Masses, r-process, neutron-stars, fission

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Collaborators on this and other projects:
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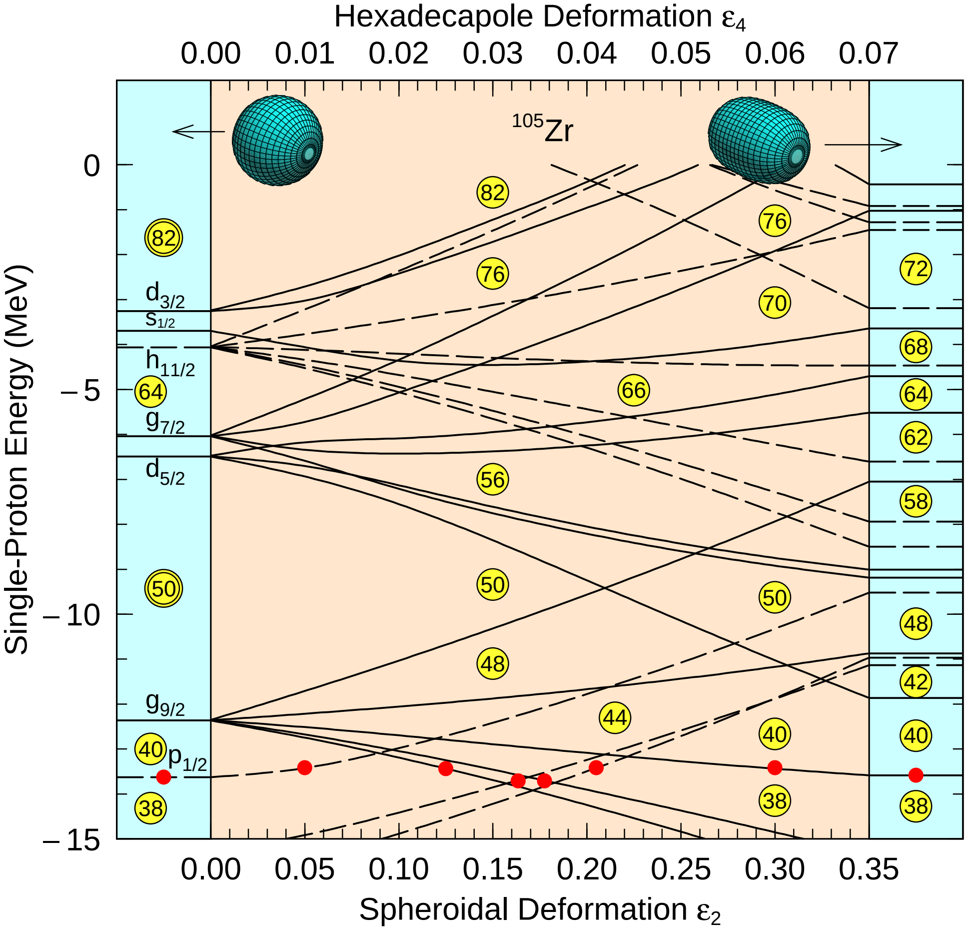
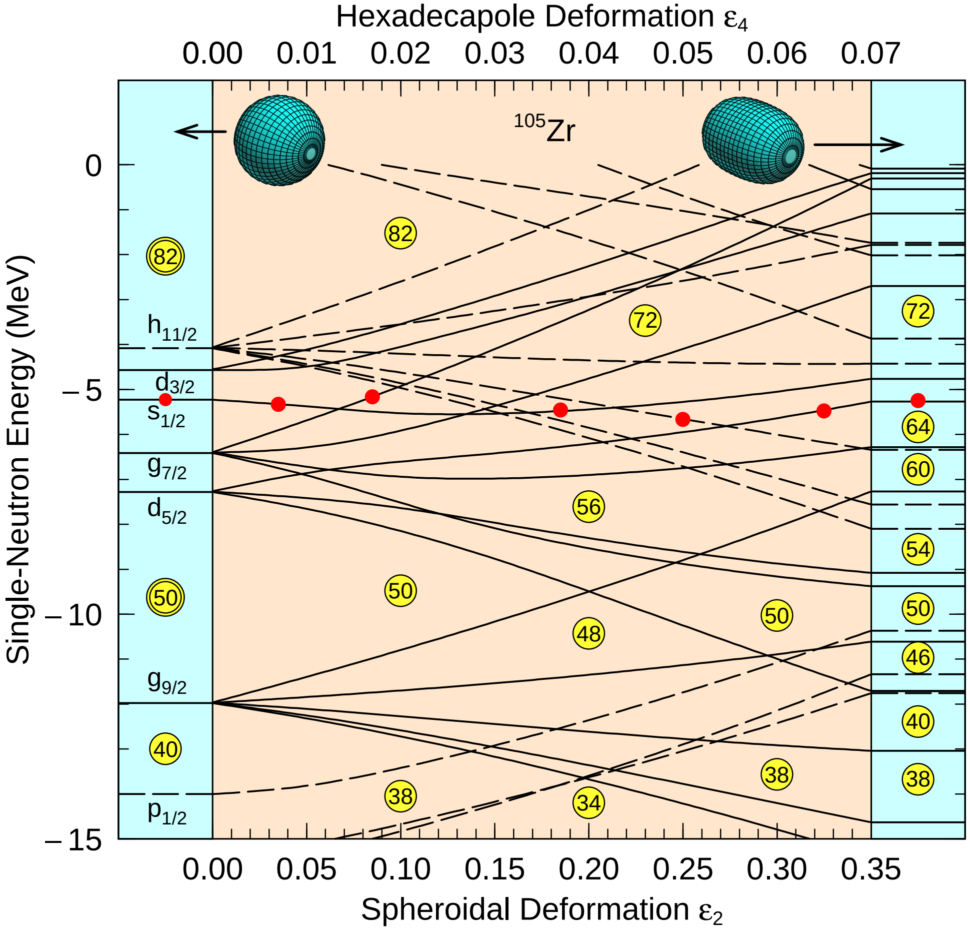
More details about masses, other projects (beta-decay,fission), associated ASCII data files, interactive access to data (type in Z, A and get specific data, contour maps) and figures are at

http://t2.lanl.gov/nis/molleretal/


Hexadecapole Deformation ε_4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
^{105}Zr
Single-Proton Energy (MeV)
0
−5
−10
−15
$d_{3/2}$
$s_{1/2}$
$h_{11/2}$
$g_{7/2}$
$d_{5/2}$
$g_{9/2}$
$p_{1/2}$
82
64
50
40
38
76
70
66
56
50
48
44
40
38
72
68
64
62
58
48
42
40
38
Spheroidal Deformation ε_2
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35


Hexadecapole Deformation ε_4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
^{105}Zr
Single-Neutron Energy (MeV)
0
−5
−10
−15
$h_{11/2}$
$d_{3/2}$
$s_{1/2}$
$g_{7/2}$
$d_{5/2}$
$g_{9/2}$
$p_{1/2}$
82
50
40
82
72
56
50
48
38
34
50
38
72
64
60
54
50
46
40
38
Spheroidal Deformation ε_2
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

Nuclear Physics **A417** (1984) 419–446
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CALCULATION OF GAMOW–TELLER β-STRENGTH FUNCTIONS IN THE RUBIDIUM REGION IN THE RPA APPROXIMATION WITH NILSSON-MODEL WAVE FUNCTIONS

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Received 14 March 1983
(Revised 3 August 1983)

Abstract: We calculate allowed Gamow–Teller and, in a few cases, Fermi β-strength functions in a model that is applicable to studies of nuclei throughout the periodic system. For our first study we have selected a sequence of rubidium isotopes, namely $^{89}_{37}$Rb–$^{99}_{37}$Rb. We develop a model that uses calculated Nilsson-model wave functions, spherical or deformed, as the case may be, as the starting point for determining the wave functions of the mother and daughter nuclei in the β-decay. Pairing is treated in the BCS approximation. To account for the retardation of low-energy GT decay rates we add, as is customarily done, a simple residual interaction specific to GT decay, namely $V_{\mathrm{GT}} = :\beta^{1-}\beta^{1+}:$, to the hamiltonian. This residual interaction is treated in the RPA approximation. The strength of the interaction is adjusted to get agreement between the calculated and experimental energy of the giant Gamow–Teller resonance for ^{208}Pb and ^{144}Sm. Since the present model is based on calculated wave functions and single-particle levels, studies of nuclei far from stability, where little experimental information is available, are more straightforward relative to calculations where "experimental" levels are used. The model can treat deformed nuclei employing wave functions calculated to desired accuracy, within the framework of the model, for the deformed single-particle well. The calculations show that use of single-particle parameters appropriate to the region studied and taking deformation into account is important. We find good agreement between calculated and experimental spectra over the region studied, provided an appropriate choice of single-particle parameters and deformation is made.

1. Introduction

A theoretical understanding of β-strength functions is important for the interpretation of the large amount of experimental data that is now being collected on, for instance, the giant Gamow–Teller resonance [1-2]) and on β-decay spectra of nuclei far from stability [3]). More references on these subjects are found in the conference report [4]) of the 4th International Conference on Nuclei far from Stability and references quoted therein. The β-strength function must also be known for theoretical studies of phenomena where the β-strength function cannot be easily measured. Examples of such processes are the decay from the r-process line to the line of β-stability [5-7]), β-delayed particle emission [7]) and the production of transuranium elements by neutron capture and subsequent decay by β-emission, fission and neutron emission [8,9]).

A variety of models have been used to calculate β-strength functions. The gross theory of β-decay [10]) describes, because of its statistical character, only the average

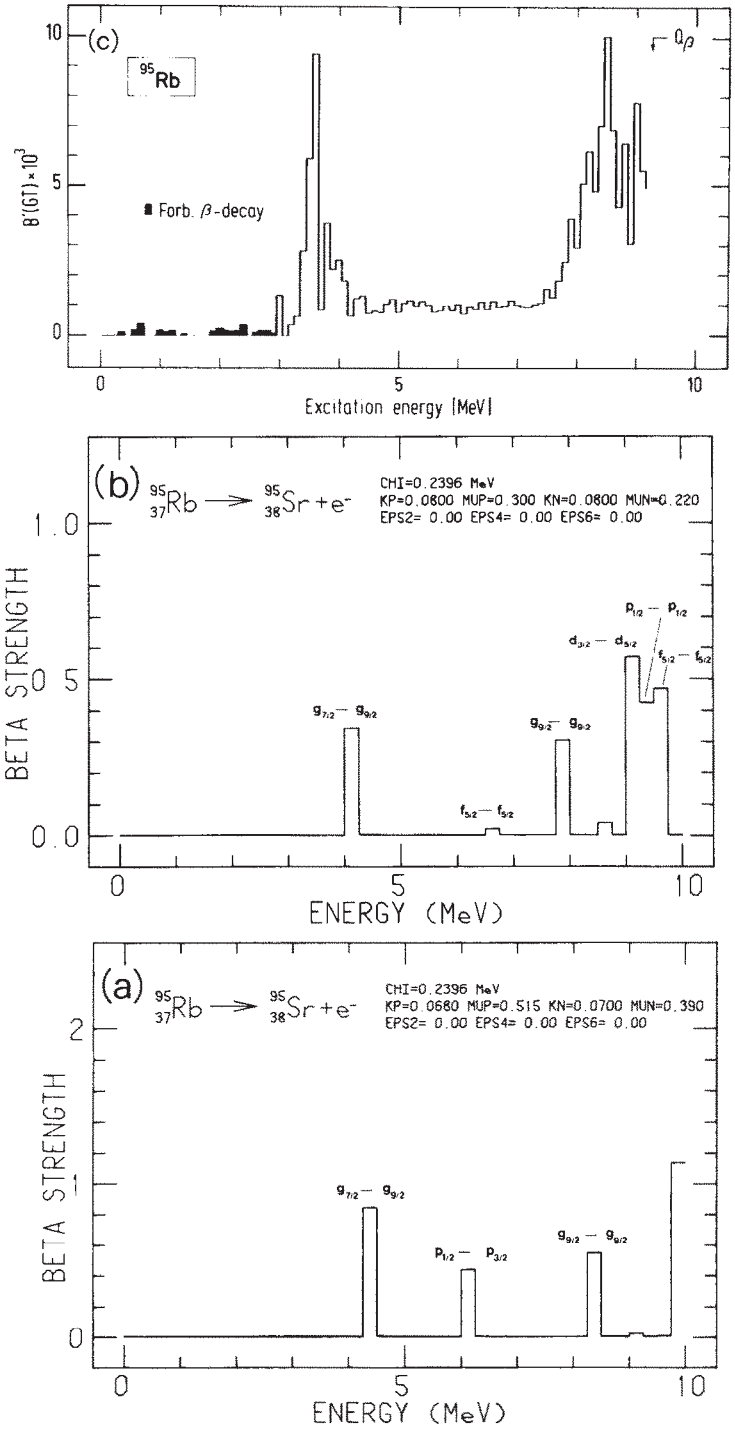


Fig. 8. Calculated β^- GT strength function for ^{95}Rb with (a) the $A = 100$ set of κ and μ, and (b) the $N = 60$ set of κ and μ, in units of $4f^2$ MeV^{-1}. The peaks are labeled with the quantum numbers of the neutron (first) and proton (last) orbital involved in the transition. (c) Experimental results from ref. [3]).

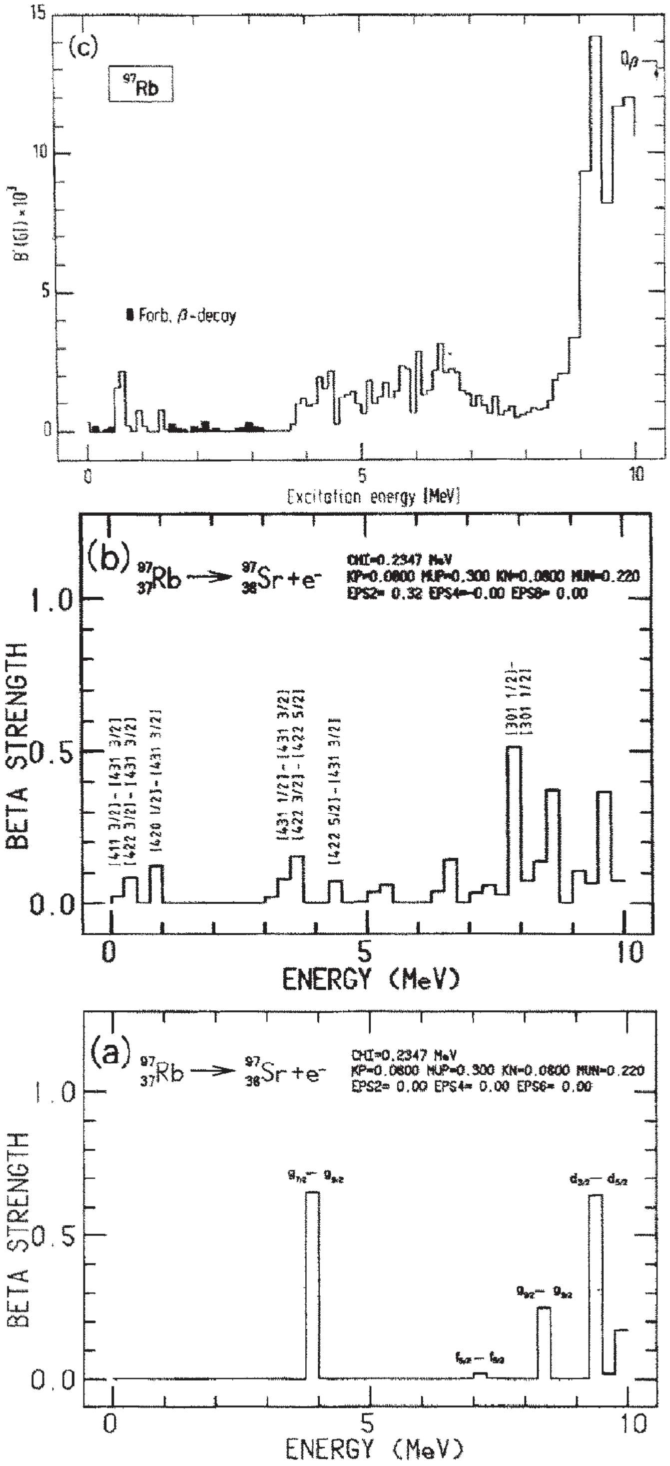


Fig. 9. Calculated β^- GT strength function for ^{97}Rb treated as (a) a spherical nucleus, and (b) a deformed nucleus, in units of $4f^2$ MeV^{-1}. The peaks in (b) are labeled with the asymptotic quantum numbers of the neutron (first) and proton (last) orbital involved in the transition. (c) Experimental results from ref. [3]).

Successive FRDM enhancements

Optimization (2006)

Better search for optimum FRDM parameters.

Accuracy improvement: 0.01 MeV

New mass data base (AME2003) (2006)

Better agreement than with AME1989.

Accuracy improvement: 0.04 MeV

Full 4D energy minimization (2006–2008)

Full 4D minimization($\epsilon_2, \epsilon_3, \epsilon_4, \epsilon_6$) step=0.01.

Accuracy improvement: 0.02 MeV

Axial asymmetry (2002–2006)

Also yields correct SHE gs assignments.

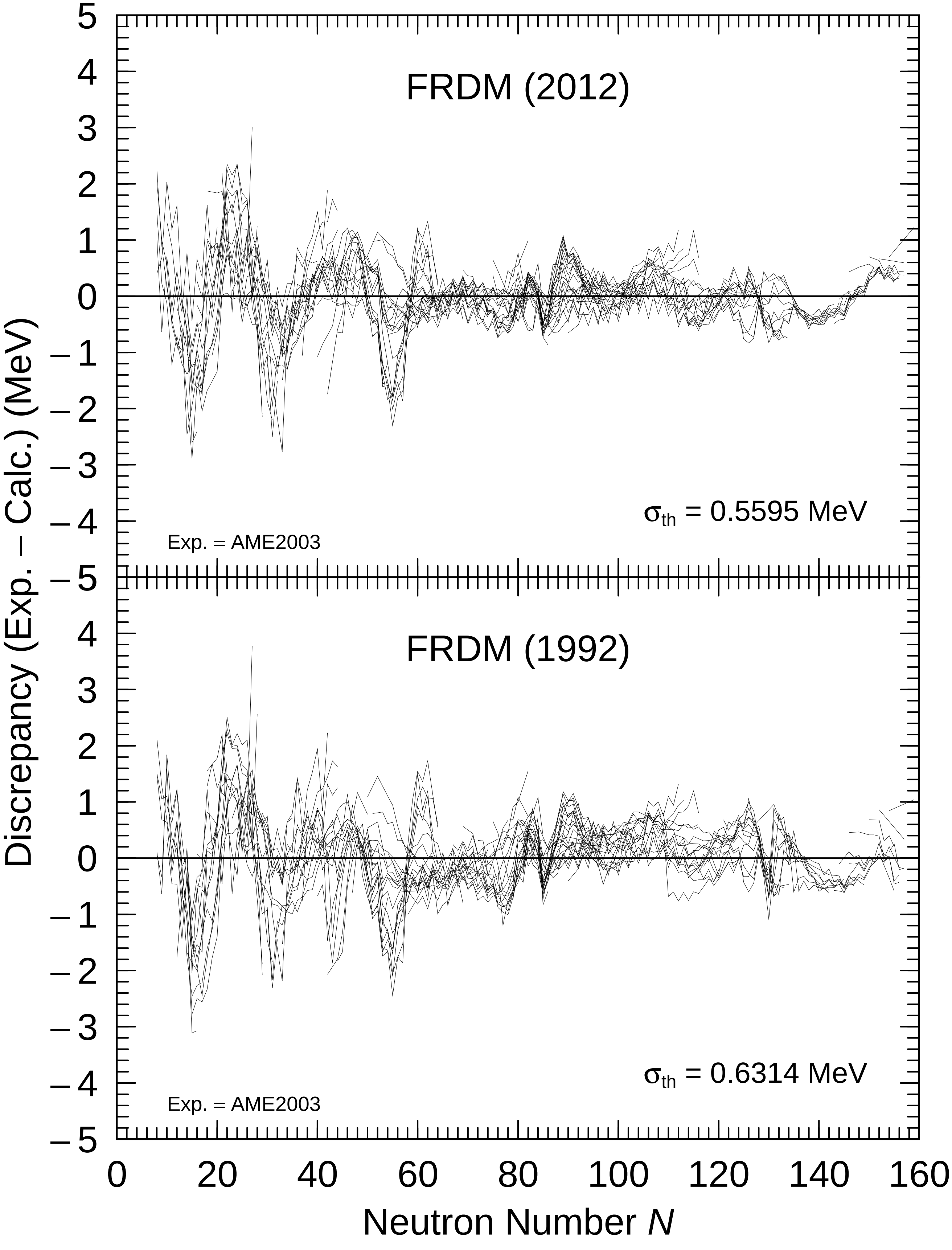
Accuracy improvement: 0.01 MeV

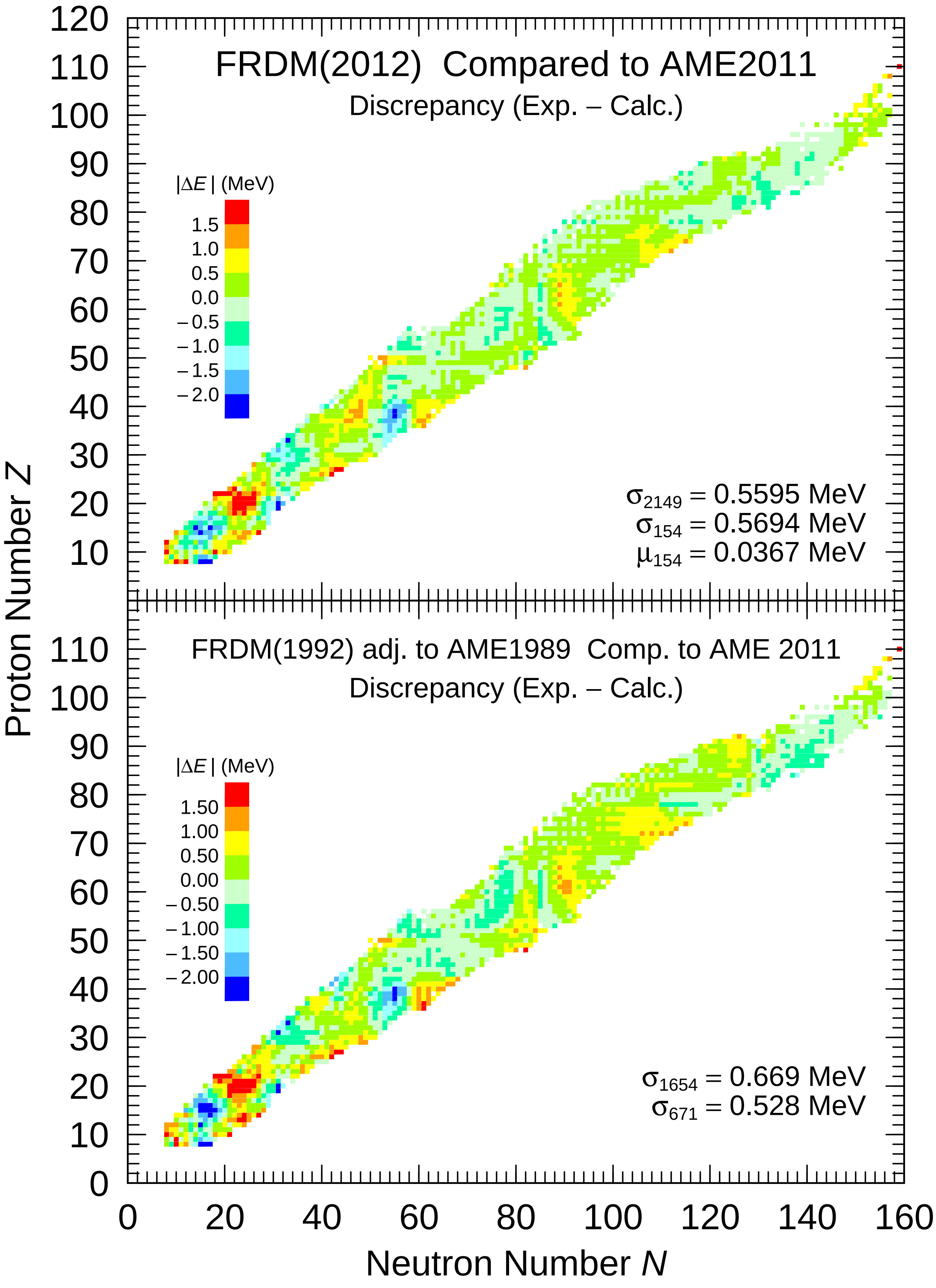
L **variation** (2009–2011)

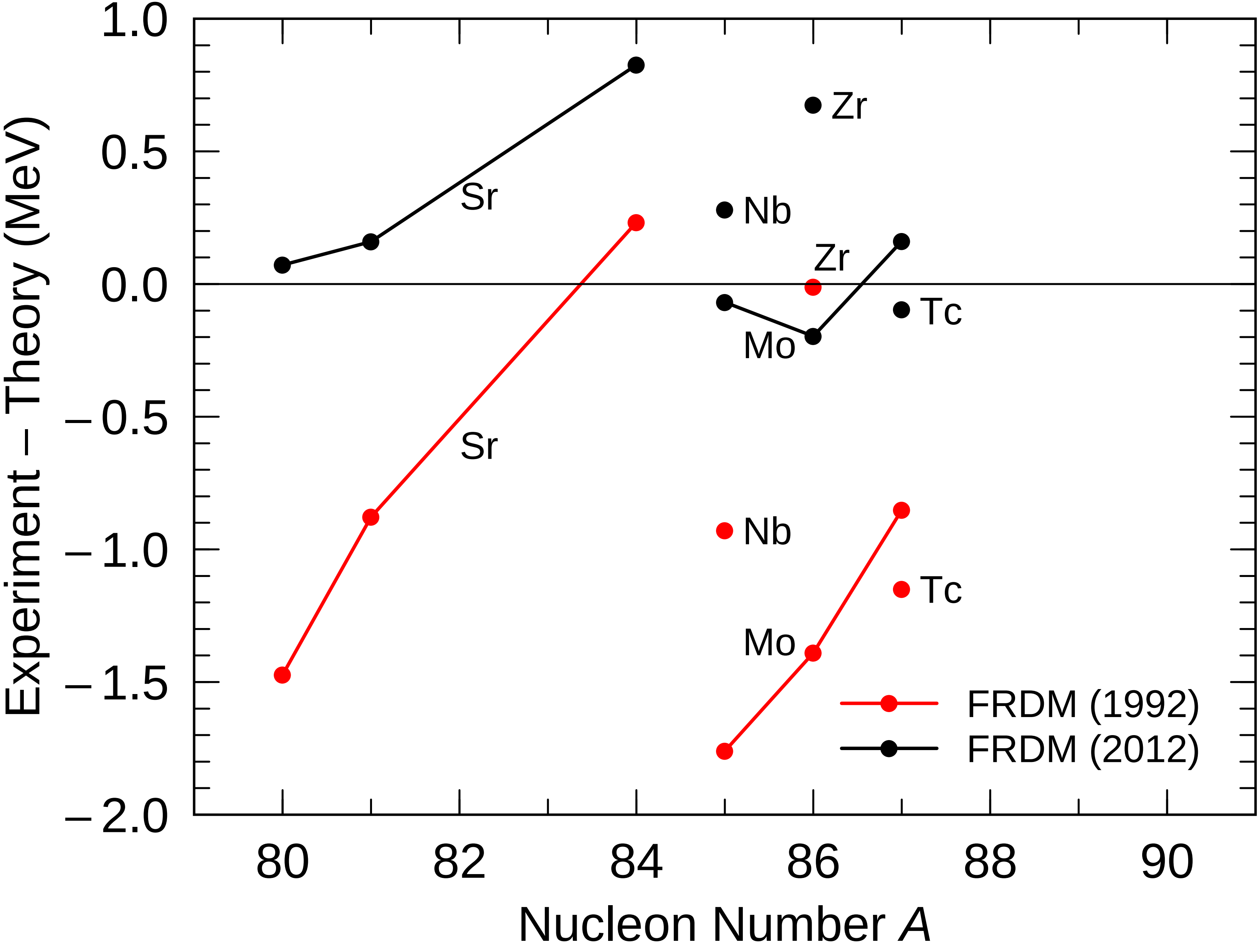
Accuracy improvement: 0.02 MeV

Improved gs correlation energies (2012)

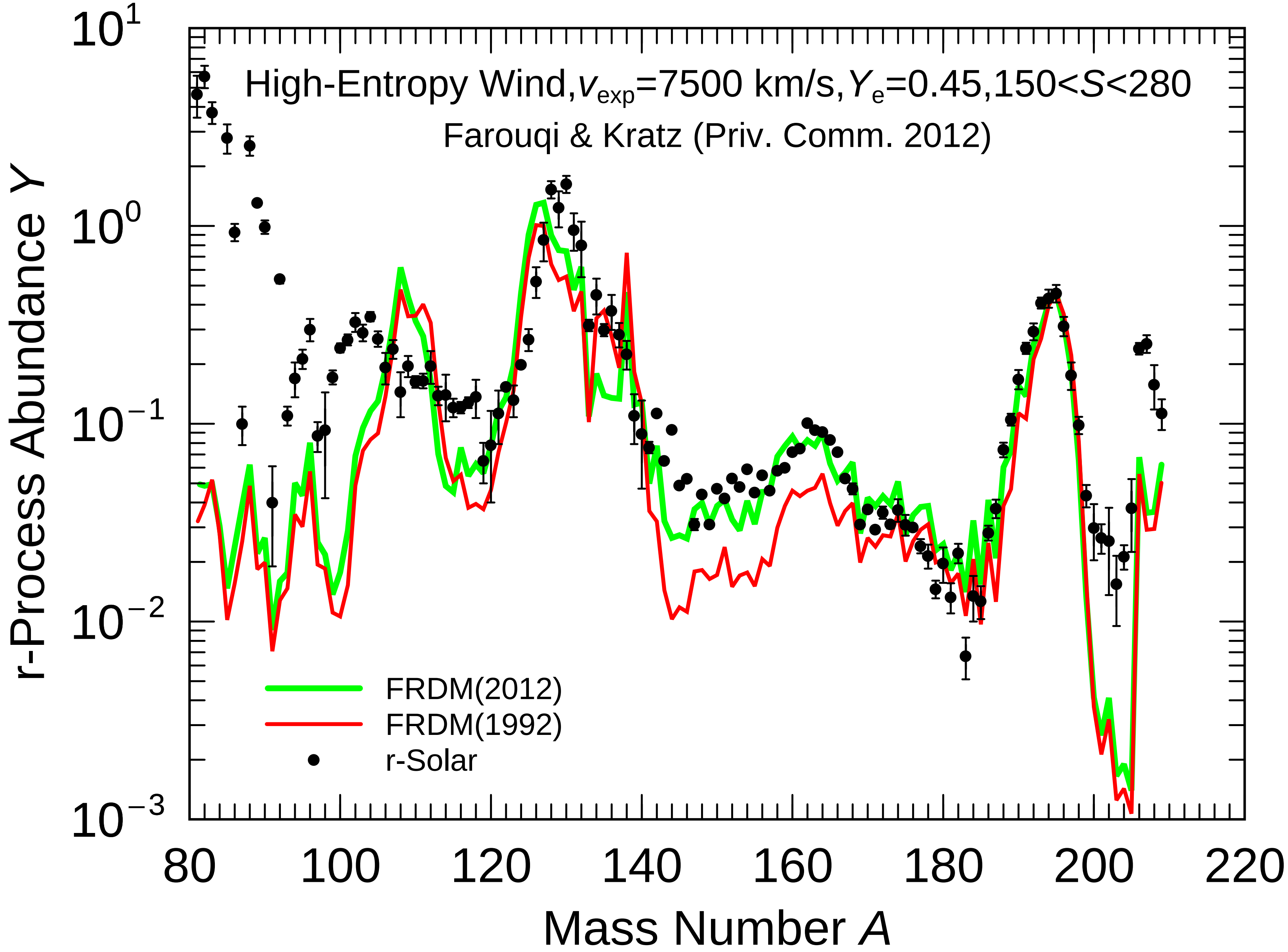
Accuracy improvement: 0.01 MeV


FRDM (2012)
σ_th = 0.5595 MeV
Exp. = AME2003
FRDM (1992)
σ_th = 0.6314 MeV
Exp. = AME2003
Discrepancy (Exp. − Calc.) (MeV)
5
4
3
2
1
0
−1
−2
−3
−4
−5
Neutron Number N
0
20
40
60
80
100
120
140
160


FRDM(2012) Compared to AME2011
Discrepancy (Exp. – Calc.)
|ΔE| (MeV)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
σ_{2149} = 0.5595 MeV
σ_{154} = 0.5694 MeV
μ_{154} = 0.0367 MeV
FRDM(1992) adj. to AME1989 Comp. to AME 2011
Discrepancy (Exp. – Calc.)
|ΔE| (MeV)
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
σ_{1654} = 0.669 MeV
σ_{671} = 0.528 MeV
Proton Number Z
Neutron Number N
0
10
20
30
40
50
60
70
80
90
100
110
120
0
20
40
60
80
100
120
140
160



Trap Data from Haettner et al. (PRL 106 (2011) 122501)


High-Entropy Wind, v_{exp}=7500 km/s, Y_e=0.45, 150<S<280
Farouqi & Kratz (Priv. Comm. 2012)
r-Process Abundance Y
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
80
100
120
140
160
180
200
220
Mass Number A
FRDM(2012)
FRDM(1992)
r-Solar