

# Pacific Ocean Neutrino Experiment

The future of high-energy neutrino detection

**Felix Henningsen**

for the P-ONE Collaboration

TRIUMF Science Week 2022

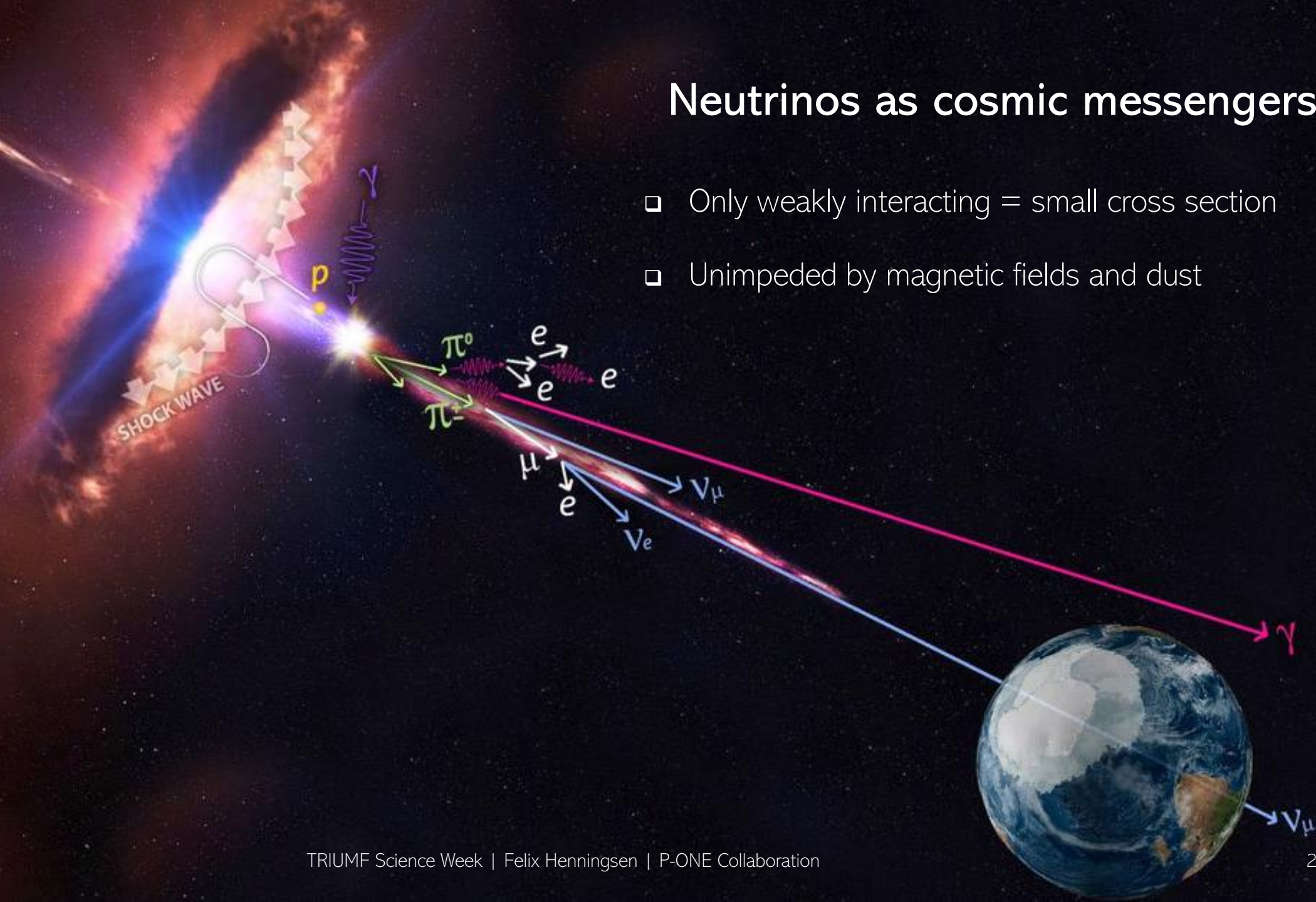


UNIVERSITY OF ALBERTA



# Neutrinos as cosmic messengers

- Only weakly interacting = small cross section
- Unimpeded by magnetic fields and dust



# Neutrino detectors

## Detection principles

- Use array of sensors in optical medium to detect **Cherenkov light** of neutrino secondaries

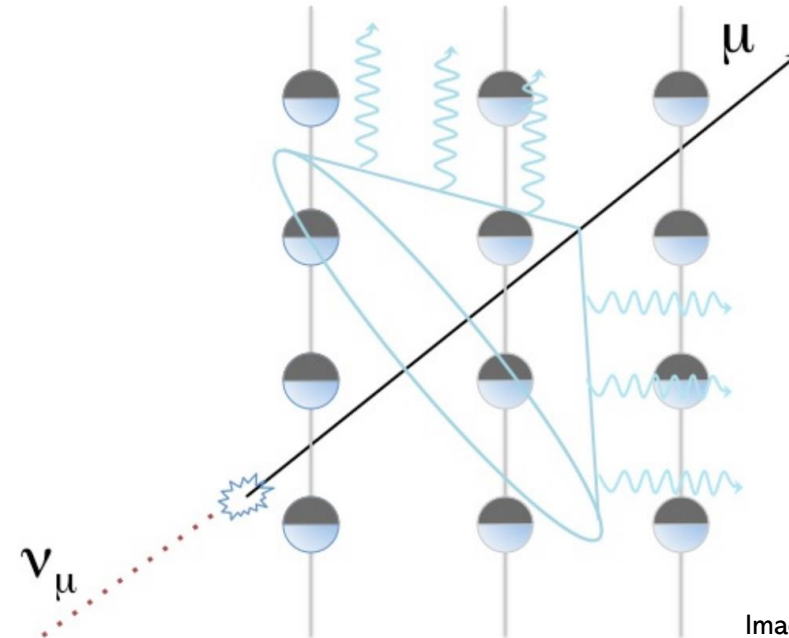


Image M. Danninger



# Neutrino detectors

## Detection principles

- ❑ Use array of sensors in optical medium to detect **Cherenkov light** of neutrino secondaries
- ❑ Low flux = require **gigantic** volumes
- ❑ Natural detector media are used
  - Ocean, lakes, glaciers

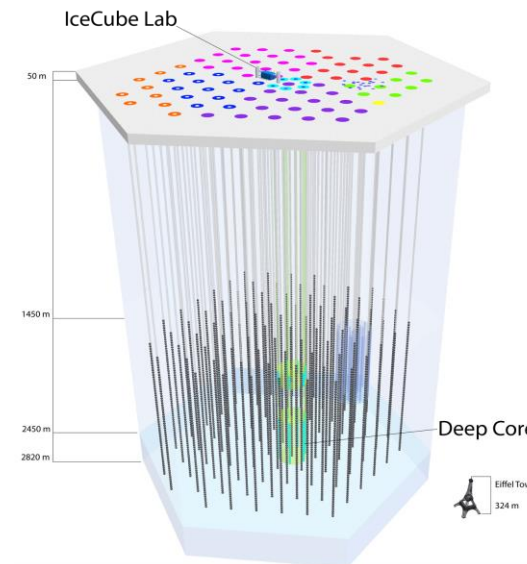


Image IceCube Collaboration (in operation since 2010)

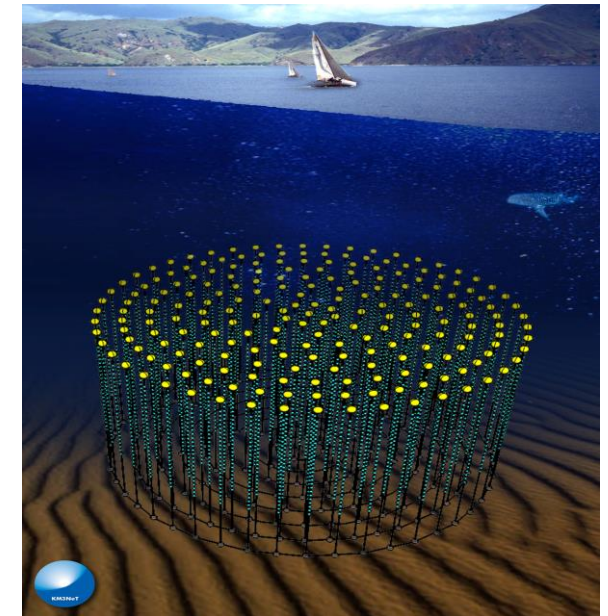


Image KM3NeT Collaboration (in construction since 2015)

# Neutrino detectors

## Global effort

- ❑ Use array of sensors in optical medium to detect **Cherenkov light** of neutrino secondaries
- ❑ Low flux = require **gigantic** volumes
- ❑ Natural detector media are used
  - Ocean, lakes, glaciers
- ❑ Global experimental effort
  - **Experiments** IceCube, KM3NeT, GVD, P-ONE
  - **Medium** Water, ice
  - **Energies** GeV – PeV

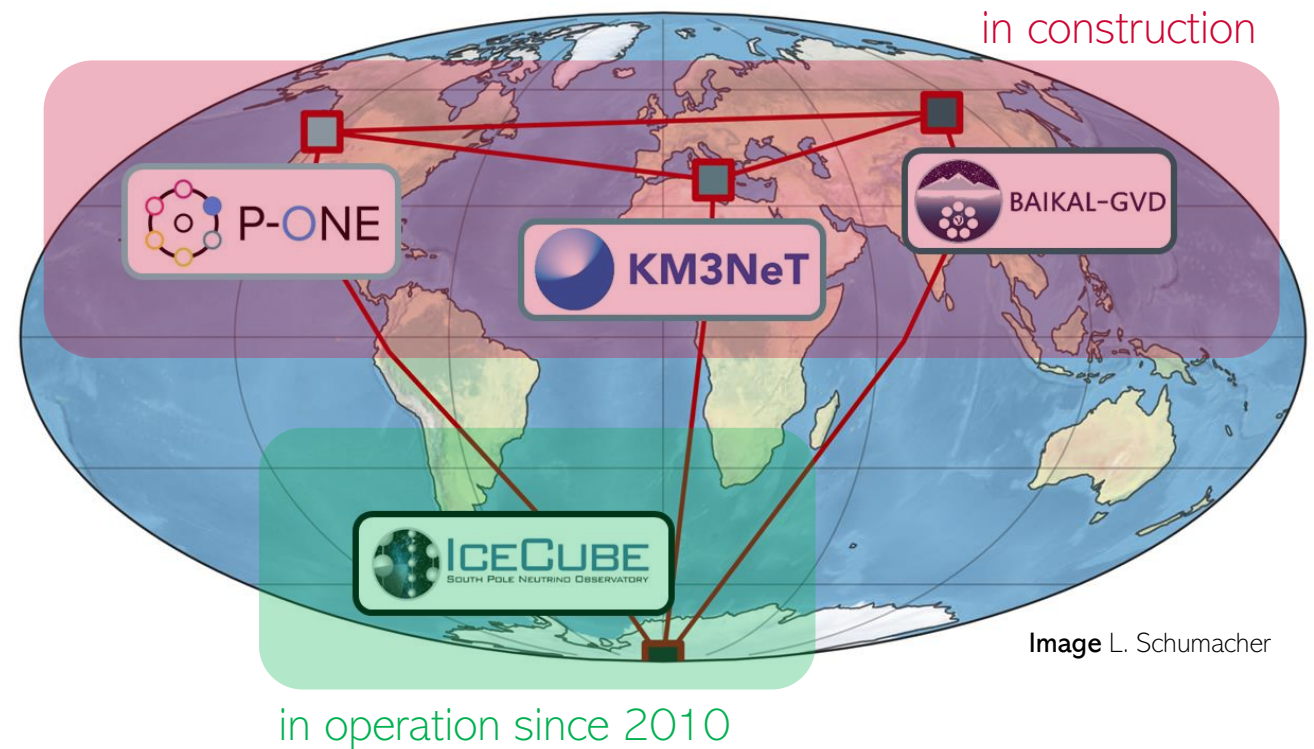


Image L. Schumacher

# Neutrino detectors

## Global effort

- Use array of sensors in optical medium to detect **Cherenkov light** of neutrino secondaries
- Low flux → require large detection volumes
- Natural sources
  - Ocean, atmosphere
- Global experimental effort
  - Experiments IceCube, KM3NeT, GVD, P-ONE
  - Medium Water, ice
  - Energies GeV – PeV

**Water construction, operation and maintenance are challenging...**



Image L. Schumacher

# The Pacific Ocean Neutrino Experiment



What's different?

- ❑ Deep-sea optical cable network operated by **Ocean Networks Canada** (completed 2009)
- ❑ Annual budget ~\$27M (CDN)

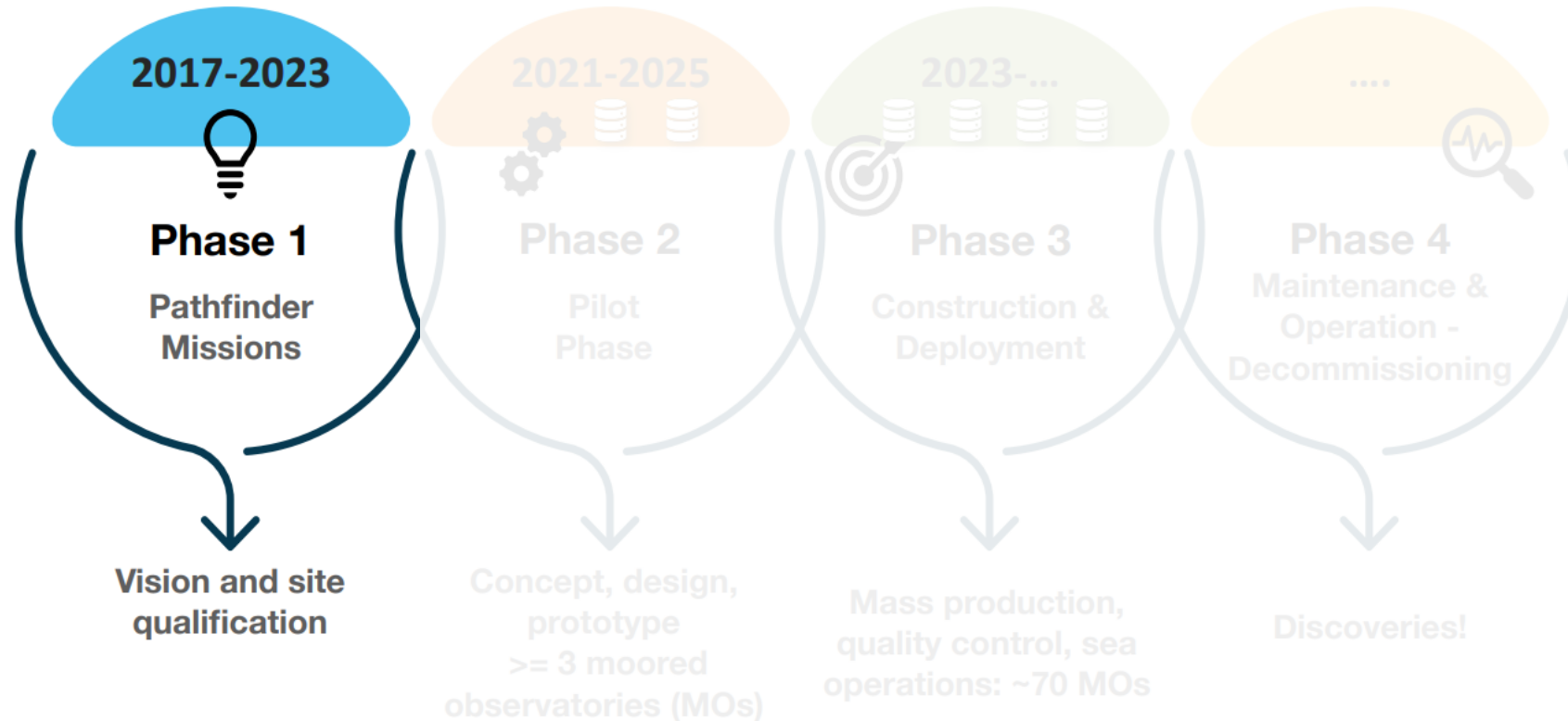




# The Pacific Ocean Neutrino Experiment



## Phase 1: Pathfinders

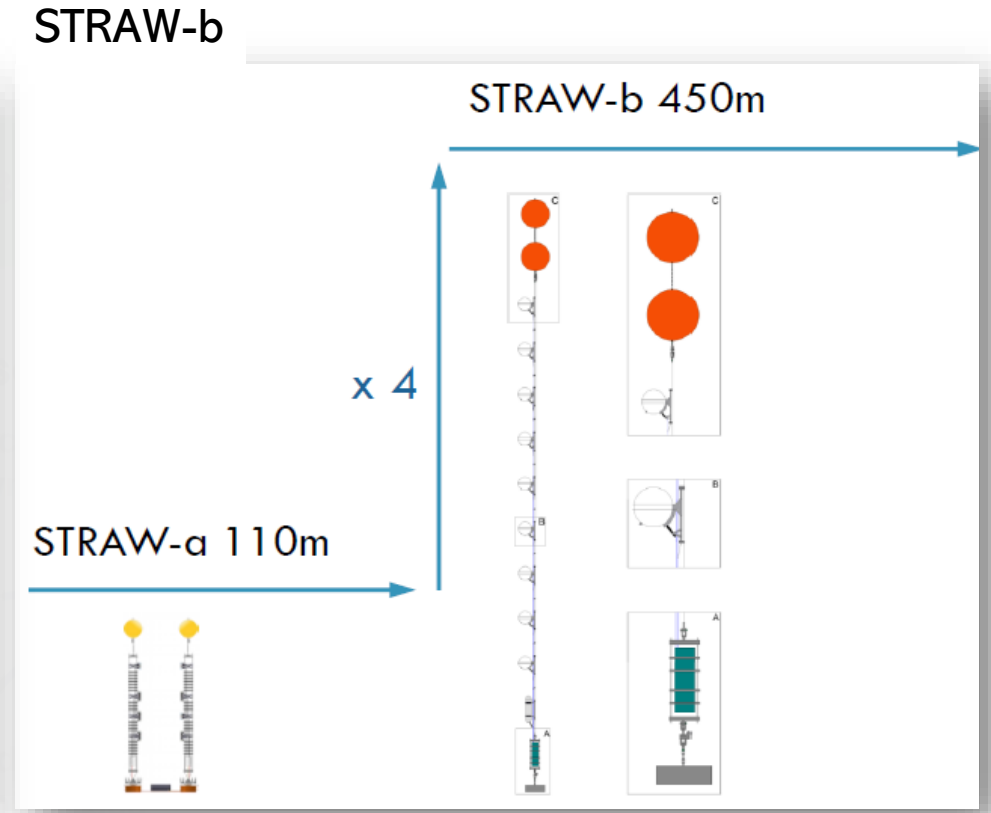
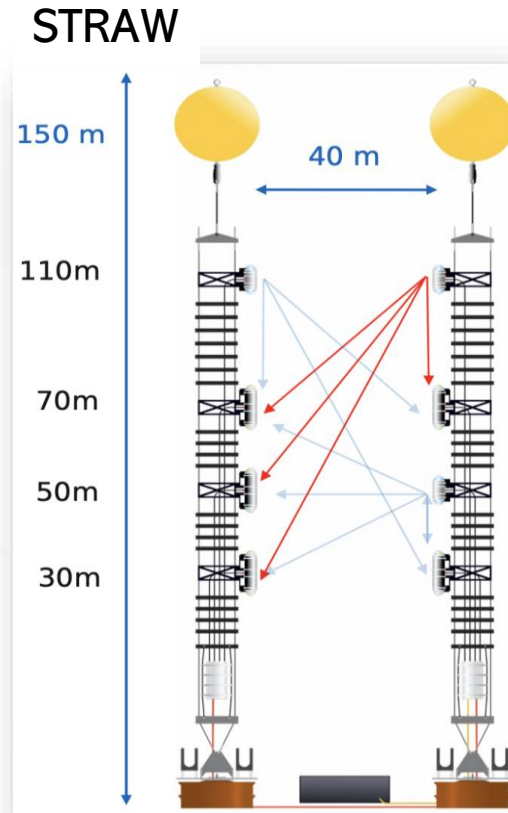




# The Pacific Ocean Neutrino Experiment



## Phase 1: Pathfinders

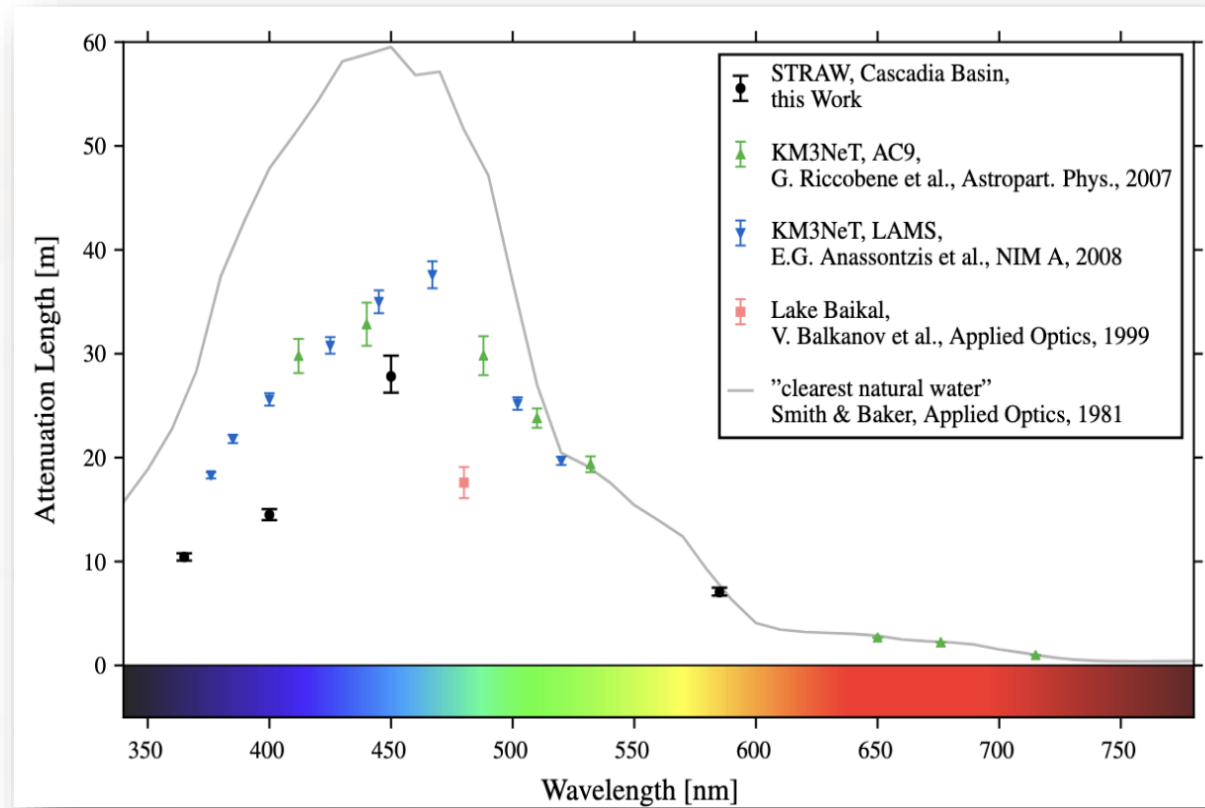
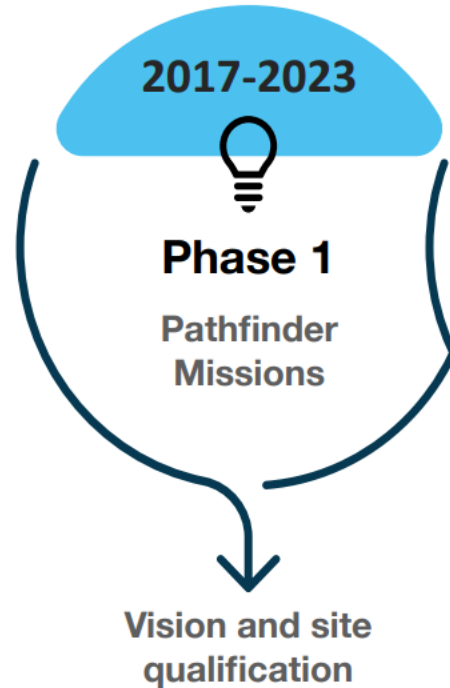


**Publications** JINST 14 P02013 (2019) – Nature Astronomy 4(2020) – Eur. Phys. J. C **81**, 1071 (2021)

# The Pacific Ocean Neutrino Experiment



## Phase 1: Pathfinders

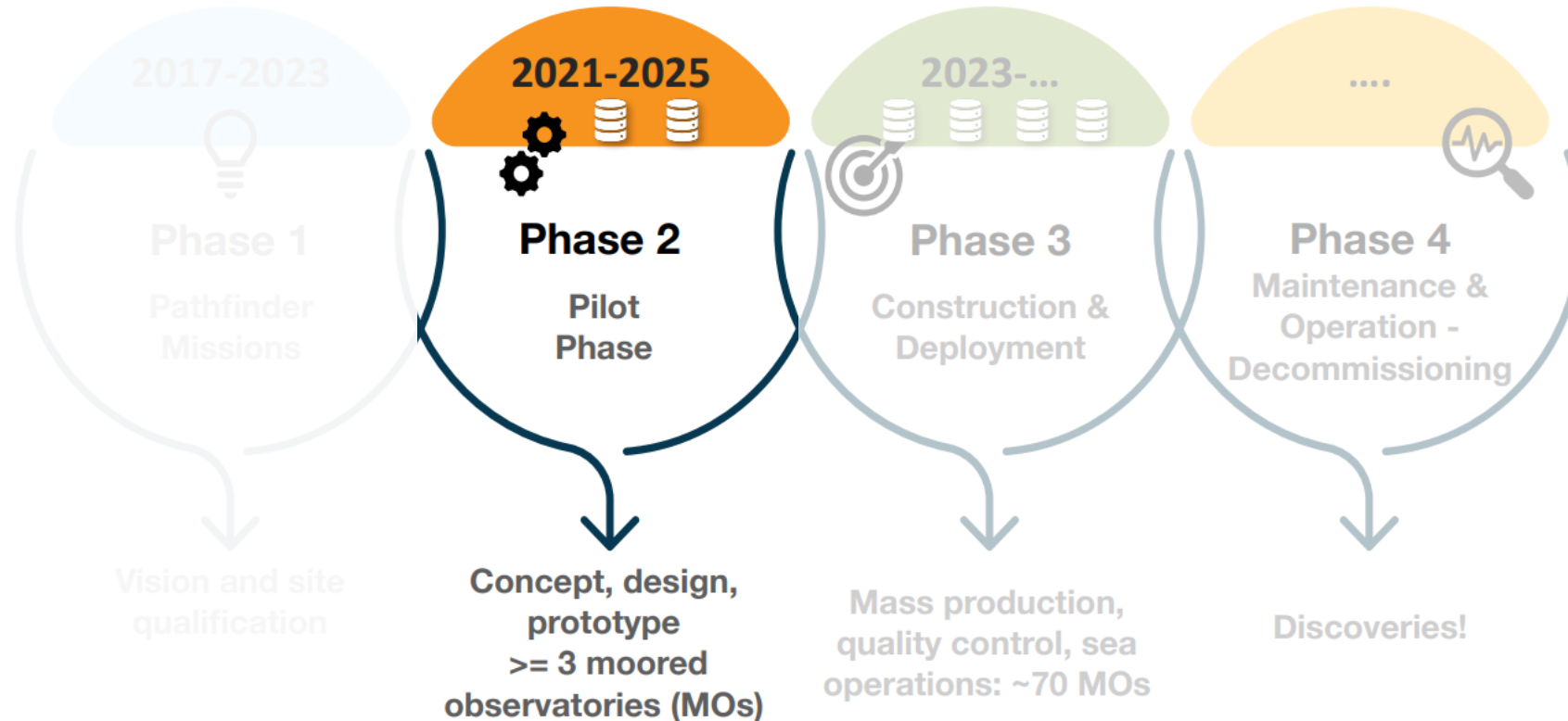


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# The Pacific Ocean Neutrino Experiment



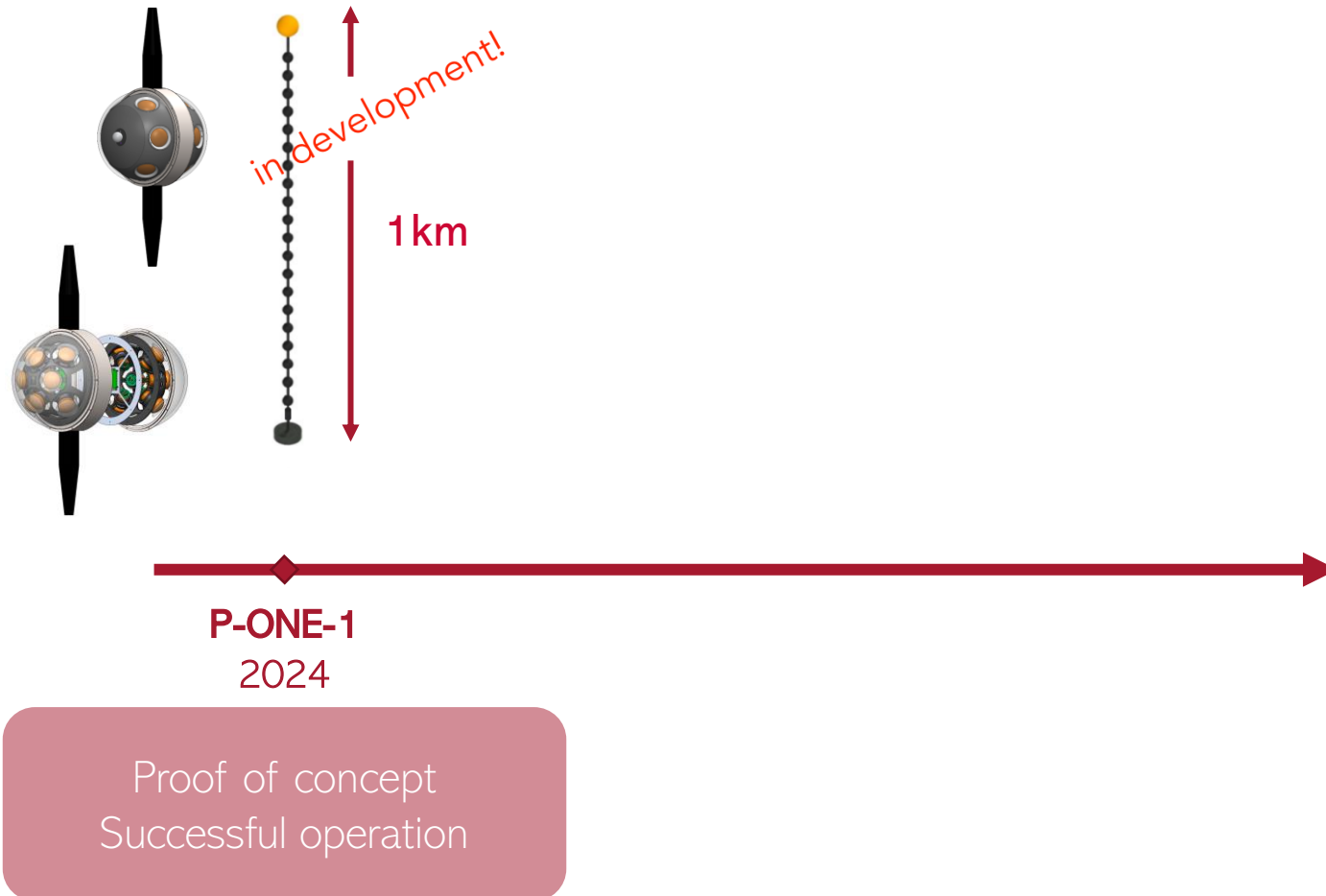
## Phase 2: Project status



# The Pacific Ocean Neutrino Experiment



Phase 2: Project status

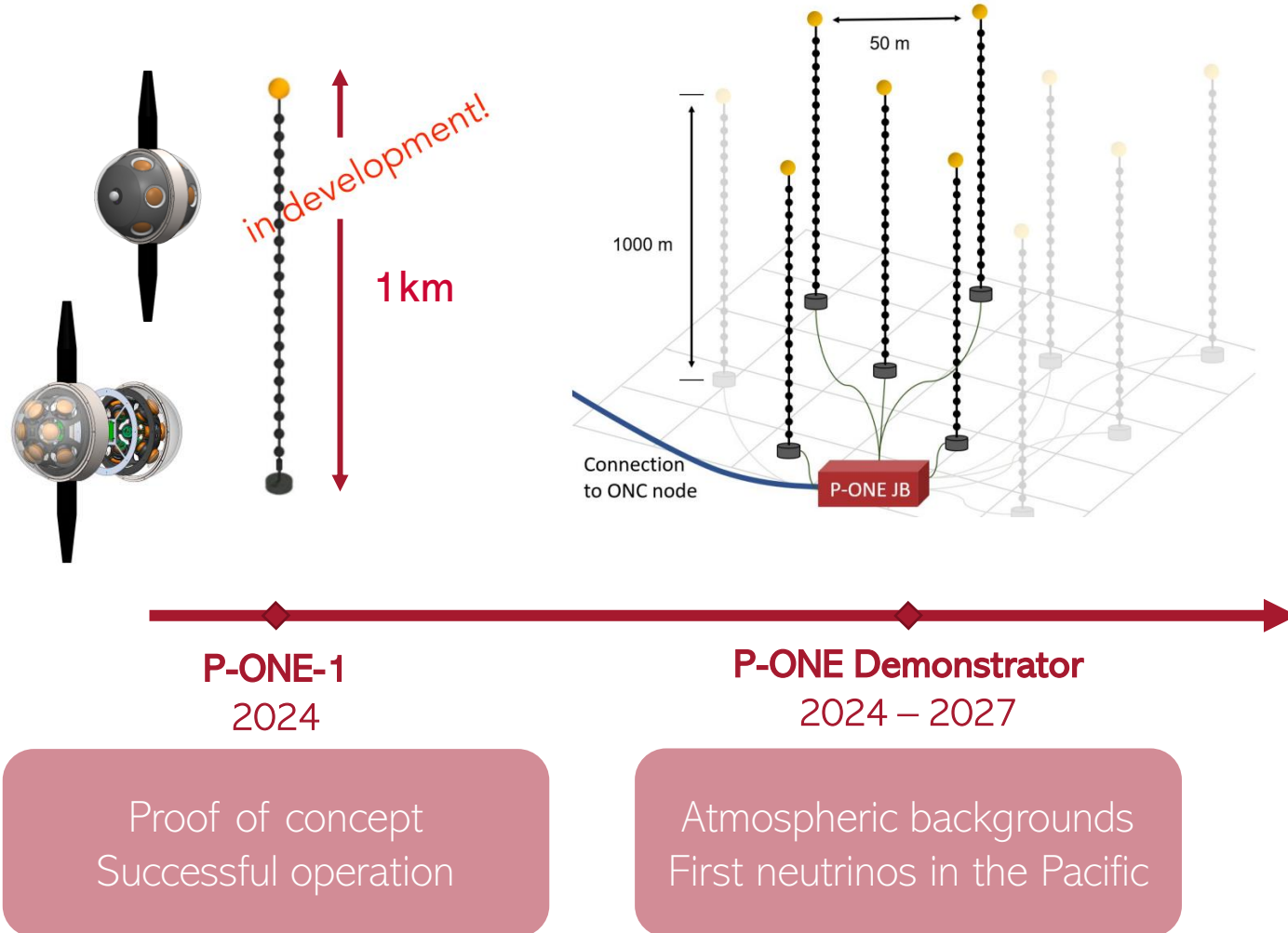




# The Pacific Ocean Neutrino Experiment



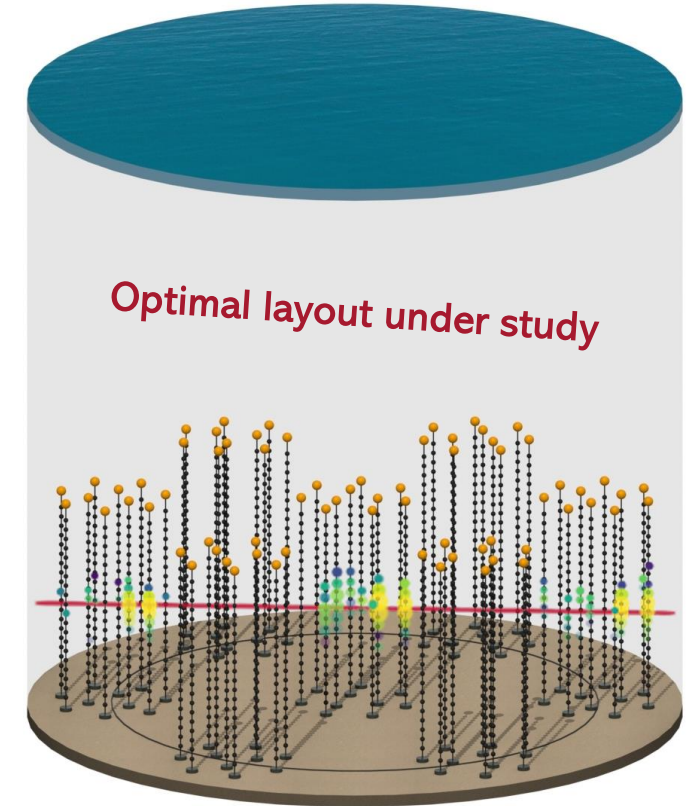
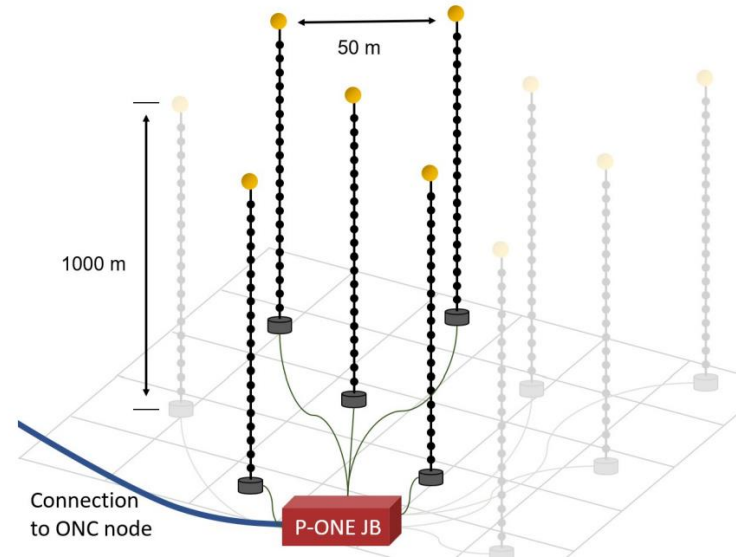
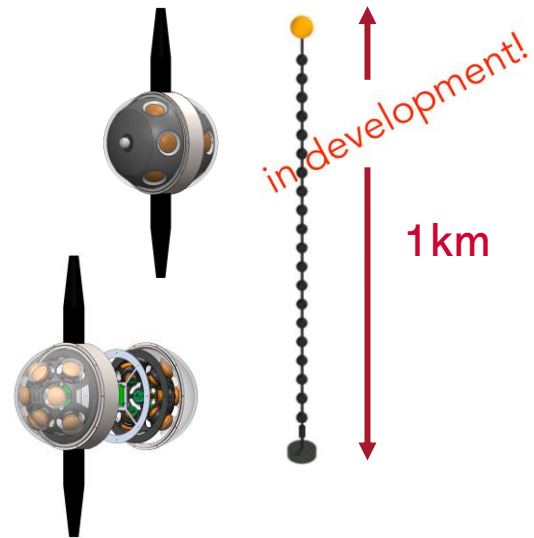
Phase 2: Project status



# The Pacific Ocean Neutrino Experiment



Phase 2: Project status



Proof of concept  
Successful operation

Atmospheric backgrounds  
First neutrinos in the Pacific

Discoveries  
International synergy

# The Pacific Ocean Neutrino Experiment



Key innovations

**Key 1** Hosted by professional deep-sea infrastructure

**Key 2** Integrated cable design

**Key 3** Hybrid detection / calibration module

**Key 4** Full waveform digitization

**Key 5** Unprecedented pointing + particle identification

Successful operation

First neutrinos in the Pacific

International synergy

# Final thoughts



DEPARTMENT  
OF PHYSICS



- ❑ **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
- ❑ New collaborators are welcome to join our efforts!

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



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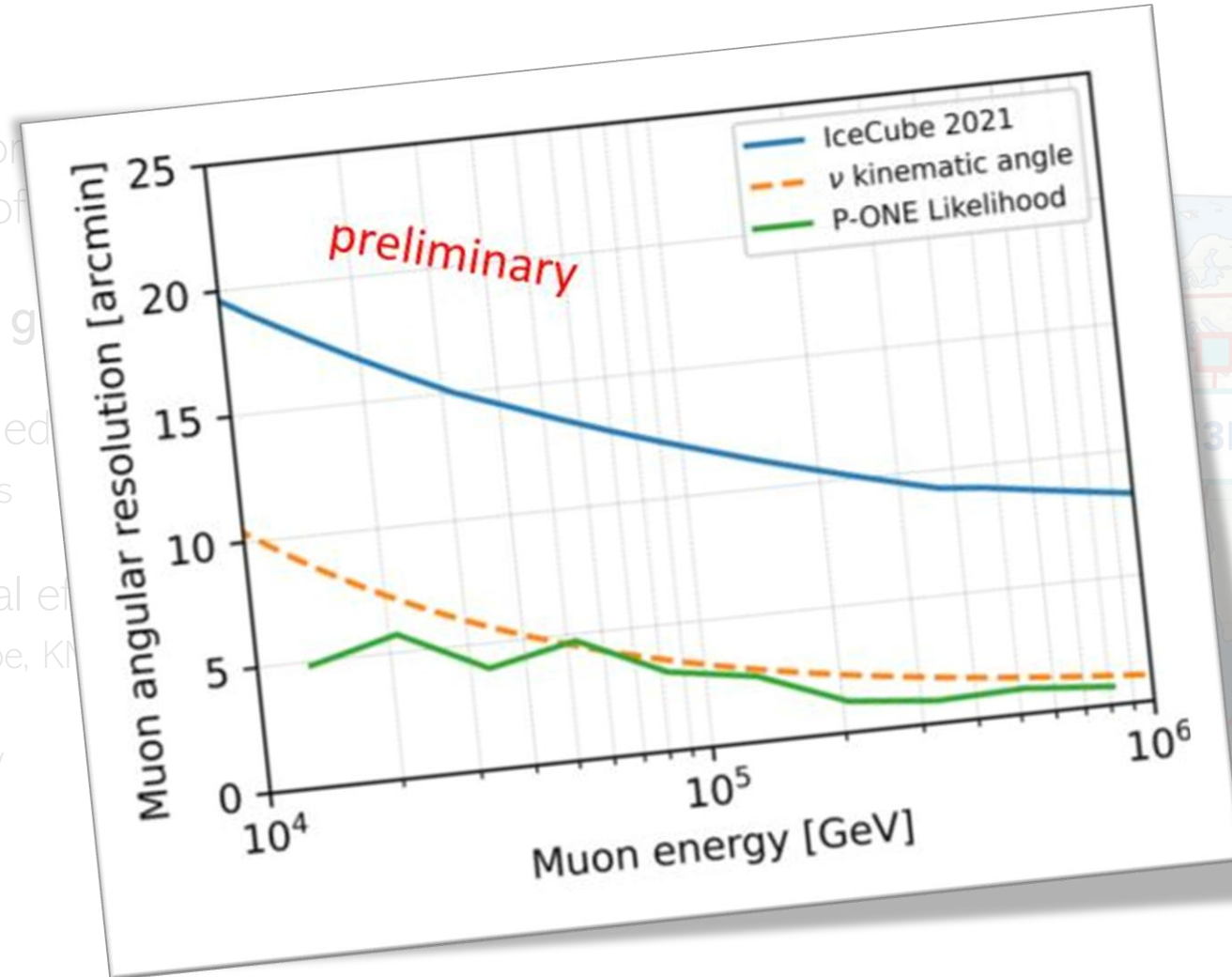




# Neutrino detectors

## Global effort

- Use array of sensors to detect Cherenkov light of muons
- Low flux = require global effort
- Natural detector media
  - Ocean, lakes, glaciers
- Global experimental effort
  - Experiments IceCube, KM3NeT, Baikal-GVD
  - Medium Water, ice
  - Energies GeV – PeV

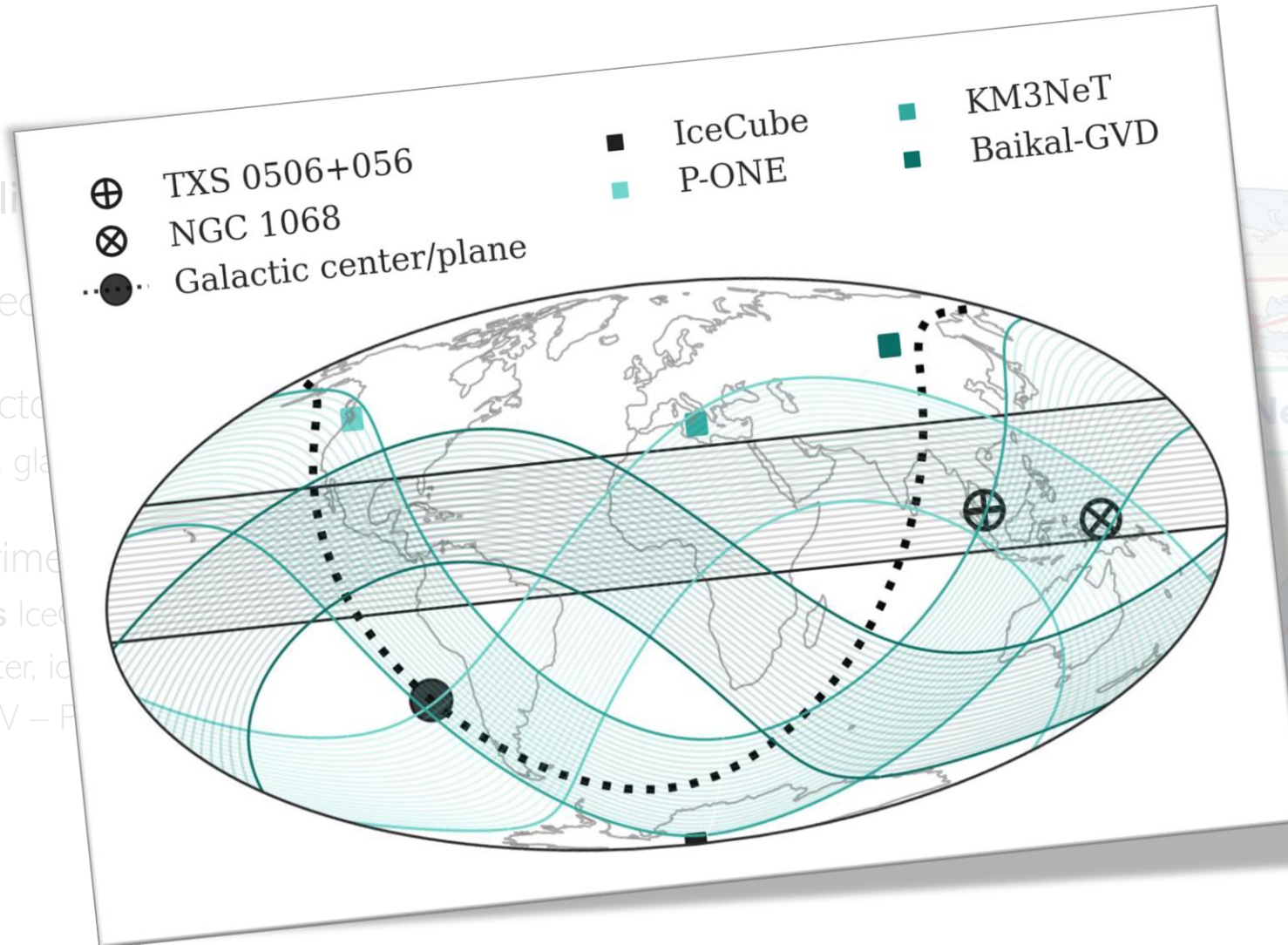


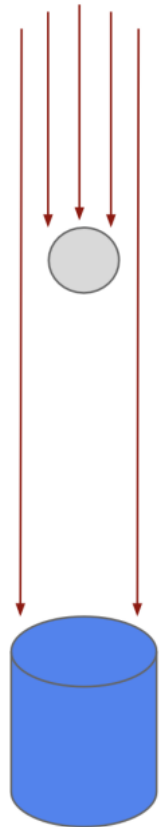
# Neutrino detectors



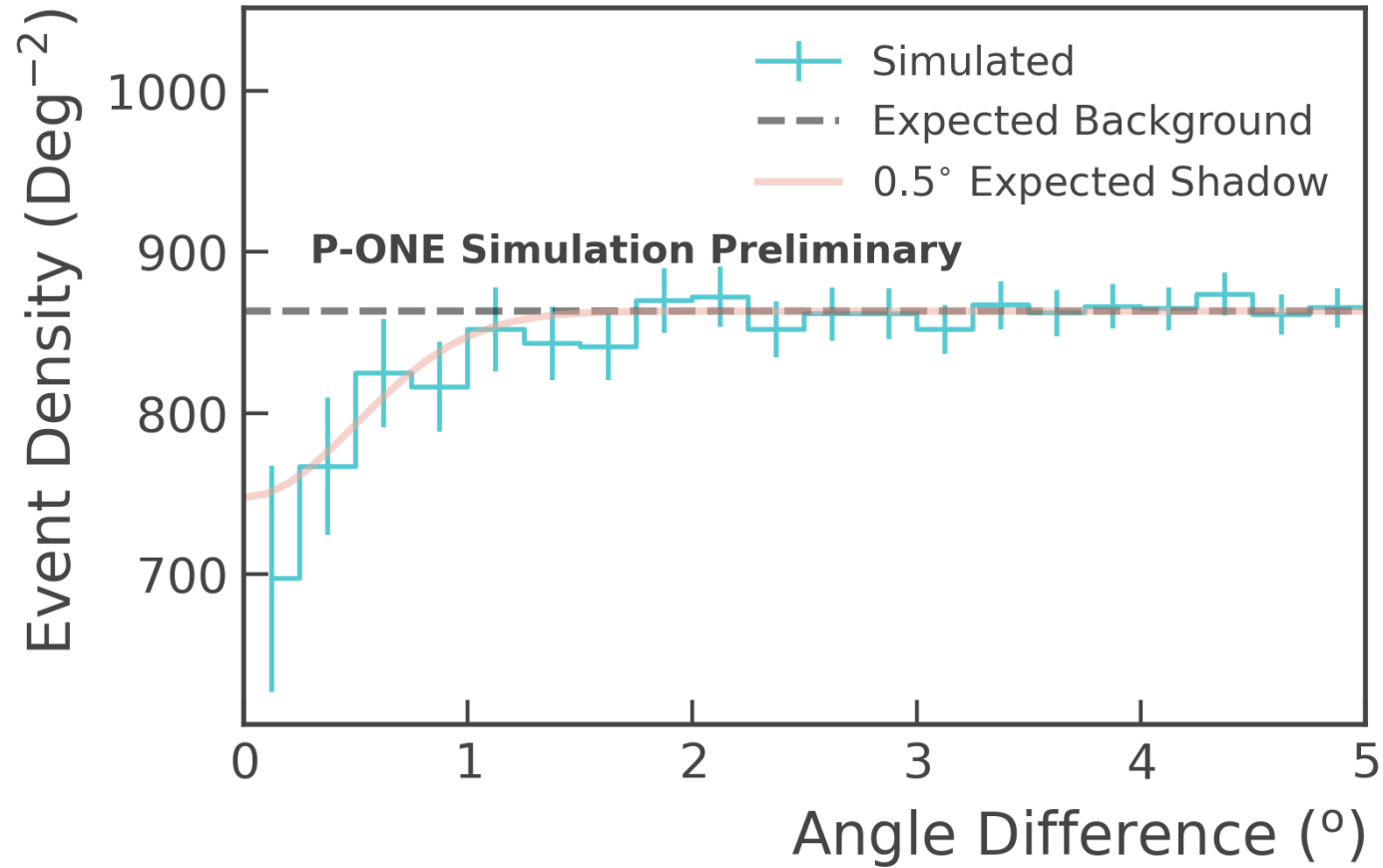
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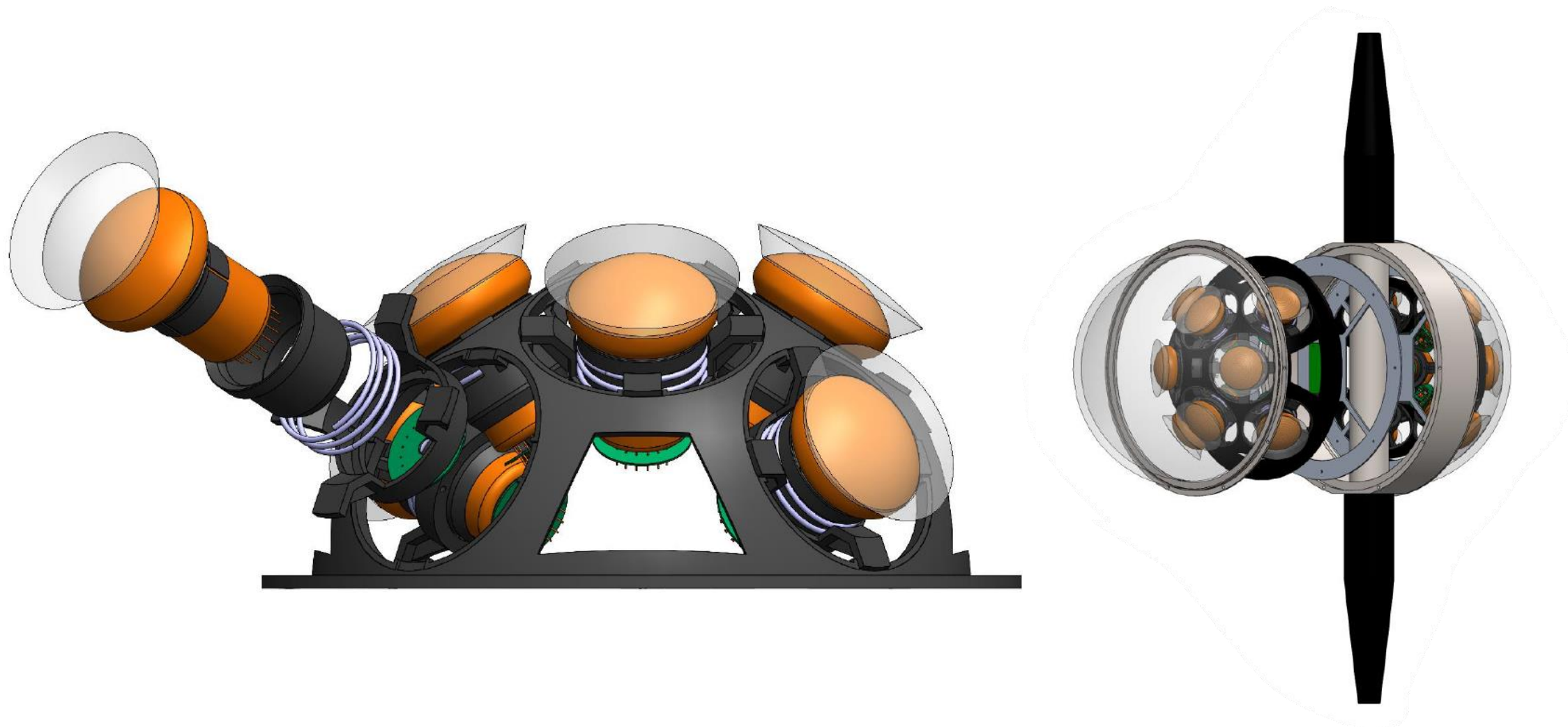




## 3 Year Avg Moon Shadow

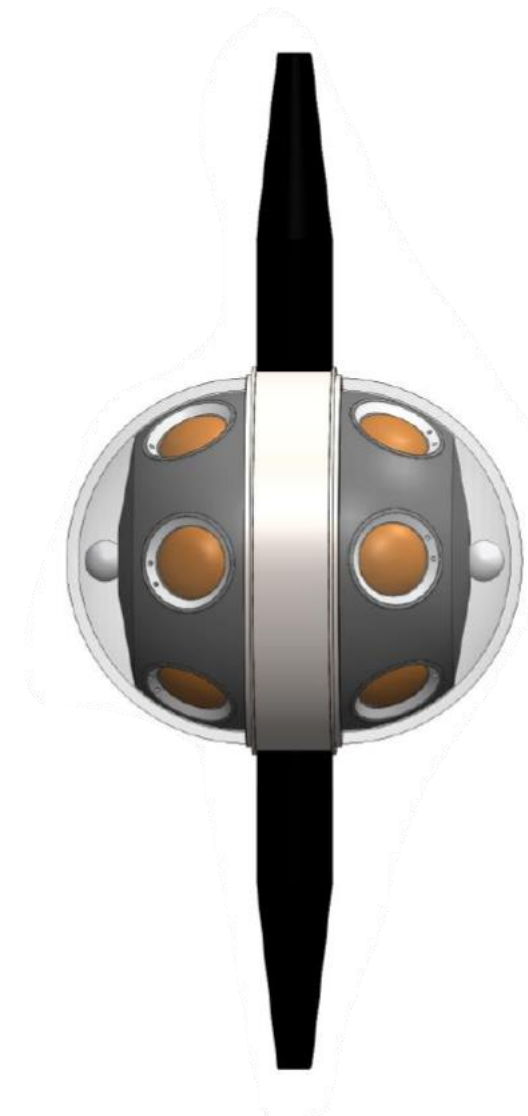


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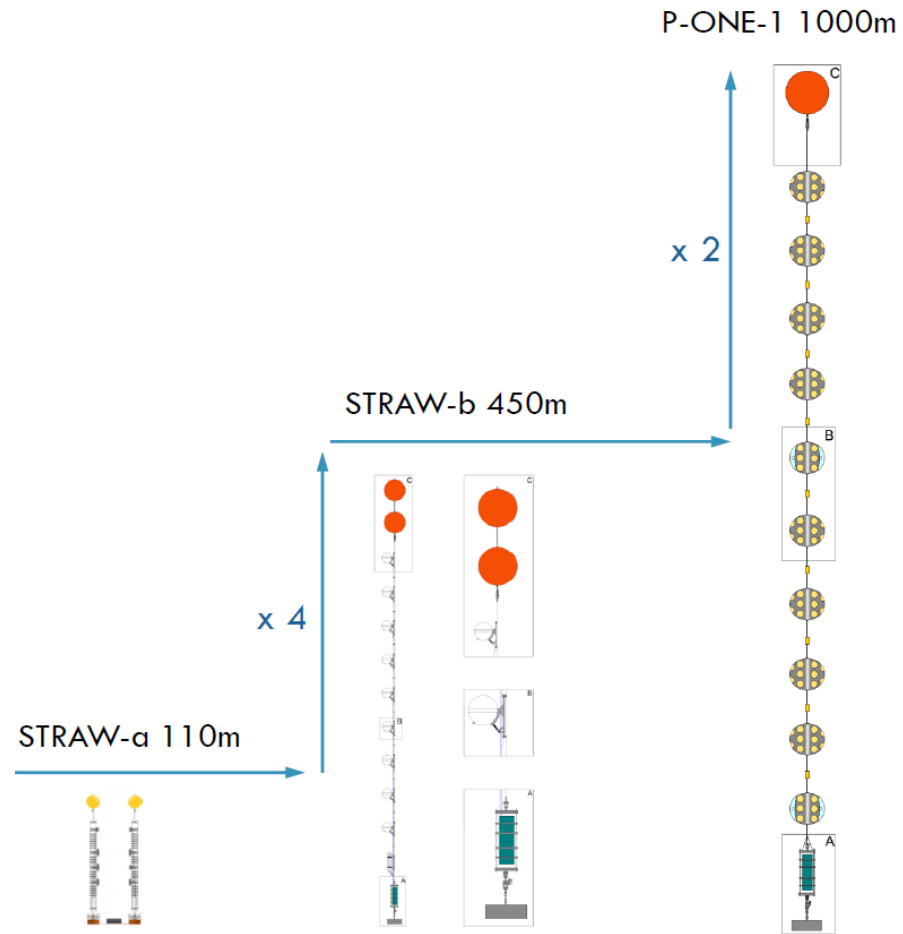




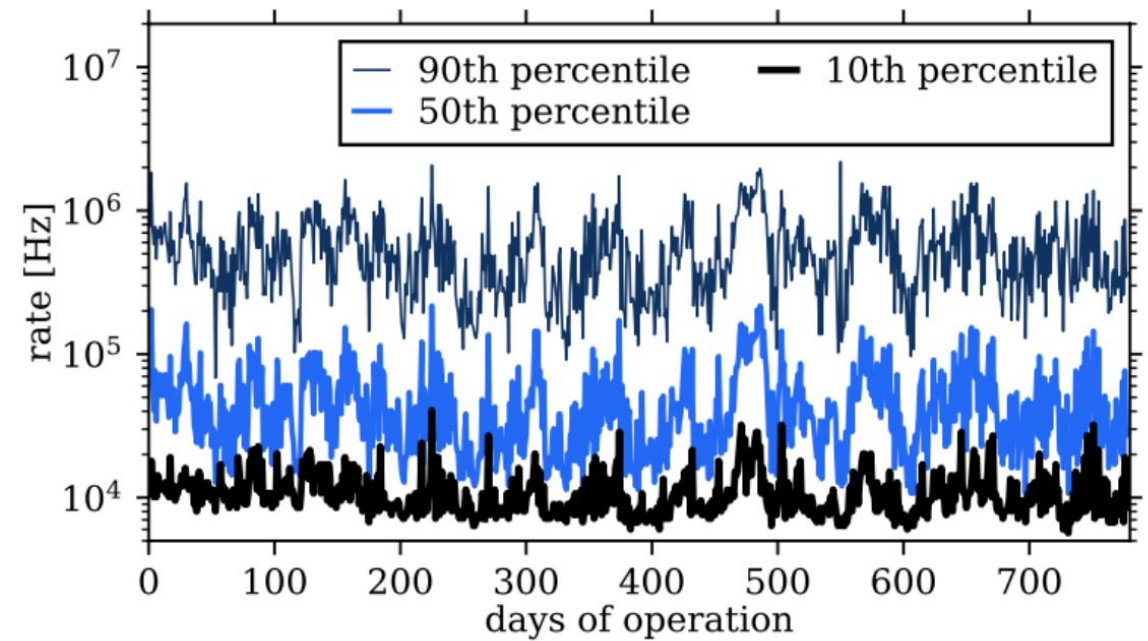
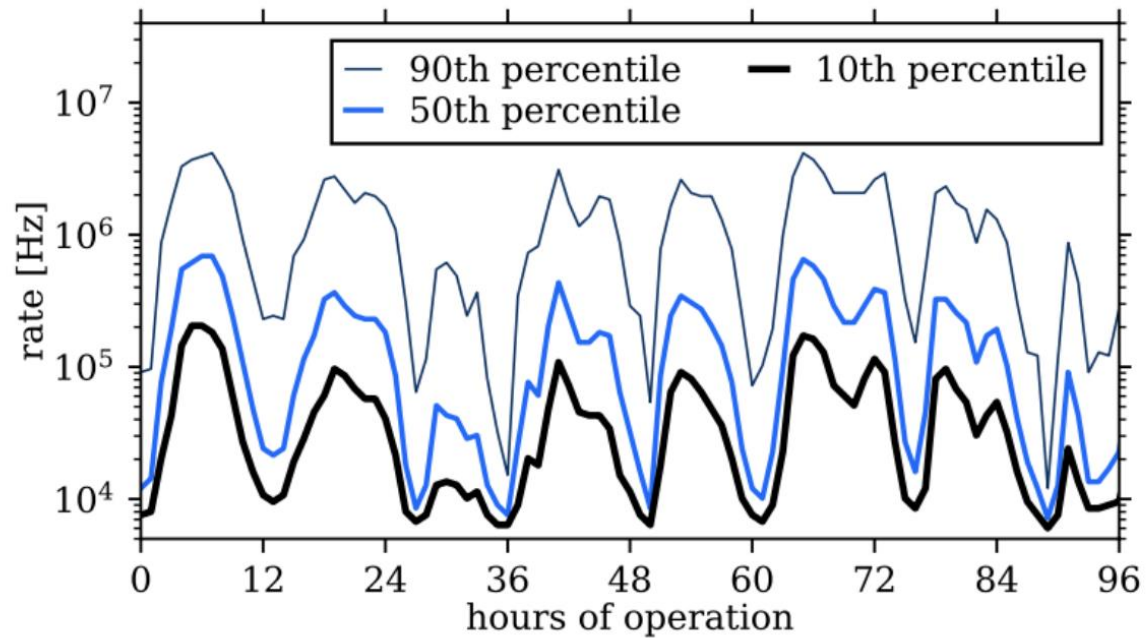
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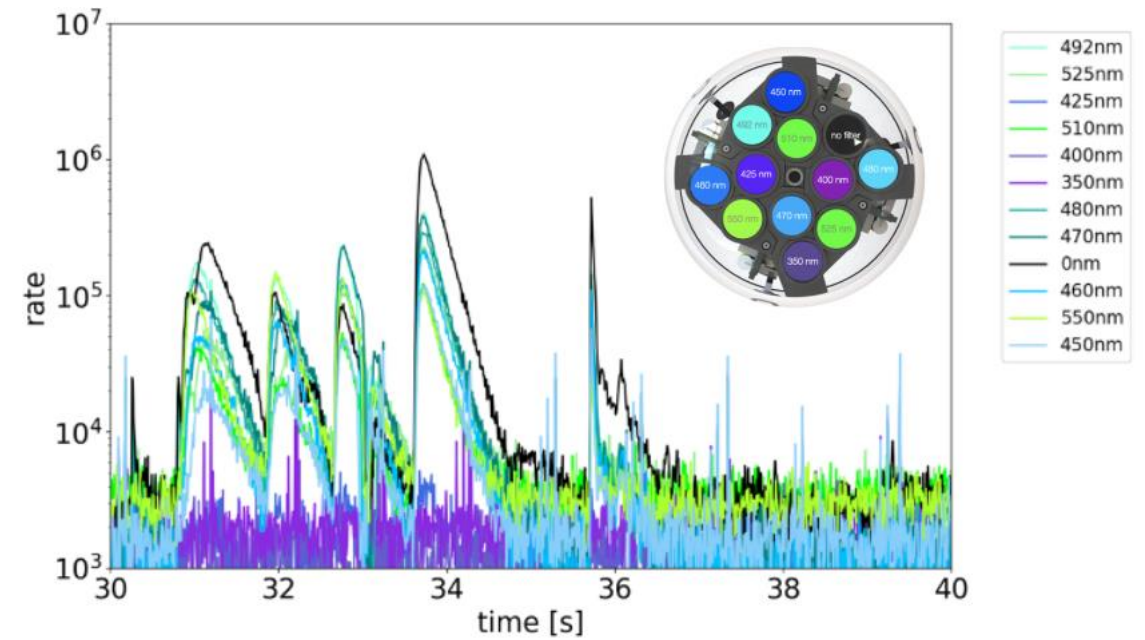
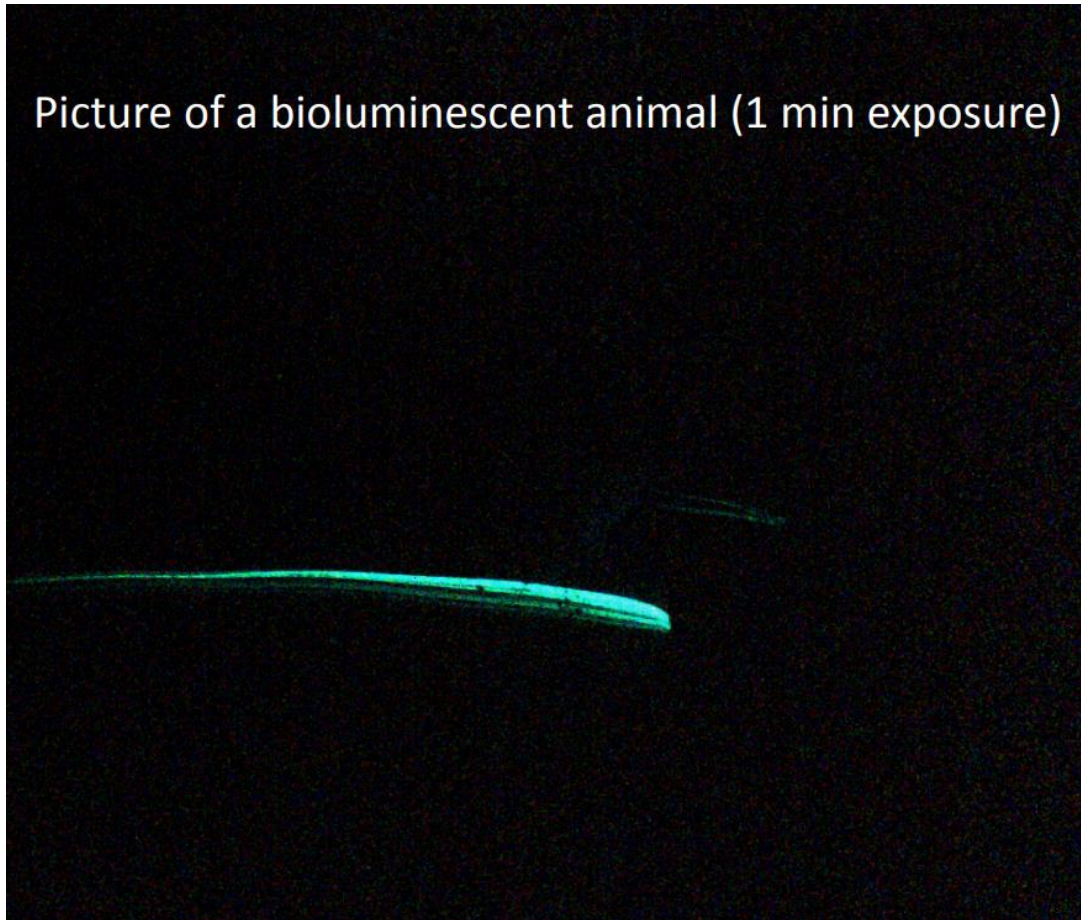
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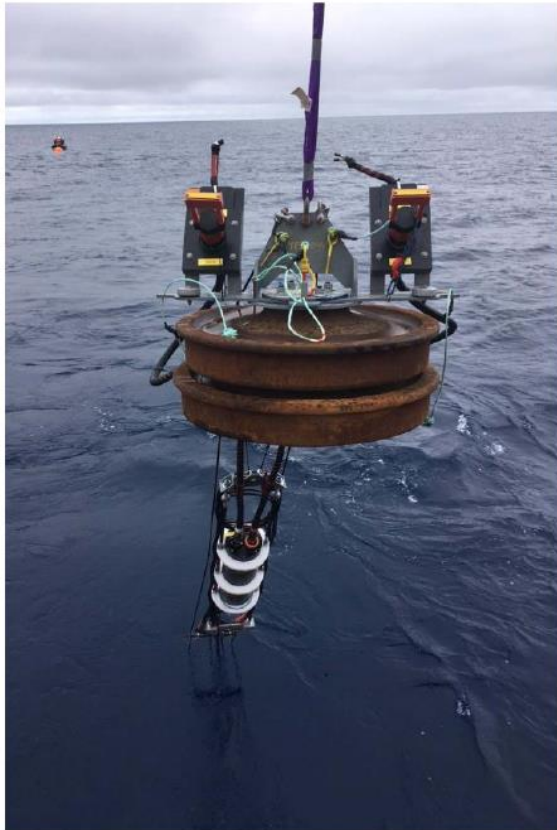


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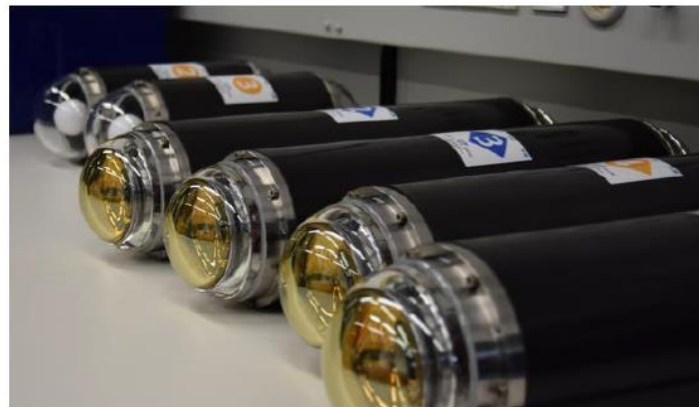




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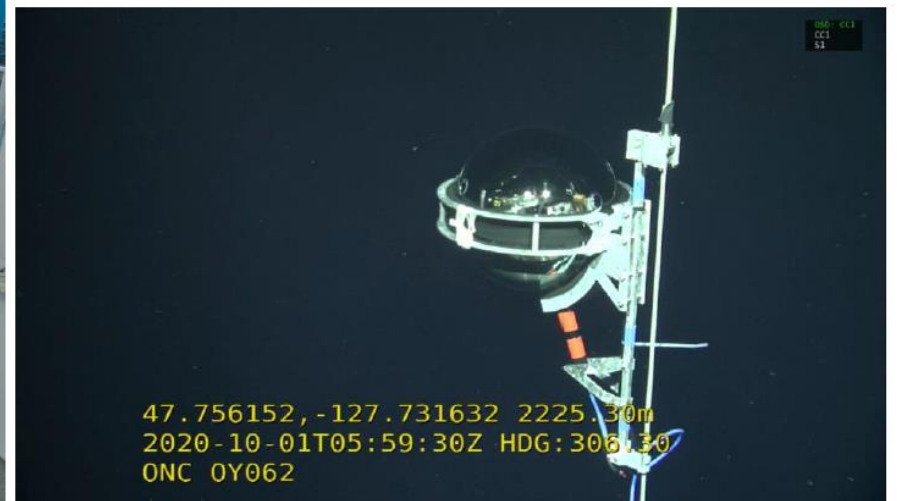
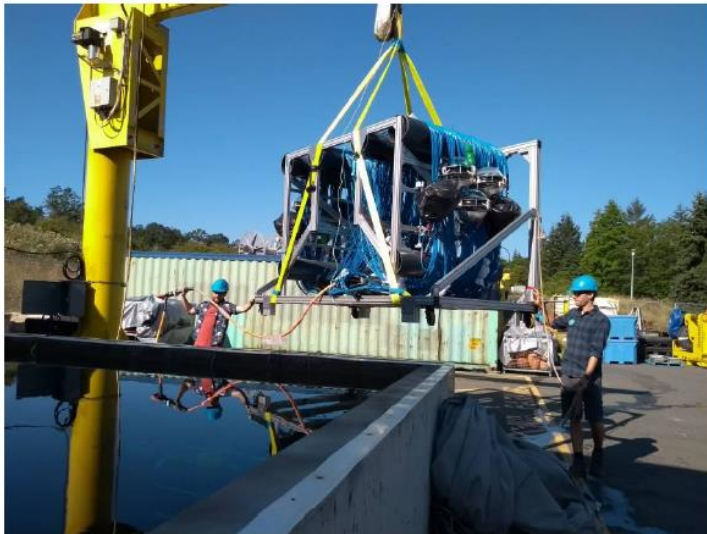
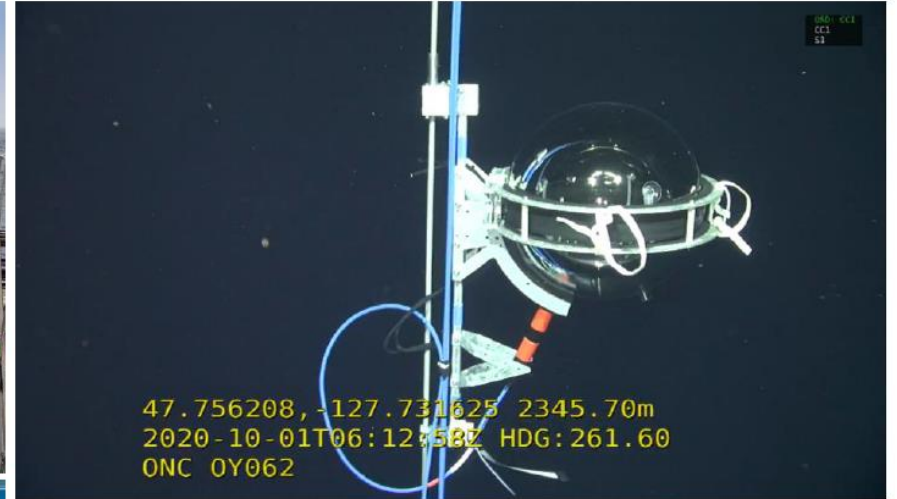
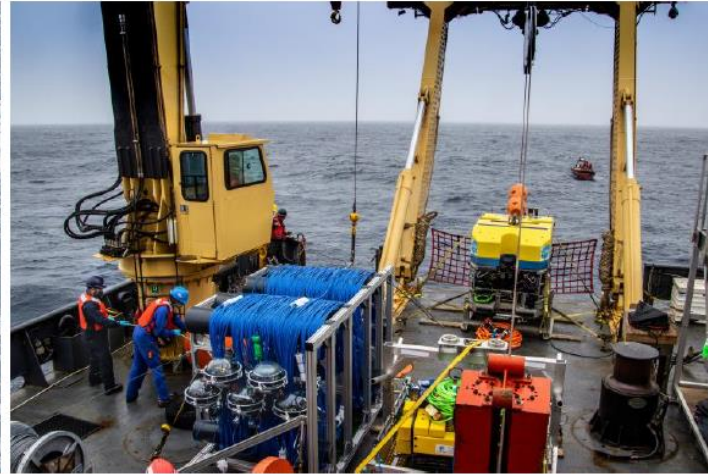
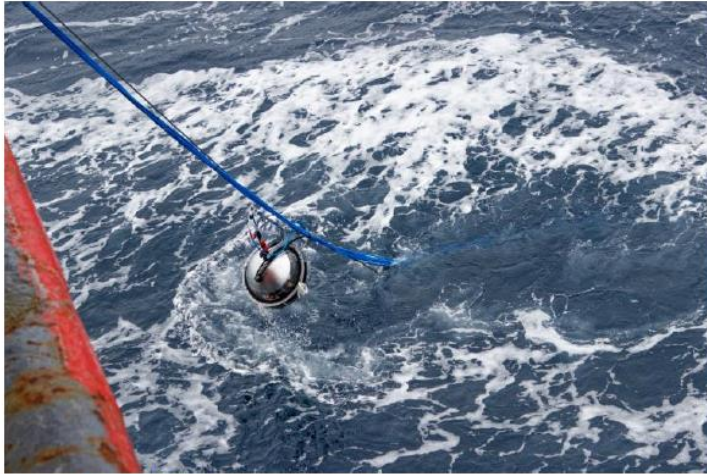
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Images: ONC, TUM



# Backup



# Backup

## Muon animation

- Use array
- Cherenk

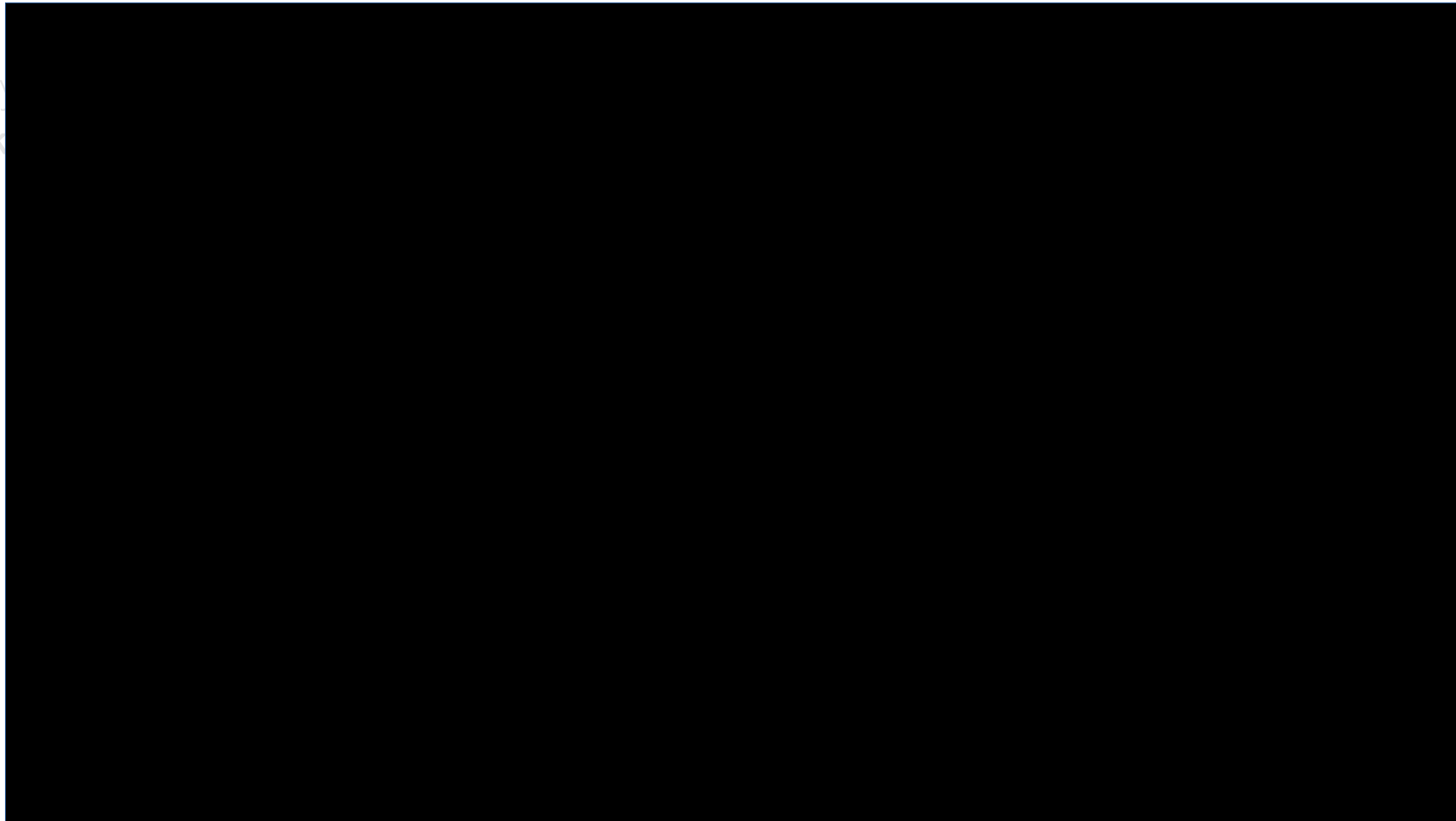
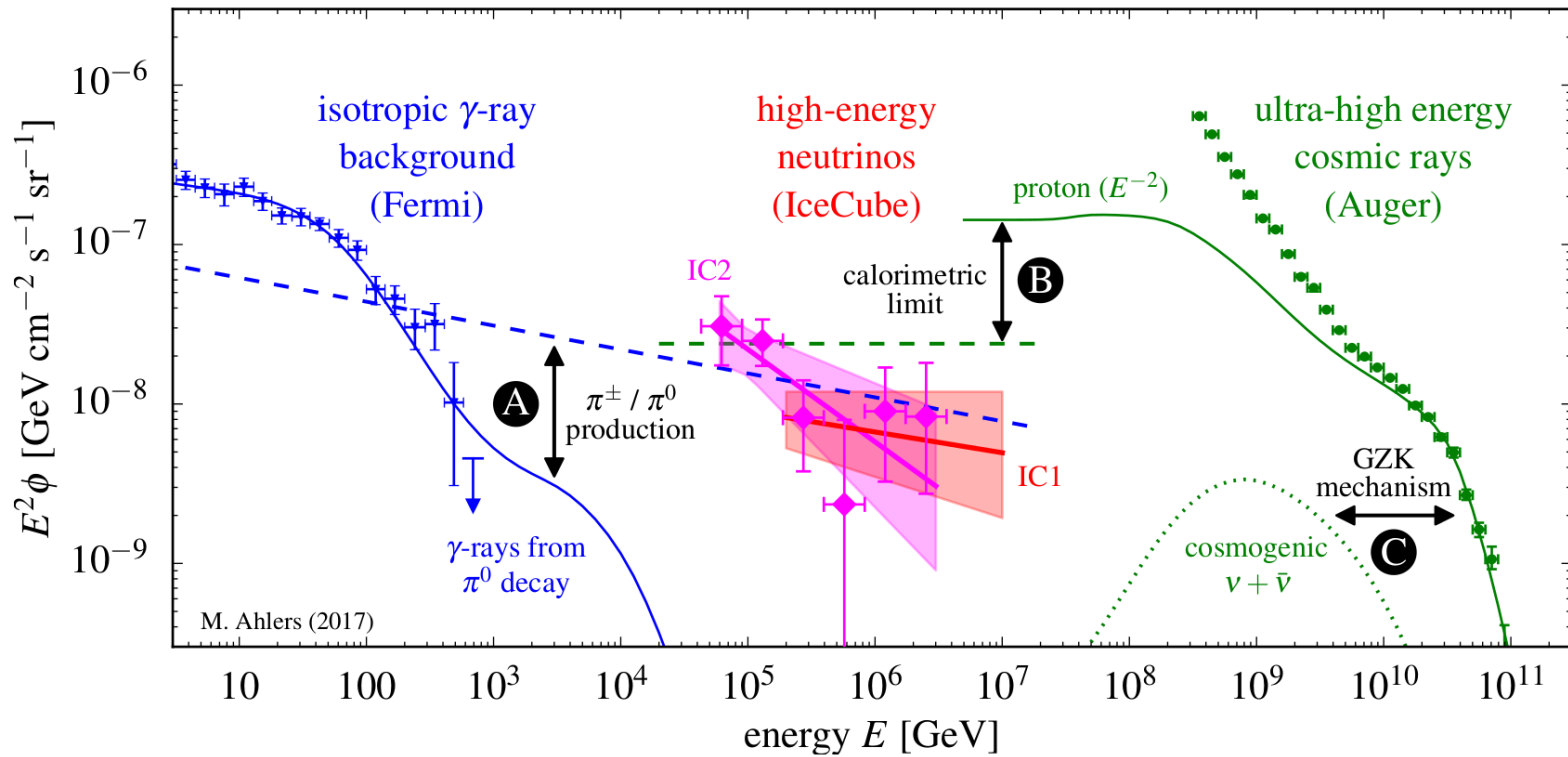


Image L. Schumacher

Animation C. Kopper



Plot Niels Bohr Institute "Neutrino Astronomy"

## Measurements

## Experimental Parameters

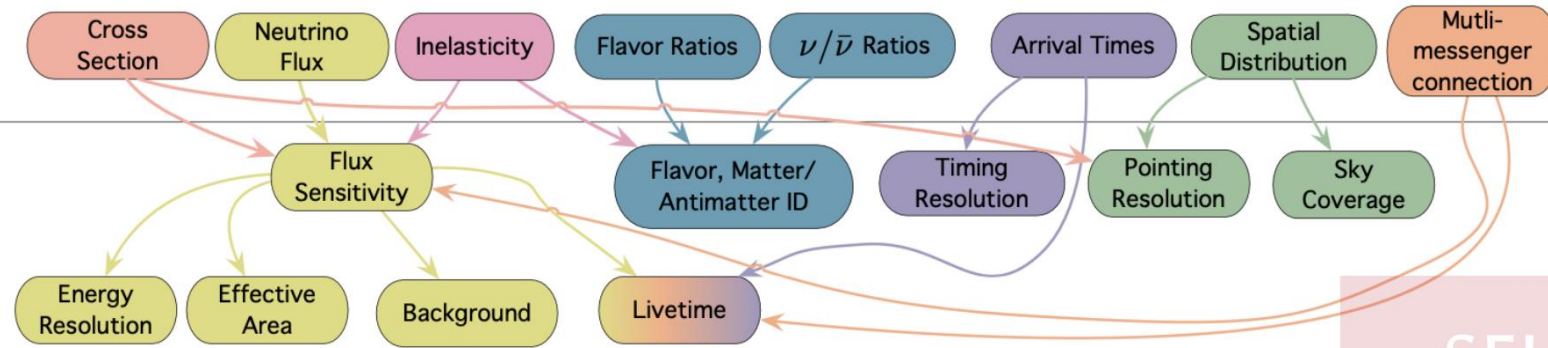


 Image M. Danninger