Basics & Fundamentals of Radiation Interactions

IMAGING LAB
MPHY 487

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- Radiation
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Radiation

- The emission or transmission of energy in the form of waves or particles through space or through a material medium. This includes:
- Electromagnetic radiation, such as heat, radio waves, visible light, X - ray and γ – ray.
- Particle radiation, such as α & β particles and neutron radiation.
- Acoustic radiation, such as US.

Type of Radiation

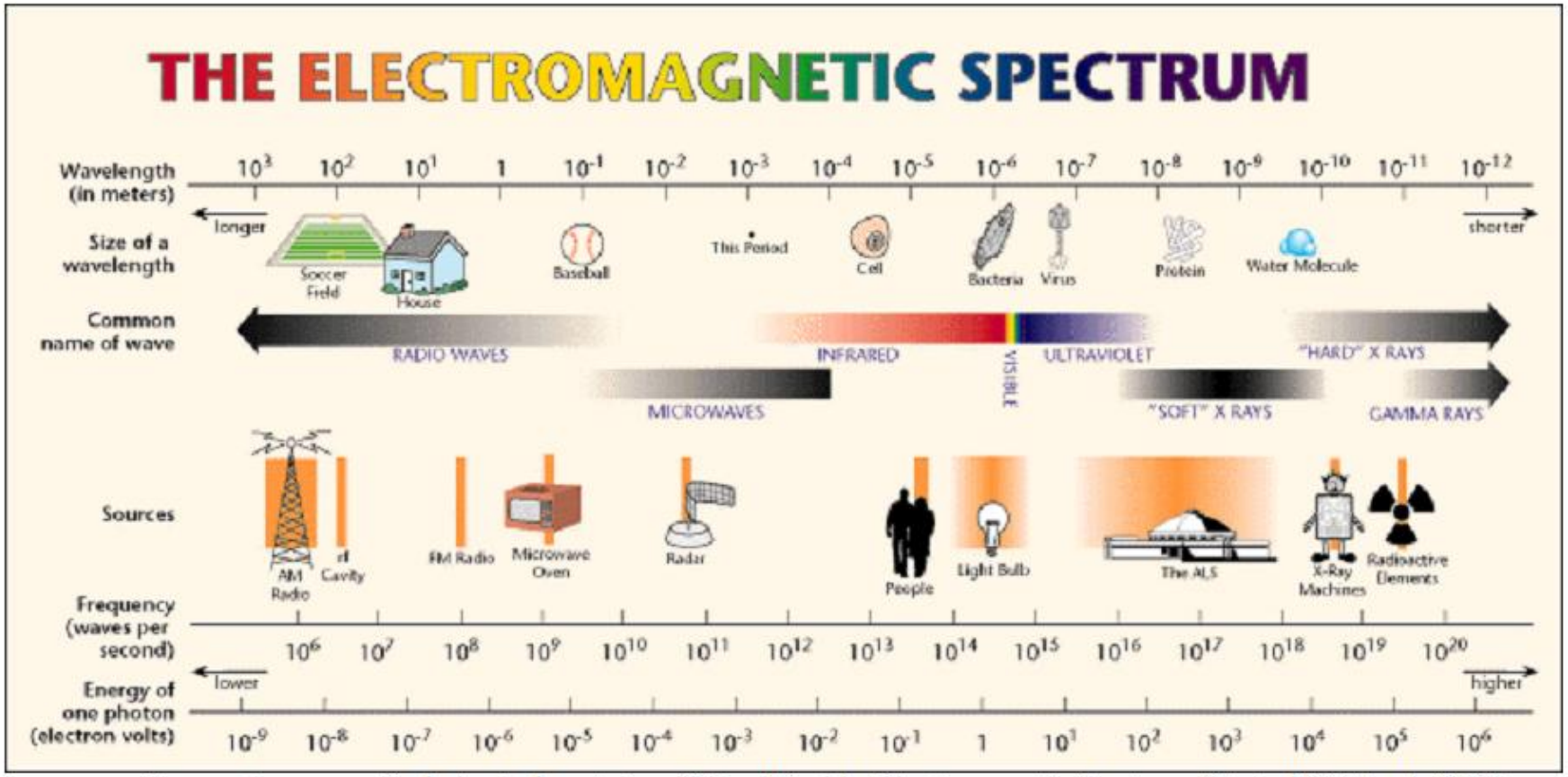
Non- Ionising Radiation:

Refers to any type of electromagnetic radiation that does not carry enough energy to ionize atoms to remove an electron from an atom.

Ionising Radiation:

Consists of particles or electromagnetic waves energetic enough to remove electrons from atoms.

Type of Radiation



Source: Lawrence Berkeley Laboratories, "MicroWorlds: Electrmagnetic Spectrum." [cited 26 March 2003.] http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

Characteristics of Ionization Radiation

- Radiation with enough energy to remove tightly bound electron from their orbit when interacting with matter, and the atoms; will become charged or ionized.
- Given off by radioactive material, X-ray tubes, particles accelerators, nuclear reactions and is present in the environment.
- It is invisible and not directly detectable by human senses, needs special instruments to detect and measure it.

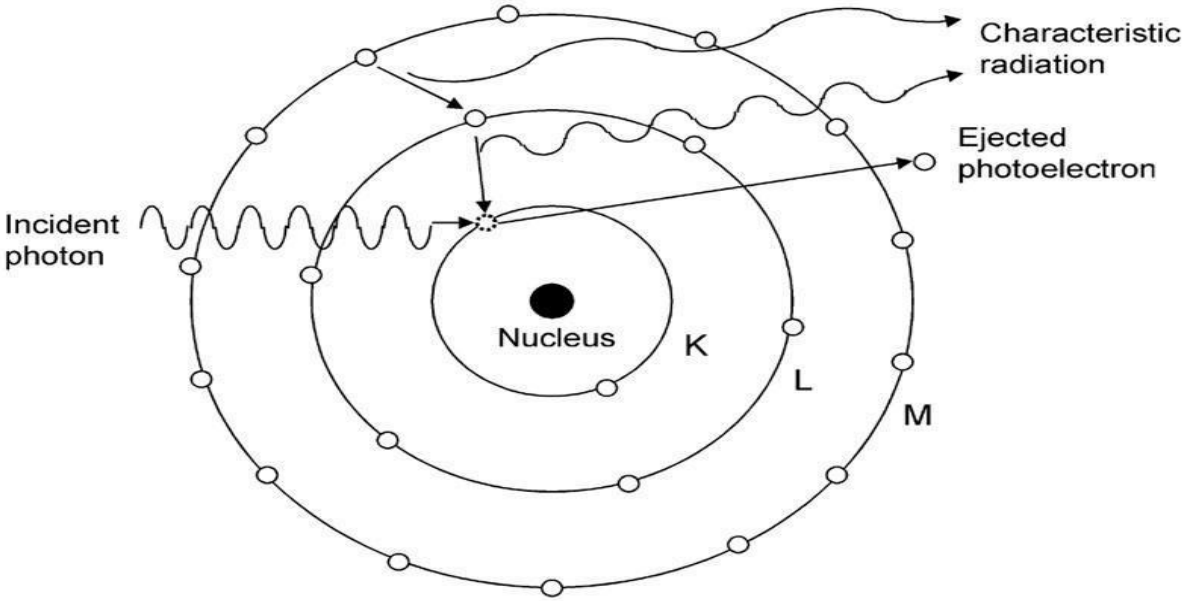
Type of X-Ray Generation

- **Characteristic X – Ray**
- **Bremsstrahlung X – Ray**

Characteristic X – Ray

•If an orbital electron has a sufficient energy from a collision with another electron or an incident photon to be ejected from its orbit, the new electron vacancy will be filled with an outer shell's electron.

•The energy differences between the two shells will be emitted as an X-ray.



Bremsstrahlung X-Ray

A type of X-ray produced by light charged particles when they undergo inelastic collisions with nuclei of absorber atoms.

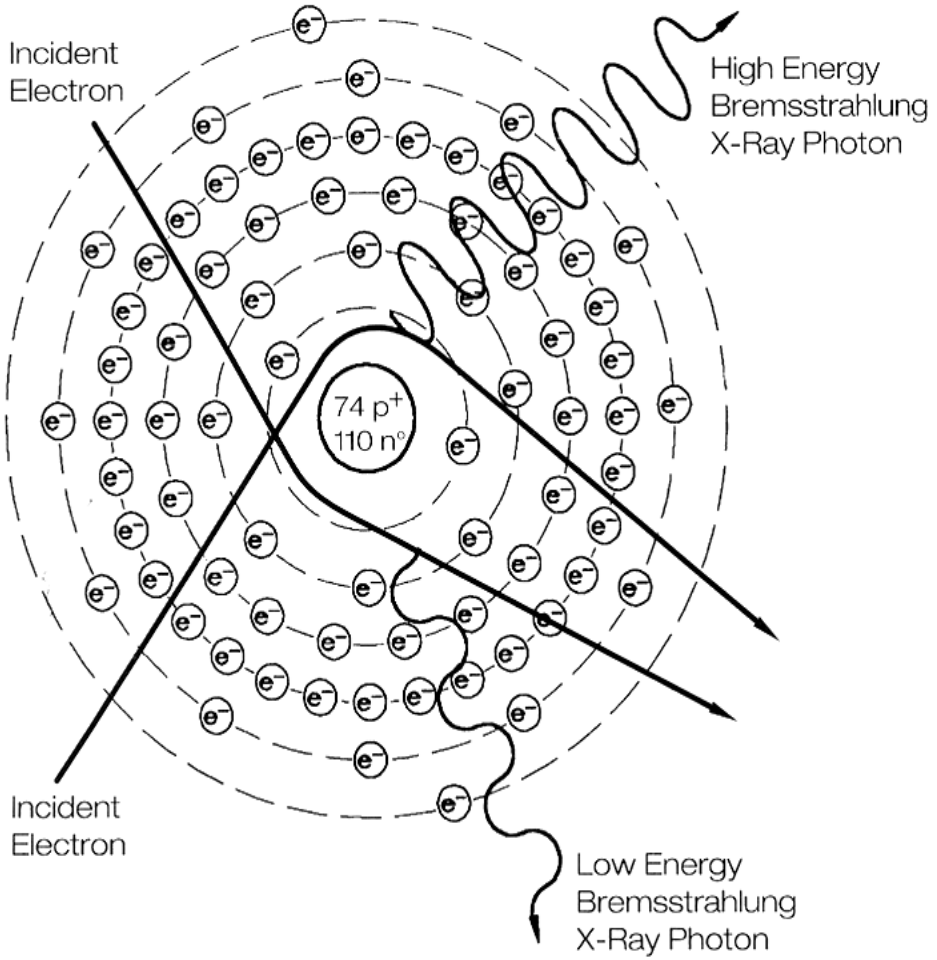
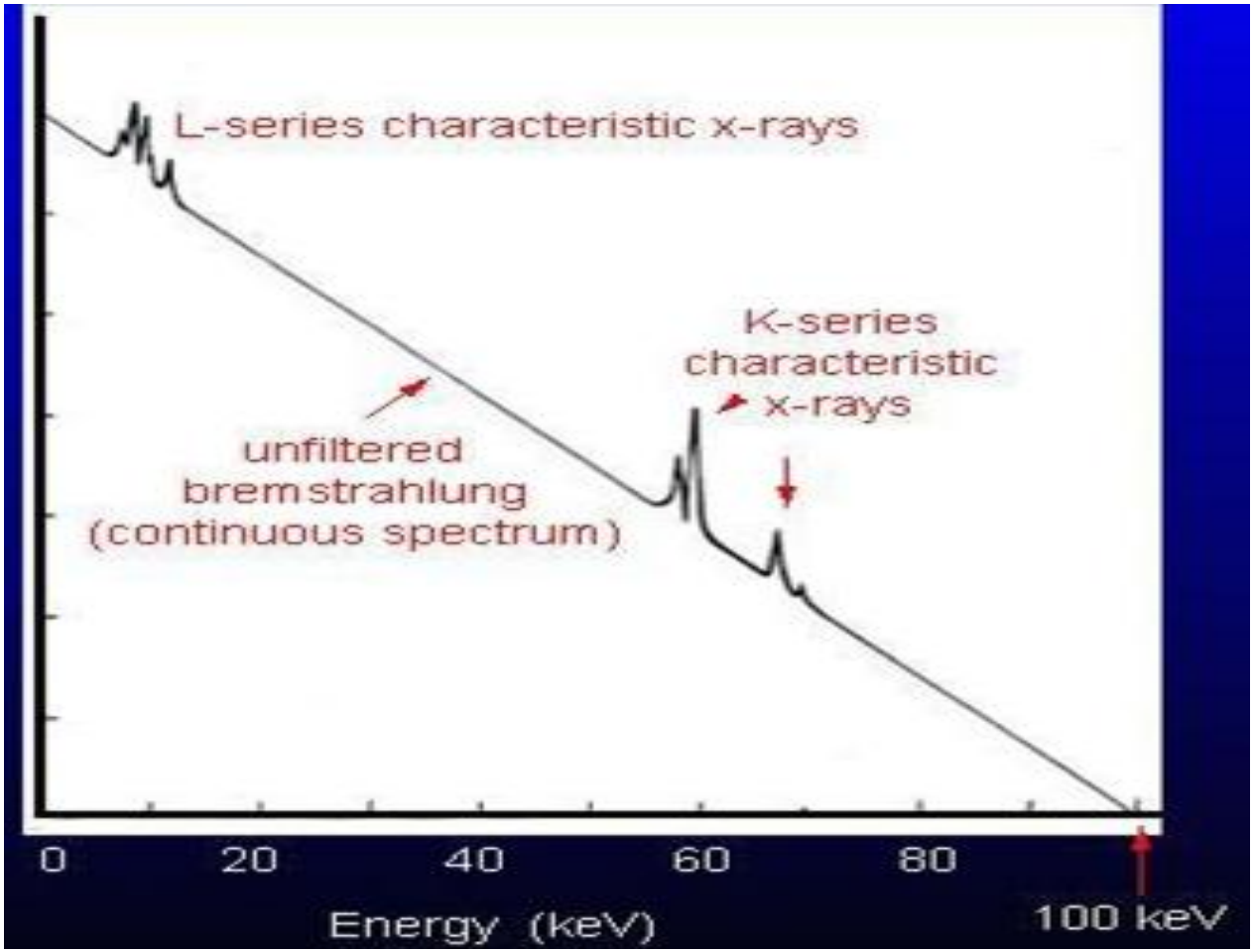


FIGURE 7–1. The bremsstrahlung interaction.

Characteristic and Bremesthaluong Spectrums

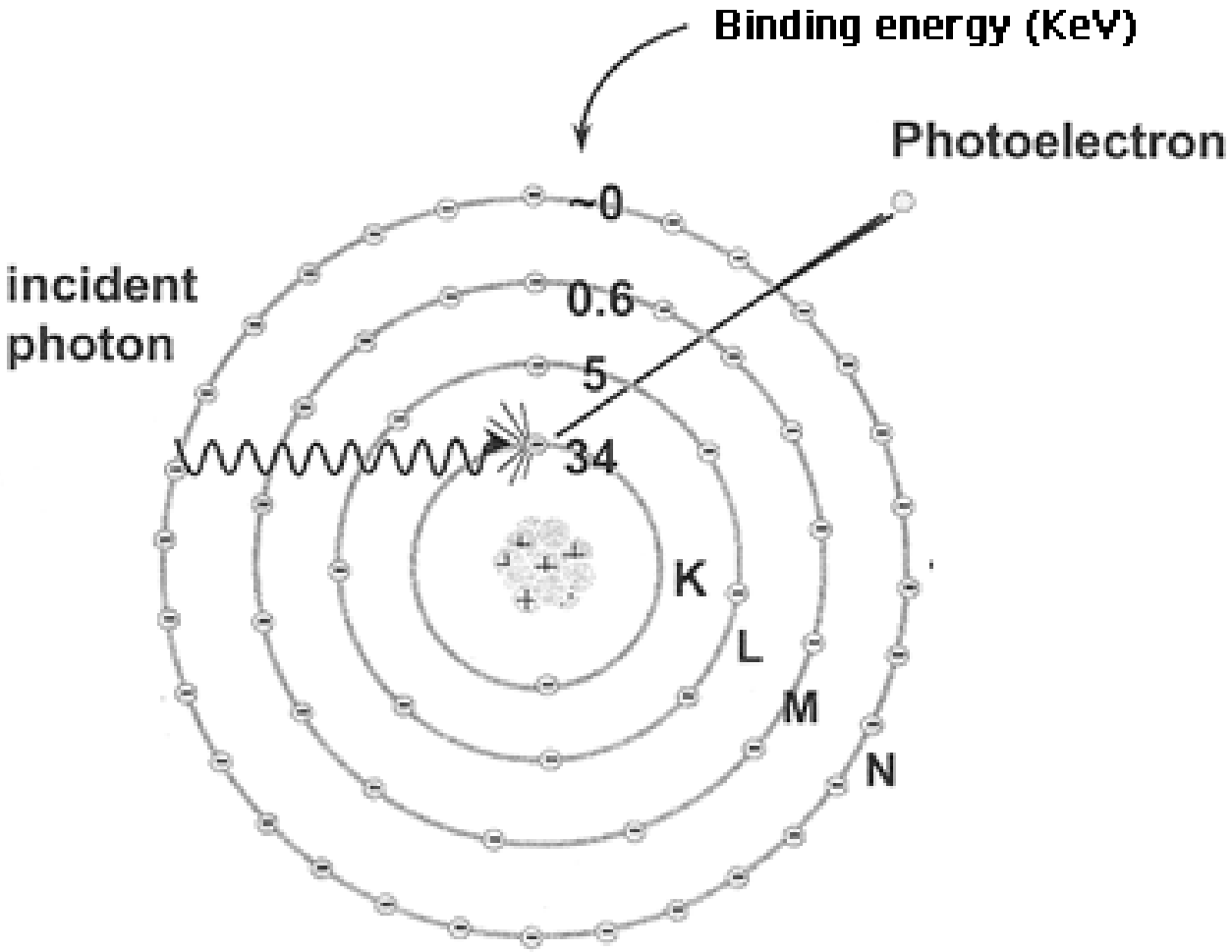


Interaction of radiation with matter

1. **Photoelectric Effect**
2. **Compton Scattering**
3. **Pair Production Effect**

Photoelectric Effect

(Complete absorption of incident photon)

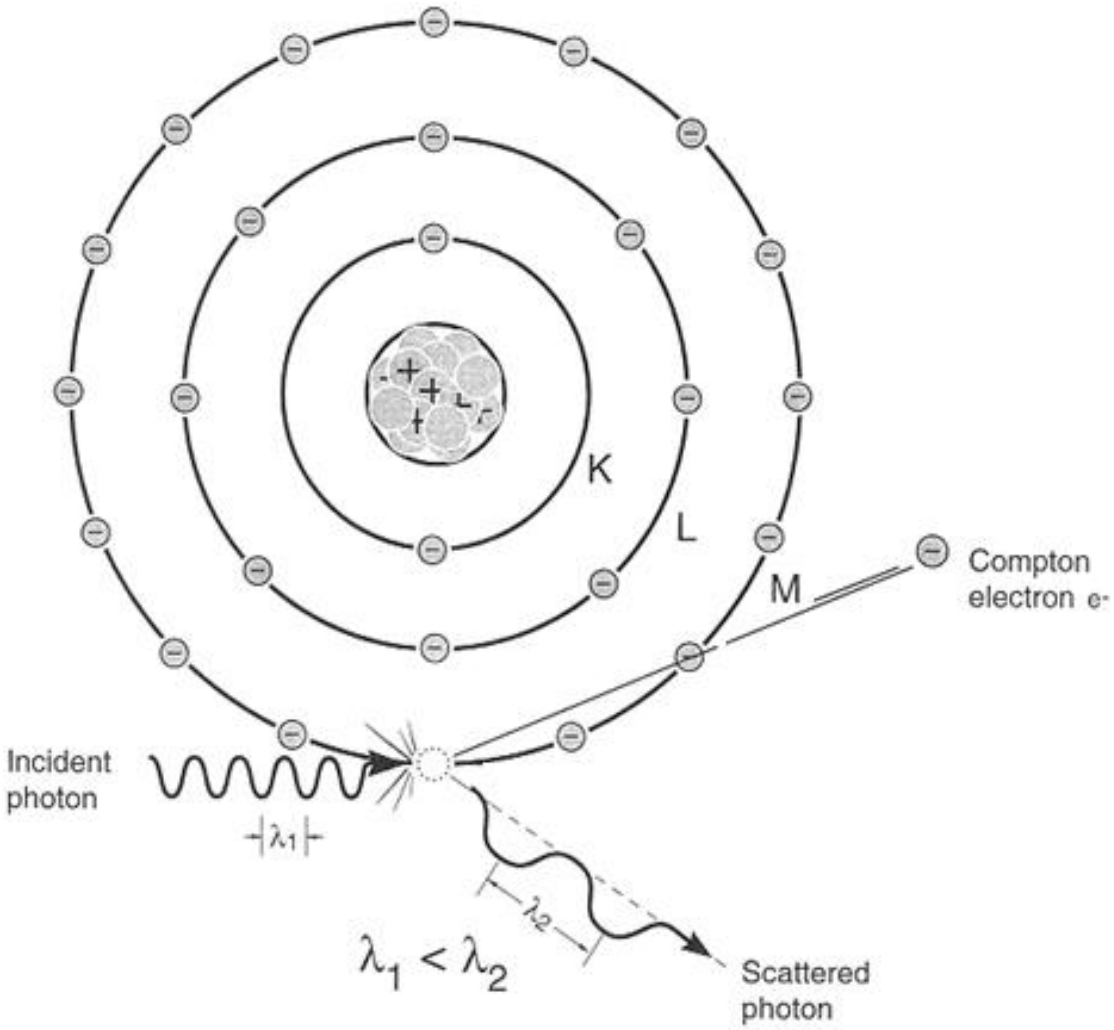


Photoelectric Effect

1. The photoelectric effect is the most important interaction between low-energy photons and high Z matter.
2. The photon disappears and the energy absorbed is used to eject the orbital electron from the atom.
3. The ejected electron is called a photoelectron and is most likely to be derived from the K-shell.
4. The electron receives kinetic energy E_{pe}, equal to the difference between the incident photon energy E_o and the binding energy of the electron shell from which it was ejected. If a K-shell electron is ejected, the kinetic energy of the photoelectron is:

$$E_{pe} = E_o - K_B$$

Compton Scattering

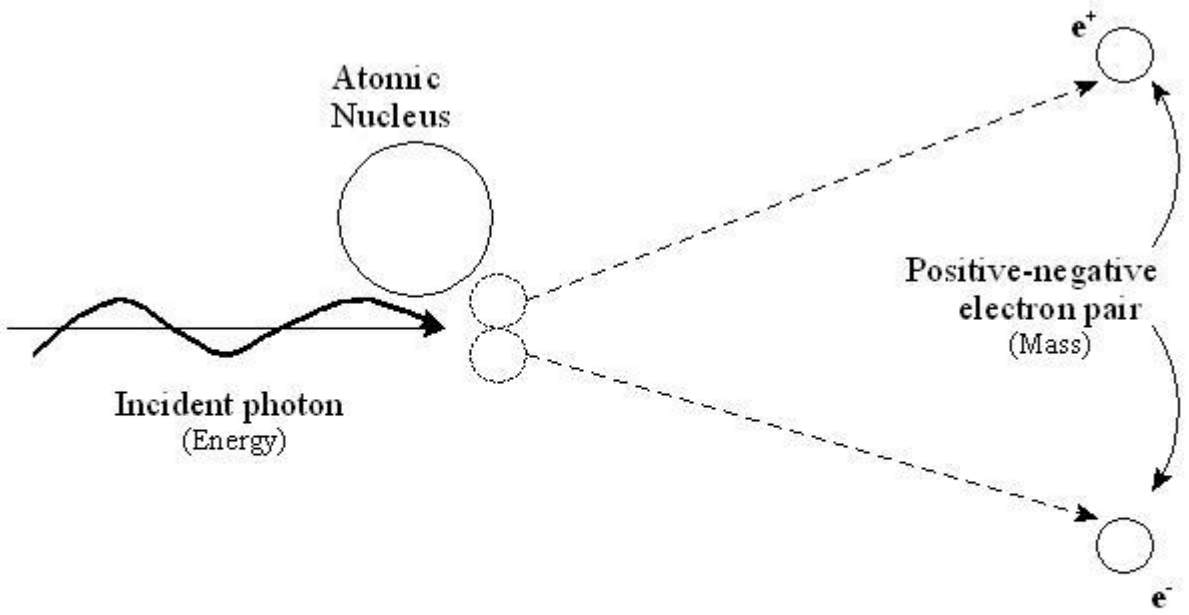


Compton Scattering

1. Compton scattering is a collision between an incident photon and a loosely bound outer shell orbital electron of an atom.
2. This interaction dominate for low-Z materials (e.g. tissue) and is in the region between 0.65 to 8 MeV.
3. Since the incident photon energy greatly exceeds the binding energy of the electron to the atom, the interaction appears as a collision between the photon and a free electron.
4. However, the photon doses not disappear; instead it is deflected through a scattering angle (θ).
5. Part of its energy is transferred to the recoil electron; thus, the photon loses energy in the process.
6. The energy of the scattering photon is related to the scattering angle (θ) by consideration of energy and momentum conservation according to:

$$E_{sc} = \frac{E_o}{1 + \left(\frac{E_o}{m_o c^2}\right)(1 - cos\vartheta)}$$

Pair Production Effect

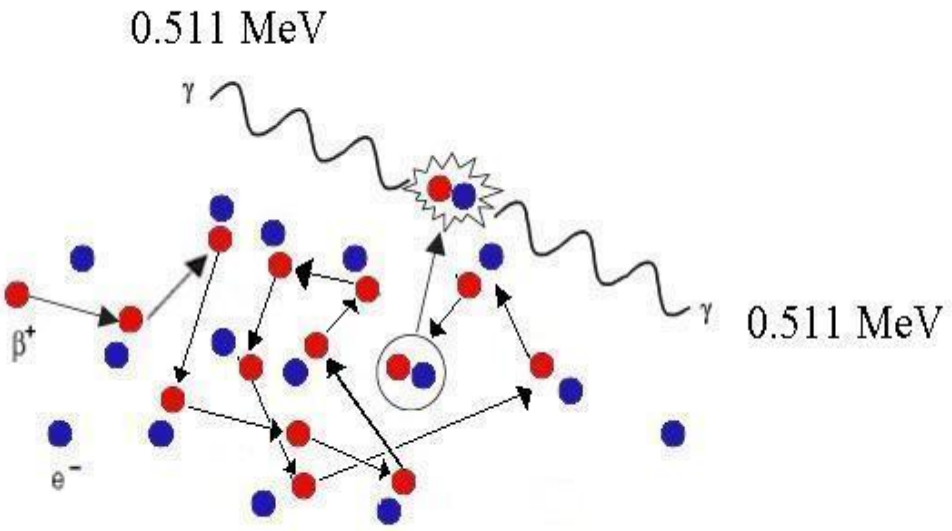


Pair Production - Energy Converstion to Mass

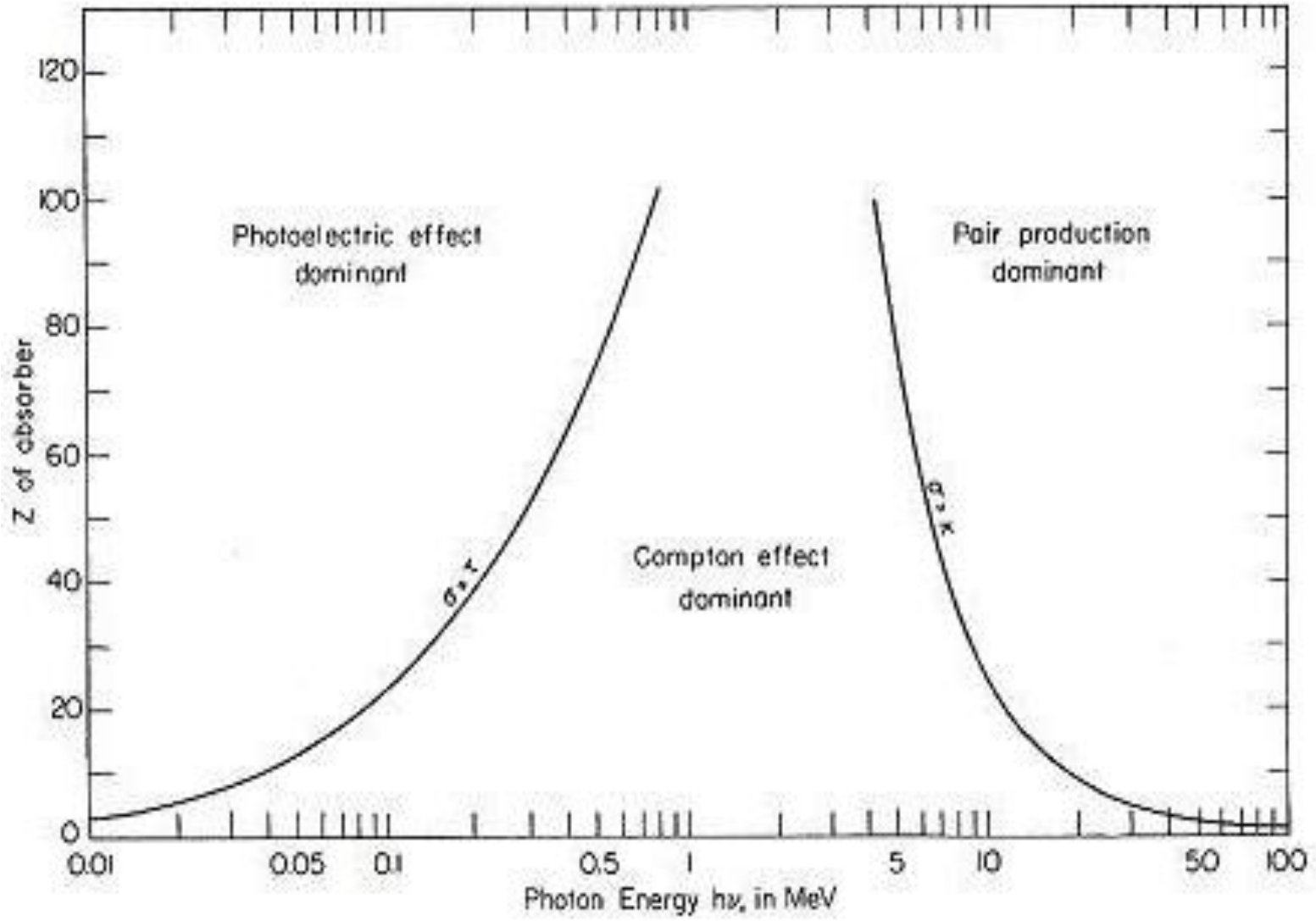
$E_o > 2m_0c^2$, where m_0 is the electron rest mass

Pair Production Effect

Positron (β^+) is emitted. It travels a certain distance (1-3 mm) before it undergoes an annihilation with an electron (β^-) creating a pair of gamma rays, the angle between they 180º.



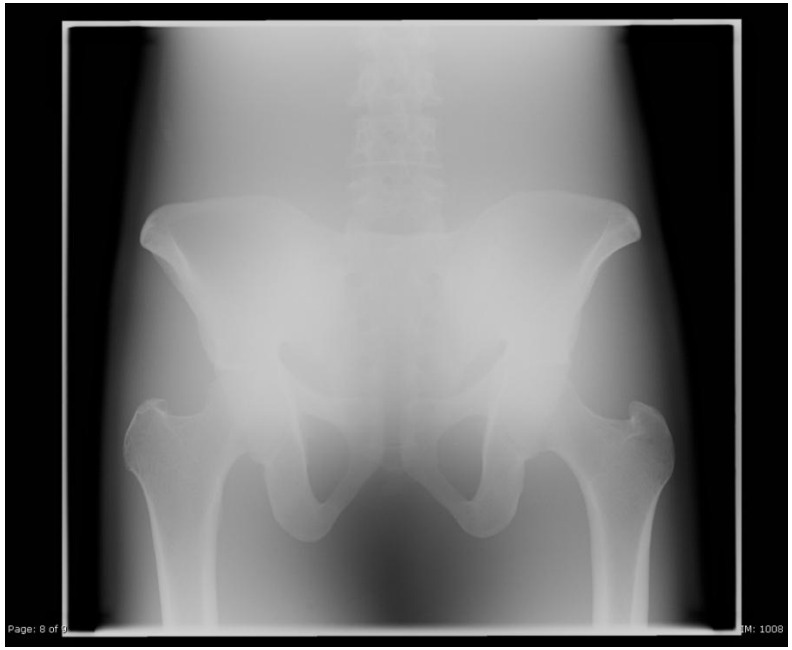
Interaction of Radiation with Matter



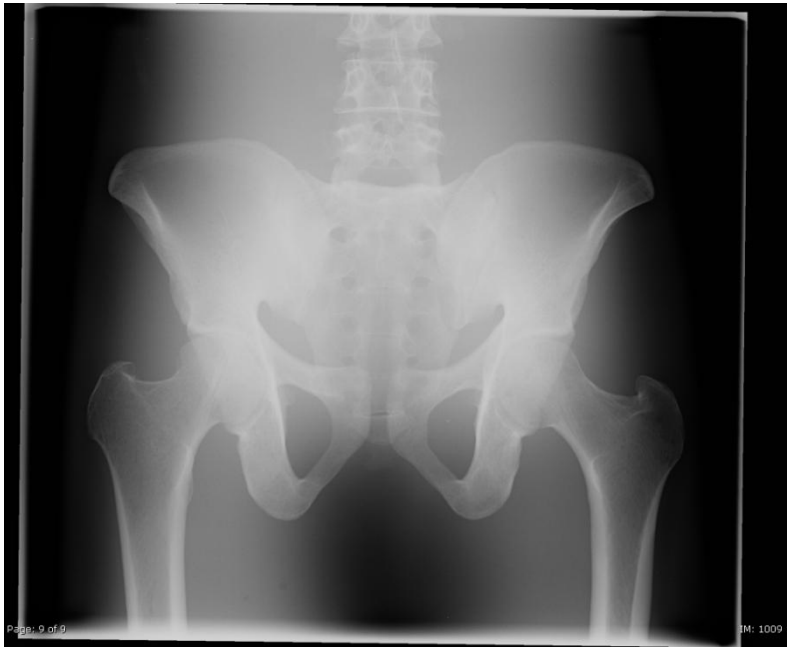
Photoelectric Effect

Compton Scattering

Effect of Compton Scattering



KV = 75
mAS = 3
Scatter Grid Removed



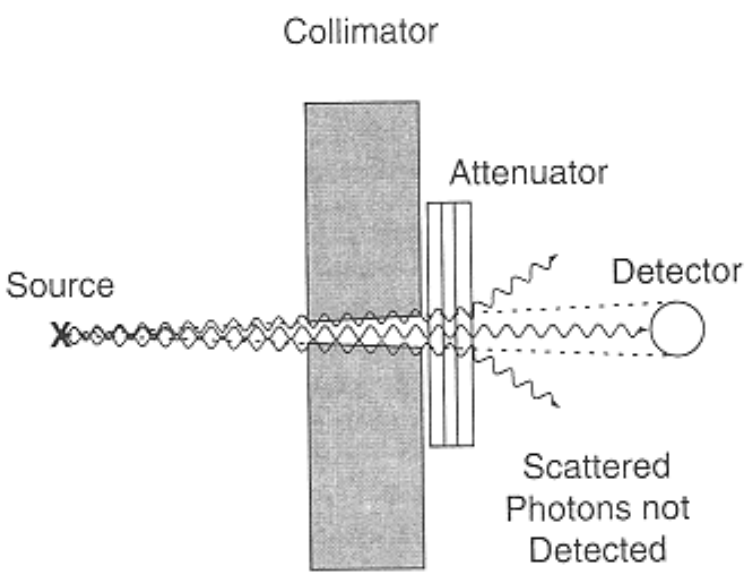
KV = 75
mAS = 25
Scatter Grid Include

X – Ray Parameters

Generators permit x-ray operators to control three key parameters:

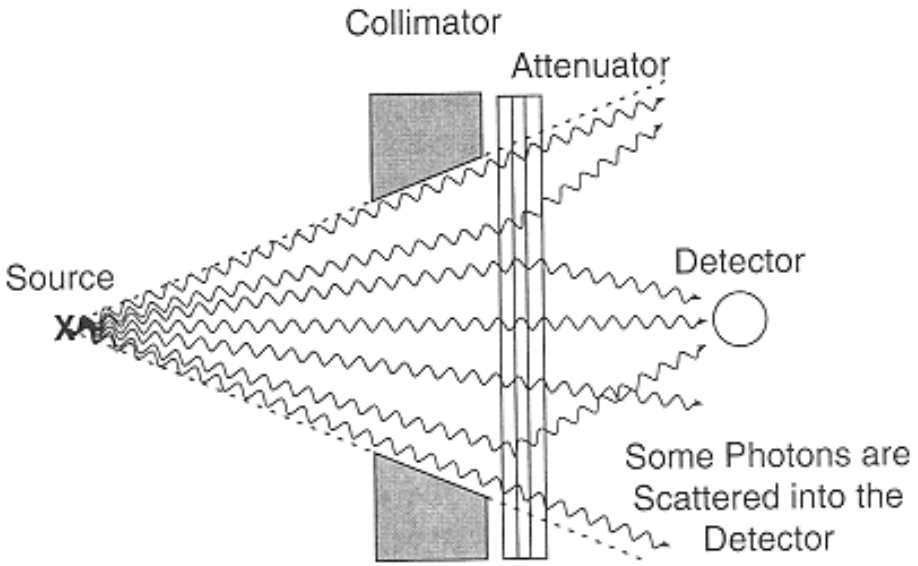
- X - Ray tube voltage (kV), which affect the x-ray energy.
- X – Ray tube current (mA), which affect the radiation quantity.
- X – Ray exposure time (seconds).

Effect of FOV



Narrow-Beam Geometry

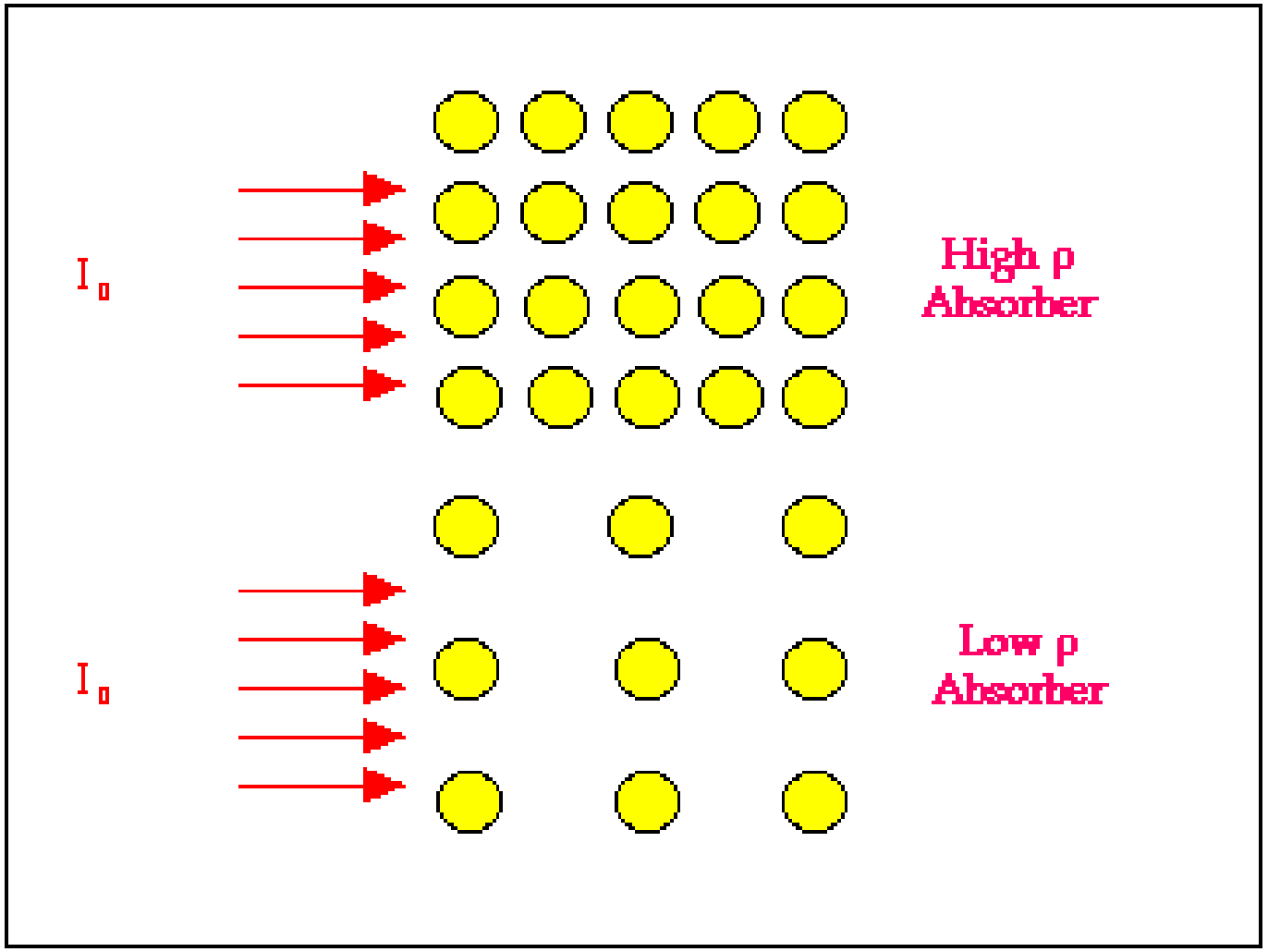
A



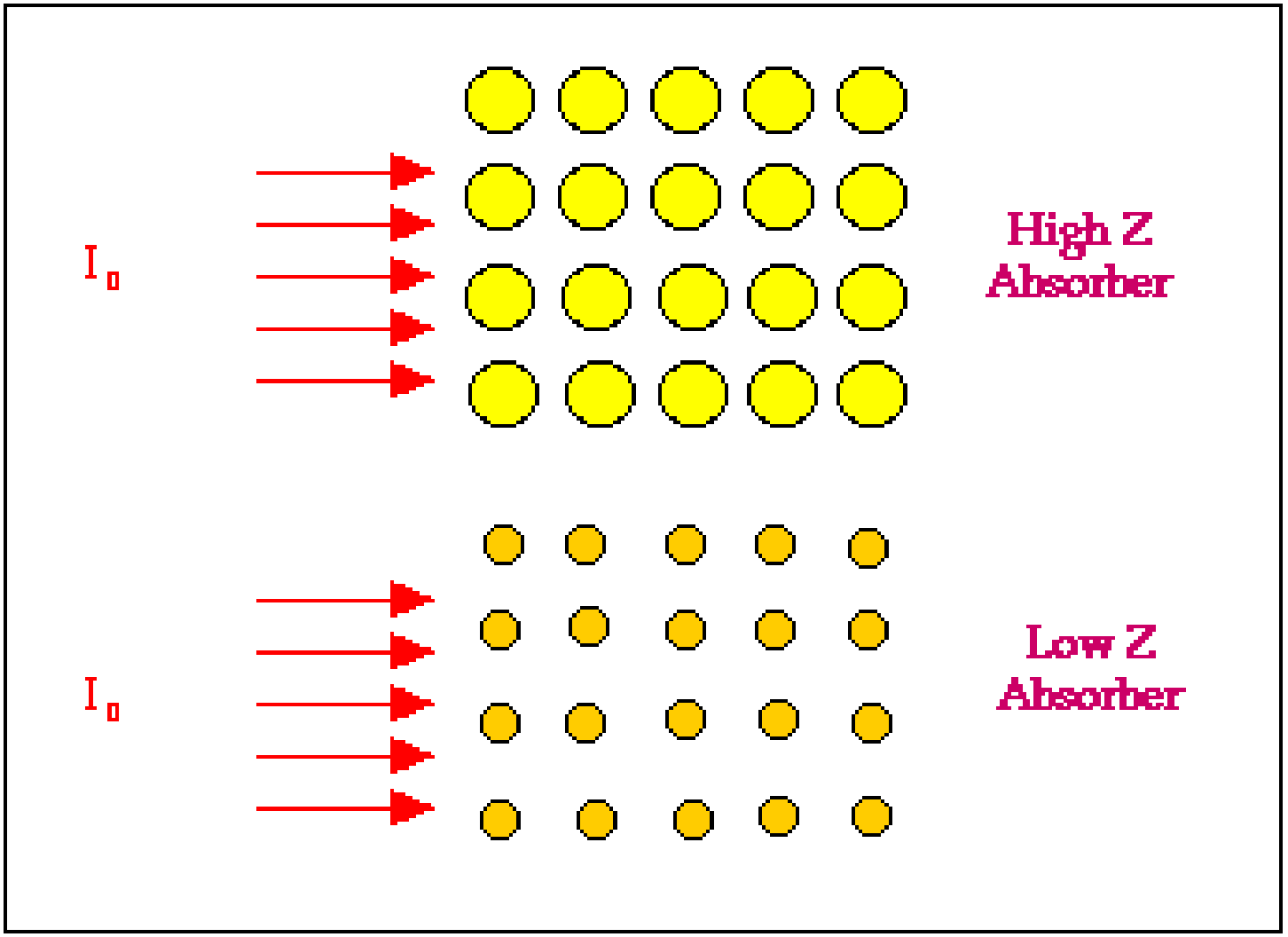
Broad-Beam Geometry

B

Effect of Density



Effect of Atomic Number



X-ray Tube Filtration

- The primary reason for tube filtration is to remove as many of the low energy photons from the emitted x-ray beam as possible before they reach the patient, since they can not be used to image the patient but can add to the overall patient absorbed dose.