

Configuration mixing within coherent states

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The shell model description of halo nuclei requires quite different single particle states for core nucleons and those in the dilute and far out reaching halo. The expansion of those widespread states in a harmonic oscillator basis for example is not advisable. The representation on a spatial grid might be useful for a Hartree-Fock mean-field calculation but configuration mixing of several Slater determinants by means of a two-body residual interaction is not feasible because the calculation of the two-body matrix elements is too costly.

A possible way out may be the use of Gaussian single-particle states $|\vec{r}, \vec{p}, a\rangle$ (coherent states) with a variable width parameter a

$$\langle \vec{x} | \vec{r}, \vec{p}, a \rangle = \exp\left\{-\frac{(\vec{x}-\vec{r})^2}{2a} + i\vec{x} \cdot \vec{p}\right\}. \quad (1)$$

In single-particle space these states form an overcomplete set. A good representation of the single-particle state should therefore be obtainable by using a few gaussians adjusted to the narrow core and to the wide halo

$$|\nu\rangle = \sum_i |\vec{r}_i, \vec{p}_i, a_i\rangle c_i \quad (2)$$

The general A -body state $|\Psi\rangle$ can be approximated by a linear combination of Slaterdeterminants $|Q_k\rangle$

$$|\Psi\rangle = \sum_k |Q_k\rangle C_k, \quad (3)$$

where the $|Q_k\rangle$ are constructed from A single-particle states of type $|\nu\rangle$. The mixing coefficients can be determined by diagonalizing the Hamiltonian \tilde{H} in the nonorthogonal basis $|Q_k\rangle$. The matrix elements $\langle Q_k | \tilde{H} | Q_l \rangle$ can be calculated analytically if the interaction is also represented by Gaussians because only Gaussian integrals and determinants appear.

We have performed first calculations[1] to demonstrate the usefulness of these concepts. We used the ATS3M-Interaction with our *Unitary Correlator Operator Method* (UCOM)[2] in the *Fermionic Molecular Dynamics* (FMD)[3] model.

The advantages of a more flexible one-particle state are demonstrated on ${}^6\text{He}$ with its loosely bound neutrons. By using two gaussians instead of only one for the one-particle state the exponential tail of the nucleon density and the existence of an α -core can be described. This goes together with an increase in binding energy of 3.5 MeV.

The concept of configuration mixing is illustrated with ${}^{12}\text{C}$. The FMD groundstate using only one Slaterdeterminant has a pronounced intrinsic α -structure. This is in accordance with experimental results and the freedom to describe such structures is one of the advantages of the FMD model. Nevertheless this description lacks good quantum numbers in angular momentum and parity. By a configuration mixing calculation within a set of randomly rotated basis states we achieve a much improved description of the groundstate and also the rotational spectrum complete with the right quantum numbers. Compared to the FMD groundstate we gain about 12 MeV in binding energy.

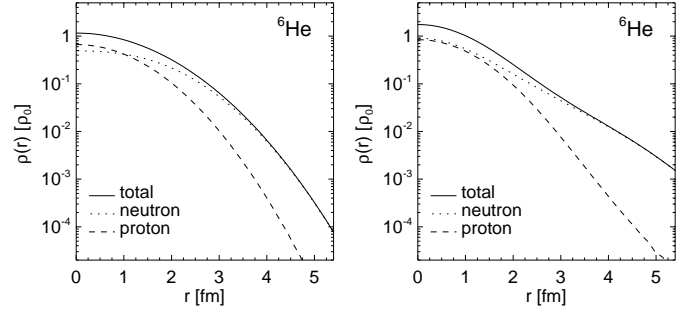


Fig. 1: Radial nucleon density distributions of the ${}^6\text{He}$ ground-state calculated with one (left) and two gaussians (right) per one-particle state

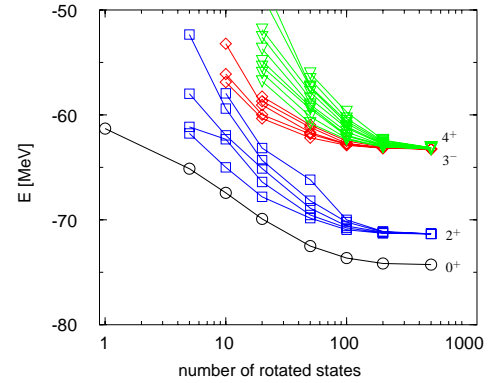
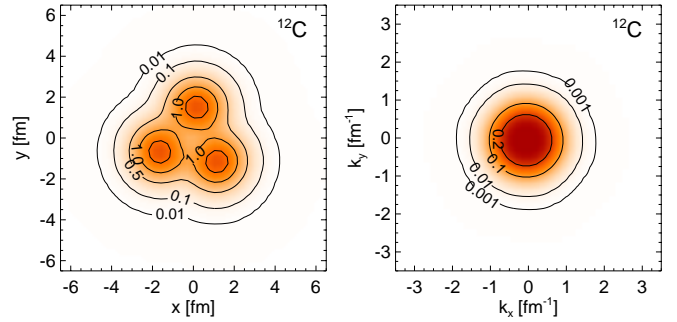


Fig. 2: Densityplot in coordinate and momentum space of the intrinsically deformed ${}^{12}\text{C}$ groundstate (top), result of configuration mixing calculation – binding energy of the lowest states as a function of the basis dimension (bottom)

References

- [1] T. Neff, Fermionische Molekularodynamik mit Konfigurationsmischungen und realistischen Wechselwirkungen, Diplomarbeit TU Darmstadt (1998)
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