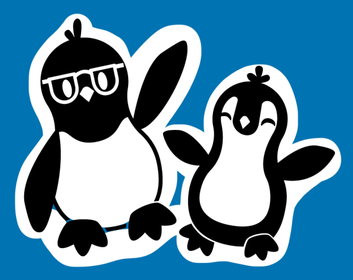
The Wavelength-Shifting Optical Module for the IceCube Upgrade

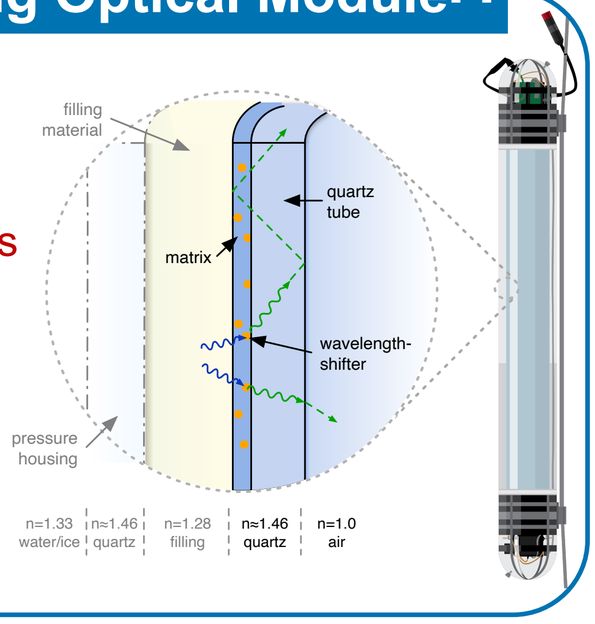
Lea Schlickmann for the IceCube Collaboration

Johannes Gutenberg University Mainz, lschlick@uni-mainz.de



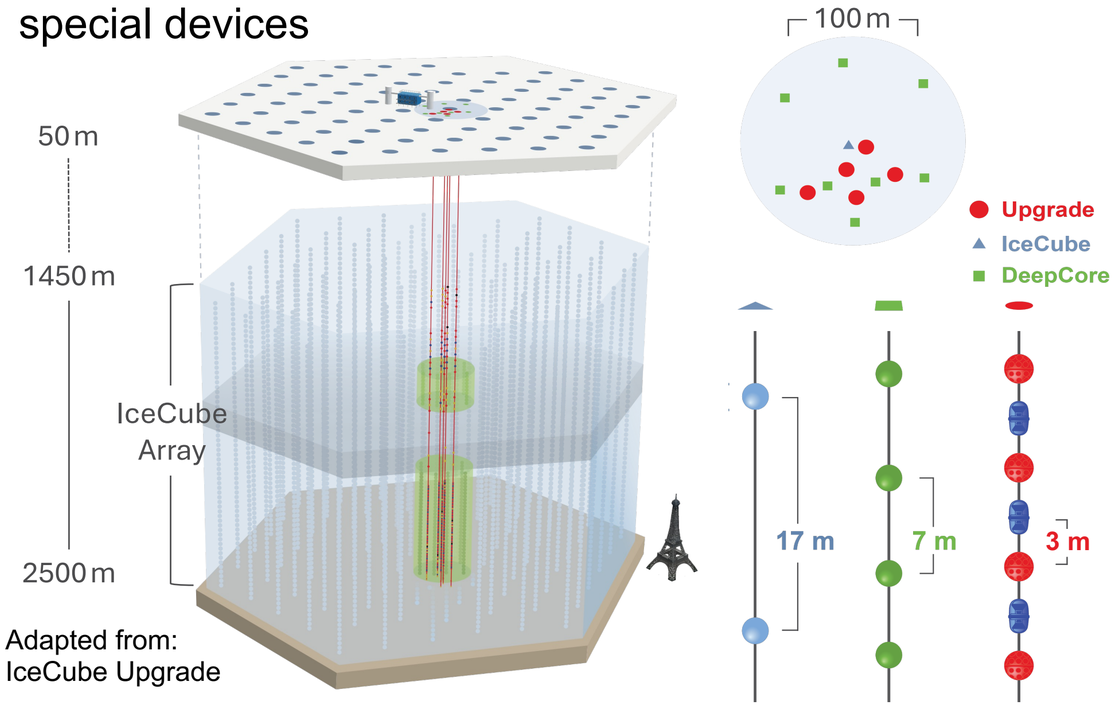
1. Wavelength-Shifting Optical Module[1]

1. Cherenkov photons are absorbed by wavelength-shifting coating
   - ➢ Specialized on UV-photons
2. Photons are re-emitted at longer wavelengths
3. Photons can be trapped by total internal reflection
4. Trapped photons are guided to a PMT and detected



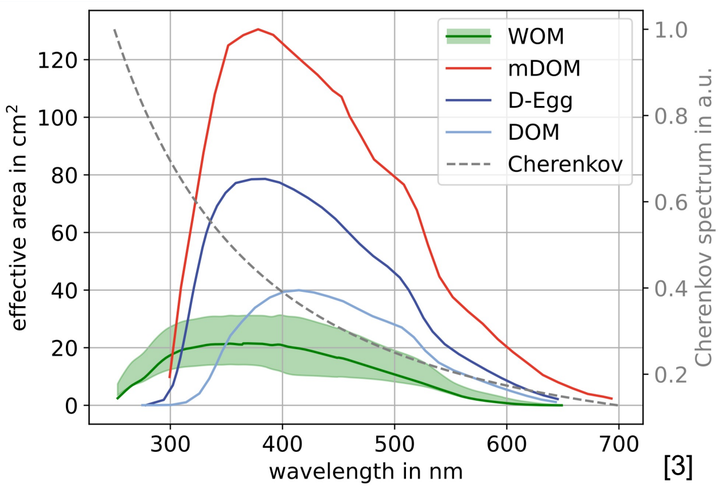
2. IceCube Upgrade[2]

- Installed five additional strings in the center of IceCube in the Antarctic summer season 2025/26
  - ➢ Denser instrumentation
  - ➢ Low-energy extension for IceCube
- New modules: multi-PMT modules, calibration, and special devices

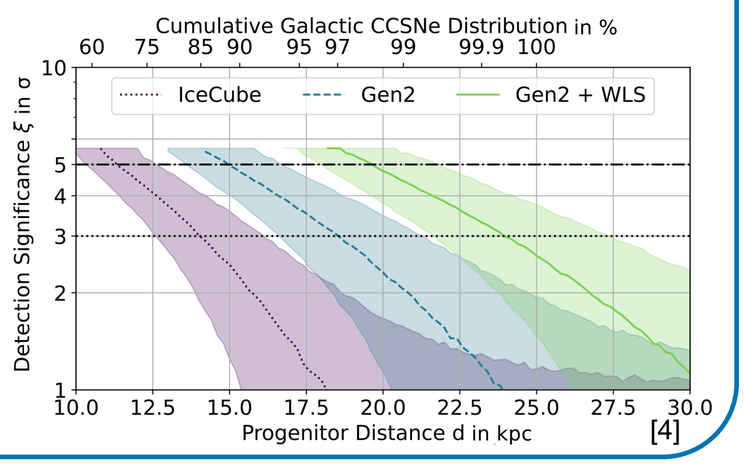


3. Physics Potential

- WOM has unique sensitivity to UV region in which Cherenkov photon emission is high
- High effective photosensitive area with a small photocathode area improves the signal-to-noise ratio
- Wavelength-shifting (WLS) techniques can enhance IceCube's sensitivity to supernova neutrinos



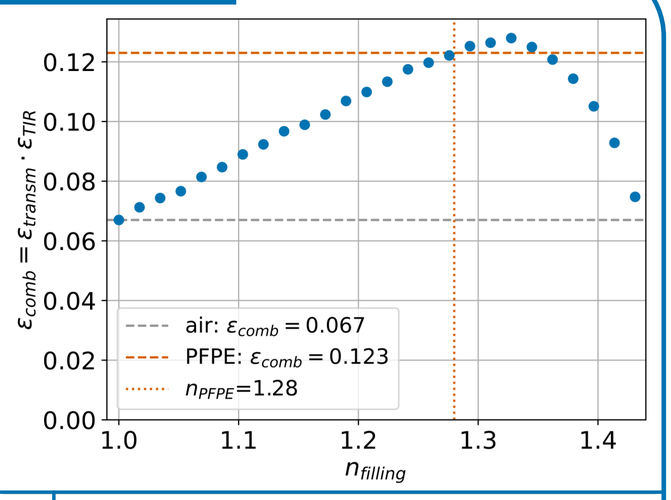
[3]



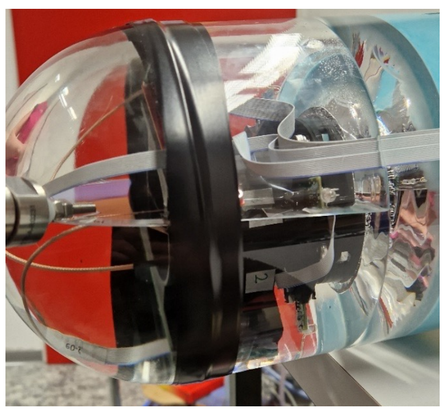
[4]

4. Challenge: Filling Liquid

- Purpose: increase efficiency by matching of refractive index n
- Between pressure vessel and coated tube
- Material: PFPE[5]
- Properties: inert, dielectric, and n=1.280



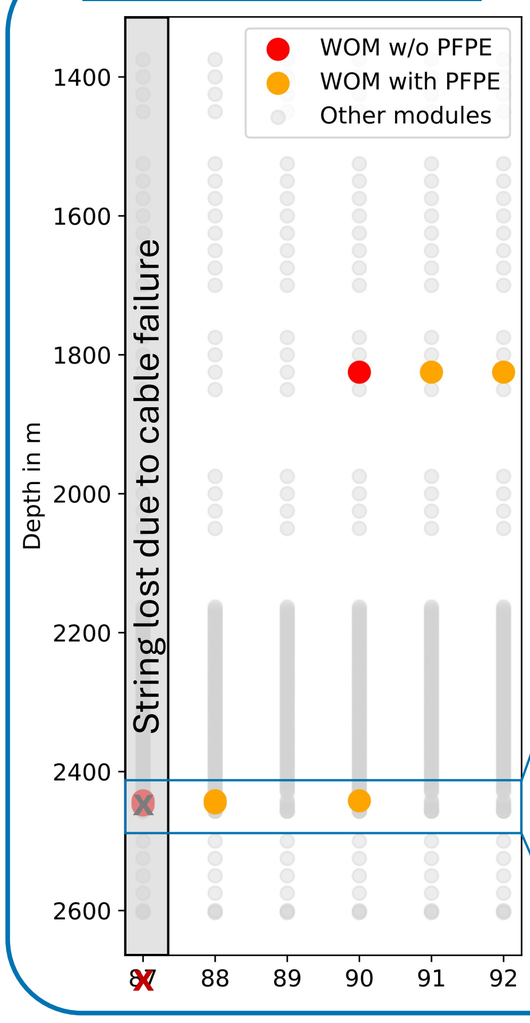
Compartment Leakage

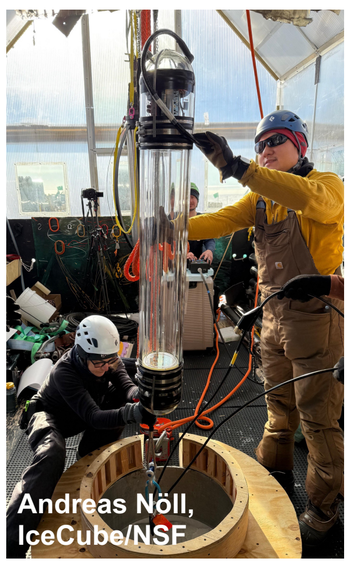


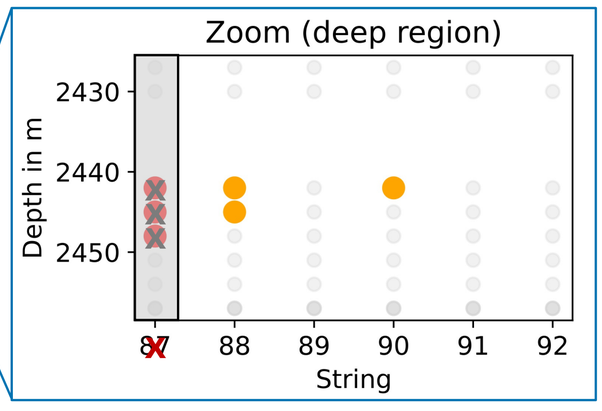
Inner Tube Leakage

- No PFPE in first five modules
- Tested that leakages do not damage basic functionality of WOMs
- ➢ PFPE for second batch of five WOMs

5. Deployment







6. Next Steps

- Analyze monitoring data: pressure and temperature
- Prepare data taking: first runs and implementation in continuous DAQ
- Analyze in-ice data

[1] Bastian-Querner et al., 2022, **"The Wavelength-Shifting Optical Module"**, *Sensors* 22 (2022) 4, 1385
[2] Ishihara (IceCube), 2019, **"The IceCube Upgrade – Design and Science Goals"**, PoS-ICRC2019-1031
[3] Popovych, 2025, **"Development and Performance Evaluation of the Wavelength-shifting Optical Module for the IceCube Upgrade"**, PhD Thesis
[4] Beise, 2026, **"Improving Supernova Neutrino Detection in IceCube-Gen2"**, PhD Thesis
[5] Solvay Specialty Polymers, **"Galden® HT PFPE – Heat Transfer Fluids"**, Technical Datasheet

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