LBL-17345
Preprint c.2

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Submitted to Zeitschrift für Physik

BETA-DELAYED PROTON EMISSION OBSERVED IN NEW LANTHANIDE ISOTOPES

J.M. Nitschke, P.A. Wilmarth, P.K. Lemmertz,
W.-D. Zeitz, and J.A. Honkanen

February 1984

NUCLEAR SCIENCE DIVISION

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

LBL - 17345

Beta-Delayed Proton Emission Observed in New Lanthanide Isotopes

J. M. Nitschke, P. A. Wilmarth and P. K. Lemmertz
Nuclear Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720 USA

W.-D. Zeitz
Hahn-Meitner-Institut für Kernforschung Berlin GmbH
D-1000 Berlin 39, Germany

J. A. Honkanen
Department of Physics
University of Jyväskylä, 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.

Abstract:

The following new, beta-delayed proton emitters have been observed at the on-line isotope separator OASIS: ^{120}La (2.8 ± .2s), ^{122}La (8.7 ± .7s), ^{123}Ce (3.8 ± .2s), ^{141}Dy (1.0 ± .2s), ^{141}Gd, and ^{143}Dy (3.2 ± .6s). Z-identification was achieved through observation of characteristic x-rays in coincidence with protons.

We previously reported the discovery of several new, beta-delayed proton emitters in the lanthanide region [1]. The masses of these new isotopes were uniquely determined by the on-line isotope separator OASIS at the SuperHILAC [2] and the Z-values were inferred from half-lives, mass-energy systematics and cross sections. A major addition to OASIS now allows us to obtain unique Z-identifications of new isotopes by observing characteristic x-rays in coincidence with beta-delayed protons. The isotope under study is passed through a slit in the focal plane of the isotope separator and is transported via ionoptical devices to a low background spectroscopy laboratory. Here the isotope is deposited on a fast-cycling tape and moved within 65 ms to an array of detectors which register protons, α- and β-particles, x-rays, and γ-rays. For neutron deficient isotopes two classes of events are recorded: (1) protons (or alphas) in coincidence with positrons, γ's, and x-rays, and (2) positrons and x-rays in coincidence with γ's. This preliminary report covers only events of the first category.

The new results summarized in Table I are listed below by mass number.

A = 143: This mass was investigated because ^{143}Ho has been predicted to be a ground state proton emitter [3]. We previously reported the observation of a beta-delayed proton activity with 4.1 s half-life which was assigned to ^{143}Dy. This assignment was based on the good agreement with the predicted half-life of 3.1 s from the gross theory of beta decay and a predicted (Q_{EC} - S_p) value of 7.56 MeV (Q_{EC} = Q value for electron capture, S_p = proton separation energy). We have repeated this experment with the new tape system and observed a low background x-ray spectrum of K_α- and K_β-x-rays from Tb in coincidence with protons. These protons are "electron capture delayed" since it is the capture of a K-electron which subsequently gives rise to the observed x-ray that is emitted when the K-vacancy is filled from the L- or M-shell of the Tb atom. This method yields an unambiguous Z-identification of the proton precursor. We have also observed γ-rays in coincidence with protons and positrons. These measurements will be reported at a later date.

A = 141: The reactions leading to isobars in this mass chain are listed in Table I. Measurable cross sections are expected for the three unknown isotopes ^{141}Dy, ^{141}Tb, and ^{141}Gd. ^{141}Dy has the highest calculated (Q_{EC} - S_p) value (9.15 MeV), while the other two are 4.98 and 4.96 MeV; the predicted half-lives are 1, 4, and 11 s, respectively. Two experiments with tape cycles of 5 and 50 s were carried out. In both cases Tb and Eu but no Gd x-rays in coincidence with protons were observed. The shorter cycle time showed a larger Tb/Eu x-ray ratio than the 50 s cycle; it also produced a higher average proton evergy. Protons in coincidence with Tb x-rays showed higher energies than protons in coincidence with Eu x-rays, and the half-life of the Tb-related proton-decay seemed to be shorter than the protons coincident with Eu x-rays. The ensemble of these observations lead us to the conclusion that two new beta delayed proton emitters ^{141}Dy and ^{141}Gd were being observed. No evidence for proton emission from ^{141}Tb was found. From data of the 5 s tape cycle an average half-life for all observed protons of 1.0 s was calculated. The arguments presented above indicate that this should be due mostly to ^{141}Dy with a small, as yet unknown contribution from ^{141}Gd. The half-life of protons in coincidence with the Tb x-rays is approximately 0.7 s with a large error due to poor statistics but in agreement with the 1s half-life of ^{141}Dy.

A = 123: In an experiment in which ^{92}Mo was bombarded with ^{36}Ar an intense proton activity was observed. The proton energy spectrum (fig. 1) is characteristic for beta-delayed proton decay. The spectrum of x-rays obtained in coincidence with protons is shown in fig. 2a. The energies of the two x-ray lines are in excellent agreement with the literature values for La K_α- and K_β- radiation, which uniquely identifies the new isotope as ^{123}Ce. The half-life obtained from the proton decay data is 3.9 ± .2 s; the decay of the La x-ray gives 3.3 ± .6 s. Additional information about the decay of ^{123}Ce was obtained from a γ-spectrum measured in coincidence with the protons (fig. 2b). It clearly shows that the proton decay populates the known rotational 2+, 4+, and perhaps 6+ levels in ^{122}Ba. Since some of the proton decay is subsequent to electron capture in ^{123}Ce, several weak lines in the γ-spectrum are observed at energies which correspond to the sum of transition energies in ^{122}Ba and K_α- and K_β-x-ray energies in La. A preliminary evaluation of the proton branches to different rotational levels in ^{122}Ba and a comparison with calculations yields a spin of 5/2 for the new ^{123}Ce precursor.

A = 122: Two experiments were performed at this mass value: one with a dual proton telescope [1] where a total of about 1800 protons were recorded and one with the tape system where x-and γ-rays were measured in coincidence with protons. The x-ray spectrum in the second experiment showed only Ba K_α- and K_β- lines which lead us to the conclusion that the new beta-delayed proton precursor is ^{122}La. The calculated low $(Q_{EC} - S_p)$ value of 5.50 MeV is reflected in the observed low upper proton energy of 4.6 MeV.

A = 120: The systematics of $(Q_{EC} - S_p)$ (Z) for A=120 predicts that in this mass chain beta-delayed proton emission becomes possible for $Z \geq 56$. In an experiment with a ^{64}Zn beam and a ^{58}Ni target we observed beta-delayed protons in coincidence with Ba x-rays and conclude that the new precursor is ^{120}La. Additional evidence for the ^{120}La assignment comes from the γ-spectrum measured in coincidence with protons where a weak γ-line at 237 keV is seen which corresponds to the $11/2^+ \rightarrow 9/2^+$ (g.s.) transition in ^{119}Cs.

The half-life of 2.8 s is in poor agreement with the calculated value of 1.2 s, and it can not be excluded that we are observing an isomer similar to the case of ^{118}Cs.

The above experiment also served to test the separating power of OASIS which is defined as the intensity that an adjacent mass contributes to the mass under study: In the ^{120}La experiment a very strong, delayed proton precursor is produced concurrently at mass 119 (^{119}Ba). It generates characteristic γ-lines in the (mass 119) β-γ coincidence spectrum but none of these lines are visible in the corresponding spectrum at mass 120 at a level of less than 1 part in 10^4.

Table I: Target projectile combinations and reaction channels for the production of new beta-delayed proton precursors. E_{lab} = bombarding energy, E_p = observed proton energy range, and $T_{1/2}$ = half-life of the precursor.

Table I

Reaction	E_{lab} (MeV)	Precursor	E_p (MeV)	$T_{1/2}$ (s)	$K_{\alpha,\beta}$ x-rays
^{92}Mo(^{56}Fe,αn)	275	^{143}Dy	2.5–6.5	3.2±.6	Tb
^{92}Mo(^{54}Fe,αn)	274	^{141}Dy	2.4–6.1	1.0±.2	Tb
^{92}Mo(^{54}Fe,4pn)	274	^{141}Gd	2.0–5.8	–	Eu
^{92}Mo(^{36}Ar,αn)	196	^{123}Ce	2.0–5.8	3.8±.2	La
^{92}Mo(^{36}Ar,αpn)	205	^{122}La	2.0–4.6	8.7±.7	Ba
^{58}Ni(^{64}Zn,pn)	253	^{120}La	2.1–5.6	2.8±.2	Ba

References

1. J. M. Nitschke, M.D. Cable, and W.-D. Zeitz, Z. Phys. A 312, 256 (1983).
2. J. M. Nitschke, Nucl. Inst. and Meth. 206, 341 (1983).
3. W. F. Feix and E. R. Hilf, Darmstadt, IKDA 82/12.

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.

Figure Captions

Fig. 1. Beta-delayed proton spectrum observed in the reaction ^{92}Mo (^{36}Ar, αn) ^{123}Ce.

Fig. 2. (a) x-ray and (b) γ-spectra observed in coincidence with beta-delayed protons (Fig. 1) from ^{123}Ce. $m_e c^2$ = annihilation radiation.

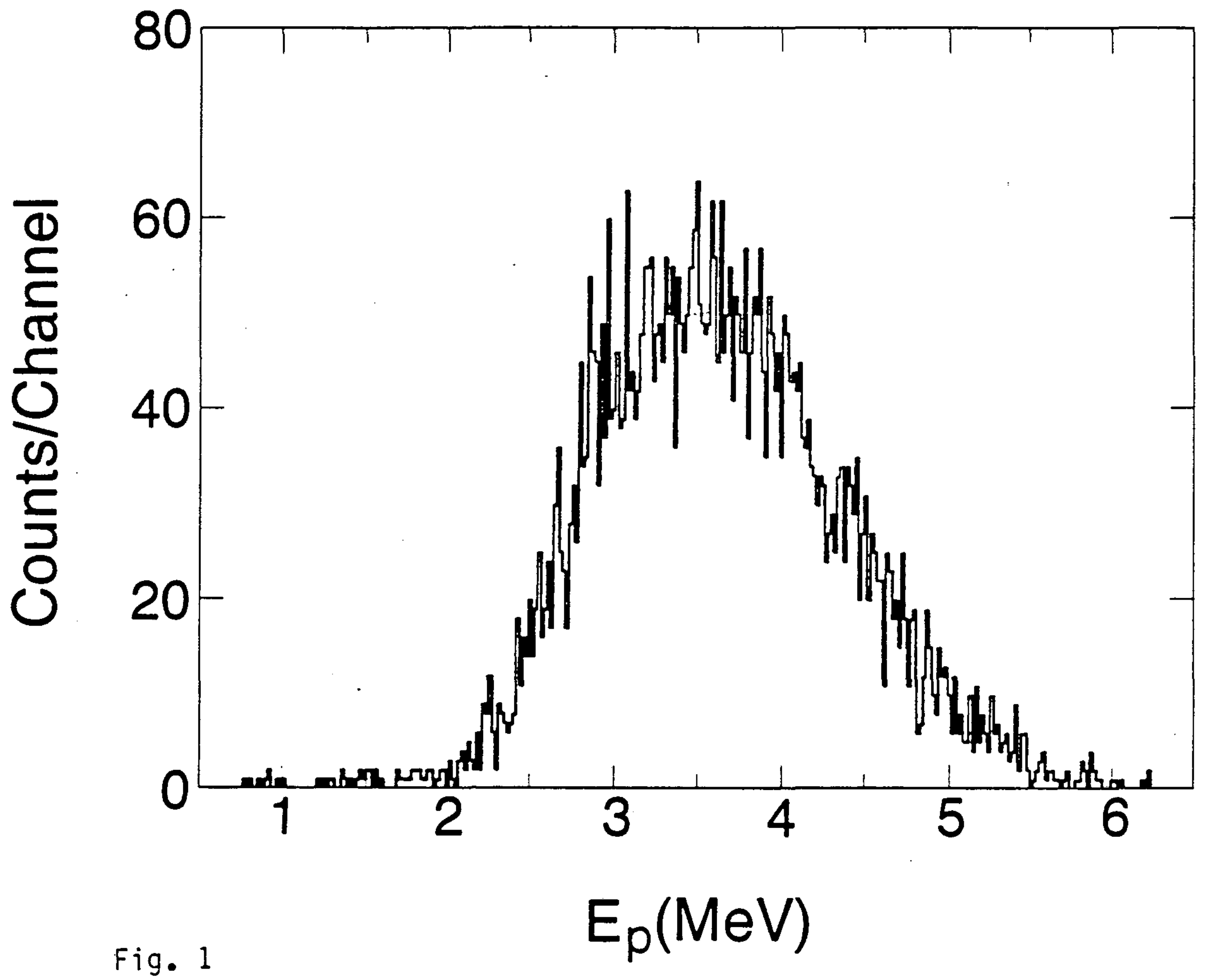

Fig. 1

XBL 8312-6724

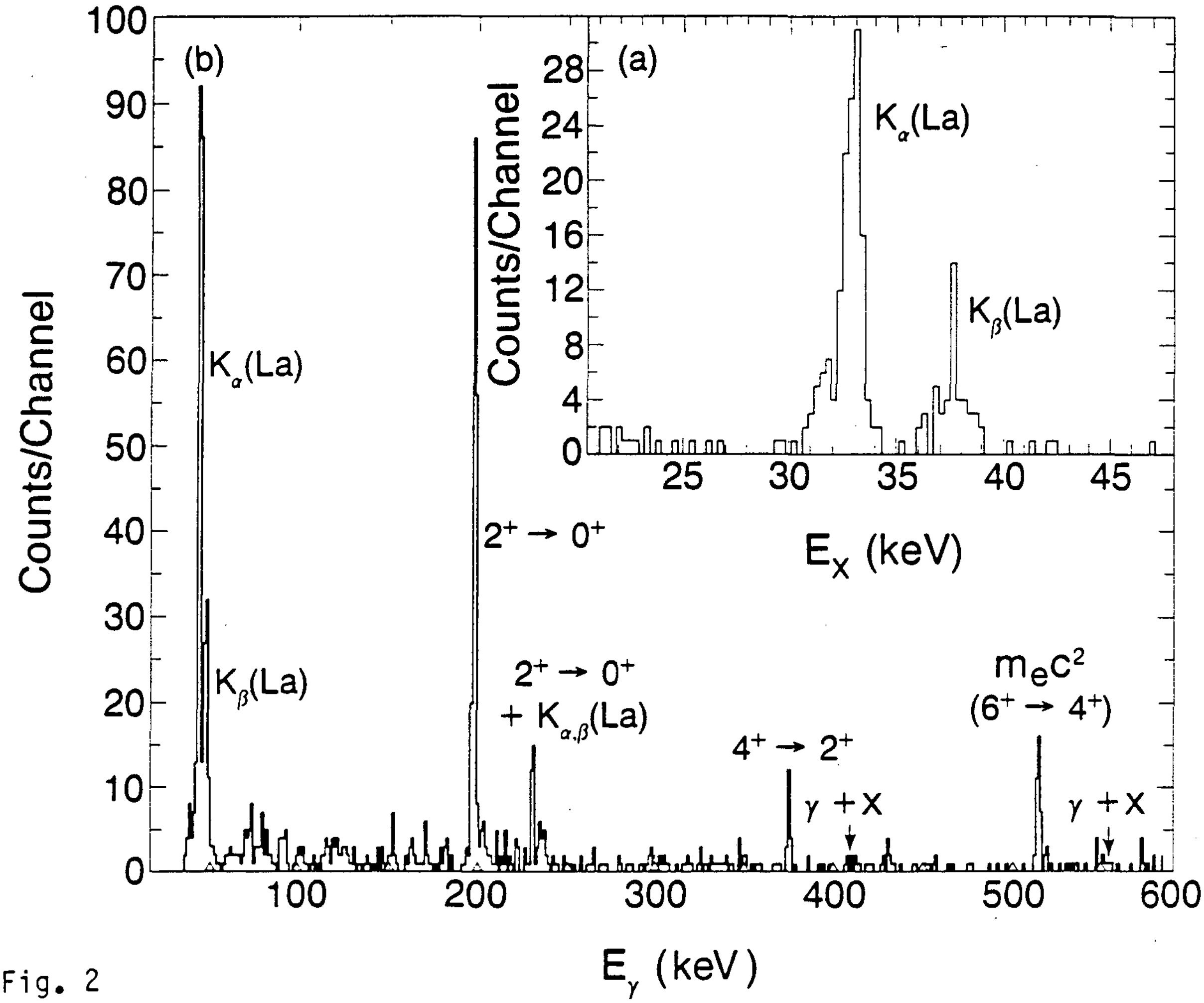

Fig. 2

XBL 8312-6725

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