SAND2011-3254C

Title: Prospects of Reactor Monitoring with a Germanium Antineutrino Detection System

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Abstract:

An operating 3GW nuclear reactor emits about 10^{22} antineutrinos per second in all directions that cannot be shielded, and thus, exploiting this antineutrino signature has the advantage of providing a verification tool independent of the declaration of the reactor operator. An antineutrino detector has the potential to monitor in real-time the operational status, power and fissile content of the reactor core.

The focus of this work is the development of a High-Purity Germanium (HPGe) detector system that will enable us to be sensitive to an as-yet undetected antineutrino interaction: coherent neutrino-nucleus scattering (CNNS). The result of a coherent elastic scattering of an (anti)neutrino in the detector target mass is a recoiling Ge nucleus. For the energy range of incident reactor antineutrinos, the recoiling energy of the heavy Ge nucleus is of the order of a few keV, of which only 20% is converted into the ionization of electron-hole pairs. Therefore, the detection of this interaction requires an unprecedented low electronic-noise threshold not available in commercial detectors with the desired target mass (about 1kg-scale).

In recent years, there has been a qualitative advance in the development of a new type of HPGe detector that combines a large mass-crystal with a low noise threshold. As first proposed by LBNL[i], the electronic noise is significantly reduced by changing the center electrode to a point contact, as opposed to a bore hole type contact in standard coaxial HPGe detectors. These detectors have found application in astroparticle and neutrino physics[ii,iii]. Canberra Inc has developed a commercial version of a point contact detector, the Broad Energy Germanium (BEGe) detector[iv]. A modified version of the BEGe was demonstrated to achieve an already very-low noise threshold of 400 eV. However, in order to detect CNNS the required noise threshold must be reduced to at least 180 eV. Cutting in half an already low noise figure will require another qualitative advance in HPGe technology.

Using electrical contact preparation and surface passivation methods developed at LBNL, a new ~1kg detector has been fabricated with a point contact diameter of ~1 mm, targeting a significant reduction in capacitance-driven electronic noise and leakage current. The detector element has been inserted in an optimized low-noise electronic readout, based on a front-end prototype developed at LBNL. Optimization of the front-end electronics readout has consisted in the systematic testing of different FET amplifiers and of various parameters like feedback capacitance, feedback resistance and thermal properties of the FET assembly.

A chamber encapsulating the detector element and the front-end holder have been designed and built to fit an existing Canberra cryostat. This first prototype is made of regular materials (not of low-background materials) since the goal is to demonstrate rigidity against microphonics noise, high voltage isolation, IR shielding, thermal conductance and isolation, and ruggedness for a future deployment. ,

Controlling background signals is another imperative target, which is addressed by building a robust shield and eventually, using low-background materials in the proximity of the detector element. We have built a plastic scintillator veto to act as an anticoincidence detector surrounding the target Germanium detector, and present preliminary tests of its detection efficiency and light collection. We also present Geant4 simulation results evaluating the effectiveness of this detector as a neutron and gamma veto in the reactor tendon gallery (30mwe), compared to a similar NaI(Tl) veto detector.

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[i] P. N. Luke *et al*, "Low capacitance large volume shaped-field Germanium detector", IEEE *Trans. Nucl. Sci*. vol. 36, pp. 926 (1989).
[ii] C. E. Aalseth *et al.* "Results from a Search for Light-Mass Dark Matter with a P-type Point Contact Germanium Detector", by CoGeNT Collaboration, arXiv :1002.4703, Feb. 2010.
[iii] C. E. Aalseth *et al.* "Astroparticle Physics with a Customized Low-Brackground Broad Energy Germanium Detector", by Majorana Collaboration, arXiv:1007.3231, Jul 2010.
[iv] CANBERRA Broad Energy Ge (BEGe) Detector
http://www.canberra.com/products/485.asp