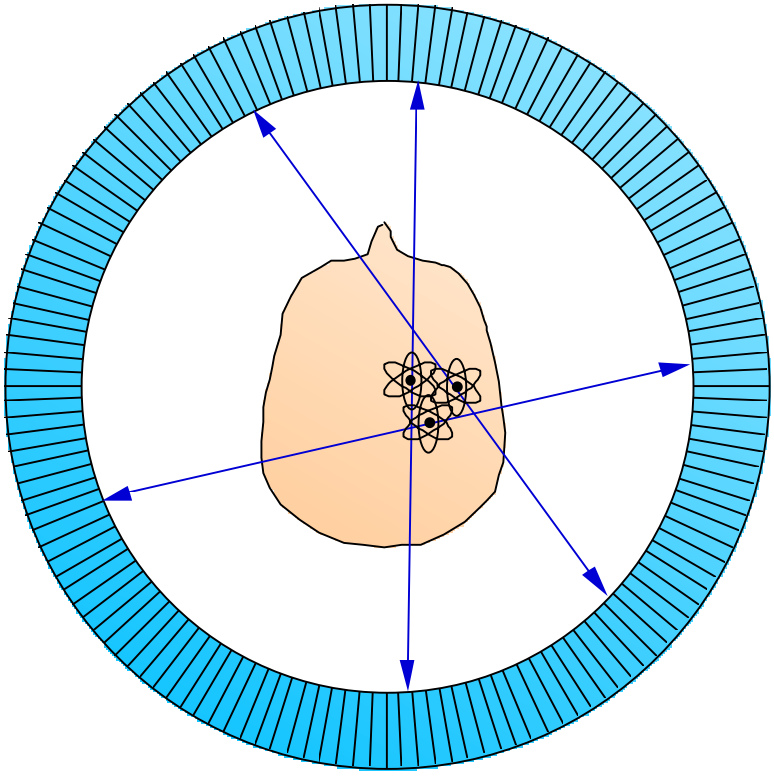
Medical Imaging – Positron Emission Tomography

(thanks to Bill Moses, Life Sciences Div. LBNL)

What is Positron Emission Tomography (PET)?

- Patient injected with drug having β^+ emitting isotope.
- Drug localizes in patient.
- Isotope decays, emitting β^+.
- β^+ annihilates with e^- from tissue, forming back-to-back 511 keV photon pair.



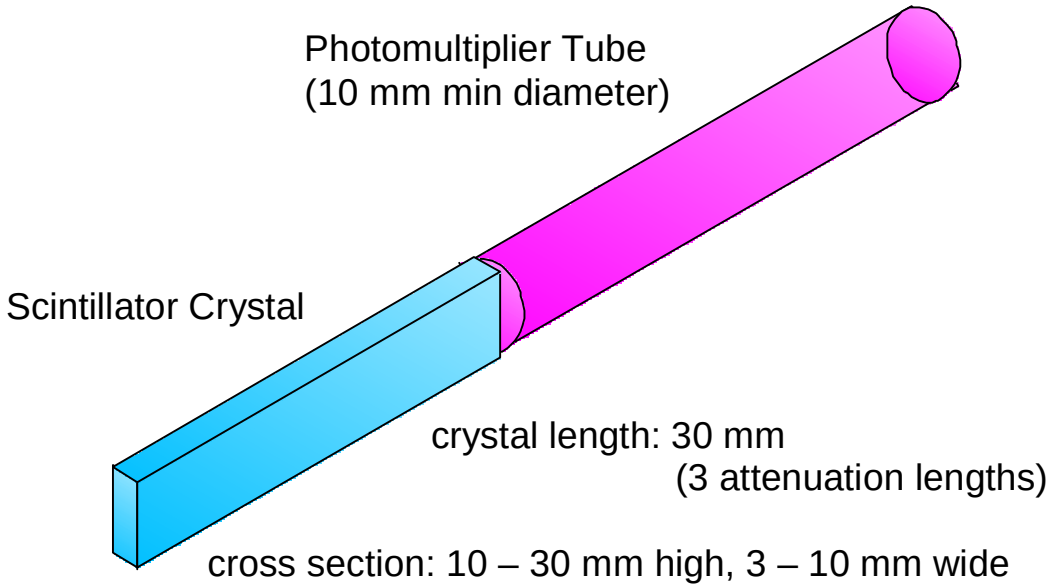
- 511 keV photon pairs detected via time coincidence.
- Positron lies on line defined by detector pair (a *chord*).

Forms planar image of a “slice” through the patient.

Common Tracer Isotopes

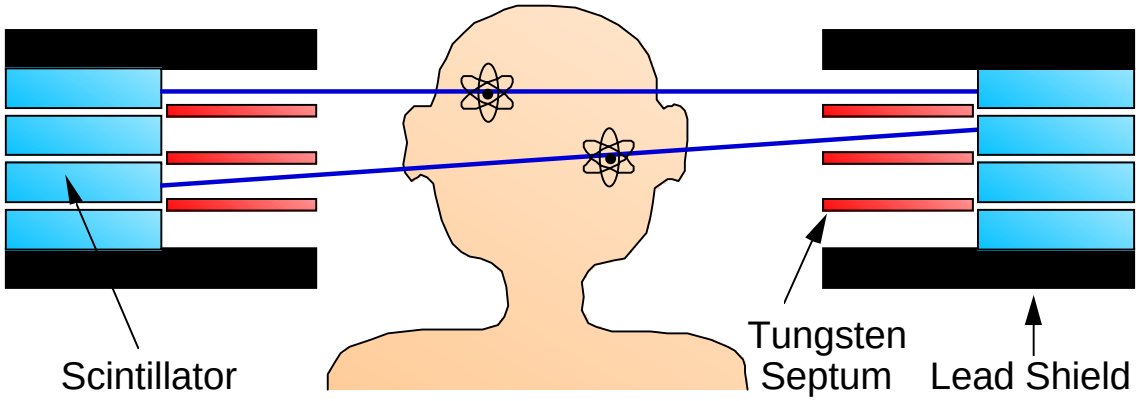
^{18}F	2 hour half life (+) Chemically “so-so” (±) Cyclotron-produced (-)
^{15}O, ^{11}C, ^{13}N	2 to 20 min. half-life (-) Chemically excellent (+) Cyclotron-produced (-)
^{82}Rb	2 min. half-life (-) Chemically boring (-) Generator-produced (+)

Individual Detector Element



Scintillator converts photon energy into light
Photomultiplier tube converts light into electrical signal

Multi-Layer PET Cameras



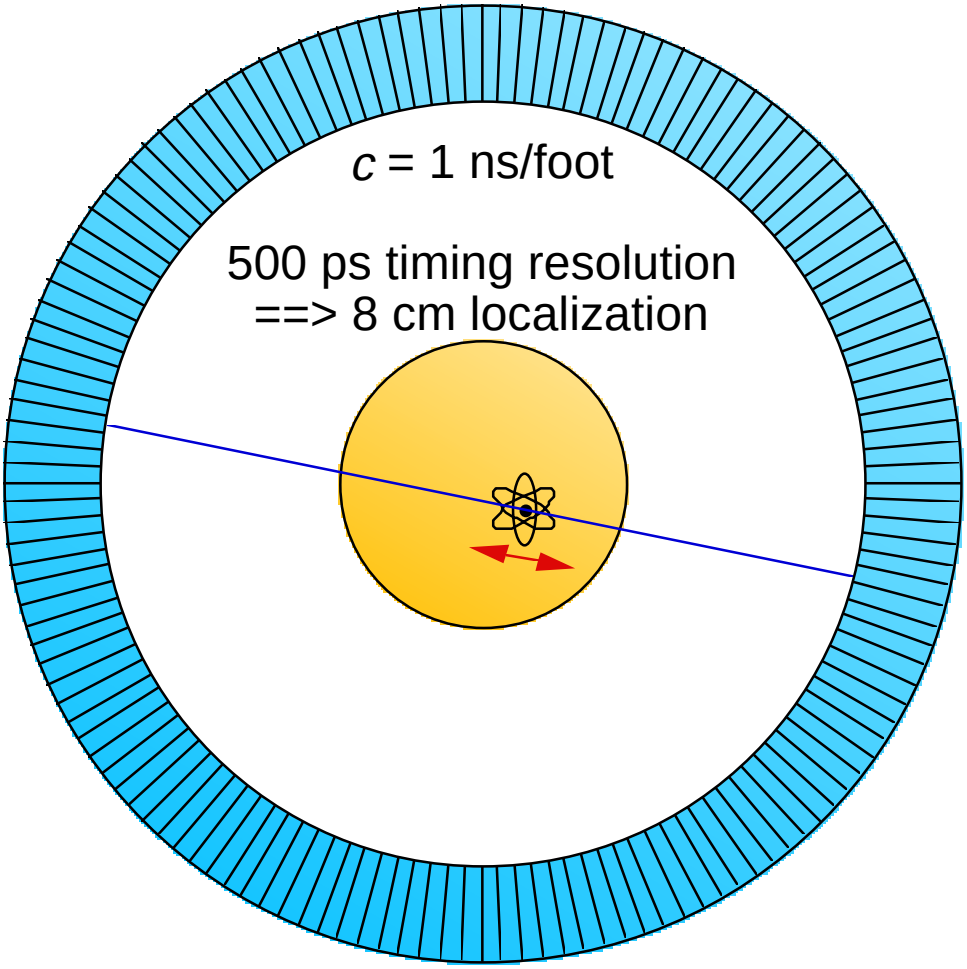
- Can image several slices simultaneously
- Can image cross-plane slices
- Can remove septa to increase efficiency (“3-D PET”)

However,

- More expensive

Planar images are “stacked” to form 3-D image

Time-of-Flight Tomograph



- Utilize difference in time of arrival between the two detectors
- Can localize source along line of flight
- Time-of-flight information reduces noise in images

However,

- Difficult to control timing of all detectors
- More expensive

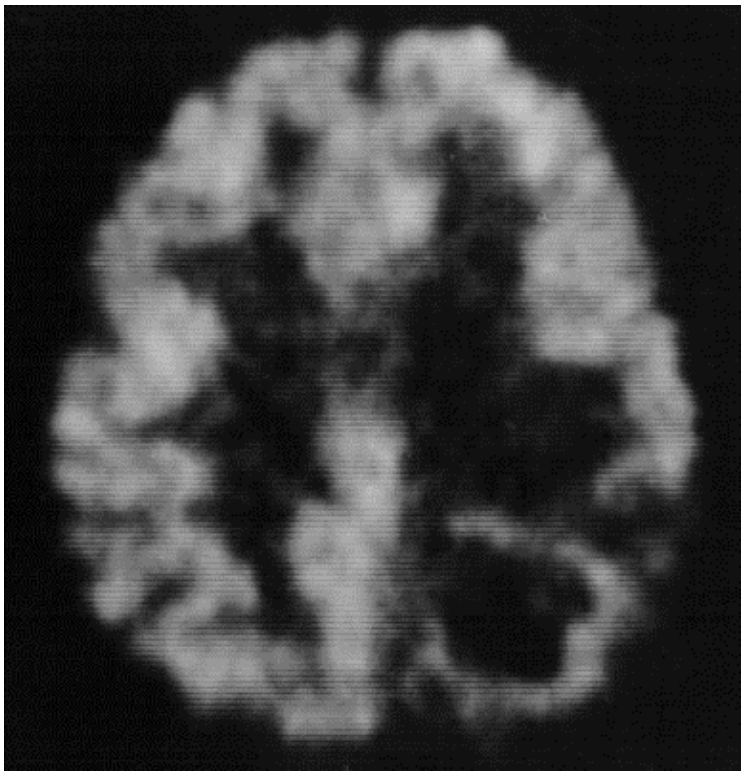
Typically used to augment “standard” PET to reduce background.

Typical Tomograph Parameters

- Patient port 30 cm diameter (head machine) or 50 cm diameter (body machine).
- 3.5 to 6 mm scintillator crystal width.
- 24 to 48 layers, covering 15 cm axially.
- 8 liters of BGO scintillator crystal.
- 500 photomultiplier tubes.
- "Several" million dollars
  - Scintillator is 25% of total parts cost
  - PMTs are 25% of total parts cost
  - Next component is <5% total parts cost

Applications

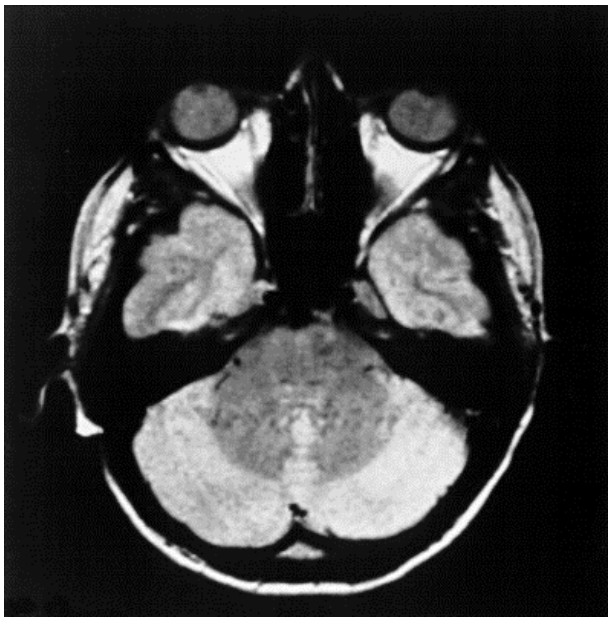
Tumor vs. Necrosis



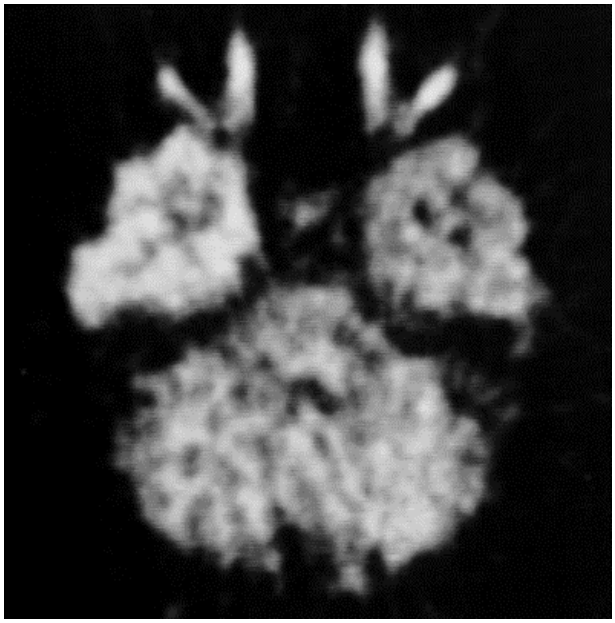
- Brain tumor treated by radiation therapy.
- Symptoms recur
- Too much or too little radiation
- Check with PET

Too much radiation	⇒	dead area
Too little radiation	⇒	rapid metabolism blood circulation increases tracer concentration

Epilepsy – Comparison of NMR with PET



NMR
(now called MRI)



PET

note bright left
frontal lobe of brain

NMR and PET are complementary.

PET depends on rate of metabolism – allows dynamic measurements.