A free electron absorbs a photon

\[ A \xrightarrow{\gamma} e^- \]

Assume \( e^- \) at rest initially.

Initial state \( M_i^2 = (E_i + E_\gamma)^2 - (p_i + p_\gamma)^2 \)

\[ = E_i^2 + E_\gamma^2 + 2E_iE_\gamma - p_i^2 - p_\gamma^2 - 2p_ip_\gamma \]

\[ = m_e^2 + m_\gamma^2 + 2E_iE_\gamma - 2E_iE_\gamma \]

\[ = m_e^2 + 2E_iE_\gamma \]

Final state \( M_f^2 = E_f^2 - p_f^2 = m_c^2 \)

Lorentz invariance \( M_i^2 = M_f^2 \)

\[ m_c^2 + 2E_iE_\gamma = m_c^2 \]

\[ > 0 \]

\( m_i > m_f \), \( E, p \) not conserved.

But if we allow \( m_c \neq m_e \), it is off-shell electron

\( m_c^2 > m_e^2 \) \( \Rightarrow \) \( e^- \) is a virtual electron

\[ \text{Not a physical process} \]

\[ \text{Need a second vertex in the Feynman diagram} \]

\[ \text{\( e^- \) in atoms are bound & can absorb single \( \gamma \) as they have internal degrees of freedom} \]