Computational studies of BEGe detectors

Presented by Marco Salathe, marco.salathe@mpi-hd.mpg.de

Max Planck Institute for Nuclear Physics, Heidelberg

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• **BEGe**: Broad Energy Germanium detector
  - Produced by Canberra Industries, Olen, Belgium
• **GERDA**: GERmanium Detector Array
  - Tues, 17:15, HSZ-401, GERDA status report, Mark Heisel
  - Thu, 16:45, WIL-A317, Gerda status report, Matteo Agostini
• **HEROICA**: Hades Experimental Research Of Intrinsic Crystal Appliances
  - Tues, 16:45, HSZ-101, HEROICA: a test facility for the characterization of BEGe detectors for the Gerda experiment, Raphael Falkenstein
Pulse Shape Simulation

1) Calculate electric potential $\phi_E$ and weighting potential $\phi_W$:
   - Initial condition: potential on electrodes, detector dimensions, impurity gradient

![Electric potential for BEGe](image1)

![Weighting potential for BEGe](image2)
Pulse Shape Simulation

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2) Calculate the trajectory of the charge $x_{e^-}/h$, which depends on:
   - the point of charge deposition
   - the electric field $\vec{E}$ defining the drift velocity
   - specific mobility parameters for crystal axes
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3) Calculate the induced charge at the electrode:
   - Shockley–Ramo theorem: $Q(t) = -Q_0 \cdot [\phi_W(x_h(t)) - \phi_W(x_e(t))]$
A few details and references:

- Simulation is based on the ADL 3.0 (AGATA Detector simulation Library)
  - http://www.ikp.uni-koeln.de/research/agata/download.php
  - B. Birkenbach - DPG 2011 / HK 54.2 : Characterisation of AGATA detectors
- Calculation of potential:
  - Usually poisson equation: \( \nabla^2 \phi = \rho_f / \epsilon \)
  - Not precise due to variable permittivity: \( \nabla^2 \phi(\vec{x}) \cdot \epsilon(\vec{x}) + \nabla \phi(\vec{x}) \cdot \nabla \epsilon(\vec{x}) = \rho_f(\vec{x}) \)
  - Solve in cylindrical (2D) or cartesian coordinates (3D) on a rectangular grid by successive over relaxation
  - D. Radford, http://radware.phy.ornl.gov/MJ/m3dcr
- Evaluation of charge trajectory:
- Shockley-Ramo theorem:
- Pulse shape simulation with BEGe detectors:
A few applications

$^{241}$Am scans in Heroica:

- Measurements of 30 detectors with collimated $^{241}$Am source on up to three Padova Scanning Tables on up to 600 different points
- Analysis of data for each point: position of 60keV peak, FWHM, A/E peak, different pulse rise time
A few applications

**Am scans in Heroica, 2 – 70% rise time:**
- Increasing risetime for large radius
- Fast oscillations for large radius
- Slow oscillations for small radius

![Graph showing measured and simulated risetime](image-url)
A few applications

Am scans in Heroica, 2 – 70% rise time:

- Increasing risetime for large radius due to longer drift path
- Fast oscillations for large radius due to different mobilities along crystal axes
- Slow oscillations for small radius due to a misalignment of detector of up to 1mm
A few applications

Double peak structure in A/E in $^{228}$Th measurement in Heroica:
- A/E is used for pulse shape discrimination:
  - E: energy (moving window average filter)
  - A: amplitude of weakly smoothed current pulse
- A double peak structure was observed in double escape peak of $^{228}$Th for many detectors
  - *Tues, 17:05, HSZ-101, Pulse Shape Analysis of Enriched BEGe Detectors in Vacuum Cryostat and Liquid Argon, Victoria Wagner*
- Idea: Inhomogeneous charge within the groove
A few applications

High voltage scans in Heroica:

- Measuring peak count rate and resolution of $^{60}\text{Co}$ peaks for different applied high voltage
- Evaluation of depletion voltage
- Sensitive to detector parameters (especially impurity gradient)
A few applications

Detector optimization:

• For a crystal slice many fixed parameters: Impurity gradient, height, radius
• There are a few free parameters: size of point contact, groove width
• Depletion voltage as a function of the free parameters
• A compromise between values of free parameter and depletion voltage can be found
Thanks for your interest
**Extended ADL 3.0:**

- Many detectors implemented: coaxial, BEGe, planar
- Field calculation in cylindrical and cartesian coordinates
  - Fields of 0.1mm resolution can be calculated in roughly 1min on a single core (1.5GB/field for 3D structure)
- Crystal effects (axes, trapping) are included
- Electronic response can be implemented
- Implemented in C: Library can be used with ROOT, etc.

**Validation of electric field simulation:**

- Field solving with successive over-relaxation (SOR), a widely used method
- Comparison between cylindrical and cartesian method: Excellent agreement
- Comparison between different programs: In agreement

**Validation of pulse simulation:**

- Previous validation by AGATA collaboration
- Continues use by AGATA for position reconstruction within their germanium array
- Ongoing investigation together with HEROICA $^{241}$Am surface scans
Capacitance of detectors:

- The definition of the capacitance is given by:

\[ C = \frac{Q_f}{V} \]  

(1)

with \( Q_f \) the amount of free charge in the electrodes and \( V \) the potential difference between the electrodes.

- Maxwell's equations can be used to calculate the amount of charge in the electrodes:

\[ \int_{\partial \Omega} \mathbf{D} \cdot d\mathbf{S} = Q_f \]  

(2)

- The potential difference is simply the applied voltage.

- Hence the capacitance can be calculated from the calculated fields.