Configuration mixing within coherent states

T. Neff, H. Feldmeier, R. Roth (GSI), J. Schnack (Uni Osnabrück)

The shell model description of halo nuclei requires quite different single–particle states for core nucleons and nucleons in the dilute and far out reaching halo. The standard shell–model expansion of these wide–spread states in a harmonic oscillator basis requires many shells and a large numerical effort. A better representation is possible in terms of Gaussian single-particle states (coherent states) which are defined by their parameters $\{\vec{r},\vec{p},a\}$ as

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

In single-particle space these states form an overcomplete set. A good representation of a general single–particle state $\left|\,\nu\,\right\rangle$ should therefore be given by a superposition of a few Gaussians with properly chosen parameters

$$\left|\,\nu\,\right\rangle = \sum_i c_i\,\left|\,\vec{r}_i,\vec{p}_i,a_i\,\right\rangle\ . \qquad (2)$$

The general A–body state $\left|\,\Psi\,\right\rangle$ can then be approximated by a linear combination of Slater determinants $\left|\,Q_k\,\right\rangle$

$$\left|\,\Psi\,\right\rangle = \sum_k C_k\,\left|\,Q_k\,\right\rangle\ , \qquad (3)$$

where the $\left|\,Q_k\,\right\rangle$ are constructed from A single–particle states of type $\left|\,\nu\,\right\rangle$. The mixing coefficients are determined by diagonalizing the Hamiltonian $\underset{\sim}{H}$ in the nonorthogonal basis $\left|\,Q_k\,\right\rangle$. The matrix elements $\left\langle Q_k\middle|\underset{\sim}{H}\middle|Q_l\right\rangle$ 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 test 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 flexible coherent one–particle states are demonstrated in the case of ^{6}He. By using only two Gaussians for each state $\left|\,\nu\,\right\rangle$ in a single Slater determinant the exponential tail of the nucleon density and the existence of a low density neutron skin can already be described (Fig. 1). There is also an increase in binding energy of 3.5 MeV compared to one Gaussian per state.

The concept of configuration mixing is illustrated in Fig. 2. The FMD ground state of ^{12}C using only one Slaterdeterminant has a pronounced α-structure. This intrinsic state is in accordance with experimental results and can easily be represented in FMD by only one Gaussian per state. But the single Slater determinant lacks good quantum numbers in angular momentum and parity. By a configuration mixing calculation within a set of randomly rotated determinants we achieve a much improved description of the ground state and also get the rotational spectrum with the right quantum numbers. Compared to the FMD ground state we gain about 12 MeV in binding energy.

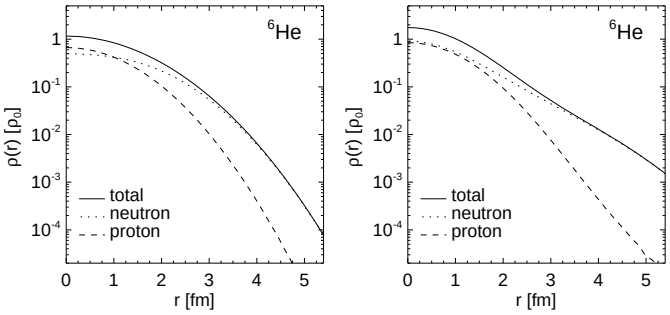

Fig. 1: Radial nucleon density distributions of the ^{6}He ground state calculated with one (left) and two Gaussians (right) per one-particle state

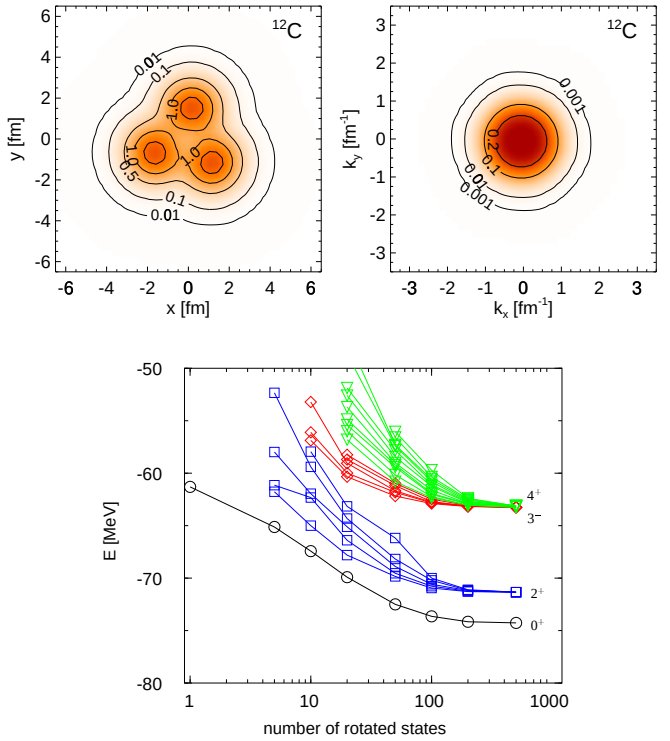

Fig. 2: Density plot in coordinate and momentum space of the intrinsically deformed ^{12}C ground state (top); result of configuration mixing calculation – energy of the lowest states as a function of the basis dimension (bottom)

References

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

[2] H. Feldmeier, T. Neff, R. Roth, J. Schnack, Nucl. Phys. **A632** (1998) 61

[3] H. Feldmeier, J. Schnack, Prog. Part. Nucl. Phys. **39** (1997) 393