Microscopic Description of Charge and Matter Distributions of Long-Tailed and Halo Nuclei

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Elastic proton scattering experiments in inverse kinematics recently performed at GSI [1] have reopened important, partially unresolved questions concerning the physics of the halo nucleus ^{11}Li. In order to obtain a deeper insight into the halo structure of light exotic nuclei and to understand the difference between the matter and the charge distributions, microscopic calculations for the ground states of the ^{6,7,9,11}Li and ^{7,9}Be isotopes have been performed within the Dynamic-Correlation Model (DCM) [2].

The DCM describes the ground states of nuclei in terms of interacting clusters: valence particles and intrinsic vacuum states. The amplitudes of the mixed-mode wave-functions are derived in the framework of non-perturbative solutions of the Equation of Motion. Theoretically, the model spaces for the ground states of the ^{6,7,9,11}Li and the ^{7,9}Be isotopes 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, p-shell. The single-particle states used as input in the DCM 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. [2].

The matter and charge distributions calculated with this microscopic approach can be used to predict experimentally accessible quantities. In this report we present and discuss the matter distributions for the lithium isotopes ^{7,9,11}Li. Root-mean-square matter and charge radii obtained for the above mentioned beryllium isotopes are also given.

The DCM matter distributions for the lithium isotopes are presented in Fig. 1. The oscillations in the theoretical matter distribution result from the interferences of the valence and the intrinsic states. For ^{11}Li two matter distributions are shown. The dotted line has been obtained by taking the three neutrons in the p-shell into account, while the solid line considers the effect of the neutons moving in the p, s, and d shells and interacting with the vacuum states. It is obvious that the s and d neutrons as well as the core excitations have a profound influence on the halo structure [4]. While there are experimental values for the matter radii of all accessible lithium and beryllium isotopes [5], the charge radii are only known for the stable isotopes [5, 6]. Experimental and theoretical values are in good agreement. However, for a better understanding of the neutron halos influence on the core nucleus, it is desirable to determine the charge radii of the radioactive lithium isotopes experimentally, particularly for ^{11}Li. For this purpose an experiment is being prepared at GSI and ISOLDE, CERN [7] to determine this value by means of an optical isotope-shift measurement. The agreement of the calculated (rms) charge and matter radii for the lithium isotopes with experimental data [5] is good in all cases with the exception of the matter radius of ^{11}Li, which is considerably larger than the experimental value. For ^{7}Be and ^{9}Be the calculated radii (Tab.1) are close to the values of Ref. [5]. It should be mentioned that the experimental values for the matter distribution are model-dependent and that new proton-scattering data from GSI [3] indicate a larger matter radius than the one given previously in Ref. [5]. The matter distribution of ^{11}Li (solid line) and the calculated matter radius of 3.64 fm agree with the phenomenological distribution and with the radius of 3.65 fm given in Ref. [3].

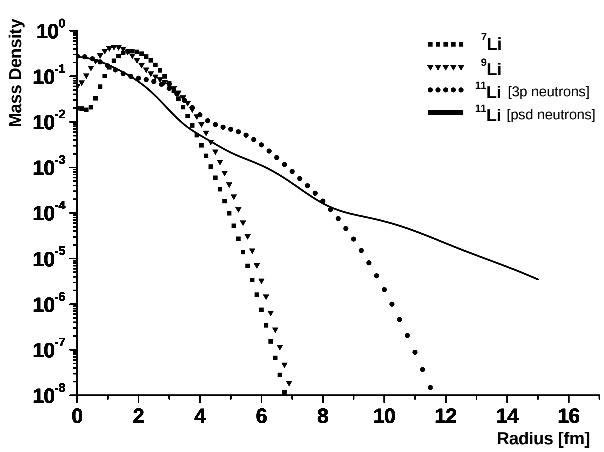

Fig. 1: Calculated mass distribution for ^{7,9,11}Li. The halo structure of ^{11}Li is mainly associated to sd neutrons and to core excitations.

Table 1: Rms-mass and -charge radii for beryllium isotopes

	$R^{calc.}_{matter}$	$R^{calc.}_{charge}$	$R^{exp.}_{matter}$[5]	$R^{exp.}_{charge}$[5]
^{7}Be	2.38 fm	2.39 fm	2.31(2) fm	? fm
^{9}Be	2.46 fm	2.62 fm	2.38(1) fm	2.47(1) fm

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