Double Beta Decay in the Context of EMPM and STDA Methods

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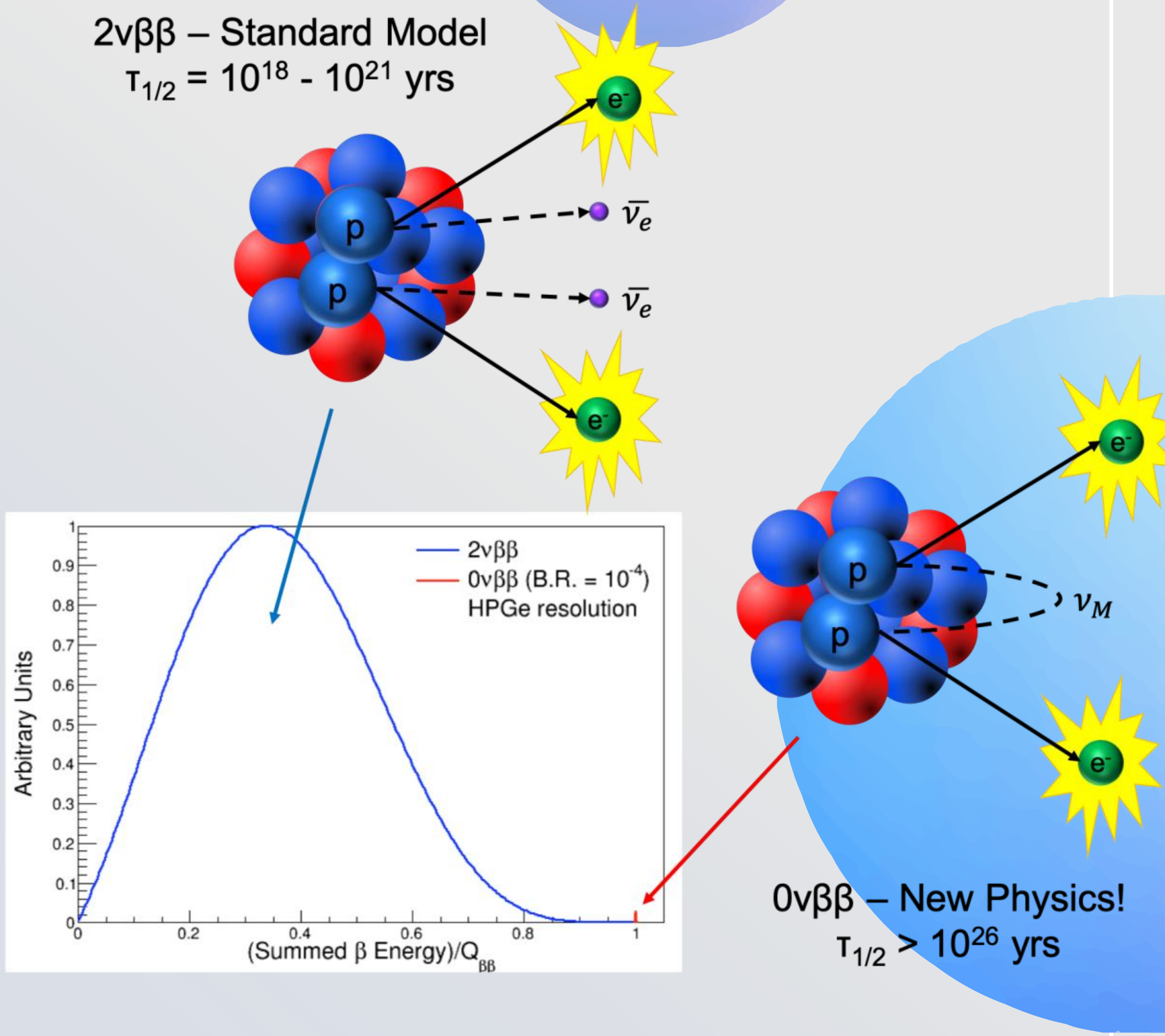
MOTIVATION

- Double beta decay is a rare nuclear process where particle, nuclear, and atomic physics intersect.
- It provides a testing ground for the Standard Model through two-neutrino double beta decay ($2\nu\beta\beta$).
- It also offers a pathway to physics beyond the Standard Model via neutrinoless double beta decay ($0\nu\beta\beta$).
- This decay may uncover properties of the neutrino, one of the least understood particles.
- It presents a significant experimental challenge, being among the slowest known decay processes in nature.
- We focus our effort on the calculations of Nuclear Matrix Elements (NMEs).



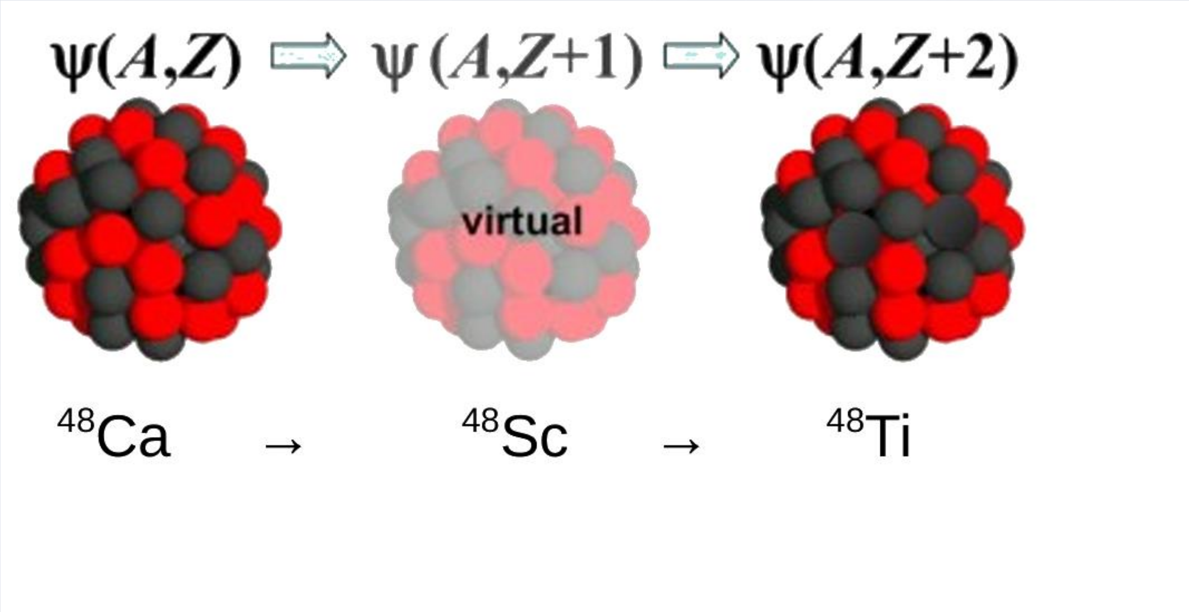
THEORETICAL FRAMEWORK

- **Models Employed**

Mean-Field Approximation
Hartree-Fock (HF)
Wood-Saxon (WS)
- 1p–1h Excitations

Tamm-Dancoff Approximation (TDA)
Proton-Neutron TDA (pnTDA)
- 2p–2h Excitations

Second Tamm-Dancoff Approximation (STDA)
Equation of Motion Phonon Method (EMPM)



- **Objective**

- Accurate computation of Nuclear Matrix Elements (NMEs) for:

Two-neutrino double beta decay ($2\nu\beta\beta$)Neutrinoless double beta decay ($0\nu\beta\beta$)

Nuclear Matrix Element Results for ^{48}Ca

Transition chain:

$^{48}Ca \rightarrow {}^{48}Sc \rightarrow {}^{48}Ti$

$$(T_{\frac{1}{2}}^{2\nu})^{-1} = g_A^4 m_e^2 |M_{GT} - \frac{M_F}{g_A^2}|^2 G^{2\nu}$$

$$M_{F,GT}^{2\nu} = \sum_n \frac{\langle f||O_{F,GT}||J_n^+\rangle\langle J_n^+||O_{F,GT}||i\rangle}{E_n - (E_i + E_f)/2}$$

$$NME\ (total) = g_A^2 m_e |M_{GT} - \frac{M_F}{g_A^2}|$$

$$q = \sqrt{\frac{M_F + \sqrt{\frac{1}{T_{\frac{1}{2}}^{2\nu} G^{2\nu} m_e^2}}}{g_A^2 M_{GT}}}$$

Implication: Theoretical NME values are too high — suggests **quenching (q) of gA** to ~0.46.

Summary & Outlook

- EMPM and STDA possibly offer consistent NME predictions but require CM correction, inclusion of 2p-2h configurations to calculation of ^{48}Sc.

- Potentially g_a quenching can be, to large extend, explained by EMPM or STDA if they are consistently used in calculations of ^{48}Sc and ^{48}Ti.

Next steps:

- Generalize to quasiparticle formalism (e.g., ^{76}Ge, ^{82}Se).
- Apply CM correction to STDA.
- Study effect of 2p-2h or more-p-h on NMEs.

Thank you