High-spin states feeding seniority isomers in the heaviest *N*=82 isotones

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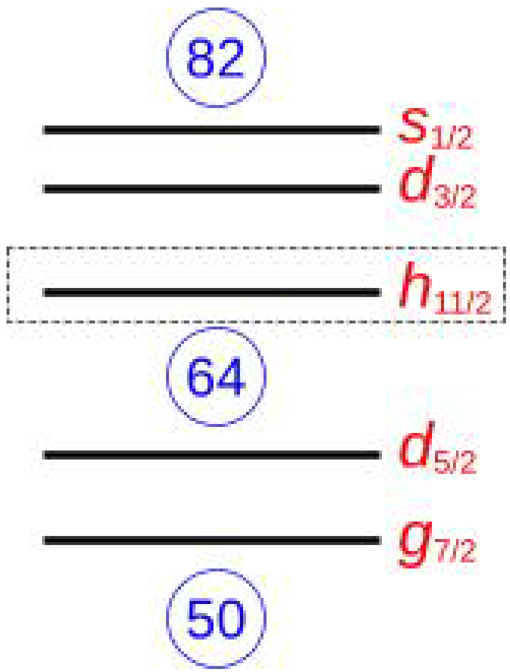
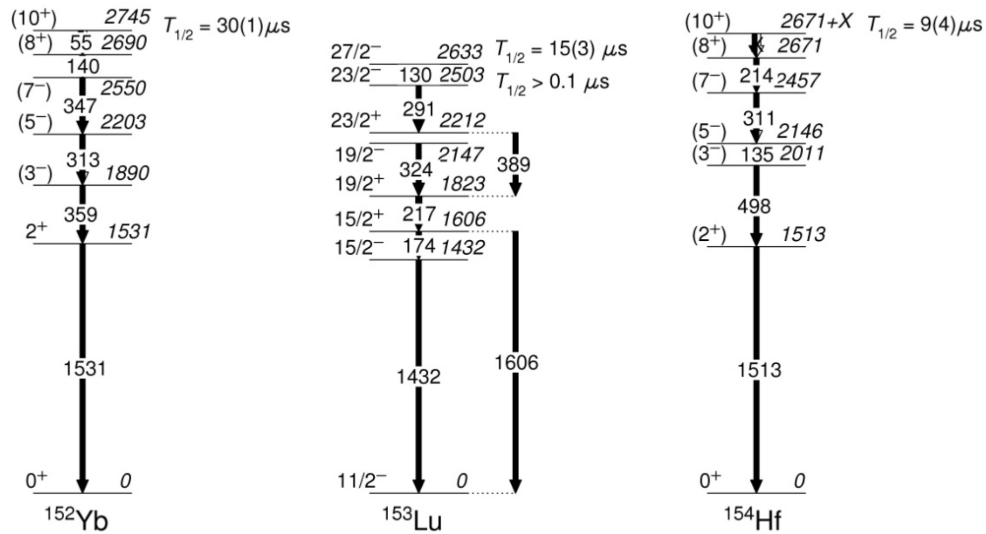
Motivation: *N*=82 isotones

- ^{146}Gd displays characteristics of doubly-magic nucleus
- Closed N = 82 shell and subshell closure at Z = 64
- Neighbours well described by shell model calculations $\pi(h_{11/2})^n \otimes$ ^{146}Gd core
- What about heavier isotones?



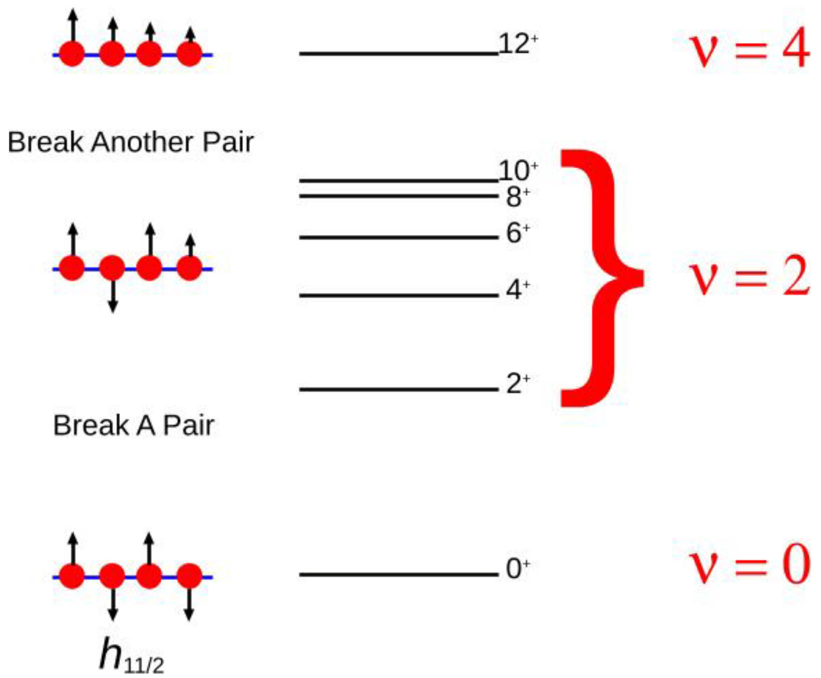
Heaviest $N = 82$ isotones



- Level schemes for ^{152}Yb, ^{153}Lu and ^{154}Hf established to 10^+ or $27/2^-$ twenty years ago
- These states are seniority isomers, decaying via low-energy E2 transitions
- No $\nu > 2$ states have been reported

What is a seniority isomer?

- Seniority, ν, is minimum number of nucleons not coupled to 0^+
- For even-even and odd-odd nuclei ν is even; for odd-*A* nuclei ν is odd
- Isomerism results from proximity of nuclear levels



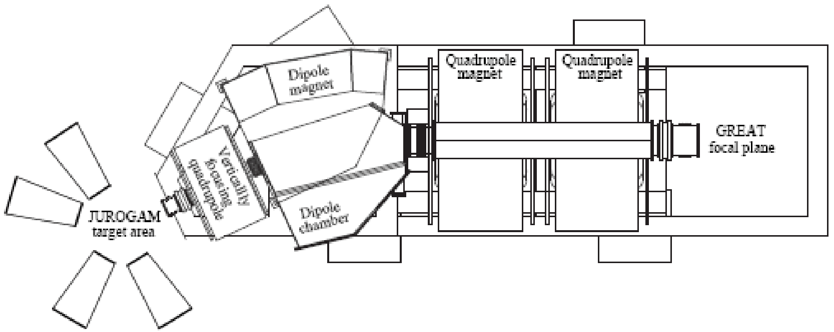
Experimental details

- ^{64}Zn (265-295 MeV) + ^{92}Mo -> ^{156}Hf * at Jyväskylä, Finland
- Main targets of experiment ^{154}Hf (2*n*), ^{153}Lu (*p*2n) and ^{152}Yb (2*p*2n)
- Range of beam energies as cross sections maximised at different energies
- Recoil Isomer Tagging used to unambiguously identify prompt γ rays

$Z = 72$	^{153}Hf	^{154}Hf 10^{+} 9μs	^{155}Hf	^{156}Hf CN
	^{152}Lu	^{153}Lu $27/2^{-}$ 15μs	^{154}Lu	^{155}Lu
$Z = 70$	^{151}Yb $27/2^{-}$ 20μs	^{152}Yb 10^{+} 30μs	^{153}Yb $27/2^{-}$ 15μs	^{154}Yb 16^{+} 18.6ns
	^{150}Tm	^{151}Tm $27/2^{-}$ 0.45μs	^{152}Tm 17^{+} 0.294μs	^{153}Tm
$Z = 68$	^{149}Er $27/2^{-}$ 4.8μs	^{150}Er 10^{+} 2.55μs	^{151}Er $27/2^{-}$ 0.5s	^{152}Er
	^{148}Ho	^{149}Ho $27/2^{-}$ 0.45μs	^{150}Ho	^{151}Ho
$Z = 66$	^{147}Dy	^{148}Dy 10^{+} 0.47μs	^{149}Dy	^{150}Dy
		$N = 82$		$N = 84$

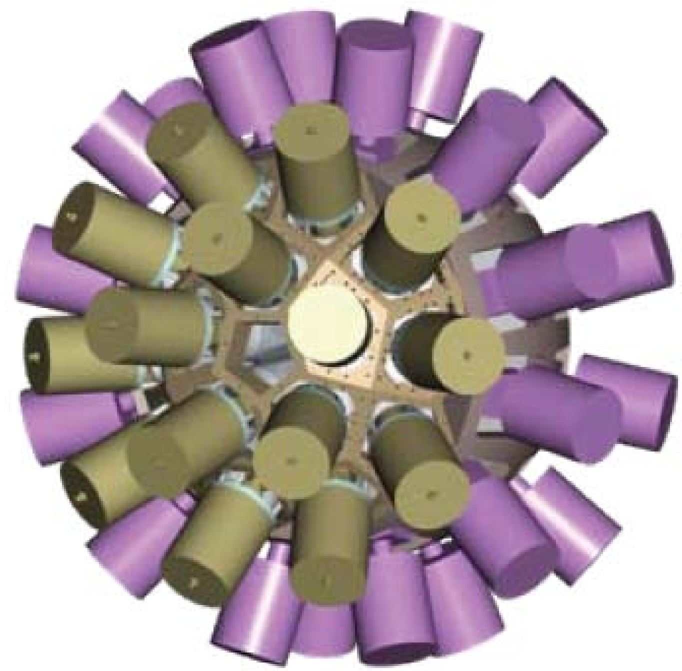
Recoil Isomer Tagging

- Similar to Recoil Decay Tagging
- Gate on delayed γ rays in the absence of (or in addition to) charged particle decay
- Temporally correlate delayed γ rays with prompt γ rays at target position
- High γ-ray efficiency at both ends of recoil separator



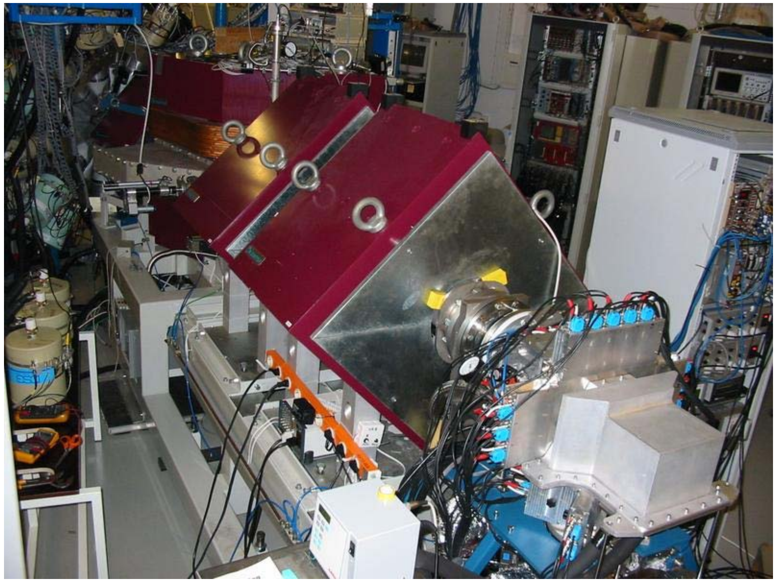
Recoil Isomer Tagging at JYFL

- JUROGAM II located around target position
- Fully digitised 39 Compton-suppressed HP-Ge detectors (15 EB phase 1 & 24 clovers)
- Detect prompt γ radiation
- $\varepsilon \sim 6\%$ at 1.3 MeV
- Four rings of detectors (three of which $\theta > 90°$)



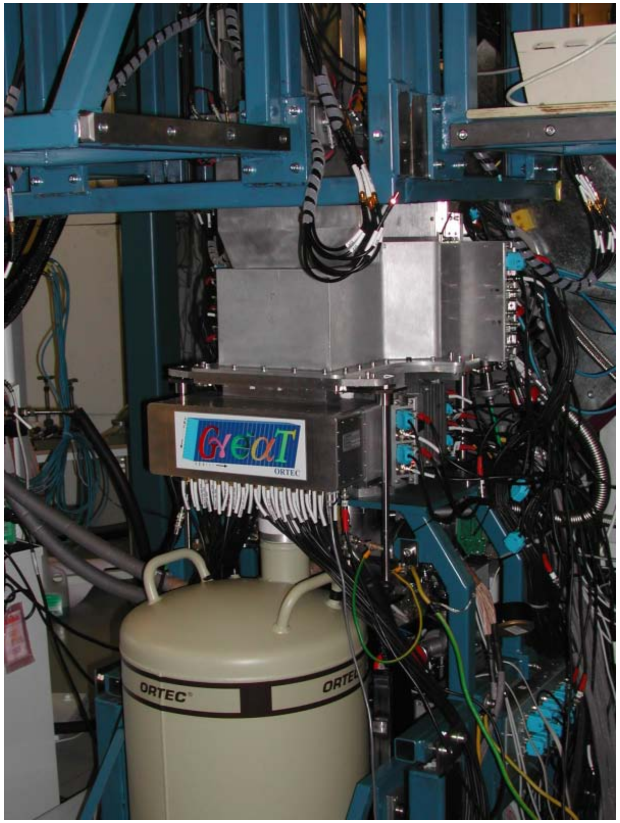
Recoil Isomer Tagging at JYFL

- RITU – Recoil Ion Transportation Unit
- He – filled recoil separator
- QDQQ configuration
- Angular acceptance ~ 10 msr
- $\varepsilon \sim$ 30-50 %
- Zero degree operation
- ToF ~ 0.5 μs



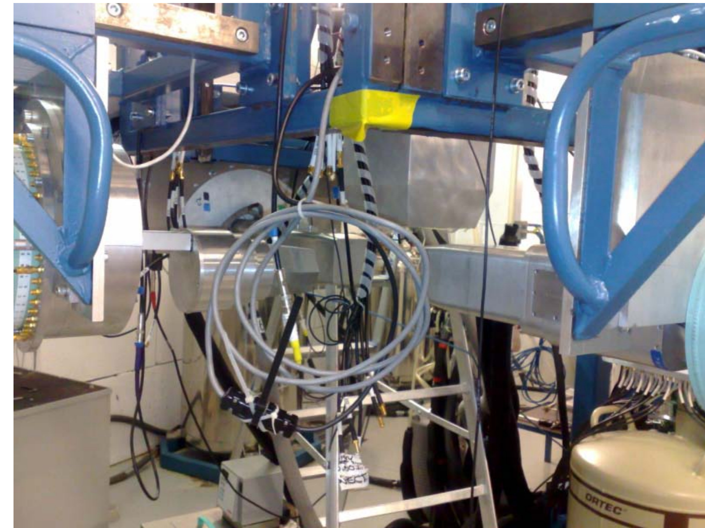
Recoil Isomer Tagging at JYFL

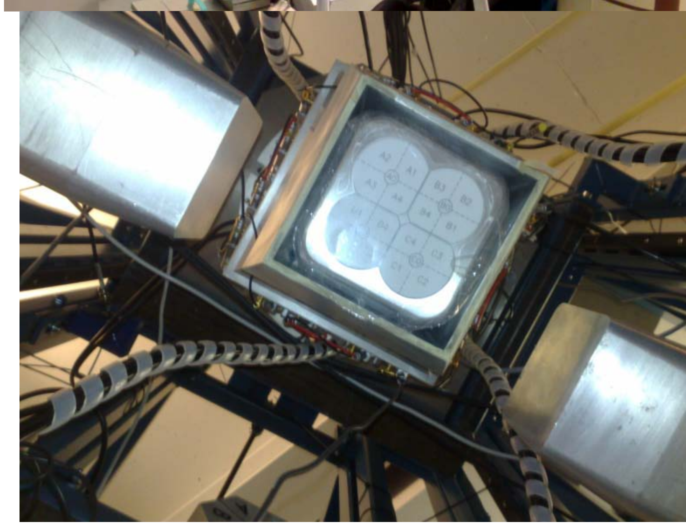
- GREAT – Gamma Ray Electron Alpha Tagging
- Normally consists of MWPC, 2xDSSDs, Si PiN diodes, planar Ge detector and Ge clover detector
- Under normal conditions ToF measured between MWPC and implantation in DSSDs



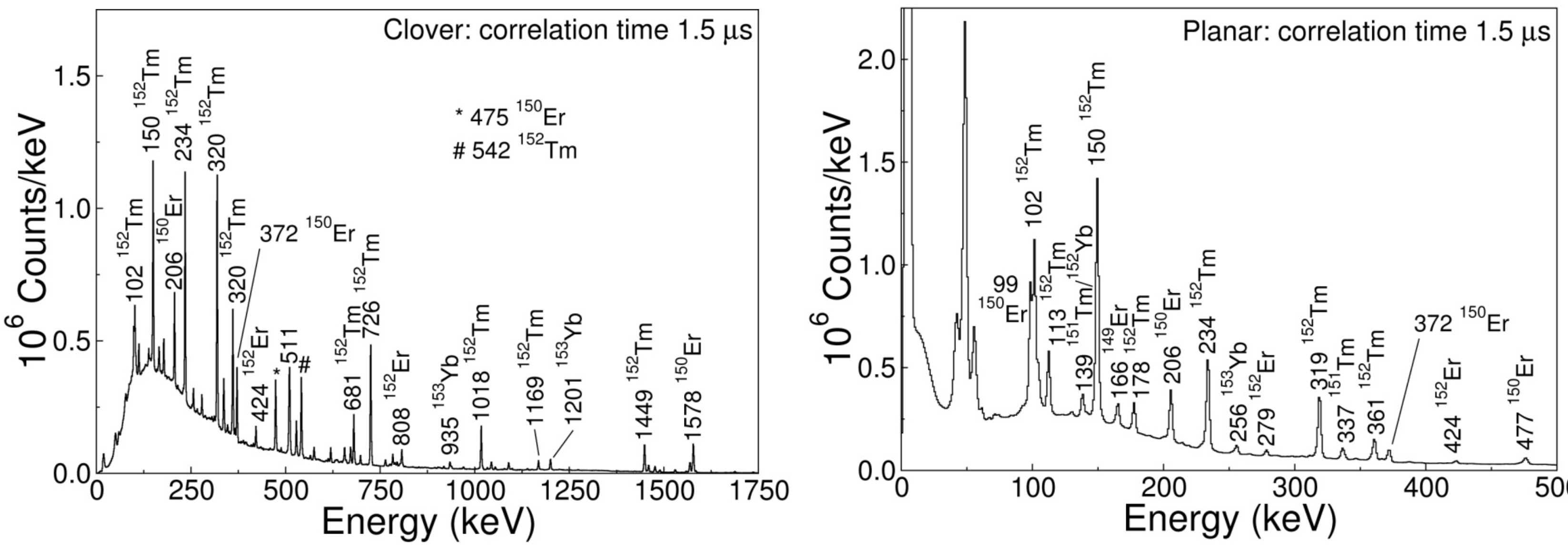
Recoil Isomer Tagging at JYFL

- Present work: DSSDs removed and replaced with second MWPC and passive stopper
- ToF then measured between signals in gas detectors
- Three further clover detectors added to focal plane Ge to maximise γ-ray efficiency
- ε~30 % at 100 keV and ε~2% at 1.3 MeV



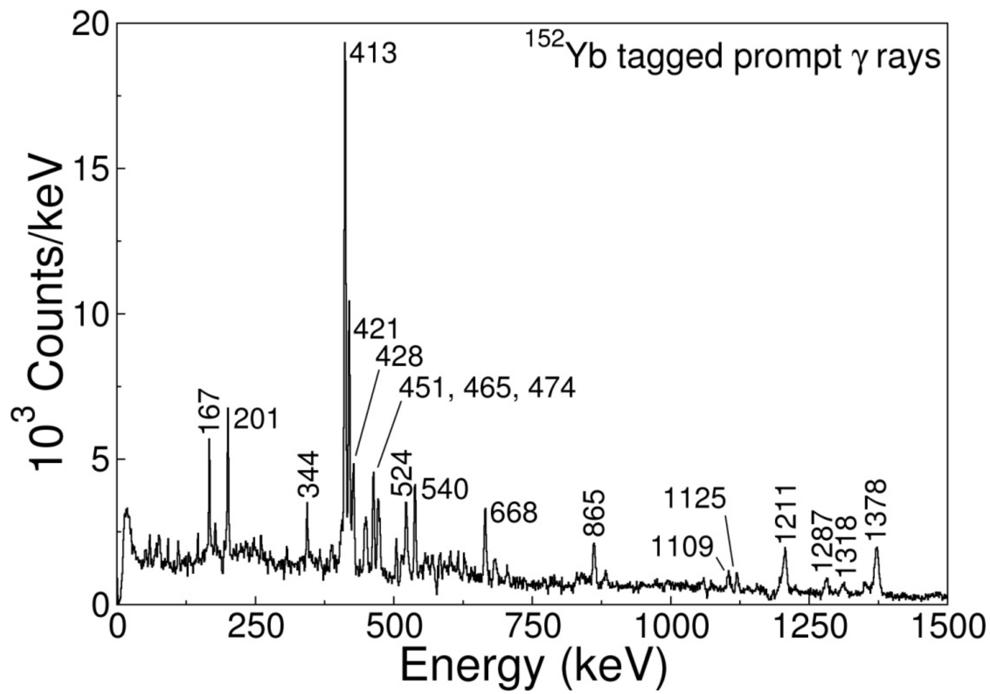


Some results



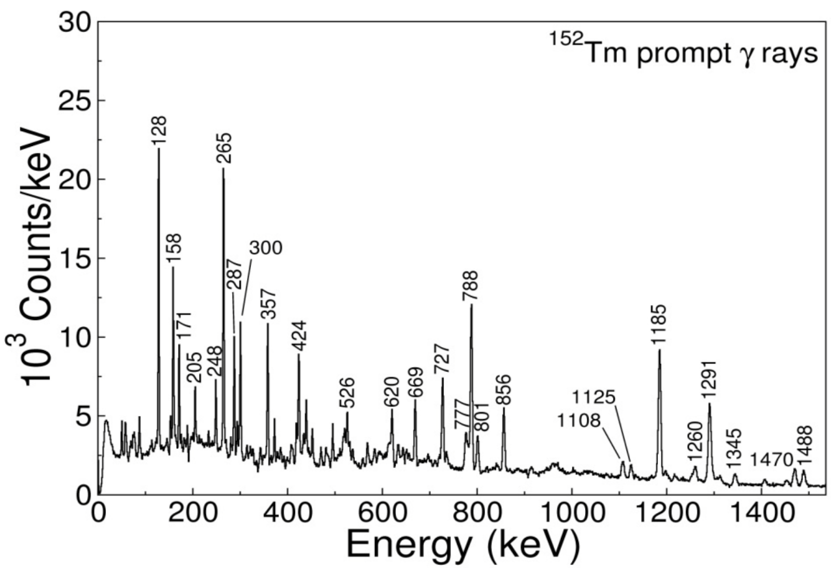
- Establish coincidences between delayed and prompt γ radiation
- Allowing prompt γ rays to be unambiguously identified

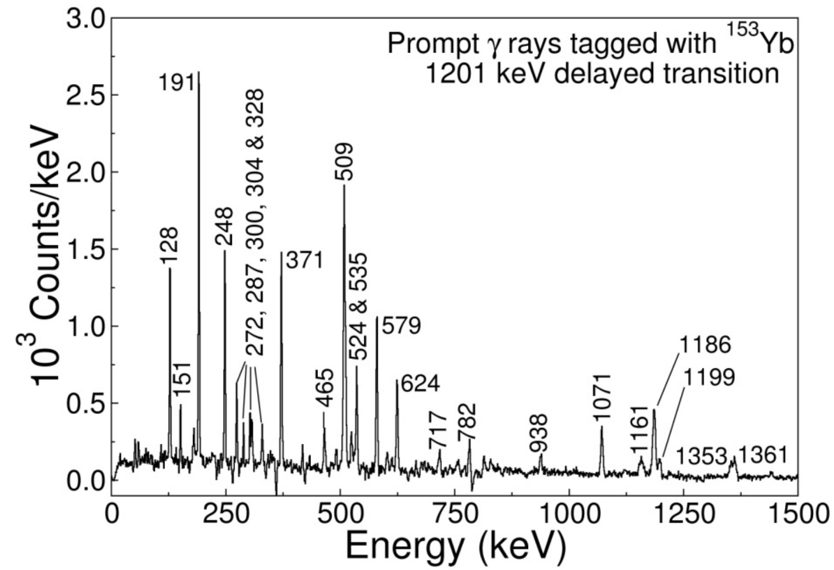
Results: ^{152}Yb



- Once prompt radiation is identified can use γ–γ and γ–γ–γ coincidences
- Analysis currently being performed by student

Results: *N*=83 nuclei





- Transitions decaying from high-spin ν > 2 states which have to date not been published
- Analysis is still in progress but nearing completion

Conclusions/Further work

- Successful in populating high-spin $\nu > 2$ states in $N = 82$ nucleus ^{152}Yb and $N = 83$ nuclei ^{152}Tm and ^{153}Yb
- Analysis is on-going but progressing well
- Compare experimental observations with shell model calculations (P. Van Isacker *et al.*)
- Search for deformed bands ^{152}Er and ^{153}Tm
- Based on success, apply for remaining three days beam time to study ^{153}Lu and ^{154}Hf

Collaborators

- M. Labiche, J. Simpson - STFC Daresbury Laboratory
- R. Carroll, L. Donosa, D. Joss, R. Page, P. Papadakis, E. Paul, H. Watkins - University of Liverpool
- D. Cullen, M. Procter - University of Manchester
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