Instrumentation and Simulation for the SEGA Germanium Detector

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The Segmented and Enriched Germanium Array (SEGA) is a 1.6 kg prototype germanium detector for the Majorana Project, a proposed experiment to search for double β-decay processes in the ^{76}Ge isotope. Majorana will be able to address the fundamental question whether the electron-type neutrino, ν_e, is its own anti-particle. The SEGA detector has a segmented readout structure with 6 equally spaced exterior ϕ segments and 2 independent Z readouts from the inner contact. All together 8 signal waveforms are readout and digitized for each gamma event. SEGA is the only ^{76}Ge enriched and segmented detector in the world at this point. The waveforms are important that they can provide information about the interaction-site multiplicity and location of the event. Besides having an extremely stringent requirement on low radioactive background including minimal cosmic ray exposure, the overall energy resolution of the detector is also vital for the experiment to reach its predicted sensitivity for observing double β-decay. One of the key factors in affecting th resolution is from the analogue electronics, typically comprises of a front-end FET and a preamplifier. At LBNL, we have examined the possibility of incorporating some of the locally designed electronics to SEGA. A bare cryostat manufactured by AMTEK has been acquired for this purpose. The scope of the prototype implementation includes 8 preamps (each populated with an warm FET), two small motherboards, and an internal high voltage filter circuit bought commercially from AMETEK. All the compennts are integrated inside a removable cylindrical aluminum module.

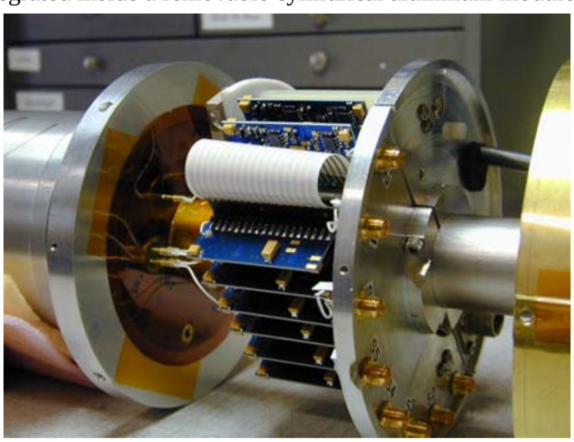
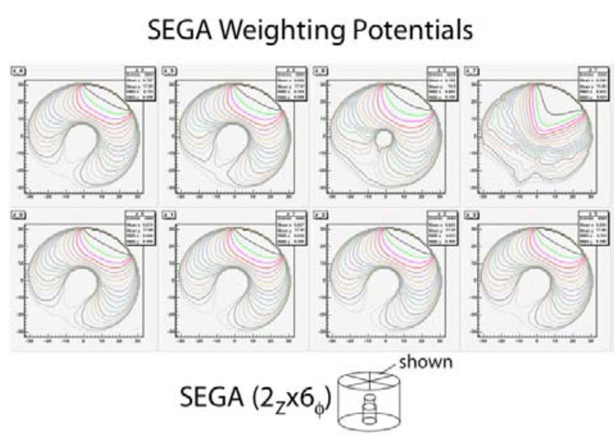


Fig.1 LBNL electronics for the SEGA detector. Shown are the 8 preamps and the removable housing assemble. Not shown are the HV filtering circuit elements.

The mechanical and electrical fabrication of the electronics has been completed (Fig.1). The next stage will be transferring the SEGA crystal into the cryostat in the near future, so that in-situ evaluation of the detector waveform and energy resolution can be studied, preferably in a low background counting laboratory such as the LBNL Oroville Facility.

In addition to the electronics hardware, a full understanding of the waveform outputs from the detector is also important, especially SEGA has an unusual "internal" z-segmentation scheme. An independent program to perform waveform simulation for the SEGA detector is underway. One of the critical inputs required for such calculations is to know the actual charge trajectories inside the crystal, after the initial ionization process. According to standard approaches, the trajectories are determined by the internal collecting electric field after a high voltage bias is applied, together with empirical electron and hole drift coefficients inside the crystal. To calculate the E-fields accurately, besides a detailed detector geometry input, one would also need to take into account of the impurities distributions (charge centers) inside the crystal. The SEGA manufacturer has provided us with measured impurity concentrations during the fabrication process. All these information are fed into a numerical Maxwell equation solver and generate all the weighting potentials and internal fields required. Fig.2 shows a sample calculation of one of the weighting potential for one external phi component, as a function of z.

The waveform was then calculated according to standard Ramo[1] procedures. The simulated results will be compared with experimental data once the SEGA crystal is transferred into the new cryostat. Software algorithms for pulse-shape analysis are also in development based on the simulation.



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[1] S. Ramo, "Currents Induced by Electron Motion", Proceedings of the IRE, V27 (1939). W. Shockley, "Currents to Conductors Induced by a Moving Point Charge", Journal of Applied Physics, V9 (1938).