# Development of Alternative Designs of the SIGMA Detector for Reduced Technical Risk

Emily Richardson

Oliver Lodge Laboratory, University of Liverpool, Liverpool, L69 7ZE

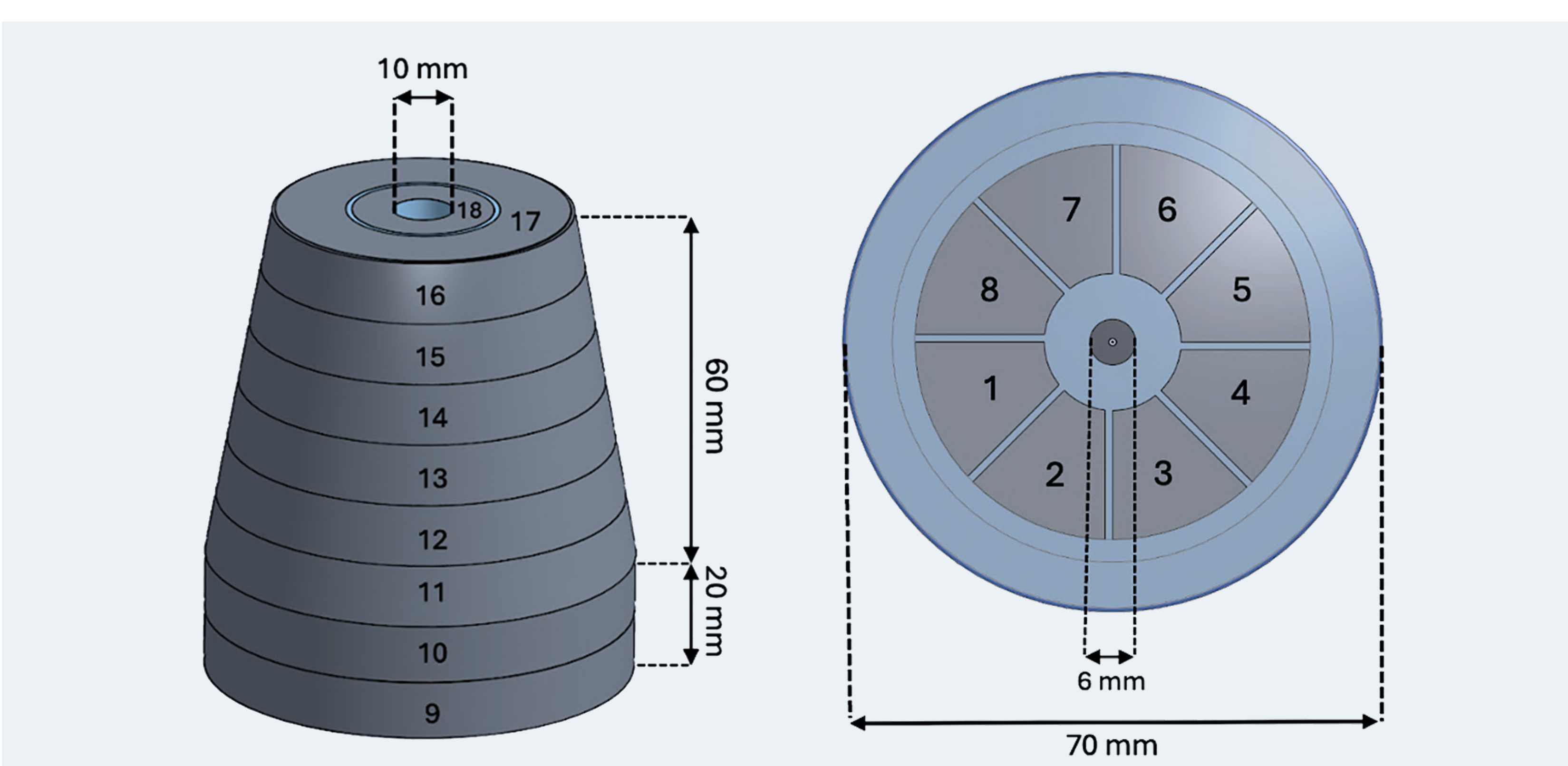
## Introduction

- The Segmented Inverted Coaxial Germanium (SIGMA) detector is a large-volume High Purity Germanium (HPGe) detector designed for gamma-ray imaging and tracking.
- Specific applications of SIGMA include use as a spectroscopic gamma-ray imager in nuclear decommissioning. SIGMA will also be part of a portable detector array at international accelerator laboratories for nuclear structure and astrophysics research.
- This project aims to design novel SIGMA-like geometries to reduce the technical risks associated with the original design and optimise future manufacturing yield while maintaining energy and position resolution. To analyse performance, the AGATA Detector Library (ADL), a simulation package used to create realistic simulations of semiconductor detectors, is used to produce the electric and weighting potentials and generate signals.

## Original SIGMA Design

SIGMA follows a complex segmentation scheme to maximise position sensitivity:

- Two radial segments aid in resolving the radial position.
- Eight azimuthal segments provide angular information.
- Eight longitudinal segments offer depth of gamma ray interaction.
- A $P+$ point-like contact collects primary charge carriers (holes) and has a reduced capacitance (around one pF), providing excellent energy resolution: 0.84 keV at 122 keV and 2.21 keV at 1332 keV [1].



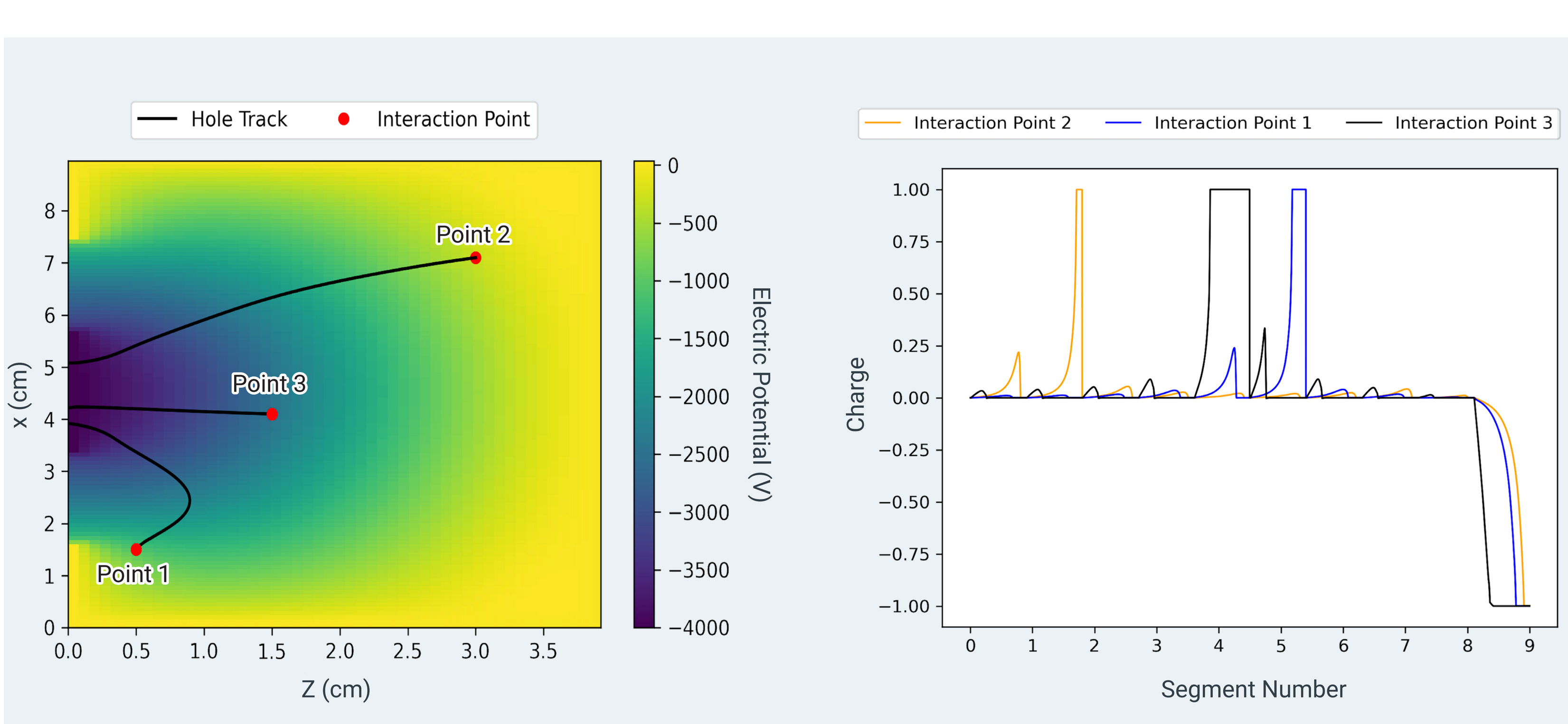

## Electric Field Simulation

- The electric field determines the trajectory and velocity of charge carriers, produced following a gamma ray interaction, as they move through the detector. The operating voltage was set to -4000 V in ADL to ensure the crystal is fully depleted.

It was found that the electric potential, as expected, reduces in strength by half at approximately the detector's height.

It was found that there is a clear temporal variation in the signals (bottom) when different gamma-ray interaction points are simulated, establishing a strong connection between the drift time to the point of contact and the interaction position, providing position sensitivity.

Additionally, the other seven-point contact segments provide supplementary information.

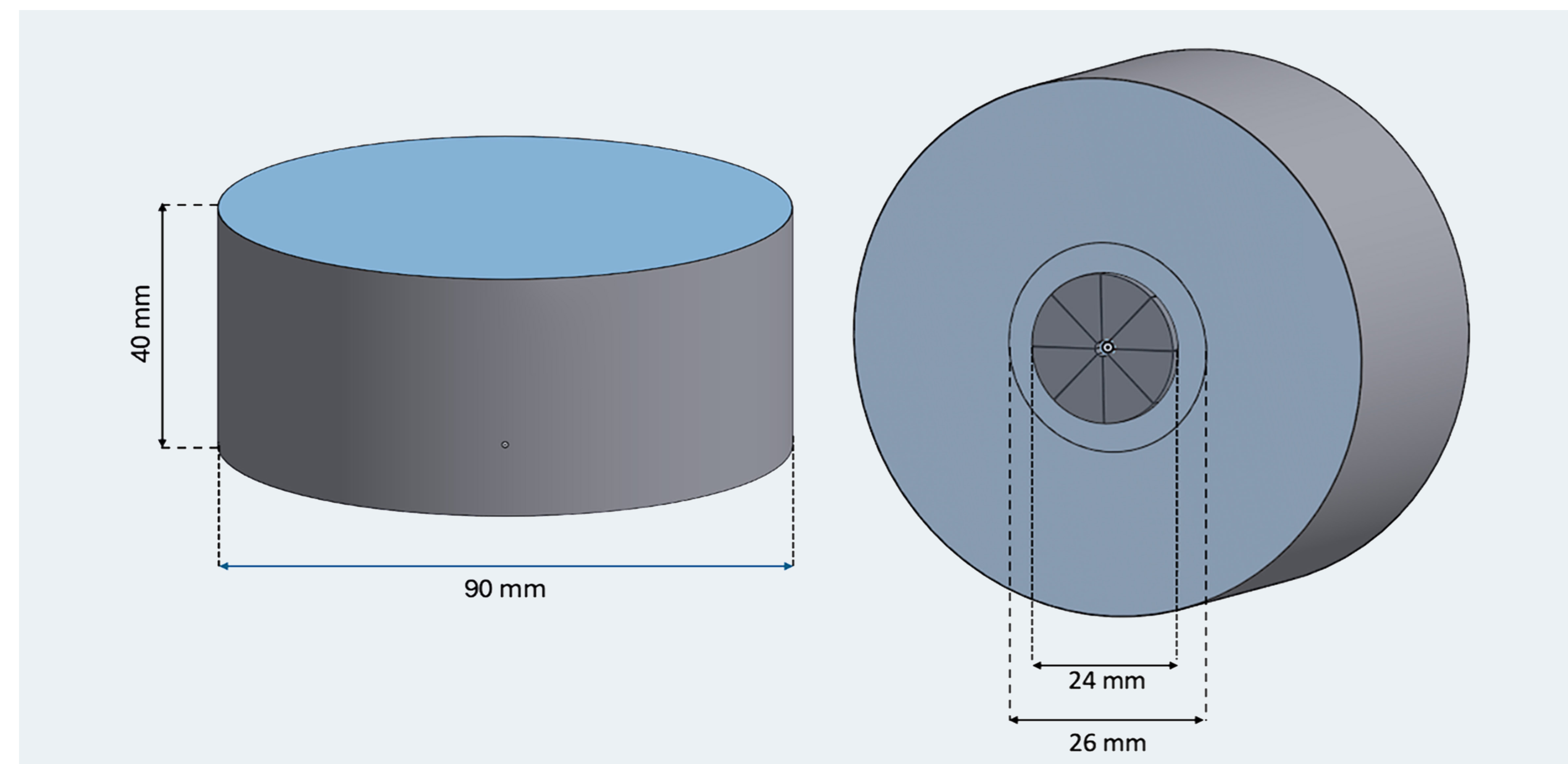



## New Proposed Design

In order to minimise technical risk, a new design has been proposed.

The design follows a BEGe convention;

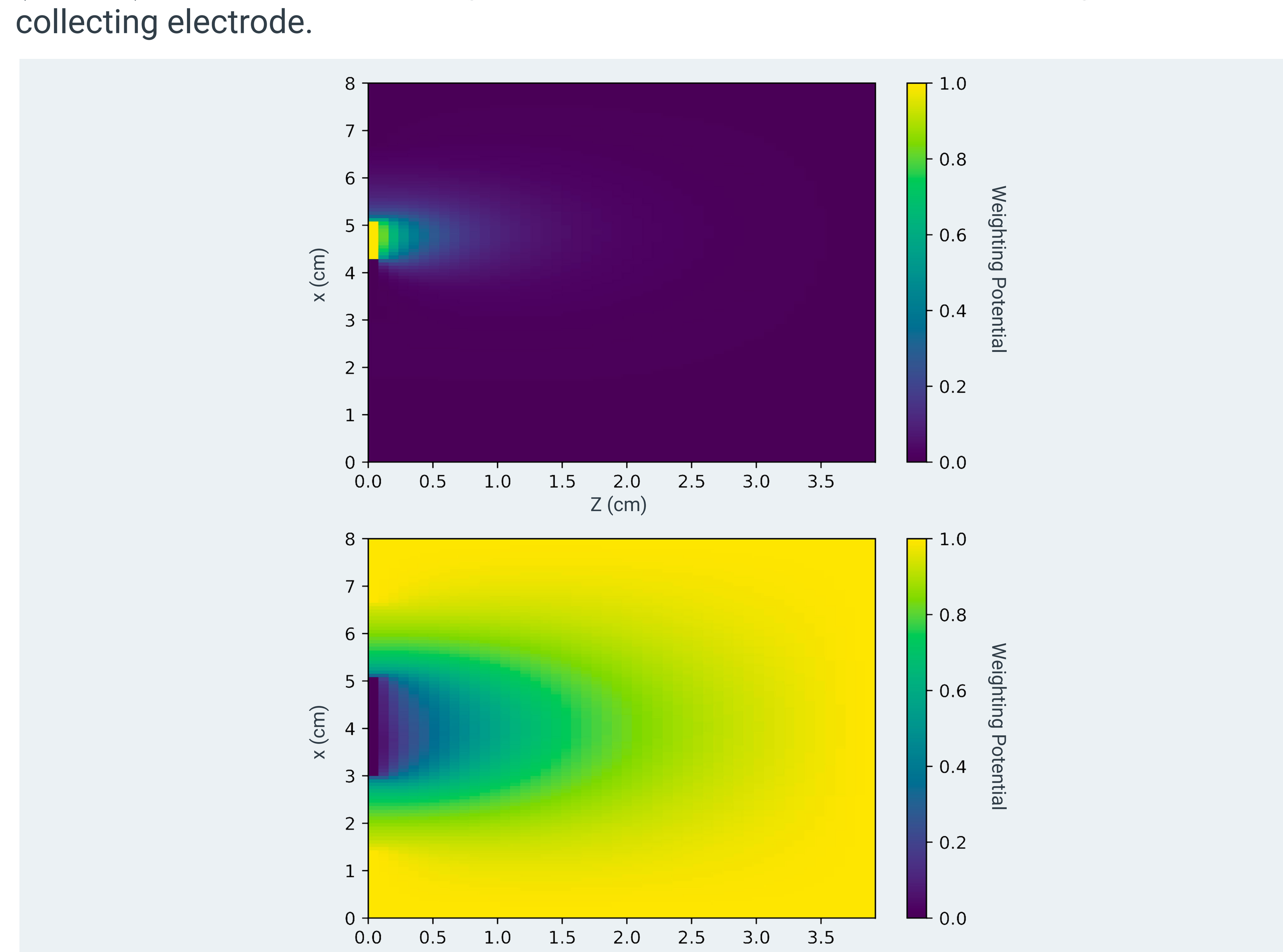
- A segmented $P+$ point-like contact collects primary charge carriers (holes), providing angular information.
- A $n$-type contact surrounds the outside of the crystal.
- A guard ring is found on the back face (to be simulated).




## Weighting Potential Simulation

The weighting field relates the motion of a charge carrier through the detector to a specific electrode and the resulting induced signal. Thus, the weighting potential is responsible for the shape of the charge pulses.

The weighting potential of an azimuthal segment (top), located in the point contact, has a short range when compared to the secondary charge collecting electrode (bottom); this difference in range is due to the increased size of the charge collecting electrode.




## Future Work

To assess the detector design presented in this work, the achievable position and energy resolution will be determined. Furthermore, to enhance the design, an unsegmented guard ring will be added around the segmented point contact. The purpose of this guard ring is to capture events occurring from the back of the crystal and to provide additional height information.

## References

1. F.J. Pearce, L.J. Harkness-Brennan, A. Alharbi, A.J. Boston, O. Griffiths, F. Holloway, D.S. Judson, M. Labiche, P.J. Nolan, R.D. Page, D.C. Radford, E. Rintoul, J. Simpson, C. Unsworth, and J.P. Wright. First experimental measurements with the segmented inverted-coaxial germanium (sigma) detector. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1027:166044, 2022.

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