Calibration Hardware and Radioactive Sources for SNO+

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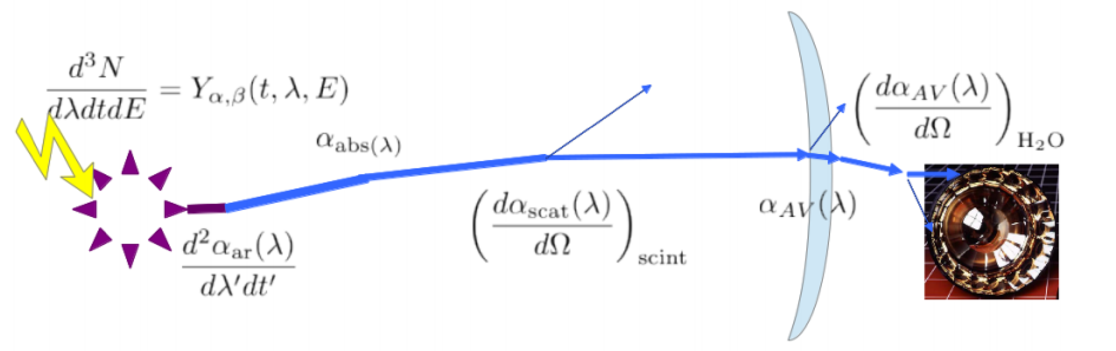
Calibration Source Selection

The goals of SNO+'s calibration campaign strategy are to characterize the detector's response to different particles: βs, γs, ns from external sources, in addition to using internal background radiation as sources. Some external sources will only be deployed in either the water or scintillator phase, others in both phases. We will use the data to measure input parameters for our Monte Carlo and verify our simulation of energy resolution.

Source	Particle	Energy	Tag
AmBe	n, γ	2.2, 4.4 MeV	coinc
^{16}N	γ	6.1 MeV	yes
^{24}Na	γ	2.7, 1.3 MeV	yes
^{48}Sc	γ	1.0, 1.2, 1.3 MeV	no
^{57}Co	γ	122 keV	no
^{60}Co	γ	1.2, 1.4 MeV	yes
^{90}Y	β	2.3 MeV	no

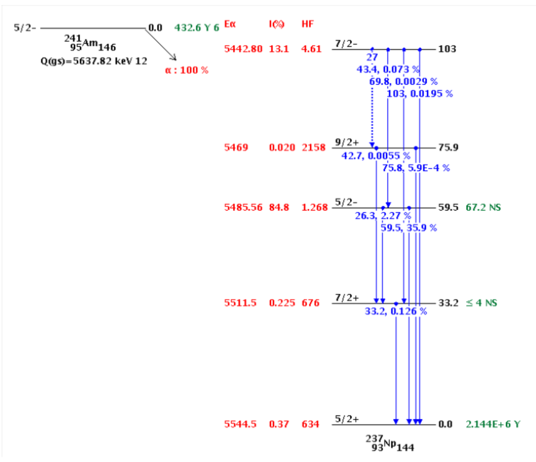


Americium-Beryllium

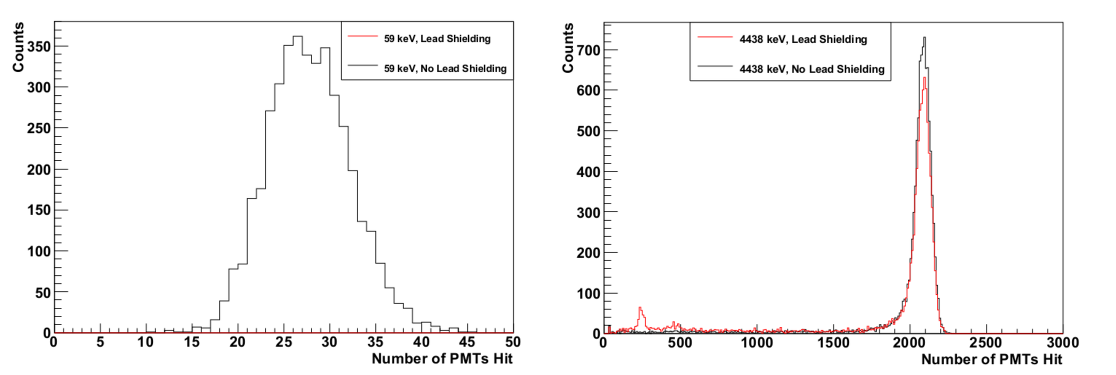
^{241}Am exclusively α decays. When mixed in a foil or powder with ^{9}Be, this induces

$$^{9}\mathrm{Be}(\alpha,n)^{12}\mathrm{C}.$$

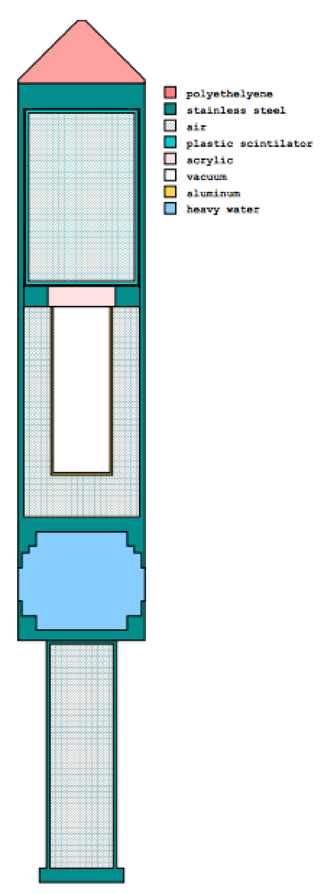
Depending on the energy of the neutron released, ^{12}C may be in an excited state and releases a 4.438 MeV γ around 60% of the time. We will use this source to measure the detector's energy scale, resolution, and our vertex reconstruction.



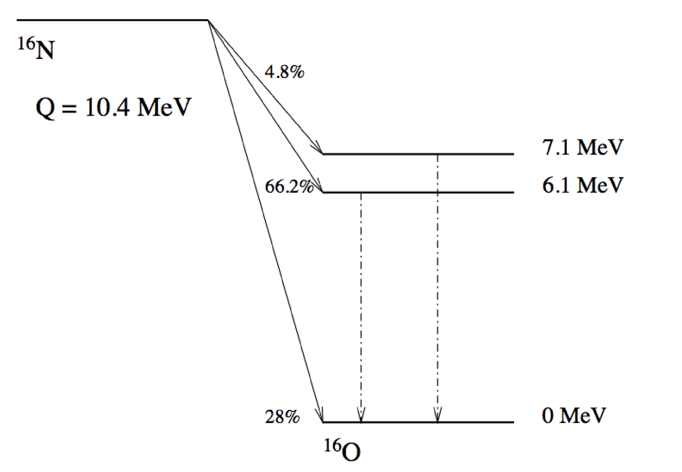
Unfortunately, for every (α, n) reaction that is seen in the detector there are $\sim 10^5$ αs released, along with many low energy x-rays. We will shield the source with a few millimetres of lead to avoid blinding our detector.



Nitrogen-16

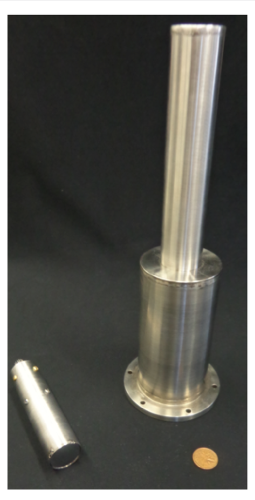


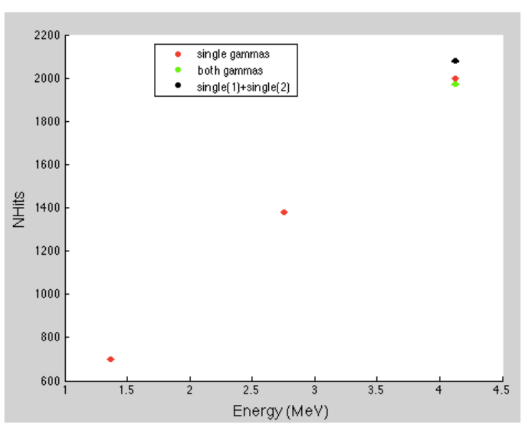
^{16}N will be used to calibrate the energy scale in SNO+. ^{16}N is produced in a nearby DT generator via $^{16}\mathrm{O}(n,p)^{16}\mathrm{N}$ of CO_2 gas, which is quickly transported to the detector through the umbilical since the half-life of ^{16}N is 7.13 seconds. 66% of its β decays are associated with a 6.12 MeV γ, which is used as an internal tag.

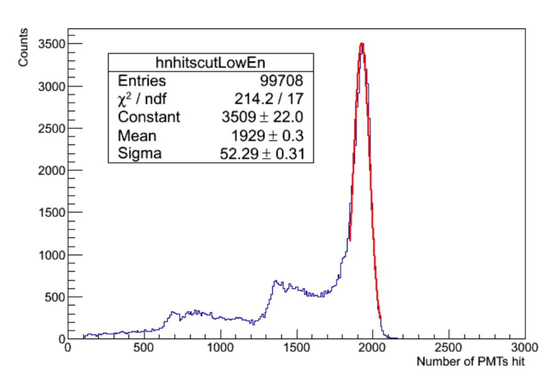


Sodium-24

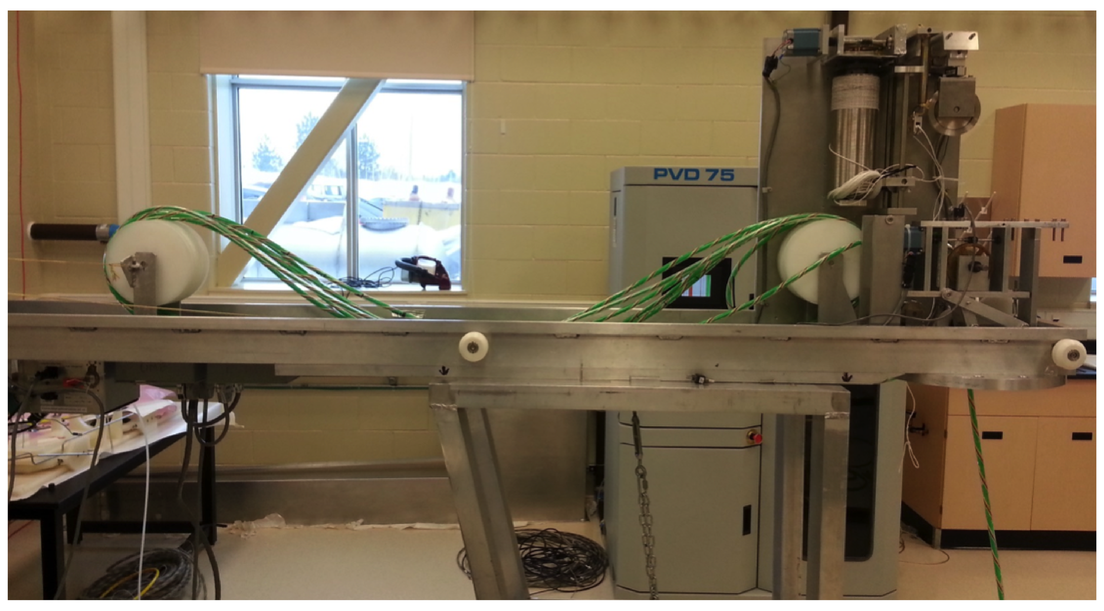
^{24}Na is a tagged gamma source. After activating a NaI source originally built for SNO at Ontario's Royal Military College we will bring the source to site. By deploying ^{24}Na in SNO+ when filled with scintillator, we can check the linearity of our energy range with just one source. ^{24}Na β decays (Q=5.514 MeV) releasing two γs of 2.754 and 1.386 MeV that we will likely detected together, at 4.12 MeV.







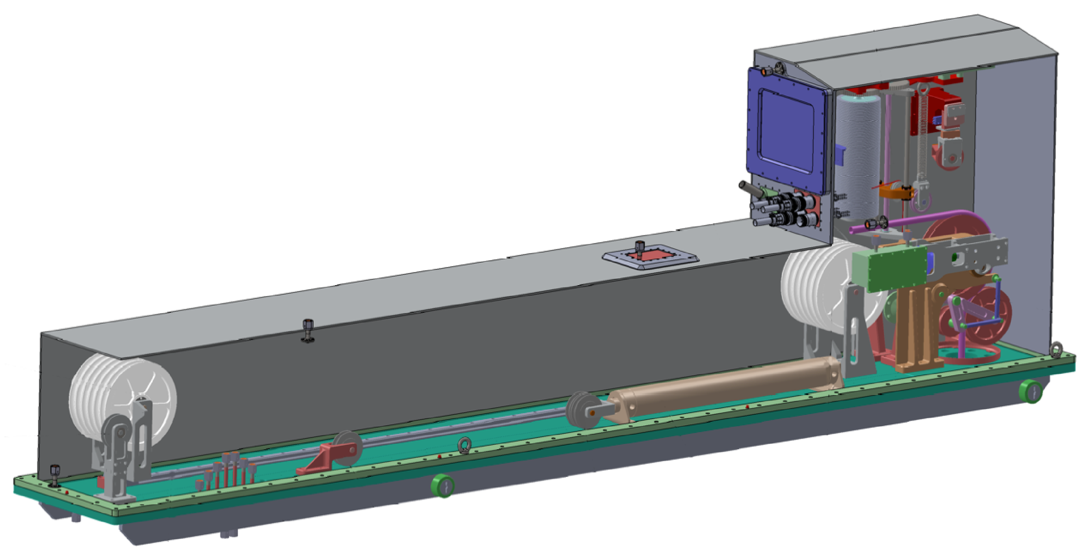
Calibration Hardware: from SNO to SNO+



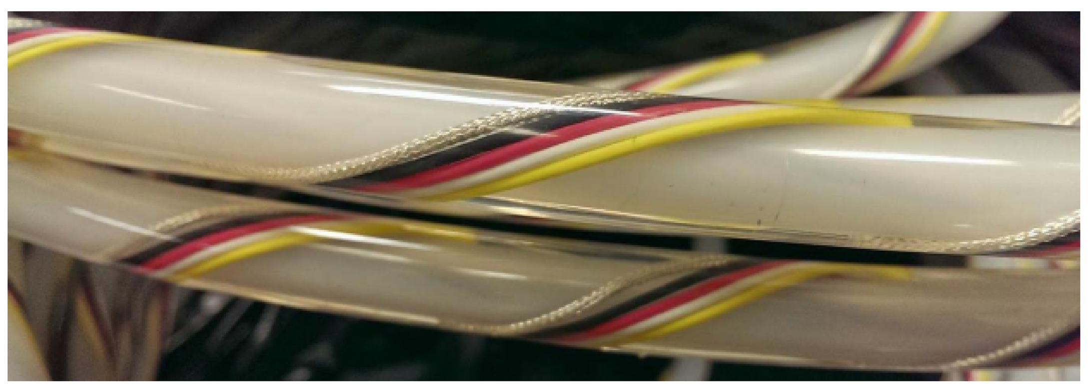
The Umbilical Retrieval Mechanism (URM) allows us to deploy the calibration sources to specific locations in the detector. It controls the movement of a Tensylon rope which holds the weight of the source and the umbilical which contains the electrical and gas connections that different sources require.

For water-fill, we will deploy sources with the URMs from the original SNO experiment. After the detector is filled with LAB-based scintillator, we will use new URMs that are currently being designed with changes that are prototyped and tested at SNOLAB.

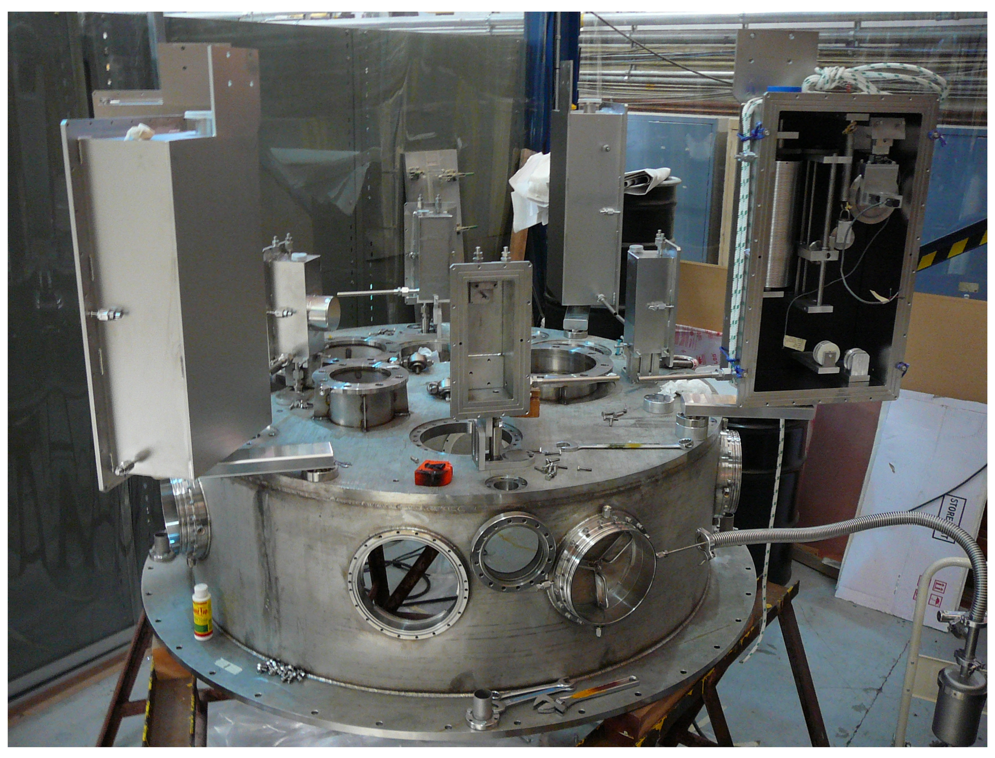
The motor-driven pulley system must drive a umbilical covered in LAB, an excellent lubricant, with little to no slippage. We are currently testing different pulley designs and methods to increase the friction and tension in the system.



New URMs must be completely compatible with LAB. To avoid mine air getting into the detector, the URMs are sealed and filled with nitrogen gas. The source containment tubes (not shown) will be air-tight and closed with gate valves until connected to the Universal Interface (see below).



The umbilical contains a co-axial cable for a PMT and wires for positioning LEDs. These surround a central tube for the deployment of gaseous sources and contains quartz fibres for the Cherenkov source (see S. Peeter's poster). The outer tube is made of Tygothane, which is compatible with LAB. The volume between the tubes is filled with a silicon mixture to protect the wires.



The Universal Interface (UI) connects the URM and the detector. It contains many sensors providing information about liquid levels and nitrogen cover gas quality. The UI contains motor boxes for the side ropes that let us deploy sources off-centre, and glove ports for attaching those sources. Three ports where sources enter the UI will be sealed with gate valves, shown below.

When not being used in the detector, the sources will be stored in a "source storage box" that resembles the UI in function. It will also be a nitrogen environment, preventing radon in the lab air from contaminating the sources. The storage box will be sealed with another set of gate valves, matching the URM and UI.

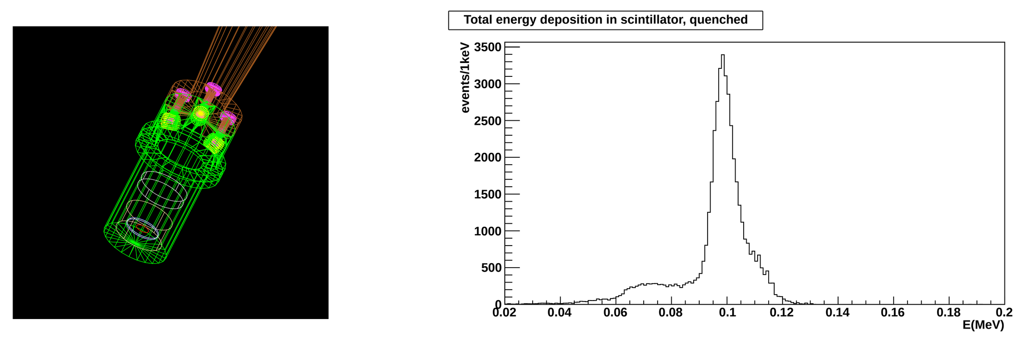
Scandium-48

^{48}Sc produces many low energy gammas (1.037, 1.312, 0.983 MeV) which will be used to understand the energy dependence of the scintillator's energy response. ^{48}Sc will be produced in a DT generator in Dresden through neutron activation of ^{48}Ti at the Helmholtz-Zentrum Dresden-Rossendorf Laboratory then shipped to site. The half-life of ^{48}Sc is $\sim$ 44 hours, so much coordination and organization is needed for this deployment.

The ^{48}Sc source (prototype shown) is double contained in acrylic containers sealed with o-rings that have been tested for compatibility and radon emanation. The entire container has been leak and pressure checked.

Cobalt-57

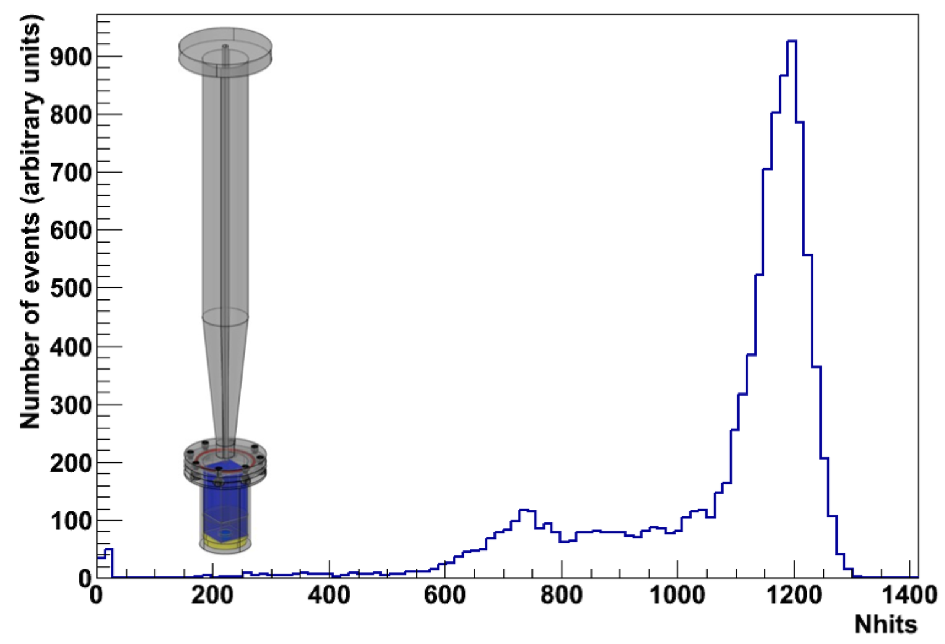
^{57}Co is a very low energy calibration source. Its half life is 271 d, much longer than any of the impurities in the source, so it becomes purer with time. The ^{57}Co source is made from a commercially available solution which is evaporated onto a thin polyethylene foil and sealed into a polyethylene disk. This will be surrounded by multiple layers of acrylic and sealed with perfluoro-elastomer o-rings to prevent leakage.



^{57}Co gives a 122 keV γ (89%) or a 136 keV γ (11%). We will have a high activity source to distinguish the signal from ^{14}C and ^{210}Bi backgrounds, as well as use radial cuts in analysis.

Cobalt-60

The ^{60}Co calibration source is a tagged source, where ^{60}Co is encapsulated in a small disk of plastic scintillator that is optically coupled to a fast photomultiplier tube (PMT), all contained in an o-ring sealed plastic housing. ^{60}Co decays 99.88% of the time to an electron with endpoint energy 0.318 MeV and two gamma rays of 1.17 MeV and 1.33 MeV. The electron is fully contained in the plastic scintillator and observed by the source PMT.

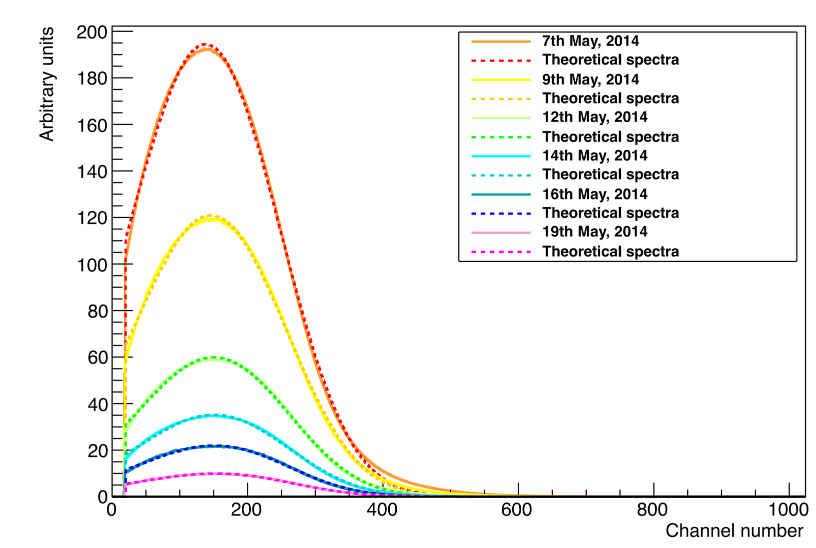


The gamma rays escape into the main SNO+ volume largely unimpeded, and the detector triggers on their sum energy, giving a calibration point near the endpoint energy of the ^{130}Te decay. The electron tag creates a nearly background-free set of calibration data that may be used, for example, to study low statistics non-Gaussian tails in the detector resolution function.

Yttrium-90

We are also investigating the use of ^{90}Y for direct beta calibration (2.2 MeV endpoint), which will help us understand differences in quenching and the spatial distribution of energy deposits between betas and gammas.

A droplet of ^{90}Y solution is contained within a thin glass capillary resulting in minimal attenuation of the betas. This is confirmed by first measurements of the ^{90}Y spectrum in SNO+ scintillator made with the experimental setup (see S. Grullon's poster) at Penn.



Measurements of a prototype ^{90}Y filled capillary in a small desk-top setup at U. Sussex over a period of 2 weeks showing source decay. The measured scintillator energy deposit has been fitted to the theoretical ^{90}Y β spectrum. The earliest measurement is thought to show the effects of event pileup.