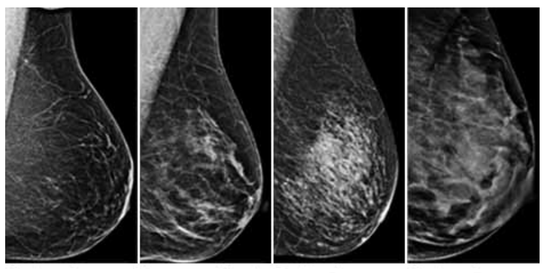
A Monte Carlo study for system development in low dose Molecular Breast Imaging (MBI)

H. R. Brown[1], L. Harkness-Brennan[1], D. Judson[1], E. J. Rintoul[1] , A. J. Boston[1], A. Cherlin[2], I. Baistow[2] & I. Radley[2]

1- Department of Physics, University of Liverpool, Liverpool, UK; 2- Kromek Group plc, Sedgefield, TS21 3FD, UK

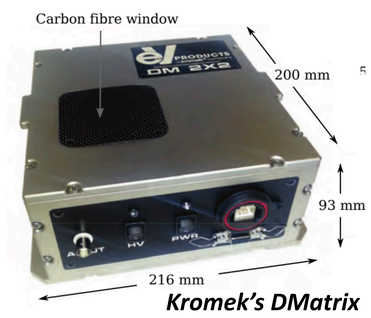
Overview



A B C D

Increasing breast density A-D [1]

- Breast cancer is the most common form of the disease directly affecting 1 in 8 women.
- 50% of women of screening age have mammographically dense breasts- limiting diagnostic abilities.
- Molecular Breast Imaging (MBI) is a nuclear medicine technique which has the potential to detect lesions of the breast at an early stage.
- Cadmium Zinc Telluride (CZT) is a desirable detector material for this application primarily due to its good position resolution.
- One of the fundamental challenges in maximizing the position resolution in CZT detectors involves accounting for multiple pixel events.
- The study forms the foundation on which future work will be conducted in order to enhance the position resolution and, in turn, the performance of the system.



Kromek's DMatrix Nuclear Gamma Imager [2]

System Design

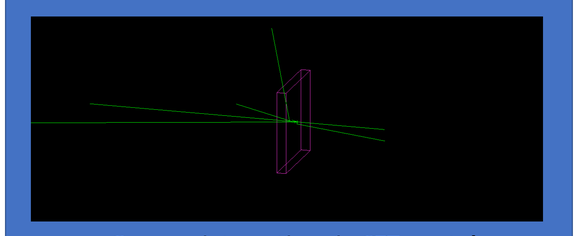
- Within this preliminary study, Geant4 was used to simulate gamma interactions within Kromek's Dmatrix system to quantify radiation transport effects.
- Gamma energies of 122 keV and 141 keV were independently studied, representative of gamma rays emitted from ^{99m}Tc which is directly applicable to MBI and ^{57}Co which is the longer half-life analogue.
- This enabled the transferrable experimental use of ^{57}Co to be validated.
- Kromek's DMatrix Nuclear Gamma Imager is a **pixelated CZT** detector consisting of a **44 x 44 x 5 mm crystal** with **2 mm pixel pitch**.
- It has previously been characterised at the University of Liverpool for use in Molecular Therapy.
- Its design for application in MBI faces different challenges as to maximise the performance with limited statistics.

Geant4 Simulation

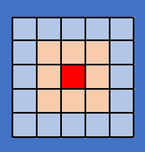
Geant4 simulation- 44mm x 44mm x 5mm CZT crystal

Monochromatic gamma beam incident on crystal (122 keV and 141 keV)

Interaction study determining interaction positions & type and energy deposited in crystal



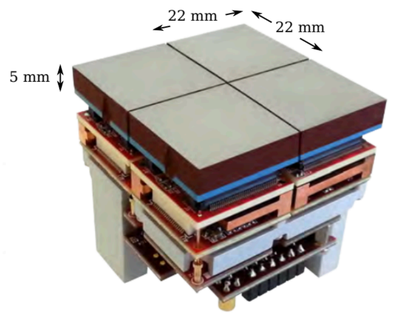
Gamma interactions in CZT crystal



- Pixel of interaction
- Nearest neighbour pixels
- Next nearest neighbour pixels

22 x 22 pixelation implementation

Classification of events: nearest neighbour (NN) & next nearest neighbour (NNN)

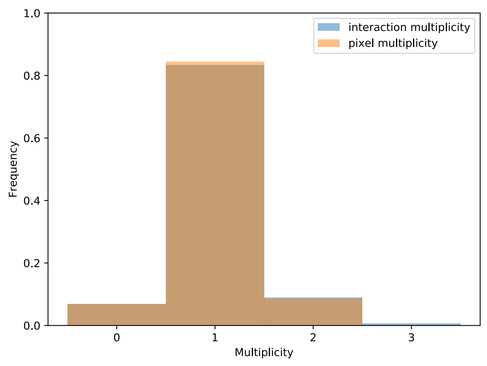


Kromek's DMatrix Nuclear Gamma Imager [2]

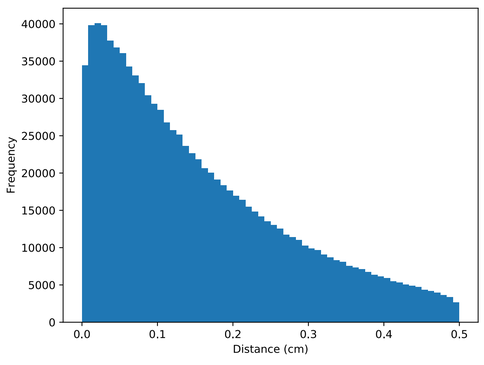
Results

122 keV

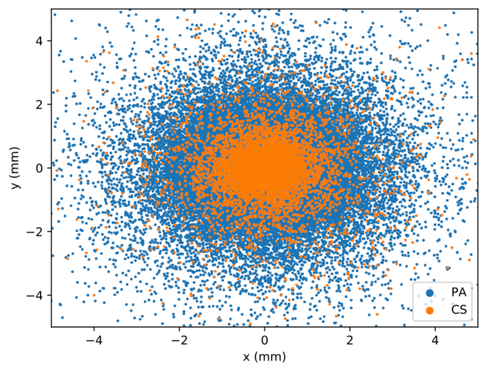
Interaction multiplicity



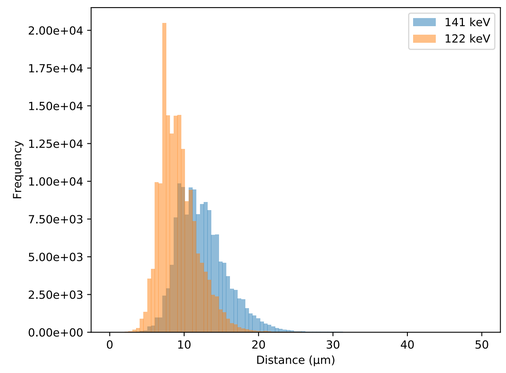
γ interaction depth



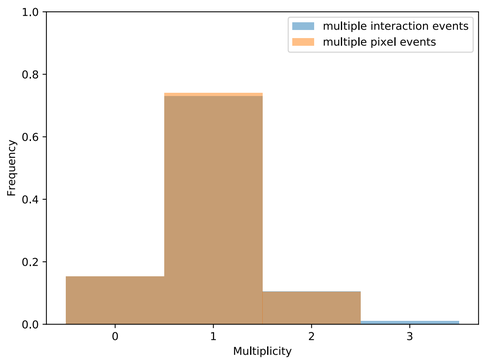
γ interaction distribution

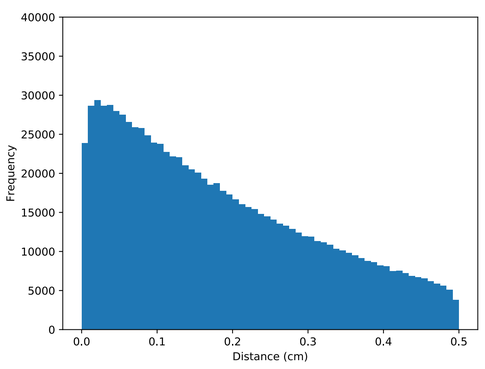


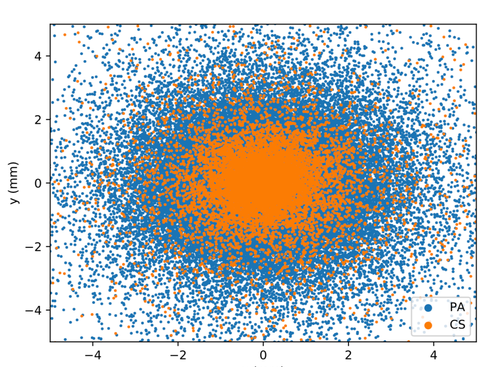
e- charge cloud size



141 keV







	non interacting gammas	nearest neighbour events	average distance between γ interactions	average e- charge cloud size
122 keV	7 %	93 %	106 μm	9.3 μm
141 keV	15 %	91 %	134 μm	12.5 μm

Future Work:

- Couple COMSOL model with Geant4 data to better inform position sensitive algorithms
- Determine optimal CZT detector geometries for application in MBI
- Characterise new detector of 10 mm thickness and 0.8 mm pixel pitch

References:

1. SS. Nazari and P. Mukherjee. "An overview of mammographic density and its association with breast cancer." *Breast cancer (Tokyo, Japan)* vol. 25,3 (2018): 259-267. doi:10.1007/s12282-018-0857-5

2. L. Mcareavey, L. Harkness-Brennan, S. Colosimo, D. Judson, A. Boston, H. Boston, P. Nolan, G. Flux, A. Denis-Bacelar, B. Harris, I. Radley, and M. Carroll, "Characterisation of a czt detector for dosimetry of molecular radiotherapy," Journal of Instrumentation, vol. 12, pp. P03 001–P03 001, 03 2017