

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

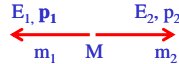
- W couples preferentially to LH fermions (RH anti-fermions)

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

- "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} or ν_e
- Masses (MeV/c²): $\pi^+ = 139.6$, $\mu^+ = 105.7$, $e^+ = 0.511$



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. $\sim 10^4$, 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. $n \rightarrow pe^- \bar{\nu}_e$
- Charged current WI change quark flavour
 - ▶ Observed change in hadron flavour $D^+ \rightarrow \bar{K}^0 \pi^+$
 $(c\bar{d}) \rightarrow (s\bar{d})(u\bar{d})$
- Can violate parity and charge conjugation invariance
 - ▶ At much lower level, also violates T and the combined symmetry of CP