First observation of E1 transitions from the octupole band to the excited 0^{+}_{2} pairing isomer band in the rare earth nucleus ^{154}Dy

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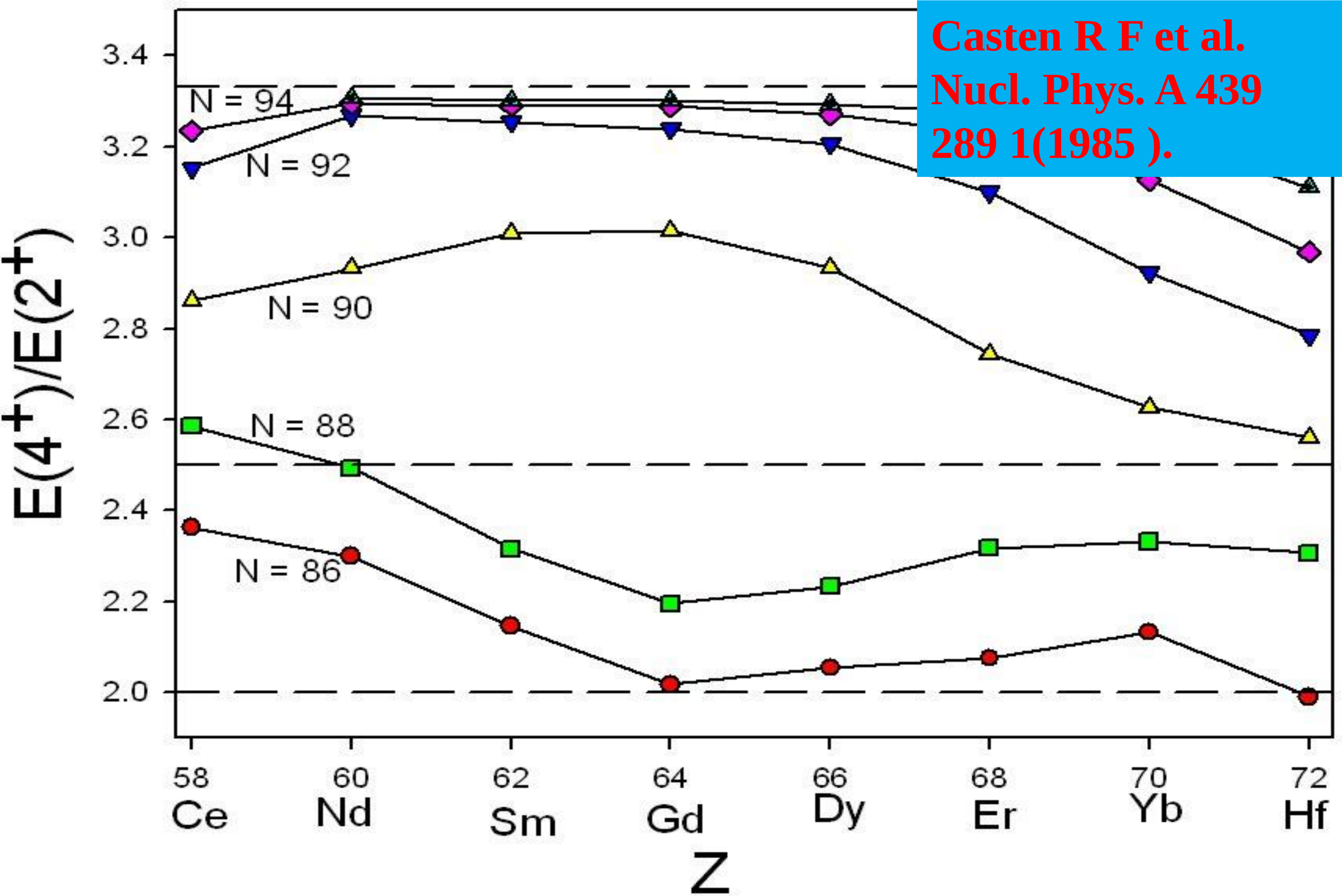
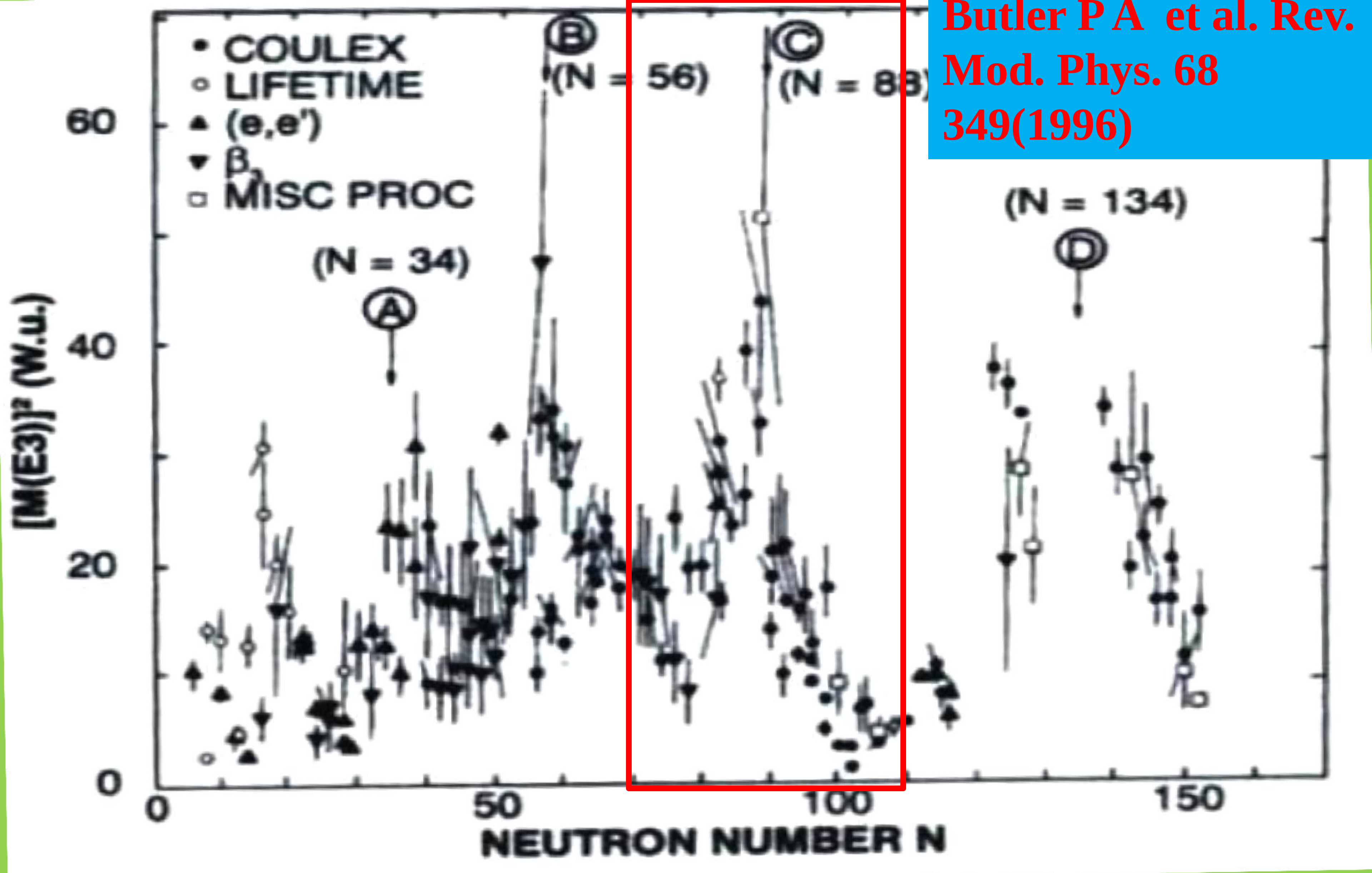
		Er 151 23 s m	Er 152 10,1 s α 4,80 ε g	Er 153 36 s α 4,67 ε g	Er 154 3,75 m ε α 4,17 g	Er 155 5,3 m ε; α 4,012 γ 110; 242; 234...	Er 156 18,6 m ε γ 35; 30... m_1	Er 157 ~ 25 m ε β+ γ 121; 391...	Er 158 2,25 h ε β+ 3,8 γ 72; 387... m_1	Er 159 36 m ε β+ 1,1... γ 624; 649... g; m	Er 160 28,6 h ε no γ m_1	Er 161 3,24 h ε β+... γ 827... g; m	Er 16 0,14 σ 19
148 s 662	Ho 149 21 s β+ γ 1091; 1073; 1584	Ho 150 24 s | 88 s ε; β+ | β+ γ 803	Ho 151 42 s | 35,6 s α 4,61 | α 4,52	Ho 152 52,3 s | 2,4 m β+ | β+ α 4,45 | α 4,38 γ 614 | γ 614	Ho 153 2,0 m | 9,3 m α 3,91 | α 4,01	Ho 154 3,3 m | 11,8 m ε; β+ | ε; β+ α 3,72 | α 3,93	Ho 155 48 m ε β+ 1,8 γ 240; 136...	Ho 156 5,8m | 56m | ~2m	Ho 157 12,6 m ε β+ 1,2; 1,5... γ 280; 341; 193; 87...	Ho 158 21m | 27m | 11m	Ho 159 8,3 s | 33 m ε; β+ γ 121; 132	Ho 160 ~ 1h | 5,0h | 26m	Ho 16 6,7 s
147 ? γ 101	Dy 148 3,1 m ε; β+ γ 620 g	Dy 149 4,1 m β+ γ 101; 1777; 789; 1806... g; m	Dy 150 7,2 m β+ α 4,23 γ 397 g	Dy 151 17 m ε; α 4,07 γ 386; 49; 546; 176... g; m	Dy 152 2,4 h ε α 3,63 γ 257 g	Dy 153 6,29 h ε; β+... α 3,46... γ 81; 214; 100; 254...	Dy 154 ~ 10^7 a α 2,87	Dy 155 10,0 h ε β+ 0,9; 1,1... γ 227...	Dy 156 0,06 σ 3	Dy 157 8,1 h ε γ 326...	Dy 158 0,10 σ 43	Dy 159 144,4 d ε γ 58... e^-	Dy 16 2,34 σ 61
46 s 1079;	Tb 147 1,83 m | 1,65 h ε | ε β+ | β+ γ 1398 | γ 1152	Tb 148 2,2 m | 60 m ε | β+ 4,6... γ 784 | γ 784	Tb 149 4,2 m | 4,1 h ε | α 3,97 β+ | β+ 1,8... α 3,99	Tb 150 5,8 m | 3,67 h β+ | ε; β+ 3,1 γ 638 | α 3,49 | γ 638	Tb 151 25 s | 17,6 h | ε; β+ | α 3,41	Tb 152 4,2 m | 17,5 h | β+ 2,8 γ 344 | γ 344	Tb 153 2,34 d ε β+ γ 212; 170; 110; 102; 83...	Tb 154 23h | 9,0h | 21h	Tb 155 5,32 d ε γ 87; 105; 180; 262...	Tb 156 24h? | 5,4h | 5,4d	Tb 157 150 a ε γ (54) e^-	Tb 158 10,5 s | 150 a | β− 0,8... | γ 944	Tb 15 100 σ 25,5
45 23,9 m	Gd 146 48,3 d ε β+ γ 155; 116; 115...	Gd 147 38,1 h ε; β+... γ 229; 396; 929...	Gd 148 ~ 90 a α 3,183	Gd 149 9,5 d ε; α 3,01 γ 150; 299; 347...	Gd 150 1,8 · 10^6 a α 2,72	Gd 151 120 d ε; α 2,60 γ 154; 243; 175...	Gd 152 0,20 1,1 · 10^{14} a α 2,14 σ 1100	Gd 153 241,6 d ε γ 97; 103...	Gd 154 2,18 σ 85	Gd 155 14,80 σ 61000	Gd 156 20,47 σ 1,5	Gd 157 15,65 σ 254000	Gd 15 24,84 σ 2,5
44 s 18...	Eu 145 5,93 d ε β+ 1,7... γ 894; 1659; 654...	Eu 146 4,51 d ε; β+ 1,5; 2,1... γ 747; 633; 634...	Eu 147 24,6 d ε; β+...; α 2,91 γ 197; 121; 678...	Eu 148 55,6 d ε; β+...; α 2,63 γ 550; 630; 611...	Eu 149 93,1 d ε γ 328; 277...	Eu 150 12,6 h | 35,8 a β− 1,0 | ε β+ | γ 334	Eu 151 47,8 σ 4,0+3300+ 5900	Eu 152 96m | 9,3h | 13,33a	Eu 153 52,2 σ 390	Eu 154 46,0 m | 8,8 a | β− 0,6; | 1,8... | γ 123; | 1274; 723	Eu 155 4,96 a β− 0,1; 0,2... γ 87; 105... σ 4040	Eu 156 15,2 d β− 0,5; 2,4... γ 812; 89; 1231...	Eu 15 15,15 h β− 1,3... γ 413; 64; 373...
43 ,83 m	Sm 144 3,1 σ ~ 0,7	Sm 145 340 d ε; γ 61; (492...) e^- σ ~ 110	Sm 146 1,03 · 10^8 a α 2,55	Sm 147 15,0 1,06 · 10^{11} a α 2,234 σ 64	Sm 148 11,3 7 · 10^{15} a α 1,96 σ 2,7	Sm 149 13,8 σ 41000	Sm 150 7,4 σ 102	Sm 151 93 a β− 0,1... γ (22); e^- σ 15000	Sm 152 26,7 σ 206	Sm 153 46,75 h β− 0,7; 0,8... γ 103; 70...	Sm 154 22,7 σ 5,5	Sm 155 22,4 m β− 1,5... γ 104; 246; 141...	Sm 15 9,4 h β− 0,7... γ 204; 88; 1 e^-
42 s	Pm 143 265 d ε no β+ γ 742	Pm 144 1,0 a ε; no β+ γ 618; 697; 477...	Pm 145 17,7 a ε; α 2,24 γ 72; (67) e^-	Pm 146 5,53 a ε; β− 0,8... γ 454; 747; 736... σ 8400	Pm 147 2,62 a β− 0,2... γ (121...) σ 85 + 96	Pm 148 41,3 d | 5,37 d β− 0,4 | β− 2,5 σ 22000 | σ 2000	Pm 149 53,1 h β− 1,1... γ 286... σ 1400	Pm 150 2,7 h β− 2,3; 3,4 γ 334; 1325; 1166...	Pm 151 28 h β− 0,8; 1,2... γ 340; 168... σ 700	Pm 152 15m | 7,5m | 4,2m	Pm 153 5,3 m β− 1,7... γ 36; 127; 28; 120...	Pm 154 2,7 m | 1,7 m β− 2,8 | β− 1,9	
41 5 h	Nd 142 27,13 σ 18,7	Nd 143 12,18 σ 325 $σ_{n,α}$ 0,0174	Nd 144 23,80 2,1 · 10^{15} a α 1,83 σ 3,6	Nd 145 8,30 σ 42	Nd 146 17,19 σ 1,3	Nd 147 10,98 d β− 0,8; 0,9... γ 91; 531... σ	Nd 148 5,76 σ 2,48	Nd 149 1,73 h β− 1,4; 1,6... γ 211; 114; 270...	Nd 150 5,64 σ 1,2	Nd 151 12,4 m β− 1,2; 2,3... γ 117; 256; 1181...	Nd 152 11,4 m β− 0,9; 1,2... γ 279; 250... g	Nd 153 32 s β− γ 418; 105; 475...	Nd 15 40 s β− γ 400; 700 g



Casten R F et al. Nucl. Phys. A 439 289 1(1985).

$\frac{E(4+)}{E(2+)}$ energy-ratio systematics for even-even nuclei as a function of atomic number Z. The horizontal dashed lines represent limits expected for pure vibrational (2.00), rotational (3.33), and gamma-soft (2.50) behavior, respectively .



Butler P A et al. Rev. Mod. Phys. 68 349(1996)

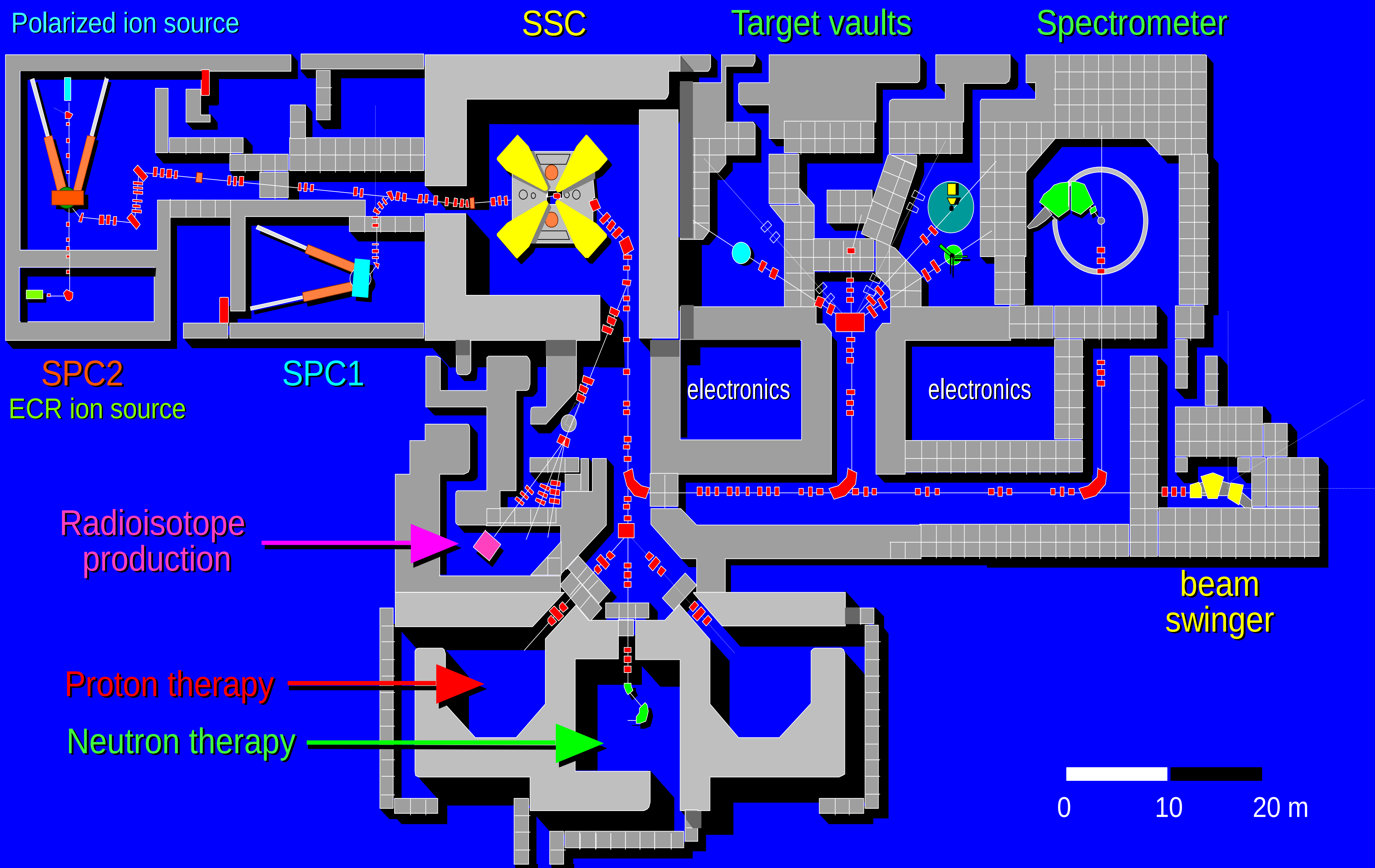
Plot of $|M(E3)|^2$, the E3 transition strength of $0^+_1 \rightarrow 3^-_1$ transitions for even-even nuclei, as a function of neutron number N

Octupole excitations

- The octupole excitations in nuclei are related to coupling of two single particle orbitals with opposite parities and a difference of three units in the orbital and total angular momenta.
- The experimental fingerprints in even-even nuclei :

1. Presence of low-lying 1^- and/or 3^- states
2. Enhanced E3 transitions (e.g ^{148}Nd)
3. Strong E1 transitions connecting levels of opposite parity

Separated-Sector Cyclotron Facility



Experiment

- The low spin state of ^{154}Dy were populated using the reaction:

  $$^{155}_{64}\mathrm{Gd}_{91}(^{3}_{2}\mathrm{He},\ 4n)\ ^{154}_{66}\mathrm{Dy}_{88}$$

- Beam energy of :

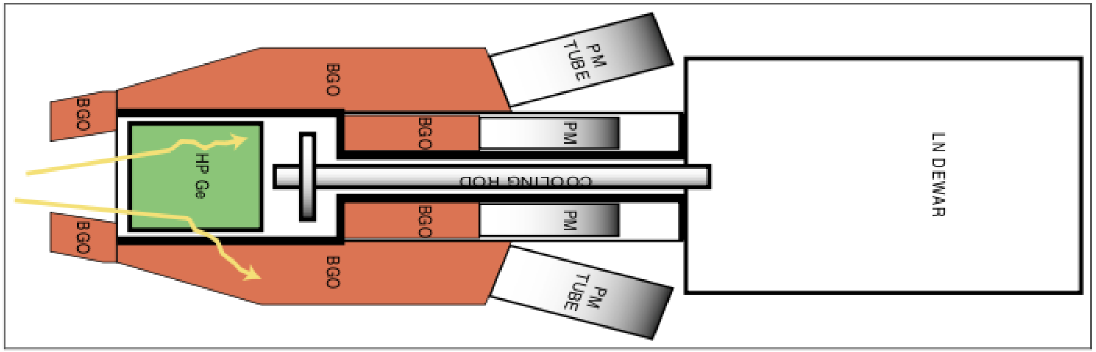
  37MeV

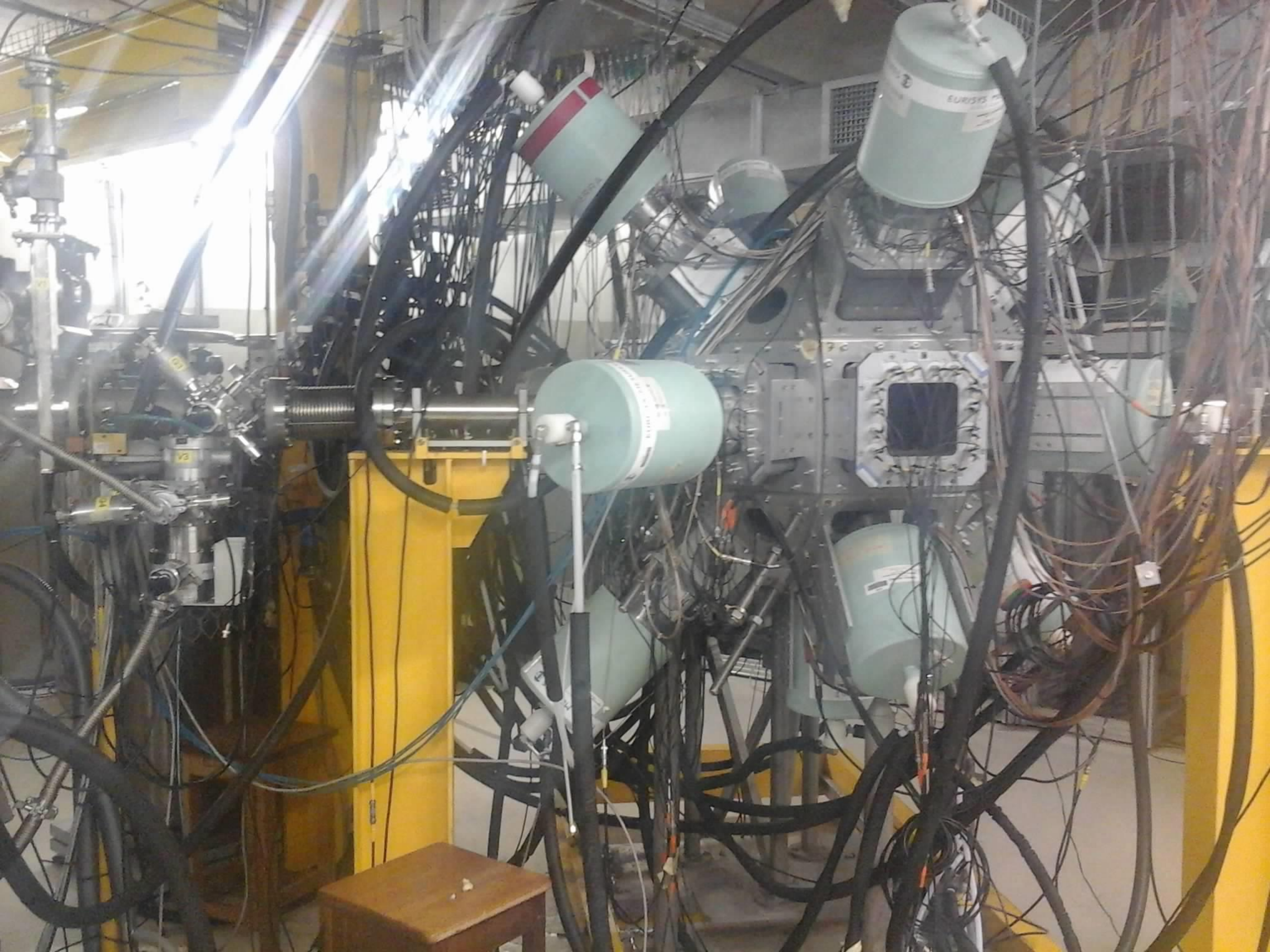
- Target thickness:

  3.2mg/cm^2

Cont: Experiment

- The gamma rays emitted from the excited ^{154}Dy were detected by the AFRODITE spectrometer array.
- Nine clover detectors were used. Four at 135° and five at 90 °

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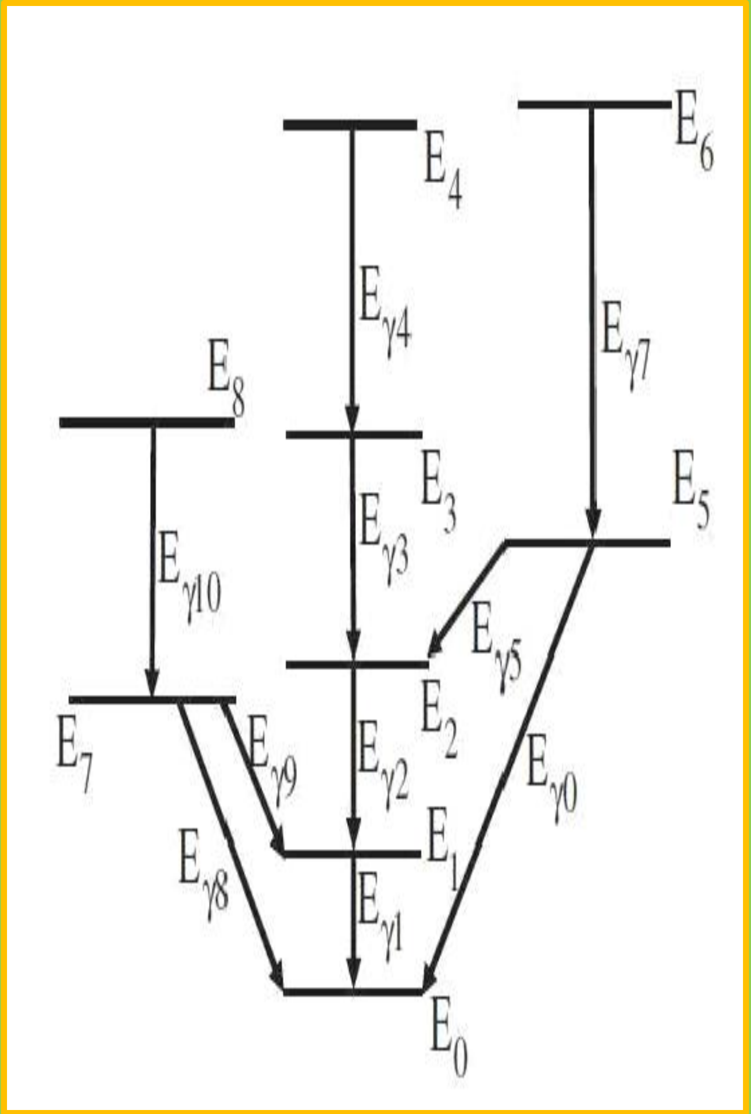
Gamma-gamma coincidence analysis

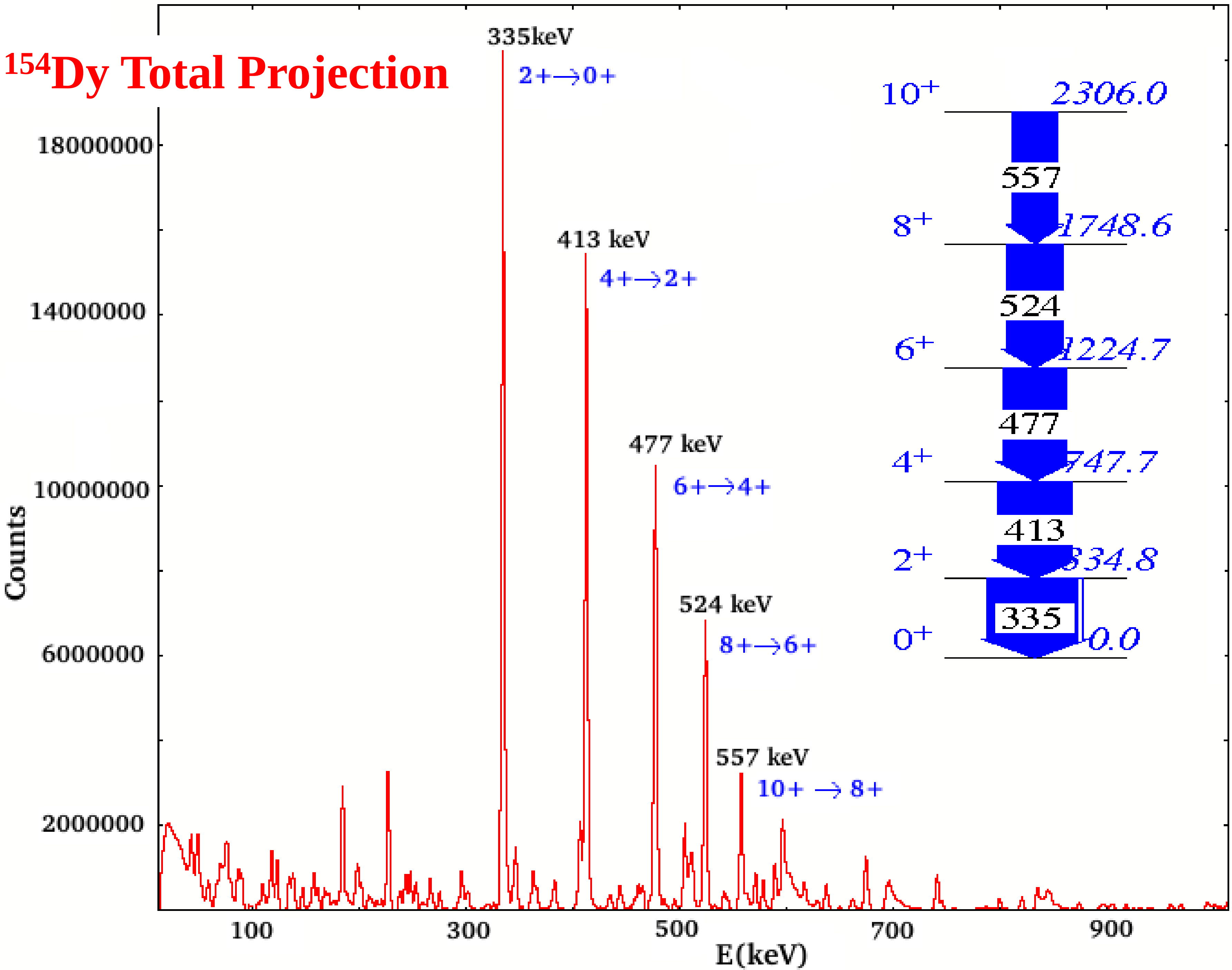
- A symmetric matrix was constructed to deduce the decay scheme of ^{154}Dy
- For each event, the energy of the two detected gamma-rays were stored into a two dimensional matrix.

<u>How</u>

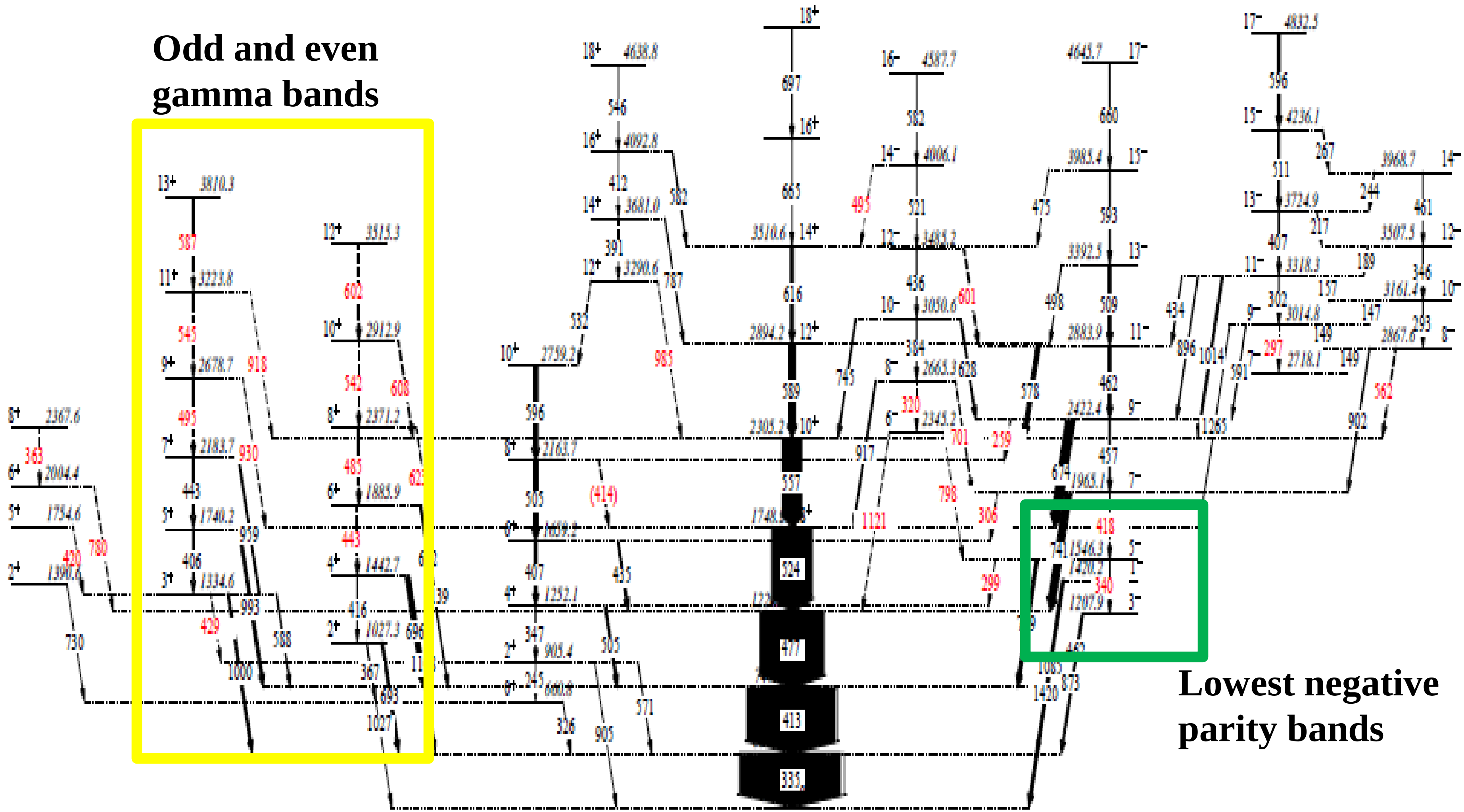
1. Put a gate in one transition & observed the transition in coincidence with the gating transition
2. Position the observed transition in the decay scheme.



^{154}Dy Total Projection

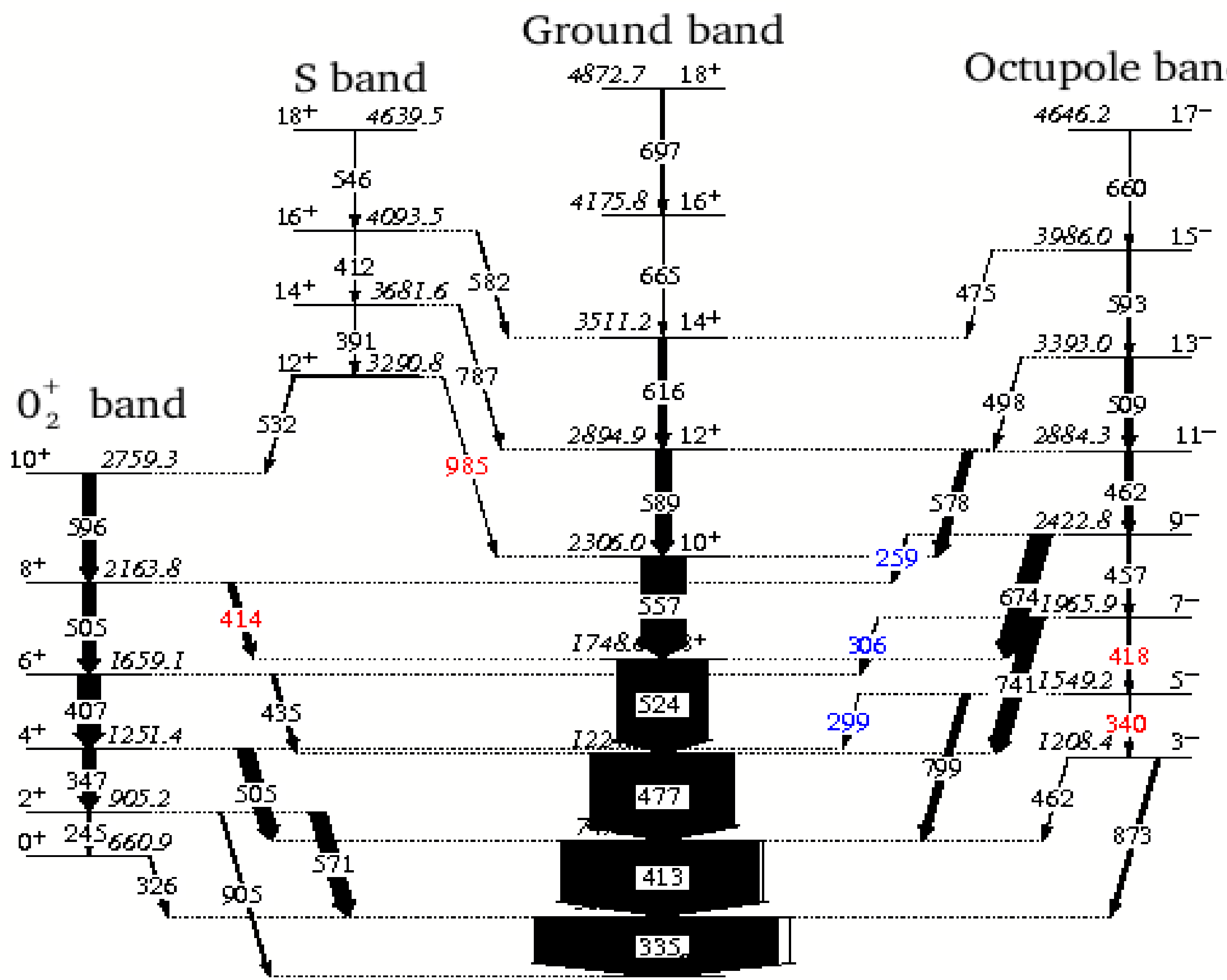


Results



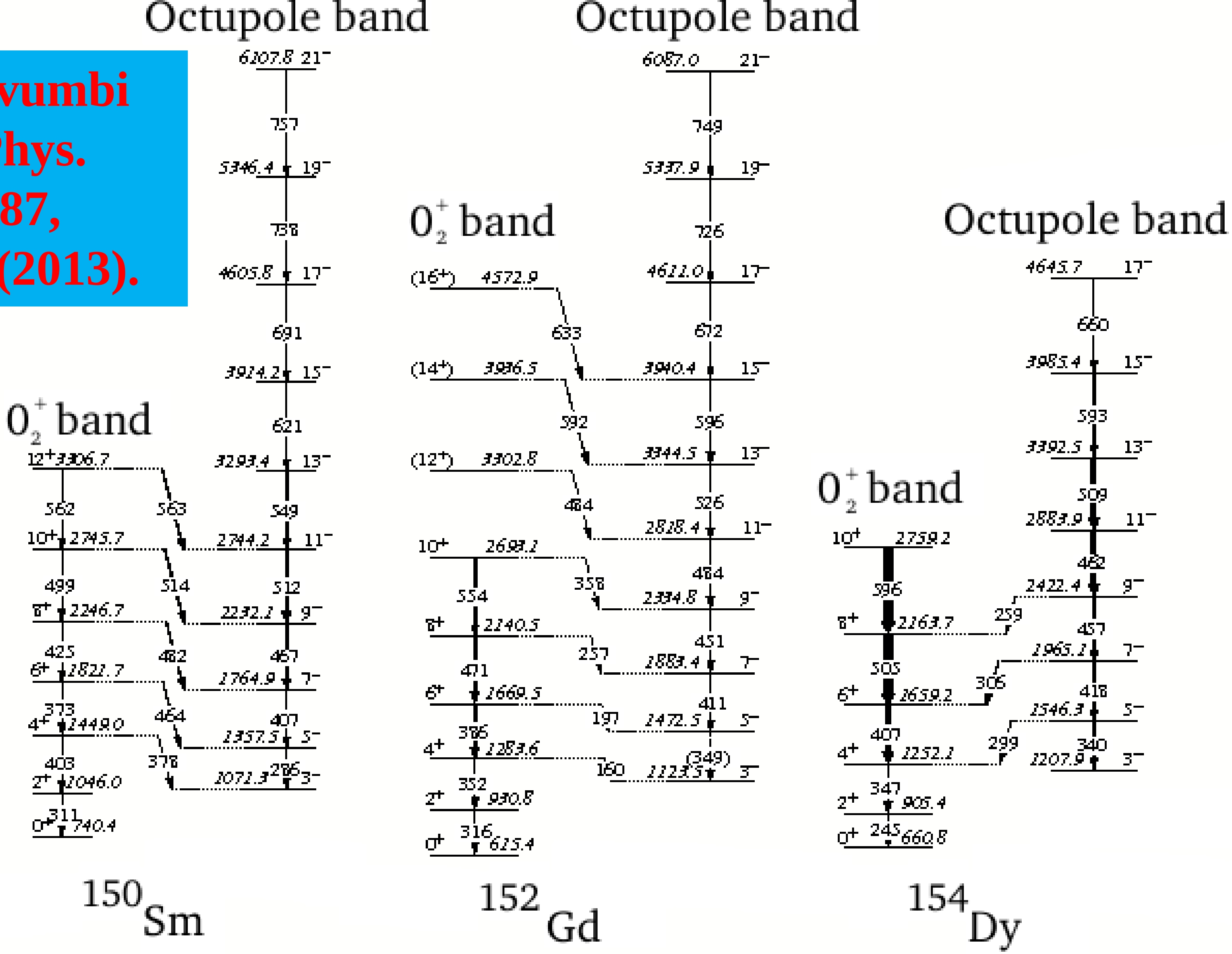
Partial level scheme of ^{154}Dy obtained from $^{155}_{64}Gd_{91}(^{3}_{2}He, 4n)^{154}_{66}Dy_{88}$ reaction at 37MeV showing new transitions are shown in red.

Results

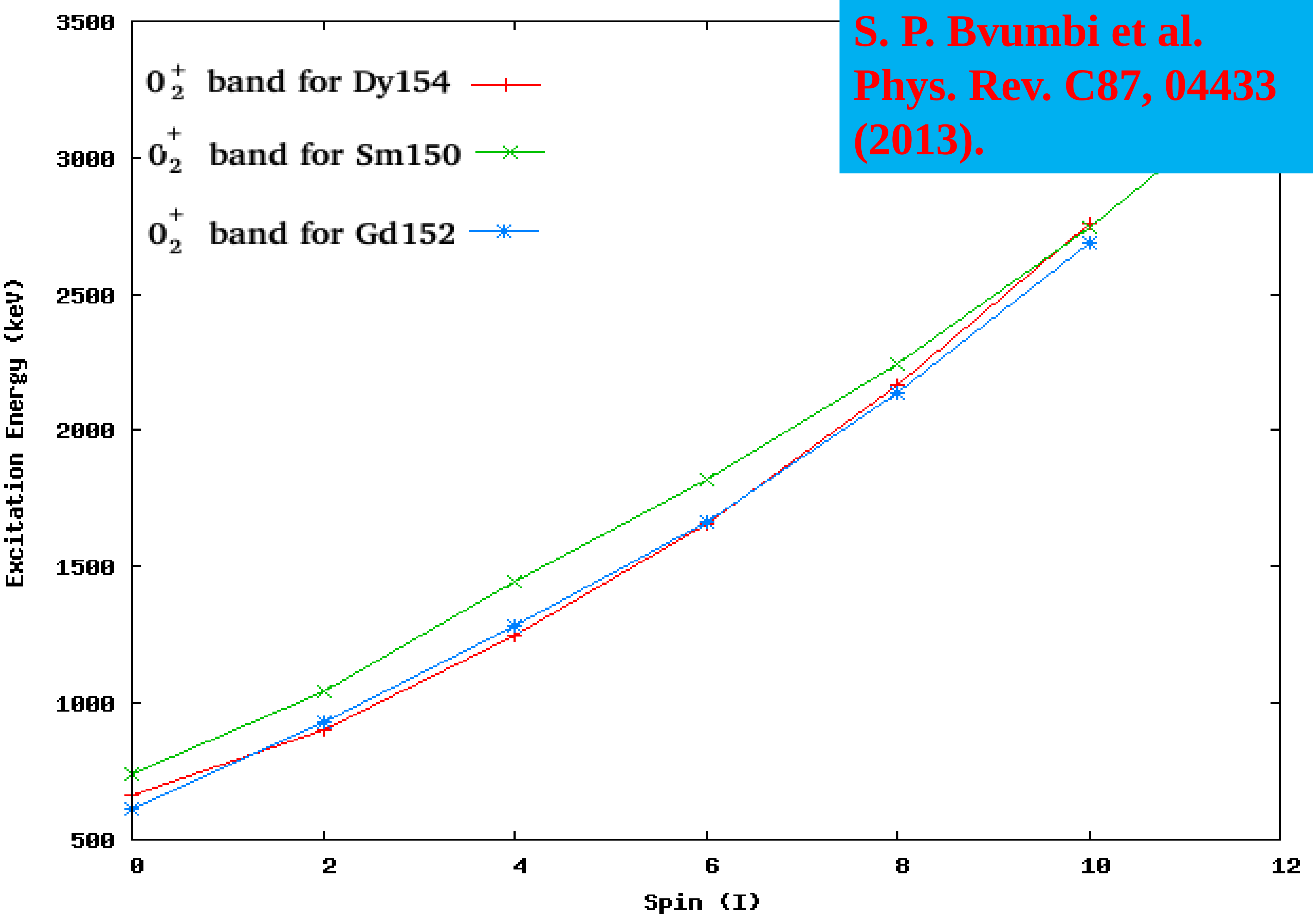


Partial level scheme of ^{154}Dy obtained from $^{155}_{64}Gd_{91}(^{3}_{2}He, 4n)^{154}_{66}Dy_{88}$ reaction at 37MeV showing new transitions are shown in red and E1 transitions from the octupole band to the band built on 0^+_2 are shown in blue.

S. P. Bvumbi et al. Phys. Rev. C87, 04433 (2013).



$0^+_2 \rightarrow 3^-_2$ for ^{152}Gd and ^{150}Sm and the first observation of $3^-_1 \rightarrow 0^+_2$ observed in ^{154}Dy.



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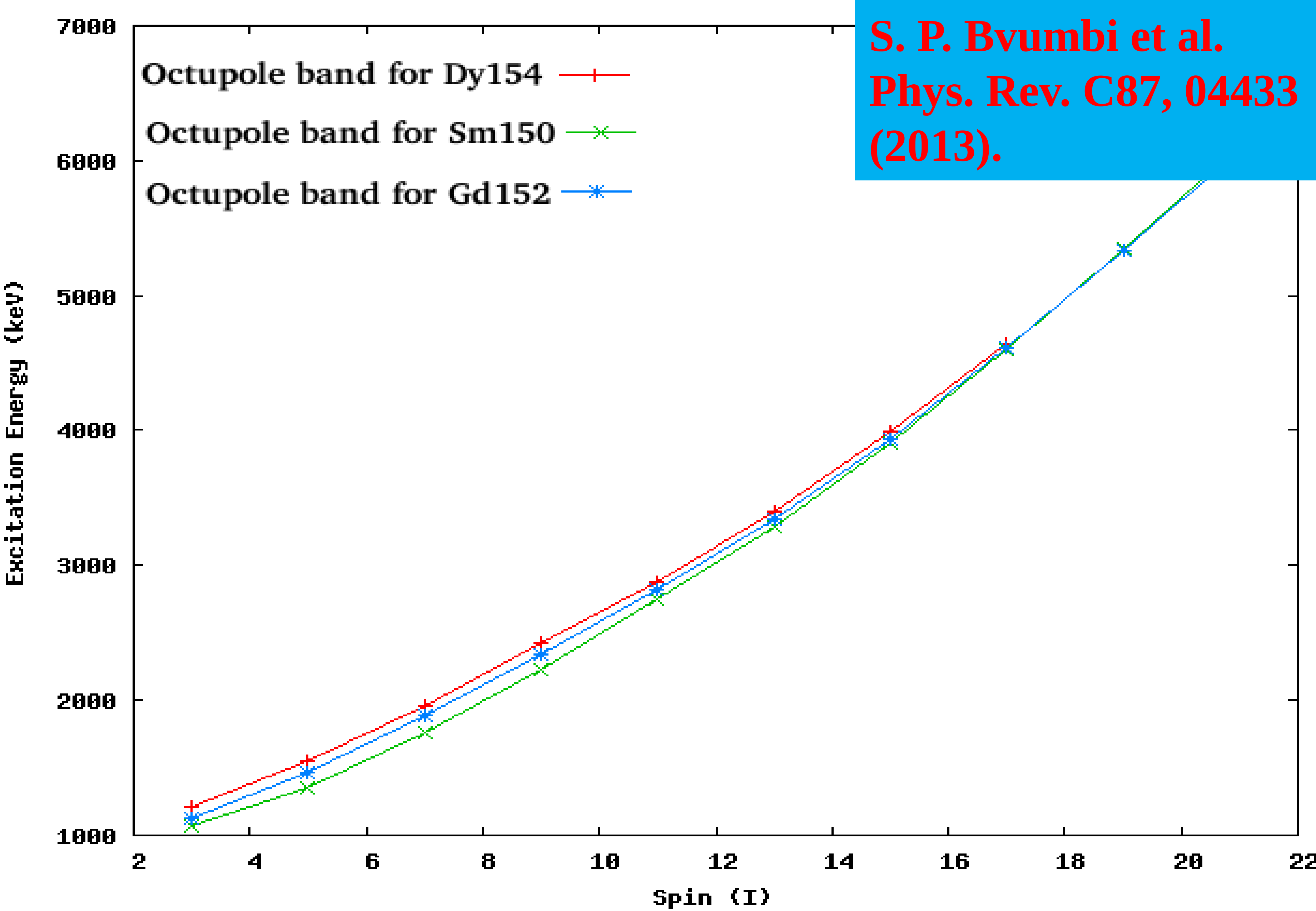
Plot of the level excitation energies against spin for the bands built on 0^+_2 for ^{154}Dy, ^{150}Sm and ^{152}Gd .



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(2013).

Plot of the level excitation energies against spin for the octupole bands for ^{154}Dy, ^{150}Sm and ^{152}Gd
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Conclusions

- The experiment showed that $3^-_1 \rightarrow 0^+_2$ is present in low-lying states of ^{154}Dy.
- As Z increases the relative excitation energies of the Octupole bands increases. This is probably the primary cause of the direction of the E1s transitions between them changing from ^{150}Sm and ^{152}Gd to the case of ^{154}Dy

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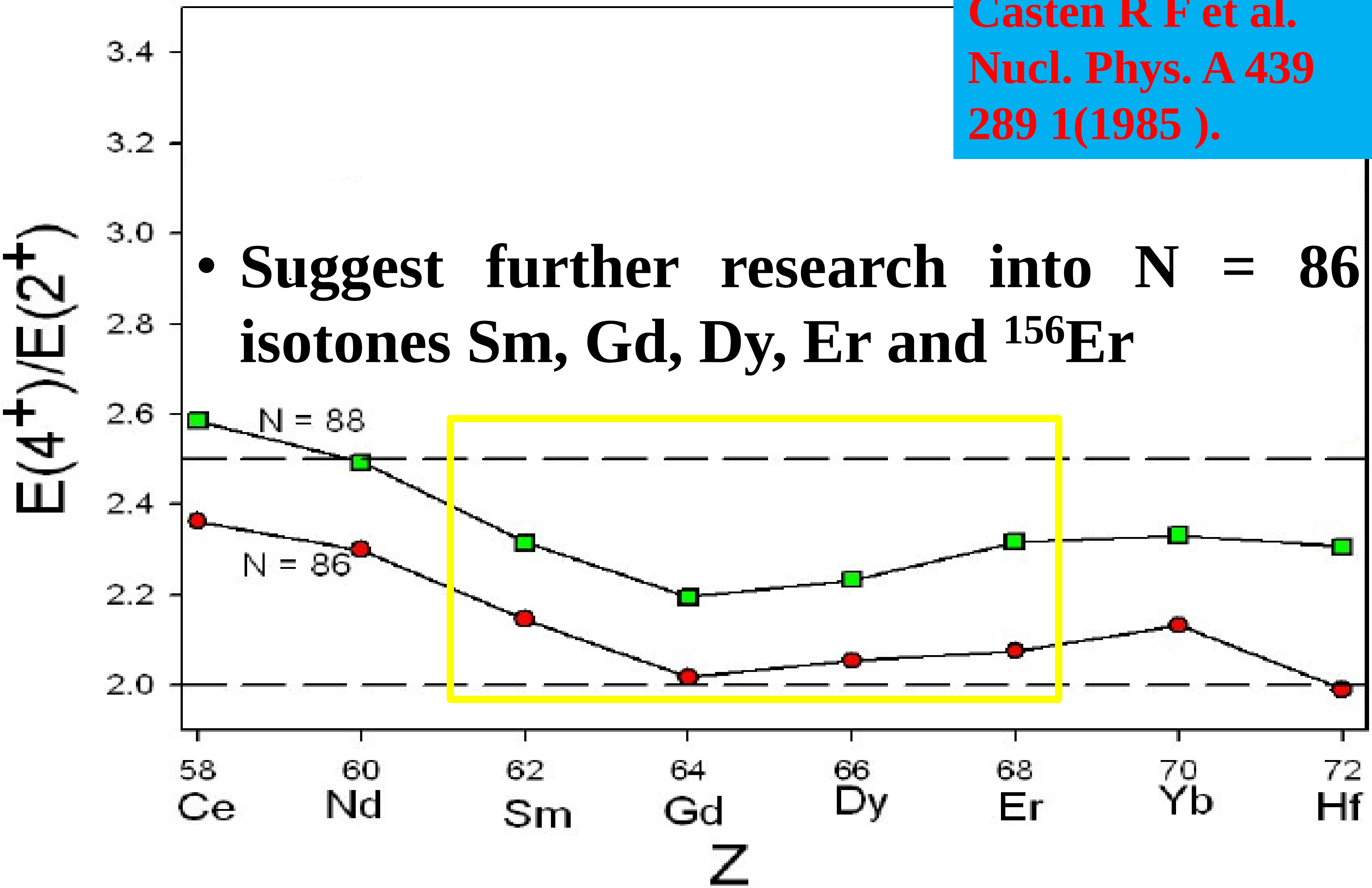
- **Suggest further research into N = 86 isotones Sm, Gd, Dy, Er and ^{156}Er**



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Thank You

Energy	DCO	LP	Transition
985	1.17(0.1)	0.2(0.1)	$12^+ \rightarrow 10^+$
418	1.14(0.22)	)*	$7^- \rightarrow 5^-$
414	)*	)*	$8^+ \rightarrow 8^+$
340	)*	)*	$5^- \rightarrow 3^-$
306	)*	)*	$7^- \rightarrow 6^+$
299	0.8(0.2)	)*	$5^- \rightarrow 4^+$
259	0.7(0.03)	0.19(0.09	$9^- \rightarrow 8^+$

Radiation Type	a_2	a_4	A_P
Stretched M1	-	0	-
Unstretched M1	+	0	+
Stretched E1	-	0	+
Unstretched E1	+	0	-
Stretched M2	-	+	-
Stretched E2	+	-	+

The table on the right is showing DCO and linear polarization results,)*sign represents when we do not have enough statistics.