# Advances towards the IceCube-Gen2 Neutrino Observatory


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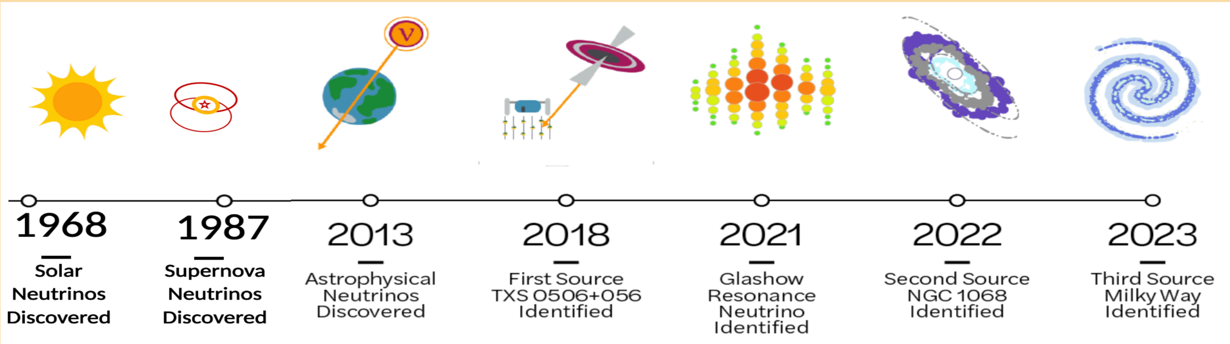
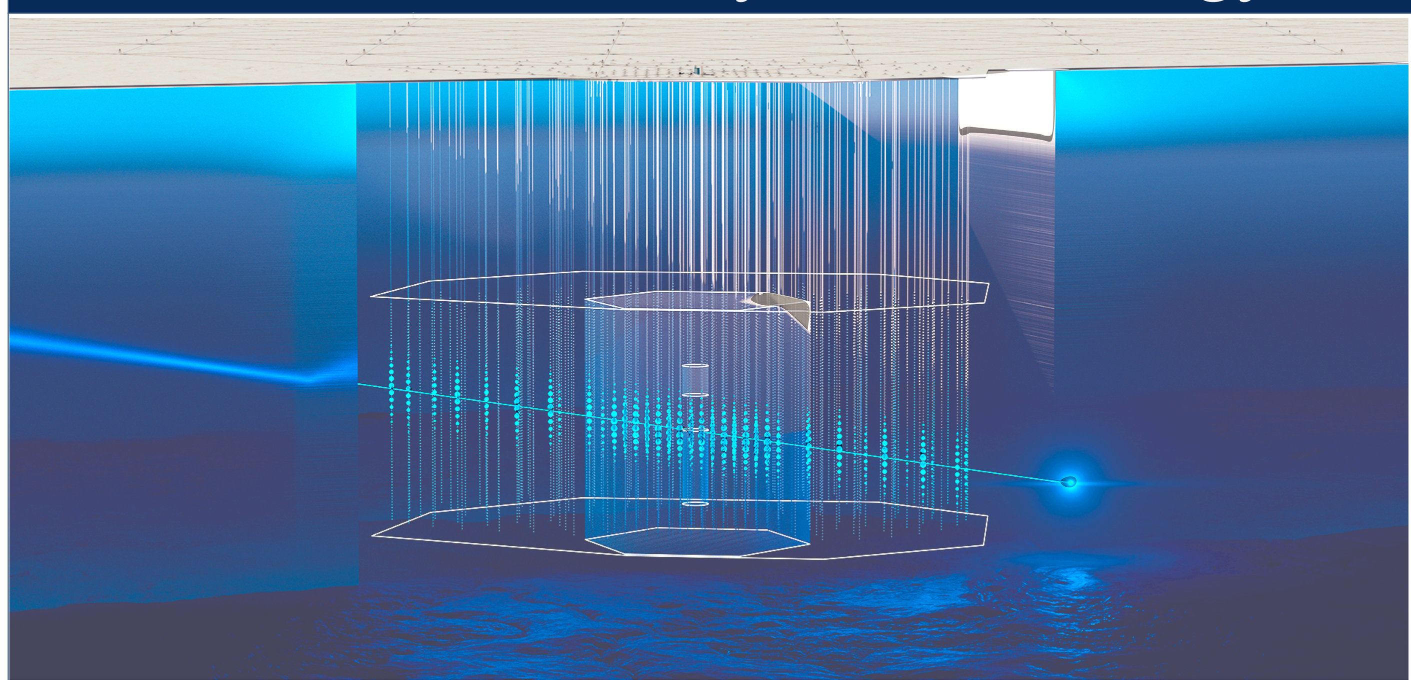



## Abstract

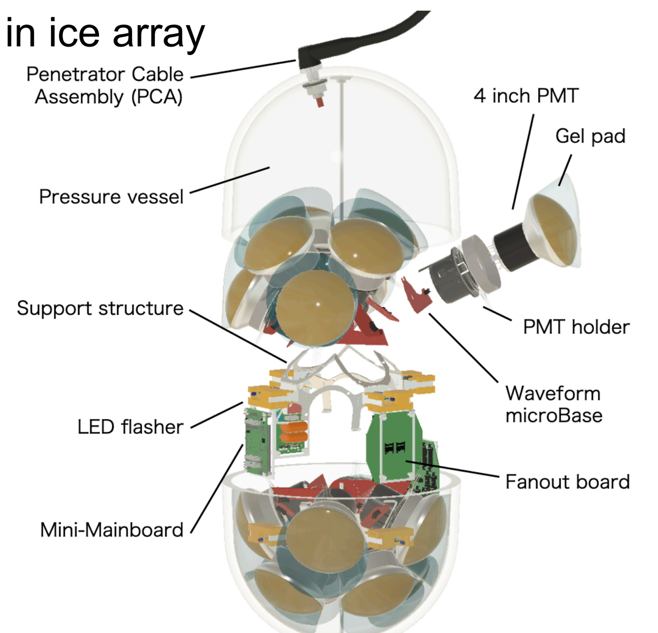

IceCube-Gen2 is a planned extension of the IceCube Neutrino Observatory at the geographic South Pole. The array is optimized to search for sources of astrophysical neutrinos from TeV to EeV energies and characterize the astrophysical flux with high statistics. Gen2 builds on more than a decade of successful scientific observations with IceCube. The observatory will utilize optical sensor modules integrated into the deep ultra-clear Antarctic ice for the detection of Cherenkov light from neutrino interactions, surface detectors on the ice for the detection of cosmic-ray air showers, and an extended radio array focusing on the ultra-high energy neutrinos. The array will be able to explore energy scales beyond the reach of accelerators with the potential to discover new phenomena beyond the standard model of physics. Sustainability, minimizing the environmental impact on the experiment, and resource optimization are priorities of the project.


## IceCube-Gen2 - Array & Technology



Gen2 consists of a radio, surface, and in ice array

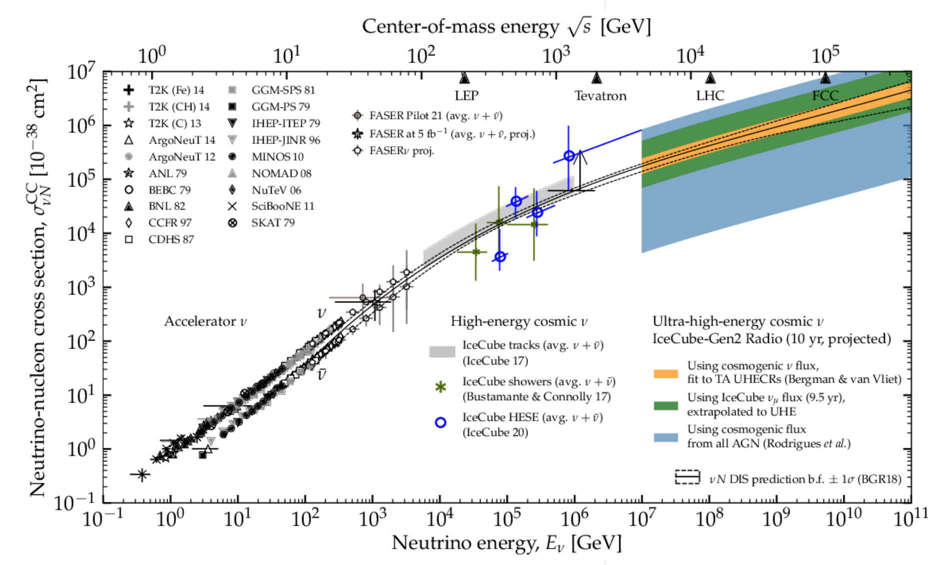
- Radio array:
  - ~ 360 stations to target neutrinos above 10 PeV
- Surface Array:
  - 131 surface stations for cosmic ray physics and atmospheric neutrino veto
- Optical Array:
  - Optical sensor modules provide directional sensitivity via segmentations (16-18 PMTs)
  - ~10,000 modules distributed over 120 strings

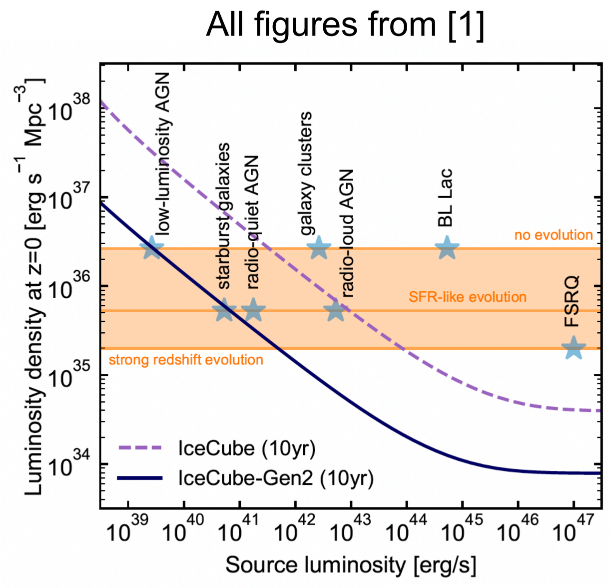


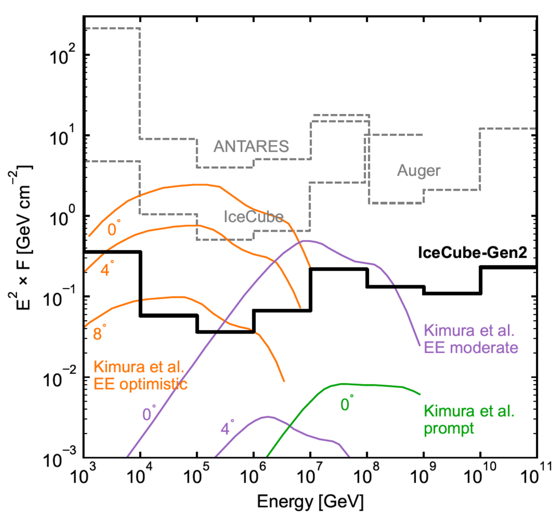

Optical module ref. design [2]

## IceCube-Gen2 Science

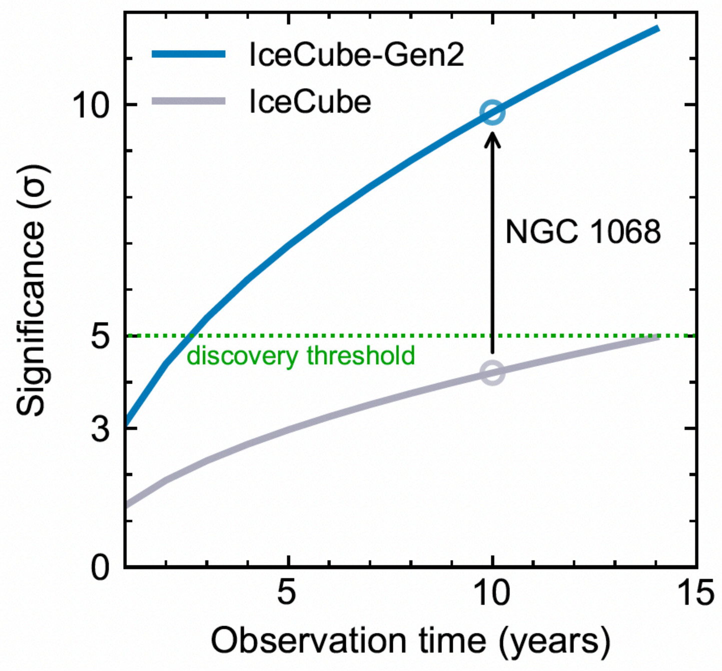
All figures from [1]

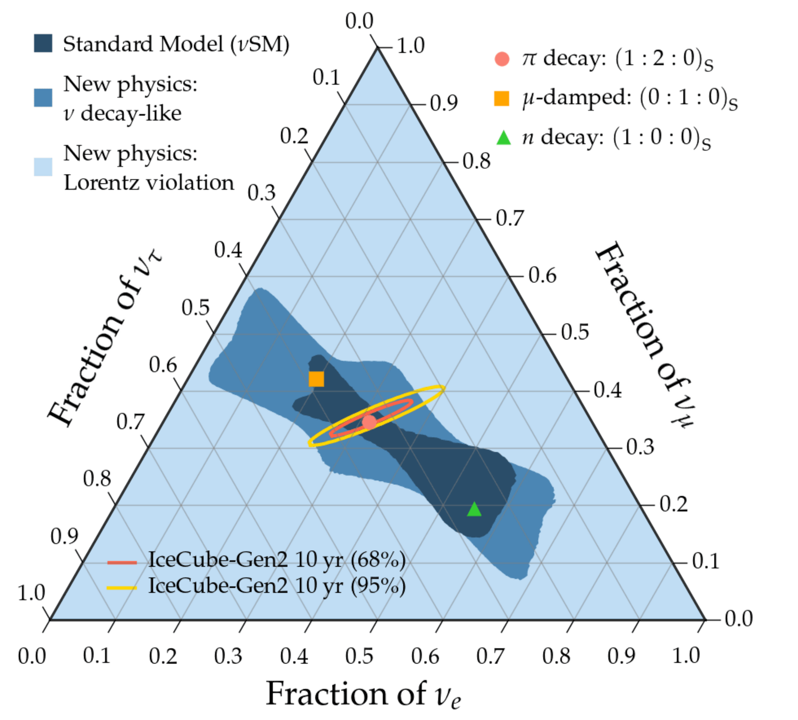



- Probing cross sections at highest energies - adopted from [3]
- Enabling firmer associations with bright sources.
- Synergies with gravitational waves from neutron star mergers
- More than 10x expanded volume for steady-state sources, plus extension to the highest energies
- Precise flavor composition measurements, with the potential to discover new physics [4]

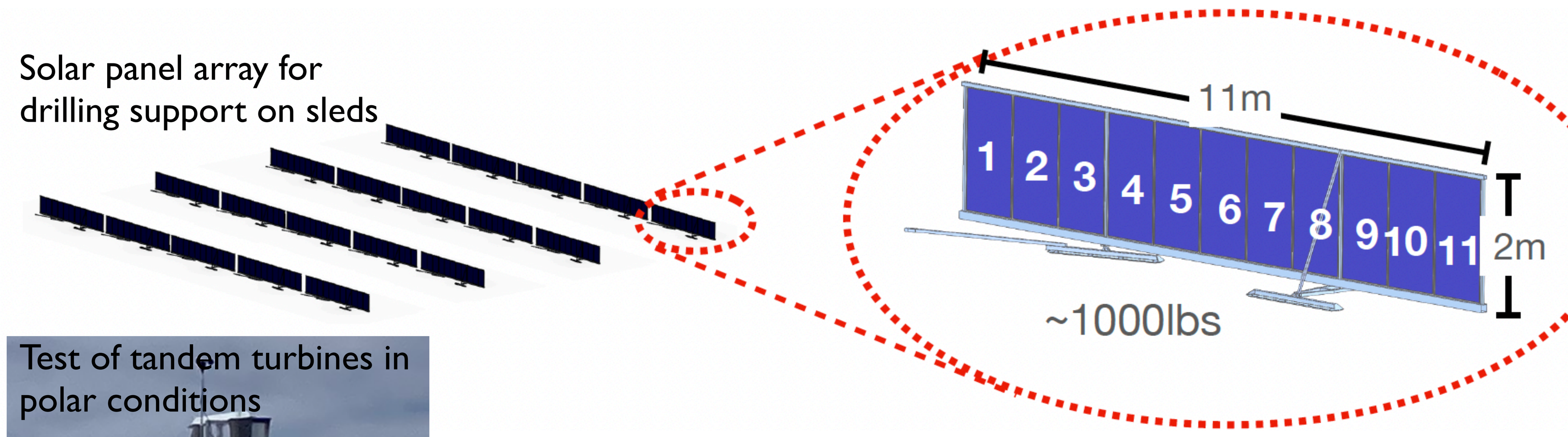



## Renewable energy options for the South Pole

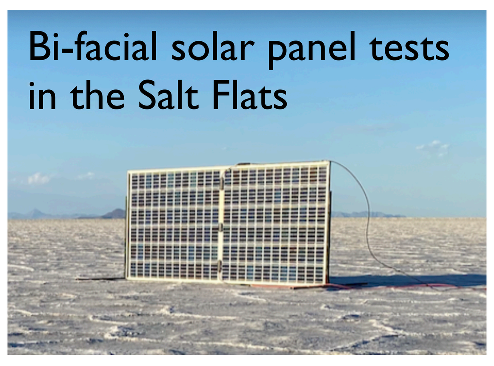
- **Application of renewable energy** for detector construction and operations offer potential for significant cost savings compared to "standard" operation schemes at pole
  - Reduction of logistics footprint by augmenting power generation for drilling and operations
- **Case for Solar:**
  - During drilling Sun is 10º above the horizon, reducing atmospheric extinction
  - High albedo in the polar environment
  - PV Panels very durable that have been successfully used with low maintenance needs in extreme environments (include Antartica and the Arctic)
  - High level of insolation
  - Low cloud cover at South Pole
  - Efficiency of PV cells increases with reduced temperature (Silicon -0.4% / ºC)
  - Mounting options:
    - Vertical sled mounted bi-facial panels allow efficient energy production during summer.
    - Horizontal panels mounted on surface array detectors for minimizing maintenance
- **Solar for drilling**
  - Supplement water heating with solar (DC) + feed into micro turbine for AC generation
  - Solar array with a capacity of up to 960 kW
    - 800kW for resistive heaters in the water tanks
    - 160kW for integrated into the overall electrical power generation system (replaces one Capstone CS1000S)
- **Case for Wind:**
  - Year round available
- **Energy Storage:**
  - Bridge periods of low wind & cloud coverage
- **Energy efficiency / optimization:** Cabling minimize transmission losses, ASIC for operational power reduction

Solar panel array for drilling support on sleds

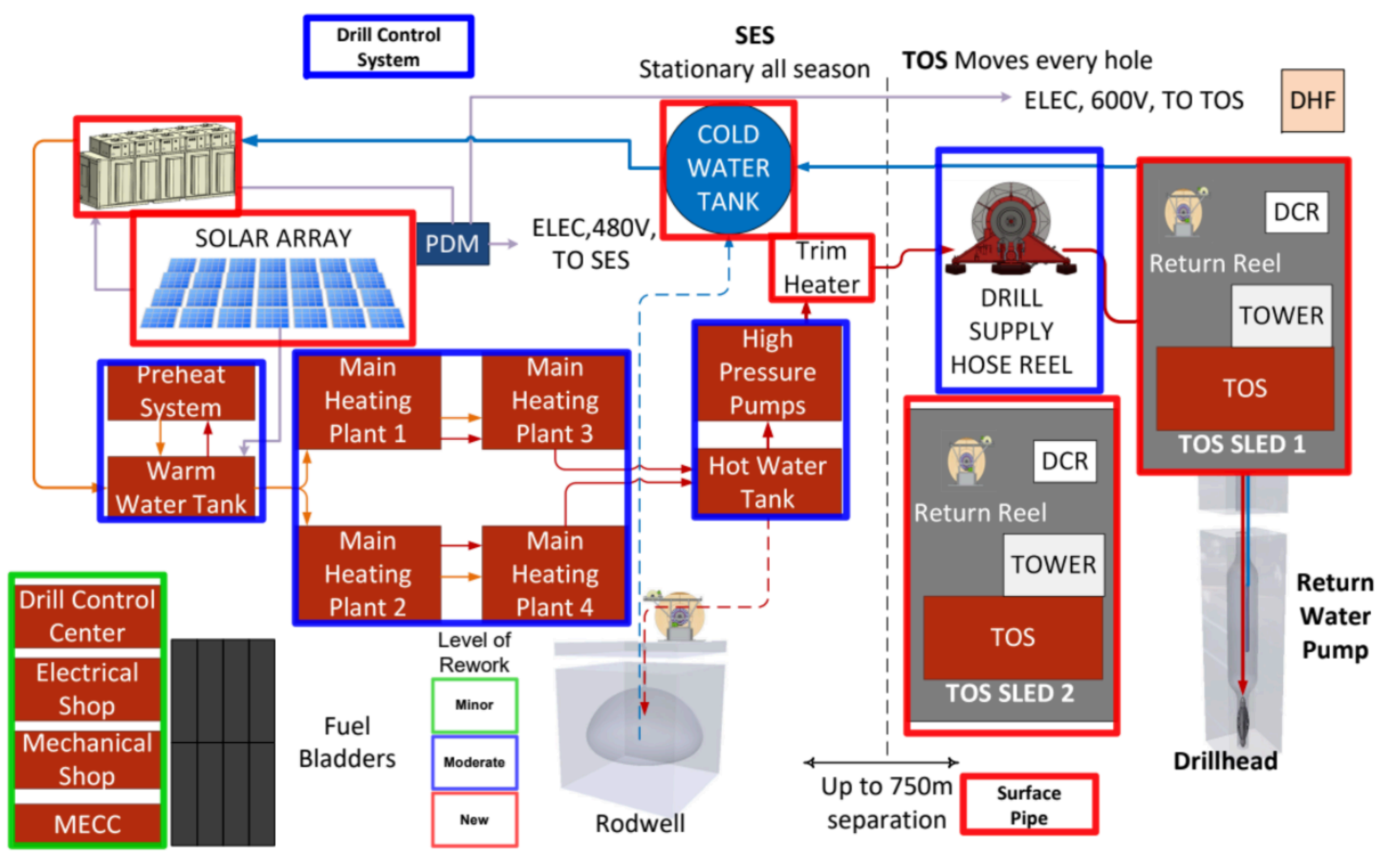



Test of tandem turbines in polar conditions

Bi-facial solar panel tests in the Salt Flats



Scope of work to change the IceCube Upgrade drill system to the Gen2 drill system / figure from [1]




## Conclusions

- Gen2 the next generation neutrino telescope expected to continue the path of discovery of IceCube
- Optimized for the detection of TeV to EeV astrophysical neutrinos combining radio, surface, and optical detection
- Significant cost saving and logistics footprint reduction achievable by augmenting power generation for operations and drilling with renewable energy concepts.
- Hybrid systems consisting of wind, solar, energy storage are capable to provide autonomous power for large South Pole experiments (see also [5])

## References


[1] IceCube Collaboration, Technical Design Review
https://icecube-gen2.wisc.edu/science/publications/tdr/
[2] Y. Makino ICRC2023 (979) - [arXiv:2308.09786]
[3] V. B. Valera, M. Bustamante, and C. Glaser JHEP 06 (2022) 105
[4] Bustamante, Beacom, and Winter PRL 2015 [arXiv:1506.02645]
[5] Babinec, S., et. al "Feasibility of Renewable Energy for Power Generation at the South Pole" [arXiv:2306.13552]