^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Coral M. Baglin	NDS 112, 1163 (2011)	15-Dec-2010

Other: 2005Mc13.

2010Or01, 2007Or01, 2006Or09: E(p)=11.5-19 MeV; 96.93% enriched ^{94}Zr target; HORUS spectrometer (16 HPGe detectors; 7 of these formed the EUROBALL cluster array with the central detector placed at θ=90° and ϕ=0°, four were placed at θ=45° and 135° in a vertical plane and had Compton-suppression shields, and the remainder were placed in θ=90° plane and at ϕ=55°, 125°, 235° and 305°; measured Eγ, photon branching, $\gamma\gamma$ coin, $\gamma\gamma(\theta)$, excit. See also 2005Mc13. shell-model calculations; identification of mixed-symmetry states.

^{93}Nb Levels

E(level)[†]	J$^\pi$[‡]	Comments
0	9/2$^+$	configuration: π 1g$_{9/2}$ particle state.
30.89 *17*	1/2$^-$	configuration: π 2p$_{1/2}$ hole state (2006Or09).
686.90[@] *14*	3/2$^-$	
744.01[d] *5*	7/2$^+$	
808.94[d] *7*	5/2$^+$	
810.42[@] *11*	5/2$^-$	
949.80[d] *7*	13/2$^+$	
979.01[d] *5*	11/2$^+$	
1082.72[d] *6*	9/2$^+$	
1127.14[a] *18*	7/2$^+$	
1284.36[b] *16*	5/2$^-$	
1297.28[c] *6*	9/2$^+$	
1315.59[c] *11*	5/2$^+$	
1334.95[a] *16*	17/2$^+$	
1369.96 *18*	5/2$^-$	
1395.56[b] *15*	7/2$^-$	
1483.63[c] *6*	7/2$^+$	
1490.99[a] *12*	15/2$^+$	
1500.00[b] *6*	9/2$^-$	
1571.92[b] *16*	3/2$^-$	
1588.16[a] *18*	5/2$^-$	
1603.48 *9*	11/2$^+$	
1665.73[a] *12*	5/2$^+$	
1679.59[a] *9*	7/2$^+$	
1683.40 *8*	9/2$^+$	
1686.38 *9*	13/2$^+$	
1703.62[a] *16*	3/2$^+$	
1773.05[a] *18*	(1/2$^+$)	J$^\pi$: not adopted; see comment on 646γ.
1779.36[#] *18*	5/2$^-$	
1812.2 *3*	(19/2$^+$)	
1840.16[#] *18*	3/2$^-$	
1910.71[&] *7*	11/2$^+$	
1915.98[&] *10*	7/2$^+$	
1947.82 *23*	7/2$^{(-)}$	
1949.80[a] *10*	7/2$^+$	
1949.84 *13*	(7/2$^+$)	authors do not report an Iγ=100 branch.
1968.39 *17*	(11/2$^+$,13/2$^+$)	
1968.91[a] *6*	11/2$^+$	

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^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 (continued)

^{93}Nb Levels (continued)

E(level)[†]	J$^\pi$[‡]	T$_{1/2}$	Comments
1997.22 *18*	5/2$^-$		
2002.56[a] *10*	11/2$^+$		
2012.52 *20*	3/2$^-$	21 fs *+20−8*	level reported by 2005Mc13 and 2010Or01. J$^\pi$: 5/2$^-$ deduced from (1326γ)(656γ)(θ) (2005Mc13), but a $\gamma\gamma(\theta)$ data analysis problem necessitated a reanalysis of those data and 3/2$^-$ is now recommended by 2010Or01. T$_{1/2}$: from 2005Mc13.
2024.02[a] *20*	3/2$^-$		
2099.34 *19*	7/2$^{(-)}$		
2122.72[a] *6*	9/2$^+$		
2126.98 *13*			
2153.7 *3*			
2162.67[a] *13*	(13/2$^+$)		
2170.69[a] *10*	9/2$^+$		E(level): inconsistency of Eγ for deexciting transitions suggests the possibility of a close doublet At 2171 keV.
2184.1 *3*	(19/2$^+$)		
2506.93 *8*	9/2$^+$		J$^\pi$: not adopted; justification for assignment unknown.

[†] From least-squares fit to Eγ.

[‡] Values recommended by 2010Or01 based on their $\gamma\gamma(\theta)$ data, level decay patterns and shell-model calculations. Several of these had been proposed previously by 2006Or09. The low-lying structure of ^{93}Nb is dominated by π 1g$_{9/2}$ particle and 2p$_{1/2}$ hole excitations (for π=+ and − states, respectively) and jj-couplings built on these (2010Or01).

[#] Band(A): π=− mixed-symmetry states. Interpreted as mixed-symmetry state associated with (π 2p$_{1/2}$)⊗(first 2$^+$ in ^{94}Mo). The assignment is based on M1 and E2 transition strengths to 687 and 811 states (interpreted as symmetric one-phonon states), energy systematics, spins and parities and comparison with shell-model calculation (2006Or09).

[@] Band(B): π 2p$^{-1}_{1/2}$⊗(2$^+$,^{94}Mo). Interpreted as symmetric one-phonon state.

[&] Isovector excitation is proposed by 2010Or01 for this state.

[a] Isoscalar excitation is proposed by 2010Or01 for this state.

[b] Band(C): π=− 2-phonon IS states. Interpreted by 2010Or01 As 2-phonon isoscalar excitations, expected based on particle-core weak-coupling model.

[c] Band(D): π=+ 1-phonon IV states. π=+ first-order isovector excitations. large B(M1) to isoscalar states.

[d] Band(E): π 1g$_{9/2}$⊗(2$^+$,^{92}Zr). First-order isoscalar π=+ excitations, forming a J=5/2 through 13/2 quintet of states. shell-model calculations indicate strongly collective E2 transition rates to 9/2$^+$ g.s. with predominantly isoscalar character (2010Or01).

γ(^{93}Nb)

IT is unclear whether Eγ data quoted In 2006Or09, 2007Or01 and 2010Or01 were determined In the (p,2nγ) or (n,n$'\gamma$) studies or both. They are listed In this evaluation with the (p,2nγ) data set alone.

E,Iγ,M,δ from 2007Or01, except As noted. multipolarity and δ are based on authors' $\gamma\gamma(\theta)$ data.

E$_i$(level)	J$_i^\pi$	E$_\gamma$	I$_\gamma$	E$_f$	J$_f^\pi$	Mult.	δ	Comments
30.89	1/2$^-$	(30.89)		0	9/2$^+$			Eγ from level energy difference. there is No evidence that 2010Or01 detected this γ, so the M4 multipolarity they indicate for it is presumed to have been taken from the literature.
686.90	3/2$^-$	655.9[‡] *2*	100[‡]	30.89	1/2$^-$	&		
744.01	7/2$^+$	744.2 *1*	100	0	9/2$^+$	D+Q	+0.26 *8*	

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^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 (continued)

γ(^{93}Nb) (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
808.94	5/2+	65.0‡ 2	<1‡	744.01	7/2+	&		
		808.6‡ 2	100‡ 2	0	9/2+	@		
810.42	5/2−	123.3‡ 2	<1‡	686.90	3/2−	&		
		779.6‡ 2	100‡	30.89	1/2−	@		
949.80	13/2+	949.8 *1*	100	0	9/2+	@		
979.01	11/2+	979.3 *1*	100	0	9/2+	D+Q	−0.13 *7*	E_γ: other Eγ: 978.8 *2* (2010Or01).
1082.72	9/2+	103.7‡ 2	3‡ 2	979.01	11/2+	#		
		338.6‡ 2	100‡ 2	744.01	7/2+	D+Q	−0.09 *2*	
		1082.6‡ 2	38‡ 2	0	9/2+	#		
1127.14	7/2+	318.3‡ 2	100‡	808.94	5/2+	D+Q‡	−0.20‡ *6*	
1284.36	5/2−	473.9‡ 2	5‡ *4*	810.42	5/2−	&		
		597.3‡ 2	25‡ *4*	686.90	3/2−	D+Q‡	+0.14‡ *4*	
		1253.5‡ 2	100‡ *4*	30.89	1/2−	@		
1297.28	9/2+	318.3 *1*	31 *5*	979.01	11/2+	&		
		553.1 *1*	61 *5*	744.01	7/2+	D(+Q)	+0.02 *3*	Mult.,δ: from 2010Or01. δ=−0.03 *5* from 2007Or01.
		1297.4 *1*	100 *5*	0	9/2+	D+Q	+0.31 *9*	
1315.59	5/2+	506.7‡ 2	24‡ *4*	808.94	5/2+	D+Q‡	−1.4‡ *8*	
		571.5‡ 2	100‡ *4*	744.01	7/2+	D+Q‡	+0.14‡ *4*	
1334.95	17/2+	385.1‡ 2	100‡	949.80	13/2+	@		
1369.96	5/2−	559.4‡ 2	100‡ *4*	810.42	5/2−	D+Q‡	−0.32‡ *7*	
		683.2‡ 2	30‡ *4*	686.90	3/2−	D+Q‡	−0.34‡ *5*	
1395.56	7/2−	585.1† 2	100† *4*	810.42	5/2−	D+Q†	−0.10† *2*	
		708.6† 2	9† *4*	686.90	3/2−	@		
1483.63	7/2+	400.8 *1*	7 *2*	1082.72	9/2+	&		
		674.8 *1*	27 *2*	808.94	5/2+	D+Q	−0.11 *8*	
		1483.5 *1*	100 *2*	0	9/2+	D+Q	−0.13 *7*	E_γ: 1483.8 *2* In 2010Or01.
1490.99	15/2+	156.0‡ 2	14‡ 2	1334.95	17/2+	&		
		541.1‡ 2	100‡ 2	949.80	13/2+	D+Q‡	−0.11‡ *2*	
1500.00	9/2−	520.9 *1*	2 *2*	979.01	11/2+			
		689.6 *1*	18 *3*	810.42	5/2−	@		
		756.1 *1*	8 *2*	744.01	7/2+			
		1499.9 *1*	100 *2*	0	9/2+			
1571.92	3/2−	287.4† 2	20† *5*	1284.36	5/2−	&		
		761.4† 2	100† *5*	810.42	5/2−	D+Q†	−0.28† *3*	
		885.1† 2	37† *5*	686.90	3/2−	D+Q†	−1.60† *14*	
1588.16	5/2−	777.8† 2	18† *8*	810.42	5/2−	D+Q†	−4.0† *+13−35*	
		901.2† 2	100† *8*	686.90	3/2−	D+Q†	−0.53† *6*	
1603.48	11/2+	520.9‡ 2	13‡ *3*	1082.72	9/2+	D(+Q)‡	−0.07‡ *9*	
		624.4‡ 2	32‡ *3*	979.01	11/2+	D+Q‡	+0.11‡ *6*	
		653.6‡ 2	100‡ *3*	949.80	13/2+	D+Q‡	+0.17‡ *3*	
		859.6‡ 2	22‡ *3*	744.01	7/2+			
		1603.5‡ 2	23‡ *3*	0	9/2+	&		
1665.73	5/2+	856.9‡ 2	<1‡	808.94	5/2+	&		
		921.6‡ 2	100‡ 2	744.01	7/2+	D+Q‡	+1.4‡ *2*	
		1665.7 *2*	2 *2*	0	9/2+	@		

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^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 (continued)

γ(^{93}Nb) (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
1679.59	7/2$^+$	364.1‡ *2*	60‡ *3*	1315.59	5/2$^+$	D+Q‡	−0.17‡ *9*	
		382.4‡ *2*	16‡ *3*	1297.28	9/2$^+$	&		
		870.1‡ *2*	7‡ *3*	808.94	5/2$^+$	&		
		935.7‡ *2*	100‡ *3*	744.01	7/2$^+$	D(+Q)‡	+0.09‡ *9*	
		1679.7‡ *2*	36‡ *3*	0	9/2$^+$	&		
1683.40	9/2$^+$	600.7‡ *2*	17‡ *4*	1082.72	9/2$^+$	&		
		704.2‡ *2*	42‡ *4*	979.01	11/2$^+$	D+Q‡	+0.21‡ *4*	
		939.3‡ *2*	100‡ *4*	744.01	7/2$^+$	D+Q‡	−0.20‡ *4*	
		1683.2‡ *2*	54‡ *4*	0	9/2$^+$	D+Q‡	−0.34‡ *25*	
1686.38	13/2$^+$	707.4‡ *2*	88‡ *4*	979.01	11/2$^+$	D+Q‡	−0.09‡ *3*	
		736.5‡ *2*	90‡ *4*	949.80	13/2$^+$	D+Q‡	−0.27‡ *13*	
		1686.3‡ *2*	100‡ *4*	0	9/2$^+$	@		
1703.62	3/2$^+$	387.9 *2*	100 *4*	1315.59	5/2$^+$	D(+Q)	−0.02 *6*	
		894.8 *2*	87 *4*	808.94	5/2$^+$	D+Q	−0.3 *1*	
1773.05	(1/2$^+$)	646.0‡ *2*	86‡ *4*	1127.14	7/2$^+$			Mult.: D,E2 from RUL and adopted level $T_{1/2}$. however, 2010Or01 indicate E2 multipolarity and propose an inconsistent (1/2$^+$) to 7/2$^+$ placement. if placement is correct, the authors′ J^π assignment for the 1773 or 1127 level must Be incorrect.
		964.0‡ *2*	100‡ *4*	808.94	5/2$^+$	@		
1779.36	5/2$^-$	969.0† *2*	100† *5*	810.42	5/2$^-$	D(+Q)†	+0.04† *6*	
		1092.4† *2*	8† *5*	686.90	3/2$^-$	D(+Q)†	+0.05† *9*	
1812.2	(19/2$^+$)	477.3‡ *2*	100‡	1334.95	17/2$^+$			
1840.16	3/2$^-$	1029.6 *2*	20 *4*	810.42	5/2$^-$	D+Q		δ: +0.32 *6* or +0.17 *8* (2006Or09). uncertainty In Eγ is from 2010Or01. all other data are taken from 2006Or09; these supersede data from 2005Mc13 for which an analysis error resulted In different branching (49 *4*) and δ (−0.23 *7*) values.
		1153.4 *2*	100 *4*	686.90	3/2$^-$	D+Q		δ: +0.14 *4* or +0.26 *6* (2006Or09). uncertainty In Eγ is from 2010Or01. all other data are taken from 2006Or09; these supersede data from 2005Mc13 for which an analysis error resulted In a different δ value (−0.13 *6*).
1910.71	11/2$^+$	613.4 *1*	10 *3*	1297.28	9/2$^+$	D+Q	−0.20 *12*	E_γ,I_γ: uncertainty is a factor of two larger In 2010Or01.
		828.1 *1*	7 *3*	1082.72	9/2$^+$	D+Q	−0.61 *17*	E_γ,I_γ: uncertainty is a factor of two larger In 2010Or01.
		1910.6 *1*	100 *3*	0	9/2$^+$	&		E_γ,I_γ: uncertainty is a factor of two larger In 2010Or01.
1915.98	7/2$^+$	600.4‡ *2*	36‡ *4*	1315.59	5/2$^+$	D+Q‡	+0.06‡ *4*	
		833.4‡ *2*	100‡ *4*	1082.72	9/2$^+$	D(+Q)‡	−0.01‡ *2*	
		1107.2‡ *2*	4‡ *4*	808.94	5/2$^+$	&		
		1172.1‡ *2*	12‡ *4*	744.01	7/2$^+$	&		
		1915.5‡ *2*	5‡ *4*	0	9/2$^+$	&		
1947.82	7/2$^{(-)}$	1137.4† *2*	100†	810.42	5/2$^-$	D(+Q)†	+0.05† *4*	

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^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 (continued)

$\gamma(^{93}Nb)$ (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
1949.80	$7/2^+$	270.1‡ *2*	100‡ *5*	1679.59	$7/2^+$	#		
		866.8‡ *2*	9‡ *5*	1082.72	$9/2^+$	#		
		971.1‡ *2*	<2‡	979.01	$11/2^+$	@		
		1140.8‡ *2*	100‡ *5*	808.94	$5/2^+$	D+Q‡	+0.21‡ *5*	
		1205.9‡ *2*	92‡ *5*	744.01	$7/2^+$	#		
1949.84	$(7/2^+)$	266.4‡ *2*	26‡ *4*	1683.40	$9/2^+$	&		
		346.4‡ *2*	41‡ *4*	1603.48	$11/2^+$	@		
		1949.8‡ *2*	82‡ *4*	0	$9/2^+$	&		
1968.39	$(11/2^+,13/2^+)$	365.0‡ *2*	45‡ *3*	1603.48	$11/2^+$	&		
		477.3‡ *2*	100‡ *3*	1490.99	$15/2^+$	&		
1968.91	$11/2^+$	282.5 *1*	27 *5*	1686.38	$13/2^+$	&		
		285.4 *1*	34 *5*	1683.40	$9/2^+$	&		E_γ: 285.6 *2* from 2010Or01.
		990.0 *1*	64 *5*	979.01	$11/2^+$	D+Q	−0.83 *16*	
		1019.0 *1*	38 *5*	949.80	$13/2^+$	D+Q	−0.28 *7*	
		1225.0 *1*	12 *5*	744.01	$7/2^+$	@		
		1968.9 *1*	100 *5*	0	$9/2^+$	&		
1997.22	$5/2^-$	1186.9† *2*	100† *5*	810.42	$5/2^-$	D+Q†	−0.31† *11*	
		1310.2† *2*	12† *5*	686.90	$3/2^-$	D+Q†	−0.29† *12*	
2002.56	$11/2^+$	399.1‡ *2*	20‡ *2*	1603.48	$11/2^+$	&		
		502.4‡ *2*	12‡ *2*	1500.00	$9/2^-$			Mult.: authors′ attribution of E2 multipolarity to this γ appears to Be erroneous; they place it connecting $11/2^+$ and $9/2^-$ levels.
		511.5‡ *2*	<2‡	1490.99	$15/2^+$	@		
		1023.7‡ *2*	10‡ *2*	979.01	$11/2^+$	#		
		1052.8‡ *2*	100‡ *2*	949.80	$13/2^+$	D+Q‡	−0.63‡ *7*	
2012.52	$3/2^-$	440.4‡ *2*	6‡ *5*	1571.92	$3/2^-$			
		1325.8‡ *2*	100‡ *5*	686.90	$3/2^-$	D+Q	+4.5 *+15−9*	Mult.: from 2005Mc13. δ: from 2010Or01. δ=−0.14 *5* from (1326γ)(656γ)(θ) (2005Mc13); however this is presumably erroneous due to the data analysis problem reported In the authors′ erratum.
2024.02	$3/2^-$	452.1‡ *2*	3‡ *3*	1571.92	$3/2^-$	&		
		1337.1‡ *2*	100‡ *3*	686.90	$3/2^-$	D+Q‡	−4.7‡ *+8−13*	
2099.34	$7/2^{(-)}$	703.8‡ *2*	100‡ *7*	1395.56	$7/2^-$			
		1288.9‡ *2*	46‡ *7*	810.42	$5/2^-$	D(+Q)‡	−0.05‡ *5*	
2122.72	$9/2^+$	639.0 *1*	36 *3*	1483.63	$7/2^+$	&		
		1143.7 *1*	71 *3*	979.01	$11/2^+$	D+Q	+3.8 *+19−10*	
		1378.9 *1*	29 *3*	744.01	$7/2^+$	D+Q	−0.19 *8*	δ: −1.9 *8* reported by 2010Or01 is inconsistent with authors′ stated B(E2)(W.u.); evaluator presumes it to Be a typographical error and adopts the value (=−0.19 *8*) given by 2007Or01.
		2122.6 *1*	100 *3*	0	$9/2^+$	&		

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^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 (continued)

$\gamma(^{93}Nb)$ (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	Comments
2126.98		626.9‡ *2*	100‡ *4*	1500.00	9/2$^-$		
		731.3‡ *2*	18‡ *4*	1395.56	7/2$^-$		
		1316.61‡ *20*	10‡ *4*	810.42	5/2$^-$		
		1383.1‡ *2*	13‡ *4*	744.01	7/2$^+$		
2153.7		2122.8‡ *2*	100‡	30.89	1/2$^-$		
2162.67	(13/2$^+$)	671.7‡ *2*	25‡ *4*	1490.99	15/2$^+$	&	
		1183.7‡ *2*	100‡ *4*	979.01	11/2$^+$	&	
		1212.8‡ *2*	61‡ *4*	949.80	13/2$^+$	&	
2170.69	9/2$^+$	1087.6‡ *2*	10‡ *3*	1082.72	9/2$^+$	&	
		1192.5‡ *2*	100‡ *3*	979.01	11/2$^+$	&	E_γ: 4σ high cf. least-squares prediction.
		1221.6‡ *2*	60‡ *3*	949.80	13/2$^+$	@	E_γ: 3σ high cf. least-squares prediction.
		1361.1‡ *2*	31‡ *3*	808.94	5/2$^+$	@	E_γ: 3σ low cf. least-squares prediction.
		1426.1‡ *2*	27‡ *3*	744.01	7/2$^+$	&	E_γ: 2σ low cf. least-squares prediction.
2184.1	(19/2$^+$)	849.1‡ *2*	100‡ *2*	1334.95	17/2$^+$	&	
2506.93	9/2$^+$	1527.9 *1*		979.01	11/2$^+$		
		2506.9 *1*		0	9/2$^+$		

† From 2006Or09. Multipolarity and δ are based on authors' $\gamma\gamma(\theta)$ data. uncertainty In Eγ unstated by 2006Or09, so value has been taken from 2010Or01.

‡ From $\gamma\gamma(\theta)$ (2010Or01).

2010Or01 designate multipolarity As M1/E2 but it is unclear whether this was measured or assumed.

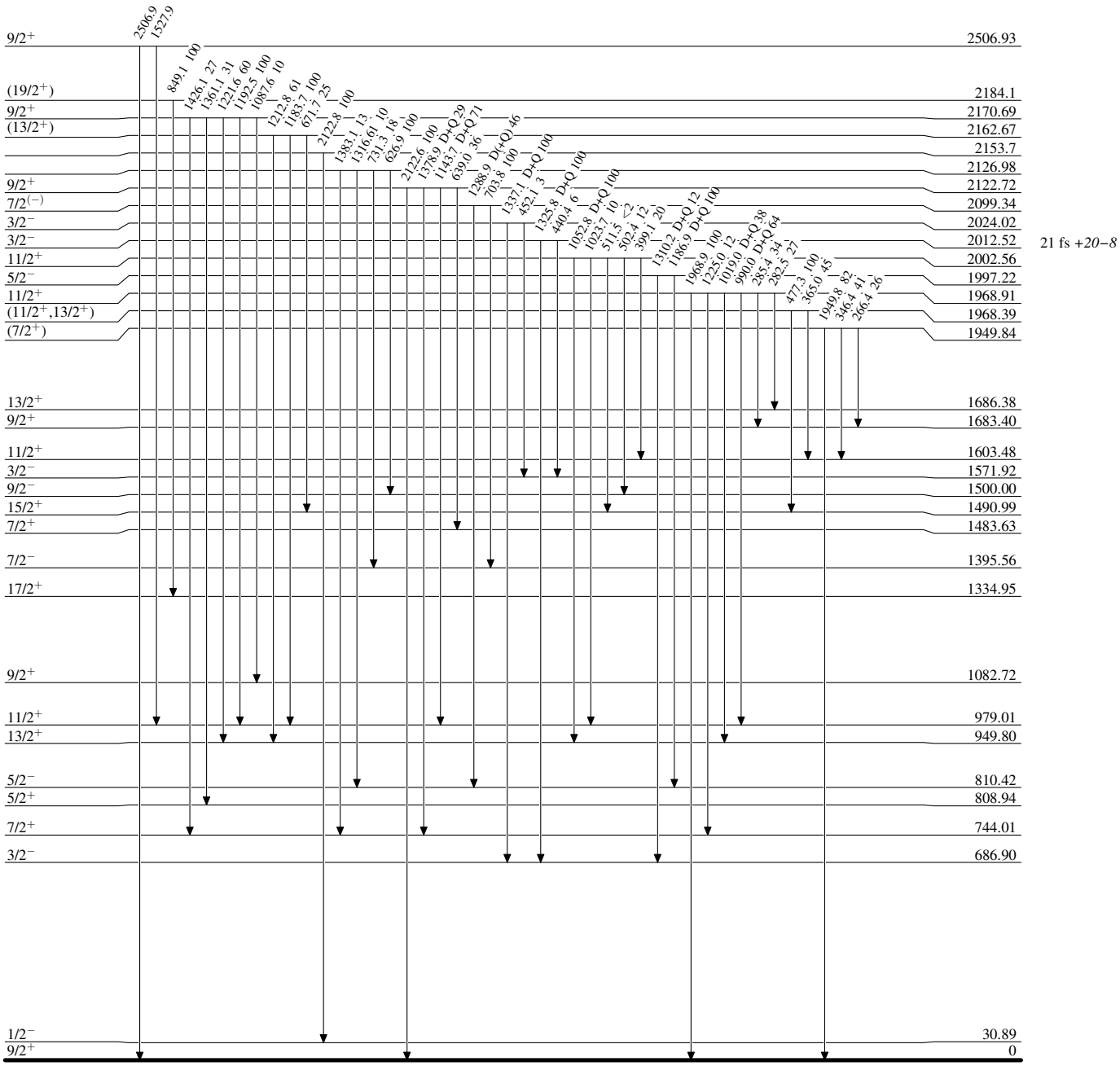
@ 2010Or01 indicate E2 multipolarity for this transition, but it is unclear whether this is based on $\gamma\gamma(\theta)$ measurements or assumed. In some instances this assignment is shown for transitions with quite weak branching, so the evaluator presumes that $\gamma\gamma(\theta)$ did not establish pure Q character for this transition In this experiment.

& 2010Or01 designate transition As (M1/E2) or (M1) but, because details of the $\gamma\gamma(\theta)$ data are not given, it is unclear whether multipolarity was measured or merely assumed. since many transitions with this designation are relatively weak, the compiler presumes the the latter to Be the case.

^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09

Level Scheme

Intensities: Relative photon branching from each level

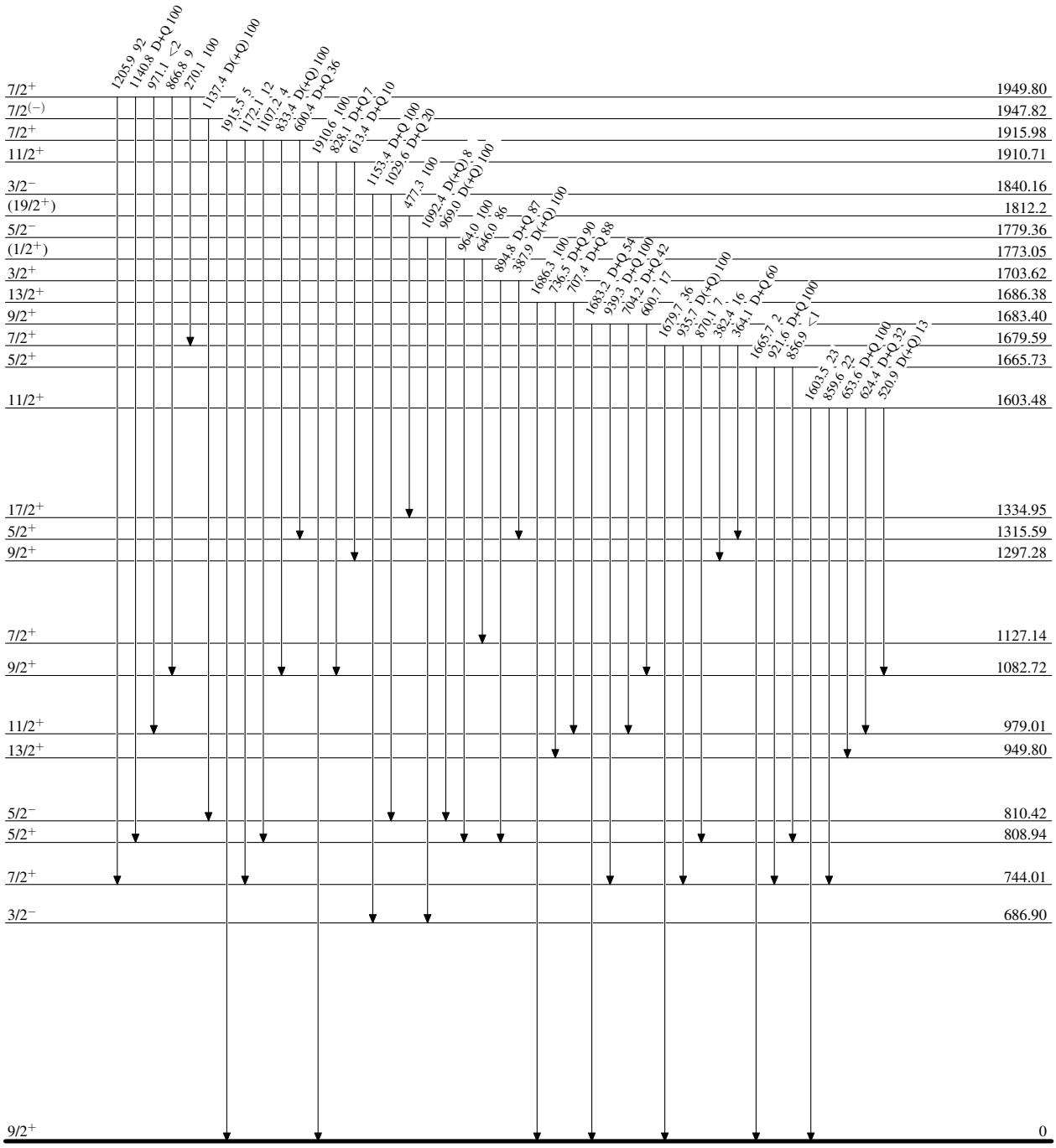


$^{93}_{41}Nb_{52}$

^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09

Level Scheme (continued)

Intensities: Relative photon branching from each level



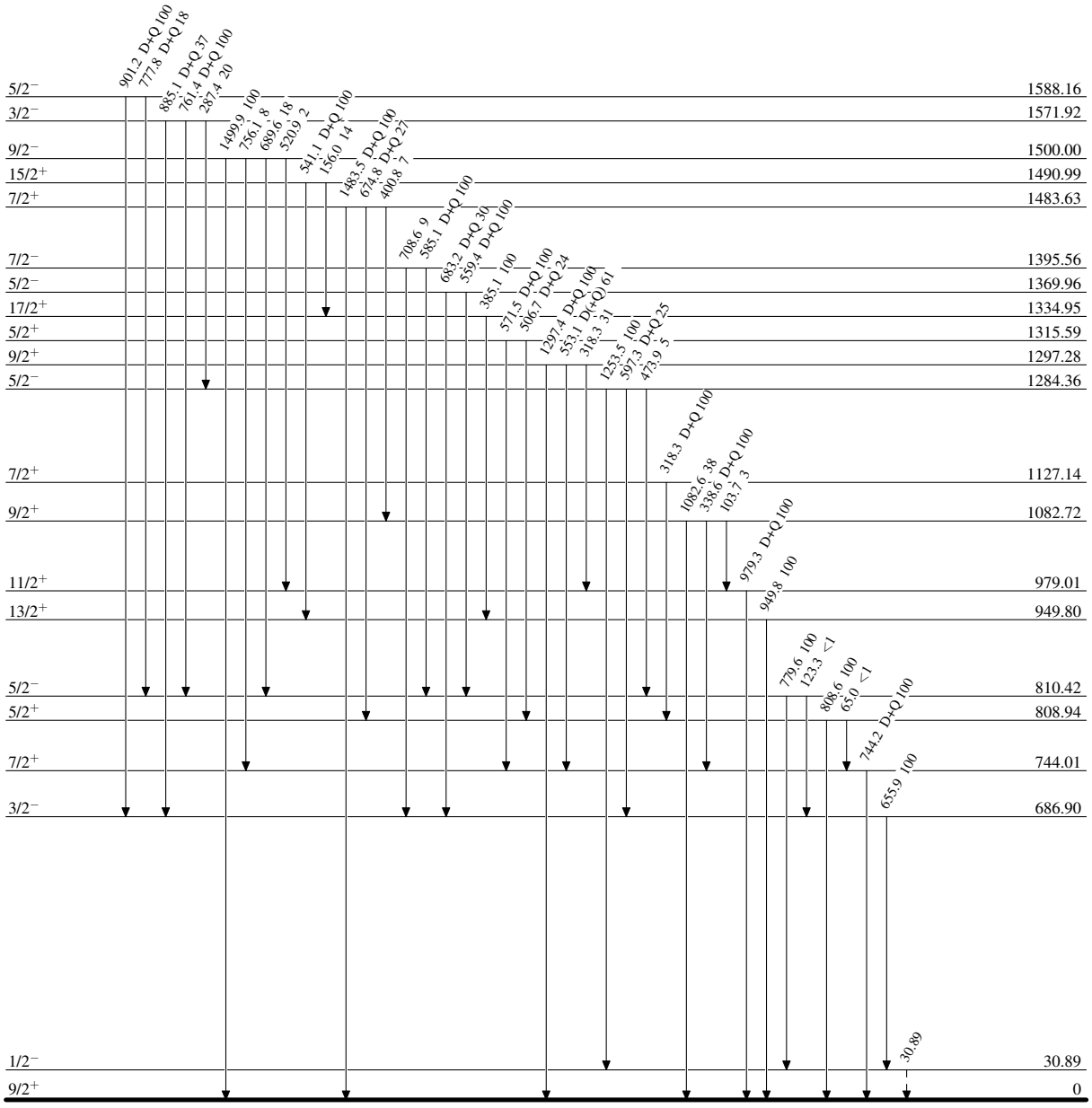
$^{93}_{41}Nb_{52}$

^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09 Legend

Level Scheme (continued)

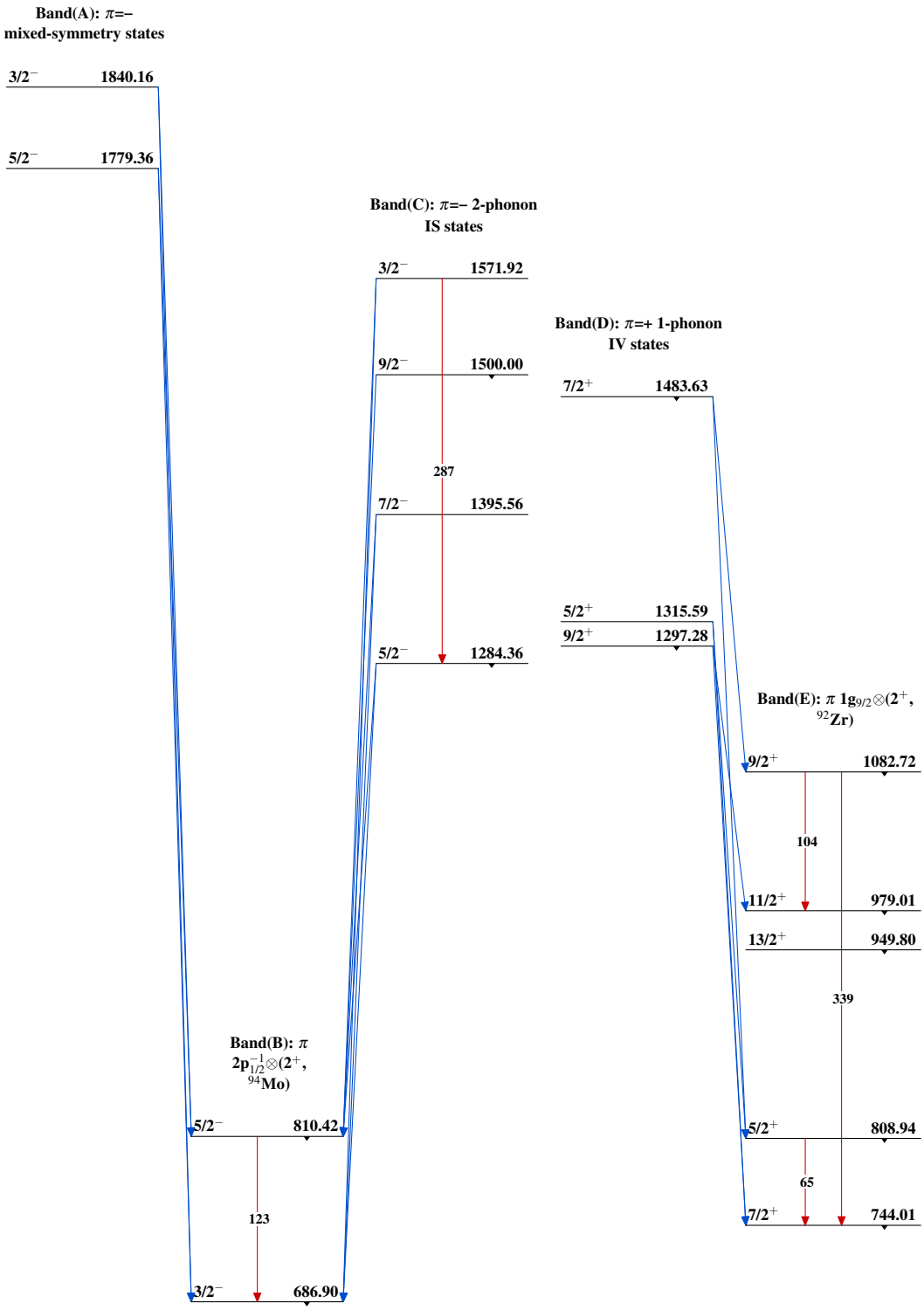
Intensities: Relative photon branching from each level

– – – – – – ► γ Decay (Uncertain)



$^{93}_{41}Nb_{52}$

^{94}Zr(p,2nγ) 2010Or01,2007Or01,2006Or09



$^{93}_{41}Nb_{52}$