8.701

Introduction to Nuclear and Particle Physics

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1. Fermions, bosons, and fields

1.1 Quantum field and matter

Quantum fields and matter

Particles come to exist as quantised fields

Extension of quantum mechanics where particles are quantised

We will create and annihilate particles in reactions and decays

Identical particles

Swapping any two **fermions** adds a negative sign to the wavefunction

$$\psi(\boldsymbol{r}_2, \boldsymbol{r}_1) = -\psi(\boldsymbol{r}_1, \boldsymbol{r}_2)$$

This property leads to the Pauli exclusion principle, namely, two fermions can not be in the same state as this would mean

$$\psi(\boldsymbol{r}_2, \boldsymbol{r}_1) = \psi(\boldsymbol{r}_1, \boldsymbol{r}_2)$$

One can construct the wave function a total wavefunction of two fermions by

$$\Psi(\boldsymbol{r}_1, \boldsymbol{r}_2) \propto \psi(\boldsymbol{r}_1, \boldsymbol{r}_2) - \psi(\boldsymbol{r}_2, \boldsymbol{r}_1)$$

Identical particles

Antiparticles, such as a positron, are not identical to particles, such as the electron

Bosons exchange is symmetric, i.e.

$$\psi(\boldsymbol{r}_2, \boldsymbol{r}_1) = \psi(\boldsymbol{r}_1, \boldsymbol{r}_2)$$

and a two boson wave function can be constructed by

$$\Psi(\boldsymbol{r}_1, \boldsymbol{r}_2) \propto \psi(\boldsymbol{r}_1, \boldsymbol{r}_2) + \psi(\boldsymbol{r}_2, \boldsymbol{r}_1)$$

Forces and exchange particle

Modern picture of how a force acts under quantisation is by emission and absorption of force particles, specifically bosons, between particles of matter.