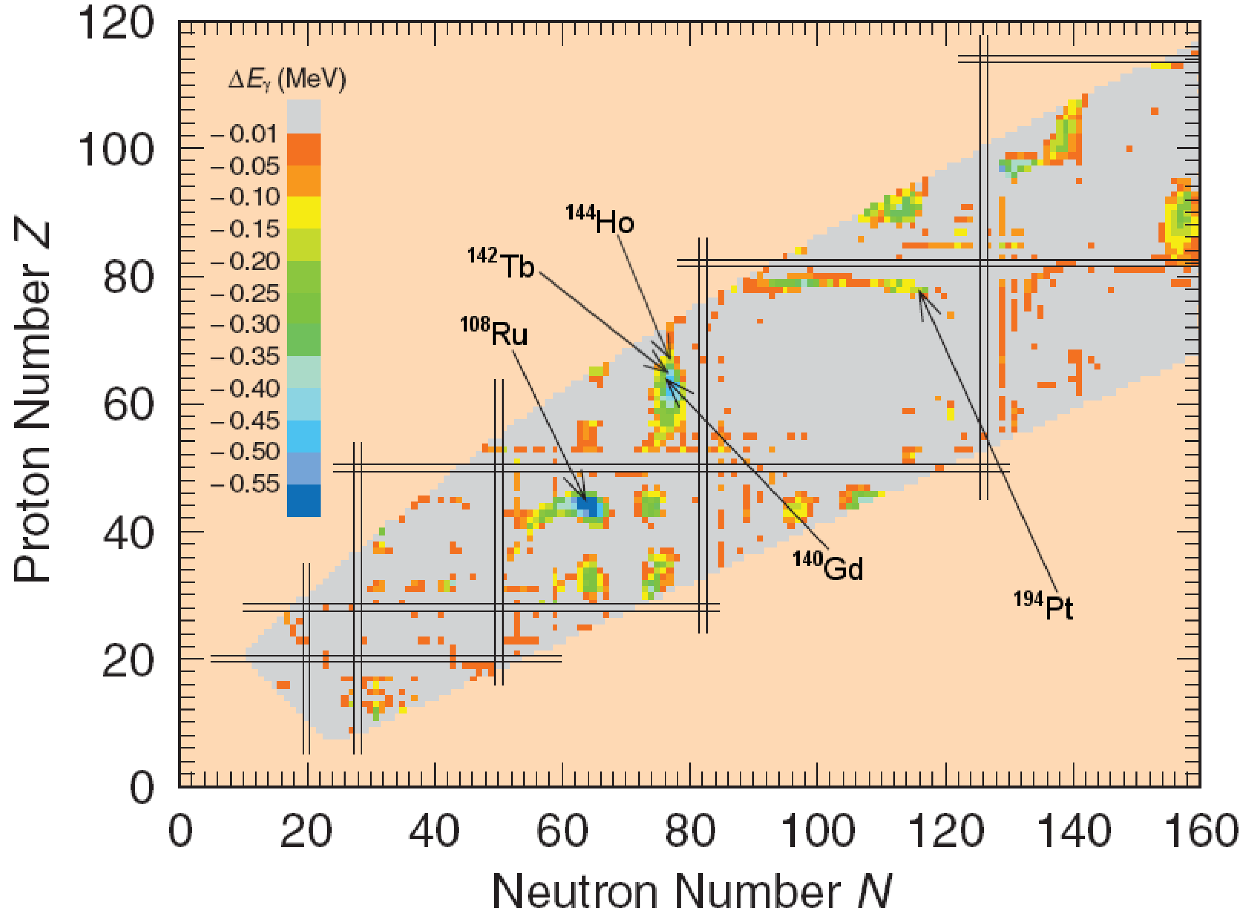
Recoil-Isomer Tagging of Extremely Neutron-Deficient Nuclei, ^{142}Tb and ^{144}Ho

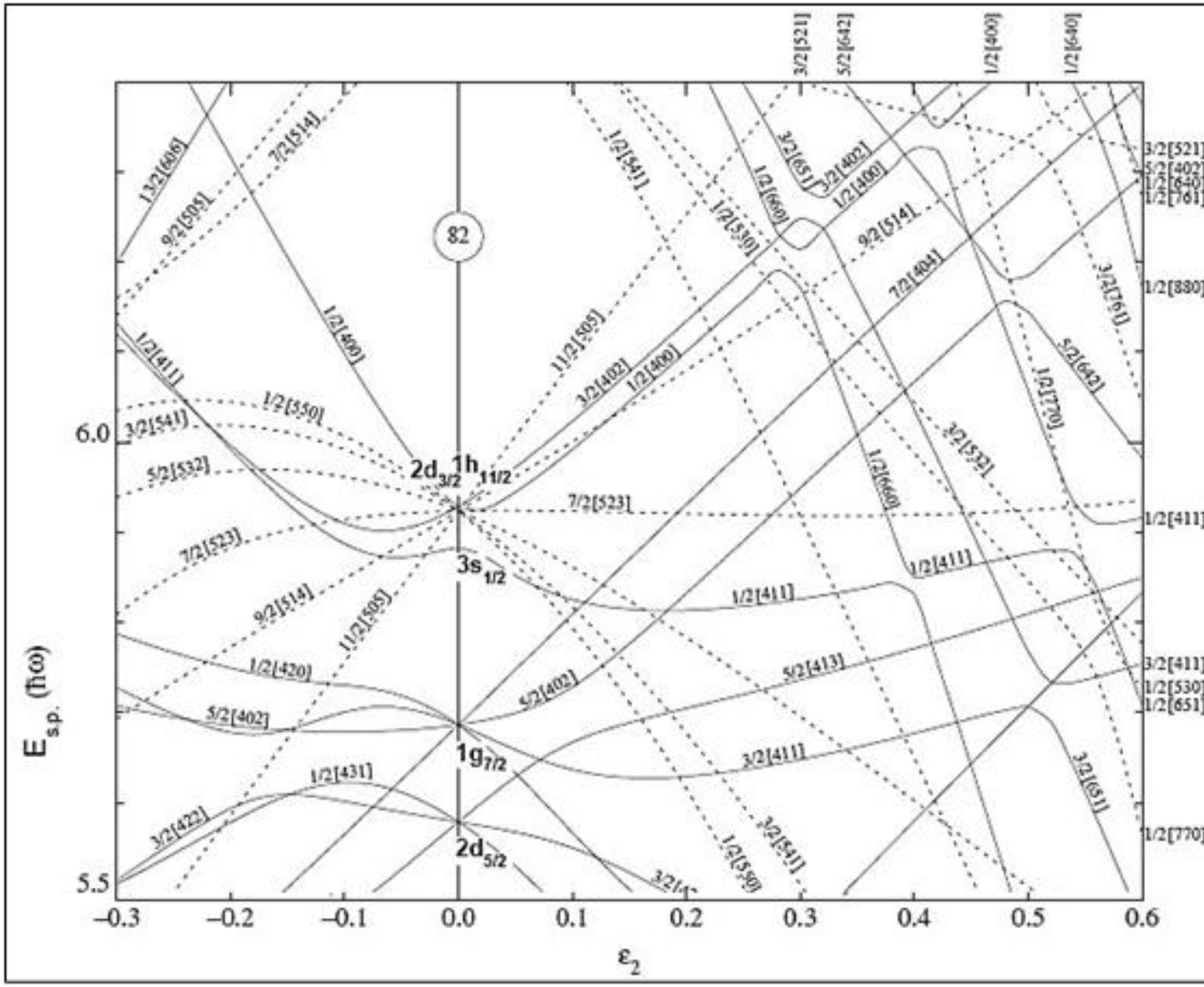
Pete J.R. Mason

Introduction and Physical Background

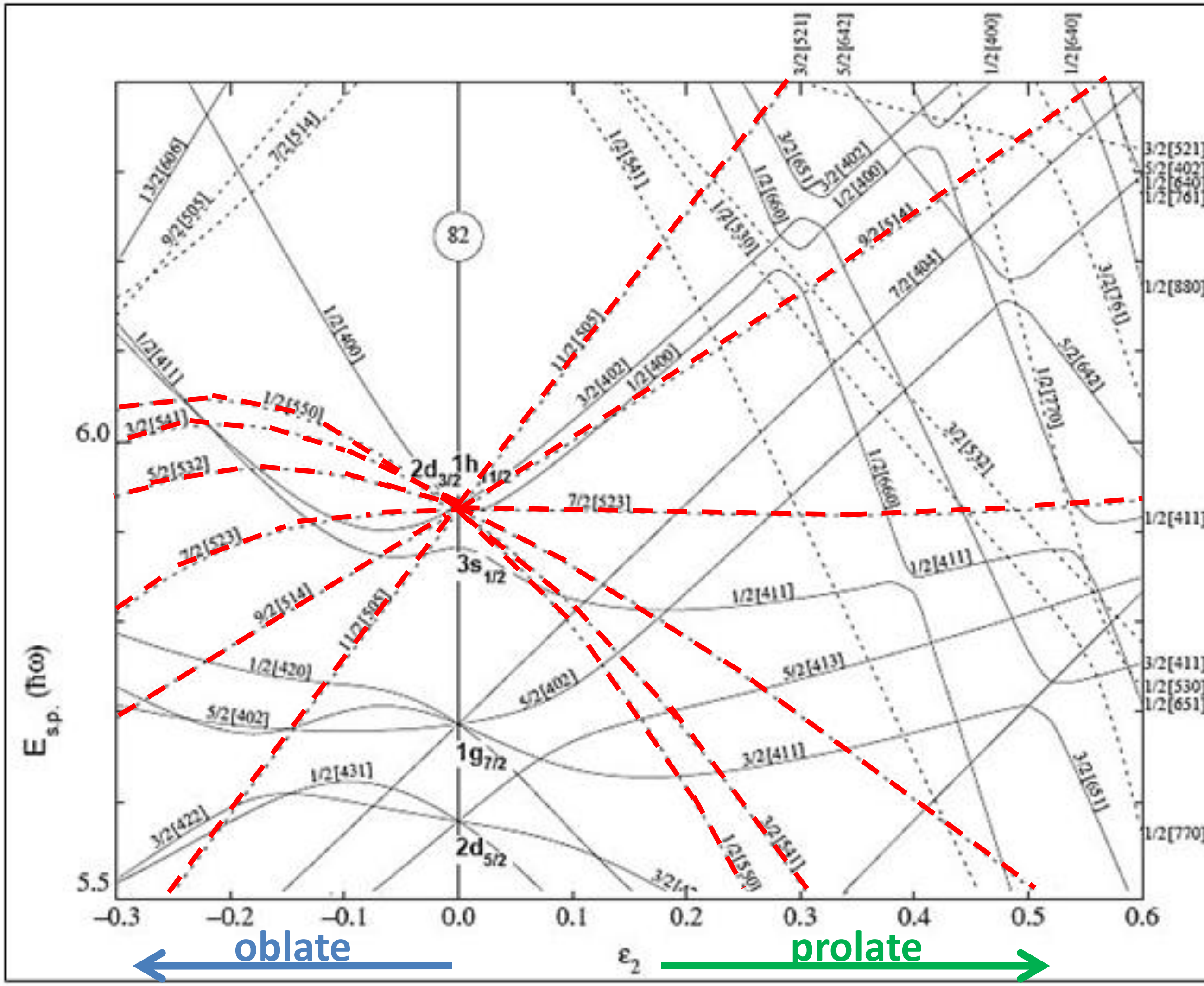


- Region of axial asymmetry in nuclear shape
- Nilsson quantum numbers no longer conserved
- γ-softness can lead to shape isomerism

P. Möller *et al,* PRL**97**, 162502 (2006)



- Competition between $\pi\mathbf{h_{11/2}}$ and $\nu\mathbf{h_{11/2}}$ intruder orbitals near Fermi surface
- Protons favour a **prolate** shape, neutrons favour **oblate** shape



- Competition between $\pi h_{11/2}$ and $\nu h_{11/2}$ intruder orbitals near Fermi surface
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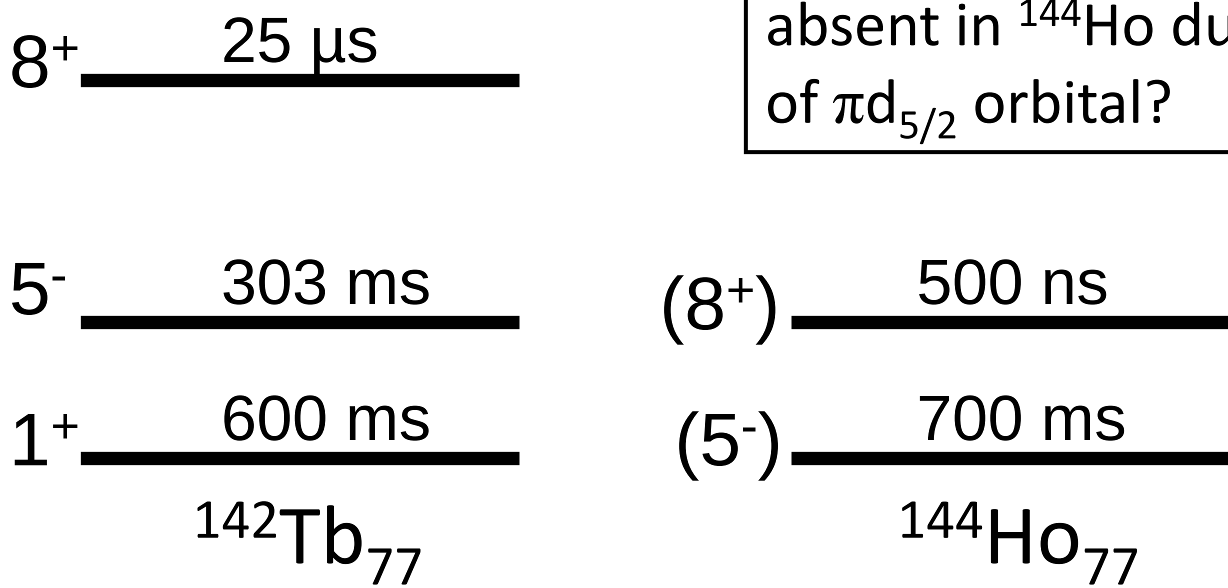
(8$^+$) Isomeric states predicted to be based on $\pi h_{11/2}$ x $\nu h_{11/2}$ configurations

Longer-lived (5$^-$) states based on $\pi h_{11/2}$ x $\nu s_{1/2}, d_{3/2}$ configurations

$\pi d_{5/2}$ x $\nu d_{3/2}$ 1$^+$ ground state absent in ^{144}Ho due to filling of $\pi d_{5/2}$ orbital?



C. Scholey *et al,* PRC**63**, 034321 (2001)

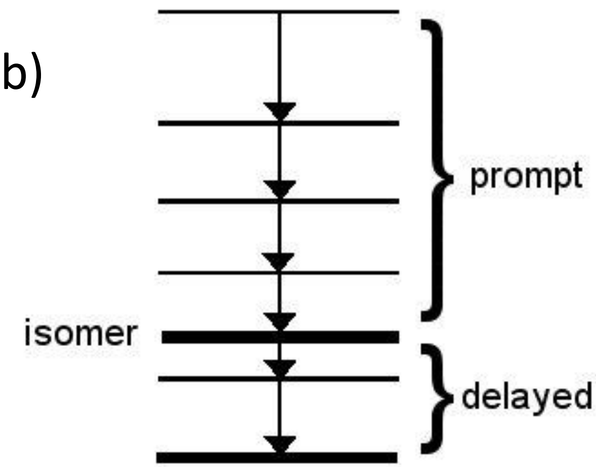
M.N. Tantawy *et al,* PRC**73**, 024316 (2006)

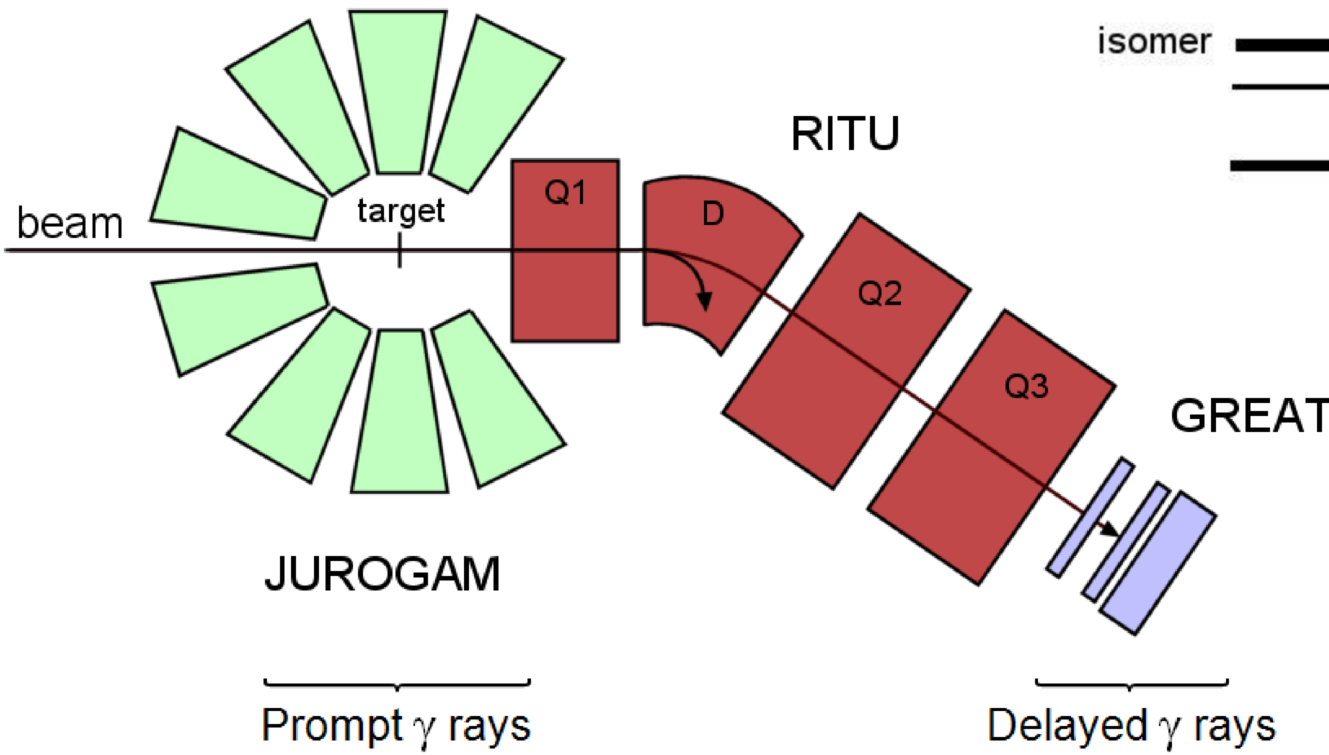
and references therein.

^{144}Ho is proton unbound - C. Rauth *et al.* PRL**100**, 012501 (2008)

Experimental setup

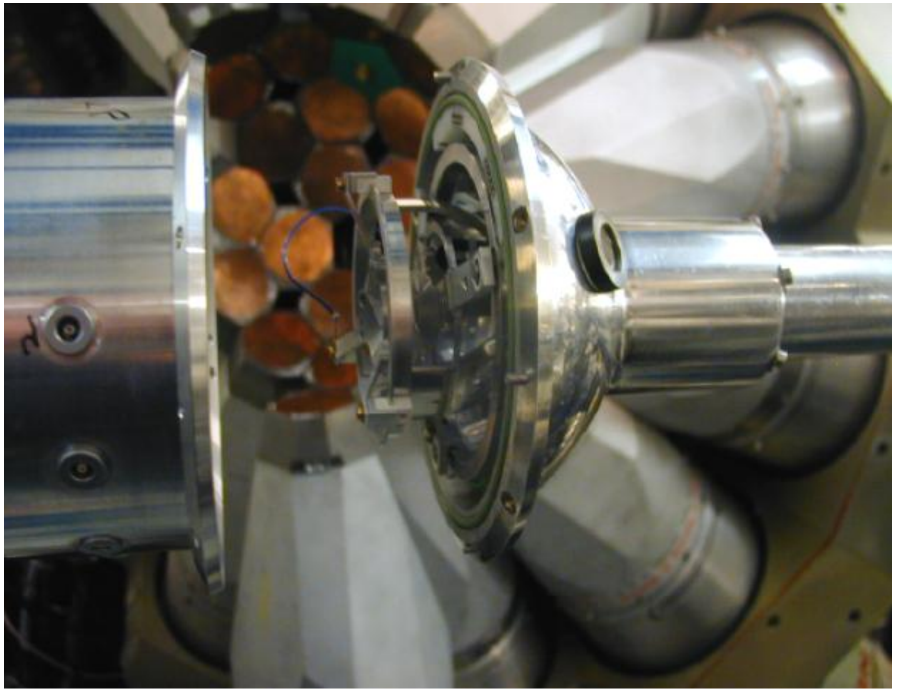
- $^{92}Mo(^{54}Fe,xnyp)$ fusion-evaporation reaction
- 226 MeV (^{144}Ho); 245, 252 and 265 MeV (^{142}Tb)
- JUROGAM - RITU
- Recoil-isomer tagging

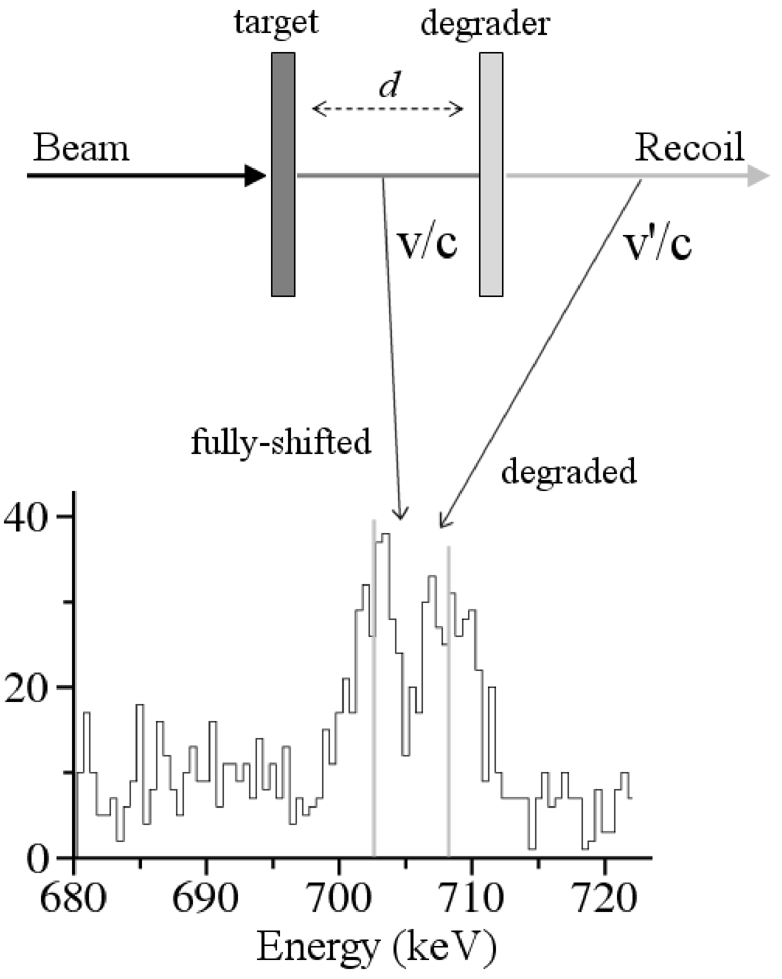




Lifetime measurements for ^{144}Ho

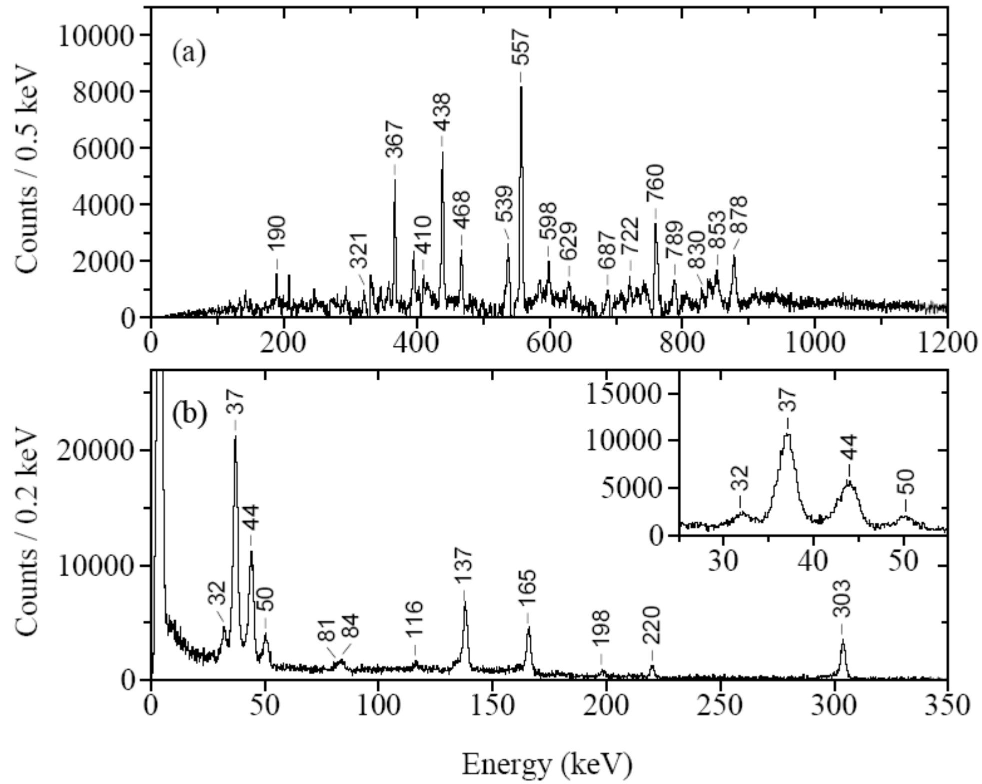
- Köln differential plunger
- Differential decay curve method
- Recoil-isomer tagging employed to isolate prompt ^{144}Ho transitions
- Intensities of fully-shifted and degraded peaks give lifetime

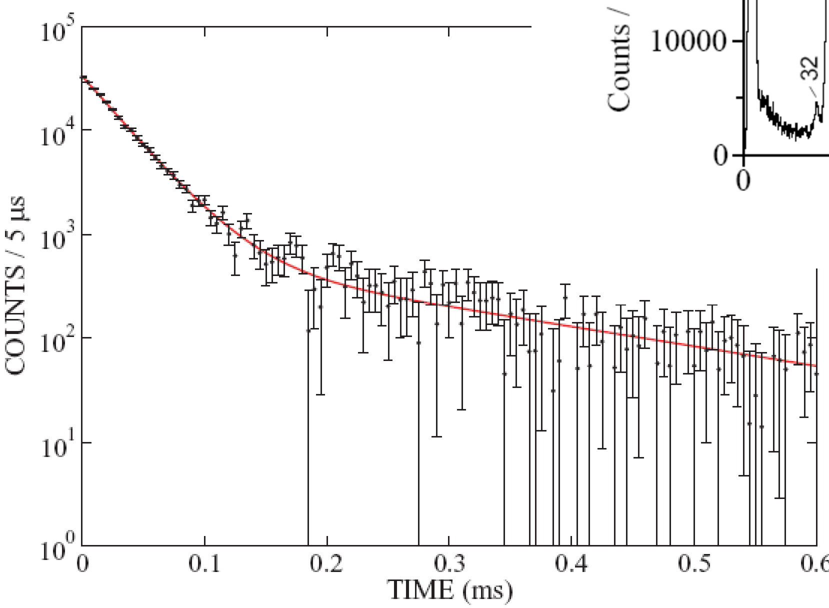




Results – ^{142}Tb

- Isomer-tagged prompt γ- γ matrix to construct above-isomer level scheme
- Additional bands observed in recoil-gated cube

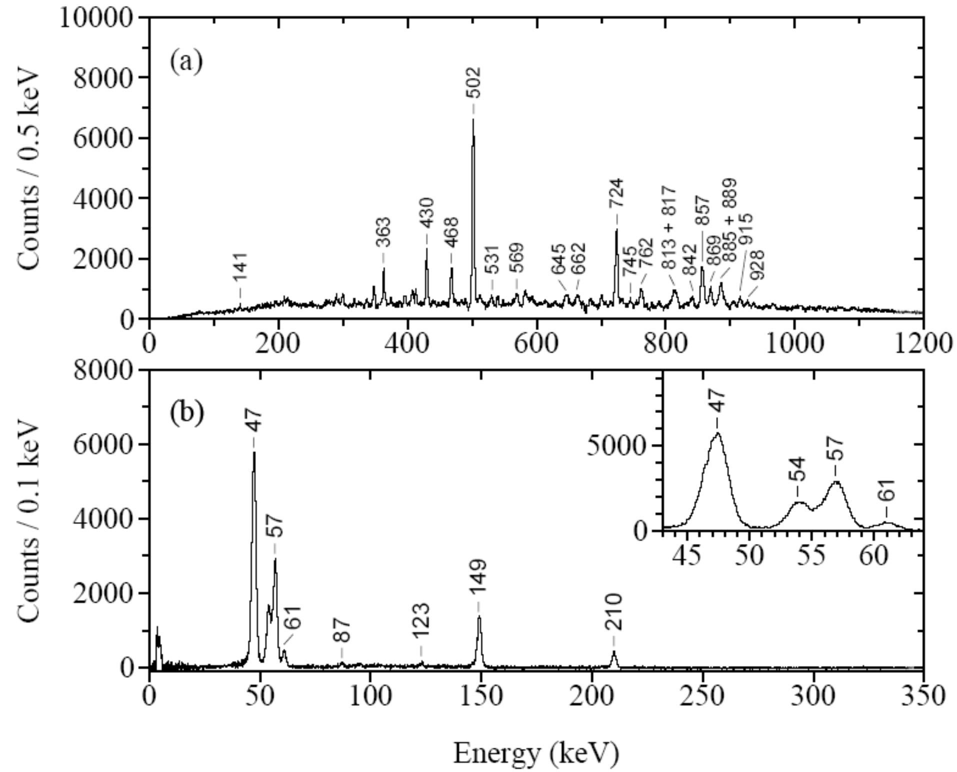


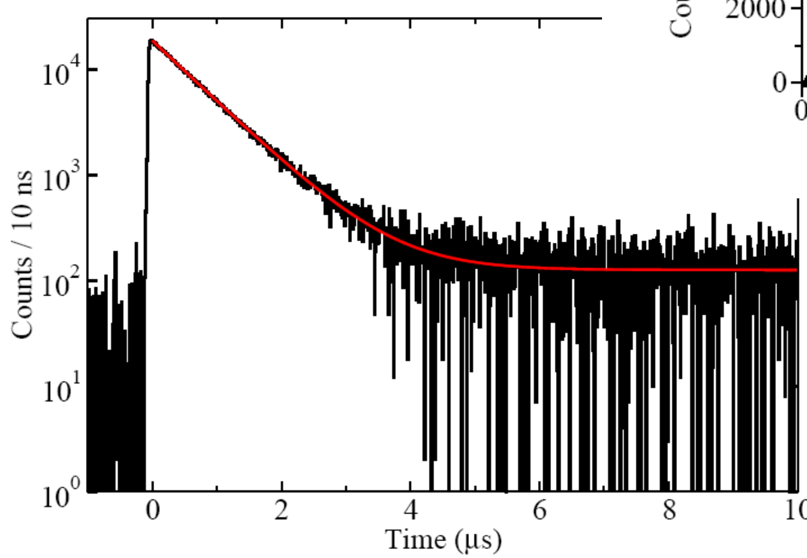


$T_{1/2}$ = 26(1) μs
Corrected for high recoil implantation rate

Results – ^{144}Ho

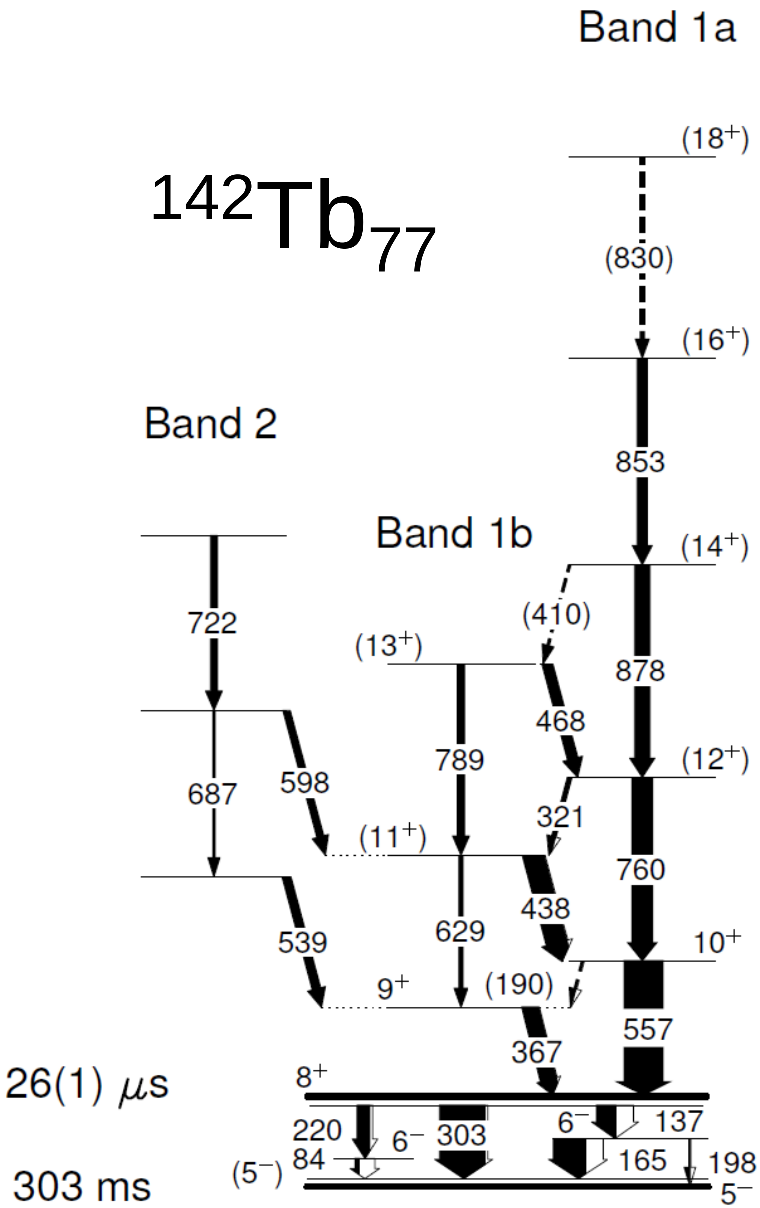
- Isomer-tagged prompt γ - γ matrix to construct above-isomer level scheme





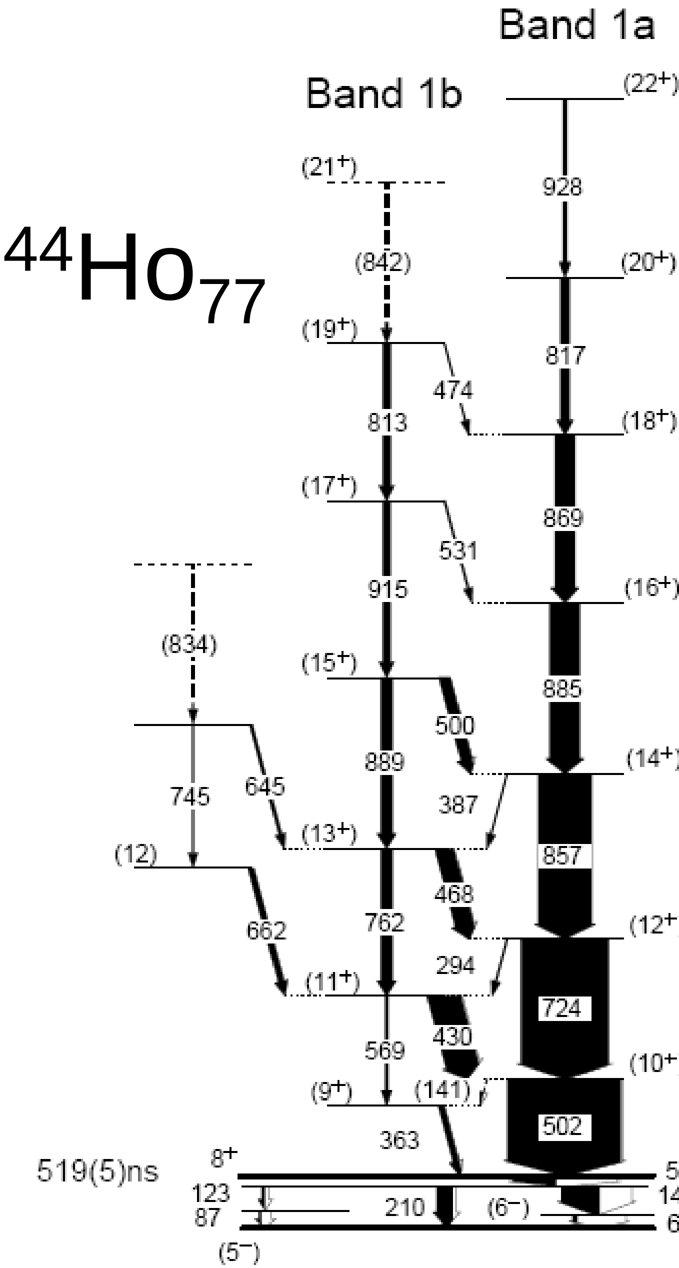
$T_{1/2}$ = 519 (5) ns

$^{142}Tb_{77}$

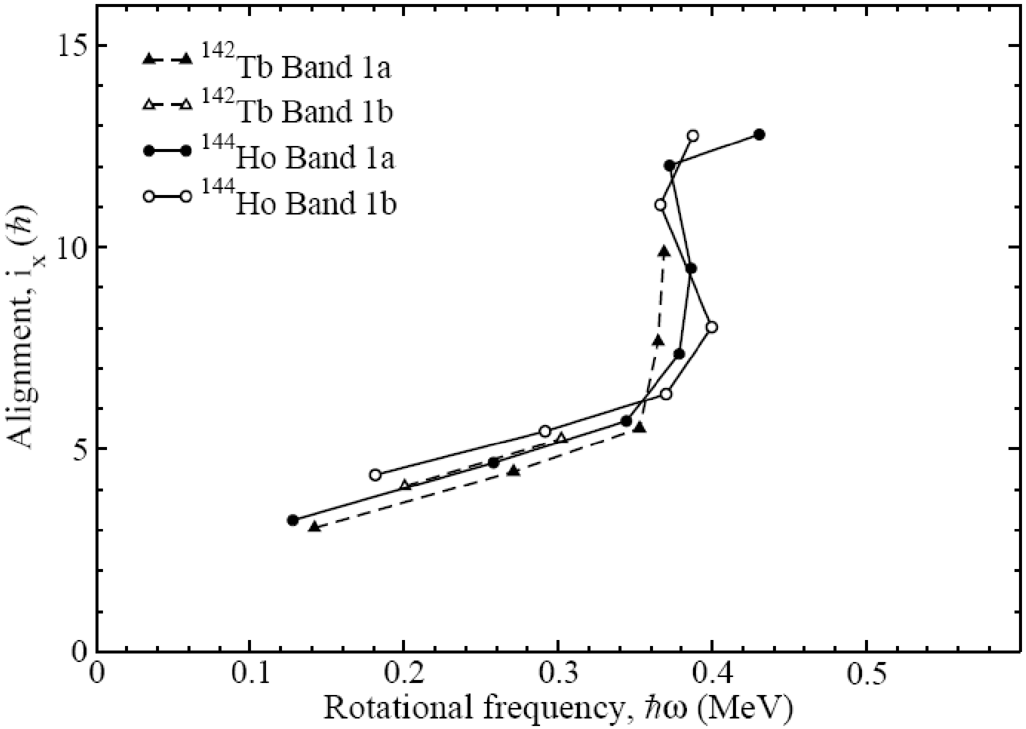


P.J.R. Mason *et al,* PRC**79**, 024318 (2009)

$^{144}Ho_{77}$



P.J.R. Mason *et al,* PRC**81**, 024302 (2010)



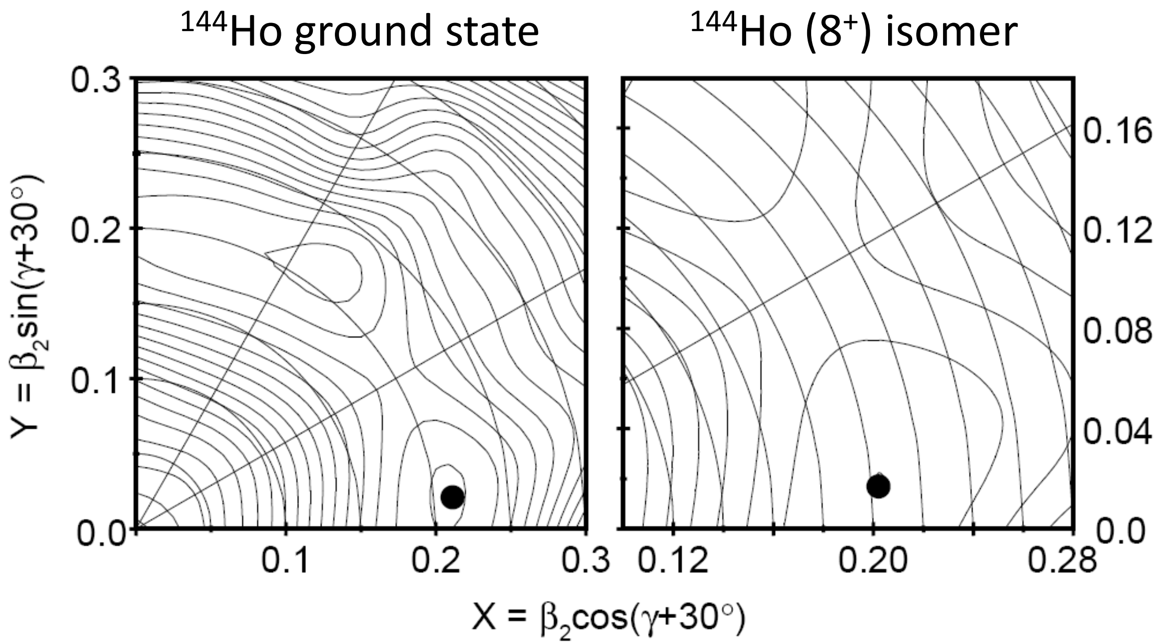
Consider:

- Rotational properties of bands above isomer
- Orbitals at the Fermi surface

$\Rightarrow$ Isomers based on $\pi h_{11/2}$ x $\nu h_{11/2}$ 2-quasiparicle configurations

Hindrance

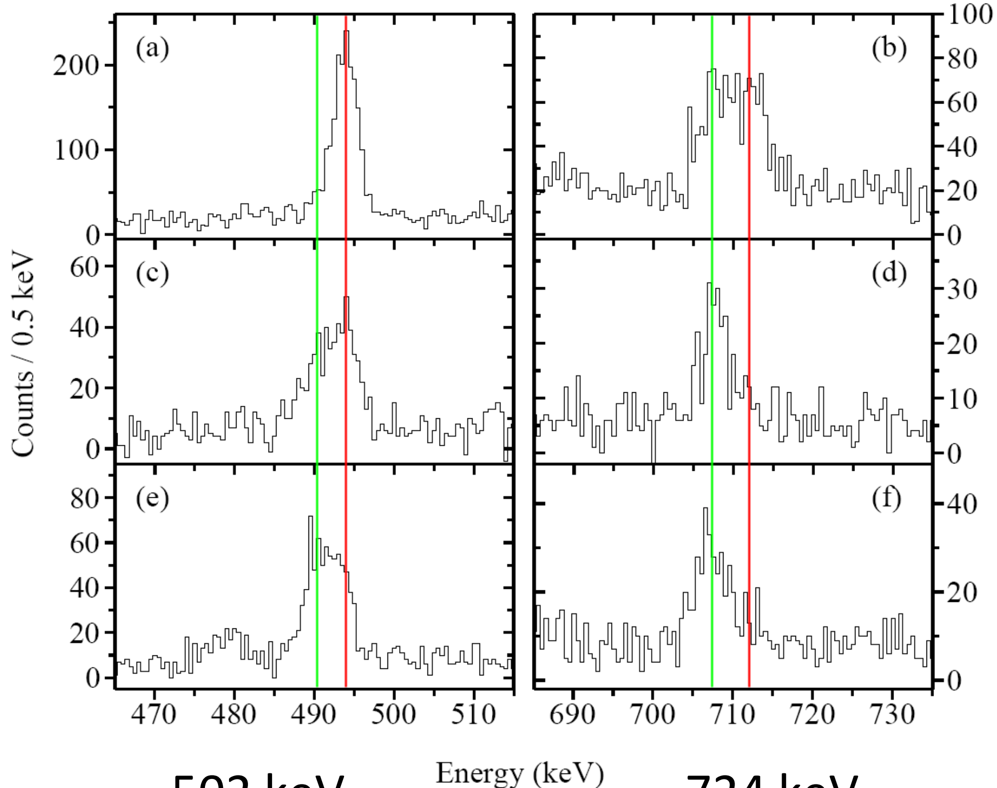
- Shape isomers?
- K isomers??
- 'natural' hindrance of E1 decays?



- PES calculations predict $\beta_2 \approx 0.2$, $\gamma \approx -30^o$ for isomers
- Very similar deformation for ^{144}Ho g.s.

- ^{142}Tb, B(E1) = 1.1(1) x 10^{-7} W.u
- ^{144}Ho, B(E1) = 1.11(1) x 10^{-6} W.u

- P. M. Endt, Atomic and Nuclear Data Tables **26** (1981) 41 $\Rightarrow$ typical hindrance for E1 decays in A =91-150 is $10^{-5} - 10^{-4}$ W.u



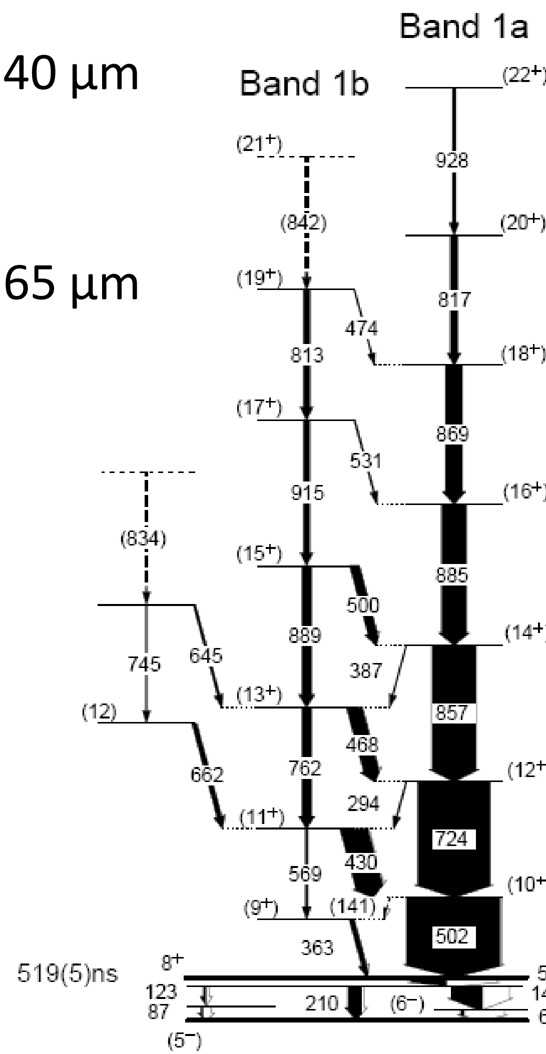
8 µm

40 µm

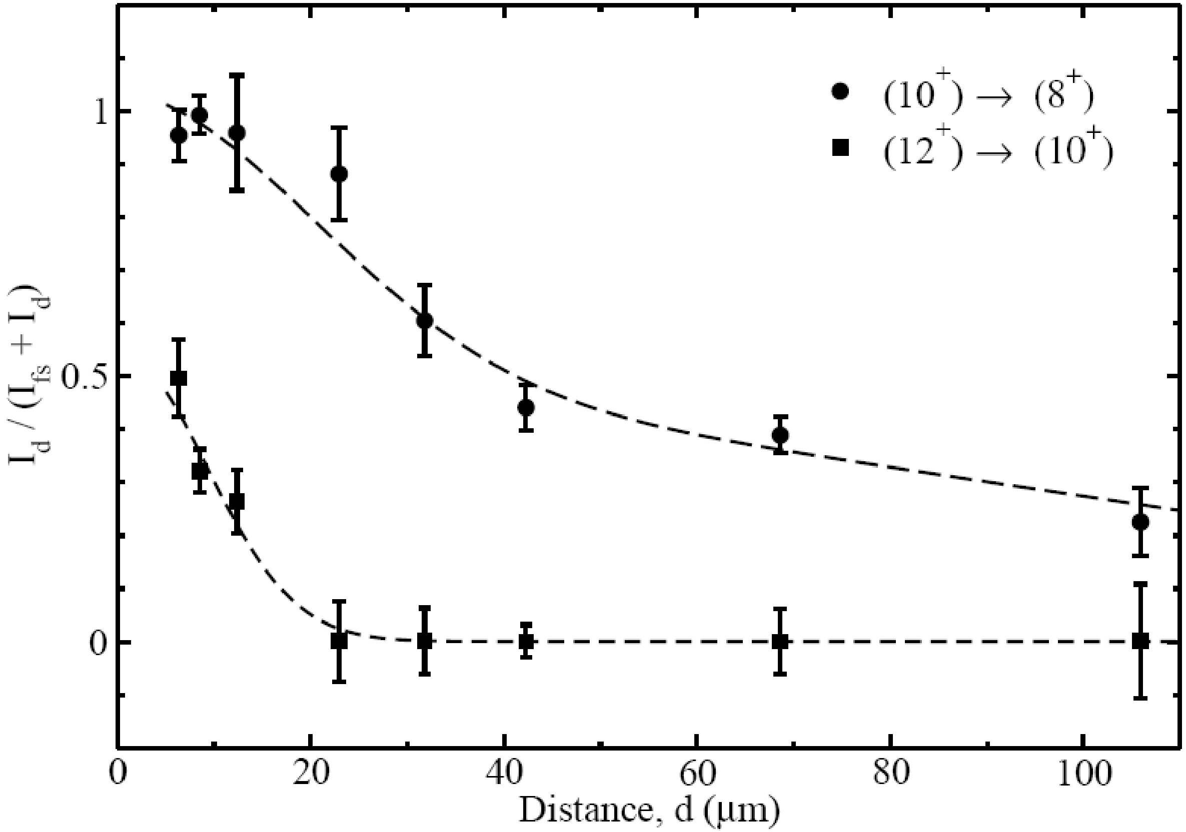
65 µm

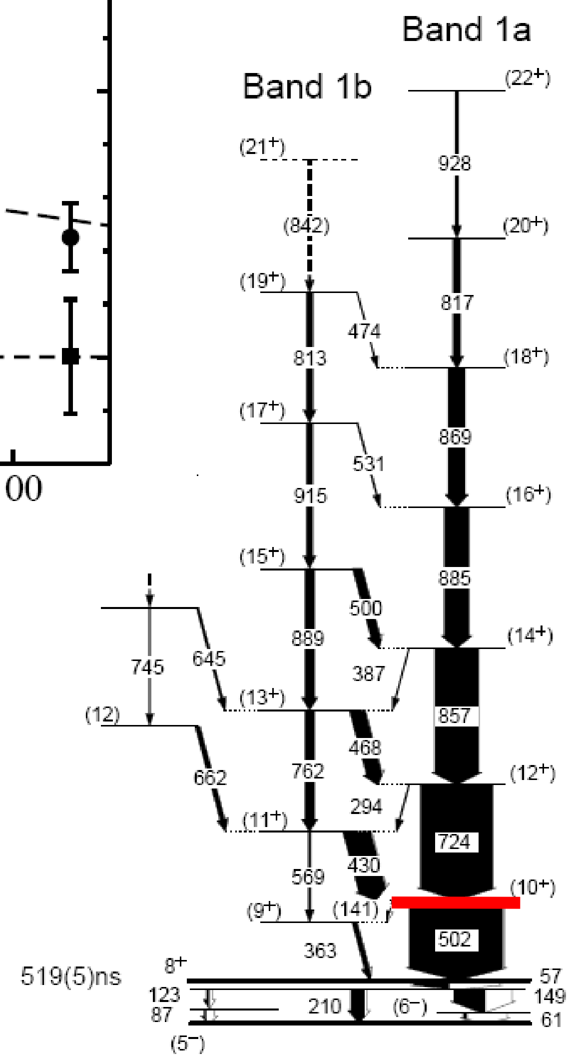
502 keV

724 keV



- Differential plunger measurements at 8 target-to-degrader distances
- Decay curves measured for 502- and 724-keV transitions
- Allows calculation of lifetime for (10⁺) state





$\tau(10^+)$ = 6(1) ps, B(E2) = 94(16) W.u

Similar side-feeding assumption

P.J.R. Mason *et al, submitted to* PLB (2009)

Lifetime of the (10^+) state in ^{144}Ho

From configuration constrained PES calculations Q_t = 6.01 eb,

Experimental $\tau(10^+)$ = 6(1) ps

1) $B(E2; KI \rightarrow KI-2) = \frac{5}{16\pi} Q_t^2 \langle IK20 | I-2K \rangle^2$ Bohr and Mottelson

2) $B(E2; 2 \rightarrow 0) = \frac{Q_0^2}{32\pi}\left[1 + \frac{3 - 2\sin^2(3\gamma)}{\sqrt{9 - 8\sin^2(3\gamma)}}\right],$ Davydov and Filippov

$$Q_0 = \frac{3ZR^2\beta}{\sqrt{5\pi}}e,$$

1) τ = 27 ps (K = 8)

2) τ = 8 ps

Summary and future prospects

- Isomer tagging gives means to study exotic nuclei (with suitable isomeric states).
- ^{142}Tb and ^{144}Ho predicted to be axially asymmetric and γ soft.
- (8^+) isomers based on $\pi h_{11/2} \otimes \nu h_{11/2}$ two-quasiparticle configurations.
- Isomerism likely from shape differences and hindered nature of E1 decays in this mass region.
- Simple rotational model cannot satisfactorily describe lifetime of (10^+) state in ^{144}Ho.

- Combining selection techniques with indirect methods for measuring lifetimes is viable even in very weakly-populated systems.
- Development of theoretical techniques to describe these nuclei necessary to interpret results.

Acknowledgements

P. J. R. MASON, D. M. Cullen, N. M. Lumley, J.Dare, S. Khan, A. M. Kishada, B. Niclasen, B. J. Varley

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