STRAW

STRAW - Strings for Absorption Length in Water

Optical Characterization of the Deep Pacific Ocean for a Potential Future Underwater Neutrino Telescope

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The STRAW experiment aims to characterize optical properties of the deep-sea water at the *Cascadia Basin* site in view of its feasibility to host a neutrino telescope. With a depth of 2600 meters, the site off the coast of Vancouver Island has the unprecedented advantage of in-place electrical and optical infrastructure operated and maintained by deep-sea experts of *Ocean Networks Canada*.

The STRAW detector will make use of a two-string geometry with light emitters and sensors to primarily probe the attenuation properties of the deep-sea water. Measurements will allow the deduction of absorption and scattering lengths and monitoring of backround radiation from biolumenescence and radioactivity. Ultimately this will enable the assessment of the site and its compatibility to host a potential large-volume neutrino telescope.

Expectation & Geometry

- Cherenkov light yield for neutrinos peaks towards small wavelengths ($\sim\lambda^{-1}$)
- Expected water properties at 400 – 600 nm [1][2][3]
  - Absorption length 20 – 60 m
  - Scattering length 100 – 300 m
  - Attenuation length 15 – 55 m
- STRAW detector constists of two strings with three light emitters and five light sensors
- Geometry based on ocean water expectation and emission/detection characteristics of instruments

$$I(r,\lambda) = \frac{I_0}{4\pi r^2} \exp\left(-\frac{r}{L_{att}(\lambda)}\right) A_{\mathrm{eff}}$$

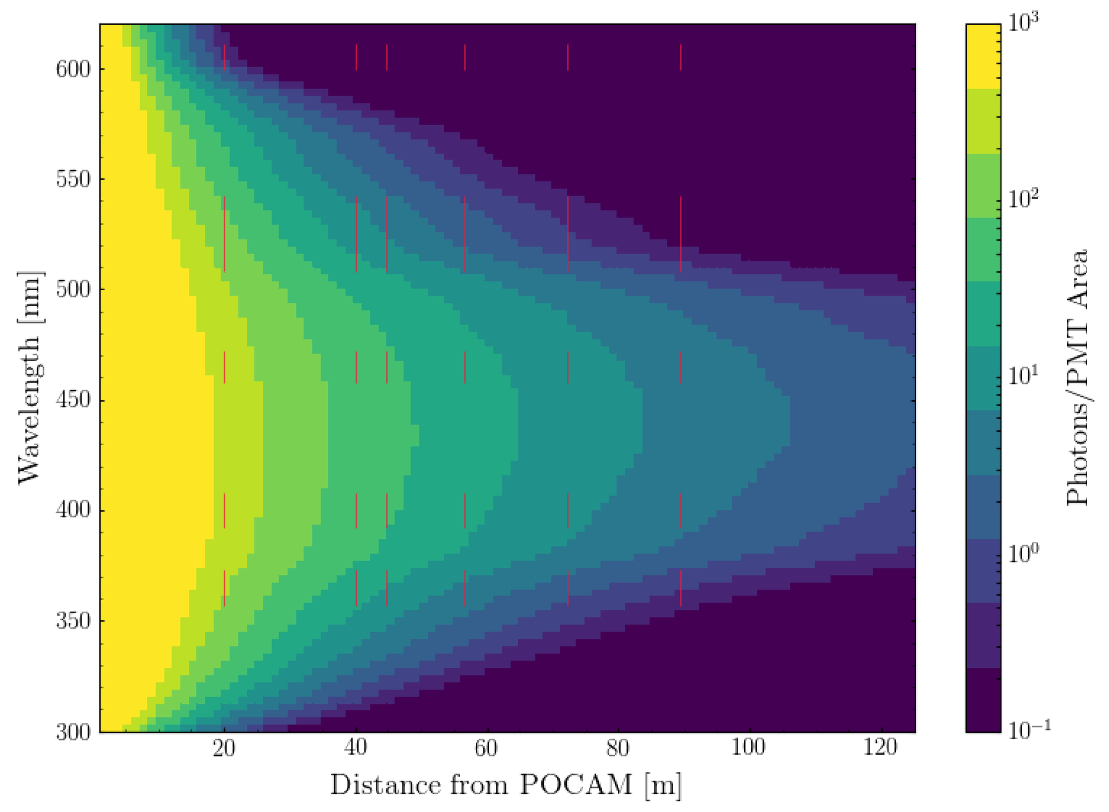
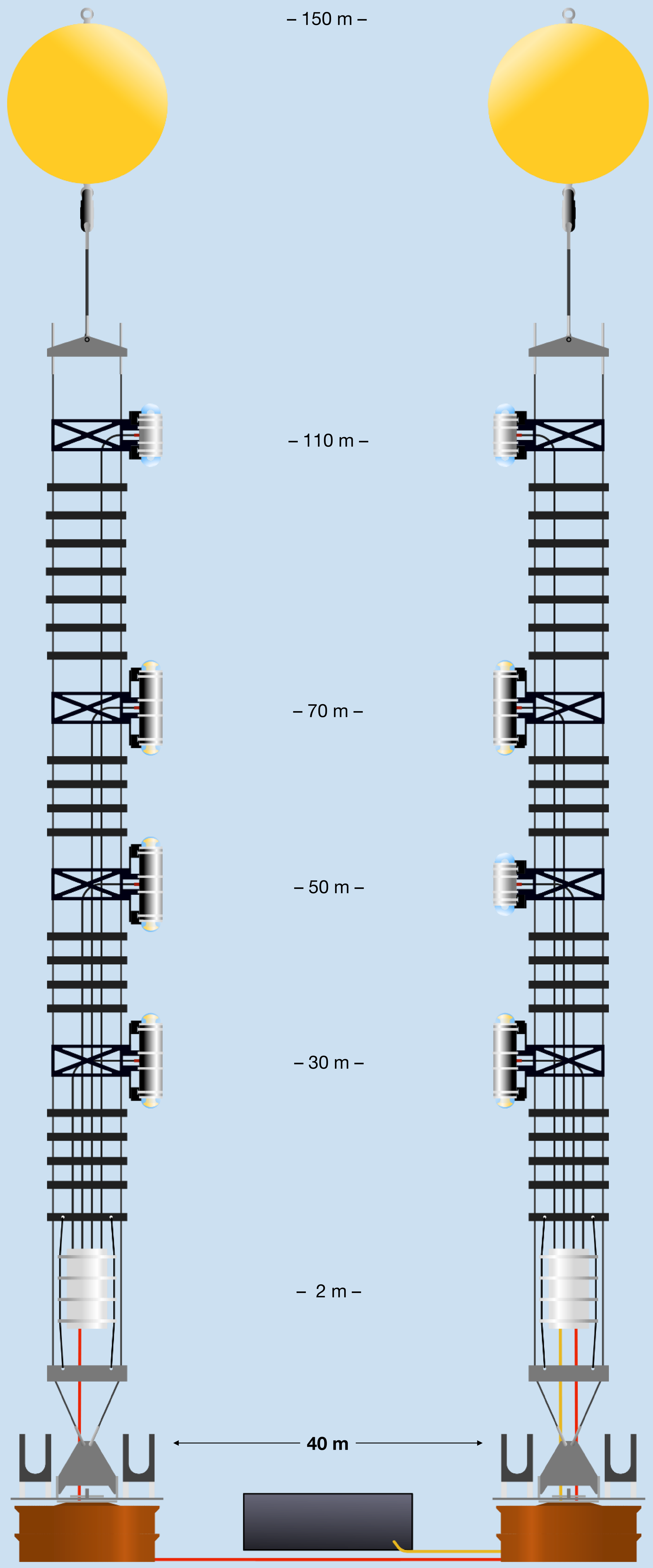


Fig. 1: Photon number expectation of an isotropic light flash of 10^9 photons in ocean water [3] versus distance (x-axis) and wavelength (y-axis) which defined the STRAW geometry indicated with spectral width and position (red).



Light Emitter – POCAM

- POCAM = Precision Optical Calibration Module
- Isotropic, in-situ calibrated nanosecond light pulser
- Wavelengths 365, 405, 465, 515 and 605 nm
- Pulse widths 4 – 8 ns
- Intensity $0.1 - 4 \times 10^8/2\pi$
- Isotropy ~4.7% (polar), ~5.4% (azimuthal)

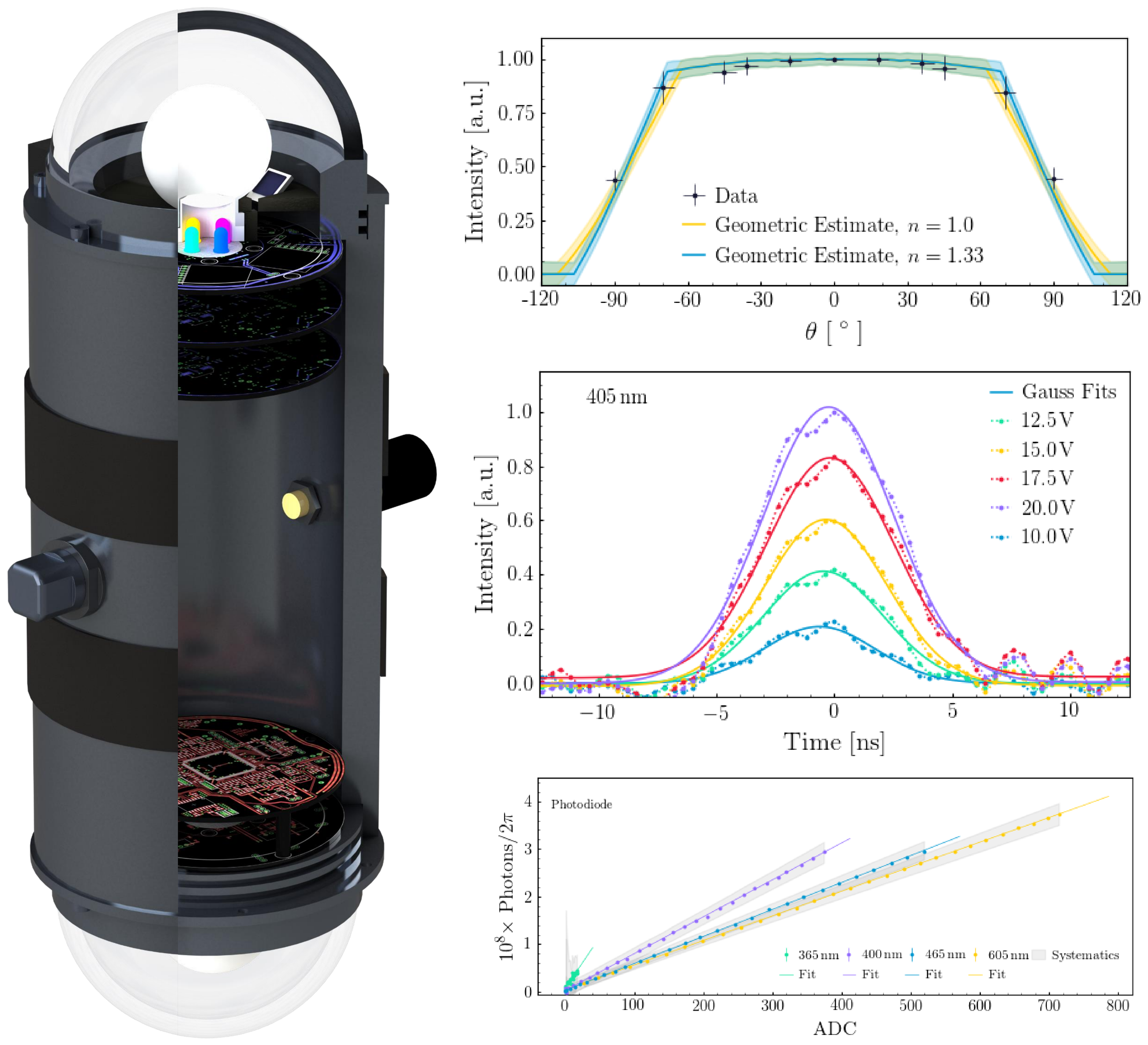
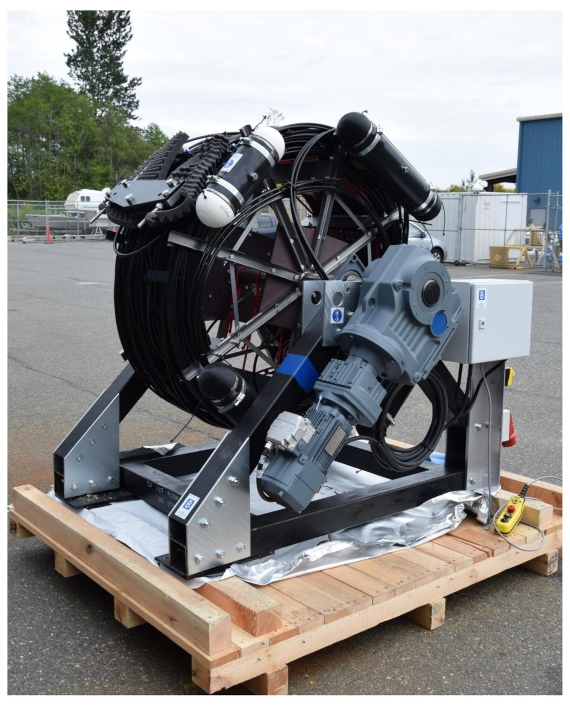
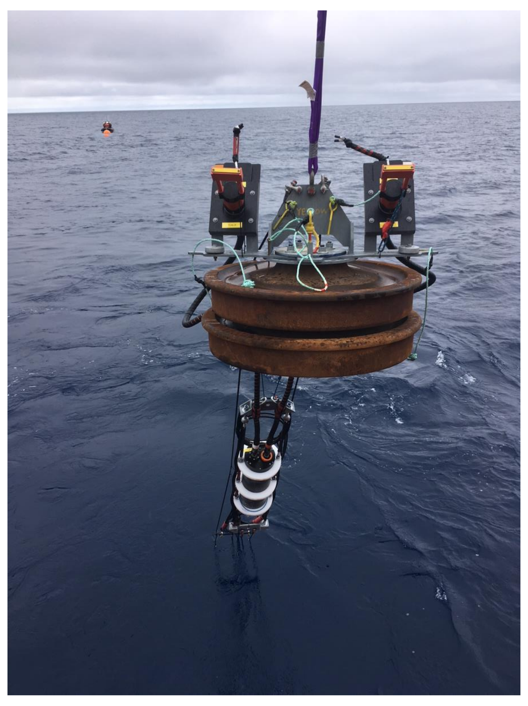


Fig. 2: Top: Emission profile of a POCAM hemisphere with the cylinder axis in $\theta = 0°$ direction showing the emission profile and the isotropy of a POCAM hemisphere **Center:** Light pulse shape of one of the POCAM light flashers (405 nm) showing the narrow pulse widths over a range of intensities **Bottom:** POCAM calibration with internal photosensor read-out (ADC) versus reference light output showing the internal calibration precision and ist linearity.

Deep-sea Structure & Deployment

- Deep-sea approved, qualified and tested compo-nents only
- String design to minimize potential rotation
- Custom spooling system for string assembly, de-ployment and compact storage / shipment
- Successful deployment in June 2018
- System fully functional since deployment





First Light

- First detector run in July 2018
- POCAM flashes with light of 470 nm were detected over the full 90 m distance
- Analysis ongoing, results soon!

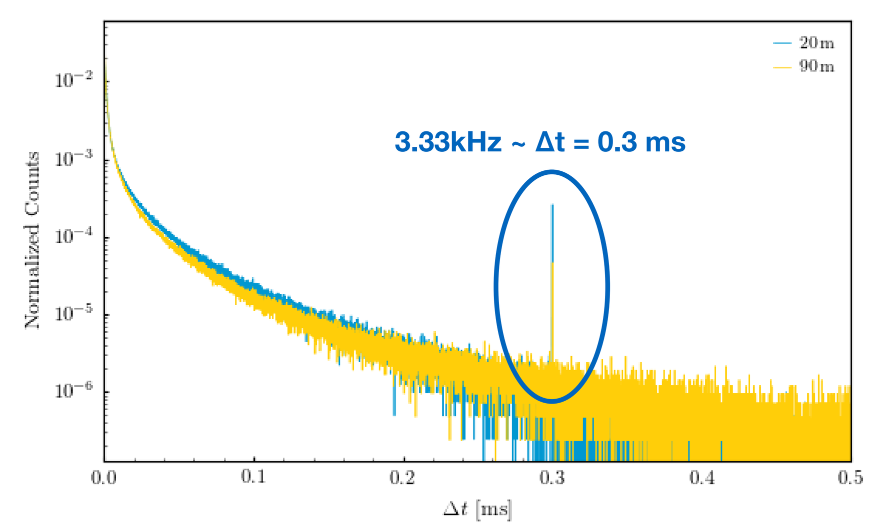


Fig. 4: Δt histograms for sDOMs at 20 m (blue) and 90 m (yellow) from a POCAM flashing at 3.33 kHz with 470 nm and showing signal.

Light Sensor – sDOM

- sDOM = STRAW Digital Optical Module
- Newly developed for STRAW
- Two 3“ photomultipliers to detect flashes from the POCAM light emitters
- Read-out with picosecond TDC front-end by GSI
- Multichannel read-out for charge reconstruction
- Nanosecond-precision synchronization

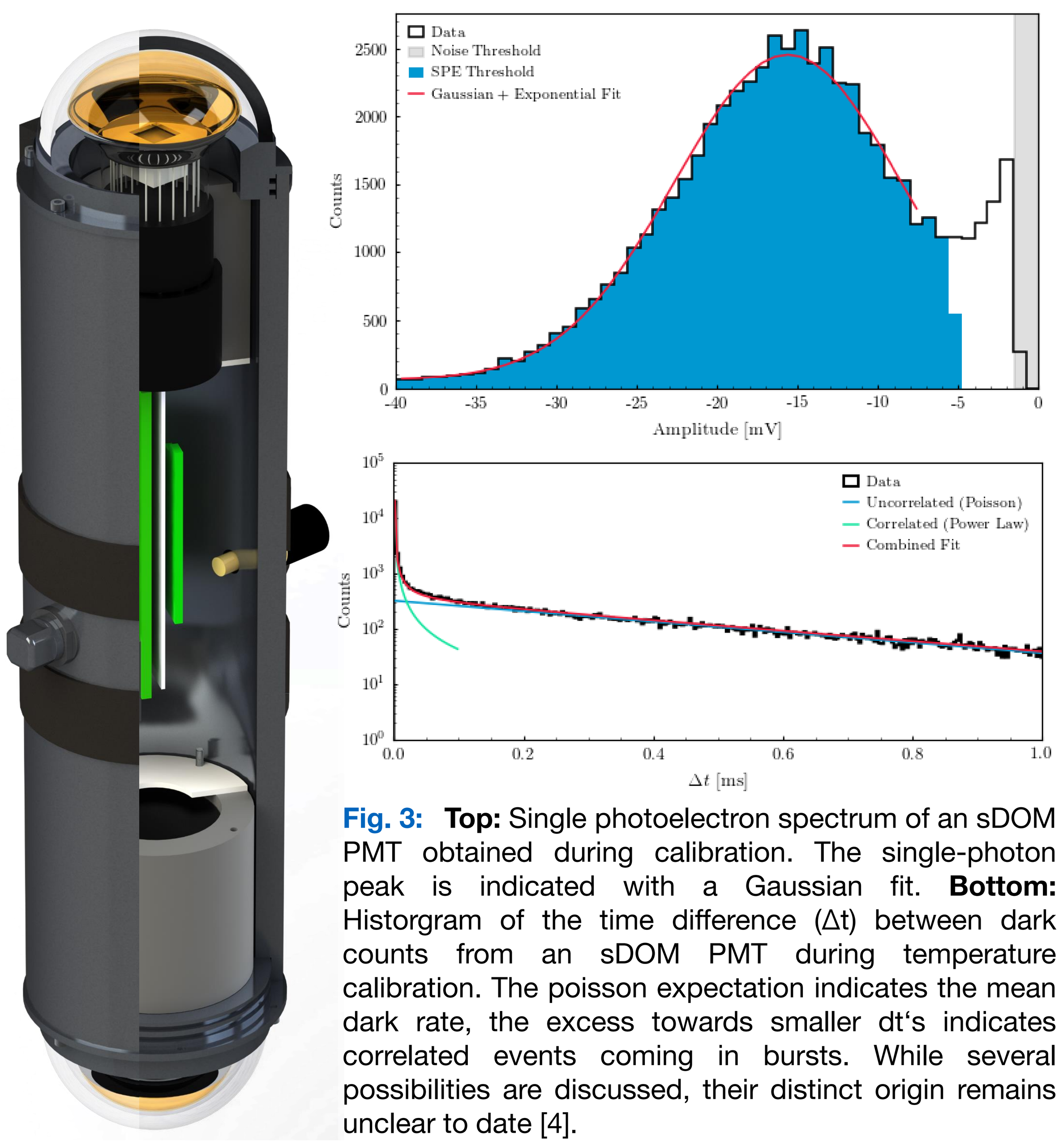


Fig. 3: Top: Single photoelectron spectrum of an sDOM PMT obtained during calibration. The single-photon peak is indicated with a Gaussian fit. **Bottom:** Historgram of the time difference (Δt) between dark counts from an sDOM PMT during temperature calibration. The poisson expectation indicates the mean dark rate, the excess towards smaller dt's indicates correlated events coming in bursts. While several possibilities are discussed, their distinct origin remains unclear to date [4].

References & Acknowledgements

[1] KM3NeT: Technical Design Report (2009), KM3NeT Collaboration
[2] Astropart. Phys. 27 1-9 (2007), G. Riccobene and A. Capone
[3] Appl. Opt. 20 177–184 (1981), R.C. Smith and K. Baker
[4] JINST 12 P03012 (2017), IceCube Collaboration

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