LBL-24653
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

RECEIVED
LAWRENCE
BERKELEY LABORATORY

APR 1 9 1988

LIBRARY AND
DOCUMENTS SECTION

Submitted to Zeitschrift fuer Physik A

Beta-Delayed Proton Decay of the N = 83 Precursor ^{153}Yb

P.A. Wilmarth, J.M. Nitschke, and K. Vierinen,
K.S. Toth, and M. Kortelahti

January 1988

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks.

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-24653 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-24653

Beta-Delayed Proton Decay of the N = 83 Precursor ^{153}Yb

P.A. Wilmarth, J.M. Nitschke, and K. Vierinen

Lawrence Berkeley Laboratory, University of California,
Berkeley, CA 94720, USA

K.S. Toth

Oak Ridge National Laboratory, Martin Marietta
Energy Systems, Inc., Oak Ridge, TN 37831, USA

M. Kortelahti

Louisiana State University, Baton Rouge, LA 70803, USA
Permanent address: University of Jyväskylä,
SF-401000 Jyväskylä 10, Finland

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098. Oak Ridge National Laboratory is operated by Martin Marietta Energy Systems, Inc. for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400. Support was also provided by the U.S. Department of Energy through Contract No. DE-FG05-84ER4-0159 with Louisiana State University.

Abstract:
Beta-delayed proton emission was observed for the N=83 precursor ^{153}Yb. This extends the region of delayed proton emission in the lanthanides across the N=82 shell for the first time. The 4.0±0.5 s delayed proton activity was assigned to ^{153}Yb on the basis of mass separation, coincident Tm K x rays, and coincident γ-ray transitions in the daughter nucleus ^{152}Er. Proton final state branching ratios are consistent with a $7/2^-$ precursor spin. The proton branching ratio is $(8\pm2)x10^{-5}$.

The isotope ^{153}Yb was first produced in a study of α emission in the neutron-deficient ytterbium nuclides above N=82 [1]. Although ^{153}Yb was not an α emitter, its existence could be inferred from the daughter α activity ^{153}Tm growing in with a 4 s half-life; no additional information on the decay of ^{153}Yb was reported. We recently undertook an investigation of β and particle decays of A=153 isobars at the OASIS mass separation facility [2] on-line at the Lawrence Berkeley Laboratory's SuperHILAC. Part of the study involved the investigation of ^{153}Yb decay properties. About 30 γ rays were observed to follow the β decay of ^{153}Yb. This decay scheme will be discussed in a subsequent paper [3]. Presented here is the first observation of a β-delayed proton branch in ^{153}Yb, the only known N=83 precursor.

A 1.85 mg/cm^2 molybdenum target foil enriched to 97% in ^{92}Mo was bombarded with 285-Mev ^{64}Zn ions. The isotope separator was calibrated with the stable mass marker ^{153}Eu introduced into the surface ionization source. The A=153 products were selected by an analyzing slit in the focal plane of the separator, transported ionoptically to a fast cycling tape system, and periodically positioned between an array of detectors. A Si ΔE-E charged particle telescope and a planar hyperpure Ge detector faced the radioactive layer while a 1-mm thick plastic scintillator and an n-type Ge detector with a relative efficiency of 52% were located on the opposite side of the collection tape. A second n-type Ge detector with a relative efficiency of 24% was placed at 90° to the other detectors, about 4.5 cm from the radioactive source. Coincidences between particles, γ rays, x rays, and positrons were recorded in an event-by-event mode; all events were tagged with a time signal for half-life determinations. Singles data were also acquired from the 52% detector and the hyperpure Ge detector in a multispectrum mode in which the tape cycle time was

divided into 8 equal intervals. Detection of the weak delayed proton branch was complicated by the intense α background (~8×10^6 α's) from ^{153}Tm and ^{153}Er. This background was, however, quantitatively eliminated since the response of the ΔE-E particle telescope to protons (without interfering α decay) is well understood from many previous experiments with N$\leq$80 precursors.

Delayed protons were observed during both the 1.28 and 12.80 s collection intervals used to study the A=153 isobars. They were assigned to a Yb precursor on the basis of Tm K x rays (following electron capture) observed in coincidence with the protons, while the mass number was determined by the separator. These two measurements uniquely identify the new delayed proton precursor as ^{153}Yb. The 4.0±0.5 s half-life of the delayed proton activity measured during the 12.80 s experiment is in agreement with the previously reported value [1] and with the 3.9±0.1 s half-life derived from the strongest γ rays following ^{153}Yb β decay [3]. The results for each counting interval, along with the combined data, are given in Table 1 and shown in Fig. 1. Proton-coincident γ rays from the 808-keV $2^+\rightarrow0^+$ and the 673-keV $4^+\rightarrow2^+$ transitions in the delayed proton daughter ^{152}Er [4] were also observed. The measured final state branching ratios are: (4^+) 3±3%, (2^+) 40±12%, and (0^+) 57±17%. The proton branching ratio (P_p) from the 12.80 s data is $(8\pm2)\times10^{-5}$. The total β decay intensity used for the P_p calculation was estimated as the sum of the Tm K x-ray intensity (corrected for detection efficiency, fluorescence yield, and contributions from internal conversion of γ-ray transitions in ^{153}Tm) and the 4 s component of the 511-keV intensity (corrected for detection efficiency and annihilation in flight). The quoted uncertainty in P_p is the statistical error only; the largest systematic error may be in the fraction of K x rays due to internal conversion, since knowledge of the γ-ray multipolarities in ^{153}Tm is not available (it was assumed that the strong 92-keV $3/2^+\rightarrow1/2^+$ and 370-keV $5/2^+\rightarrow3/2^+$ M1 transitions [3] represent most of the internal conversion contribution). The β-delayed proton decay of ^{153}Yb is summarized in Fig. 2.

Statistical model calculations of the delayed proton emission process (described in detail in Ref. 5) were performed using the following parameters: mass values from [6], a precursor spin of $7/2^-$ [3] (all known even Z, N = 83 nuclei have $J^\pi = 7/2^-$), calculated [7] or constant β-strength functions, and optical model parameters from [8]. The results of the calculations are compared with the experimental values in Table 2. Using either β-strength function, the statistical model adequately accounts

for the experimental results with the measured values in general falling between the two calculations. Given the experimental uncertainties and the large number of parameters in the statistical model, no conclusion about which set of parameters best describes the experiment can be made at this time. It would, however, seem that the delayed proton decay of ^{153}Yb (an N=84 emitter) can be well understood in terms of the standard statistical model, in contrast to ^{151}Yb (an N=82 emitter) which exhibits pronounced structure in its delayed proton spectrum (Ref. 5 and references therein). The delayed proton spectrum in Fig. 1(a). shows no clear indication of the pronounced structure seen in the even-Z, N=81 precursors [5, 9], but the number of events is not large enough to rule out weaker structure. This is analogous to the N=79 precursors (N=80 emitters) which have no apparent structure in their delayed proton spectra [9, 10]. The low level density associated with the N=82 shell closure that gives rise to this structure changes rapidly enough with both decreasing and increasing neutron number so that N=80 emitters and, from this work, an N=84 emitter, exhibit structureless delayed proton spectra.

The assistance of L. Archambault, F. Avignone III, R. Chasteler, R. Firestone, A. Shihab-Eldin, and A. Wydler during this experiment is gratefully acknowledged.

References:

1. E. Hagberg, *et al.*, Nucl. Phys. **A293**, 1(1977).
2. J.M. Nitschke, Nucl. Instr. Meth. **206**, 341(1983).
3. M. Kortelahti, *et al.*, to be published.
4. D. Horn, *et al.*, Phys. Rev. **C23**, 1047(1981).
5. J.M. Nitschke, *et al.*, Proc. 5th Intl. Conf. on Nuclei far from Stability, I.S. Towner (ed.) Rosseau Lake, Ontario, Canada (1987) to be published.
6. A.H. Wapstra and G. Audi, Nucl. Phys **A432**, 1(1985).
7. J. Krumlinde and P. Möller, Nucl. Phys. **A417**, 419(1984).
8. C.H. Johnson, A. Galonsky, and R.L. Kernell, Phys. Rev. **C20**, 2052(1979).
9. D. Schardt, *et al.*, Proc. 7th Intl. Conf. Atomic Masses and Fundamental Constants (AMCO7) O. Klepper (ed.) Darmstadt, FRG (1984) p. 229.
10. K.S. Toth, *et al.*, Proc. 5th Intl. Conf. on Nuclei far from Stability, I.S. Towner (ed.) Rosseau Lake, Ontario, Canada (1987) to be published.

TABLE 1. Results of ^{153}Yb delayed proton decay; TIME =counting interval, #P's=number of observed delayed protons, E_p=mean and range of the delayed proton energies, X=proton-coincident $K_{\alpha,ave}$ and $K_{\beta,ave}$ x-ray energies, γ=proton-coincident γ-ray energies.

TIME	#P's	E_p(MeV)	X(keV)	γ(keV)
1.28 s	295	3.9[2.2,5.7]	50.5,58.0	511,808
12.80 s	506	3.9[2.1,5.7]	50.6,57.8	511,808,673
Σ	801	3.9[2.1,5.7]	50.6,57.9	511,808,673

TABLE 2. Comparison of statistical model calculations and experimental values for ^{153}Yb; S_β=β-strength function used, E_p=mean proton energy, P_p=proton branching ratio, 0^+, 2^+, 4^+=branches to the ground, first, and second excited states in ^{152}Er, respectively.

S_β	E_p(MeV)	$P_p(10^{-5})$	0^+(%)	2^+(%)	4^+(%)
Exp.	3.9	8±2	57±17	40±12	3±3
Ref. 7.	3.5	3	61	37	2
Const.	4.2	2	39	55	6

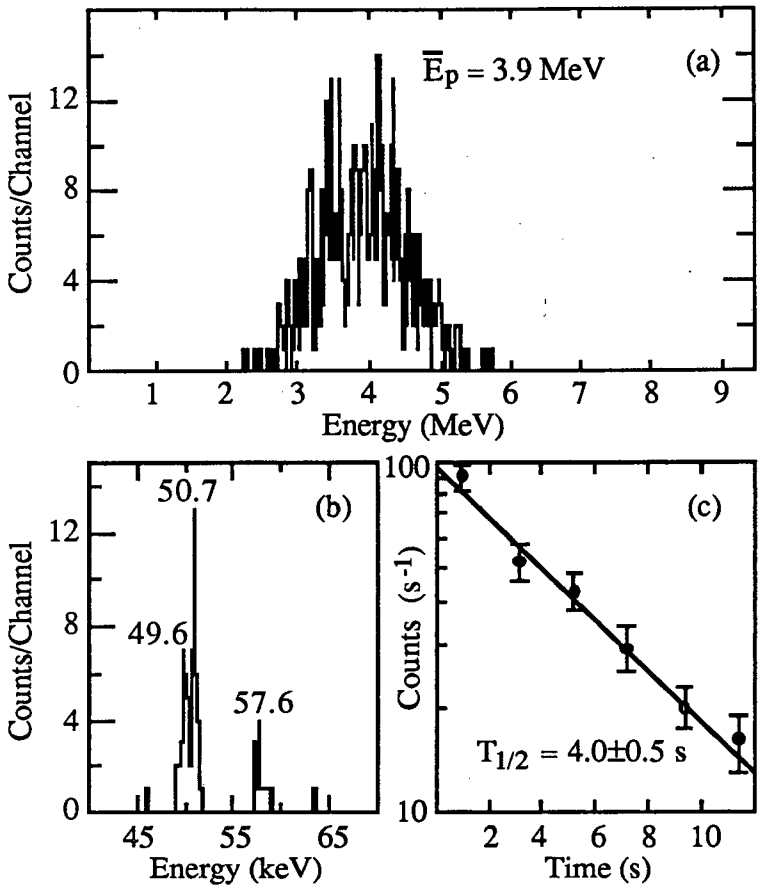

FIG. 1. Beta-delayed proton energy spectrum for ^{153}Yb from the combined data (a). Proton-coincident x rays measured with the hyperpure Ge detector (b); the literature values for Tm $K_{\alpha 2}$, $K_{\alpha 1}$, and $K_{\beta 1}$ energies are 49.8, 50.7 and 57.5 keV, respectively. The decay curve for the proton activity from the 12.80 s counting interval (c).

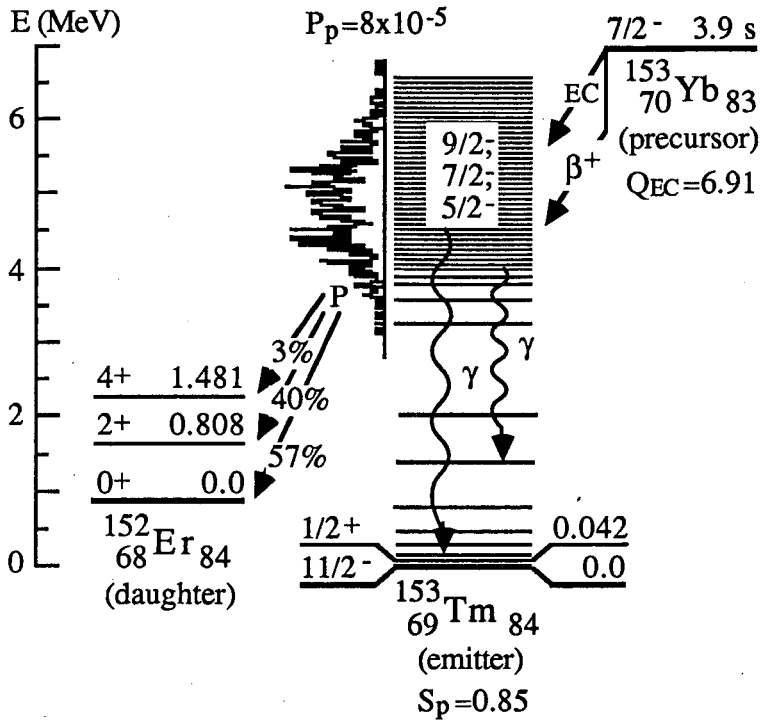

FIG. 2. Energetics and branching ratios for ^{153}Yb delayed proton decay. The values for Q_{EC} and S_p were taken from Ref. 6. All energies are in MeV. The ground state and isomer energies in ^{153}Tm are from Ref. 3.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720