Eur. Phys. J. A **20**, 47–48 (2004)
DOI 10.1140/epja/i2002-10320-5

THE EUROPEAN PHYSICAL JOURNAL A

New nanosecond isomers identified with the AFRODITE array

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Received: 12 November 2002 /
Published online: 17 February 2004 –

Abstract. The Recoil Shadow Anisotropy Method for measuring nanosecond lifetimes is being implemented on the AFRODITE array and four new isomers were found in ^{198,200}Bi, ^{164}Ta and ^{162}Lu.

PACS. 21.10.Tg Lifetimes

1 Introduction

Lifetimes of the order of a few nanoseconds are not easy to measure using only the timing spectra of the large Ge detectors usually included in the big γ-ray arrays. Thus, in order to search for nanosecond isomers, we applied the Recoil Shadow Anisotropy Method (RSAM) [1]. In this contribution, the application of the RSAM with the AFRODITE array will be discussed and the first new nanosecond isomers identified will be shown.

2 The RSAM and the AFRODITE array

The AFRODITE array [2] is operated at the iThemba LABS near Cape Town, South Africa. It consists of up to 8 clover detectors (EUROGAM-II type) and up to 8 four-way segmented LEPS detectors, arranged in rings at 45°, 90° and 135° with respect to the beam direction. Hevimet collimators are placed in front of the clover detectors.

For delayed γ-rays emitted from recoiling residual nuclei, the collimators impose a shadow effect on the clover crystals of the array. In the following, the clover elements located at 39°, 84° and 129° are referred to as shaded elements, and the others as un-shaded. In order to identify isomers, the difference (sum) spectra are generated as the difference (sum) of the spectra obtained in the un-shaded and shaded elements. The prompt transitions, emitted at the centre of the array, are detected through the same solid angles by the un-shaded and shaded clover elements, while for the delayed transitions a difference in the the counting rate appears due to the collimator shadow effect. Thus, only delayed transitions will be observed in the difference spectrum, while all γ-rays will be present in the sum spectrum. Therefore, delayed transitions can be identified and isomeric states can be located in the level scheme.

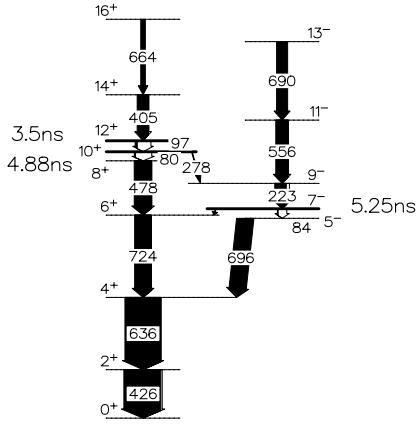

Fig. 1. Partial level scheme of ^{196}Hg.

In order to test this technique with the AFRODITE array, it was applied for the known isomers in ^{196}Hg. A partial level scheme of ^{196}Hg is shown in fig. 1 [3]. The ^{196}Hg nuclei were produced using the ^{198}Pt(α,6n)^{196}Hg reaction at beam energy of 65 MeV. The target was a thin

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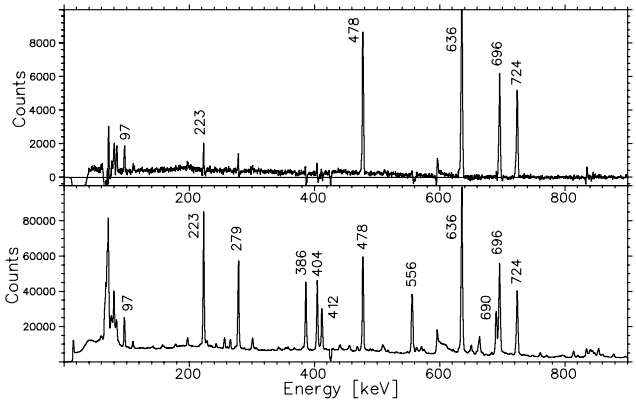

Fig. 2. Difference (top panel) and sum (bottom panel) spectra gated on the 426 keV transition in ^{196}Hg.

Table 1. The measured anisotropy of the delayed transitions in ^{196}Hg, using the spectra gated on the 556-, 223- and 405-keV transitions.

E_γ	g556keV	g223keV	g405keV
97	–	–	9.1%
426	14.0%	14.3%	22.3%
478	–	–	19.7%
636	13.3%	14.2%	22.5%
696	11.8%	12.0%	30.3%
724	–	–	19.4%

self-supported foil of 0.2 mg/cm^2 and the recoil velocity of the residual nuclei was $v/c = 0.23(5)\%$. Six clover detectors were placed at 90° with respect to the beam direction and were used to test the RSAM technique.

Difference and sum spectra, gated on the $2^+ \rightarrow 0^+$ transition in ^{196}Hg are shown in fig. 2. From consideration of the observed delayed transitions, the 12^+ and 7^- levels are identified as isomeric. The anisotropies of the delayed γ-rays were measured using the difference and sum spectra gated on the 556-, 223- and 405-keV transitions and are listed in table 1. The uncertainty of the anisotropy values was estimated to be $\sim 1\%$. The anisotropies obtained for the transitions below the 7^- level using the former two gated spectra are similar for all the observed transitions in both spectra. This shows that: i) there is no evidence for another isomeric level below the 7^- level, ii) the choice of the gating transition is not important, iii) no evidence for dependence of the measured anisotropy on the energy of the γ-ray transition (for $\sim 400 \leq E_\gamma \leq \sim 700$ keV) is found. The measured anisotropy of the delayed transitions below the 12^+ level obtained using the latter gated spectra shows anisotropy of only 9% for the 97 keV γ-ray, while it is $\sim$ 20% for the 478- and 724-keV transitions. This clearly indicates the presence of an additional isomeric state between these transitions. Indeed, the 10^+ level is known to have a nanosecond half-life. The large anisotropy of the 696 keV transition is consistent with the transition location below the 12^+, 10^+, and 7^- isomeric states, and for the 636- and 426-keV transitions it is consistent with their position below the 12^+ and 10^+ isomeric states with partial feeding from a path passing through the 12^+, 10^+ and 7^- isomers. In order to extract the half-lives of isomers using the average values of the anisotropy, a calibration curve for the AFRODITE array has to be generated and tested. This work is still in progress, and thus we are only using the RSAM technique for identifying isomers for now.

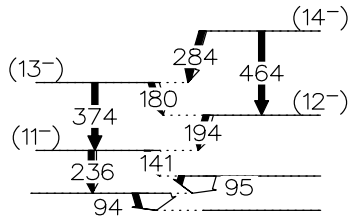

Fig. 3. Partial level scheme of ^{164}Ta.

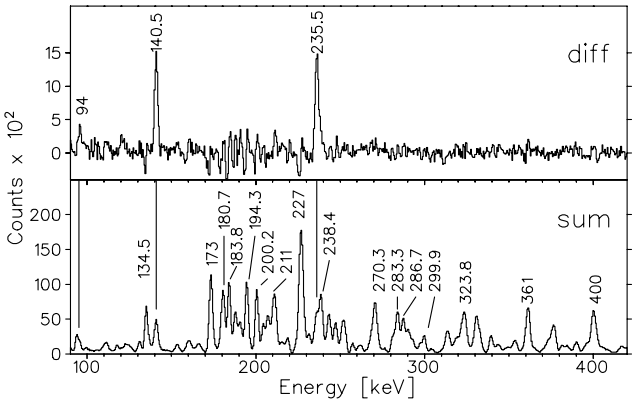

Fig. 4. Difference (top panel) and sum (bottom panel) spectra gated on the Ta X-rays.

3 Search for new isomers

Using the RSAM technique, new isomers have so far been identified in the ^{198,200}Bi, ^{164}Ta and ^{162}Lu nuclei. A partial level scheme of ^{164}Ta is shown in fig. 3 [4]. The ^{164}Ta nuclei were produced using the ^{142}Nd(^{27}Al,5n) reaction at beam energy of 150 MeV. The difference and sum spectra, gated on the Ta X-rays are plotted in fig. 4. Only the 95-, 141- and 236-keV transitions are present in the difference spectrum, showing that the (11^-) level should have a nanosecond half-life. This is the first nanosecond isomer found at this level in this mass region, suggesting that the bandhead of the yrast band might be lying at much higher spin than usually believed. More comprehensive studies are planned in ^{162}Lu in order to locate the position of the bandhead and measure its spin.

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