The 49/2+ Isomer in $^{147}Gd_{83}$

Study of the most complex isomeric decay

R. Broda[1], J. Wrzesiński[1], S. Lunardi[2], C. Michelagnoli[2], C. A. Ur[2], D. Bazzacco[2], E. Farnea[2], R. Menegazzo[3], D. Mengoni[2], F. Recchia[2]

[1] Niewodniczanski Institute of Nuclear Physics PAN, Krakow, Poland
[2] Dipartimento di Fisica dell' Universita and INFN Sezione di Padova, Padova, Italy
[3] INFN Laboratori Nazionali di Legnaro, Italy

1. Brief history of high-spin state study in ^{147}Gd -
   - properties of the 49/2^{+} isomer.
2. ^{76}Ge + ^{76}Ge experiment – two aims, catcher geometry, demonstration of the data quality.
3. The 49/2^{+} isomer decay results -
   - general summary of results, complexity of branchings, decay paths, number of states populated, yrast and non-yrast states population intensity.
4. Initial remarks on the observed state structures.

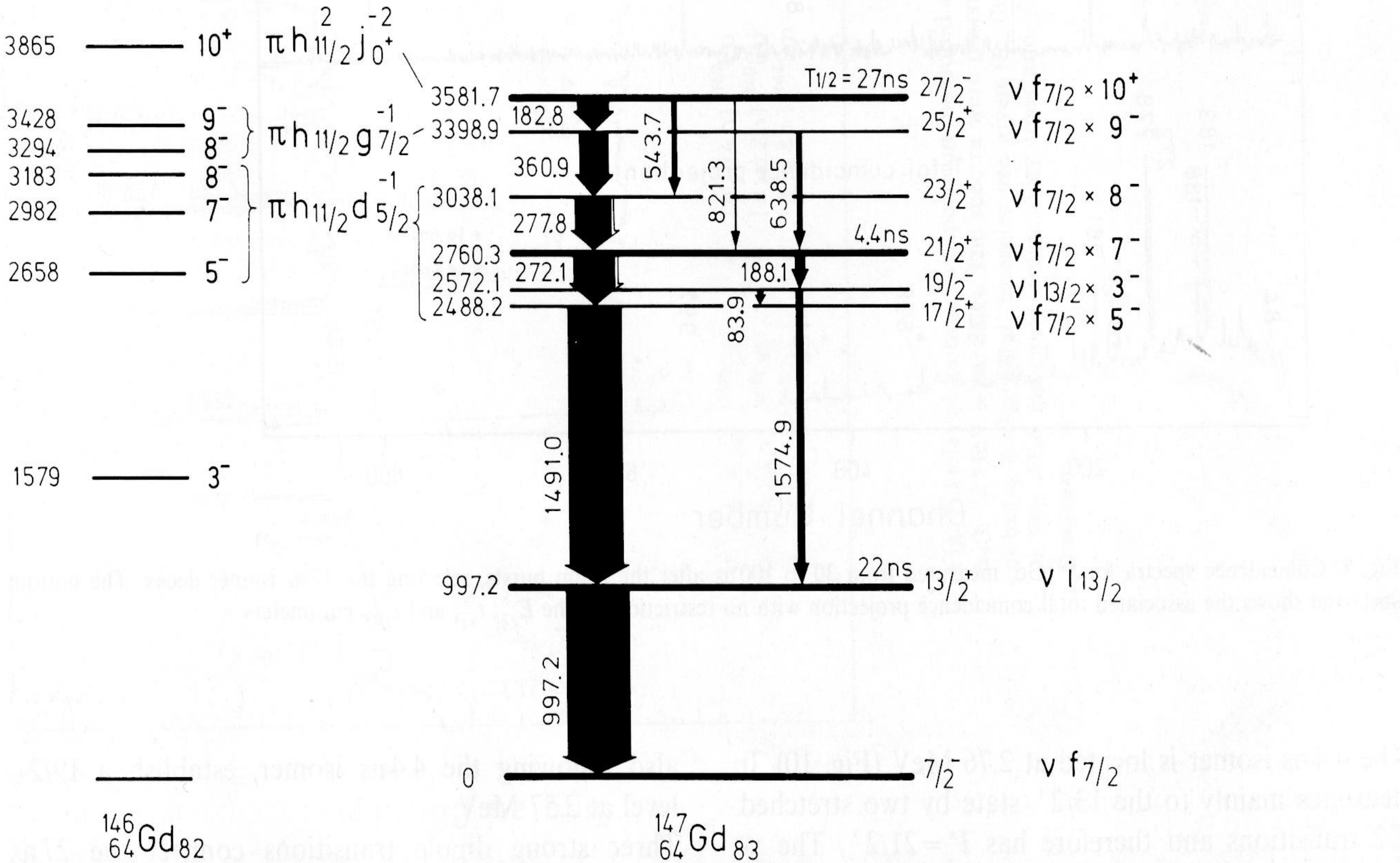


Fig. 10. Level scheme of ^{147}Gd. Configuration assignments and comparison with the ^{146}Gd core energies (left) are discussed in Sect. IV.3. For higher-lying ^{147}Gd states cf. Refs. 8 and 9

P.Kleinheinz, R.Broda, P.J.Daly, S.Lunardi, M.Ogawa, J.Blomqvist,
Z.Physik, A 290, 279 (1979)

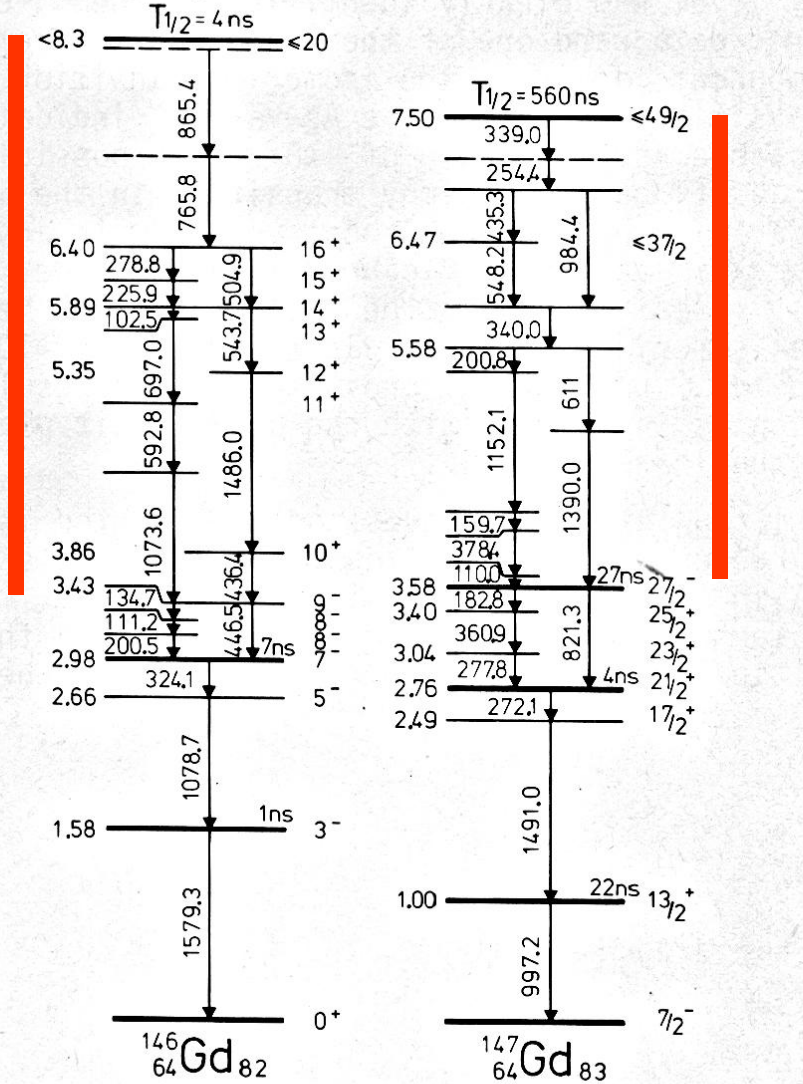


Fig. 1: Partial isomeric decay schemes for ^{146}Gd and ^{147}Gd, including selected high multiplicity and lower multiplicity decay cascades. More detailed level schemes are given in ref. 5. Dashed levels indicate tentative transition ordering.

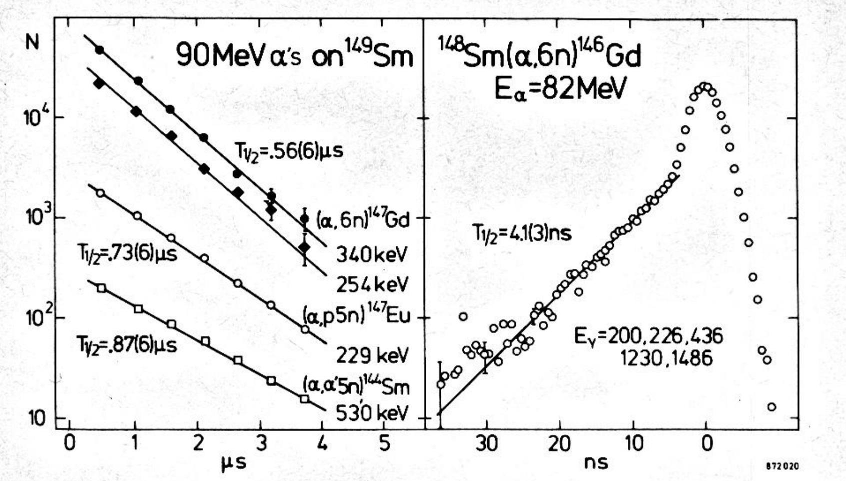


Fig. 2a: Half-life measurement of the 7.5 MeV high spin isomer in ^{147}Gd using a μs beam pulsing system. Decay curves for γ-rays deexciting previously known isomers in neighbouring nuclei, which are also produced at 90 MeV bombarding energy, are included. 2b: Half-life of the high spin isomer in ^{146}Gd from a between-beam-burst timing measurement, derived from the summed time distributions of five intense high-lying ^{146}Gd γ-transitions.

R.Broda, M.Ogawa, S.Lunardi,M.R.Maier, P.J.Daly, P.Kleinheinz
Z.Physik A285, 423 (1978)

R.Broda, P.Kleinheinz, S.Lunardi, J.Styczeń, J.Blomqvist

Z.Physik A 305, 281 (1982).

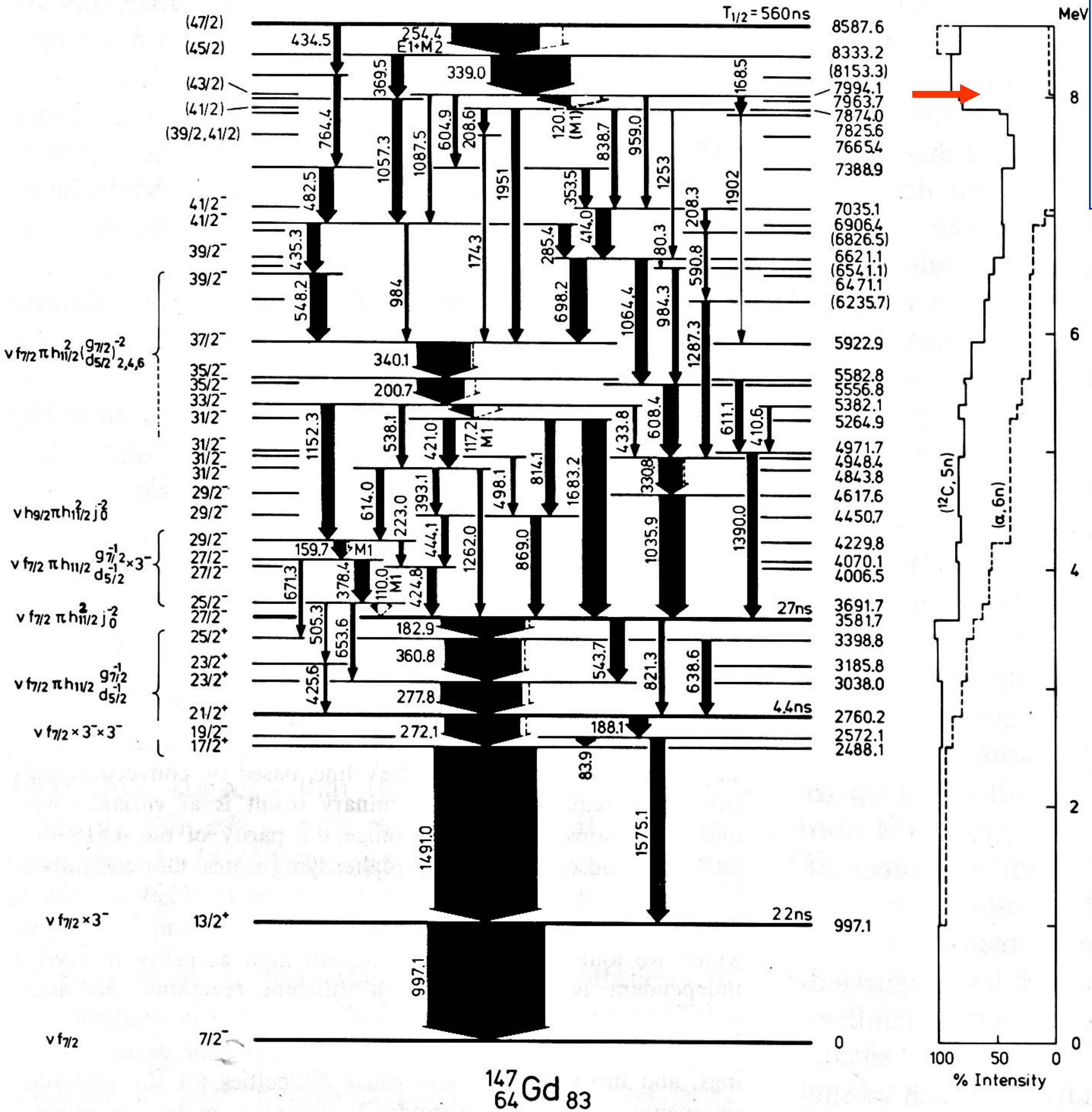


Fig. 3. The decay scheme of the 0.56 μs high-spin isomer in ^{147}Gd in full splendor. The diagram to the right gives the isomeric decay intensity identified at each level (assuming *M*1 for the 120.1 keV line). The dashed line gives the in-beam intensities from the (α, 6*n*) reaction and illustrates why originally 7.5 MeV was proposed for the isomeric excitation

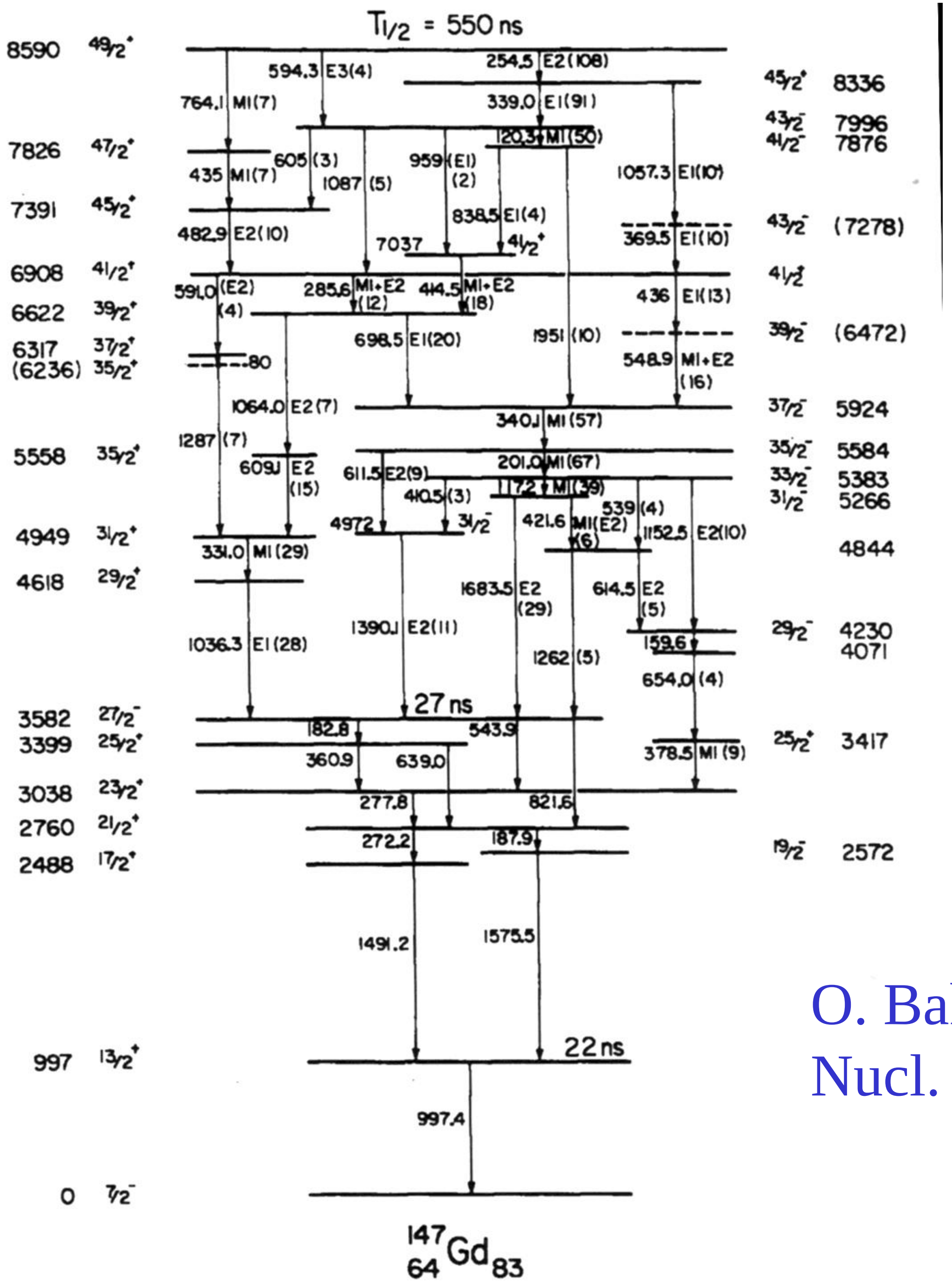


Fig. 8. The level scheme for ^{147}Gd. The transition intensities shown in parentheses include conversion

O. Bakander et al.
Nucl. Phys. A389, 93 (1982)

The spin of the isomer is 47/2 or 49/2?

1b) Decay of the isomer

$49/2^+$ is generally accepted, based also on electron conversion results

47/2 from our precise angular distribution data and the **quadrupole moment measurement**

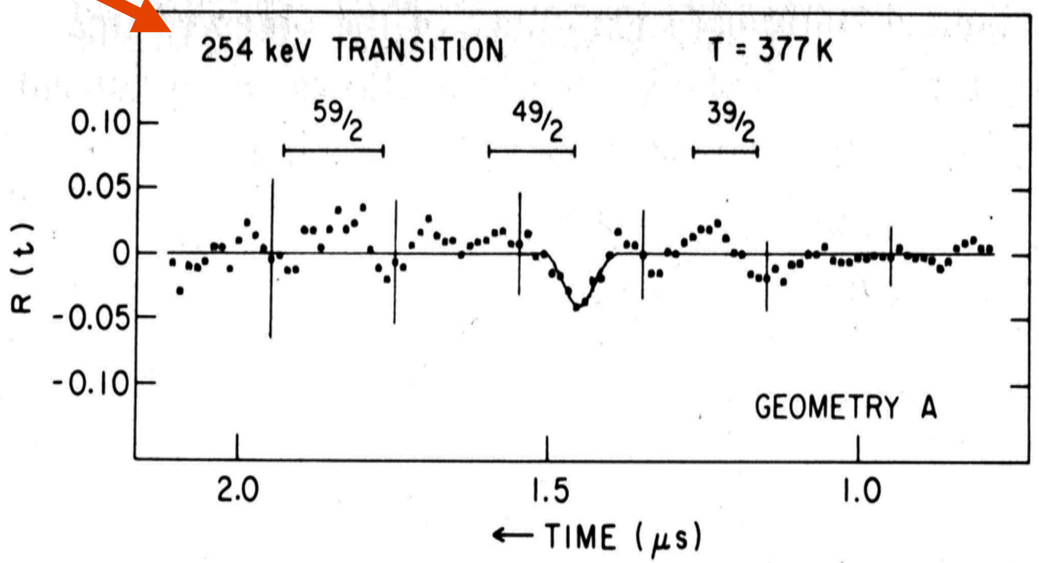


Fig. 7. Modulation spectrum for the 510 ns isomer in ^{147}Gd observed in geometry A at $T = 377$ K. The spike near $\frac{1}{2}T_0 \sim 1.5$ μs indicates a spin value of $(\frac{47}{2} \pm 1)$ for the 510 ns isomer (compare fig. 2A).

$49/2^+$ isomer in ^{147}Gd Moments

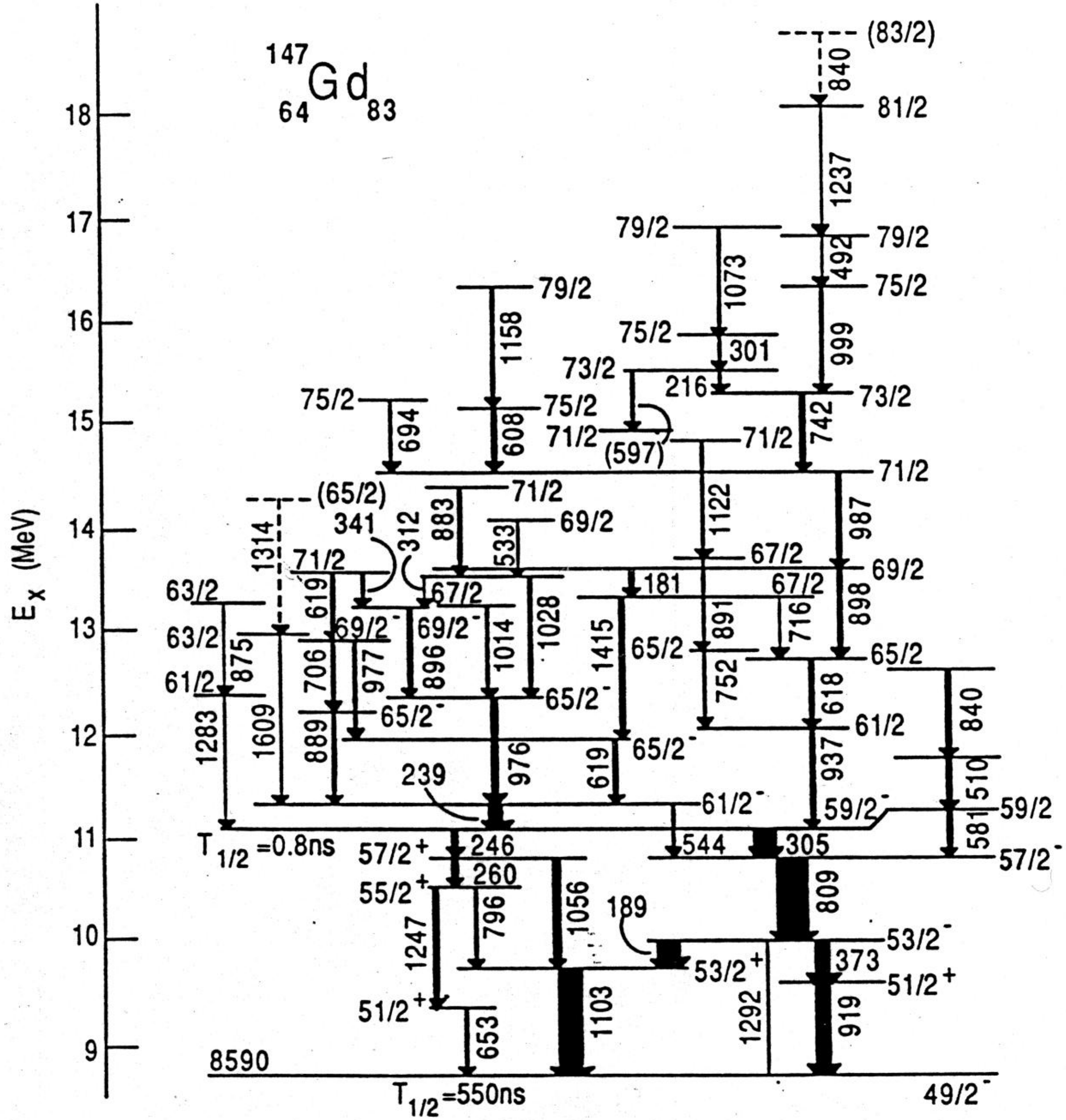
g = 0.446(8) O.Häusser et al. , Nucl. Phys. A379, 287 (1982)

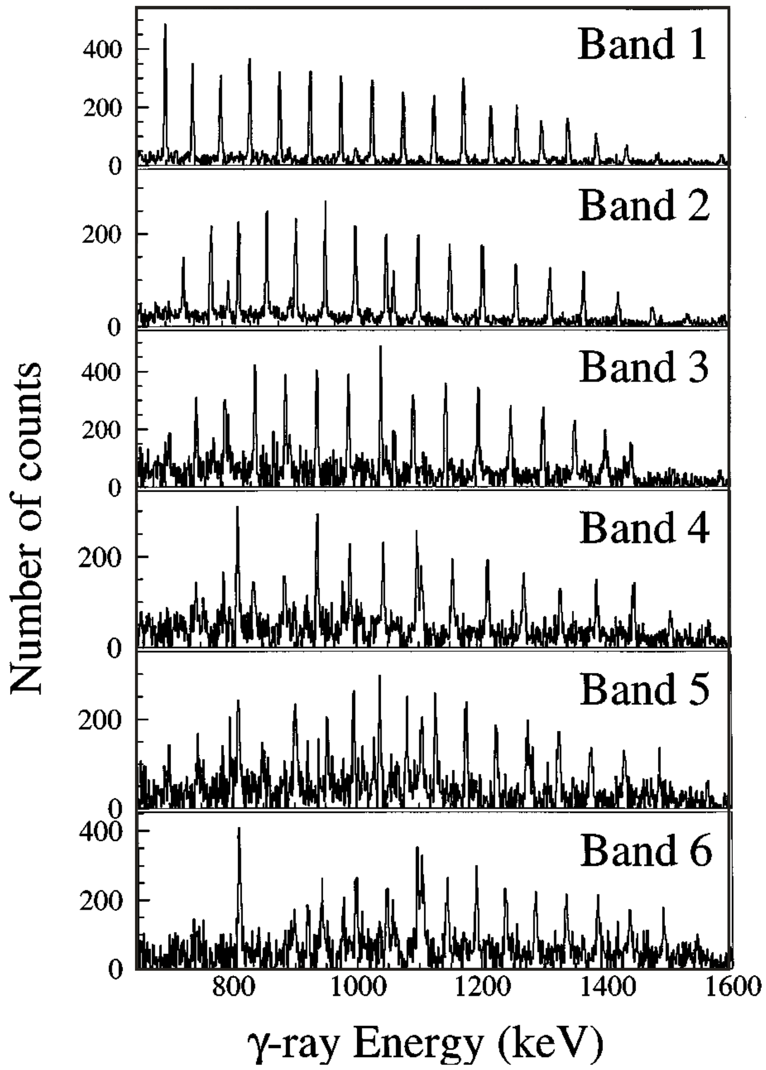
$(\pi\, d_{5/2}^{-2}\ h_{11/2}^{2})_{10}\ (\nu h_{11/2}^{-1} i_{13/2} f_{7/2})_{29/2}$ g = 0.45

$(\pi\, d_{5/2}^{-2}\ h_{11/2}^{2})_{10}\ (\nu\, d_{3/2}^{-2}\, h_{9/2}\, i_{13/2}\, f_{7/2})_{29/2}$ g = 0.47

Q = -3.24(18) → $\boldsymbol{\beta_2 = -0.19}$

O.Häusser et al. , Nucl. Phys. A379, 287 (1982)

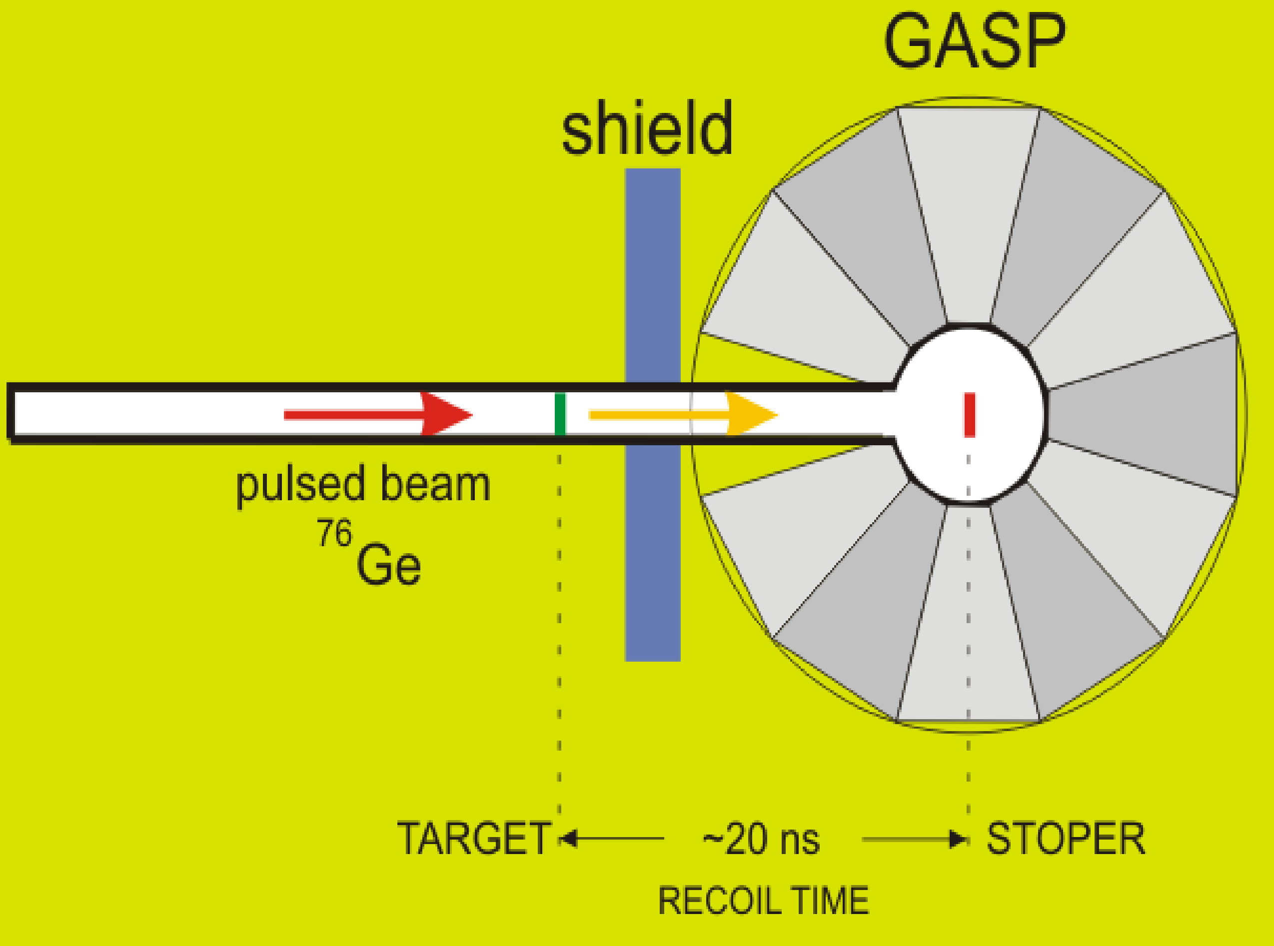




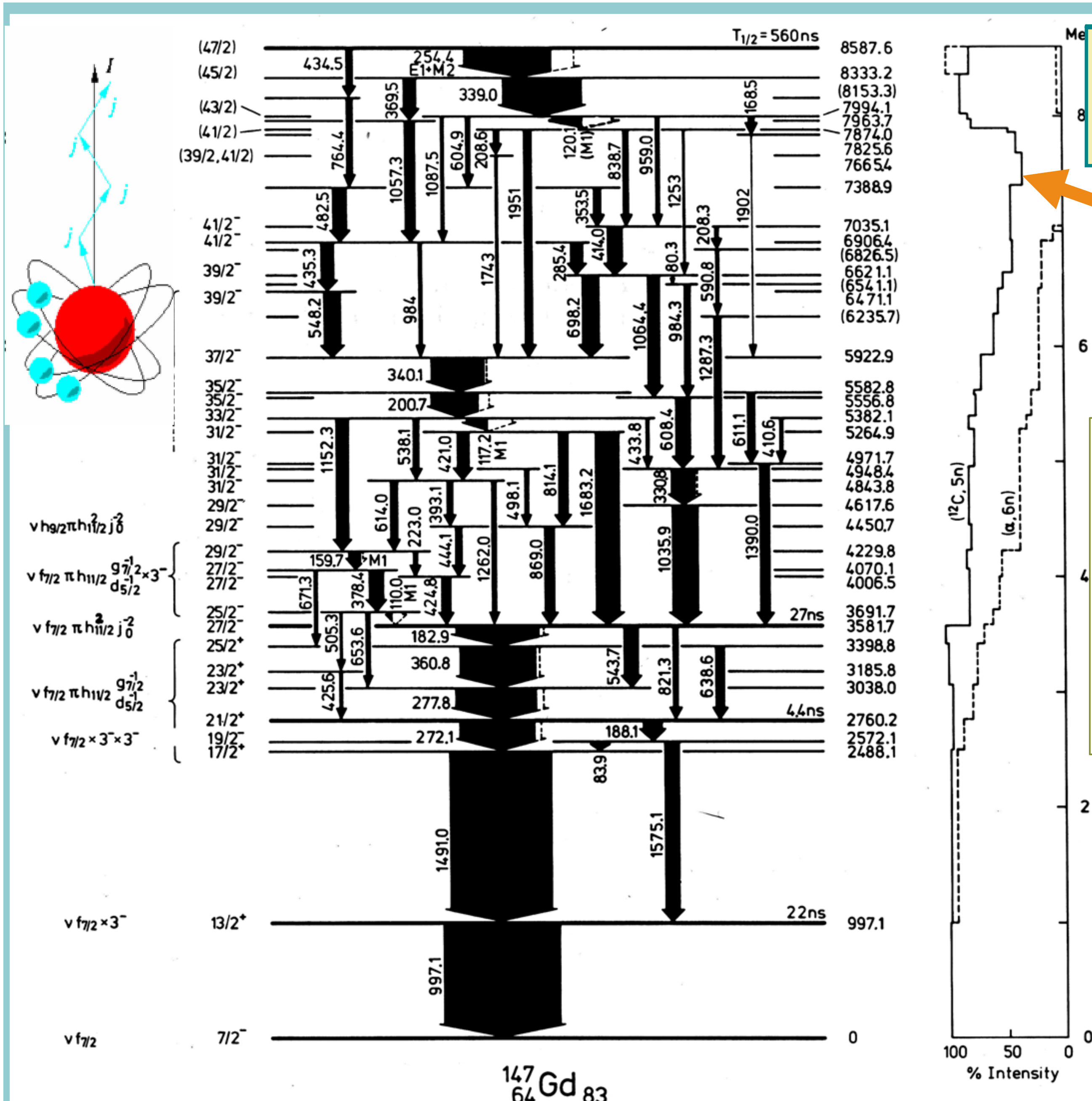
B.Haas et al.
Nucl. Phys. A 561,251 (1993)
2 SD bands

Ch. Theisen et al.
Phys. Rev. C54, 2910 (1996)
2+4 SD bands

$^{76}Ge + 290\ MeV\ ^{76}Ge \longrightarrow\ ^{147}Gd + 5n$



1a) Decay of the isomer



missing intensity

The decay involves
50 unobserved branches

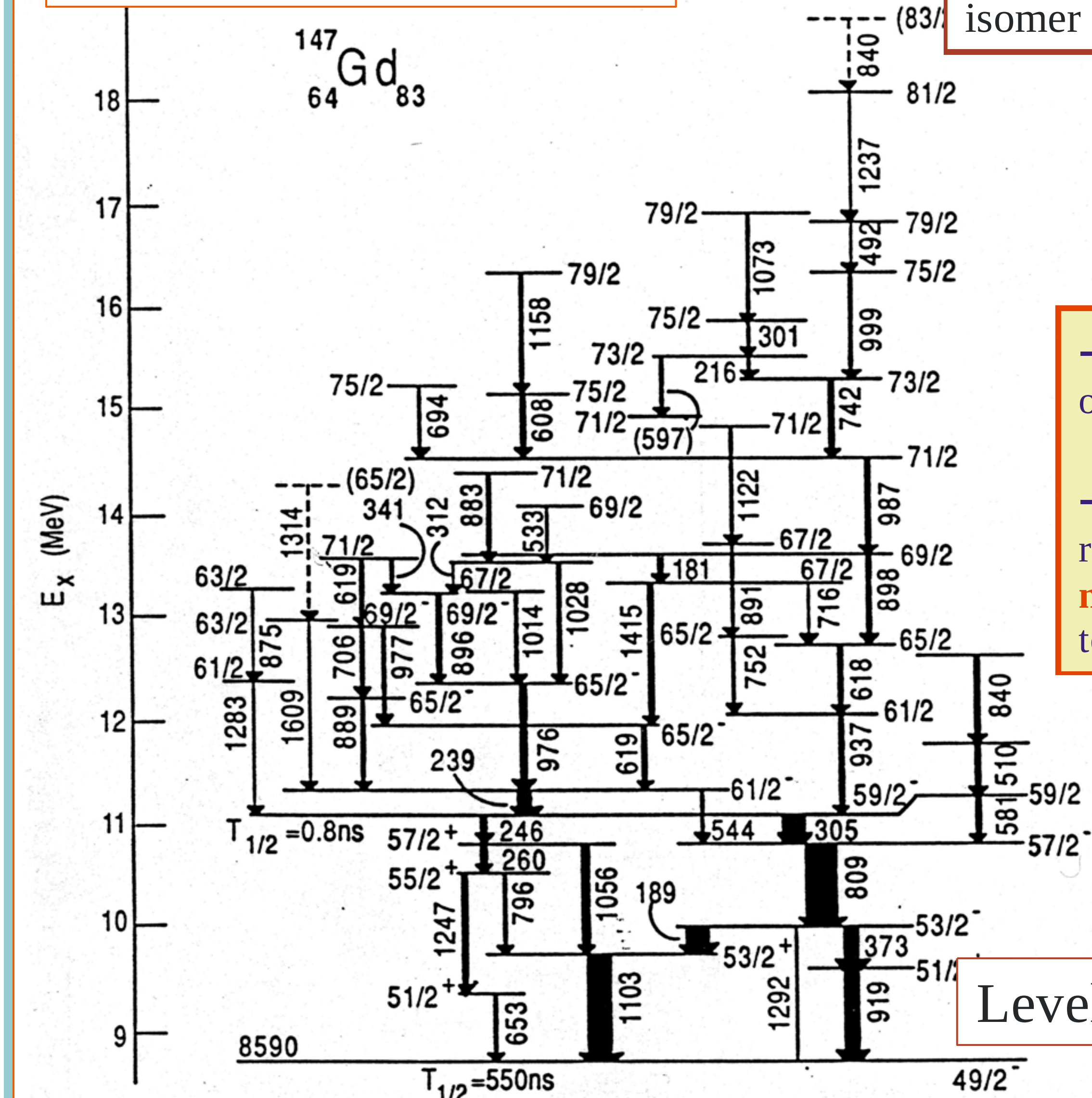
decay through **continuum**

analogies with
decay from SD to ND states
in nuclei

R. Broda et al.,
Z. Physik A305 (1982) 281

2) Coulomb excitation above the isomer

Using the isomeric **49/2 beam** the idea is to detect Coulomb excited states above the isomer

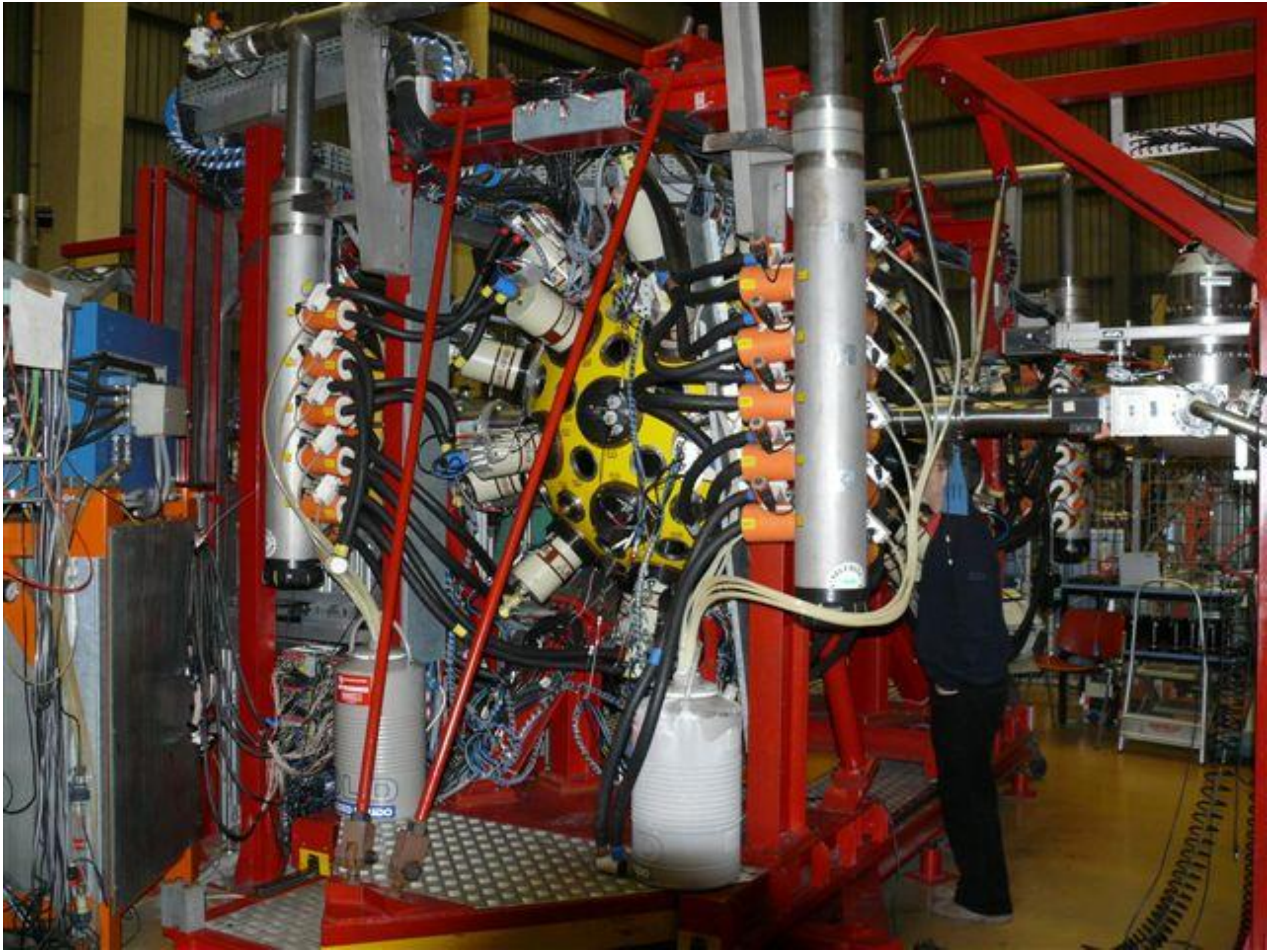


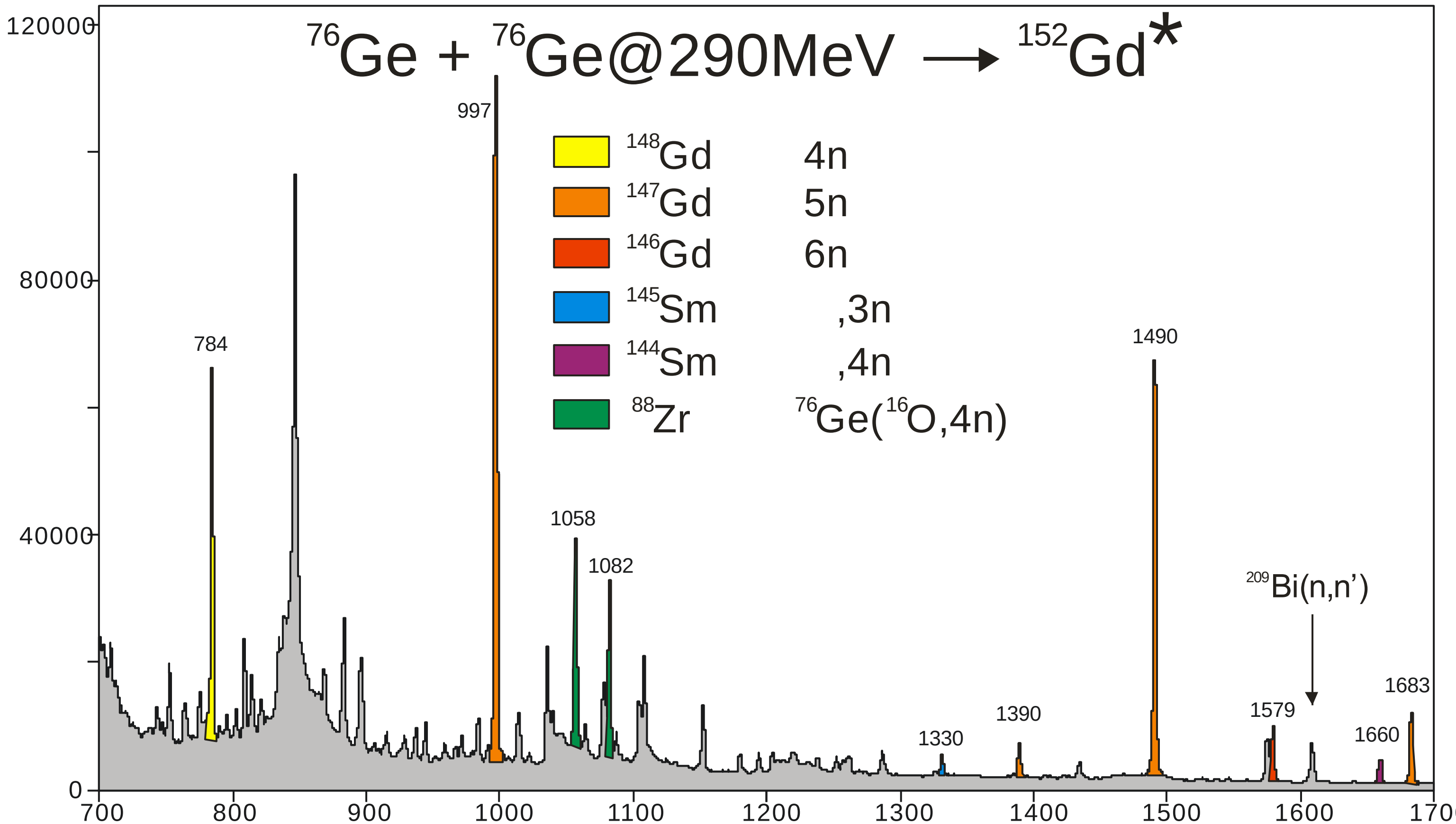
- Extract **CE matrix elements** for some of the known yrast transitions

- Observe new non-yrast states possibly related to the **rotation of an oblate nucleus** around the axis perpendicular to the symmetry axis

Level scheme above the **isomer**

J. Borgreen, NP A466 (1987) 371

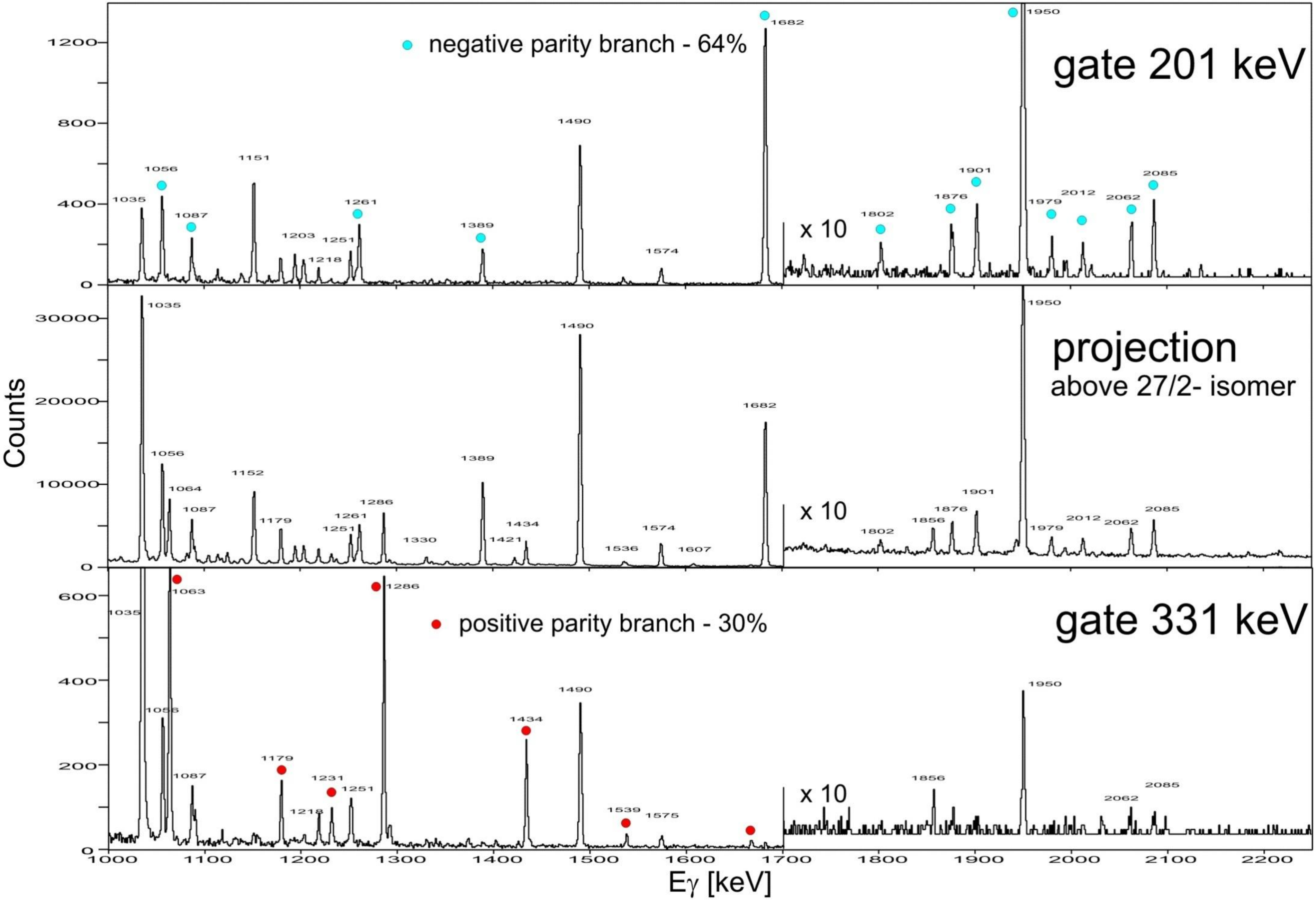




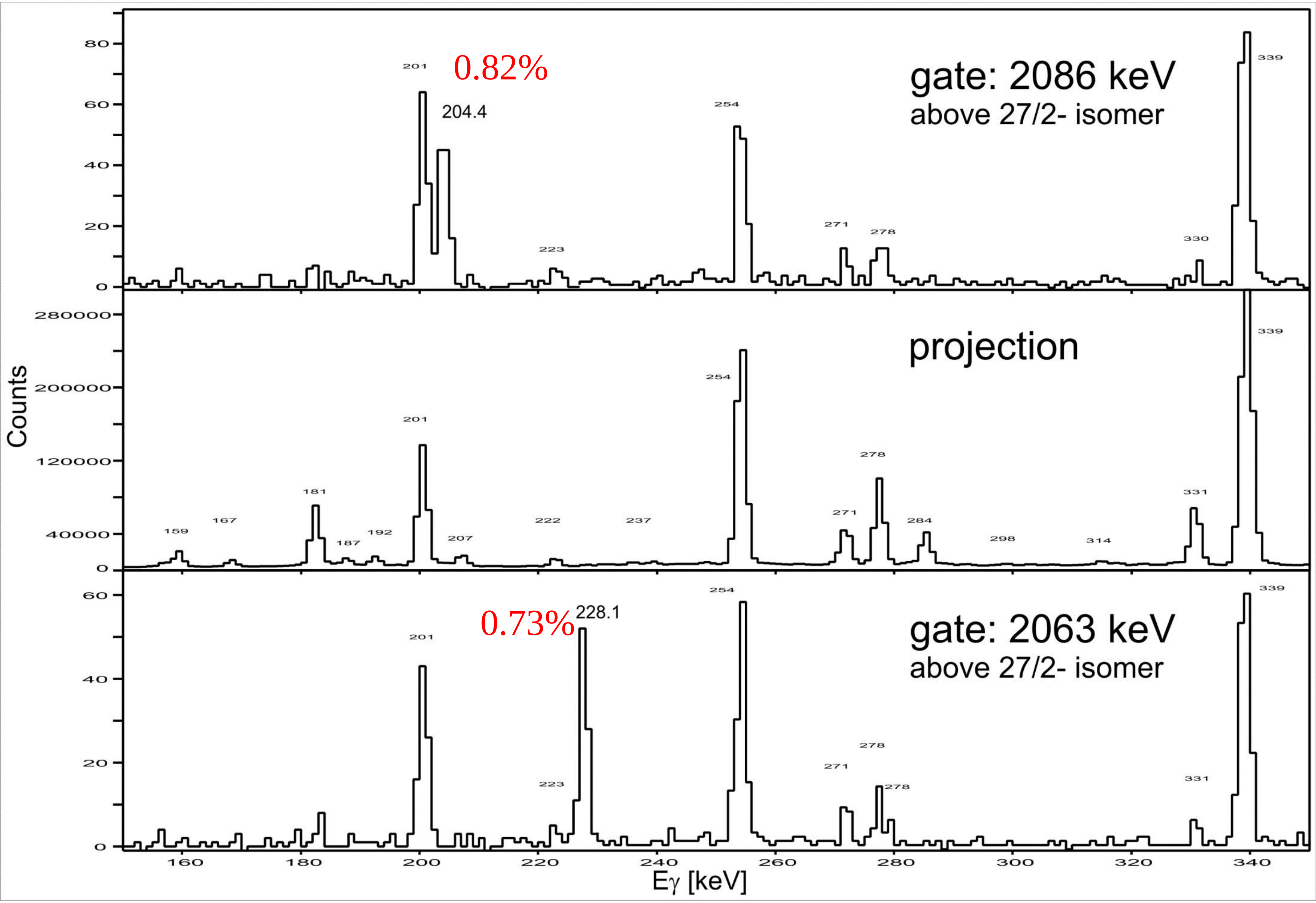
Widmo - proste

E (keV)

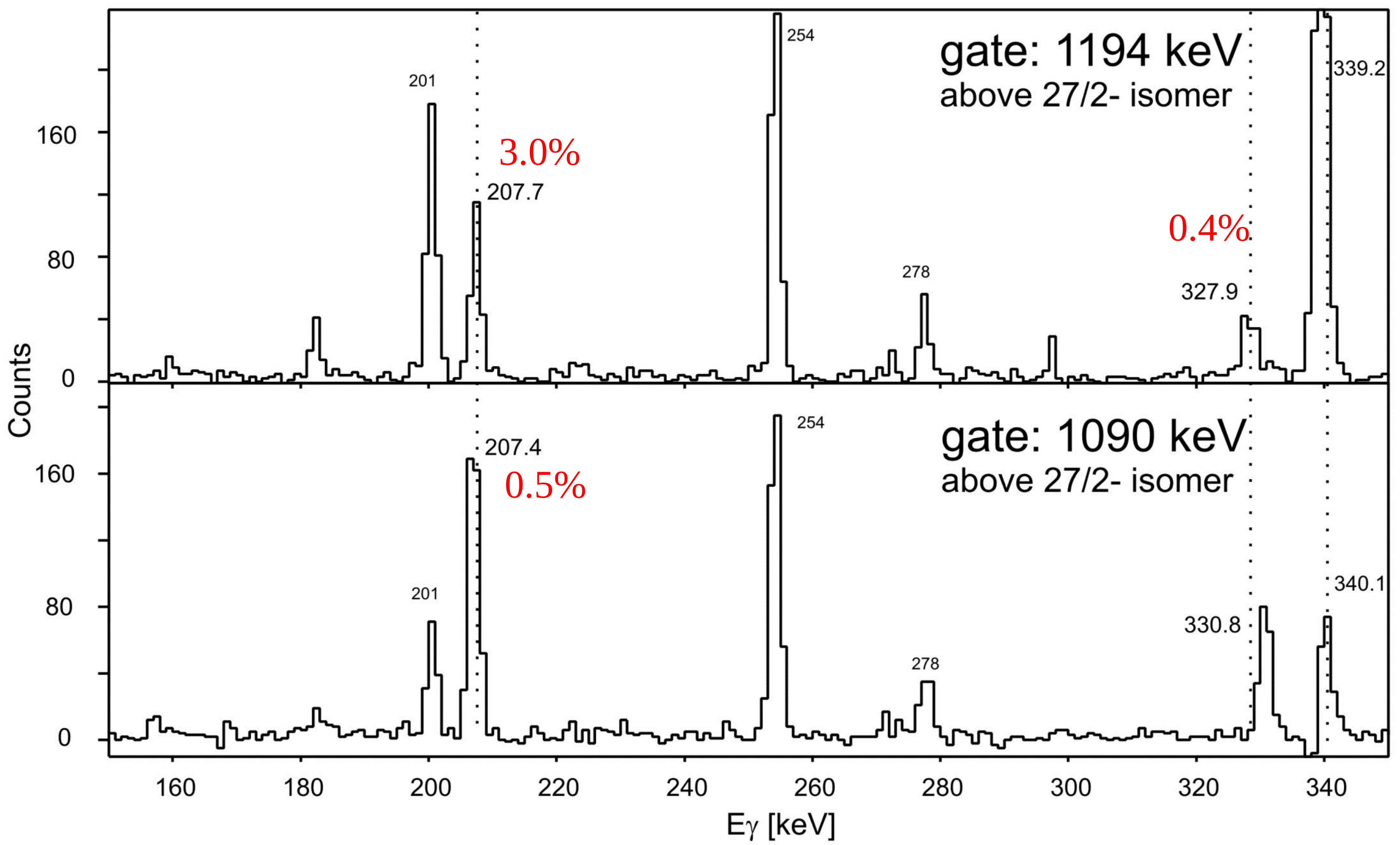
g-singles-3-5.dat



negative parity branch - 64%
gate 201 keV
1035
1056
1087
1151
1203
1218
1251
1261
1389
1490
1574
1682
x 10
1802
1876
1901
1950
1979
2012
2062
2085
projection
above 27/2- isomer
1035
1056
1064
1087
1152
1179
1251
1261
1286
1330
1389
1421
1434
1490
1536
1574
1607
1682
x 10
1802
1856
1876
1901
1950
1979
2012
2062
2085
gate 331 keV
positive parity branch - 30%
1035
1063
1286
1056
1087
1179
1218
1231
1251
1434
1490
1539
1575
x 10
1856
1950
2062
2085
Counts
Eγ [keV]
0
400
800
1200
10000
20000
30000
200
400
600
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200



gate: 2086 keV
above 27/2- isomer
0.82%
204.4
201
254
223
271
278
330
339
projection
181
159
167
187
192
207
222
237
271
278
284
298
314
331
gate: 2063 keV
above 27/2- isomer
0.73%
228.1
Counts
Eγ [keV]



gate: 1194 keV
above 27/2- isomer
201
207.7
3.0%
254
278
327.9
0.4%
339.2
gate: 1090 keV
above 27/2- isomer
201
207.4
0.5%
254
278
330.8
340.1
Counts
0
80
160
160
180
200
220
240
260
280
300
320
340
Eγ [keV]

^{147}Gd 49/2^{+} isomeric decay – summary of results

Studied down to **1 x 10^{-3}** intensity/decay
(for many transitions even below this limit, down to 2 x 10^{-4})

288 γ-transitions placed in the decay scheme
(before – 73 transitions + 13 unplaced)

84 levels established (before – 38)

perfect intensity balance at all levels (I^{in}/I_{out} ~ 1)

spin-parity assigned to all levels, using:

from the earlier study: **W(θ), DCO and EC-α_K** results

From the present study:
α_T EC values deduced from the intensity balance for γ-transitions Eγ<400 keV
observed gamma branching

	Level energy	Iπ	E γ keV	Intensity	branching %	multipolarity	Final level	Iπ	feed-in	decay-out
	8587,7	49/2+	254,4	828,0	91,2	E2 a)	8333,3	45/2+		1000
			434,5	57,8	5,9	E2 a)	8153,3	45/2+		
4			593,7	27,4	2,8	E3 a)	7994,1	43/2-		
			623,8	1,3	0,1	E3	7963,8	43/2-		
	8333,3	45/2+	179,8	1,4	0,2	M1	8153,3	45/2+	911,7	921,2
			207,4	29,8	4,1	M1	8125,9	43/2+		
			236,2	8,2	1,0	M1	8097,1	43/2+		
9			339,2	782,7	86,0	E1 a)	7994,1	43/2-		
			369,4	59,8	6,6	E1 a)	7963,8	43/2-		
			561,6	2,4	0,3	M1	7771,8	43/2+		
			944	11,3	1,2	M1	7389,2	43/2+		
			1298,1	3,6	0,4	E2	7035,2	41/2+		
			1426,6	2,3	0,3	E2	6906,6	41/2+		
	8153,3	45/2+	381,5	5,5	8,3	M1	7771,8	43/2+	60,9	66,4
3			764,1	56,1	84,5	M1 a)	7389,2	43/2+		
			1118,1	4,7	7,2	E2	7035,2	41/2+		
	8125,9	43/2+	913,3	2,2	7,1	E1	7212,6	41/2-	37,4	31,2
3			1090,7	15,9	50,9	M1	7035,2	41/2+		
			1219,2	13,1	42,0	M1	6906,6	41/2+		
	8097,1	43/2+	884,7	0,9	9,3	E1	7212,6	41/2-	9,6	9,5
			1061,9	6,5	68,6	M1	7035,2	41/2+		
3			1190,2	2,1	22,1	M1	6906,6	41/2+		
	7994,1	43/2-	30,2	6,3	9,0	M1unobs	7963,8	43/2-	820,2	811,3
			77,2	0,4	0,3	M1unobs.	7917,0	41/2-		
			90,8	0,9	0,4	M1 obs	7903,5	41/2-		
			120,2	223,0	60,7	M1 a)	7873,9	41/2-		
			168,6	26,7	4,8	M1	7825,6	41/2-		
17			192,9	32,3	4,0	M1	7801,2	41/2-		
			193,9	0,2	0,03	E2	7800,4	39/2-		
			288,3	0,2	0,03	E2	7705,7	39/2-		
			327,9	4,2	0,5	M1	7666,2	41/2-		
			374,5	3,0	0,4	E1	7619,6	41/2+		
			463,3	15,8	1,9	E1	7530,8	41/2+		
			598,2	19,1	2,4	E1	7396,0	41/2+		
			605	28,8	3,6	E1	7389,2	43/2+		
			686,7	5,5	0,7	E2	7307,5	39/2-		
			781,7	15,8	1,9	M1	7212,6	41/2-		
			958,9	40,0	4,9	E1 a)	7035,2	41/2+		
			1087,4	36,2	4,5	E1	6906,6	41/2+		
	7963,8	43/2-	297,8	1,4	1,1	M1	7666,2	41/2-	132,7	147,5

	7963,8	43/2-	297,8	1,4	1,1	M1	7666,2	41/2-	132,7	147,5
			433,1	11,3	7,6	E1	7530,8	41/2+		
			567,9	5,6	3,8	E1	7396,0	41/2+		
8			574,5	10,7	7,3	E1	7389,2	43/2+		
			656,3	2,4	1,6	E2	7307,5	39/2-		
			751,3	5,5	3,7	M1	7212,6	41/2-		
			928,6	23,0	15,6	E1	7035,2	41/2+		
			1057,1	87,4	59,3	E1 a)	6906,6	41/2+		
1	7917,0	41/2-	1994,1	2,1	100,0	E2	5922,9	37/2-	2,1	2,1
1	7903,5	41/2-	1980,6	4,1	100,0	E2	5922,9	37/2-	3,3	4,1
	7873,9	41/2-	48,3	5,5	4,6	M1 unobs	7825,6	41/2-	492,8	427,8
			72,7	14,4	20,3	M1	7801,2	41/2-		
			73,7	1,1	1,5	M1	7800,4	39/2-		
			105,5	0,4	0,3	M1	7768,5	39/2-		
			155,5	0,7	0,2	M1	7718,4	39/2-		
			168,2	0,4	0,2	M1	7705,7	39/2-		
			204,4	9,1	2,7	M1	7669,6	39/2-		
23			207,7	5,5	1,6	M1	7666,2	41/2-		
			228,1	7,3	2,0	M1	7645,8	39/2-		
			278	1,7	0,4	M1	7595,9	39/2-		
			488	1,9	0,5	M1	7386,0	39/2-		
			566,3	4,1	1,0	M1	7307,5	39/2-		
			598,7	2,6	0,6	M1	7275,5	41/2-		
			691,1	4,2	1,0	M1	7182,7	39/2-		
			747,1	17,3	4,1	M1	7126,9	39/2-		
			838,7	48,4	11,3	E1 a)	7035,2	41/2+		
			937,2	40,0	9,3	E1 a)	6936,7	39/2+		
			967,1	26,4	6,2	E1 a)	6906,6	41/2+		
			979,2	19,7	4,6	M1	6894,5	39/2-		
			1035,4	7,2	1,7	E1	6838,4	39/2+		
			1040,4	5,5	1,3	E2 a)	6833,6	37/2-		
			1252,7	37,4	8,7	E1	6621,2	39/2+		
			1951,1	67,9	15,9	E2 a)	5922,9	37/2-		
	7825,6	41/2-	229,7	4,9	10,9	M1	7595,9	39/2-	58,8	54,4
			517,8	4,0	7,3	M1	7307,5	39/2-		
			550,3	2,4	4,5	M1	7275,5	41/2-		
8			790,3	21,9	40,2	E1	7035,2	41/2+		
			1167,9	2,9	5,3	E2	6658,5	37/2-		
			1204,5	7,5	13,8	E1	6621,2	39/2+		
			1354	0,9	1,6	M1	6471,3	39/2-		
			1902,7	8,9	16,4	E2	5922,9	37/2-		
	7801,2	41/2-	618,7	2,2	2,1	M1	7182,7	39/2-	104,9	104,5
			765,9	2,8	2,6	E1	7035,2	41/2+		
			864,6	19,0	18,2	E1	6936,7	39/2+		
			894,6	14,0	13,4	E1	6906,6	41/2+		
			906,7	21,5	20,6	M1	6894,5	39/2-		
			962,9	3,1	3,0	E1	6838,4	39/2+		
			1180,2	42,0	40,1	E1	6621,2	39/2+		

Decay ways from the $49/2^+$ isomer to $7/2^-$ g.s.

ΔE = 8.5877 MeV **ΔI = 21**

Most intense path – **1.31×10^{-2}/decay, <M> =14, <ΔL> =1.5**

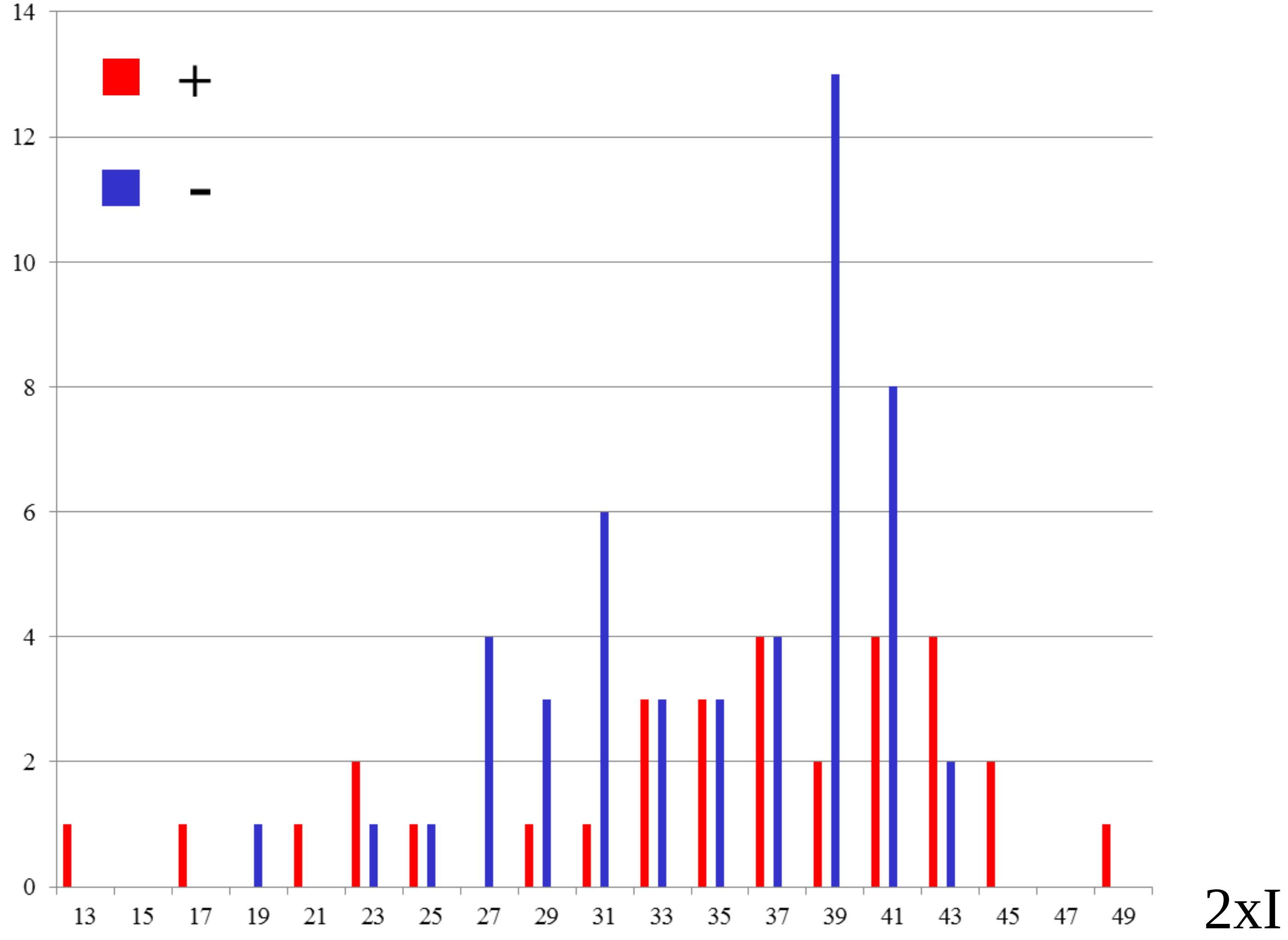
Shortest path - **1.35×10^{-6}/decay, <M> = 10, <ΔL> = 2.1**

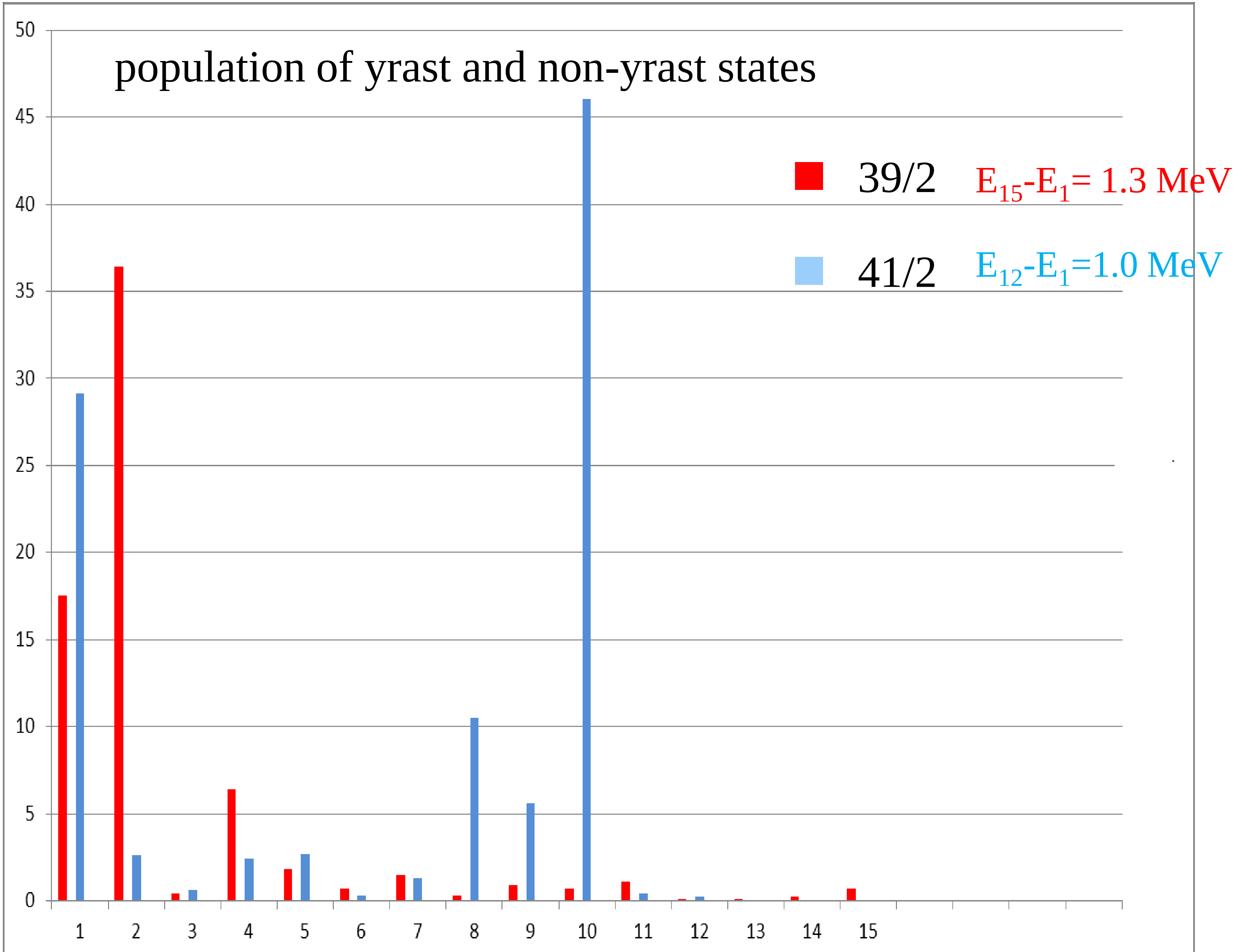
Longest path - **1.68×10^{-7}/decay, <M> = 21, <ΔL> = 1.0**

Weakest path? - **2.1×10^{-15}/decay**
4.6×10^{-16}/decay

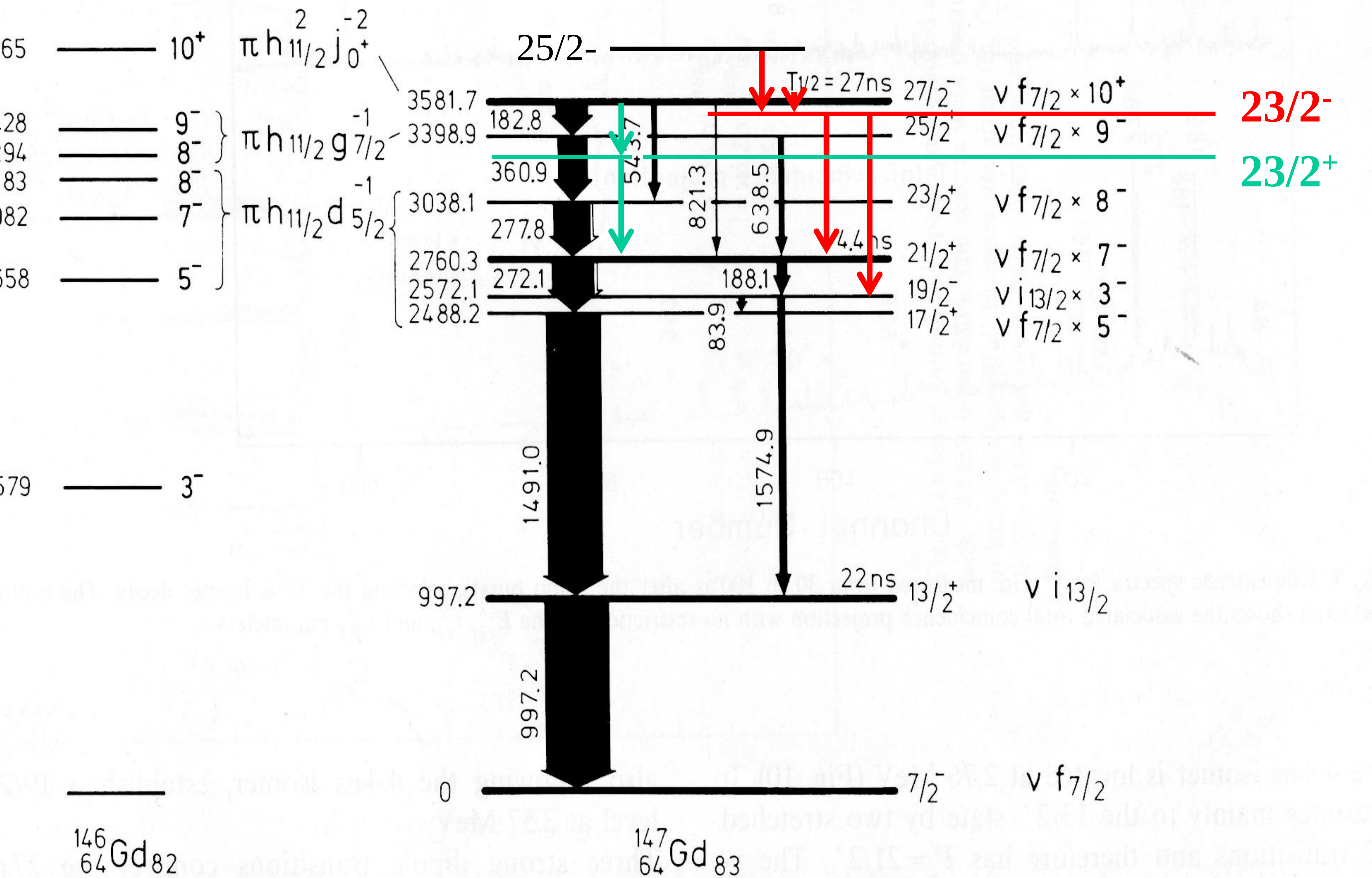
Number of decay ways: ???

number of populated states





population of yrast and non-yrast states
39/2
41/2
E15-E1= 1.3 MeV
E12-E1=1.0 MeV
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15



ig. 10. Level scheme of ^{147}Gd. Configuration assignments and comparison with the ^{146}Gd core energies (left) are discussed in Sect. IV
or higher-lying ^{147}Gd states cf. Refs. 8 and 9