Two- and three-body halos in helium and lithium isotopes

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Exotic radioactive beams, which are obtained by fragmentation of heavy ions, have largely contributed to the investigation of the structure of nuclei far from stability [1]. Experiments have revealed new properties that characterize the light neutron-rich nuclei, i.e. the existence of a neutron halo which extends outwards to large radii. Theoretically this effect has been analyzed mainly in terms of the Borromean approximation. This model assumes that the halo structure of the ground states of exotic nuclei is determined only by the valence neutrons which are confined into the lowest shell, while collective excitations of the system are neglected [2]. However, according to Ref. [3] these excitations play an important role in modelling the two-body and three-body halo structure of the matter and charge distibutions of light exotic nuclei.

In order to proof the role of the collective excitations, calculations for the wave function of the ground state of ^{6}Li and for the matter distribution of ^{6}He have been performed. The DCM describes the ground states of nuclei in terms of interacting clusters: valence particles and intrinsic vacuum states. It allows a separated analysis of the valence particle and the collective excitations of the core. The amplitudes of the mixed-mode wave-functions are derived in the framework of non-perturbative solutions of the equation of motion.

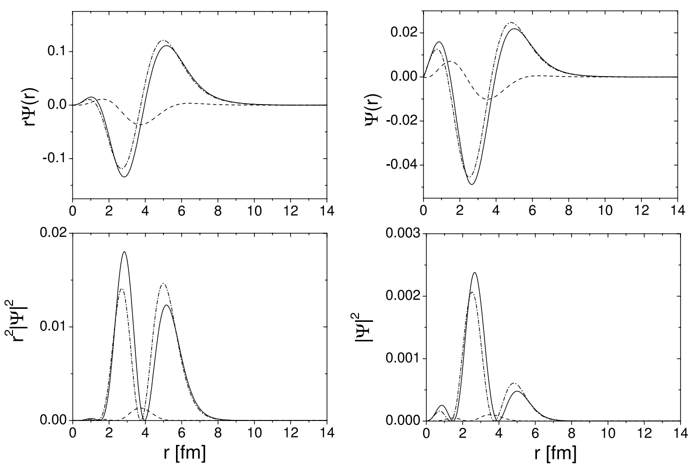

Figure 1: Calculated wave function and probablity distributions of the ground state of ^{6}Li. The dash-dotted line gives the CM result for the two particles in the shell-model approximation, the dashed line the DCM contributions, and the solid line the results for the dressed two particles.

The model spaces for the ground state of ^{6}Li and ^{6}He are constructed by allowing valence particles to be scattered to higher configuration states ($2\hbar\omega$) and to interact with the core intrinsic states formed by exciting particles from the s-shell. The single-particle states, used as input in the DCM calculations, have been approximated by harmonic oscillators with a state-dependent range introduced to reproduce the single-particle radii as calculated in a Wood-Saxon potential well. The single-particle energies are also obtained in this procedure. The two-body matrix elements are the same as used in Ref. [3].

In Fig. 1, the wave function of the dressed two particles ground state is given for ^{6}Li in terms of the shell-model (dashed-dot line) and DCM (dashed line) contributions. The core excitation terms are moving the first maximum of the ψ^2 distribution to larger r values, thus contributing to the formation of a long tail in the matter distribution. In Fig. 2 the effect of different center-of-mass (CM) components on the matter distribution of ^{6}He is shown. The dotted line has been calculated considering only the $L = 0$ center-of-mass components and has been presented previously [3], while for the dashed line all allowed CM components have been included. It should be noted that the higher-order CM components are typical for the core excitation mechanism. Finally, the solid line was calculated like the dashed line but including the $L = 0, 1, 2, 3, 4$ CM components as well and increasing the spin-orbit term of the d shells. This energy variation simulates the different shell closure postulated in Ref. [4] for the neutron-rich nuclei.

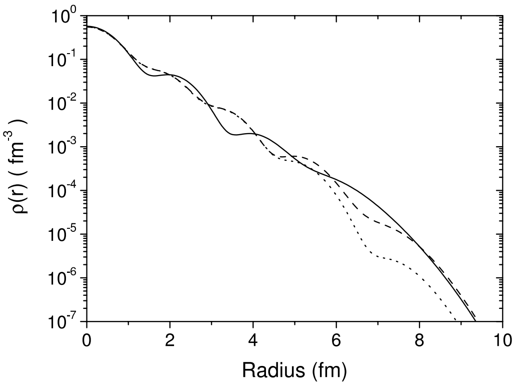

Figure 2: Calculated matter densities of ^{6}He: the dotted line included only the L=0 CM components, the dashed line was calculated considering the L=0,1,2,3,4 CM components, and the solid line distribution was calculated increasing the spin-orbit splitting of the d states.

References

[1] S.R. Neumaier *et al.*, Nucl. Phys. A, to be published; G.D. Alkhazov *et al.*, Phys. Rev. Lett. **78**, 2313 (1997)

[2] P.G. Hansen and B. Jonson, Europhys. Lett. **4**, 409 (1987)

[3] M. Tomaselli *et al.*, Phys. Rev. **C62**, 67305 (2000); M. Tomaselli *et al.*, Proc. NPBL, Lipari (2001), in press; M. Tomaselli *et al.*, Proc. DANF, Casta-Papiernicka (2001), in press

[4] R. Kanungo, I. Tanihata, and A. Ozawa, Proc. INPC, Berkeley, USA (2001), in press