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Bariery rozszczepieniowe najcięższych jąder

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Instytut Problemów Jądrowych

I. Wstęp
II. Metoda obliczeń
III. Przestrzeń deformacji
IV. Wyniki i dyskusja
    1. Deformacja jądra w punktach równowagi i siodłowym oraz jej wpływ na Bf
    2. Efekt struktury powłokowej na energię pot. jądra w punktach równowagi i siodłowym
V. Wnioski

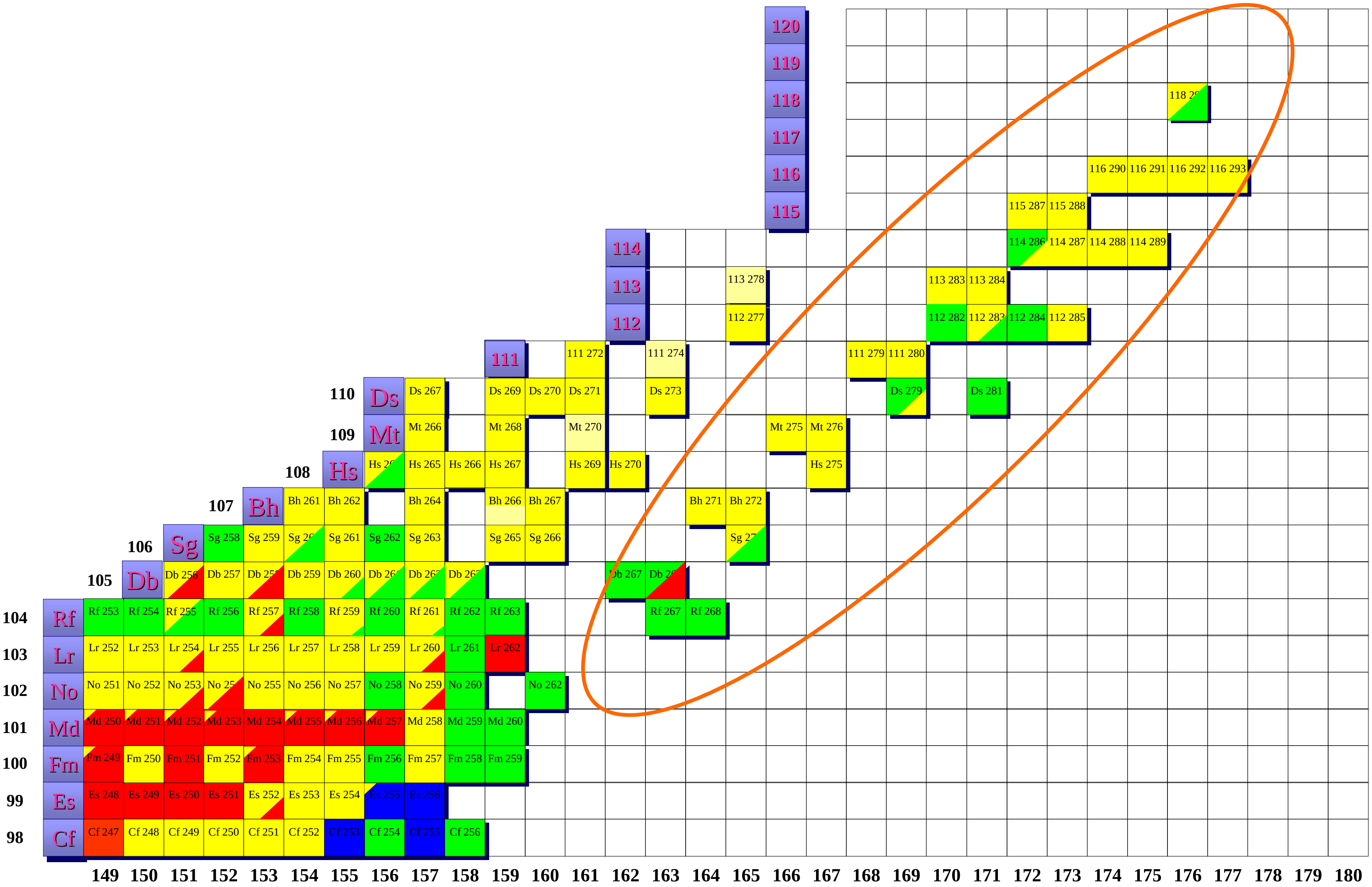
I. Introduction

1. **Two main problems with heaviest nuclei (HN):**
   - **cross sections σ (~1 pb $\rightarrow$ ~50 fb) $\leftarrow$ B_f^{st}**
   - **half-lives**

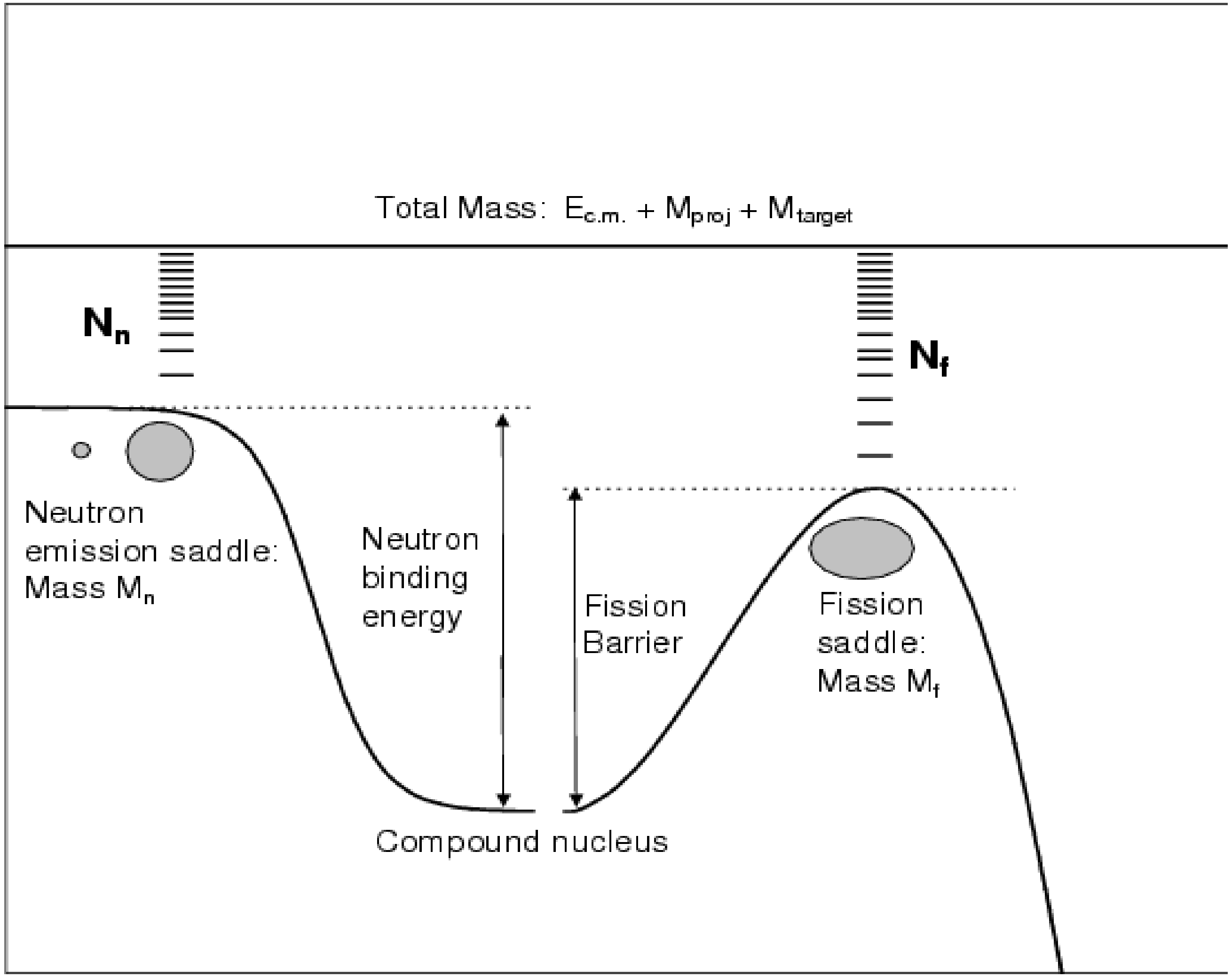
2. **Present state of HN** **(map of HN)**

3. **Role of B_f^{st}** **-**
   - **sensitivity of σ to B_f^{st}**
   - **a need for a large accuracy of B_f^{st}**

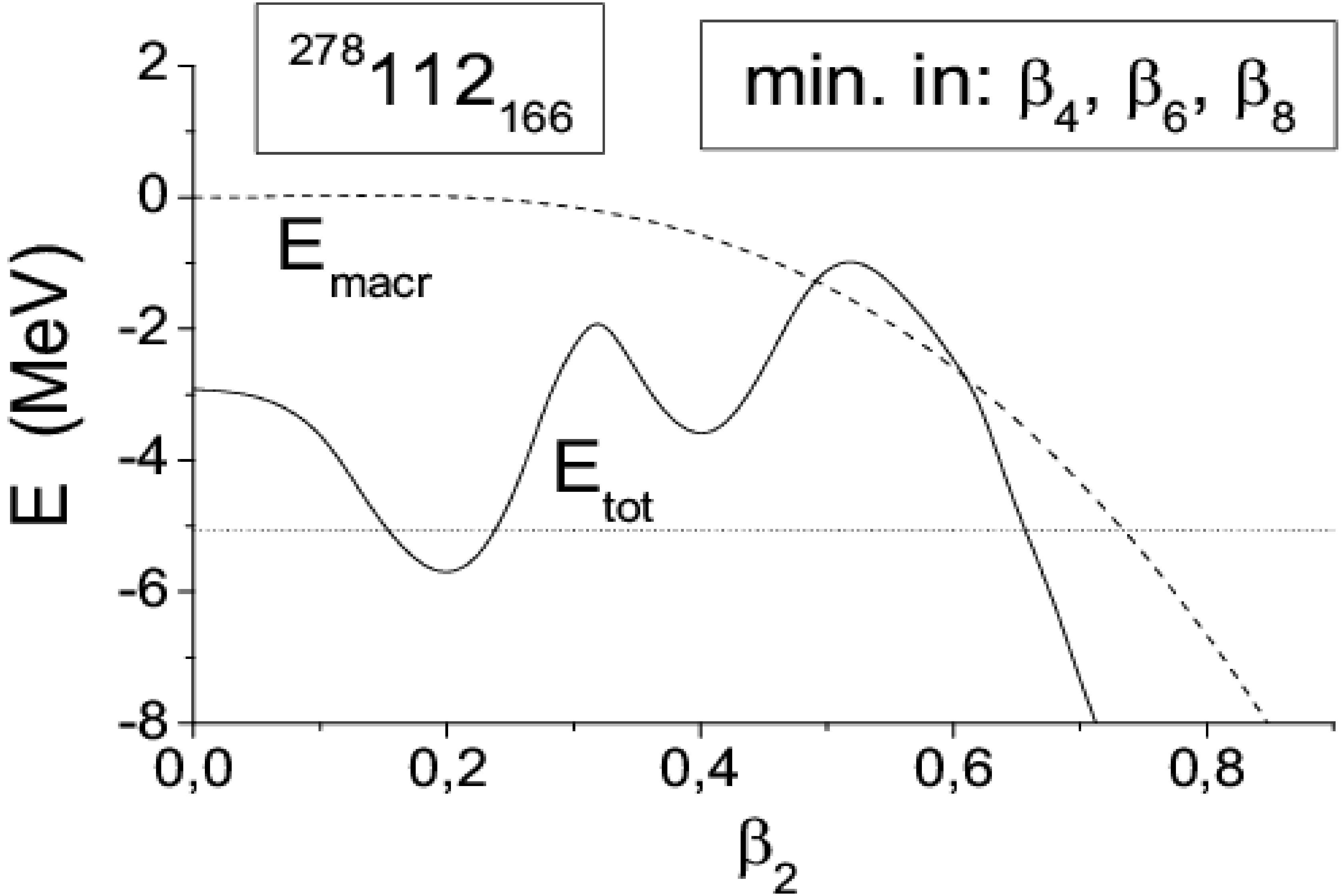
4. **Two configurations important for B_f^{st}**
   - **eq. and s.p.** **(example of fission barrier)**



120
119
118
117
116
115
114
113
112
111
110 Ds
109 Mt
108 Hs
107 Bh
106 Sg
105 Db
104 Rf
103 Lr
102 No
101 Md
100 Fm
99 Es
98 Cf
149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180
116 290 116 291 116 292 116 293
115 287 115 288
114 287 114 288 114 289
113 278 113 283 113 284
112 277 112 282 112 284 112 285
111 272 111 274 111 279 111 280
Ds 267 Ds 269 Ds 270 Ds 271 Ds 273 Ds 279 Ds 281
Mt 266 Mt 268 Mt 270 Mt 275 Mt 276
Hs 265 Hs 266 Hs 267 Hs 269 Hs 270 Hs 275
Bh 261 Bh 262 Bh 264 Bh 266 Bh 267 Bh 271 Bh 272
Sg 258 Sg 259 Sg 261 Sg 262 Sg 263 Sg 265 Sg 266
Db 256 Db 257 Db 259 Db 260 Db 267
Rf 253 Rf 254 Rf 255 Rf 256 Rf 257 Rf 258 Rf 259 Rf 260 Rf 261 Rf 262 Rf 263 Rf 267 Rf 268
Lr 252 Lr 253 Lr 254 Lr 255 Lr 256 Lr 257 Lr 258 Lr 259 Lr 260 Lr 261 Lr 262
No 251 No 252 No 253 No 255 No 256 No 257 No 258 No 259 No 260 No 262
Md 250 Md 251 Md 252 Md 253 Md 254 Md 255 Md 256 Md 257 Md 258 Md 259 Md 260
Fm 249 Fm 250 Fm 251 Fm 252 Fm 253 Fm 254 Fm 255 Fm 256 Fm 257 Fm 258 Fm 259
Es 248 Es 249 Es 250 Es 251 Es 252 Es 253 Es 254 Es 255 Es 256
Cf 247 Cf 248 Cf 249 Cf 250 Cf 251 Cf 252 Cf 253 Cf 254 Cf 255 Cf 256



Total Mass: $E_{c.m.} + M_{proj} + M_{target}$
N_n
N_f
Neutron emission saddle: Mass M_n
Neutron binding energy
Fission Barrier
Fission saddle: Mass M_f
Compound nucleus



The barrier: thin but high,
created totally by shell effects

$$
\begin{aligned}
R(\vartheta,\varphi) = R_0 \{1 \; & + \beta_2 \left[\cos\gamma_2 \mathrm{Y}_{20} + \sin\gamma_2 \mathrm{Y}_{22}^{(+)}\right] \\
& + \beta_4 \mathrm{Y}_{40} + \beta_6 \mathrm{Y}_{60} + \beta_8 \mathrm{Y}_{80} \\
& + \; \beta_3 \mathrm{Y}_{30} + \beta_5 \mathrm{Y}_{50} + \beta_7 \mathrm{Y}_{70} \} \, ,
\end{aligned}
$$

II. Method

Macro-micro (same as used for description of many properties of HN)

Etot = Emacr + Emicr

Emacr = Yukawa + exp
Emicr = shell corr.

III. Deformation space

1. **As large as possible**
2. **Larger space, better description of the properties**

   (e.g. mass, especially B_f^{st} and T_{sf})
3. **Specification of the space: axial, non-axial and reflection-asymmetric shapes included**

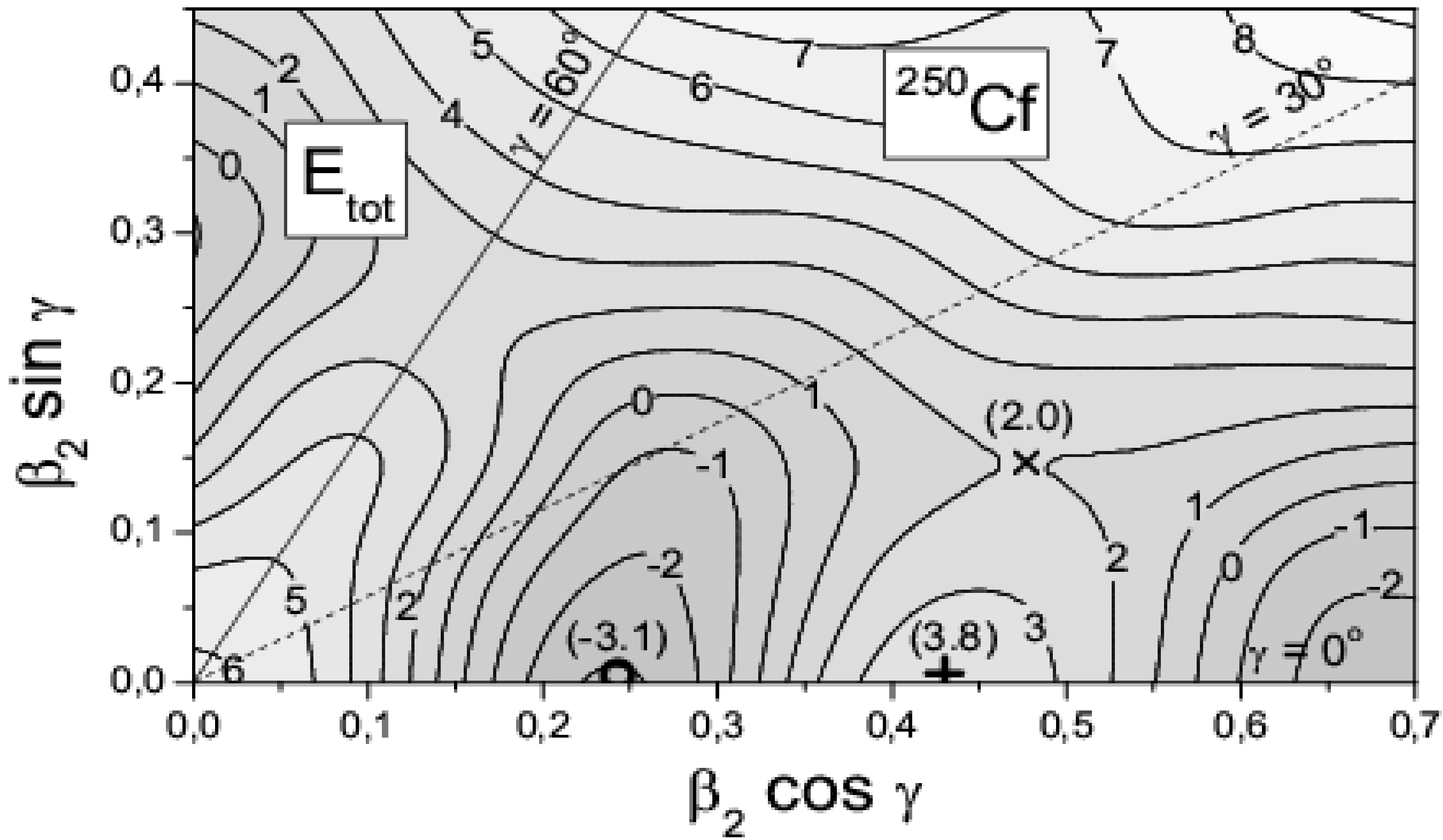
IV. Results

1. Examples of the potential energy maps: 250Cf, 262Sg
   - axial sym. of eq. conf.
   - generally non-axial s.p. shapes
   - effect of non-axiality may be large

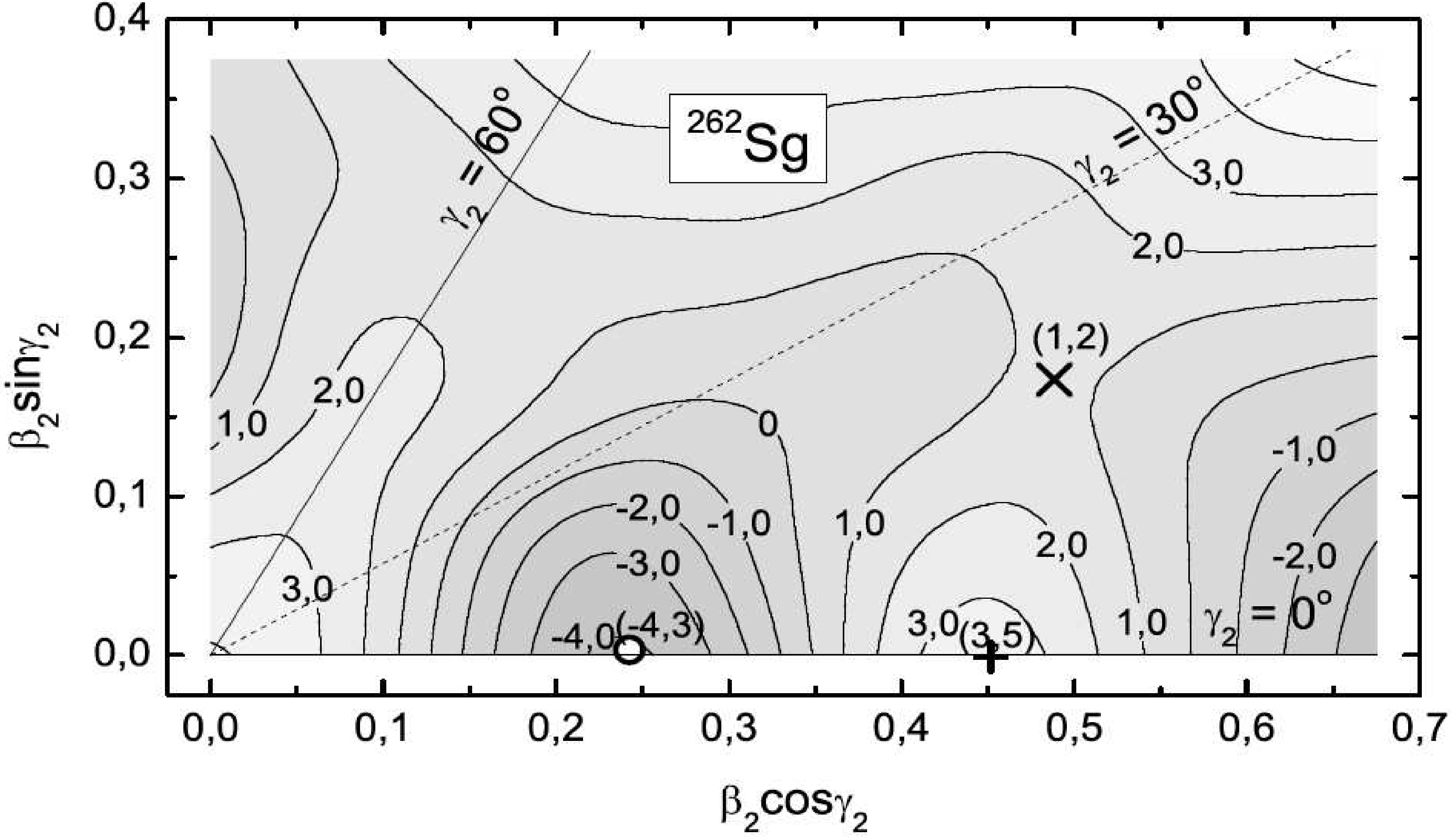
2. Shapes at eq. and s.p. conf.

3. Shell correction
   - at eq. conf.
   - at s.p. conf. (although smaller than at eq., it is still large,
     up to about 2.5 MeV)

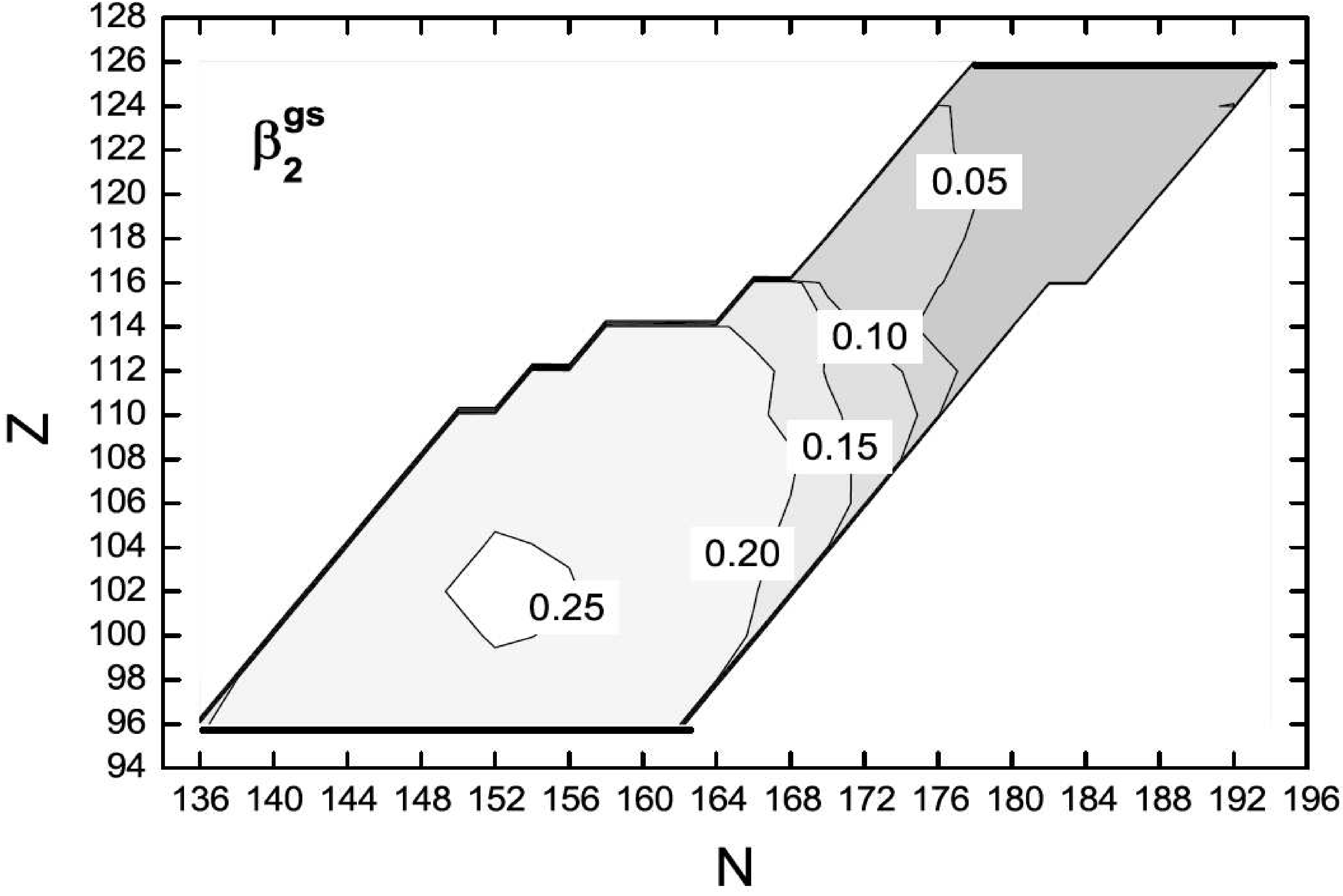
-



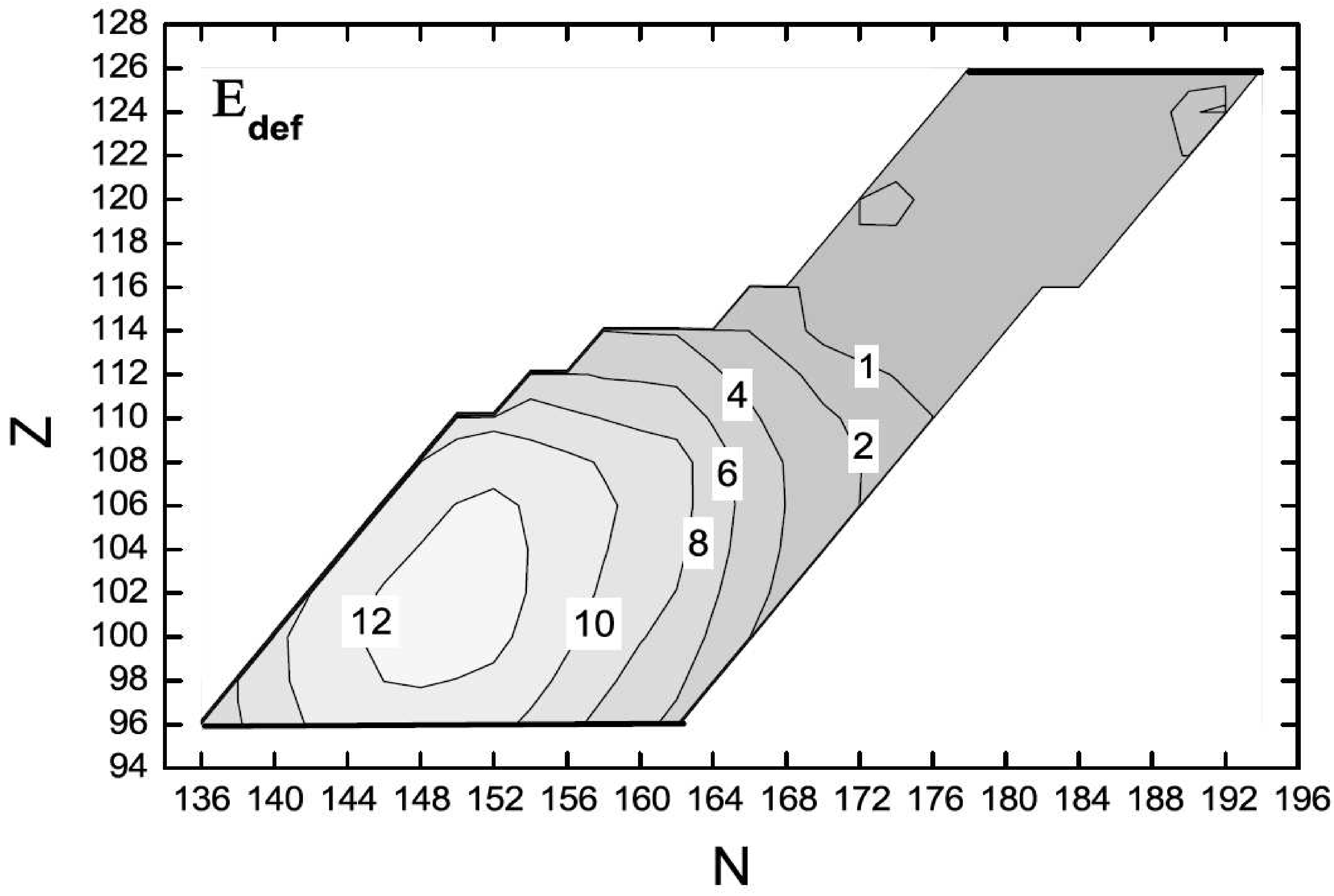
E_tot
250Cf
β2 sin γ
β2 cos γ
γ = 60°
γ = 30°
γ = 0°
(2.0)
(-3.1)
(3.8)



0,4
0,3
0,2
0,1
0,0
$\beta_2\sin\gamma_2$
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
$\beta_2\cos\gamma_2$
^{262}Sg
$\gamma_2 = 60°$
$\gamma_2 = 30°$
$\gamma_2 = 0°$
3,0
2,0
2,0
1,0
2,0
0
(1,2)
-1,0
-2,0
-1,0
1,0
2,0
-2,0
-3,0
3,0
-4,0
(-4,3)
3,0
(3,5)
1,0



β_2^{gs}
0.05
0.10
0.15
0.20
0.25
Z
N
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
136
140
144
148
152
156
160
164
168
172
176
180
184
188
192
196



E_def
12
10
8
6
4
2
1
Z
N
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
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136
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184
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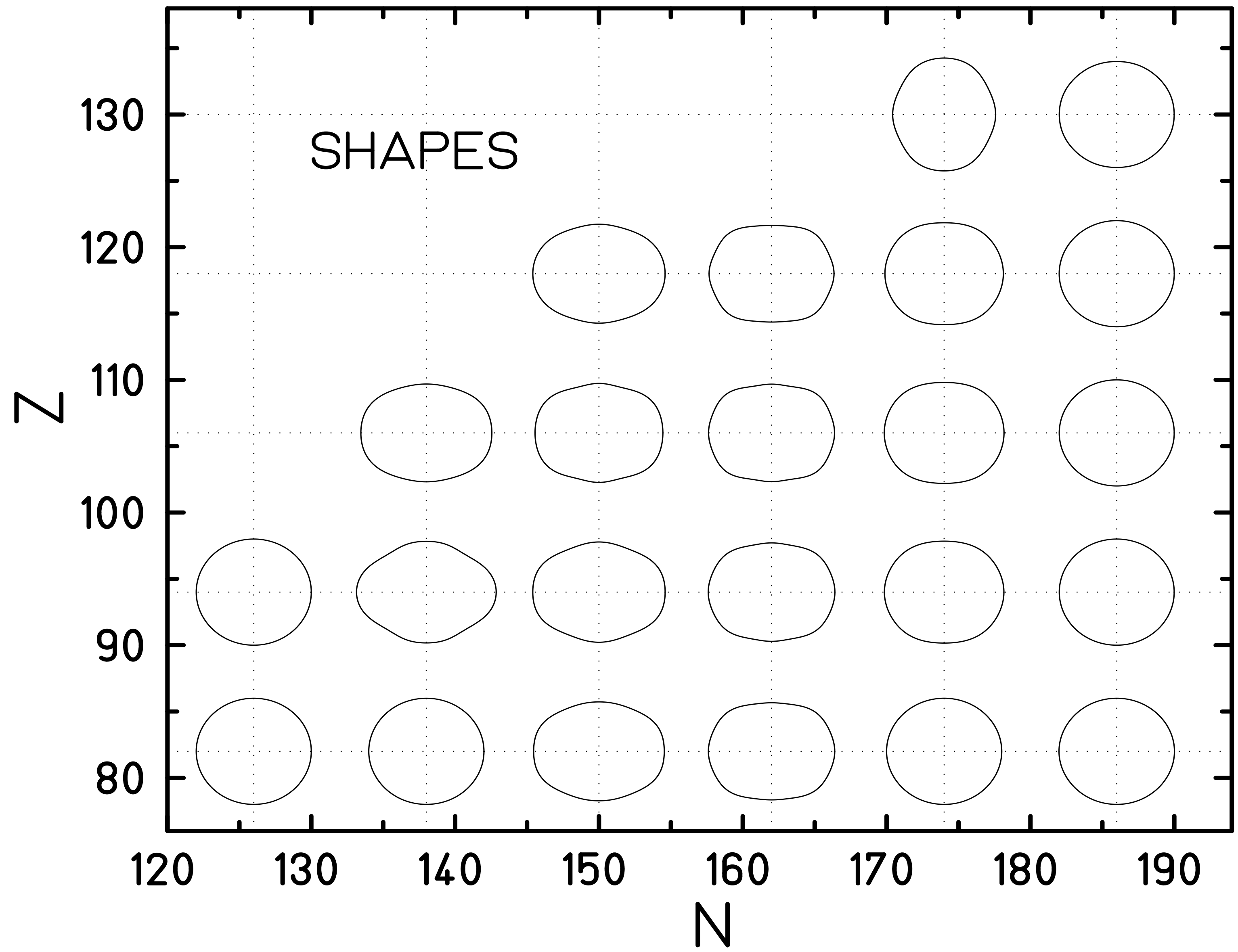
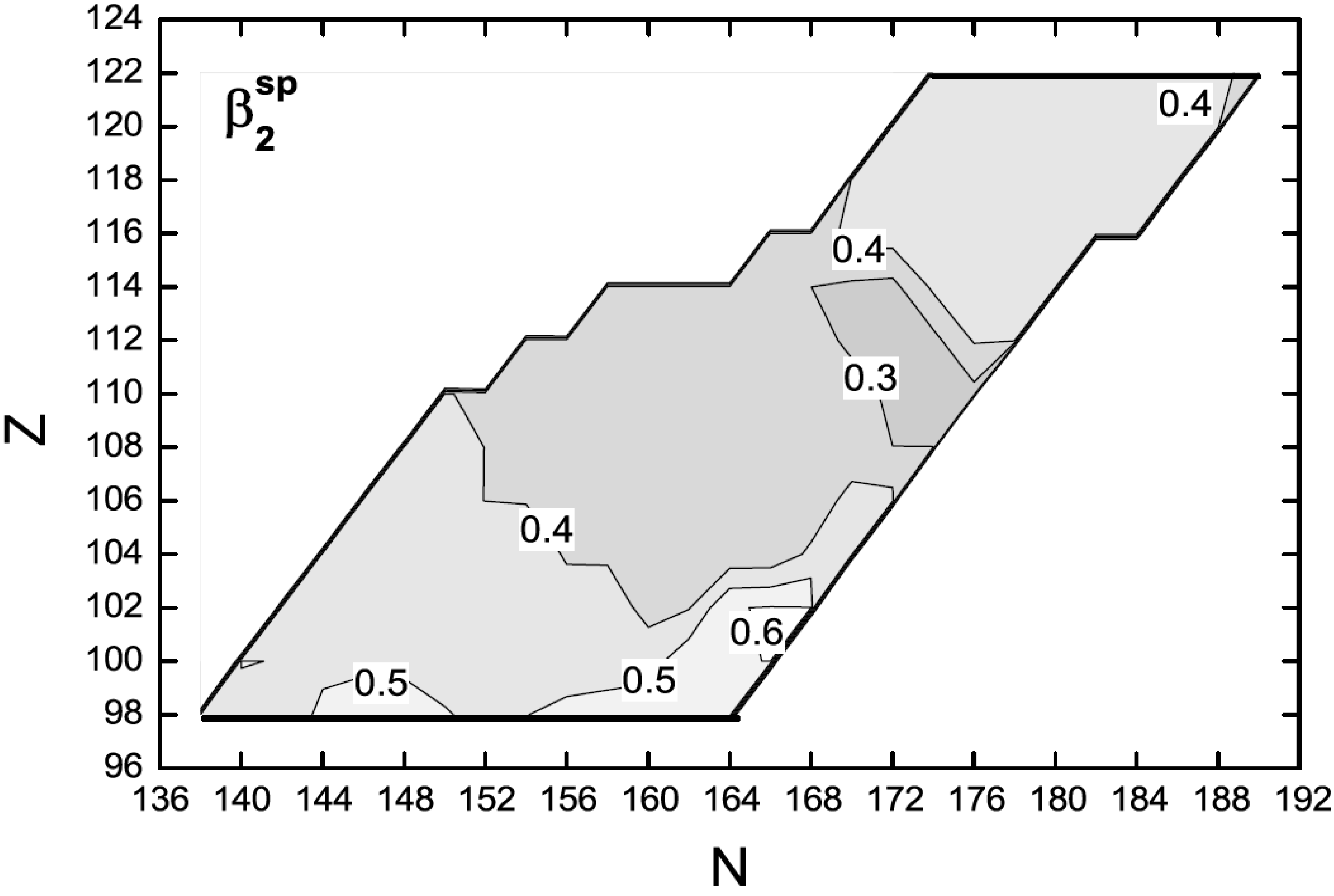
192
196


SHAPES
Z
N
130
120
110
100
90
80
120
130
140
150
160
170
180
190



β_2^{sp}
0.4
0.4
0.3
0.4
0.6
0.5
0.5
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
136
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144
148
152
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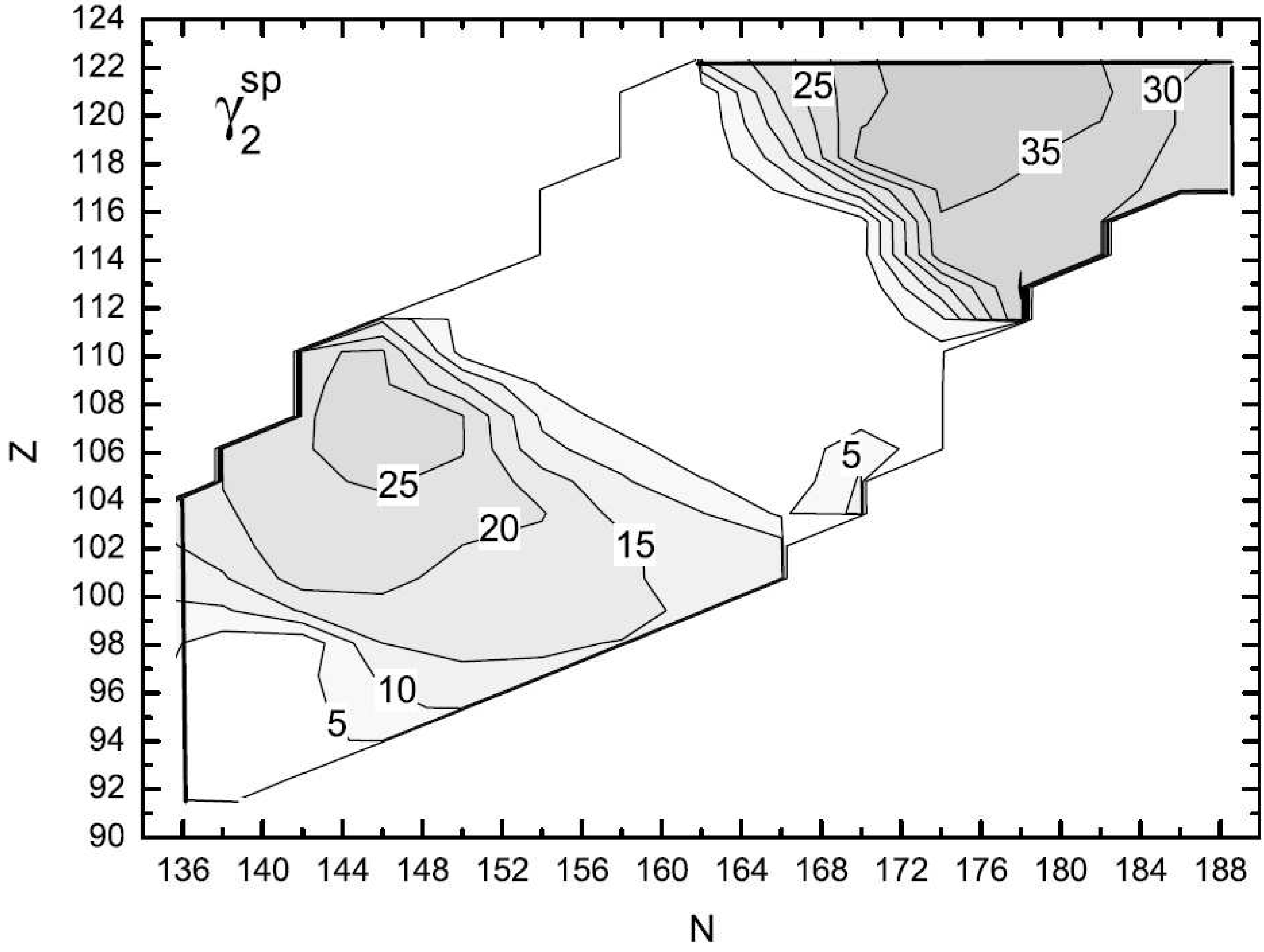
164
168
172
176
180
184
188
192



γ_2^{sp}
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
136
140
144
148
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164
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15
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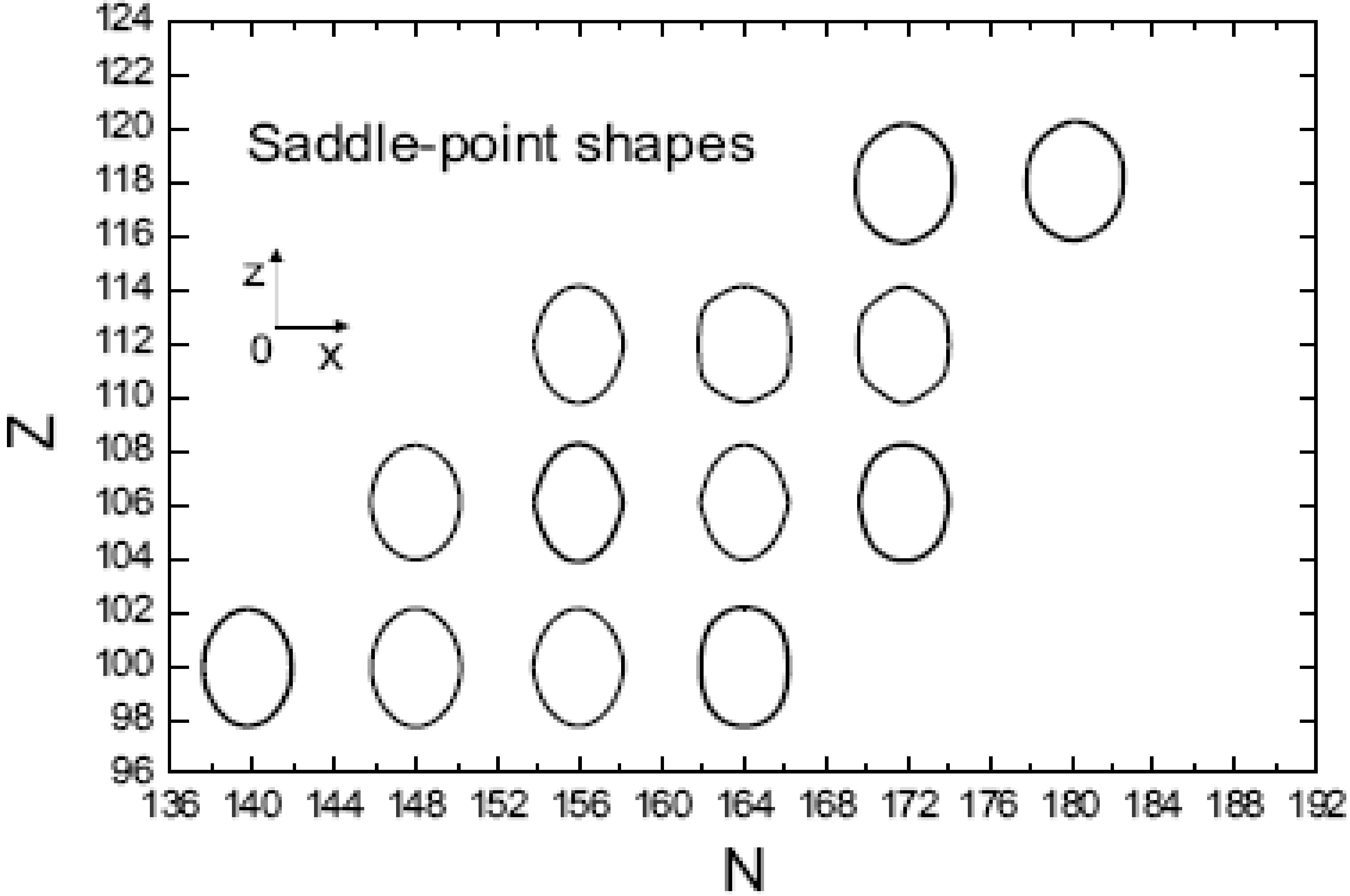
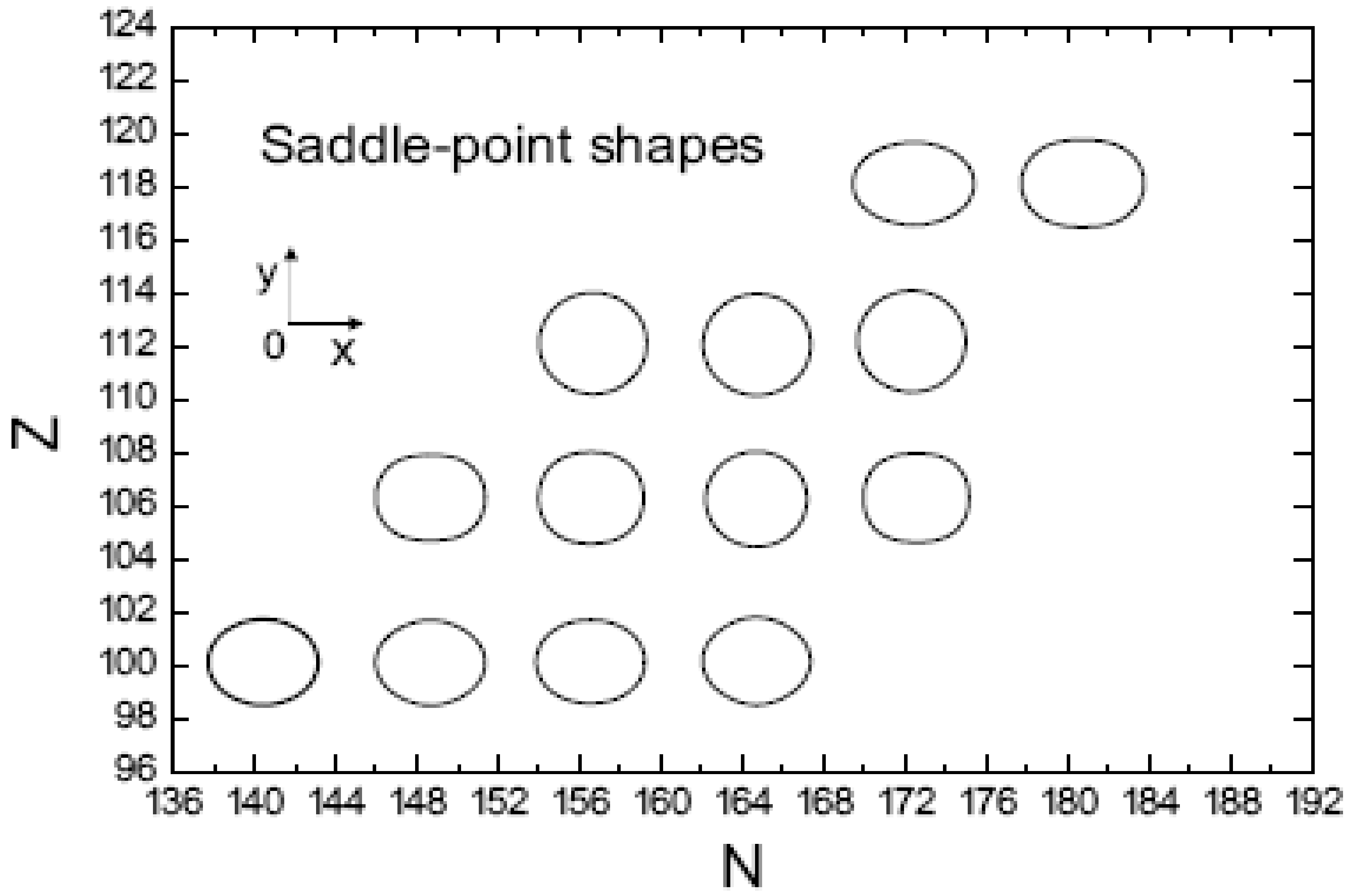
5
5



Saddle-point shapes
z
0
x
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
136
140
144
148
152
156
160
164
168
172
176
180
184
188
192


Saddle-point shapes
y
0
x
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
136
140
144
148
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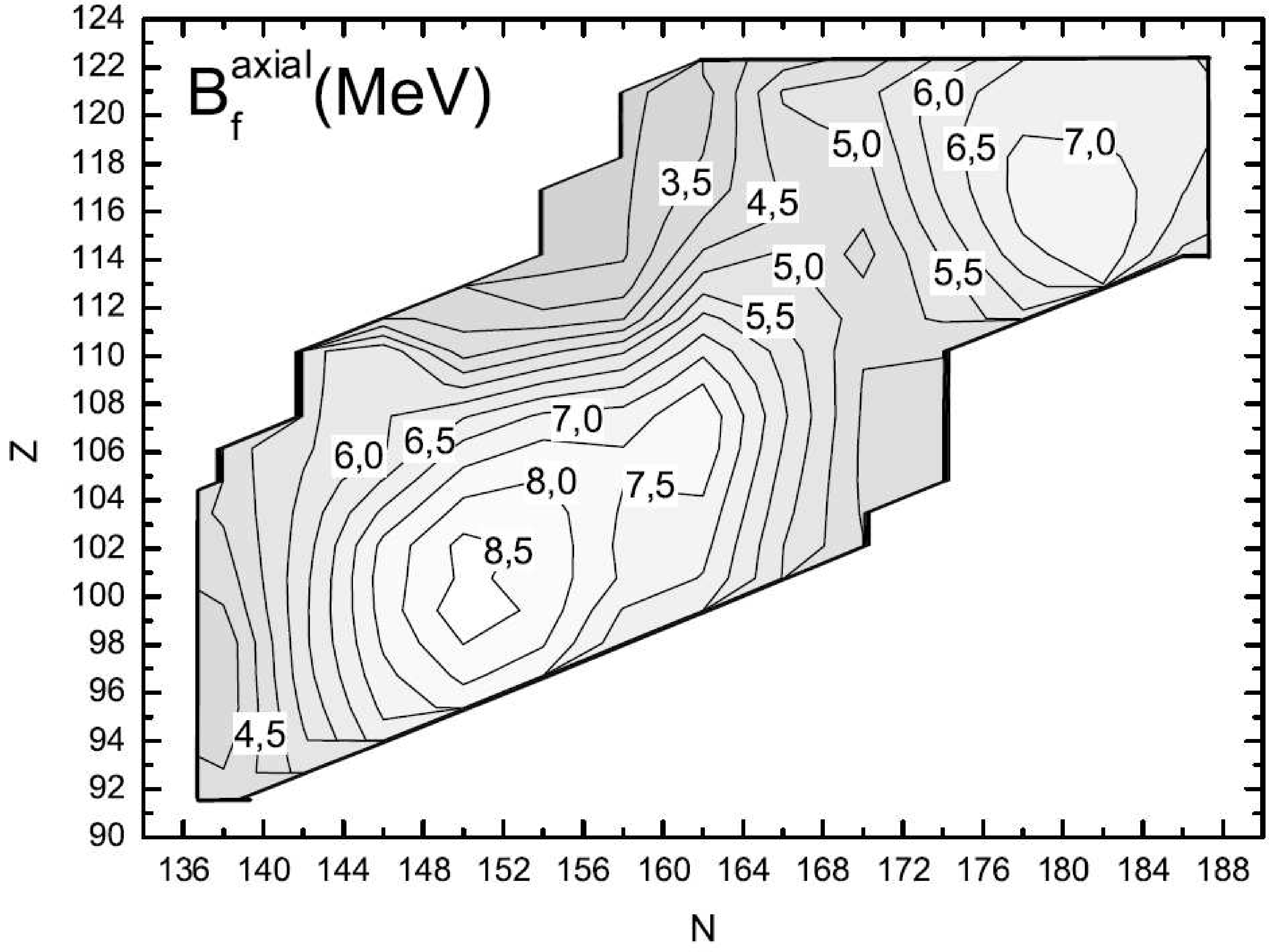
192



B_f^{axial}(MeV)
3,5
4,5
5,0
5,0
5,5
5,5
6,0
6,5
7,0
6,0
6,5
7,0
7,5
8,0
8,5
4,5
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
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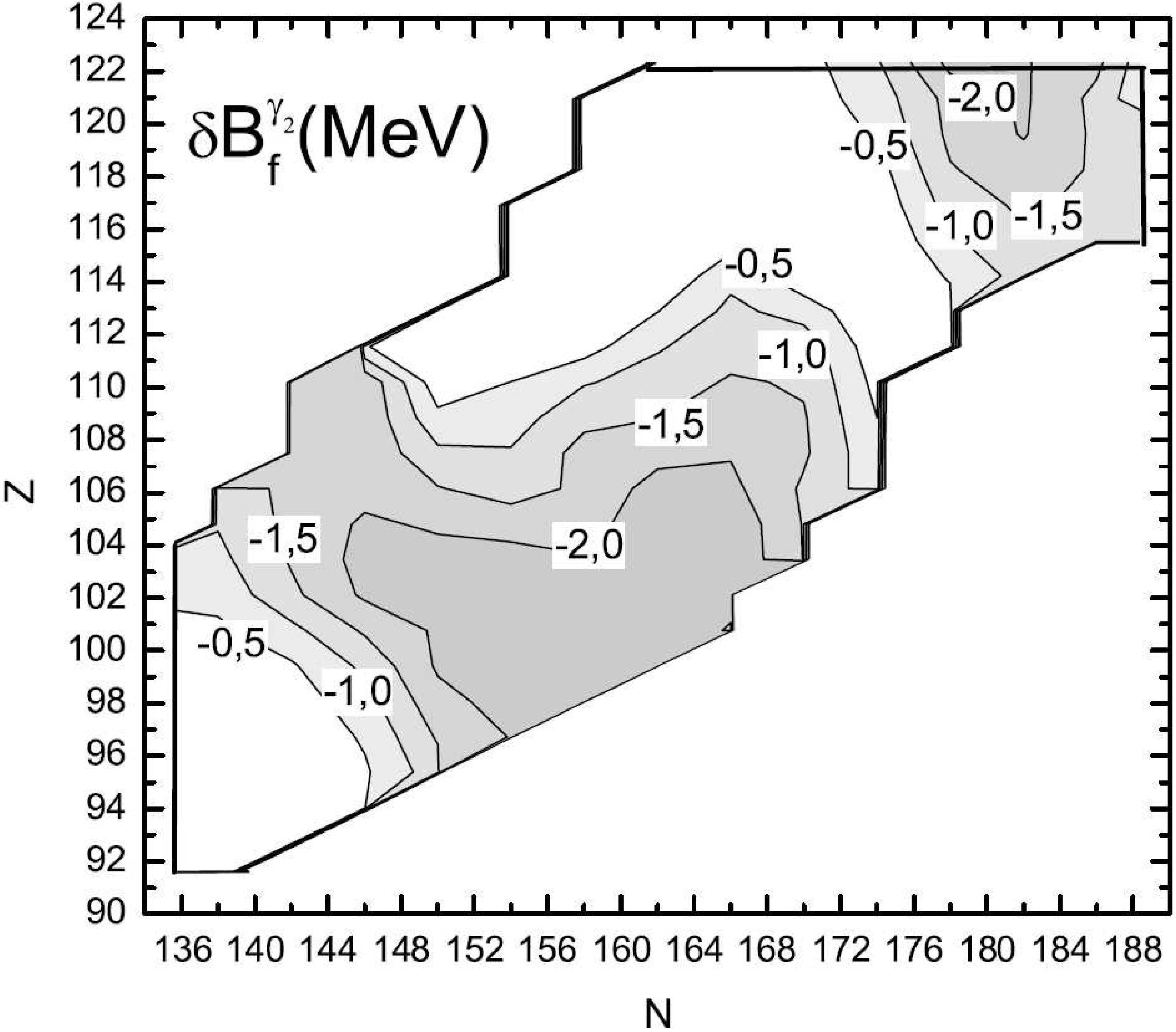
δB_f^γ2 (MeV)
-2,0
-0,5
-1,0
-1,5
-0,5
-1,0
-1,5
-2,0
-1,5
-0,5
-1,0
Z
N
124
122
120
118
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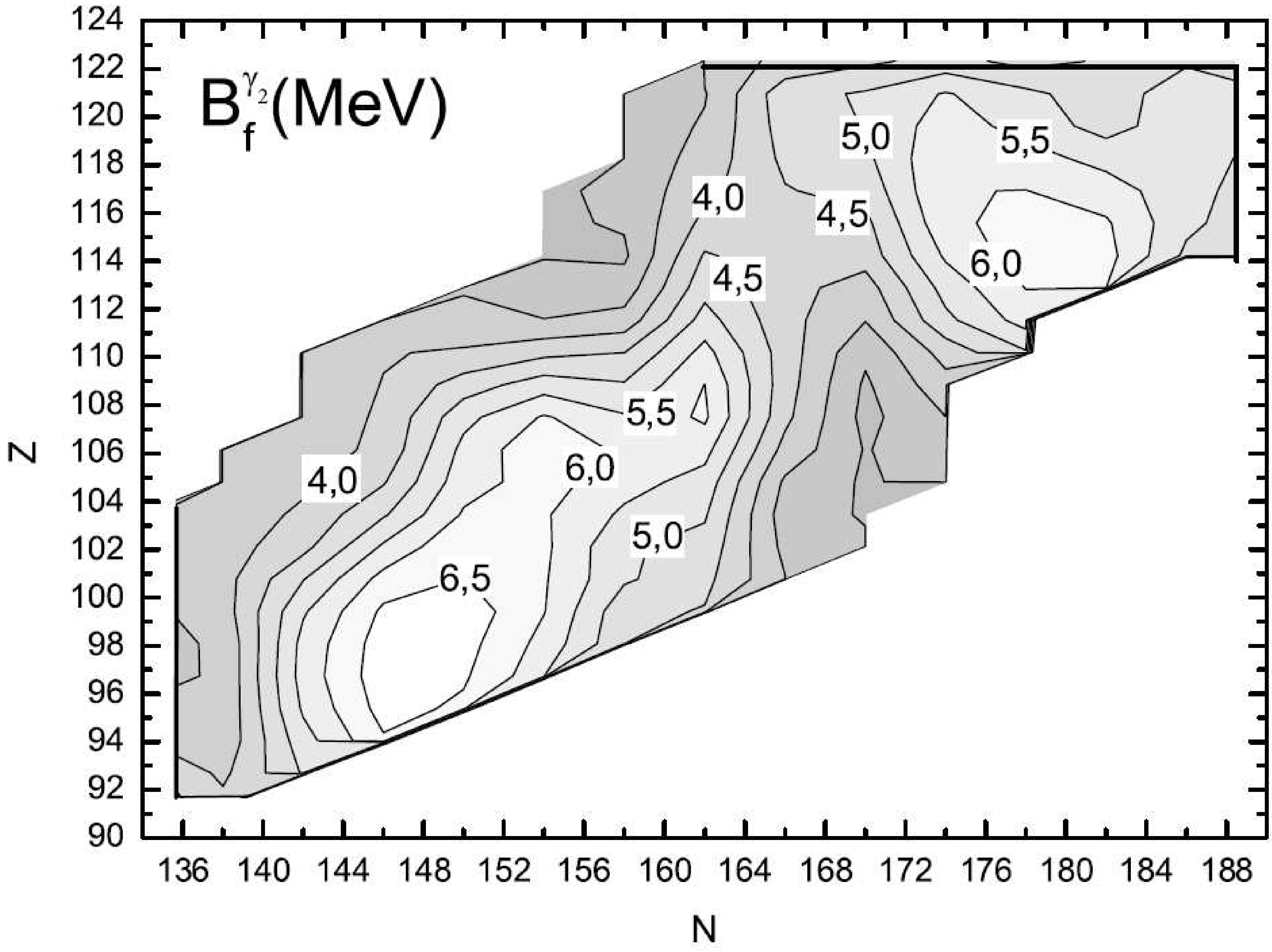
90
136 140 144 148 152 156 160 164 168 172 176 180 184 188



$B_f^{\gamma_2}$(MeV)
4,0
4,0
4,5
4,5
5,0
5,0
5,5
5,5
6,0
6,0
6,5
Z
N
124
122
120
118
116
114
112
110
108
106
104
102
100
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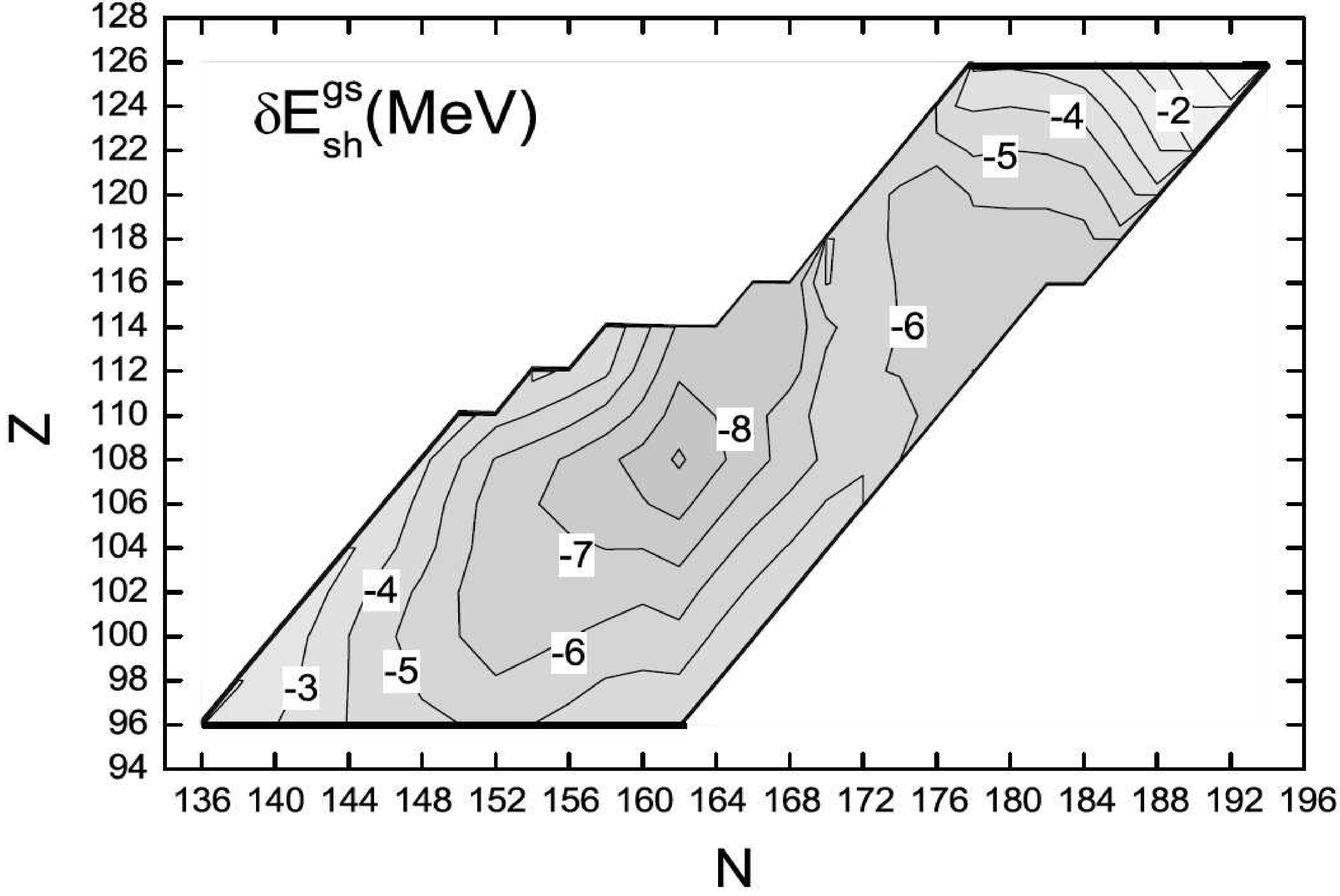

δE^{gs}_{sh}(MeV)
-2
-4
-5
-6
-8
-7
-4
-6
-3
-5
Z
N
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
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136
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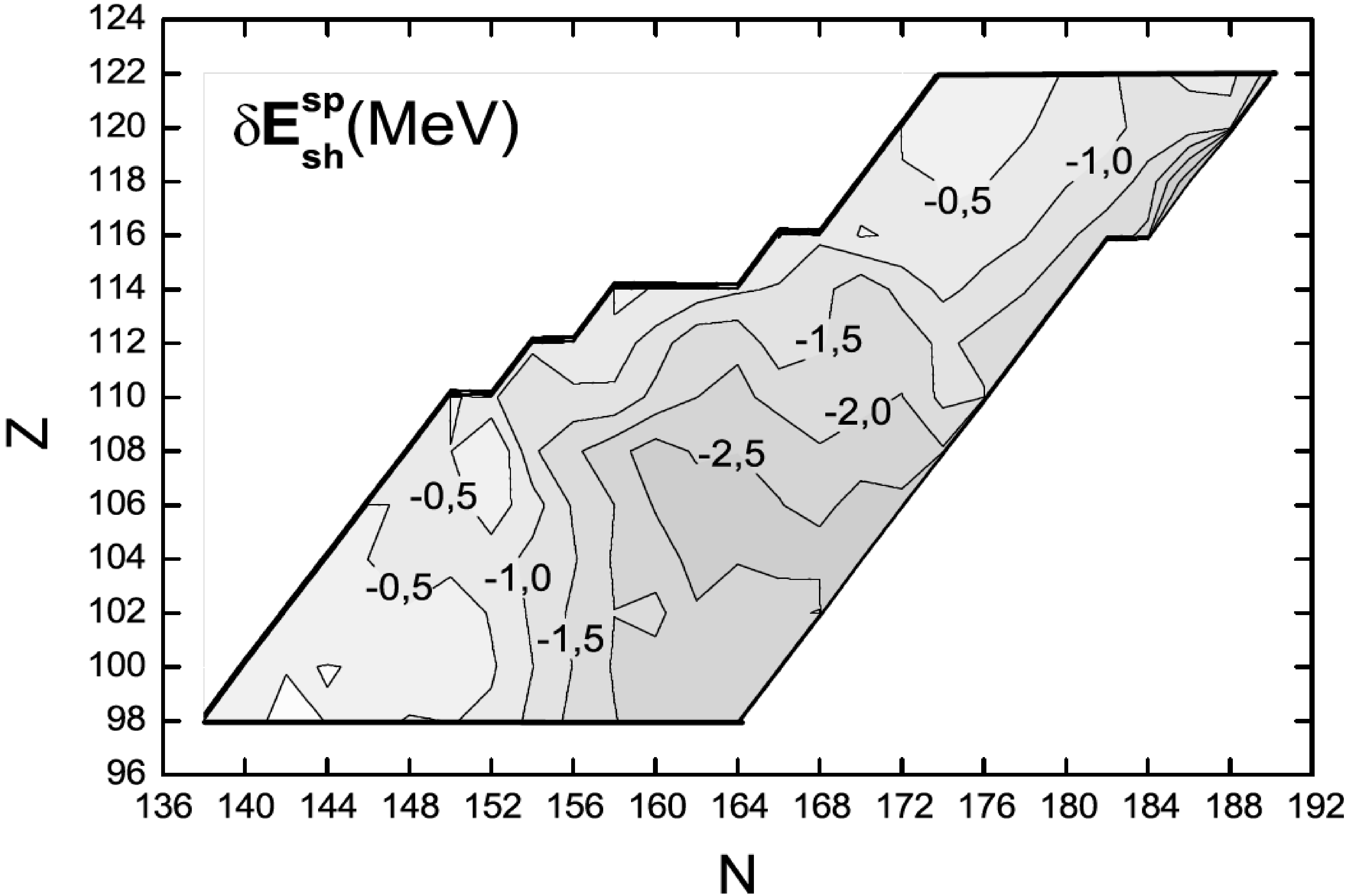

δE$_{sh}^{sp}$(MeV)
Z
N
-0,5
-1,0
-1,5
-2,0
-2,5

Conclusions

1. **Shapes and shell correction of HN have been studied at two configurations: equil. (ground state) and saddle point.**

2. **For an accurate study, a large deformation space is needed (10-dimensional space has been used).**

3. **Equil. config.:**
   - **the shapes are axially- and reflection-symmetric for all studied nuclei**
   - **shell correction is large (up to about 9 MeV for a doubly magic def. nucleus with Z=108, N=162 and a spherical one with Z=114, N=184).**

4. **Sadlle-point config.:**
   - **shapes are generally non-axial, but reflection sym.; only lighter nuclei (around uranium and below) are reflection asym. at their saddle point.**
   - **shell corr., although smaller than at equil., is still large (up to about 2.5 MeV). It should not be disregarded (as quite often done).**
   - **effect of non-axiality is large, up to more than 2 MeV. This is a big effect, if one keeps in mind that a 1 MeV change in B_f^{st} changes the calculated σ by one order of magnitude or even more.**