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Short note

A new high spin isomer in ^{146}Eu

E. Ideguchi[1,2], X.H. Zhou[2], Y. Gono[3], S. Mitarai[3], T. Morikawa[3], M. Kidera[3], H. Tsuchida[3], M. Shibata[3], H. Watanabe[2,3], M. Miyake[3], A. Odahara[4], M. Oshima[5], Y. Hatsukawa[5], S. Hamada[5], H. Iimura[5], M. Shibata[5], T. Ishi[5], T. Kishida[2], M. Ishihara[2]

[1] Department of physics, Royal Institute of Technology, Frescativägen 24, 104 05 Stockholm, Sweden
[2] The Institute of Chemical and Physical Research (RIKEN), Hirosawa 2-1, Wako, Saitama 351-0198, Japan
[3] Department of Physics, Faculty of Science, Kyushu University, Hakozaki 6-10-1, Fukuoka 812-8581, Japan
[4] Nishinippon Institute of Technology, Fukuoka 800-0394, Japan
[5] Japan Atomic Energy Research Institute(JAERI), Ibaraki 319-1195, Japan

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Abstract. High spin states of ^{146}Eu were studied by in-beam gamma ray spectroscopic techniques using ^{140}Ce(^{10}B,4n)^{146}Eu and ^{139}La(^{13}C,6n)^{146}Eu reactions. The level scheme was established up to 10MeV. A new high spin isomer with 10ns half life was found. Configurations of yrast states were understood by a weak coupling of $f_{7/2}$ neutron to those of ^{145}Eu.

PACS. 21.10.-k Properties of nuclei; nuclear energy levels – 23.20.Lv Gamma transitions and level energies – 25.70.Gh Compount nucleus – 27.60.+j $90 \leq A \leq 149$

In N=83 isotones high spin isomers were found systematically [1–5]. Their excitation energies and half-lives were found almost same as 8.5MeV and 1μs, respectively. Among them the level structure of ^{147}Gd was most extensively studied both experimentally and theoretically. The calculation of the deformed independent particle model (DIPM) [6] reproduced well the experimentally determined deformation parameters β of three isomeric states in ^{147}Gd [7]. The results of experiments for ^{147}Gd [7], ^{145}Sm [8] and ^{148}Tb [9] as well as the DIPM calculation suggest that the existence of high spin isomers was originated from abrupt shape changes from spherical to oblate shapes.

Although ^{146}Eu is one of the N=83 isotones located in between ^{145}Sm and ^{147}Gd, high spin isomer was not found so far in spite of the systematic search in the region between Ba and Pb [10,11]. In the previous measurements, isomers with $T_{1/2} \leq 20$ ns could not be observed due to the limits of experimental arrangement. These results could not exclude the existence of a high spin isomer in ^{146}Eu with shorter half-lives than 20ns.

The level scheme of ^{146}Eu was reported [12] up to a (15^+) state at 3.47MeV. These levels were interpreted to originate from the coupling of one proton hole and one neutron particle, or octupole excitations built on low-lying two particle state. The high spin states above 3.5MeV level are expected to be the multi-particle-hole states of $f_{7/2}$ neutron and $d^{-1}_{5/2}$, $g^{-1}_{7/2}$ proton-holes and $h_{11/2}$ protons coupling with ^{146}Gd core. Especially, an $h_{11/2}$ proton plays an important role to build high spin states.

In order to establish the level structure above 3.5MeV level and search for a new high spin isomer, in-beam γ ray measurements were performed at Kyushu University and Japan Atomic Energy Research Institute (JAERI).

Since the complicated level structure of the odd-odd nucleus makes it difficult to extend its high spin level scheme, it is of great use to establish low spin states by using a reaction which brings low angular momentum. In the experiment at Kyushu University ^{140}Ce(^{10}B,4n)^{146}Eu reaction was chosen so that low lying states up to spin $\sim 20\ \hbar$ could be populated. A 50MeV ^{10}B beam was used to irradiate a ^{140}Ce target of 1.6mg/cm^2 thickness. Four Ge detectors with BGO anti-Compton shields (BGOACS) were used to acquire $\gamma - \gamma$ coincidence events. By analyzing the coincidence relations between the newly observed transitions and those previously reported, the level scheme up to 5MeV was established.

In the JAERI experiment a 98MeV ^{13}C beam was used to investigate higher spin states as well as high spin isomers. The RF-γ, $\gamma - \gamma$ coincidence and angular distribution measurements were performed by using 6 Ge detectors with BGOACS located at 35, 60, 90 and 150 degrees with respect to the beam axis. A pulsed beam having 250ns duration and 40ns width was used to find high spin

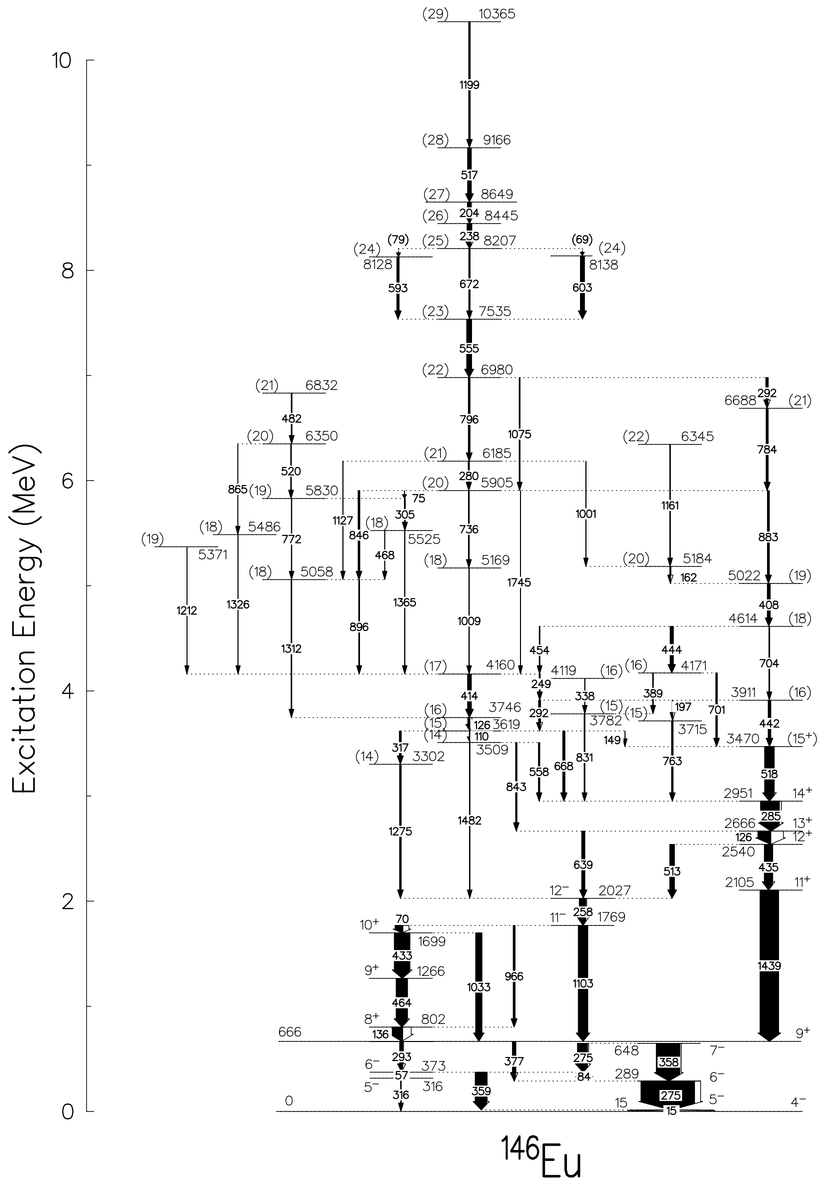

Fig. 1. Level scheme of ^{146}Eu constructed in the present study. Width of arrows is proportional to the intensities of transitions

isomers and to determine the half-lives of them. The level scheme was extended up to 10MeV analyzing the $\gamma - \gamma$ coincidence data. Spin assignment of each level was made based on the angular distribution analysis.

The level scheme of ^{146}Eu constructed in the present study is shown in Fig. 1. The order of transitions was determined by using coincidence relations and intensity balances.

In order to search for high spin isomers, RF-γ time spectrum was analyzed by gating on each γ ray transition. In Fig. 2(a), time spectra gated by a 1199keV transition (prompt) and 555keV transition (delayed) that is one of the delayed transitions deexciting a high spin isomer are shown. All transitions below the 8.649MeV level have delayed components with the same half lives, while the 1199keV transition has a prompt time structure.

The time spectrum of 517keV has also a delayed component but the slope is steeper than the other spectra as shown in Fig. 2(b). Since the 517keV and 518keV transitions are components of a doublet peak, the time spectrum of 517keV is strongly affected by the component of 518keV transition which is a transition between (15^+) and 14^+ states. By adding a prompt and a delayed time spectrum gated by 1199keV and 518keV peaks, respectively, with a normalization factor, the slope of the time spectrum for the 517keV transition was well reproduced. The delayed component in 517keV transition was estimated to be 40%, which was consistent with their intensities obtained by analyzing the doublet peak structure. Therefore, 517keV was interpreted as a prompt transition located above the high spin isomer, and the delayed component was originated from 518keV transition.

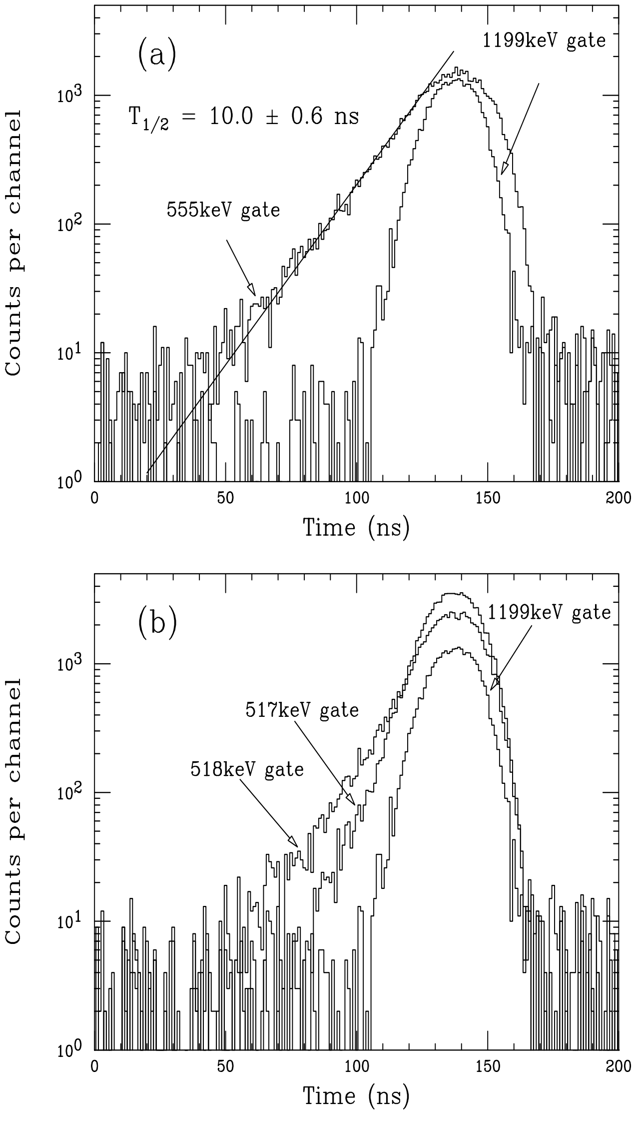

Fig. 2. (a) RF-γ time spectra gated by 1199keV (prompt) and 555keV (delayed). (b) Comparison of time spectra between 517keV and 518keV gate. Time spectrum of 1199keV transition (prompt) is also shown

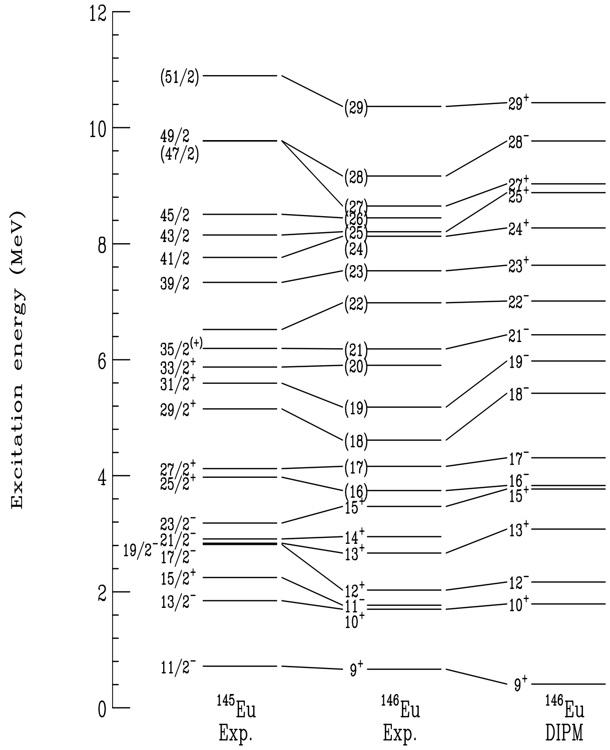

Fig. 3. Comparison of yrast levels of ^{145}Eu, ^{146}Eu and DIPM calculation. States connected between ^{145}Eu and ^{146}Eu levels are interpreted to have configurations of $\nu f_{7/2}$ coupled to those in ^{145}Eu

Based on these results it was concluded that the high spin isomer was located at 8.649MeV which is almost the same excitation energy as the other N=83 isotones. Applying the χ^2 fitting to the slope of the delayed components, half life of the high spin isomer was deduced to be 10.0 $\pm$ 0.6 ns.

In Fig. 3, yrast states of ^{146}Eu above 9^+ state (center) were compared with those of neighboring nucleus ^{145}Eu [13] (left side) and those obtained by a DIPM calculation (right side). Good correspondences were obtained between the levels of the two nuclei experimentally observed as well as those calculated by DIPM. It may indicate that most of the states of ^{146}Eu could be understood as resulted from the weak coupling of $f_{7/2}$ neutron to those of ^{145}Eu.

High energy γ transitions ($\geq$ 1.2MeV) between the levels at about 4MeV and 5.5MeV were also observed in the same energy region of the ^{145}Eu level scheme. These high energy γ transitions might be originated from the promotion of proton across the Z=64 shell gap. By taking similar interpretations as ^{145}Eu [13], these transitions were suggested as excitations from 4 quasi-particle(qp) states, $\nu f_{7/2} \otimes \pi h^2_{11/2} g^{-1}_{7/2}$, to 6 qp states, $\nu f_{7/2} \otimes \pi h^3_{11/2}(d_{5/2}/g_{7/2})^{-2}$ or $\nu f_{7/2} \otimes \pi h^2_{11/2}(d_{5/2}/g_{7/2})^{-3}$.

Configuration of the high spin isomer was suggested in the DIPM calculation as $[\nu f_{7/2} h_{9/2} i_{13/2} \otimes \pi h^2_{11/2} d^{-1}_{5/2}]_{27+}$, which is the same as that reported for ^{148}Tb [9]. Deformation parameter β was also calculated to be -0.178, an oblate deformation, as found in the other N=83 isotones. Levels between 5.8 and 7.8MeV in ^{145}Eu were reported to have $\nu\nu^{-1}$ or $\nu^2\nu^{-2}$ configurations by breaking the neutron N=82 core. By coupling a $\nu f_{7/2}$ to these configurations of ^{145}Eu, similar configurations as that of the high spin isomer such as $\nu f_{7/2} h_{9/2} i_{13/2} \otimes \pi h_{11/2}$ are obtained. These levels can appear at lower energy than the high spin isomer. Similarity of the configurations between the high spin isomer and these levels may quicken the decay of the isomer. It might be the reason why the high spin isomer of ^{146}Eu has much shorter half-life, 10ns, than those of the other N=83 isotones, $\sim 1\mu$s. On the other hand the high spin isomers with long half-lives in other isotones should be rather isolated from the levels with similar configurations.

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