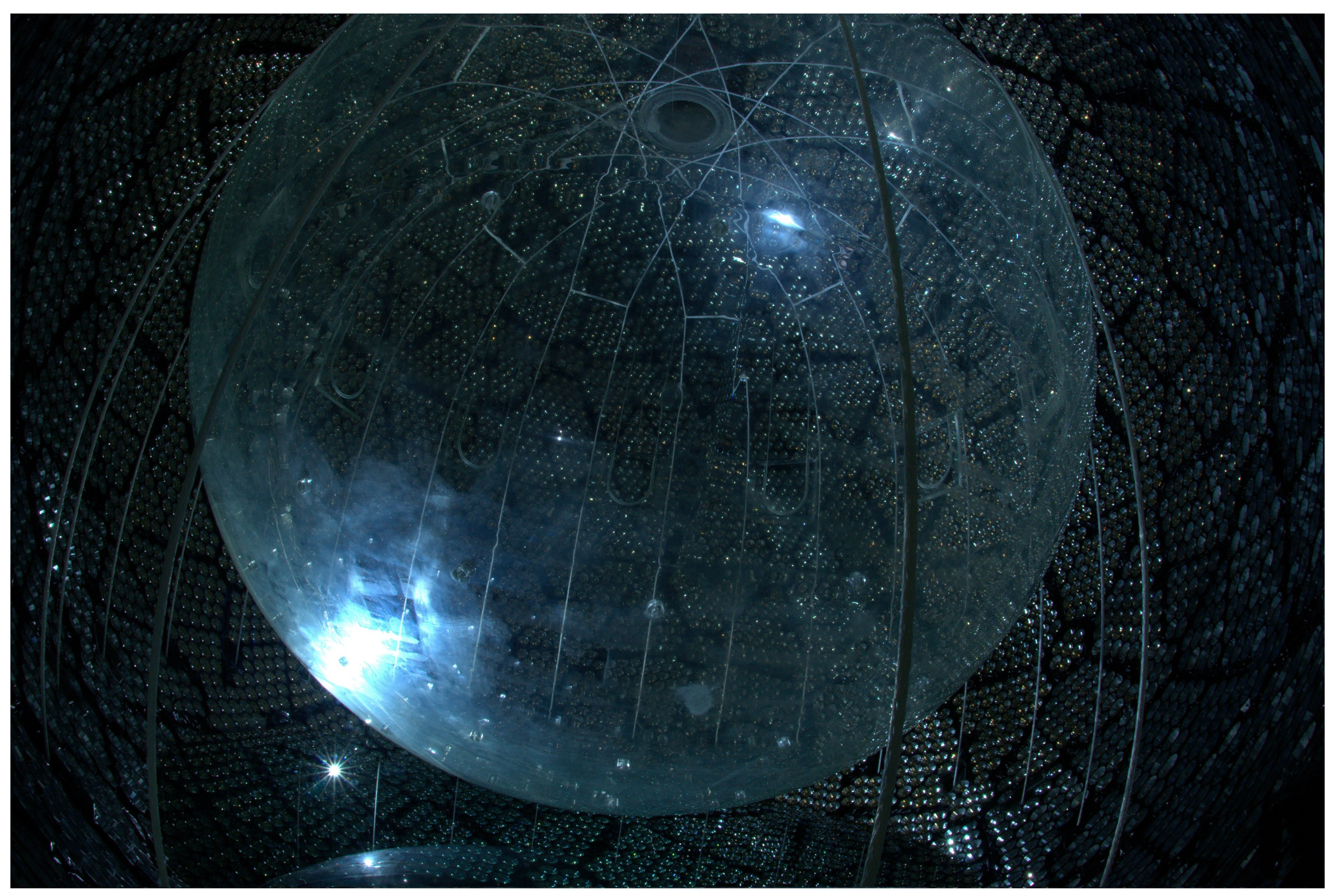
Light Yield & Scintillation Timing Profiles of Te-loaded Liquid Scintillator for SNO+

Sean Grullon for the SNO+ collaboration

SNO+ & Motivation

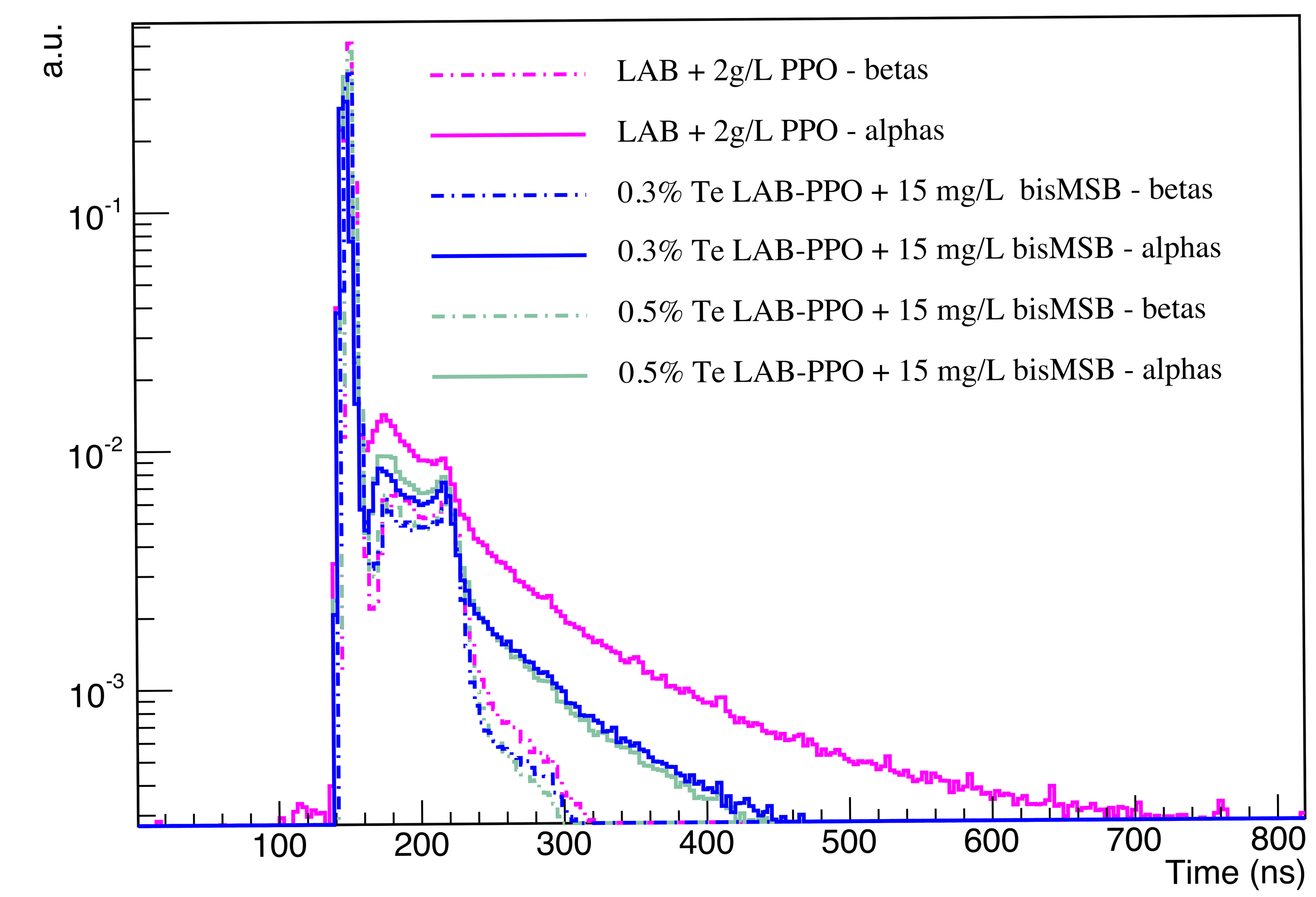
The SNO+ experiment is the follow-up to the Sudbury Neutrino Observatory (SNO) where the heavy water will be replaced with a liquid scintillator of linear alkyl-benzene (LAB). SNO+ will have a broad physics program which will include solar neutrinos, geo-neutrinos, reactor neutrino oscillations, supernova neutrinos, and a search for neutrinoless double beta decay by loading 2.3 tons of natural tellurium into LAB. Since energy resolution directly affects the physics reach of SNO+, it is extremely important to accurately measure the light yield of the liquid scintillator. Pulse shape discrimination is used for background rejection and it is therefore critical to measure the scintillation decay times for α and β electron excitations.



Photograph of the SNO+ Acrylic Vessel, taken by an in-situ camera.

Scintillation Decay Times

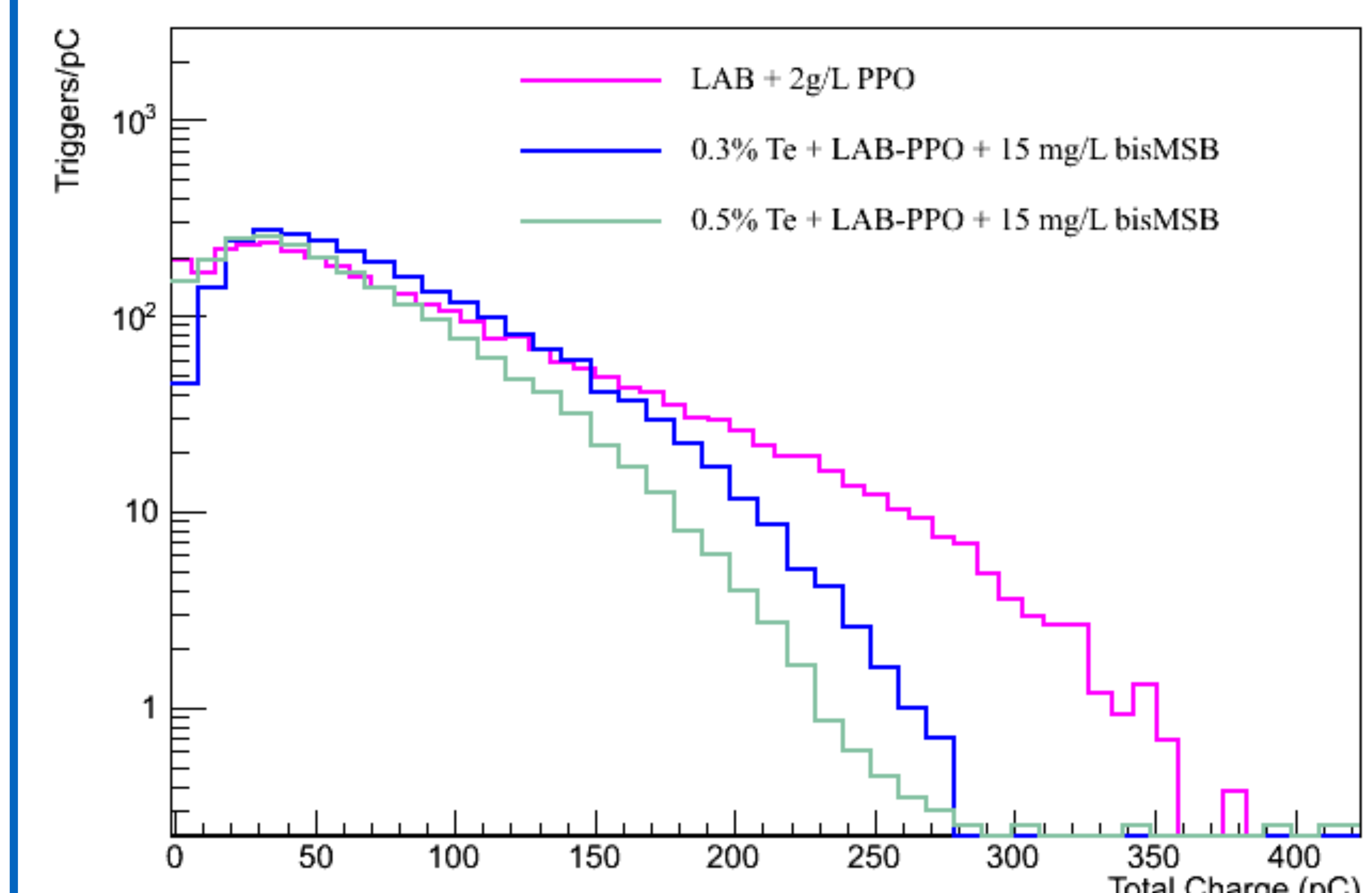
We measured the scintillation decay times of LAB + 2g/L PPO, 0.3% Te + 5% PRS + 2% H_20 LAB-PPO + 15 mg/L bisMSB, and 0.5% Te + 9% PRS + 4% H_20 LAB-PPO + 15 mg/L bisMSB with β particles from a ^{90}Sr disc source and α particles from a ^{210}Po disc source. Since the presence of oxygen significantly alters the timing, we first deoxygenated the samples with a dry nitrogen gas bubbler for 45 minutes. We applied ROOT's TSpectrum to the waveform traces as a peak finder to extract the photon arrival times from all three in a single histogram. α particles produce much more late light than the βs, which is related to the ionization density of the αs and βs interacting with the scintillator.



β and α particle scintillation timing profiles for pure LAB-PPO and Te-loaded LAB-PPO.

Scintillation Light Yield

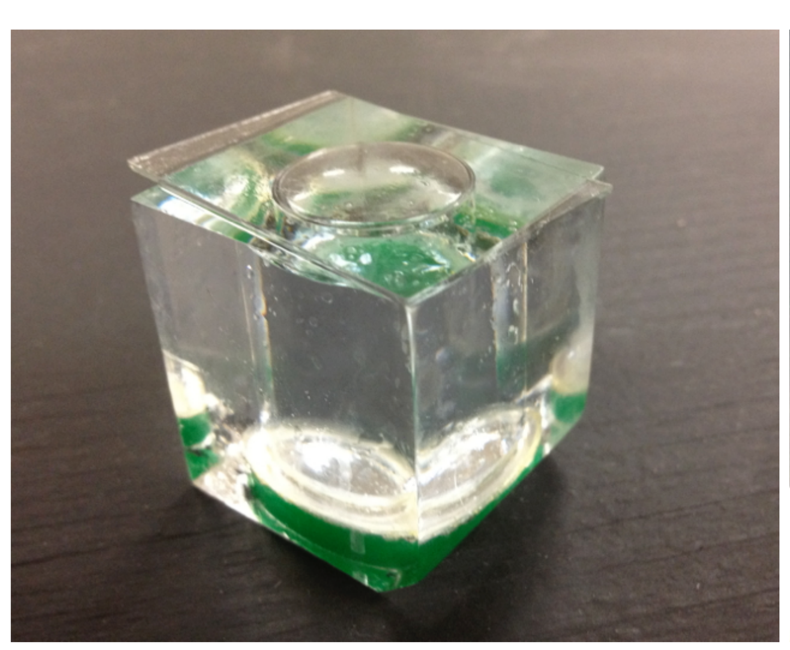
We measured the intrinsic light yield of pure LAB + 2g/L PPO, 0.3% Te + 5% PRS + 2% H_20 LAB-PPO + 15 mg/L bisMSB, and 0.5% Te + 9% PRS + 4% H_20 LAB-PPO + 15 mg/L bisMSB with β particles from the ^{90}Sr disc source. The total charge across all PMT channels was calculated. The intrinsic light yield of pure LAB + 2g/L PPO was measured by scaling the light yield in a Monte Carlo simulation of the dark box setup until the simulated charge spectrum for LAB-PPO matched the observed charge spectrum in the data. We derived the light yield of Te-loaded LAB by scaling the relative light output of the Te-loaded samples to the pure LAB samples.

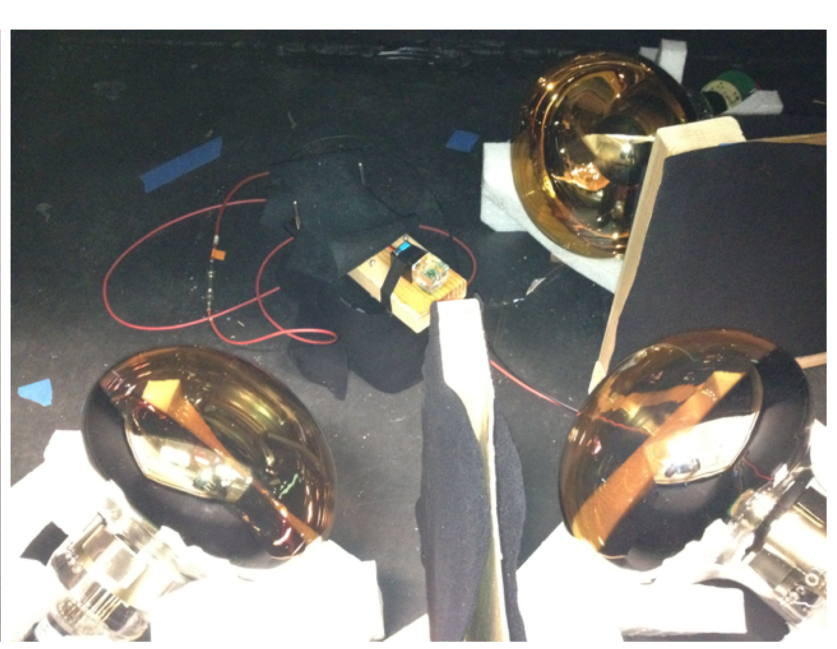


Charge spectra comparing pure LAB+2g/L PPO with Te-loaded LAB-PPO.

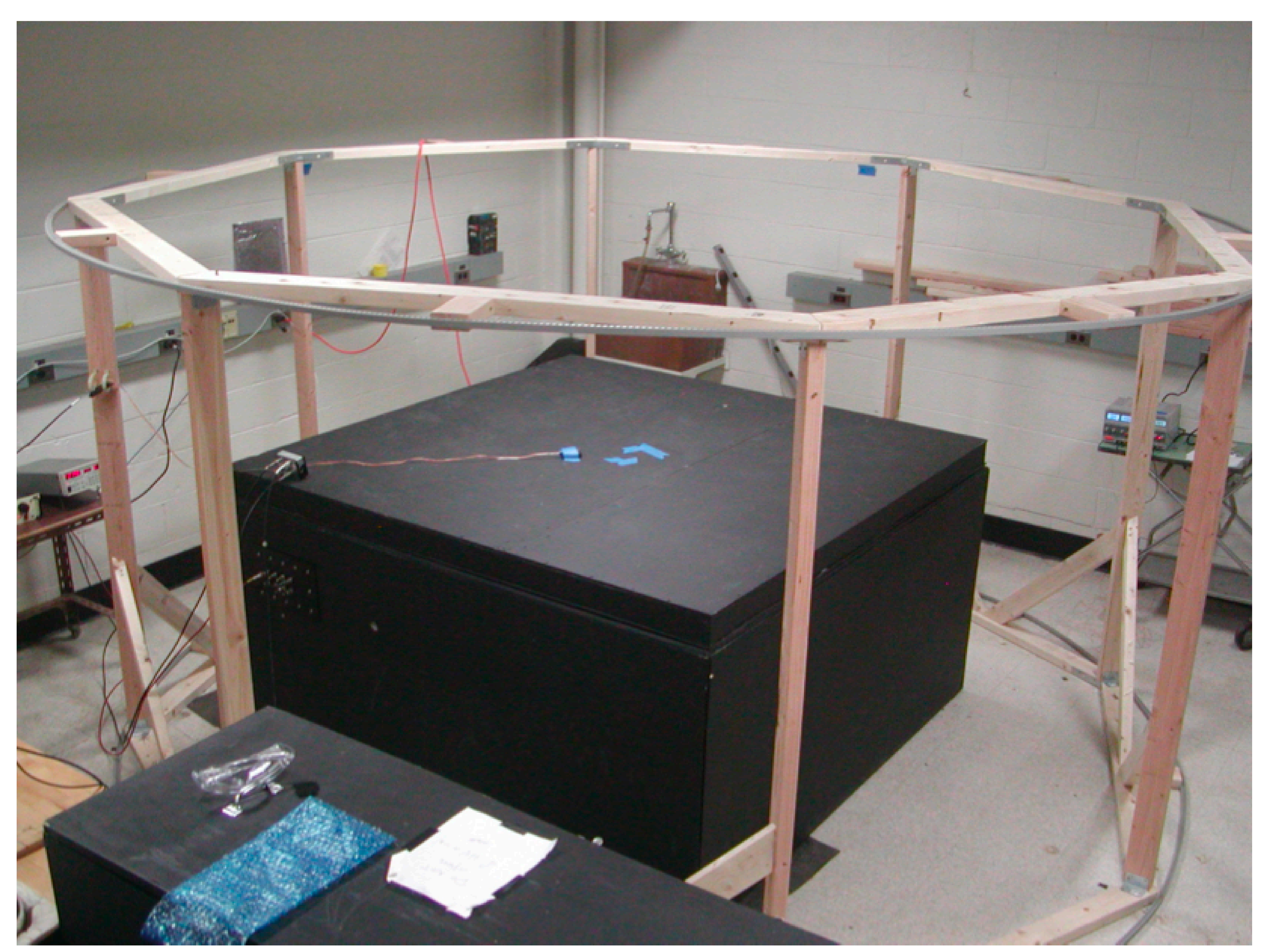
Dark Box Setup

Our measurements were performed with a hollowed-out acrylic source machined into a 3.5 cm cube with a 2 cm diameter cylindrical cavity and optically coupled to a 1-inch Hamamatsu R7600-200 ultra-fast trigger PMT. A 0.1 μCi ^{90}Sr disc source was used to measure the intrinsic scintillation light yield and the scintillation decay time constants for βs. We used a 0.1 μCi ^{210}Po disc source to measure the scintillation timing profiles of α particles. A 2m X 2m X 0.9m dark box was used to house the light source surrounded by three 12 inch Hamamatsu R11780 High-Quantum Efficiency PMTs operated at a gain of 10^7.





The left picture shows the acrylic light source. The right picture shows the source placed inside a dark box surrounded by three 12-inch Hamamatsu R11780 High Quantum Efficiency PMTs.



The dark box setup with Helmholtz coils for cancellation of the vertical component of Earth's magnetic field.

Sample	Light Yield (Photons/MeV)
LAB + 2g/L PPO	10800 ± 574
0.3% Te + 5% PRS + 2% H_20 LAB-PPO + 15 mg/L bisMSB	9725 ± 515
0.5% Te + 9% PRS + 4% H_20 LAB-PPO + 15 mg/L bisMSB	9245 ± 491

Measured Scintillation light yields for pure LAB + 2g/L PPO, 0.3% Te LAB-PPO + 15mg/L bisMSB, and 0.5% Te LAB-PPO + 15 mg/L bisMSB.

Conclusions

We find that the loading of tellurium in LAB significantly affects the α timing profiles, resulting in less distinct α and β scintillation timing. This loading technique therefore will lower the ultimate U/Th background rejection efficiency of a large-volume scintillator detector. We also find that the intrinsic light yield of Te-loaded LAB remains high, with a relatively modest drop off of about 10% in light yield. The ultimate energy resolution of such a detector will therefore be limited by other factors such as the optical properties of the scintillator cocktail.