^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh	ENSDF	30-Nov-2021

1993We04: ^{58}Ni(^{36}Ar,4pnγ) E=149 MeV. Measured Eγ, Iγ, $\gamma\gamma$, (particle)$\gamma\gamma$ coin, $\gamma(\theta)$, $\gamma\gamma(\theta)$(DCO) using an array of six Compton-suppressed Ge detectors and particle-detector arrays. Comparisons with shell-model calculations. See related studies: 1995We12, 1995Ka06, 1995Za11, 1993Ka24.

1993Ga19: ^{60}Ni(^{32}S,2pnγ) E=110 MeV. Measured Eγ, Iγ, $\gamma\gamma$, nγ coin, $\gamma(\theta)$.

1995We12: ^{58}Ni(^{36}Ar,4pnγ) E=154 MeV. Measured g factor for isomer at 2584 using time-differential perturbed-angular distribution method after recoil implantation.

1995Ka06: ^{58}Ni(^{36}Ar,4pnγ) E=149 MeV. Measured lifetimes by electronic timing.

1995Za11: ^{58}Ni(^{35}Cl,3pnγ) E=120 MeV. Measured lifetimes by recoil-distance Doppler-shift (RDDS) method.

1993Ka24: ^{58}Ni(^{36}Ar,4pnγ) E=149 MeV and ^{58}Ni(^{35}Cl,3pnγ) E=120 MeV. Measured $\gamma(\theta)$ and $\gamma\gamma(\theta)$ (DCO).

1992WeZS (also Wen et al., Proc. Int. Nucl. Phys. Conf. Wiesbaden, Germany 1992 and 1991 Annual Rep. China Ins. Atomic Energy, p19 (1992)): ^{58}Ni(^{35}Cl,3pnγ) E=124 MeV. Measured Eγ, Iγ, $\gamma\gamma$, nγ, $\gamma\gamma(\theta)$(DCO), excitation functions (E=112-136 MeV).

Multi-particle shell model configurations of seniority=3,5,7 are given in detail by 1993We04 and 1993Ga19. Comparisons of experimental γ branching ratios with those calculated for these configurations are given by 1995Za11.

^{89}Mo Levels

E(level)[†]	J$^\pi$[‡]	T$_{1/2}$[#]	Comments
0.0	(9/2$^+$)		
118.8 *1*	(7/2$^+$)		
387.6 *3*	(1/2$^-$)		Configuration=$\nu p_{1/2}^{-1}$.
1000.7 *1*	(11/2$^+$)		
1016.4 *1*	(13/2$^+$)		
1645.8 *1*	(11/2$^+$)		
2008.4 *1*	(13/2$^-$)		
2096.4 *1*	(17/2$^+$)		
2271.2 *1*	(17/2$^-$)	1.14 ns *8*	T$_{1/2}$: from RDDS for 175γ (1995Za11). Other: 1.11 ns *28* from γ(t) of 175γ and 263γ (1995Ka06).
2415.8 *1*	(17/2$^+$)		
2454.5 *2*	(17/2$^-$)	5.8 ps *11*	
2548?[&]	(17/2$^-$)		
2583.7 *1*	(21/2$^+$)	9.49 ns *21*	g=+0.79 *4* (1995We12) T$_{1/2}$: from γ(t) of 168γ, 487γ, 320γ, 1016γ, 1080γ, 1399γ (1995Ka06). Other: ≈21 ns (1993We04). Configuration=40%(($\pi g_{9/2}^2)_{8+}\nu g_{9/2}^{-1}$)+ 21%(($\pi g_{9/2}^2)_{6+}\nu g_{9/2}^{-1}$)+ 15%(($\pi g_{9/2}^2)_{8+}(\nu g_{9/2}^{-3})_{7/2+}$)+1%($\nu g_{9/2}^{-3}$) gives calculated g=+0.79 (1995We12).
2911?[&]			
3134.0 *2*	(23/2$^+$)	<1.1 ps	
3151.1 *2*	(21/2$^-$)	1.8 ps *+6−10*	
3503?[&]	(23/2$^-$)		
3558.4 *2*	(25/2$^+$)	<1.0 ps	
3701.8 *2*	(23/2$^-$)		
3716.7 *2*	(25/2$^+$)	0.8 ps *6*	
4069.0 *2*	(25/2$^-$)	2.8 ps *+6−3*	
4260.6 *2*	(27/2$^+$)	0.28 ps *+7−14*	
4366?[&]	(27/2$^-$)		
4575.4 *2*	(27/2$^-$)	0.69 ps *+28−14*	
4649.1 *2*	(29/2$^+$)		
4980.7 *2*	(29/2$^+$)	<0.7 ps	
5170.9 *2*	(29/2$^-$)	<0.76 ps	

Continued on next page (footnotes at end of table)

^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19 (continued)

^{89}Mo Levels (continued)

E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]	E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]
5251.0 *2*	(31/2$^+$)	2.3 ps *8*	6436.4 *2*	(35/2$^-$)	2.6 ps *6*
5420.0 *2*	(31/2$^-$)	<0.7 ps	6470.6 *3*	(35/2$^+$)	
5643.0 *2*	(33/2$^+$)	0.55[@] ps *14*	6755.9 *3*	(37/2$^+$)	
			7590.1 *3*	(39/2$^-$)	1.39[@] ps *14*

[†] From least-squares fit to Eγ data.
[‡] From 1995Za11, based on $\gamma(\theta)$ (1993We04,1993Ga19) and $\gamma\gamma(\theta)$(DCO) of 1993We04. J^{π} values of g.s., 119 and 388 states are based on systematics and probable shell-model configurations.
[#] From RDDS (1995Za11), unless otherwise stated.
[@] Effective $T_{1/2}$ not corrected for feeding.
[&] From 1992WeZS only. It is considered uncertain (evaluator) and is omitted from Adopted Levels.

γ(^{89}Mo)

A_2, A_4 and DCO values are from 1993We04, unless otherwise stated.

γ-ray intensities in ^{60}Ni(^{32}S,2pnγ) E=110 MeV (1993Ga19)

Eγ	Iγ	Eγ	Iγ
118.8 *3*	5 *1*	550.5 *3*	7
167.7 *2*	18 *4*	582.7 *2*	15 *2*
174.5 *2*	21 *3*	595.5 *2*	17 *3*
183.3 *2*	4	696.5 *3*	3
249.4 *3*	17 *3*	702.4 *2*	10 *2*
262.6 *2*	17 *3*	845.3 *4*	3
268.8 *3*	4 *1*	879.9 *2*	27 *4*
319.6 *2*	9 *1*	917.7 *3*	19 *3*
362.2 *4*	6 *1*	992.0 *3*	17 *3*
367.5 *4*	3 *1*	1016.3 *2*	100 *12*
424.2 *2*	14 *2*	1080.0 *2*	60 *8*
487.4 *2*	27 *4*	1102.1 *3*	3
506.6 *3*	23 *4*	1399.6 *4*	16 *2*
543.6 *3*	6 *1*	1526.9 *4*	weak
550.4 *2*	34 *5*	1646.1 *4*	weak

E_{γ}[†]	I_{γ}[†]	E_i(level)	J_i^{π}	E_f	J_f^{π}	Mult.[‡]	α[c]	Comments
118.8 *1*	3.1 *8*	118.8	(7/2$^+$)	0.0	(9/2$^+$)			$\gamma(\theta)$: isotropic.
168.0 *1*	15.3 *3*	2583.7	(21/2$^+$)	2415.8	(17/2$^+$)	(E2)[&]	0.185	A_2=+0.22 *5*; A_4=−0.14 *10* (1993Ga19); DCO=0.73 *8* (1993We04)
174.8 *1*	31.2 *7*	2271.2	(17/2$^-$)	2096.4	(17/2$^+$)	(E1)[b]	0.0250	A_2=+0.33 *2*; A_4=+0.02 *2*; DCO=0.71 *8* A_2=+0.37 *6*; A_4=−0.06 *6* (1993Ga19)
183.5 *1*	5.9 *2*	2454.5	(17/2$^-$)	2271.2	(17/2$^-$)			
249.0 *1*	12.5 *4*	5420.0	(31/2$^-$)	5170.9	(29/2$^-$)	D[a]		A_2=−0.34 *6*; A_4=+0.02 *6*; DCO=0.55 *7* A_2=−0.58 *6*; A_4=+0.03 *12* (1993Ga19)
262.8 *1*	18.7 *4*	2271.2	(17/2$^-$)	2008.4	(13/2$^-$)	(E2)[&]	0.0380	A_2=+0.27 *3*; A_4=−0.07 *3*; DCO=0.65 *8* A_2=+0.13 *6*; A_4=−0.06 *6* (1993Ga19) DCO is too low for suggested (1993We04) ΔJ=2.

Continued on next page (footnotes at end of table)

^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19 (continued)

γ(^{89}Mo) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[‡]	δ	Comments
268.8 3		387.6	(1/2⁻)	118.8	(7/2⁺)	(E3)		E_γ: from 1993Ga19. Mult.: from Adopted Gammas.
270.3 1	8.3 2	5251.0	(31/2⁺)	4980.7	(29/2⁺)	D[a]		A_2=−0.41 6; A_4=+0.05 6; DCO=0.77 8
277[#d]		2548?	(17/2⁻)	2271.2	(17/2⁻)			
285.3 1	4.3 6	6755.9	(37/2⁺)	6470.6	(35/2⁺)			
297[#d]		4366?	(27/2⁻)	4069.0	(25/2⁻)			
319.5 1	5.3 2	2415.8	(17/2⁺)	2096.4	(17/2⁺)	[b]		γ(θ): isotropic. DCO=0.80 12.
327[#d]		2911?		2583.7	(21/2⁺)			
331.6 1	3.2 2	4980.7	(29/2⁺)	4649.1	(29/2⁺)			DCO=0.78 10
352[#d]		3503?	(23/2⁻)	3151.1	(21/2⁻)			
362.6 1	8.3 7	2008.4	(13/2⁻)	1645.8	(11/2⁺)	D[a]		DCO=0.51 9
367.2 1	5.2 2	4069.0	(25/2⁻)	3701.8	(23/2⁻)	D[a]		A_2=−0.33 7; A_4=−0.04 8; DCO=0.66 13
388.4 1	8.8 3	4649.1	(29/2⁺)	4260.6	(27/2⁺)	D[a]		A_2=−0.52 8; A_4=+0.10 3; DCO=0.62 9
392.0 1	8.8 3	5643.0	(33/2⁺)	5251.0	(31/2⁺)	D[a]		A_2=−0.51 7; A_4=+0.13 7; DCO=0.53 8
424.4 1	10.3 5	3558.4	(25/2⁺)	3134.0	(23/2⁺)	D[a]		A_2=−0.60 10; A_4=+0.19 10 (1993Ga19); DCO=0.58 8 (1993We04)
487.3 1	19.5 4	2583.7	(21/2⁺)	2096.4	(17/2⁺)	(E2)[&]		A_2=+0.15 6; A_4=−0.03 3 (1993Ga19); DCO=1.07 8 γ(θ) is isotropic (1993We04).
506.5 1	14.4 4	4575.4	(27/2⁻)	4069.0	(25/2⁻)	D[a]		A_2=−0.51 4; A_4=+0.20 5; DCO=0.52 7
543.9 1	3.7 4	4260.6	(27/2⁺)	3716.7	(25/2⁺)			DCO=0.84 11
550.3 1	24.4[@] 14	3134.0	(23/2⁺)	2583.7	(21/2⁺)	D[a]		A_2=−0.54 6; A_4=+0.14 8 (1993Ga19); DCO=0.46 10 γ(θ) is for doublet.
550.7 1	4.2[@] 4	3701.8	(23/2⁻)	3151.1	(21/2⁻)	D[a]		DCO=0.56 11
582.6 1	11.5 3	3716.7	(25/2⁺)	3134.0	(23/2⁺)	M1+E2[a]	−3.4 17	A_2=−0.62 4; A_4=+0.17 5; DCO=0.51 7 (1993We04,1993Ka24) A_2=−0.53 6; A_4=+0.14 10 (1993Ga19) δ: spans minimum and maximum limits of δ=−2.4 7 (from γ(θ)) and −3.7 +17−13 (from R(DCO)) (1993Ka24).
595.5 1	10.0 4	5170.9	(29/2⁻)	4575.4	(27/2⁻)	D[a]		A_2=−0.52 6; A_4=+0.16 7; DCO=0.59 8
601.9 1	3.3 2	5251.0	(31/2⁺)	4649.1	(29/2⁺)			
629.5 2	1.0 3	1645.8	(11/2⁺)	1016.4	(13/2⁺)			
696.8 1	1.2 2	3151.1	(21/2⁻)	2454.5	(17/2⁻)			
702.3 1	8.9 4	4260.6	(27/2⁺)	3558.4	(25/2⁺)	D[a]		A_2=−0.63 6; A_4=+0.24 7; DCO=0.54 10
720.1 1	5.1 3	4980.7	(29/2⁺)	4260.6	(27/2⁺)			
806[#d]		5170.9	(29/2⁻)	4366?	(27/2⁻)			
827.6 1	9.2 4	6470.6	(35/2⁺)	5643.0	(33/2⁺)			
844.9 2	5.4 4	5420.0	(31/2⁻)	4575.4	(27/2⁻)	(E2)[&]		DCO=0.96 15
879.8 1	25.6 7	3151.1	(21/2⁻)	2271.2	(17/2⁻)	(E2)[&]		A_2=+0.28 3; A_4=−0.03 4; DCO=1.06 8 (1993We04,1993Ka24) A_2=+0.11 6; A_4=+0.08 8 (1993Ga19) δ(Q/D)=0.00 +10−6 from γ(θ), +0.05 8 from DCO (1993Ka24).
917.8 1	14.2 6	4069.0	(25/2⁻)	3151.1	(21/2⁻)	(E2)[&]		DCO=1.07 8
975[#d]		3558.4	(25/2⁺)	2583.7	(21/2⁺)			
990.4 2	3.9 2	5251.0	(31/2⁺)	4260.6	(27/2⁺)			
991.8 1	20.6 5	2008.4	(13/2⁻)	1016.4	(13/2⁺)	(D)[b]		A_2=+0.25 9; A_4=+0.02 10; DCO=0.90 22 γ(θ) data from 1993We04, 1993Ka24. δ(Q/D)=0.00 +7−13 from γ(θ), −0.4 from DCO (1993Ka24).
1000.7 1	12.0 13	1000.7	(11/2⁺)	0.0	(9/2⁺)			

Continued on next page (footnotes at end of table)

^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19 (continued)

γ(^{89}Mo) (continued)

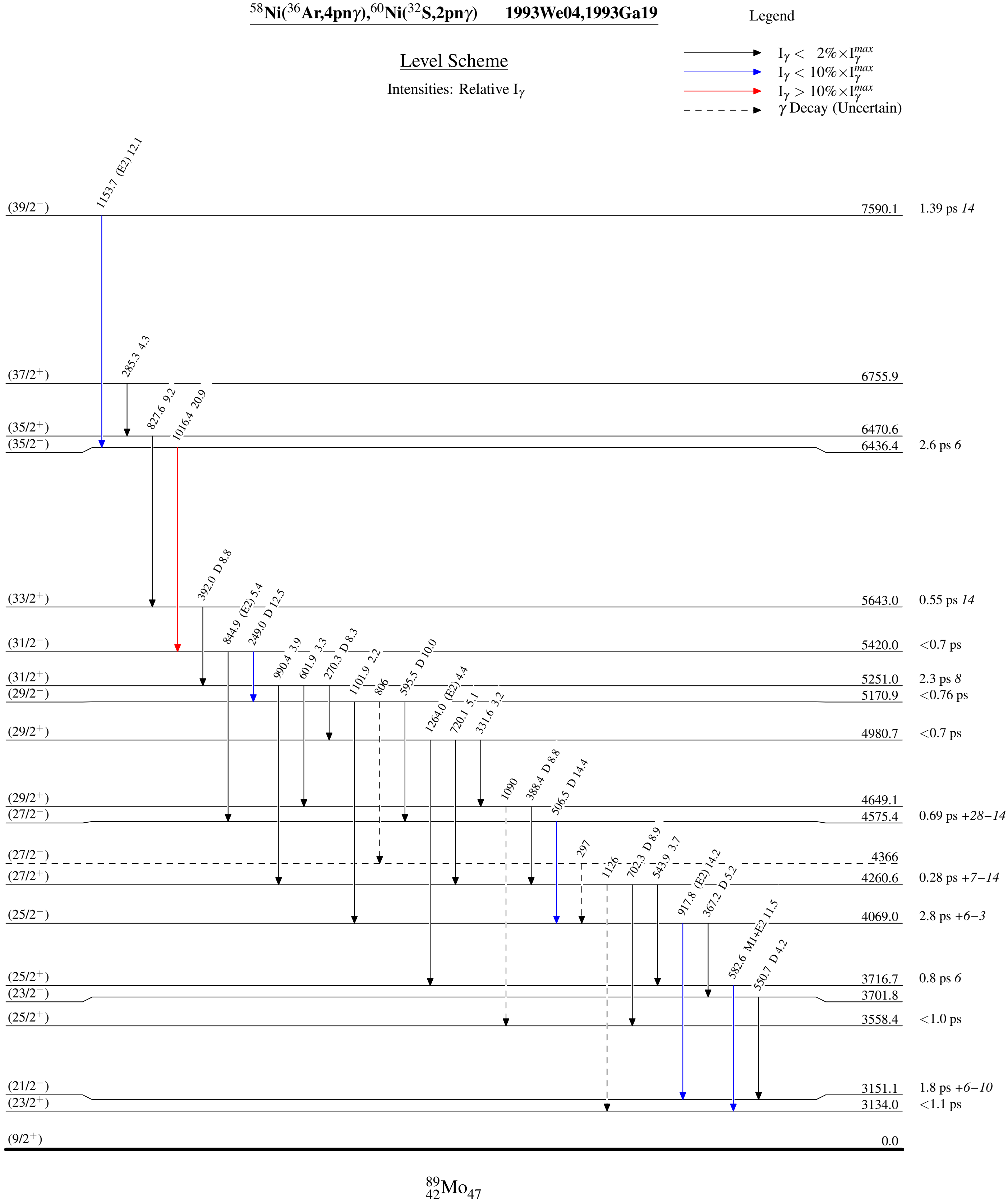
E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[‡]	Comments
1007.9 *2*	11.1 *7*	2008.4	(13/2$^-$)	1000.7	(11/2$^+$)	D[a]	A_2=−0.34 *7*; A_4=−0.03 *8*
1016.3 *1*	100[@] *5*	1016.4	(13/2$^+$)	0.0	(9/2$^+$)	(Q)[&]	A_2=+0.22 *2*; A_4=−0.03 *2*; DCO=1.04 *7* A_2=+0.28 *6*; A_4=−0.08 *6* (1993Ga19) $\gamma(\theta)$ data for doublet.
1016.4 *1*	20.9[@] *10*	6436.4	(35/2$^-$)	5420.0	(31/2$^-$)		
1080.0 *1*	64.9 *9*	2096.4	(17/2$^+$)	1016.4	(13/2$^+$)	Q[&]	A_2=+0.17 *2*; A_4=0.00 *2*; DCO=0.94 *7* A_2=+0.26 *6*; A_4=−0.06 *2* (1993Ga19)
1090[#d]		4649.1	(29/2$^+$)	3558.4	(25/2$^+$)		
1101.9 *1*	2.2 *4*	5170.9	(29/2$^-$)	4069.0	(25/2$^-$)		
1126[#d]		4260.6	(27/2$^+$)	3134.0	(23/2$^+$)		
1153.7 *1*	12.1 *5*	7590.1	(39/2$^-$)	6436.4	(35/2$^-$)	(E2)[&]	DCO=1.09 *13*
1264.0 *1*	4.4 *4*	4980.7	(29/2$^+$)	3716.7	(25/2$^+$)	(E2)[&]	DCO=1.12 *18*
1399.3 *1*	12.4 *4*	2415.8	(17/2$^+$)	1016.4	(13/2$^+$)	Q[&]	A_2=+0.08 *2*; A_4=+0.02 *2*; DCO=0.88 *12* A_2=+0.25 *8*; A_4=−0.10 *7* (1993Ga19)
1527.2 *2*	4.8 *3*	1645.8	(11/2$^+$)	118.8	(7/2$^+$)		
1645.9 *2*	2.6 *3*	1645.8	(11/2$^+$)	0.0	(9/2$^+$)		

† From 1993We04, unless otherwise stated. See 1995Za11 for experimental branching ratios and comparisons with those from shell-model calculations.
‡ From $\gamma(\theta)$ and/or $\gamma\gamma(\theta)$(DCO) combined with RUL for quadrupole transitions.
# From 1992WeZS only. It is considered uncertain (evaluator). This γ ray must be very weak since it is not shown in nγ coin spectrum of 1992WeZS. This γ ray is omitted from Adopted Gammas.
@ Unresolved doublet, intensity is divided in two components.
& R(DCO) and/or $\gamma(\theta)$ suggest ΔJ=2, quadrupole. Mult=E2 from RUL.
a R(DCO) and/or $\gamma(\theta)$ suggest ΔJ=1, dipole or D+Q.
b R(DCO) and/or $\gamma(\theta)$ consistent with ΔJ=0, dipole or D+Q.
c Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
d Placement of transition in the level scheme is uncertain.

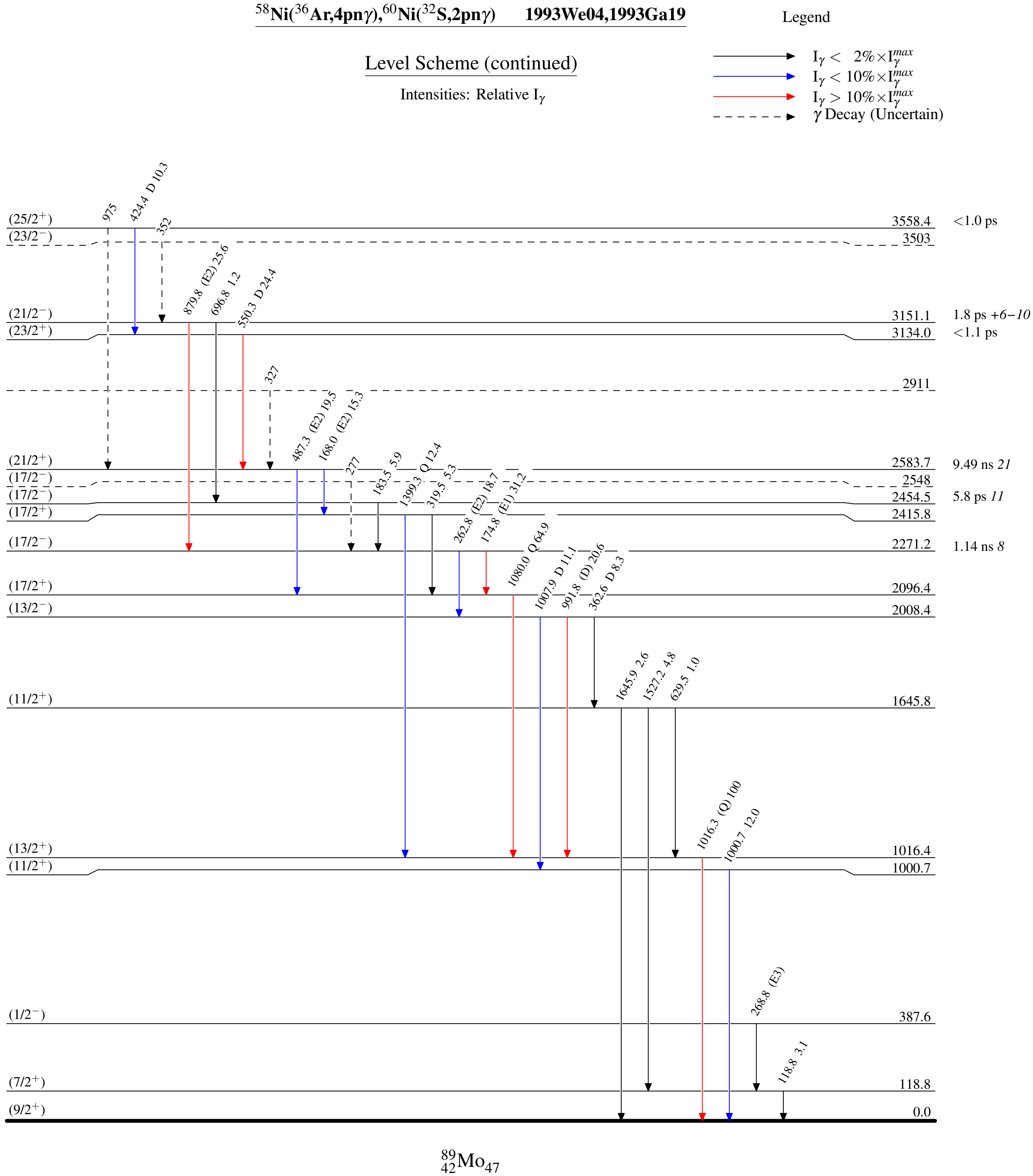
^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19

Level Scheme

Intensities: Relative I_γ



$^{89}_{42}Mo_{47}$


^{58}Ni(^{36}Ar,4pnγ),^{60}Ni(^{32}S,2pnγ) 1993We04,1993Ga19
Level Scheme (continued)
Intensities: Relative Iγ
Legend
Iγ < 2%×Iγmax
Iγ < 10%×Iγmax
Iγ > 10%×Iγmax
γ Decay (Uncertain)
(25/2+) 3558.4 <1.0 ps
(23/2−) 3503
(21/2−) 3151.1 1.8 ps +6−10
(23/2+) 3134.0 <1.1 ps
2911
(21/2+) 2583.7 9.49 ns 21
(17/2−) 2548
(17/2−) 2454.5 5.8 ps 11
(17/2+) 2415.8
(17/2−) 2271.2 1.14 ns 8
(17/2+) 2096.4
(13/2−) 2008.4
(11/2+) 1645.8
(13/2+) 1016.4
(11/2+) 1000.7
(1/2−) 387.6
(7/2+) 118.8
(9/2+) 0.0
975
424.4 D 10.3
352
879.8 (E2) 25.6
696.8 1.2
550.3 D 24.4
327
487.3 (E2) 19.5
168.0 (E2) 15.3
277
183.5 5.9
1399.3 Q 12.4
319.5 5.3
262.8 (E2) 18.7
174.8 (E1) 31.2
1080.0 Q 64.9
1007.9 D 11.1
991.8 (D) 20.6
362.6 D 8.3
1645.9 2.6
1527.2 4.8
629.5 1.0
1016.3 (Q) 100
1000.7 12.0
268.8 (E3)
118.8 3.1
$^{89}_{42}$Mo$_{47}$