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Particle-core coupling in the transitional proton emitters ^{145,146,147}Tm

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Abstract. Excited states in 3 transitional proton emitters ^{145,146,147}Tm were studied using the Gammasphere Ge array coupled with the Argonne Fragment Mass Analyzer. The ^{147}Tm level scheme was extended and the unfavored signature partner of the decoupled proton $h_{11/2}$ band was found. A rotational band feeding the high-spin isomer in ^{146}Tm was observed with properties similar to the ^{147}Tm ground-state band. A regular sequence of γ rays correlated with the ground-state ^{145}Tm proton decay has properties of the $h_{11/2}$ band as well. In addition, coincidences between the fine structure proton line and the $2^+ \rightarrow 0^+$ γ-ray transition in the daughter nucleus were detected. Comparison between level energies measured and calculated using the Particle Rotor model indicates that ^{145}Tm might be γ-soft.

PACS. 23.20.Lv γ transitions and level energies – 23.50.+z Decay by proton emission – 27.60.+j $90 \leq A \leq 149$

1 Introduction

In recent years, proton emitters have become a testing ground for nuclear structure far from the line of stability. The discovery of the deformed proton emitters ^{131}Eu and ^{141}Ho [1] and the proton-decay fine structure in ^{131}Eu [2] initiated detailed studies of the role of deformation in proton decay. The observation of excited states in ^{141}Ho elucidated the role of the Coriolis interaction in proton decay [3].

2 Experimental results

In this work, excited states in the moderately deformed proton emitters ^{145,146,147}Tm were studied using the Recoil-Decay Tagging method. A ^{92}Mo beam at 417, 460 and 512 MeV impinged on a 0.6 mg/cm^2 ^{58}Ni target to produce ^{147}Tm, ^{146}Tm, and ^{145}Tm, respectively. Prompt γ rays were detected in the Gammasphere Ge array. The γ rays were tagged by proton decays observed in a Double-Sided Si Strip Detector placed at the focal plane of the Argonne Fragment Mass Analyzer (FMA). Excited states in ^{147}Tm have been studied previously using a modest Ge array [4]. Due to a much larger γ detection efficiency the ^{147}Tm ground-state band was significantly extended and evidence was found for the unfavored signature partner band.

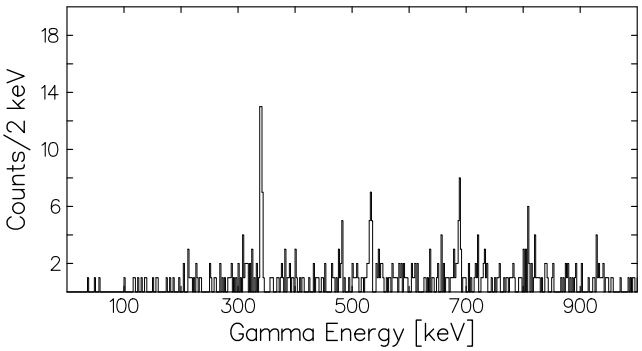

Fig. 1. Gamma rays correlated with protons emitted from ^{145}Tm.

The ^{146}Tm proton emitter exhibits a complex proton-decay level scheme. At least 5 proton lines have been associated with this nucleus [5]. In this work prompt γ-ray spectra correlated with the individual ^{146}Tm proton lines

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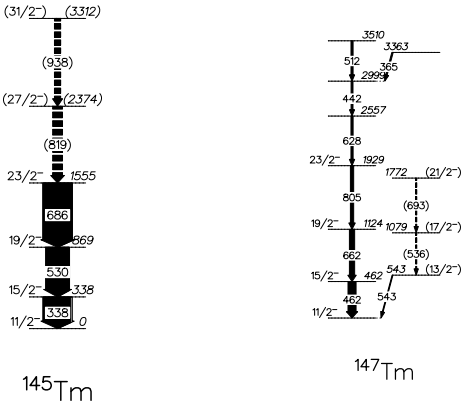

Fig. 2. The level schemes proposed for ^{145,147}Tm isotopes.

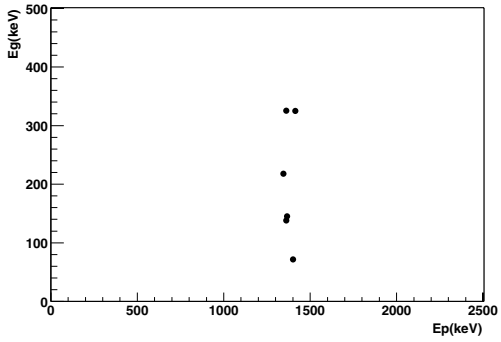

Fig. 3. ^{145}Tm proton-gamma coincidences detected at the focal plane of the FMA.

were obtained. A rotational band feeding the high-spin isomer, which decays via 1122 keV proton emission, was established in ^{146}Tm. The energies of the transitions in the band are very similar to those of the ground-state band in ^{147}Tm. This suggests that both bands are based on the $h_{11/2}$ proton state and that both nuclei have similar deformation. The ^{145}Tm ground state decays primarily to the 0^+ ground state in the daughter ^{144}Er nucleus. A branch to the 2^+ state has been observed recently [6]. The cross-section for producing ^{145}Tm is about 200 nb. The ^{145}Tm half-life is only 3 μs. To avoid pileup of protons with implants, fast delay-line amplifiers were developed. They allowed the observation of protons with decay times as short as 1 μs. The γ-ray spectrum tagged by the ^{145}Tm protons is shown in fig. 1. A regular sequence of mutually coincident γ rays have properties of a decoupled proton $h_{11/2}$ band. The ^{145}Tm and ^{147}Tm level schemes are shown in fig. 2. In addition, coincidences between the proton fine structure line and the $2^+ \rightarrow 0^+$ transition in ^{144}Er were detected at the focal plane of the FMA (see fig. 3). This is the first time that coincidences between ground-state proton decays and γ rays have been seen. A precise energy of 329(1) keV was measured for the 2^+ state in ^{144}Er.

3 Discussion

The calculated deformation changes rapidly from oblate in ^{147}Tm ($\beta_2 = -0.18$) to prolate in ^{145}Tm ($\beta_2 = 0.25$) [7].

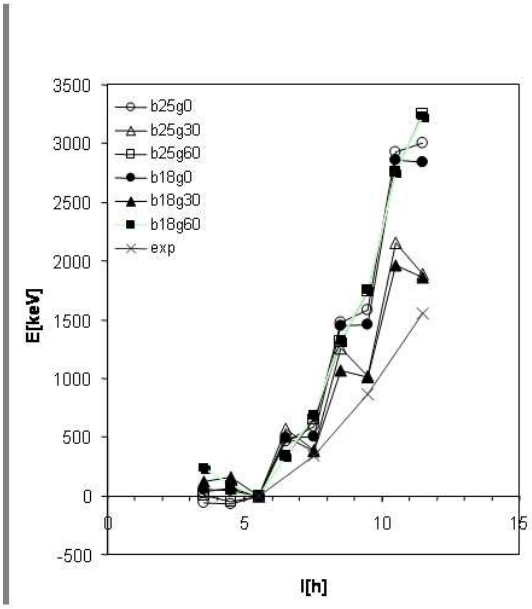

Fig. 4. Calculated and measured (crosses) level energies in ^{145}Tm for different values of β_2 (b) and γ (g) (see the legends). The moment of inertia was adjusted to fit the 2^+ excitation energy of the core.

The dominant γ-ray sequences feeding the ground states in ^{147}Tm and ^{145}Tm have properties of decoupled $\pi h_{11/2}$ bands. The $E_\gamma(15/2^- \rightarrow 11/2^-)$ energies, which are close to $E(2^+)$ in the even-even core, indicate deformation lower than calculated for both ^{145}Tm and ^{147}Tm. The $E(19/2^-)$ to $E(15/2^-)$ ratio, equivalent to $E(4^+)/E(2^+)$ ratio, is about 2.5, which is characteristic of a γ-soft rotor, and is greater than 2.2 for a typical harmonic vibrator, but below the rotor value of 3.33. This suggests an alternative way of viewing the proton decay in ^{145,147}Tm as emission of the $h_{11/2}$ proton aligned with the angular momentum of the γ-soft deformed core. Results of Particle-Rotor model calculations for the level energies in the ^{145}Tm ground-state band are shown in fig. 4. The best agreement between the experimental and calculated values both for ^{145}Tm and ^{147}Tm was found for an asymmetry parameter of $\gamma \approx 30°$.

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