Scintillating Counter of Uranium and Thorium (SCOUT)

Morgan Askins

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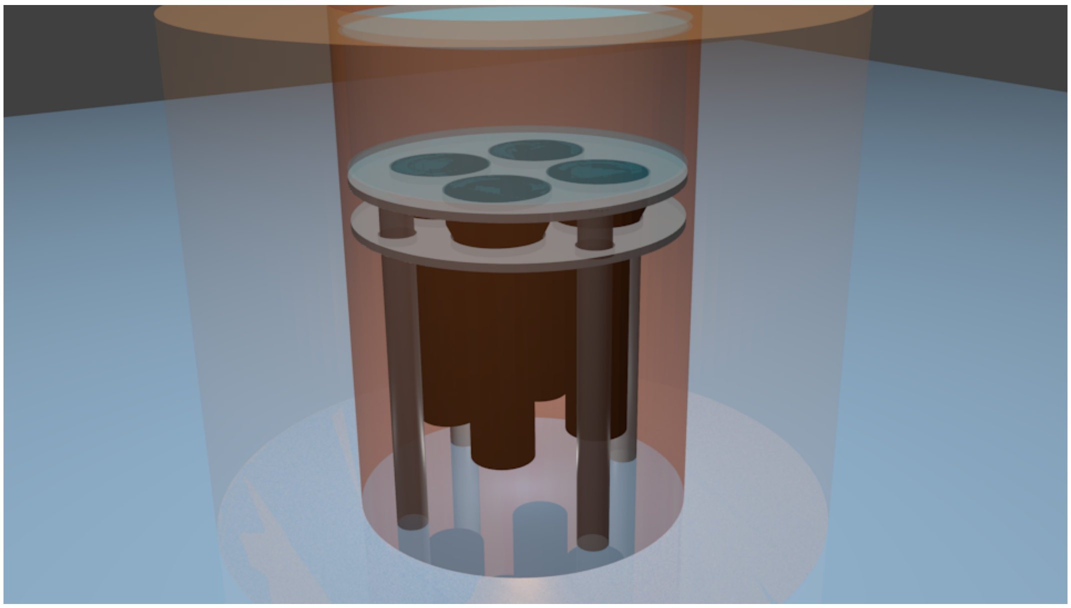
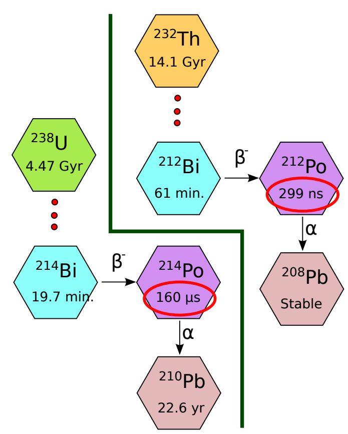


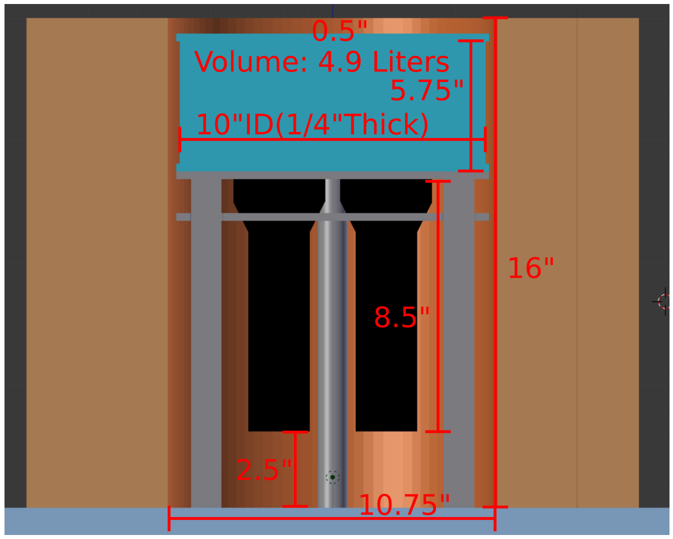
1 Introduction

Scout is an alpha beta coincidence counter designed to assess the radiopurity of the SNO+ liquid scintillator (Linear Alkylbenzene + 2 g/L 2,5 diphenyloxazole) that arrives at the surface transfer facility at Snolab. By counting the decays of $^{214}Bi \rightarrow ^{214} Po \rightarrow ^{210} Pb$ in the Uranium decay chain and $^{212}Bi \rightarrow ^{212} Po \rightarrow ^{208} Pb$ in the Thorium decay chain, the radiopurity can be determined. The expected sensitivity for each of these is of order 10^{-10} g/g for a 24 hour measurement.



2 Design

The design for Scout consists of a lead shield from a previous Germanium counter at UCDavis roughly 4.5" thick. The shield is copper lined on the inside. The inner vessel is made of acrylic which is coupled to the PMTs. The vessel holds roughly 5 liters of fluid in a short, but wide cylindrical volume. Room is left at the bottom for high voltage and signal cables to run from the voltage dividers out the hole in the bottom of the shield to the DAQ. Room is left at the top to accommodate quick-connect ports for gas and liquid exchange at the top.



3 Data Acquisition

The four photomultipliers are powered by a desktop CAEN high voltage power supply. The supply has four channels, so the voltage can be individually adjusted for proper gain matching. The voltage dividers are negative with a BNC and SHV connector coming directly from them. The BNC will convert to LIMO and plug into the 16-channel SIS3316 250MHz ADC where only four channels will be used. The trigger scheme in software can either be set to sum the four channels or trigger on individual channels. There is not currently a way to require two channels to go above threshold, but this may be looked into in the future. The coincidence trigger will be done offline using timing and energy cuts.

4 Sensitivity

With the assumption that the LAB is clean to begin with, limtis will be set based on the background rates, detector volume, and live time. The coincidence window for Bi-Po will help to reject most single events except those that fall in the same random coincidence window. Based on the energy resolution of the final design, an energy cut can help to further reduce the background event rate. For a detector volume of about 5 liters, the sensitivity for a 1 hour run would be about 10^{-10} g/g for each isotope, with ^{238}U having a slightly better result due to the shorter half-life.

5 Procedure

1. Assuming we use 5 liters of LAB, measure out PPO at 2g/L (10 grams total) into the mixing vessel.
2. Seal the mixing vessel and connect the nitrogen supply line to the vessel.
3. Set the pressure on the nitrogen supply to about 0.5 to 1 psi. A check valve located at the top of the vessel will open at 0.5 psi purging the vessel. Allow the purging to continue for about 1 minute.
4. Turn off and disconnect the nitrogen supply.
5. Fill the mixing vessel with 5 liters of LAB, keeping track of the mass of LAB added on a scale. This will be the primary means of knowing the sensitive volume in Scout.

6. Gently swirl the mixture to make sure the PPO dissolves into the LAB. It is likely that the PPO will already be mixed in due to the turbulence from adding the LAB.
7. Seal the acrylic vessel and connect the nitrogen supply line and purge just like the mixing vessel. The acrylic vessel has the same connections and check valve that the mixing vessel does.
8. Turn off and disconnect the nitrogen supply. This time keep both hoses attached to the acrylic vessel and filled with nitrogen.
9. Quick-connect the hoses to the mixing vessel, using one for fluid transfer and the other to allow free gas exchange between the two.
10. Tilt the vessel in such a way that fluid flows freely through the fluid port, and gas flows freely through the gas port. A small portion of the scintillator will be left in the mixing vessel which can be discarded at the end.
11. Weigh the mass of the mixing vessel once more to determine the mass transfered into the acrylic vessel.
12. Disconnect the fluid and gas lines from the acrylic vessel, close the top of the lead shield, and wrap the shield in a black tarp (just in case of small light leaks).
13. Begin data acquisition (procedure to be written).
14. Once all data has been acquired the top of the acrylic vessel can be taken off for draining and cleaning.
15. Using a hand pump start a siphon from the acrylic vessel into the 55-gallon waste drum.
16. Clean up any remaining LAB in the vessel with an absorbant cloth and dispose of properly.
17. [It may be possible to clean the AV by filling and rinsing with UPW or clean LAB]

6 Component List

- 1 metric tonne lead shield on Stand: 2'x2'x5' tall
- Waste drum (55 Gallon)
- Acrylic Measurement Vessel (5 liters)
- Mobile mixing vessel
- Fluid transfer hose with hand valves on both ends
- Gas transfer hose with hand valves on both ends
- 4x3" Photomultipliers
- Desktop High Voltage Supply (Caen)
- VME Crate
- VME Waveform Digitizer (sis3316 ADC)
- Intel NUC for data recording
- External backup storage
- Chemical Spill Kit
- Tubing to connect

7 Images

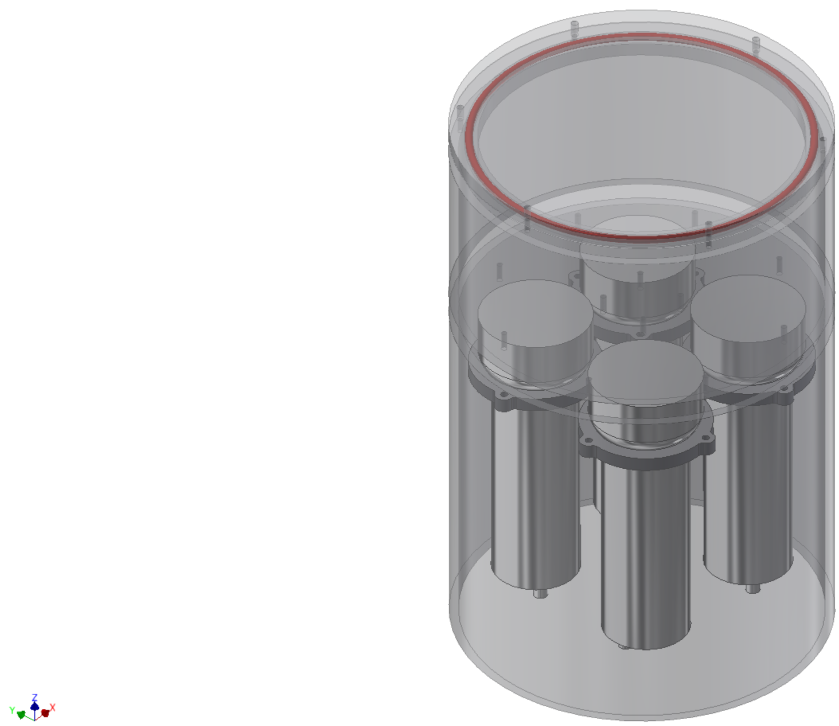


Figure 1: 3D Model of the acrylic vessel with 3 inch photomultipliers. The red ring is a silicone O-ring around the removable lid.

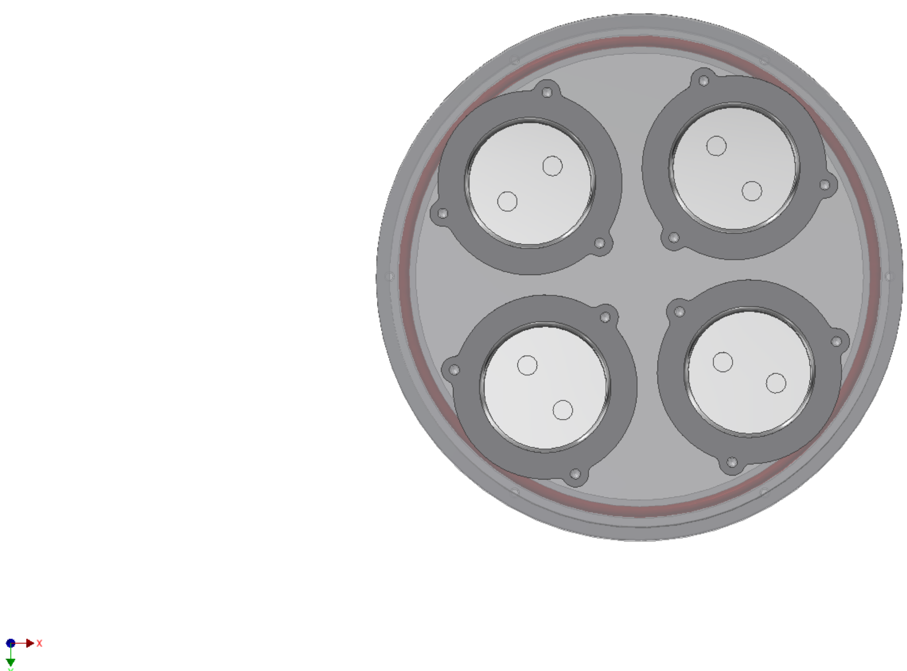


Figure 2: Top down view showing the photomultiplier foot-print looking into the acrylic vessel

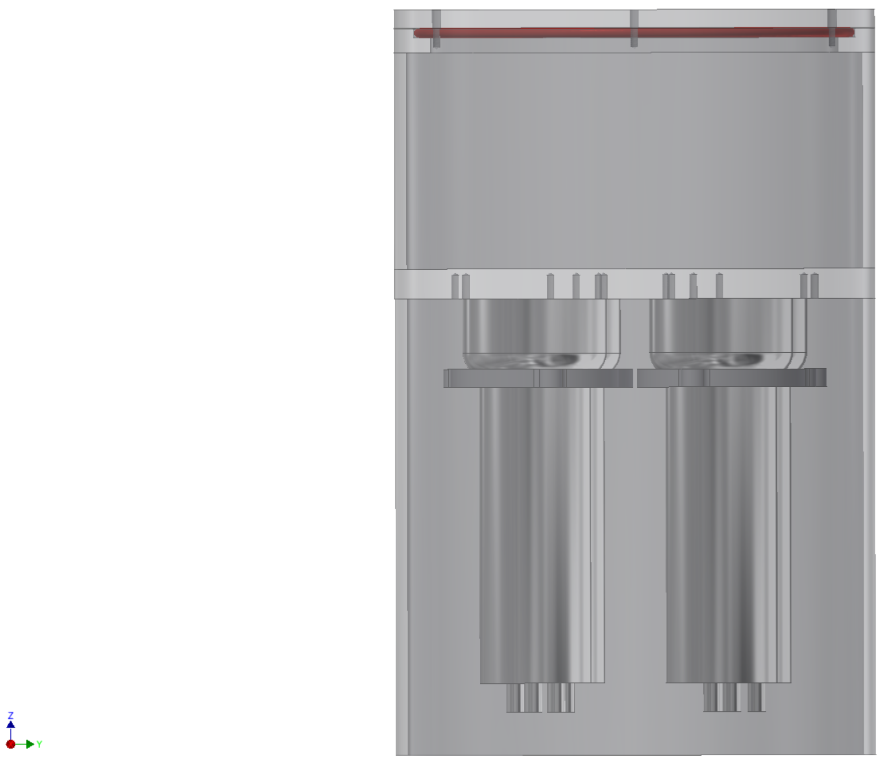


Figure 3: Scout as seen from the side.

Figure 4: 3 inch ADIT photomultiplier

Figure 5: Flashpoint optical coupling pads, used in place of optical grease, to couple the photomultipliers with the bottom of the acrylic vessel

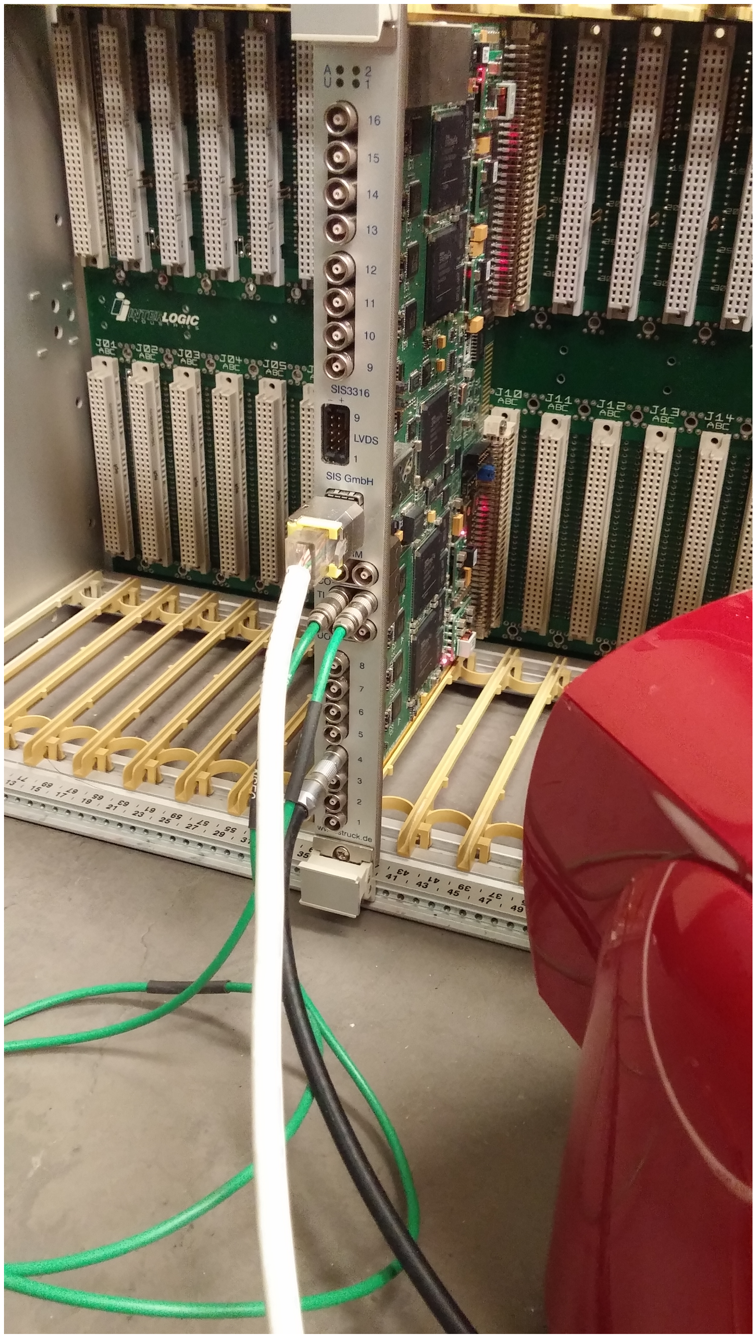


Figure 6: Struck SIS3316 16 channel 250 MS/s 14-bit digitizer with an ethernet SFP cage used for programming and data collection

Figure 7: Intel NUC which records the data from the digitizer via an ethernet connection

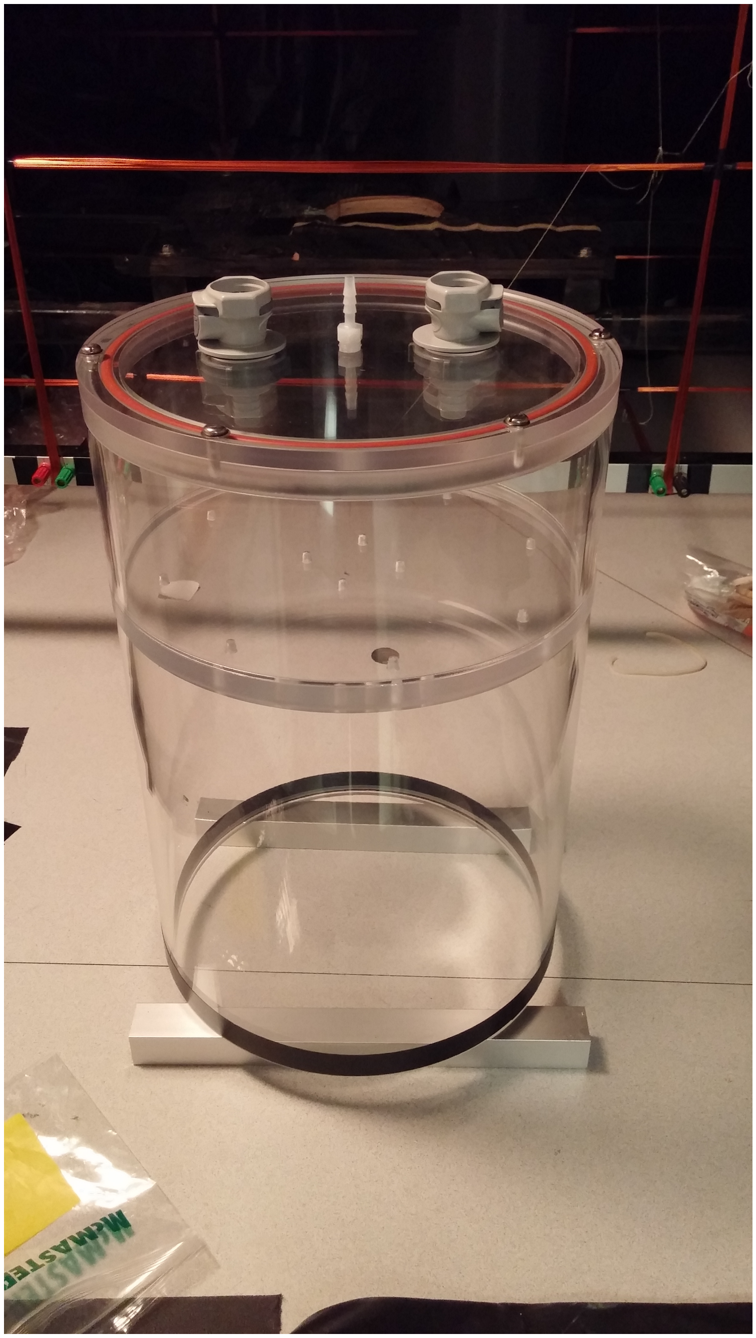


Figure 8: Scout acrylic vessel with a 0.5 psi check valve (small white port in the center of the lid), and two quick-disconnects for fluid/gas transfer. The lid is removed via the 6 flat-head screws around the top for easy cleaning.

Figure 9: Scout with a single photomultiplier attached at the bottom demonstrating how it is held in place and the total clearance at the bottom.

Figure 10: 1 tonne lead shield as seen from the outside. The lid rotates off allowing direct access to the acrylic vessel from the top.

Figure 11: Inside of the lead shield showing the copper lining and access whole at the bottom.