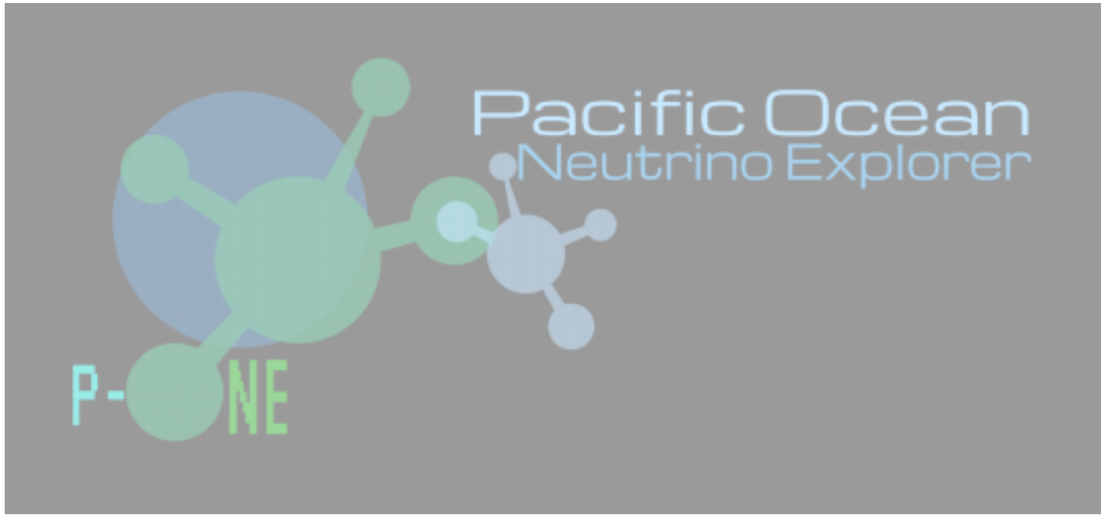
Pacific Ocean Neutrino Explorer — P-ONE — Status update

Matthias Danninger, Simon Fraser University
On behalf of the P-ONE Collaboration
2019-09-05



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Outline

Material and slides shamelessly stolen from many P-ONE Collaborators — Thank you!

- Why are we here?
- What have we achieved so far?
  - What has been deployed
  - How well are the site characteristics known
- What comes next?
- Why another neutrino telescope?

Collaborating Institutes: Canada (UoA, Queen's, SFU, ONC), Internationally (TUM, MSU, GSI)
Supported/Interest expressed: TRIUMF, SNOLAB, McDonald Institute

Members of the Proto-Collaboration

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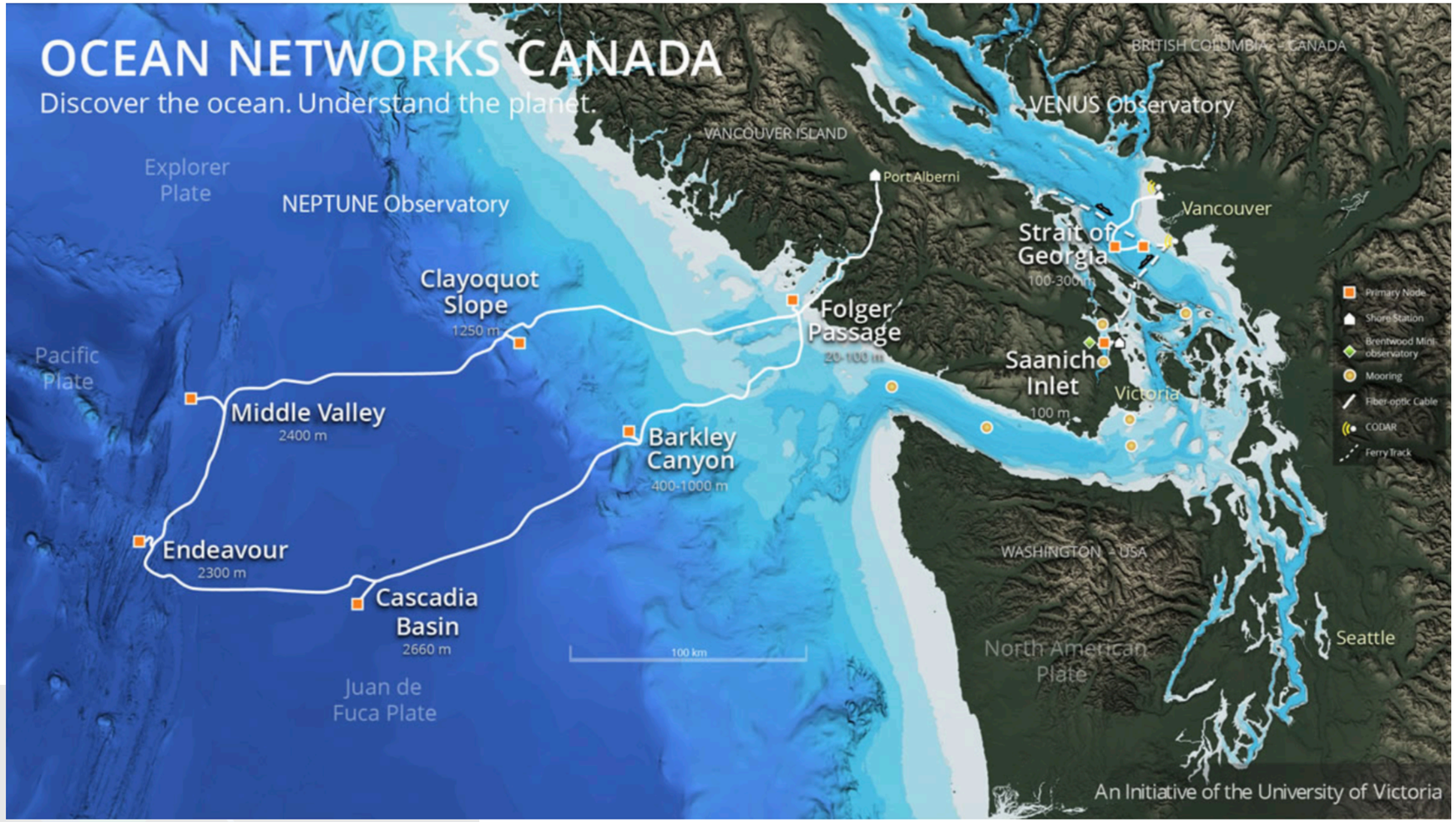
[8] *Department of Physics, Engineering Physics & Astronomy, 64 Bader Lane, Queen's University, Kingston, ON, Canada, K7L 3N6*

[9] *Department of Physics, Simon Fraser University, 8888 University Drive Burnaby, B.C. Canada, V5A 1S6*

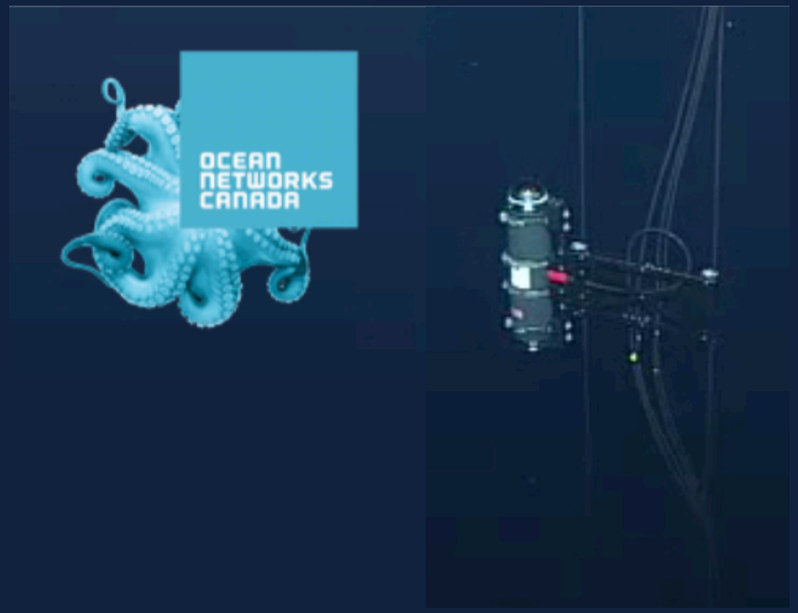
[10] *Ocean Networks Canada, University of Victoria, Victoria, British Columbia, Canada*

Why are we here?

- Because of the existing ONC deep sea infrastructure!



- One of world's largest and most advanced cabled ocean observatory
- Consists of NEPTUNE & VENUS & number of smaller observatories
- NEPTUNE:
  - completed in 2009
  - 800km loop of fibre optic cable, data flow and power infrastructure
  - designed for long-lived, highly reliable underwater operations
  - high-speed data link (1Gb/s)
  - high power (at least 8kW/node)



- Why are we here?
- What have we achieved so far?
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- Why another neutrino telescope?

Pacific Ocean Neutrino Explorer

P-ONE

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STRAW — Strings for absorption length in water

mid 2017 — STRAW Idea

09/17 — Construction

05/18 — Shipment / Test on site

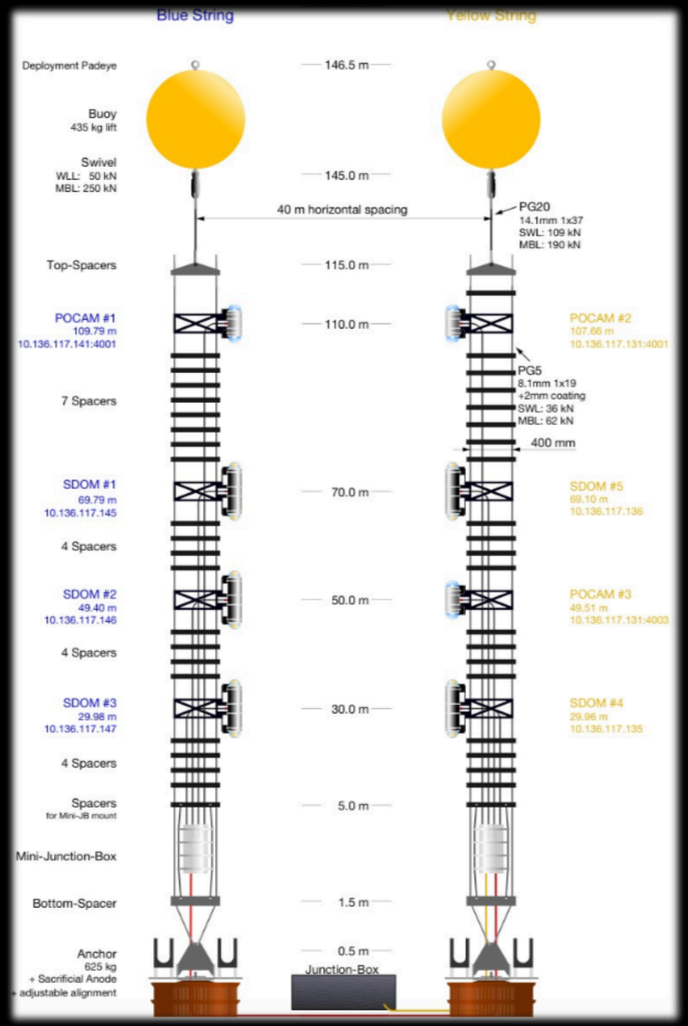
06/18 — Deployment

06/18 — Commissioning

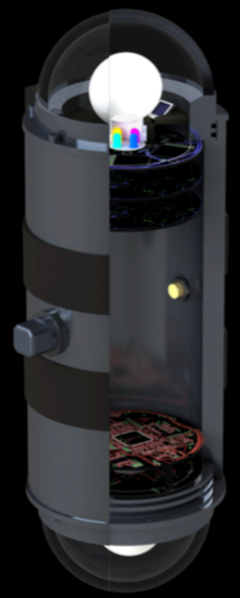
11/18 — Data Taken

x5

sDOM
(STRAW Digital Optical Module)

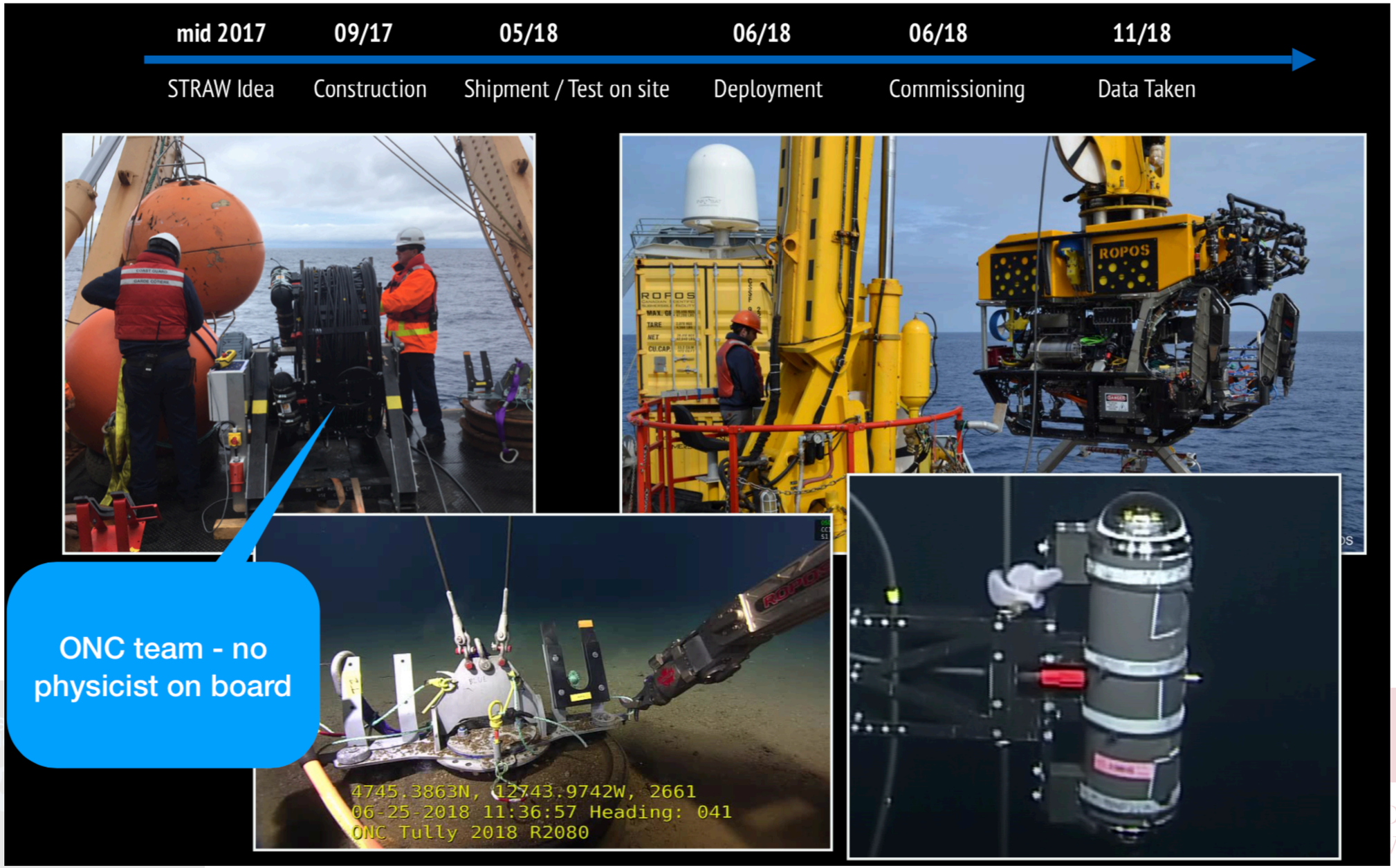


x3



POCAM
(Precision Optical Calibration Module)

STRAW — Strings for absorption length in water

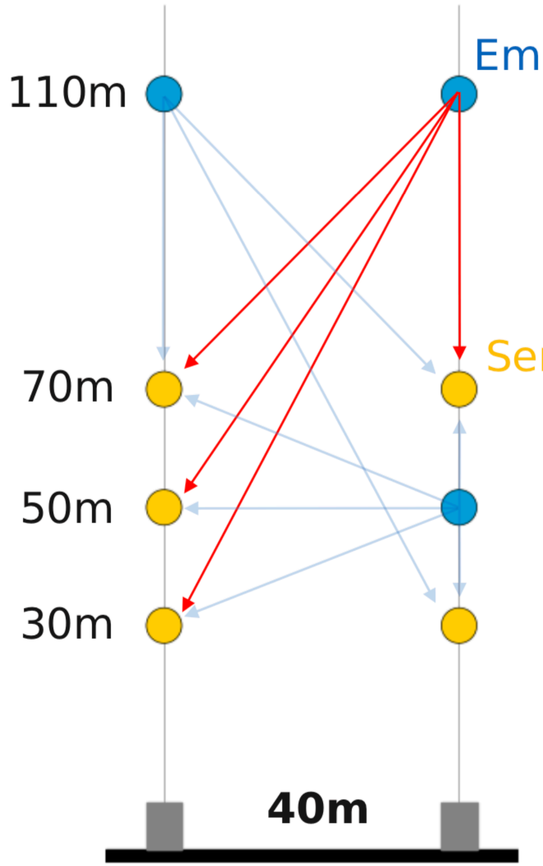


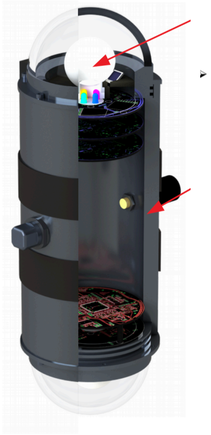
What can we measure with STRAW

- How good are the optical properties in the Cascadia Basin:
  1. Local bioluminescence activity (expected main emission spectrum 440-540 nm)
     - (I) Identification of burst periods
     - (II) Bioluminescence vs. water current
  2. Background characterization
     - (I) Baseline (^{40}K and diffuse bioluminescence)
     - (II) Sedimentation effect
  3. Optical properties of the water

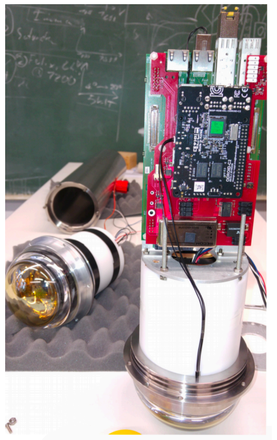
Deployment was a 100% success, all sDOMS are taking data!
(see M. Boehmer et al 2019 JINST 14 P02013)

- Two-string detector with eight instruments
  - **Emitter:** Precision Optical Calibration Module (POCAM)
  - **Sensor:** STRAW Digital Optical Module (sDOM)
    → counting single photons

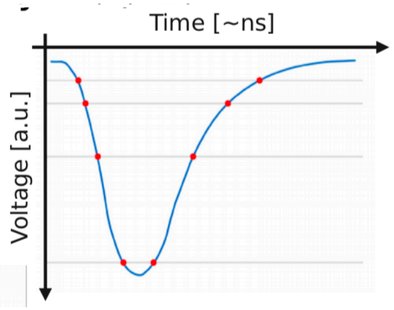




- Multi-wavelength emission for spectral studies
  - 365, 405, 465, 525, 605nm

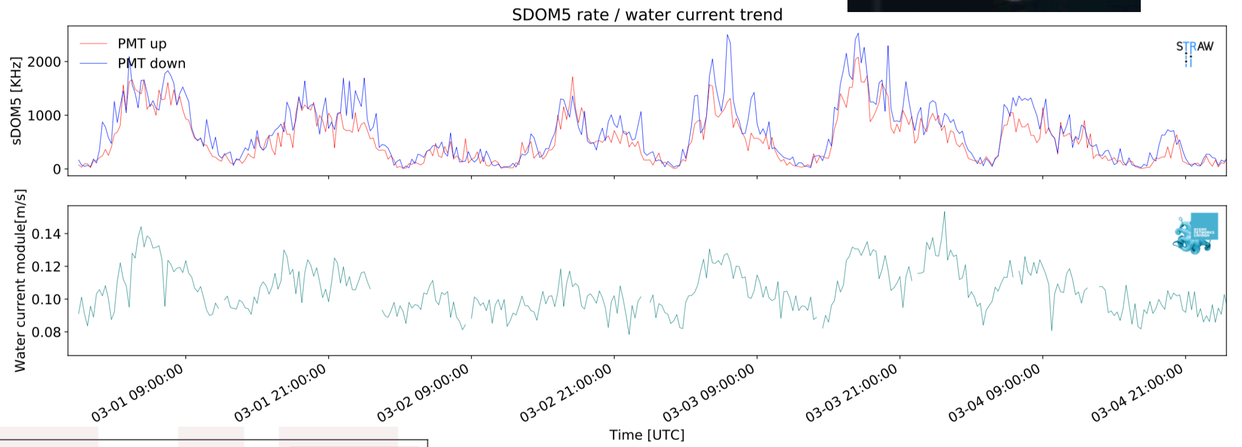


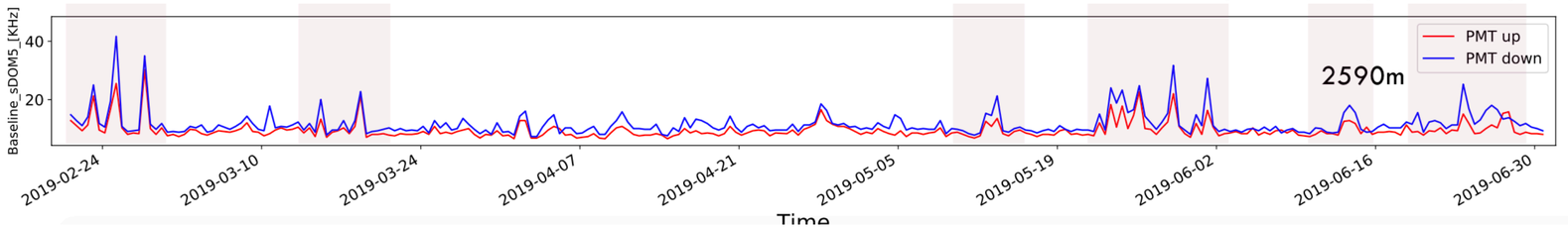
- Two 3“ PMTs (Hamamatsu R12199)
- 4 channels per PMT

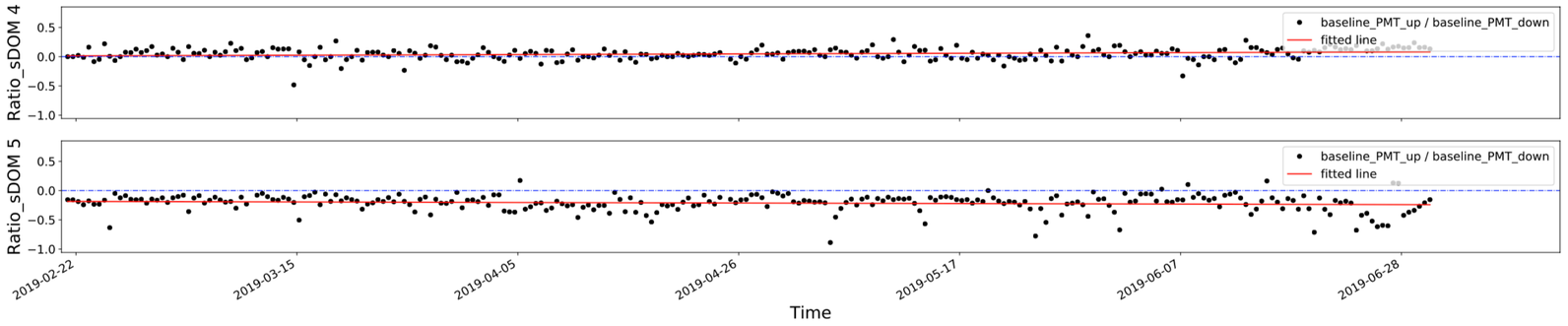


What can we measure with STRAW

1. Local bioluminescence activity (expected main emission spectrum 440-540 nm)
   - (I) Identification of burst periods —> typical length of 30s
   - (II) Bioluminescence vs. water current —> well known, detailed correlation analysis ongoing
2. Background characterization
   - (I) Baseline (^{40}K and diffuse bioluminescence)
   - (II) Sedimentation effect
     —> no indication so far







Preliminary (analyses ongoing)

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What can we measure with STRAW

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   (I) Identification of
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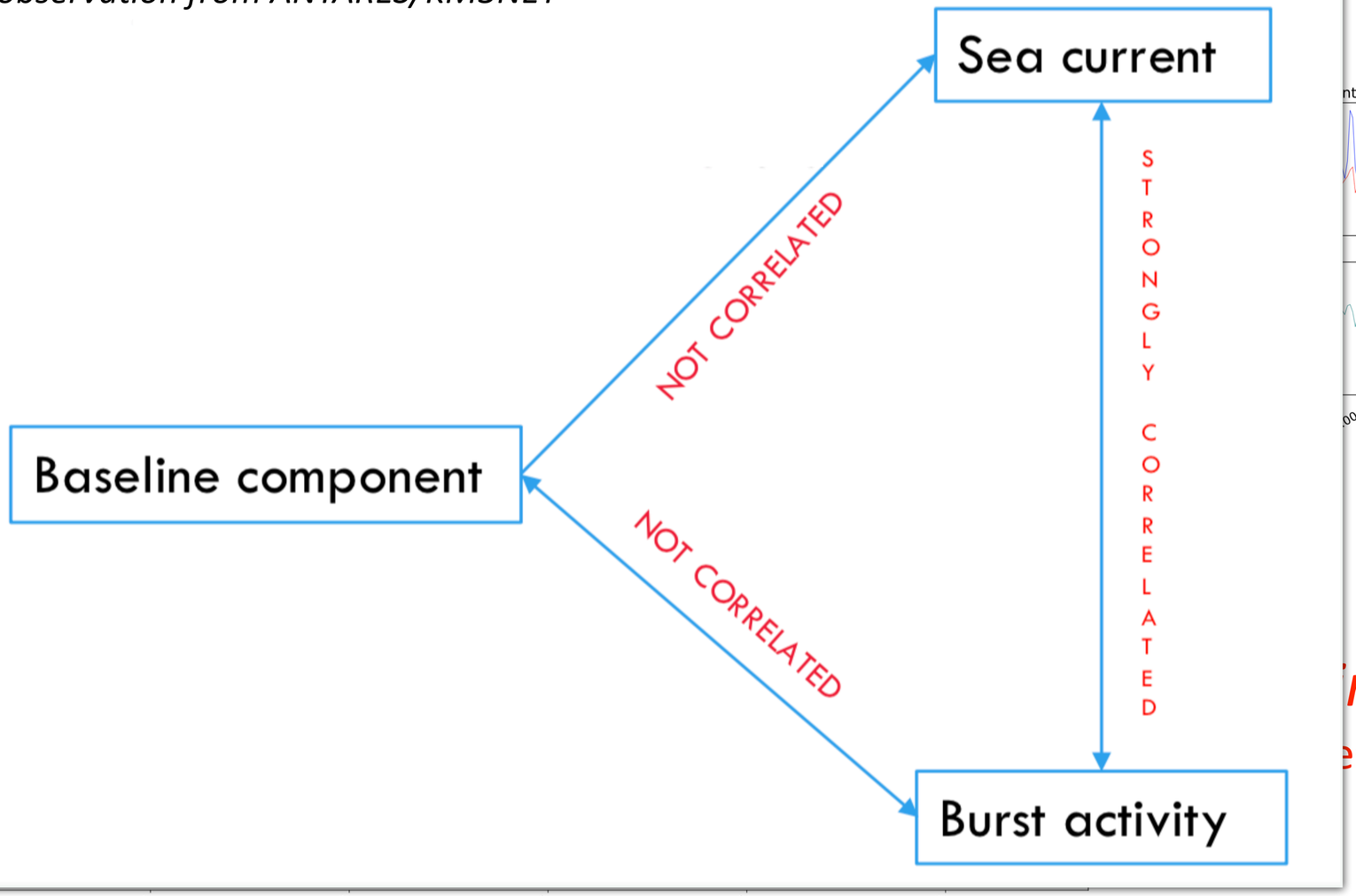
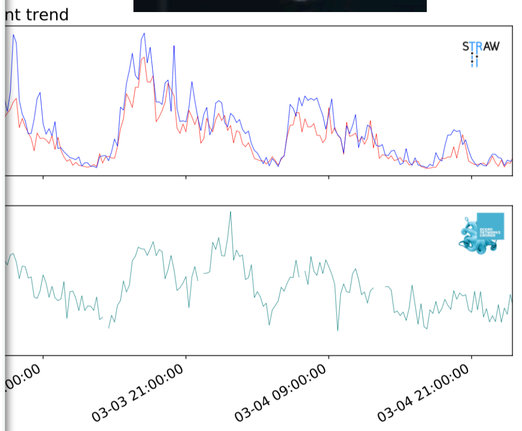
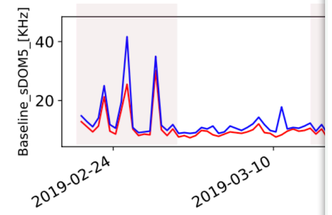
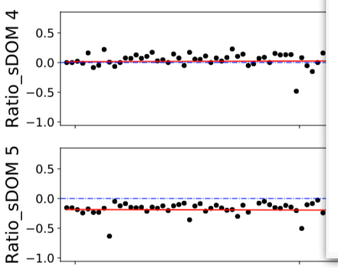
observation from ANTARES/KM3NET









*iminary**

es ongoing)

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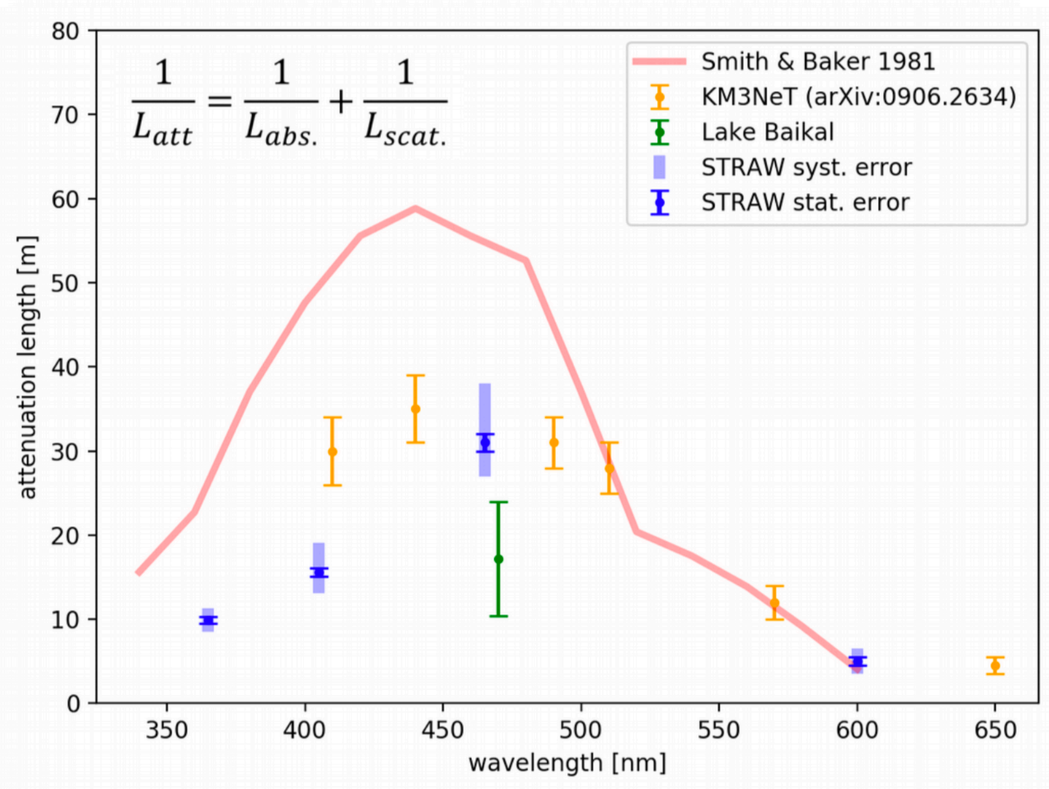
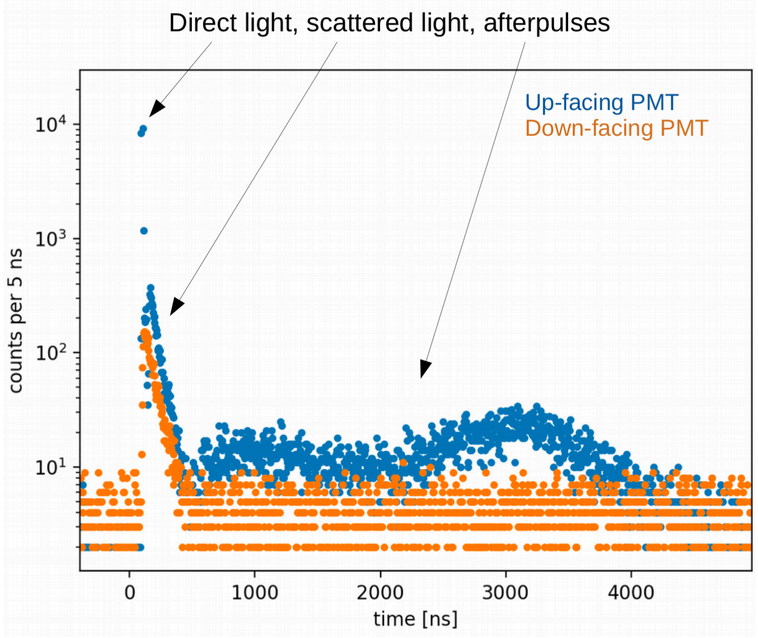
Optical properties of the Water

- Measure Attenuation length in the water
  - For different wavelength
  - Scattering and absorption separately
  - First results look promising!

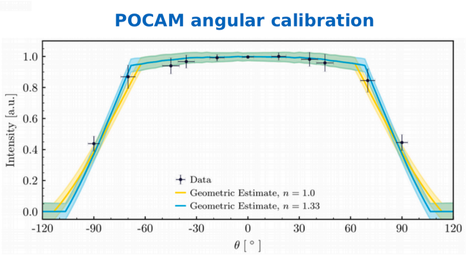


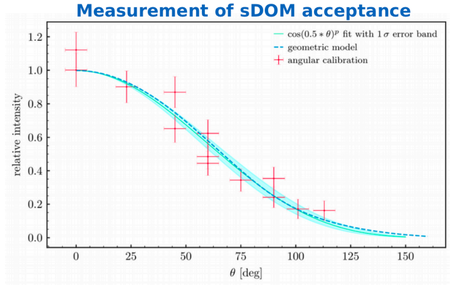


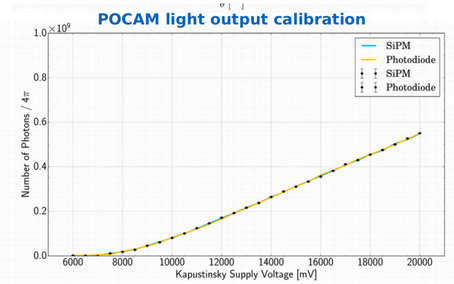
$$I(r) = \frac{I_0}{r^2} e^{\frac{-r}{\lambda_{att}}}$$

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

Inputs:







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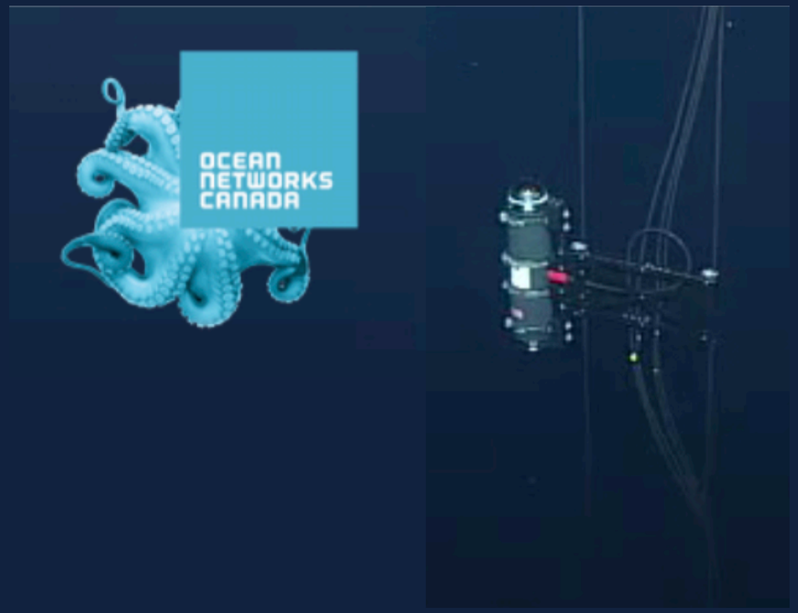

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Pacific Ocean Neutrino Explorer

P-ONE

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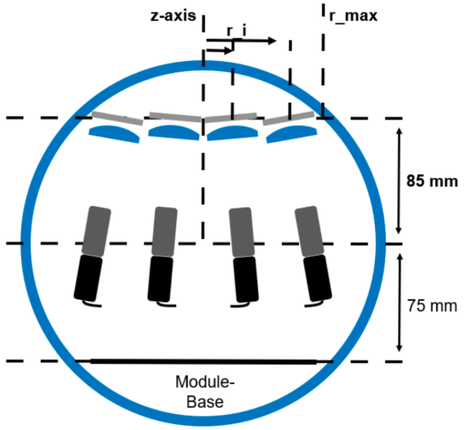
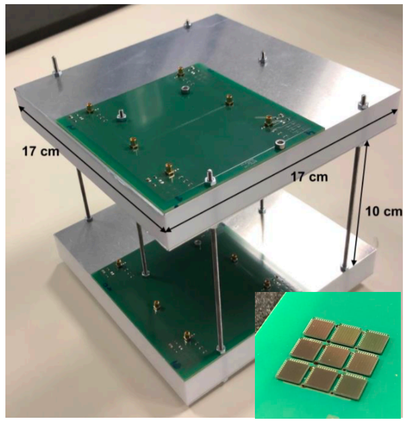
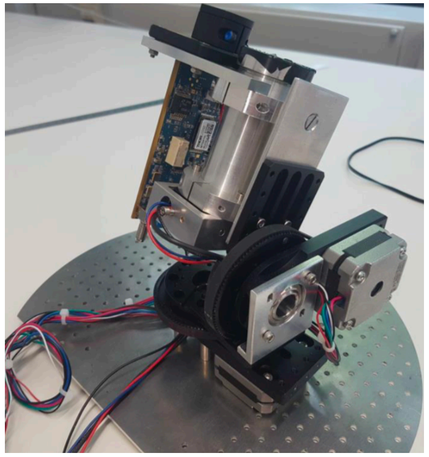
STRAWb — The 2nd pathfinder towards P-ONE

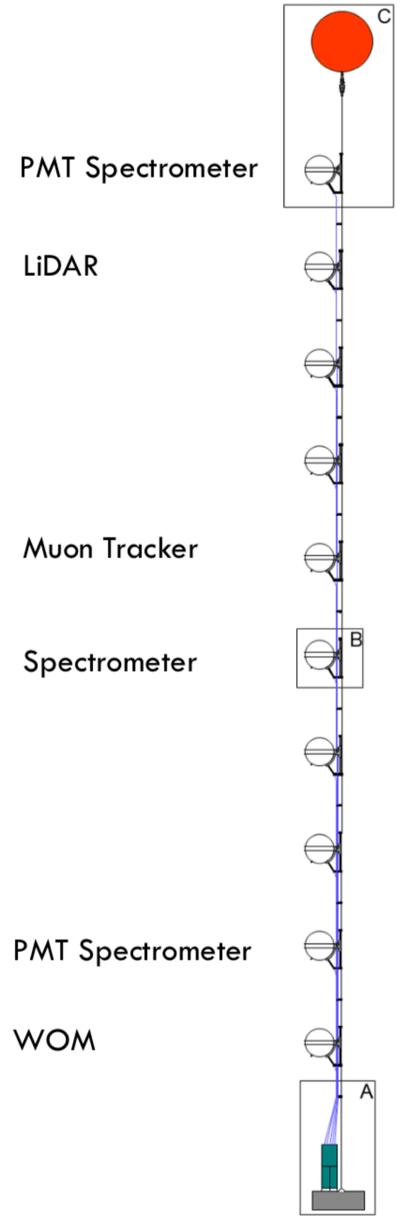
- Calibration — calibration — better calibration
- Background calibration
  - PMT Spectrometer (12 PMTs w. different wavelength filters)
  - Muon spectrometer (SiPMT readout)
- Water properties
  - LiDAR (450nm)
- Standard modules
  - p/T/H and magnetic field sensors for ping signal

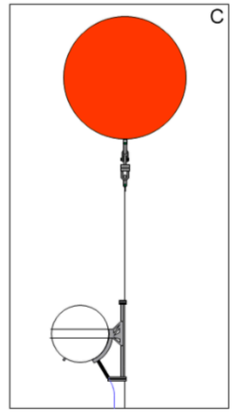
Timeline:
Testing at ONC 2019 with deployment in summer 2020

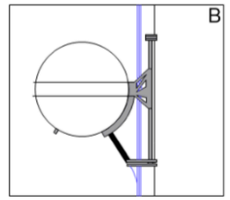


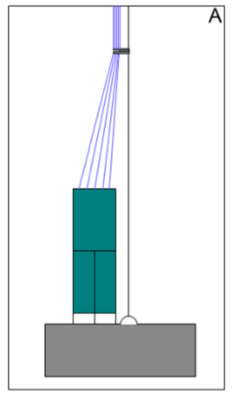




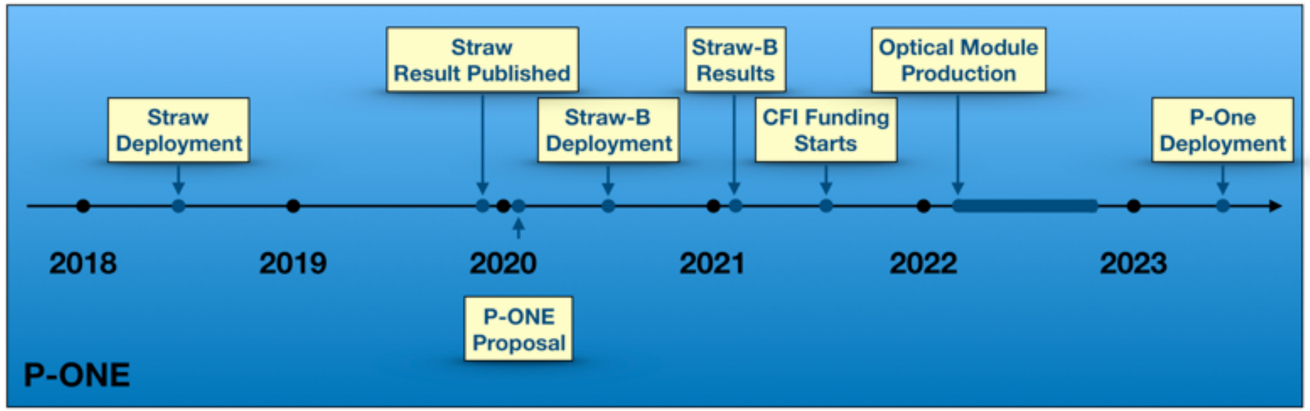




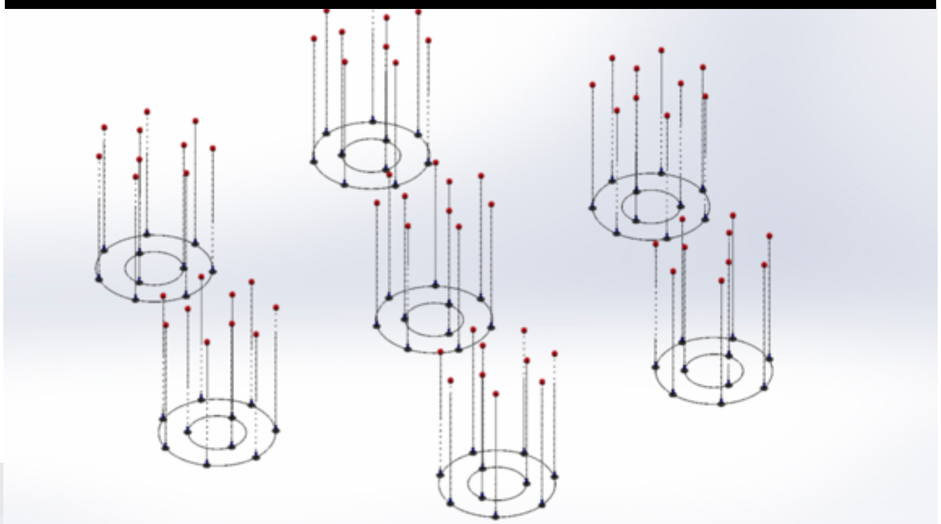


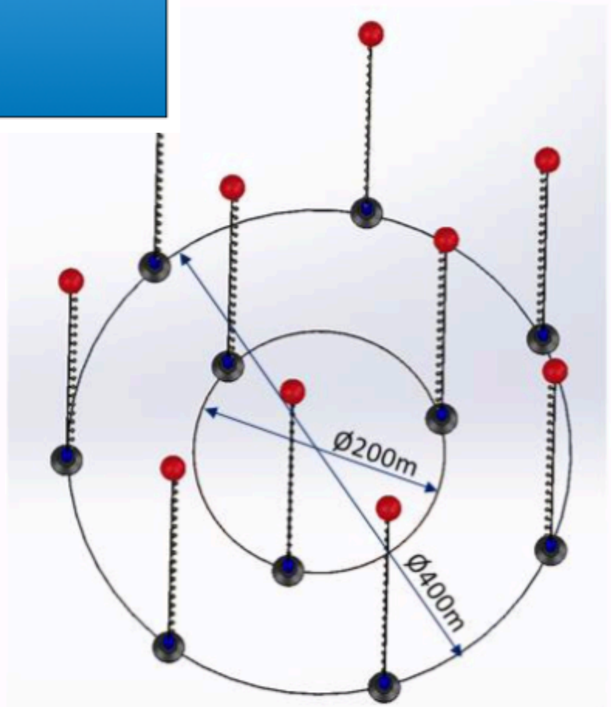


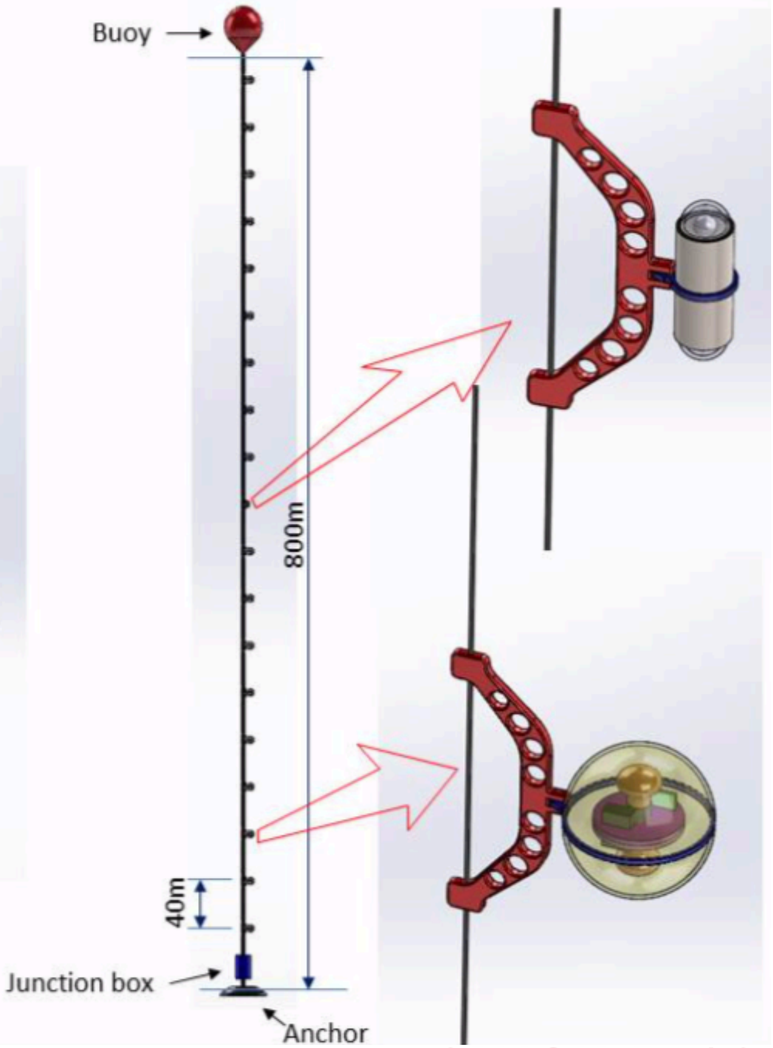
Pacific Ocean Neutrino Explorer (P-ONE)



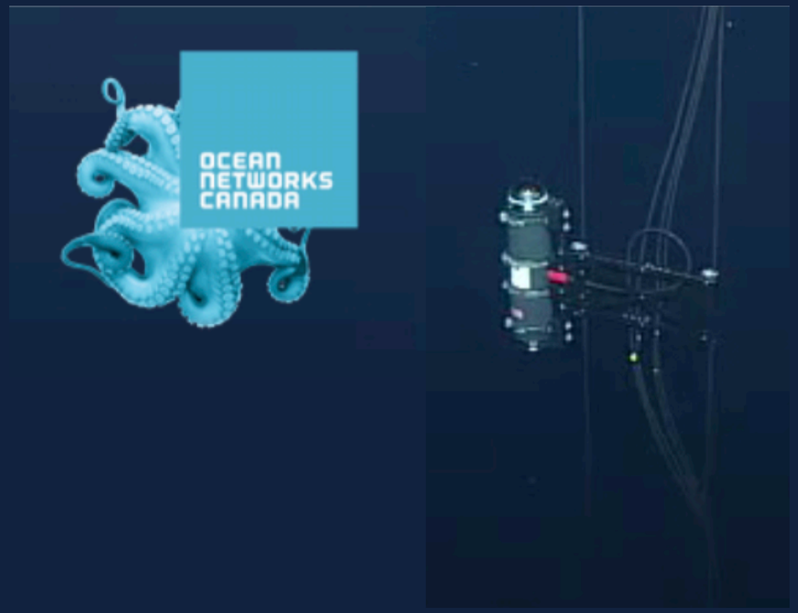
Longer term prospective: extend to more 10-strings bundles
3 x 10-strings bundles: possible within the existing infrastructure







- Unlike IceCube, we can design for service and reconfiguration



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- Why another neutrino telescope?

Pacific Ocean Neutrino Explorer

P-ONE

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Why another neutrino telescope?

Neutrino telescopes are discovery oriented instruments in the areas of:

- Astrophysics:
  - high energy (>50 TeV): galactic and extragalactic cosmic accelerators [first association to an extragalactic source by IceCube in 2018];
  - low energy (MeV): neutrinos from core collapse SuperNovae, geoneutrinos;
- Particle Physics:
  - high energy:
    - cosmic rays interaction at energies > LHC
    - search for exotic particles, beyond the Standard Model complementary to LHC
  - low / intermediate energy: neutrino properties

In addition:

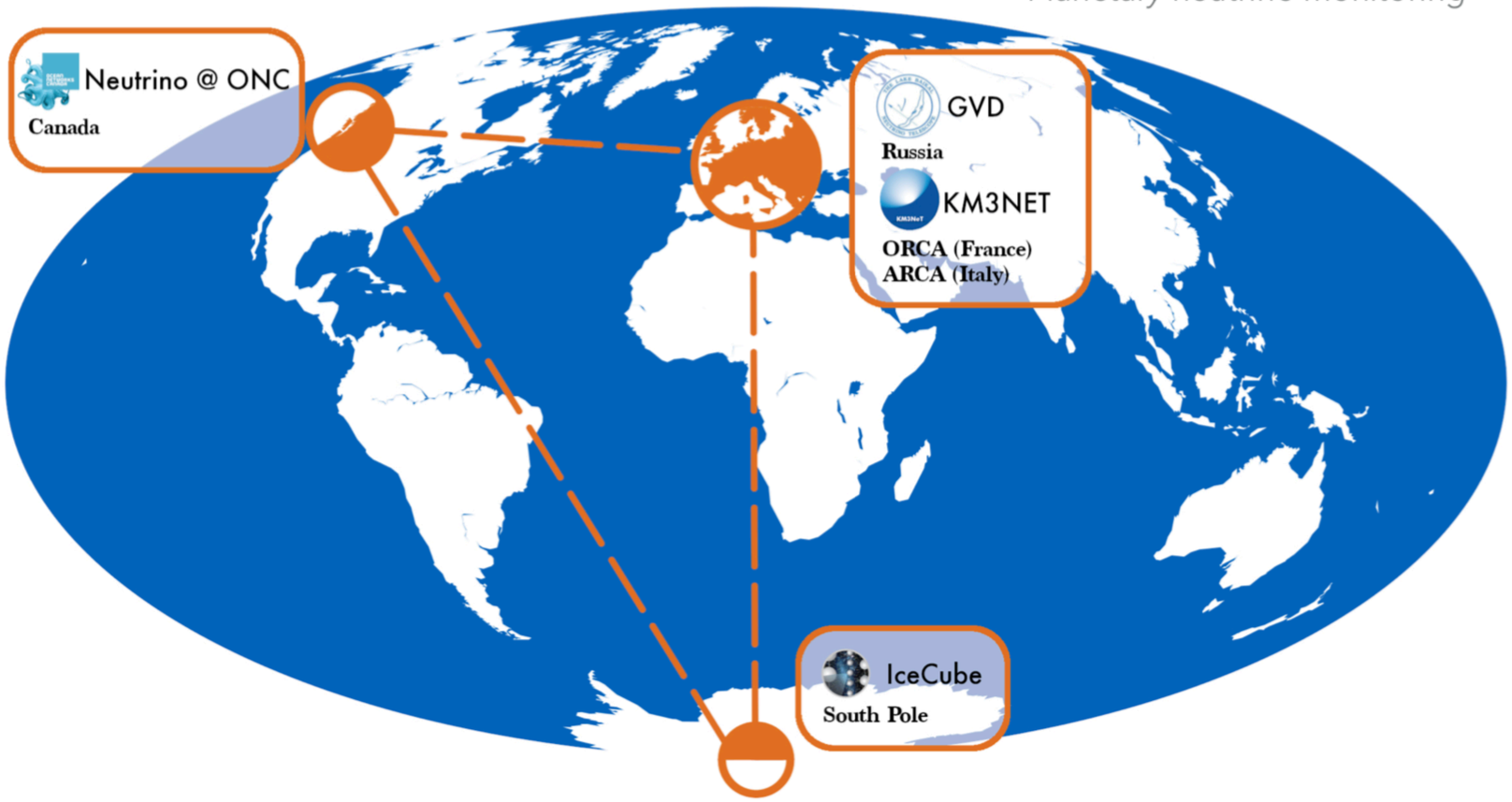
- P-ONE project has large emphasis on collaboration and complementarity with existing efforts such as IceCube, GvD (Baikal), and KM3NeT
- We aim for combined cross-calibration efforts to boost precision of all measurements at all neutrino telescope sites worldwide (POCAM, LiDAR, etc..)

Why another neutrino telescope?

- Exposure — exposure — exposure
- Connectors — connectors — connectors —> ONC! Overcome difficulties/failures of KM3NET

PLEνM

*Planetary neutrino monitoring



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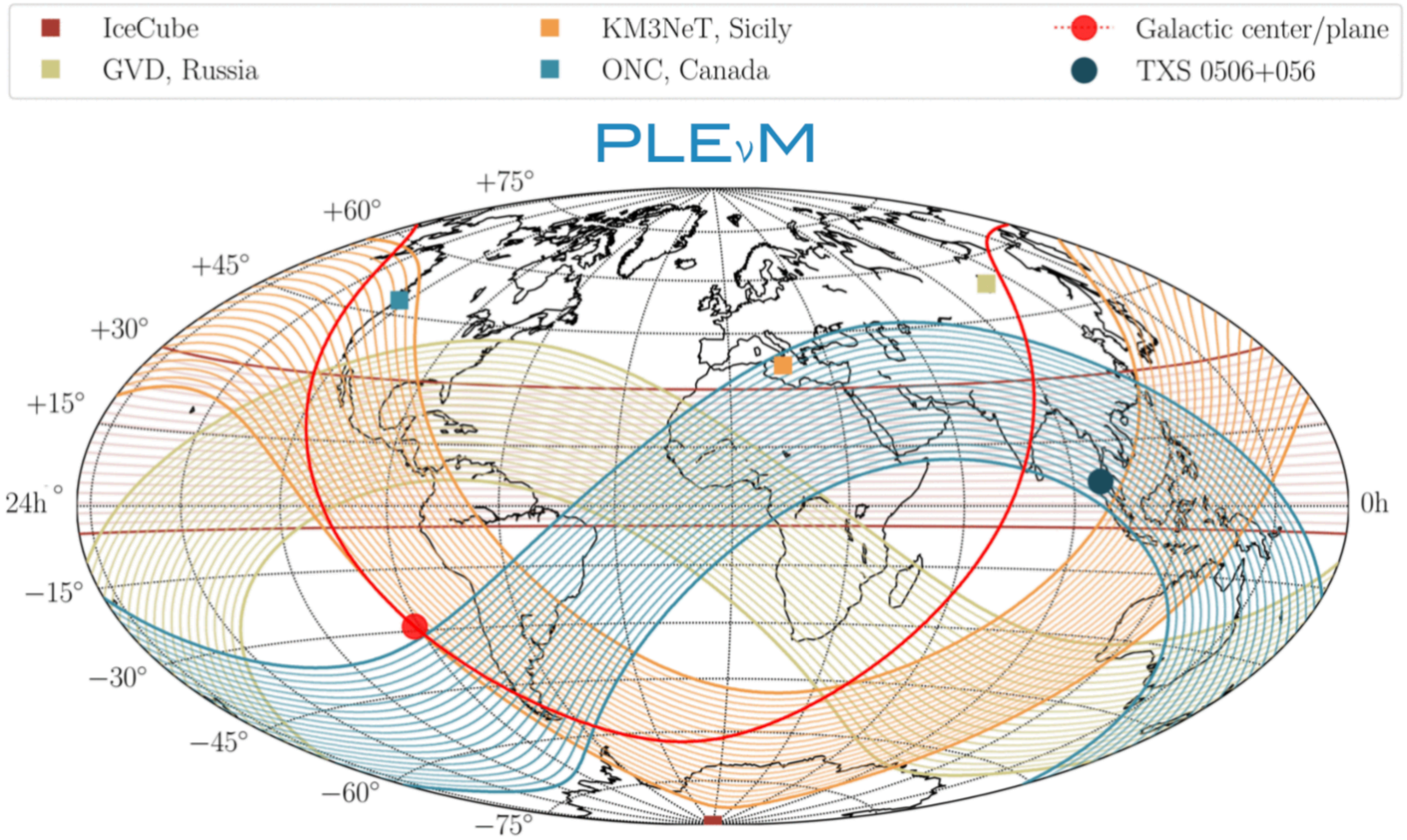
Why another neutrino telescope?

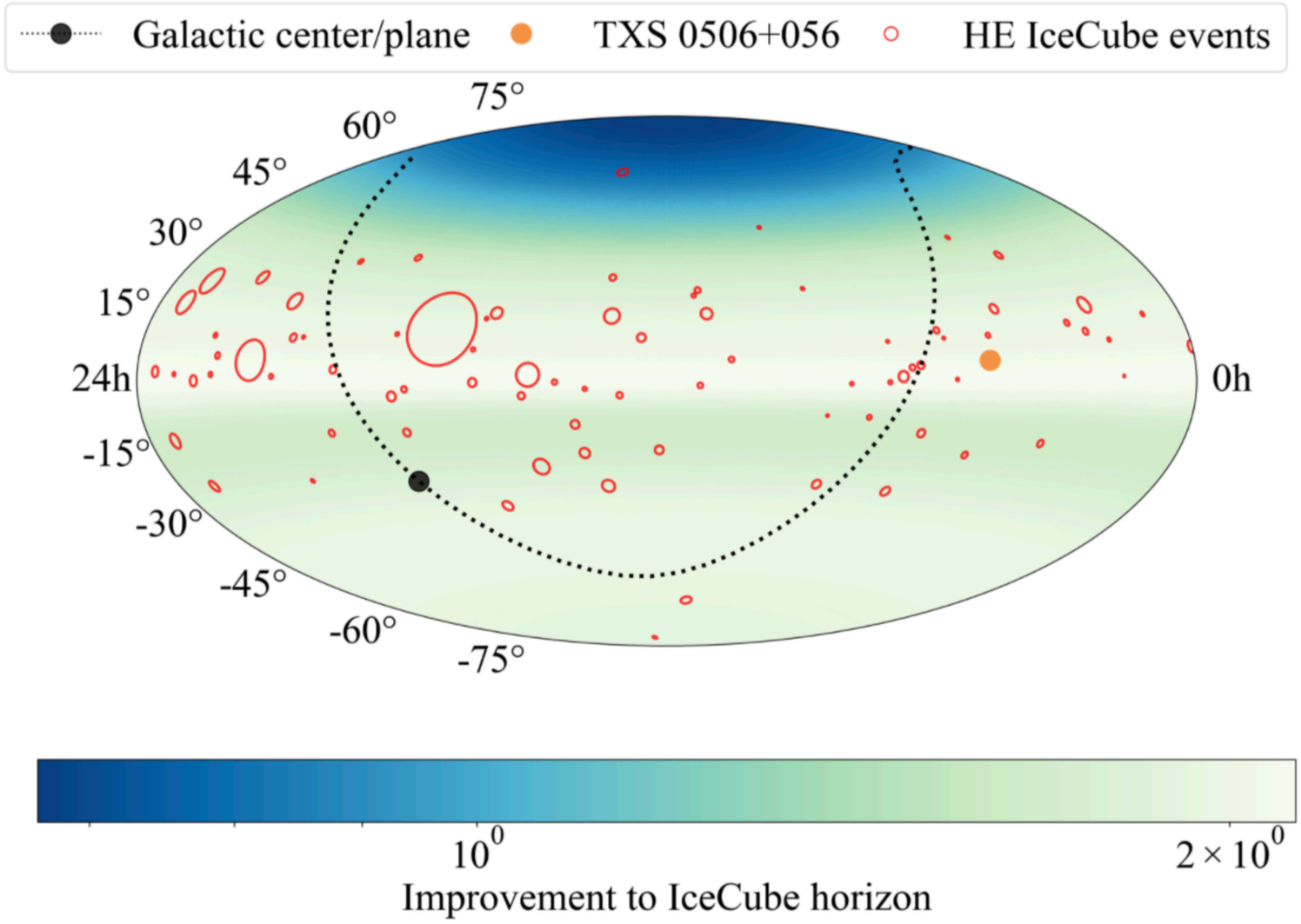
- Exposure — exposure — exposure
- Horizontal coverage from which HE ν will not be affected by the Earth absorption



PLEνM

ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

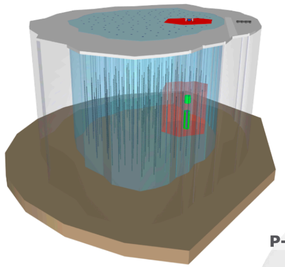
➡ RELATIVE IMPROVEMENT VS ICECUBE HORIZON BEST SENSITIVITY



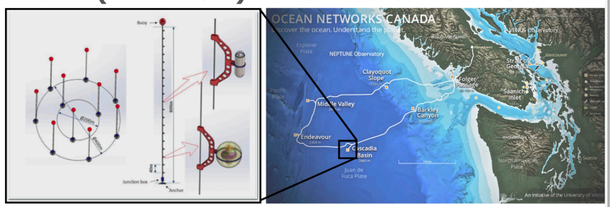
P-ONE is gaining traction fast!

Future neutrino telescopes

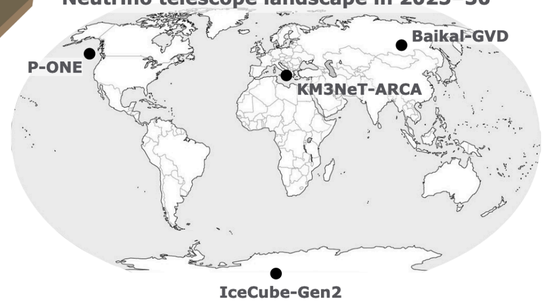
IceCube-Gen2



P-ONE (E. Resconi) — New kid on the block



Neutrino telescope landscape in 2025–30



- In conceptual phase
- Up to 500 strings optimized for horizontal HE muon tracks
- STRAW pathfinder mission successfully operating (PoS(ICRC2019)890)

Alexander Kappes, ICRC'19, Madison, Aug 1, 2019 22

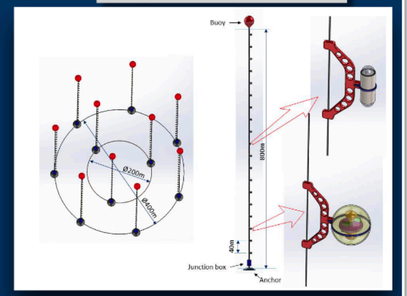
ICRC 2019 rapporteur talk by A. Kappes

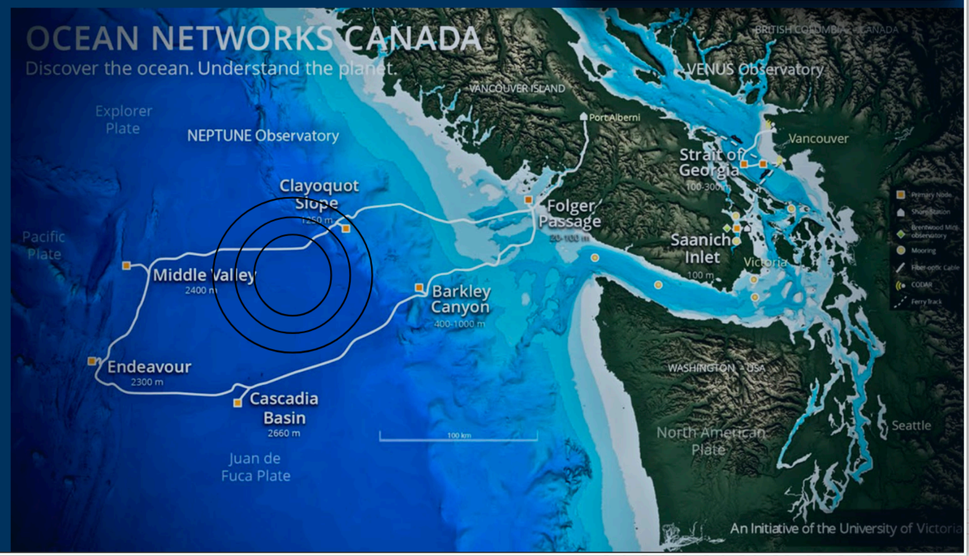
Canadian Scientists are proposing to establish a high energy neutrino detector using an existing underwater network off Vancouver Island

Pacific Ocean Neutrino Explorer (P-ONE)

First 10 String Bundle

10 x 800 metre strings
20 photosensors

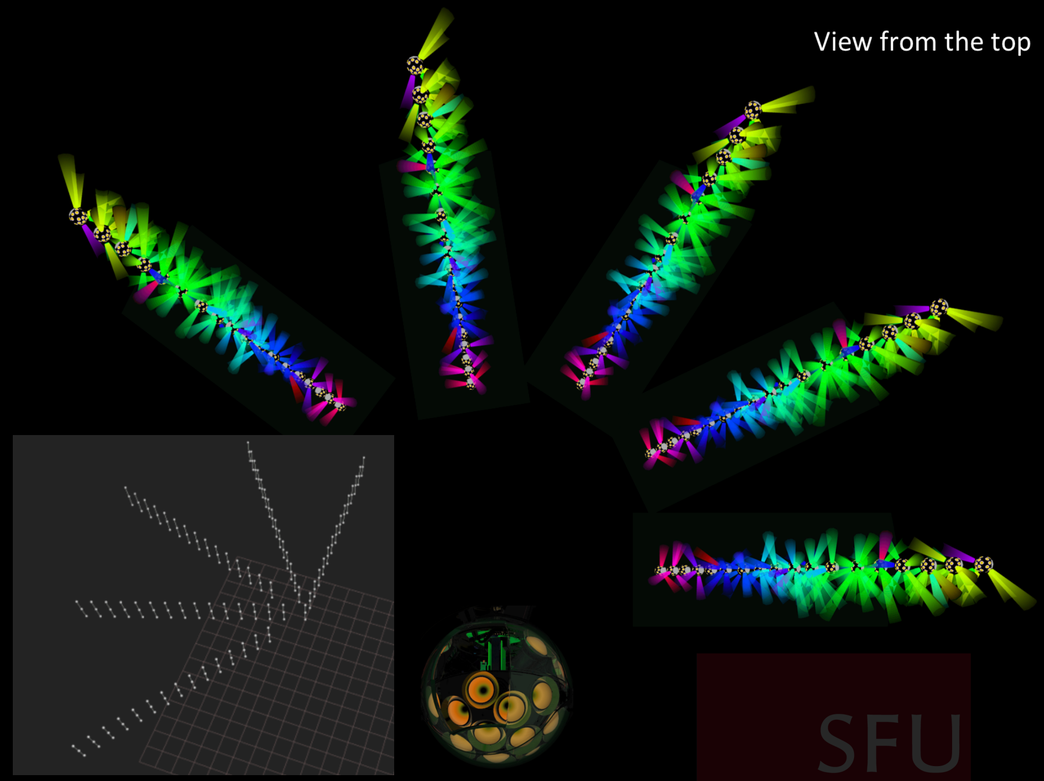




Lepton-Photon 2019 talk by Art McDonald

In Summary

- Why are we here?
  - Because ONC is opening new exiting opportunities (10y experience deep sea operation/ deployment, infrastructure, deployment is fast and reliable with minimal overhead)
- What have we been able to achieve so far?
  - A new interdisciplinary international collaboration
  - Successful deployment of STRAW —> first results
- What comes next?
  - Complete the qualification of the deep sea site
  - Design 10-string bundle (we have a baseline, but dreaming is allowed)
  - Secure funds for it!
- Why another neutrino telescope?
  - Exposure-exposure-exposure



Planned Canadian Contributions — *not final list*

- Calibration and testing of components (in-lab and in-situ)
- Commissioning, Construction & Deployment
  (DOMs contributed from international partners)
- Simulation, Reconstruction & Data analysis
- In-situ trigger system (Hardware & Software)
  - Highly efficient in its data transmission and bandwidth requirements (less optical fibre cables —> significantly cheaper $$)

Pacific Ocean Neutrino Explorer

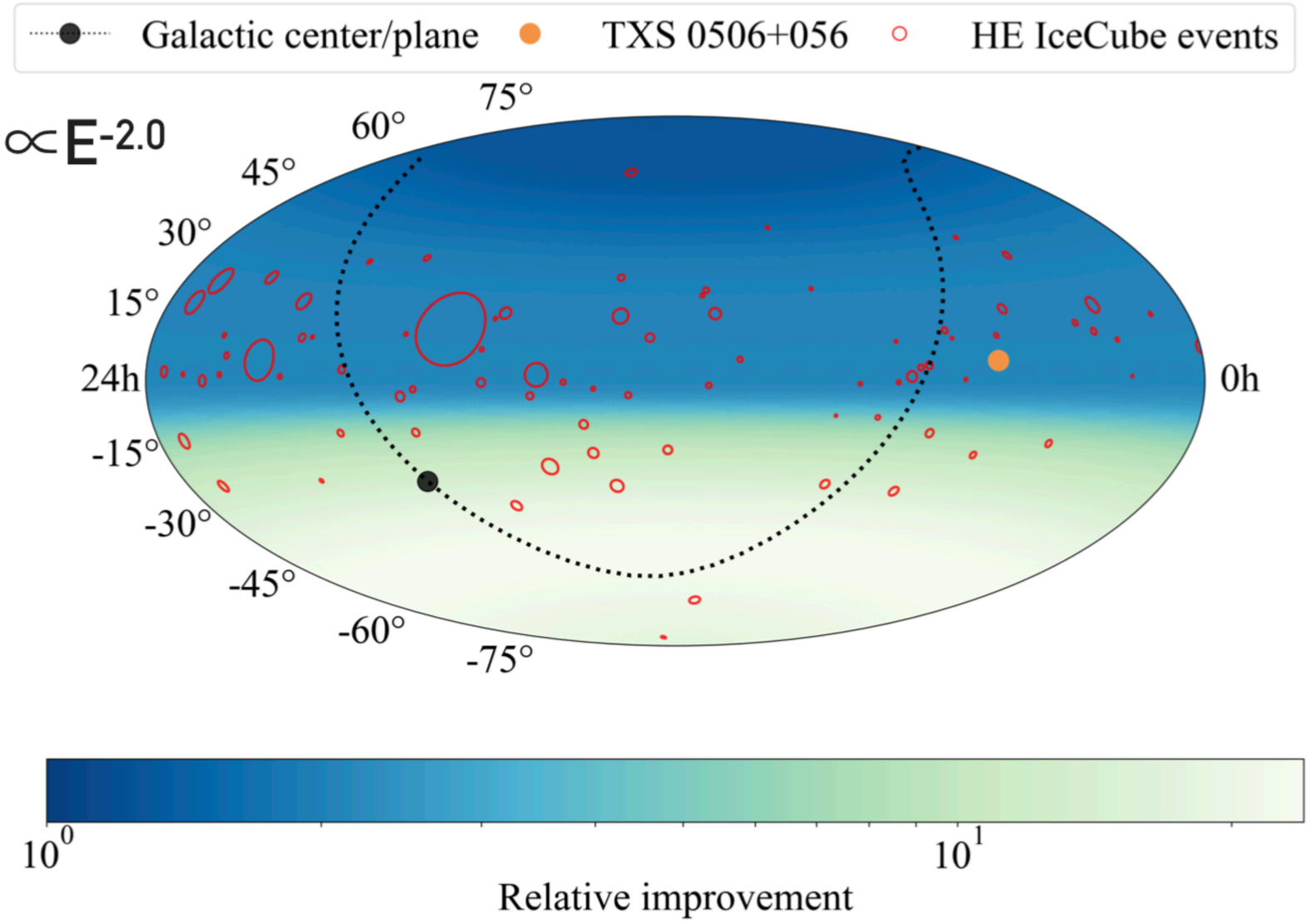
P-ONE

SFU
SIMON FRASER UNIVERSITY

Additional Material

ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

➡ RELATIVE IMPROVEMENT VS ICECUBE ALL SKY



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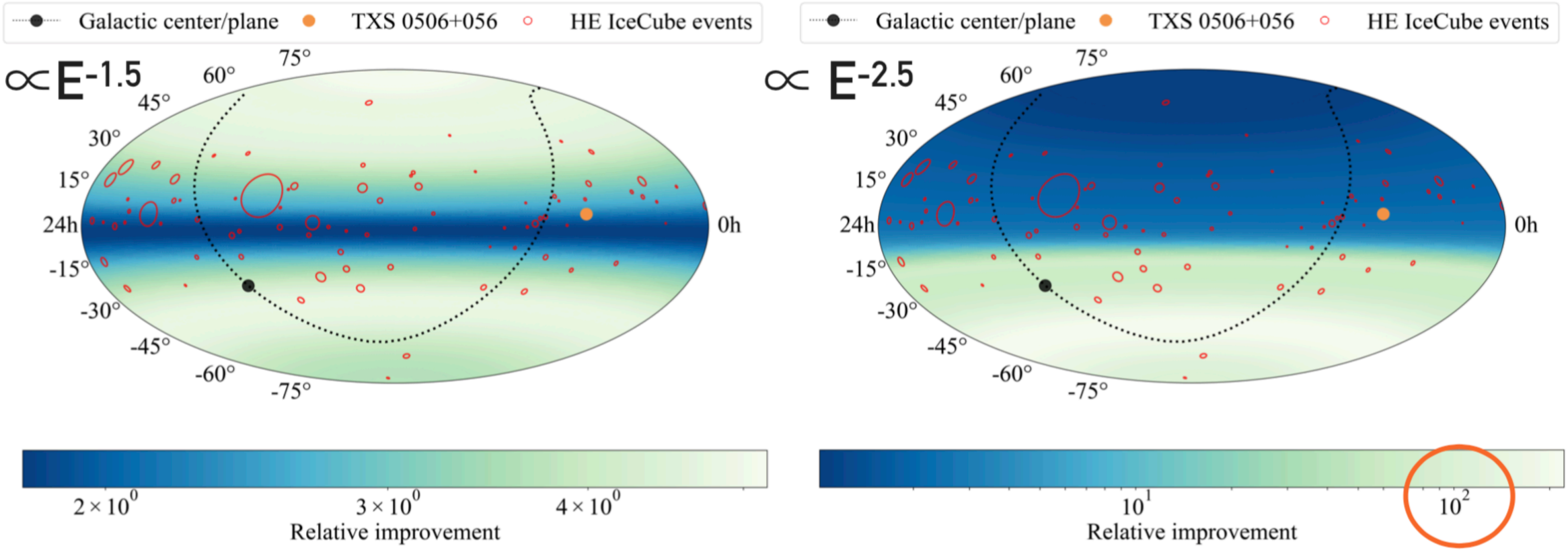
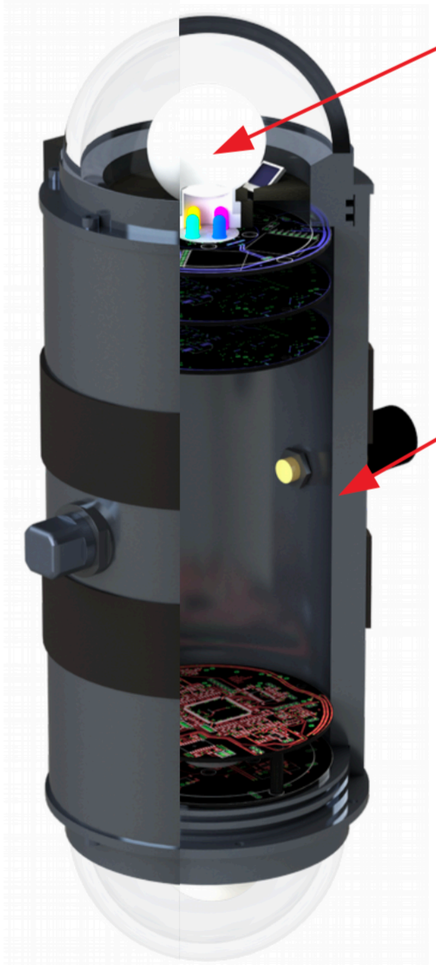
ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

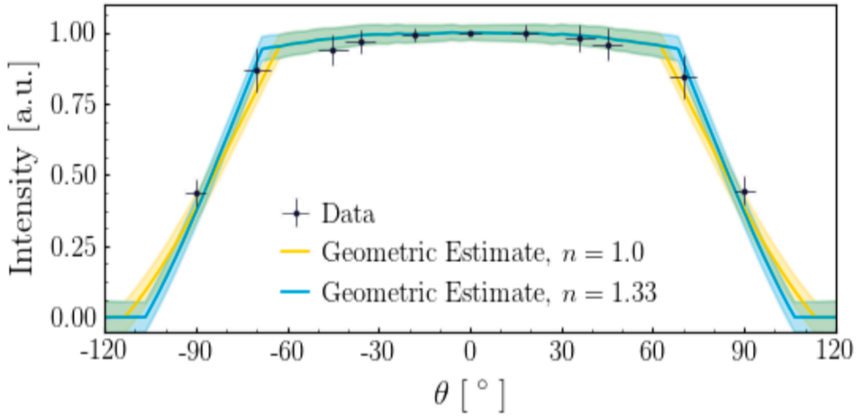
➡ RELATIVE IMPROVEMENT VS ICECUBE ALL SKY

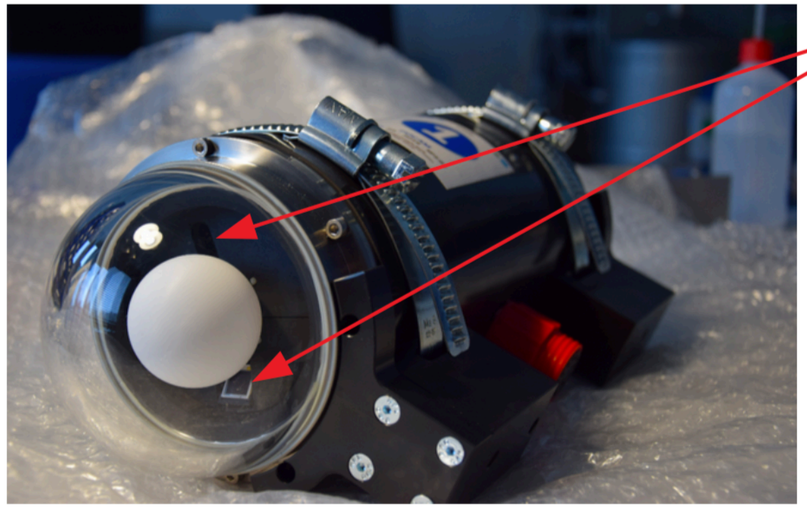


POCAM



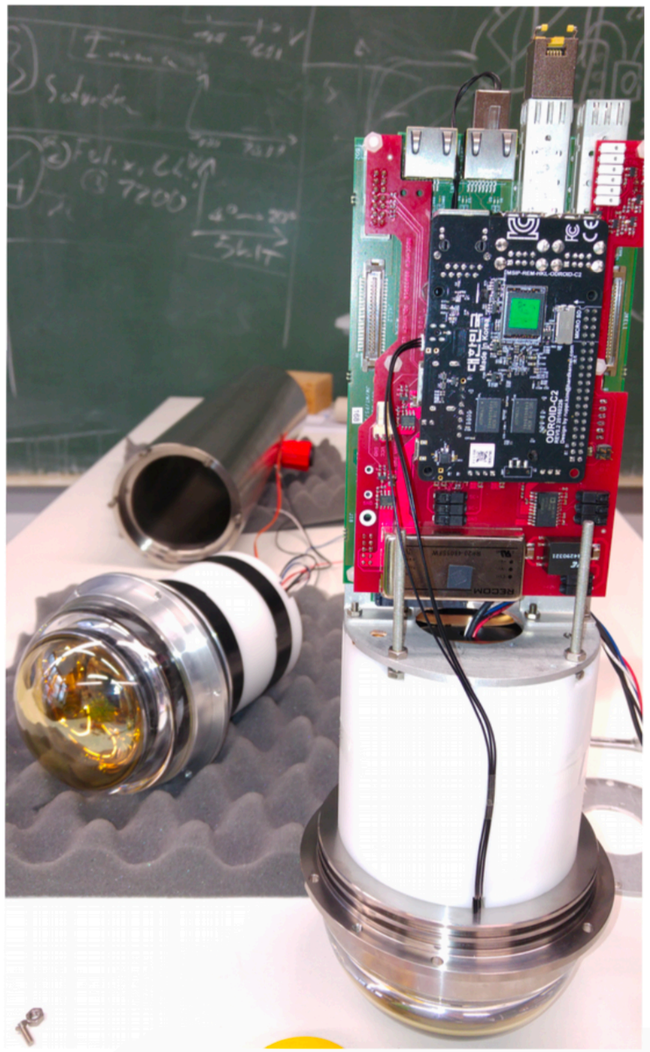
- Precision Optical Calibration Module
- Create isotropic light flash using a PTFE integrating sphere
  - Intensity adjustable over at least 2 orders of magnitude
  - PTFE is Lambertian reflector
  - High reflection across broad wavelength range
  - Spherical integration isotropy
- Titanium housing designed for 1400 bar



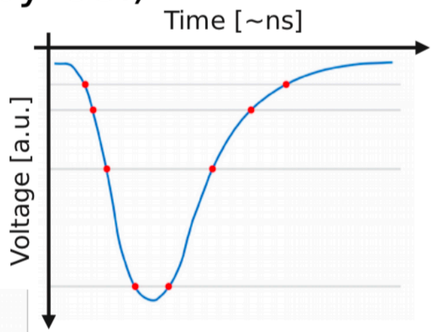


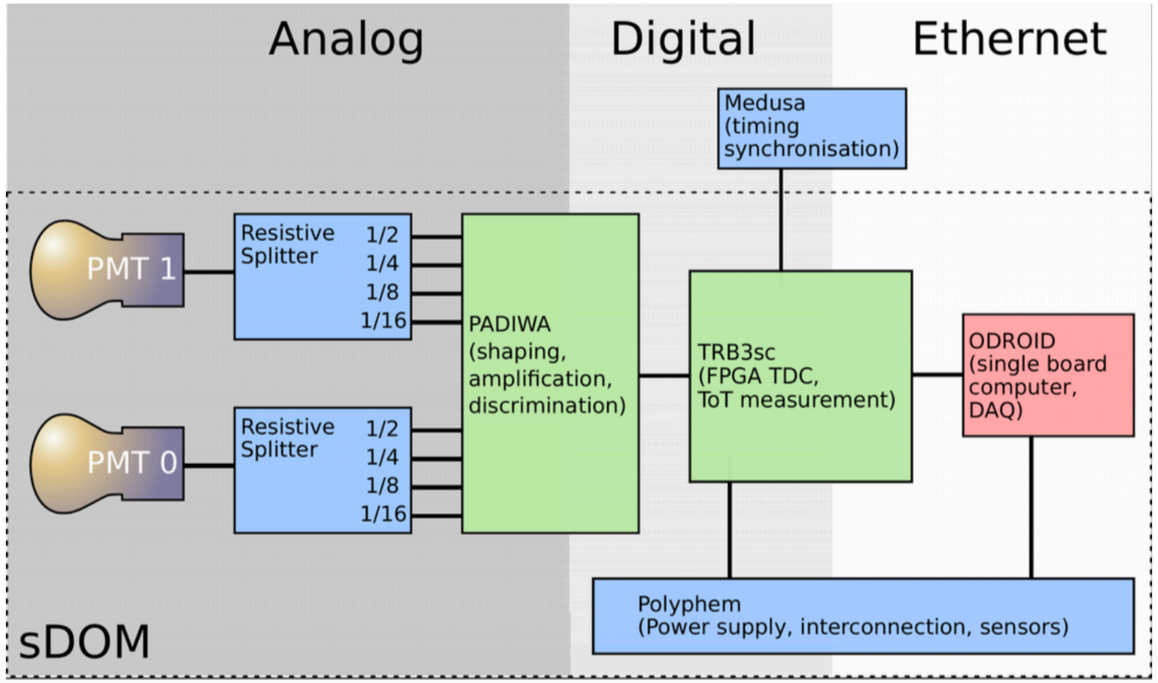
- Use internal photosensors for self-calibration
  - SiPM and Photodiode for high dynamic range
  - Multi-wavelength emission for spectral studies
    - 365, 405, 465, 525, 605nm

sDOM

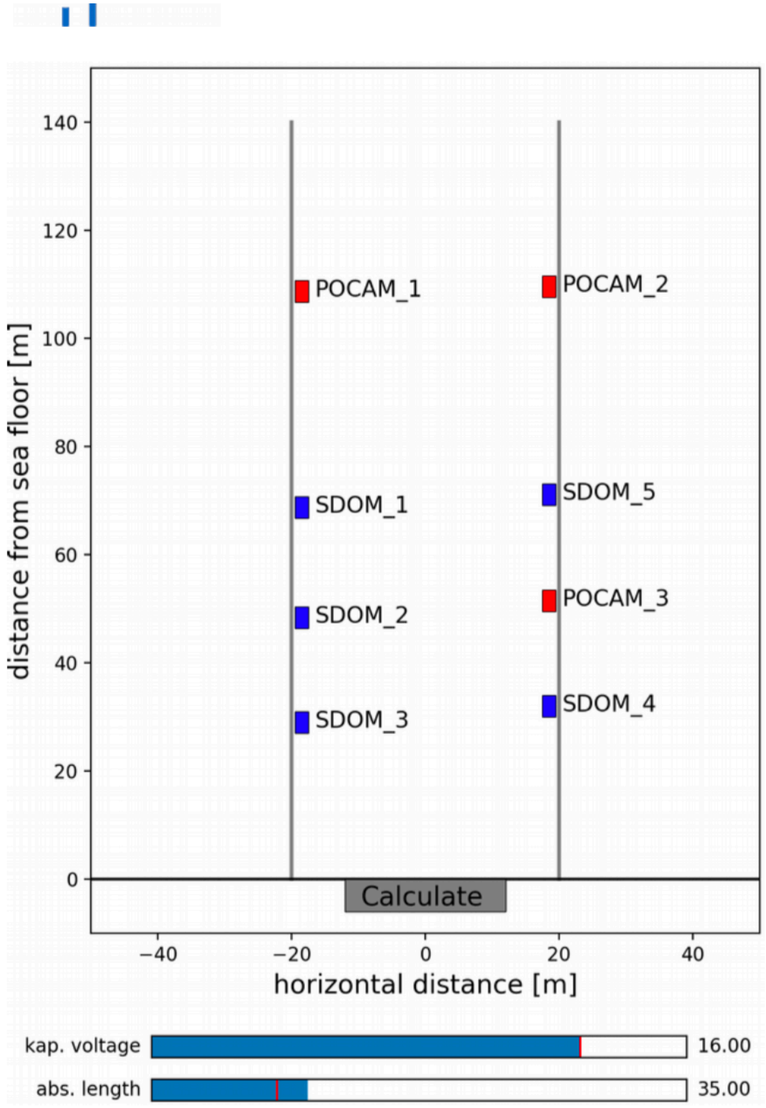


- Two 3“ PMTs (Hamamatsu R12199)
- Readout with TRB3 and PaDiWa (TDC designed by GSI) http://trb.gsi.de/
- 4 channels per PMT
- Control via Ethernet and single board computer Odroid C2





Attenuation measurement



Model has the following parameters:

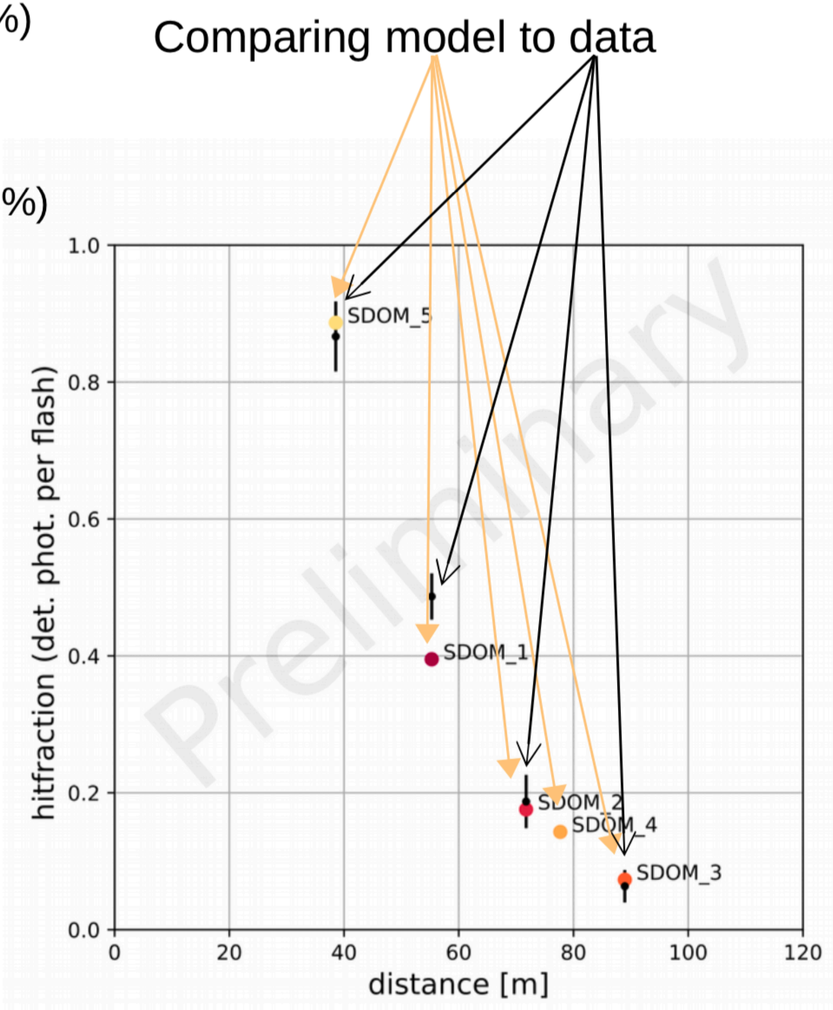
POCAM:
- → Calibration error 1x per POCAM (+/- 3%)
- → Global calibration error (+/- 3%)

sDOM:
- → QE/PDE error per 1x per sDOM (+/- 10%)
- → QE global (~25%)
- → Threshold efficiency (~80%)

STRAW:
- → **attenuation length**
- → y offset (+- 2m)

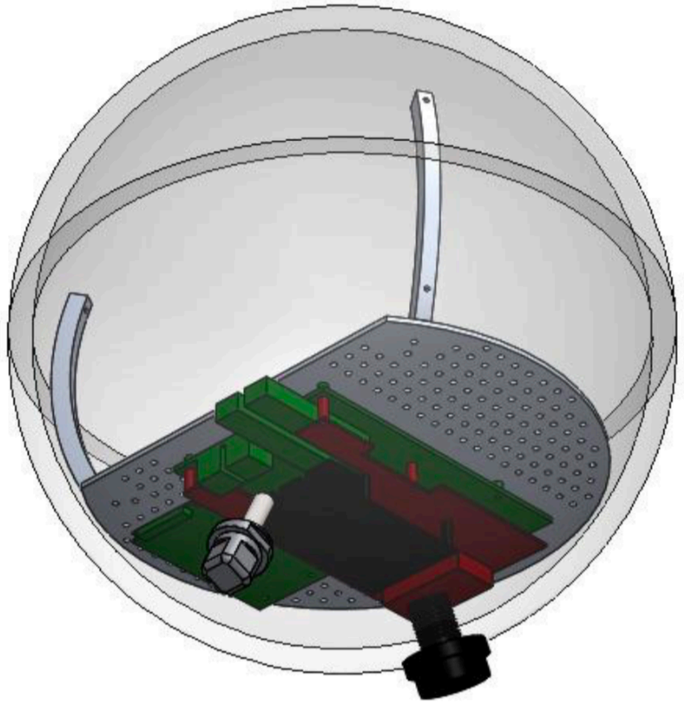
Fit 365 nm, 405 nm and 465 nm simultaneously

→ **MCMC sampling using emcee**
http://dfm.io/emcee/current/



Standard Modules

- Check positions of mooring line
- p/T/H and magnetic field sensors for ping signal
- 48V (DC) and Ethernet connection
- Read-out electronic from sDOM
- Basically two categories of modules
  - Standard Modules
  - Specialised Modules



Slides and thoughts by John G. Learned

OK, where are we and where are we going soon with neutrinos?

At lower energies (<TeV) we have found neutrino oscillations and mass and much more about neutrinos… amazing experimental results

~ lifetime, they make it from distant objects at ~c
~ standard model cross sections, but >EeV quite uncertain
~ 3 families and weak hints of more (revolution if so)
~ mixing angles curiously larger than for quarks, forget Cabibbo
~ mass trending towards m1 < m2 < m3 as with quarks, but why?
~ unclear about CP violation (but really so what, RH nus?)
~ some peculiarities in nuclear reactor nu expts (RNA and 5 MeV bump)
~ solar models and atm nu fluxes ~ OK (to 15% or so!)
~ no observation of expected Direct Production (OK?)

And still no theory guidance from a grand scale GUT

Still we know very little more about cosmic rays and sources > PeV

Slides and thoughts by John G. Learned

Review of opportunities for natural neutrinos by energy:

- **Big Bang Relics**: No good ideas out there… biggest challenge, only indirect inferences
- **Pre-white dwarves**: Dominant radiation in neutrinos but keV energies, no flux calcs
- **<MeV Geo neutrinos**: particularly K40, important challenge
- **Relic SN Neutrinos**: in few MeV range, maybe in reach of HyperK
- **Galactic SN**: 10's of MeV… few/century, could be any time
- **Atmospheric Neutrinos**: 100 MeV to >TeV, continue to be a gold mine for nu properties
- **Few TeV from mostly galactic sources**: IceCube now, others follow
- **<100 TeV astro nus:** could yield wonderful surprises, IC in progress
- **1-10PeV:** as now seen in IC: the promised land and probably most fruitful in ~10 yrs
- **Glashow ~6.4 PeV and Double Bang:** astro nu flavors coming, slowly
- **EeV**: Where are the BZ neutrinos?
- **And what are those ANITA events?** This is indeed *terra incognita*

Some Advice for Ocean Neutrino Hunters

some controversial from jgl experiences (random order)

- First off plan to test, test, test and in-ocean!
- Connectors are the bane of our experiments… source of most failures.
- Experienced Physicists should be overall involved in the design details, not handing over to engineers.
- Avoid review committees without ocean experience!
- Unlike IceCube, design for service and reconfiguration.
- Buy all possible components, from proven mfrs.
- Reprogrammable software in ocean.
- More than one data link to shore, no single point fail.
- In the past, large stupid light collectors always won. Now?
- Beware stored charge in HV ocean cables… Total power an issue.
- Neutrino induced showers, not muons, are your future.
- Work on shower directionality reconstruction to go beyond IC.
- Plan for eventual ~10 KM^3