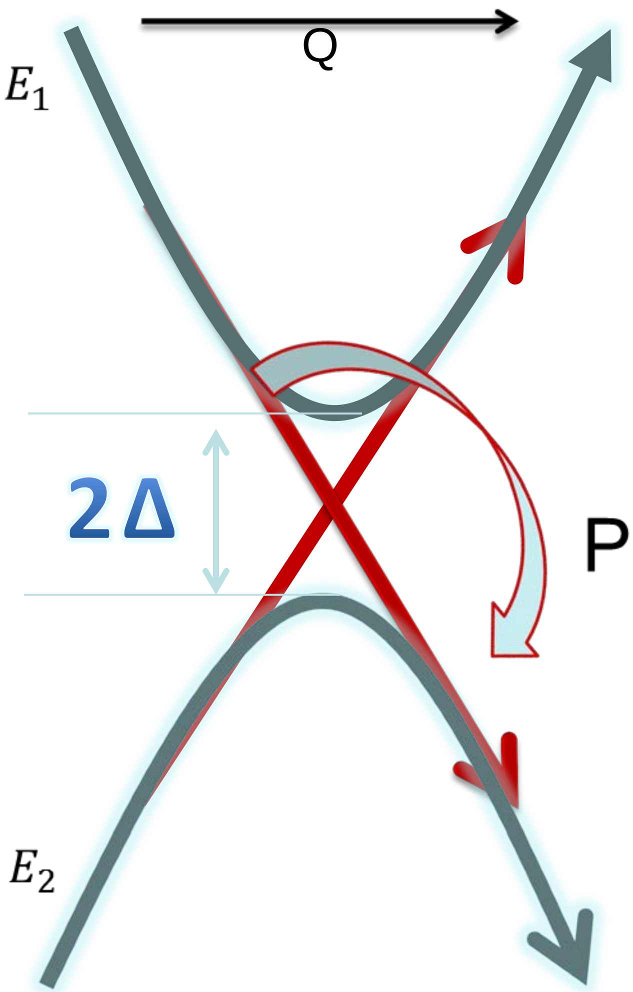
IS THE LASD ADIABATIC OR NON ADIABATIC ?

To CROSS or NOT to CROSS ?

W. Nazarewicz, Nucl. Phys ***A 557*** *(1993)*



Landau – Zener effect

$$P(\text{of jump}) \sim e^{-\frac{2\Delta^2}{\frac{\partial Q}{\partial t}\frac{\partial(|E_1 - E_2|)}{\partial Q}}}$$

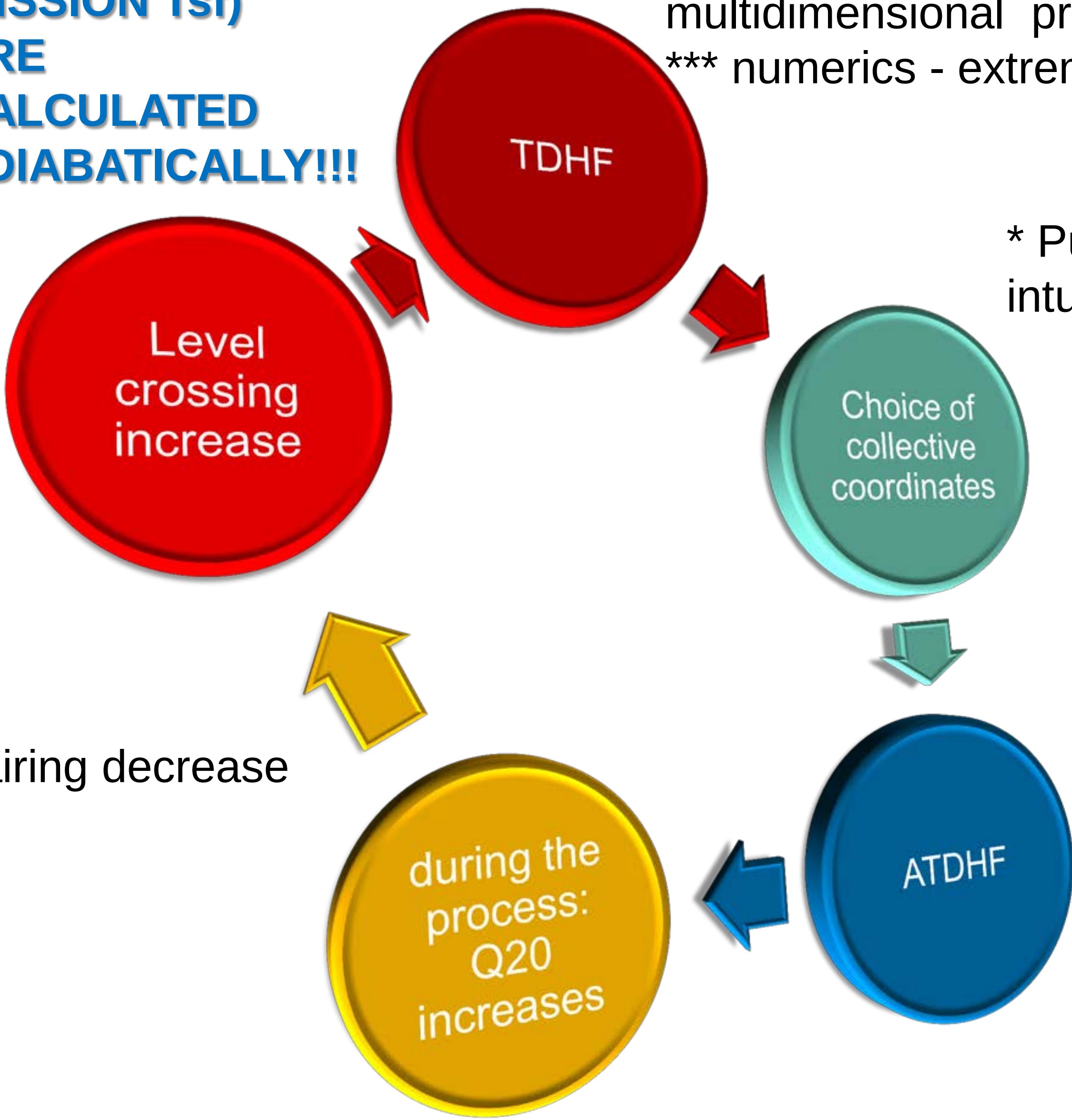
$$\Delta \sim e^{-\frac{1}{G\,\rho(\epsilon_F)}}$$

Diabatic

ADiabatic

BUT MASS PARAMETERS (FISSION Tsf) ARE CALCULATED ADIABATICALLY!!!

* How to include residual interactions?
** All symetries are broken – multidimensional projections is necesary!!!
*** numerics - extremely difficult



* Put by hand – „physical intuition ☺” e.g., Q20

controlling parameter - topological phase (Berry phase)

pairing decrease

Superheavy nuclei – predictions of structure and stability

M. Kowal, J. Skalski
National Centre for Nuclear Research (Warsaw)
P. Jachimowicz
University of Zielona Gora

1. Introduction
2. Calculation of Potential Energy surface (PES)
3. First minima - ground state properties GS (Masses, Shapes, Q-alpha energies,Vibrations)
4. First saddle points (Masses, Shapes, First Fission barriers Ba)
5. Second minima – properties of super-deformed state (SD) (Masses, Shapes SD Vibrations).
6. Second Fission barriers Bb
7. Puzzle of Third minima in actinides.
8. Superdeformed Oblate Minima in SHE
9. Cross sections predictions

Macroscopic-microscopic approach:

$$E = E_{tot}(\beta_{\lambda\mu}) - E_{MACRO}(\beta_{\lambda\mu}=0)$$

$$E_{MACRO}(\beta_{\lambda\mu}) + E_{MICRO}(\beta_{\lambda\mu})$$

- $E_{MACRO}(\beta_{\lambda\mu})$ = Yukawa + exp

Shape Parametrization:

12-DIM !

Fit to the experimental masses

- Z>82, N>126,
- Number of nuclei: 252

- Calculation for even-even, even-odd, odd-even and odd-odd systems - 1364 nuclei !

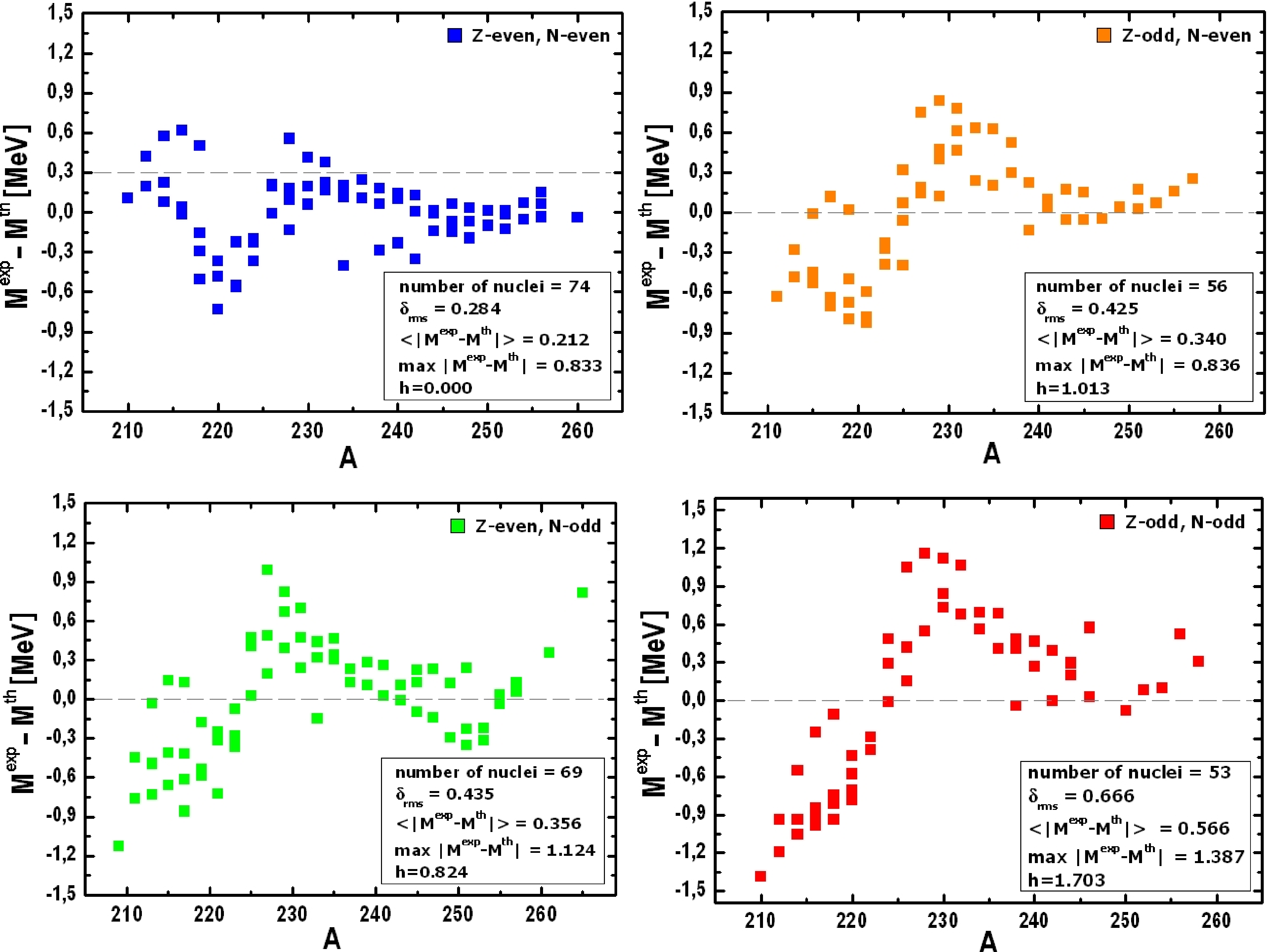
Predictions for SHE: Z=101-128,

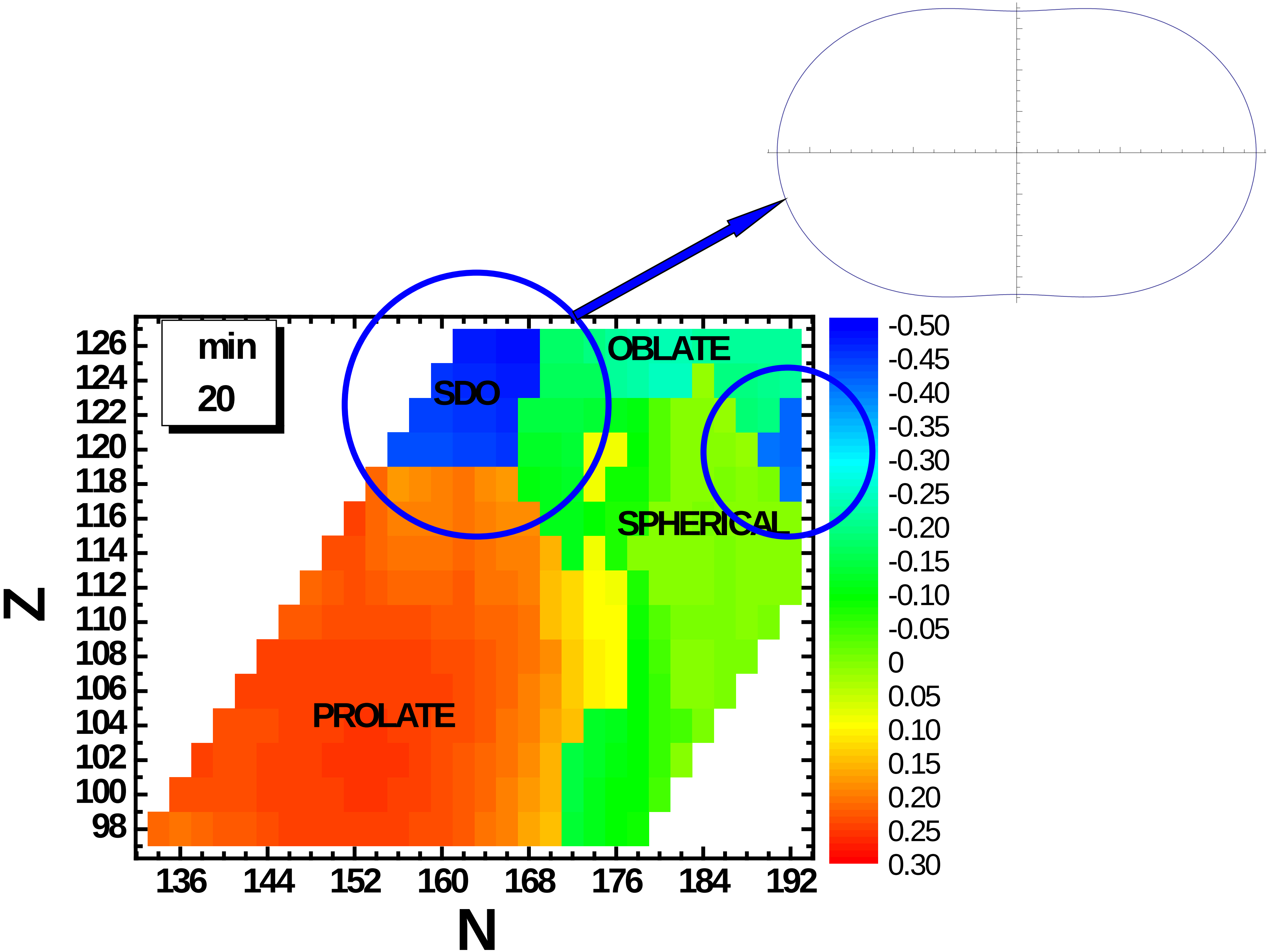
Statistical parameters of the fit to masses in the model with blocking in separate groups of even-even, odd-even, even-odd and odd-odd heavy nuclei:

	e - e	o - e	e - o	o - o
N	74	56	69	53
h	0.0	1.013	0.824	1.703
$<\mid M^{th} - M^{exp} \mid>$	0.212	0.340	0.356	0.566
$Max \mid M^{th} - M^{exp} \mid$	0.833	0.836	1.124	1.387
δ_{RMS}	0.284	0.425	0.435	0.666

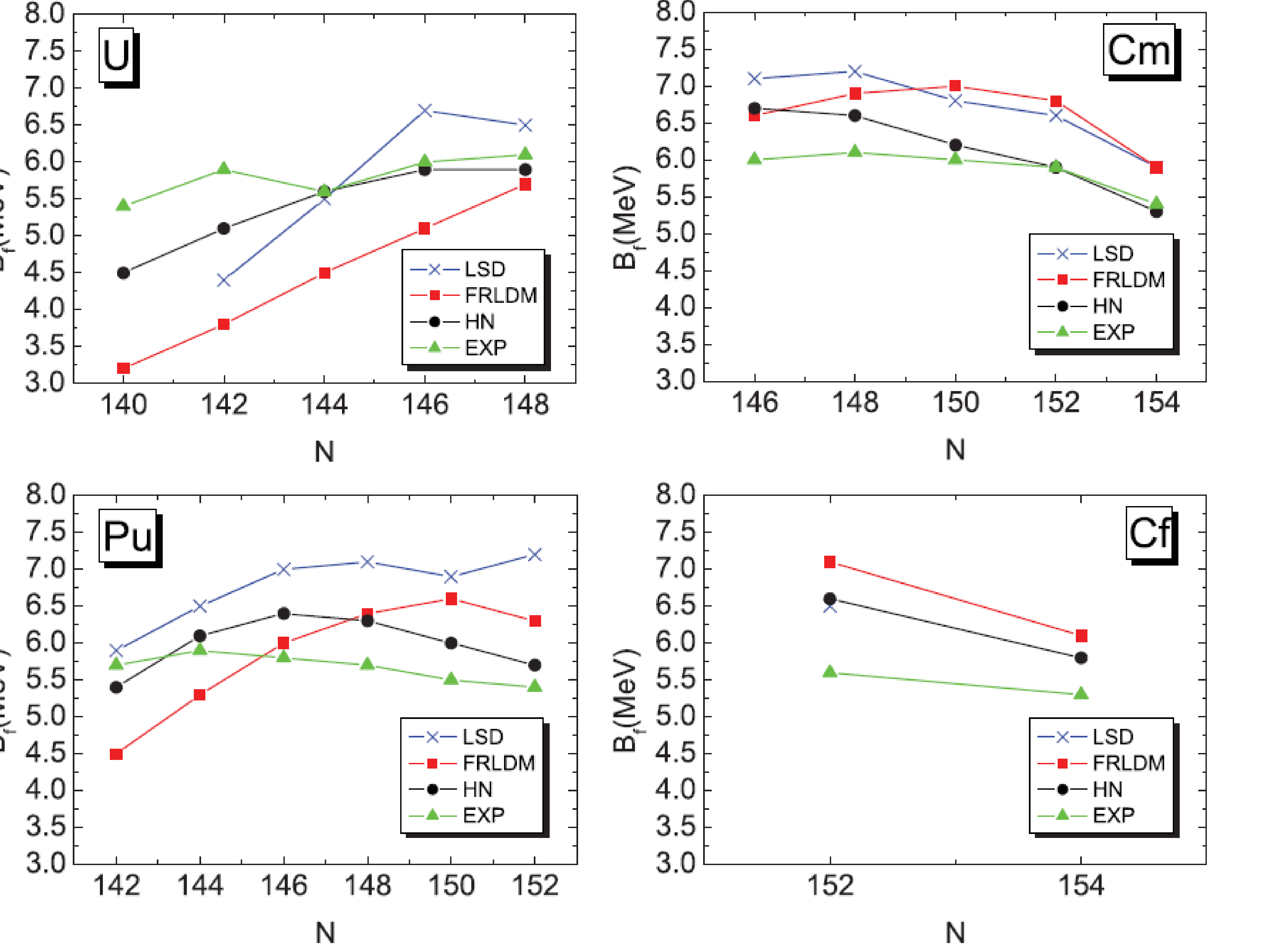
The same but for the method without blocking.

	e - e	o - e	e - o	o - o
N	74	56	69	53
h	0.0	-0.751	0.268	0.234
$<\mid M^{th} - M^{exp} \mid>$	0.187	0.460	0.273	0.295
$Max \mid M^{th} - M^{exp} \mid$	0.652	1.398	0.892	0.853
δ_{RMS}	0.251	0.551	0.343	0.366


Z-even, N-even
number of nuclei = 74
δrms = 0.284
<|Mexp-Mth|> = 0.212
max |Mexp-Mth| = 0.833
h=0.000
Z-odd, N-even
number of nuclei = 56
δrms = 0.425
<|Mexp-Mth|> = 0.340
max |Mexp-Mth| = 0.836
h=1.013
Z-even, N-odd
number of nuclei = 69
δrms = 0.435
<|Mexp-Mth|> = 0.356
max |Mexp-Mth| = 1.124
h=0.824
Z-odd, N-odd
number of nuclei = 53
δrms = 0.666
<|Mexp-Mth|> = 0.566
max |Mexp-Mth| = 1.387
h=1.703
Mexp - Mth [MeV]
A



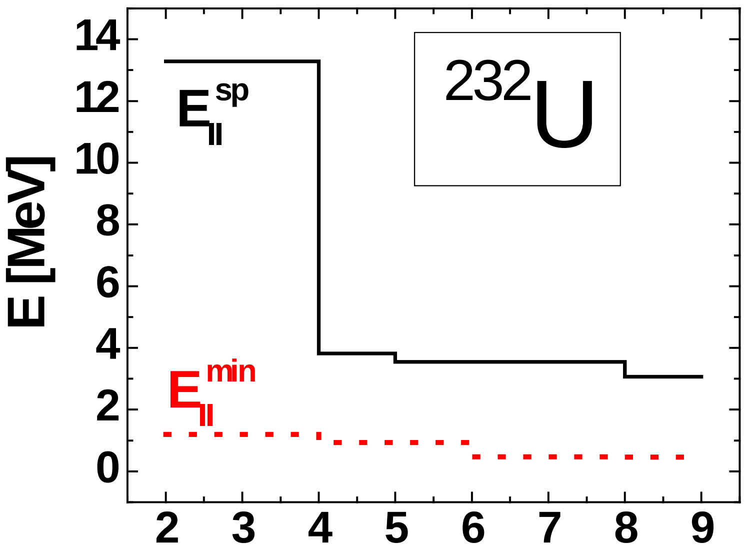
min
20
SDO
OBLATE
SPHERICAL
PROLATE
Z
N
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
136
144
152
160
168
176
184
192
-0.50
-0.45
-0.40
-0.35
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0
0.05
0.10
0.15
0.20
0.25
0.30



U
Cm
Pu
Cf
LSD
FRLDM
HN
EXP
B_f(MeV)
N
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
140
142
144
146
148
150
152
154

Second saddles:

$$
\begin{aligned}
\beta_{20} &= 0.65\ (0.05)\ 0.85 \\
\beta_{30} &= 0.00\ (0.05)\ 0.30 \\
\beta_{40} &= -0.30\ (0.05)\ 0.30 \\
\beta_{50} &= 0.00\ (0.05)\ 0.20 \\
\beta_{60} &= -0.20\ (0.05)\ 0.20 \\
\beta_{80} &= -0.15\ (0.05)\ 0.15.
\end{aligned}
$$



Interpolation

1.059.926.301 grid points !

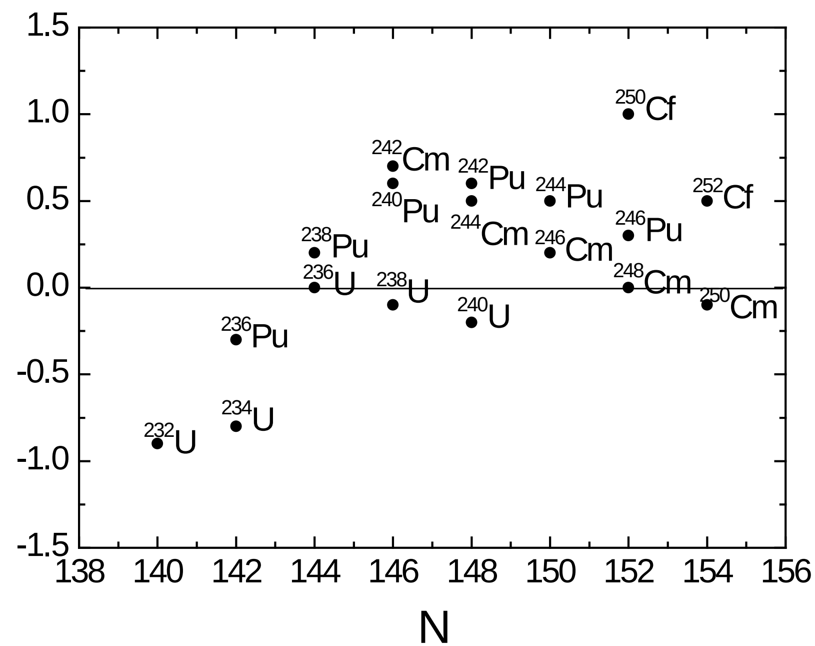
DMP & IWF method has been used

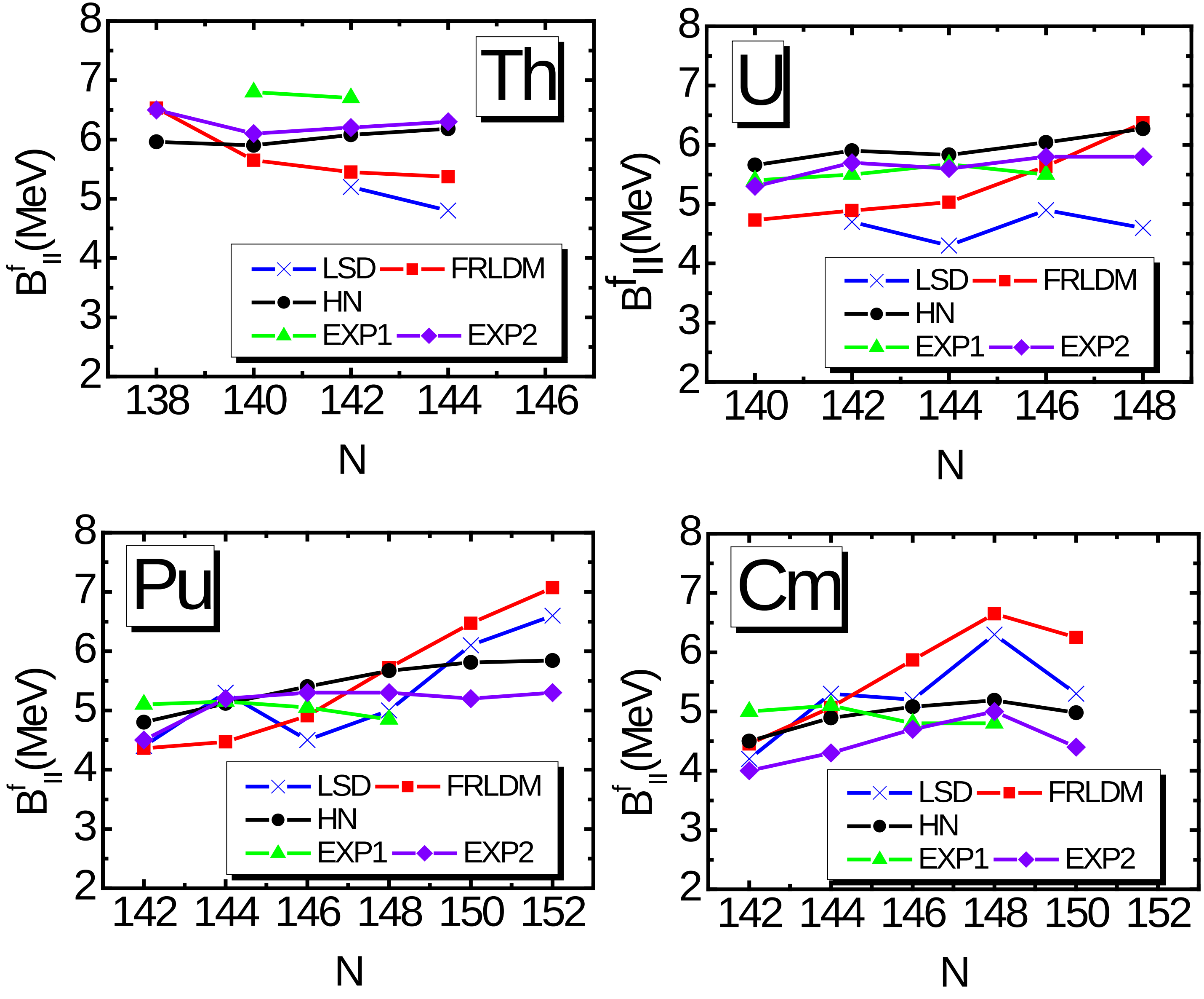
~~Minimization in remaining degrees of freedom~~

P. Jachimowicz, M. Kowal, and J. Skalski
Phys. Rev. C **85**, 034305 (2012)

Z	N	A	LSD	FRLDM	HN	EXP
92	140	232	–	3.2	4.5	5.4
	142	234	4.4	3.8	5.1	5.9
	144	236	5.5	4.5	5.6	5.6
	146	238	6.7	5.1	5.9	6.0
	148	240	6.5	5.7	5.9	6.1
94	142	236	5.9	4.5	5.4	5.7
	144	238	6.5	5.3	6.1	5.9
	146	240	7.0	6.0	6.4	5.8
	148	242	7.1	6.4	6.3	5.7
	150	244	6.9	6.6	6.0	5.5
	152	246	7.2	6.3	5.7	5.4
96	146	242	7.1	6.6	6.7	6.0
	148	244	7.2	6.9	6.6	6.1
	150	246	6.8	7.0	6.2	6.0
	152	248	6.6	6.8	5.9	5.9
	154	250	5.9	5.9	5.3	5.4
98	152	250	6.5	7.1	6.5	5.6
	154	252	–	6.1	5.8	5.3

Models	LSD	FRLDM	HN
N	16	18	18
$\langle \lvert B_f^{\mathrm{th}} - B_f^{\mathrm{expt}} \rvert \rangle$	0.9	1.0	0.4
$\mathrm{Max}\lvert B_f^{\mathrm{th}} - B_f^{\mathrm{expt}} \rvert$	1.8	2.2	1.0
rms	1.0	1.1	0.5

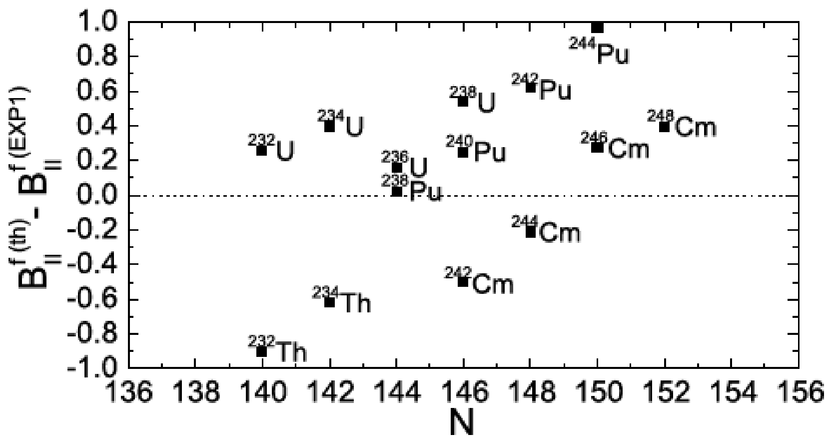


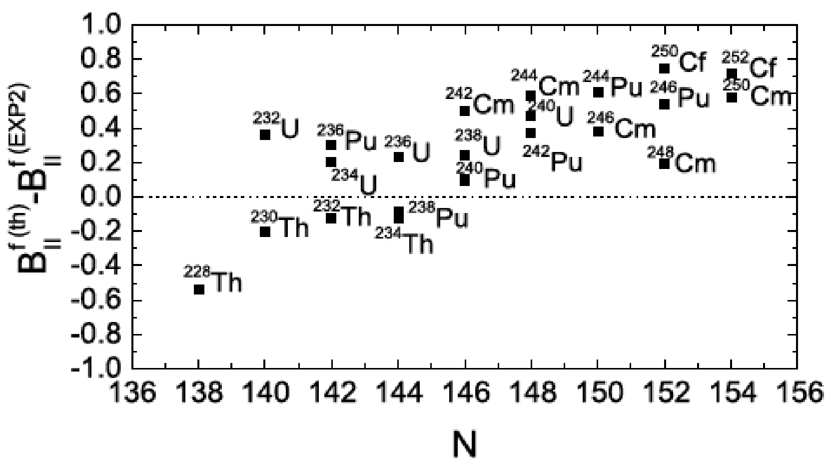


Th
U
Pu
Cm
LSD
FRLDM
HN
EXP1
EXP2
B^f_{II}(MeV)
N

Z	N	A	LSD	FRLDM	HN	EXP1	EXP2
90	136	226	–	7.20	6.26	–	–
	138	228	–	6.53	5.92	–	6.5
	140	230	–	5.65	5.97	6.80	6.1
	142	232	5.2	5.45	6.07	6.70	6.2
	144	234	4.8	5.37	6.07	–	6.3
	146	236	–	6.04	6.35	–	–
92	138	230	–	4.28	5.64	–	–
	140	232	–	4.73	5.66	5.40	5.3
	142	234	4.7	4.89	5.84	5.50	5.7
	144	236	4.3	5.03	5.78	5.67	5.6
	146	238	4.9	5.64	5.93	5.50	5.8
	148	240	4.6	6.37	6.04	–	5.8
	150	242	–	7.10	6.23	–	–
94	140	234	–	–	4.68	–	–
	142	236	4.4	4.36	5.06	–	4.5
	144	238	5.3	4.47	5.15	5.10	5.2
	146	240	4.5	4.91	5.28	5.15	5.3
	148	242	5.0	5.72	5.52	5.05	5.3
	150	244	6.1	6.47	5.63	4.85	5.2
	152	246	6.6	7.07	5.75	–	5.3
	154	248	–	–	5.42	–	–
96	144	240	–	3.92	4.25	–	–
	146	242	4.2	4.45	4.42	5.00	4.0
	148	244	5.3	5.07	4.72	5.10	4.3
	150	246	5.2	5.87	4.98	4.80	4.7
	152	248	6.3	6.65	5.14	4.80	5.0
	154	250	5.3	6.25	4.87	–	4.4
	156	252	–	5.68	4.31	–	–
98	150	248	–	5.18	4.14	–	–
	152	250	4.6	5.92	4.57	–	3.8
	154	252	–	5.83	4.36	–	3.5
	156	254	–	5.27	3.95	–	–

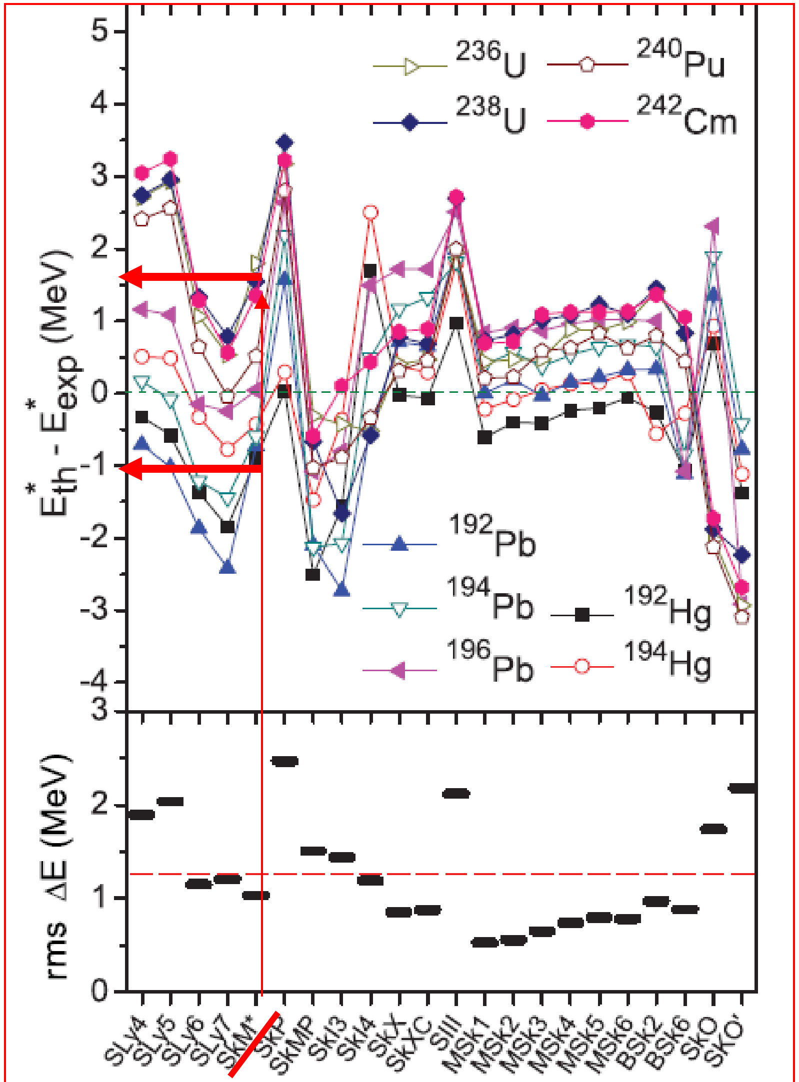
Theoretical models:	LSD		FRLDM		HN	
Experimental data:	[23]	[24]	[23]	[24]	[23]	[24]
N	12	18	14	22	14	22
$<\mid B_f^{th} - B_f^{exp} \mid>$	0.78	0.84	0.79	0.90	0.39	0.33
$Max \mid B_f^{th} - B_f^{exp} \mid$	1.50	1.50	1.85	2.33	0.83	0.86
δ_{RMS}	0.92	0.94	0.95	1.11	0.46	0.40



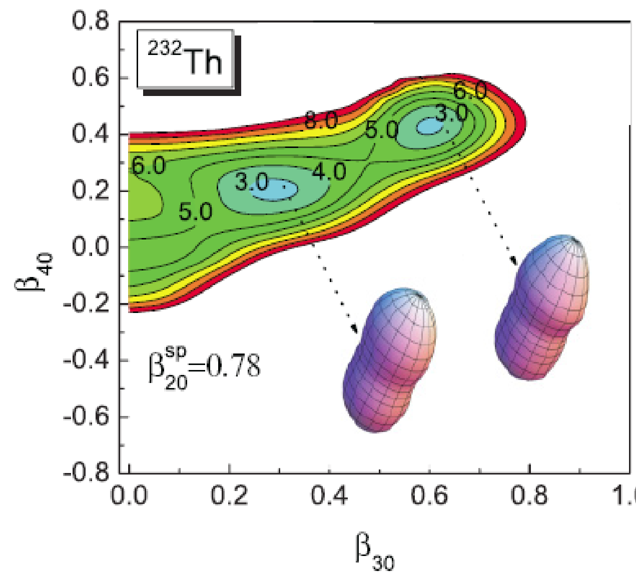


Second minima in actinides,

N. Nikolov, N. Schunck, W. Nazarewicz, M. Bender, and J. Pei, PRC **83**, 034305 (2011).



Z	N	A	$E_{II}^{min}(th)^*$	$E_{II}^{min}(exp)^*$
92	144	236	2.04	2.75
92	146	238	1.94	2.56
94	142	236	2.43	3.00
94	144	238	2.05	2.40
94	146	240	1.95	2.80
94	148	242	1.99	2.20
96	144	240	1.69	2.00
96	146	242	1.64	1.90
96	148	244	1.68	2.20(?)

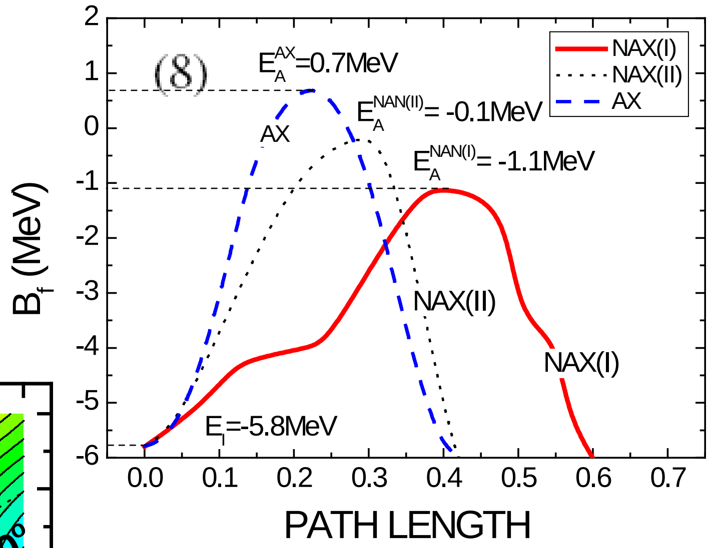


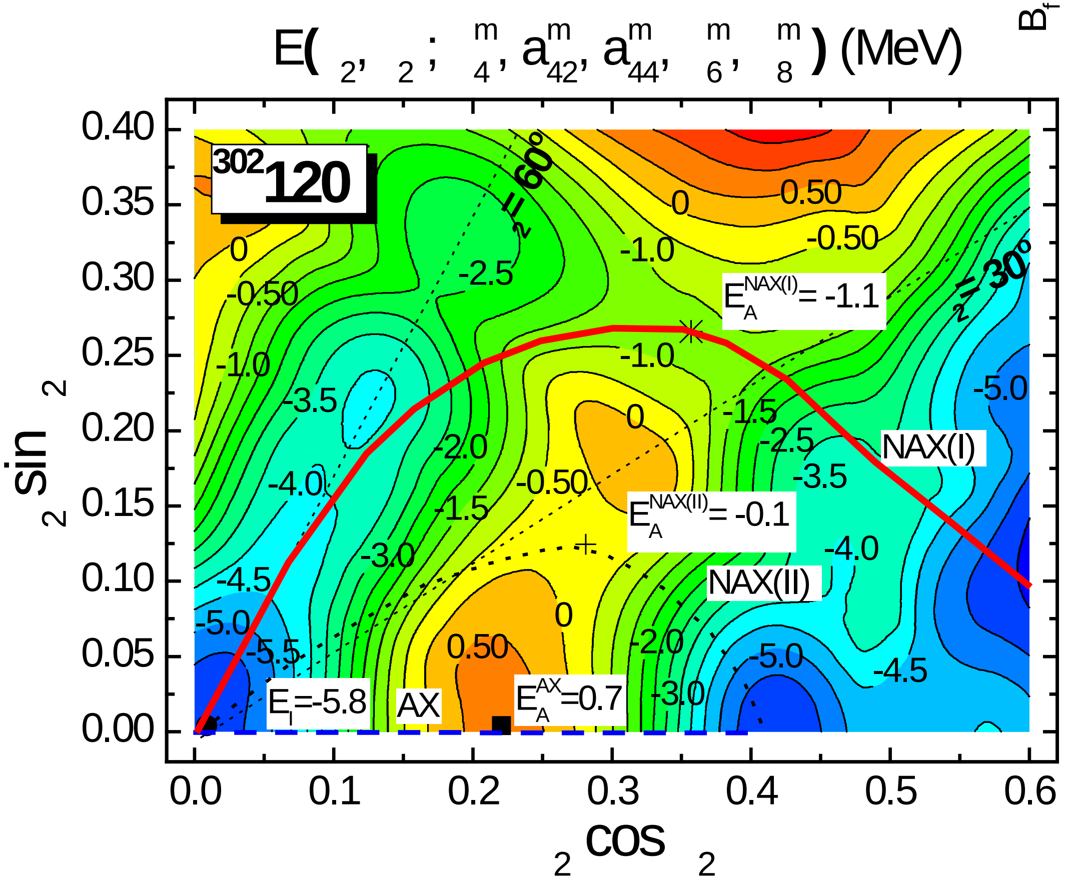
M. Kowal and J. Skalski, *PRC* **82**, 054303 (2010).

P. Jachimowicz, M. Kowal, and J. Skalski, *PRC* **85**, 034305 (2012).

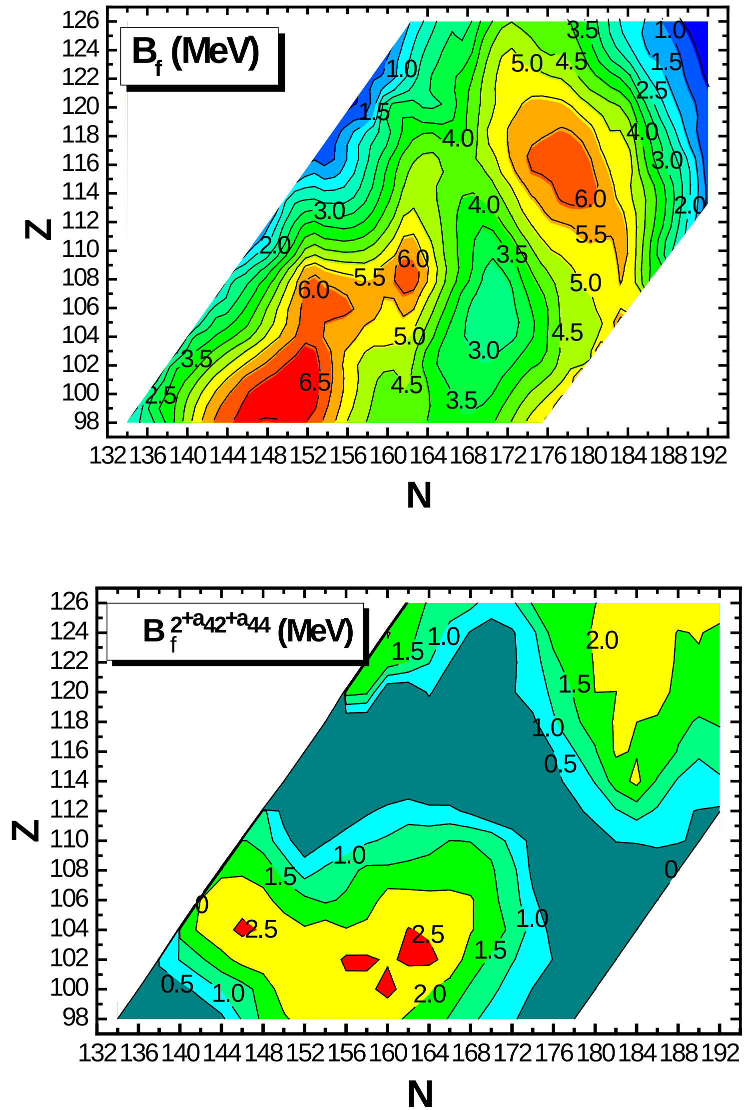
The potential energy is calculated in the following grid points:

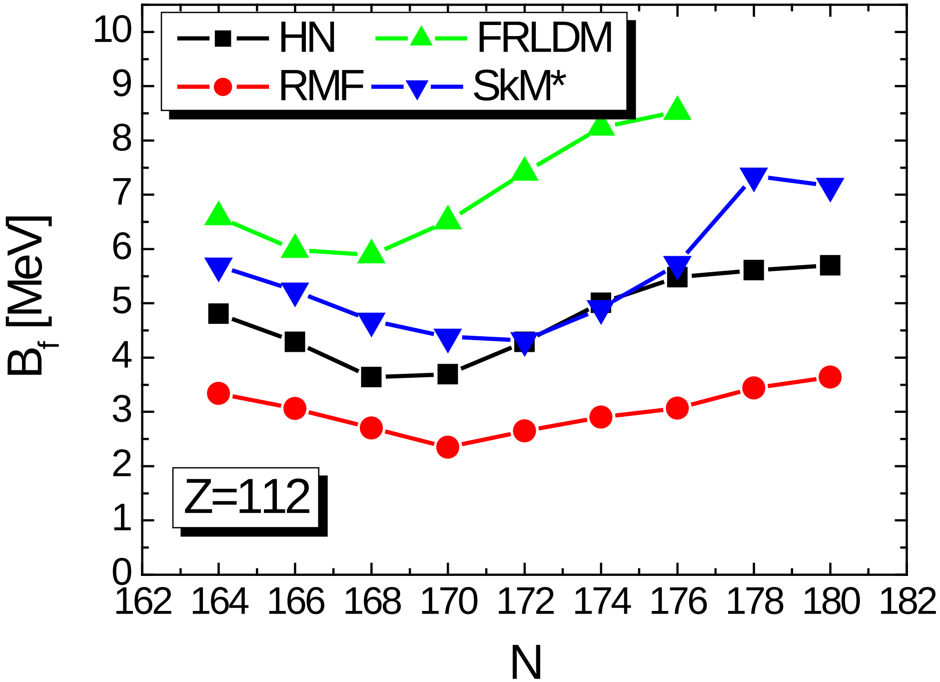
$$\beta_2 \cos\gamma_2 = 0(0.05)0.65,$$
$$\beta_2 \sin\gamma_2 = 0(0.05)0.40,$$
$$\beta_4 = -0.20(0.05)0.20.$$

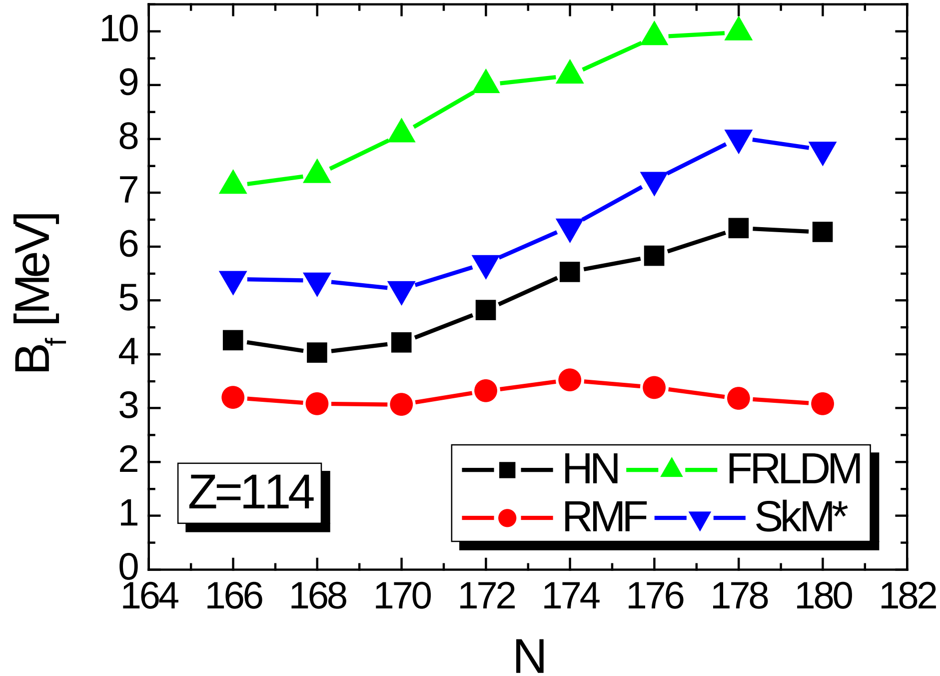


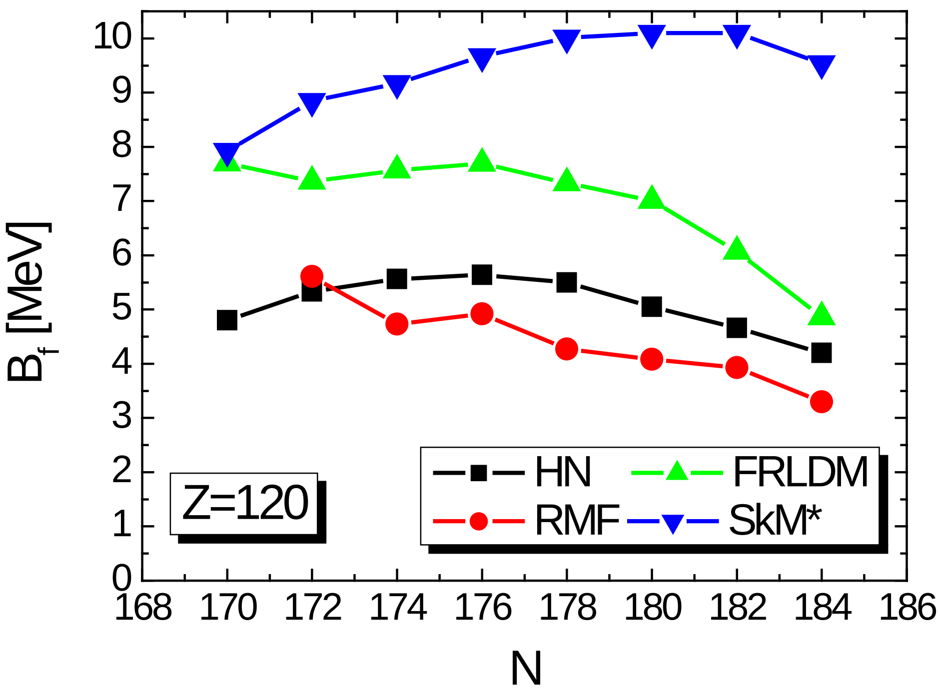


Nucleus	SHF	FRLDM	ETFSI	HN	EXP
$^{284}112_{172}$	6.06	7.41	2.2	4.29	5.5
$^{286}112_{174}$	6.91	8.24	3.6	5.01	5.5
$^{288}114_{174}$	8.12	9.18	6.1	5.53	6.7
$^{290}114_{176}$	8.52	9.89	6.6	5.83	6.7
$^{292}114_{178}$	–	9.98	7.2	6.34	6.7
$^{292}116_{176}$	9.35	9.26	6.5	6.22	6.4
$^{294}116_{178}$	9.59	9.46	7.2	6.28	6.4
$^{296}116_{180}$	–	9.10	7.2	6.07	6.4
$^{294}118_{176}$	–	8.48	6.6	5.99	–
$^{296}118_{178}$	–	8.36	7.0	6.04	–
$^{298}118_{180}$	–	8.05	7.4	5.72	–
$^{296}120_{176}$	–	7.69	6.2	5.64	–
$^{298}120_{178}$	–	7.33	6.6	5.50	–
$^{300}120_{180}$	–	7.01	6.8	5.05	–
$^{302}120_{182}$	–	6.07	7.2	4.66	–
$^{304}120_{184}$	–	4.86	6.8	4.20	–









HN – M. Kowal et. al.

FRLDM – P. Moller et al.

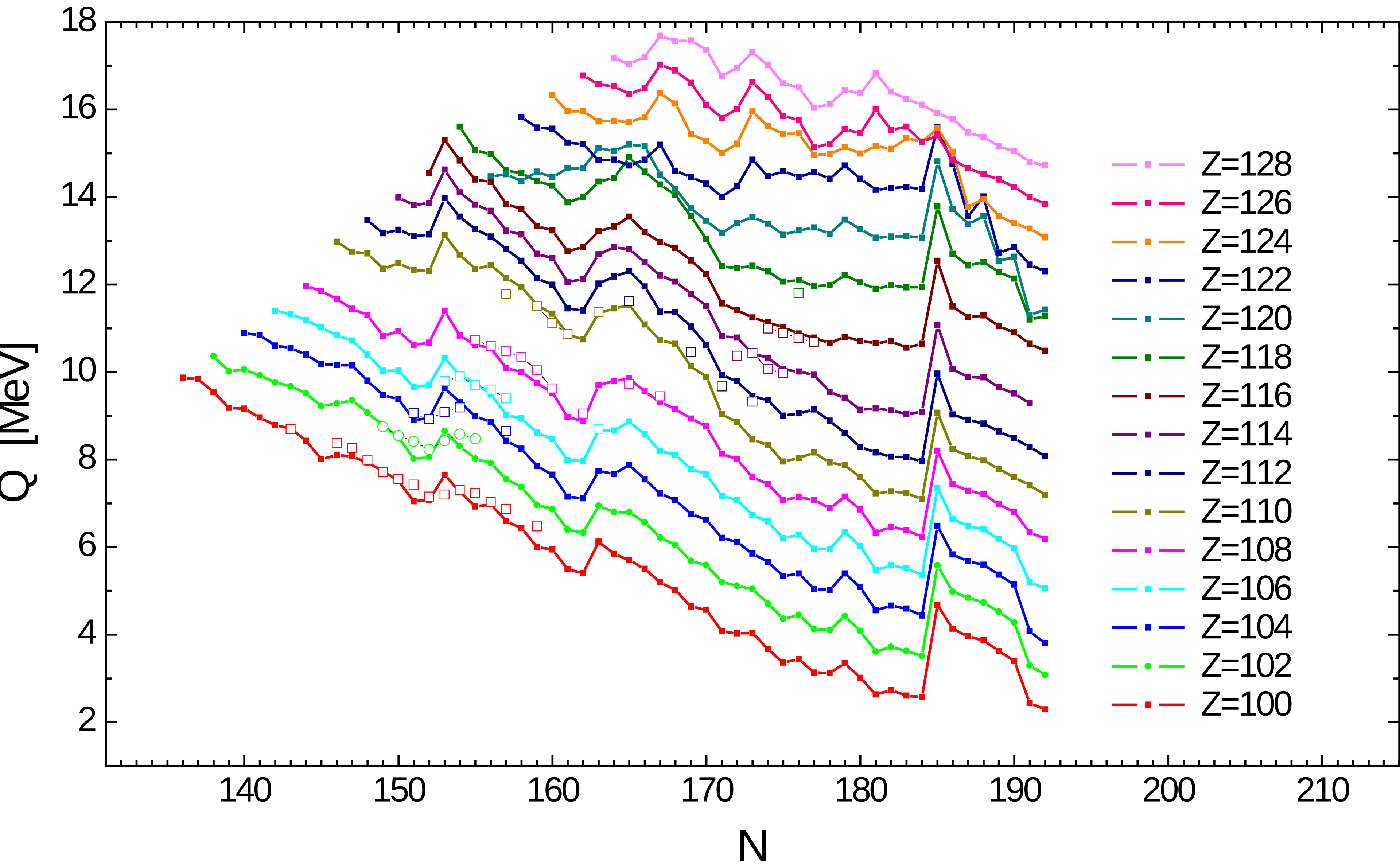
SkM* - A. Staszczak et al.

RMF – H. Abusara et al.

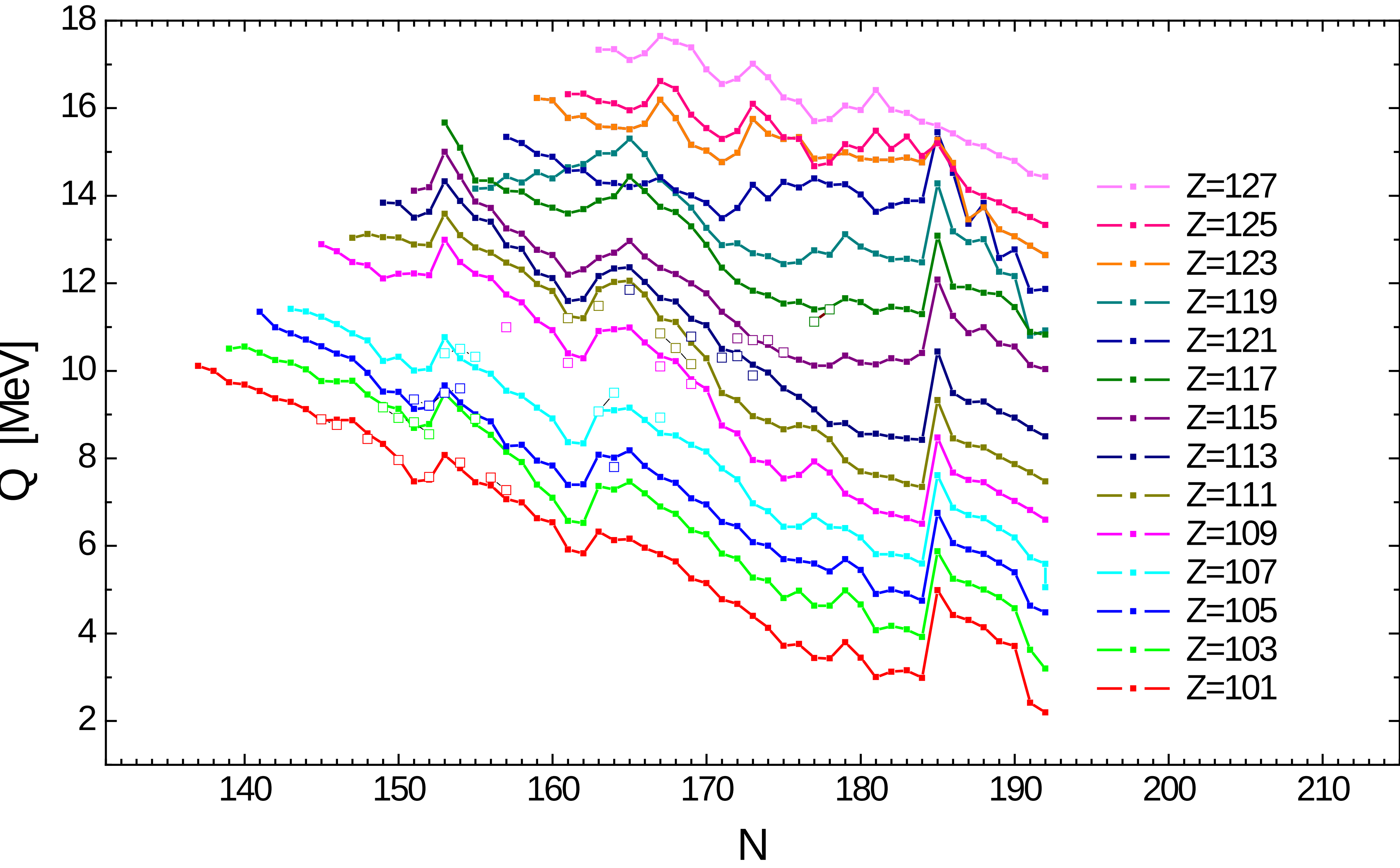
Q alpha predictions in SH nuclei including odd & odd-odd

Some aspects not quite clear

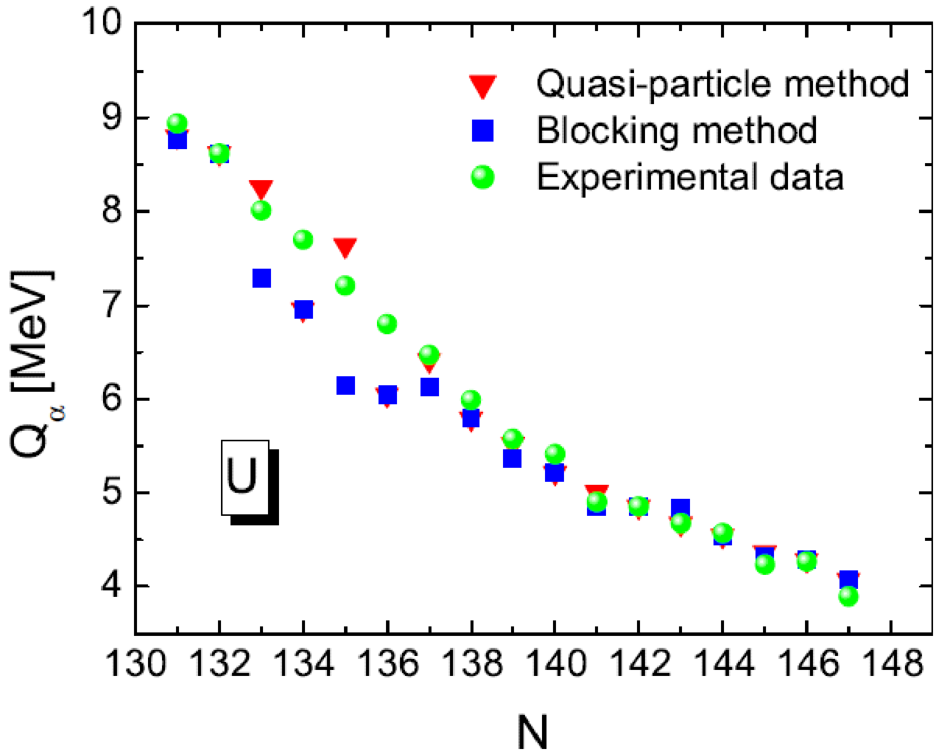
- We use blocking procedure; this causes often a sharp decrease of pairing effect. For comparison, we also calculate masses by adding quasiparticle energy.



Q [MeV]
N
Z=128
Z=126
Z=124
Z=122
Z=120
Z=118
Z=116
Z=114
Z=112
Z=110
Z=108
Z=106
Z=104
Z=102
Z=100

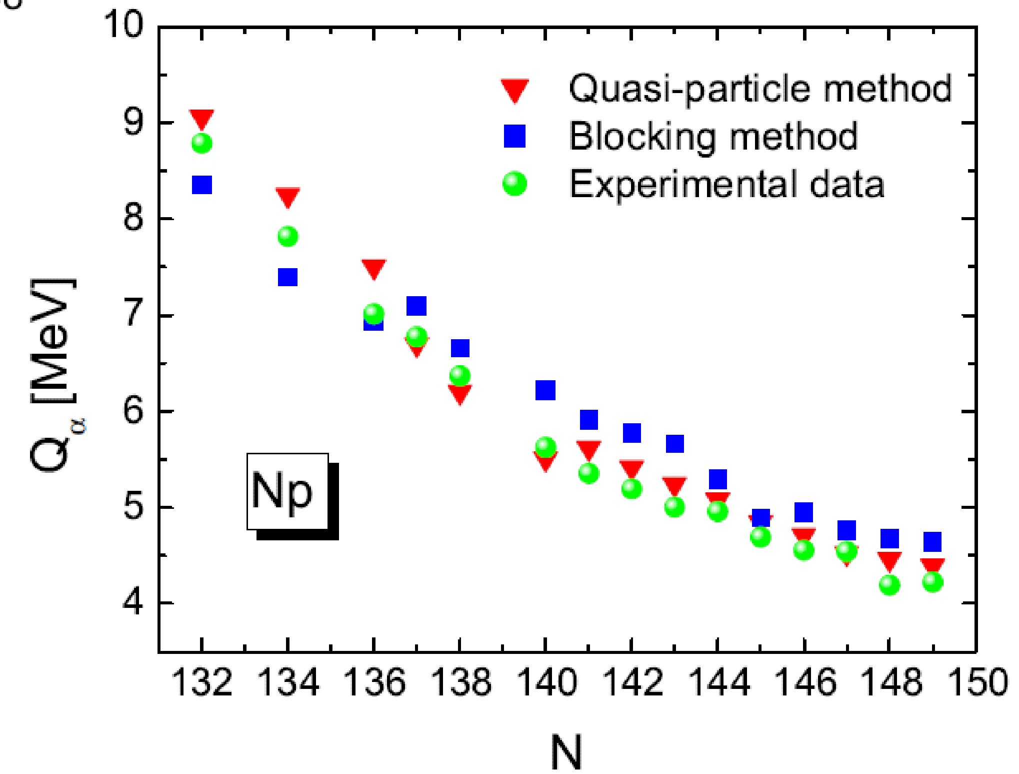


Q [MeV]
N
Z=127
Z=125
Z=123
Z=119
Z=121
Z=117
Z=115
Z=113
Z=111
Z=109
Z=107
Z=105
Z=103
Z=101

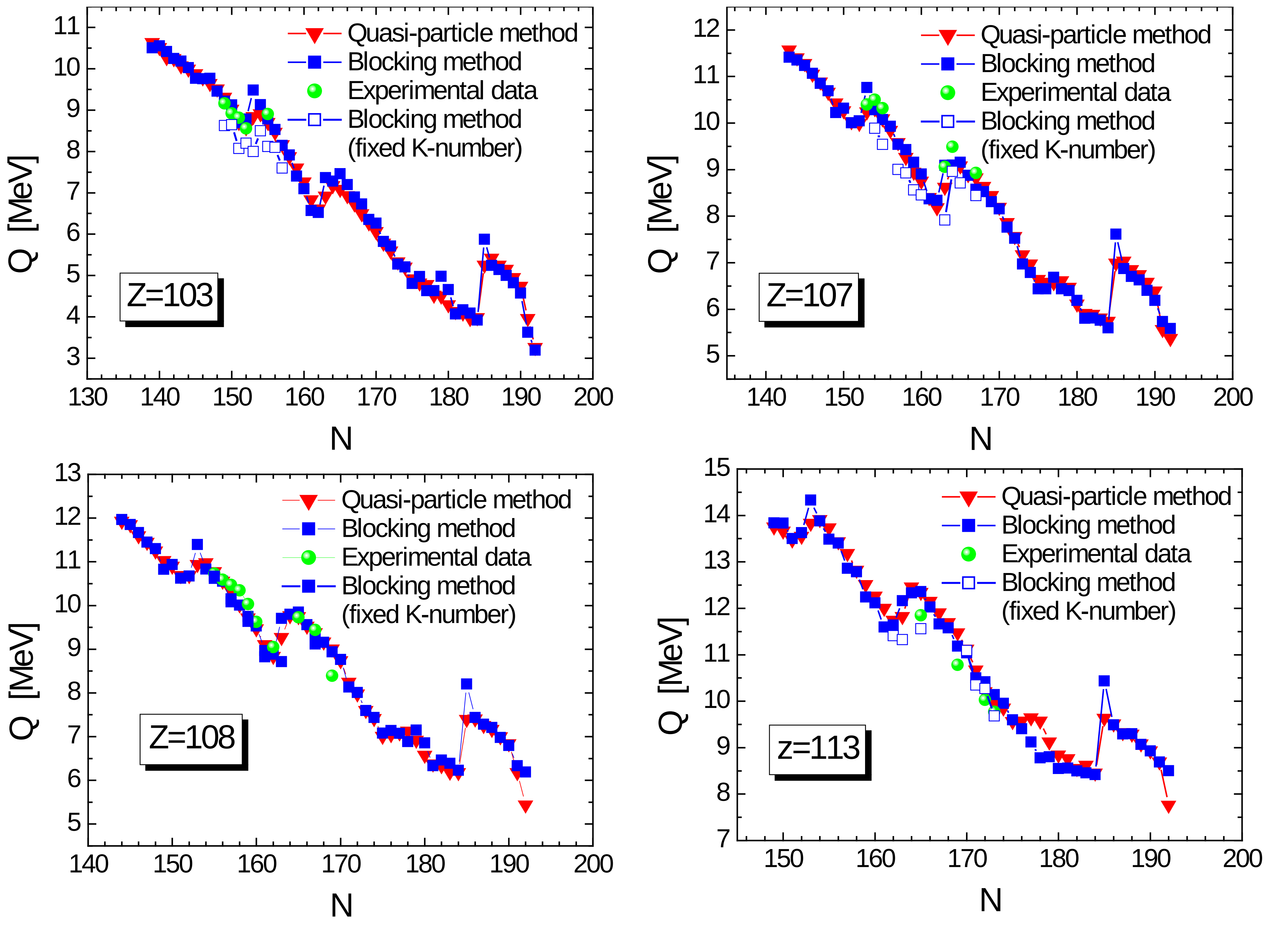


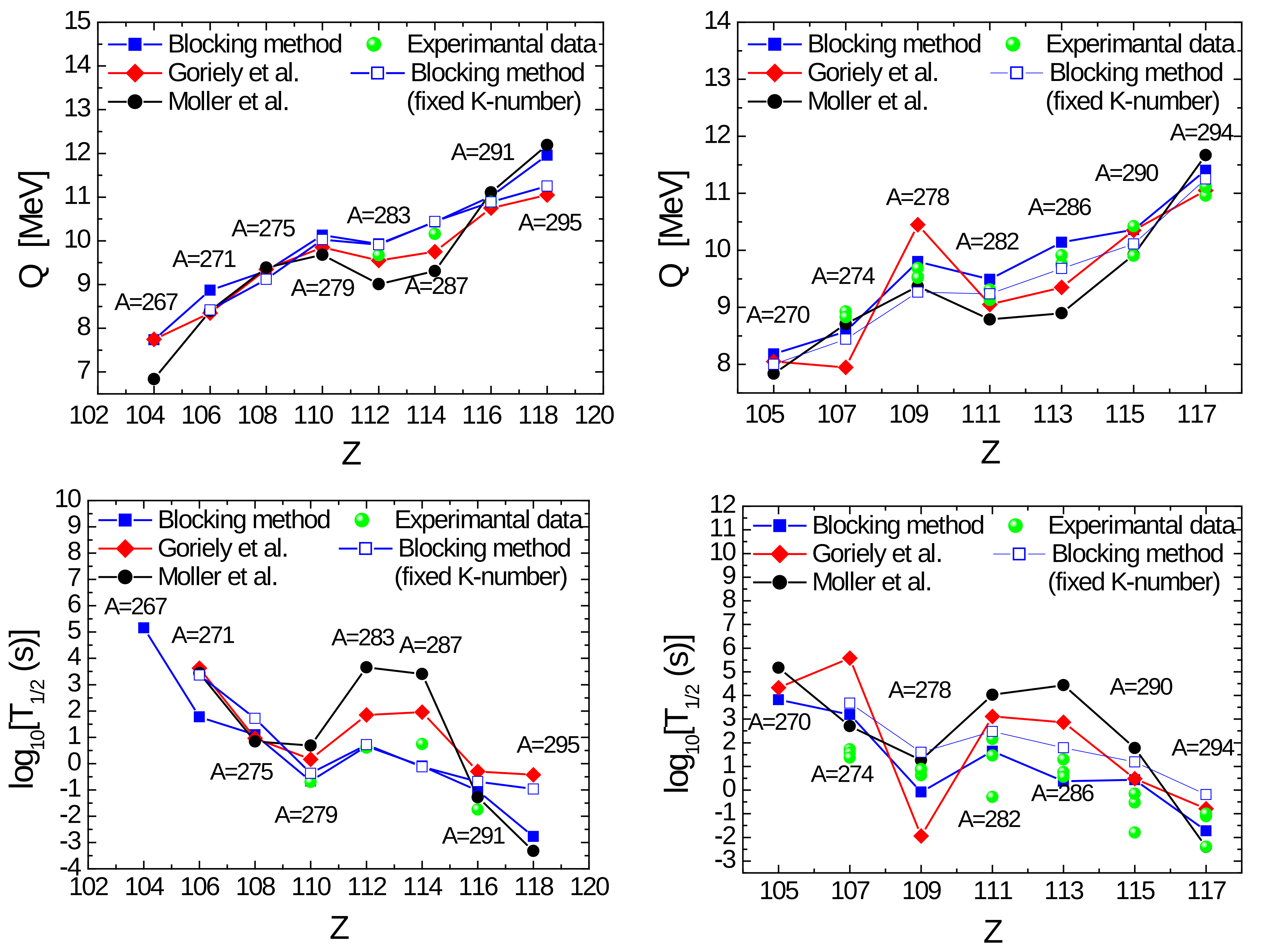
U
Quasi-particle method
Blocking method
Experimental data
Q_α [MeV]
N
10
9
8
7
6
5
4
130 132 134 136 138 140 142 144 146 148

G.S. to G.S.

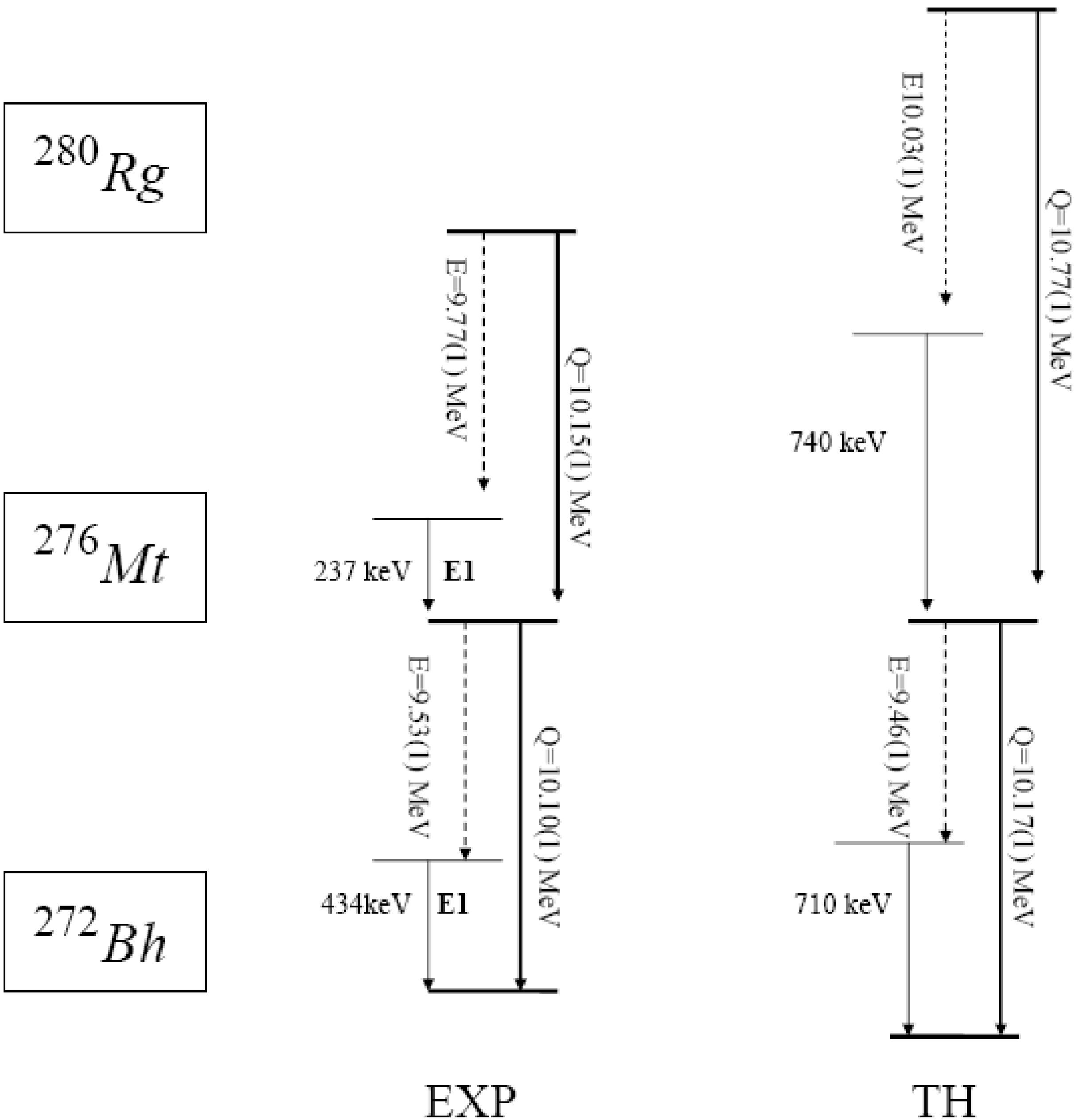


Np
Quasi-particle method
Blocking method
Experimental data
Q_α [MeV]
N
10
9
8
7
6
5
4
132 134 136 138 140 142 144 146 148 150

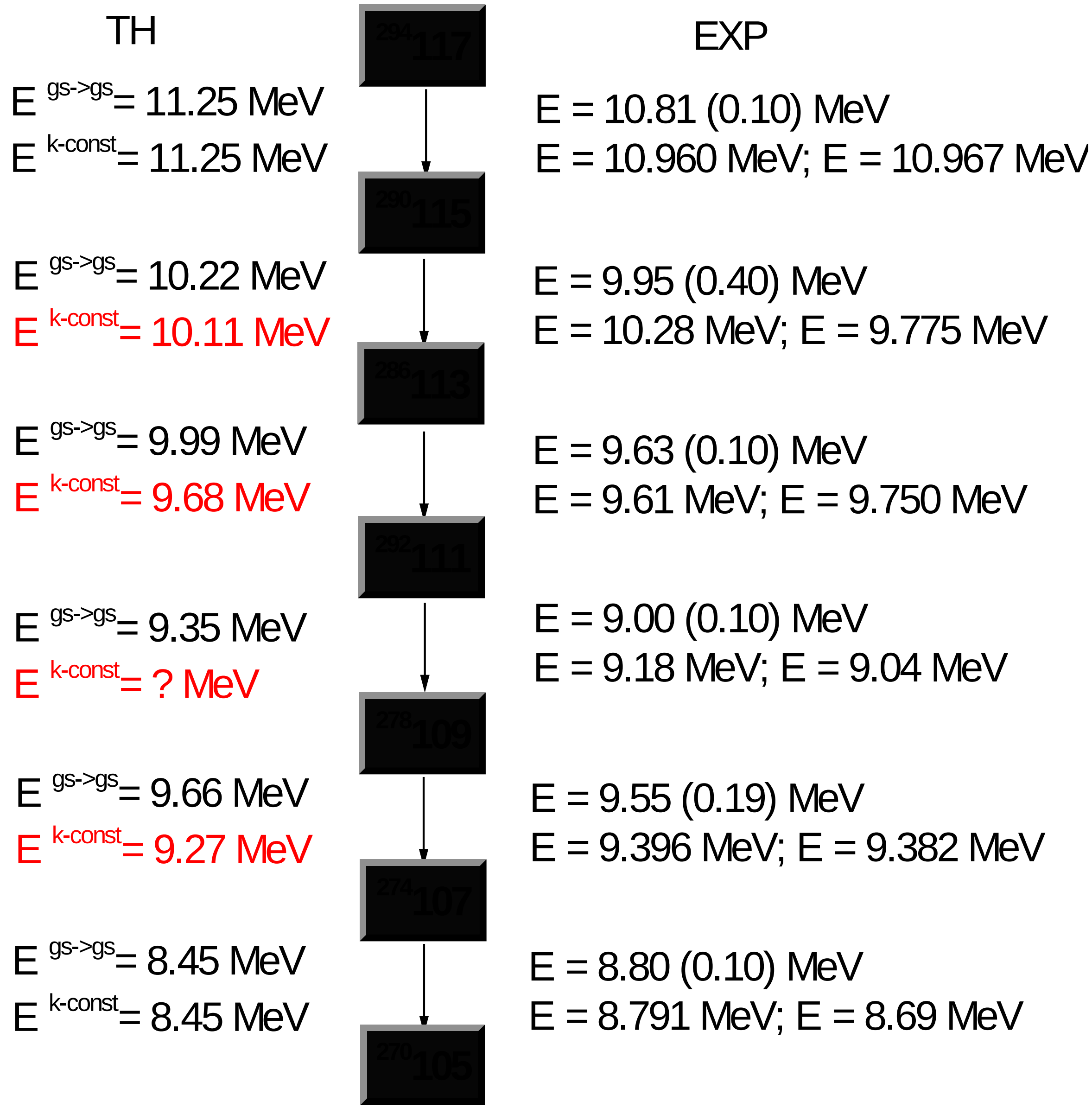

Quasi-particle method
Blocking method
Experimental data
Blocking method
(fixed K-number)
Z=103
Z=107
Z=108
z=113
Q [MeV]
N



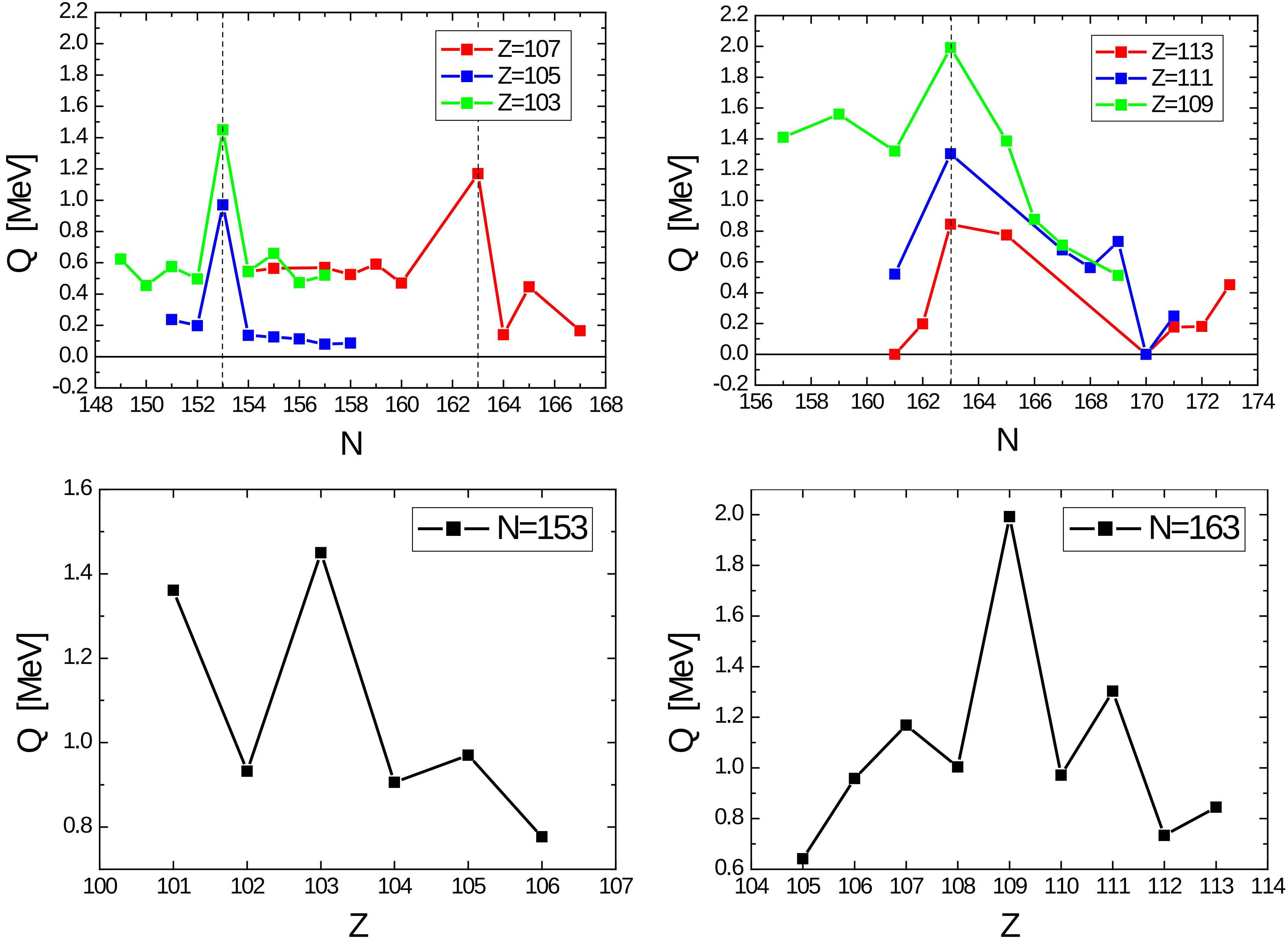
Blocking method
Experimantal data
Goriely et al.
Blocking method
(fixed K-number)
Moller et al.
Q [MeV]
Z
log10[T1/2 (s)]
A=267
A=270
A=271
A=274
A=275
A=278
A=279
A=282
A=283
A=286
A=287
A=290
A=291
A=294
A=295



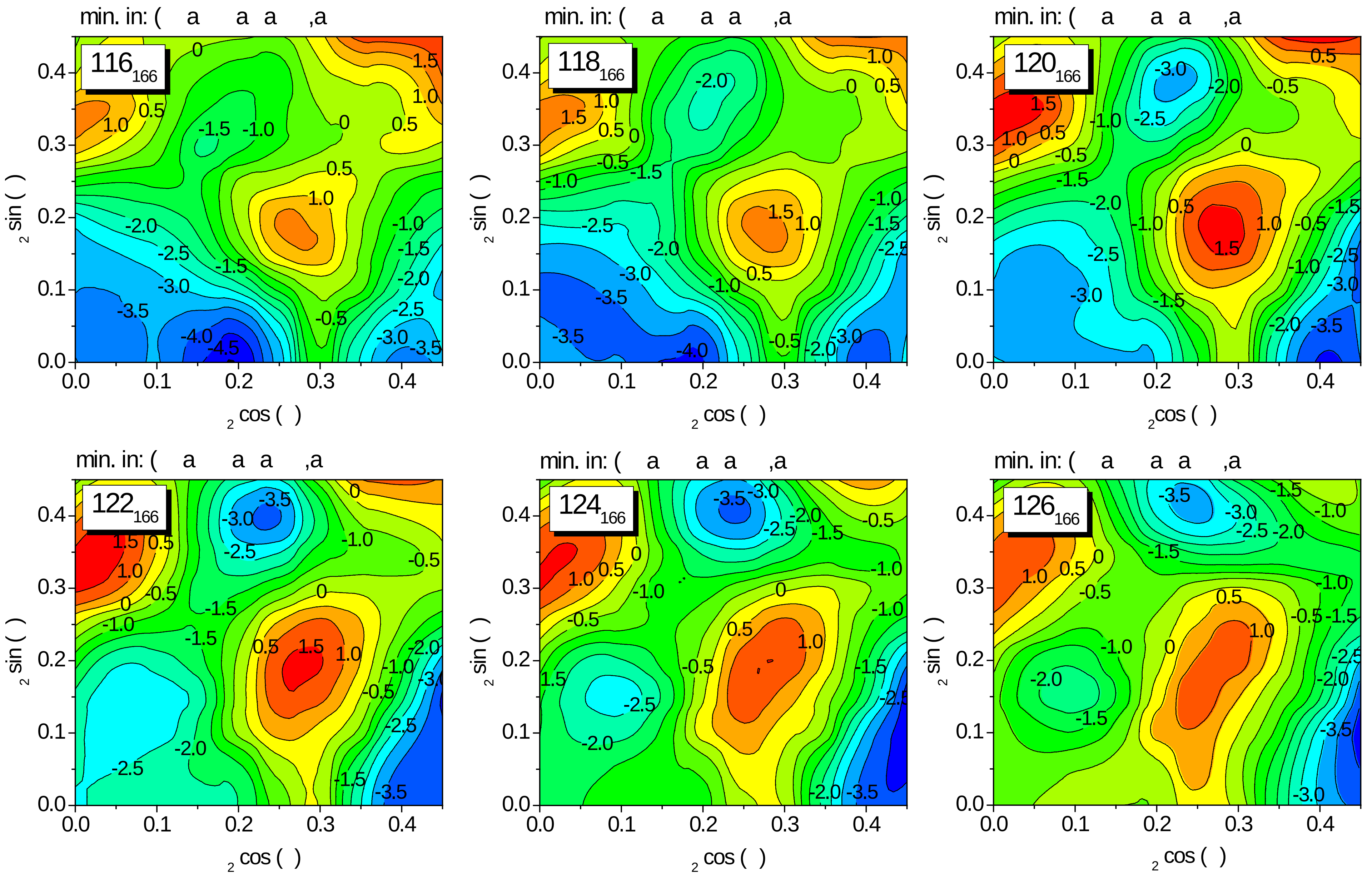
^{280}Rg
^{276}Mt
^{272}Bh
E=9.77(1) MeV
Q=10.15(1) MeV
237 keV
E1
E=9.53(1) MeV
Q=10.10(1) MeV
434keV
E1
E10.03(1) MeV
Q=10.77(1) MeV
740 keV
E=9.46(1) MeV
Q=10.17(1) MeV
710 keV
EXP
TH



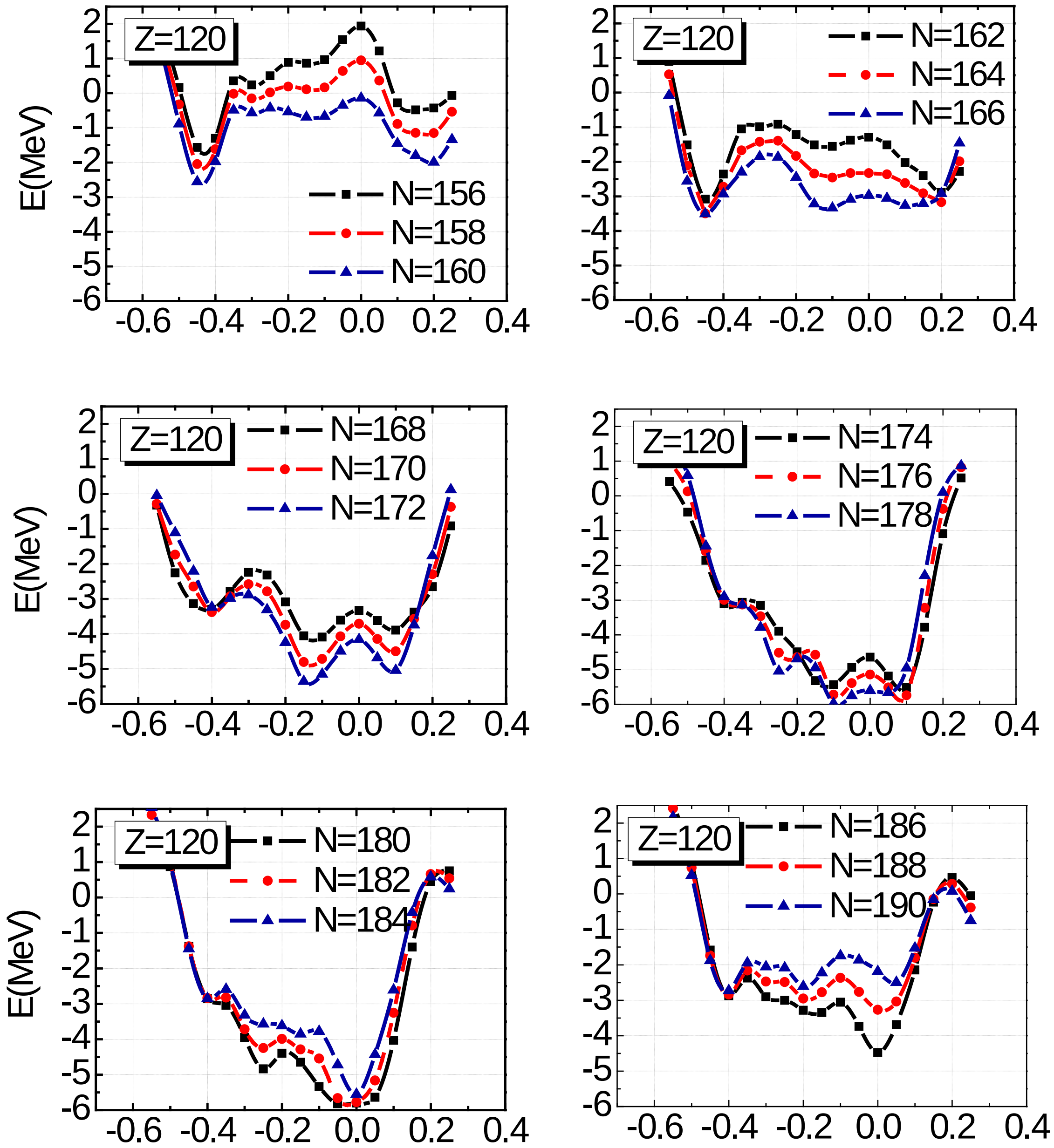
TH
EXP
294 117
E gs->gs= 11.25 MeV
E k-const= 11.25 MeV
E = 10.81 (0.10) MeV
E = 10.960 MeV; E = 10.967 MeV
290 115
E gs->gs= 10.22 MeV
E k-const= 10.11 MeV
E = 9.95 (0.40) MeV
E = 10.28 MeV; E = 9.775 MeV
286 113
E gs->gs= 9.99 MeV
E k-const= 9.68 MeV
E = 9.63 (0.10) MeV
E = 9.61 MeV; E = 9.750 MeV
292 111
E gs->gs= 9.35 MeV
E k-const= ? MeV
E = 9.00 (0.10) MeV
E = 9.18 MeV; E = 9.04 MeV
278 109
E gs->gs= 9.66 MeV
E k-const= 9.27 MeV
E = 9.55 (0.19) MeV
E = 9.396 MeV; E = 9.382 MeV
274 107
E gs->gs= 8.45 MeV
E k-const= 8.45 MeV
E = 8.80 (0.10) MeV
E = 8.791 MeV; E = 8.69 MeV
270 105


Z=107
Z=105
Z=103
Q [MeV]
N
Z=113
Z=111
Z=109
Q [MeV]
N
N=153
Q [MeV]
Z
N=163
Q [MeV]
Z

SDO minima


min. in: (a a a ,a
116 166
118 166
120 166
122 166
124 166
126 166
2 sin ( )
2 cos ( )
0.0
0.1
0.2
0.3
0.4

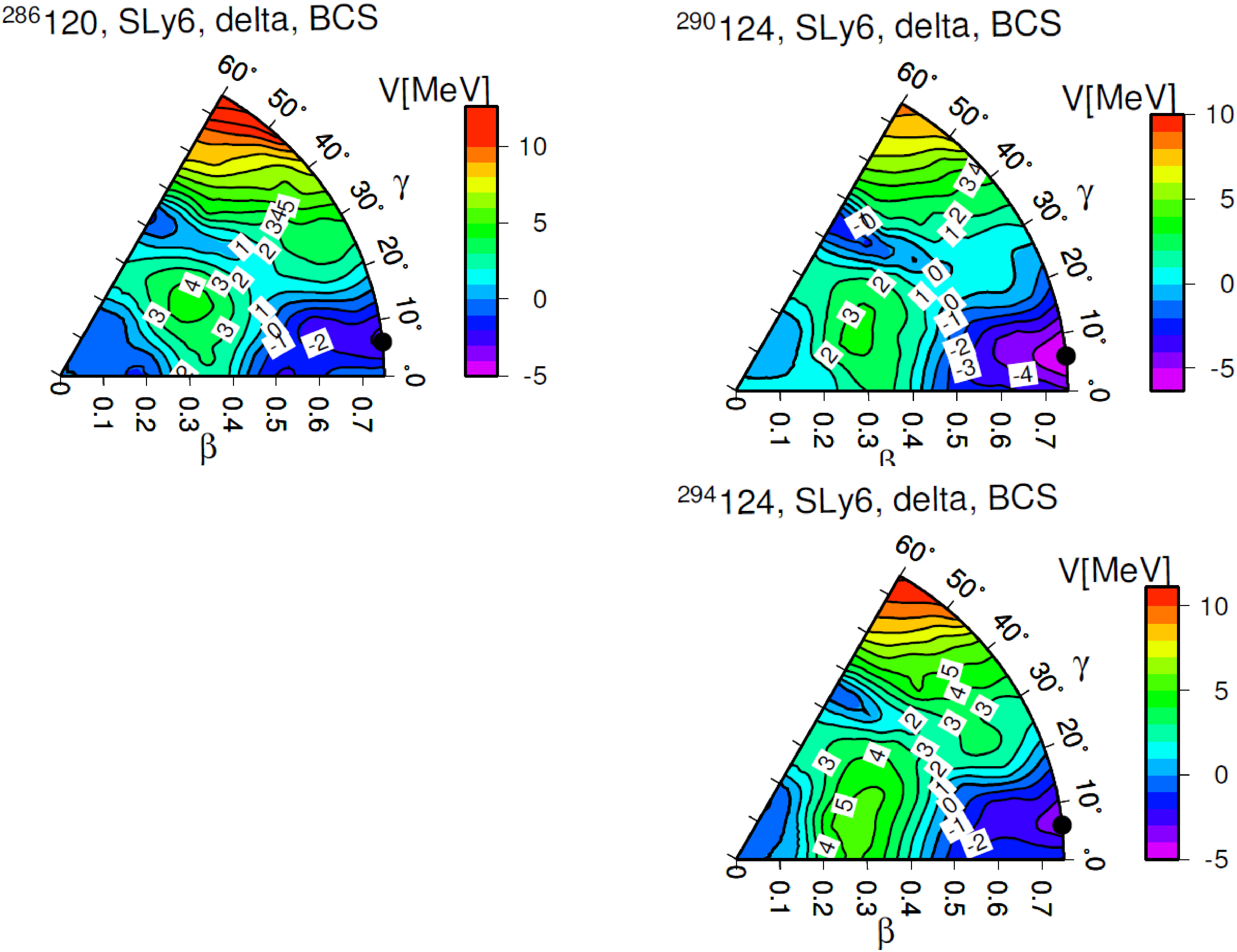
YpE



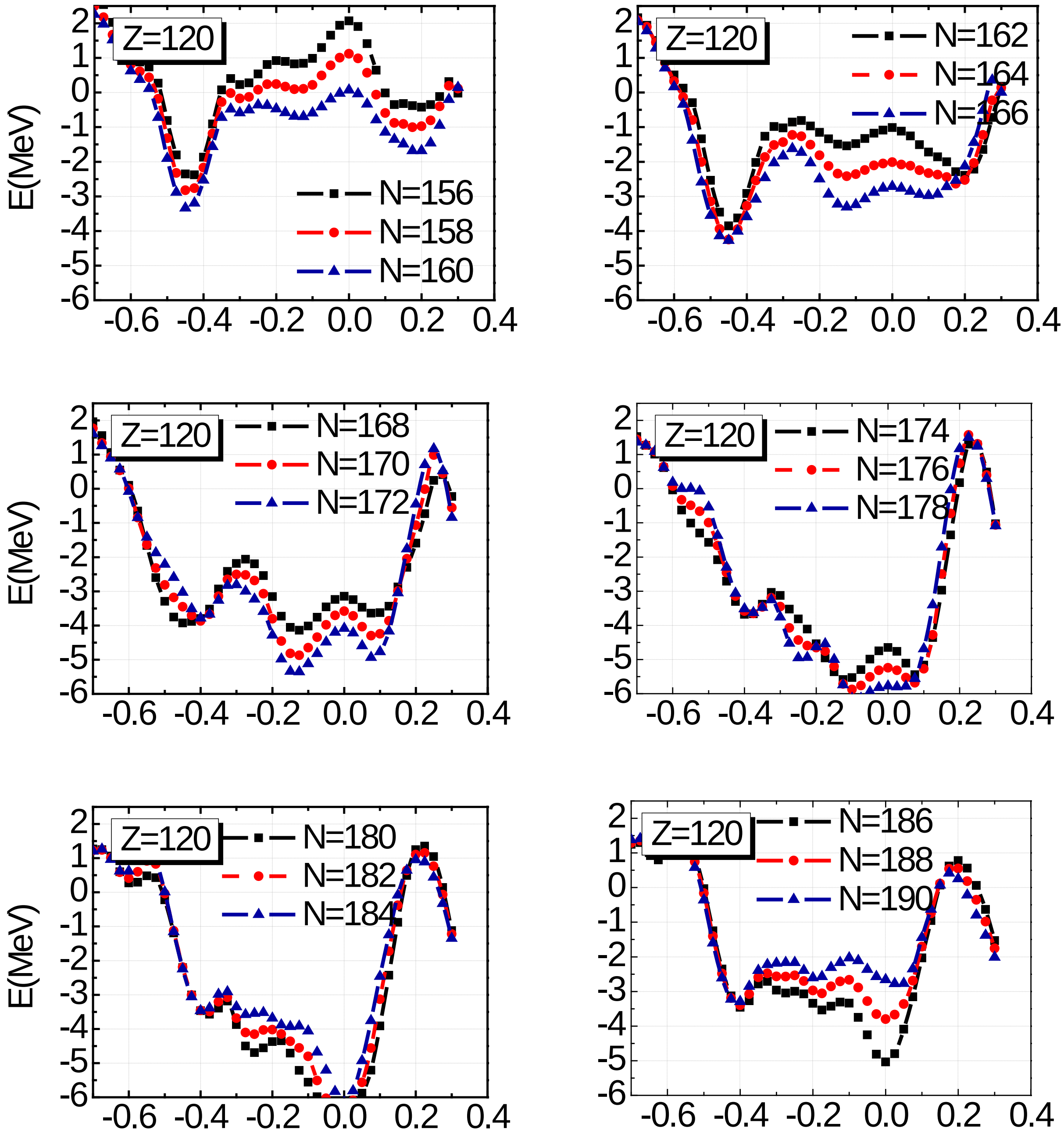
Z=120
N=156
N=158
N=160
Z=120
N=162
N=164
N=166
Z=120
N=168
N=170
N=172
Z=120
N=174
N=176
N=178
Z=120
N=180
N=182
N=184
Z=120
N=186
N=188
N=190
E(MeV)
2 1 0 -1 -2 -3 -4 -5 -6
-0.6 -0.4 -0.2 0.0 0.2 0.4

20

20



^{286}120, SLy6, delta, BCS
V[MeV]
γ
β
^{290}124, SLy6, delta, BCS
V[MeV]
γ
β
^{294}124, SLy6, delta, BCS
V[MeV]
γ
β

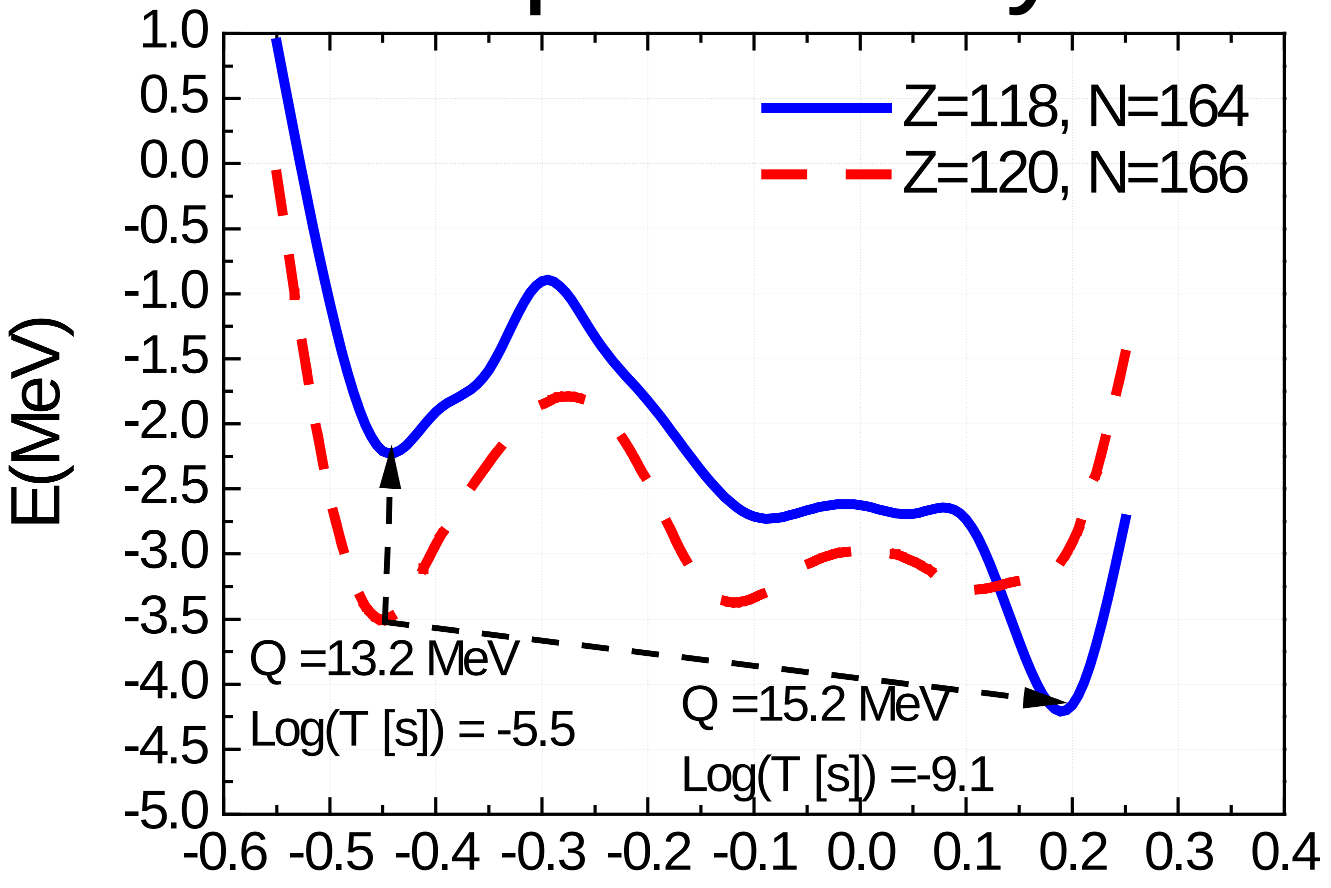


LSD

•LSD → 1 MeV deeper minima!

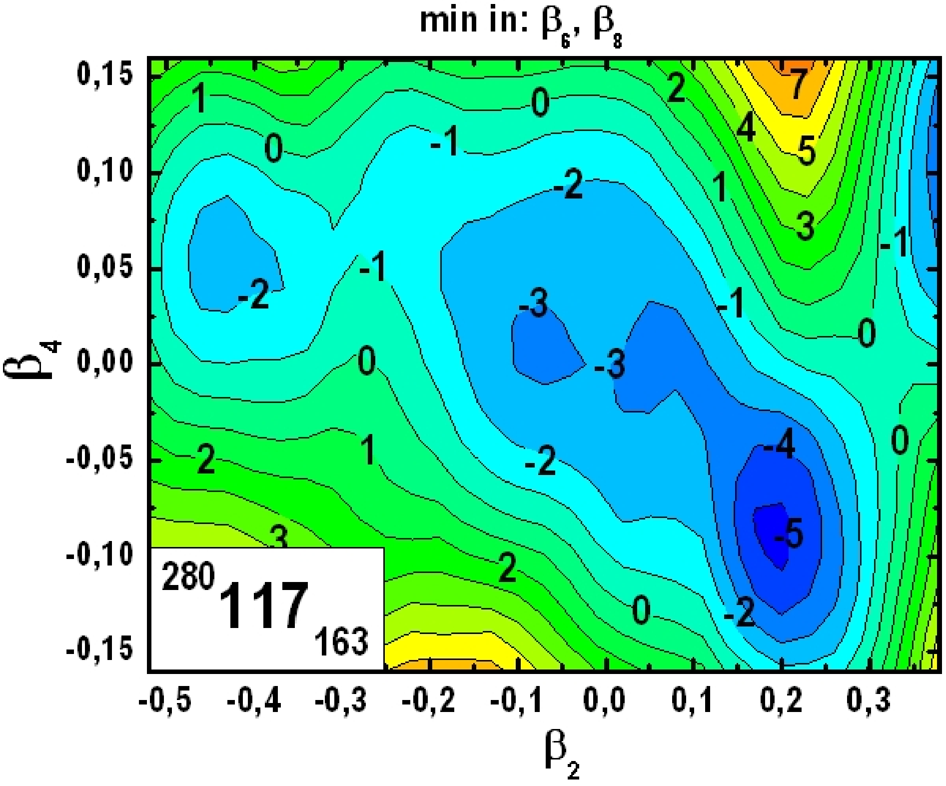
20

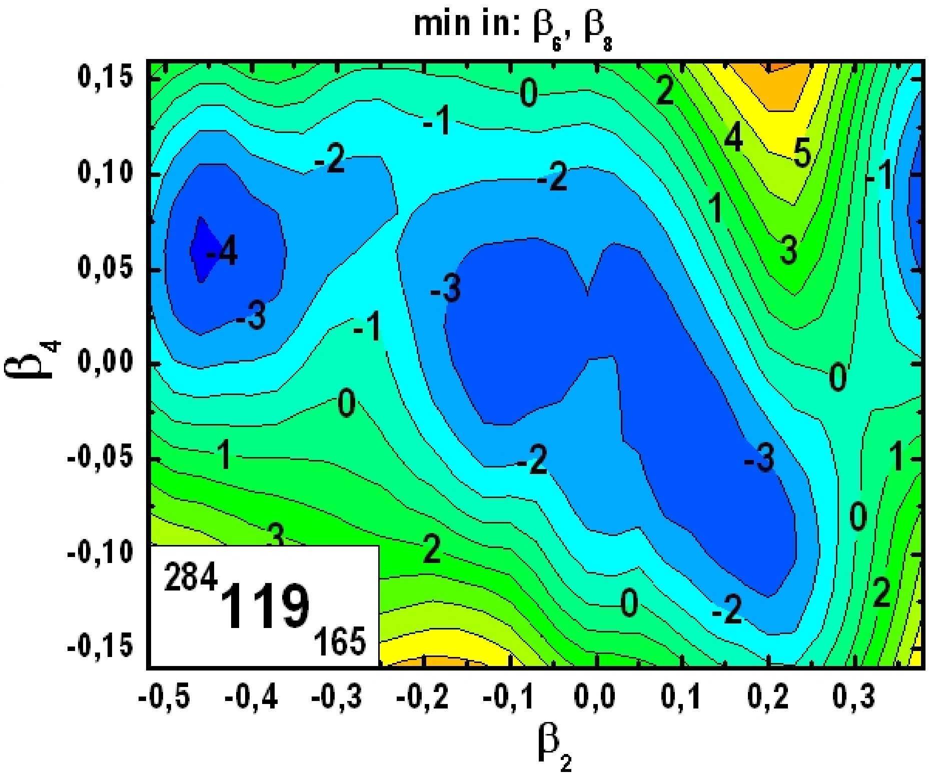
Alpha decay



2

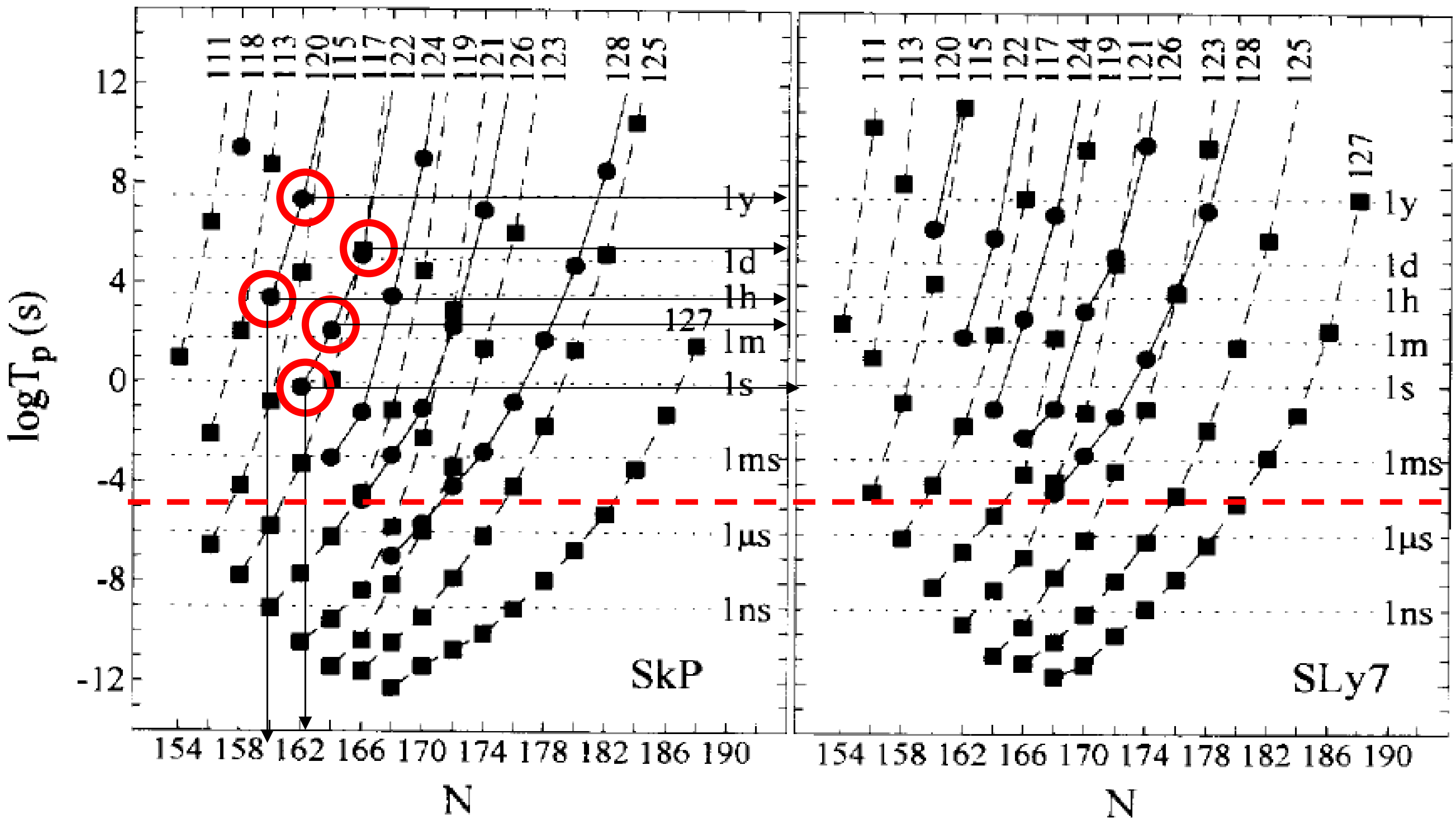
- Formula a'laViola Seaborg from Royer





Possible Q-alpha hindrance: the 14- SD oblate ground state in parent.
The G.S. to G.S. transition inhibited; SDO to SDO has smaller Q.

One proton emission half lives

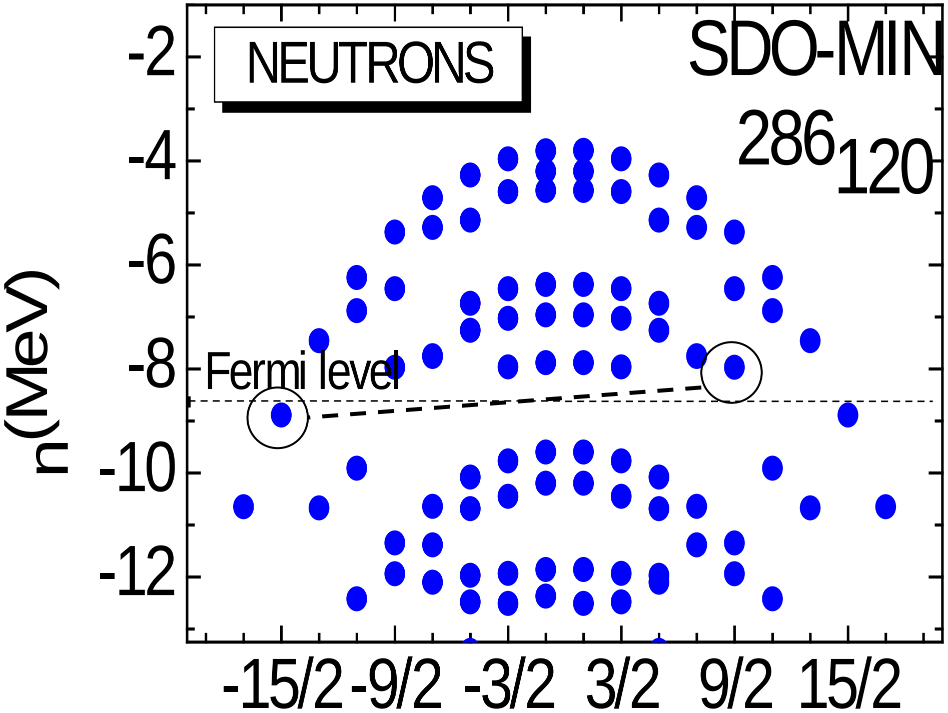


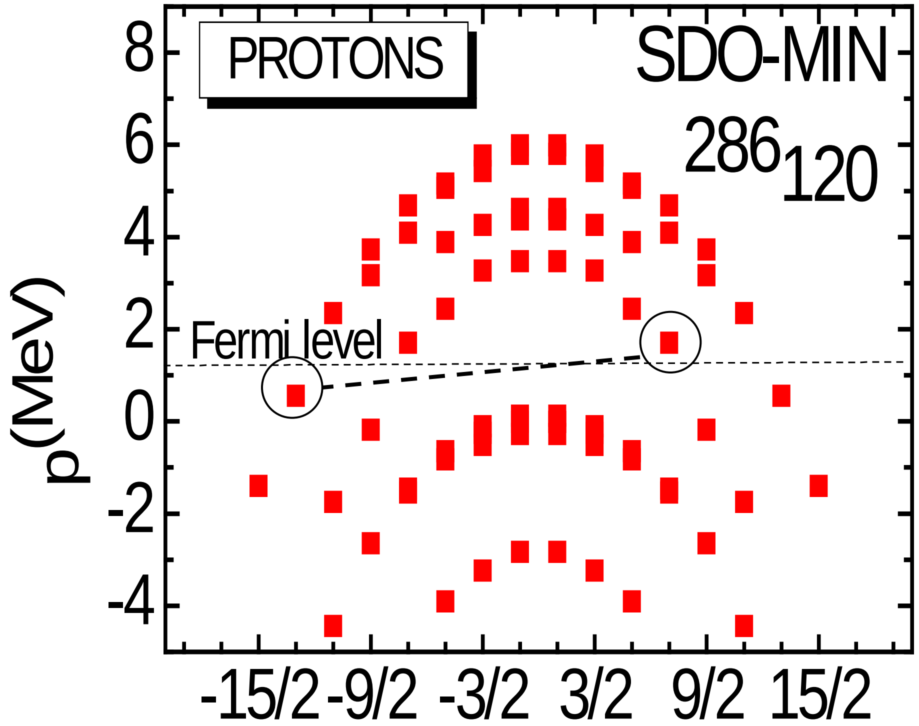
S. Ćwiok[a,b], J. Dobaczewski[a,c], P.-H. Heenen[d], P. Magierski[b], W. Nazarewicz[c,e,f]

Beta decay

Since for high-K isomers |M| is reduced, their beta+ decay is even slower.

A fascinating possibility for their longer life-times is related to K-isomerism, high-K configurations at the SDO shape are very likely!!!





OPTIMAL CONFIGURATION:

(15/2+)+(9/2)-=>12-

(13/2-)+(7/2)+=>10-

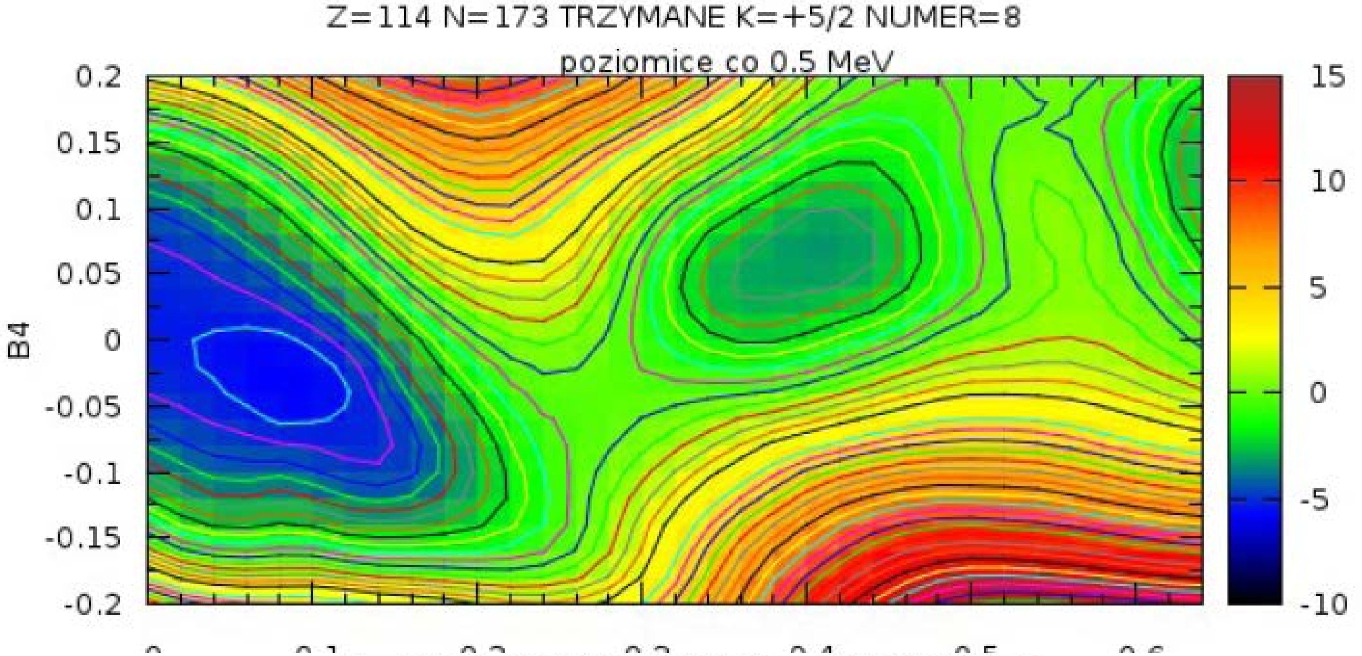
K-isomerism (discussion) !

FISSION HINDRANCE:

- T_{sf} for odd and odd-odd heavy and superheavy nuclei are by 3-5 orders longer than for their even-even neighbours.
- Increase was found for high-K isomers, with respect to (prolate) shape isomers on which they are built, in even 240Cm-244Cm.
- For SDO superheavy K-isomers two factors combine to increase fission half-life:
- A) the axial fission path is closed by the conservation of the K quantum number.
- B) triaxial barriers increase due to a decrease in pairing caused by the blocking of two neutrons or protons.
- C) additional hindrance of fission is expected for configurations involving blocked high-Omega intruder states.

ALPHA HINDRANCE:

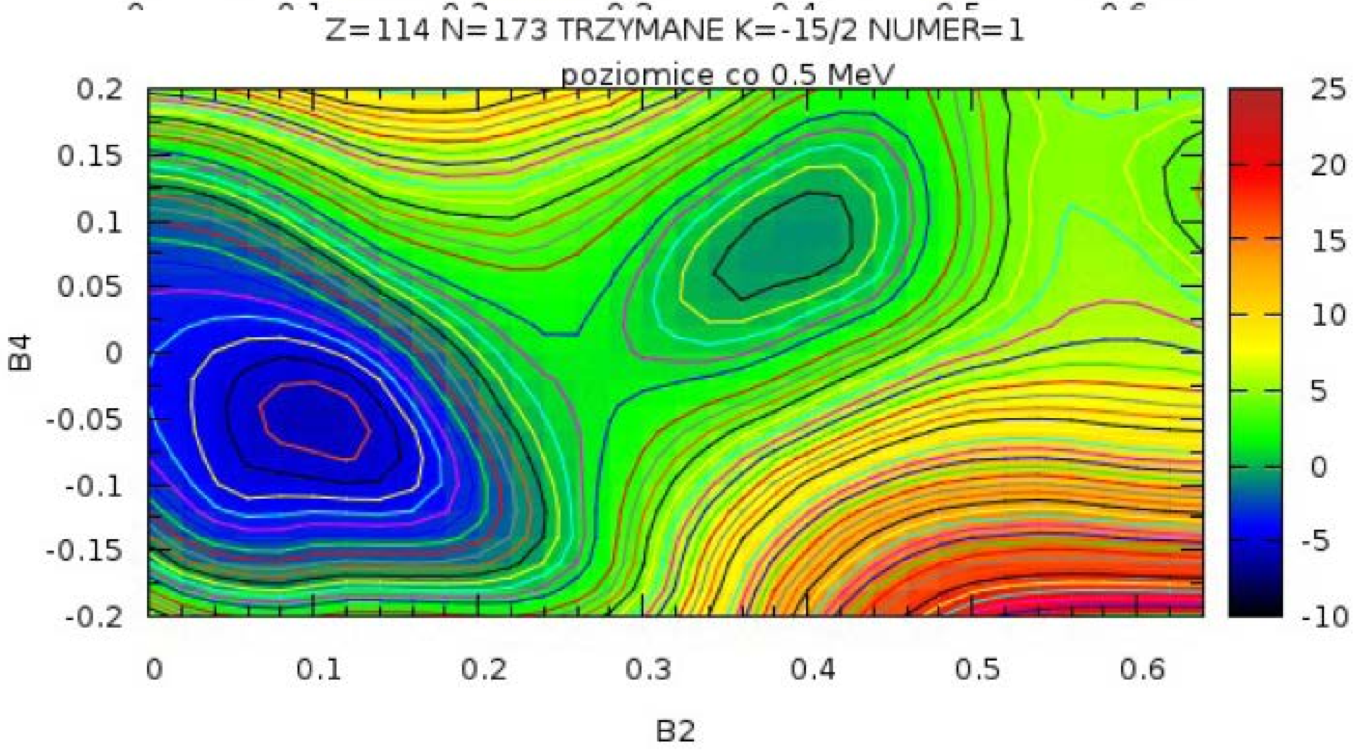
- High-K isomer in 270Ds has longer (partial) half-live T_{alpha}= 6.0 ms than the g.s., T_{alpha}(g.s.)=100 microsec.
- For SDO nuclei, an additional hindrance may result from a difference between the parent and daughter high-K configuration.
- Extra excitation in the daughter, leading to a smaller Q_{alpha}.



G.S. 5/2+

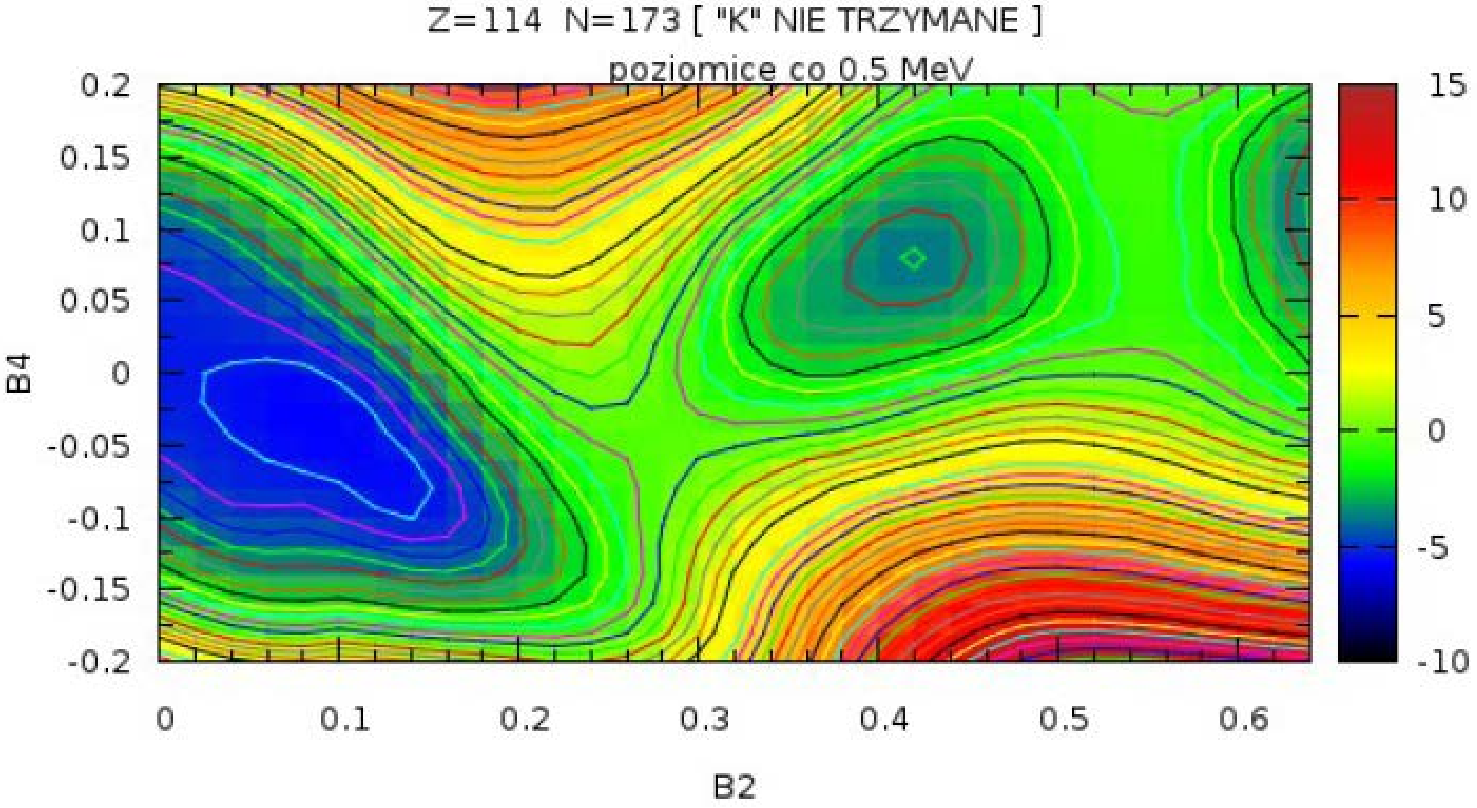
B=6.0 MeV

Fixed K



K=15/2-

B>10 MeV



K depending on the point – from energy minimization

B=5.7 MeV

Eight-Dimensional calculations of the third barrier in 232Th and a conflict between theory and experiment on uranium nuclei.

Status of third minimum in actinides:

Shallow minima

(0.5 MeV or less)

?

Deep minima

(3 - 4 MeV)

(a) Fission probability of ^{232}U as a function of the excitation energy. The result of the fitting procedure assuming five parabolas is indicated by a continuous line. (b) The potential energy of ^{232}U as a function of the quadrupole deformation parameter (β_2) obtained from the fitting procedure. Based on Csige et al. (2009)

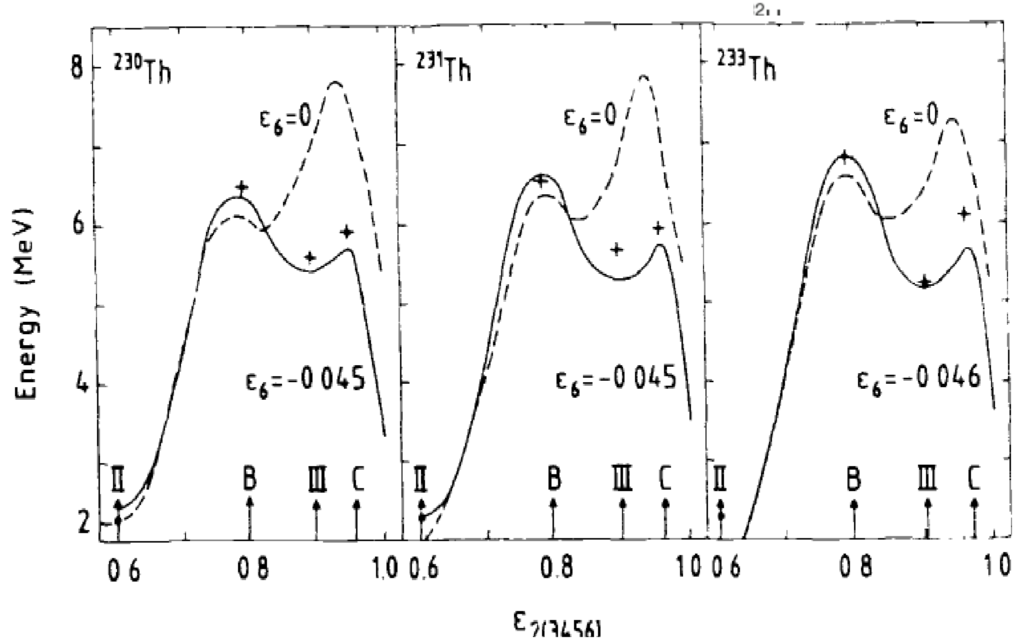
? ≠

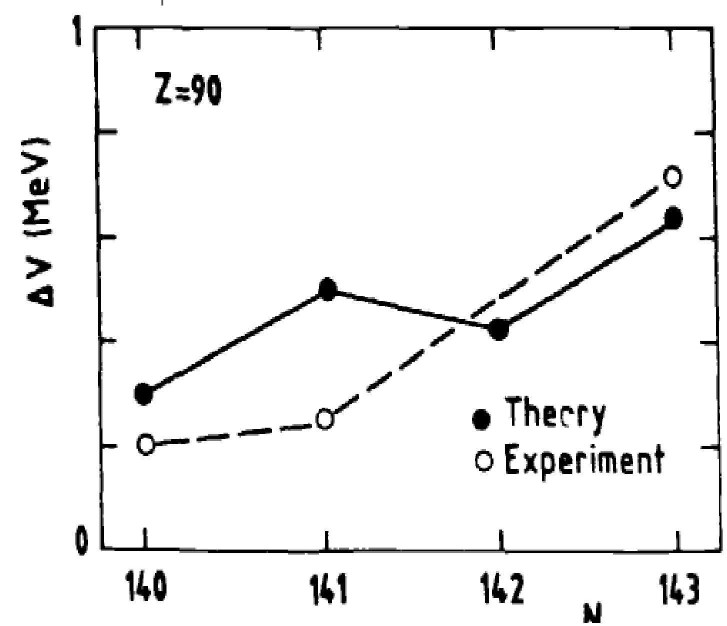
mac-mic model

S. • wiok et, al.

J.-P. Delaroche et al. / Nuclear Physics A 771 (2006) 103–168

ACTA PHYSICA POLONICA B





BLONS J.- PAYA D.
CEA Centre d'Etudes Nucleaires de Saclay, 91 - Gif-sur-Yvette
Dept. de Physique Nucleaire

Communication présentée à : International Conference on High Spin Physics and Gamma-Soft Nuclei

Pittsburg, PA (US)
17-21 Sep 1990

Importance of the subject

1. IIIrd minima in actinides, if exist, are low-spin hyperdeformed states (axis ratio close to 3:1)

maybe the only ones in both medium and heavy nuclei.

2. Their large quadrupole deformation & mass-assymetry makes them unique (collective E1 ca 10keV rotational transitions)
3. Experiments confirming predicted minima may validate nuclear models.
4. S.p. orbits at the Fermi level in super- and hyper-deformed actinides are those occupied at normal shape in SHN; they can provide a test of a model.

some facts supporting the existence of a deep third minimum

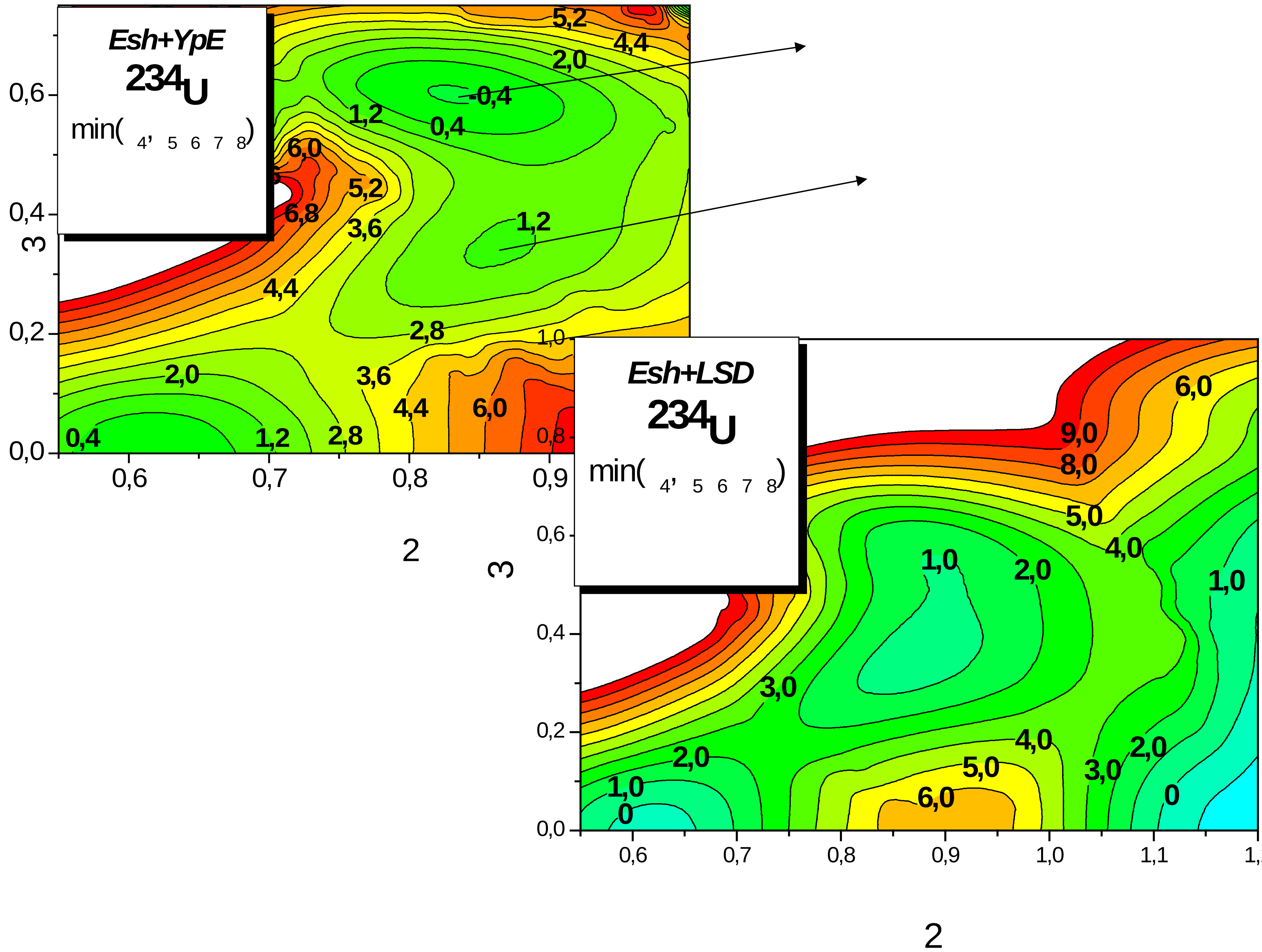
- the most of experimental evidence for a deep third well does not stem from global fits of fission probabilities where one may argue about parameters, but rather from transmission resonances of rotational bands that give quite direct information.
- measurements of the angular distribution of the fragments arising from the induced fission (including some information about the spin and K-quantum number).
- The rotational parameters obtained by fitting the high resolution excitation energy spectrum are characteristic for the HD shapes.
- Clustering phenomenon in the actinide region is a dramatic manifestation of the shell structure at the very large deformations. HD low laying states trapped in the III'd minimum may play the role of a doorway-like states before fission. Then only a limited number of fission paths can occur contributing to sharper mass distribution.

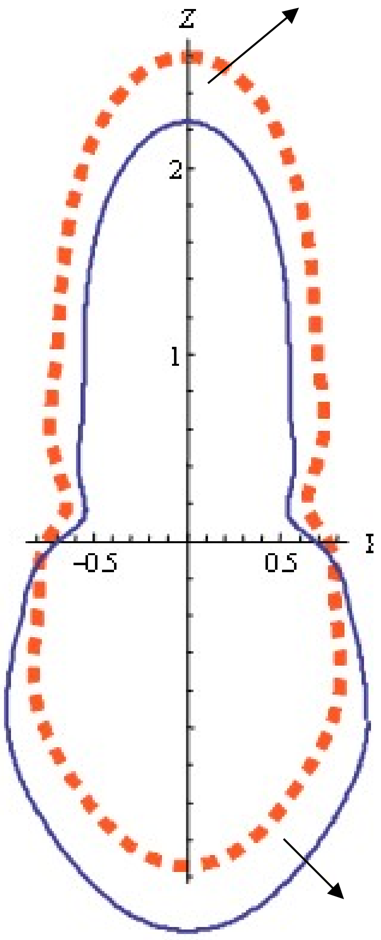
There is still no convincing evidence for discrete HD line - rotational bands.

Good methods should give similar predictions.

- Micro-macro, as a simpler one, is better tested/fitted against various data, eg. fission half-lives.

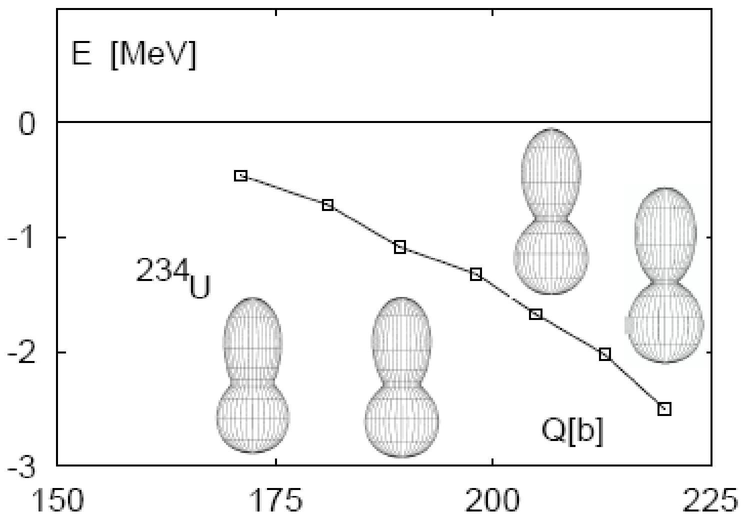
- Selfconsistent methods could (if constructed properly) give better extrapolations. But it is not guarateed at present. Hence, a prudent idea is to see whether both methods give similar results.


Esh+YpE
234U
min(4' 5 6 7 8)
Esh+LSD
234U
min(4' 5 6 7 8)
2
3



- The dipole deformation b1 is omitted there, as corresponding to a shift of the origin of coordinates which leaves energy (always calculated in the center of mass frame) invariant. However, this is true only for weakly deformed shapes. For large elongations, b1 acquires a meaning of a real shape variable.

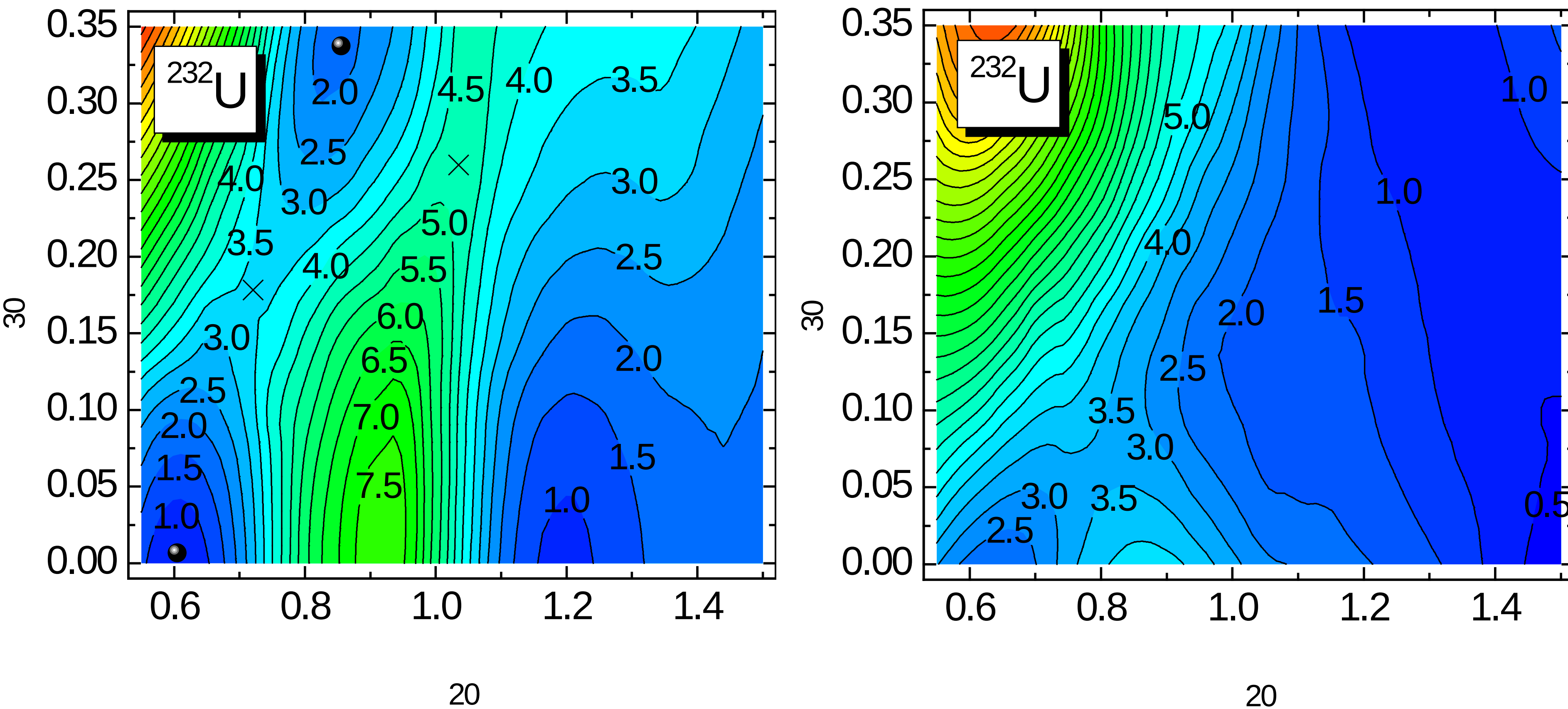
IIIrd minima – type: A



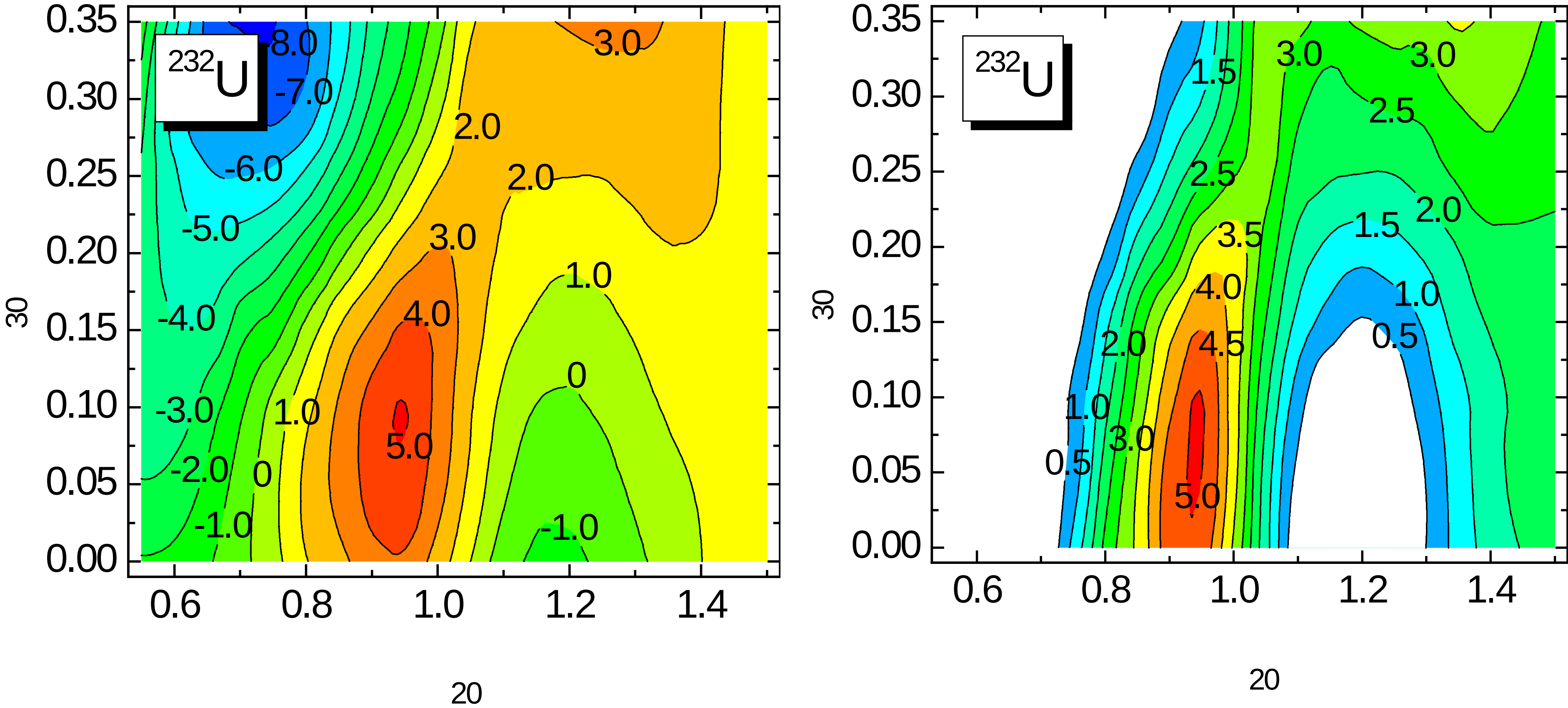
*M. Kowal, J. Skalski, PRC **85**, 061302(R) (2012)*

- minima with larger octupole deformations (A) have quadrupole moments Q=170 b, disturbingly close to the scission region.
- minima (A) are just intermediate congurations on the scission path, whose energy was calculated erroneously because of limitations of the admitted class of shapes.

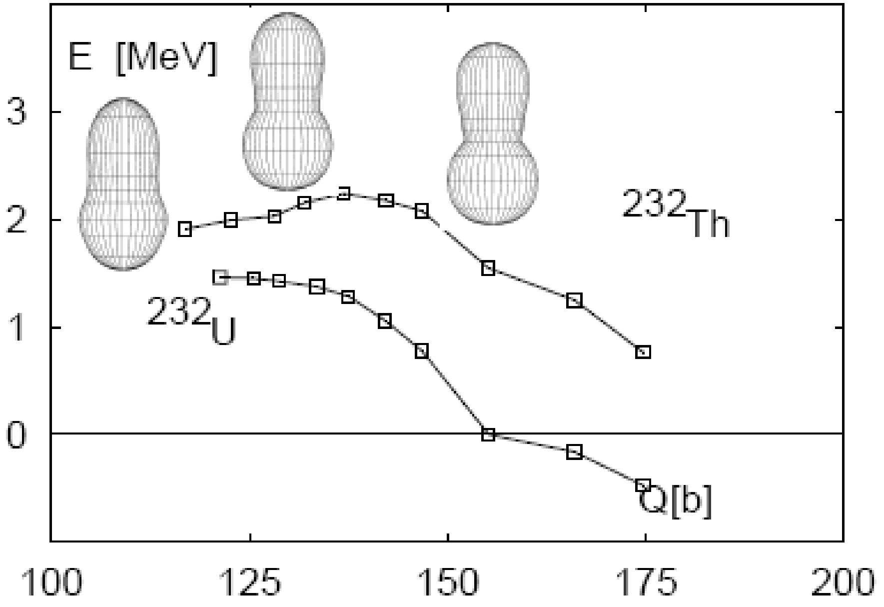
IIIrd minima – type: B



IIIrd minima – type: B

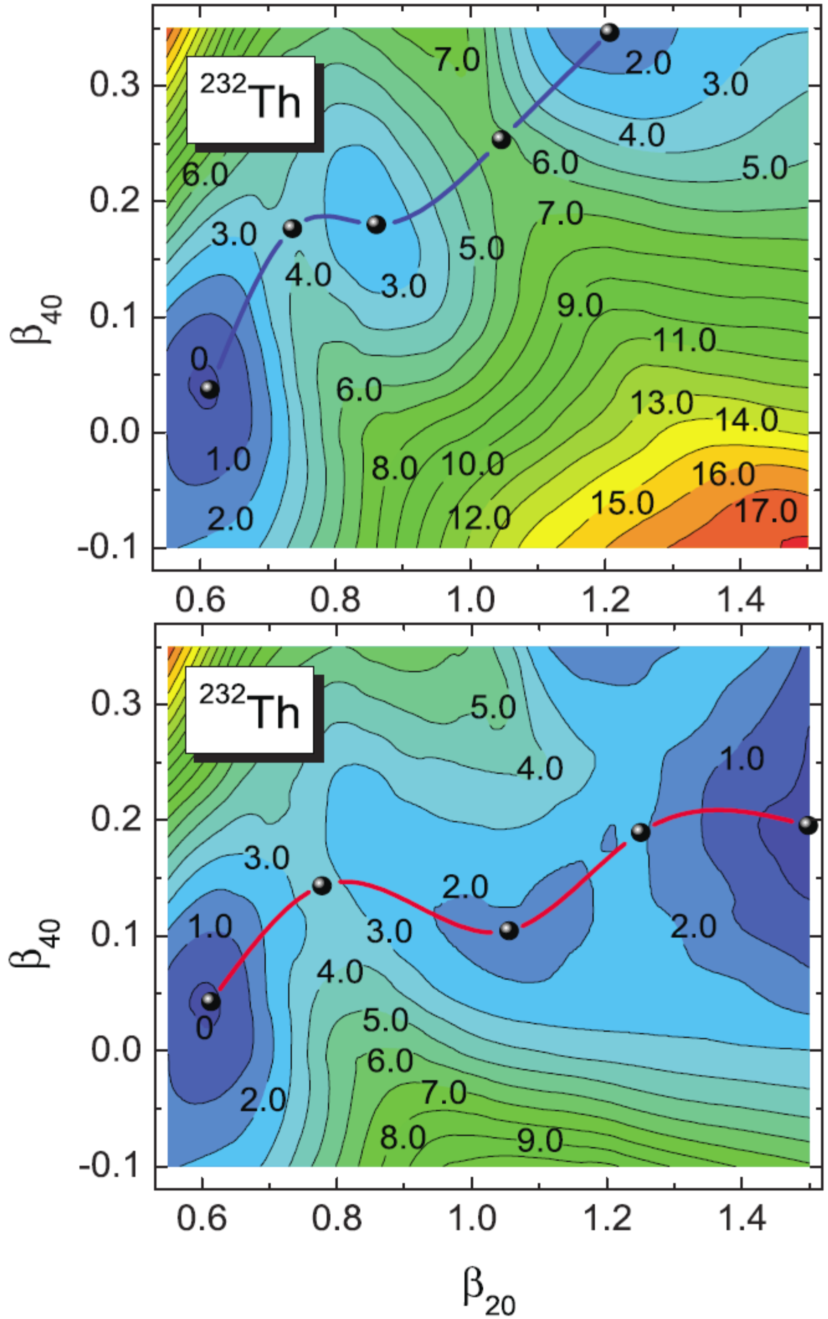


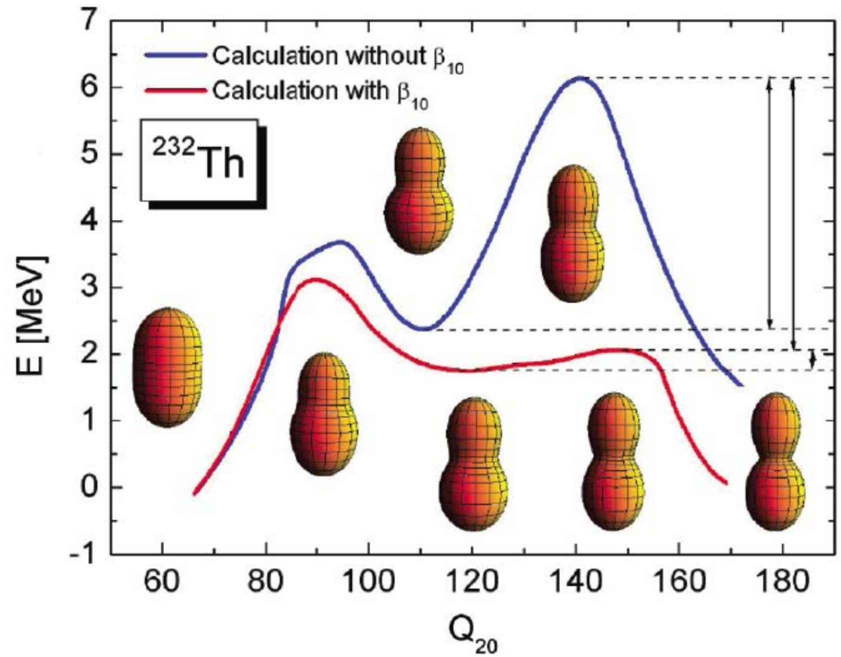
IIIrd minima – type: B



- the barrier vanishes in uranium and must be smaller than 330 keV in 232Th. The only other nonzero upper limit on the IIIrd barrier of 200 keV we nd in 230Th.

IIIrd minima – type: B





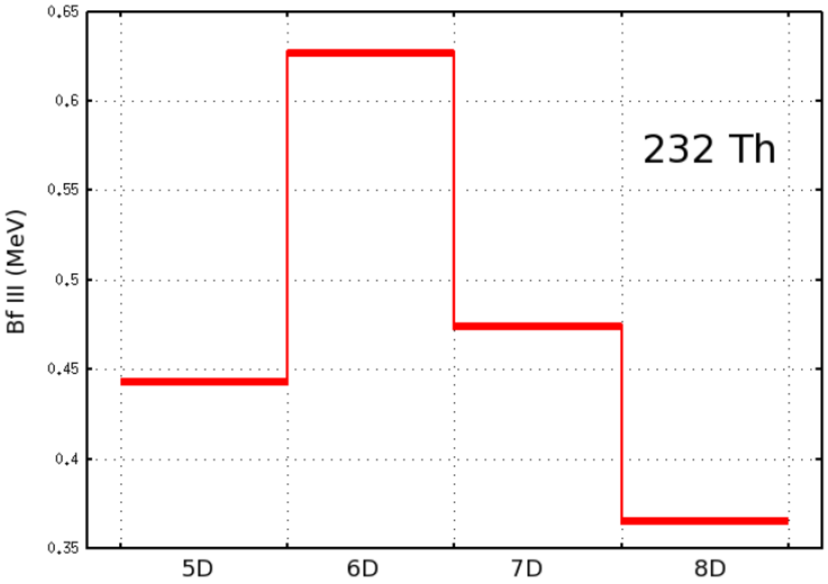
Isotope	M^{theor} / M^{expt}	$B_{\text{I}}^{\text{theor}}$ / $B_{\text{I}}^{\text{expt}}$	$E_{\text{II}}^{\text{theor}}$ / $E_{\text{II}}^{\text{expt}}$	$B_{\text{II}}^{\text{theor}}$ / $B_{\text{II}}^{\text{expt}}$	$E_{\text{III}}^{\text{theor}}$ / $E_{\text{III}}^{\text{expt}}$	$B_{\text{III}}^{\text{theor}}$ / $B_{\text{III}}^{\text{expt}}$
^{232}Th	35.33	4.4	2.2	6.1	4.1	4.4
[29]	35.45	5.8		6.7 (6.2)		
[31,32]		5.2 (4.6)	2.4	6.6	2.8	7.0
^{232}U	34.34	4.5	3.2	5.7	0.0	0.0
[29]	34.61	5.4		5.4 (5.3)		
[30]		4.0	3.1	4.9	3.2	6.0

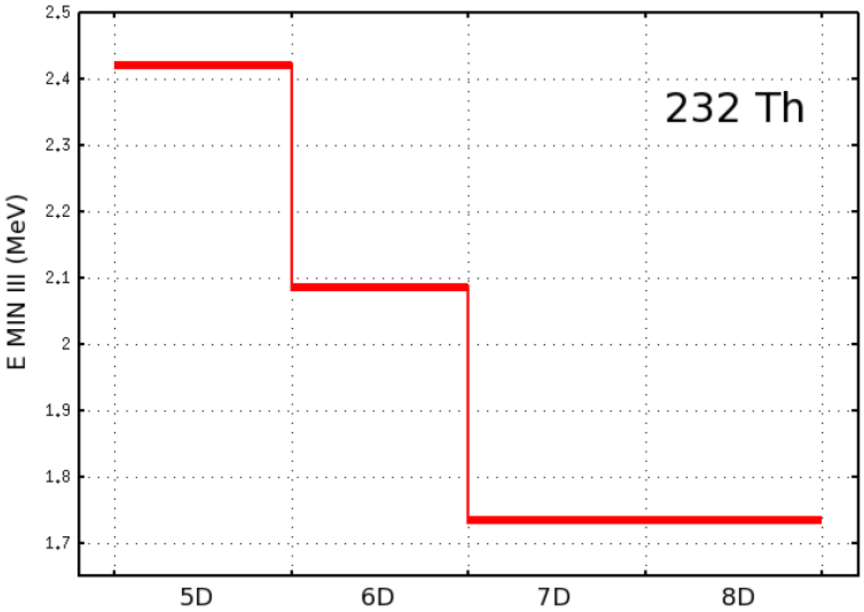
P. Jachimowicz, M. Kowal, J. Skalski,

PRC **87**, 044308 (2013)

IIIrd saddle from the mesh 5D-8D;

8D mesh (beta1-beta8) – 50803200 points!





Status of third minimum in actinides:

Shallow minima
(0.5 MeV or less)

?

Deep minima
(3 - 4 MeV)

Theory:

self-consistent models = **mac-mic model P. Moller et, al.** $\neq$? **mac-mic model S. • wiok et, al.**

||　　　　　　||

Experiment:

Blons et, al. (231,232,233Th) $\neq$? **Debrecen-Munich (232,234,236U)**

Present status of IIIrd minima in actinides; How deep? Do they exist?

- We have presented, for the firs time, full 8D hyper-cube calculation for 232Th (till now only 5-dimensional macroscopic-microscopic calculations of fission saddles were available in the literature). To find the third barrier on such giant grid IWF method has been applied. After proper inclusion of dipole deformation deep of third minimum is only about 300 KeV what rather will not allow to trap the states and carry out the spectroscopic studies.

  At present no predictions of deep IIIrd minima;

- Including a dipole distortion lowers the third saddle by more than 4 MeV. It seems likely that, with the shape parametrization, the dipole deformation is important everywhere, where large elongation and necking is combined with a sizable mass asymmetry. For example, it may be the case of the Poinare shape transition at high spins in medium-heavy nuclei.

- In 232,230Th shallow minima – (old) experiment & theory consistent;

- Uranium nuclei: predictions conflicting experimental results.

how to solve the problem ? (prospects for the future)

- Other data interpretation?

  Assuming, that the existing resonances can not be interpreted otherwise, all current meaningful theoretical models must be reconstructed anew to give appropriate hyperdeformed deep III minima.
- Theory change? - Possibilities for theory:

 - Rotation ? ; Temperature?

 - Importance of beyond-mean-field effects?

- New experimental study dedicated to hyperdeformation in 232Th is essential for understanding of existence of third minima in all actinides nuclei. Particularly promising are experiments employing highly monochromatic gamma-ray beams for photofission studies. With a high quality of photon and spectral intensity, exceeding the performance of existing facilities by several orders of magnitude seems to be possible in the near future (ELI – Project)

if the result of Blons et al is confirmed, we will have to understand why between 232Th and 232U, two beta decays away, the energy landscape changes so dramatically.

if in the future experiment, a depth of the IIIrd minimum is obtained similar as that in 232U, we will have a total contradiction between theory and experiment.

Bibliography (latest articles)

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M. Kowal, J. Skalski, ” *Examination of the existence of third, hyperdeformed minima in actinide nuclei***”,** PHYSICAL REVIEW C **85**, 061302(R) (2012).

P. Jachimowicz, M. Kowal, J. Skalski,” *Eight-dimensional calculations of the third barrier in 232Th***”,** PHYSICAL REVIEW C **87**, 044308 (2013).

T. Ichikawa, P. Moller, and A. J. Sierk, ”*Character and prevalence of third minima in actinide fission barriers”***,** PHYSICAL REVIEW C **87**, 054326 (2013).

J. D. McDonnell,W. Nazarewicz, and J. A. Sheikh,”*Third minima in thorium and uranium isotopes in a self-consistent theory*” PHYSICAL REVIEW C **87**, 054327 (2013).

- Experiment:

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