Technical University of Munich

Max-Planck-Institut für Physik

SFB 1258 Neutrinos Dark Matter Messengers

STRAW

Pathfinder for a potential new neutrino telescope site in the Pacific

VLVNT 2018 – Dubna

Felix Henningsen for

M. Boehmer, C. Fruck, D. Grant, K. Holzapfel, R. Gernhauser, A. Gartner, S. Hiller, K. Krings, K. Leissmuller, L. Papp, I.C. Rea, E. Resconi, C. Spannfellner, Ocean Networks Canada

03.10.2018

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Outline

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- **POCAM** (Precision Optical Calibration Module)
  - Concept
  - GVD Deployment
  - Analysis & Results
- **STRAW** (Strings for Absorption Length in Water)
  - Motivation
  - Scientific Objective
  - Detector Design
  - Instrumentation & Deployment
  - First Impressions of the site
- **Summary**

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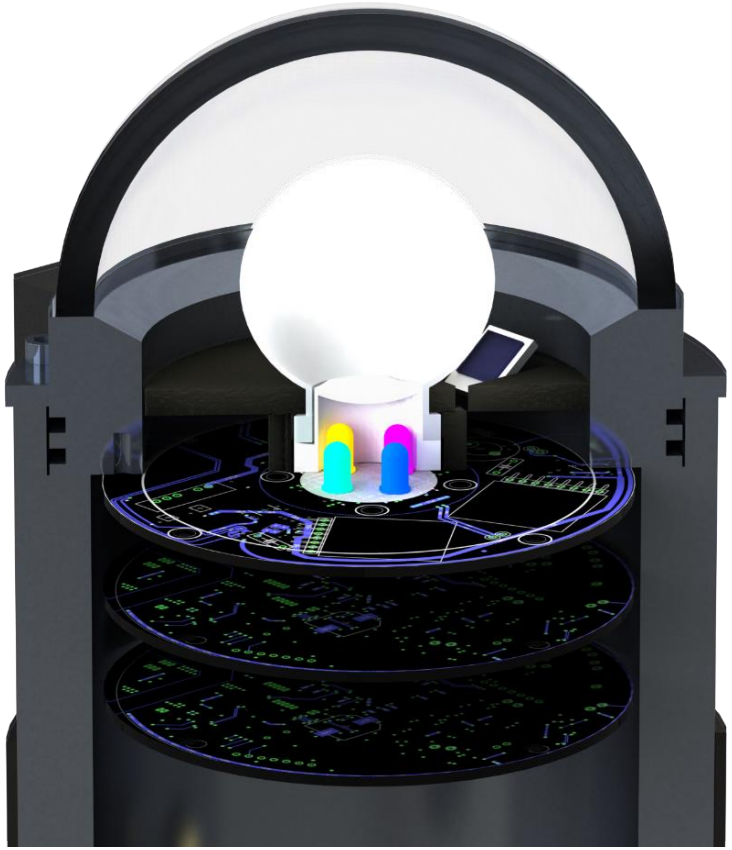
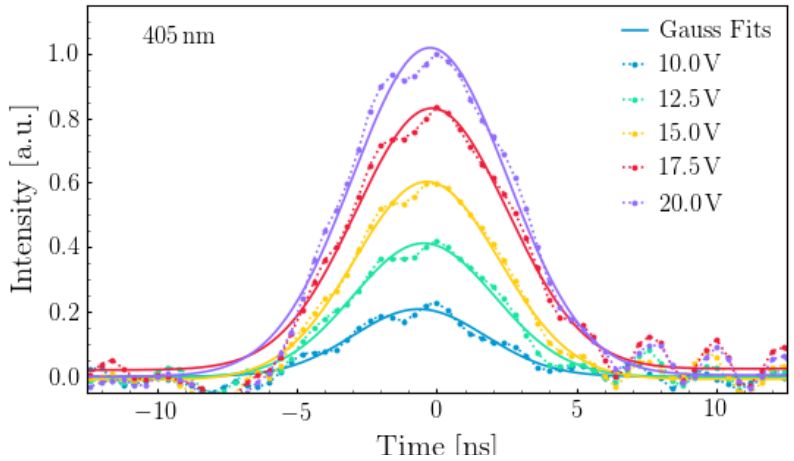
POCAM in GVD

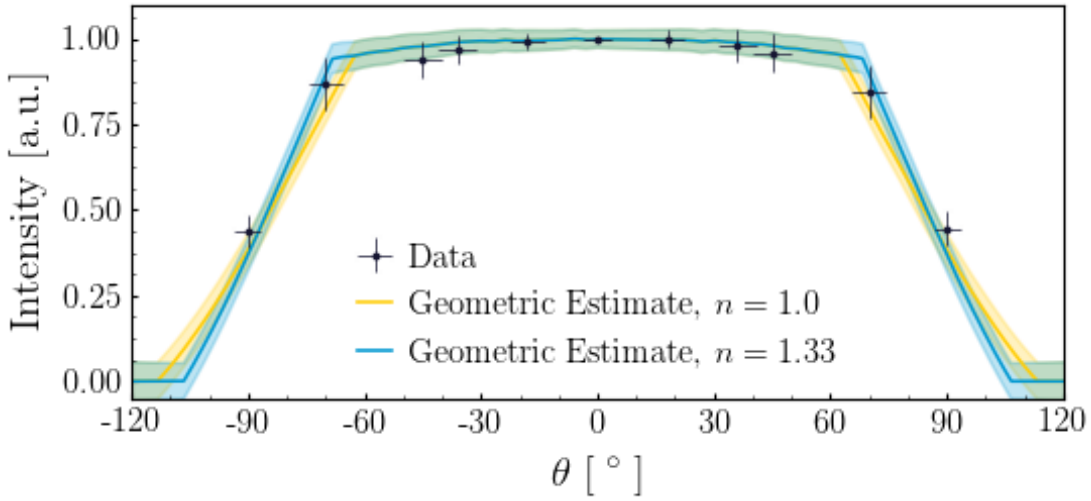
POCAM in GVD



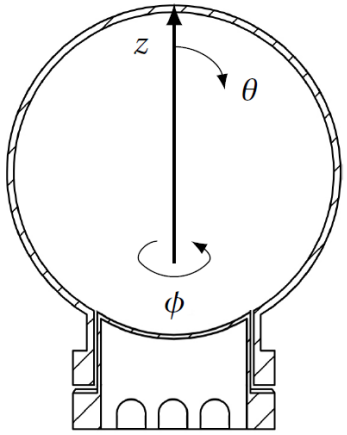
- POCAM = Precision Optical Calibration Module
- Create isotropic light flash using a PTFE integrating sphere
  - PTFE is Lambertian reflector
  - High reflection across broad wavelength range
  - Spherical integration → isotropy
- Use internal photosensors for self-calibration
  - SiPM and Photodiode for high dynamic range
- Multi-wavelength emission for spectral studies
  - **GVD:** 470, 525nm
  - **STRAW:** 365, 405, 465, 525, 605nm

POCAM in GVD





- Flasher based on Kapustinsky's circuit design [1]
  - Fast capacitor discharge through LED via transistors
  - Nanosecond flashes (FWHM 4 – 8 ns)
- Semi-transparent sphere from PTFE
  - PTFE plug pre-diffuses LED flashes
  - Light is integrated in sphere interior
  - Semi-transparency provides isotropic emission



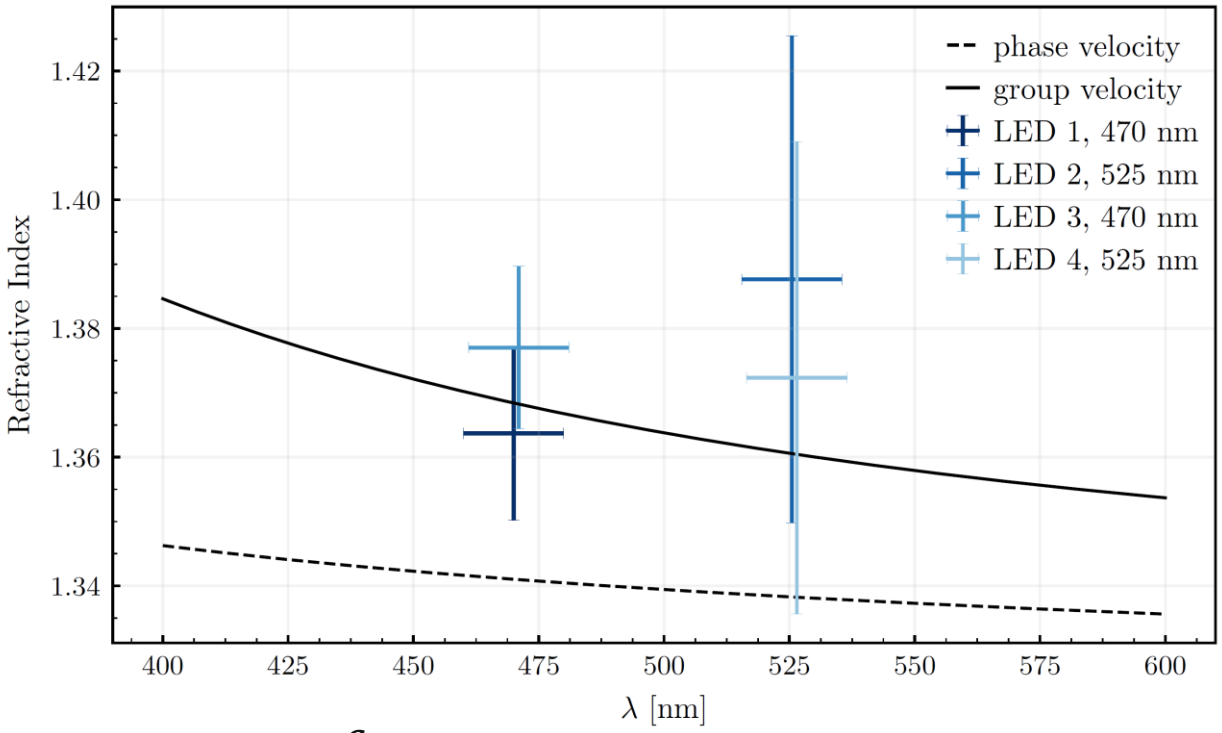
[1] Kapustinsky, J. et al. Nucl. Inst. 241, 612–613 (1985).

POCAM in GVD

- POCAM deployed within GVD in March 2017
- Detailed analysis done by K. Holzapfel (based on data provided by GVD)
  - Verifiy speed of light
  - Verify geometry
  - Model POCAM flashes
  - Fit attenuation length

[2] IAPWS (2007). The International Association for the Properties of Water and Steam. Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, 1997.

POCAM in GVD

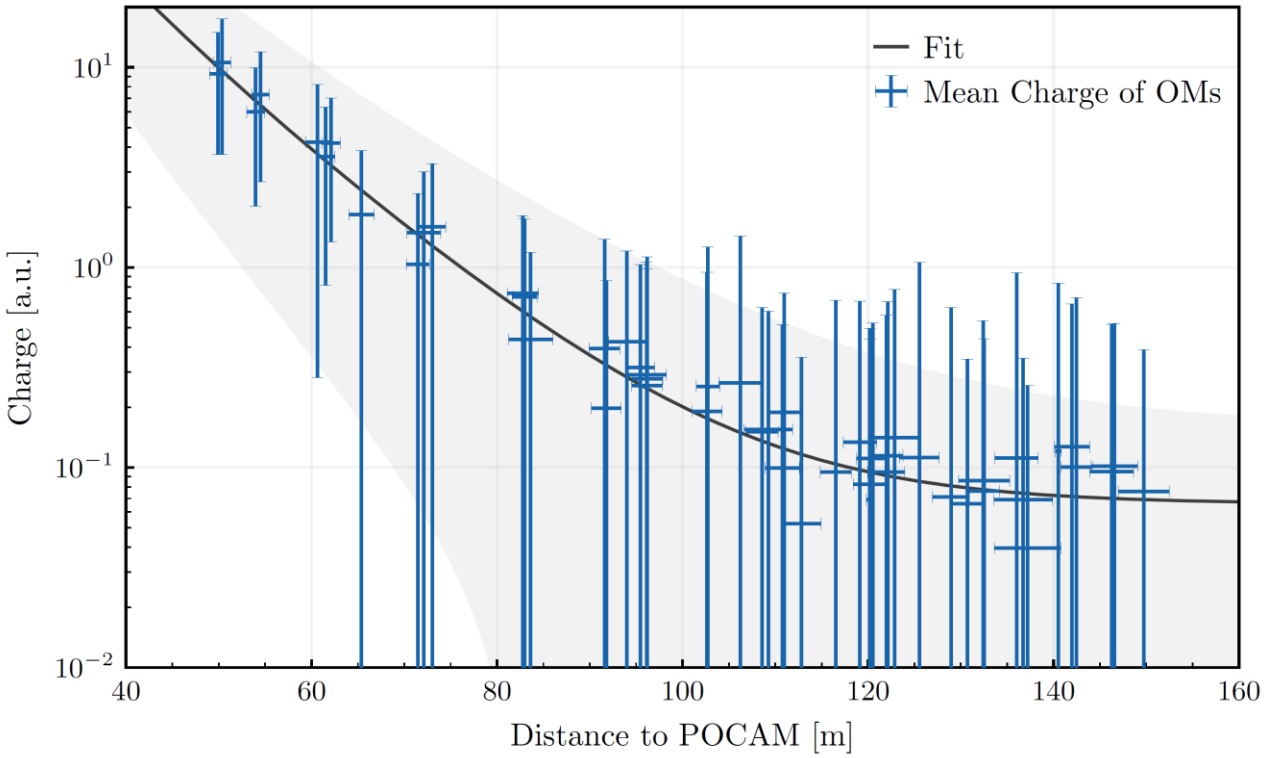


$$v_g = \frac{c}{n - \lambda \cdot \frac{dn}{d\lambda}}$$

- Speed of light consistent with expectation [2]
- Distances in agreement with the GVD geometry calibration

[2] IAPWS. (2007). The International Association for the Properties of Water and Steam. Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, 1997.

POCAM in GVD



- Speed of light consistent with expectation [2]
- Distances in agreement with the GVD geometry calibration
- Results are consistent with previous measurements, e.g. [3]
  - $\lambda_{att}\ (460 - 535\ \mathrm{nm}) = (17.2\ \pm\ 6.8)\ \mathrm{m}$

[3] Balkanov et al. Appl. Opt. 33, 6818 (1999)

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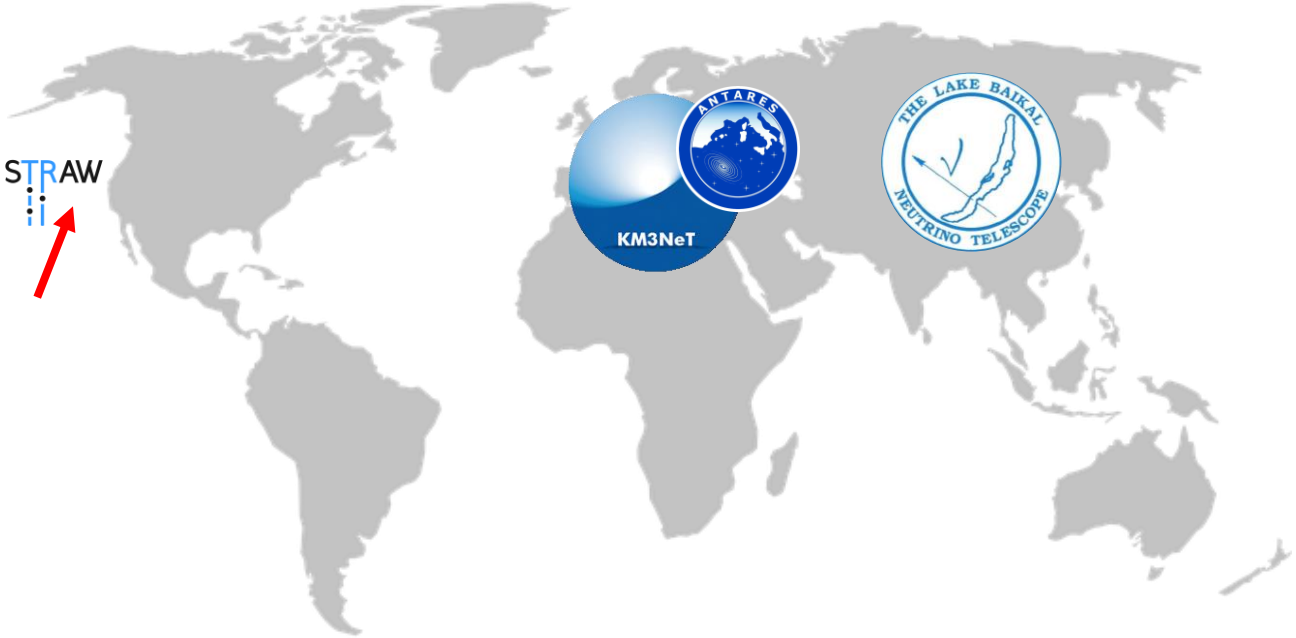
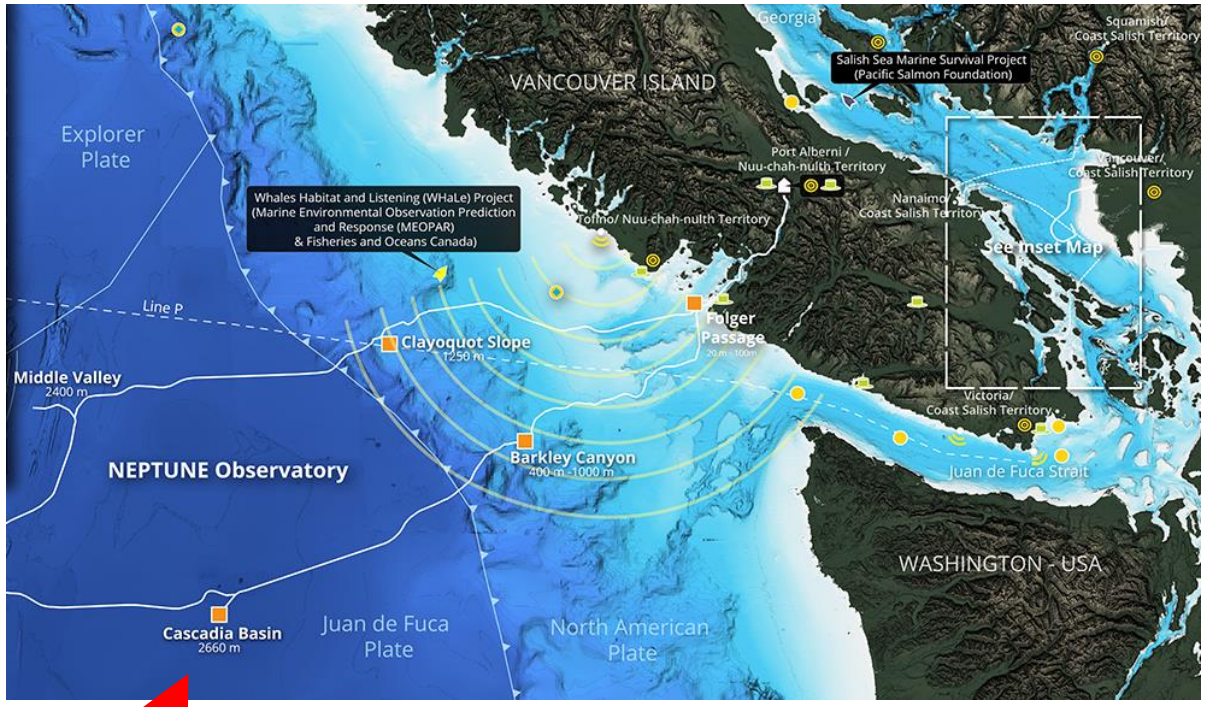


- Two neutrino telescopes fully operational
  - IceCube – South
  - ANTARES – North
- Two next-gen telescopes under construction
  - Baikal GVD – North
  - KM3NeT – North
- Northern telescopes for full sky coverage
- Unique opportunity near the coast of Canada

  ⟶ In-place deep-sea infrastructure

STRAW

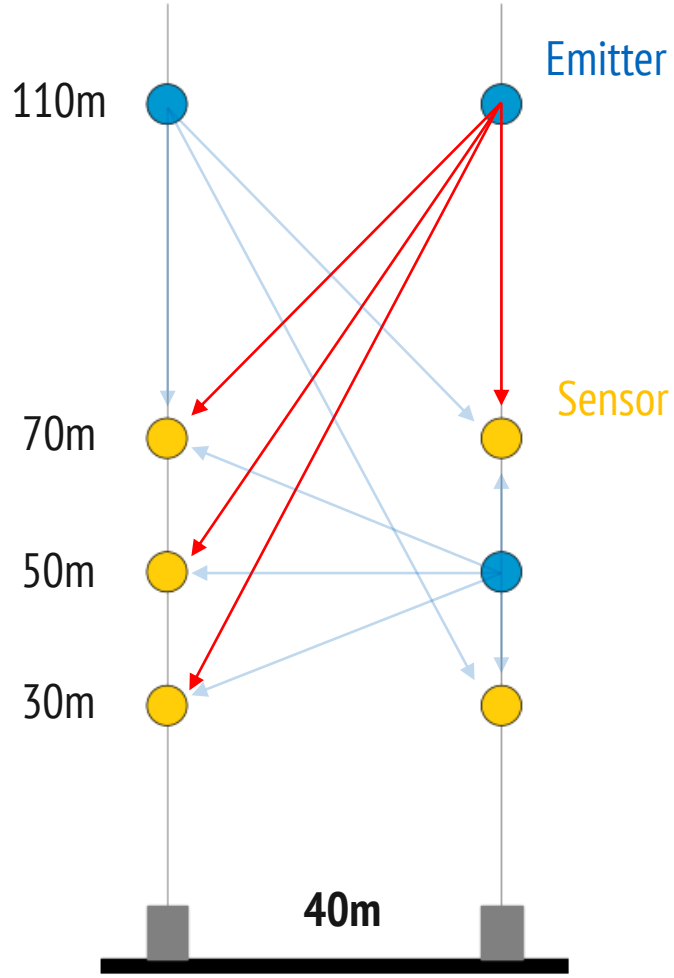


- STRAW = Strings for Absorption Length in Water
- Ocean Networks Canada
  - Deep-sea optical/electrical operations for ~10y
  - Deep-sea deployments and maintenance
- Investigate optical properties of Cascadia Basin
  - Absorption
  - Scattering
  - Backgrounds (radioactivity, biolumescence)

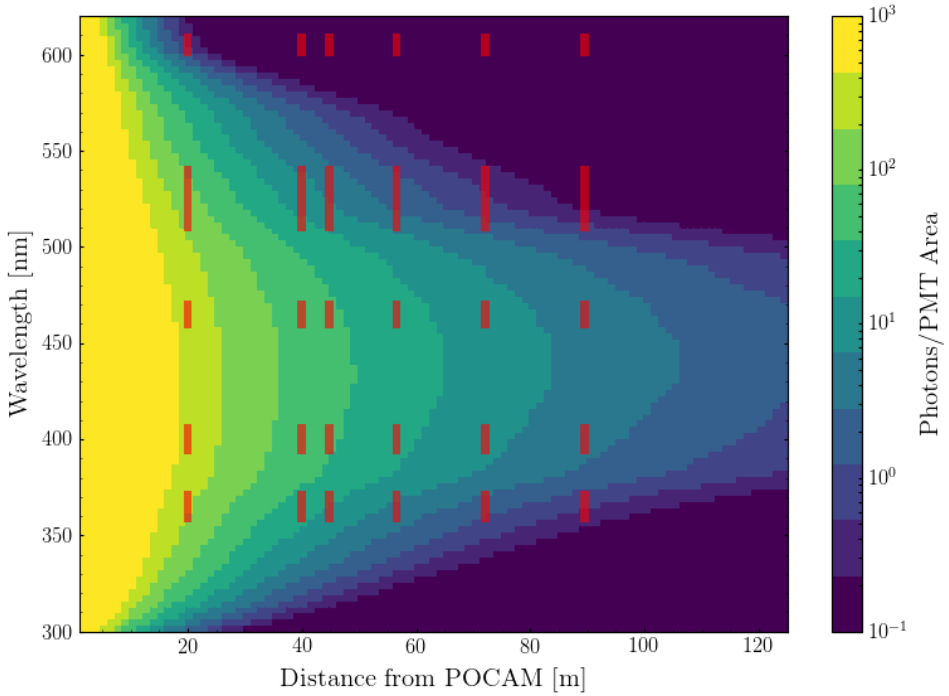
mid 2017	09/17	05/18	06/18
Idea	R&D Start	End	Deployment

Graphics: Ocean Networks Canada

STRAW



- Two-string detector with eight instruments
  - **Emitter:** Precision Optical Calibration Module (POCAM)
  - **Sensor:** STRAW Digital Optical Module (sDOM)
- Design based on expected optical properties [3]

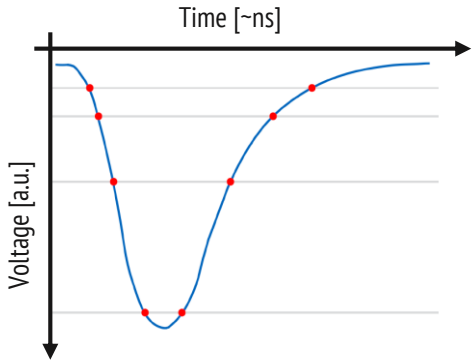


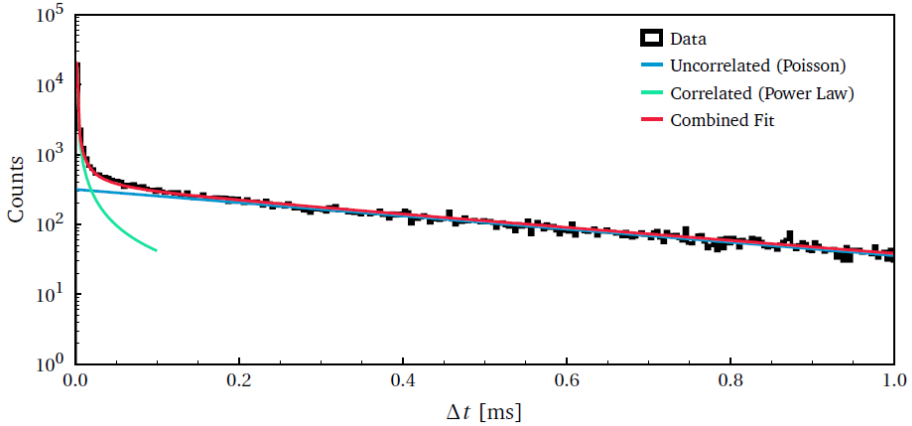
[3] Smith, R. C. & Baker, K. S. Appl. Opt. 20, 177–184 (Jan. 1981).

POCAM

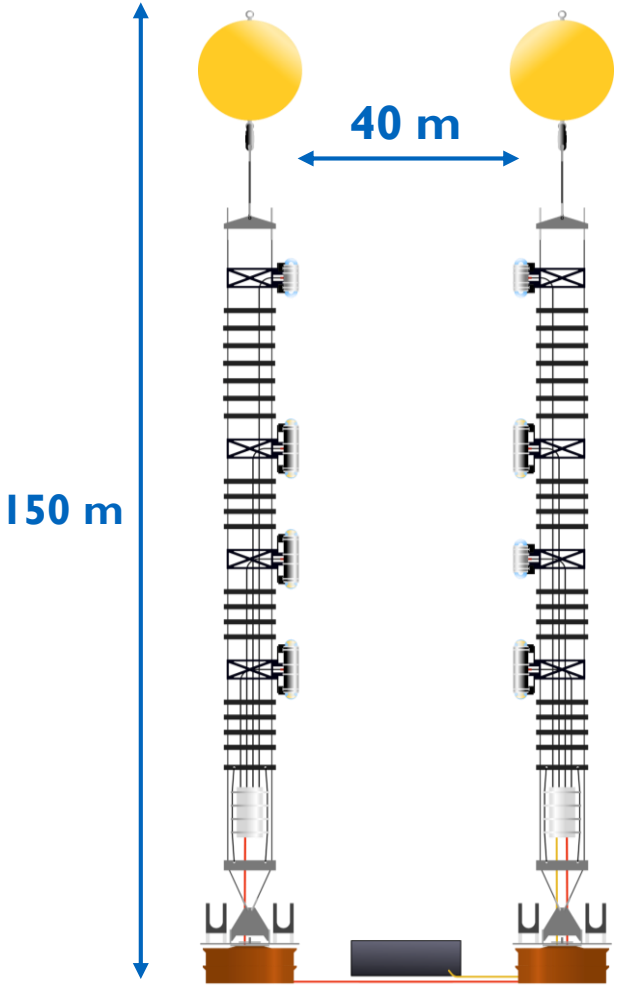
sDOM = STRAW Digital Optical Module

- Based on proven POCAM design
  - Longer housing for electronics
- 3“ PMTs with optical gel in both end-caps
  - Multi-channel TDC read-out
- Single-chip computer control via Ethernet

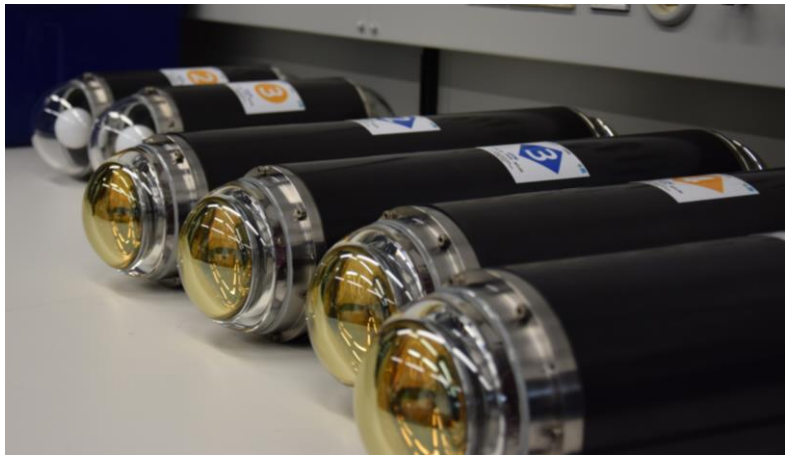


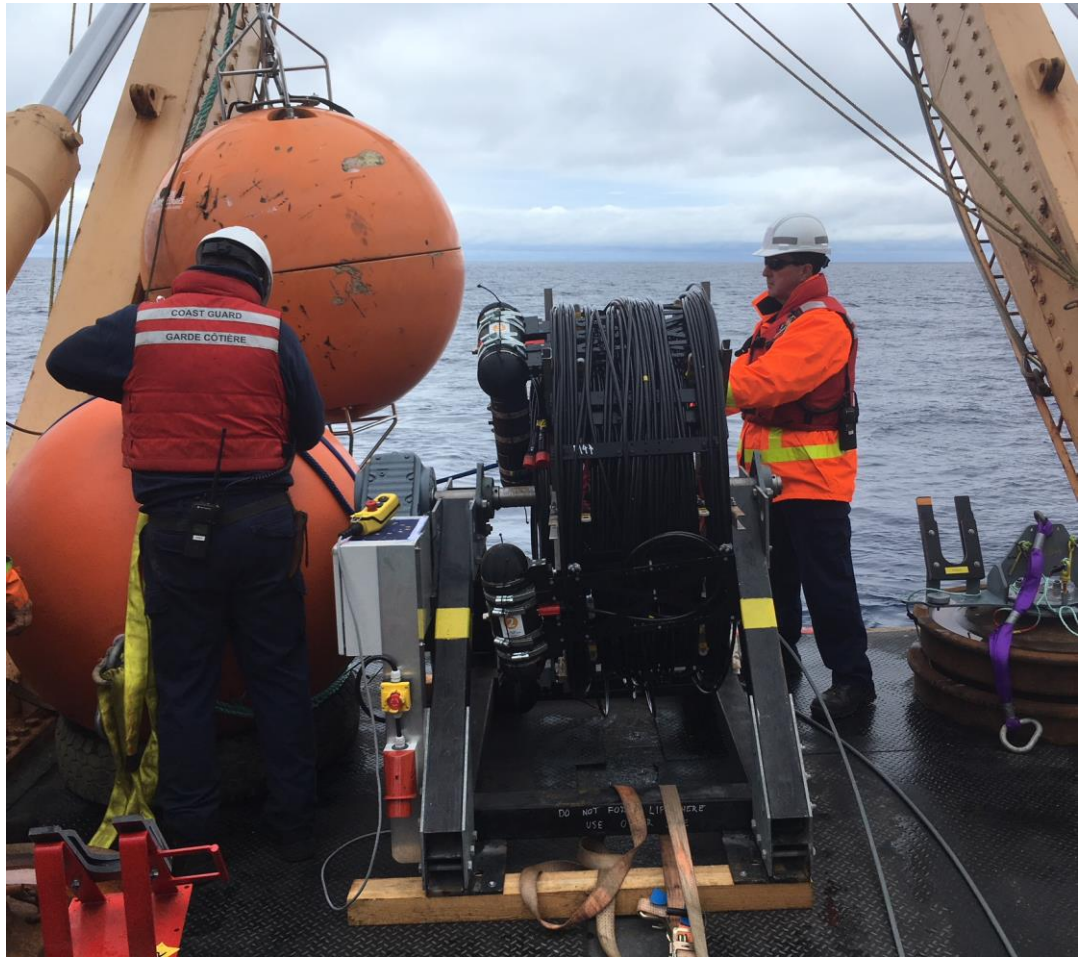


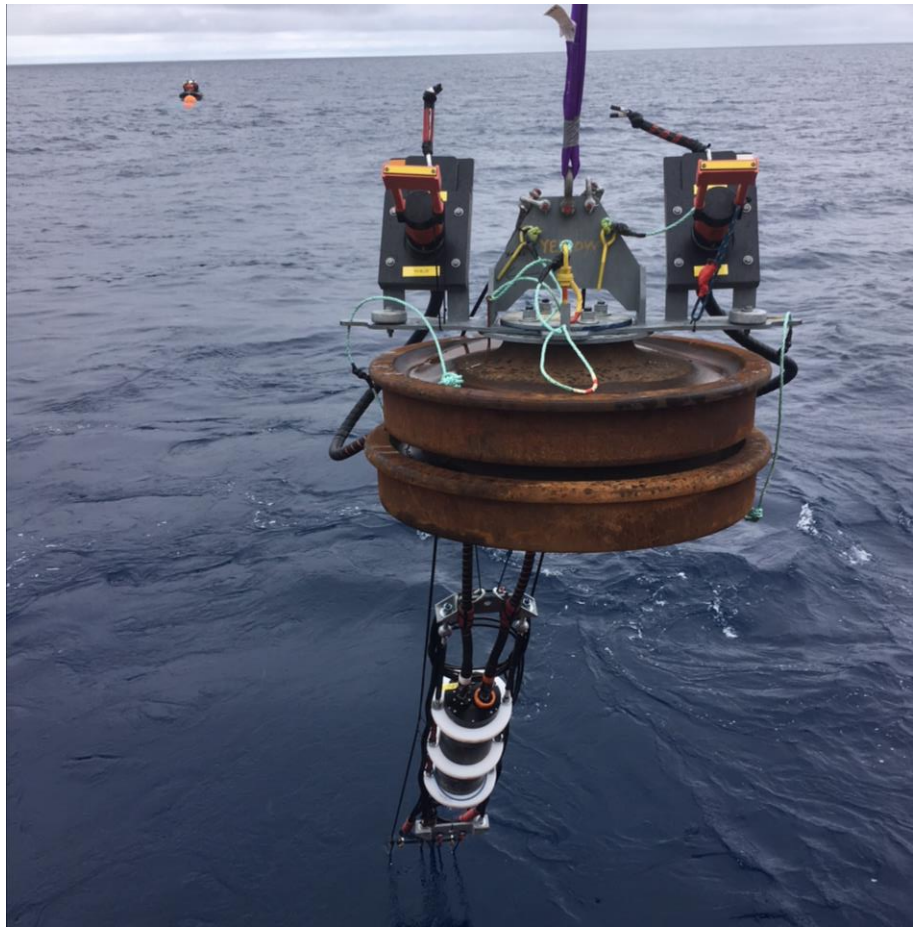
STRAW

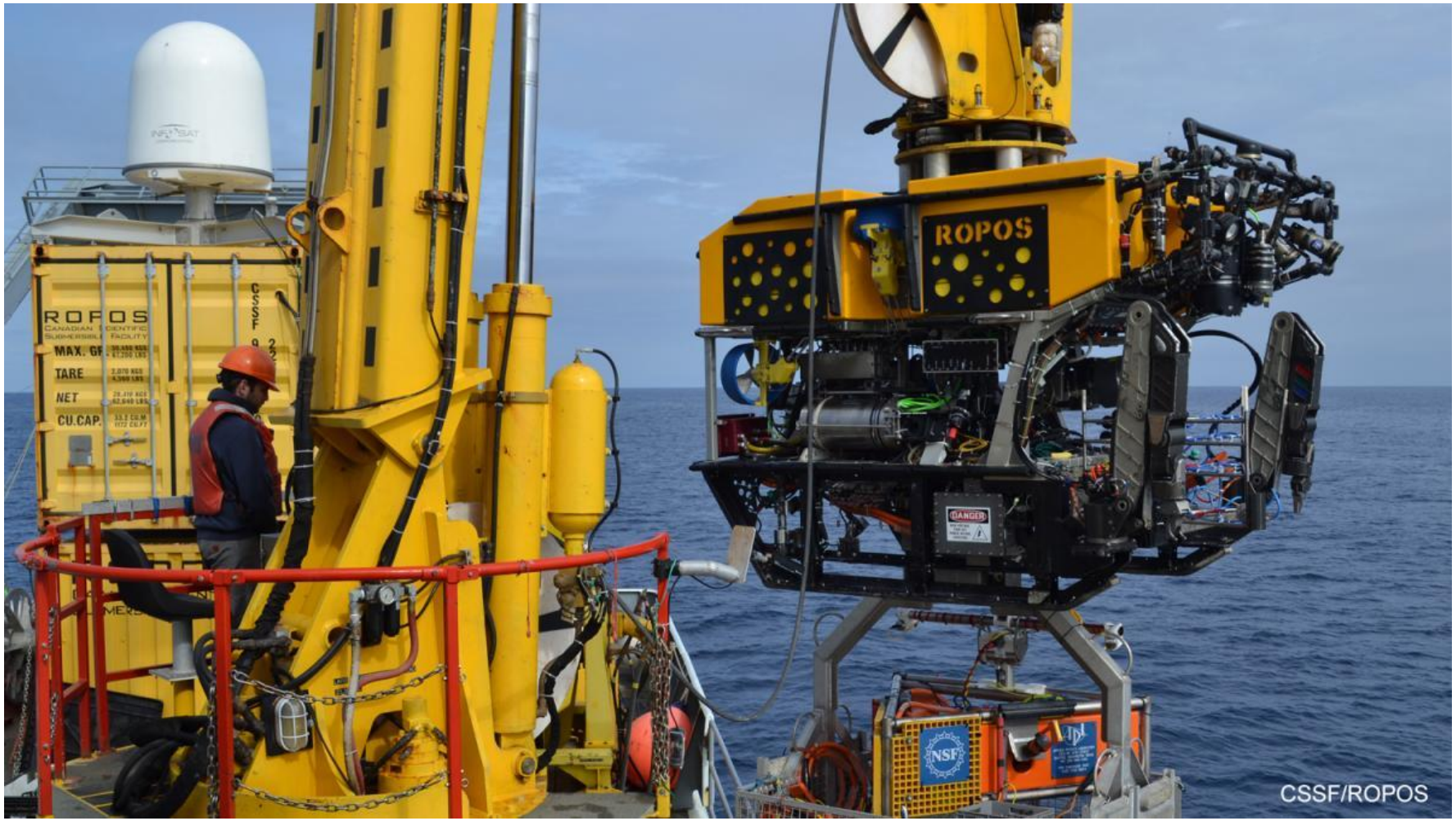


- Mechanical design minimizes bending and rotation in currents
  - Two-line strings
  - Strong up-lift float
- Rotational anchor for ROV alignment of the strings
  - Post-deployment rotation
- Spooling system for shipment and deployment




COAST GUARD
GARDE CÔTIÈRE




ROPOS
CANADIAN SCIENTIFIC SUBMERSIBLE FACILITY
MAX. GR
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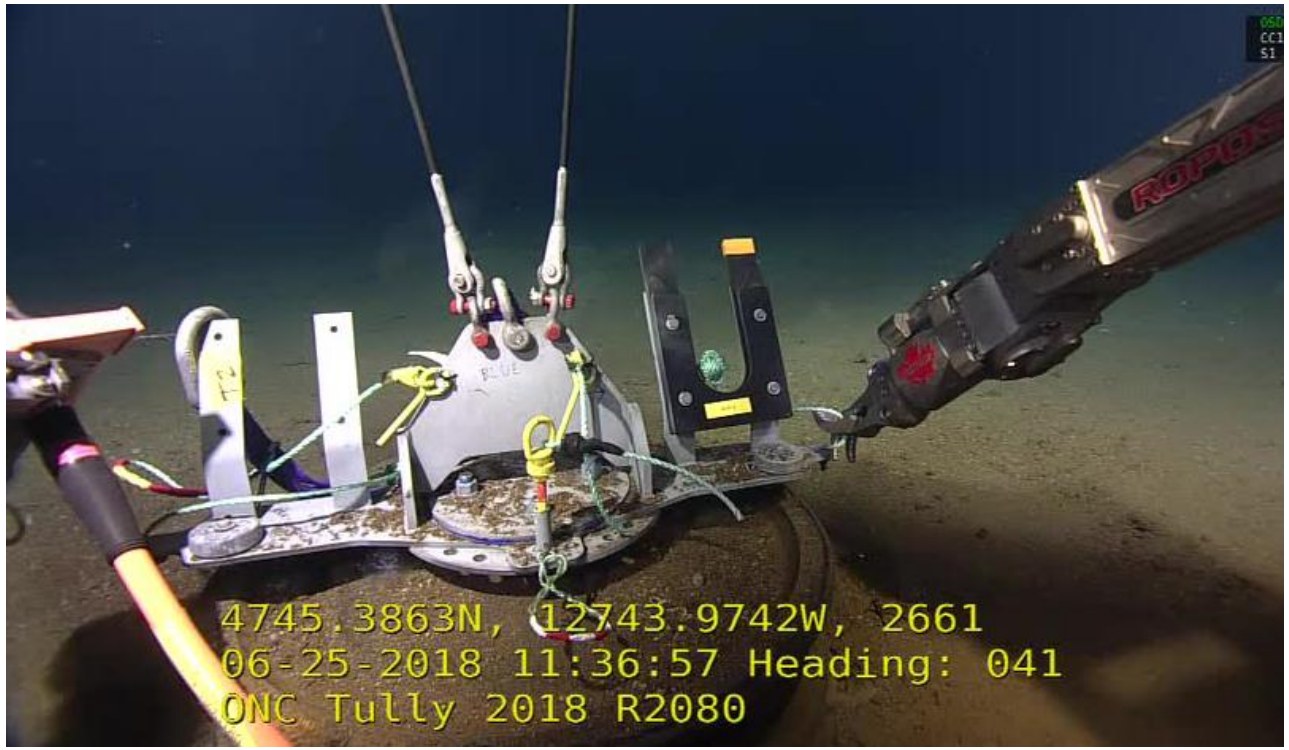
CU.CAP.
ROPOS
DANGER
NSF
CSSF/ROPOS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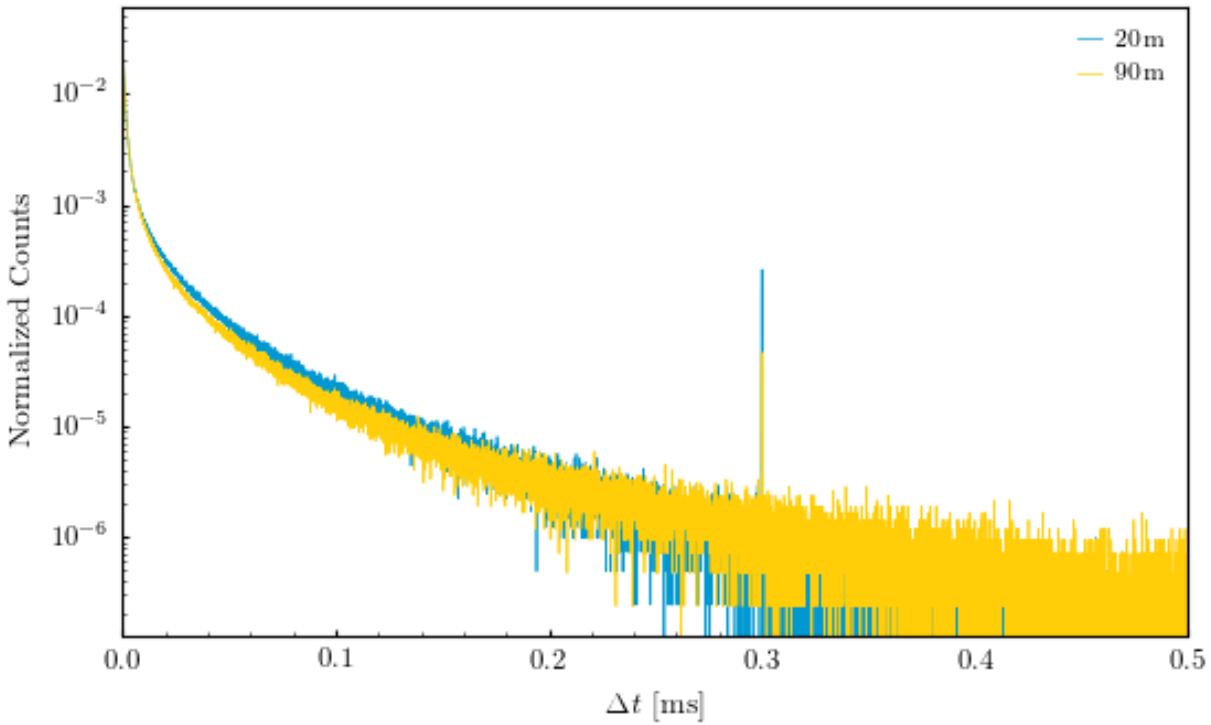
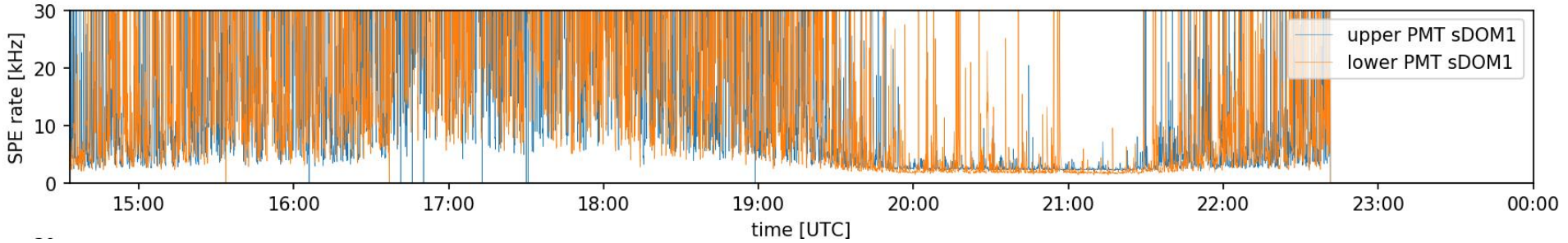
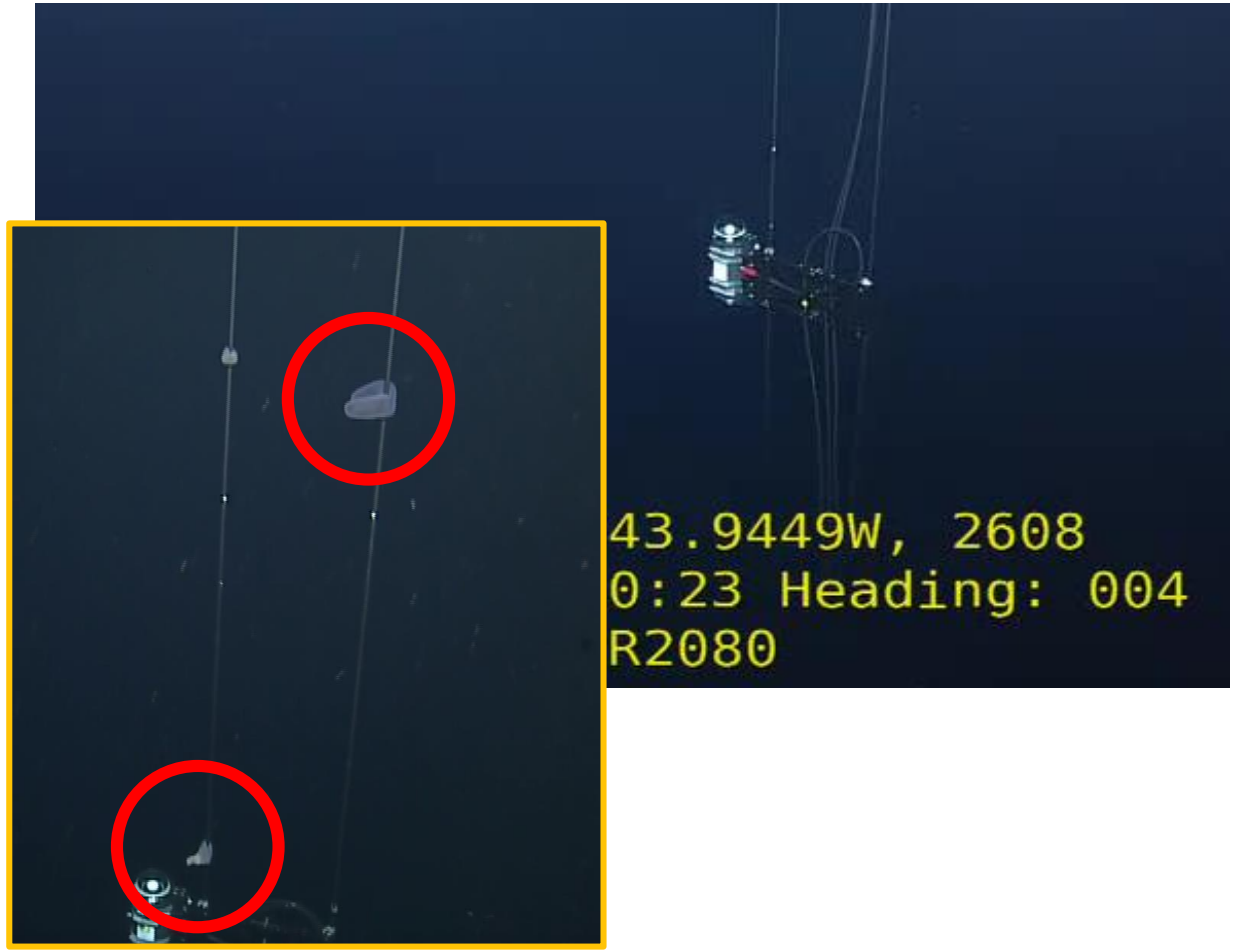


- Detector response analysis is work-in-progress
- Preliminary analyses so far suggest
  - Promising absorption characteristics
  - Observed biolumenescent activitities
  - No showstoppers for a neutrino telescope
- In parallel AC9 data was taken at the site, results are expected soon





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Summary

The Prospects

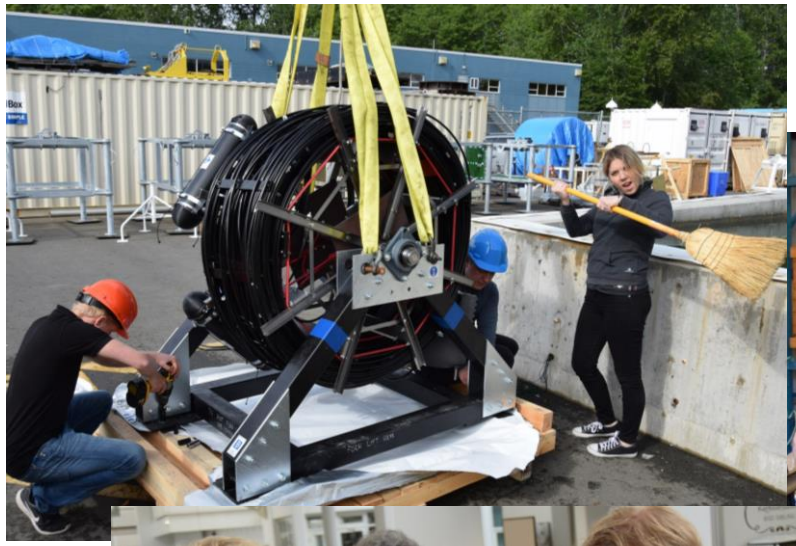
- Summary
  - Analysis for POCAM in GVD shows consistent results
  - Successfully designed, built and deployed the STRAW two-string detector in 8 months
  - Smooth deep-sea R&D, operation and deployment with ONC
  - STRAW is fully operational and taking data
  - Preliminary results are promising and more thorough analyses ongoing

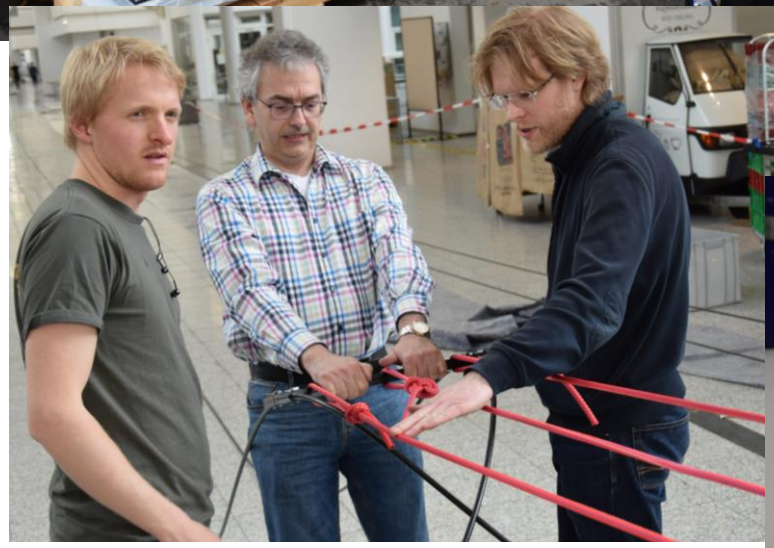
- Future Plans
  - Noveaux idea using artificial swarm intelligence
    - Conceptually at the moment, follow up soon

  - **Potential testing facility for various sensor prototypes with new, third mooring**
    - mDOM, D-Egg, multi-PMT, pDOM, …
    - Criteria: Deployment Summer 2019

    → **talk to us if you're interested!**

Thank You





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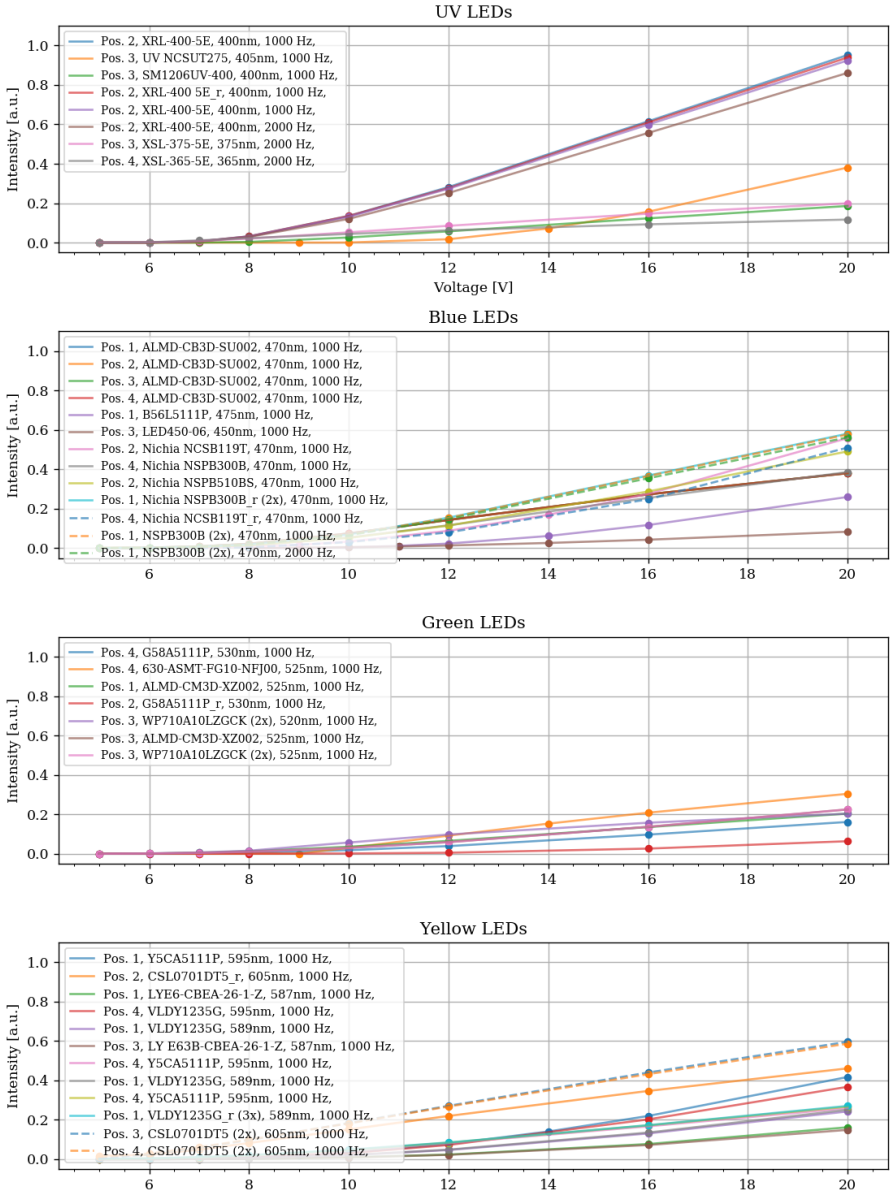
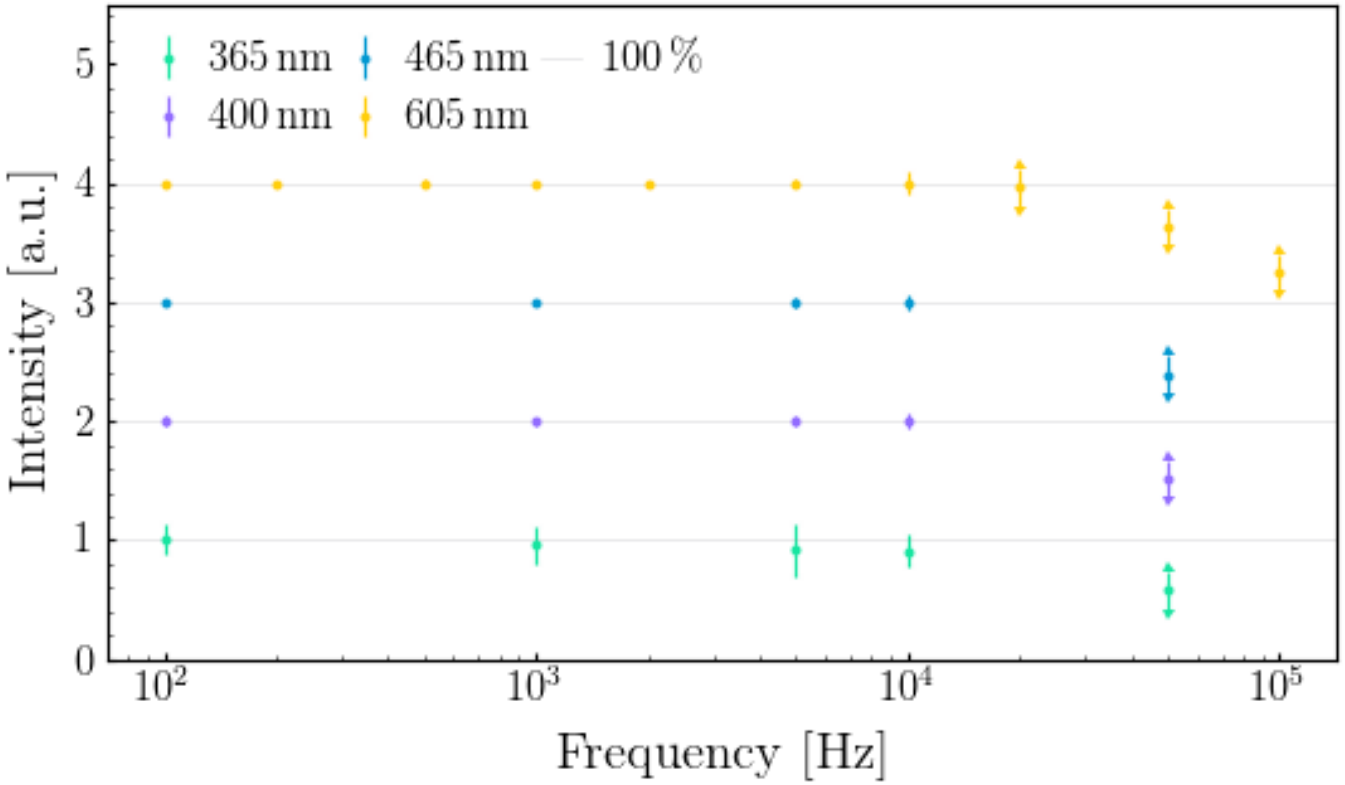
Backup

POCAM - Backup





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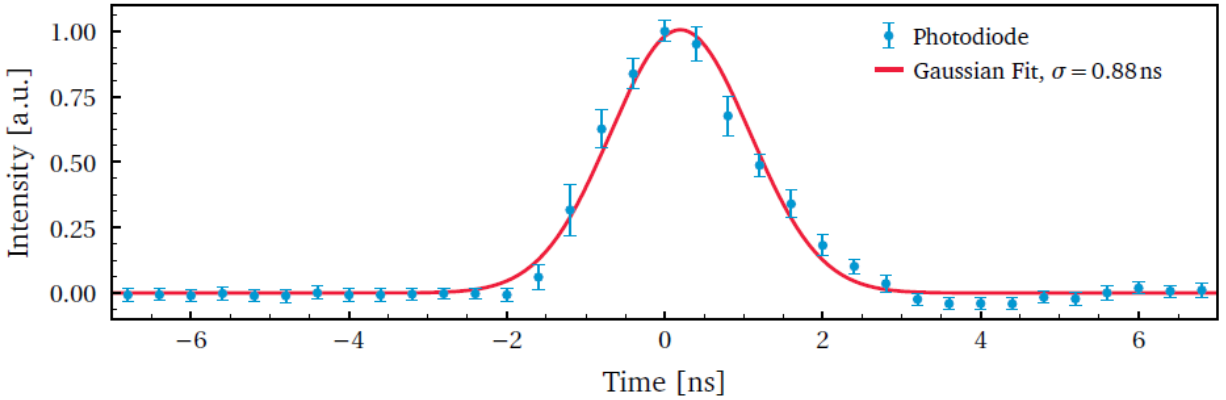

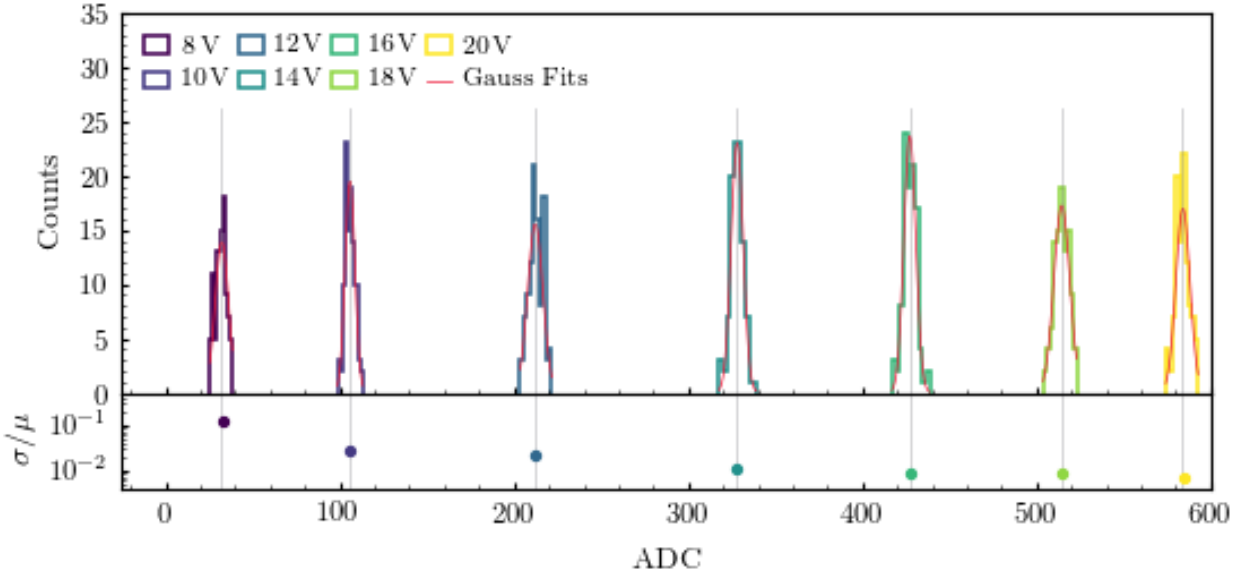

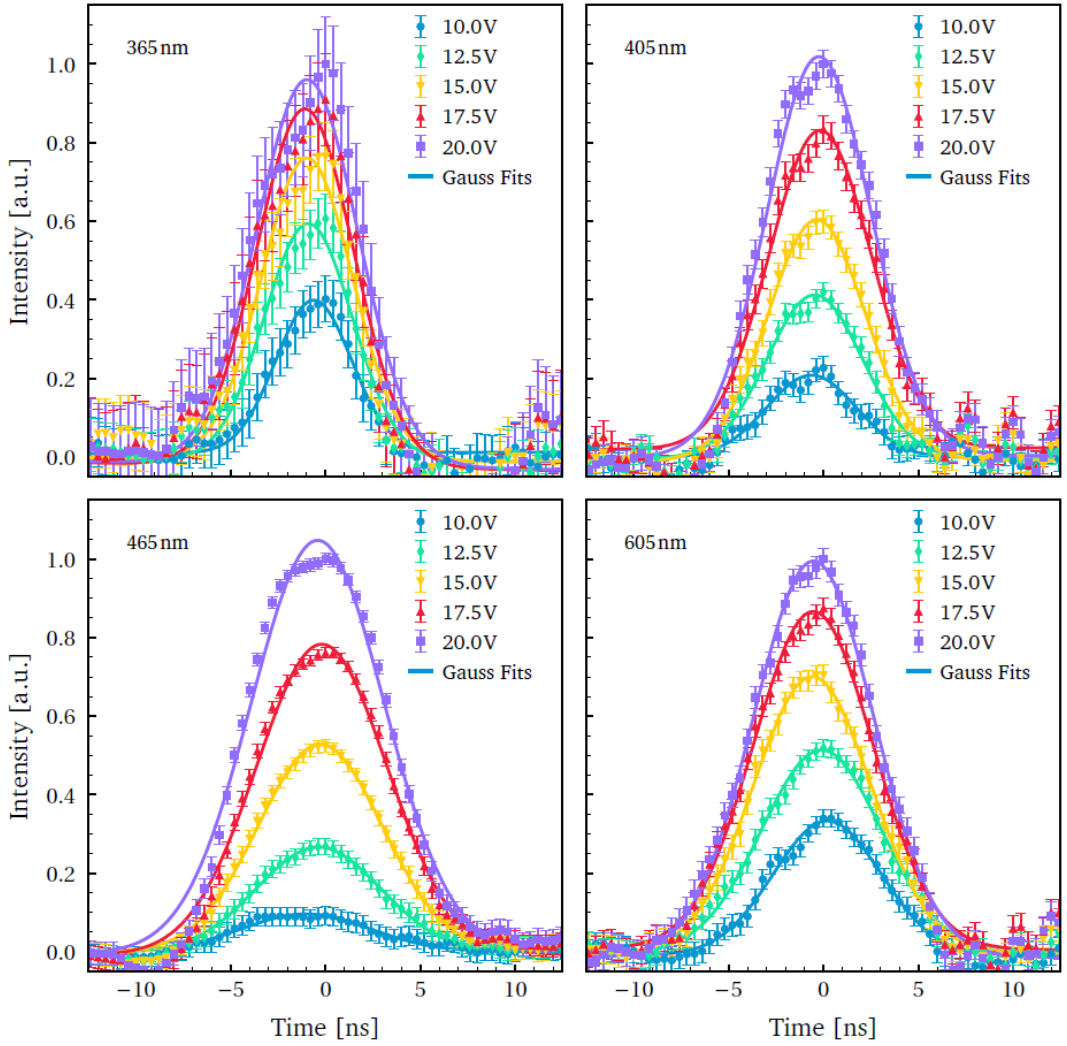

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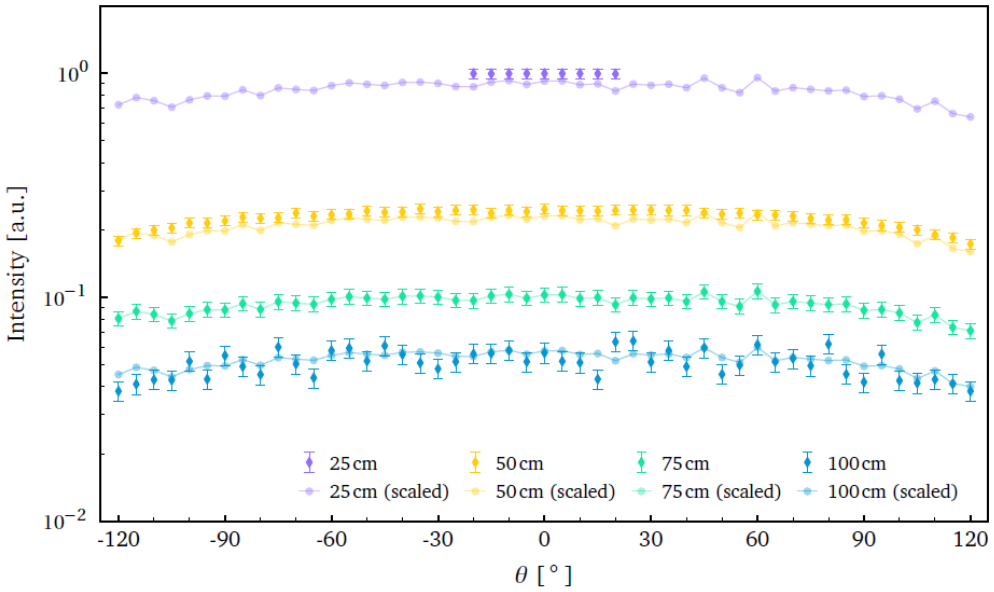
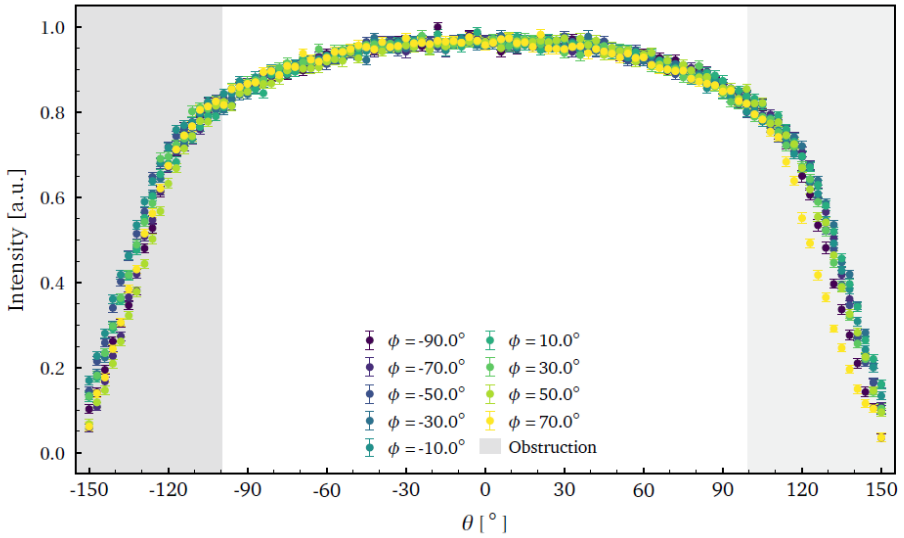
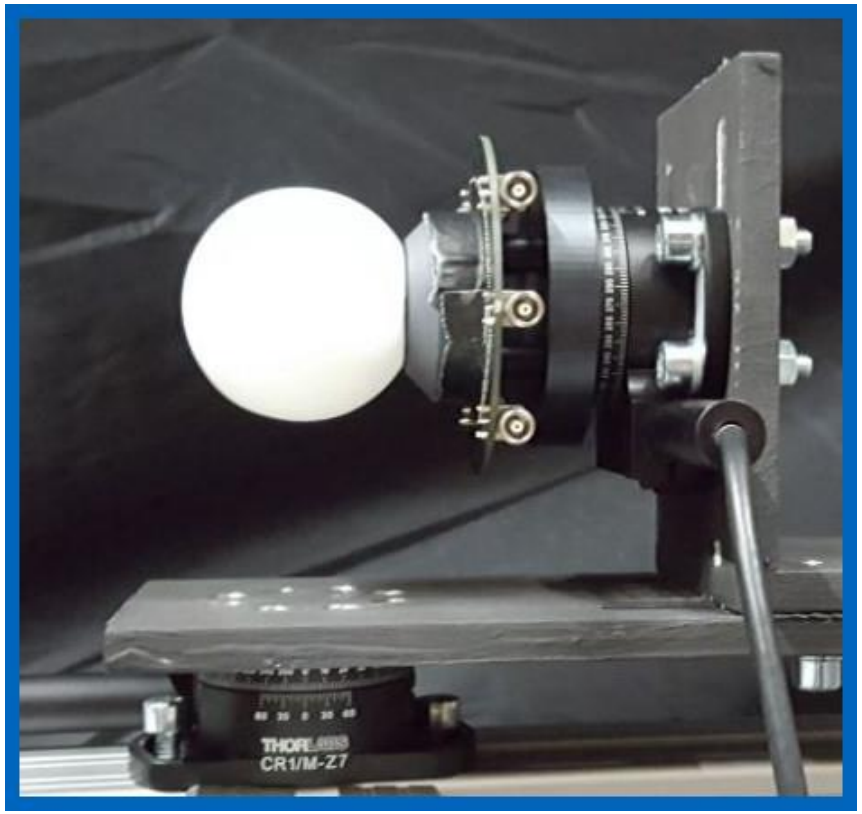
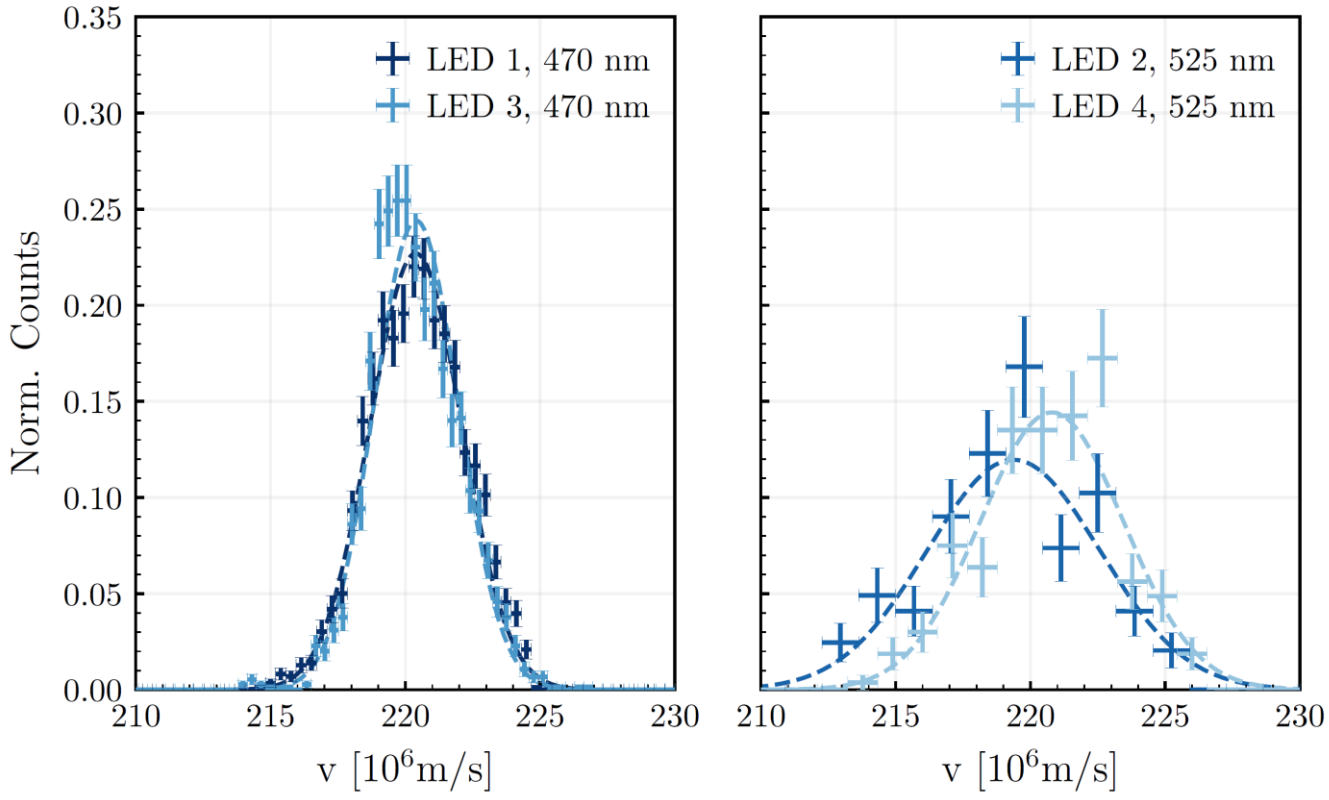






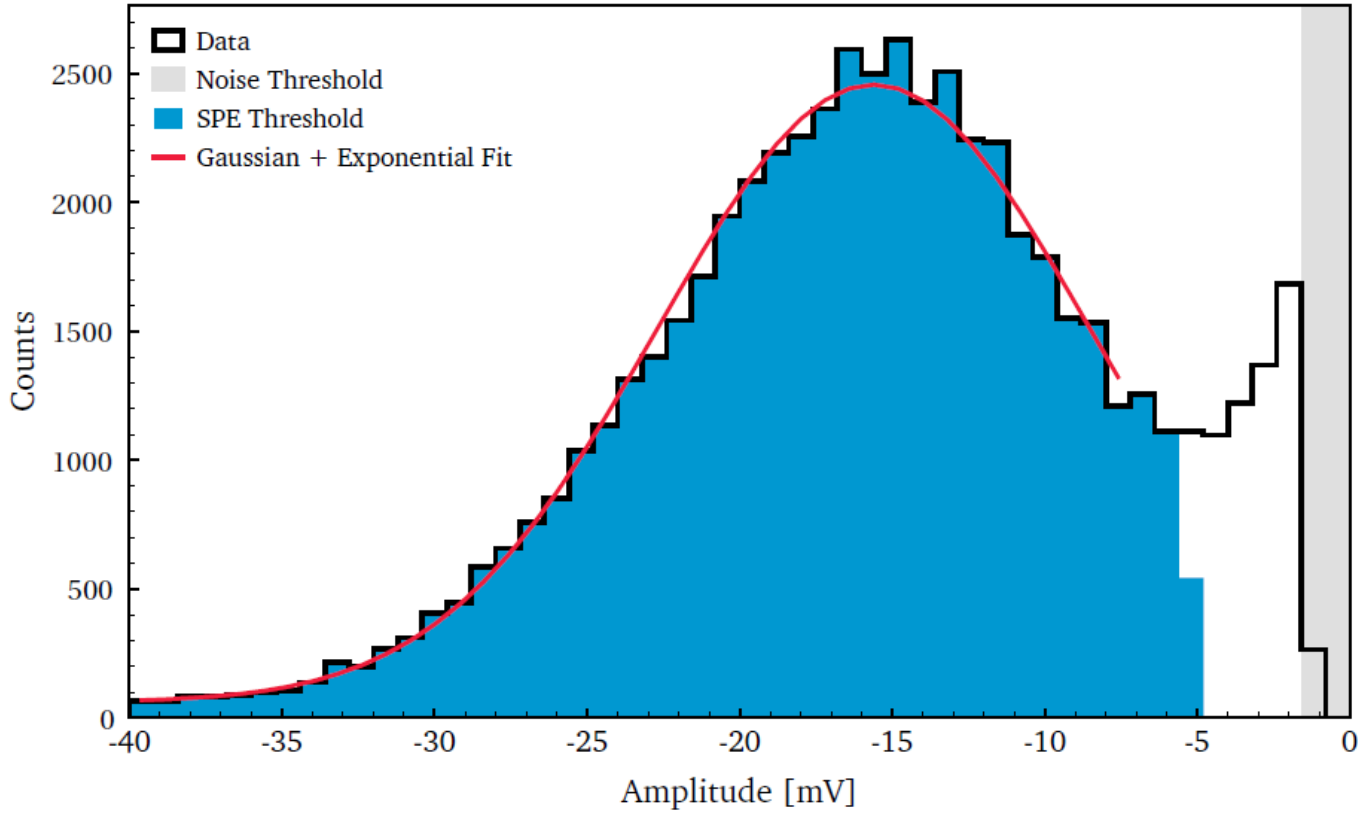
$$N_{\text{fired}} = N_{\text{pixel}} \cdot \left[1 - \exp\left(-\frac{N_\gamma \cdot \text{PDE}}{N_{\text{pixel}}}\right)\right]$$

POCAM - Backup



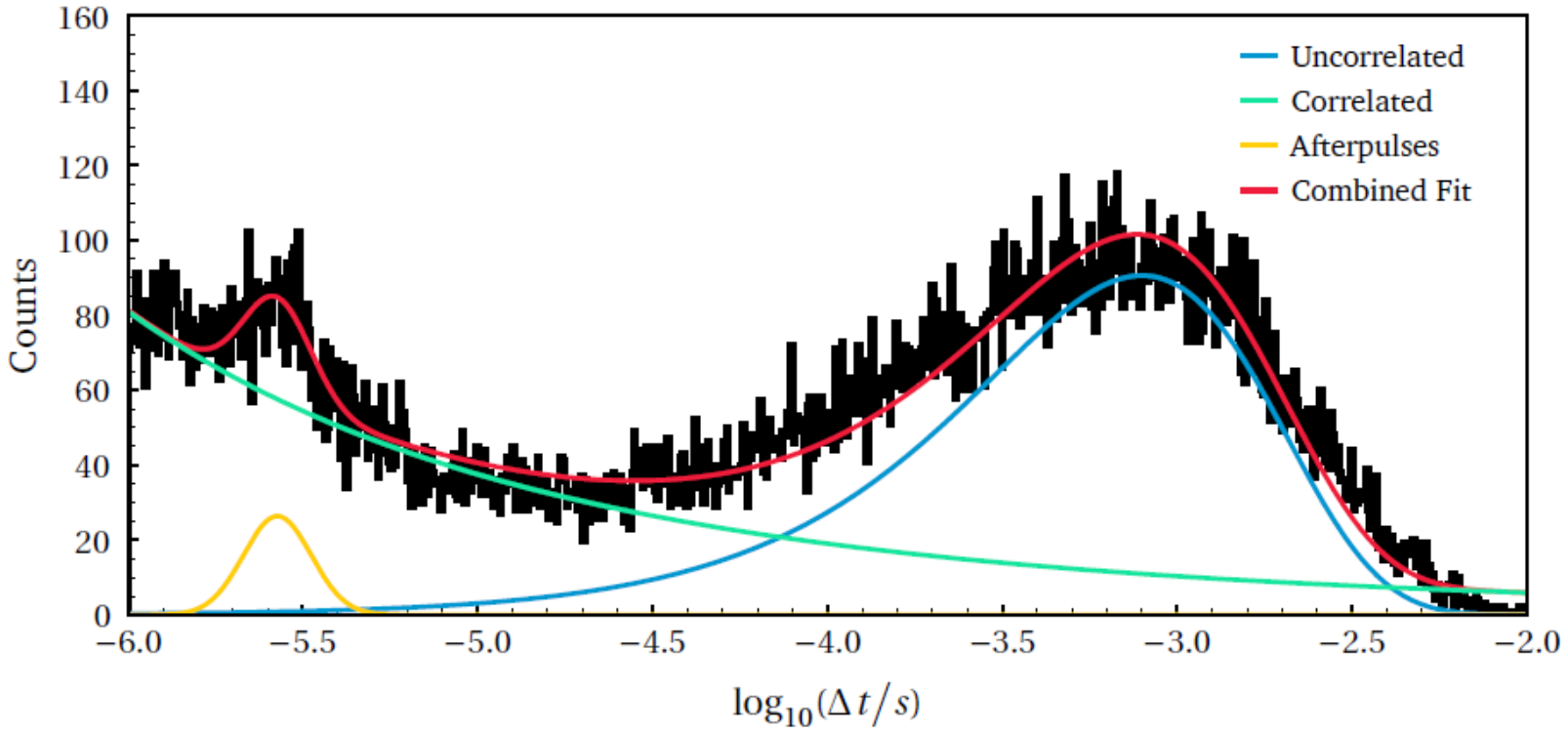
sDOM – Characterization

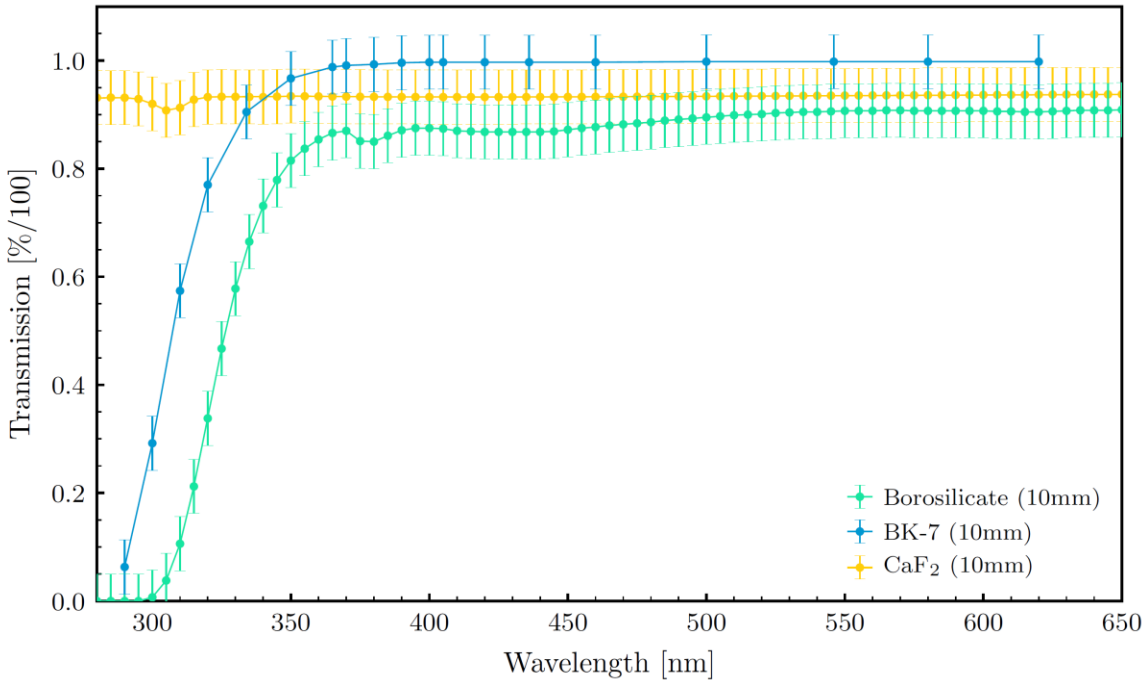
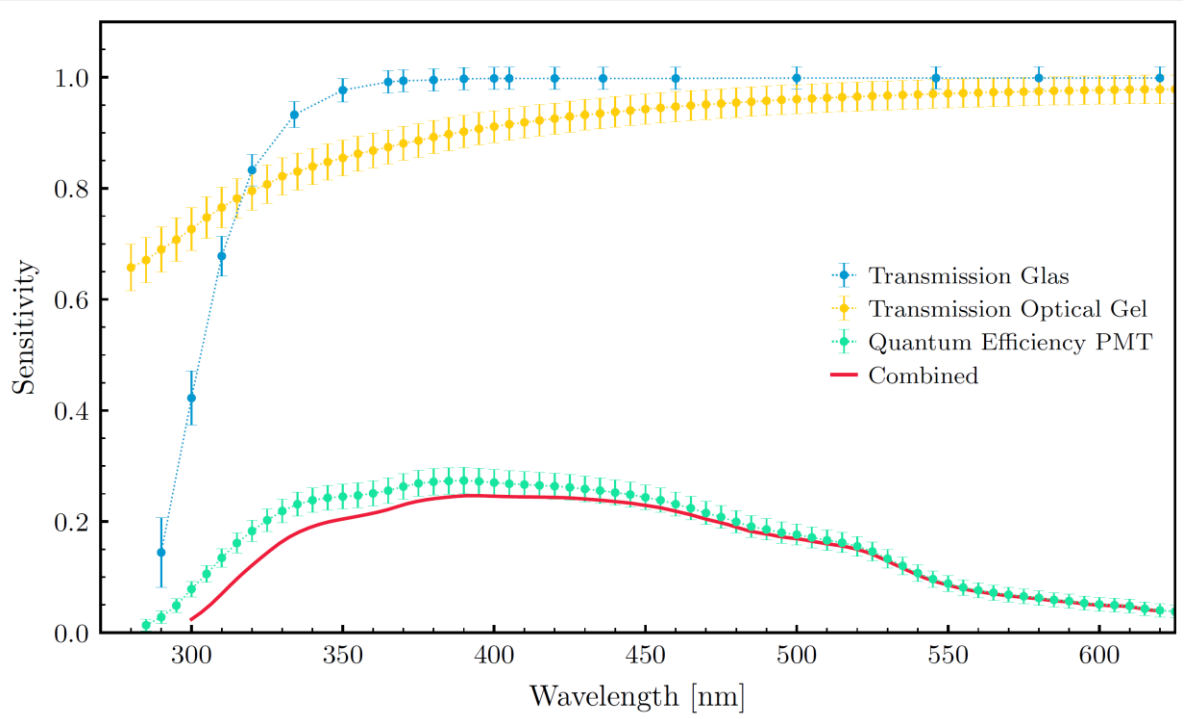
- Individual calibration of all STRAW PMTs
  - Characterization: I.C. Rea (PhD)
  - Dark Rate and Temperature: this work



sDOM – Dark Rate Calibration

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



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

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