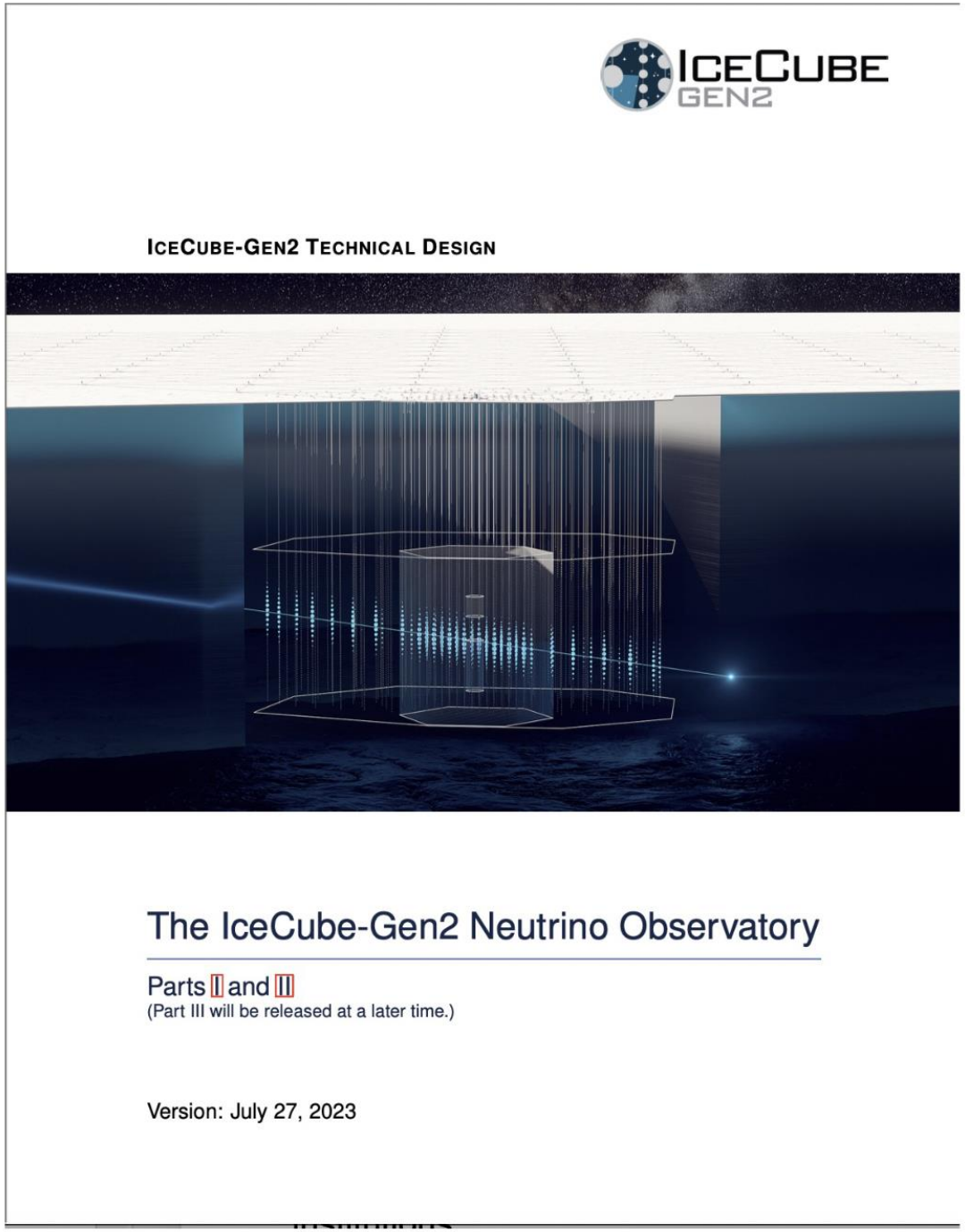


Fig: sensitivity of IceCube-Gen2 to the neutrino flux from GRB

IceCube-Gen2 in nutshell

- Multipurpose neutrino (and cosmic ray) observatory with unique discovery potential from 10^9 to 10^{20} eV
- International collaboration of 400+ scientists from 14 countries. Germany is the second strongest partner after the USA (DESY+KIT+9 German universities, ~25% of all authors)
- IceCube-Gen2 Technical Design Report completed: Parts I and II covering science and detector released in July 2023, Part III covering construction and logistics released June 2024 (370 pages).



IceCube-Gen2 Costs: Construction & Operation

Construction costs:

- 55,3 Mio. € are requested for investments into optical sensors, surface array and radio array.
- This is complemented by 15,5 Mio. € personal in-kind contributions from German groups.
- German contribution corresponds to roughly 18 % of total project costs.
- Cost assumptions are calibrated on experience from IceCube, IceCube Upgrade and RNO-G. They have been reviewed within the US Astro Decadal Survey and deemed mature.

Operation costs:

- Operation cost model based on that of IceCube.
- 13 Mio. € / a for the full project (including IceCube, 2024 costing).
- 2.3 Mio. € / a anticipated for Germany, dependent on # authors. >2/3 to be provided in-kind.

IceCube-Gen2 technology on the way to the South Pole

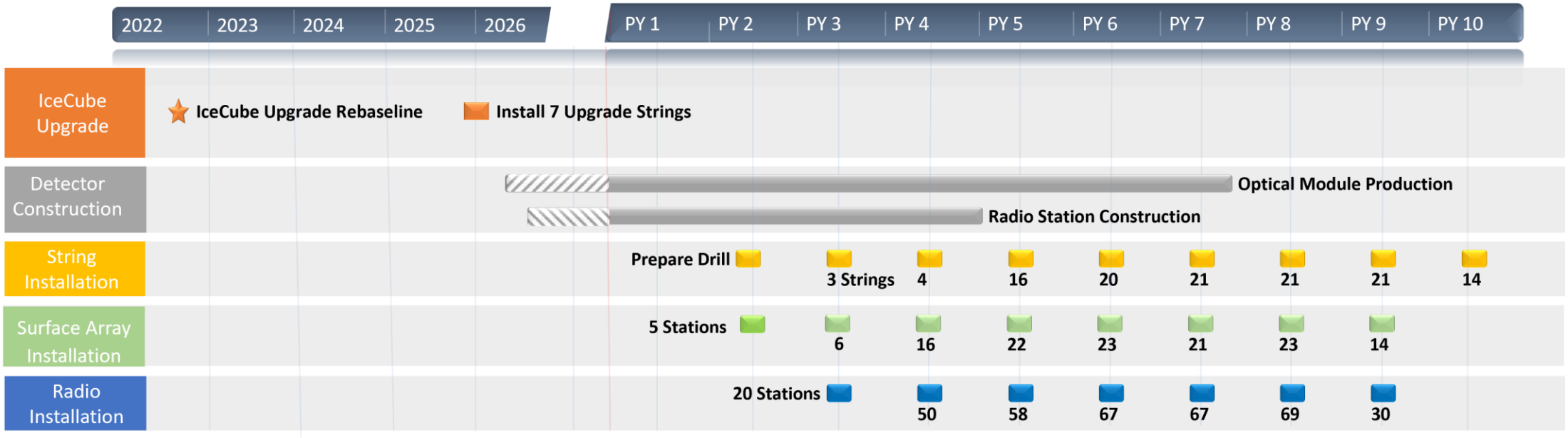
The IceCube-Upgrade

- The IceCube-Upgrade is an ongoing 7-string extension of IceCube, improving its low-energy and calibration capabilities. It also serves as a technology step-stone to IceCube-Gen2.
- Both drill and new sensors have been developed and are being tested in IceCube-Gen2.
- The first batch of 128 mDOMs, as well as many other detector components developed and build in Germany, have left DESY in August for the South Pole.
- Value of German contribution to the IceCube Upgrade: >9 Mio. €

The mDOM has been developed and is being build by German institutions.

mDOM assembly @ DESY

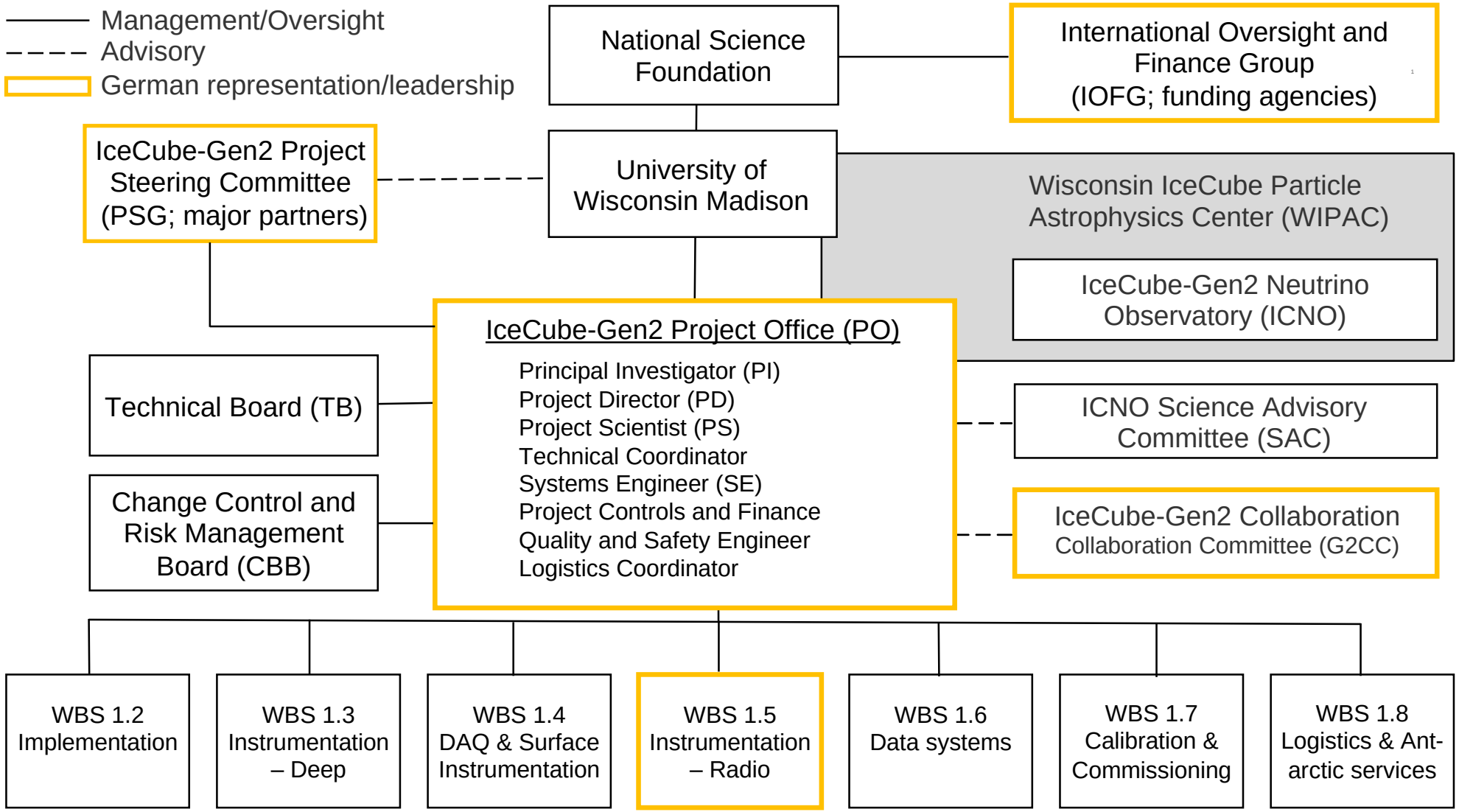
IceCube-Gen2: Schedule



Initial Technical Design Report public, working on preliminary design to be completed in 2026, after deployment of IceCube Upgrade. Final design completed in 2028, after which construction can start.

Construction will take ten years, initial data from partial configurations already available after five years

IceCube-Gen2 Organizational Structure



The international perspective

- Project was favorably evaluated in various roadmap processes, including in Astro 2020 US Decadal Survey, the Particle Physics Project Prioritization Panel (P5 panel), the Japanese MEXT or the European APPEC roadmap.
- NSF South Pole Master Plan foresees infrastructure modernization at South Pole over the next decade
  - CMB-S4 can't go ahead at South Pole (for now)
  - IceCube Upgrade remains a priority
  - IceCube-Gen2 time line needs to be finalized, with a potential delay by ~2 years if no parallel work at South Pole possible
- Wide community support to do science in parallel and pressure even from the US Senate Appropriations Committee: *"NSF should consider development activities for IceCube-Gen2 and ensure an appropriate transition between the IceCube upgrade and IceCube-Gen2 projects to leverage lessons learned and knowledge transfer from one project to another."*
- Funding for new planes (LC130s) being allocated to help NSF realize the program

Summary

- IceCube-Gen2 is a unique multipurpose neutrino observatory with discovery potential from 10^9 to 10^{20} eV.

- International collaboration: USA host nation, Germany with DESY, KIT and ten Universities second largest partner nation.

- German in-kind contribution to the detector requires 55 MEuro investment funds. Operation model follows that of IceCube, requring ~2.3 MEuro / a (German part, 2/3 provided in-kind, DESY part €).

- Technical Design Report completed. Preliminary Design foreseen for 2026 and Final Design and start of construction foreseen for 2028/29.