Lifetime Measurements and Coulomb Excitation of Light Hg Nuclei

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Abstract. Two complementary experimental programs have taken place to investigate the origin and evolution of shape coexistence in the light mercury region. Recoil Distance Doppler-shift measurements were performed at the University of Jyväskylä utilizing the Köln plunger device in conjunction with the JUROGAM + RITU + GREAT setup. In addition, Coulomb excitation measurements of ^{184,186,188}Hg were performed at REX-ISOLDE using the MINIBALL Ge-detector array. The results of the lifetime measurements of the yrast states up to $I^{\pi} = 10^{+}$ in ^{182}Hg are reported. Preliminary analysis of the Coulomb excitation data is also discussed.

Keywords: Coulomb excitation, Recoil Distance Doppler-shift, lifetimes, shape coexistence, Hg
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INTRODUCTION

In light, even-mass mercury isotopes shape coexistence was first observed when isotope shift measurements revealed a sharp transition between ^{187}Hg and ^{185}Hg [1]. This was interpreted as being due to a transition from a weakly deformed oblate structure to a more deformed prolate one. It has been predicted for ^{184,186,188}Hg [2] that a $\beta_2 \approx -0.15$ oblate ground state band coexists with a $\beta_2 \approx 0.25$ prolate band. These N=104-108 mid-shell nuclei are thought to represent the zenith of shape coexistence in the region. Lifetime measurements will allow the experimental value of the magnitude of the quadrupole deformation parameter and the mixing of the two bands to be determined whilst Coulomb excitation measurements will allow the extraction of the sign of the quadrupole moment Q_0. This will improve the understanding of the evolution and origin of quadrupole collectivity and shape coexistence in neutron-deficient, mid-shell mercury nuclei.

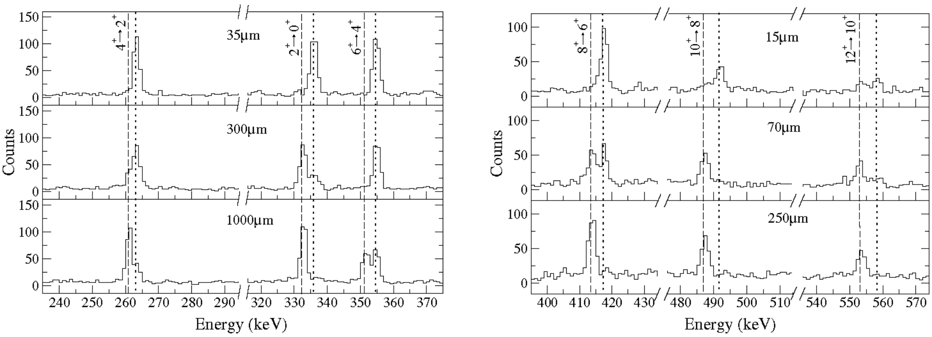

FIGURE 1. Recoil gated $\gamma\gamma$-coincidence spectra showing six yrast transitions for ^{182}Hg. Dashed and dotted lines indicate the fully Doppler-shifted and degraded components, respectively, of the γ rays under investigation.

RDDS LIFETIME MEASUREMENTS OF ^{182}Hg

Experimental Details

Excited states of ^{182}Hg were populated by the ^{96}Mo(^{88}Sr,2n)^{182}Hg reaction with the beam delivered by the K130 cyclotron at the Accelerator Laboratory of the University of Jyväskylä at an energy of 351 MeV, producing an initial recoil velocity of 0.042c. A stretched, self-supporting 1 mg·cm^{-2} thick ^{96}Mo target was housed in the Köln plunger device along with a 1 mg·cm^{-2} Mg degrader foil. Prompt γ rays gated with recoils detected at the focal plane were measured at 15 target-to-degrader distances ranging from 15 μm to 3000 μm. Prompt γ rays were detected at the target position by JUROGAM, an array of 43 BGO Compton-suppressed high-purity Ge detectors. Of the 43 detectors, only 15 were positioned at an angle with respect to the beam line that was suitable for Recoil Distance Doppler-Shift (RDDS) measurements; five detectors at an angle of 138°, ten at an angle of 154°. The standard target chamber of JUROGAM was replaced by the Köln plunger device. The use of the degrader foil rather than the standard stopper foil inside the plunger device was in this instance required, as the detection of recoiling fusion-evaporation products was needed for the employment of the recoil gating technique. To optimise both the transmission of the fusion-evaporation residues through the gas filled separator RITU, [3] and the magnitude of the Doppler-shift difference of γ rays emitted before and after the degrader foil, a $1\,\mathrm{mg{\cdot}cm^{-2}}$ Mg degrader foil was used. This provided the recoils with the necessary energy loss for a noticeable change in Doppler-shift, whilst only reducing the transmission efficiency by a factor of two thirds [4].

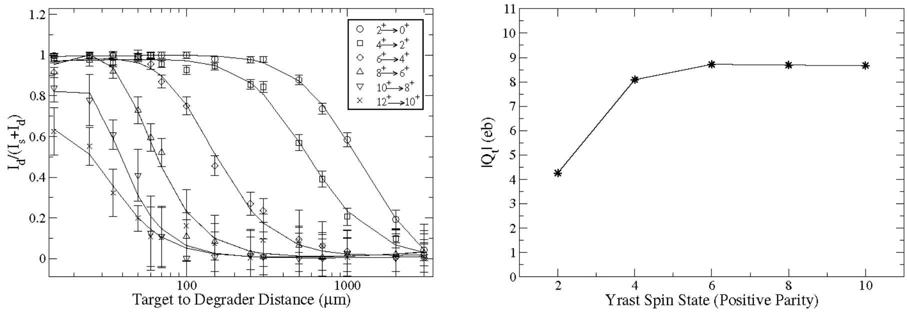

FIGURE 2. Left panel: Decay curves of yrast transitions under study in ^{182}Hg extracted from $\gamma\gamma$-coincidence spectra. Smooth lines are drawn as a guide only. Right panel: Average values for the transitional quadrupole moment, $|Q_t|$ for the corresponding yrast levels in ^{182}Hg.

Preliminary Results

Recoil-gated $\gamma\gamma$-coincidence spectra were obtained for ^{182}Hg from each of the 15 target-to-degrader distances. Sample spectra are show in Fig. 1 where the evolution of the fully shifted and degraded components is clear. The production of $\gamma\gamma$-coincidence matrices for ^{182}Hg enabled one to gate on the full line shapes of directly feeding transitions. This ensured that the detrimental effects of unobserved side feeding to the extraction of lifetimes were not encountered. Decay curves for each observed yrast transition in ^{182}Hg were produced and normalised to the sum of the intensities of the shifted (I_s) and degraded (I_d) components, $I_d/(I_d+I_s)$ (see left panel Fig. 2). Lifetimes were extracted for each observed transition using the Differential Decay Curve Method (DDCM) [5]. The resulting preliminary lifetimes are average values obtained from the separate analysis of the data recorded with the two JUROGAM rings. The resulting magnitude of deformation is seen to change quite dramatically from the 2^+ state to the 4^+ state and remain approximately constant thereafter. The right panel of Fig. 2 shows the evolution of the transition quadrupole moment, $|Q_t|$, with respect to the yrast state spin. The almost constant nature of the quadrupole moment from the 4^+ state onwards suggests the states are members of a rotational band with the same intrinsic structure. The $|Q_t|$ value of the 2^+ state is significantly lower suggesting a change to a less collective structure.

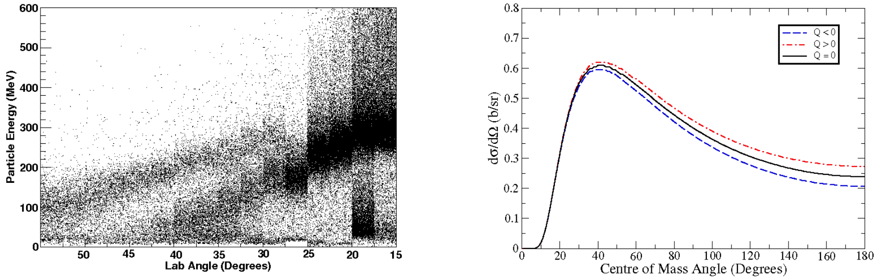

FIGURE 3. Observed Kinematics for ^{186}Hg on ^{120}Sn (left panel). The right panel shows the sensitivity to the quadrupole moment, Q_t, of the differential cross section, $d\sigma/d\Omega$.

COULOMB EXCITATION OF ^{184,186,188}Hg

Experimental Details

Beams of ^{184,186,188}Hg were provided by ISOLDE and post accelerated by the linear accelerator REX [6], for the first time, to an energy of 2.85 MeV/u and delivered to the target position of the highly segmented, high resolution MINIBALL Ge-detector array. The nuclei were charge bred in the electron beam ion source REXEBIS [6] to charge states of 43^+ (^{184,186}Hg) and 44^+ (^{188}Hg). The isotopes produced by this process passed through REX with an efficiency of 0.19%, one tenth of what was expected. Post accelerated beams of mercury isotopes were delivered to ^{120}Sn and ^{107}Ag targets at intensities of 3000 pps (^{184}Hg) and $1.05\text{x}10^5$ pps (^{186,188}Hg). Coulomb-excited beam and target particles were detected by the CD detector, consisting of four independent double-sided silicon strip quadrants capable of providing position, energy loss and particle identification information within an angular range of 15° - 53°.

Preliminary Analysis

The low Coulomb excitation cross section for states in ^{120}Sn meant a complimentary target was required to normalise the Hg transitions. The use of ^{107}Ag as a secondary target meant the cross normalisation technique was possible, as low lying states in ^{107}Ag have sufficient Coulomb excitation cross section. The kinematics observed when using a ^{120}Sn target are close to what was predicted. At low centre-of-mass (COM) angles ^{120}Sn is indistinguishable from Hg, though the cross section is not sensitive to the quadrupole moment in this angular range (see Fig. 3). Inside the angular range in which the cross section is sensitive to the quadrupole moment tin and mercury are discernible. This will enable the yields for each to be extracted in this angular range and prolate or oblate structure to be assigned to all three mercury nuclei investigated. Fig. 4 shows the γ-ray yields for ^{184}Hg and ^{188}Hg. For all three nuclei the $2_1^+ \rightarrow 0_1^+$ transitions have been observed enabling the $\langle 0^+ \| E2 \| 2^+ \rangle$ and the $\langle 2^+ \| E2 \| 2^+ \rangle$ matrix elements to be obtained.

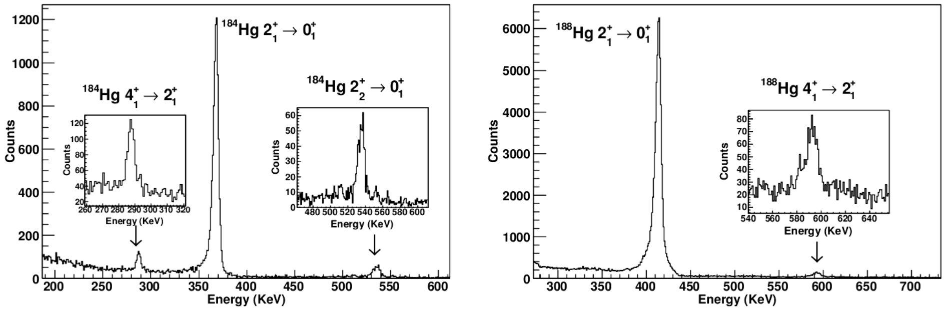

FIGURE 4. Particle-gated γ-ray spectra for ^{184}Hg (left) and ^{188}Hg (right) on ^{120}Sn.

For the case of ^{184}Hg the $4_1^+ \rightarrow 2_1^+$ and the $2_2^+ \rightarrow 0_1^+$ transitions have been observed enabling the $\langle 2^+ \| E2 \| 4^+ \rangle$ and $\langle 0^+ \| E2 \| 2_2^+ \rangle$ matrix elements to be extracted respectively for this nucleus. The former will be obtained in ^{188}Hg, as the $4_1^+ \rightarrow 2_1^+$ transition is observed in the spectra of this nucleus.

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