EPJ Web of Conferences **66**, 02047 (2014)
DOI: 10.1051/epjconf/ 20146602047

Spectroscopy of ^{193}Bi

A. Herzáň[1, a], S. Juutinen[1], T. Grahn[1], P.T. Greenlees[1], K. Hauschild[1,2], U. Jakobsson[1], P. Jones[1,3], R. Julin[1], S. Ketelhut[1,4], M. Leino[1], A. Lopez-Martens[1,2], P. Nieminen[1], M. Nyman[5], P. Peura[1], P. Rahkila[1], S. Rinta-Antila[1], P. Ruotsalainen[1], M. Sandzelius[1], J. Sarén[1], C. Scholey[1], J. Sorri[1], and J. Uusitalo[1]

[1] *Department of Physics, University of Jyväskylä, P.O. Box 35, Jyväskylä FI-40014, Finland*
[2] *CSNSM , IN2P3-CNRS, F-91405 Orsay Campus, France*
[3] *iThemba Laboratory for Accelerator Based Sciences, P.O. Box 722, 7129 Somerset West, South Africa*
[4] *TRIUMF, Westbrook Mall, Vancouver, BC, V6T 2A3, Canada*
[5] *European Commission, Joint Research Centre, IRMM, Retieseweg 111, B-2440 Geel, Belgium*

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].

a. e-mail: andrej.a.herzan@jyu.fi

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: $T_{1/2} = 84.4(6)\ \mu$s (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 ∼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.

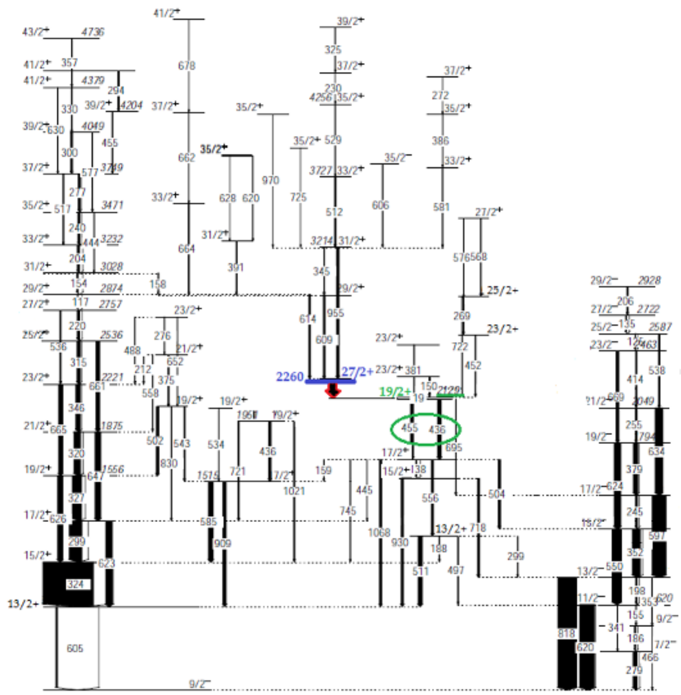

Figure 1. (Color online) Partial level scheme of ^{193}Bi, showing the structure built on top of the long-lived isomer with only tentative spin assignment of the states, together with the feeding of the long-lived isomer from the upper part of the $\pi i_{13/2}$ band. Red-border arrow indicates a cascade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

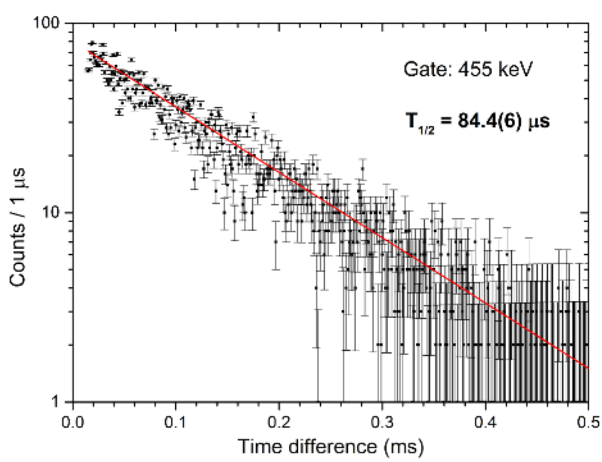

Figure 2. Time difference spectrum of the recoil formation and observation of the 455 keV transition (as one of the many transitions below the long-lived isomer) in the focal plane clover detector. The exponential decay law was fitted to the data and is shown as the solid line through data points.

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.

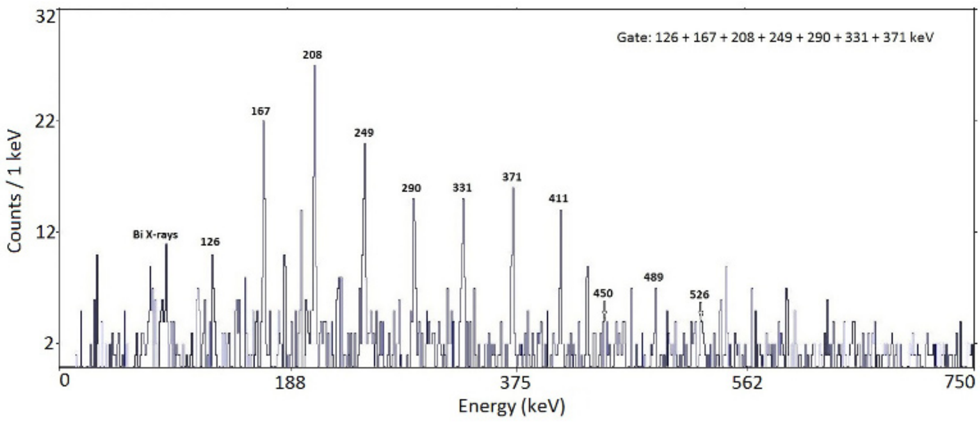

Figure 3. The γ-ray spectrum of the superdeformed band assigned to ^{193}Bi as found in the $\frac{1}{2}^{+}$ proton intruder α-decay tagged spectrum.

4 Acknowledgments

This work was supported by the Academy of Finland under the Finnish CoE Programme. The authors would like to thank the GAMMAPOOL European Spectroscopy Resource for the loan of germanium detectors for JUROGAM II.

References

[1] K. Heyde, P. Van Isacker, M. Waroquier, J.L. Wood and R.A. Meyer, Phys. Rep. **82**, 291 (1983)
[2] S.G. Nilsson, Kgl. Dan. Viden. Selsk. Mat. Fys. Medd. No. **16**, 29 (1955)
[3] A. Hürstel et al., Eur. Phys. J. **A 15**, 329 (2002)
[4] T. Chapuran et al., Phys. Rev. **C 33**, 130 (1986)
[5] R.M. Clark et al., Phys. Rev. **C 53**, 117-123 (1996)
[6] J. Sarén et al., Nucl. Instr. and Meth. **A 654**, 508-521 (2011)
[7] R.D Page et al., Nucl. Instr. and Meth. **B 204**, 634-637 (2003)
[8] I.H. Lazarus at al., IEEE Trans. Nucl. Sci. **48**, 567 (2001)
[9] P. Rahkila, Nucl. Instr. and Meth. **A 595**, 637-642 (2008)
[10] P. Nieminen et al., Phys. Rev. **C 69**, 064326 (2004)
[11] M. Nyman, PhD Thesis, JYFL Research Report 12/2009