

P-ONE

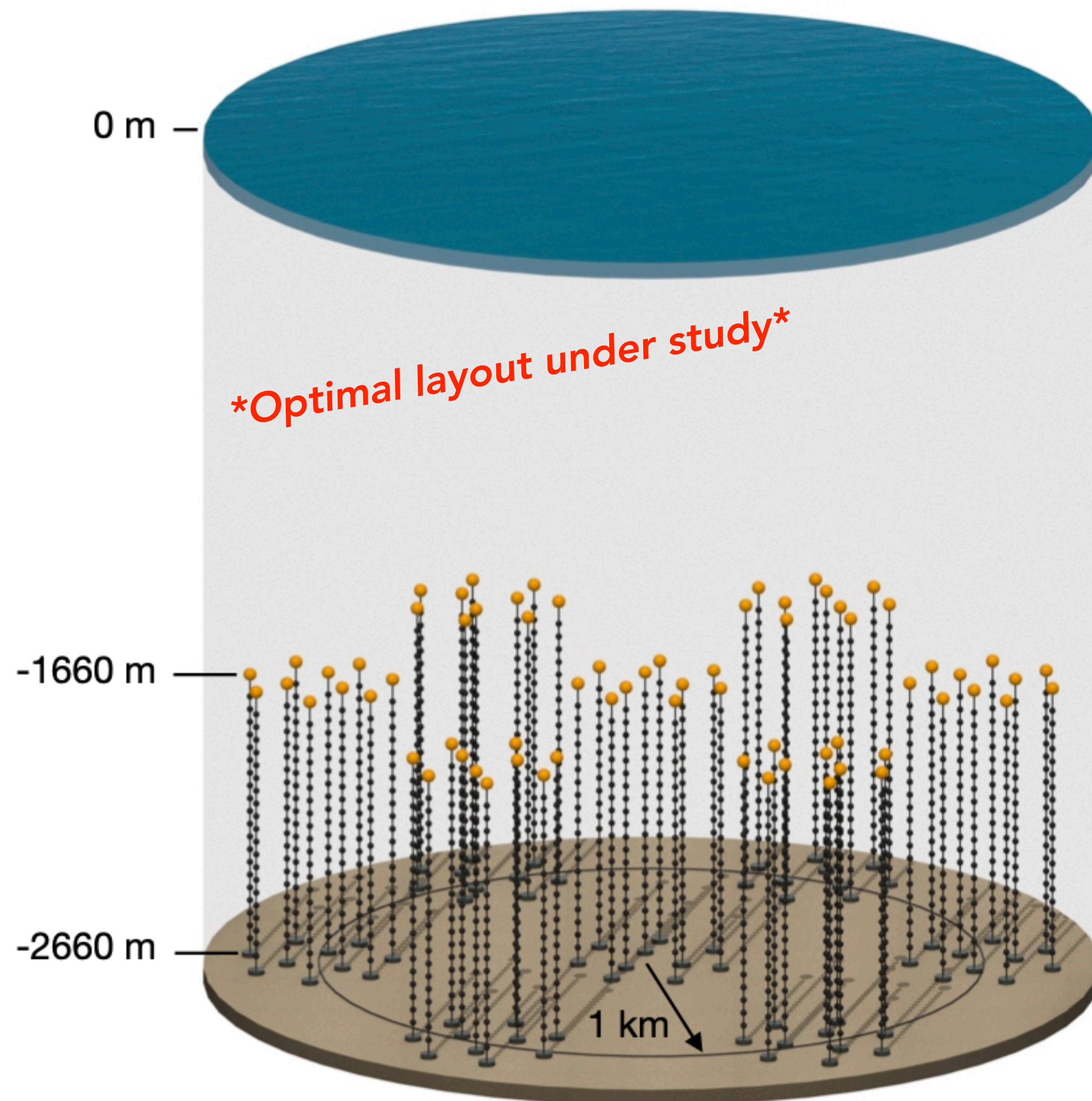
— The Pacific Ocean Neutrino Explorer —

Matthias Danninger
for the P-ONE Collaboration
Lake Louise Winter Institute 2022



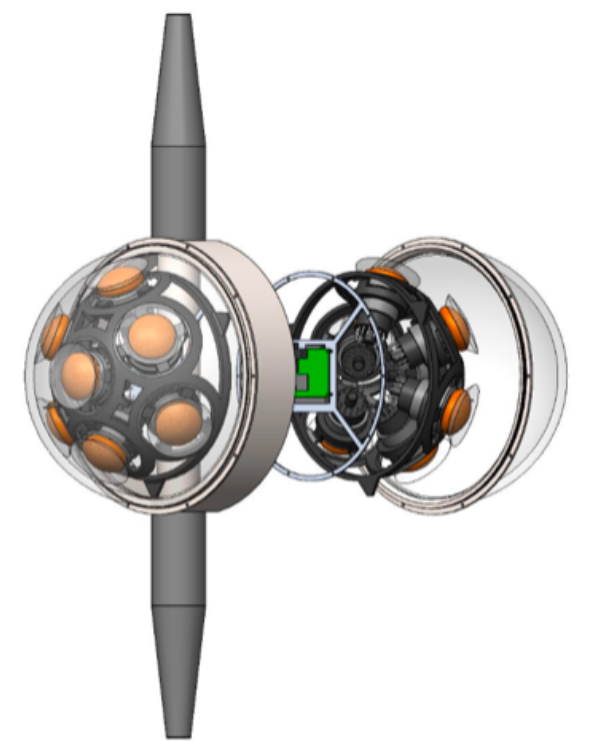
P-ONE — The current vision

P-ONE Collaboration, Nature Astronomy (2020)



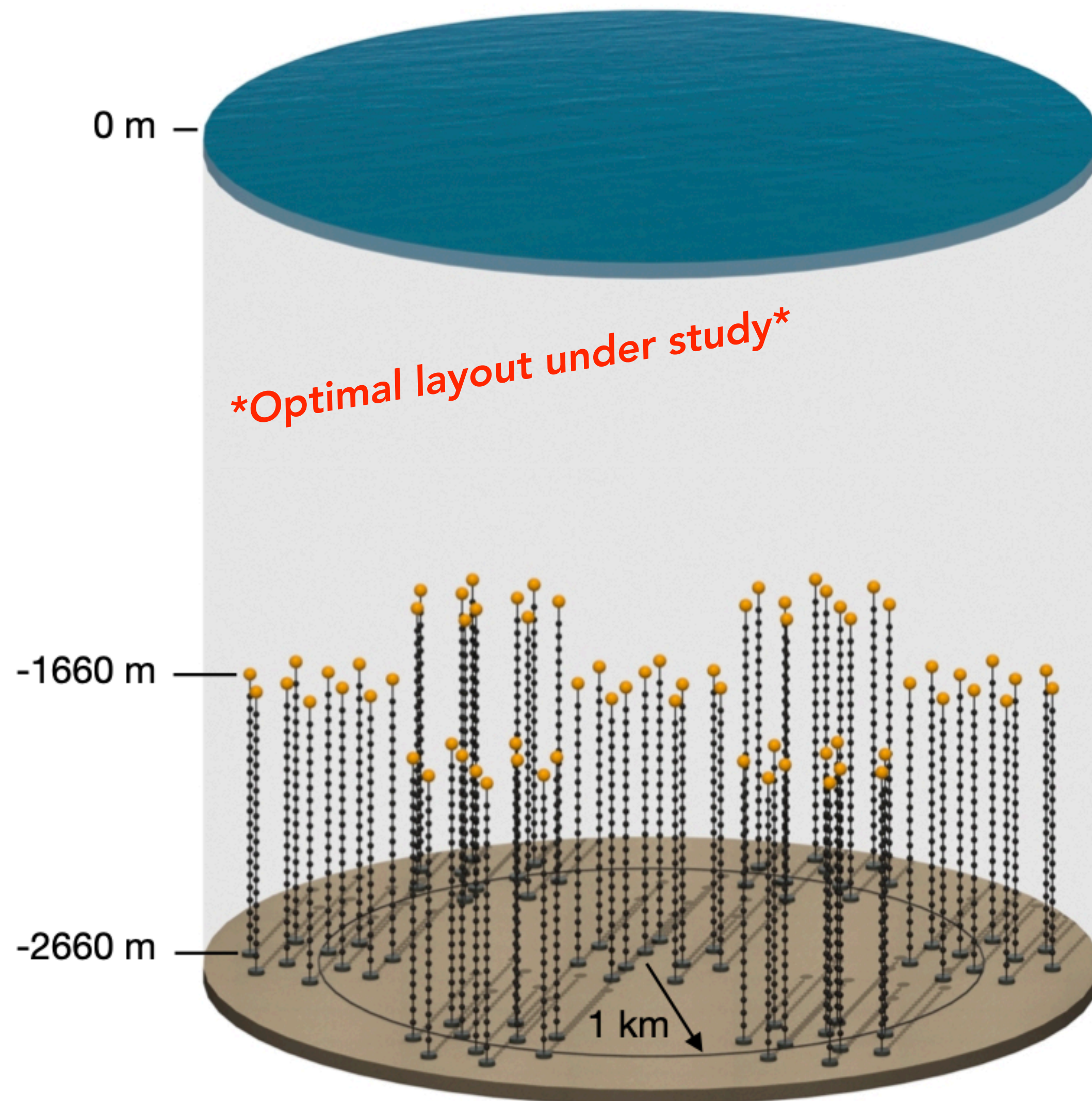
Design inspired by existing experiments:

- Array of instrumented vertical lines (IceCube)
- Multi PMT optical sensors (KM3Net)
- Clustered deployment (GVD)



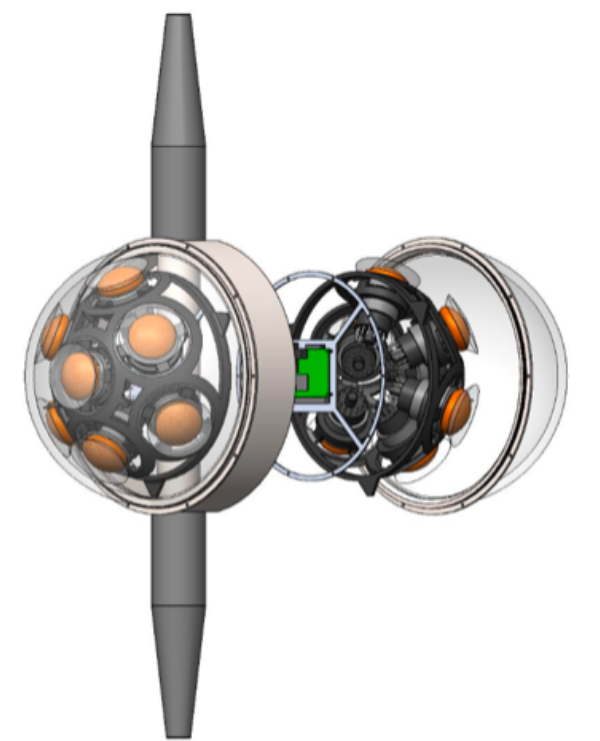
What is different?

P-ONE Collaboration, Nature Astronomy (2020)



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What is different?

First Neutrino Telescope hosted by an existing large scale oceanographic infrastructure:

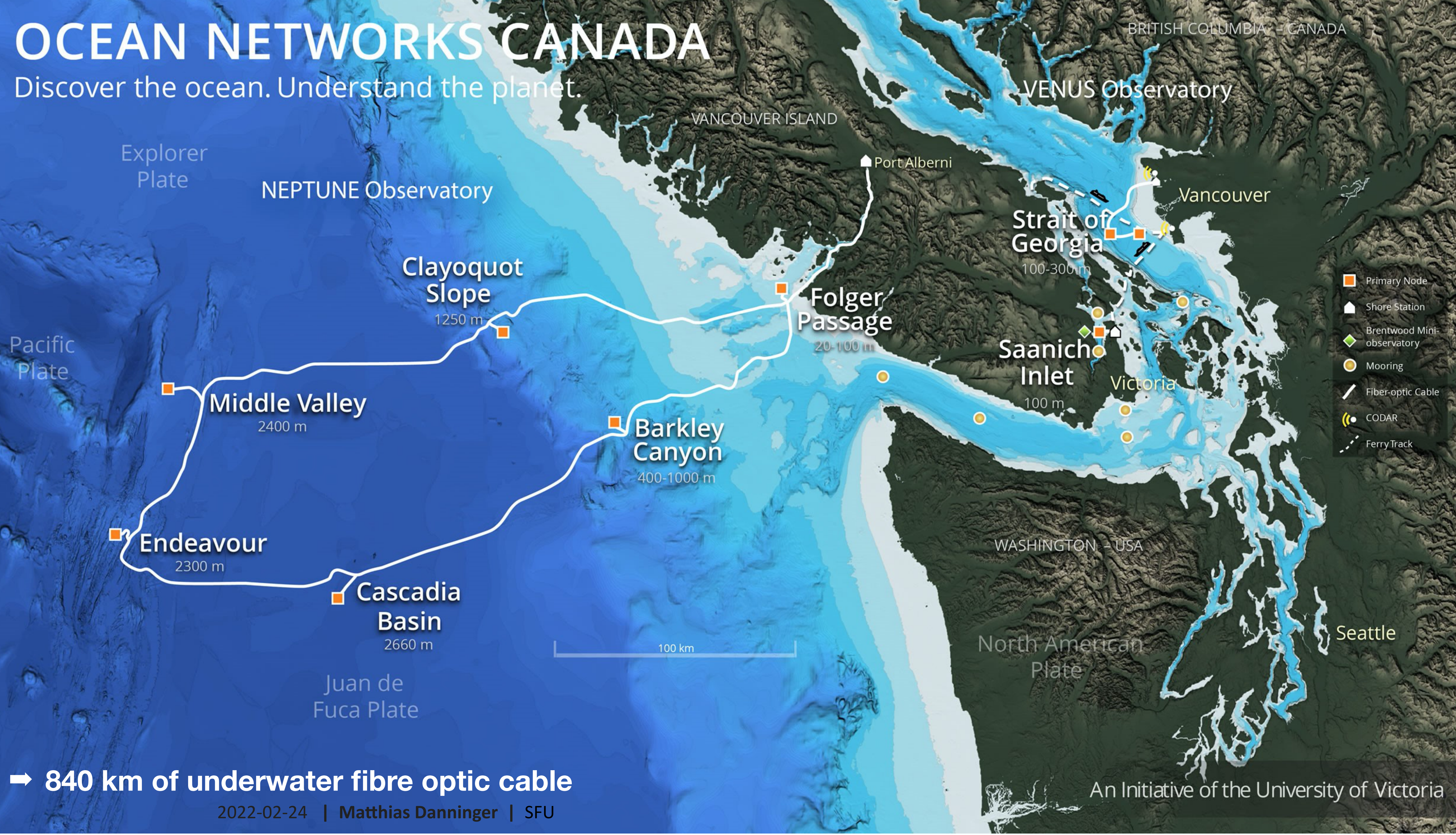
OCEAN NETWORKS CANADA

SFU

SIMON FRASER
UNIVERSITY

OCEAN NETWORKS CANADA

Discover the ocean. Understand the planet.



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

OCEAN NETWORKS CANADA

Discover the ocean. Understand the planet.

- One of world's largest and most advanced cabled ocean observatory
- **NEPTUNE observatory:**
 - 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

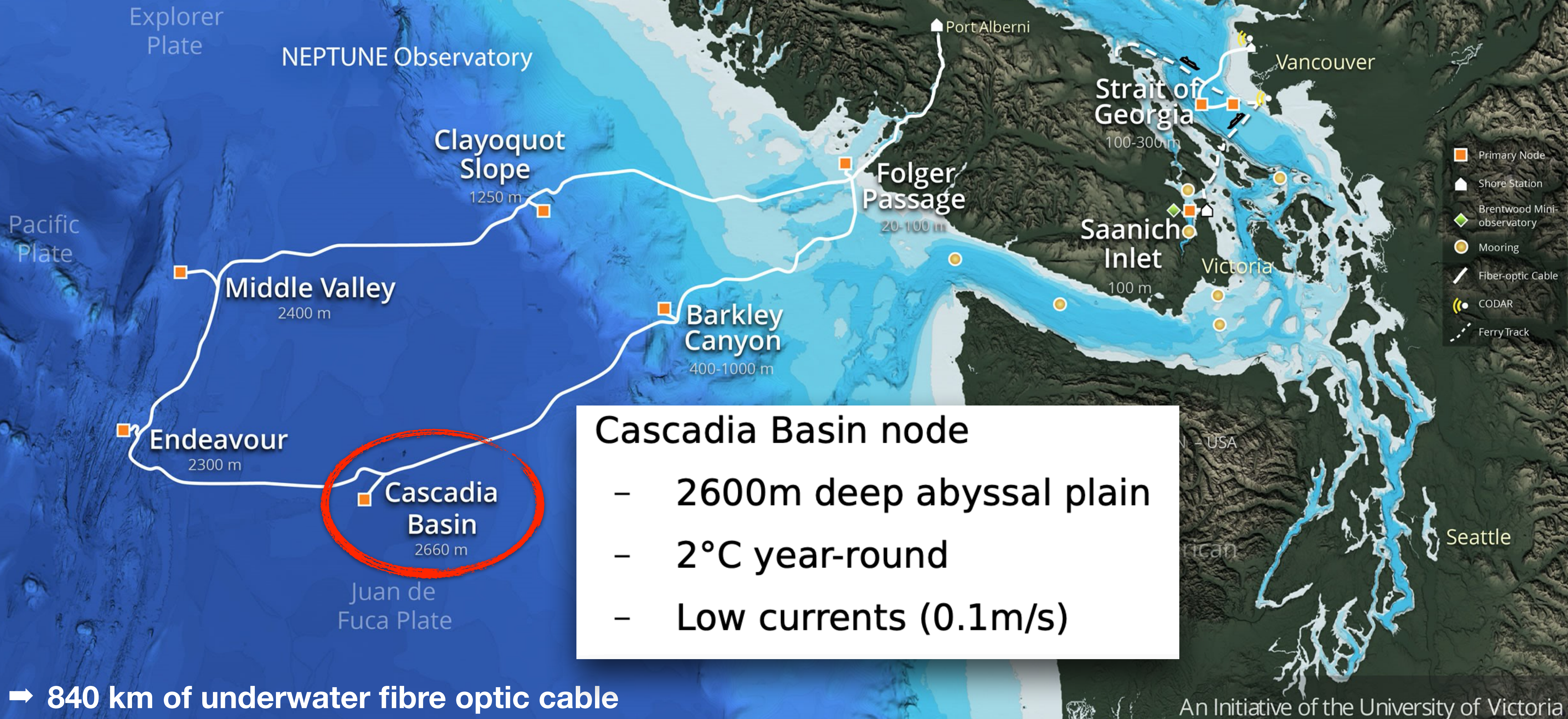
➔ 840 km of underwater fibre optic cable

2022-02-24 | Matthias Danninger | SFU

An Initiative of the University of Victoria

OCEAN NETWORKS CANADA

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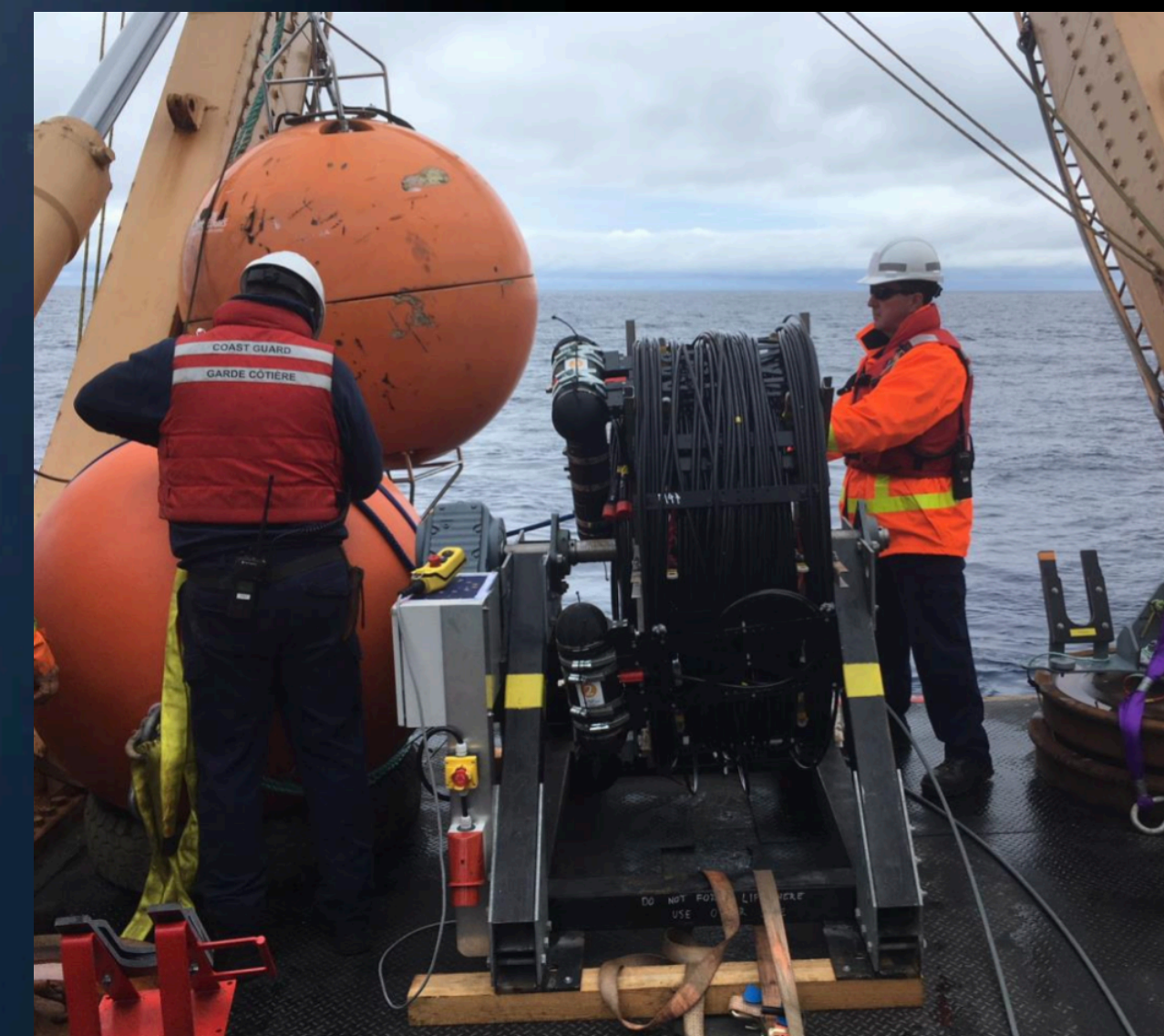


2 P-ONE pathfinder missions (2018 & 2020)

- Goal — Characterize optical properties
- Interface, anchoring and deployment operation by ONC
 - *JINST 14, P02013 (2019) and EPJC 81, 1071 (2021)*

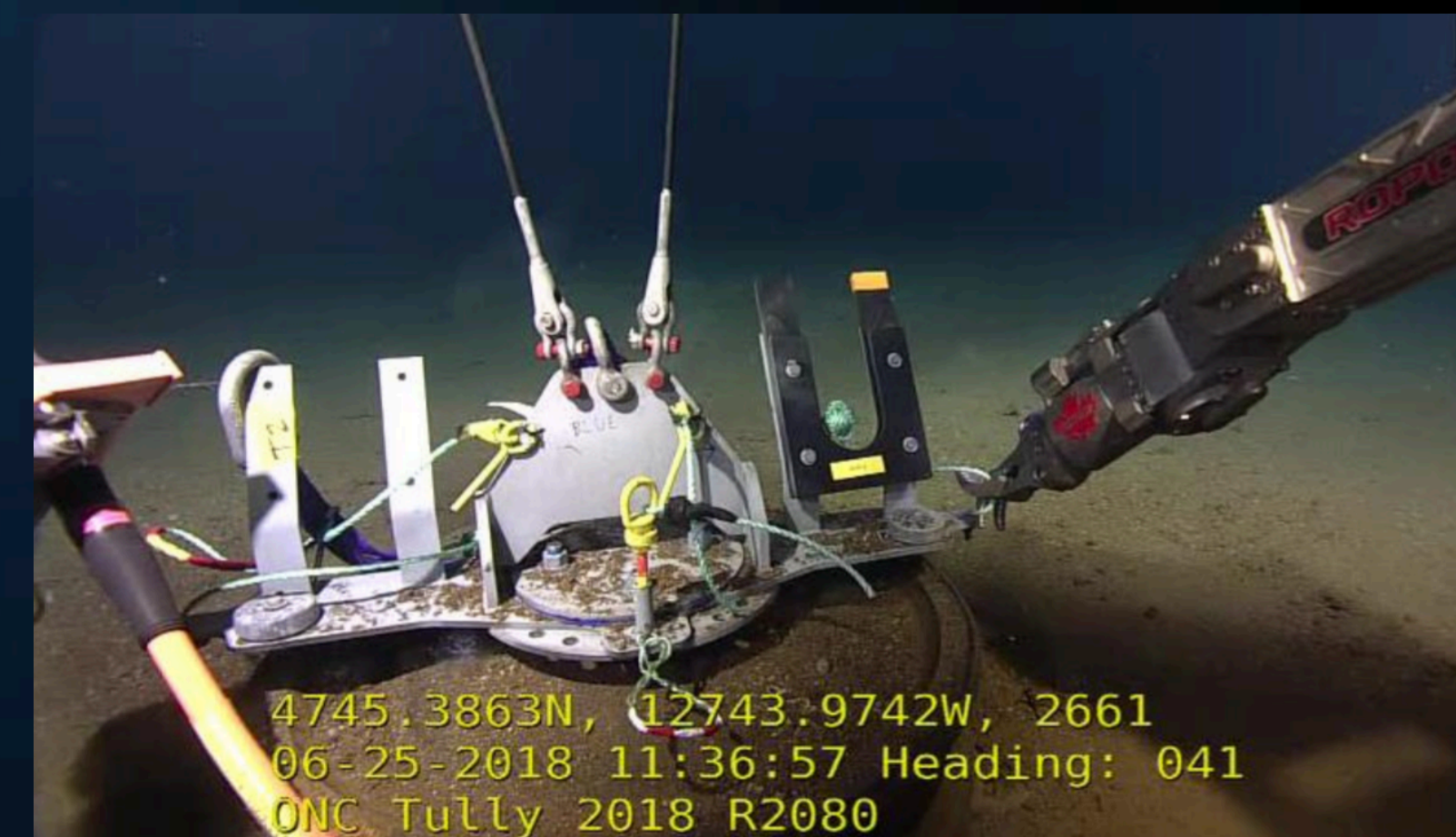
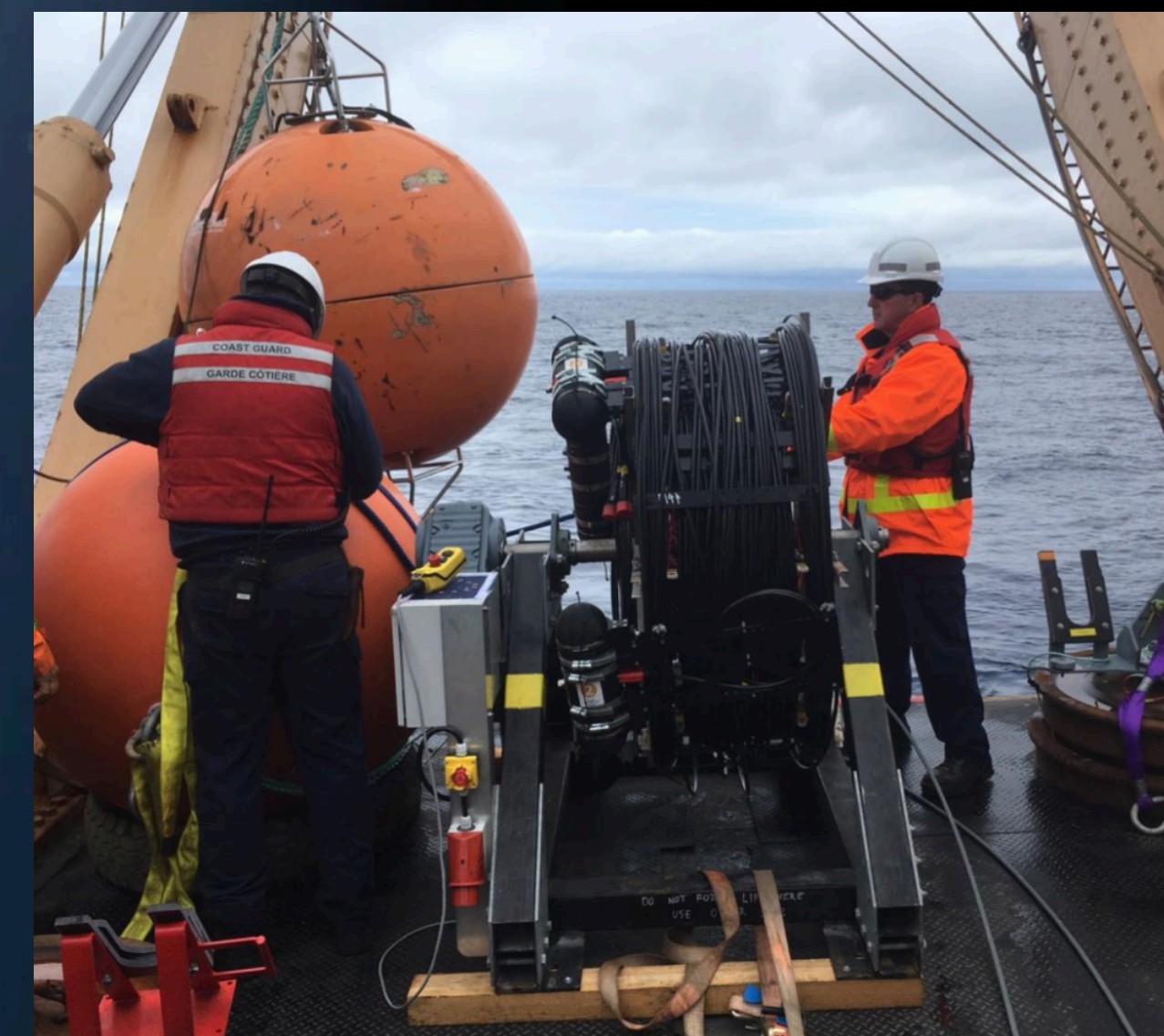
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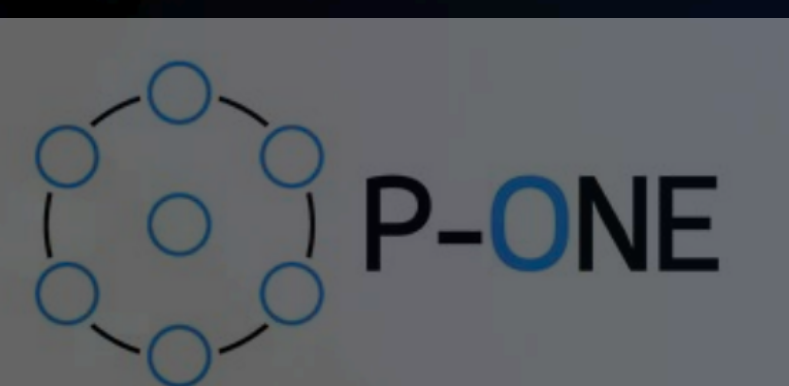
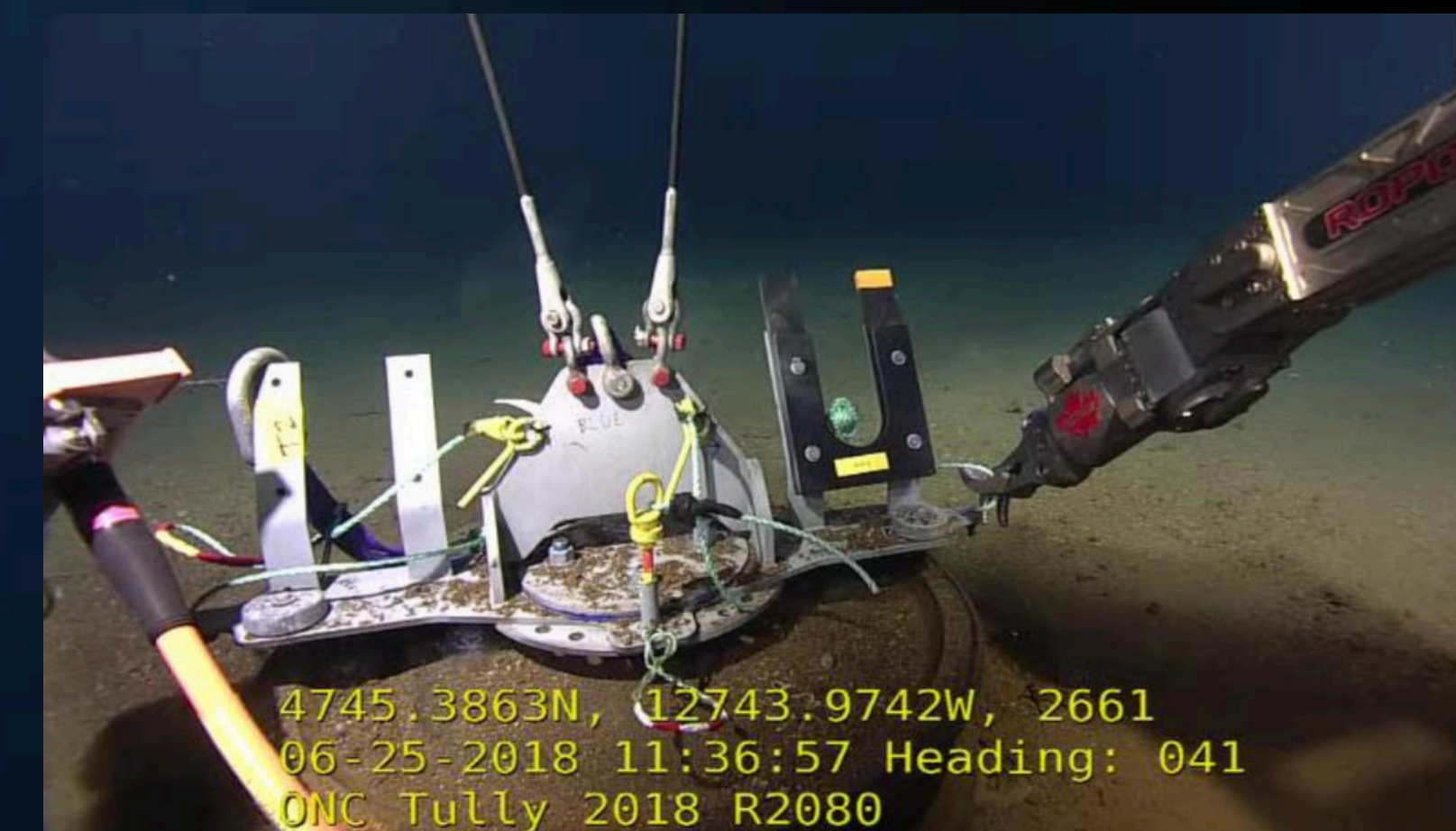
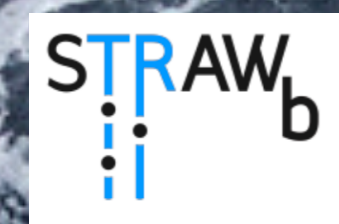
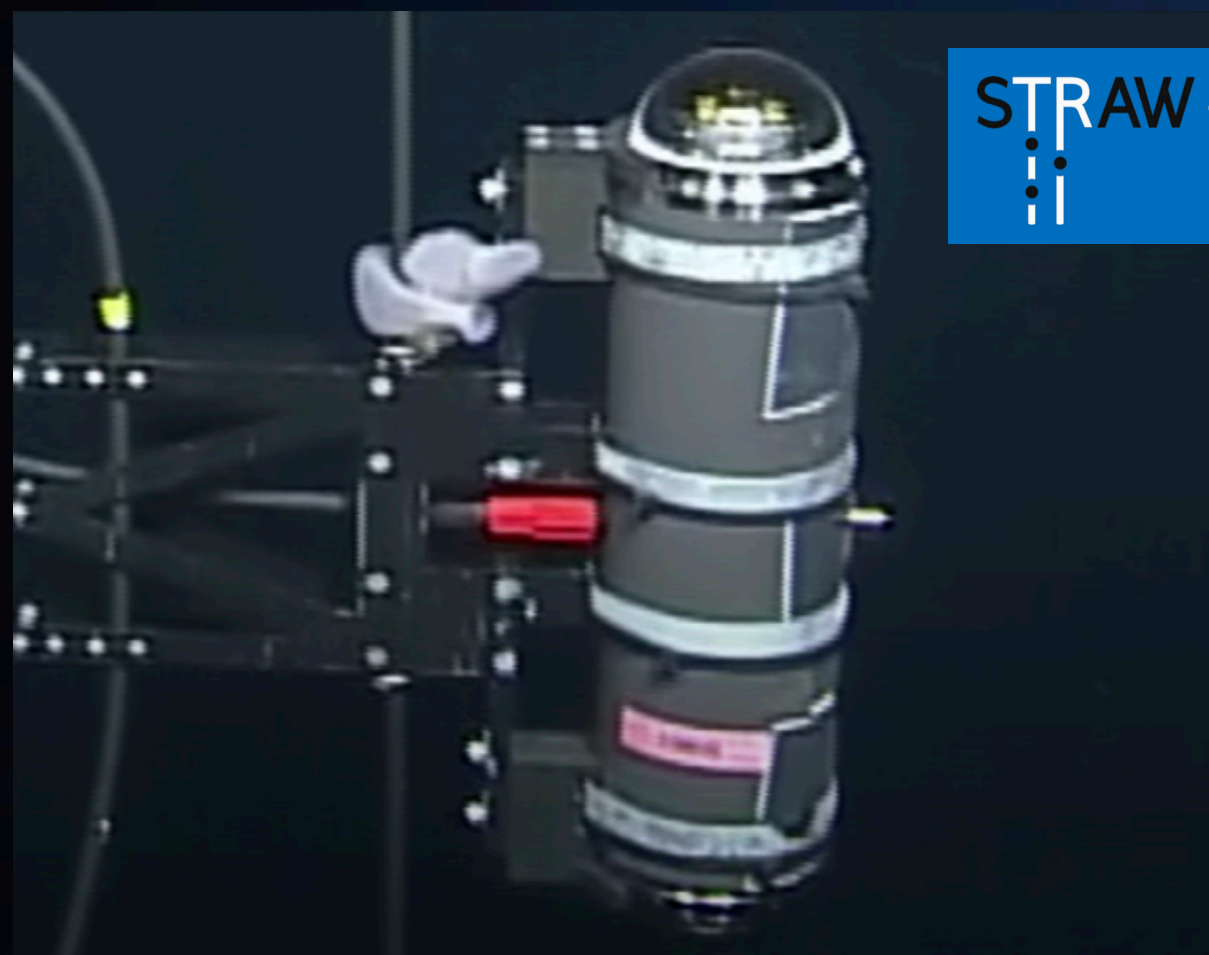
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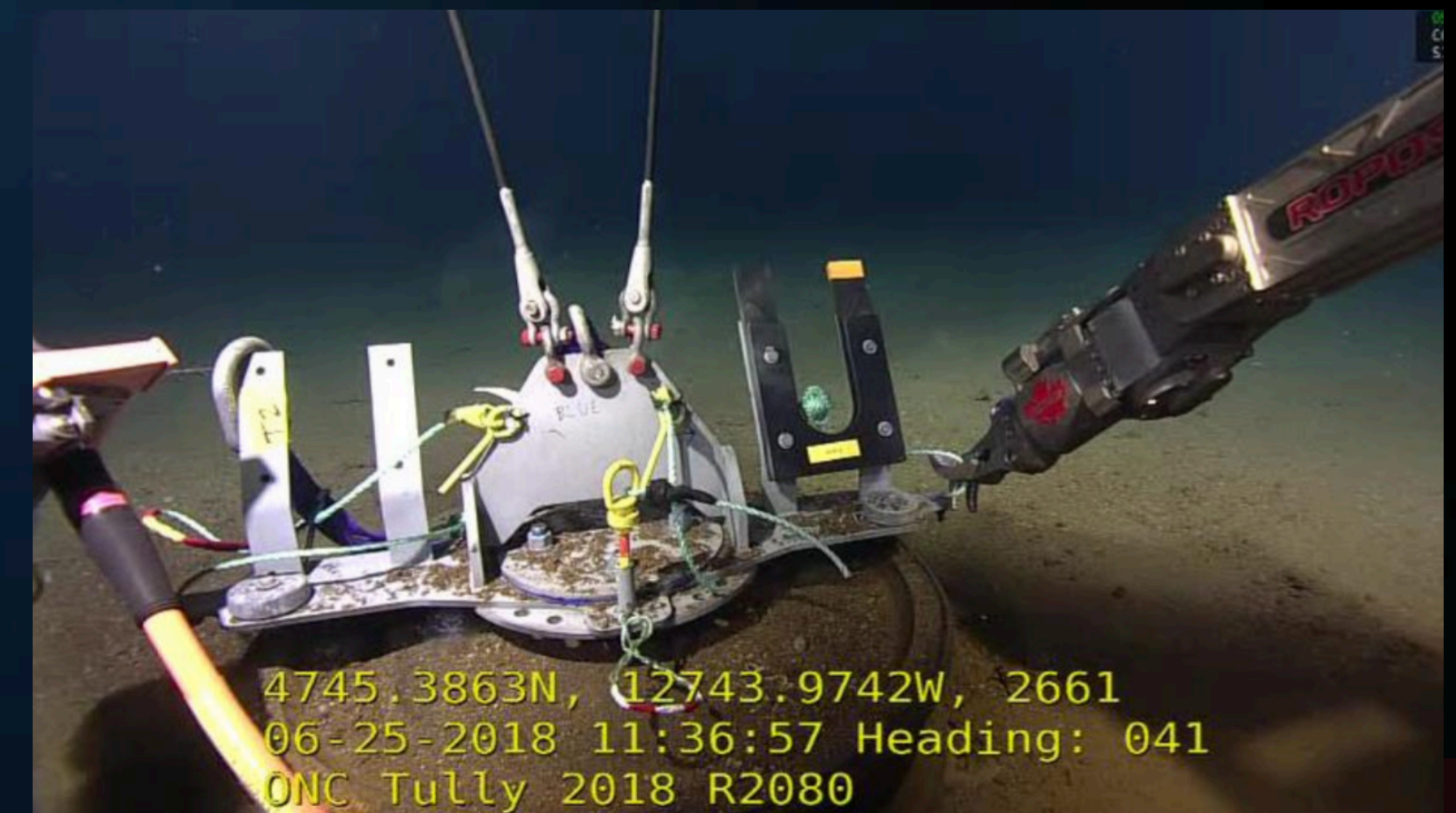
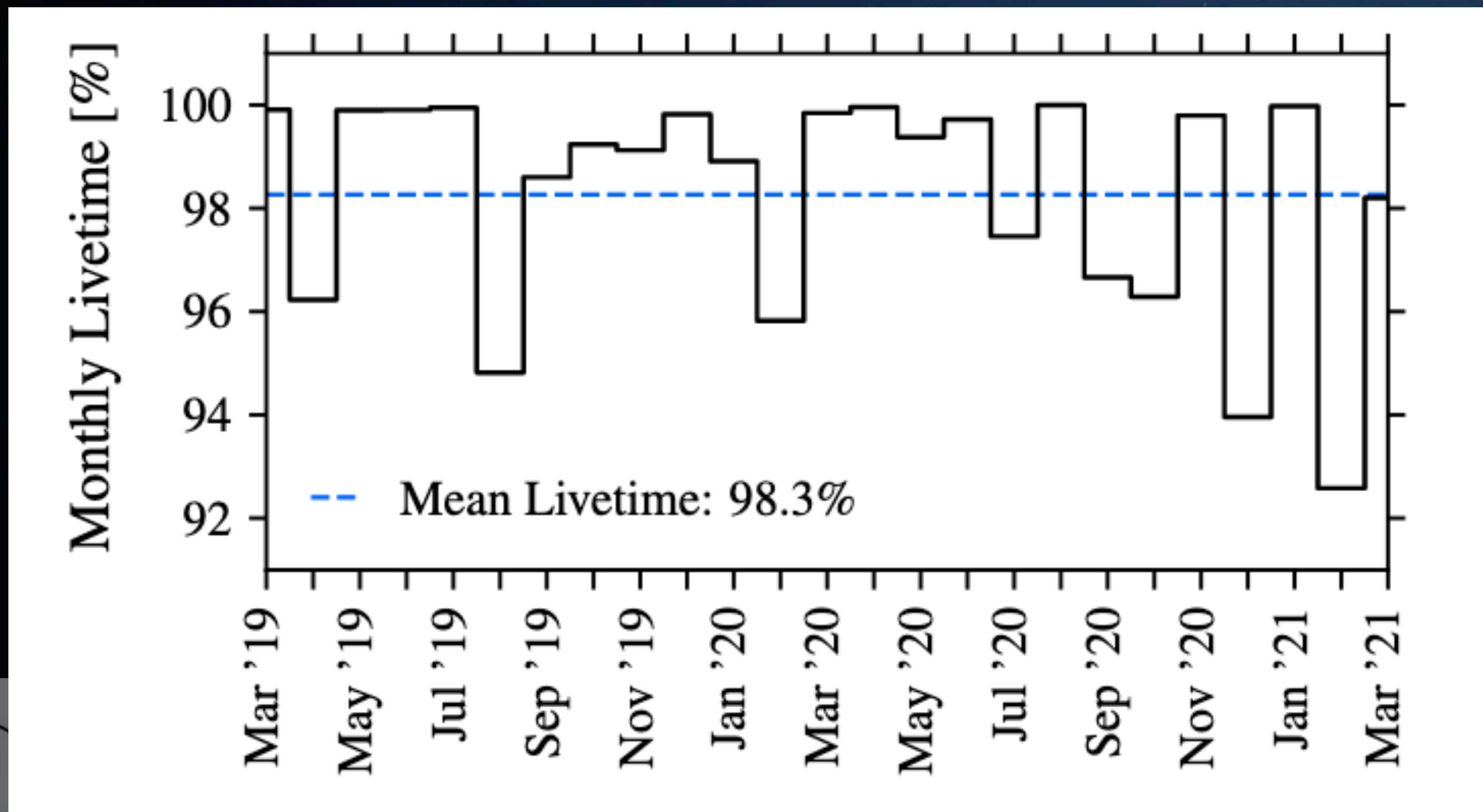
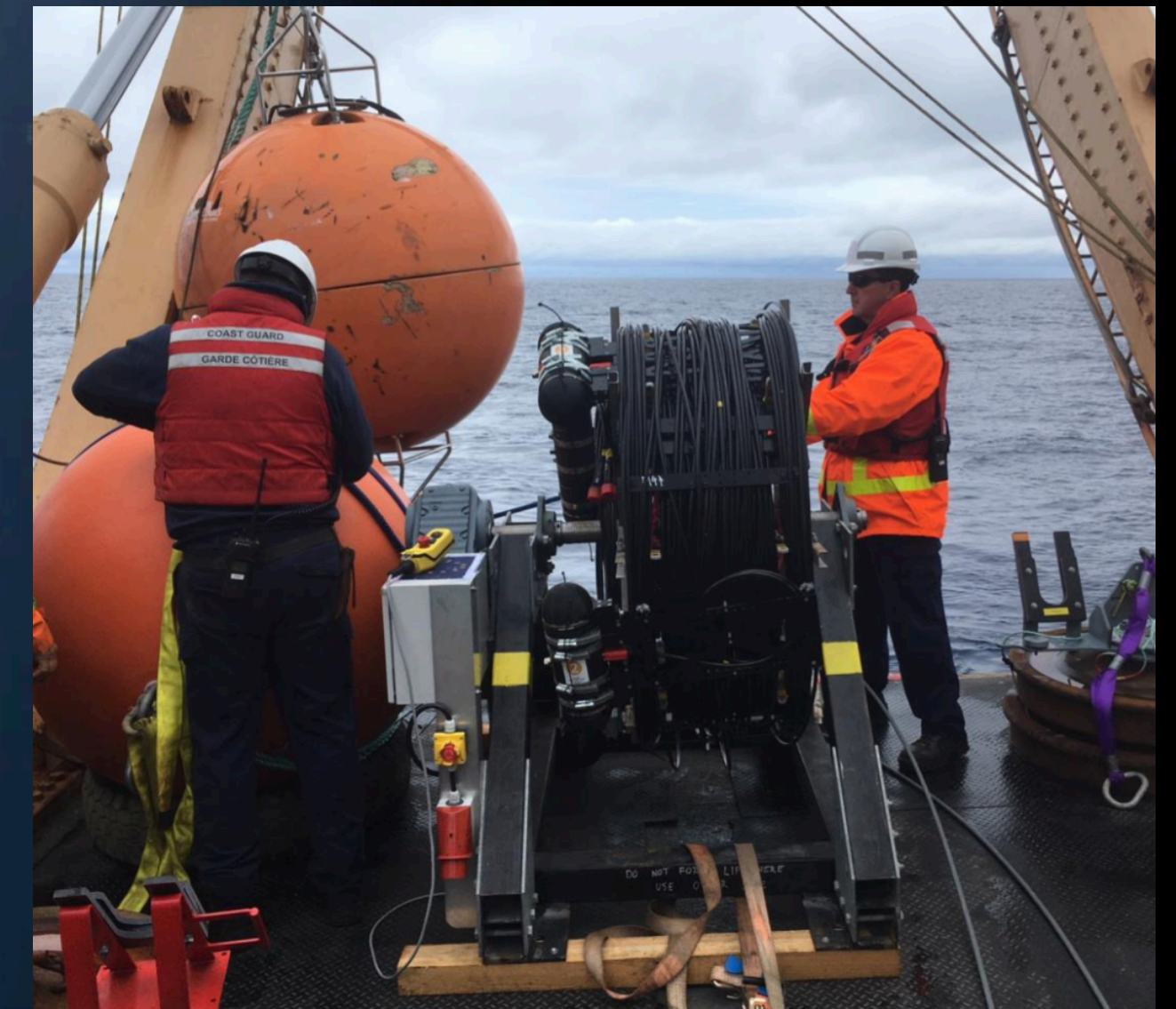
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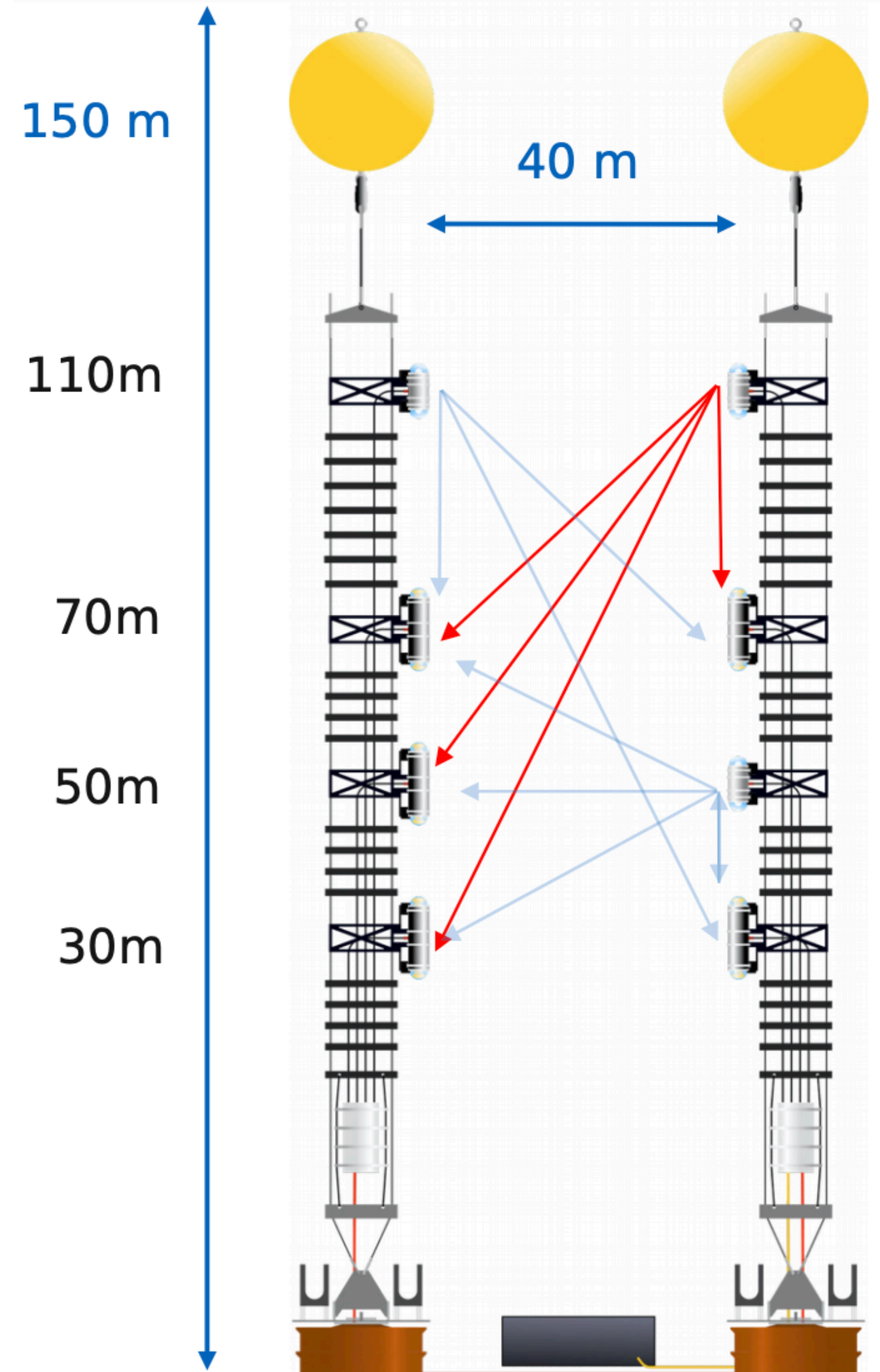
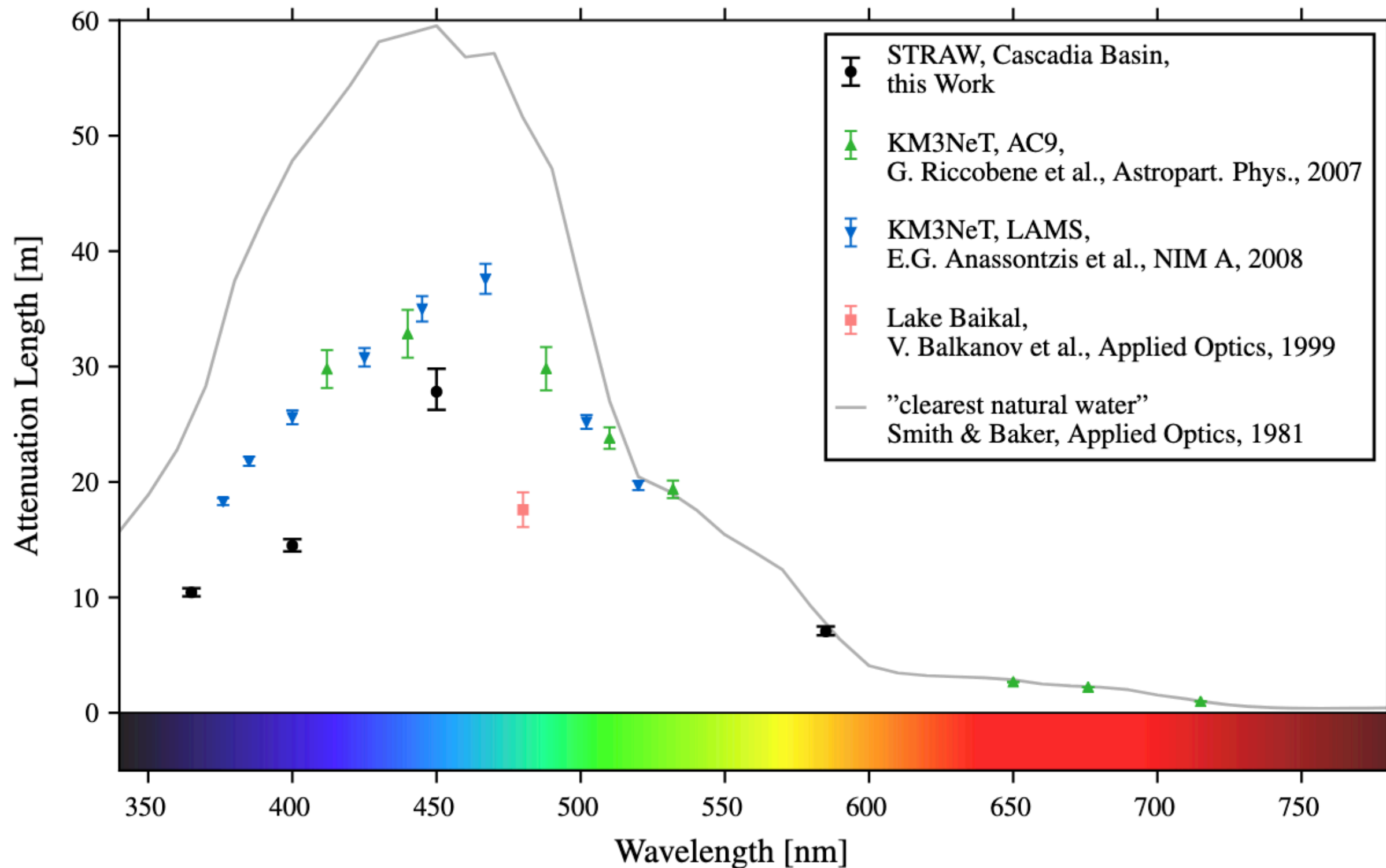


Key result 1: Attenuation length

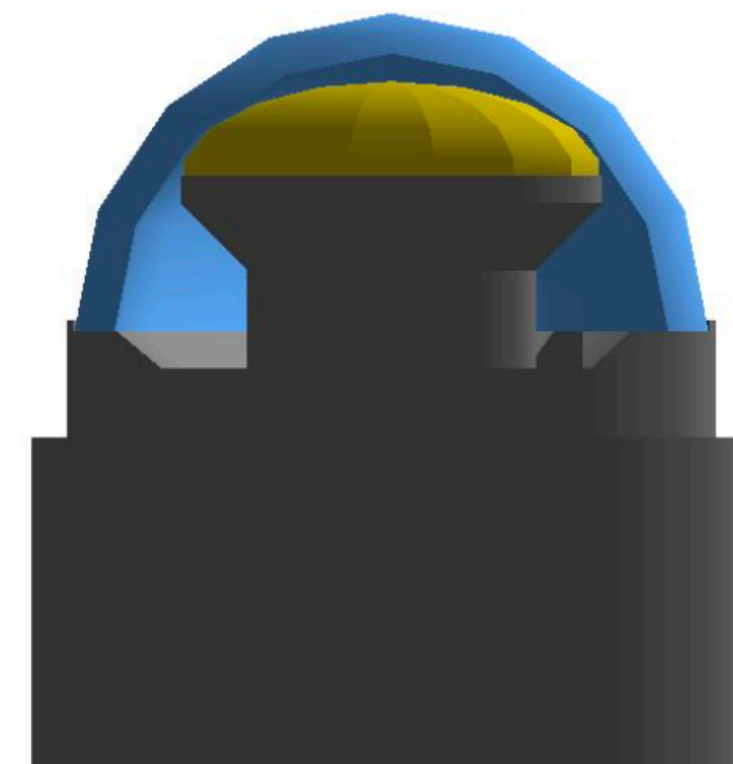
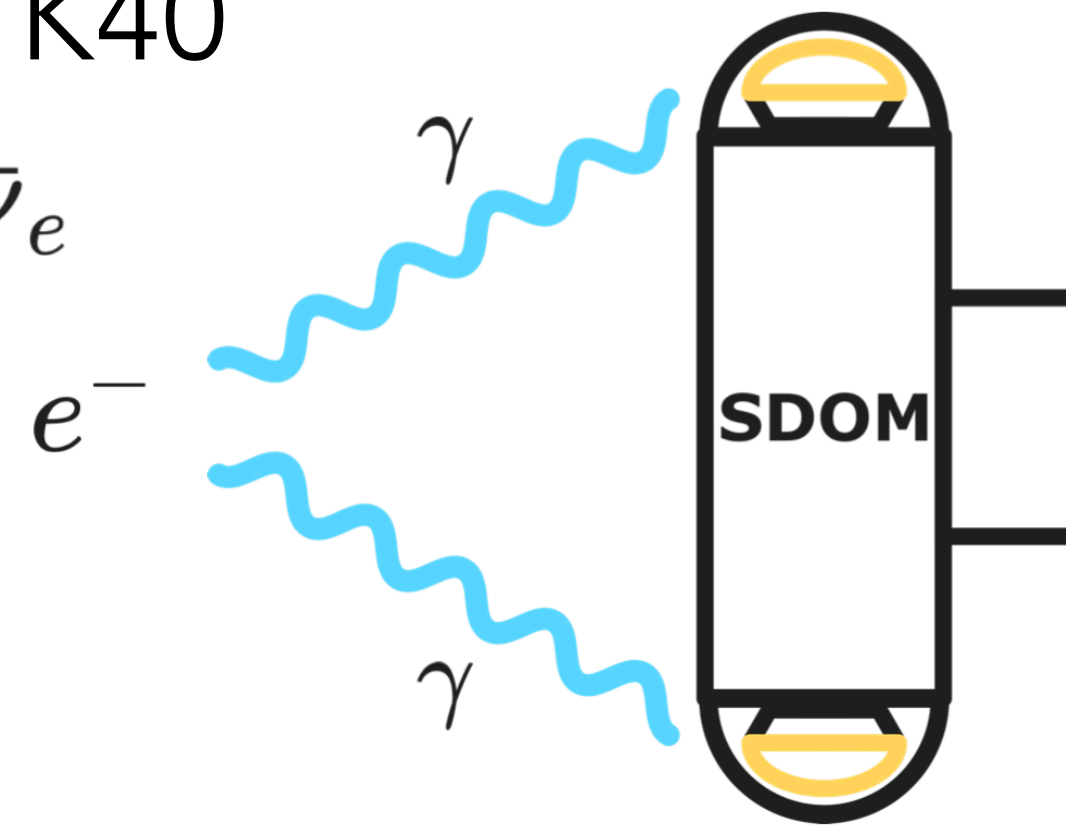
- Measure Attenuation length in the water
- For different wavelength
- Constant over 2 years of measurements
- **Optical properties are good!**

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

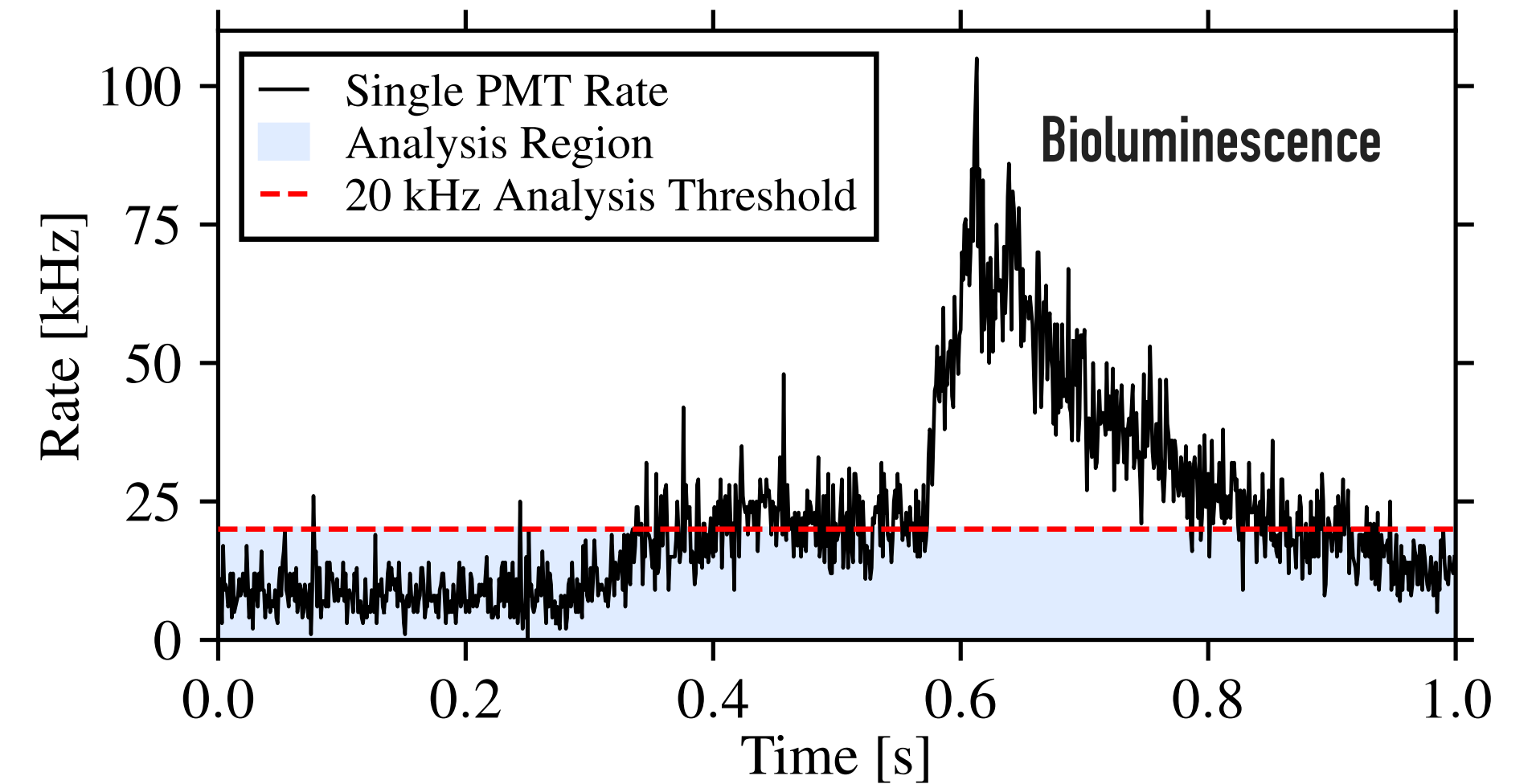
$$\frac{1}{\lambda_{att}} = \frac{1}{\lambda_{sct}} + \frac{1}{\lambda_{abs}}$$



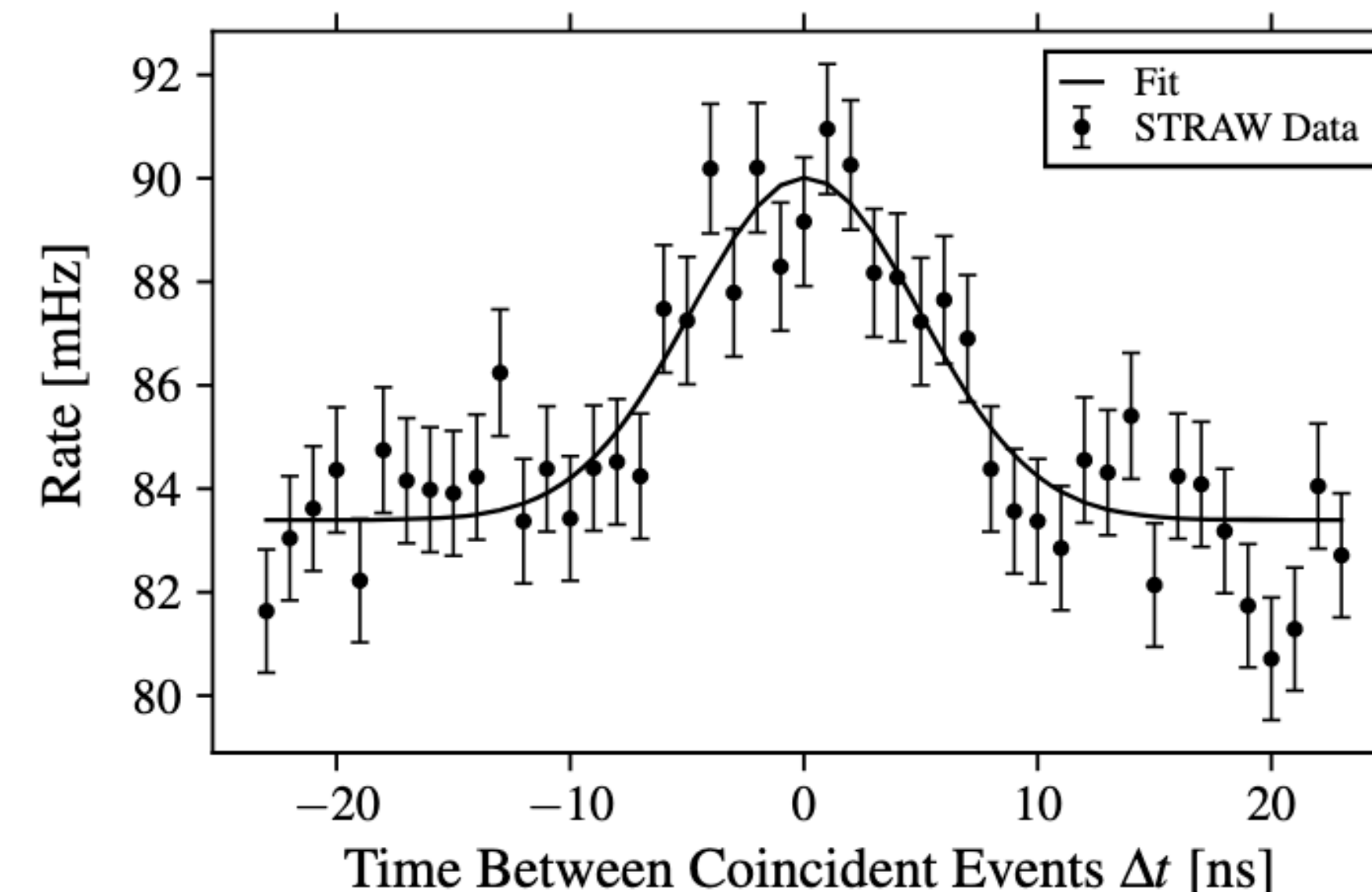
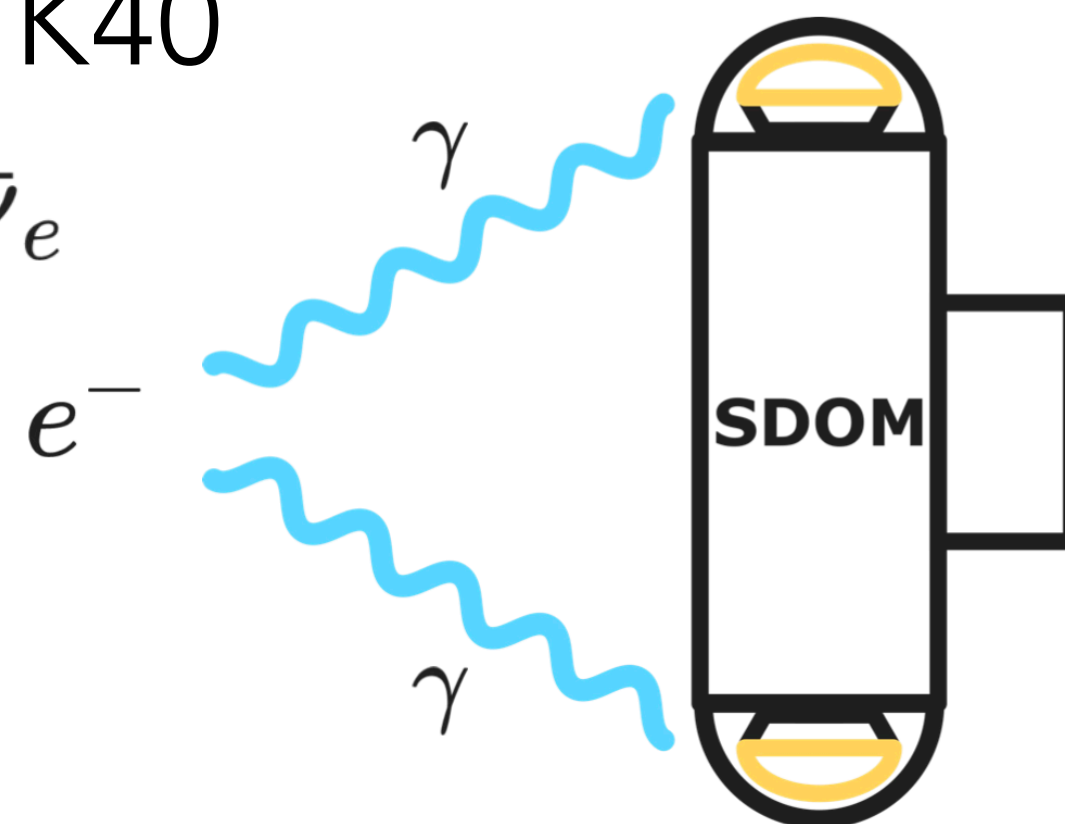
- Understanding the 40K background
- Natural in-situ calibration with K40
possible $^{40}\text{K} \rightarrow ^{40}\text{Ca} + e^- + \bar{\nu}_e$
- Cross-check of λ_{att} results, detector and site model



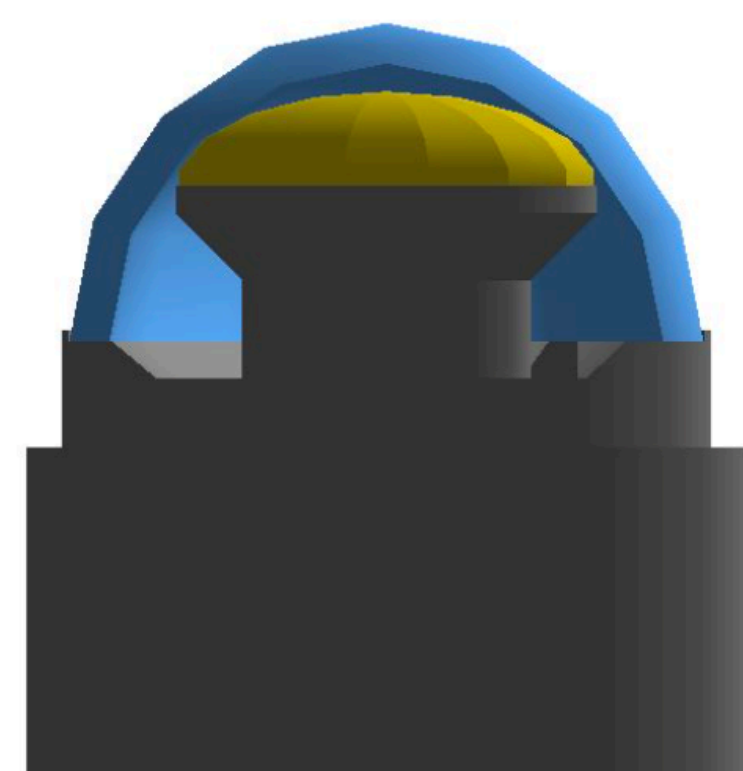
SDOM PMT housing Geant4 model



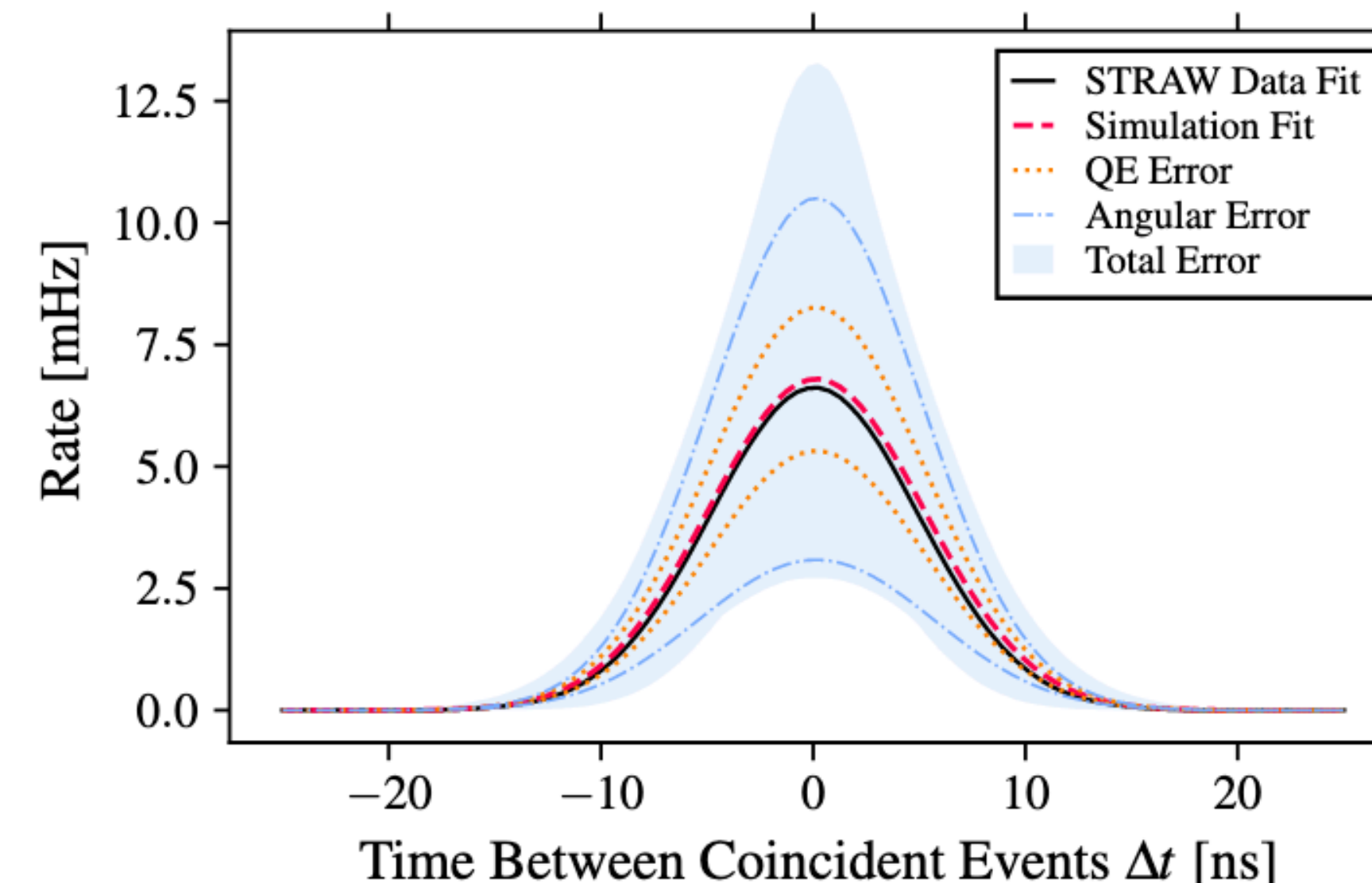
- Understanding the ^{40}K background
- Natural in-situ calibration with K40 possible $^{40}\text{K} \rightarrow ^{40}\text{Ca} + e^- + \bar{\nu}_e$
- Cross-check of λ_{att} results, detector and site model
- **Consistent results!**



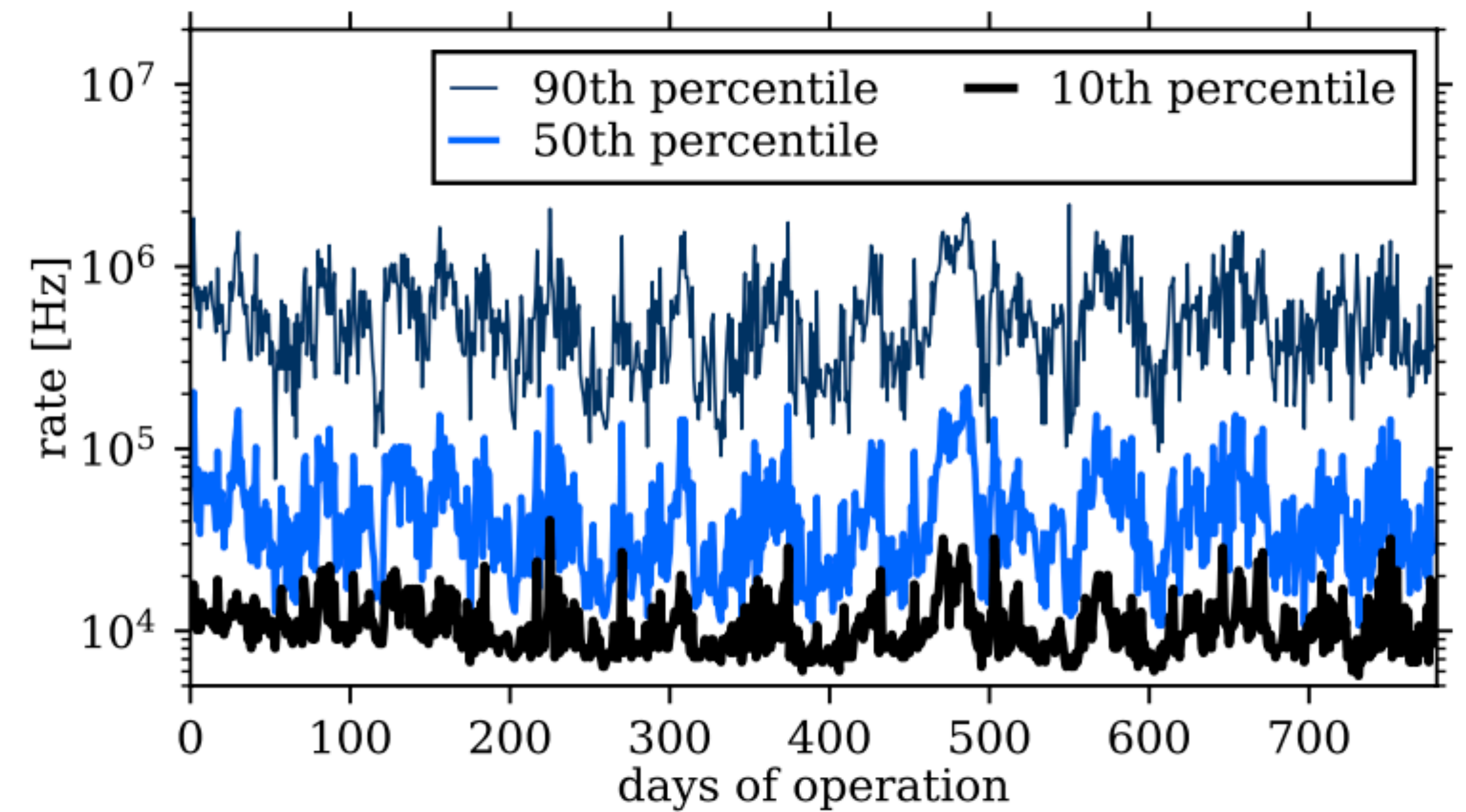
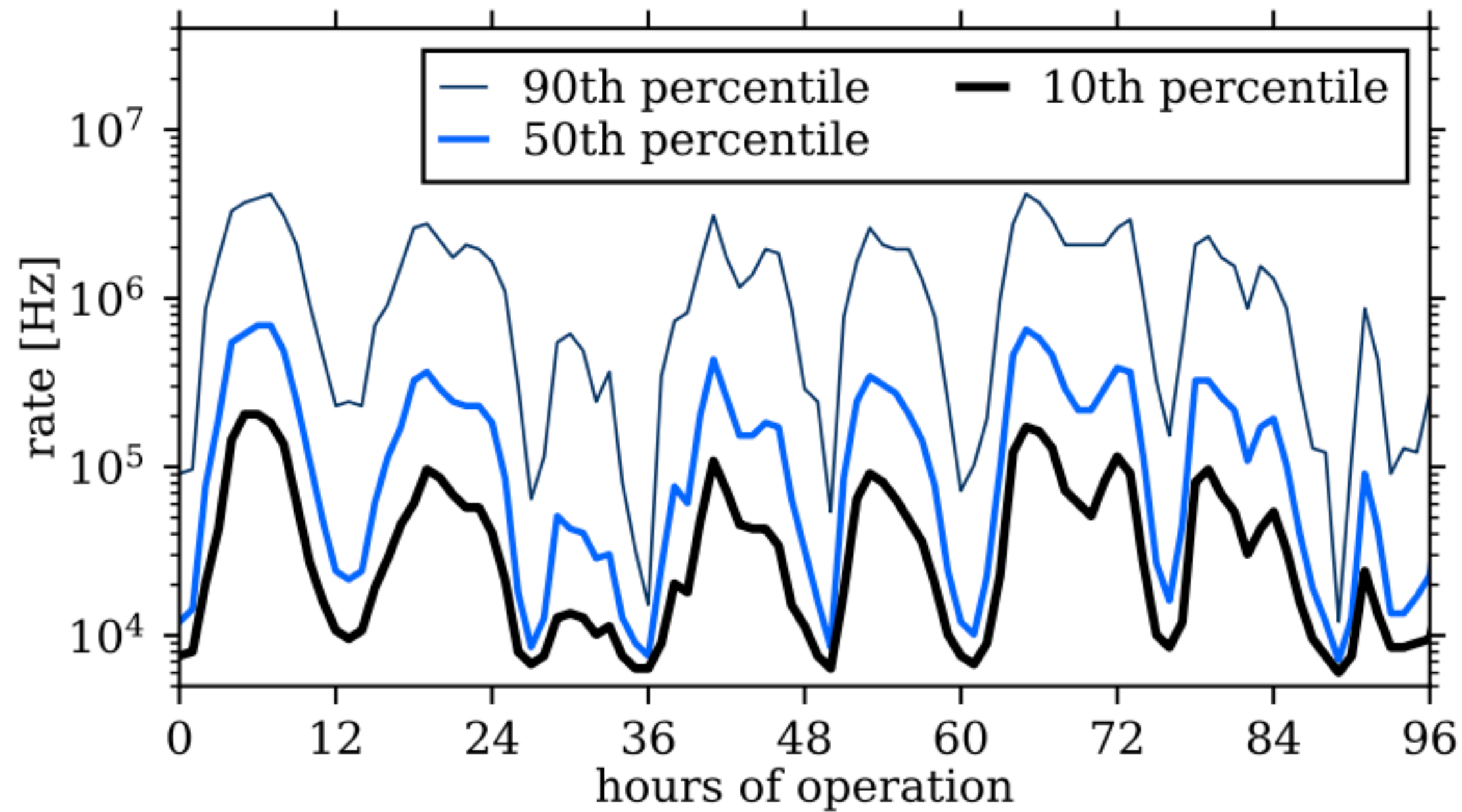
Salinity from this work: $2.5 \pm 1.4\%$
 Salinity from ONC: $3.482 \pm 0.001\%$
 Salinity at ANTARES site: 3.844%



SDOM PMT housing Geant4 model



Key result 3: Bioluminescence as expected

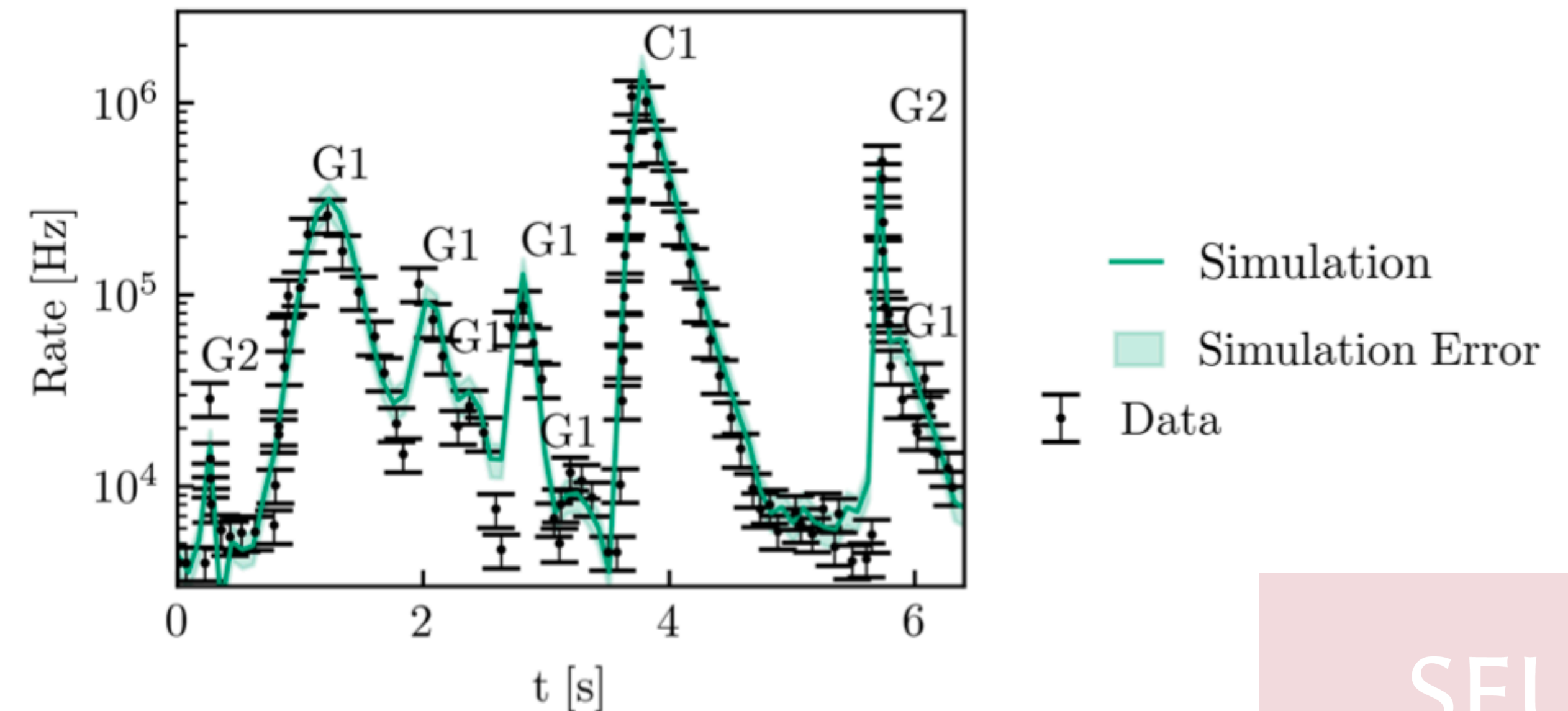
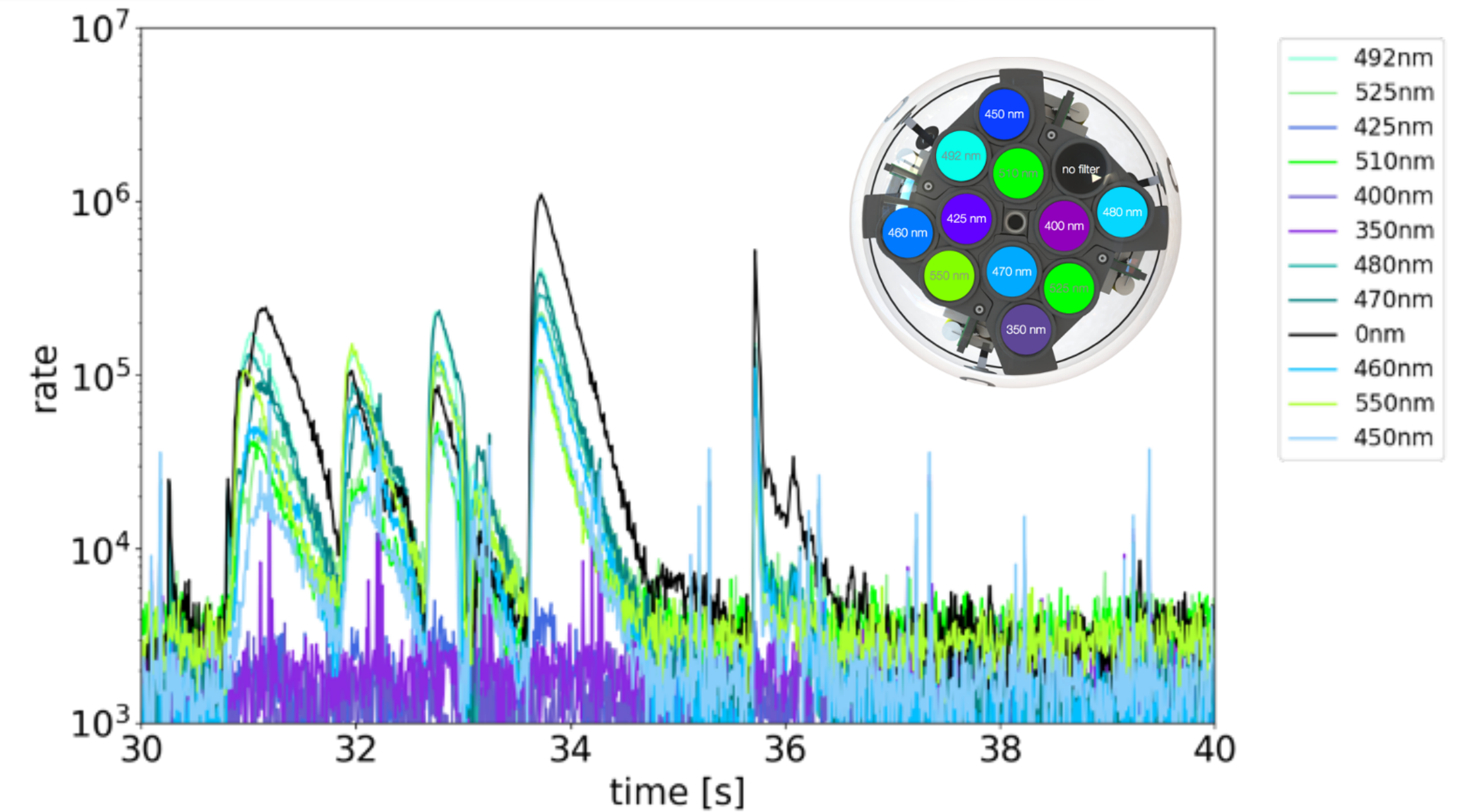


- Bioluminescence is modulated with the tides
- Constant over more than 2 years of operations —> no big bursts

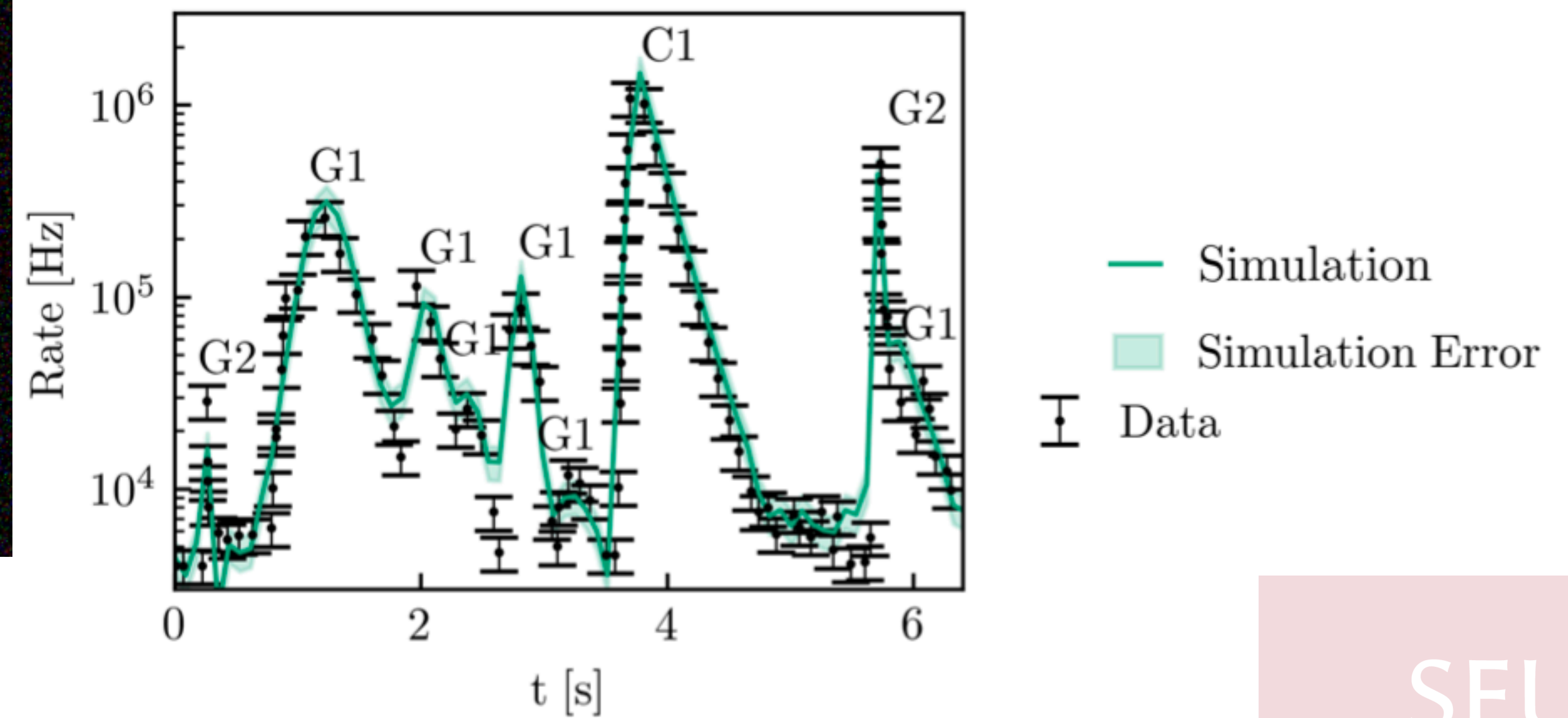
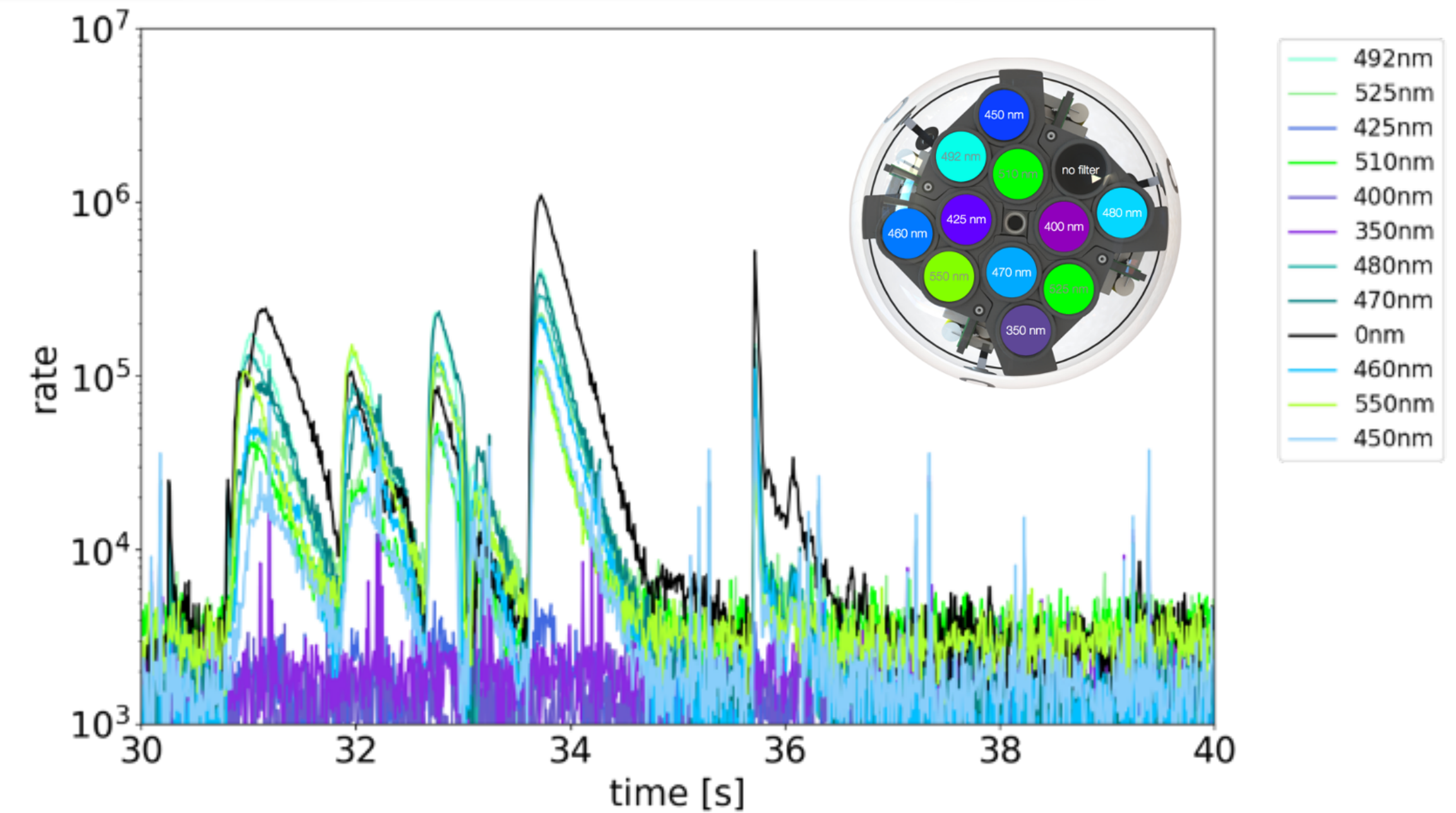
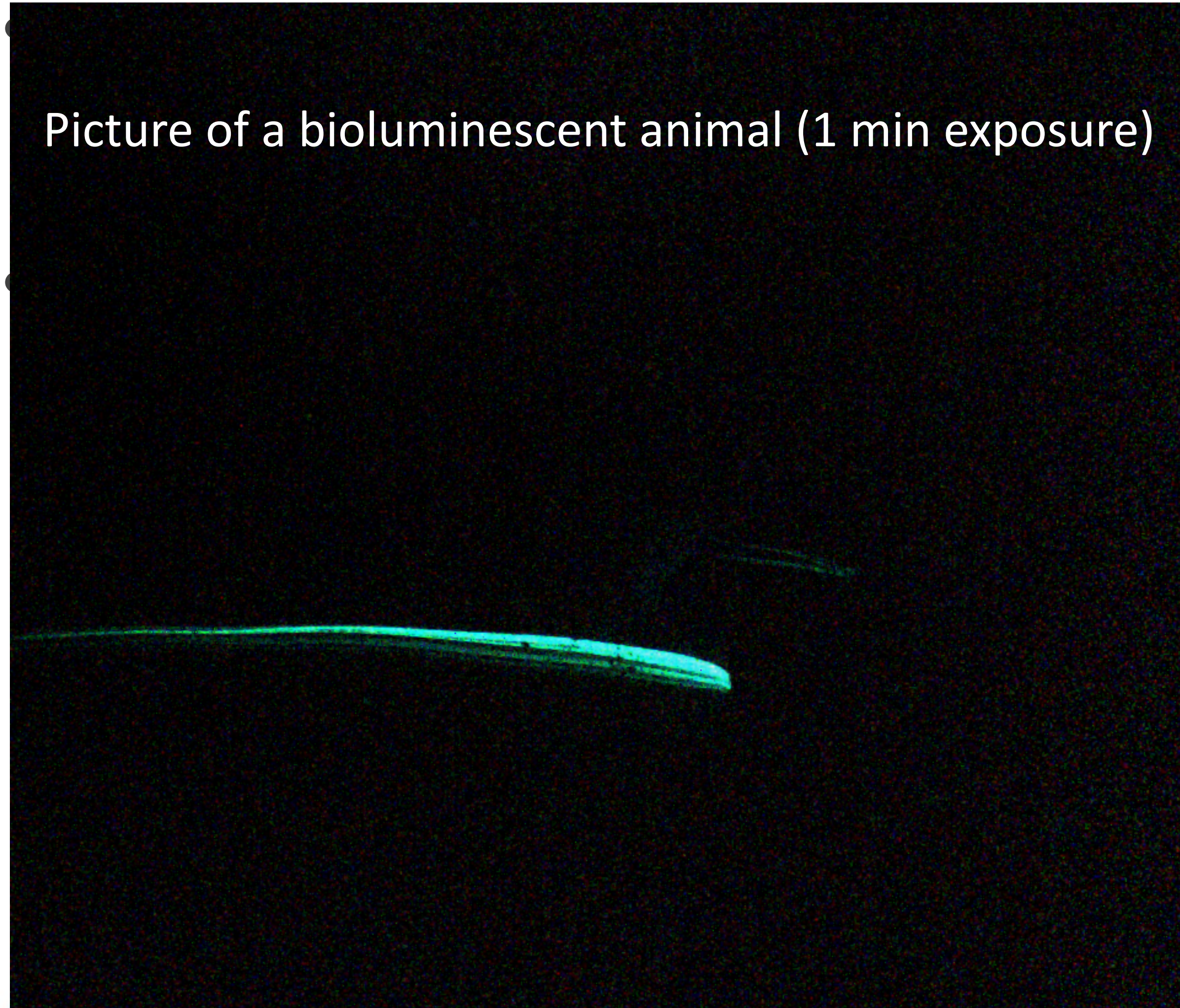
The deep sea site of Cascadia basin is optically qualified to host P-ONE

- Measurement of wavelength dependent emission spectrum of bioluminescence with PMT spectrometers
- Comparison to detailed simulation of bioluminescence

Interdisciplinary: oceanography, microbiology, climate change related studies



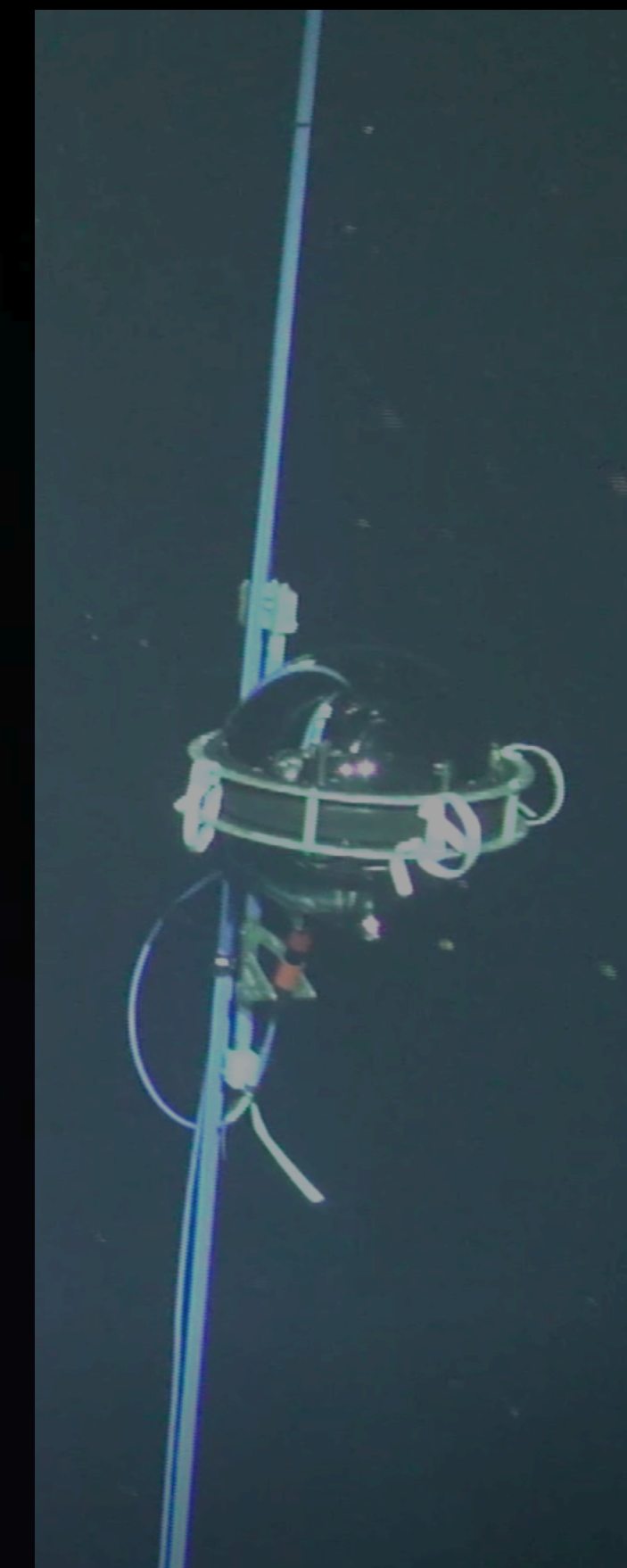
Picture of a bioluminescent animal (1 min exposure)





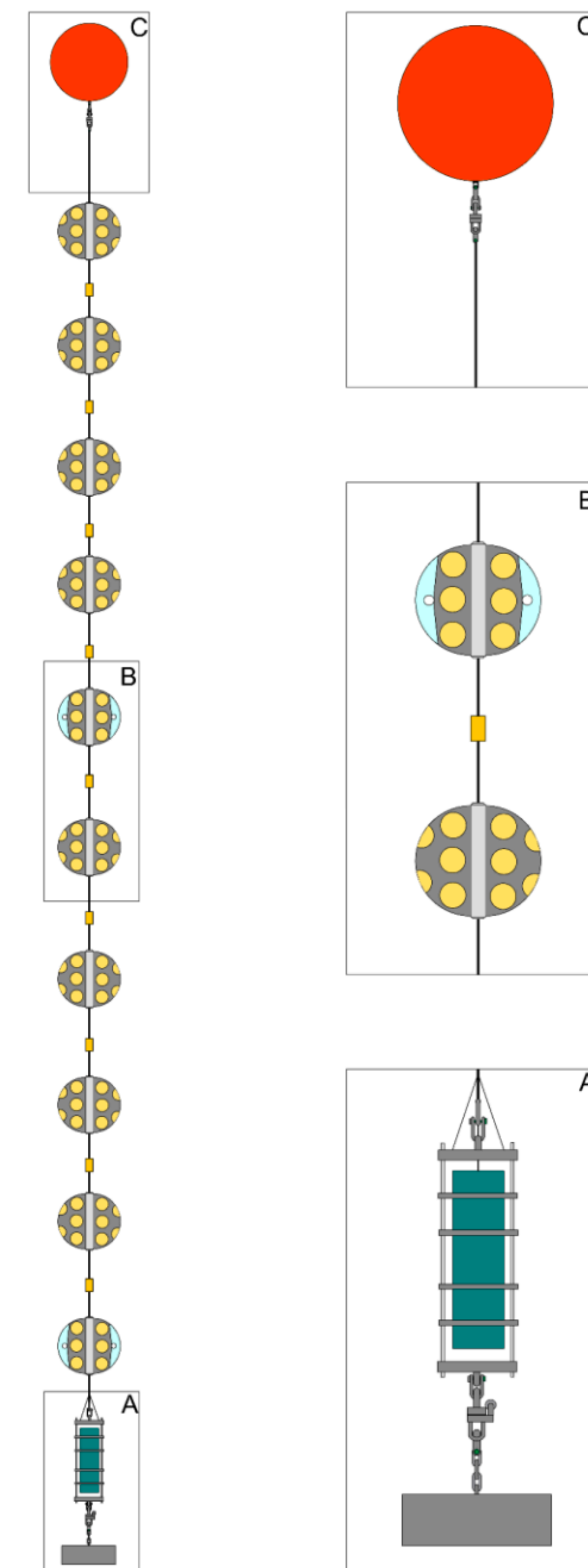
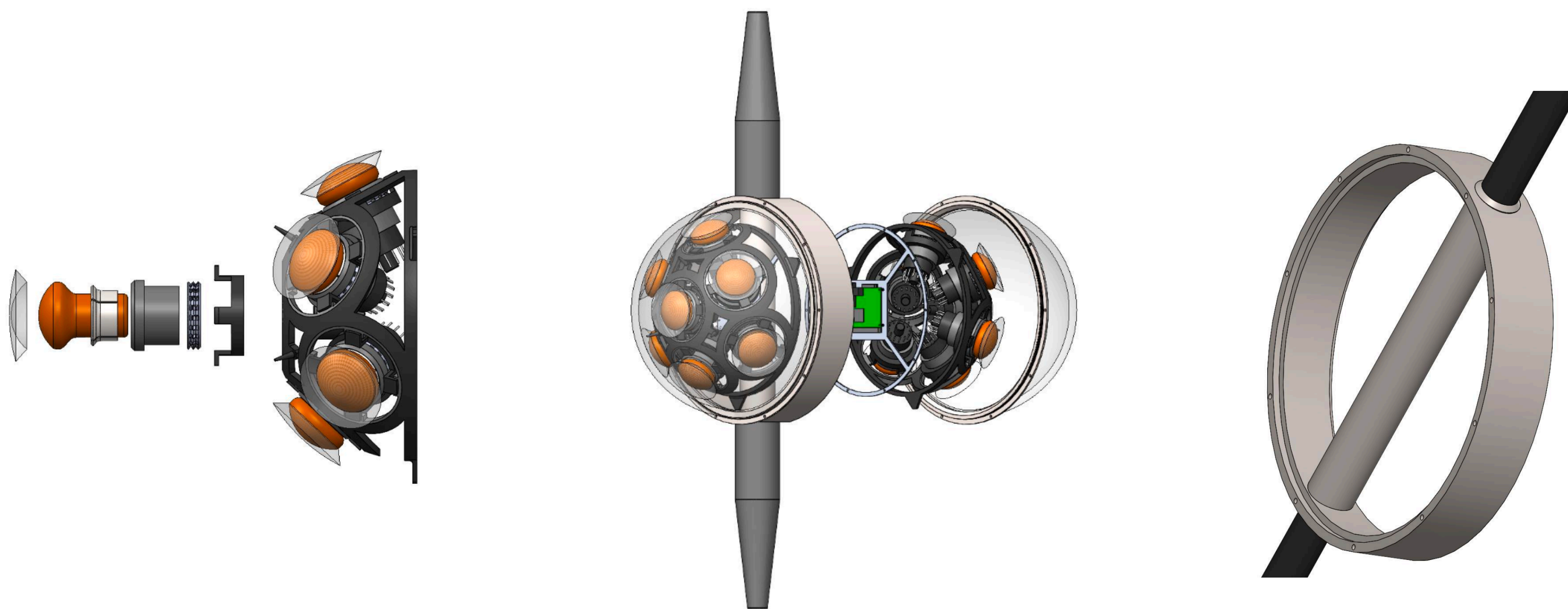
— P-ONE —

- Next steps towards a neutrino observatory



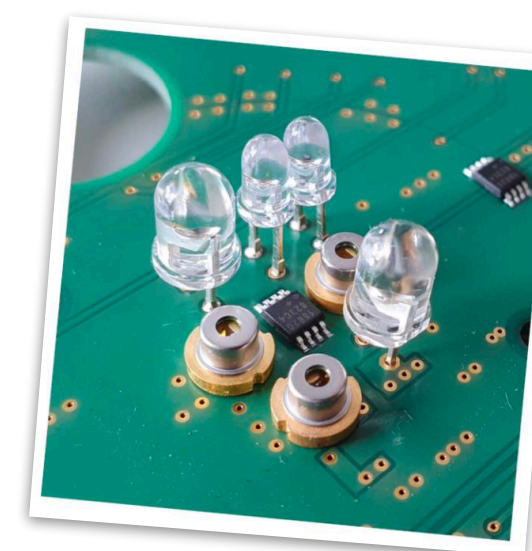
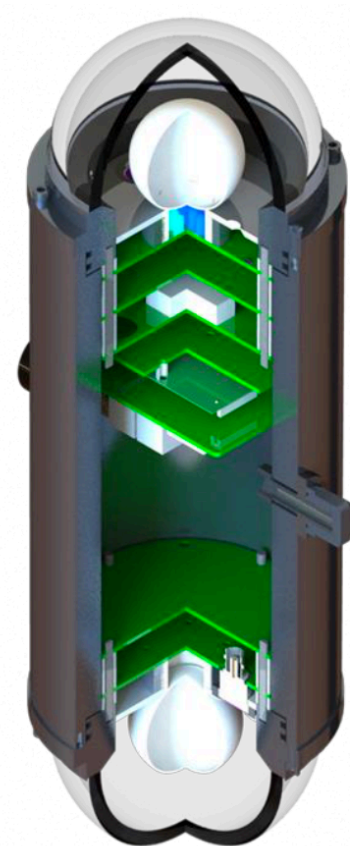
P-ONE — prototype line (2023)

- 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)



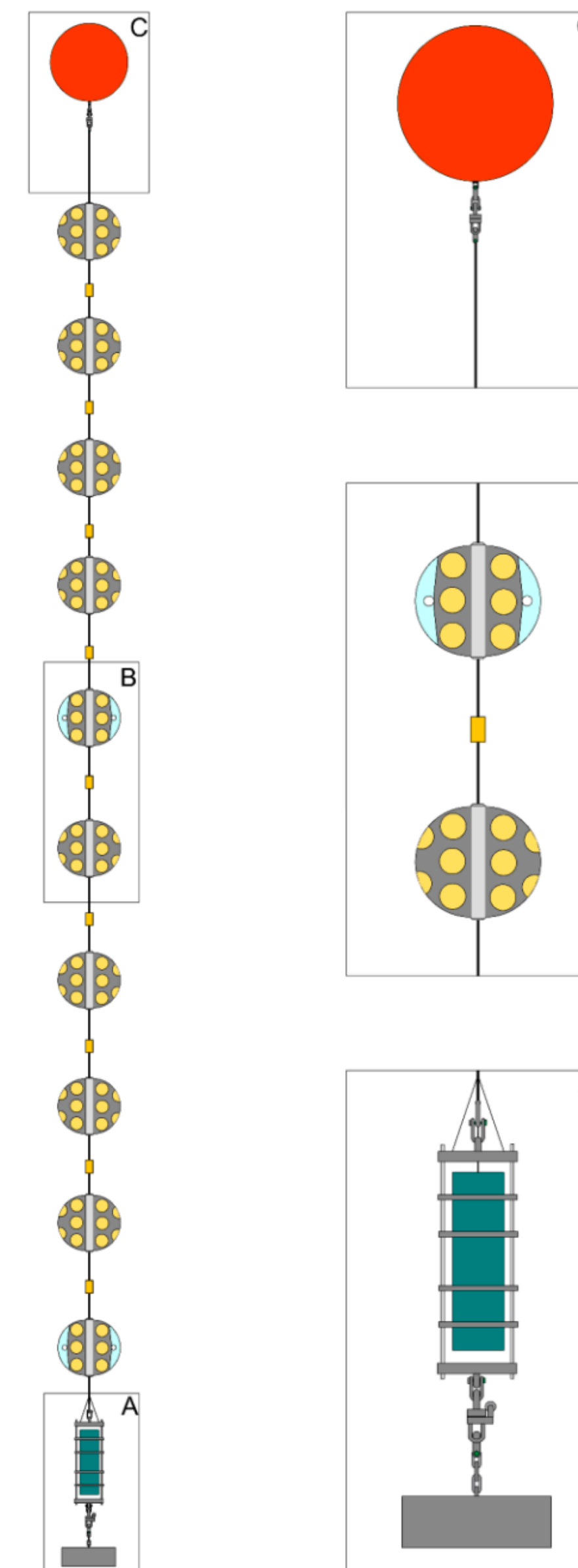
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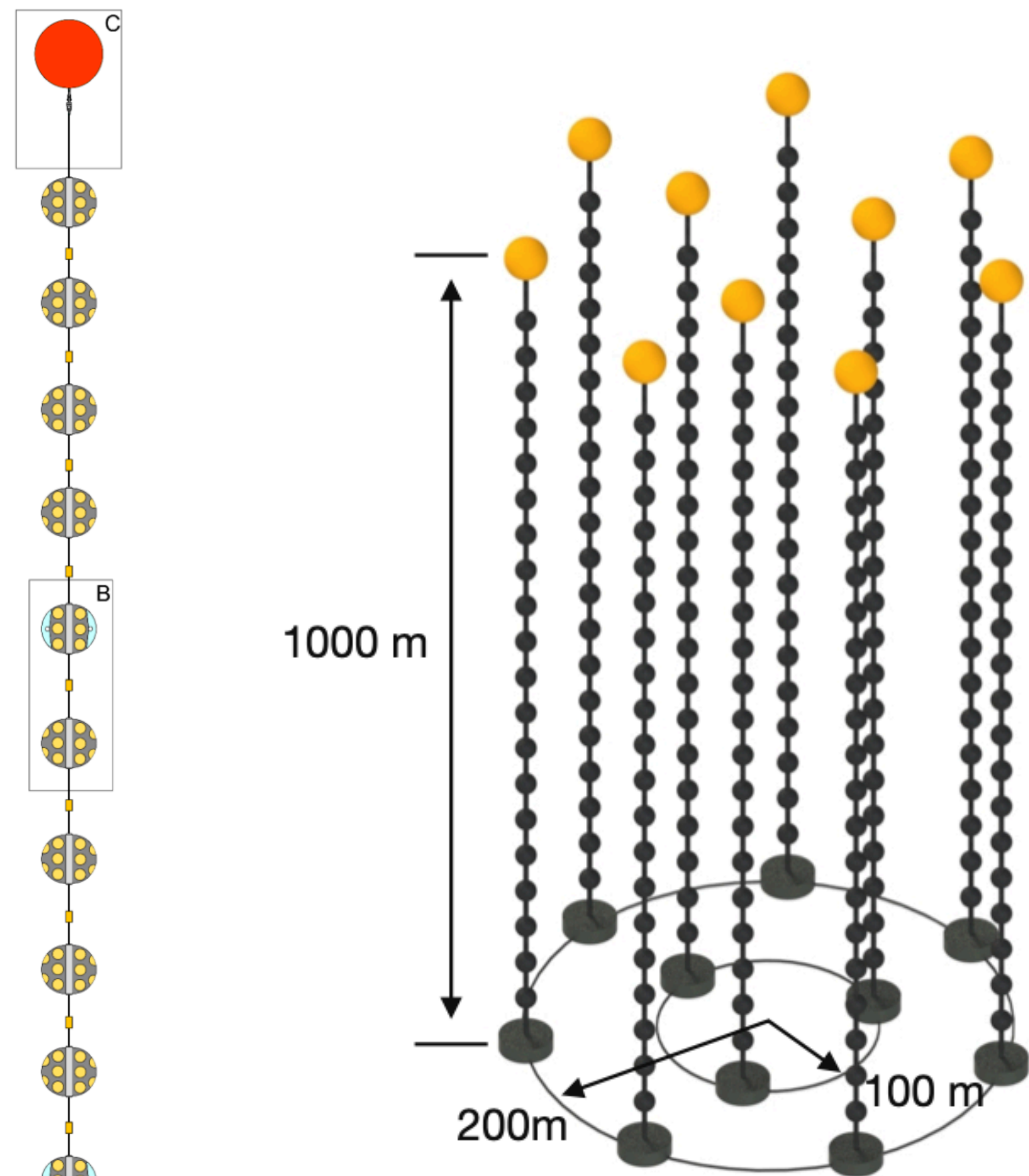


Optical Calibration

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



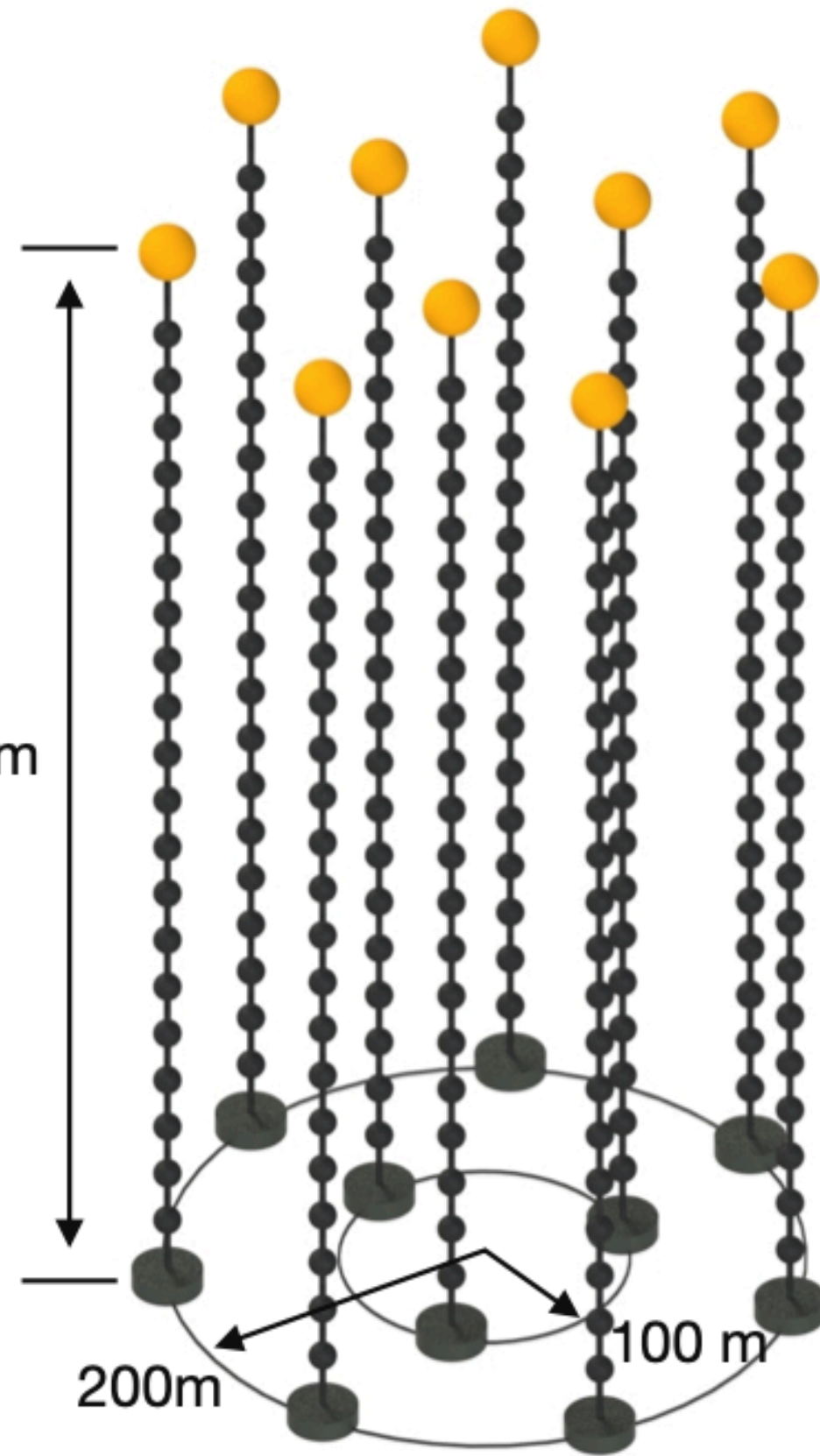
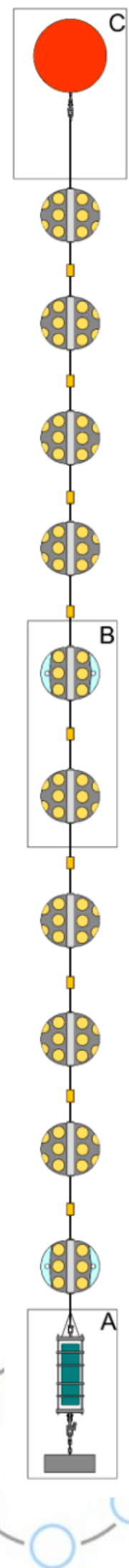
P-ONE — up to 10 line “Explorer” (2023 - 2026)



- up to 10 lines
- 200 modules
- ~100m spacing
- Instrumented Volume $\sim 1/8 \text{ km}^3$
- Exploring physics potential for:
 - atm. neutrinos
 - moon shadow
 - ambient background
 - and more...

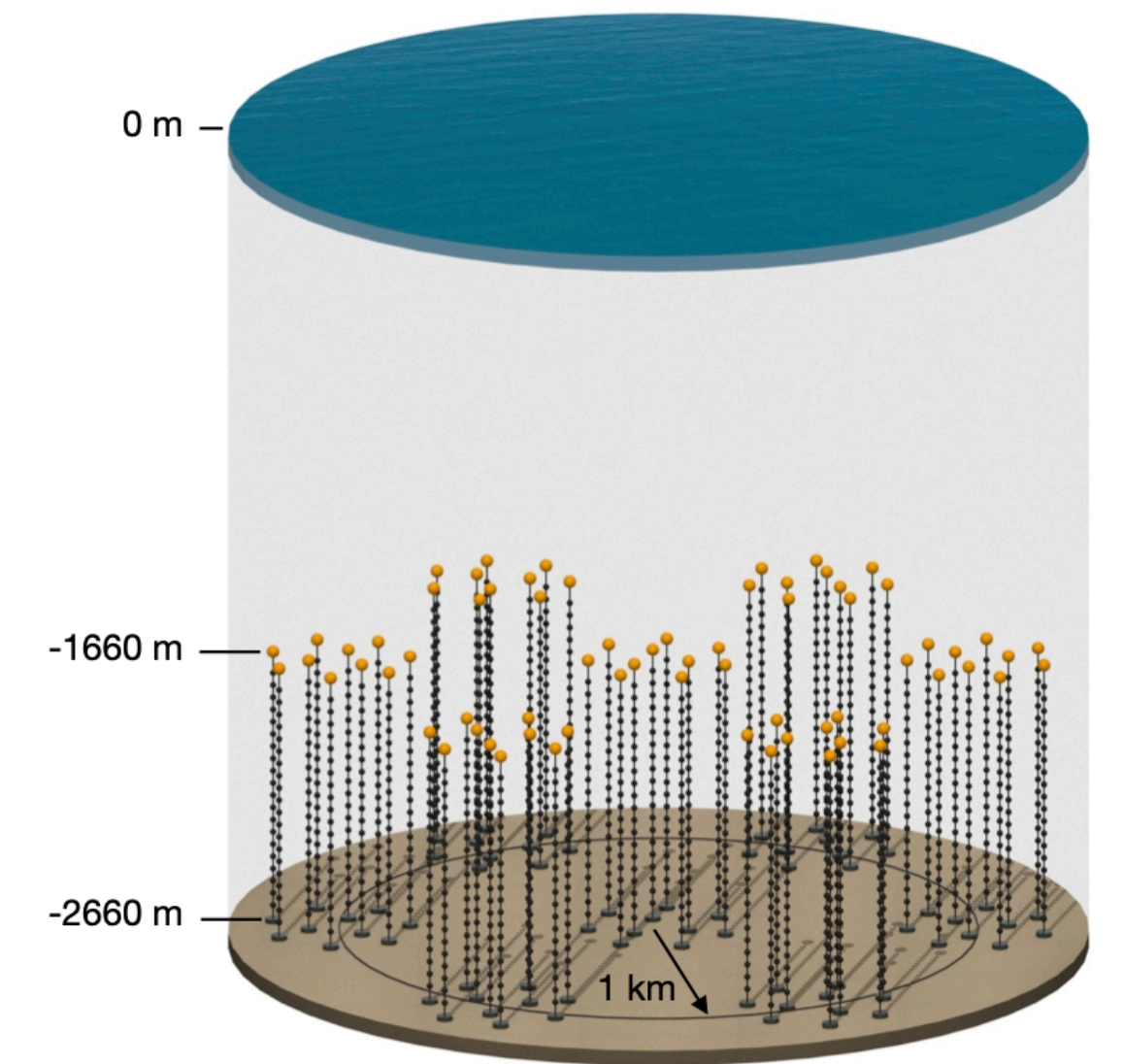


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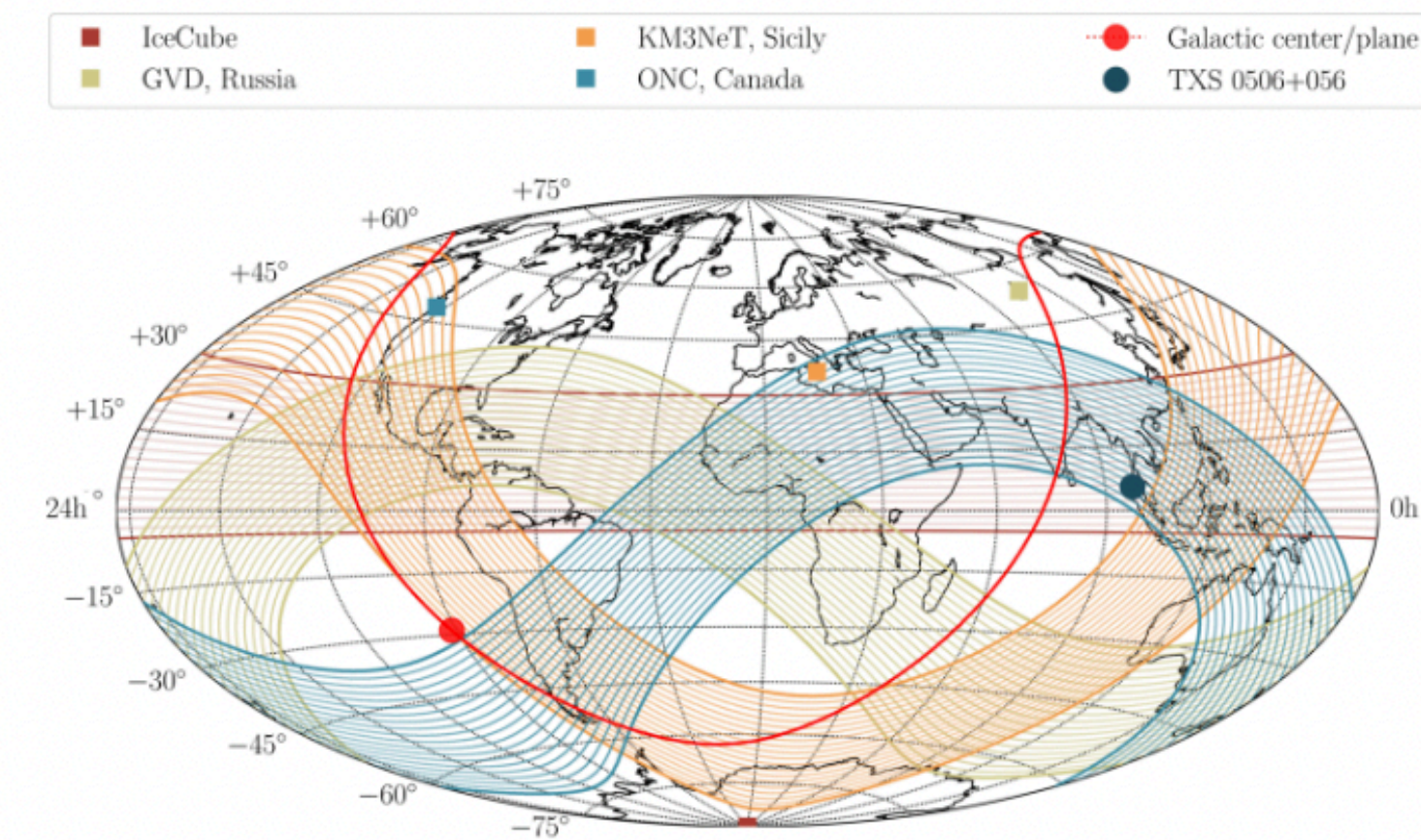
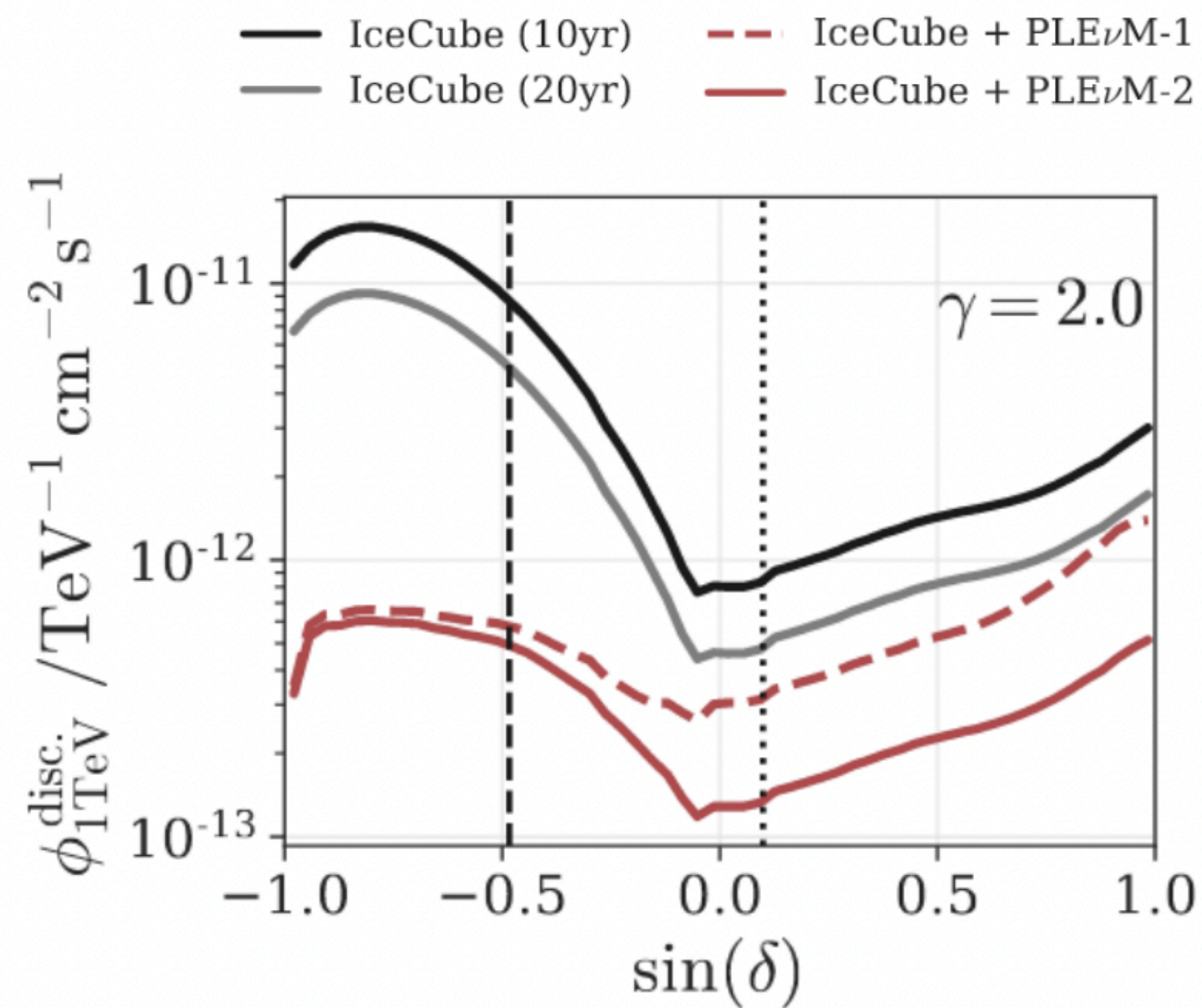
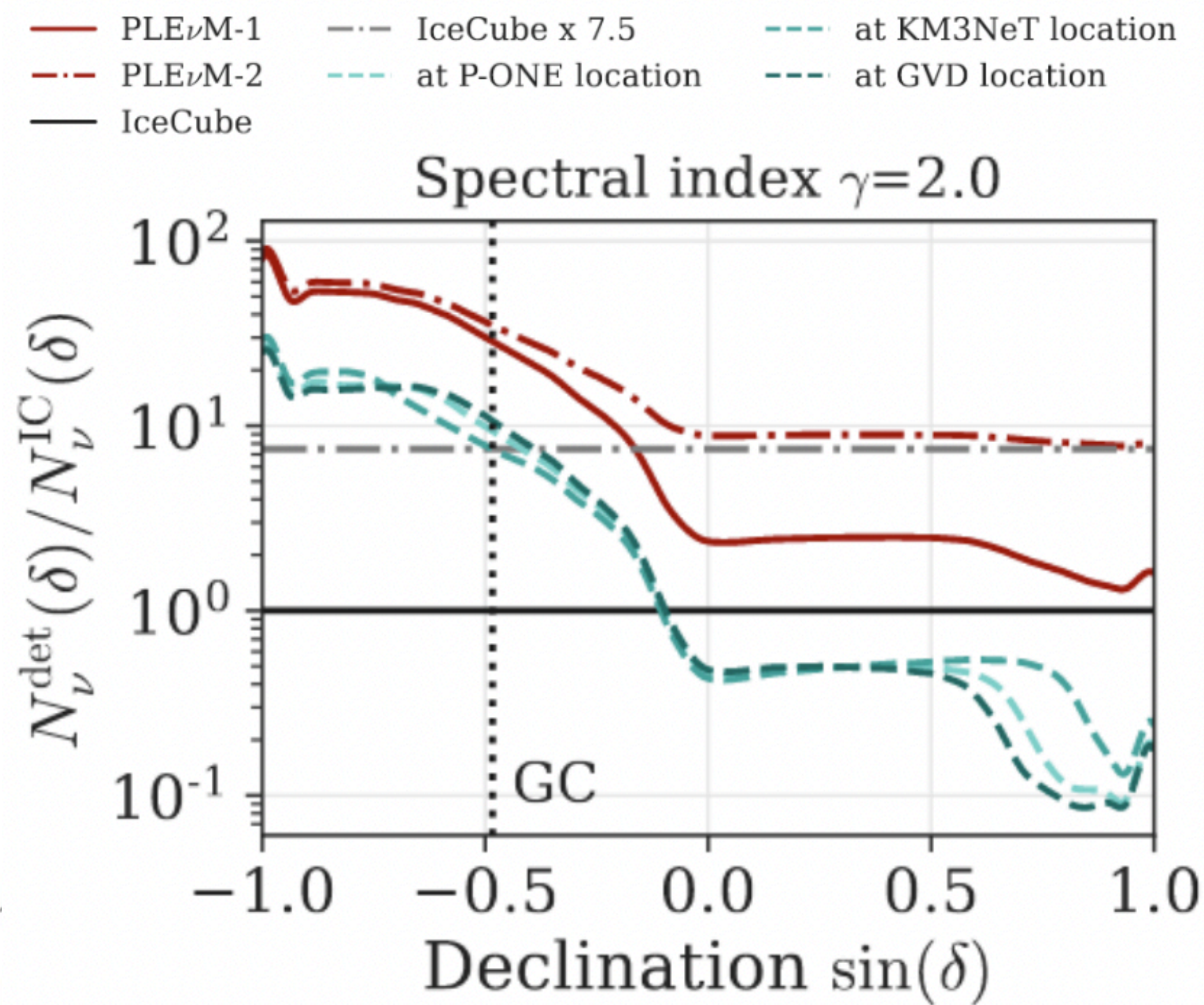
2027 and beyond



Assumption: IceCube size detector at KM3NeT, GVD, and P-ONE location

Impact:

- P-ONE will boost exposure to the Southern Sky by order of magnitudes
- A global network will achieve excellent full sky coverage for high-E astrophysical neutrinos

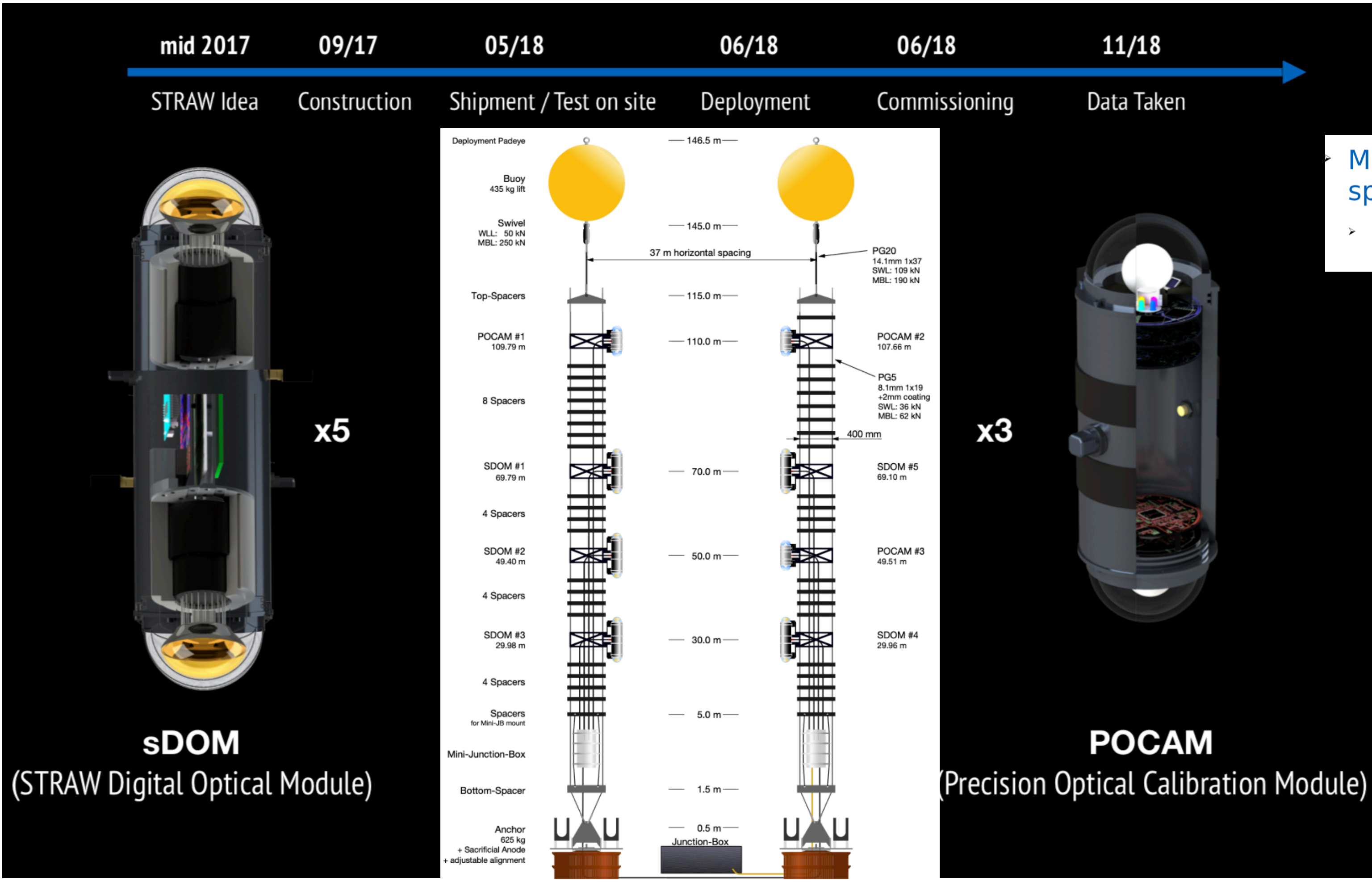
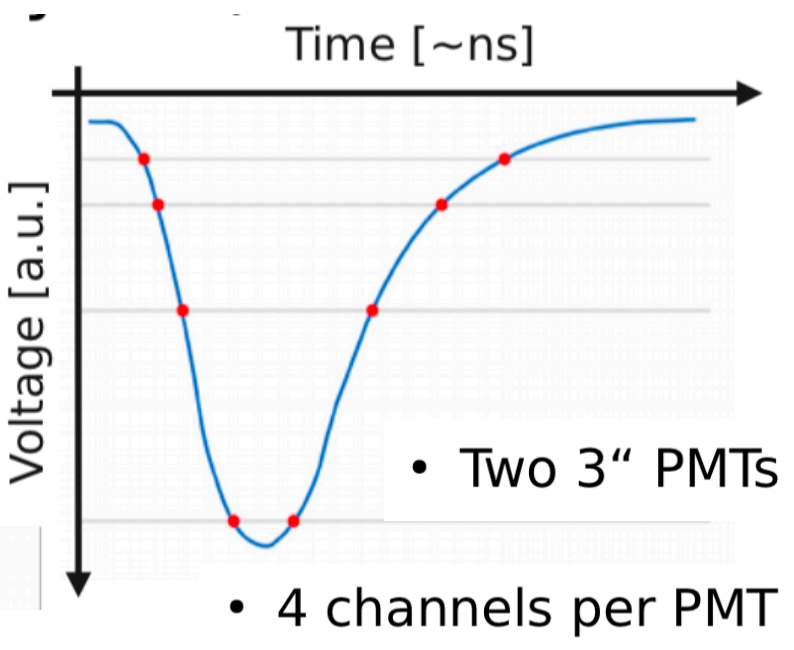




If you want to learn more:
<https://www.pacific-neutrino.org/>

- Ocean Networks Canada is an exciting opportunity for neutrino physics
 - Cascadia Basin is a suitable deep sea site
- Prototype line being developed
- New Collaborators are welcome to join and support the efforts!

Extras



Multi-wavelength emission for spectral studies

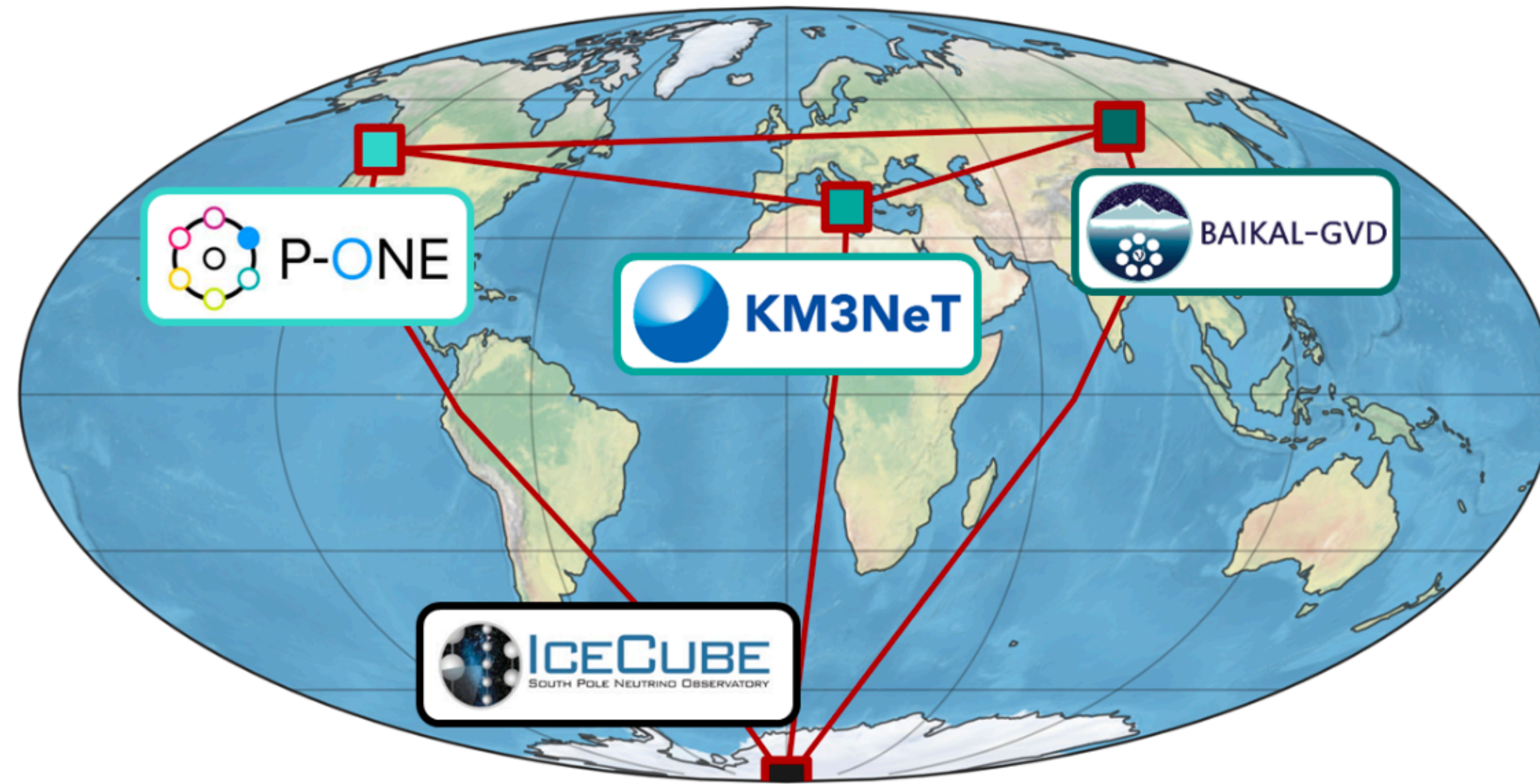
- > 365, 405, 465, 525, 605nm

Deployment was a 100% success!

- M. Boehmer et al JINST 14 P02013 (2019)
- Site characteristics EPJ C 81, 1071 (2021)

Why another neutrino telescope?

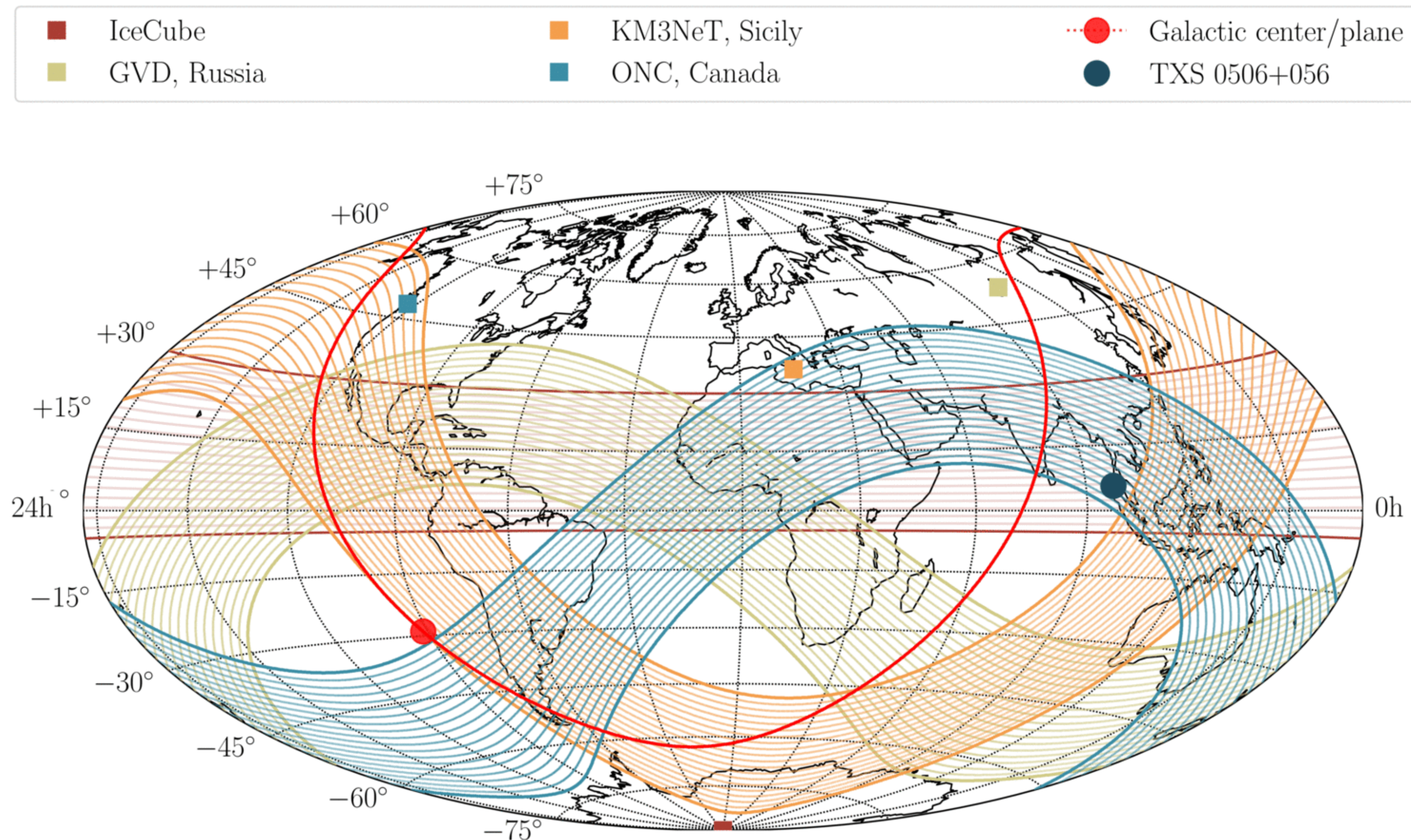
- More neutrinos, better neutrinos!



- 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..)

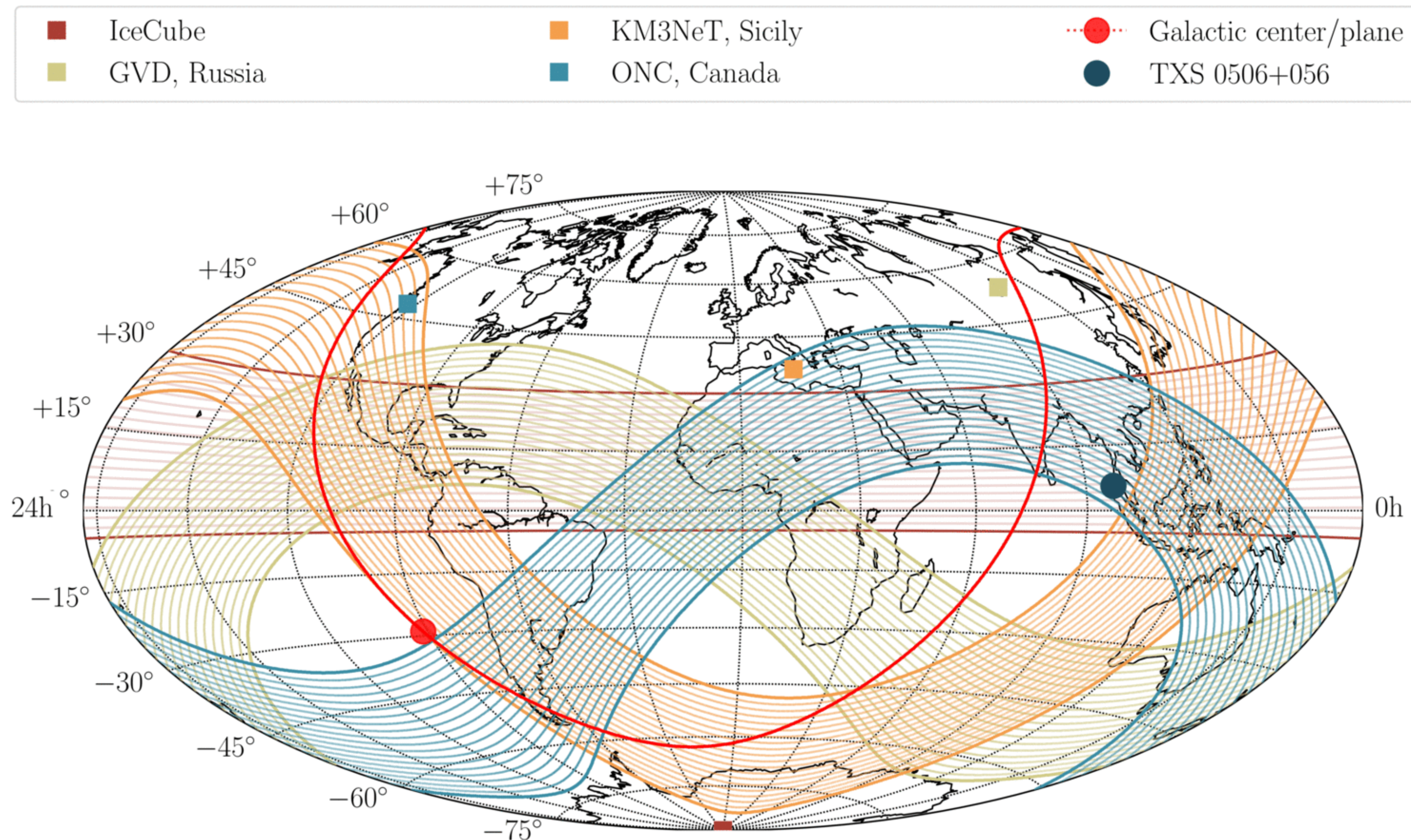
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- Horizontal coverage from which HE ν will not be affected by the Earth absorption
- With IceCube +3 neutrino telescopes (similar size), current sensitivity to astrophysical neutrinos would be improved by up two orders of magnitude (gain depends on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



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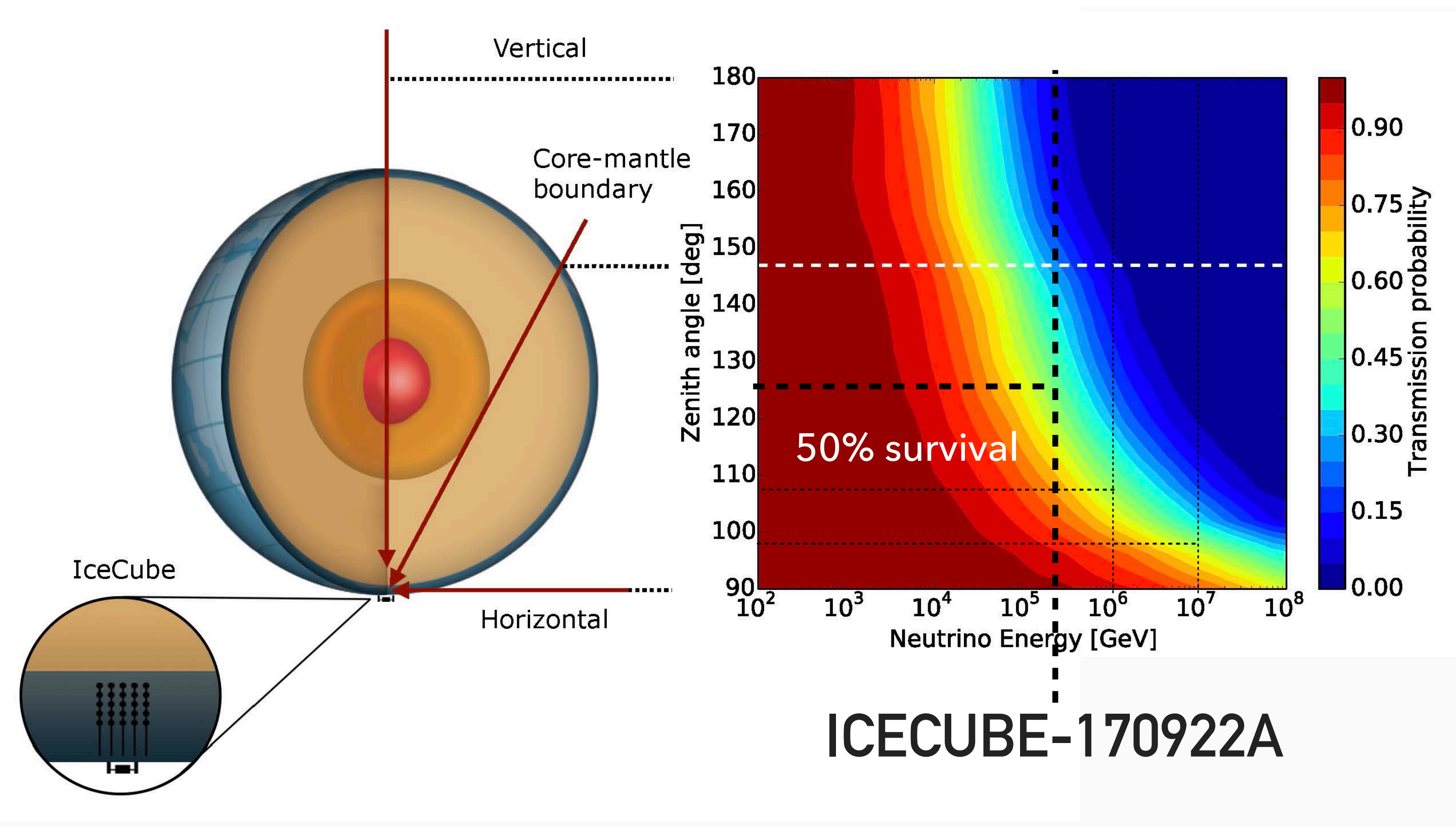
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Why another neutrino telescope?

AT HIGH ENERGY THE EARTH IS OPAQUE TO NEUTRINOS

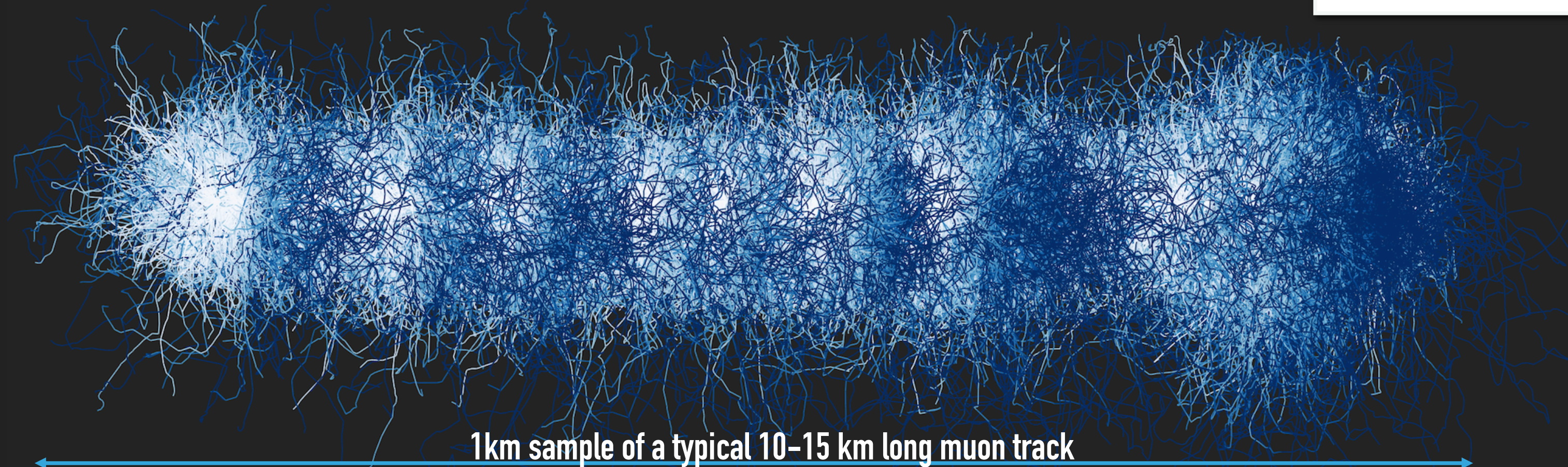
➔ THE FIELD OF VIEW OF NTs (>50TeV): THE HORIZON



HORIZONTAL HIGH ENERGY MUONS: THE SIGNATURE

1 PeV horizontal muon

medium: IceCube ice



medium: seawater

