A Search for the Neutrinoless Double Beta Decay of Xenon-136 with Improved Sensitivity from Waveform Denoising

Clayton G. Davis

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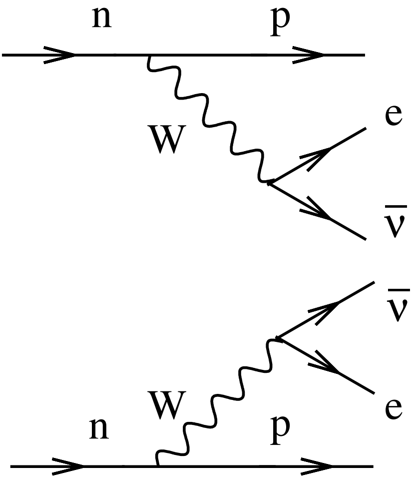
Outline

$\beta\beta 2\nu$ and $\beta\beta 0\nu$ Decay

Usage
- Use 1
- Use 2

Examples
- Example 1

What is Double-Beta Decay?

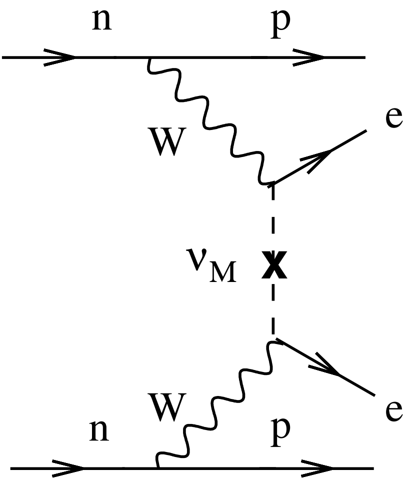


Avignone et al., RMP 2008.

Feynman diagram for $\beta\beta 2\nu$ decay. Equivalent to two single-β decays:

$$2n \to 2p + 2e^- + 2\bar{\nu}_e$$

What is Double-Beta Decay?



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Feynman diagram for $\beta\beta 2\nu$ decay. Equivalent to two single-β decays:

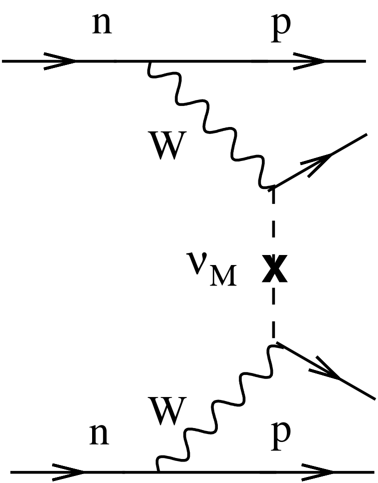
$$2n \rightarrow 2p + 2e^{-} + 2\bar{\nu}_e$$

Feynman diagram for $\beta\beta 0\nu$ decay. Neutrinos annihilate each other:

$$2n \rightarrow 2p + 2e^{-}$$

$\beta\beta 2\nu$ is allowed in the Standard Model; $\beta\beta 0\nu$ is not.

Implications of Double-Beta Decay



Avignone et al., RMP 2008.

- Lepton number changes:

$$\Delta L = +2$$

- Neutrinos can convert to their own antiparticle:

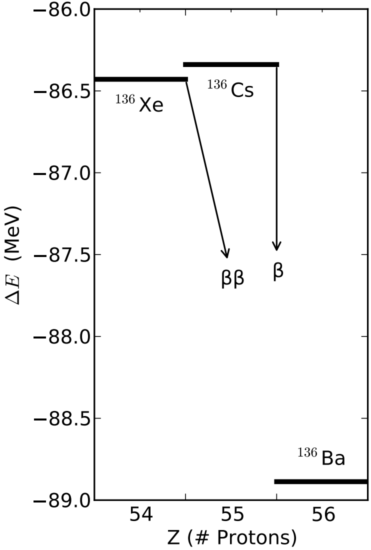
$$\bar{\nu}_R \to \nu_L$$

- Neutrinos have mass through a Majorana interaction:

$$-\frac{m_L}{2}\left(\overline{\Psi_L^c}\Psi_L + \overline{\Psi_L}\Psi_L^c\right)$$

$$-\frac{m_R}{2}\left(\overline{\Psi_R^c}\Psi_R + \overline{\Psi_R}\Psi_R^c\right)$$

The $A = 136$ Isobar



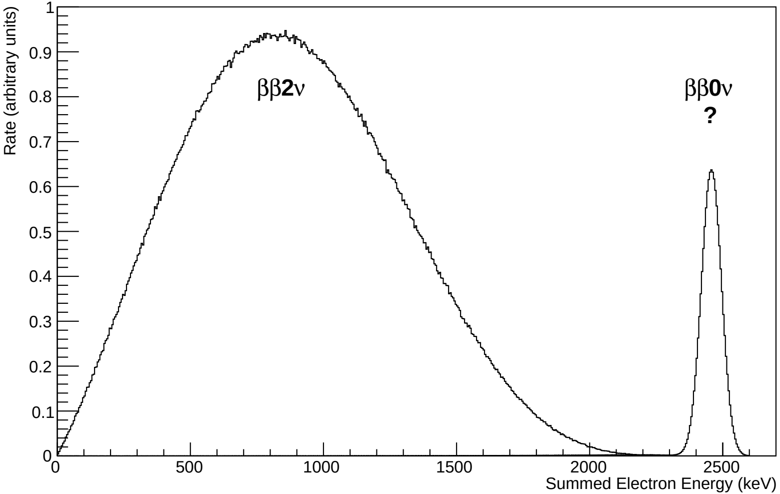
^{136}Cs undergoes single-β decay.

^{136}Xe cannot, due to energy conservation – but it can $\beta\beta$ decay through ^{136}Cs to ^{136}Ba.

The Q-value of $^{136}\text{Xe} \rightarrow ^{136}\text{Ba}$ is 2457.83 ± 0.37 keV, shared between all final products of the decay.

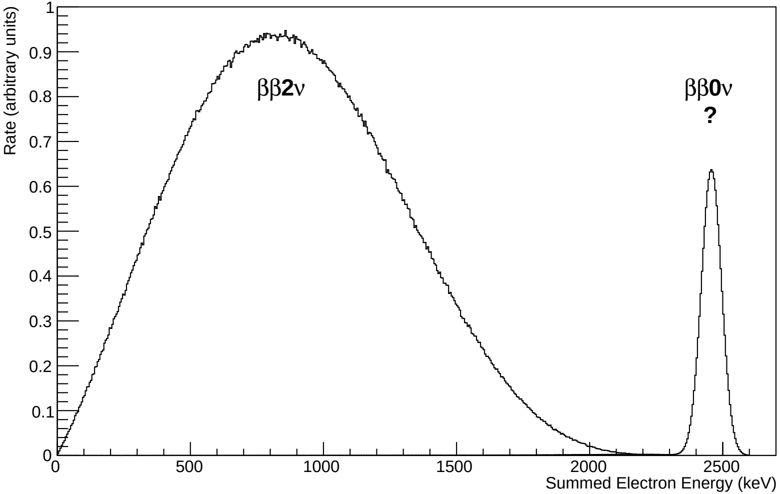
We observe energy in electrons; energy in neutrinos is lost.

Ideal Double-Beta Energy Spectrum



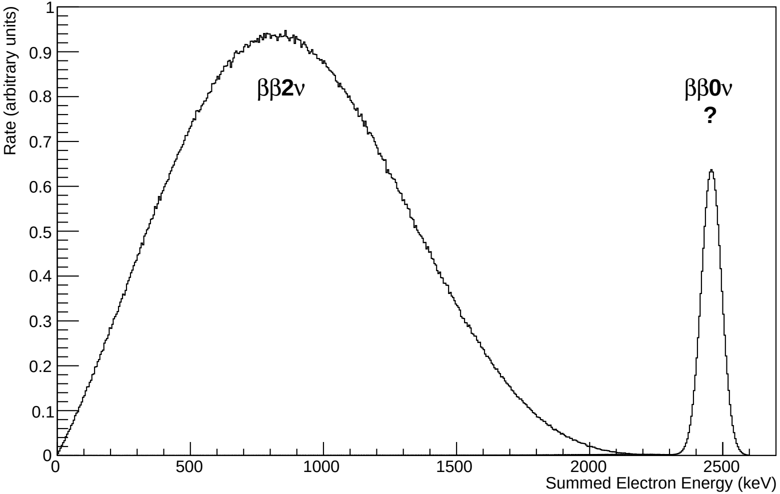
^{136}Xe $\beta\beta 2\nu$ produces a smooth energy spectrum; "missing" energy carried off by neutrinos.

Ideal Double-Beta Energy Spectrum



^{136}Xe $\beta\beta0\nu$ has no neutrinos, so no "missing" energy; mono-energetic peak at $Q = 2458$ keV.

Ideal Double-Beta Energy Spectrum



If the $\beta\beta 0\nu$ peak exists, neutrinos have Majorana mass; peak height gives the scale of that mass.

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