

Title: The Pacific Ocean Neutrino Experiment

Speakers: Matthias Danninger

Series: Particle Physics

Date: March 28, 2023 - 11:00 AM

URL: <https://pirsa.org/23030086>

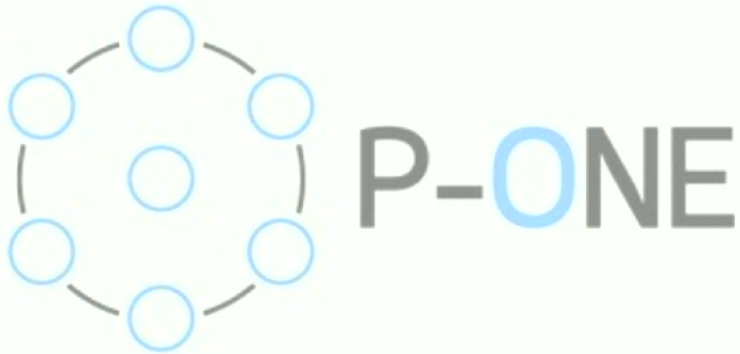
Abstract: Every time researchers have pushed the energy boundary in particle physics we have found something new about our Universe. Recently, IceCube has demonstrated that Neutrino Telescopes can use neutrinos from the cosmos as excellent tools to continue this exploration. The true potential of this field, however, remains to be realized due to limited observations of neutrinos at the highest energies. To unlock this potential, advanced detectors are needed that will push the forefront of the cosmic frontier, revealing new knowledge of extreme astrophysical phenomena, including through multi-messenger follow-up programs, and testing fundamental physics at scales well beyond those reachable by Earth-bound accelerators. The Pacific Ocean Neutrino Experiment (P-ONE) is a proposed initiative to construct one of the largest neutrino telescopes deep in the northern Pacific Ocean off the coast of British Columbia. To overcome the challenges of a deep-sea installation, we have deployed two pathfinder mooring lines STRAW and STRAW-b in 2018 and 2020. These provide continuous monitoring of optical water properties at a potential detector site in the Pacific. In this talk I will cover results from these pathfinders and discuss the status of P-ONE.

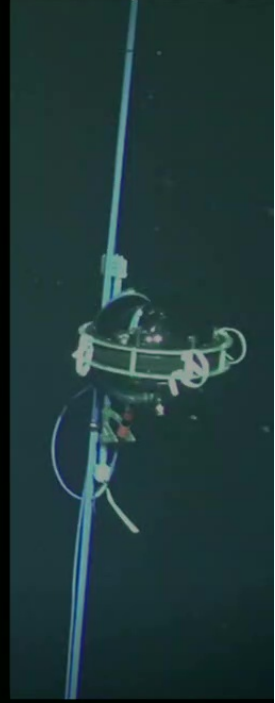
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P-ONE

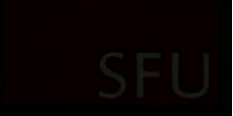
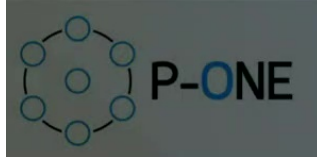
— The Pacific Ocean Neutrino Experiment —

Matthias Danninger
for the P-ONE Collaboration
2023 - 03 - 28



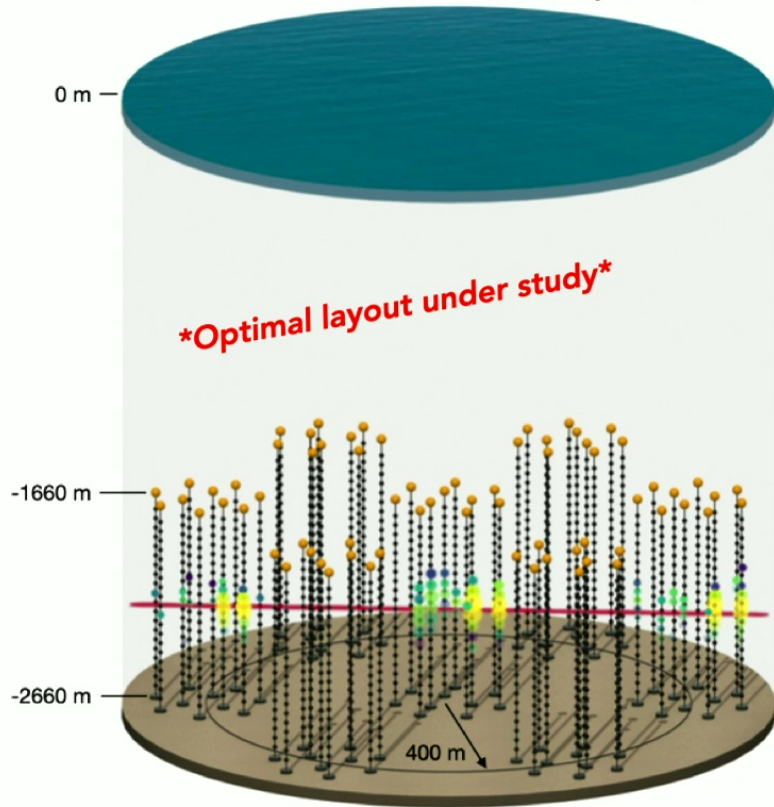


— Why another neutrino telescope? —



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?

Modern, cutting-edge design + new line concept

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

OCEAN NETWORKS CANADA

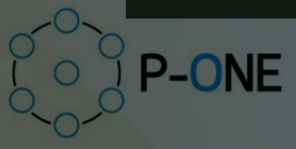


neutrino

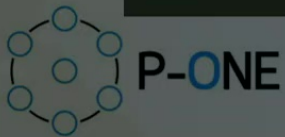
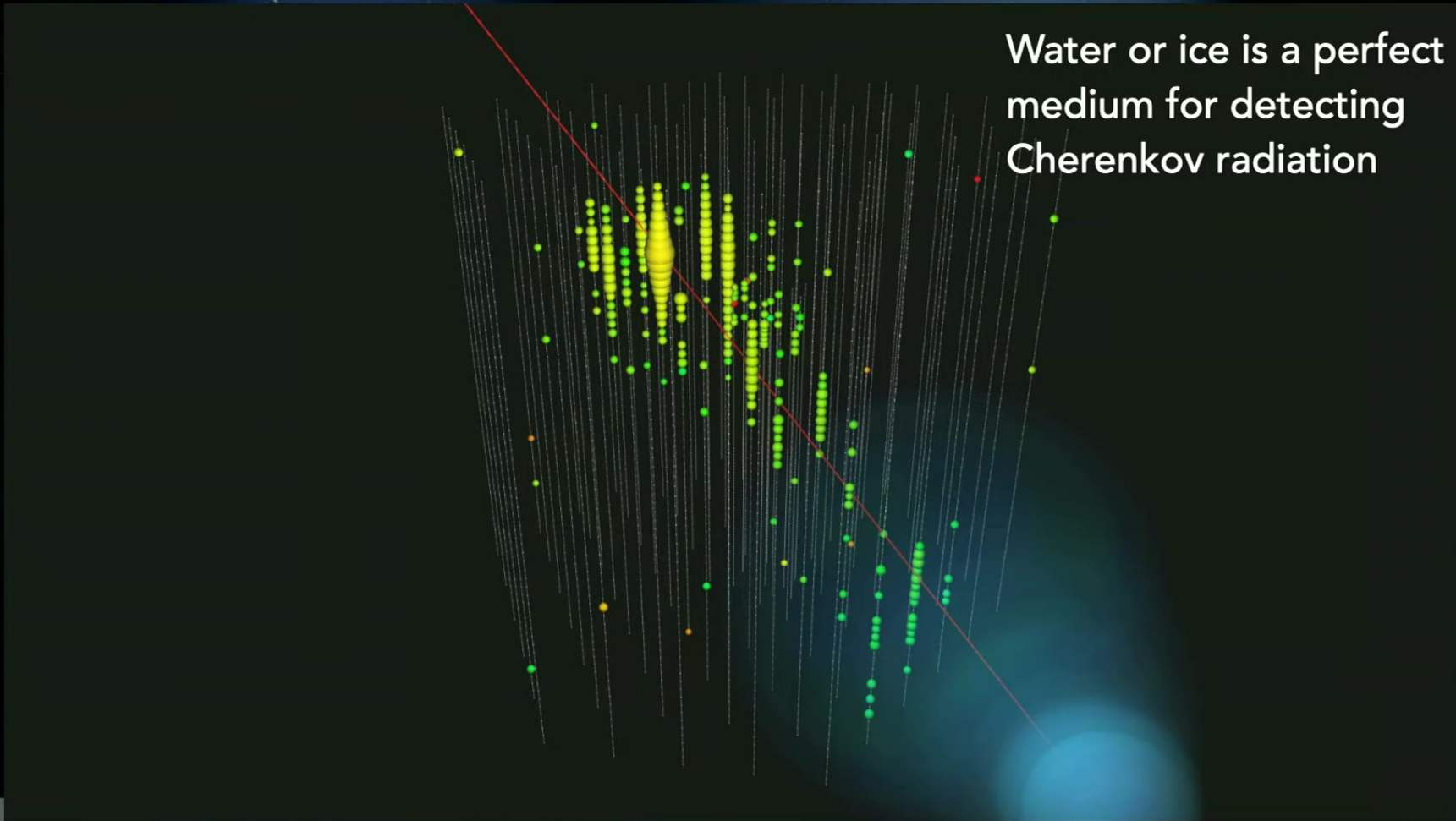
Water or ice is a perfect medium for detecting Cherenkov radiation

interaction

muon



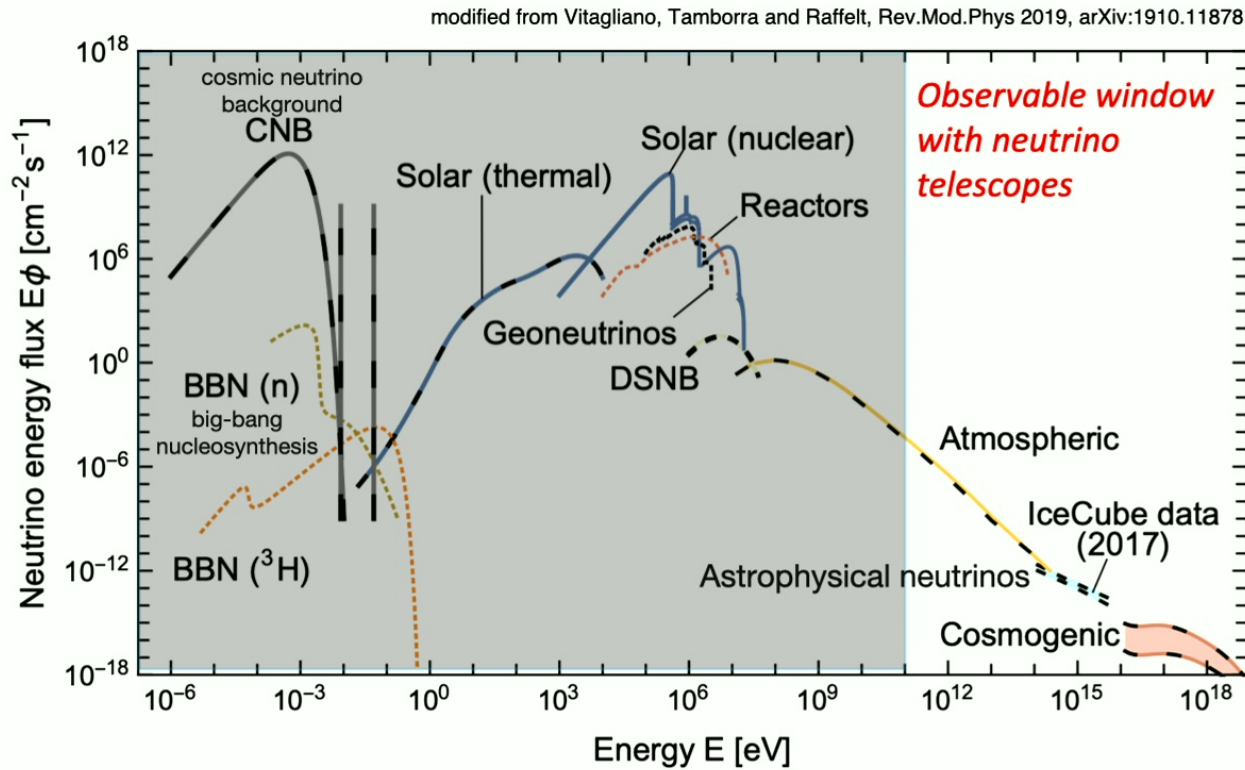
Water or ice is a perfect medium for detecting Cherenkov radiation



muon track: time is color; number of photons is energy

SFU

Neutrinos from the Universe



-naturally occurring neutrinos can have **extreme energies**

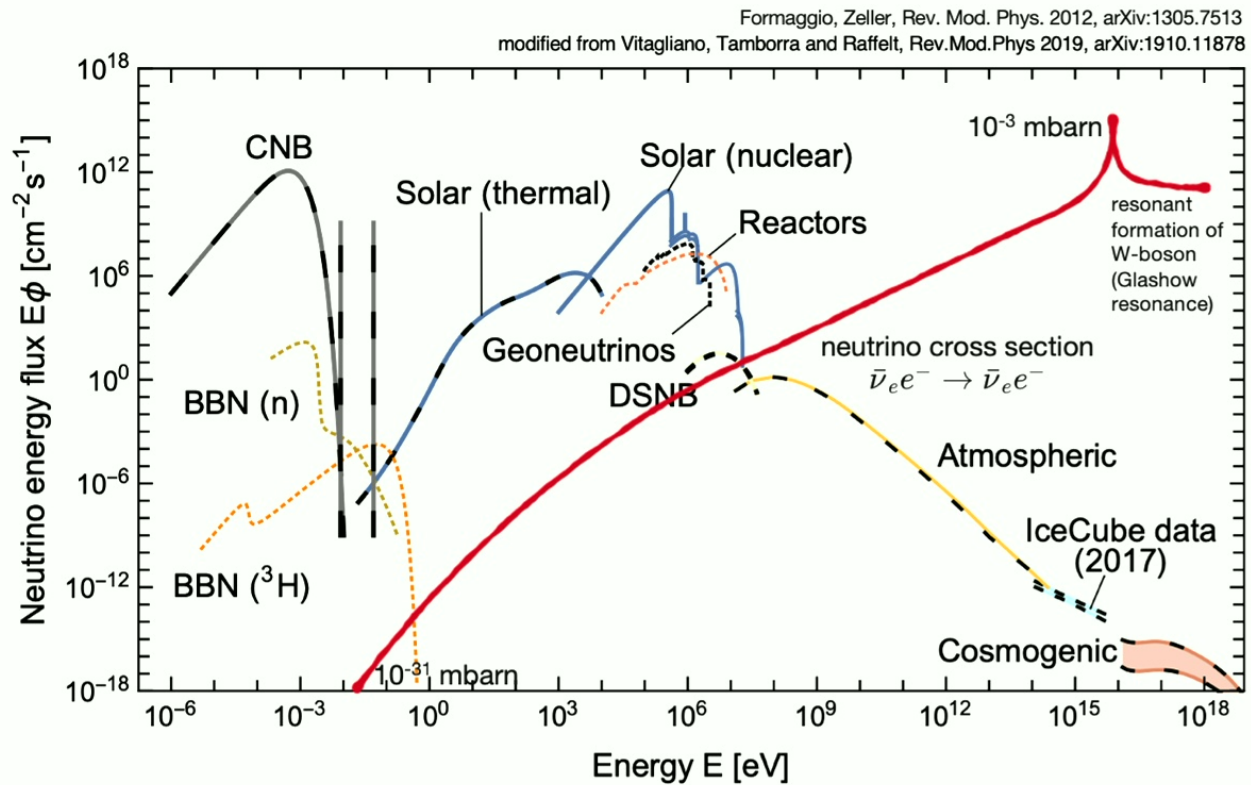
-manmade beams can reach $E \sim 50 \text{ GeV}$ at **most**

-but the fluxes are low, so you need **really large detectors**

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



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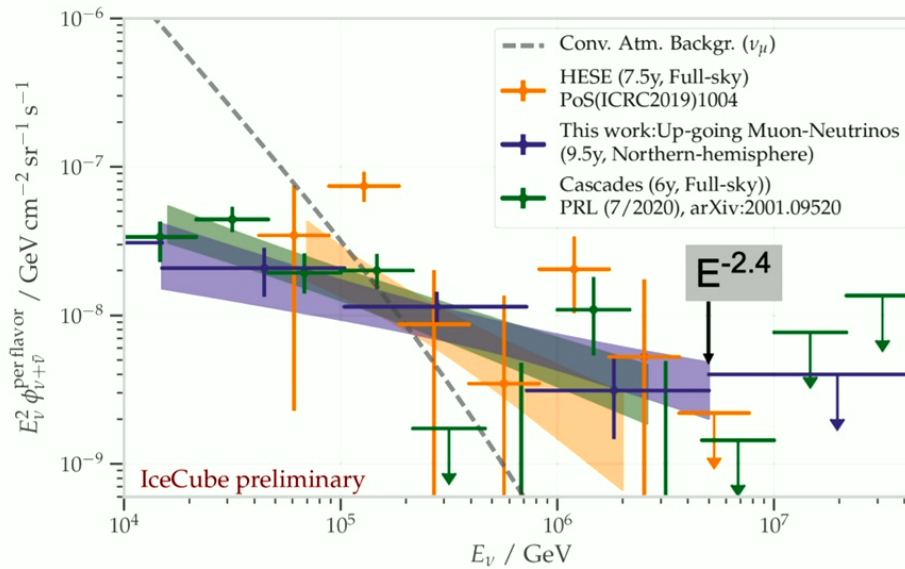
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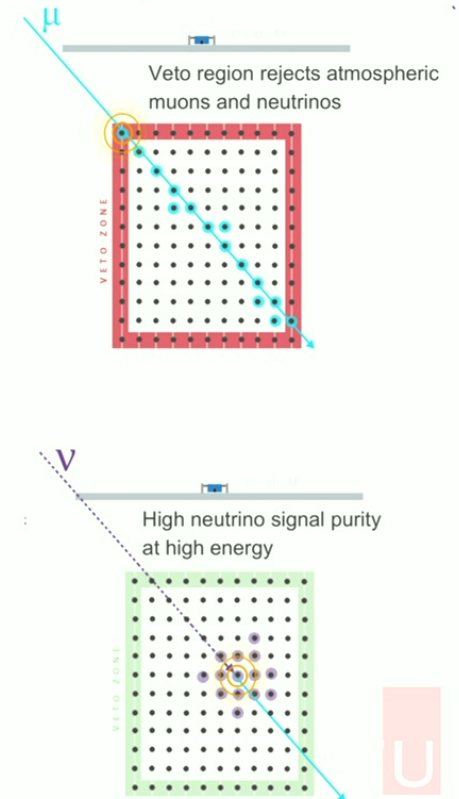


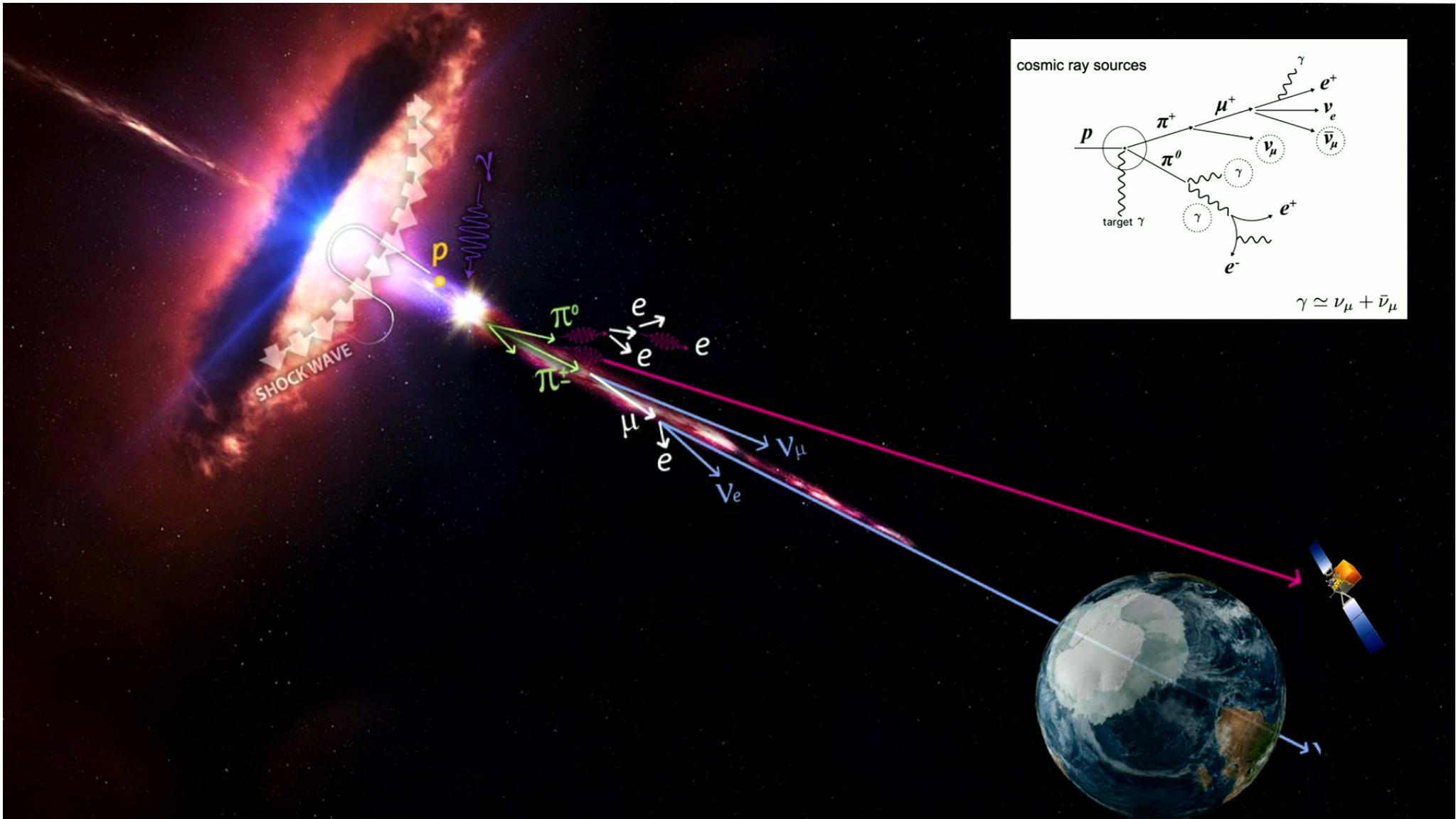
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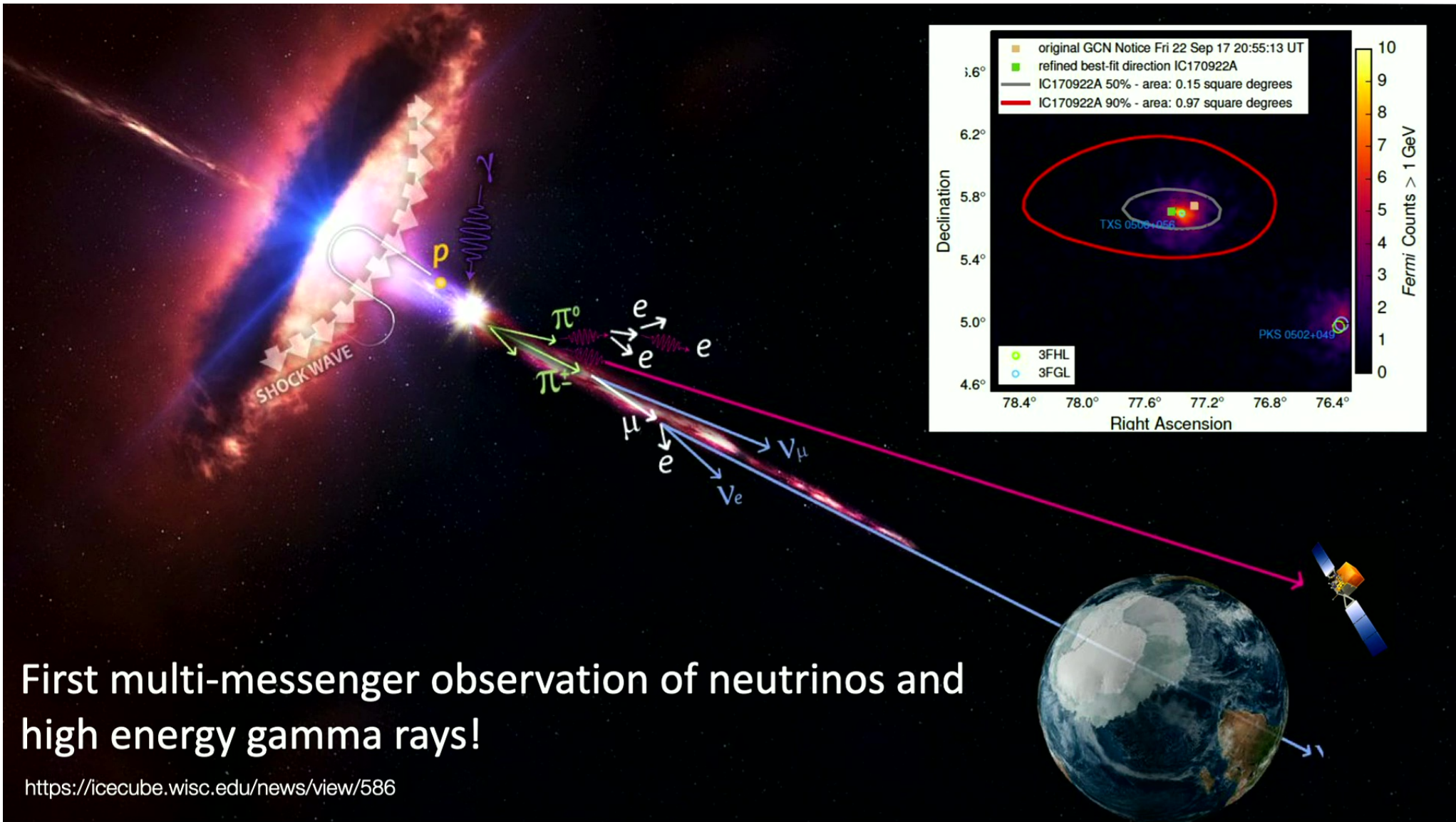
- Since 2013 — Astrophysical neutrinos discovered



Starting Events

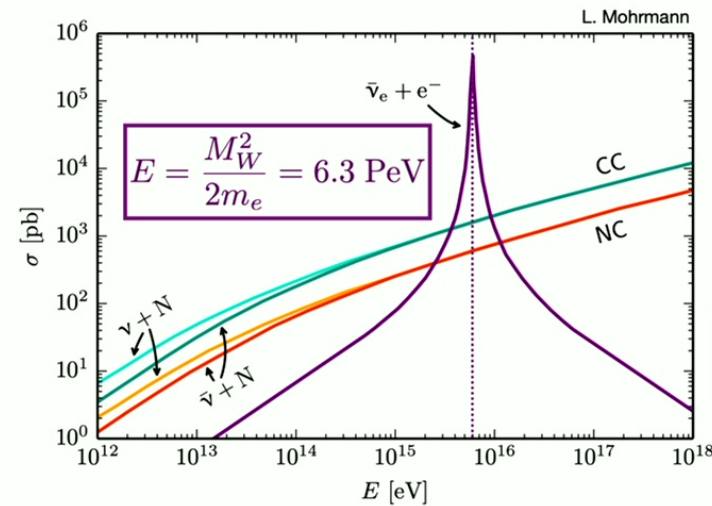
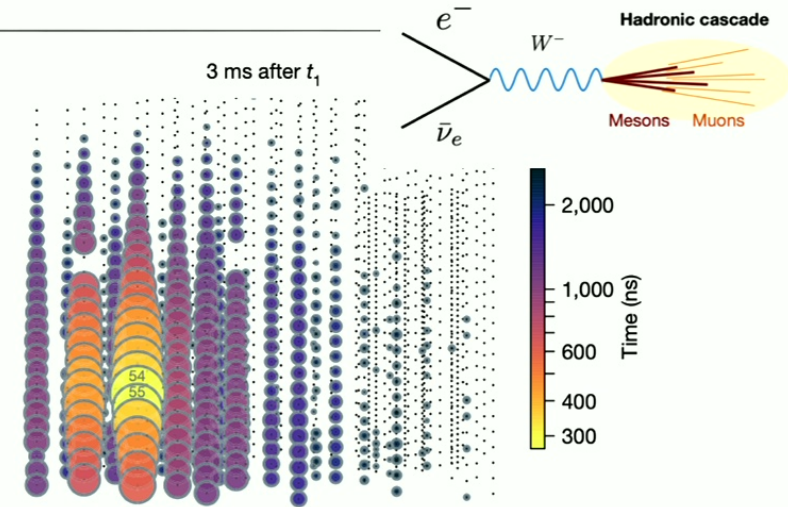






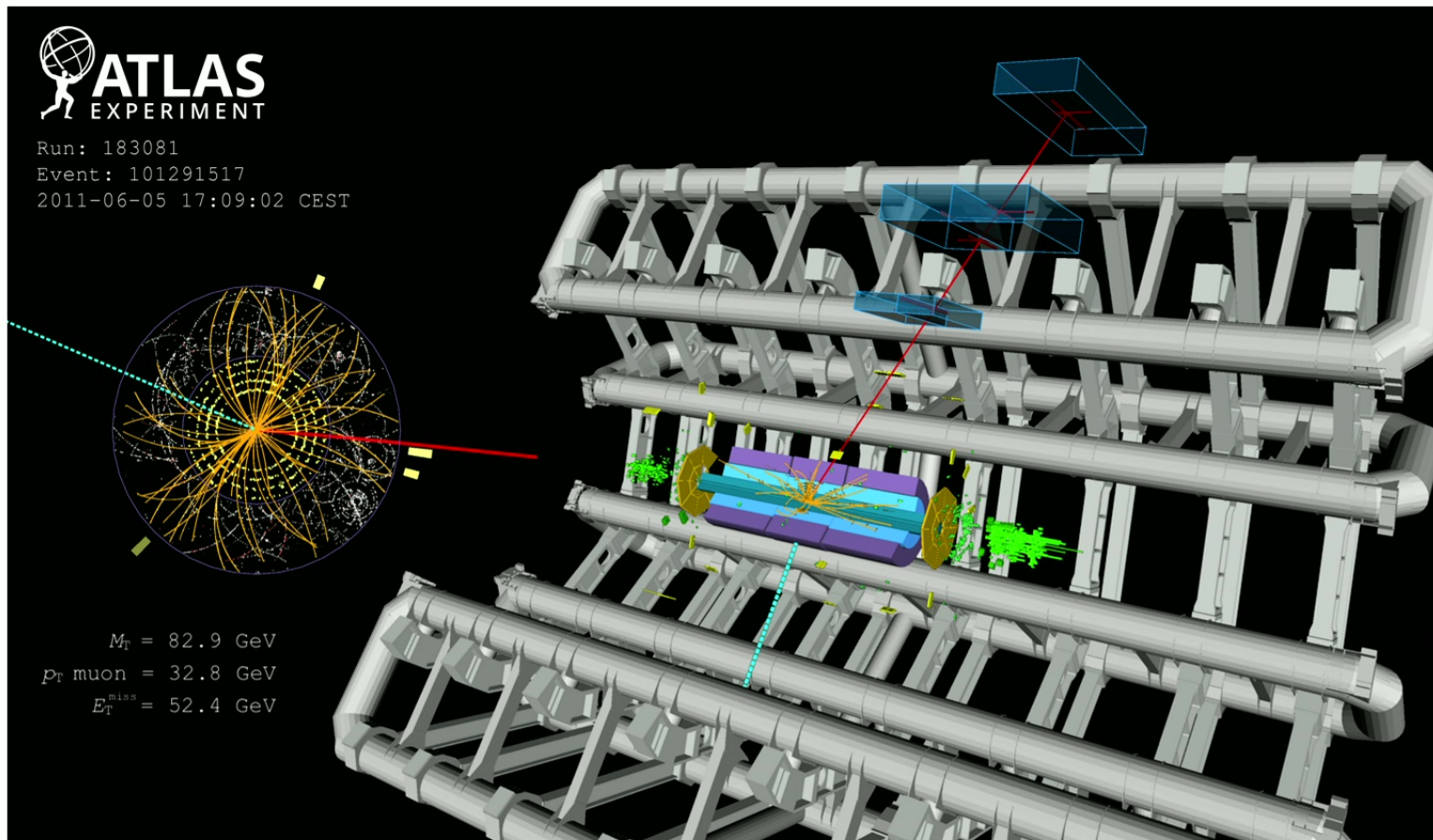
Neutrinos from the Universe

- Since 2013 — Astrophysical neutrinos discovered
- 2018 — Evidence for First source: Neutrino events in a direction of a flaring blazar, TXS 0506+056
- 2019/20 — Very likely the first event at the Glashow resonance observed



Neutrinos from the Universe

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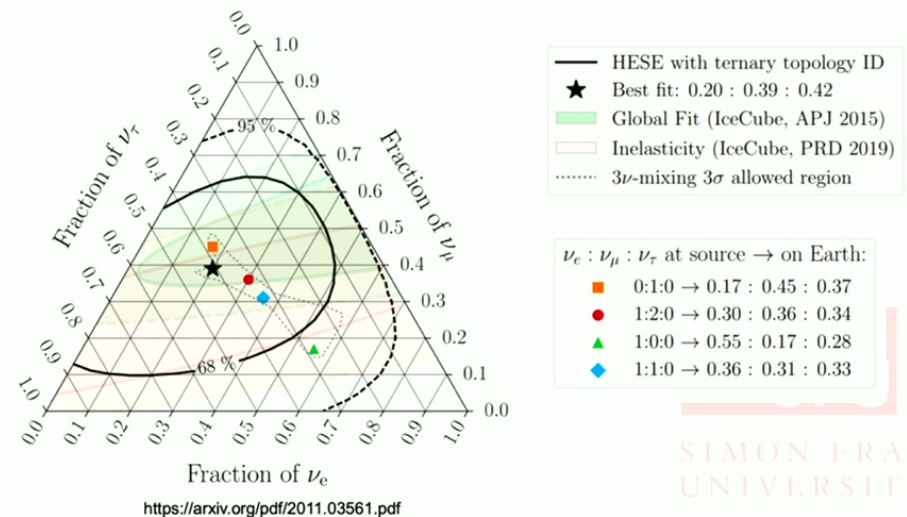
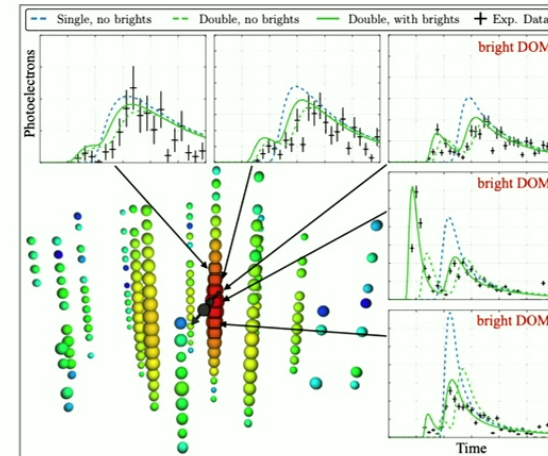
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SIMON FRASER
UNIVERSITY

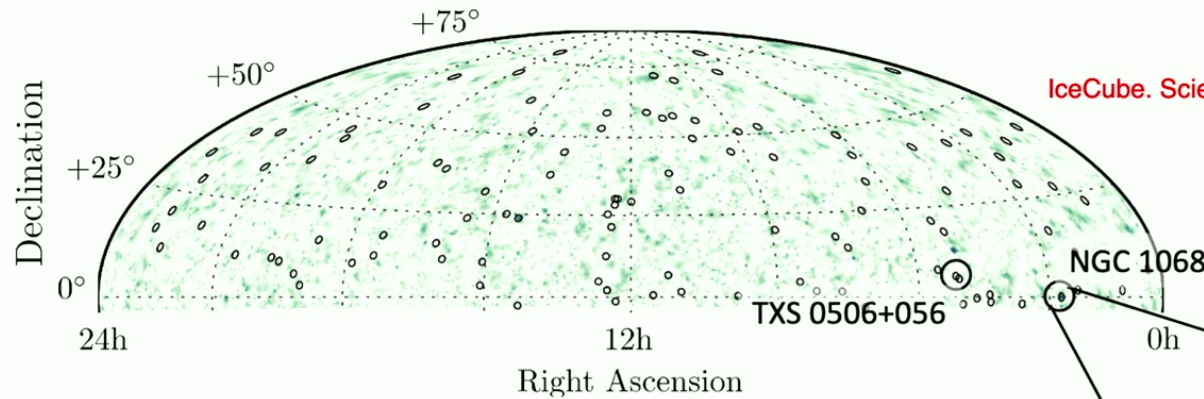
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Neutrinos from the Universe

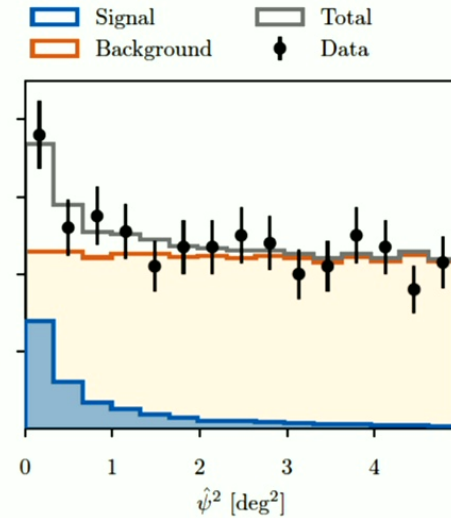
Second neutrino source!



IceCube. Science (2022)

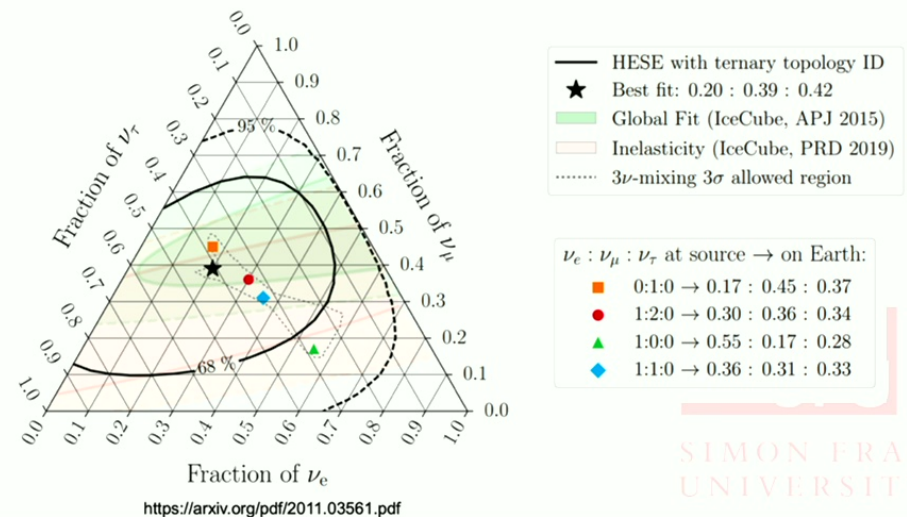
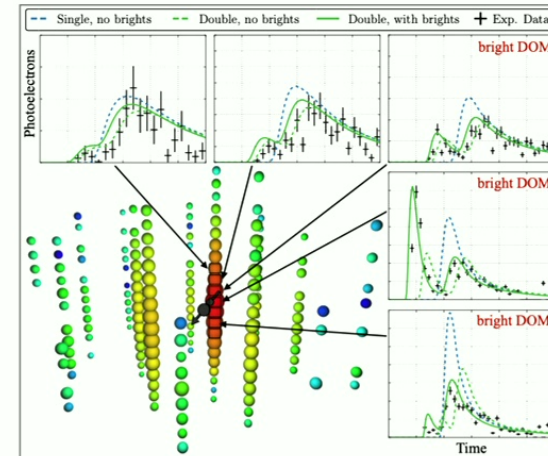
Improved data processing
At the location of NGC 1068:
79⁺²²₋₂₀ neutrinos
Spectral index: -3.2 ± 0.2

Post-trial significance 4.2 σ



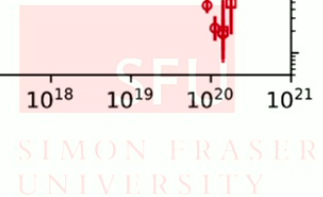
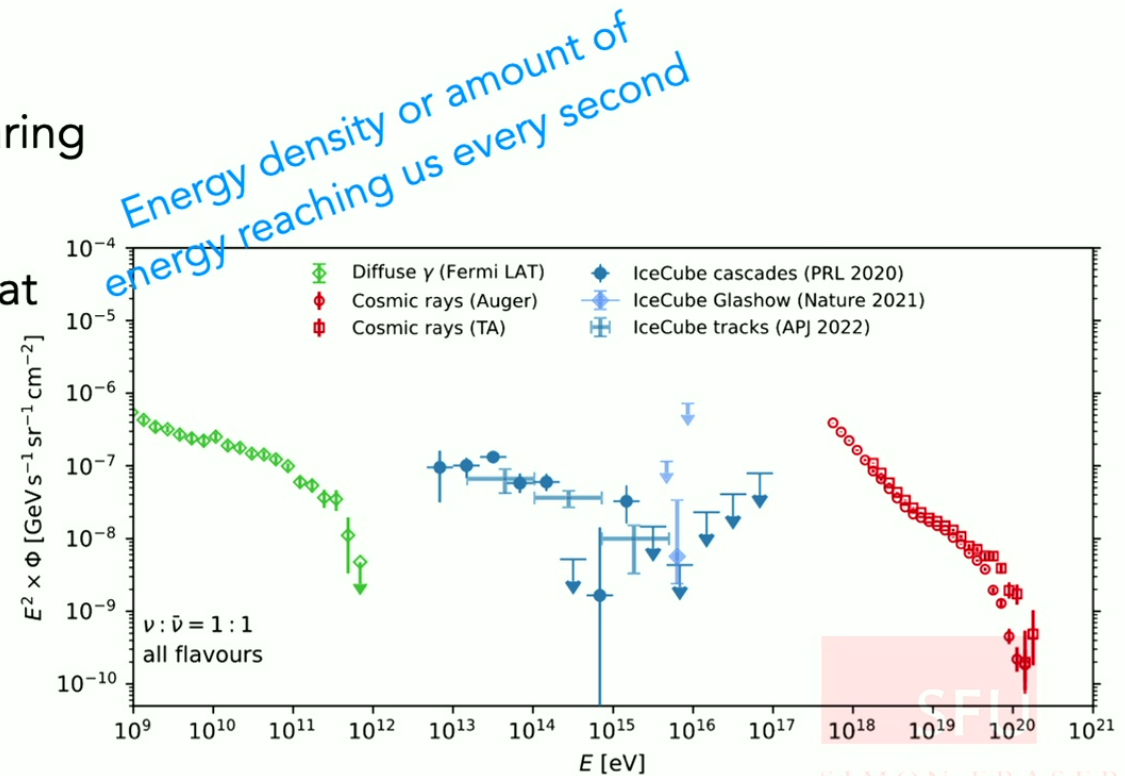
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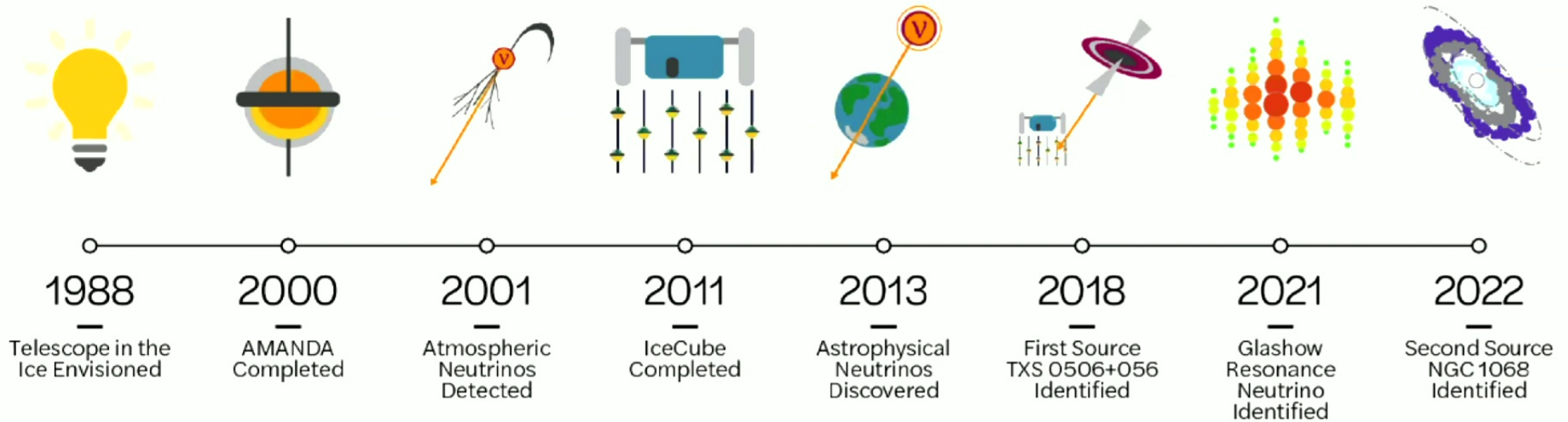


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- 2019/20 — Very likely the first event at the Glashow resonance observed
- 2020 — Neutrino oscillation measurements at PeV scale!
- 2022 — Second source

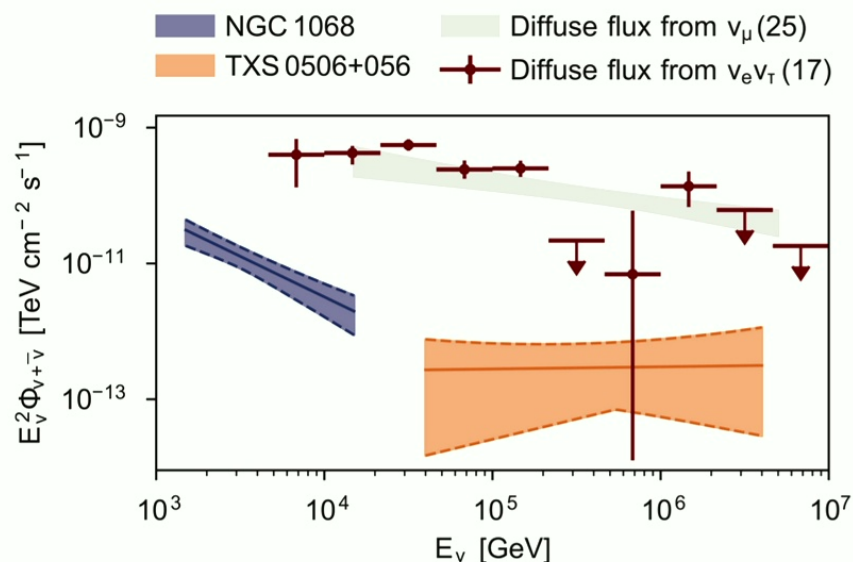


Why another neutrino telescope?



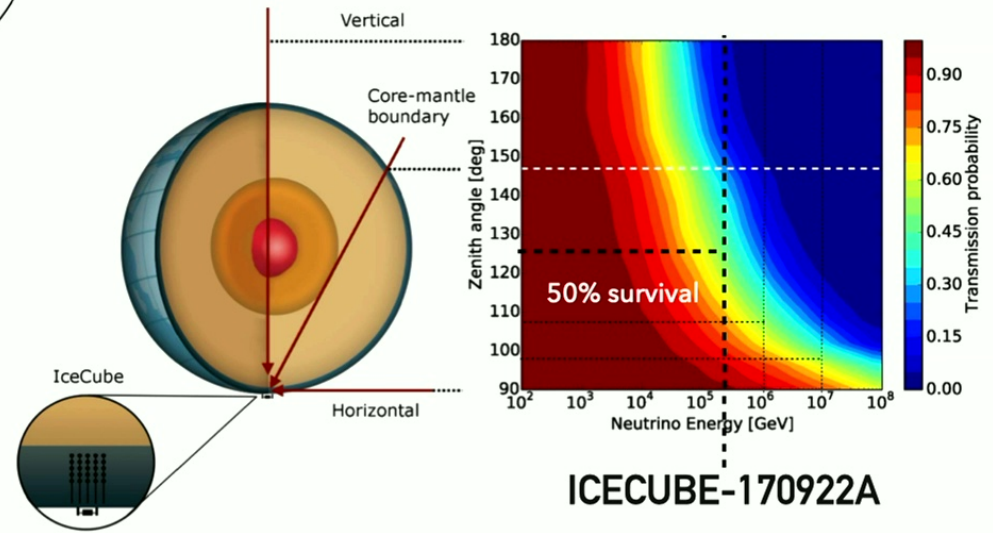
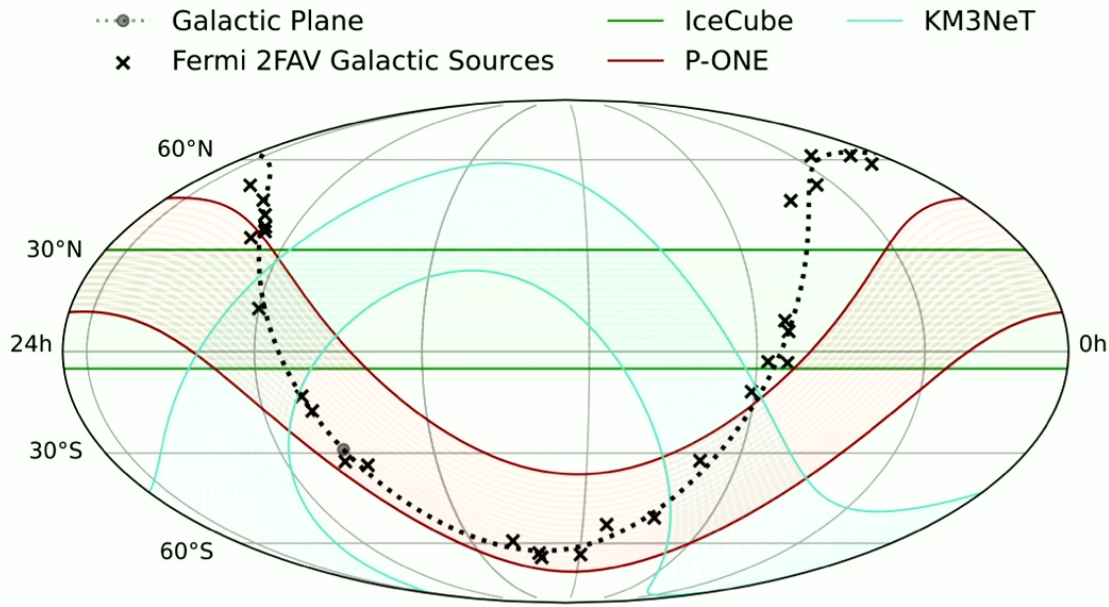
How to understand the current picture?

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- Discrepancy between diffuse flux and 2 identified sources
 - sources are only 1% of observed extragalactic flux?
 - TXS source is very distant (rare?)
 - NGC is steady and closer (should be common?)
- Where are galactic sources? In case of galactic emission — can we resolve sources?

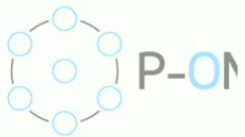
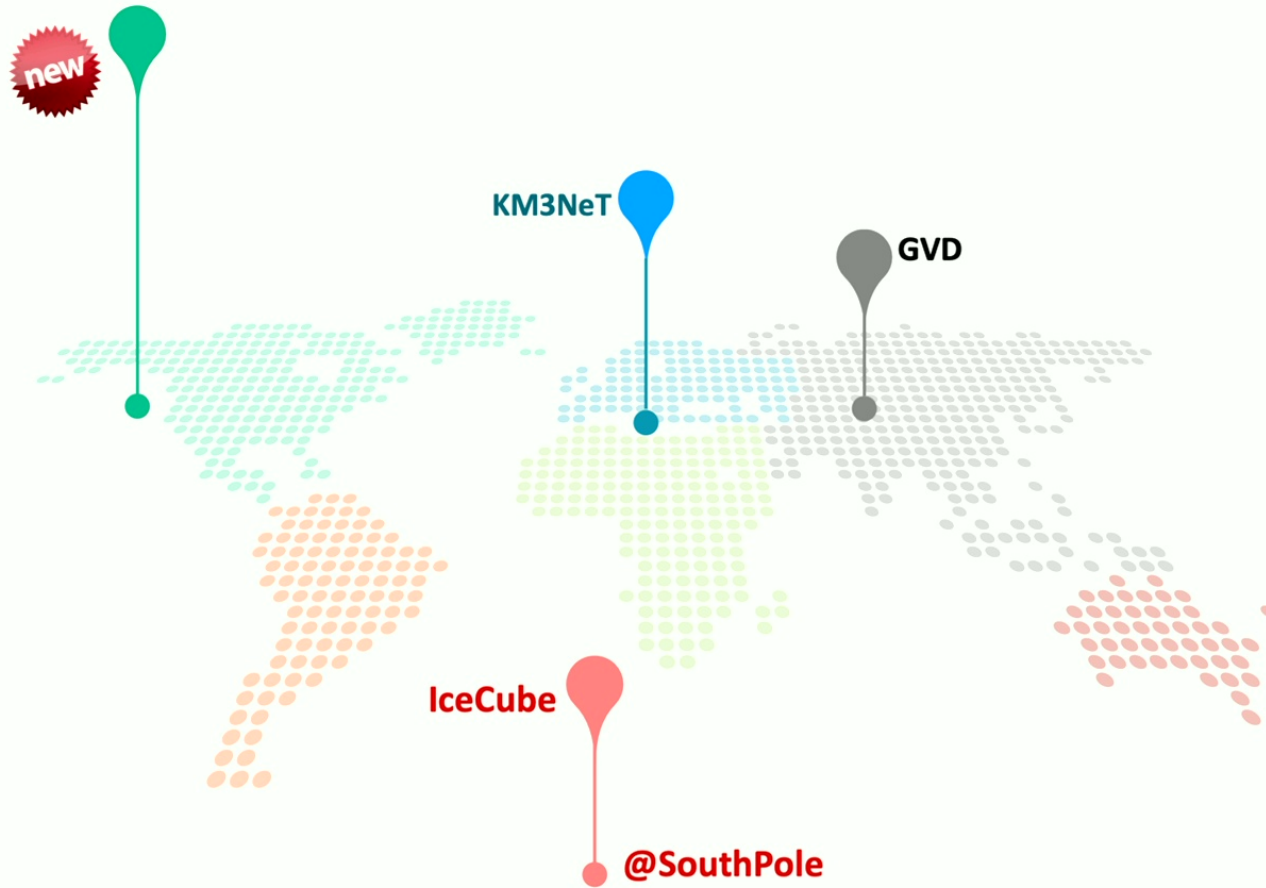
How to understand the current picture?



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Why a new neutrino telescope?

P-ONE@Ocean Networks Canada



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image E. Resconi



Why another neutrino telescope?

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Conclusion slide from Francis Halzen's talk at
Int. Workshop on nu-telescopes (Feb 2021)!

neutrino astronomy 2021

- it exists
- more neutrinos, better neutrinos
- closing in on cosmic ray sources

icecube.wisc.edu



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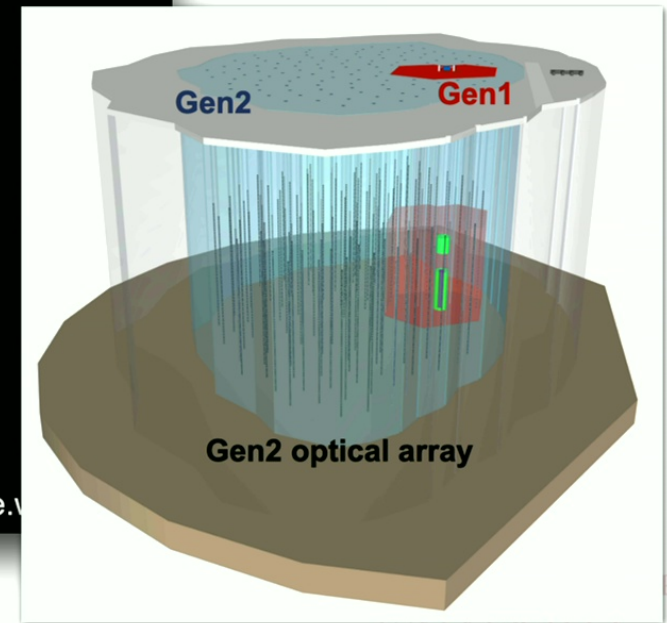
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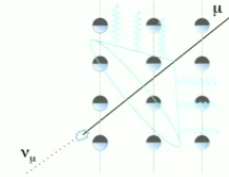
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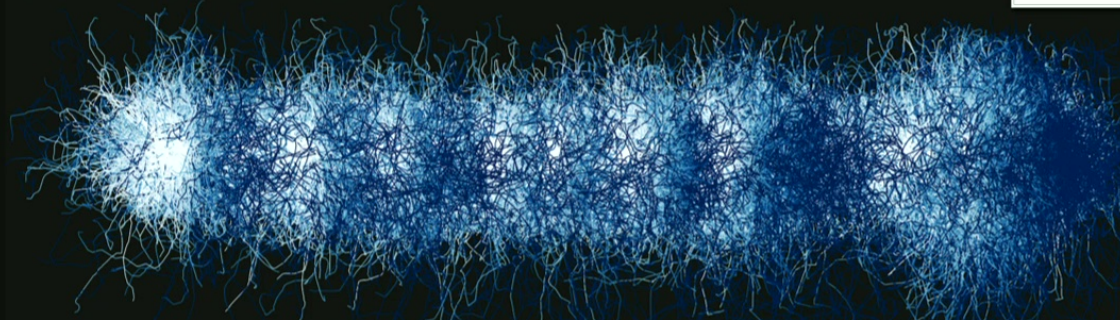
Photons in ice and water

HORIZONTAL HIGH ENERGY MUONS: THE SIGNATURE

1 PeV horizontal muon

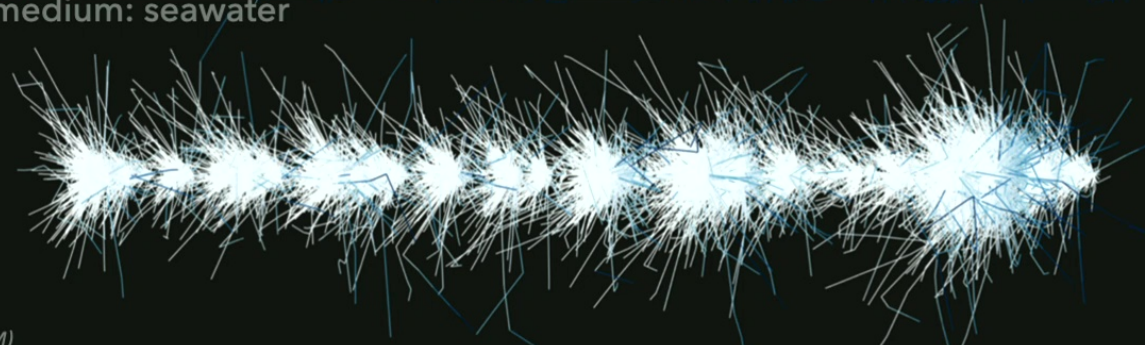


medium: IceCube ice



1km sample of a typical 10-15 km long muon track

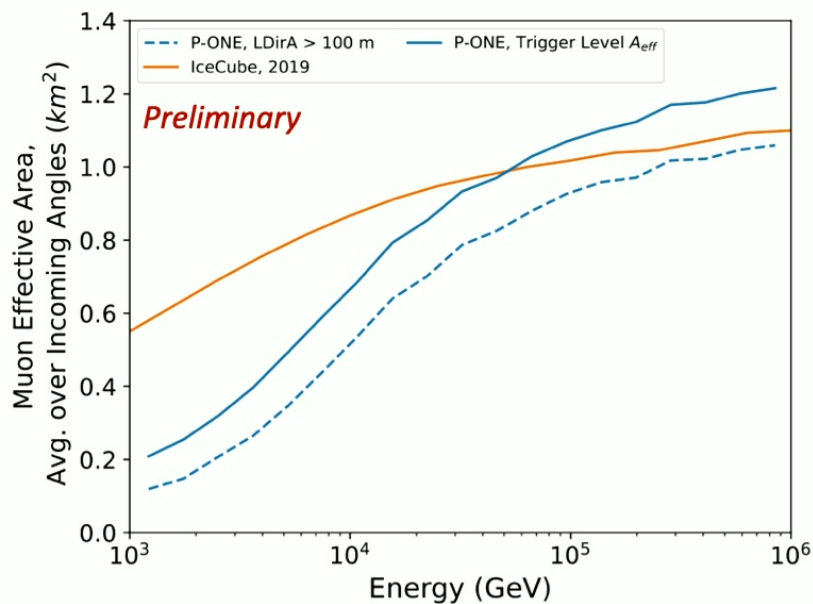
medium: seawater



K. Krings (TUM)



Why another neutrino telescope?



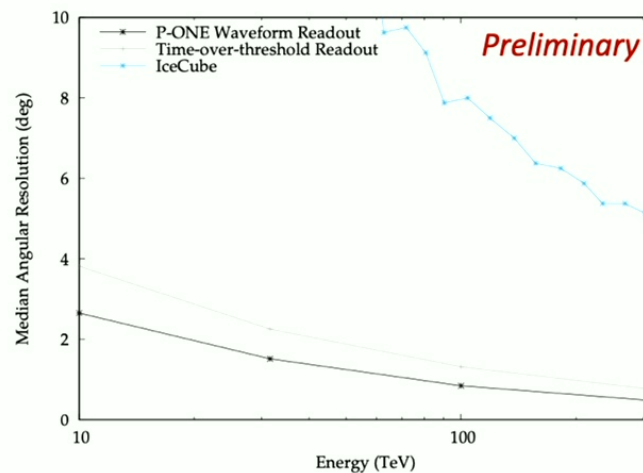
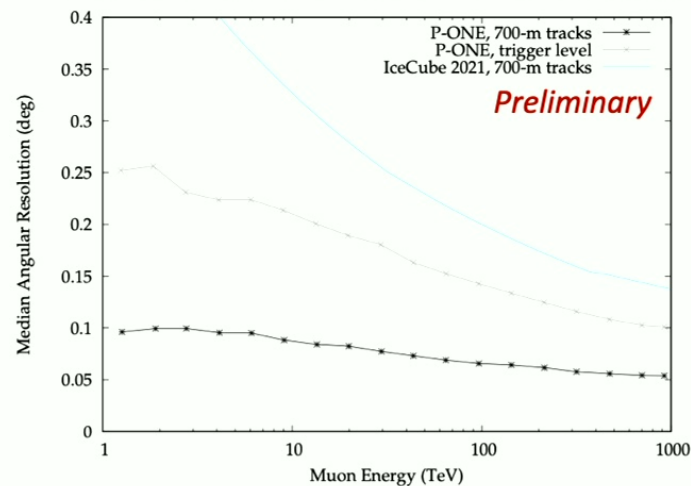
- Simplistic euclidean universe approx.

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

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

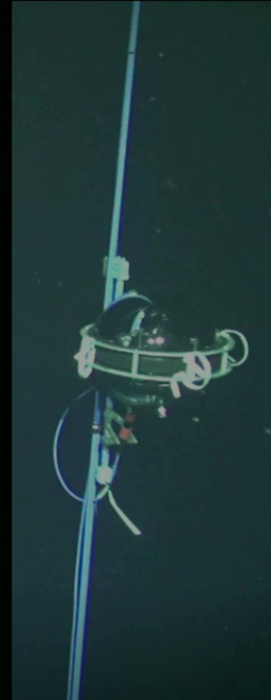


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- The neutrino is the PeV messenger of the Universe
- We must now figure out what it is telling us!



Ocean Networks Canada

— and opportunity for the neutrino community —

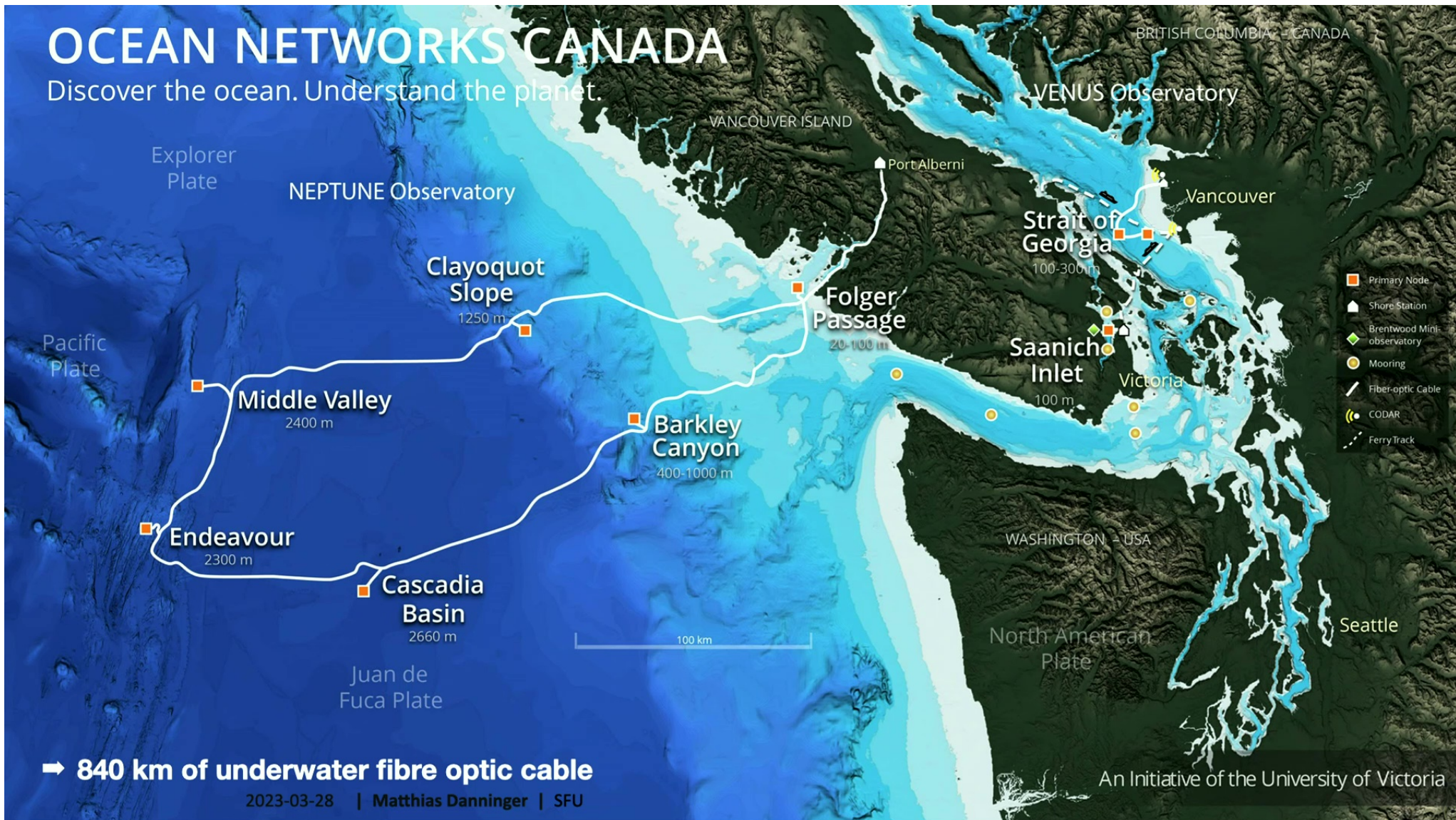


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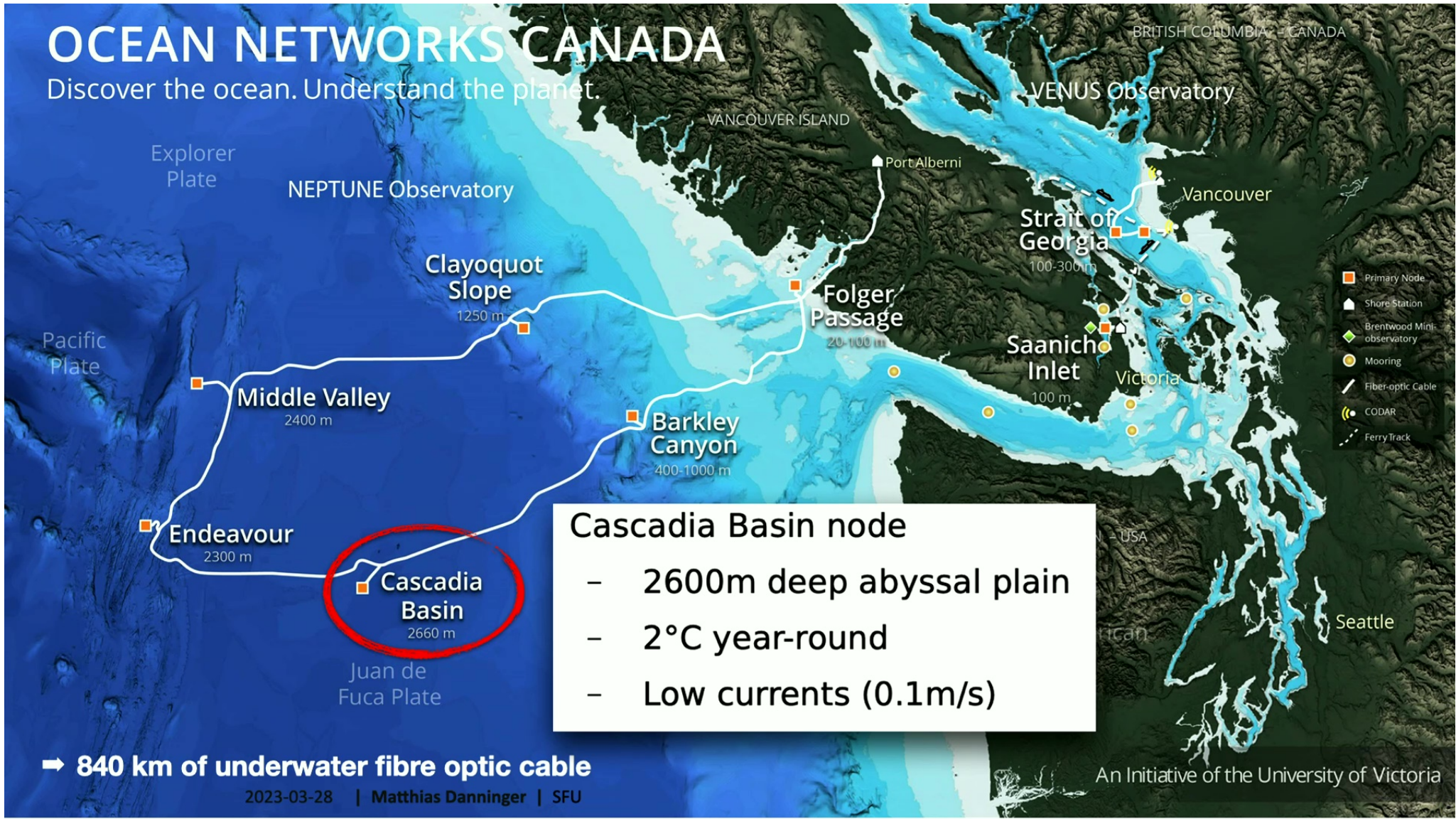
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Discover the ocean. Understand the planet.

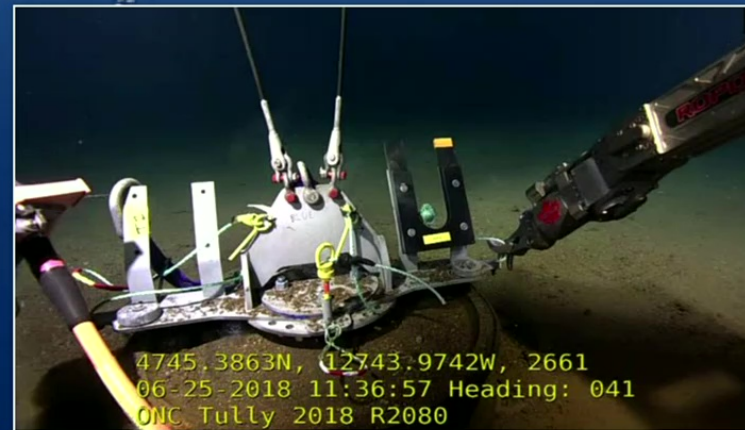
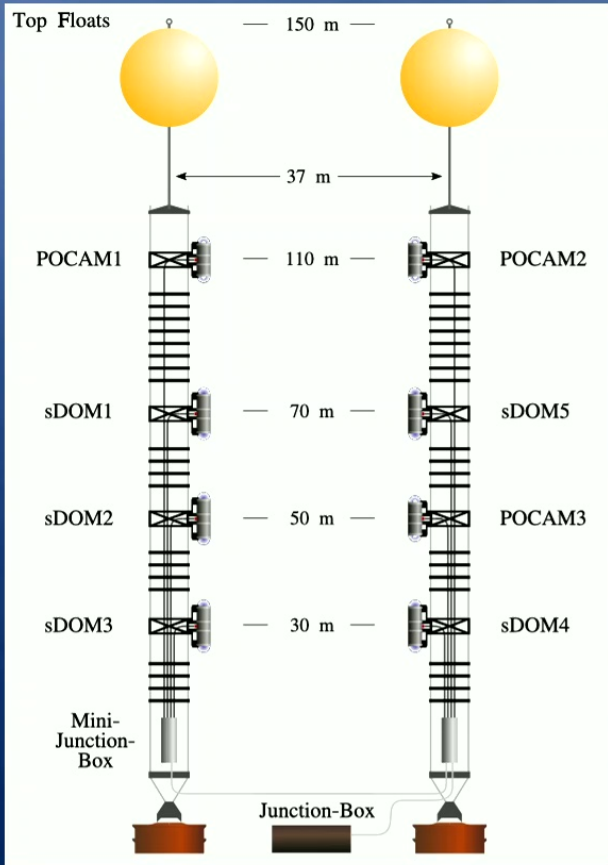


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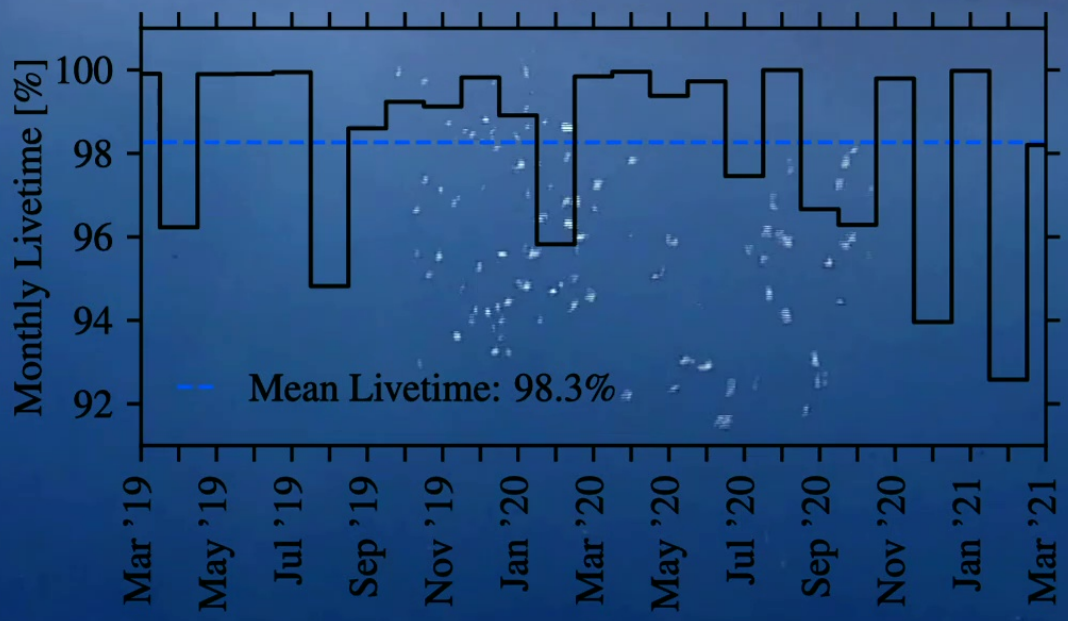
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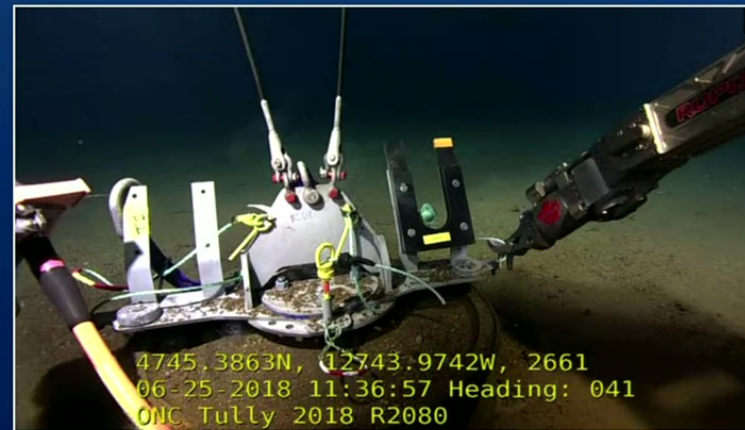
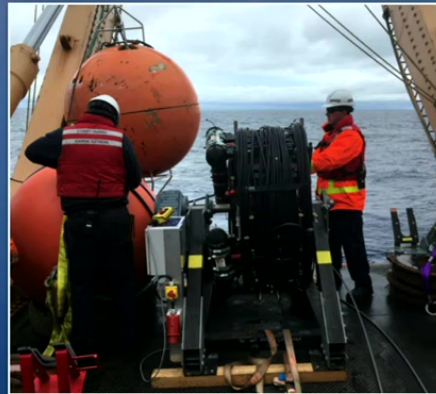
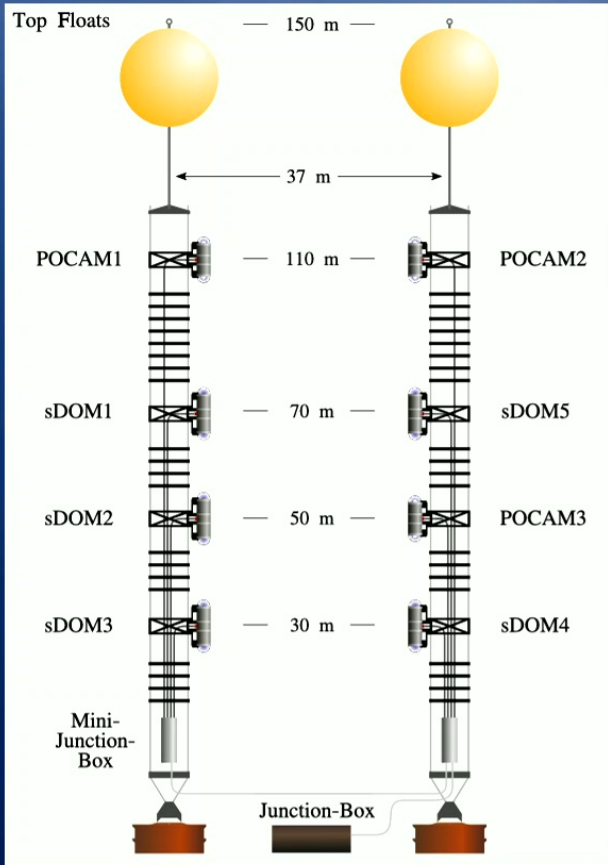
OPTICAL PROPERTIES INVESTIGATION TWO PATHFINDER MISSIONS (2018, 2020)



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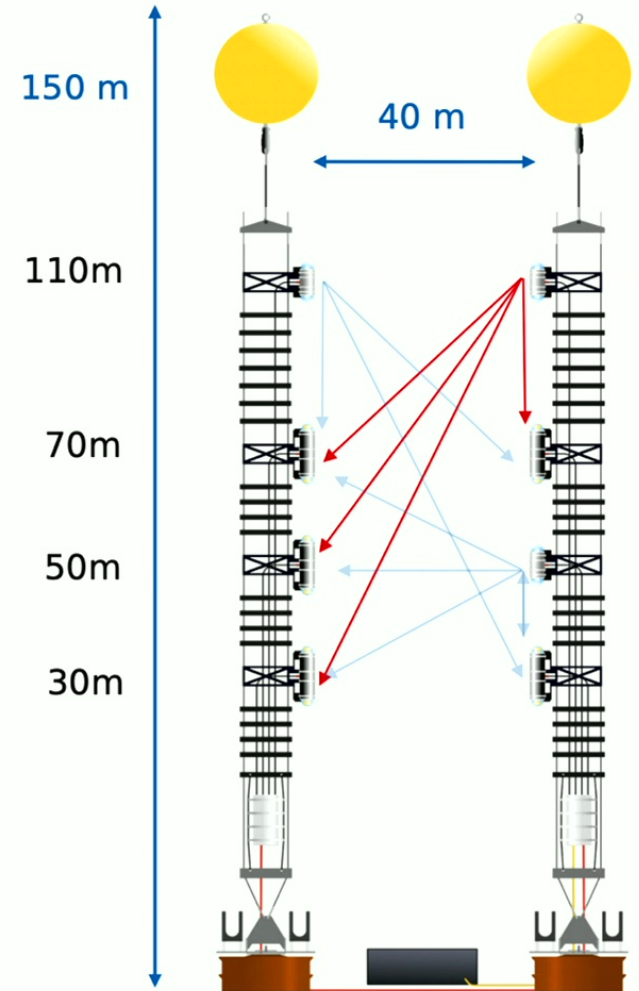
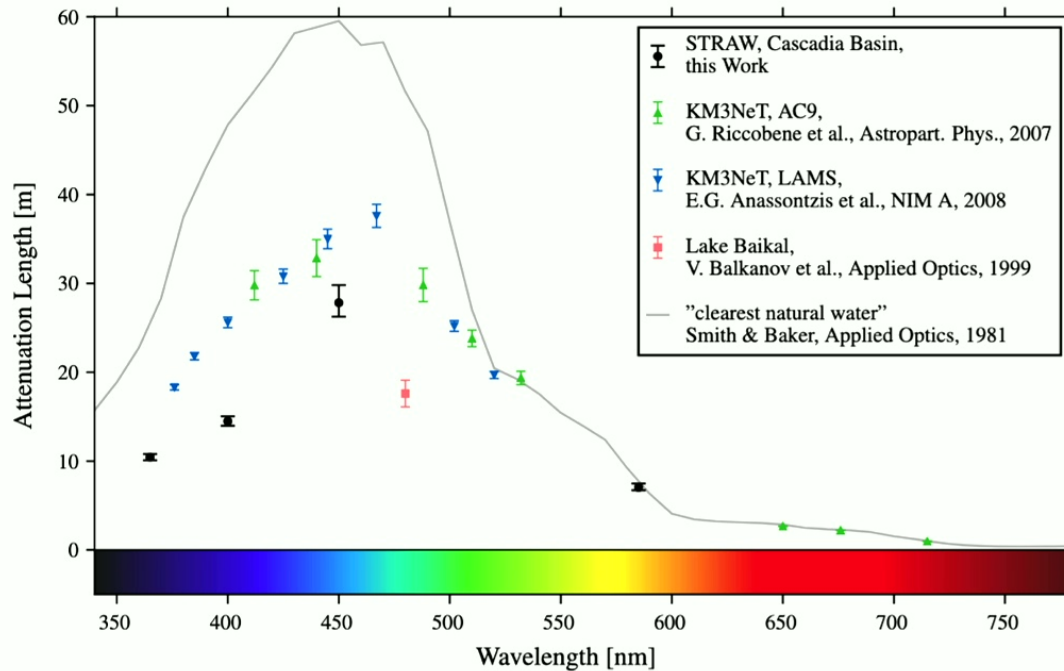


Very good optical properties

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

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

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

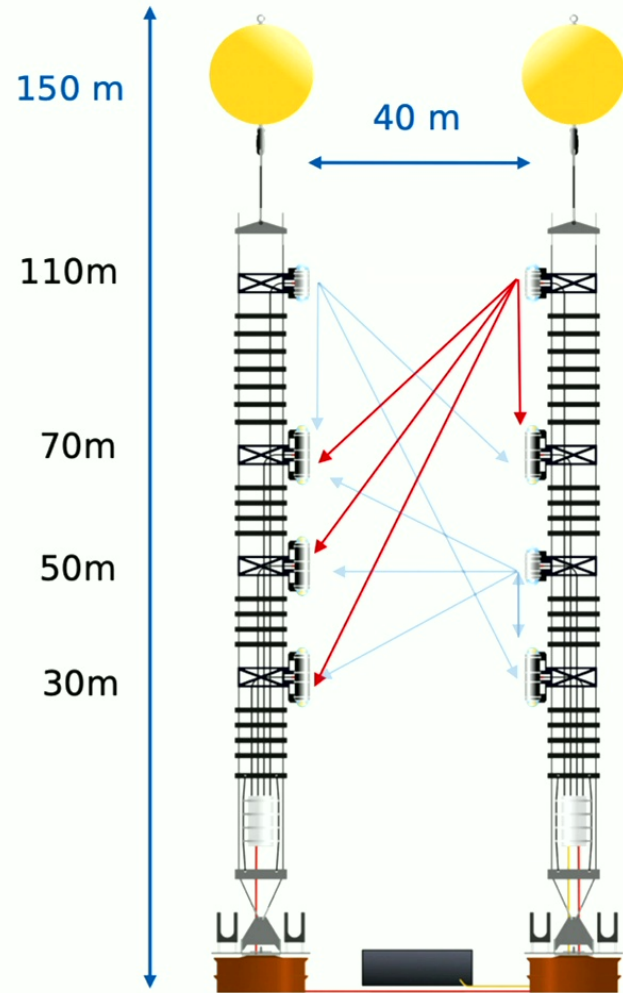
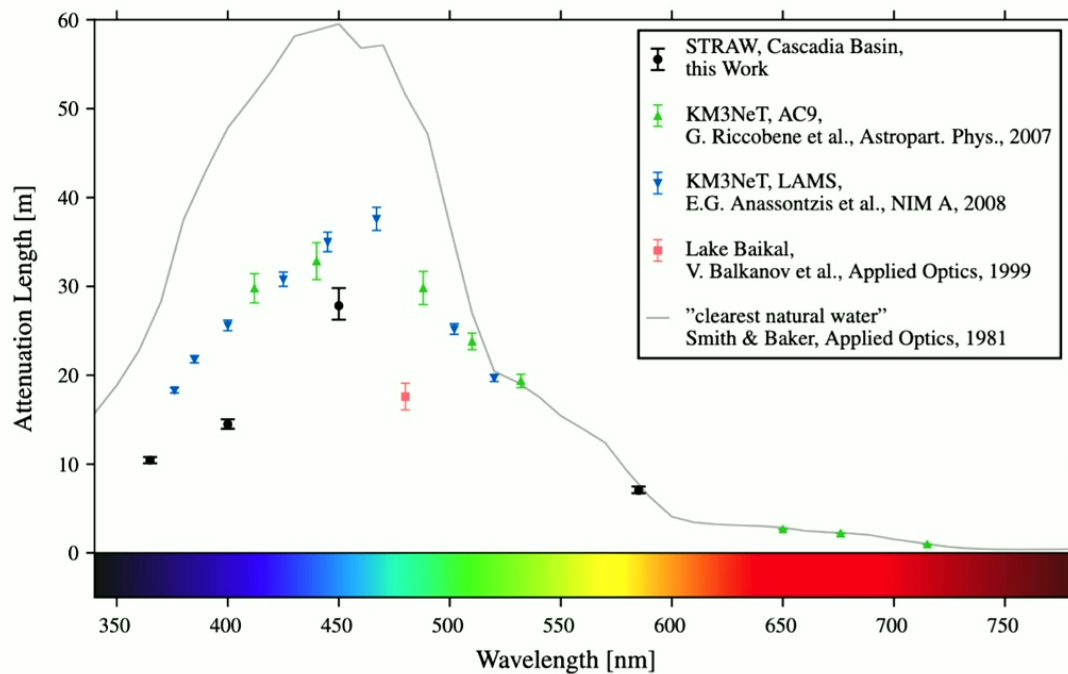


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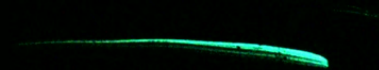


OPTICAL PROPERTIES INVESTIGATION TWO PATHFINDER MISSIONS (2018, 2020)

EPJ C 81 (2021)

THE DEEP SEA SITE OF CASCADIA BASIN IS
OPTICALLY QUALIFIED TO HOST P-ONE

INTERDISCIPLINARY: OCEANOGRAPHY, MICROBIOLOGY,
CLIMATE CHANGE RELATED STUDIES

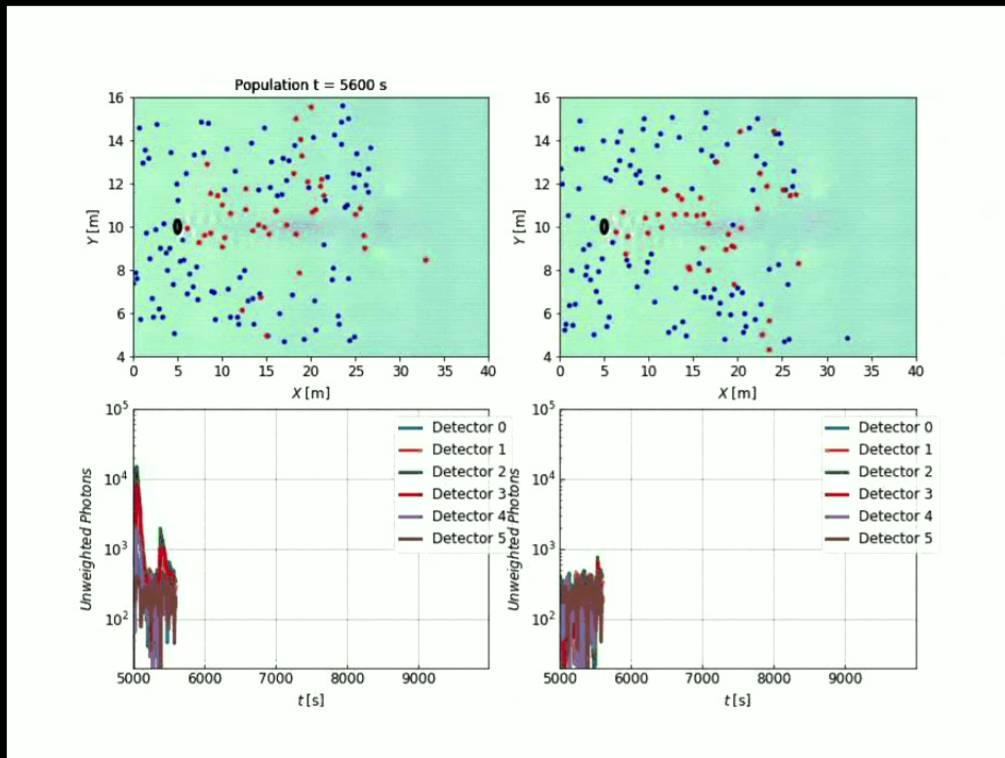


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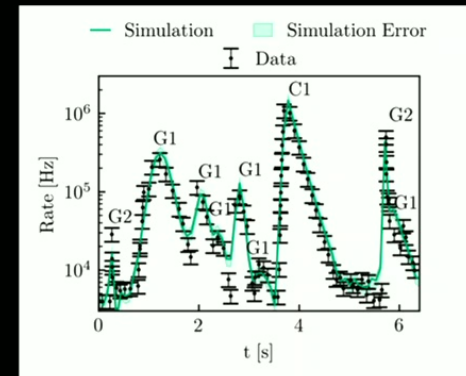
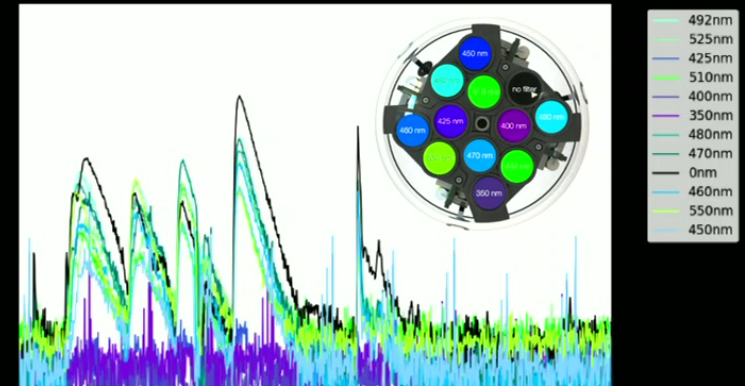
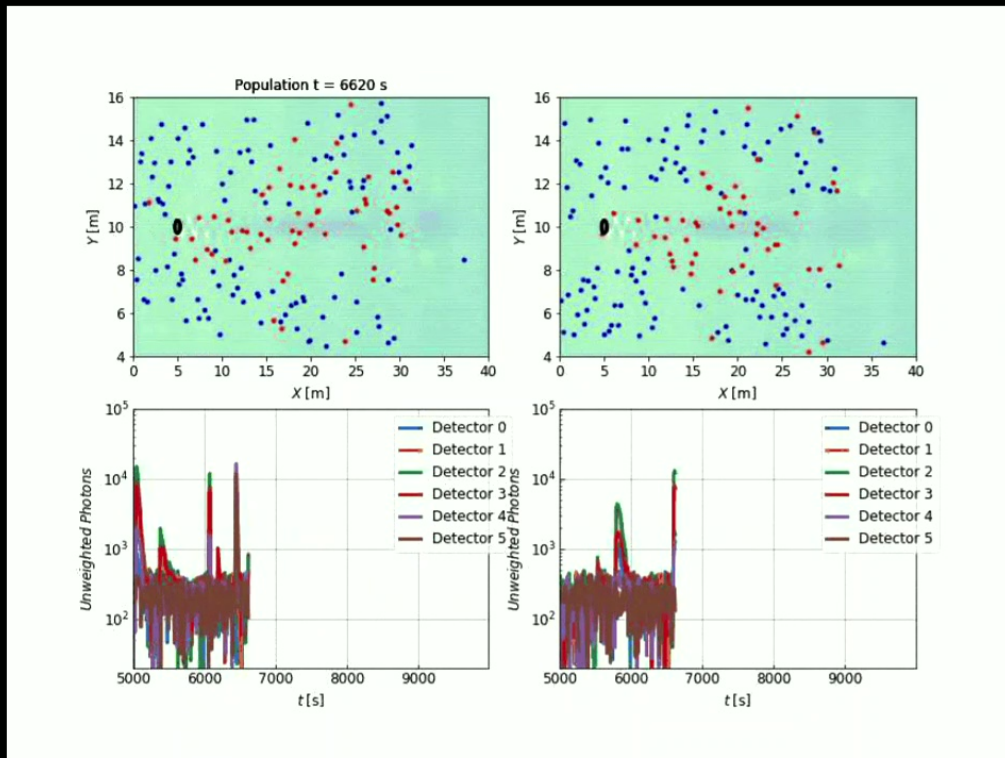


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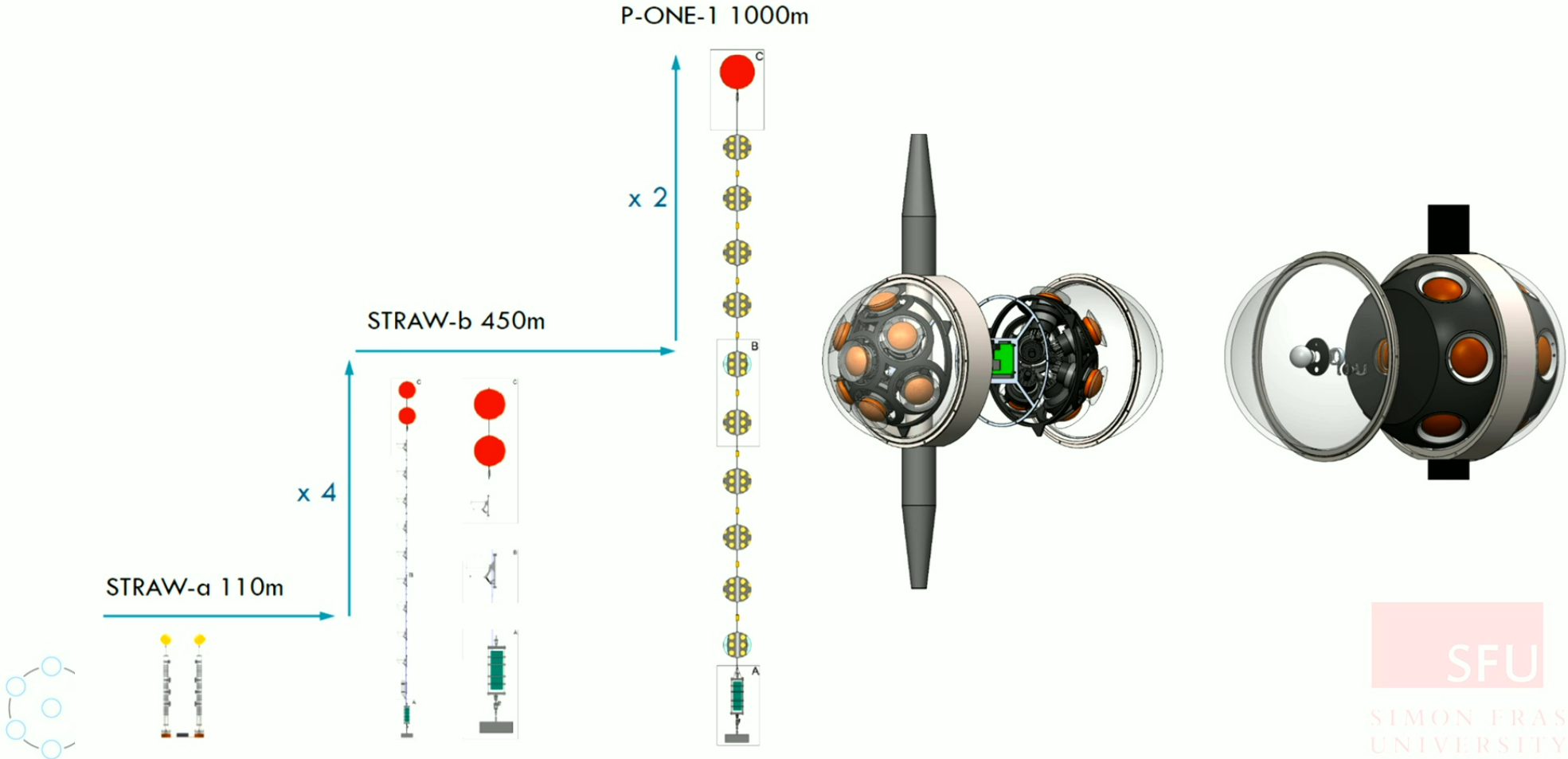
INTERDISCIPLINARY: OCEANOGRAPHY, MICROBIOLOGY,
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Towards P-ONE — prototype line (2024)

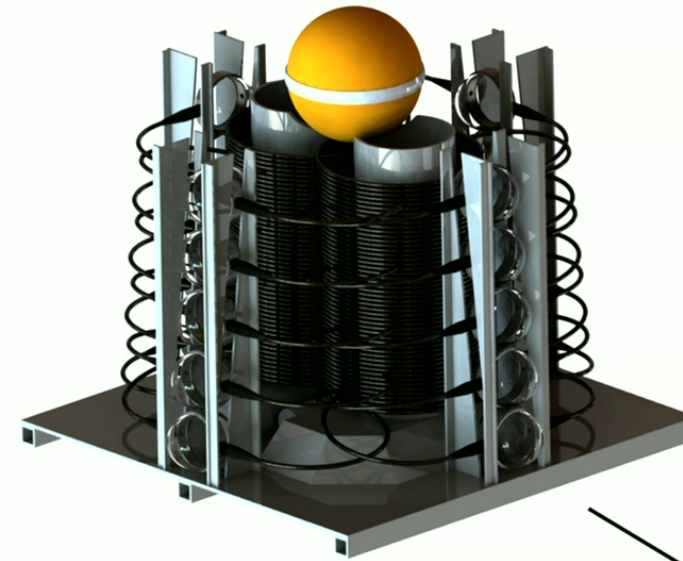
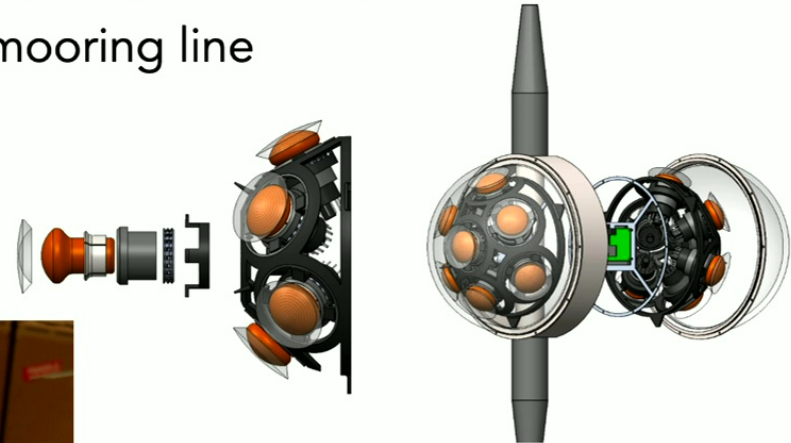
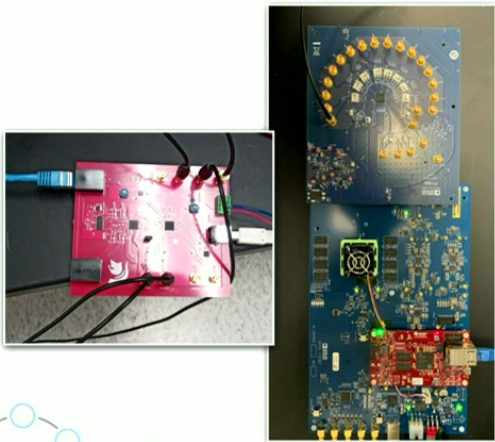


P-ONE — prototype line (2024)

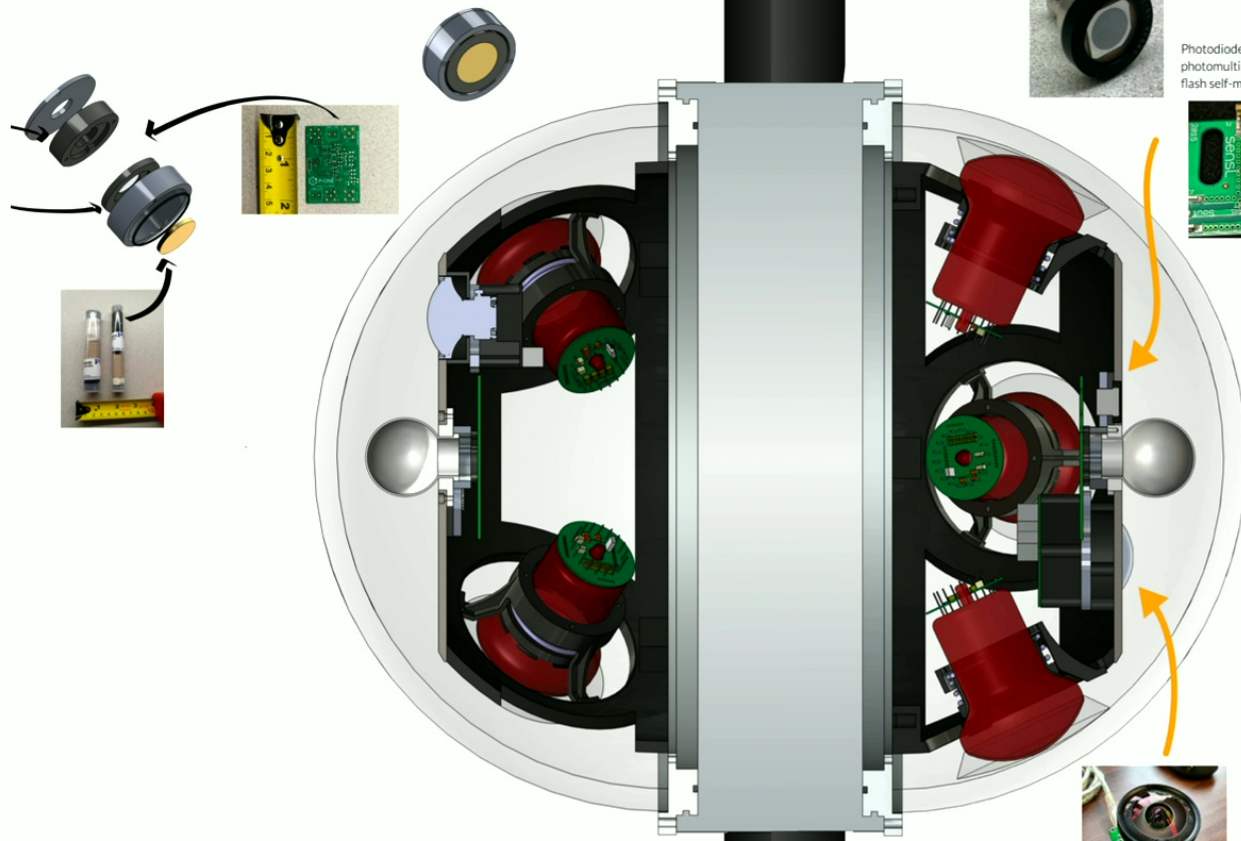


P-ONE — prototype line development (2024)

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

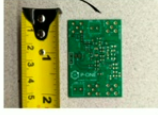


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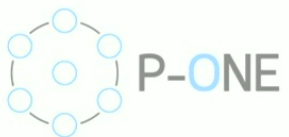


Photodiode and silicon photomultiplier used for flash self-monitoring

20



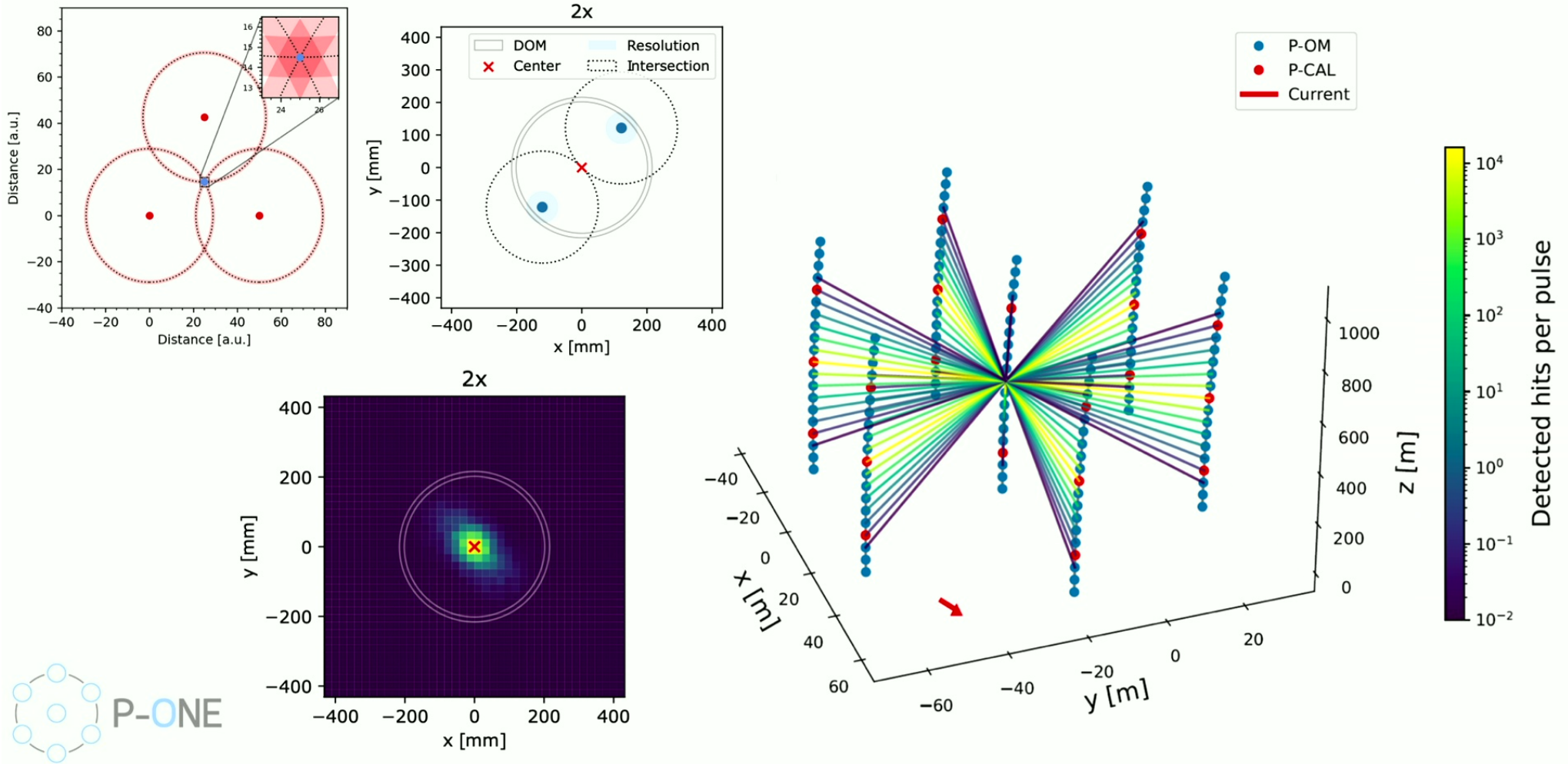
Fish-eye lens camera for monitoring bioluminescence and sedimentation



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P-ONE — prototype line (2024)



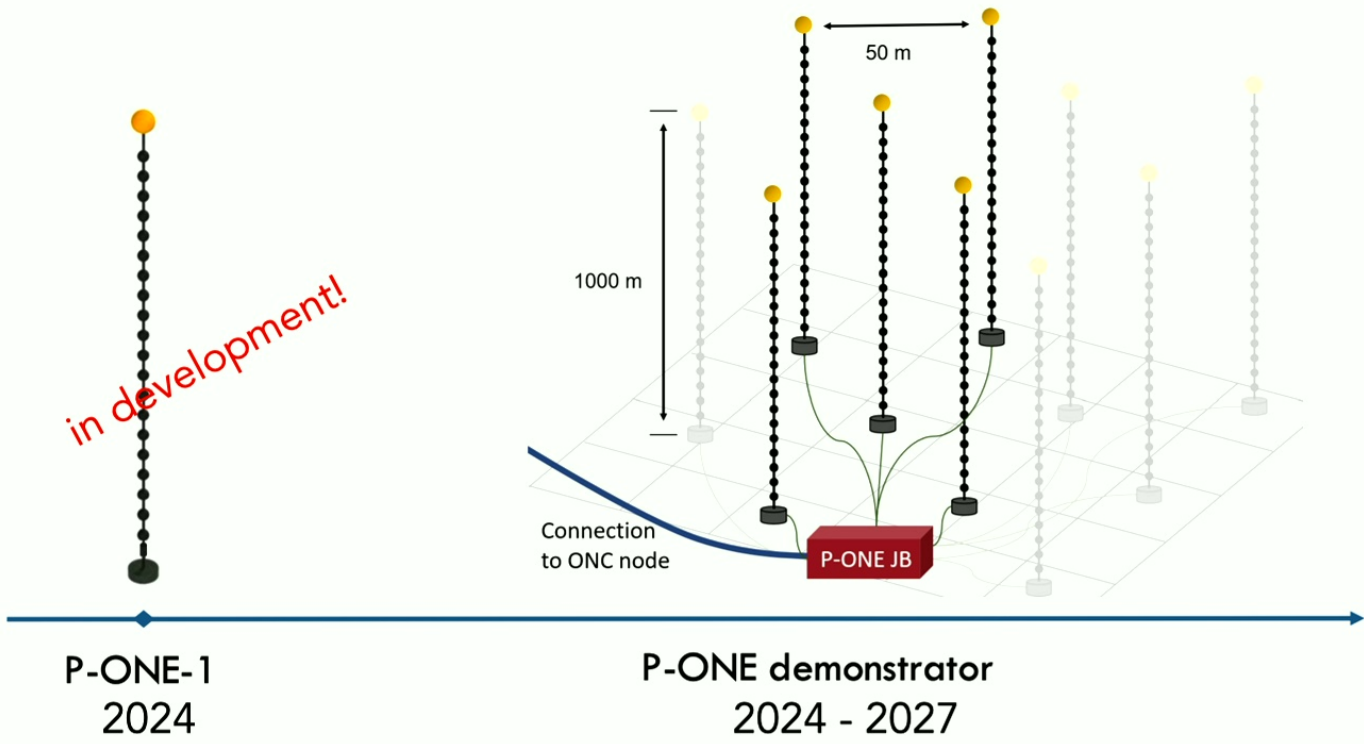
P-ONE — time-line



Proof of concept
Successful operation



P-ONE — time-line



Proof of concept
Successful operation

Atmospheric backgrounds
First neutrinos in the Pacific

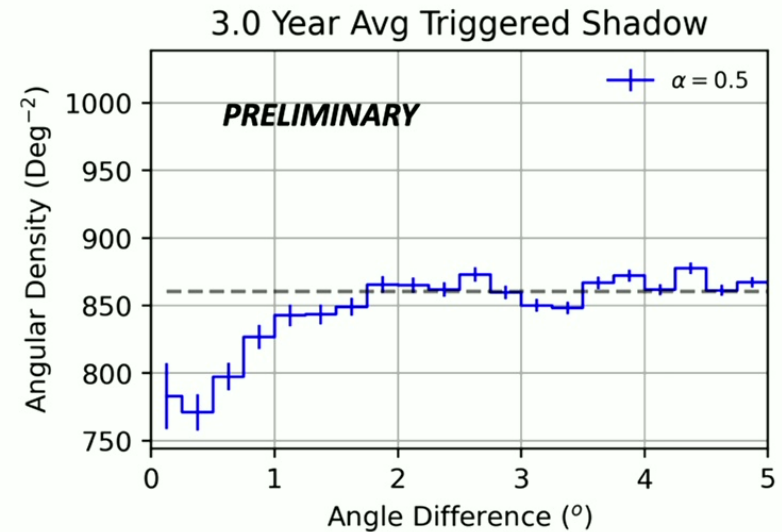
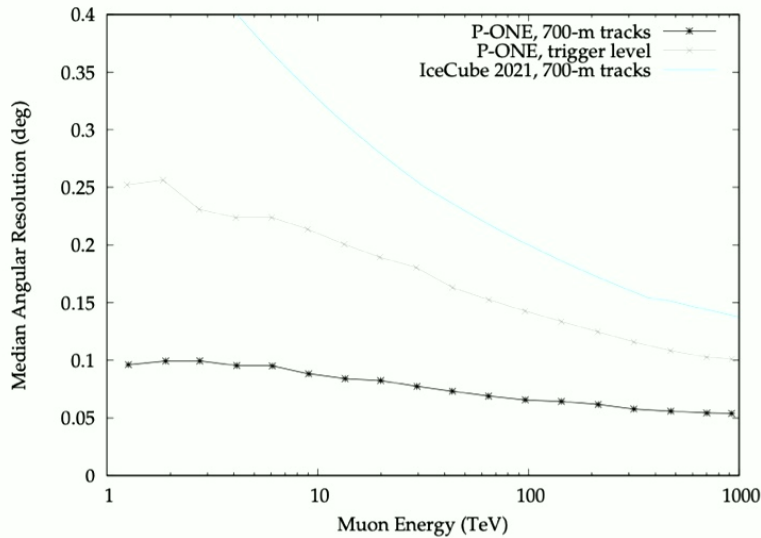


P-ONE demonstrator — Science goals

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

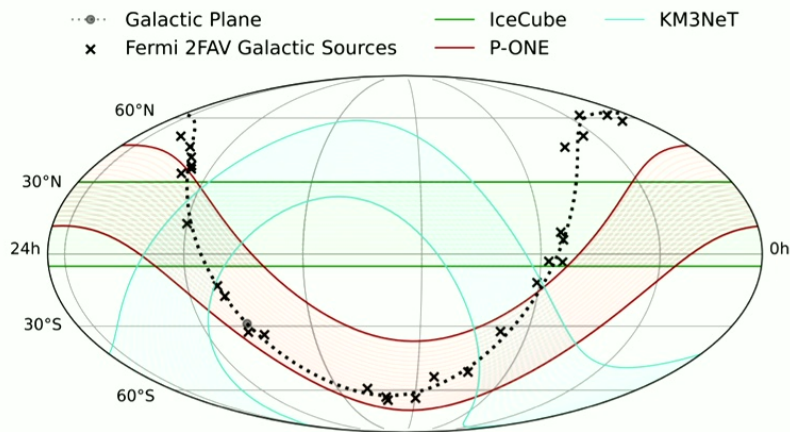


CALIBRATION! IN-SITU BACKGROUNDS,
DETECTORS, ATMOSPHERIC BACKGROUNDS



P-ONE demonstrator — Science goals

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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



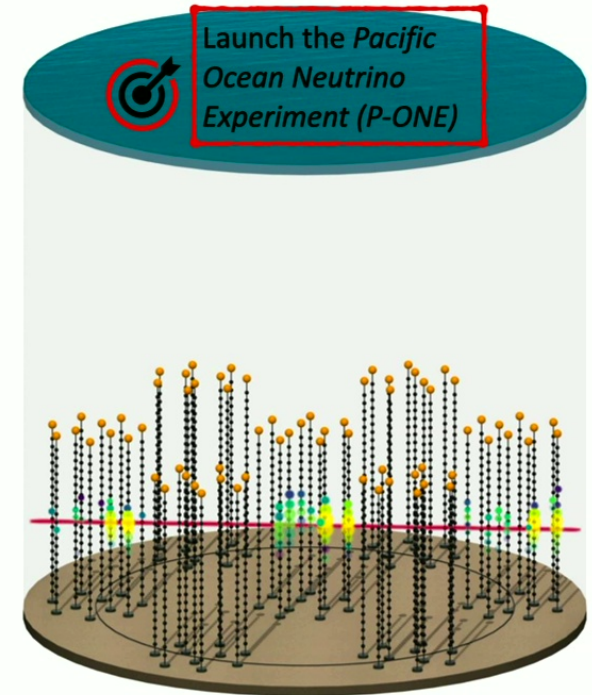
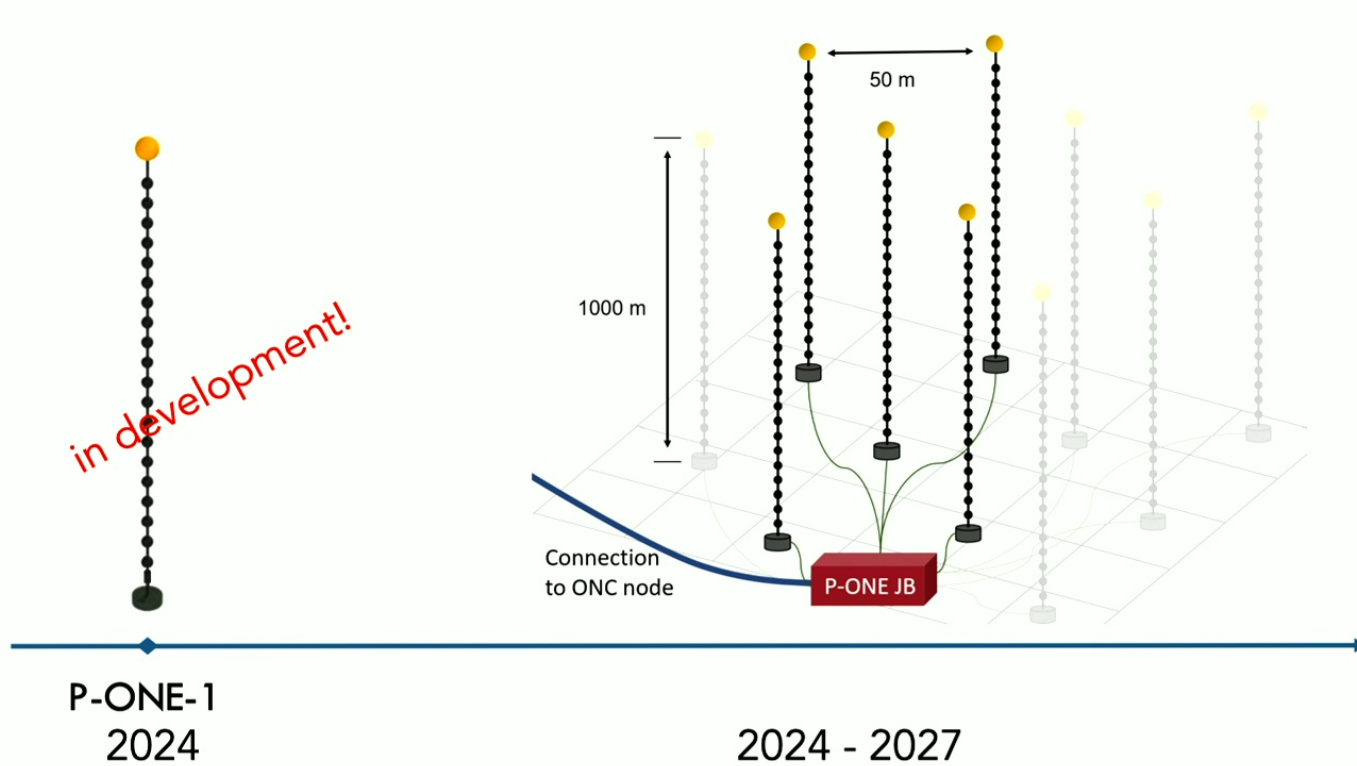
TRIGGER AN INTERNATIONAL EFFORT (P-ONE)
SYNERGETIC OPERATION ν -TELESCOPES



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SIMON FRASER
UNIVERSITY
image adapted from E. Resconi

P-ONE — time-line



Proof of concept
Successful operation

Atmospheric backgrounds
First neutrinos in the Pacific

Discoveries
International synergy

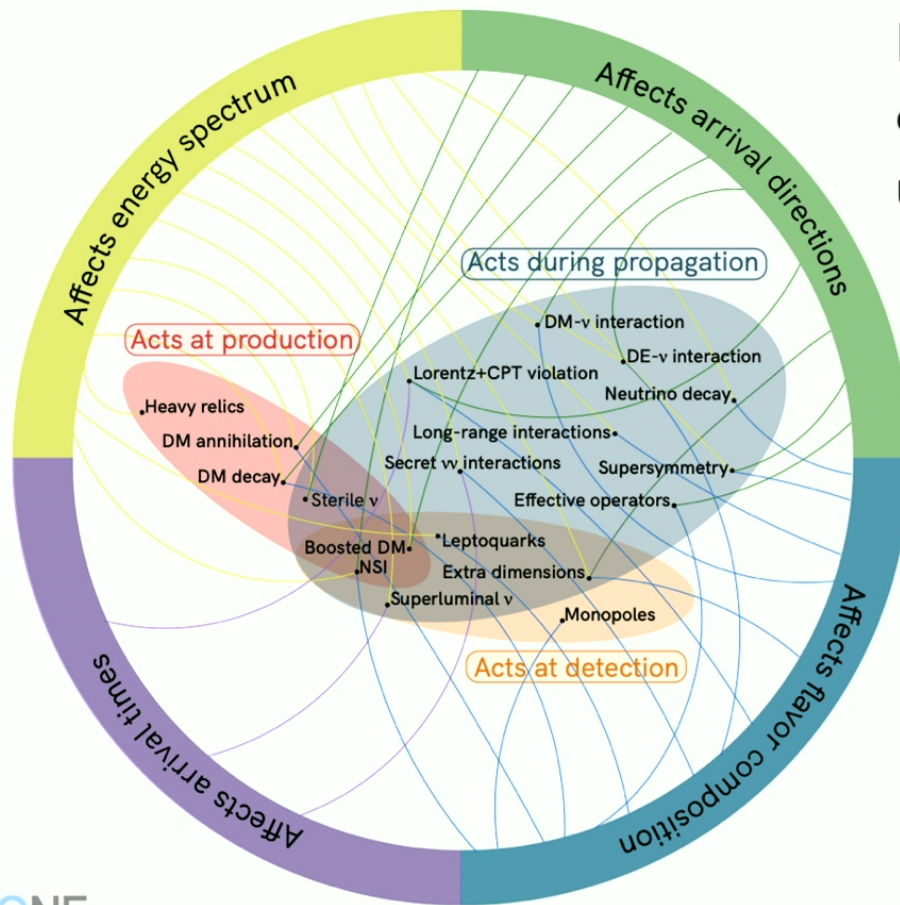


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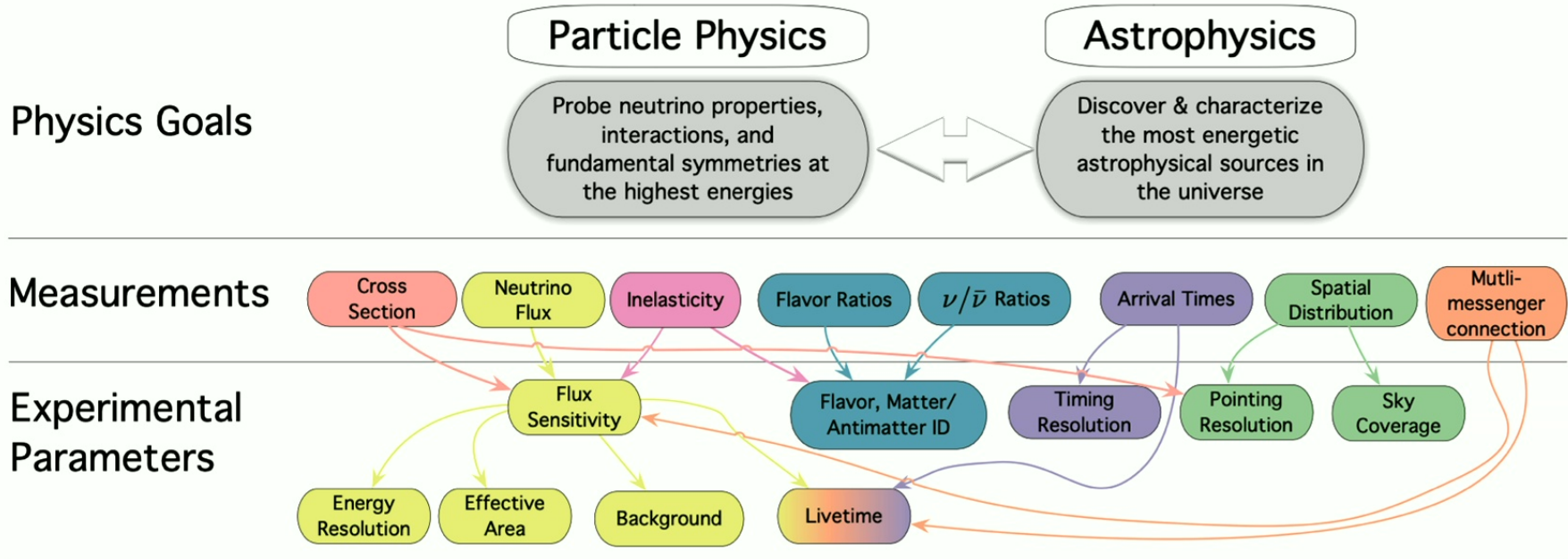
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Why high-energy neutrinos

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



Why high-energy neutrinos



Summary

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- Ocean Networks Canada is an exciting partner for deep-ocean (neutrino) physics
- P-ONE is an exciting project for Canadian-based leadership
- Project is growing fast with clear path towards P-ONE demonstrator
- Synergies to climate change studies, marine biology, oceanography are immense
- If you want to learn more: <https://www.pacific-neutrino.org/>



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Why high-energy neutrinos

