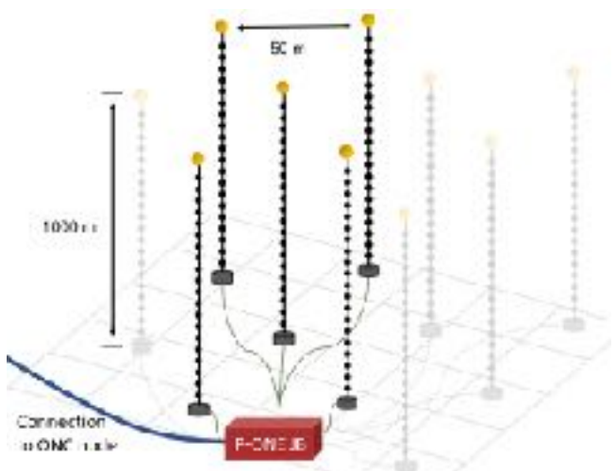
The P-ONE Neutrino Experiment and SNOLAB

Carsten B Krauss
University of Alberta

April 29, 2025
SNOLAB Future Projects Workshop

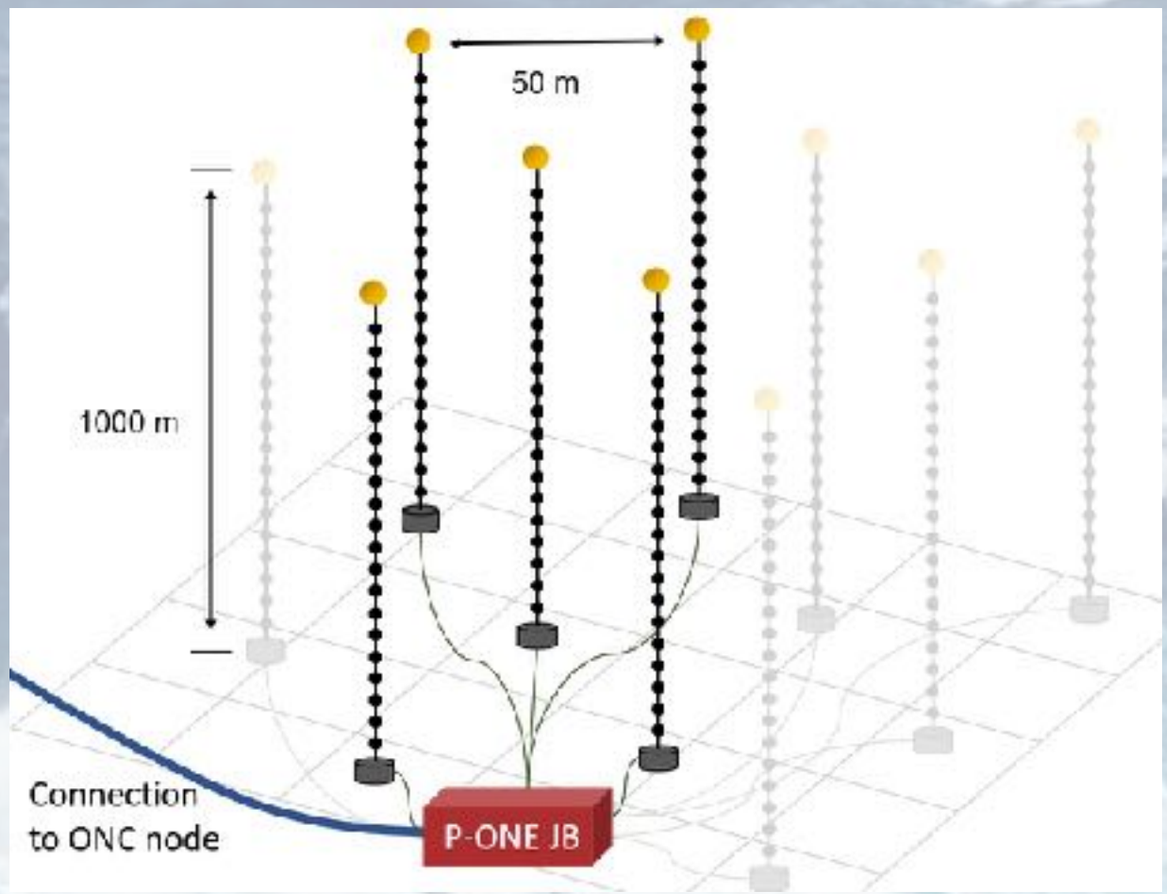


P-ONE

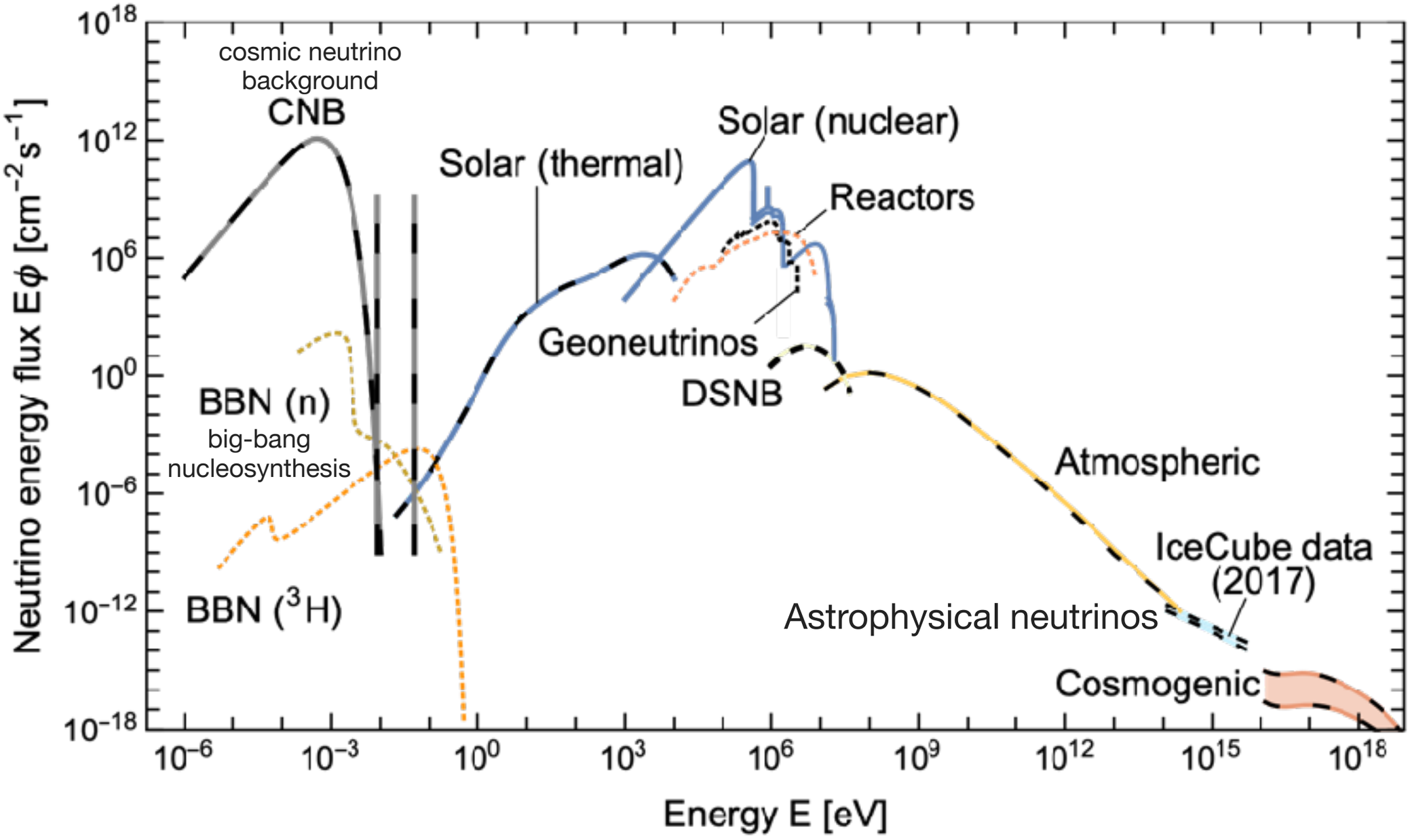
UNIVERSITY OF ALBERTA

Outline

- Neutrino Astronomy & Particle Physics
- Neutrino Telescopes
- **P-ONE**
  - P-ONE Physics
  - P-ONE Site: Cascadia Basin
  - STRAW and STRAWb
  - P-ONE Physics & Canadian Activities



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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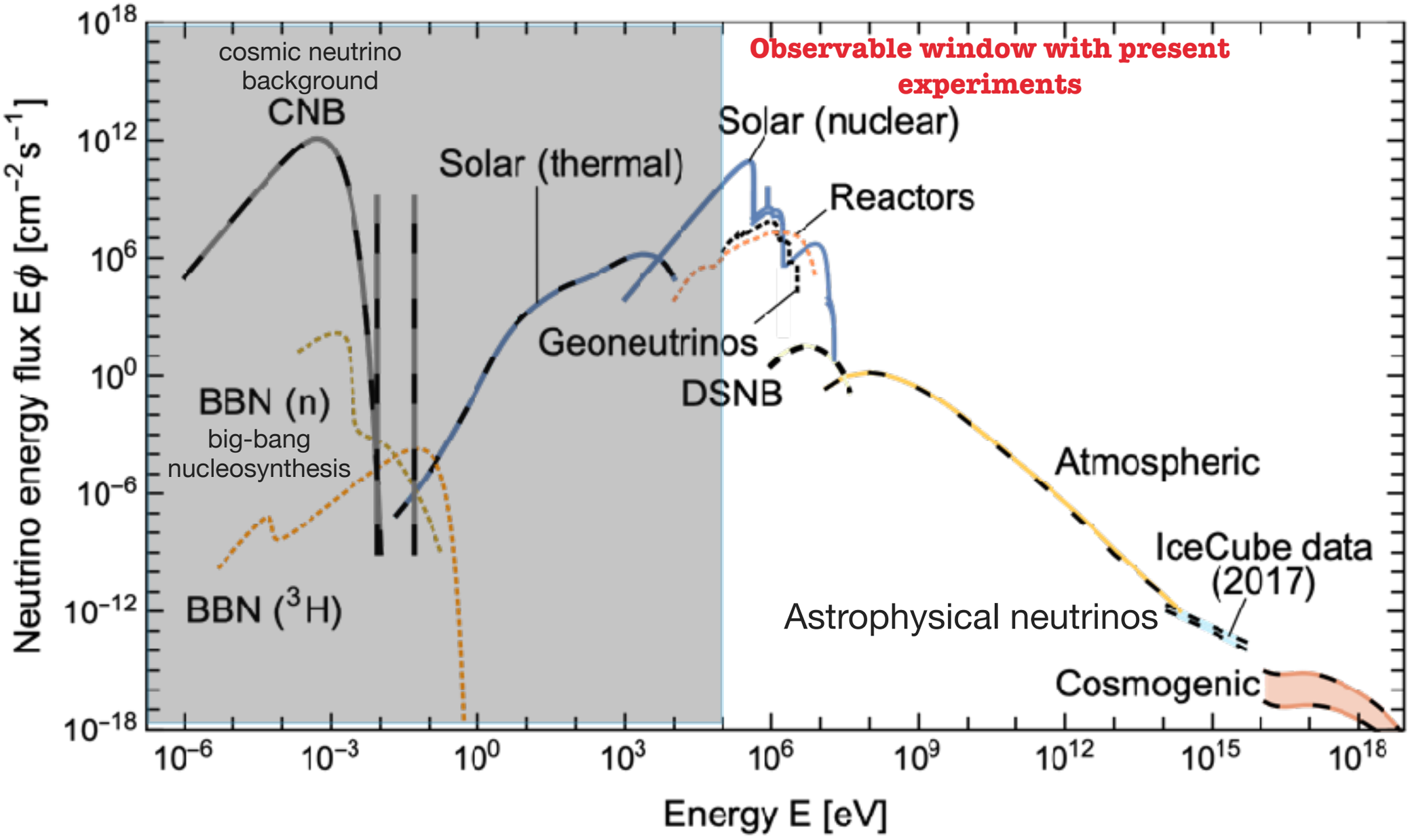

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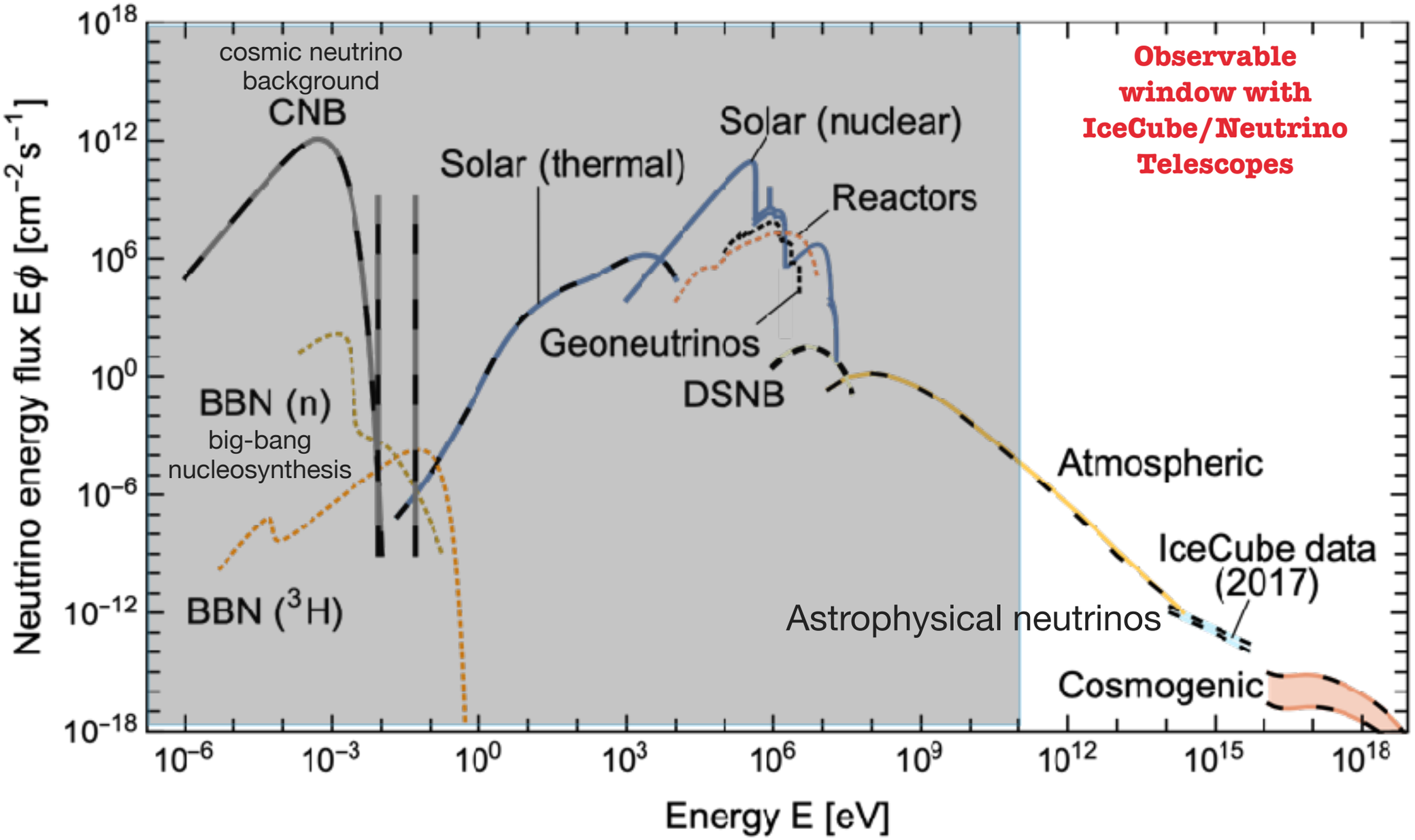

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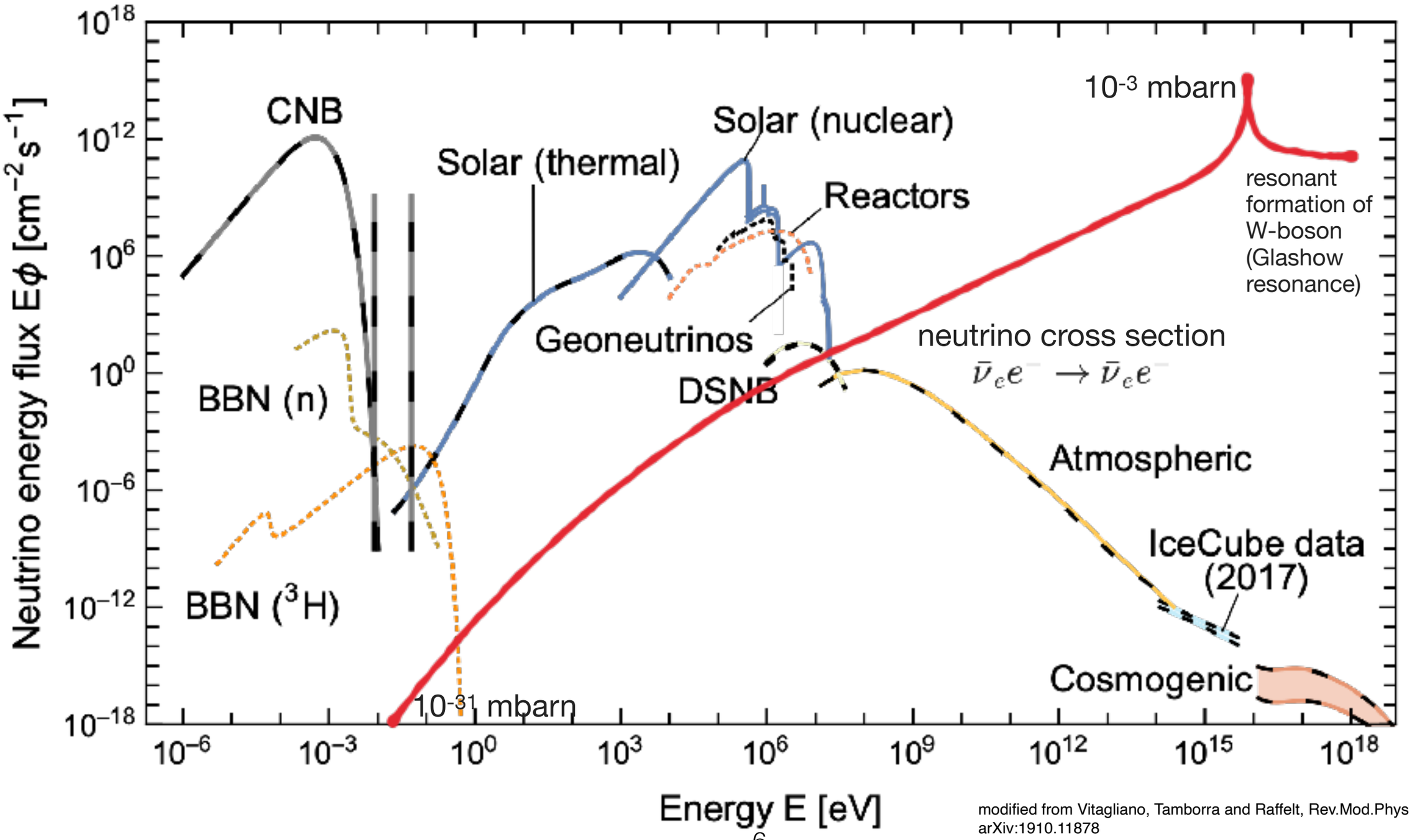
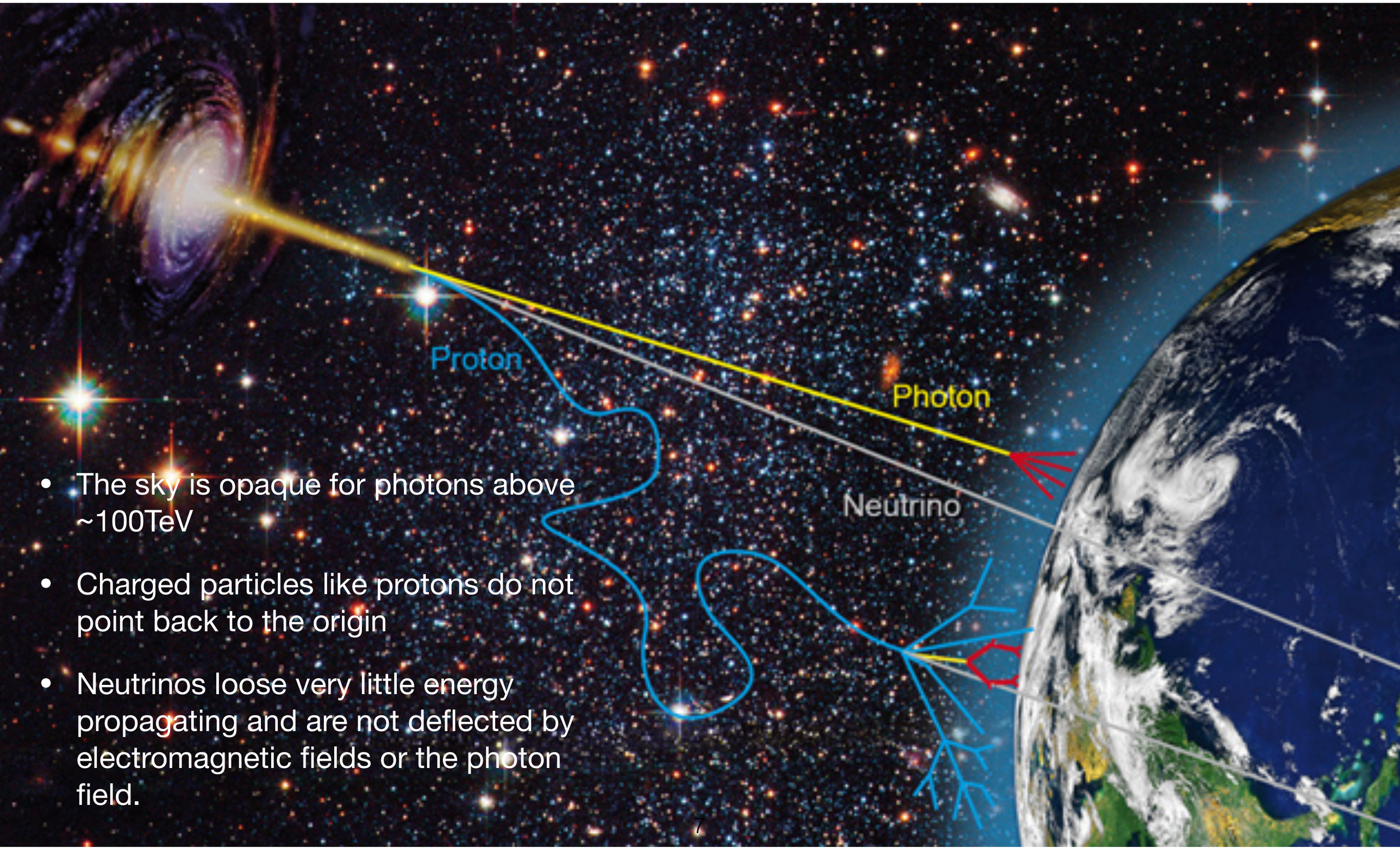


modified from Vitagliano, Tamborra and Raffelt, Rev.Mod.Phys 2019, arXiv:1910.11878

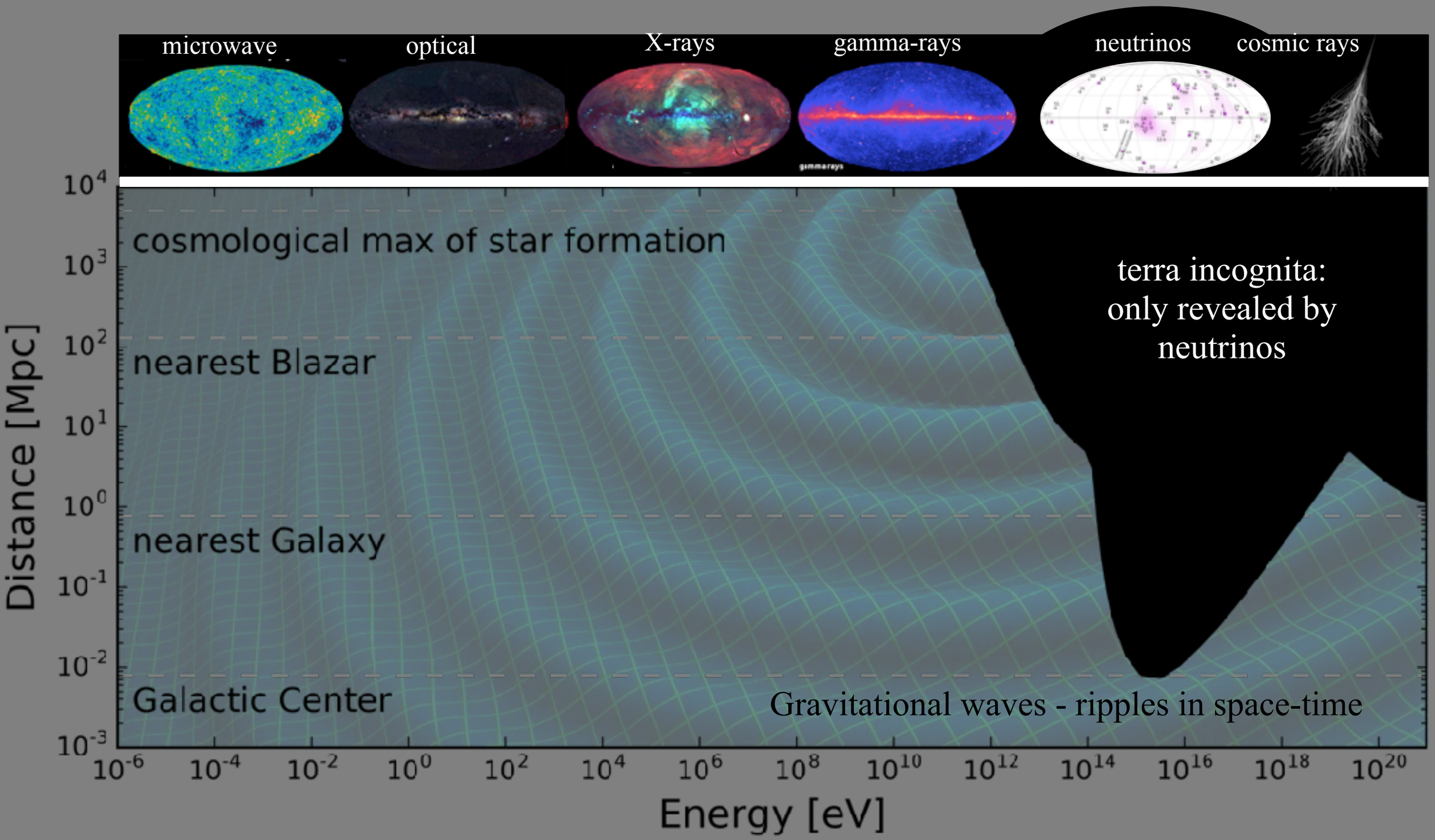
Formaggio, Zeller, Rev. Mod. Phys. 2012, arXiv:1305.7513

Neutrino Sources?



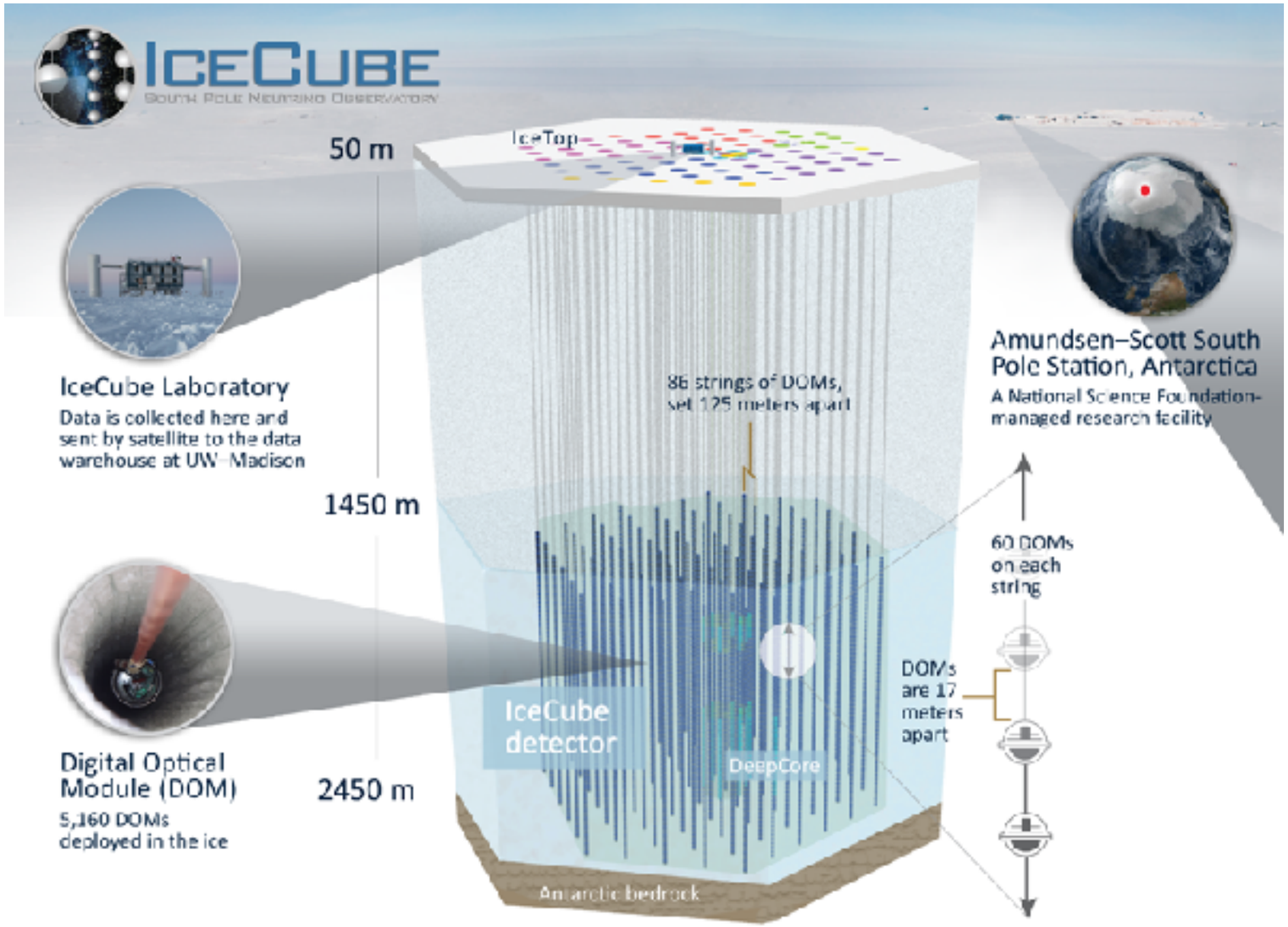
- The sky is opaque for photons above ~100TeV
- Charged particles like protons do not point back to the origin
- Neutrinos loose very little energy propagating and are not deflected by electromagnetic fields or the photon field.

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

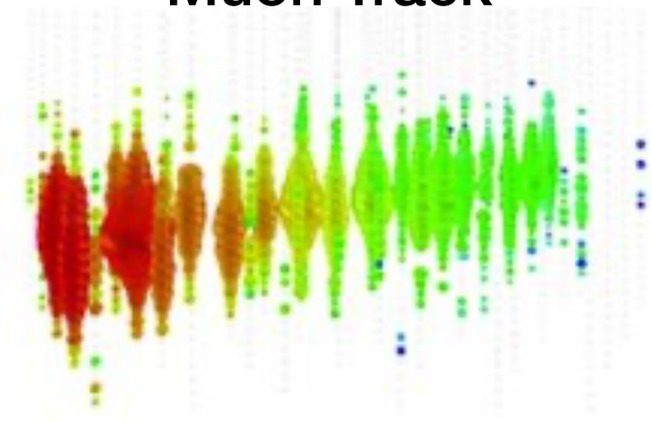


Universe is opaque above ~100 TeV energy

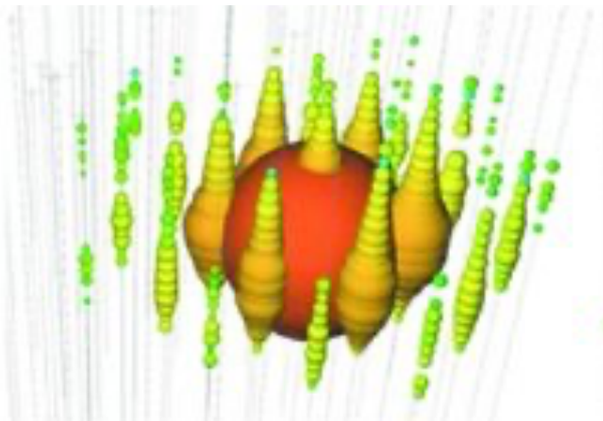
IceCube & DeepCore



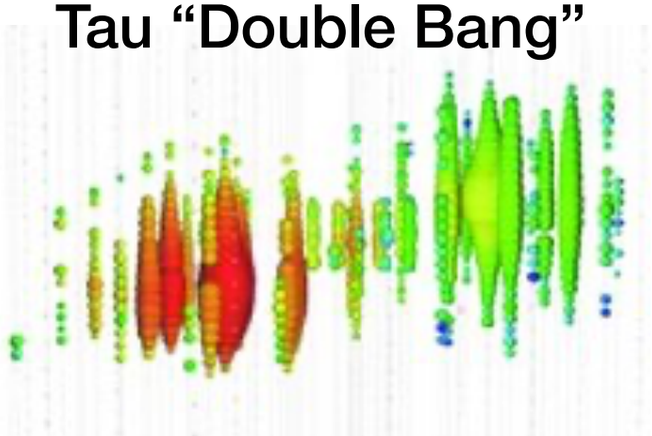
Muon Track



Electron Cascade

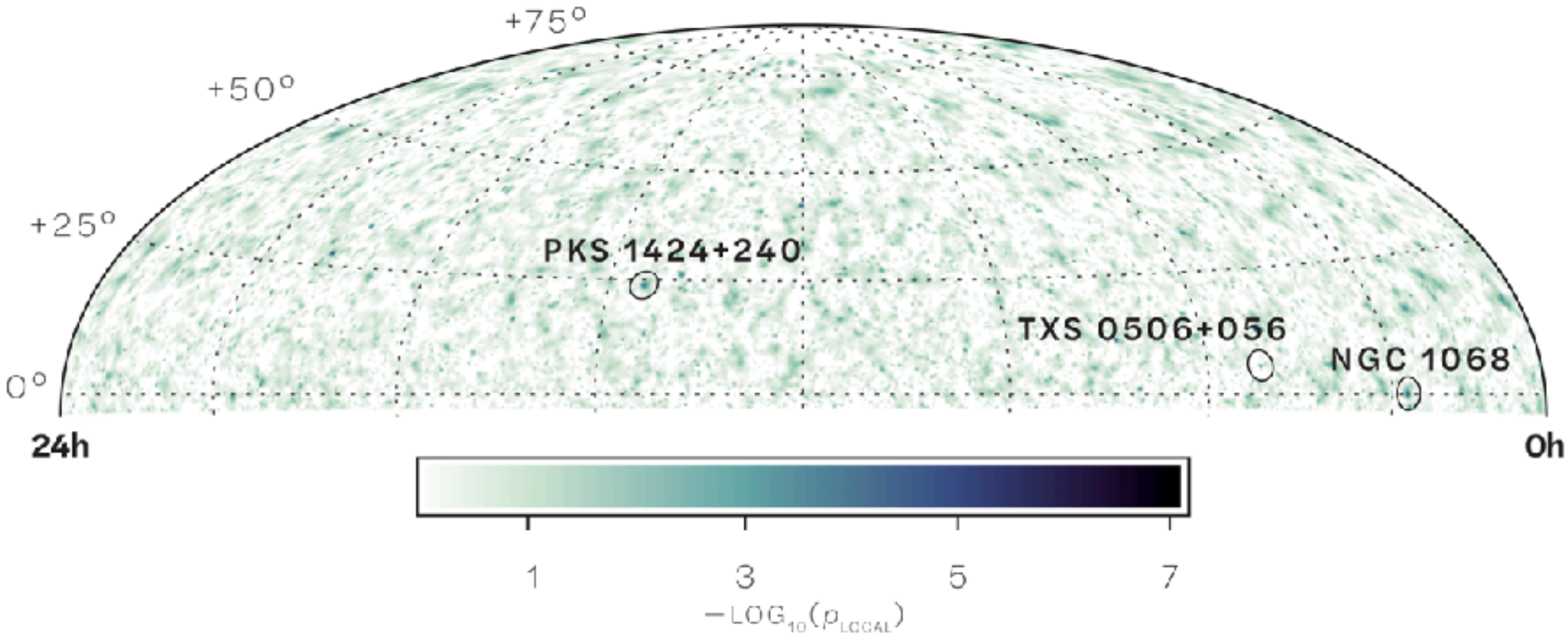


Tau “Double Bang”



- Completed in 2011

Search for Neutrino Sources



- The first neutrino sources have been identified using IceCube!

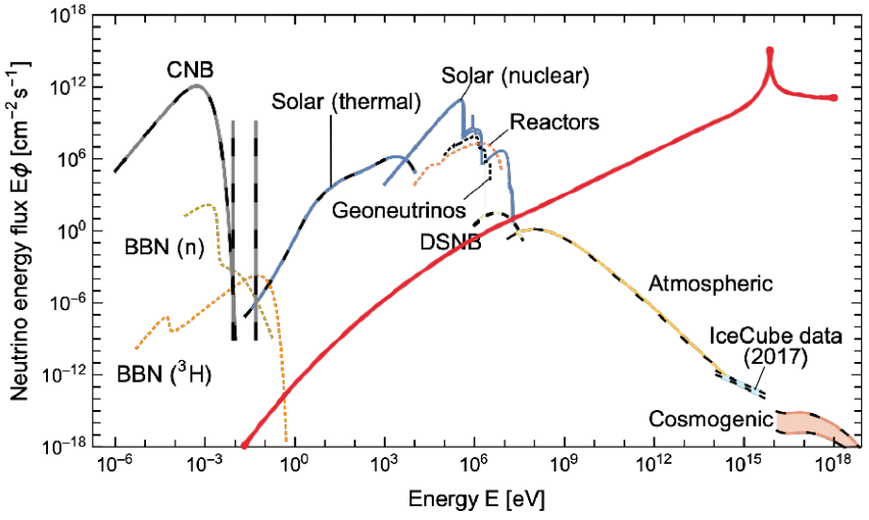
Science 378, 6619, 538–543 (2022)

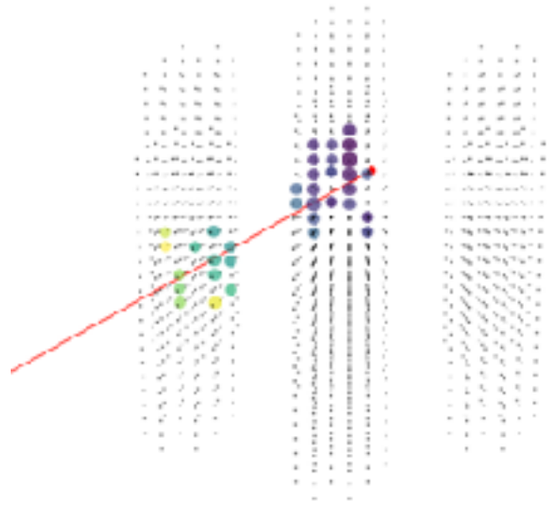
P-ONE Physics

- 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

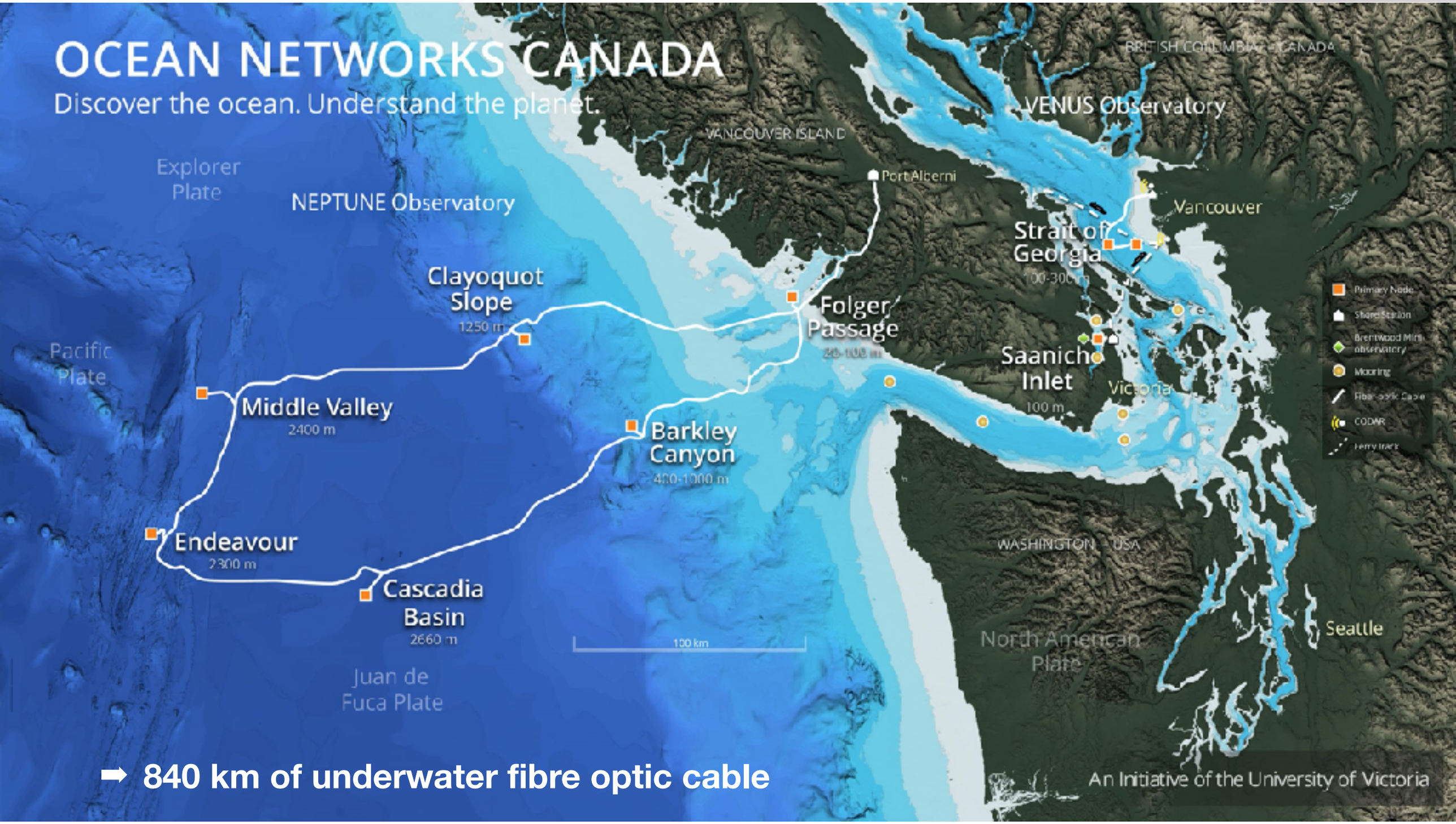
- Even a ~small detector will be able to join the larger detectors to contribute to point source searches, especially in the sky region not covered by the other detectors in the northern hemisphere and even improve overall sensitivity as the pointing accuracy is so much better in water





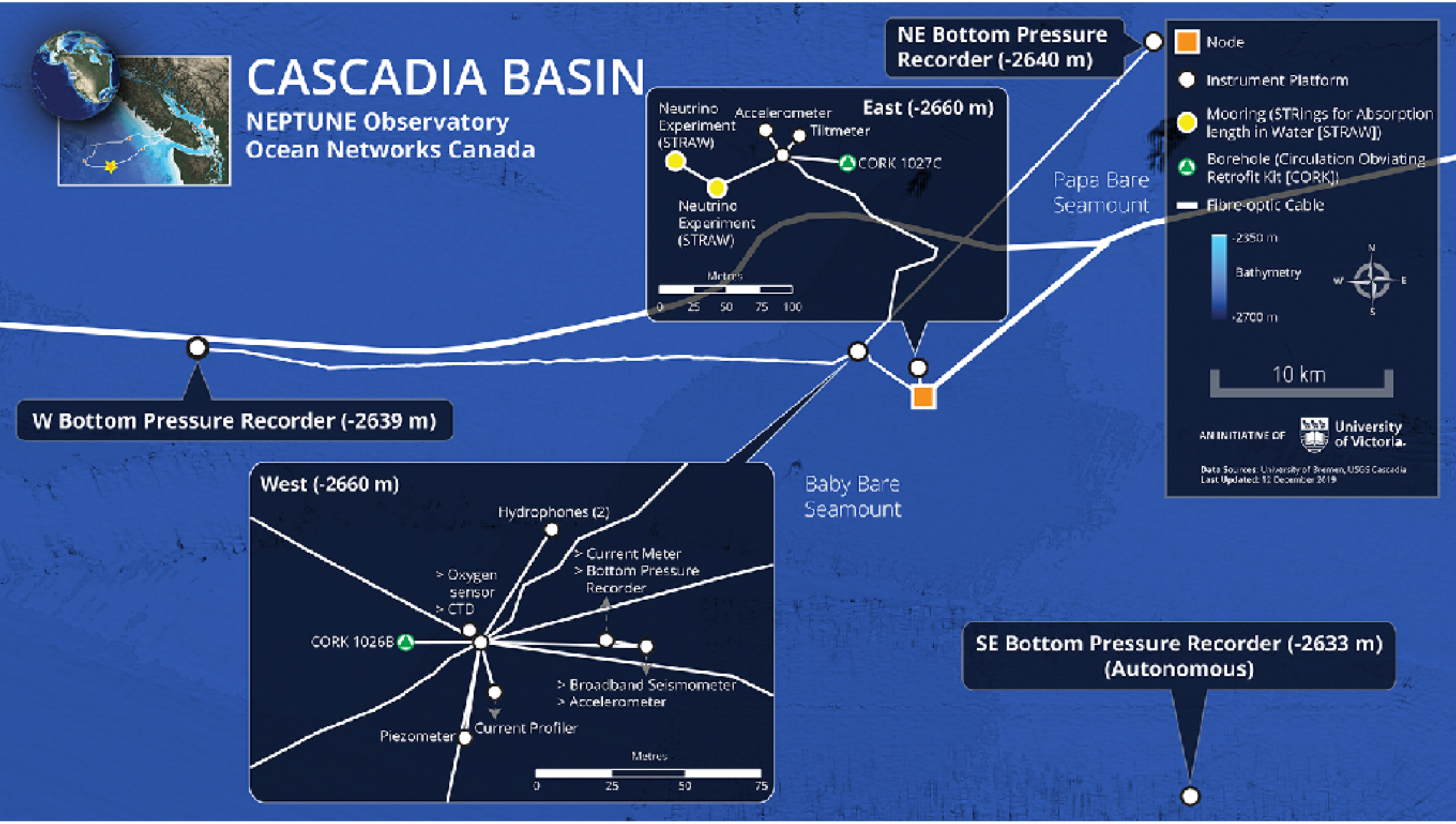
The Cascadia Basin Site

ONC

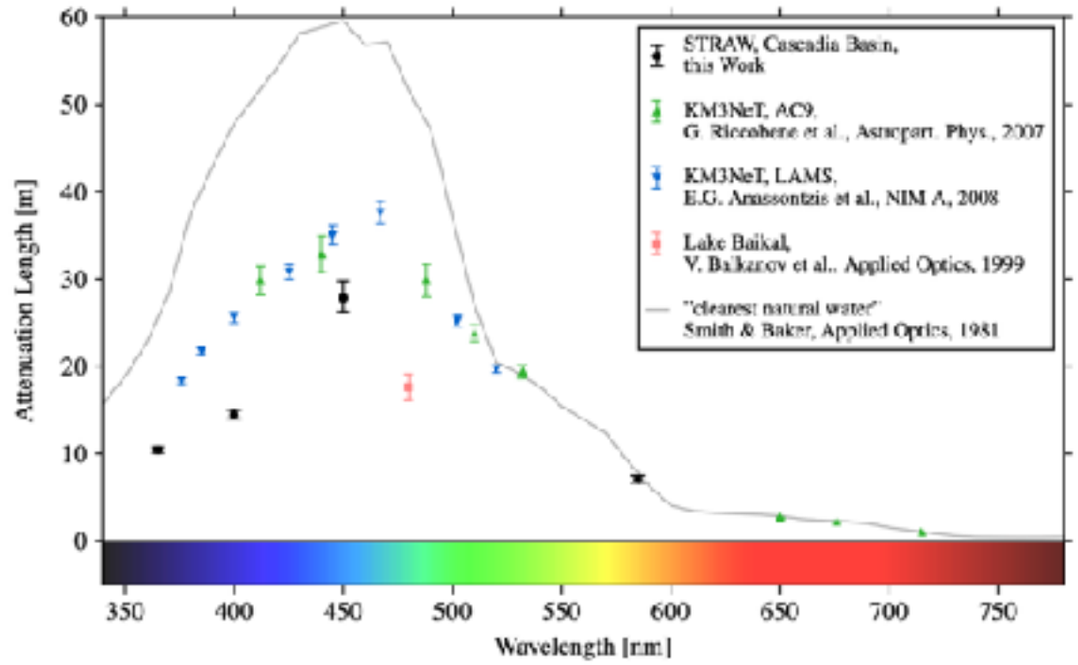


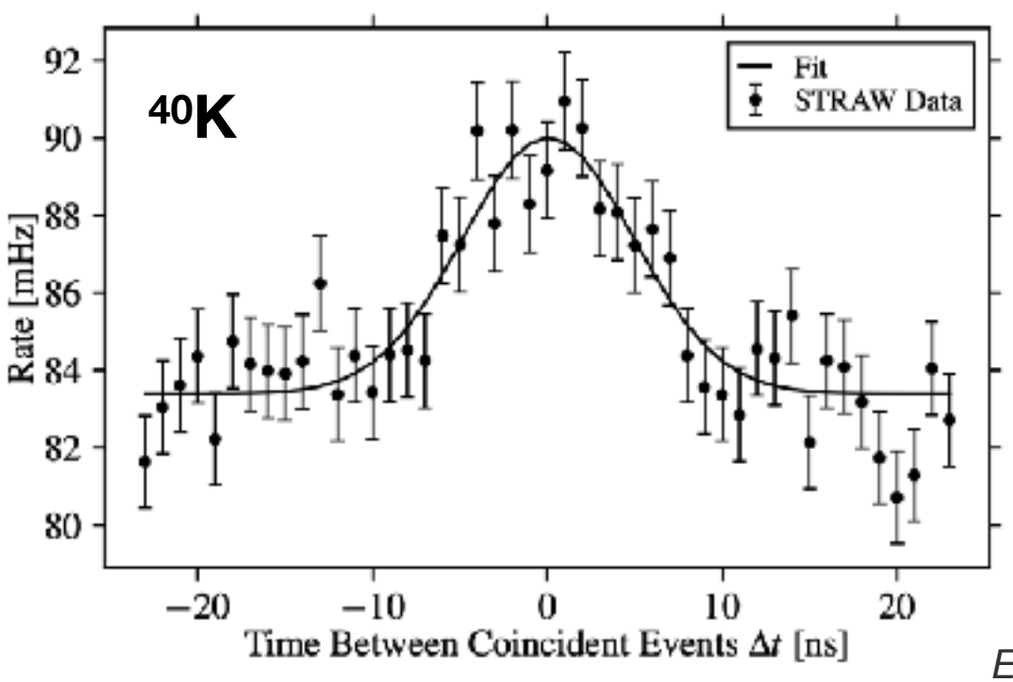
➡ **840 km of underwater fibre optic cable**

Cascadia Basin Site

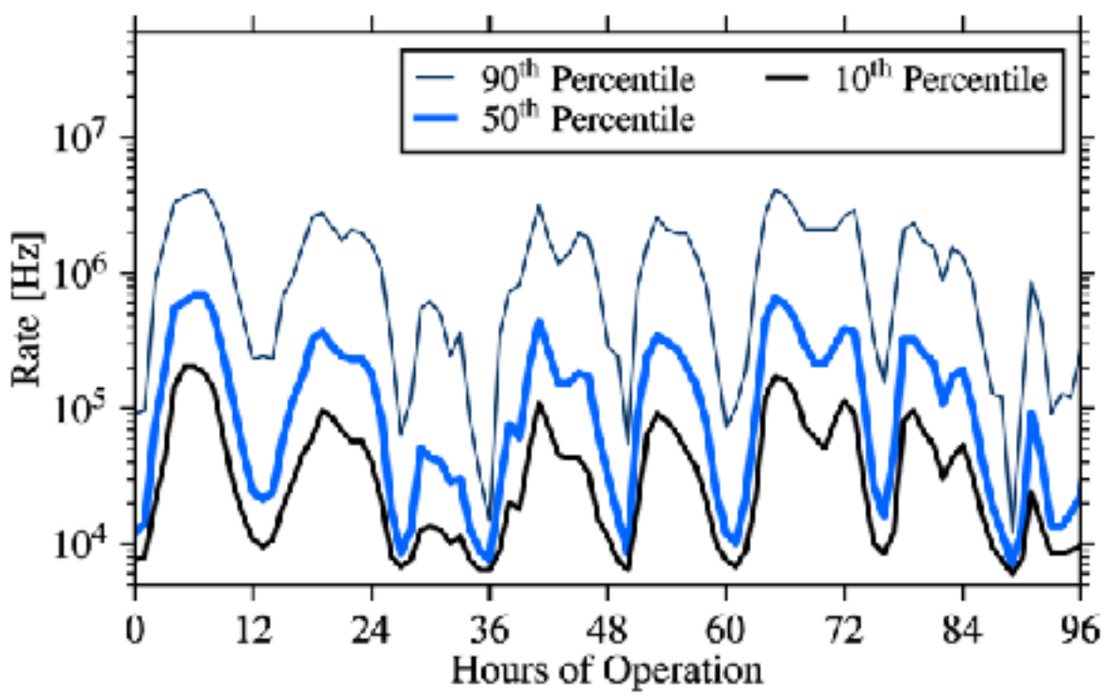


Results: Attenuation Length & Bioluminescence





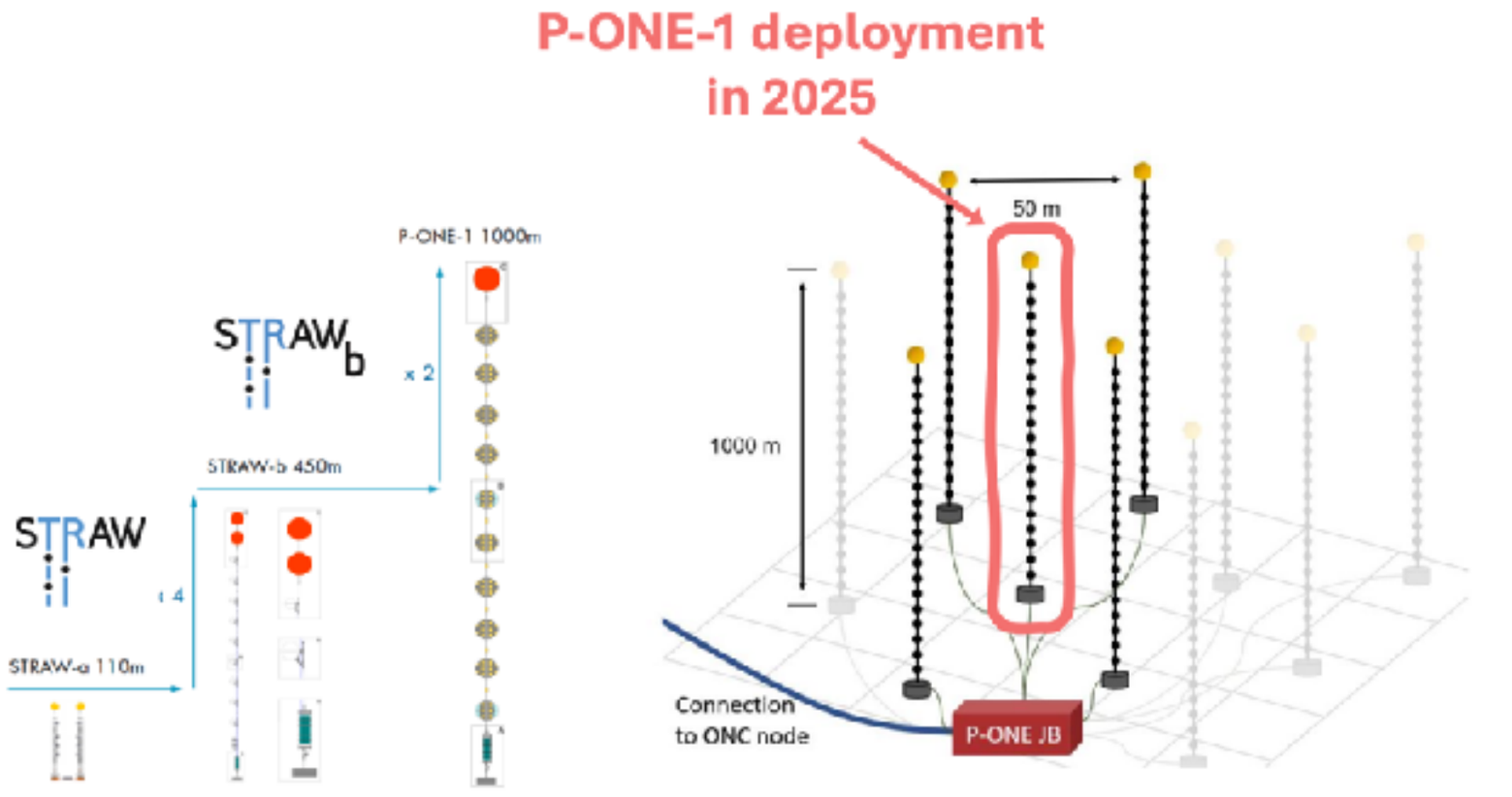
- Full publication with optical parameters:
- Bioluminescence is modulated with the tides
- ^{40}K Rate is consistent with ONC salinity measurements and expectations
- Attenuation length is good enough for a large scale neutrino telescope



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

P-ONE plan

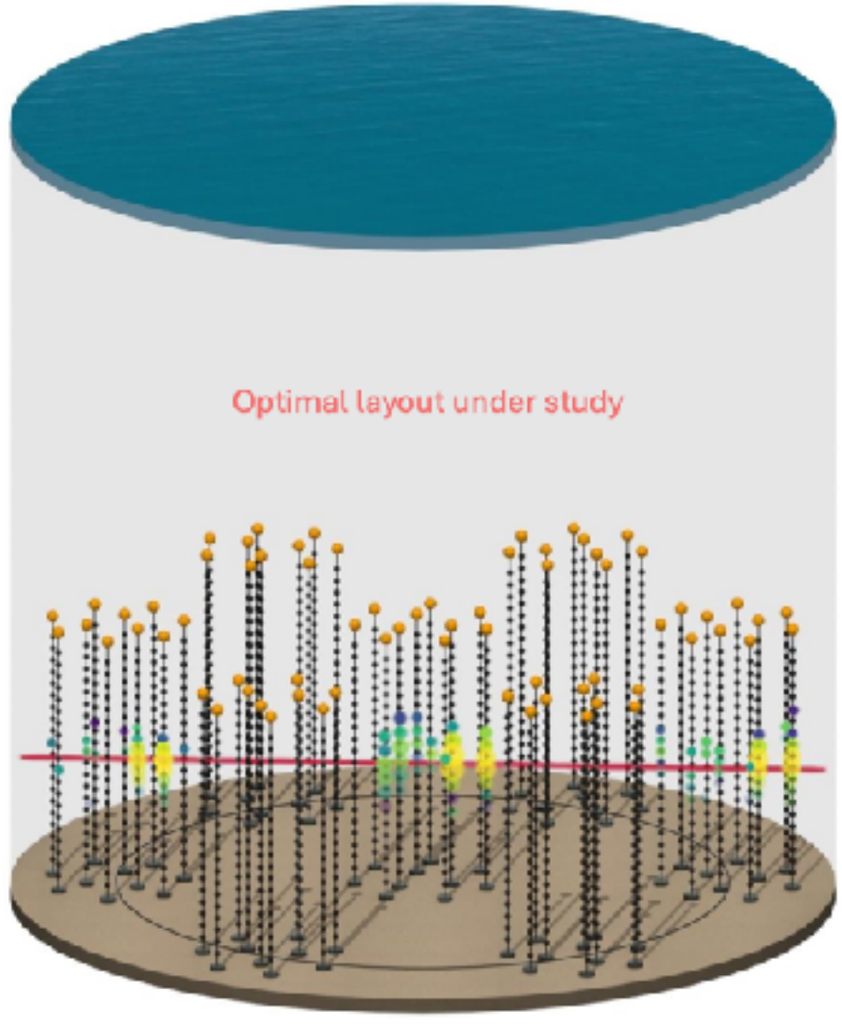
Project status



Pathfinders
2018 – 2023

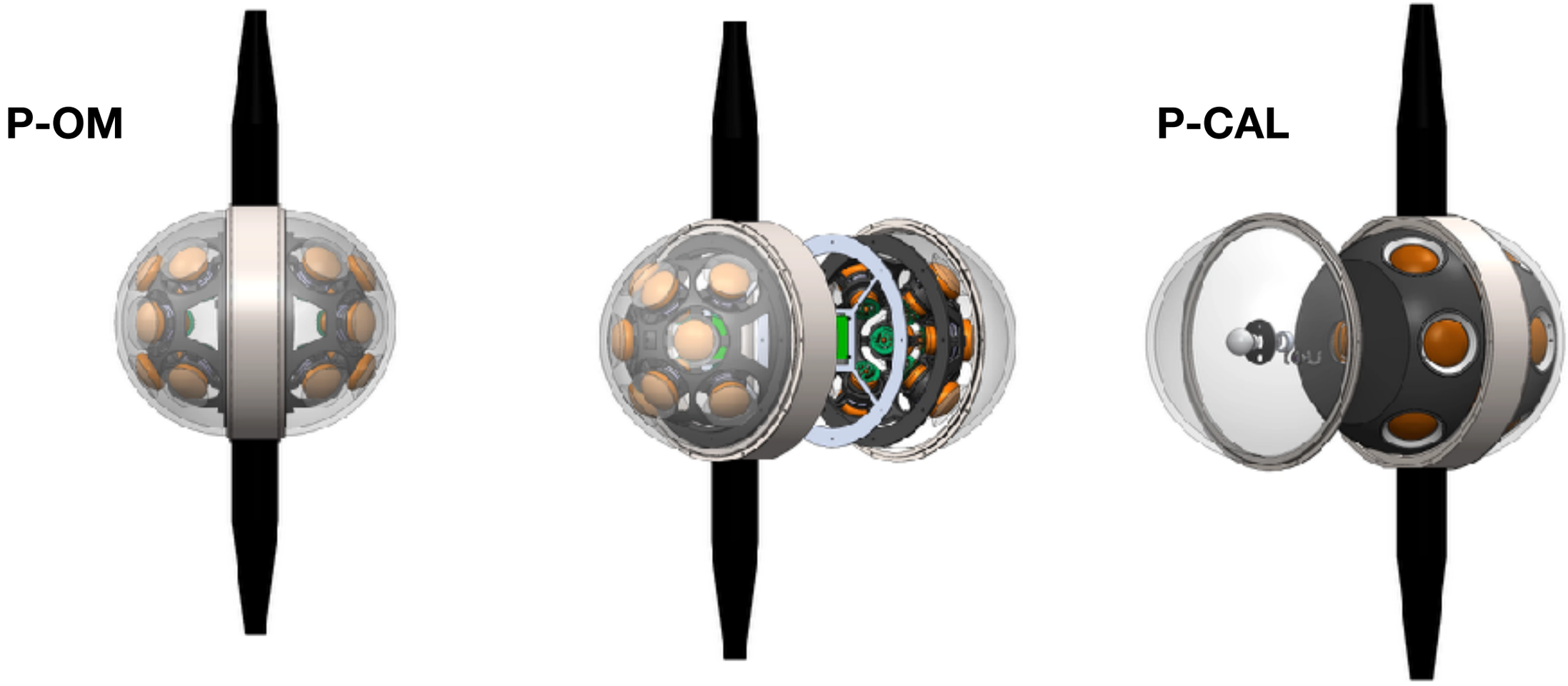
Eur. Phys. J. C **81**, 1071 (2021)
JINST **19** P05072 (2024)

Demonstrator (6-10 lines)
2023 – 2028
Funded



Array
2028+

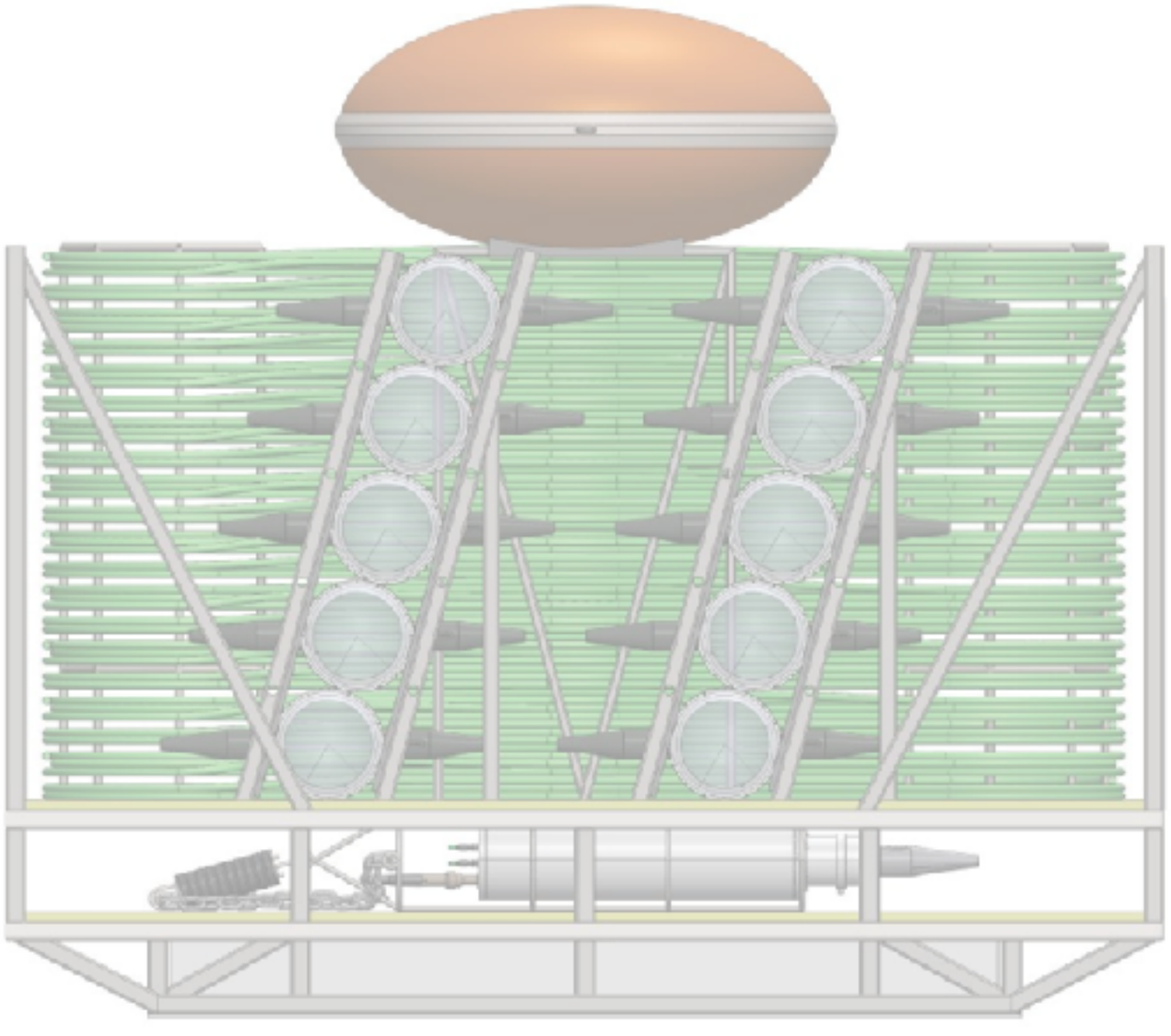
Large Area Photon Detection



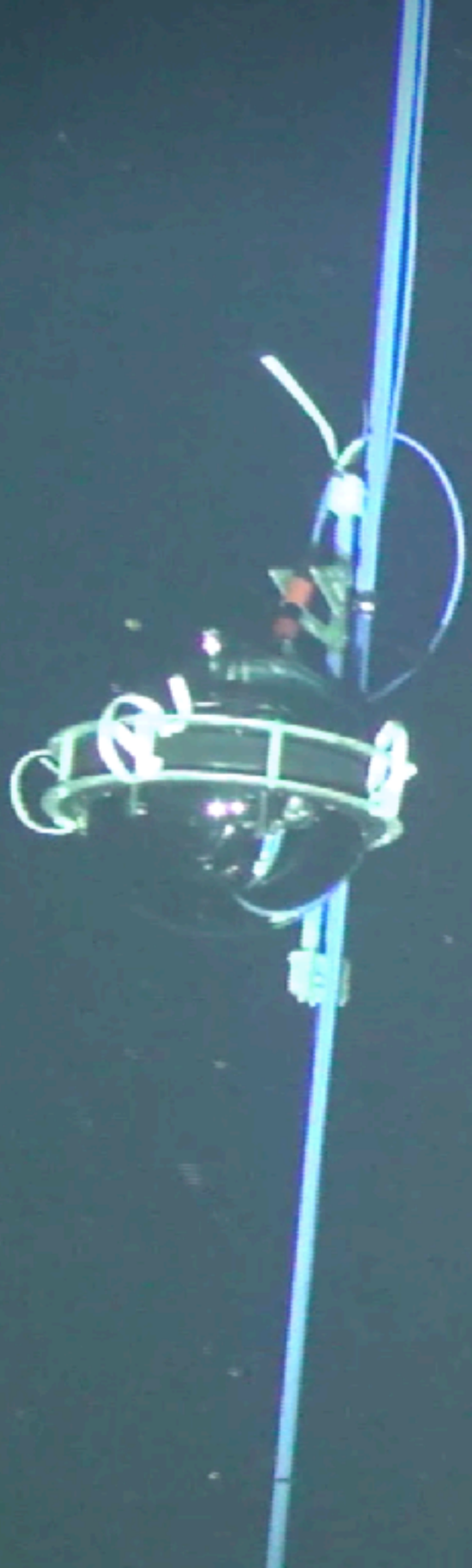
- The instrumentation of the ~200 optical modules of P-ONE will use KM3NeT/IceCube-like multi PMT digital optical modules
- 3” PMTs offer a good cost to surface area ratio
- Using a novel, side mounted housing allows obstruction-free observation

Deployment Frame

Optical module
(P-OM)



Calibration module
(P-CAL)



Synergies with SNOLAB

- Science labs for Physics have plenty project management experience and project implementation know-how

- Engineering for the Ocean is different, but…

- Light sensing is the same, options for better, cheaper, lower background light detectors are a real necessity for all future rare event searches, providing opportunity for SNOLAB expertise

- Precision test beds for sensor calibration in controlled environment are very interesting also for P-ONE

Summary

- Neutrino Astronomy will allow new and exciting studies for particle physics - The only thing keeping us from breakthrough discoveries is the small size of the current detectors

- The northern Pacific Ocean is ideally located and already instrumented by ONC for a new observatory to achieve full sky coverage

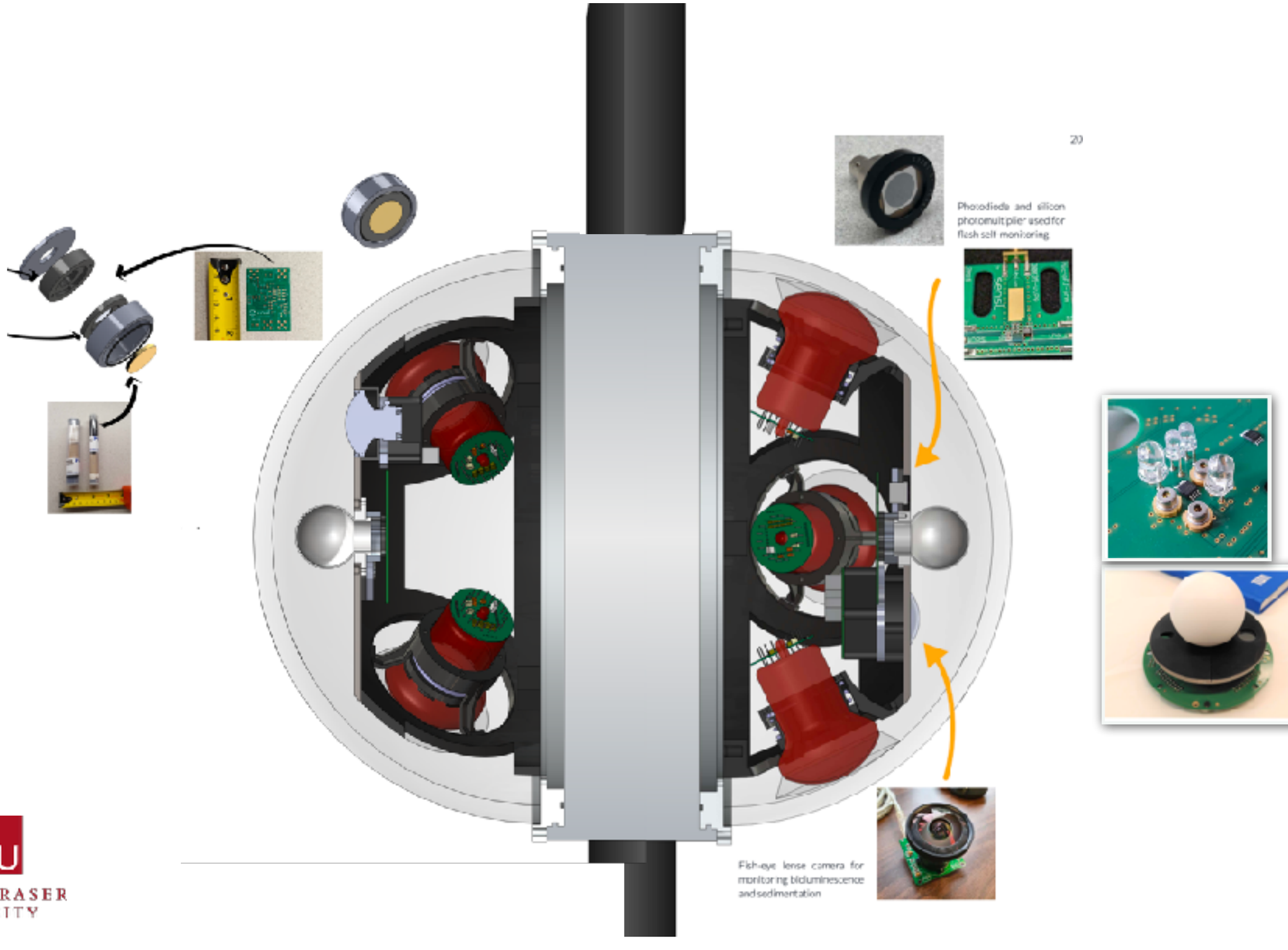
- Canadian groups haven taken on major responsibilities for the initial string and are leading calibration systems, trigger systems and final assembly planning efforts towards the P-ONE demonstrator - the collaboration remains interested in exploring synergies with SNOLAB

P-ONE

Activities In Canada

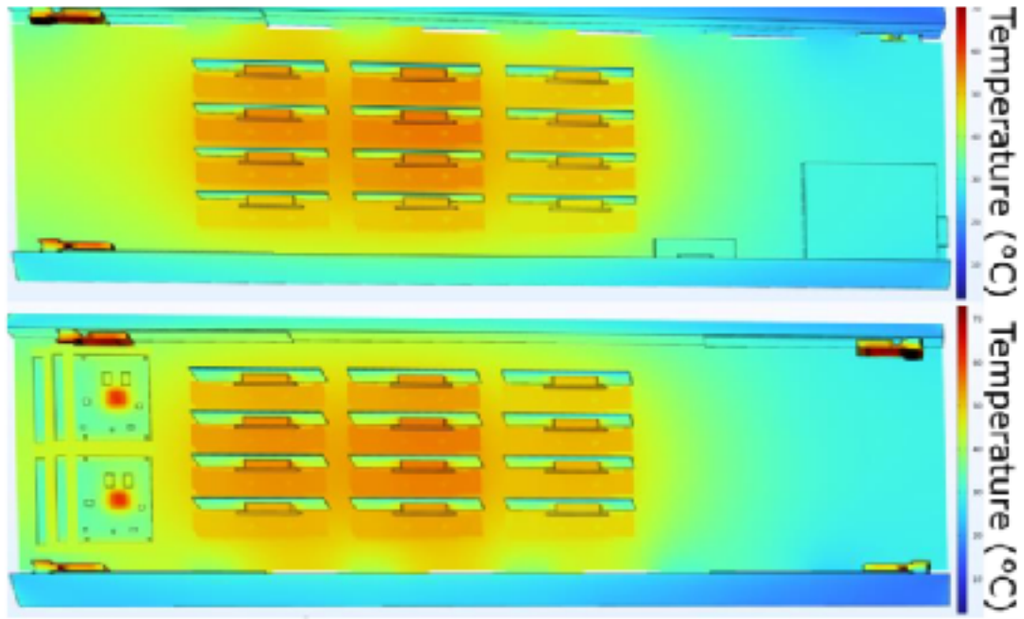
- Testing of Straw-B modules before deployment
- Biofouling studies and remedies
- Leadership in the STRAW data taking and analysis to extract optical properties and performance data
- Reconstruction algorithm development, PMT testing for demonstrator phase
- Development of a new algorithm for tau event identification
- Background simulation (^{40}K and others)
- Trigger algorithm development and implementation
- Hardware development, flasher system, acoustic calibration and positioning system, electronics, calibration systems
- Final assembly and testing at TRIUMF for P-ONE.1, the first string
- Development of an internal muon tracker for reconstruction accuracy calibration
- DAQ development

Calibration Module

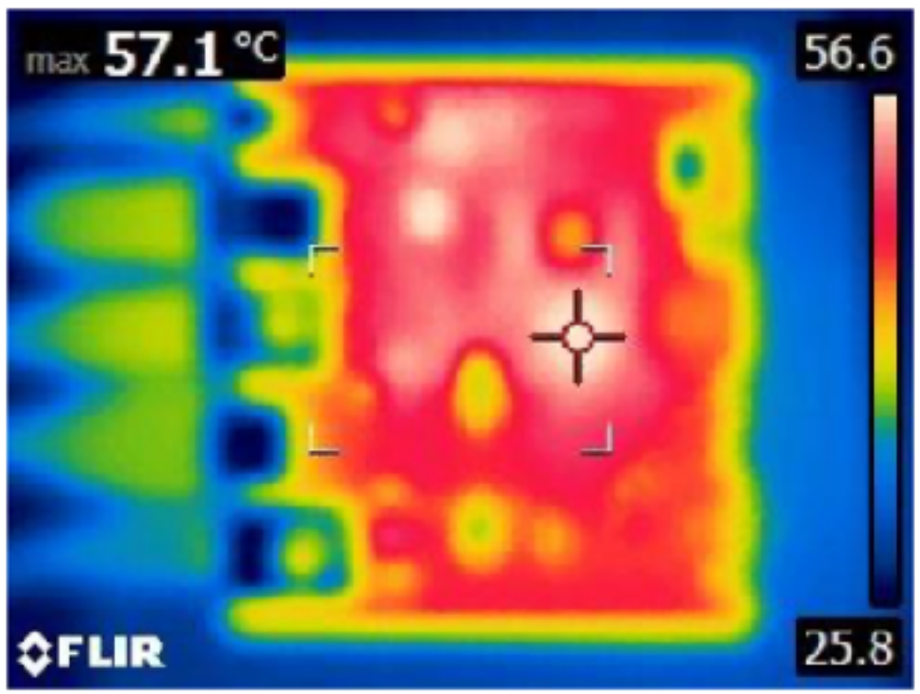


SFU
SIMON FRASER UNIVERSITY

MiniJunction Box - trigger and mooring line power & data distribution



Simulated temperature on surface of solids in module



- The MiniJunction Box is the primary data and power system hub for each mooring line
- All systems are contained in a titanium pressure housing
- Thermal measurement and FEA simulations have shown that the current design is meeting requirements well

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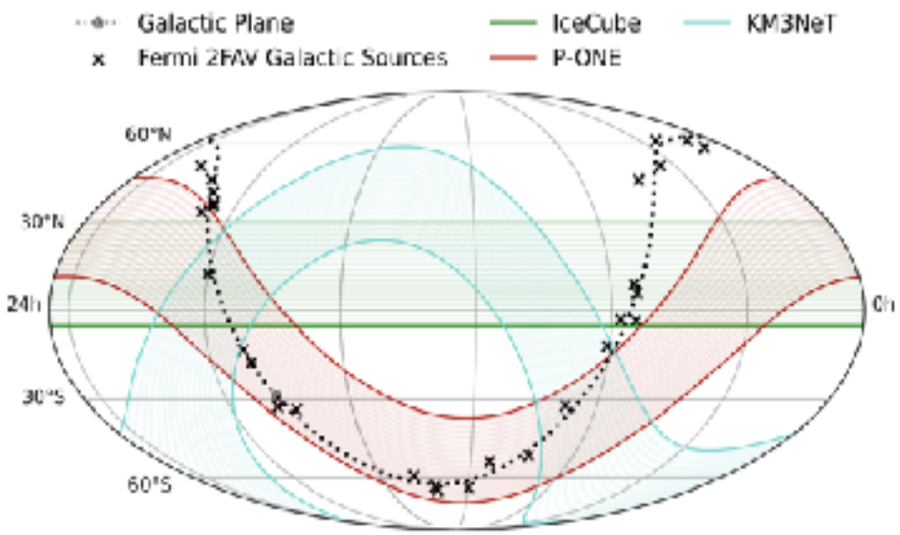
P-ONE Goals - Demonstrator



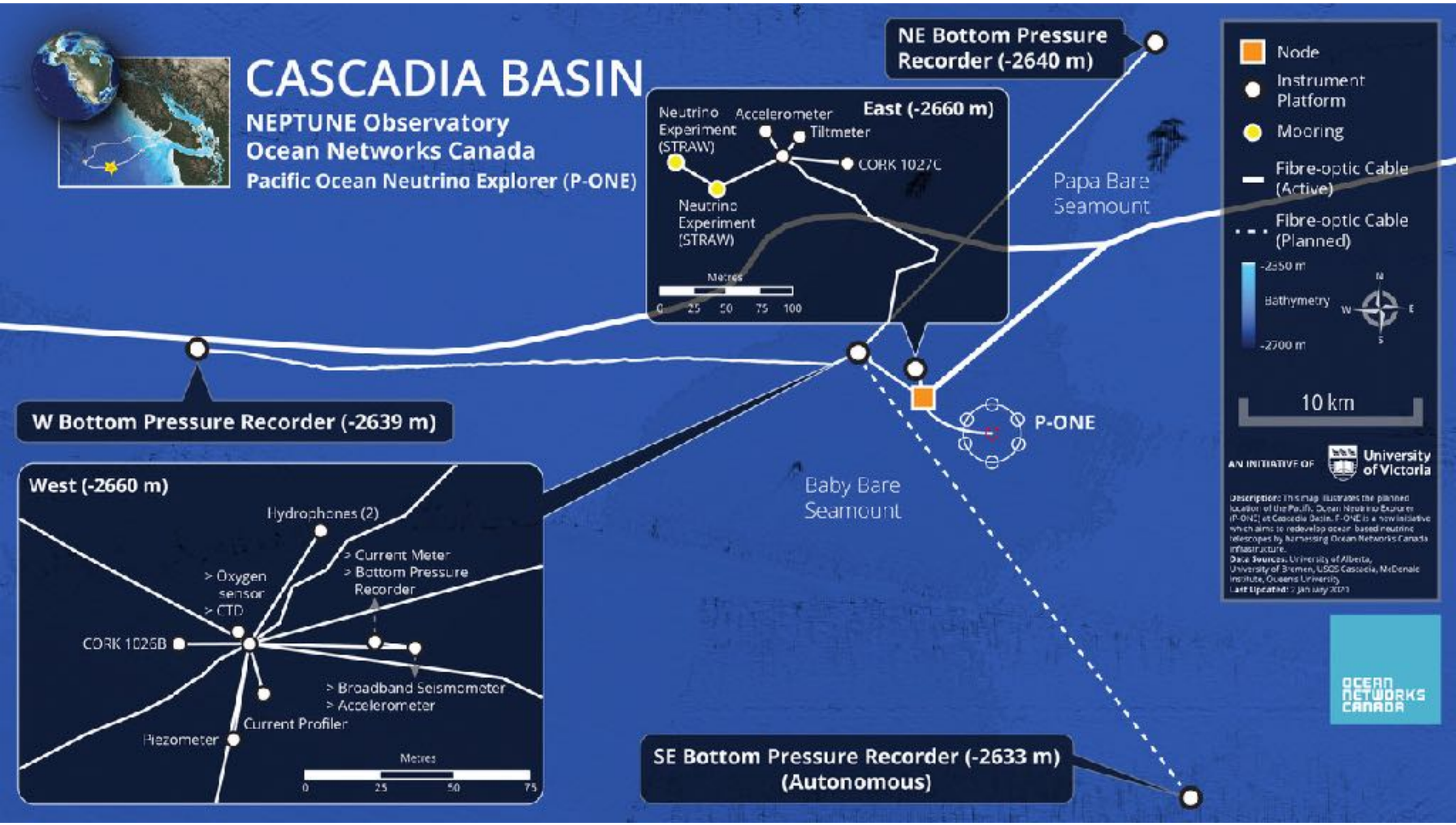
COMMISSIONING! PROOF OF CONCEPT,
SUCCESSFUL OPERATION 100% DUTY CYCLE

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)
-2650 m
Bathymetry
-2700 m
N
W
E
S
10 km
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, Queens University
Last Updated: 2 January 2021
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