

Elastic Scattering

Scattering Process	Cross Section
pointlike charge [no spin] on pointlike charge [no recoil, no spin]	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Rutherford}} = \frac{e^4 z^2 Z^2}{4E^2 \sin^4 \frac{\theta}{2}}$
pointlike charge [spin] on pointlike charge [no recoil, no spin]	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott, no recoil}} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{R}} \cos^2 \frac{\theta}{2}$
pointlike charge [spin] on extended charge [no recoil, no spin]	$\left(\frac{d\sigma}{d\Omega}\right)_{\rho} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott, no recoil}} F(\underline{q}^2) ^2$
pointlike charge [spin] on pointlike charge [recoil , no spin]	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott, no recoil}} \cdot \frac{E'}{E}$
pointlike charge [spin] on pointlike charge [recoil , spin]	$\left(\frac{d\sigma}{d\Omega}\right) = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \cdot \left(1 + 2\tau \tan^2 \frac{\theta}{2}\right)$
pointlike charge [spin] on extended charge [recoil , spin]	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Rosenbluth}} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \left[\frac{G_E^2(\underline{q}^2) + \tau G_M^2(\underline{q}^2)}{1 + \tau} + 2\tau G_M^2(\underline{q}^2) \tan^2 \frac{\theta}{2} \right]$

Full QFT calculation of the Rosenbluth formula

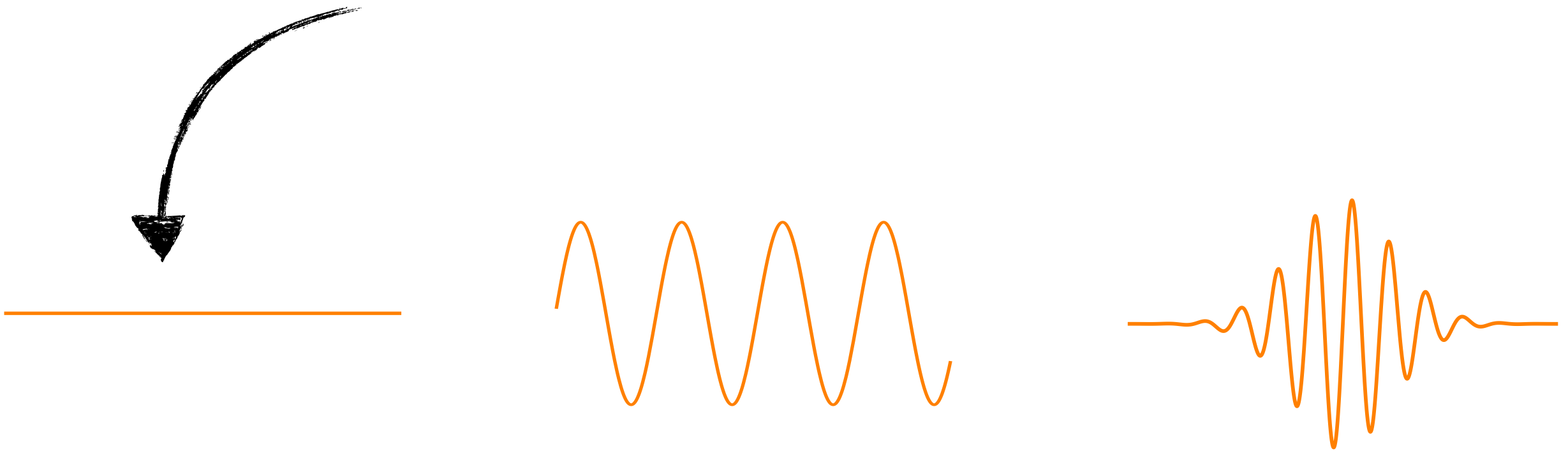
$$i\mathcal{M} = \text{Diagram} = \bar{u}(k')(-ie\gamma_\mu)u(k)\frac{-i}{q^2}\bar{u}(p')(-ie\Gamma^\mu)u(p).$$

The diagram illustrates the full QFT calculation of the Rosenbluth formula. It shows a scattering process involving a proton (p) and an electron (e^-). The proton is represented by a red shaded circle, and the electron is represented by a green shaded circle. A wavy line representing a photon with momentum q connects the two vertices. The incoming proton momentum is p , and the outgoing proton momentum is p' . The incoming electron momentum is k , and the outgoing electron momentum is k' . The diagram is labeled with $i\mathcal{M}$ on the left and the corresponding mathematical expression on the right. The expression is $\bar{u}(k')(-ie\gamma_\mu)u(k)\frac{-i}{q^2}\bar{u}(p')(-ie\Gamma^\mu)u(p)$. The terms in the expression are color-coded to match the diagram: a red box for $-ie\gamma_\mu$, a blue box for $\frac{-i}{q^2}$, and a green box for $-ie\Gamma^\mu$.

Quantum **field** theory

What is a quantum field?

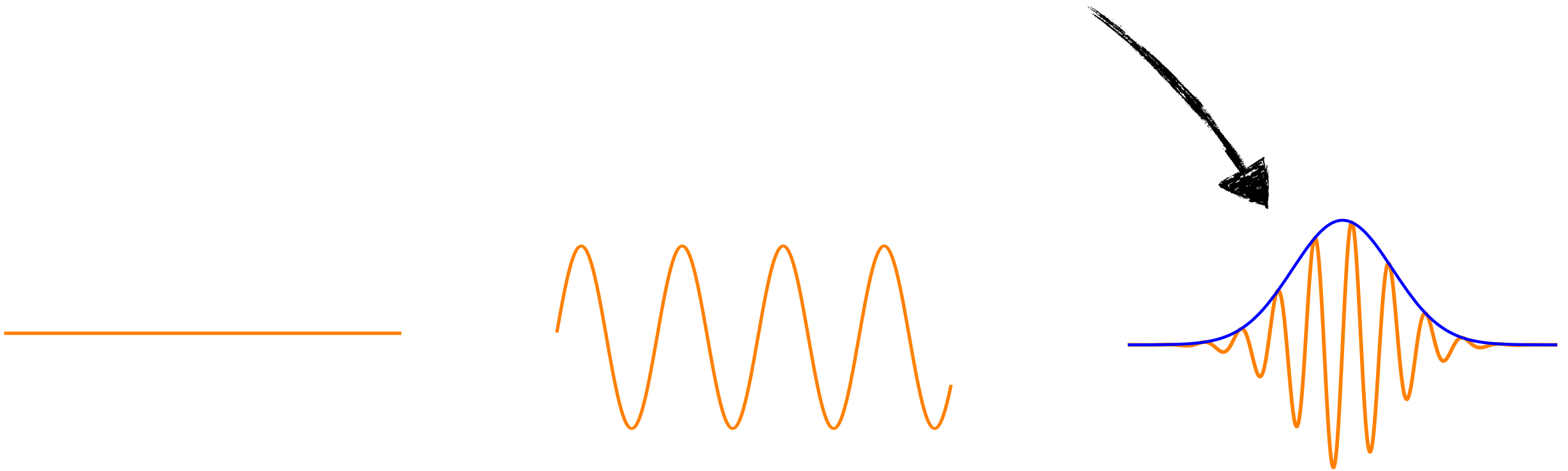
1-dimensional Field



Quantum **field** theory

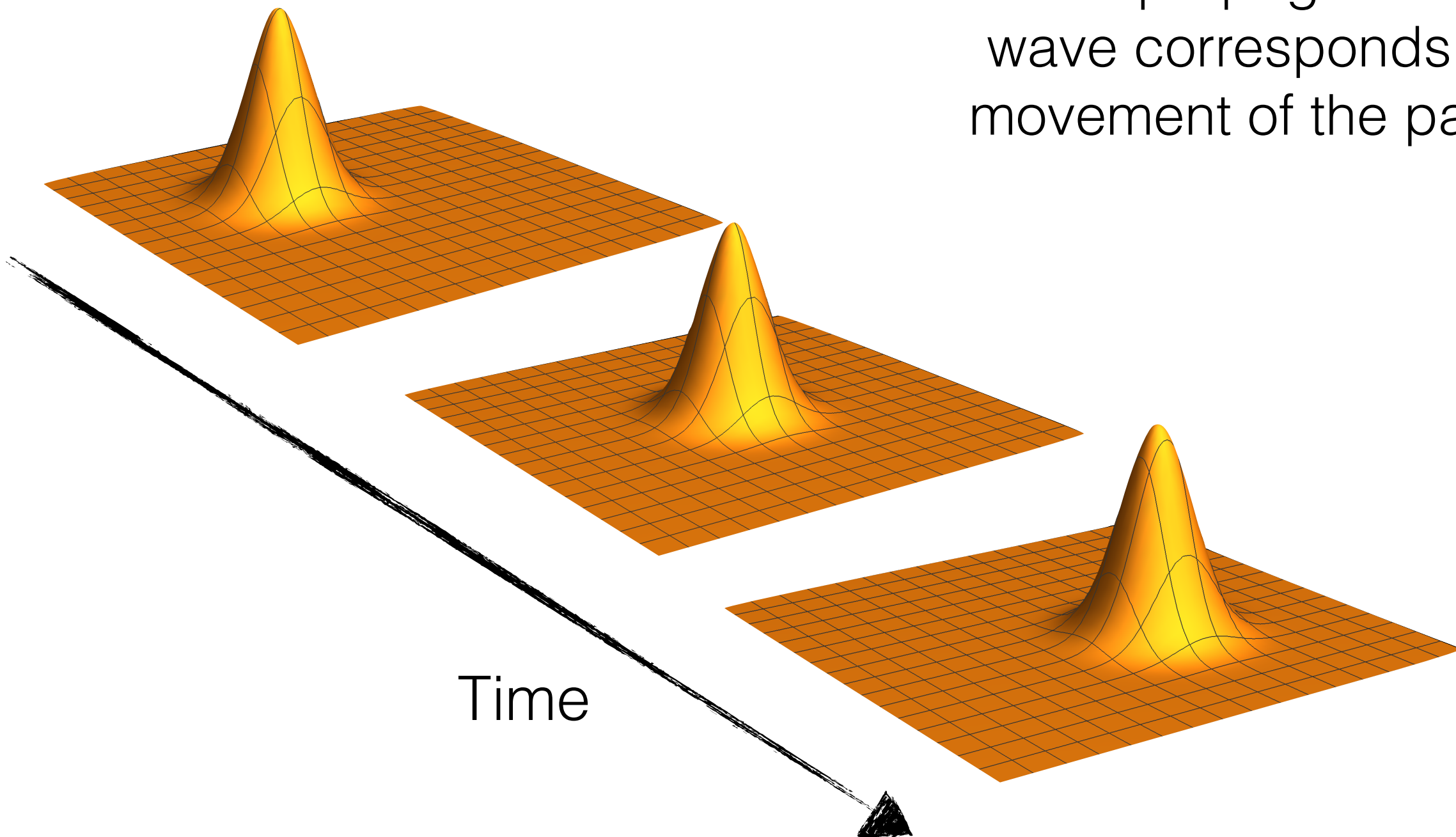
What is a quantum field?

smallest localised wave
can be interpreted as a
particle = quantum

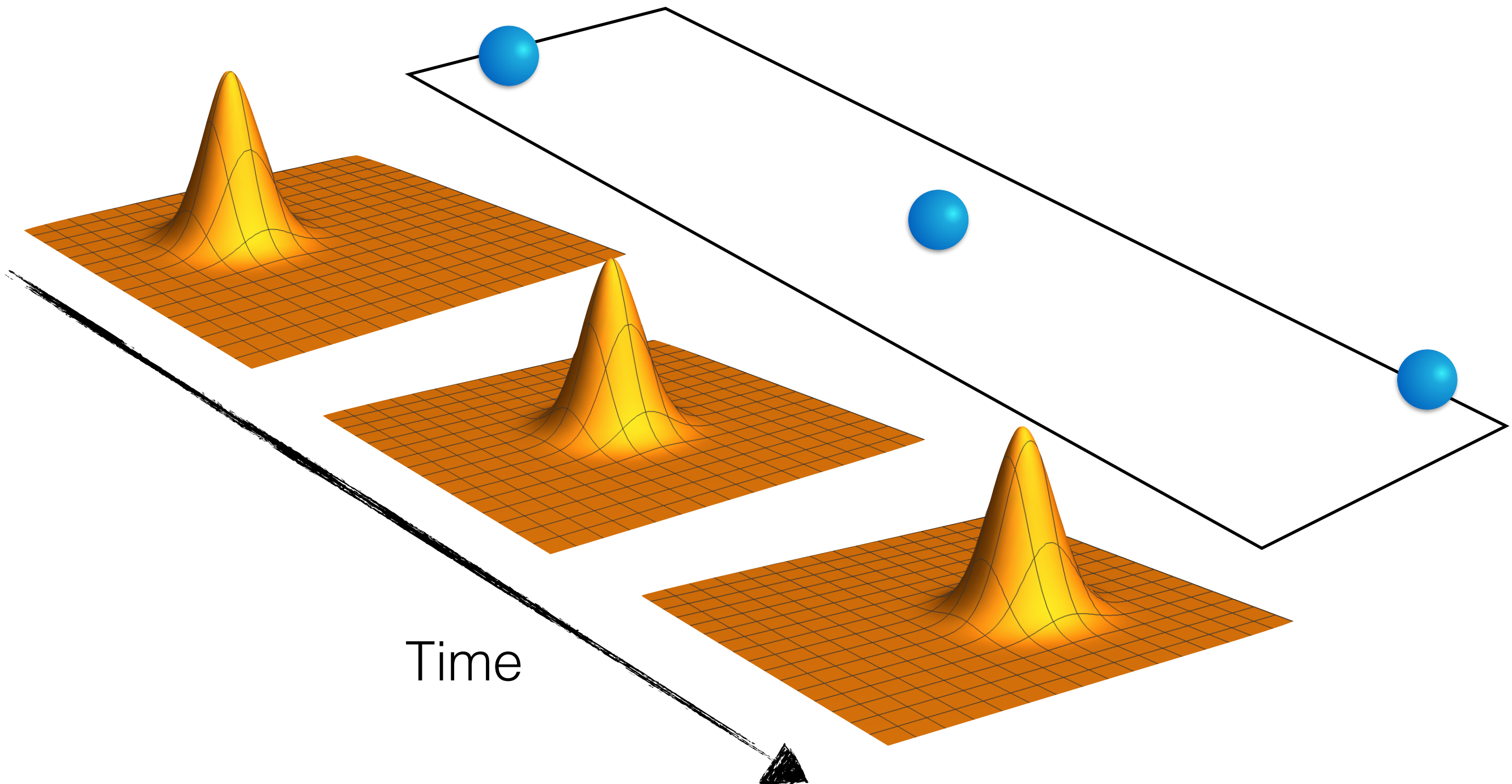


Quantum **field** theory

The propagation of this wave corresponds to the movement of the particle.

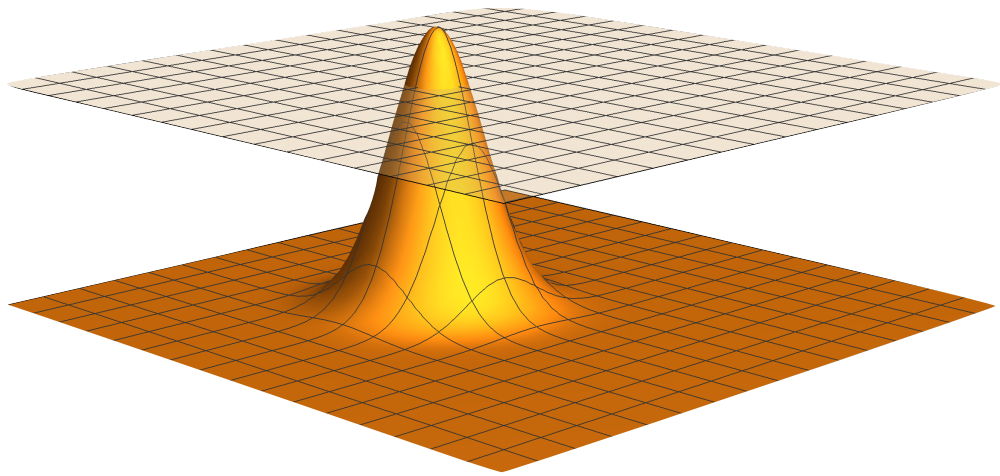


Quantum **field** theory



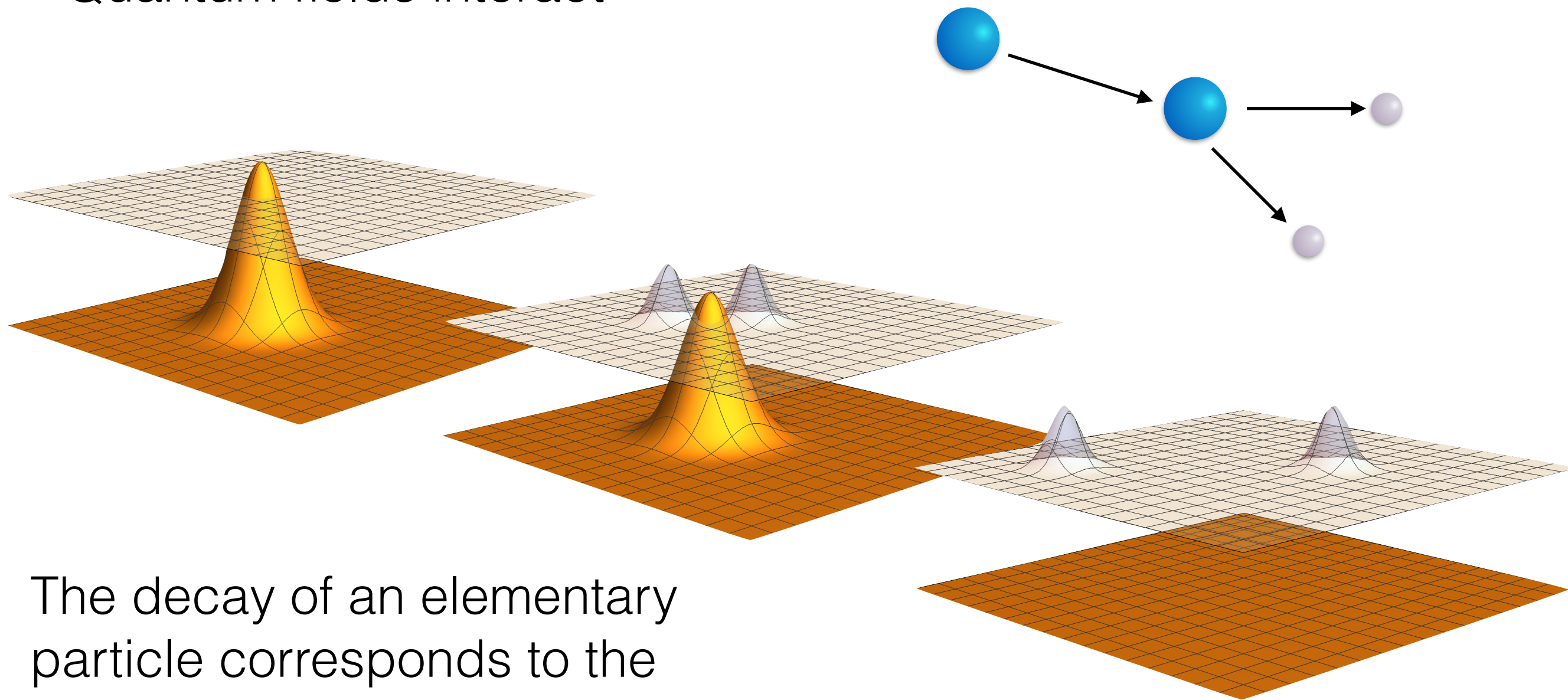
Quantum **field** theory

Quantum fields interact



Quantum **field** theory

Quantum fields interact



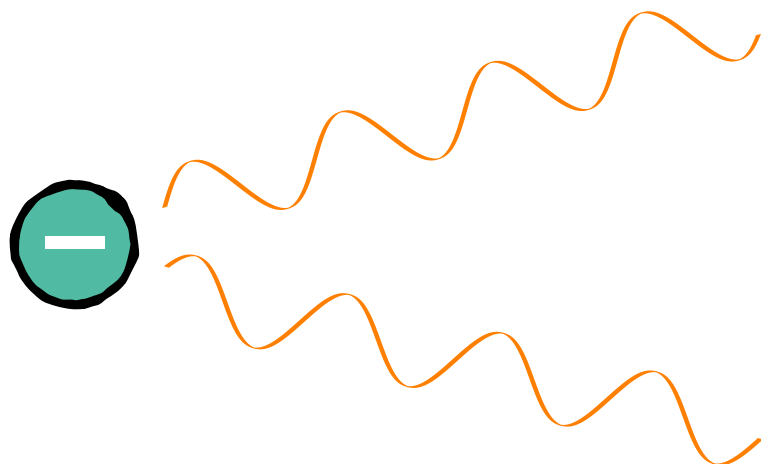
The decay of an elementary particle corresponds to the wave of one quantum field exciting waves in a different quantum field.

Quantum **field** theory

Certain quantities (quantum numbers) are conserved in this process, e.g. electric charge is conserved.

The lightest particle with a given set of quantum numbers is stable.

The electron is the lightest field with electric charge -1. It can interact with other quantum fields, but it can never decay.

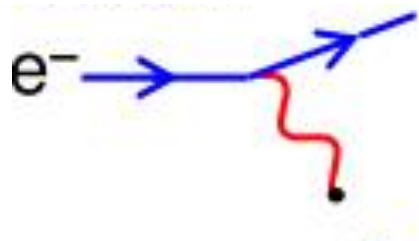


Inelastic scattering

The photon wavelength determines the resolution of the scattering process

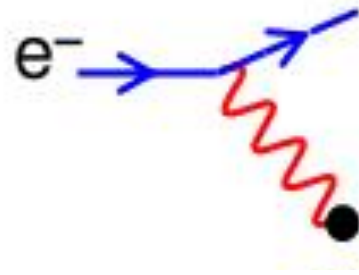
$$\lambda \gg R_{\text{Proton}}$$

Rutherford



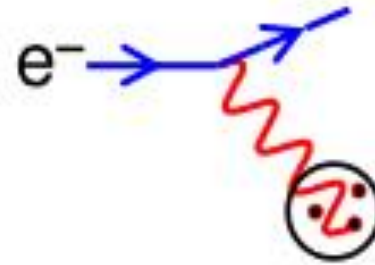
$$\lambda \sim R_{\text{Proton}}$$

Rosenbluth



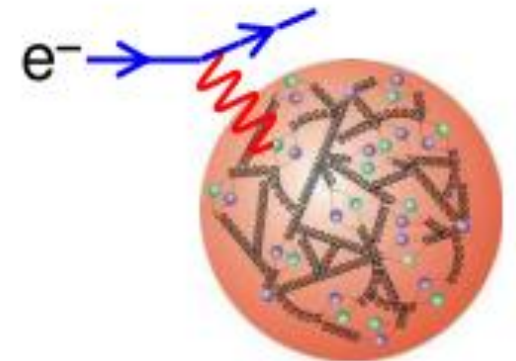
$$\lambda < R_{\text{Proton}}$$

Inelastic

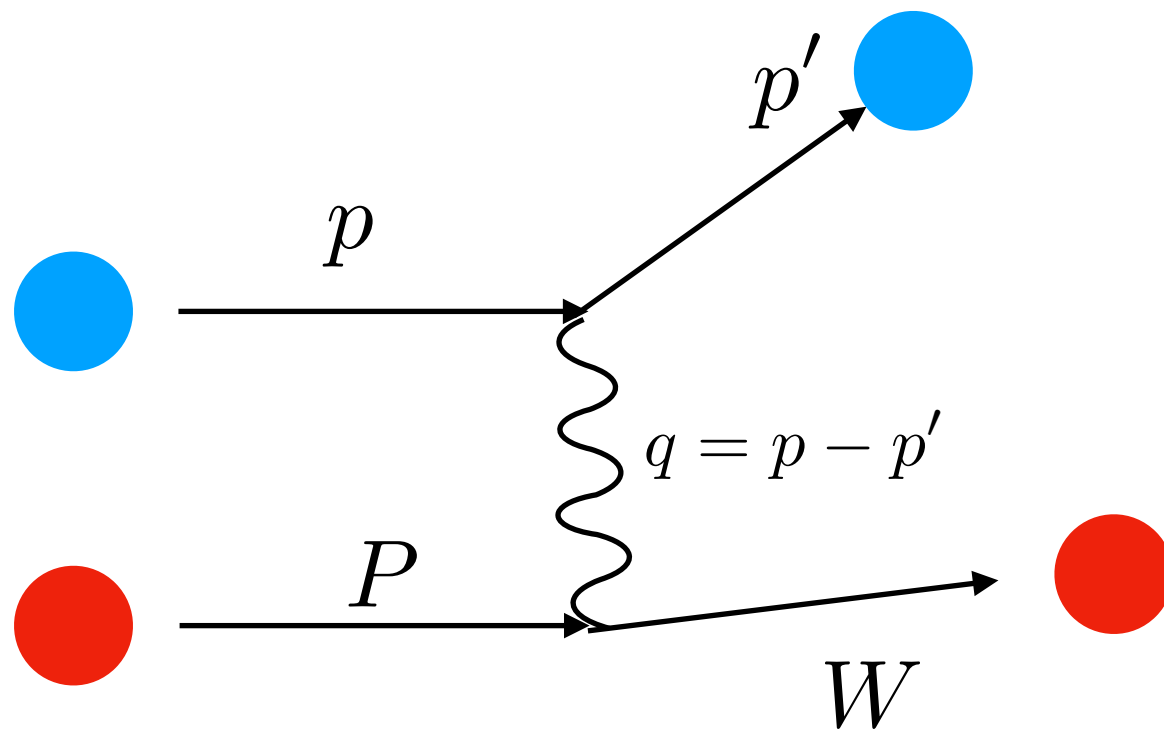


$$\lambda \ll R_{\text{Proton}}$$

Deep inelastic



Inelastic scattering



Inelastic scattering:

Kinetic energy not conserved.
The number and type of initial and final state particles is the same.

Elastic scattering:

Kinetic energy conserved.
The number and type of initial and final state particles is the same.

