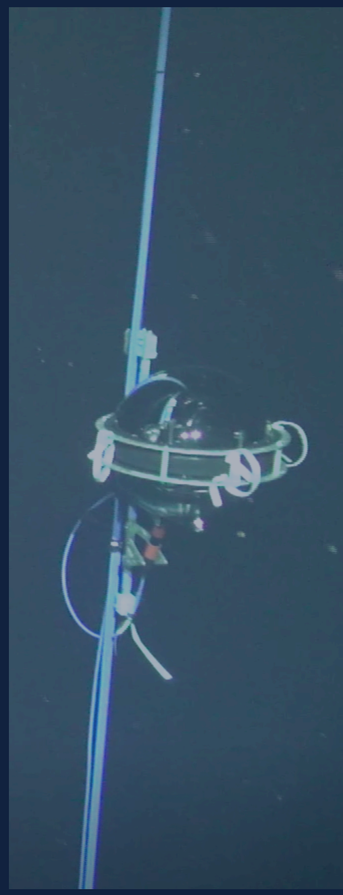
P-ONE

— The Pacific Ocean Neutrino Explorer —

Matthias Danninger
for the P-ONE Collaboration

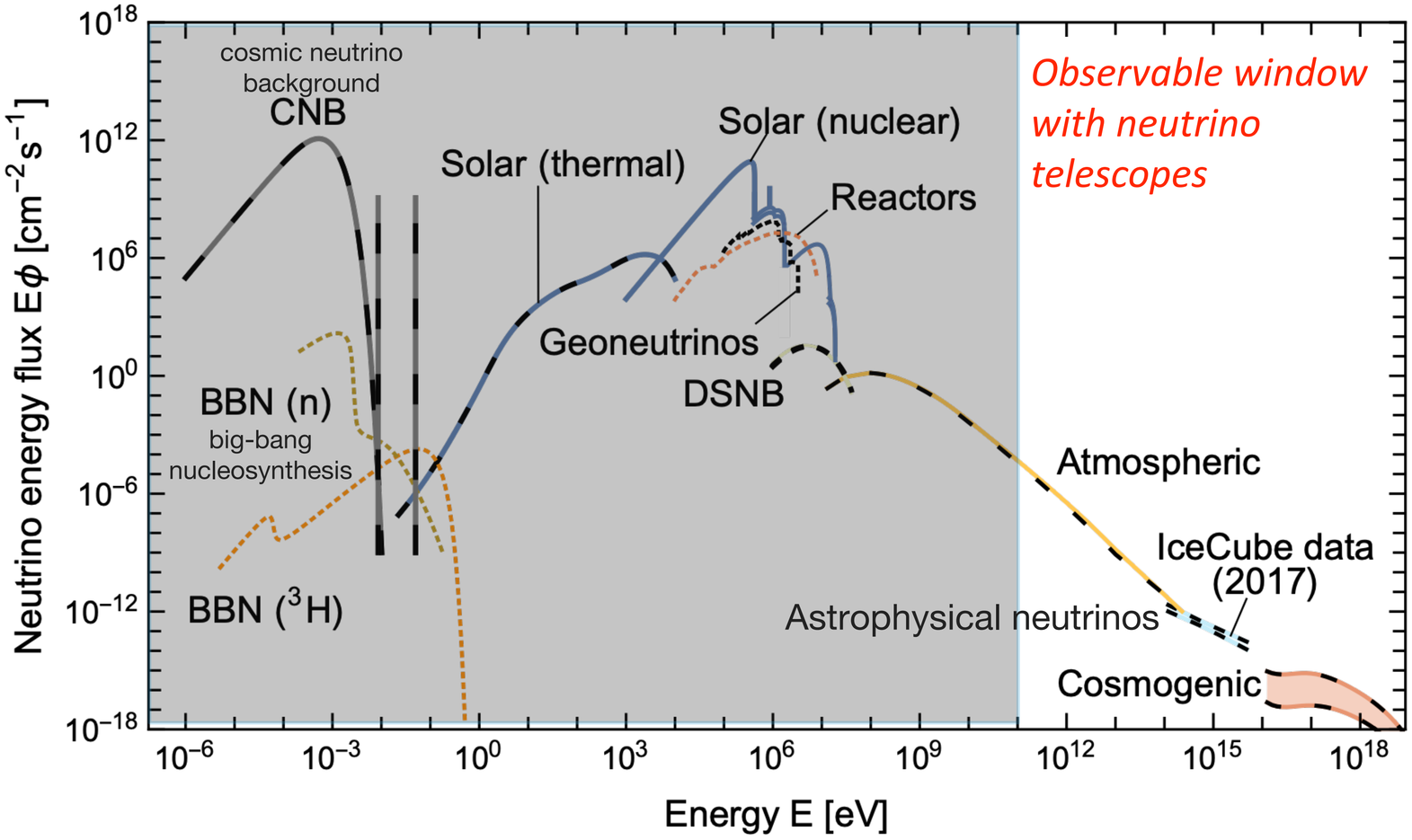
TIPP 2021

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

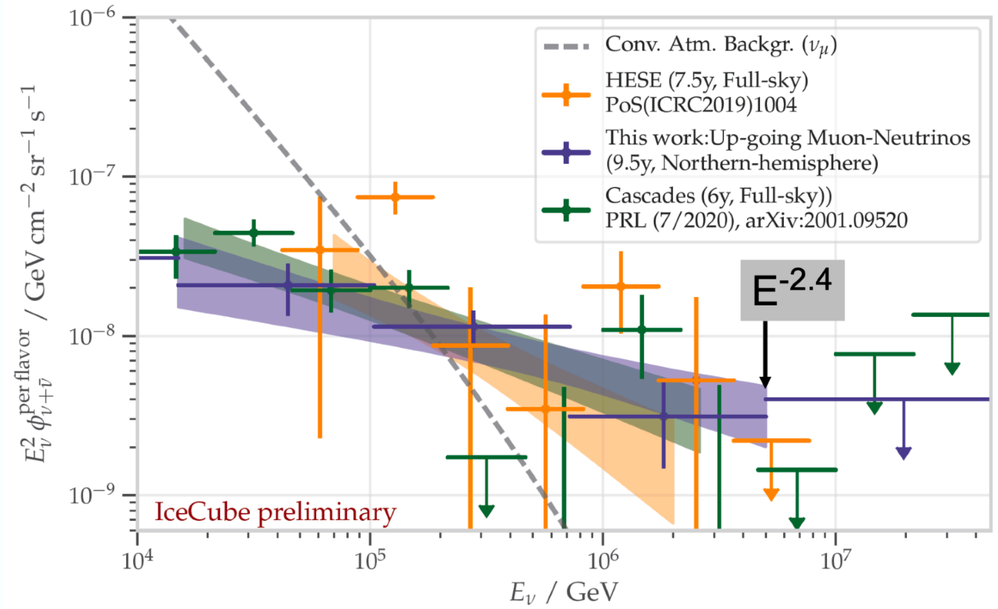
-naturally occurring neutrinos can have extreme energies

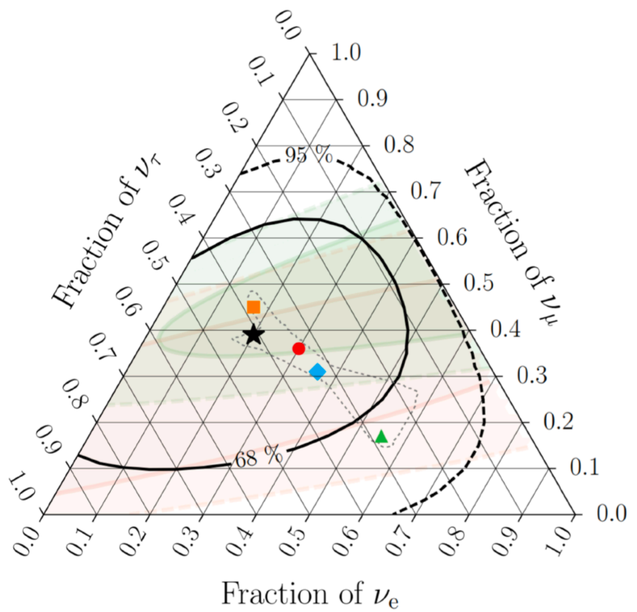
-manmade beams can reach E ~ 50 GeV at most

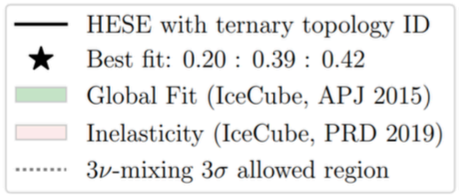
-but the fluxes are low, so you need really large detectors

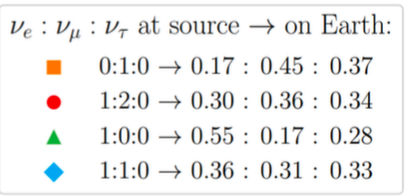
Neutrinos from the Universe

- 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









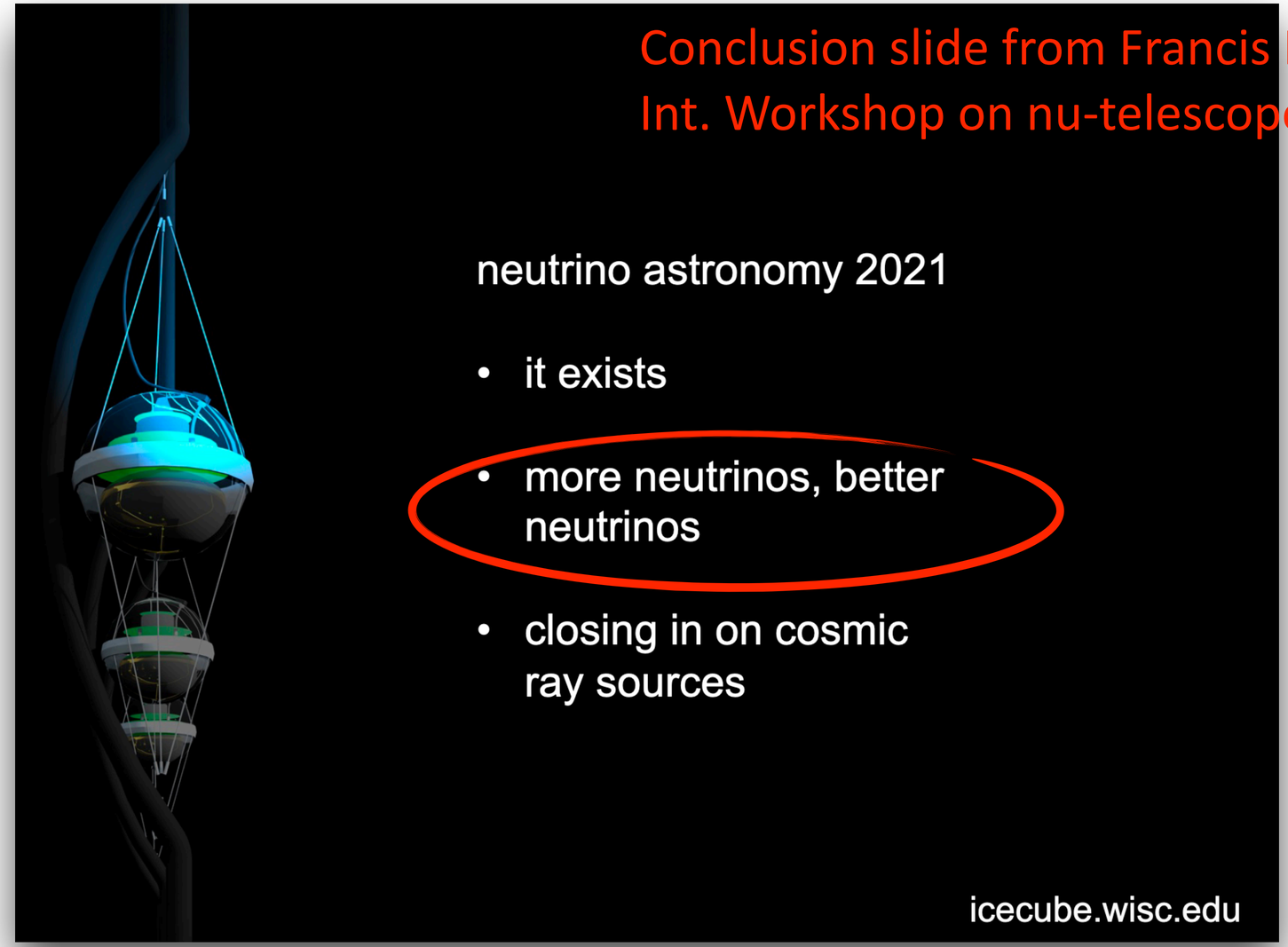
https://arxiv.org/pdf/2011.03561.pdf

P-ONE

SIMON FRASER UNIVERSITY

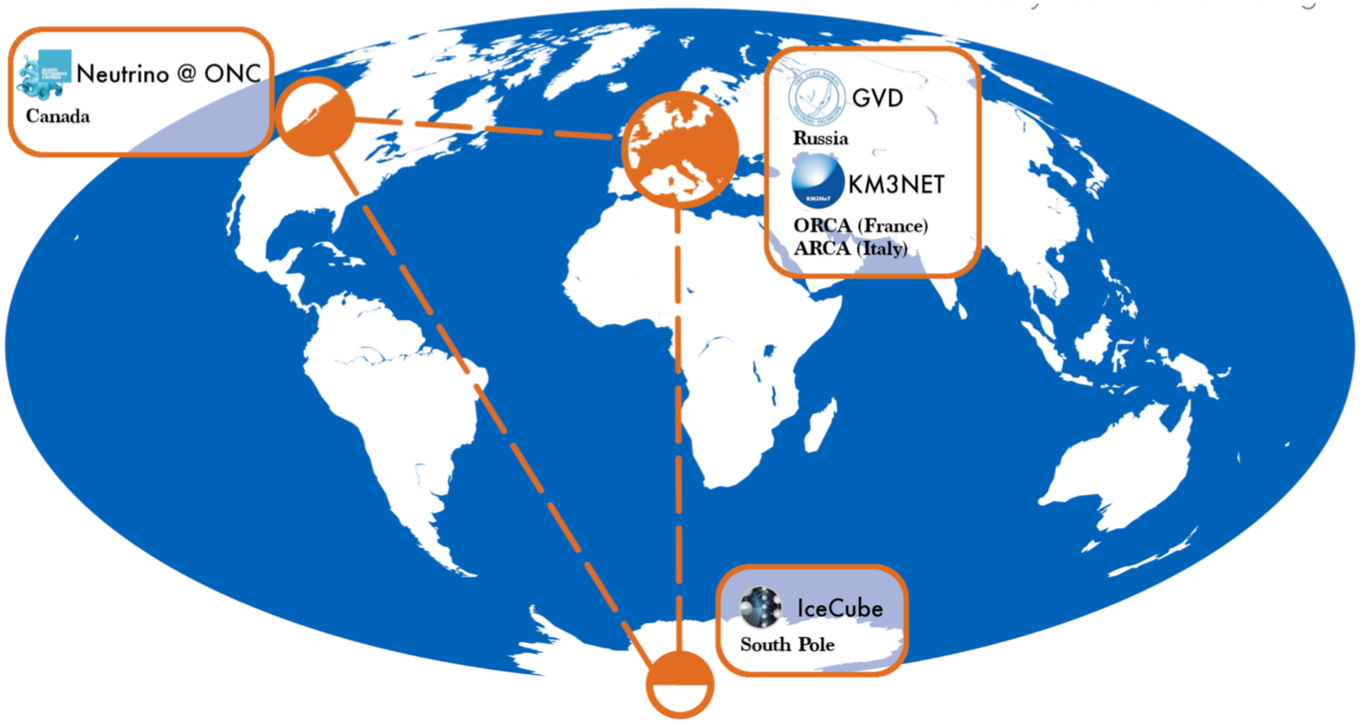
Why another neutrino telescope?

Conclusion slide from Francis Halzen's talk at Int. Workshop on nu-telescopes (Feb 2021)!



Why another neutrino telescope?

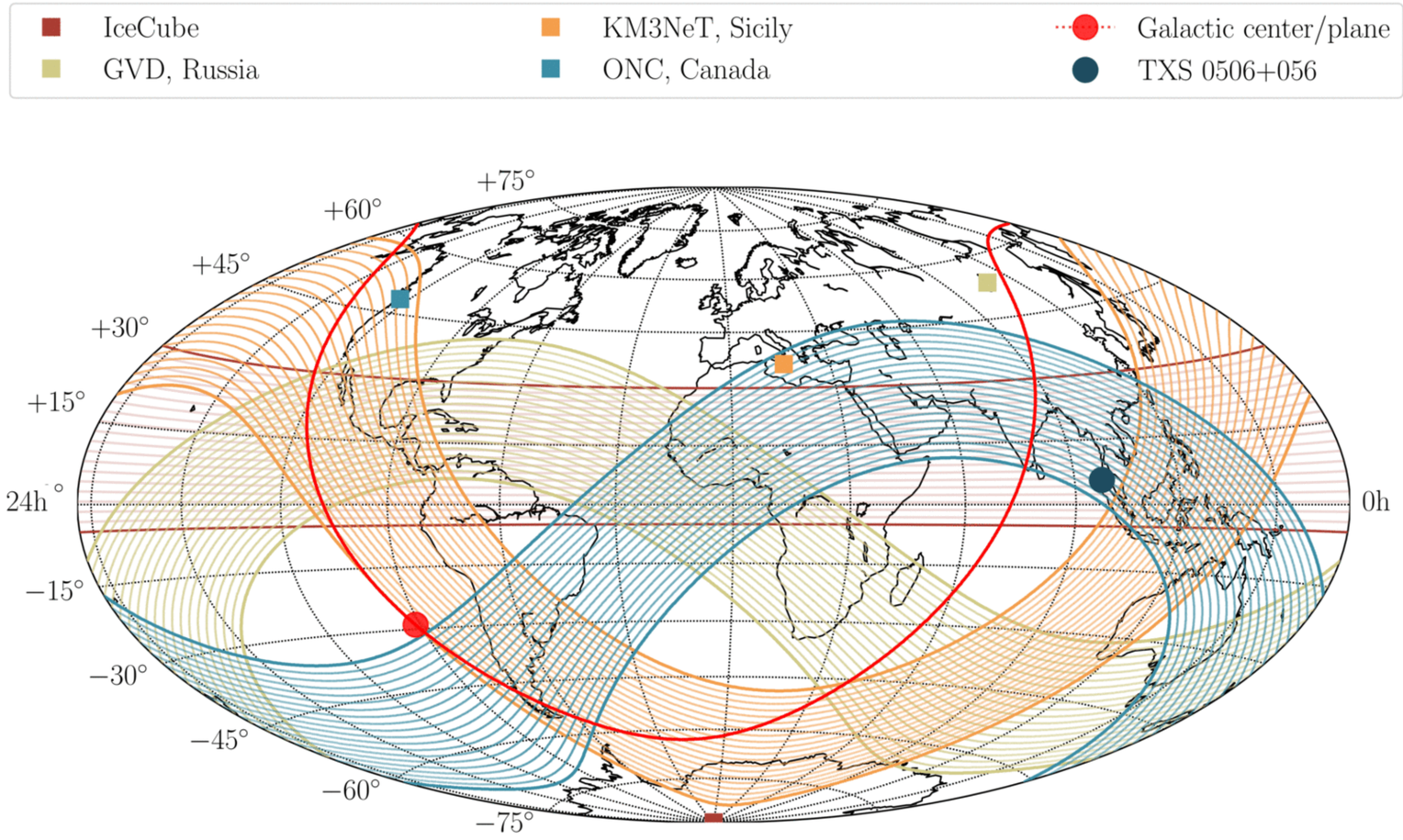
- More neutrinos, better neutrinos!



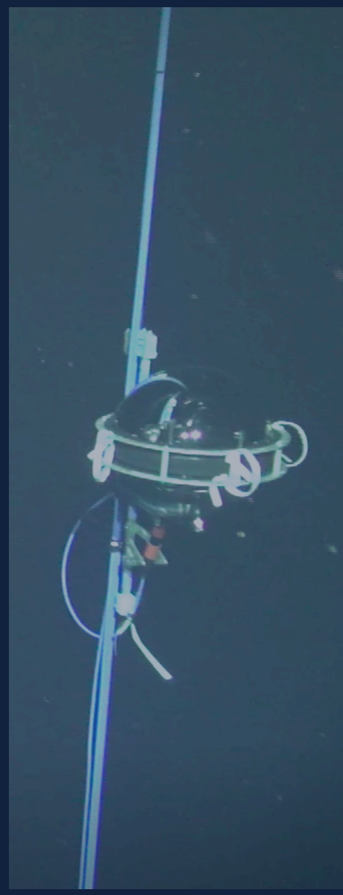
- P-ONE project has large emphasis on collaboration and complementarity with existing efforts such as IceCube, GvD (Baikal), and KM3NeT —> we welcome collaboration/participation
- We aim for combined cross-calibration efforts to boost precision of all measurements at all neutrino telescope sites worldwide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

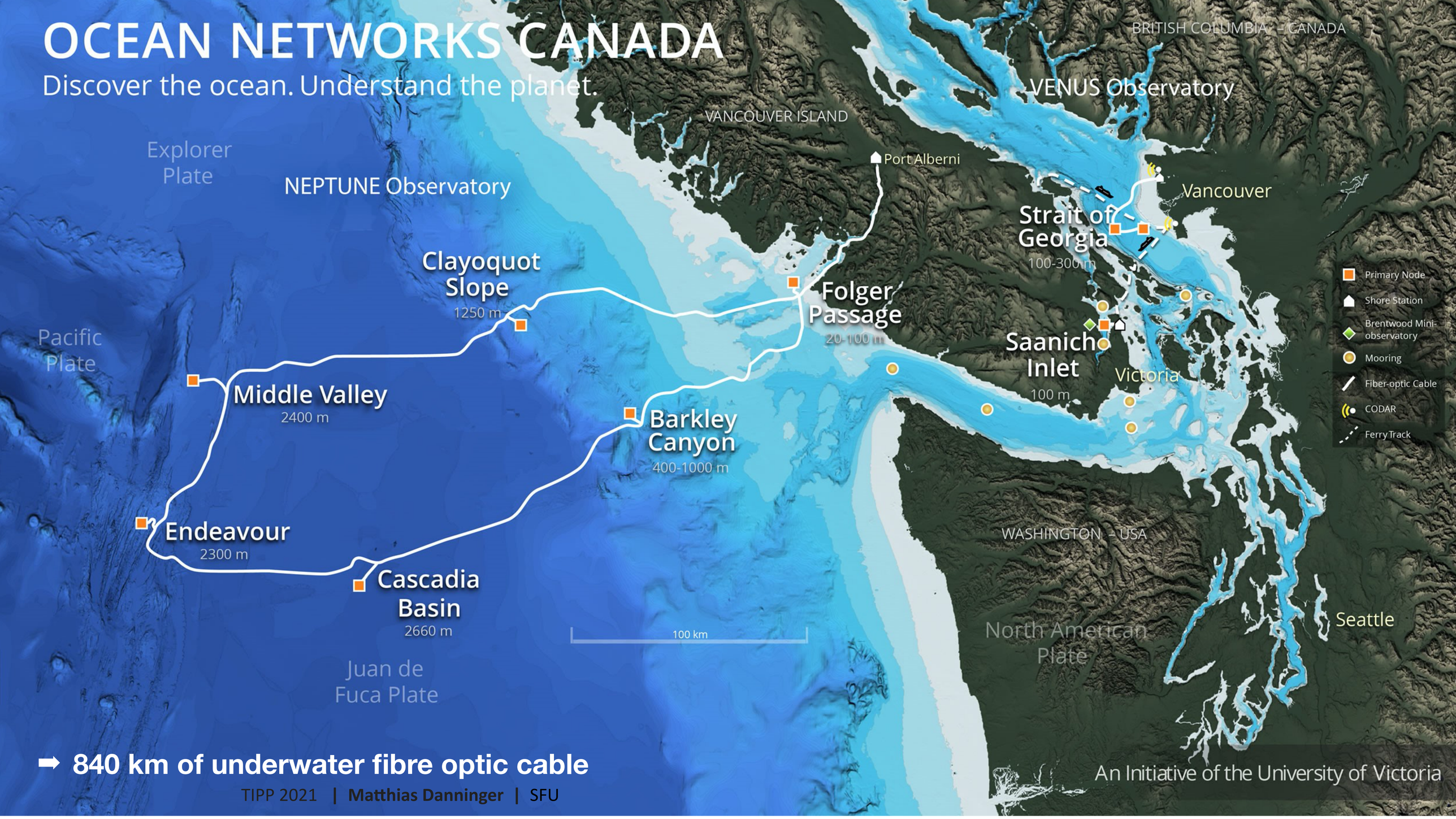


Ocean Networks Canada

— and opportunity for the neutrino community —

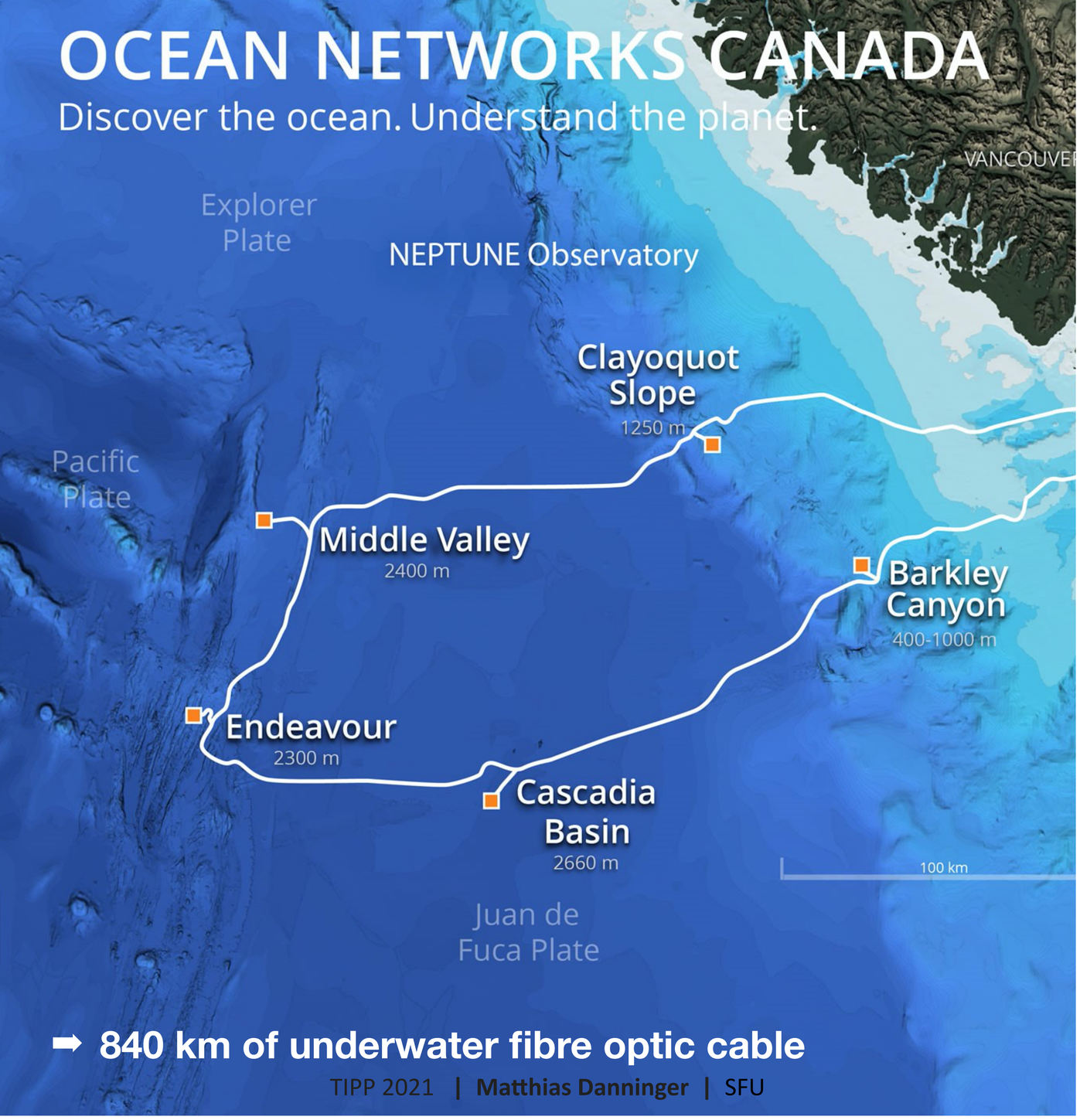
P-ONE

SFU



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

TIPP 2021 | **Matthias Danninger** | SFU



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

- 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

NEPTUNE Observatory
Ocean Networks Canada
Pacific Ocean Neutrino Explorer (P-ONE)

NE Bottom Pressure Recorder (-2640 m)

East (-2660 m)
Neutrino Experiment (STRAW)
Accelerometer
Tiltmeter
CORK 1027C
Neutrino Experiment (STRAW)
Metres
0 25 50 75 100

Papa Bare Seamount

Node
Instrument Platform
Mooring
Fibre-optic Cable (Active)
Fibre-optic Cable (Planned)
-2350 m
Bathymetry
-2700 m
N W E S
10 km

W Bottom Pressure Recorder (-2639 m)

West (-2660 m)

P-ONE

Baby Bare Seamount

AN INITIATIVE OF University of Victoria

Description: This map illustrates the planned location of the Pacific Ocean Neutrino Explorer (P-ONE) at Cascadia Basin. P-ONE is a new initiative which aims to redevelop ocean-based neutrino telescopes by harnessing Ocean Networks Canada infrastructure.
Data Sources: University of Alberta, University of Bremen, USGS Cascadia, McDonald Institute, Queen's University
Last Updated: 2 January 2020

OCEAN NETWORKS CANADA

Cascadia Basin node

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

Metres
0 25 50 75

SE Bottom Pressure Recorder (-2633 m) (Autonomous)

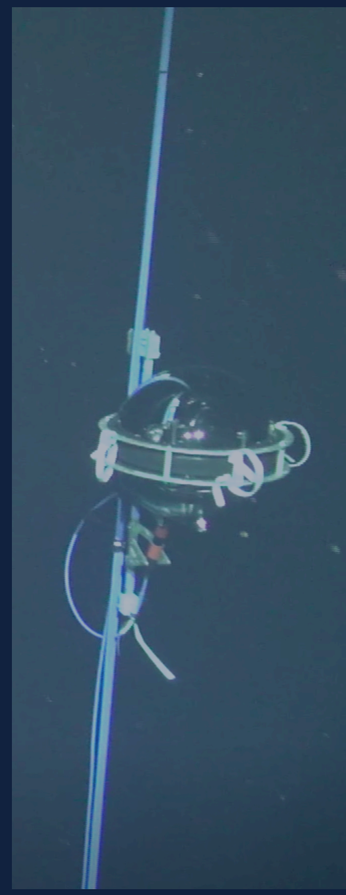
ONC — Expert support & deployment

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

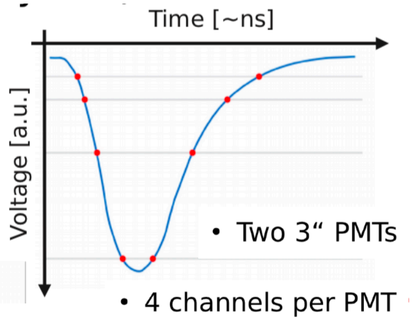
STRAW b

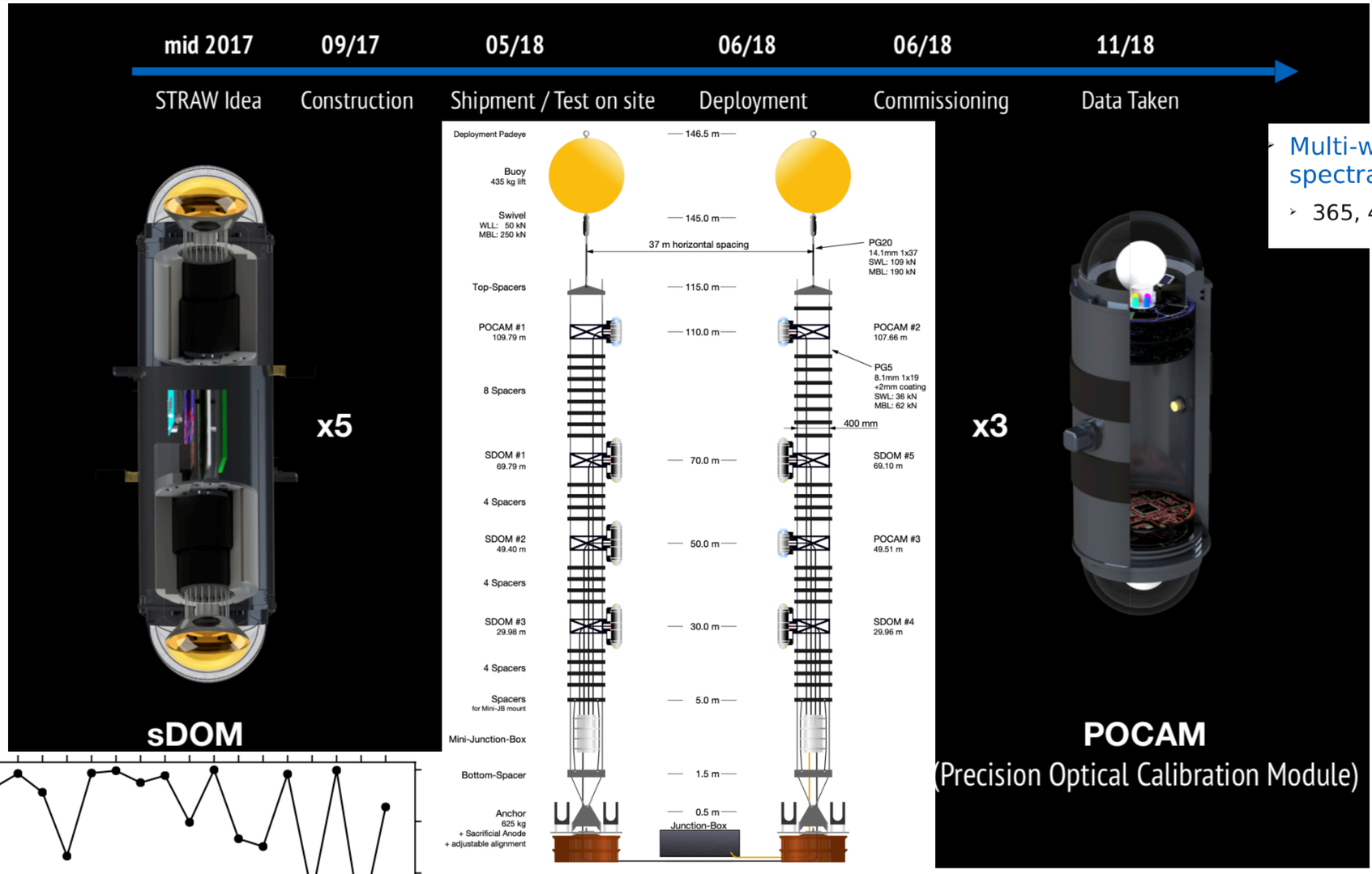
R&D on optical modules, further characterisation

P-ONE

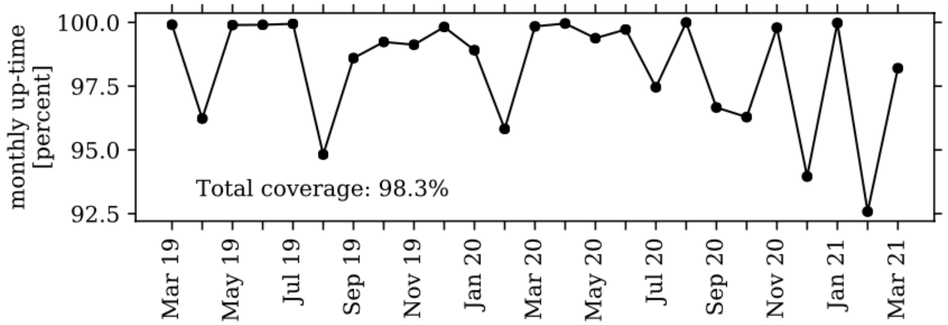
SFU

STRAW — Strings for absorption length in water





- Multi-wavelength emission for spectral studies
  - 365, 405, 465, 525, 605nm



Deployment was a 100% success, all sDOMS are taking data! (2019 JINST 14 P02013)

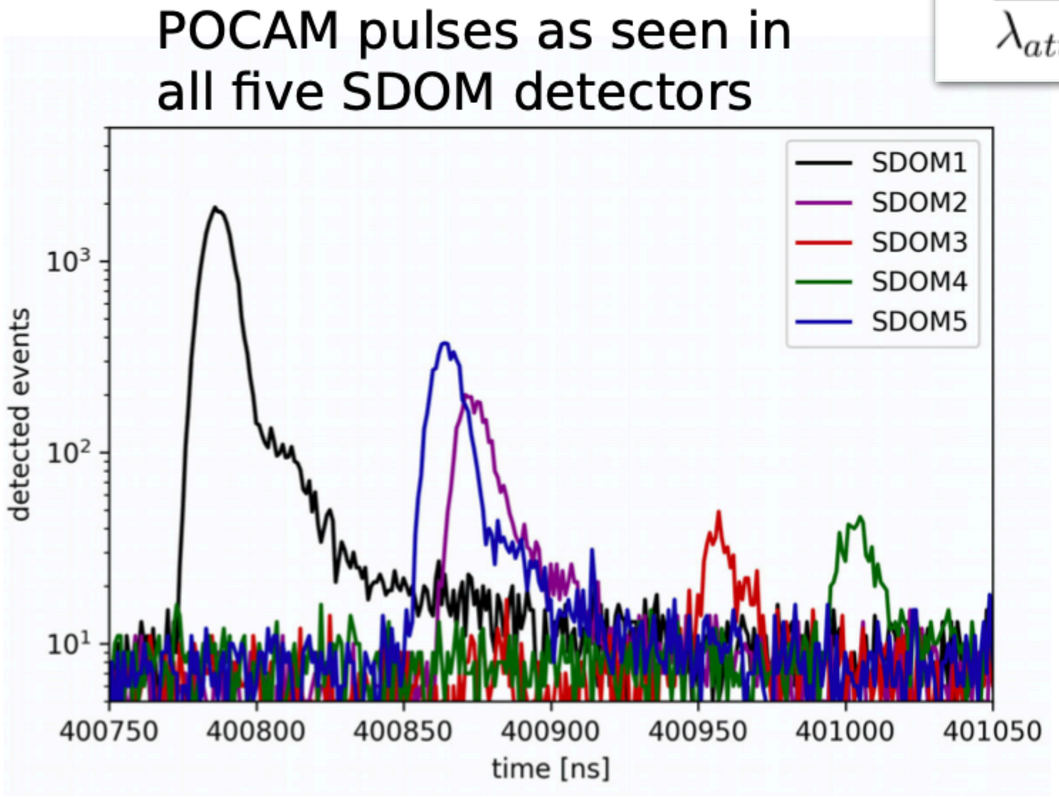
Optical properties of the Water

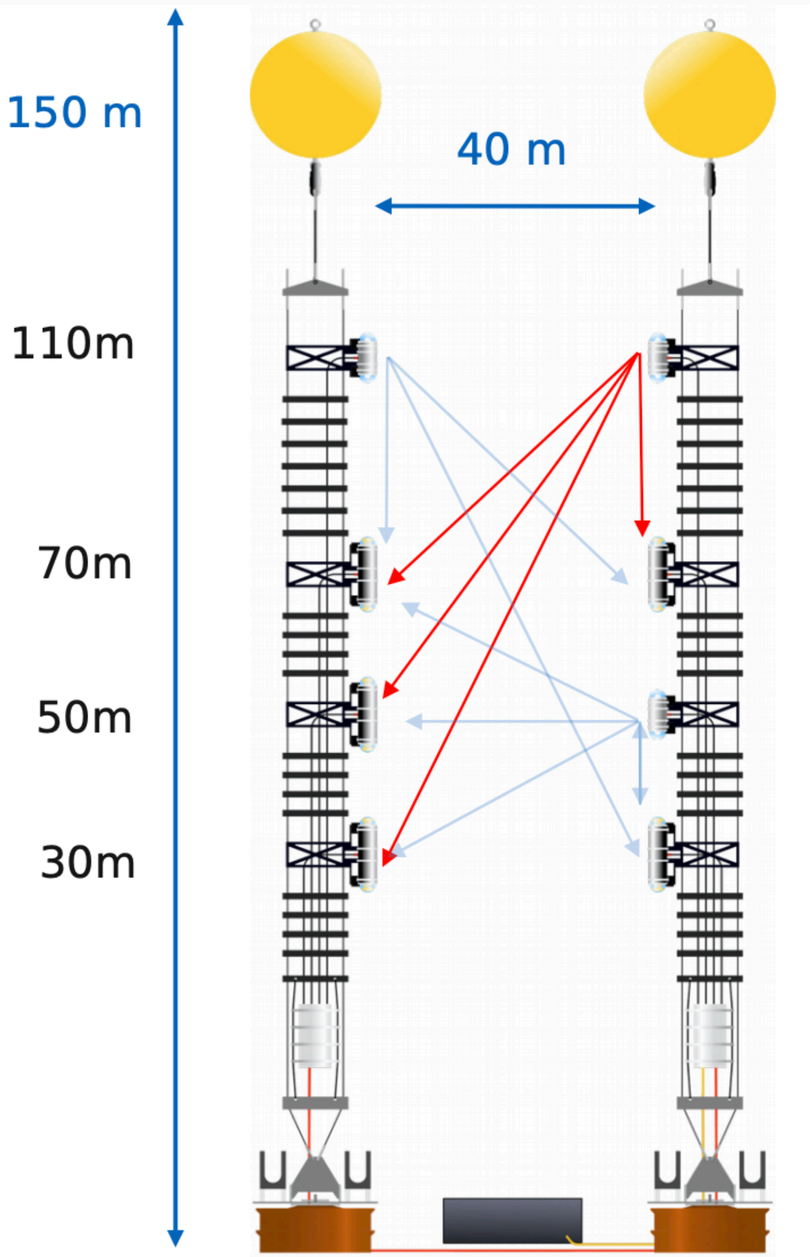
Preliminary

- Measure Attenuation length in the water
  - For different wavelength
  - Scattering and absorption separately

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

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

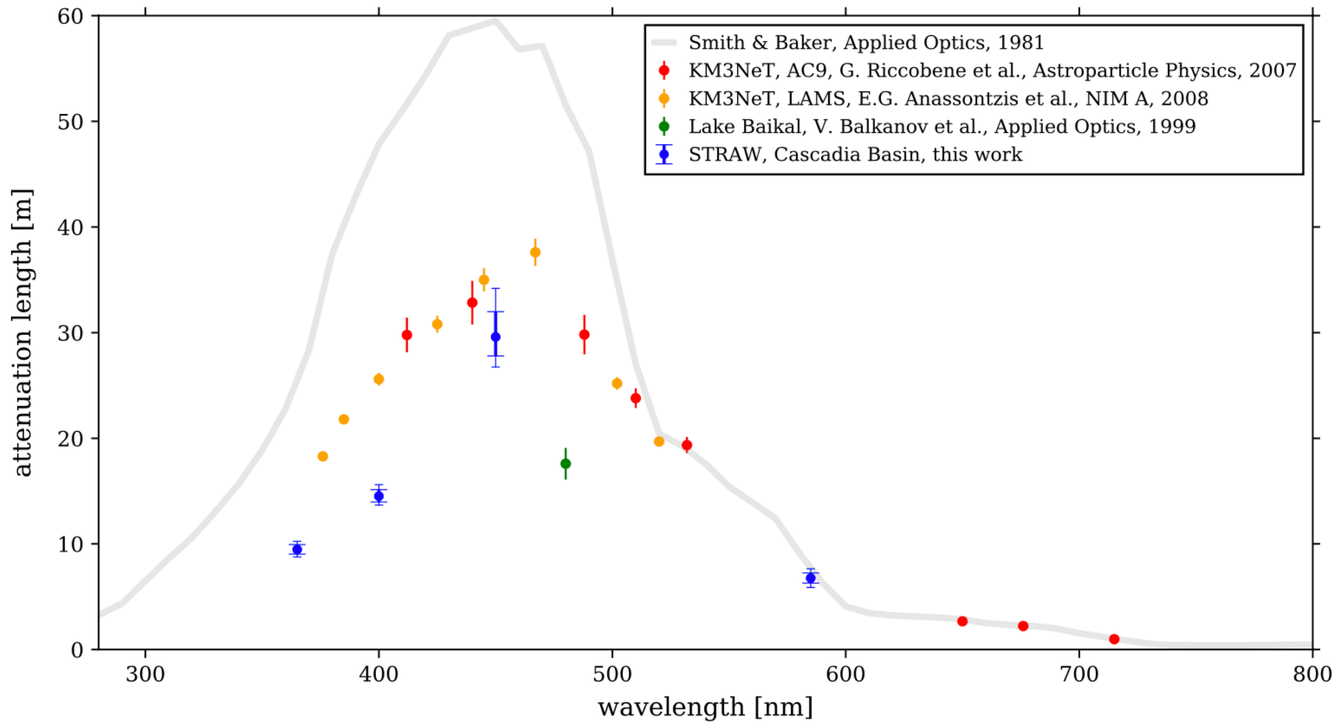


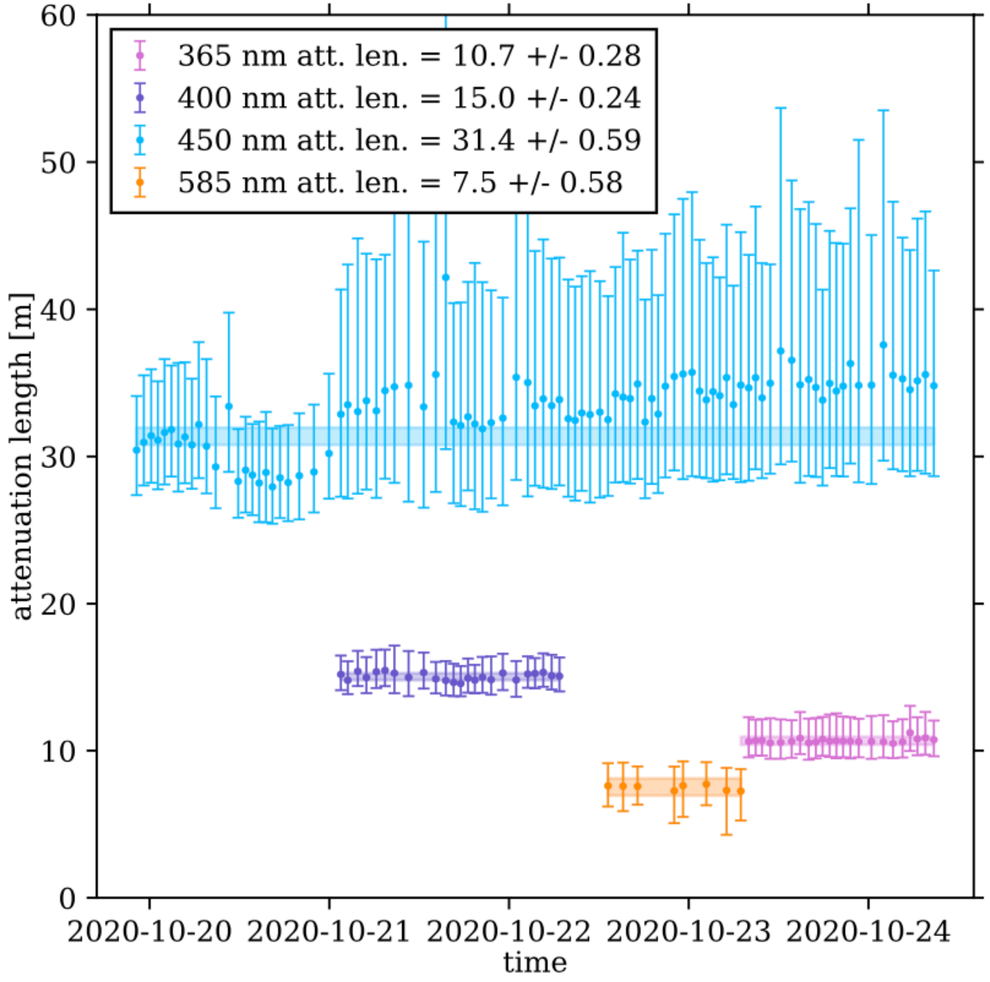


Optical properties of the Water

Preliminary

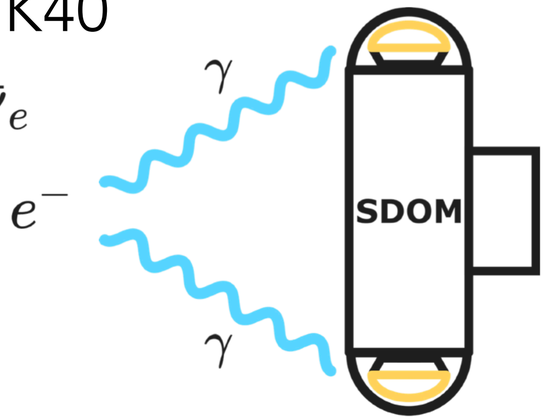
- Measure Attenuation length in the water
  - For different wavelength
  - Scattering and absorption separately
  - Optical properties are good!





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

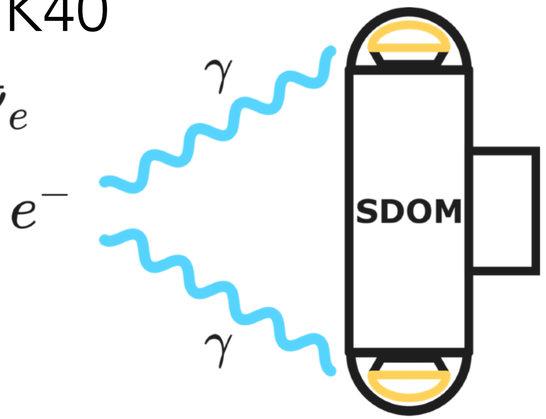


SDOM PMT housing Geant4 model

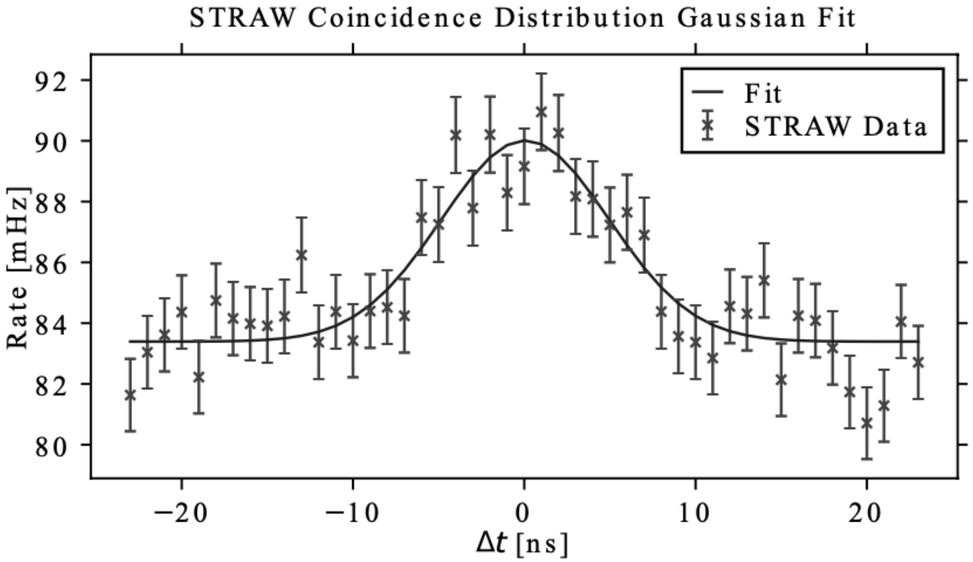
Optical properties of the Water

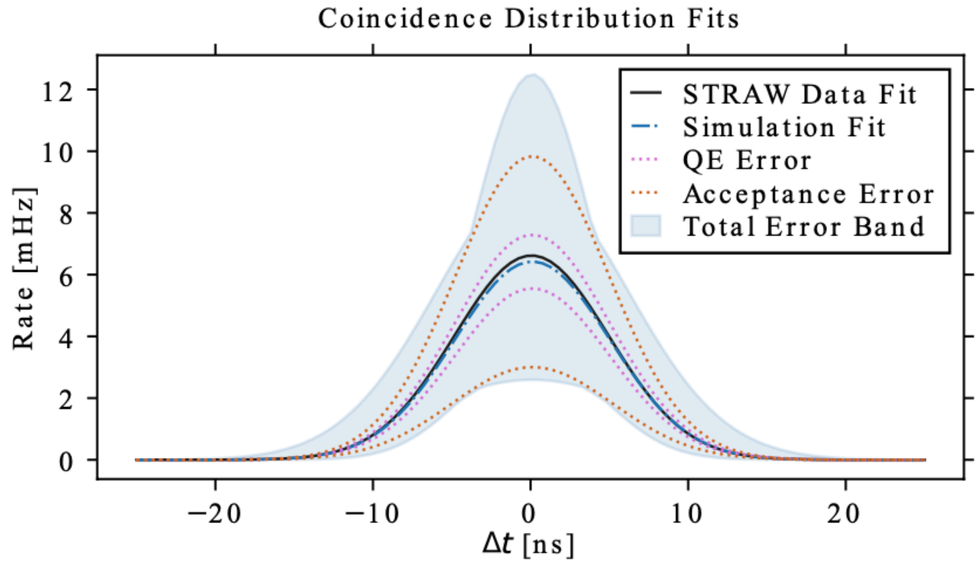
- Understanding the 40K background
  - Natural in-situ calibration with K40 possible $^{40}\mathrm{K} \rightarrow ^{40}\mathrm{Ca} + e^- + \bar{\nu}_e$
  - Cross-check of λatt results, detector and site model
  - Consistent results!
  - Measured Salinity matches independent ONC measurements at 3.48%

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

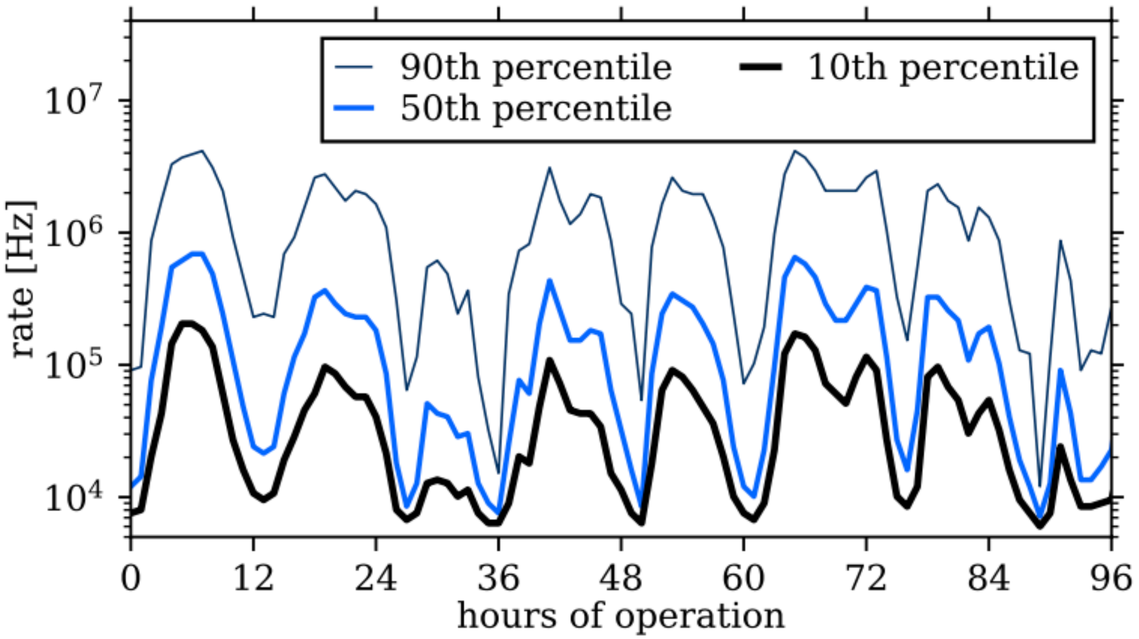


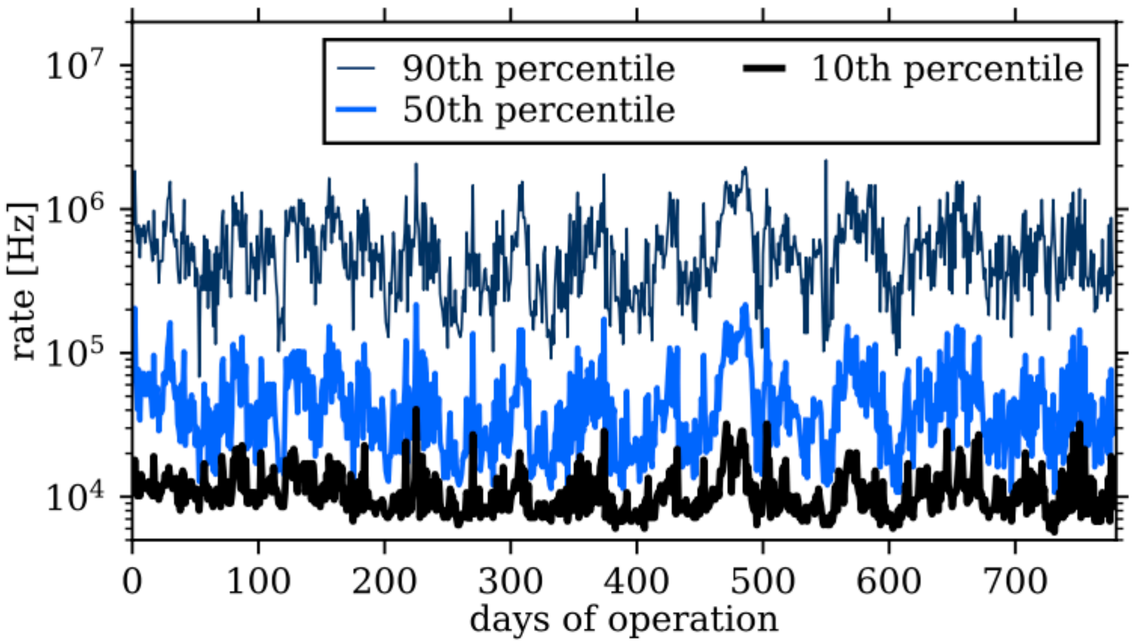
SDOM PMT housing Geant4 model





Optical properties of the Water

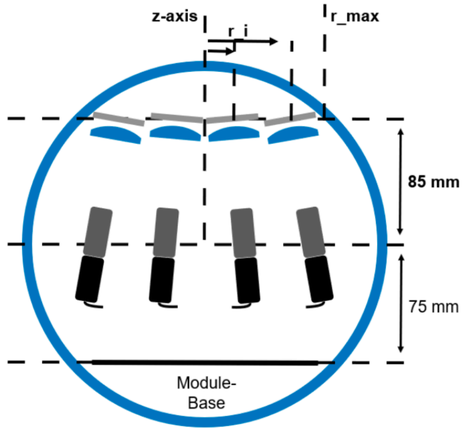


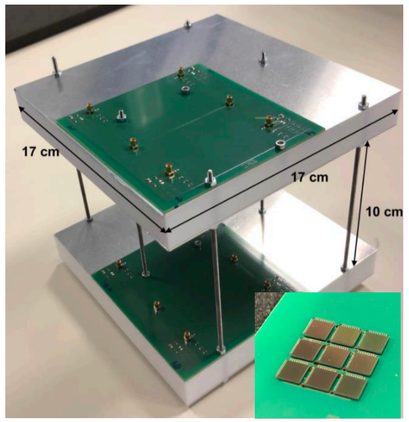


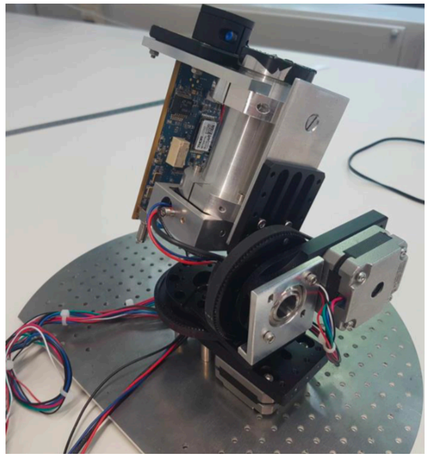
- Bioluminescence is modulated with the tides
  —> more detailed analysis and modelling ongoing
- Full publication with optical parameters and site characterization in progress

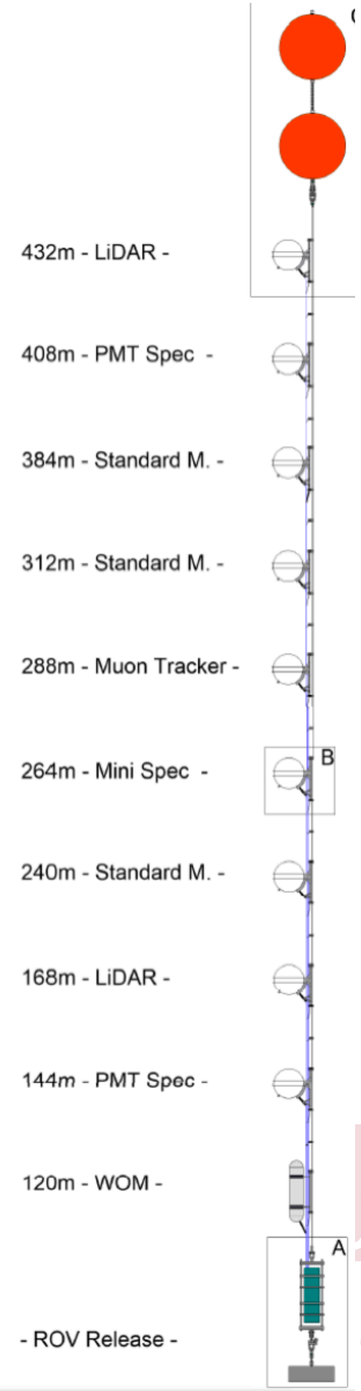
The 2nd pathfinder towards P-ONE

- 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





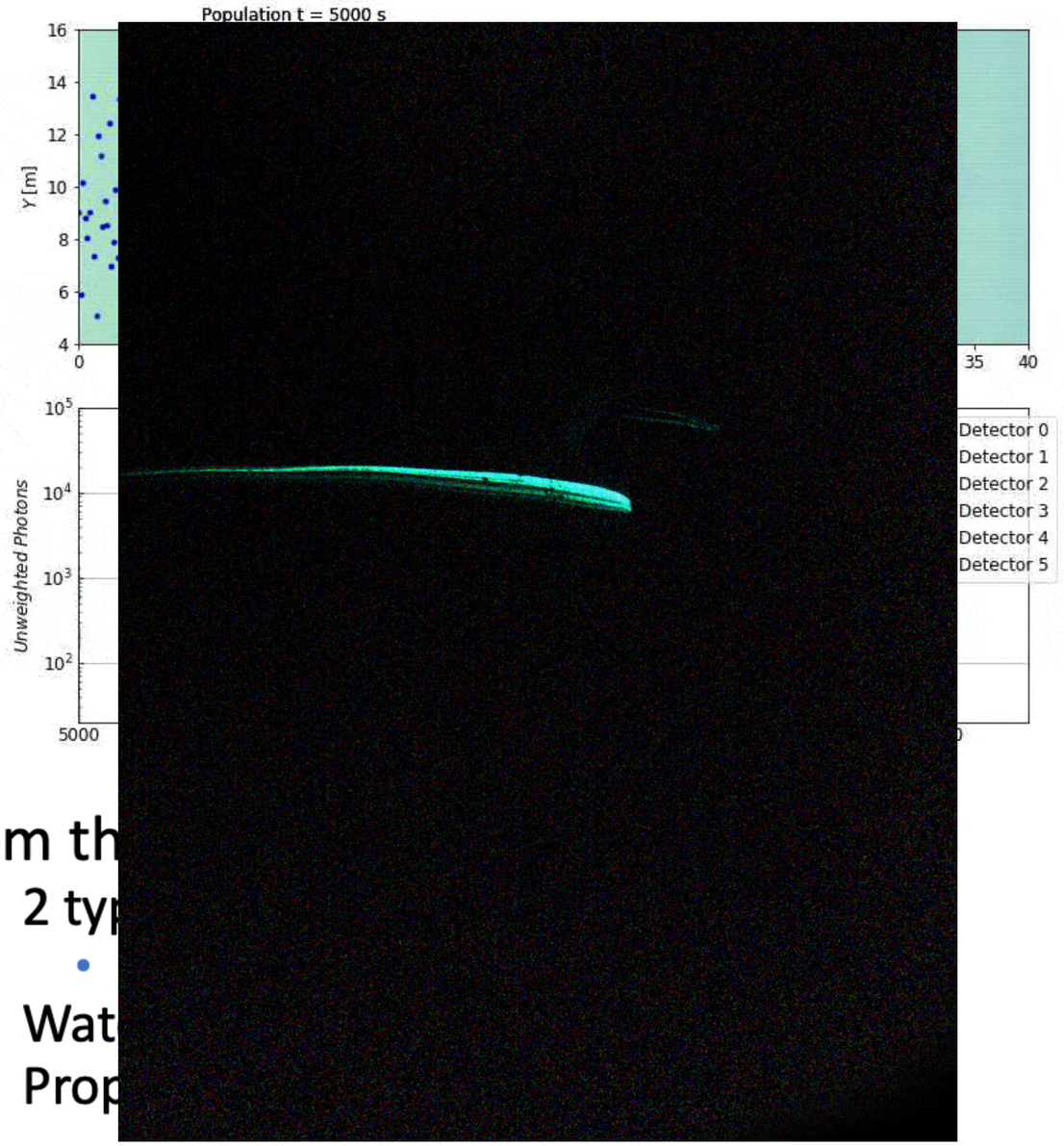


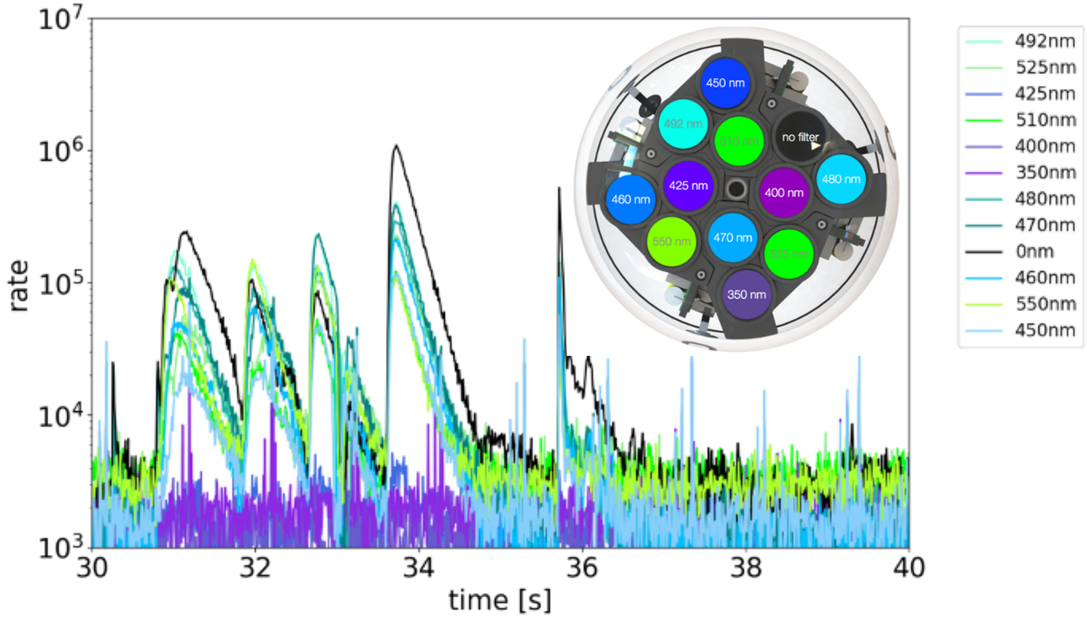


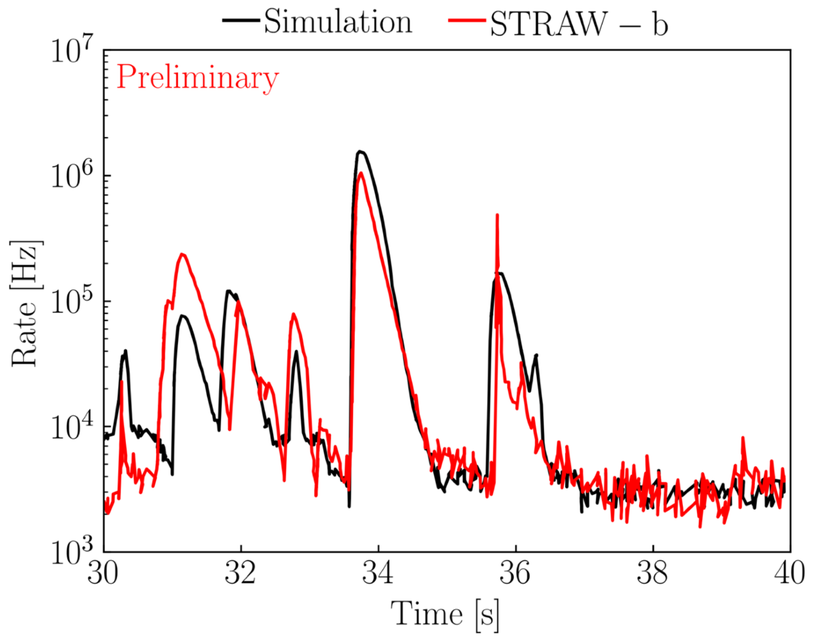
Timeline:

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

Understanding Bioluminescence — let's talk to them



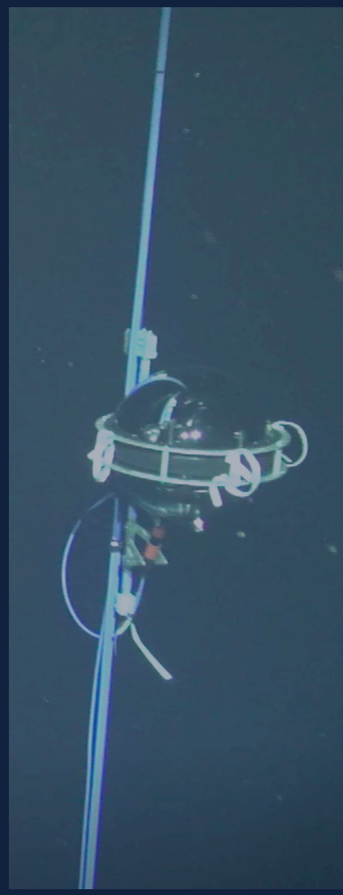




- From th
  - 2 typ
    -
  - Wat
  - Prop

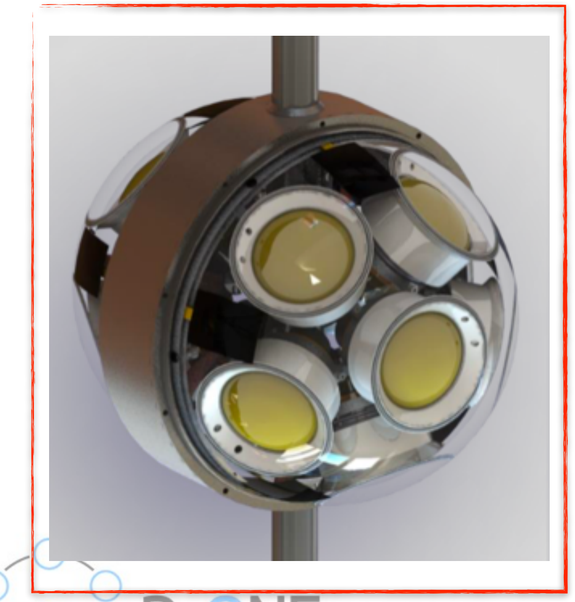
— P-ONE —

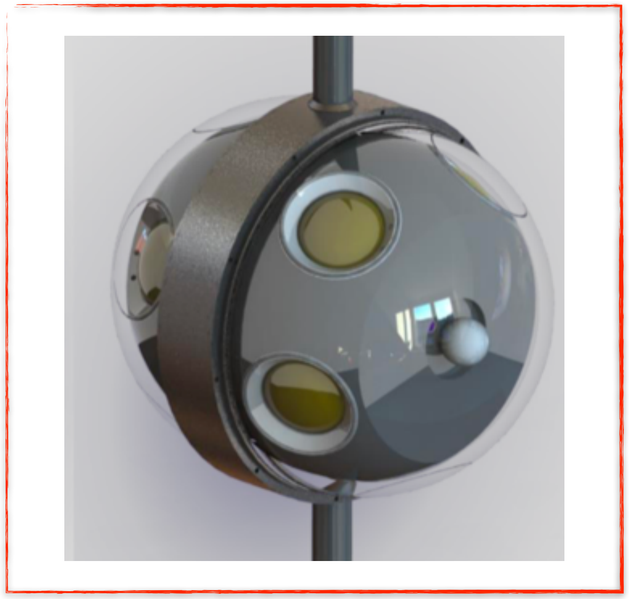
- Next steps towards a neutrino observatory

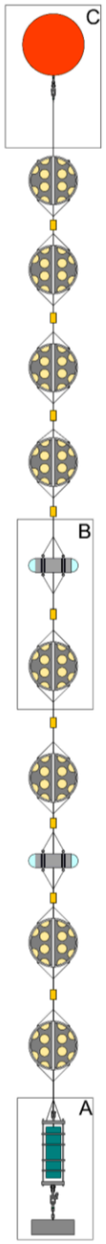


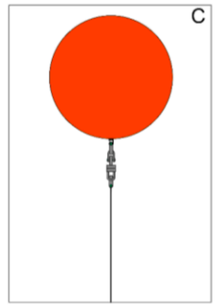
P-ONE — prototype line

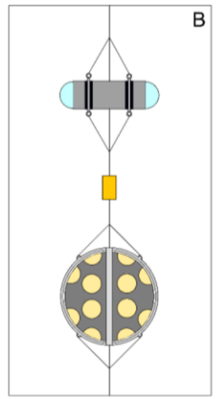
- Construction and deployment of a complete P-ONE mooring line
- Proof and verification of;
  - detector design
  - deployment techniques
  - positioning calibration (we aim to use optical position system)
- Some project corner stones

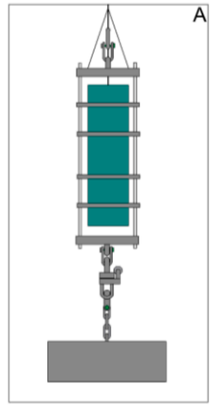








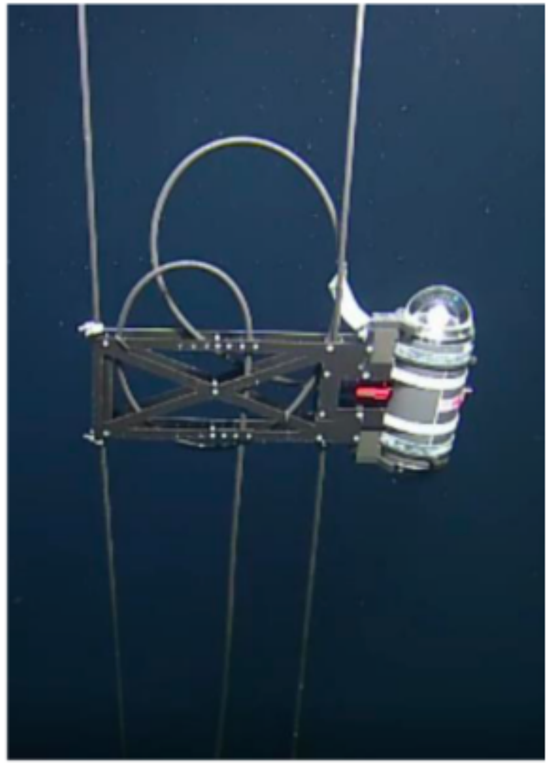


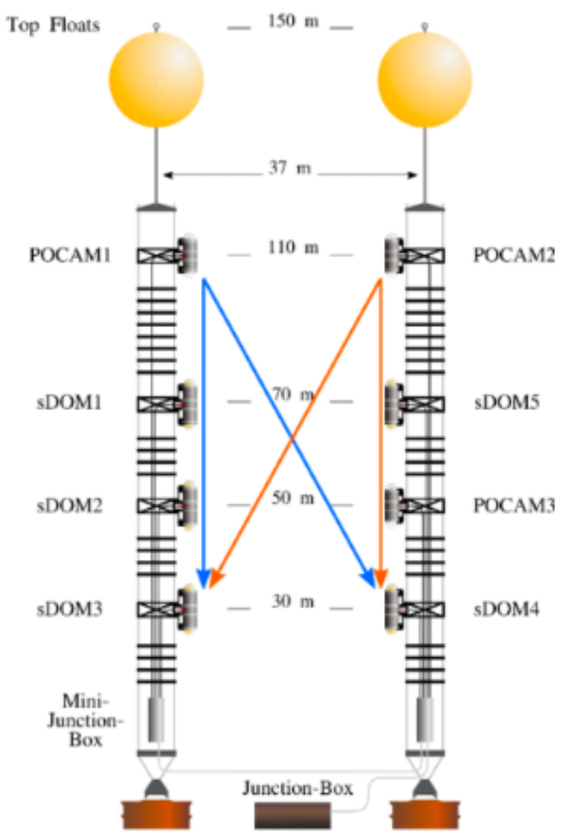


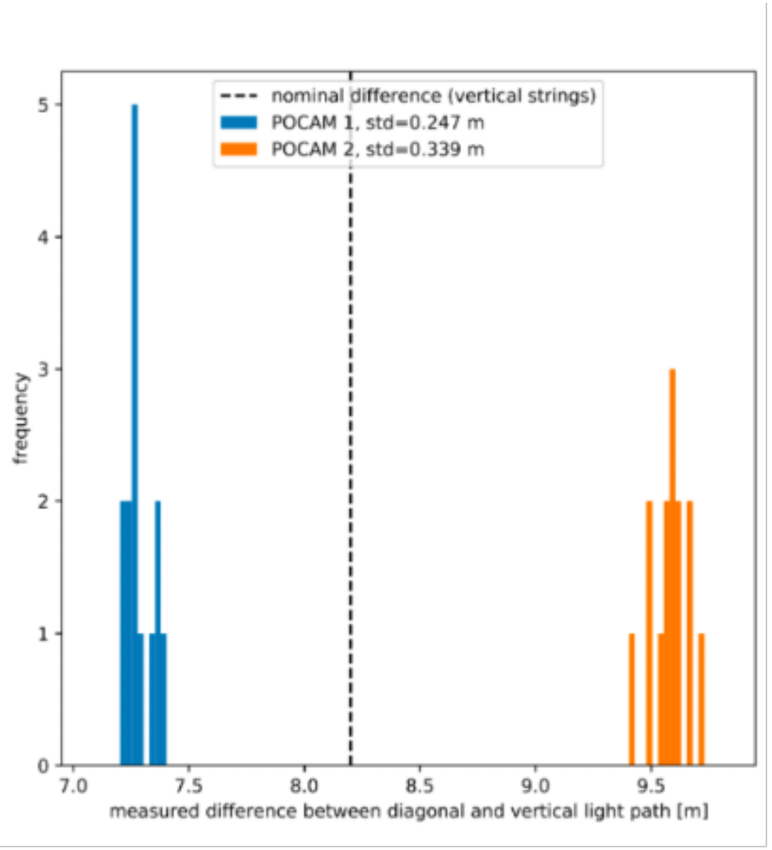
R&D and design ongoing for prototype

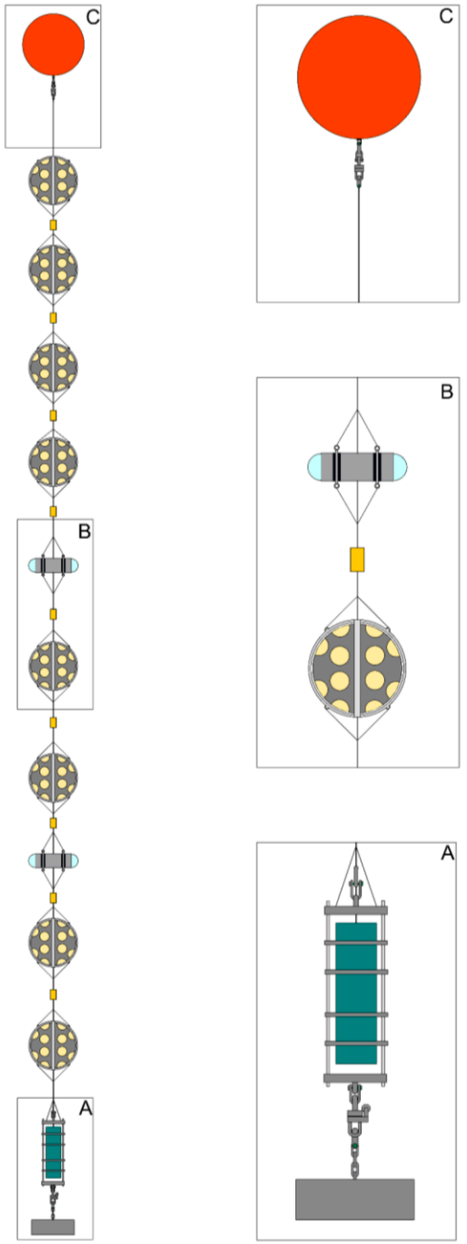
P-ONE — prototype line

- Can we do a purely optical calibration system?
  - No additional acoustic system
  - Precision optical calibration and geometry calibration with same system
  - Implement direct and automated “prompt calibration loop”





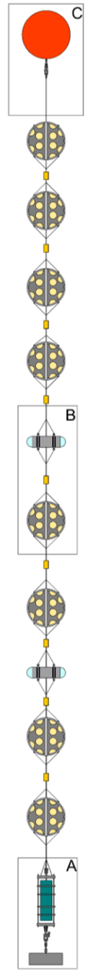


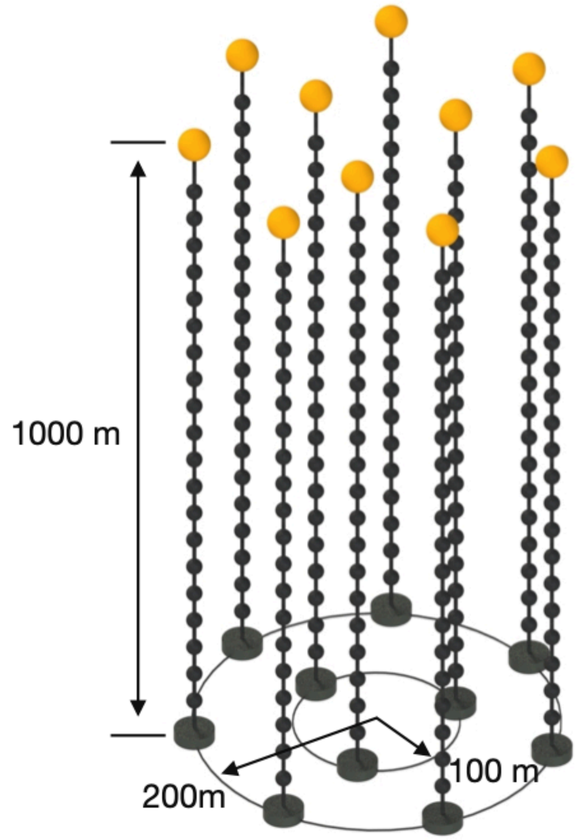


P-ONE — 10 string "Explorer"

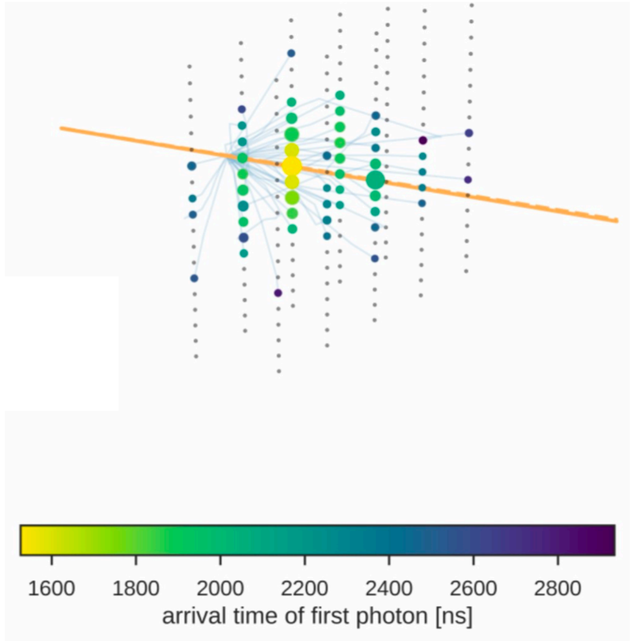
Prototype

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



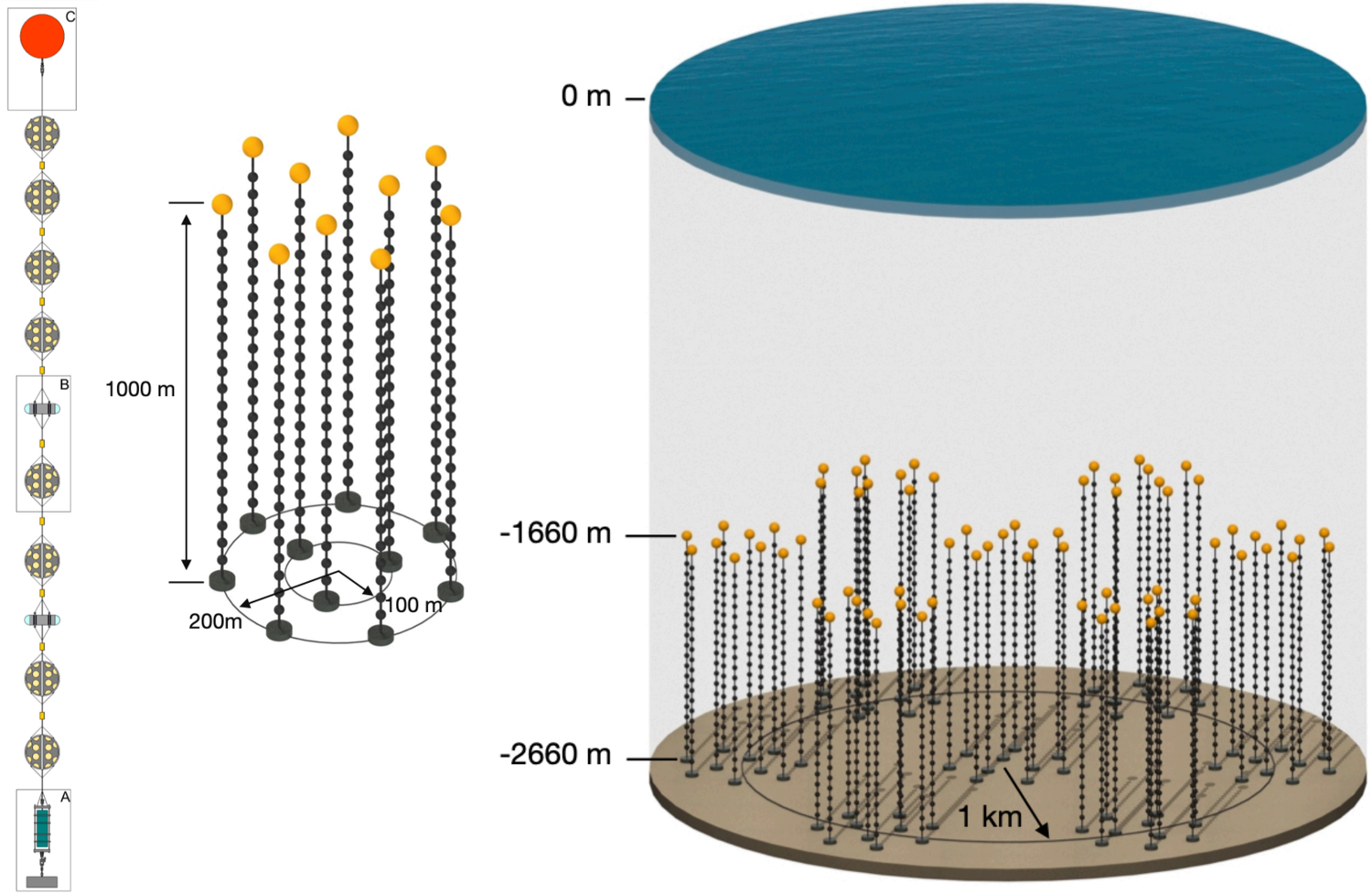
P-ONE

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

SFU SIMON FRASER UNIVERSITY

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

P-ONE

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

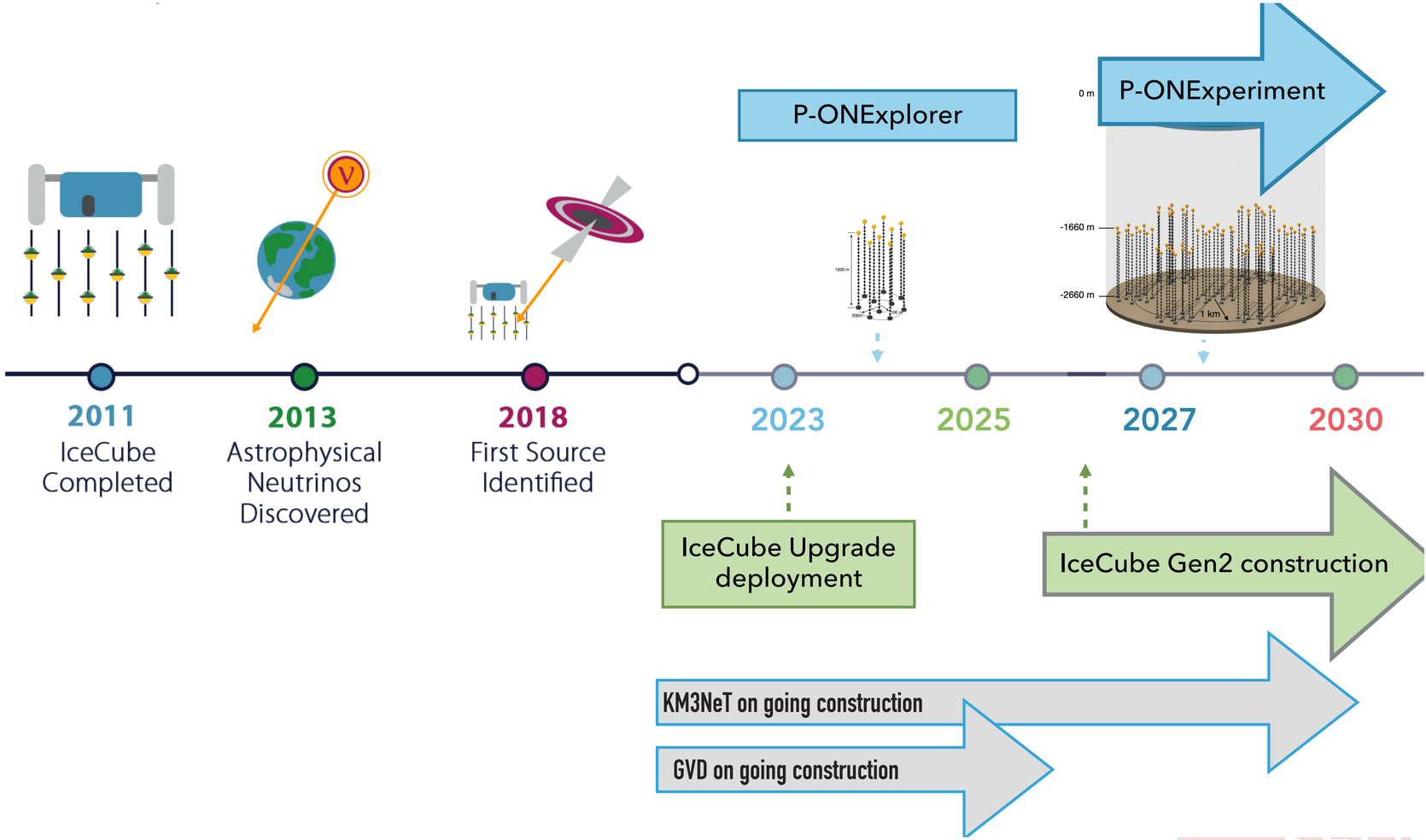
SFU SIMON FRASER UNIVERSITY

Summary

- The vision: from a single site telescope (IceCube) to a multi/global network

- share hardware developments
- share software packages
- cross-calibration
- combined analyses
- on line sky monitor for astrophysical alerts

Boost of the exposure for cosmic accelerators up to factor 100!



Summary

- 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!

To know more, pay us a visit in

http://www.pacific-neutrino.org/

P-ONE Collaboration Members

Matteo Agostini[1], Michael Böhmer[1], Nicolai Bailly[2], Jeannette Bedard[2], Jeff Bosma[2], Dirk Brussow[2], Jonathan Cheng[2], Ken Clark[3], Beckey Croteau[2], Matthias Danninger[4], Nathan Deis[2], Matthew Ens[4], Rowan Fox[2], Christian Fruck[1], Andreas Gärtner[5], Roman Gernhäuser[1], Darren Grant[6], Helen He[2], Felix Henningsen[7], Kilian Holzapfel[1], Ryan Hotte[2], Matthias Huber[1], Reyna Jenkyns[2], Claudio Kopper[6], Carsten B. Krauss[5], Kai Krings[1], Ian Kulin[2], Klaus Leismüller[1], Fabio de Leo[2], Sally Leys[8], Tony Lin[2], Paul Macoun[2], Stephan Meighen-Berger[1], Jan Michel[9], Roger Moore[5], Mike Morley[2], Paolo Padovani[10], Laszlo Papp[1], Benoit Pirenne[2], Tom Qiu[2], Mark Rankin[2], Immacolata Carmen Rea[1], Elisa Resconi[1], Adrian Round[2], Albert Ruskey[2], Ryan Rutley[2], Christian Spannfellner[1], Jakub Stacho[4], Ross Timmerman[2], Meghan Tomlin[2], Matt Tradewell[2], Michael Traxler[11], Andrea Turcati[1], Matt Uganecz[2], Seann Wagner[2], Yinsong Zheng[2], Juan Pablo Yañez[5]

Extras