The Pacific Ocean Neutrino Experiment

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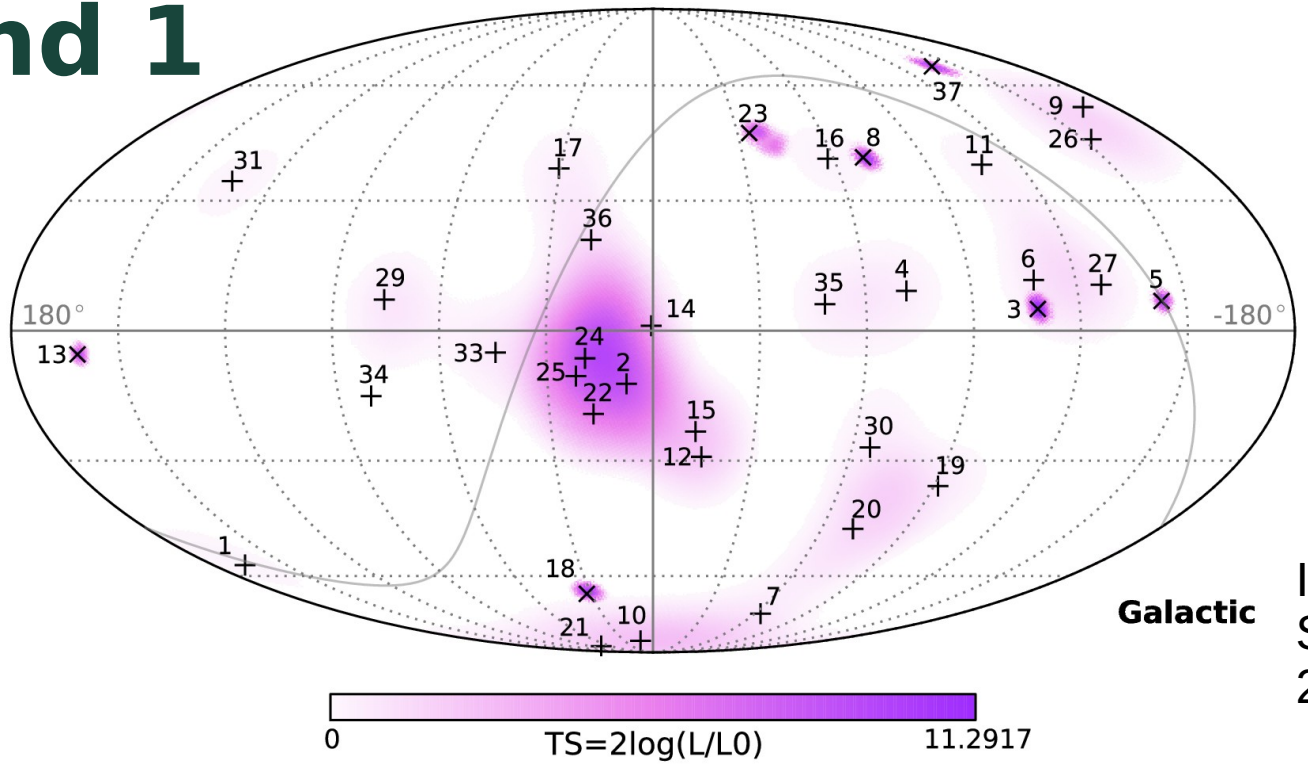
31 August, 2023

P-ONE

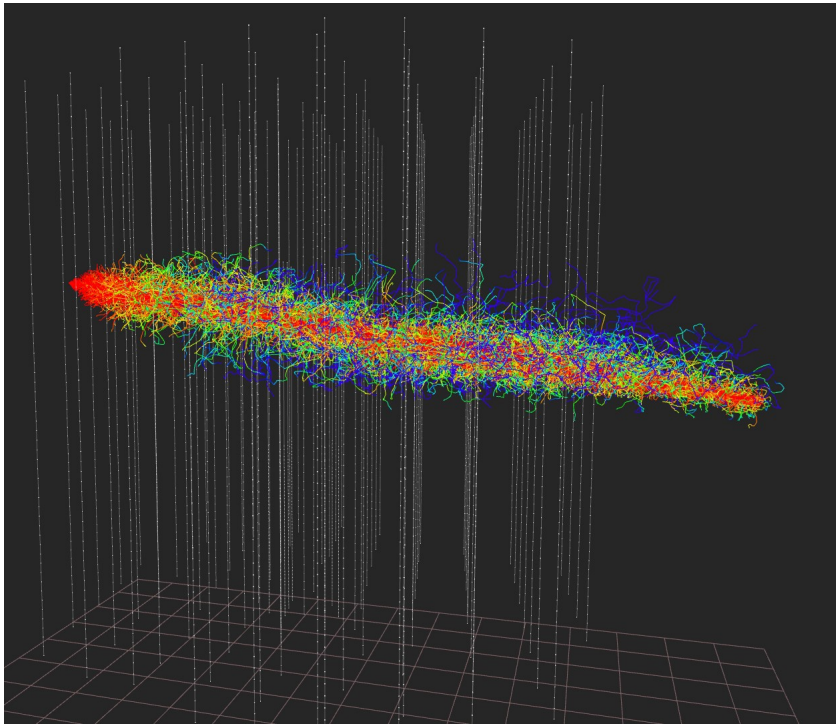
The Neutrino Sky: Round 1

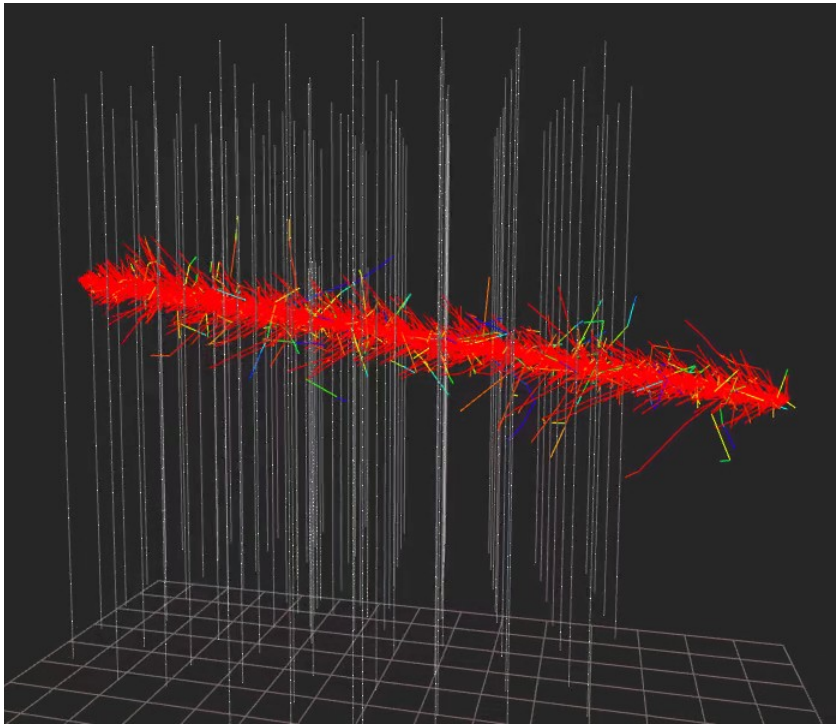


IceCube, Science 2013

Q: How do we make this less blurry?

Ice → Water





Simulated 100 TeV Muon

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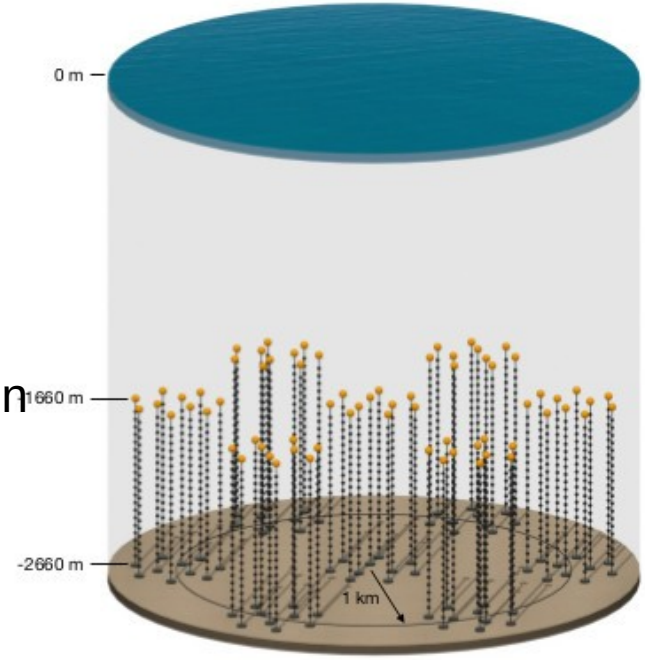
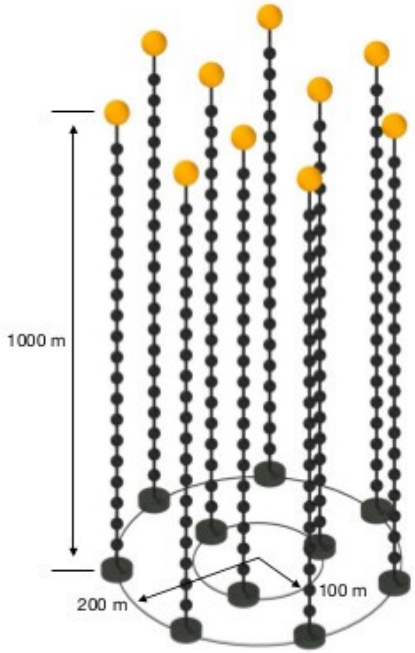
- Goals for the field after IceCube:
  - More sources → **Better resolution**
  - Better view of our galaxy → **Northern hemisphere site**
  - Full-sky coverage → **Multiple Telescopes**
- Much-reduced optical scattering in sea water: 5x better angular resolution, 5x better sensitivity, **10x more sources**
- Planning similar km^3 volume to IceCube
- **Precision flavor and direction**





Nature Astronomy 4, 913-915, 2020

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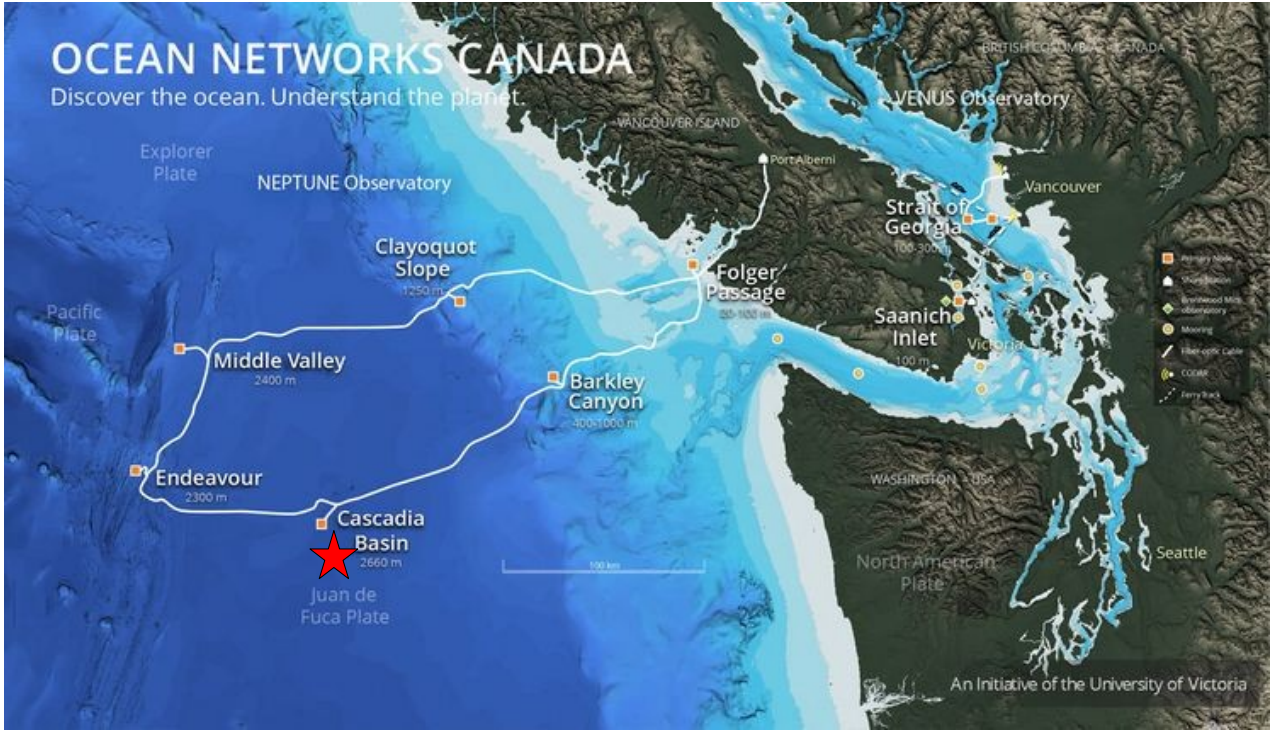
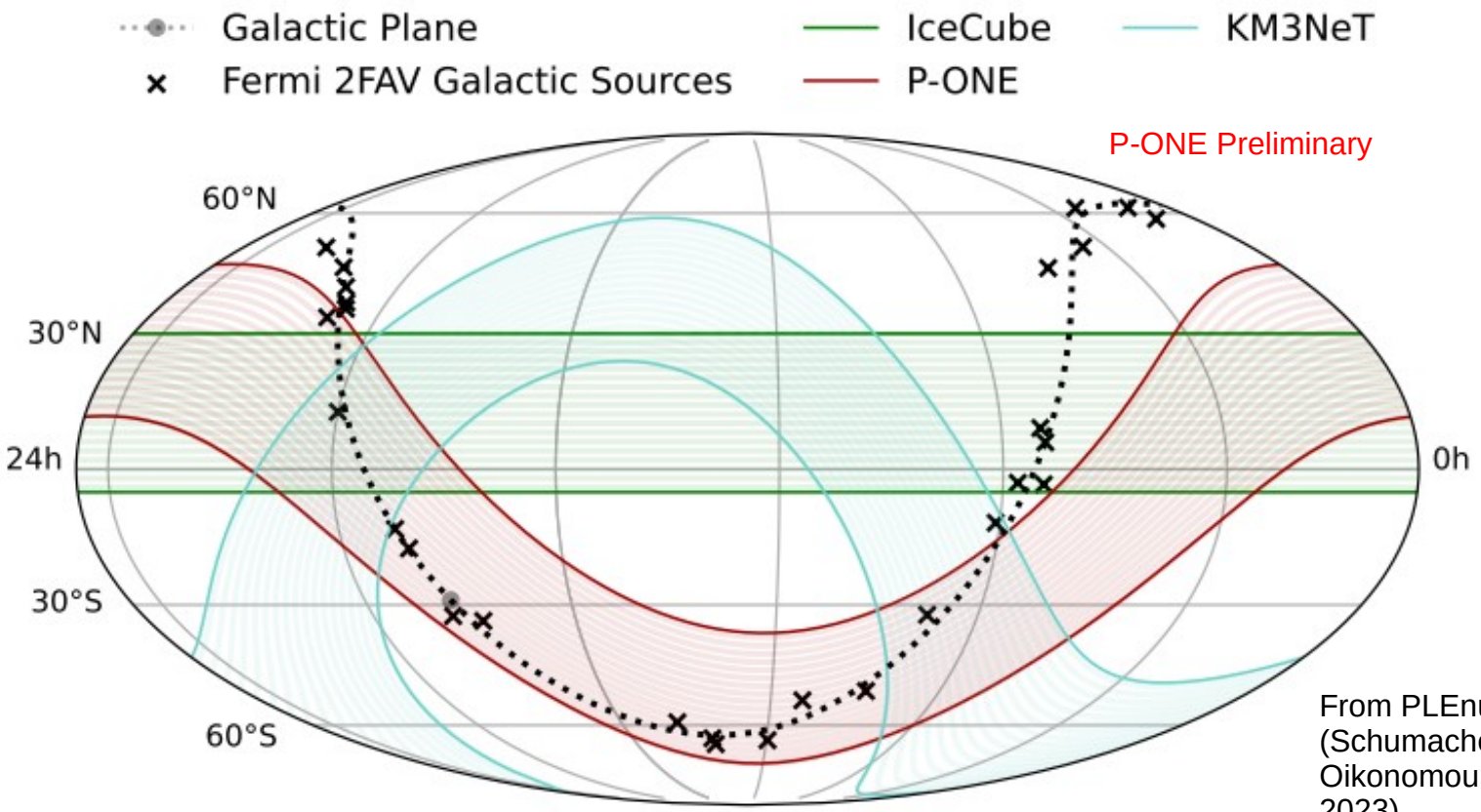
- Deep (below 2500 m), low-sediment-burden water
- NEPTUNE subsea cable provides power (8-60 KW) and data transport (> 2 Gbit/s)
- **Northern-hemisphere site sees complementary sky to IceCube and KM3net**



P-ONE Collaboration

- Joint European, US, and Canadian project:
  - **Germany**: TUM, Erlangen
  - **US**: Georgia Tech, Drexel, Michigan State
  - **Canada**: Alberta, Simon Fraser, Queen's, Ocean Networks Canada
  - **UK**: University College London
  - **Poland**: Institute for Nuclear Sciences
- **Initial ERC+CFI+NSF funding secured, sufficient for the first ~6-7 mooring lines**

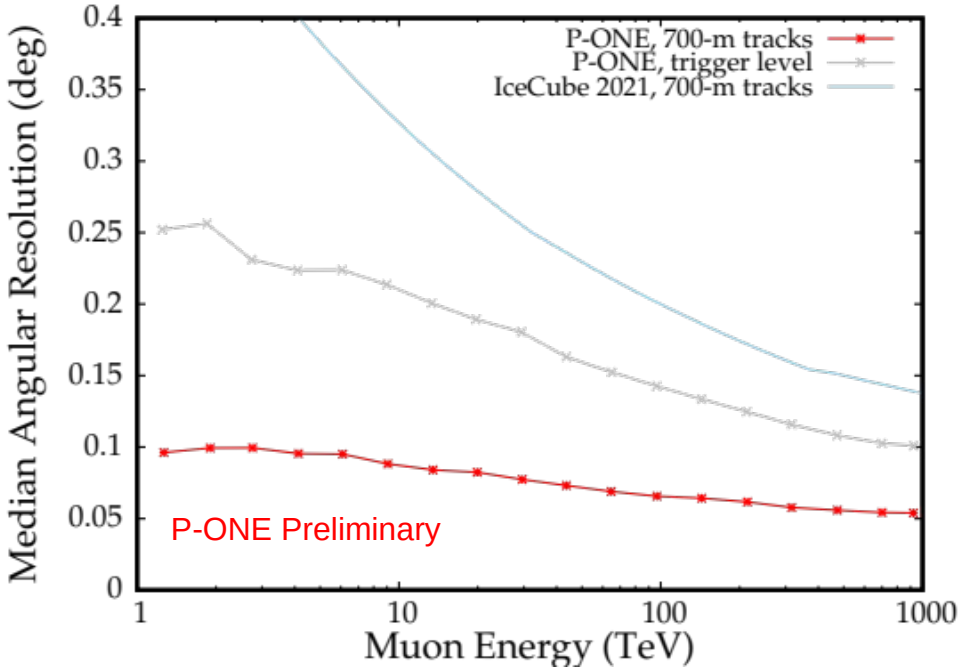
More Events



From PLEnuM (Schumacher & Oikonomou, ICRC 2023)

Better Events

- Expected performance ~ 5x IceCube
- Enabled by less scattering and newer electronics design
- **Expect to detect 10-15 times as many sources as IceCube – enough to find what they have in common**
- TXS 0506+056 from 3.5 sigma to ~15, detectable without EM data

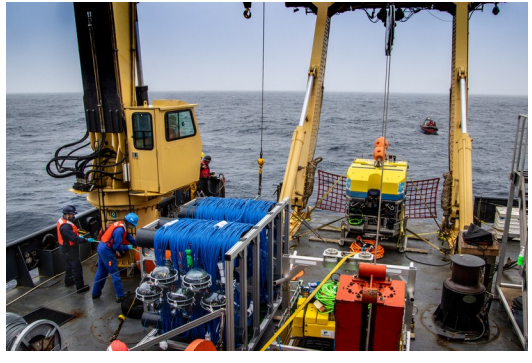


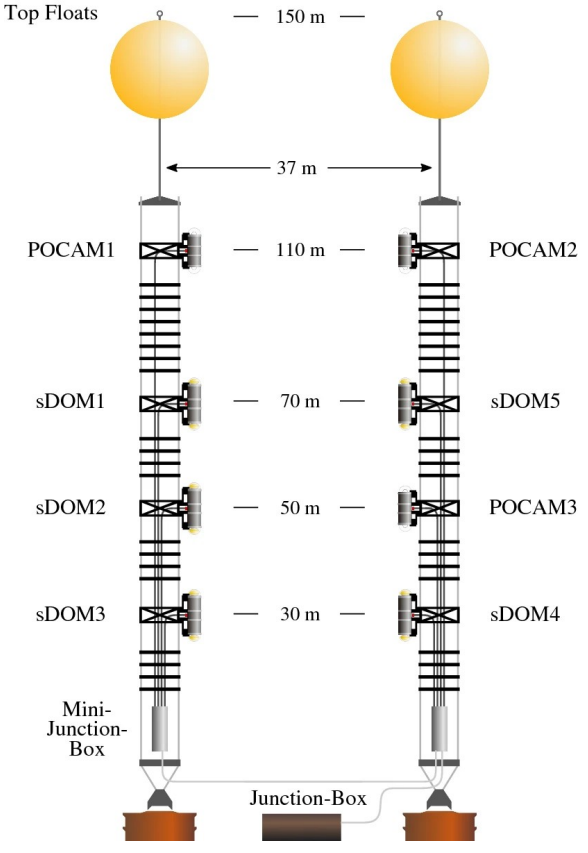
J.P. Twagirayezu (MSU, NSBP 2022)

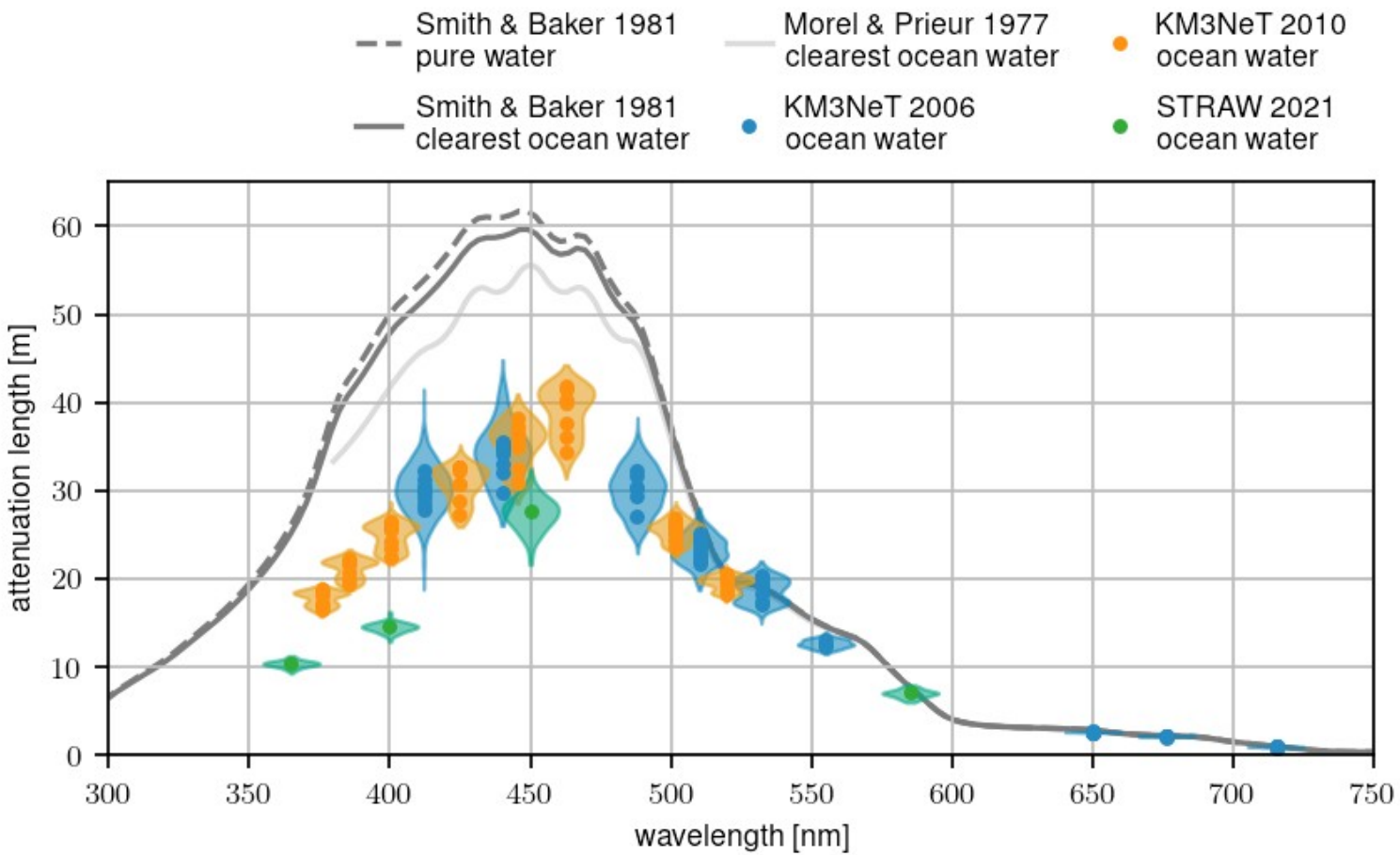
* assumes Euclidean source distribution, average scaling of significance with resolution

Pathfinder Instrument: STRAW

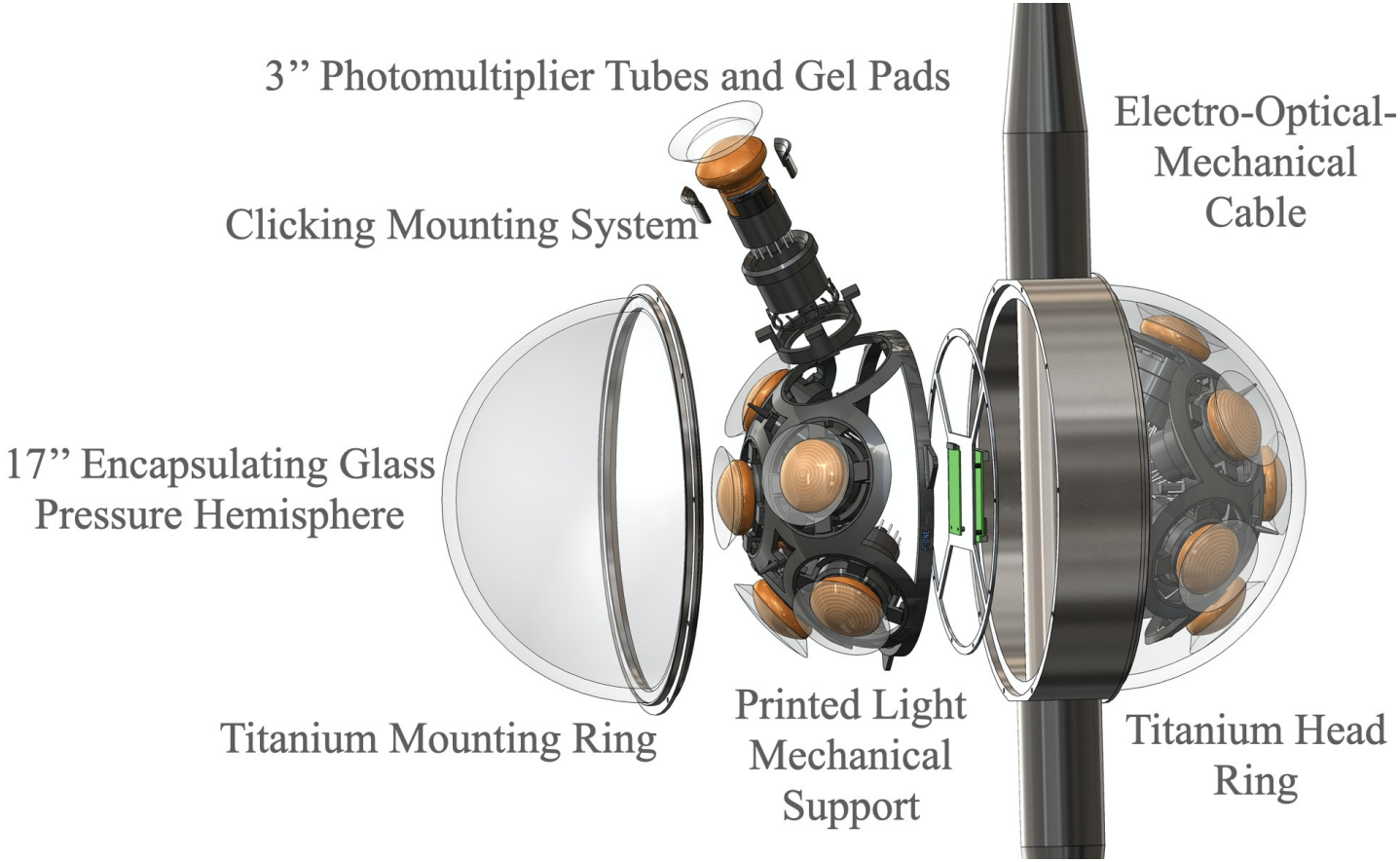
- Laser calibrator, cameras, spectrometer
- 10 phototubes on 150-m lines
- Deployed at Cascadia site in 2018 by ONC
- Successfully taking data since
- Successor survey instrument, STRAW-b, deployed fall 2020: 500-meter lines






Smith & Baker 1981
pure water
Smith & Baker 1981
clearest ocean water
Morel & Prieur 1977
clearest ocean water
KM3NeT 2006
ocean water
KM3NeT 2010
ocean water
STRAW 2021
ocean water
attenuation length [m]
0
10
20
30
40
50
60
300
350
400
450
500
550
600
650
700
750
wavelength [nm]

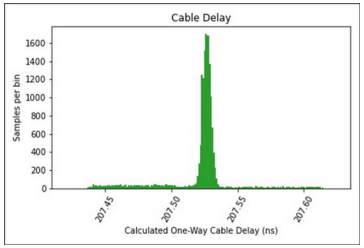
P-ONE Instrument Design: Optical Module

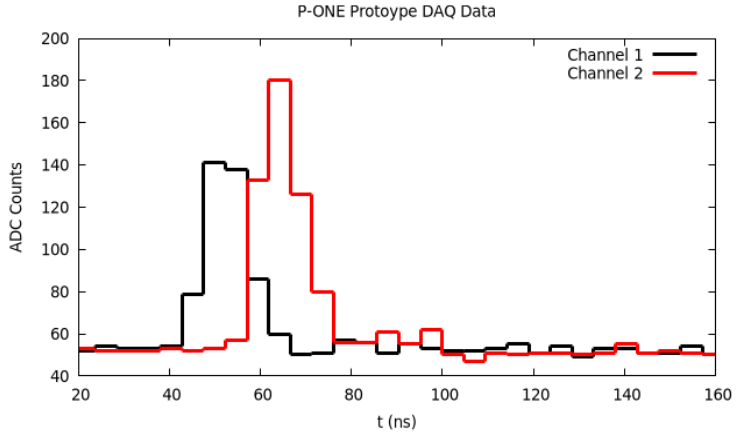


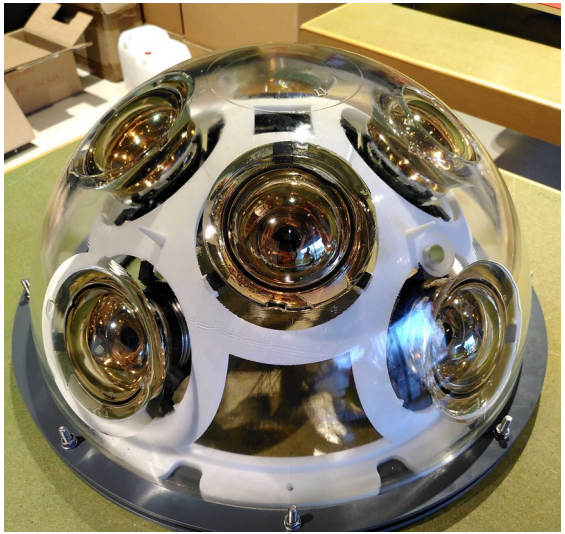
Instrument Design: Optical Module

J. Garriz, MSU

- 16 photomultiplier tubes in all-direction array: < 10 ps stat. error on timing
- Acoustic positioning sensors
- Hybrid copper/fiber timing and data backhaul
- **Full waveforms: 210 MSPS, 12-bit readout on all channels**
- Firmware trigger logic on FPGA
- ~ 6 W per module power consumption





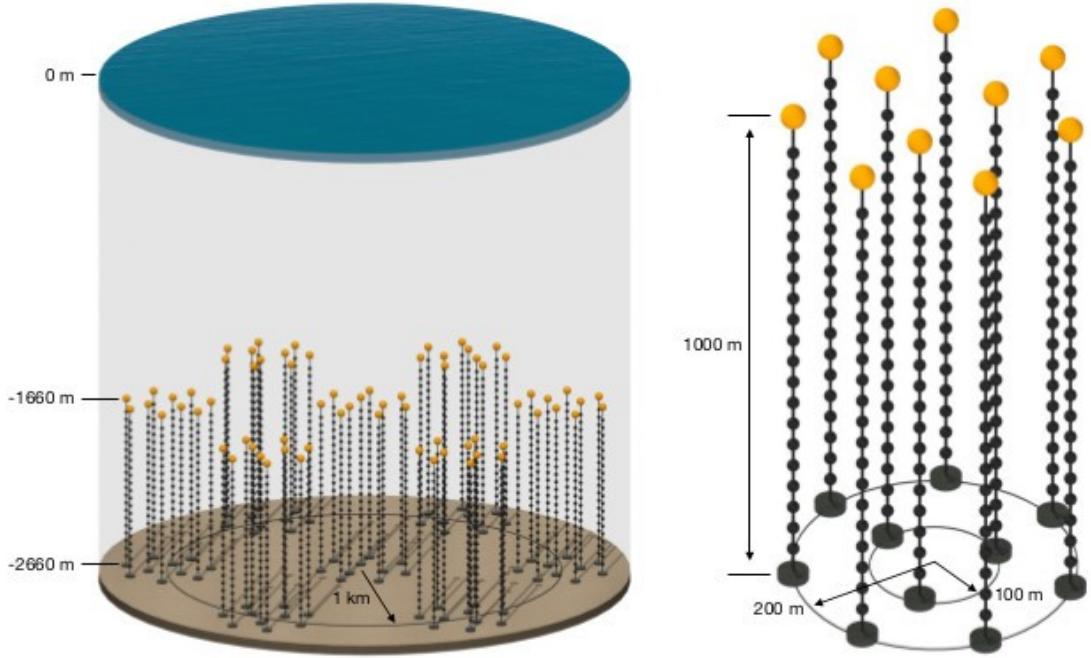


Project Timeline

- 2018: STRAW-a site survey deployed
- 2020: STRAW-b site survey deployed
- 2022: Finalizing hardware design, core instrumentation acquired
- **2024-25: First full mooring line deployed (P-ONE-1)**
- **~2026: Next funded lines deployed**
- Late 2020s: Full buildout

Conclusions

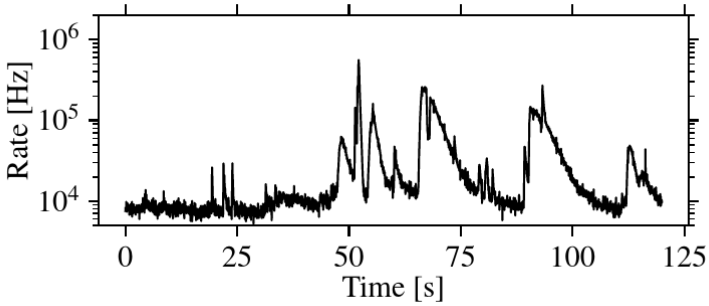
- Large diffuse neutrino background up to very high energies seen by IceCube, **requires next-generation precision detectors to understand**
- P-ONE **complementary to KM3net and IceCube-Gen2**, at low cost with low logistical risk
- Beginning construction in ~ 1 year!

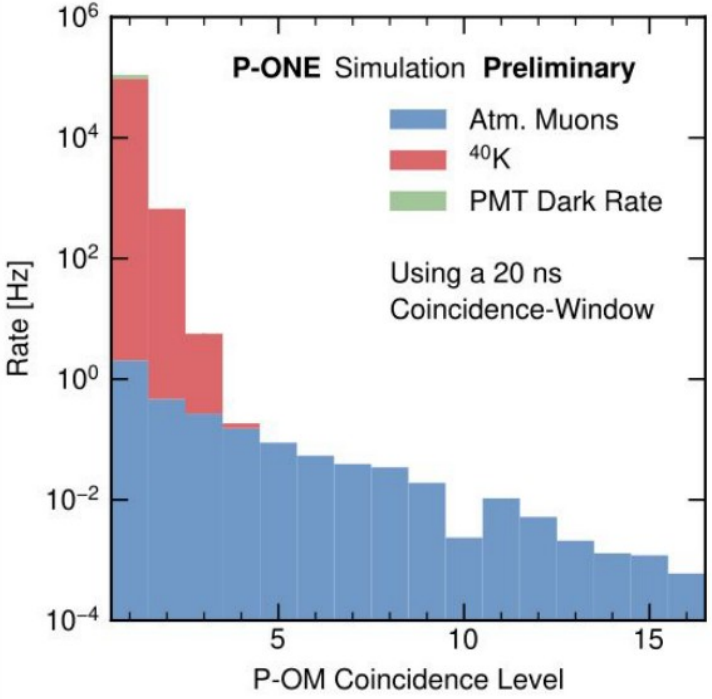


Backup

Radioactive Decays

- Continuous process responsible for baseline noise
- Largely K_{40} decay in potassium salts
- Rate traces salinity

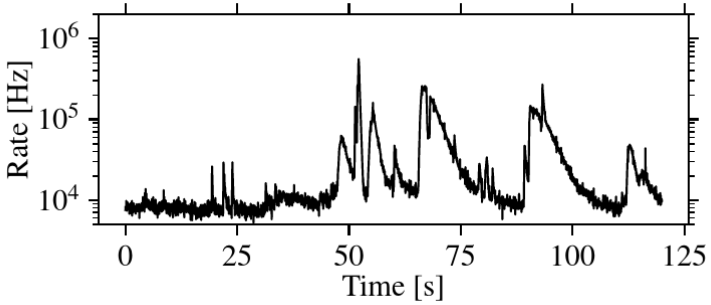


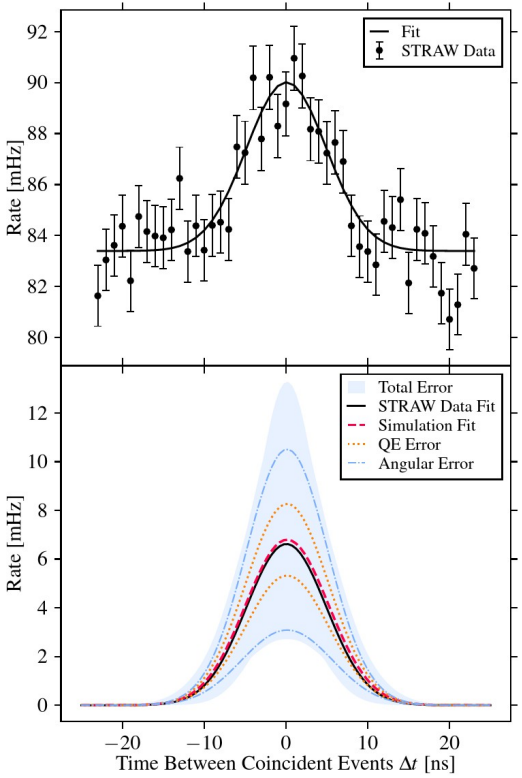


Jakub Stucho

Measurement of Radioactive Decays

- Light from Cerenkov and ionization emission from betas
- Multiple correlated photons detected
- Can distinguish energies (and isotopes) weakly
- Sub-0.1% daily concentration measurement, 3D abundance measurement





Bioluminescence

- Major time-variable source of noise
- Mostly microbial (with large-scale correlations)
- Some large organisms (right)
- Large variation with water conditions and currents, seasonality

60-second exposure

Bioluminescence Measurements

- Emission correlation timescale
- Brightness
- Position:
  - Side current is from
  - 3D positions
  - Correlation with turbidity
- Photographs for large organisms