Centre for the Clinical Application of Particles

December 28, 2020

Nuclear medicine

Week 1; Lecture 3; Section 2: Gamma camera

K. Long (k.long@imperial.ac.uk)
Department of Physics, Imperial College London/STFC
R. McLauchlan (ruth.mclauchlan@nhs.net)
Radiation Physics & Radiobiology Department, Imperial College Healthcare NHS Trust

Section 2

Gamma camera

The Gamma camera

"Imaging collimator" defines direction of detected γs

- Forms projected image on scintillator

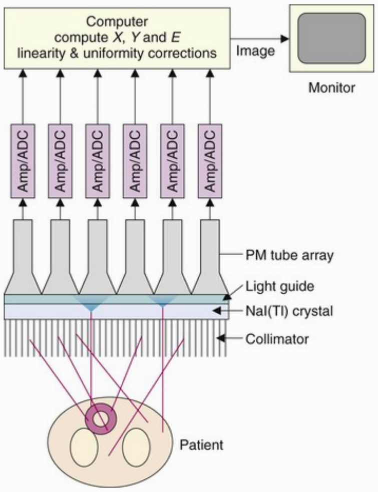
Large, single-crystal NaI scintillator coupled to a clear plastic or glass light guide

Light detected using PMT array

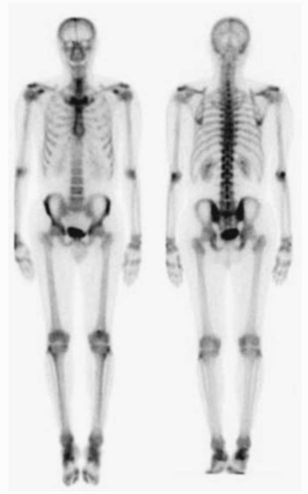
PMT readout by pulse-height-sensitive electronics; events are recorded if energy falls within the desired window

Many events are required for an image to be built up:

- x, y intensity map;
- γ-energy spectrum
- Possibly also the time evolution of the image



Example image



Example whole-body image taken using ^{99m}Tc-MDP

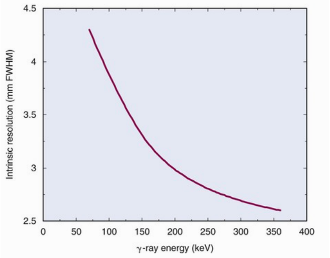
Resolution

Contributions to intrinsic resolution:

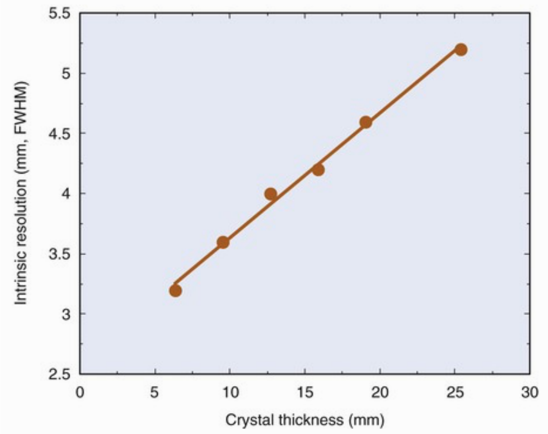
- Detector thickness (geometrical effect)
- Compton scattering on atomic electron:
  - $\gamma_i + e \rightarrow \gamma_o + e'$; γ_o not parallel to γ_i
  - Small effect: $< 10\%$ of γs displaced by > 2.5 mm in 6.4 mm thick detector
- Statistical fluctuations in photon count:
  - Scintillation photons & photoelectrons Poisson distributed
  - If N photoelectrons expected, variance of number detected will be N
  - Consequence is that distribution of γs over surface of detector will fluctuate
- Intrinsic resolution degrades with decreasing E_γ:
  - Fewer scintillation photons expected for low-energy γs
  - So, RMS of fluctuations ($\propto \frac{\sqrt{N}}{N}$) grows as E_γ decreases

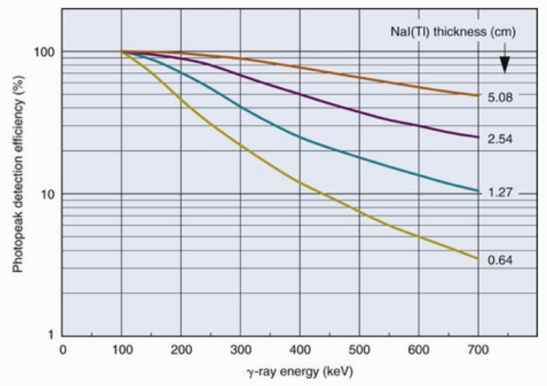
Intrinsic spatial resolution for 6.3 mm thick NaI(Tl) crystal.

Thallium (Tl) doping improves light production efficiency through recombination of electrons/holes at dopant site in lattice.



Trade off between resolution and efficiency

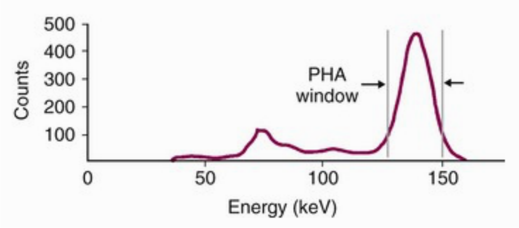




For practical sources (e.g. ^{99m}Tc), $100 \lesssim E_\gamma \lesssim 200$ keV. Motivates thickness of 5–6 mm to get high efficiency and good resolution.

Decay γ selection

Compton-scattered photons have an energy lower than that of the decay photons.
Atomic transitions from electrons excited in the lead shield or the NaI detector also contribute low-energy photons.



PHA: pulse height analyser

Exploit energy resolution to select γs that emerge without scattering:

- Energy resolution $\propto \frac{1}{E_\gamma}$.
- Typical energy resolution, $\frac{\Delta E_\gamma}{E_\gamma}$, is $\sim 10\%$ at 140 keV.

Types of event

A: Good event

B: Scatter in detector:

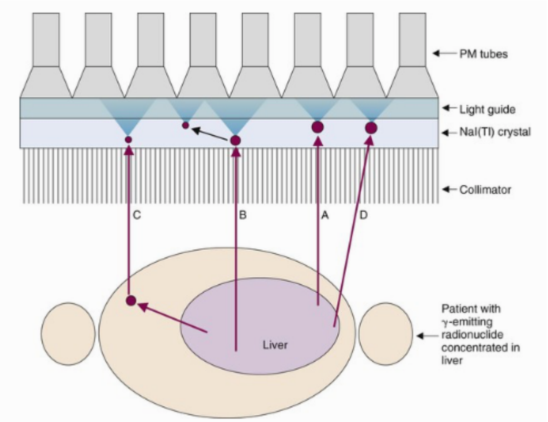
- Full energy is recorded, but
- Position information is distorted

C: Scatter in patient

- γ arriving at detector has reduced energy, but may still fall within the detection window
- Unwanted event

D: Septal penetration

- Unwanted event



Summary of section 2

The gamma camera exploits a large NaI crystal viewed using and array of photomultipliers to generate an image of the take-up of a gamma-emitting radionuclide

A collimator is used to define “pointing” accuracy

The intrinsic resolution of the gamma camera is related to the thickness of the scintillator; it improves with photon energy

Selection of high-energy photons reduces the contribution from photons that have undergone Compton scattering