Translational and Rotational symmetry Restoration with Lipkin method

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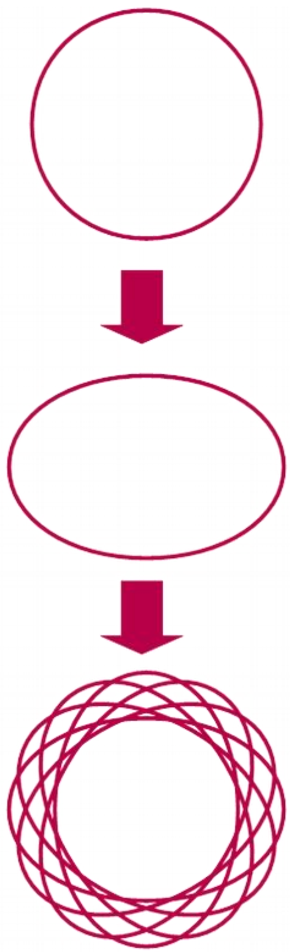
Symmetry Breaking and Restoration



Breaking

- The ground state of the system in a given variation space has a lower symmetry than the Hamiltonian.
- Price of including important correlations while keeping the wave function as a simple single Slater determinant.
- Typical symmetries broken in the calculation can be: translational symmetry, rotational symmetry, particle number and so on.

Restoration

- Projection : PAV, VAP
- Search for simultaneous eigenstates of H and the symmetry operator S in a subspace that invariant under the elements of the symmetry group generated by S.
- Functions in this subspace are superpositions of slater determinants.
- Problems: Time consumming, Singularities when doesn't use real interaction.

Lipkin Method

- The mean-field ground state is viewed as a superposition of eigenstates of a given symmetry operator.

$$|\Phi\rangle = \Sigma_s |s\rangle$$

- *H* is flattened by a Lipkin operator *K*. If the flattened Routhian has the same expectation value on any eigen component in the ground state, one can obtain the same expectation value from the mean-field ground state.

$$E_s = \frac{\langle\Phi|\hat{H}|s\rangle}{\langle\Phi|s\rangle} = E_0 + K(s)$$

$$E_0 = \frac{\langle\Phi|\hat{H}-\hat{K}(\hat{S})|s\rangle}{\langle\Phi|s\rangle} \rightarrow E_0 = \frac{\langle\Phi|\hat{H}-\hat{K}(\hat{S})|\Phi\rangle}{\langle\Phi|\Phi\rangle}$$

Lipkin Method

- The Lipkin operator is expressed as a power series of the symmetry operator.

$$\hat{K} = \Sigma_n k_n \hat{S}^n$$

- Its coefficients are determined with the help of off-diagonal overlaps.

$$h(r) = E_0 + \Sigma_n k_n s_n(r)$$

$$h(r) = \frac{\langle \Phi | \hat{H} | \Phi(r) \rangle}{\langle \Phi | \Phi(r) \rangle}, \; s_n(r) = \frac{\langle \Phi | \hat{S}^n | \Phi(r) \rangle}{\langle \Phi | \Phi(r) \rangle}, \; |\Phi(r)\rangle = e^{-i\hat{S}r} |\Phi\rangle$$

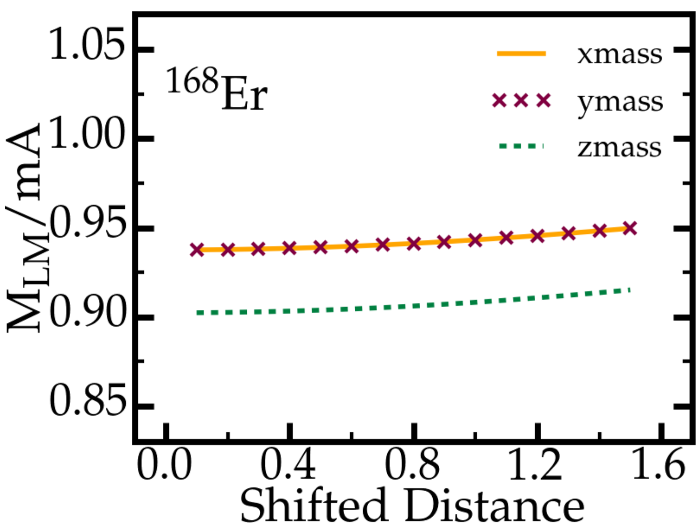
- Less cost, Avoid some singularities

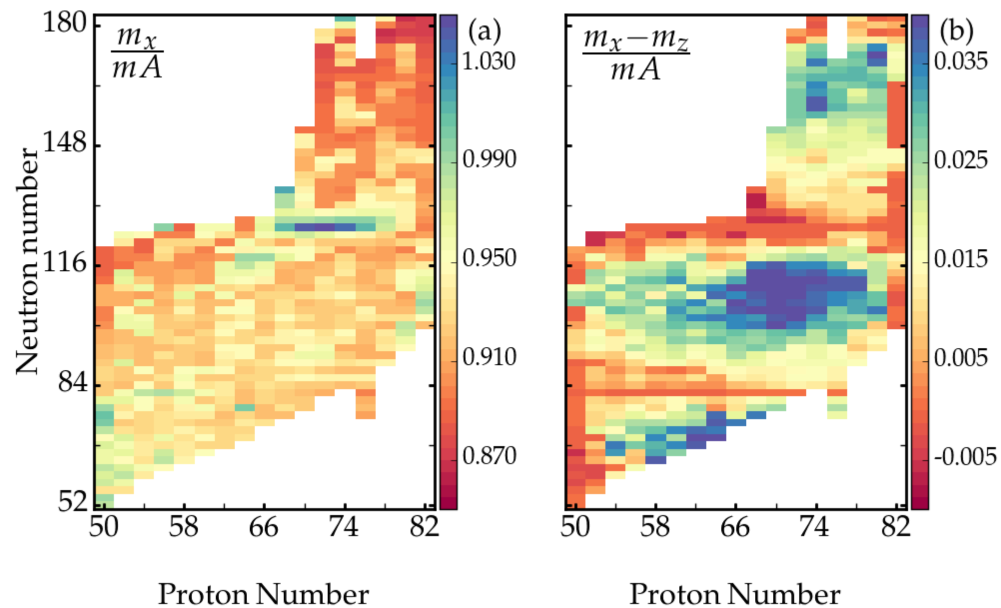
Results

Translational Symmetry

$$\hat{K} = \Sigma_{i=x,y,z}\frac{1}{2m_i}\hat{P}_i^2$$

- The coefficient doesn't change much when the shifting distance changed in a certain range.
- The Lipkin masses are different from the real masses and can be different in different directions.





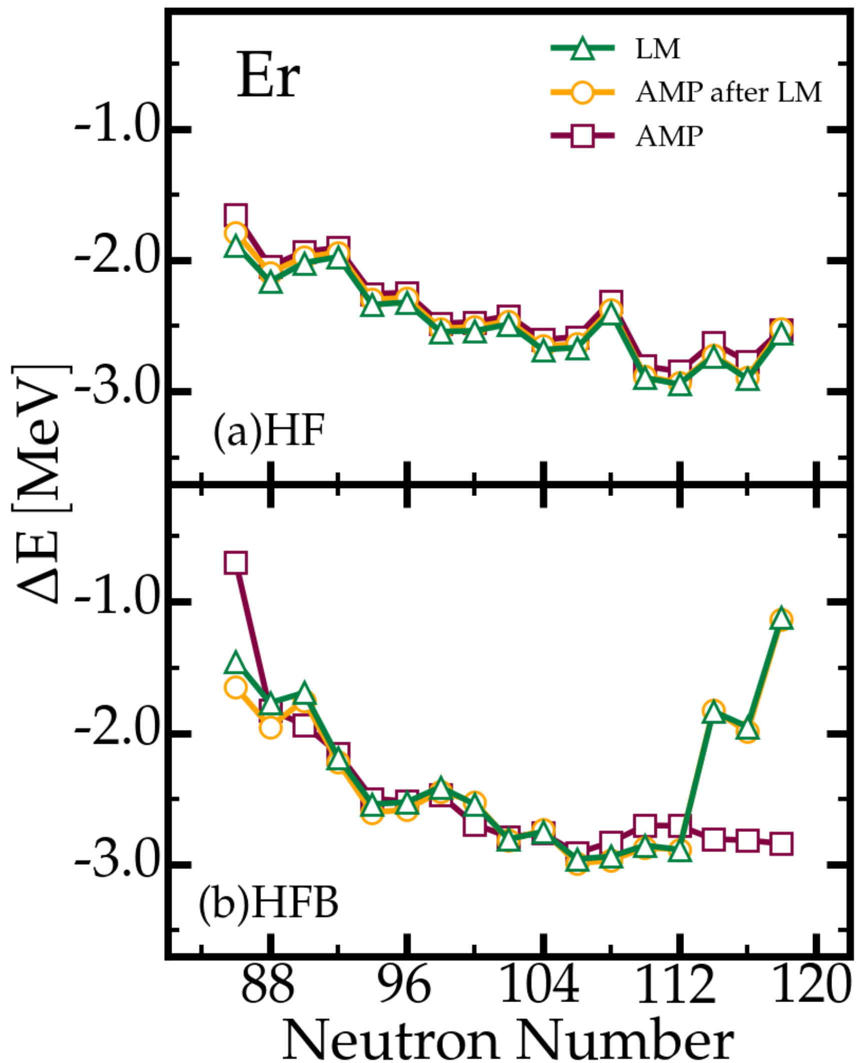
Y.G., J.D., etc., To be published

Results

Rotational Symmetry

$$\hat{K} = k(\hat{J}_x^2 + \hat{J}_y^2)$$

- Axial deformed nuclei.
- The energy corrections from Lipkin method and from projection method are similar.



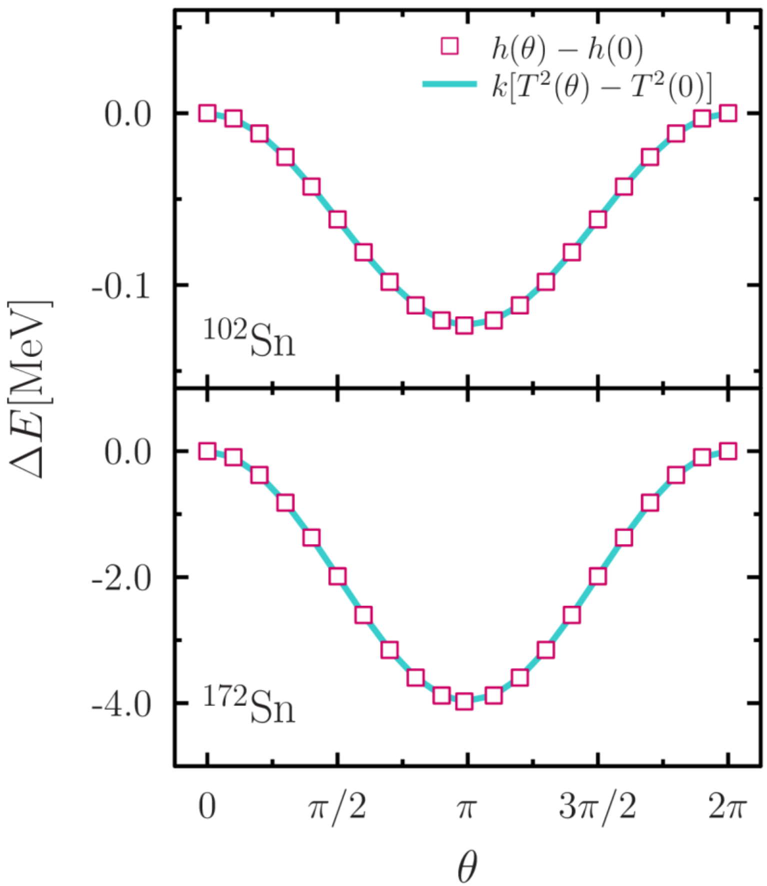
Y.G., J.D., etc., To be published

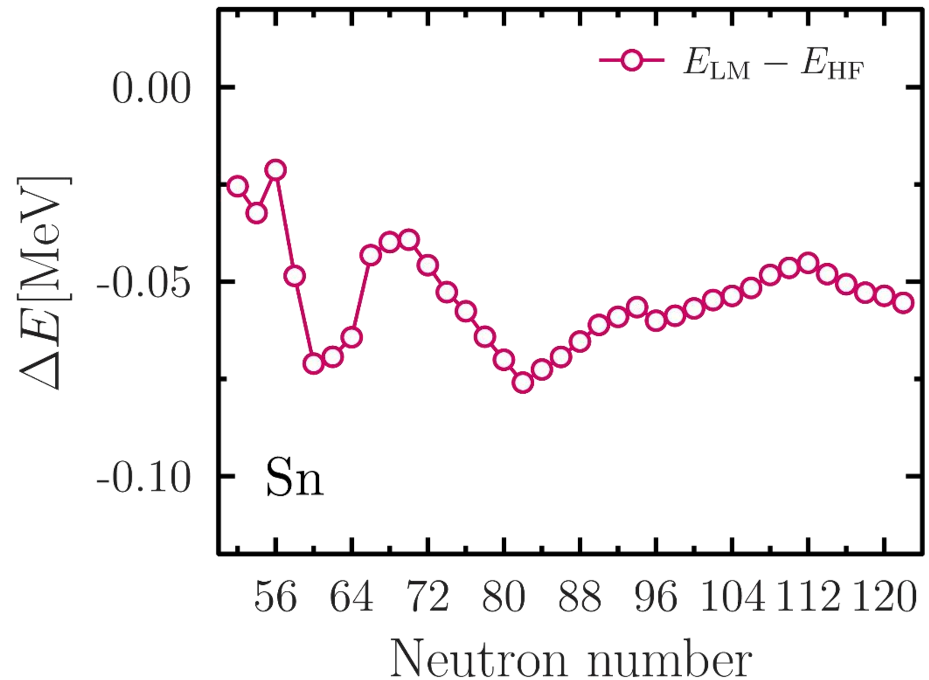
Outlook

Isospin Symmetry

- Currently No Coulomb interaction and No pairing.
- *k[T^2(θ)-T^2 (0)]* with fixed *k* gives almost the same curve as *h(θ)-h(0)*.
- The energy corrections seem to be small.

$$\hat{K} = k[\hat{T}^2 - T_z(T_z+1)]$$





Thank You