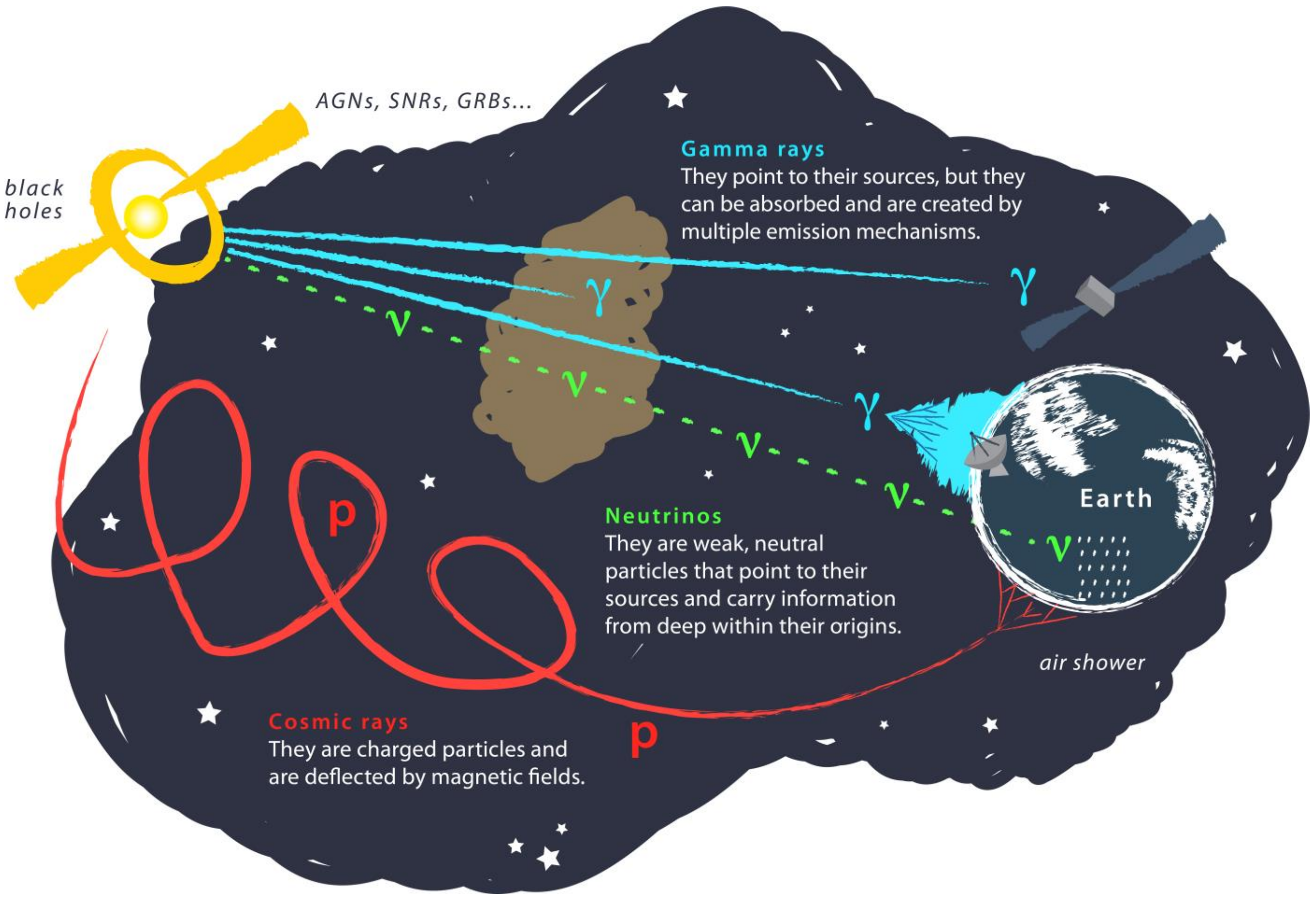
IceCube

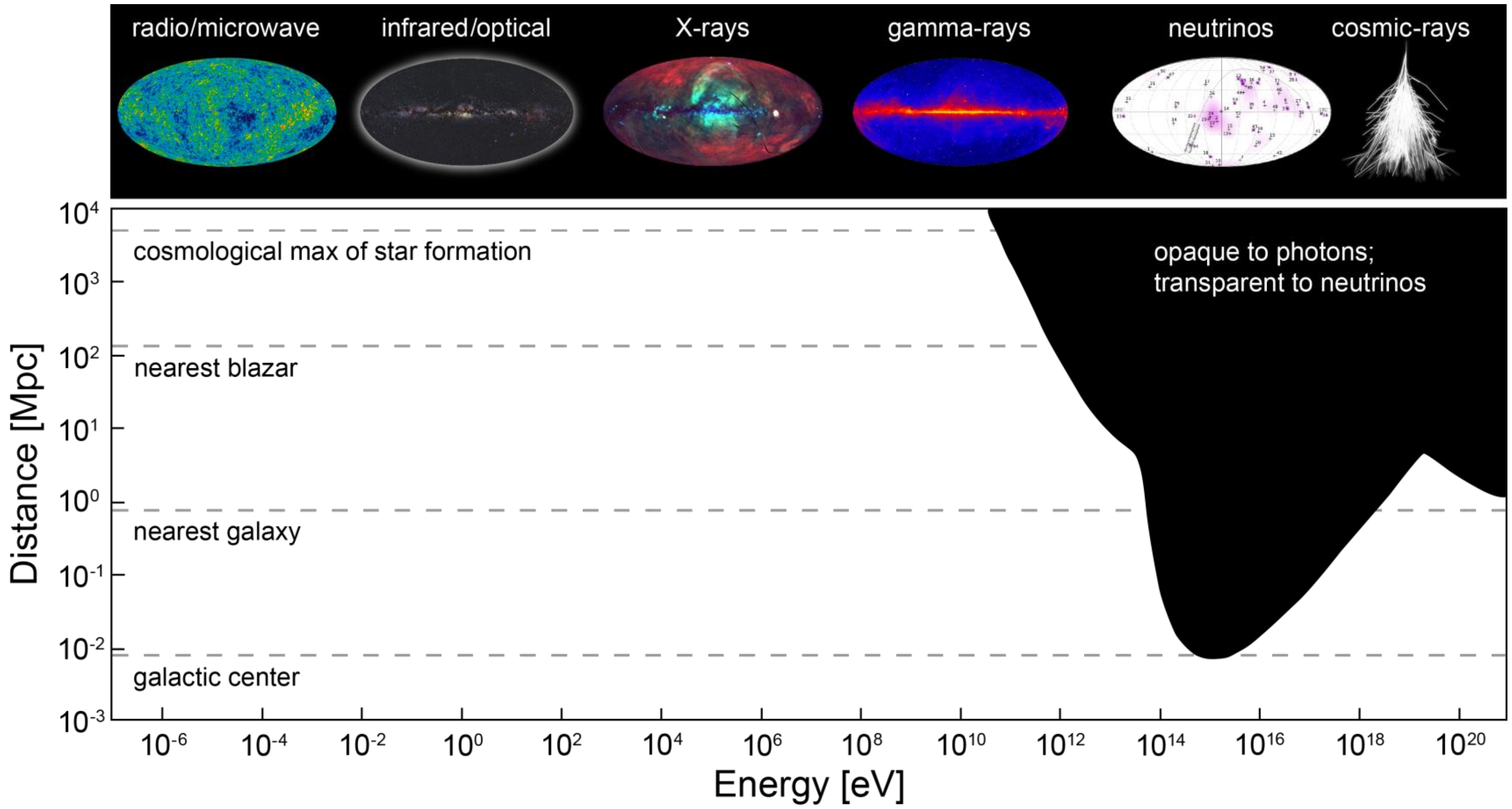
Martina Karl

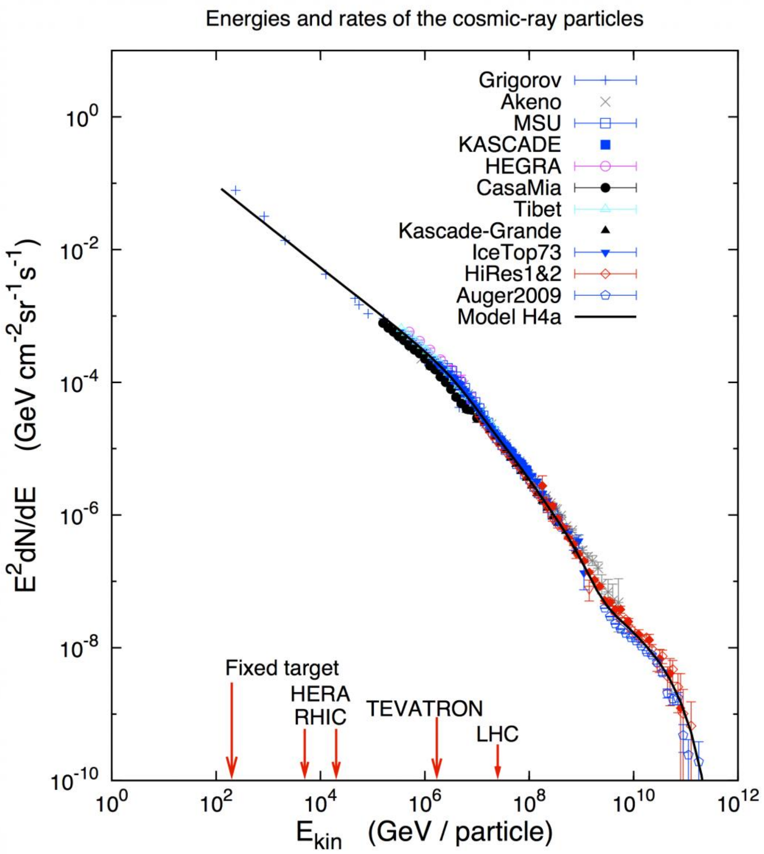
Multi-messenger Astronomy



IceCube Collaboration

IceCube – Neutrino Telescope

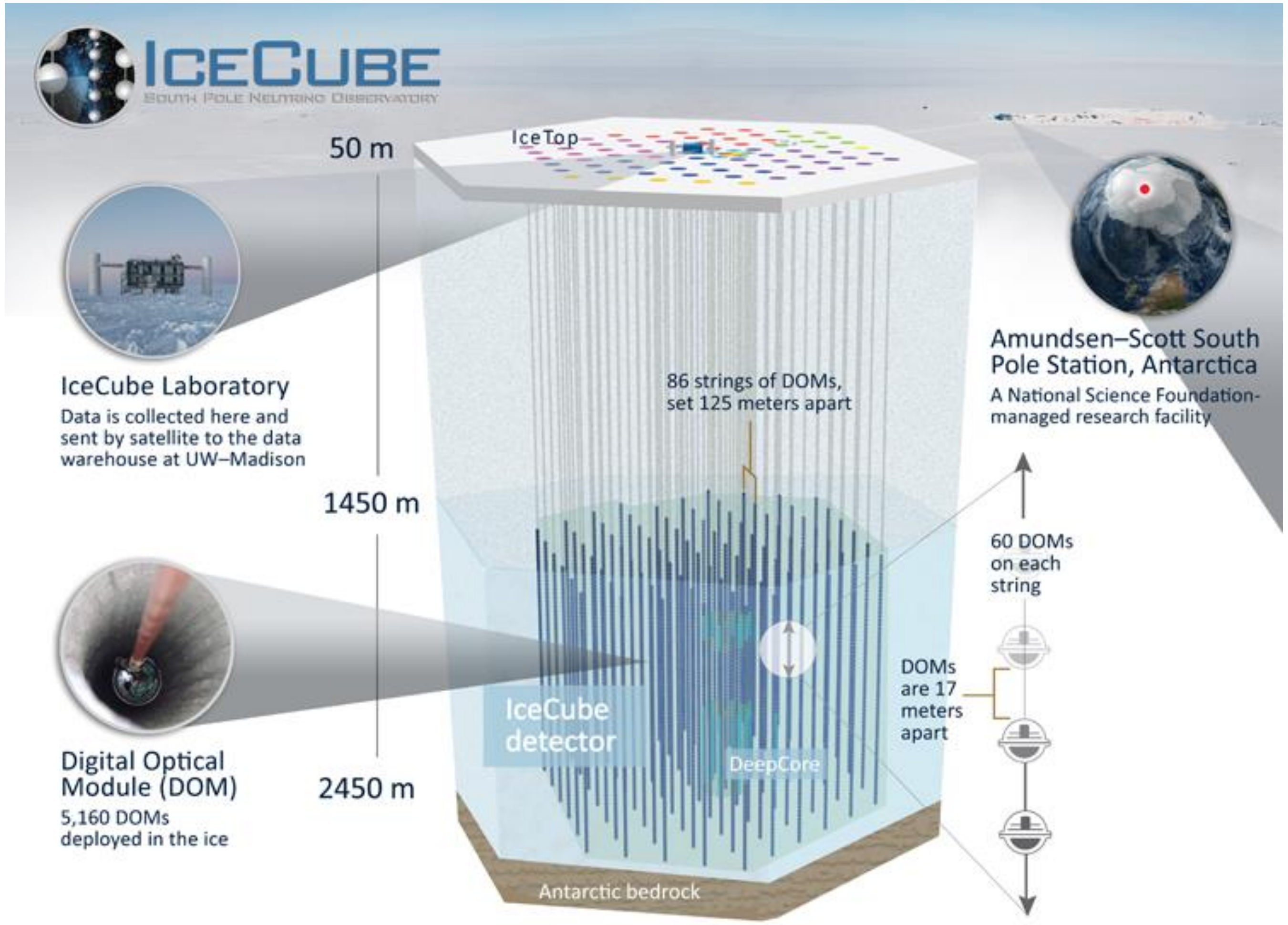


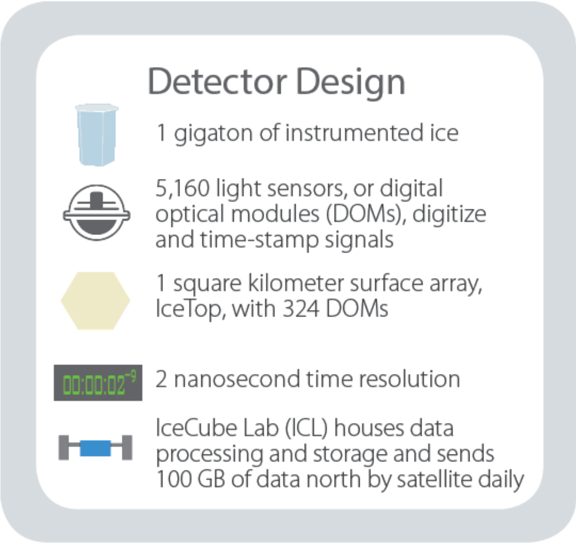


https://icecube.wisc.edu/science/highlights/neutrino_astronomy

https://masterclass.icecube.wisc.edu/en/analyses/cosmic-neutrinos

IceCube – Neutrino Telescope

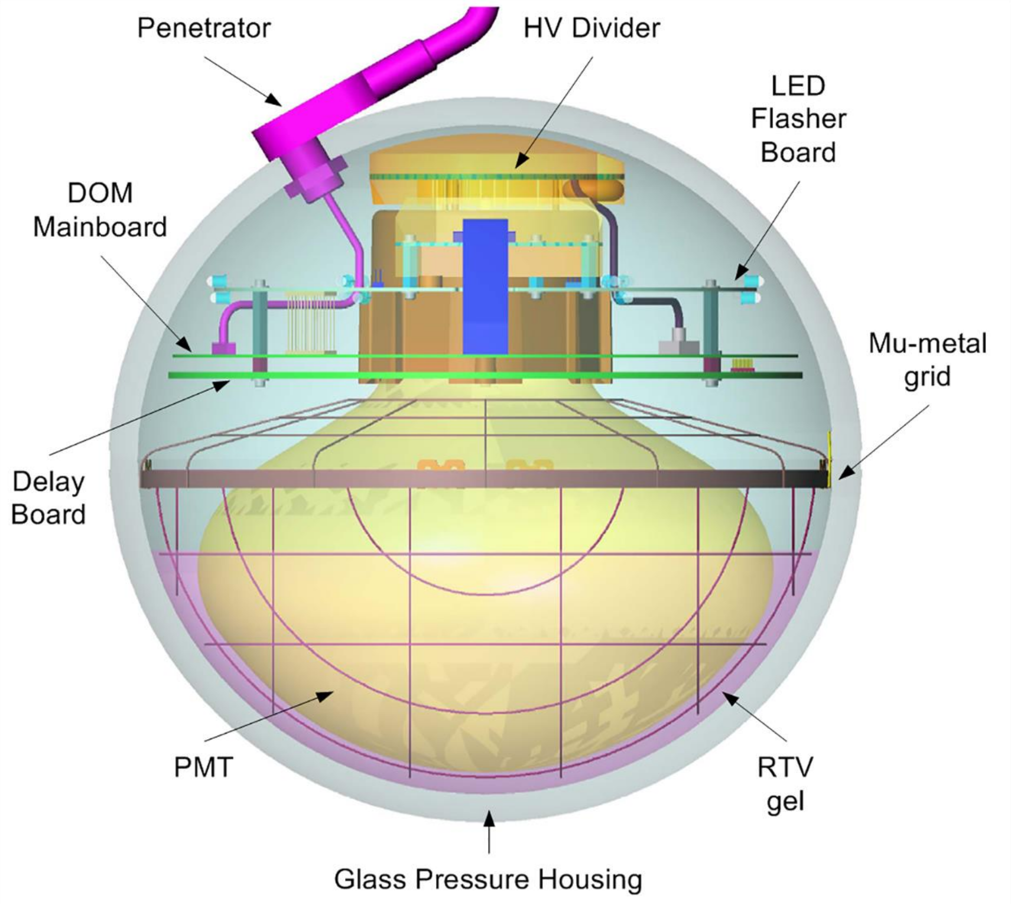




https://icecube.wisc.edu/science/icecube/detector

DOM - Digital Optical Module

- 10-inch photomultiplier tube
- own processing unit
- signal gets digitized
- flash LED for calibration of ice
- 13 inch glass sphere



https://arxiv.org/pdf/1612.05093.pdf

https://icecube.wisc.edu/gallery/view/140

Detection of Neutrinos

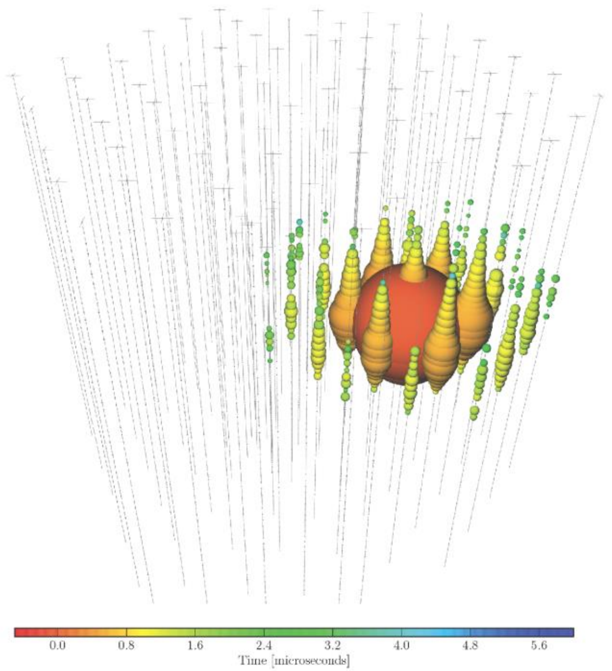
Interaction	Signature
$\nu_e + N \to e + had.$	Cascade
$\nu_\mu + N \to \mu + had.$	Track (+ Cascade)
$\nu_\tau + N \to \tau + had. \to had.$	Cascade/Double Bang
$\nu_\tau + N \to \tau + had. \to \mu + had.$	Cascade + Track
$\nu_l + N \to \nu_l + had.$	Cascade

https://arxiv.org/pdf/1311.4767.pdf

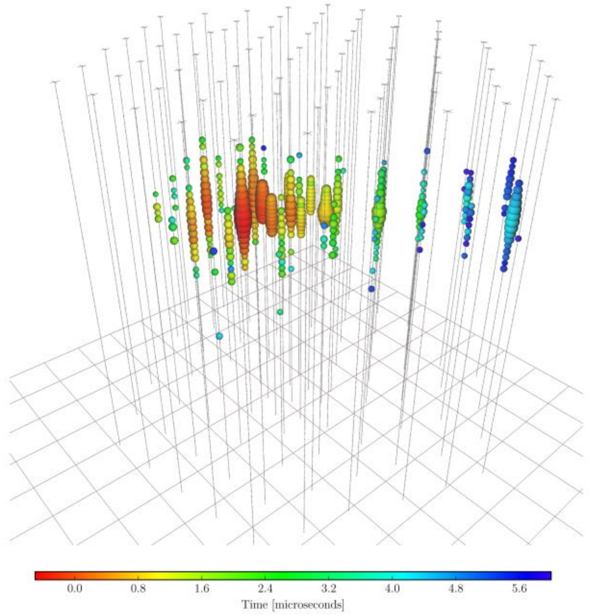
Reconstruction uncertainty

Cascade: ~10°

Track: ~ 0.2° - 1°



https://icecube.wisc.edu/gallery/view/1337



https://icecube.wisc.edu/gallery/press/view/1964

Event Selection

- Background: atmospheric muons → veto
- Events which were reconstructed to pass through earth ($\cos(\theta_Z) \leq 0$)
- Single point (hadronic) and along a track (muon)
- Direct photon if three or more DOMs were hit (20 ns)
- Event selected if at least five DOMs with direct photons
- $E_\nu \approx E_{shower} + a \cdot R_\mu$

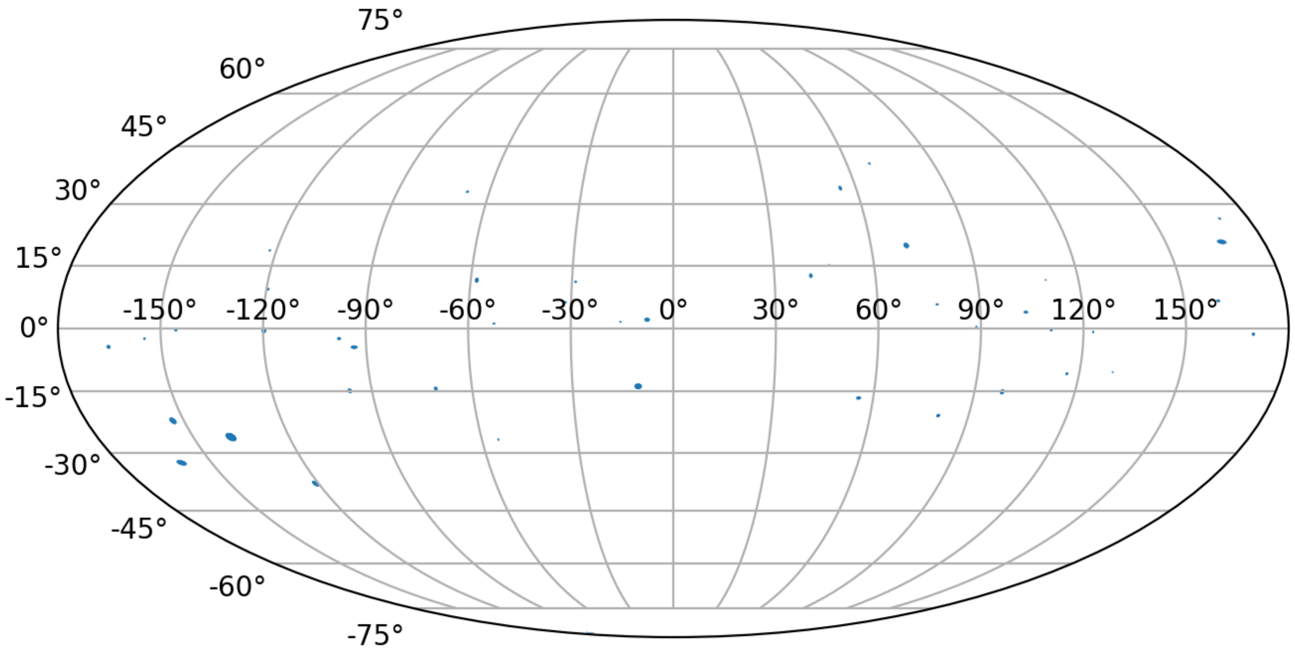
R_μ = range of muon, a = const. energy loss for μ in ice

(a= 0.226 GeV/m)

https://arxiv.org/pdf/1612.05093.pdf

Neutrino Astronomy

- Relevant for Astronomy: tracks ("good" angular resolution ~0.2° - 1°)
- IceCube most sensitive at horizon and north
- South is background dominated



Where do high energy Neutrinos come from?

Neutrino(s) from a Blazar

https://icecube.wisc.edu/gallery/press/view/2239

Source of cosmic 'ghost' particle revealed

By Mary Halton
Science reporter, BBC News

A ghostly particle detected in Antarctica has led astronomers to a super-massive spinning black hole called a 'blazar'

BI Dave Mosher, Business Insider
12.07.2018, 17:00

Neutrino 'ghost particle' detected in Antarctica leads to huge achievement in astronomy

DETECTED deep beneath the ice, scientists have traced a particle back to a volatile galaxy in an achievement set to improve our knowledge of fundamental physics.

'Ghost particle' found in Antarctica provides astronomy breakthrough

By Ashley Strickland, CNN
Updated 1726 GMT (0126 HKT) July 12, 2018

High-Energy 'Ghost Particle' Traced to Distant Galaxy in Astronomy Breakthrough

By Mike Wall, Space.com Senior Writer | July 12, 2018 11:00am ET

It Came From a Black Hole, and Landed in Antarctica

For the first time, astronomers followed cosmic neutrinos into the fire-spitting heart of a supermassive blazar.

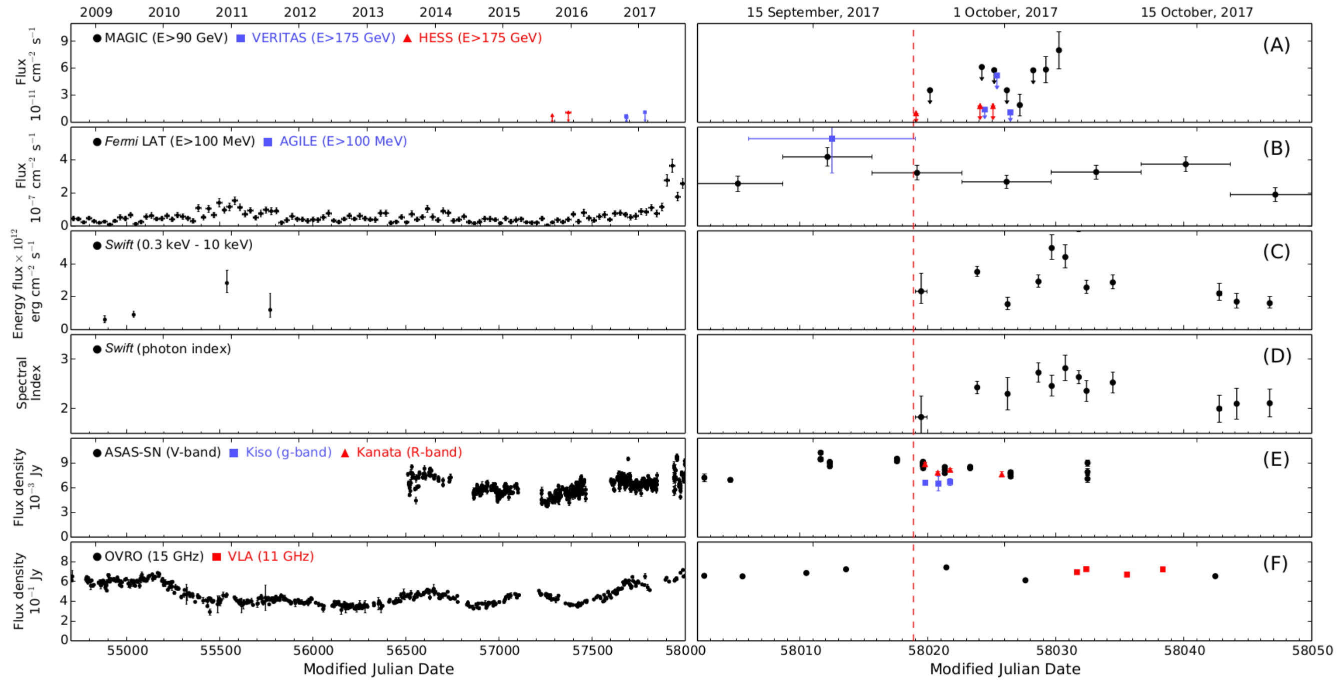
'Ghost particle' from ANOTHER GALAXY to spark astronomical breakthrough

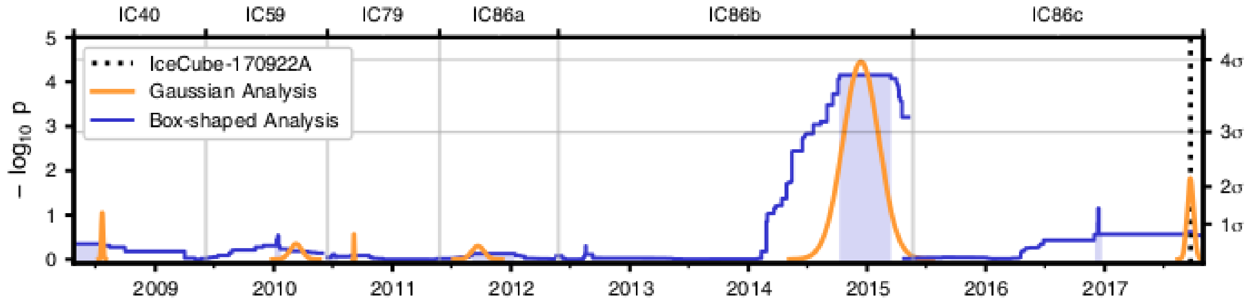
EXPERTS are ushering in a new era of astronomy after they managed to trace a ghost subatomic particle back to its origins more than four billion lightyears away.

GHOST PARTICLE SENT FROM DEEP IN SPACE COULD CHANGE OUR UNDERSTANDING OF THE UNIVERSE, SCIENTISTS REVEAL

Neutrino Source TXS-0506+056

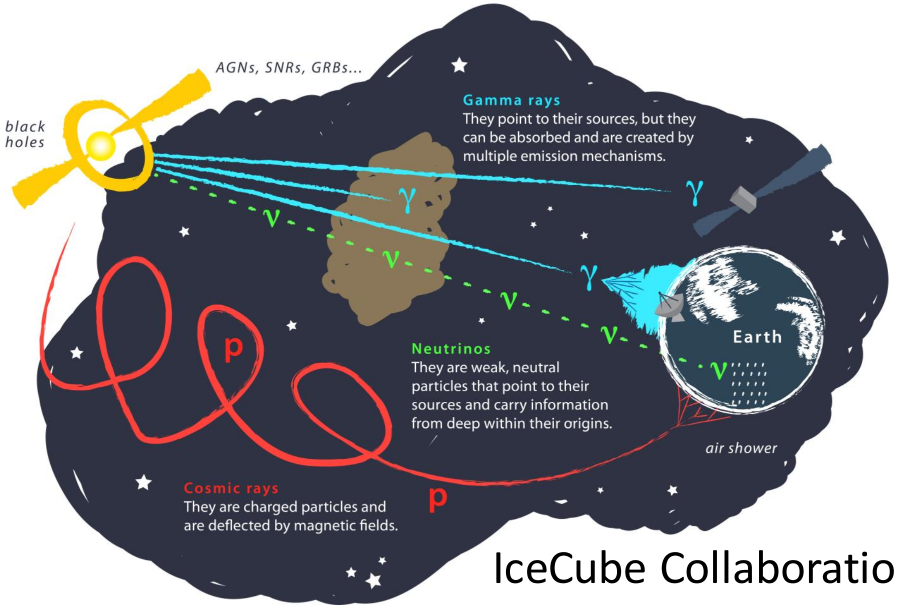
- Event 170922A
- Follow up by Fermi
  -> flaring blazar (ɣ-ray)!
- Follow up by MAGIC
  -> flaring blazar (ɣ-ray)!
- Check archival data:
  neutrino flare in 2014/2015 from same origin





https://arxiv.org/pdf/1807.08816.pdf
IceCube Collaboration

Summary



IceCube Collaboration

- Mulit-messenger astronomy with neutrinos
- 1 km^3 of instrumented ice
- 47 high energetic tracks
- 1 neutrino source -> neutrino from a blazar!
- Background dominated in south (muons)
- Need telescope in the northern hemisphere → Felix

Technical University of Munich
Max-Planck-Institut für Physik

STRAW
Pathfinder for a Future Neutrino Telescope

IMPRS Young Scientist Workshop 2018 – Schloss Ringberg

Felix Henningsen

Motivation

Motivation

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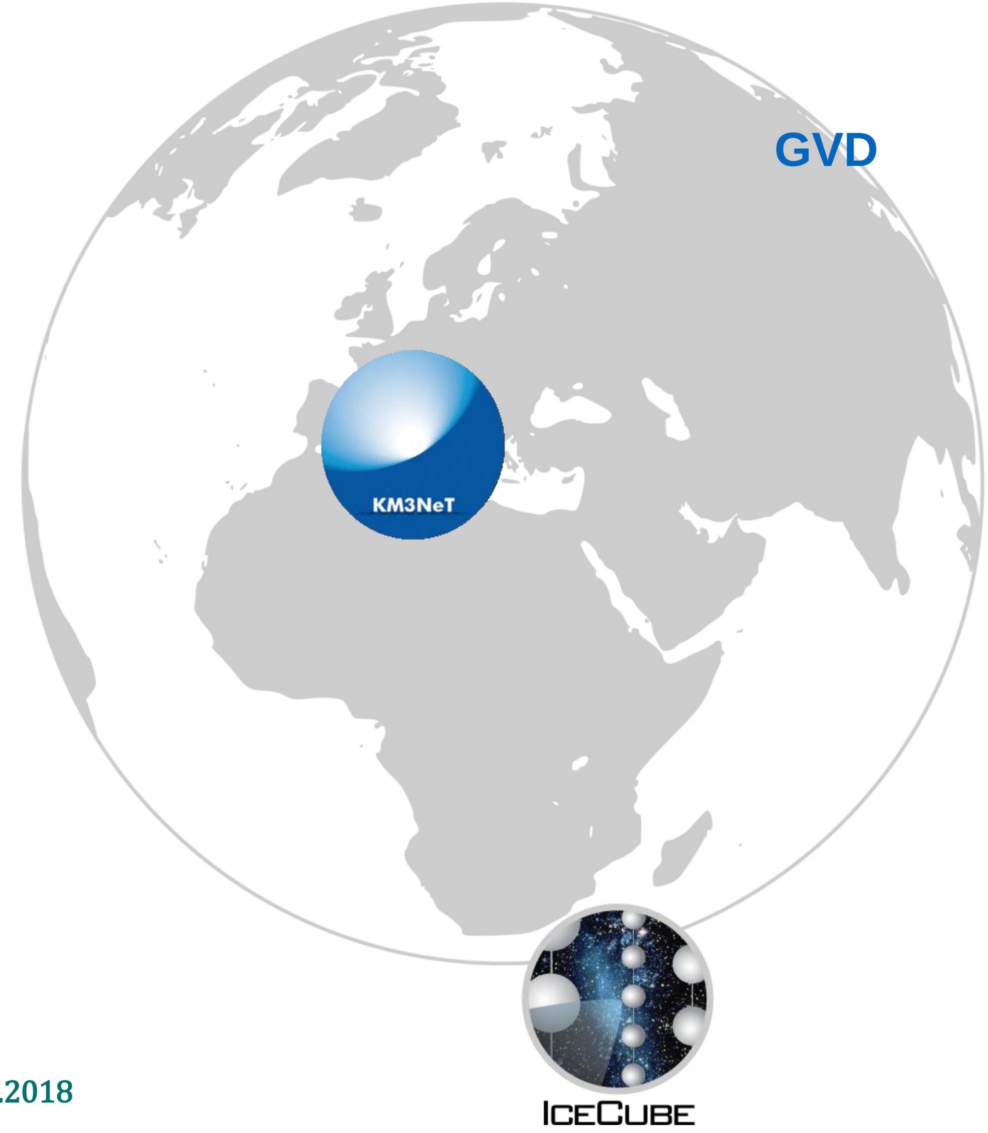
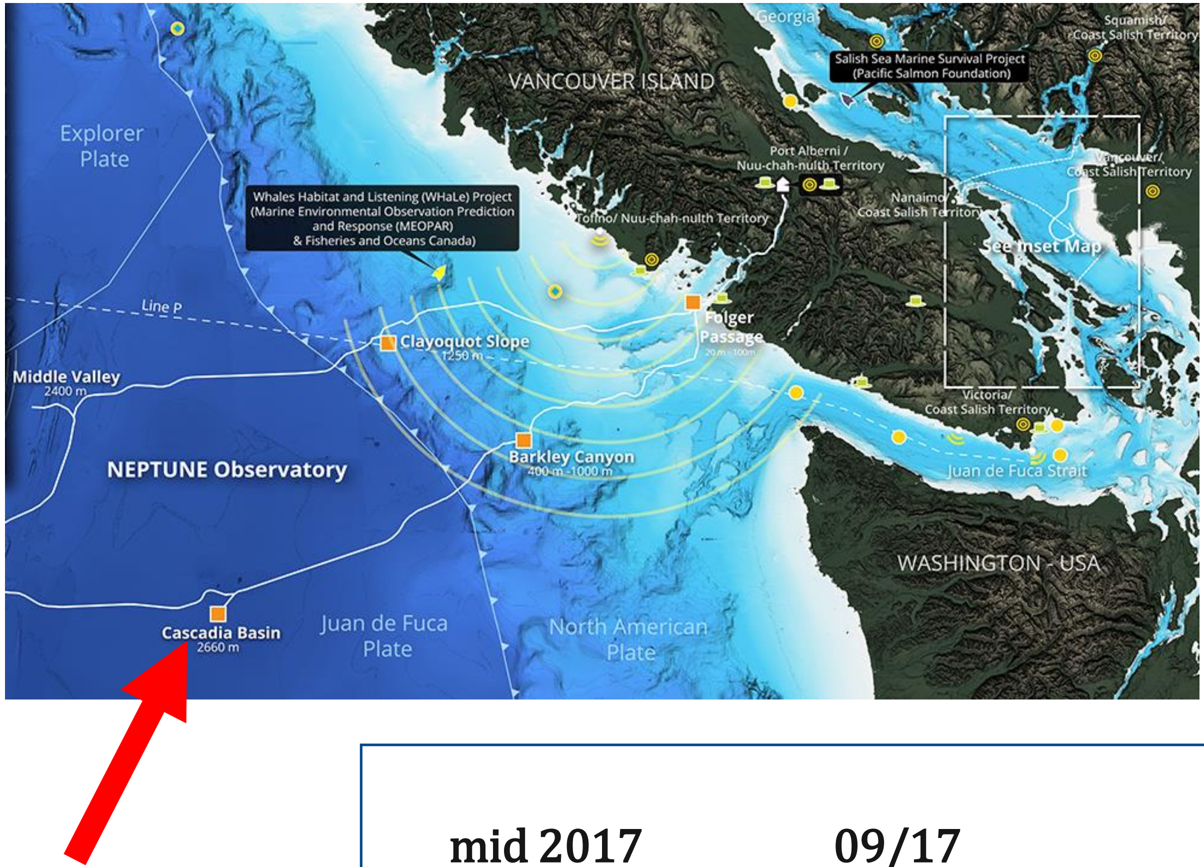


- Three neutrino telescope collaborations
  - IceCube (**operating**) - South
  - KM3NeT (construction / R&D) - North
  - Baikal GVD (construction) – North
- All large-volume telescopes face challenges
- Northern telescopes are necessary for full sky coverage

→ **Learn from ongoing constructions in order to investigate a new possible site**

STRAW
Scientific Objective

STRAW – Scientific Objective



- **STRAW = Strings for Absorption Length in Water**
- Investigate optical properties of Cascadia Basin
- **Optical water quality of the deep sea**
  - Absorption
  - Scattering
  - Backgrounds (radioactivity, biolumescence)

$$I(r) \sim \exp(-r/L_{att})$$

- **Deep-Sea maintenance and deployment**

mid 2017	09/17	05/18	06/18
Idea	Project Start	End	Deployment

Graphic: Ocean Networks Canada

STRAW
Detector Geometry

STRAW Concept - Geometry

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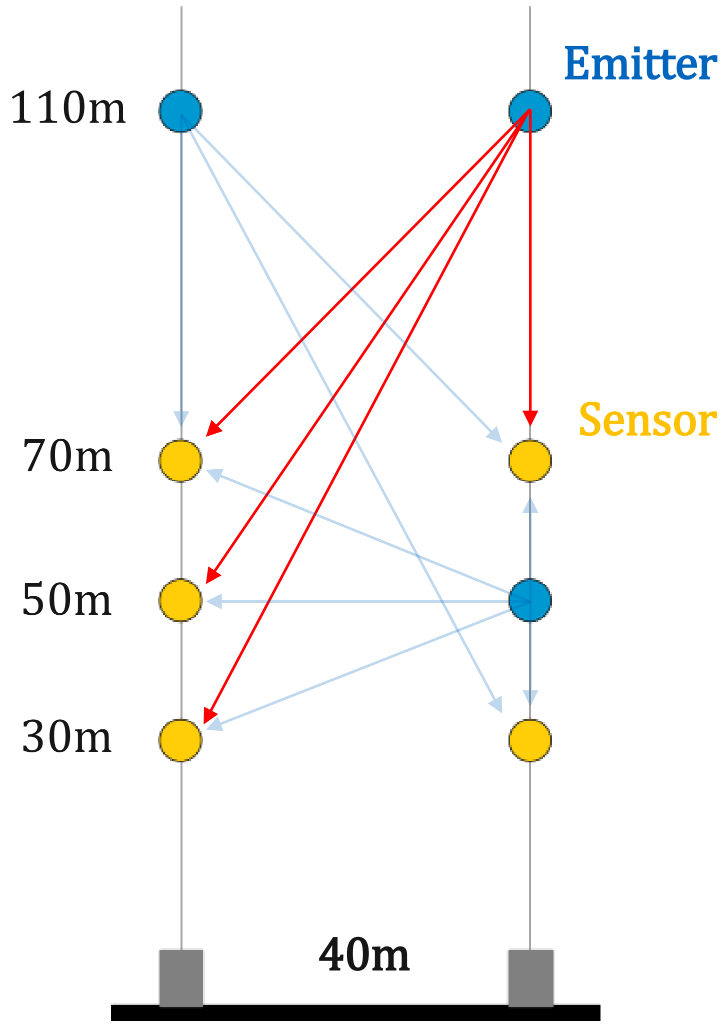
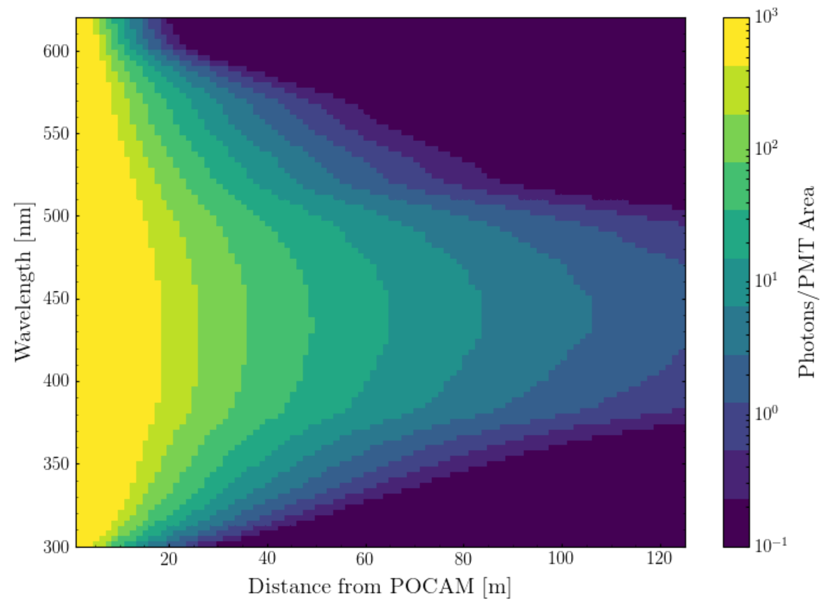


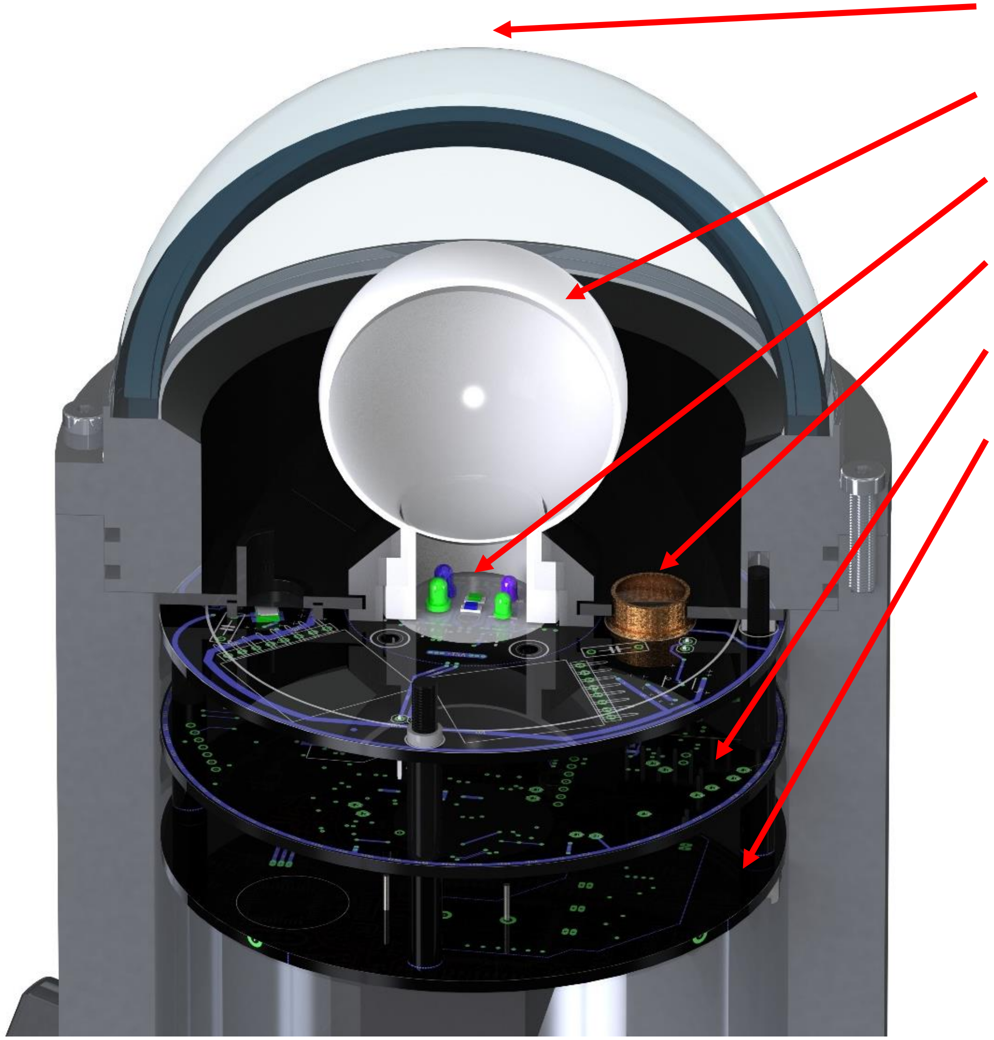
1. Emit and detect light over various distances
2. Fit attenuation length
3. Use simulations to deduce absorption / scattering
4. Monitor properties and backgrounds over two years

- **Emitter:** Precision Optical Calibration Module
- **Sensor:** STRAW Digital Optical Module

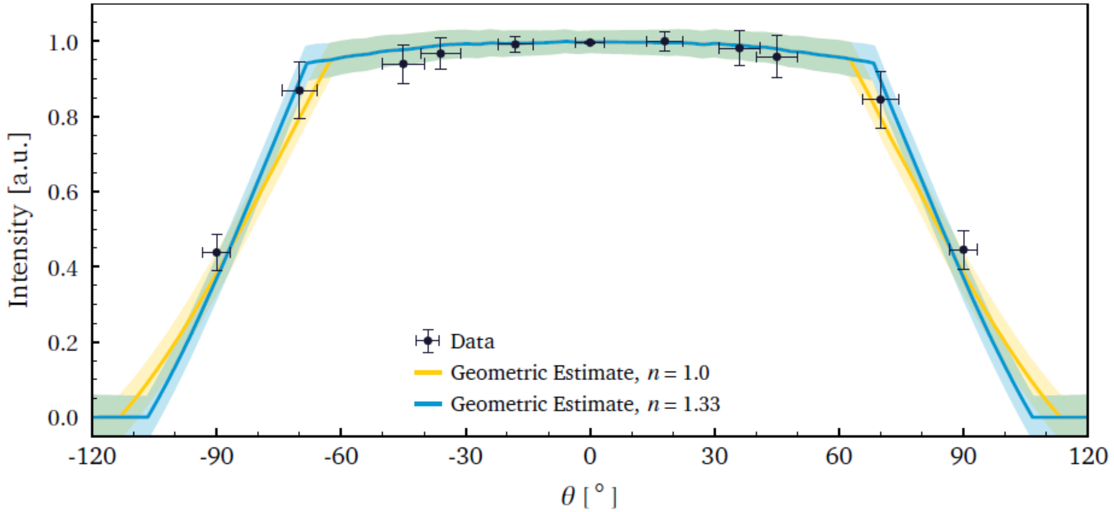


STRAW Instrumentation

POCAM – Precision Optical Calibration Module



- Pressure housing
- PTFE integrating sphere
- LED flashers
- Internal photosensors
- Read-out and DAQ
- Slow Control and Power



sDOM – STRAW Digital Optical Module

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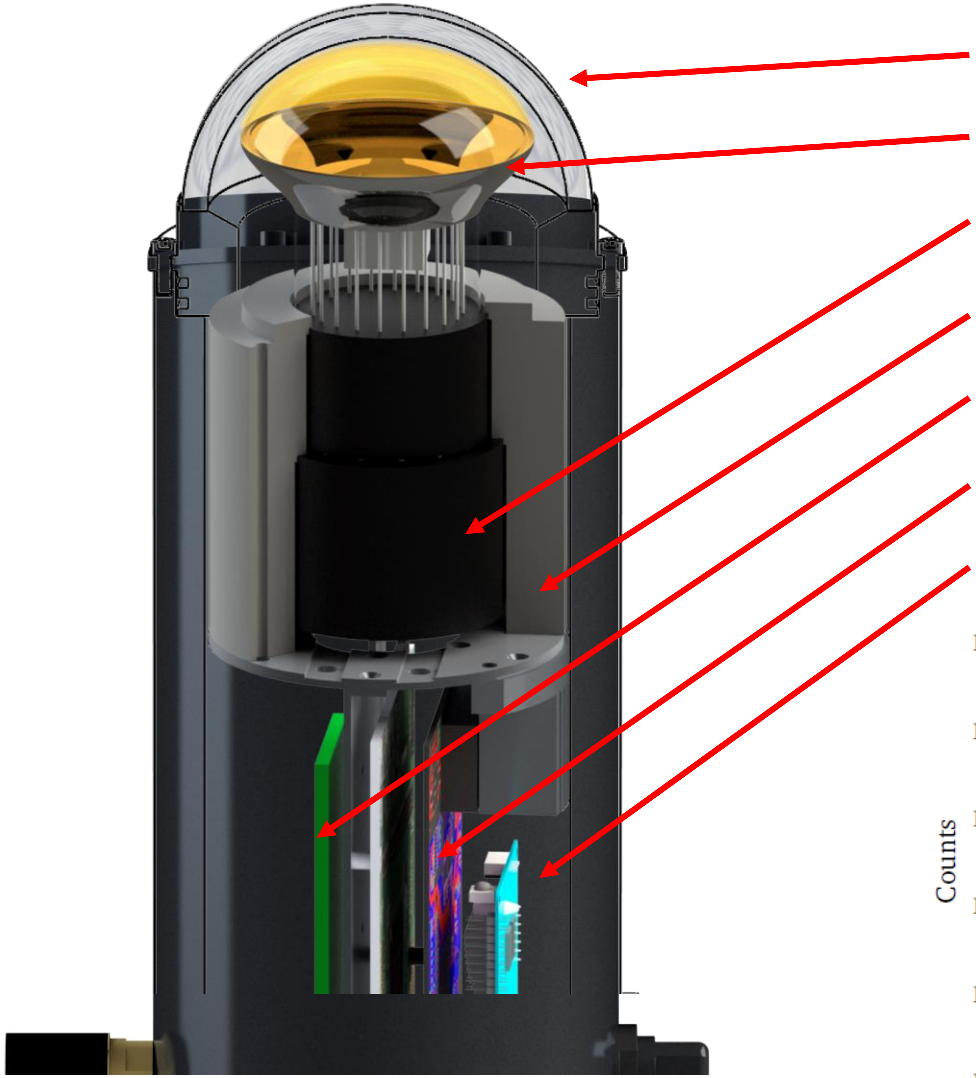
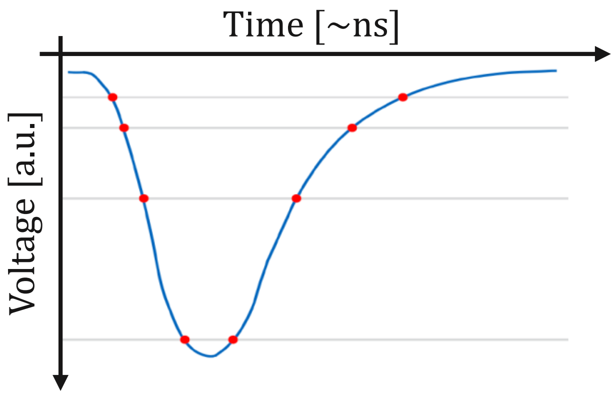
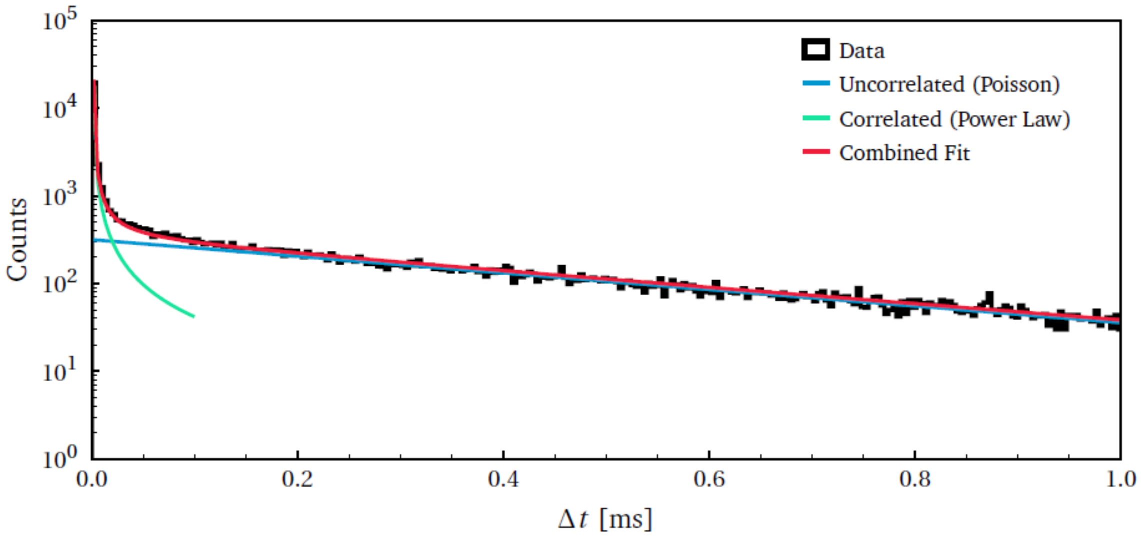


- Pressure housing
- 3“ PMT
- High-voltage base
- Mounting
- TDC and front-end
- DAQ and control electronics
- Single-board CPU





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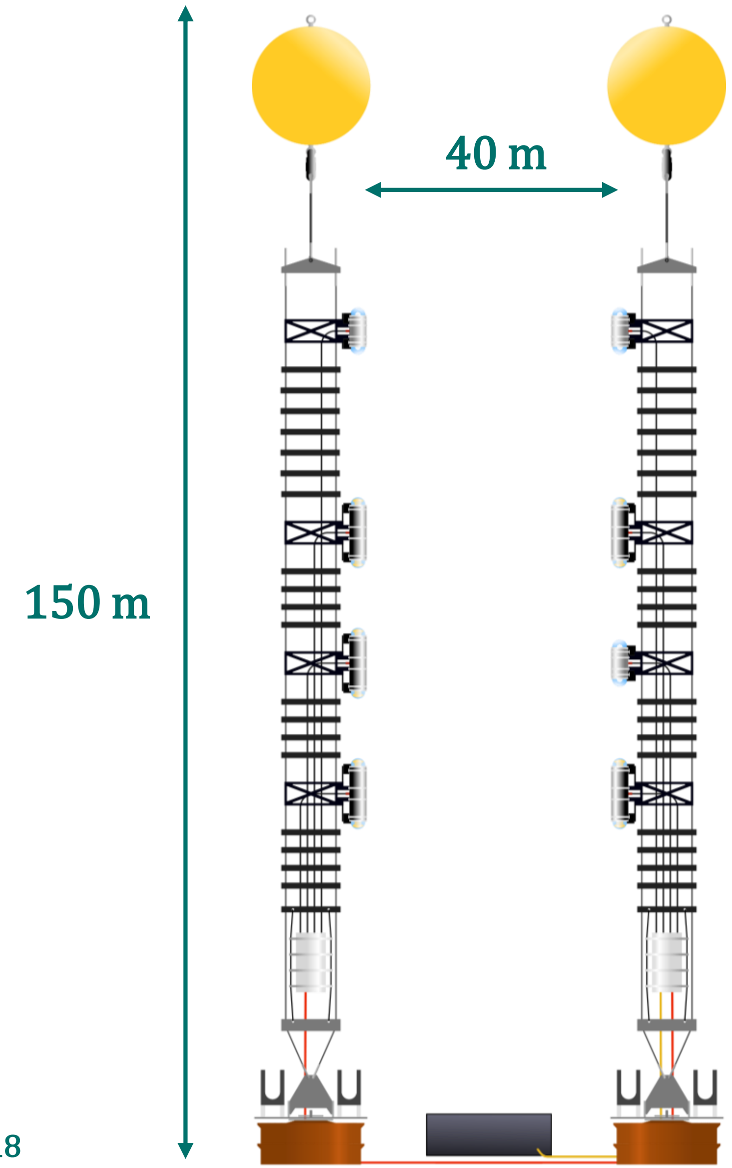
STRAW
Assembly & Deployment

STRAW – Detector Structure



- Two steel lines per string for
  → **Minimal rotational freedom**
  Maximum sea current resistance
- Float for sea current / tilt resistance
- Rotational anchor for face-to-face orientation

STRAW – Detector Structure

- Two steel lines per string for
  → Minimal rotational freedom
  Maximum sea current resistance
- Float for sea current / tilt resistance
- Rotational anchor for face-to-face orientation
- **Spooling system for shipment / deployment**

STRAW – Deployment

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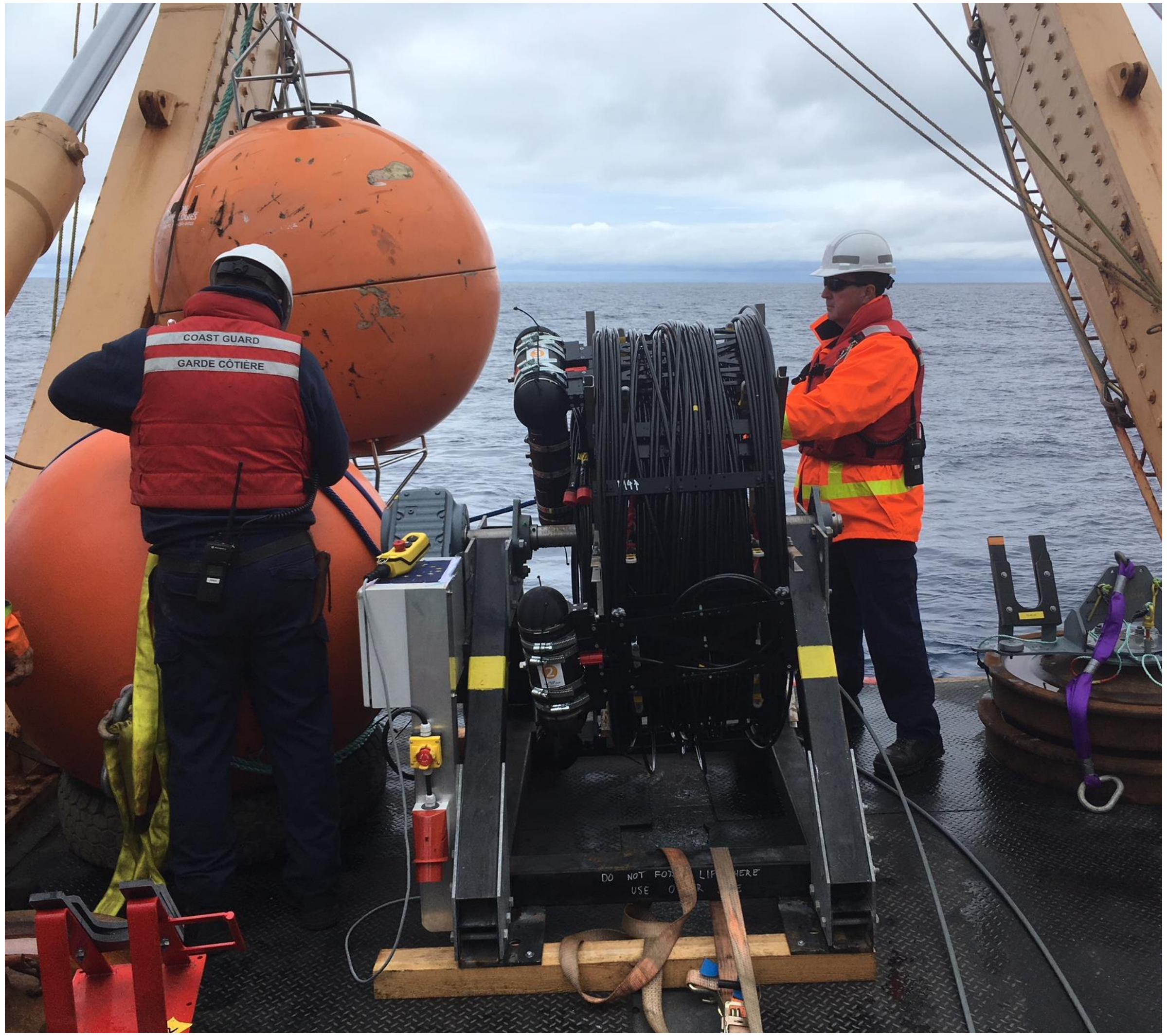
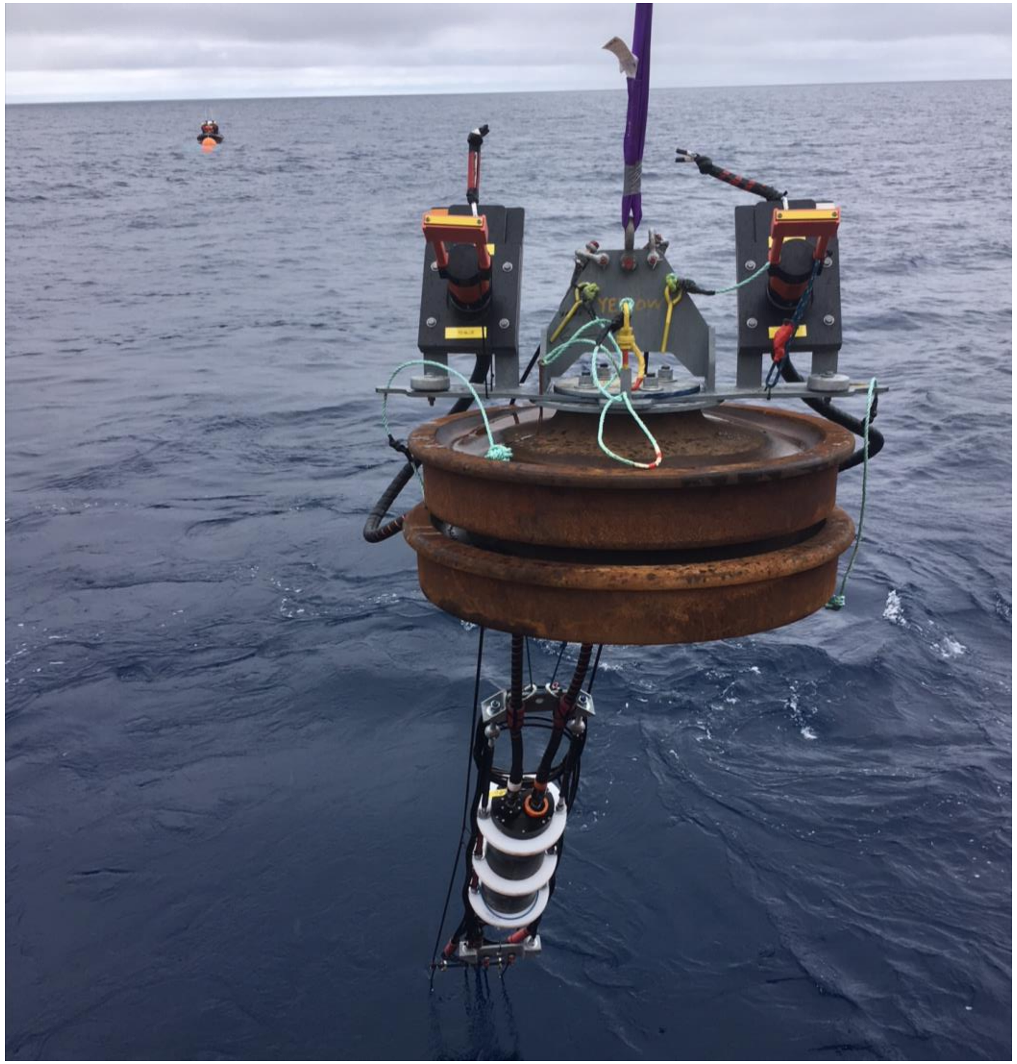
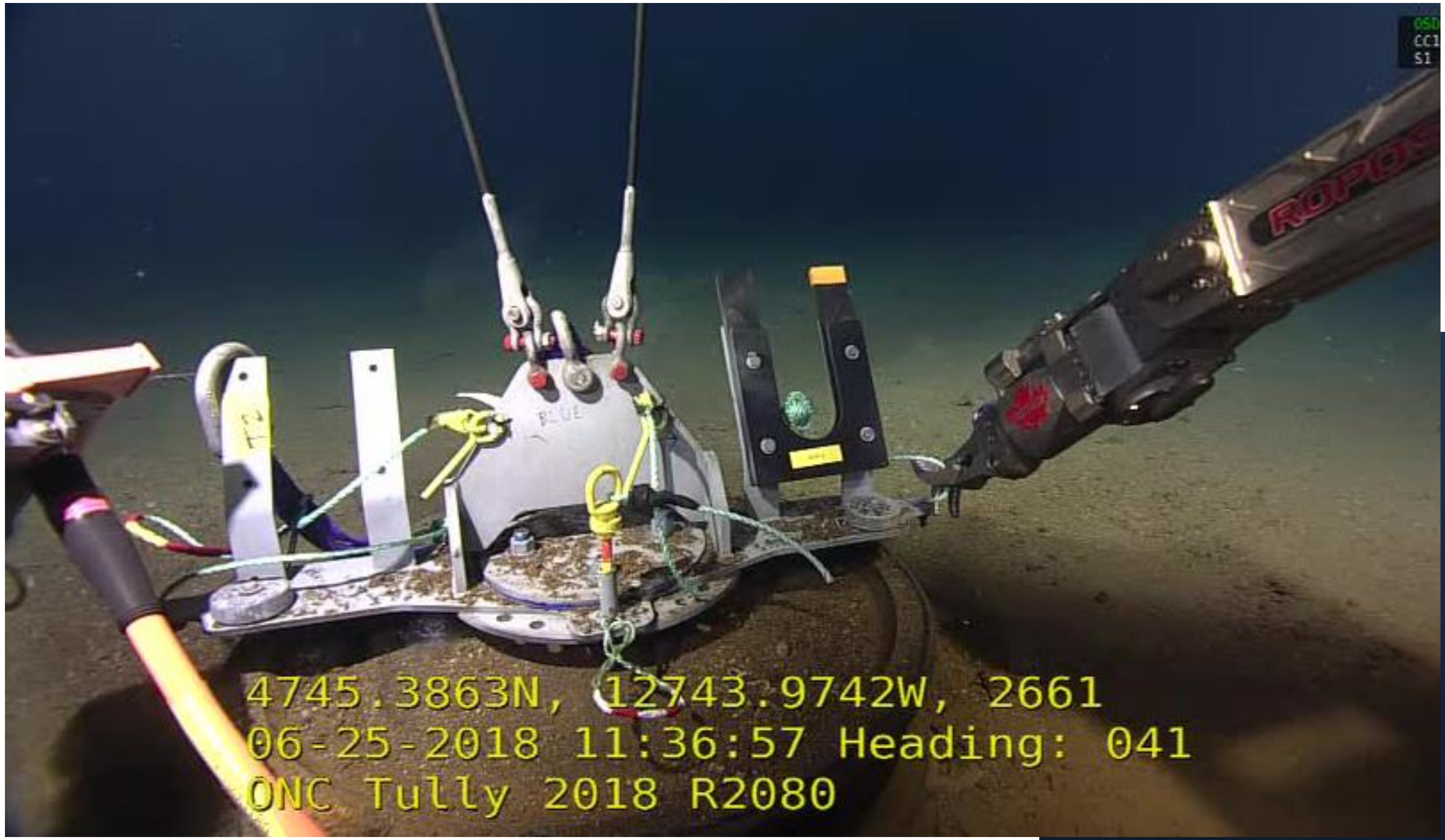




STRAW – Deployment

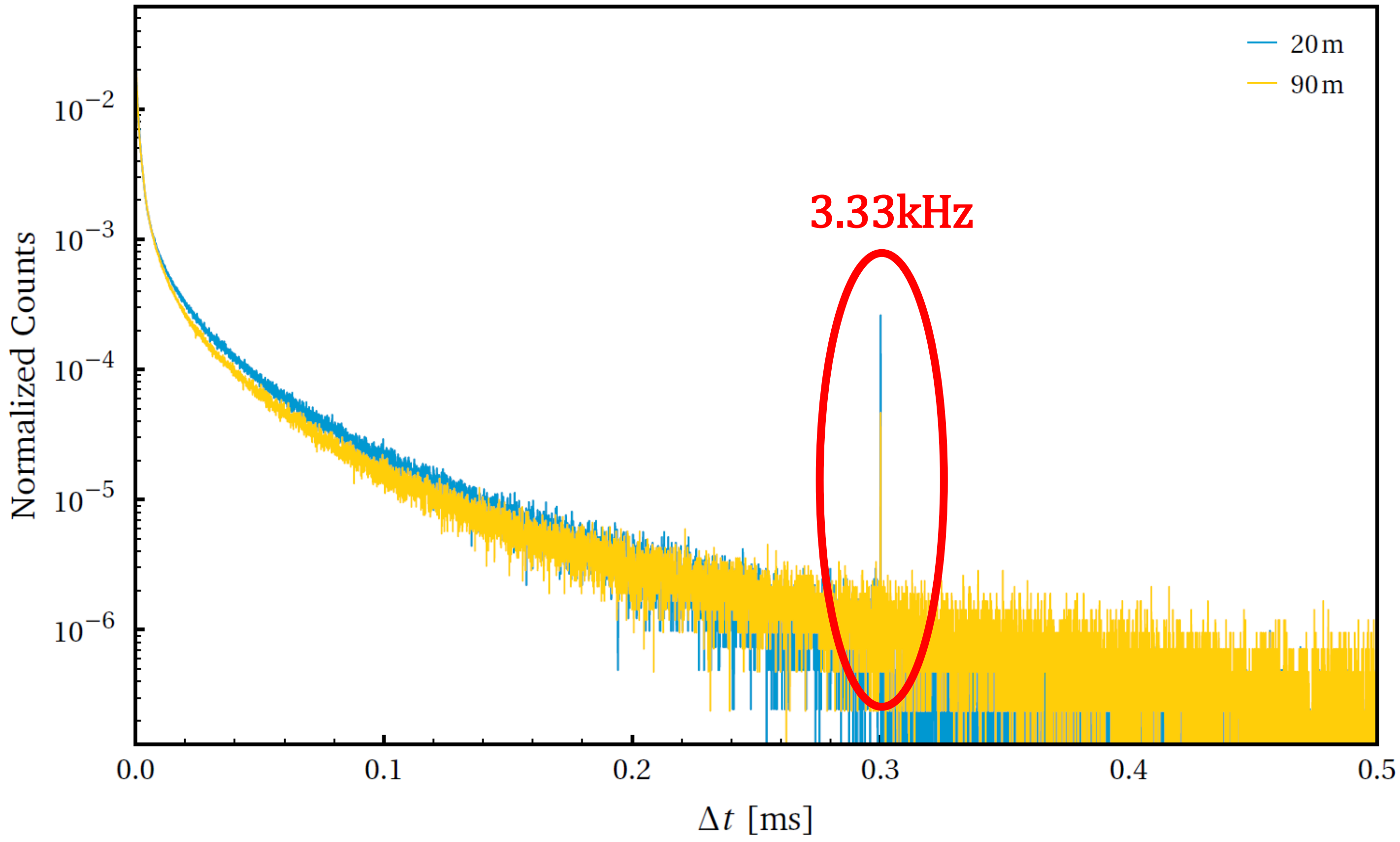


Photographs: ONC/ROPOS

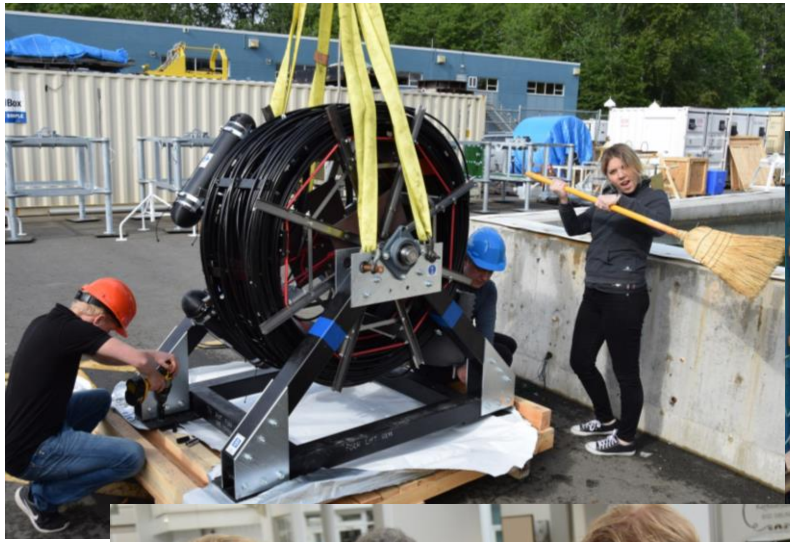
STRAW – First Light & Summary

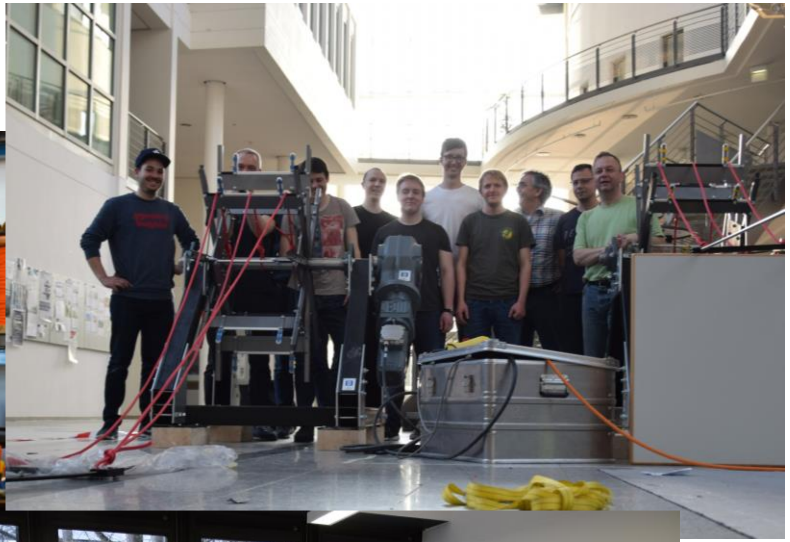
- STRAW Detector fully operational since 21st of June 2018
- Data taking, analysis and simulations on-going

→ **Results within the next months!**



Thank you!





Backup

sDOM – Characterization

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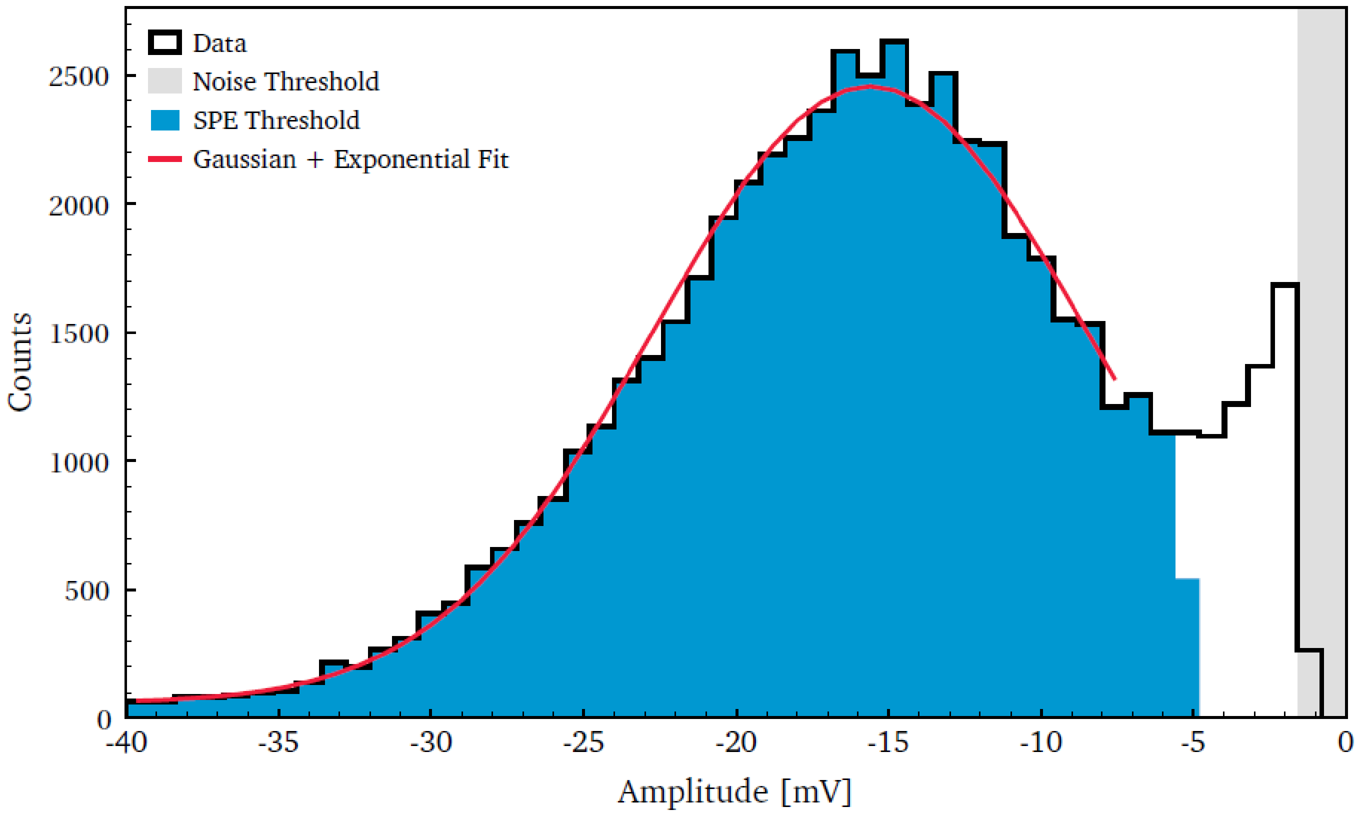
- Individual calibration of all STRAW PMTs
  - **Characterization:** I.C. Rea (PhD)
  - **Dark Rate and Temperature:** this work



sDOM – Dark Rate Calibration

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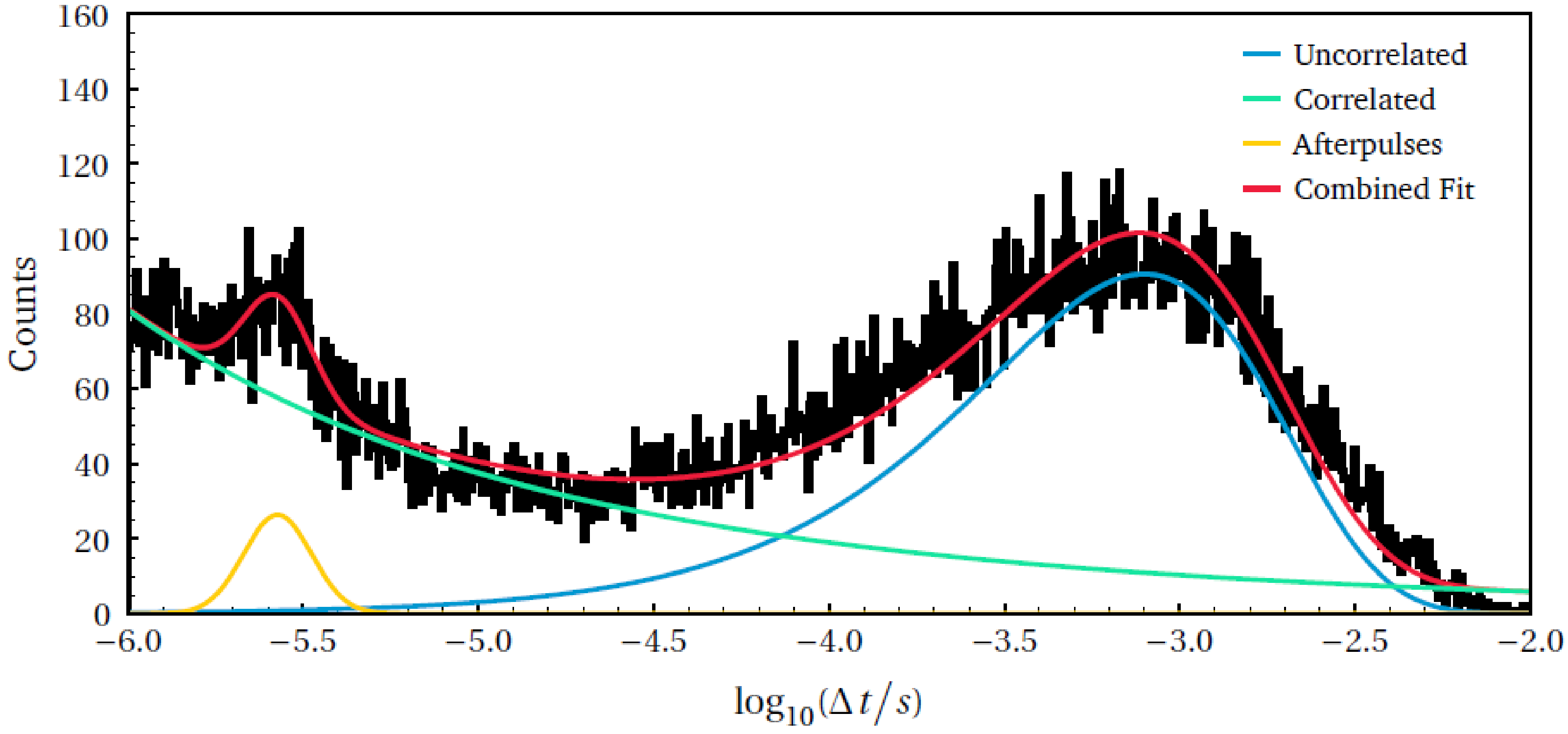
- Uncorrelated noise is composed of thermal and radioactive noise and provides mean dark rate
- Correlated noise is high-frequent and currently not well understood (possibly luminescence or scintillation), see e.g. [5, 6]



[5] Aartsen, M. G. *et al.* The IceCube Neutrino Observatory: Instrumentation and Online Systems. *JINST* **12,** P03012 (2017).
[6] Stanisha, N. *Characterization of Low-dt Non-Poissonian Noise in the IceCube Neutrino Detector* Bachelor's Thesis (Pennsylvania State University, 2014).