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Design and Performance of an Ultra-Low Background Cryostat for High-Purity Germanium Spectrometers

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Content

High purity germanium (HPGe) detectors are the gold standard for gamma-ray spectroscopy with counting rooms typically employing multiple detectors ranging in type from the standard p-type semi-coax to high-efficiency well detectors. Improving the sensitivity of these measurements is possible by utilizing commercial low-background (LB) HPGe instruments, using carefully designed passive shielding, and employing a cosmic-ray muon veto. If additional sensitivity is required, these instruments can be located in an underground laboratory where cosmic-ray secondary muons, neutrons, and protons are reduced or eliminated. At a certain depth, the trace radioactive impurities remaining in the cryostat and front-end electronics become the dominant background that limits sensitivity. To achieve ultimate sensitivity at deep laboratories, it is necessary to consider the production of a custom ultra-low background (ULB) cryostat. Such a cryostat would be produced with carefully screened materials, fabricated using clean machining practices, cleaned using published ULB cleaning procedures, and assembled in a cleanroom environment.

Recently, a new ULB cryostat has been produced for a custom low-noise (57eV FWHM pulser) large-volume (1.3kg) modified Canberra BEGe crystal. The cryostat design is of the inverted-J type. This design has three benefits – the crystal can be located far from the non-low-background components (Dewar, preamplifier, etc), there is no direct thermal connection to the Dewar (minimize microphonics), and there is no direct gamma-ray shine path onto the crystal. The downside to the design is that the thermal path can be quite long, limiting the operating temperature of the HPGe crystal. Extensive modeling of the new design was performed and indicated a crystal operating temperature of 91.5K, which corresponds exactly to the measured value in final lab testing. In this cryostat, the germanium crystal is mounted in a low-mass holder and surrounded by a thin copper IR shield. By eliminating as much mass as possible and limiting the pallet of materials to electro-refined copper, screened OFHC copper, and clean polymers is it possible to achieve very low backgrounds. Finally, front-end electronics are a significant contributor to background due to their close proximity to the HPGe crystal and the use of non-low-background components. For this cryostat, a custom front-end electronics package was produced, eliminating resistors known to be radioactive.

In this talk I will review the unique features of this cryostat and discuss the fundamental principles in designing, fabricating and assembling an ultra-low background HPGe spectrometer. Deployed to the Soudan Underground Laboratory (1800 meters water equivalent) in late 2015 the detector has been continuously operating; the initial and most recent background spectra from the instrument and projected sensitivity for gamma-assay will be presented.

About the Presenter

Dr. Todd Hossbach is a research physicist in the Radiation Detection and Nuclear Sciences group at the Pacific Northwest National Laboratory. For more than 19 years his research has focused on the design, production, testing, and deployment of radiation detectors and instrumentation for national security and environmental monitoring as well as nuclear and high-energy physics. Since 2001, Dr. Hossbach has been focused on the development of ultra-low background detectors (semiconductor, scintillation, and gas proportional counters) and detector arrays for the measurement of weak radioactivity in the environment as well as the discovery of rare physics processes.

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