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Letter of Intent to the INTC

Measurement of nuclear moments of short-lived magnesium isotopes by β-NMR spectroscopy

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We are planning to propose measurements of nuclear moments of magnesium isotopes, in particular those near the shell closures $N = 8$ and $N = 20$.

With the ISOLDE RILIS laser ion source clean beams of magnesium isotopes have become available for experiments on the nuclear structure all the way through the *sd* shell. The ground state magnetic dipole and electric quadrupole moments of short-lived isotopes should be well accessible to the techniques of β-NMR spectroscopy, provided the nuclei are polarized and implanted into suitable host crystal lattices. As in earlier experiments with the collinear laser spectroscopy setup, the polarization will be achieved by optical Zeeman pumping in the excitation of an atomic resonance transition by a cw laser.

For magnesium, the most suitable optical pumping scheme is found in the excitation from the $3s\,^2S_{1/2}$ ground state to one of the first excited *p*-states, $3p\,^2P_{1/2}$ or $3p\,^2P_{3/2}$ of the singly charged ion Mg^+. The analogous transition has been used already in beryllium for a measurement of the magnetic moment of ^{11}Be [1]. For the light alkaline earth elements these transitions lie in the ultraviolet spectral range (313 nm for Be^+ and 280 nm for Mg^+). Therefore, as the available laser power is crucial for the degree of polarization that can be achieved, an efficient frequency doubling of cw dye laser radiation is necessary. For this purpose we have recently installed an external ring cavity containing a frequency-doubling crystal, which should give considerable advantages over the earlier concept of intracavity frequency doubling. The installation for 280 nm will be tested and optimized in the present shutdown period. From earlier experience we estimate that with a uv-beam power of a few milliwatts we will achieve nuclear polarizations of at least 20 %.

The observed β-decay asymmetries not only depend on the polarization of the nuclei, but also on the decay schemes. These are not well known for all isotopes, but with the expected yields of ^{29}Mg and ^{31}Mg from a UC_2 target, and ^{21}Mg and ^{23}Mg from a SiC target (to be tested) and good polarization, detectable asymmetry signals should be obtained in all cases. This would immediately allow us to measure the magnetic moments by inducing radiofrequency transitions between the nuclear Zeeman levels in the static magnetic field. The magnetic field calibration can be performed by using the same technique on suitable sodium isotopes of which the magnetic moments are known, and which are produced from the same target. Upon further optimization it will also be possible to measure the quadrupole splittings of the NMR signals in non-cubic host lattices and to deduce nuclear quadrupole moments.

From the nuclear physics point of view there is a special interest in both regions that are accessible to our technique. ^{21}Mg at the proton drip line, for which the spin is not known, has one neutron outside the closed $N = 8$ shell and continues the sequence of isotones ^{17}O, ^{19}Ne for which the ground state properties are well known. For the systematics of mirror nuclei, ^{21}Mg will be one of the few accessible $T_z = -3/2$ cases.

A particularly interesting case is ^{31}Mg in the context of the "island of inversion" around $N = 20$ and $Z = 12$. Different models are not consistent in the description of this nucleus. Within the *sd*-shell model it should have a $3/2^+$ ground state, whereas the *sdpf* model, without mixing $0\hbar\omega$ and $2\hbar\omega$, results in a deformed $7/2^-$ ($1\hbar\omega$) ground state. The *sdpf* model, with mixing of the $3/2^+$ ($0\hbar\omega$) and $3/2^+$ ($2\hbar\omega$), gives a $7/2^-$ ground state as well, but a much lower deformed $3/2^+$ state [2].

A recent measurement at LISE-GANIL [3] on a pure ^{31}Mg fragment beam has revealed the presence of the $I = 7/2$ state with a lifetime of at least 10 μs (possibly several ms). The experiment was however not conclusive on the fact whether this "long-lived" intruder state is the ^{31}Mg ground state. A recent ISOLDE fast-timing measurement [4] on some excited levels in ^{31}Mg populated via β-decay of ^{31,32}Na nuclei, has revealed an isomeric $T_{1/2} = 10.5(8)$ ns state at 461 keV. This isomeric state was interpreted as a possible intruder $7/2^-$ or $3/2^-$ state. Finally, a ^{31,32}Na beta-decay study performed by Klotz [5] et al. suggests a deformed $3/2^+$ ground state that comes out as a 50 % mixing of normal and intruder components. A way to conclude, whether the ground state of ^{31}Mg is a normal *sd* state, an intruder $1\hbar\omega$ or an intruder $2\hbar\omega$, is by determining the spin and the magnetic moment via β-NMR.

To our knowledge there has been good experience [6] with the production of neutron-rich Mg isotopes by laser ionization from the UC_2 target. The feasibility estimates of the proposed NMR measurements are based on yield numbers achieved in this way. With this letter of intend we want to emphasize our interest in the target development for the production of neutron-deficient isotopes for which SiC seems to be most promising. We also ask for the permission to start testing in more detail the experimental conditions for the planned measurements. This could be done by participating in production runs for other experiments on the neutron-rich isotopes or in target tests on the neutron-deficient isotopes.

In order to be able to locate the optical resonances of the isotopes of interest, we have to perform preparatory measurements of isotope shifts on beams of isotopes closer to stability which are sufficiently intense for conventional collinear laser spectroscopy.

A full proposal will be submitted at a forthcoming INTC meeting.

References

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