P-ONE

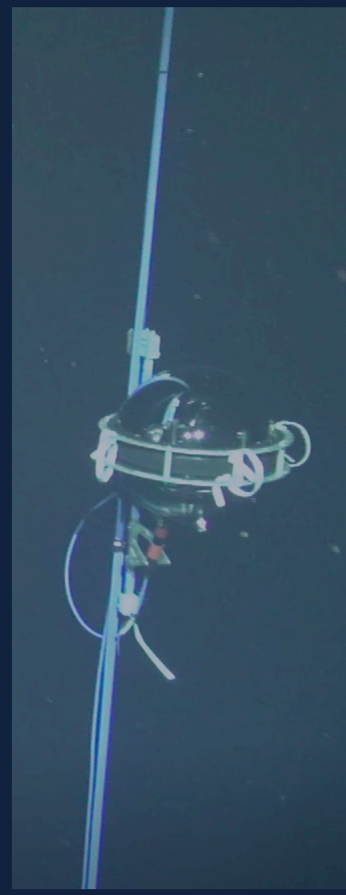
— The Pacific Ocean Neutrino Explorer —

Matthias Danninger
for the P-ONE Collaboration

2021 - 02 - 23

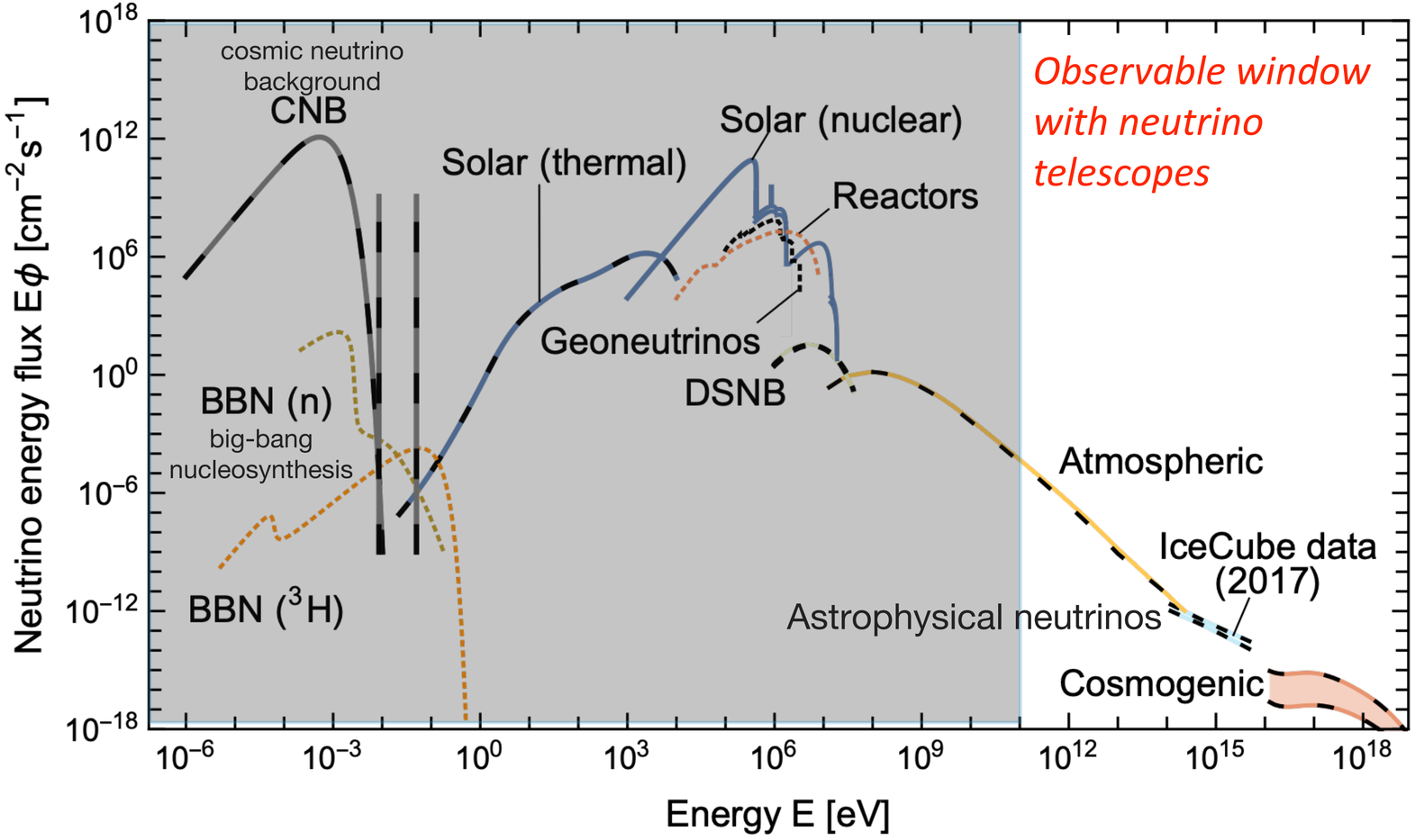
SIMON FRASER UNIVERSITY

Why another neutrino telescope?



Neutrinos from the Universe

modified from Vitagliano, Tamborra and Raffelt, Rev.Mod.Phys 2019, arXiv:1910.11878



Grand Unified Neutrino Spectrum (GUNS) at Earth integrated over directions and flavors

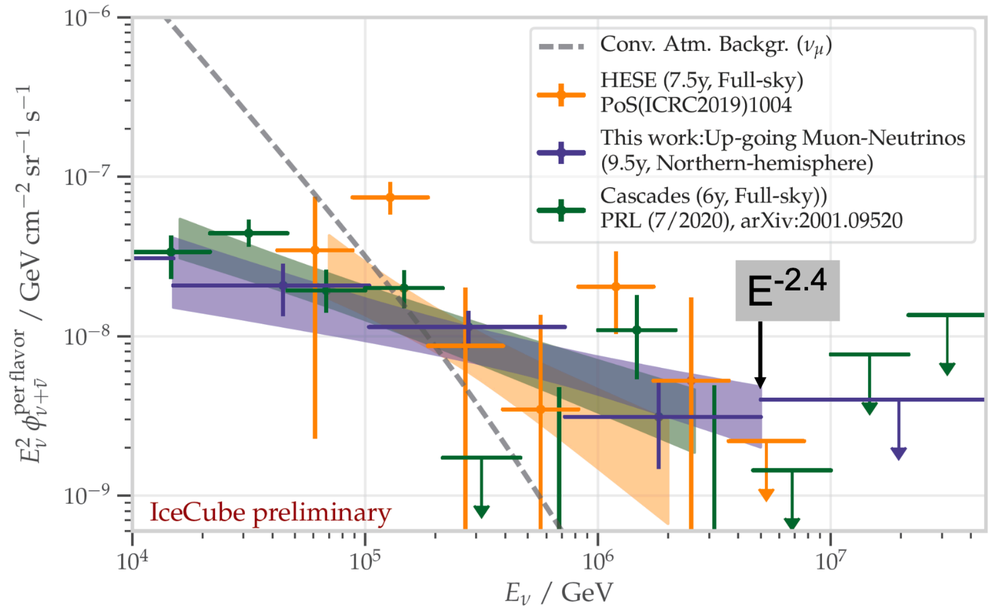
-naturally occurring neutrinos can have extreme energies

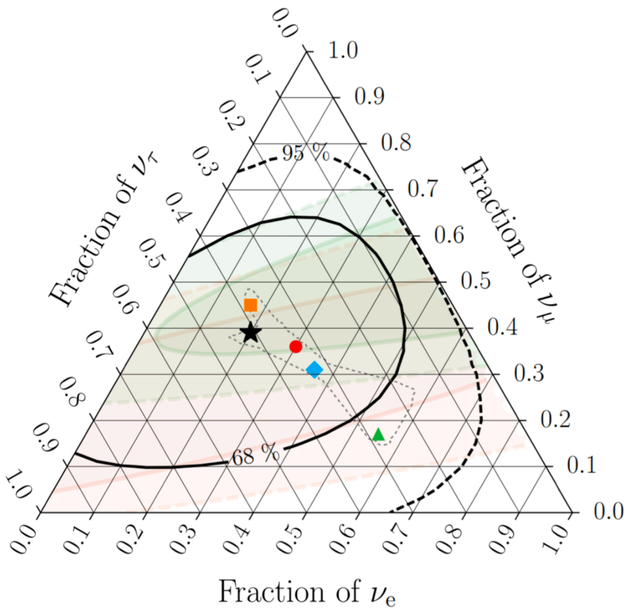
-manmade beams can reach E ~ 50 GeV at most

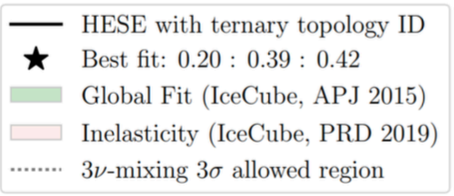
-but the fluxes are low, so you need really large detectors

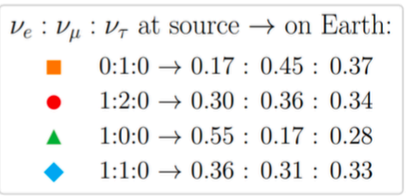
Neutrinos from the Universe

- Since 2013 — Astrophysical neutrinos discovered
- 2018 — Evidence for First source: Neutrino events in a direction of a flaring blazar, TXS 0506+056
- 2019 — Very likely the first Glashow resonance observed
- Neutrino oscillation measurements at PeV scale!
- ….and so much more yet to be discovered









https://arxiv.org/pdf/2011.03561.pdf

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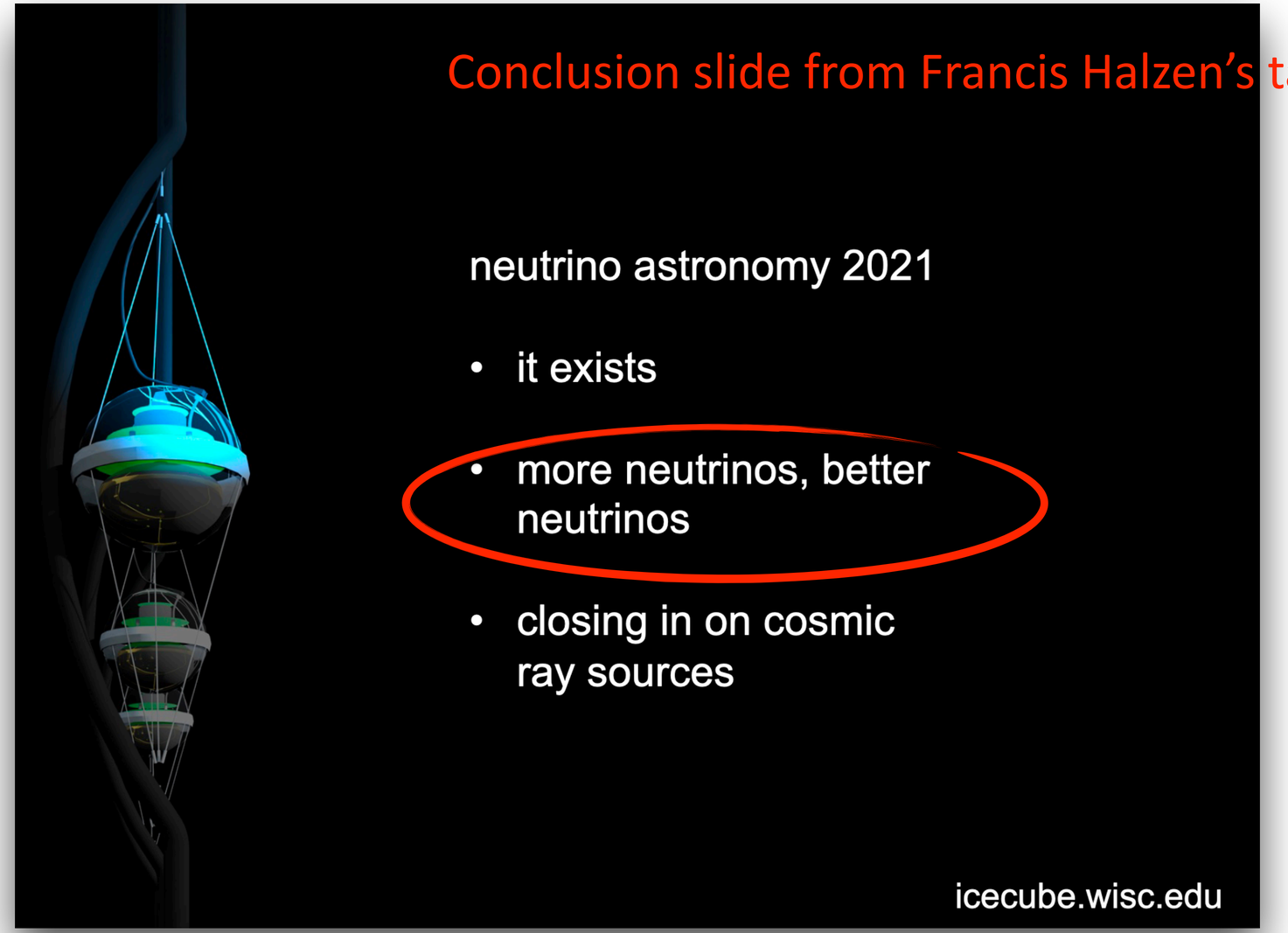
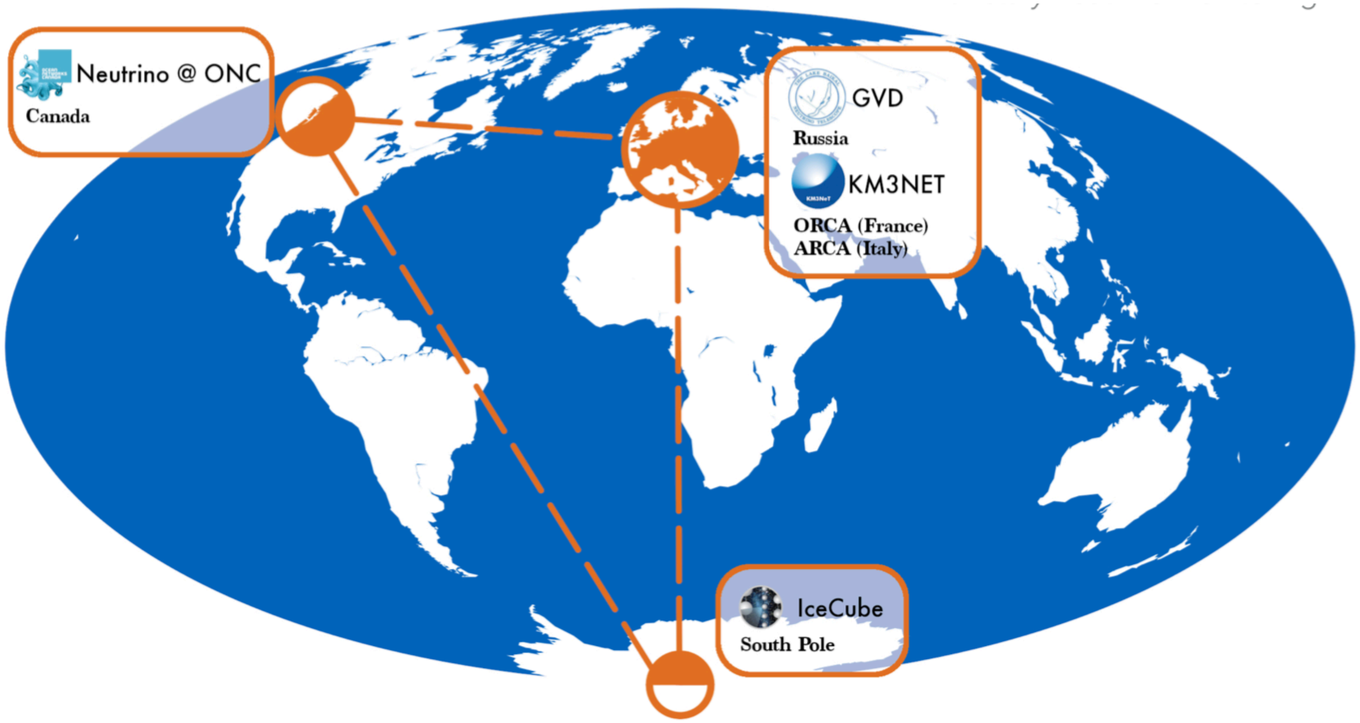
Why another neutrino telescope?

Conclusion slide from Francis Halzen's talk on Thursday!



Why another neutrino telescope?

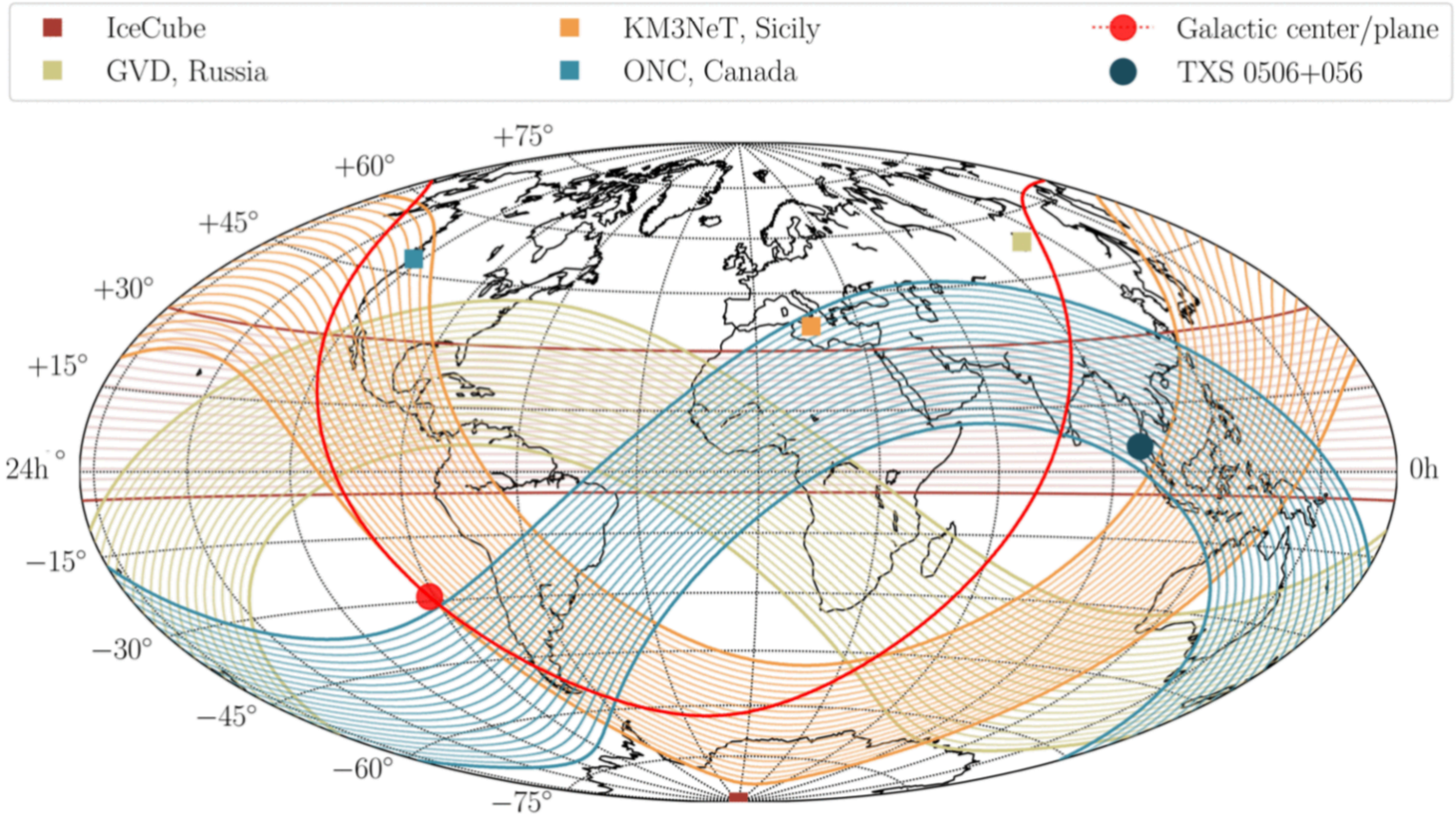
- More neutrinos, better neutrinos!



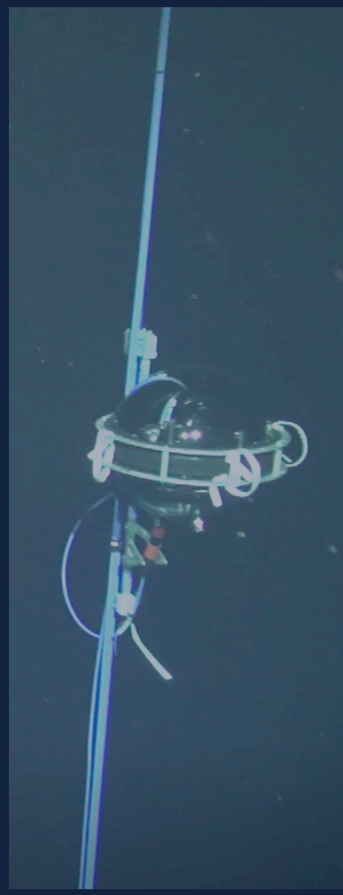
- P-ONE project has large emphasis on collaboration and complementarity with existing efforts such as IceCube, GvD (Baikal), and KM3NeT —> we welcome collaboration/participation
- We aim for combined cross-calibration efforts to boost precision of all measurements at all neutrino telescope sites worldwide (POCAM, LiDAR, etc..)

Why another neutrino telescope?

- Horizontal coverage from which HE ν will not be affected by the Earth absorption
- With IceCube +3 neutrino telescopes (similar size), current sensitivity to astrophysical neutrinos would be improved by up two orders of magnitude (gain depends on energy)!

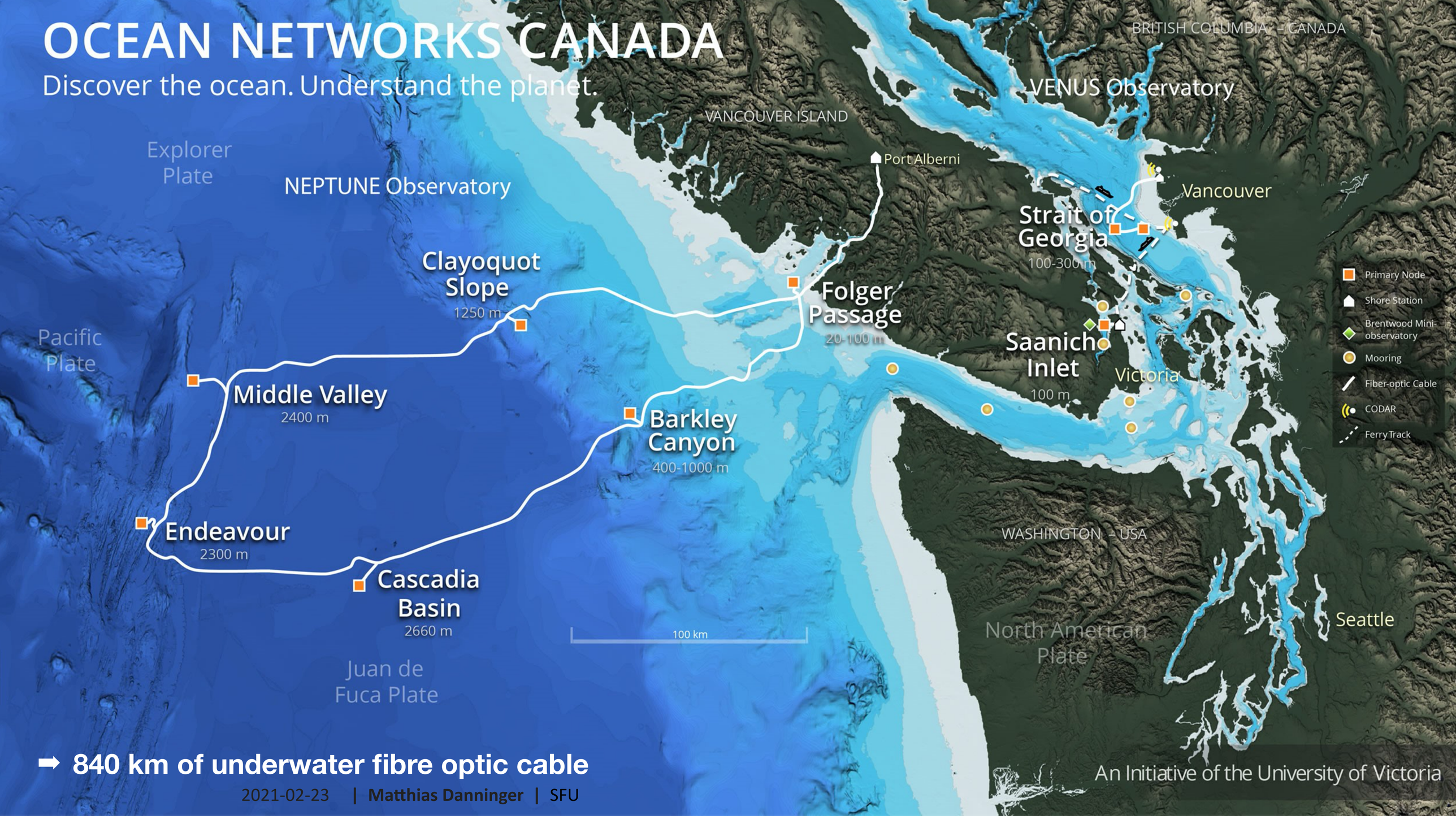


- The neutrino is the PeV messenger of the Universe
- We must now figure out what it is telling us!



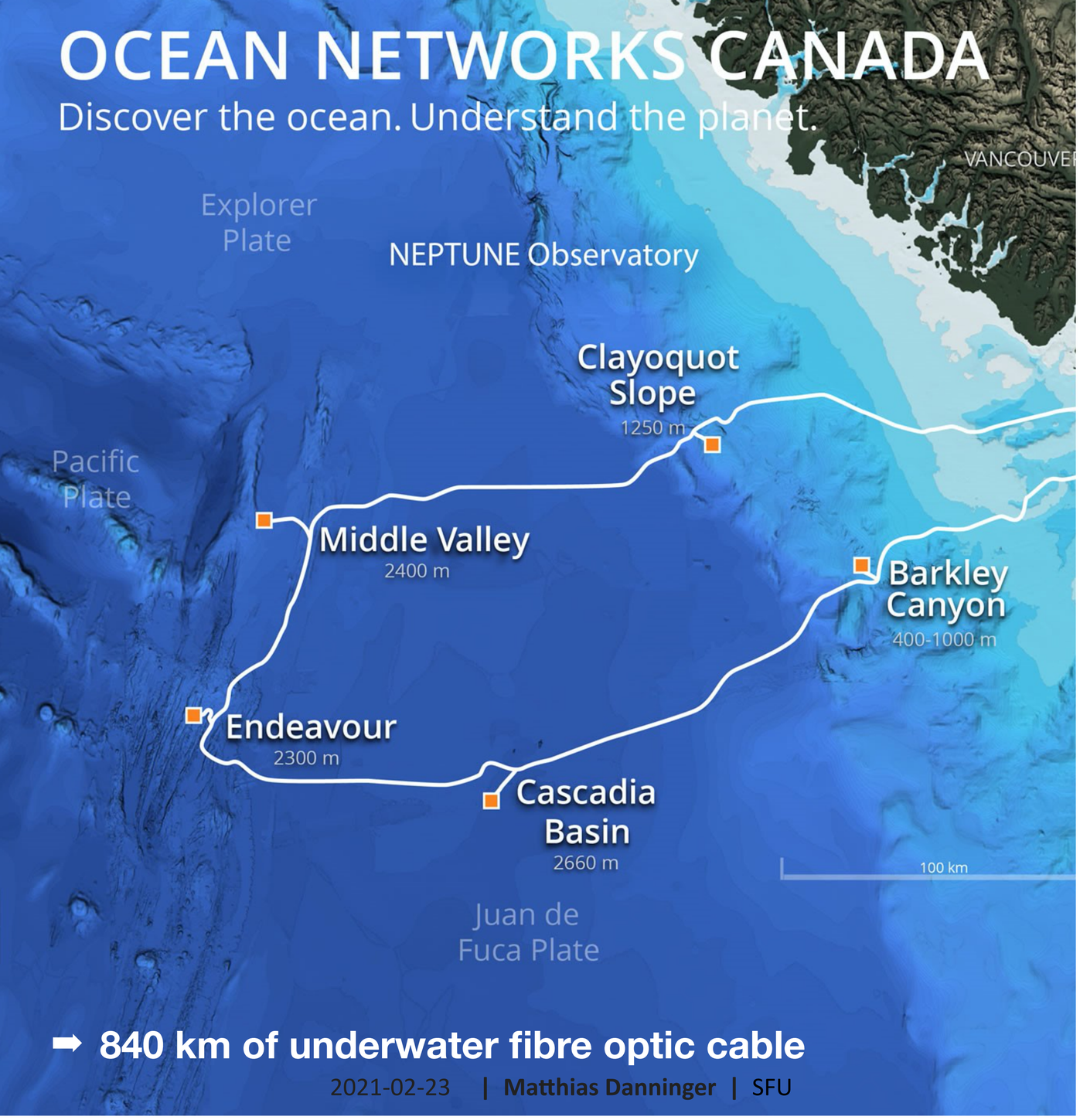
Ocean Networks Canada

— and opportunity for the neutrino community —

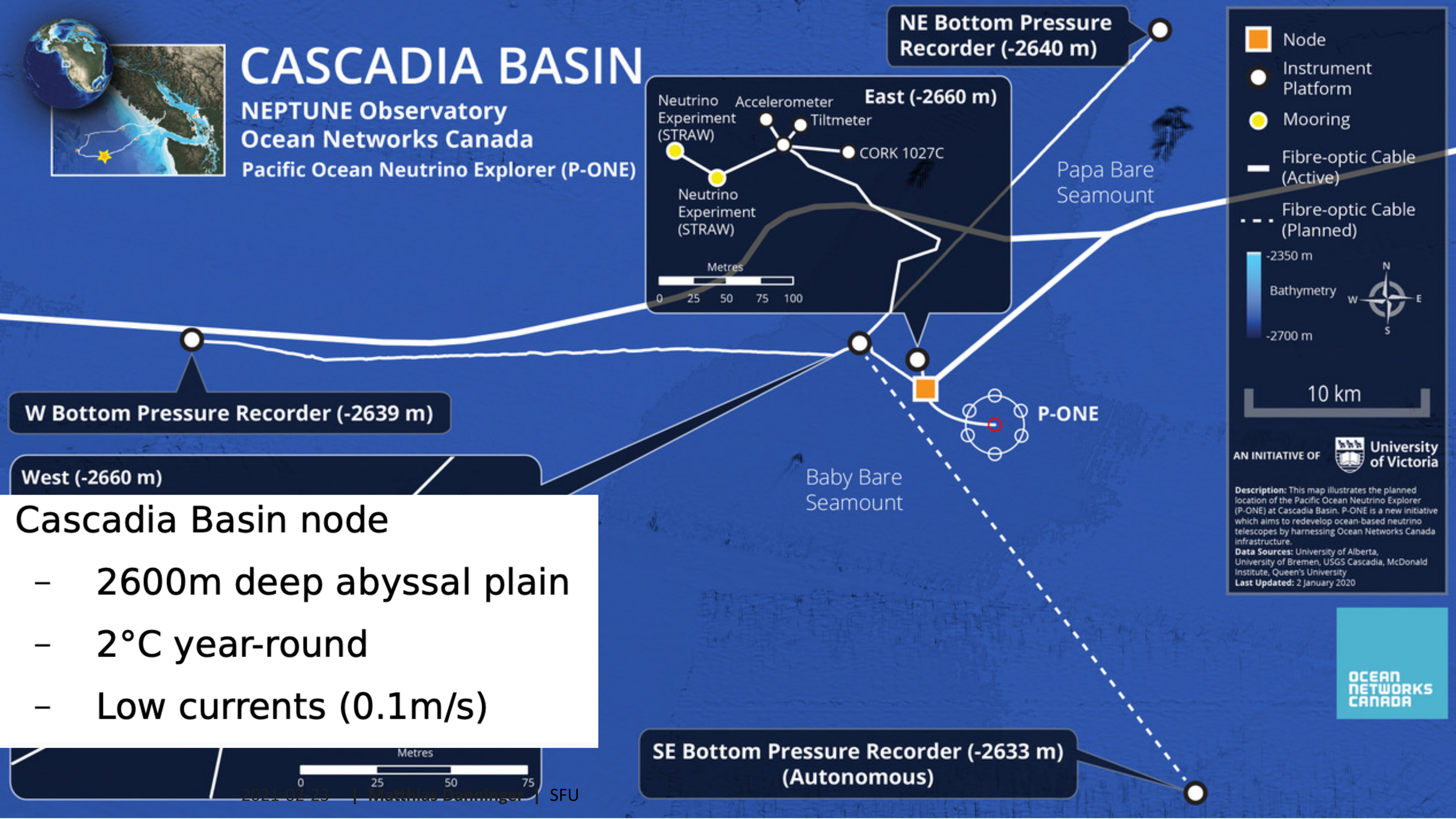


➡ **840 km of underwater fibre optic cable**

2021-02-23 | **Matthias Danninger** | SFU



- One of world's largest and most advanced cabled ocean observatory
- Consists of NEPTUNE & VENUS & number of smaller observatories
- Yearly budget ~$27M (CDN)
- ***NEPTUNE:***
  - completed in 2009
  - 800km loop of fibre optic cable, data flow and power infrastructure
  - designed for long-lived, highly reliable underwater operations
  - high-speed data link (10GB/s)
  - high power (at least 9 kW/node)
  - "plug and play" basis allowing a highly modular deployment and maintenance



Cascadia Basin node

- 2600m deep abyssal plain
- 2°C year-round
- Low currents (0.1m/s)

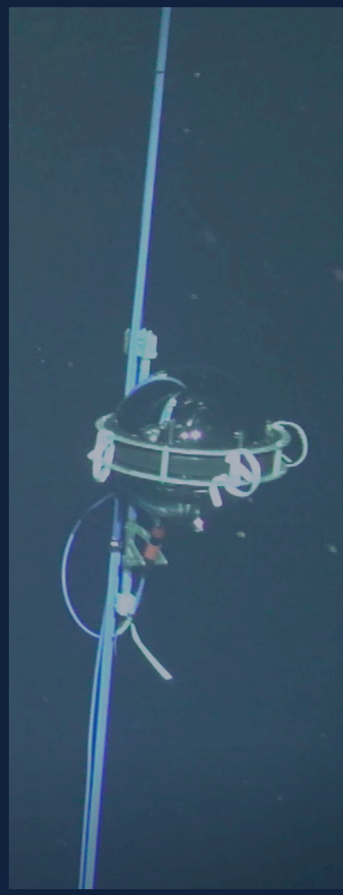
ONC — Expert support & deployment

Interface, anchoring and deployment operation by ONC

ONC team - no physicist on board

— P-ONE pathfinder missions —

- What have we achieved so far?
  - What has been deployed
  - How well are the site characteristics known



STRAW

Optical characterisation of deployment site

STRAW b

R&D on optical modules, further characterisation

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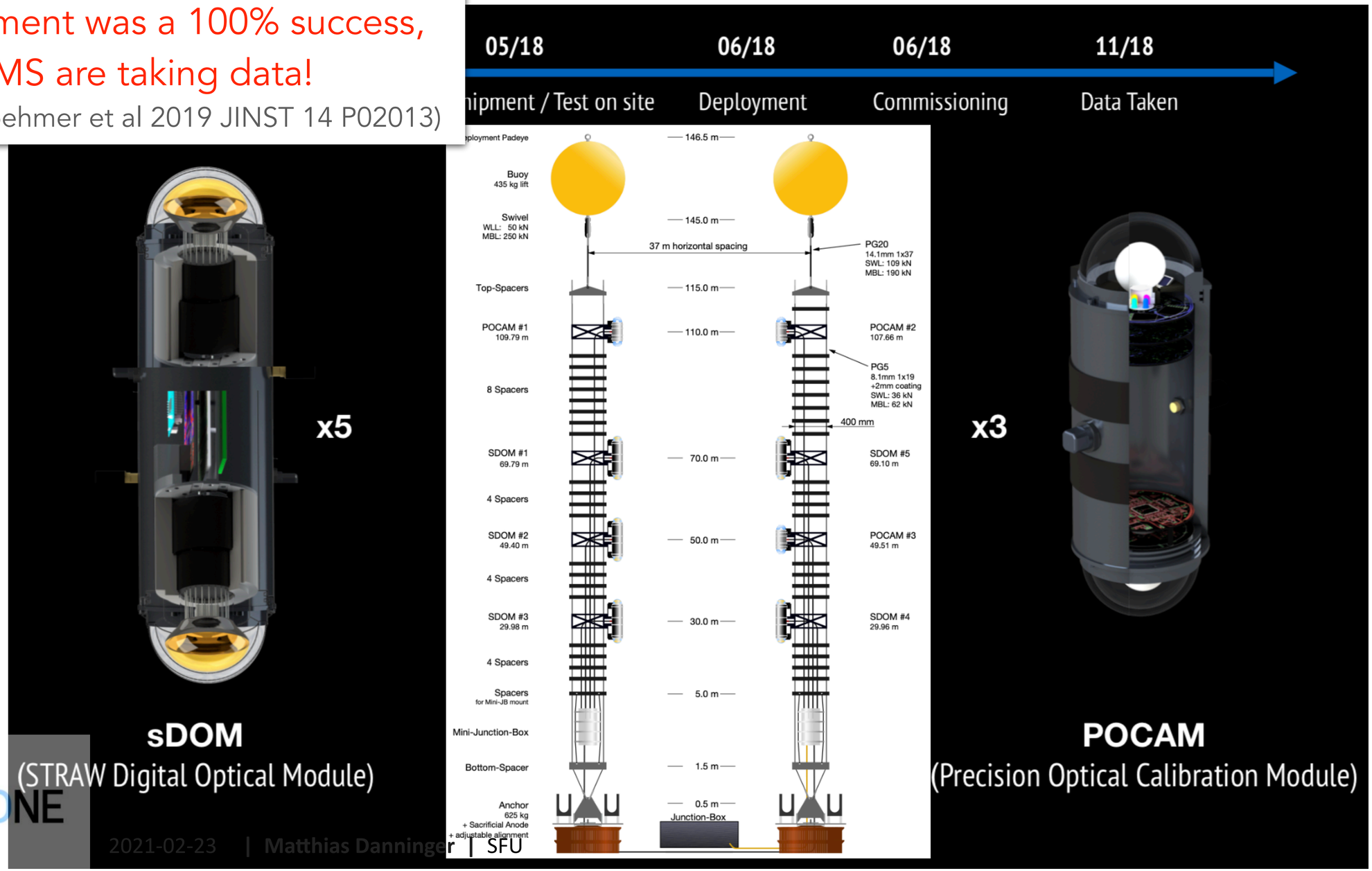
STRAW — Strings for absorption length in water

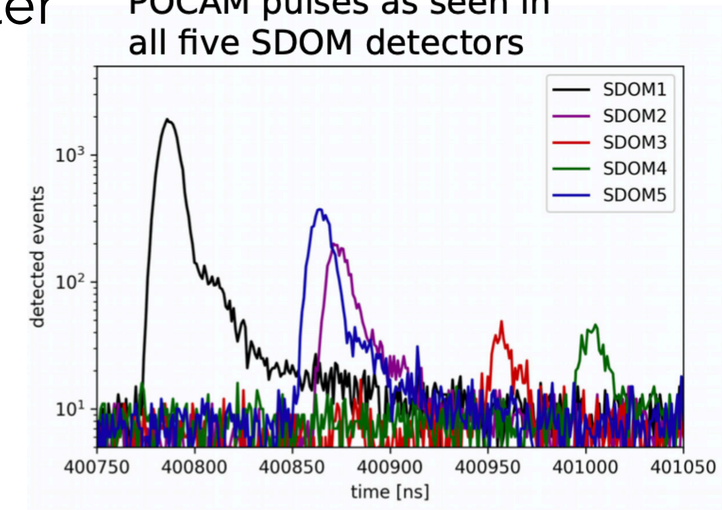
Deployment was a 100% success, all sDOMS are taking data!

(see M. Boehmer et al 2019 JINST 14 P02013)



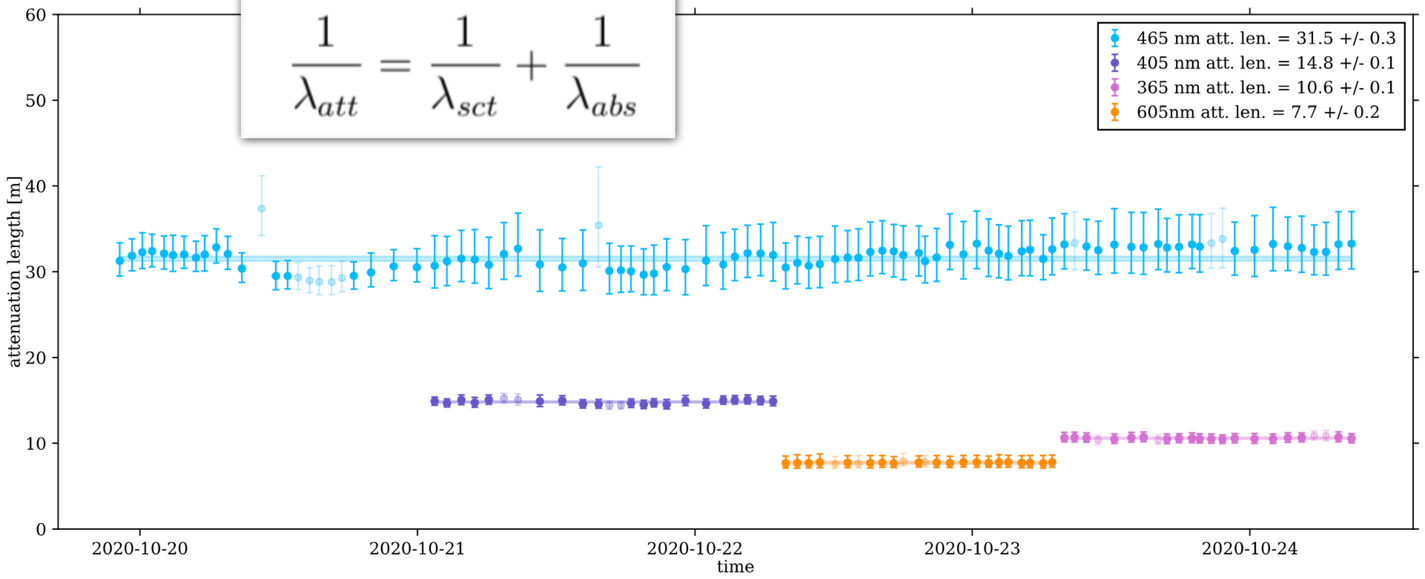
Optical properties of the Water

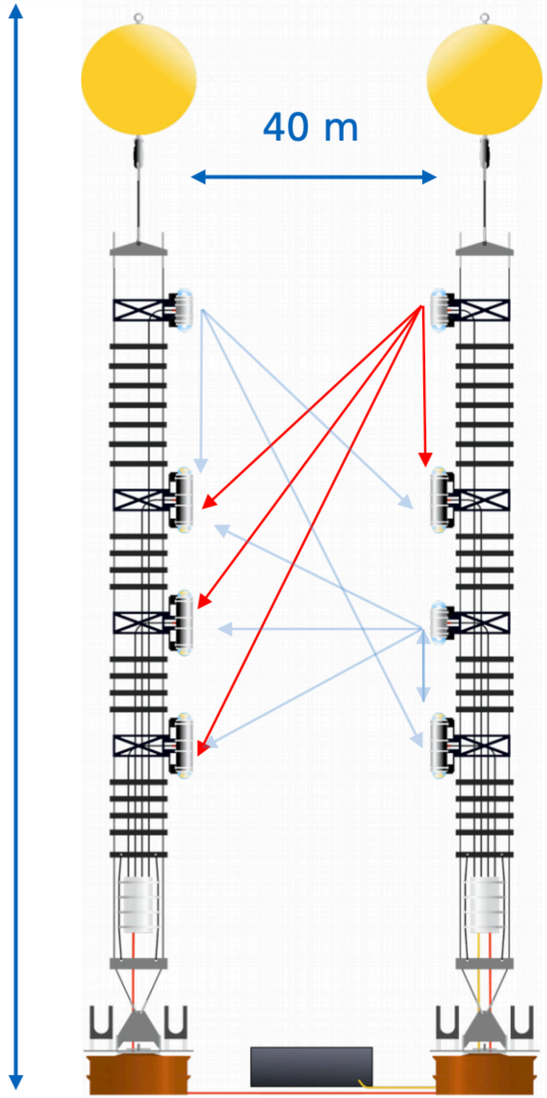
- Measure Attenuation length in the water
  - For different wavelength
  - Scattering and absorption separately
  - Optical properties are good!



$$I(r) = \frac{I_0}{r^2} e^{\frac{-r}{\lambda_{att}}}$$

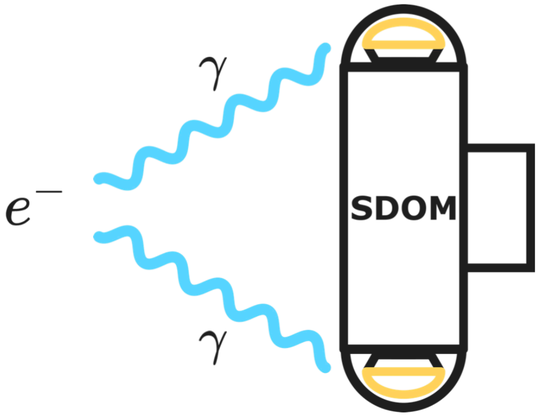
$$\frac{1}{\lambda_{att}} = \frac{1}{\lambda_{sct}} + \frac{1}{\lambda_{abs}}$$

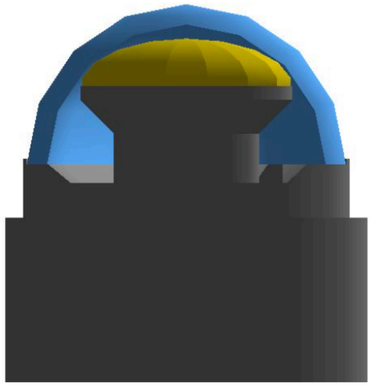




Optical properties of the Water

- Understanding the 40K background
  - Natural in-situ calibration with K40 possible $^{40}\mathrm{K} \rightarrow ^{40}\mathrm{Ca} + e^- + \bar{\nu}_e$
  - Cross-check of λatt results, detector and site model



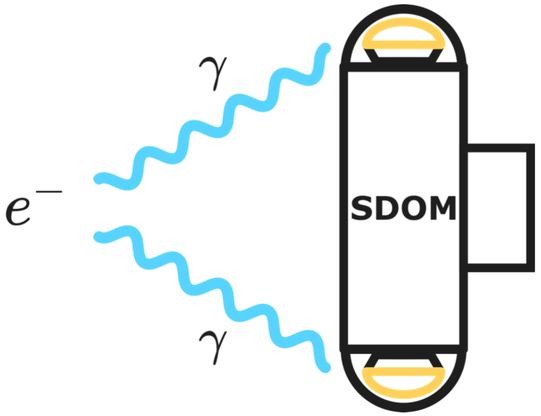


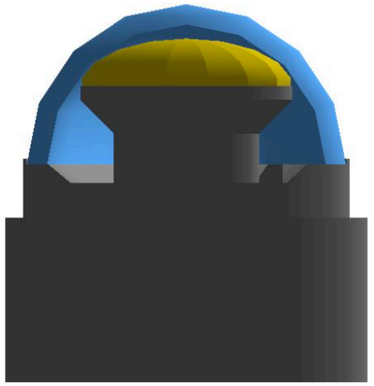
SDOM PMT housing Geant4 model

Optical properties of the Water

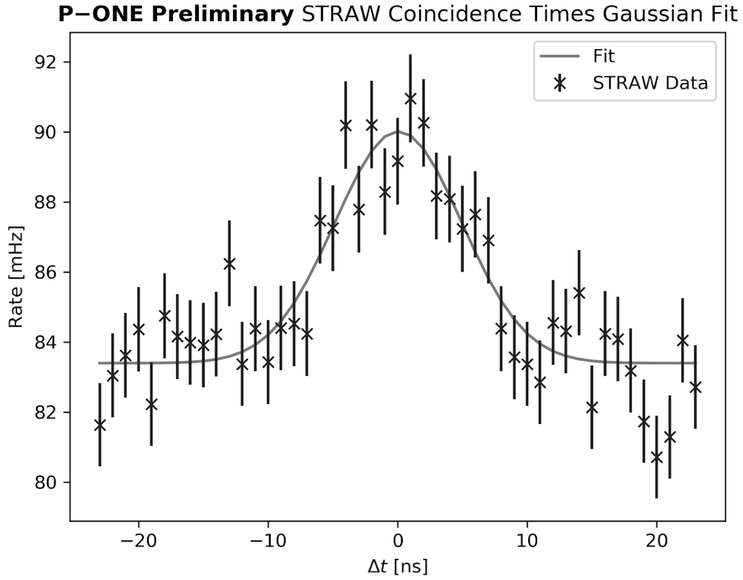
- Understanding the 40K background
  - Natural in-situ calibration with K40 possible $^{40}\mathrm{K} \rightarrow ^{40}\mathrm{Ca} + e^- + \bar{\nu}_e$
  - Cross-check of λatt results, detector and site model
  - Consistent results!
  - Measured Salinity matches independent ONC measurements at 3.48%

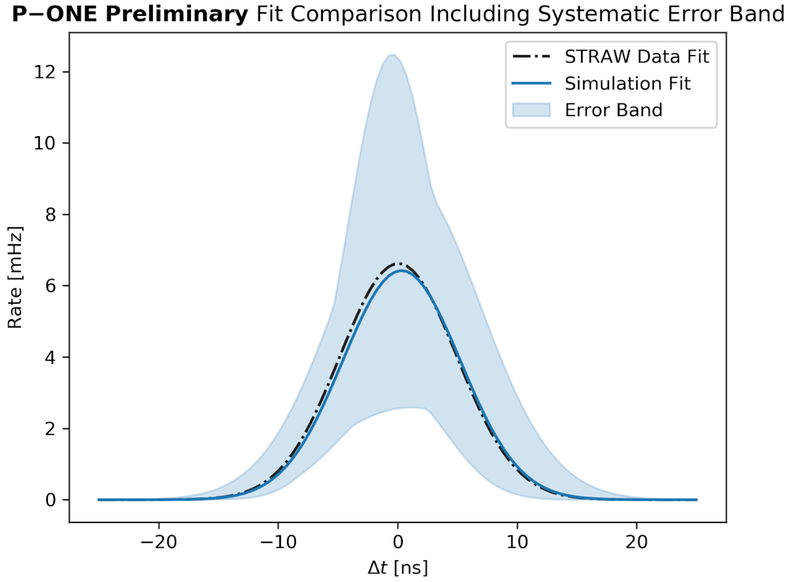
$$2.7^{+3.1}_{-0.9}\ \%$$



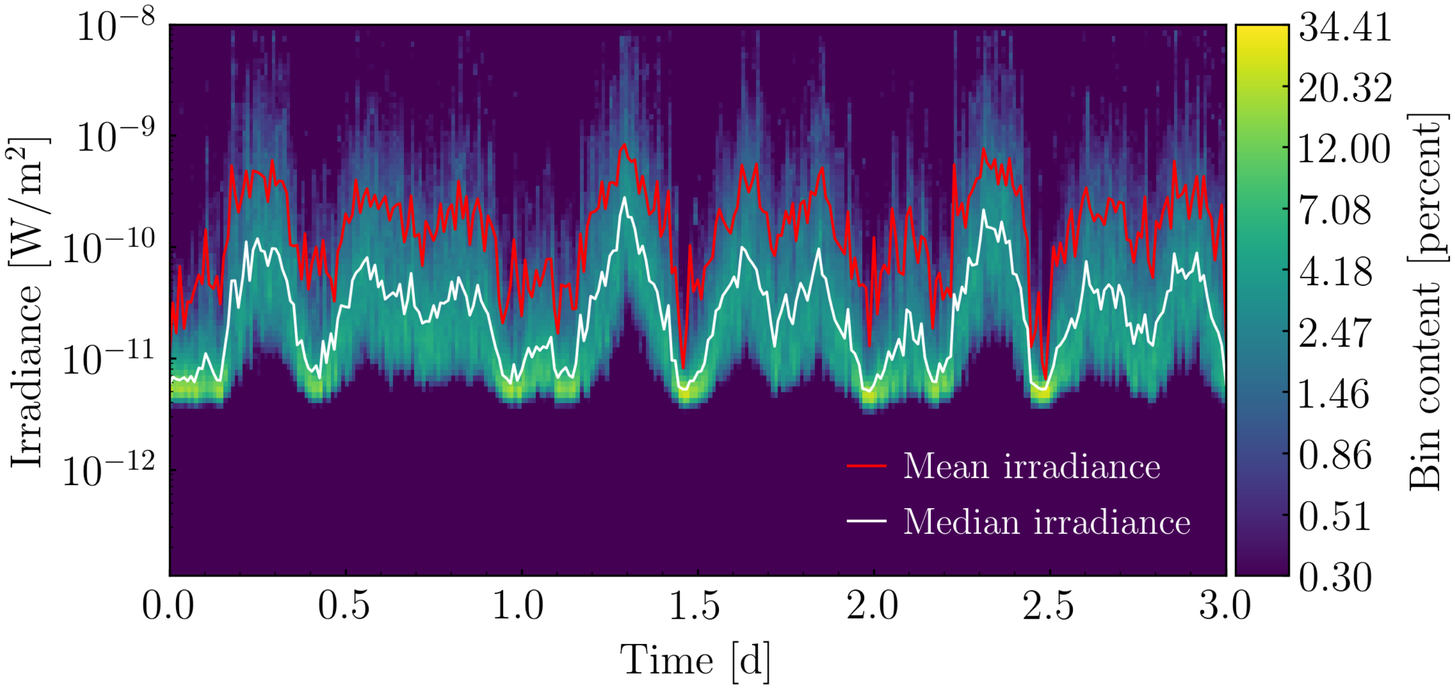


SDOM PMT housing Geant4 model





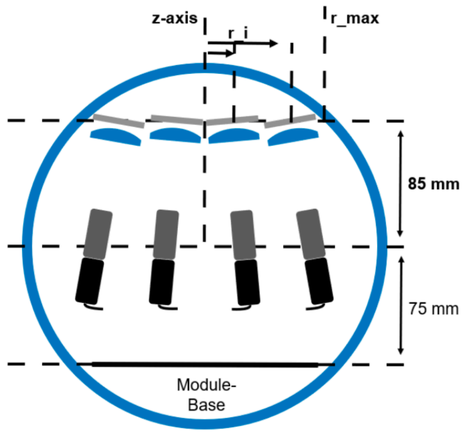
Optical properties of the Water

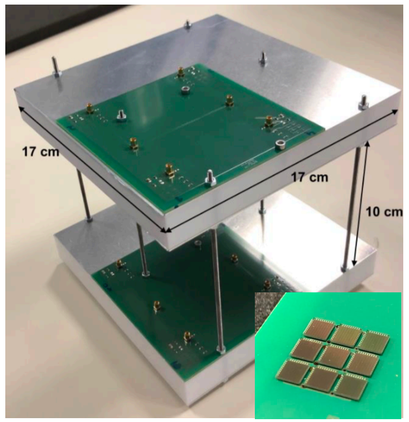


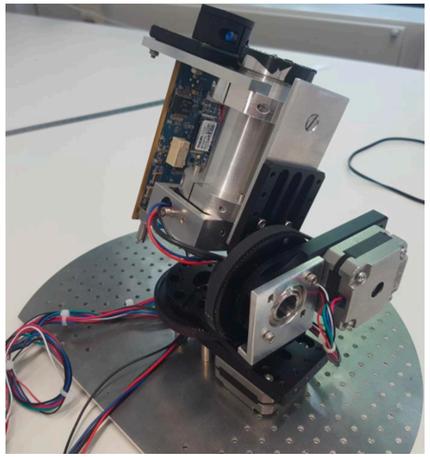
- Bioluminescence is modulated with the tides
  —> more detailed analysis and modelling ongoing
- Full publication with optical parameters and site characterization in progress

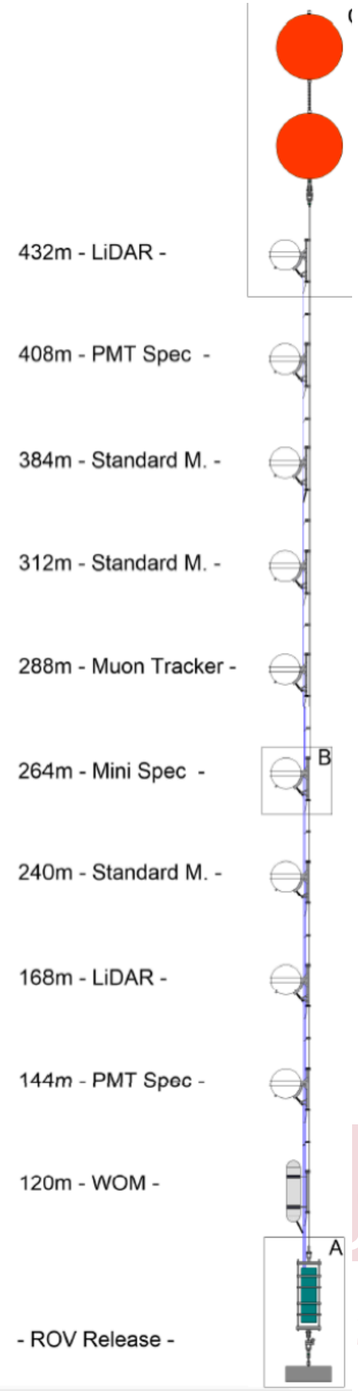
The 2nd pathfinder towards P-ONE

- Background calibration
  - PMT Spectrometer (12 PMTs w. different wavelength filters)
  - Muon spectrometer (SiPMT readout)
- Water properties
  - LiDAR (450nm)
- Standard modules
  - p/T/H and magnetic field sensors for ping signal







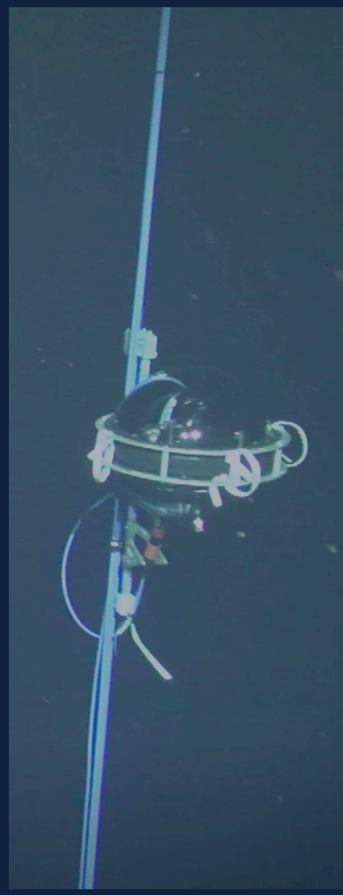


Timeline:

- Despite COVID19 challenges, successful deployment in fall 2020
- Analysis efforts ramping up

— P-ONE —

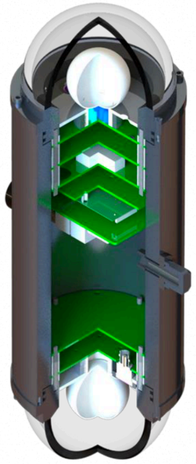
- Next steps towards a neutrino observatory



P-ONE — prototype line

- Construction and deployment of a complete P-ONE mooring line
- Proof and verification of;
  - detector design
  - deployment techniques
  - positioning calibration (we aim to use optical position system)
- Some project corner stones

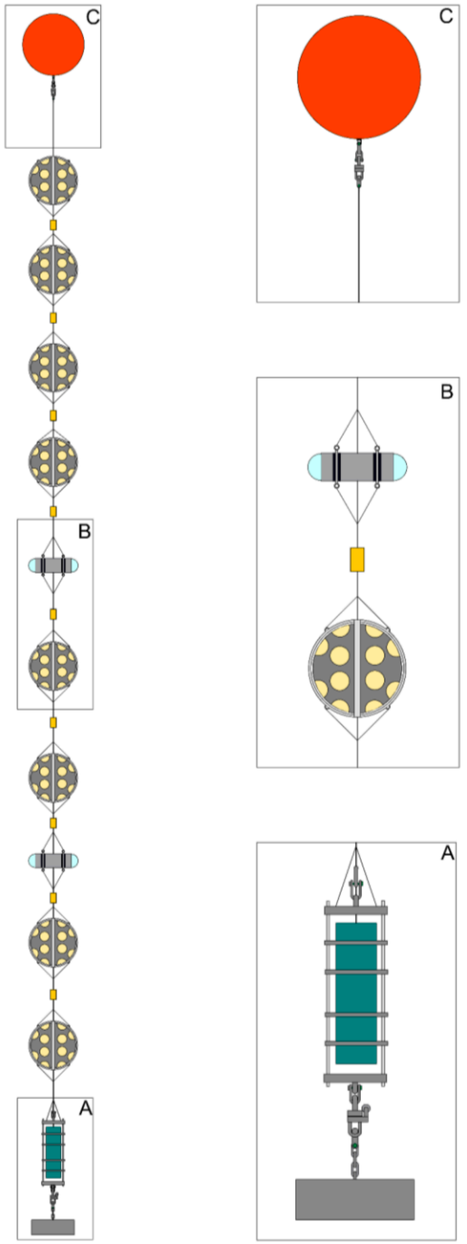
P-DOR | Preliminary concept study



Optical Calibration

- Understanding ocean water is key to the success
- Synergy with IceCube

P-CAL | Image: POCAM in development for ICU



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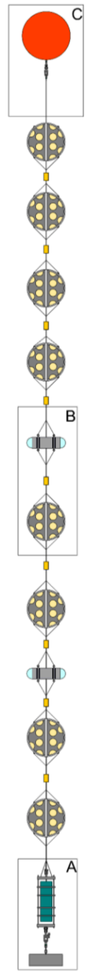
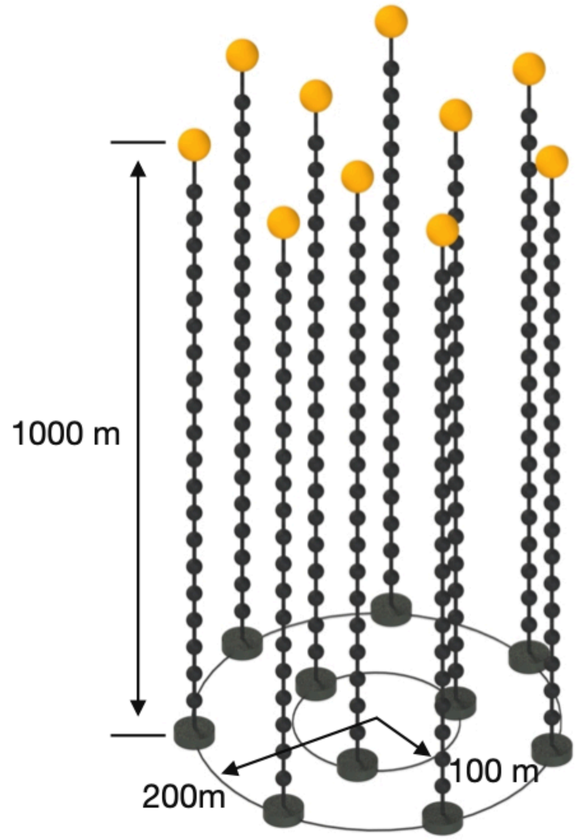
more details tomorrow by C. Spannfellner

P-ONE — 10 string "Explorer"

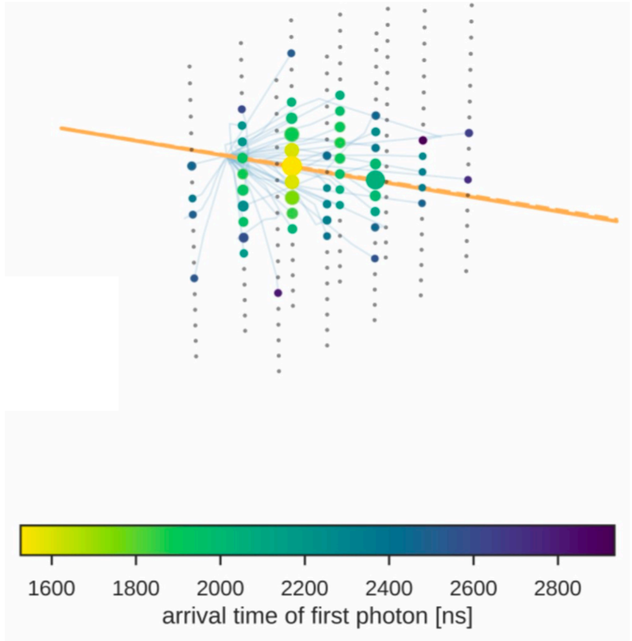
Prototype

10 string Explorer





- Timescale 2023-2025*
- 10 strings/lines
- 200 modules
- order 100m spacing
- Instrumented Volume ~1/8 km3
- Exploring physics potential for:
  - tau neutrinos
  - exotic neutrino oscillations
  - charm production



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P-ONE Collaboration, Nature Astron. (2020) e-Print: 2005.09493

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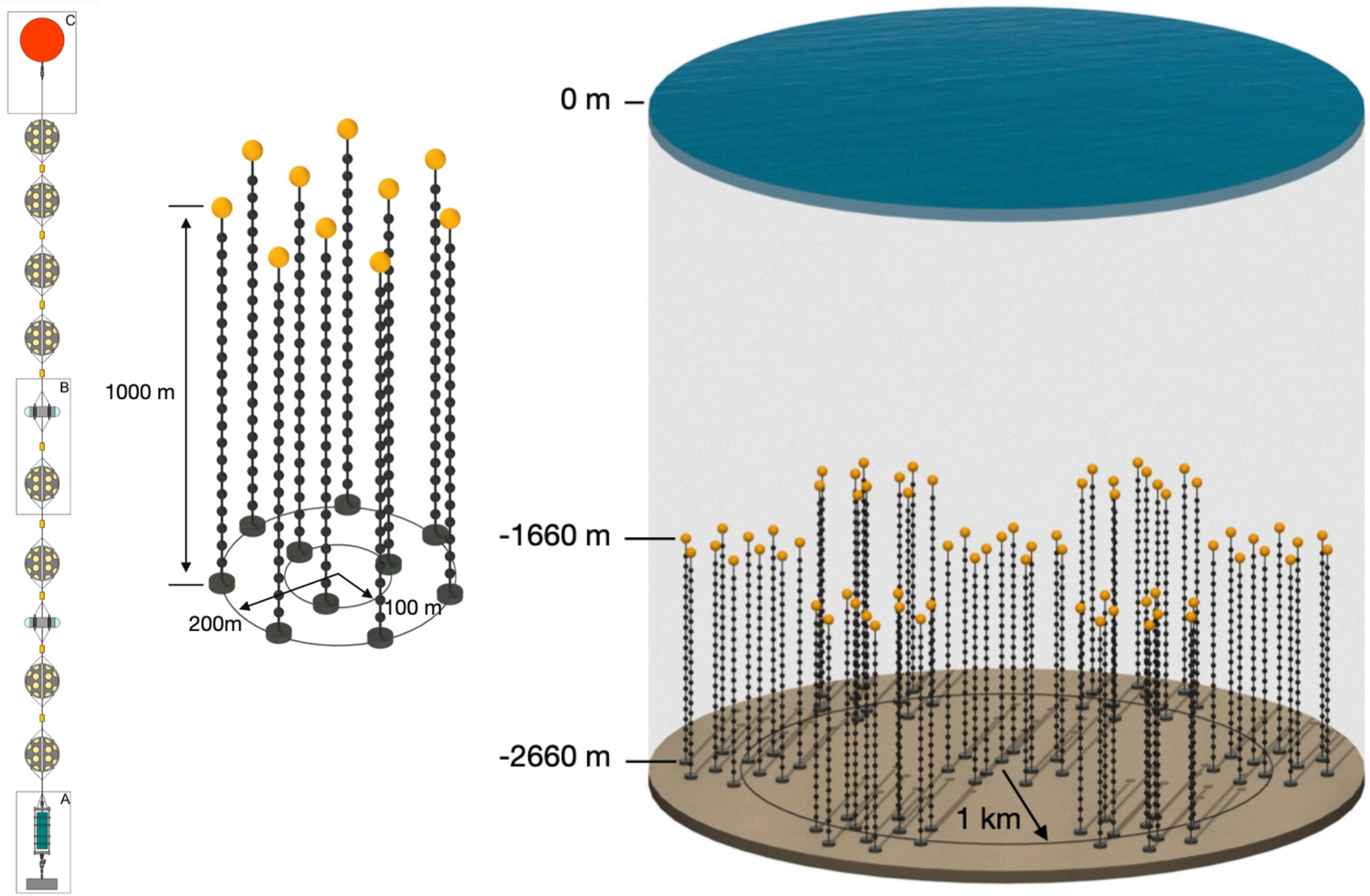
P-ONE — From "Explorer" to "Experiment"

Prototype — 10 string Explorer — Experiment



- Once the ***explorer*** demonstrates success, a larger several km^3 detector can be pursued, again using ONC infrastructure and expertise
- More neutrinos, better neutrinos!
- This is in conceptual design phase

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P-ONE Collaboration, Nature Astron. (2020) e-Print: 2005.09493

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Summary

- More neutrinos, better neutrinos!
- The northern Pacific Ocean is ideally located for a new observatory to achieve full sky coverage
    - Cascadia Basin is a suitable deep sea site
- Ocean Networks Canada is an exciting opportunity for neutrino physics
- Prototype line and 10-string Explorer are being planned and developed
- New Collaborators are welcome to join and support the efforts!

P-ONE Collaboration Members

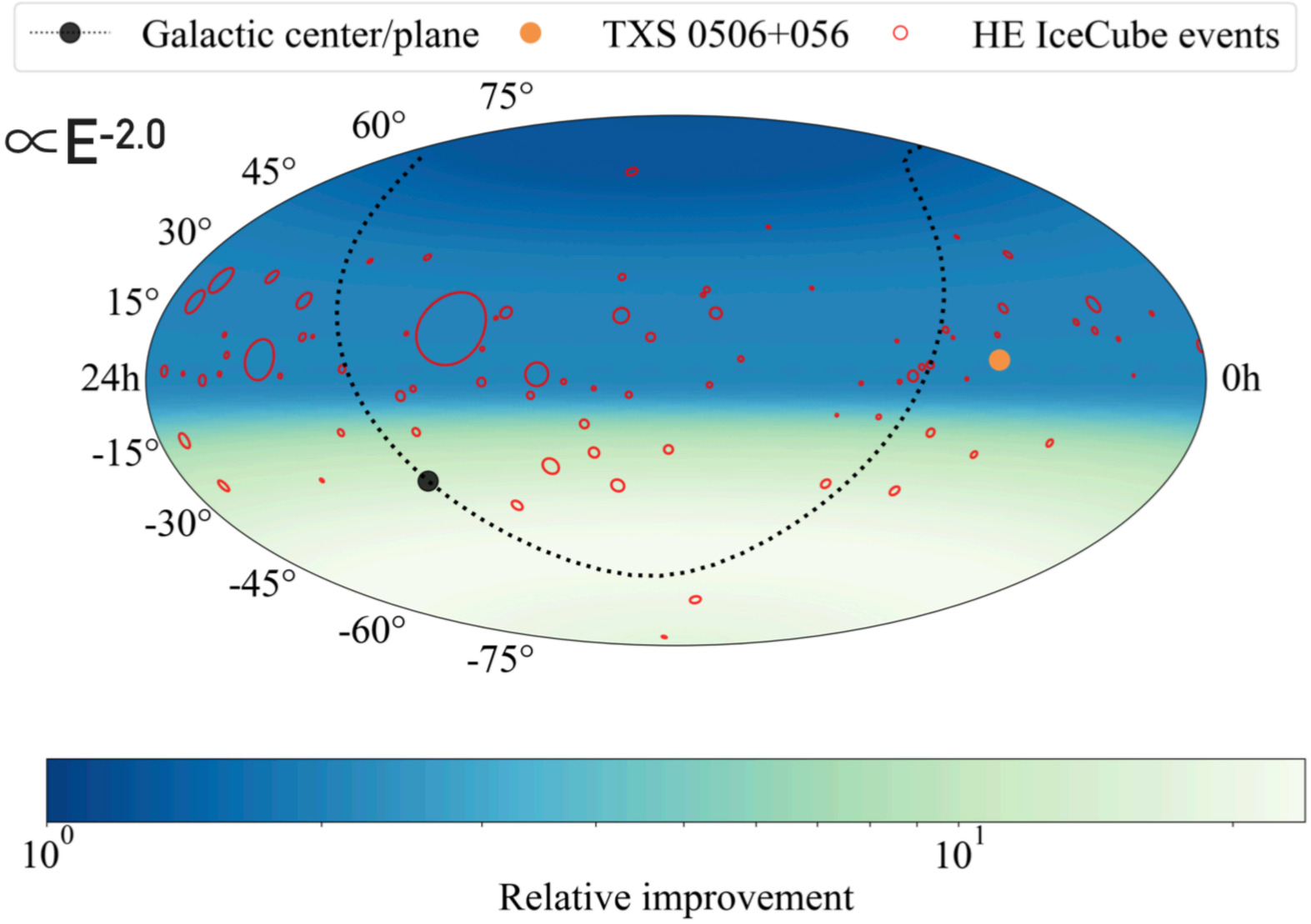
Matteo Agostini, Michael Böhmer, Jeff Bosma, Kenneth Clark, Matthias Danninger, Christian Fruck, Roman Gernhäuser, Andreas Gärtner, Darren Grant, Felix Henningsen, Kilian Holzapfel, Matthias Huber, Reyna Jenkyns, Carsten B. Krauss, Kai Krings, Claudio Kopper, Klaus Leismüller, Sally Leys, Paul Macoun, Stephan Meighen-Berger, Jan Michel, Roger Moore, Mike Morley, Paolo Padovani, Laszlo Papp, Benoit Pirenne, Chuantao Qiu, Immacolata Carmen Rea, Elisa Resconi, Adrian Round, Albert Ruskey, Christian Spannfellner, Michael Traxler, Andrea Turcati and Juan Pablo Yanez

To know more, pay us a visit in http://www.pacific-neutrino.org/

Extras

ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

➡ RELATIVE IMPROVEMENT VS ICECUBE ALL SKY



PLEνM

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➡ RELATIVE IMPROVEMENT VS ICECUBE ALL SKY