Multi-messenger Astronomy with P-ONE

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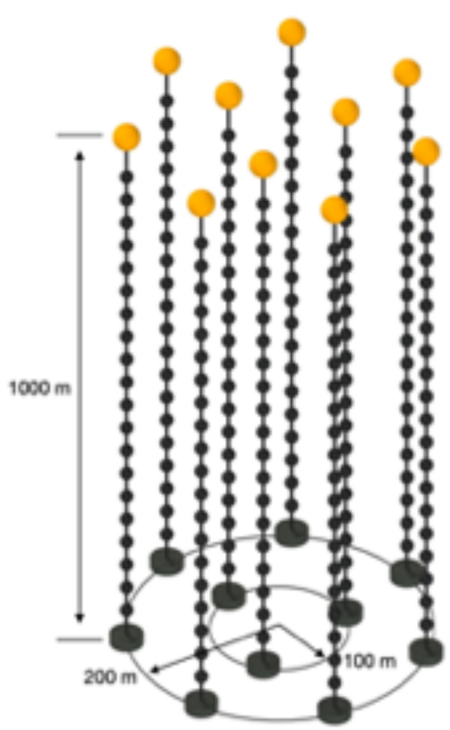

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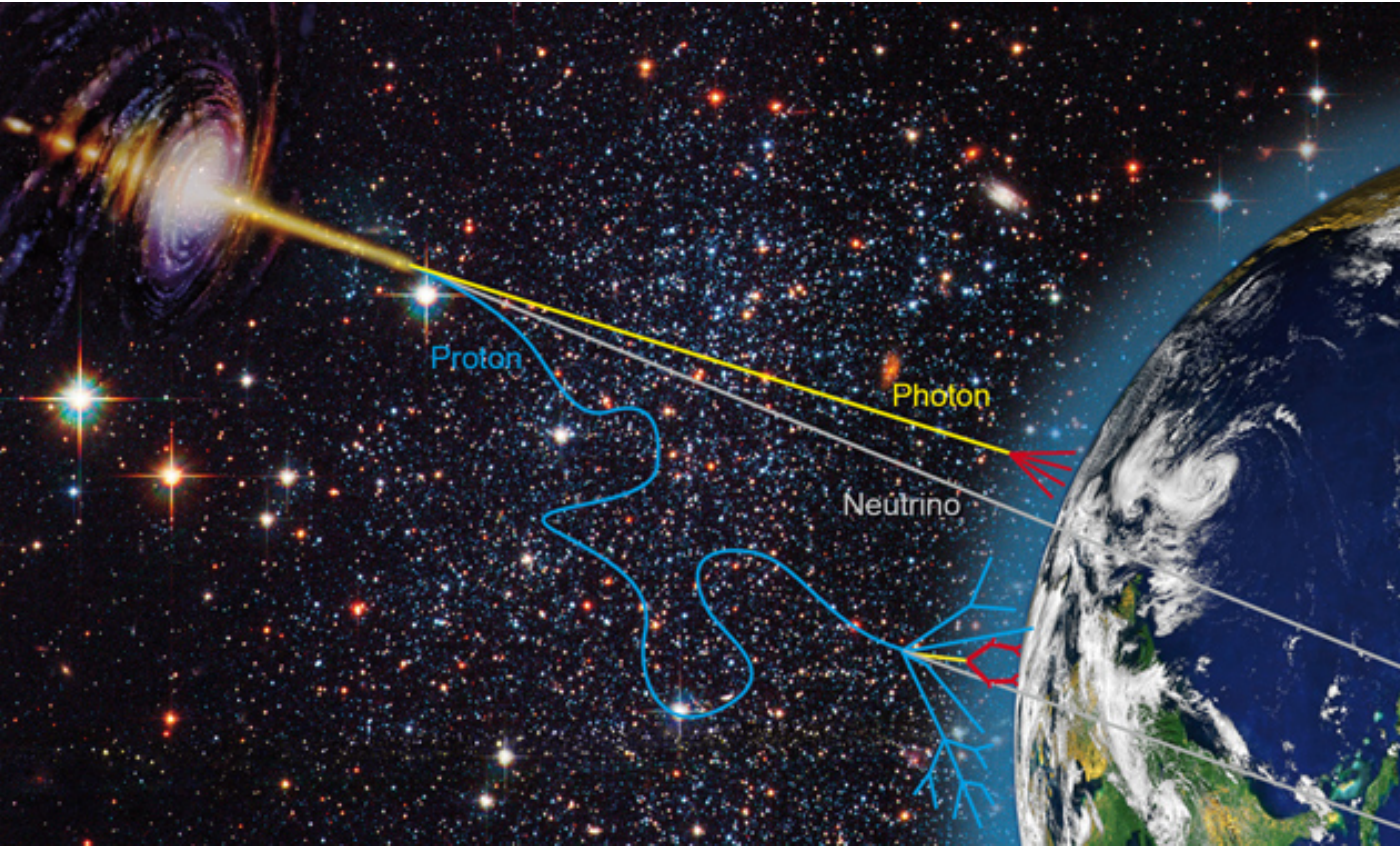
P-ONE

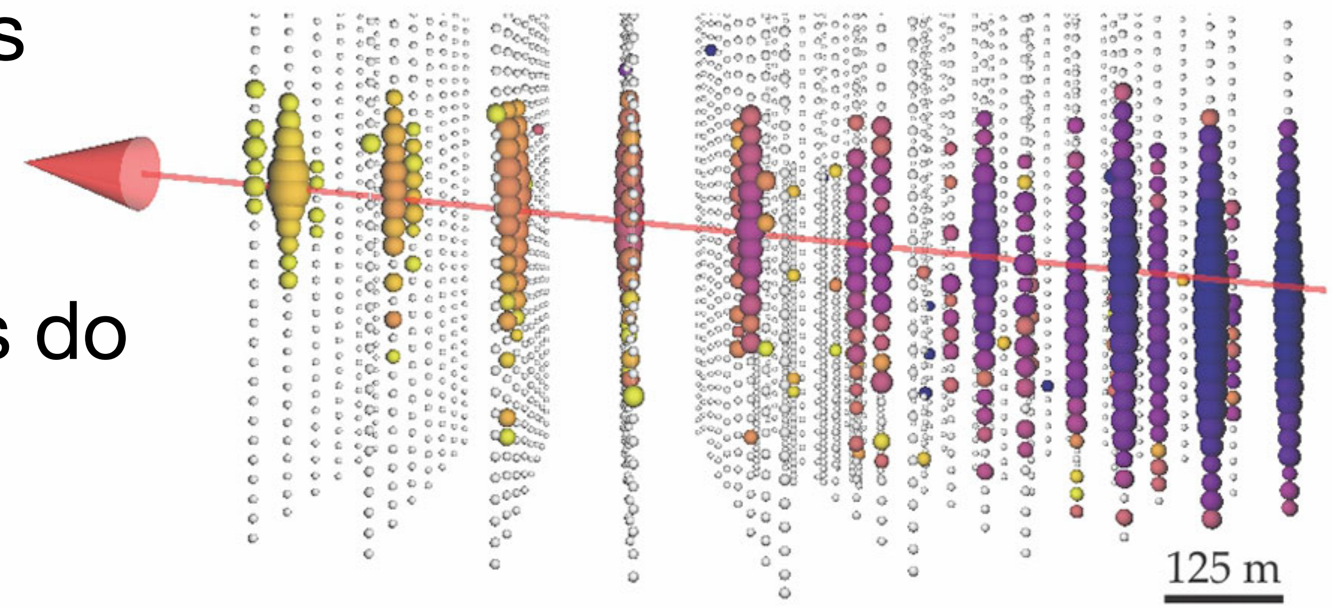
Outline

- Neutrino Multi-Messenger Astronomy
- Sensitivity for high-energy neutrinos worldwide
- P-ONE - The Explorer

Neutrino Sources?

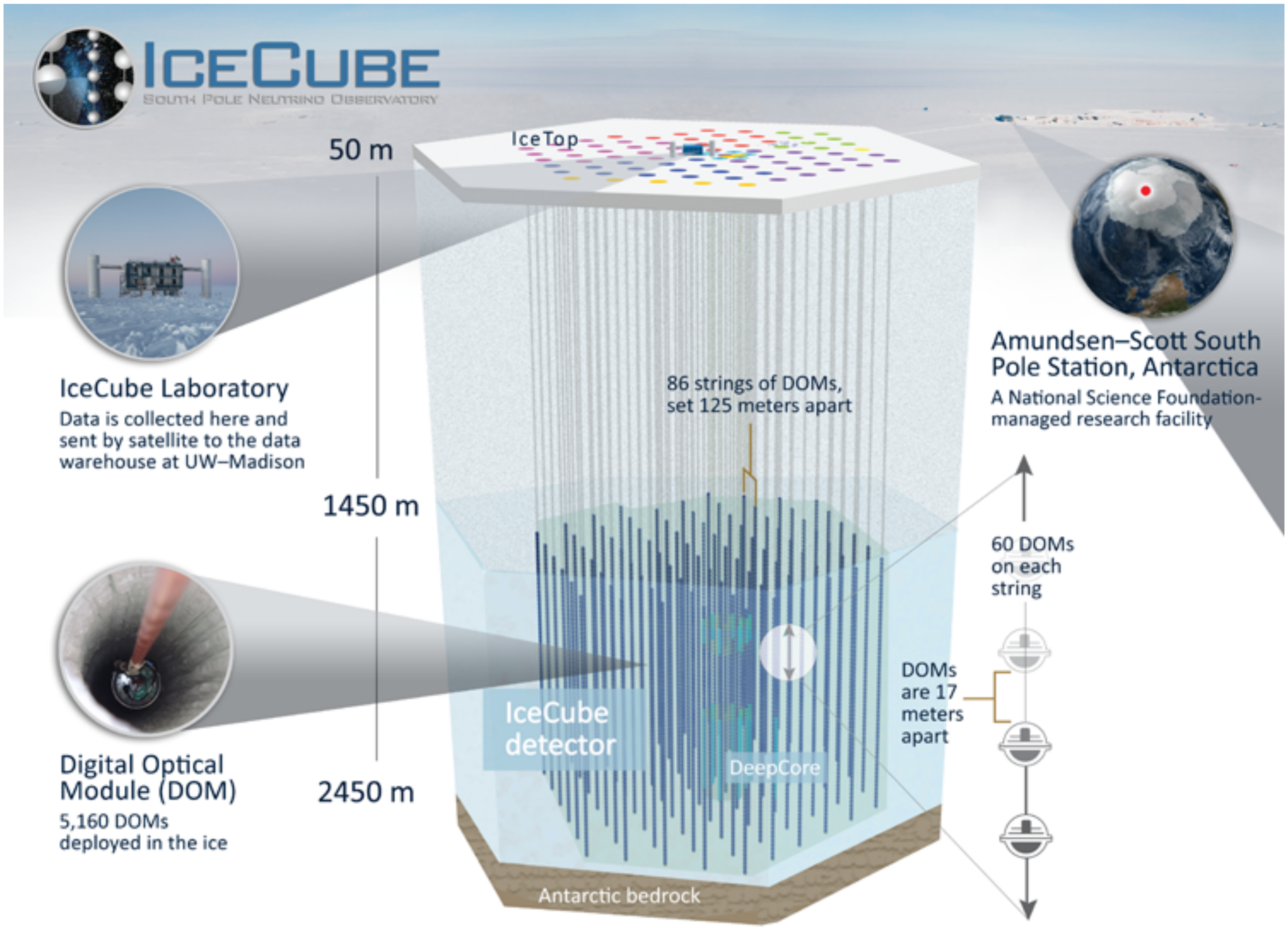


Neutrino Information for Multi-messenger Astronomy



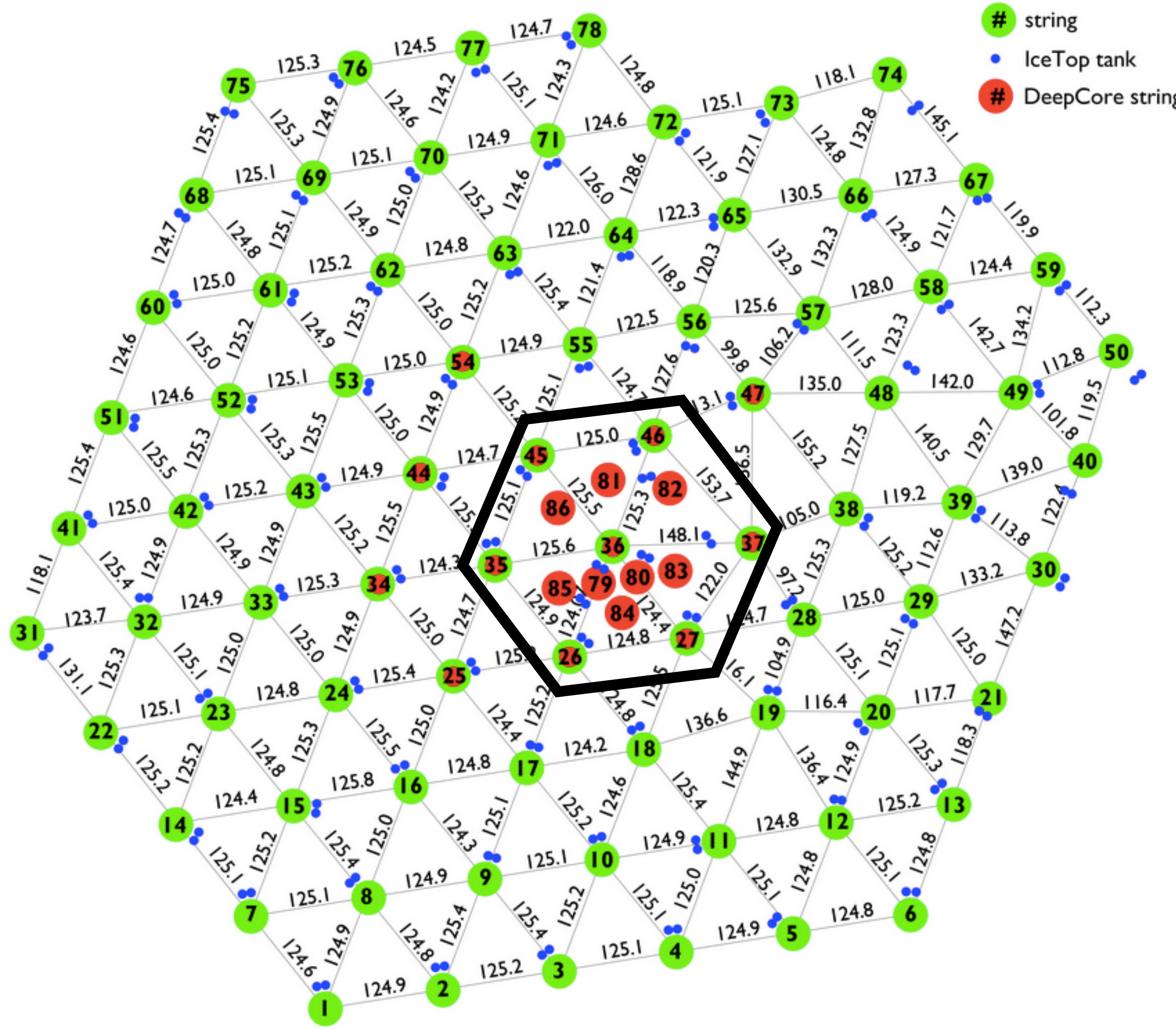
- The sky is opaque for photons above ~100TeV
- Charged particles like protons do not point back to the origin
- Neutrinos loose very little energy propagating and are not deflected by electromagnetic fields or the photon field.
- High energy neutrinos that have a very high probability to come directly from an astrophysical source have been observed by IceCube

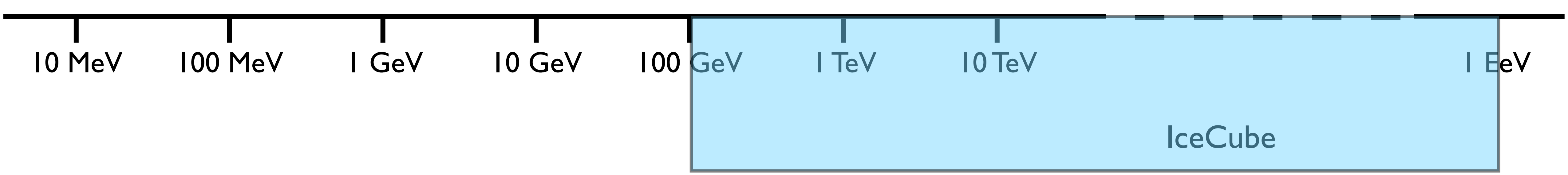
IceCube & Deep Core



IceCube

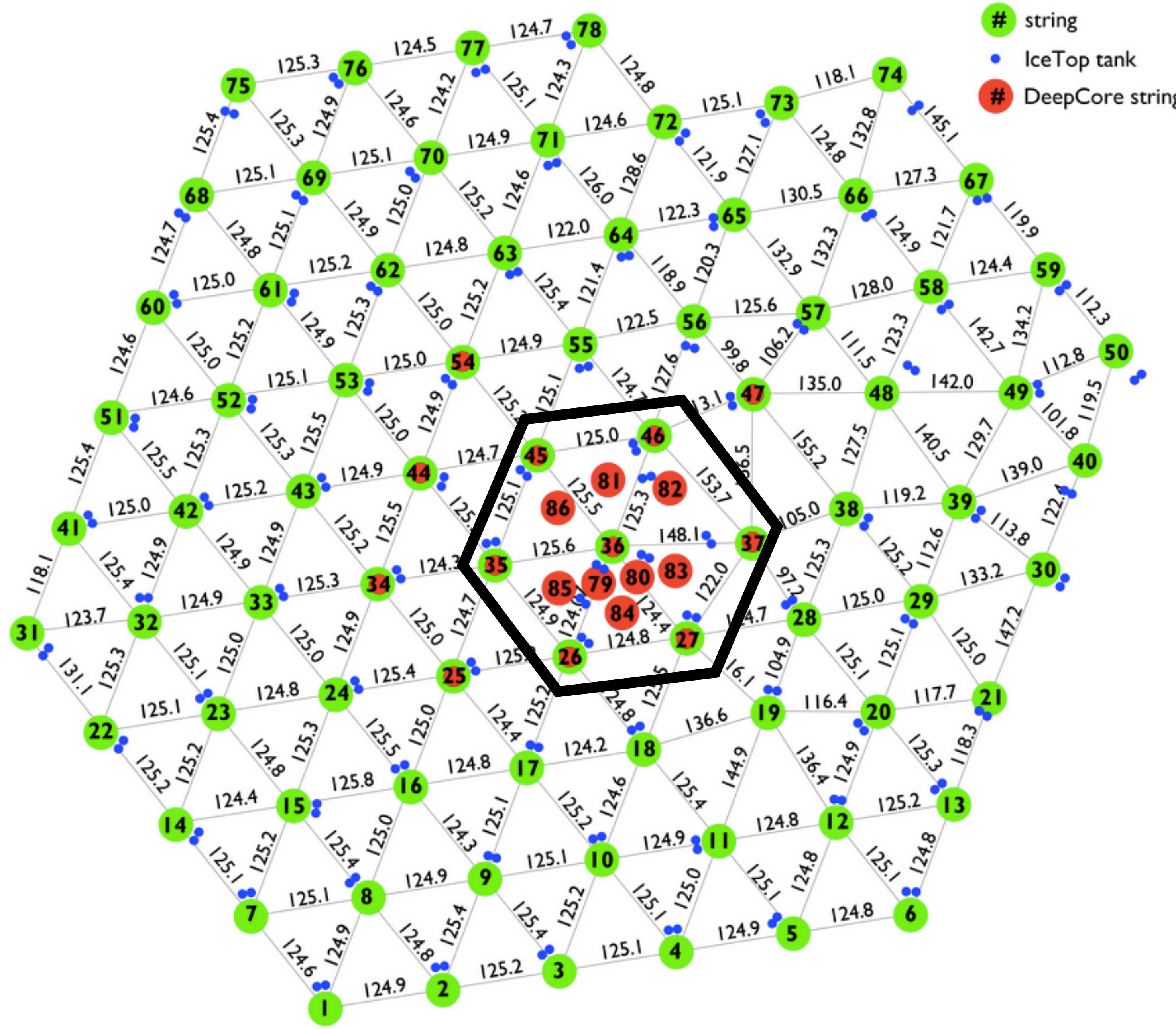
- 78 Strings
    - 125m string spacing
    - 17m DOM spacing

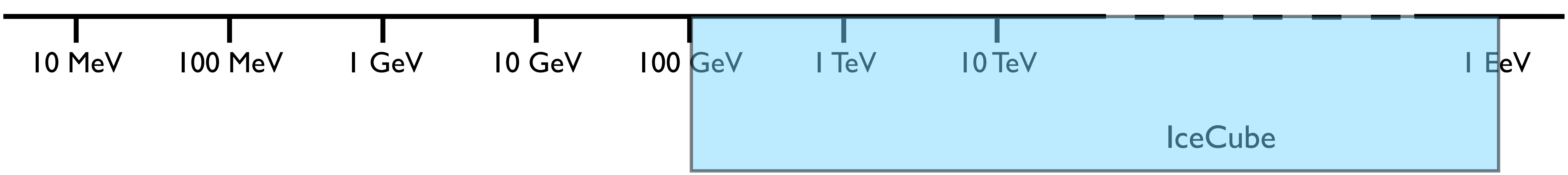




IceCube

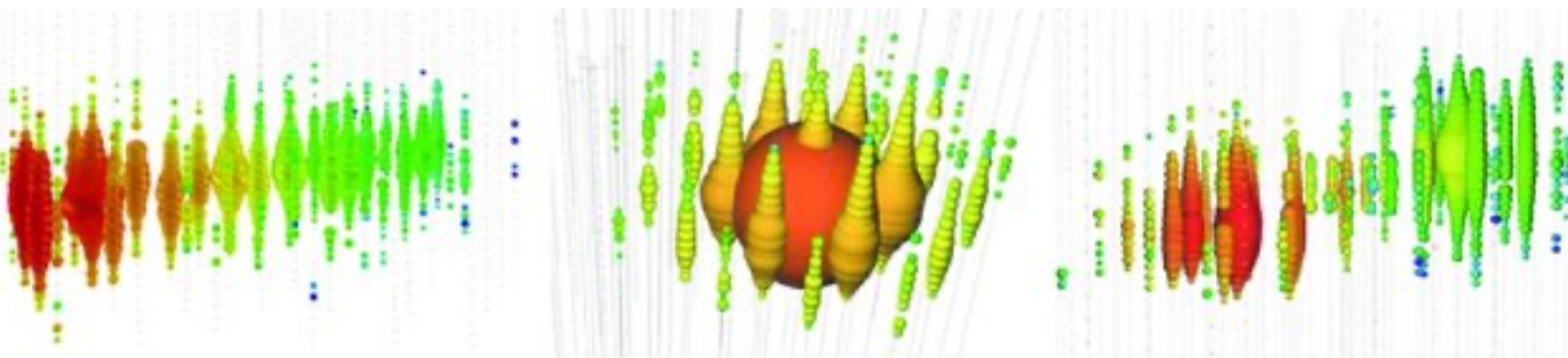
- 78 Strings
  - 125m string spacing
  - 17m DOM spacing
- Add 8 strings - Deep Core
  - 75m string spacing
  - 7m DOM spacing



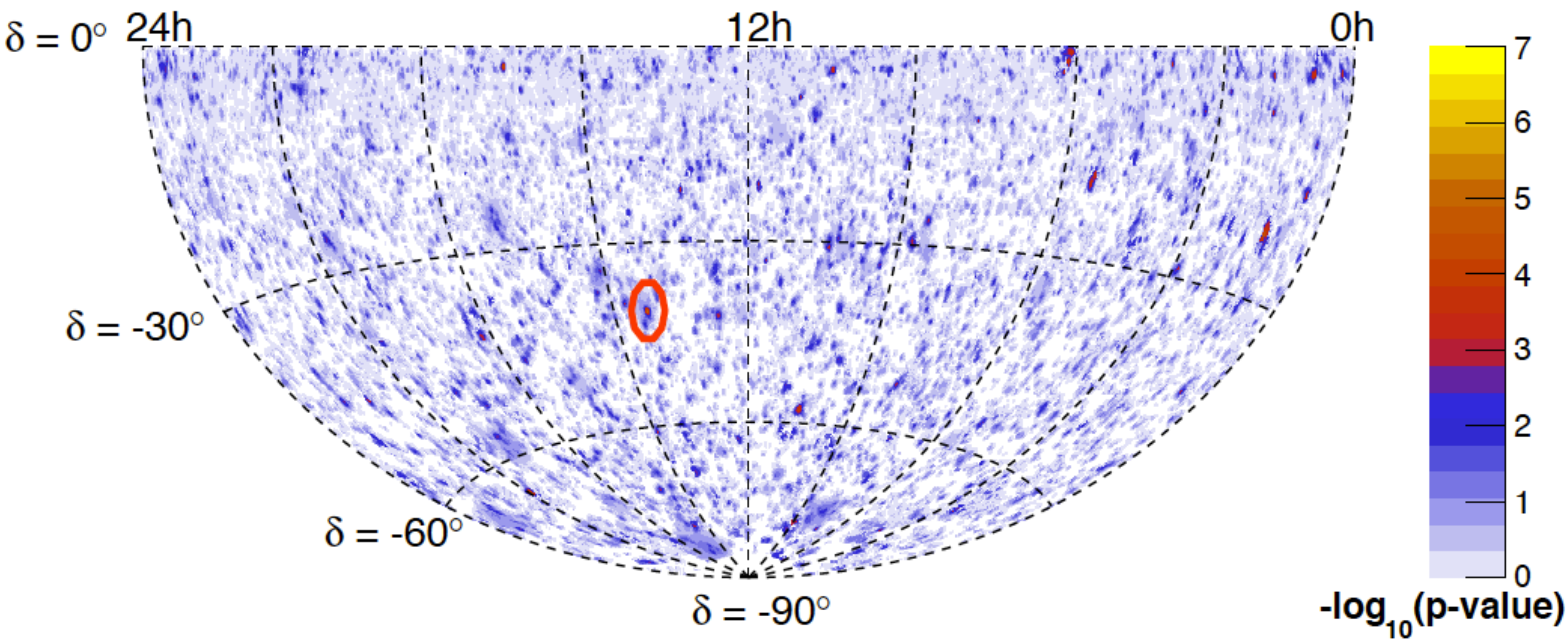


Event Signatures (in Ice)

- Distinct signatures from muon tracks, cascades and tau neutrinos



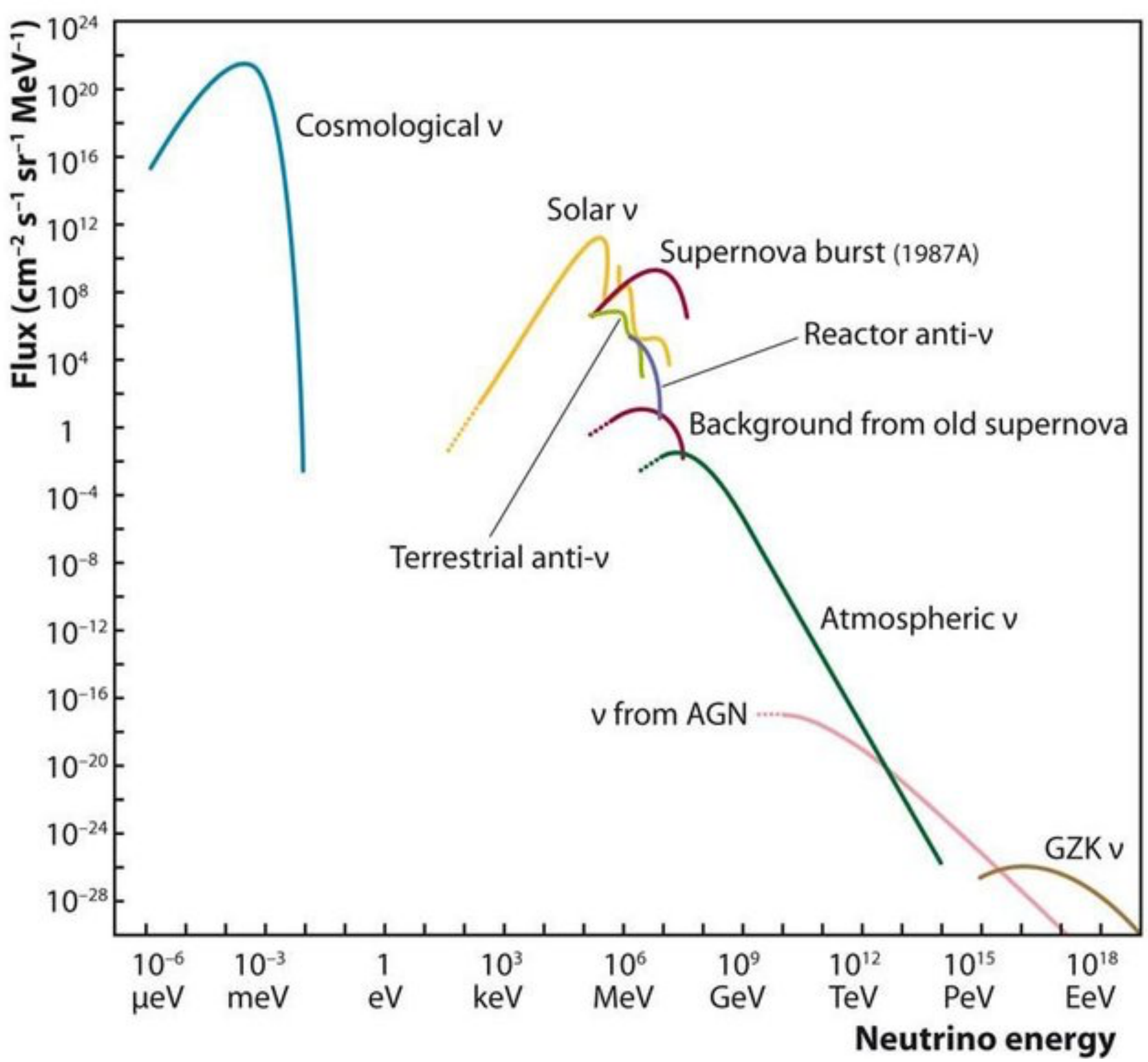
Search for Neutrino Sources



- Combined IceCube Antares skymap - no significant signal yet

https://arxiv.org/pdf/2001.04412.pdf

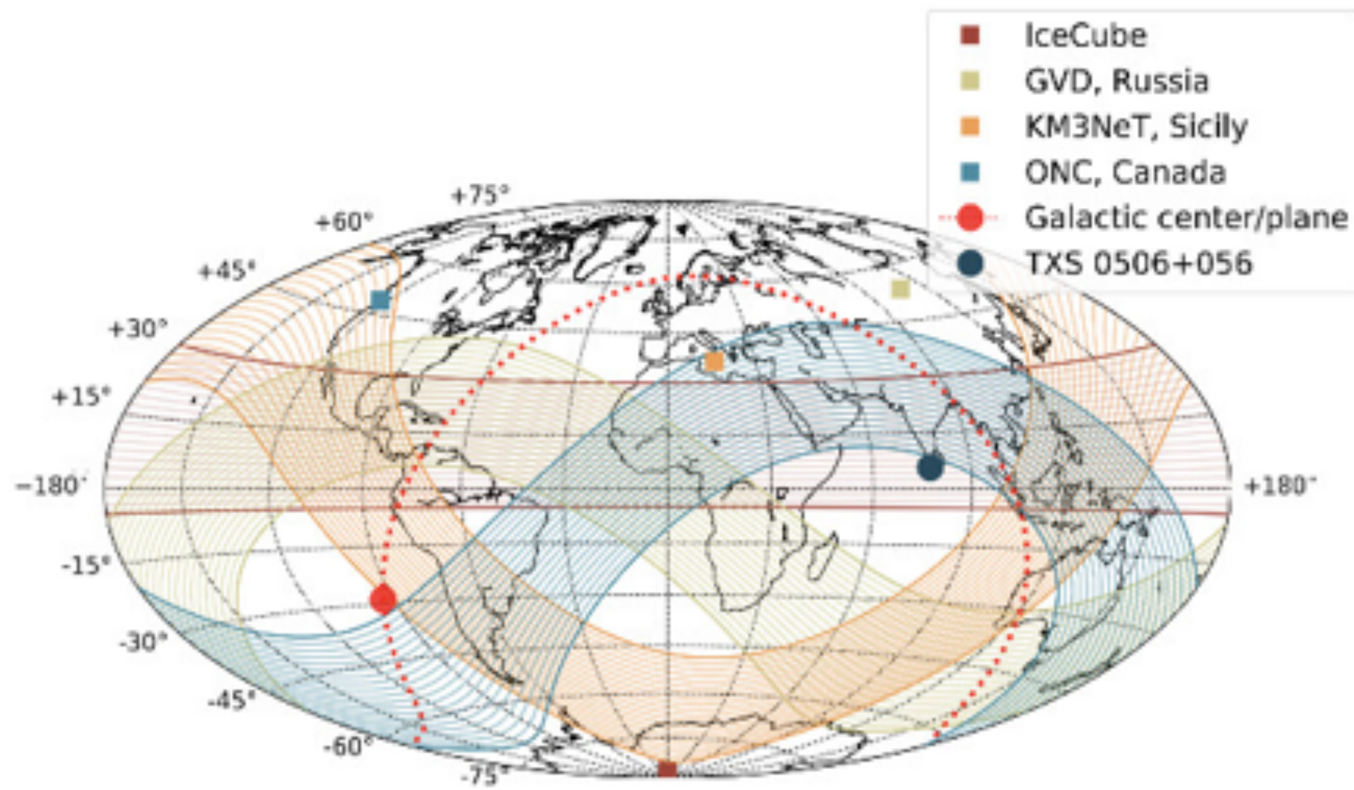
Neutrino Spectrum



- A PeV flux of cosmic neutrinos is now firmly established
- Current detectors are too small to measure fluxes at energies higher than PeV and to find sources

Arxiv 1111.0507

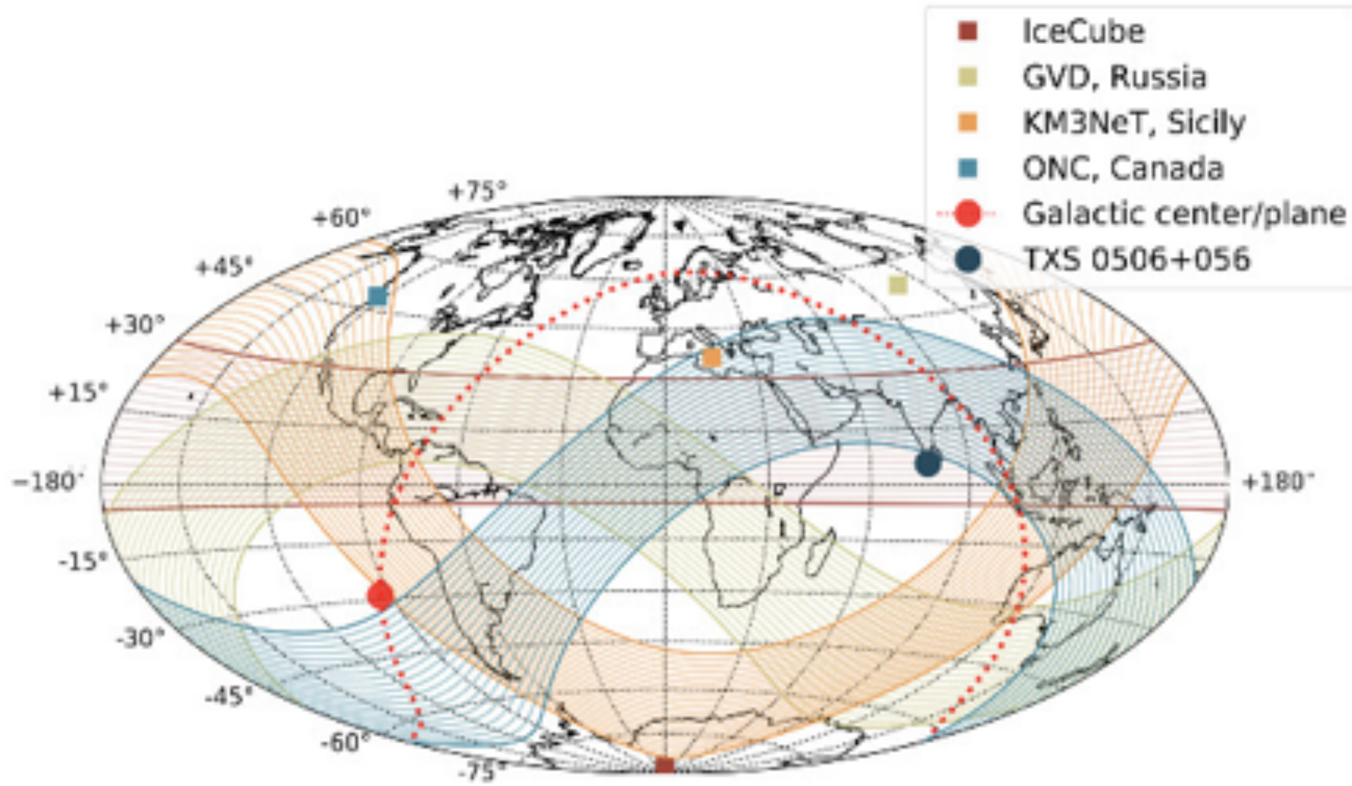
Multiple Neutrino Telescopes?



- Very high energy neutrinos do interact in the dense rock and core material of Earth. At neutrino energies above 50 TeV the planet is almost opaque to neutrinos.

- Neutrino telescopes are most sensitive to neutrinos entering around the horizon - neutrinos going downwards are obscured by cosmic ray muon background and neutrinos traveling through the planet get absorbed

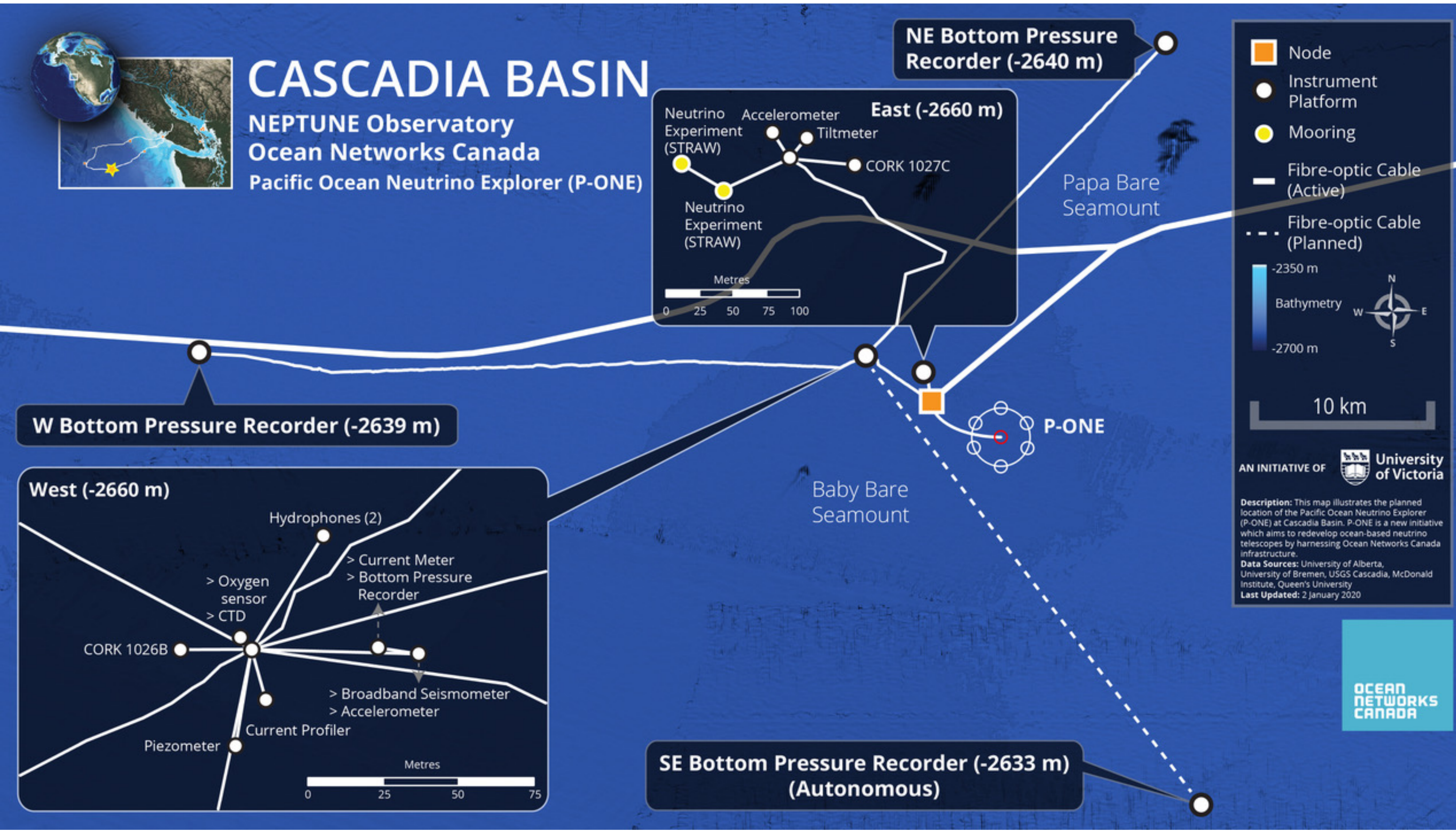
Multiple Neutrino Telescopes?



- With IceCube and three neutrino telescopes of similar size in the northern hemisphere, the current sensitivity to astrophysical neutrinos would be improved by two orders of magnitude!

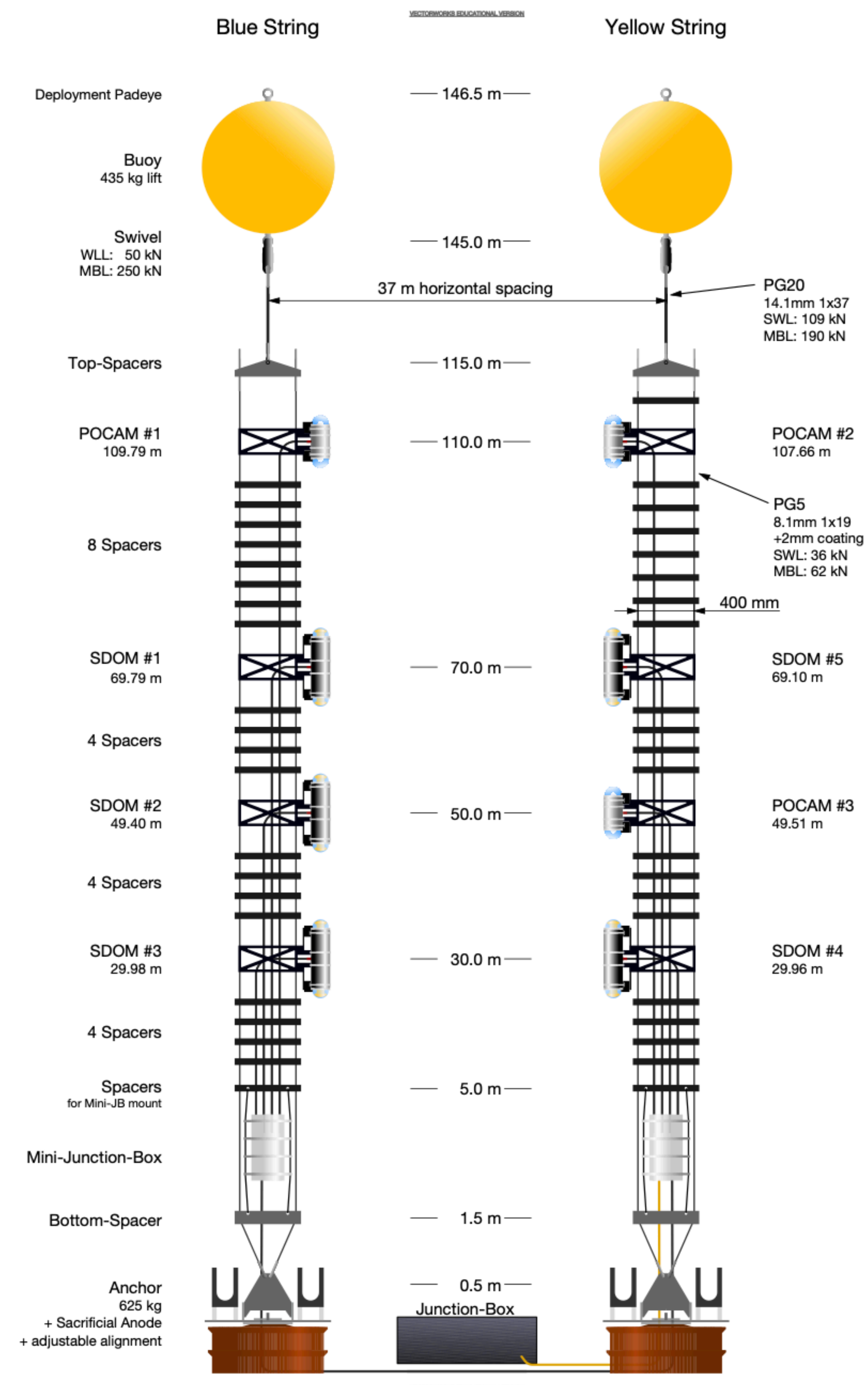
- This assumes that Baikal-GVD and KM3NeT are located where planned and have a $1km^3$ instrumented volume

Cascadia Basin Site



STRAW

- Strings for Absorption in Water
- Deployed in summer 2018
- All instruments are working
- Absorption and scattering length determined to be similar to other ocean based detector locations

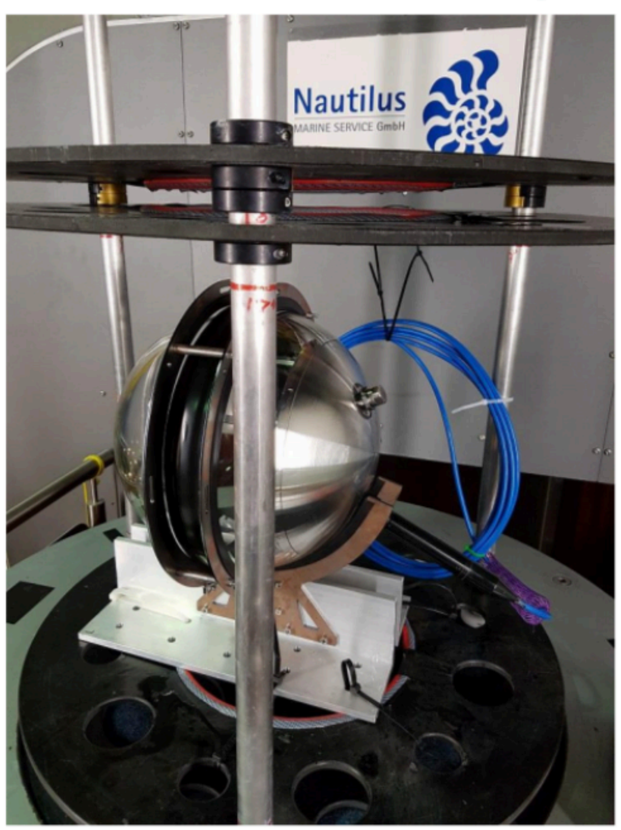


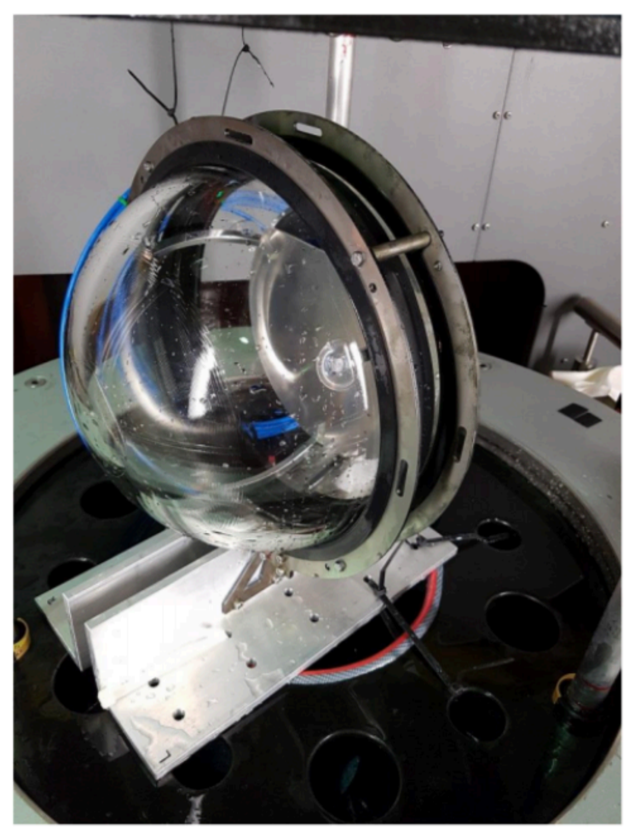
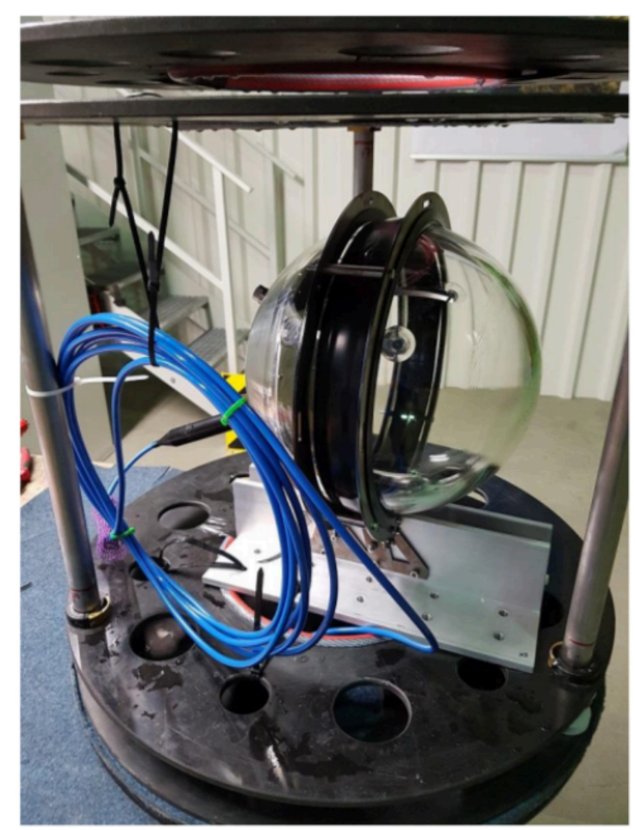
M. Boehmer *et al* 2019 *JINST* **14** P02013

STRAW-b

- Longer string with new, systematically independent measurements: LIDAR, spectrometer

- Technical development at TUM complete, testing and ocean qualification nearly complete



Pacific Ocean Neutrino Explorer

- In 2018 the Straw strings were successfully deployed at the Cascadia Basin site of ONC
- In 2020 the Straw-b follow up system with several new and more sophisticated modules for precise determination of the water properties and calibration of optical modules will be deployed
- The participating institutes are currently simulating detector geometries to optimize the impact from 200 optical modules that are planned to be deployed in 2022+ (CFI IF and TUM funded)
- Once the explorer demonstrates success, a larger several km^3 detector can be pursued, again using ONC infrastructure and expertise

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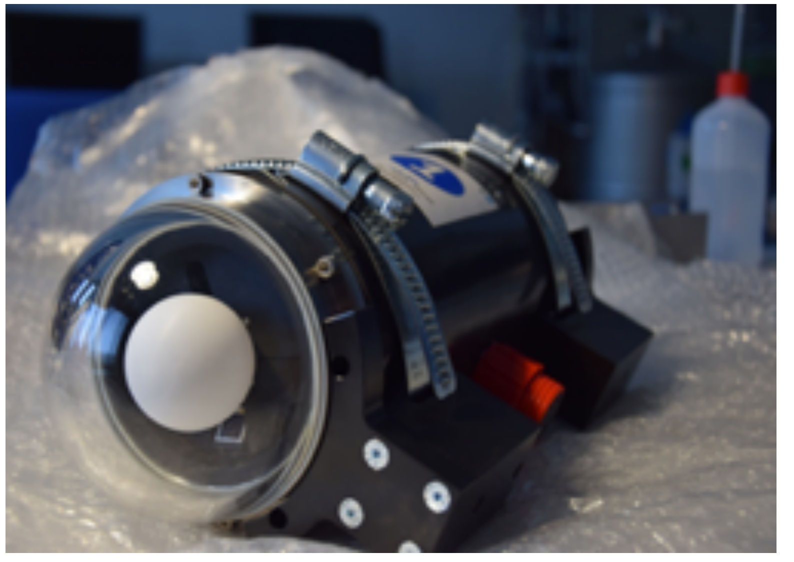
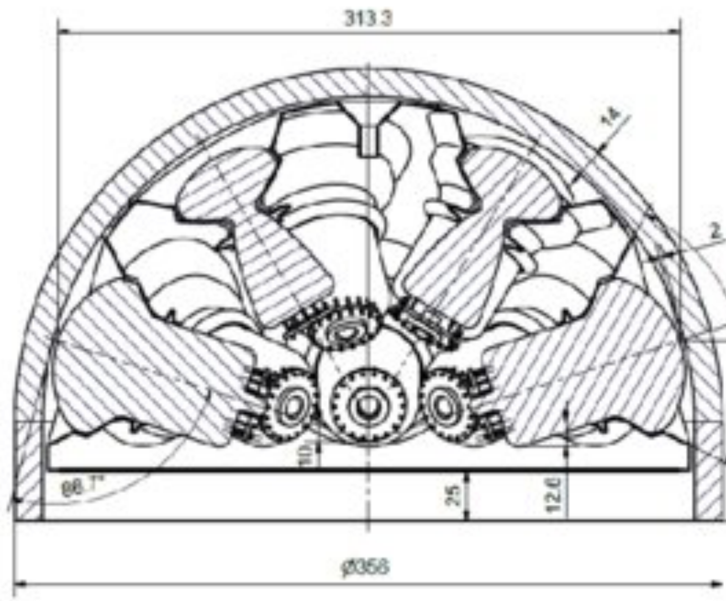
Optical Calibration

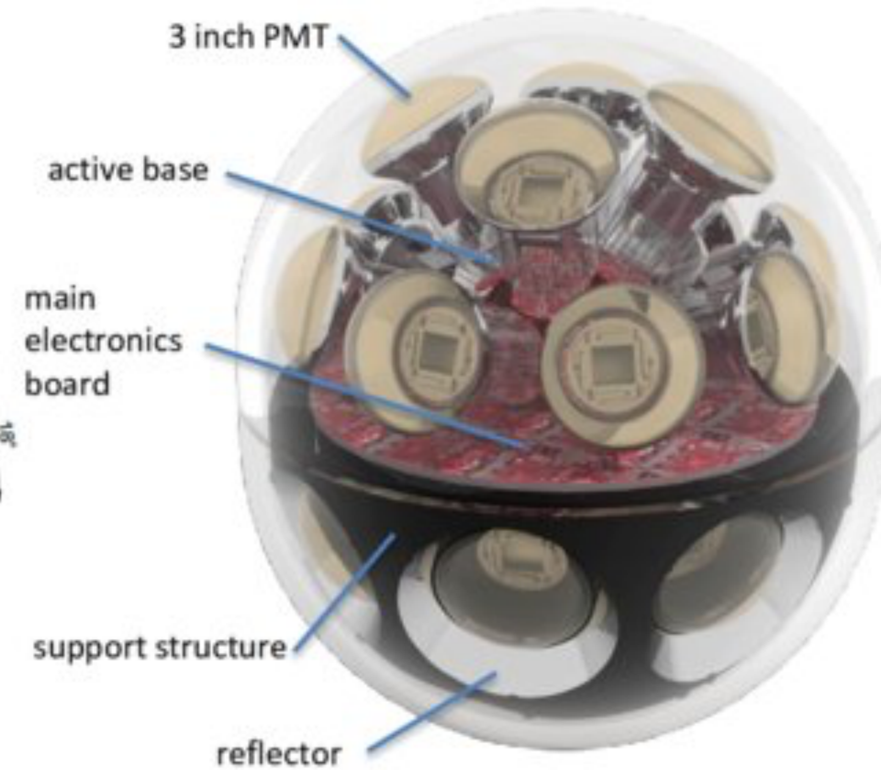


- The ability to understand the ocean water optical properties is key to the success of P-ONE

- IceCube, P-ONE (and STRAW) use the same pulsed light source to calibrate the light response of their detector system and make the energy calibration comparable.

Large Area Photon Detection





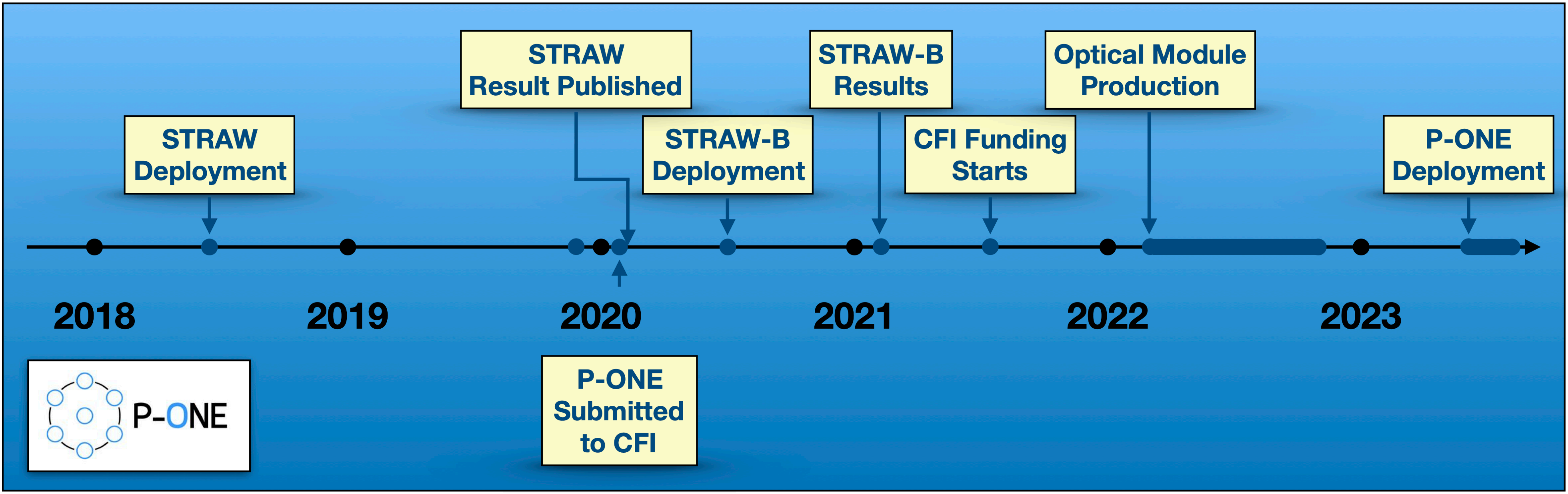
IceCube mDOM

1510.05228v1

- The baseline plan for the instrumentation of the ~200 optical modules of P-ONE is to use IceCube-like multi PMT digital optical modules

- 3” PMTs offer a good cost to surface area ratio

P-ONE Timeline



Summary

- ONC provides a unique infrastructure for under-water instruments and the optics in Cascadia Basin at 2660m depth has already been shown to be good enough for neutrino physics

- P-ONE will have about 200 optical modules and is planned to be build from European and CFI funds

- This 1/8 IceCube sized experiment will allow neutrino multi-messenger astronomy to reach the next step - in Canada with the potential to later host a large Pacific Ocean Neutrino Experiment