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LETTER OF INTENT

Measurements of shape co-existence in heavy nuclei using Coulomb excitation

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The evolution and microscopic origin of quadrupole collectivity and shape coexistence at low excitation energies in neutron mid-shell nuclei near the $Z = 82$ shell closure are still not fully understood (for recent review, see [1]). The shape coexistence phenomenon in neutron-deficient nuclei close to $Z = 82$ was first observed when isotope shift measurements for Hg nuclides revealed a sharp transition between ^{187}Hg and ^{185}Hg. This change was interpreted as a transition from a weakly oblate shape [2] to a more deformed prolate structure [3,4]. Nowadays there exists a large body of experimental information supporting the coexistence of different shapes at low excitation energies in mercury isotopes. Similarly, in neutron deficient even-mass Pb isotopes intruder states were first identified in α- and β-decay studies using on-line isotope separators [5]. The low-lying excited 0^+ states associated with weakly deformed oblate proton 2p–2h intruder structures have been observed in α-decay in several Pb isotopes with $N \geq 106$ [6, 7], and prolate deformed bands built upon 4p-4h excitations have also been identified in separate experiments (e.g. [8]). The lowest excited states in ^{186}Pb were found to have spin and parity 0+ and are associated with oblate and (predicted) more deformed prolate shape respectively [9].

While much has been learnt in recent years concerning the behaviour of the light Hg and Pb nuclei, several key questions remain outstanding, such as the degree of mixing between the various different configurations. We propose to embark on a study of the mid-shell nuclei ^{182,184}Hg since for these isotopes the co-existing configurations lie closest to each other [1] and the radionuclides are readily obtainable from the REX-ISOLDE facility. The ground states are predicted [10] to be weakly deformed 2h oblate states ($\beta \sim -0.15$) whereas the 4p-6h prolate ($\beta \sim 0.25$) band heads are expected to lie at about 300-400 keV. The availability of accelerated radioactive heavy ions at REX and the application of Coulomb excitation (Coulex) allow a number of unique observations to be made: (i) Coulex will preferentially excite states strongly coupled to the ground state so the oblate excited states will be readily observed and identified; (ii) as we have recently successfully demonstrated for ^{70}Se accelerated by REX [11], low energy Coulex will measure the sign of the diagonal quadrupole matrix element and hence distinguish between prolate and oblate excitation; (iii) the degree of mixing between the oblate and prolate structures is determined directly from the transition matrix elements. As a full set of matrix elements cannot sometimes be obtained independently from yield measurements alone, the Coulomb excitation yield measurements will be complemented by lifetime measurements to be carried out at the University of Jyväskylä for those states strongly populated by (HI,xn) reactions, using the tagged-RDDS method recently developed there.

Experimental requirements

ISOLDE is unique world-wide in having the capability of providing sufficient primary intensity (> 5 x 10^6 ions/s) that will give the minimum 10^4 ions/s delivered at the target for γ-ray transition yield measurements using MINIBALL for 3 MeV/u Hg beams. It is necessary to demonstrate that the required charge state necessary for post-acceleration can be achieved at the REX-EBIS charge breeder with a reasonable efficiency (few %). In order to reach A/q = 4.3 the Hg atoms have to be charge bred to an ionisation state 43+ (ionisation energy for 42+ to 43+ equals 2.1 keV). This ionisation energy is comparable to that required to reach Xe 34+, which has already been achieved. The breeding time is likely to be in the range 200-300 ms, so the small repetition rate will benefit from the parallel development of slow extraction.

Next steps

If the necessary efficiency for the post-acceleration of stable Hg ions can be achieved, the next step will be to submit a full proposal that requests the provision of ^{182,184}Hg beams. Because the most likely showstopper is the presence of contaminant beams, the experimental programme will include test experiments before entering the production phase.

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