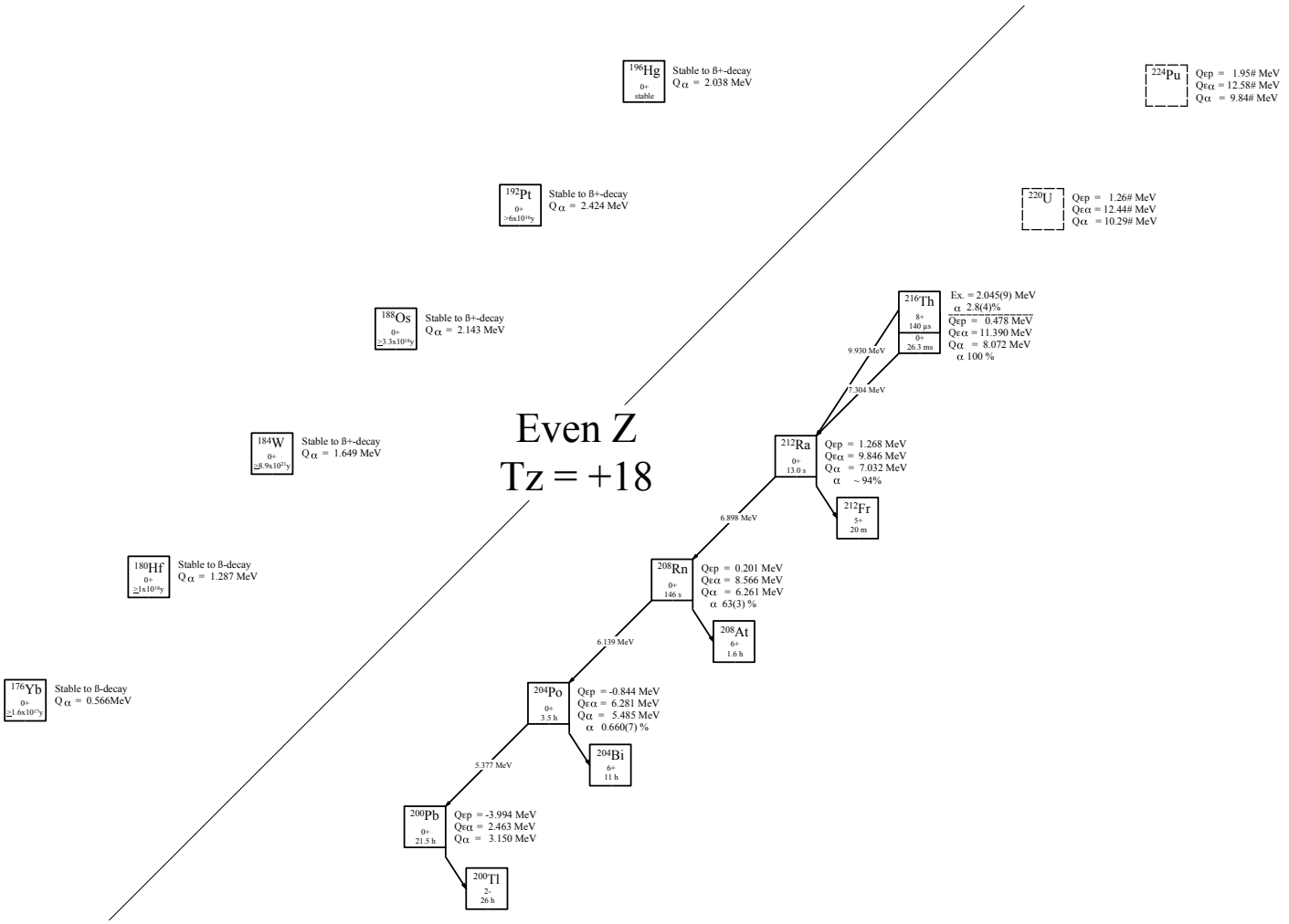

Fig. 1: Known experimental values for heavy particle emission of the even-Z T_z= +18 nuclei.

Last updated 12/14/2023

Table 1
Observed and predicted β-delayed particle emission from the even-Z, T_z = +18 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	J^π	$T_{1/2}$	Q_ε	$Q_{\varepsilon p}$	$Q_{\varepsilon\alpha}$	Experimental
^{176}Yb		0^+	$\geq 1.6 \times 10^{17}$ y	-4.12(10)	——	——	[**1996De60**]
^{180}Hf		0^+	$\geq 1 \times 10^{18}$ y	-3.100(70)	——	——	[**2020Da04**]
^{184}W		0^+	$\geq 8.9 \times 10^{21}$ y	-2.866(26)	——	——	[**2004Co26**]
^{188}Os		0^+	$\geq 3.3 \times 10^{18}$ y	-2.120	——	——	[**2020Be23**]
^{192}Pt		0^+	$>6 \times 10^{16}$ y	-1.453(2)	——	——	[**2011Be08**]
^{196}Hg		0^+	stable	-0.697(3)	——	——	
^{200}Pb		0^+	21.5(4) h	0.796(12)	-3.994(10)	2.463(10)	[**1955Be12**]
^{204}Po		0^+	3.52(1) h*	2.305(14)	-0.844(12)	6.281(12)	[**1970Ra14, 1965AnZZ, 1961La02**]
^{208}Rn		0^+	1461(8) s	2.815(14)	0.201(12)	8.566(14)	[**1971Ho01**]
^{212}Ra		0^+	13.0(2) s	3.317(13)	1.268(12)	9.846(14)	[**1974Ho27**]
^{216}Th		0^+	26.3(2) ms**	2.149(14)	0.478(13)	11.390(14)	[**2019Zh45, 2005Ku31, 2000He17**]
^{216m}Th	2.045(9)	8^+	140(5) μs***	4.194(17)	2.523(16)	13.435(17)	[**2019Zh45, 2005Ku31, 2000He17**]
^{220}U				2.74(10)#	1.26(12)#	12.44(10)#	
^{224}Pu				3.25(30)#	1.946(31)#	12.58(30)#	

* Weighted average of 3.57(2) h [1970Ra14], 3.50(1) h [1965AnZZ] and 3.53(3) h [1961La02].
** Weighted average of 26.3(5) ms [2019Zh45], 26.0(2) ms [2005Ku31] and 27.0(3) ms [2000He17].
*** Weighted average of 135(4) μs [2005Ku31] and 140(5) μs [2000He17].

Table 2
Particle separation, Q-values, and measured values for direct particle emission of the even-Z, T_z = +18 nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S_p	S_{2p}	Q_α	BR_α	Experimental
^{176}Yb	8.470(50)	16.12(30)#	0.566(4)		
^{180}Hf	8.009(5)	14.680(7)	1.287(1)		
^{184}W	7.701(2)	14.234(6)	1.649(2)		
^{188}Os	7.210(0)	13.207(1)	2.143(1)		
^{192}Pt	6.869(2)	12.159(2)	2.424(3)		
^{196}Hg	6.548(3)	11.644(3)	2.038(4)		
^{200}Pb	5.480(30)	9.874(10)	3.150(10)		
^{204}Po	4.105(16)	6.978(11)	5.485(1)	0.660(7)%	[**1970Ra14, 1970DaZM, 1967Ti04, 1965AnZZ**, 1971Go35, 1970Jo26, 1969Go23, 1967Le08, 1967Le21, 1967Ti04, 1963Be28, 1961Fo05, 1961La02, 1955Mo68, 1954Ro39, 1951Ka03, 1951Ka37]
^{208}Rn	3.717(16)	6.045(11)	6.261(2)	63(3)%*	[**1971Go35, 1971Ho01**, 1993Wa04, 1957St10, 1955Mo68, 1955Mo69, 1953AsZZ]
^{212}Ra	3.347(16)	5.172(11)	7.032(2)	$\approx$ 94%**	[**2003He06**, 2001HeZY, 1982Bo04, 1974Ho27, 1973BoXL, 1968Lo15, 1967Va22, 1961Gr42]
^{216}Th	3.021(17)	4.372(12)	8.072(4)	100%	[**2005Ku31, 2000He17**, 2019Zh45, 2014Ya19, 2005KuZZ, 2005Li17, 2001Ha46, 1968Va10, 1968Va18]
^{216m}Th	0.976(19)	2.327(15)	10.117(10)	2.8(4)%	[**2005Ku31**, 2019Zh45, 2005KuZZ, 2001Ha46, 2000He17, 1983Hi08]
^{220}U	2.86(12)#	3.93(10)#	10.29(10)#		
^{224}Pu	2.67(31)#	3.57(30)#	9.84(32)#		

* Weighted average of 67(3)% [1971Go35] and52(5)% [1971Ho01].
** Deduced by setting the HF of the α decay of ^{212}Ra to the ground state of ^{208}Rn equal to 1.0.

Table 3
direct α emission from ^{204}Po, $J_i^\pi = 0^+$, $T_{1/2}$ = 3.52(1) h*, BR_α = 0.660(7)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{200}Pb)	coincident γ-rays	R_0 (fm)]	HF
5.485(2)	5.377(2)***	0.660(7)%**	0^+	0.0	——	1.4625(22)	1.017(11)

* Weighted average of 3.57(2) h [1970Ra14], 3.50(1) h [1965AnZZ] and 3.53(3) h [1961La02].
** [1965AnZZ].
*** Weighted average of 5.379(3) MeV (adjusted to 5.378(3) MeV in [1991Ry01]) [1970Ra14], 5.375(5) MeV (adjusted to 5.374(5) MeV in [1991Ry01]) [1970DaZM] and 5.379(5) MeV [1967Ti04].

Table 4
direct α emission from ^{208}Rn, $J_i^\pi = 0^+$, $T_{1/2}$ = 31461(8) s*, BR_α = 63(3)%**.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{204}Po)	coincident γ-rays	R_0 (fm)]	HF
5.577(4)	5.470(4)***	$4.7(4) \times 10^{-3}$%***	$3.0(10) \times 10^{-3}$%	2^+	0.684	0.684	1.4755(52)	12.1(12)
6.259(3)	6.139(3)***	100%***	63(3)%**	0^+	0.0	——	1.4755(52)	0.97(5)

* [1971Ho01].
** Weighted average of 67(3)% [1971Go35] and 52(5)% [1971Ho01].
*** [1971Go35].

Table 5
direct α emission from ^{212}Ra*, $J_i^\pi = 0^+$, $T_{1/2}$ = 13.0(2) s**, $BR_\alpha = \approx 94\%$.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{208}Rn)	coincident γ-rays	R_0 (fm)]	HF
6.390(5)	6.269(5))	$\approx 0.05\%$	$\approx 0.047\%$	2^+	0.635	0.635	1.4718(31)	≈ 6.0
7.031(5)	6.898(5)	100%	$\approx 94\%$	0^+	0.0	——	1.4718(31)	1.0***

* All values from [2003He06] unless otherwise stated.
** [1974Ho27].
*** An even-even g.s to g.s. α decay should have a HF =1.0. Setting the BR_α = 94% gives this value. Using a BR_α = 100% results in a HF of 0.935(14).

Table 6
direct α emission from ^{216}Th, $J_i^\pi = 0^+$, $T_{1/2}$ = 26.3(2) ms*, BR_α = 100%.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{212}Ra)	coincident γ-rays	R_0 (fm)]	HF
7.442(4)	7.304(4)**	100.0(4)%	99.46(40)%***	2^+	0.6293(1)	0.6293(1)	1.4695(14)	1.73(12)
8.072(5)	7.923(5)**	0.0054(3)%	0.54(3)%***	0^+	0.0	——	1.4695(14)	1.013(9)

* Weighted average of 26.3(5) ms [2019Zh45], 26.0(2) ms [2005Ku31] and 27.0(3) ms [2000He17].
** [2005Ku31].
*** [2000He17].

Table 7
direct α emission from ^{216m}Th, Ex. = 2.045(9) MeV, $J_i^\pi = 8^+$, $T_{1/2}$ = 140(5) μs*, BR_α = 2.8(9)%**.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{212}Ra)	coincident γ-rays	R_0 (fm)]	HF
8.150(10)	7.999(10)	18(3)%	13(2)%	8^+	1.967(13)		1.4695(14)	$2.6^{+1.6}_{-0.8}$
9.488(12)	9.312(12)	18(4)%	13(3)%	2^+	0.6293(1)	0.6293(1)	1.4695(14)	$9^{+6}_{-3} \times 10^3$
10.117(10)	9.930(10)	100(5)%	74(4)%	0^+	0.0	——	1.4695(14)	$3.7^{+2.0}_{-1.0} \times 10^4$

* All values from [2005Ku31], except where noted.
** Weighted average of 135(4) μs [2005Ku31] and 140(5) μs [2000He17].

References used in the Tables

[1] **1951Ka03** D. G. Karraker, D. H. Templeton, Phys. Rev. **81**, 510 (1951). https://doi.org/10.1103/PhysRev.81.510

[2] **1951Ka37** D. G. Karraker, A. Ghiorso, D. H. Templeton, Phys. Rev. **83**, 390 (1951). https://doi.org/10.1103/PhysRev.83.390

[3] **1953AsZZ** F. Asaro, Thesis, Univ. California (1953); UCRL-2180 (1953).

[4] **1954Ro39** S. Rosenblum, H. Tyren, Compt. Rend. Acad. Sci. **239**, 1205 (1954).

[5] **1955Be12** K. E. Bergkvist, I. Bergstrom, C. J. Herrlander, S. Hultberg, H. Slatis, E. Sokolowski, A. H. Wapstra, T. Wiedling, Phil. Mag. **46**, 65 (1955). https://doi.org/10.1080/14786440108561195

[6] **1955Mo68** F. F. Momyer, Jr. , E. K. Hyde, J. Inorg. Nucl. Chem. **1**, 274 (1955). https://doi.org/10.1016/0022-1902(55)80033-4

[7] **1955Mo69** F. F. Momyer, Jr. , F. Asaro, E. K. Hyde, J. Inorg. Nucl. Chem. **1**, 267 (1955). https://doi.org/10.1016/0022-1902(55)80032-2

[8] **1957St10** A. W. Stoner, E. K. Hyde, J. Inorg. Nuclear Chem. **4**, 77 (1957). https://doi.org/10.1016/0022-1902(57)80087-6

[9] **1961Fo05** W. Forsling, T. Alvager, Ark. Fys. **19**, 353 (1961).

[10] **1961Gr42** R. D. Griffioen, R. D. Macfarlane, UCRL-10023, p. 47 (1961).

[11] **1961La02** R. M. Latimer, G. E. Gordon, T. D. Thomas, J. Inorg. Nuclear Chem. **17**, 1 (1961). https://doi.org/10.1016/0022-1902(61)80177-2

[12] **1963Be28** B. N. Belyaev, A. V. Kalyamin, A. N. Murin, Zh. Eksperim. i Teor. Fiz. **44**, 10 (1963); Soviet Phys. JETP **17**, 6 (1963).

[13] **1965AnZZ** J. -M. An, Thesis, Univ. California (1965); UCRL-16324.

[14] **1967Le08** Y. Le Beyec, M. Lefort, Nucl. Phys. A**99**, 131 (1967). https://doi.org/10.1016/0375-9474(67)90213-8

[15] **1967Le21** Y. Le Beyec, M. Lefort, Arkiv Fysik **36**, 183 (1967)

[16] **1967Ti04** E. Tielsch-Cassel, Nucl. Phys. A**100**, 425 (1967). https://doi.org/10.1016/0375-9474(67)90419-8

[17] **1967Va22** K. Valli, W. Treytl, E. K. Hyde, Phys. Rev. **161**, 1284 (1967). https://doi.org/10.1103/PhysRev.161.1284

[18] **1968Lo15** Y. V. Lobanov, V. A. Durin, Yadern. Fiz. **8**, 849 (1968); Soviet J. Nucl. Phys. **8**, 493 (1969).

[19] **1968Va10** K. Valli, E. K. Hyde, UCRL-17989, p. 17 (1968)

[20] **1968Va18** K. Valli, E. K. Hyde, Phys. Rev. **176**, 1377 (1968). https://doi.org/10.1103/PhysRev.176.1377

[21] **1969Go23** N. A. Golovkov, S. Guetkh, B. S. Dzhelepov, Y. V. Norseev, V. A. Khalkin, V. G. Chumin, Izv. Akad. Nauk SSSR, Ser. Fiz. **33**, 1622 (1969); Bull. Acad. Sci. USSR, Phys. Ser. **33**, 1489 (1970).

[22] **1970DaZM** J. M. Dairiki, Thesis, Univ. California (1970); UCRL-20412 (1970).

[23] **1970Jo26** A. G. Jones, A. H. W. Aten, Jr., Radiochim. Acta **13**, 176 (1970).

[24] **1970Ra14** K. Raichev, L. Tron, Acta Phys. **28**, 263 (1970).

[25] **1971Go35** N. A. Golovkov, R. B. Ivanov, A. Kolaczkowski, Y. V. Norseev, V. G. Chumin, Izv. Akad. Nauk SSSR, Ser. Fiz. **35**, 2272 (1971); Bull. Acad. Sci. USSR, Phys. Ser. **35**, 2063 (1972).

[26] **1971Ho01** P. Hornshoj, K. Wilsky, P. G. Hansen, A. Lindahl, O. B. Nielsen, Nucl. Phys. A**163**, 277 (1971). https://doi.org/10.1016/0375-9474(71)90536-7

[27] **1973BoXL** J. D. Bowman, E. K. Hyde, R. E. Eppley, LBL-1666, p. 4 (1973).

[28] **1974Ho27** P. Hornshoj, P. G. Hansen, B. Jonson, Nucl. Phys. A**230**, 380 (1974). https://doi.org/10.1016/0375-9474(74)90144-4

[29] **1982Bo04** J D Bowman, R E Eppley, E K Hyde, Phys Rev C**25**, 941 (1982). https://doi.org/10.1103/PhysRevC.25.941

[30] **1983Hi08** R. Hingmann, H. -G. Clerc, C. -C. Sahm, D. Vermeulen, K. -H. Schmidt, J. G. Keller, Nucl. Phys. A**404**, 51 (1983). https://doi.org/10.1016/0375-9474(83)90413-X

[31] **1993Wa04** J. Wauters, P. Dendooven, M. Huyse, G. Reusen, P. Van Duppen, P. Lievens, and the ISOLDE Collaboration, Phys. Rev. C**47**, 1447 (1993). https://doi.org/10.1103/PhysRevC.47.1447

[32] **1996De60** A. V. Derbin, A. I. Egorov, V. N. Muratova, S. V. Baklanov, Yad. Fiz. **59**, No 12, 2117 (1996); Phys. Atomic Nuclei **59**, 2037 (1996).

[33] **2000He17** F. P. Hessberger, S. Hofmann, D. Ackermann, V. Ninov, M. Leino, S. Saro, A. Andreyev, A. Lavrentev, A. G. Popeko, A. V. Yeremin, Eur. Phys. J. A **8**, 521 (2000); Erratum Eur. Phys. J. A **9**, 433 (2000). https://doi.org/10.1007/s100500070075

[34] **2001Ha46** K. Hauschild, M. Rejmund, H. Grawe, E. Caurier, F. Nowacki, F. Becker, Y. Le Coz, W. Korten, J. Doring, M. Gorska, K. Schmidt, O. Dorvaux, K. Helariutta, P. Jones, R. Julin, S. Juutinen, H. Kettunen, M. Leino,

M. Muikku, P. Nieminen, P. Rahkila, J. Uusitalo, F. Azaiez, M. Belleguic, Phys. Rev. Lett. **87**, 072501 (2001). https://doi.org/10.1103/PhysRevLett.87.072501

[35] **2001HeZY** F. P. Hessberger, S. Hofmann, D. Ackermann, GSI 2001-1, p. 18 (2001).

[36] **2003He06** F. P. Hessberger, S. Hofmann, D. Ackermann, Eur. Phys. J. A **16**, 365 (2003). https://doi.org/10.1140/epja/i2002-10111-0

[37] **2004Co26** C. Cozzini, G. Angloher, C. Bucci, F. von Feilitzsch, D. Hauff, S. Henry, Th. Jagemann, J. Jochum, H. Kraus, B. Majorovits, V. Mikhailik, J. Ninkovic, F. Petricca, W. Potzel, F. Probst, Y. Ramachers, W. Rau, M. Razeti, W. Seidel, M. Stark, L. Stodolsky, A. J. B. Tolhurst, W. Westphal, H. Wulandari, Phys. Rev. C **70**, 064606 (2004). https://doi.org/10.1103/PhysRevC.70.064606

[38] **2005Ku31** P. Kuusiniemi, F. P. Hessberger, D. Ackermann, S. Hofmann, B. Sulignano, I. Kojouharov, R. Mann, Eur. Phys. J. A **25**, 397 (2005). https://doi.org/10.1140/epja/i2005-10117-0

[39] **2005KuZZ** P. Kuusiniemi, Proc. Nuclei at the Limits, Argonne, Illinois, D. Seweryniak and T. L. Khoo, eds. , p. 231 (2005); AIP Conf. Proc 764 (2005). https://doi.org/10.1063/1.1905316

[40] **2005Li17** Z. Liu, J. Kurcewicz, P. J. Woods, C. Mazzocchi, F. Attallah, E. Badura, C. N. Davids, T. Davinson, J. Doring, H. Geissel, M. Gorska, R. Grzywacz, M. Hellstrom, Z. Janas, M. Karny, A. Korgul, I. Mukha, M. Pfutzner, C. Plettner, A. Robinson, E. Roeckl, K. Rykaczewski, K. Schmidt, D. Seweryniak, H. Weick, Nucl. Instrum. Methods Phys. Res. A**543**, 591 (2005). https://doi.org/10.1016/j.nima.2004.12.023

[41] **2011Be08** P. Belli, R. Bernabei, F. Cappella, R. Cerulli, F. A. Danevich, A. Incicchitti, M. Laubenstein, S. S. Nagorny, S. Nisi, O. G. Polischuk, V. I. Tretyak, Phys. Rev. C **83**, 034603 (2011). https://doi.org/10.1103/PhysRevC.83.034603

[42] **2014Ya19** H. Yang, L. Ma, Z. Zhang, L. Yu, G. Jia, M. Huang, Z. Gan, T. Huang, G. Li, X. Wu, Y. Fang, Z. Wang, B. Gao, W. Hua, J. Phys. (London) G**41**, 105104 (2014). https://doi.org/10.1088/0954-3899/41/10/105104

[43] **2020Be23** P. Belli, R. Bernabei, F. Cappella, V. Caracciolo, R. Cerulli, F. A. Danevich, A. Incicchitti, D. V. Kasperovych, V. V. Kobychev, G. P. Kovtun, N. G. Kovtun, M. Laubenstein, D. V. Poda, O. G. Polischuk, A. P. Shcherban, S. Tessalina, V. I. Tretyak, Phys. Rev. C **102**, 024605 (2020). https://doi.org/10.1103/PhysRevC.102.024605

[44] **2020Da04** F. A. Danevich, M. Hult, D. V. Kasperovych, G. P. Kovtun, K. V. Kovtun, G. Lutter, G. Marissens, O. G. Polischuk, S. P. Stetsenko, V. I. Tretyak, Eur. Phys. J. A **56**, 5 (2020). https://doi.org/10.1140/epja/s10050-019-00005-x

[45] **2021Wa16** M. Wang, W. J. Huang, F. G. Kondev, G. Audi, S. Naimi, Chin. Phys. C **45**, 030003 (2021). https://doi.org/10.1088/1674-1137/abddaf