A High-Resolution Gamma-Optical Hybrid Camera for Medical Imaging

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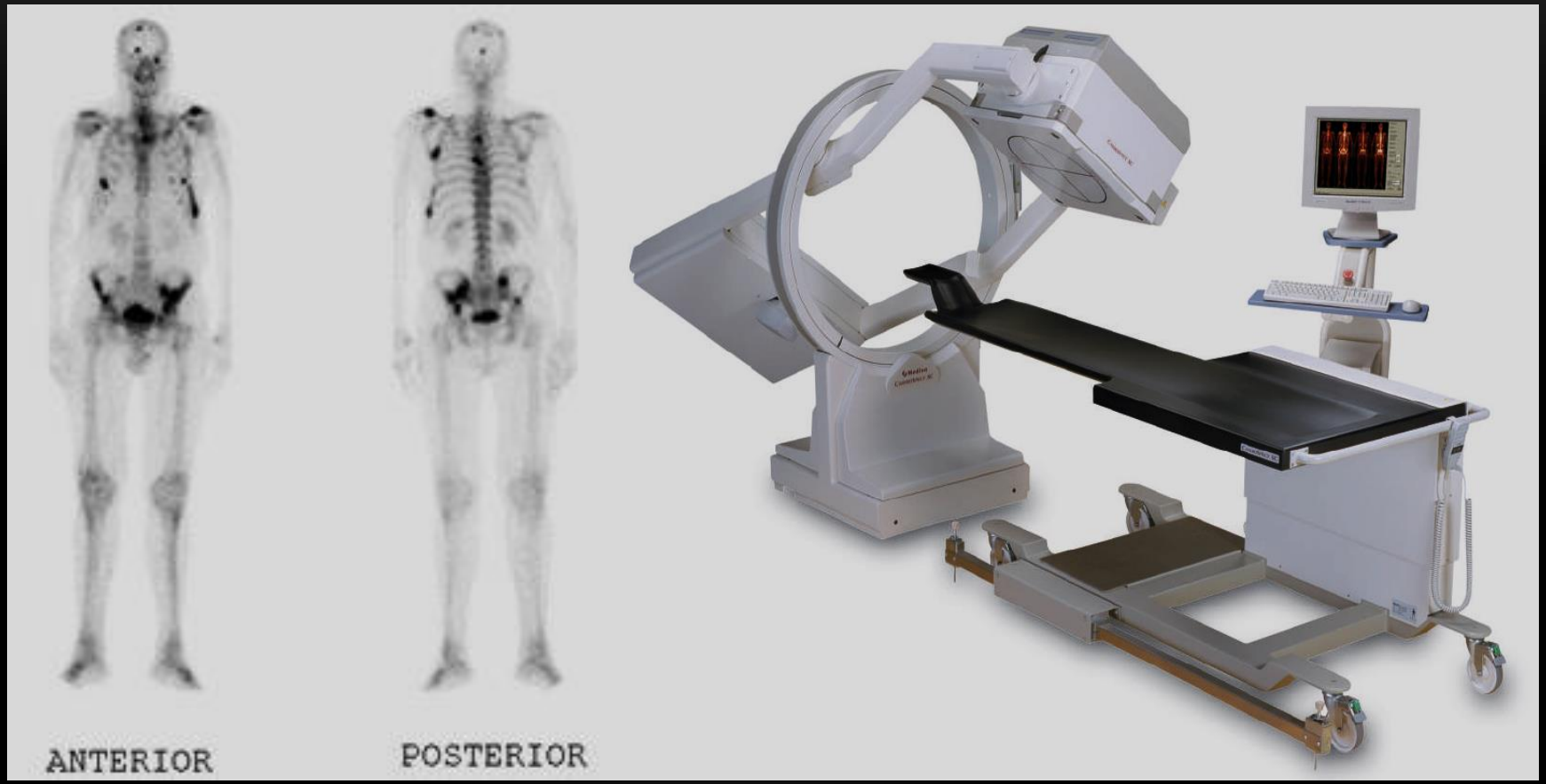
The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

OUTLINES

- Hybrid Compact Gamma Camera (HCGC) design
- Performance characterisation of the HCGC
    - Spatial resolution
    - Uniformity
    - Sensitivity
    - Count rate capability
- Conclusion

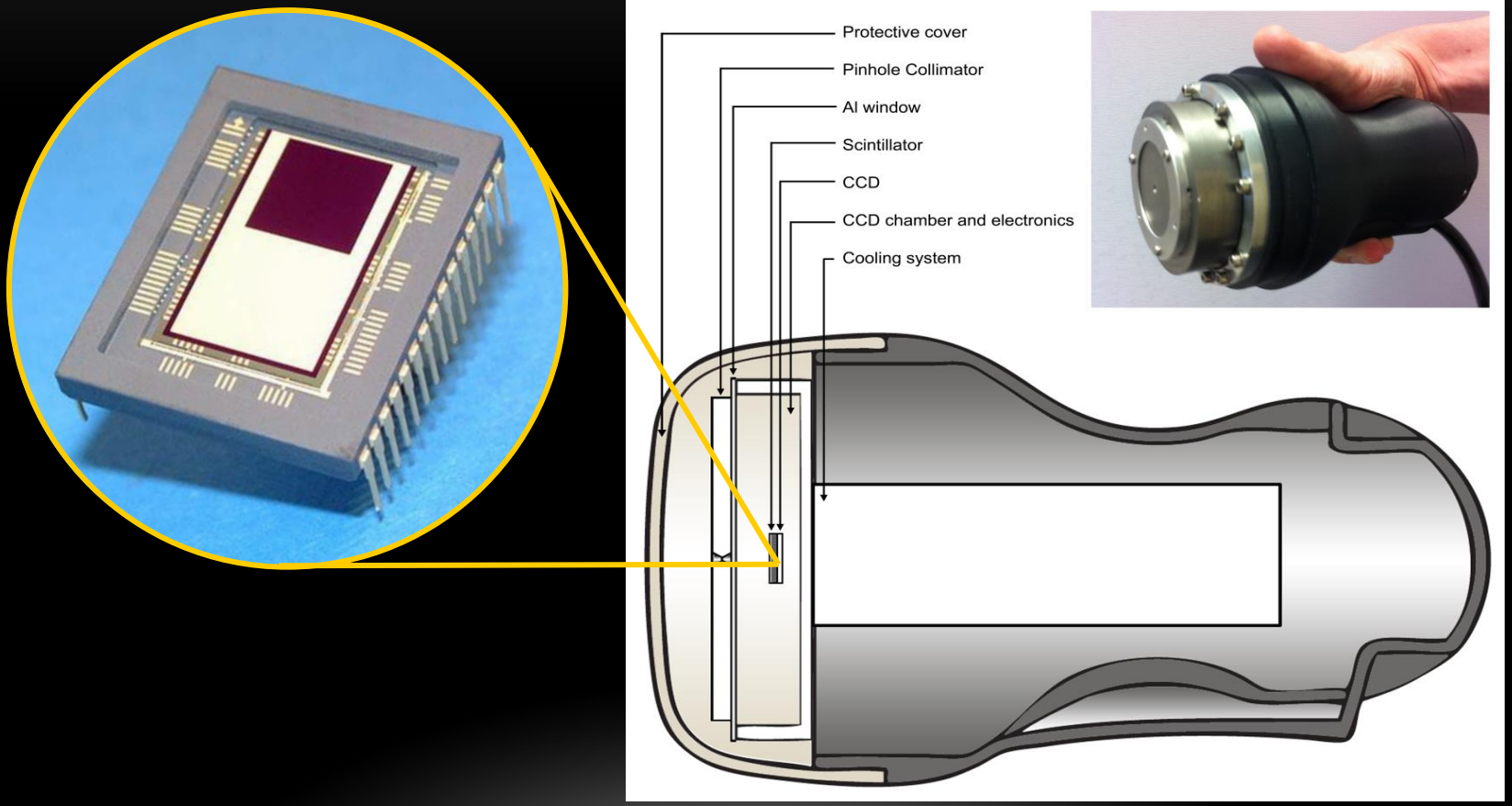
NUCLEAR MEDICINE – IMAGING AND TREATMENT



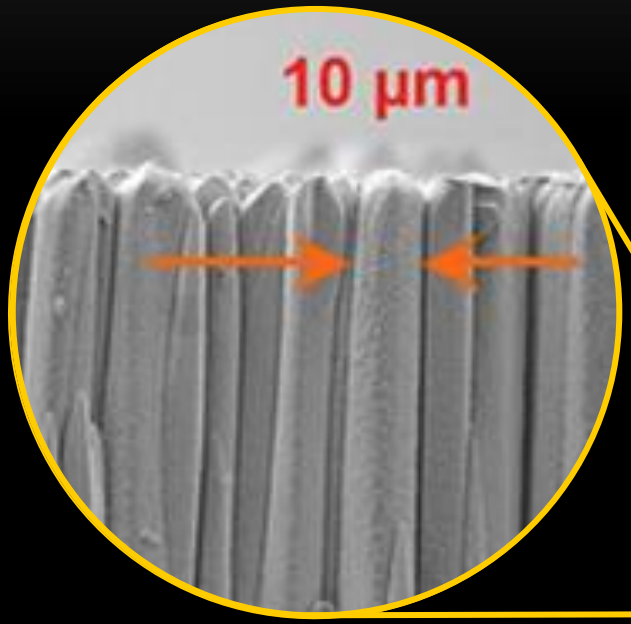
Whole body bone scan

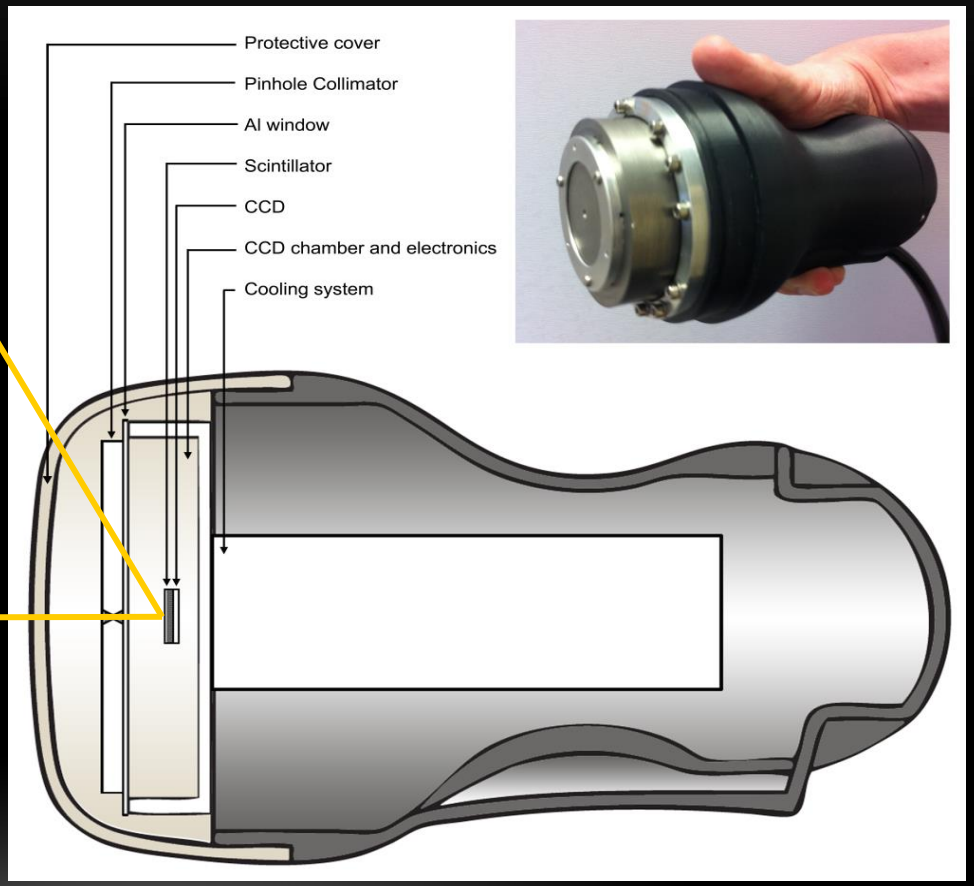
multipurpose single-head LFOV gamma camera
(Nucline™ X-Ring-R (HR), -C)

HYBRID COMPACT GAMMA CAMERA (HCGC) DESIGN

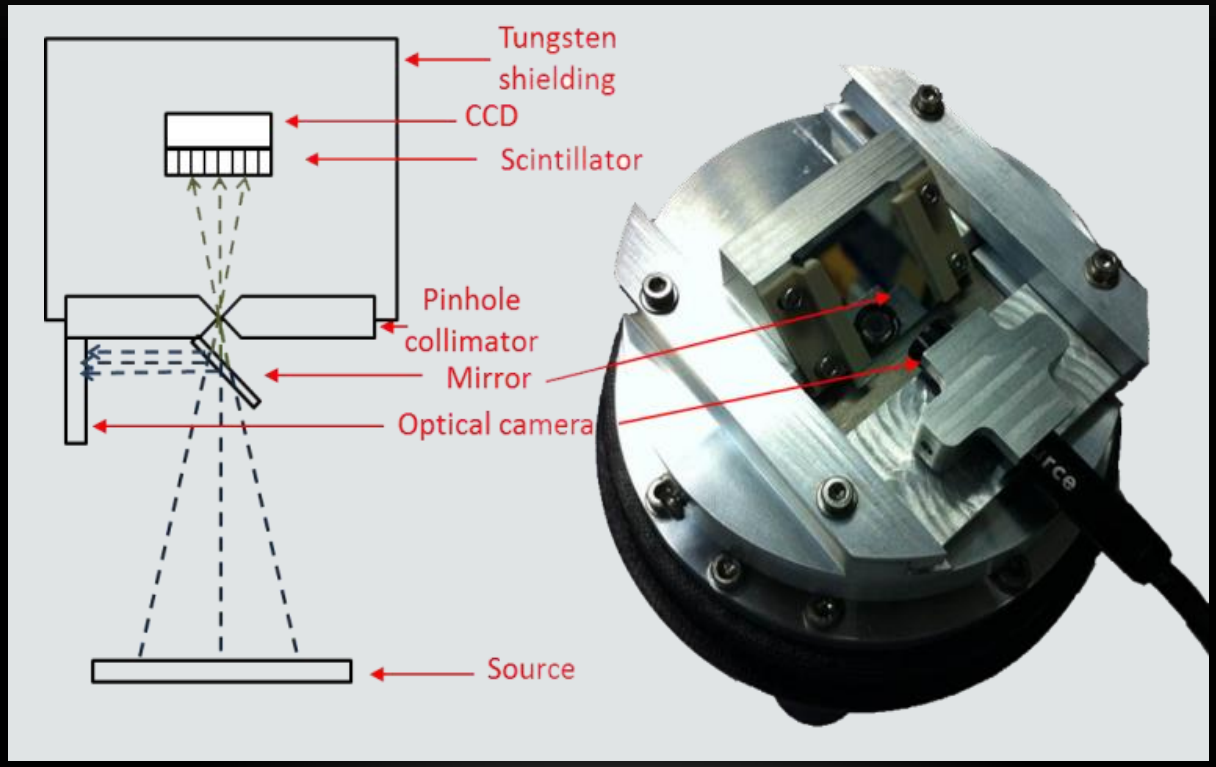


HYBRID COMPACT GAMMA CAMERA (HCGC) DESIGN

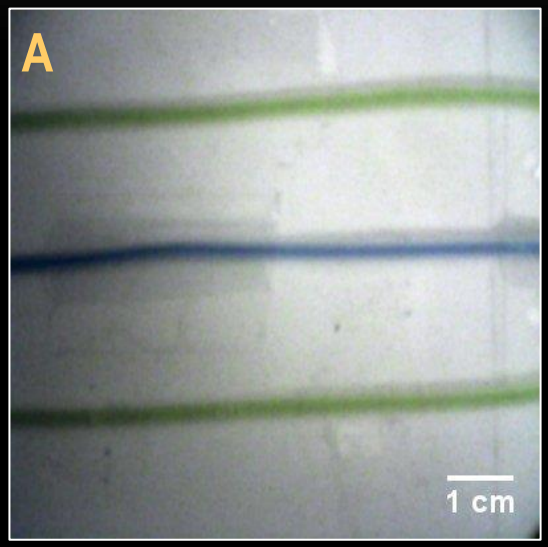




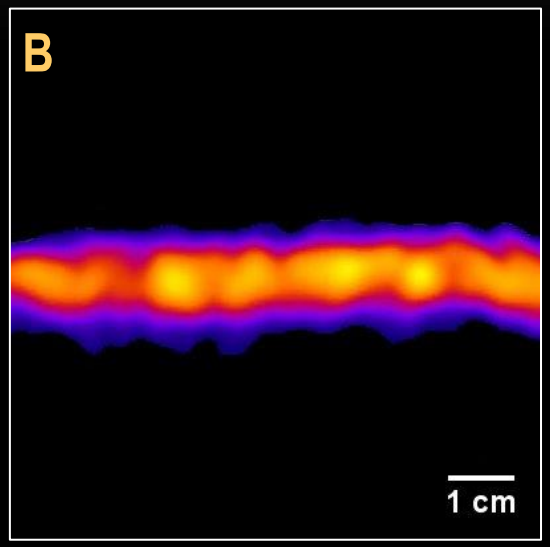
HYBRID COMPACT GAMMA CAMERA (HCGC) DESIGN



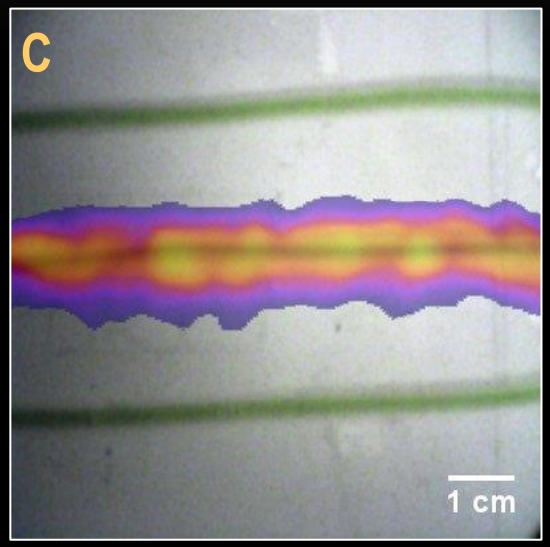
HYBRID ALIGNMENT



A) optical image



B) gamma image



C) fused gamma optical image

Optical and gamma images acquired by the HCGC. A cannula was used to mimic a lymphatic vessel. The middle cannula was filled with 2MBq of ^{99m}Tc mixed with blue dye, the upper and lower one filled with green dye only. The acquisition time was 1000 frame (~ 120sec).

PERFORMANCE CHARACTERISATION OF THE HCGC

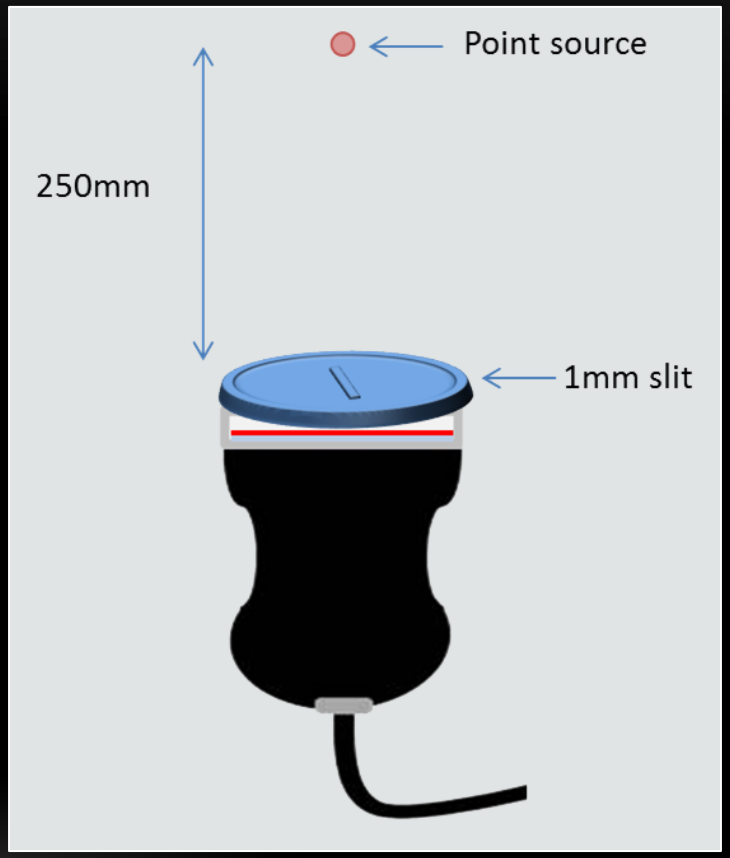
- Parameters investigated:
  - Spatial resolution
  - Uniformity
  - Sensitivity
  - Count rate capability

- Developed by the Institute of Physics and Engineering in Medicine (IPEM)

SPATIAL RESOLUTION

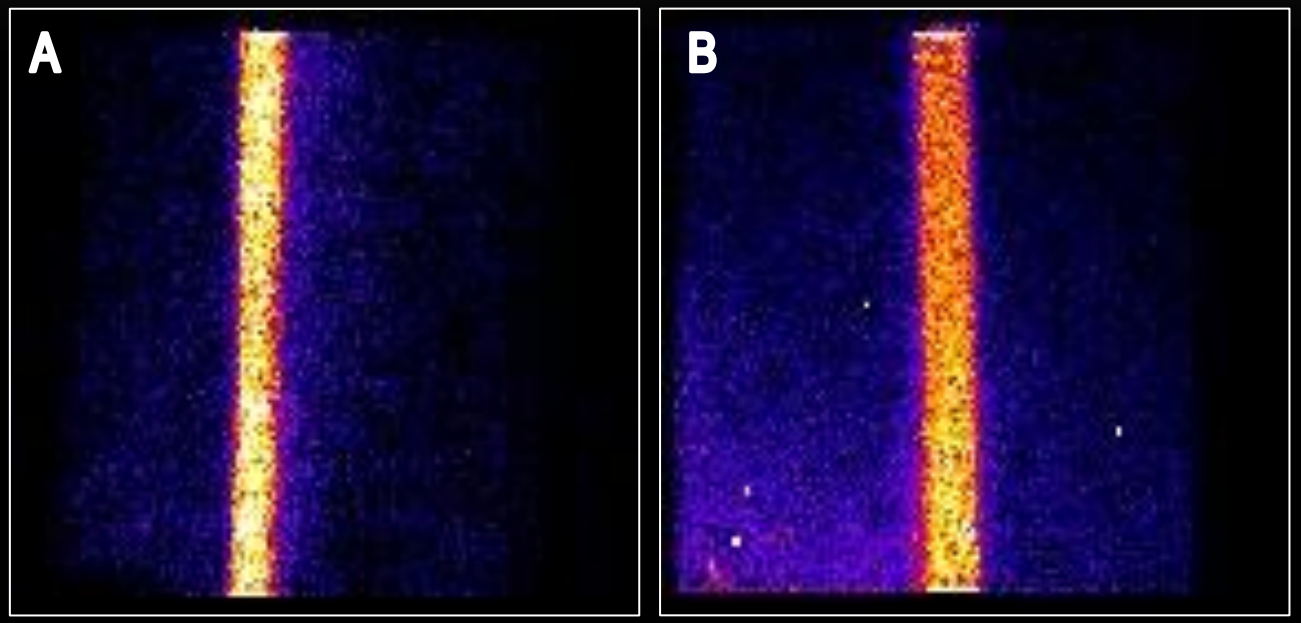
- Intrinsic Spatial Resolution

It is the full width at half maximum (FWHM) of a line spread function (LSF) or of a point spread function (PSF) without a collimator.



SPATIAL RESOLUTION

- Intrinsic Spatial Resolution

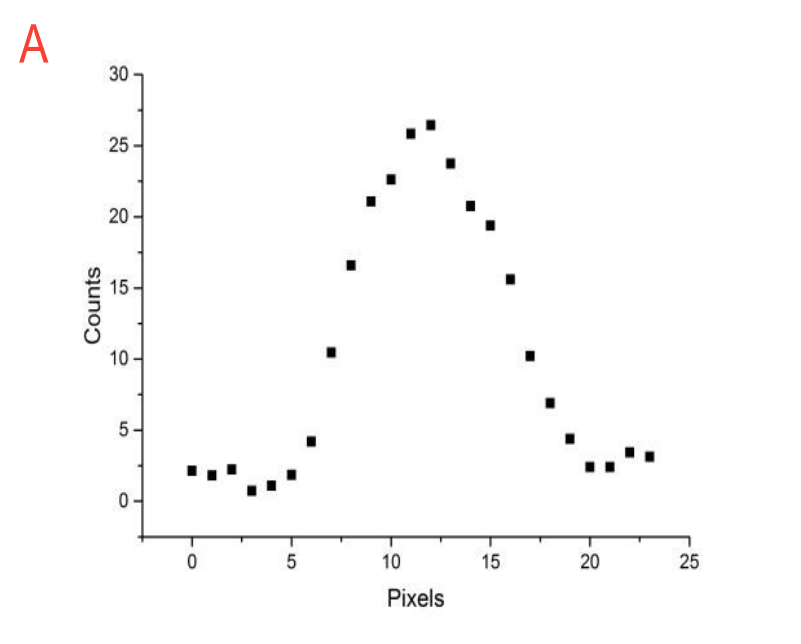


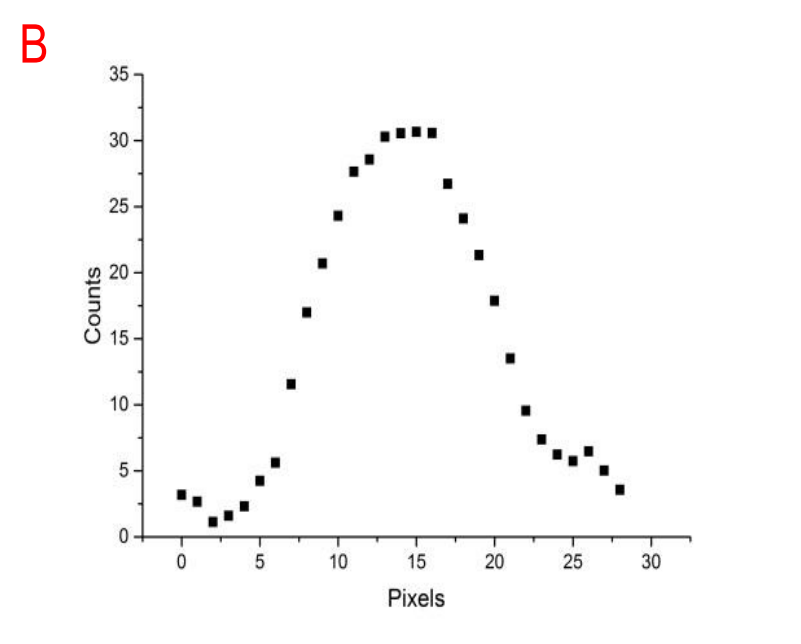
A) 600µm B) 1500µm

Gamma image of 20MBq ^{99m}Tc point source, placed at 250mm distance from the 1mm width slit. The acquisition time was 10000 frames (~ 1200sec).

SPATIAL RESOLUTION

- Intrinsic Spatial Resolution



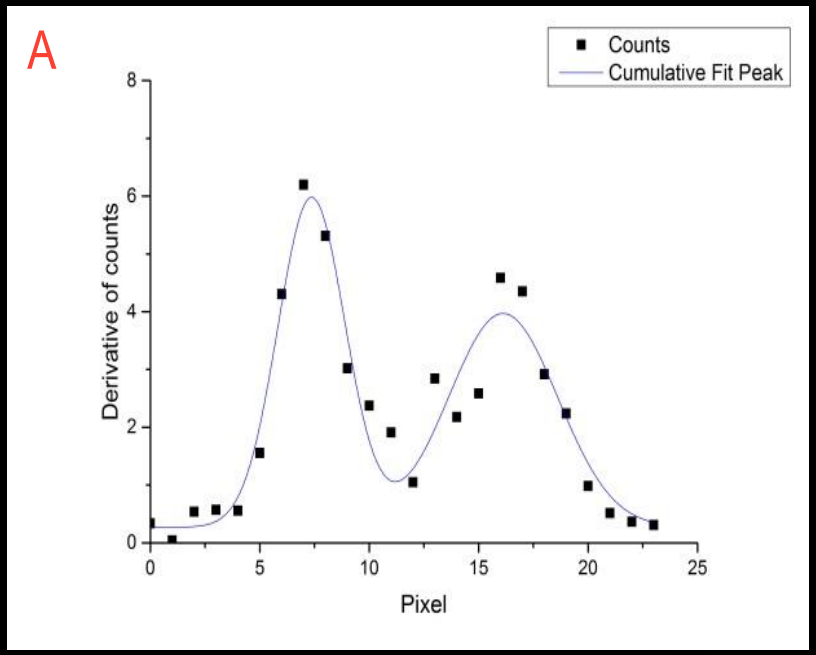


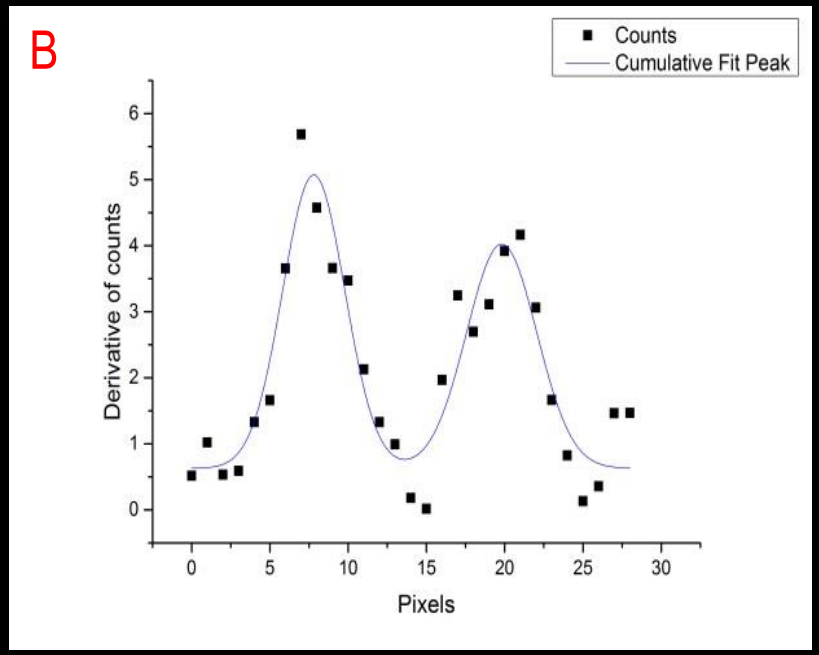
A) 600µm B) 1500µm

Edge response function (ERF) for ^{99m}Tc source.

SPATIAL RESOLUTION

- Intrinsic Spatial Resolution





A) 600µm B) 1500µm

Modulus of LSF with fitted Gaussians.

SPATIAL RESOLUTION

- Intrinsic Spatial Resolution

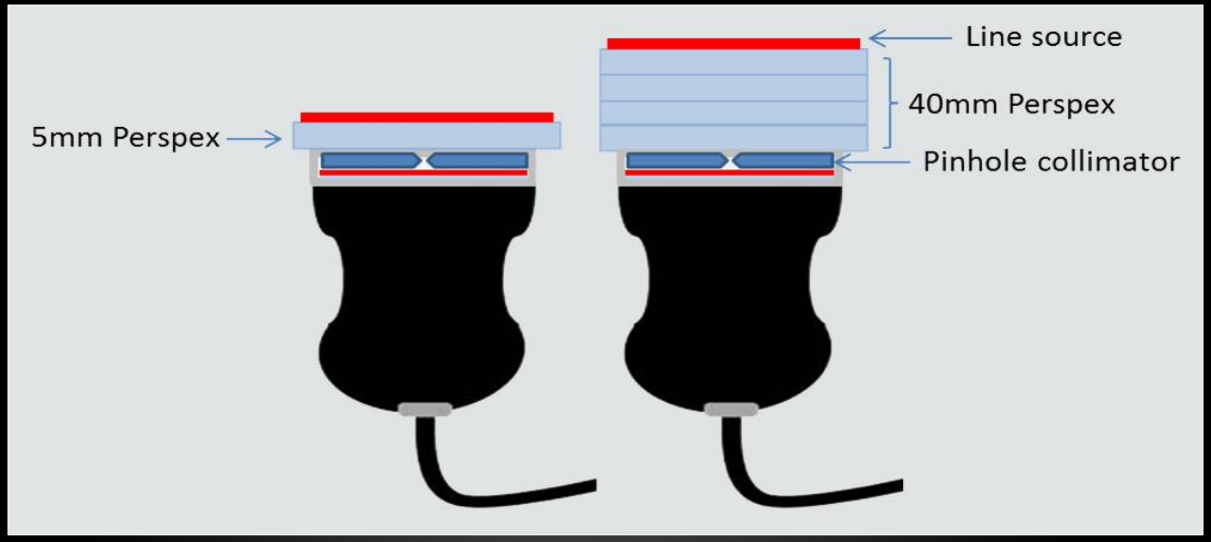
Better →

FWHM (mm)	
600µm	0.30 ± 0.03
1500µm	0.32 ± 0.05

SPATIAL RESOLUTION

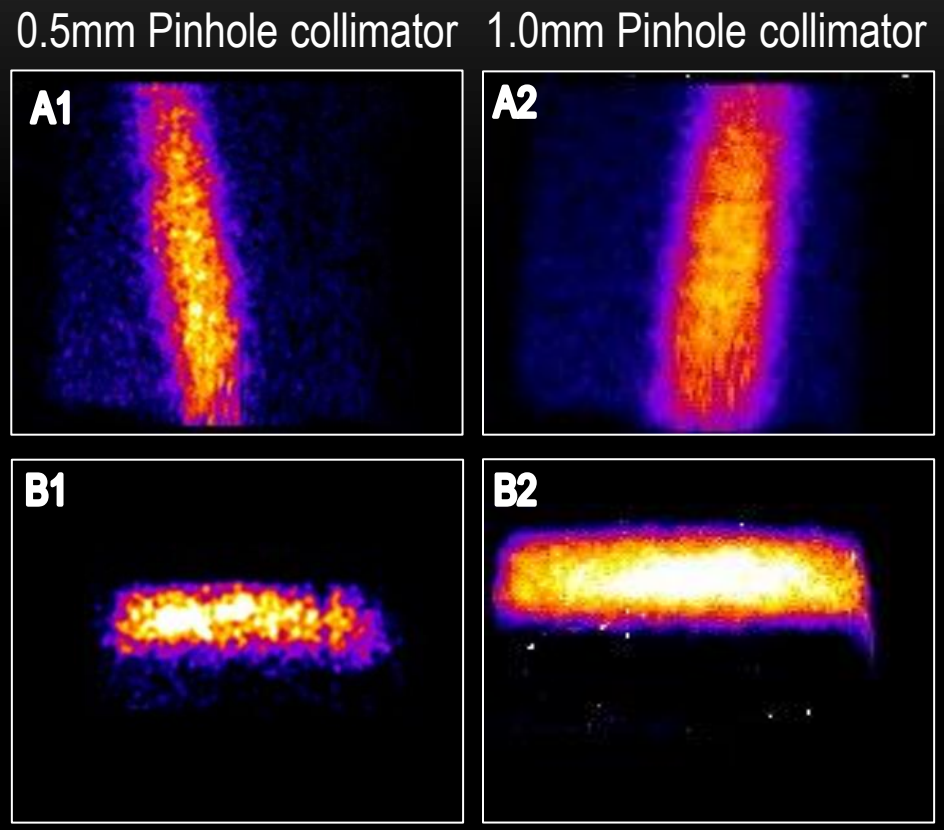
- Extrinsic Spatial Resolution

The FWHM of a LSF or of a PSF with the imaging collimator in place.



SPATIAL RESOLUTION

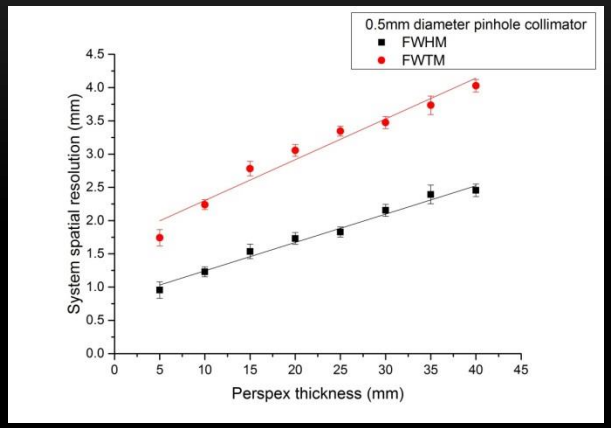
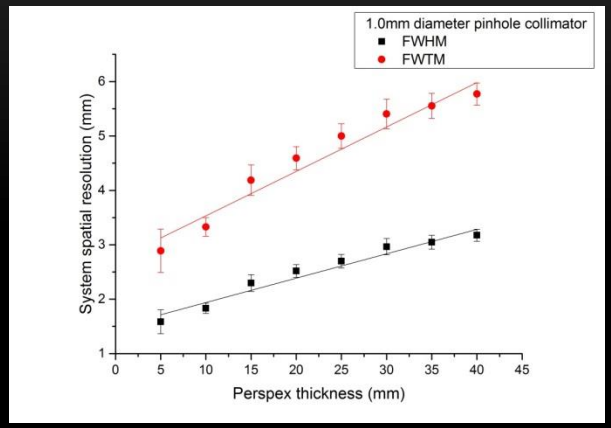
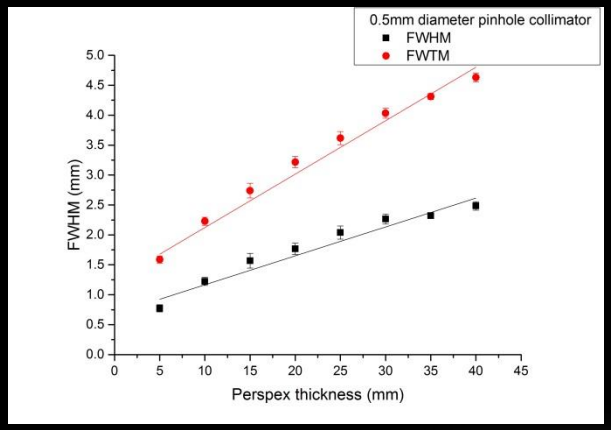
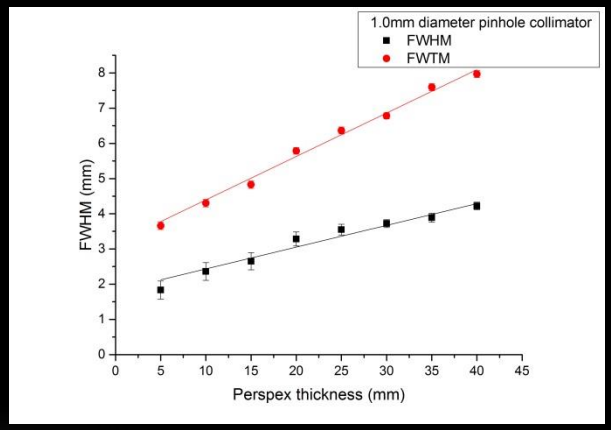
- Extrinsic Spatial Resolution



A 1.1mm diameter cannula filled with 30MBq ^{99m}Tc imaged with both 1.0mm and 0.5mm diameter pinhole collimators. Layers of Perspex ranging from 5mm to 40mm were placed directly between the line source and the camera face. The acquisition time was 3000 frames (~ 360sec).

SPATIAL RESOLUTION

- Extrinsic Spatial Resolution

	0.5mm Pinhole collimator	1.0mm Pinhole collimator
600µm		
1500µm		

Graphs showing the extrinsic spatial resolution vs Perspex thickness. FWHM (black square) and FWTM (red dots) calculated for 1.1mm diameter cannula filled with 30MBq ^{99m}Tc which was used as a line source.

SPATIAL RESOLUTION

- Extrinsic Spatial Resolution

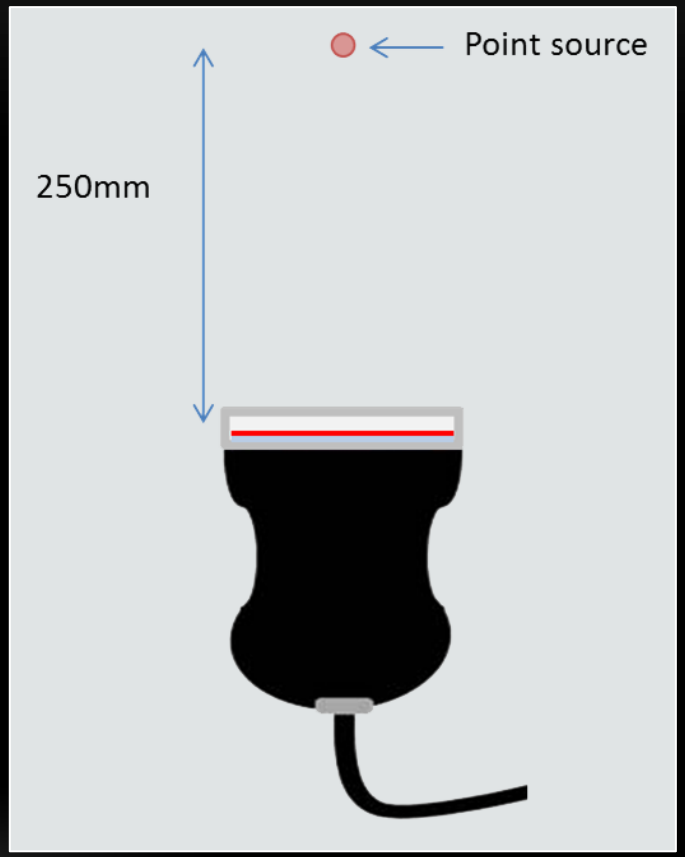
CsI scintillator	Pinhole collimator	FWHM (mm)
600µm	0.5mm	1.24 ± 0.08
	1.0mm	1.94 ± 0.14
1500µm	0.5mm	1.17 ± 0.15
	1.0mm	1.80 ± 0.25

Better →

UNIFORMITY

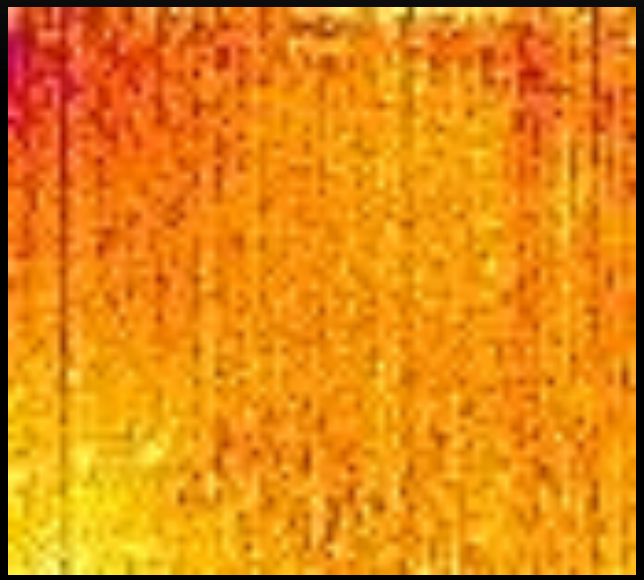
- Intrinsic Spatial Uniformity

Describe the variation in counts per pixel.

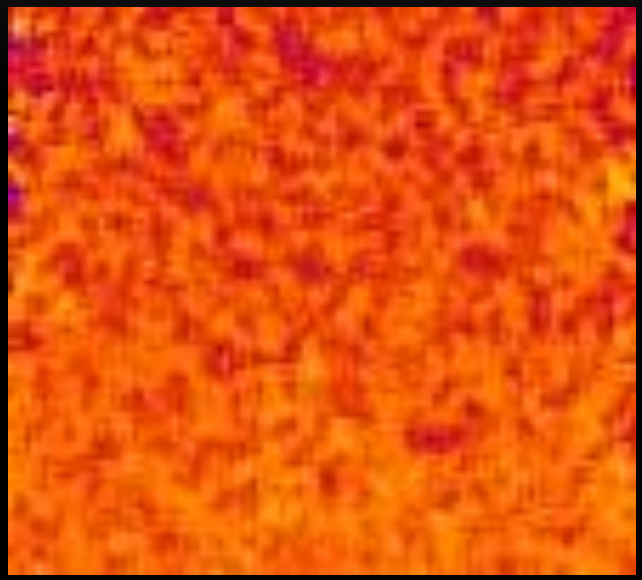


INTRINSIC SPATIAL UNIFORMITY

A



B



A) 600µm

B) 1500µm

Raw flood images of a 20MBq ^{99m}Tc point source, 3mm diameter, placed at 250mm away from the un-collimated camera to measure the spatial uniformity. The acquisition time was 30000 frames (~ 3600sec).

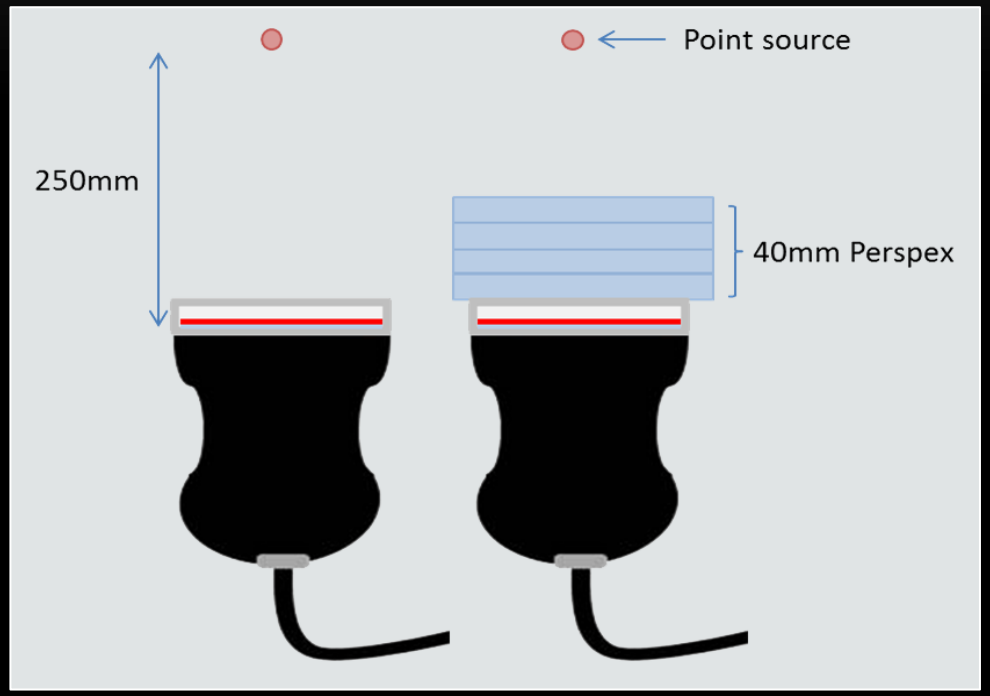
INTRINSIC SPATIAL UNIFORMITY

	Coefficient of variation (COV)	
	600μm	1.83%
Better →	1500μm	1.30%

SENSITIVITY

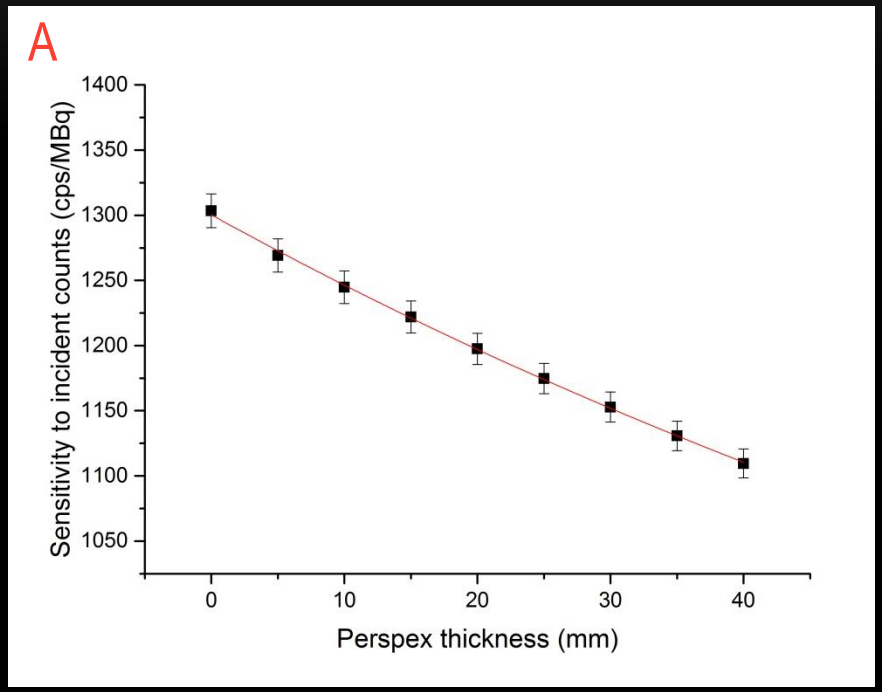
Intrinsic Spatial Sensitivity

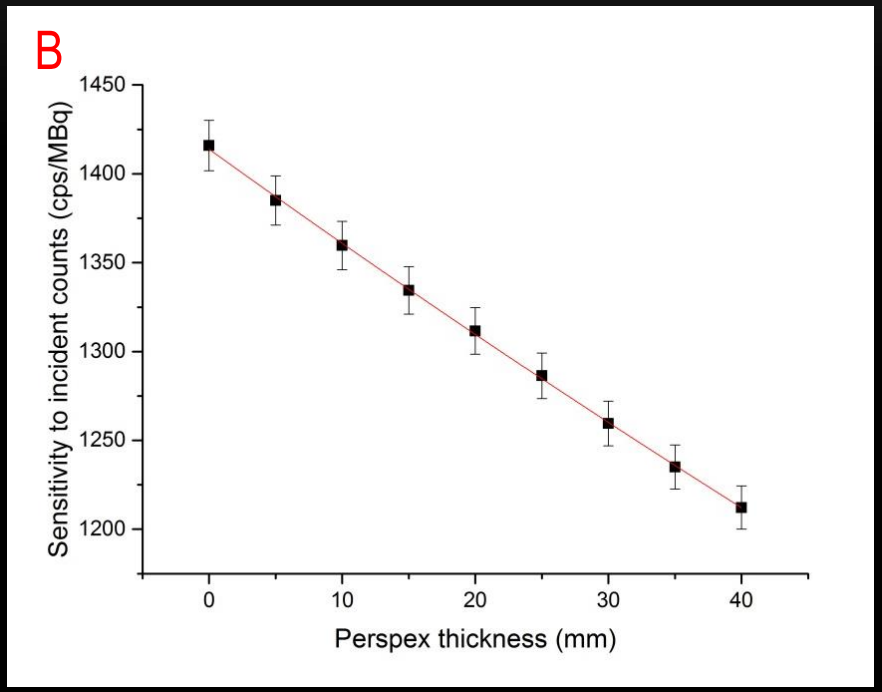
- The proportion of photon flux incident on the detector that is recorded within the photopeak energy window being used.



SENSITIVITY

- Intrinsic Spatial Sensitivity





A) 600µm

B) 1500µm

A 20MBq ^{99m}Tc point source placed at 250mm away from the HCGC with increasing layers of Perspex added in between to show the relationship between the intrinsic sensitivity of the HCGC and the Perspex thickness. The acquisition time was 5000 frames (~ 600sec).

SENSITIVITY

- Intrinsic Spatial Sensitivity

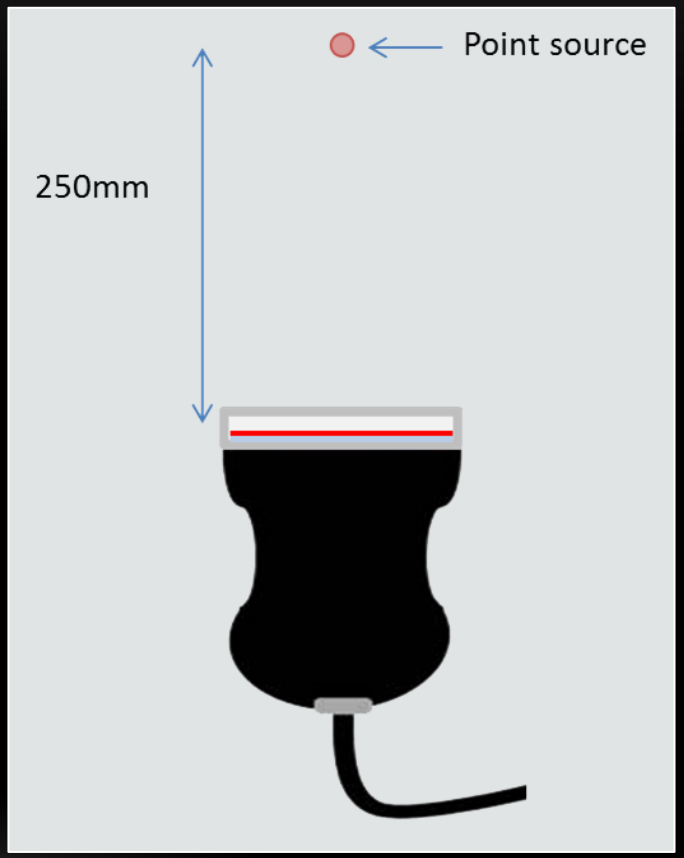
Intrinsic sensitivity	
600µm	16.7%
1500µm	30%

Better →

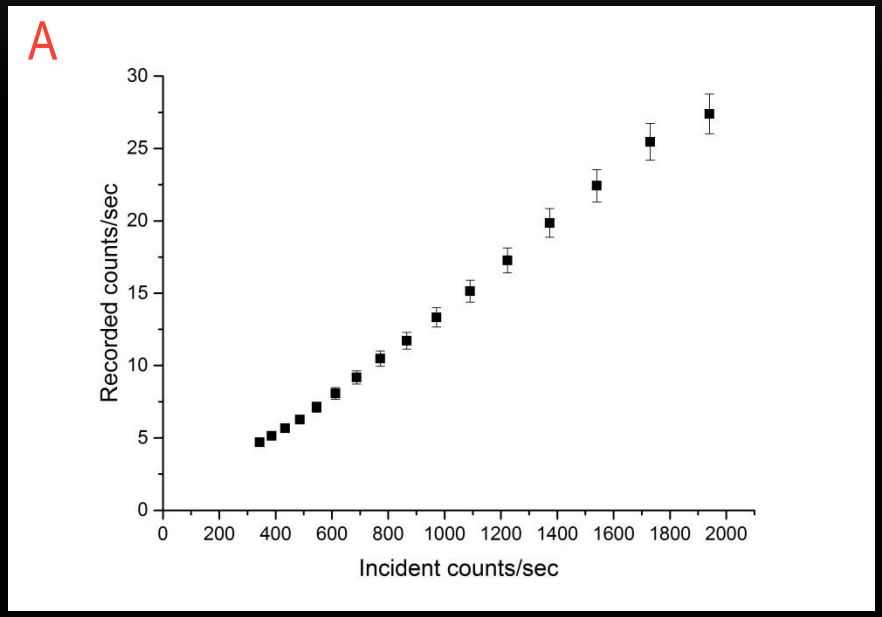
COUNT RATE CAPABILITY

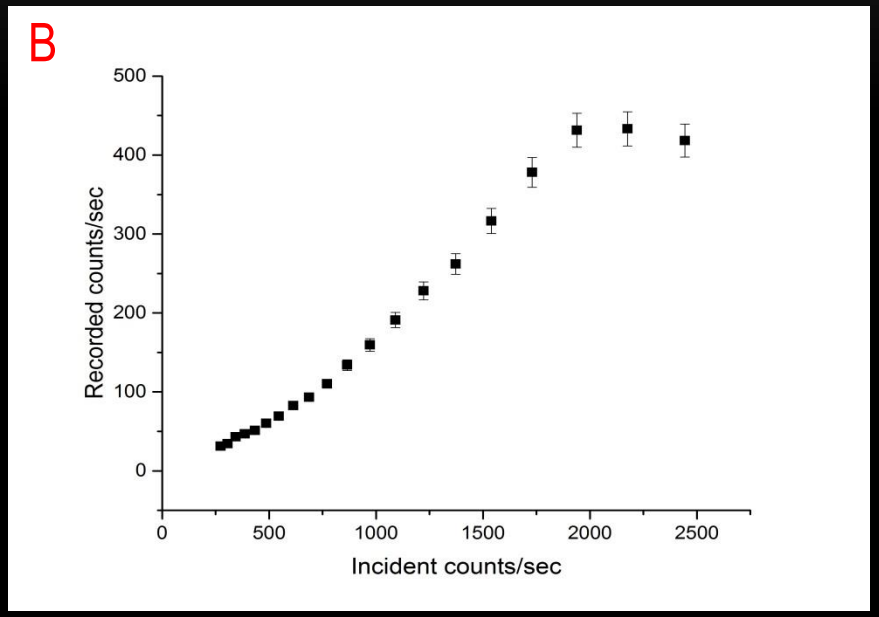
- Count rate capability

The ability of the detector to linearly measure counts.



COUNT RATE CAPABILITY





A) 600µm

B) 1500µm

Recorded count rate capability for HCGC by using 10mm diameter point source filled with 30MBq ^{99m}Tc placed 250mm away from the un-collimated camera. Images were taken over the course of 24hrs. The acquisition time was 2000 frames (~ 240sec).

COUNT RATE CAPABILITY

Count rate capability	
600µm	1940
1500µm	2175

Better →

SUMMARY

Performance specification		600µm	1500µm
Intrinsic spatial resolution	FWHM (mm)	0.30 ± 0.03	0.32 ± 0.05
Extrinsic spatial resolution	0.5mm pinhole collimator FWHM(mm)	1.24 ± 0.08	1.17 ± 0.15
	1.0mm pinhole collimator FWHM(mm)	1.94 ± 0.14	1.80 ± 0.25
Intrinsic spatial uniformity	Coefficient of variation (%)	1.83	1.30
Intrinsic sensitivity	Intrinsic sensitivity (%)	16.7	30
Count rate capability	Incident counts/sec	1940	2175

FUTURE WORK

Gadolinium-oxysulfide scintillator Gd_2O_2S

- Ceramic pixelated scintillator
- 1500µm thick

A Raw flood image of a 20MBq ^{99m}Tc point source, 3mm diameter. The acquisition time was 30000 frames (~ 3600sec).

CONCLUSION

- Preclinical and clinical evaluation of the HCGC

ACKNOWLEDGEMENTS

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- **Leicester Royal Infirmary**

Chris Hastings and David Monk

FURTHER INFORMATION

- Lees, J. E., S. L. Bugby, B. S. Bhatia, L. K. Jambi, M. S. Alqahtani, W. R. McKnight, A. H. Ng and A. C. Perkins. "A Small Field of View Camera for Hybrid Gamma and Optical Imaging." *Journal of Instrumentation* 9, no. 12 (2014): C12020-C12020.
- Bhatia, B.S., S.L. Bugby, J.E. Lees, and A.C. Perkins, "A scheme for assessing the performance characteristics of small field-of-view gamma cameras". *Phys Med*, 2015. 31(1): p. 98-103.
- Bugby, S.L., J.E. Lees, B.S. Bhatia, and A.C. Perkins, "Characterisation of a high resolution small field of view portable gamma camera". *Phys Med*, 2014. 30(3): p. 331-9.

Contact

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PRELIMINARY EVALUATION

Performance specification		HCGC		Typical LFOV
		600µm	1500µm	
Field of view	Nominal (mm)	40 x 40		210 Ø
Intrinsic spatial resolution	FWHM (mm)	0.30 ± 0.03	0.32 ± 0.05	2.7
Extrinsic spatial resolution	0.5mm pinhole collimator FWHM(mm)	1.24 ± 0.08	1.17 ± 0.15	7.8
	1.0mm pinhole collimator FWHM(mm)	1.94 ± 0.14	1.80 ± 0.25	
Intrinsic spatial uniformity	Coefficient of variation	1.83	1.30	x
Intrinsic sensitivity	Intrinsic sensitivity (%)	16.7	30	x
Count rate capability	Incident counts/sec	1940	2175	25000