Outline

- Relativistic Kinematics
  - (4-momentum)2 invariance, invariant mass
  - Hypothesis testing, production thresholds
  - Cross-sections, flux and luminosity, accelerators
  - Particle lifetime, decay length, width
- Classification of particles
  - Fermions and bosons
  - Leptons, hadrons, quarks
  - Mesons, baryons
- Quark Model
  - Meson and baryon multiplets
  - Isospin, strangeness, c, b, t quarks
- Particle Interactions
  - Colour charge, QCD, gluons, fragmentation, running couplings
  - Strong and weak decays, conservation rules
  - Virtual particles and range of forces
  - Parity, charge conjugation, CP
  - Weak decays of quarks
  - Charmonium and upsilon systems
- Electroweak Interactions
  - Charged and neutral currents
  - W, Z, LEP experiments
  - Higgs and the future
- LHC Experiments
- Future – introduction to accelerator physics

Today

- Lecture 19 (4 slides/page) Electroweak interaction

Previous lecture

- Lecture 18 (4 slides/page) - Parity violation in weak interaction, helicity
  - Williams, pp. 305-310, see also Lecture 17 textbook references.
  - Halzen and Martin. p. 254
  - C.S. Wu, E. Ambler, R.W. Hayward, D.D. Hoppes, R.P. Hudson, "Experimental Test of Parity Conservation in Beta Decay", Phys. Rev. 105, 1413 (1957).

Helicity for massive fermions

- W couples preferentially to LH fermions (RH anti-fermions)

$$\frac{W-RH\ \ fermion}{W-LH\ \ fermion}=\left(\frac{m_{fermion}}{E_{fermion}}\right)^2=\frac{1}{\gamma^2_{fermion}}$$

- "Wrong" helicity states strongly suppressed
- Suppression greater for lighter fermions (of a given energy)
- Example: charged pion decay

Calculation of helicity suppression

- π^+ decays to particles 1, 2

- $E_1+E_2=M$
- $|p_1|=|p_2|$
- Use $E^2=p^2+m^2$, solve for E_1, find
  - $E_1=(M^2+m_1^2-m_2^2)/2M$
- Consider particle 1 as either μ^+ or e^+, particle 2 as ν_μ, ν_e
- Masses (MeV/c^2) : π^+=139.6, μ^+=105.7,e^+=0.511

Particle 1	Energy (MeV)	Lorentz γ
μ	109.8	1.039
e	69.8	139.6

- Relative suppression= $(\gamma_\mu/\gamma_e)^2$=18000 (expt. ~10^{-4} , prediction agrees with experiment when phase space factors are included).

Weak Interaction

- Universal: acts on all quarks and all leptons
- Characterised by long lifetimes and small cross-sections
- At low energies, WI overwhelmed by SI and EM
  - Can be observed when SI and EM forbidden, or by very precise measurements
- Often involve neutrinos, e.g. $n \to pe^-\bar{\nu}_e$
- Charged current WI change quark flavour
  - Observed change in hadron flavour $D^+ \to \bar{K}^0\ \pi^+$

$$(c\bar{d}) \to (s\bar{d})(u\bar{d})$$

- Can violate parity and charge conjugation invariance
  - At much lower level, also violates T and the combined symmetry of CP