Nucl. Sci. and Tech., Vol.6, No. 4 (2016), pp. 26-31

Nuclear Science and Technology

Journal homepage: https://jnst.vn/index.php/nst

First results in the study of level scheme for ^{172}Yb based on gamma-gamma coincidence spectrometer

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Abstract: Nuclear level scheme permits to determine nuclear level density, gamma strength function, and to evaluate nuclear models. In comparison to light nuclei, the structure of heavy nuclei is much more complicated because of their strong deformation. In order to study nuclear level scheme, gamma – gamma coincidence spectrometer with advantages of low Compton background and the ability of identifying correlated gamma transitionshas been often used. This paper presents the first results of an experimentalstudy of level scheme of ^{172}Yb using gamma – gamma coincidence spectrometer at the Dalat Nuclear Research Institute.

Keywords: *gamma - gamma coincidence, nuclear level scheme, ^{172}Yb.*

I. INTRODUCTION

Until now, level scheme, gamma transitions and their intensity are primary “ingredient” to determine level density parameters and gamma strength function of a nucleus in excited energy region from 2 MeV to less than neutron binding energy. In ENSDF library, the obtained nuclear levels and gamma transitions of ^{172}Yb are considerably determined by analyzing experimental data from ^{171}Yb(n,γ)^{172}Yb reaction [1]. Based on the neutron capture reaction with both thermal and 2 keV neutron, *Greenwood et al.*,[2] has detected, by using Ge(Li) detector, in total 127 primary gamma transitions and 136 secondary gamma transitions, including their intensities from the prompt gamma spectrum of ^{172}Yb. Using the same type of reaction with the use of pair formation spectrometer, *Gellety et al.*,[2] has measured the primary transitions of ^{172}Yb and the results were found in good agreement with *Greenwood et al.* It is inevitable that the number of gamma-rays detected in prompt gamma spectrum[2,3] relies on the energies resolution of their Ge(Li) detectors and the level density of ^{172}Yb.

The gamma-gamma coincidence method [4–6] has advantages in achieving the low Compton background and identifying the correlated gamma transitions. The advantages not only improve the detection limit gamma transition from (n,γ) reaction but also provide information of state, from which secondary transition decays. This method was applied in ref. [7] to measure Two-Step-Cascade intensities of ^{172}Yb from ^{171}Yb(n,γ)^{172}Yb reaction. At the same time, the spectroscopic data of ^{172}Yb were also presented but has not been shown in detail because of its low statisticsfor which only 4000 cascade events corresponding to the decays from the compound state to the ground state are collected.

https://doi.org/10.53747/jnst.v6i4.173
Received 24 November 2016, accepted 18 January 2017

For this reason, wehave measured the gamma cascades of ^{172}Yb from ^{171}Yb(n,γ)^{172}Yb reaction using the gamma-gamma coincidence spectrometer[5] with 10 times statistics higher than reported in ref [7], for the aim of improving knowledge of level scheme of ^{172}Yb.

II. EXPERIMENTAL

Experiment was performed at the tangential beam port of Dalat Nuclear Research Reactor (DNRR) using a gamma coincidence spectrometer[5], which was designed for measuring cascade gamma transitions. The neutron flux at target position was 1.7×10^5 n.cm^{-2}s^{-1} and beam diameter was around2.5 cm. The Cadmium ratio was 230 ± 20 using a Cadmium box with a thickness of 1 mm. The activated target was measured for approximately 800 hours in order to obtain at least 10000 useful events on each summation peak marked in Fig. **3**.

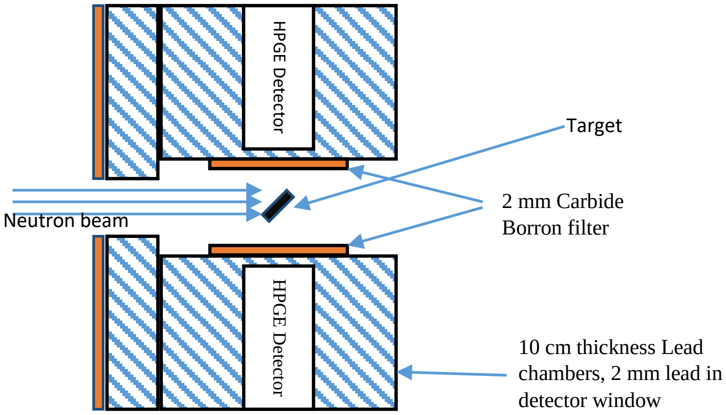

Fig. 1. Experimental arrangement for gamma coincidence

Experiment arrangement and detector parameters

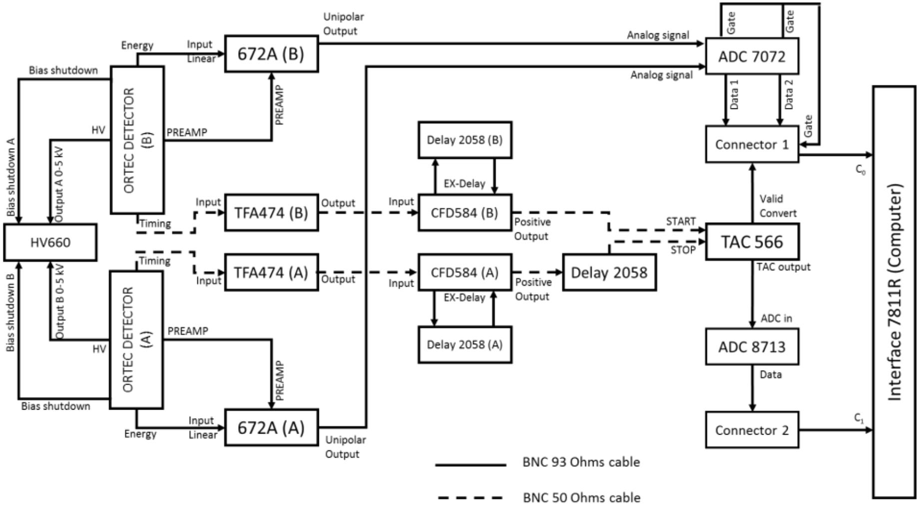

Fig. 2. Electronics configuration for gamma-gamma coincidence setup

As shown in Figure 1, two ORTEC coaxial HPGe detectors type GMX35 were used. The energy resolution of the detectors was 1.8 keV at 1332 keV peak of ^{60}Co. The detector efficiency is 35% relative to 3” × 3” NaI(Tl) scintillation detector. The detectors were located opposite to each other, perpendicular to neutron beam. Cube lead chambers of 10 cm thickness surrounded detectors for shielding from gamma background in the reactor building. In front of the detector windows, a lead plate of 2 mm was put in order to cut down X-rays, back-scattered and other low-energy photons, which would only increase the dead time of electronics. Between neutron beam and detectors, boron carbide filters were placed to protect detectors from neutron damage.

Target was put in the center of neutron beam, between the two detectors. The distance from detector windows to target was 5 cm.

Electronics arrangements

Electronics arrangement of gamma coincidence spectrometer is given in Figure 2 and the detail edope rating principle is given in [5]. However, two amplifiers, ORTEC 572A model, were replaced by 672 model ones. The range of time-to-amplitude (TAC) converter was set to 100 ns, and the coincidence resolving time was around 15 ns at Full Width Half Maximum (FWHM).

Target information

Ytterbium target was in powder form, and put in plastic bag. The target chemical form is Yb_2O_3, and the Ytterbium net mass is 500 mg. The abundanceof^{171}Yb in target is more than 95.5%, certificated by The Open Joint Stock Company “Isotope”.

Data analysis

The detail of the data treatment process can be found in[4]. Below we explain two main types of spectrum that we have used.

Summation spectrum: is the frequency histogram of summation of absorbed energy in two detectors for each coincident event. Analyzing peaks in the summation spectrum provide filter parameters for creating TSC spectrum.

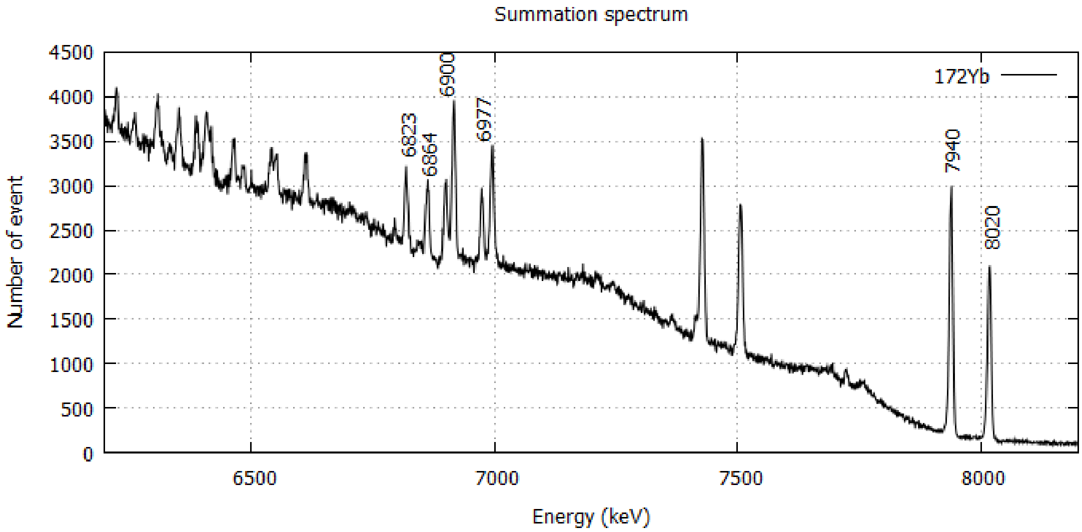

Fig. 3. Summation spectrum of ^{172}Yb. Gamma ray energies are in keV

TSC spectrum: is the frequency histogram of coincident events which contribute to the summation peaks (peaks appear in summation spectrum). In TSC spectrum, pairs of peaks, which are symmetric with respect to the center of the spectrum, correspond with gamma cascades.

Since the gamma-gamma coincidence technique is not able to indicate which gamma in the cascade comes from the primary transition, a general rule, which assumes that if the transitions appear in at least two TSC spectra, they are considered as the primary transitions, was proposed in ref. [4].However, this rule has not completely confirmed yet. Therefore, in order to ensure the reliability of data, in this work, we restrict to only analyzing the coincident events, which contain a transition that had been reported in ENSDF library as a primary transition.

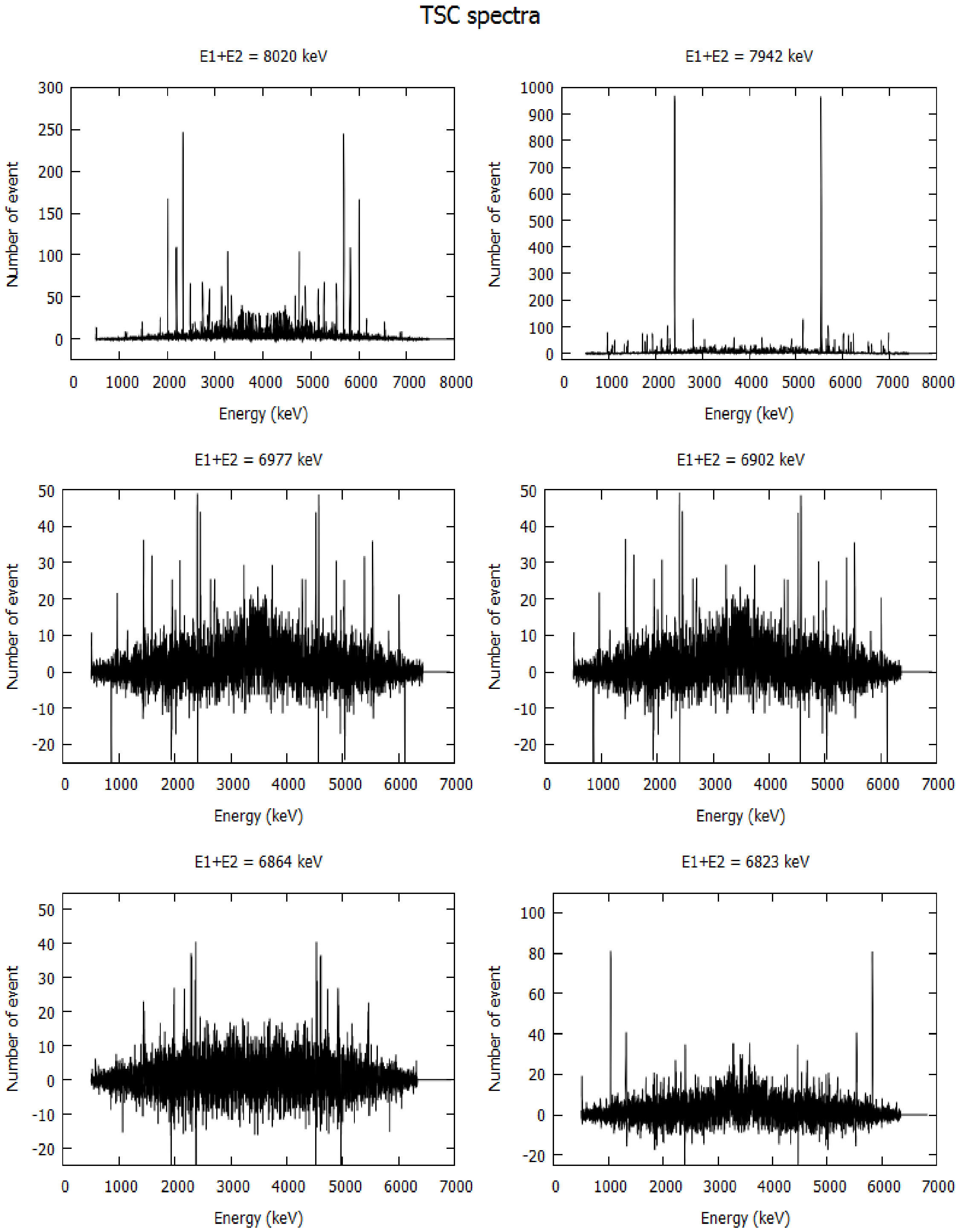

Fig. 4. TSC spectra of ^{172}Yb

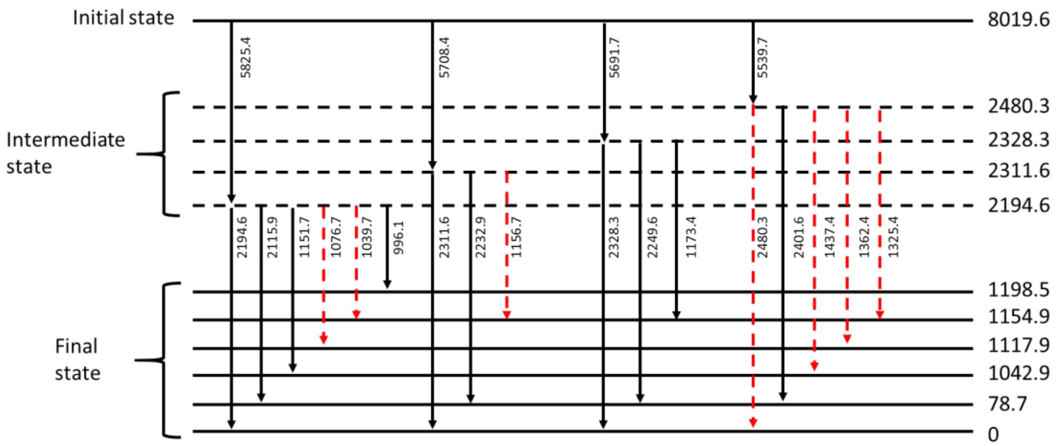

Fig.5. Part of ^{172}Yb level scheme, that contains new transitions detected in this work. Levels and gamma transitions are energy in keV.

IV. RESULTS AND DISCUSSION

The summation spectrum of ^{172}Yb is given in Figure 3. We found 6 summation peaks, correspond with 6 TSC spectra. The summation energies are marked in Figure 3.

All TSC spectra are shown in Figure 4. We have found 8 secondary transitions, which currently do not exist in ENSDF library. A list of these transitions is given in Table I. The uncertainty of energy is less than 0.3 keV for all experimental transitions. Part of level scheme, which contain these transitions is shown in Figure 5.

Table I. A list of gamma transitions, which were detected in this work. Some of secondary transitions (bold) currently do not exist in the ENSDF library.

Primary transition (keV)	Intermediate state (keV)	Secondary transition (keV)	Final state (keV)
5825.4	2194.6	2194.6	0
		2115.9	78.7
		1151.7	1042.9
		1076.7	1117.9
		1039.7	1154.9
		996.1	1198.5
5708.4	2311.6	2311.6	0
		2232.9	78.7
		1156.7	1154.9
5691.7	2328.3	2328.3	0
		2249.6	78.7
		1173.4	1154.9
5539.7	2480.3	**2480.3**	0
		2401.6	78.7
		1437.4	1042.9
		1362.4	1117.9
		1325.4	1154.9

Based on the coincident that the energies of primary gamma transitions, intermediate state, and final level are well-known, it can be said that our obtained transitions may be considered as new ones.

Besides, 43 transitions from following states 2607.7, 2627.7, 3038, 3130.1, 3261.1, 3346.7, 3382.7, 3558, 3682.2, 3741.5, 3767.8, 3799.8 keV were also detected. These states exist in ENSDF library, however there is a significantly lack of information such as spin and parity. In practice, only E1, M1 and E2 transitions are observed in the (n,2γ) reaction[4]. By knowing the type of transition, in combination with values of spin and parity of the corresponding first compound state and final state, which are provided in library, spin and parity of intermediate level can be determined through gamma transition selection rules.

CONCLUSIONS

Due to the fact that a huge number of transitions, which currently exist in ENSDF library, were detected in this work, we can trust the validity of the new reported transitions. The detection of these new transitions contributes to the complete level scheme of ^{172}Yb and provides useful information to either confirm or evaluate the spin and parity of corresponding states.

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