COMPARISON BETWEEN ANGER AND COMPTON CAMERAS FOR MEDICAL IMAGING: A MONTE CARLO SIMULATION STUDY

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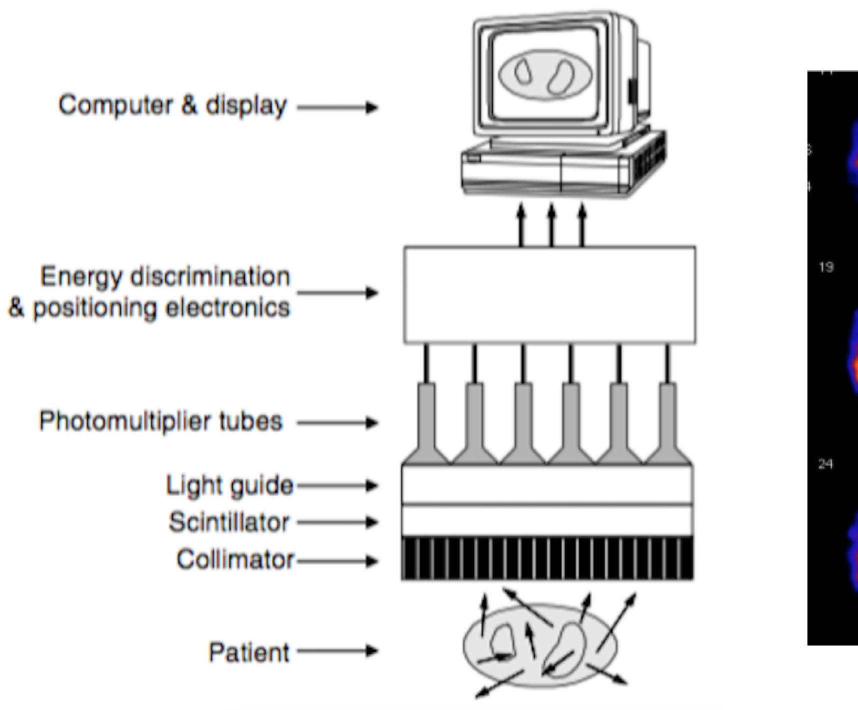
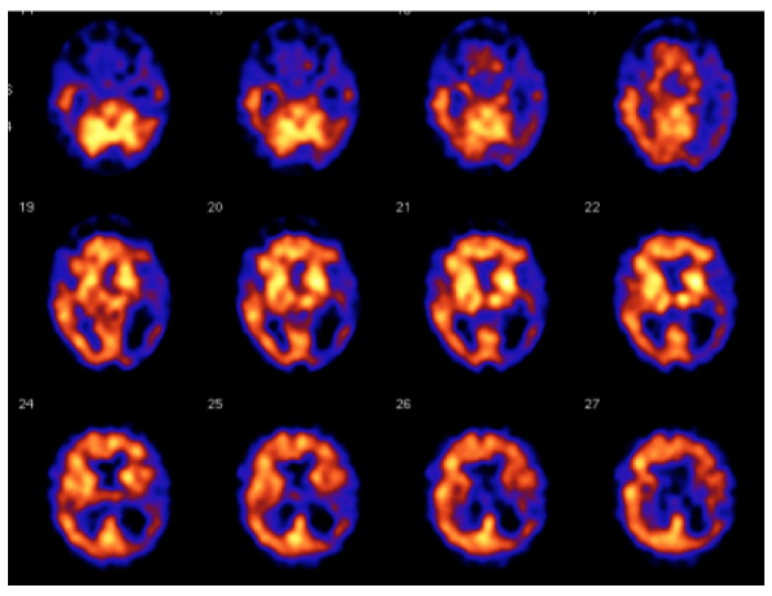
NUCLEAR MEDICINE: STATE OF THE ART

- Detection of γ-rays emitted by radioactive isotopes injected into the patient
  - ⋆ **SPECT** (Single Photon Emission Computed Tomography)
  - ↪ Anger camera: detector with mechanical collimation systems
  - ↪ Low energy radiotracers e.g. ^{99m}Tc (140 keV), ^{131}I (364 keV)
  - ↪ Forced trade-off between efficiency and spatial resolution
    - · 3×10^{-4} and about 10 mm respectively [1] (10 cm source distance)
  - ↪ Important γ-rays attenuation in the patient (loss of spatial information and patient dose)

⇒ Higher energy radiotracers suggested
⇒ Need for new detection solutions



Standard SPECT system scheme, in Wernick-Aarsvold, *Emission Tomography: The fundamentals of PET and SPECT*



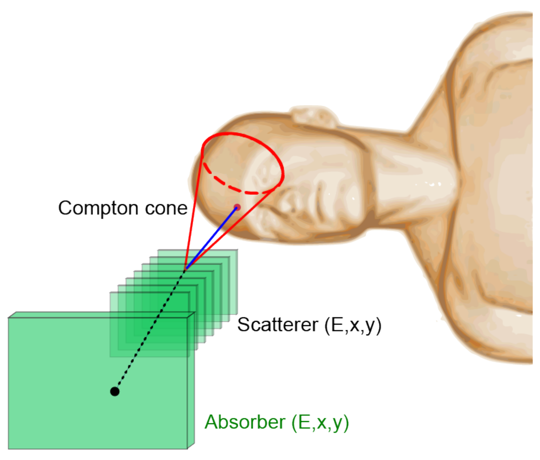
SPECT brain image.

⇒ **Simulation study for direct comparison of a commercial Anger camera to a novel Compton camera prototype[2]**

COMPTON CAMERA (CC)

Prototype development [3] by CLaRyS collaboration (5 French labs).
Modeled with Geant4 v.9.6, MLEM reconstruction algorithm

- **Absorber**
  - ⋆ 8×6 BGO streaked block matrix, 28×21 cm^3, 15 cm distance from the last scatterer plane
  - ⋆ 4 PMs (Photo-Multipliers) for each block
  - ⋆ FWHM resolutions: 3 ns time, 21% energy @ 667 keV, 4.4 mm spatial transverse plane
- **Scatterer**
  - ⋆ 7 DSSD (Double-Sided Silicon Detectors) 96x96x2 mm^3 planes, 1.4 mm strip pitch, 1 cm distance between each plane
  - ⋆ FWHM resolutions: 20 ns time, ≃ 5 keV energy, 1 mm spatial



Compton camera scheme.

- 2D-3D imaging
- Wide energy range acceptance
- High detection efficiency

ANGER CAMERA (AC)

General purpose Infinia gamma camera provided by GE Healthcare [4].
Modeled with GATE v7.1 (Geant4 Application for Tomographic Emission)

- **HEGP (High Energy General Purpose) collimator**
  - ⋆ 19×28×6.6 cm^3 - Lead
  - ⋆ Hexagonal holes 2.0 mm radius in quincunx structure, 1.8 mm septal thickness
- **Gamma detector**
  - ⋆ 19×28×1 cm^3 - NaI 4 mm FWHM spatial resolution, 10% FWHM energy resolution @ 140 keV, 80 keV energy threshold
- Back compartment (photo-multiplier tubes)
  - ⋆ 19×28×2.5 cm^3 - Glass

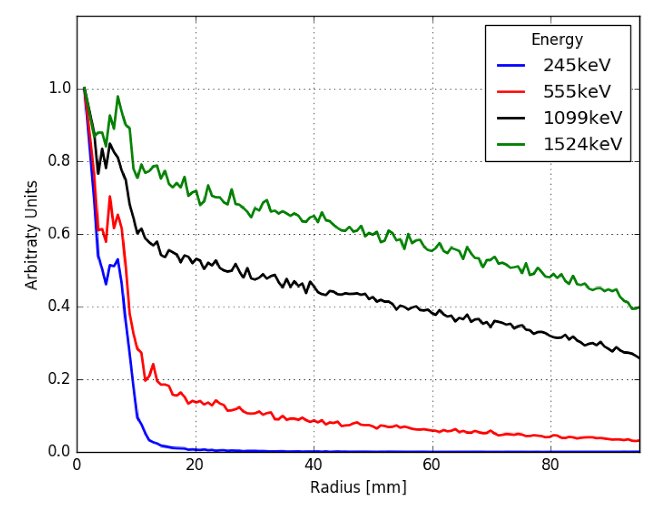
Infinia camera by GE Healthcare.

- 2D transmission image
- Optimized for energies below 364 keV
- Low transmission efficiency

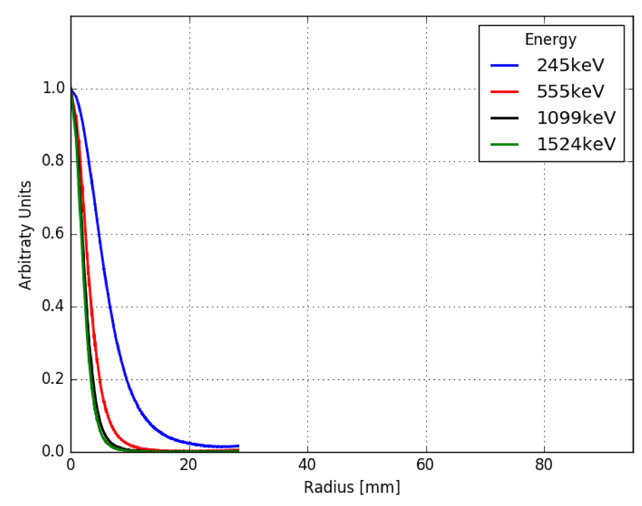
METHODS

Detectors exposition to point-like mono-energetic γ sources at 10 cm distance from the first scatterer plane (CC) or from the collimator entrance (AC)

- 13 actual sources with γ emission ranging from 245 keV to 2614 keV studied
- Background rejection analysis performed on Anger camera data to retrieve the useful signal
- Compton camera events selected as coincidences between an interaction in a single scatterer plane and an interaction in a single absorber block
- Timing study for coincidence detection in Compton camera (20 ns coincidence window): 50% of random coincidences @ 200 MBq source activity
- System comparison based on three figures of merit:
  - ⋆ **RMS of radial events distribution** after background subtraction
  - ⋆ **Detection efficiency**: ratio between selected events and total emitted primary photons
  - ⋆ **Selected events efficiency**: ratio between selected events and all detected events



Anger camera event radial distribution for four reference energies, 10^8 primary photons simulated.

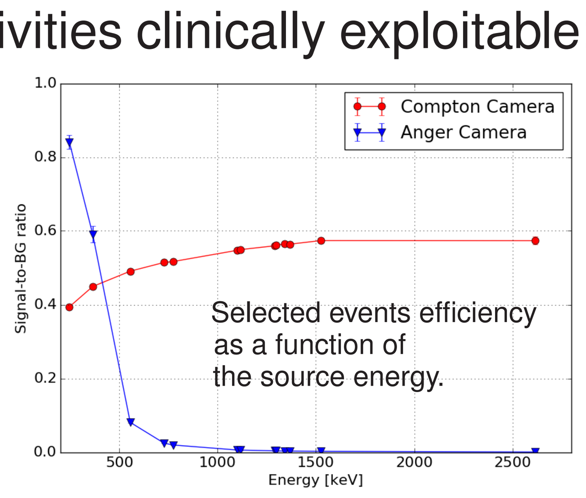


Compton camera event radial distribution for four reference energies, 10^7 primary photons simulated in the camera acceptance solid angle.

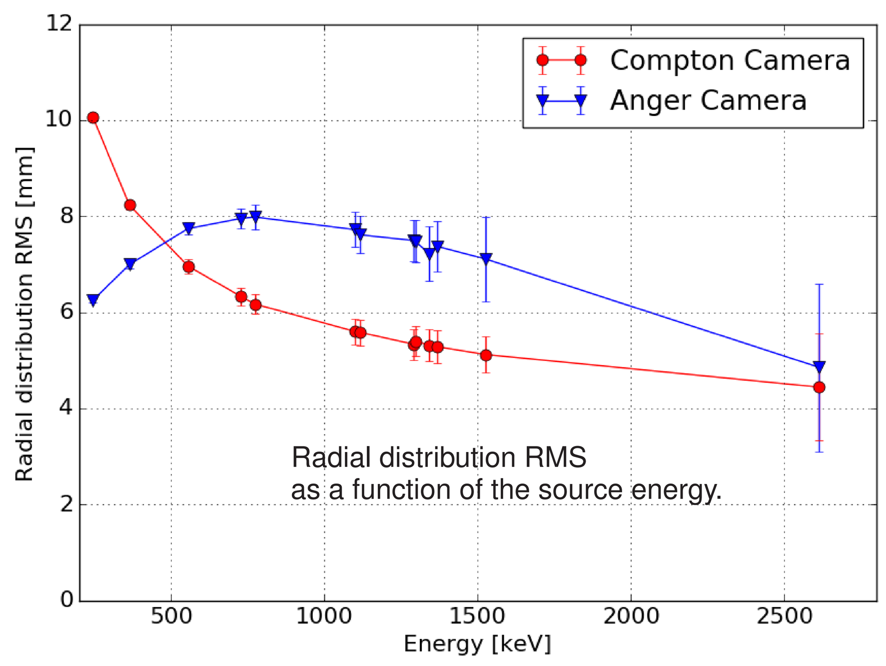
RESULTS

↪ **CC efficiency: gain of a factor > 20**
↪ **CC spatial resolution: favorable for E > 500 keV**
↪ New source energies and activities clinically exploitable:

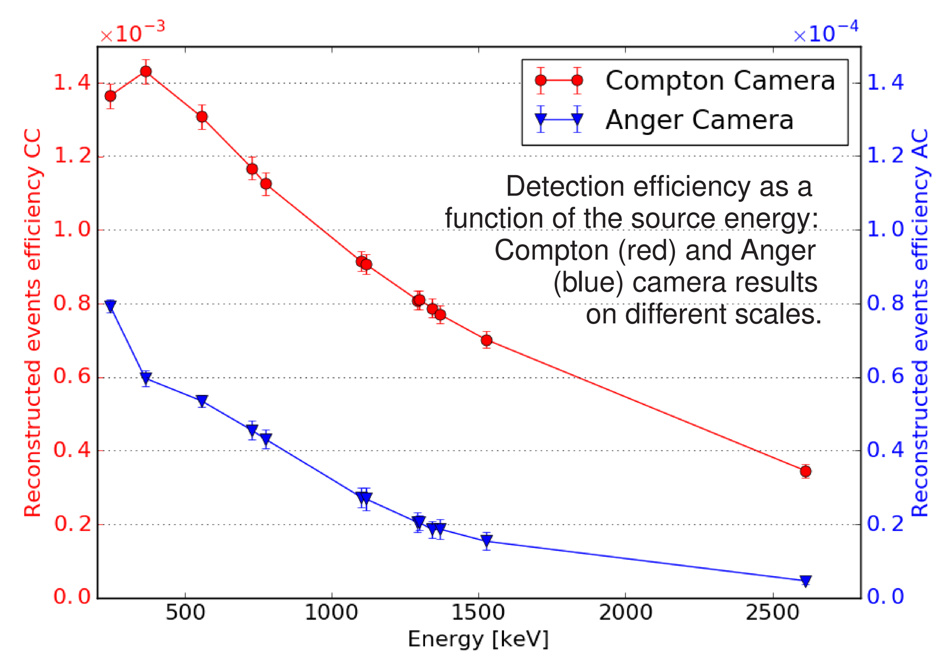
⇒ **reduced patient dose**
⇒ **reduced photon attenuation effects**
⇒ **improved imaging performance**



Selected events efficiency as a function of the source energy.



Radial distribution RMS as a function of the source energy.



Detection efficiency as a function of the source energy: Compton (red) and Anger (blue) camera results on different scales.

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