Optical properties of water and liquid scintillator for the Daya Bay Neutrino Oscillation Experiment

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Overview

1. Motivation
2. Apparatus
3. Attenuation Length
4. Index of Refraction
5. Conclusions & Future Work
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Motivation

- Ultrapure water $\equiv$ Money
- Daya Bay simulations indicate $< 1\%$
  effect between 20 - 30 m
- $18M\Omega cm H_2O$ has $l > 100m$ in the near UV
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Motivation

- Linear Alkyl Benzene (LAB) will be used as liquid scintillator (see Wei Wang's talk)
- Optical transparency should give $\lambda_{1/e} > 10$ m
- Absorbance at 430 nm is very close to baseline requirements
- A long path-length attenuation system is needed for precision measurements
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Apparatus

- LED/Pulser
- Beam Splitter
- 2m fiber optic
- 40m fiber optic
- collimation/focusing optics
- variable water column
- PMT
- DAQ

Graph showing time [ns] and ADC channels.
Fit ratios of integrated charge in prompt and delayed pulses:

\[ \chi^2 / \text{ndf} = 56.57 / 69 \]

- Constant: 71.2 ± 2.0
- Mean: 1.1 ± 0.0
- Sigma: 0.1025 ± 0.0018
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Attenuation Length

Plot as a function of path length through sample...

Extinction of 525 nm light in RO treated $H_2O$

$R_0 = 3.26E-1 \pm 1E-3$

$\lambda = 1541 \pm 113$

...and fit to convolution of exponentials.
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Attenuation Length

![Light Attenuation in H₂O](image)

- 18 MΩ cm H₂O
- RO treated H₂O
- 18MΩ cm H₂O (Pope + Fry)
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Index of Refraction

Travelling through a high index material, the attenuated light is delayed by a few ns.

The red trace comes from light that has traversed a meter of LAB.
Find difference in time delay between centroids of prompt and delayed pulses for each path length through the liquid sample.

The red trace comes from light that has traversed a meter of LAB.
Plot as a function of path length through sample... and fit.

**Time Shifts in Purified Linear-Alkyl-Benzene**

\[ N_{LAB} = 1.410 \pm 0.004 \]

\[ T_{off} = 171.95 \pm 0.01 \text{ ns} \]
Conclusions & Future Work

- We have built a system to take precision measurements of attenuation length and index of refraction.
- We have demonstrated the benefit of RO water for small Water Cerenkov detectors.
- Optical characterization is useful for determining uniformity of scintillator batches and online monitoring of water quality in polishing loops.
- Characterization of LAB and Gd-LAB is in-progress.
- Work on reducing systematics is in-progress.