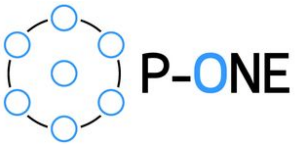
The Pacific Ocean Neutrino Experiment (P-ONE)

Andreas Gaertner for the P-ONE Collaboration
04 May 2023



Neutrino Astronomy

- Classical astronomy: photons only
- Multi-messenger astronomy:
  - Cosmic rays
  - Gravitational waves
  - Neutrinos

- Neutrinos are the only particles that travel unperturbed by matter or magnetic fields

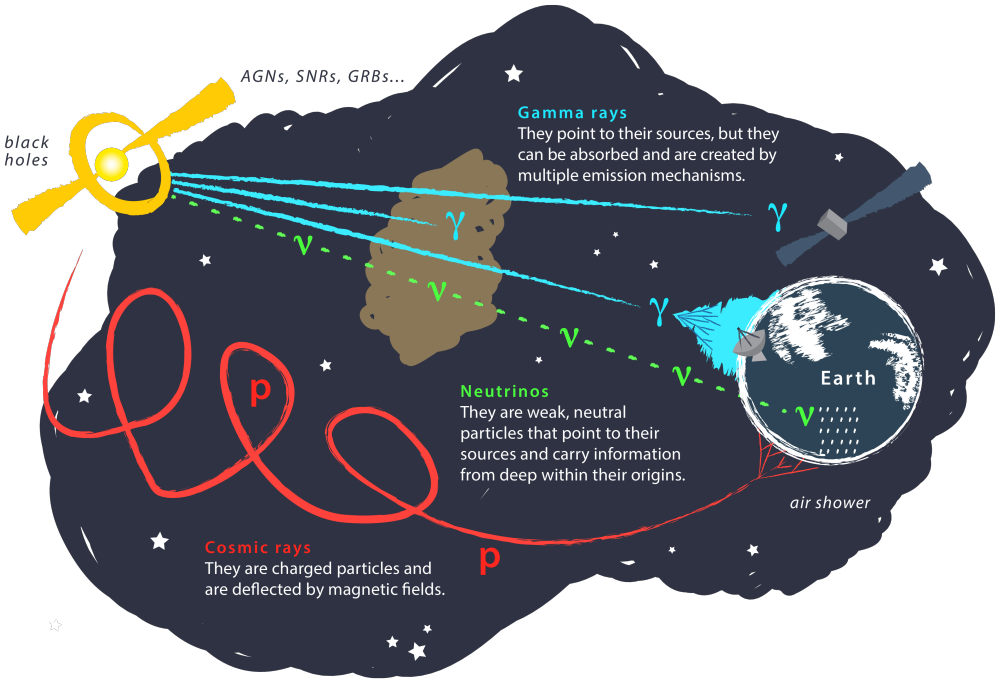
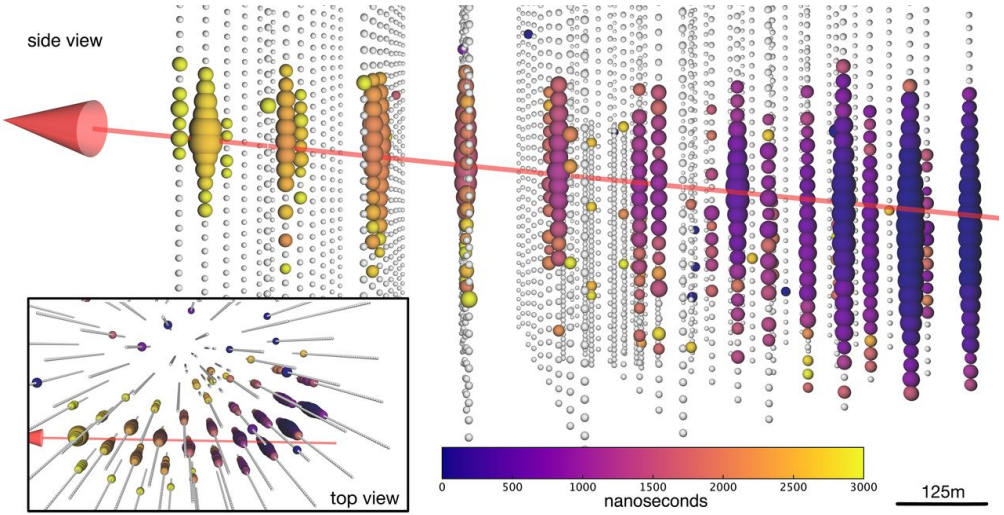


Image: IceCube Collaboration

Neutrino Telescopes

- Neutrinos interact with matter to produce high-energy charged lepton
- Charged lepton produces Cherenkov light

- ➔ Photomultipliers (PMTs) for light detection
- ➔ Large volume of transparent medium (water or ice)



Visualization of a muon track (red) in IceCube. Each dot represents an optical module with a PMT.
Image: IceCube Collaboration

Neutrino Telescopes

IceCube (South Pole)
Operational

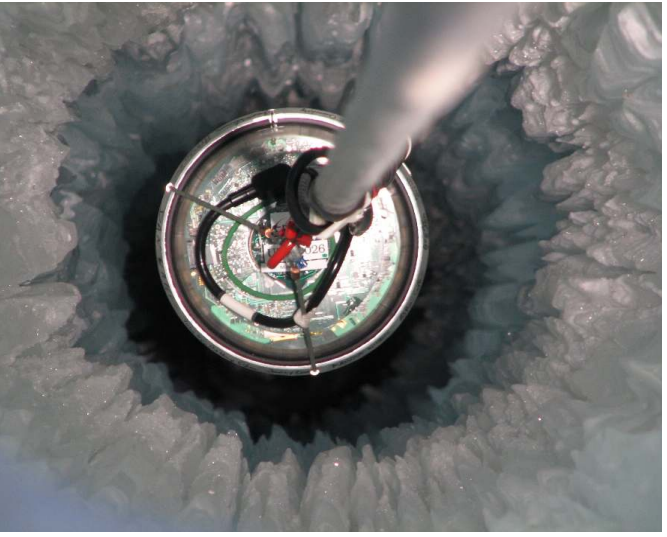


Image: IceCube Collaboration

GVD (Lake Baikal)
Under construction

KM3NeT (Mediterranean)
Under construction

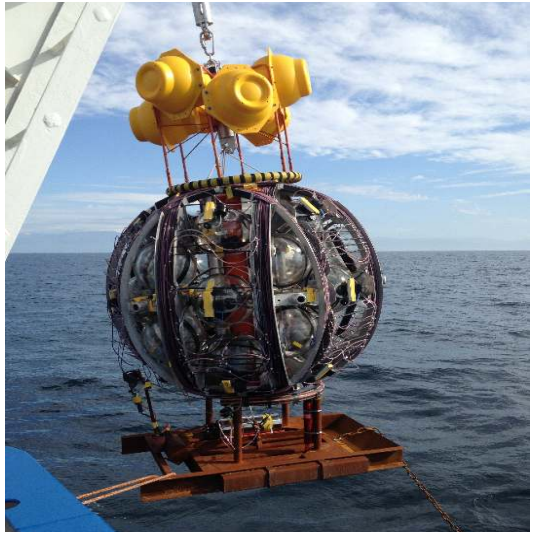
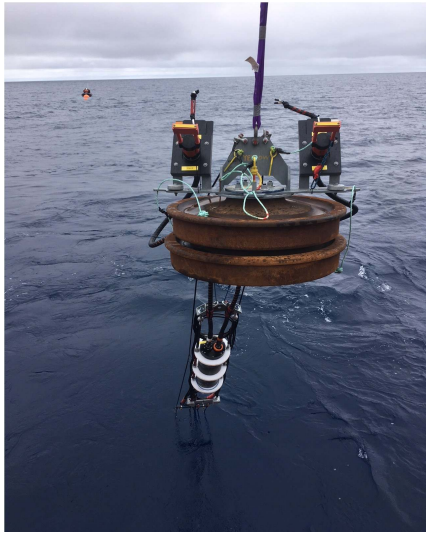


Image: KM3NeT

P-ONE (Pacific)
Under construction



Neutrino Telescopes

Looking up:

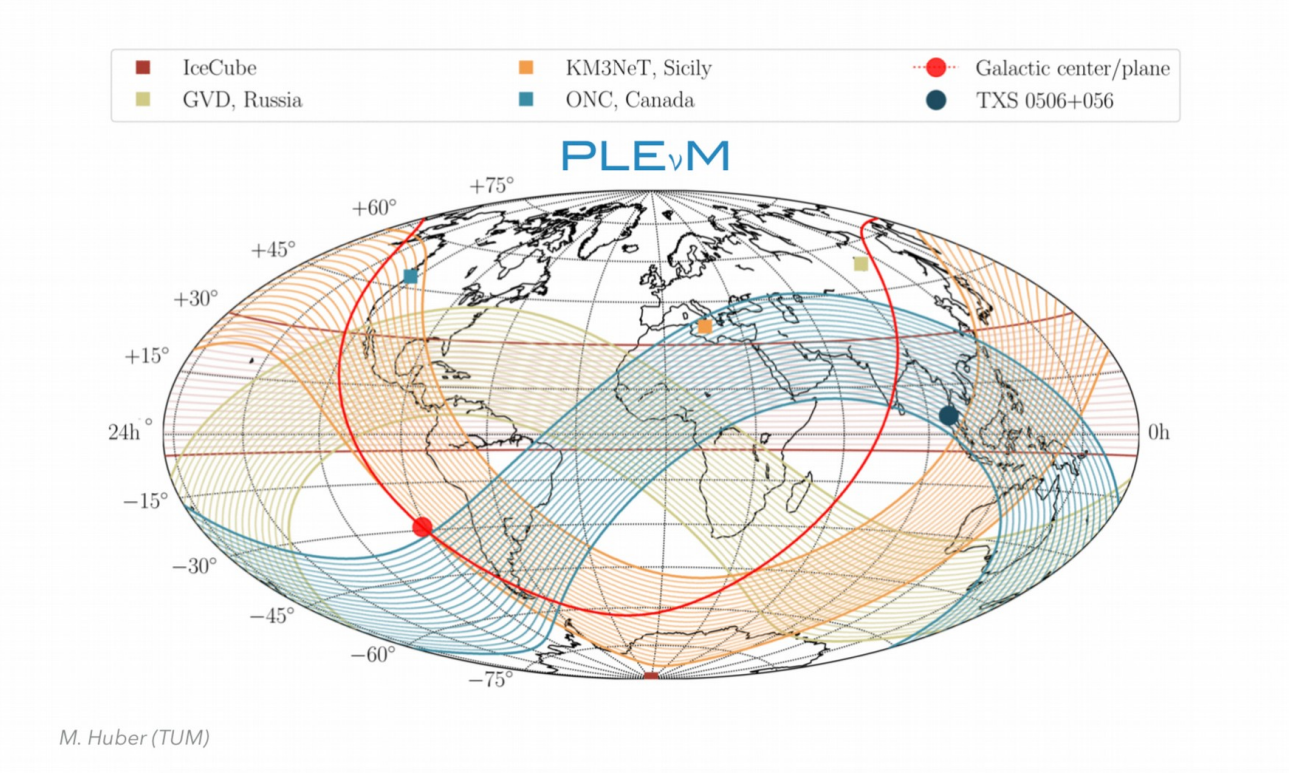
- Background from atmospheric muons

Looking down:

- Works for low energies
- At high energies (PeV) earth becomes opaque

→ Small band around horizon

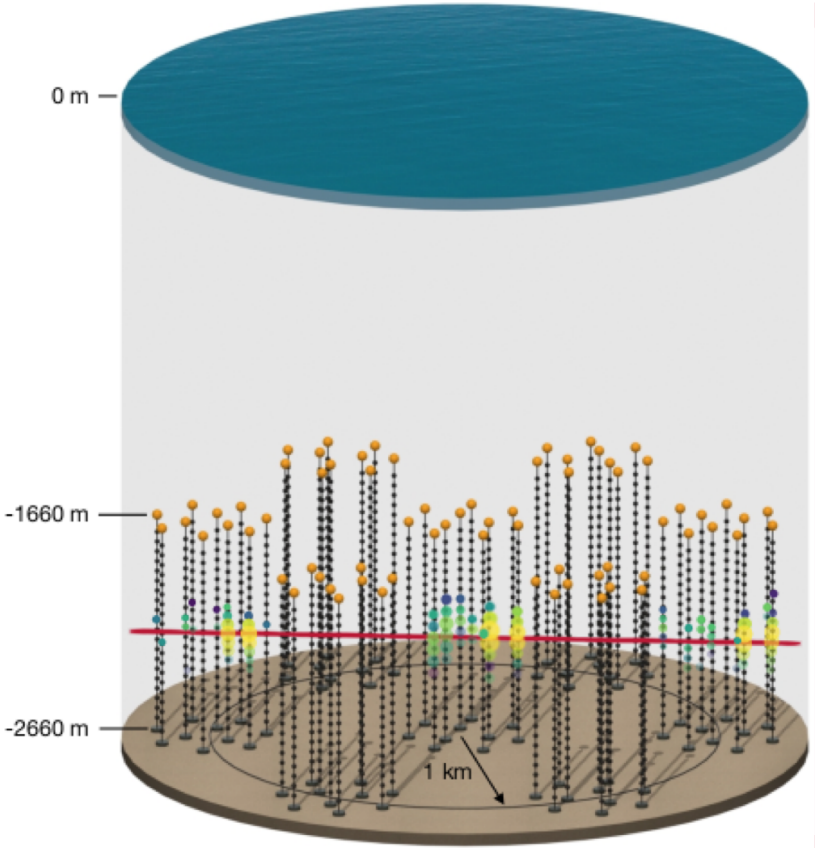
→ Multiple telescopes are needed across the planet



The Pacific Ocean Neutrino Experiment (P-ONE)

- New neutrino telescope in the Pacific Ocean
- >1 km³ instrumented volume
- Aimed at high neutrino energies (TeV-PeV)

- Using existing infrastructure of Ocean Networks Canada
- 2 successful pathfinder missions
- → Working on first string of P-ONE



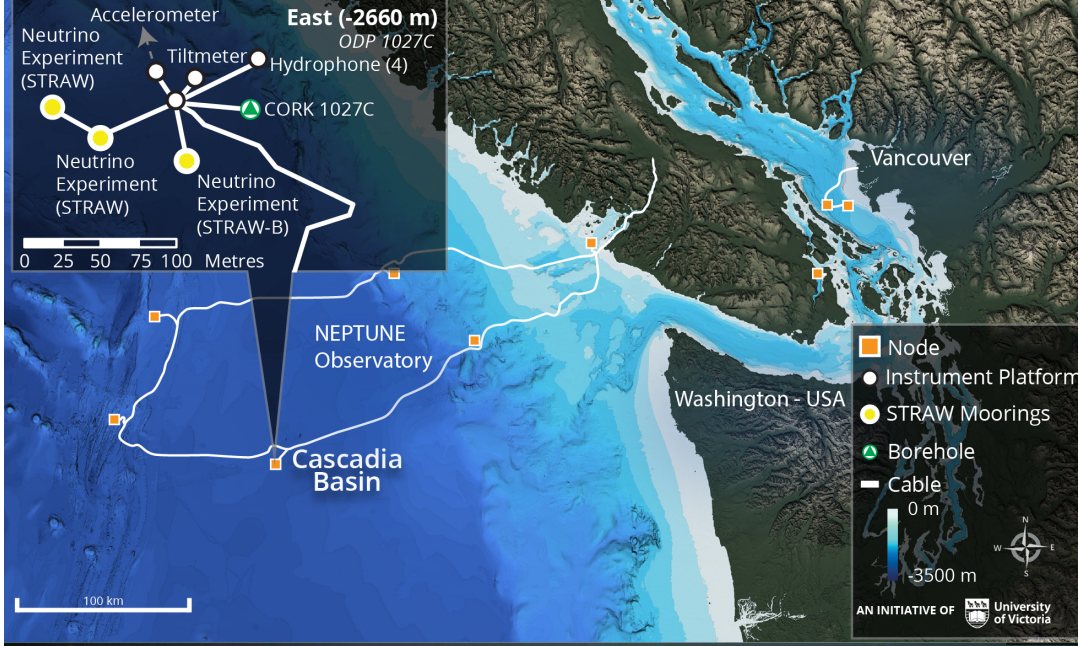
Ocean Networks Canada (ONC)

- Initiative of the University of Victoria
- Provides power and network connections on the sea floor for scientific instruments
- Over 15 years of experience in deploying and maintaining sea floor infrastructure
- Multiple observatories all over Canada

NEPTUNE Observatory

- 800 km cable loop in the Pacific Ocean
- Cascadia Basin
  - Abyssal plain
  - Low currents (0.1 m/s)
  - Low temperature (2°C)
  - Flat sea floor
  - 2.6 km depth

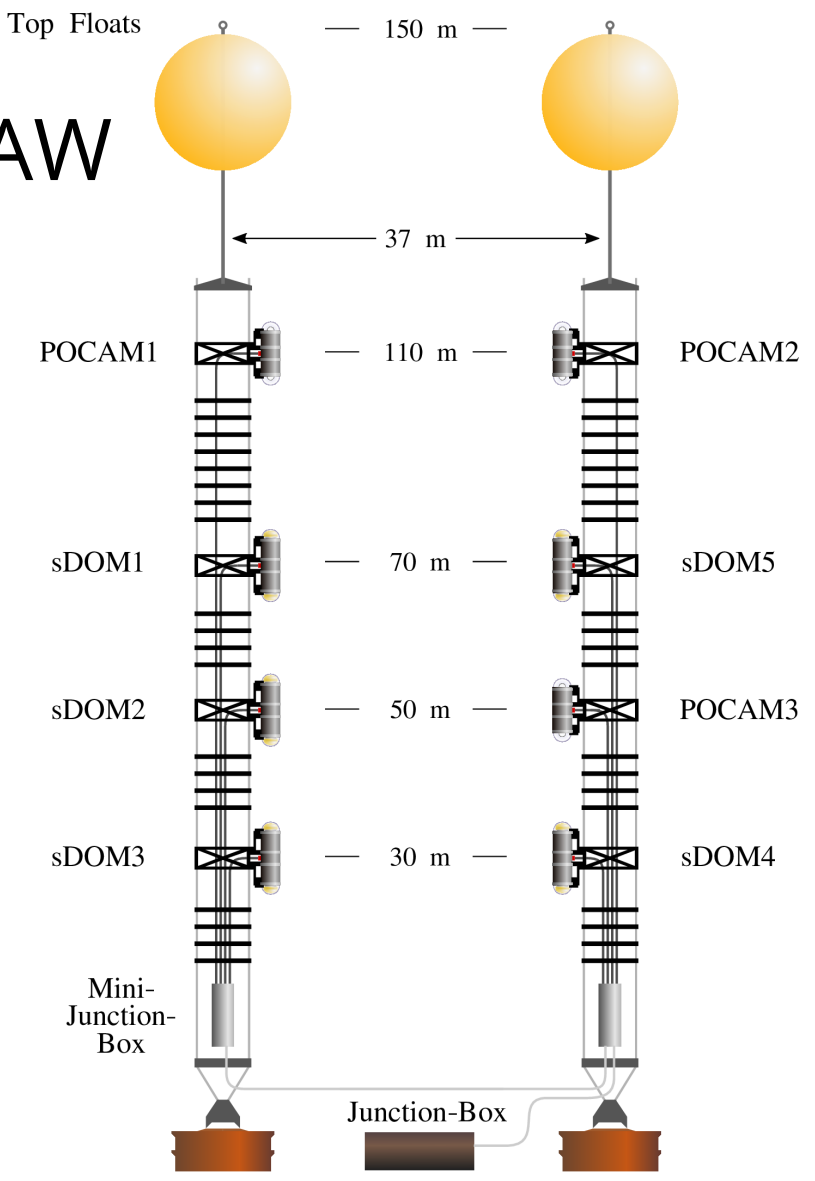
→ ideal environment for neutrino telescope



First pathfinder mission - STRAW

- Measure optical properties of water (optical attenuation, bioluminescence, radioactivity)
- Two 150m strings with four modules each
  - POCAMs: create isotropic light pulses
  - sDOMs: contain 2 PMTs each, detect POCAM pulses and background light

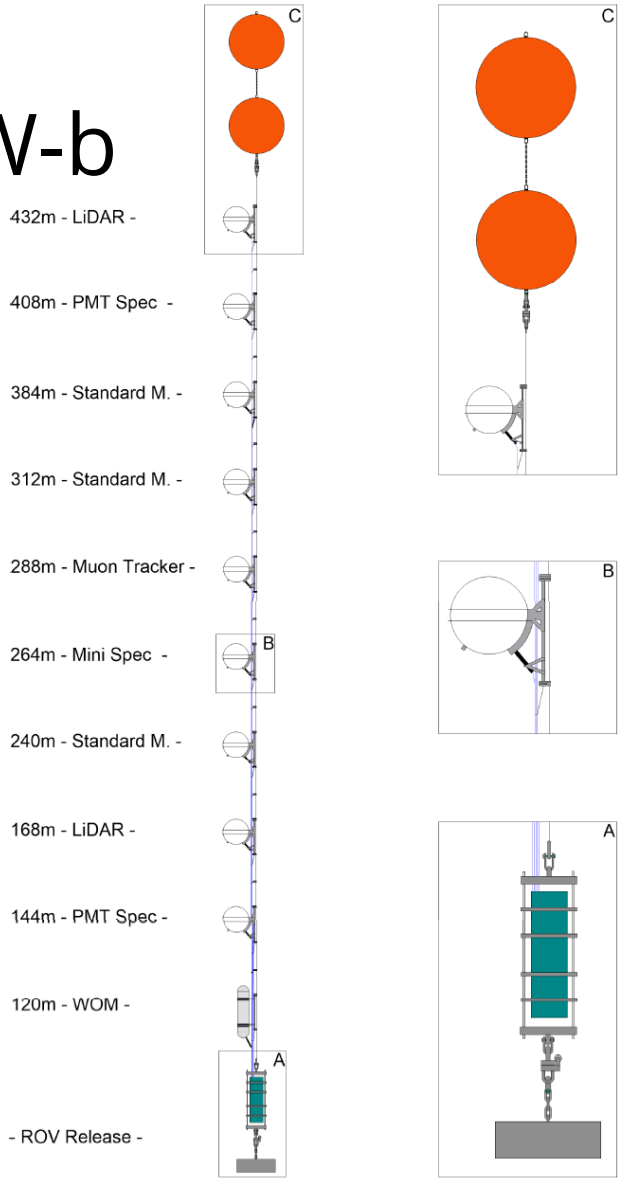
Deployed in 2018



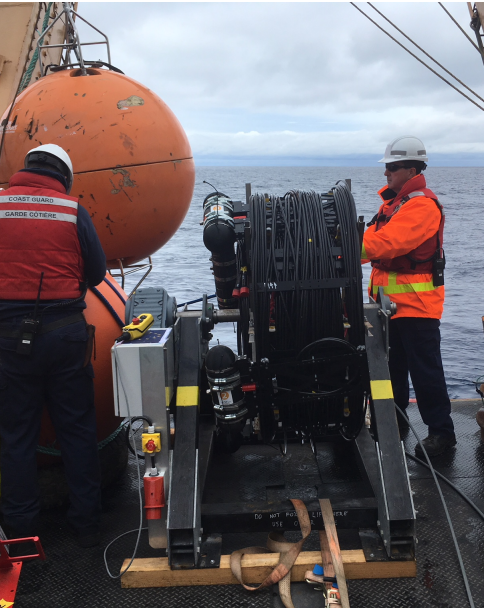
Second pathfinder mission - STRAW-b

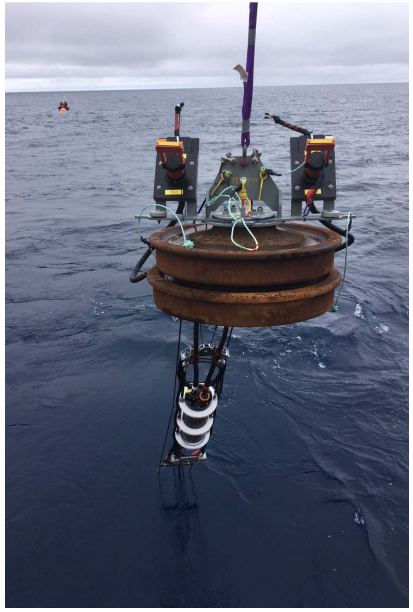
- Complement STRAW measurements
- Single 1km string with 10 modules
  - Spectrometers
  - LiDARs
  - Cameras
  - …

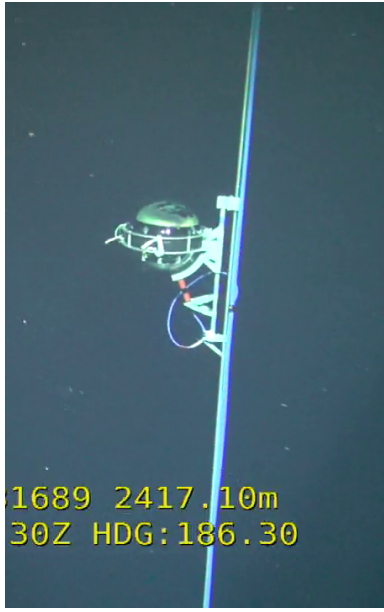
Deployed in 2020



Pathfinder missions - Deployment





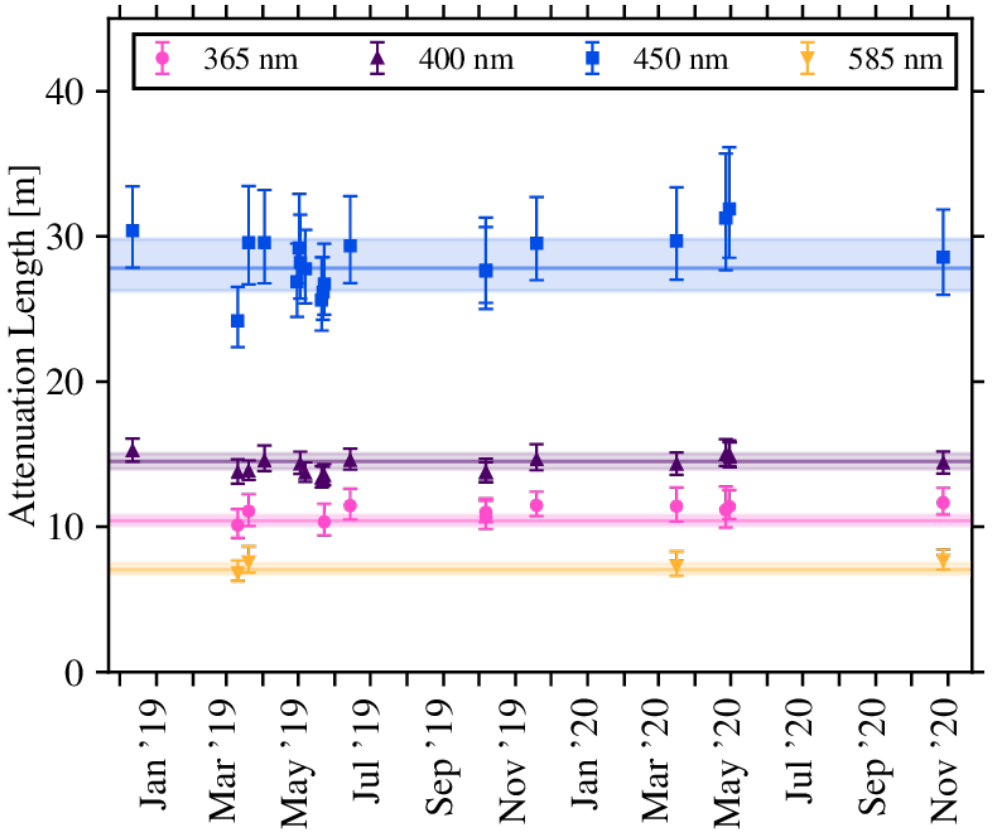


Pathfinder missions - Results

Attenuation length

- Determines P-ONE module spacing and energy resolution
- Measured at 28m for 450nm

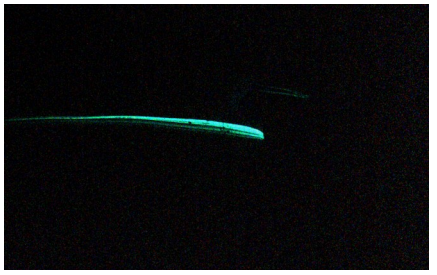
→ **Site is suitable for neutrino telescope**



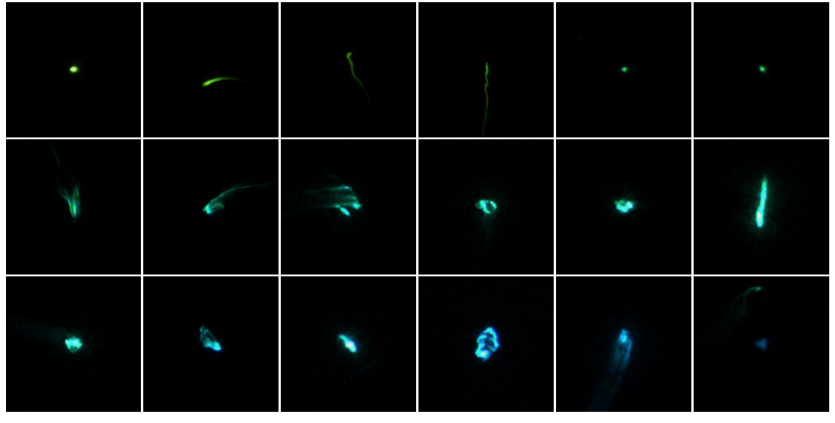
Pathfinder missions - Results

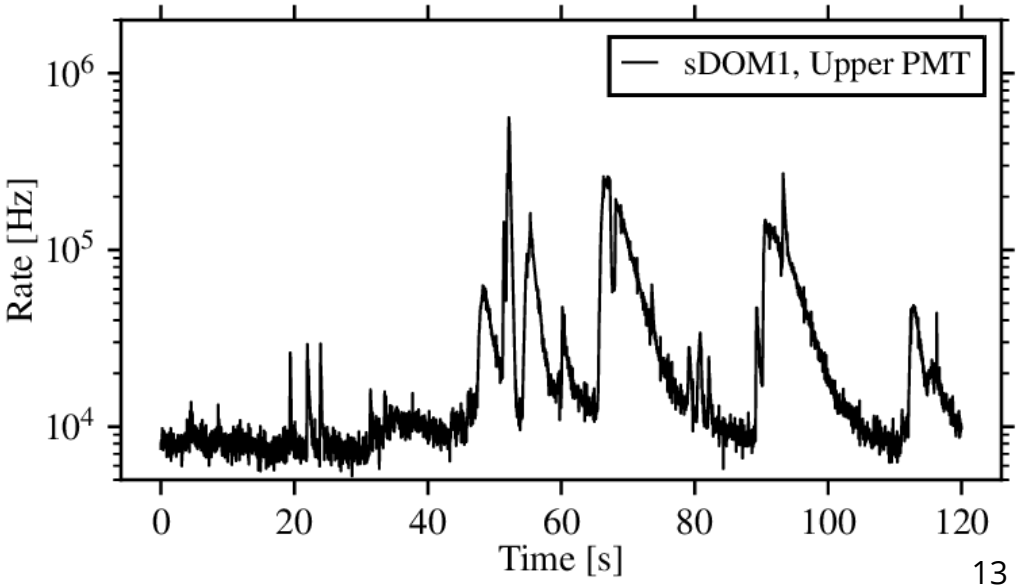
Bioluminescence

- 10kHz – Mhz background
- Spikes of a few seconds
- Varies with tides and seasons
- → **Need appropriate coincidence trigger**



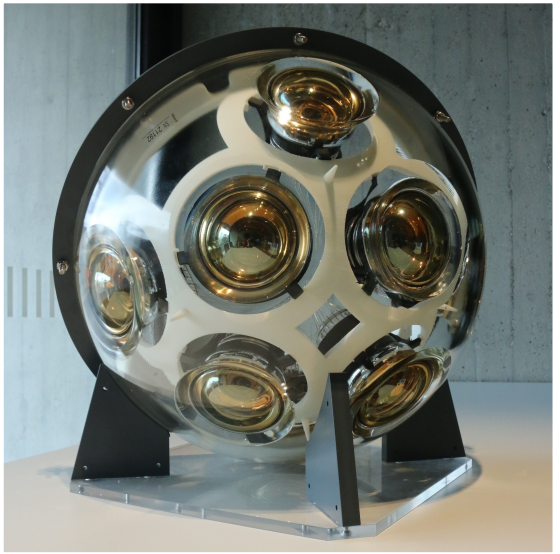
Picture of bioluminescent organism from STRAW-b camera, 60s exposure time





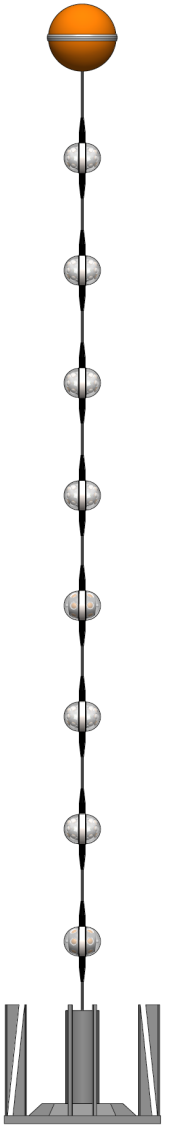
Current work: First P-ONE string

- 20 modules on 1km string
- 16 PMTs per module can measure direction of incident light



- Proof of concept, no relevant physical measurements with only one string
- Collect background data
- Test time synchronisation, triggering, …

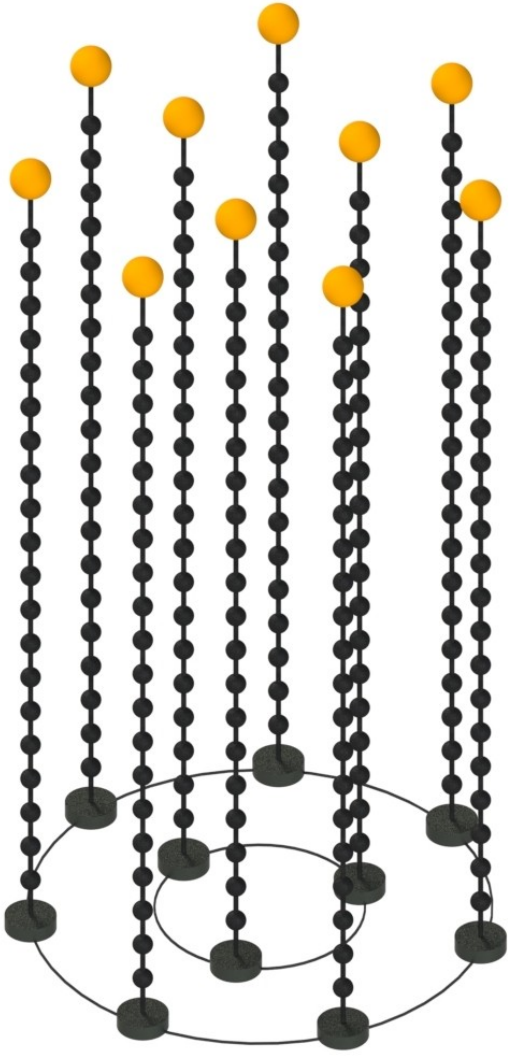
Planned deployment: Summer 2024



Next step: 10-string cluster

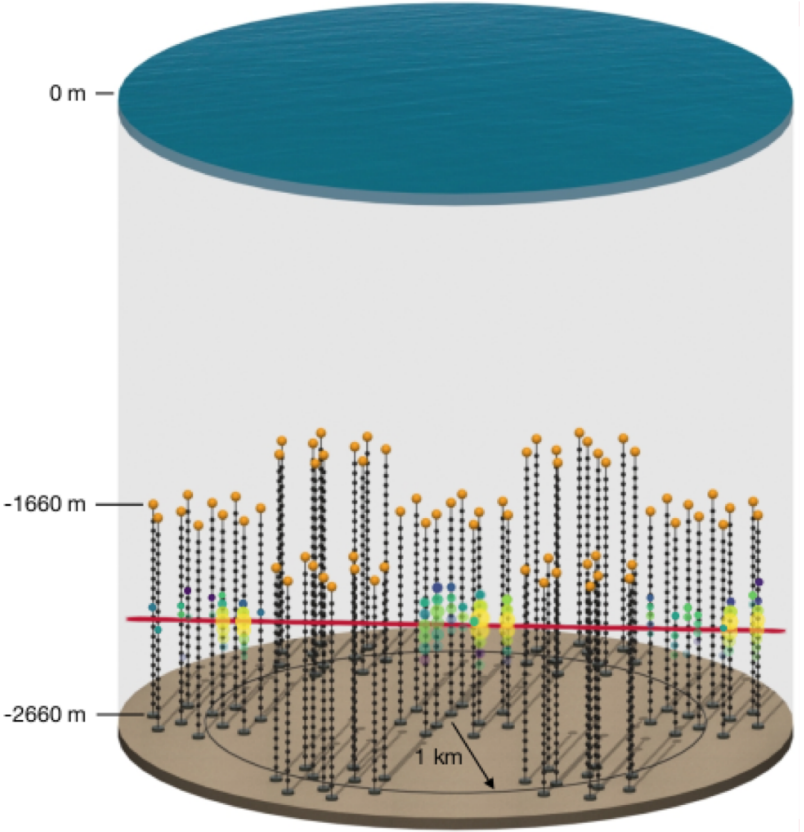
- 200 modules, ~1/8 km³
- No new physics with only 10 strings, but first measurements
  - Atmospheric neutrinos
  - Moon shadow
  - Background

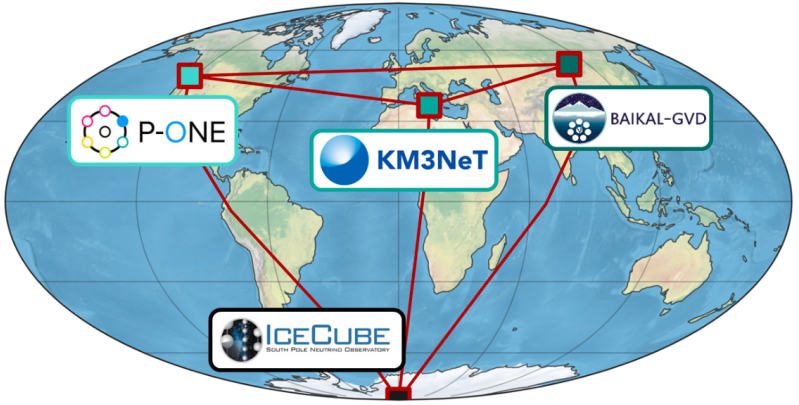
Deployment: 2024 - 2027



The full detector

- 7 clusters of 10 strings
- >1 km³ instrumented volume
- Built over several years





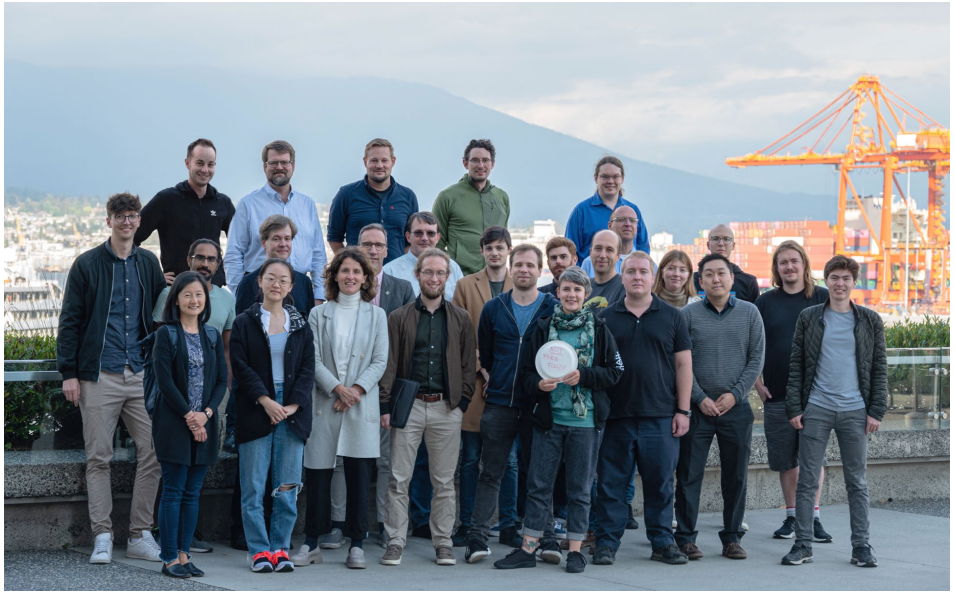
Long term goal: Planetary Neutrino Monitoring System (PLEvUM), using data from all neutrino telescopes

M. Agostini et al., Nat. Astron. 4, p913–915 (2020), arXiv:2005.09493

M. Boehmer et al., JINST 14 (2019) 02, P02013, arxiv:1810.13265

N. Bailly et al., Eur. Phys. J. C (2021) 81: 1071, arxiv:2108.04961

www.pacific-neutrino.org



P-ONE collaboration meeting, Fall 2022

P-ONE

UNIVERSITY OF ALBERTA

OCEAN NETWORKS CANADA

Queen's UNIVERSITY

SFU SIMON FRASER UNIVERSITY

TRIUMF

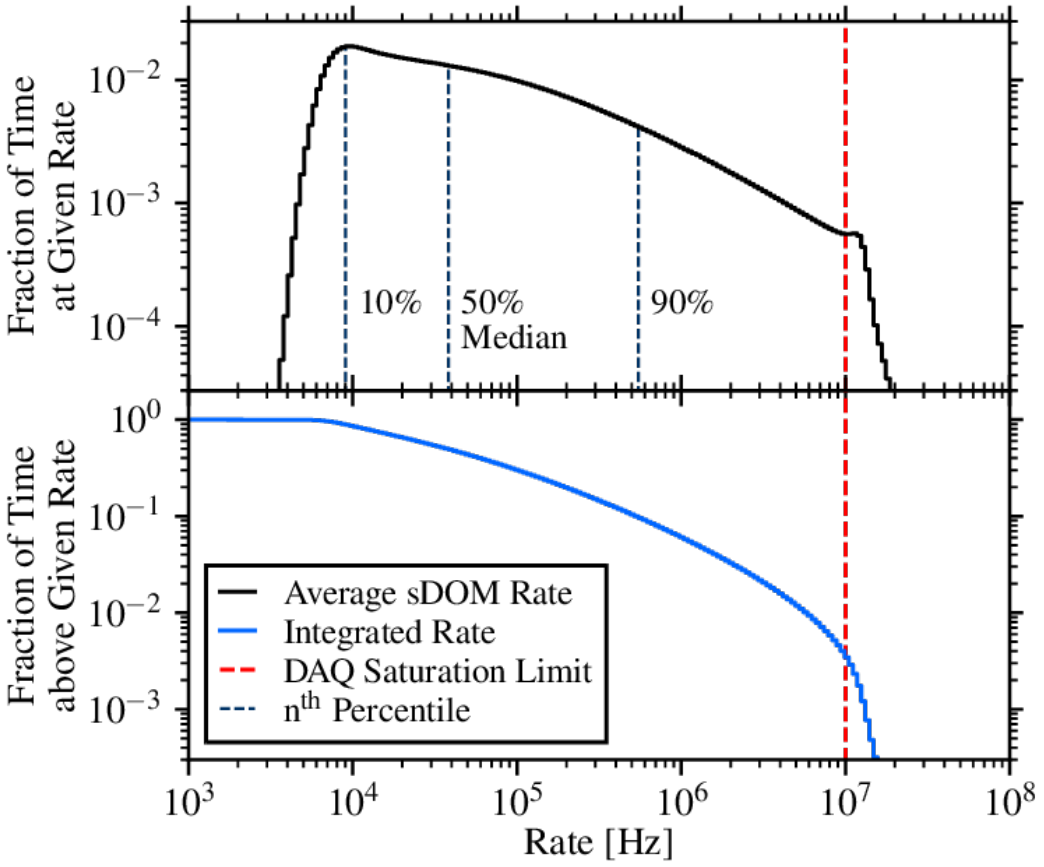
NSERC CRSNG

MICHIGAN STATE UNIVERSITY

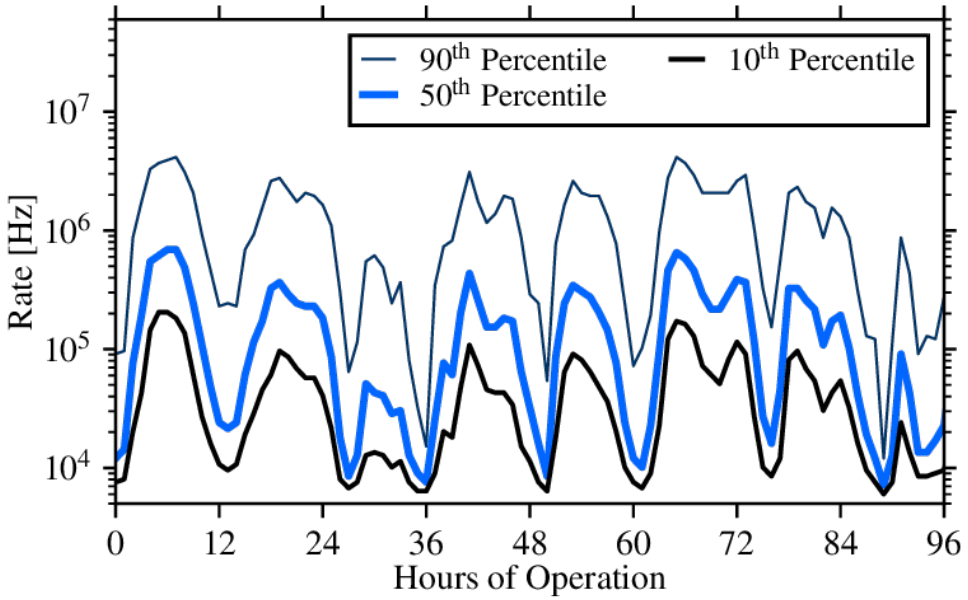
Drexel

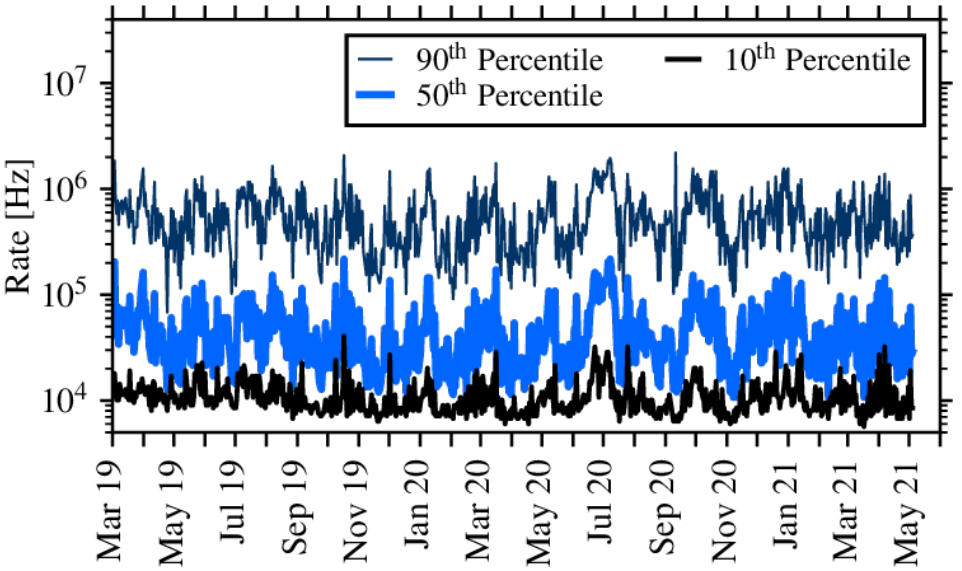
UCL

Backup – Bioluminescence

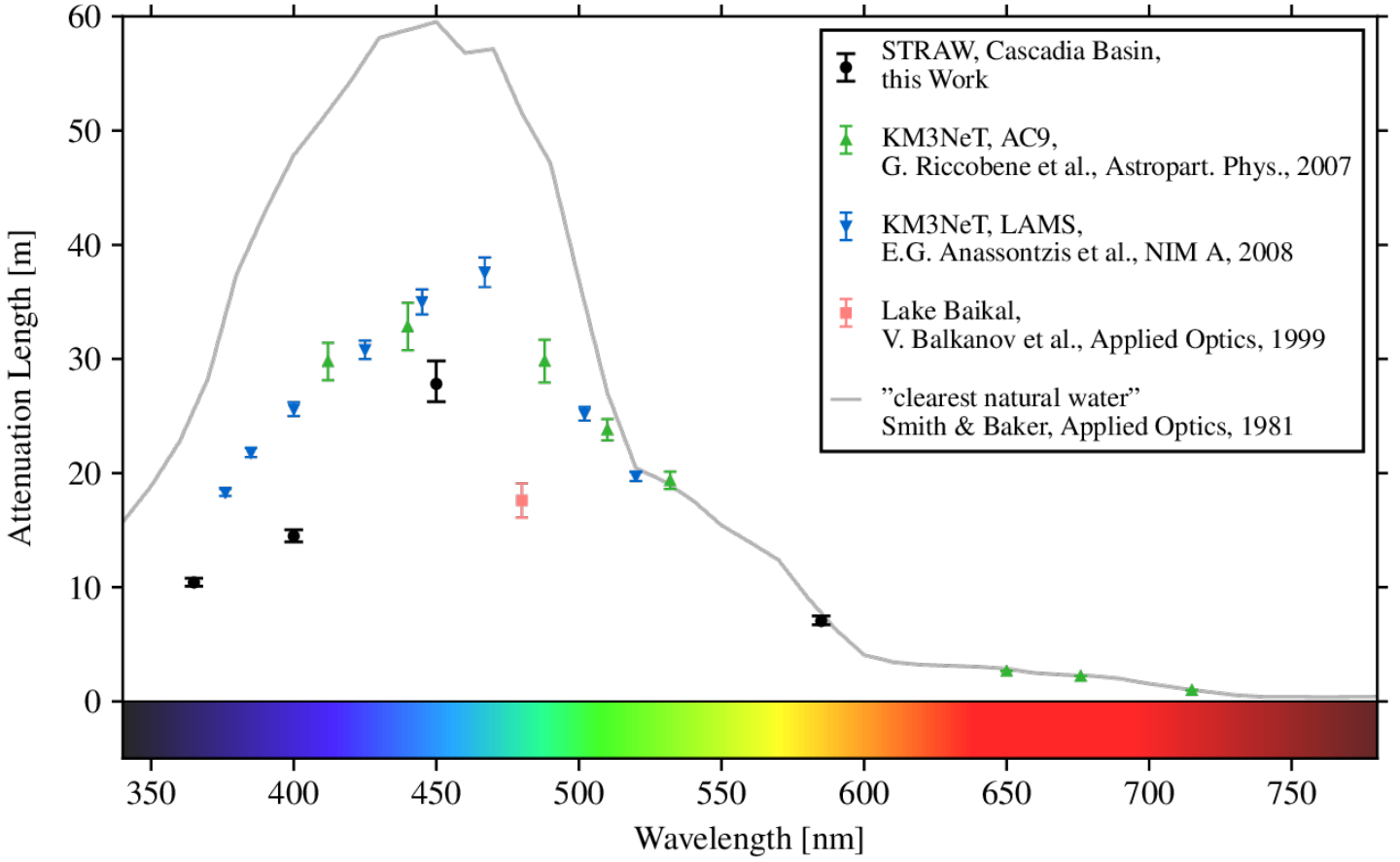


Backup – Bioluminescence

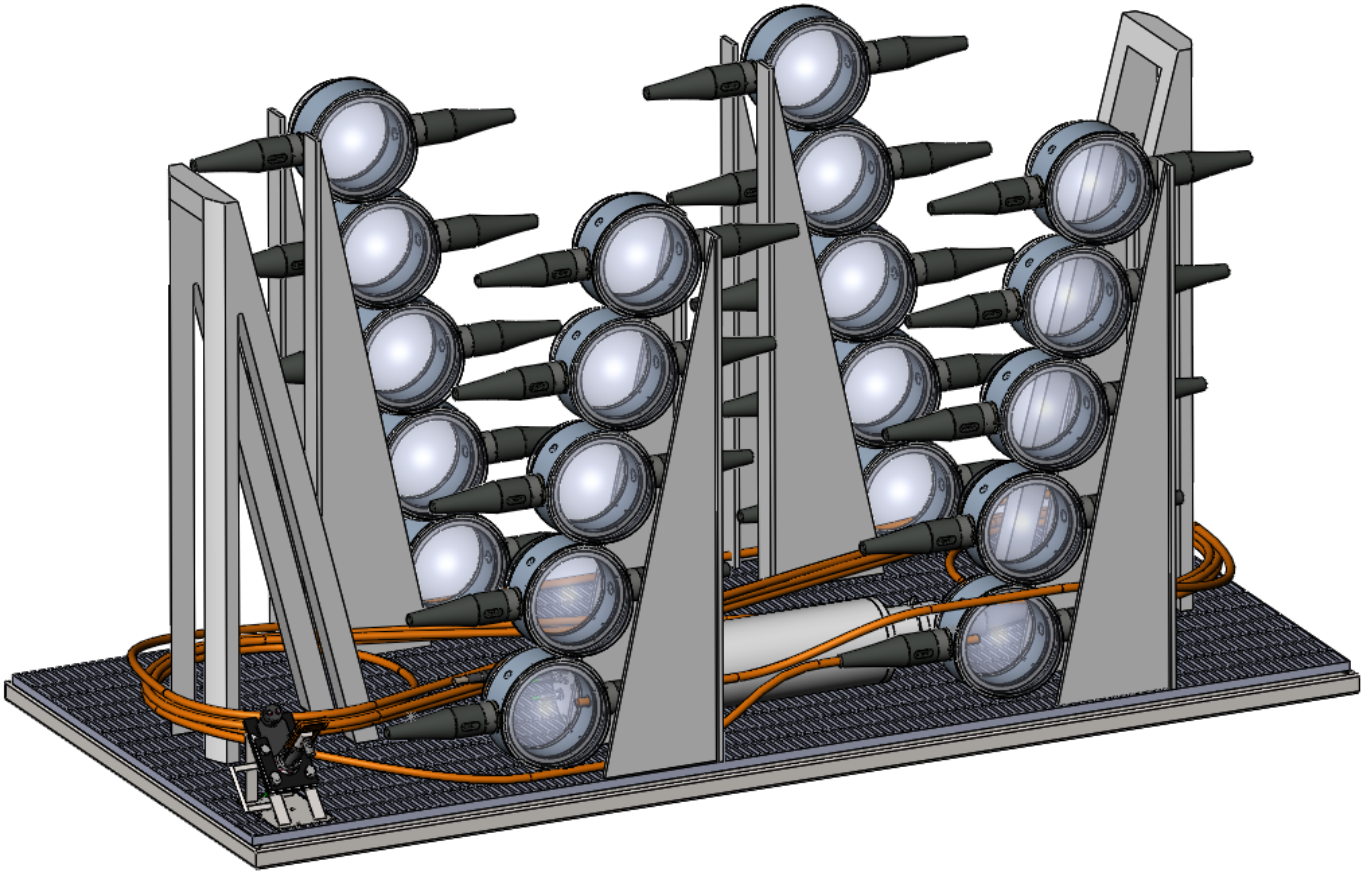




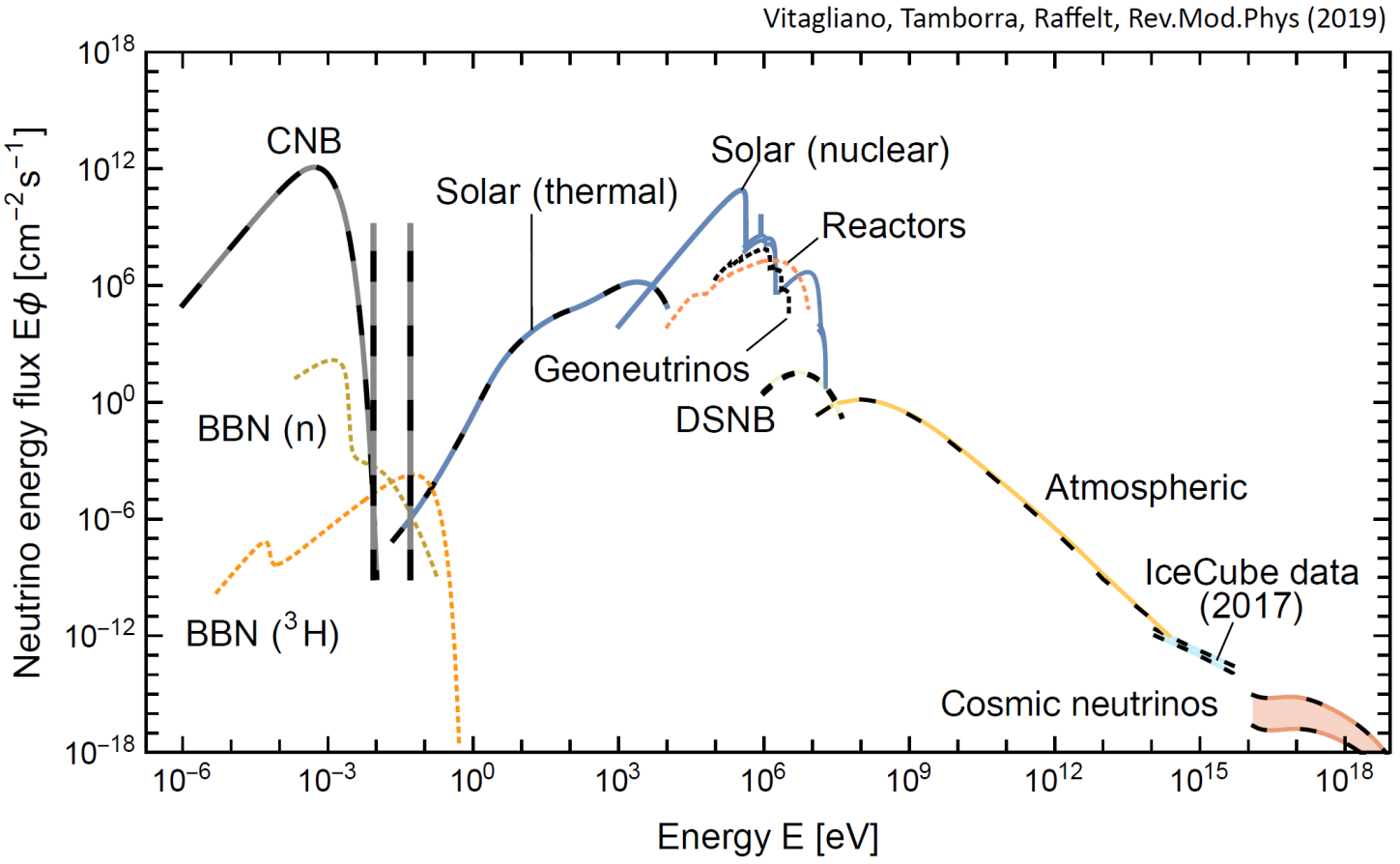
Backup – Attenuation length



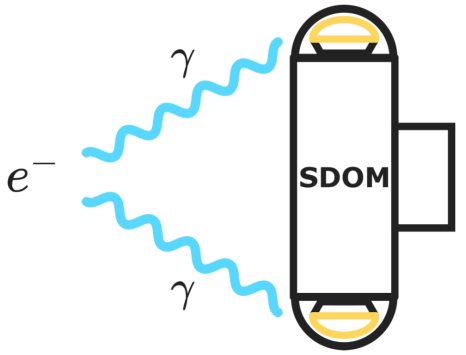
Backup – Deployment frame



Backup - Neutrino spectrum

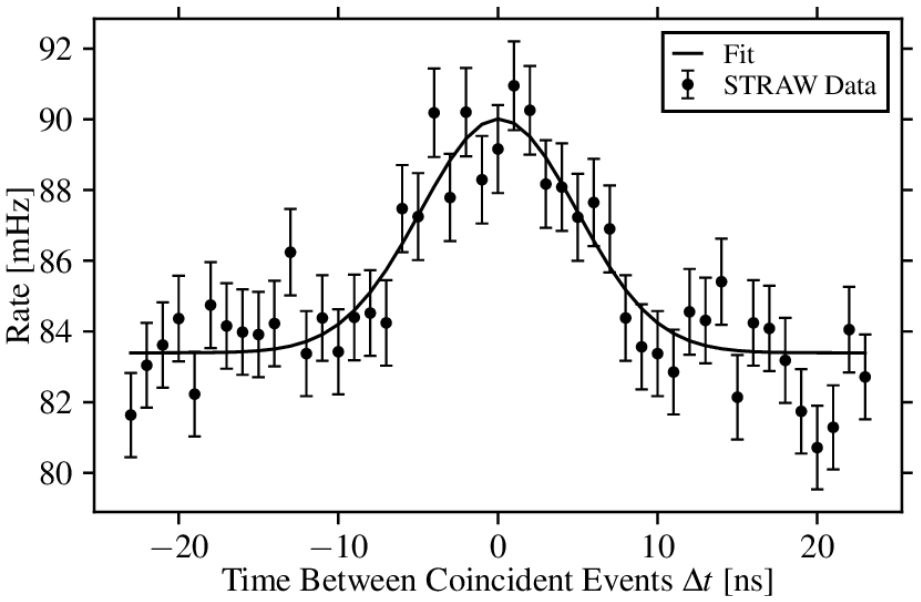


Backup - K40



Potassium-40 decays

- Source of coincident photons
- K-40 measurements agree with predictions



Backup - Biofouling