Modeling the ORTEC EX-100 Detector using MCNP

MCNP is a general-purpose Monte Carlo radiation transport code for modeling the interaction of radiation with materials based on composition and density. MCNP is capable of modeling nearly all particles, energies, and applications and is fully three-dimensional and time dependent. MCNP utilizes the latest nuclear cross section libraries and physics models for particle types and energies when tabular data are not available. Applications of MCNP include nuclear medicine, safeguards, criticality and accelerator modeling.

In this work, the ORTEC EX-100 detector response to a Cs-137 source (0.6616 MeV, 5.0 μC, $T_{1/2}$ =30.2 yr) was modeled using MCNP (version X). The modeling was accomplished in a stepwise fashion as follows and results were compared to actual experimental data to confirm the validity of the simulation results:

- Bare detector (Figure 1)
    - Ge detector mount cap and end cap only
    - source and detector surrounded in Pb with an 1/8" air tube connecting the source to the detector to eliminate background contributions
- Detector with plastic (Figure 2)
    - Ge detector mount cap, end cap, and plastic housing
    - source and detector surrounded by Pb with an 1/8" air tube connecting the source to the detector to eliminate background contributions
- Full experimental set-up (Figure 3)
    - Ge detector with plastic mounted as in EX-100 design
    - tabletop experimental set-up surrounded by air
    - no Pb shielding

The detector energy broadening response was modeled using FWHM information provided by ORTEC as was the detector geometry and material composition. For materials in which there was some ambiguity on composition and density, best guesses were taken based on available information. Both photon and electron collisions were included in the modeling. Neutrons were neglected. Results were then normalized to the observed experimental peak intensity for a comparison of the shape of the simulated detector response.

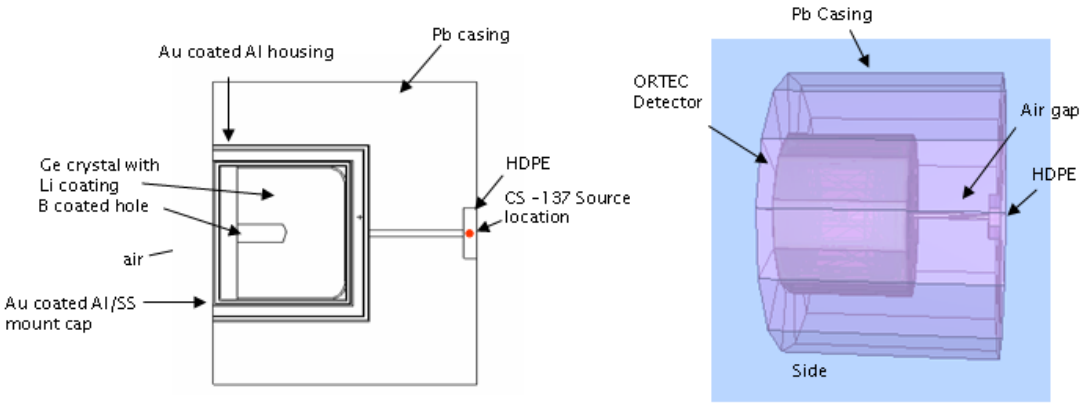

Figure 1. Ge detector mount cap and end cap only in a Pb-shielded experimental configuration.

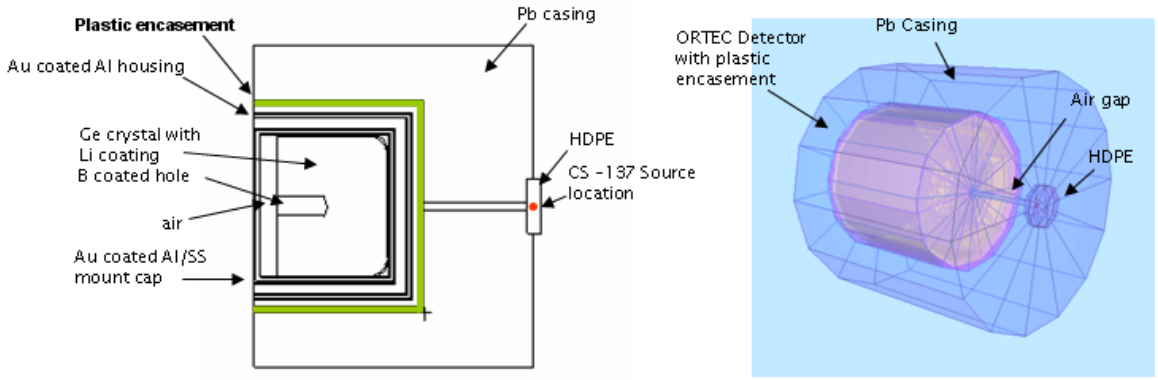

Figure 2. Ge detector mount cap, end cap, and plastic housing in a Pb-shielded experimental configuration.

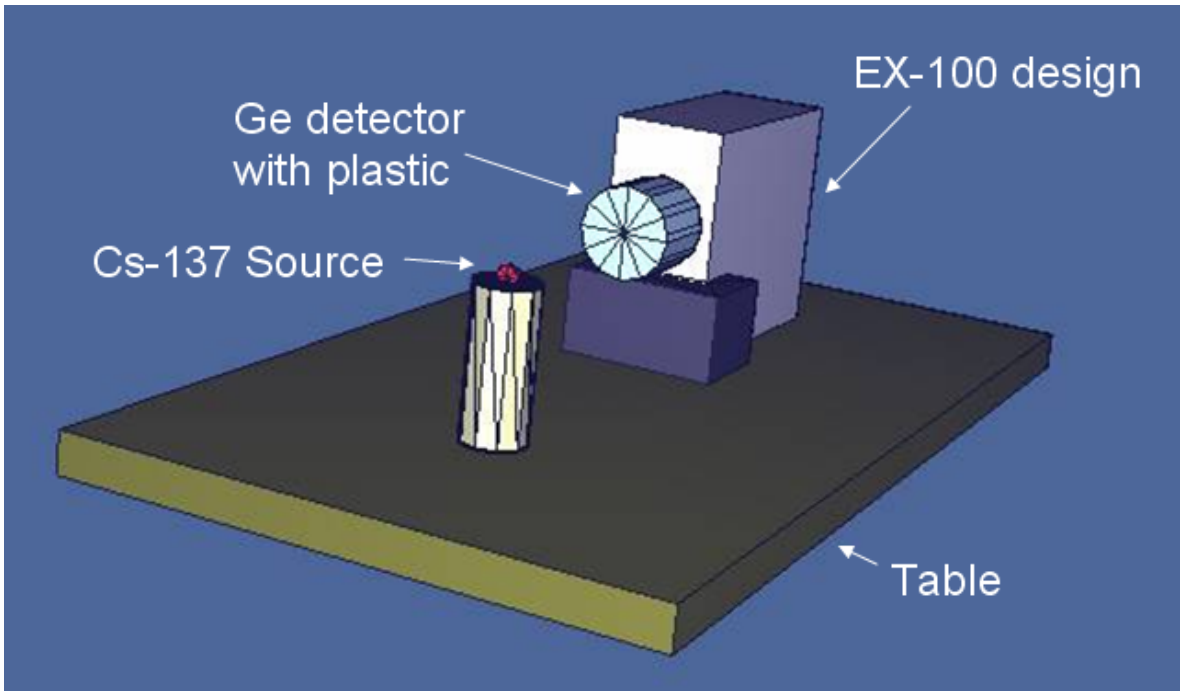

Figure 3. Full experimental set-up in air.

First, the effect of the plastic housing on detector performance was investigated. To do this, a comparison of the two geometries illustrated in Figures 1 & 2 was made by running MCNP for similar time periods (18 hrs and 16 hours respectively) and comparing the results. It was found that the plastic housing had little to no effect on the spectral response of the detector (See Figure 4).

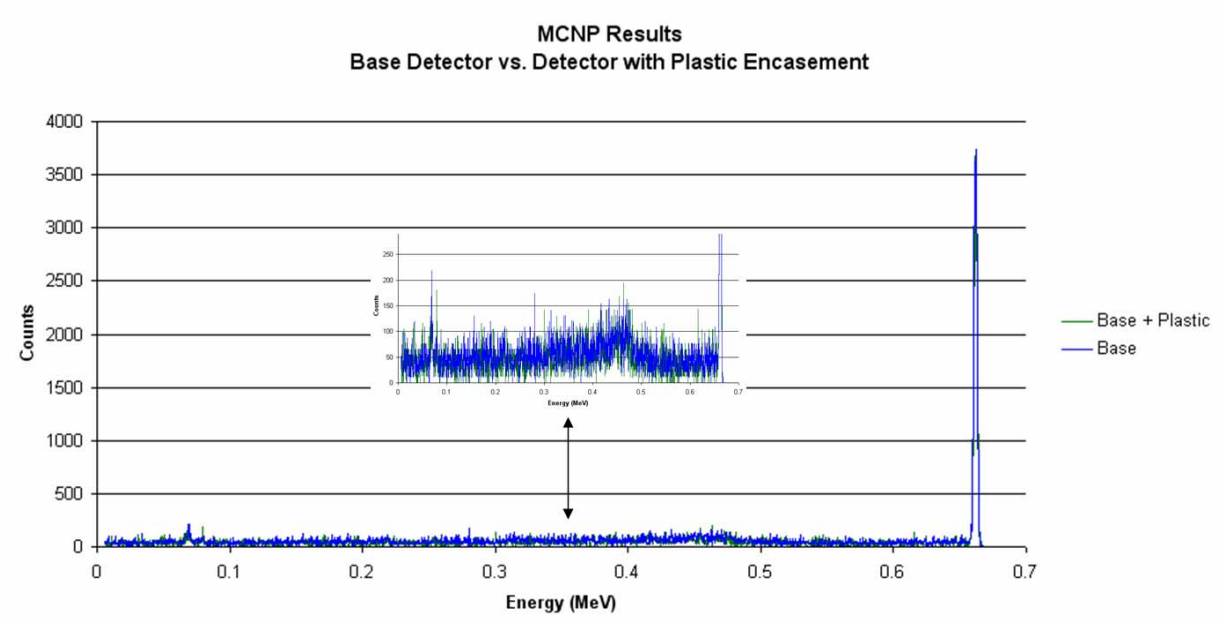

Figure 4. MCNP simulation results for Ge detector without plastic housing (Base) compared to results for Ge detector with plastic housing (Base + Plastic).

The simulation results for the Ge detector with the plastic housing and Pb shielding around the detector and source were then compared to experimental results and reasonable agreement was observed for a 16 hour run (see Figure 5).

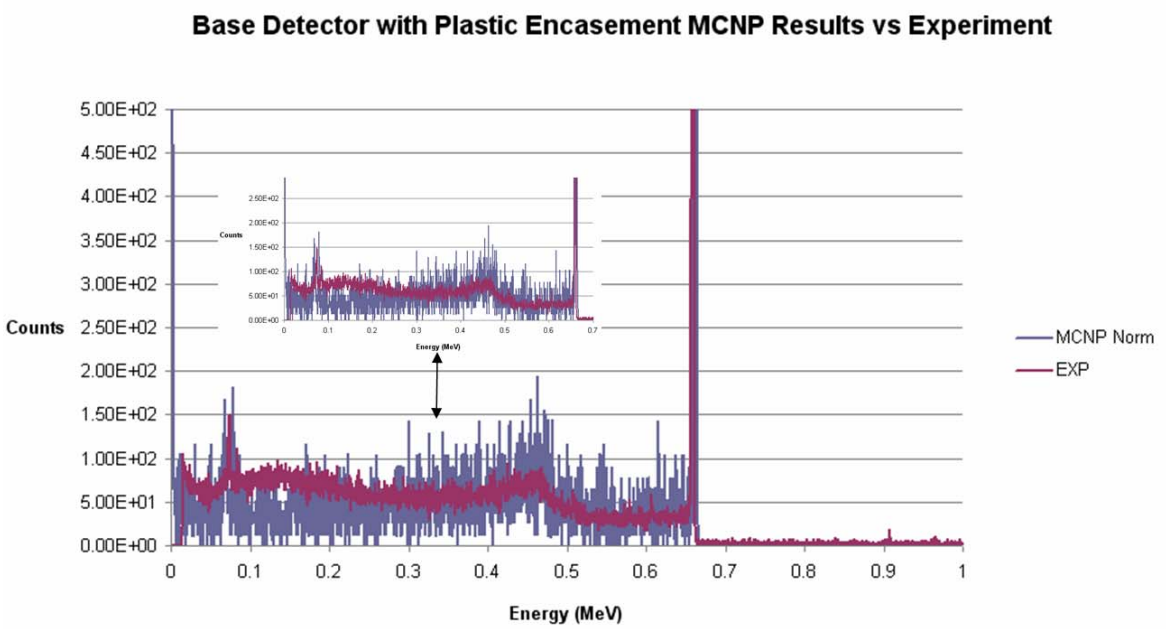

Figure 5. MCNP results for Pb-shielded configuration normalized and compared to experiment for a 16 hr simulation.

To study the effect of run time on the simulation results, MCNP was then run for a 65 hour period (see Figure 6). Running MCNP for a longer period resulted in a reduction of the variation in the simulated response.

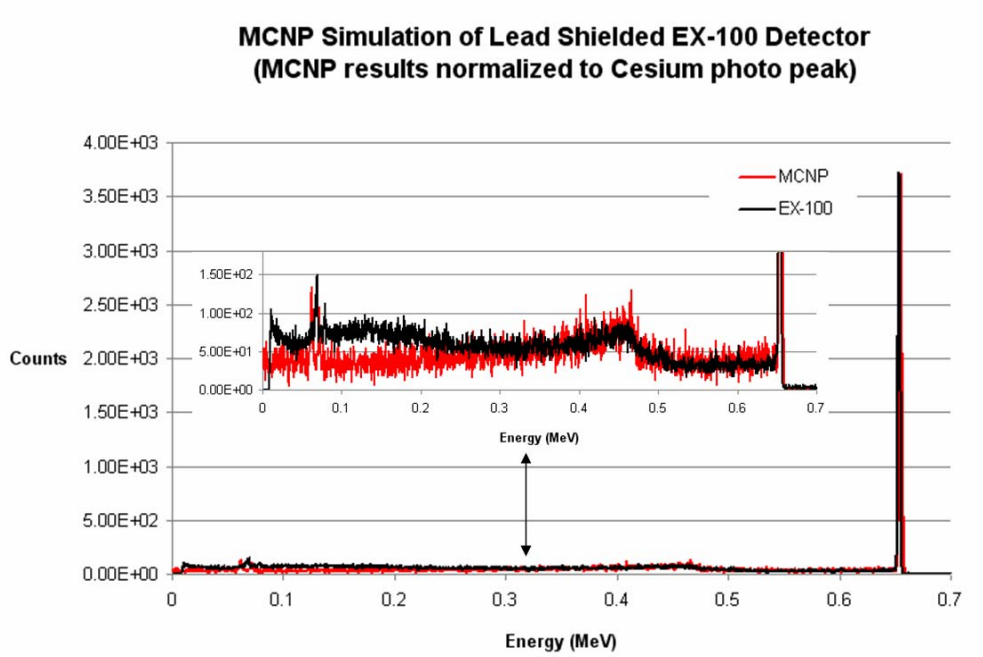

Figure 6. MCNP results for Pb-shielded configuration normalized and compared to experiment for a 65 hr simulation.

Once the validity of the MCNP results in the Pb-shielded experimental configuration was established, the full experimental set-up in air was modeled with the Ge detector mounted in the EX-100 design. The results of a 65 hour MCNP run compared to the background subtracted experimental data showed good agreement between simulation & experiment (see Figure 7).

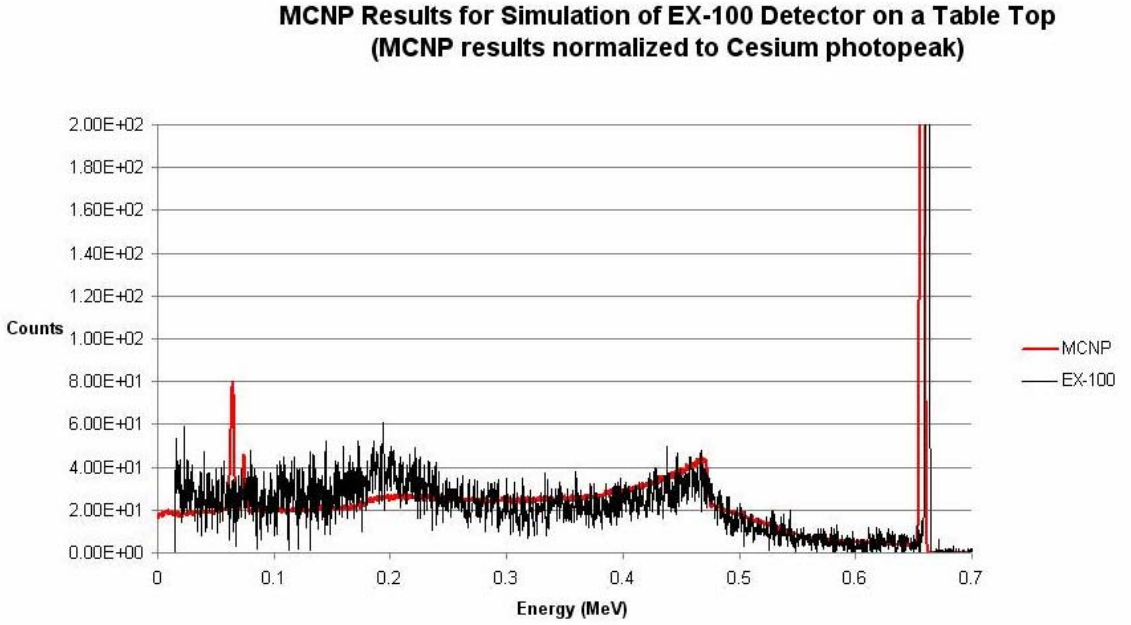

Figure 7. MCNP results for table top experimental configuration in air normalized and compared to background subtracted experimental results for a 65 hr simulation.

In summary, MCNP successfully simulated experimental results for both Pb-shielded experimental configurations and for a table top experimental configuration in air. It was found that the plastic housing on the Ge detector has little to no effect on the detector response. In addition, it was found that running MCNP for longer periods resulted in reduced statistical variation of the results. Background was not considered in this work and was eliminated via Pb-shielding or comparison to background subtracted experimental results. The next step in this modeling will be to add the simulation of the natural background radiation to the table top experimental configuration.