P-ONE

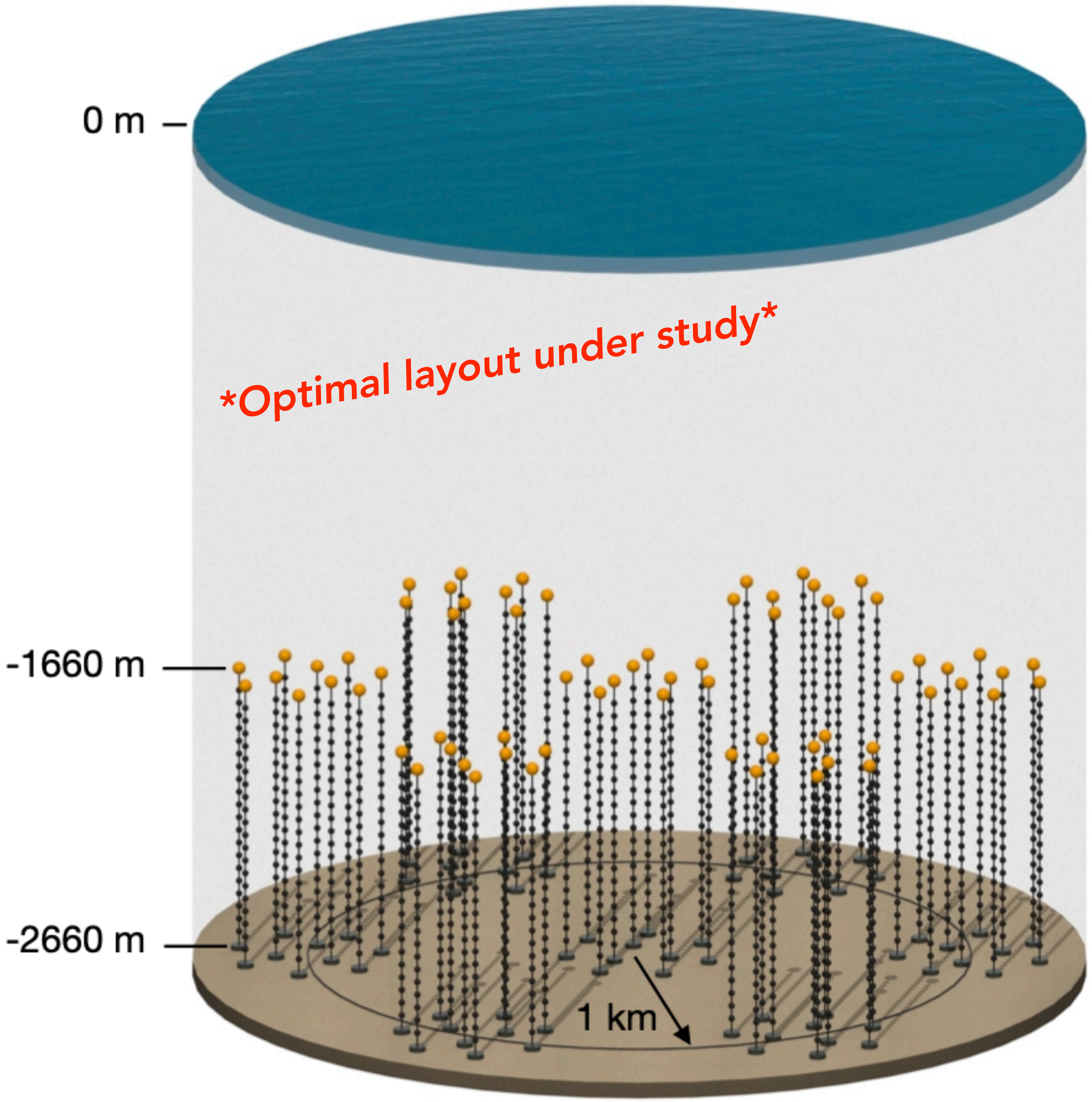
— The Pacific Ocean Neutrino Explorer —

Matthias Danninger
for the P-ONE Collaboration
IPP 50th Anniversary Symposium

SIMON FRASER UNIVERSITY

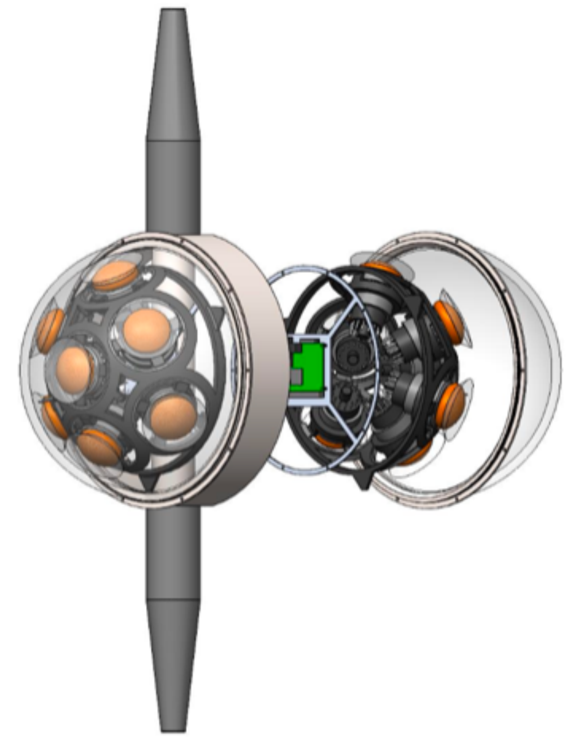
P-ONE — The current vision

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 — The current vision

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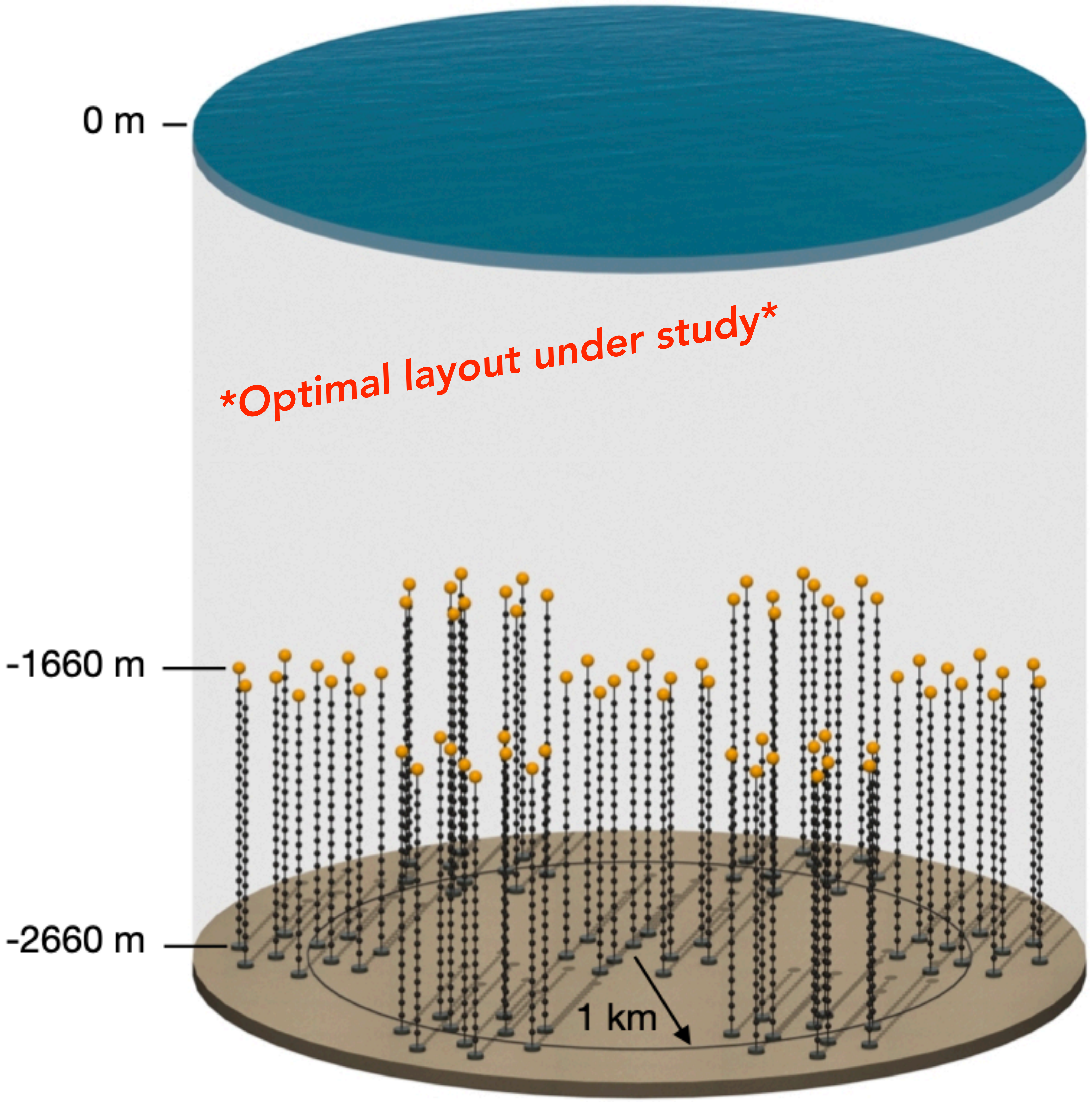

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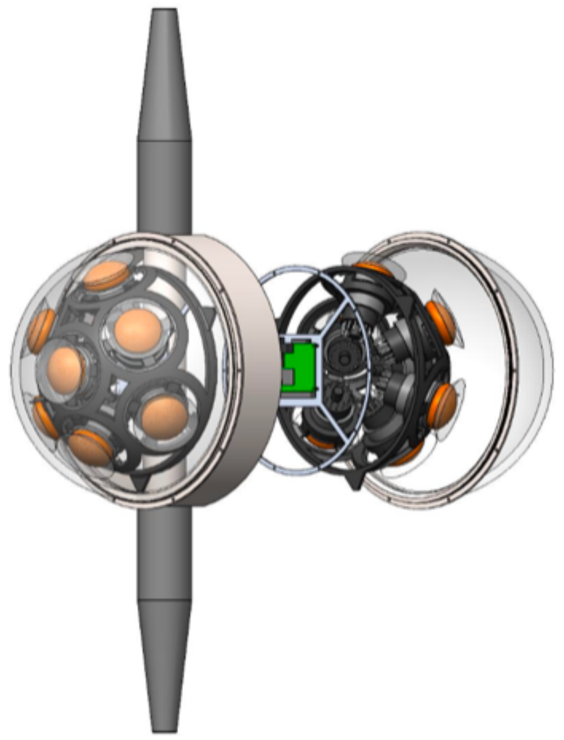


What is different?

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

Cascadia Basin node

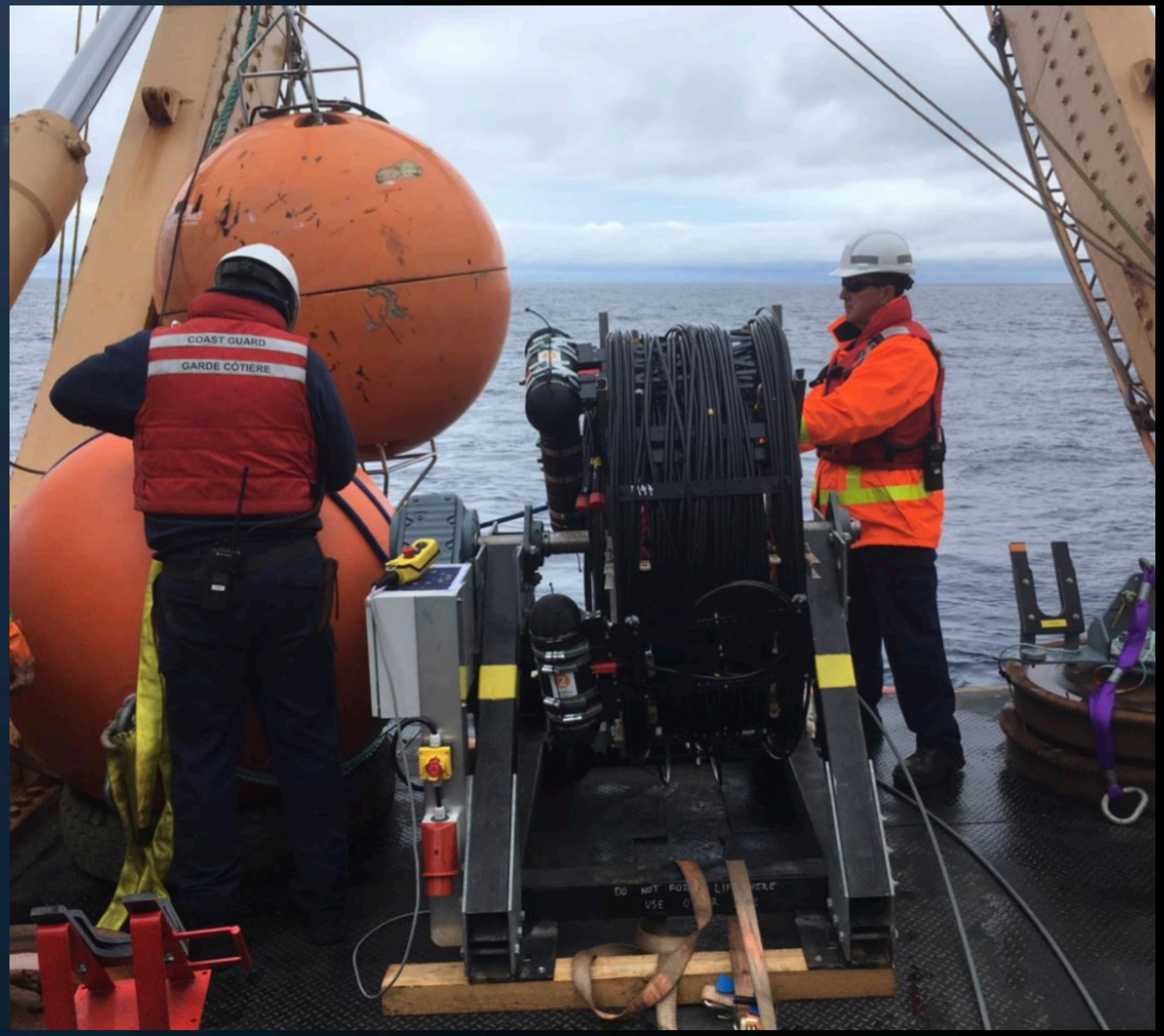
- 2600m deep abyssal plain
- 2°C year-round
- Low currents (0.1m/s)

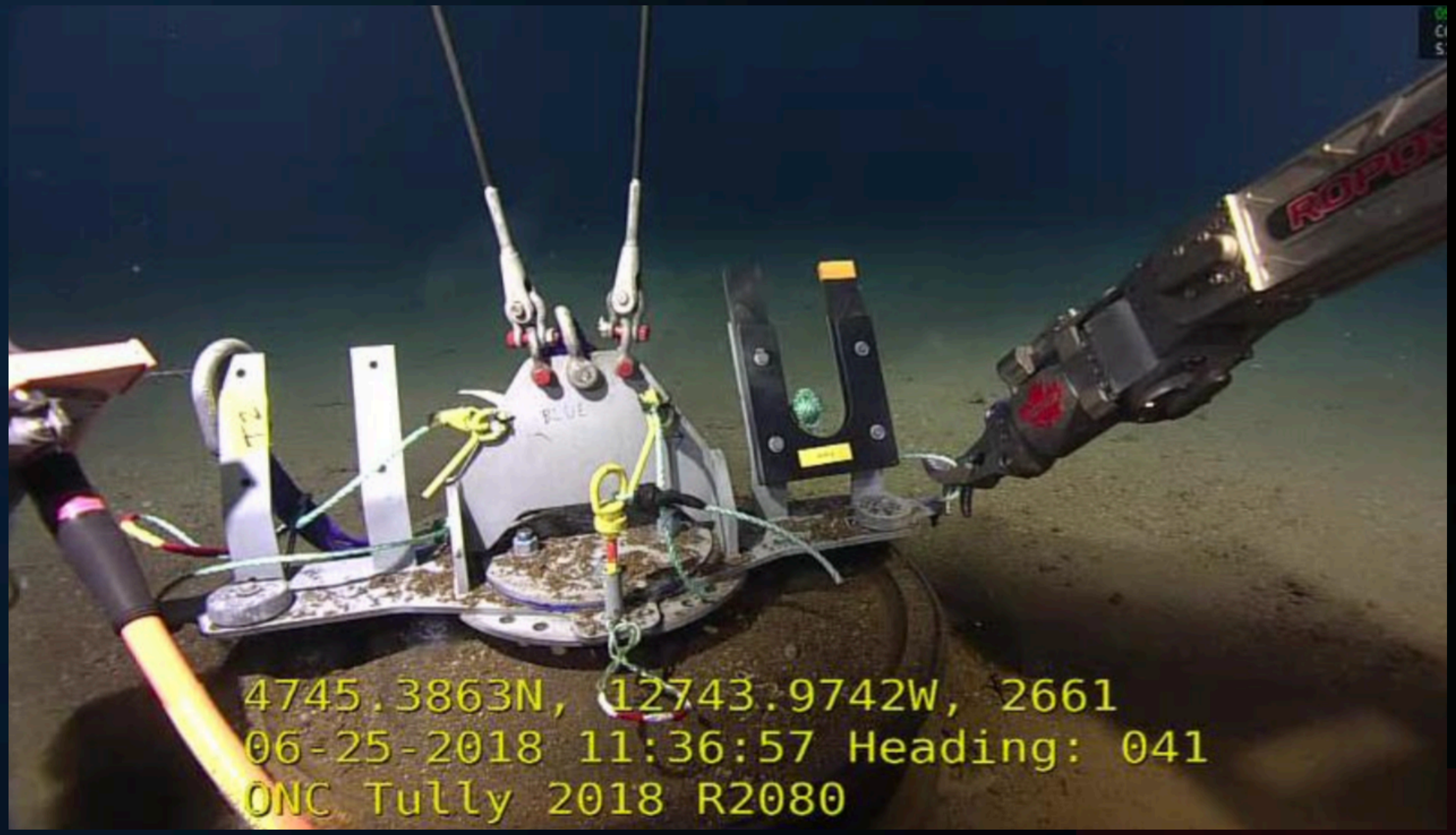
➡ **840 km of underwater fibre optic cable**

2 P-ONE pathfinder missions (2018 & 2020)

STRAW STRAW$_b$

- Cascadia Basin optically qualified
- Interface, anchoring and deployment operation by ONC
  - *JINST 14, P02013 (2019) and EPJC 81, 1071 (2021)*





P-ONE

SFU

2 P-ONE pathfinder missions (2018 & 2020)

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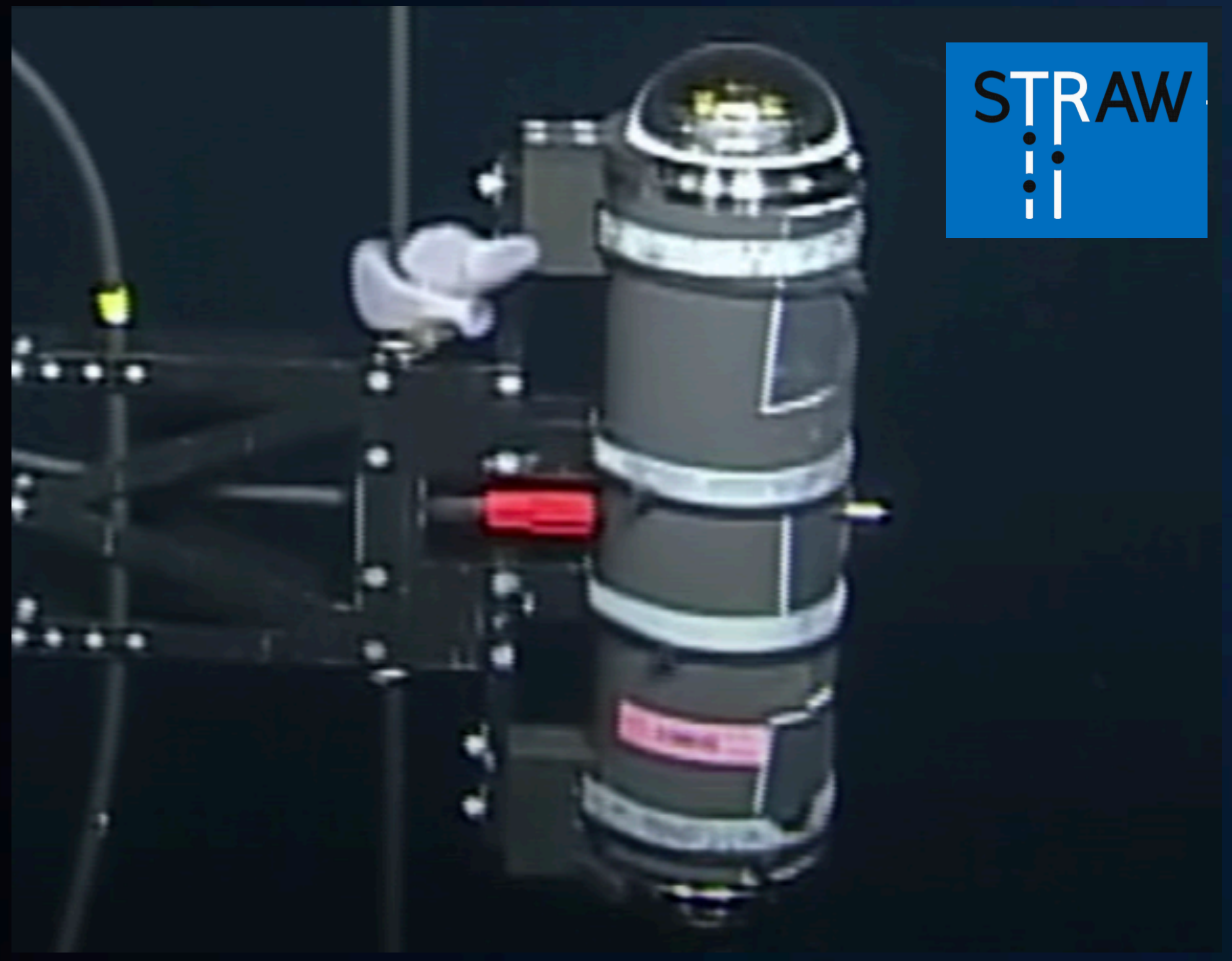

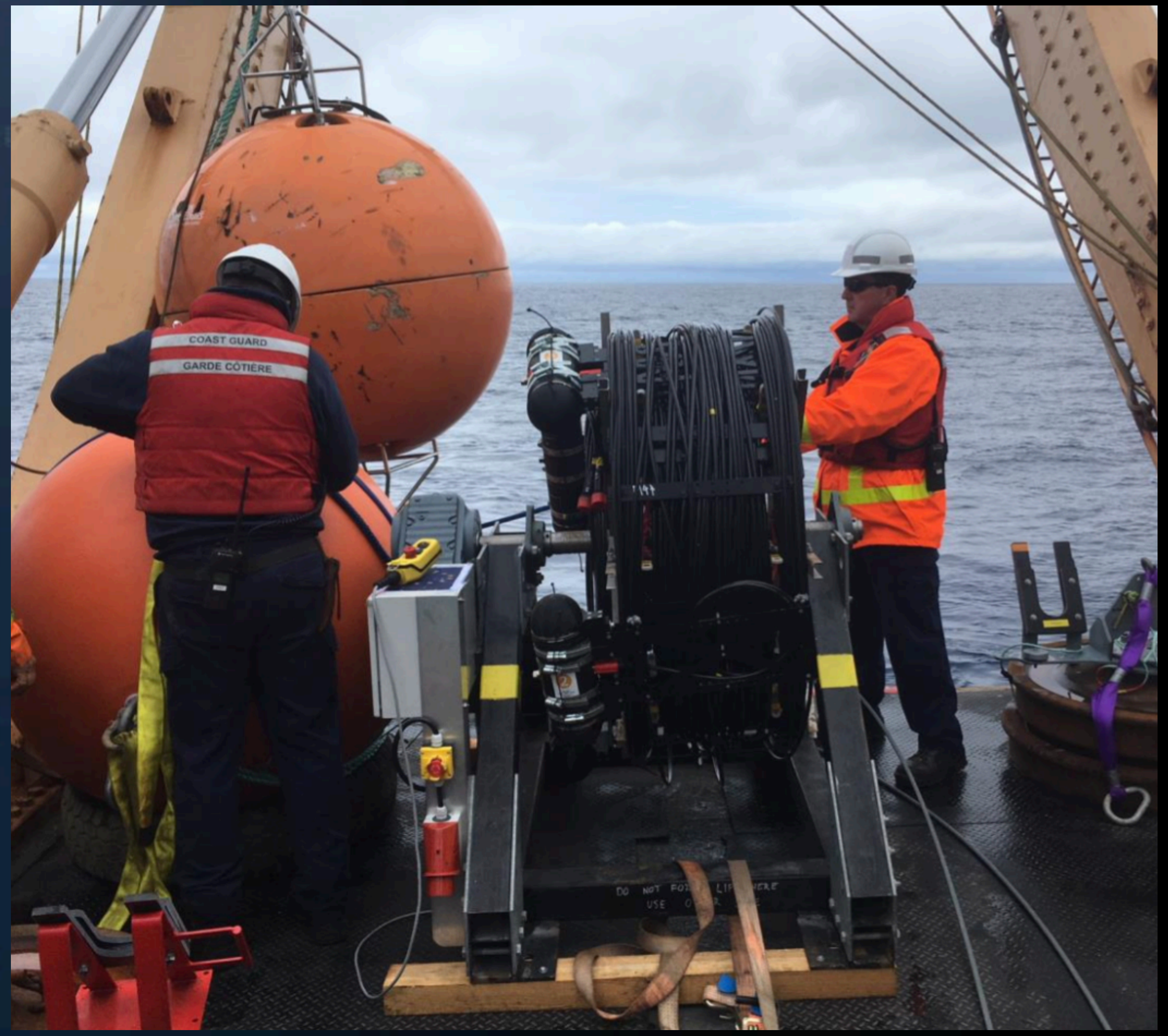

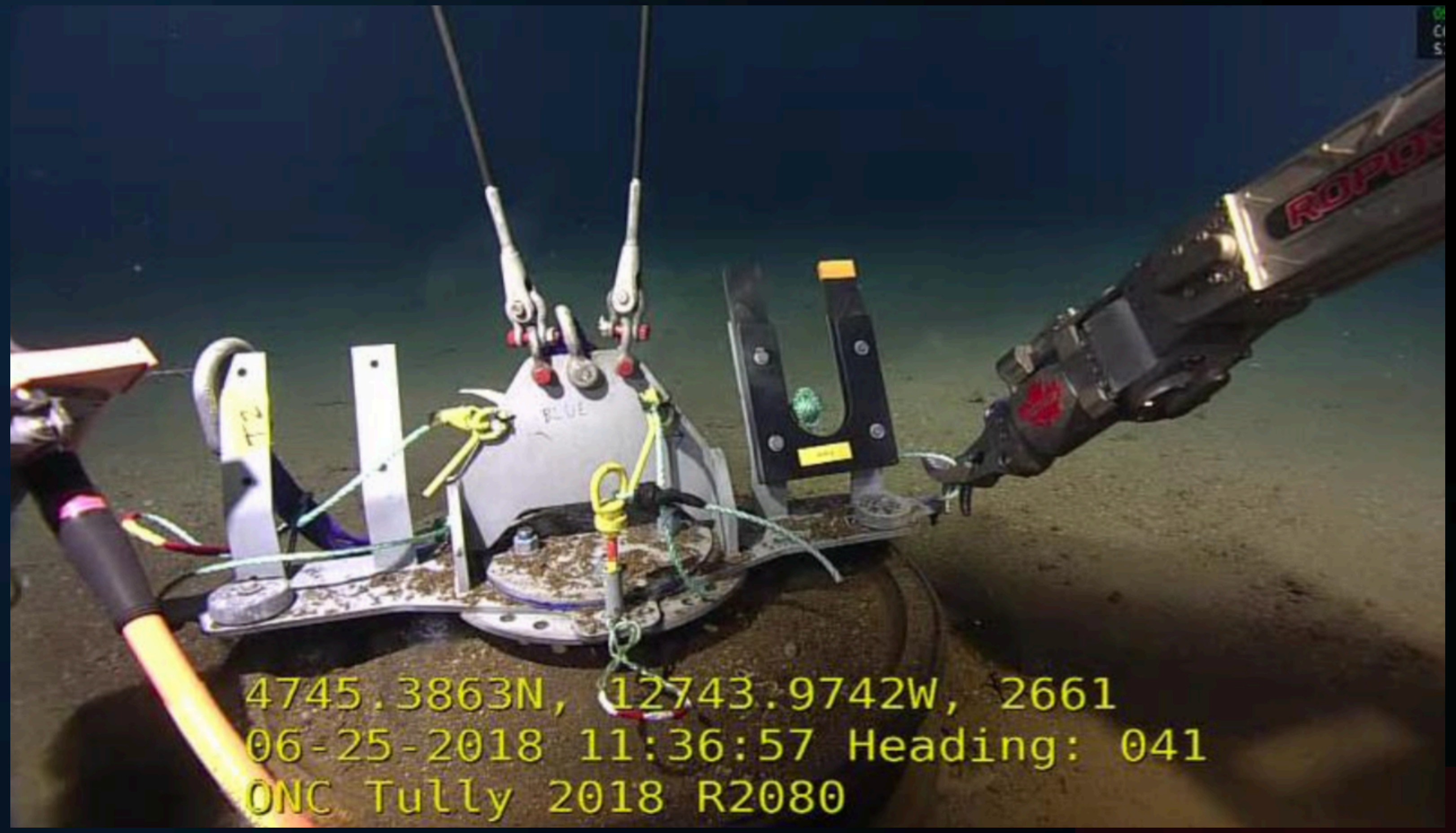

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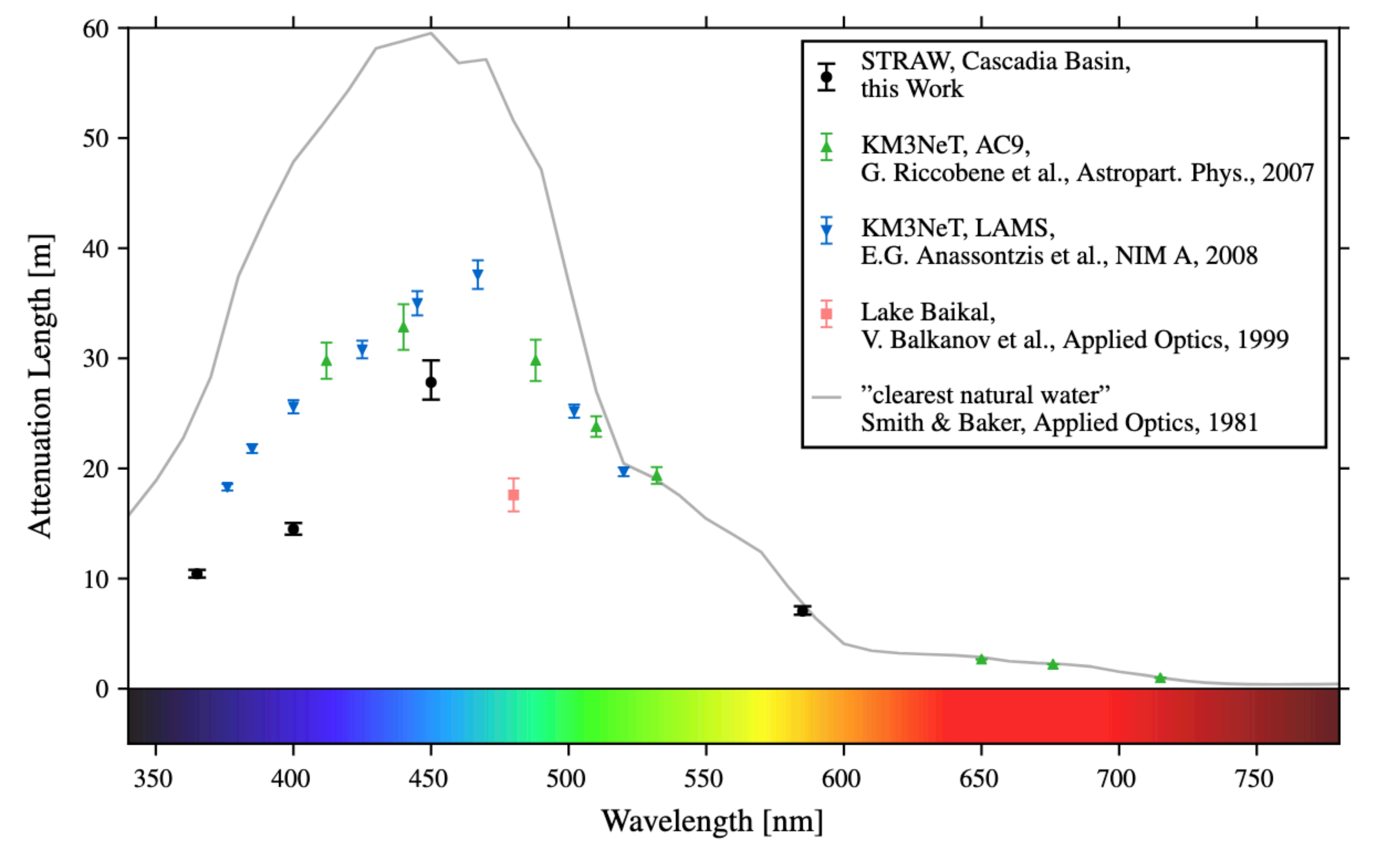
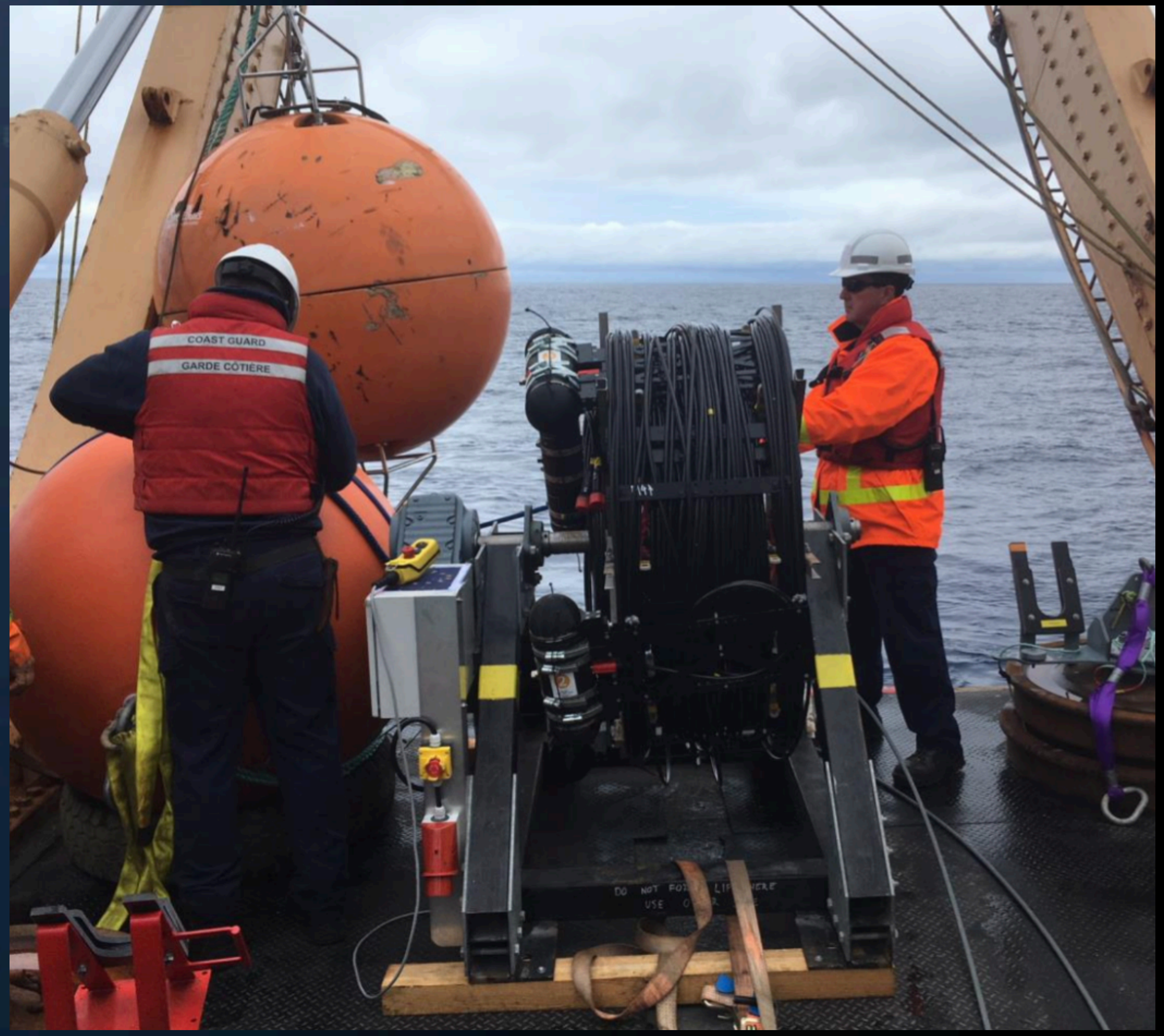
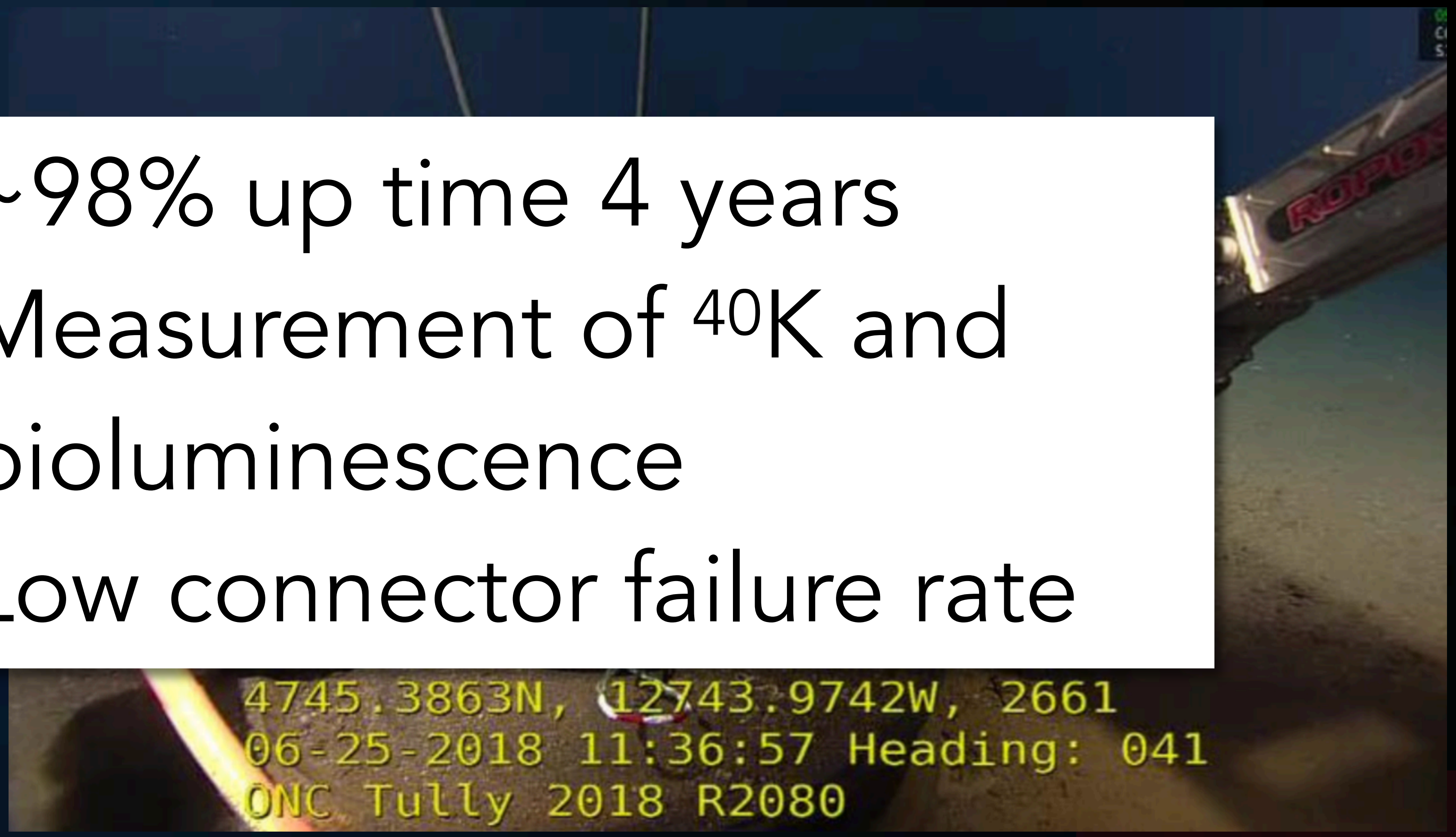


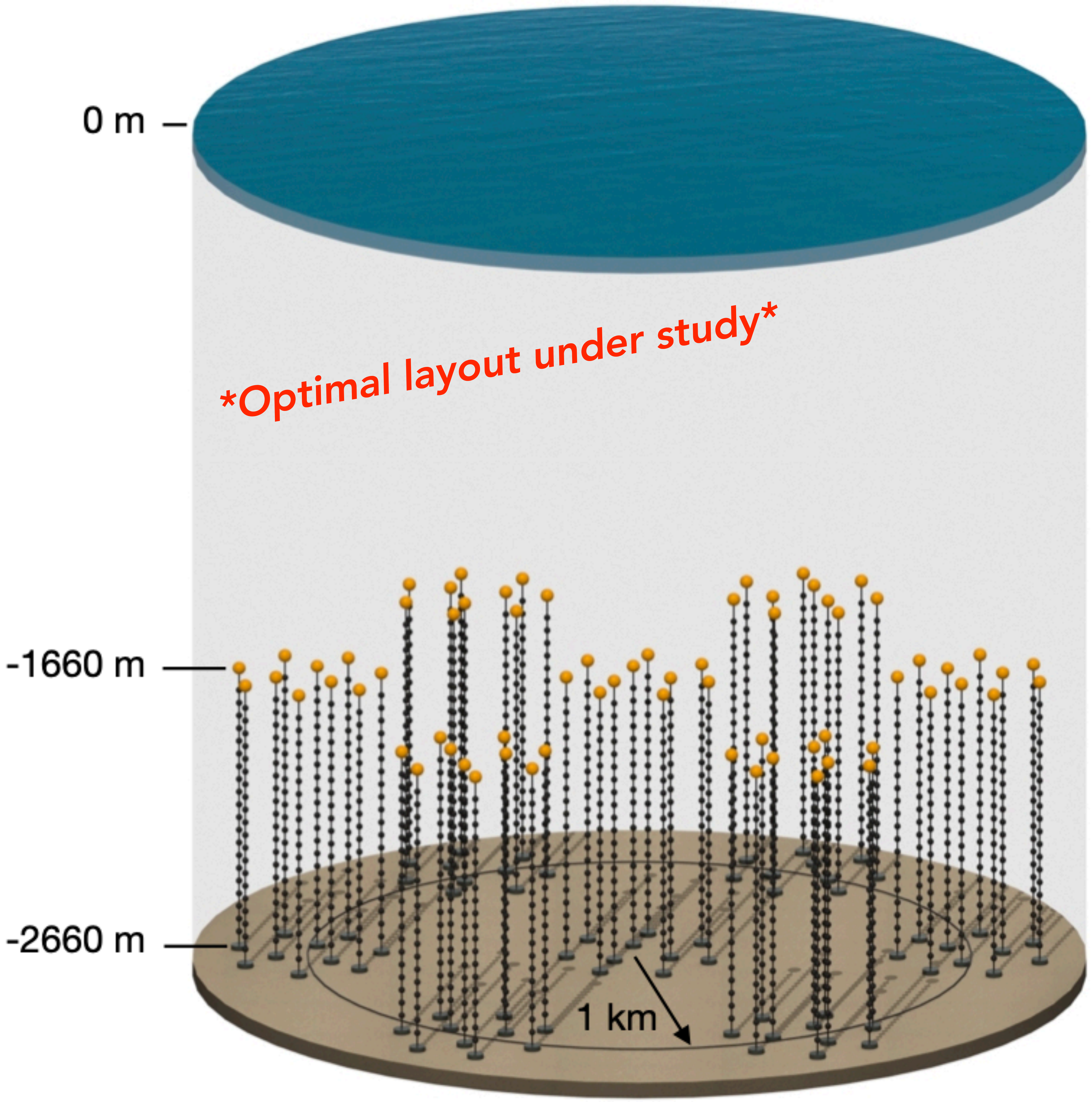




- ~98% up time 4 years
- Measurement of ^{40}K and bioluminescence
- Low connector failure rate

P-ONE — The current vision

P-ONE Collaboration, Nature Astronomy (2020)



A NEW MULTI-KM^3 $\boldsymbol{\nu}$-TELESCOPE

LEVERAGING ONC INFRASTRUCTURE

INNOVATIVE DETECTOR DESIGNS PAIRED WITH PROVEN CONCEPTS

SCALABLE TECHNOLOGY

Why a new neutrino telescope?

Neutrino telescope(s) sensitive to TeV-PeV cosmic neutrinos: only ONE

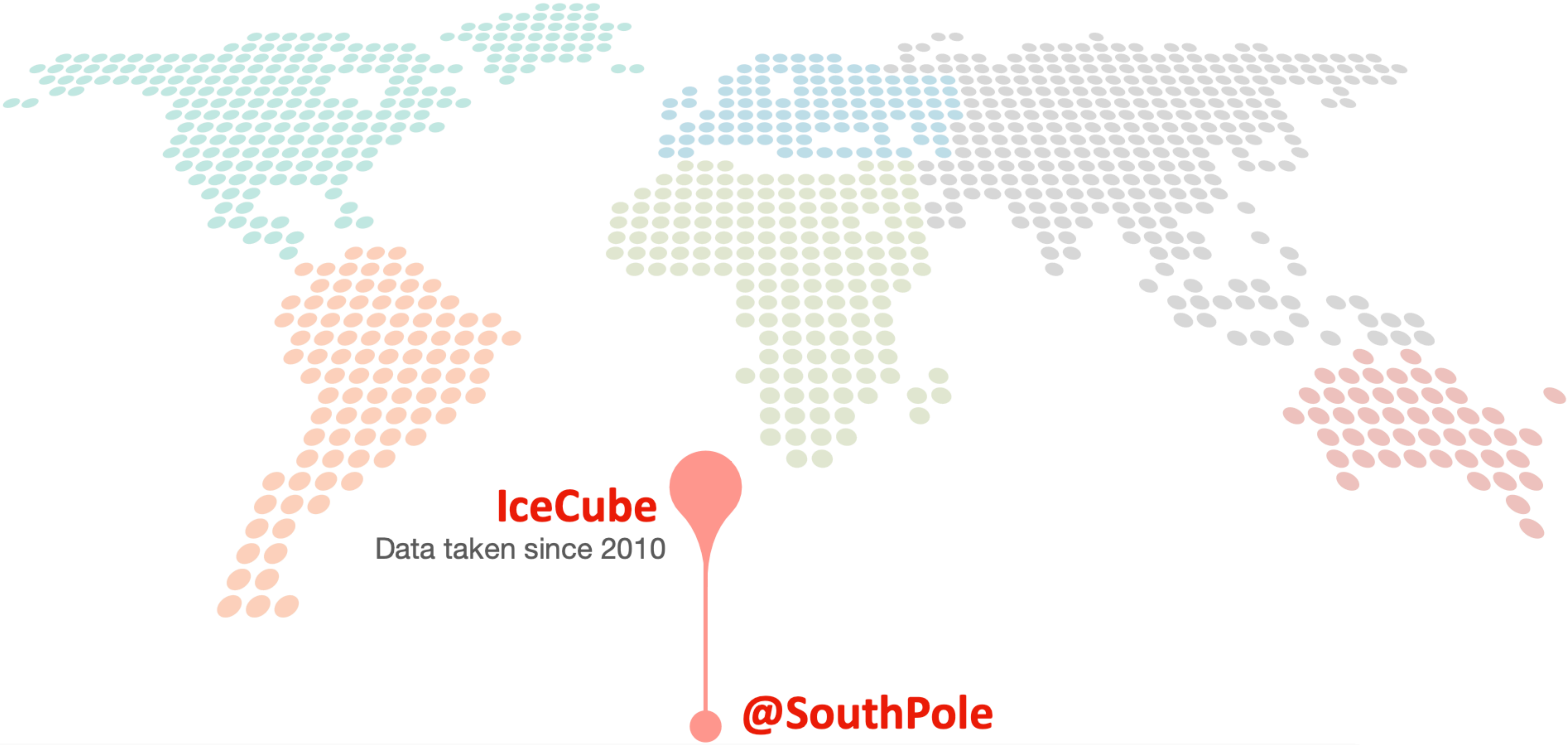


image E. Resconi

Why a new neutrino telescope?

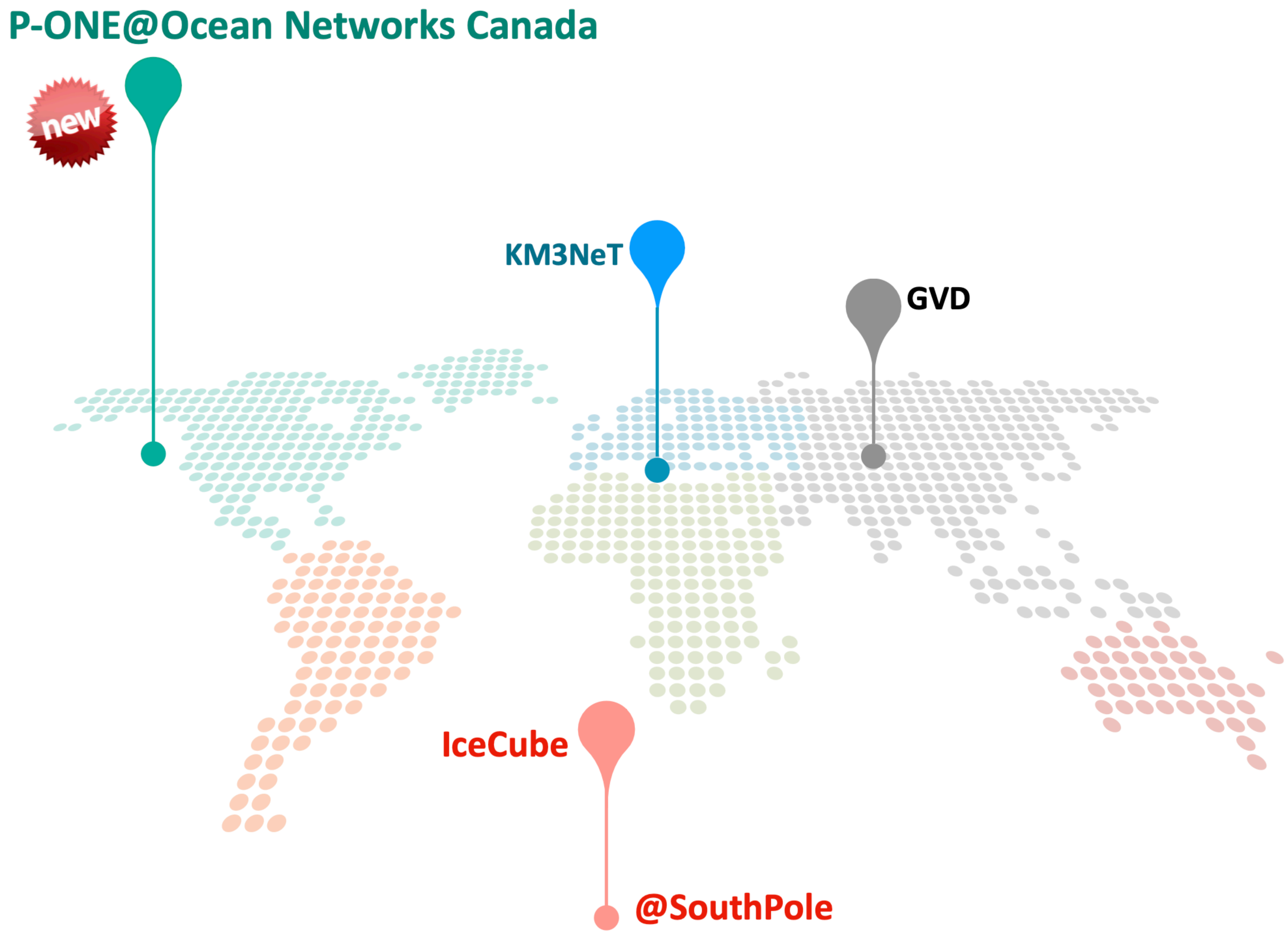
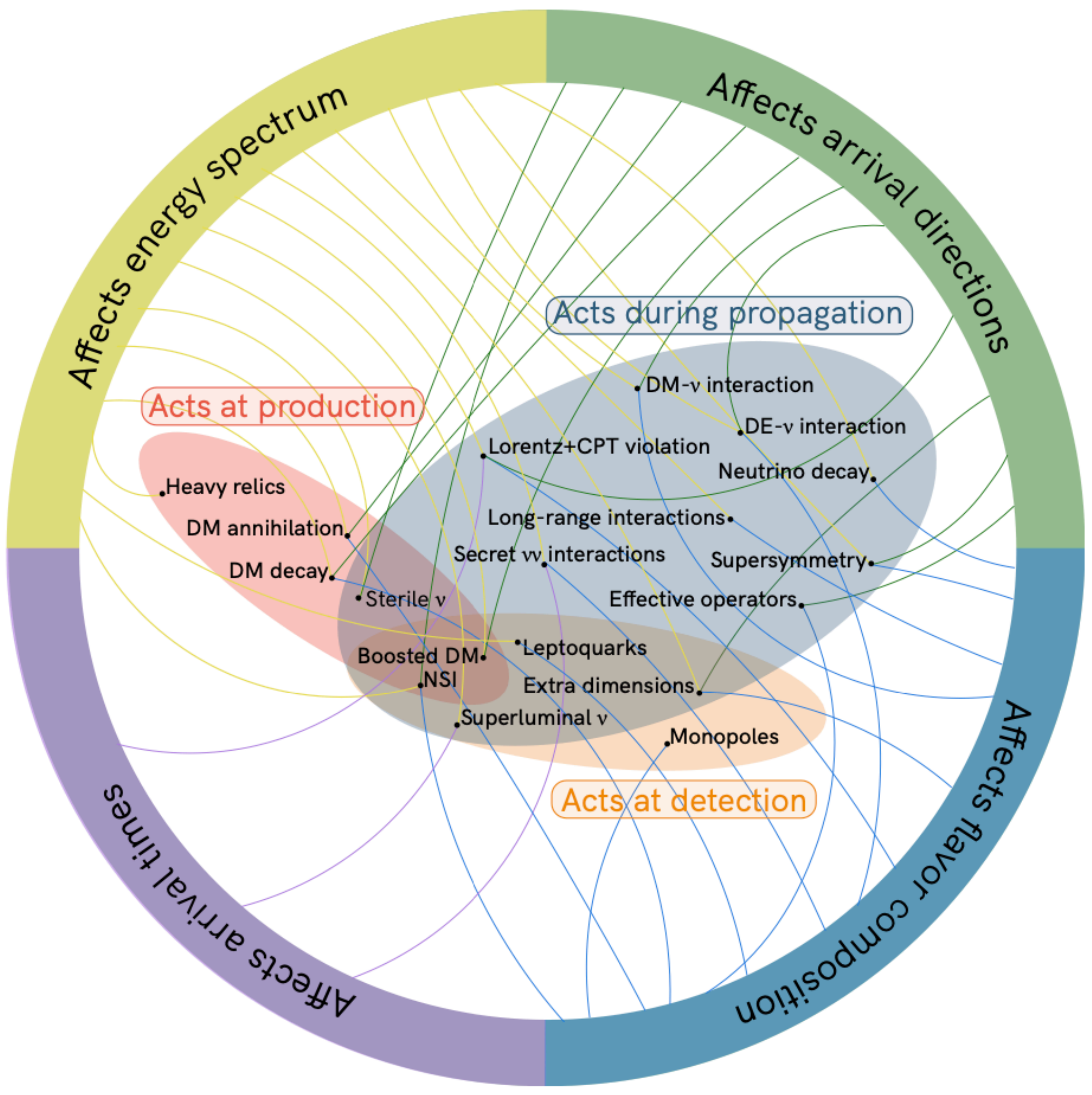


image E. Resconi

Why high-energy neutrinos



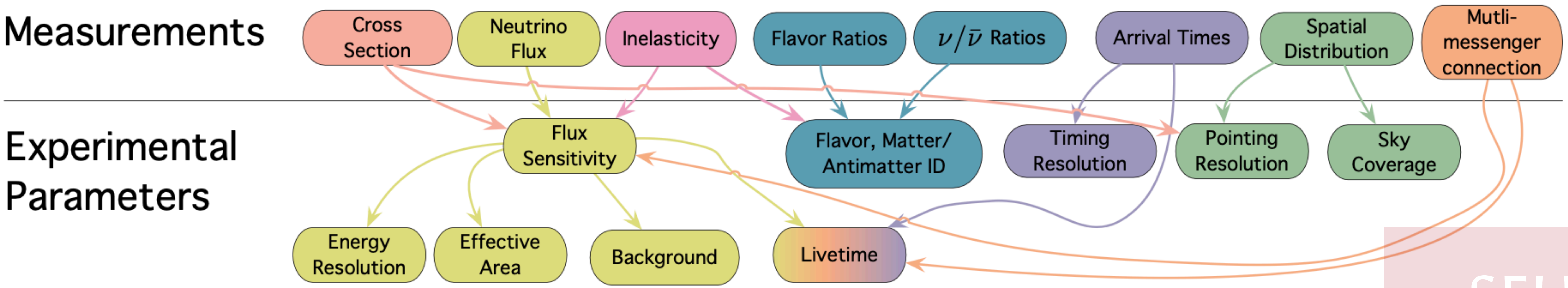
Learn about the darkest and most energetic mechanisms in the universe & the neutrino itself!

Particle Physics

Probe neutrino properties, interactions, and fundamental symmetries at the highest energies

Astrophysics

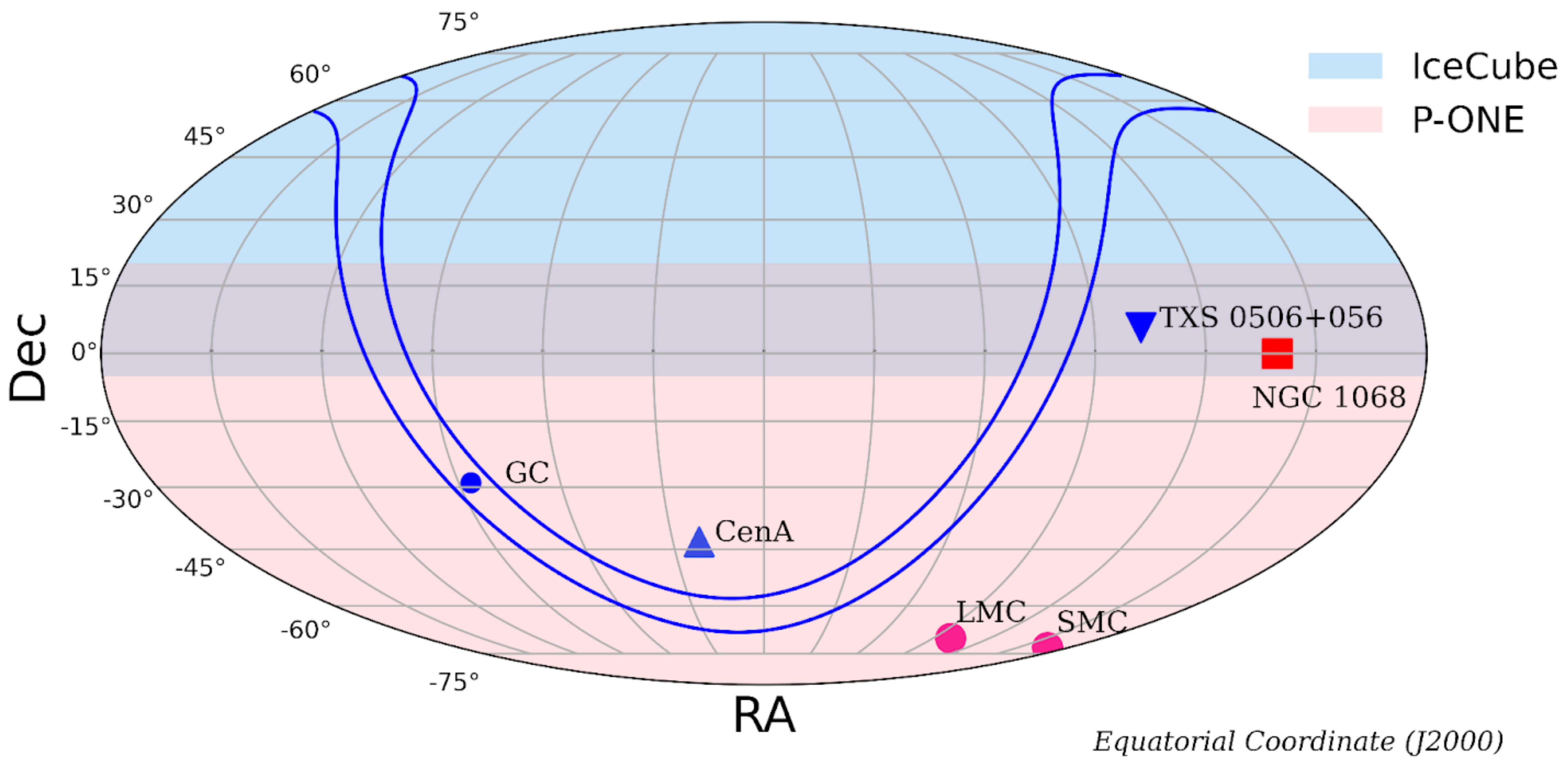
Discover & characterize the most energetic astrophysical sources in the universe

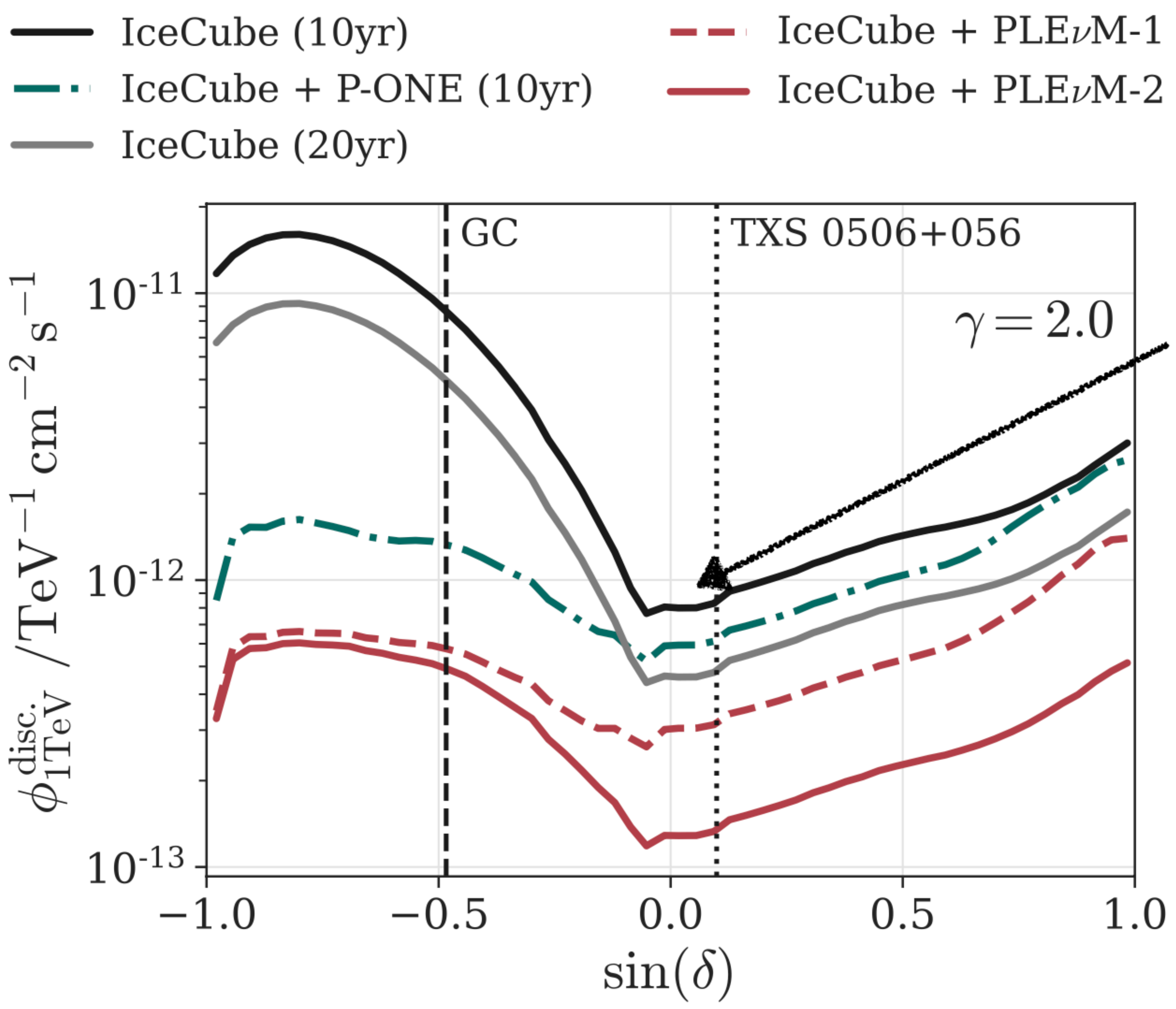


images from SNOWMASS WP, arXiv:2203.08096

Why high-energy neutrinos

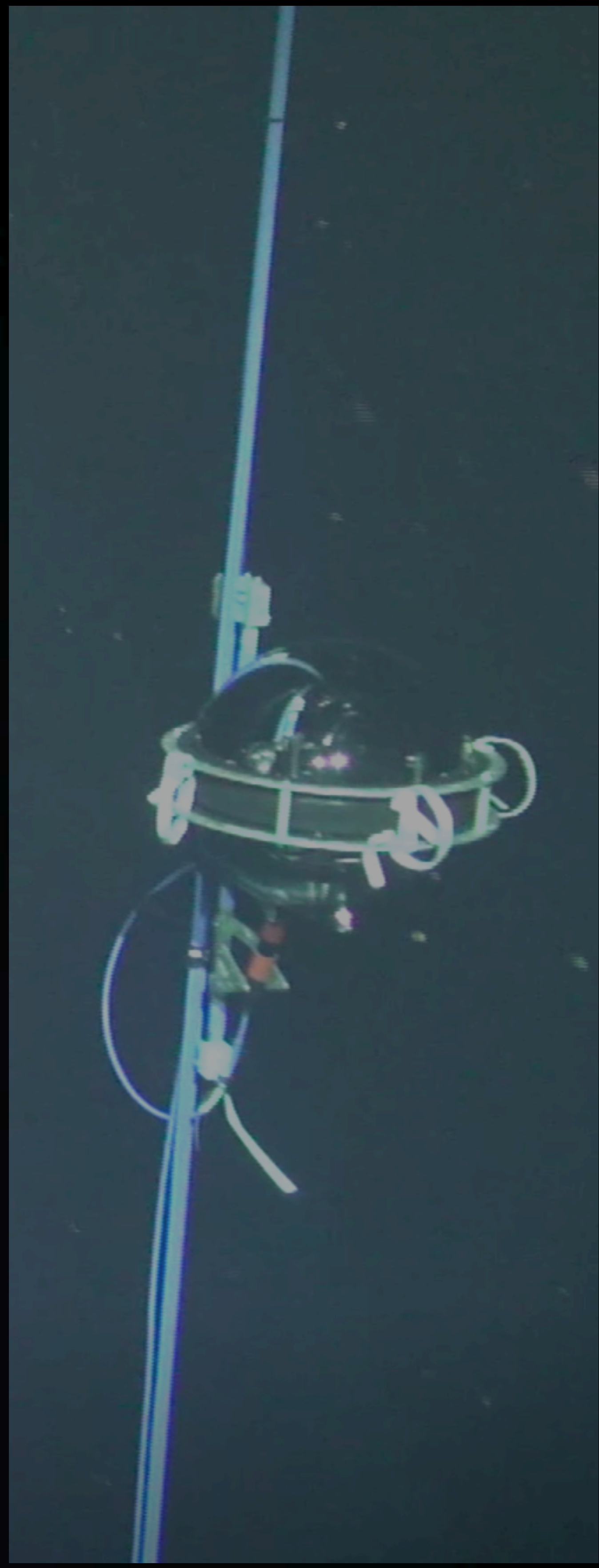
PoS(ICRC2021)1185



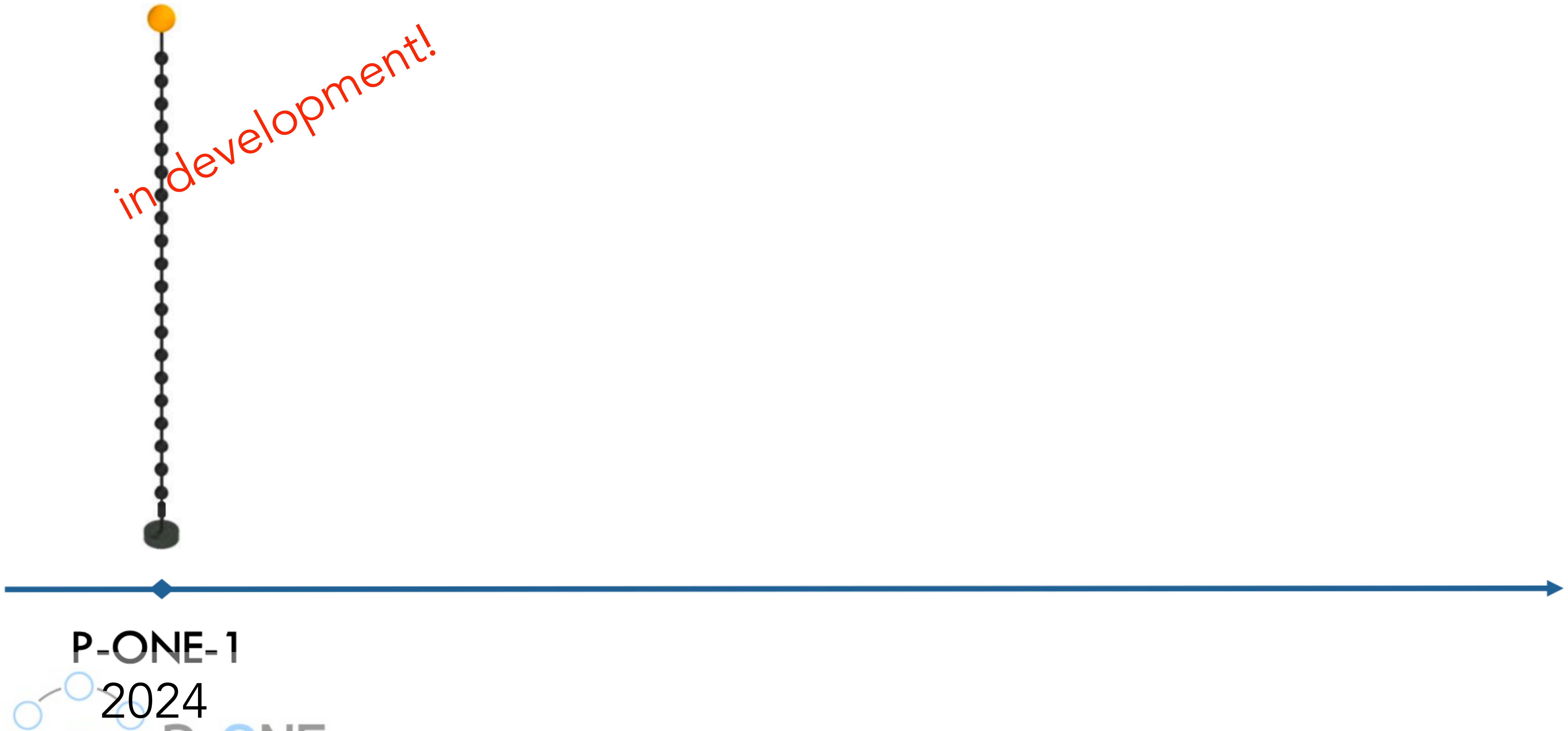


FIRST HINTS OF SOURCES FROM ICECUBE

— P-ONE project status—

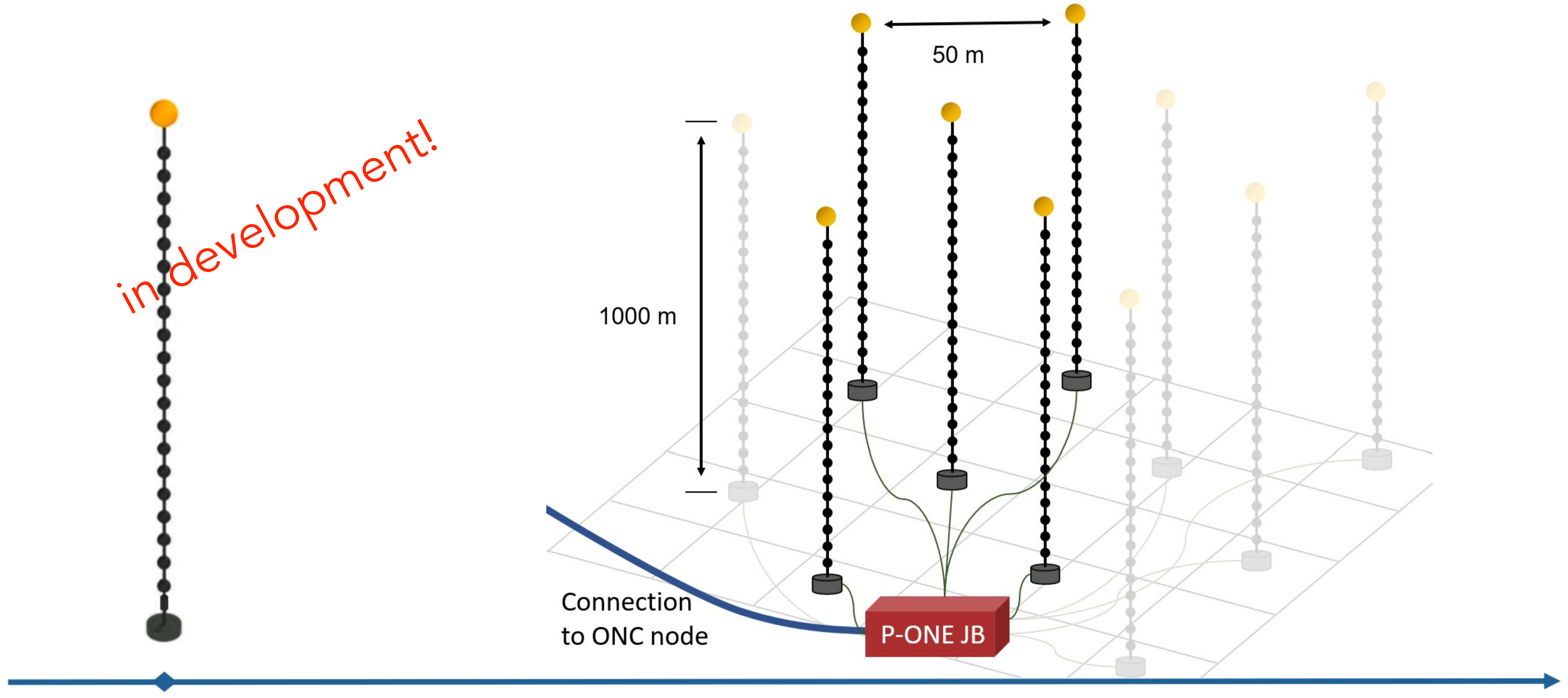


P-ONE — time-line



P-ONE — time-line

- Partially funded by ERC (3 lines)
- 2022 CFI-IF in preparation (2 lines + crucial infrastructure)
- US-partner application to complete demonstrator



P-ONE-1
2024

P-ONE demonstrator
2024 - 2027

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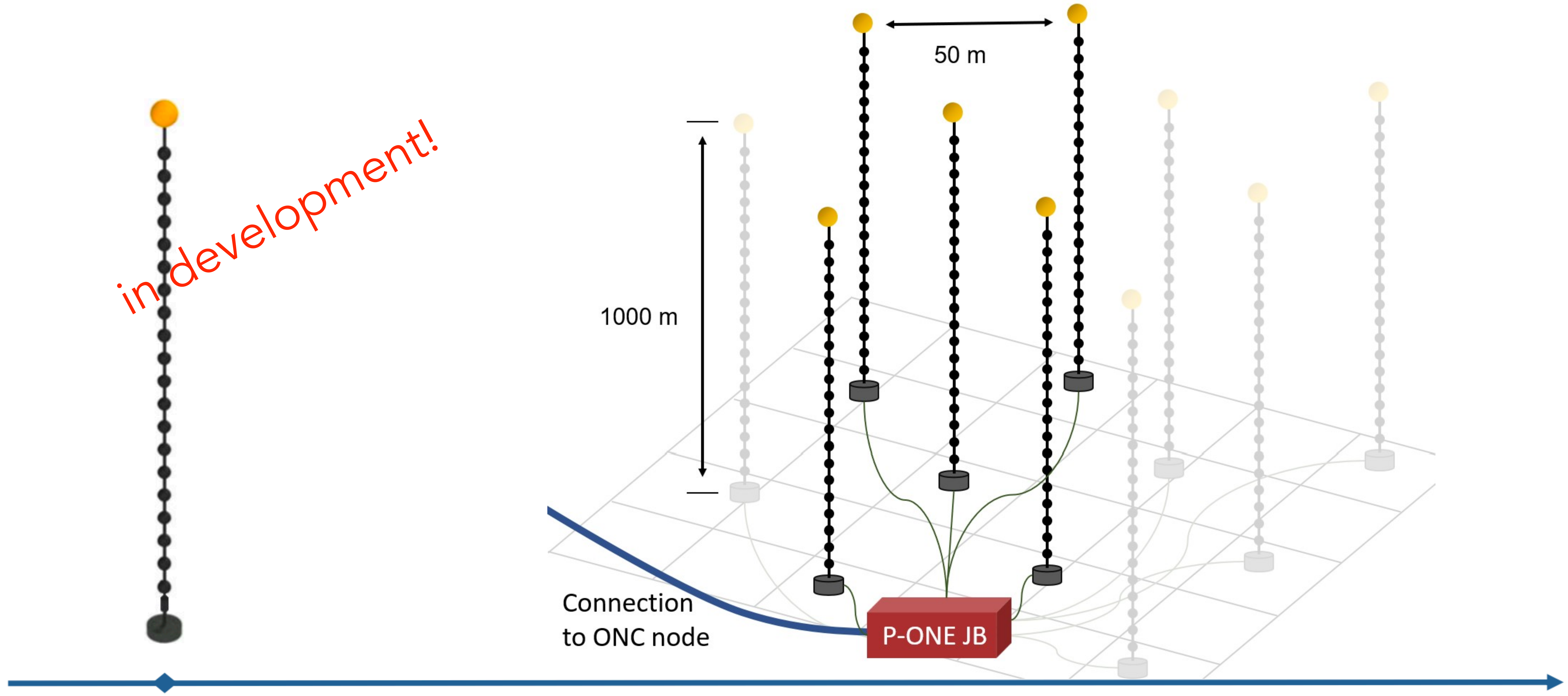
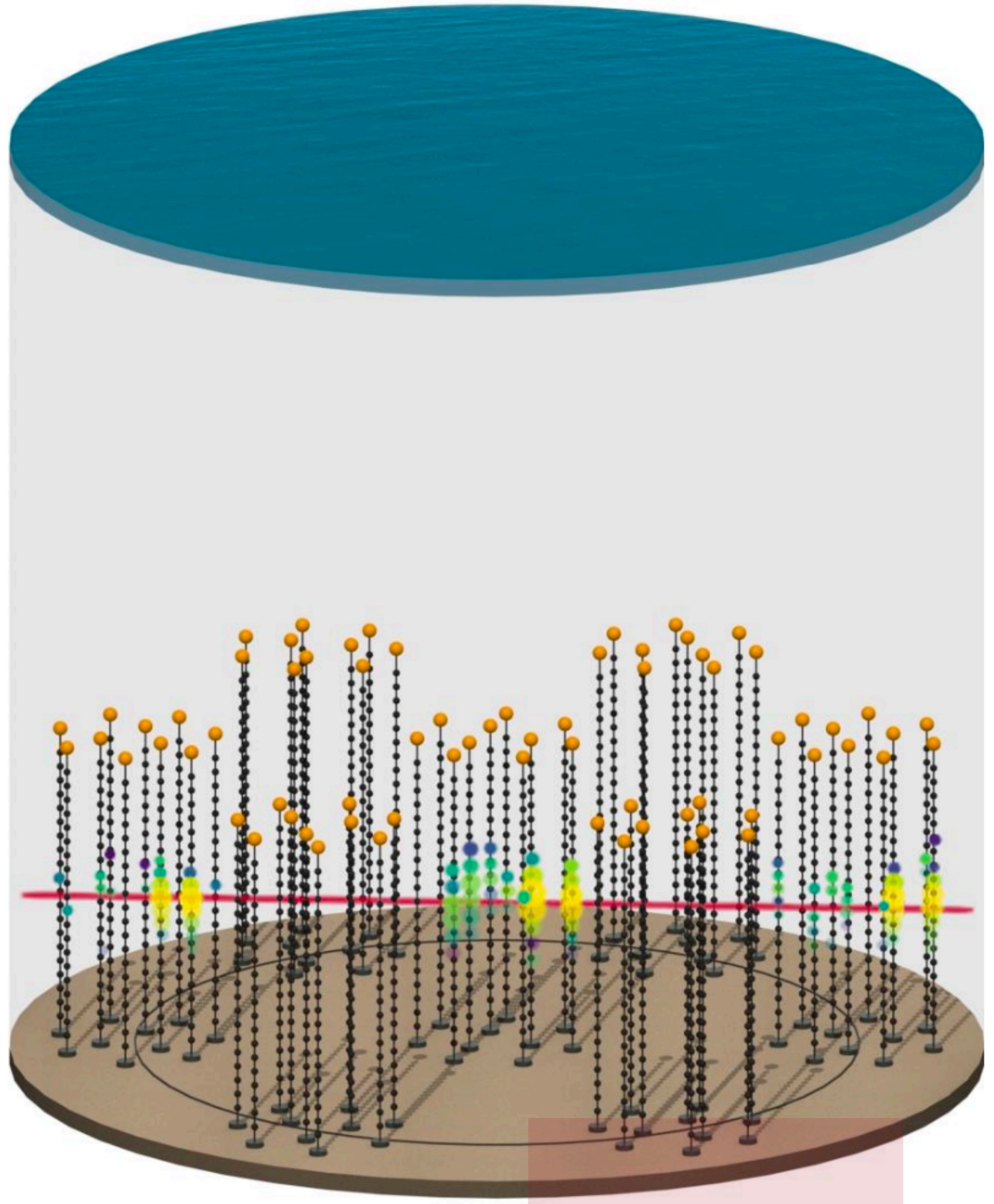
Launch the *Pacific Ocean Neutrino Experiment (P-ONE)*



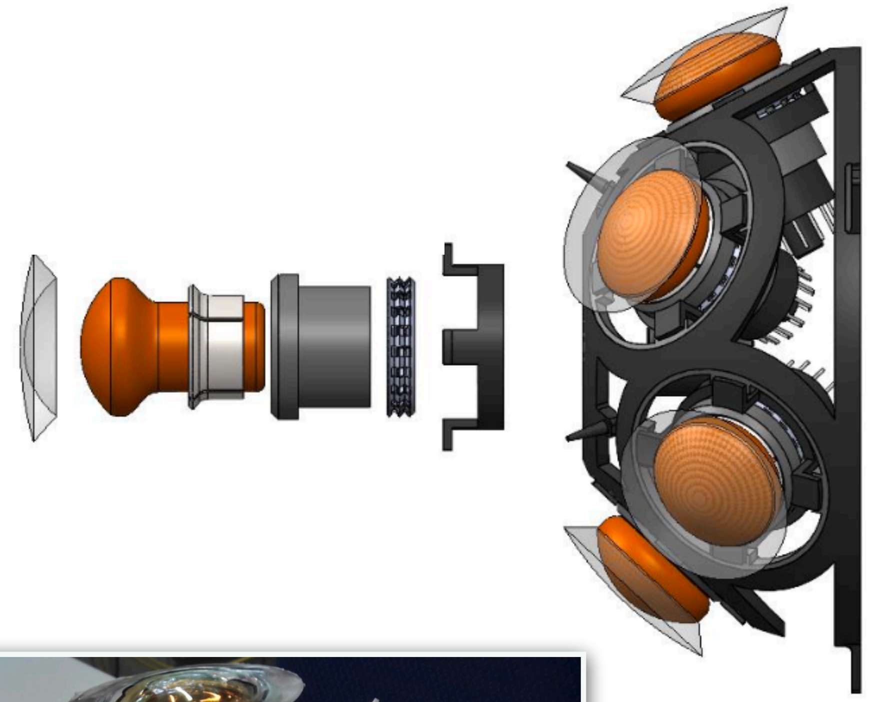


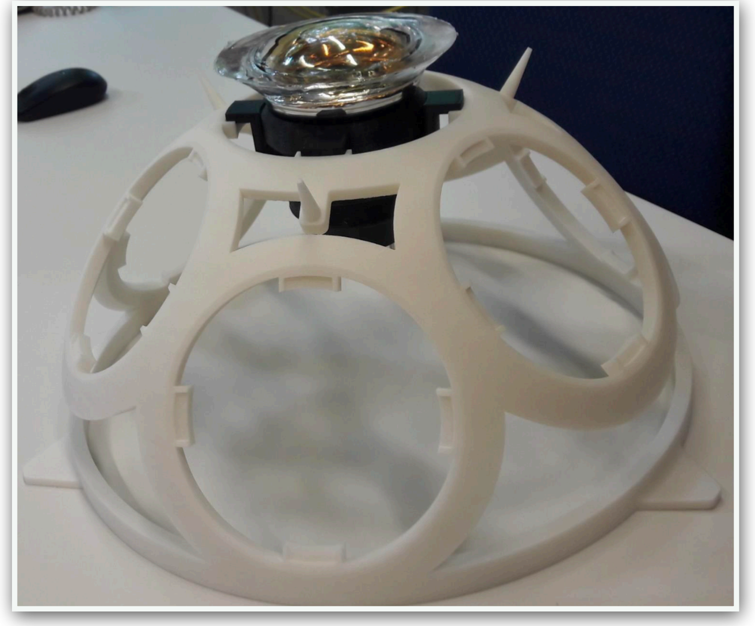
P-ONE-1
2024

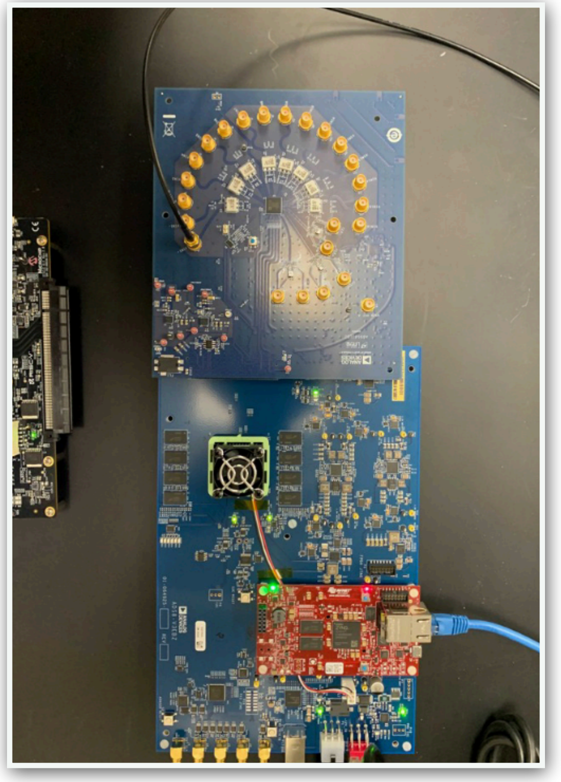
P-ONE demonstrator
2024 - 2027

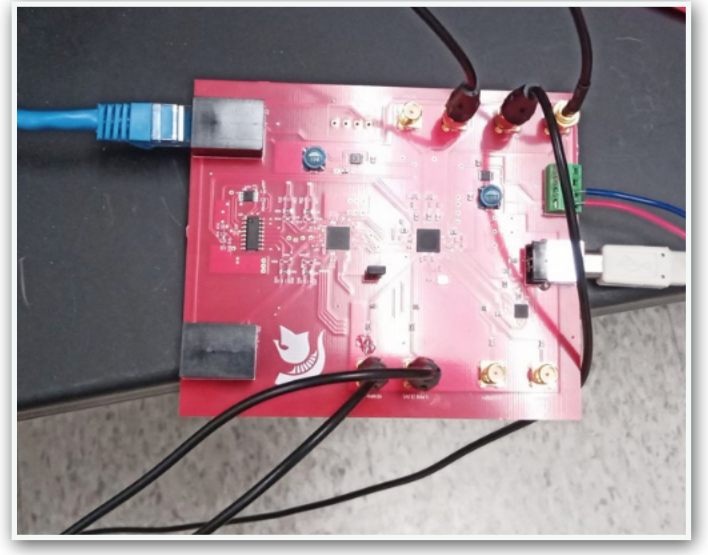
P-ONE — prototype line development (2024)

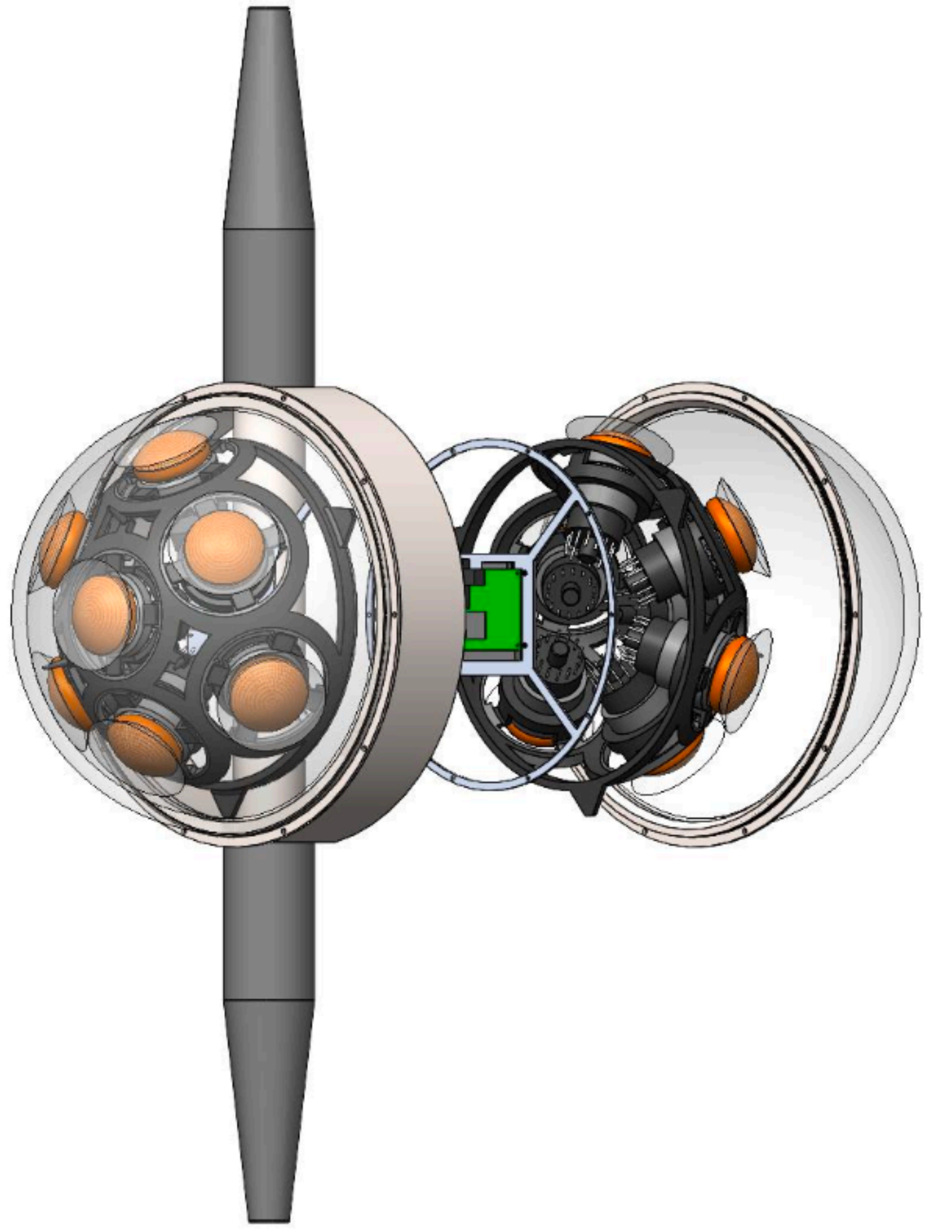
- Construction and deployment of a complete P-ONE mooring line
- Proof and verification of;
  - detector design
  - deployment techniques
  - positioning calibration

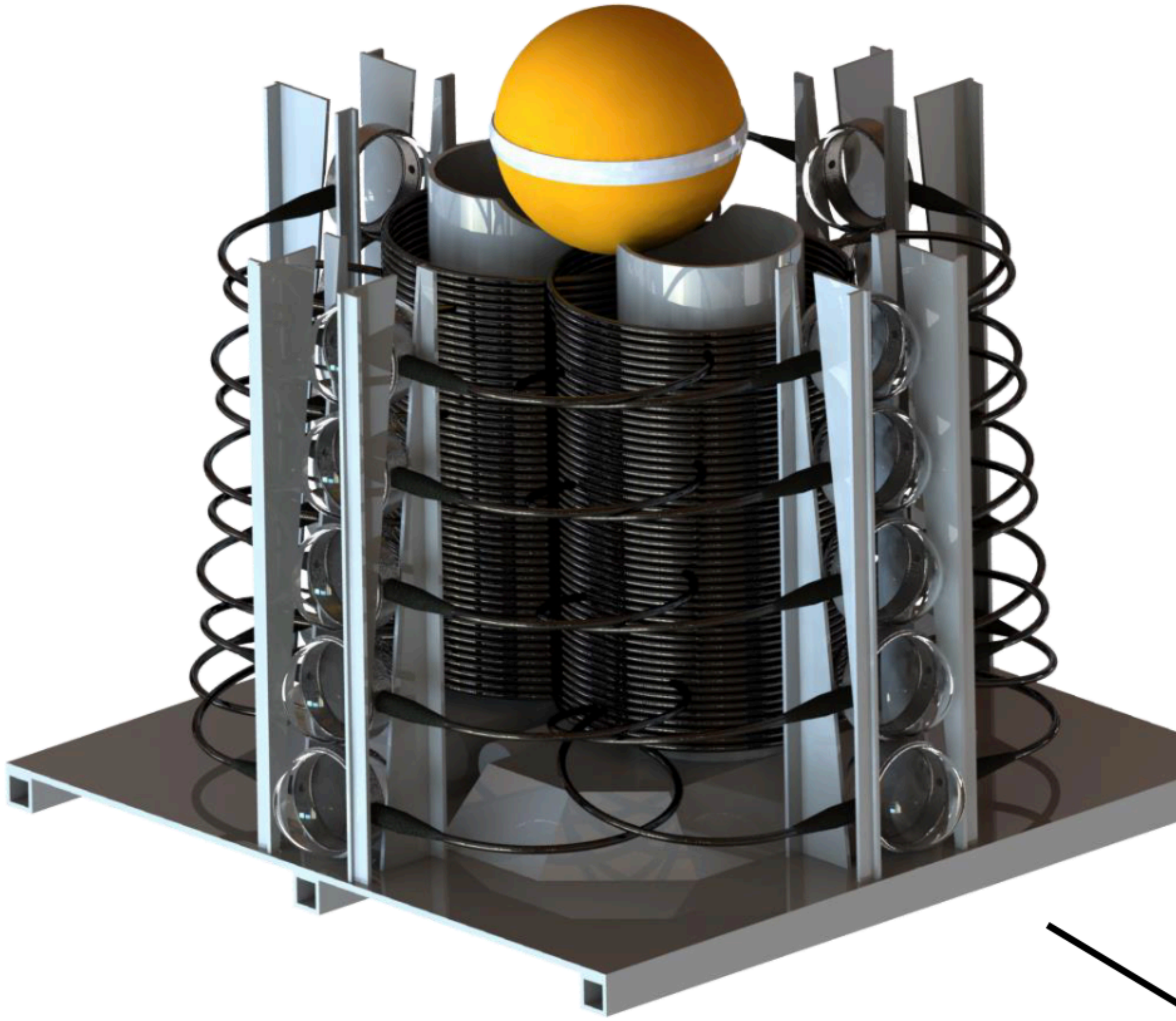












Optical Module | In development | 16 pcs

P-ONE — prototype line (2023)

- Construction and deployment of a complete P-ONE mooring line
- Proof and verification of;
  - detector design
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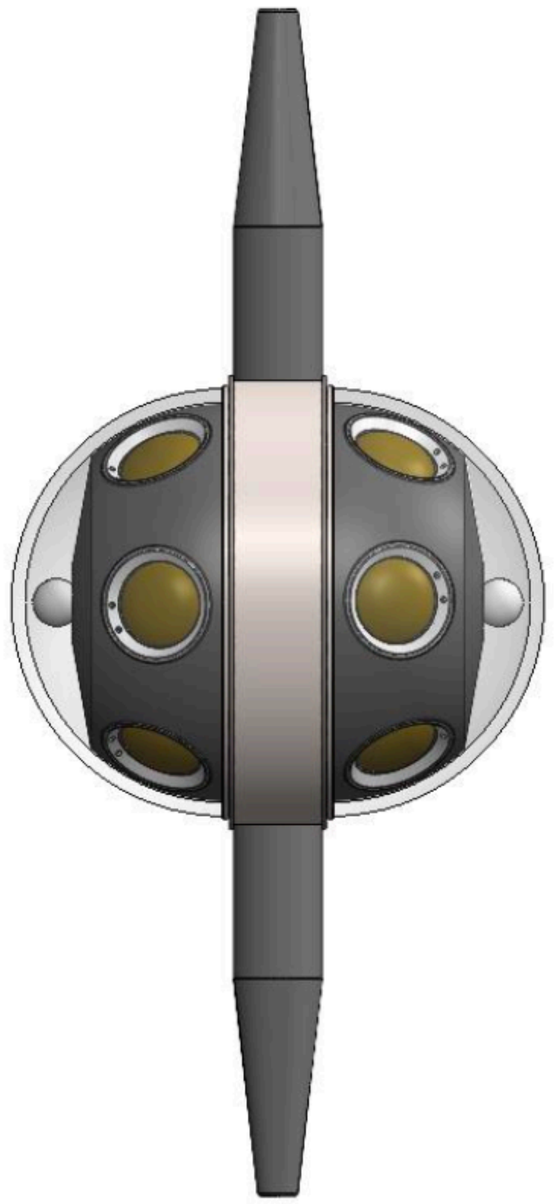
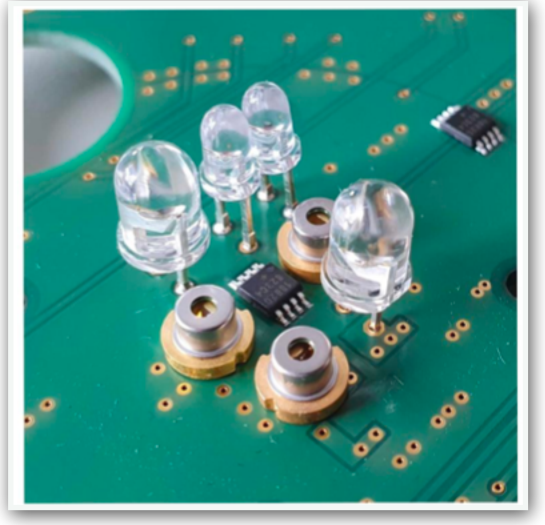
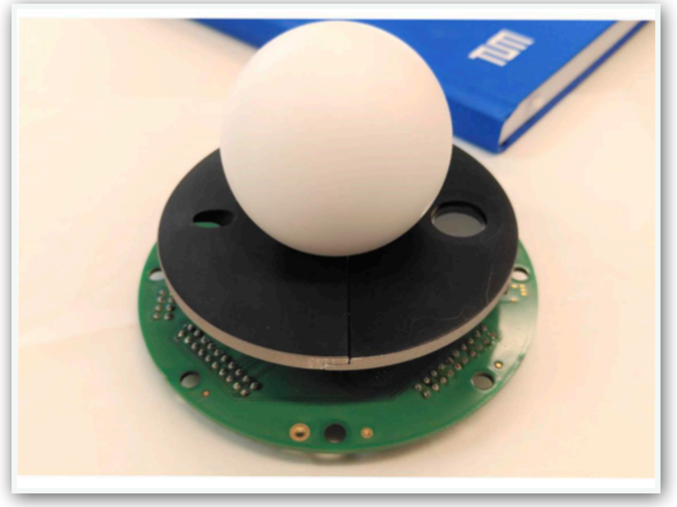
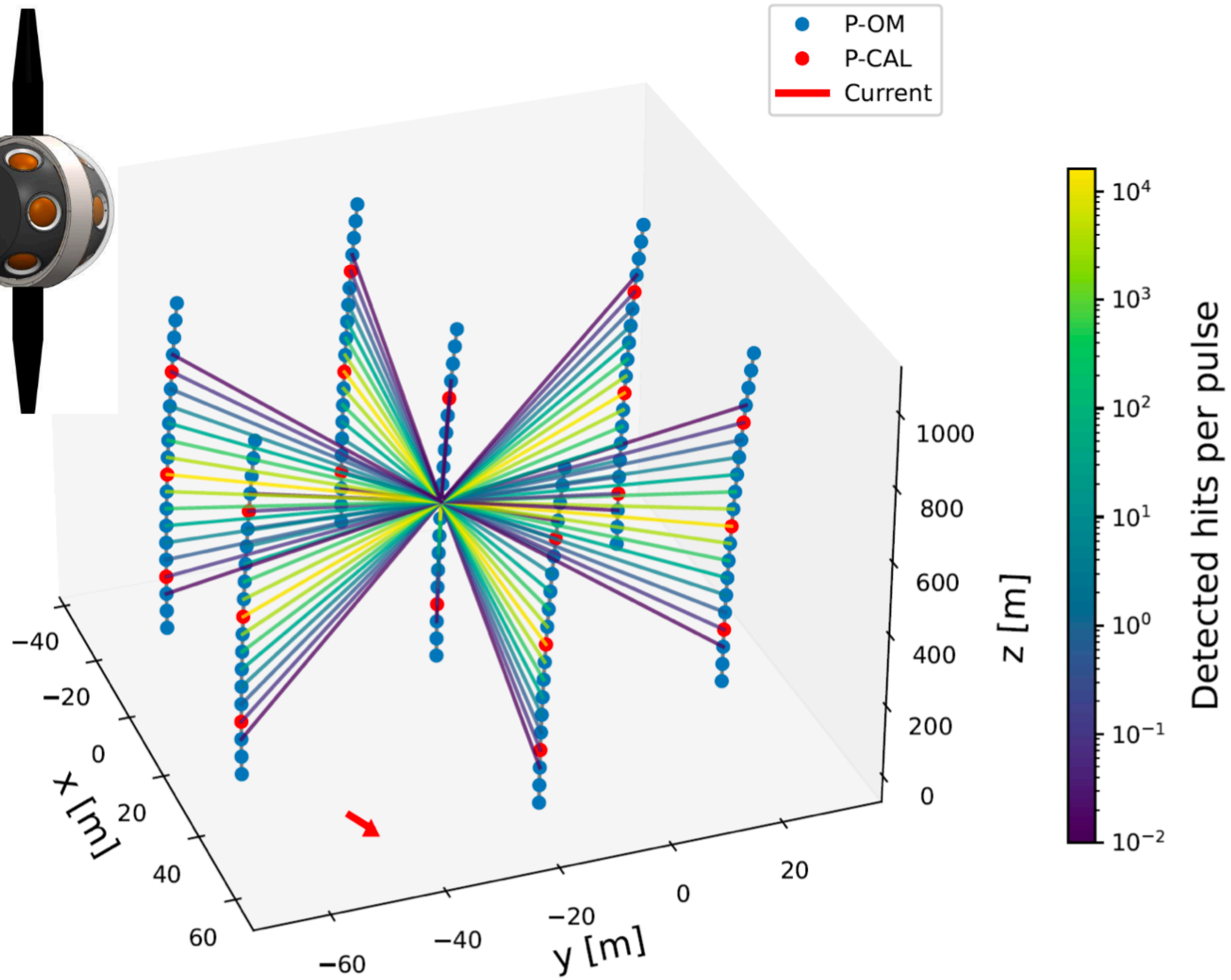
  - positioning calibration









Optical Calibration

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

Calibration Module | **Adapted POCAM** | **4 pcs**

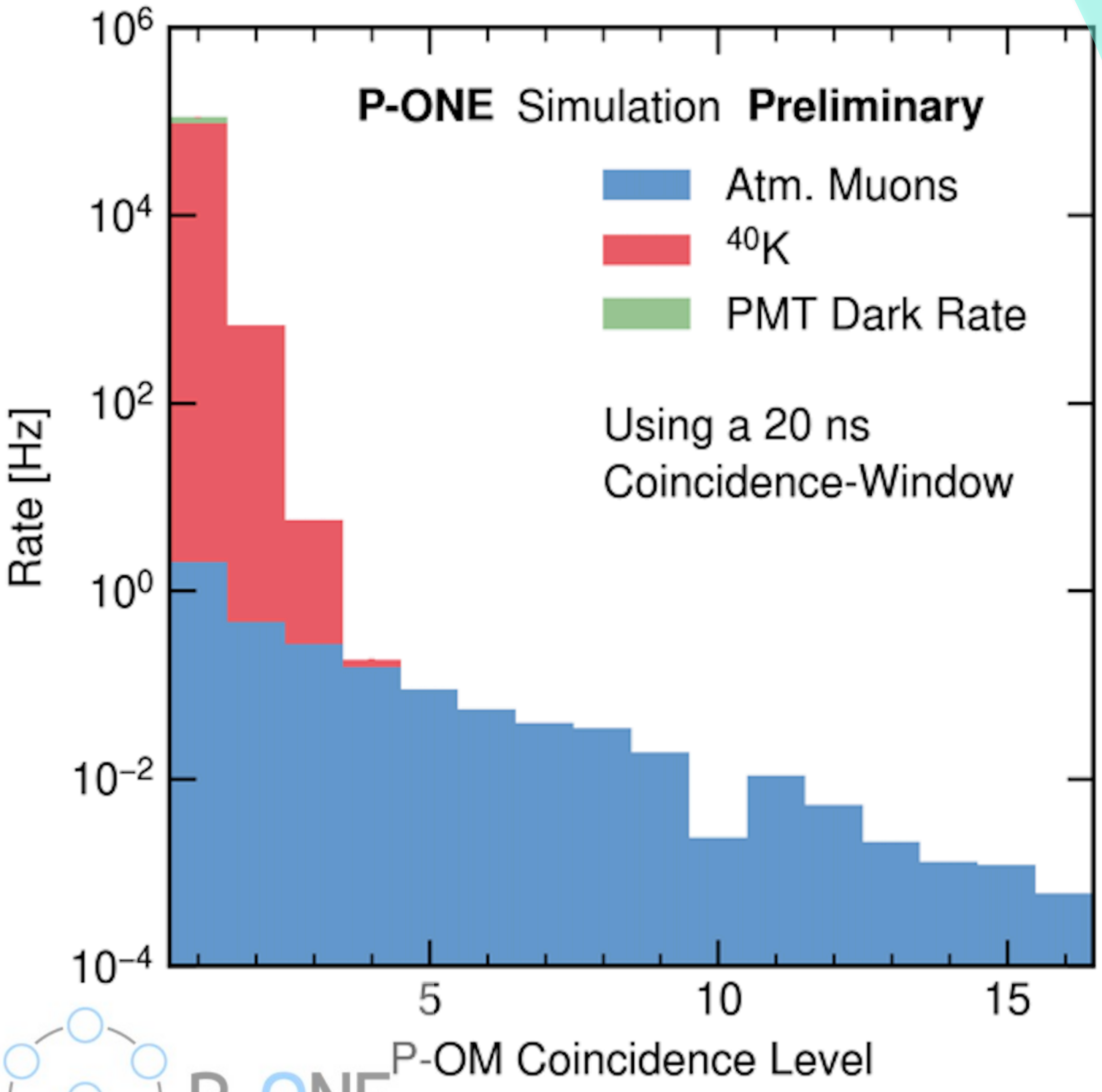
P-ONE demonstrator — Science goals

COMMISSIONING! PROOF OF CONCEPT, SUCCESSFUL OPERATION 100% DUTY CYCLE

SFU SIMON FRASER UNIVERSITY

image adapted from E. Resconi

P-ONE demonstrator — Science goals



COMMISSIONING! PROOF OF CONCEPT, SUCCESSFUL OPERATION 100% DUTY CYCLE

CALIBRATION! IN-SITU BACKGROUNDS, DETECTORS, ATMOSPHERIC BACKGROUNDS

image adapted from E. Resconi

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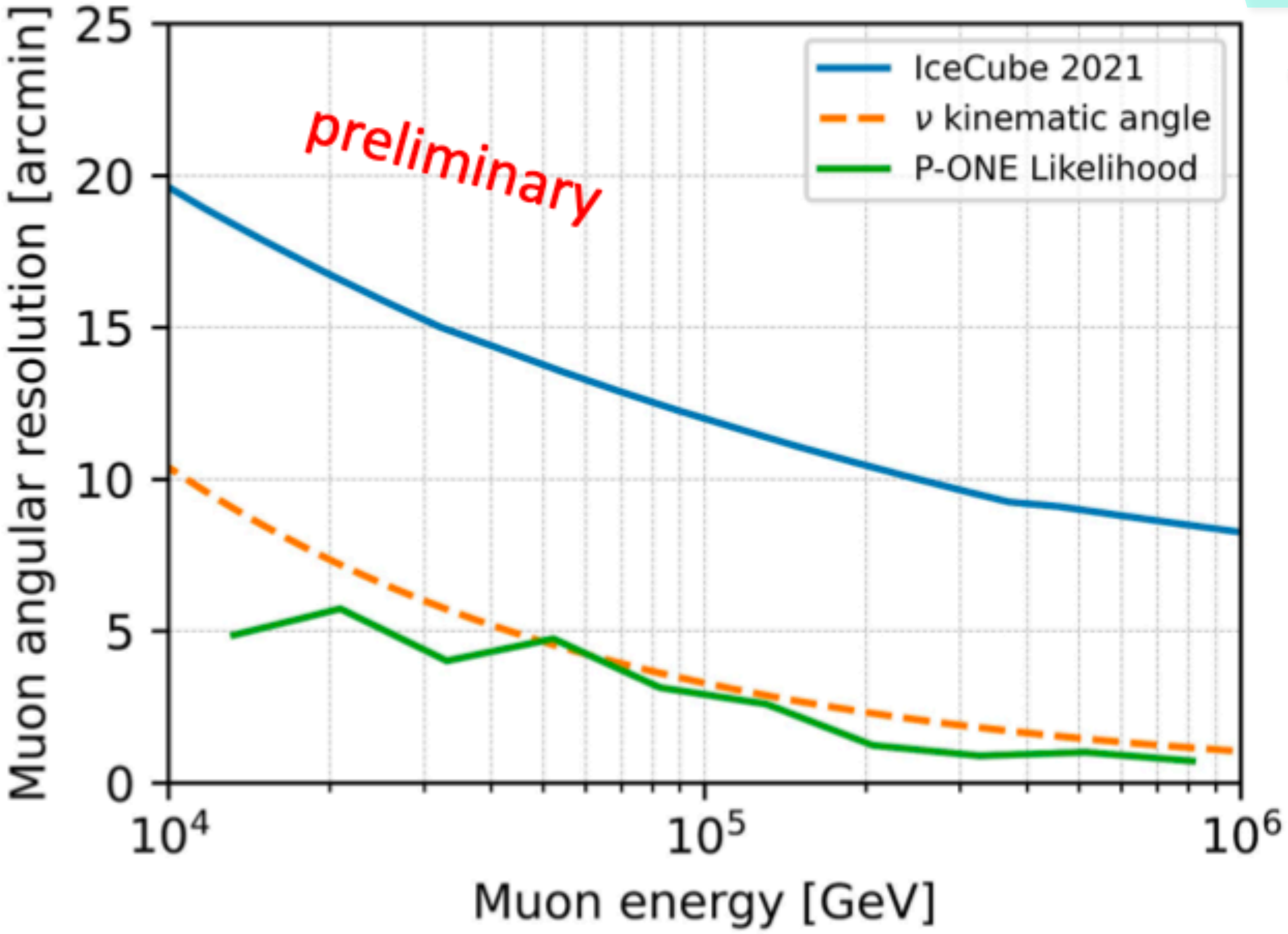
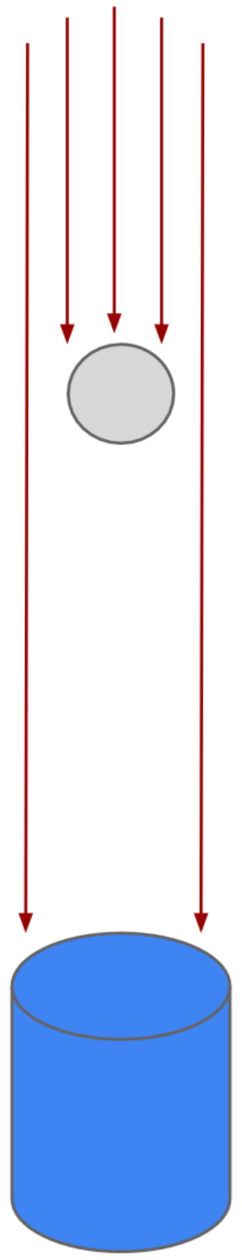
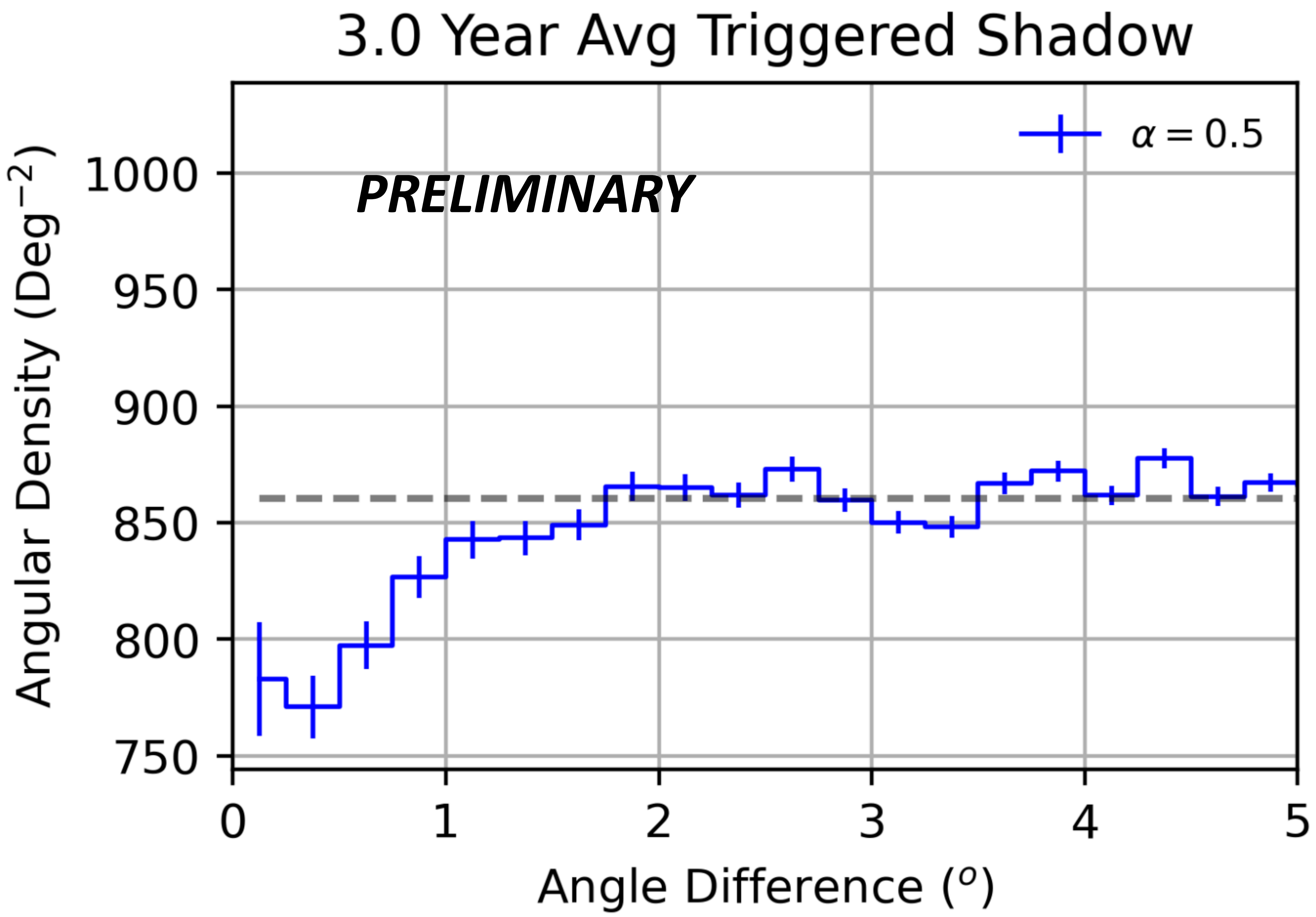
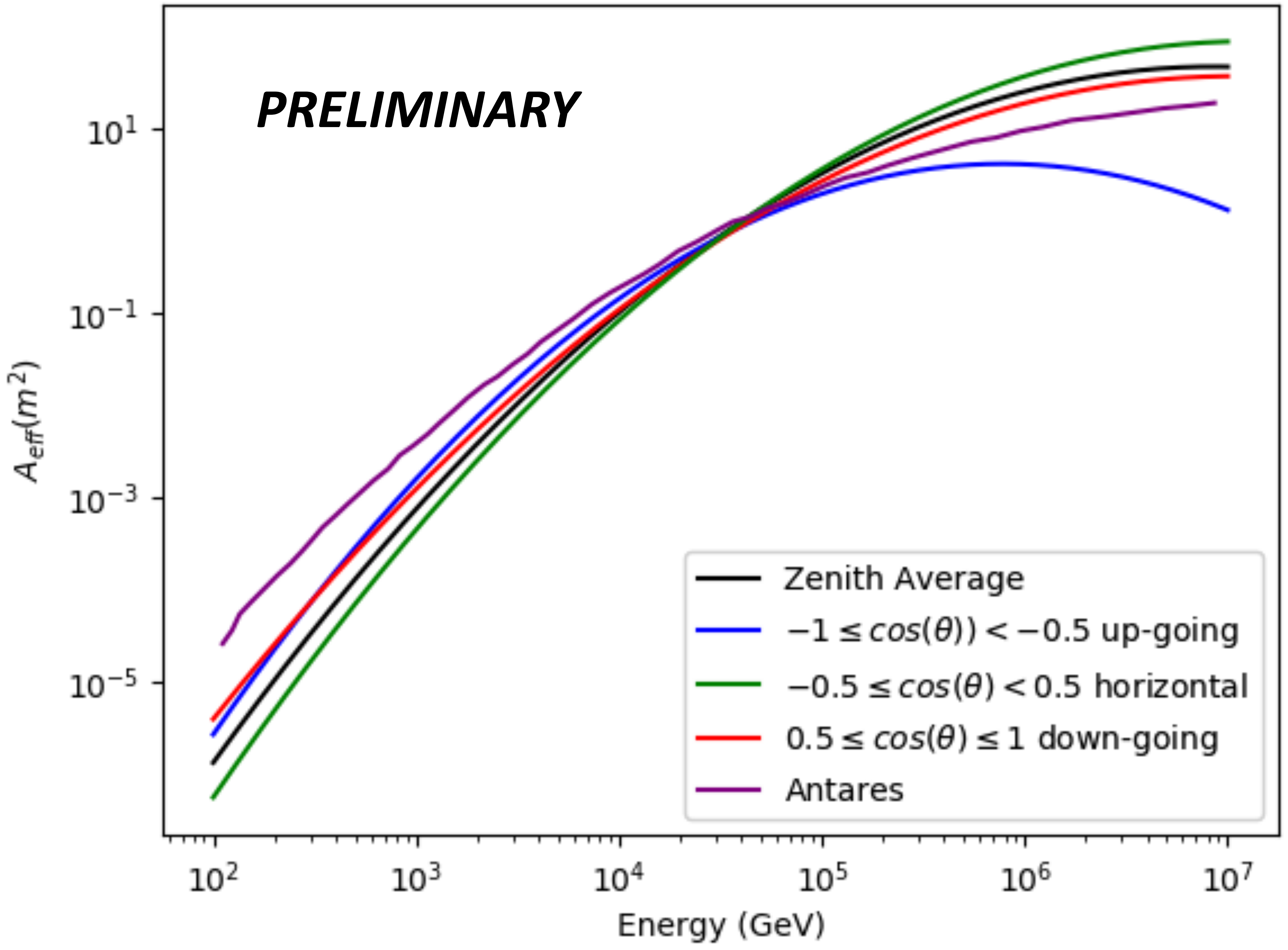






P-ONE demonstrator — Science goals



COMMISSIONING! PROOF OF CONCEPT, SUCCESSFUL OPERATION 100% DUTY CYCLE

CALIBRATION! IN-SITU BACKGROUNDS, DETECTORS, ATMOSPHERIC BACKGROUNDS

PHYSICS GOALS:

- FIRST NEUTRINOS IN PACIFIC OCEAN
- IMPLEMENTATION OF MULTI MESSENGER PROTOCOL
- DEVELOPMENT OF ν-FLAVOUR PARTICLE ID

TRIGGER AN INTERNATIONAL EFFORT (P-ONE) SYNERGETIC OPERATION ν-TELESCOPES

image adapted from E. Resconi

Summary

- Ocean Networks Canada is an exciting opportunity for neutrino physics
- P-ONE is an exciting project for Canadian-based leadership in neutrino physics
- Project is growing fast and we have a clear path towards a P-ONE demonstrator
- New Collaborators are welcome to join and support the efforts!

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

Extras

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**

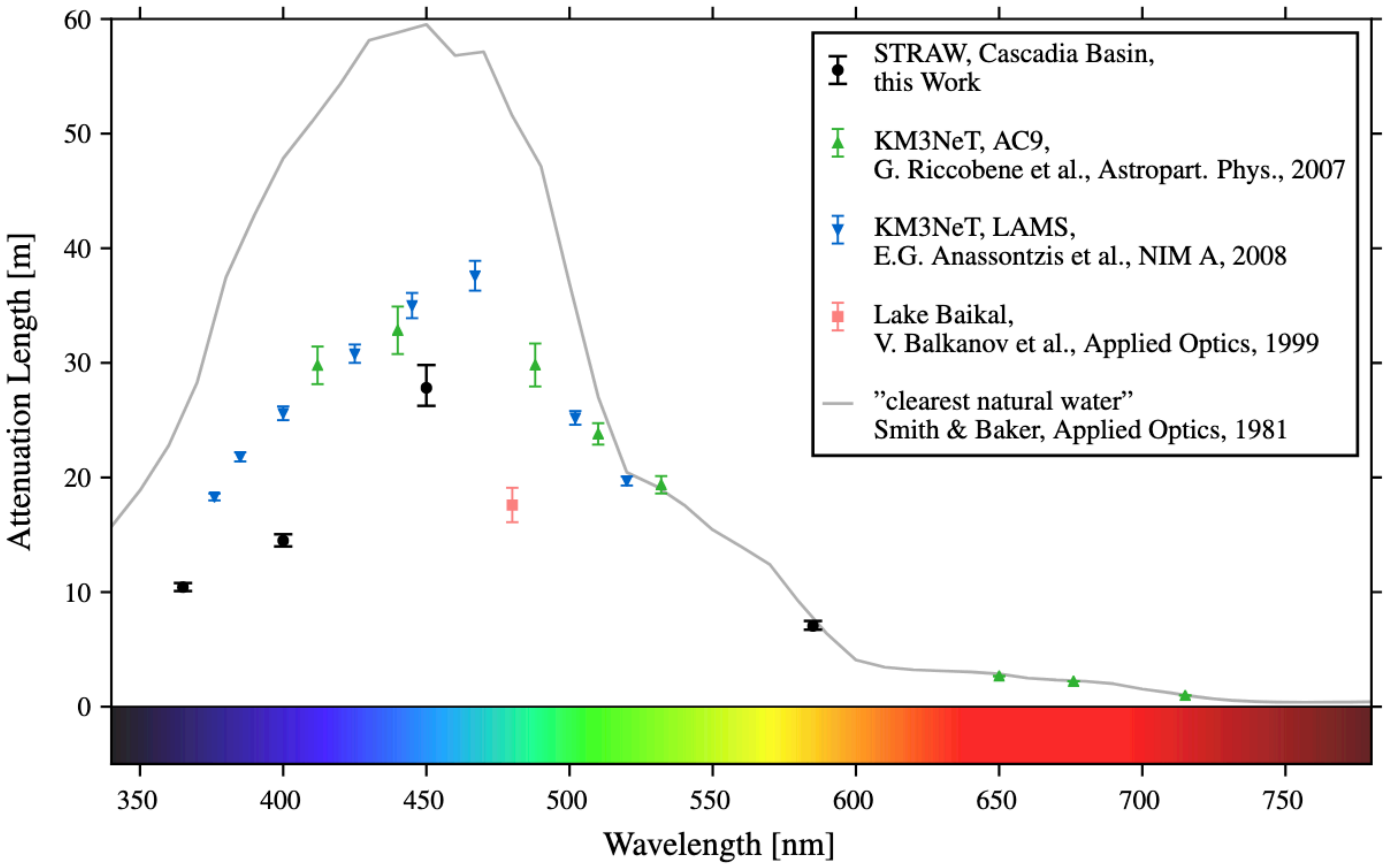
An Initiative of the University of Victoria

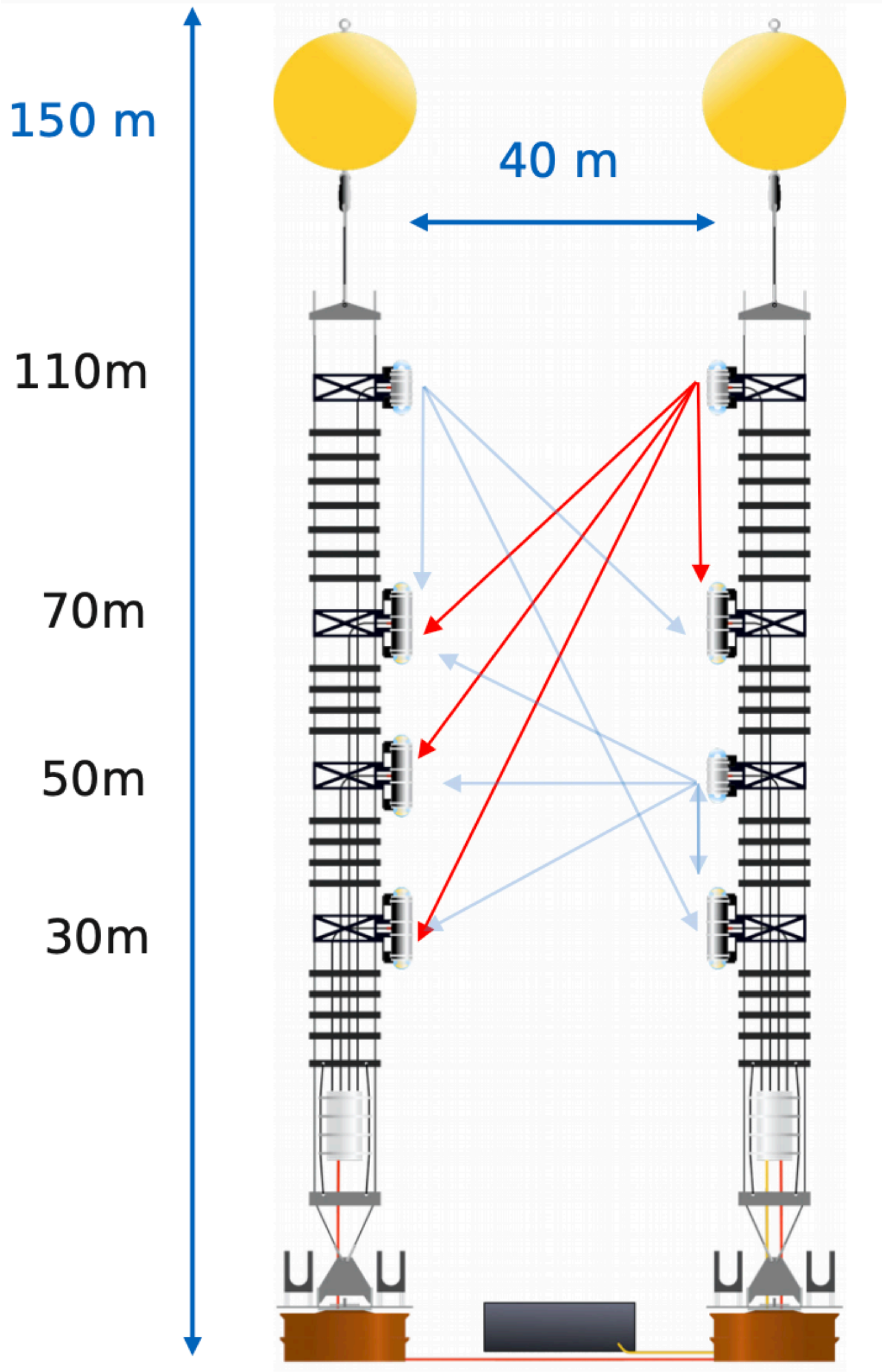
Key result 1: Attenuation length

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

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

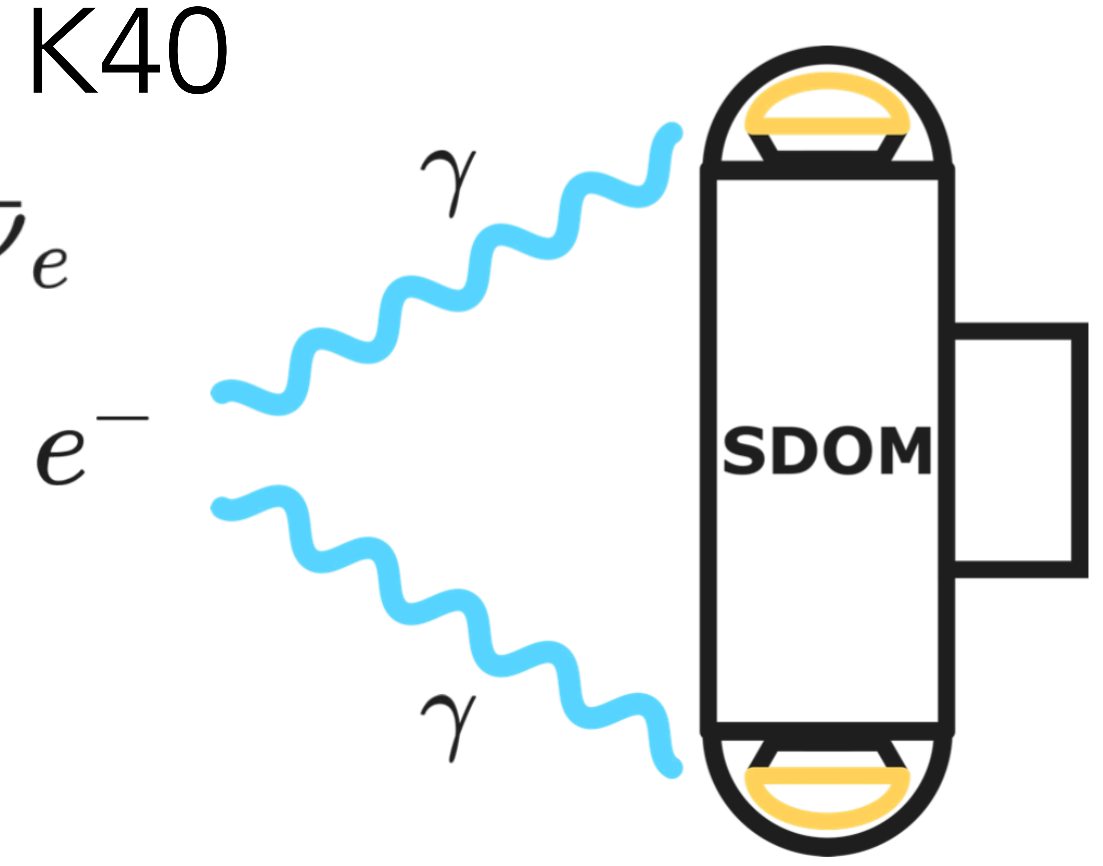
$$\frac{1}{\lambda_{att}} = \frac{1}{\lambda_{sct}} + \frac{1}{\lambda_{abs}}$$

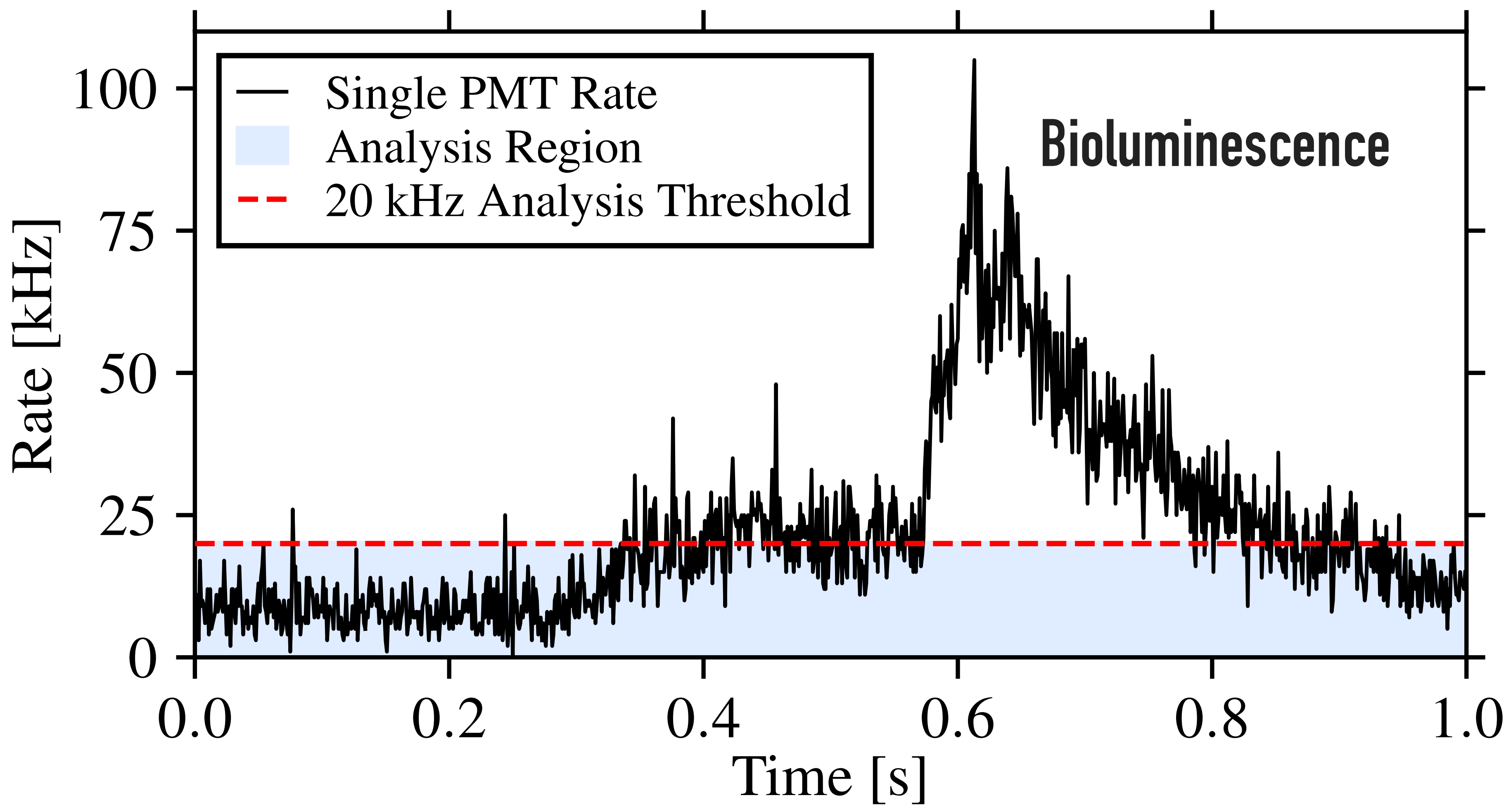




Key result 2: ^{40}K in situ measurement

- 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 λ_{att} results, detector and site model





SDOM PMT housing Geant4 model

Key result 2: ^{40}K in situ measurement

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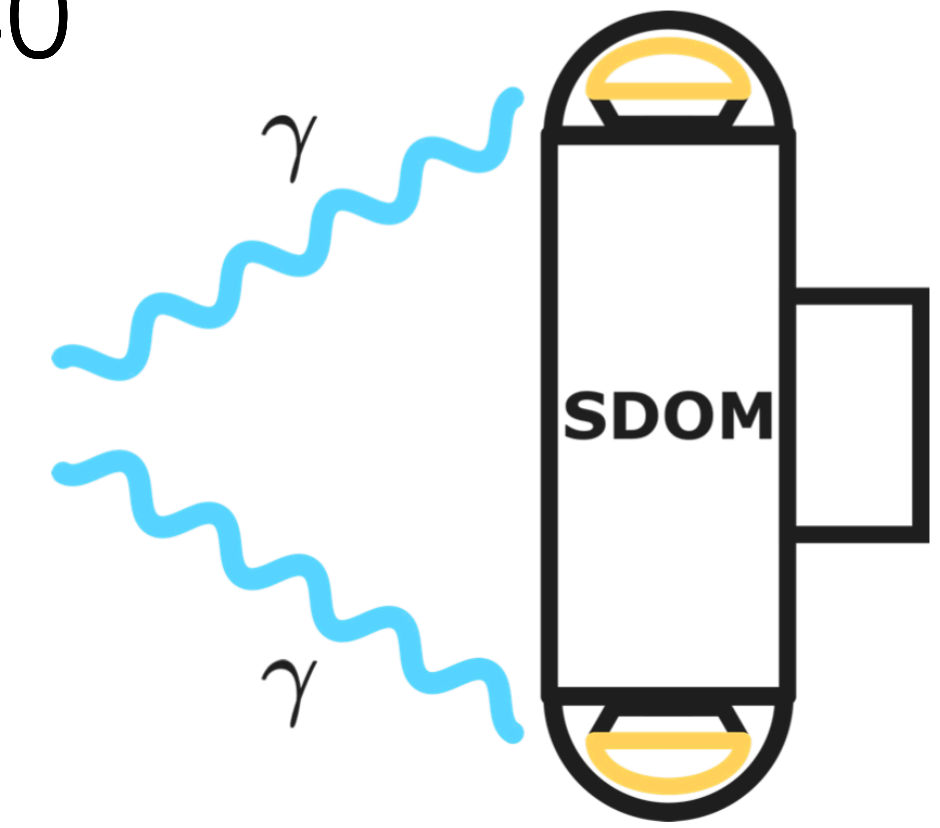
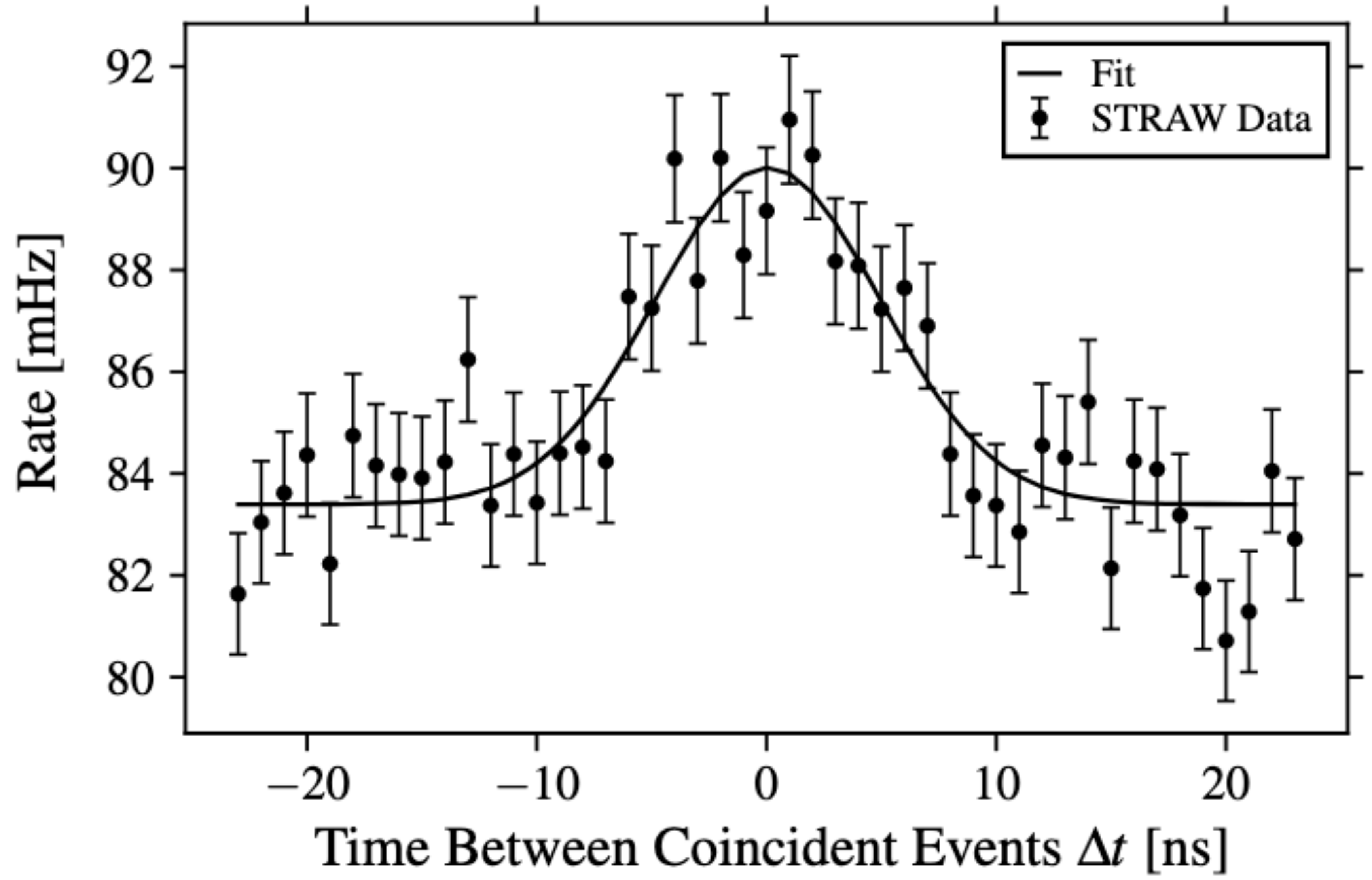
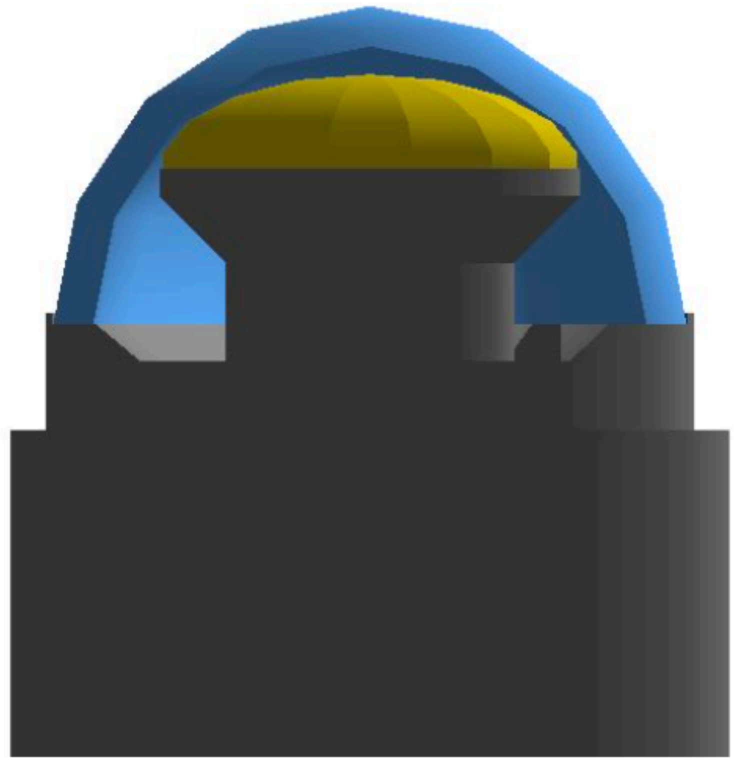
  - Natural in-situ calibration with K40 possible $^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + e^- + \bar{\nu}_e$
  - Cross-check of λ_{att} results, detector and site model
  - **Consistent results!**

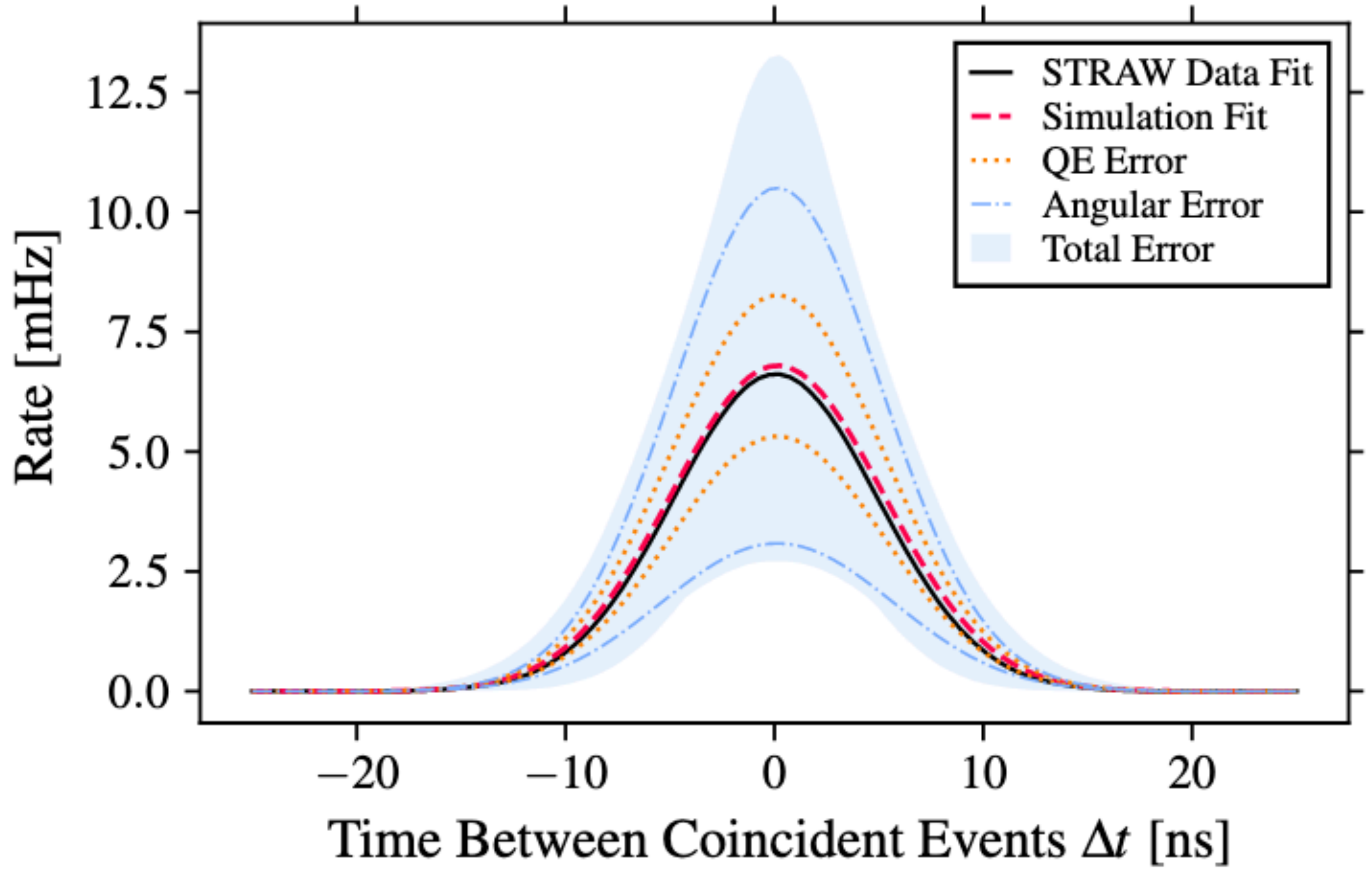




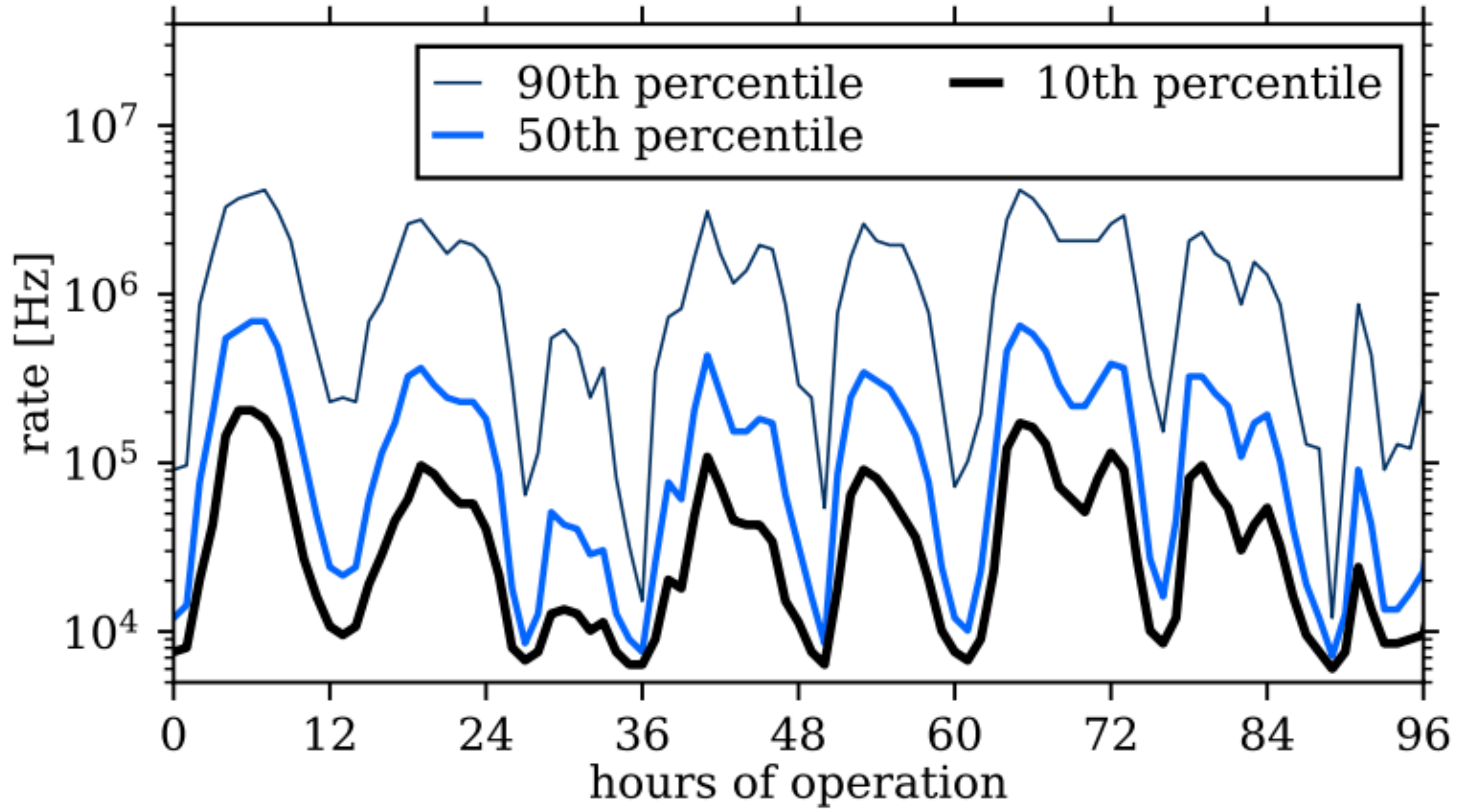
Salinity from this work: 2.5±1.4%
Salinity from ONC: 3.482±0.001%
Salinity at ANTARES site: 3.844%

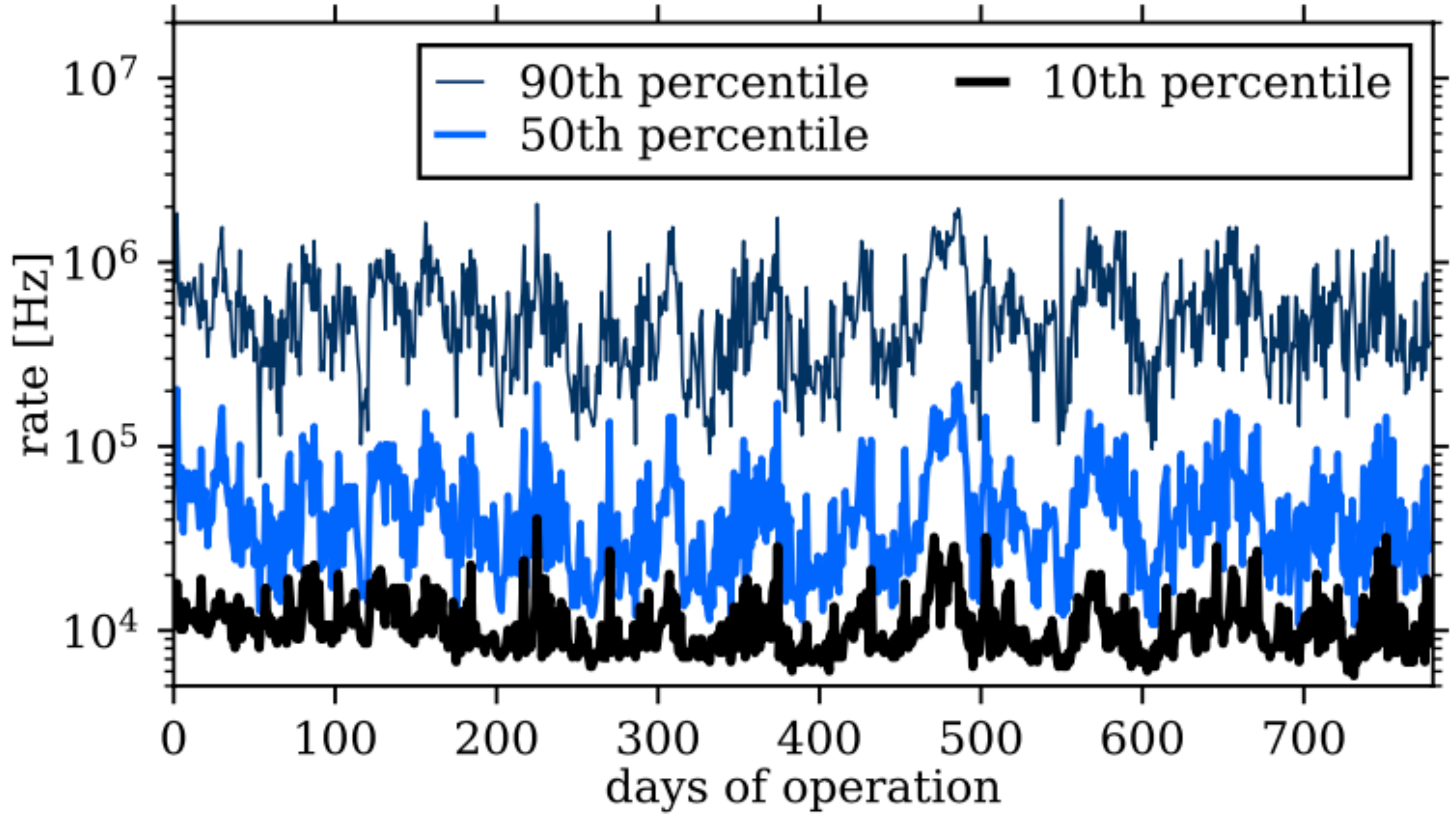


SDOM PMT housing Geant4 model



Key result 3: Bioluminescence as expected



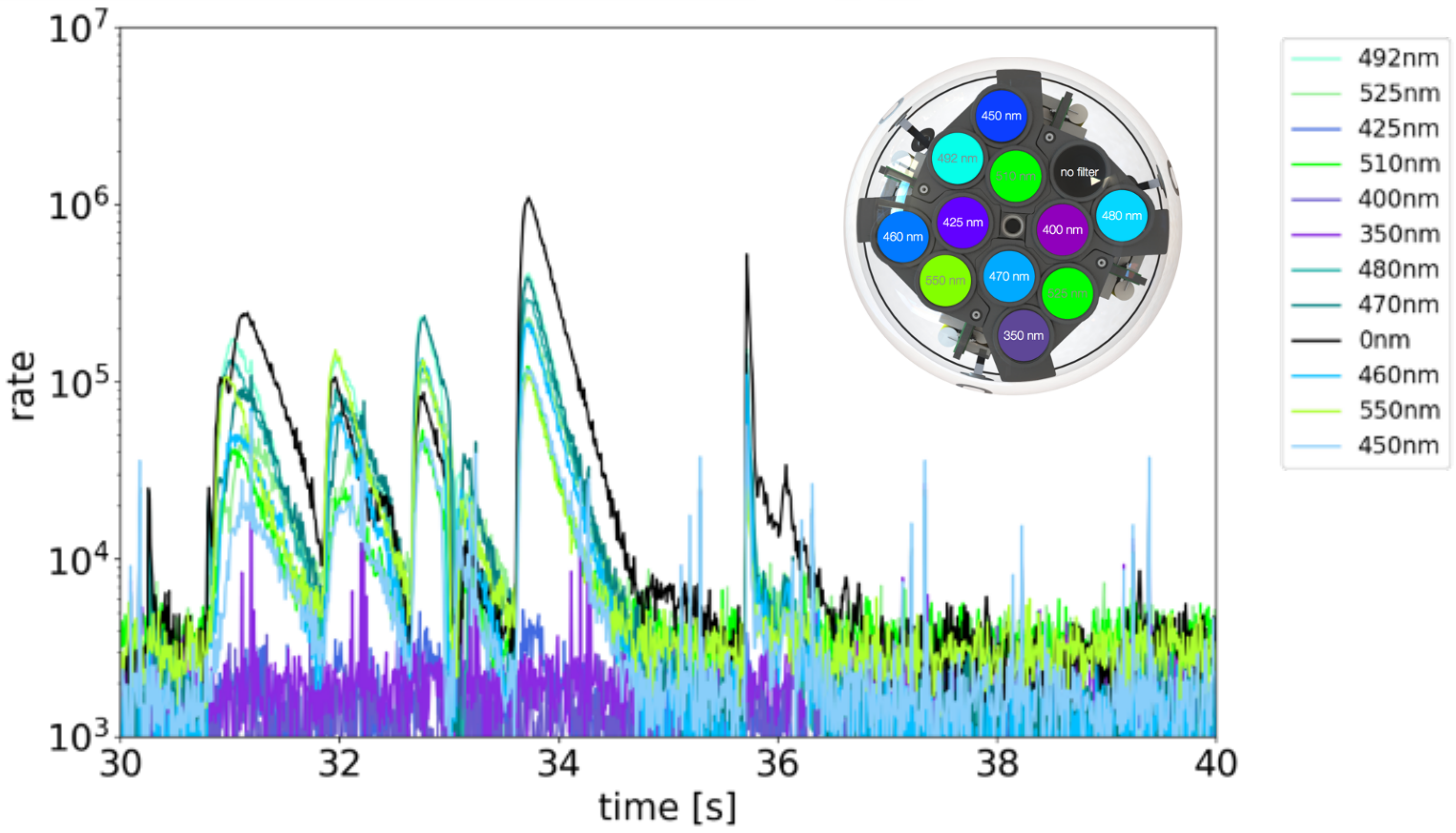


- Bioluminescence is modulated with the tides
- Constant over more than 2 years of operations —> no big bursts

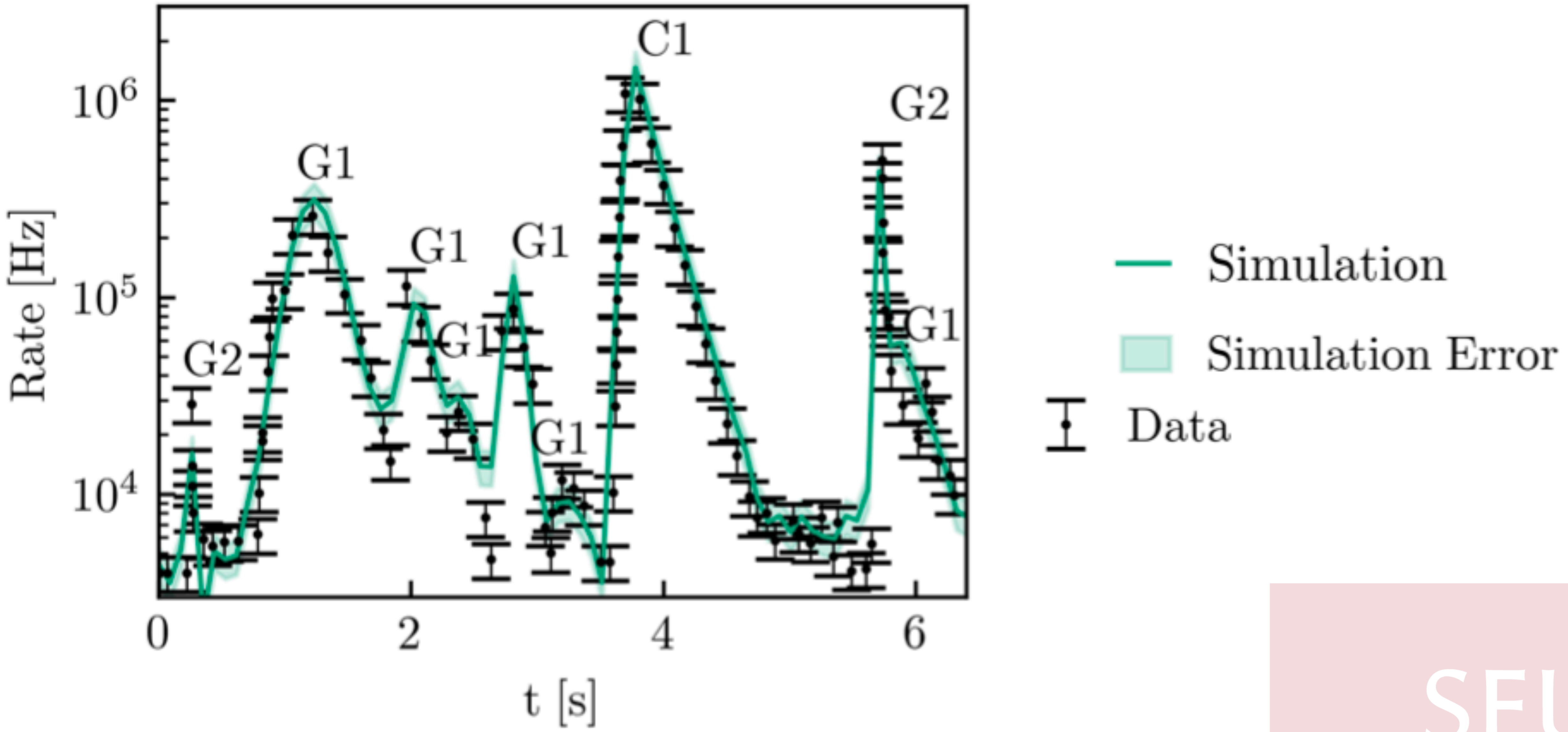
The deep sea site of Cascadia basin is optically qualified to host P-ONE

Better characterization of Bioluminescence

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

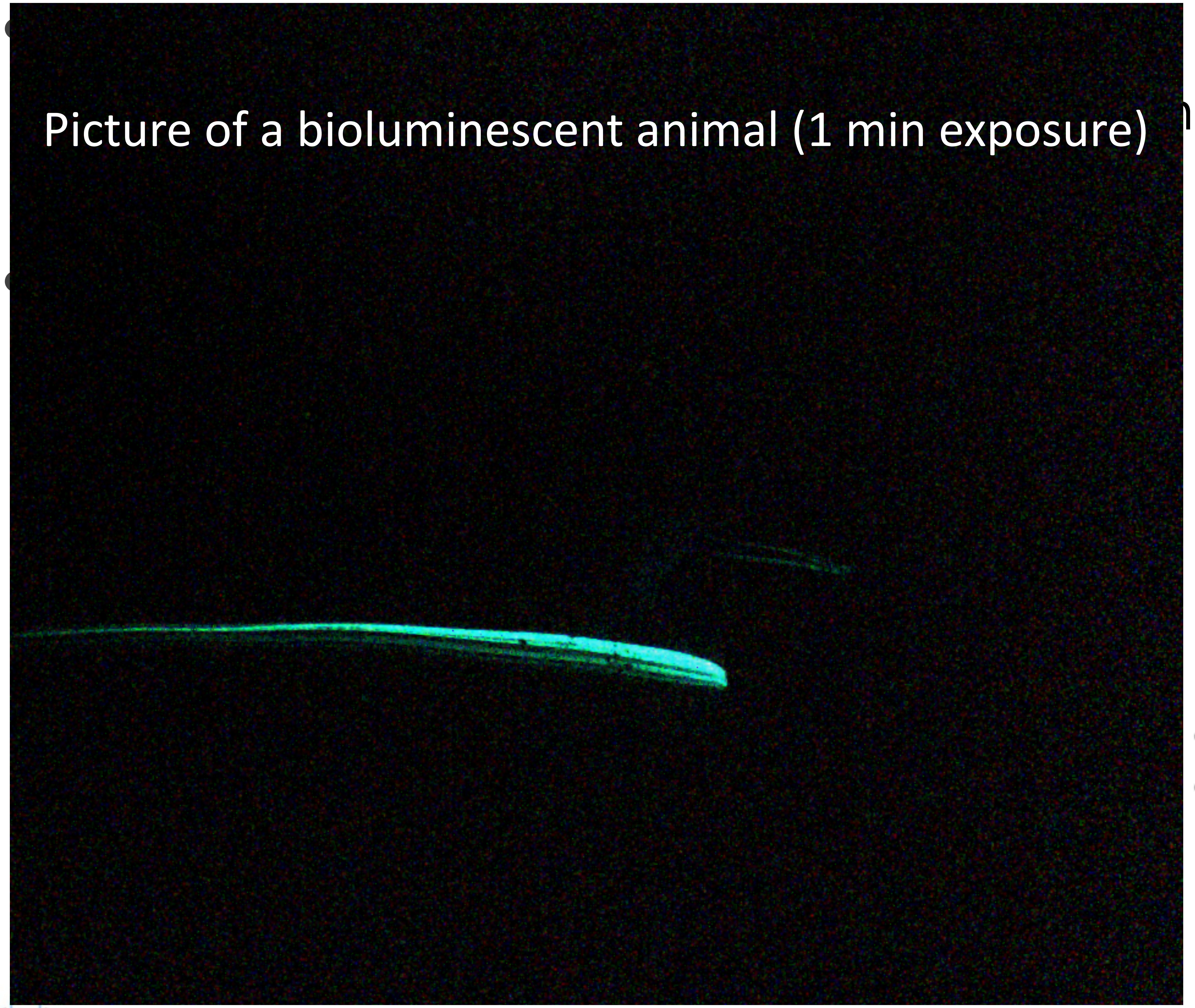


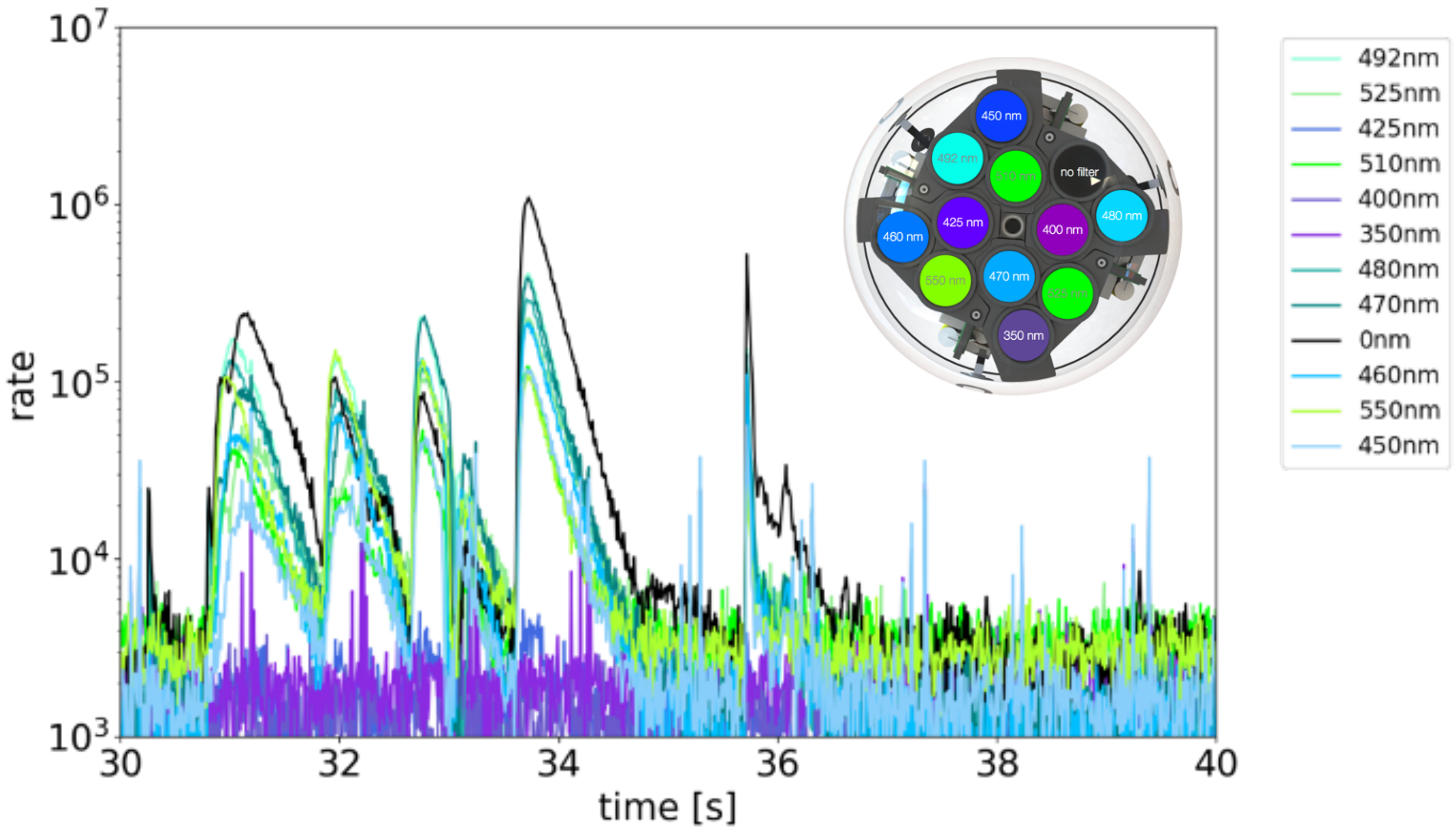
Interdisciplinary: oceanography, microbiology, climate change related studies

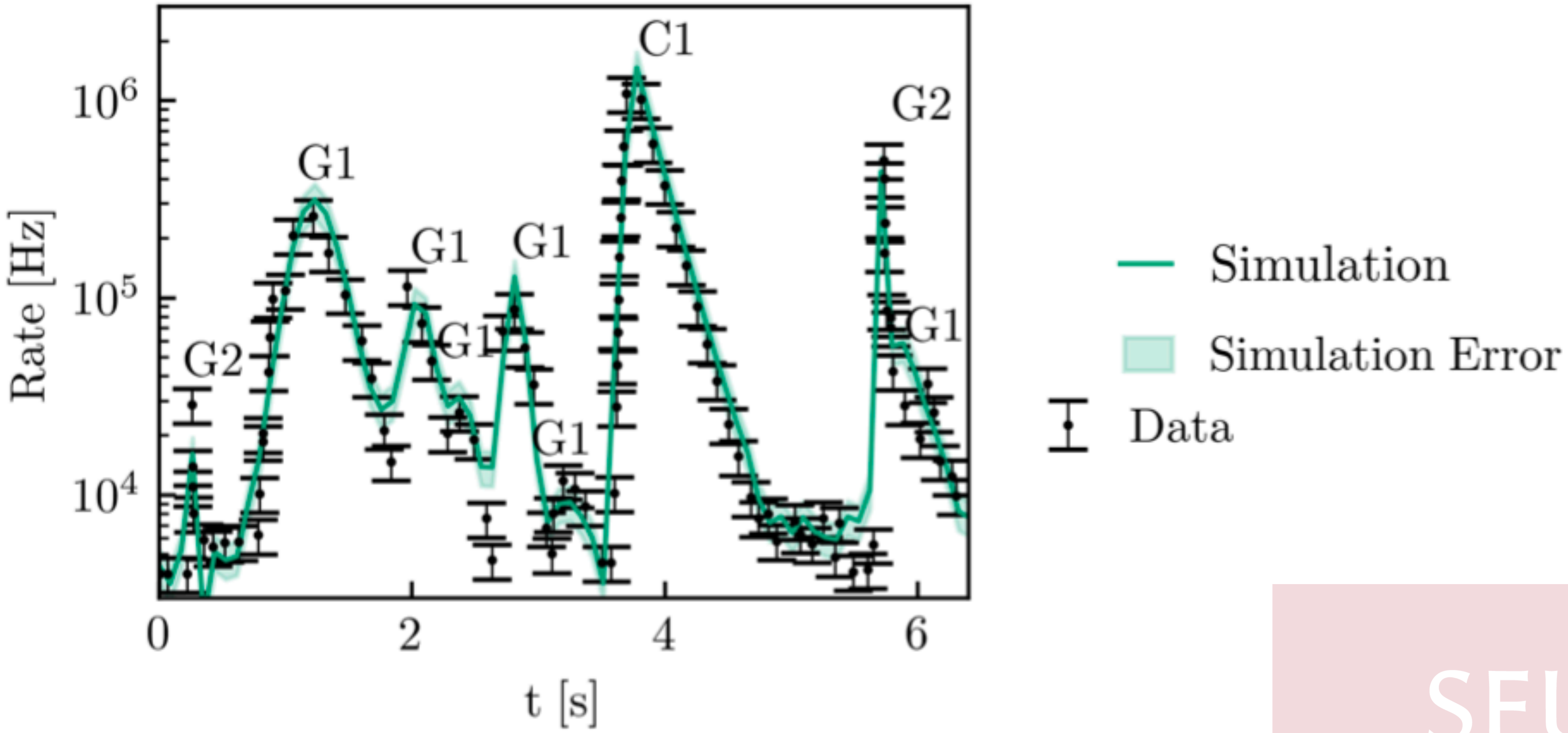


P-ONE

Better characterization of Bioluminescence





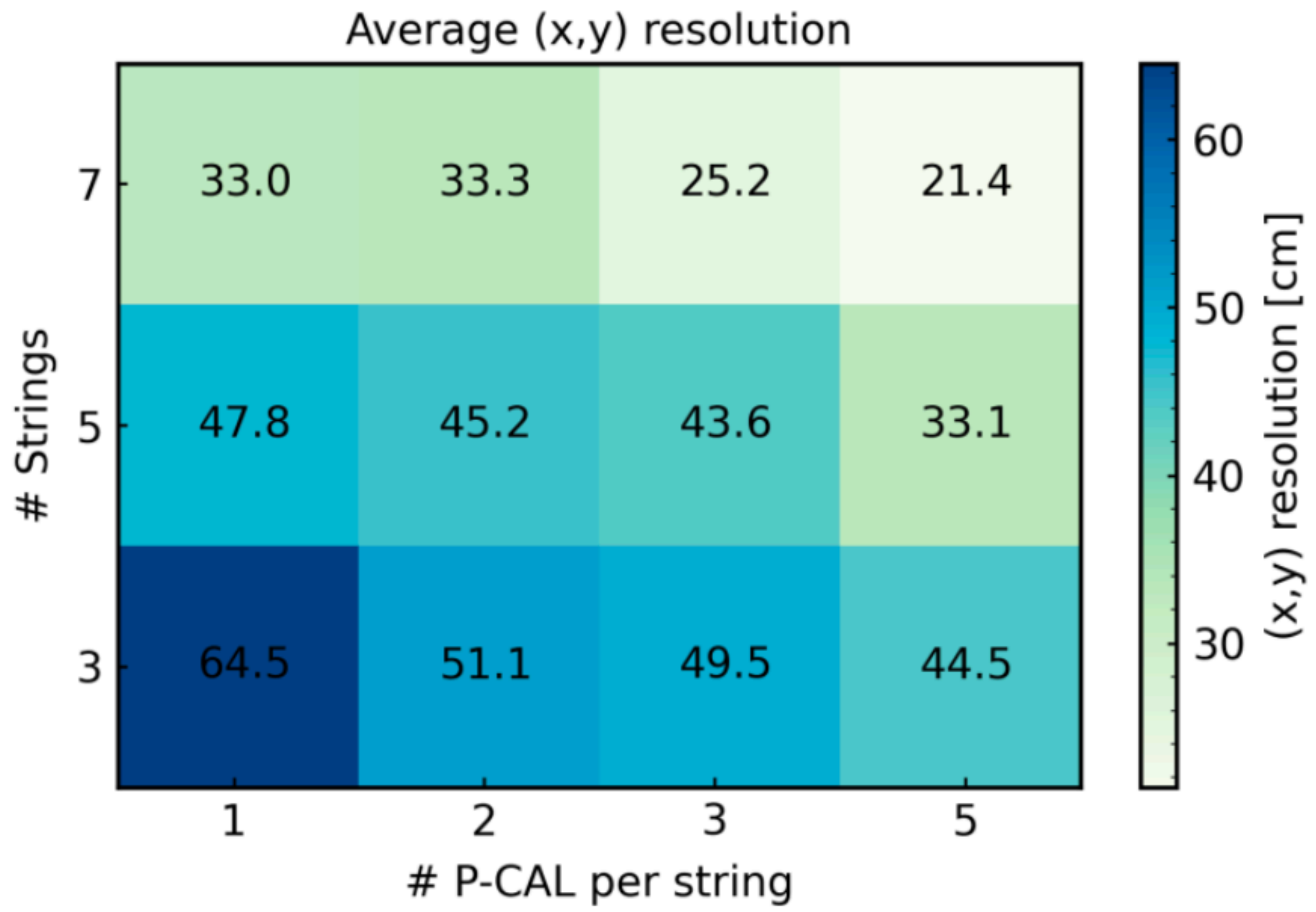


Geometry calibration

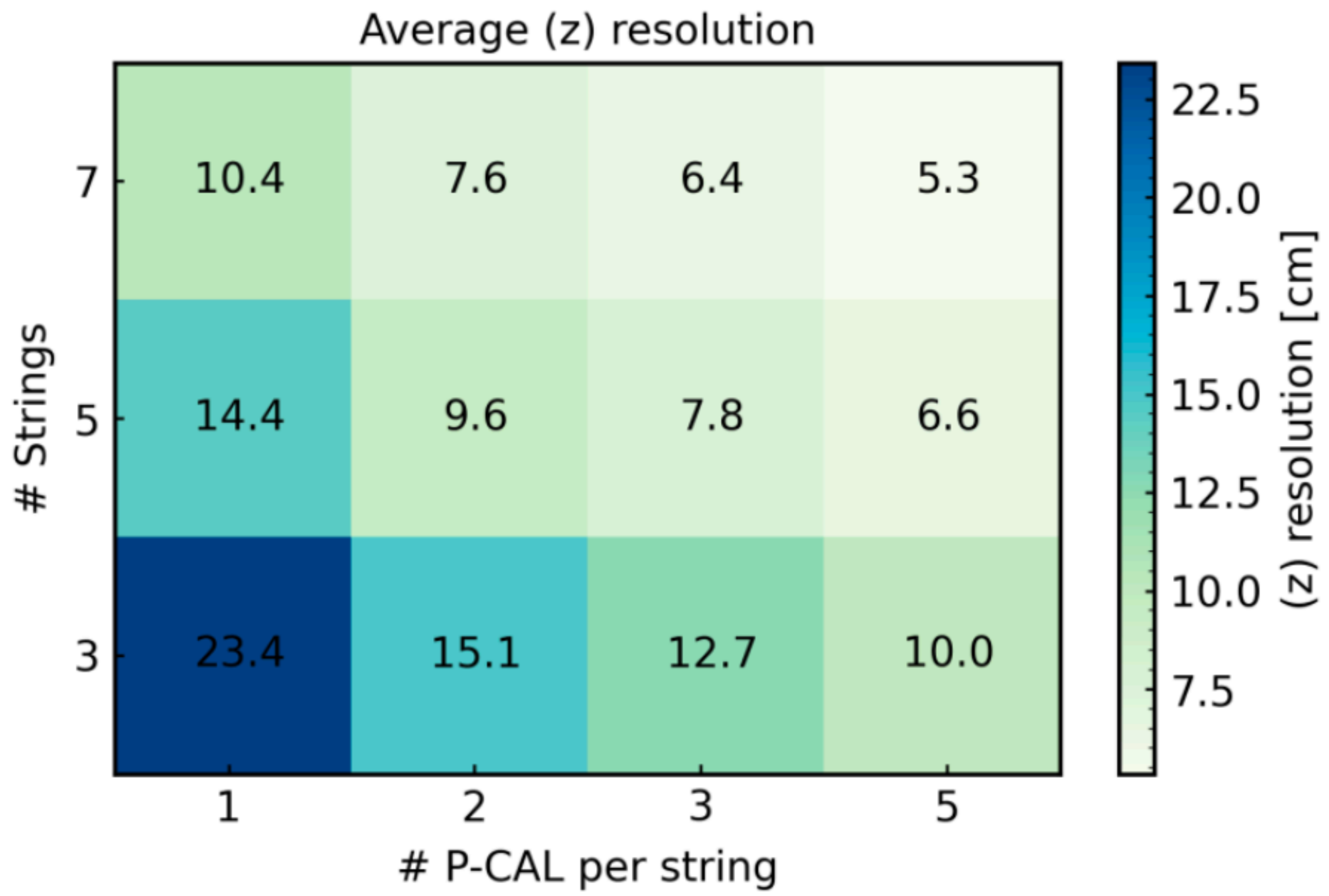
First MCMC fit results – Symmetric geometries

- POCAM Upgrade configuration
  - *1e11 photons / pulse – increase challenging*
  - *Up to 10kHz baseline – increase possible*
  - *405nm default – 450nm available*

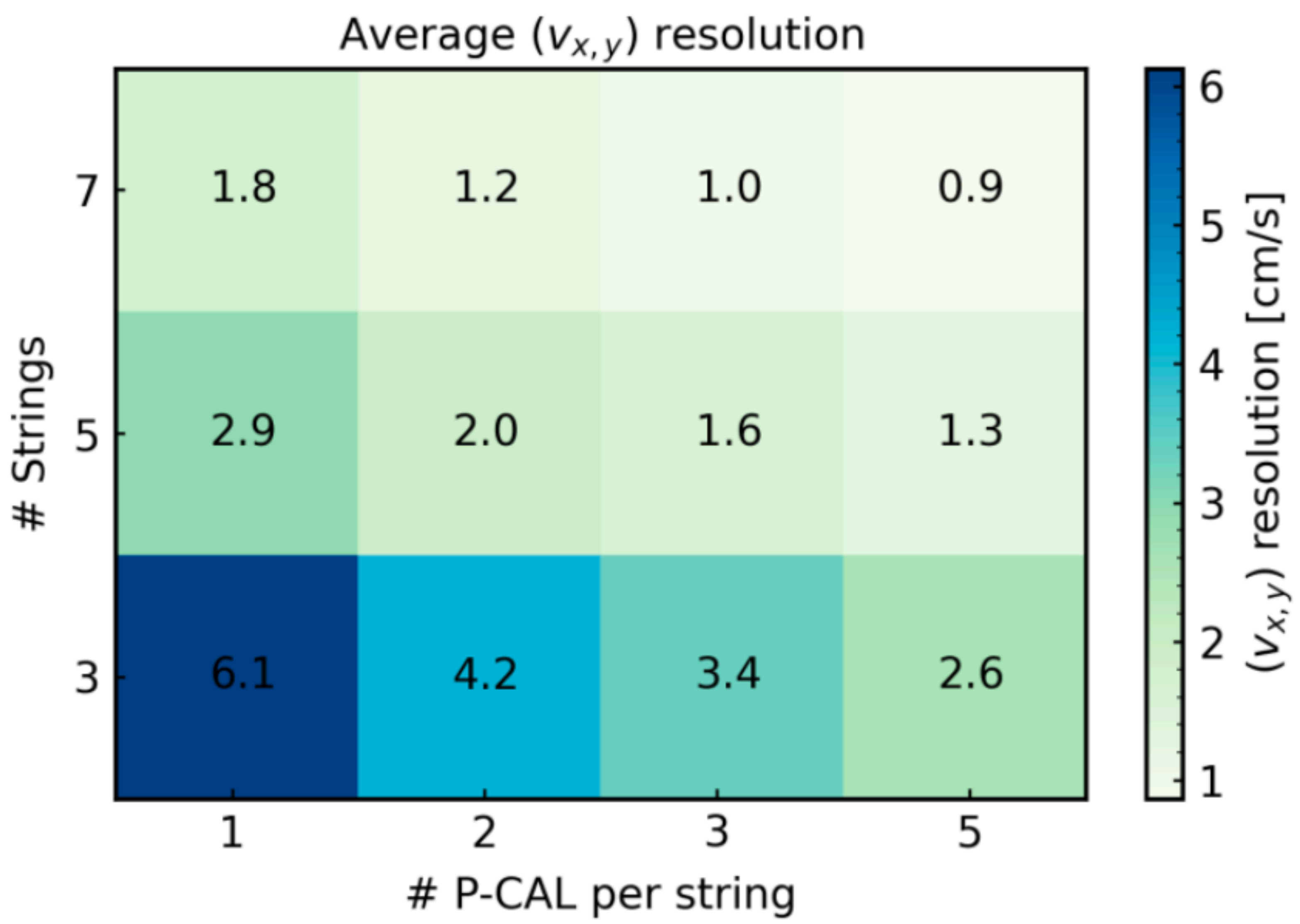
- ❑ Fitting posterior distributions
  - Gaussian approximations
  - Sigma + deviations = resolution
- ❑ Resolution ~5-30cm promising
  - (x,y) harder to calibrate than (z)
  - Dependent on string positions + P-CAL placement



# Strings \ # P-CAL per string	1	2	3	5
7	33.0	33.3	25.2	21.4
5	47.8	45.2	43.6	33.1
3	64.5	51.1	49.5	44.5



# Strings \ # P-CAL per string	1	2	3	5
7	10.4	7.6	6.4	5.3
5	14.4	9.6	7.8	6.6
3	23.4	15.1	12.7	10.0



# Strings \ # P-CAL per string	1	2	3	5
7	1.8	1.2	1.0	0.9
5	2.9	2.0	1.6	1.3
3	6.1	4.2	3.4	2.6

Photons in ice and water