CLUSTERS AND SHELL-STRUCTURE IN LIGHT NUCLEI

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The structure of light nuclei up to the drip lines is studied using the Fermionic Molecular Dynamics model [1]. The calculations make no a priori assumptions about a core or single particle-states and energies. The many-body states are described as parity and angular momentum projected Slater determinants. The single-particle states are given as a single or a sum of two Gaussian wave-packets. The position and width of each Gaussian wave-packet and the orientation of the spins are the variational parameters. FMD states are able to describe shell-model states as well as cluster-model states or states with halo structure.

Intrinsic states are obtained by minimizing the energy under constraints on radius, dipole, quadrupole or octupole deformations. In the spirit of the Generator Coordinate Method we obtain ground and excited states by multiconfiguration calculations with these parity and angular momentum projected intrinsic states.

The same effective interaction derived from the realistic Bonn-A or the Argonne V18 interactions is used for all nuclei. It includes the short-range central and tensor correlations induced by the repulsive core and the tensor force by means of a unitary correlation operator [2]. The correlated interaction no longer connects to high momenta and can thus be used directly within product-state model spaces. The effects of three-body correlations and genuine three-body forces are simulated by an additional two-body force that contains momentum-dependence and spin-orbit forces. This correction term is adjusted to reproduce the binding energies and radii of ^{4}He, ^{16}O, ^{40}Ca, ^{24}O and ^{48}Ca and contributes about 10% to the potential energy. In the case of ^{16}O and ^{40}Ca we find that after angular momentum projection the tetrahedral configurations of α-clusters are favored energetically versus the shell model configurations.

Within this model we study nuclei in the p-shell. In many nuclei cluster structures are found and allow a description of observed radii and quadrupole moments. In ^{12}C the intrinsic structure of the ground state rotational band is found to be an interpolation between a shell model and triangular α-cluster configuration. We are able to describe the binding energy as well as radius and the $B(E2)$-value for the 0^+ to 2^+ transitions. With increasing neutron number the clustering is reduced and for ^{16}C we find an almost round proton distribution and consequently a very small $B(E2)$ value.

In the He-isotopes the soft-dipole mode in form of ground-state correlations is found to be necessary for an understanding of the experimentally observed staggering of the binding energies. Also the matter radii are well described. The soft-dipole mode is also found to be important in other halo nuclei like ^{11}Li.

[1] T. Neff, H. Feldmeier, Nuc. Phys. **A738C** (2004) 357.
[2] T. Neff, H. Feldmeier, Nuc. Phys. **A713** (2003) 311.