BEGe pulse shape simulation

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Outline

1. **The simulation**
    - I. The dynamics of electrons and photons
    - II. Signals induced by the charge motion inside the detector
    - III. The total charge pulse and the preamplifier response
2. **Validation of the simulation**
3. **MSE and SSE simulated signals**
4. **Summary**

The simulation structure

I. The dynamics of electrons and photons (MaGe)

<– the production processes of charged particles and photons
–> the position and the type of the interaction with the germanium crystal
–> the energy loss in each interaction

II. Signals induced by the charge motion inside the detector (MGS)

<– interaction coordinates
–> trajectories
–> signal induced on the electrodes

III. The total charge pulse and the preamplifier response

<– the energy loss in each interaction
<– the signals induced by each interaction
<– the preamplifier transfer function (PTF)
–> the total charge pulse convolved with the PTF

II. Signals induced by the charge motion inside the detector - Trajectories

Mobility Model

$$\mathbf{v}_h = \mu_h(\mathbf{r}, \mathbf{E}) \cdot \mathbf{E} \qquad \mathbf{v}_e = \mu_e(\mathbf{r}, \mathbf{E}) \cdot \mathbf{E}$$

- Electron mobility [L. Mihailescu]
- Hole mobility [B. Brynell]

Field Computation

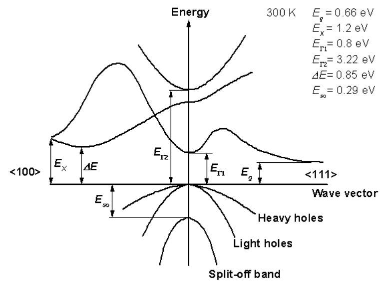
$$\nabla^2 \phi(\mathbf{r}) = -\frac{\rho(\mathbf{r})}{\varepsilon} \rightarrow \mathbf{E}(\mathbf{r}) = -\nabla\left(\varphi(\mathbf{r})\right)$$

- cathode at 0 V, anode at 3500 V
- vacuum grounded chamber
- detector fully depleted: $\rho(\mathbf{r}) = eN_A(\mathbf{r})$

Trajectory Computation

$$\mathbf{r}(t + \Delta t) = \mathbf{r}(t) + \mathbf{v}(\mathbf{r}(t)) \cdot \Delta t$$

where $\Delta t = 1$ ns



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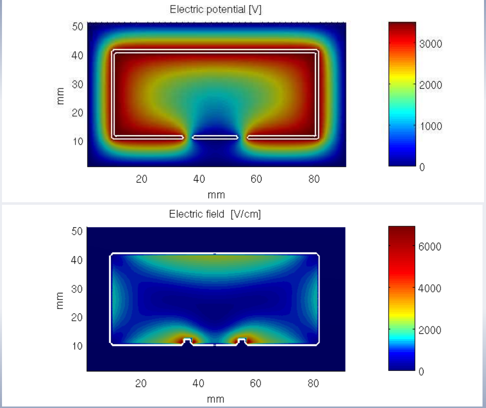

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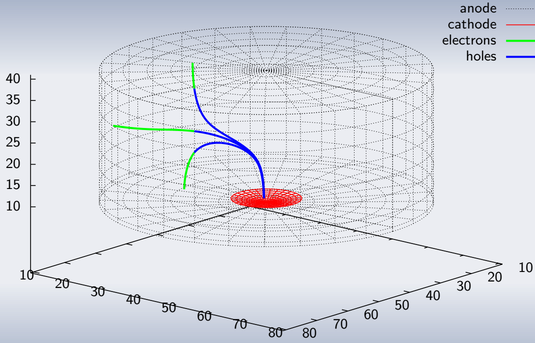


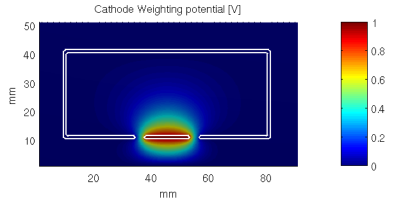
II. Signals induced by the charge motion inside the detector - Signal induced on the electrodes

Signal induced on a electrode

Shockley-Ramo Theorem :

$$Q(t) = -q\phi_w(\mathbf{r}(t))$$

where $\phi_w(\mathbf{r}(t))$ is the weighting potential.



The **weighting potential** is defined as the electric potential calculated when the considered electrode is kept at a unit potential, all other electrodes are grounded and all charges inside the device are removed.

III. The total charge pulse and the preamplifier response

Preamplifier transfer function

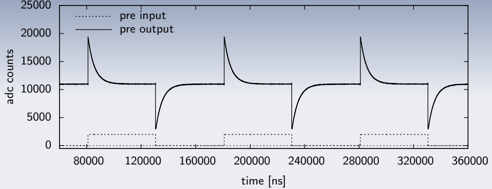
the averaged output pulses is differentiated by simply shifting the signal by one sample and subtracting it from the original signal

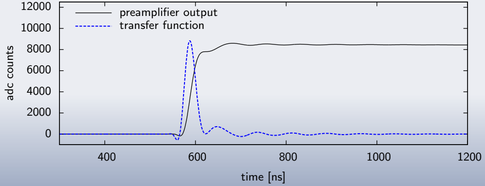
Total charge pulse and convolution with the PTF

– the total charge pulse of a SSE is the sum of the electron pulse and the hole pulse
– the total charge is convolved with the experimental transfer function

MSE

the total charge pulse of a MSE is the sum of the SSE signals weighted by the energy transfered in each interaction





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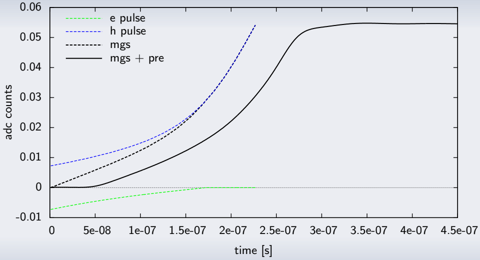

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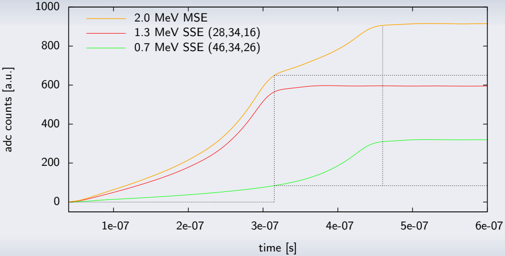


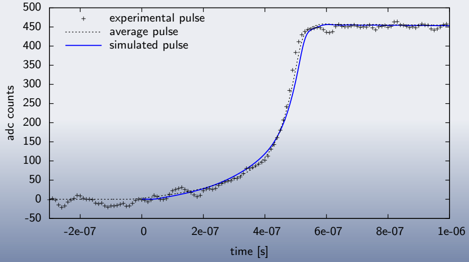
The validation measurements and the Averaging algorithm

The validation was carried out by comparing directly the simulated and the experimental signals:

- ^{241}Am colimated source ⇒ well localized events close to the detector surface;
- $\sim$ 600 s acquisitions for each position
- averaging up the experimental signals ⇒ very low noise

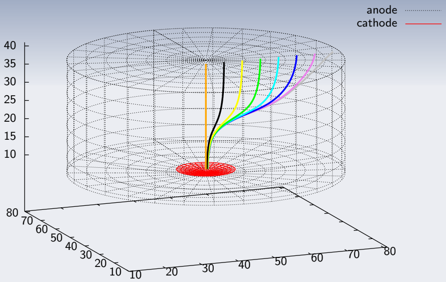
The averaging algorithm steps:

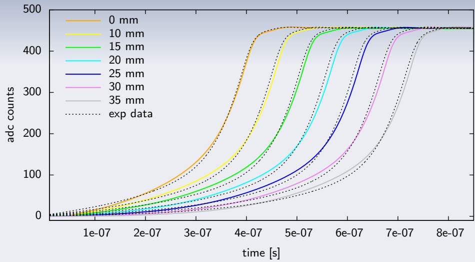
1. the experimental signal (sampled at 10 ns) is resampled at 1 ns interpolating the original points with a linear function;
2. the resampled signal is fitted with the average in order to obtain the best possible time alignment;
3. if the average rms is minor than the threshold value, the resampled and shifted signal is accepted in the average.



Radial scanning

–> ^{241}Am source –> 2 mm collimator –> 600 s acquisitions for each position





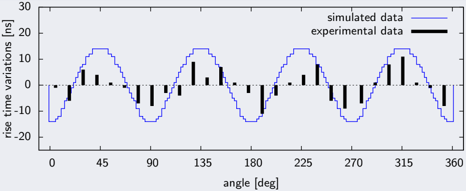
The holes are dragged to the center of the detector and then drift to the p+ contact with a common trajectory

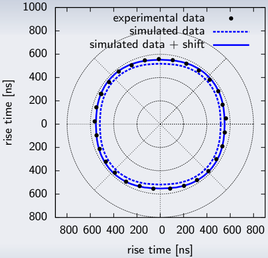
⇒ Significant differences are expected to occur only in the first rising part of the pulses

Circular Scanning

–> ^{241}Am source –> 1 mm collimator –> 500 s acquisitions for each position

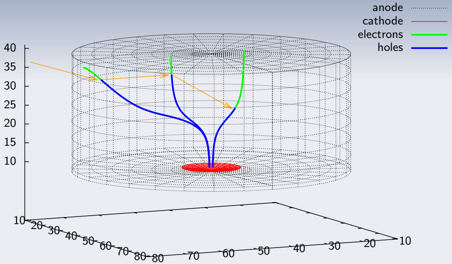
We study the rise time as a function of the angle.
–> To observe variations we used the rise time between 1% and 90%

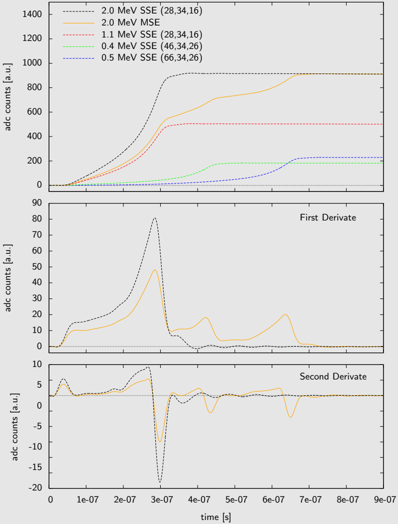




Although the experimental data show a behaviour coherent with the simulation, the agreement is only qualitative.
⇒ the result is remarkable taking into account the problems related to the identification of the time corresponding to the 1% of the maximum amplitude

MSE vs SSE





SSE → 2 MeV

MSE → 0.5 MeV+0.4 MeV+1.1 MeV

Summary

Results:

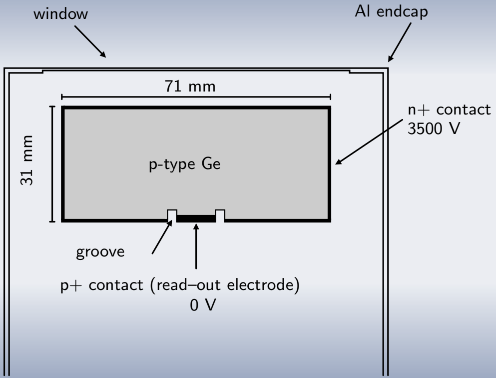
- The simulated data show a good agreement with the average experimental signals;
- we have achieved a deeper insight into the peculiar shapes of the BEGe detector signals and the time dependence of the pulses from the interaction position;
- a preliminary study of the BEGe pulse shape discrimination performance was carried out by using the simulation providing excellent results.

Future works:

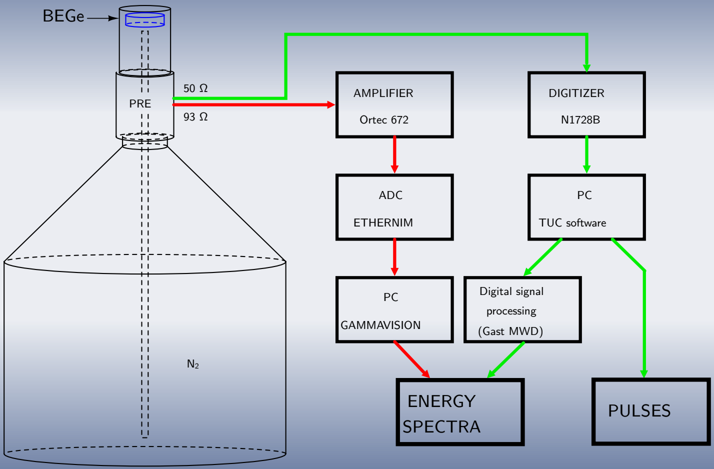
- fully validate the simulation by performing a inner scanning of the detector;
- include in the MAGE simulation a library of the simulated pulses;
- investigate the BEGe geometry by studying which are the geometry parameters that provide the most accurate pulse shapes.

backup slides

BEGe detector

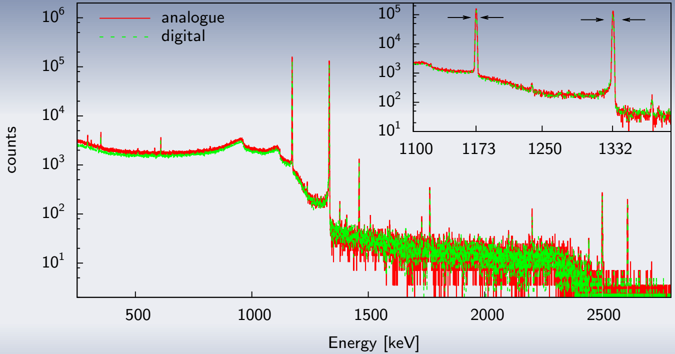


DAQ systems



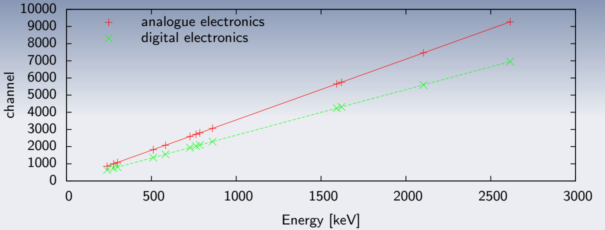
BEGe
PRE
50 Ω
93 Ω
N$_2$
AMPLIFIER
Ortec 672
DIGITIZER
N1728B
ADC
ETHERNIM
PC
TUC software
PC
GAMMAVISION
Digital signal
processing
(Gast MWD)
ENERGY
SPECTRA
PULSES

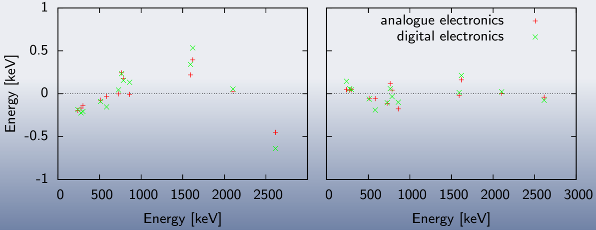
Characterization measurements - Resolution



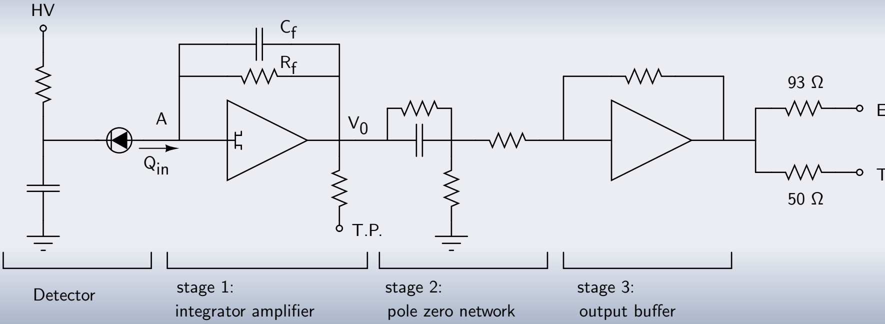
Energy [keV]	Analogue DAQ system		Digital DAQ system	
	peak counts	FWHM [keV]	peak counts	FWHM [keV]
1173	259899 (510)	1.529 (0.002)	224857 (506)	1.520 (0.002)
1332	225023 (474)	1.617 (0.002)	200137 (518)	1.607 (0.003)

Characterization measurements - Linearity

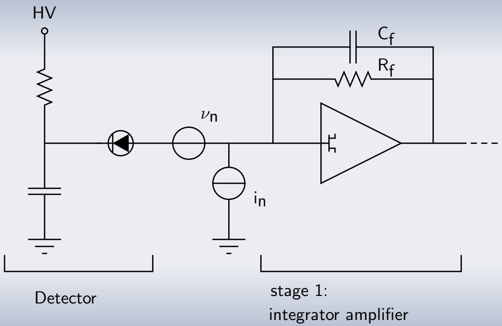




Characterization measurements - Preamplifier



Characterization measurements - Preamplifier noise



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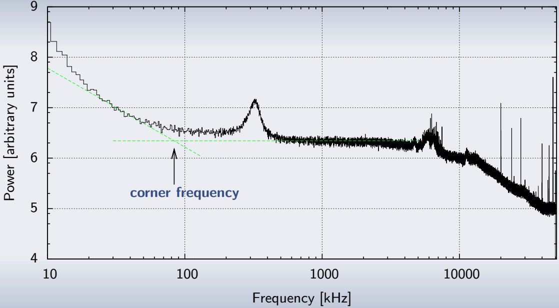
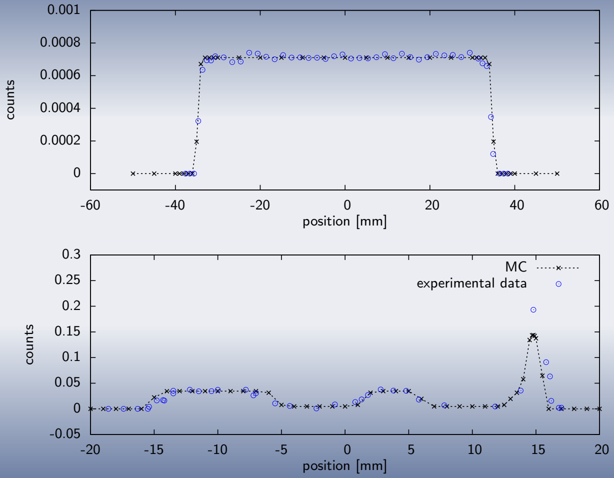
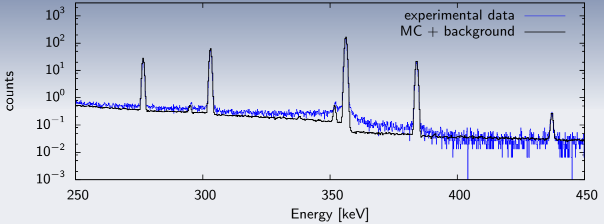
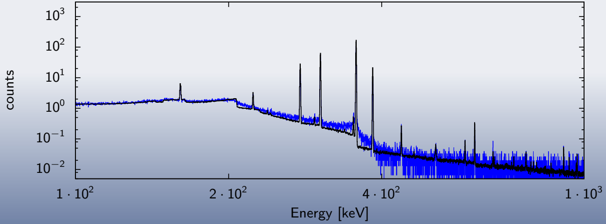


Validation of the MaGe simulation - Absorption



Validation of the MaGe simulation - Barium spectrum





Validation of the MaGe simulation - DL