Lecture 7/8

Unstable states (particle, nucleus, atom, . . .)

Decay rate: λ (probability per unit time)

- lifetime: $\tau = 1/\lambda$; half-life: $\tau_{1/2} = \ln(2)/\lambda$
- width in energy: $\Gamma = \hbar/\tau$
- $N(t)$, no. of unstable particles at time t, satisfies decay equation

$$\frac{\mathrm{d}N}{\mathrm{d}t} = -\lambda N$$

or

$$N(t) = N_0 \mathrm{e}^{-\lambda t}$$

- activity: λN (number of decays per unit time)

Hadron lifetimes (very rough rule of thumb)

$\tau < 10^{-20}$ s	strong
$\tau \sim 10^{-20} - 10^{-15}$ s	EM
$\tau > 10^{-15}$ s	weak

Weak interaction

Charged current: $W^{\pm}$ exchange
Neutral current: Z^0 exchange

β decay: ${}^{A}Z \rightarrow {}^{A}(Z+1) + e^{-} + \overline{\nu}_e$, kinetic energy release

$$Q = [M_{\mathrm{nuc}}(Z,A) - M_{\mathrm{nuc}}(Z+1,A) - m_e - m_\nu]\,c^2$$

shared between e and $\overline{\nu} \rightarrow$ continuous spectrum, end point: Q

Parity violation

β decay of polarised ^{60}Co

- more electrons emitted opposite to nuclear spin

$\rightarrow$ breaks parity symmetry (**p** odd but **J** even)

- electrons mostly negative helicity
- antineutrinos positive helicity

Helicity and chirality

Helicity: sign of spin eigenvalue along momentum

- $+$: right-handed
- $-$: left-handed

Weak bosons couple only to

- left-handed fermions (u_L, d_L), (e_L^-, ν_{eL}) (doublets)
- right-handed antifermions $(\overline{u}_R, \overline{d}_R)$, $(e_R^+, \overline{\nu}_{eR})$

$\rightarrow$ P and C violated (no coupling to e_R^-, e_L^+ etc: singlets)
but CP preserved (almost)

Problem: Weak bosons couple to conserved LH current $(V - A)$

- helicity independent of frame only for massless particles: chirality
- and all fermions have masses: e, N, q, and even ν

(Resolution by Nambu, Anderson, Brout, Englert and Higgs)