Simulation of Radioactive Backgrounds in a 57 Crystal HPGe Array

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The Majorana experiment's most difficult challenge is to identify and mitigate its backgrounds. A critical step in achieving this goal is to estimate the contributions to the signal region of interest (ROI) from these different backgrounds. One source of these backgrounds is radioactive contamination inside the detector crystals and surrounding structures. A comprehensive Monte Carlo study of these backgrounds has been initiated, using the combined Majorana/Gerda simulation package, MaGe. The simulations are performed at the PDSF facility at NERSC.

The simulated geometry consists of 57 crystals in the so-called "Banger" configuration with 3 layers of 19 crystals each. See figure 1. The crystals were assumed to be n-type with a 1.08-kg mass. The support structures consist of 3 copper tubes holding 3 plastic support rings that each support a crystal. Each tube is 24.8 cm in length with inner and outer radii of 0.25 cm and 0.175 cm respectively. This yields a mass of 1 gram per centimeter for the tube. The support rings were simulated as polyethylene. The banger was enclosed by a copper cryostat, with a wall thickness of 0.5 cm and mass of 37.05 kg. The initial simulations were performed with a 50 cm lead shield, but subsequent simulations were done with 20 cm lead shield to increase sampling efficiency. An air-filled cavity of height 4.0 cm and radius 18.53 cm was located directly above the cryostat.

The summed energy deposit in each crystal was convoluted with a Gaussian distribution to simulate electronic and detector noise. A crystal-to-crystal anticoincidence analysis was also performed. An event was considered to be coincident between two or more crystals if the energy deposits in two or more crystals exceeded 5 keV each. All energy deposit and tracking information from Geant 4 were saved and will be used in future segmentation and pulse-shape studies. An example spectrum is shown in figure 2. Figure 2 also shows the rejection efficiency of a crystal array against external gamma rays.

A comprehensive list of radioactive isotope decays in various parts of the detector were simulated. The main result to date is that contamination in the crystals and internal support structures is not a concern, but certain radioactive isotopes, especially ^{232}Th, in the shielding and cryostat, are the dominant source of background. Their contributions are still within the required limits of the experiment, though.

The simulations are ongoing, with more refined geometries and additional isotopes being added.

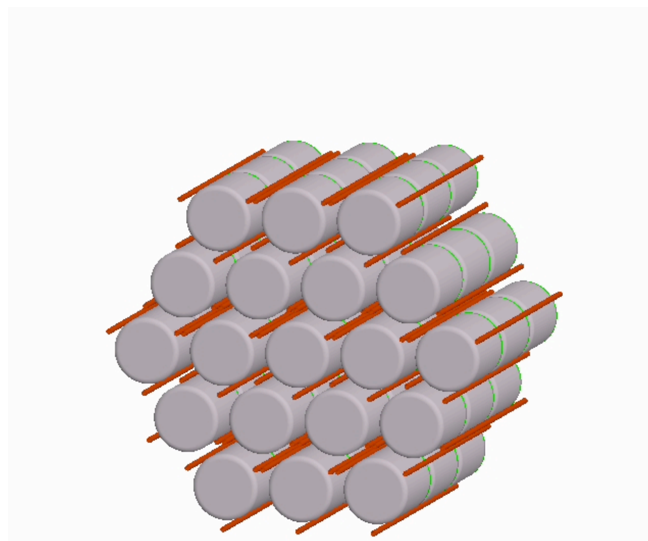

Figure 1: Simulated 57 Crystal Array.

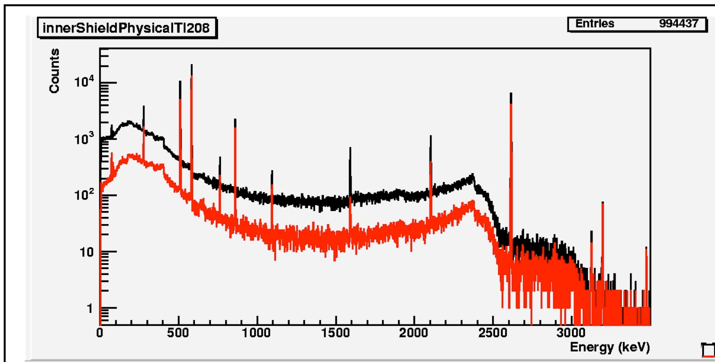

Figure 2: Simulated Spectra from ^{208}Tl Decay in the Cryostat. The black spectrum is for all decay events and the red specrum is events where only one crystal registered a hit.