Liquid Scintillator for the PROSPECT Antineutrino Detector

Pieter Mumm for the PROSPECT Collaboration (prospect.yale.edu)
National Institute of Standards and Technology

PROSPECT: 4-ton segmented ⁶Li-loaded liquid scintillator detector

PROSPECT will probe short-baseline oscillations & spectral distortions using a compact, segmented, high-resolution antineutrino detector.

Antineutrino detector (AD)

- Minimal (~0.5m) overburden and proximity to a reactor core (~7m) requires excellent control of backgrounds.
- Backgrounds include accidental gammas and neutron capture. Importantly cosmogenic BG often involve nuclear recoils.
- Signal (inverse Beta Decay) is neutron-capture correlated and low rate.
- Neutron capture distinctive tag: capture time long compared to scattering physics, short compared to accidental rate.
- PSD allows for the separation of gamma-like and n-like events, as well as capture.

High Flux Isotope Reactor

Base materials purified, and then mixed in stages to produce final LS

28 x 200L drums shipped from BNL to ORNL, in a temperature controlled truck, ultimately mixed in a PTFE lined ISOtank prior to AD filling.

2LiLS optical absorbance at 420nm wavelength. All drums had a better absorbance than the requirement

Extensive QA/QC performed on each batch, with very good consistency observed between batches.

0.5 Bq of dissolved ¹³¹Ce yields a Re-Po chain that is easily separated from backgrounds. Excellent calibration source and determines relative cell volume

Scintillator performance

Ultimate energy resolution requires high light yield and efficient collection.

Capture peaks demonstrate excellent energy resolution (~4.5%/sqrt(E))

⁶Li, ¹H, and ³⁵Cl neutron capture peaks shown.

Capture peaks

Light yield and collection efficiency yields excellent Pulse Shape Discrimination

Li capture peak as a function of time for the 2 cell P50X prototype, change in peak position and PSD consistent with oxygen quenching.

Li capture peak as a function of energy from in situ measurement (with selective cuts), right plot shows PSD in the energy region of the neutron capture peak.

Production, QA/QC, mixing, filling, and environmental control.

Base materials purified, and then mixed in stages to produce final LS

28 x 200L drums shipped from BNL to ORNL, in a temperature controlled truck, ultimately mixed in a PTFE lined ISOtank prior to AD filling.

2LiLS optical absorbance at 420nm wavelength. All drums had a better absorbance than the requirement

Extensive QA/QC performed on each batch, with very good consistency observed between batches.

Microemulsion based LS allows precise stable doping of radionuclides

0.5 Bq of dissolved ¹³¹Ce yields a Re-Po chain that is easily separated from backgrounds. Excellent calibration source and determines relative cell volume

Light yield relative to linear alkyl benzene for 59 batches of 2LiLS (measured by a LS6500 counter with a Cs137 source)

59 batches were produced. The quality control (QA/QC) program analyzed optical transparencies (CFT), Light Yield (LY) and Pulse-Shape-Discrimination (PSD) based on the performance of prototypes.

Scintillator performance

Ultimate energy resolution requires high light yield and efficient collection.

Capture peaks demonstrate excellent energy resolution (~4.5%/sqrt(E))

⁶Li, ¹H, and ³⁵Cl neutron capture peaks shown.

Capture peaks

Light yield and collection efficiency yields excellent Pulse Shape Discrimination

Li capture peak as a function of energy from in situ measurement (with selective cuts), right plot shows PSD in the energy region of the neutron capture peak.

Production, QA/QC, mixing, filling, and environmental control.

Base materials purified, and then mixed in stages to produce final LS

28 x 200L drums shipped from BNL to ORNL, in a temperature controlled truck, ultimately mixed in a PTFE lined ISOtank prior to AD filling.

2LiLS optical absorbance at 420nm wavelength. All drums had a better absorbance than the requirement

Extensive QA/QC performed on each batch, with very good consistency observed between batches.

Microemulsion based LS allows precise stable doping of radionuclides

0.5 Bq of dissolved ¹³¹Ce yields a Re-Po chain that is easily separated from backgrounds. Excellent calibration source and determines relative cell volume

Light yield relative to linear alkyl benzene for 59 batches of 2LiLS (measured by a LS6500 counter with a Cs137 source)

Acknowledgements

This material is based upon work supported by the U.S. Department of Energy Office of Science and the Heising-Simons Foundation. Addition support is provided by Illinois Institute of Technology, LLNL, NIST, ORNL, Temple University, and Yale University. We gratefully acknowledge the support and hospitality of the High Flux Isotope Reactor, managed by UT-Battelle for the U.S. Department of Energy.