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IPP Summer Student Fellowship Report

SCOUT ^{212}BiPo coincidence counting

SNO+

SNO+ is the successor experiment to the Sudbury Neutrino Observatory, located 2km underground, in VALE's Creighton mine. It is a neutrino detector with an extensive physics program, including solar neutrinos, antineutrinos, supernova neutrinos, and invisible nucleon decay. However, the main physics goal of SNO+ will be the search for neutrinoless double beta decay ($0\nu\beta\beta$). In order to have the sensitivity required to achieve these physics goals, the SNO+ detector will need very low backgrounds and extreme radiopurity.

The main detector is a 12m diameter acrylic vessel, which will be filled with 780 tonnes of linear alkylbenzene (LAB), a liquid scintillator, mixed with a the fluor (2,5)Di-Phenyl Oxazole (PPO). Purification of the LAB will be very important in maintaining the low background required for SNO+. Two internal backgrounds of interest are those produced by the ^{238}U chain, and the ^{232}Th chain. The SNO+ detector has target levels for these two backgrounds at $1.6\times10^{-17}g/g_{LAB}$ for the ^{238}U chain, and $6.8\times10^{-18}g/g_{LAB}$ for the ^{232}Th chain.

In order to monitor the purification of the LAB for the SNO+ detector, the Scintillator Counter of Uranium and Thorium (SCOUT) detector was built.

SCOUT

SCOUT was designed to measure the radiopurity of LAB through counting α/β coincidences. SCOUT is designed to mimic the SNO+ detector on much smaller scale.

SCOUT holds 3L of LAB mixed with 2g/L PPO in a cylindrical acrylic vessel. The vessel is 9.75 inches in internal diameter and 5.75 inches tall. To increase photo-coverage, the acrylic is painted with titanium white acrylic paint, which provides some reflectivity. A lead shield provides a barrier to external radiation. It has a copper-plating to shield from the radiation produced by the lead. The central volume is monitored by four ADIT 3-inch photomultiplier tubes (PMTs). For each channel, for every event, waveforms are collected out to 1024 ns (512 bytes).

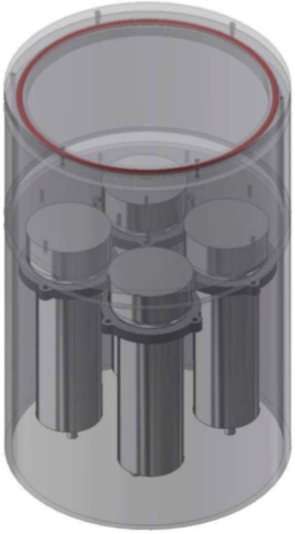

Figure 1: CAD drawing of SCOUT showing acrylic vessel atop four PMTs.

Currently at SNOLAB, the SCOUT filling procedure does not have the LAB remaining under nitrogen cover gas. This leads to increased radon contamination.

Analysis

This report, and the accompanying code, focuses on counting the number of coincidence events occurring as a result of the decay ^{212}Bi $\rightarrow$ ^{212}Po $\rightarrow$ ^{208}Pb in the Thorium decay chain.

The events being examined in this analysis are those from the $\beta-\alpha$ coincidences. Due to the short half-life of ^{212}Po of 300 ns, the coincidences happen within one 1024 ns event window.

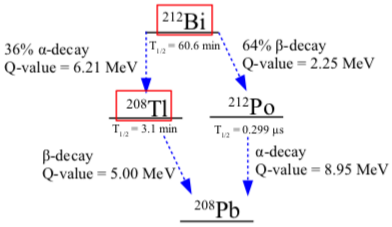

Figure 2: Section of the ^{232}Th decay chain relevant to coincidence counting, showing Q-values, half-life, and decay modes.

Code was written that goes through all the events in a SCOUT run and looks for multiple peaks in an event window.

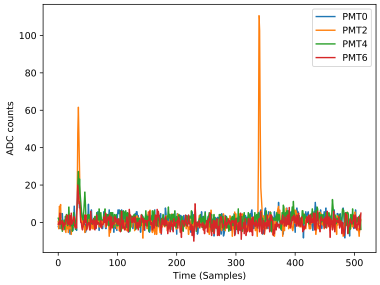

Figure 3: SCOUT waveforms for a coincidence event.

The code has a CLI written so users can enter the SCOUT ROOT file to be analysed, as well as putting in their own cuts. Three cuts are built in: a low energy summed cut, a low energy individual PMT cut, and a high energy summed cut. The summed cuts determine the minimum and maximum threshold for an event based on the summed, background subtracted, ADC counts. The individual PMT cut is the minimum ADC count for at least one PMT in order to register a signal. This cut helps to reduce triggering on PMT ringing.

The high energy cut was initially implemented to rule out muons. This allows the code to run on surface data, where the muon rate is around 8 Hz. Underground however, the muon rate is expected to be closer to 10^{-9} Hz, and is likely unnecessary.

Further Work

Currently there are still many unknowns with regard to how accurately the ^{212}BiPo coincidence counting on SCOUT can be done.

Firstly, re-implementing the nitrogen cover gas on SCOUT runs would allow for a more accurate measurement of abnormalities in the ^{232}Th levels in the LAB going into the SNO+ detector. Under the current condition the LAB is exposed to air, and thus radon, before being loaded into SCOUT, leading to unknown contamination levels.

Several calibrations could also be done. Doing a calibration with a γ source would allow for an estimation of the energy scale. The ^{212}BiPo β and α decays are of known energy and check of the relative energies could be done.

Additionally, to estimate the sensitivity, a thoron spike could be used.

Additionally, to estimate the sensitivity, a thoron spike could be used. This calibration was done on surface using a source container holding ^{228}Th. This decays to ^{224}Rn and then ^{220}Rn, which is gaseous. Nitrogen gas flowed through the source chamber, collecting the ^{220}Rn, and was bubbled through LAB for 24h. That sample was subsequently diluted for SCOUT. Unfortunately, it may not be possible to do this underground. Instead, a low background LAB sample, with cover gas, could be compared to a sample which has been left exposed to air.

Alternatively, with a better known energy scale, one could look for ^{208}Tl decays. ^{212}Bi has a branching ratio of 35.94% to α decay to ^{208}Tl. ^{208}Tl has a β^- endpoint of 4.999 MeV and a half-life of 3.053 minutes. Thus with suitable background subtraction, this may also be useful for determining the ^{228}Th contamination.

ALICE

Background

A Large Ion Collider Experiment (ALICE), is one of the experiemnts hosted at CERN, the European Organization for Nuclear Research, optimized to study heavy-ion collisions from the Large Hadron Collider (LHC). One of the main physics goals of ALICE is to study the strongly interacting state of matter, known as the Quark-Gluon Plasma. Recent research has suggested that this state of matter may be reached not only with the heavy-ion lead-lead collisions, but also with high multiplicity proton-proton (pp) collisions.

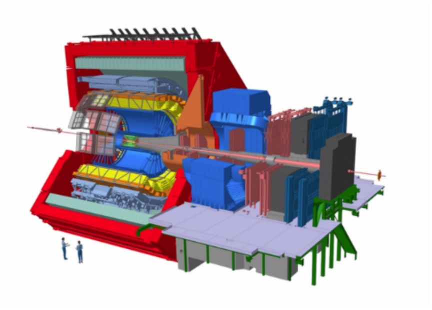

Figure 4: Schematic of the full ALICE detector.

The ALICE experiment houses many individual detectors. The V0 detector and SPD are used to trigger high-multiplicity events in the ALICE detector. The V0 detectors, V0A and V0C, are two scintillator arrays located on both sides of the interaction point along the beam axis. They provide a minimum bias event trigger as well as multiplicity information. The SPD inside the Inner Tracking System (ITS) is used for vertex reconstruction and can also provide multiplicity information at mid-rapidity. The ALICE Time Projection Chamber (TPC) is a large drift detector which provides charged particle tracking down to very low momenta as well as particle identification via their energy loss signal. In addition, the ALICE central barrel also houses two electromagnetic calorimeters, EMCal and PHOS, which cover different acceptances and have different resolutions.

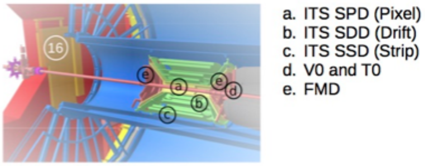

Figure 5: Schematic of the ALICE ITS, including the V0 detector and the SPD.

Quality Assurance

A preliminary step in the analysis of ALICE data is the quality assurance of both the recorded data and Monte Carlo productions. It is important to ensure that all detectors behave as expected, and observables are well described by the Monte Carlo. Additionally, the quality assurance step in analysis can be used to determine high multiplicity runs within a given period of data taking.

Photon quality assurance was run on pp collision periods for LHC Run 2. This was used to determine which run numbers from each period contained high multiplicity events to be used in further analysis. The runs examined in the quality assurance used the Photon Conversion Method (PCM) in the photon reconstruction.

Two high multiplicity event triggers were used: one from the high multiplicity V0 trigger and one for the high multiplicity SPD trigger. The photon quality assurance must be run, in general, for all PCM related analysis, including any hybrid PCM-calorimeter analyses.

The output of the quality assurance provided the number of events in a given run as well as the quality of the conversion photon sample in the respective run. The run numbers containing high multiplicity events were then collated for each period. This was done separately for the V0 and SPD high-multiplicity triggers separately.