# Comparison of the Monte Carlo Simulations for Modeling a Well-type HPGe Detector

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# SCOPE

- Gamma-ray Spectrometry
- Well-type HPGe Detector
- Monte Carlo (MC) Simulation Methods
  - PHITS MC Simulation Program
  - GESPECOR MC Simulation Program
- Results and Discussion

# Gamma-ray Spectrometry

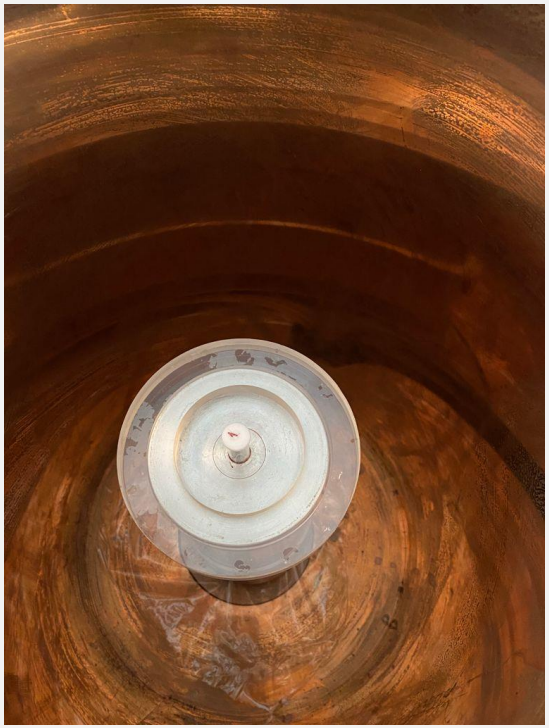
Gamma spectrometry is one of the fast, practical and sensitive methods of measuring radioactivity.


https://www.ortec-online.com/products/radiation detectors/germanium-hpge-radiation-detectors

Since the energies of the gamma-rays emitted from the radioactive nucleus are specific to the nucleus, the radioactive nuclei in the sample can be identified by measuring the energy of the photons emitted from the sample with the gamma spectrometric method, and then the activity of that radioactive nucleus can be determined.

# Well-type HPGe Detector

Well-type HPGe detectors are preferred in gamma-ray spectroscopy laboratories, especially in radioactivity analyzes of samples with low amount and activity, because of their high counting statistics, since 4π counting geometry is provided in the well.



# Monte Carlo (MC) Simulation Methods

- Monte Carlo (MC) is a method that provides great convenience to users both in the validation of experimental results and in conducting research that cannot be done experimentally. Parallel to the developing technology in nuclear instrumentation, the use of MC simulation method with proven accuracy and reliability in gamma spectrometry is increasing day by day.

- MC-based simulation techniques have been successfully used to evaluate HPGe detector response for wide energy range gamma-rays and different geometries.

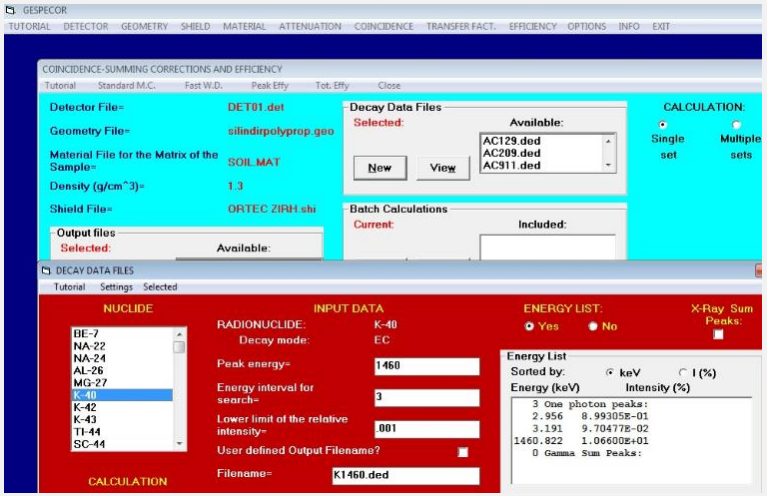
# Monte Carlo (MC) Simulation Methods

Since MC programs have advantages/deficiencies relative to each other, making a comparative evaluation using several MC software at the same time for selected situations leads the user to the most accurate result.

❖ In this study, a well-type HPGe detector was modeled using;

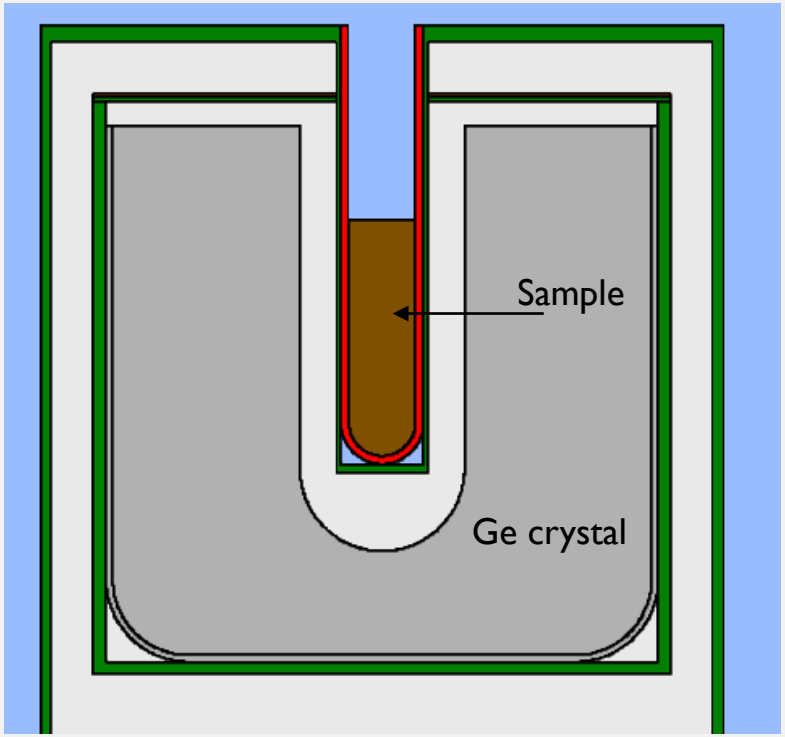
✓ PHITS, a general-purpose MC program,


✓ In addition, both method validation and MC programs were compared by using GESPECOR, which is a specific-purpose MC program



# PHITS MC Simulation Program

In the PHITS MC simulation program;
The well-type detector was modeled by defining all the geometric parameters of the detector given by the manufacturer, such as the dimensions of the crystal, the dimensions of the well, the dimensions of the end cap, the thickness of the dead layer.

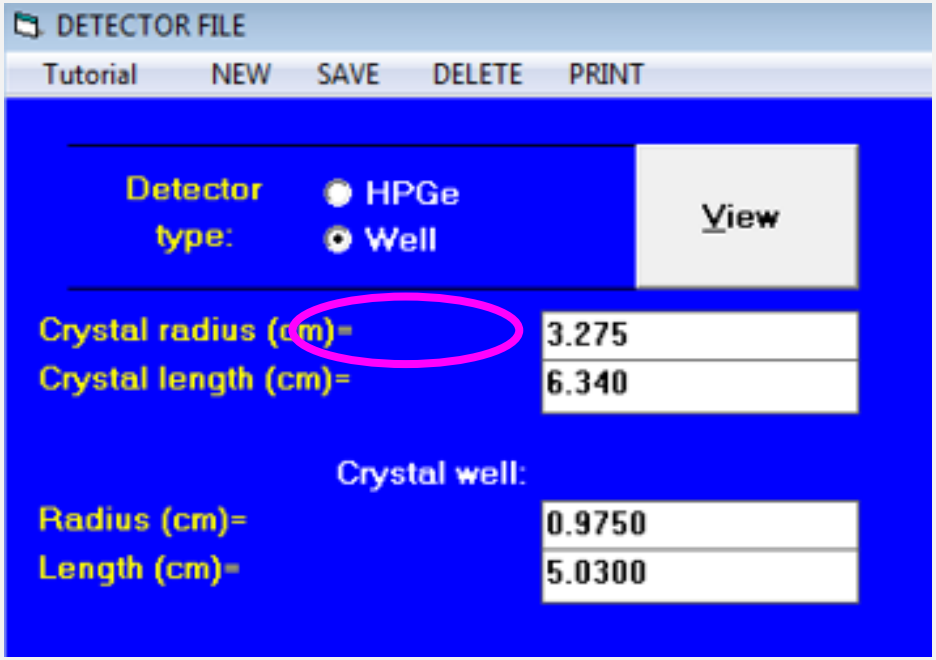


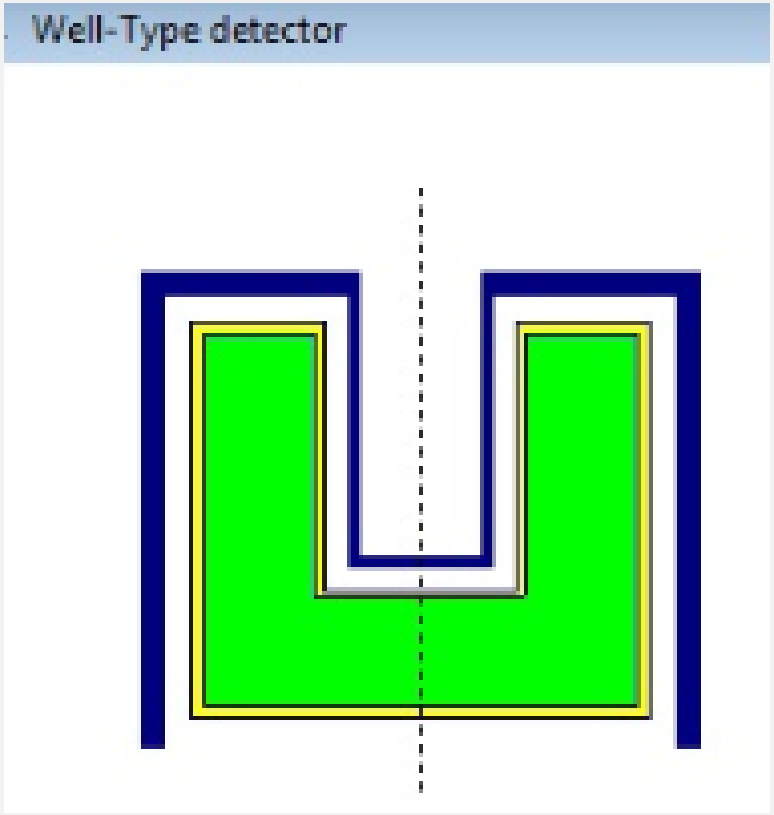

In PHITS, after the detector is modeled using cylinder, sphere and torus geometric shapes, the size information given by the manufacturer is entered.

History number = 10 million

# GESPECOR MC Simulation Program

Since well type detector modeling is available in the program in GESPECOR, the modeling was done by entering all the information given by the manufacturer.



# Results and Discussion

For comparison, full energy peak efficiency values of 63.3 keV at low energy and 1460 keV at high energy of a sample in $SiO_2$ composition in small tube geometry placed inside the well were used in both programs.

When the full energy peak efficiency values obtained were examined, a difference of <7% was found between PHITS and GESPECOR MC programs.

| Energy (keV) | MC calculated efficiency* | | Difference**, % |
|---|---|---|---|
| | PHITS | GESPECOR | |
| 63.3 | 0.5821 | 0.6206 | 6.6 |
| 1460.8 | 0.0614 | 0.0632 | 2.9 |

*In both MC programs the uncertainty is <0.1% as history is run at $10^7$.
** (PHITS-GESPECOR) MC calculated efficiency/PHITS MC calculated efficiency×100

# Results and Discussion

In this study, a well-type HPGe detector was modeled using PHITS, a general-purpose MC program, which has been shown in our previous studies* to be used reliably in modeling coaxial HPGe detectors.

In our future plans, it is aimed to characterize the well-type detector by matching the experimental measurements on various samples with the MC simulation programs.

*Bölükdemir, M.H., Uyar, E., Aksoy, G., Ünlü, H., Dikmen, H., Özgür, M., 2021. Investigation of shape effects and dead layer thicknesses of a coaxial HPGe crystal on detector efficiency by using PHITS Monte Carlo simulation. Radiation Physics and Chemistry 189, 109746.

*Uyar, E., Bölükdemir, M.H., 2022. The effect of front edge on efficiency for point and volume source geometries in p-type HPGe detectors. Nuclear Engineering and Technology, in press, https://doi.org/10.1016/j.net.2022.06.009

# References


1. Guerra, J. G., Rubiano, J. G., Winter, G., Guerra, A. G., Alonso, H., Arnedo, M. A., Tejera, A., Martel, P., Bolivar, J.P. (2018). Modeling of a HPGe well detector using PENELOPE for the calculation of full energy peak efficiencies for environmental samples. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*. *908*, 206-214.
2. Huy, N.Q. Binh, D.Q. An, V.X. (2007). Study on the increase of inactive germanium layer in a high-purity germanium detector after a long time operation applying MCNP code, Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 573, 384–388.
3. Conti, C.C., Salinas, I.C.P., Zylberberg, H. (2013). A detailed procedure to simulate an HPGe detector with MCNP5, Progress in Nuclear Energy. 66, 35–40.
4. Sima, O., Arnold, D., Dovlete, C. (2001). GESPECOR: A versatile tool in gamma-ray spectrometry, Journal of Radioanalytical and Nuclear Chemistry. 248, 359–364.
5. Bölükdemir, M.H., Uyar, E., Aksoy, G., Ünlü, H., Dikmen, H., Özgür, M., (2021). Investigation of shape effects and dead layer thicknesses of a coaxial HPGe crystal on detector efficiency by using PHITS Monte Carlo simulation. Radiation Physics and Chemistry. 189, 109746.
6. Uyar, E., Bölükdemir, M.H. (2022). The effect of front edge on efficiency for point and volume source geometries in p-type HPGe detectors. Nuclear Engineering and Technology, in press, https://doi.org/10.1016/j.net.2022.06.009