Microscopic description of fission in the neutron-deficient Pb region

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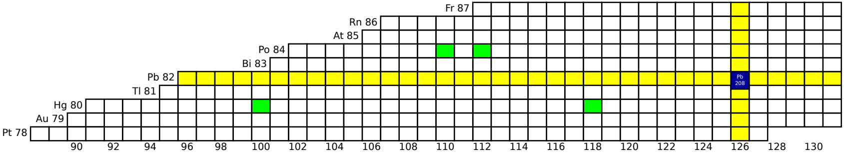
INT Seattle, 10-10-2013


Fr 87
Rn 86
At 85
Po 84
Bi 83
Pb 82
Tl 81
Hg 80
Au 79
Pt 78
Pb 208
90
92
94
96
98
100
102
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128
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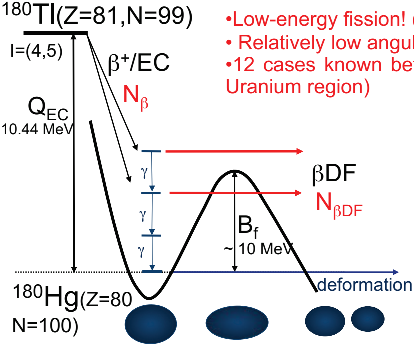


- Low-energy fission! (E^*~3-12 MeV, limited by Q_{EC})
- Relatively low angular momentum of the state
- 12 cases known before our work (neutron-deficient Uranium region)

βDF branch

$$P_{\beta DF} = \frac{N_{\beta DF}}{N_{\beta}}$$

A.N. Andreyev, FUSTIPEN 2012, Semminar

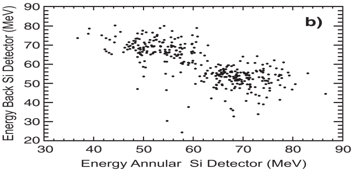


FIG. 2. (a) Singles α-decay energy spectrum from both Si detectors; (b) Si-Si coincidence spectrum in the fission-energy region. The two-peaked structure in (b) originates because the two fission fragments have different energies, a direct result of the asymmetric mass distribution.

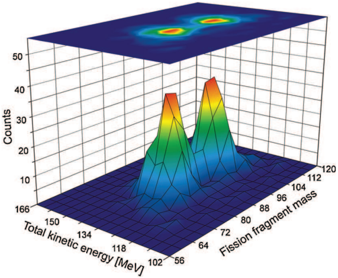


FIG. 4 (color online). The derived fission-fragment distribution of ^{180}Hg as a function of the fragment mass and the total kinetic energy.

A.N. Andreyev, et al. PRL **105**, 252502 (2010).

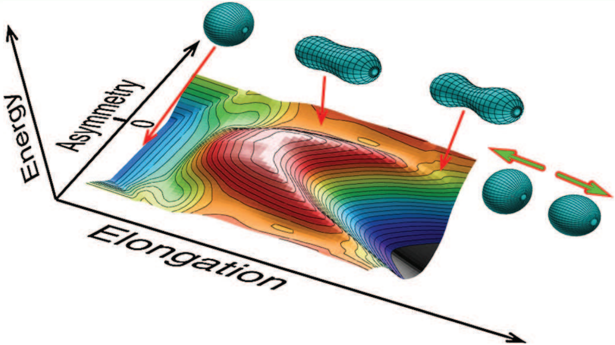


FIG. 5 (color online). A schematic representation of the potential-energy surface for ^{180}Hg in two dimensions (elongation and asymmetry) resulting from a five-dimensional analysis. The shapes shown, connected by arrows to their locations, are the ground state, the saddle point, and the point where the asymmetric valley disappears.

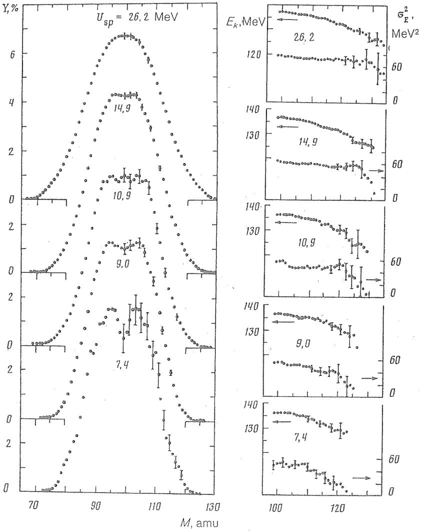


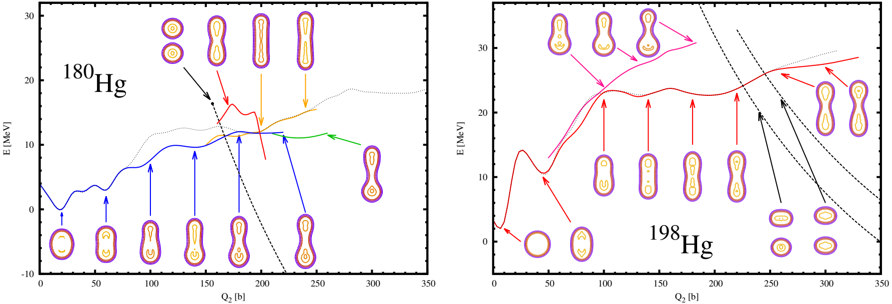
FIG. 3. Mass yields Y, total kinetic energy E_k, and its dispersion σ_E^2 as functions of fragment mass M and excitation energy for the compound nucleus ^{198}Hg.

M.G. Itkis, et al., Yad. Fiz. **52**, 944 (1990).

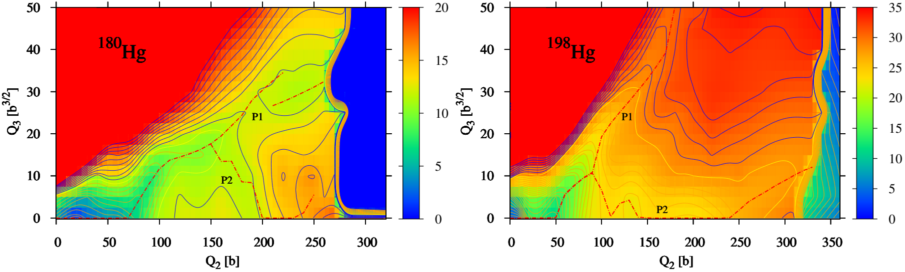
Calculations details

- Microscopic Hartree-Focka-Bogolubov theory
- Gogny D1S parameter set
- Constrains on quadrupole, octupole and hexadecapole moments as well as on the neck parameter
- Excitations of nuclei were not taken into account

Fission barriers in ^{180}Hg and ^{198}Hg

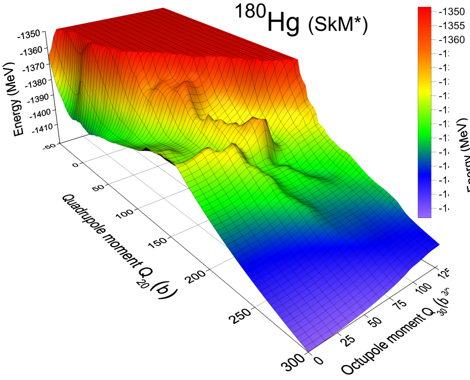


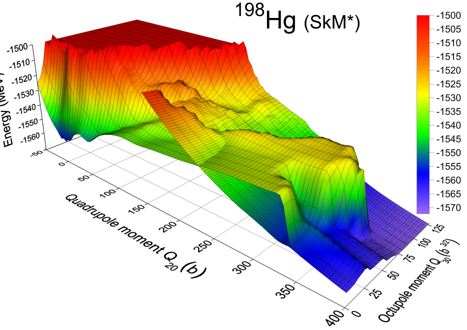
M. Warda, A. Staszczak, W. Nazarewicz, PRC 86, 024601 (2012).



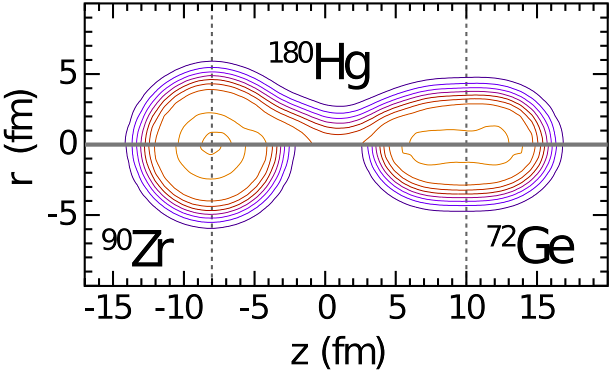
$A_H/A_L = 101/79$

$A_H/A_L = 108/90$


180Hg (SkM*)
Energy (MeV)
Quadrupole moment Q20 (b)
Octupole moment Q30 (b3/2)


198Hg (SkM*)
Energy (MeV)
Quadrupole moment Q20 (b)
Octupole moment Q30 (b3/2)

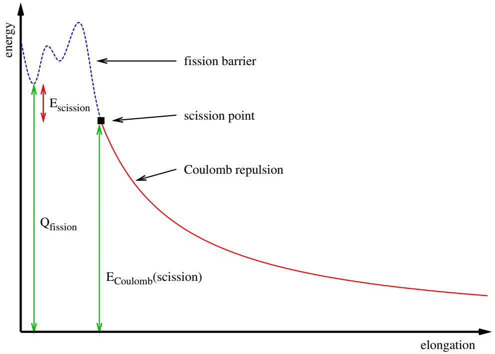
A. Staszczak



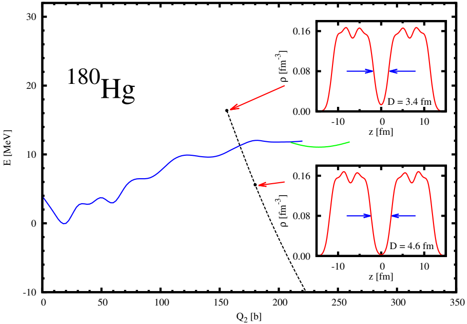
(i) reproduce N/Z ratio

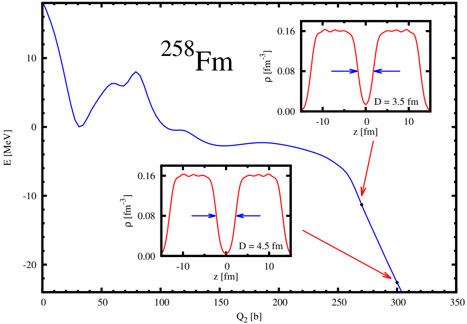
(ii) reproduce half of the mass of the outer part

(iii) reproduce mass distribution



$$E_{scission} = E_{Coul}(scission) - Q$$





$Q = 157.3$ MeV

$E_{Coul}(2R + 4 \text{ fm}) = 167.5$ MeV

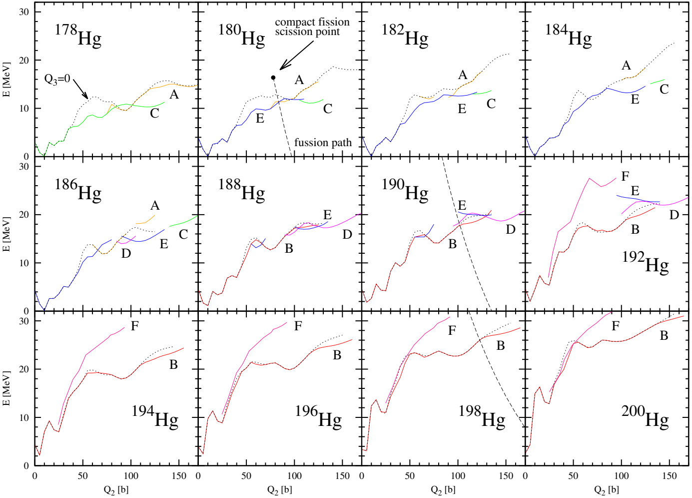
$E_{scission} = 10.3$ MeV

$Q = 251.7$ MeV

$E_{Coul}(2R + 4 \text{ fm}) = 238.0$ MeV

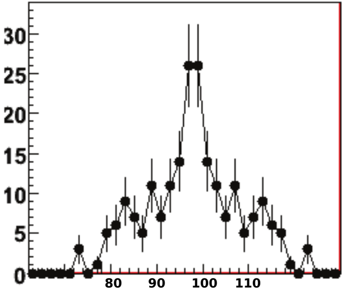
$E_{scission} = -13.7$ MeV

^{178}Hg – ^{200}Hg

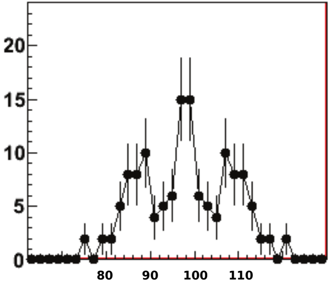


178Hg
180Hg
182Hg
184Hg
186Hg
188Hg
190Hg
192Hg
194Hg
196Hg
198Hg
200Hg
Q3=0
compact fission
scission point
fission path
A
B
C
D
E
F
E [MeV]
Q2 [b]

Fragments mass distribution:

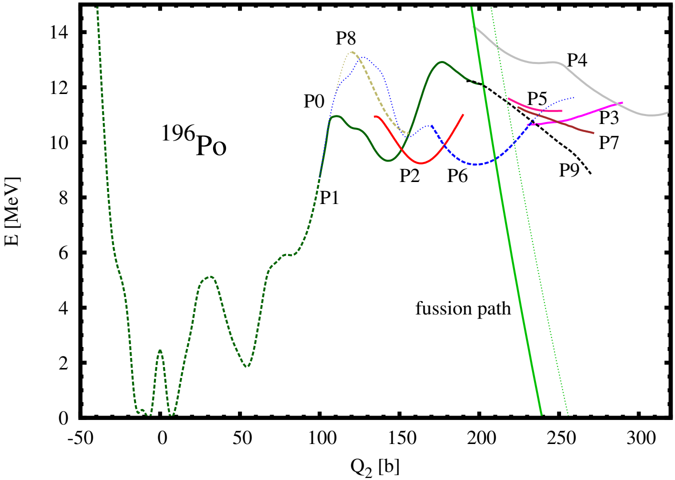


^{194}Po

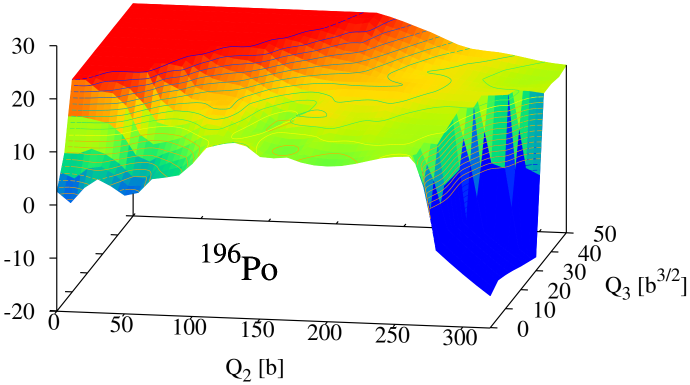


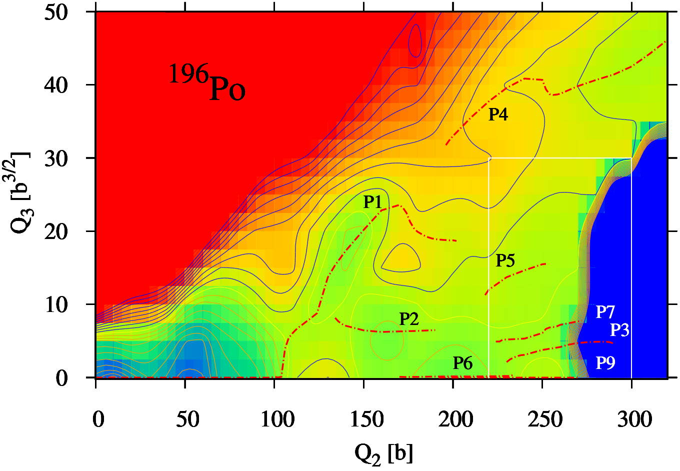
^{196}Po

A. Andreyev, L. Ghys, priv. comm.



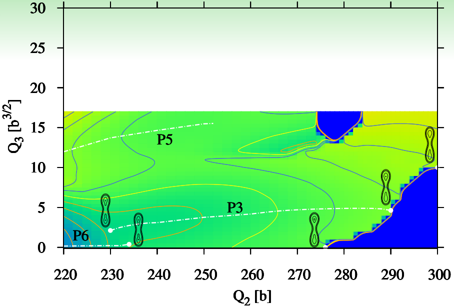
E [MeV]
Q_2 [b]
196Po
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
fussion path
14
12
10
8
6
4
2
0
-50
0
50
100
150
200
250
300


30
20
10
0
-10
-20
0
50
100
150
200
250
300
Q2 [b]
0
10
20
30
40
50
Q3 [b3/2]
196Po

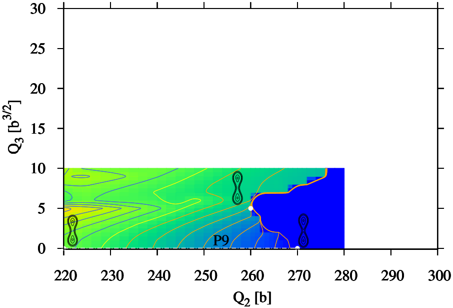


196Po
P1
P2
P3
P4
P5
P6
P7
P9
Q3 [b3/2]
Q2 [b]
0
10
20
30
40
50
0
50
100
150
200
250
300

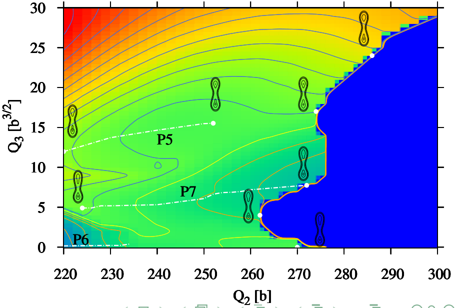
$A_H/A_L = 103/93$



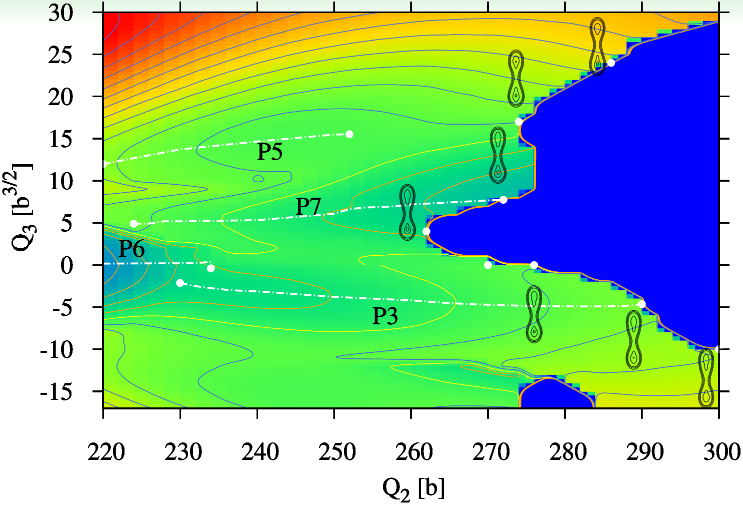
^{196}Po



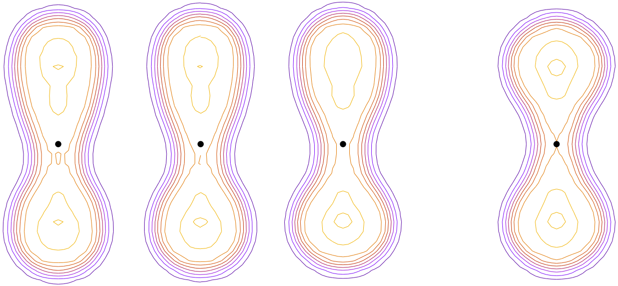
$A_H/A_L = 98/98$



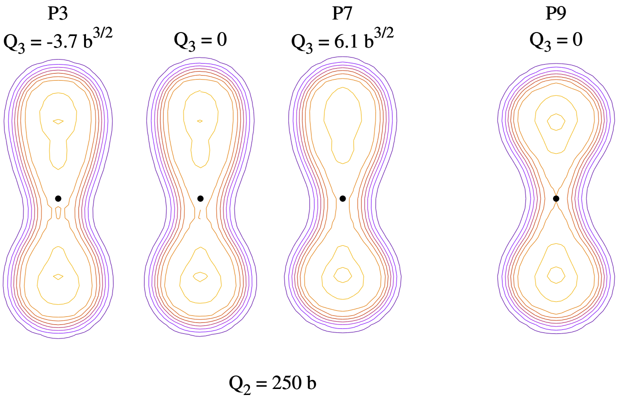
$A_H/A_L = 99/97$

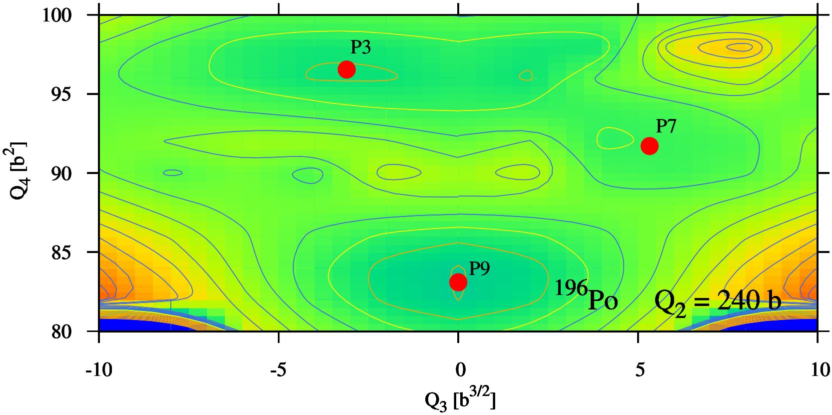


30
25
20
15
10
5
0
-5
-10
-15
Q_3 [$b^{3/2}$]
P5
P7
P6
P3
220
230
240
250
260
270
280
290
300
Q_2 [b]

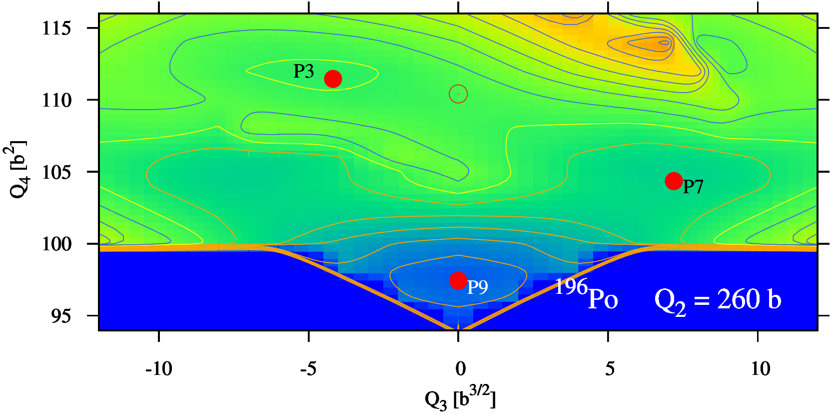


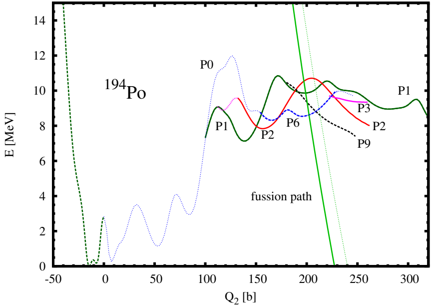
$Q_2 = 250$ b

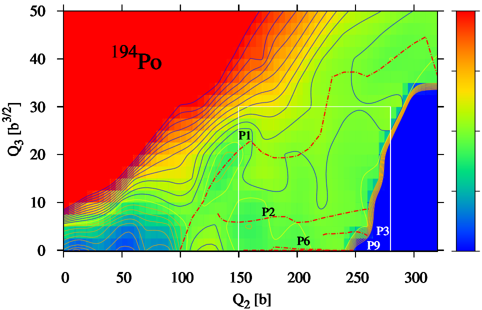

P3
$Q_3 = -3.7\ b^{3/2}$
$Q_3 = 0$
P7
$Q_3 = 6.1\ b^{3/2}$
P9
$Q_3 = 0$
$Q_2 = 250$ b



100
95
90
85
80
Q_4 [b^2]
-10
-5
0
5
10
Q_3 [$b^{3/2}$]
P3
P7
P9
^{196}Po
Q_2 = 240 b

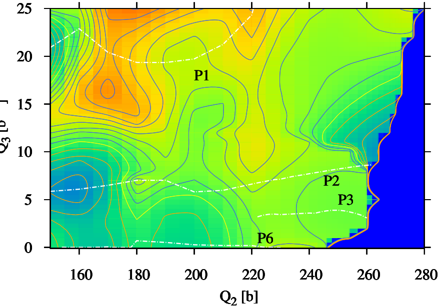

115
110
105
100
95
Q_4 [b^2]
-10
-5
0
5
10
Q_3 [b$^{3/2}$]
P3
P7
P9
^{196}Po
Q_2 = 260 b



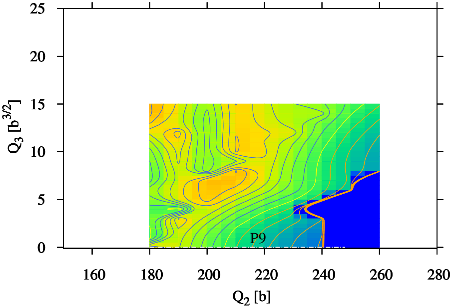


P3: $A_H/A_L = 101/93$

P9: $A_H/A_L = 97/97$



25
20
15
10
5
0
160
180
200
220
240
260
280
Q2 [b]
P1
P2
P3
P6



25
20
15
10
5
0
160
180
200
220
240
260
280
Q2 [b]
Q3 [b3/2]
P9

Conclusions:

- Potential energy surface of nuclei from neutron deficient Hg region were determined in the microscopic calculations
- Fragment mass asymmetry of ^{180}Hg and ^{198}Hg is reproduced
- Plateau of the PES at large quadrupole deformations is found around N=110
- Unexpected reflection asymmetric shapes with vanishing octupole moment were found