Liquid Scintillator for the PROSPECT Antineutrino Detector

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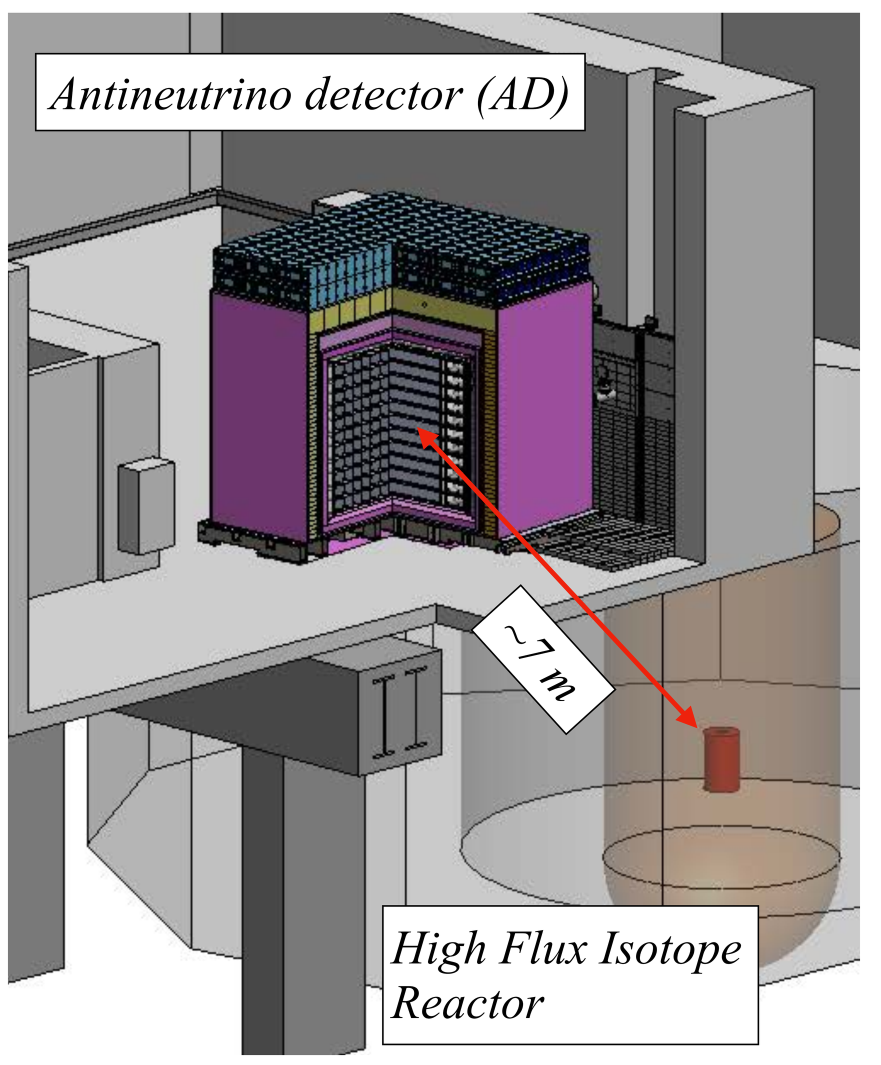
See also posters 112, 139, 188, 194; Talk Friday 12.15pm

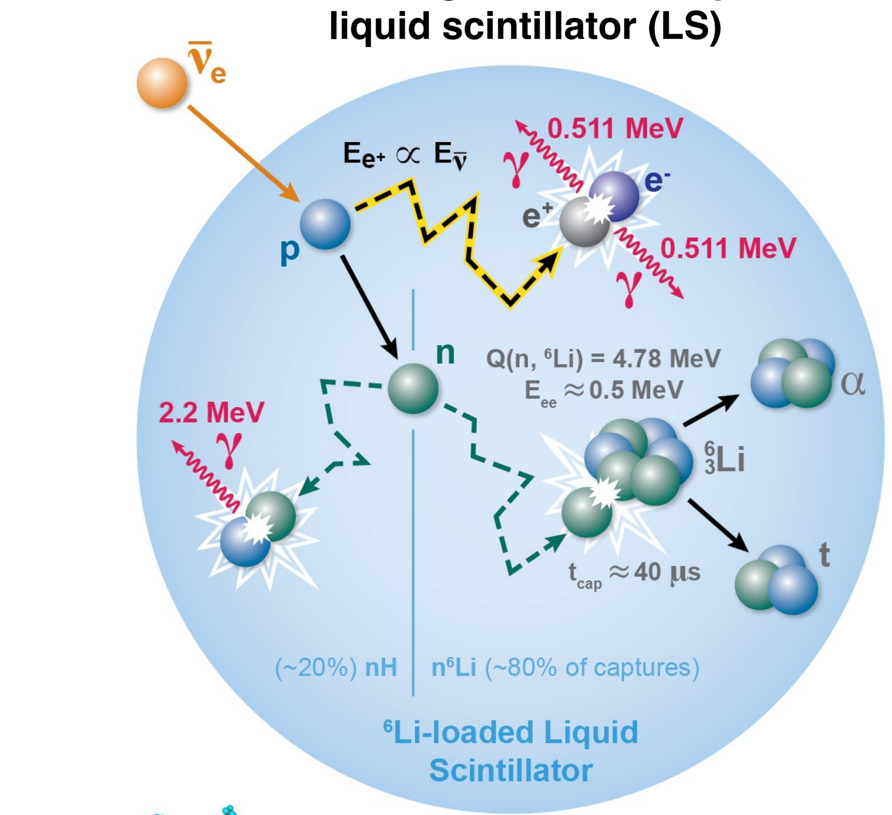
PROSPECT: 4-ton segmented ^{6}Li-loaded liquid scintillator detector

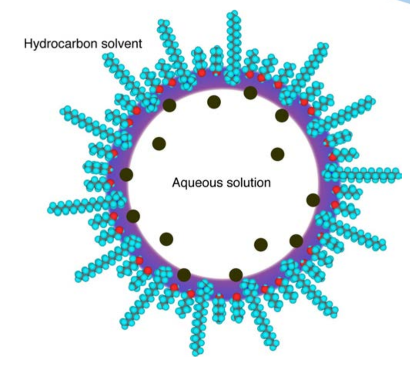
PROSPECT will probe short-baseline oscillations & spectral distortions using a compact, segmented, high-resolution antineutrino detector



- 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.

IBD signal in a ^{6}Li-doped liquid scintillator (LS)





^{6}Li loading via Reverse micelles:
- Surfactants added to base liquid scintillator
- Dynamically stable
- relatively high loading possible > 0.1%
- minimal reduction in light yield
- minimal reduction of PSD performance

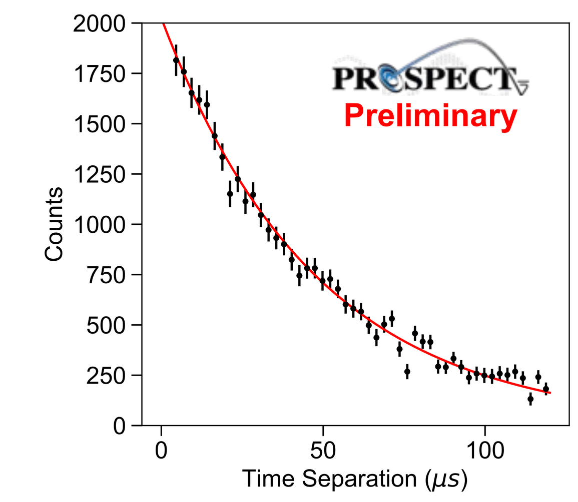
Over 2 years of R&D to develop a new water-based technique to load hydrophilic elements (i.e. Li) in liquid scintillator

Liquid scintillator developed is composed of:
- EJ-309 liquid scintillator-like base (DIPN)
- anionic surfactant
- purified 10 M ^{6}LiCl, with a total loading of 0.1% ^{6}Li by mass

LS properties yielded tight engineering constraints:

Cover gas system. Extensive material compatibility studies: long term soak tests followed by light yield and absorption measurements. Material strength tests.
- All materials in contact with LS qualified
- dominant materials, acrylic, PTFE, PLA, Viton

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

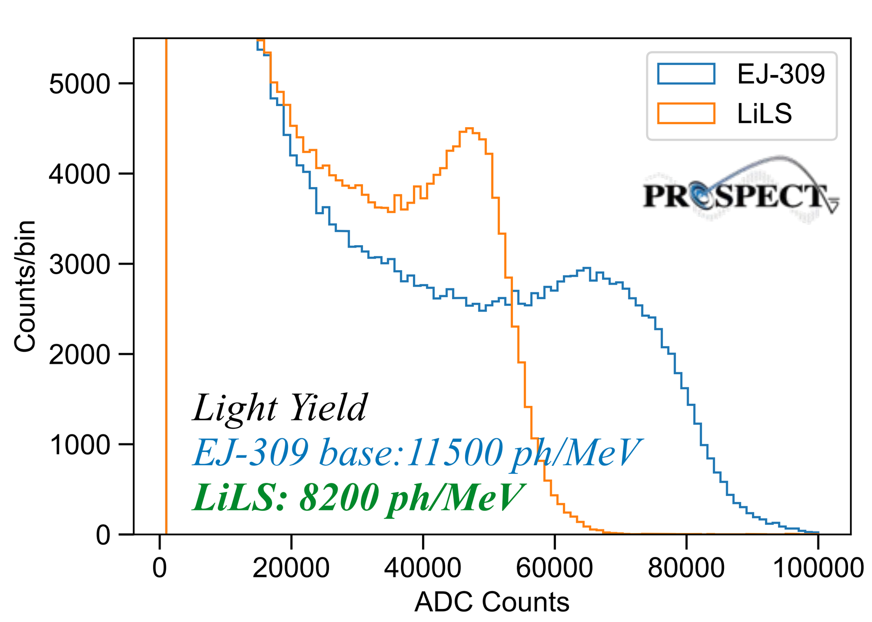


Neutron capture time for IBD events at 0.1% ^{6}Li doping shows expected purely exponential behavior

t_{cap} = 47 µs

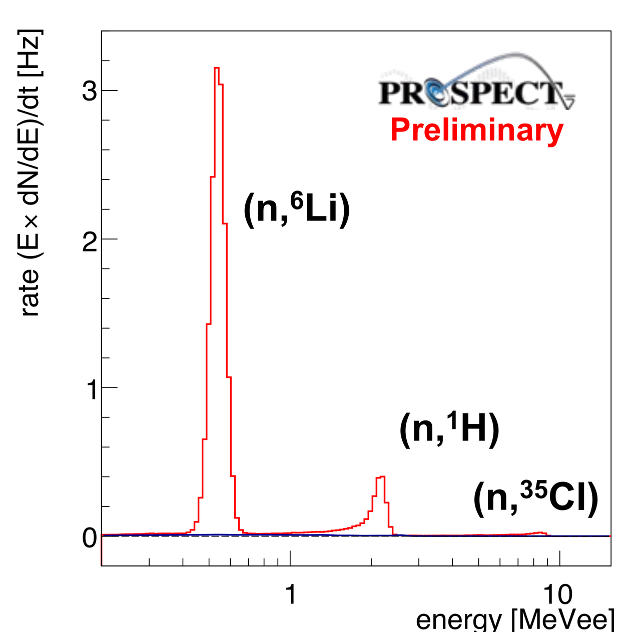
Scintillator performance

Ultimate energy resolution requires high light yield and efficient collection.



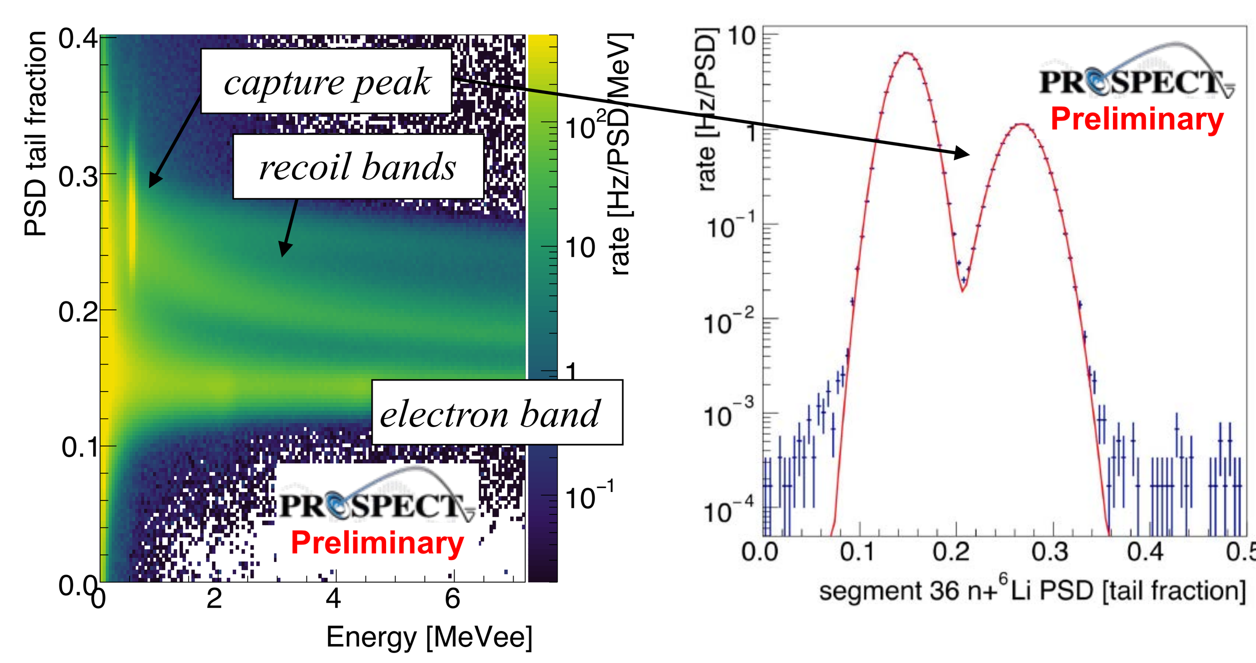
Prototype paper: https://arxiv.org/abs/1805.09245

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



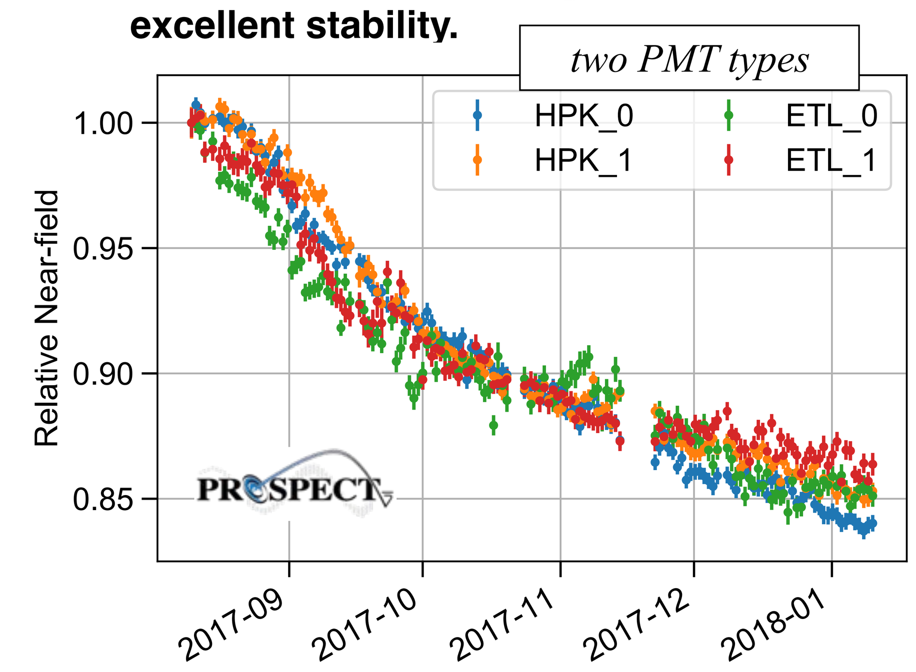
^{6}Li, ^{1}H, and ^{35}Cl neutron capture peaks shown.

Light yield and collection efficiency yields excellent Pulse Shape Discrimination



PSD 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

LS shows sensitivity to oxygen quenching, but with proper handling has shown excellent stability.



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

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

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

reaction vessel for LS mixing

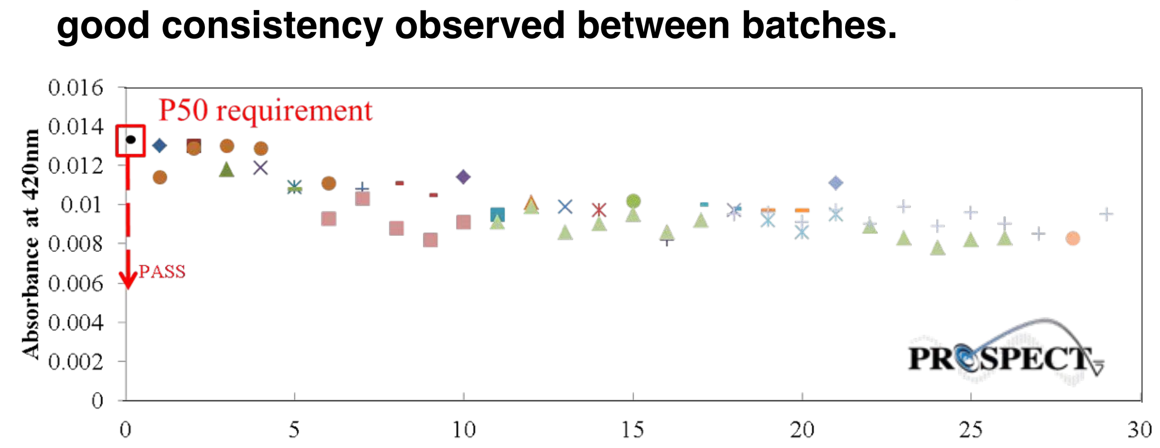
28 x 200L drums shipped from BNL to ORNL in a temperature controlled truck, ultimately mixed in a PTFE lined ISOTank prior to AD filling.

nitrogen cover gas maintained throughout

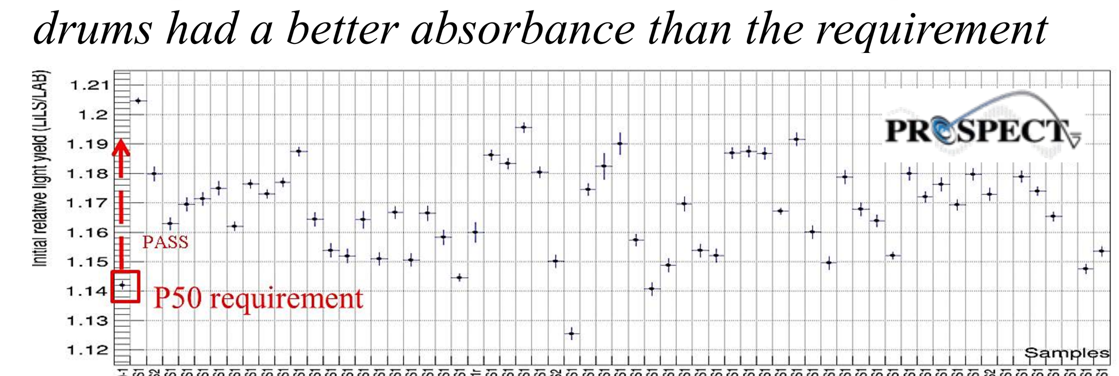
ISOtank arriving at ORNL

LS is sparged in ISOtank to ensure good mixing of batches and actinium spike and then pumped to AD with a peristaltic pump. A pure nitrogen cover gas from LN$_2$ boil-off maintained at all times over AD.

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

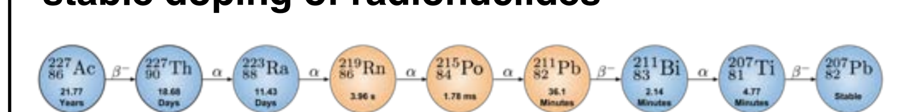


^{6}LiLS optical absorbance at 420nm wavelength. All drums had a better absorbance than the requirement

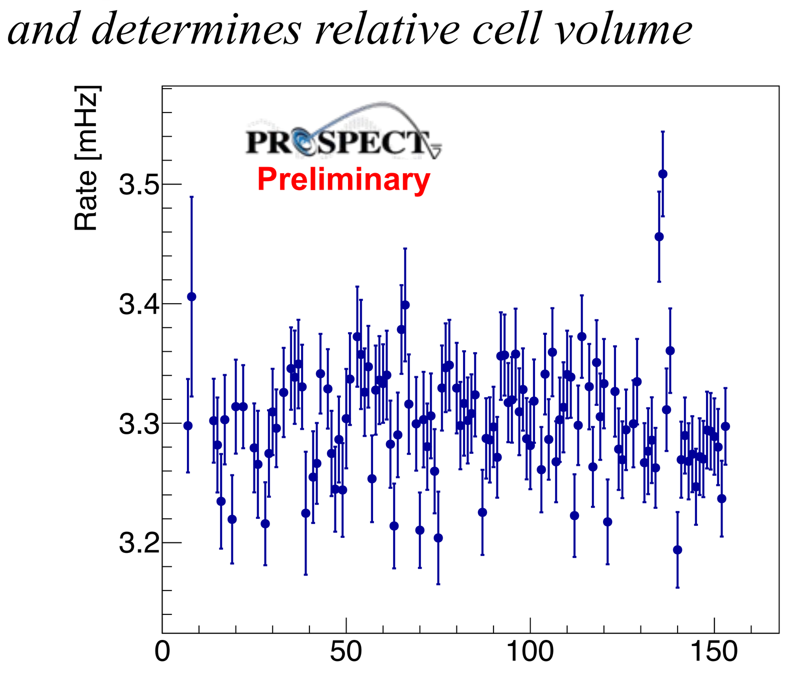


Light yield relative to linear alkyl benzene for 59 batches of ^{6}LiLS (measured by a LS6500 counter with a Cs137 source)

Microemulsion based LS allows precise stable doping of radionuclides



0.5 Bq of dissolved ^{227}Ac, yields a Rn-Po chain that is easily separated from backgrounds. Excellent calibration source and determines relative cell volume



Acknowledgements

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