NUCLEAR-STRUCTURE DEPENDENCE ON SINGLE-PARTICLE POTENTIAL PARAMETERS.

P. Möller (LANL)

We perform two large-scale calculations of nuclear ground-state masses, deformation, spins. They differ in the choice of spin-orbit strength and diffuseness of the folded-Yukawa single-particle potential.

1. In 1970 Ray Nix determined the folded-Yukawa spin-orbit strength and diffuseness parameter from adjustments to single-particle levels in (spherical) ^{208}Pb.

2. In 1973 Sven-Gösta Nilsson observed that levels in deformed actinide and rare-earth nuclei were poorly reproduced with the above original parameter choice. In collaboration with Nix and Möller the deformed level data was also considered and a new parameter set determined

Until now no quantitative comparative measure of the consequences of the new parameter set was calculated.

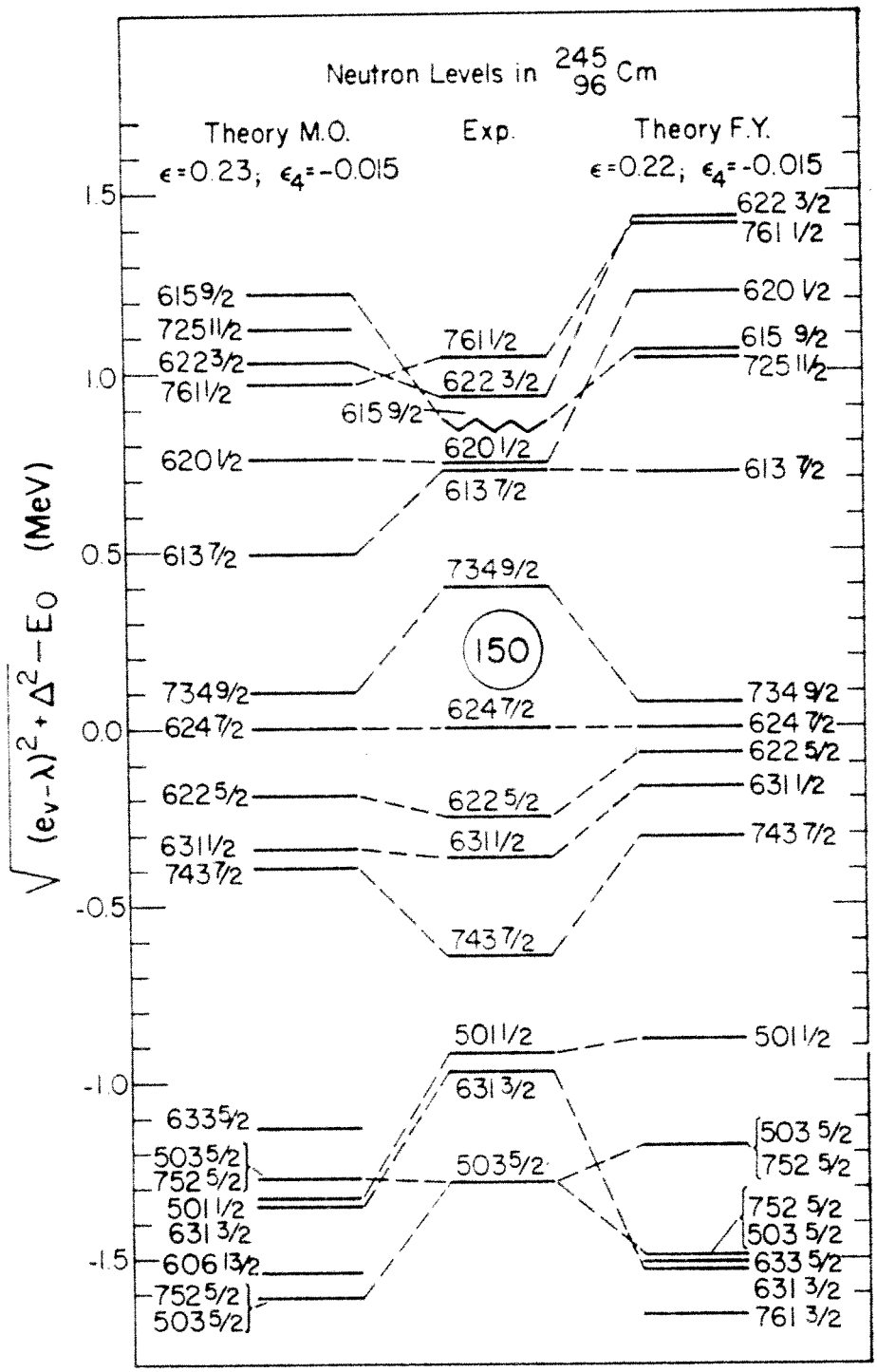
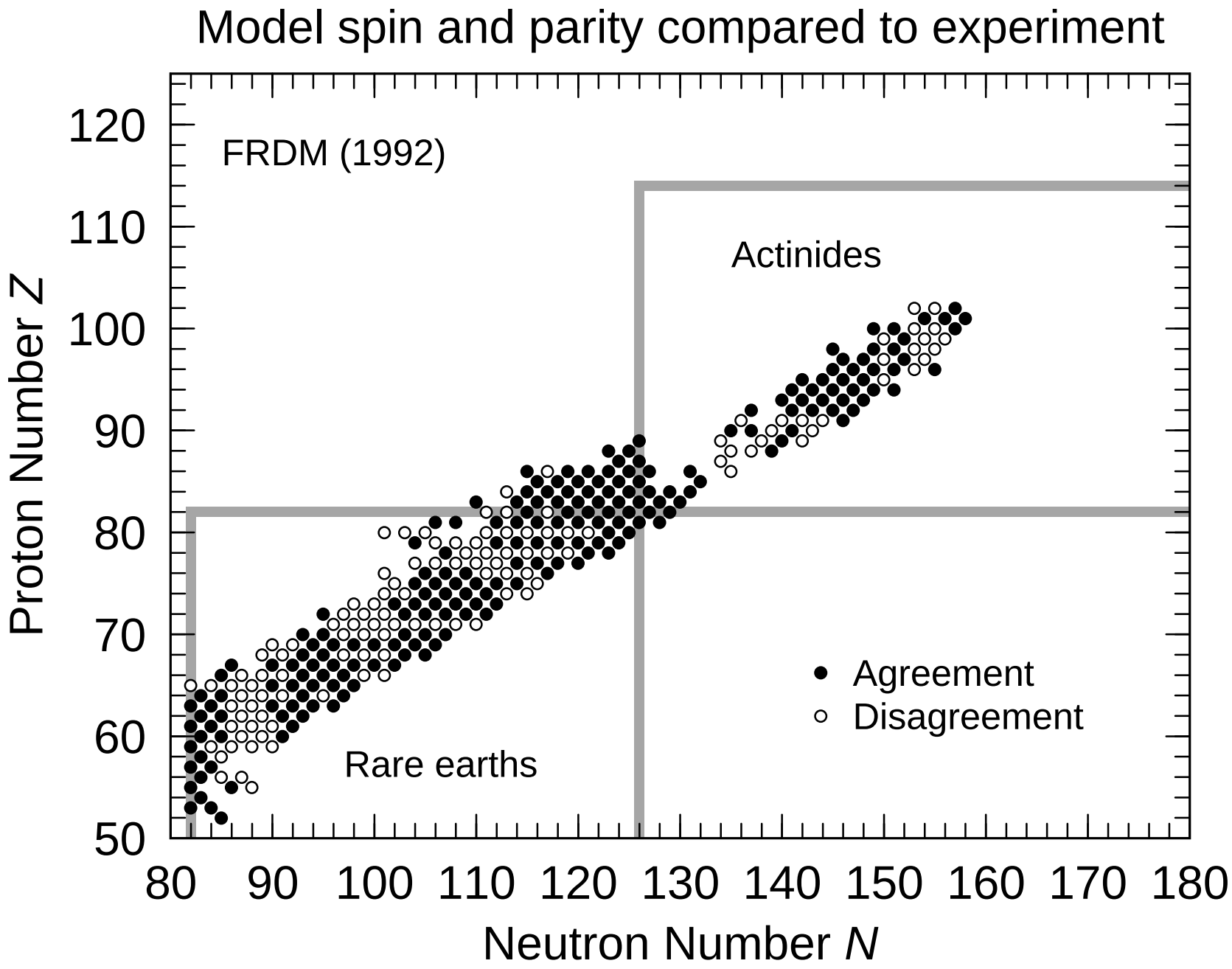


Fig. 7. Neutron quasi-particle energies in $^{245}_{96}$Cm, analogous to fig. 4.

ıtal levels in actinide nuclei. The modified oscillator (MHO) parameters are ated between the sets obtained for actinide and rare-earth nuclei. Both c


Model spin and parity compared to experiment
FRDM (1992)
Actinides
Rare earths
Agreement
Disagreement
Proton Number Z
Neutron Number N
120
110
100
90
80
70
60
50
80
90
100
110
120
130
140
150
160
170
180

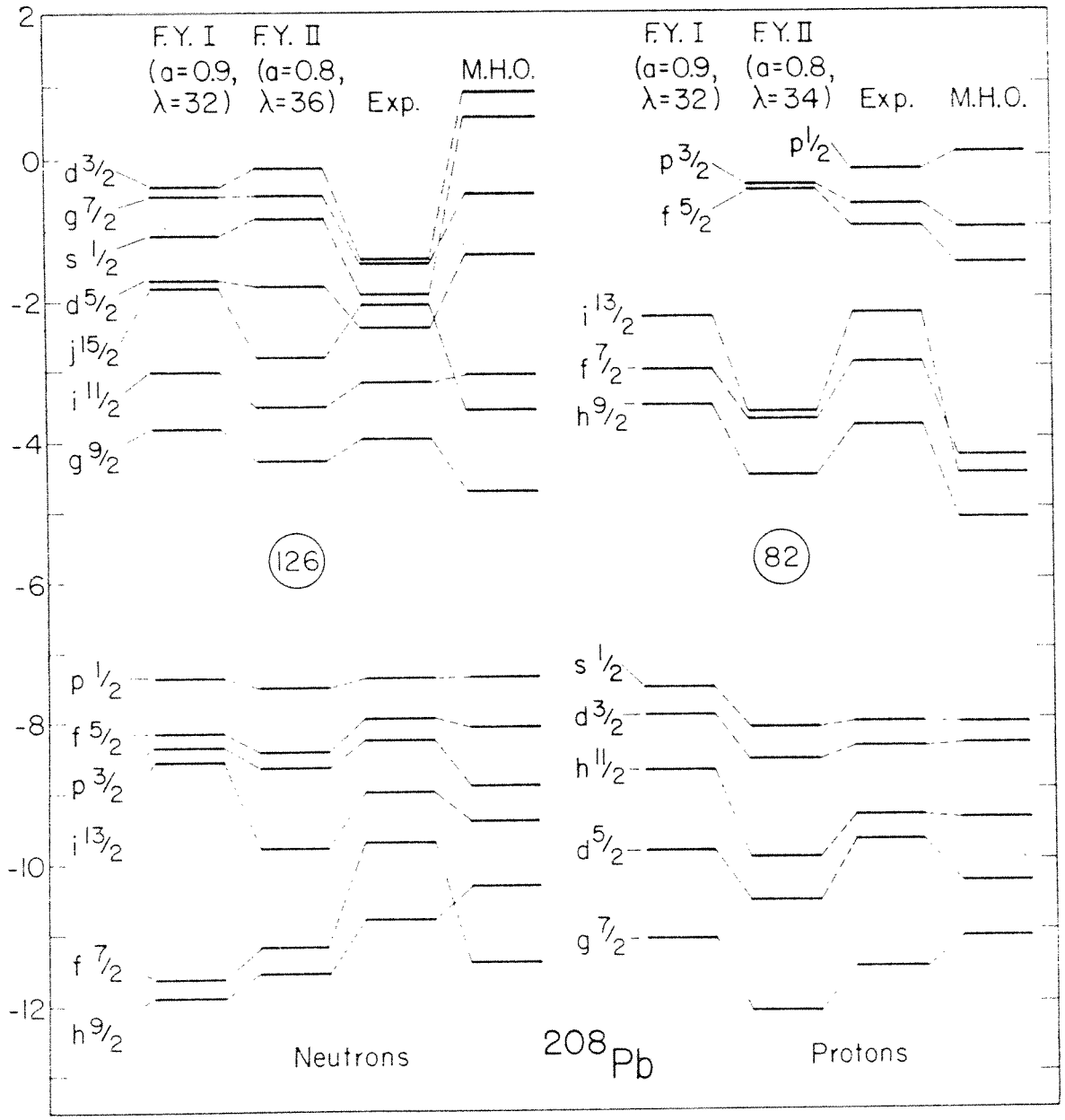
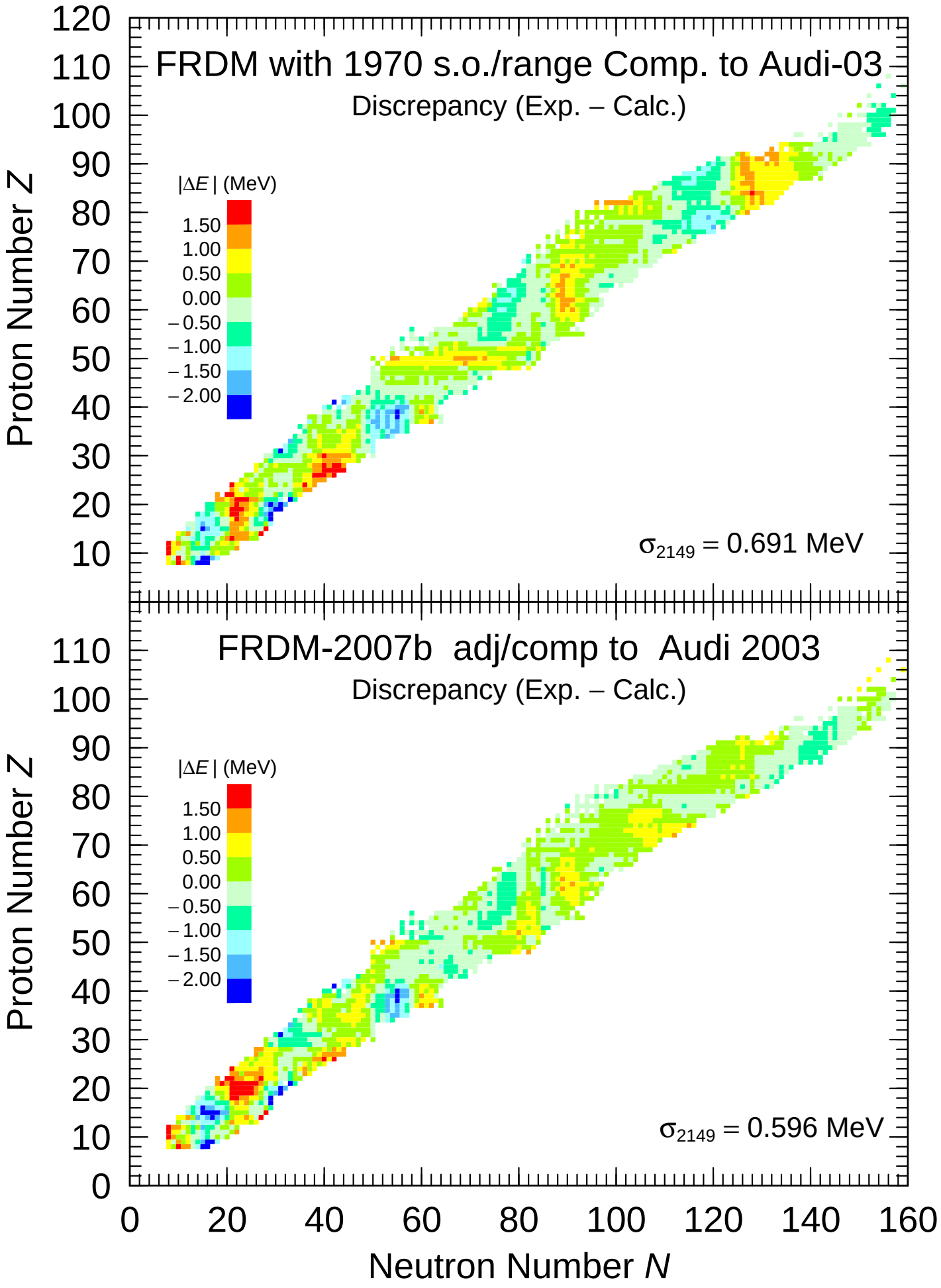
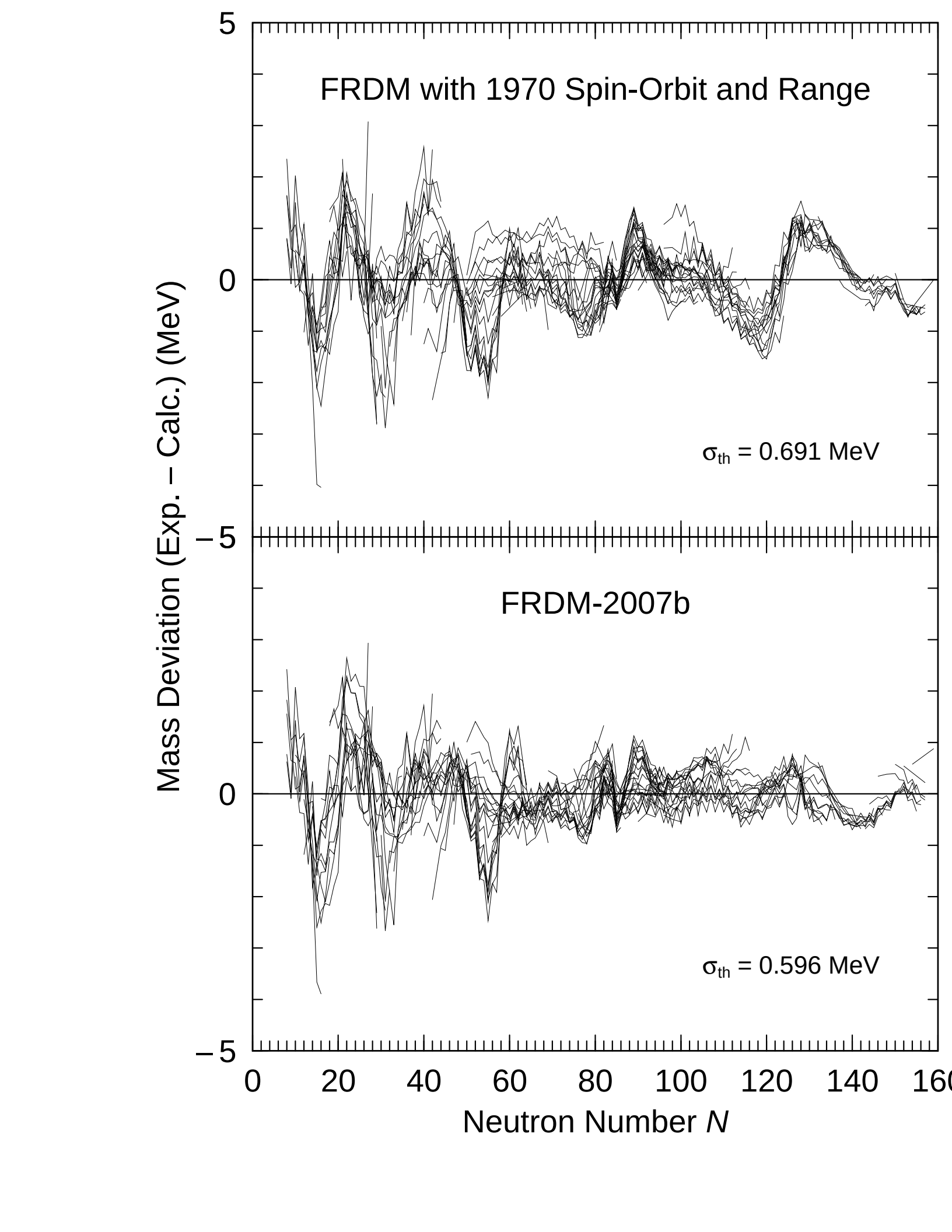


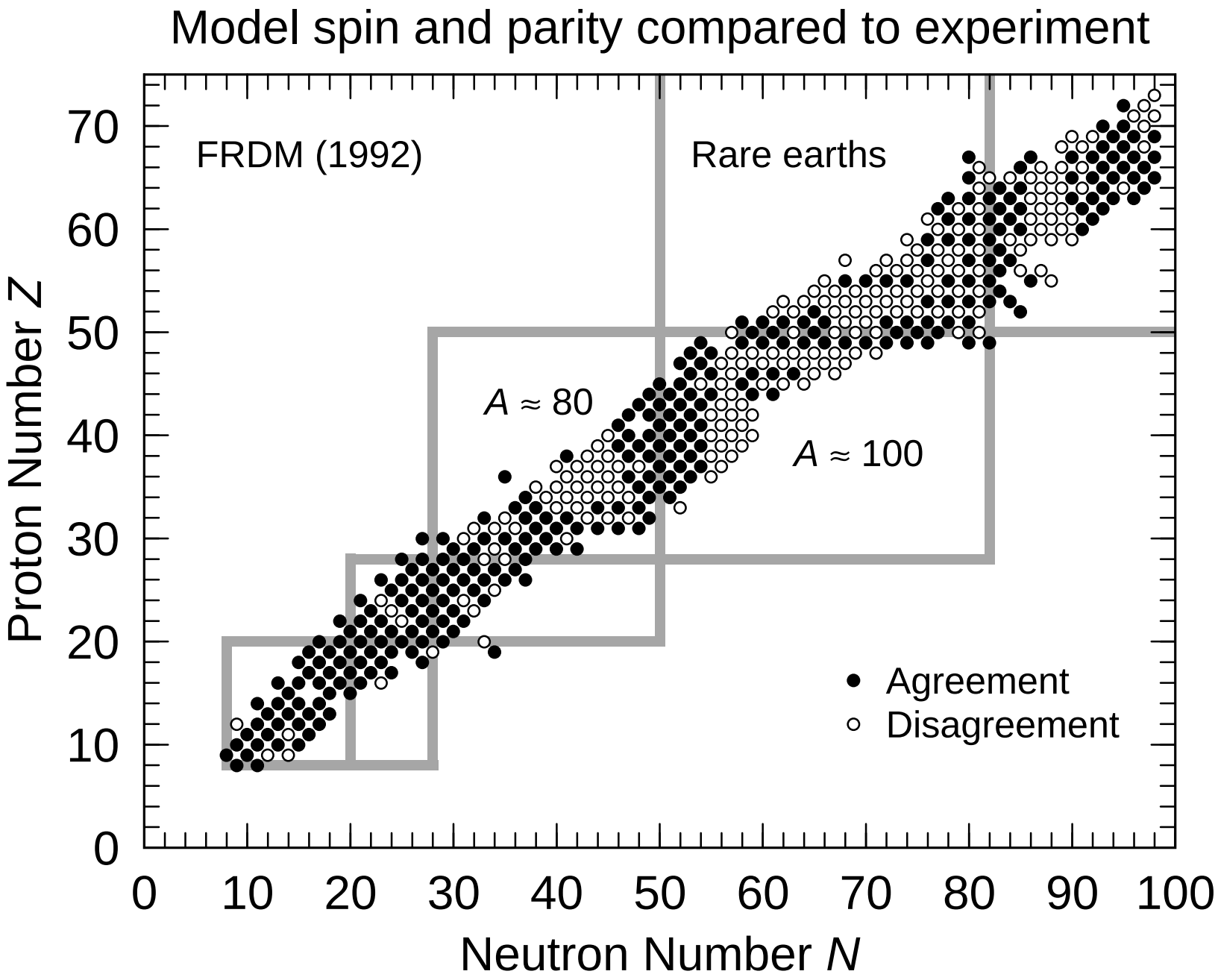
Fig. 8. Single-particle levels in $^{208}_{82}$Pb. The experimental data are taken from ref. [12]).

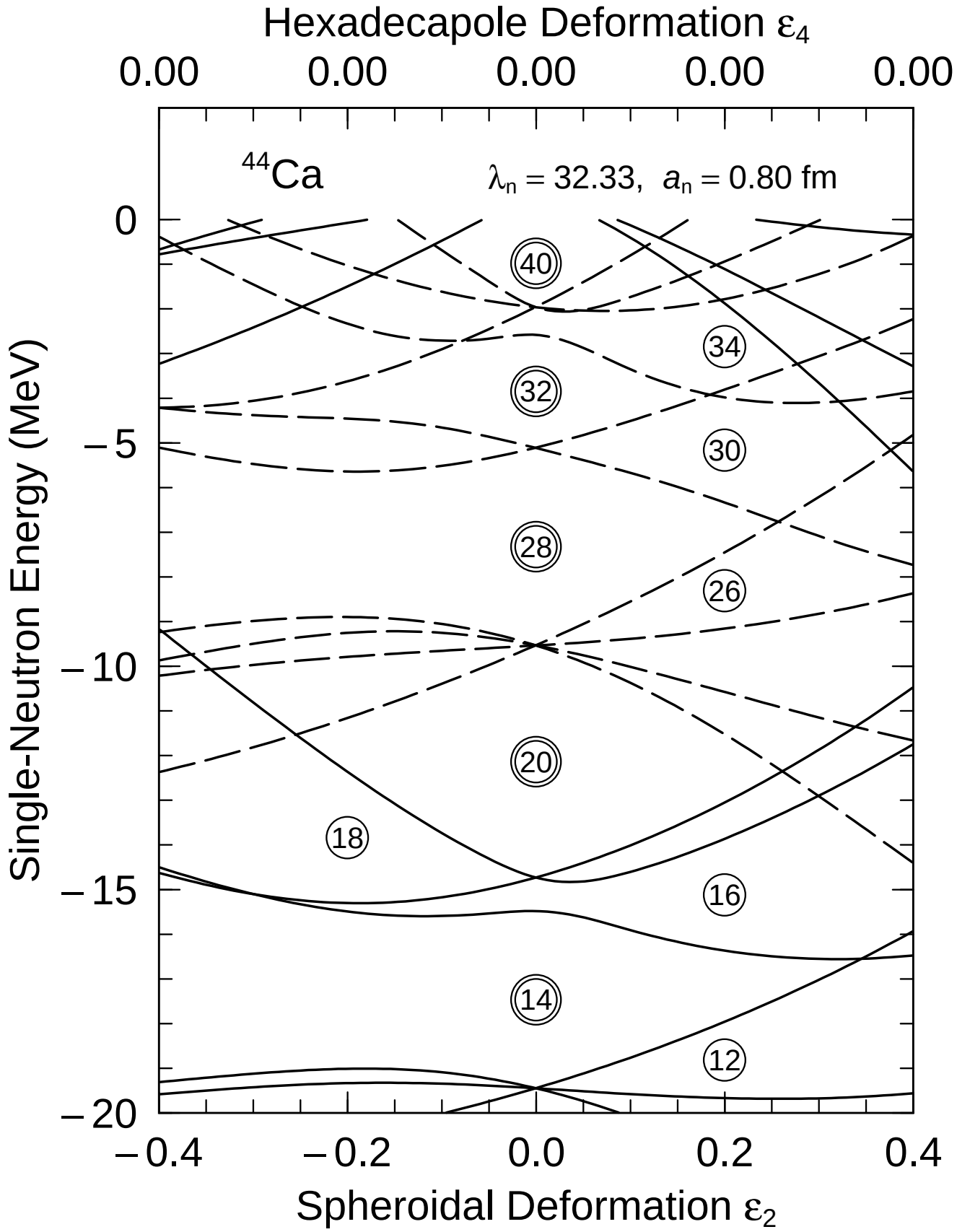
or the macroscopic energy two different methods are used, namely the
odel [3–5]) and the modified-surface-energy model [7]). The results are tabul
bles 1 and 2, respectively, for these two models.

The droplet model includes terms of higher order in $A^{-\frac{1}{3}}$ and in $I^2 = [(N-$
an are retained in the liquid-drop model. The constants of these two mod

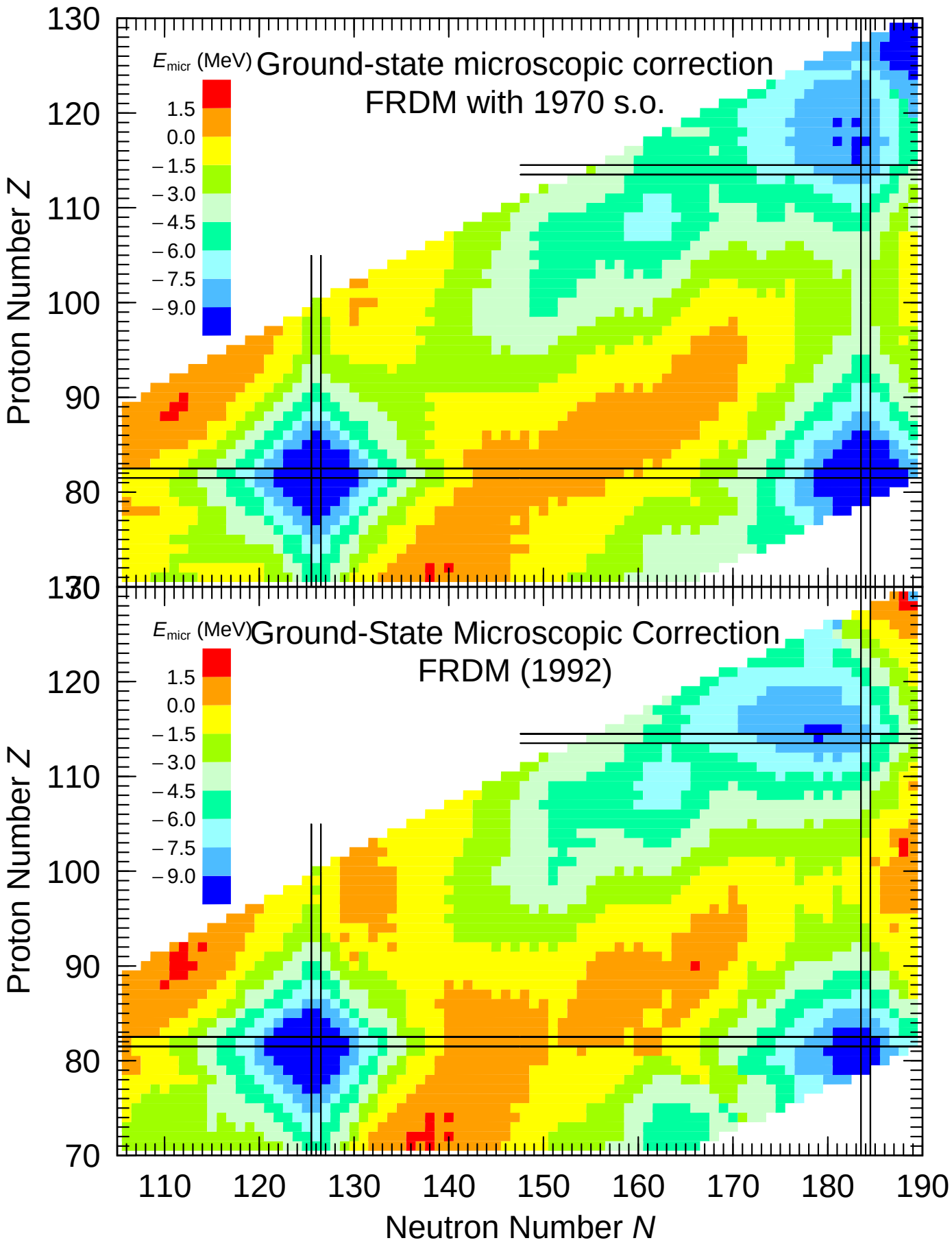

FRDM with 1970 s.o./range Comp. to Audi-03
Discrepancy (Exp. – Calc.)
|ΔE| (MeV)
1.50
1.00
0.50
0.00
– 0.50
– 1.00
– 1.50
– 2.00
σ2149 = 0.691 MeV
FRDM-2007b adj/comp to Audi 2003
Discrepancy (Exp. – Calc.)
|ΔE| (MeV)
1.50
1.00
0.50
0.00
– 0.50
– 1.00
– 1.50
– 2.00
σ2149 = 0.596 MeV
Proton Number Z
Neutron Number N
0
10
20
30
40
50
60
70
80
90
100
110
120
140
160

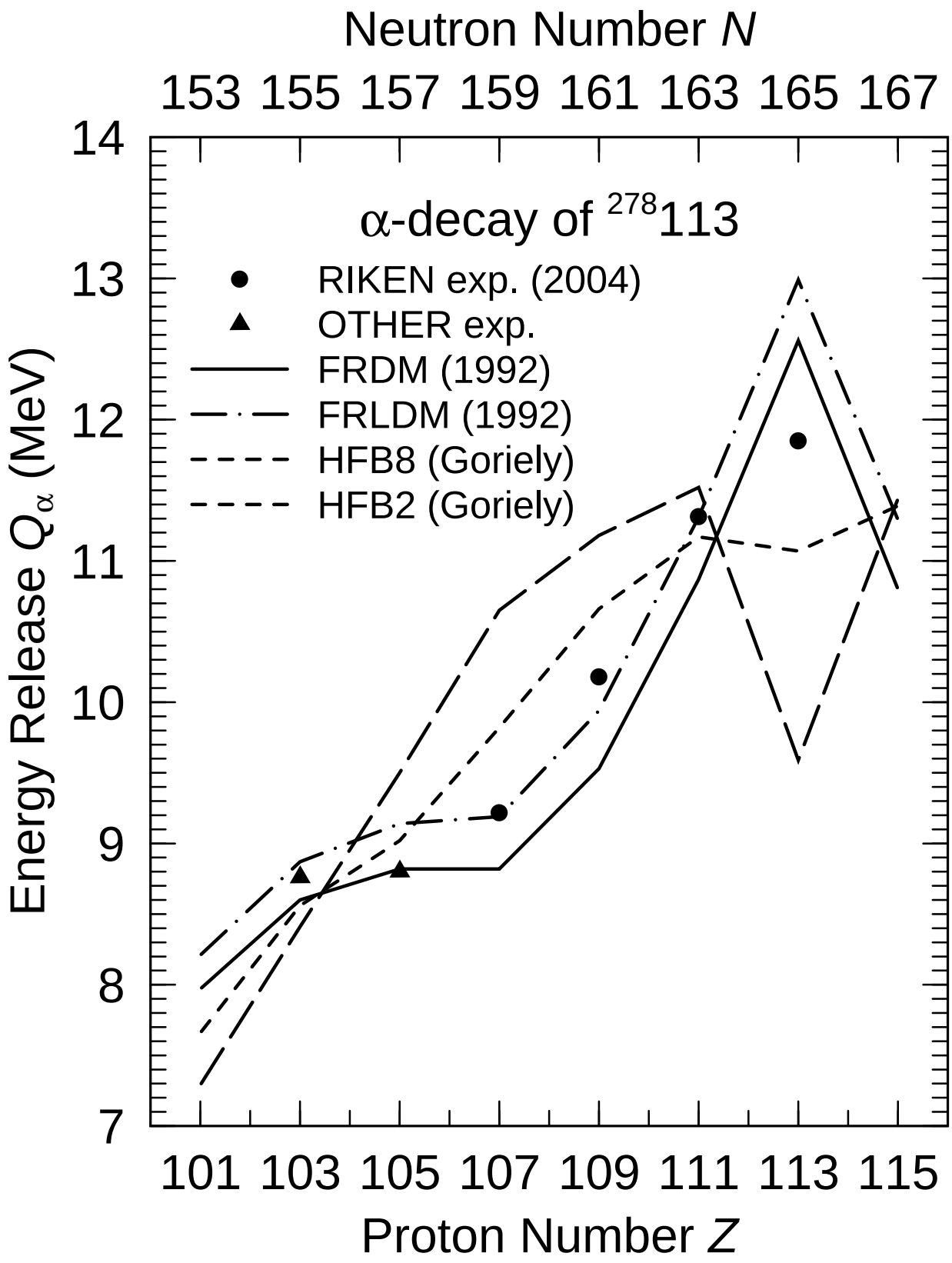

FRDM with 1970 Spin-Orbit and Range
σth = 0.691 MeV
FRDM-2007b
σth = 0.596 MeV
Mass Deviation (Exp. – Calc.) (MeV)
Neutron Number N
5
0
–5
0
20
40
60
80
100
120
140

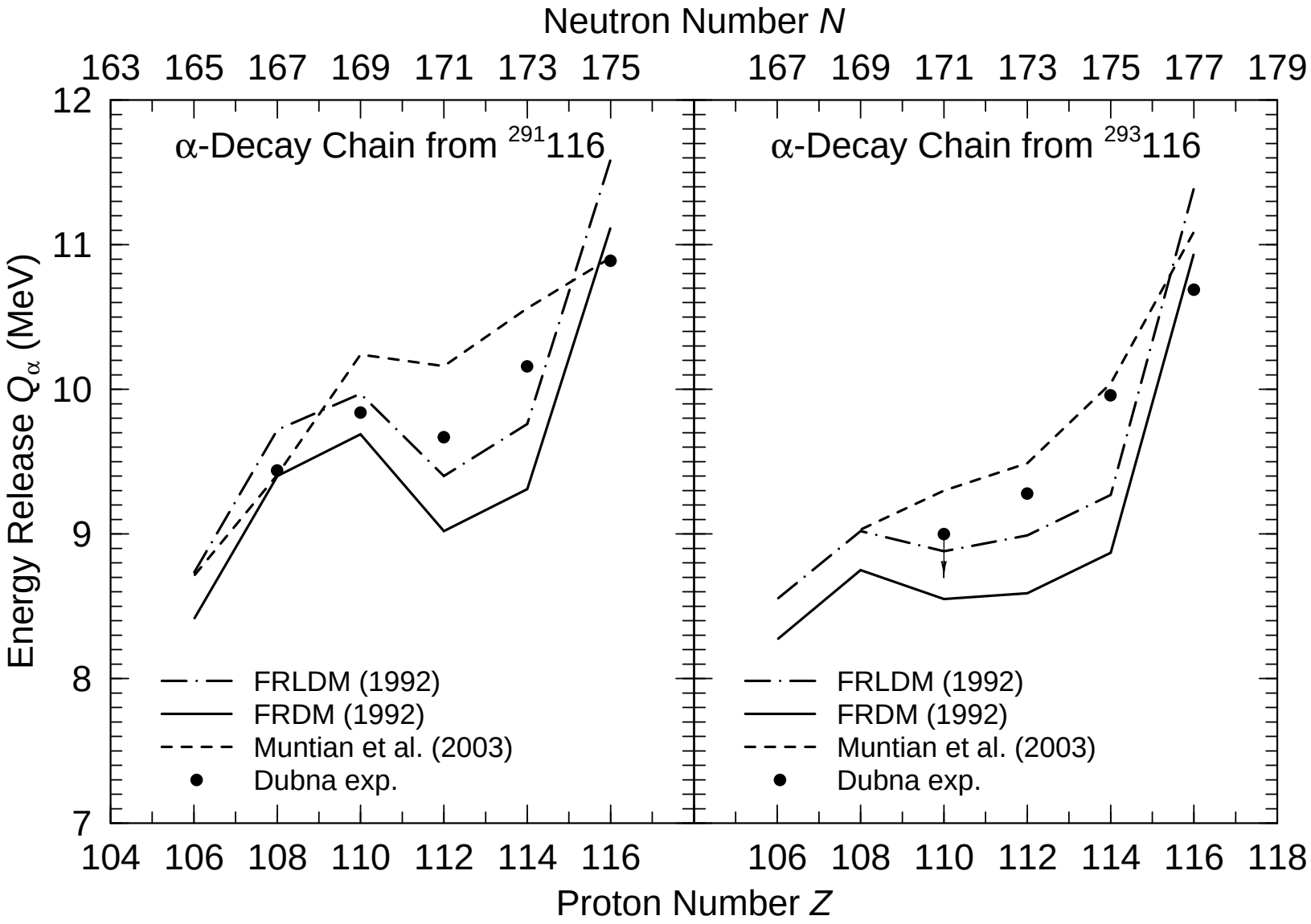

Model spin and parity compared to experiment
FRDM (1992)
Rare earths
A ≈ 80
A ≈ 100
Agreement
Disagreement
Proton Number Z
Neutron Number N
0
10
20
30
40
50
60
70
80
90
100


Hexadecapole Deformation ε_4
0.00 0.00 0.00 0.00 0.00
^{44}Ca
$\lambda_n = 32.33$, $a_n = 0.80$ fm
Single-Neutron Energy (MeV)
0
−5
−10
−15
−20
40
34
32
30
28
26
20
18
16
14
12
−0.4 −0.2 0.0 0.2 0.4
Spheroidal Deformation ε_2

Graph 6


E_{micr} (MeV)
Ground-state microscopic correction
FRDM with 1970 s.o.
1.5
0.0
−1.5
−3.0
−4.5
−6.0
−7.5
−9.0
Proton Number Z
130
120
110
100
90
80
70
E_{micr} (MeV)
Ground-State Microscopic Correction
FRDM (1992)
1.5
0.0
−1.5
−3.0
−4.5
−6.0
−7.5
−9.0
Proton Number Z
120
110
100
90
80
70
110
120
130
140
150
160
170
180
190
Neutron Number N


Neutron Number N
153 155 157 159 161 163 165 167
14
13
12
11
10
9
8
7
α-decay of 278113
RIKEN exp. (2004)
OTHER exp.
FRDM (1992)
FRLDM (1992)
HFB8 (Goriely)
HFB2 (Goriely)
Energy Release Qα (MeV)
101 103 105 107 109 111 113 115
Proton Number Z


Neutron Number N
163 165 167 169 171 173 175
167 169 171 173 175 177 179
α-Decay Chain from 291116
α-Decay Chain from 293116
Energy Release Qα (MeV)
12
11
10
9
8
7
FRLDM (1992)
FRDM (1992)
Muntian et al. (2003)
Dubna exp.
104 106 108 110 112 114 116
106 108 110 112 114 116 118
Proton Number Z

SUMMARY

- A single-particle potential optimized to reproduce experimental single-particle level order over a large section of the chart-of-the-nuclides yields a mass-model error of 0.596 MeV.

- A less well optimized single-particle potential yields a mass-model error of 0.691 MeV.

- We do observe that although **NO** consideration of nuclear masses were involved in the determination of single-particle potential parameters a model with a better optimized level spectrum resulted in very substantial improvements in mass calculations. This is a very reassuring consistency of the model.

- A possible consequence of the above result is that it is perhaps not crucial to know how much weight to put on different types of data when effective interaction parameters are determined.

- Obviously, in a perfect model you only need *n* data points to determine *n* model parameters. In a well-formulated model you may only need one type of data for parameter determination to obtain a model that reproduces other types of data well. If such consistency is absent it may well show that it is the model formulation that needs attention, not the details of the parameter determination.