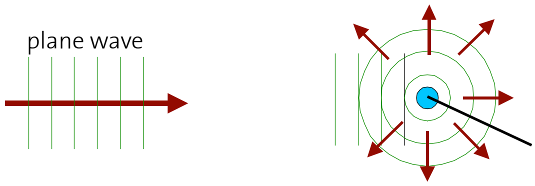
Compton Effect

Compton scattering

Electromagnetic radiation (e.g. light) propagetes as a wave.
If a propagating plane wave hits a target the characteristics of the wave change and the energy of the wave will be distributed into various directions.



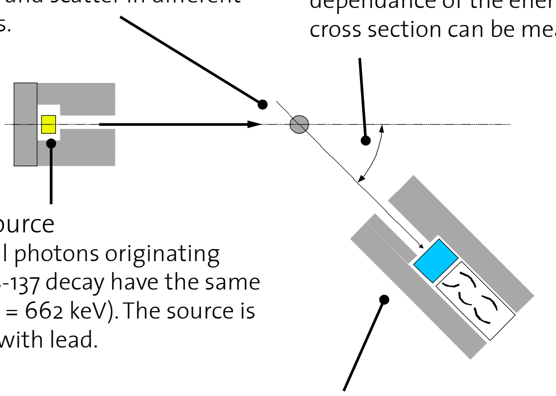
The wavelength of the scattered wave in the picture above is the same like the incoming wave.
However, in 1922 A.H. Compton discovered that the wavelength of x-rays scattered on electrons depends on the scattering angle.

As a result, we can assume for an electromagnetic wave not only its wave interpretation, but also a particle nature. Furthermore, in this experiment the angular dependence of the energy of the scattered photon, as well as, the differential cross section were measured and compared to the theoretical predictions.

Measurement setup

Target
Photons originating from the Cs-137 source hit the target electrons and scatter in different directions.

Scattering angle
The detector can be rotated around the target. Therefore, the angular dependance of the energy and cross section can be measured.



Cs-137 source
Almost all photons originating from a Cs-137 decay have the same energy (E = 662 keV). The source is shielded with lead.

Detector
The photons are detected by a NaI scintillator. The emitted scintillation light is measured by a photomultiplier.

Elastic collision

A photon carries the energy

$$E = h\nu = \frac{h}{\lambda}$$

and the momentum

$$|p| = \frac{h\nu}{c}\,.$$

In the scattering process the total energy and momenta are conserved. Thus, the change of the wavelength is

$$\lambda' - \lambda = \underbrace{\frac{h}{m_0 c}}_{\lambda_c}(1 - \cos\theta)$$

which is independent of the wavelength of the scattering photon. The constant λ_c is called Compton wavelength. For

$$\lambda \gg \lambda_c \quad \text{(classical limit)}$$

the wavelength of the photon does not change much, but for

$$\lambda \ll \lambda_c \quad \text{(relativistic)}$$

it does.

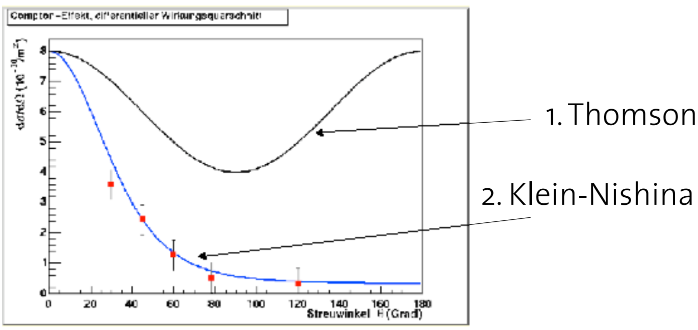
Cross section

To confirm the particle interpretation, the angular dependence of the energy and furthermore the probability that an incoming photon gets scattered in a certain direction has to be properly described. The cross section is defined as

$$\frac{d\sigma}{d\Omega} = \frac{\text{number of scattered photons}}{\text{number of incoming photons per unit area}}$$

and has the dimension of an area. It describes the strength of the interaction.
The cross section as a function of the scattering angle is the differential cross section.
1. A calculation by J.J. Thomson using the wave interpretation and not taking any quantum effects into account is disproved by the experiment.
2. The calculation using relativistic quantum mechanics was done by O. Klein & Y. Nishina a few years after discovery. It is in good agreement with the measurement.

The compton effect supports the particle interpretation of electromagnetic radiation.



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