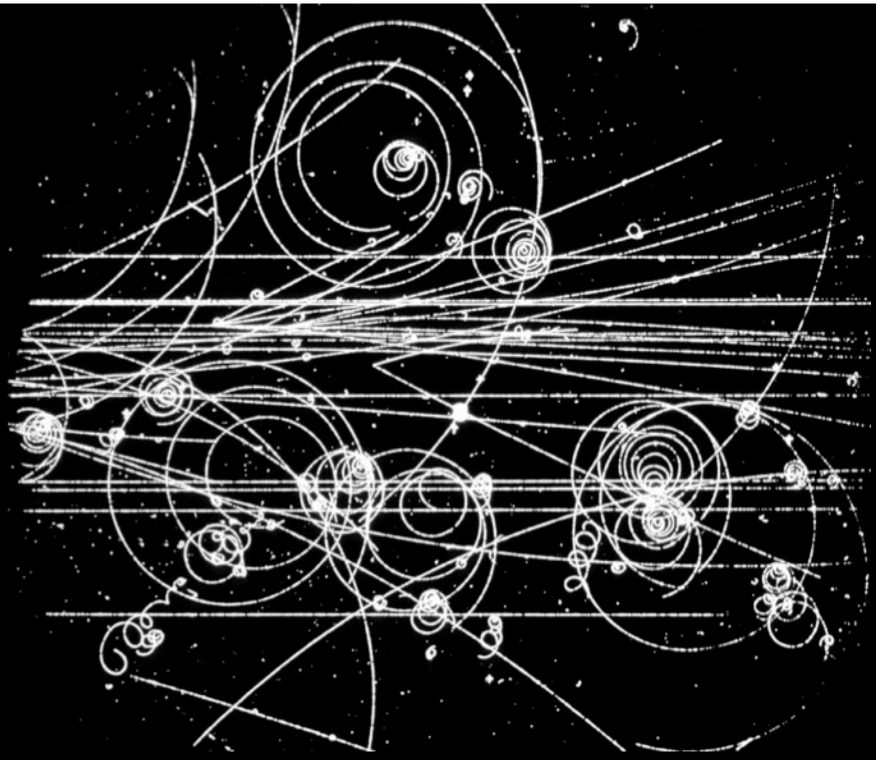
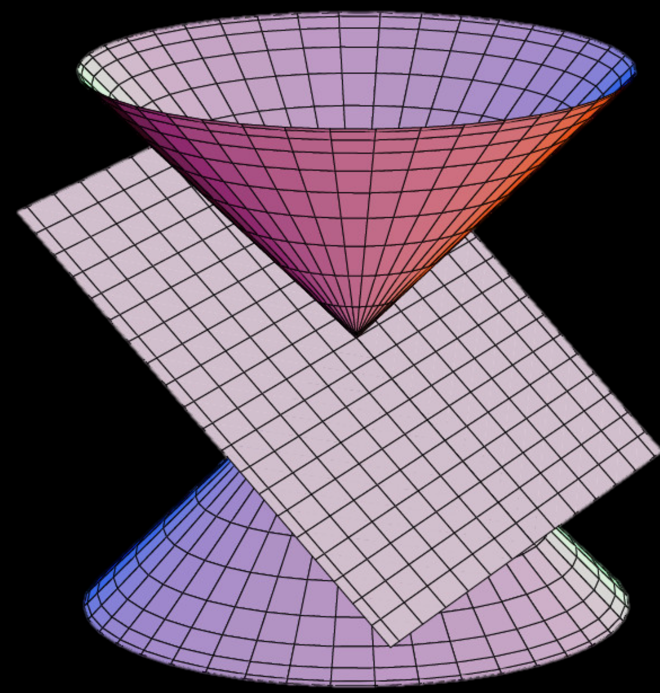
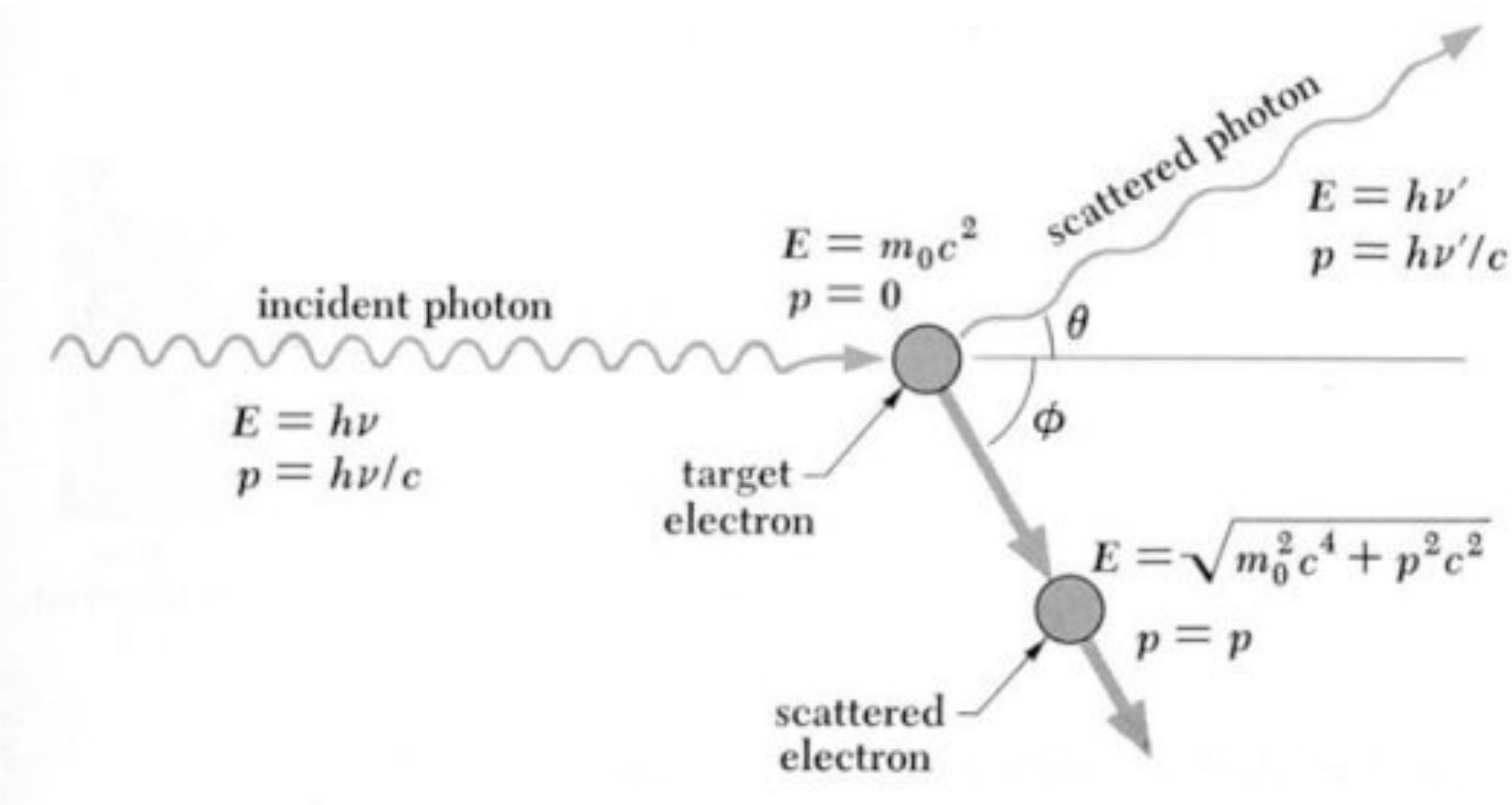




Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
Van Allen 70
MWF 12:30-1:20 Lecture

Compton Scattering



Compton Scattering

$$h\nu + m_e c^2 = h\nu' + E_e$$

$$h\nu/c = p_e \cos\varphi + \frac{h\nu'}{c}\cos\theta$$

$$0 = \frac{h\nu'}{c}\sin\theta - p_e \sin\varphi$$

$$p_e^2 \cos^2\varphi = \left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 \cos^2\theta - 2\frac{h^2\nu\nu'}{c^2}\cos\theta$$

$$p_e^2 \sin^2\varphi = \left(\frac{h\nu'}{c}\right)^2 \sin^2\theta$$

$$p_e^2 = \left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 - \frac{2h^2\nu\nu'}{c^2}\cos\theta$$

$$\begin{aligned}
E_e^2 &= p_e^2 c^2 + m_e^2 c^4 \\
&= (h\nu + m_e c^2 - h\nu')^2 \\
&= h\nu^2 + (m_e c^2)^2 + (h\nu')^2 \\
&\quad + 2h\nu m_e c^2 - 2h\nu' m_e c^2 \\
&\quad - 2h^2\nu\nu'
\end{aligned}$$

$$\Rightarrow p_e^2 = \left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 + 2h\nu m_e - 2h\nu' m_e - 2h^2\nu\nu'$$

$$\Rightarrow 2hm_e(\nu - \nu') = \frac{2h^2}{c^2}\nu\nu'[1-\cos\theta]$$

$$\text{or} \quad \nu - \nu' = \frac{h}{m_e c^2}\nu\nu'[1-\cos\theta]$$

$$\frac{\nu - \nu'}{\nu \nu'} = \frac{h}{m_e c^2}[1 - \cos\theta]$$

$$1/\nu' - 1/\nu = \frac{h}{m_e c^2}[1 - \cos\theta]$$

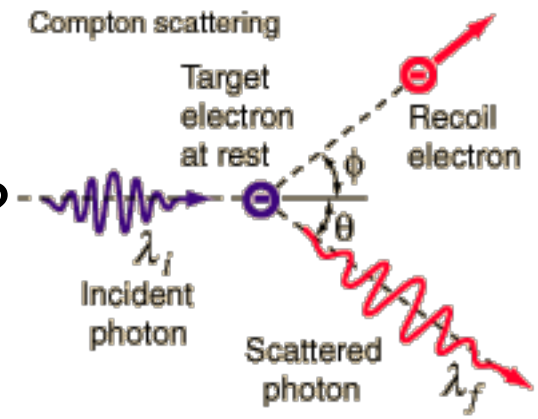
$$\lambda' - \lambda = \frac{h}{m_e c}[1 - \cos\theta]$$

$$\boxed{\Delta \lambda = \frac{h}{m_e c}[1 - \cos\theta]}$$

$\lambda_c = h/m_e c$ = "Compton wavelength"

Concept Check

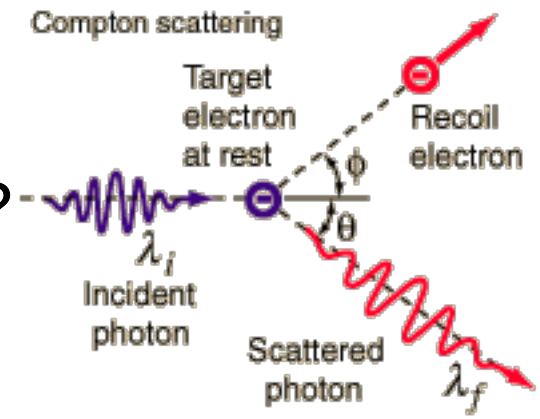
- For which angle θ does the recoil electron have the highest energy?



- 0°
- 90°
- 180°
- some other angle

Concept Check

- For which angle θ does the recoil electron have the highest energy?



- 0°
- 90°
- 180°
- some other angle

$$\Delta\lambda = \lambda_c\,[1 - \cos\theta]$$

Biggest $\Delta\lambda$ for $\cos\theta = -1$
or $\theta = 180$

$\Rightarrow$ Biggest $\Delta\nu$
$\Rightarrow$ Biggest $\Delta(h\nu)$
$\Rightarrow$ Biggest $E_e - m_e c^2$

$$\lambda' = \lambda + \lambda_c\,[1 - \cos\theta]$$

$$\nu' = \frac{c}{\lambda + \lambda_c[1-\cos\theta]}$$

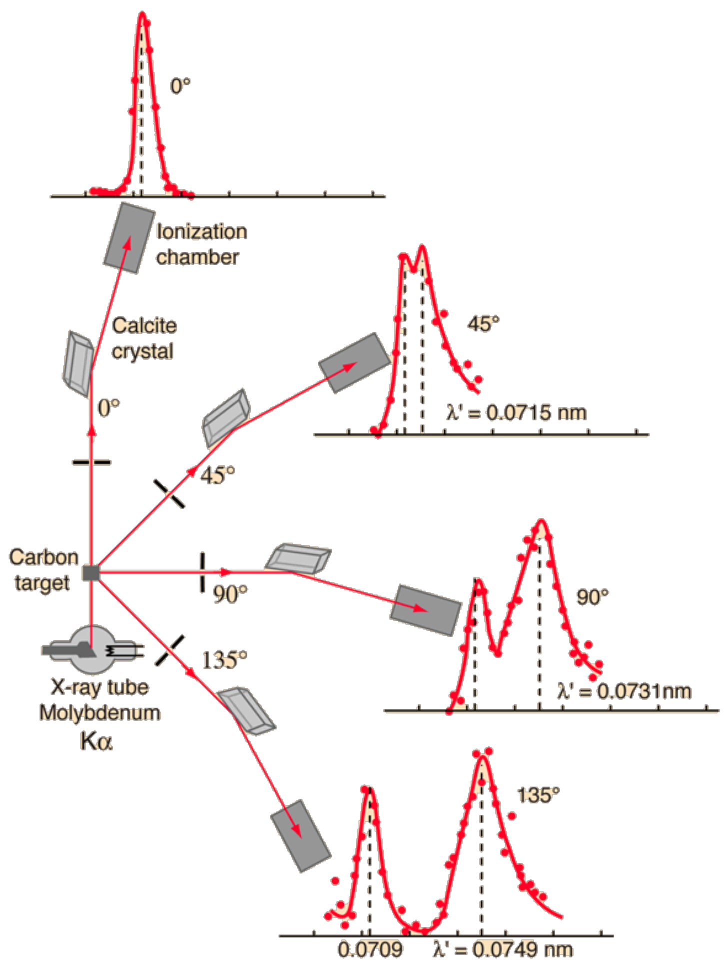
$$\nu' - \nu = \frac{c}{\lambda + \lambda_c[1-\cos\theta]} - c/\lambda$$

$$E_e = m_e c^2 + h(\nu - \nu')$$

$$= m_e c^2 + \frac{hc}{\lambda} - \frac{hc}{\lambda + \lambda_c[1-\cos\theta]}$$

- Express in terms of photon energy $h\nu$ and electron kinetic energy for homework 3.36.

Compton Scattering

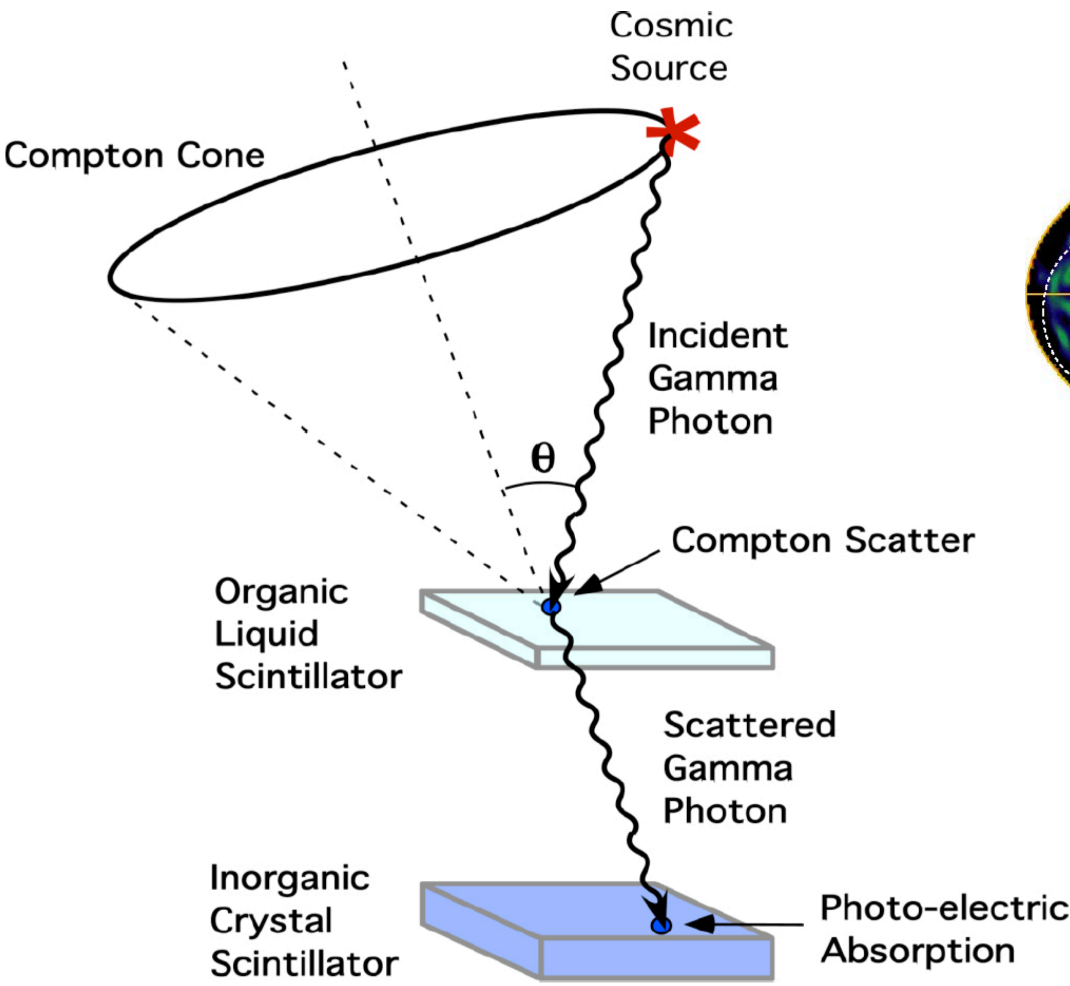


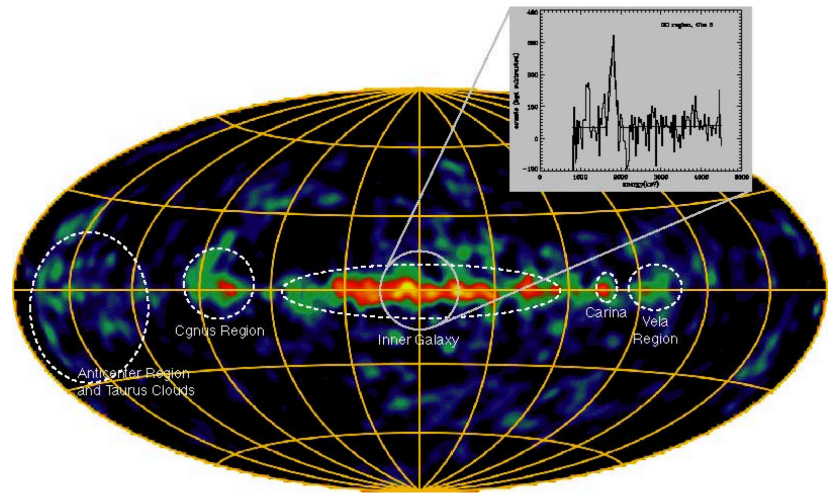
$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

Note that energy is always gained by the electron – which means energy is always lost by the photon

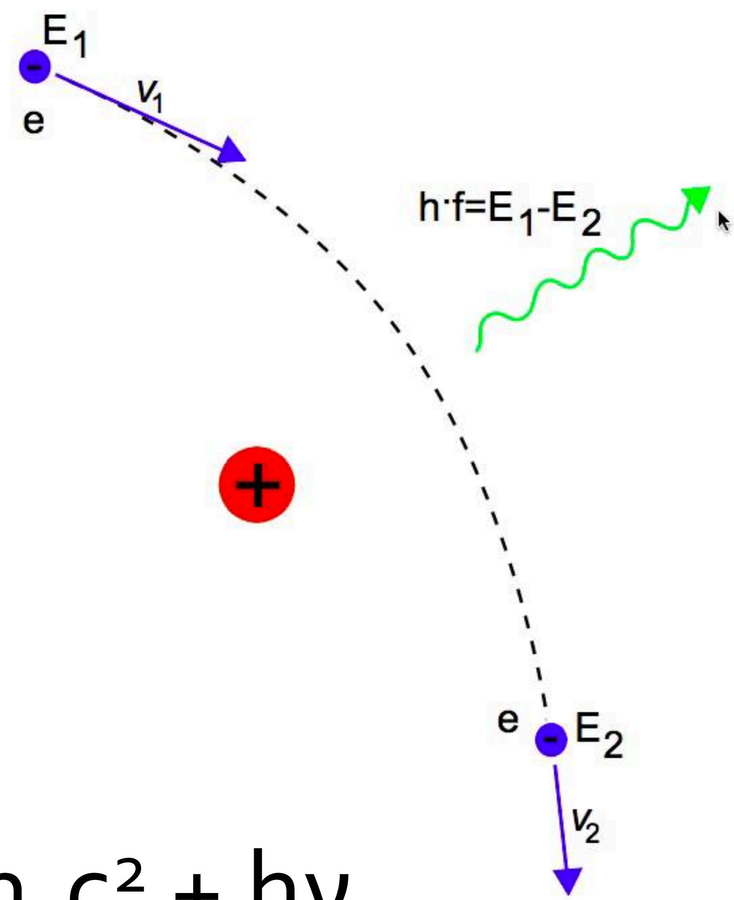
This means the scattered photon always has lower frequency (longer wavelength)

Compton Telescopes





Bremmstrahlung

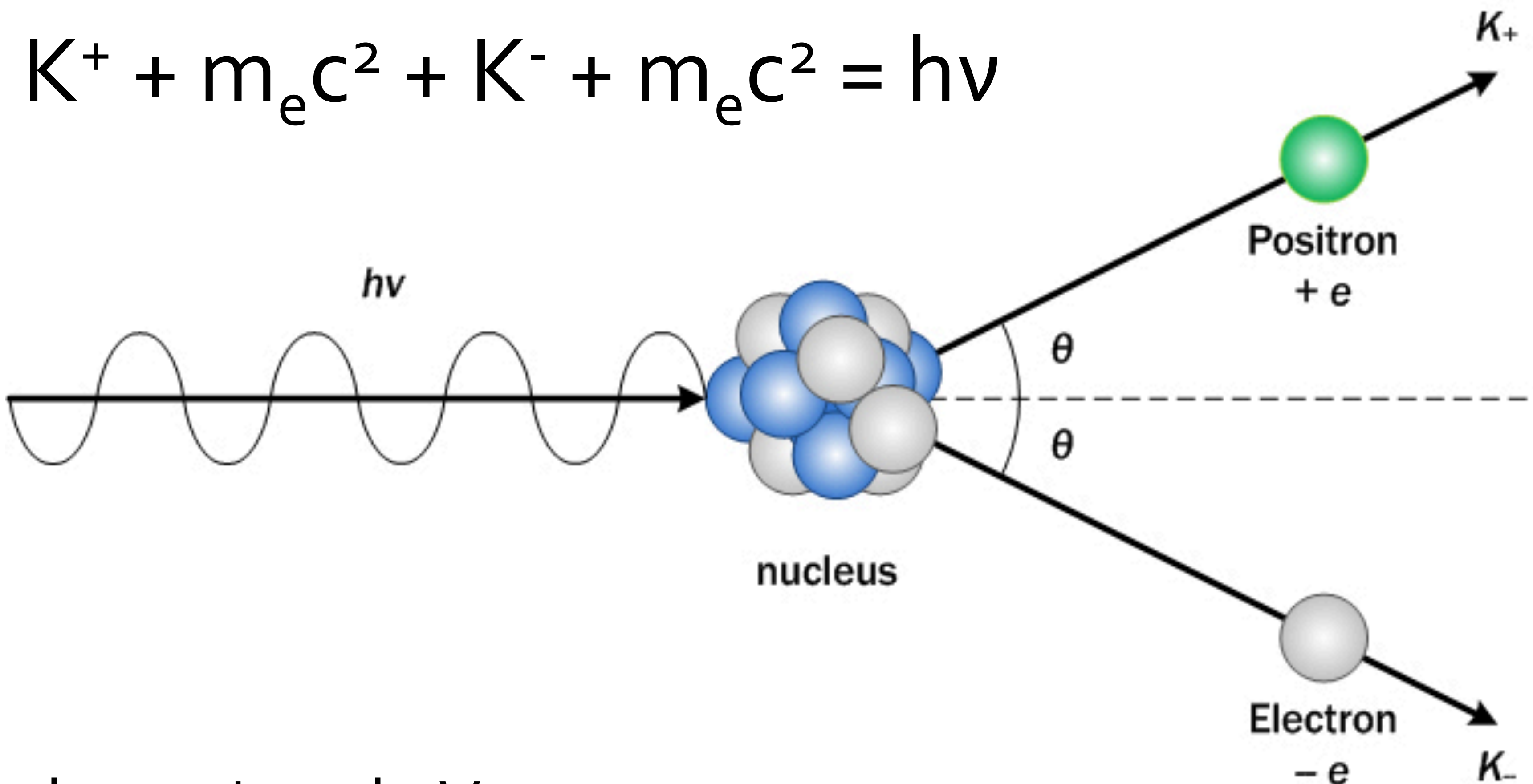


$E_1 = E_2 + h\nu$

$K_1 + m_e c^2 = K_2 + m_e c^2 + h\nu$

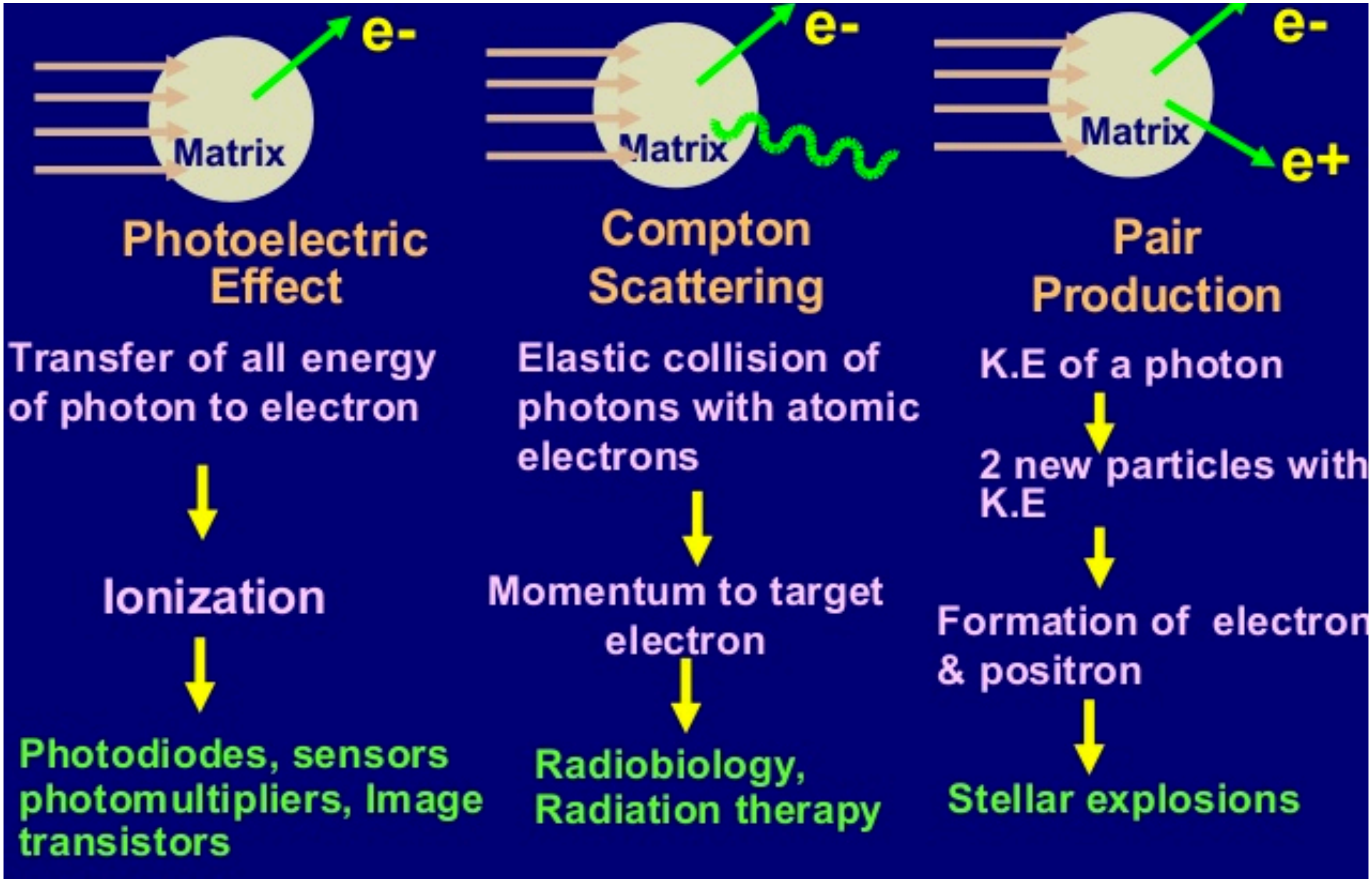
Pair Production

$$K^{+} + m_e c^2 + K^{-} + m_e c^2 = h\nu$$

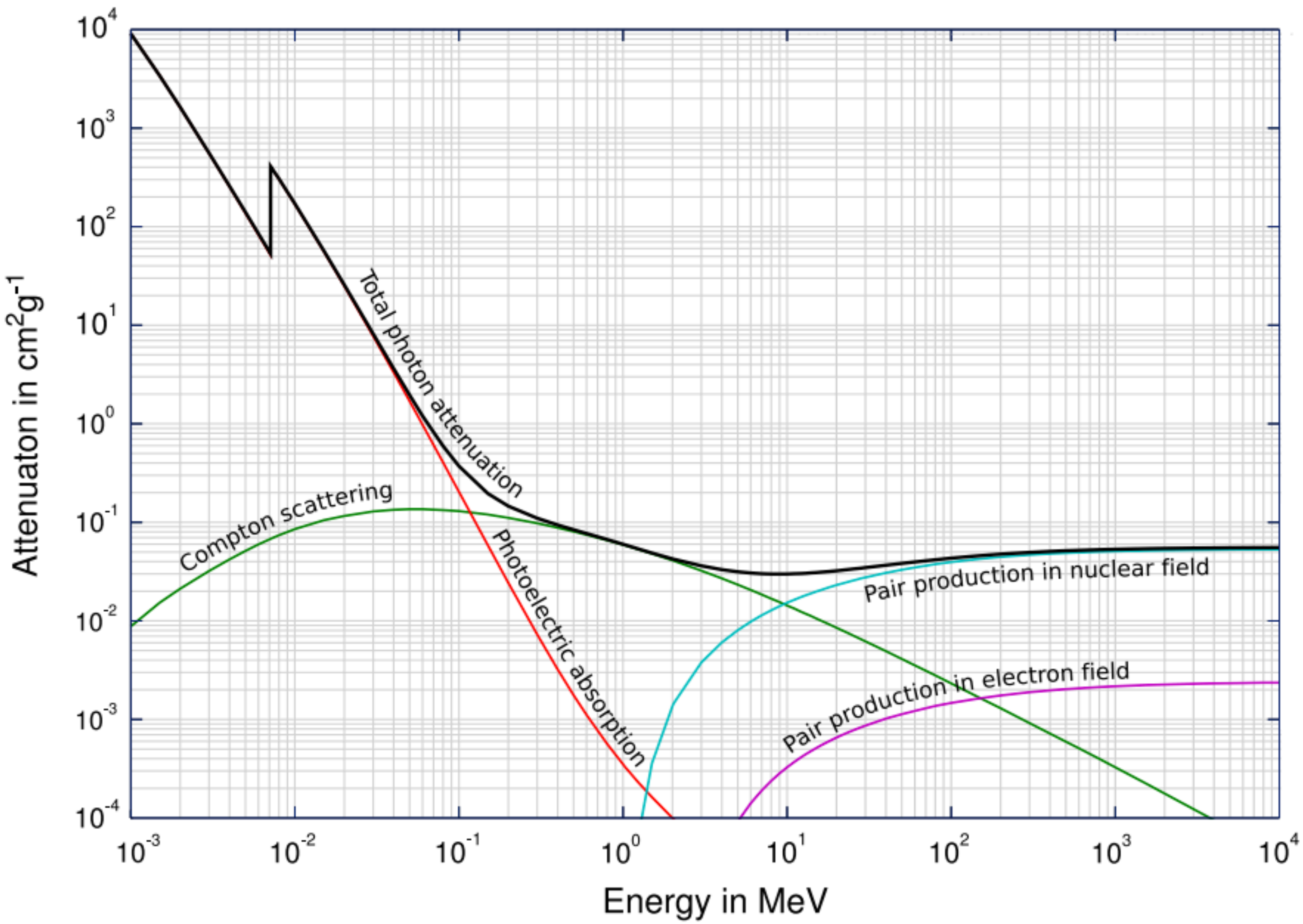


$h\nu > 2*511$ keV

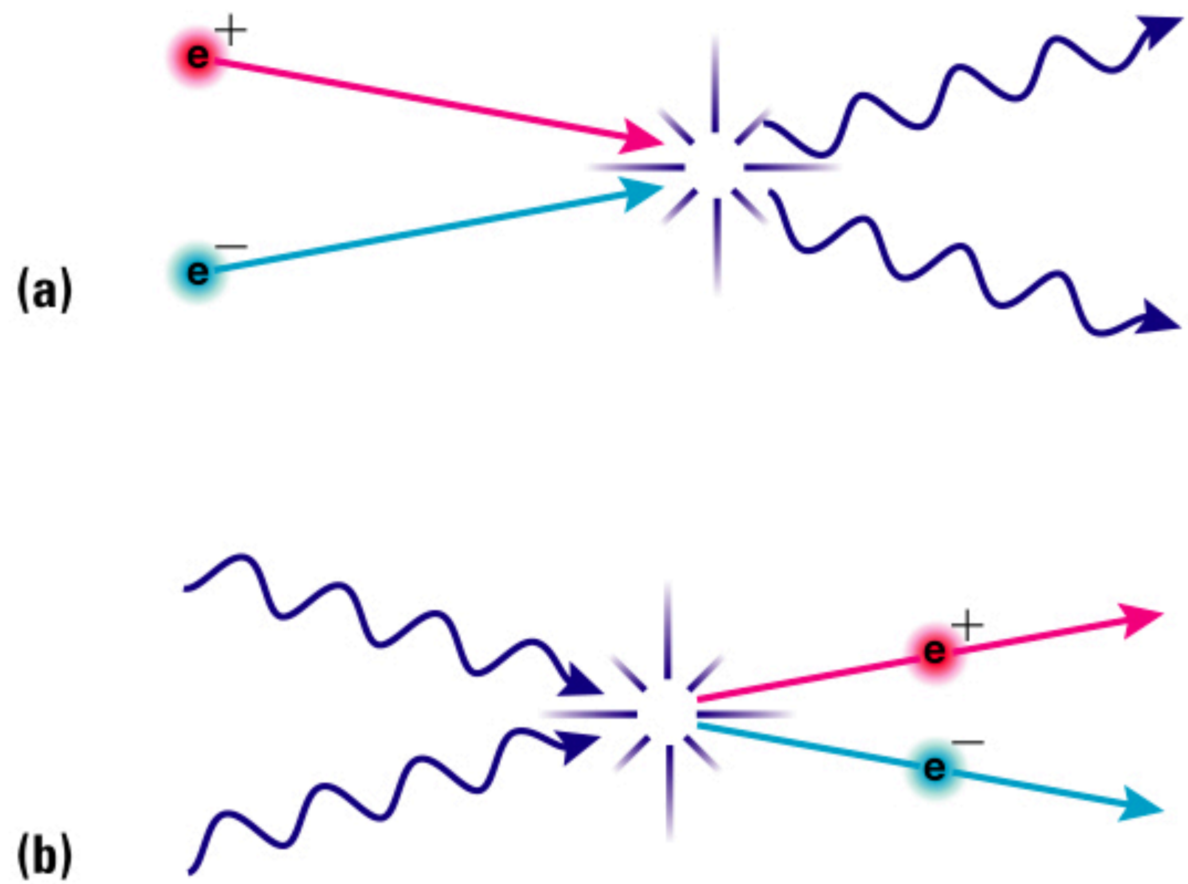
High-Energy Photon Interactions with Matter



High-Energy Photon Interactions with Matter



Inverse Interactions: Pair Production and Pair Annihilation



Concept Check

- In pair annihilation, an electron and a positron collide and annihilate to produce two photons. What are the photon energies?

A. Each has 511 keV of energy
B. Each has >511 keV of energy
C. Each has <511 keV of energy
D. Each could have any energy

Concept Check

- In pair annihilation, an electron and a positron collide and annihilate to produce two photons. What are the photon energies?

A. Each has 511 keV of energy
B. Each has >511 keV of energy
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De Broglie

Light is sometimes like a particle

What if particles are sometimes like waves?

Diffraction

Maxima for $\delta = d \sin\theta = n\lambda$