Neutron-Rich Helium Isotopes in FMD

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The *A*-body basis states in Fermionic Molecular Dynamics [1] are parity and angular momentum projected Slater determinants $\left| Q \right\rangle$

$$\left| Q^{J^\pi}_{MK} \right\rangle = P^{J^\pi}_{MK} \left| Q \right\rangle \tag{1}$$

of single particle states $\left| q \right\rangle$ that are described by Gaussian wave packets localized in phase-space

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

A FMD state $\left| Q \right\rangle$ is obtained by minimizing the intrinsic energy of the parity projected Slater determinant with respect to the parameters of all single-particle states. The projection on angular momentum is done after the minimization (PAV$^\pi$). In the often deformed or clustered nuclei of the *p*-shell the correlation energies can be very large. We therefore use additional intrinsic configurations that are obtained by minimizing the energy under constraints on collective variables like the radius or the quadrupole moment. In a multiconfiguration calculation the Hamiltonian is then diagonalized in this set of projected Slater determinants.

For our calculations we use an effective interaction that is derived from the realistic Argonne V18 interaction by means of the Unitary Correlation Operator Method (UCOM) [2, 3, 4]. The correlated interaction includes the short-range central and tensor correlations induced by the repulsive core and the tensor force. The correlated interaction no longer connects to high momenta. Thus it can be used directly with simple many-body states of a Hartree-Fock or FMD approach.

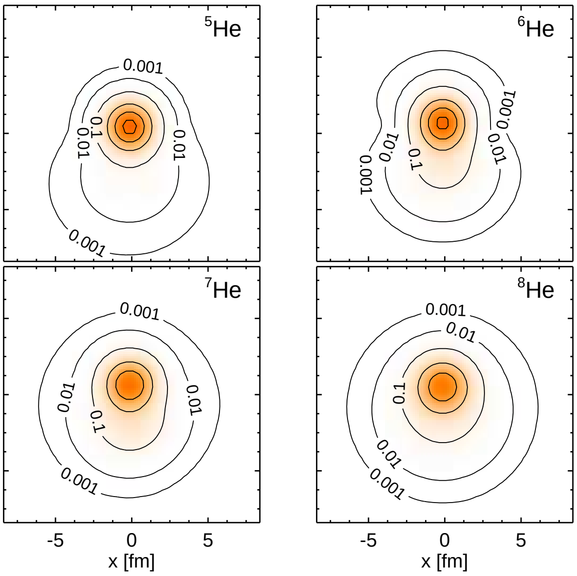

Figure 1: Intrinsic shapes of Helium isotopes corresponding to the minima in a variation after parity projection (PAV$^\pi$) calculation. Shown are cuts through the nucleon density calculated with the intrinsic state before parity projection. Densities are given in units of nuclear matter density $\rho_0 = 0.17\text{fm}^{-3}$.

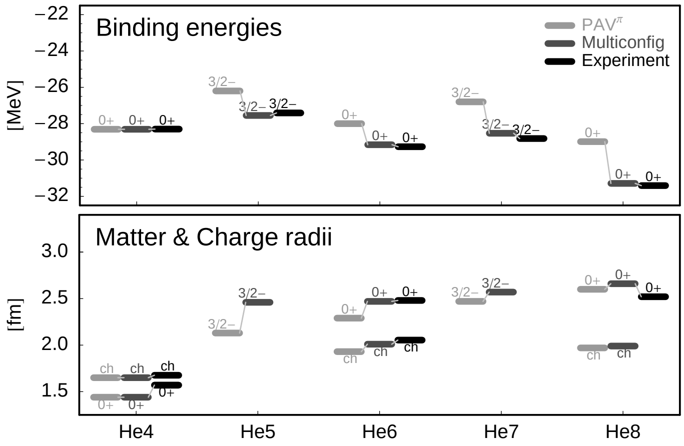

Figure 2: Binding energies and matter and charge radii for the Helium isotopes. Charge radii are indicated by ch. Results are given for the PAV$^\pi$ and the multiconfiguration calculations. Experimental matter radii are taken from [5]. The experimental charge radius of ^{6}He is given in [6].

Fig. 1 shows the intrinsic states obtained by minimizing the energy of the Helium isotopes. In all nuclei a dipole deformation caused by a displacement of the neutrons against the α-core is found. In ^{6}He the configuration with two neutrons on the same side of the core is preferred to configurations with the two neutrons located at opposite sides of the core. In ^{8}He one approaches the $p_{3/2}$ neutron shell closure with an almost spherical neutron distribution.

In Fig. 2 the binding energies and matter radii obtained after angular momentum projection (PAV$^\pi$) are compared to the experimental binding energies and radii. To improve the many-body states we create additional configurations using the dipole moment as a generator coordinate. The multiconfiguration calculations (Multiconfig) reproduce the experimental binding energies and radii very well. This illustrates the importance of the soft-dipole mode, that is realized in the form of groundstate correlations, for the understanding of the borromean nature of ^{6}He and ^{8}He. The increase of the charge radii compared to ^{4}He is mainly due to the motion of the α core against the center of mass of the nucleus. For ^{6}He we calculate a charge radius of 2.01 fm that has to be compared to the recently measured value of 2.054 ± 0.014 fm [6], for ^{8}He we predict a value of 1.99 fm.

References

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