Author(s): Scholey, C.; Cullen, D.M.; Paul, E.S.; Bentlby, M.A.; Boston, A.J.; Bruce, A.M.; Butler, P.A.; Caamaño, M.; Dorvaux, O.; Enqvist, T.; Fox, C.; Garcés, Narro J.; Greenlees, P.T.; Helariutta, K.; Jones, P.M.; Joss, D.T.; Julin, R.; Juutinen, S.; Kankaanpää, H.; Kettunen, H.; Kuusiniemi, P.; Leino, M.; Muikku, M.; Nieminen, P.; Rahkila, P.; Scraggs, H.C.; Shepherd, S.L.; Stezowski, O.; Uusitalo, J.; Walker,

Title: Recoil Isomer Tagging on Proton-Rich Odd–Odd N=77 Isotones 142Tb and 144Ho

Year: 2001

Version: Published version

Please cite the original version:

Scholey, C., Cullen, D.M., Paul, E.S., Bentlby, M.A., Boston, A.J., Bruce, A.M., Butler, P.A., Caamaño, M., Dorvaux, O., Enqvist, T., Fox, C., Garcés, N. J., Greenlees, P.T., Helariutta, K., Jones, P.M., Joss, D.T., Julin, R., Juutinen, S., Kankaanpää, H., . . . Walker, P.M. (2001). Recoil Isomer Tagging on Proton-Rich Odd–Odd N=77 Isotones 142Tb and 144Ho. Acta Physica Polonica B, 32(3), 1005-1008.
https://www.actaphys.uj.edu.pl/fulltext?series=Reg&vol=32&page=1005

RECOIL ISOMER TAGGING ON PROTON-RICH ODD–ODD $N = 77$ ISOTONES ^{142}Tb AND ^{144}Ho*

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(Received October 30, 2000)

The isomeric structure of the $N = 77$ isotones $^{142}_{65}$Tb and $^{144}_{67}$Ho have been studied with the ^{92}Mo(^{54}Fe, *xpn*) fusion evaporation reaction at the University of Jyväskylä. The Jurospehere II germanium array was employed in conjunction with the RITU gas filled recoil separator. The feeding and decay of a 500(20) ns isomeric state in ^{144}Ho has been established for the first time together with states built upon the known 15 μs isomer in ^{142}Tb. The behavior of these new structures above the isomers suggest that they are low deformation configurations which display signs of triaxiality.

PACS numbers: 21.10.Re, 23.20.–g, 23.20.Lv, 27.60.+j

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* Presented at the XXXV Zakopane School of Physics "Trends in Nuclear Physics", Zakopane, Poland, September 5–13, 2000.

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1. Introduction

The $N = 77$ isotones with $A \approx 140$ lie between two regions which have been relatively well studied. The more proton-rich region has been studied recently due to the interest in proton emission. Even though these nuclei are difficult to access, their study has been possible as the emission of a proton can be used as a tag which increases the channel selection significantly. On the other hand slightly more neutron-rich nuclei are easily accessible through fusion evaporation reactions. The nuclei in the area discussed here have small cross-sections in comparison to the more neutron-rich nuclei populated and as they do not proton decay no such particle emission tag is available. In this case some other form of channel selection is required and as there are a wealth of isomers in this region they can be utilised as a signature with which to tag the nuclei. The recoil-isomer tagging technique was first employed at the University of Jyväskylä to establish the rotational band above the $K^\pi = 8^-$ isomer in ^{138}Gd [1] and proved to be very successful. This subsequent experiment has enabled the feeding and decay of a new 500(20) ns isomeric state in ^{144}Ho to be observed, together with states built upon the known 15 μs isomer in ^{142}Tb. Such isomers are a result of the high-j states which involve the intruding $h_{11/2}$ proton orbit. An additional factor is that the last protons occupy the lower part of the shell and tend to favour collective prolate deformation ($\gamma = 0°$), where as the neutrons lying in the upper part of the $h_{11/2}$ shell tend to be of a collective oblate shape ($\gamma = -60°$). The data presented here give an insight to the single-particle configurations of these isomers and demonstrate how the competing factors discussed above give rise to triaxial nuclei.

2. Recoil-isomer tagging

The experimental setup consisted of the Jurosphere II germanium array coupled with the RITU gas filled separator [2]. At the focal plane of RITU was a MWPC (Multi-Wire Proportional Counter) [3] and a silicon strip detector. Surrounding the focal plane detector chamber was a small array of five germanium detectors. The recoil-isomer tagging technique correlates prompt and delayed events across isomeric states. This is achieved by detecting γ-ray transitions at either end of RITU [2] corresponding to the target position and focal plane respectively. Delayed γ-rays are detected within a 32 μs time gate after the implantation of a recoil into the silicon detector. The nuclei were populated using the reaction ^{92}Mo(^{54}Fe, pxn) at beam energies of 226 and 236 MeV delivered by the K130 cyclotron at the University of Jyväskylä, Finland. During the experiment, a total of 6×10^6 recoil gated prompt events were correlated with delayed events in $\approx$5 days at a beam energy of 236 MeV and 4×10^5 events in 1 day at 226 MeV. A complete description of the experimental detail can be found in Ref. [4].

3. ^{142}Tb and ^{144}Ho

The main γ rays in a 10–30 μs time gate were 37, 137, 165, and 303 keV Fig. 1(b). These are known transitions in ^{142}Tb below the 15 μs isomer [5].

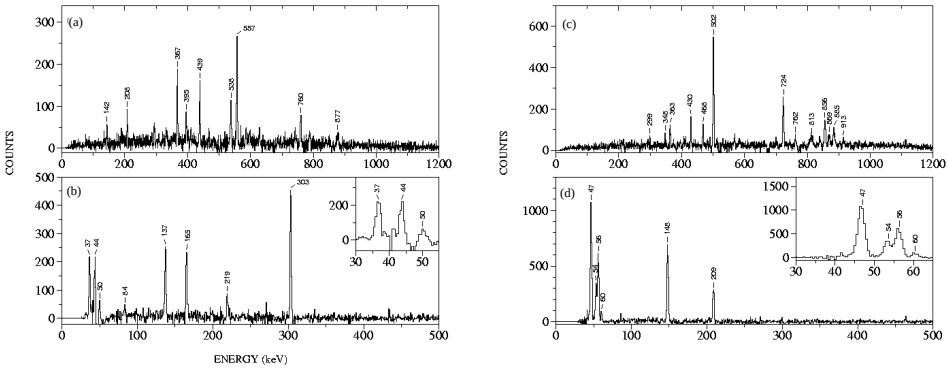

Fig. 1. Gamma-ray spectra: (a) — prompt ^{142}Tb, (b) — delayed ^{142}Tb, (c) — prompt ^{144}Ho, (d) — delayed ^{144}Ho. (a) and (c) are produced by gating on the γ rays in (b) and (d) respectively and vice versa.

By gating on this band and setting a time gate comparable to the isomer lifetime we were able to establish the decays above the isomer shown in Fig. 1(a) and construct the level scheme shown in Fig. 2. When a short time gate of ≈ 100 ns was set on the delayed γ-rays the main transitions were 56, 61, 148 and 209 keV with X-rays of 47 and 53 keV shown in Fig. 1(d). The coincident X-rays confirmed that these γ-rays belong to a holmium isotope and the relative intensities of these peaks at the two different beam energies allow them to be firmly assigned to ^{144}Ho. An isomeric state was identified and measured to have $t_{1/2} = 500(20)$ ns. Prompt (see Fig. 2(c)) and delayed events were then correlated to identify the bands above the isomer shown in Fig. 2.

Theoretical Total Routhian Surface (TRS) [6, 7] and Wood–Saxon Cranked Shell Model (CSM) [8,9] calculations have been performed for this data. The TRS calculations gave a deformation of $\beta_2 = 0.192$, $\beta_4 = -0.22$ and $\gamma = -30°$ which represents a triaxial shape. This large γ-deformation is responsible for the large energy splitting of the single-particle orbitals, which is manifested as the signature split bands above the isomers shown in Fig. 2. The calculations suggest that the single particle configurations for these nuclei are as follows $\pi h_{11/2} \otimes \nu(h_{11/2}, f_{7/2})$ or $\pi h_{11/2} \otimes \nu(s_{1/2}, d_{3/2})$. Unfortunately the low statistics for this data does not permit the spins and configurations of these bands to be unambiguously assigned.

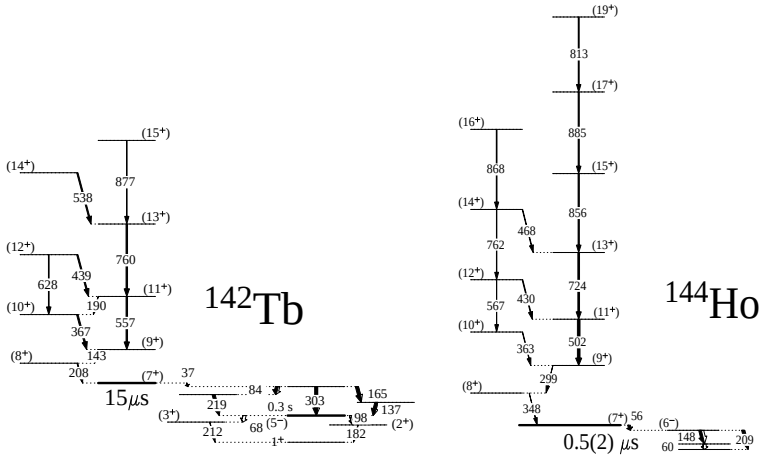

Fig. 2. The level scheme of ^{142}Tb from the present work and [5] and the newly established level scheme for ^{144}Ho.

In summary we have identified bands built upon the known isomeric state in ^{142}Tb and observed excited states in ^{144}Ho. Spin and configuration assignments have been put to these nuclei but only with more statistics can these be confirmed. In the future we hope to study ^{140}Eu which will complete the $N = 77$ isotone chain and give further insight into this region of triaxiality.

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