Monte Carlo Simulation of a Coded Aperture Imaging with Dedicated Gamma Camera System for Scintimammography

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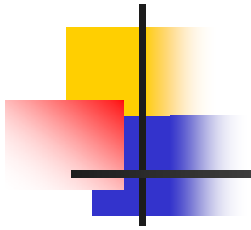


Outline

- Aim and Motivations
- Geometry and Methods of Simulation
- Validation
- Coded Aperture CdZnTe Results
- Conclusions

MOTIVATION & AIM

- Breast Cancer is a leading cause of deaths in women due to cancer.
- Mammography is **gold standard** for screening (post- menopausal) women.

Why are alternative imaging modalities needed ?

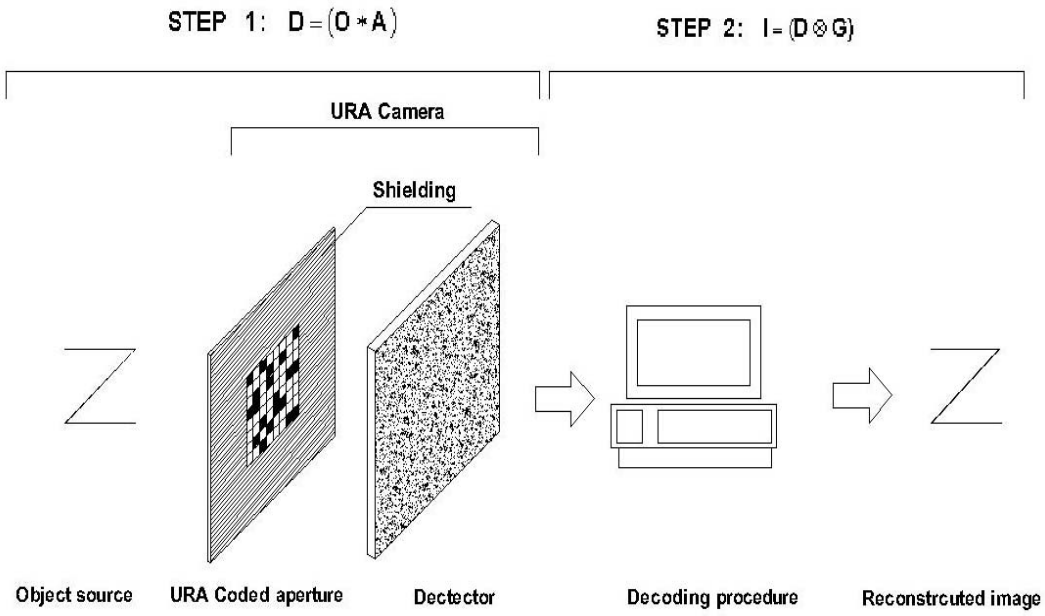
- Mammography has limitation in terms of sensitivity (ability to see abnormality ~ 90 %), specificity (ability to determine if lesion is benign or malignant ~ 93 %)[1].
- Scintimammography can be used as an adjunct imaging modality to improve specificity -> minimise invasive secondary examinations.
- This study focus on the applications of Modified Uniformly Redundant Array (MURA) coded aperture imaging methods using CdZnTe gamma camera without collimator for use in breast tumour imaging

1. Tabár L, et al. (2000) Radiol Clin North Am 38:625.651.

Why CZT camera?

- Higher charge carrier statistics leading to superior energy resolution -> Better scatter rejection
- Compact and light weight
- Have a high stopping power due to their high mass density (5.8g/cm^3) and high effective atomic No. of 49.6 ($Cd_{0.9}$:48, $Zn_{0.1}$:30, Te:52) -> high efficiency
- Efficient radiation absorption, good linearity, high stability, high sensitivity and wide dynamic range.

The Concept of Coded Aperture Imaging



- Techniques originally used in Astronomical imaging
- The detector response is

$$D=(O*A)+N \qquad (1)$$

- If G exists, then $A\otimes G=\delta$ so we can recover O through post processing

$$I=D\otimes G \qquad (2)$$

- Contribution of background term can be minimized.

The concept of the CAI system. The CA encodes the photon source location and strength information in the detector. The original source distribution may be determined by correlating the recorded image with a decoded pattern.

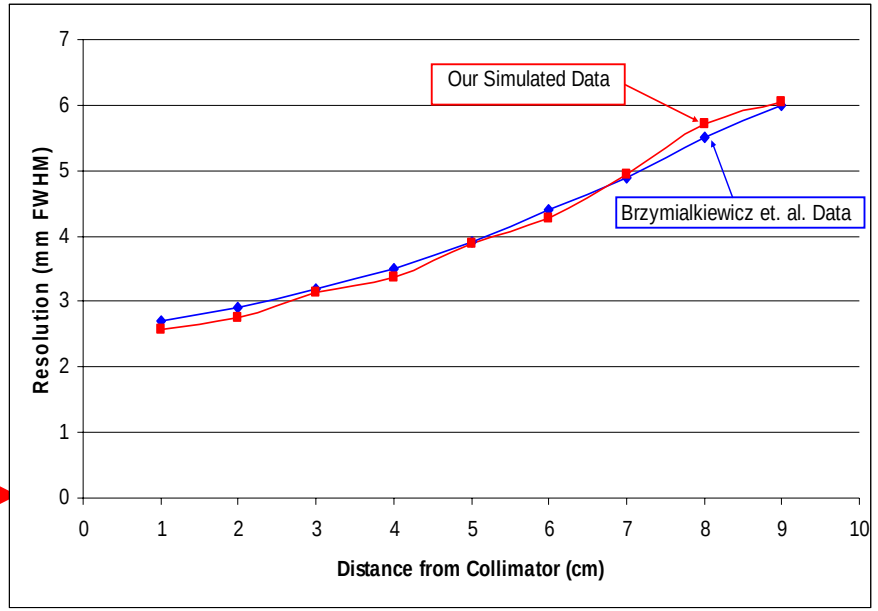
Methods of Simulation

- MCNPX (Version 2.4.0) code is used
- Point-like (99mTc isotropic emitting 140 keV) sources are located inside the breast, with or without a background activity.
- Photons are tracked on an event by event basis through scattering media, CA and CdZnTe camera, subject to Compton and photoelectric interactions.
- The recorded (x, y) spatial information is blurred by sampling a Gaussian probability distribution function with FWHM=1.58mm.
- The energy deposition process is also subject to Gaussian broadening with energy dependent FWHM values from experimental data.
- Consider limited statistics expected in a clinically realistic imaging situation

VALIDATION OF MONTE CARLO SIMULATION

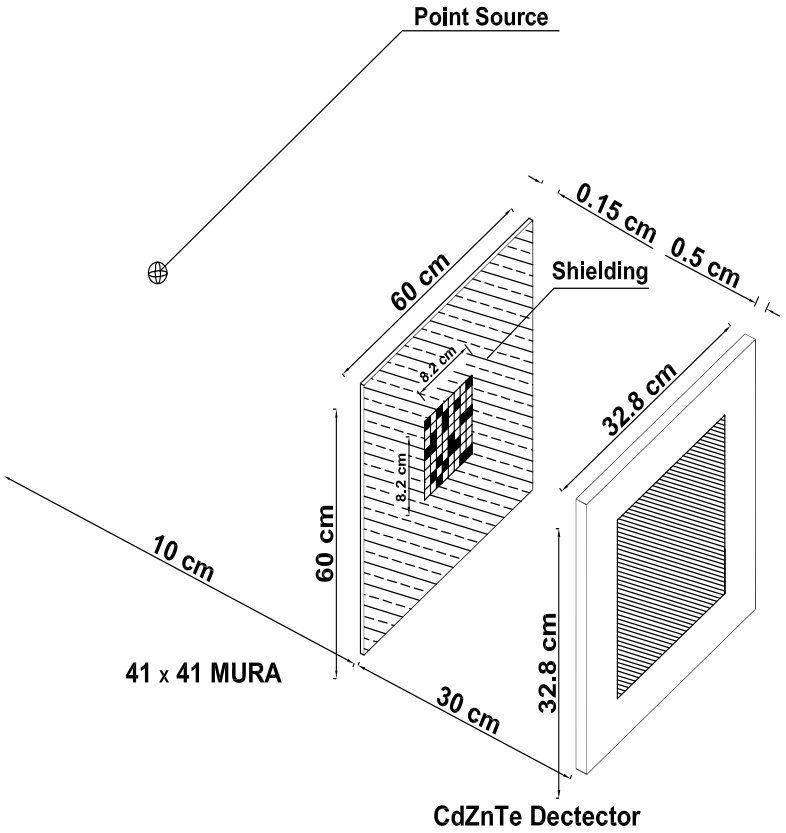
- **The developed simulation has been validated by comparison with experimental results.**

- **Comparison of the spatial resolution for ^{99m}Tc of an infinitesimally small point source in air in terms of FWHM between simulated and experimental CZT camera data (using a LEHR collimator).**

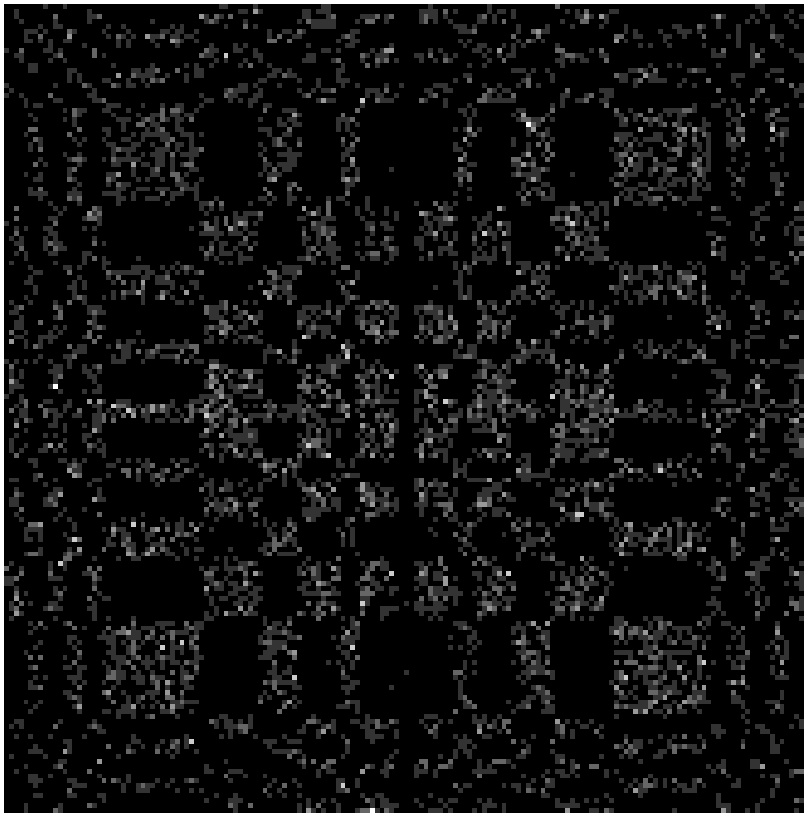


Brzymialkiewicz et. al., IEEE Trans. Med. Imaging 24 (2005) 868

Geometry of Point source in air

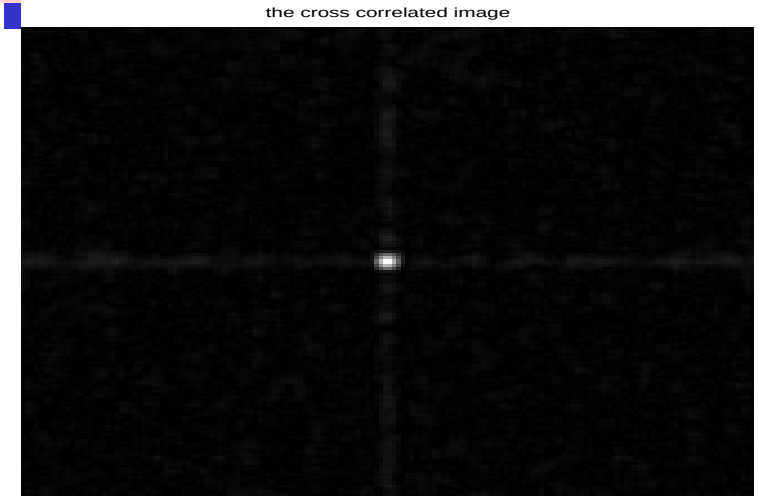


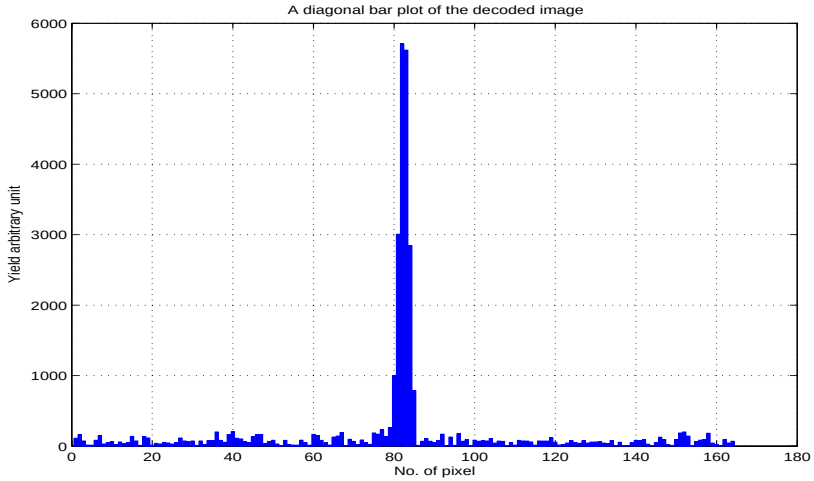
The simulated image 164 X 164

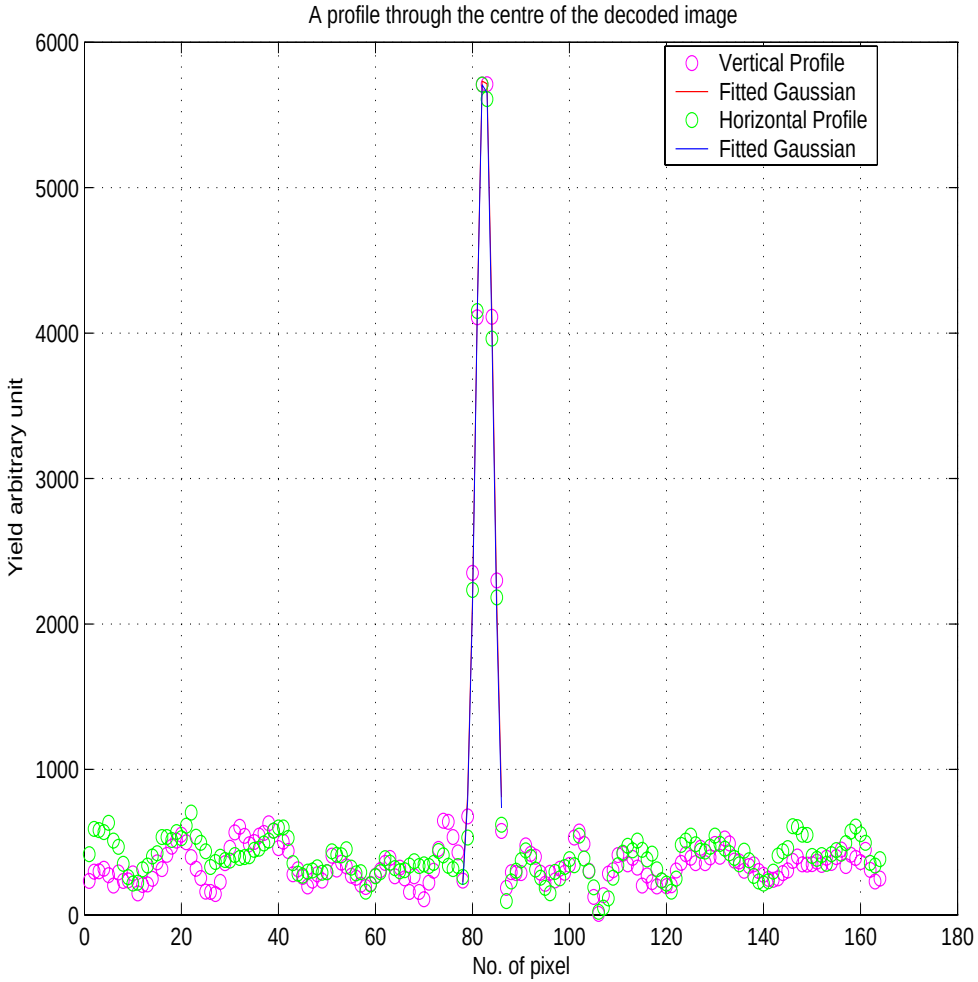


Simulated history ~0.5M

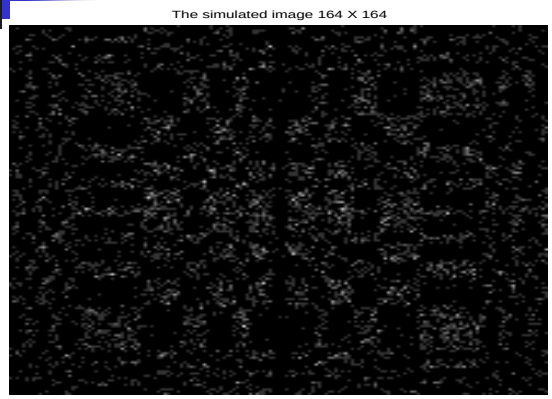
Simulation Results
Point source in air



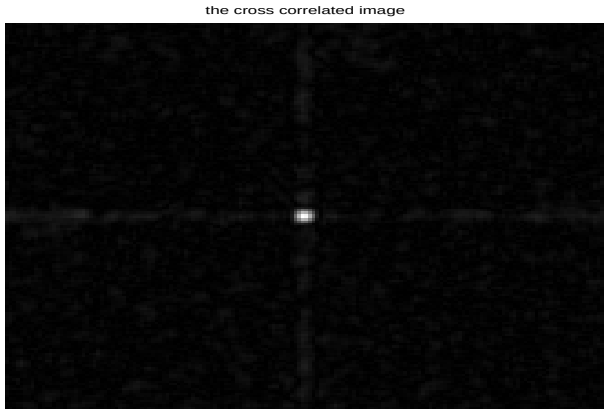


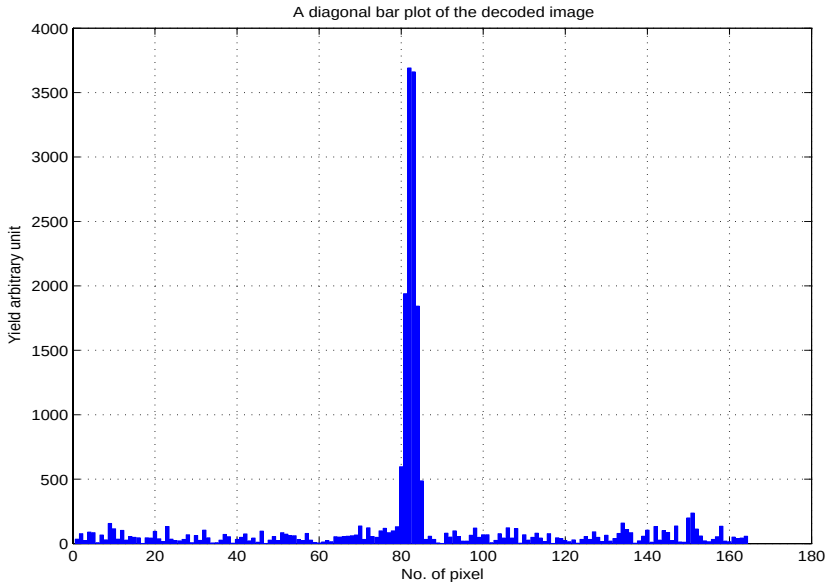


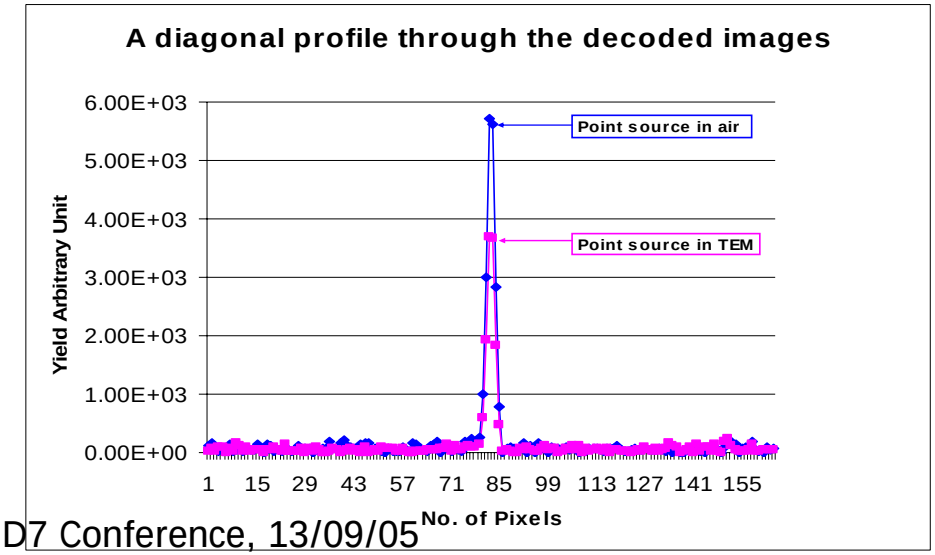
Simulation Results
Point source in Tissue Equivalent Material



Simulated history ~0.5M

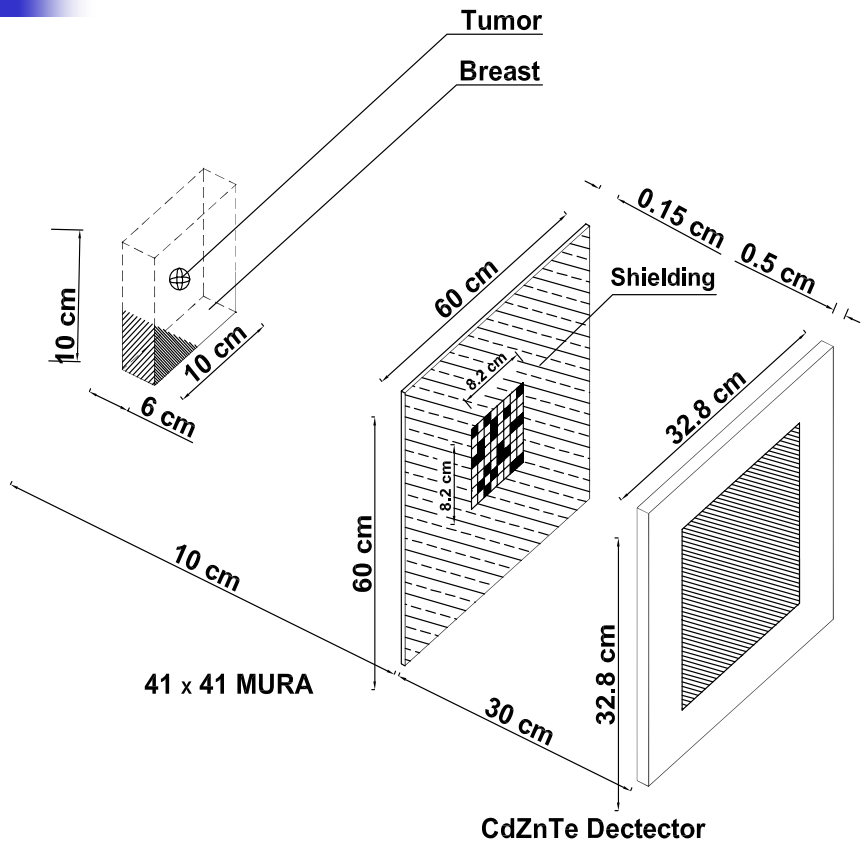




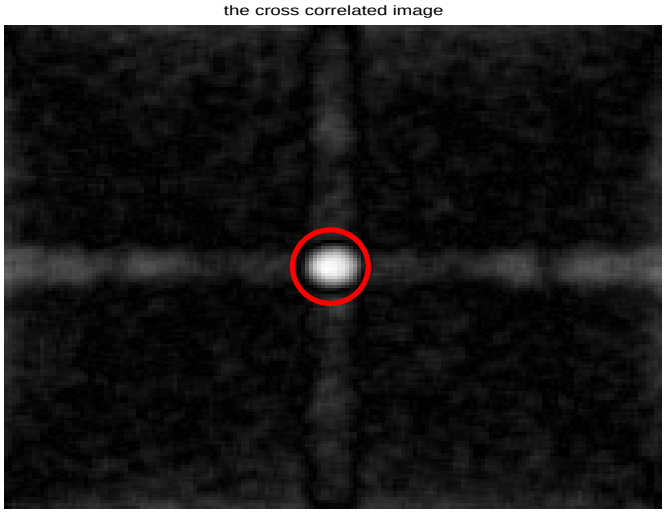


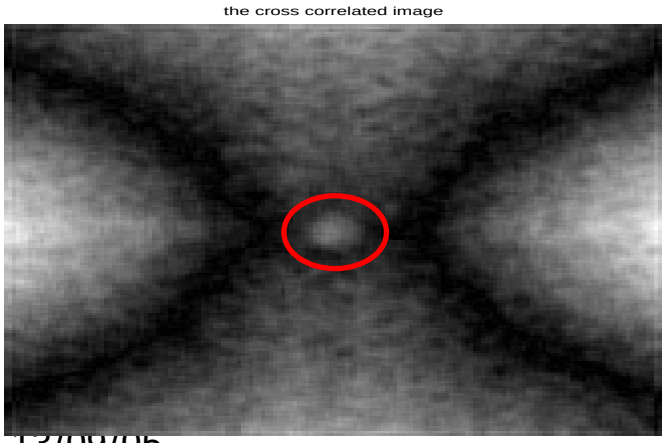
Simulation Results

10mm diameter lesion in cold and hot TEM



History Simulated
~7.7M photons

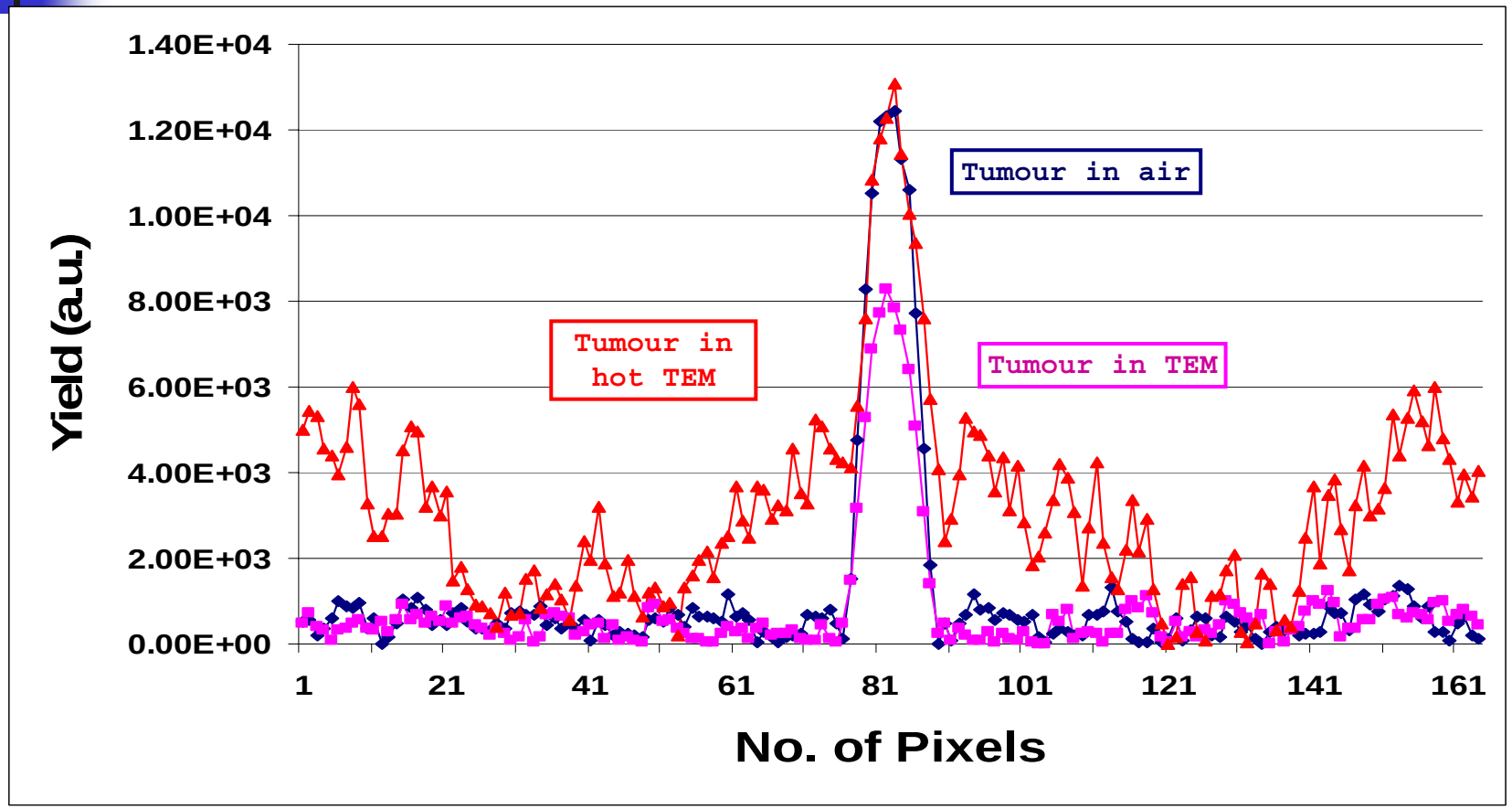




TBR 100:1

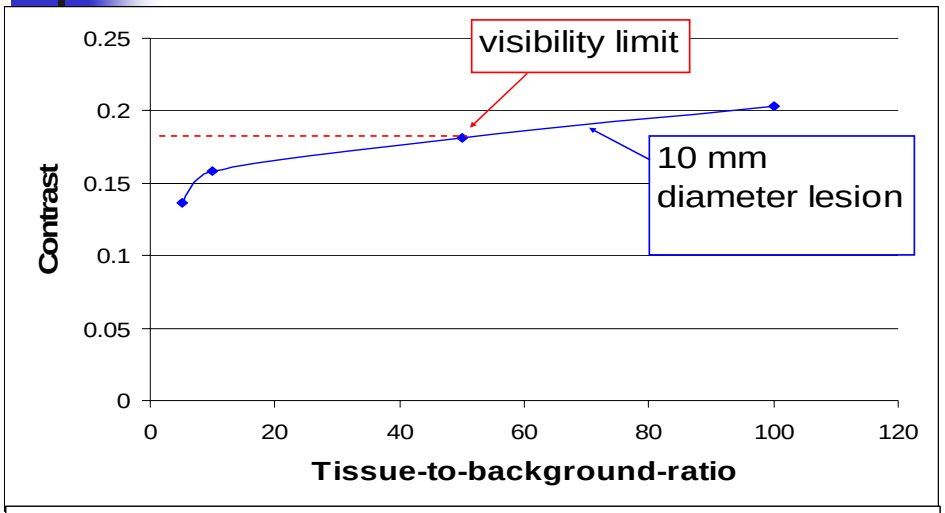
Simulation Results

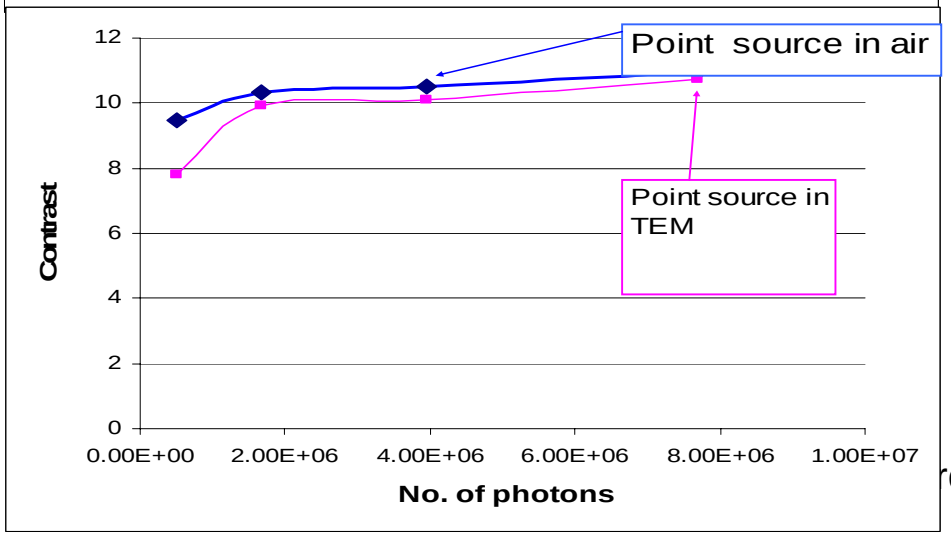
10mm diameter lesion in air, cold and hot TEM



History Simulated ~7.7M photons from each lesion

Simulation Results
Lesion Contrast



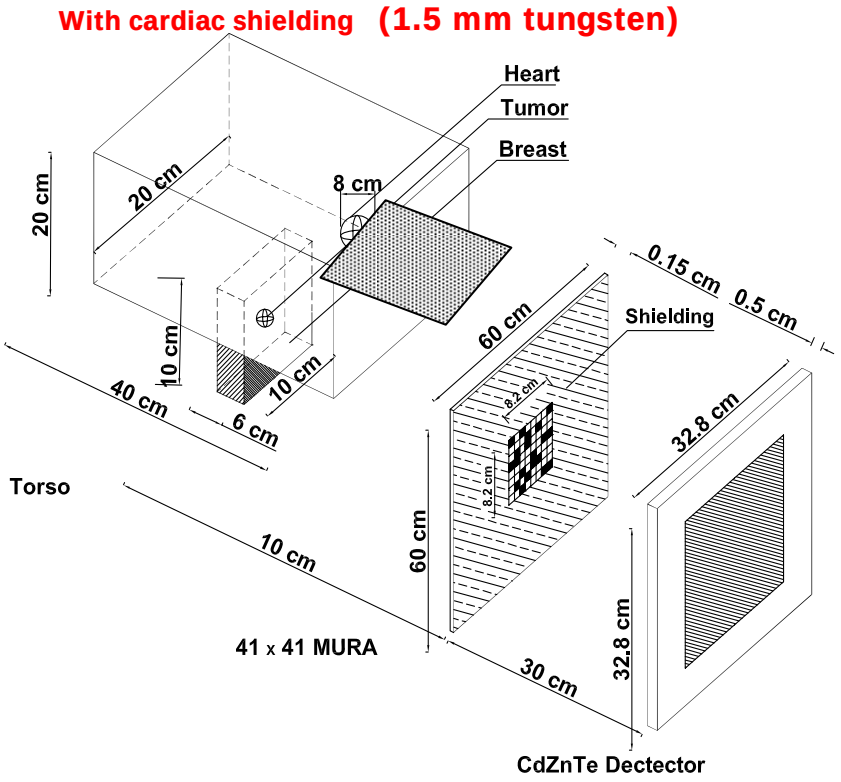


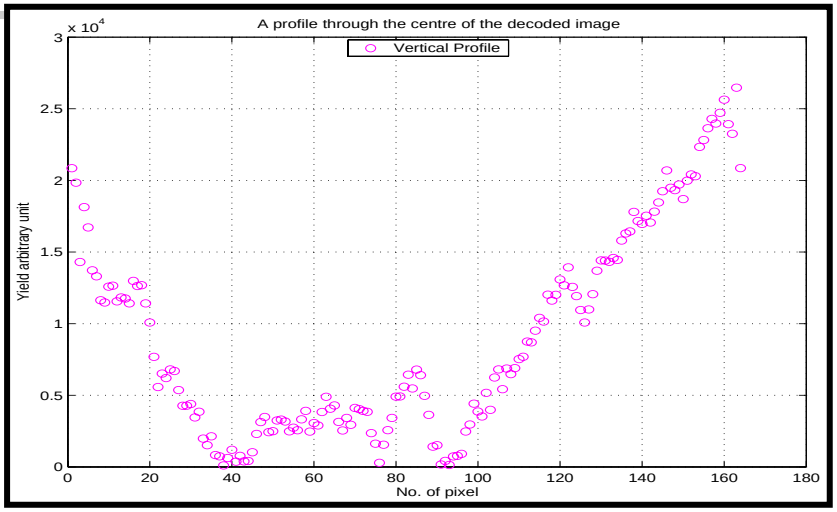
- **Lesion contrast was used to quantify the lesion visibility.**
- **The contrast *C* is defined by normalizing the signal to the background counts with the following formula:**

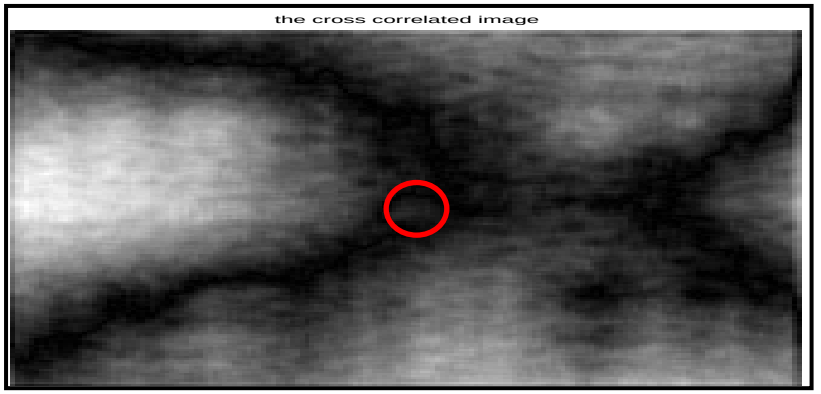
$$c = \frac{(T - B)}{B} \qquad (1)$$

- **The signal was obtained using a ROI defined by the FWHM that is calculated by taking a profile through the centre of the detected tumor after a Gaussian curve (fit) obtained to the data points.**

First Simulation Results of 3D Phantom Geometry







Demonstrates that not only cardiac shielding required, but also from non-specific uptake in the torso. Ideally image breast using a radio-opaque shielded plate

Summary

- **MURAs are attractive because displacing the gamma camera away from the breast allows access to a larger FoV (lymph nodes etc). Imaging point-like lesions [objects] in medicine akin to imaging stellar points [objects] in astronomy.**
- **The Monte Carlo Simulation provides a realistic computational tool for modelling a coded aperture camera.**
- **For this simple geometry, the 50 % open fraction of the MURA mask can detect point like objects extremely well, both in air and in TEM. However when object assumes a finite size, AND non-specific uptake coupled with limited statistics present -> correlation noise artefacts present.**
- **Future work focussed on developing better shielding geometry and developing a cross-correlation background subtraction method to reduce background correlation artefacts.**

THE END

ANY QUESTIONS