

## Nuclear Medicine

- Make images of the distribution of radioactive elements that have been "inserted" into body
  - Elements "decay" to create gamma-ray photons
  - Patient's organs "emit" gamma-ray photons

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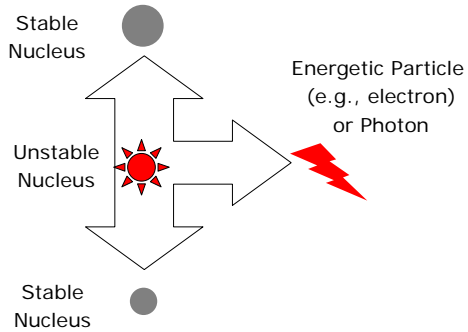
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## Radioactive Decay



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## Energetic Photons

- Byproducts of radioactive decay
  - Technetium (atomic wgt. = 99)
    - ▶  $E = 140 \text{ keV}$
    - ▶  $1 \text{ keV} = 1 \text{ "kilo-electron-volt"}$
    - ▶  $1 \text{ eV} = \text{energy of 1 electron after acceleration by a voltage of 1 volt}$
  - Rubidium (a.w. = 82)
    - ▶  $E = 777 \text{ keV}$
  - Tantalum (a.w. = 178)
    - ▶  $E = 93 \text{ keV}$

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## Meaning of "keV" "kilo"

- 140 keV = 140,000 electron volts
    - unit of "energy"  $E = h\nu$
  - 1 eV =  $1.6 \times 10^{-19}$  joule
  - 140 keV  $\Rightarrow \nu \cong 2.4 \times 10^{19}$  Hz
    - $\Rightarrow \lambda \cong 8.9 \times 10^{-12}$  m  $\cong 0.01$  nm
- VERY SHORT WAVELENGTHS!!  
NO LENSES EXIST!

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## "Tagging"

- Radioactive element is transported by body to organ of interest
- Radioactive decay of elements produces high-energy radiation
  - Gamma ray photons
  - Beta particles (electrons)
- Escaping radiation is imaged

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## Making the Radioactive Tracers

- Technetium-99 made from radioactive decay of Molybdenum-99
  - Mo-99 delivered to hospital and processed
- Many new tracers made in atomic accelerators at the hospital

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## Desirable Characteristics of Tracers

1. tag to elements that "go" to desired spot
  - e.g., iodine to thyroid gland
2. photons must be energetic enough to escape
3. radioactivity should have a very short "half-life"
  - want radiation to decrease quickly
    - minimize radioactive dose to patient

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## Gamma Camera

- "Misnomer" because only the detector of escaping radiation
- Create an "image" of distribution
- also called the "Anger Camera"
  - after inventor Hal Anger
- Scintillator + Array of Photomultiplier Tubes (PMTs) + Electronics

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## Scintillator

- Typically Cesium Iodide (CsI) or Sodium Iodide (NaI) (doped with Thallium)
- Absorbs gamma rays and creates "shower" of lower-energy photons

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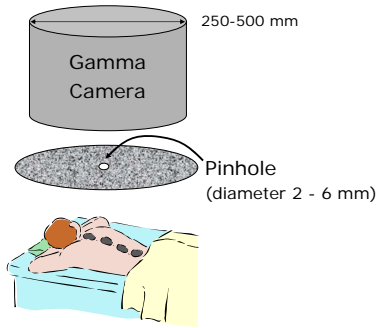
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## Photon Selector + Gamma Camera



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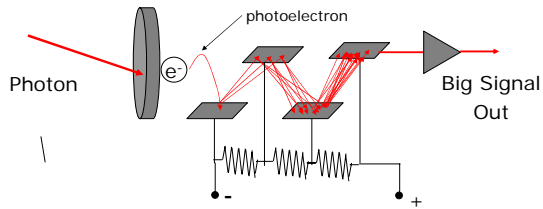
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## Photomultiplier Tube (PMT)

- Amplifies ("multiplies") photons:
  - $10^5$ - $10^7$  electrons per photon
- Counts electrons by measuring current



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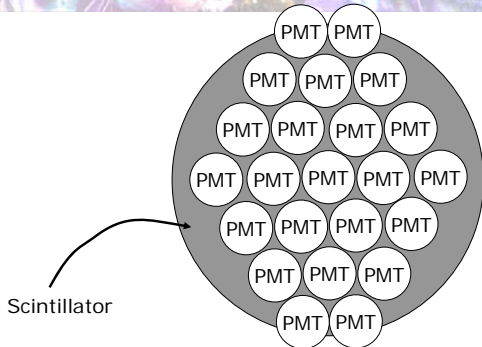
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## Gamma Camera



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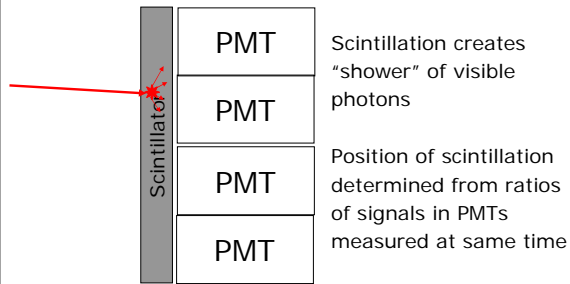
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## How Gamma Camera Works



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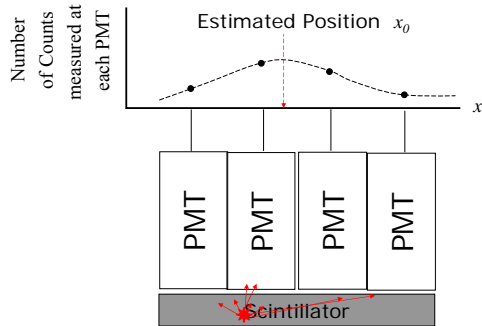
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## Electronics Calculate "Smooth Curve" of Scintillation to Estimate Position



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## Gamma Camera Constraints

- Want to see ONLY one absorption of a gamma ray at any one time
  - To measure position signal
- Number of signals can measure per second depends on the scintillator
  - maximum of 100,000 =  $10^5$  absorptions per second

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## Photon Selectors

- Pinhole (diameter 2 – 6 mm) in sheet of lead
- "Parallel-Hole Collimator"
- "Focused Collimator"
  - Slatted Grid of lead



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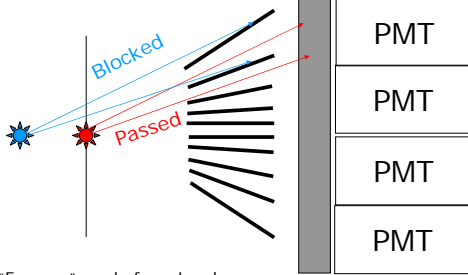
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## Gamma Camera + "Focused Collimator"



"Focuser" made from Lead  
Camera "sees" only photons from only one depth  
Camera is scanned across to make image of one plane

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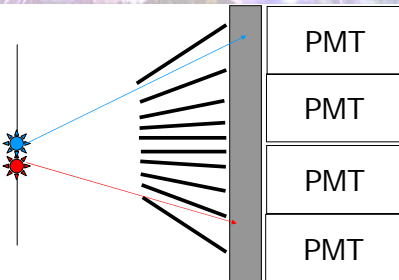
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## Focused Collimator = "Magnifying" Collimator



Images are farther apart on scintillator

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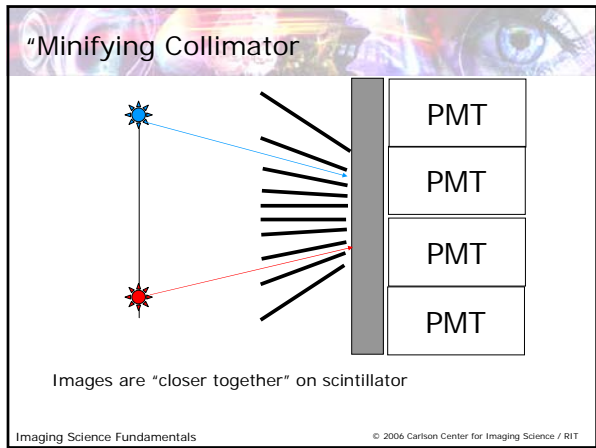
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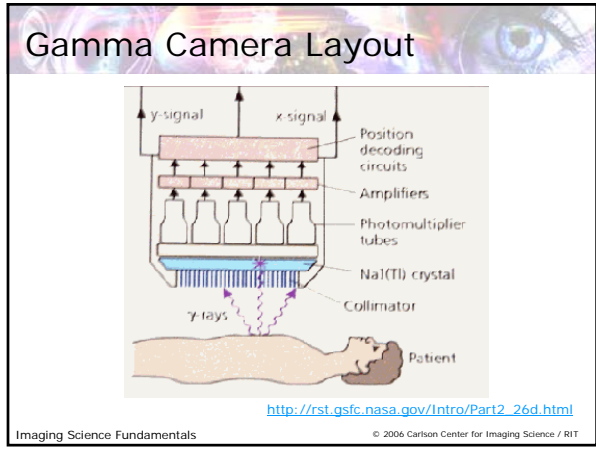
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## Body Scan with Gamma Camera



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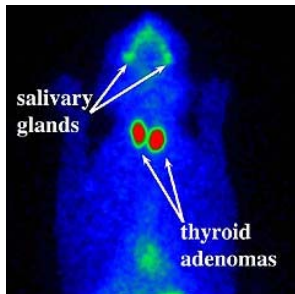
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## Image of Thyroid Gland of Cat



[http://rst.gsfc.nasa.gov/Intro/Part2\\_26d.html](http://rst.gsfc.nasa.gov/Intro/Part2_26d.html)

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