The P-ONE Neutrino Experiment and Prototype

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University of Alberta

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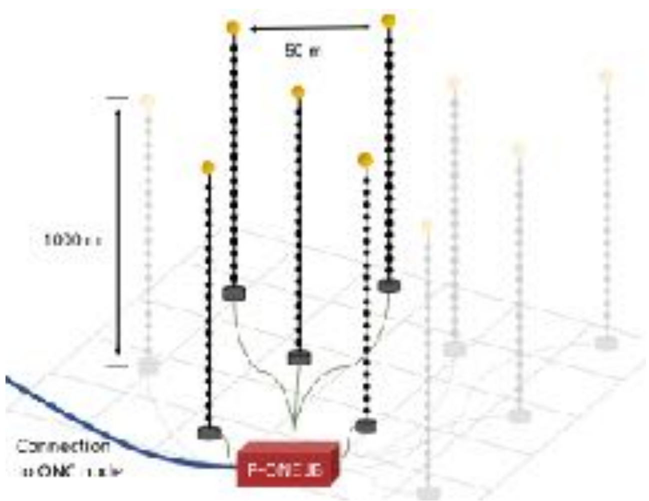
MIDAS Workshop 2023

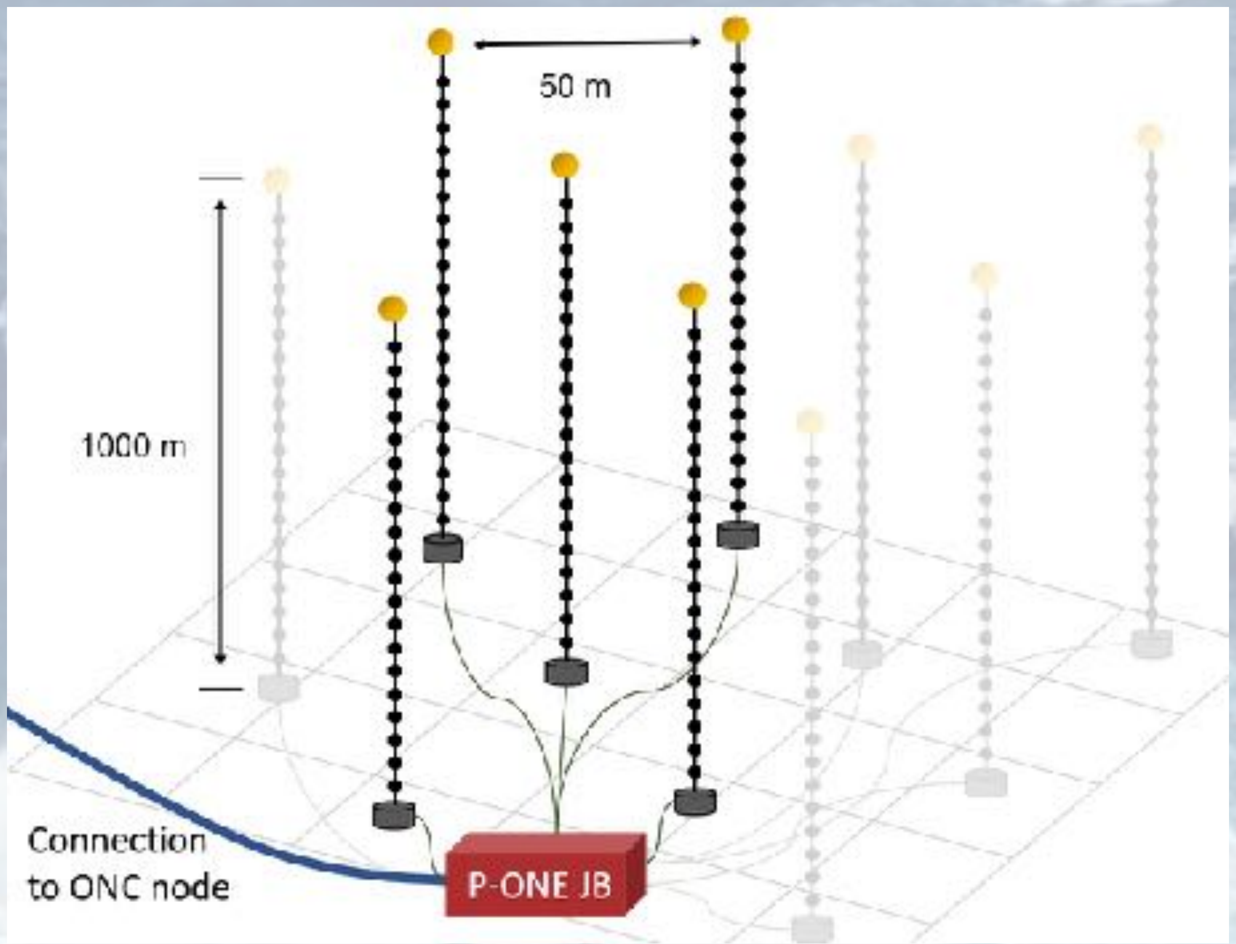


UNIVERSITY OF ALBERTA

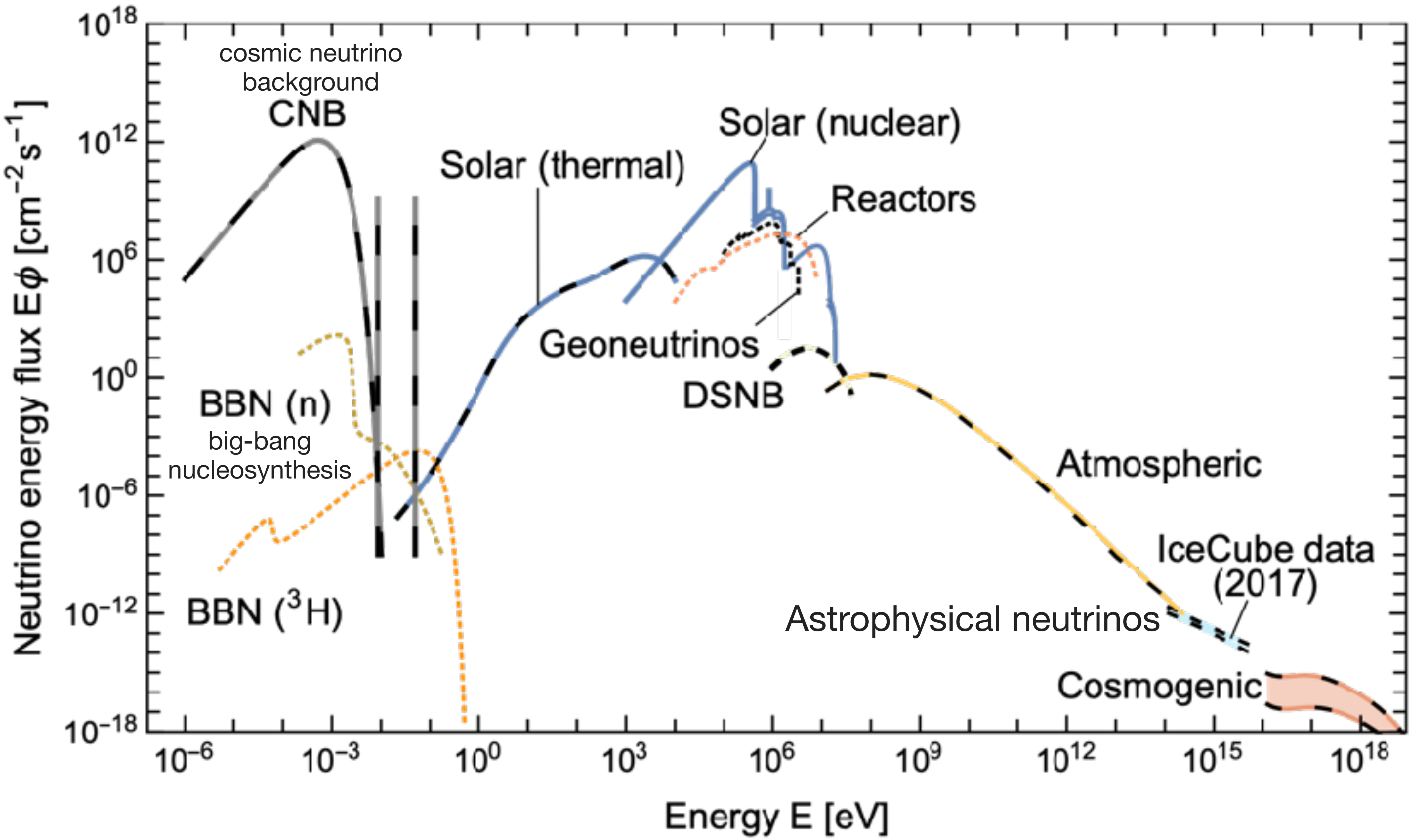
P-ONE

Outline

- Neutrino Astronomy & Particle Physics
- Neutrino Telescopes
- **P-ONE**
  - P-ONE Physics
  - P-ONE Site: Cascadia Basin
  - Data Flow and Frontend design
  - Open questions and next steps



Neutrinos from the Universe



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

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

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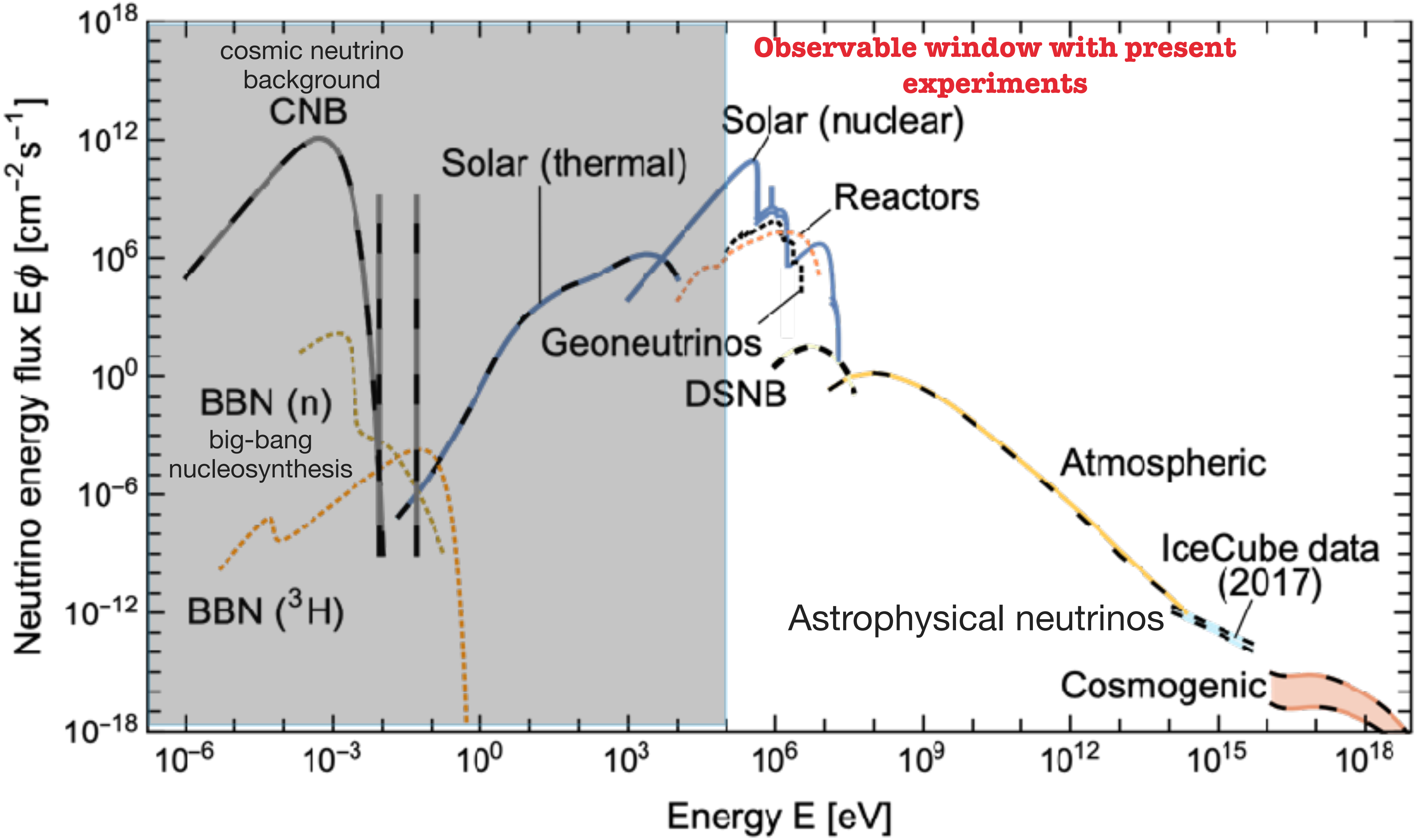

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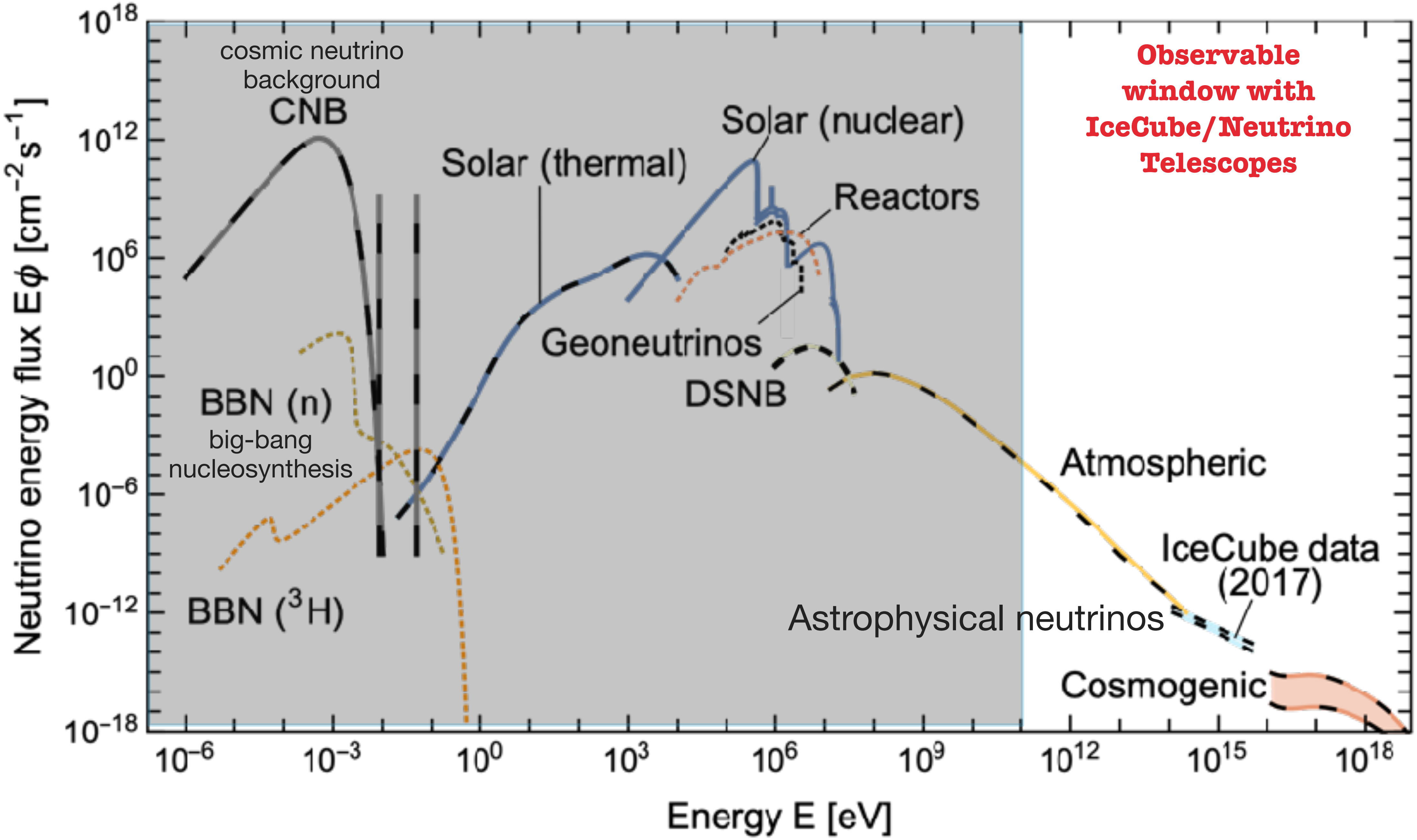

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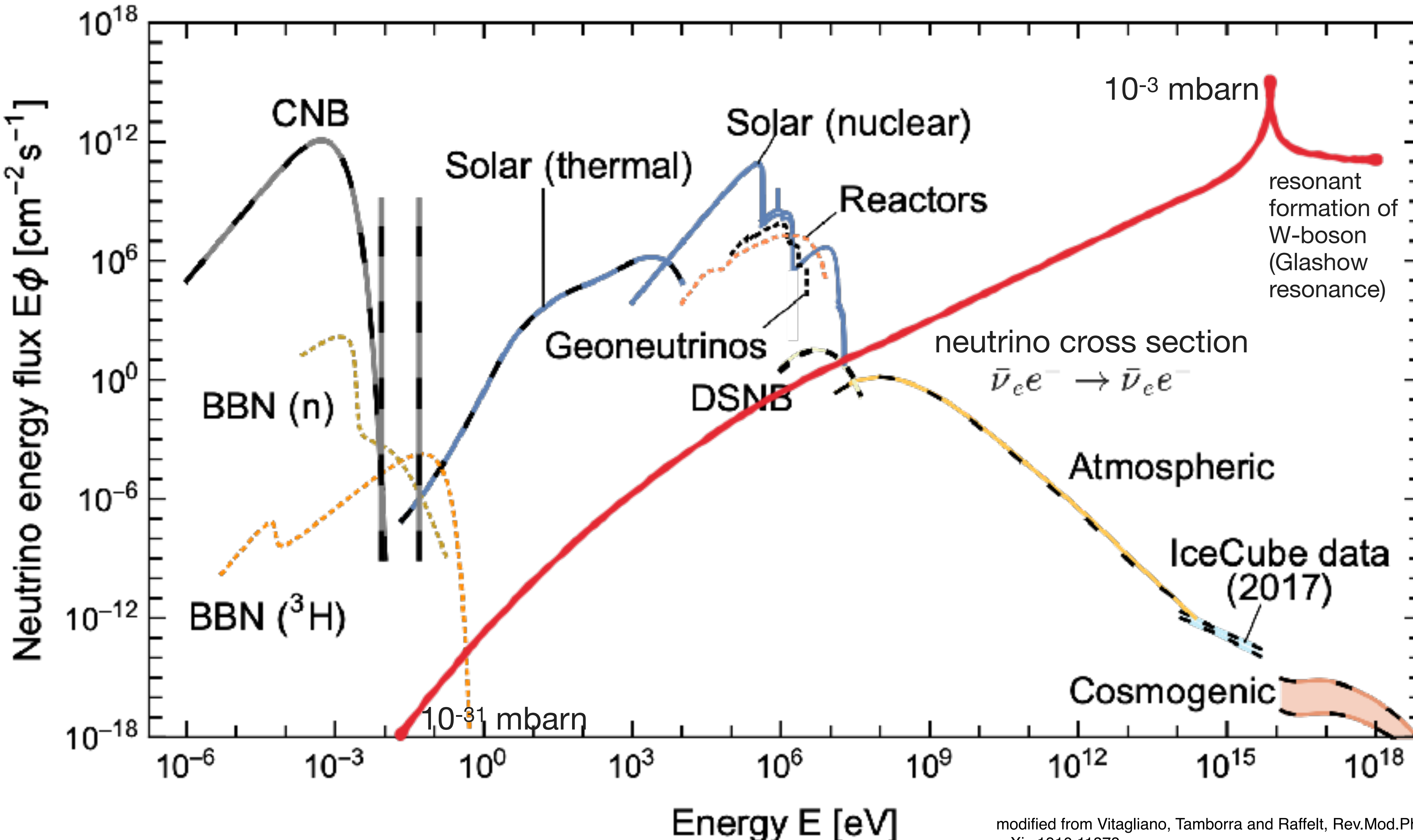
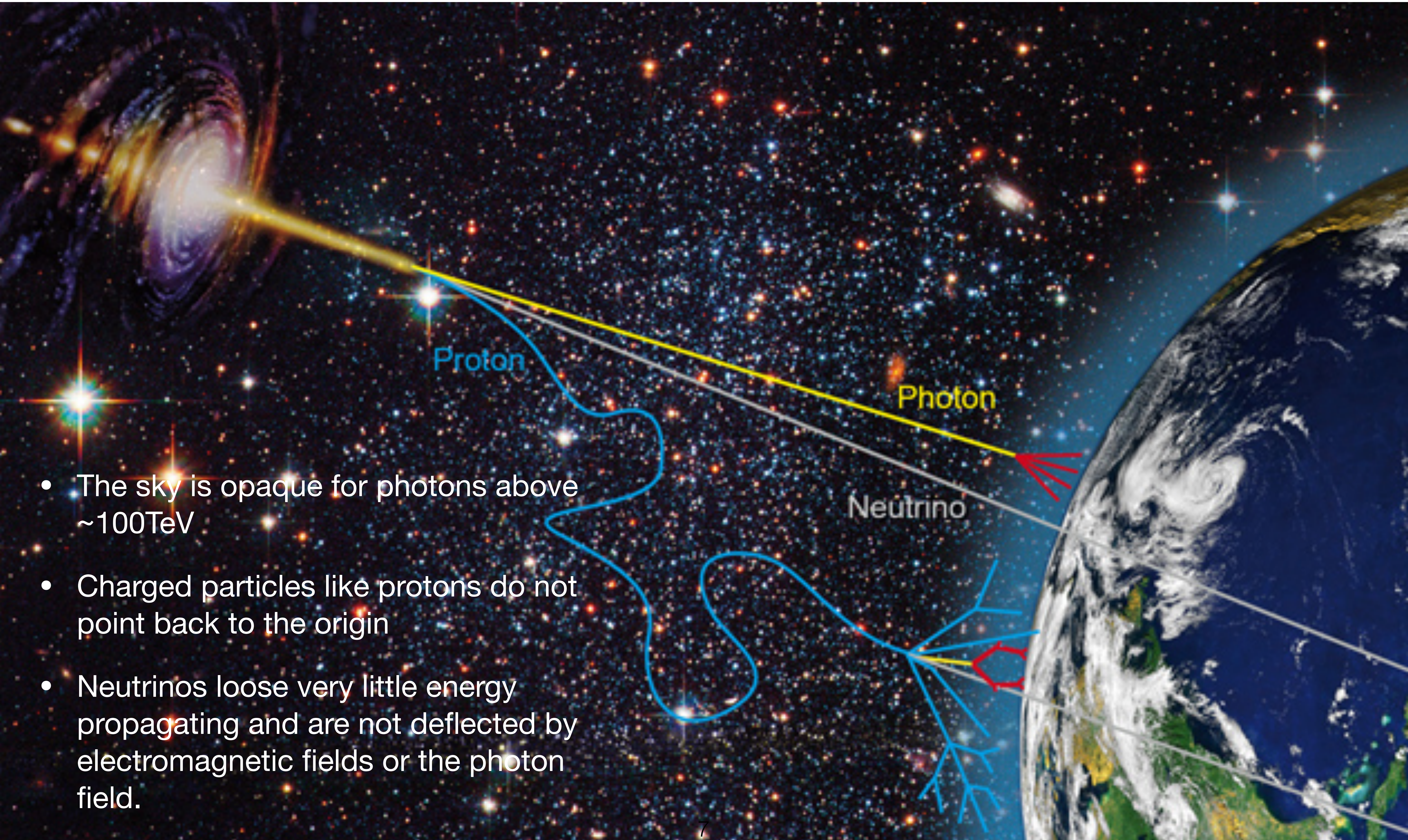


modified from Vitagliano, Tamborra and Raffelt, Rev.Mod.Phys 2019, arXiv:1910.11878

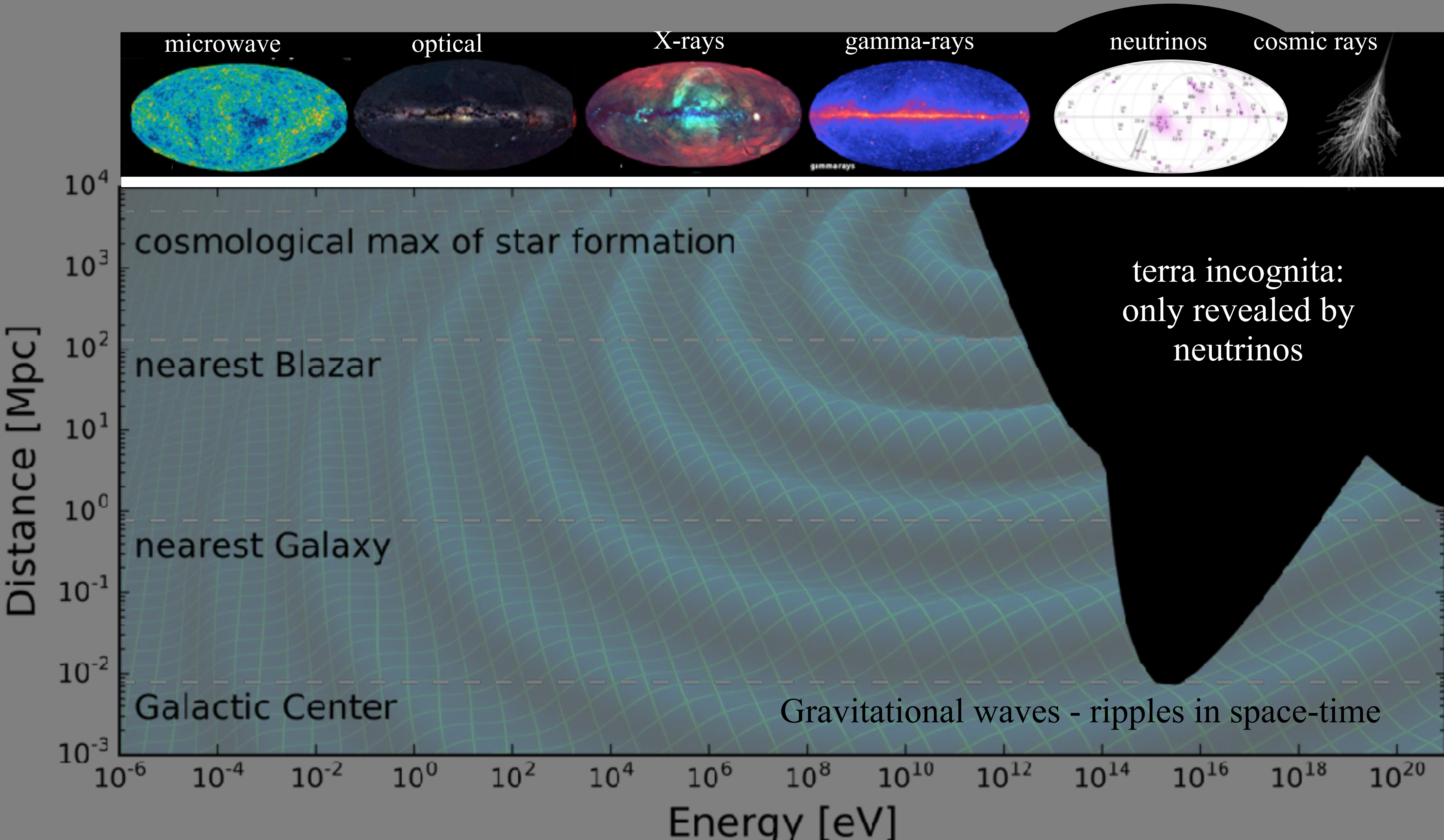
Formaggio, Zeller, Rev. Mod. Phys. 2012, arXiv:1305.7513

Neutrino Sources?



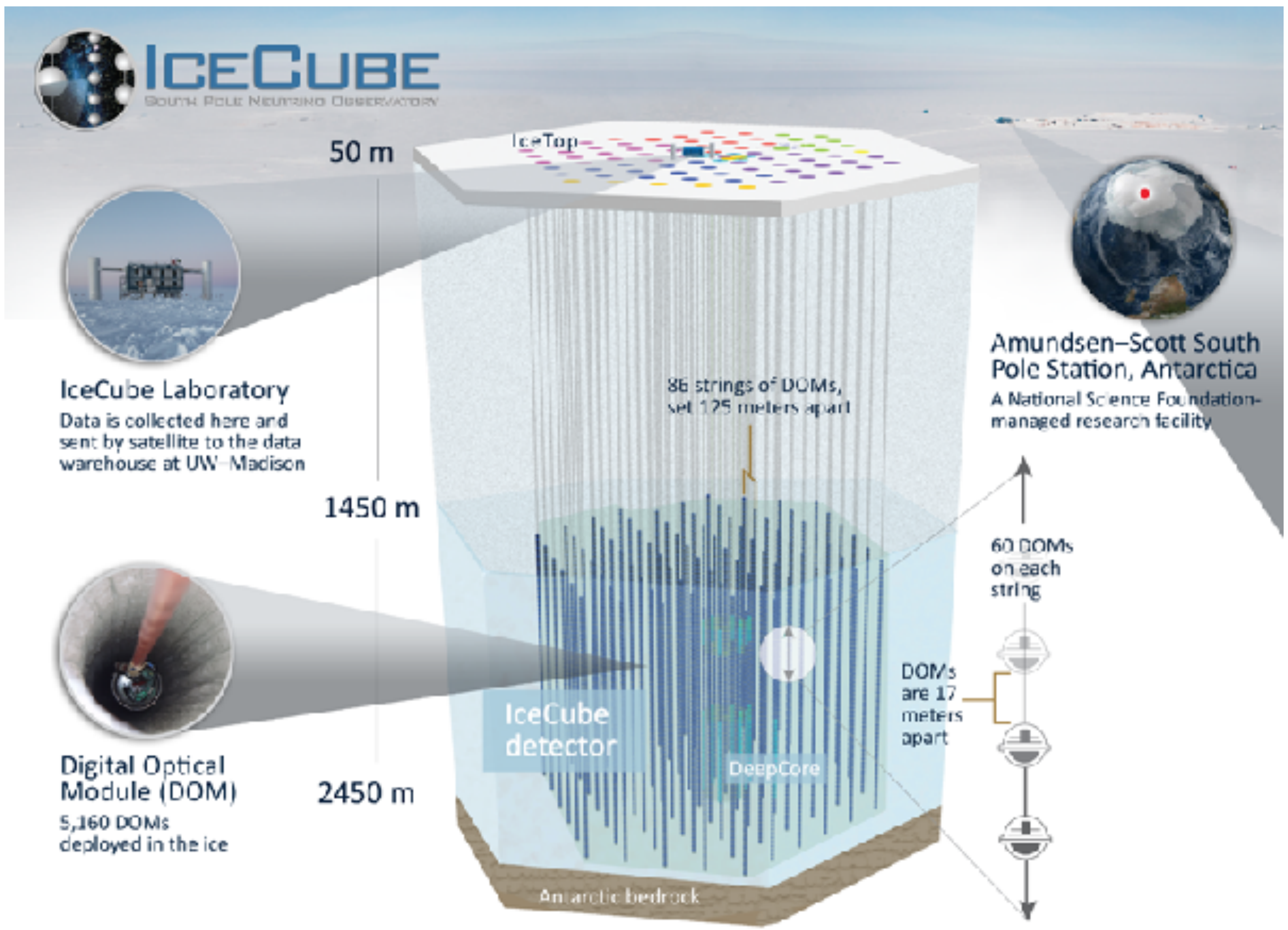
- The sky is opaque for photons above ~100TeV
- Charged particles like protons do not point back to the origin
- Neutrinos loose very little energy propagating and are not deflected by electromagnetic fields or the photon field.

highest energy “radiation” from the Universe: neutrinos and cosmic rays

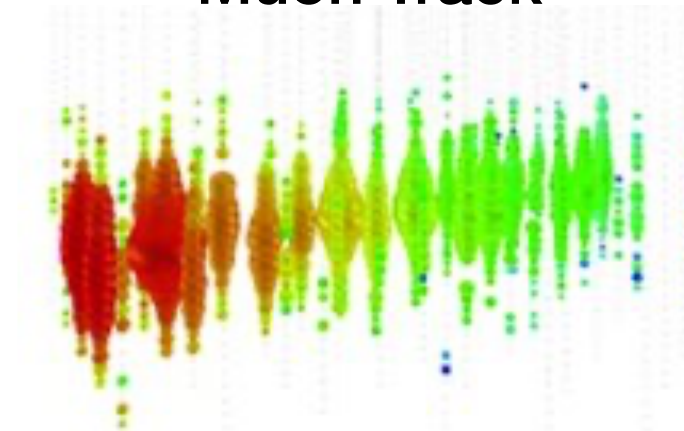


Universe is opaque above ~100 TeV energy

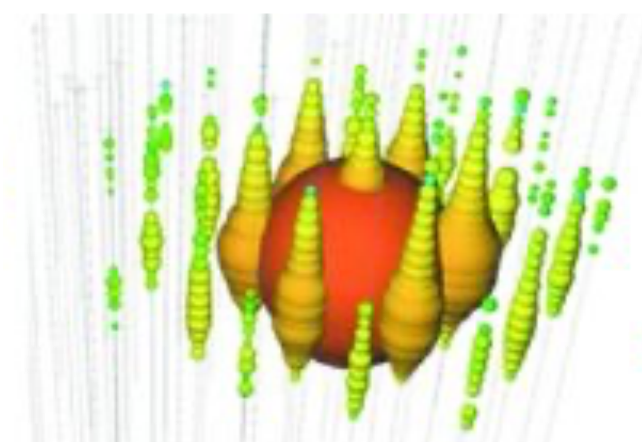
IceCube & DeepCore



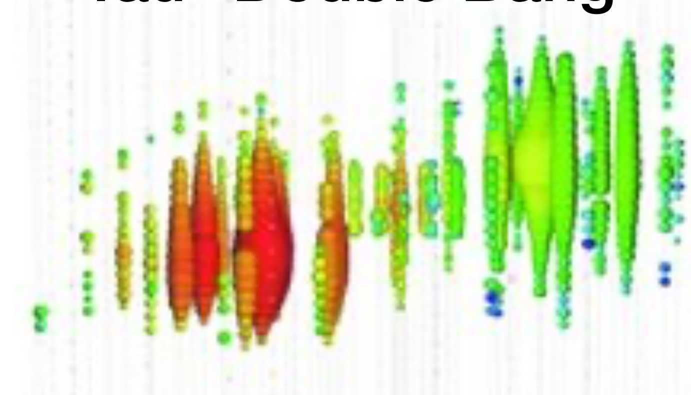
Muon Track



Electron Cascade

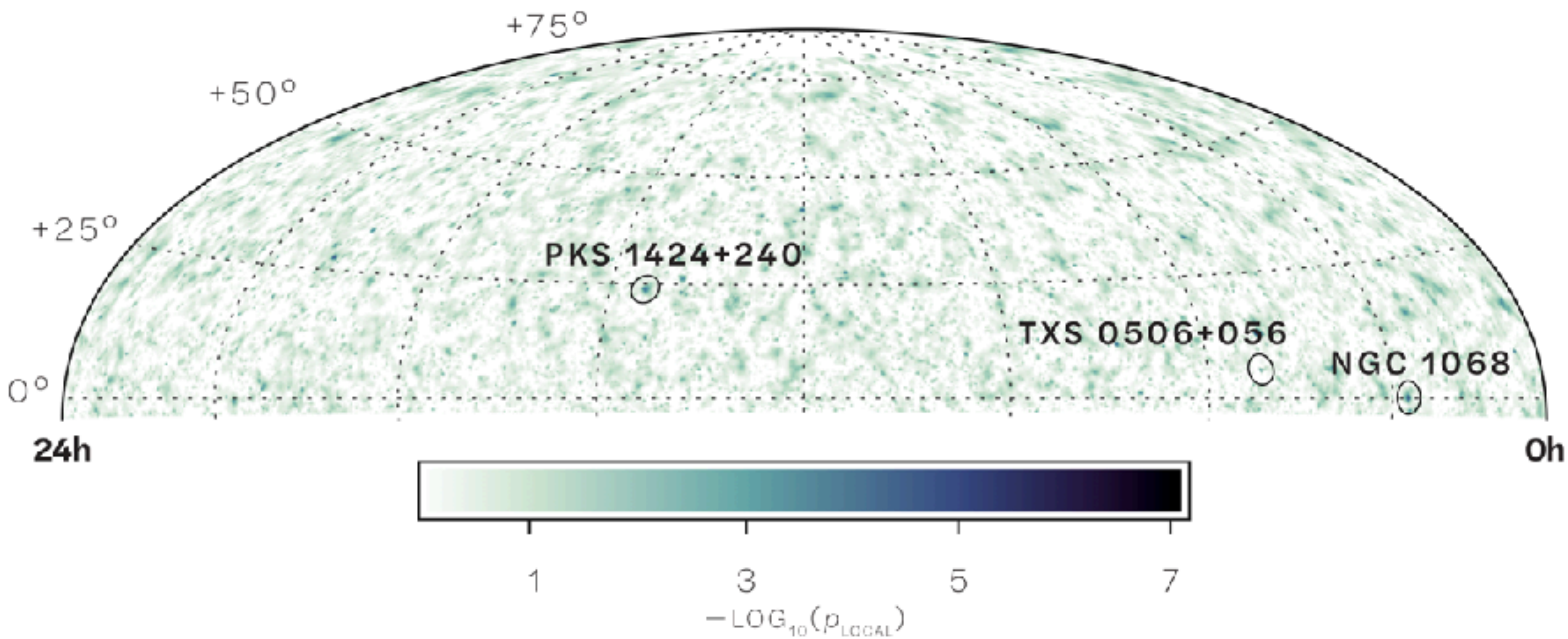


Tau “Double Bang”



- Completed in 2011

Search for Neutrino Sources



- The first neutrino sources have been identified using IceCube!

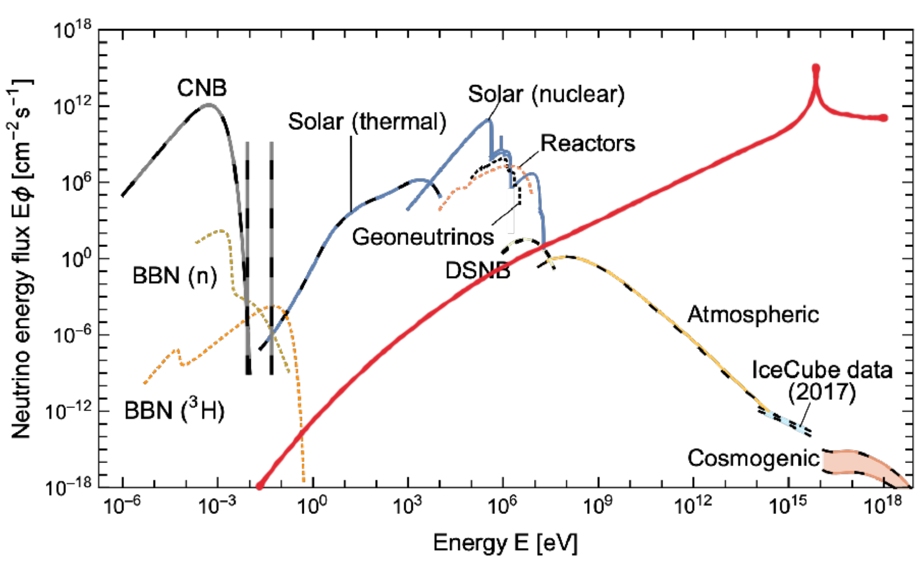
Science 378, 6619, 538-543 (2022)

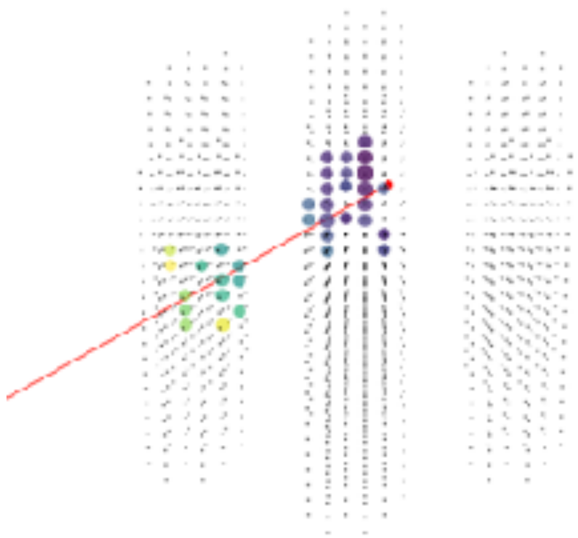
P-ONE Physics

- P-ONE will be optimized for particle identification, making it ideal for high energy neutrino flavour physics. Our system development focuses on the identification of track vs cascade vs double bang signatures, benefiting from the superior scattering properties of ocean water

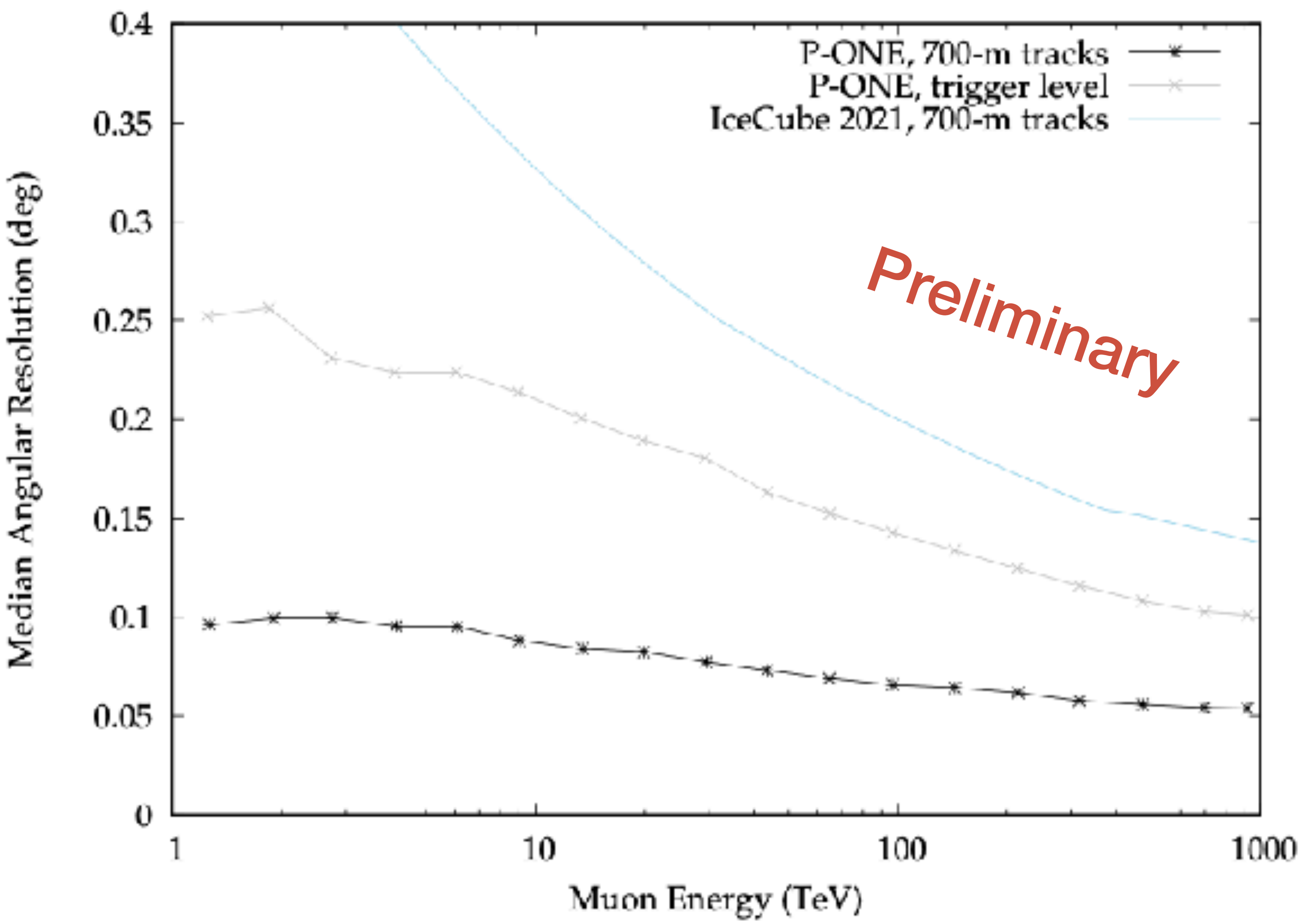
- With a large P-ONE detector it will be possible to study BSM effects and the Glashow resonance

- Even a ~small detector will be able to join the larger detectors to contribute to point source searches, especially in the sky region not covered by the other detectors in the northern hemisphere and even improve overall sensitivity as the pointing accuracy is so much better in water





The P-ONE Advantage



- Both angular resolution, particle identification ability and sensitivity of P-ONE are designed to be leading in class

- The choices of calibration tools, trigger systems, timing resolution and readout technology are chosen to optimize

P-ONE

- Alberta, Queen’s, SFU, TRIUMF, TUM, Erlangen (Germany) and Drexel, Maryland, MSU (USA), Krakow (Poland), UCL (UK) Collaboration

- Started in 2018 with the deployment of a test setup to assess the water quality

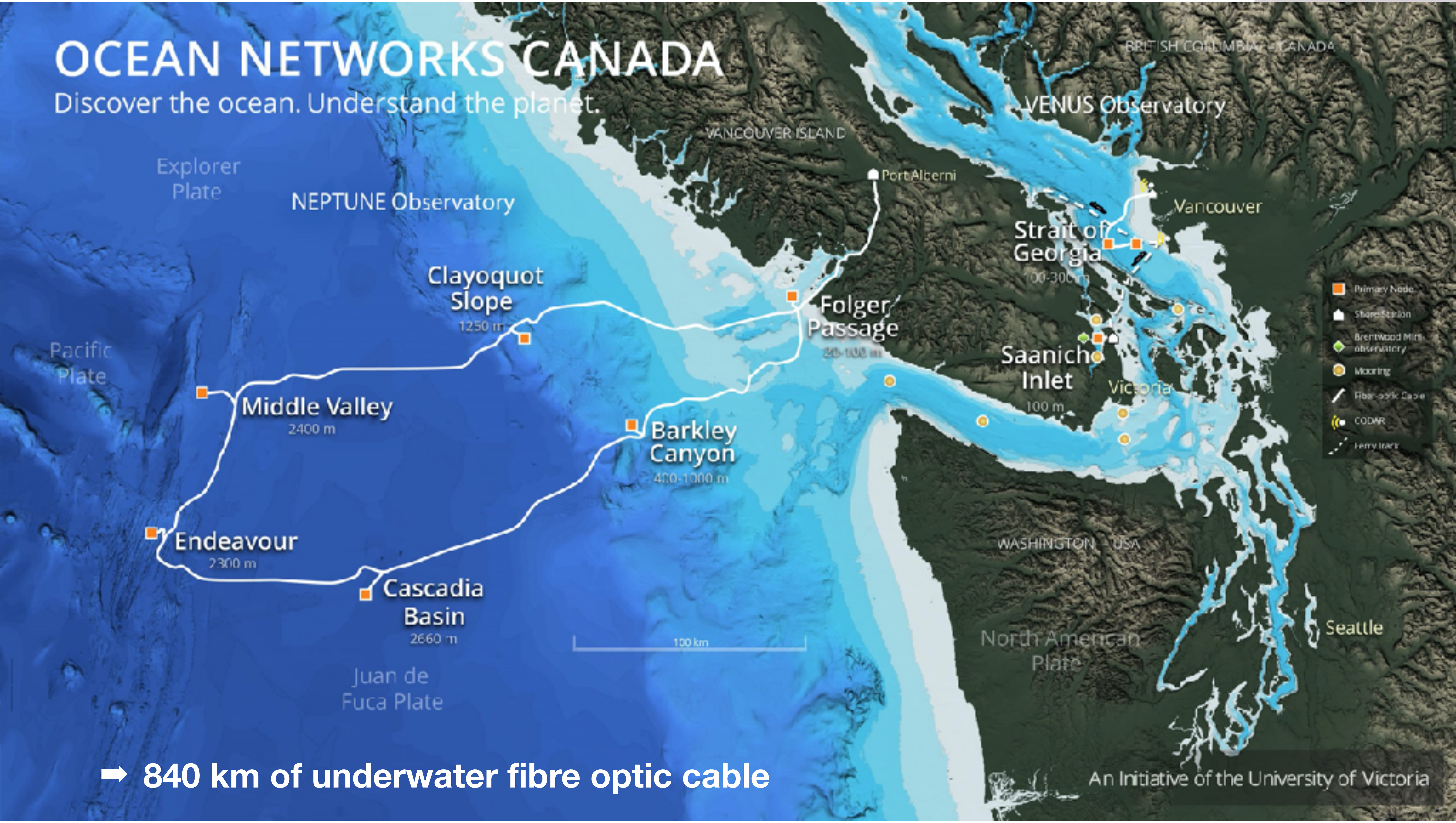
- Funding in Germany for the first strings was secured in 2022

- The first US, Canadian and Polish funding was also secured in 2022, allowing for a robust effort to start prototype development and testing

The Cascadia Basin Site

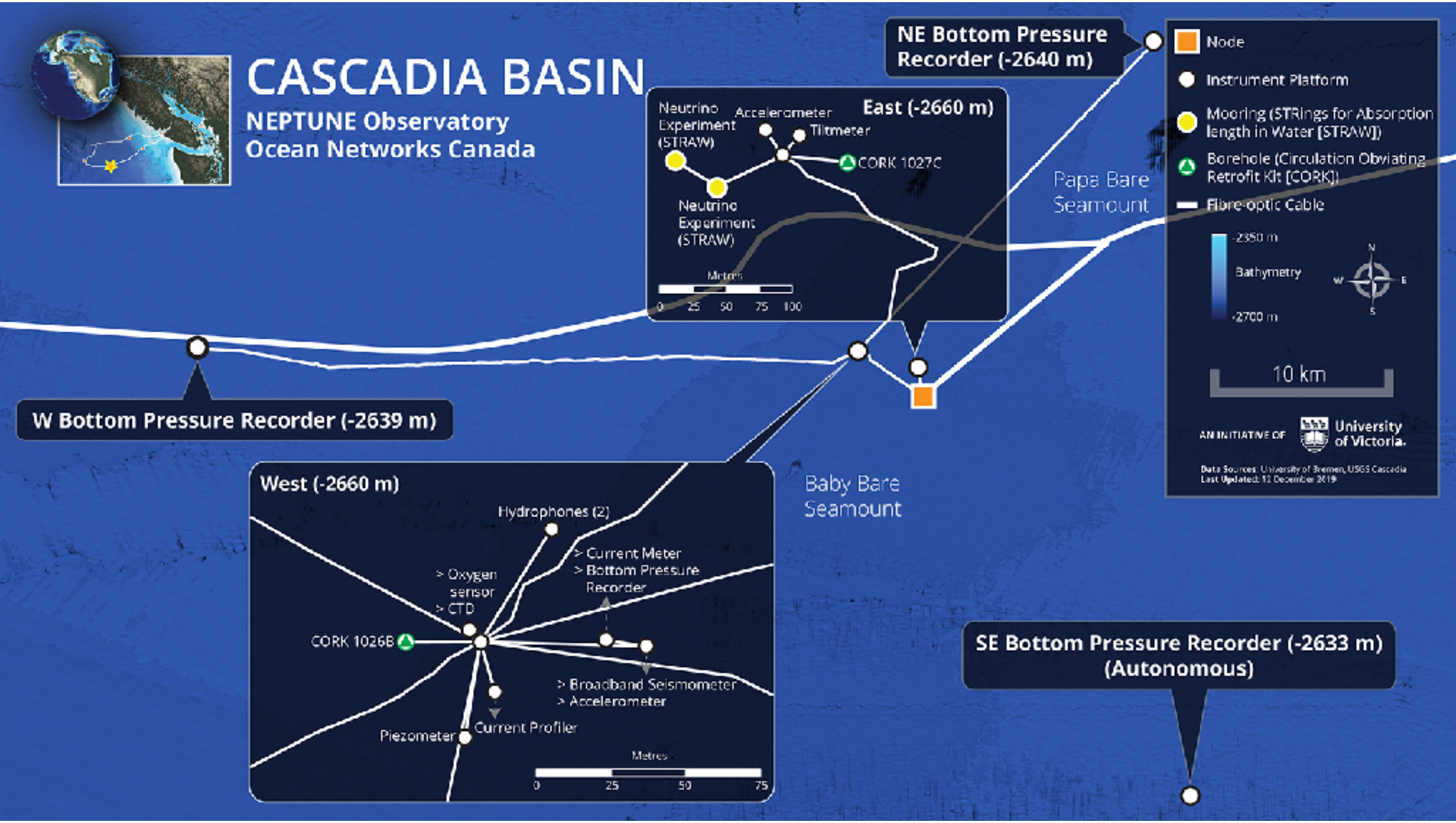
https://www.facebook.com/OceanNetworksCanada/videos/1200365743665048/

ONC

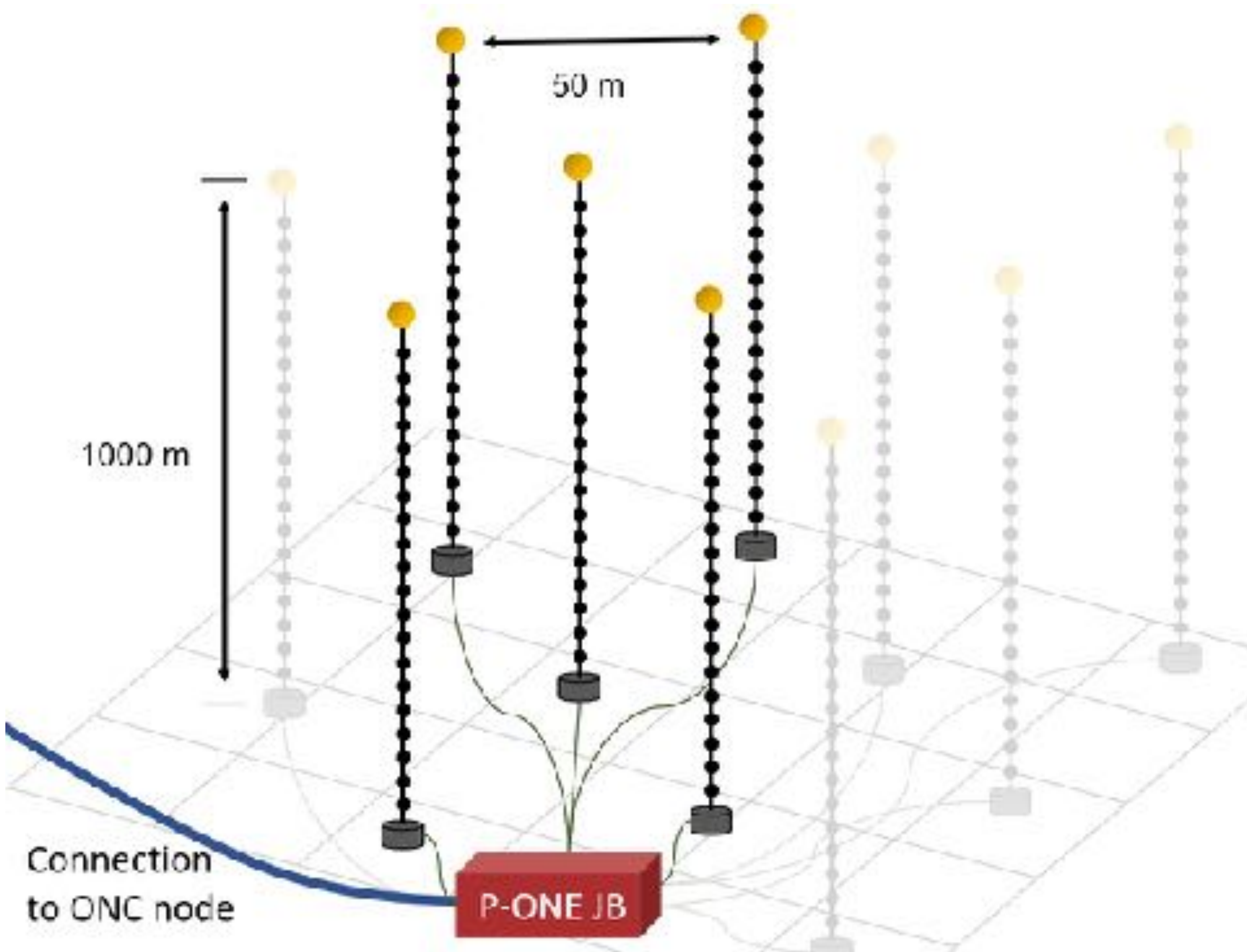


➡ **840 km of underwater fibre optic cable**

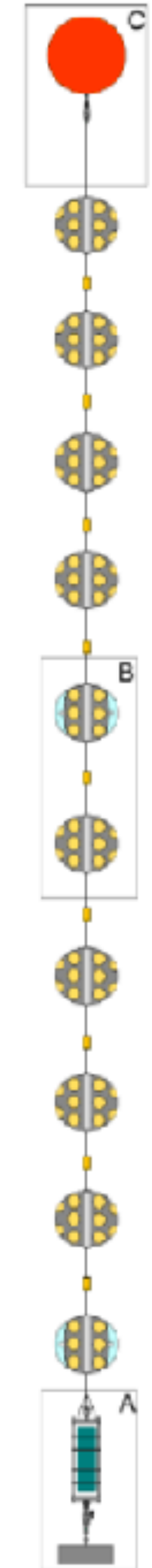
Cascadia Basin Site



Pacific Ocean Neutrino Experiment (P-ONE) Demonstrator



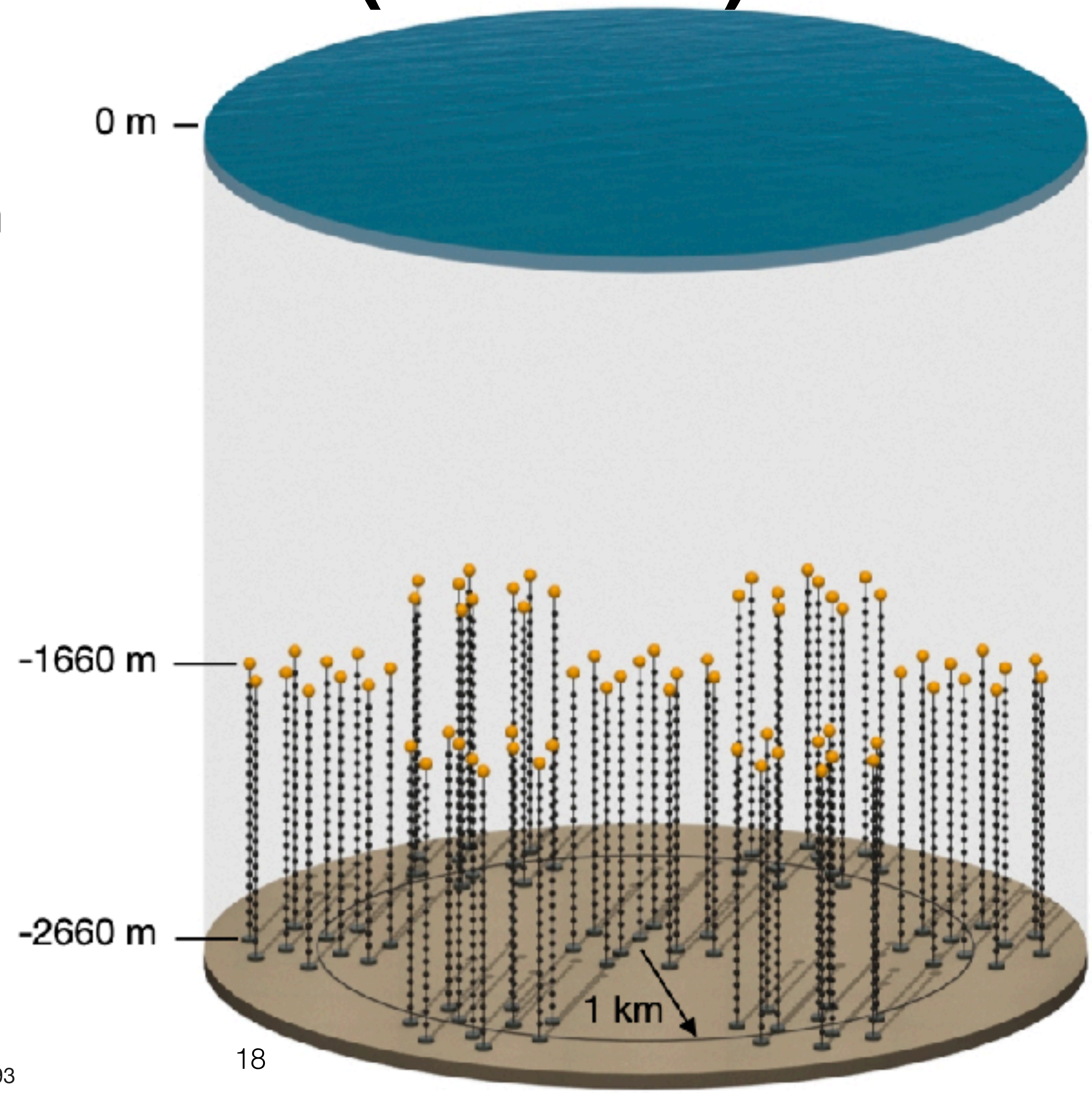
- Time scale for realization: 2024, first mooring line, more in the following years
- Up to 10 strings with 20 optical and calibration modules each
- 1 km long mooring line
- Instrumented volume >1/8 km^3



Pacific Ocean Neutrino Experiment (P-ONE)

- The P-ONE collaboration aims to construct a km^3 scale detector by constructing seven identical modules of the *Demonstrator* type

- The optimal final arrangement is currently under study



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

Large Area Photon Detection

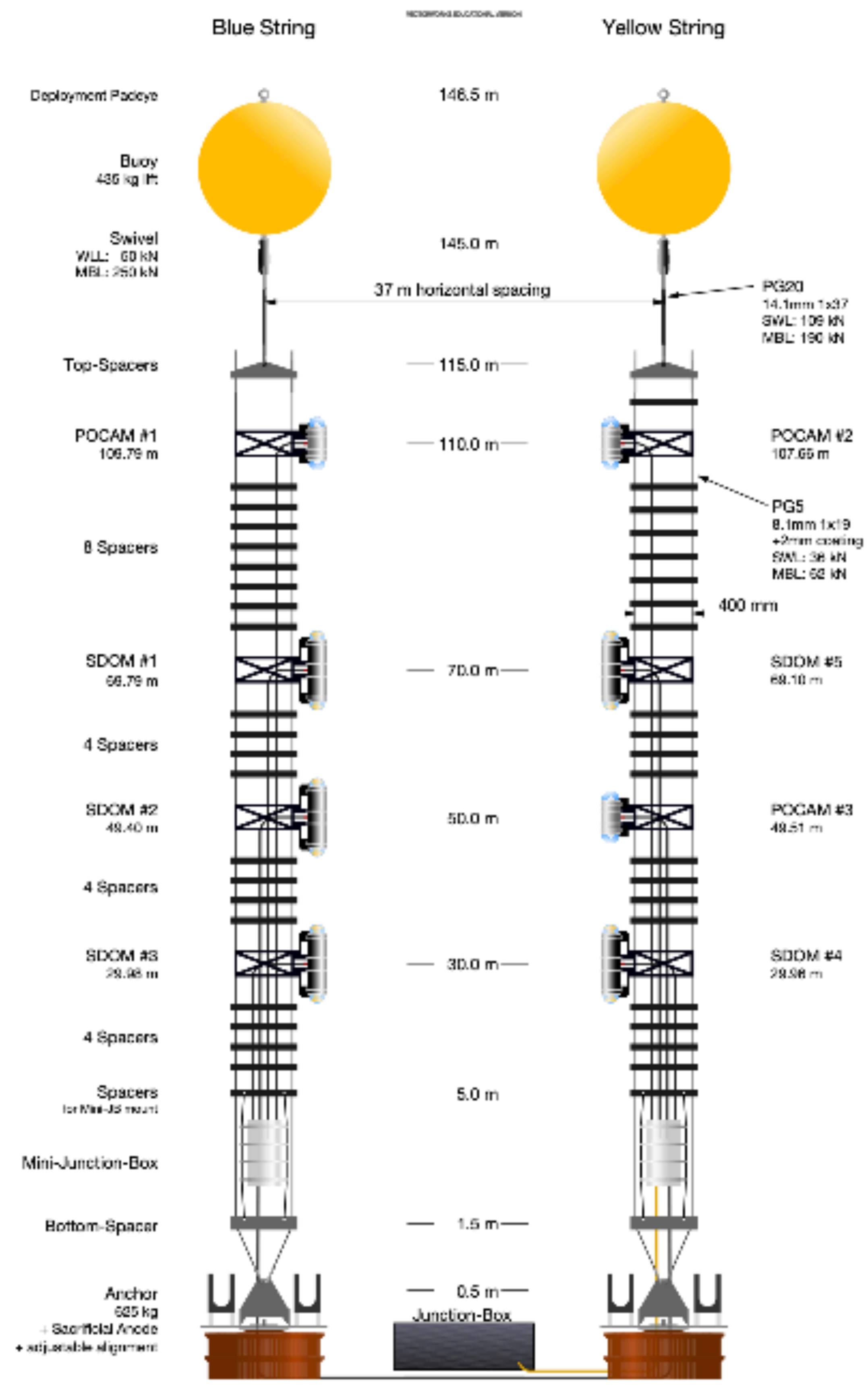
- The instrumentation of the ~200 optical modules of P-ONE will use KM3NeT/IceCube-like multi PMT digital optical modules

- 3” PMTs offer a good cost to surface area ratio

- Using a novel, side mounted housing allows obstruction-free observation

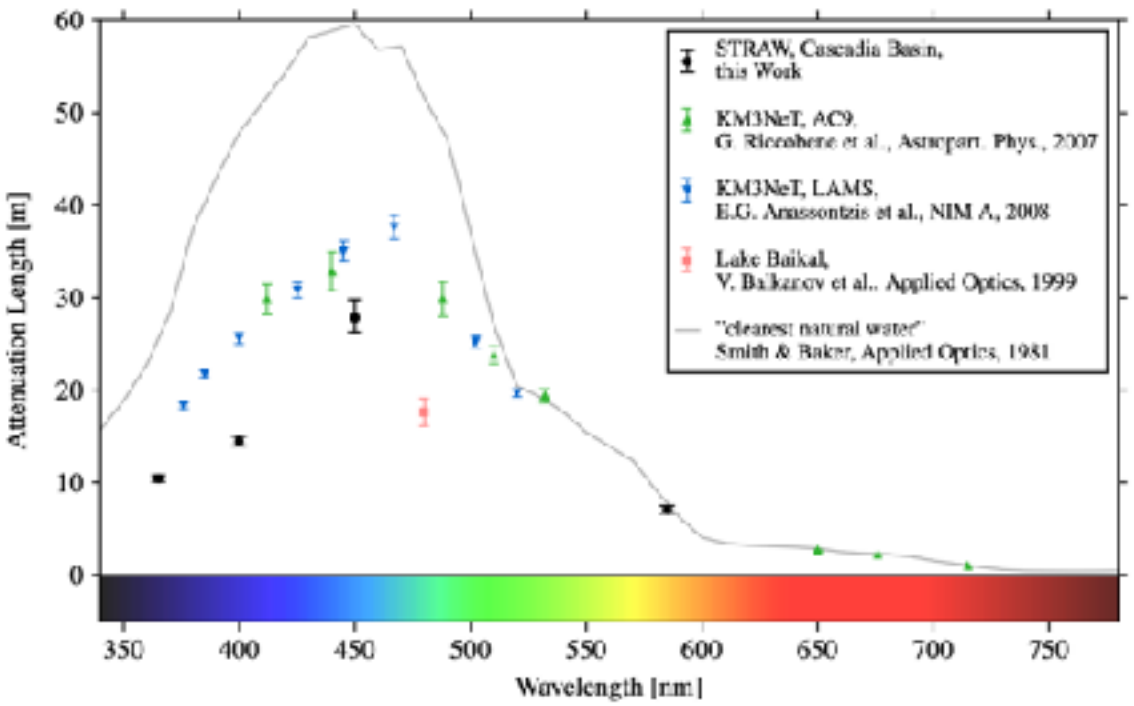
STRAW

- Strings for Absorption in Water
- Deployed in summer 2018
- All instruments are working
- Absorption and scattering length determined to be similar to other ocean based detector locations

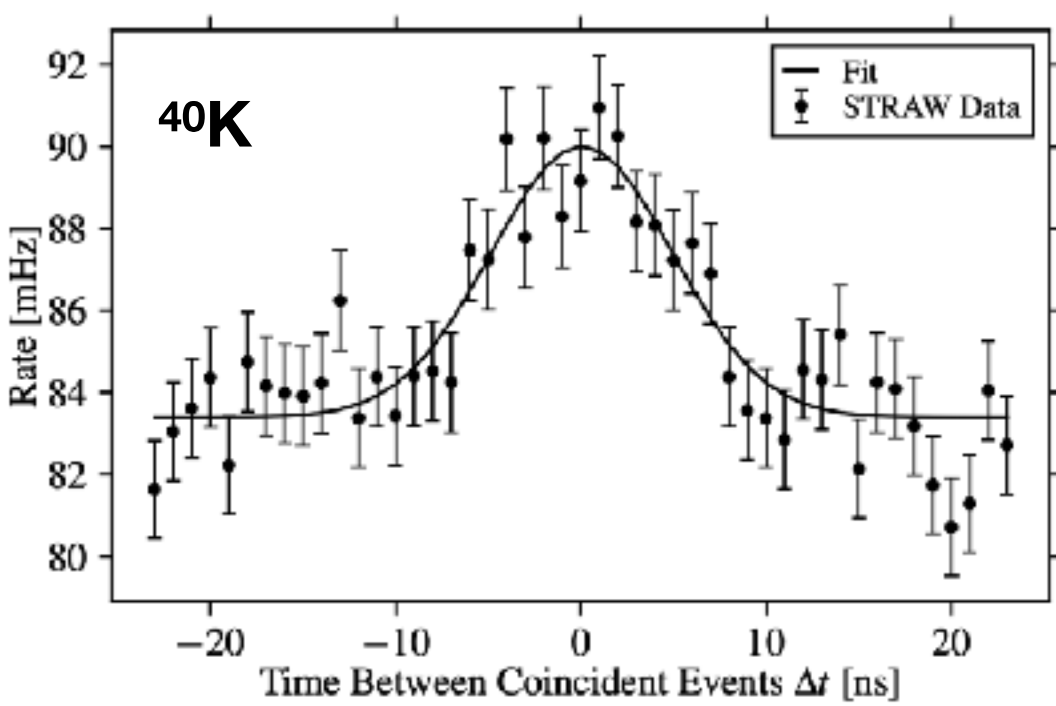


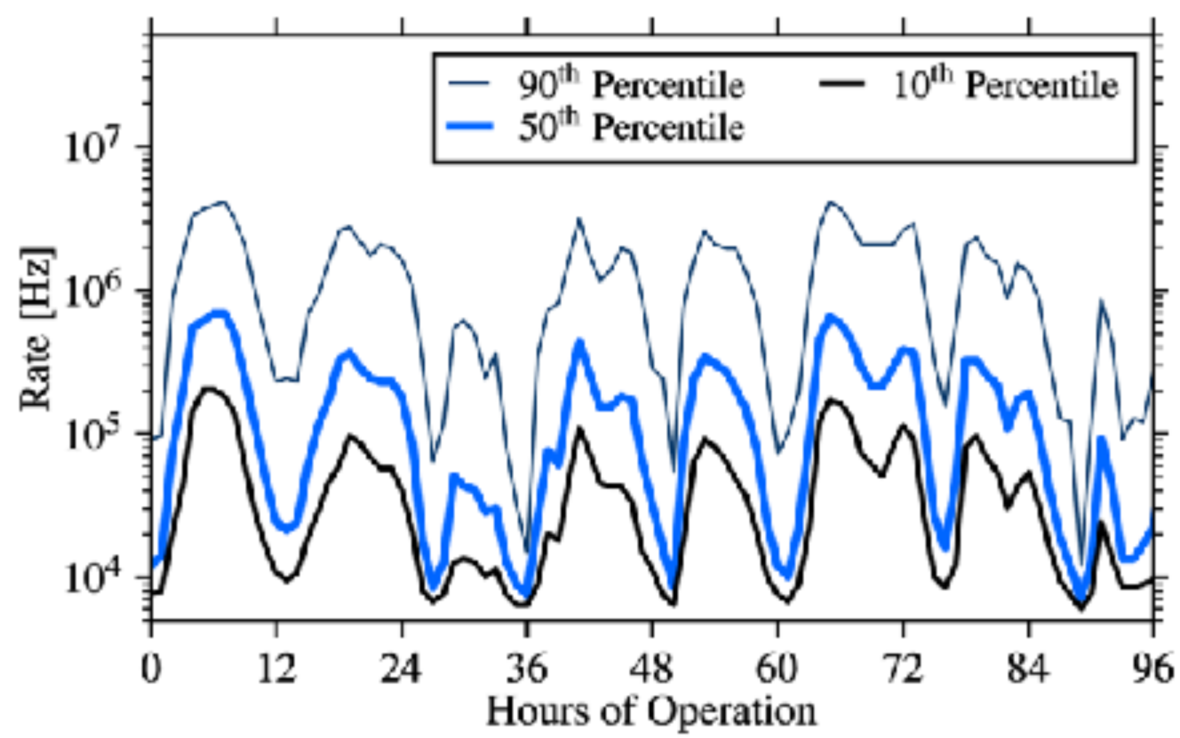
M. Boehmer *et al* 2019 *JINST* **14** P02013

Results: Attenuation Length & Bioluminescence



- Full publication with optical parameters:
- Bioluminescence is modulated with the tides
- ^{40}K Rate is consistent with ONC salinity measurements and expectations
- Attenuation length is good enough for a large scale neutrino telescope

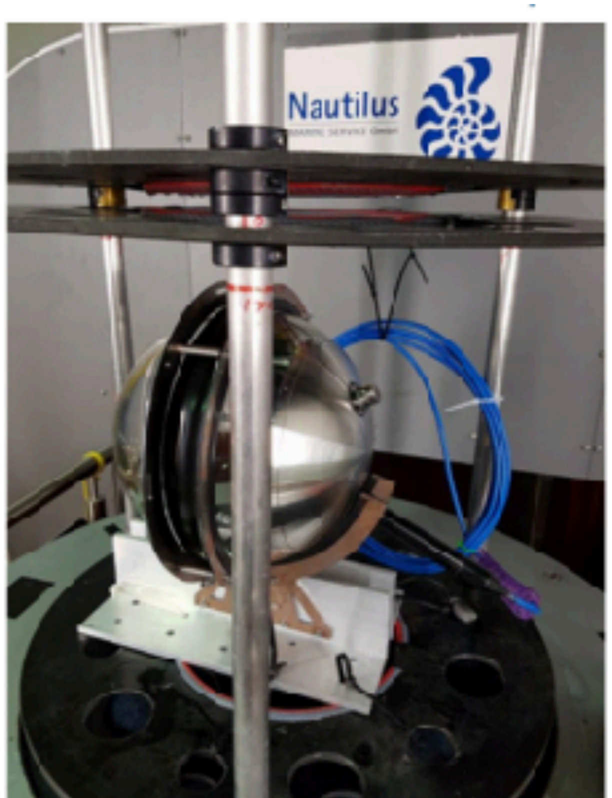


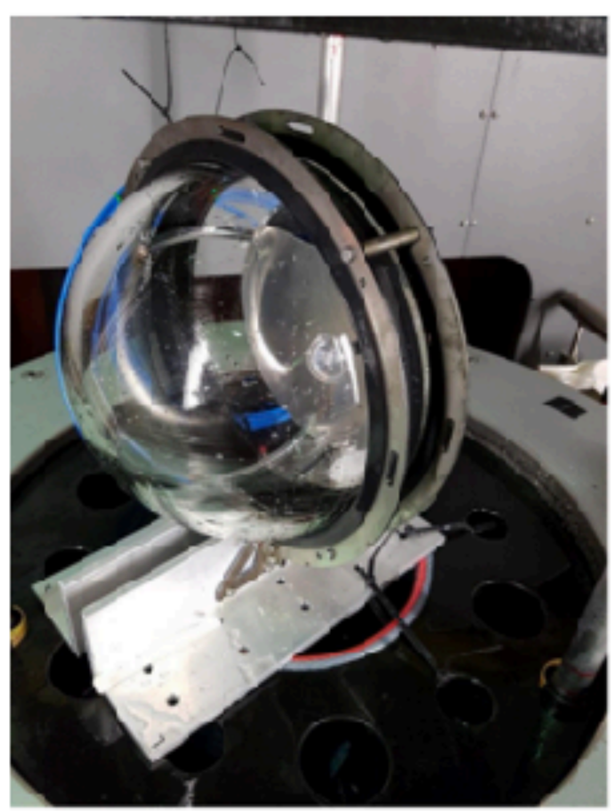


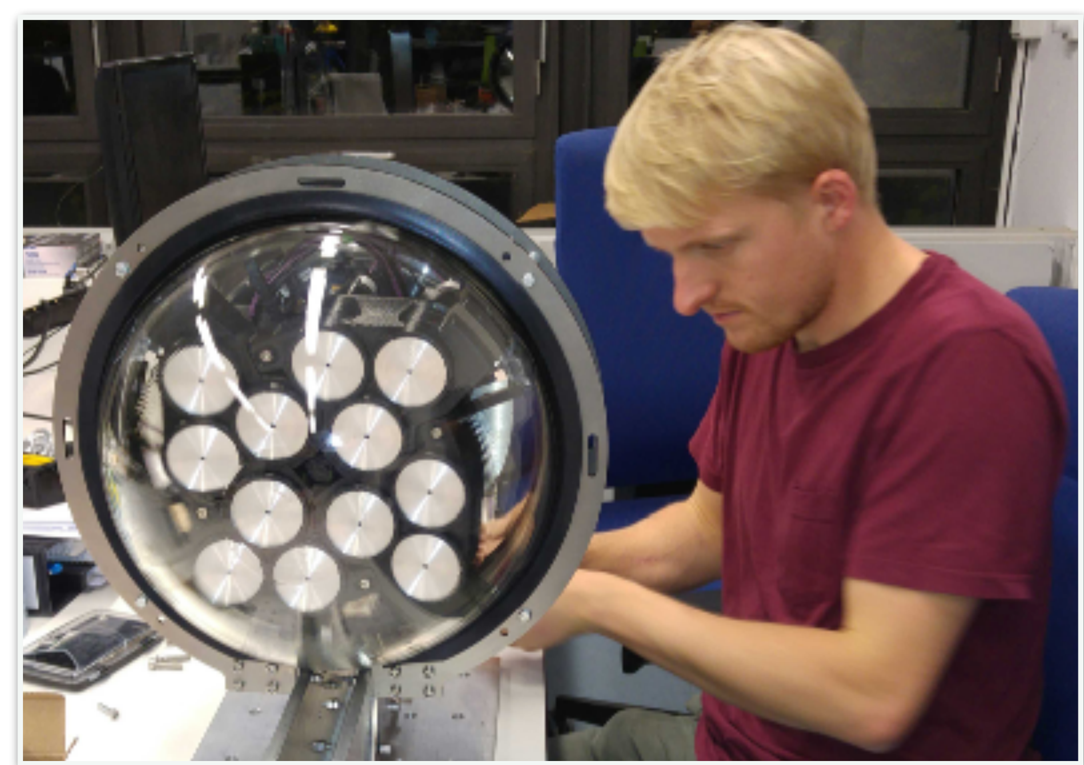
Eur. Phys. J. C **81,** 1071 (2021)

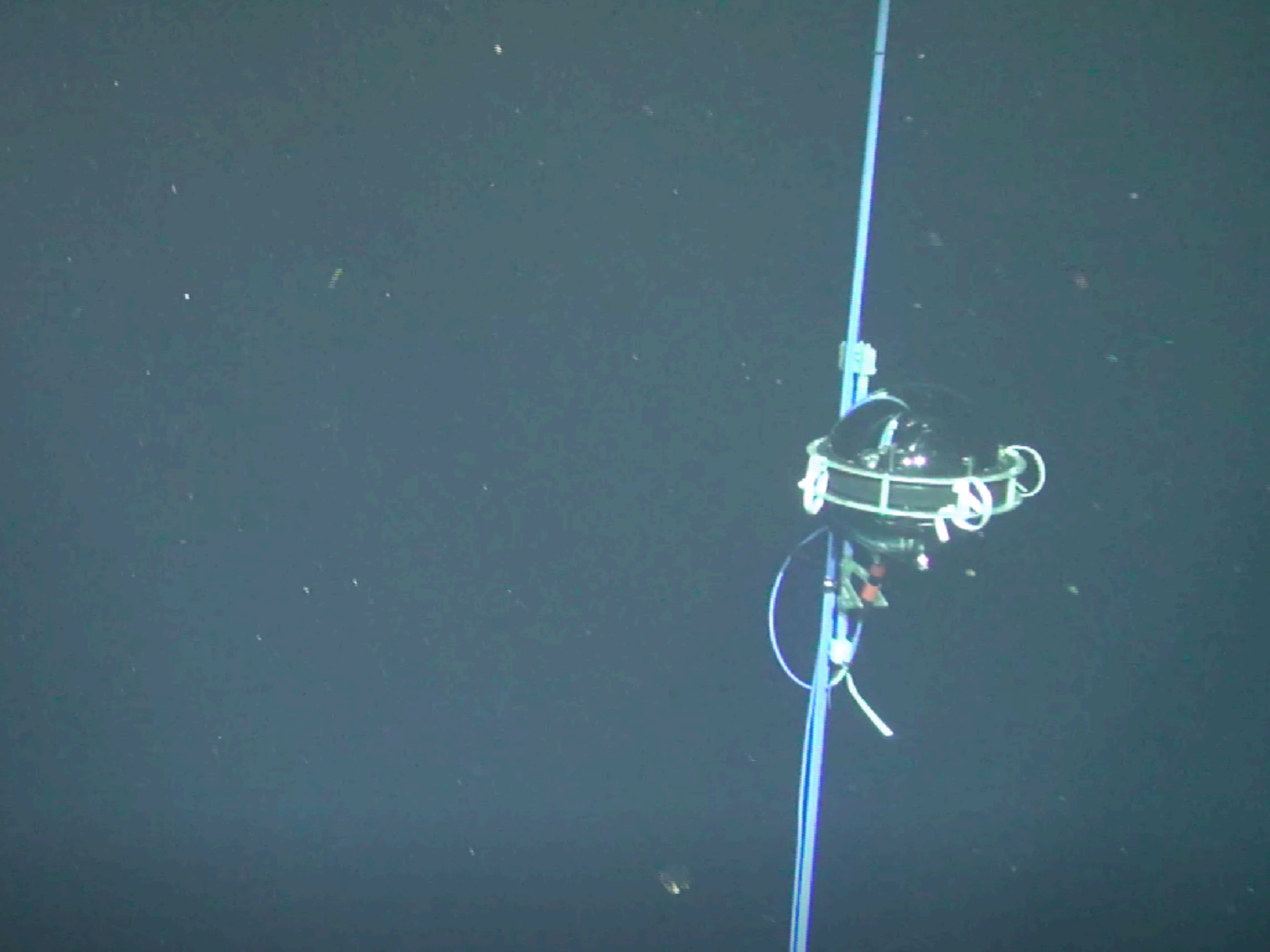
STRAW-b

- Longer string with new, systematically independent measurements: LIDAR, spectrometer
- Modules were developed at TUM, Munich and shipped to Canada for deployment
- Complete qualification of the deep site.
- Test longer mooring line (500m) and specialized devices.

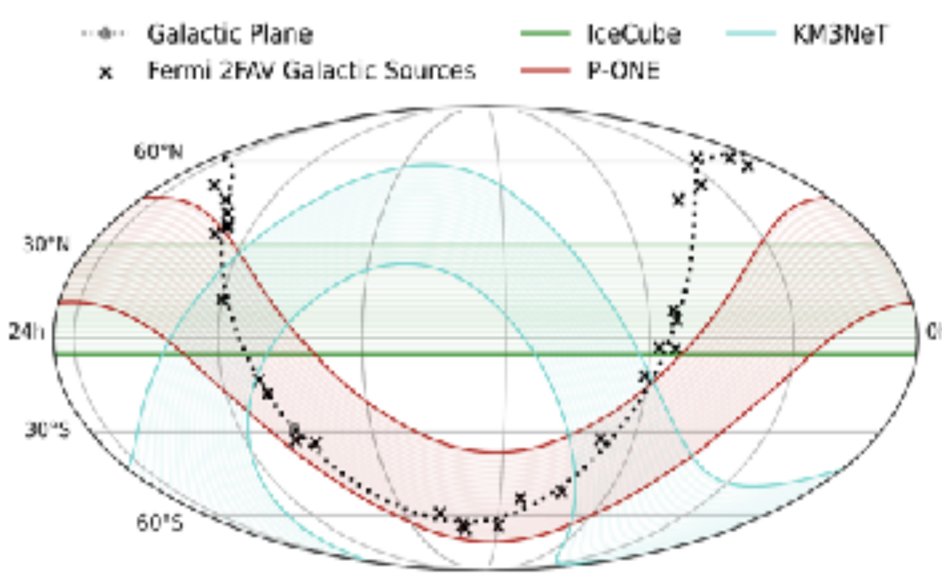








P-ONE Goals - Demonstrator



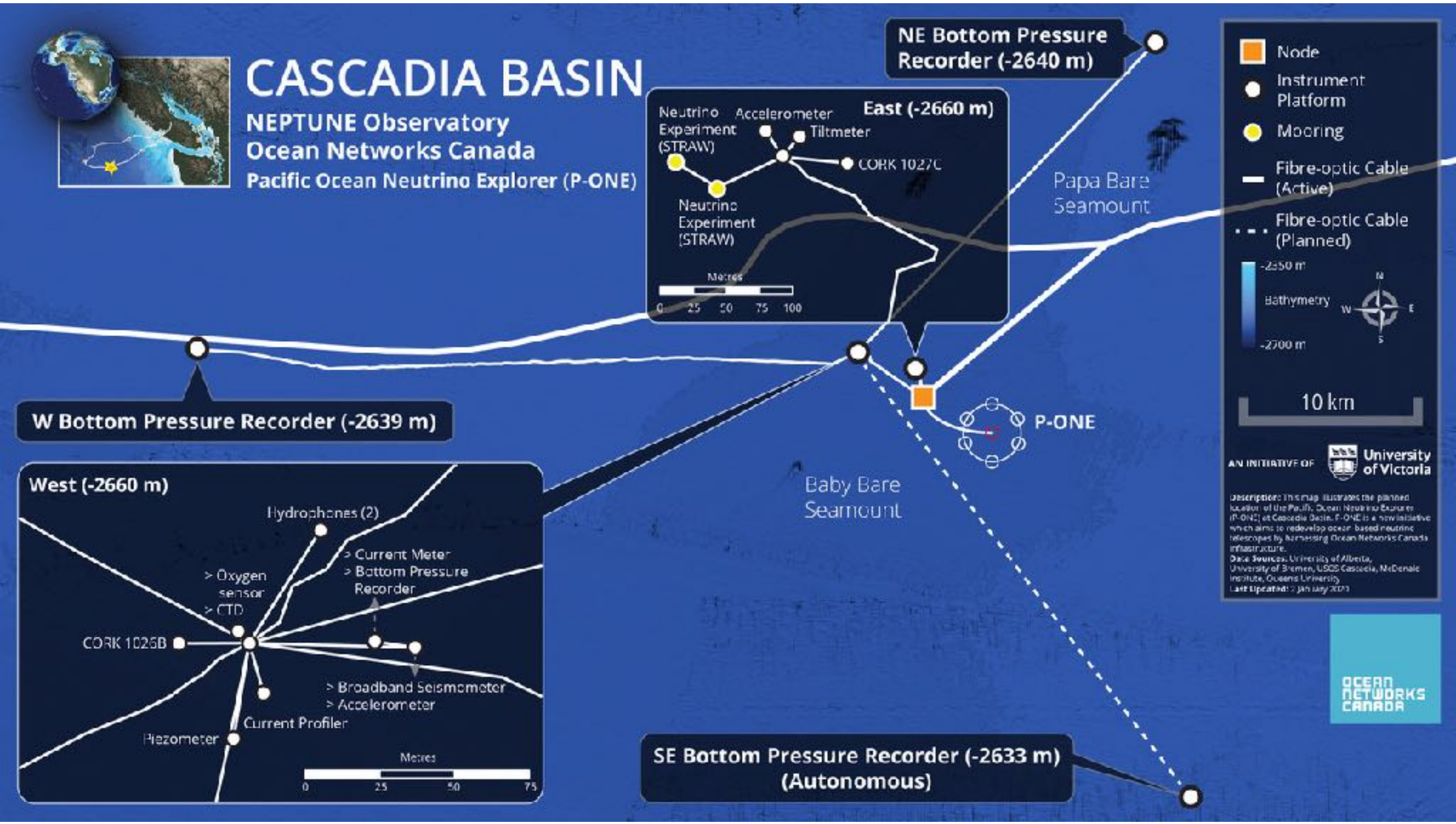
COMMISSIONING! PROOF OF CONCEPT, SUCCESSFUL OPERATION 100% DUTY CYCLE

CALIBRATION! IN-SITU BACKGROUNDS, DETECTORS, ATMOSPHERIC BACKGROUNDS

PHYSICS GOALS:

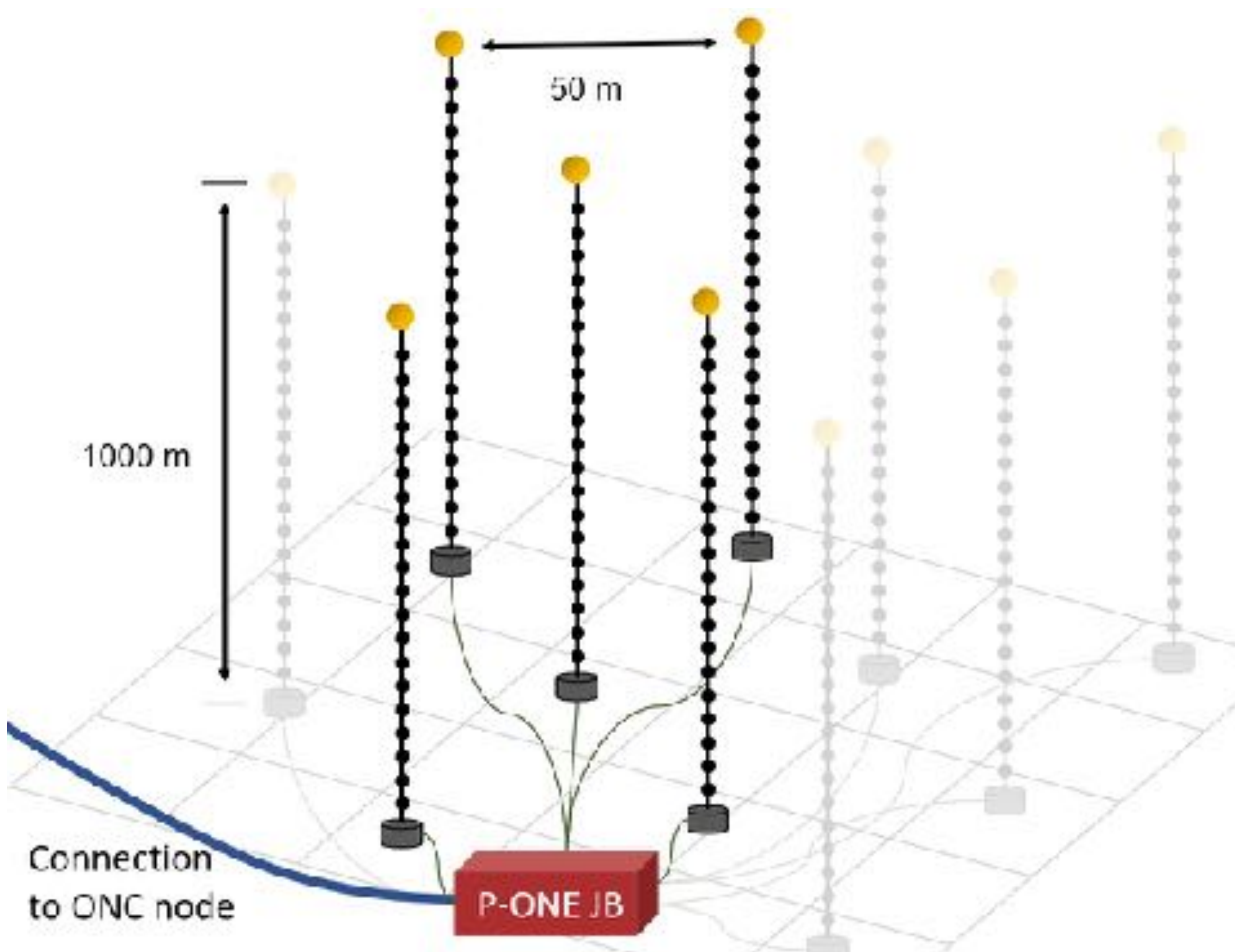
- FIRST NEUTRINOS IN PACIFIC OCEAN
- IMPLEMENTATION OF MULTI MESSENGER PROTOCOL
- DEVELOPMENT OF ν-FLAVOUR PARTICLE ID

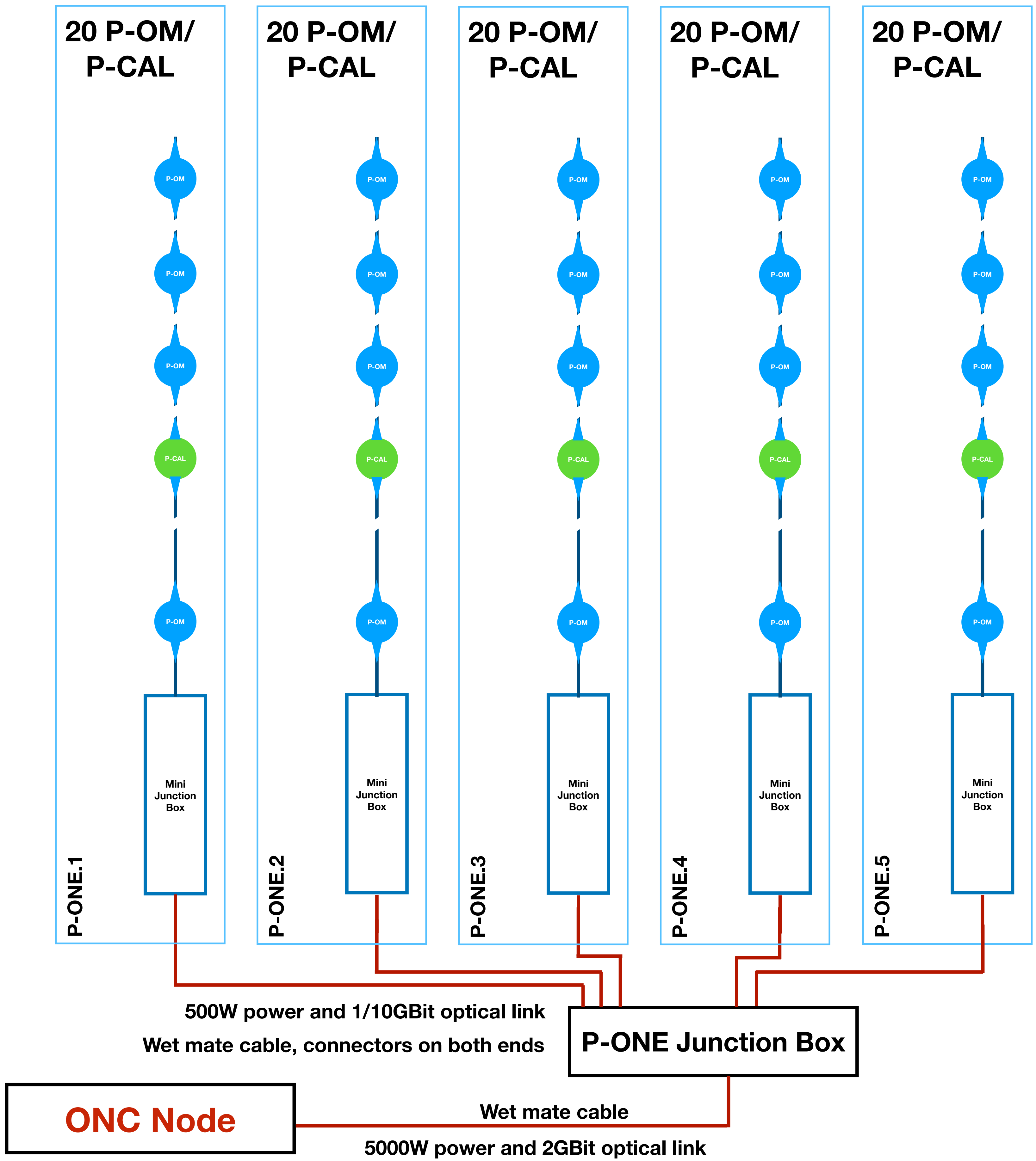
TRIGGER AN INTERNATIONAL EFFORT (P-ONE) SYNERGETIC OPERATION ν-TELESCOPES



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
AN INITIATIVE OF
University of Victoria
W Bottom Pressure Recorder (-2639 m)
P-ONE
Baby Bare Seamount
West (-2660 m)
Hydrophones (2)
> Current Meter
> Bottom Pressure Recorder
> Oxygen sensor
> CTD
CORK 1026B
> Broadband Seismometer
> Accelerometer
Current Profiler
Piezometer
Metres
0 25 50 75
SE Bottom Pressure Recorder (-2633 m) (Autonomous)
OCEAN NETWORKS CANADA

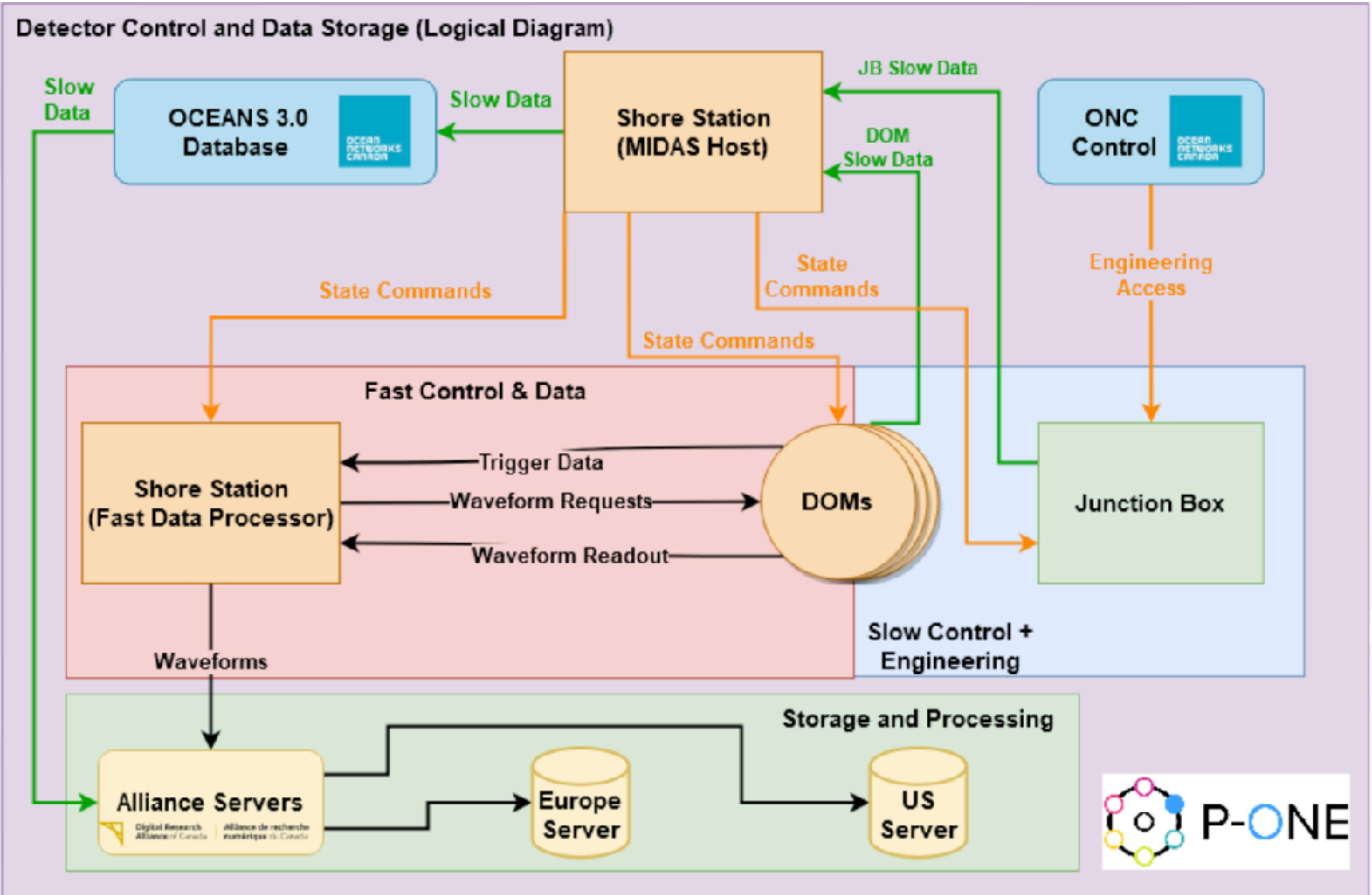
Detector (Demonstrator Phase)



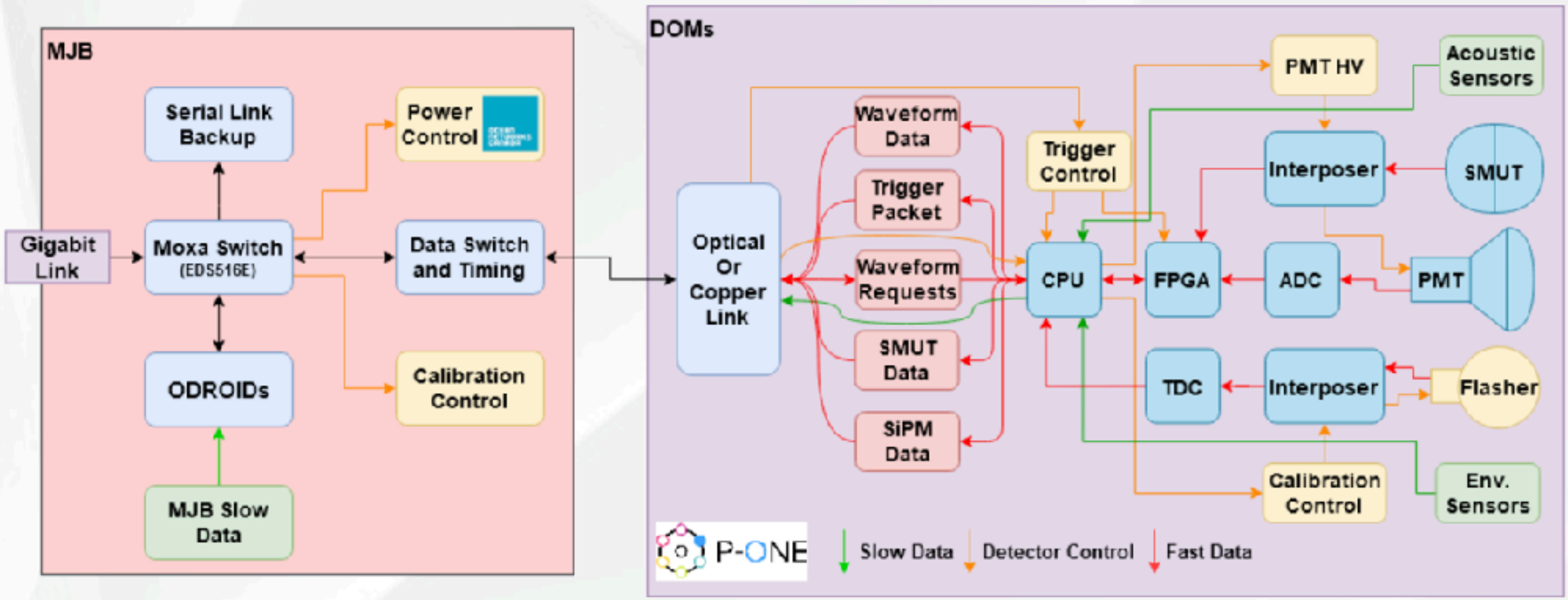


20 P-OM/ P-CAL
20 P-OM/ P-CAL
20 P-OM/ P-CAL
20 P-OM/ P-CAL
20 P-OM/ P-CAL
P-OM
P-CAL
Mini Junction Box
P-ONE.1
P-ONE.2
P-ONE.3
P-ONE.4
P-ONE.5
500W power and 1/10GBit optical link
Wet mate cable, connectors on both ends
P-ONE Junction Box
ONC Node
Wet mate cable
5000W power and 2GBit optical link

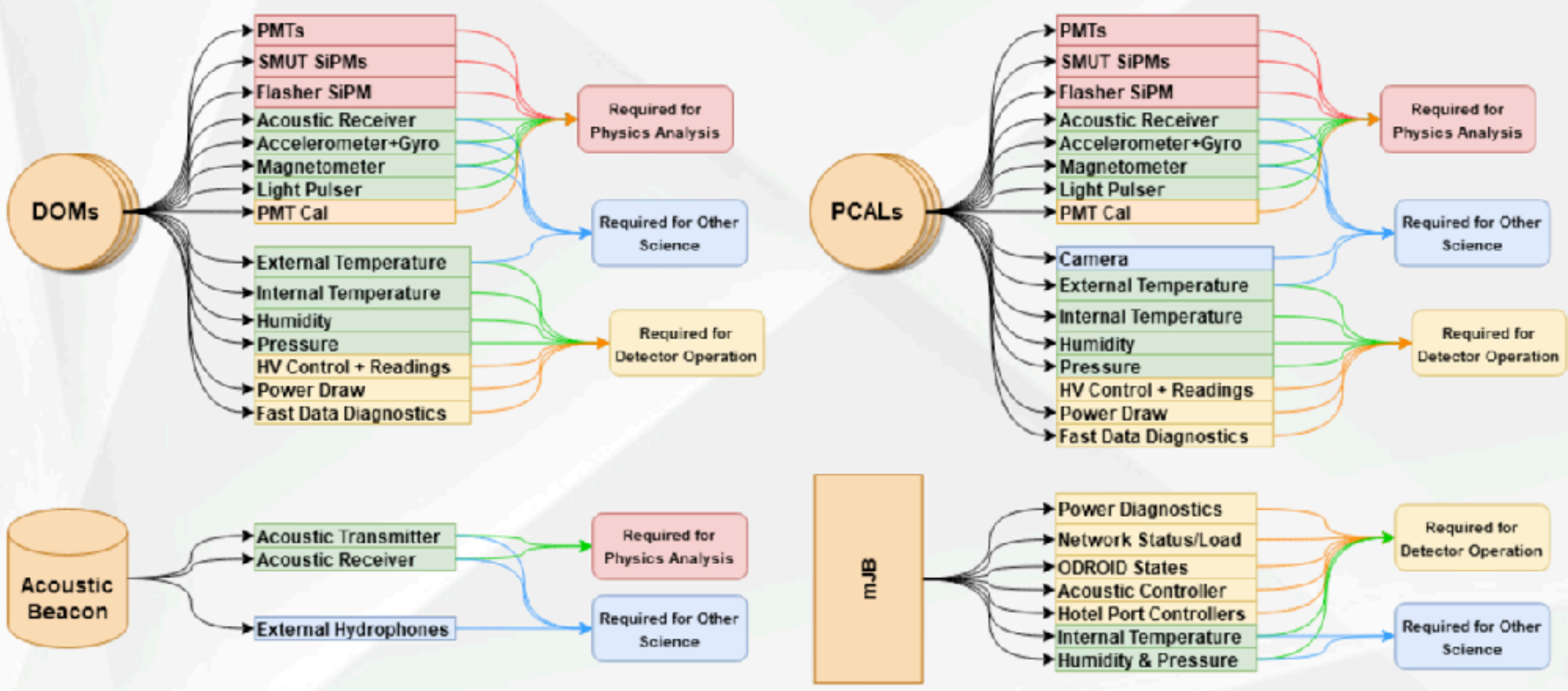
Detector Layout



Front End Data Flow



Data Objects



MIDAS?!

- We are in the process of defining how we can use MIDAS for for P-ONE.
- We are interested in a stable, reliable, well supported framework that allows us (and ONC) the amount of control that we need
  - We will need to integrate all our systems with the ONC database and OCEANS 3.0 data flow structure that is already in place.
- We have implemented a few MIDAS front ends as examples to learn how to work within the framework.
- The necessary integration between OCEANS 3.0 and MIDAS is still in need to figuring out.

Summary

- The northern Pacific Ocean is ideally located and already instrumented by ONC for a new observatory to achieve worldwide sky coverage in conjunction with existing telescopes and the ones under construction already
- We would like to use MIDAS to limit our need of re-inventing the wheel for too many aspects of the detector.
- Any suggestions for keeping it simple are welcome!

P-ONE