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Spectroscopy of ^{193}Bi

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Abstract. An experiment aiming to study the shape coexistence in ^{193}Bi has been performed at the Accelerator laboratory of the University of Jyväskylä, Finland (JYFL). Many new states have been found, hugely extending the previously known level scheme of ^{193}Bi. The $I^{\pi} = \frac{29}{2}^{+}$ member of the $\pi i_{13/2}$ band de-excites also to the previously, only tentatively placed long-lived isomeric state. This link determines the energy of the isomeric state to be 2260(1) keV and suggests a spin and parity of $\left(\frac{27}{2}^{+}\right)$. The half-life of the isomeric state was measured to be 84.4(6) μs. A level structure on top of this isomeric state was constructed. However, transition directly depopulating this state could not be identified. A superdeformed band almost identical to that present in the neighboring isotope ^{191}Bi has been identified.

1 Introduction

In certain nuclear mass regions, low-lying excited states can be associated with a variety of nuclear shapes. One such region with the large selection of nuclei in which coexistent deformed configurations at relatively low excitation energies have so far been observed, has a proton number close to the magic $Z = 82$ and lie in the neutron mid-shell region. There have been two main approaches on how to explain these structures, namely either the intruder picture, associated with shell-model intruder states formed by exciting protons across the magic shell gap [1] or an alternative approach provided by the Nilsson model [2]. As the bismuth nuclei have only one extra proton coupled to $Z = 82$ proton magic lead core, ^{193}Bi is a unique nucleus for the investigation of the shape coexistence and studies of the isomeric states built on the multiquasiparticle configurations. ^{193}Bi has shown itself to be just on the edge between very neutron deficient odd-A prolate bismuth nuclei on the left [3] and heavier odd-A bismuth isotopes with the absence of any regular bandlike structures for the low-lying states on the right in the chart of nuclei [4]. Moreover, searching for highly excited superdeformed bands for better understanding of nuclear properties under extreme deformation has proven itself to be very efficient in this region of the nuclear chart [5].

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2 Experimental setup

The ^{193}Bi nuclei were produced in the total fusion-evaporation reaction ^{165}Ho(^{32}S,4n)^{193}Bi at the bombarding energy of 152 MeV. The reaction products were studied using in-beam γ-ray spectroscopy combined with decay spectroscopy. The fully digitized JUROGAM2 array was used to detect prompt γ rays at the target position. The array consisted of 24 Clover and 10 Phase1 or GASP Compton-suppressed HPGe-detectors. The JUROGAM2 array was coupled to the gas-filled high-transmission recoil separator RITU [6] to separate the nuclei of interest from the unwanted beam and beam-like components. The ions transported through the separator were subsequently implanted in the GREAT focal plane spectrometer system [7] for the identification of fusion products of interest. The main instrument of the GREAT spectrometer - the double-sided silicon strip detector (DSSD) was used for the implantation of the fusion evaporation recoils and for the detection of their subsequent decays such as α decay (DSSD-Y side) or internal conversion (DSSD-X side). To collect the α particles and conversion electrons that have escaped from the DSSD, the PIN silicon detectors were mounted in a box arrangement upstream from the DSSD. A planar Ge-detector was mounted directly behind the DSSD to detect low energy γ rays and X-rays. A set of three clover Ge-detectors was added to face the GREAT chamber from the sides and from above to detect higher energy γ rays. All data channels were recorded synchronously using the triggerless total data readout (TDR) [8] data acquisition system. This allowed for using the very selective recoil-decay tagging, isomer-tagging and recoil gating techniques [9].

3 Results

3.1 Long-lived isomer

In the present work, the half-live and excitation energy of the long-lived isomer, only tentatively placed in the previous work [10], together with the transitions (see Fig. 1) feeding the isomeric state, have been unambiguously determined: $T_{1/2} = 84.4(6)$ μs (see Fig. 2), $E_{ex} = 2260(1)$ keV. This isomeric state is partially populated by the decay of the recently found higher lying states of the $\pi i_{13/2}$ band, indicating the spin and parity of this state to be $\left(\frac{27}{2}^{+}\right)$. The spin and parity of the states shown in Fig. 1 have been determined and confirmed, respectively, by the angular distribution (DCO) and γ-ray linear polarization measurements. We suggest the configuration of this isomer to be $\pi h_{9/2}$ coupled to the isomeric 9^- state of the ^{192}Pb core, which would be the maximum allowed spin for such configuration. Since no transition corresponding to the energy difference of $\sim$131 keV is seen in the focal plane γ-ray spectra or in the PIN diodes spectra, this isomeric state most likely decays via cascade of the low energy, highly converted transitions, overcoming the spin difference of $\Delta j = 4\hbar$ ($\frac{27}{2}^{+} \rightarrow \frac{19}{2}^{+}$, see Fig. 1). None of these transitions could be firmly identified in the planar Ge-detector intended for detecting low energy γ rays or in the PIN diodes meant for detecting conversion electrons.

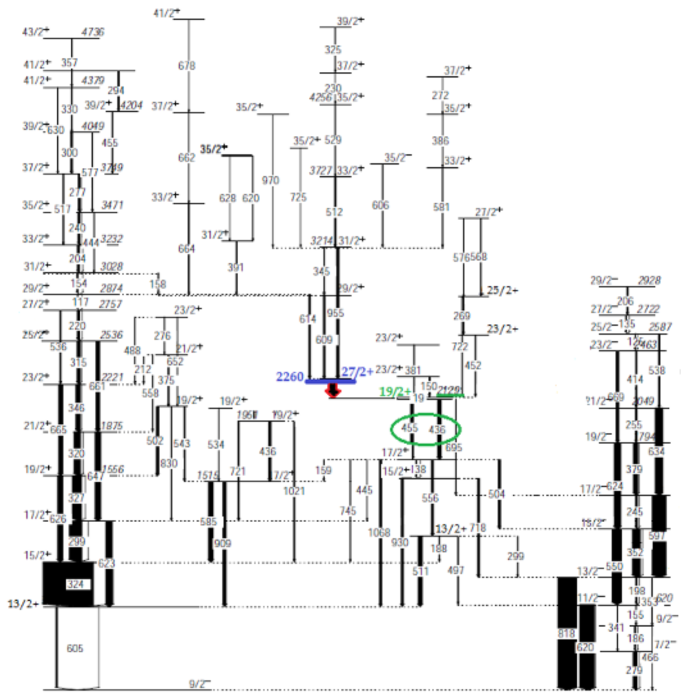

Figure 1. (Color online) Partial level scheme of ^{193}Bi, showing the structure built on top of the long-lived isomer with only tentative spin assignment of the states, together with the feeding of the long-lived isomer from the upper part of the $\pi i_{13/2}$ band. Red-border arrow indicates a cascade of the low-energy transitions discussed above.

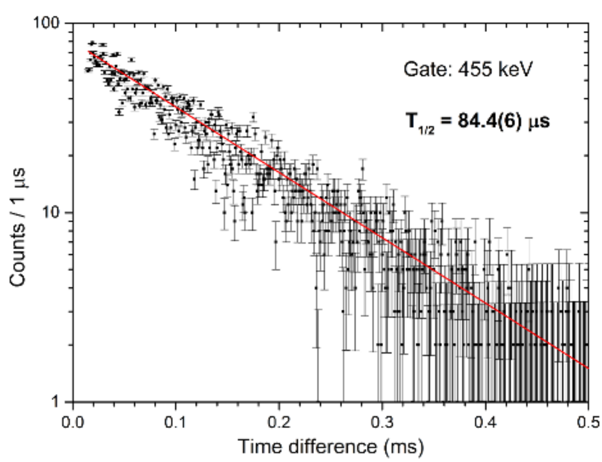

Figure 2. Time difference spectrum of the recoil formation and observation of the 455 keV transition (as one of the many transitions below the long-lived isomer) in the focal plane clover detector. The exponential decay law was fitted to the data and is shown as the solid line through data points.

3.2 Superdeformed band

A superdeformed band has been identified in ^{193}Bi. The spectrum gated on the transitions in band is shown in Fig. 3. In contrast with ^{193}Bi, two superdeformed bands have been found in ^{191}Bi [11]. They are interpreted as signature partner bands built on the proton $i_{11/2}$ $\frac{1}{2}^+$ [651] configuration. The newly found band in ^{193}Bi is identical to the other of the bands in ^{191}Bi. In both nuclei, superdeformed bands were found in the data obtained by tagging on alpha decays of the $\frac{1}{2}^+$ intruder states. However, no connecting links have been found yet.

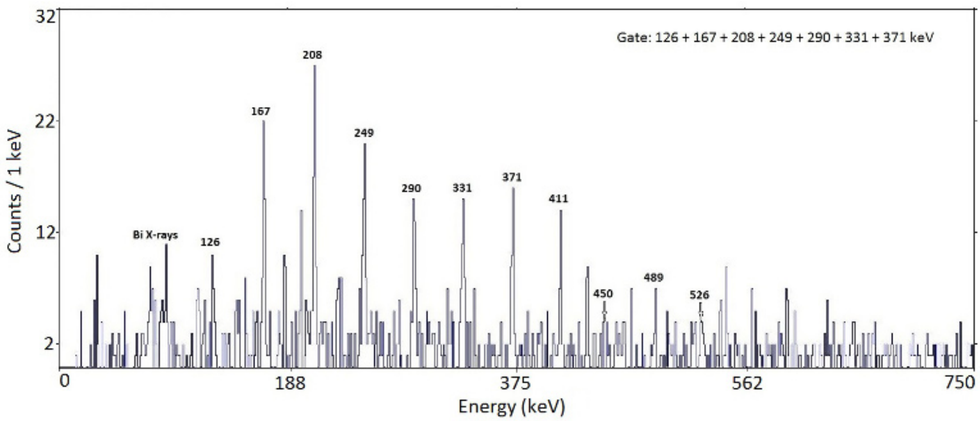

Figure 3. The γ-ray spectrum of the superdeformed band assigned to ^{193}Bi as found in the $\frac{1}{2}^+$ proton intruder α-decay tagged spectrum.

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