Simulating the position sensitivity of the segmented iThemba LABS clover detector

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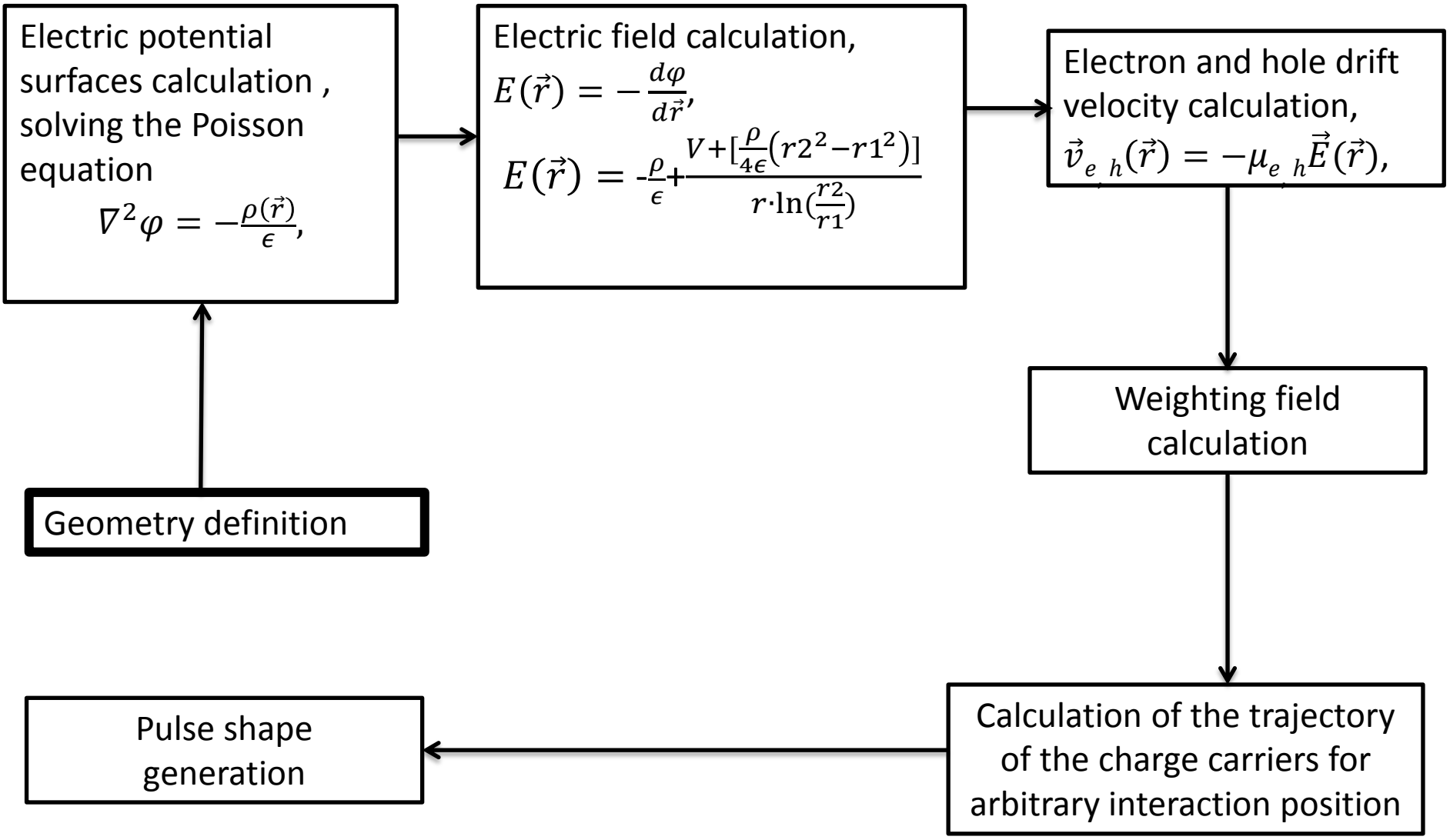
Outline

- Aim of this work
- Multi Geometry Simulation code
- iThemba LABS segmented clover detector
- Position sensitivity results
- Preamplifier response function
- Conclusion

Aim of this work

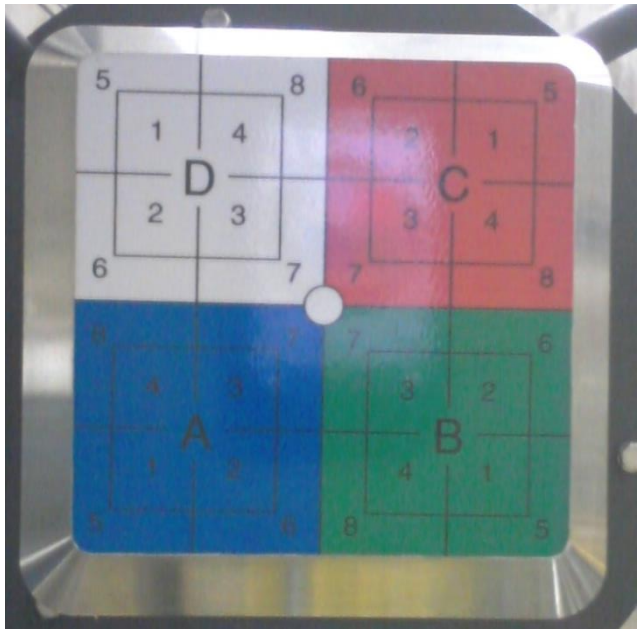
- To investigate the position sensitivity of the segmented iThemba LABS clover detector (dimensions and # of segmentation is of TIGRESS type).
- A computer software code simulates interactions at various positions, and calculate the pulse shapes response at the core and segments contacts.
- The simulated pulses are stored in a data base.
- Pulse shape analysis method compares the shapes of a set of measured pulses with a corresponding set from the data base.
- The core and segments charge pulses from the data base are used to determine the position of gamma-ray interaction in the detector.

Description of MGS code



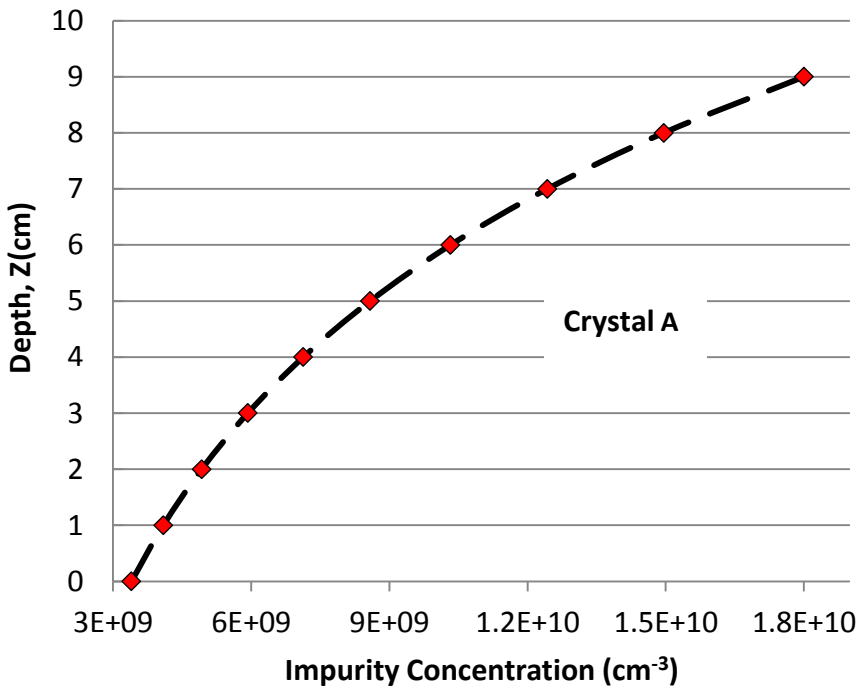
iThemba LABS segmented clover detector

- 4 segmented HPGe crystals.
- Dimensions - Ø60mm before tapering and 90mm in length.
- Each crystal is electrically segmented into 8 outer contacts and the depth segmentation is at 35 mm.
- The relative efficiency of each crystal is ~41% at 25 cm.
- Total efficiency of the detector in addback mode is 220%.

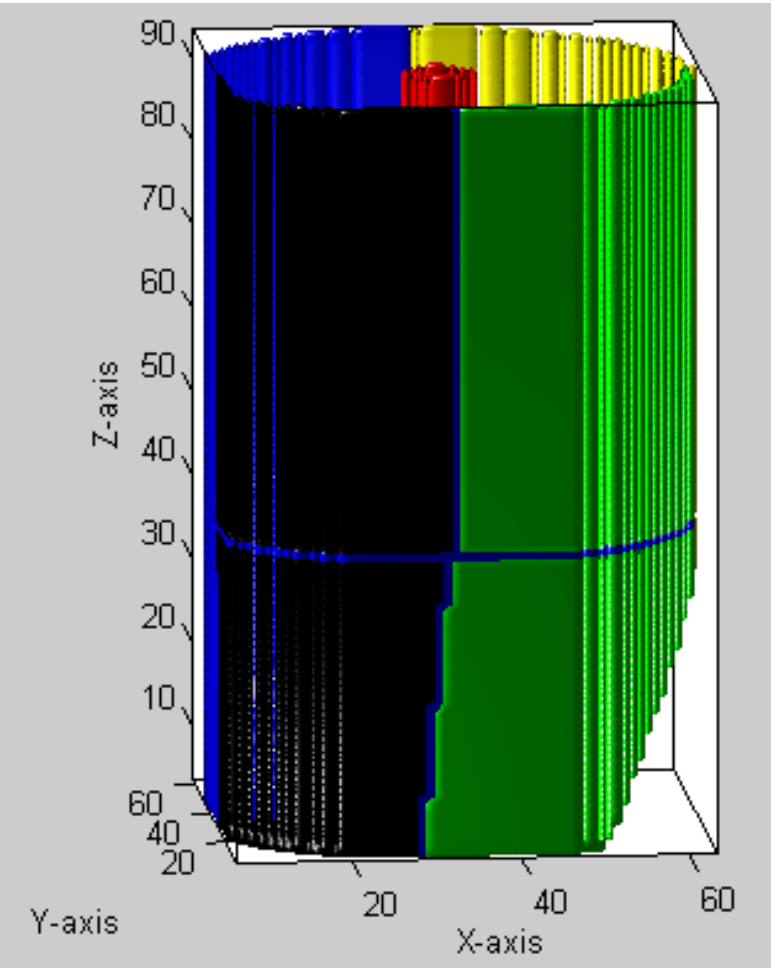


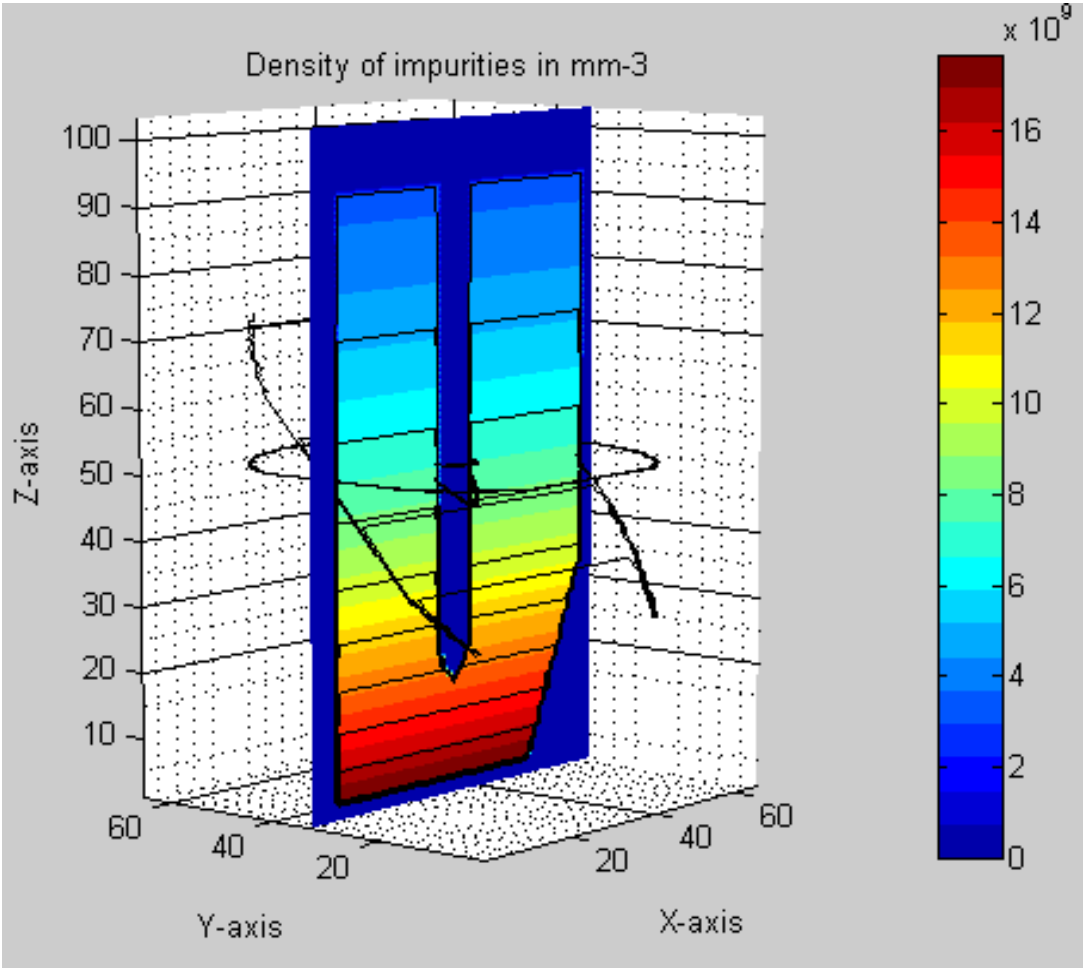
MGS input parameters for simulation of crystal A

Parameter	Value
Grid size	0.5 mm
Height	60 mm
Length	60 mm
Depth	90 mm
Anode Radius	5 mm
Inner electrode bias voltage	0 V
Outer electrode bias voltage	-3000 V
Impurity Concentration (front)	1.8 X 10^{10} cm^{-3}
Impurity Concentration (back)	3.4 X 10^{9} cm^{-3}
Temperature	78K
Distance to the Cathode	15 mm
Segmentation in depth	35 mm

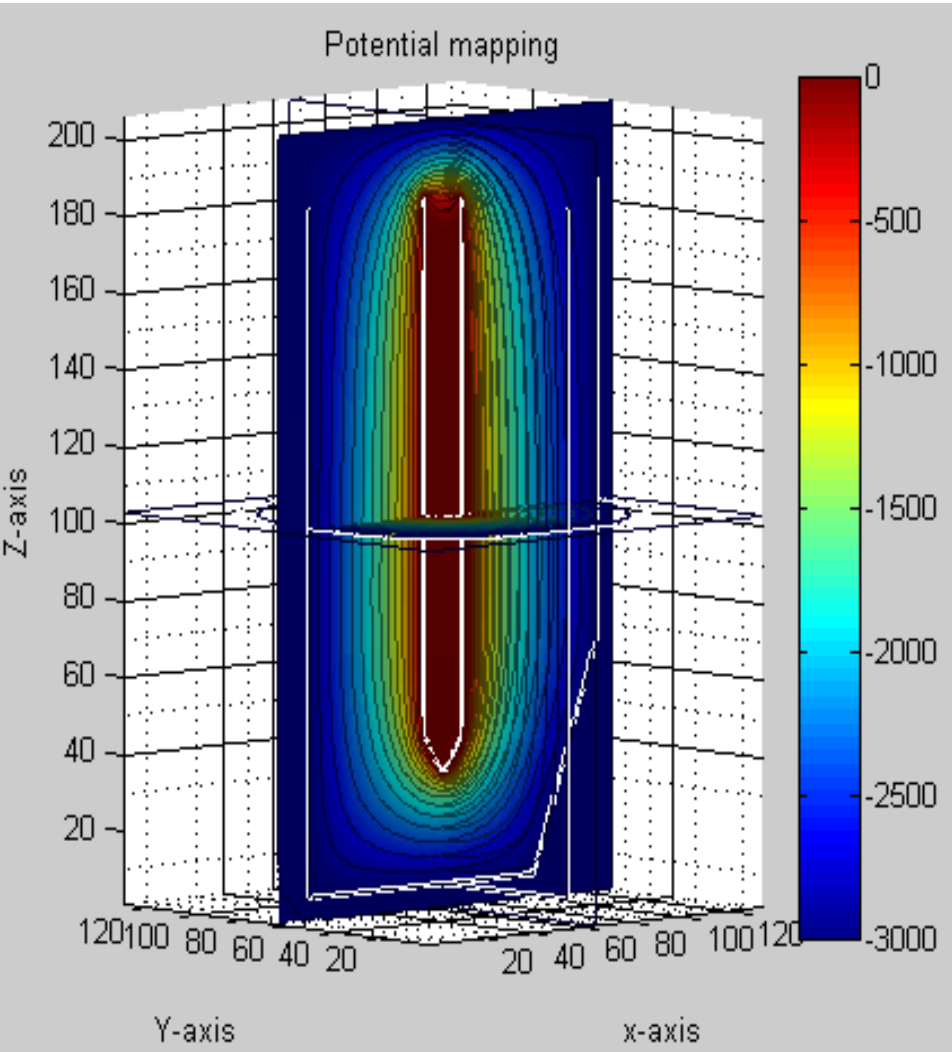


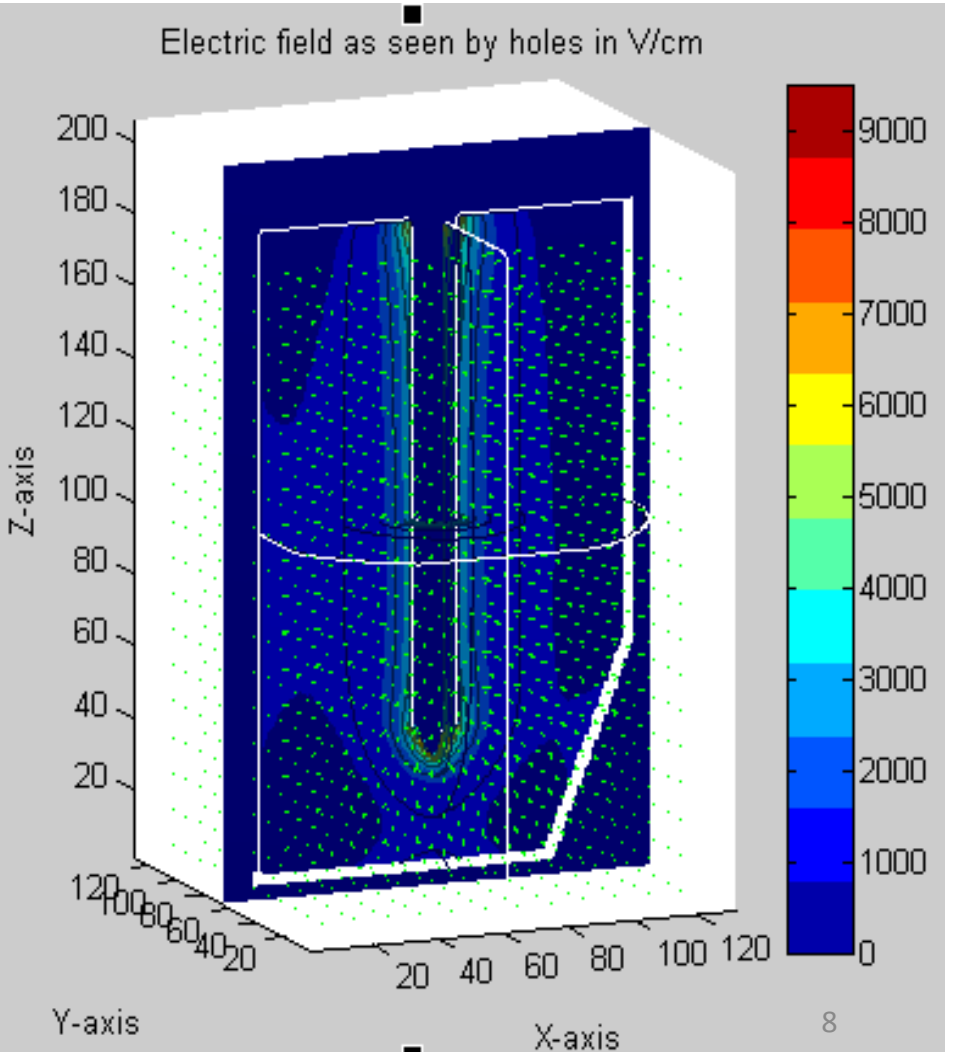
MGS simulation of detector geometry and impurity concentration



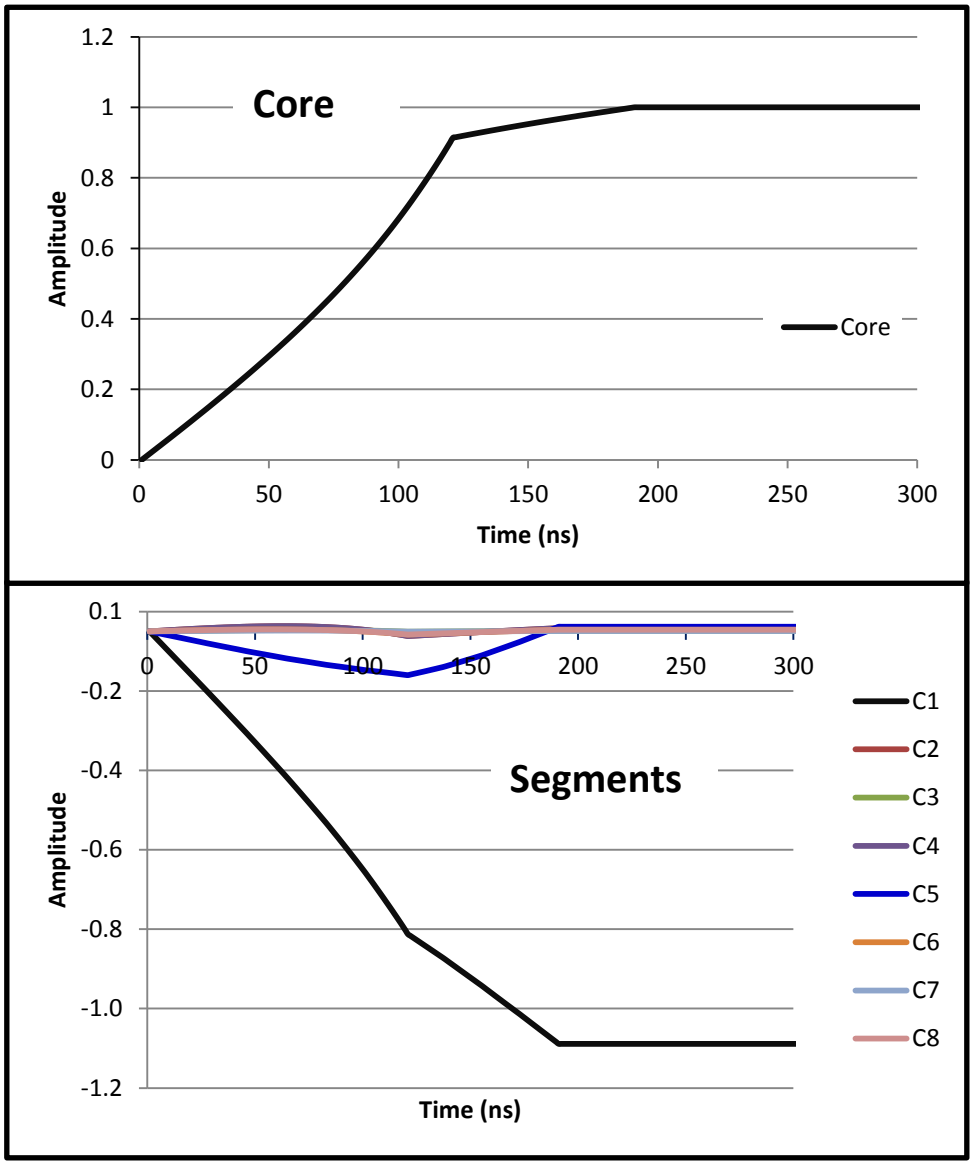


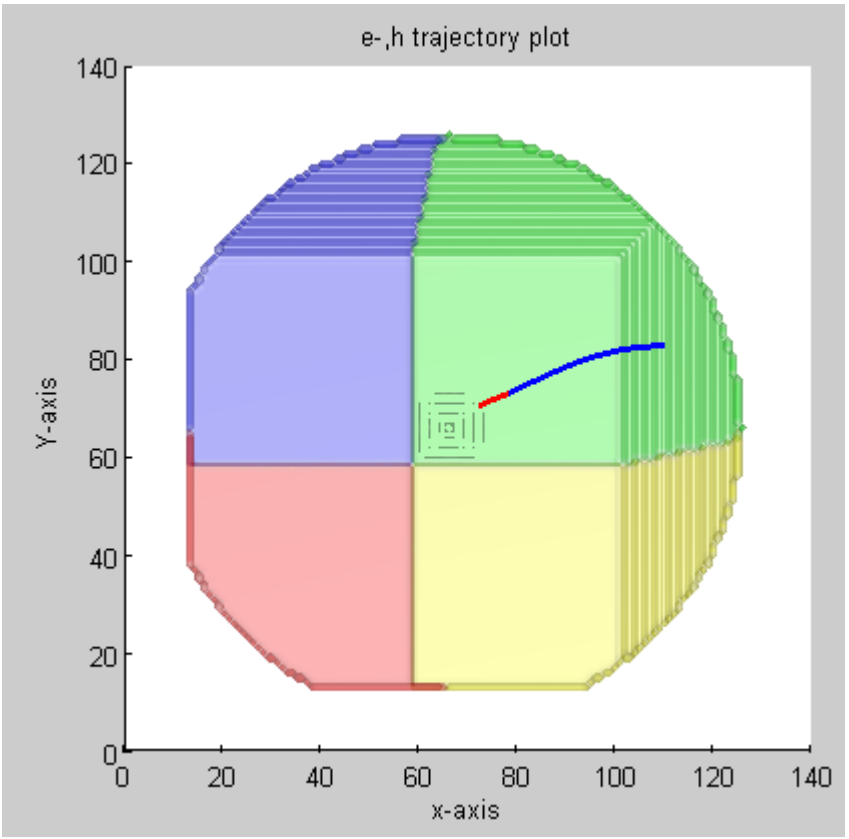
Electric potential and electric field mapping





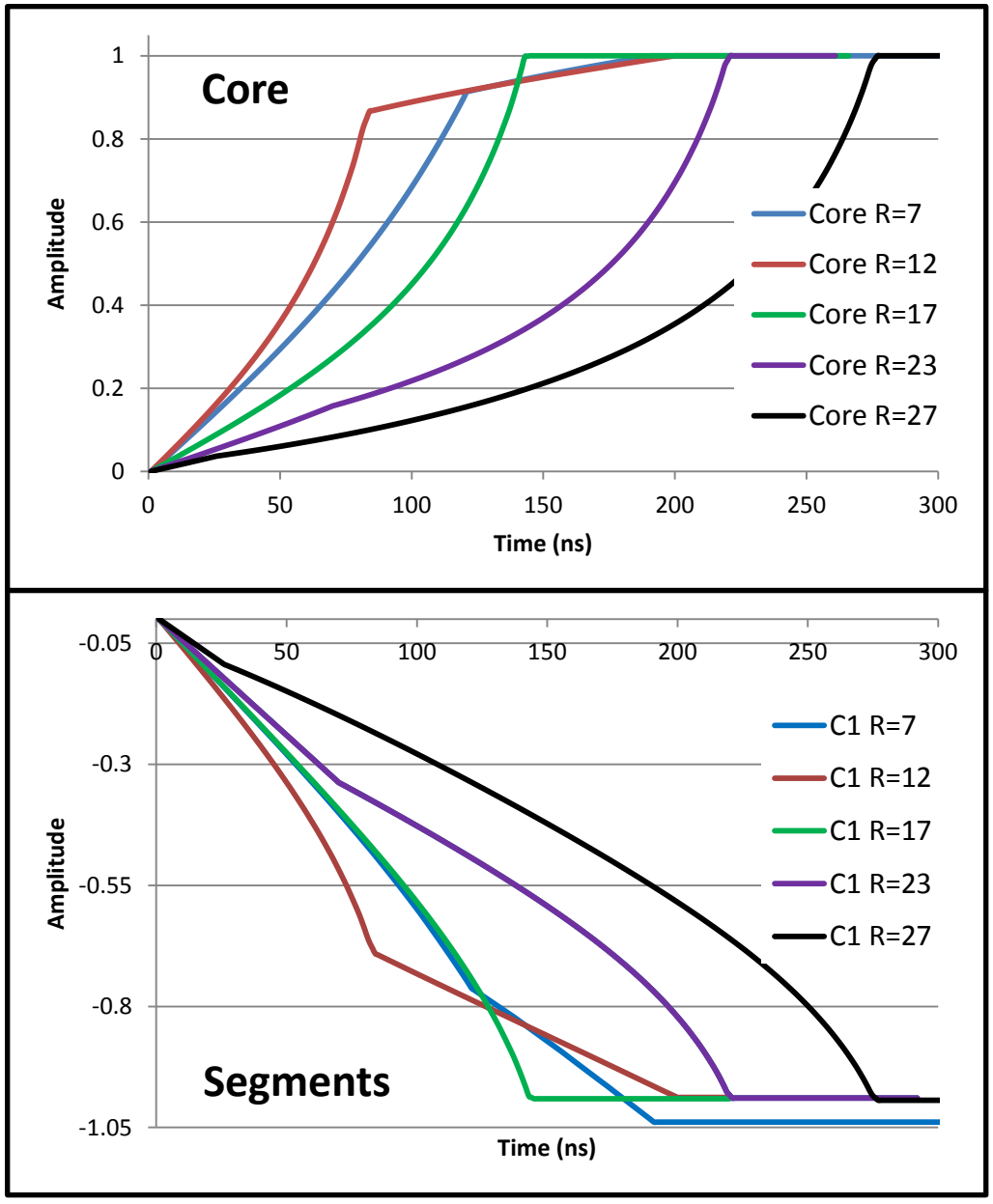
Pulse shapes generated with MGS code

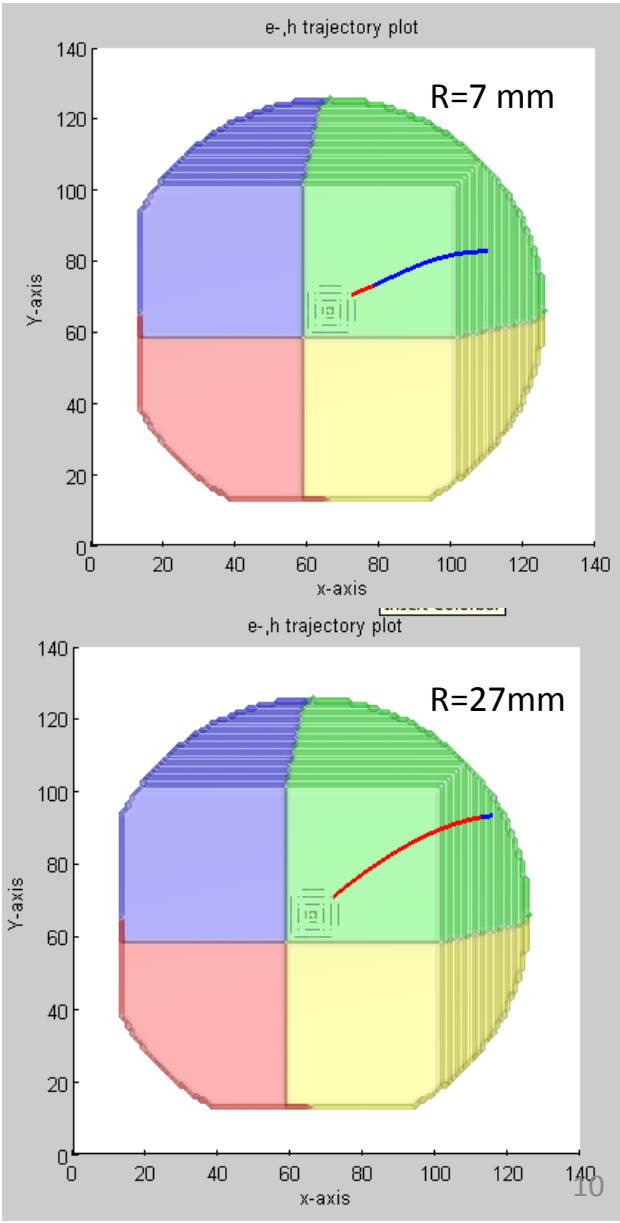




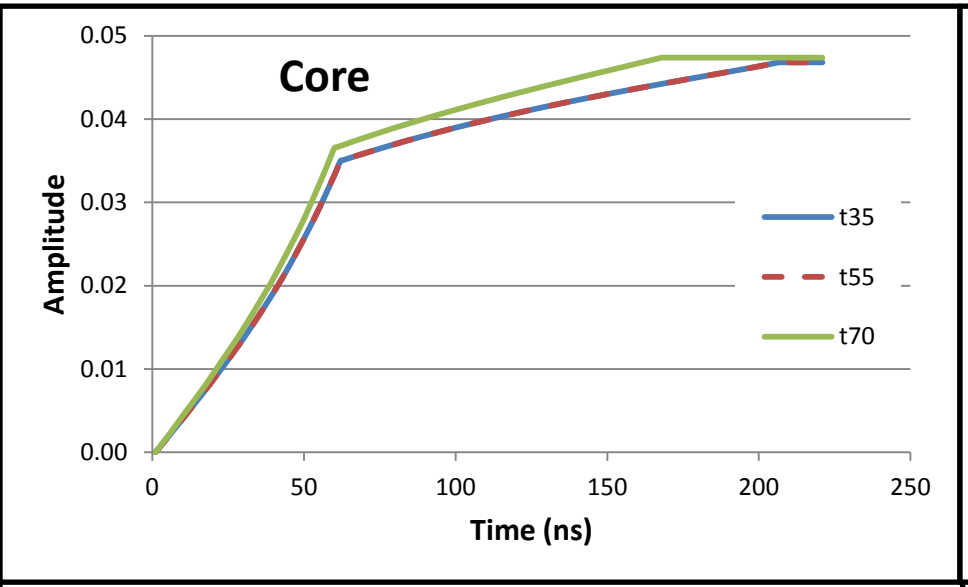
Pulse shape for interaction, R = 7 mm, azimuthal angle = 30^{o} and depth= 20 mm

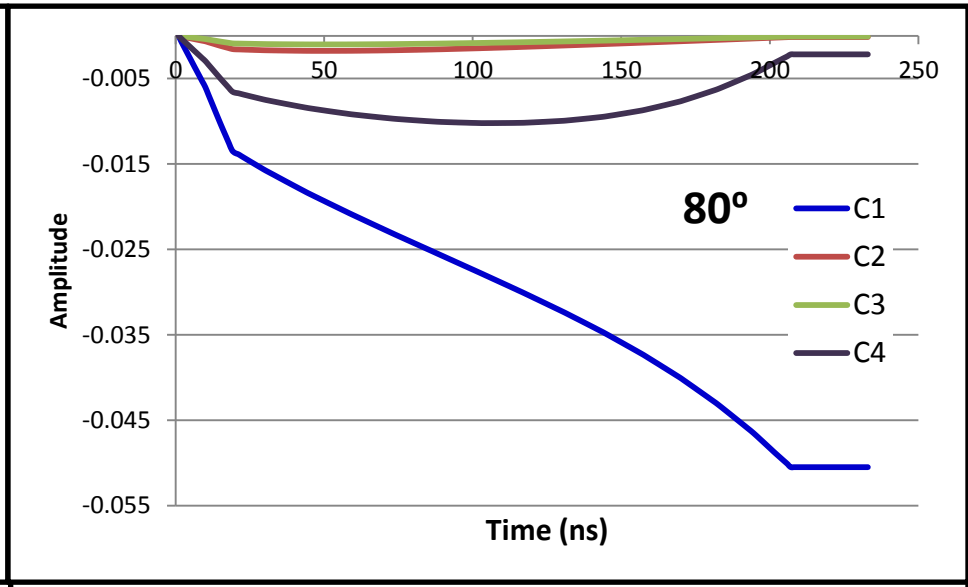
Core and segments signals at different radii

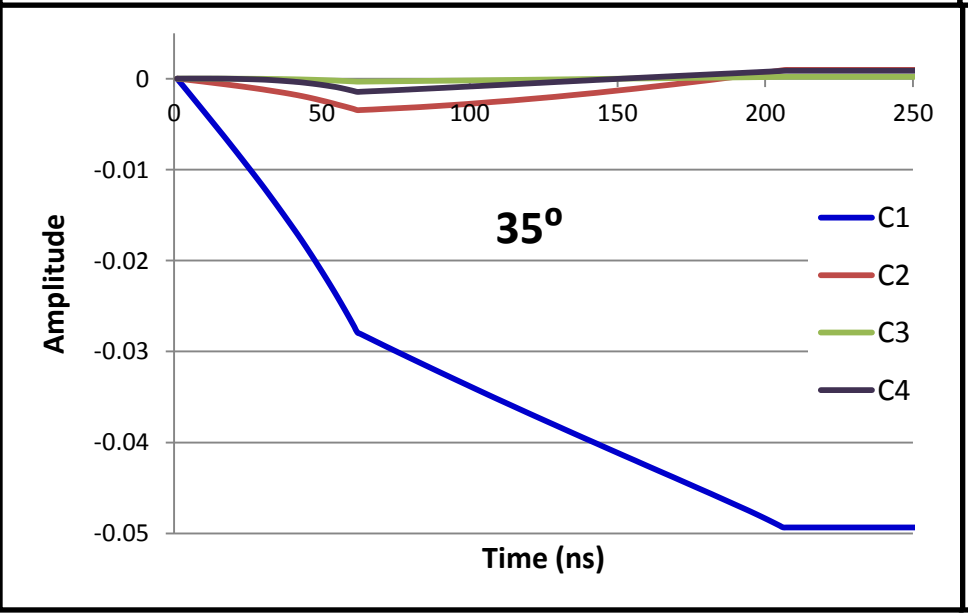


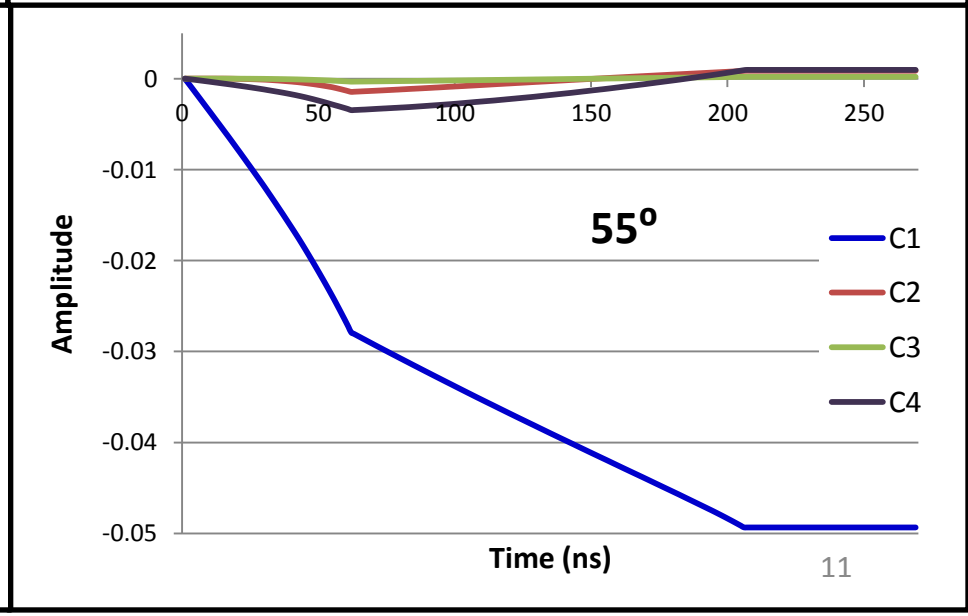


Core and segments signals at different angles

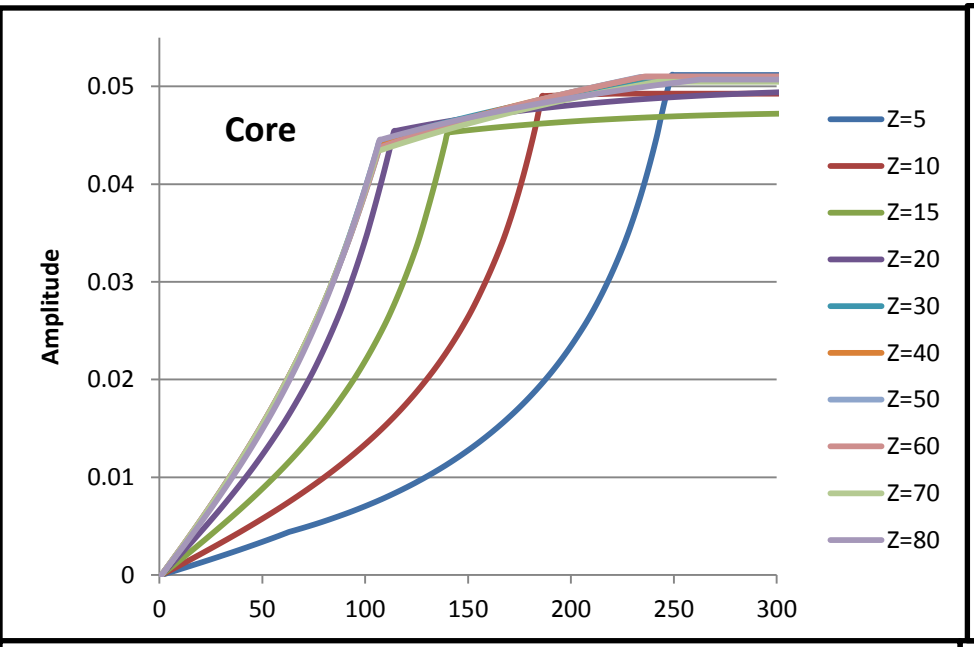


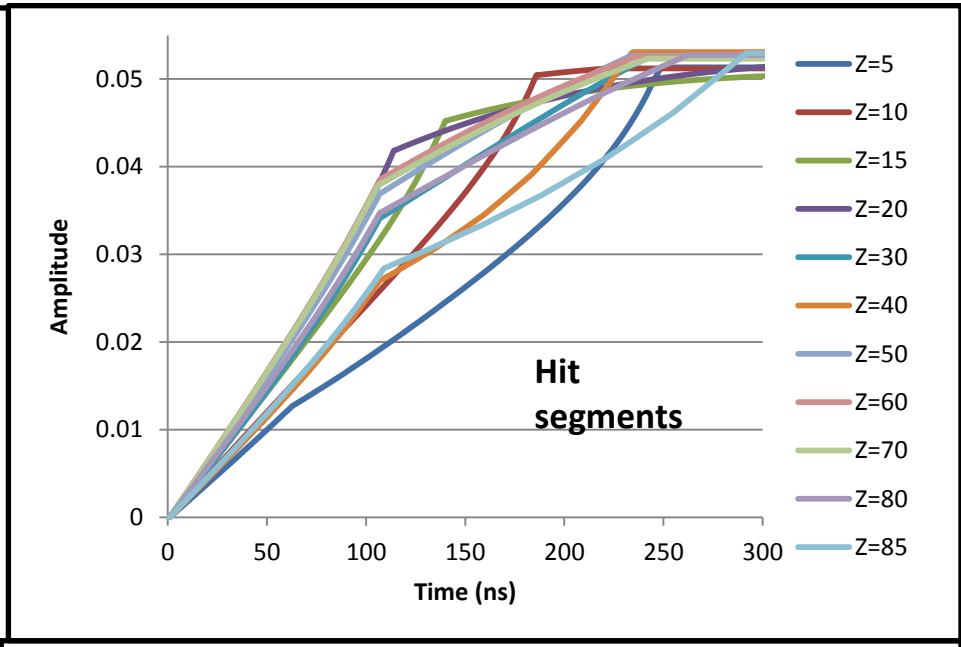


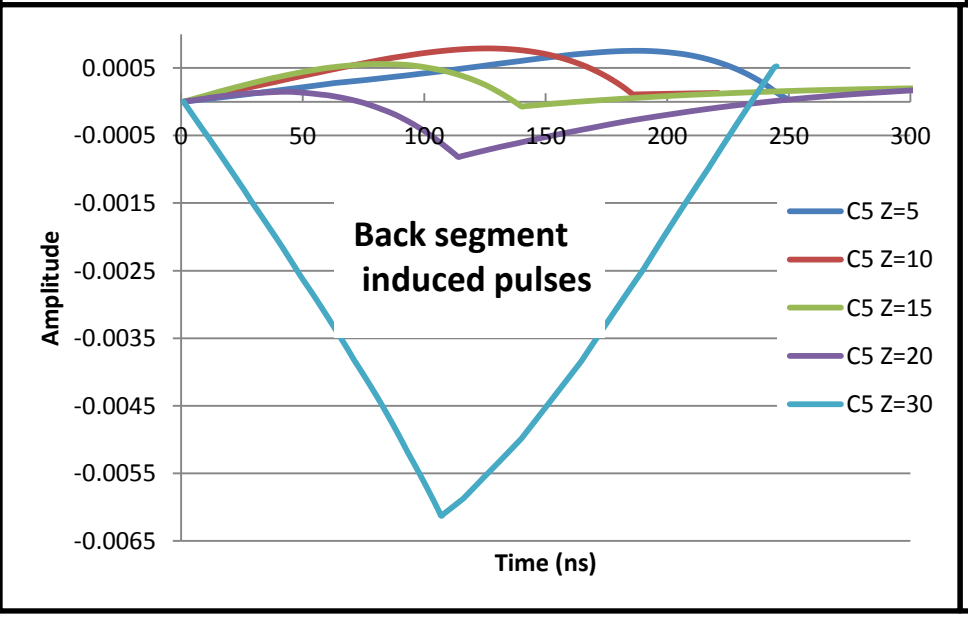


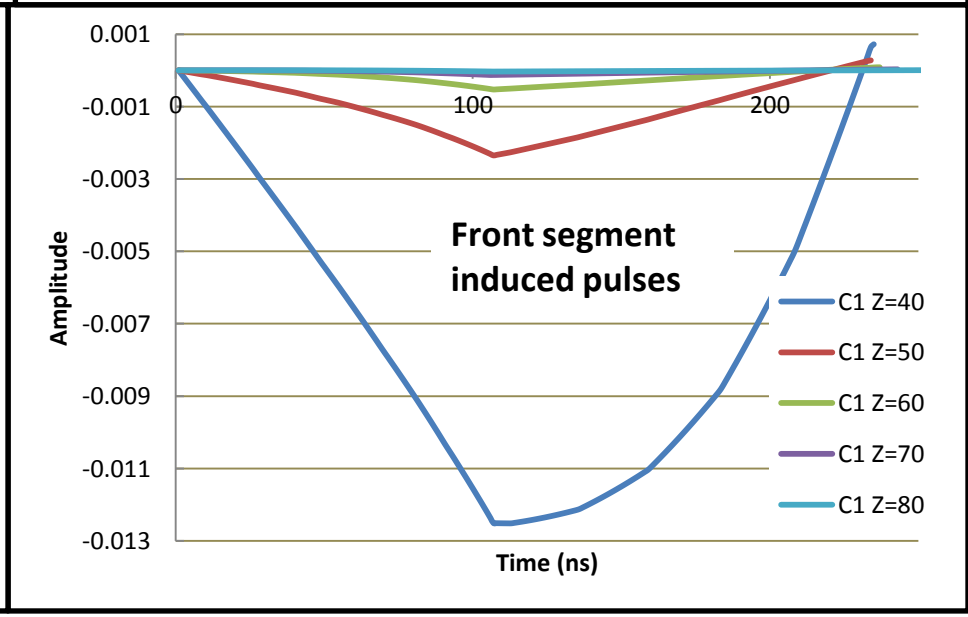


Core and segments signals at different depths









Preamplifier correction

- A signal from the preamplifier of the detector is a convolution of the input current I(t) from the electrode with the response function [1]:

$$v(t) = \int_0^t I(t - t').R(t')dt'$$

where

$$R(t) = g \cdot \frac{1}{1-c} \cdot \left(\frac{1}{1+\frac{1-c}{c}\cdot \exp(-b\cdot t)} - c \right) \cdot \exp\left(-\frac{t}{t_d}\right),$$

$$b = \frac{\ln\left(\frac{c}{1/9 + c}\right) - \ln\left(\frac{c}{9 + c}\right)}{t_{10}^{90}}$$

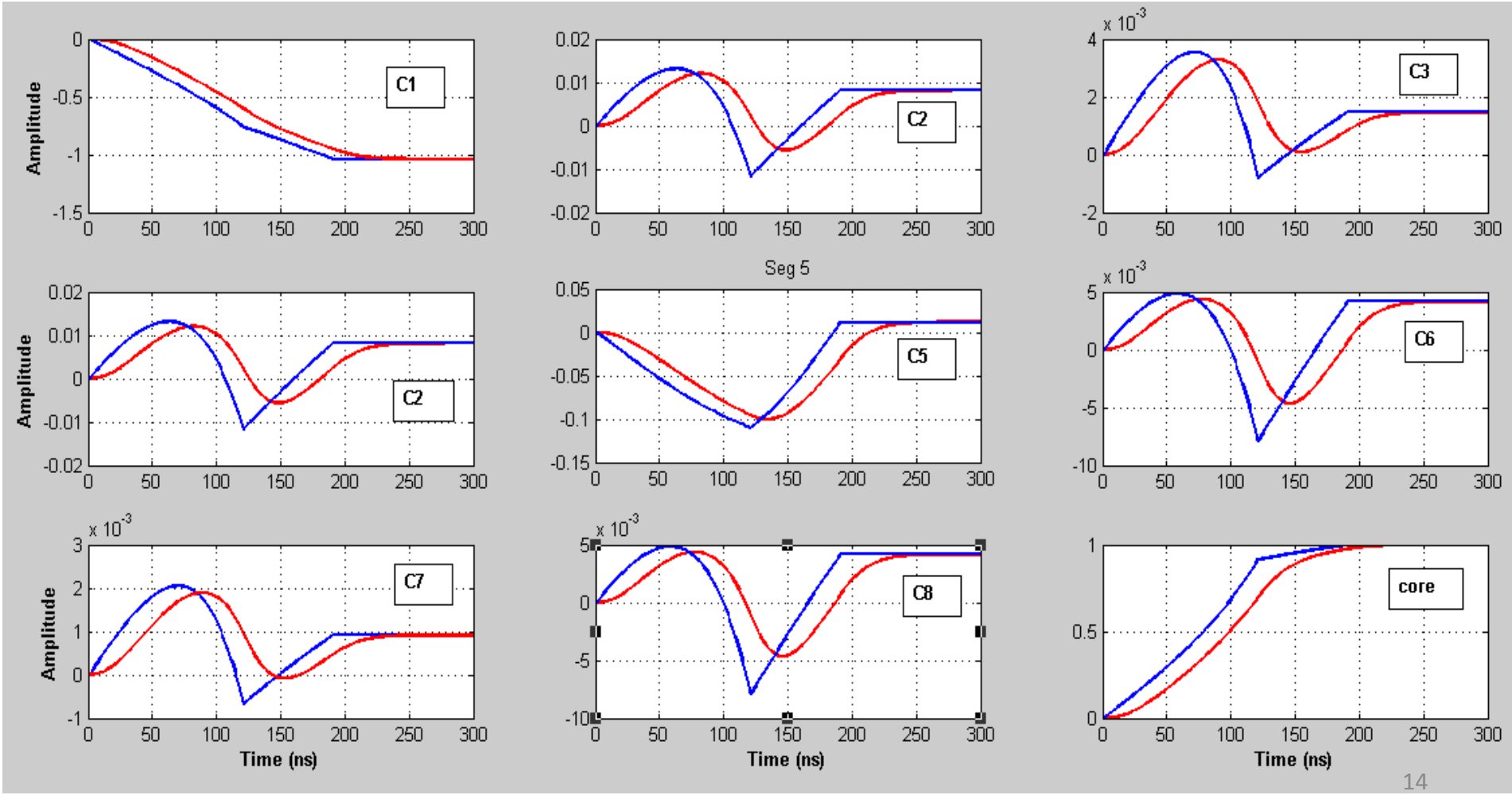
where rise time $t_{10}^{90} = 40$ ns and decay time $t_d = 50\ \mu$s.

1. M. R. Dimmock, Characterisation of AGATA Symmetric Prototype Detectors, PhD thesis, University of Liverpool, 2008.

Simulated pulse shape with preamplifier response function

MGS

MGS + correction



Summary

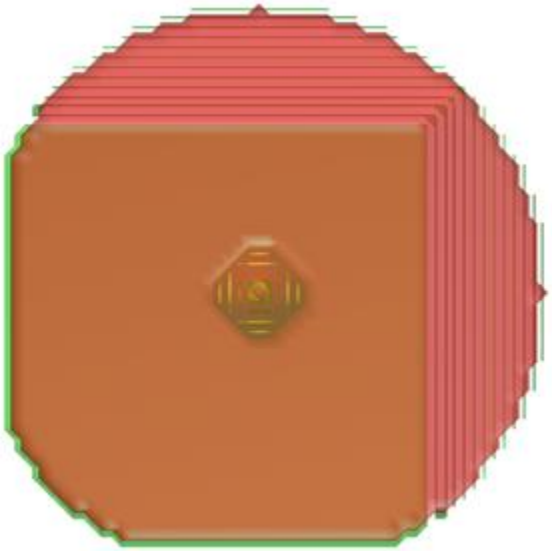
- The position sensitivity of the segmented iThemba LABS clover detector is being studied with the MGS code.
- Pulse shapes have been simulated at different positions (radii, azimuthal angle and depth) within the detector volume.
  - For interaction points at different radii – the shape of the pulses at the inner contact can be used to resolve the positions,
  - For different azimuthal angles- the induced signal at the neighbouring segments are important in determining the position.
  - For different depths- there are positions for which the depth can be determined, but it seems that the detector is not able to resolve the depth for interaction at the back of the detector.
- This is a successful first step towards building a database of simulated pulse, and establishing the position sensitivity of this segmented detector.


Thank you!

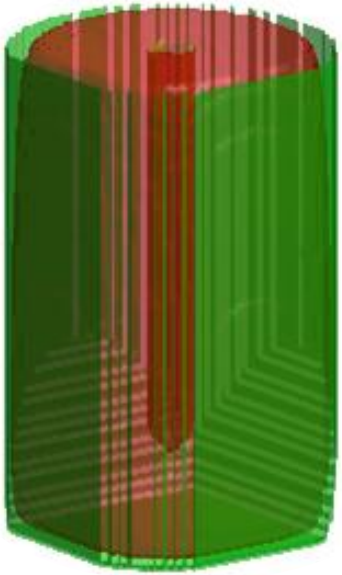
Future Plans

- Realistic simulation $\longrightarrow$ pulse + cross talk + preamp + electronics.
- Build database of simulated pulses
- Compare with experimental pulses
- Simulating more than one interaction
  - ✓Compton scattering between 2 segments
  - ✓Compton scattering inside one segments.

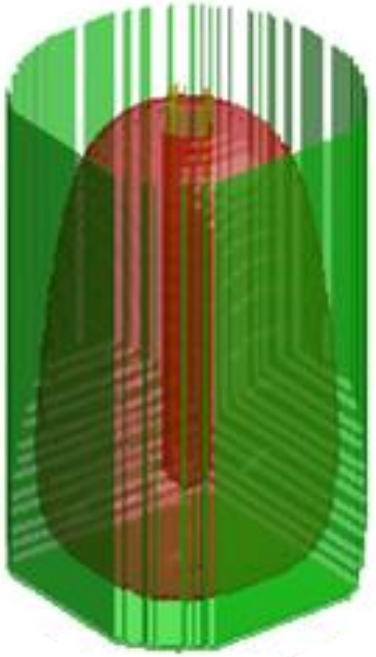
Depletion region Simulation



Inner electrode = 0 V,
outer electrode= -10 V

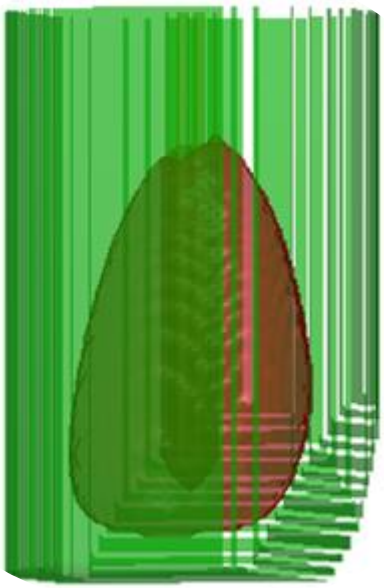


Inner electrode = 0 V,
outer electrode= -100 V

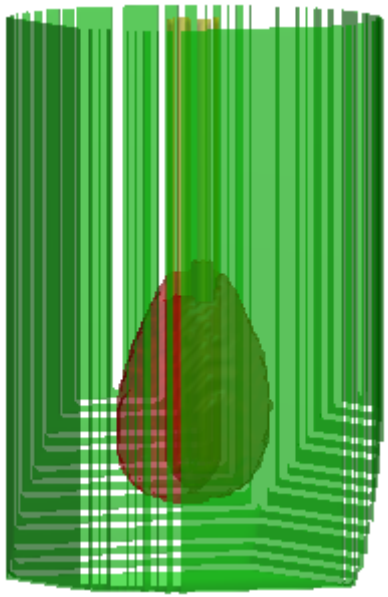


Inner electrode = 0 V,
outer electrode= -500 V

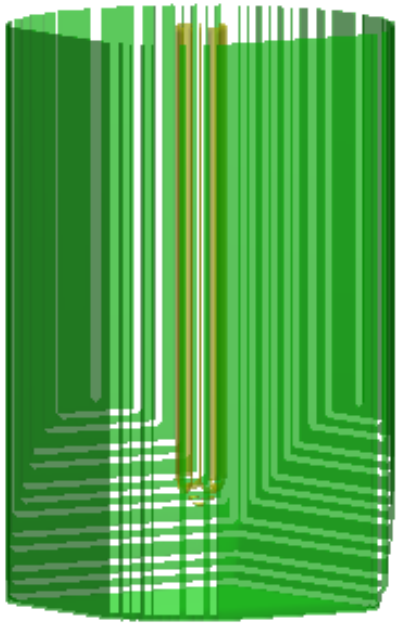
Depletion Region Simulation



Inner electrode = 0 V,
outer electrode= -1000 V



Inner electrode = 0 V,
outer electrode= -1500 V



Inner electrode = 0 V,
outer electrode= -2000 V