Preliminary Examination

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Mini-Symposium: Neutrinos and Nuclei XII: Double Beta Decay Analysis Techniques

Dirac equation and charge conjugation

- chirality
- charge conjugation and the majorana neutrino
- maybe some history on majorana's proposition.

$$\hat{\psi} \to \hat{\psi}^C = C\gamma^0\hat{\psi}^*$$

$$C = \begin{pmatrix} i\sigma_2 & 0 \\ 0 & -i\sigma_2 \end{pmatrix}$$

$$e^- \iff e^+$$

neutrinos and the standard model

- in the GWS electroweak theory, the neutrino's mass should be generated by the higgs mechanism. left handed fields couple to right handed fields to generate mass, however the neutrino only presents as a left-handed particle.
- therefore, for neutrinos to be massive, there must be some mechanism beyond the standard model that can give them mass.
- three majorana light-neutrino mixing model

$$m_\nu = U \begin{pmatrix} m_1 & 0 & 0 \\ 0 & m_2 & 0 \\ 0 & 0 & m_3 \end{pmatrix} U^T$$

$$\langle m_{\beta\beta} \rangle = |U_{ij}^2 m_j|$$

neutrtinoless-double beta decay as a probe into the weak interaction

- historically, experiments studying the weak interaction have yielded unexpected results with regards to what theory describes the leptons.

- beta spectrum, charge / parity on their own not respected, (charge-parity is), what form does the weak interaction take in its coupling (V-A)

- confirming or denying the existence of double beta decay would probe whether the chargeless lepton, the neutrino, has a majorana or dirac anti-particle.

far reaching consequences of observing $0\nu\beta\beta$

- baryogenesis through leptogenesis
- charge parity violating process in the standard model
- lepton number conservation (accidental symmetry of the standard model)

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$0\nu\beta\beta$ half-life and sensitivity

- direct detection experiments typically characterize the half-life in terms of the effective neutrino mass $m_{\beta\beta}$

$$T_{1/2}^{0\nu\beta\beta} = \left(G|\mathcal{M}|^2\langle m_{\beta\beta}\rangle\right)^{-1}$$
$$\simeq 10^{27-28}\left(\frac{0.01\ eV}{\langle m_{\beta\beta}\rangle}\right)^2 \text{years}$$

$$F_{0\nu} = \tau_{1/2}^{bkg.fluct.} = \ln(2) N_{\beta\beta}\epsilon\frac{t}{n_B}$$

$0\nu\beta\beta$ half-life and sensitivity

- to probe

$$T_{1/2}^{0\nu\beta\beta} = \left(G|\mathcal{M}|^2\langle m_{\beta\beta}\rangle\right)^{-1}$$

$$\simeq 10^{27-28}\left(\frac{0.01\ eV}{\langle m_{\beta\beta}\rangle}\right)^2 \text{years}$$

$$T_{1/2}^{0\nu\beta\beta} \sim \epsilon\sqrt{\frac{M_{iso}\,t}{b\Delta E}}$$

experimental signature and detection

- mono-energetic peak with 2 electrons leaving the reaction.
- tomography of electron tracks can help reduced backgrounds, except for the $2\nu\beta\beta$ irreducible background
- compare to Σ and m_β from cosmology