COMPETING DECAY MODES OF A HIGH-SPIN ISOMER IN THE PROTON-UNBOUND NUCLEUS ^{158}Ta*

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(Received January 29, 2015)

An isomeric state at high spin and excitation energy was recently observed in the proton-unbound nucleus ^{158}Ta. This state was observed to decay by both α and γ decay modes. The large spin change required to decay via γ-ray emission incurs a lifetime long enough for α decay to compete. The α decay has an energy of 8644(11) keV, which is among the highest observed in the region, a partial half-life of 440(70) μs and changes the spin by $11\hbar$. In this paper, additional evidence supporting the assignment of this α decay to the high-spin isomer in ^{158}Ta will be presented.

DOI:10.5506/APhysPolB.46.695
PACS numbers: 23.20.Lv, 23.35.+g, 23.50.+z, 23.60.+e

1. Introduction

The recent observation of an isomer at high spin, 19^-, and excitation energy, 2809 keV, in the proton-unbound nucleus ^{158}Ta [1] raised the possibility of a blurring to the limits of the observable nuclear landscape due to the possible existence of isomers. These isomers can be sufficiently long

* Presented at the Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", Zakopane, Poland, August 31–September 7, 2014.

to survive a separator flight time and hence be observed at the focal plane. Both α- and γ-decay modes have been associated with this isomer, as shown in Fig. 1. In this paper, additional experimental evidence supporting the previous assignment of a new α decay to this isomer will be presented.

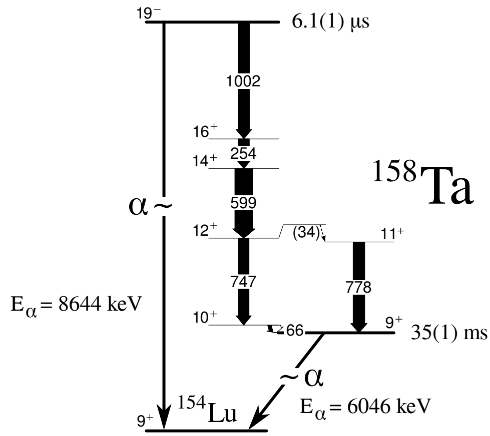

Fig. 1. Partial level scheme of ^{158}Ta including competing decay branches from the 19$^-$ isomer. Both α- and γ-decay branches lead to the population of ^{154}Lu. Transition energies are in keV.

2. Experimental details

The experiment was performed at the University of Jyväskylä accelerator laboratory. The ^{158}Ta nuclei were produced in excited states using fusion-evaporation reactions induced by ^{58}Ni ions, with a beam energy of 255 MeV, incident on an isotopically enriched ^{102}Pd target of thickness $\sim$1 mg cm^{-2}. The JUROGAM HPGe spectrometer surrounded the target position and was used to measure prompt γ-ray emissions. The RITU gas-filled separator [2] transported recoiling reaction products to its focal plane and also suppressed unreacted beam. The GREAT spectrometer [3] was situated at the focal plane. Recoiling nuclei that entered GREAT passed through a multiwire proportional counter (MWPC) before being implanted into one of two adjacently mounted double-sided silicon strip detectors (DSSDs). Subsequent radioactive α decays were detected by the DSSDs but not the MWPC, thus distinguishing between signals associated with recoils and decays. A planar and a Clover Ge detector were used to measure X-rays and γ-rays from the DSSDs that were emitted during decay processes. Data were recorded using a triggerless data acquisition system [4], time stamped with a precision of 10 ns, and events were built in software [5]. Reaction channels were identified using standard tagging techniques [6, 7].

3. Evidence for the α-decay branch

Gamma-ray transitions observed at the focal plane revealed the presence of the isomer at high spin and excitation energy, which primarily γ decays via a 1002 keV transition [1]. A new α decay (E_α = 8644(11) keV) was observed to decay with a half-life similar to that of this isomer. The decay curves of the α- and γ-decay branches are compared in Fig. 2 (a)–(b). The measured half-life of the α-decay branch is 6.4(4) μs, which is consistent with the 6.1(1) μs half-life associated with the γ-decay branches. The same γ-ray transitions feeding the isomer are observed in association with both the α- and γ-decay branches. Based on this evidence, the new α decay was assigned to the same high-spin isomer.

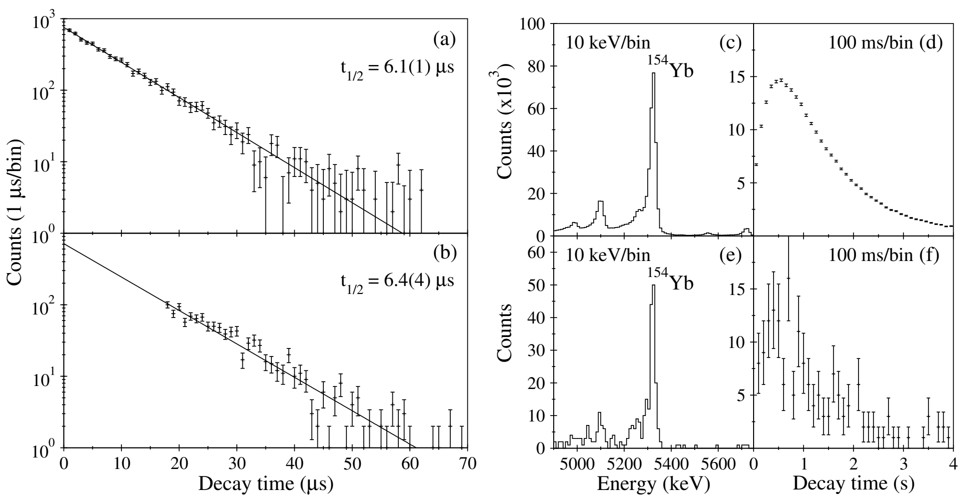

Fig. 2. Decay curves for (a) the 1002 keV γ-ray transition and (b) the 8644 keV α decay, which have consistent half-lives. (c) The energy and (d) decay time of decays following the α decay of the 9^+ state in ^{158}Ta. (e) The energy and (f) decay time of decays following the 8644 keV α decay from the high-spin isomer in ^{158}Ta. The 5331 keV ^{154}Yb peak appears strongly above the background in both (c) and (e). The ^{154}Yb decay times in (d) and (f) reveal the unobserved β decay of ^{154}Lu, completing the decay chain from ^{158}Ta$\to^{154}$Lu$\to^{154}$Yb$\to^{150}$Er, and have consistent peaks. These similarities reinforce the assignment of the 8644 keV α decay to the 19^- isomer in ^{158}Ta.

Further evidence that this α decay originates from ^{158}Ta can seen in the subsequent decays, which are shown in Fig. 2 (c)–(f). The γ-decay branches of the isomer feed the 9^+ low-lying metastable state. The decay of this state is the first step in the following decay chain:

$$^{158}\mathrm{Ta}_{9^+} \to \alpha(6046) \to ^{154}\mathrm{Lu}_{9^+} \to \beta^+ \to ^{154}\mathrm{Yb}_{0^+} \to \alpha(5331) \to ^{150}\mathrm{Er}_{0^+}\,,$$

of which, in this experiment, only the α decays could be observed. The 5331 keV ^{154}Yb α decay [8] is observed strongly above the background following the decay of the 9^+ state in ^{158}Ta. Furthermore, the decay curve reveals the unobserved β-decay component from ^{154}Lu. A similar energy and decay curve can be seen following the decay of the 8644 keV α decay, which suggests that it feeds the same decay chain, and thus originates from ^{158}Ta. A closed Q-value loop incorporating the α- and γ-decay branches depopulating the $^{158}\mathrm{Ta}_{19^-}$ isomer and populating the $^{154}\mathrm{Lu}_{9^+}$ state is evidence that the 8644 keV α decay is a direct transition between these two states [1]. The total Q-values via the α-decay branch and via the γ-ray branch are 8869(11) and 8870(14), respectively. To account for the change in spin and parity, an angular momentum change of $11\hbar$ occurs as a result of this decay.

4. Summary and acknowledgements

The 8644 keV α decay was previously assigned to the 19^- isomer in ^{158}Ta based on the feeding γ-ray transitions, the half-life and the Q-value, all of which are consistent with observations associated with the γ-decay branch. The subsequent radioactive decay data presented in this paper is consistent with a decay from ^{158}Ta, which reinforces the previous assignment.

This work has been supported through the UK Science and Technology Facilities Council, the Academy of Finland under the Finnish Centre of Excellence Programme 2006–2011 (Nuclear and Accelerator Based Physics contract 213503), EURONS (European Commission contract No. RII3-CT-2004-506065) and the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DEAC02-06CH11357. The UK/France (STFC/IN2P3) Loan Pool and GAMMAPOOL network are acknowledged for the EUROGAM detectors of JUROGAM. T.G., P.T.G. and C.S. acknowledge the support of the Academy of Finland, contract numbers 131665, 111965 and 209430, respectively.

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