Cherenkov Calibration Source for SNO+

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Introduction to SNO+

SNO+ is a liquid scintillator neutrino detector located inside SNOLAB at a depth of over 2000 meters. ^{130}Te, an isotope known to undergo double beta decay, is loaded into the liquid scintillator (LAB) to search for the rare process of neutrinoless double beta decay. This process is possible only if the neutrino is in fact its own antiparticle, or "Majorana" in nature. The scintillator volume is surrounded by 9,522 photo multiplier tubes (PMTs), which detect the light produced by the passage of charged particles through the scintillator. For more information: Freija Descamps at Session CB, Mini-Symposium on Searches for Double Beta Decay I.

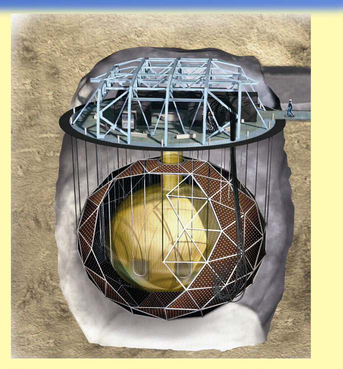

Fig. 1: The SNO+ detector

Cherenkov Source Principle

Accurate detector calibrations are critical for the sucess of SNO+. The Cherenkov source is a deployable method of calibrating the PMTs. The source provides a stable, well-understood source of optical photons, which propagate largely independently of scintillator optical properties and thus be used to calibrate the PMT efficiency.

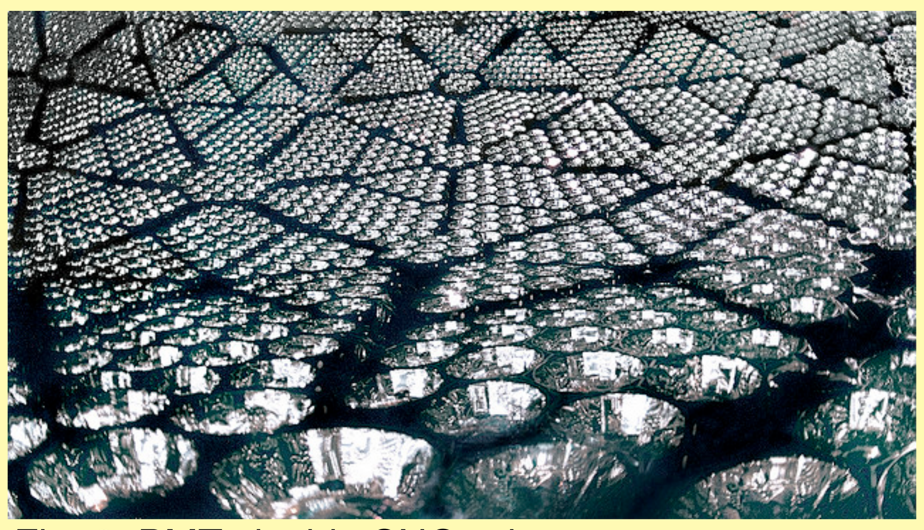

Fig. 2: PMTs inside SNO+ detector

The Cherenkov source works in the following way:

1. ^{8}Li is carried into the decay chamber by helium gas.
2. ^{8}Li decays into ^{8}Be, a beta, and a neutrino.
3. The beta enters the acrylic wall of the calibration source and produces Cherenkov light.
4. ^{8}Be decays into two alphas that scintillate in the helium gas inside the decay chamber.
5. The scintillation light is detected by the PMT in the neck, which is used to tag the event.

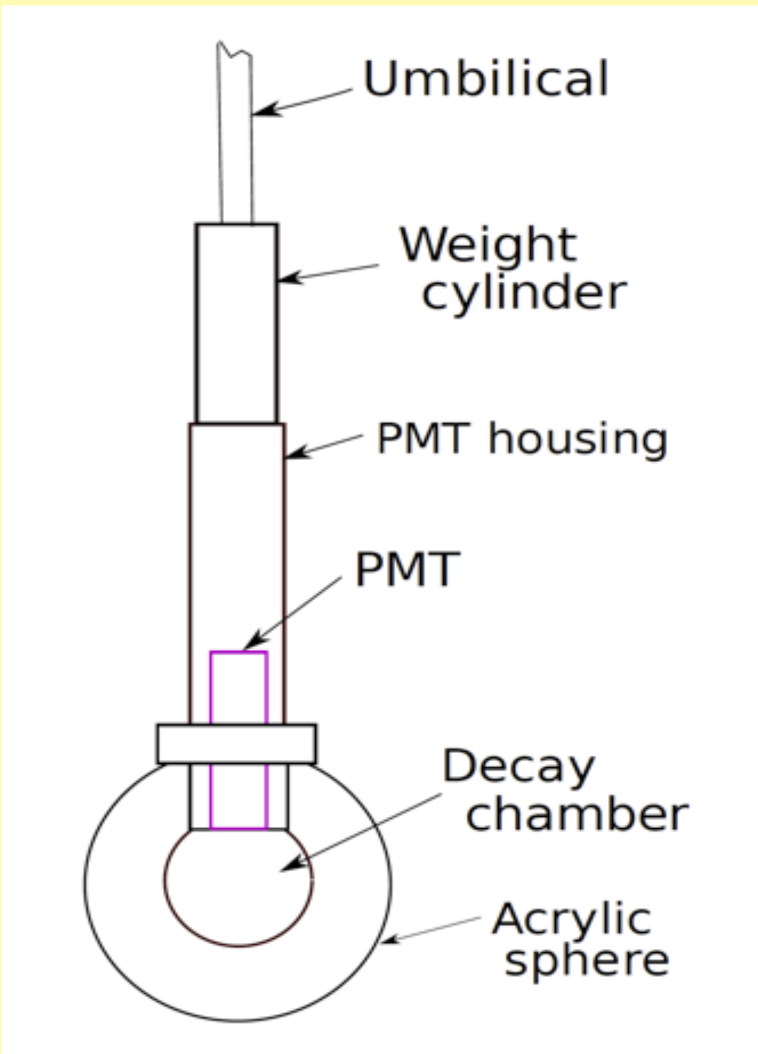

Fig. 3: Diagram of Cherenkov source

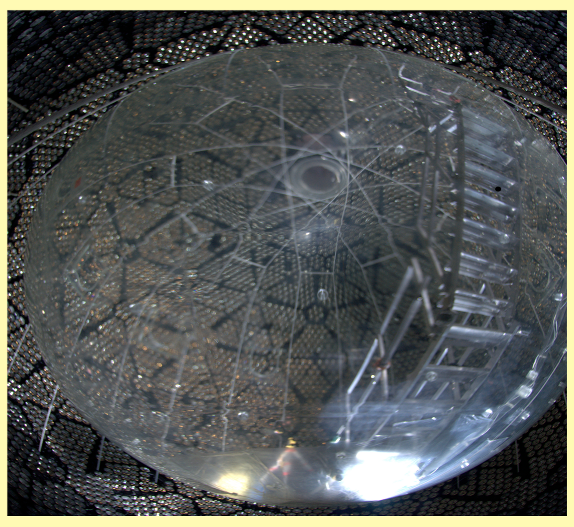

Fig. 4: The acrylic vessel surrounded by the PMTs

Alpha Simulations

The simulation software for SNO+ uses GEANT4 to simulate the underlying physics processes. Since the ultimate sensitivity of the experiment will depend upon the precision of the simulation, the collaboration is systematically verifying every piece of the underlying physics simulation. By looking at a simulation of 1000 alphas with initial energies of 100MeV propograting from the center of a water filled detector, it was clear that the energy deposition of alphas was being inaccurately characterized (Fig. 5). By changing the step length of the ionization process, problems with the energy deposition were fixed (Fig. 6). Accurate simulation of alpha interactions will be essential both for identification of background events in SNO+, and for simulations of Cherenkov source events.

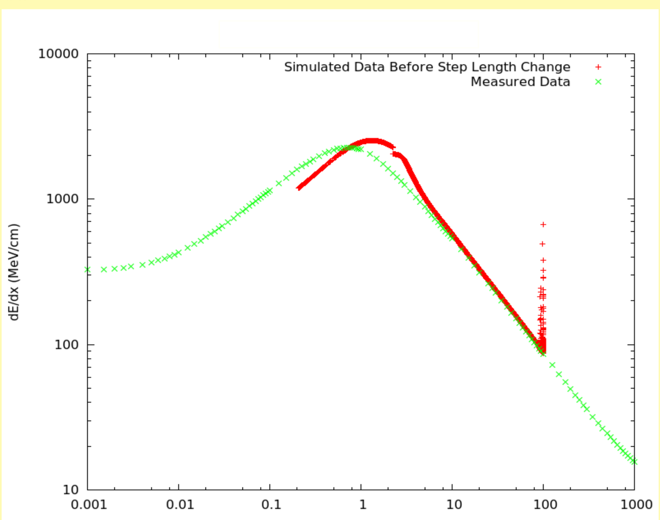

Fig. 5: Energy deposition for alphas in water before step length change

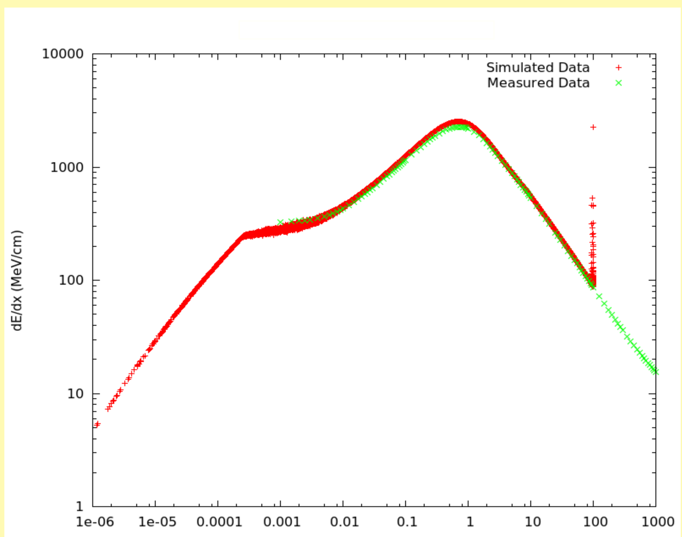

Fig. 6: Energy deposition for alphas in water after step length change

Conclusion

Overall, an effective method for testing different bonding agents and their ability to prevent leaking and withstand pressure has been developed, and a glue has been chosen. The general techniques for lining the decay chamber have been established. Additonally, problems with the simulated energy deposition of alphas have been corrected. This work is part of the ongoing effort to simulate, design, and construct the SNO+ Cherenkov source. This will ultimately contribute to the effort to calibrate the PMTs and characterize them in simulations.

Special thanks to Gabriel Orebi Gann and Freija Descamps

Cherenkov Source Design

The Cherenkov source will be constructed from two acrylic hemispheres (Fig. 7), that will be bonded together. An acrylic bonding setup (Fig. 8) is used to determine an efficient method to glue the acrylic hemispheres together. LAB sits in the PVC piping for months, and leaking is checked by shining UV light onto the collector dish. Three different glues are tested: methylene chloride, Acrifix 0190, and Weld-on #40.

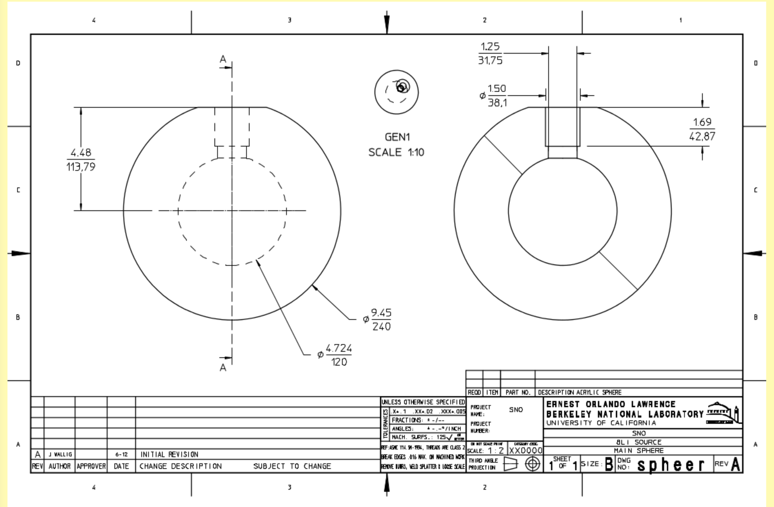

Fig. 7: Schematic of Cherenkov source

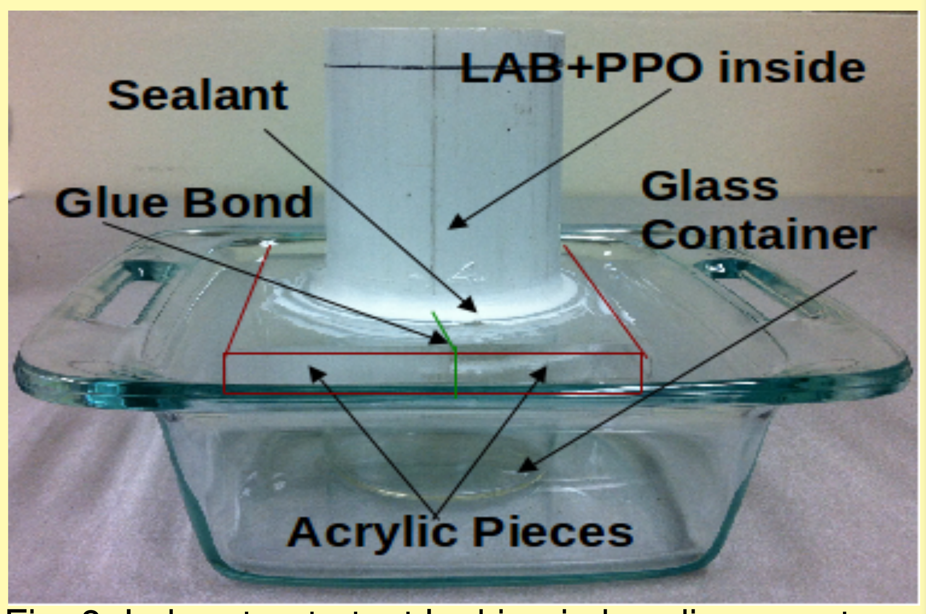

Fig. 8: Lab setup to test leaking in bonding agents

If the setup leaks, LAB scintillates in the collector dish (Fig. 9). Stress tests are used to determine how each glue will handle the increased pressure from bonding (Fig. 10). Micro-masking fluid is used to remove excess glue from the inside of the source. All of the acrylic is annealed before and after bonding to reduce stresses in the material (Fig. 11). Weld-on #40 was chosen as the bonding agent for the Cherenkov source based on these tests.

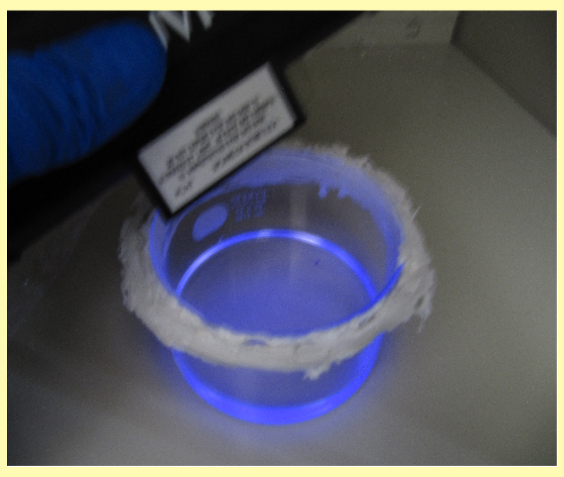

Fig. 9: LAB from leaked set-up scintillating

Fig. 10: Polarizing glasses are used to check for stresses

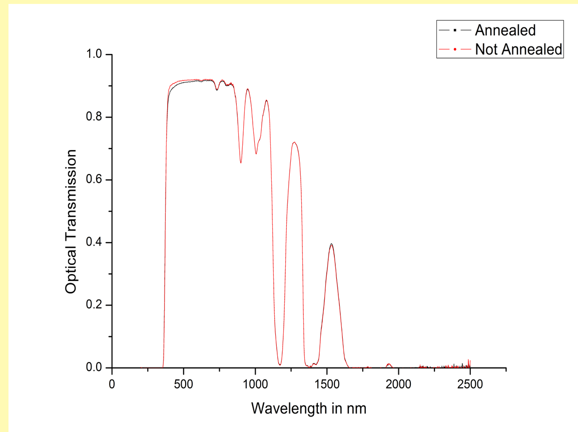

Fig. 11: Optical transmission of Weld-on #40 bonded acrylic

In order to contain the alpha scintillation light, the decay chamber will be painted. To determine the choice of chamber lining, small acrylic spheres are painted and then placed around an LED. A PMT is used to detect any light emerging from the painted sphere (Fig. 12). A black paint is used to prevent scintillation light from contaminating the Cherenkov sample in the SNO+ detector. A reflective white paint (Fig. 16) is used to relect the scintillation light into the source PMT, in order to maximize the tagging efficiency. The PMT charge spectrum is plotted for different voltages of the LED as well as for different thicknesses of paint lining (Figs. 13 & 15). Several options for the absorbent lining have been tested, and a black paint that most reliably blocks photons has been selected (Fig. 14). Additionally, since the scintillation light is emitted in the deep UV, a wavelength shifter, TPB, is deposited on the final layer of paint. The TPB shifts the scintillation light to near the peak of the PMT quantum efficiency (Fig. 17). A common method for depositing TPB is using toluene as solvent. However, toluene is known to attack acrylic, and would thus degrade both the lining and the source itself. A method for deposition is still under development.

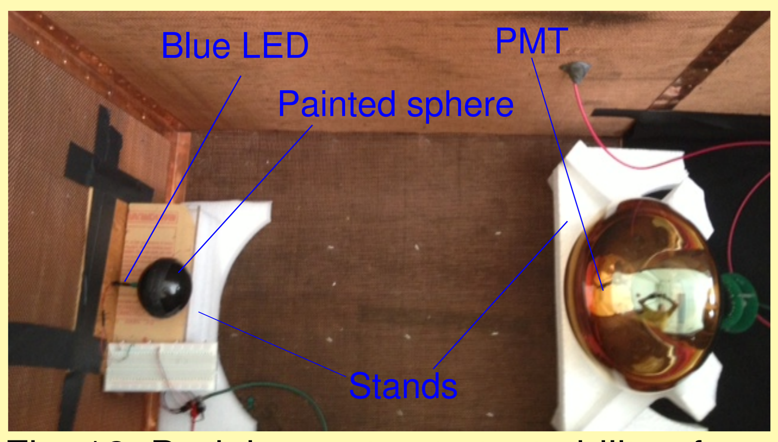

Fig. 12: Dark box setup to test ability of paint to contain light

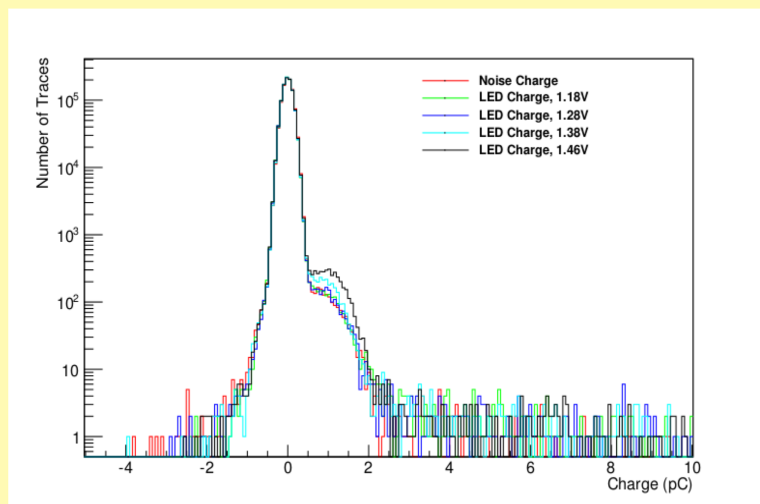

Fig. 13: Charge spectrum for sphere with four layers of black paint

Fig. 14: Absorbent black paint

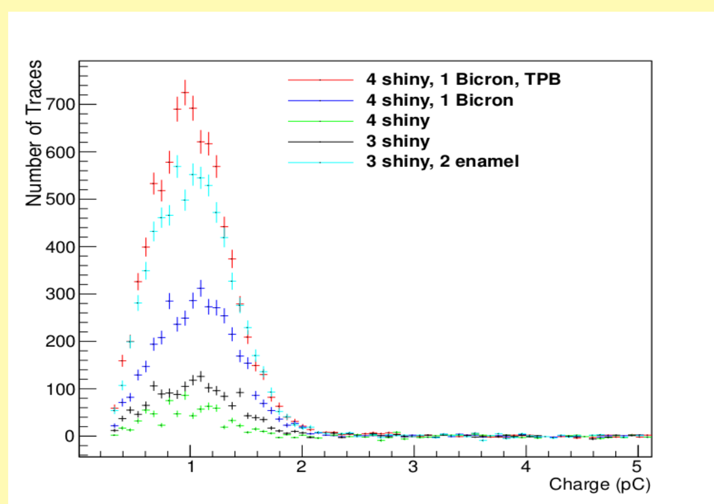

Fig. 15: SPE peak for different thickness of paint lining at LED voltage of 1.38V

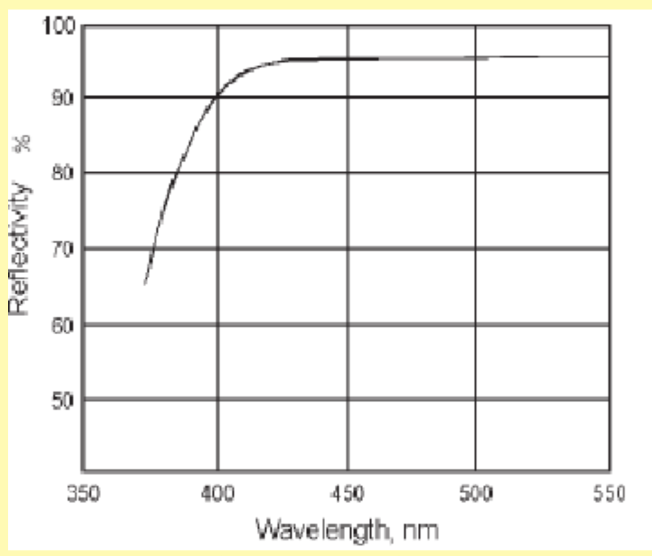

Fig. 16: Reflectivity of Bicron 620, a white reflective paint

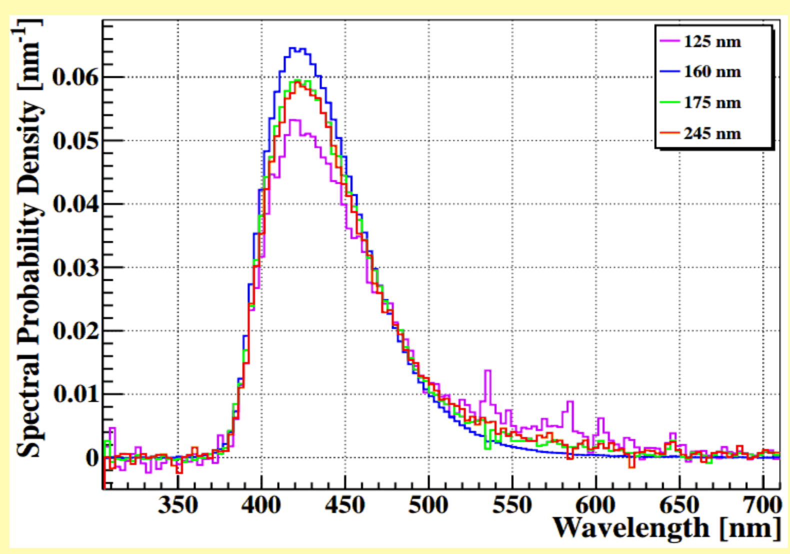

Fig. 17: TPB re-emission spectrum

V. Gehman, NIM-A 654 (2011) 116, arXiv:1104.3259 [astro-ph.IM].