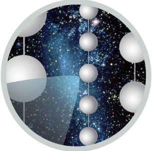
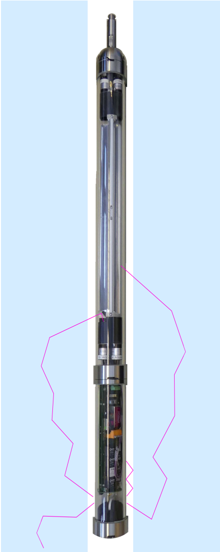
Design, performance, and analysis of a measurement of optical properties of antarctic ice below 400 nm.

Jannes Brostean-Kaiser on behalf of the IceCube collaboration



Motivation & Measurement principle

- Goal: Calibration of the antarctic ice in the UV-range for future optical modules for IceCube Neutrino Observatory
- In-situ measurement in the open SPICEcore drill hole
  → Light source and detector in one device
- Measurement of the time stamps of back-scattered photons



Design and development of an in-situ measurement

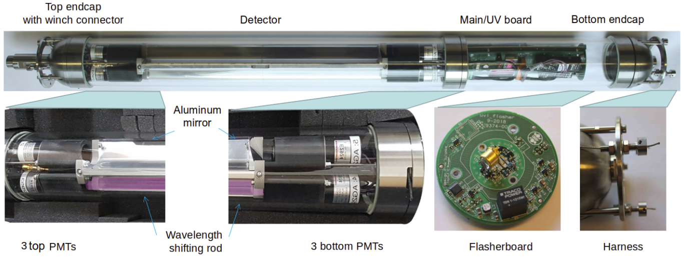


Fig. 1: Picture of the UV calibration device

- Designed to measure absorption and scattering coefficients below 400 nm
- LED driven light source with 4 wavelengths: 245 nm, 278 nm, 310 nm, 370 nm
- Detector divided longitudinally in 3 parts, by aluminum mirrors
- Detection based on 6 PMTs (3 top side, 3 bottom side):
  4 connected to wavelength shifting rods[1]
  2 open (one with an additional mirror)

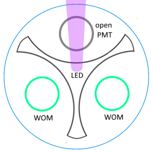


Fig. 2: Cross section of the detector

Measurement

- Measurements done in two seasons of austral summer 2018/2019 & 2019/2020
- Measurements on 7 depths in total
  - 2 at high scattering for calibration
  - 5 in IceCube depths

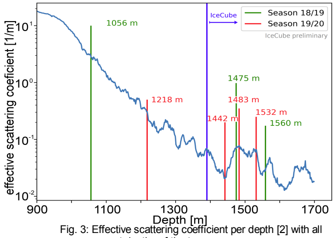


Fig. 3: Effective scattering coefficient per depth [2] with all measurement depths of the two seasons

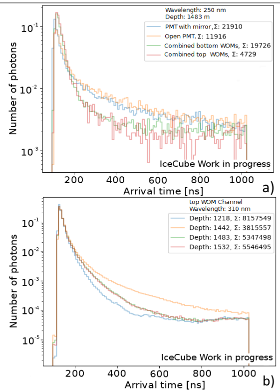


Fig. 4: Prepared example data sets of the measurements

Simulations & expectations

- In ice scattering simulated with Rayleigh scattering
  $$p(\theta) \propto (1-\cos(\theta))^2$$
- Offset and transit time is fitted to a minimal TS
- Slopes of timing distributions are highly dependent from the simulated coefficients (Fig. 5)
- Larger Scattering coefficients:
  → steeper rise
- Smaller absorption coefficients:
  → longer/wider tail

Data analysis

- Comparison of the histogrammed timestamp with a simulation using:

$$TS = \sum_{i=1}^{N} \frac{(d_i - a_i \cdot N_d/N_a)^2}{d_i + a_i \cdot N_d^2/N_a^2}$$

with d_i number of entries in data bin i, a_i number of entries in MC-bin and N_d, N_a the total number of entries over all bins

- 2D scans are performed for every measurement
  → Running the simulation with different pairs of coefficients to find a minimum
- Minimum is analysed 100 times to calculate a standard variation, used as a confidence interval around the minimum

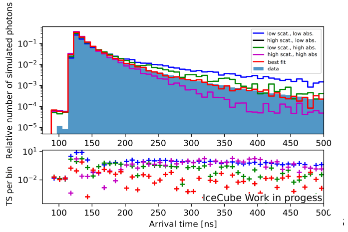


Fig. 5: Dataset of a measurement with 5 simulations for all bins

2D scans

- Very large 1σ regions, spanning over one order of magnitude (Fig. 6)
- 1σ regions don't overlap for one measurement in different PMT-channel
  → no combined results possible
- Attempt to decouple absorption and scattering by restricting the time window
  → still a large dependency on both parameters

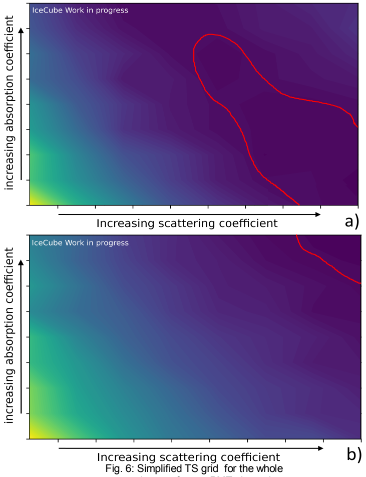


Fig. 6: Simplified TS grid for the whole dataset, for two PMT-channel

Outlook

- New measurements and more precise calibration of the experiment
- Extend the simulation grid around the 1σ regions
  Estimation of the minimum with errors from the confidence intervals
- Understand the systematic differences between the channels and measrements
- Combine the measurements to a pair of scattering and absorption coefficients per wavelength and depth
- Full Proceeding

[1]IceCubeCollaboration PoS ICRC2017 (2017) 1052
[2] IceCubeCollaboration, M. Ackermannet al. JGR 111 no. O3, (2006)