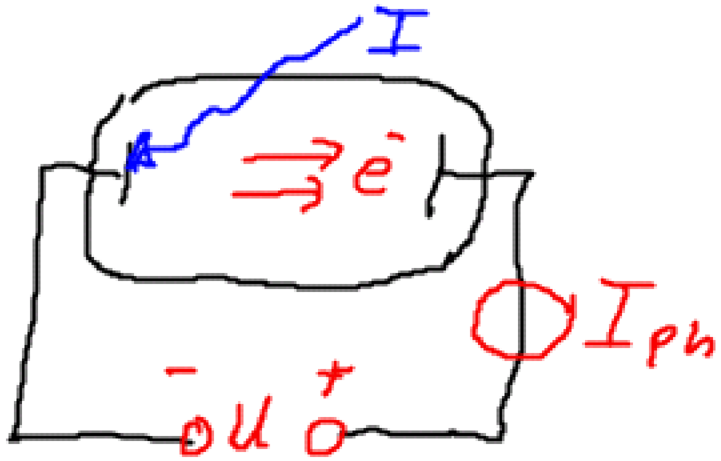
1.4 Photoeffekt

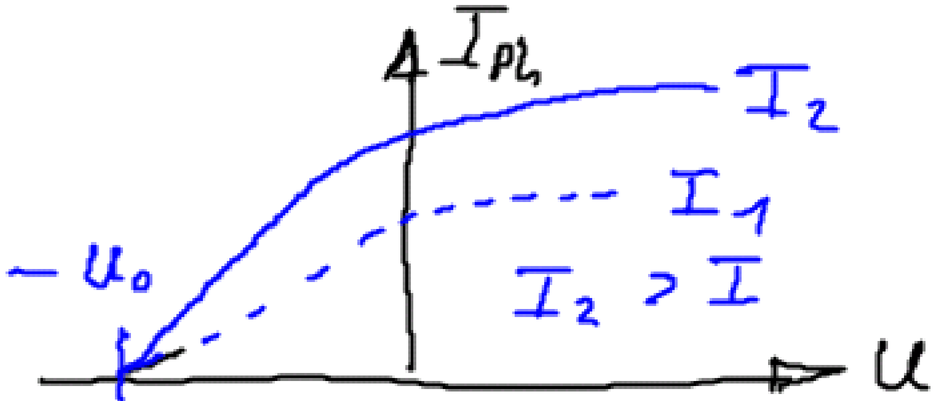
Planck $E = h\nu$, Korpuskel?



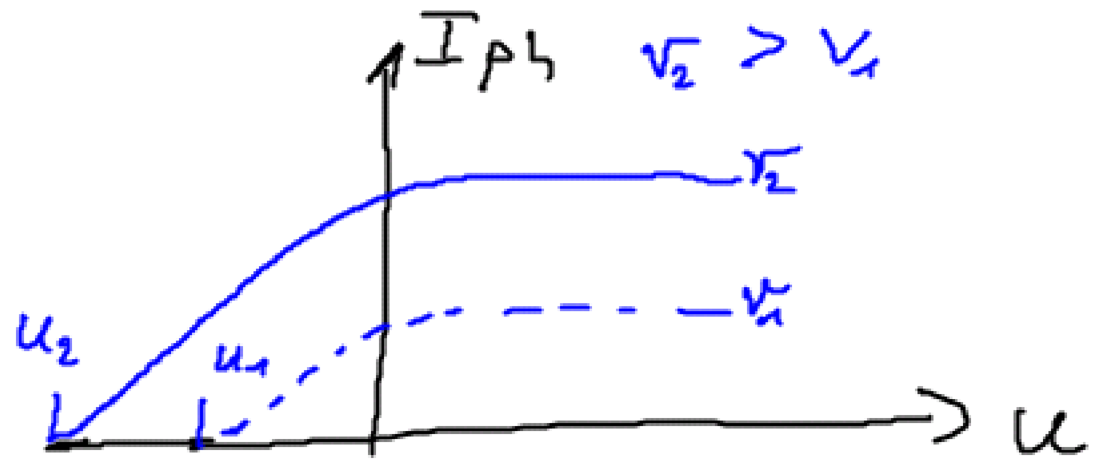
Messungen Lenard 1902

Erklärung Einstein 1905

Nobelpreis 1921



Variation I



Widerspruch klass.

1) $I \sim E^2$ Feldstärke Kraft eE

U_0 sollte mit I zunehmen

2) U_0 unabhängig von ν

3) keine Verzögerung beobachtet

Erklärung Einstein:

a) einzelnes Photon $E = h\nu$

b) jedes Photon Teilchen in Bündel Geschw c

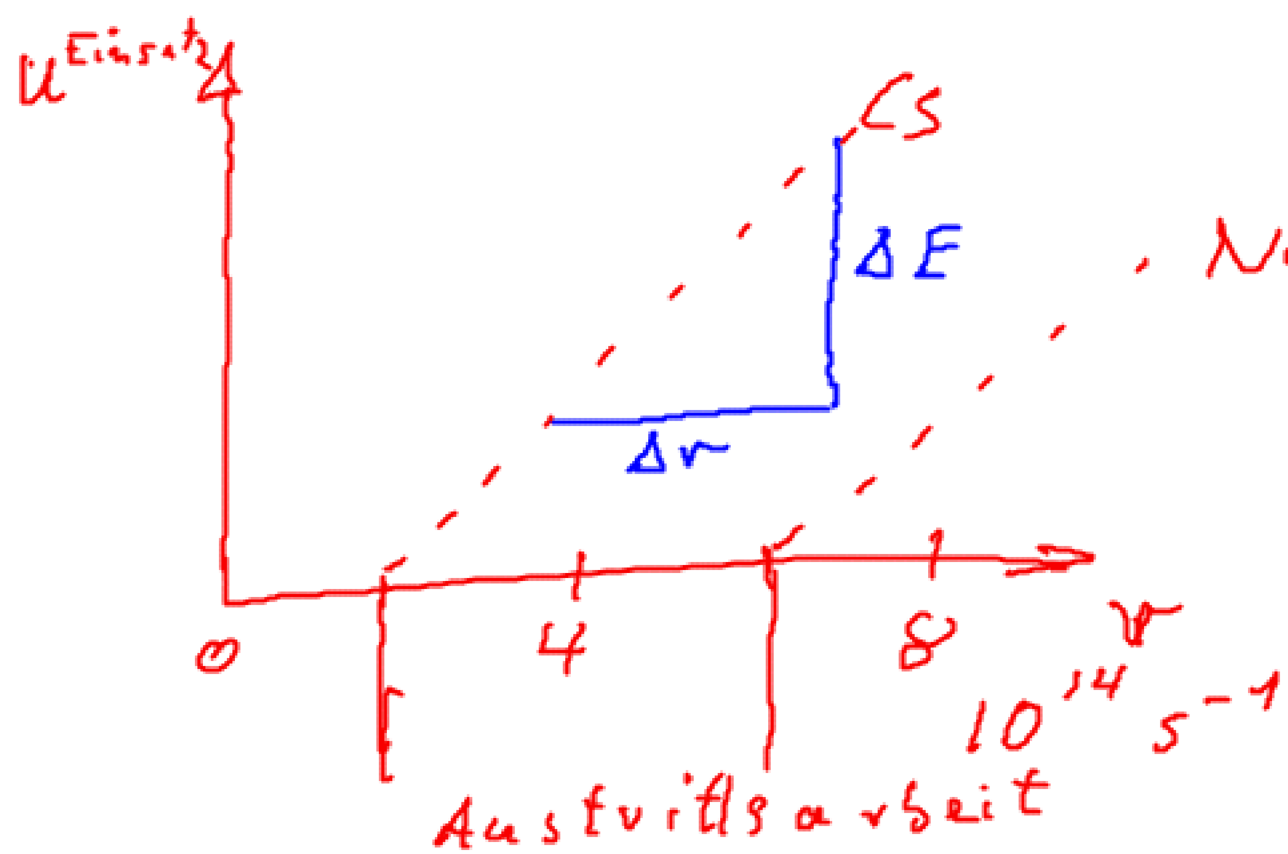
c) jedes Photon kann nur ganzes absorbiert

Löst Widersprüche

1) mehr I

2) Austrittsarbeit W_a ; $h\nu < W_a$ kein Photoef.

3) keine Verzögerung: Photon trifft Elektron

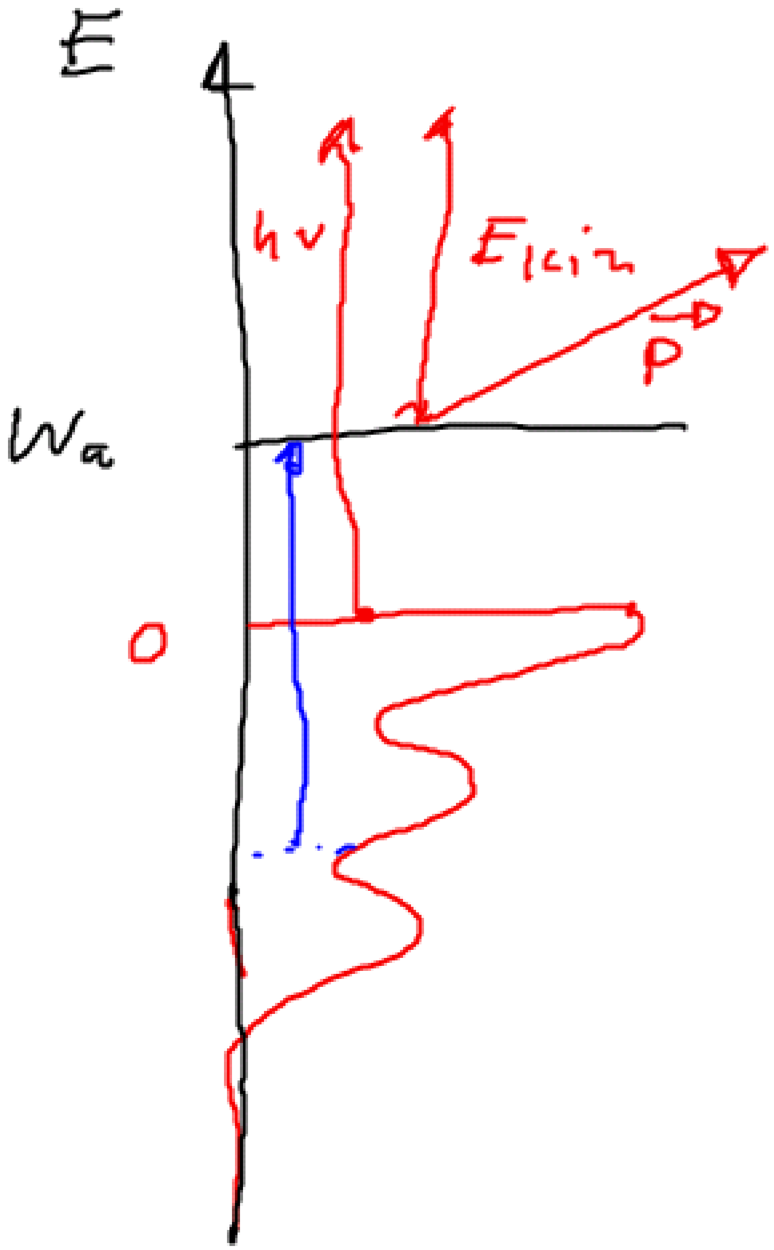


4) Steigung

$$h\nu = E_{kin} + W_a$$

$$\frac{\Delta E_{kin}}{\Delta \nu} = h$$

Photoelektronenspektroskopie



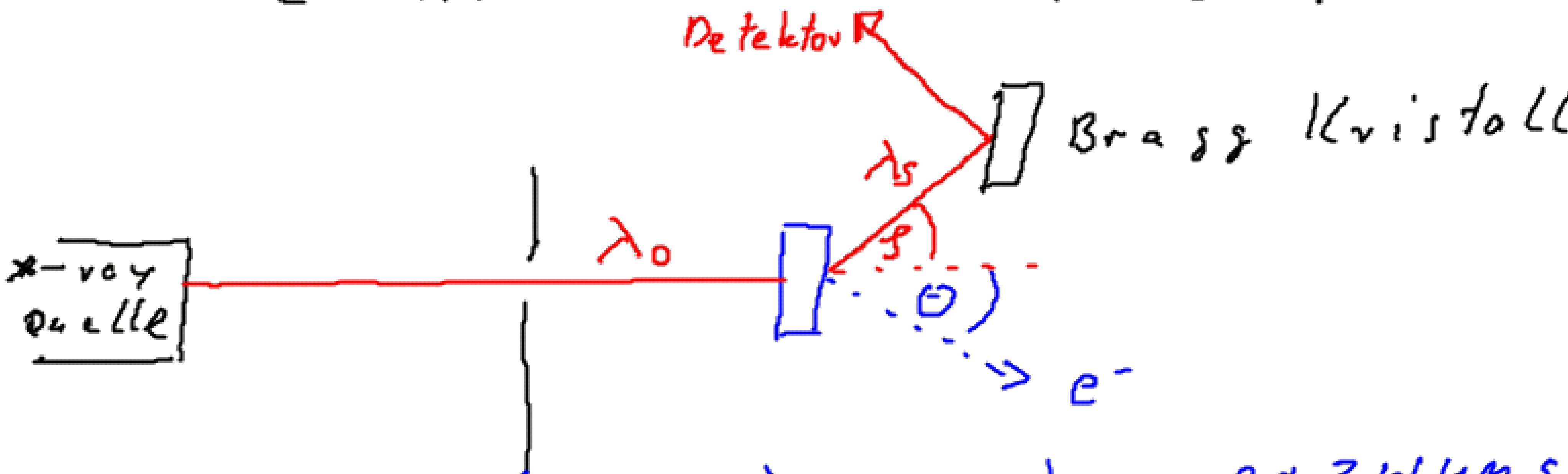
ESCA

Siegbahn 1975

Richtungsverteilung

1.5 Comptoneffekt 1923

$E = h\nu$ Teilchen – Impuls



klassisch: $\lambda_0 = \lambda_s$ erzwungene Schwingung

Messung: $\lambda_s - \lambda_0 = \Delta\lambda = \lambda_C(1-\cos\varphi)$

$$\lambda_C = 2.4262 \times 10^{-12}\,\mathrm{m} \quad (\text{unabh. } \lambda_0)$$

relativ. Energie E gegen Ruhemasse und v

$$E = m_0 c^2 / \sqrt{1 - v^2/c^2} \qquad v \to c \;\to\; \frac{1}{\sqrt{\;}} \to \infty$$

$m_0 = 0$! Ruhemasse !!

rel. E gegen m_0 und Impuls p

$$E^2 = c^2 p^2 + \underbrace{(m_0 c^2)^2}_{\to\, 0}$$

$$E = c \cdot p \;\to\; p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

Photon : Teilche $E = h\nu$ $\quad p = \frac{h}{\lambda} = \hbar k$

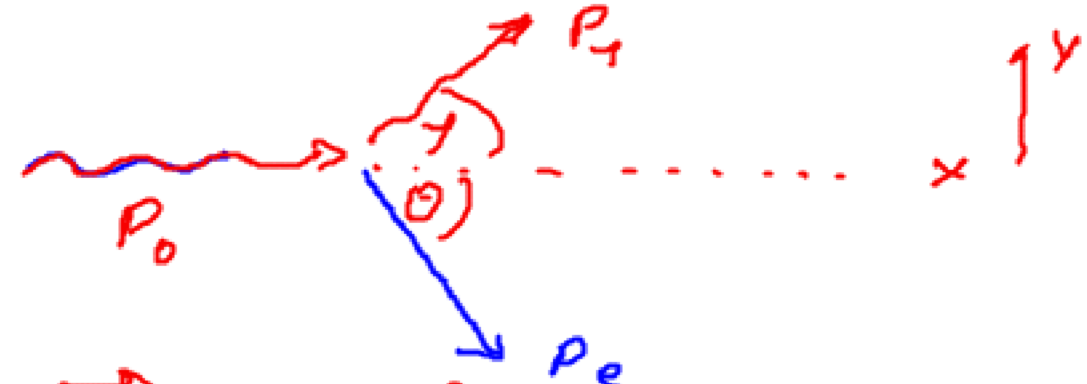
Energie

$$E_0 + m_0 c^2 = E_1 + E_{kin} + m_0 c^2$$

$$E_0 - E_1 = E_{kin}$$

$$c(p_0 - p_1) = E_{kin} \quad (2)$$

Impuls $\quad \hbar = \frac{h}{2\pi}$



$$\vec{p}_0 = \vec{p}_1 + \vec{p}_e$$

$$x: \quad p_0 = p_1 \cos\varphi + p_e \cos\theta$$

$$p_0 - p_1 \cos\varphi = p_e \cos\theta$$

$$y: \quad p_1 \sin\varphi = p_e \sin\theta$$

quad. + add

$$p_0^2 + p_1^2 - 2 p_0 p_1 \cos\varphi = p_e^2 (\sin^2\theta + \cos^2\theta) = p_e^2 \quad (1)$$

E-Satz e^-

$$(E_{kin} + m_0 c^2)^2 = c^2 p_e^2 + (m_0 c^2)^2$$

$$E_{kin}^2 + 2 E_{kin} m_0 c^2 = c^2 p_e^2$$

$$p_e^2 = E_{kin}^2 / c^2 + 2 E_{kin} m_0$$

(1) (2)

$$p_0^2 + p_1^2 - 2 p_0 p_1 \cos\varphi = (p_0 - p_1)^2 + 2 m_0 c (p_0 - p_1) \quad : 2$$

$$p_0 p_1 (1 - \cos\varphi) = m_0 c (p_0 - p_1) \quad / p_0 p_1$$

$$\frac{1}{p_1} - \frac{1}{p_0} = \frac{1}{m_0 c}(1 - \cos\varphi)$$

$$\Delta\lambda = \lambda_s - \lambda_0 = \lambda_c(1-\cos\varphi)$$

$$\lambda_c = \frac{h}{m_0 c} = 0.0024\,nm$$