

$$d\Gamma(E_2) = \frac{2\pi}{\hbar} |M_{fi}|^2 \Delta\Phi(E_2)$$

$$\Gamma = \frac{1}{\tau} \quad \Delta\Phi = \frac{V^2 2\pi p_e^2 dp_e 2\pi p_\nu^2 dp_\nu}{(2\pi\hbar)^3} \delta(E_0 - E_2 - E_\nu)$$

$$E_0 = (M_A - M_{A'}) c^2$$

$$E^2 = m^2 c^4 + p^2 c^2 \quad p dp = E dE \quad \left(\frac{4\pi^2 V^2}{(2\pi\hbar)^3} p_e E_e dE_e p_\nu E_\nu dE_\nu \delta(E_0 - E_2 - E_\nu) \right) \cdot F(E_e, z')$$

$$\frac{P_{\text{prob}}(E_0 - E_0 + dE_0)}{p_e E_e} \sim \sqrt{\frac{E_0 - m_e c^2}{2}} dE_e \quad \parallel \quad p_e E_e dE_e \sqrt{\frac{E_0 - m_e c^2}{2}} E_\nu =$$

$$m_e \nu \rightarrow E_0 - E_0 = \parallel p_e E_0 dE_0 \sqrt{\frac{E_0 - m_e c^2}{2}}$$

$$E_\nu = E_0 - E_2$$

$$\beta^- \text{-decay}$$

$${}^3\text{H} \rightarrow {}^3\text{He} + \beta^- + \bar{\nu}_e$$

KATRIN

$$\Gamma_{\text{tot}} = \frac{1}{\tau} = \frac{G_F^2}{E_0} = \frac{G_F^2}{E_{1/2}}$$

$$\sim \frac{2\pi}{\hbar} |M_{fi}|^2 \int \Delta\Phi \cdot F(E, z')$$

$$\sim (m_e c^2)^5 \int_{E_0}^{E_0 - m_e c^2} F(E, z')$$

$$\epsilon = \frac{E}{m_e c^2}$$

$$\Rightarrow \frac{2\pi}{\hbar} |M_{fi}|^2 / m_e^5 \cdot F \cdot \tau_{1/2} = \text{log ft} \approx 3 \dots 22$$

Electron f.s. $\sim e^{i\vec{b} \cdot \vec{r}} \approx \sum c_\ell Y_{\ell 0}(\theta) j_\ell(kr)$

$$\approx 1 + i\vec{k} \cdot \vec{r} - \frac{(\vec{k} \cdot \vec{r})^2}{2} \dots$$

mirror nuclei

$${}^3\text{H}$$

$${}^3\text{He}$$

$$1s$$

$$\vec{r} + \vec{\nu}_e$$

ft value = ft free n decay

or μEC

$$M_{fi} \sim g_V \langle f | \tau^\pm | i \rangle + g_A \langle f | \tau^\pm \vec{\sigma} | i \rangle$$

$|A\rangle$
 $|B\rangle$

$$= \underbrace{\langle \sum_P \psi_p | g_V \tau_n^\pm | \sum_n \psi_n \rangle_A}_{\text{Fermi Matrix Element}} + \underbrace{\langle \sum_P \psi_p | g_A \tau_n^\pm \vec{\sigma} | \sum_n \psi_n \rangle_A}_{\text{GAMOW-TELLER n.f.}}$$

nuclear Spin: J

$$\Delta S = 0, \Delta P = 0$$

$$\Delta J = 0$$

allowed Fermi transition



forbidden

$$\Delta J = \Delta L \quad | \frac{p}{p_i} = (-1)^{\Delta L} |$$

how many times
forbidden

Superallowed: perfect wf overlap

$$\Delta J = \pm 1, 0; 0 \rightarrow 0$$

$$\Delta P = 0$$

Allowed GT transitions



forbidden

$$\Delta J = \Delta L + 1$$

$${}^{40}\text{K} : J^\pi = 4^-$$



$${}^{40}\text{Ca} : J^\pi = 0^+$$