

Nuclear structure calculations in FMD

T. Neff and H. Feldmeier

GSI Darmstadt

In the Fermionic Molecular Dynamics (FMD) model [3] the A-body state is given as a Slater determinant $|Q\rangle$ of single-particle states $|q_i\rangle$

$$|Q\rangle = \mathcal{A} \left\{ |q_1\rangle \otimes \dots \otimes |q_A\rangle \right\}. \quad (1)$$

The single-particle wave functions are described by Gaussian wave packets localized in phase-space

$$\langle \vec{x} | q \rangle = \sum_i c_i \exp \left\{ -\frac{(\vec{x} - \vec{b}_i)^2}{2a_i} \right\} |\chi_i\rangle \otimes |\xi\rangle. \quad (2)$$

The FMD many-body state is obtained by varying the energy with respect to all single-particle parameters (Variation/V). The many-body state can be intrinsically deformed and has to be projected to good angular momentum (Projection after Variation/PAV). An improved description is obtained by minimizing the energy of the projected many-body state (Variation after Projection/VAP). We perform VAP calculations in the sense of the Generator Coordinate Method. The energy of the (unprojected) many-body state is first minimized under certain constraints. The energy of the projected many-body states is then minimized with respect to the constraint parameters. A further improvement is achieved by diagonalizing the Hamiltonian in a set of projected FMD states (Multiconfig).

An effective interaction derived from the realistic Bonn interaction is used. With the Unitary Correlation Operator Method [2] we explicitly include the short-range correlations induced by the repulsive core and the tensor force. The correlated interaction is then a low-momentum interaction that can be used directly in the many-body spaces of the FMD. An additional 15% two-body correction term to the correlated interaction that simulates the effects of missing three-body forces and three-body correlations is fitted to reproduce the binding energies and radii of ^4He , ^{16}O , ^{40}Ca , ^{24}O and ^{48}Ca .

Within this framework we are able to calculate the properties of stable and exotic nuclei in the p - and sd -shell. This is illustrated in the following for ^{12}C . Further examples including the neutron rich He isotopes can be found in [1].

Varying the intrinsic energy of the FMD state (V) results in a spherical shell model many-body state as depicted in Fig. 1. Projection (PAV) does not change the result here. Compared to the experimental observations the binding energy is too low and the radius is too small. If we perform a VAP calculation with constraints on the octupole moment and the radius

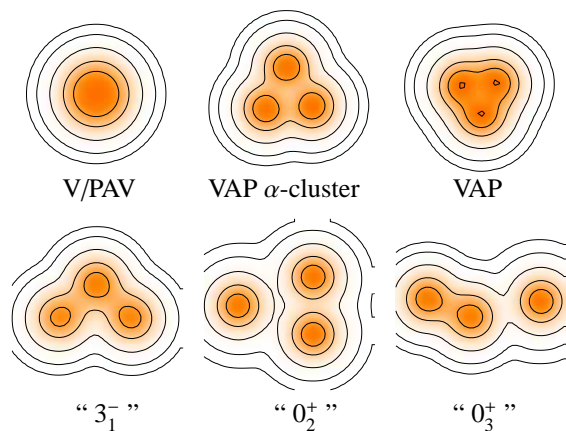


Figure 1: Intrinsic shapes used in the calculation.

where the FMD state is restricted to be of α -cluster type (VAP α -cluster) we obtain a triangle configuration that is higher in energy than the shell model configuration. The full VAP calculation where we use two Gaussian wave packets per single-particle state gives a much improved result. The obtained intrinsic state is an interpolation between the shell model and the α -cluster states. Binding energy and radii agree now much better with the experimental observations, see Tab. 1. In a multiconfiguration calculation with four shapes whose energies are minimized with respect to the first three 0^+ and the first 3^- state the results can be further improved. The admixture of more extended configurations is especially important for the radius and the $B(E2)$ values. With the multiconfiguration calculation we can also study the excited states, see Fig. 2. The structure especially of the excited 0^+ states is currently under debate.

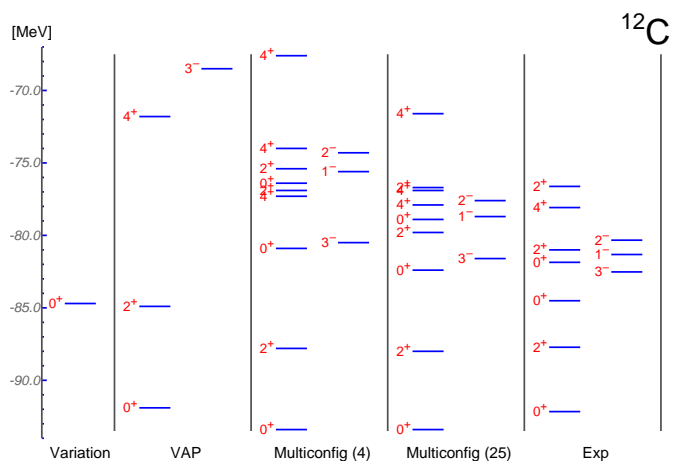


Figure 2: Calculated and experimental spectrum of ^{12}C .

	E_b [MeV]	r_{charge} [fm]	$B(E2)$ [$e^2\text{fm}^4$]
V/PAV	84.7	2.30	-
VAP α -cluster	80.4	2.64	56.3
VAP	91.9	2.36	24.7
Multiconfig	93.4	2.48	40.0
Exp	92.2	2.47	39.7 ± 3.3

Table 1: Binding energies, charge radii and $BE(2)$ -values.

References

- [1] T. Neff, H. Feldmeier, nucl-th/0312130, <http://theory.gsi.de/~fmd/>
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- [3] H. Feldmeier, J. Schnack, Rev. Mod. Phys. **72** (2000) 655