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*Short note*

# Systematics of related high-spin isomers in $^{144}$Sm and other N = 82 nuclei

K. Jessen[1], M. Bergström[2], P. von Brentano[1], A. Dewald[1], B. Herskind[2], H. Meise[1], C. Schumacher[1], G. Sletten[2], O. Stuck[1], D. Weißhaar[1], I. Wiedenhöver[1], J. Wrzesinski[2]

[1] Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany
[2] Niels Bohr Institute, University of Copenhagen, DK-4000 Roskilde, Denmark

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**Abstract.** An in-beam experiment with the reaction $^{122}$Sn($^{27}$Al,4np) at 127 MeV was performed at the NORDBALL multi-detector array in Roskilde. It provided evidence for a new high-spin isomer in $^{144}$Sm. This isomer with $T_{1/2} = (2.6 \pm 0.5)$ ns at an excitation energy $E_x = 9232$ keV seems to belong to a family of isomers of similar configuration in neighbouring $N = 82$ nuclei.

**PACS.** 21.10.Tg Lifetimes – 25.70.Gh Compound nucleus – 27.60.+j $90 \leq A \leq 149$

The existence of high-spin isomers (yrast traps) in the massregion around the quasi doubly magic nucleus $^{146}$Gd had been predicted by Døssing et al. [1]. In $N = 83$ isotones such isomers had been found from $^{144}$Pm to $^{151}$Er [2], and furthermore there had been reports on isomers in $^{145}$Eu [3], $^{146}$Gd [4], and $^{147}$Tb [5]. Excitation energies, half lives, and spins of the latter ones are of the same order of magnitude, i.e. 8–9 MeV, a few ns, and $\approx 20\hbar$, so that another high-spin isomer might be found in the neighbouring $^{144}$Sm.

In order to search the high-spin states of $^{144}$Sm for isomers, we analysed an experiment performed with the NORDBALL spectrometer at the Niels Bohr Institute's Tandem Accelerator Laboratory in Roskilde. The chosen compound reaction $^{122}$Sn($^{27}$Al,4np)$^{144}$Sm was carried out at a beam energy of 127 MeV with a 95.8% enriched target of 1.5 mg/cm$^2$ on a 10 mg/cm$^2$ $^{181}$Ta backing. Altogether $6.8 \times 10^8$ $\gamma$–$\gamma$-coincidence events were collected.

The NORDBALL array consists of 20 HPGe detectors surrounding an inner ball of 60 $BaF_2$ segments. The latter supplies a precise time reference signal given by the $BaF_2$ element that fires first. For any coincidence event the time differences between the reference signal and the Ge signals were recorded.

During the off-line analysis we set a gate on the characteristic 800 keV transition of $^{144}$Sm, in order to separate the required data from other outgoing channels well. Subsequently $4.5 \times 10^5$ events were sorted into a gated energy-time matrix, which was scanned for isomers. For $\gamma$-ray transitions of interest cuts on the energy axis of our gated matrix were made, and resulting background-subtracted time spectra were analysed by means of the centroid-shift method [6].

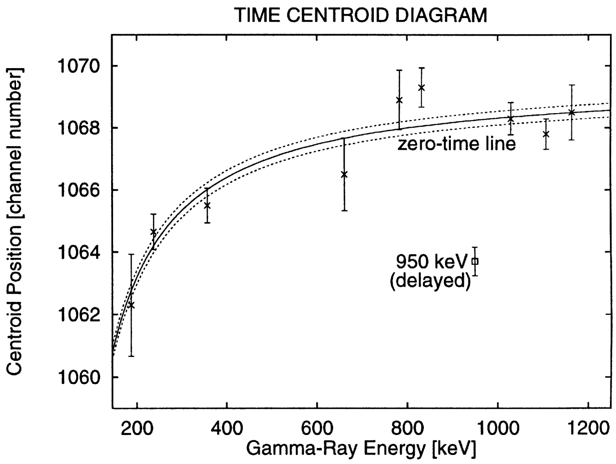


**Fig. 1.** Centroid positions of the time distributions for $^{144}$Sm transitions above 8282 keV exciation energy. Crosses (×) denote positions belonging to prompt transitions, which give the zero-time line, and a quad ( ) denotes the delayed one deexciting the isomeric level

For the observed transitions we obtained three kinds of time distributions. With the use of the $^{144}$Sm levelscheme given by E. Ott et al. [7] time centroids revealed the following results (Figs. 1 and 2):

Above an excitation energy of 8282 keV all transitions turned out to be prompt with the exception of the 950 keV transition, which is delayed providing evidence for a new high-spin isomer. Below the 8282 keV level the time

**Table 1.** Possible configurations for $N = 82$ high-spin isomers. The configuration of the Gd isomer was taken from [9]

| nucleus | $T_{1/2}$ | excitation energy | possible configuration relative to $^{146}$Gd | |
|---|---|---|---|---|
| $^{144}$Sm | 2.6(5) ns | 9232 keV | $[\pi(h^2_{11/2}(d^{-4}_{5/2})_0),$ | $\nu(f_{7/2}i_{13/2}(d^{-2}_{3/2})_0)]_{20^-}$ |
| $^{145}$Eu | 3.7(4) ns | 8528 keV | $[\pi(h^2_{11/2}(d^{-3}_{5/2})_{3/2}),$ | $\nu(f_{7/2}i_{13/2}(d^{-2}_{3/2})_0)]_{43/2^-}$ |
| $^{146}$Gd | 4.3(2) ns | 8915 keV | $[\pi(h^2_{11/2}(d^{-2}_{5/2})_0),$ | $\nu(f_{7/2}i_{13/2}(d^{-2}_{3/2})_0)]_{20^-}$ |
| $^{147}$Tb | 1.8(3) ns | 7763 keV | $[\pi(h^2_{11/2}d^{-1}_{5/2}),$ | $\nu(f_{7/2}i_{13/2}(d^{-2}_{3/2})_0)]_{43/2^-}$ |

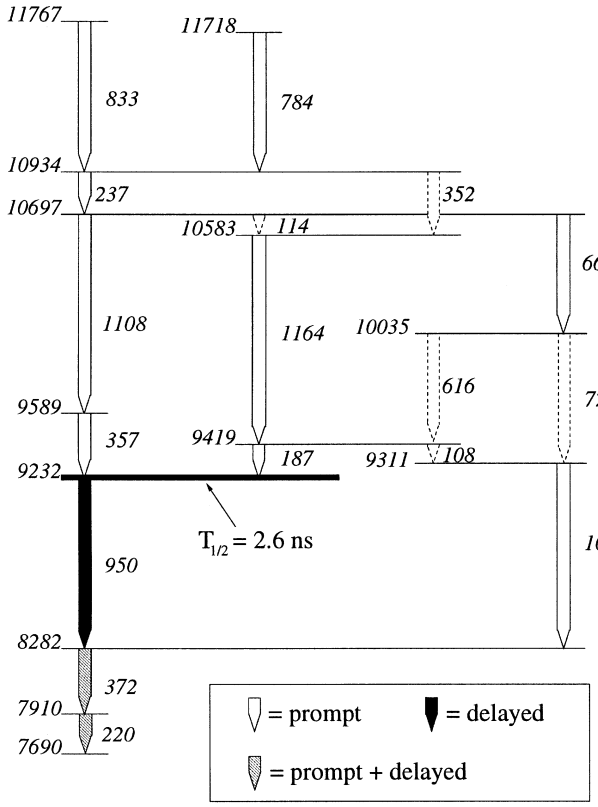


**Fig. 2.** Partial high-spin level scheme of $^{144}$Sm according to [7]. Dashed arrows denote transitions that could not be examined due to contaminations or low statistics

distributions exhibited both a prompt and a delayed part, because this level is fed by the prompt 1030 keV transition, which passes the isomer by. Thus, the isomeric level was located at an excitation energy of 9232 keV.

For a quantitative analysis of any centroid shift we had to find its relationship to a corresponding half-life $T_{1/2}$. Therefore we created a time-calibration by making use of well-known low-spin isomers belonging to byproducts of our reaction (see [3] for details). Hence follows, that the shift observed for the 950 keV transition gives a half life of

$$T_{1/2}(9232 \text{ keV}) = (2.6 \pm 0.5) \text{ ns}.$$

E. Ott proposed spin assignments for some $^{144}$Sm levels with excitation energies between 8.5 and 10.6 MeV [7]. She proposed a spin $J$ of 18 or 20, which is comparable to the spin values for the isomers in the isotones $^{145}$Eu, $^{146}$Gd and $^{147}$Tb, which have spins between $20\hbar$ and $43/2\hbar$ [4, 5, 8] and similar energies. Thus a systematic interpretation emerges. Unfortunately a definite parity assignments has been given only for the $^{146}$Gd isomer, but as follows a proposal for the configurations of these isomers is given in analogy to the $N = 83$ isomers mentioned above:

The configuration of the $20^-$ isomer in $^{146}$Gd is well known and identical to a corresponding isomer in $^{147}$Gd with the exception of an extra $h_{9/2}$ neutron [9]. For further $N = 83$ isomers calculations within the deformed independent particle model (DIPM) showed that those configurations differ from $^{147}$Gd only by their number of $d_{5/2}$ proton holes [2]. It is quite suggestive to construct the configurations of the $N = 82$ isomers by taking the configuration of the $^{146}$Gd isomer and adding to or removing from it a suitable number of $d_{5/2}$ proton holes (see Table 1).

In addition DIPM calculations associated a $43/2^-$ state in $^{147}$Tb with a configuration which is in conformity with our proposed systematics [10]. Nevertheless, model calculations have to be carried out in order to give well-founded configuration assignments. Moreover, there is a need for further experimental information on these isomers, such as definite parities and $g$ factors.

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