1 Intro to Particle Physics

Four Fundamental Forces

- Strong (gluon)
- Weak (W, Z)
- Electromagnetic (photon)
- Gravity (graviton?)

The 'Standard Model' describe the first three forces and unifies the Strong and Weak Forces known as the 'Electroweak' force. So, the Standard Model does not include gravity.

The Standard Model (SM)

- Basic building blocks: spin 1/2 particles (fermions)
- Interaction between then are mediated by force carriers: spin 1 particles (vector bosons)
- How particles get mass? → Higgs Boson (spin 0)

The Range of Forces:

- Strong: 10^{-15} m
- Weak: 10^{-18} 10^{-16} m
- EM: $1/r^2$
- Gravity: $1/r^2$

The ranges of forces are related by

$$R\ \frac{e^{-r/a}}{r^2}$$

where $a \approx 10^{-15}$ m for the Strong and Weak forces.

The Rise of Quantum Field Theory (QFT) Relativity + Quantum Mechanics → QFT

	Macroscopic	Micro
SLOW	CM	Quantum Mechanics
FAST	Special Relativity	QFT

QFT Discoveries

- Existence of anti-particles
- Spin-statistics theorem
- CPT Theorem (Charge conjugation, Parity, Time reversal)

Units!

- Mass: (kg) → (eV) from $E = mc^2$

$$m_e = 0.5 \times 10^6\,\mathrm{eV/c^2} \quad E_n = \frac{-13.6\,\mathrm{eV}}{n^2}$$
$$m_p = 1\,\mathrm{GeV/c^2} \quad 1\,\mathrm{eV} = 1.6 \times 10^{-19}\,\mathrm{J}$$

- Momentum: $\frac{eV}{C} \rightarrow p = \frac{E}{c}$
- Energy: eV

Matter Fermions are divided into two groups:

- Leptons (electrons, muon, tau, neutrinos): Doesn't have the strong force
- Quarks (up, down, charm, strange, top, bottom): Feels the strong force

e.g. the proton is made of 2 up quarks and 1 down quark (uud) and the Neurtron is (udd).

Quarks make up composite subparticles (Hadrons) are held together by the strong force.

- Mesons: 1 quark + 1 anti-quark ($q\bar{q}$) e.g. pion, kaon...
- Baryons: 3 quarks (qqq) e.g proton, neutron

Quark charges:

- $Q = +2/3$ (up, charm, top)
- $Q = -1/3$ (down, strange, bottom)

Leptons are fundamental particles

- Charged electrically (-1)
  - electron (0.5 MeV)
  - muon (105 MeV)
  - tau (1.8 GeV)
- Neutral (neutrinos)
  - electron neutrino ν_e
  - mueon neutrino ν_μ
  - tau neutrino ν_τ

Crossing Symmetry

$$\begin{aligned} A + B &\to C + D \quad \text{Scattering} \\ A &\to B + C + D \quad \text{Decay} \\ A + \bar{C} &\to \bar{B} + D \end{aligned}$$

e.g. Neutron Decay

$$n \to p + e^- + \bar{\nu}_e$$

Sum rules to think about:

- Baryon Number Conservation
- Lepton Number Conservation
- Electric Charge Conservation

another example:

$$\begin{aligned} n + e^+ &\to p + \bar{\nu}_e \\ p + e^- &\to n + \nu_e \end{aligned}$$

Particle Conservation Laws