Charge radius determination of ^{7,9,10}Be and the one-neutron halo nucleus ^{11}Be by high-resolution collinear laser spectroscopy

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After successful studies of the charge radii along the isotopic chains of the light elements lithium [1] and helium [2] by means of high-resolution laser spectroscopy, the focus of the charge radii measurements of light elements is now directed towards beryllium isotopes, because ^{11}Be is a one-neutron halo nucleus and ^{14}Be is a two or four neutron halo isotope.

We have previously proposed measurements of Be on trapped and cooled ions in a linear Paul trap [3,4] but have now found an alternative approach. The spectroscopy of the stable and radioactive beryllium ions was performed by collinear spectroscopy on a 60 keV ion beam. This appeared possible since first theoretical calculations [5,6] consistently predicted a field shift coefficient of about -17 MHz/fm^2, which means that the remaining **s** electron is 10 times more sensitive on the proton distribution than in the case of Li or He. Hence the accuracy needed in the determination of the isotope shift is on the order of 2 MHz. This can be reached by simultaneous collinear/ anti-collinear laser spectroscopy at the existing COLLAPS beamline at ISOLDE, CERN [8]. For this approach a frequency-comb-based laser locking scheme was developed and allowed the determination of the absolute transition frequencies in the D1 and D2 line for ^{7,9,10,11}Be$^+$ ions .

A preceding series of measurements on ^{9}Be$^+$ indicated that systematic errors are sufficiently small to reach the required accuracy. The main contribution is the laser beam alignment with 500 kHz and 400 kHz uncertainty introduced by the rubidium clock, which was used as a reference in the laser locking scheme.

With the determined isotope shift and high precision calculations of the mass-shift contribution it is possible to extract the charge radius for ^{7,10,11}Be based on the previous known value of ^{9}Be [9]. The development of charge radii along the isotopic chain is shown in Fig. 1 (solid circles). The theoretical models shown for comparison are the no-core-shell model (NCSM) [10], fermionic molecular dynamic (FMD) [10] and Greens function Monte Carlo calculations (GFMC) [12]. They all describe the observed trend of charge radii very well. Radii extracted with a Glauber model from interaction cross sections (open circles) [13] strongly overestimate the charge radius of ^{11}Be, which emphasizes the necessity for model-independent experimental approaches.

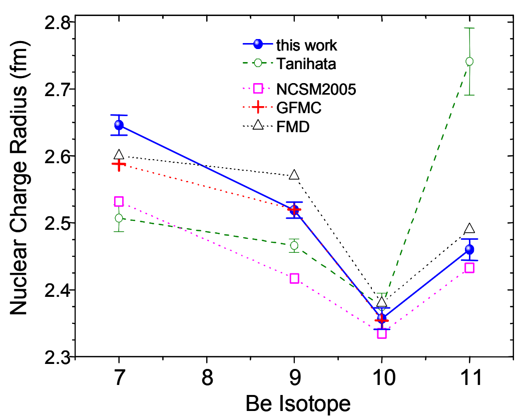

Fig. 1: Charge radii along the beryllium isotopic chain. Experimental results of this work (solid circles) in comparison with model-dependent results from earlier nuclear scattering experiments (open circles) and theoretical predictions.

If one solely allocates the increase in charge radius from ^{10}Be to ^{11}Be to an increased center of mass motion of the ^{10}Be residual core a distance of the halo neutron to the center of mass of 7.0 fm is obtained.

From fitting the observed hyperfine structure of the odd isotopes it was possible to extract the A-factors in the 2s and 2p1/2 state and therewith the magnetic moments as described in [8].

In the near future the investigation of ^{12}Be is planned for 2010 applying the ISCOOL cooler and buncher at ISOLDE. Test measurements at ISCOOL are already in progress.

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