Direct collectivity measurements via Coulomb excitation

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Introduction

The shape of the an atomic nucleus can reflect the spatial distribution of the nucleus. Shape coexistence in heavy nuclei poses a strong challenge to nuclear models, where several competing shape minima are found close to the ground state. One of the interesting classic region for investigating this phenomenon is in the region around Z = 82 and the neutron midshell at N = 104. The nuclear shape coexistence is in the proton-rich nuclei around shell closure in this region, where the strong oblate and prolate shapes compete with low-lying spherical configurations. The Physics behind this question can be directly addressed in the REX-ISOLDE through Coulomb excitation as accelerated beams of proton-rich mercury, lead, polonium and radon are available [1]. The mercury isotopes can be obtained in an isobarically pure form from a molten lead primary target, while a thorium carbide target and cooled transfer line can be used to obtain pure beams of light radon isotopes.

It is clear from the energy-level systematics of the even-spin positive-parity states in the light even-mass radon isotopes, where one can observe decreasing excitation energy of the 2^+ state towards ^{198}Rn. The radon isotopes (Z = 86) can be expected to have similar proton-hole analogs to the platinum isotopes, where spectroscopic information on deformed intruder states exists beyond the neutron midshell. A corresponding deviation from sphericity at N = 116 is observed in the mean-square-charge radii, earlier still than in the Po isotopes. This may indicate that there is indeed a region of deformation towards the neutron midshell that is unreachable within the current experimental limitations. A more detailed understanding, with complementary experimental probes, of the isotopes around this transition region, $^{198-204}$Rn (N = 112 − 118), would help to determine if this behavior is, in fact, attributable to the presence of shape-coexisting intruder states.

Several of the expected members of vibrational multiplets are missing in ^{202}Rn and ^{204}Rn [2], although it is not presently clear if this is attributable to an experimental limitation. Partial low-lying level schemes of interest are shown in Fig. 1. Because low-lying 0^+ states are key to the understanding of these nuclei, exploring the possibility of populating

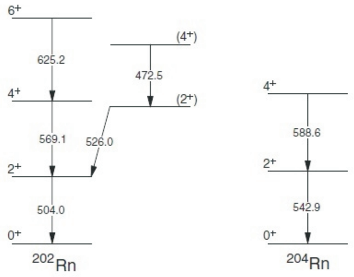

FIG. 1: Partial level schemes for ^{202}Rn and ^{204}Rn showing low-energy states.

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a 0_2^+ state via a two-step Coulomb excitation process is desirable.

Experiment and Analysis

Radioactive beams of ^{202}Rn and ^{204}Rn were produced at the ISOLDE facility [1] in CERN via bombardment of a uranium-carbide primary target with 1.4-GeV protons from the Proton Synchrotron Booster. The target-ion-source coupling in this experiment was key to reducing isobaric impurities expected when working with a noble-gas beam. A plasma ion source was utilized and an extraction voltage of 30 kV was applied along the transfer line and continuously cooled by a water flow to suppress the transport of less volatile elements. At the beginning of the running period, the yield of the two radioactive species were measured using the dedicated ISOLDE tape station and found to be 9×10^5 ions/μC (^{202}Rn) and 2×10^7 ions/μC for ^{204}Rn. The singly charged ions were accumulated and cooled in an ion trap, REX-TRAP. At intervals of 58 ms, the potential barrier was lowered, allowing bunches of cooled ions to escape into an electron-beam ion source, REX-EBIS [3], where the charge state of the ions was increased by charge breeding up to 47^+. The ^{202}Rn and ^{204}Rn beams were then accelerated to 2.9 and 2.845 MeV/u, respectively, by the REX linear accelerator.

The secondary radioactive beams were incident on thin metallic foil targets positioned at the center of the Miniball Ge array [4]. The isobaric purity of the beam was monitored through inspection of the γ-ray spectrum obtained with a Ge detector positioned at the beam dump, approximately 3 m downstream of the target chamber. Fig. 2 is showing the γ-ray deexcitation spectra associated with the Coulomb excitation of (a) ^{202}Rn, (b) ^{204}Rn on ^{109}Ag at 2.90 MeV/u, Doppler corrected for projectiles (black) and target recoils (red).

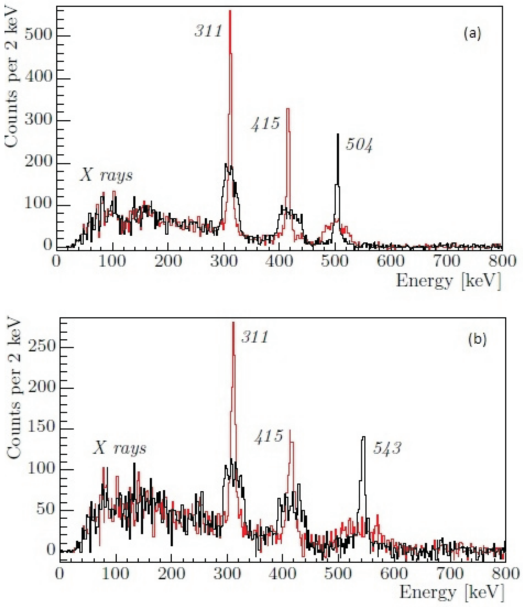

FIG. 2: γ-ray deexcitation spectra associated with the Coulomb excitation of (a) ^{202}Rn, (b) ^{204}Rn on ^{109}Ag at 2.90 MeV/u, Doppler corrected for projectiles (black) and target recoils (red).

Results

The electric-quadrupole (E2) matrix element connecting the ground state and first excited 2_1^+ state was extracted for both ^{202}Rn and ^{204}Rn, corresponding to B(E2; $2_1^+ \to 0_1^+$) $= 29^{+8}_{-8}$ and 43^{+17}_{-12} W.u., respectively. Additionally, $E2$ matrix elements connecting the 2_1^+ state with the 4_1^+ and 2_2^+ states were determined in ^{202}Rn.

Acknowledgments

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