Simulation and modeling of BEGe detectors for GERDA Phase II

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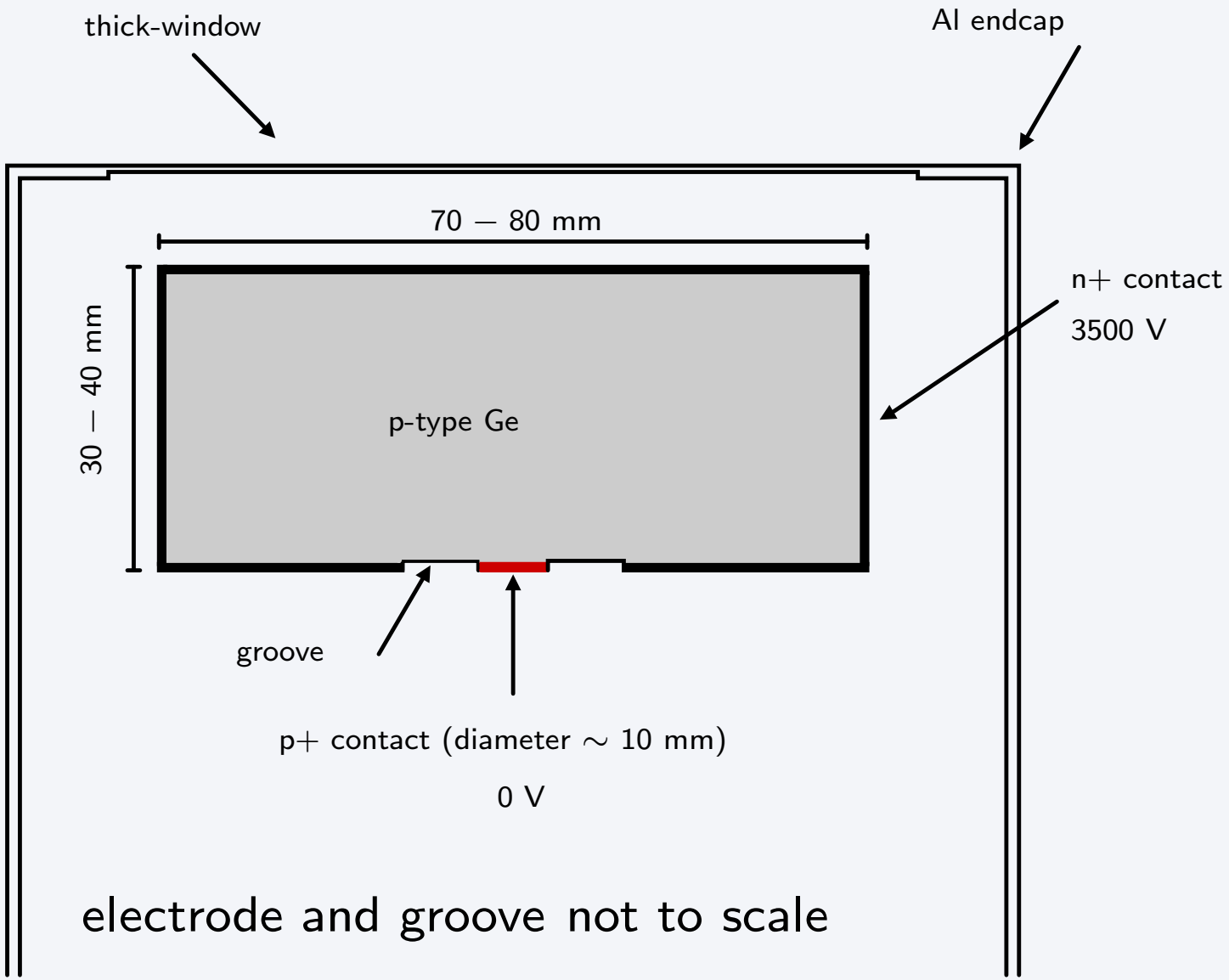
Outline

The BEGe geometry



The structure of the simulation

I. MC simulation

-> coordinates and energy of the hits

II. Signal formation and development

<- coordinate of each hit

-> electron and hole trajectories

-> the signal induced on the point size electrode

III. DAQ simulations

<- energy and signal for each hit in an event

<- the Preamplifier Transfer Function (PTF)

-> each pulse is convolved with the PTF

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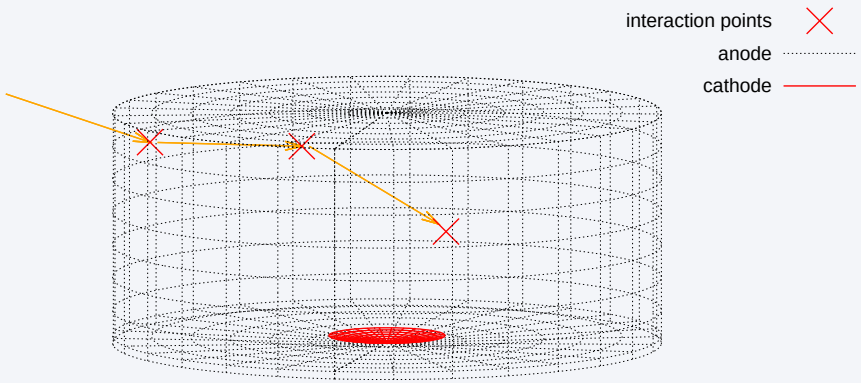

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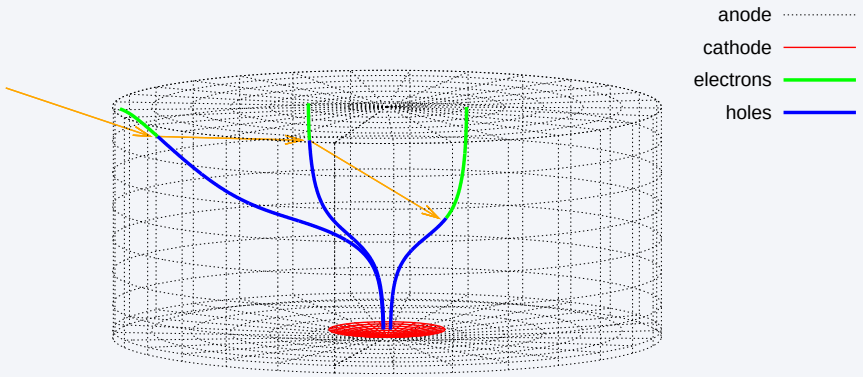

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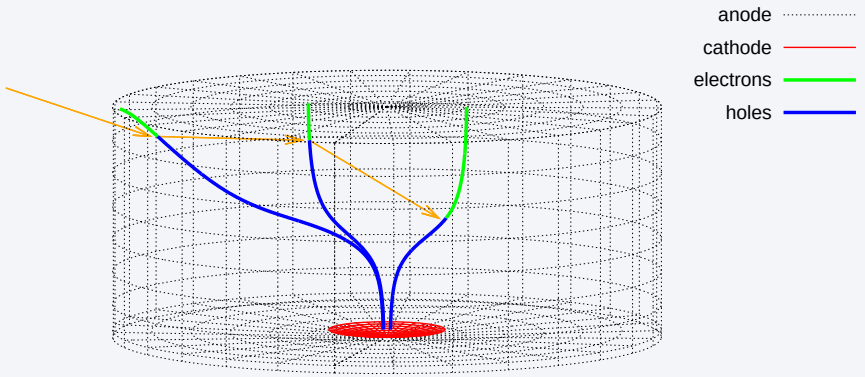

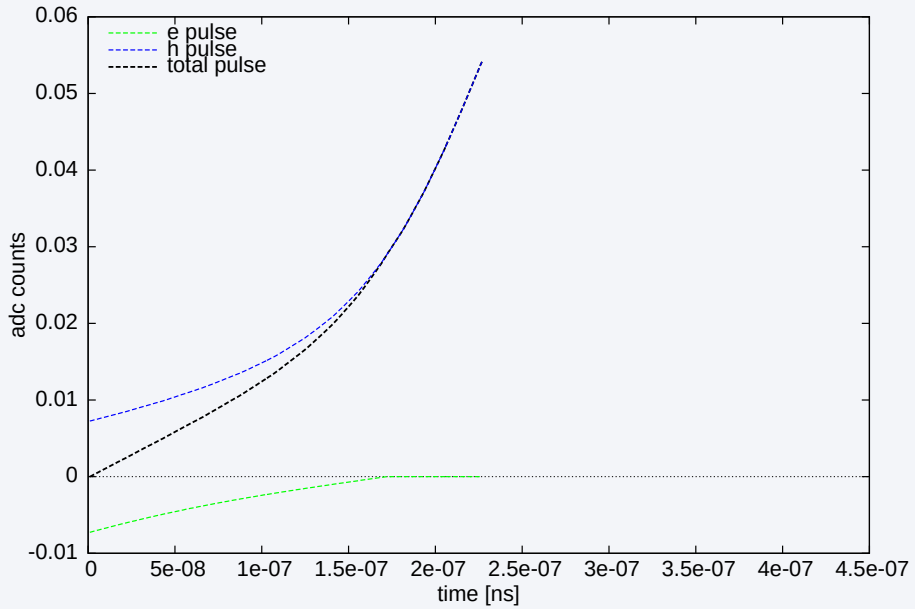

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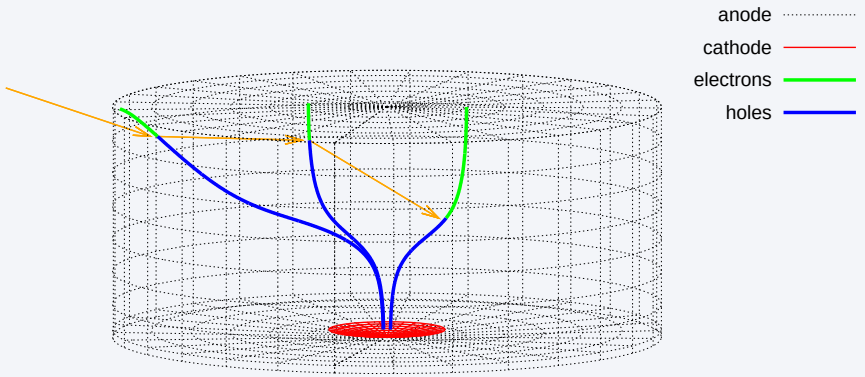

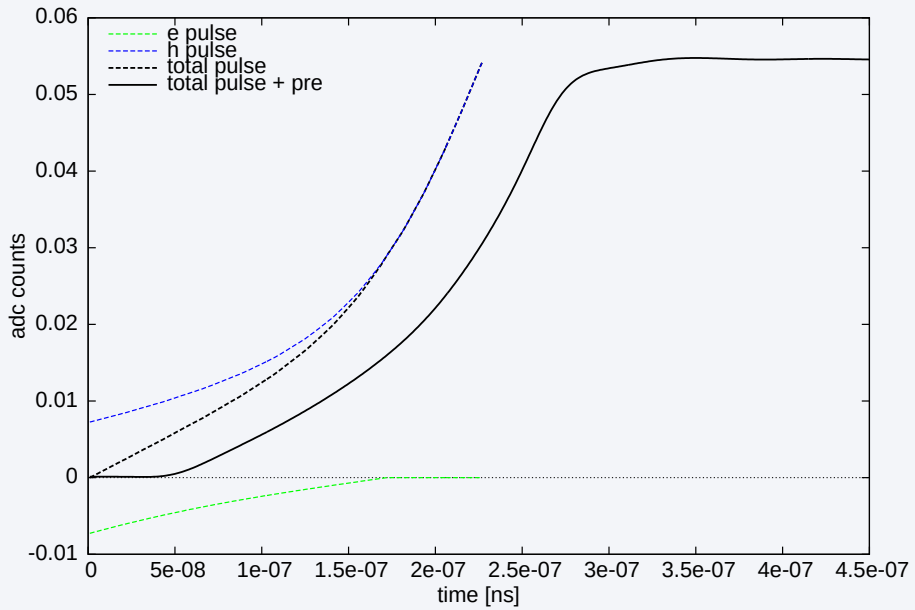

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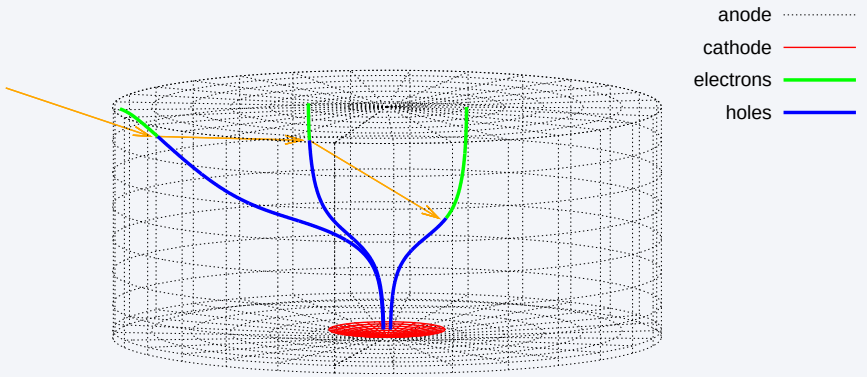

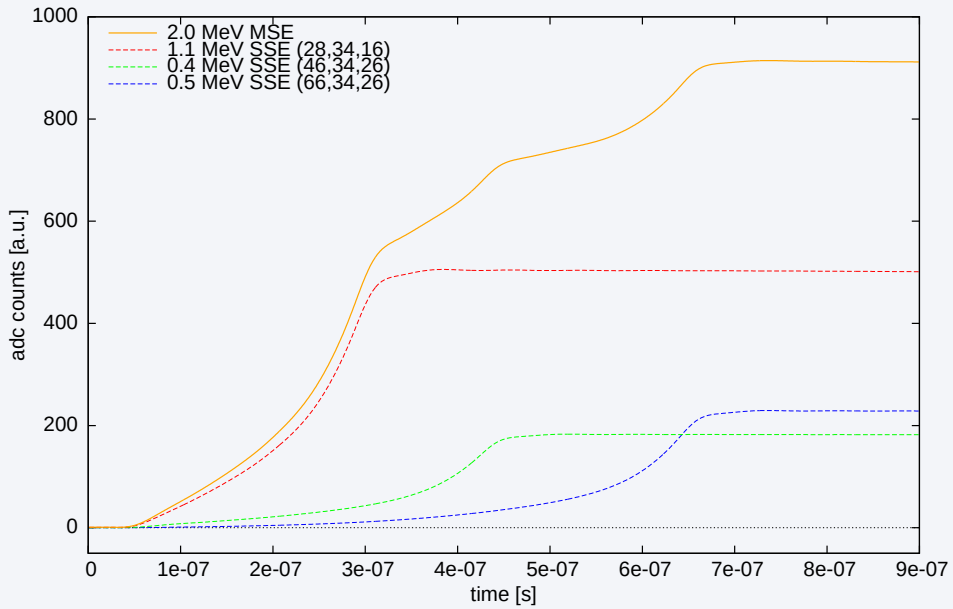

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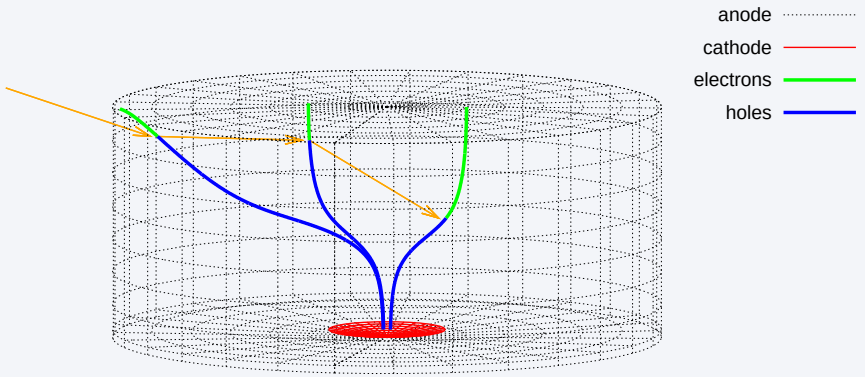
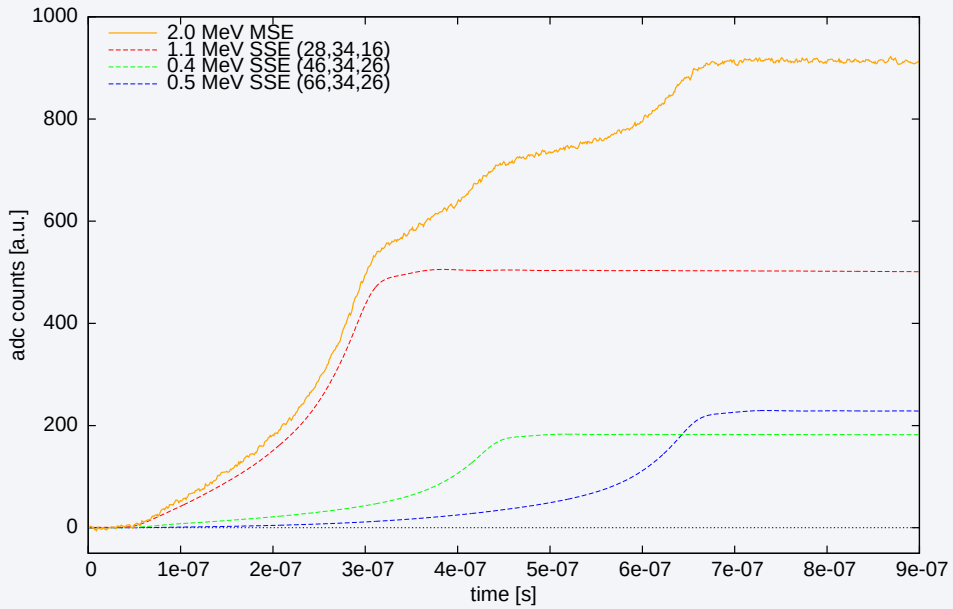
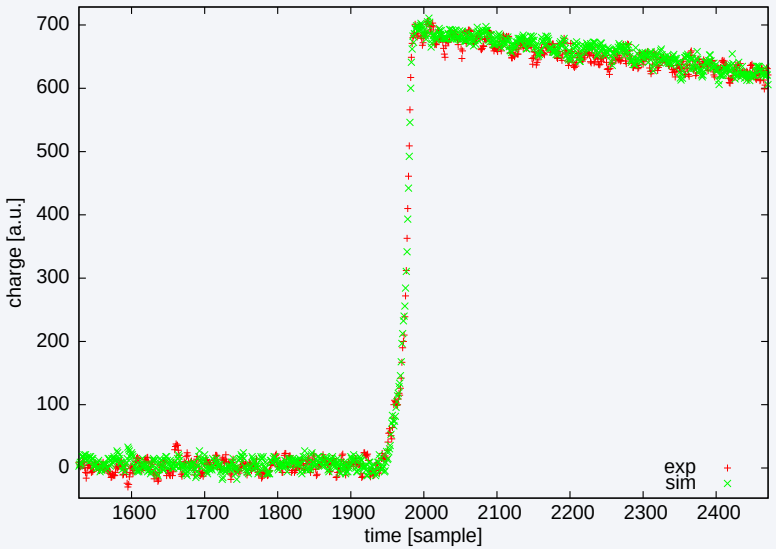


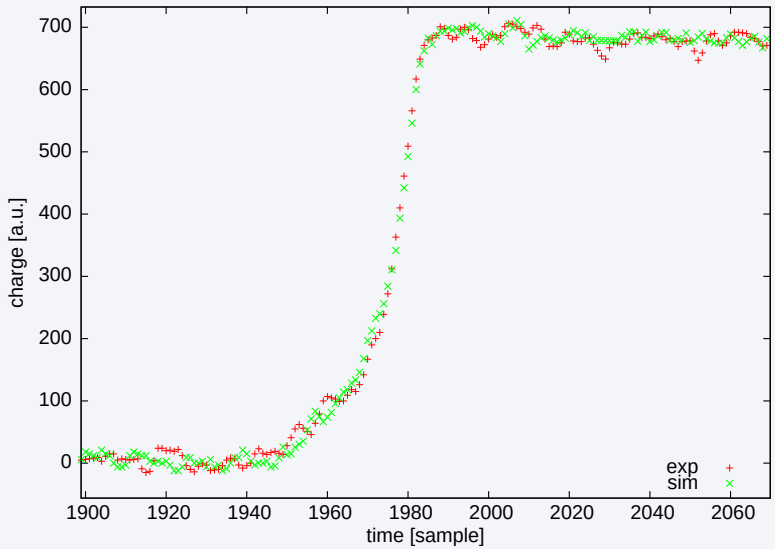


Validation of the PSS

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

- ^{241}Am collimated source $\Rightarrow$ well localized events close to the detector surface;



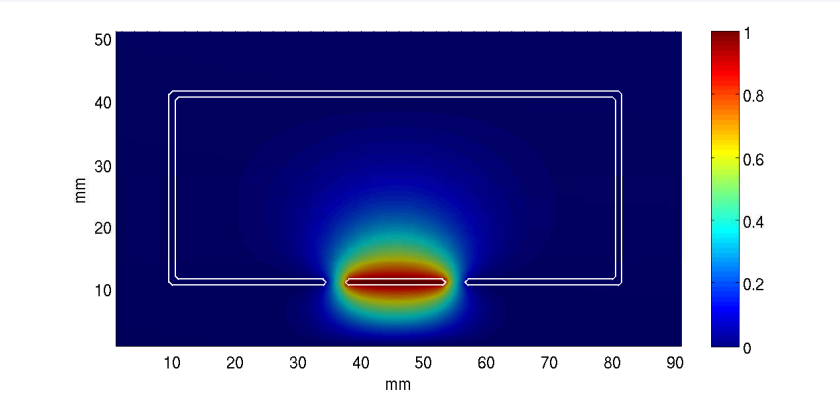


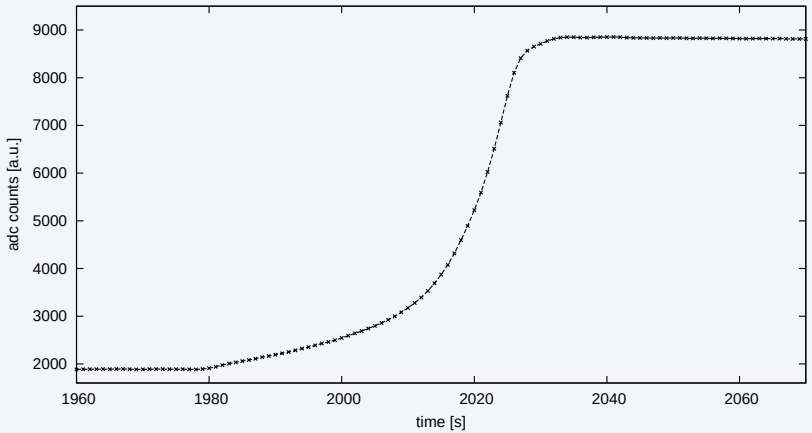
BEGE Charge-signal development

The charge signal is provided by the Shockley-Ramo:

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

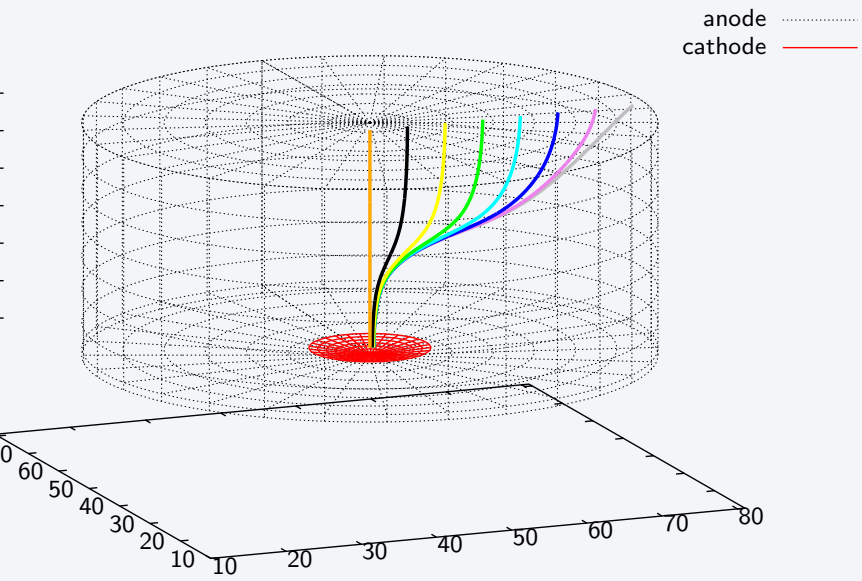
where $\mathbf{r}(t)$ is the position of the charge bunch q at the time t and $\phi_w(\mathbf{r}(t))$ is the *weighting potential* (defined as as the electric potential calculated when the considered electrode is kept at a unit potential, all other electrodes are grounded and all charges inside the device are removed).

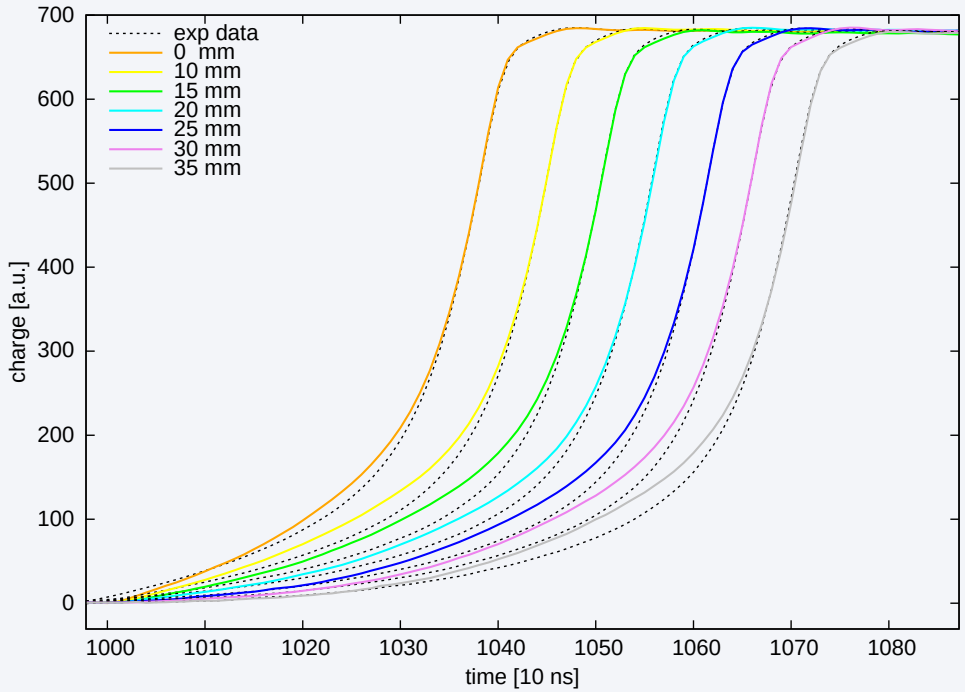




The signal grows slowly at the beginning when the charges are far from the point-size contact. The fast part of the signal starts when the holes are 1 cm far from the point-size electrode.

Pulse shape dependence of interaction position





The hole are collected to the point-size contact along the same trajectories
$\Rightarrow$ the final part of the charge signals is the same

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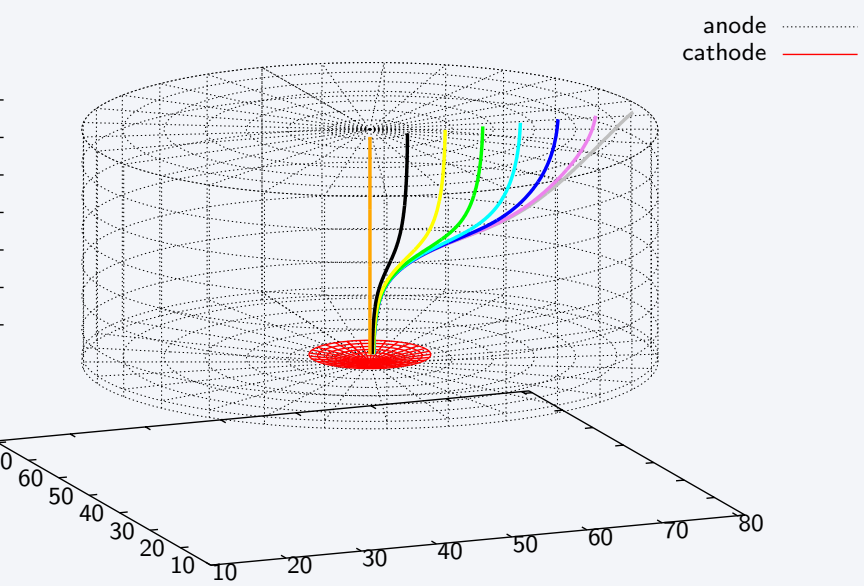

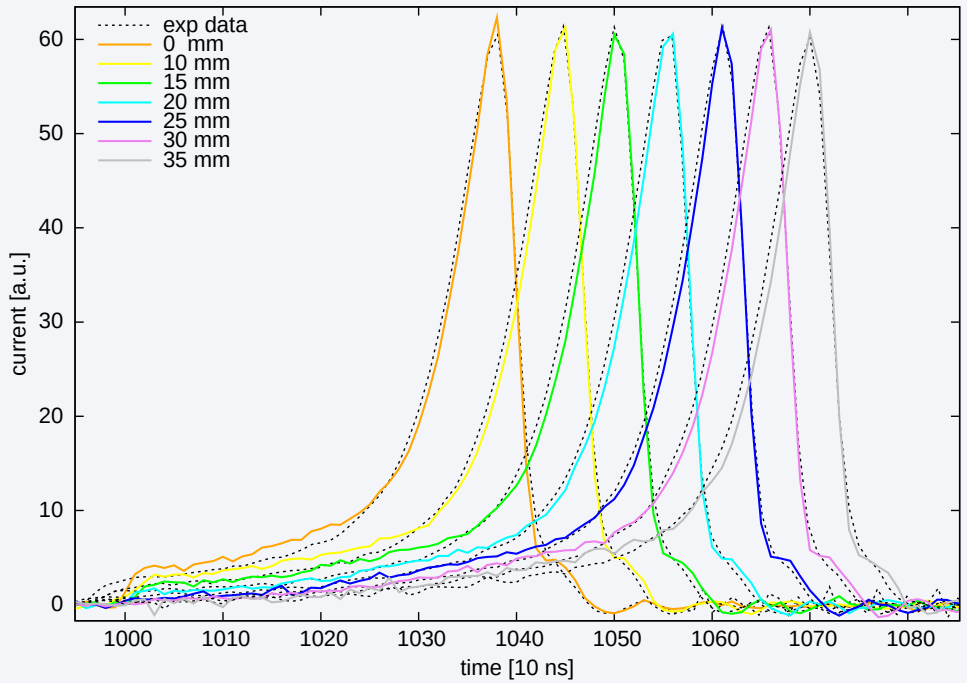

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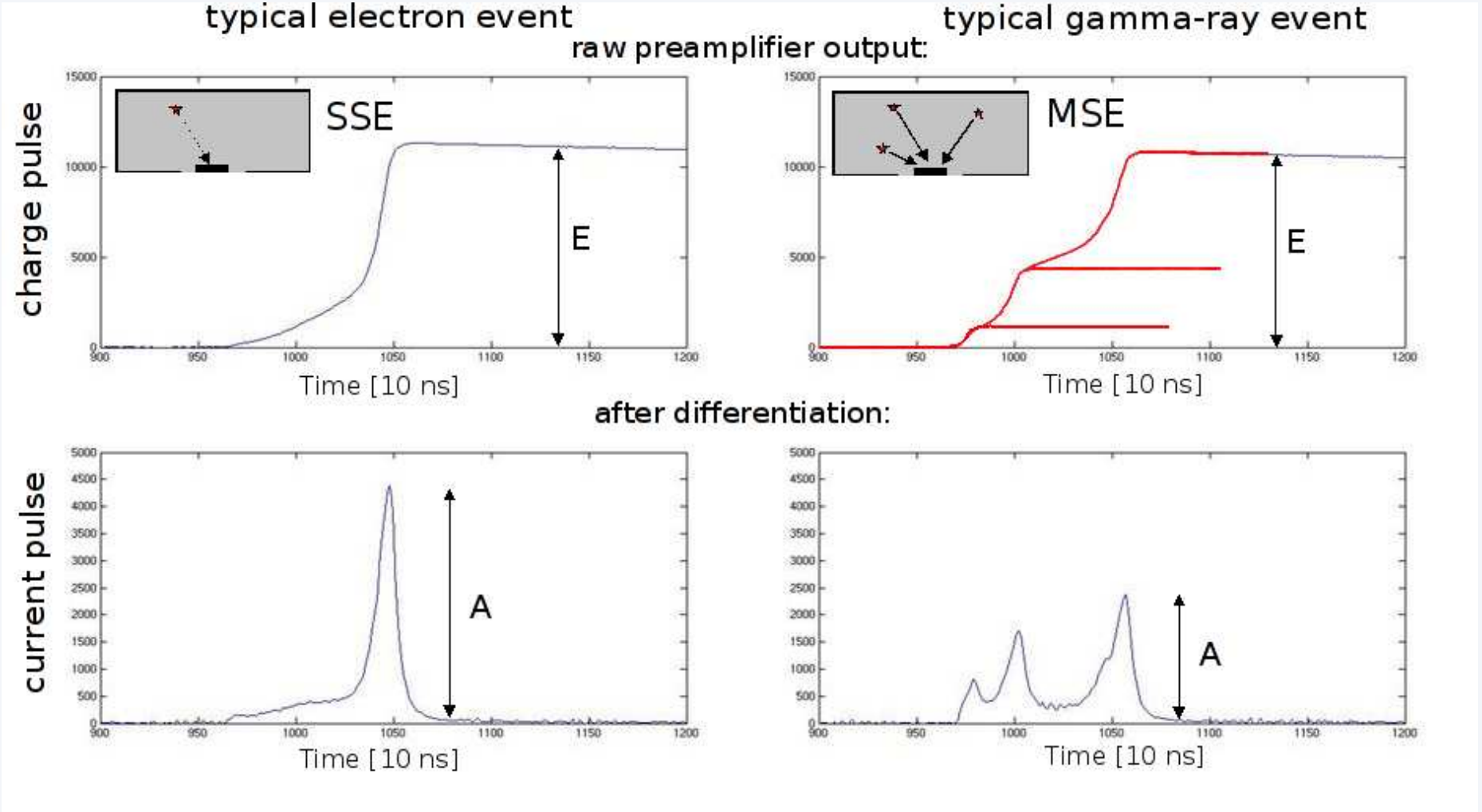
$$Q(t) = -q\phi_w(\mathbf{r}(t)) \Rightarrow I(t) = -\frac{dQ(t)}{dt} = q\frac{d\phi_w(\mathbf{r}(t))}{dt} \Rightarrow I_{max} \propto q$$

PSD: A/E parameter



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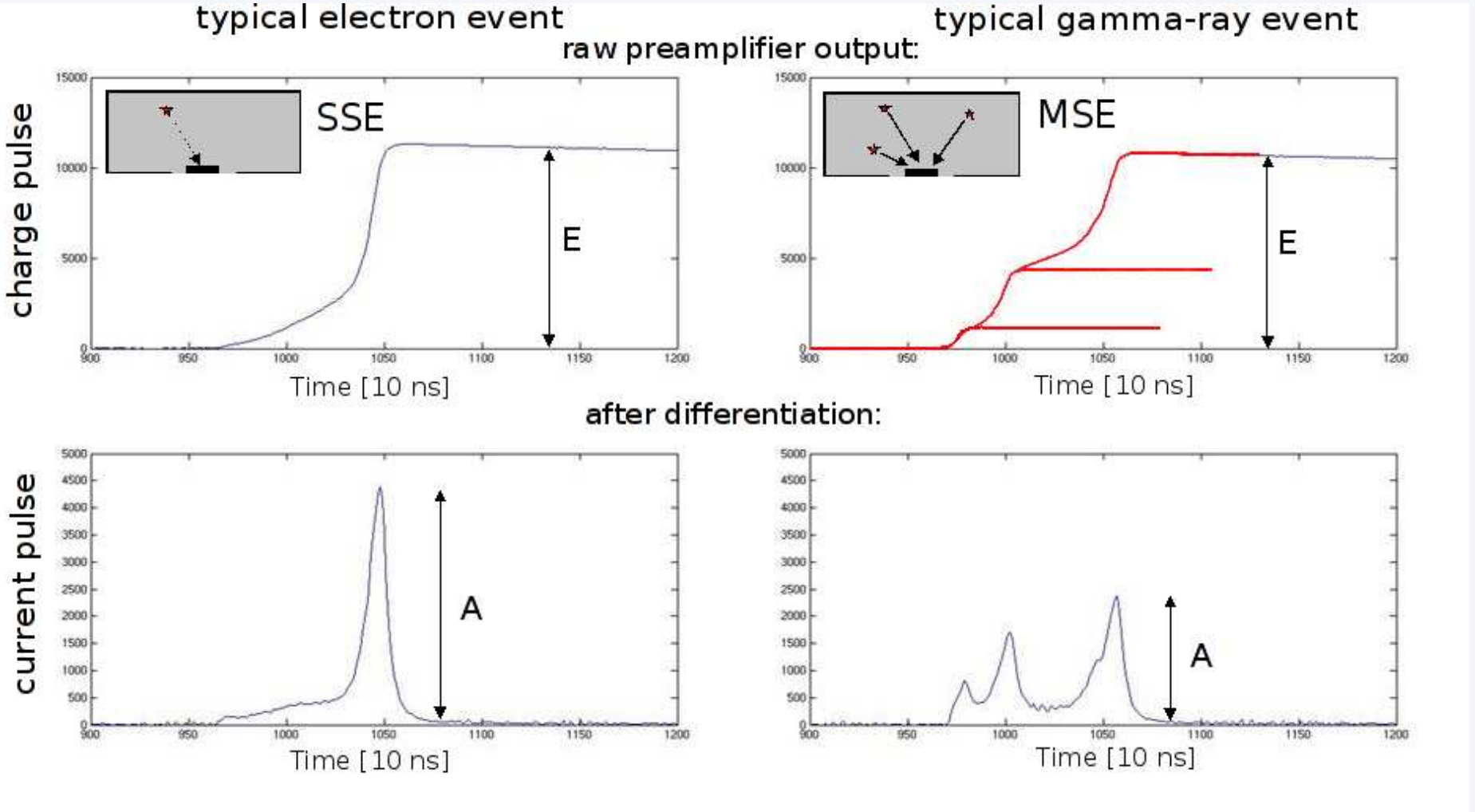

$A_{SSE} \propto q_{tot}$ $E_{SSE} \propto q_{tot}$

$\Rightarrow (A/E)_{SSE} = k$, constant

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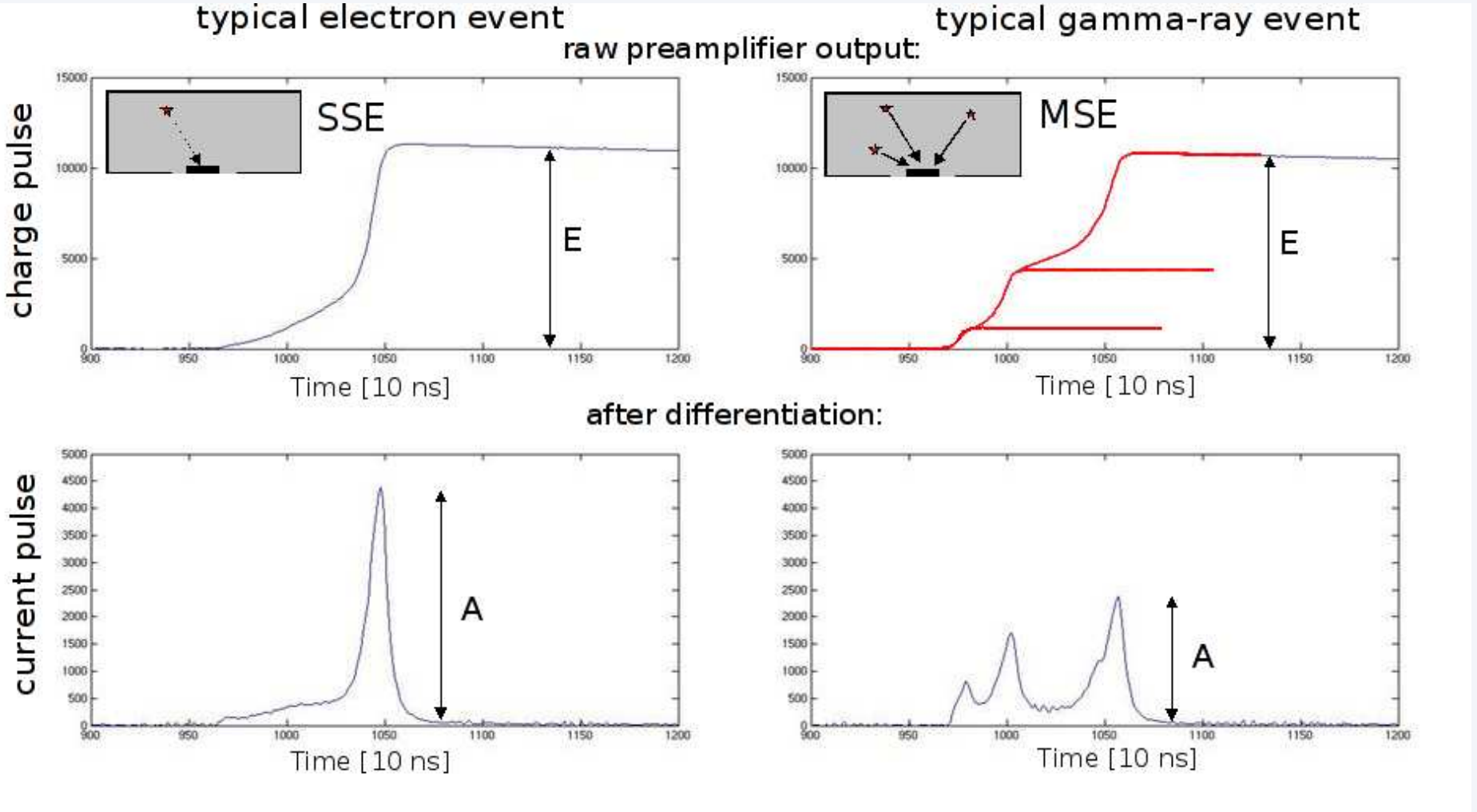

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$\Rightarrow (A/E)_{SSE} = k$, constant

$A_{MSE} \propto q_{SSE_{max}}$ $E_{MSE} \propto q_{tot}$

$\Rightarrow (A/E)_{MSE} < (A/E)_{SSE} = k$

PSD applied to simulated data

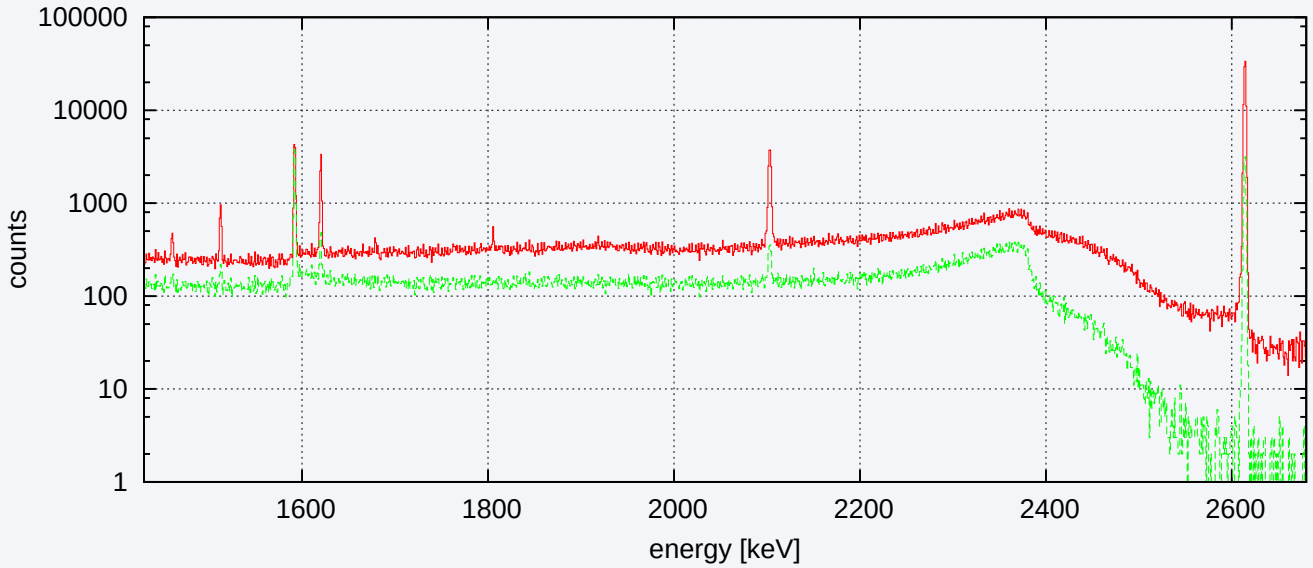
Validate the simulated PSD estimations by comparison with experimental data:

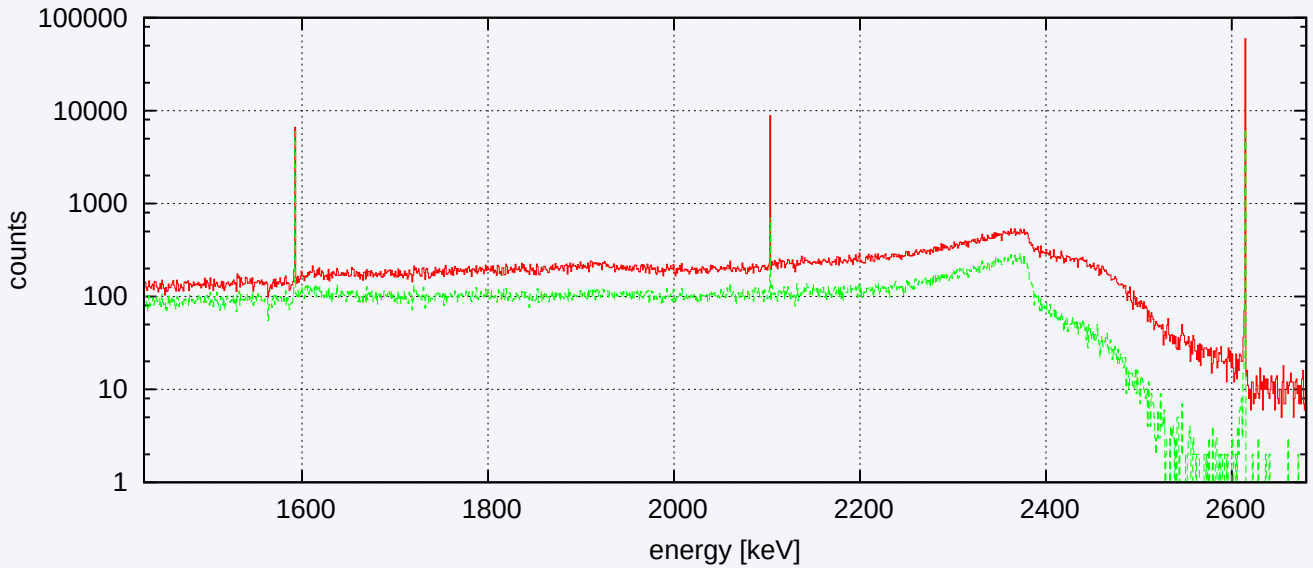
- discrimination results for ^{228}Th and ^{60}Co measurements

Estimation of the rejection performances for internal sources of background:

- acceptance results for $Q_{\beta\beta}$
- discrimination results for ^{68}Ge and ^{60}Co measurements

PSD applied to simulated and experimental data: ^{228}Th





experimental ^{228}Th:

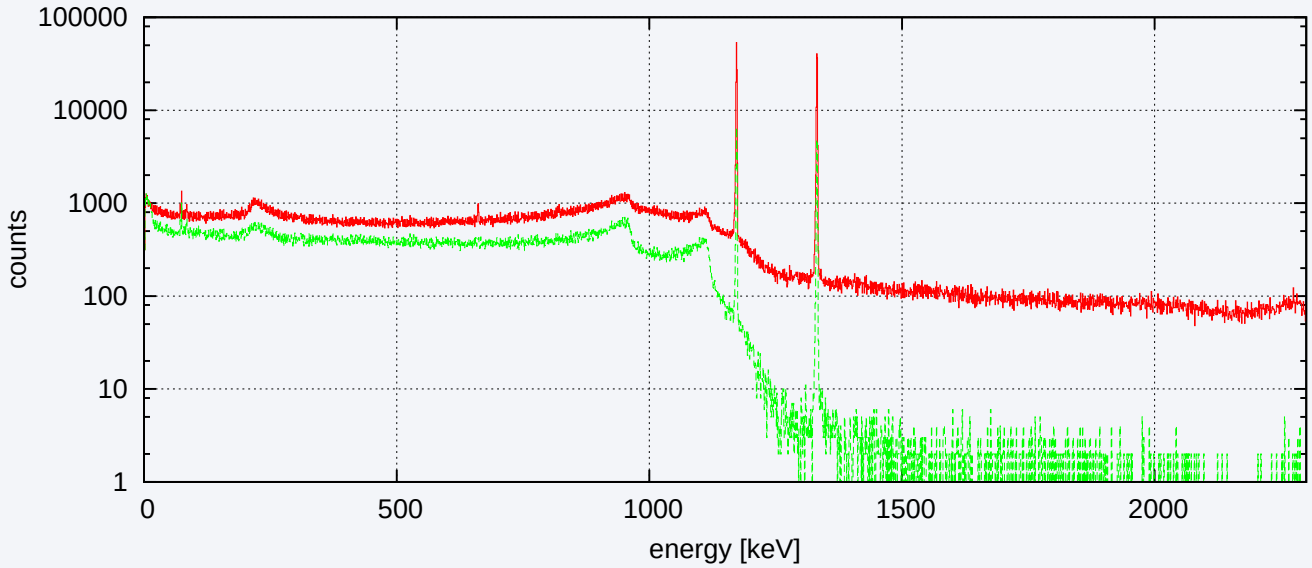
DEP	90%
SEP	7%
FEP	11%
$Q_{\beta\beta}$	52%

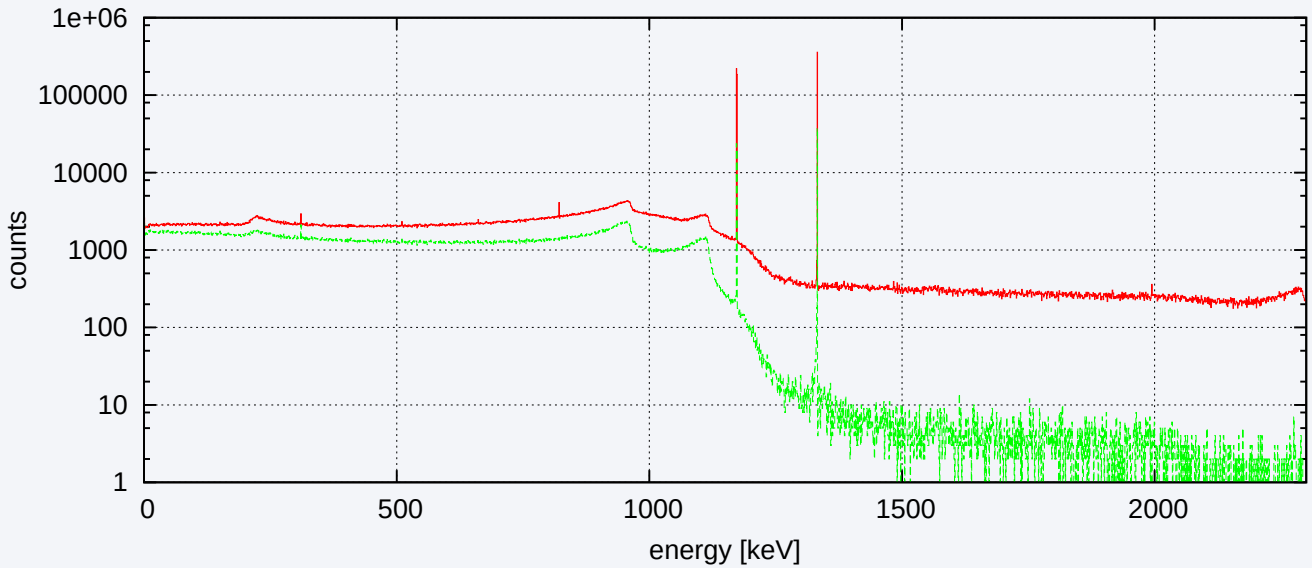
simulated ^{208}Tl (^{228}Th daughter):

DEP	90%
SEP	6%
FEP	9%
($Q_{\beta\beta}$	43%)

shielding not included in the simulation

PSD applied to simulated and experimental data: ^{60}Co





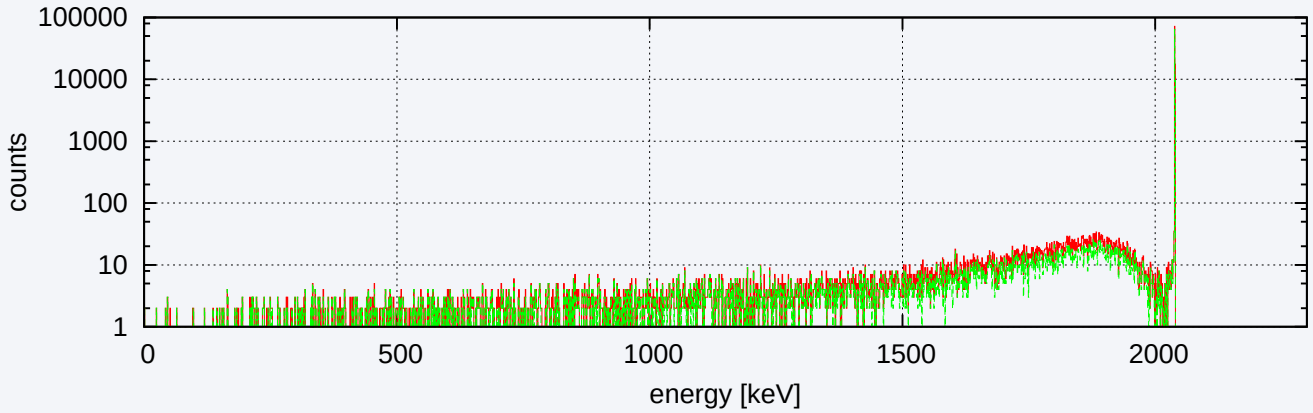
experimental ^{60}Co:

$Q_{\beta\beta}$ 1.2%

simulated ^{60}Co:

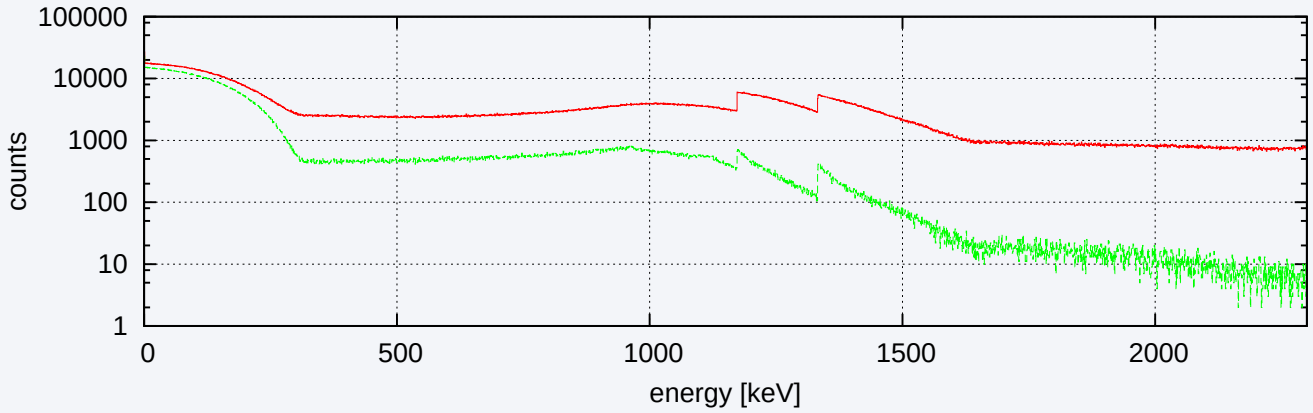
$Q_{\beta\beta}$ 1.0%

PSD of internal background



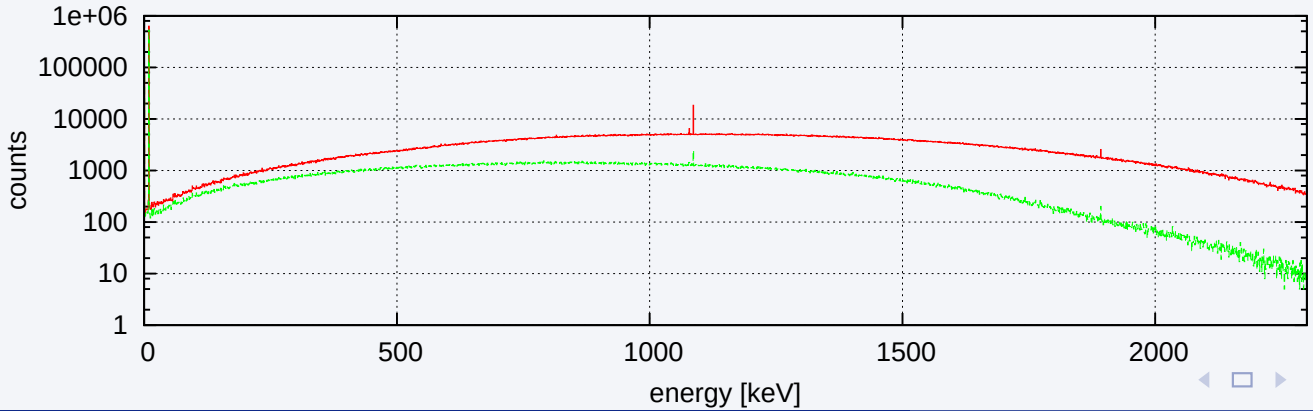
simulated $0\nu\beta\beta$:

$Q_{\beta\beta}$ 85%



simulated ^{60}Co:

$Q_{\beta\beta}$ 1.1%



simulated ^{68}Ge:

$Q_{\beta\beta}$ 5%

Conclusion

Results and future works:

- A complete simulation of the signal formation and development has been developed and used to investigate the the Pulse Shape Discrimination features of BEGe detectors
- for the first time the BEGe PSD rejection performances for internal sources of background were studied and the acceptance is $\sim 1\%$ for ^{60}Co and $\sim 5\%$ for ^{68}Ge.
- keep on studying the impact of the detector parameters on pulse shape discrimination performances and the robustness of A/E method
- use the simulation to improve the PSD efficiency