Segmented Broad Energy Germanium Detectors

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Motivation

Development of segmented Germanium detectors for future low background applications, such as $0\nu\beta\beta$ experiments.

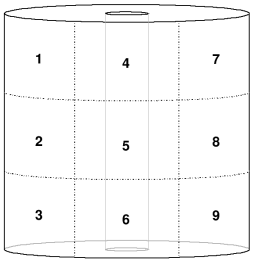
One ton initiative:

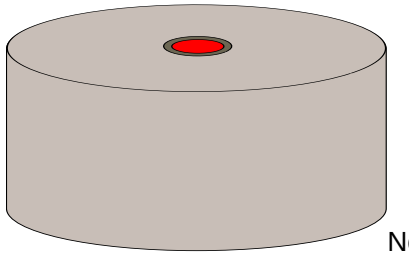
- Increase mass to increase sensitivity
- Reduce background index
- Use intelligent detectors

Can we improve current detector geometries?

Segmentation of germanium detectors are very useful for extracting event topologies.

True-coaxial segmented





Non-segmented BEGe

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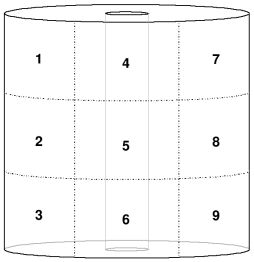
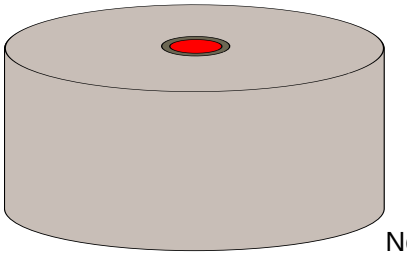
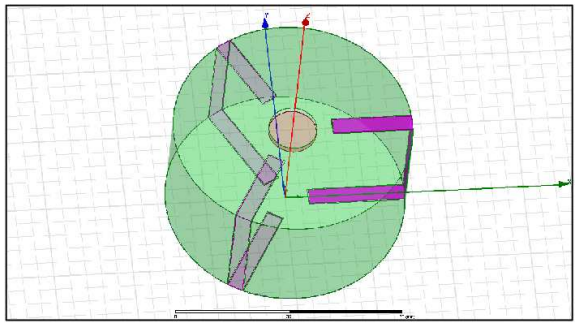




Non-segmented BEGe



Segmented BEGe

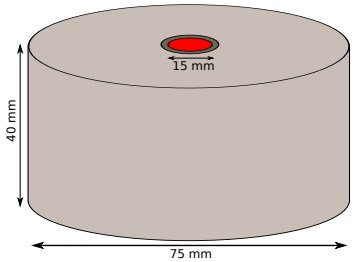
Low capacitance

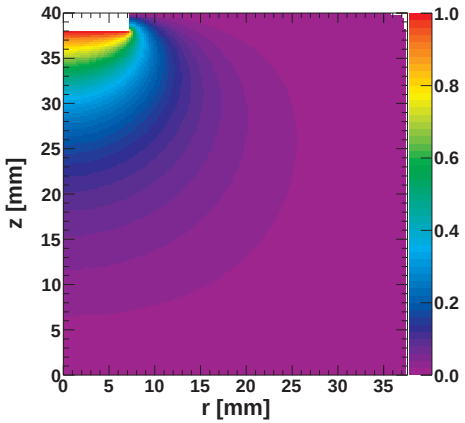
→ Lower threshold

→ Better energy resolution

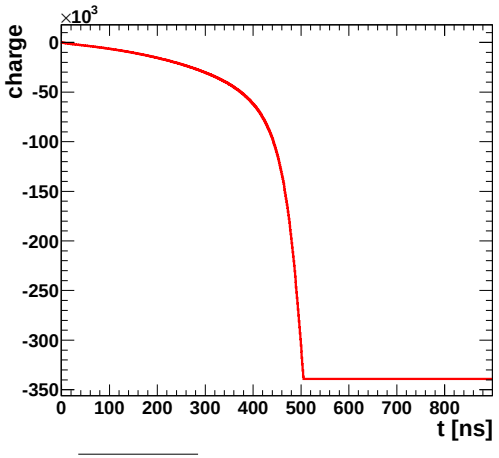
Non-segmented BEGe detectors

BEGe detectors have special field distributions due to their contact geometry.
$\rightarrow$ Improved PSA capabilities.





Weighting potential

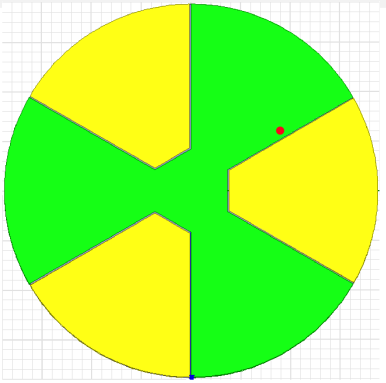


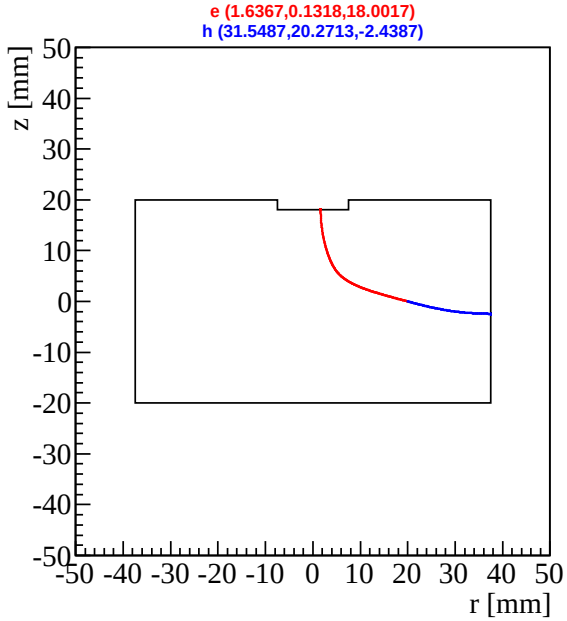
Point contact pulse

Degeneracy in r and ϕ coordinate.

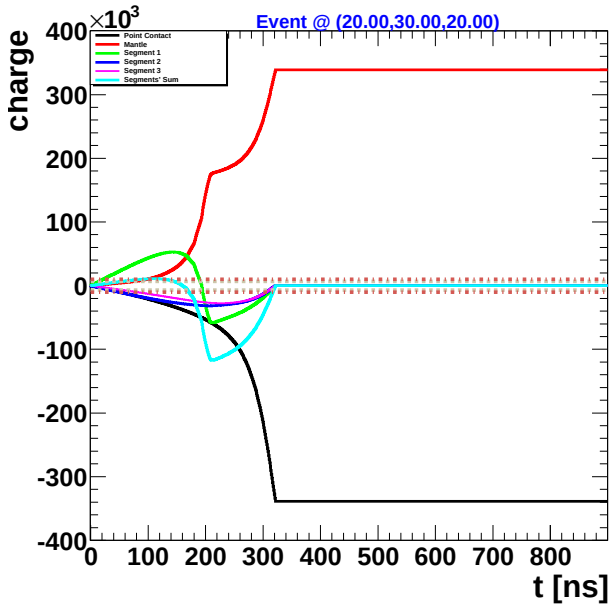
Segmented BEGe detectors

Example: Event located at $r = 20$ mm, $\phi = 30^\circ$, $z = 20$ mm.



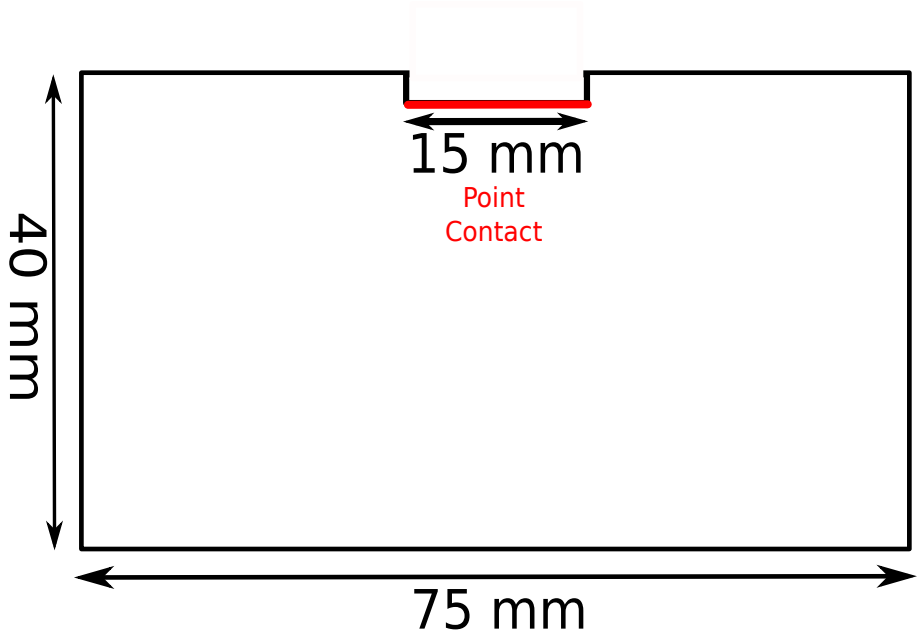


Charge carrier drift.



Pulse waveforms for each electrode.

BEGe's - General design

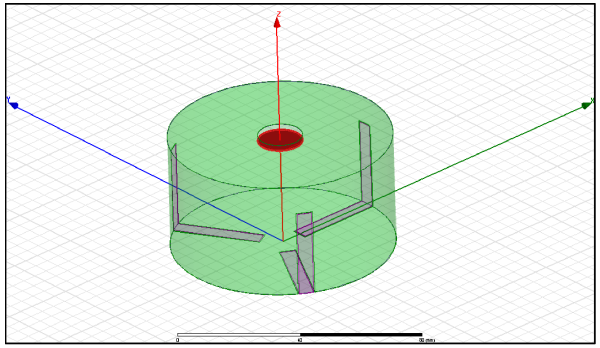
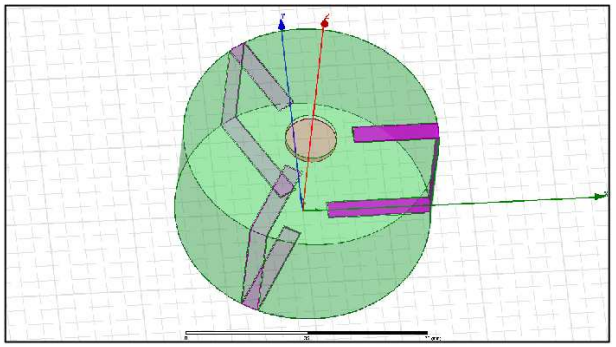
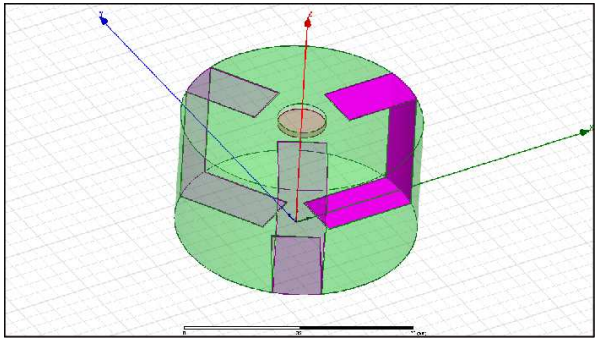
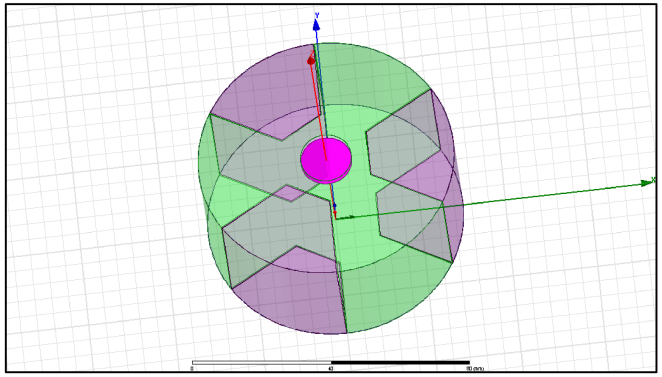
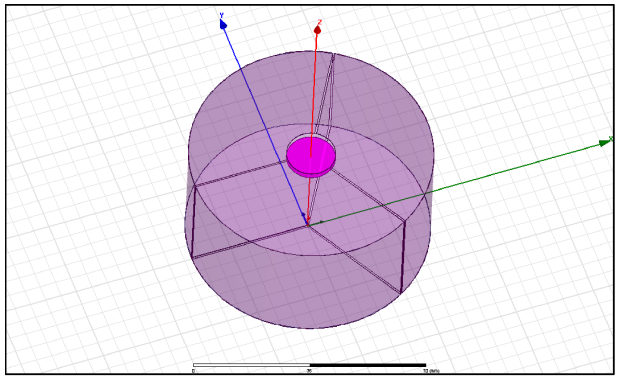


1. Detector dimensions. Height is 40 mm, diameter is 75 mm and point contact diameter is 15 mm.
2. n-type detector.
3. Detector bias is 4500 V.
4. Linear Impurity density. $0.7 \times 10^{10} cm^{-3}$ (bottom) and $1.5 \times 10^{10} cm^{-3}$ (top).

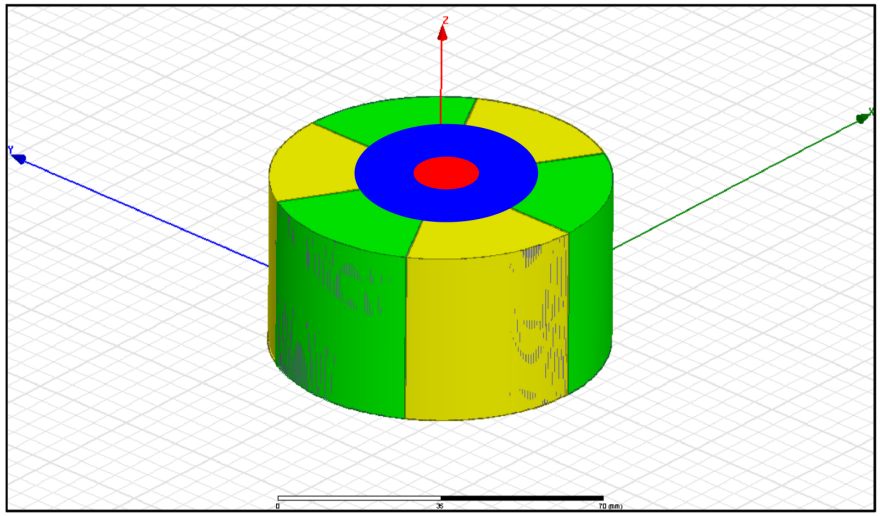
Electrode design and field calculations are done in Maxwell.
Pulse shape analysis performed in MaGe.

Design Evolution

Several designs are considered.

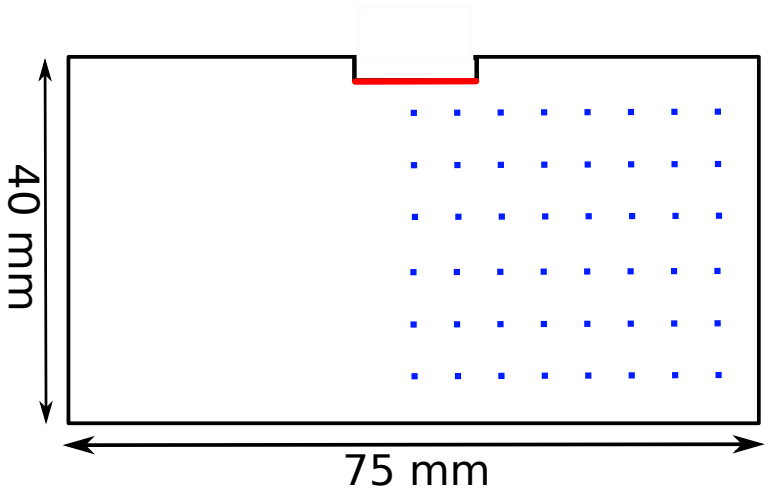






Final design after discussions with CANBERRA



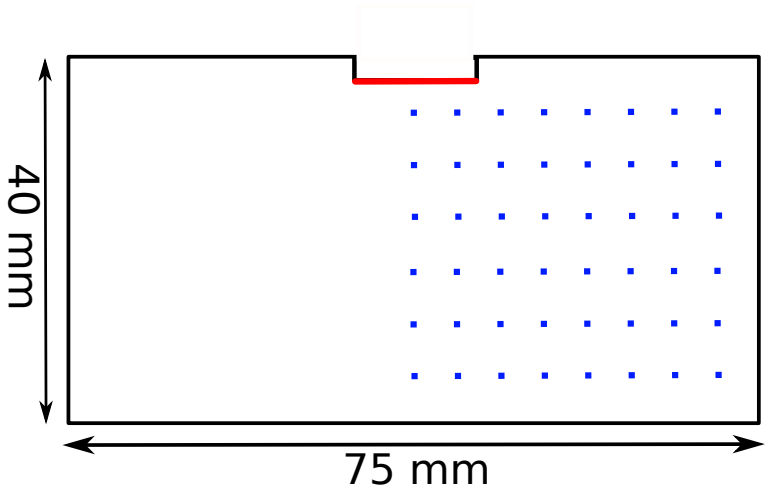
1. Detector dimensions are the same.
2. No groove.
3. Segment width is 40 mm
4. Gap between segments and mantle is 700μm.
5. Length of the segment on top is 18 mm and on bottom is 30 mm.

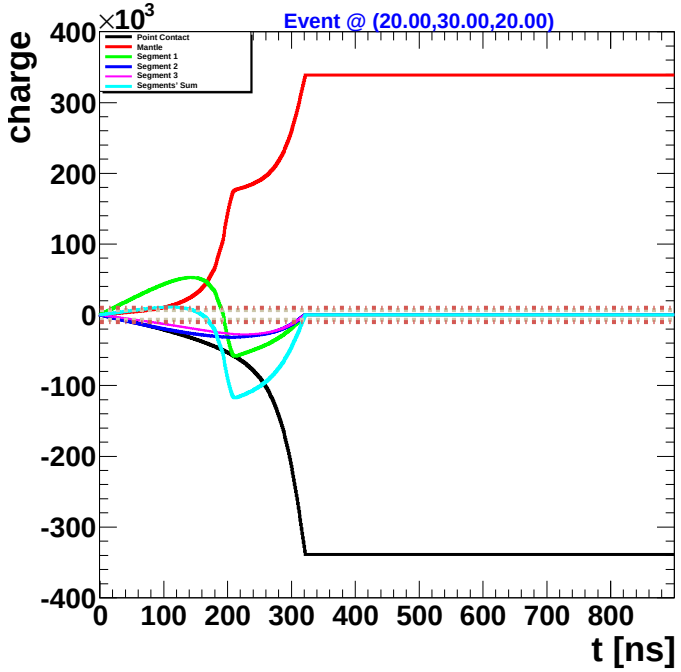
Pulse shapes



1. z from 5 mm to 35 mm in 5 mm steps.
2. r from 0 mm to 36 mm in 4 mm steps.
3. $\phi = 60°$.

Pulse shapes



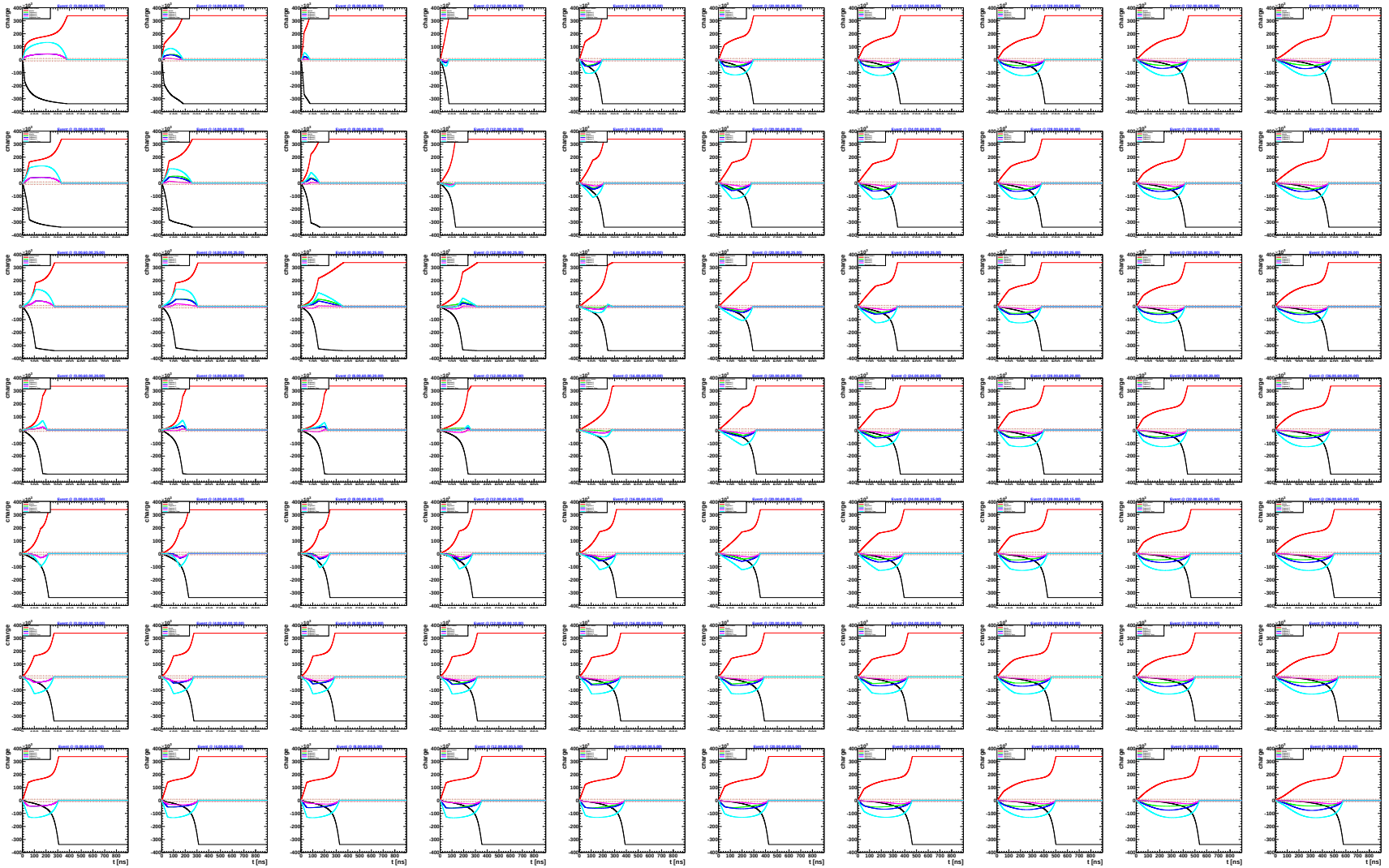


For segment signals most important parameters are

1. amplitude
2. time over threshold

Pulse Shapes

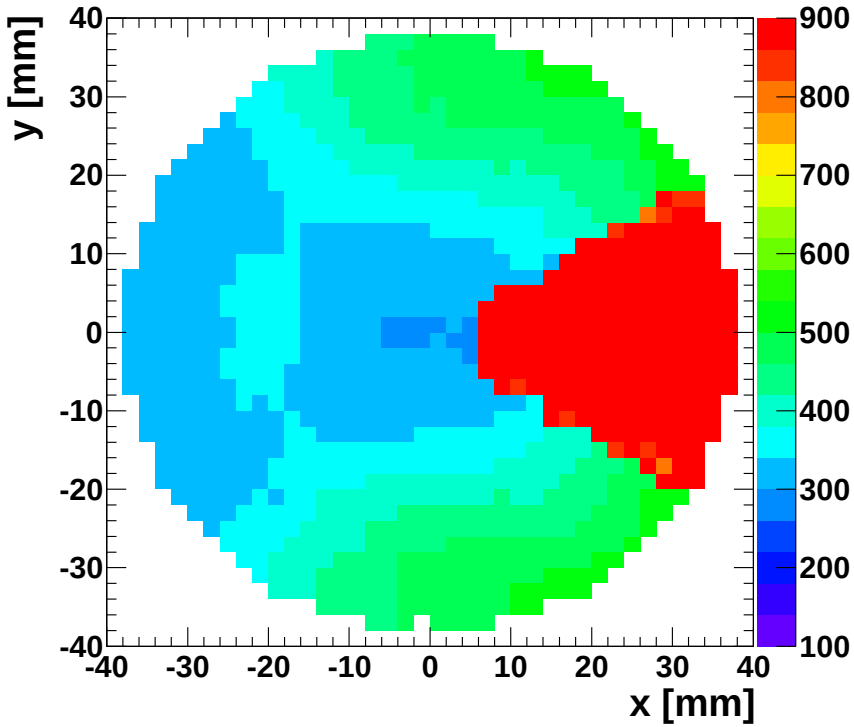
$$\phi = 60°$$

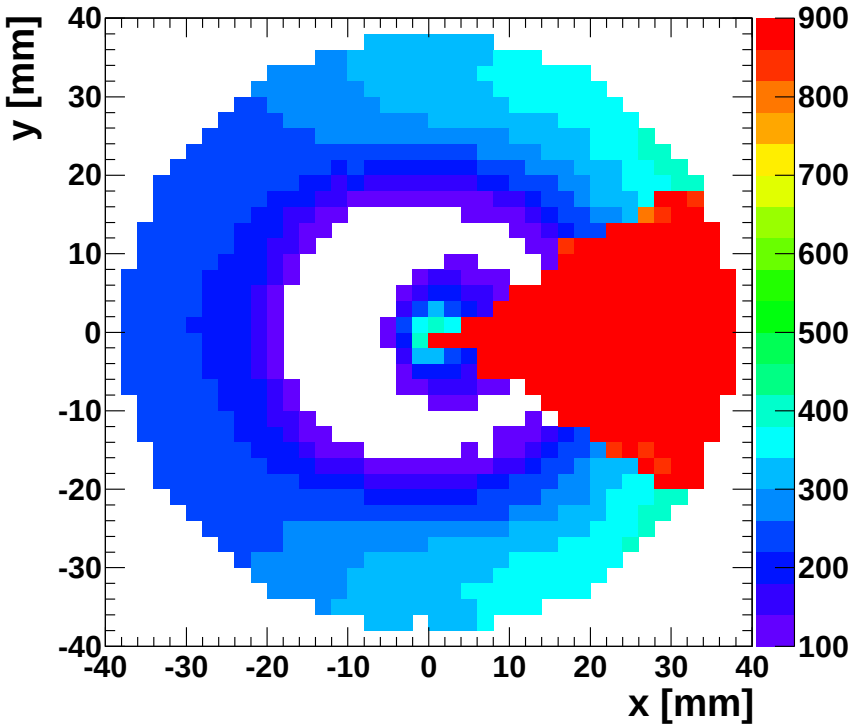


$\uparrow z, \rightarrow r.$

Segment 1 time over threshold

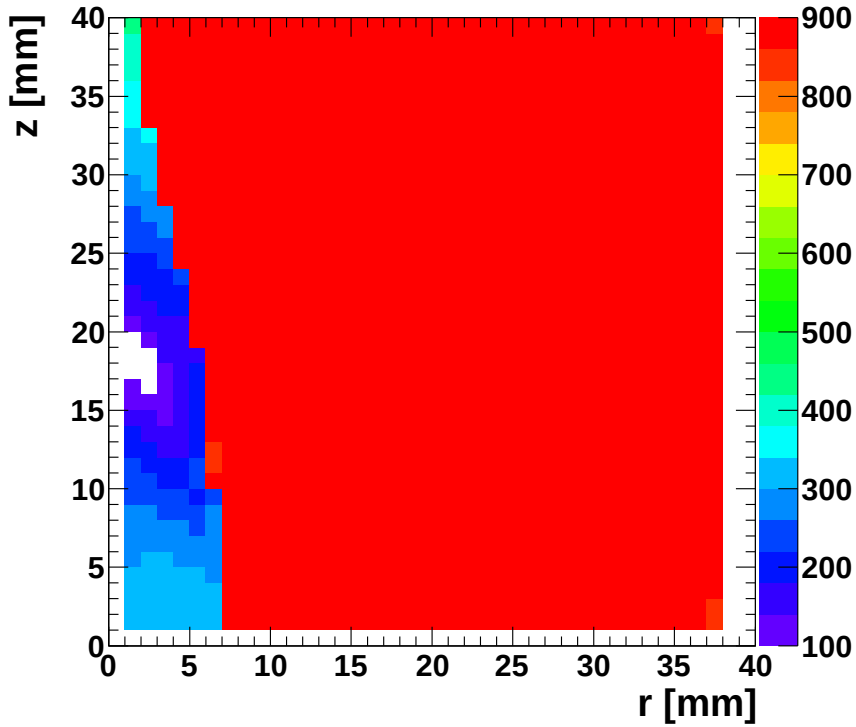
Time over threshold for segment 1 in x-y for $z = 5$mm (left) and $z = 35$mm (right).

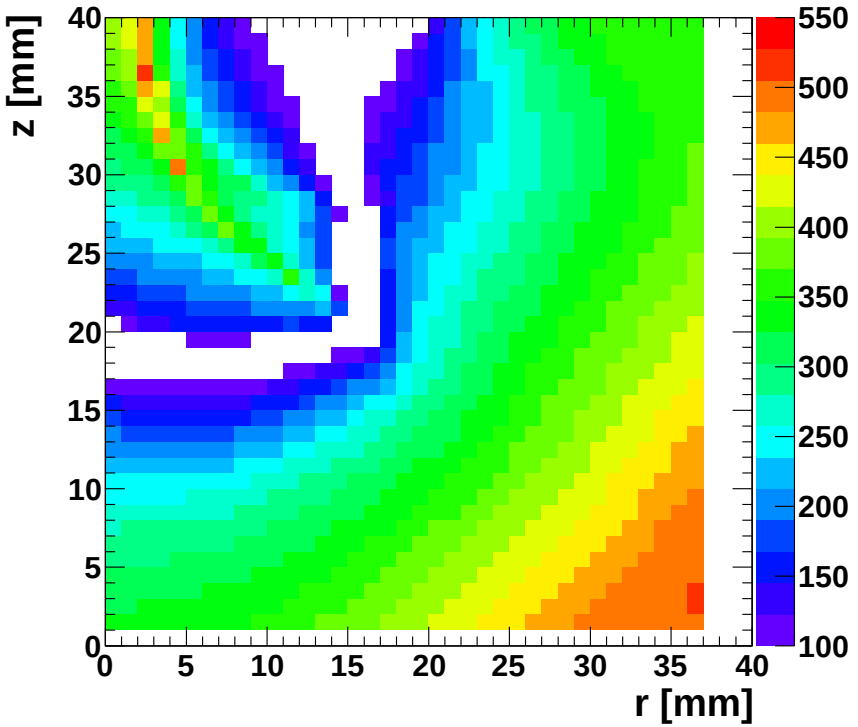




Segment 1 time over threshold

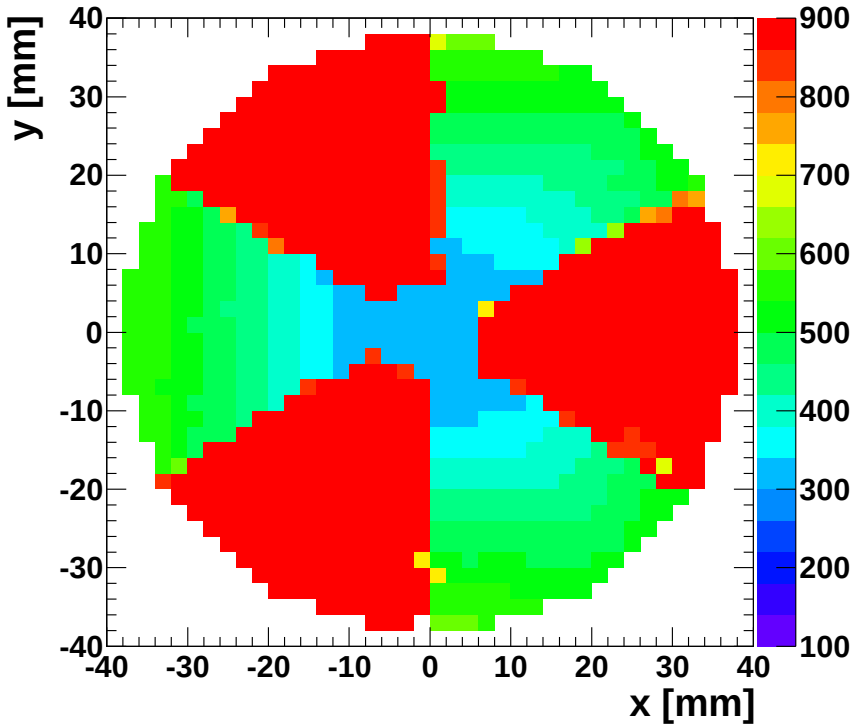
Time over threshold for segment 1 in r-z for $\phi = 0°$ (left) and $\phi = 60°$ (right).

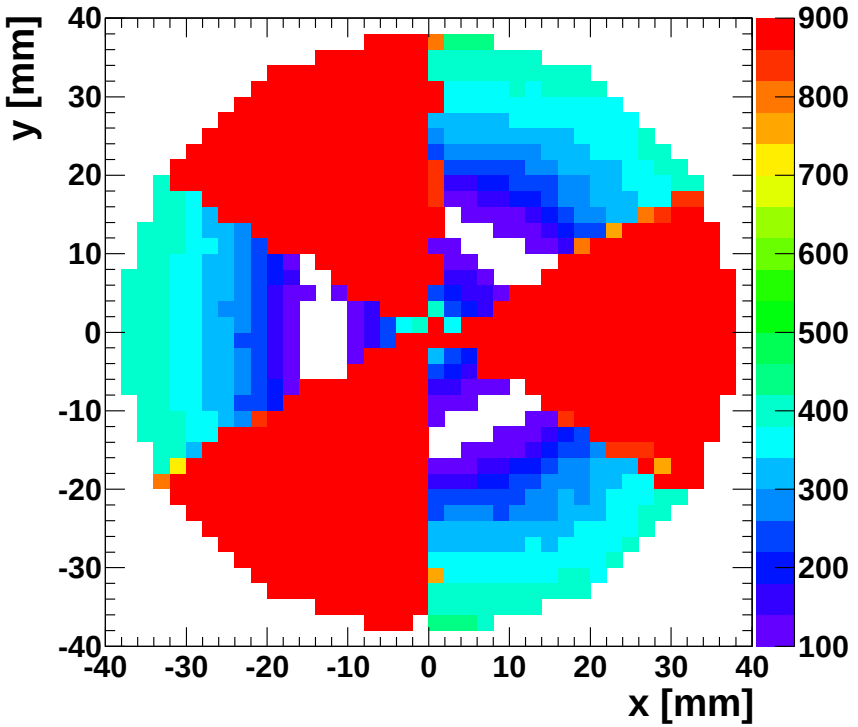




Segment sum time over threshold

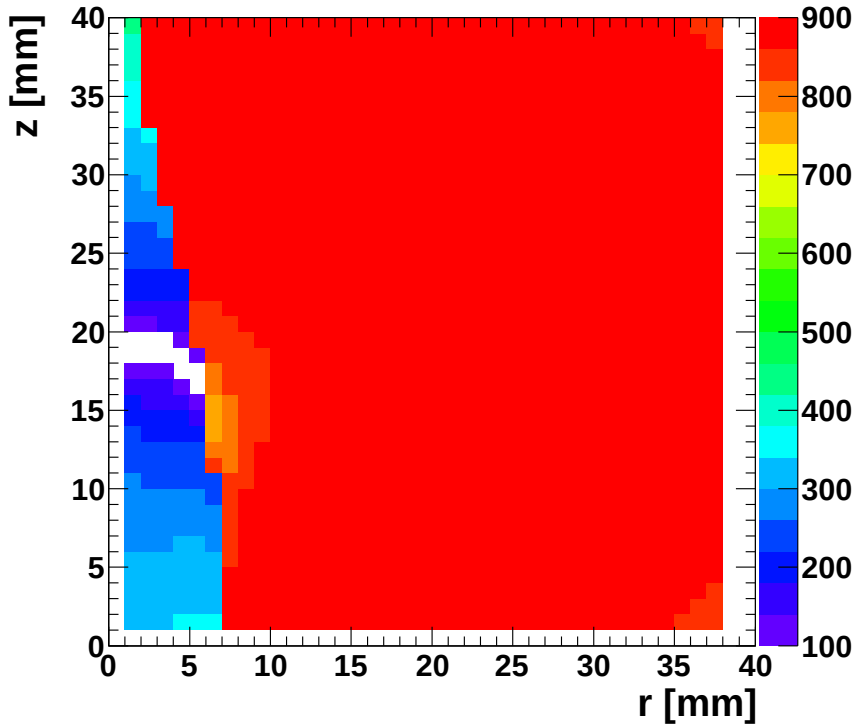
Time over threshold for segment sum in x-y for $z = 5$mm (left) and $z = 35$mm (right).

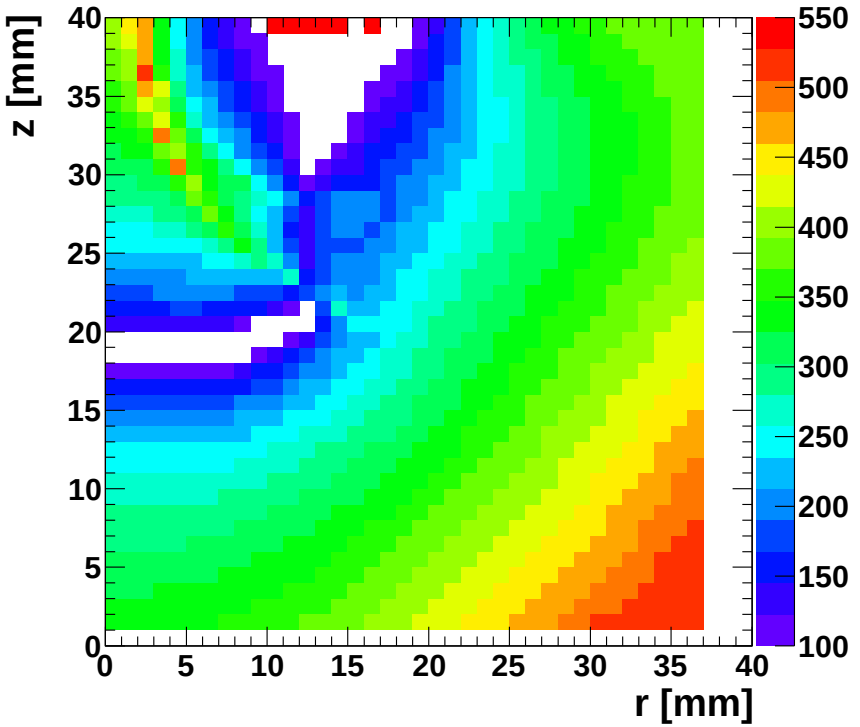




Segment sum time over threshold

Time over threshold for segment sum in r-z for $\phi = 0°$ (left) and $\phi = 60°$ (right).





Summary

- Designed a novel detector geometry for future germanium detectors.
- First prototype will look like a radiation sign (1/2 of surface is segments).
- Currently developing pulse shape analysis tools to study event topologies.