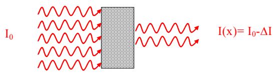
The interaction of γ-radiation with matter

The γ-radiation transfers its energy to matter through 3 different processes:

- Photoelectric effect
  The γ-quantum is totally absorbed by a bound electron
- Compton-effect
  The γ-quantum gives off part of its energy to an electron through an elastic collision.
- Pair production
  The γ-quantum gives off its entire energy by materialising in an electron/positron (e^+e^-) pair
- (Coherent scattering does not imply energy transfer.)

Absorption of γ-radiation in matter



$$\Delta I \propto I_0$$
$$\Delta I \propto \Delta x$$

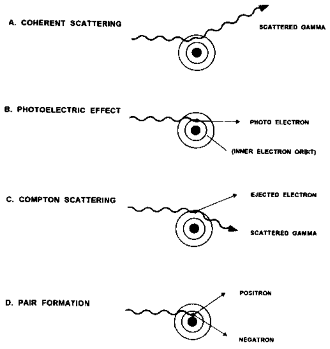
$$\Rightarrow \quad \Delta I = -\mu \cdot I_0 \cdot \Delta x$$

(Absorptionscoeffizient μ [cm^2/g]
Thickness x [g/ cm^2])

$$\Rightarrow \quad I(x) = I_0 \cdot e^{-\mu x}$$

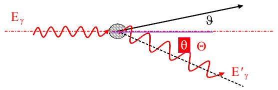
$$D_{1/2} = \frac{\ln 2}{\mu}$$

The four modes of intereaction



(Coherent),photoelectric,compton, pair formation

Compton-effect.



The Compton-effect is a quasi-elastic interaction between a “free” electron in matter an a high energy photon with initial energy E_γ. Energy is transfered to the electron, and a photon with reduced energy E_γ’ continues at the angle θ. The relationship between E_γ’ and θ id given by the formula:

$$\frac{1}{E_\gamma'} = \frac{1}{E_\gamma} + \frac{(1-\cos\theta)}{m_ec^2}$$

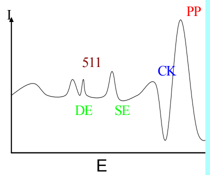
Compton-effekt.

$$\frac{1}{E_\gamma'} = \frac{1}{E_\gamma} + \frac{(1-\cos\theta)}{m_ec^2}$$

We see from this formula that the energy at full backscattering is given as:

$$\frac{1}{E_\gamma'} = \frac{1}{E_\gamma} + \frac{2}{m_ec^2}$$

At high energies for initial γ, this value goes towards the limit E_γ’= 255 keV



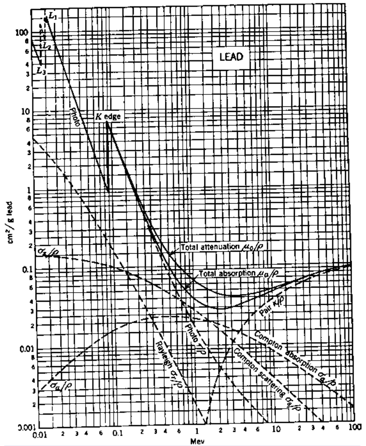
PP - Photopeak; the whole γ-energy deposits in the detector
CK - Compton edge. At CK maximum energy transferred to the electron in a Compton event. The Compton continuum proceeds down to E = 0
At high γ-energies there is pair production. The positron gives away its kinetic energy and annihilates by reaction with an electron from the surroundings:
$e^+ + e^- \rightarrow 2$ γ-quants (511 keV)
SE - single escape; one quant escapes the detector; deposited energy $E_{dep} = E_\gamma$-511 keV
DE - double escape; both quants escape; deposited energy $E_{dep} = E_\gamma$-1022 keV
If no quants escape, $E_{dep} = E_\gamma$, all are summed due to time resolution.

Z- and energy dependence:

- Photoelectric: $\propto Z^4 - Z^5$; $\propto E^{-3.5} - E^{-1}$
- Compton: $\propto Z$; $\propto E^{-1}$
- Pair prod.: $\propto Z^2$; $\propto \mathit{ln} E$ (E> 1022 keV)

In practical detection, we always try to enhance the photoelectric component and supress the Compton and pair components in our detectors. There are several methods avaiable for this.

γ in lead



γ in water: