Frequency-Comb Based Optical Isotope Shift Measurements of ^{12}Be

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Introduction: The charge radii of the lightest elements are benchmark tests for nuclear structure models. Moreover, the appearance of the so-called halo nuclei, having an extended nuclear matter distribution due to weakly bound nucleons, makes this region particularly interesting. In 2008 we successfully measured the charge radii of ^{7,9,10}Be and the one neutron halo ^{11}Be by high-resolution laser spectroscopy. We could now extend the measurements to ^{12}Be at ISOLDE/CERN even this isotope has smaller lifetime and lower production rate than the other beryllium isotopes. The structure of this nucleus is not sufficiently well understood yet.

Experimental: Measuring the isotope shift of the 2*s* $^2S_{1/2} \rightarrow 2p\ ^2P_{1/2,3/2}$ (D1,D2) transitions of $^{10,12}Be^+$ delivers information about the nuclear charge radii [1]. Therefore we performed high-resolution collinear laser spectroscopy on a fast beryllium ion beam at the radioactive beam facility ISOLDE. After resonant laser ionization the accelerated ion beam was mass separated and deflected into the collinear laser spectroscopy experiment COLLAPS. There, the ion beam is superimposed with two counter-propagating laser beams at fixed frequencies. Scanning across a resonance is achieved by the so-called Doppler tuning, applying stepwise an additional voltage to the detection region. A detailed description of the laser system and scanning procedure can be found in [2, 3].
The classical optical fluorescence detection system used in the previous studies was now combined with coincident detection of photons and ions to suppress the scattered light of the laser beams. This technique requires that the signal of the photodetector is correlated to the detected ion signal when (after a certain time of flight) an ion was detected, so that only fluorescence photons contribute to the resonance signal.

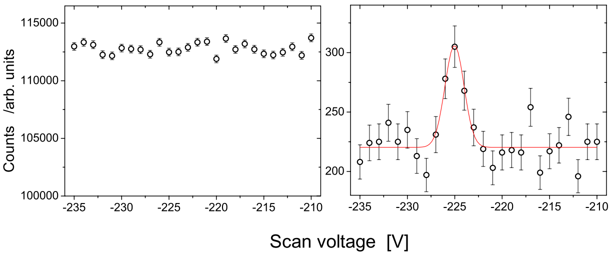

Fig. 1: Pure optical spectrum (left) and coincidence spectrum (right) after 30 minutes with 9.000 $^{40}Ca^+$ ions/s. The coincidence technique increases the sensitivity of the measurement and shows a clear resonance spectrum.

A coincidence detection chamber was built and tested at the TRIGA LASER experiment using a weak ion beam of 9.000 $^{40}Ca^+$ ions / s [4]. A comparison between the pure optical detection without coincidence and the spectrum obtained from the same data using the coincidence is shown in Fig. 1 and depicts a clear resonance only in the coincidence spectrum, where the background is reduced by a factor of about 500.

Results: At COLLAPS, spectra in collinear and anticollinear geometry were simultaneously recorded. The absolute transition frequency ν_0 can be extracted according to $\nu_0 = \sqrt{\nu_a \cdot \nu_c}$. Here ν_a and ν_c denote the center of gravity frequency in the collinear and anticollinear spectrum, respectively. The difference $\delta\nu_{IS}^{A,A'}$ of these extracted absolute frequencies ν_0 for two different isotopes is the isotope shift, which is related to the change in the nuclear charge radii $\delta < r^2 >^{A,A'}$ according to: $\delta < r^2 >^{A,A'} = \left(\delta\nu_{IS}^{A,A'} - \delta\nu_{MS}^{A,A'}\right)/C$. The mass shift contribution $\delta\nu_{MS}^{A,A'}$ and the field shift coefficient *C* must be provided by theory. For the three-electron-system Be^+ they can be calculated to a relative accuracy of 10^{-5} [5,6], which is sufficient to extract the charge radius.
Typical spectra for ^{12}Be at production rates of less than 10.000 ions / proton pulse are shown in Fig. 2. Several systematic effects, *e.g.* ion beam acceleration or deceleration by the resonant laser light, were investigated. The data analysis and determination of the nuclear charge radii are now in progress.

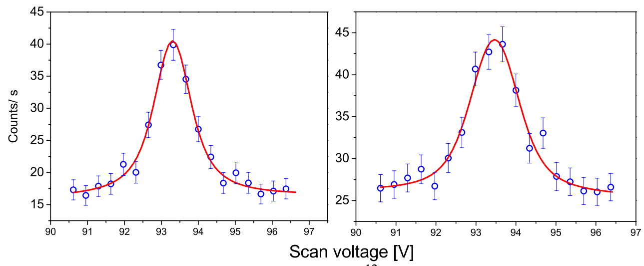

Fig. 2: Resonance spectra obtained for ^{12}Be in the D1 line in collinear geometry (left) and anticollinear geometry (right). The signal was accumulated for 2 hours at a production rate of about 10.000 ions / pulse.

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