Argonne NATIONAL LABORATORY

Member of the US Nuclear Data Program

Negative Effective Beta Decay Q values

F.G. Kondev
Physics Division, Argonne National Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Science

Nuclear Physics

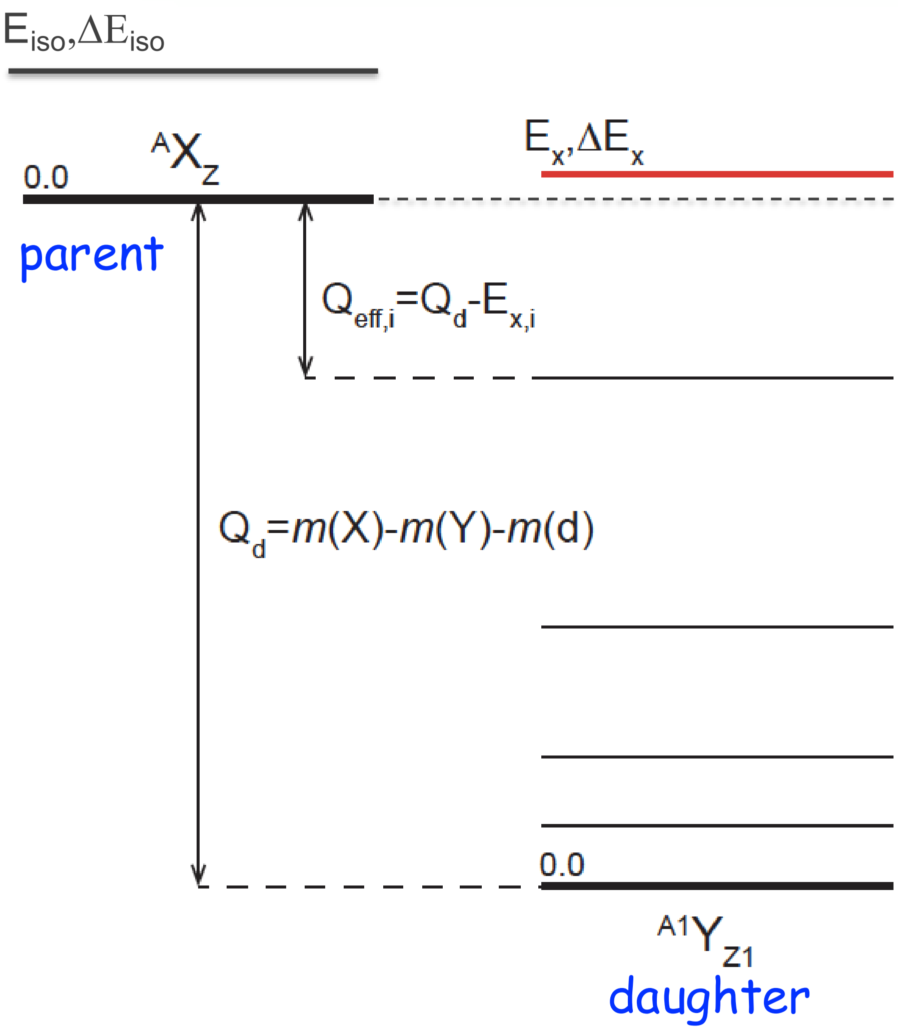
Introduction

- Decay Q values – governed by the masses of the parent and daughter nuclei

⇒ control the speed and phase space of the decays

⇒ influence the decay transition probabilities – log *ft*, HFα …

⇒ influence the average decay properties - applications



- $Q_{eff} \geq 0$ or $E_{x\,(last\ level)} \leq Q_d$

⇒ but not always the case

- using AME20 & ENSDF21

⇒ **8** EC cases where $Q_{eff}<0$

⇒ **3** B- cases where $Q_{eff}<0$

Why?

- deficiencies in the decay data
- deficiencies in the mass data
- deficiencies in both the decay & mass data
- existence of isomers & deficiencies in the decay data

Example 1: Q_{EC} for ^{99}Rh

Q_{EC} for ^{99}Rh in keV
2043(7) AME12
2044(7) AME16
2041(19) AME20

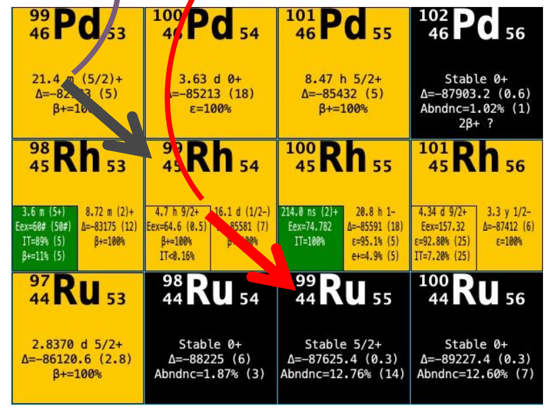
2059.6(0.1) ENSDF

Q_{EC} for ^{99}Pd in keV – 89%
3410(20) 69Ph01
M.E.Phelps & D.G.Sarantites, Nucl.Phys. A135, 116 (1969)

ME(^{99}Pd)=-82183(5) keV
JYT: 09El08

discrepant

Q_{EC} for ^{99}Rh in keV – 11%
2038(10) 52Sc11
2053(10) 59To25
2170(30) 74An23
N.M. Antonev et al., Bull. Acad. Sci. USSR, 38, 61 (1974)



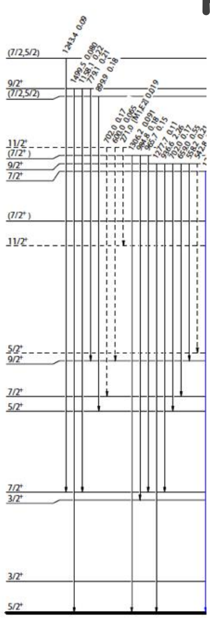
ME(^{100}Ru)=-89227.4(0.3)
JYT: 08Ra09

E_γ (n,γ)=9673.324(0.026) keV
ME(^{99}Ru)=-87625.4(0.3) keV

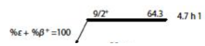
$$\Delta=ME(^{99}Pd)-ME(^{99}Ru)=Q_{EC}(^{99}Pd)+Q_{EC}(^{99}Rh)=5442(5)\text{ keV}$$
$$\Delta-Q_{EC}(^{99}Pd)=Q_{EC}(^{99}Rh)=2040(20)\text{ keV}$$

1974An23@2000Mi05
ENSDF2017

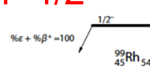
^{99}Rh



Jπ=9/2+ 64.3 keV

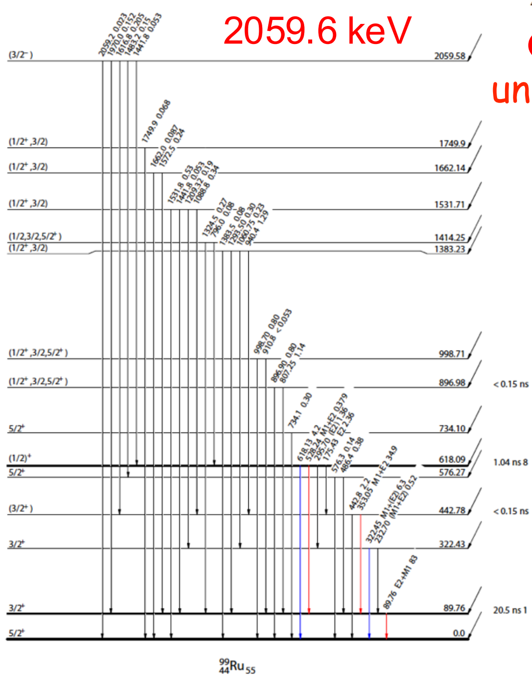


Jπ=1/2-



2059.6 keV

Q_{eff}<0
unphysical



What would be useful

- Penning trap mass measurements for ^{99}Rh
- decay spectroscopy data to help solving the ordering of the low & high-spin decaying states in ^{99}Rh

Example 2: $Q_{\beta-}$ for ^{133}Te

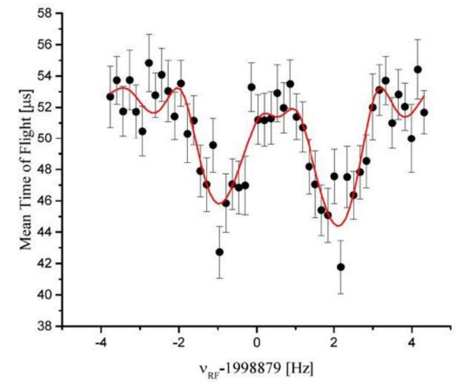
Nuclide	$I^{\pi a)}$	$T_{1/2}{}^{a)}$	Literature values, [keV] $ME^{a,b)}$	$ME^{c)}$	$ME^{e)}$
^{133g}Sb	$(7/2^{+})$	2.34 (5) *m*	-78 924 (3)	-78 921.3 (76)	-78 921.0 (40)
^{133g}Te	$3/2^{+}$#	12.5 (3) *m*	-82 937.1 (21)	-82 899.8 (65)	-82 938.2 (22)
^{133m}Te	$(11/2^{-})$	55.4 (5) *m*	-82 602.8 (21)	-82 599.1 (24)$^{d)}$	-82 595.8 (24)$^{f)}$
^{133g}I	$7/2^{+}$	20.83 (8) *h*	-85 857 (6)	-85 858.2 (64)	
^{133m}I	$(19/2^{-})$	9 (2) *s*	-84 223 (6)		

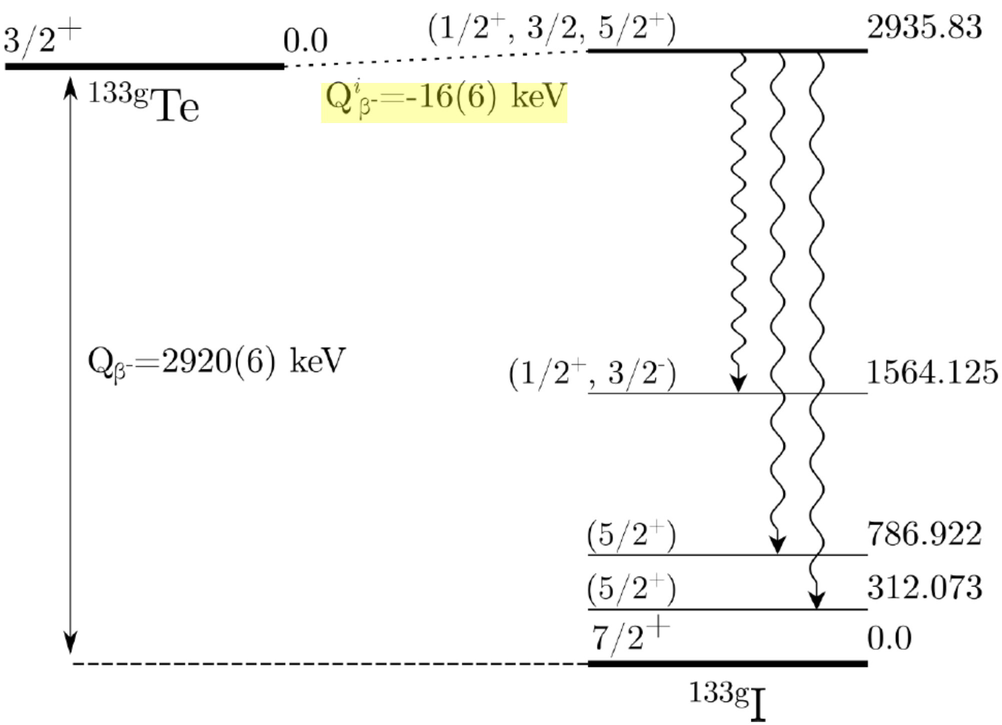
Δ=38.4 keV!!!

$^{a)}$NUBASE2020 [2].; $^{b)}$AME2020 [3].; $^{c)}$Van Schelt *et al.* [8].; $^{d)}$Van Schelt [17].; $^{e)}$Hakala *et al.* [7].; $^{f)}$Kankainen *et al.* [18].

CPT JYT

TOF-ICR method





H. Hicks et al., Phys, Rev. C27 (1983) 2203 @ ENSDF2010

AME2020

- ME(^{133}Te) 93% from 12Ha25 – JYT
  7% from MRTOF@GSI
  ⇒ discrepant value in 13Va12 – CPT
- ME(^{133}I) 84% from 13Va12 – CPT
  17% from ^{133}Sb(B-)

Example 2: $Q_{\beta-}$ for ^{133}Te – cont.

CARIBU@CPT

Phys. Lett. B 858 (2024) 139037

Contents lists available at ScienceDirect

Physics Letters B

journal homepage: www.elsevier.com/locate/physletb

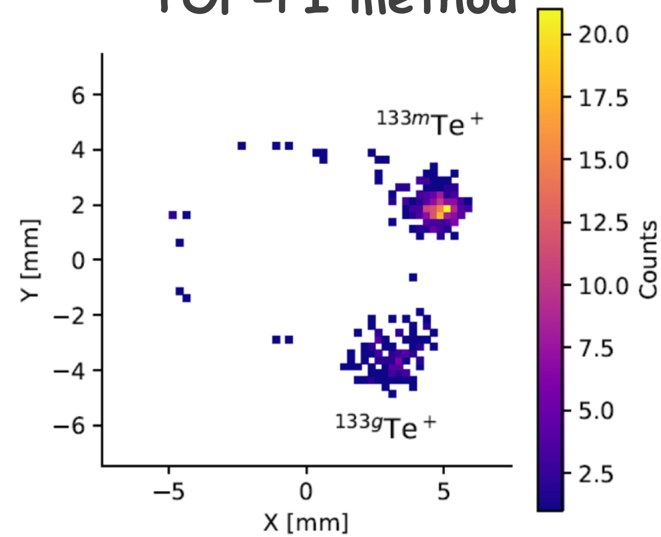
ELSEVIER

Letter

Precise mass measurements of $A = 133$ isobars with the Canadian Penning Trap: Resolving the Q_{β^-} anomaly at ^{133}Te

A.A. Valverde [a,b,*], F.G. Kondev [a], B. Liu [a,c], D. Ray [a,b,1], M. Brodeur [c], D.P. Burdette [a], N. Callahan [a], A. Cannon [a,c], J.A. Clark [a,b], D.E.M. Hoff [d], R. Orford [e], W.S. Porter [c], G. Savard [a,f], K.S. Sharma [b], L. Varriano [a,f,2]

TOF-PI method



NEW

Nuclide	$I^{\pi a)}$	$T_{1/2}{}^{a)}$	Present work: $R = \bar{\nu}_c(^{133}\mathrm{Cs}^+)/\bar{\nu}_c(^{133}\mathrm{X}^+)$	Present work: ME [keV]	Literature values, [keV]: $ME^{a,b)}$	Literature values, [keV]: $ME^{c)}$	Literature values, [keV]: $ME^{e)}$
^{133g}Sb	$(7/2^+)$	2.34 (5) *m*	1.000073910 (9)	-78 920.9 (11)	-78 924 (3)	-78 921.3 (76)	-78 921.0 (40)
^{133g}Te	$3/2^+$#	12.5 (3) *m*	1.000041494 (6)	-82 934.0 (7)	-82 937.1 (21)	-82 899.8 (65)	-82 938.2 (22)
^{133m}Te	$(11/2^-)$	55.4 (5) *m*	1.000044209 (6)	-82 597.8 (7)	-82 602.8 (21)	-82 599.1 (24)$^{d)}$	-82 595.8 (24)$^{f)}$
^{133g}I	$7/2^+$	20.83 (8) *h*	1.000017788 (7)	-85 868.7 (9)	-85 857 (6)	-85 858.2 (64)	
^{133m}I	$(19/2^-)$	9 (2) *s*	1.000031003 (46)	-84 232.8 (57)	-84 223 (6)		

$^{a)}$NUBASE2020 [2].; $^{b)}$AME2020 [3].; $^{c)}$Van Schelt *et al.* [8].; $^{d)}$Van Schelt [17].; $^{e)}$Hakala *et al.* [7].; $^{f)}$Kankainen *et al.* [18].

CPT

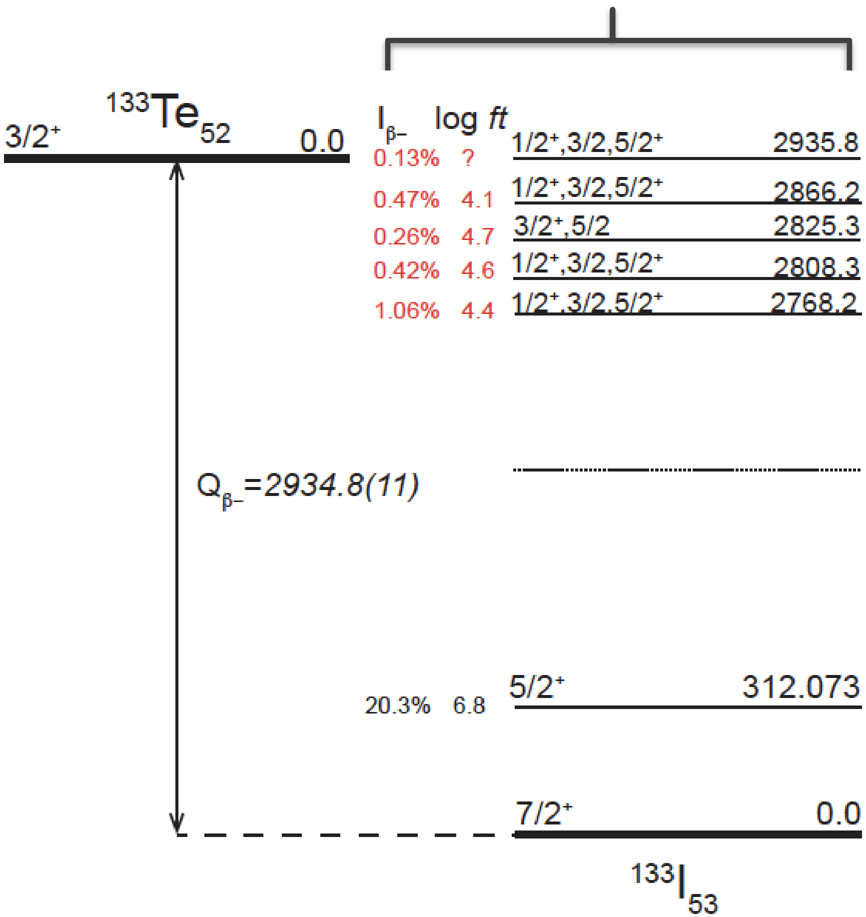
JYT

- $Q_{\beta-}$=2934.8(1.1) keV (new) compared to 2920(6) keV (AME2020)
  $\Rightarrow$ increase by 15 keV & improved uncertainty (5σ)

Example 2: $Q_{\beta-}$ for ^{133}Te – cont.

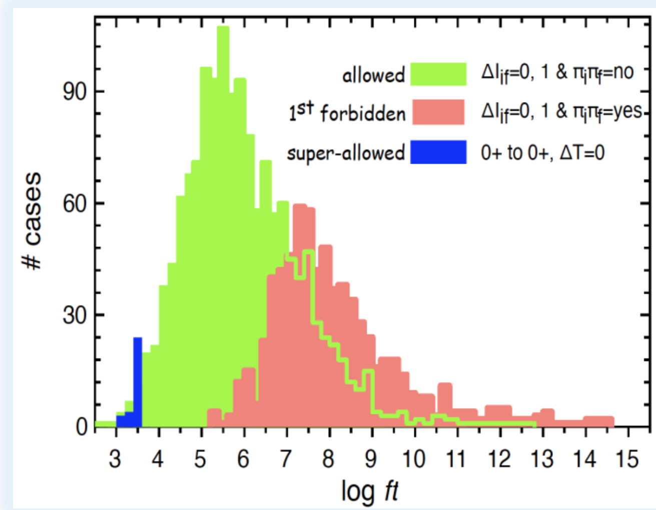
Q_{eff}[2935 keV]=-1.0(1.2) keV (new) compared to -16(6) keV (AME2020)

H. Hicks et al., Phys, Rev. C27 (1983) 2203 @ ENSDF2010



BUT

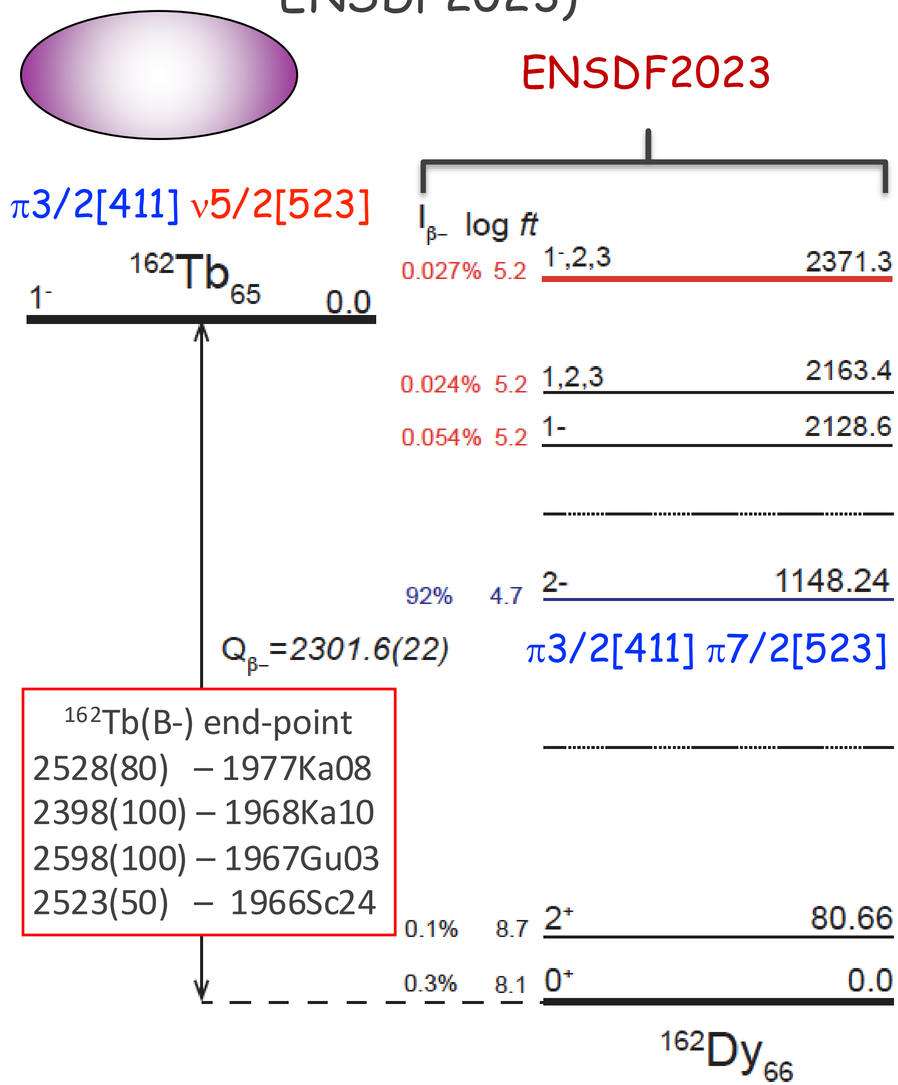
- small log ft values to several HE levels
  - ⇒ unphysical to the 2935.8 keV level
  - ⇒ 4.1-4.7 implying very fast decays ??



- new beta-decay spectroscopy studies would be valuable to improve the decay scheme and $I_{\beta-}$

Example 3: $Q_{\beta-}$ for ^{162}Tb

Q_{eff}[2371.3 keV]=**-69.7(2.2)** keV (AME2020 & ENSDF2023)



- main decay (92%) to the 1148-keV level – spin-flip AU transition: ν5/2[523]->π7/2[523]
- small log *ft* values to several HE levels
  - ⇒ unphysical to the 2371 keV level
  - ⇒ log *ft*=5.2 to the 2163-keV level would imply AU decay and Jπ=1- or 2-, but not 3

- m(^{162}Tb) – from TOF-PI CPT (2020Or03)
- m(^{162}Dy) – from ^{162}Dy(n,γ) – highly-precise & reliable result: average of 1982Is05, 1989Sc31 & 2006Fi.A

- 2371.3-keV level seems firmly established
  - ⇒ observed in ^{162}Tb(B-) studies of Kawade et al., Nucl. Phys. A279 (1977) 2 [1977Ka08]
  - ⇒ fed by a primary γ in ^{161}Dy(n,γ) [Jπ=2^+,3^+]

Example 3: $Q_{\beta-}$ for ^{162}Tb – cont.

PHYSICAL REVIEW C **102**, 011303(R) (2020)
Rapid Communications

2020Or03

Spin-trap isomers in deformed, odd-odd nuclei in the light rare-earth region near $N = 98$

R. Orford,[1,2,*] F. G. Kondev,[1] G. Savard,[1,3] J. A. Clark,[1,4] W. S. Porter,[1,†] D. Ray,[1,4] F. Buchinger,[2] M. T. Burkey,[1,3,‡] D. A. Gorelov,[1,4] D. J. Hartley,[5] J. W. Klimes,[1,§] K. S. Sharma,[4] A. A. Valverde,[1,4] and X. L. Yan[1,6]

CARIBU@CPT

Nuclear Physics A 794 (2007) 149–165

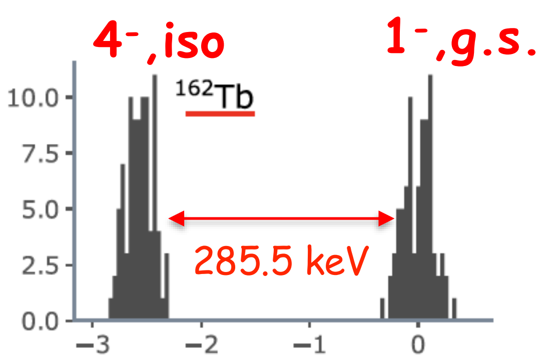
Nuclear level structures in ^{160,162}Tb studied with ^{161,163}Dy(t, α) reactions

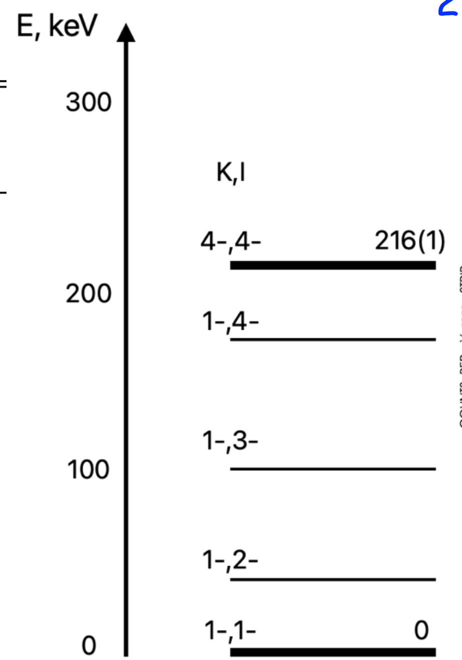
D.G. Burke *, P.E. Garrett [1], P.C. Sood [2]

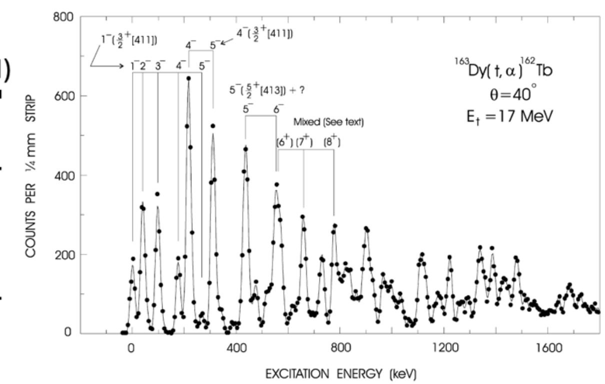
2007Bu29

Nuclide	Ref. Ion	Measured		
		ν_c^{ref}/ν_c	*ME* [keV]	E_x [keV]
^{162}Tb^{2+}	$C_6H_6^+$	1.037 384 012 (14)	−65879.4 (20)	0.0
^{162m}Tb^{2+}	$C_6H_6^+$	1.037 385 975 (17)	−65593.9 (25)	285.5 (32)

π3/2[411] ν5/2[523]







π3/2[411] ν5/2[523]

285.5(3.2) keV [mass spectrometry] vs 216(1) keV [^{163}Dy(t,a)] – discrepant

Example 3: $Q_{\beta-}$ for ^{162}Tb – cont.

PHYSICAL REVIEW C **111**, 049801 (2025)

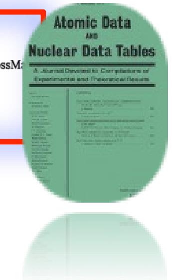
Comment on "Spin-trap isomers in deformed, odd-odd nuclei in the light rare-earth region near $N = 98$"

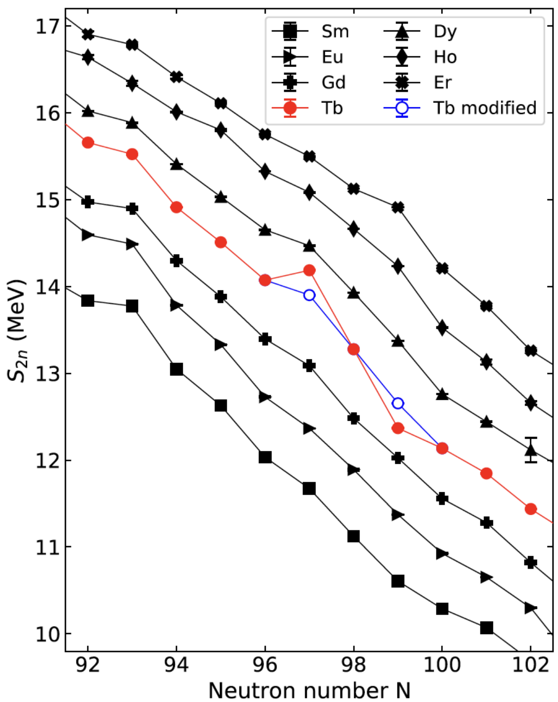
M. Stryjczyk[*,†] A. Jaries[‡] A. Kankainen[§] and T. Eronen[¶]
University of Jyvaskyla, Department of Physics, Accelerator laboratory, P.O. Box 35(YFL) FI-40014 Jyvaskyla, Finland

Atomic Data and Nuclear Data Tables 103–104 (2015) 50–105

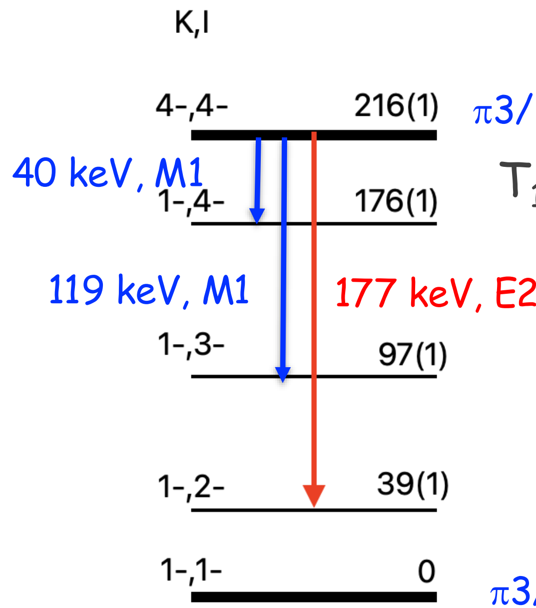
Configurations and hindered decays of K isomers in deformed nuclei with A > 100

F.G. Kondev[a,*], G.D. Dracoulis[b,1], T. Kibédi[b]





F_W[for E2, ΔK=3] ~10^6



$\pi 3/2[411]$ $\nu 5/2[523]$, $K^\pi=4^-$

$T_{1/2,\gamma}$[177 keV E2, ΔK=3]=61 ms

1% BR -> $T_{1/2}$=610 μs

$\pi 3/2[411]$ $\nu 5/2[523]$, $K^\pi=1^-$

Compare 2020Or03 gs and isomer masses

- $Q_{\beta-}$=2301.6(22) if mass of the ^{162}Tb gs
- $Q_{\beta-}$=2587.3(26) if mass of the ^{162}Tb iso

What would be useful

- new TOF-PI mass measurements for ^{162}Tb
- new spectroscopy data for ^{162}Tb to establish and characterize the K^π=4- isomer

^{162}Tb gs and isomer will be updated in AME2026 & NUBASE2026