1 Question 9

What detector parameters (volume? PMT gain? energy calibration? other?) must remain constant, and to what level, when the detectors are moved for this cross-calibration to work?

"Cross-calibration" of the detectors by moving them is intended as a bottom-line test of Braidwood's entire data acquisition, calibration, and analysis chain. The requirements for constancy of detector parameters is minimal, however, because nearly all the parameters will be re-measured before and after any move. The most important part of the detector which must remain the same is therefore the calibration system itself, in particular its geometry and its positioning accuracy, as these can affect the calibration we will do at each position. As we hope to have a positioning accuracy of the calibration system to be better than 2 cm, we would not like this to change significantly more than that when we move. Even here, however, we will be able to check for changes in the system, for example by comparing the expected point at which a source just touches the inner vessel to the point when it actually does. We are not concerned with changes in the calibration sources themselves, as these can be moved from one detector to another at any time. We will also check our relative efficiencies to a precision of $\sim$0.5% using the β-decays from ^{12}B. The ^{12}B decays will be produced via muon spallation throughout the volume of each detector, and at a nearly identical rate near and far because of Braidwood's uniform overburden. We outline below the some of the explicit detector parameters whose changes we have considered.

1.1 Handling of Explicit Parameter Changes

We describe here how we will deal with the changes in detector parameters that can be affected by moving.

1.1.1 Volume

A change in detector volume will result in a change in the effective number of hydrogen targets, which in turn will appear to be a loss of efficiency. We will measure the volume at both locations using the known expansion coefficients, temperature, and height of the scintillator in the neck region. Nevertheless, the analysis is simpler if the volume stays constant at a level small compared to 0.1% ($\sim$ 75kg).

1.1.2 Vessel Shape

Our simulations have shown that a change in the sphericity of the acrylic vessel holding the scintillator is a small effect even if the result is that the major and minor axes differ by as much as 20%. We will explicitly check this, however, by deploying sources near the edges of the active volume and comparing the response there to what we expect based on our calibrations of the optical, PMT, and electronics responses made before and after the move.

1.2 Neutron Capture Efficiency

The neutron capture efficiency depends primarily on the Gd fraction within the scintillator. We will measure this before and after the move both through Americium-Beryllium (AmBe) source deployments and by the capture time profile of the neutrons produced by antineutrino interactions. These measurements are independent of any other changes in the detector parameters, and therefore we can tolerate large variations, although we do not anticipate any changes at all to this mixture during the move.

1.2.1 PMT Gains and Efficiencies

The most likely change during the move will be to some fraction of the PMTs and associated electronics. The number of tubes (if any) which fail during the move will be easily determined through the measurements by the embedded LED sources, and can be accounted for in the detector model to allow us to predict the response after the move. Changes in gains will likewise be measured with the single photoelectron spectrum created by the light sources. Changes in the tube-by-tube (and related electronics) efficiencies will be measured using a normalized light source deployed at the center of the detector, and checked by the depolyment of a radioactive source (probably AmBe). The local magnetic field differences between the two sites will also be known through explicit field measurements, and our knowledge of the PMT responses as a function of field strength and direction will have to be incorporated in the detector model. As a final comparison, the mean and width of the Gd capture peak from antineutrino reactions will be used to check for changes before and after the move.

We are very insensitive to changes in these efficiencies and the consequent change in the energy response because our analysis thresholds are low compared to the Gd capture peak and the positron annihilation edge. Only catastrophically large changes—perhaps 50% or more—leading to a substantial broadening of the energy response will make it difficult to accurately re-calibrate the energy response.

1.2.2 Optical Parameters

Extinction and scattering lengths at wavelengths spanning the scintillator response will be re-measured through the use of both the embedded sources and a diffuse optical source deployed inside the active volume. Our measurements and simulations currently show that we are very insensitive to these parameters, in part because the relevant lengths are large compared to the size of the detector itself, and in part because our energy thresholds are low. Again, we would not like to see a dramatic change in these lengths (less than a factor of two) because then the requirements on the precision of the new measurements will be far higher. The same is true of the reflection coefficients of the vessel and the PMTs.

1.2.3 Scintillation Light Output

A change in the light output or quenching of the scintillator must be re-measured after the move through a combination of radioactive source deployments and the mean and width of the Gd capture peak. Our energy response depends directly on the number of photons/MeV produced in the scintillator, and therefore small changes can have a big effect. The fact that the Gd peak integrates over positions and that the radioactive sources can be deployed at many locations within the vessel will allow us to break the covariance between these changes and those associated with optical parameters and PMT efficiencies.

1.2.4 Temperature

Changes in temperature can lead to changes in PMT noise rates, electronics constants (e.g., pedestals), and of course detector volume. Anecdotal evidence from SNO shows that large temperature excursions may also alter PMT angular response, perhaps due to biological growth on the tubes (which would not be a problem in oil-based detectors like Braidwood). Although we will re-calibrate all of these characteristics before and after the move, and can therefore tolerate large (non-catastrophic) differences, we nevertheless have several mechanisms for ensuring that the temperature remains constant at the $\pm 1^\circ$ level during the move. The first of these will be to plan on moving the detectors during months where the outdoor temperatures are nearly those of cavities in which the detectors normally reside. In addition, the large volume of the detectors would require exposure to a temperature difference for much longer than the ~ 1 day moving time in order to produce a large change within the detector. Lastly, the cooling system for the detector (which will remove heat generated by the PMTs and associated electronics during normal running) will help ensure that once the move is completed the detector returns to its equilibrium state as quickly as possible.