

P-ONE

— The Pacific Ocean Neutrino Experiment —

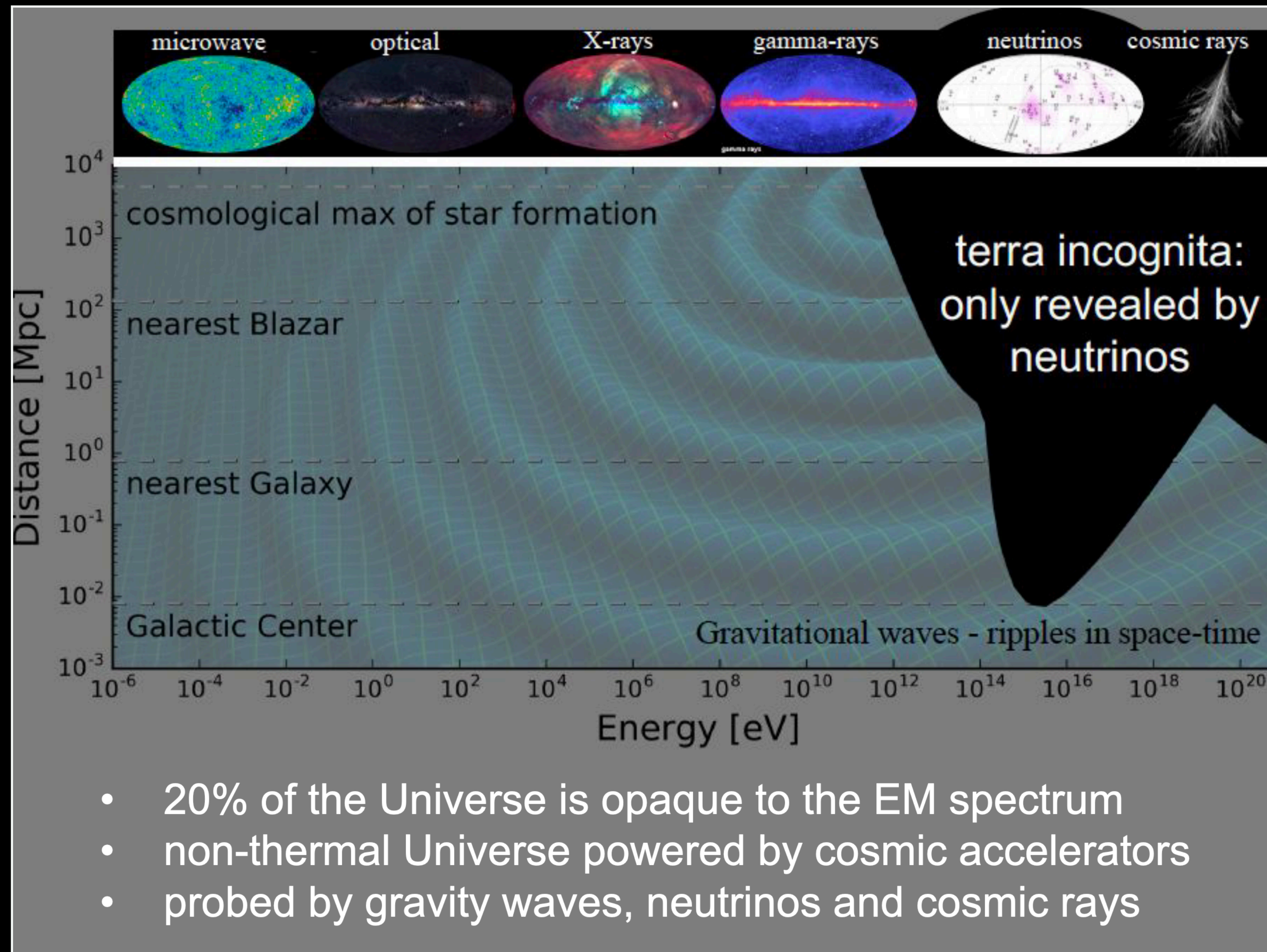
Matthias Danninger
for the P-ONE Collaboration

2024 - 03 - 07



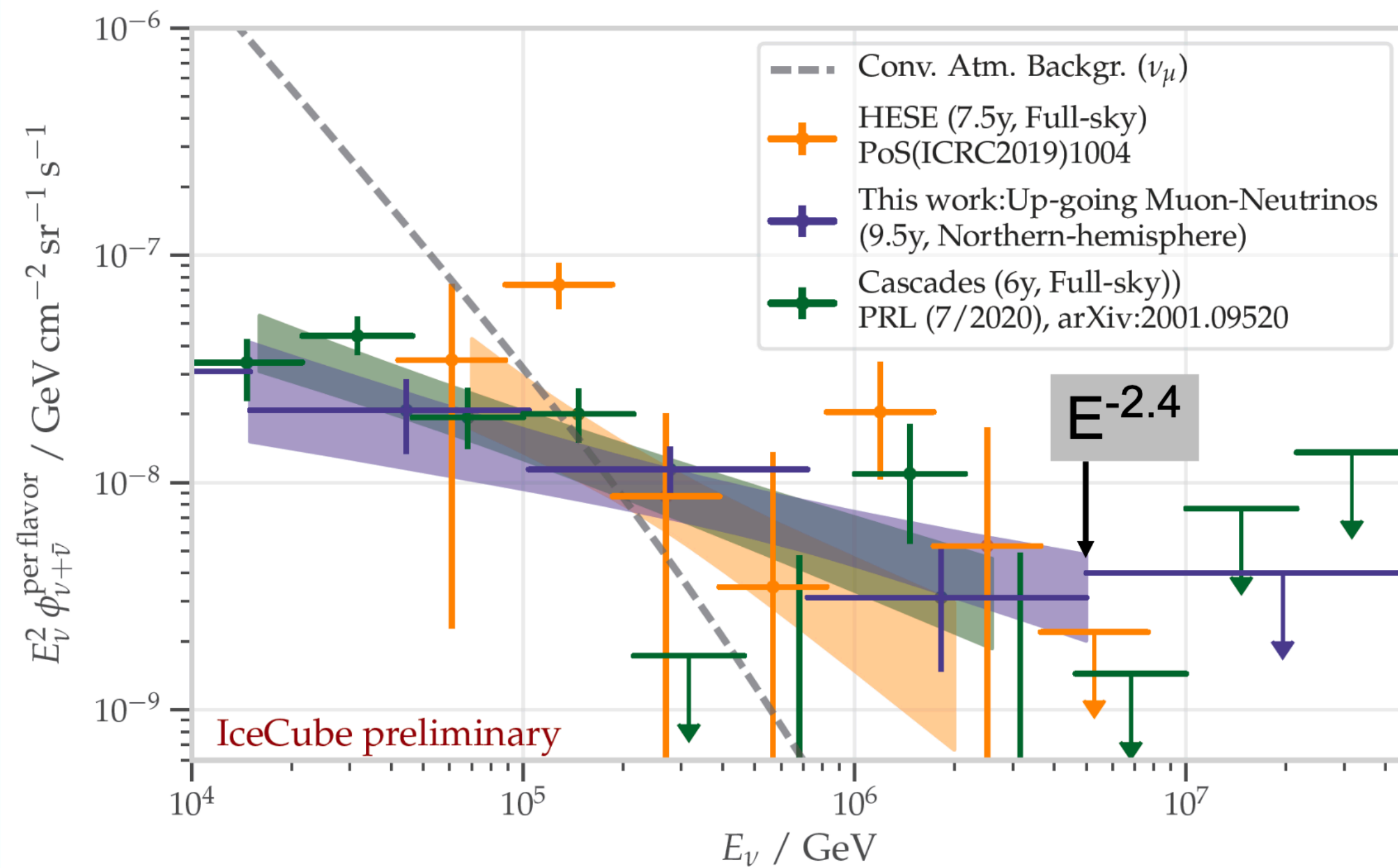
— Our Motivation —
...IceCube's legacy...

Neutrino astronomy — key to 20% of Universe

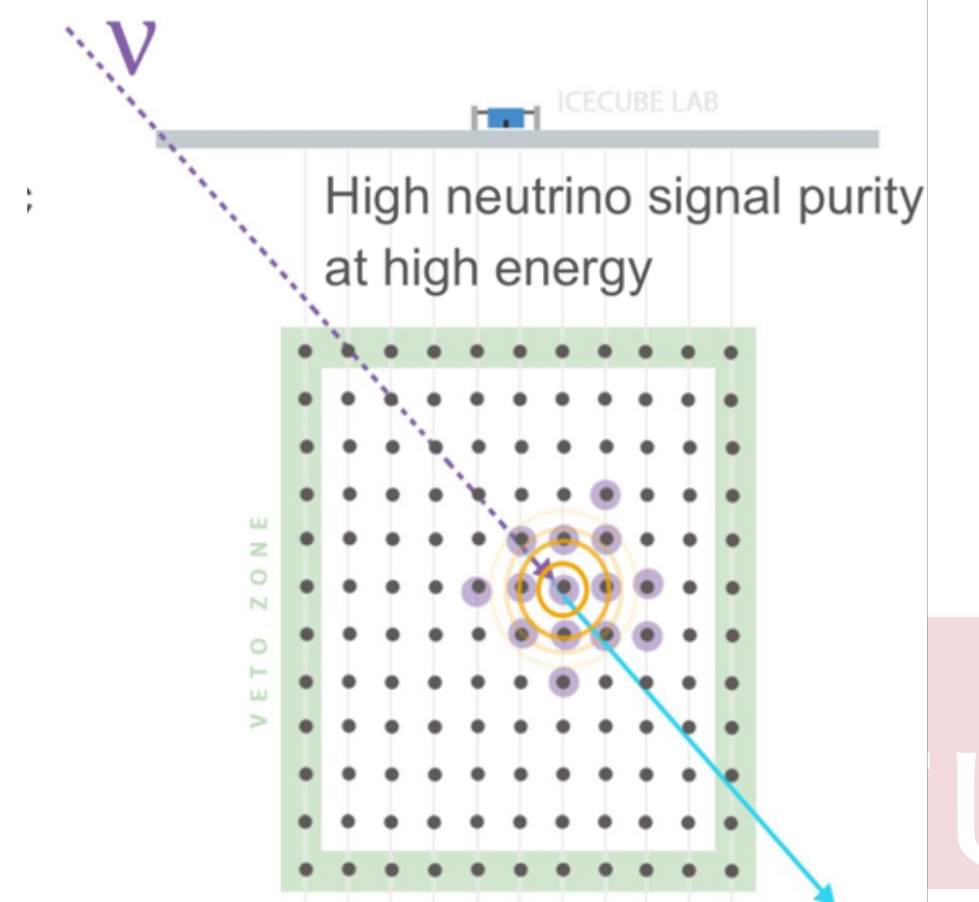
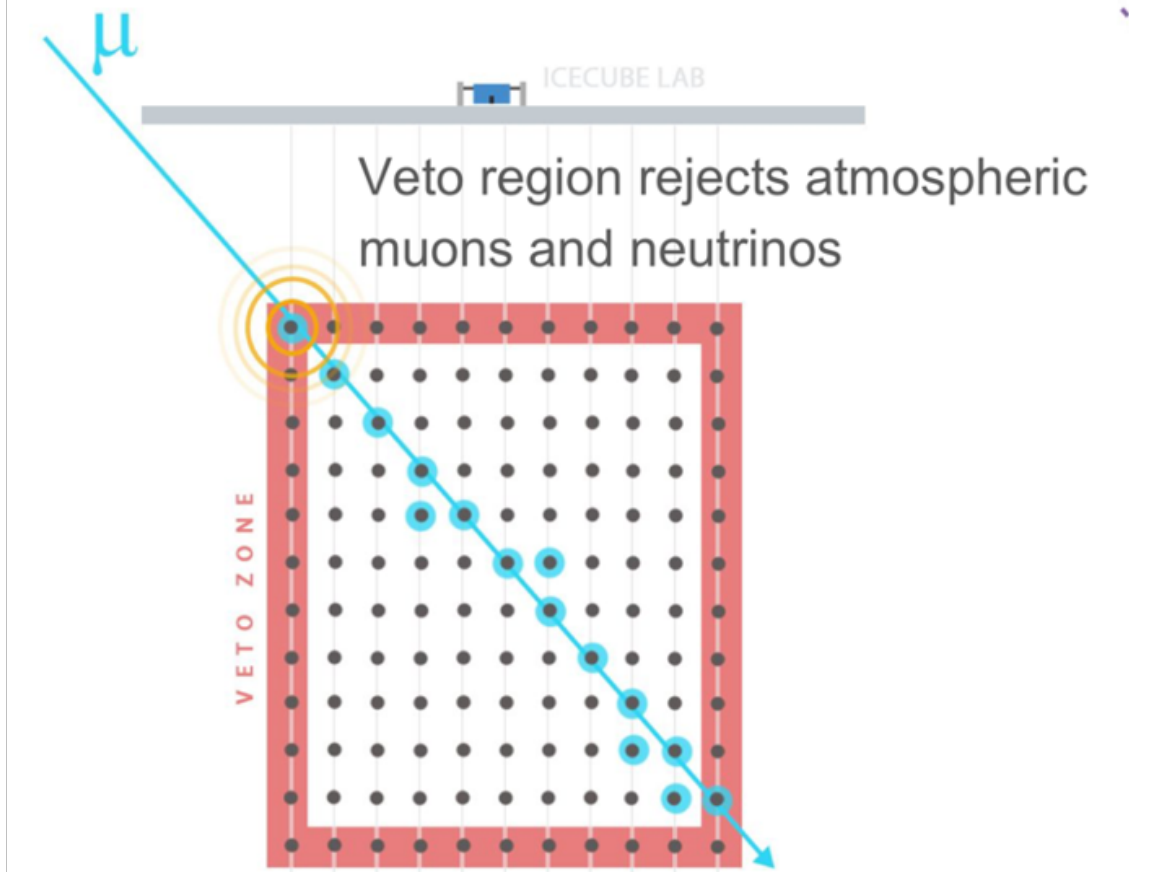


Neutrinos from the Universe

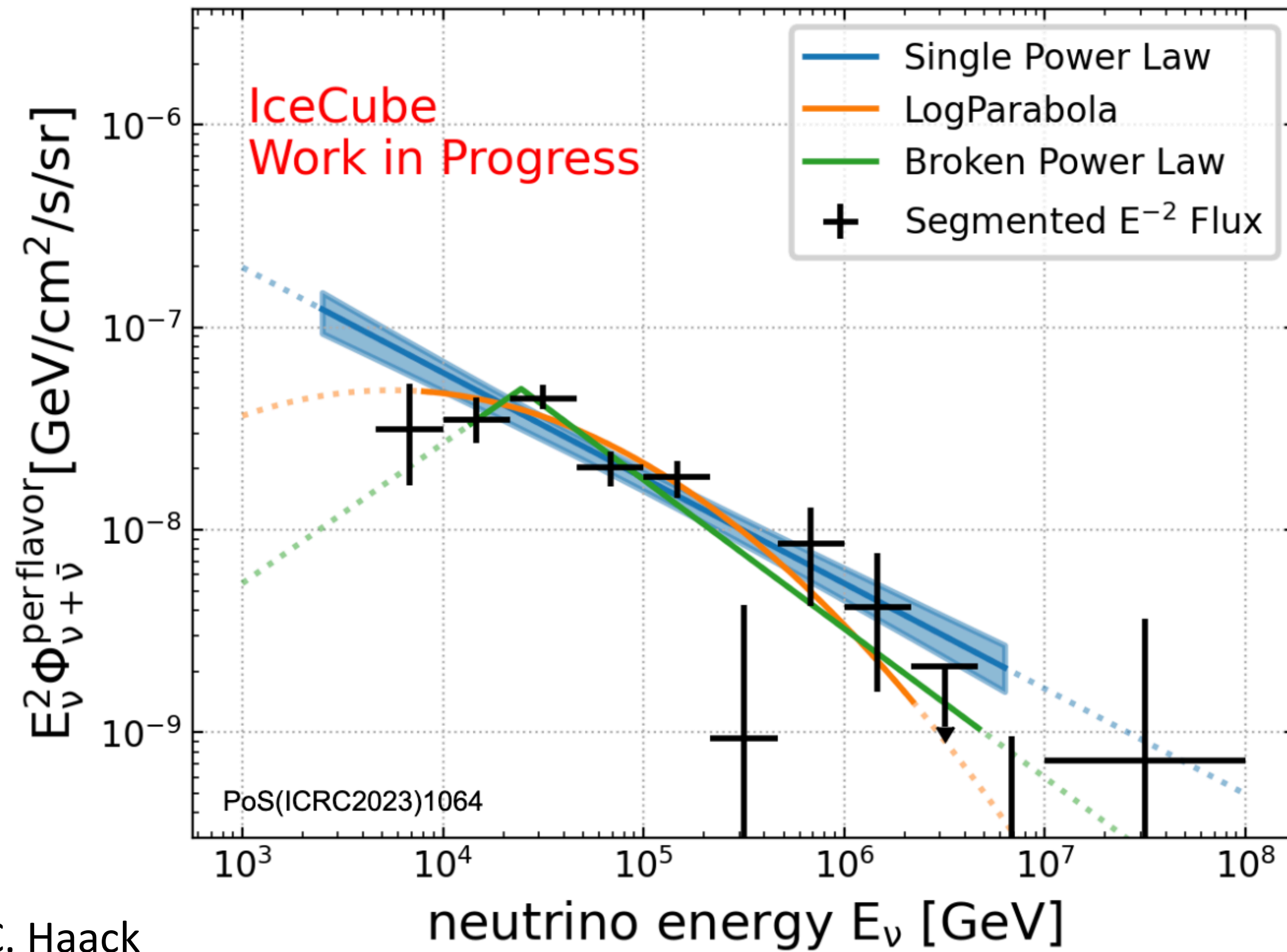
- Since 2013 — Astrophysical neutrinos discovered



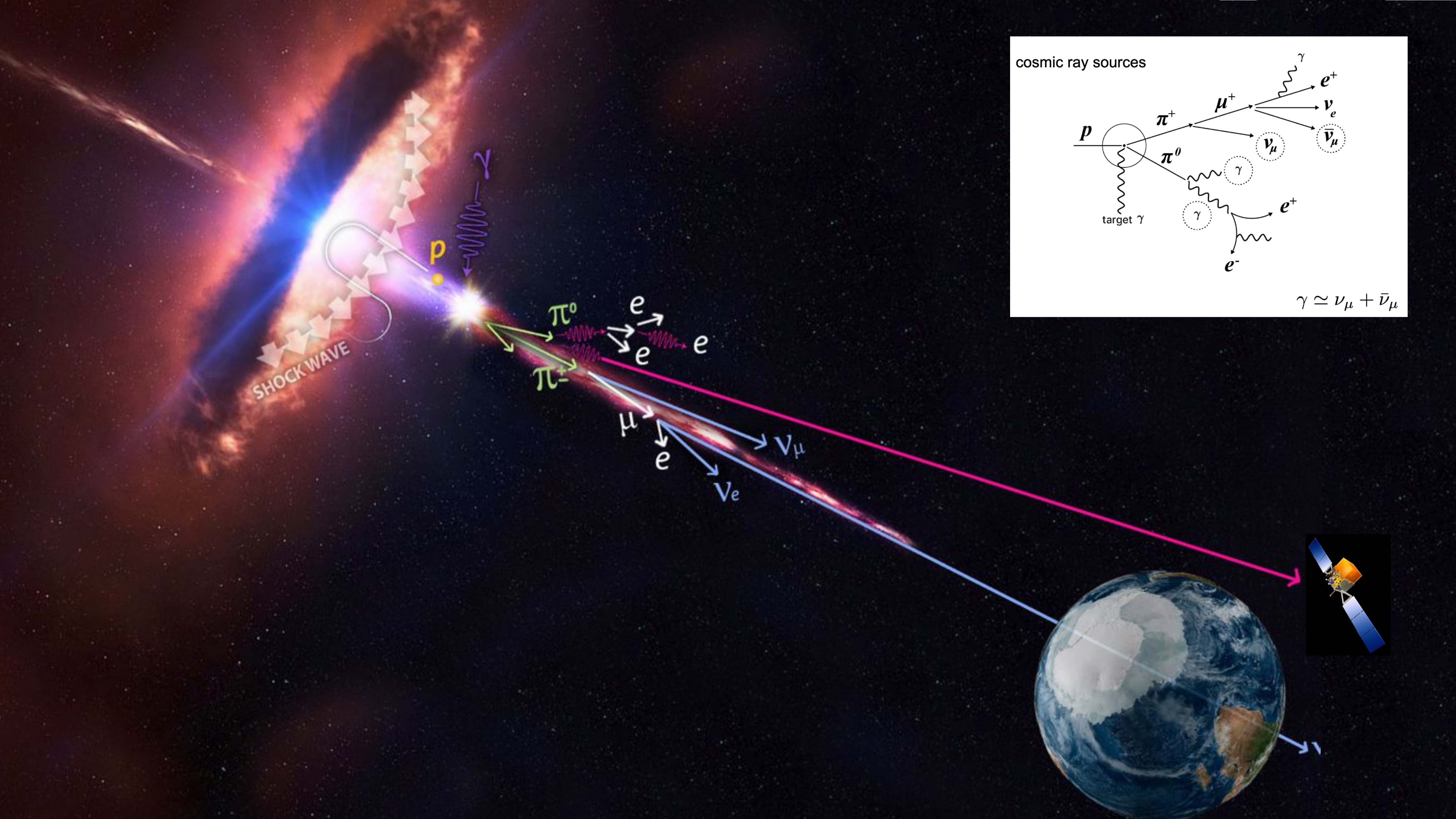
Starting Events



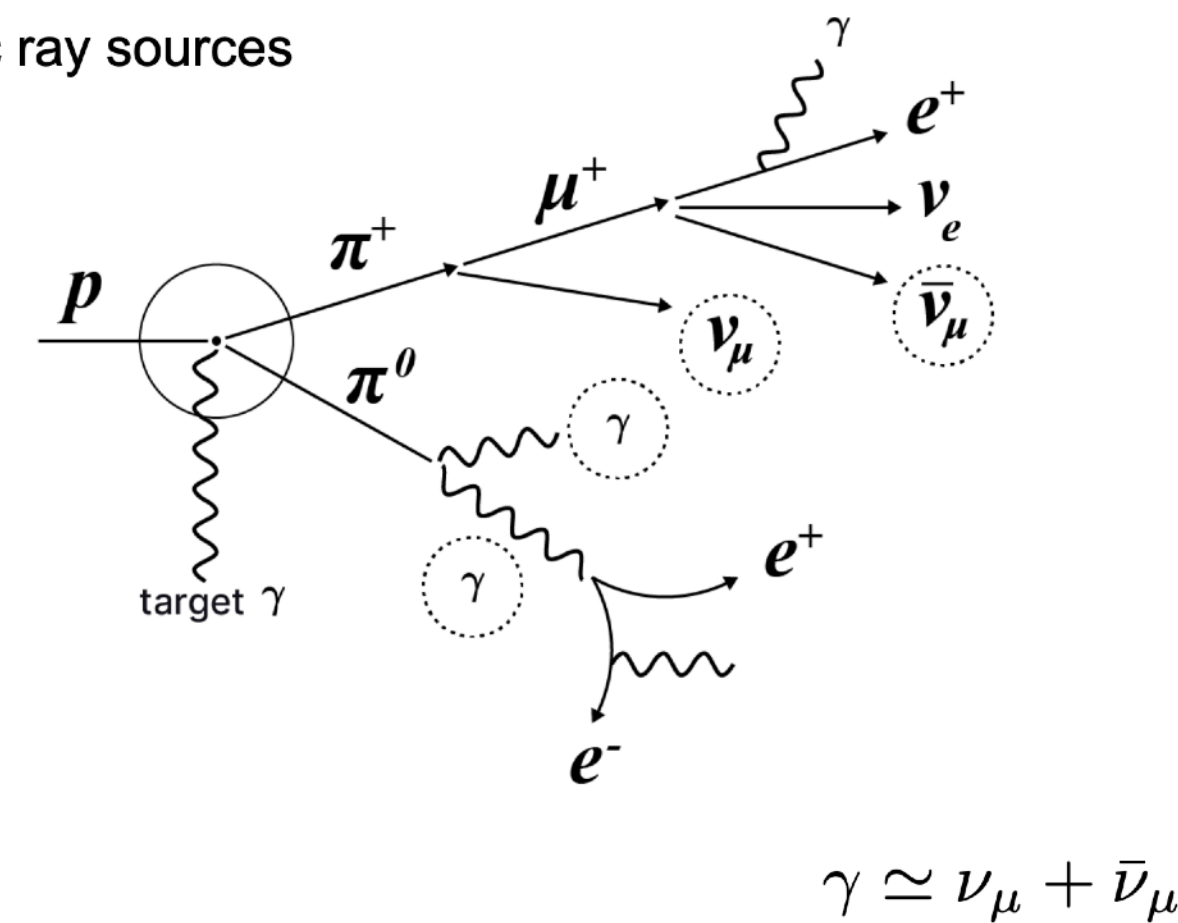
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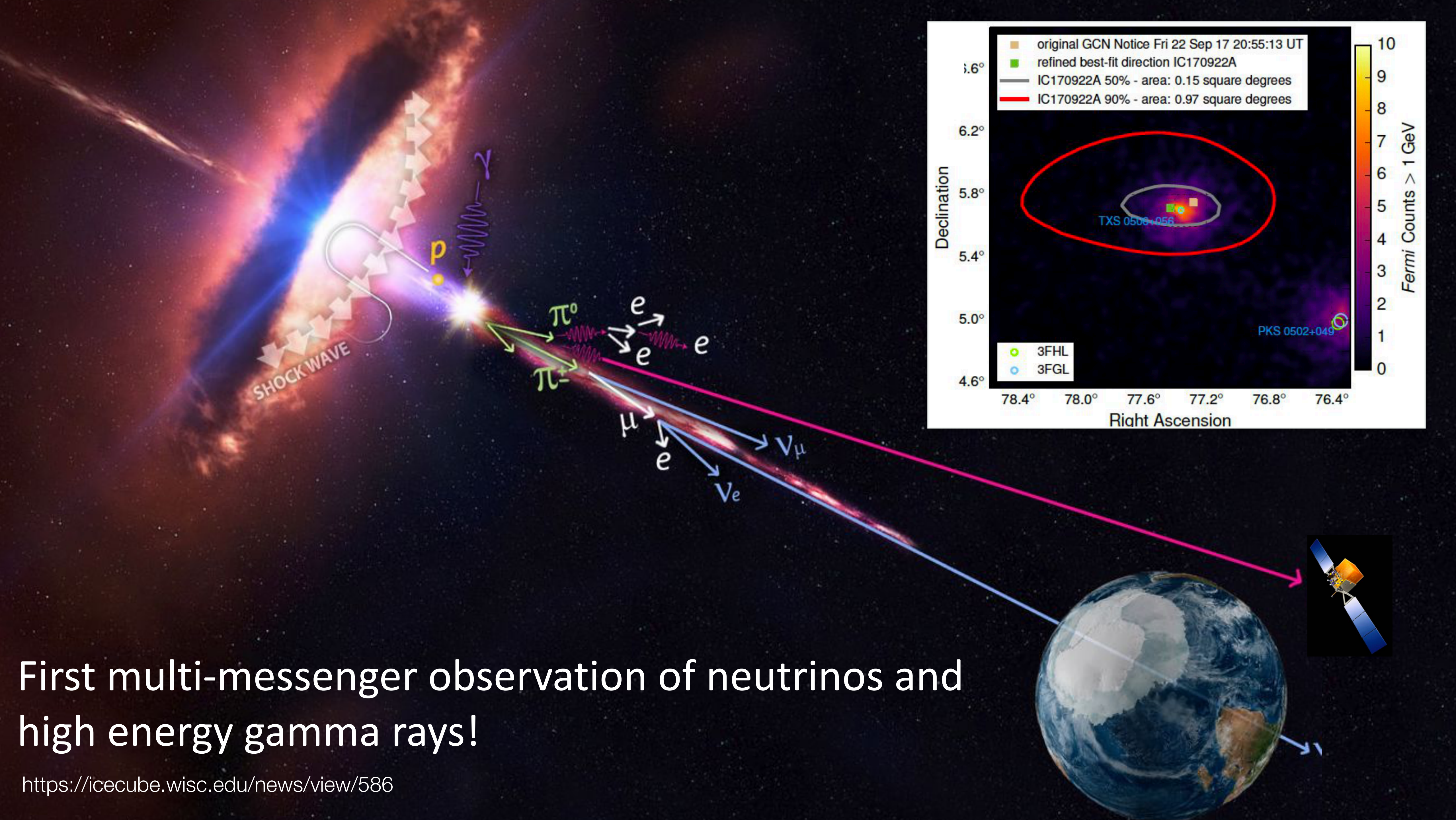


see talk at LLWI24, C. Haack



cosmic ray sources

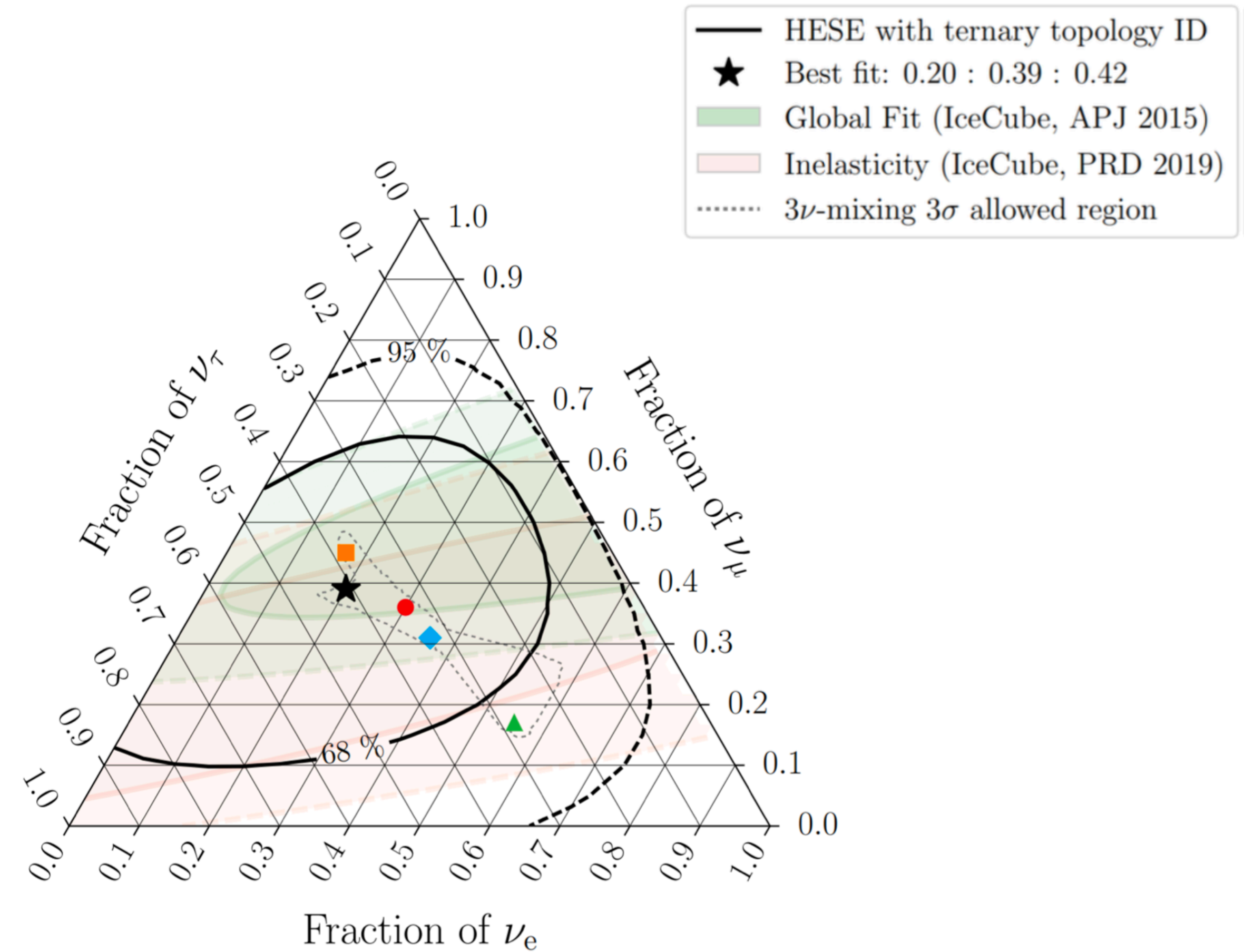




First multi-messenger observation of neutrinos and high energy gamma rays!

<https://icecube.wisc.edu/news/view/586>

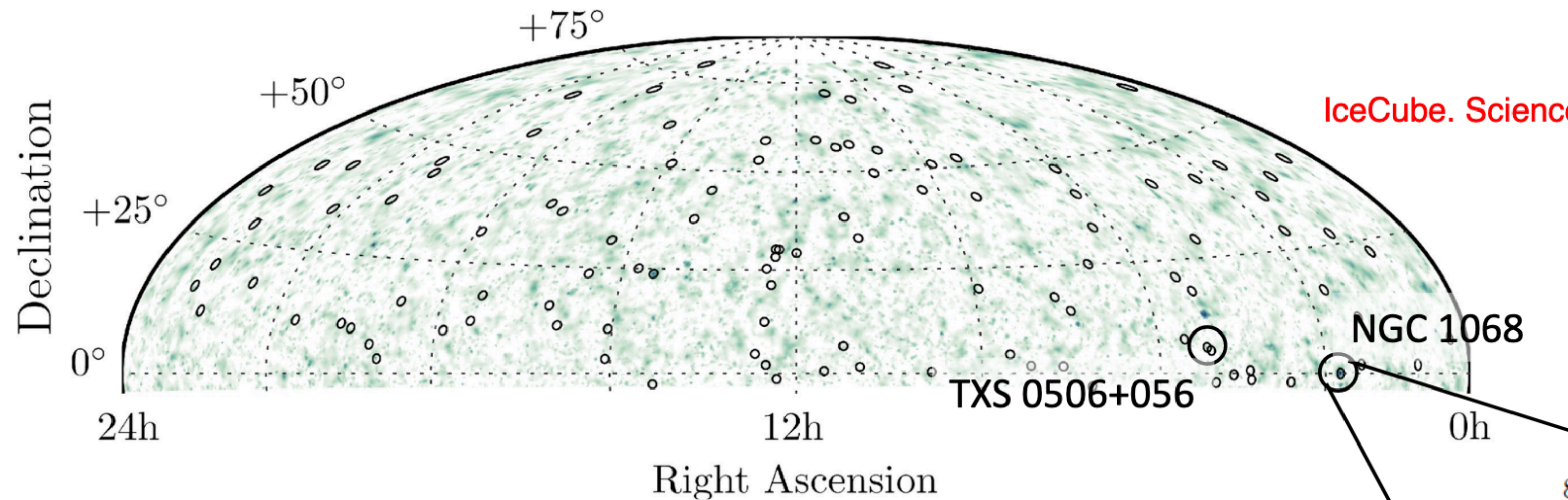
- Since 2013 — Astrophysical neutrinos discovered
- 2018 — Evidence for First source: Neutrino events in a direction of a flaring blazar, TXS 0506+056
- 2020 — Neutrino oscillation measurements at PeV scale!



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

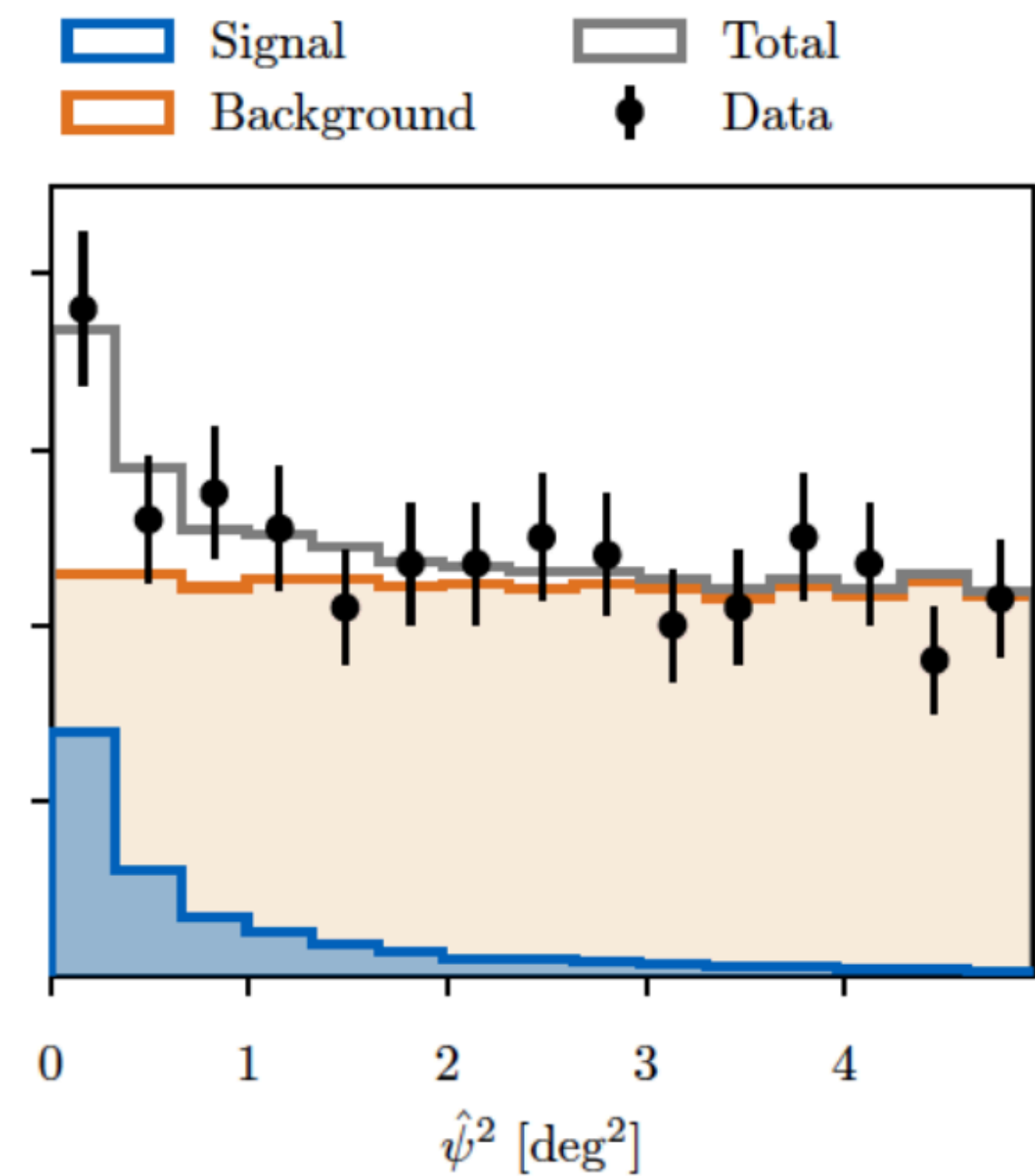
$\nu_e : \nu_\mu : \nu_\tau$ at source	→ on Earth:
0:1:0	→ 0.17 : 0.45 : 0.37
1:2:0	→ 0.30 : 0.36 : 0.34
1:0:0	→ 0.55 : 0.17 : 0.28
1:1:0	→ 0.36 : 0.31 : 0.33

Second neutrino source!

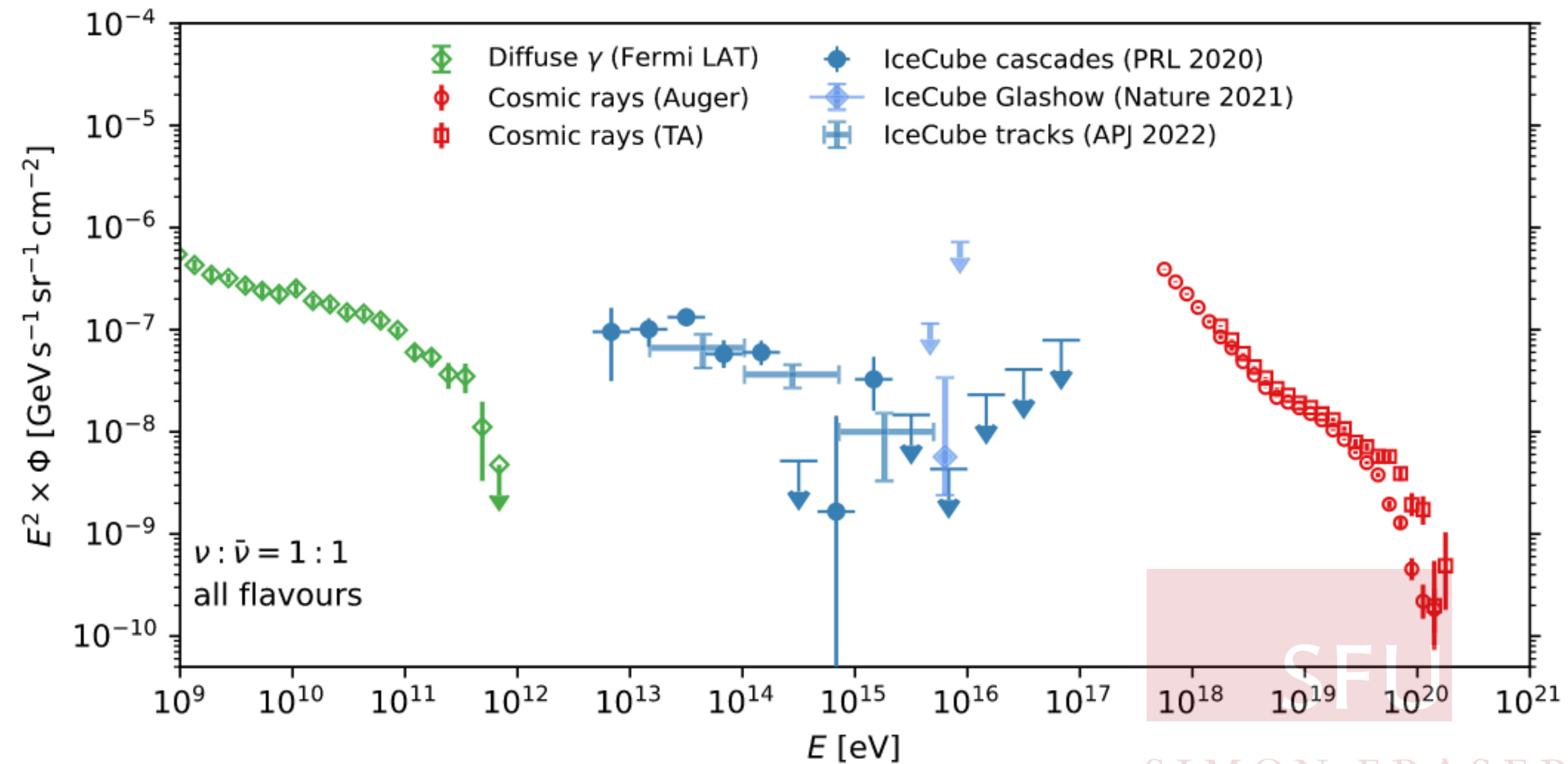


Improved data processing
At the location of NGC 1068:
 79^{+22}_{-20} neutrinos
Spectral index: -3.2 ± 0.2

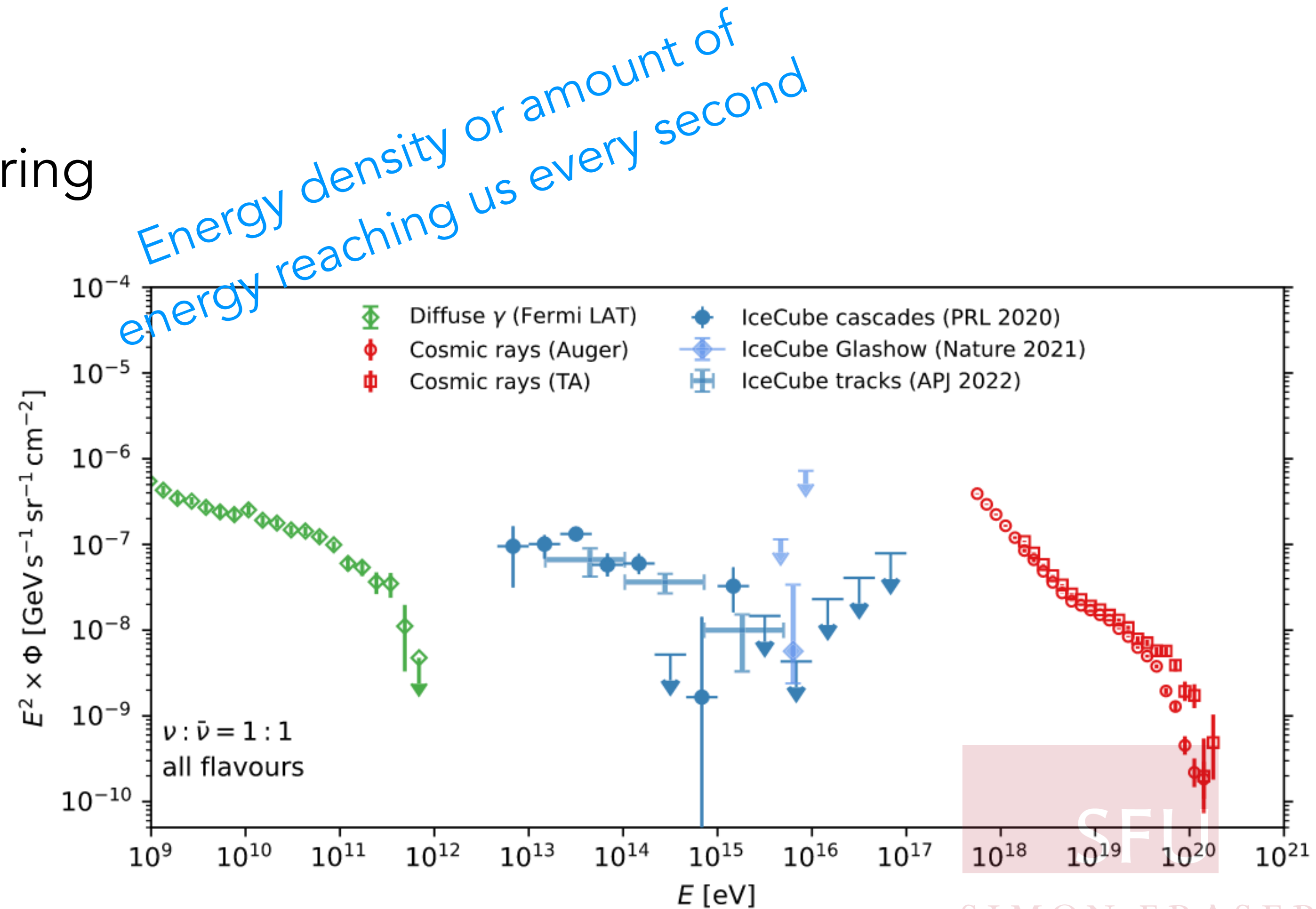
Post-trial significance 4.2σ



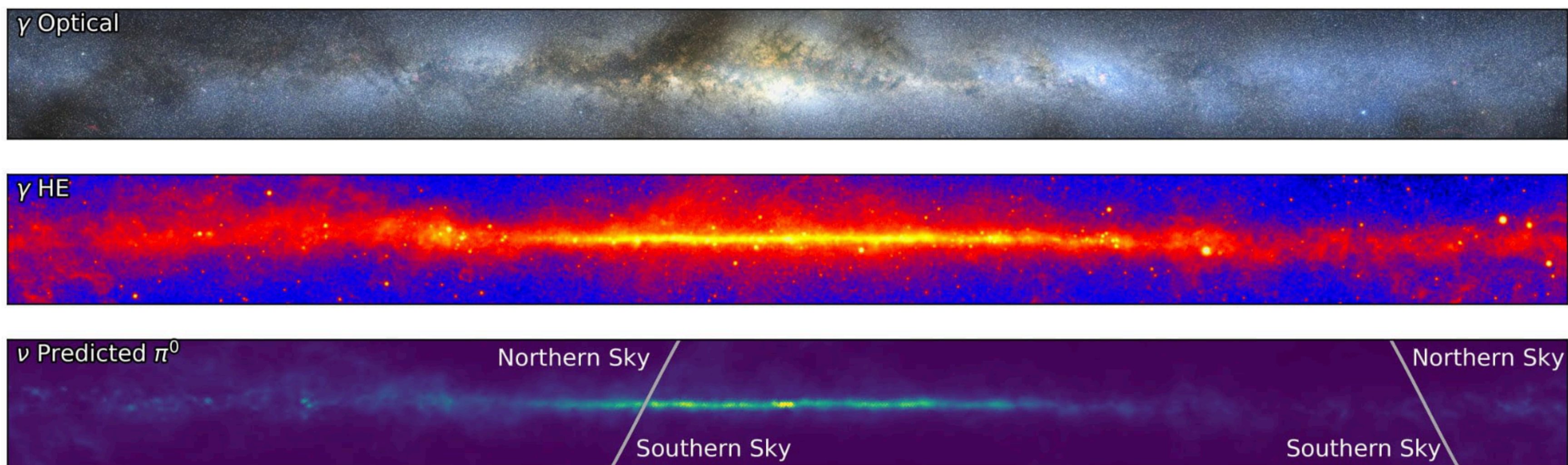
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- 2022 — Second source



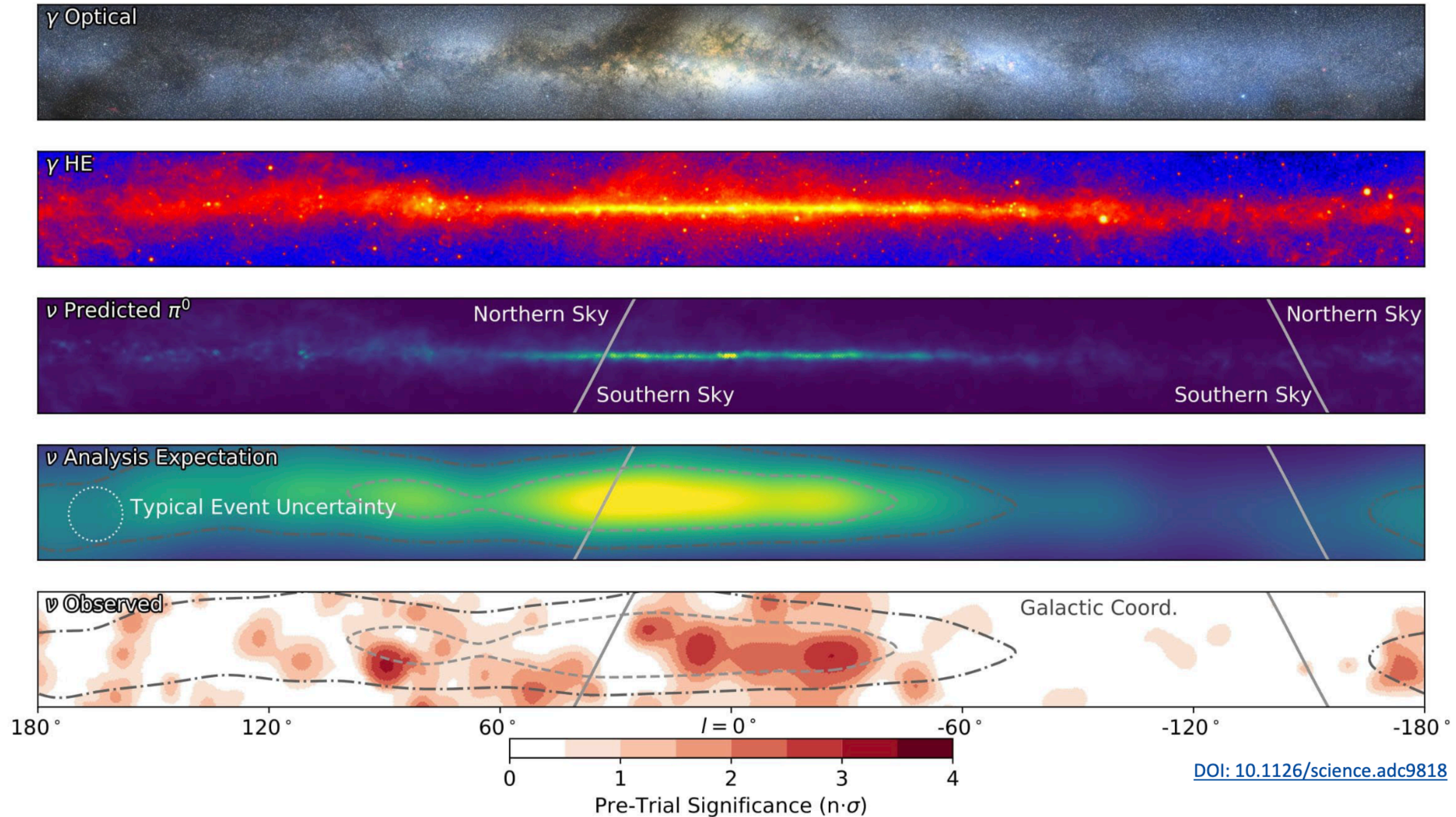
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- 2023 — Galactic sources?



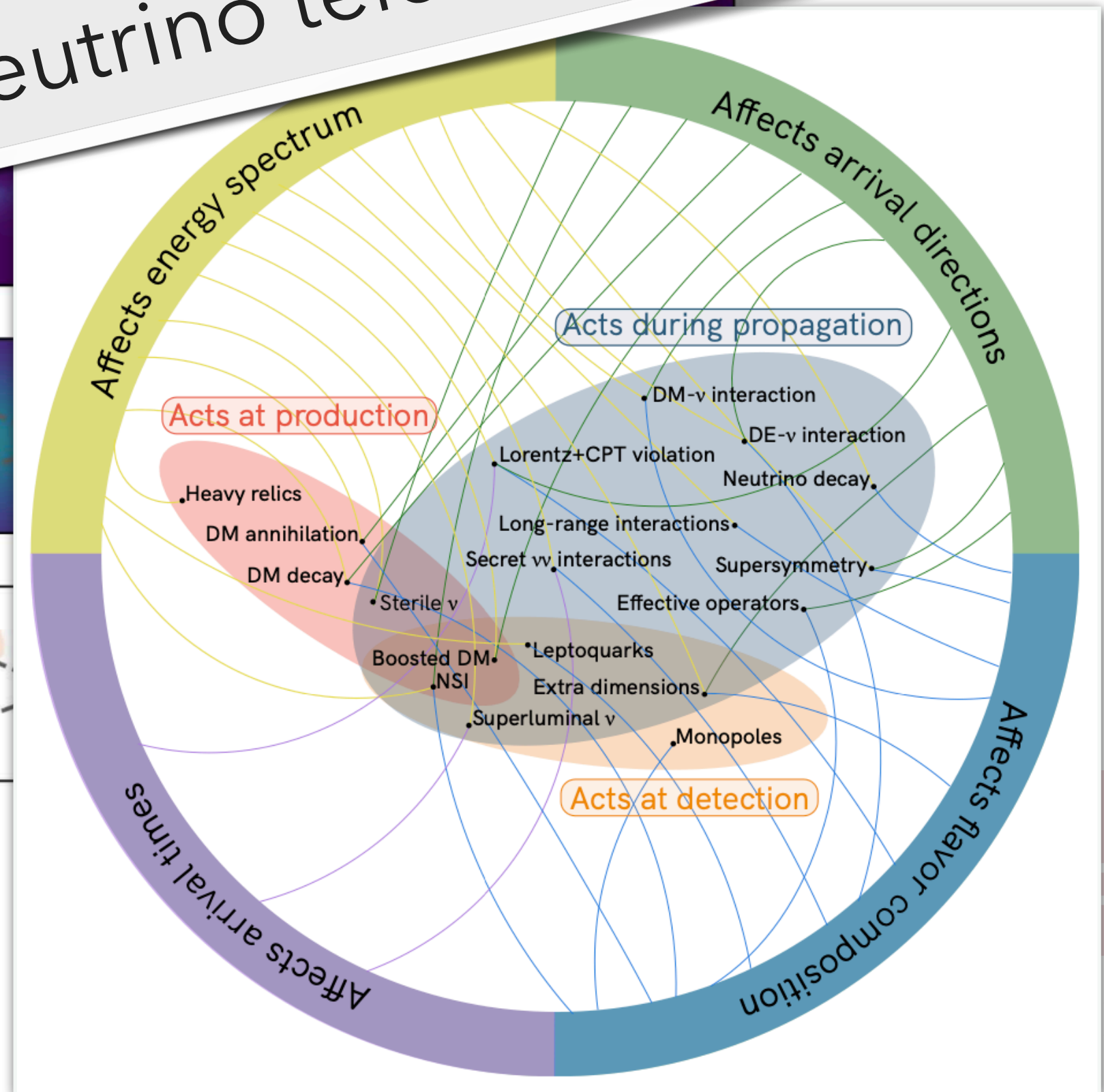
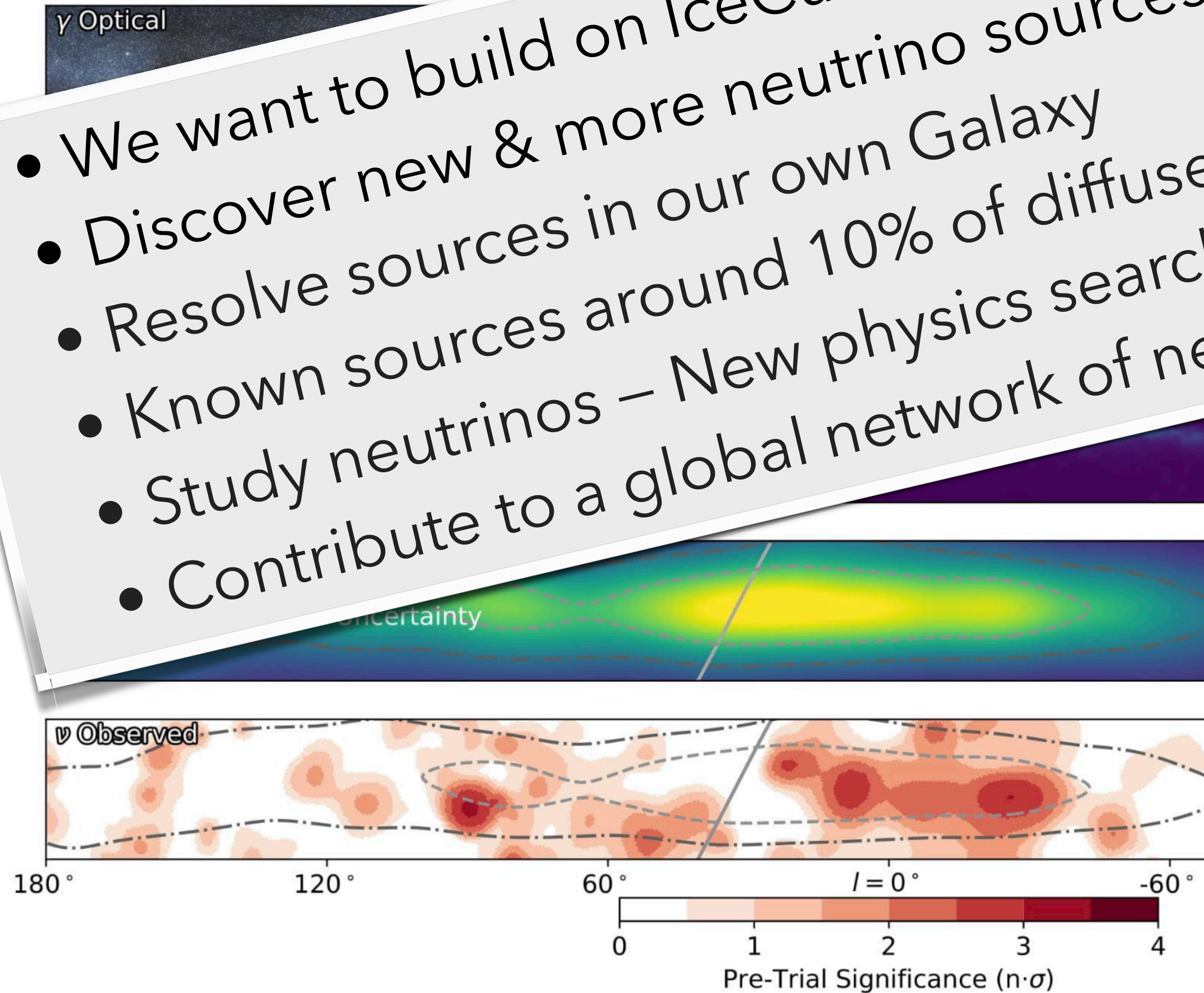
- 2023 — Galactic sources?



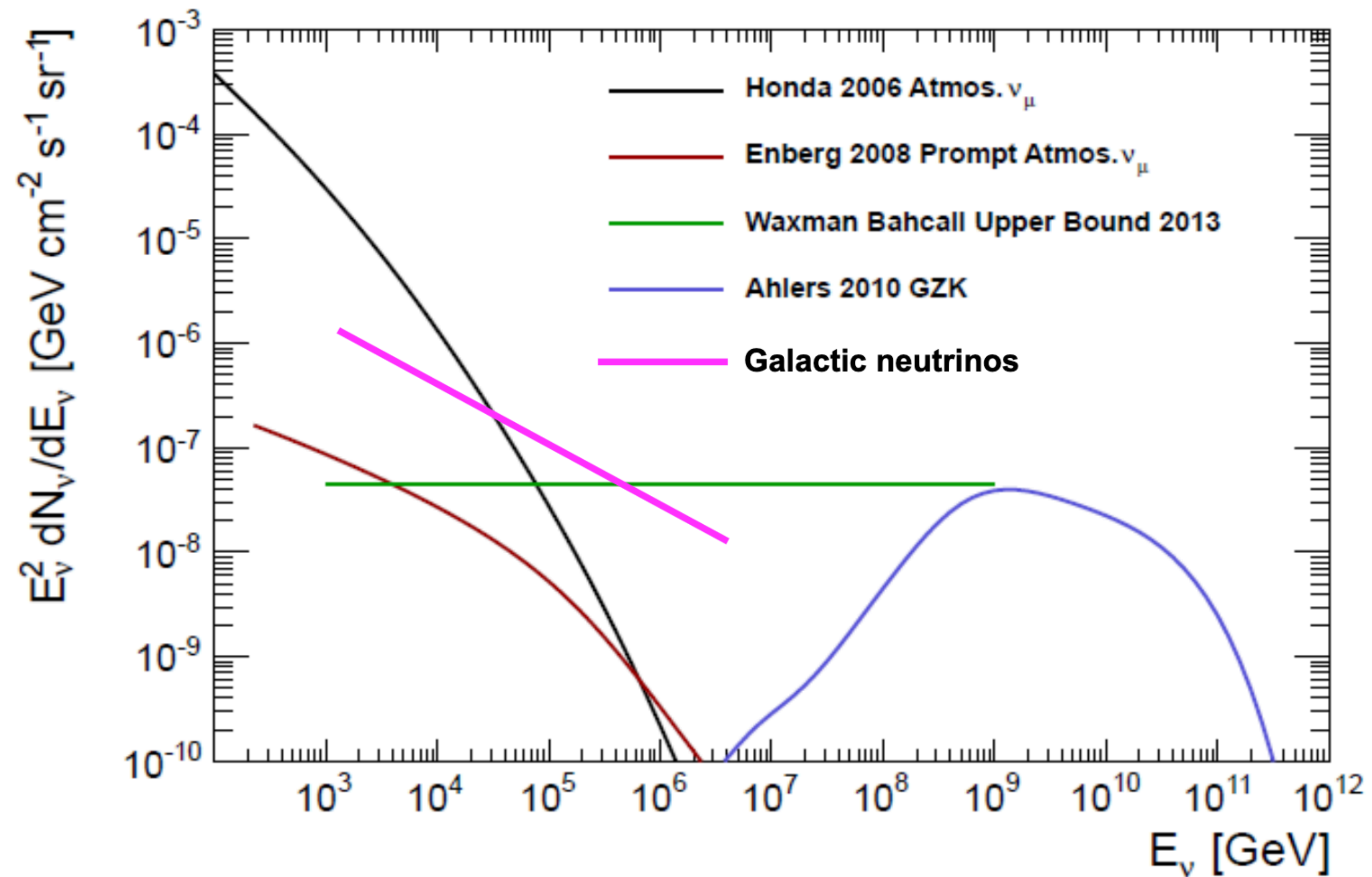
Neutrinos from the Universe

- 2023 — Galactic sources?

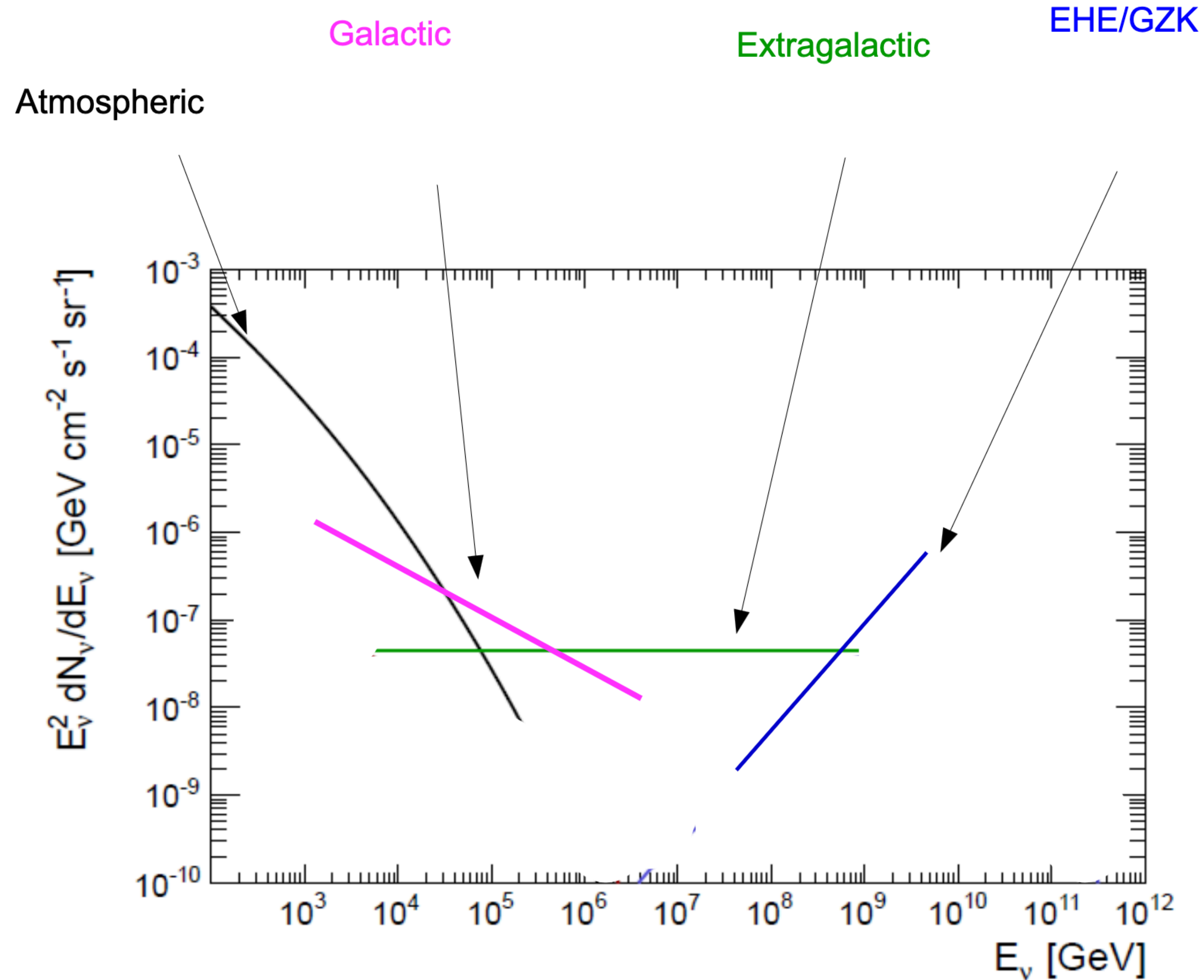
- We want to build on IceCube's neutrino legacy
- Discover new & more neutrino sources
- Resolve sources in our own Galaxy
- Known sources around 10% of diffuse flux
- Study neutrinos – New physics searches
- Contribute to a global network of neutrino telescopes



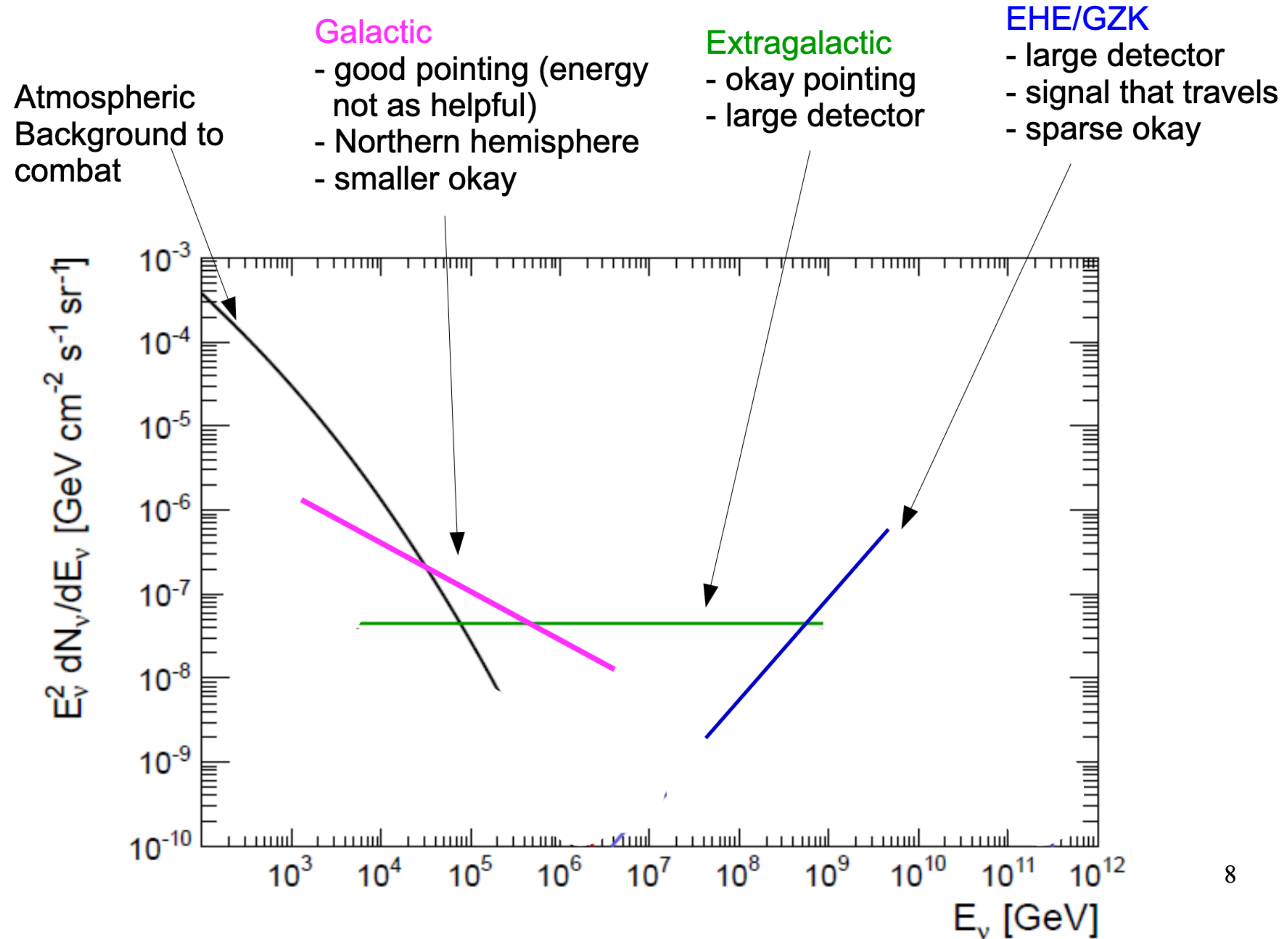
Diverse Neutrino Astronomy Targets



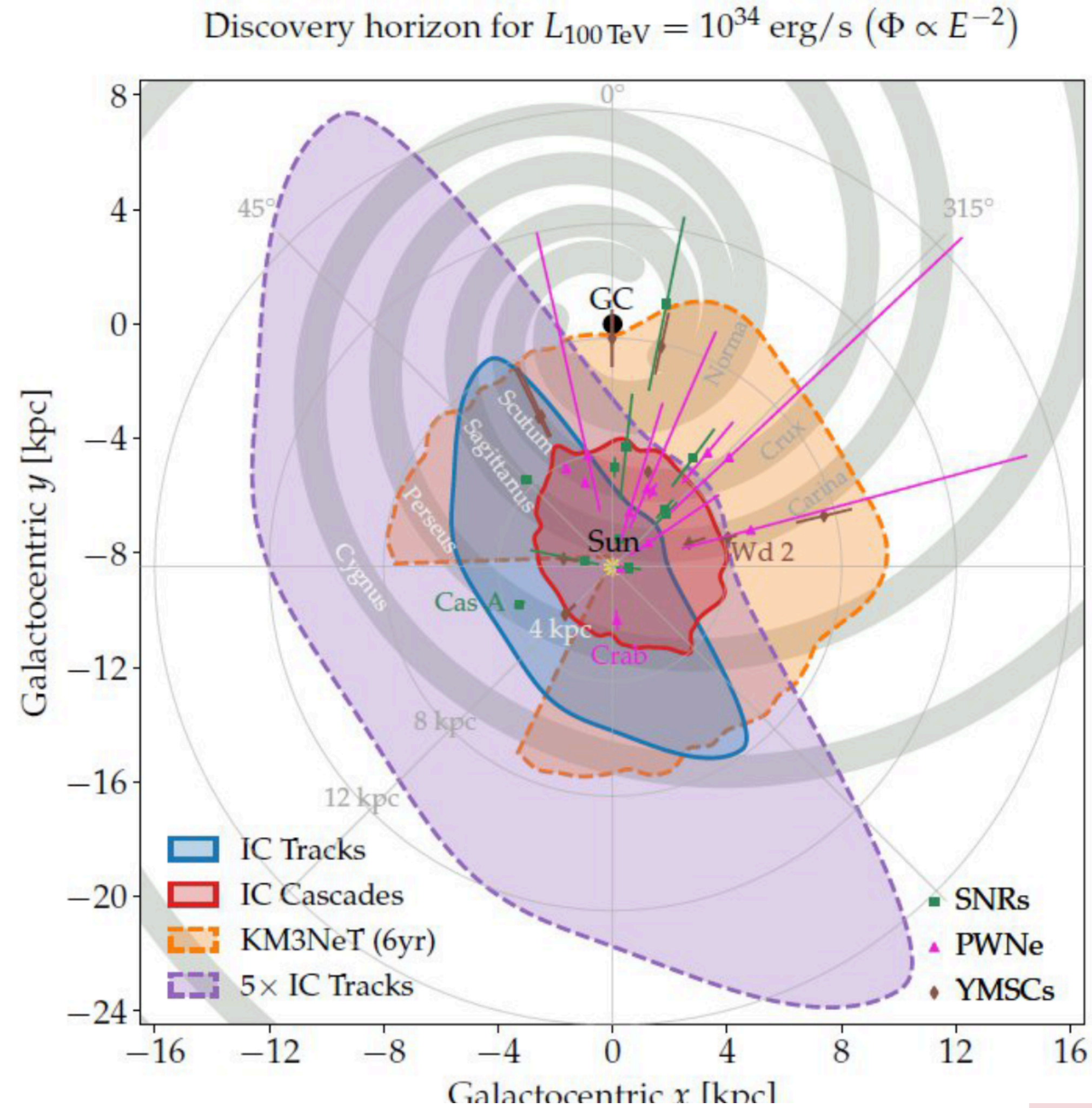
Diverse Neutrino Astronomy Targets



Diverse Neutrino Astronomy Targets



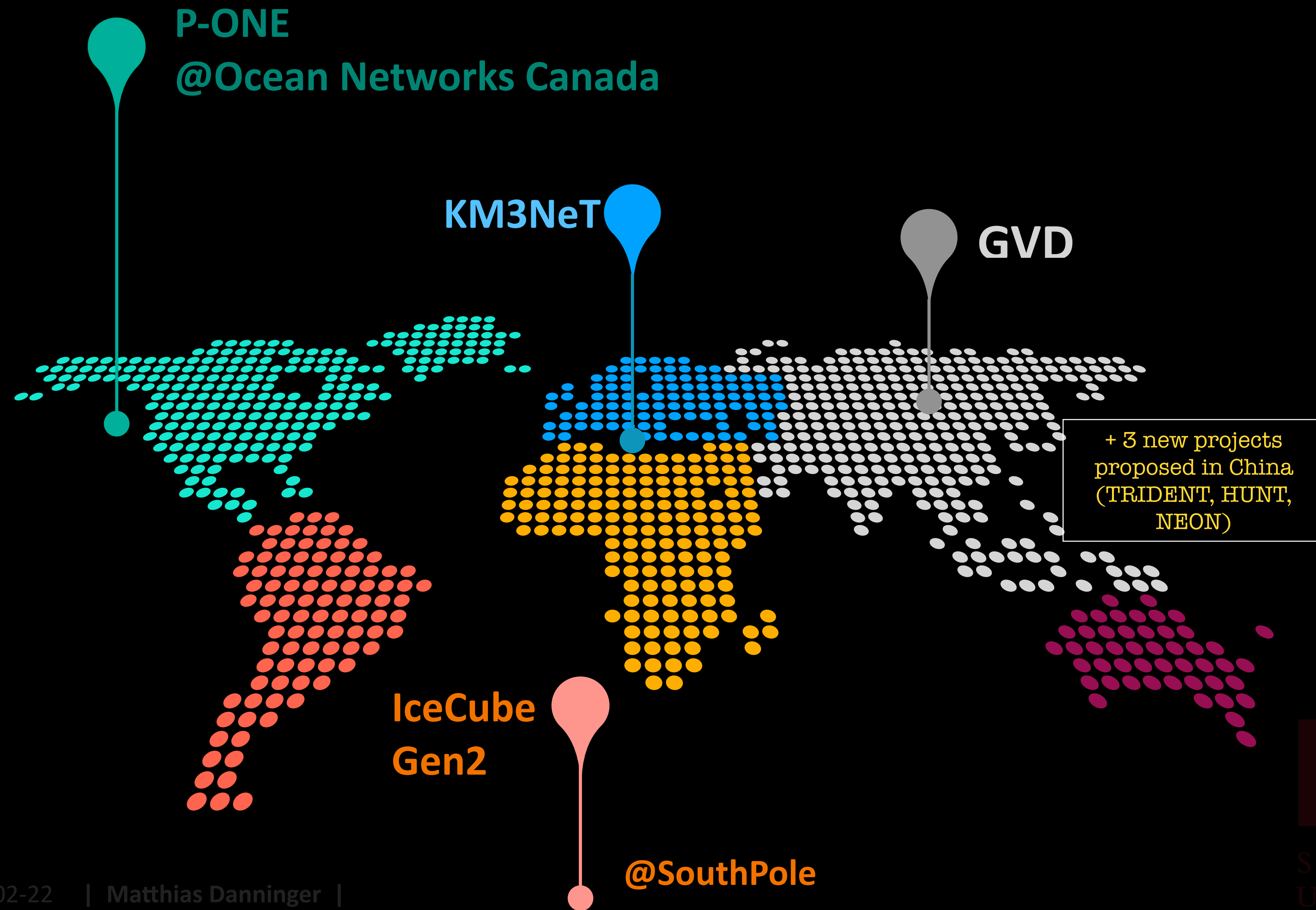
- Field of view for neutrino telescopes matter
- P-ONE has latest technology + new line concept
- With P-ONE we expect unprecedented performance & particle ID
- First Neutrino Telescope hosted by an existing large scale oceanographic infrastructure (ONC)
- Infrastructure can realistically support multi-km³ detector



arXiv:2306.17285

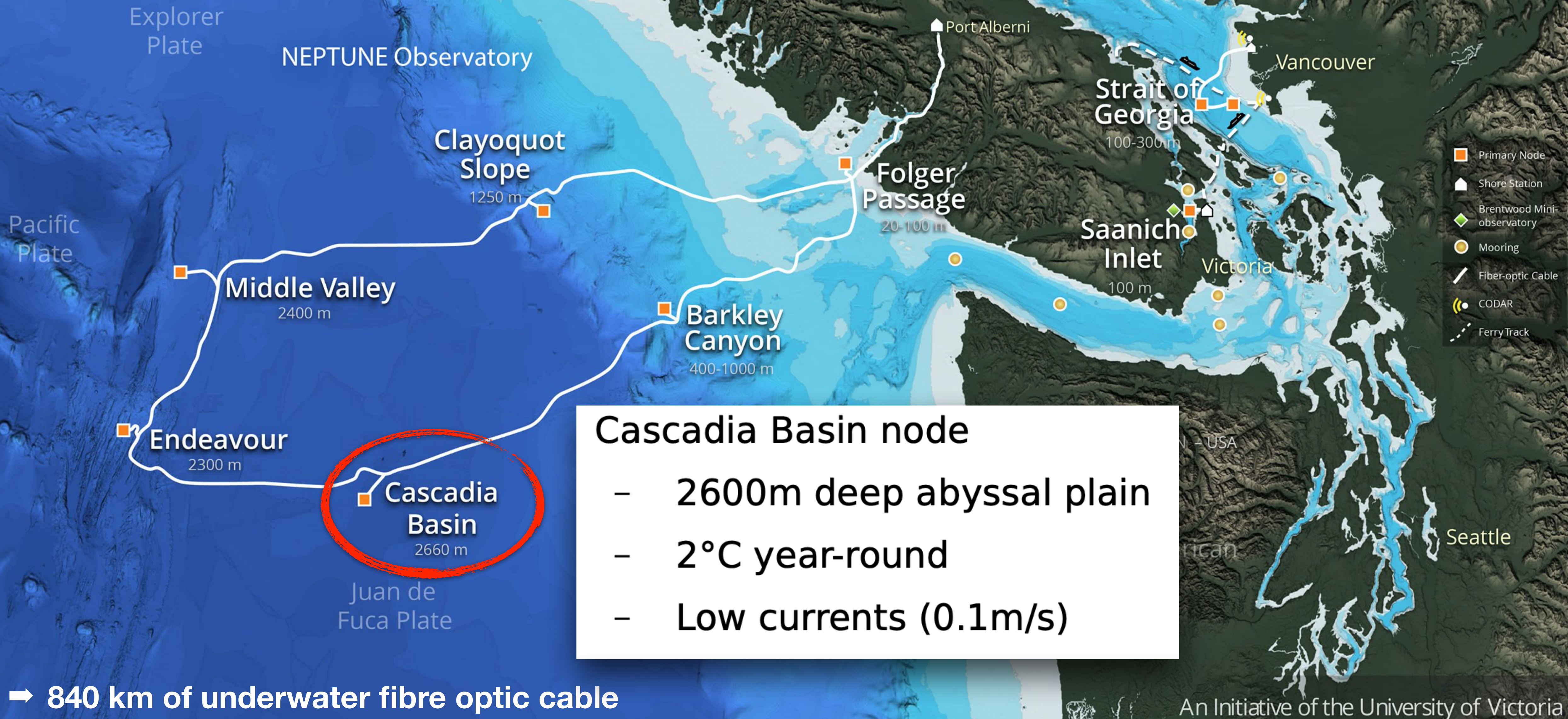
A. Ambrosone, K. M. Groth, E. Peretti, and M. Ahlers

We need more neutrinos: Expanding the Neutrino Net



OCEAN NETWORKS CANADA

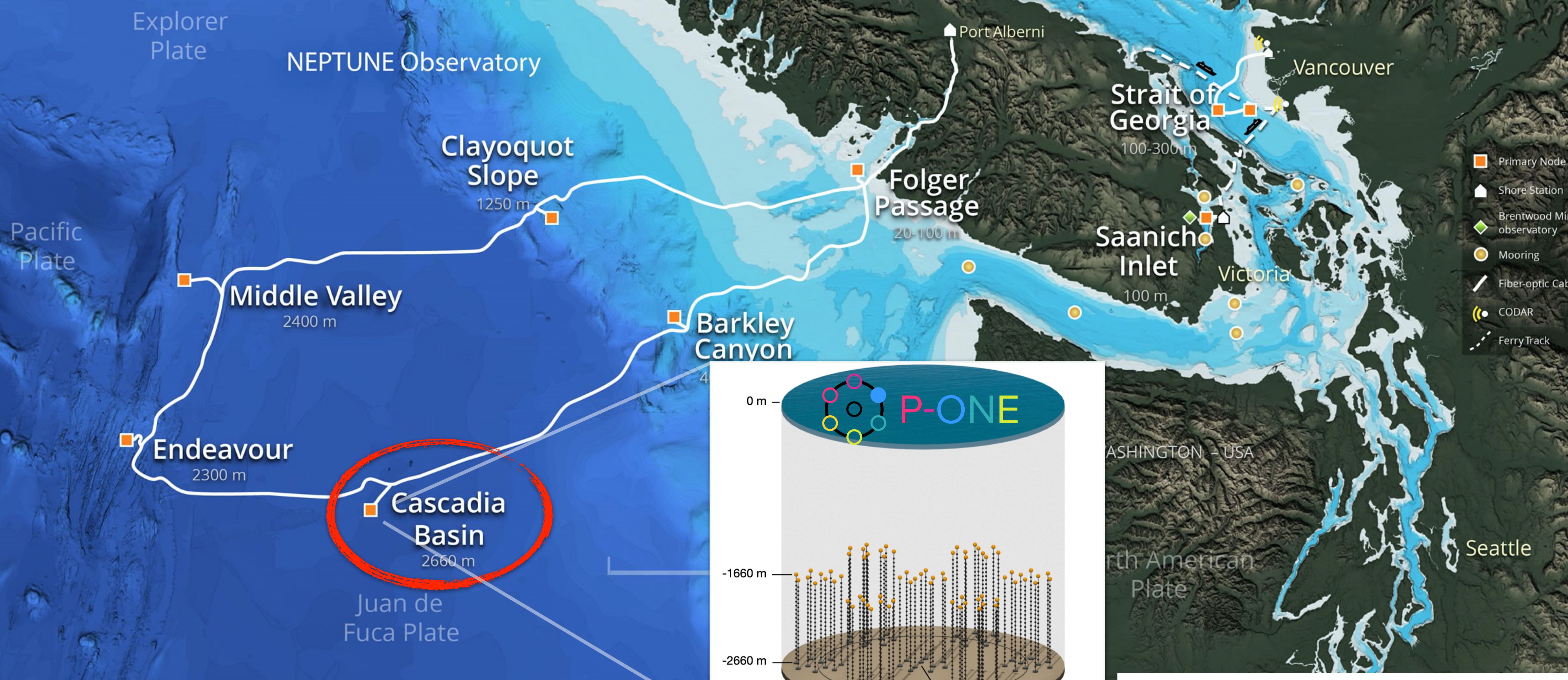
Discover the ocean. Understand the planet.



OCEAN NETWORKS CANADA

Discover the ocean. Understand the planet.

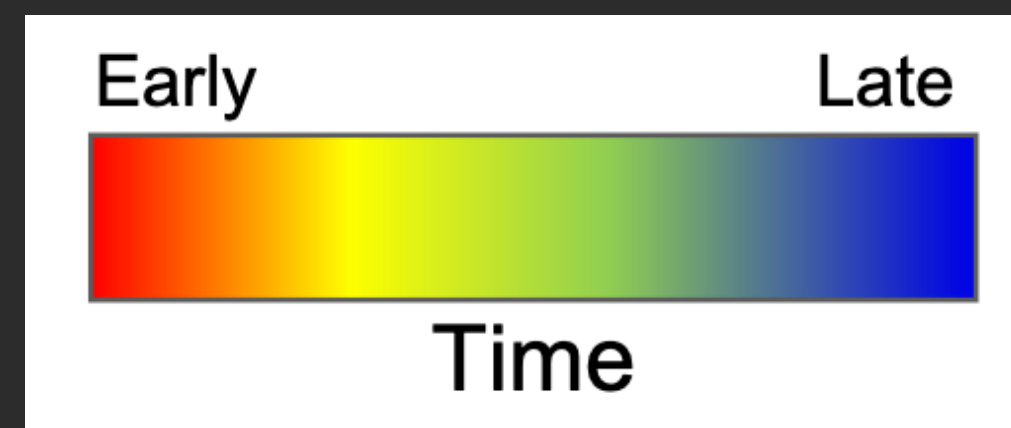
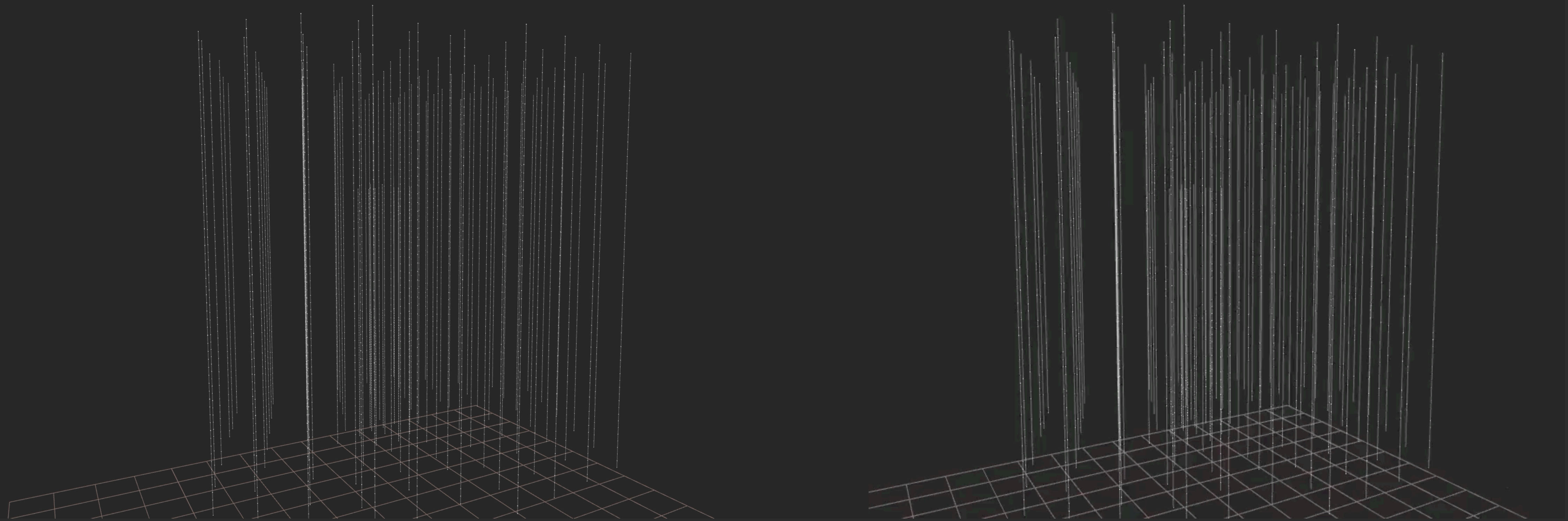
BRITISH COLUMBIA - CANADA



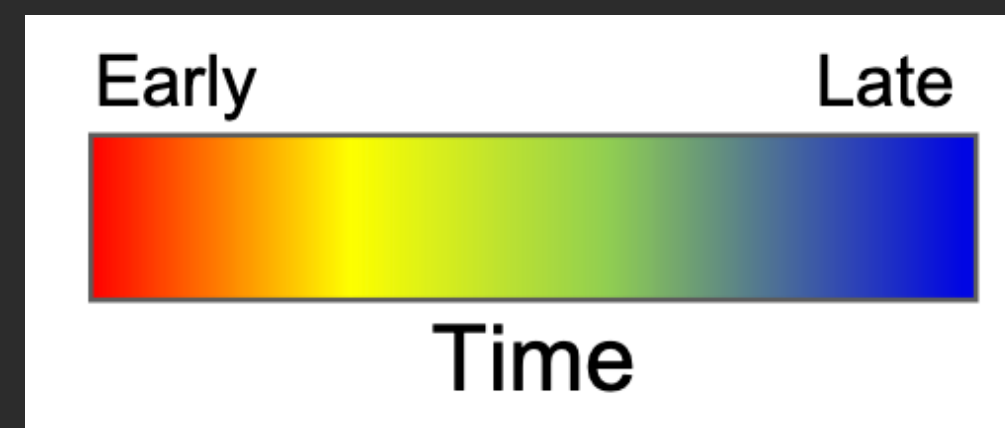
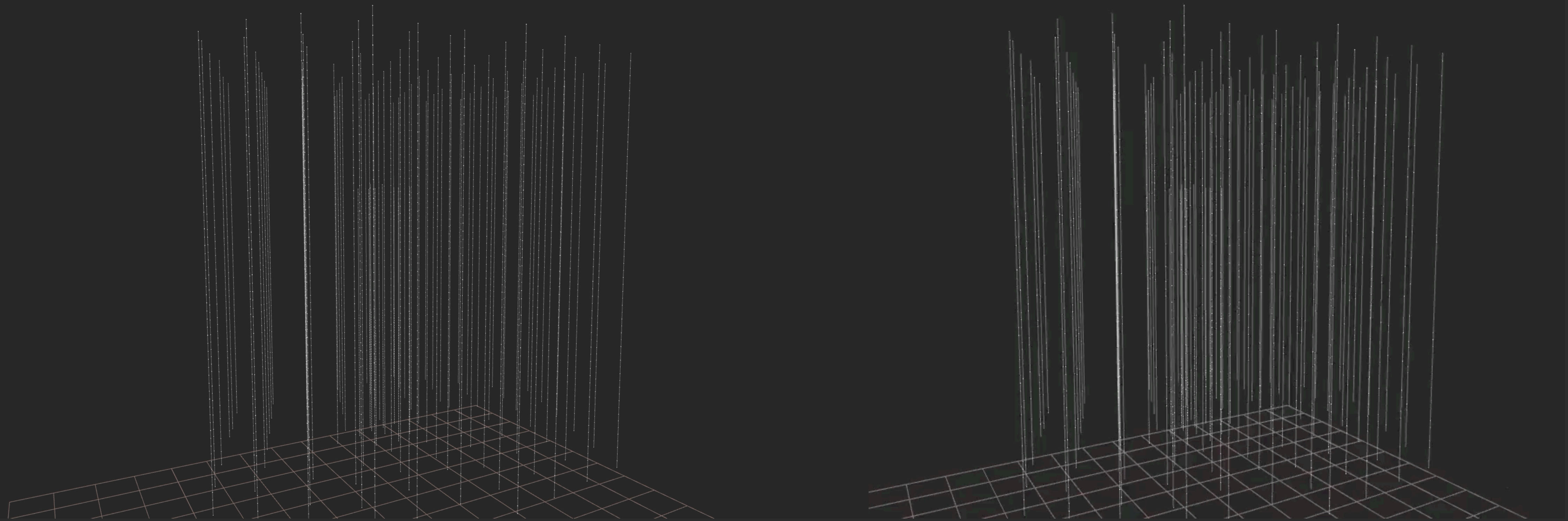
➔ 840 km of underwater fibre optic cable

P-ONE Collaboration, *Nature Astron.* 4 (2020)

P-ONE — Not just big — focus on precision

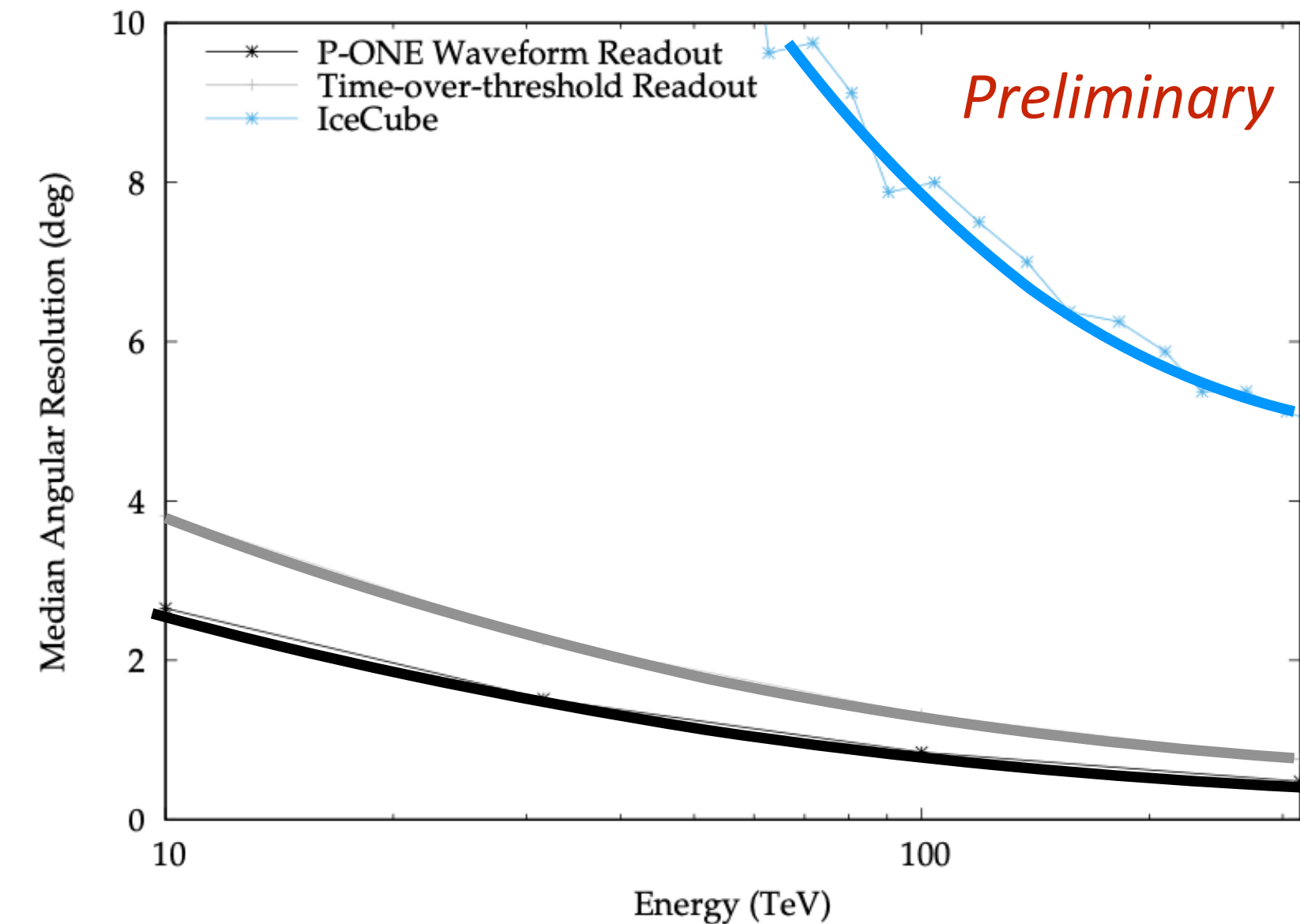
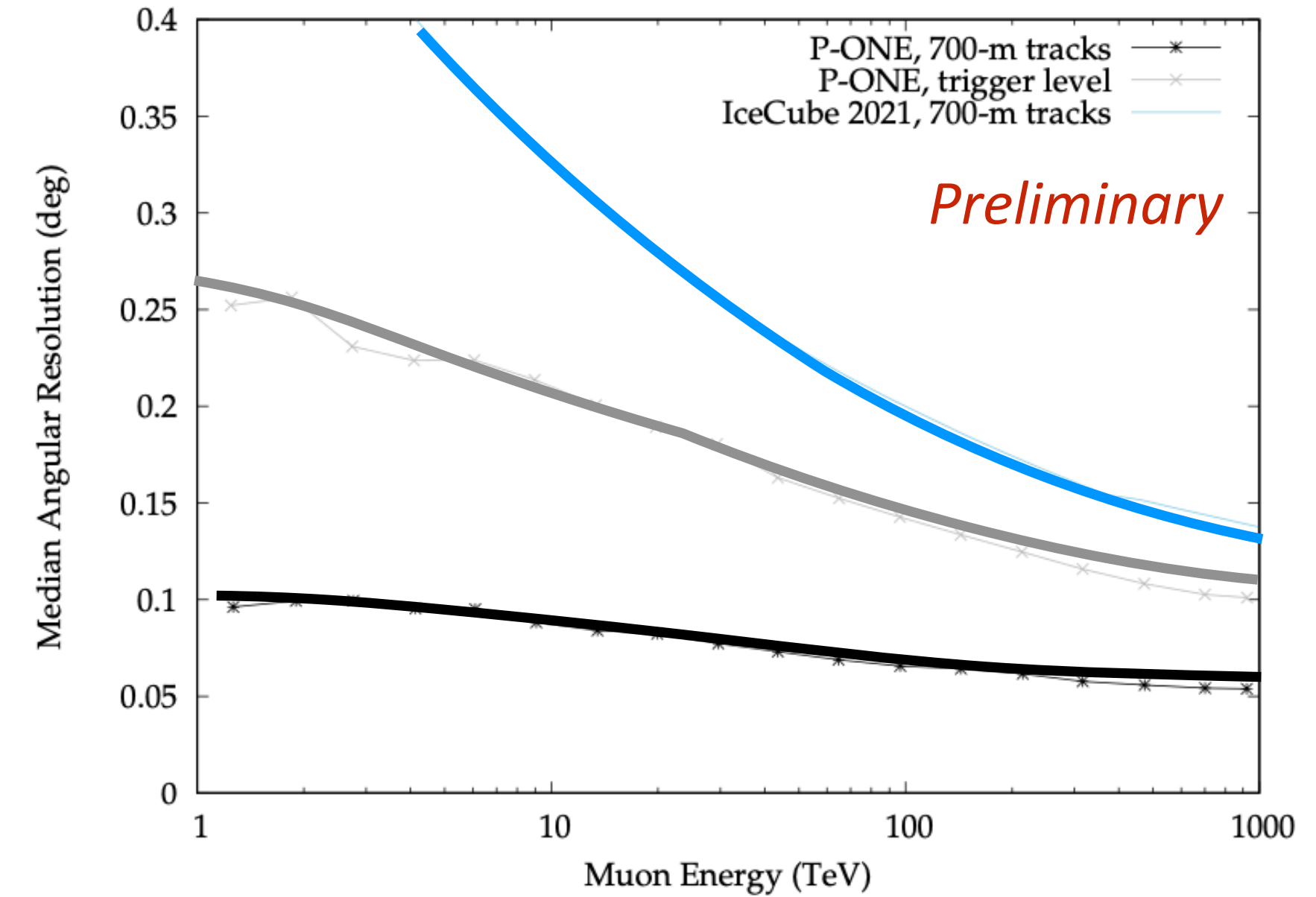
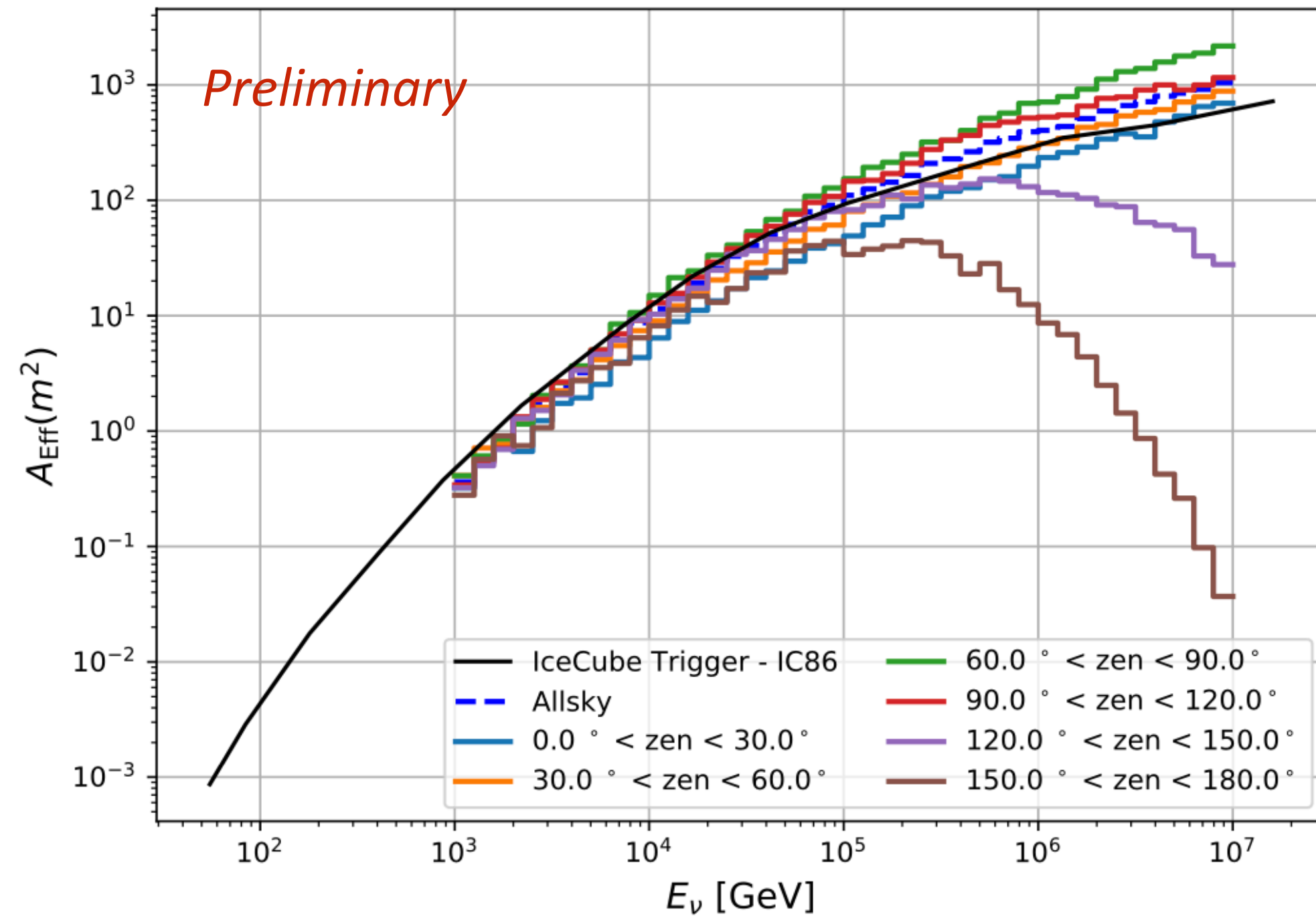


P-ONE — Not just big — focus on precision



P-ONE — Not just big — focus on precision

PoS (ICRC2023) 1175



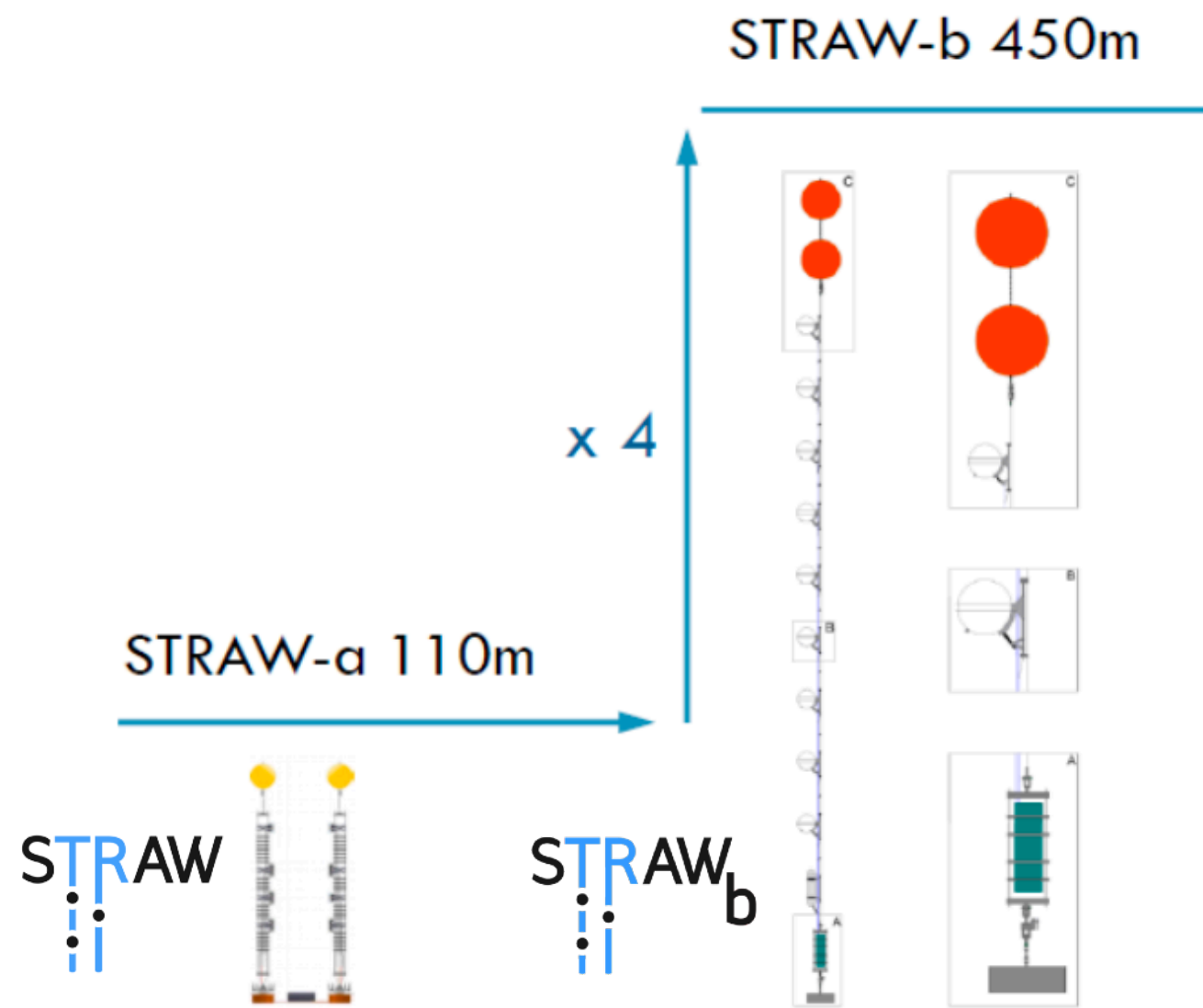
- Simplistic euclidean universe approx.

$$N(> f) \propto f^{-3/2}$$

- 5 times better sensitivity results in *more than 10 times more* sources



P-ONE — project timeline



Pathfinder

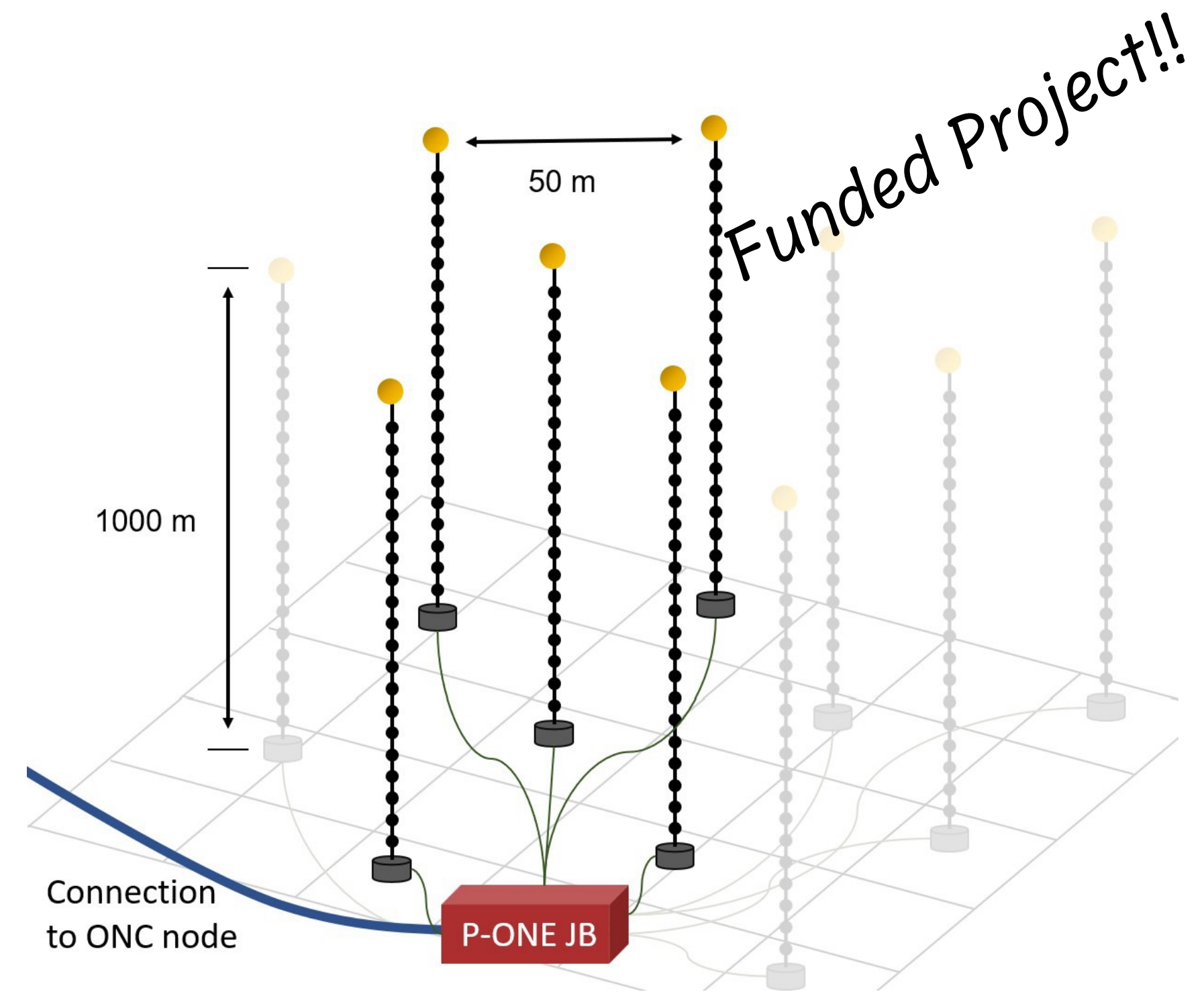
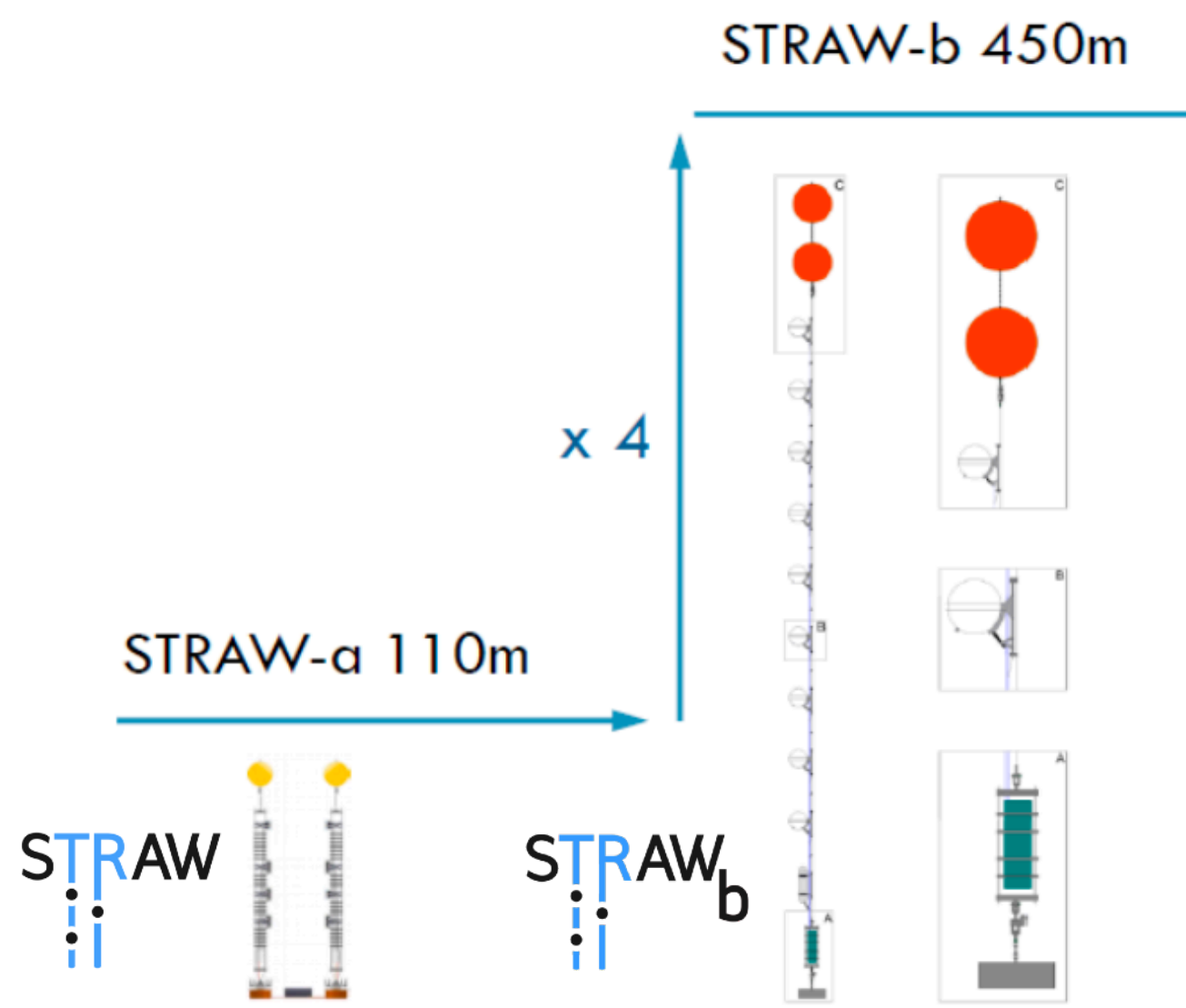
Phase 1 (2018-2023)

P-ONE



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P-ONE — project timeline

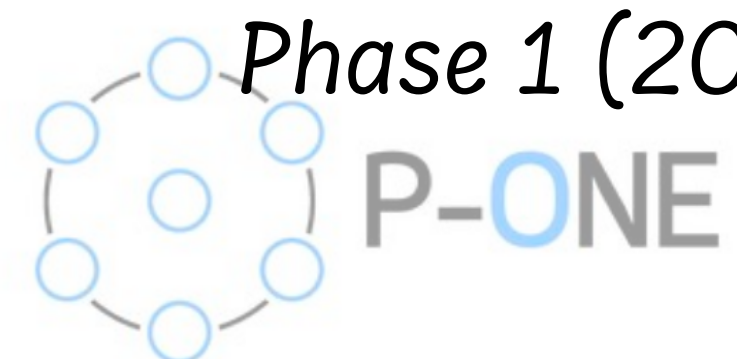


Pathfinder

Demonstrator (7-10 lines)

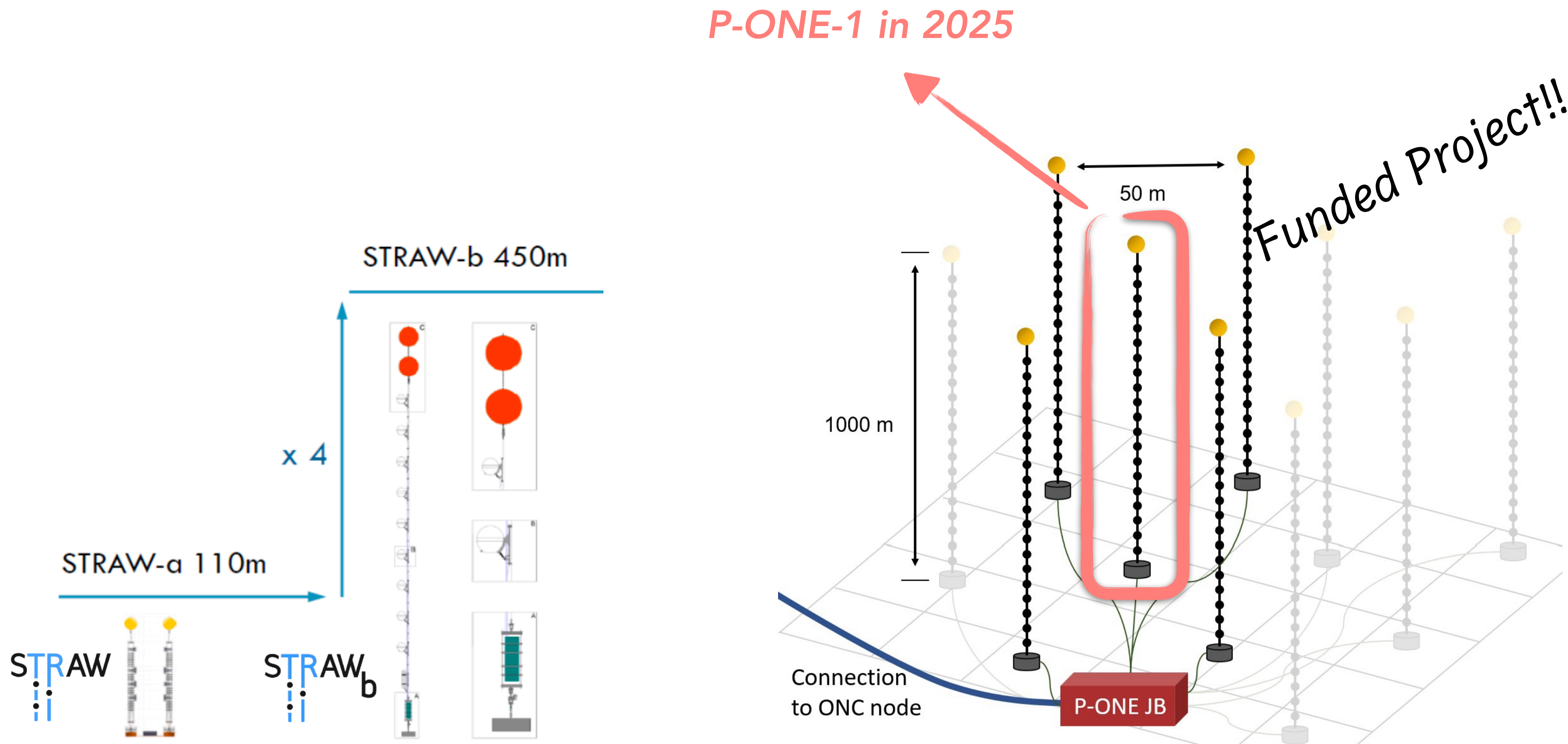
Phase 1 (2018-2023)

Phase 2 (2023-2028)



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P-ONE — project timeline

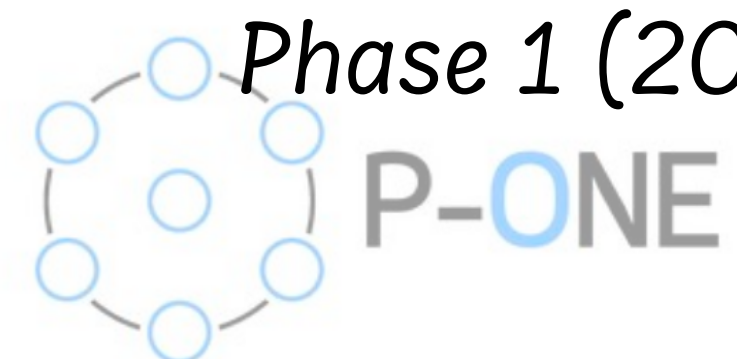


Pathfinder

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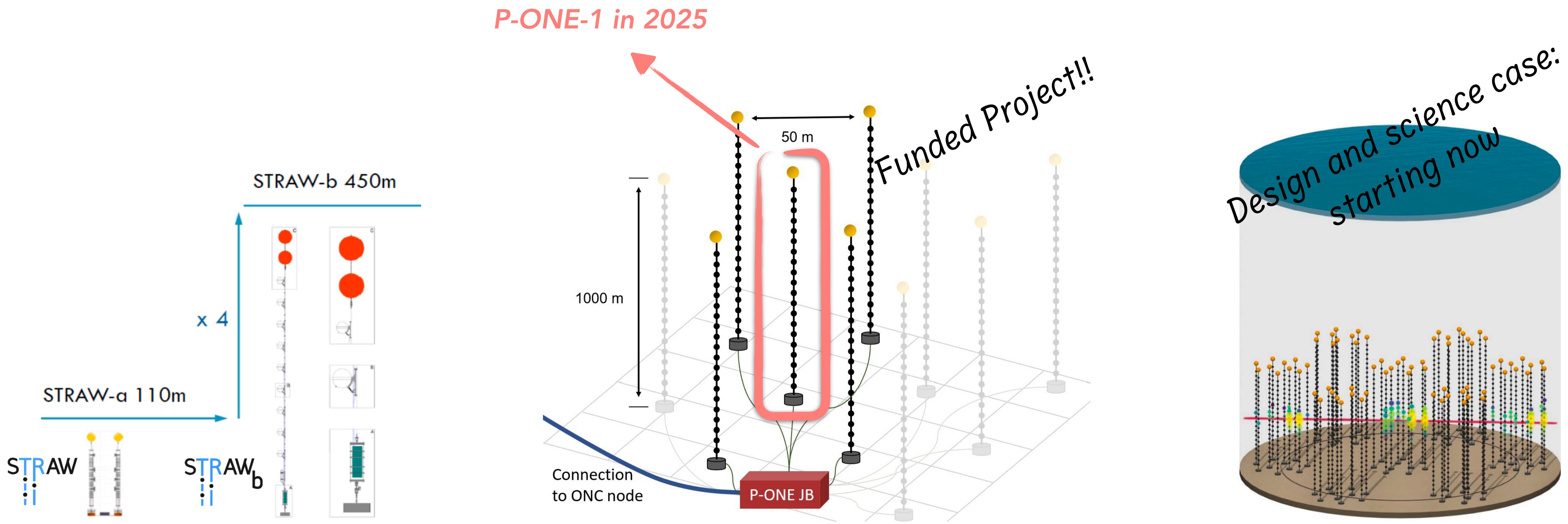
Phase 1 (2018-2023)

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P-ONE — project timeline



Pathfinder

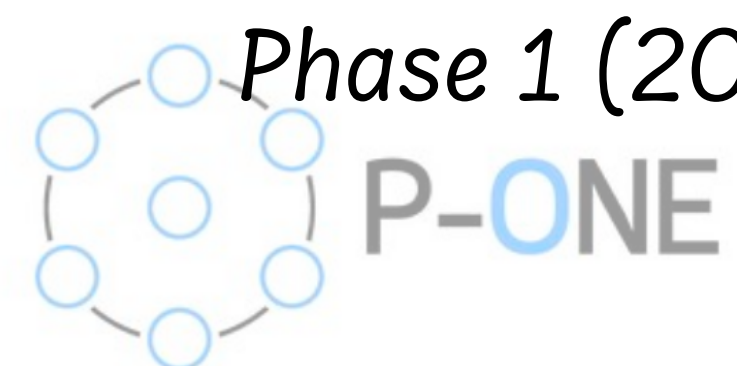
Phase 1 (2018-2023)

Demonstrator (7-10 lines)

Phase 2 (2023-2028)

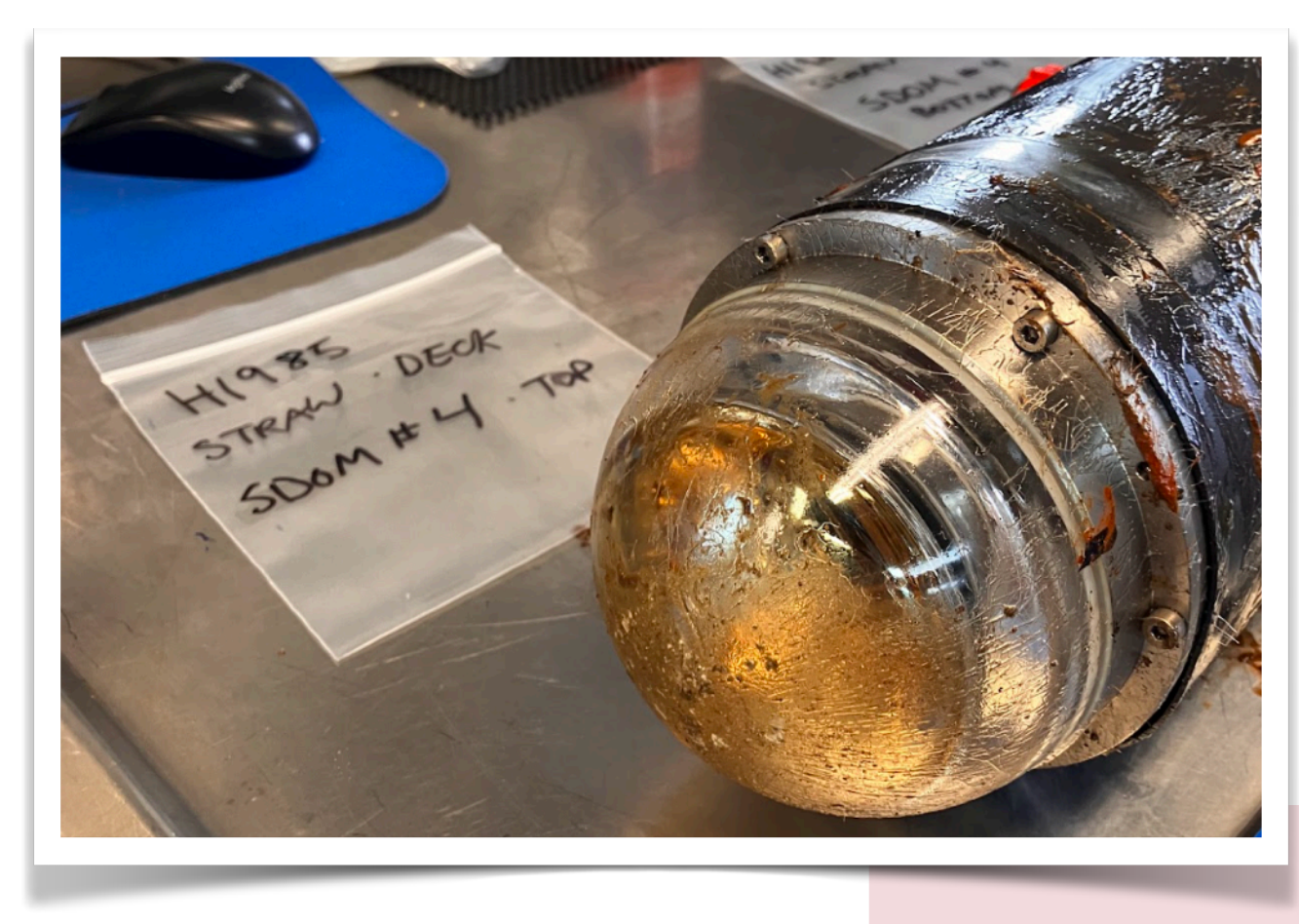
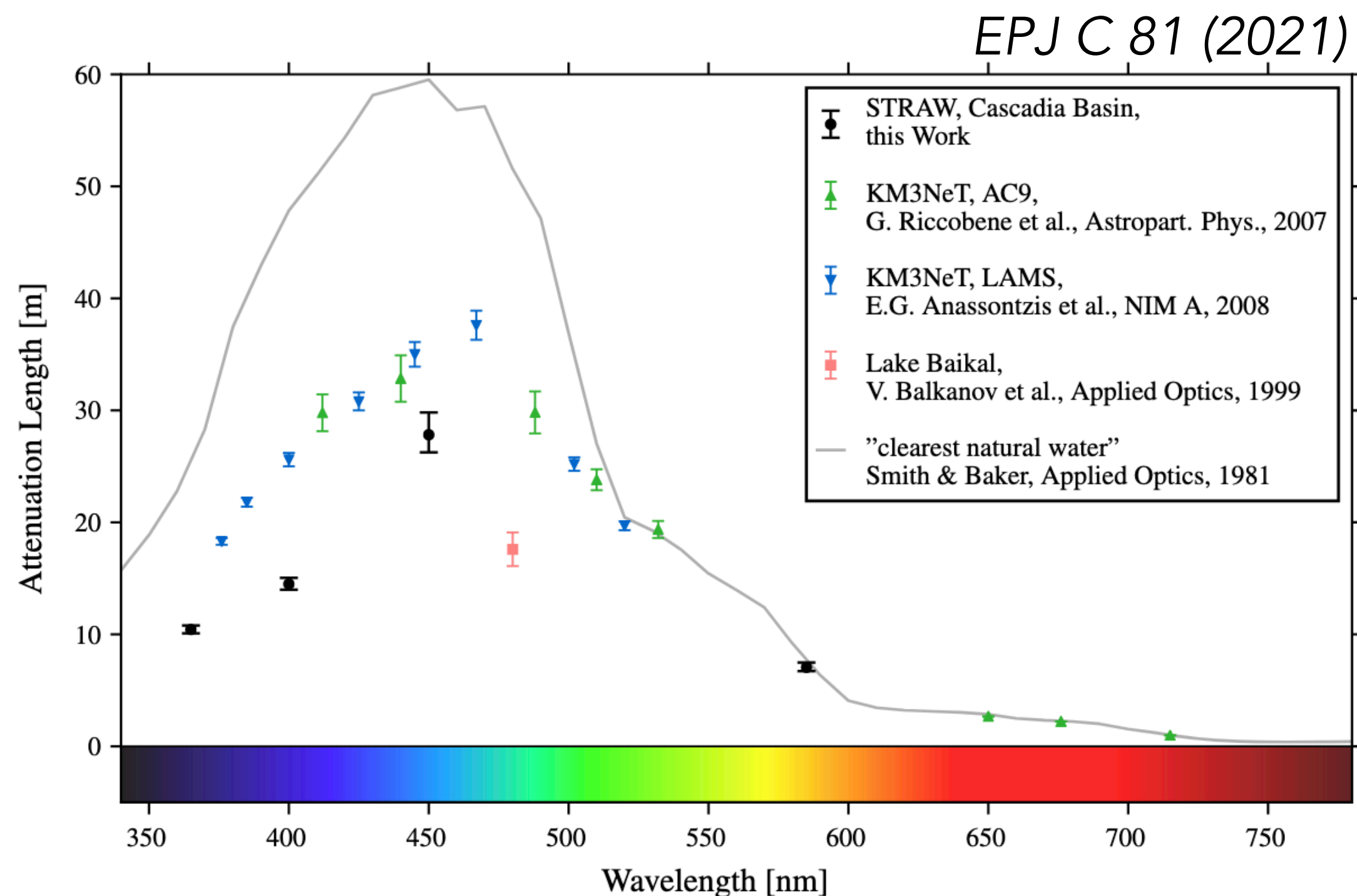
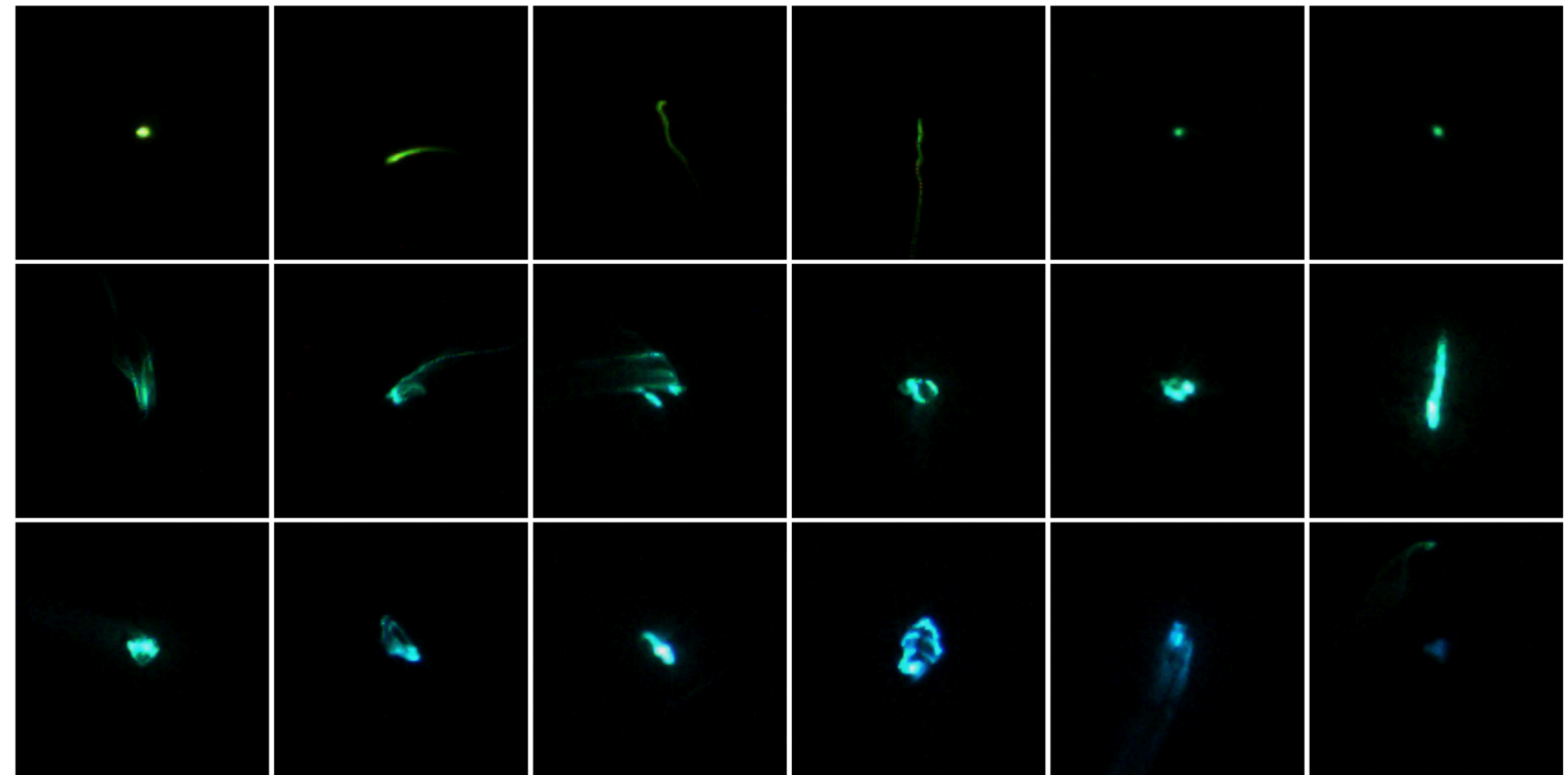
P-ONE

Phase 3 (2028->)



- [5-years operation](#) of STRAW (98% uptime)
- Attenuation Length $\sim 30\text{m}$ @ 450nm
- K40 background quantified
- Bioluminescence, sedimentation and biofouling as main challenges identified.

PoS (ICRC2023) 1166



— P-ONE detector line concept —

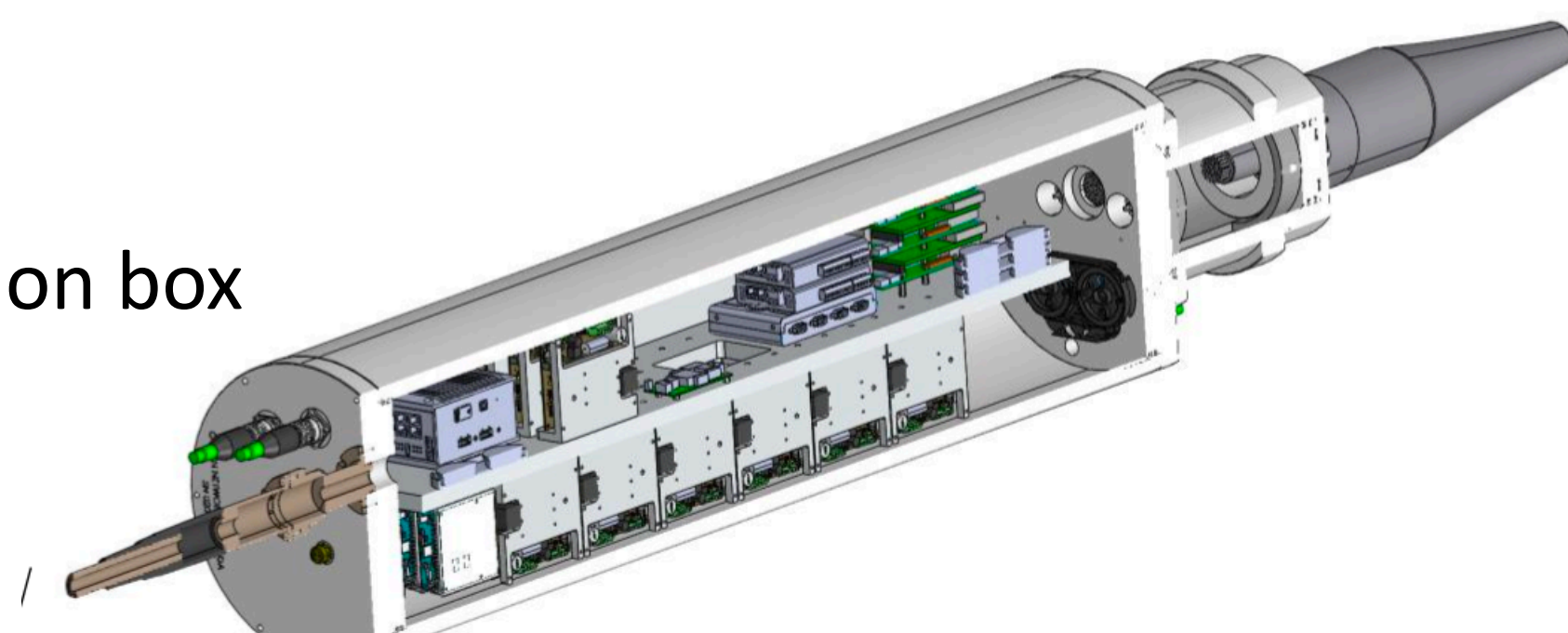


P-ONE detector line concept

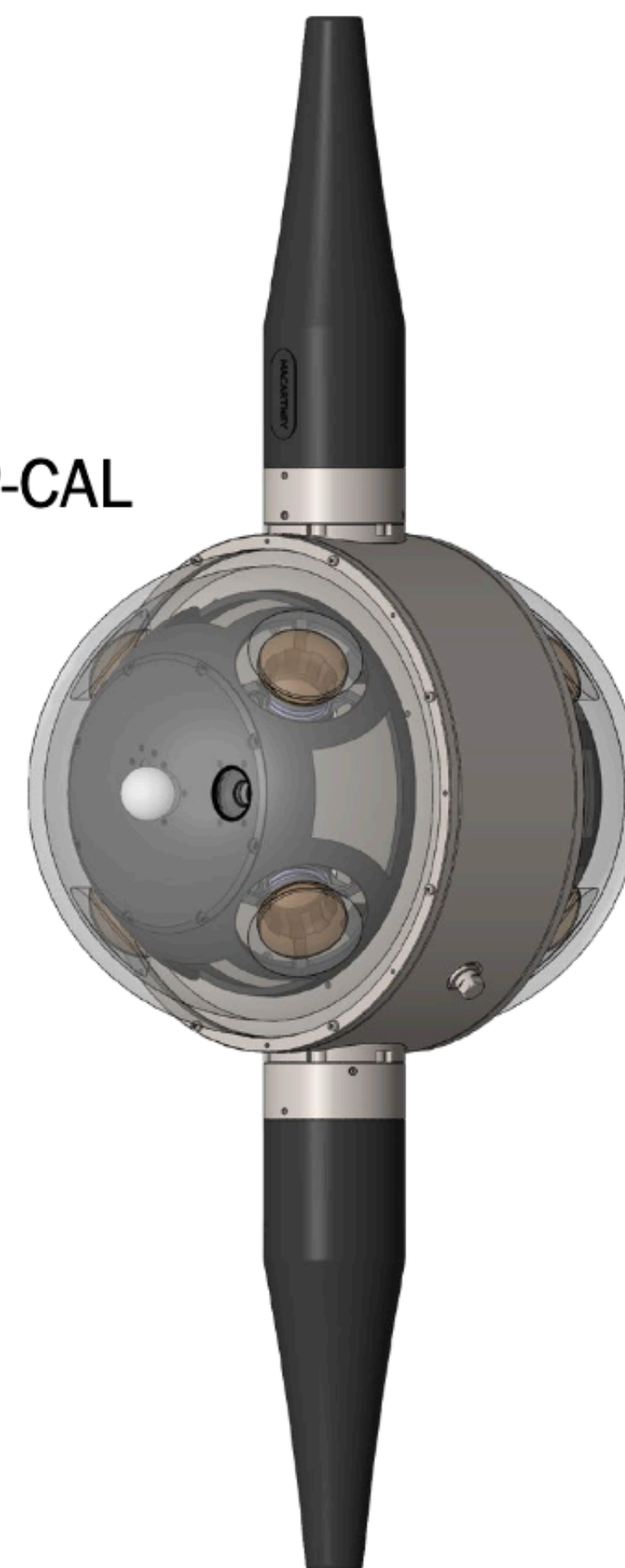
Key facts

- 1 km long mooring line with 20 modules
- Connector-less design
- Optical and calibration modules
- Acoustic & optical calibration systems
- Sub-ns time synchronization
- Mooring network infrastructure

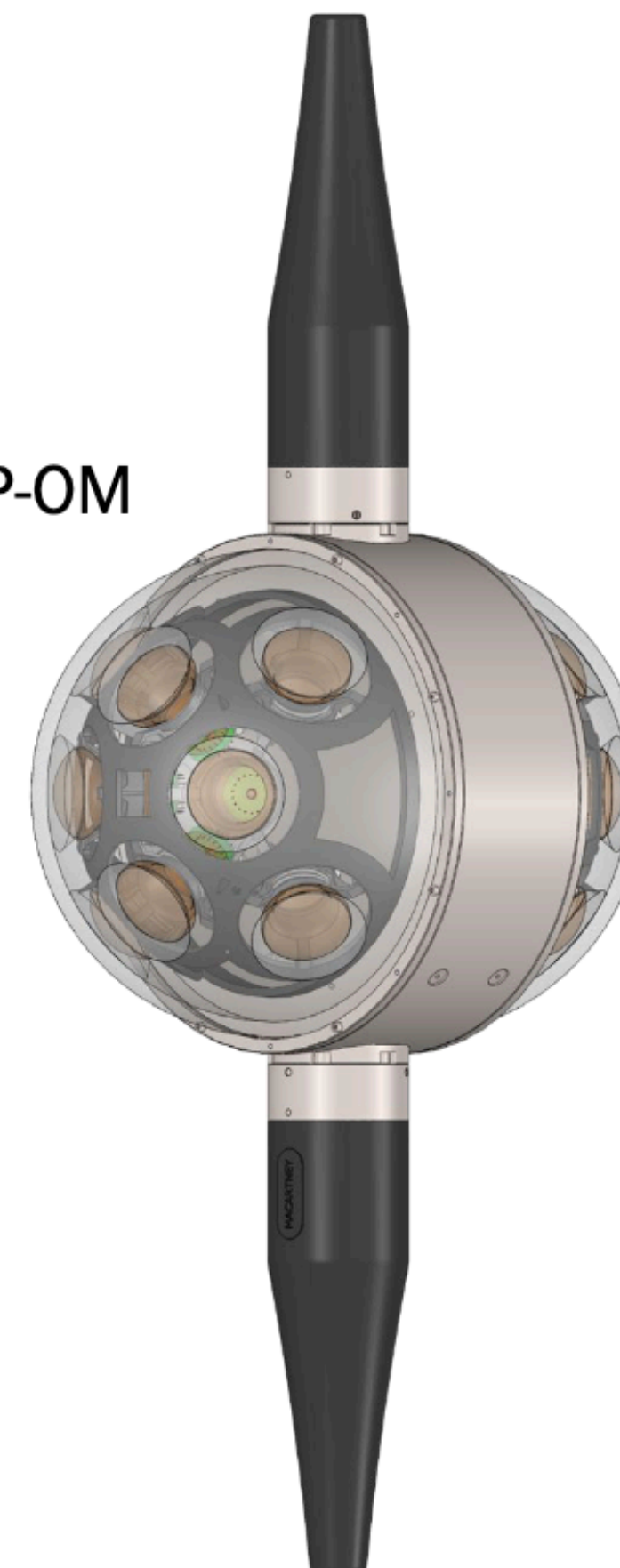
String junction box



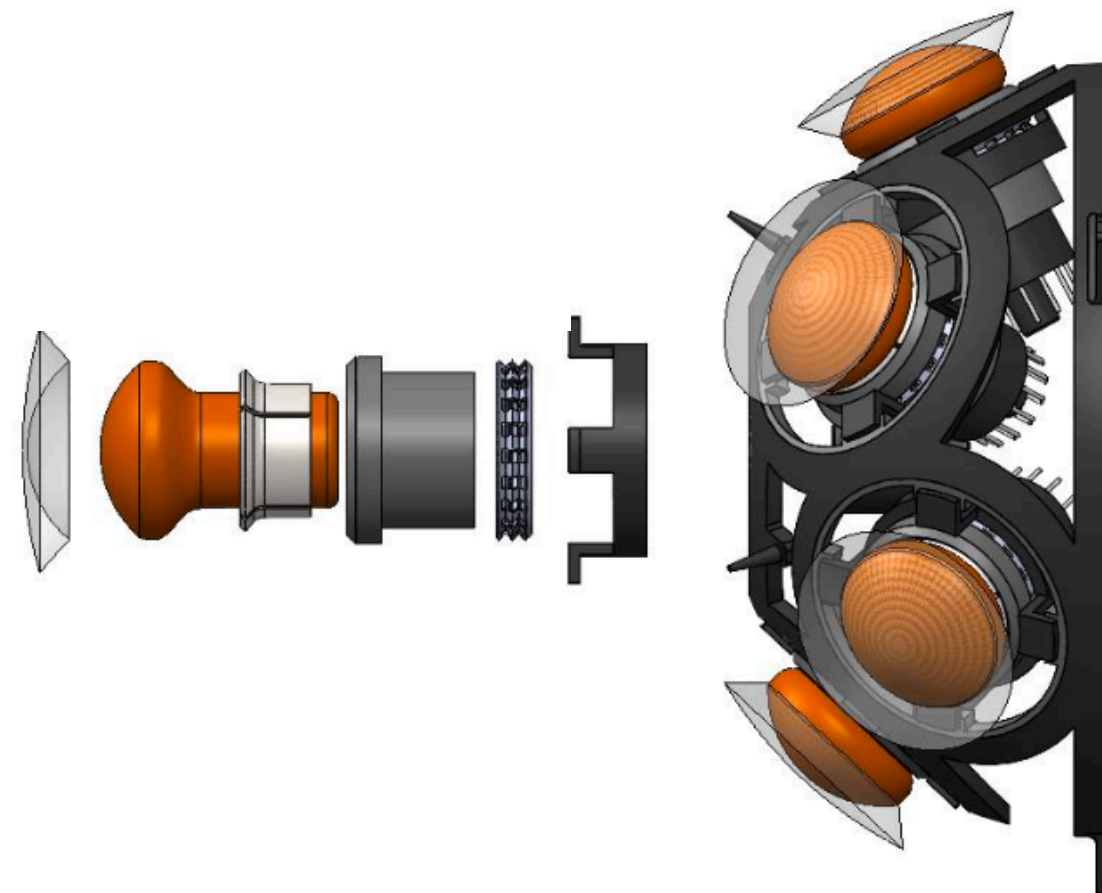
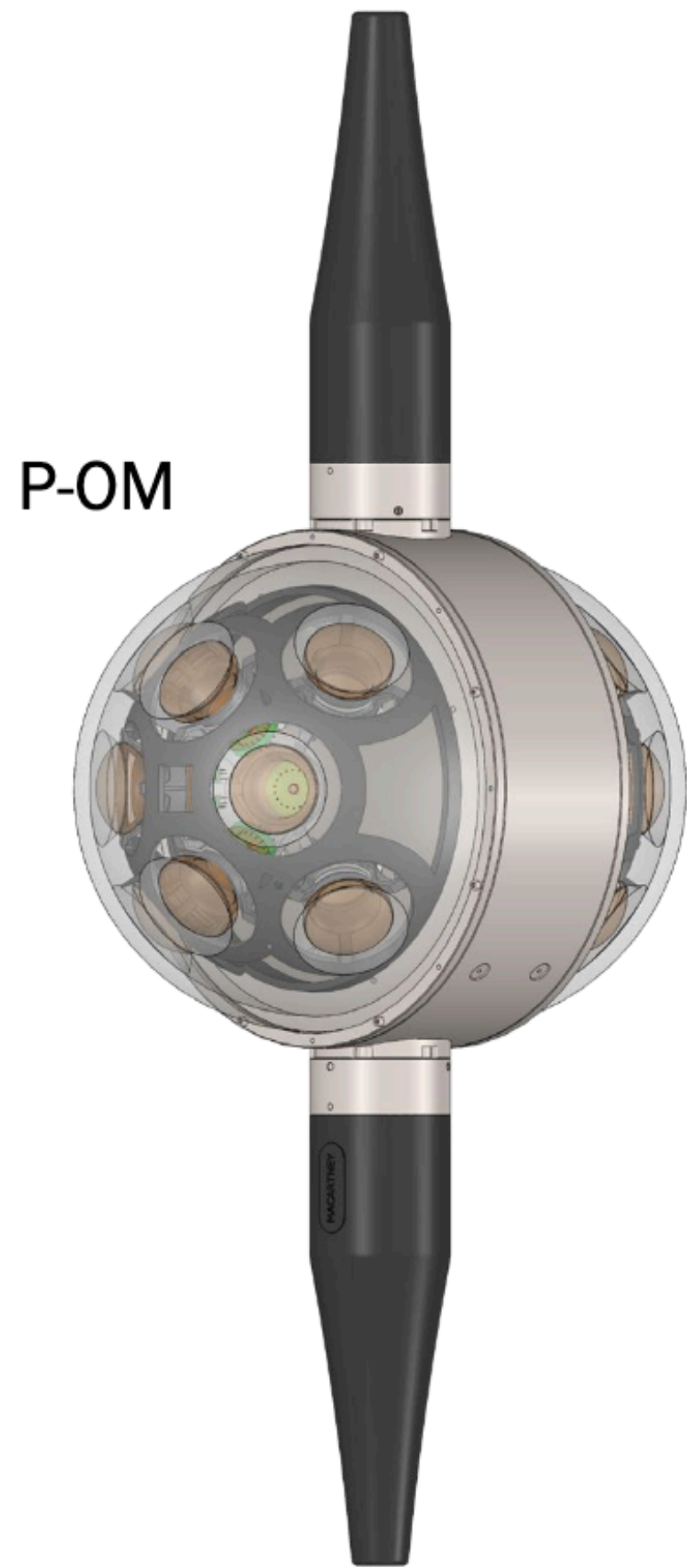
P-CAL



P-OM

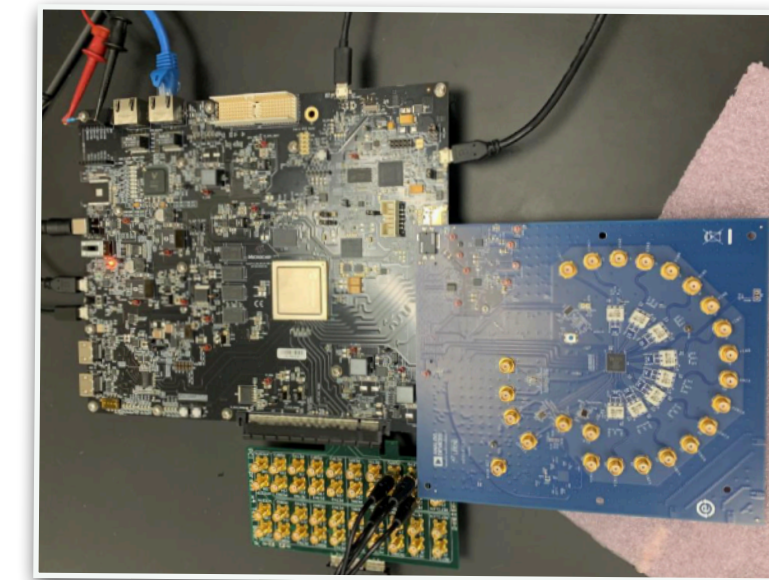


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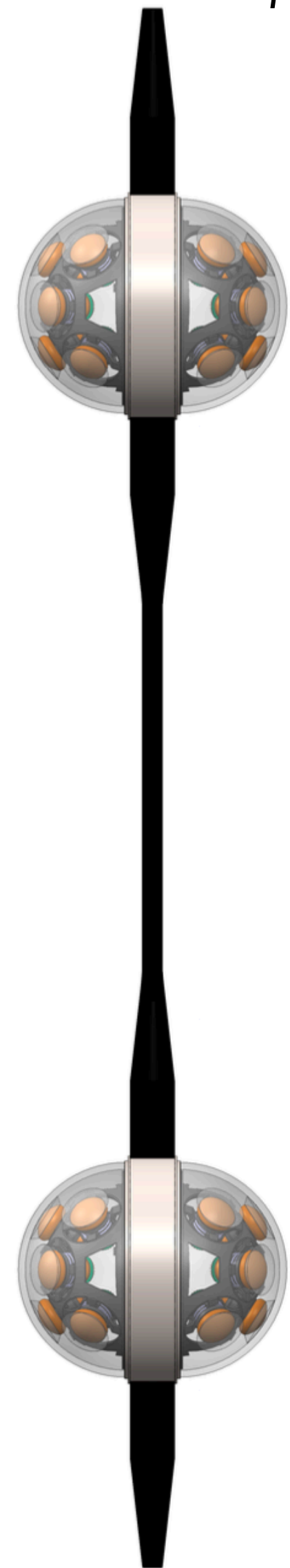
- Optical module with 16 PMTs
- PMT: Hamamatsu R14374-10
- Modular, spring loaded mounting structure
- Optical gel pads used to increase light yield

Few DAQ highlights:

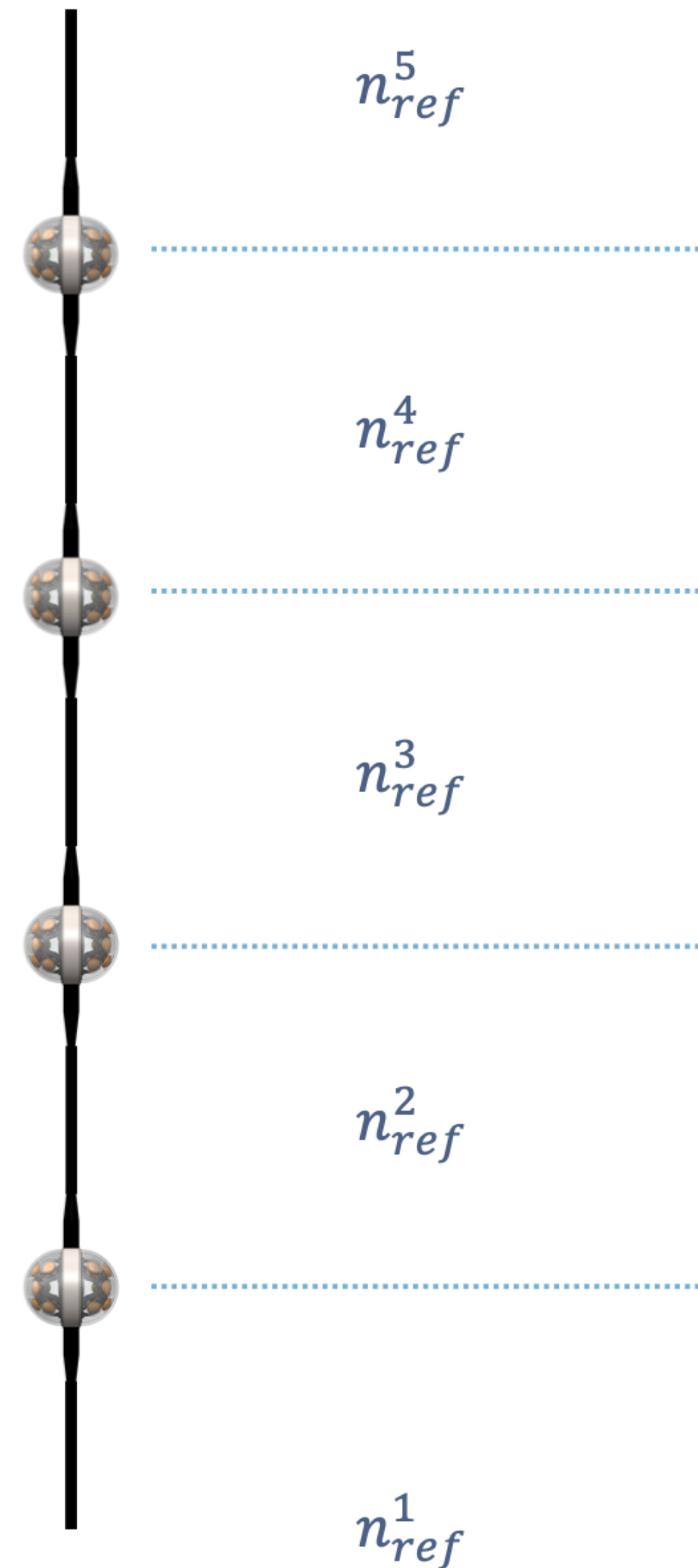


- 16 channel ADC (full waveform digitization)
- 210 MHz sampling rate – reconstruction of full waveform
- Online buffering capability (module local ~ 4GB)

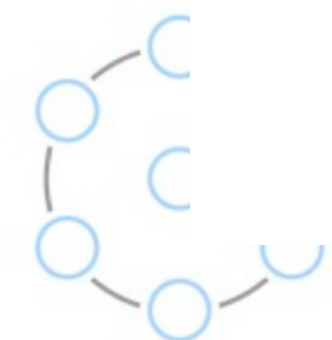
PoS (ICRC2023) 1113



Optical properties
 $l_{abs}, l_{sca}, n_{ref} \sim \lambda$

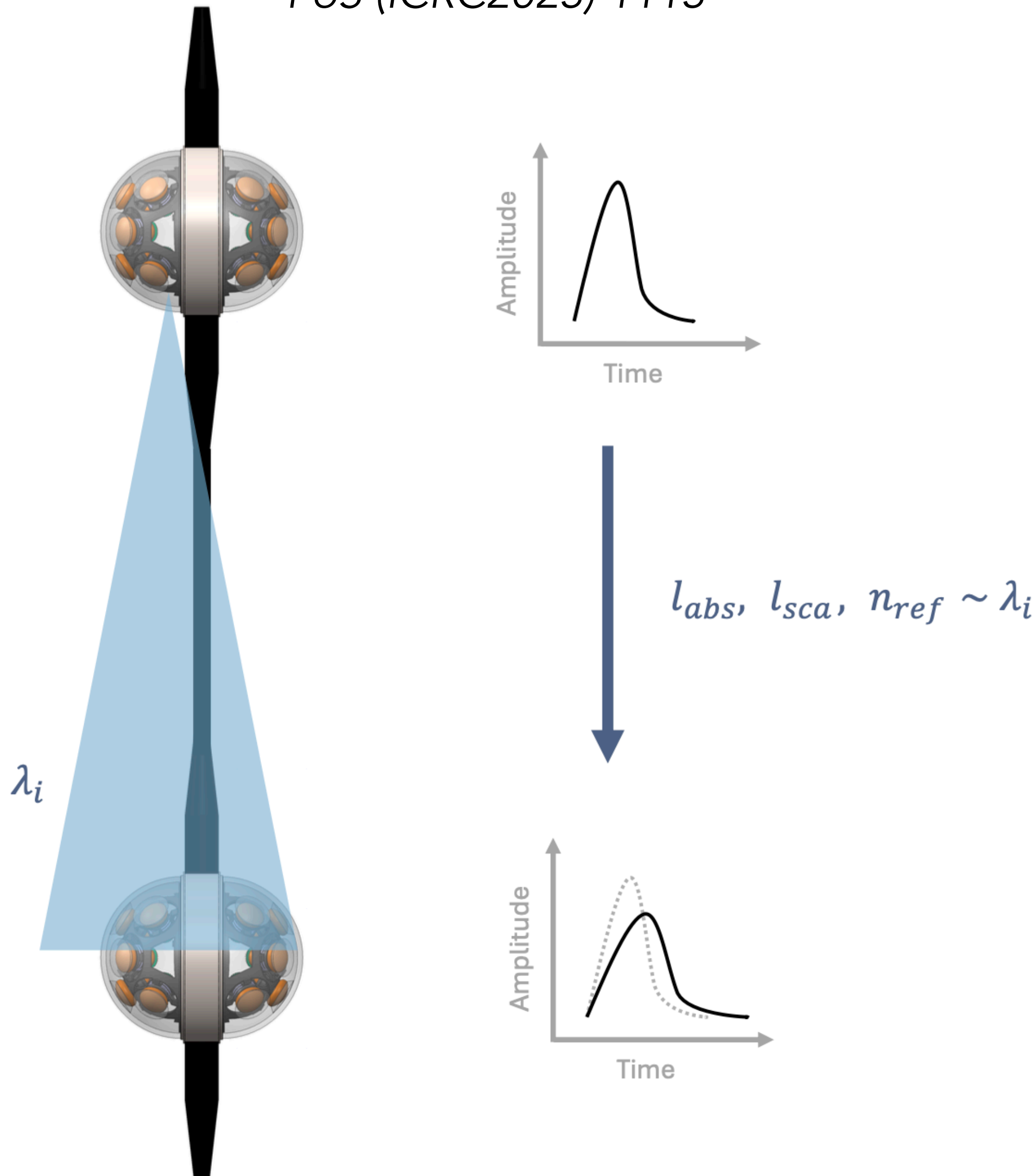


- Depth dependent optical water properties
- Refractive index, scattering & absorption length
- Refractive index crucial for track reconstruction
- Depth-dependent calibration required (!)



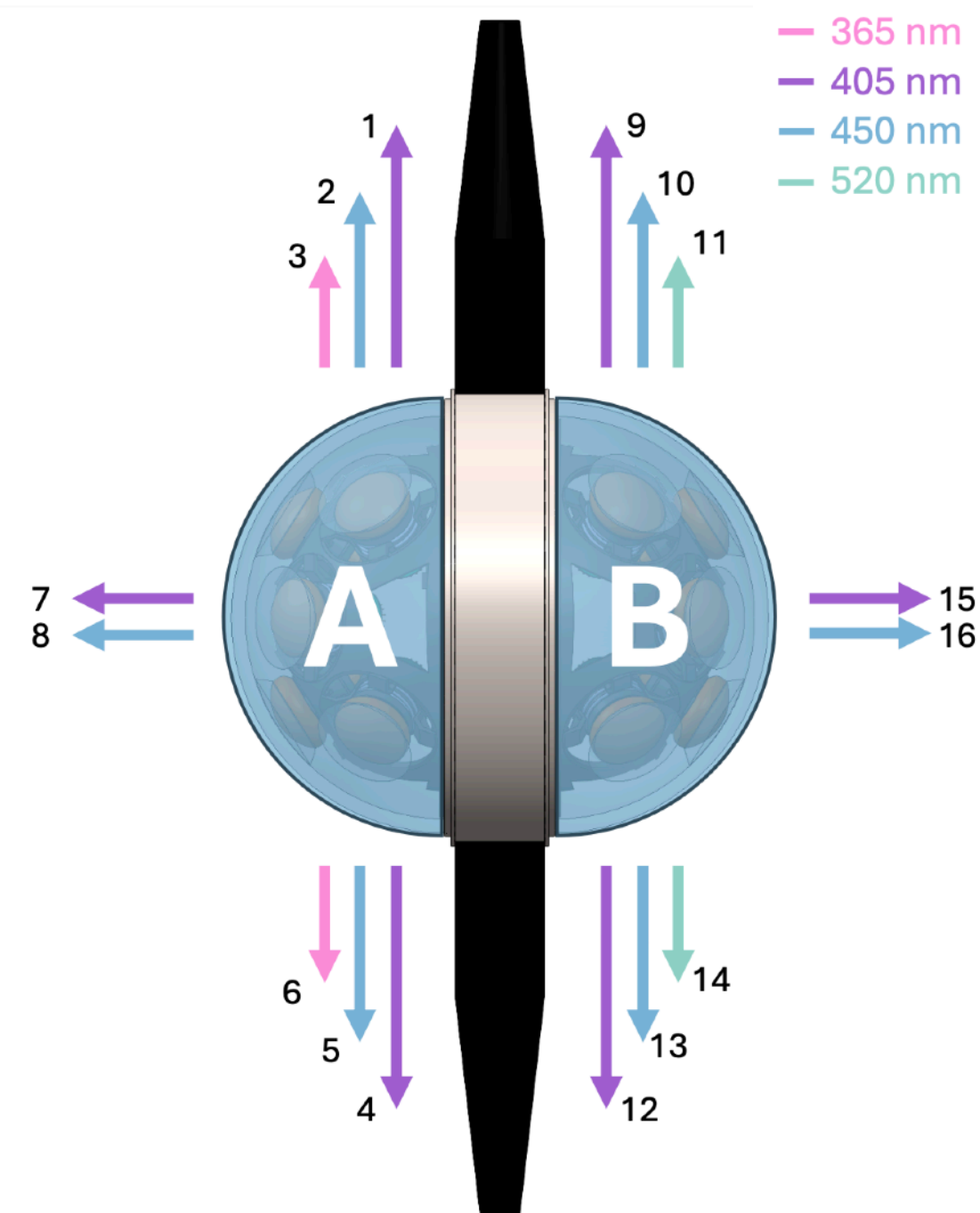
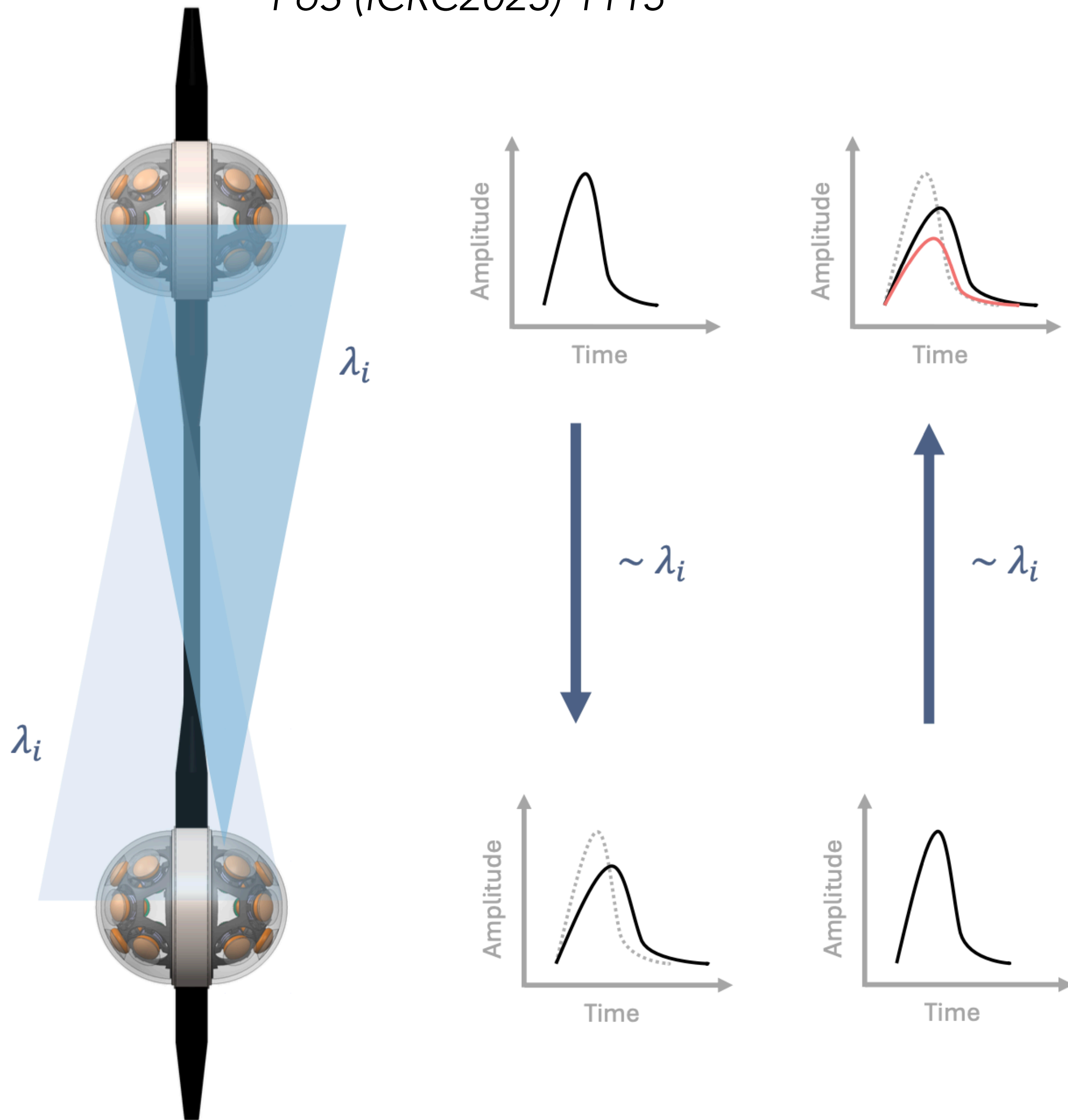
PoS (ICRC2023) 1113

- Light pulses to calibrate column properties
- Emit + receive in neighbouring modules
- Can use multiple wavelengths

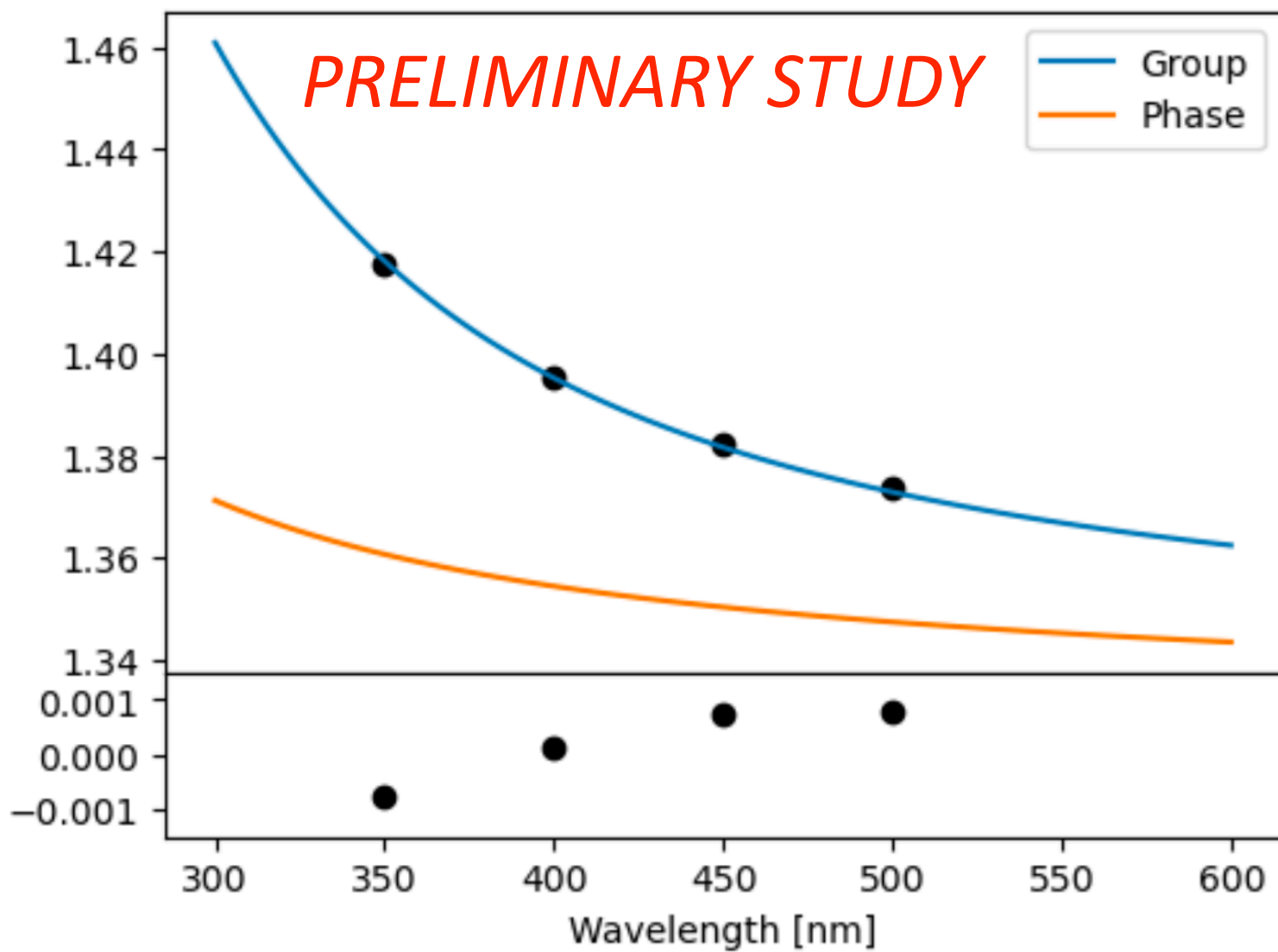
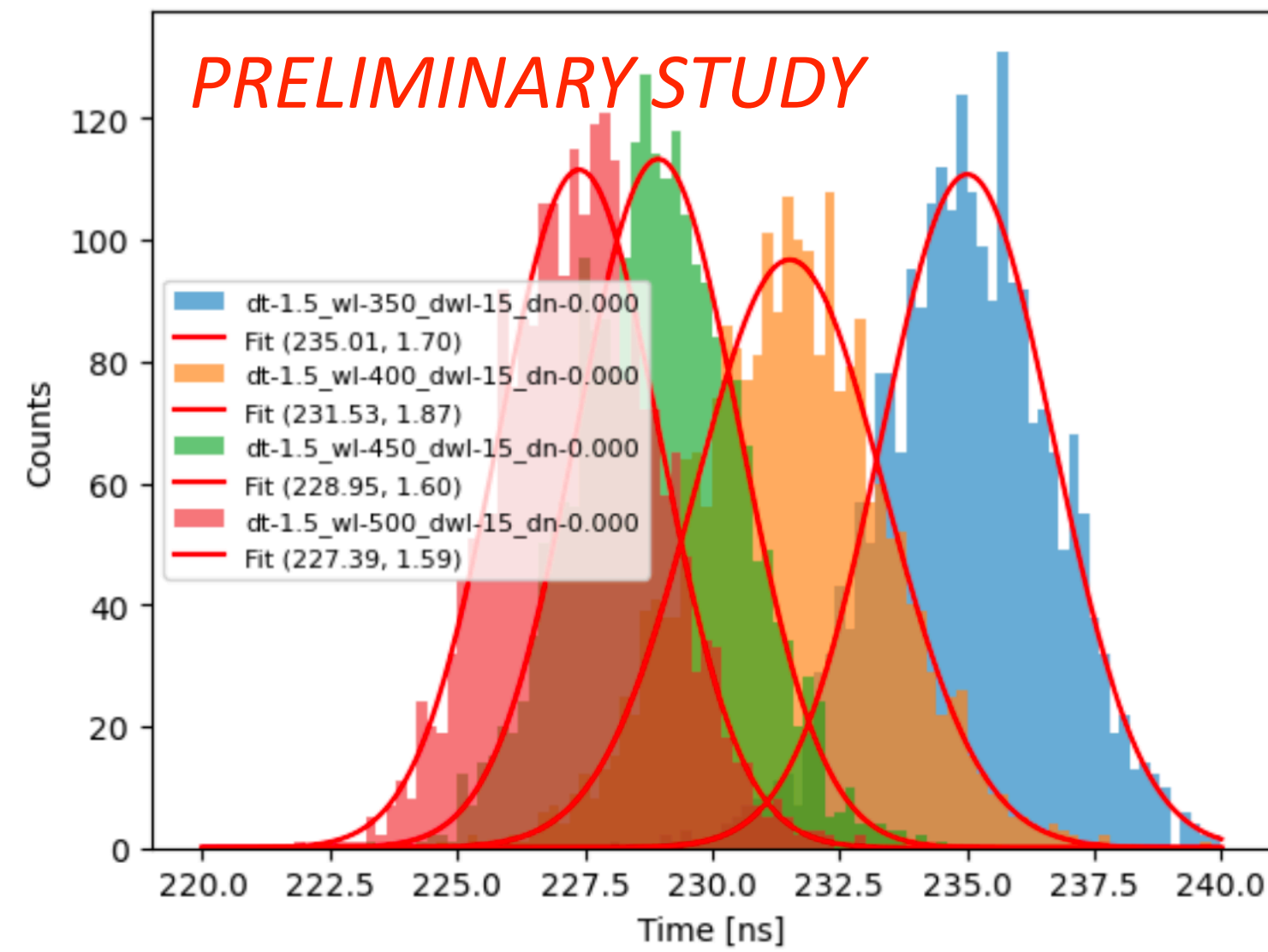


PoS (ICRC2023) 1113

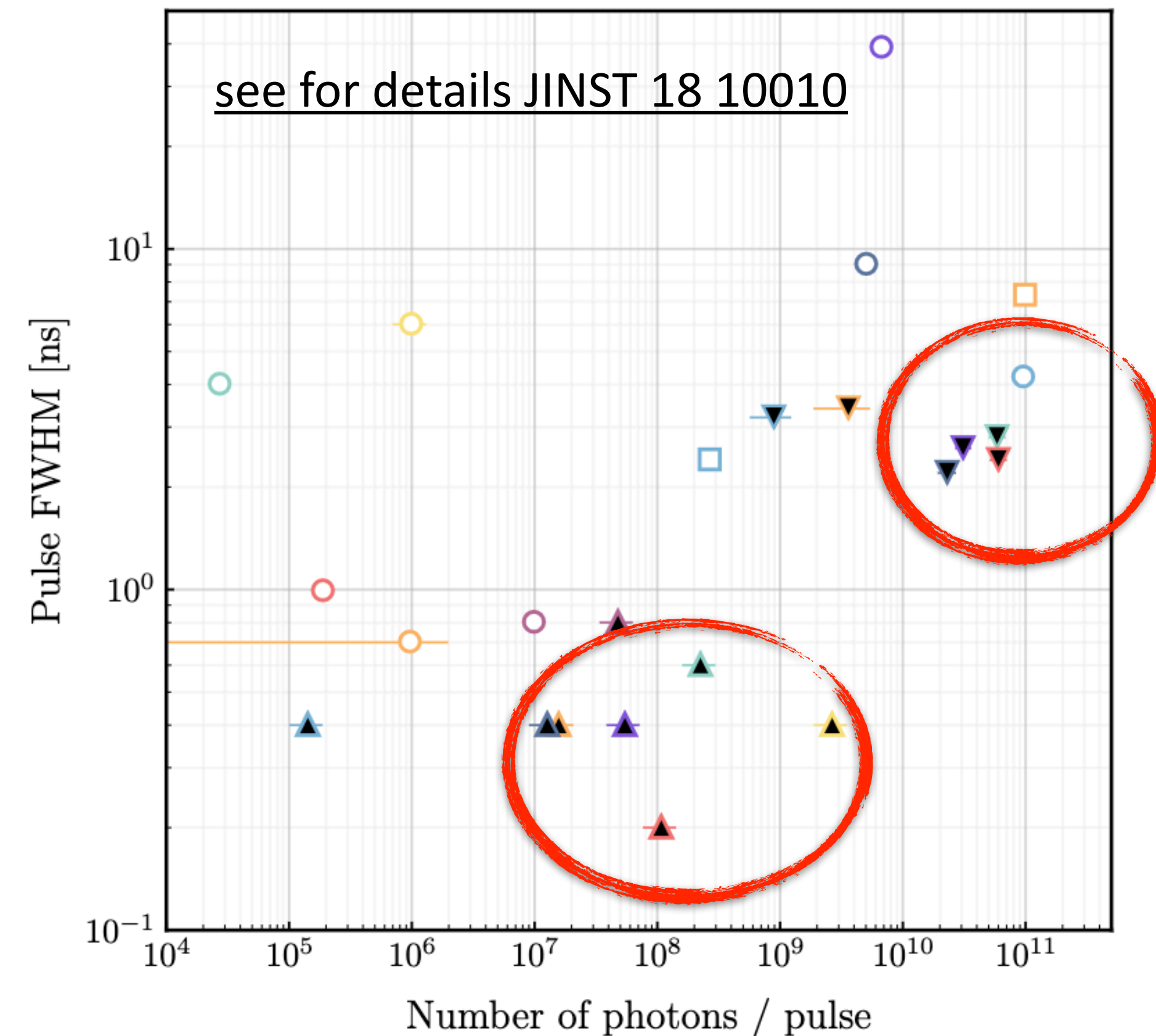
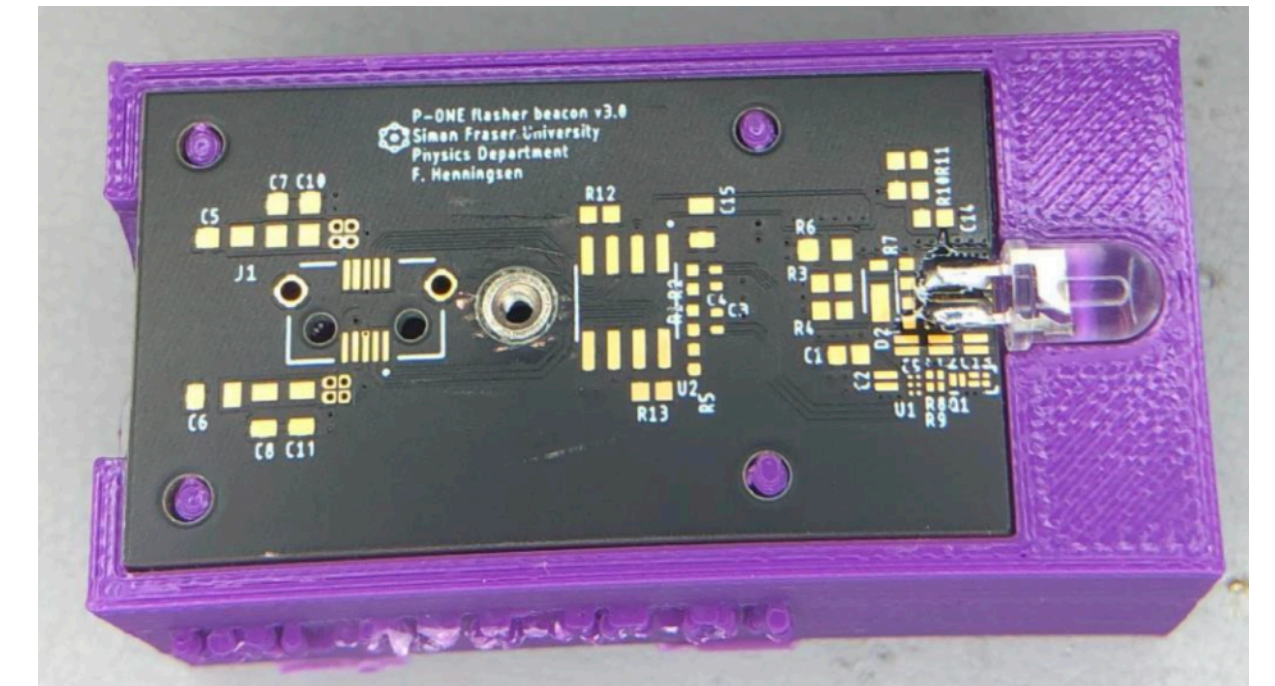
- Light pulses to calibrate column properties
- Emit + receive in neighbouring modules
- Can use multiple wavelengths
- Cross-correlation with up/down symmetries
- Sedimentation + biofouling with up/down ratios



Optical in-situ Calibration inside P-OMs

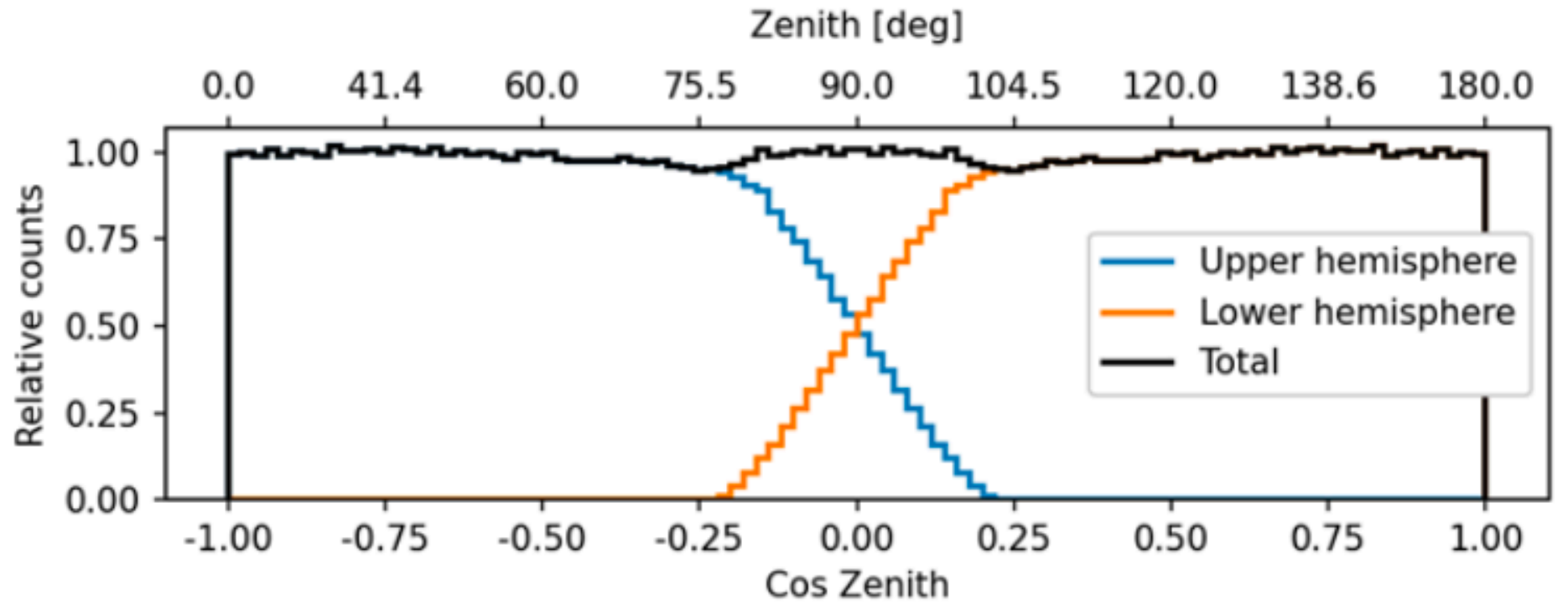


To make this work, we developed cost-effective and high-performance picosecond and high-power light pulsers.

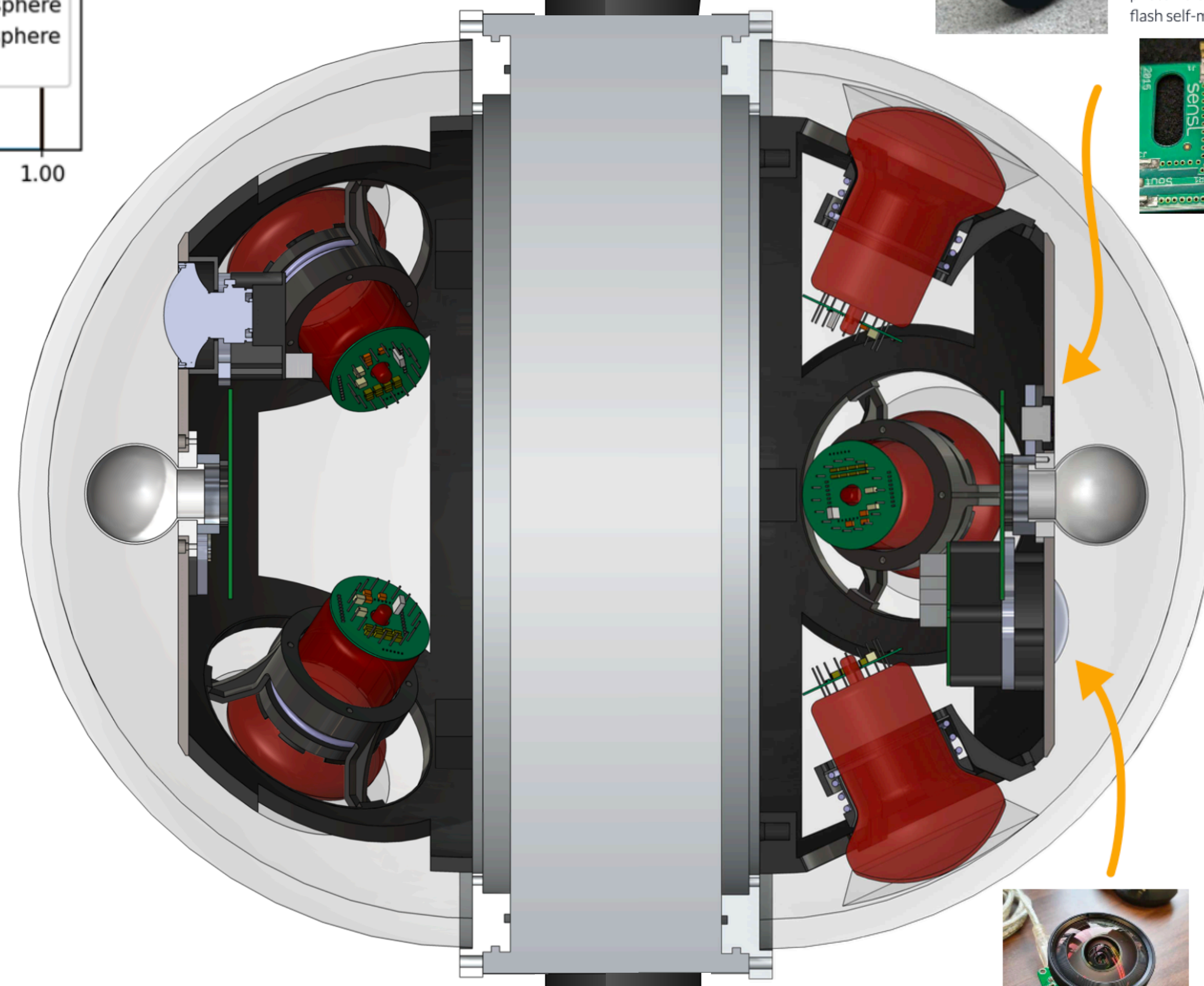


PoS (ICRC2023) 1113

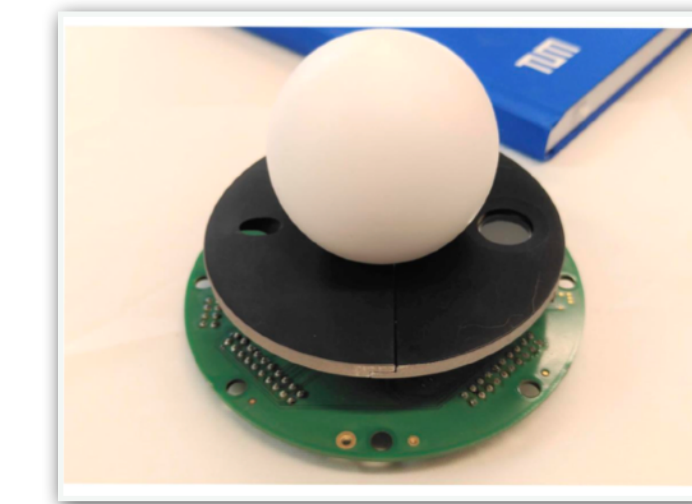
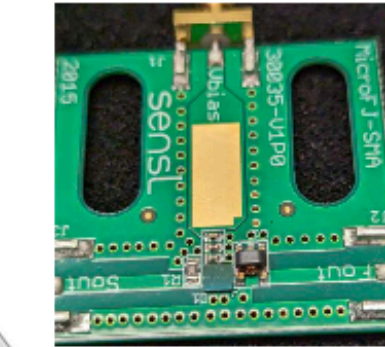
20



- Absolute efficiency calibration in multiple wavelength (self-monitored)
- Optical properties of water
- Camera systems
- Novel positioning calibration system

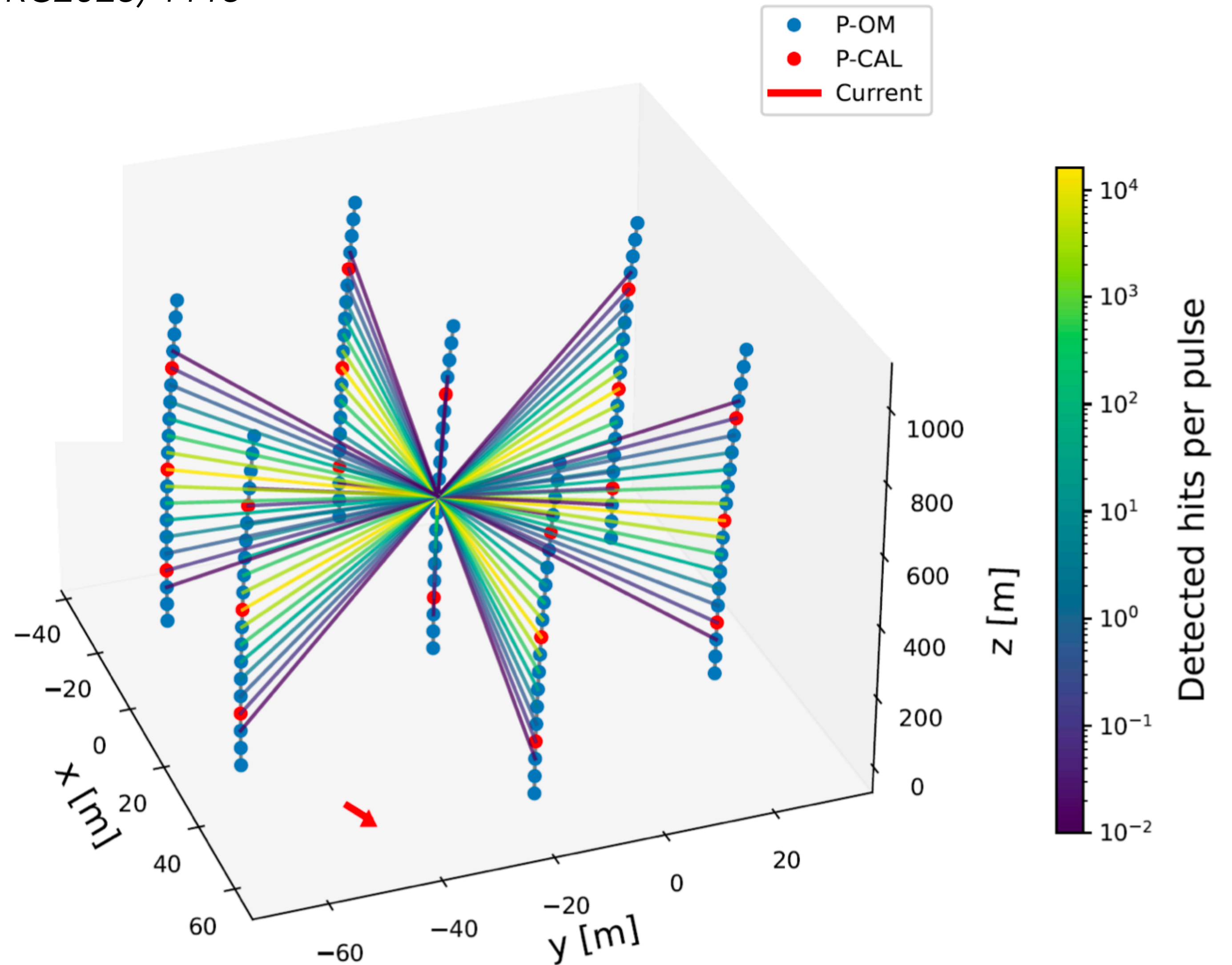
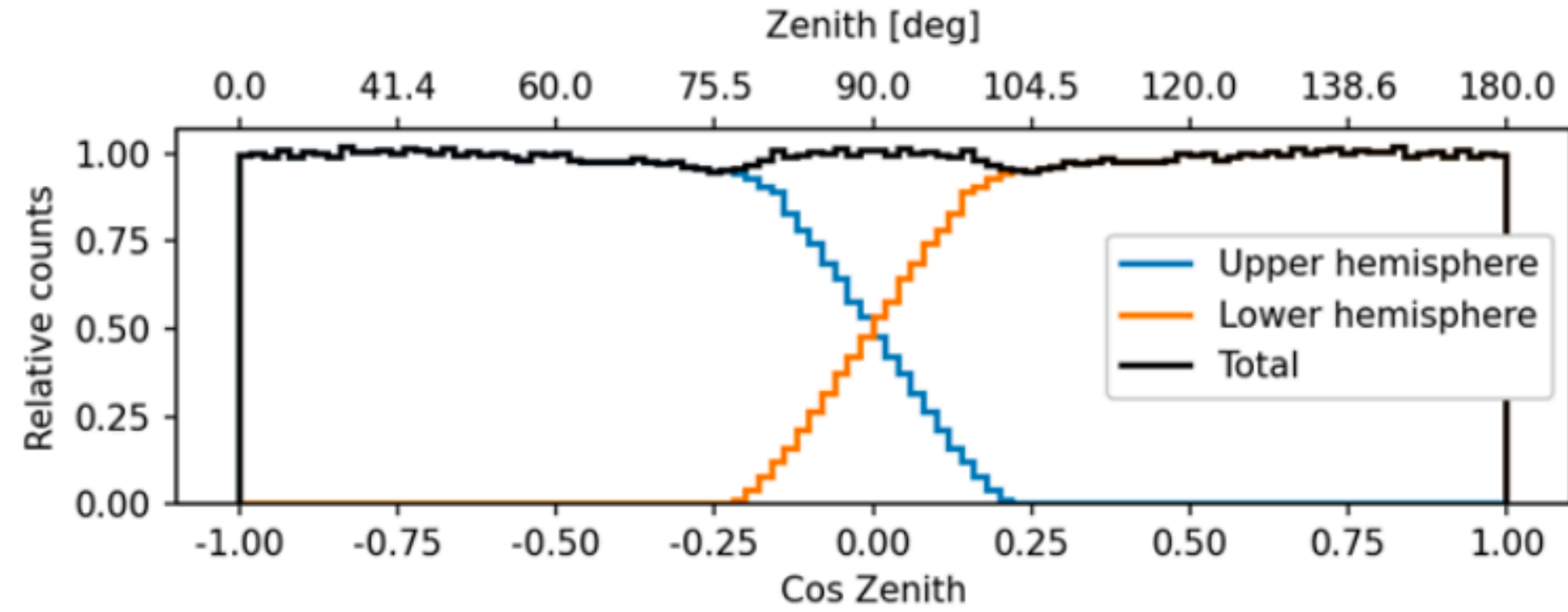


Photodiode and silicon photomultiplier used for flash self-monitoring



Fish-eye lens camera for monitoring bioluminescence and sedimentation

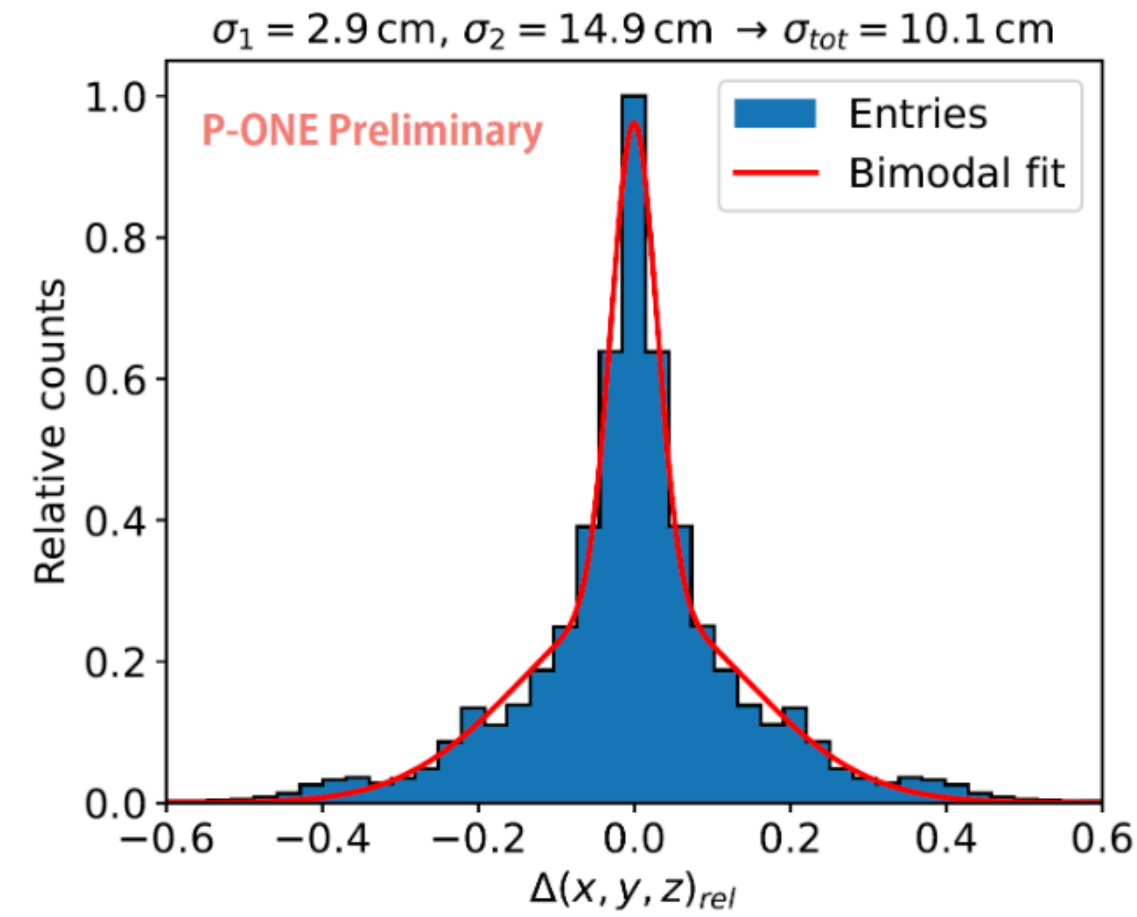
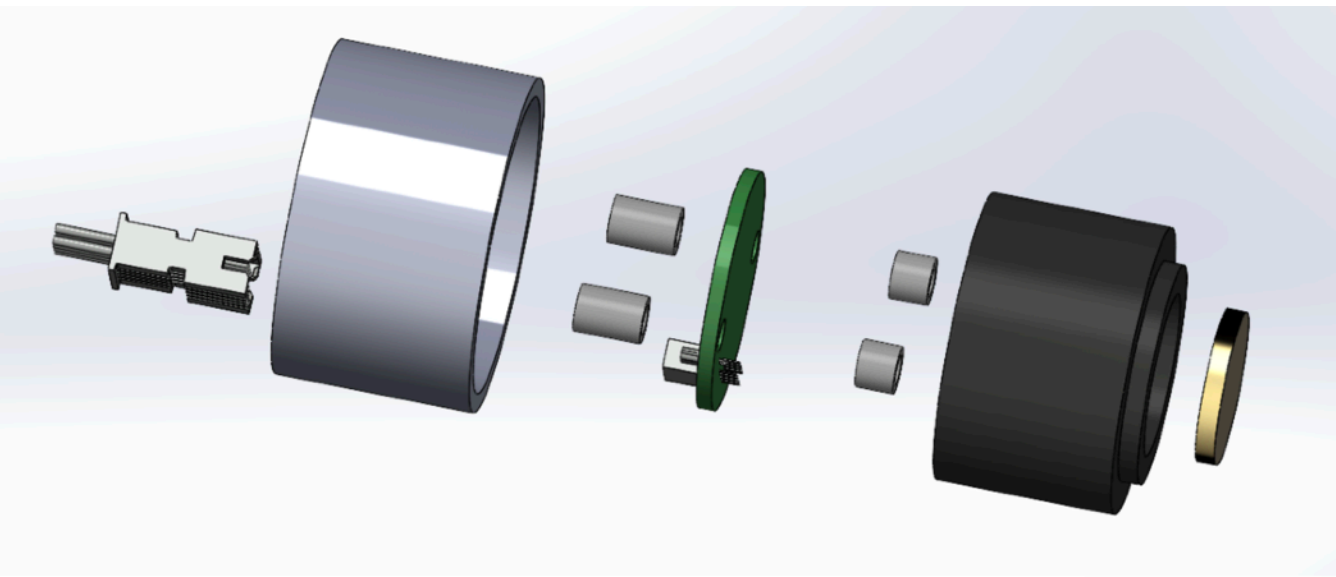
PoS (ICRC2023) 1113



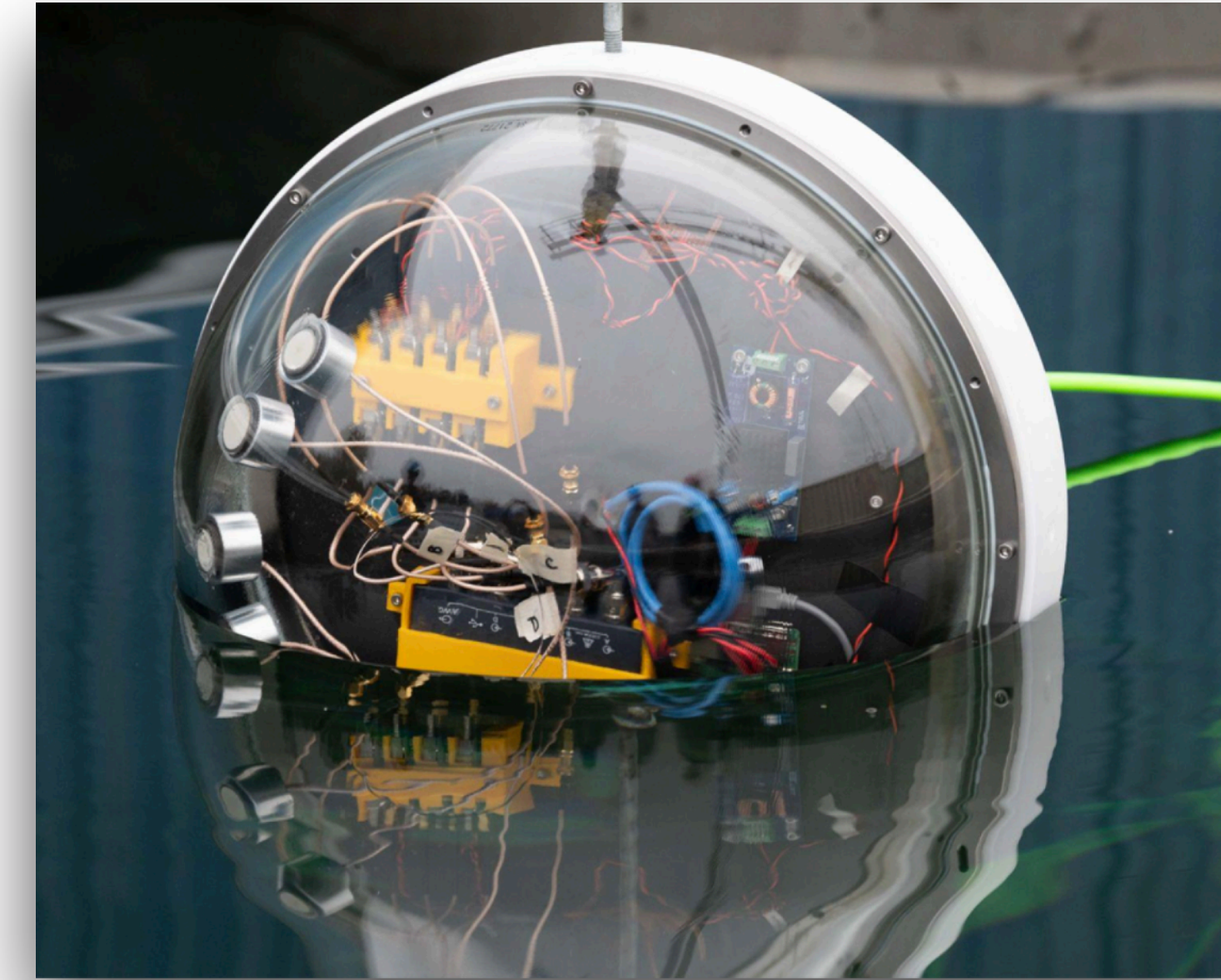
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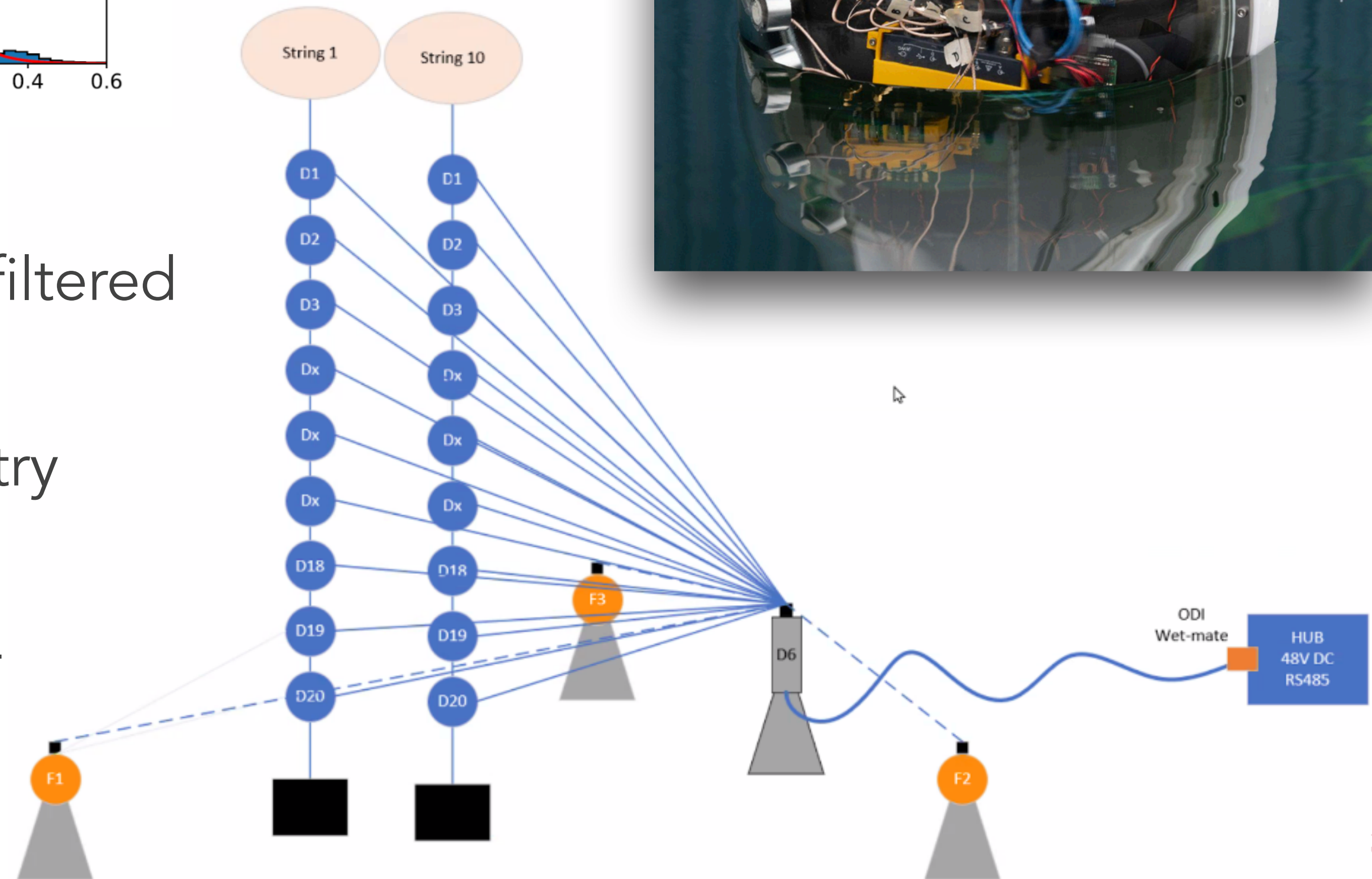
Acoustic position Calibration



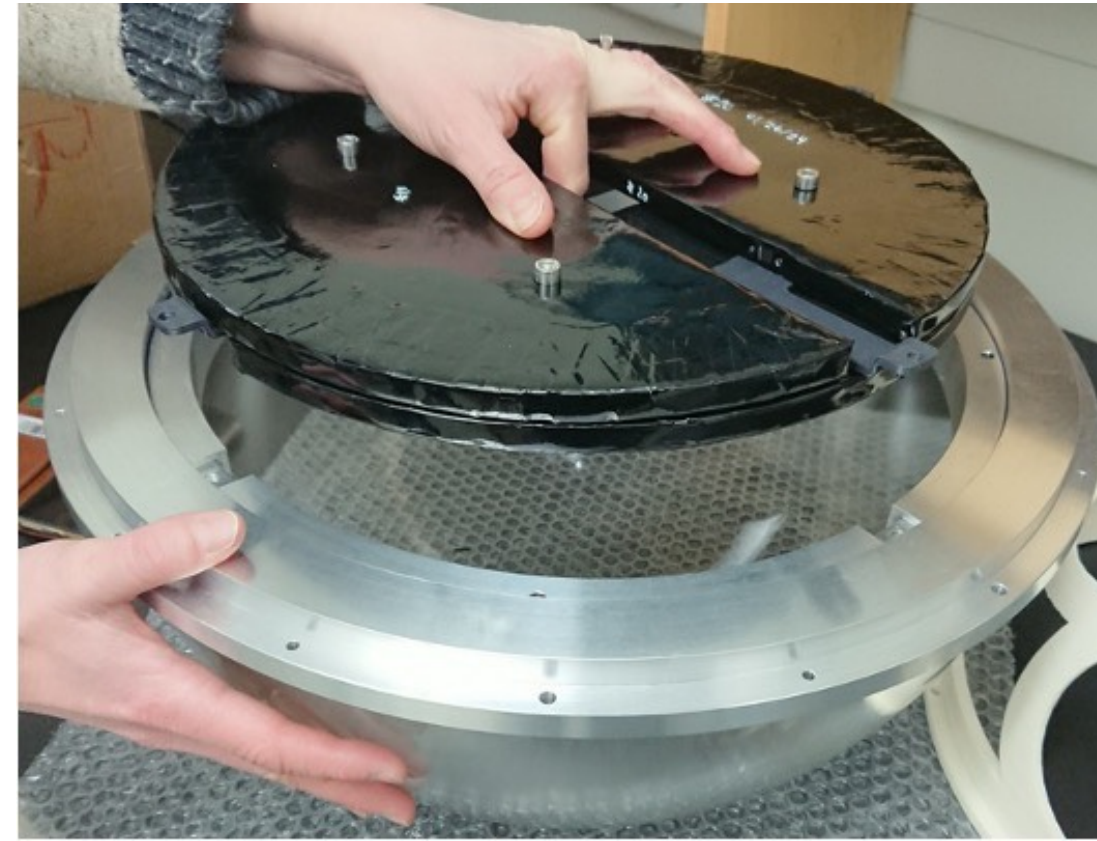
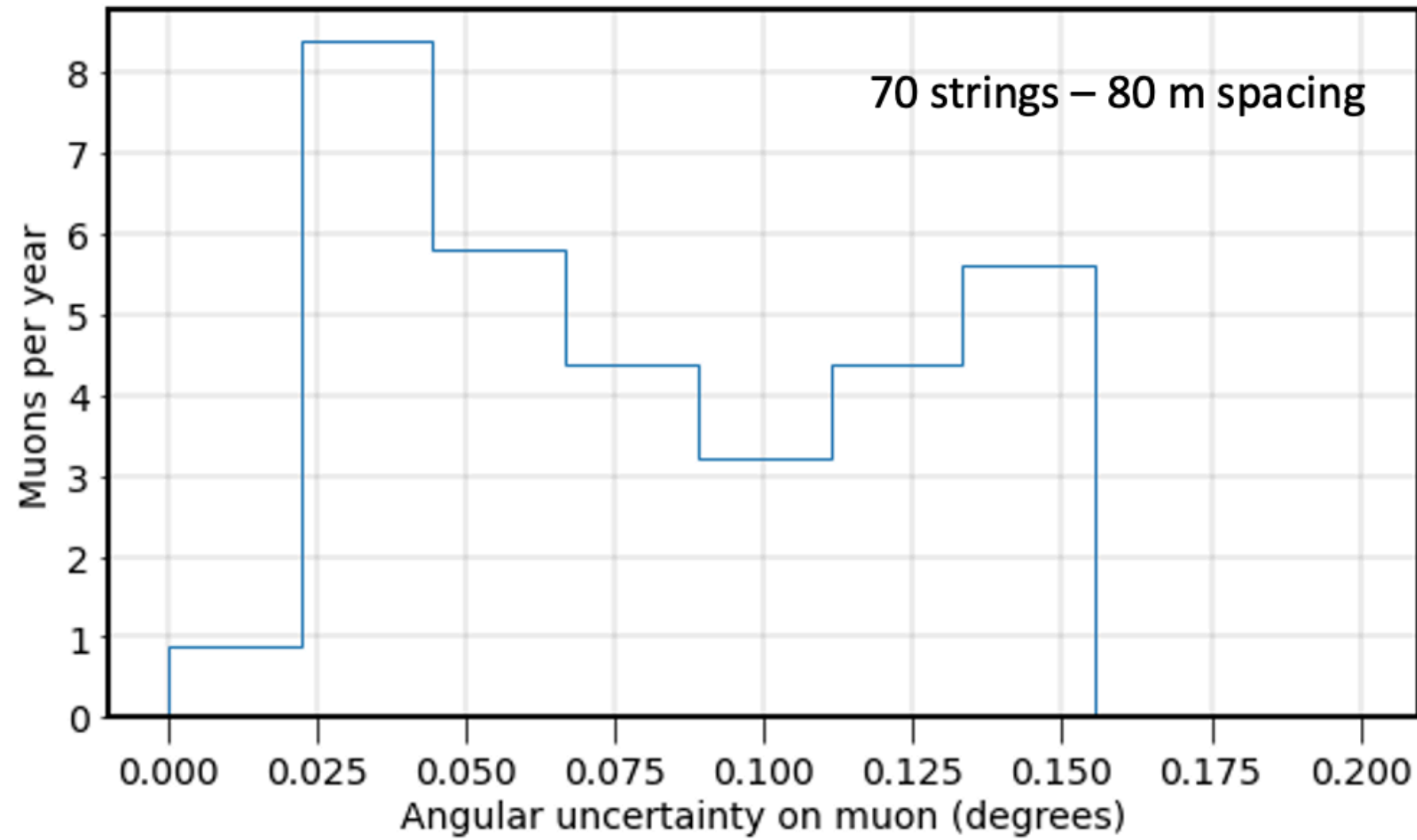
PoS (ICRC2023) 1112



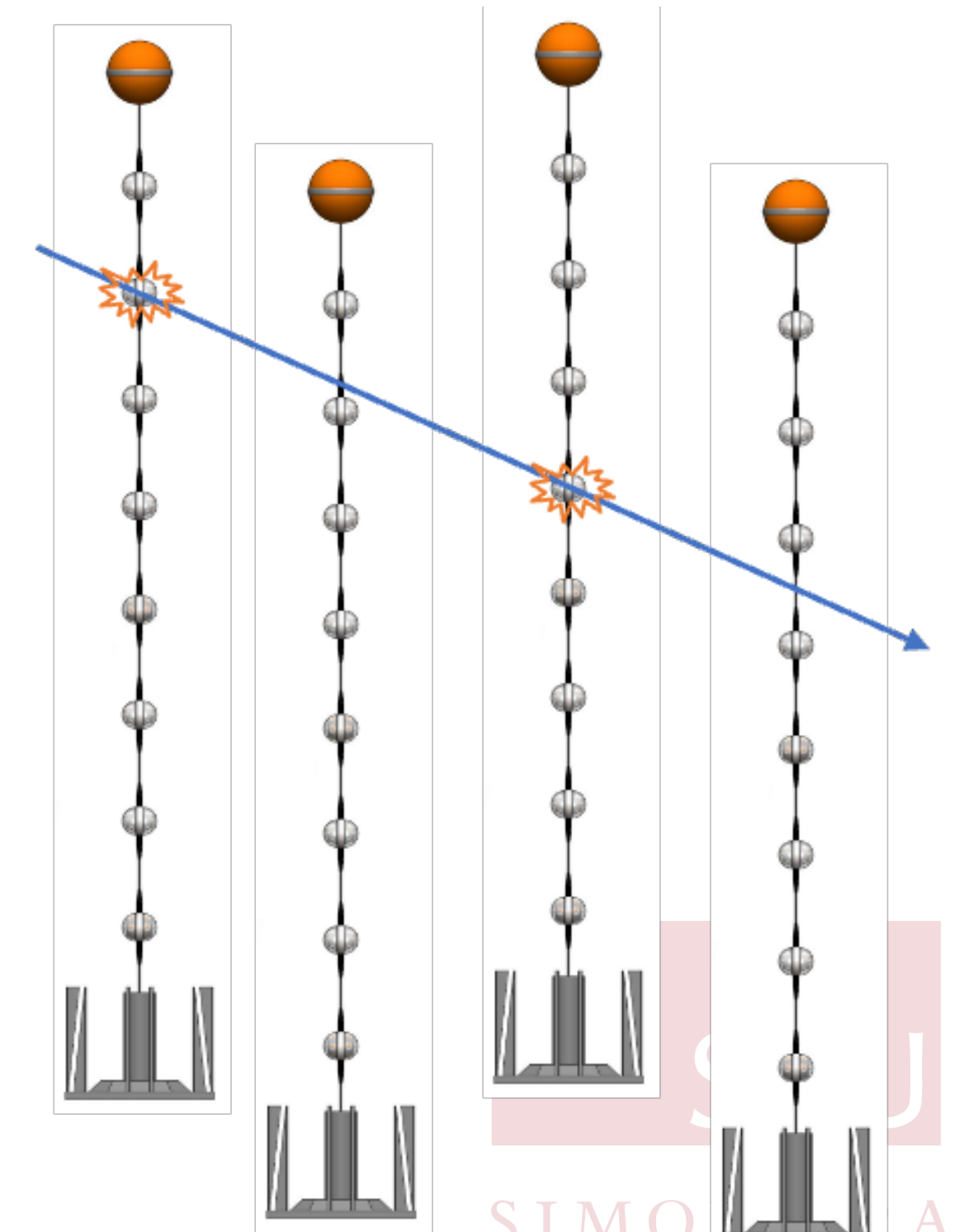
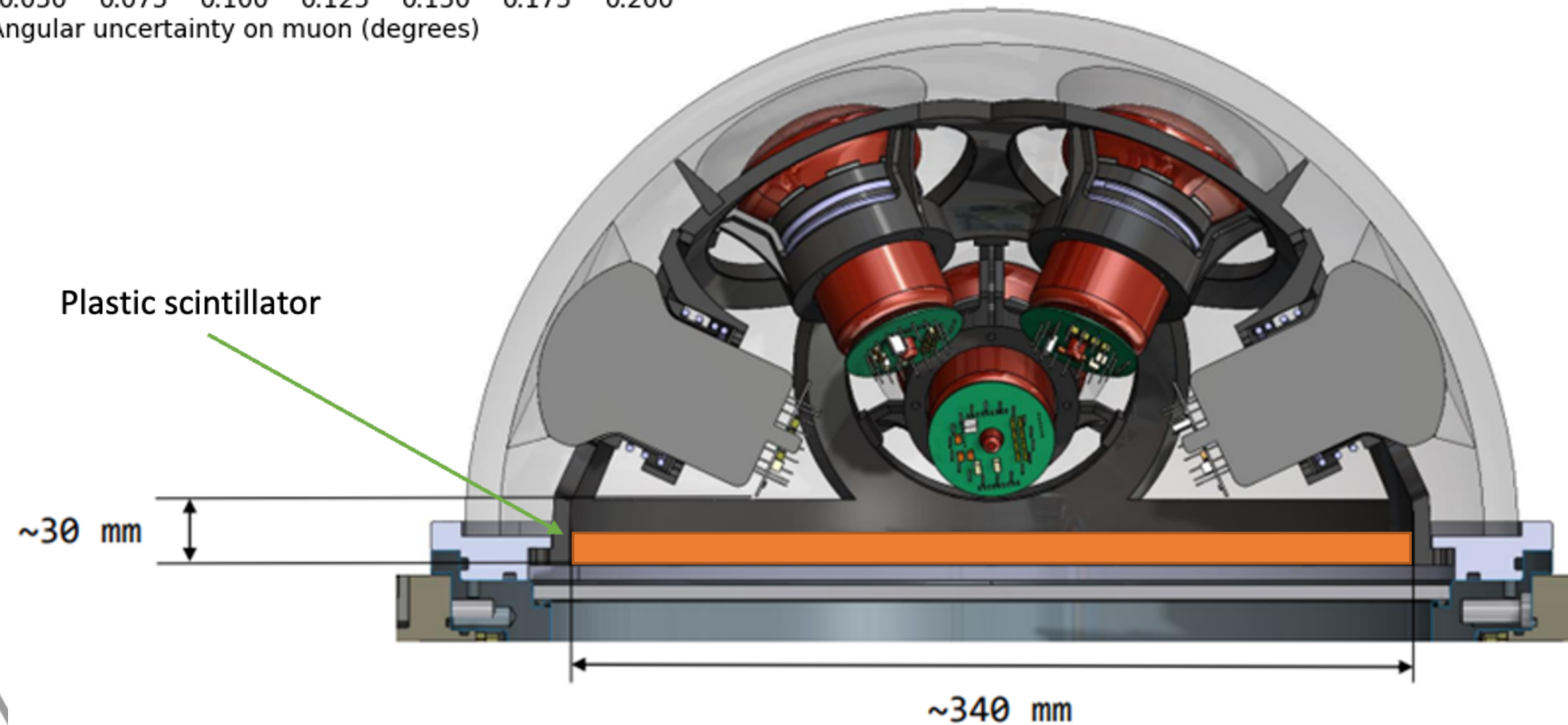
- 2 Piezo-acoustic receivers per module
- Signals are amplified & high/low-pass filtered —> digitized with ADC on mainboard
- Accuracy of ~10cm for relative geometry
- Collaboration with Northern Cascadia Subduction Zone Observatory for geo-referencing of beacons



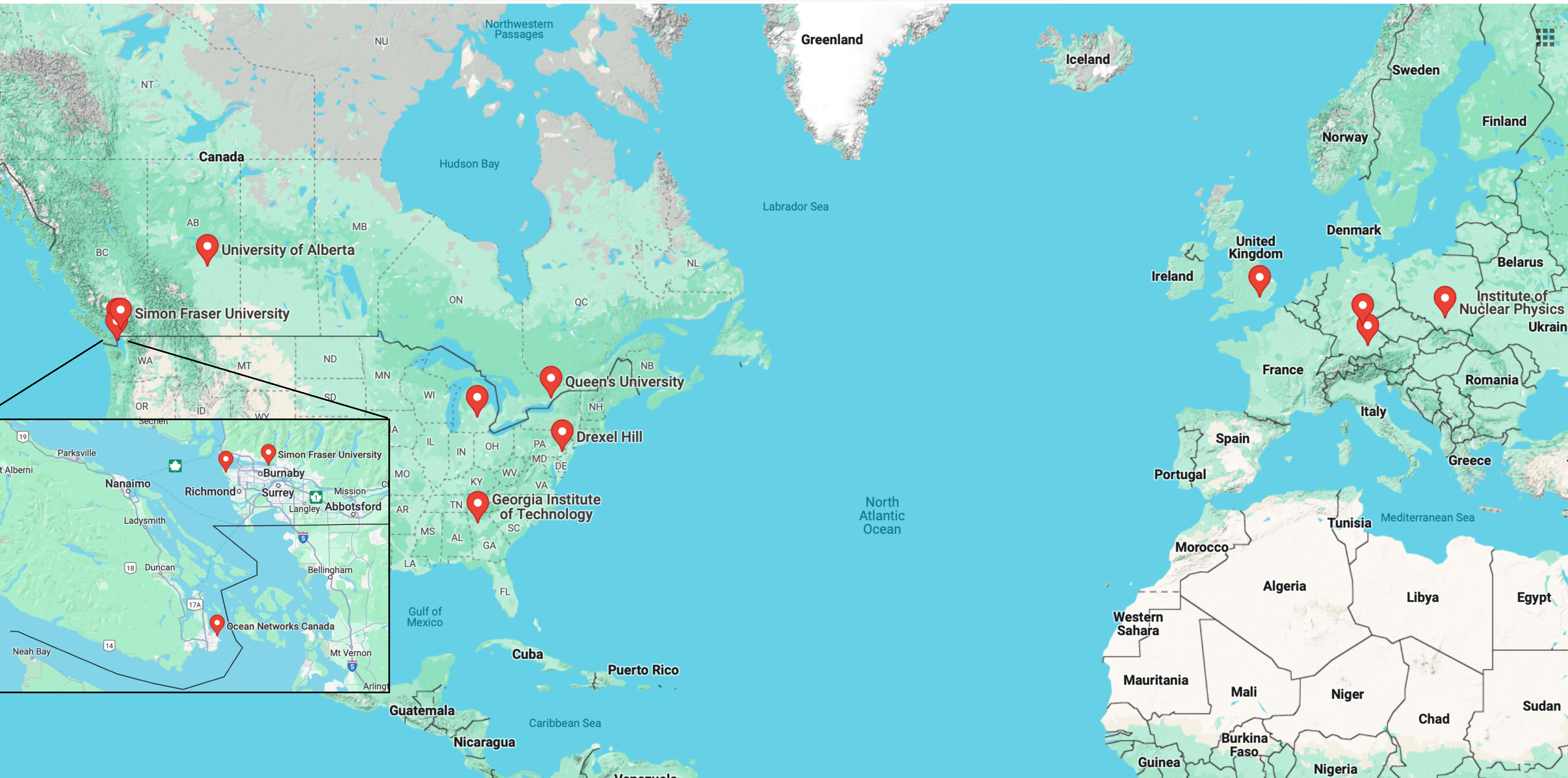
Another muon pointing calibration system



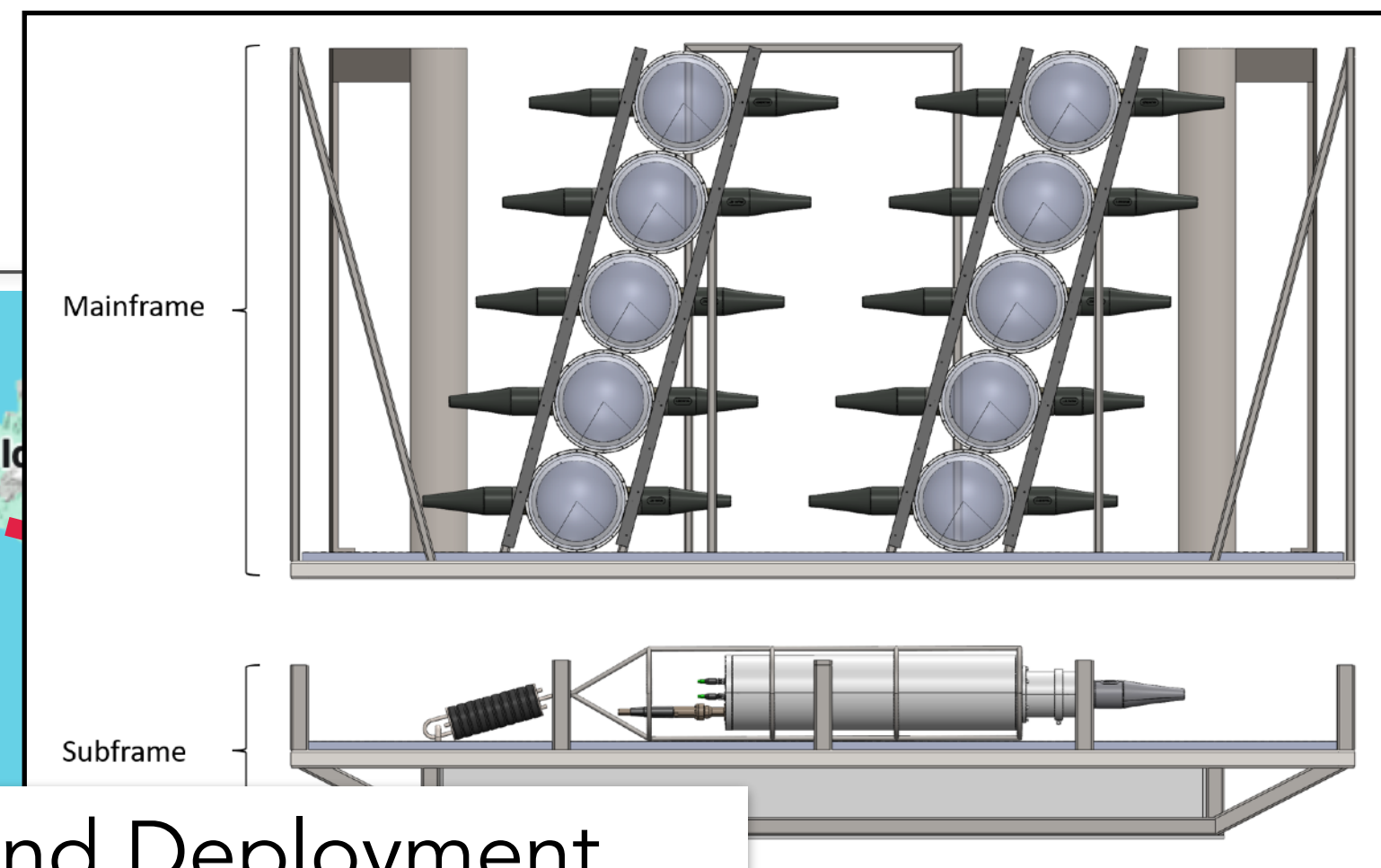
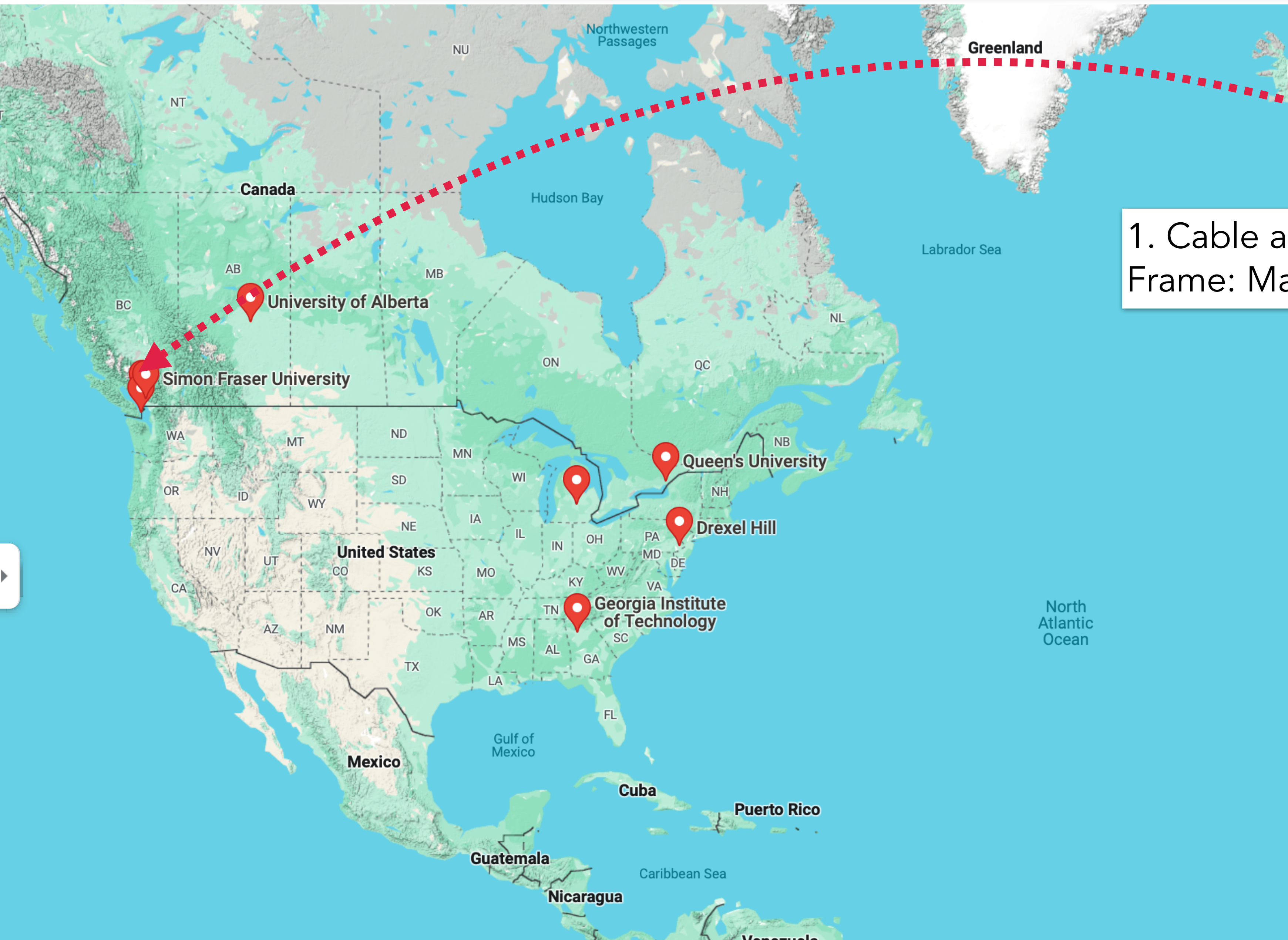
Idea:
track muons using a scintillator plate in a hemisphere, read out by a SiPM, to compare their reconstruction



P-ONE Collaboration on the Map



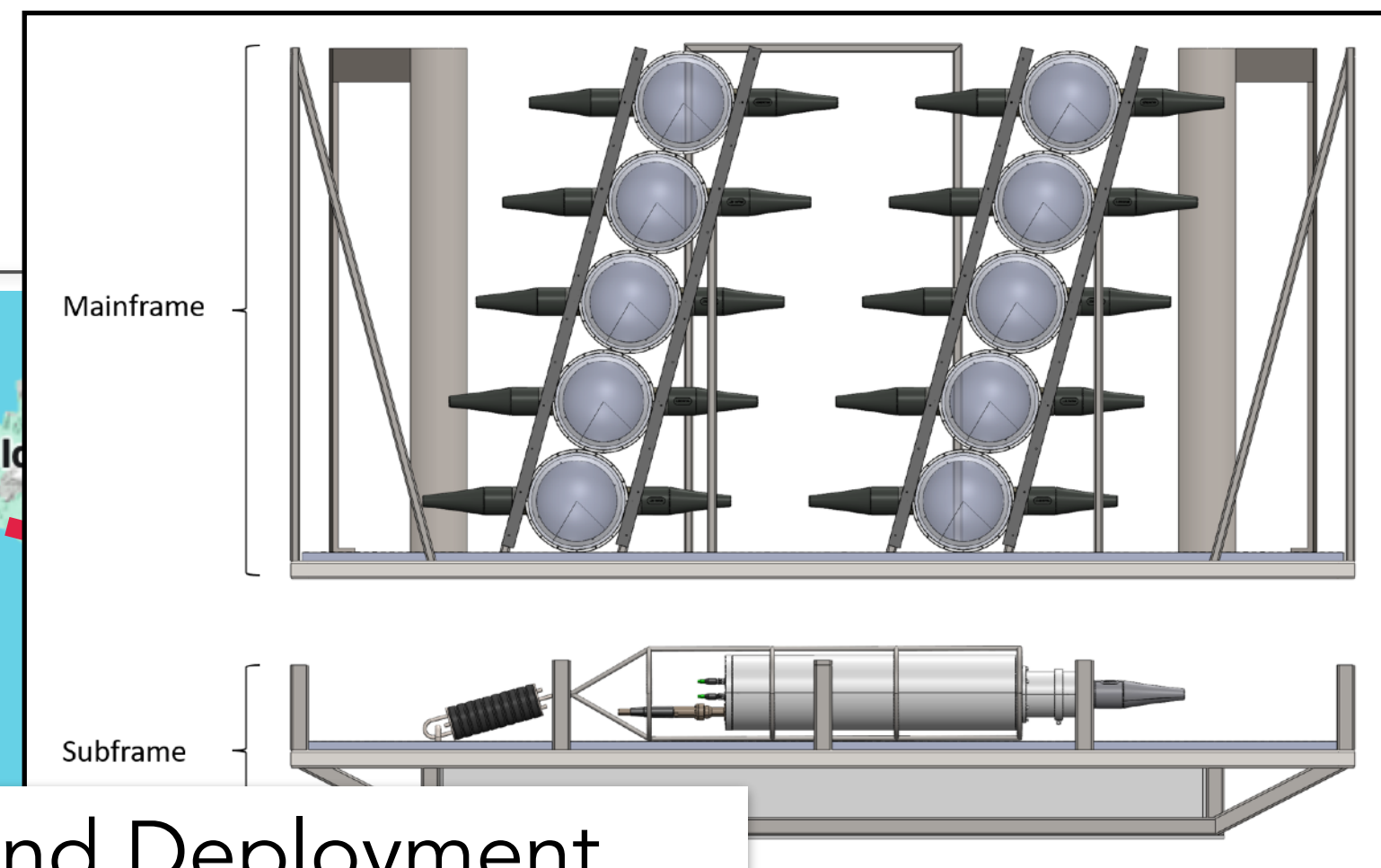
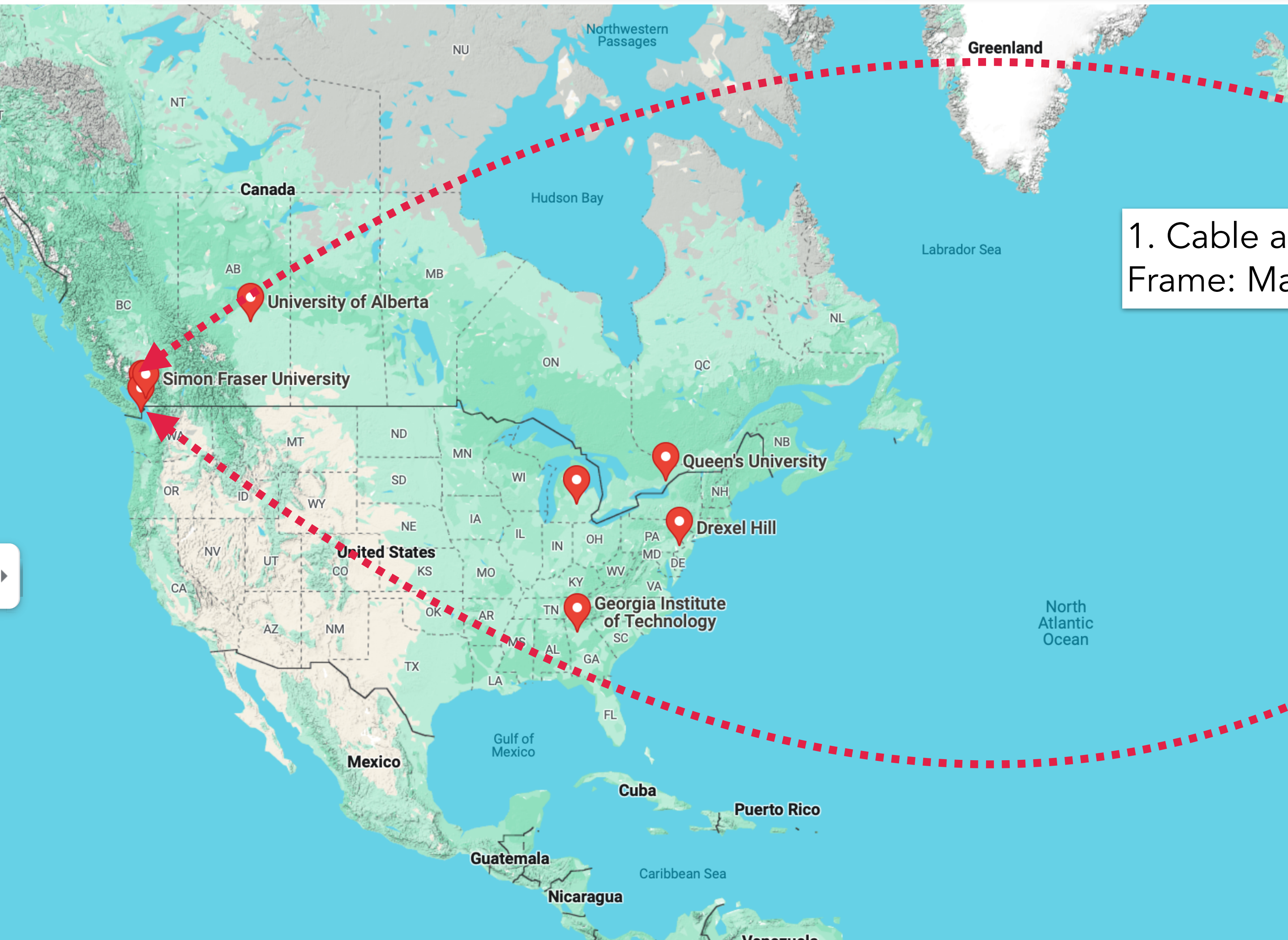
P-ONE-1 Logistics



1. Cable and Deployment Frame: MacArtney, Denmark

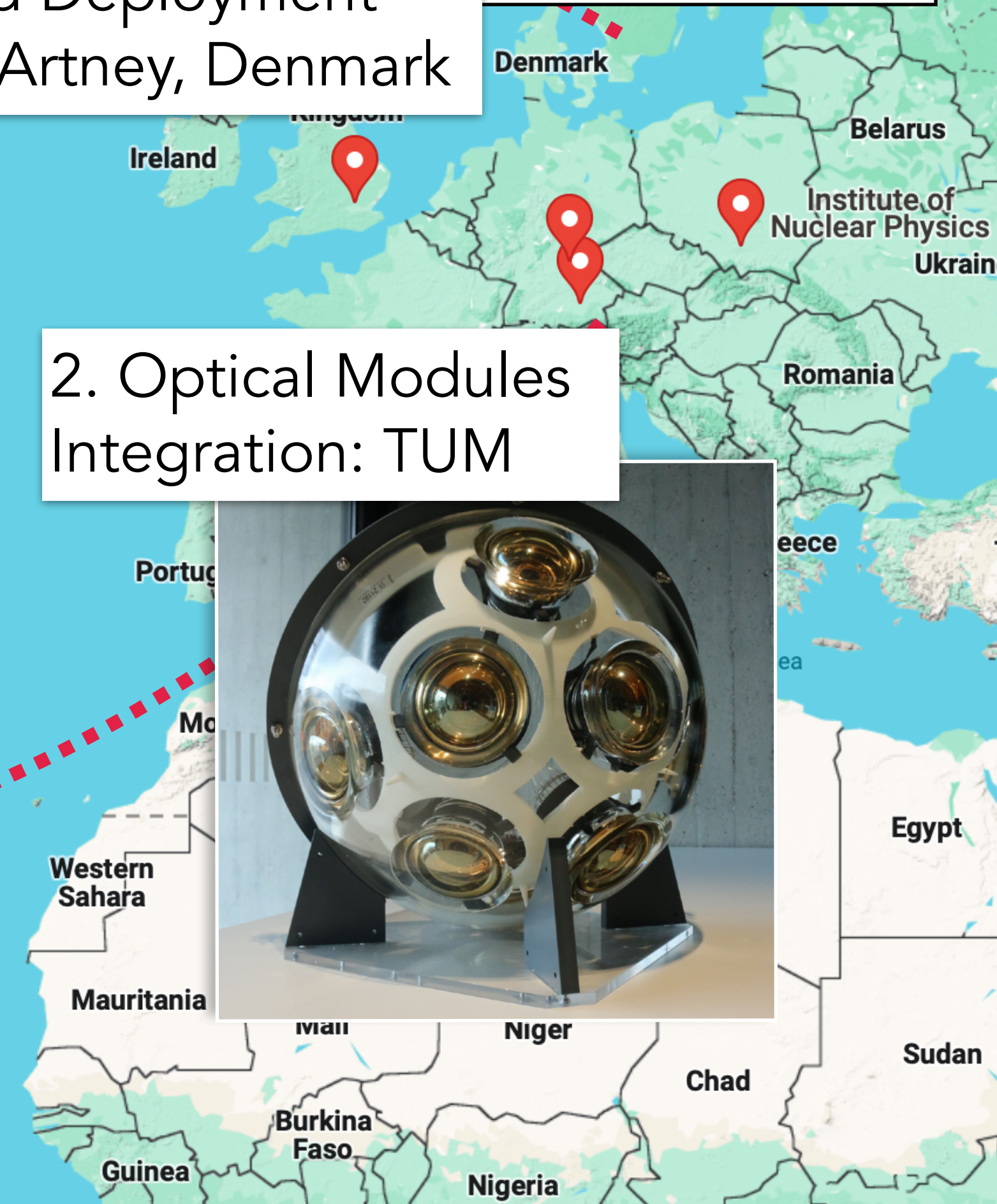
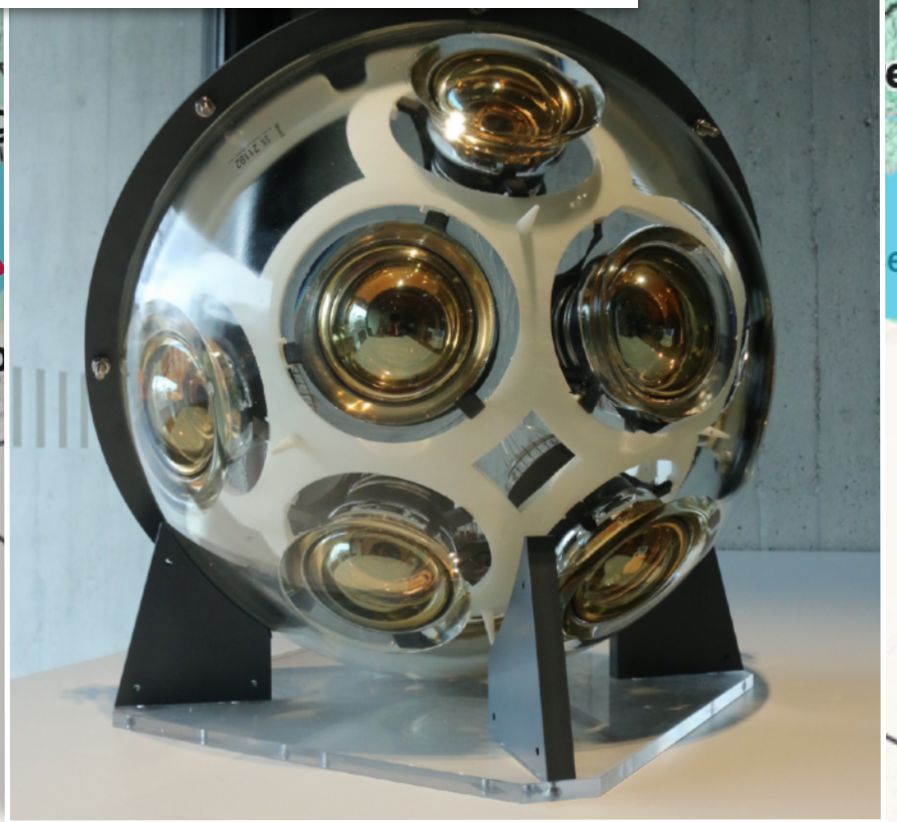


P-ONE-1 Logistics

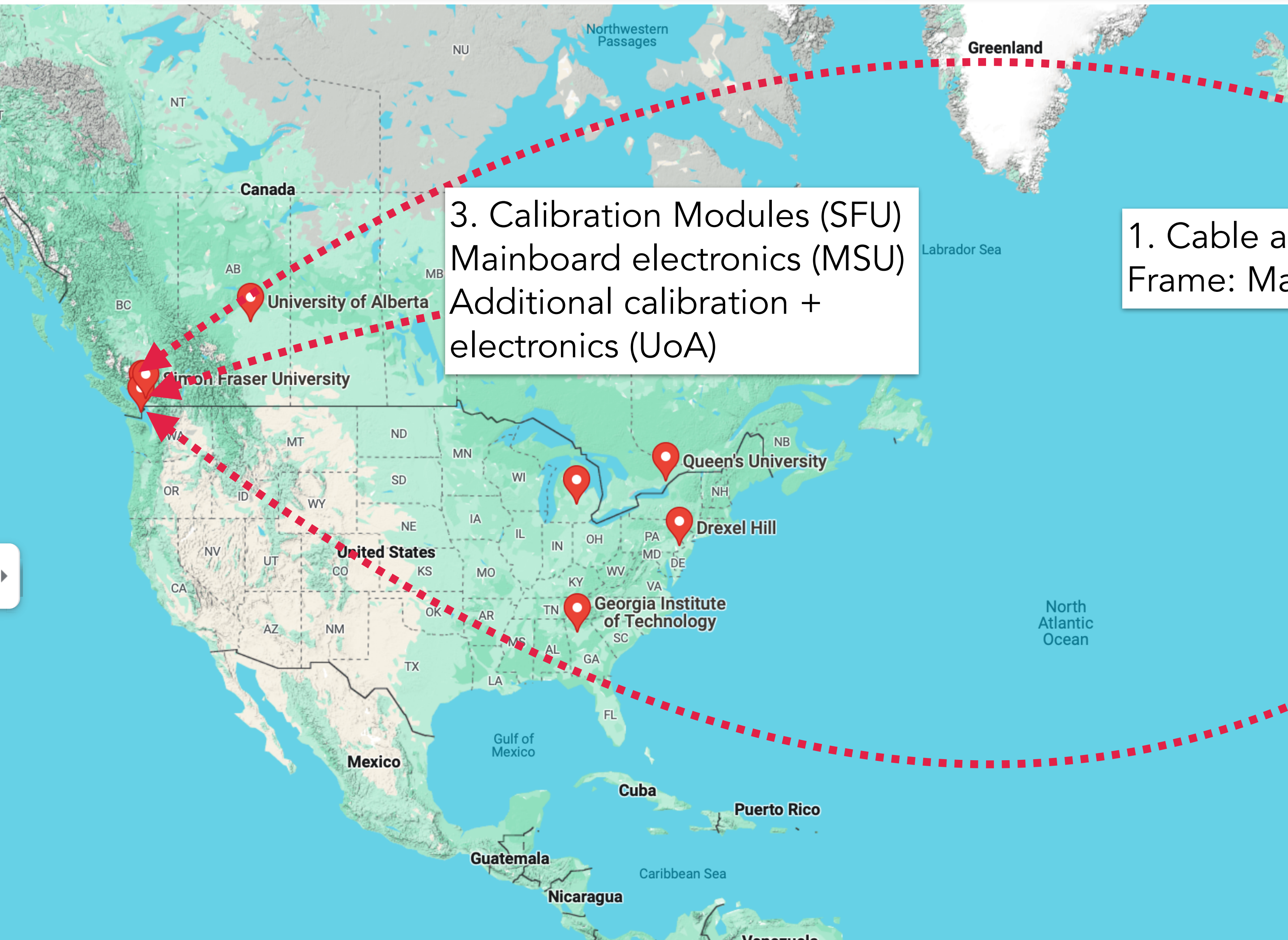


1. Cable and Deployment Frame: MacArtney, Denmark

2. Optical Modules Integration: TUM



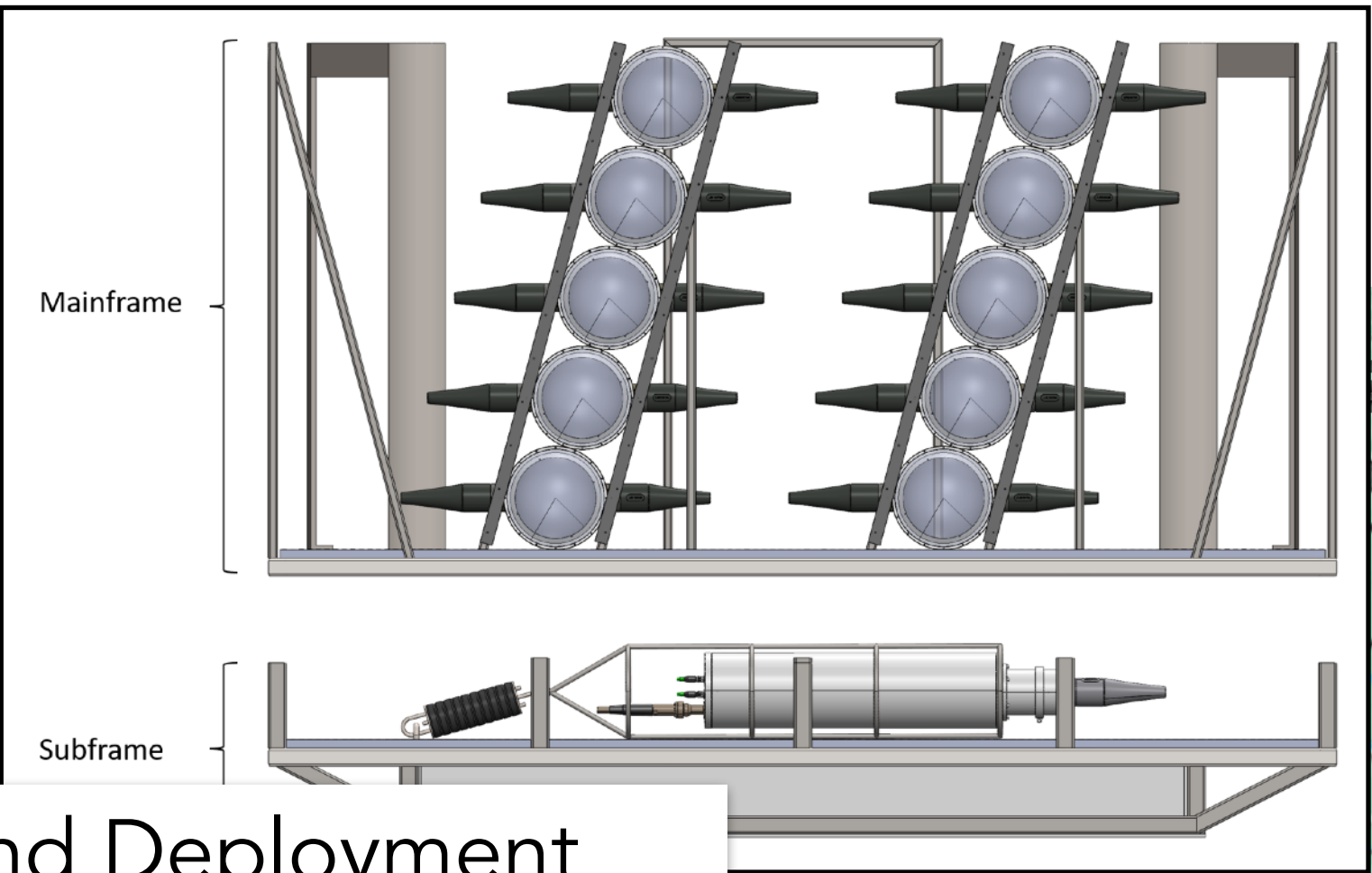
P-ONE-1 Logistics



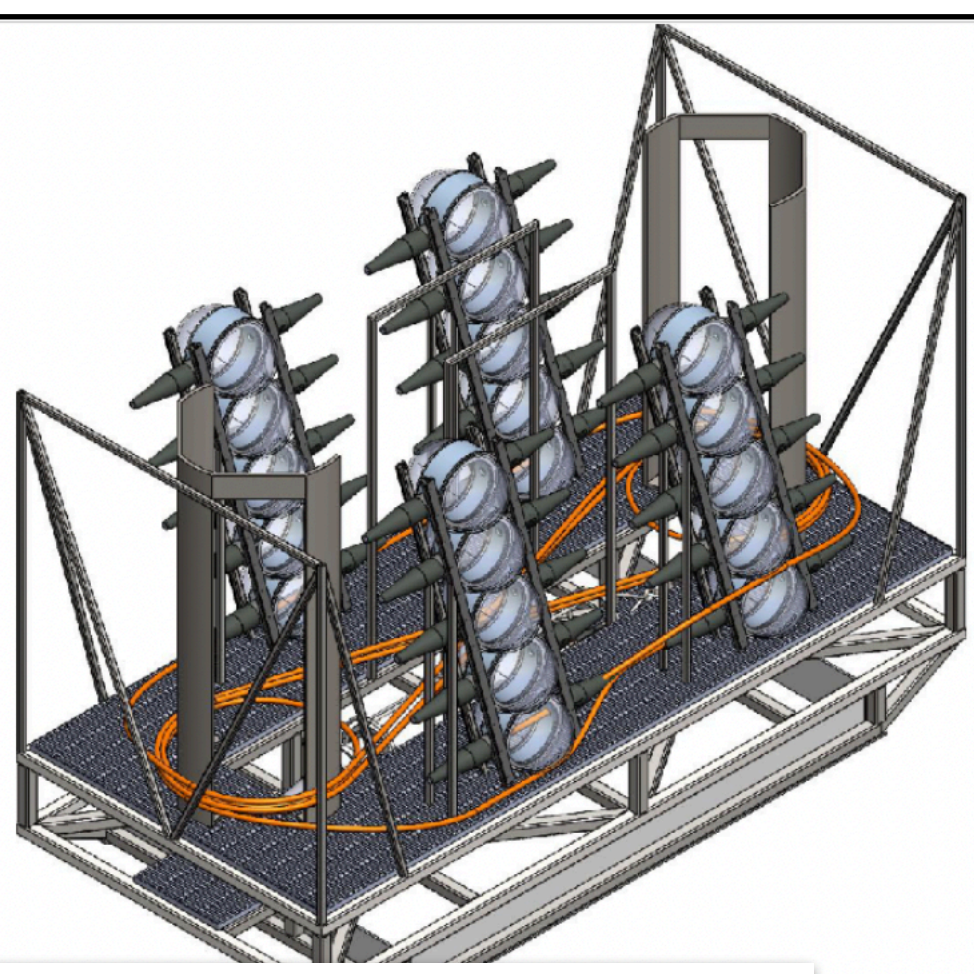
3. Calibration Modules (SFU)
Mainboard electronics (MSU)
Additional calibration +
electronics (UoA)

1. Cable and Deployment
Frame: MacArtney, Denmark

2. Optical Modules
Integration: TUM



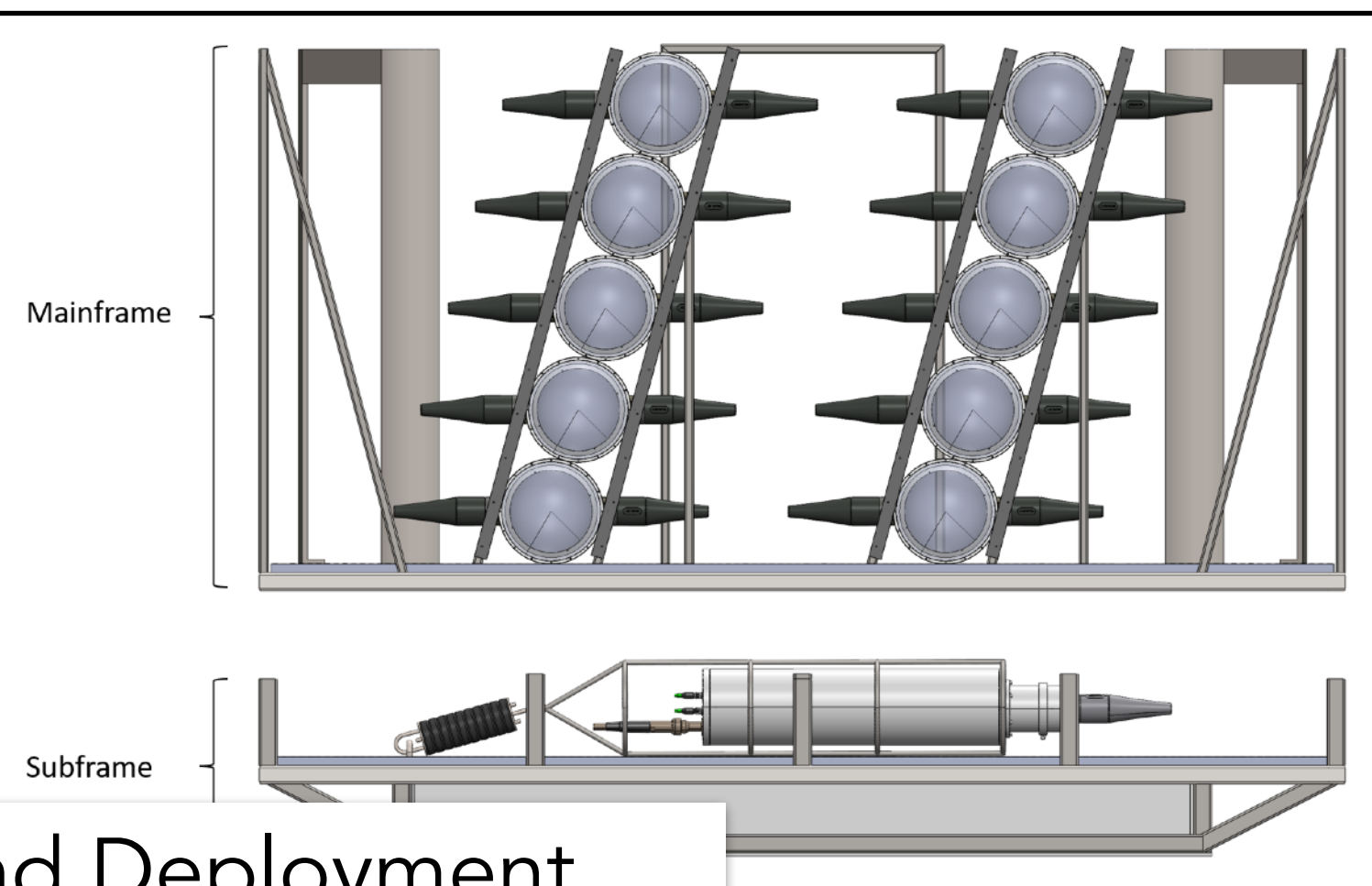
P-ONE-1 Logistics



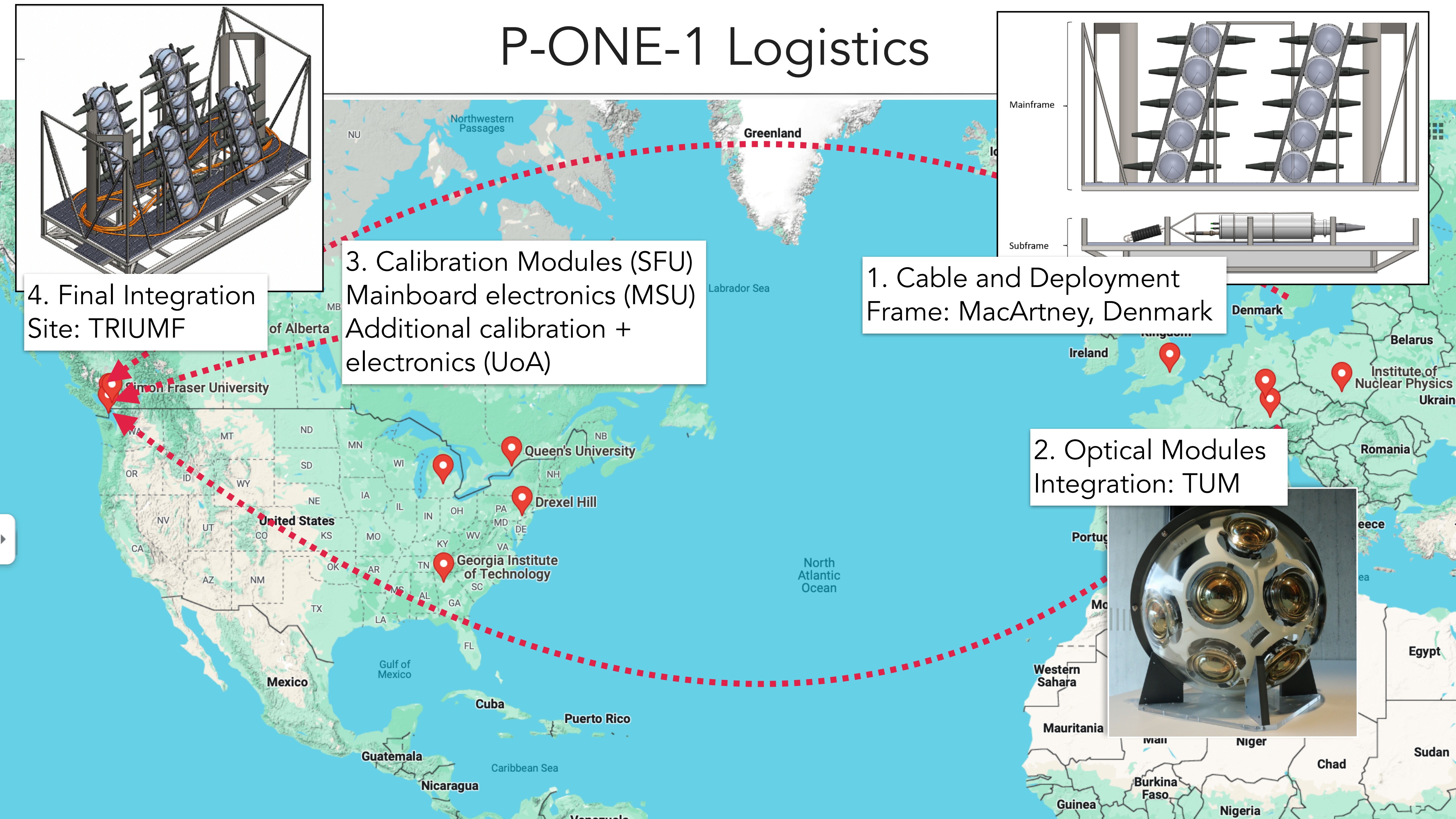
4. Final Integration Site: TRIUMF

3. Calibration Modules (SFU)
Mainboard electronics (MSU)
Additional calibration + electronics (UoA)

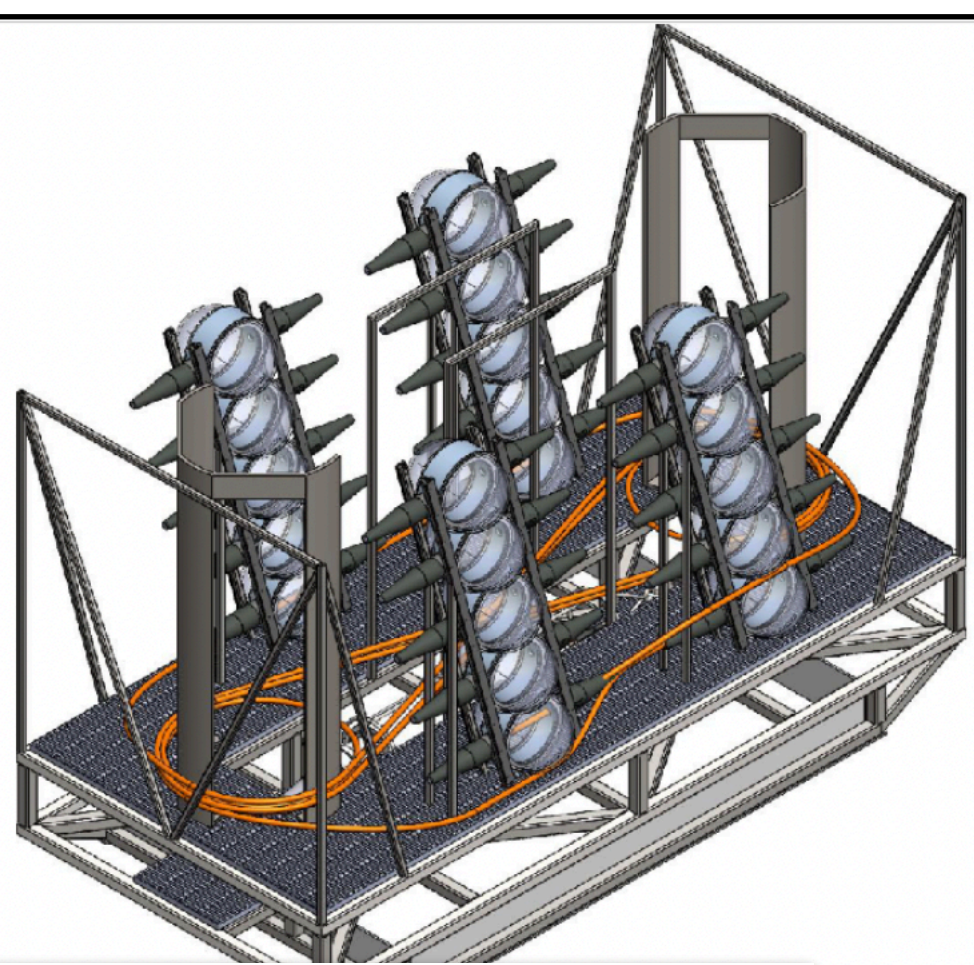
1. Cable and Deployment Frame: MacArtney, Denmark



2. Optical Modules Integration: TUM



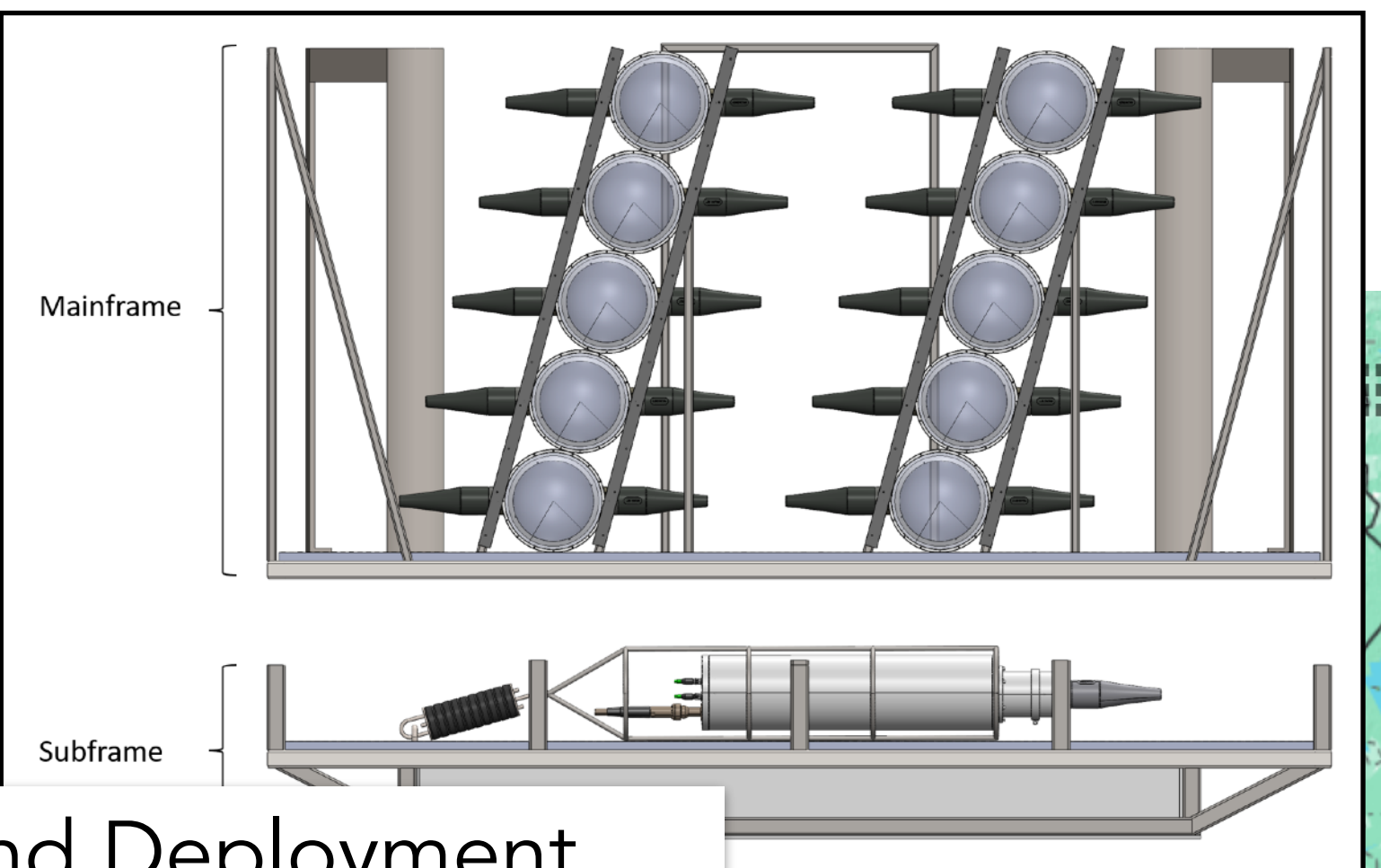
P-ONE-1 Logistics



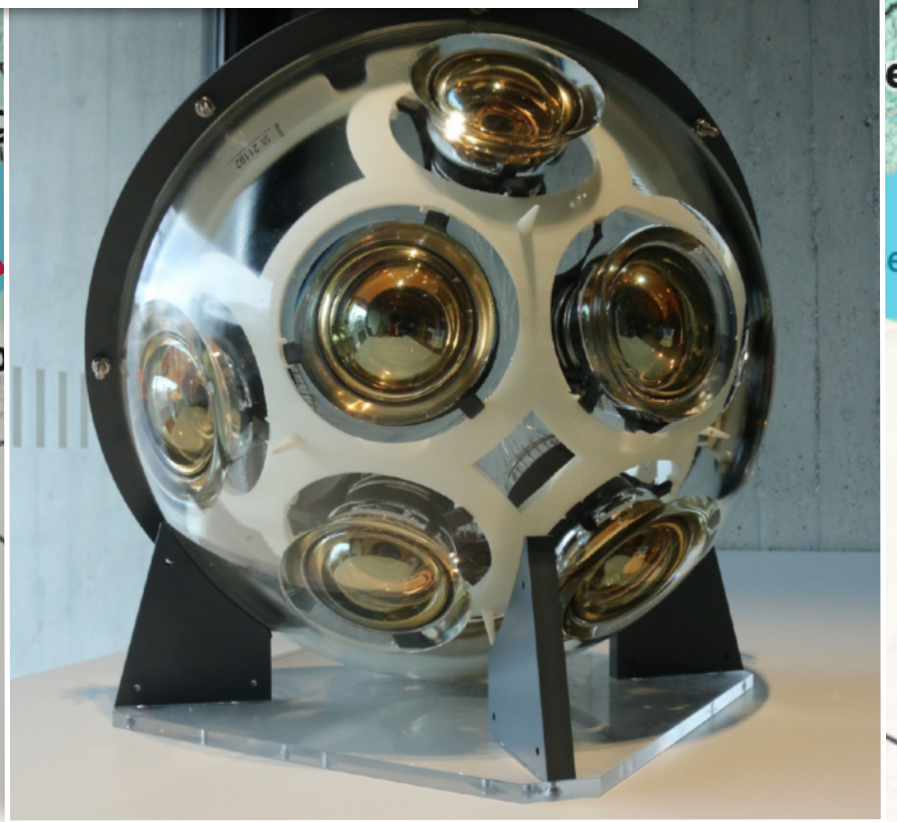
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3. Calibration Modules (SFU)
Mainboard electronics (MSU)
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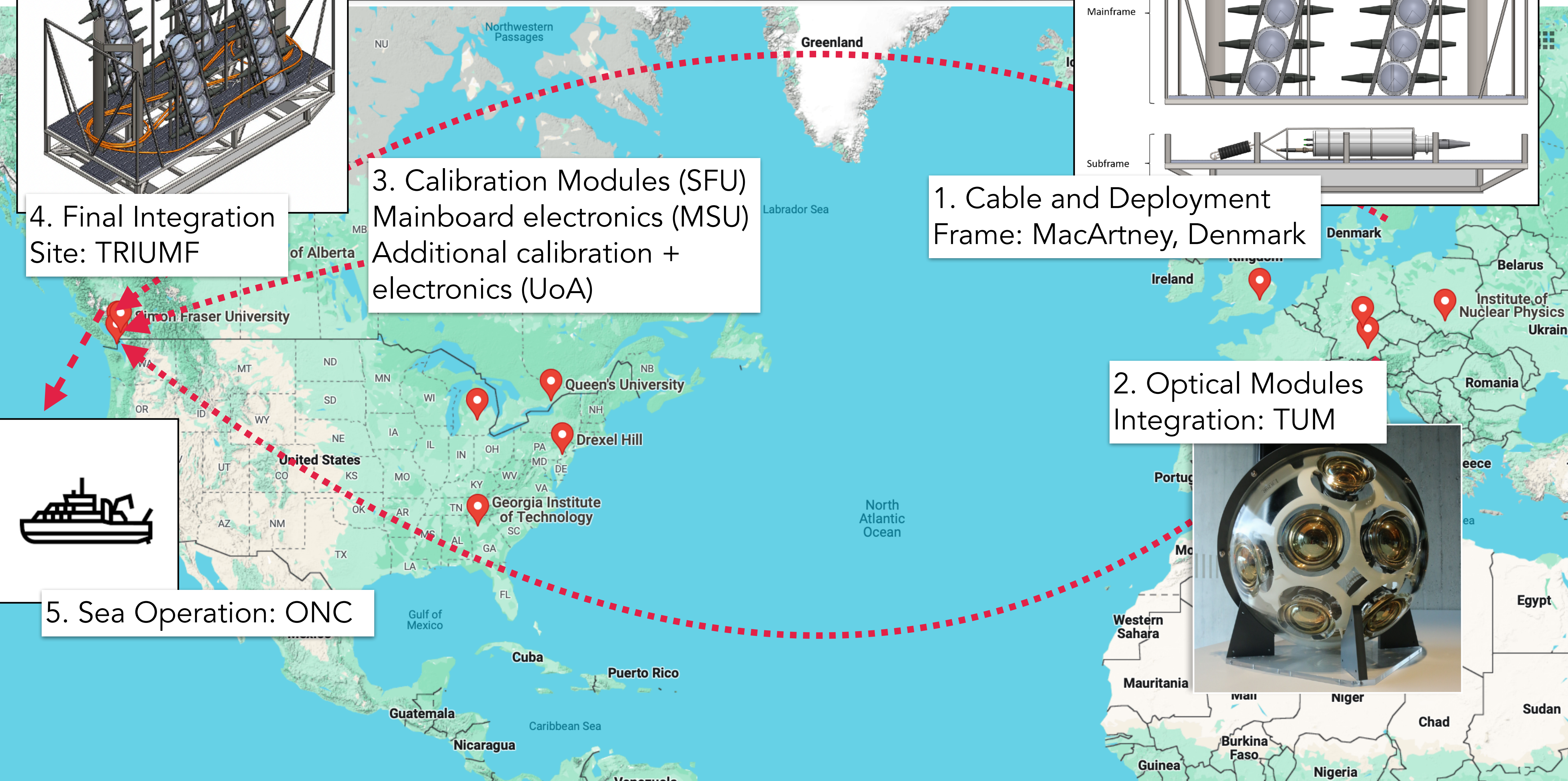
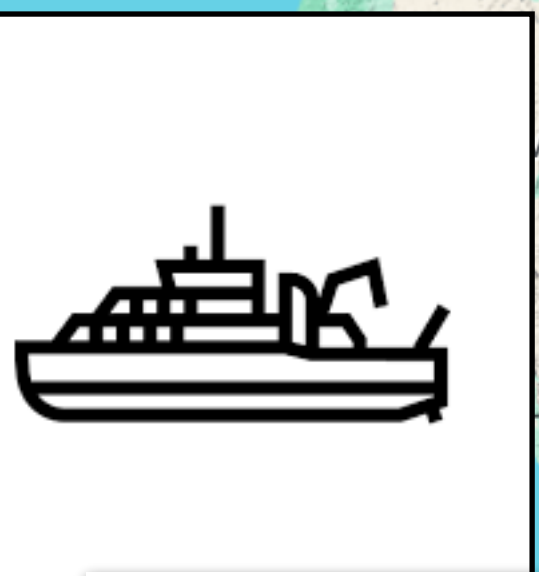
1. Cable and Deployment Frame: MacArtney, Denmark



2. Optical Modules Integration: TUM

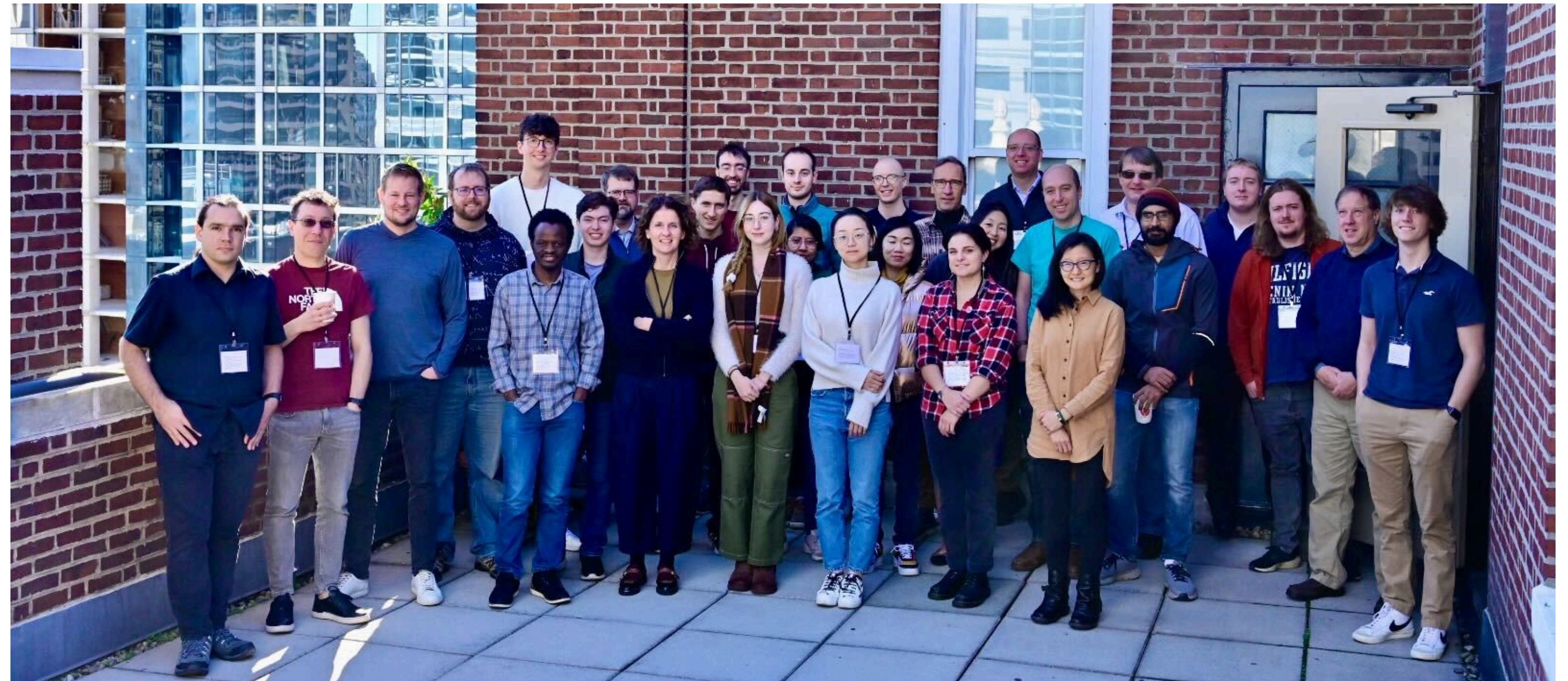


5. Sea Operation: ONC



Thank you

- Phase 2 of the P-ONE project has started.
- Exciting 2024 and 2025 are ahead for the P-ONE project.
- We are looking forward to deploy and test our new line concept!
- Stay tuned for updates....



P-ONE Collaboration meeting Philadelphia Nov. 2023