Introducing WOM: The Wavelength-Shifting Optical Module

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Experimental Astroparticle Physics and Cosmology

Future Neutrino Telescopes

- Low Energy: Precision
  - Improve resolution (oscillations!)
    - ➔ Improve signal/noise
    - ➔ Reduce module noise
- High Energy: Size
  - Need high photocoverage
    - ➔ Increase size of optical modules
  - Need good veto
    - ➔ Reduce module noise
  - Keep cost at bay

- How can we reach that?

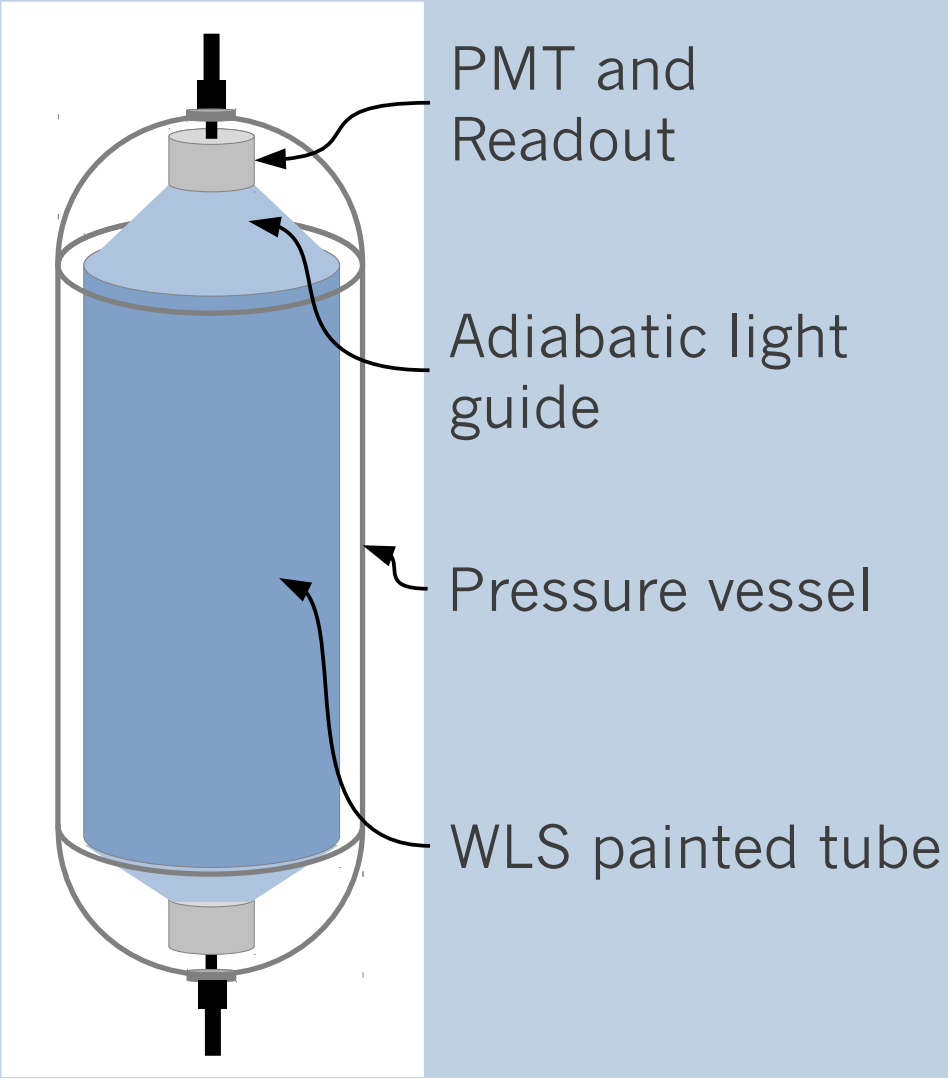
The Idea

Increase effective area per module

- Use large area passive components
  - No electronic noise
- Small PMTs for readout
  - Small cathode → low noise
  - Inexpensive
- Detect UV photons
  - Cherenkov light mostly in UV

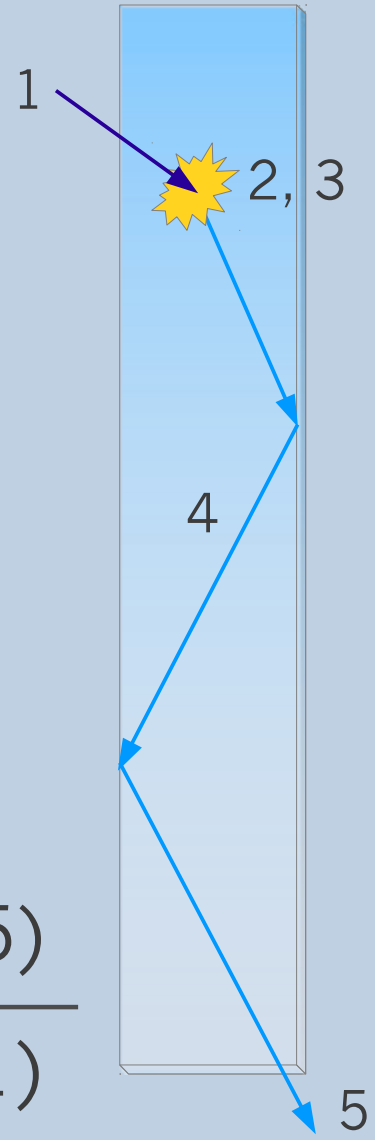
WOM concept

- **WOM** – Wavelength-shifting Optical Module
- Wavelength shifter (WLS):
  - (arbitrarily) large collection area
  - low noise (<1 Hz/kg)
  - affordable
- Readout: small, low-noise PMTs
- Housing: fused quartz
  - UV transparent
  - low noise (<0.1 Hz/kg)
- Mostly passive components:
  - Total noise rate O(10 Hz)



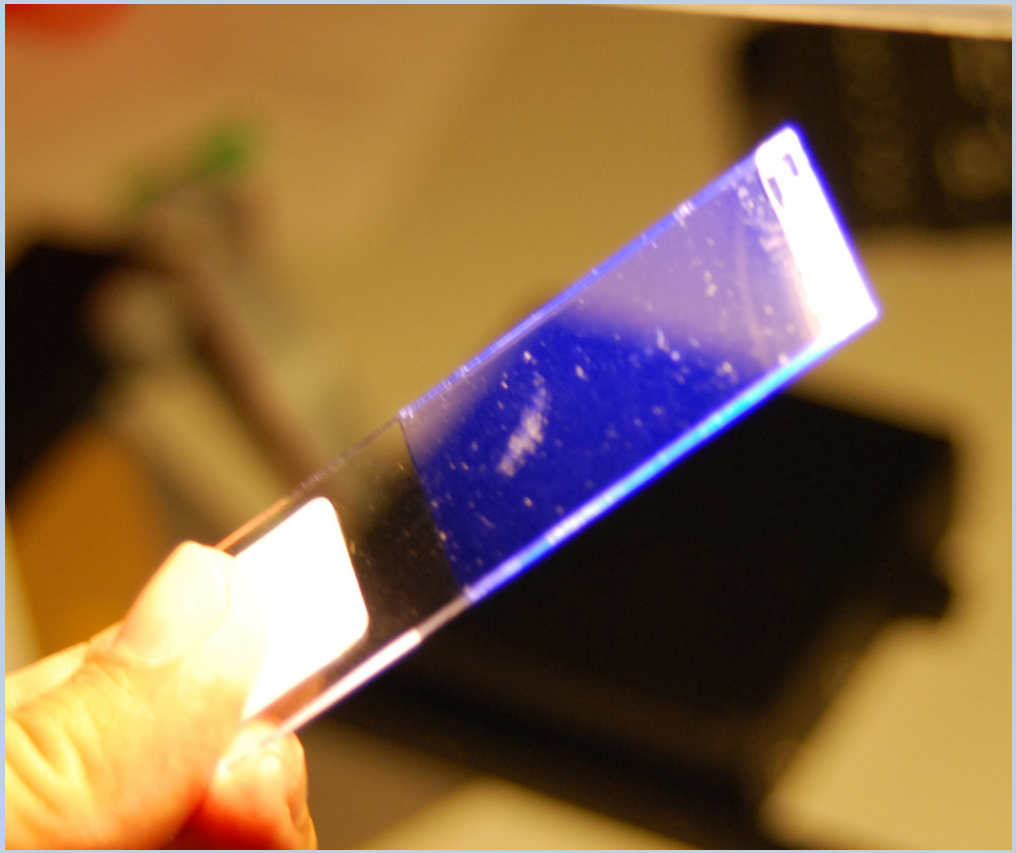
Reminder: Wavelength Shifter

1) Incoming UV photon
2) Gets absorbed by WLS molecule
3) Isotropic re-emission at larger wavelength (blue)
4) Captured inside tube/bar like in optical fiber
5) Detection at end



$$\text{Capture efficiency} = \frac{\#\ \text{detected photons (5)}}{\#\ \text{injected photons (1)}}$$

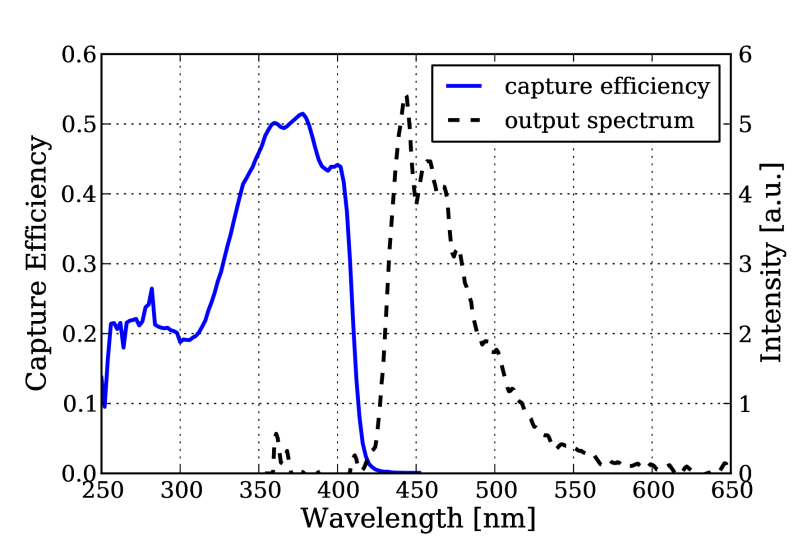
Wavelength Shifter



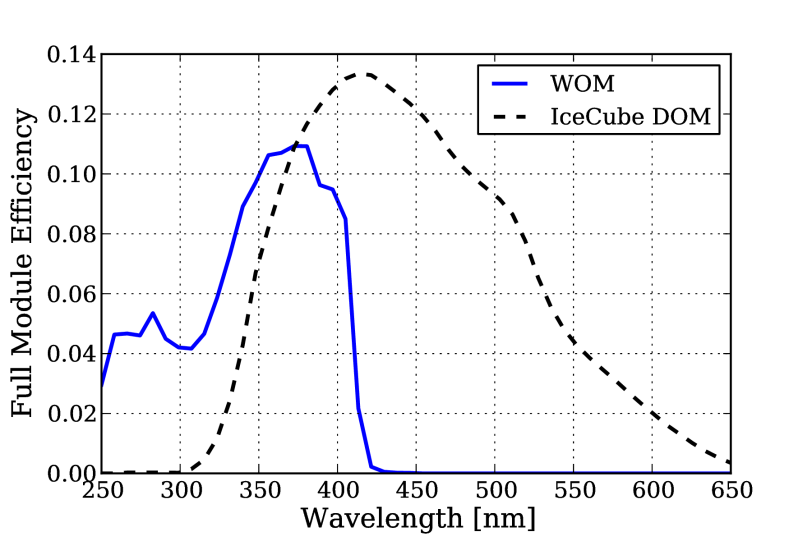
Producing the Samples

Estimated sensitivity

WLS painted tube only



Full module (incl. readout, ...)

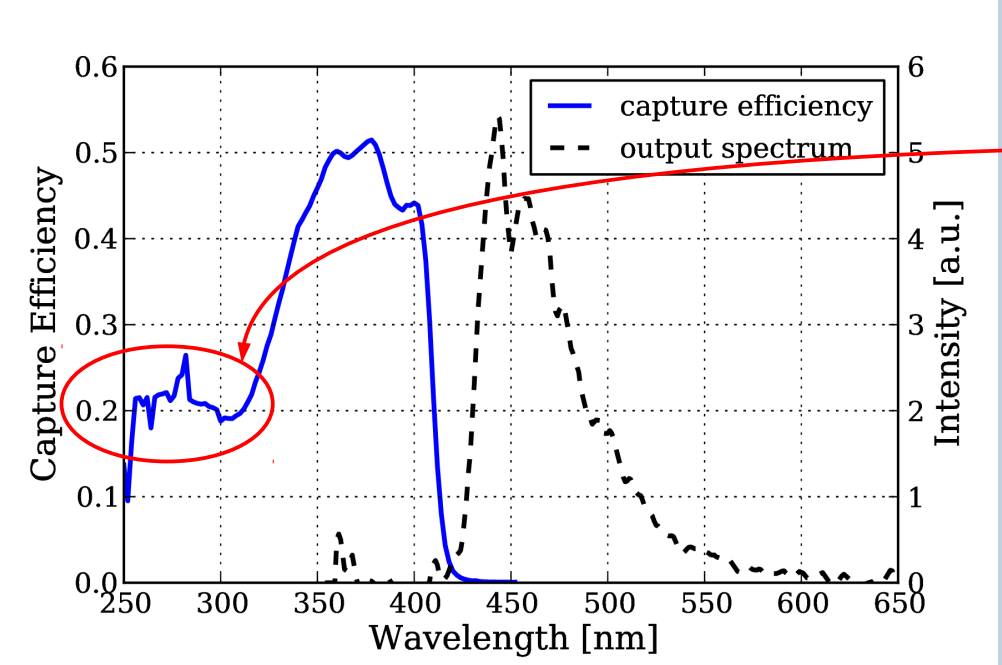


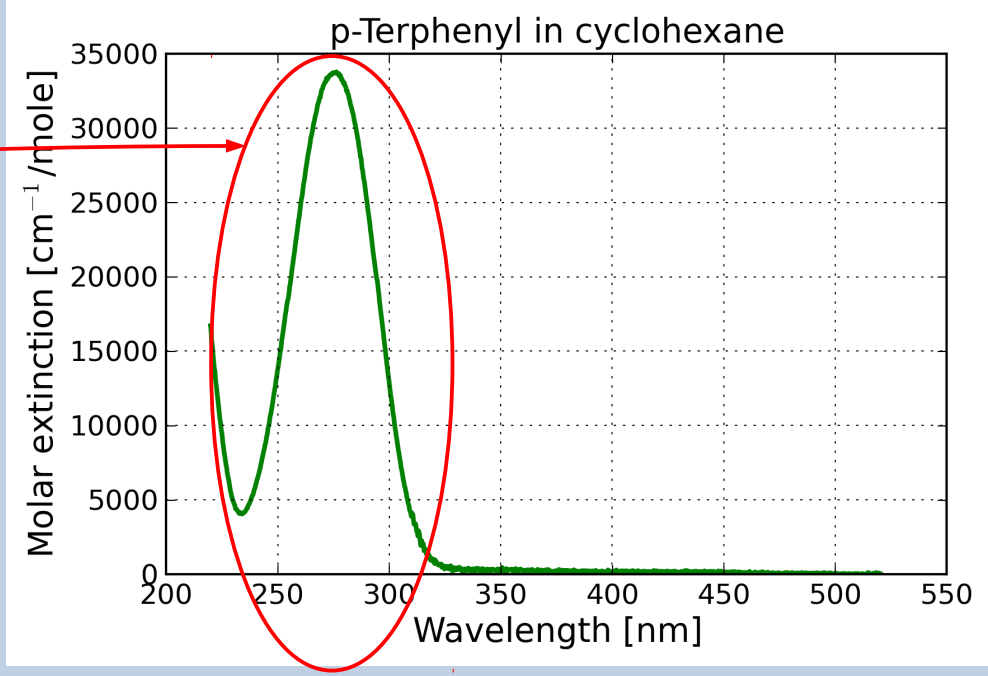
WOM with R = 10 cm, L = 2 m; integrated down to 250 nm

Module	$\overline{ME}$	$\bar{\varepsilon}_\Omega$	Eff. Area	Noise
WOM	4.40 %	57.5 %	101 cm^2	$\approx$ 10 Hz
DOM	5.36 %	34.1 %	12.9 cm^2	800 Hz

arXiv:1307.6713

Optimization of Dye

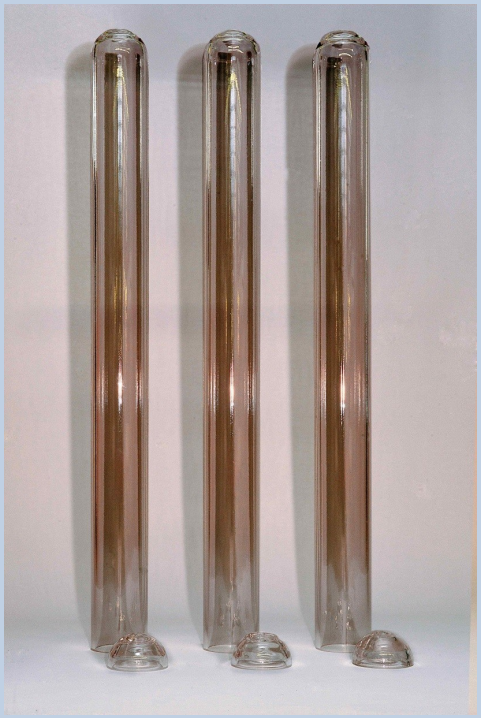




- Enhance sensitivity below 350 nm
- Combine with other dyes (e.g. p-Terphenyl)
- Double overall sensitivity (Cherenkov spectrum ~$1/\lambda^2$)?

Work in Progress

- Dip Coater for controlled production of samples now in operation
  - Find optimal film thickness
- Find optimal shape of light guide (WLS → PMT)
  - Bachelor student working on this problem
- Single photon source + test bench for PMT readout of samples
  - Demonstrate single photon detection
- Optimization of dye for UV efficiency and long-time stability
- Long term: assemble first prototype
  - Pressure vessels have been ordered



To Do Next...