Lecture 5: Tomographic nuclear systems: SPECT

Field trip this saturday at 11 AM at UWMC

- meet in main hospital lobby at 11 AM
- if you miss the 'boat', page me at 540-4950
- should take ~1 to 1.5 hours, depending

No class next week

Exam will will be emailed to class email list Wednesday afternoon

Submit to class website - closes at 10 PM Nov 1st.

Next homework

- Read chp 7 Seutens
- Find 2 medical images of abnormal anatomy or physiology (pathology) formed using ultrasound (AKA 'sonography'). Place these images in a document. Write 1-2 brief sentences describing each image. Write 1-2 brief sentences describing differences between the images. Write 1-2 sentence what the image values represent physically.

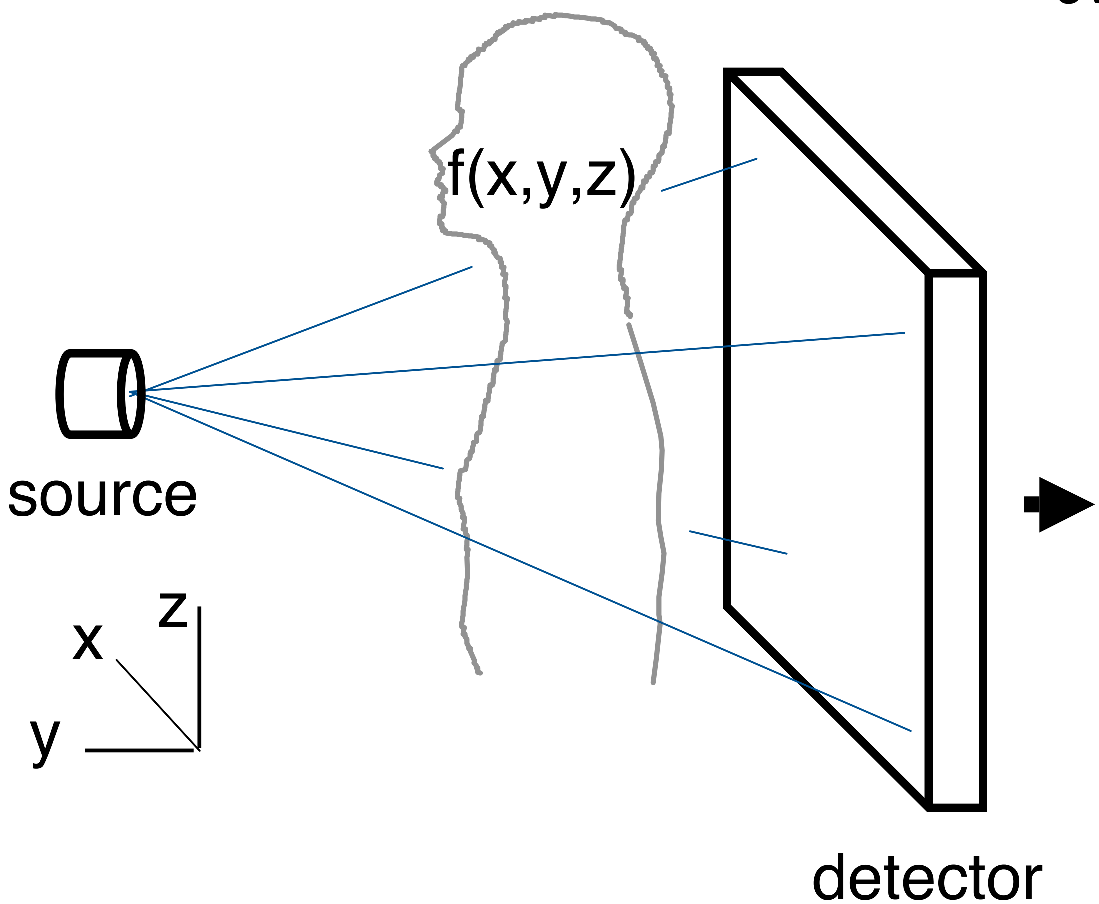
Project Groups

1. Rodriguez, Dones
2. Romig, Martinez, Sung, Harmelin
3. Pham, Wong, Legesse
4. Braddock, Mauro
5. Jeddi, Miller, Zhang
6. Morrow, Dahl, Clayton
7. Rundgren, Lam

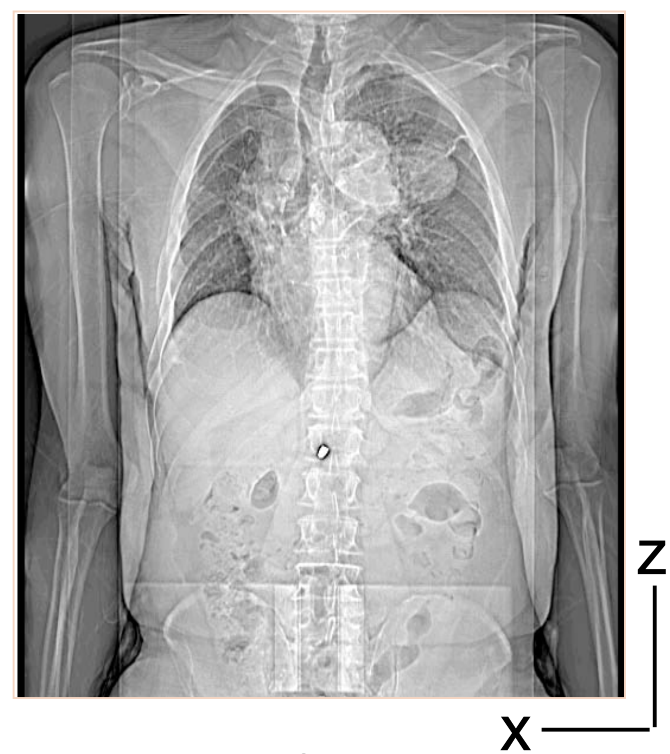
Deadlines:

Nov 1:	Outline due	30% of mark for project
Nov 29:	Final report due	50% of mark for project
Dec 6:	Class presentation	20% of mark for project

X-ray Projection Imaging



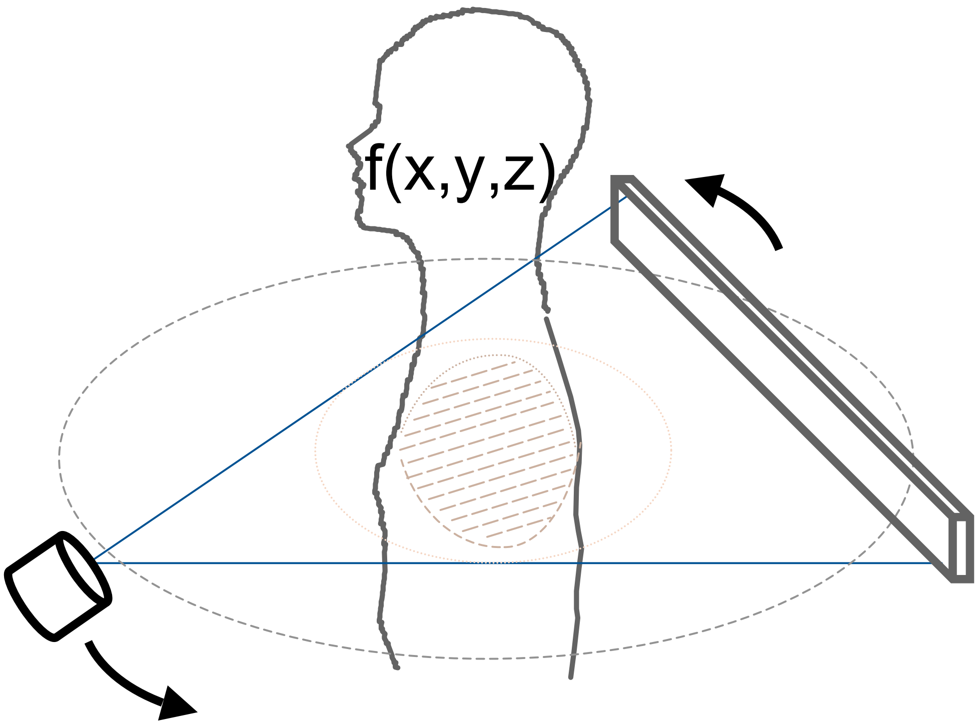
'overlay' of all information (non quantitative)



$$p(x,z) = \int f(x,y,z)\, dy$$

X-ray Tomographic Imaging

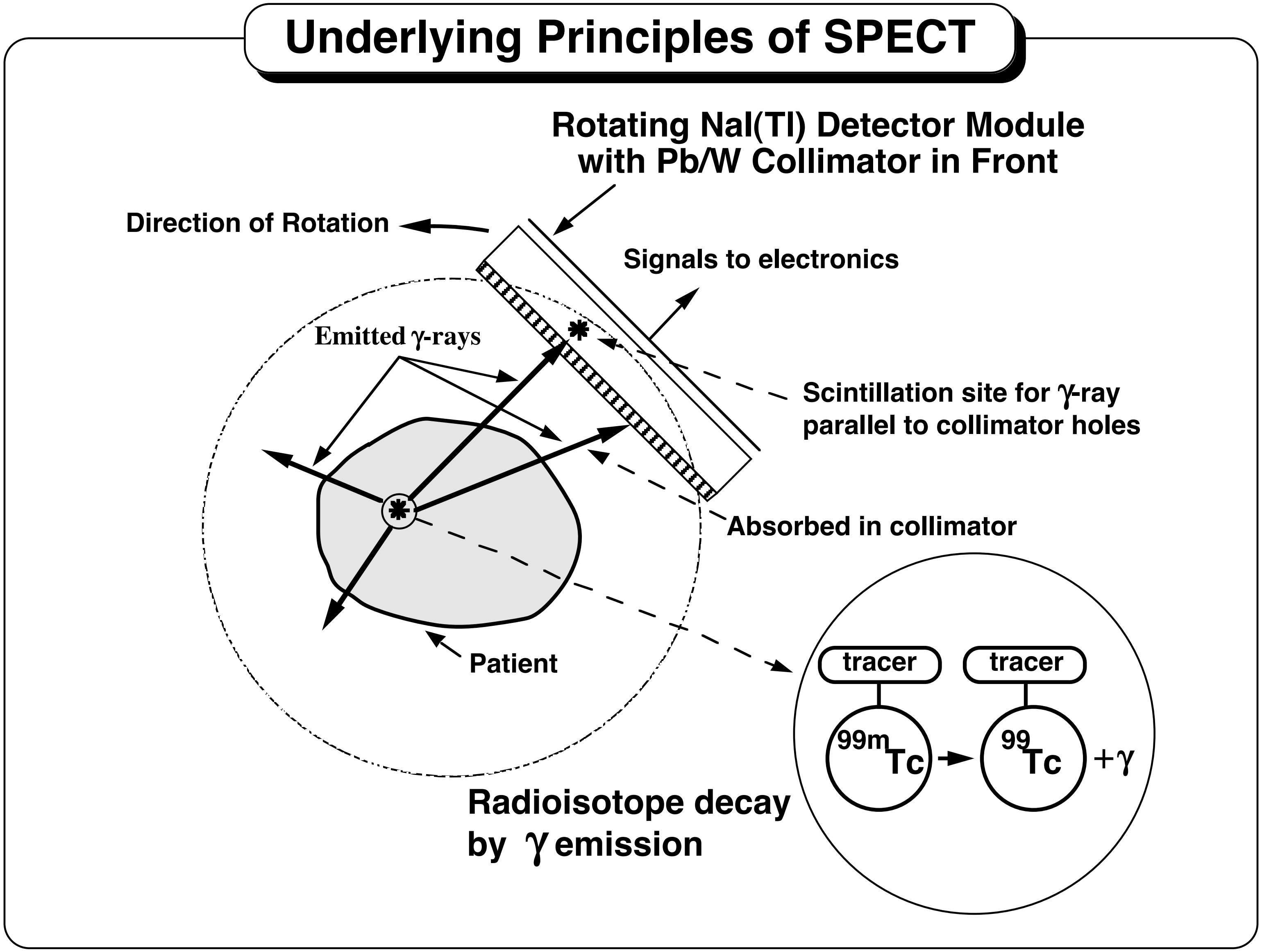
'Tomo' + 'graphy' = Greek: 'slice' + 'picture'



orbiting source + detector
data for all angles

true cross-sectional image

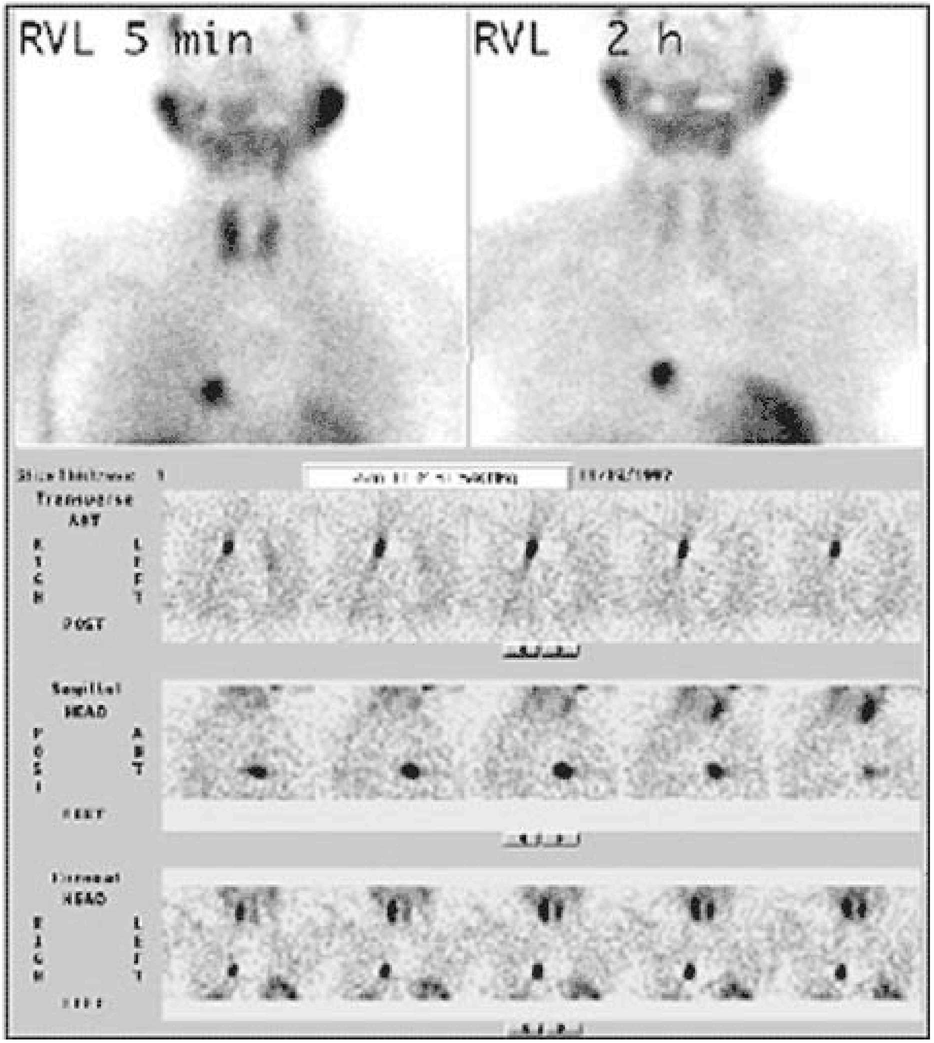
Nuclear Medicine Tomographic Imaging:
single photon emission computed tomography (SPECT)



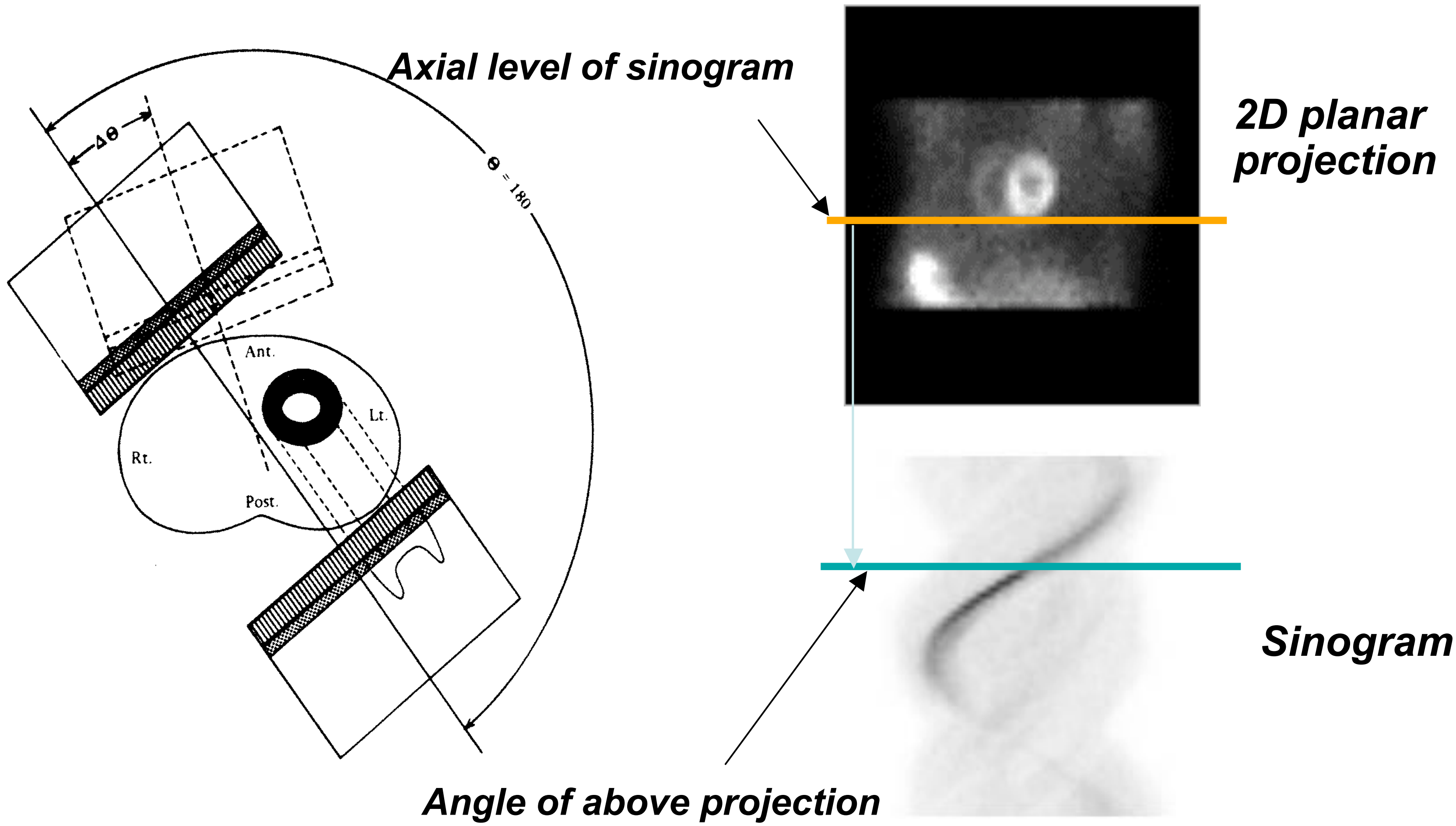
Nuclear Medicine Imaging

Projection Images

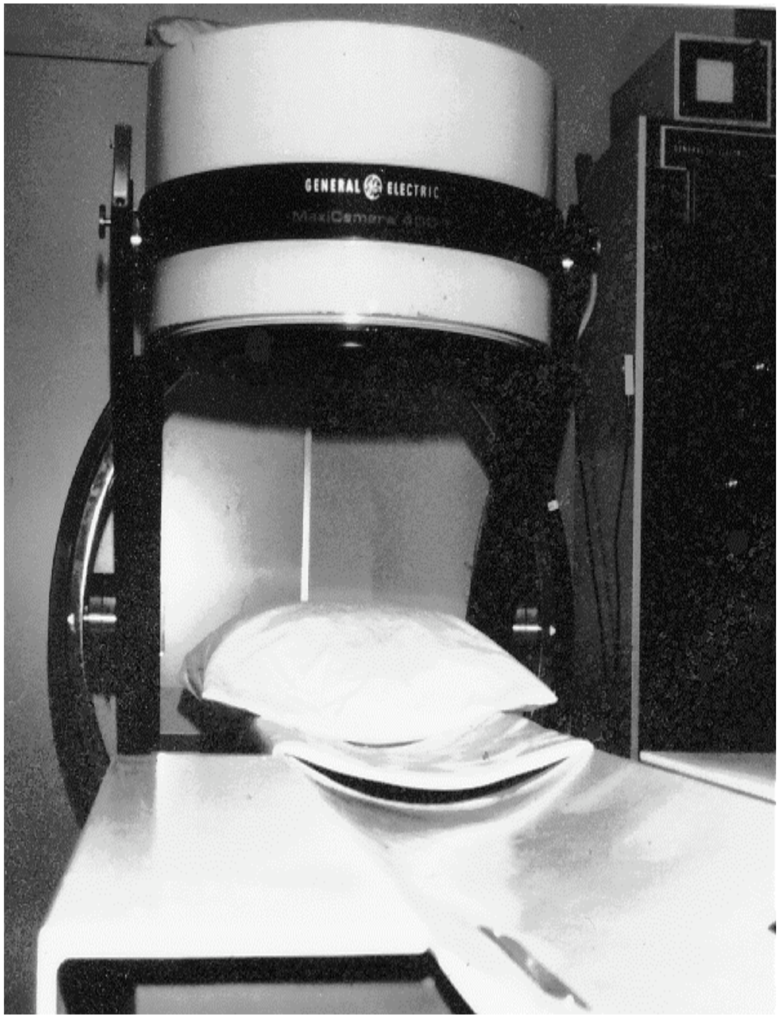
Tomographic Images

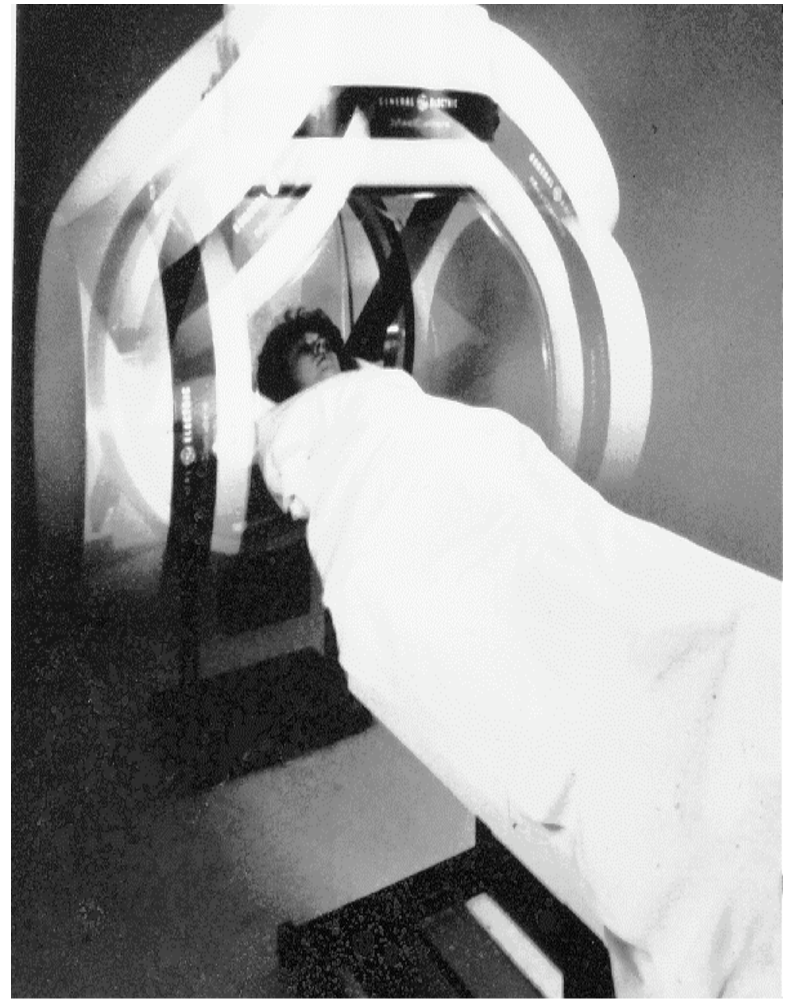


Basic SPECT


Axial level of sinogram
2D planar projection
Sinogram
Angle of above projection
Δθ
θ = 180
Ant.
Lt.
Rt.
Post.

Early Clinical SPECT





GE 400T Rotating Anger Camera (ca. 1981)

Modern Clinical Systems

GE Millenium VG

Philips Cardio 60

Siemens e.cam
Variable Angle

Conventional Anger Camera

PMTs coupled to large, continuous NaI(Tl) crystal

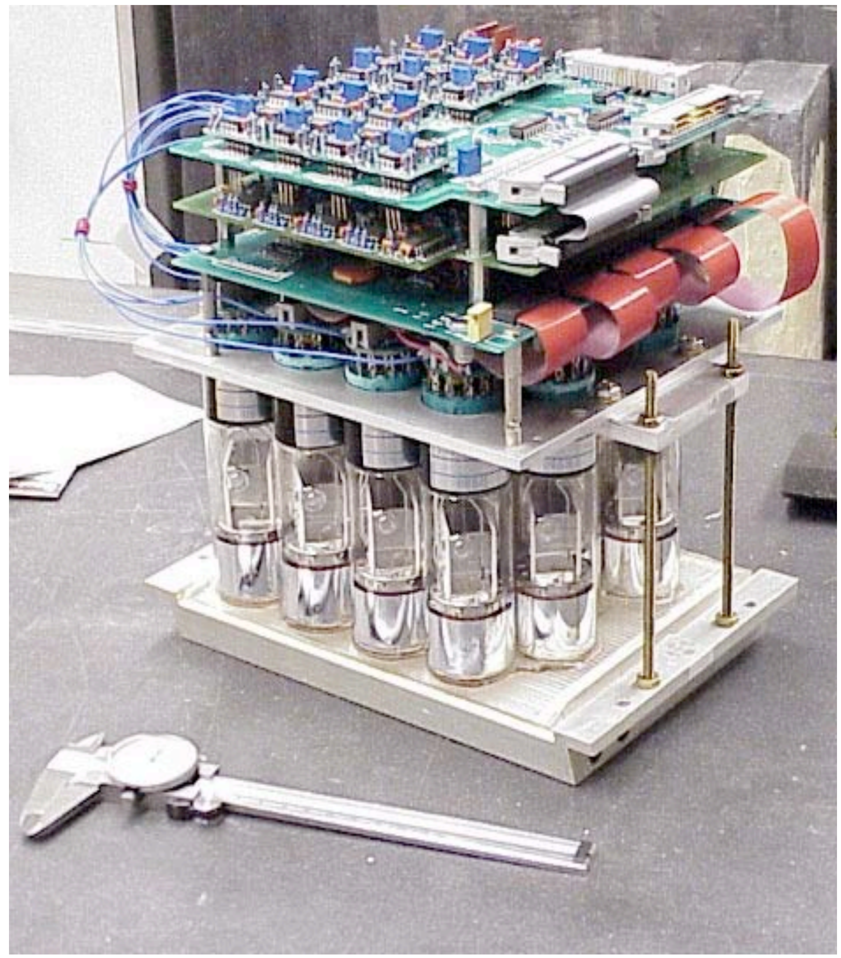
Spatial resolution 3–4 mm FWHM

Energy resolution 8–10% FWHM

Mature technology (DoB ~1957)

Large-area, >40cm x 40cm typical

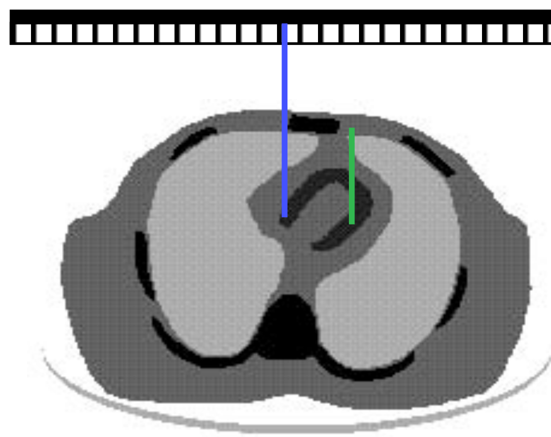
Simple and cost-effective



SPRINT II camera module

Photon Absorption

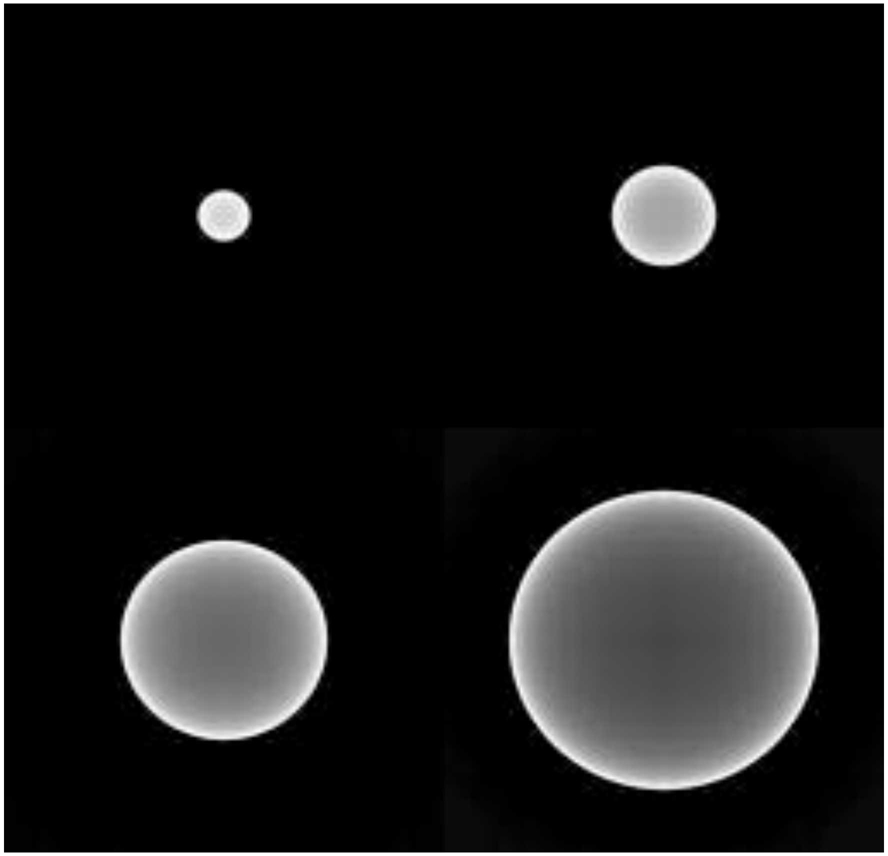
- Ideal Photon Detection
- Absorbed Photon



NOTE: at 30cm cylinder center

SPECT (μ=0.153/cm): I/I_o = 0.10

Attenuation Effects



5 cm dia.

10 cm

20 cm

30 cm

Attenuation 0.15/cm (140 keV photons in water)

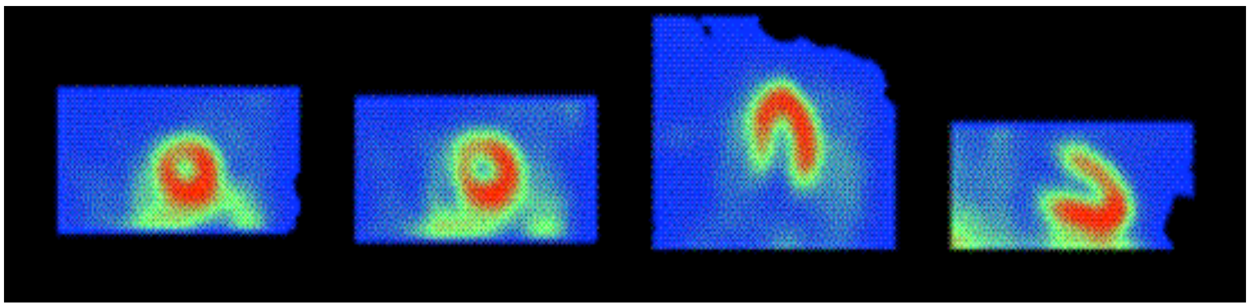
Reconstructions of disks should be uniform

Attenuation causes a distortion that increases with object size

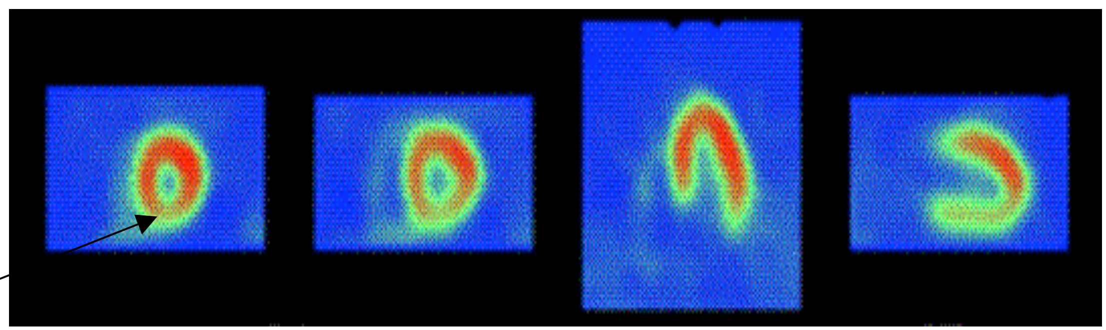
Possible Attenuation Artifacts

Activity in myocardium should be uniform but isn't
Could be interpreted as abnormal

Breast Attenuation



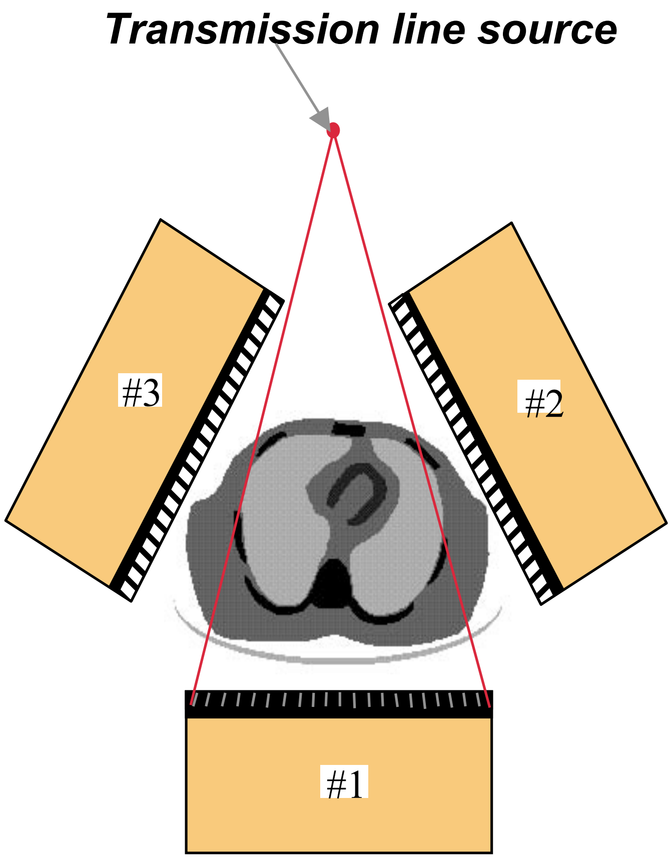
Diaphragmatic Attenuation



Should be uniform intensit y

Tc-99m Sestimibi Myocardial Perfusion Images

TCT/ECT Acquisition Geometry



Detector 1 - Transmission and emission

65cm focal distance fanbeam collimator

Detectors 2&3 - Emission only

Parallel hole collimator

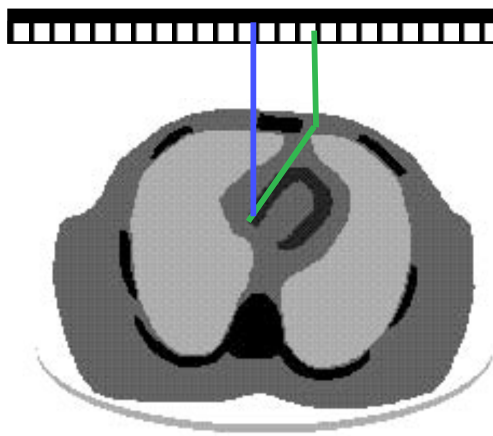
Transmission Source

Am-241 (60 keV photons)

This is one configuration; Many others are in use

Photon Scatter

- **Ideal Photon Detection**
- **Scattered Photon**



<u>NOTES:</u>

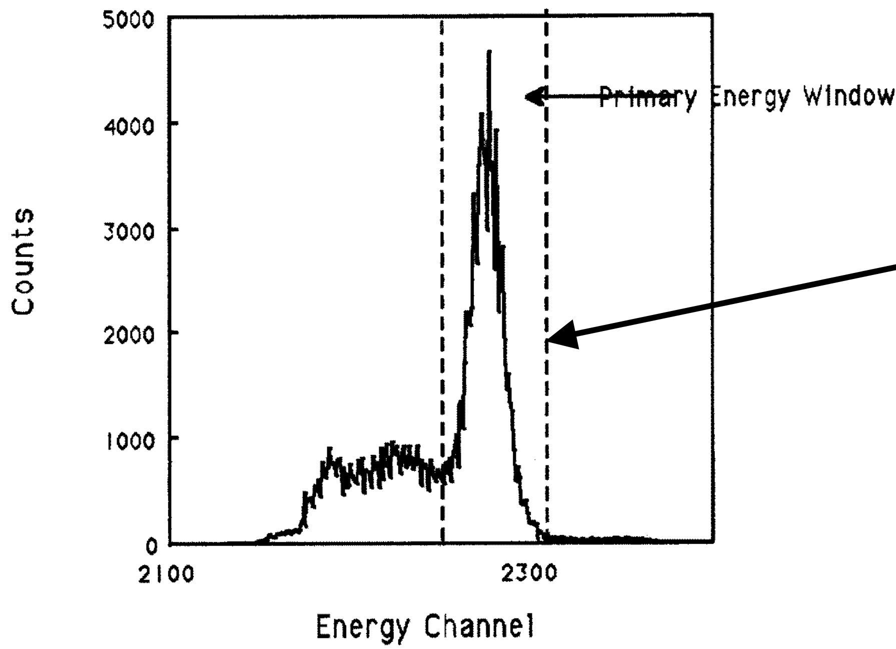
-Additive

-Loss in resolution and contrast

-Typical scatter fractions. Tl:1.0, Tc:0.3-0.4, PET: 0.15-0.40

Camera Energy Spectrum

140 keV



15–20% Energy window

Typical Anger camera has from 8–10% FWHM energy resolution at 140 keV

Collimation Systems

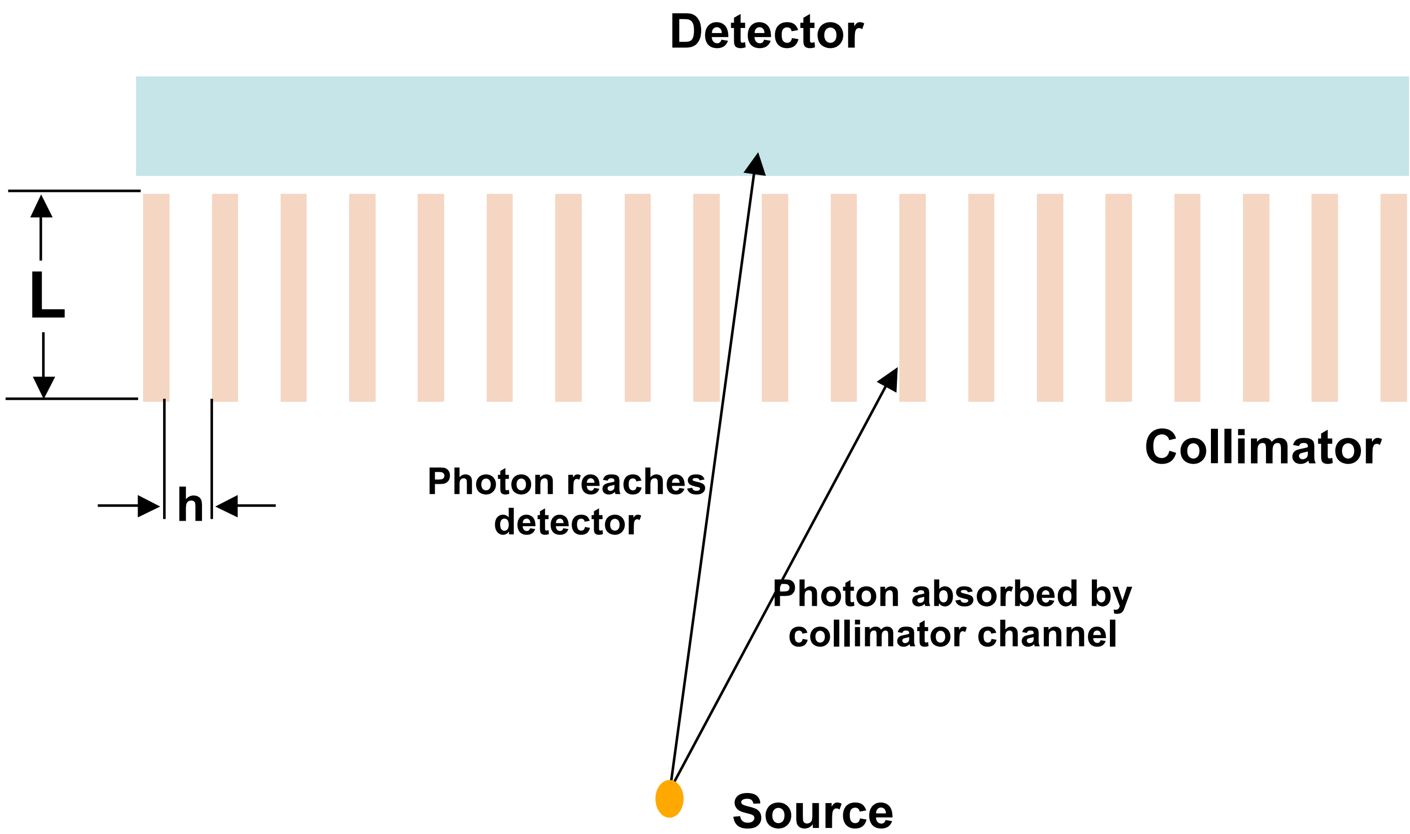
The collimation system is the heart of the SPECT instrument – it's the front-end and has the biggest impact on SNR

Its function is to form an image by determining the direction along which gamma-rays propagate

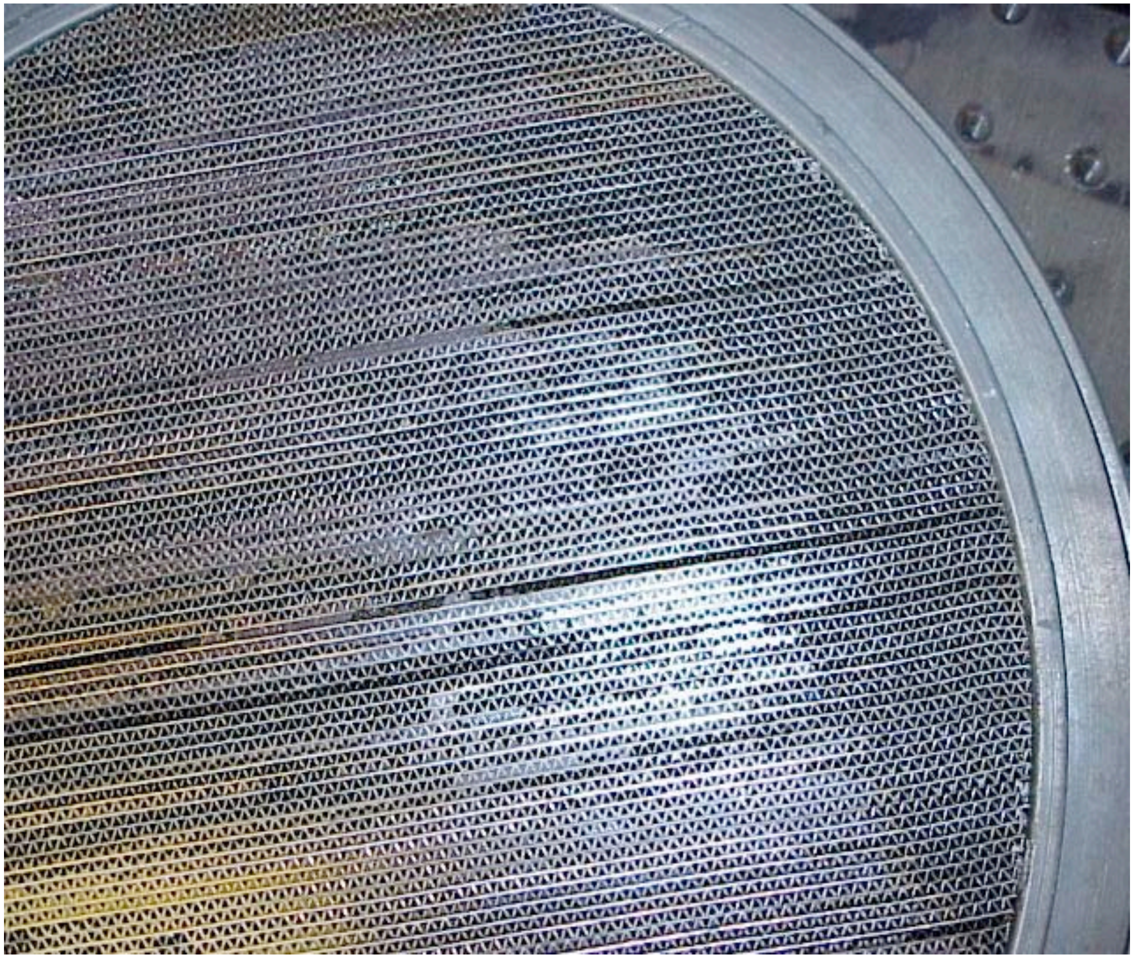
Ideally, a lens similar to that used for visible photon wavelengths would be used for high efficiency – not feasible at gamma-ray wavelengths

Absorbing collimation typically used

Parallel Hole Collimation



Typical Parallel Hole Collimator



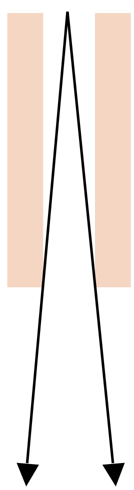
Parallel Hole Collimation

$$\eta \approx \frac{h^2}{16L^2} \times F$$

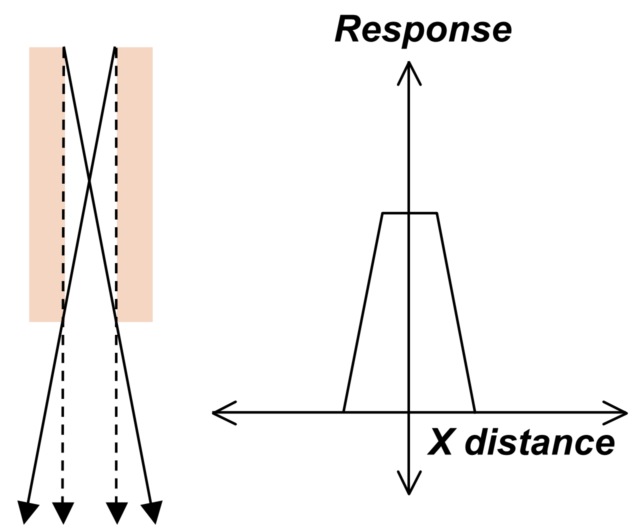
Efficiency

$$R \approx h + \frac{h}{L} \times d$$

Intrinsic Resolution (FWHM)



Single collimator channel



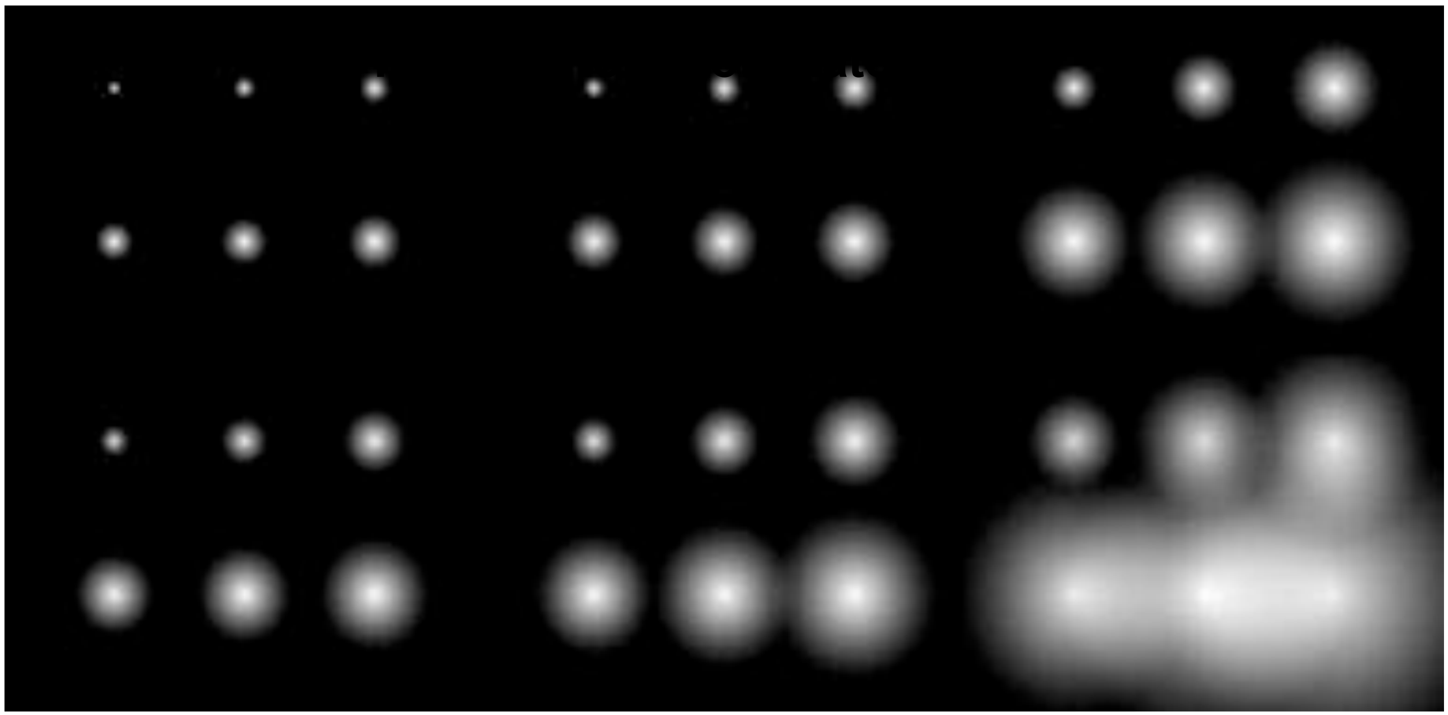
Essentially solid-angle efficiency of single channel

Response is trapezoidal becoming triangular at larger distances

Resolution vs. Depth

h = 1mm

h = 2mm



L = 30mm

L = 20mm

L = 10mm

Point source depths: 10, 15, 20, 25, 30, 35 cm

Sad Facts About Absorbing Collimation

In the best case efficiency is only a few photons detected for 10,000 emitted

Performance of absorbing collimation decreases rapidly with increasing energy

Photoelectric absorption coefficient changes as ~ Z^4 / E^3

Typical collimator for 140 keV Tc-99m – 9mm FHWM @ 10cm, 2.3e-4

Typical for 364 keV (I-131) – 12mm FWHM @ 10cm, 1e-4

Radionuclides with even a small fraction of higher energy radiation will result in severely compromised imaging performance

Alternatives for Increasing Efficiency

- ***Surround patient with more cameras***
- ***Use fan-beam or cone-beam collimation to trade FOV size for efficiency at given resolution***