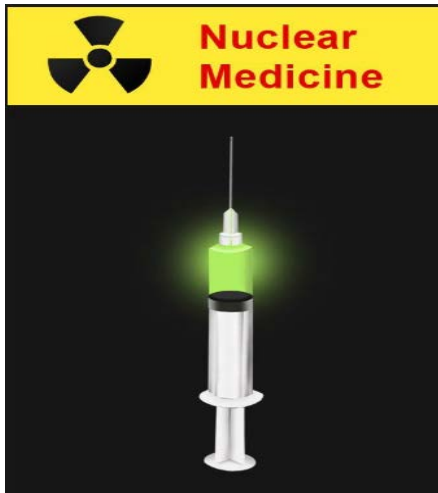


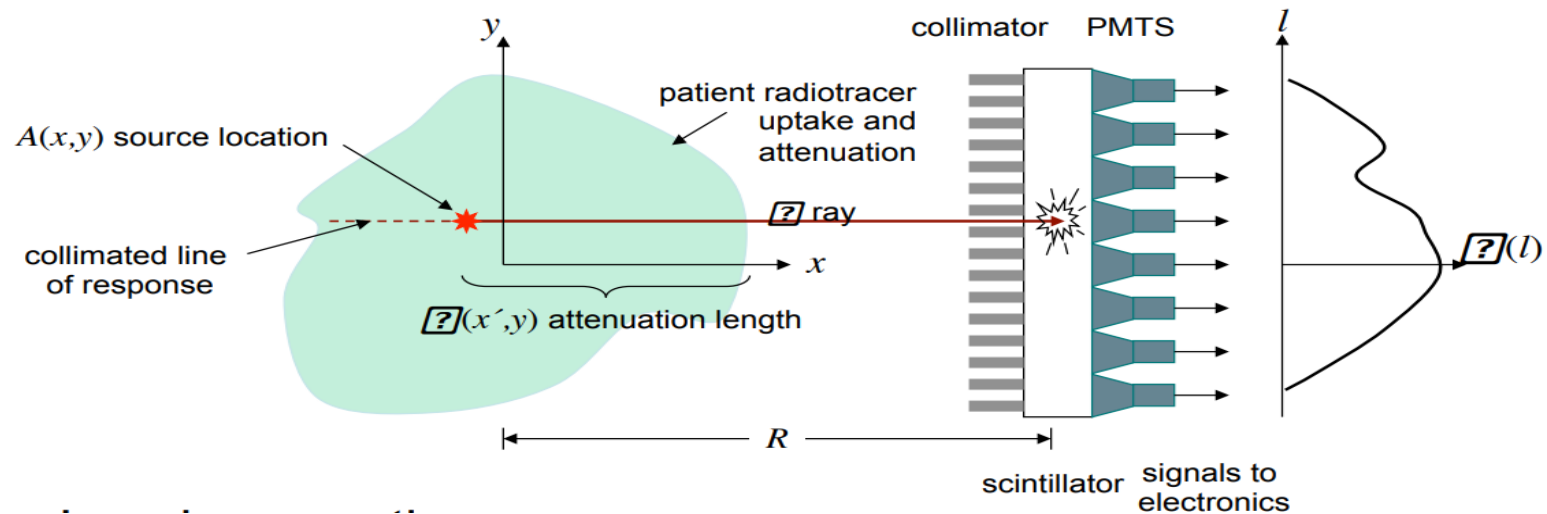
Monte Carlo simulation of the Compton Camera for Nuclear Medical Imaging

CHIBUEZE UCHE *PhD*

Nuclear Medicine Imaging System – Gamma camera

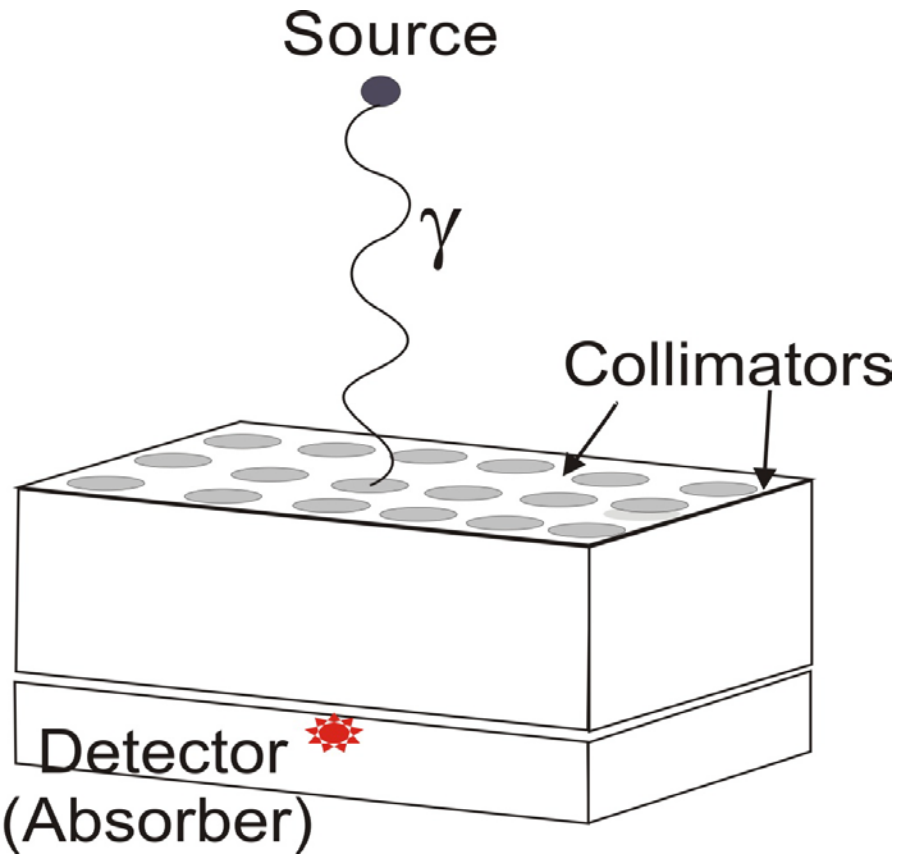


Gamma camera head

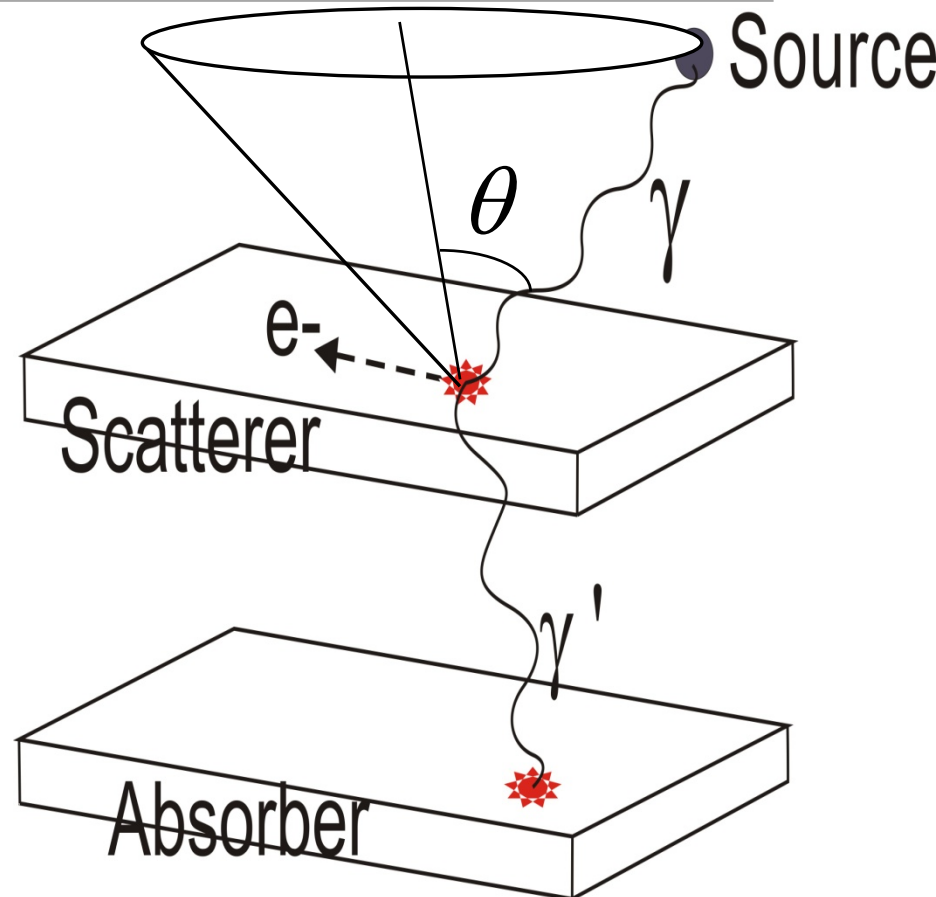


- ❖ Bulky
- ❖ Low detection efficiency – typical 0.01% (1 in 10000 photons detected)
- ❖ Trade-off between detection efficiency and resolution
- ❖ Allows mostly low energy radiotracers e.g. $^{99}\text{Tc} \approx 140 \text{ keV}$

Compton camera

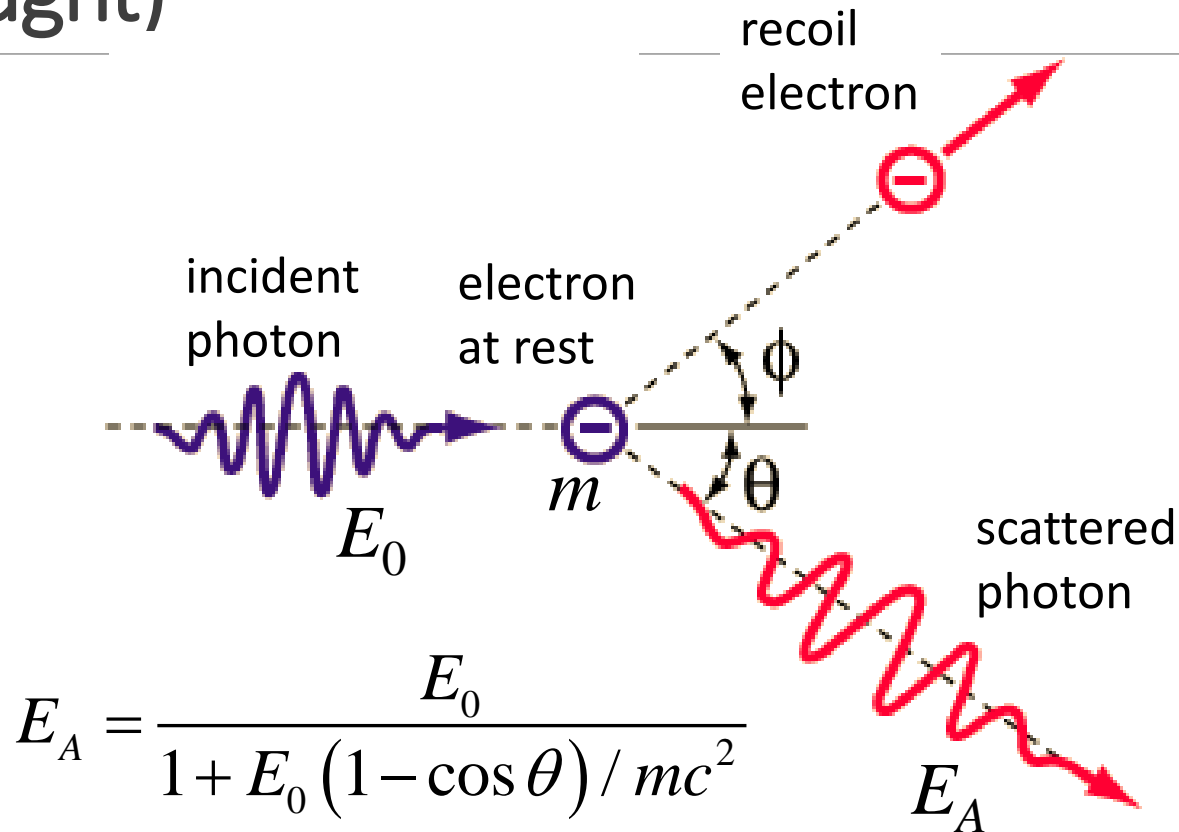


Gamma camera

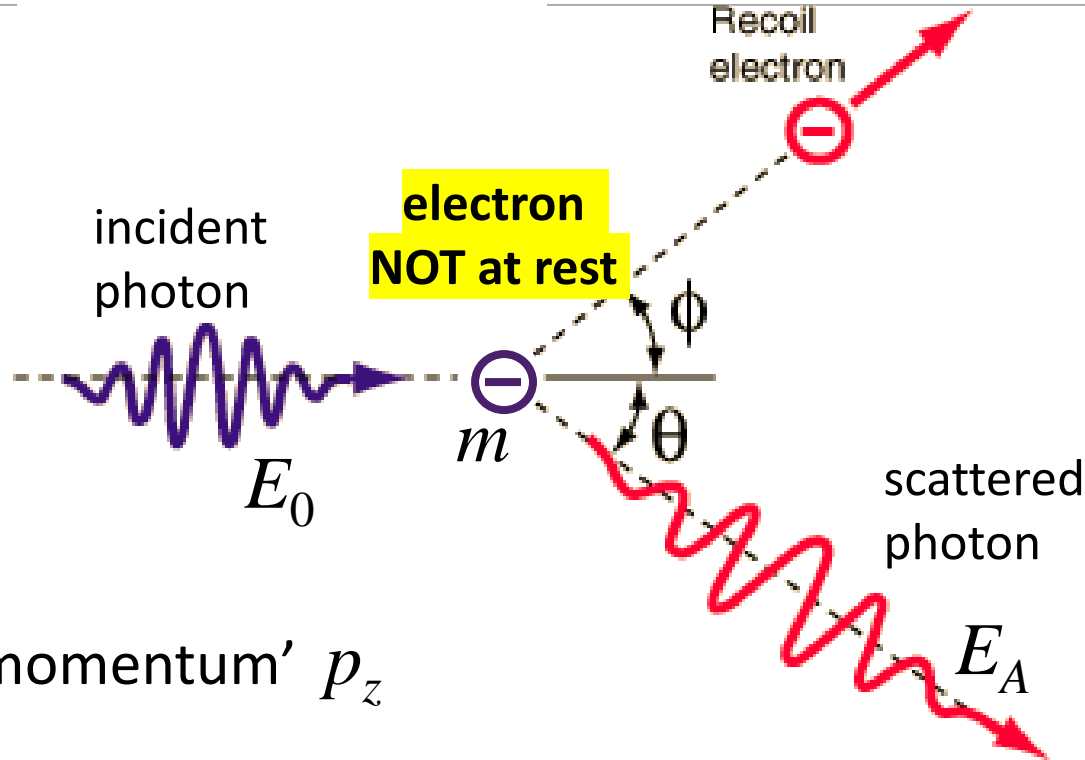


Compton camera

Compton scattering (what you were taught)



Compton scattering (what really happens)



'electron momentum' p_z

$$p_z = -mc \frac{E_0 - E_A - E_0 E_A (1 - \cos \theta) / mc^2}{\sqrt{E_0^2 + E_A^2 - 2E_0 E_A \cos \theta}}$$

Doppler Broadening

So incident photon can be scattered over a range of angles, NOT a specific angle

How Doppler broadening affects the electron energy spectrum at $\theta = 90^\circ$

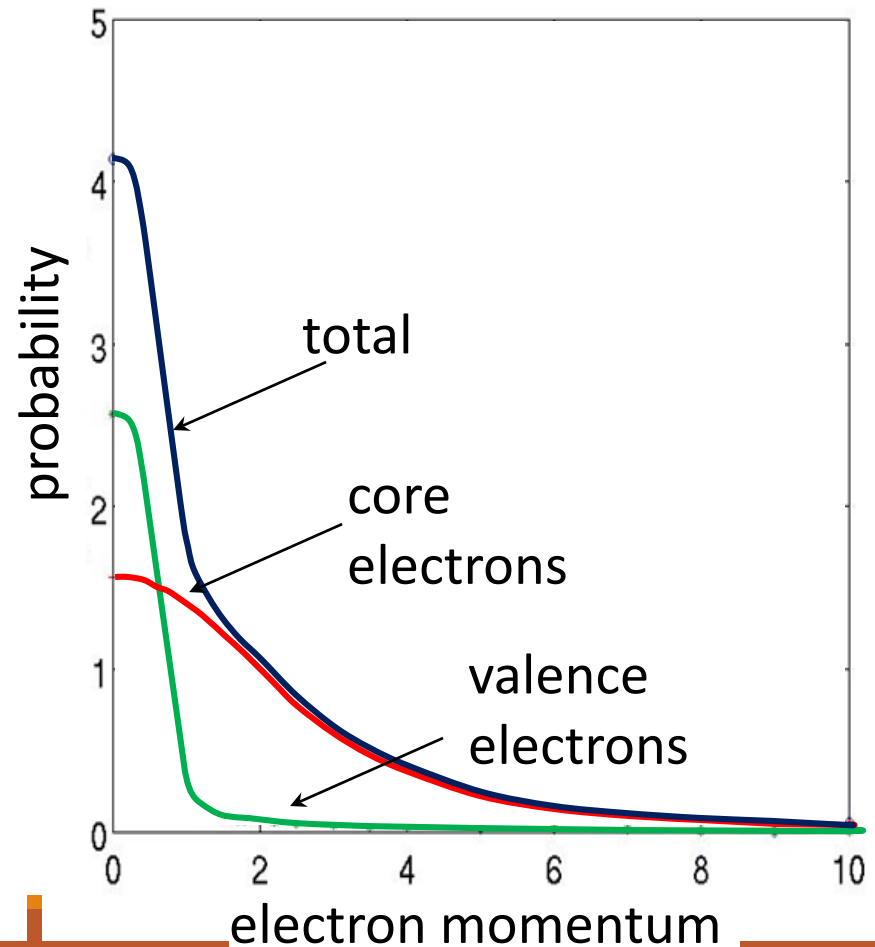
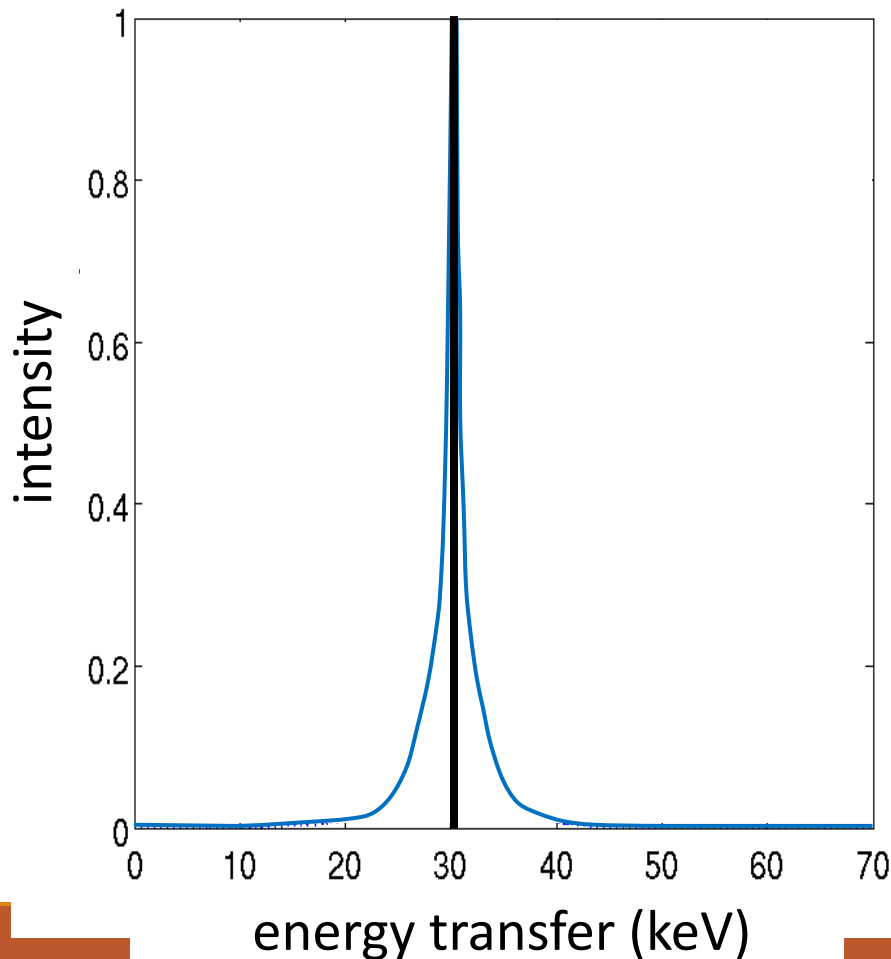
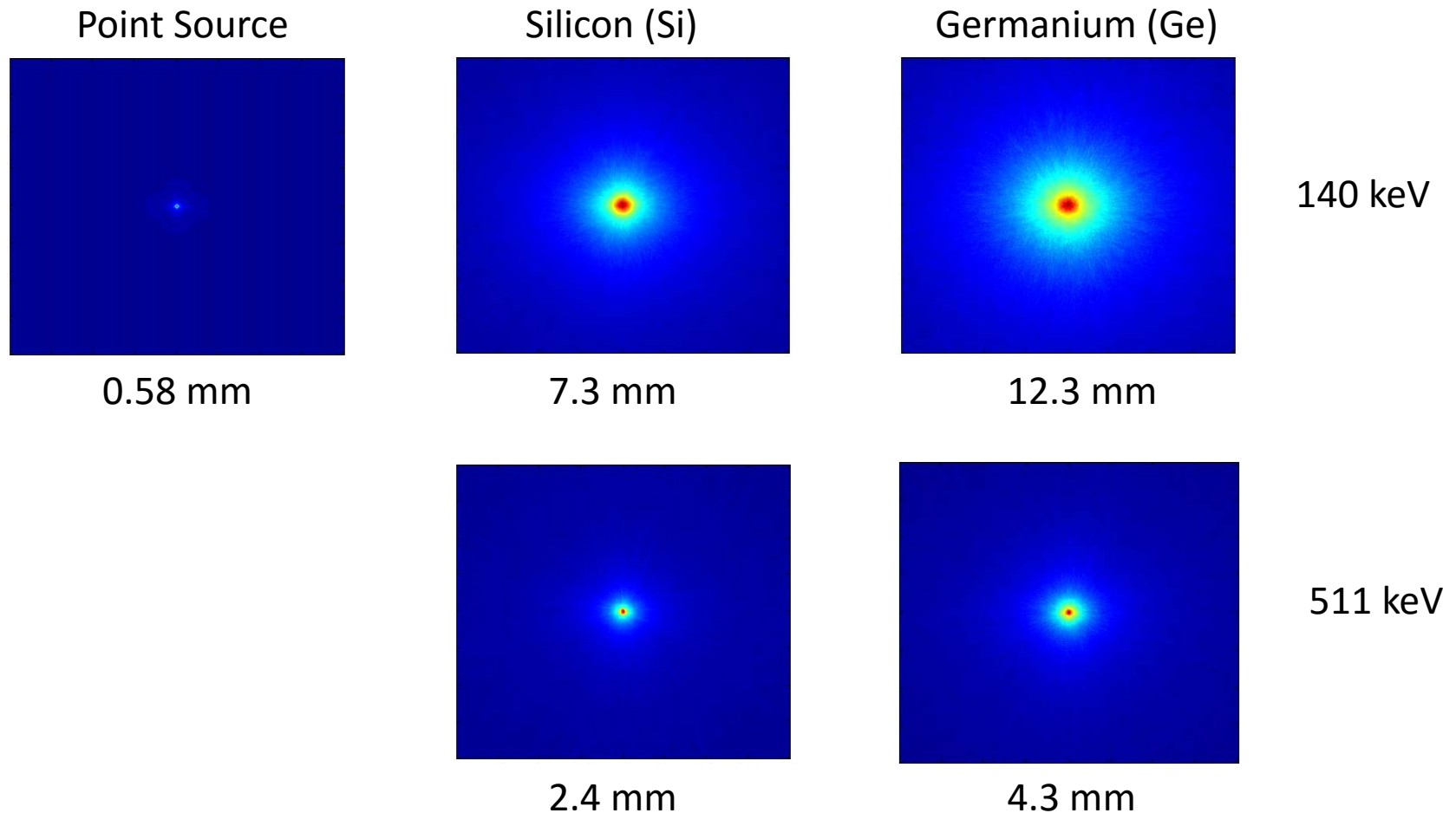
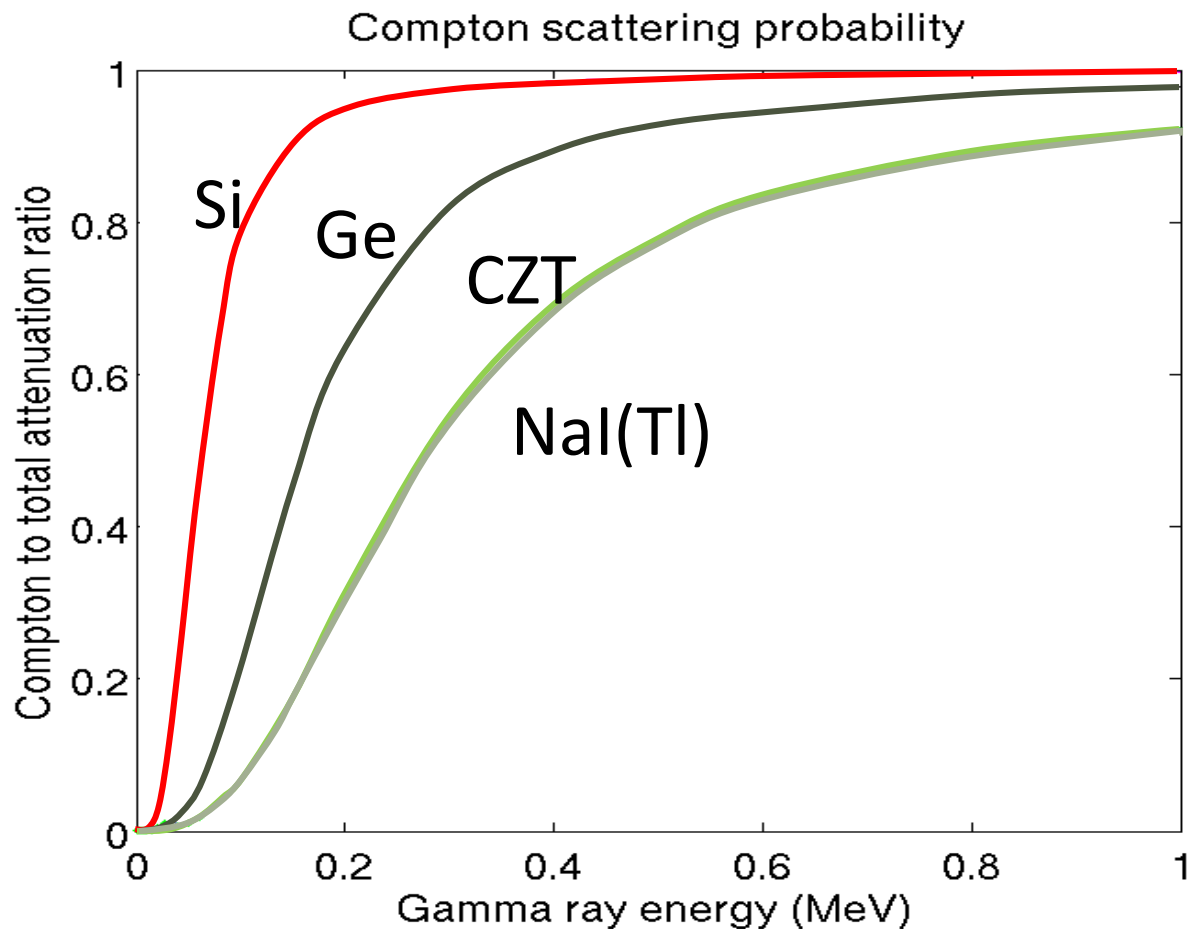


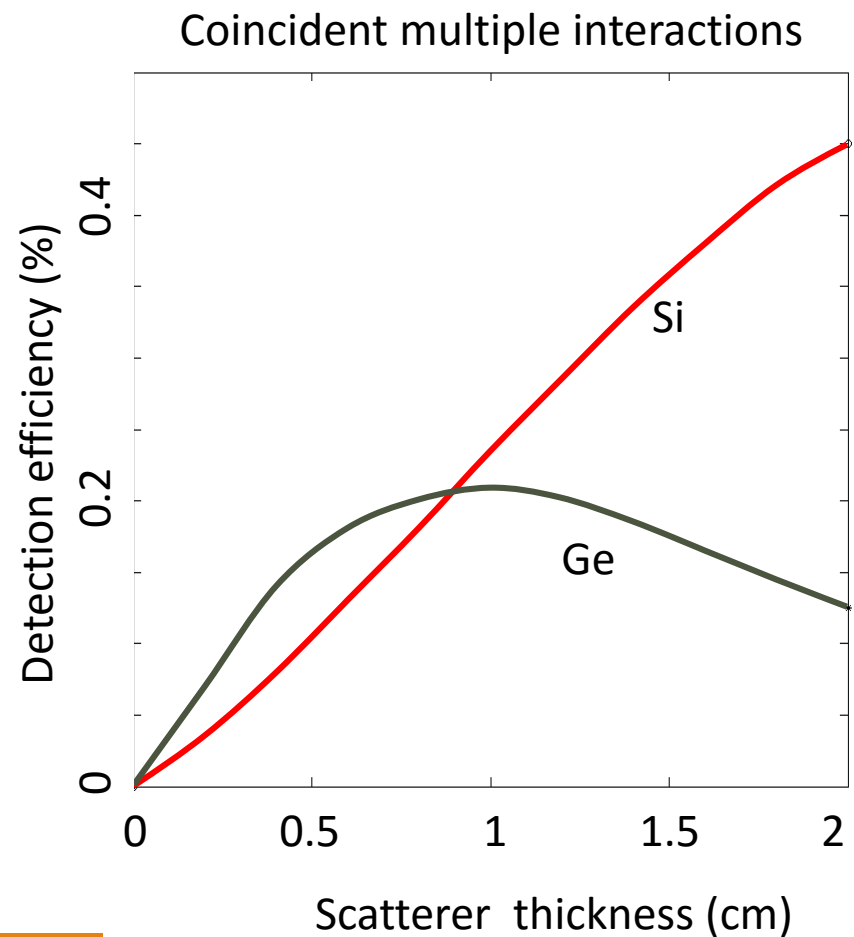
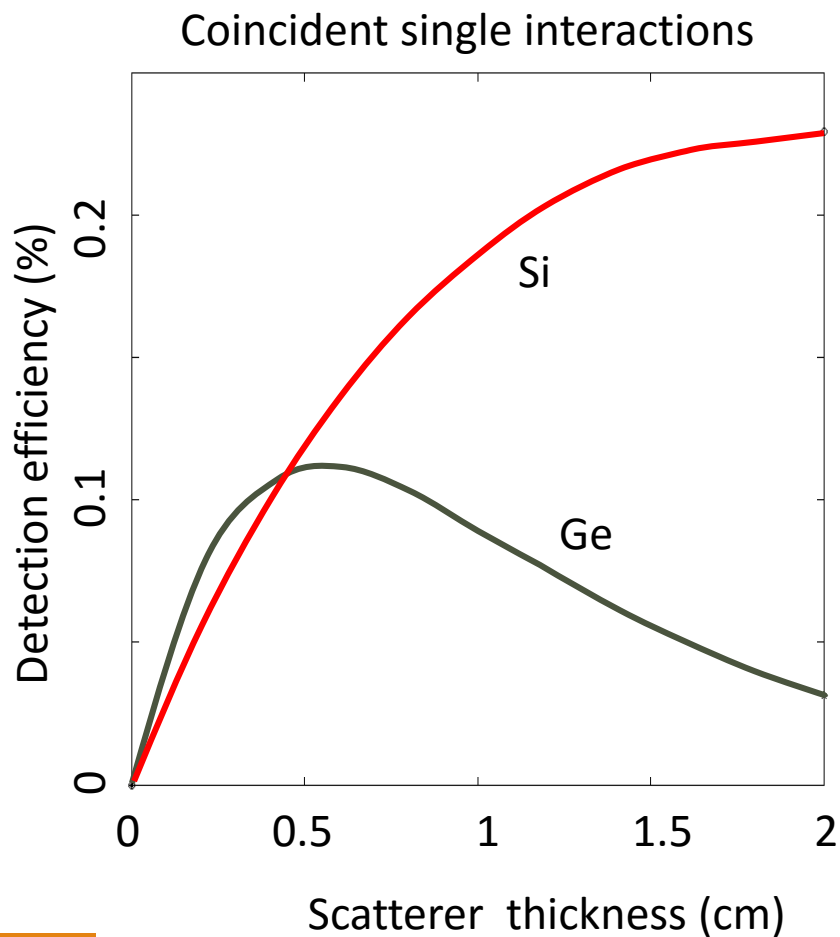
Image degradation (FWHM) due to Doppler broadening for the selected materials



Theoretical efficiencies with respect to Compton scattering for selected materials



Efficiency evaluation of the two detectors across experimental thickness at 140.5 keV



Preliminary findings

Si may be a better scatter detector (scatterer) than Ge

- ✓ less Doppler broadening – improve image resolution
- ✓ More Compton scattering – more detection efficient.

Pre-clinical evaluations

To test the viability of Compton camera for breast and brain imaging

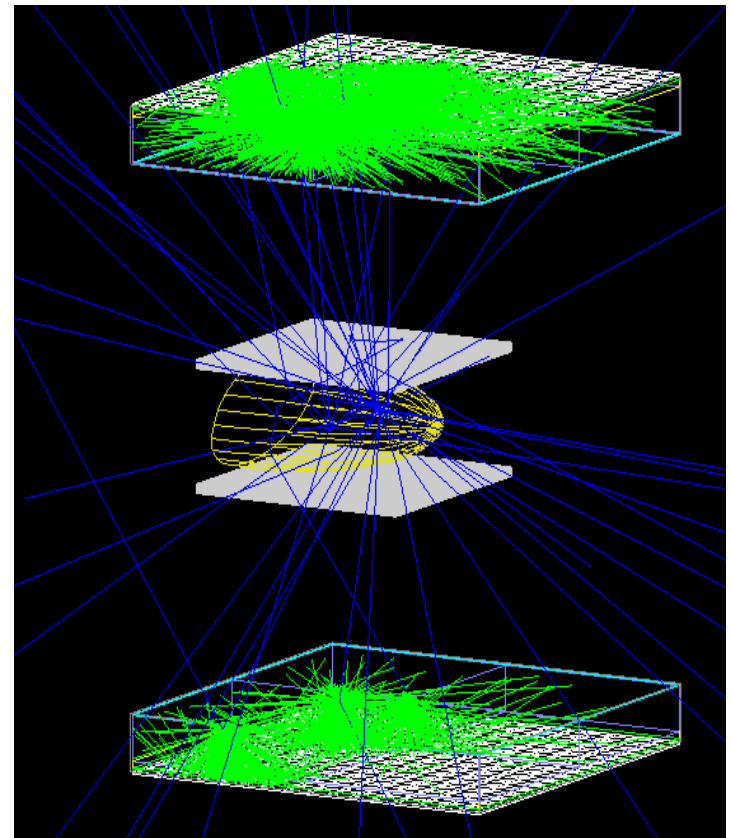
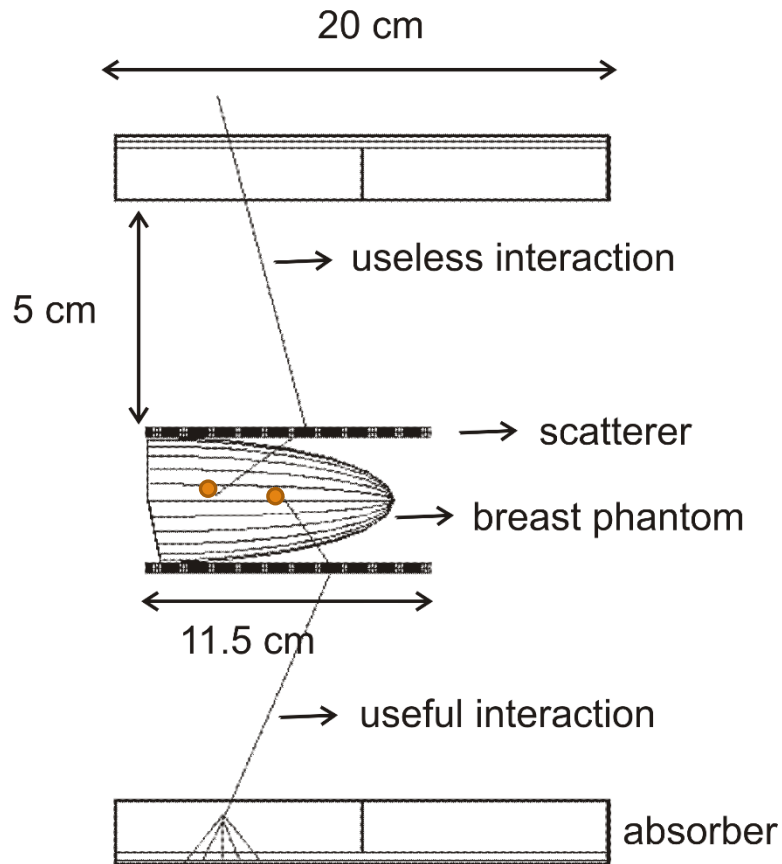
Targeted imaging scenarios

- ✓ Breast imaging (tumors near chest wall)
- ✓ Brain imaging (multitracer technique)

Approach – **GEANT4 simulation software**

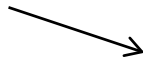
- ✓ it offers the flexibility of understanding steps of the imaging process and identifies changes that have impact on imaging systems.

Diagram illustrating the imaging of two spherical 5mm diameter breast tumours in craniocaudal view with a dual-head Compton camera



Challenging imaging scenarios for breast lesions (5 mm) located close to the chest wall for ^{18}F (511 keV)

TRU = 10:1
SNR = 9.7

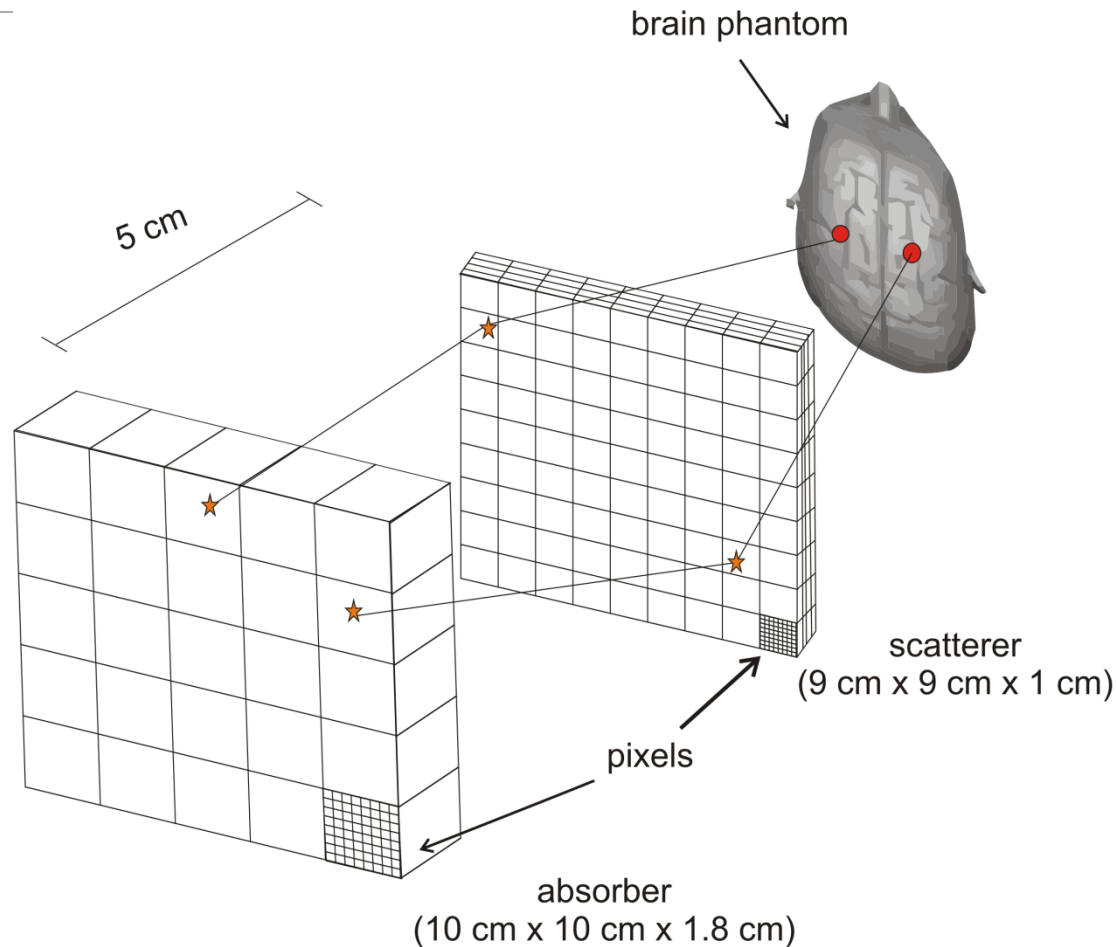


TRU = 6:1
SNR = 5.3

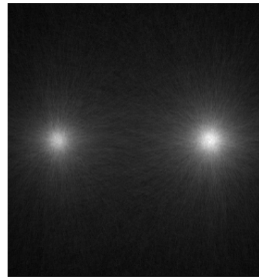


TRU = tumour-to-tissue radiation uptake
SNR = signal-to-noise ratio

Diagram illustrating the imaging of two spherical brain tumours of 5mm diameter filled with ^{113m}In and ^{18}F radiotracers



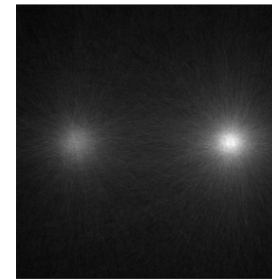
The reconstructed images of the brain lesions (5 mm) filled with ^{18}F (left) and $^{113\text{m}}\text{In}$ (right) radiotracers



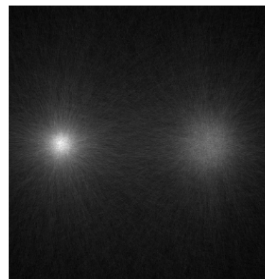
(a)



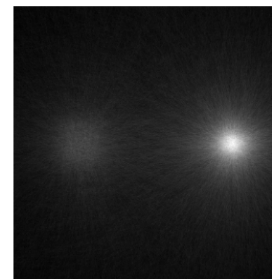
(b)



(d)



(c)



(e)

- (a) Lesions placed at their initial position (10 cm from the camera).
- (b) The $^{113\text{m}}\text{In}$ radiotracer was moved backwards by 1 cm and (c) 2 cm.
- (d) The ^{18}F radiotracer was moved backwards by 1 cm and (e) 2 cm.

Conclusion

The Compton camera shows promise for breast and brain imaging in that spherical tumours of 5mm diameter were modelled as being clearly visualised.