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Double beta decay in the nuclear density functional theory

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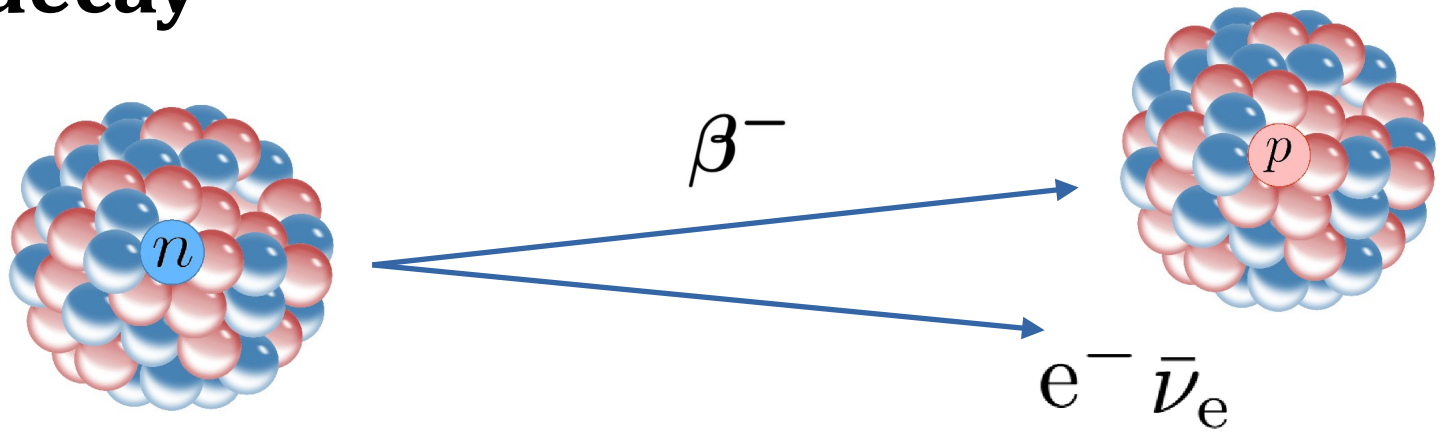
Beta decay

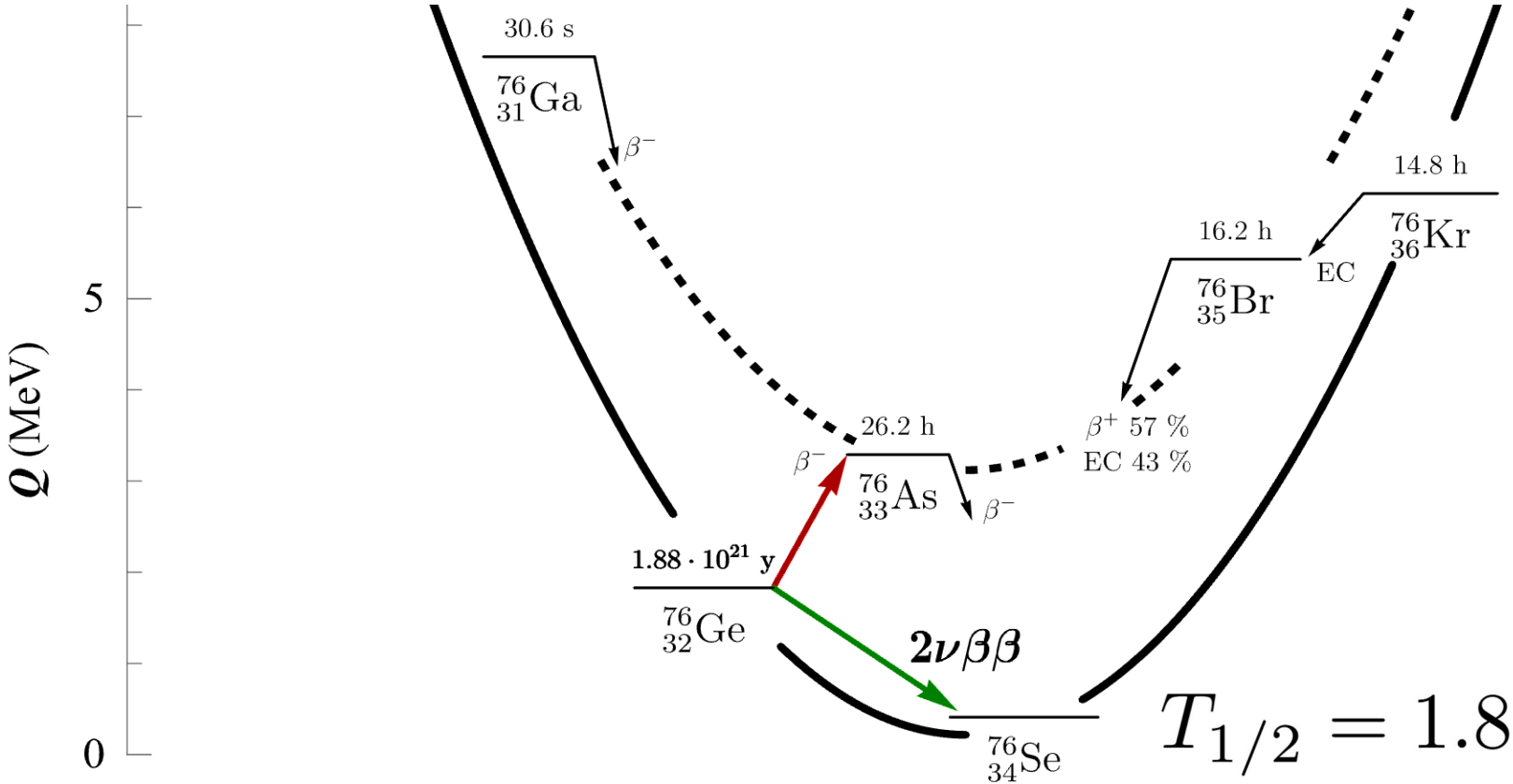


Quantum-wise: $\hat{\mathcal{H}}_\beta = \frac{G_F}{\sqrt{2}} J^{\mu\dagger} j_\mu + \text{h.c.}$

Annihilation-creation of a hadron (p,n)

Annihilation-creation of a lepton (e,ν_e)

Double beta decay



$$T_{1/2} = 1.88 \cdot 10^{21}\text{y.}\ !$$

Energy parabolas of the even-even and odd-odd isobars of A =76.

Data from F. Kondev et al., Chinese Phys. C **45**, 030001 (2021).

Nuclear matrix element

$$T_{1/2}^{-1} = \underbrace{G_{2\nu\beta\beta}(Z,E)}_{\textit{leptonic part}} \cdot \underbrace{|\mathcal{M}_{2\nu\beta\beta}|^2}_{\textbf{\textit{nuclear matrix element}}}$$

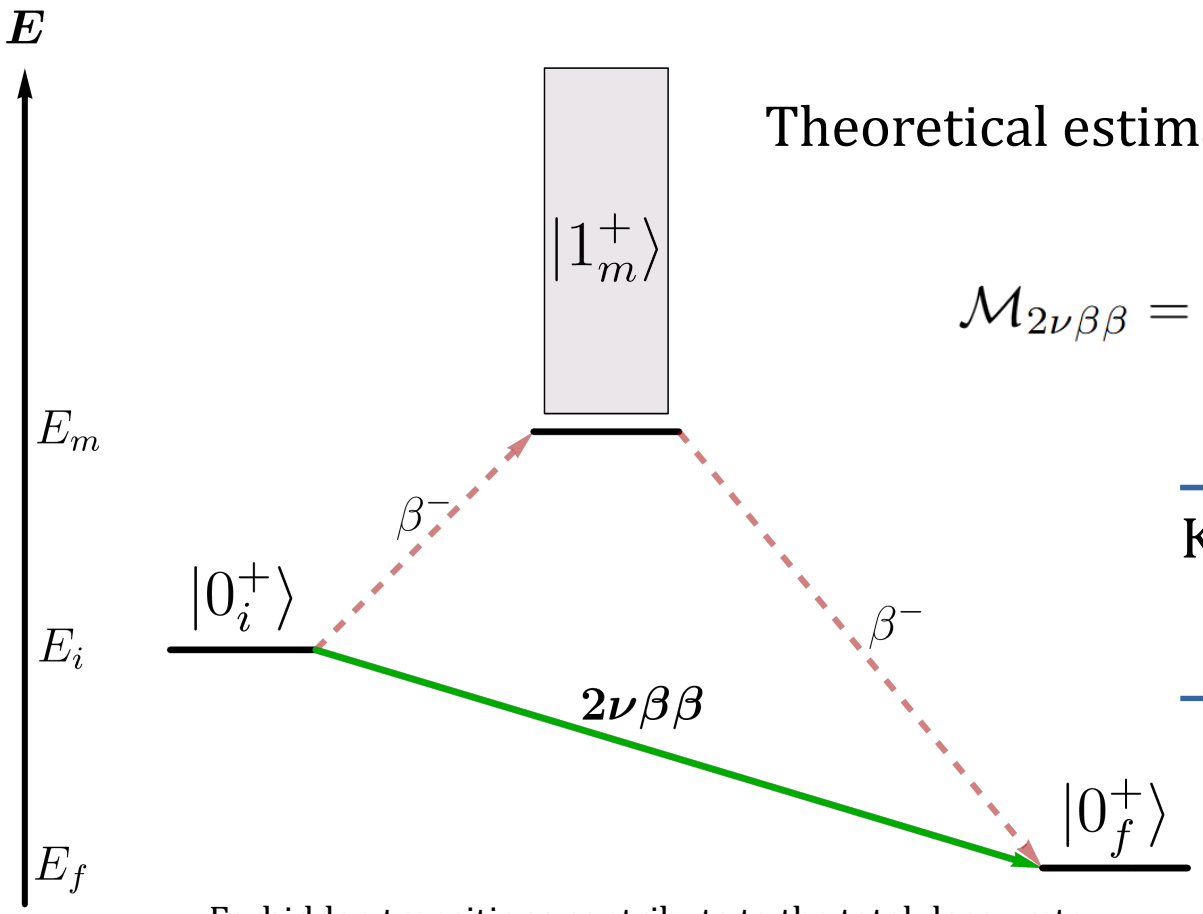
(all nuclear QM)

$$\sim G_F^4$$

Extremely rare!

(only **11** nuclei)

Fermi golden rule of the 2nd order



Theoretical estimation via **virtual** transitions:

$$\mathcal{M}_{2\nu\beta\beta} = \sum_m \frac{\langle 0_f^+ | \hat{H}_\beta | \mathbf{1_m^+} \rangle \langle \mathbf{1_m^+} | \hat{H}_\beta | 0_i^+ \rangle}{\boldsymbol{\Delta E_m} + \frac{1}{2} Q_{\beta\beta} + \Delta M}$$

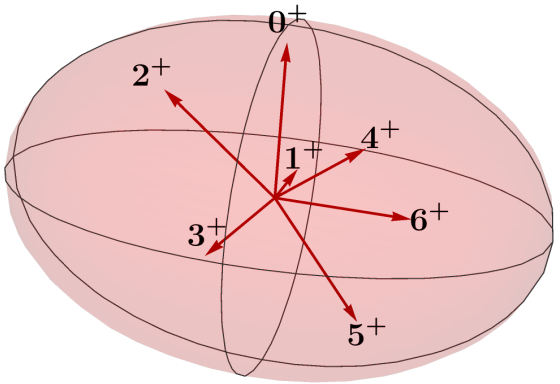
Key difficulty: constructing

$$|0_i^+\rangle, |1_m^+\rangle, |0_f^+\rangle$$

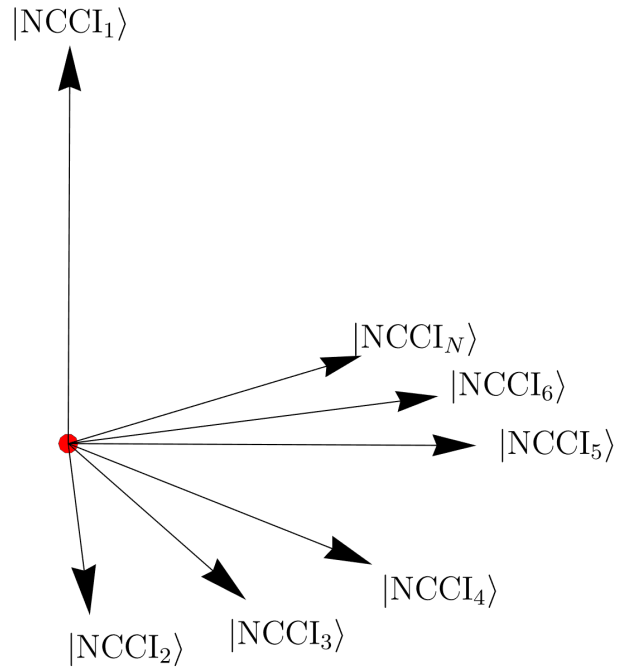
Forbidden transitions contribute to the total decay rate.

NCCI based on Skyrme nuclear density functional

Kohn-Sham $\left|\Psi_i\right\rangle$



$I^\pi(T)$ – projection
configuration mixing
rediagonalization

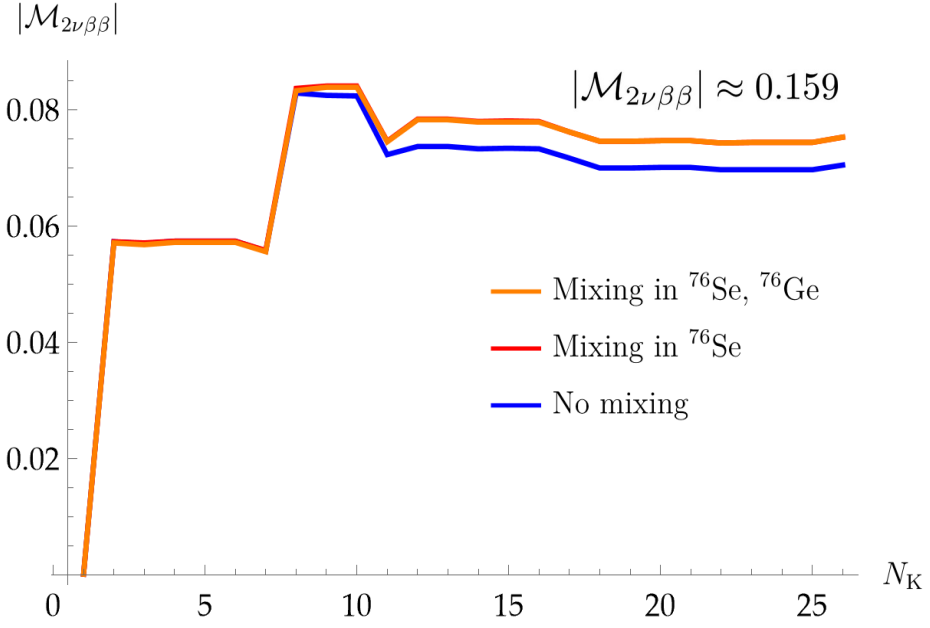


no good quantum numbers
~~γ, β transitions~~

good quantum numbers
γ, β transitions

Status and future plans for the model

Exemplary estimation for 76Ge nucleus



Summing contributions from $\mathbf{1^+_m}$ up to saturation.

What next?

- $2\nu\beta\beta$ decay calculation of 136Xe (in progress) and other nuclei
- Implementation of neutrinoless matrix elements into NCCI framework
- Tests of the model on (hypothetical) $\mathbf{0\nu\beta\beta}$ decay.