SH nuclei at ŚLCJ – what could be possible?

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A priori interesting:

- structure studies of very heavy and SH (largest A) nuclei: collective modes, pairing (A), shapes, single-particle configurations etc.;
- high-K ground states in odd and odd-odd nuclei and high-K isomers – characteristic of filled high-j shells;
- study of decays – alpha and fission – from g.s. and isomeric states, their competition & structural hindrances;
- reaction mechanisms (as a byproduct);
- chemistry for isotopes living for ca 10 s/longer

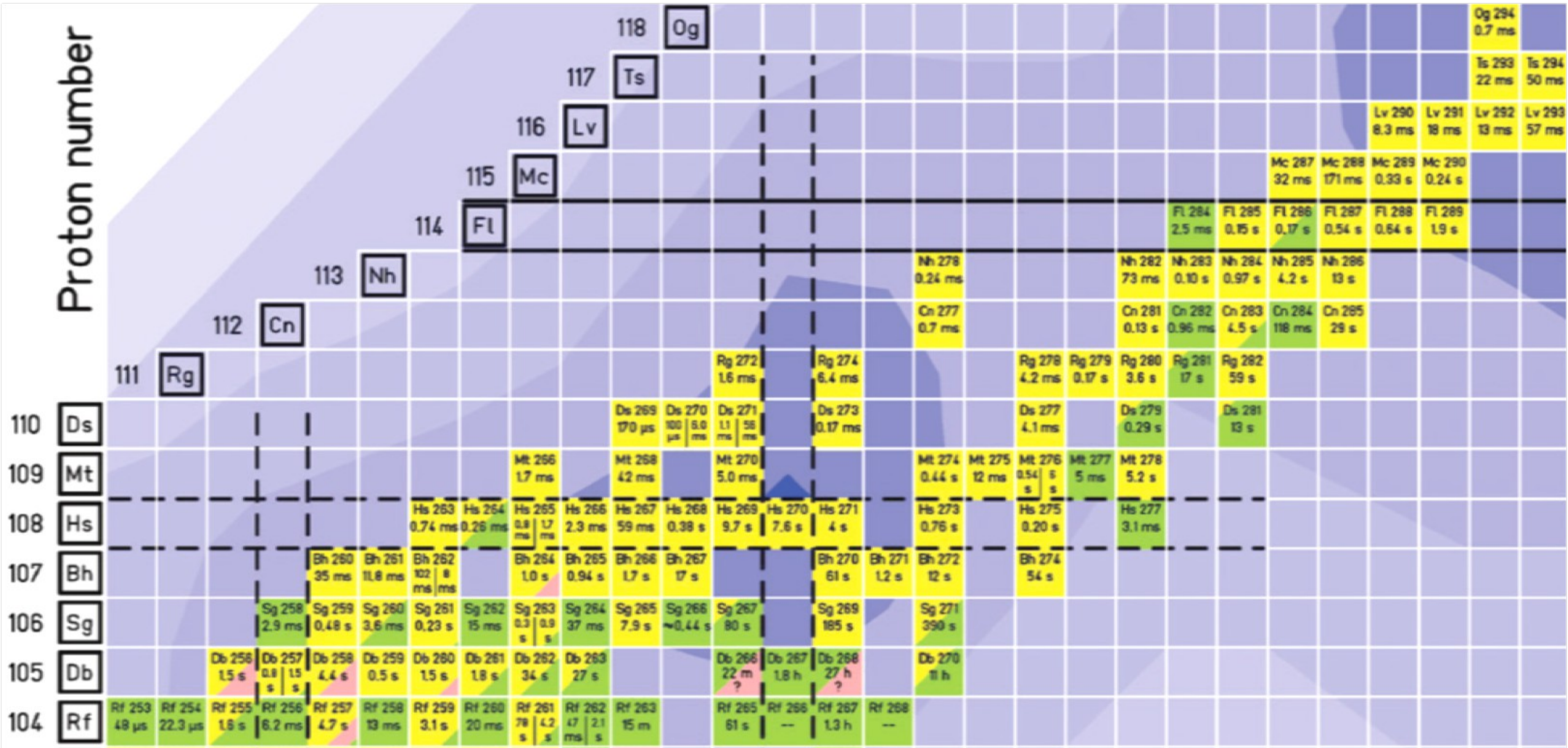
  but:

  cross sections and statistics are small, radioactive targets are difficult/dear, instrumentation requirements many ...

	Name	Symbol	Year of discovery	Most stable isotope	Half-life
101	mendelevium	Md	1955	^{258}Md	51.5 days
	nobelium	No	1958	^{259}No	58 m
	lawrencium	Lr	1961	^{266}Lr	11 h
	rutherfordium	Rf	1964-1969	^{267}Rf	1.3 h
	dubnium	Db	1967-1970	^{268}Db	30.8 h
	seaborgium	Sg	1974	^{271}Sg	2.4 m
	bohrium	Bh	1981	^{270}Bh	3.8 m
	hassium	Hs	1984	^{269}Hs	27 s
	meitnerium	Mt	1984	^{278}Mt	7.6 s
	darmstadtium	Ds	1994	^{281}Ds	9.6 s
	roentgenium	Rg	1994	^{281}Rg	26 s
	copernicium	Cn	1996	^{285}Cn	29 s
	nihonium	Nh	2003-2004	^{286}Nh	19.6 s
	flerovium	Fl	1999-2000	^{289}Fl	2.6 s
	moscovium	Mc	2003	^{289}Mc	220 ms
	livermorium	Lv	2000	^{293}Lv	53 ms
	tennessine	Ts	2010	^{294}Ts	51 ms
118	oganesson	Og	2002	^{294}Og	0.89 ms

Chemistry?

Sigurd Hofmann et al., Pure Appl. Chem. 2018; 90(11): 1773–1832



Impediments

1) Isotopes $A \geq 265$ of Rf, $A \geq 266$ of Db,..., all of Mt except ^{266}Mt, $A \geq 277$ of Ds were produced in decays of heavier nuclei.
It makes structure studies of the longest-lived isotopes difficult, an chemistry of some elements impossible.

2) Cross sections in reactions producing the lighter isotopes decrease steeply between $Z = 104$ and $Z = 110$.

$^{50}Ti + ^{208}Pb \rightarrow ^{257}Rf$ - 38 nb
$^{50}Ti + ^{208}Pb \rightarrow ^{256}Rf$ - 12 nb
$^{50}Ti + ^{206}Pb \rightarrow ^{254}Rf$ - 2.4 nb

$^{26}Mg + ^{238}U \rightarrow ^{259}Rf$ - 1.1 nb
$^{22}Ne + ^{244}Pu \rightarrow ^{261}Rf$ - 4 nb
$^{18}O + ^{248}Cm \rightarrow ^{261}Rf$ - 13 nb
++++++++++++++++++++++++
$^{50}Ti + ^{209}Bi \rightarrow ^{258}Db$ - 4.64 nb
$^{50}Ti + ^{209}Bi \rightarrow ^{257}Db$ - 2.4 nb

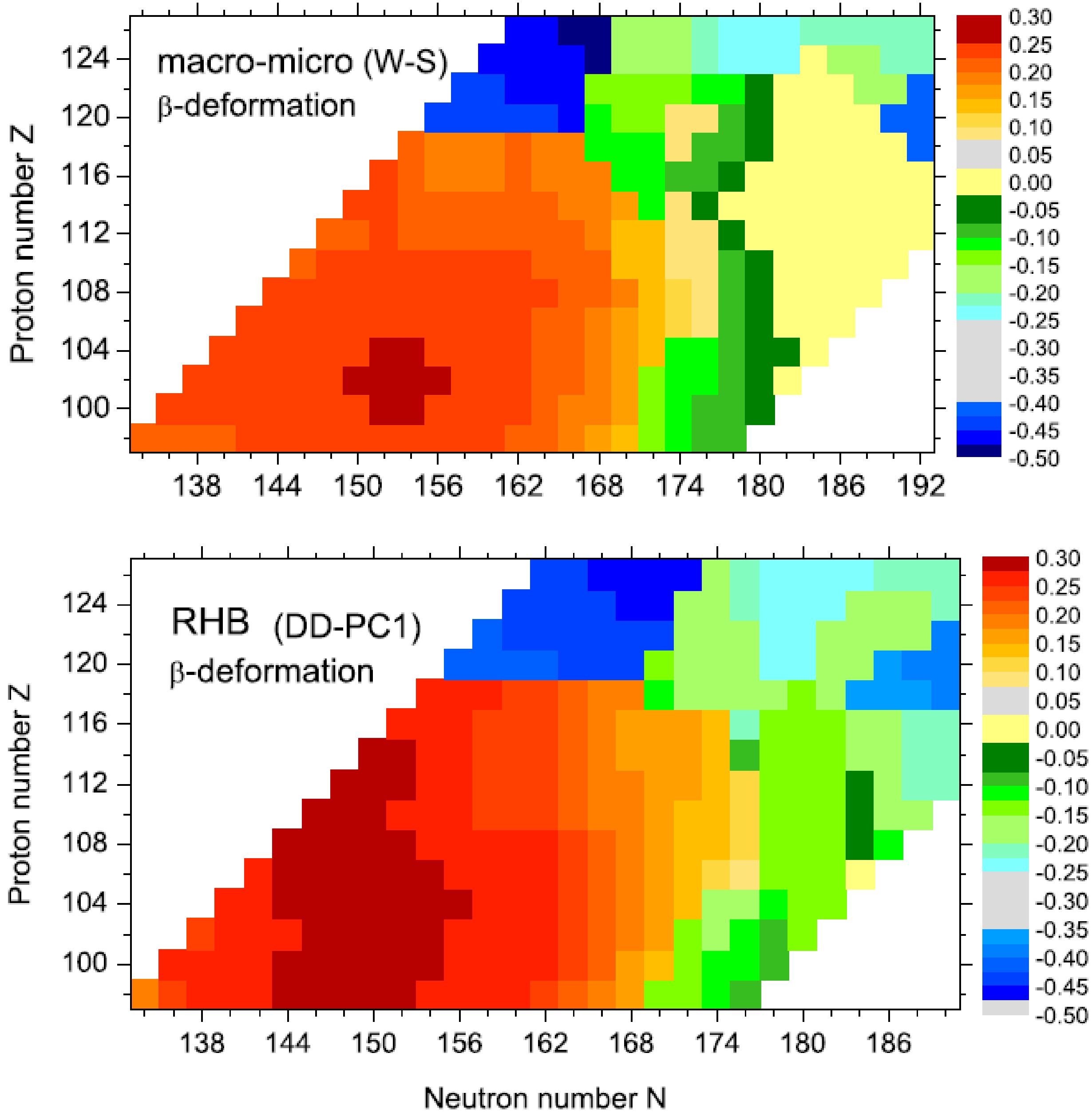
nb – could be possible

$^{22}Ne + ^{241}Am \rightarrow ^{259}Db$ - 1.6 nb
$^{19}F + ^{248}Cm \rightarrow ^{262}Db$ - 1 nb
$^{18}O + ^{249}Bk \rightarrow ^{263}Db$ - 10 nb
+++++++++++++++++++++++++
$^{58}Fe + ^{209}Bi \rightarrow ^{266}Mt$ - 7.5 pb
$^{37}Cl + ^{238}U$ - failed
+++++++++++++++++++++++++
$Ni + Pb \rightarrow ^{269,270,271}Ds$ - 3-10 pb
$^{34}S + ^{244}Pu \rightarrow Ds$ 1 atom ???
$^{48}Ca + ^{232}Th$ - failed

pb - difficult

P.-H. Heenen et al. / Nuclear Physics A 944 (2015) 415–441

Shapes - similar predictions



Fission barriers – different predictions

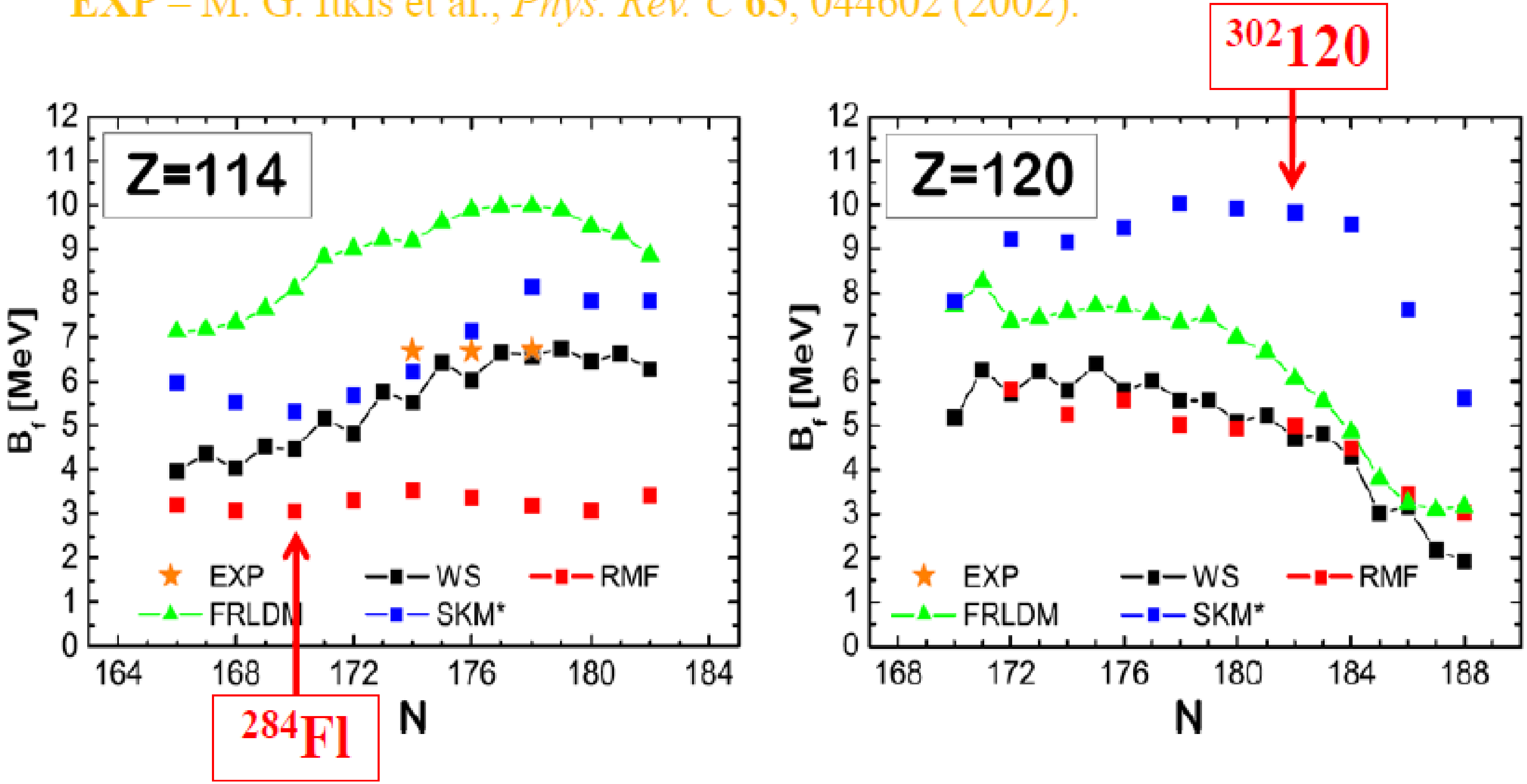
WS – our results

FRLDM – P. Möller et al., *Phys. Rev. C* **91**, 024310 (2015).

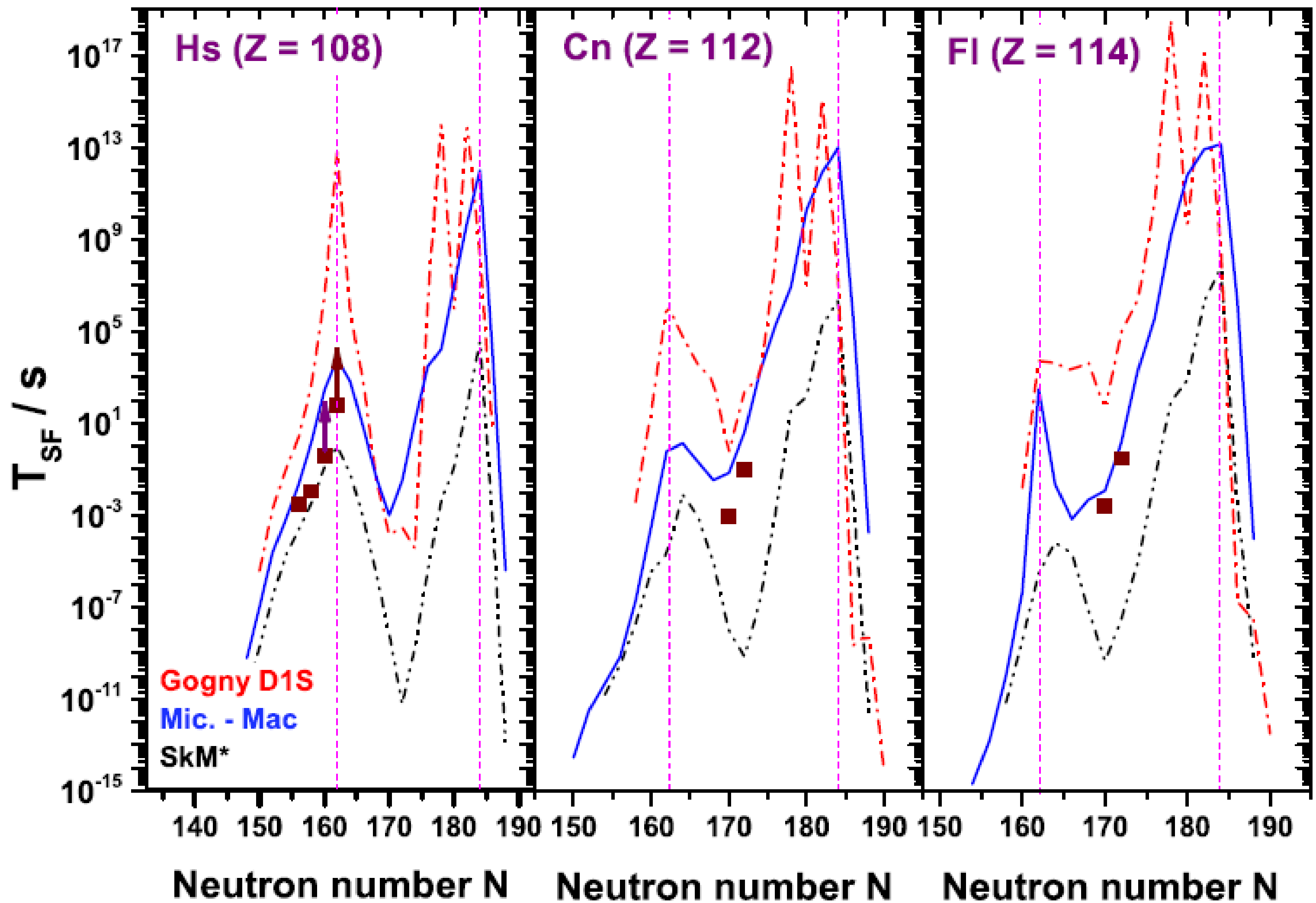
SKM* – A. Staszczak et al., *Phys. Rev. C* **87**, 024320 (2013).

RMF – H. Abusara et al. : *Phys. Rev. C* **85**, 024314 (2012); **82**, 044303 (2010).

EXP – M. G. Itkis et al., *Phys. Rev. C* **65**, 044602 (2002).



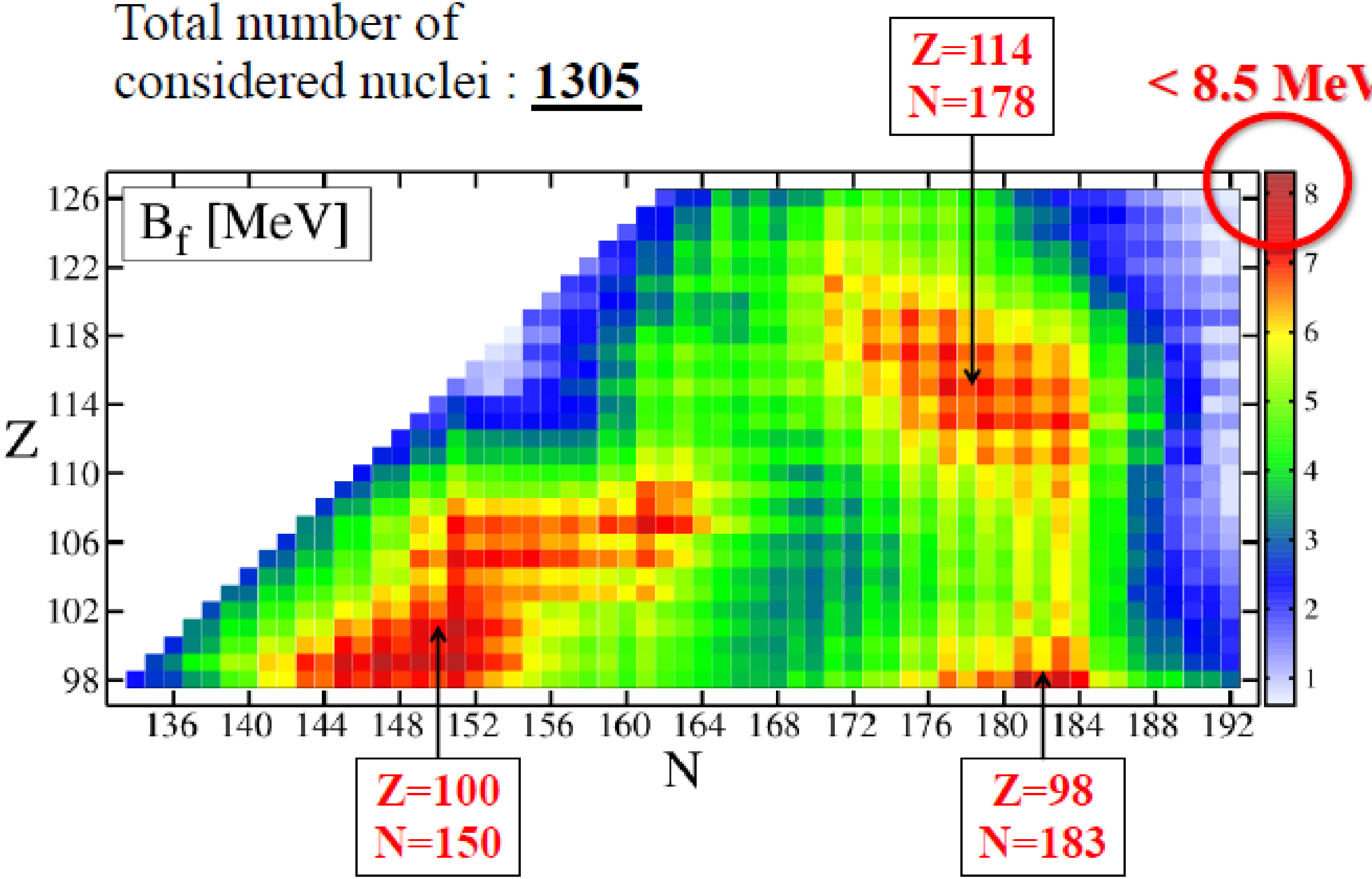
F. P. Hessberger, Eur. Phys. J. A 53 (2017) 75 Exp. vs predictions



CALCULATED FISSION BARRIER HEIGHTS

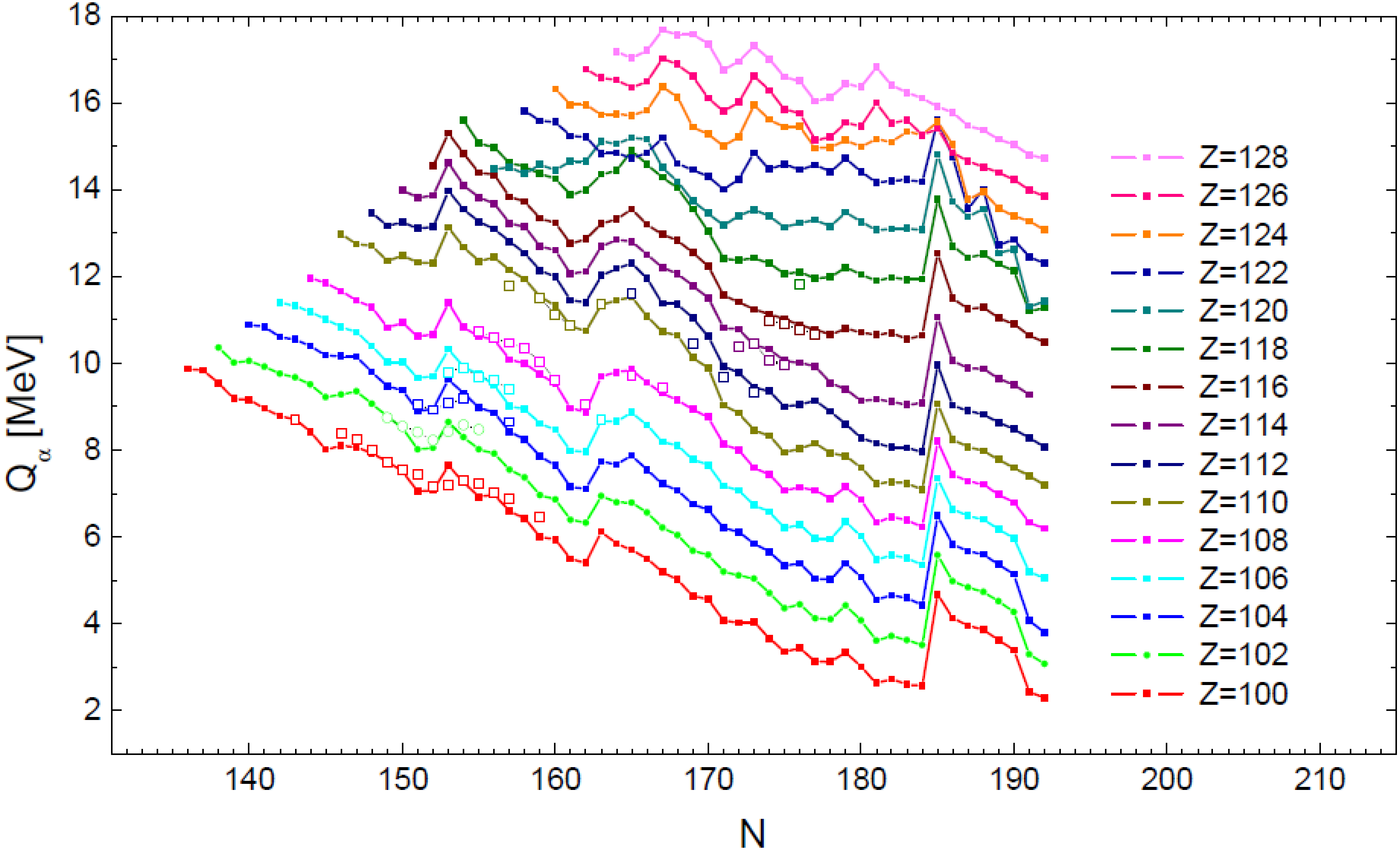
P.Jachimowicz, M.Kowal, J.Skalski PRC 95, 014303 (2017)

Total number of considered nuclei : **1305**



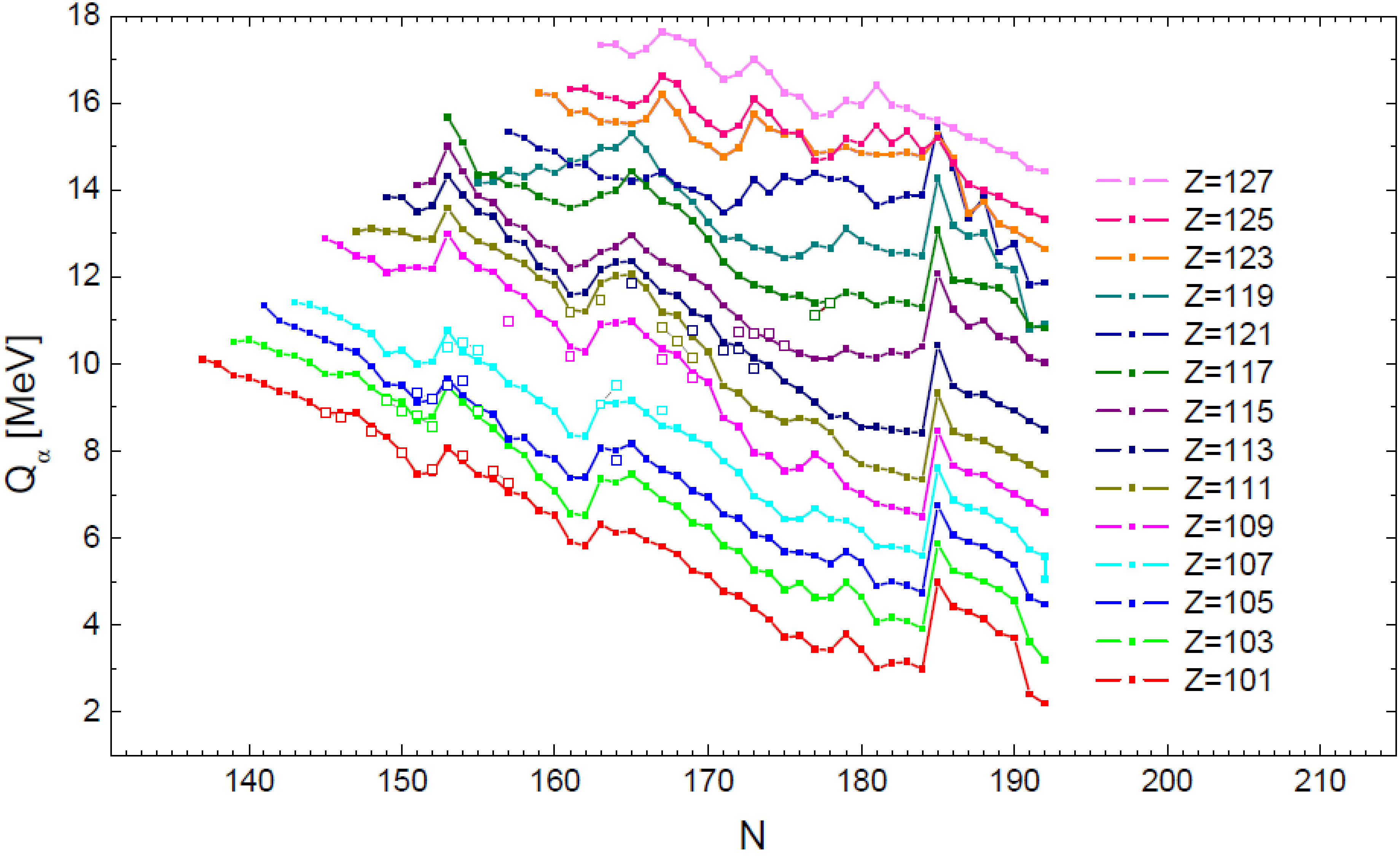
Exp. vs predictions

P.Jachimowicz, M.Kowal, J.Skalski, PRC 89 (2014) 024304



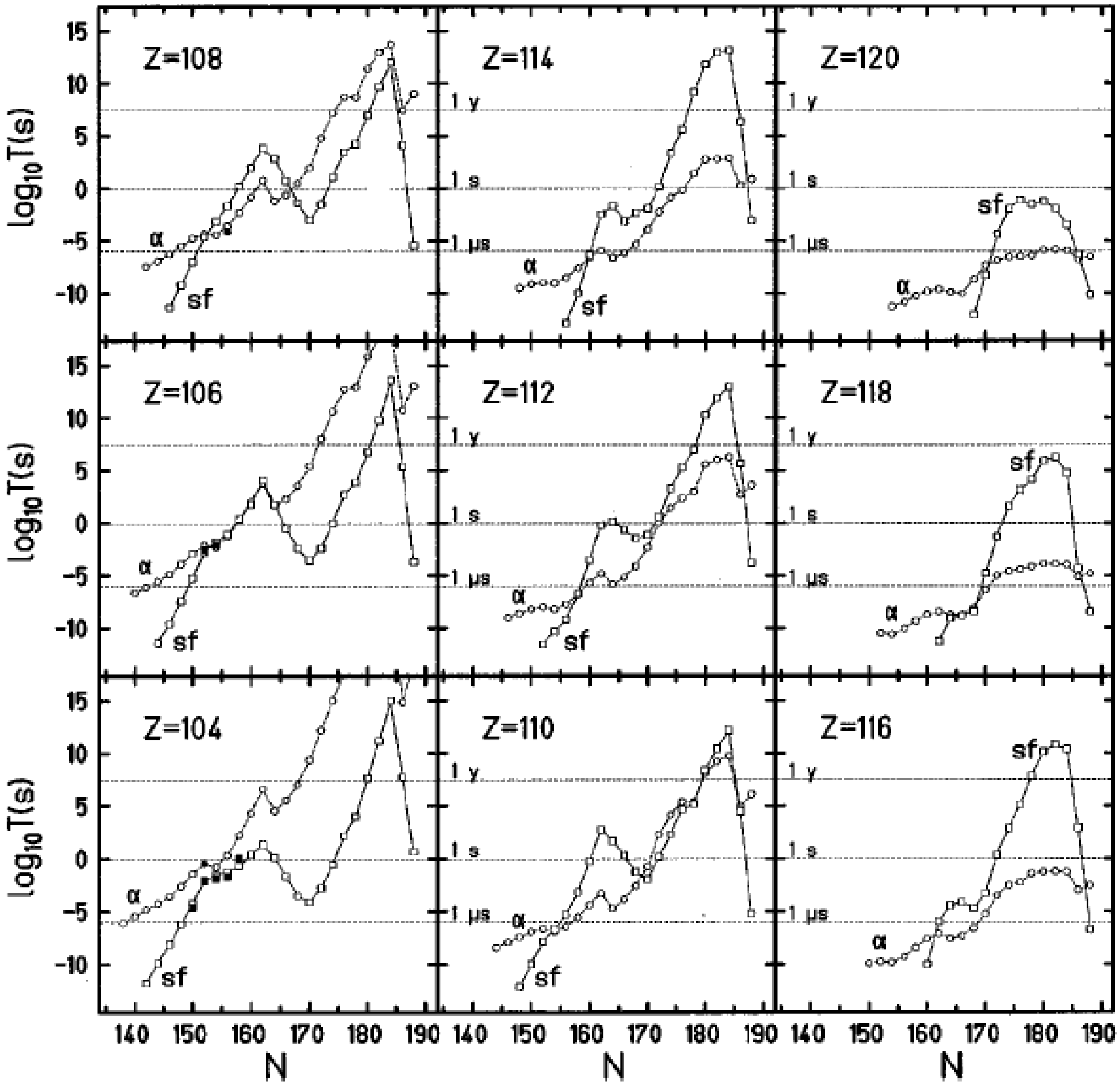
Exp. vs predictions

P.Jachimowicz, M.Kowal, J.Skalski, PRC 89 (2014) 024304



More neutrons – usually more stable, but difficult to make

ROBERT SMOLAŃCZUK ,Phys. Rev. C 56 (1997) 812



Fission vs alpha-decay

Z	N	Omega(n)	Omega(p)	K
113	173	5/2+	7/2-	6-
112	173	15/2-		15/2-
111	170		11/2+	11/2+
	169	5/2+	9/2-	7-
	163	13/2-	3/2-	8+
110	163	13/2-		13/2-
109	All		11/2+	> 11/2
	169	9/2+	„	10+
	161	„	„	„
	159	„	„	„
	163	13/2-	„	12-
108	163	„		13/2-
	157	11/2-		11/2-
107	163	13/2-	5/2-	9+
	157	11/2-	„	8+
•	163	13/2-		13/2-
	157	11/2-		11/2-
•	157	11/2-	9/2+	10-
	151	9/2-	9/2+	9-
•	157	11/2-		11/2-
•	157	11/2-	7/2-	9+
	151	9/2-	7/2-	8+
	149	7/2+	7/2-	7-
101	157	11/2-	1/2-	6+

High-K states: a chance for longer half-lives.

< Candidates for high-K g.s. in odd or odd-odd SHN in the W-S model

In even-even systems one should block high-K close-lying orbitals, like:
9/2+ and 5/2- protons below Z=108 or
11/2- and 9/2+ neutrons below N=162

Conclusions

- It should be possible to study structure of some Rf, Db, (Sg?) isotopes (even more Lr, No, Md, Fm ...), including isomerism and decay hindrances.

- Perhaps, after a long work, it could be possible to repeat syntheses of some $107 \leq Z \leq 110$ nuclides in long-runs, maybe, also looking for some signature of isomers.

-If radioactive targets could be used, one could study, perhaps, reactions leading to some neutron-rich $Z<112$, with a hope to produce some long-lived (~10 s) ones. However, this would be costly and require long runs. The same goes for any $Z>= 112$ synthesis.