# RIPL - Reference Input Parameter Library for calculation of nuclear reactions and nuclear data evaluations

Roberto Capote, Nuclear Data Section

International Atomic Energy Agency

# RIPL Objective (1993)

Improve the methodology of nuclear data evaluation by increasing predictive power, accuracy and reliability of theoretical calculations by nuclear reaction model codes

**1994 – 2009**

**The longest running IAEA/NDS project**

Nuclear Data Sheets **110** (2009) 3107–3214

RIPL – Reference Input Parameter Library for Calculation of Nuclear Reactions and Nuclear Data Evaluations

R. Capote,[1] M. Herman,[1,2] P. Obložinský,[1,2] P.G. Young,[3] S. Goriely,[4] T. Belgya,[5] A.V. Ignatyuk,[6] A.J. Koning,[7] S. Hilaire,[8] V.A. Plujko,[9] M. Avrigeanu,[10] O. Bersillon,[8] M.B. Chadwick,[3] T. Fukahori,[11] Zhigang Ge,[12] Yinlu Han,[12] S. Kailas,[13] J. Kopecky,[14] V.M. Maslov,[15] G. Reffo,[16] M. Sin,[17] E.Sh. Soukhovitskii,[15] and P. Talou[3]

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**M. Herman**
S. Hilaire
**A.V. Ignatyuk**
S. Kailas
A.J. Koning
**P. Obložinský**
V. A. Plujko
E. S. Soukhovitskii
P. Talou
**P. G. Young**
Zhigang Ge

# TALYS & EMPIRE modeling codes

TALYS

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**What is TALYS?**

**TALYS** is software for the simulation of nuclear reactions. Many state-of-the-art nuclear models are included to cover all main reaction mechanisms encountered in light particle-induced nuclear reactions. **TALYS** provides a complete description of all reaction channels and observables, and is user-friendly.

**TALYS** is a versatile tool to analyse basic microscopic experiments and to generate nuclear data for applications.

News

Download TALYS-1.2!

The official TALYS-1.2 is now available.


Available online at www.sciencedirect.com

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Nuclear Data Sheets

Nuclear Data Sheets 108 (2007) 2655–2715

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## EMPIRE paper

EMPIRE: Nuclear Reaction Model Code System for Data Evaluation


M. Herman[1,*], R. Capote[2], B.V. Carlson[3], P. Obložinský[1], M. Sin[4], A. Trkov[5], H. Wienke[6], and V. Zerkin[2]

[1] *National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA*
[2] *Nuclear Data Section, International Atomic Energy Agency, Wagramer Strasse, A-1400 Vienna, Austria*
[3] *Departamento de Física, Instituto Tecnológico de Aeronáutica, 12228-900, SP, Sao José dos Campos, Brazil*
[4] *Nuclear Physics Department, Bucharest University, P.O. Box MG-11, Bucharest-Magurele, Romania*
[5] *Jozef Stefan Institute, Reactor Physics Division R-1, Jamova 39, 1000 Ljubljana, Slovenia and*
[6] *Belgonucleaire, Dessel, B2480, Belgium*

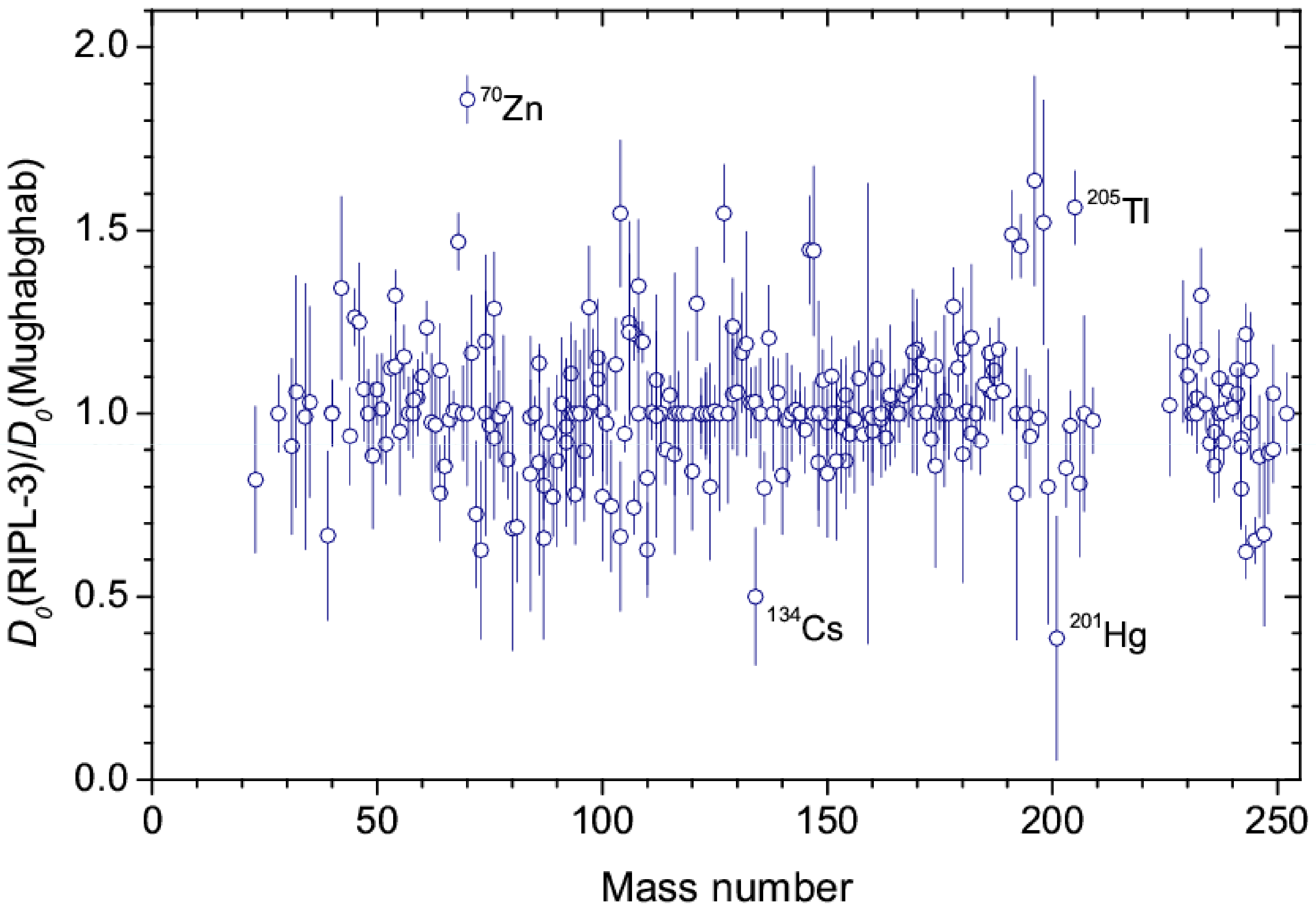
# RIPL contents

| No | Directory | Contents |
|---|---|---|
| 1 | MASSES | Atomic Masses and Deformations |
| 2 | LEVELS | Discrete Level Schemes |
| 3 | RESONANCES | Average Neutron Resonance Parameters |
| 4 | OPTICAL | Optical Model Parameters |
| 5 | DENSITIES | Level Densities (Total, Partial) |
| 6 | GAMMA | Gamma-Ray Strength Functions |
| 7 | FISSION | Fission Barriers and Level Densities |

~~http://www-nds.iaea.org/RIPL-2/~~ X

http://www-nds.iaea.org/RIPL-3/

# 3.- RESONANCES



# 5.- LEVEL DENSITIES

**Based on OBSERVABLES:**

RIPL-3 discrete levels (2) and Neutron resonances (3)

Provide **PHENOMENOLOGICAL** level density parameters for :

CTM: Constant Temperature Model (TALYS)

BFM: Back-shifted Fermi gas model (TALYS)

GSM: Generalized Superfluid Model

EGSM: Enhanced GSM (EMPIRE)

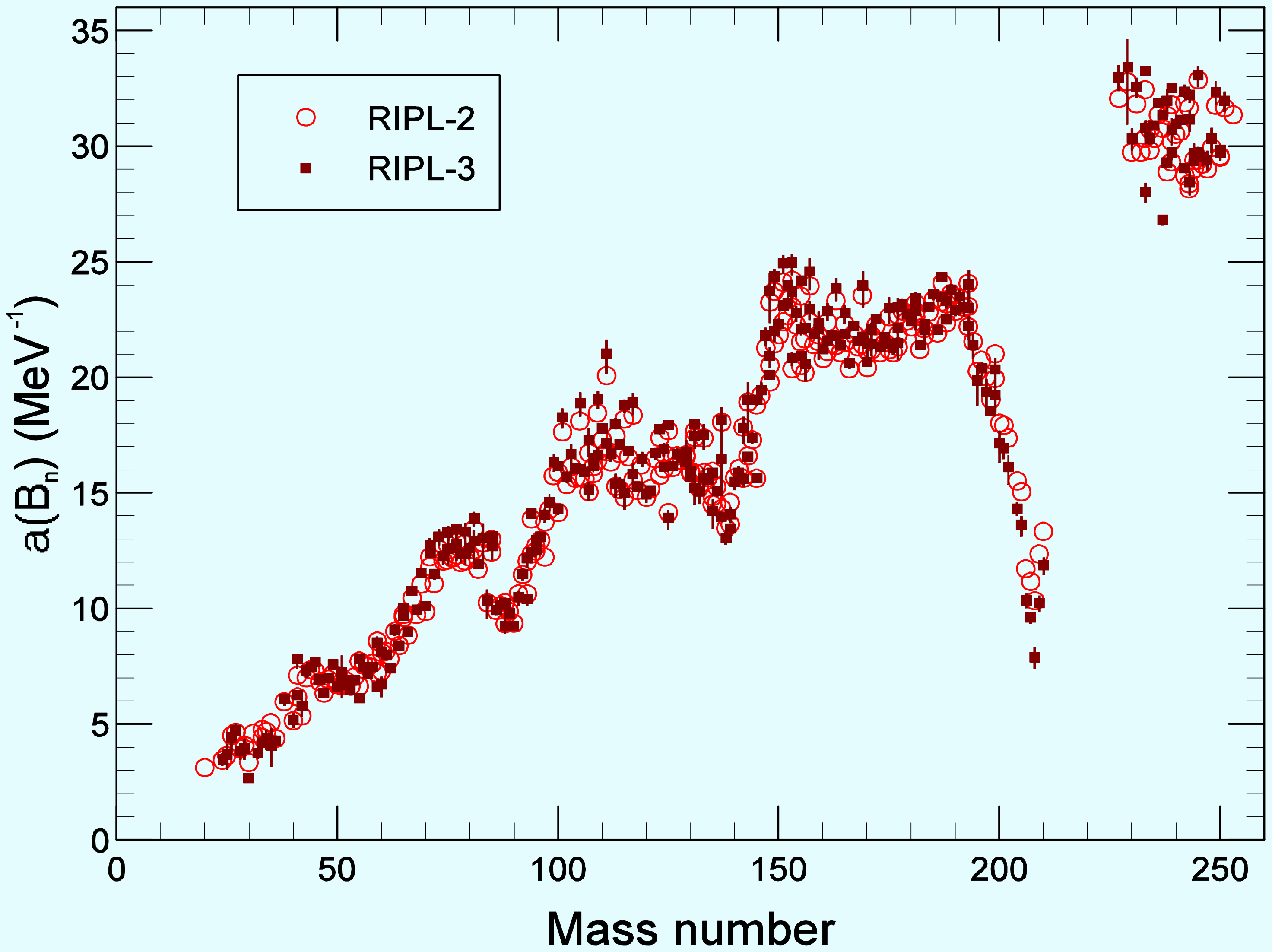
$$a \equiv a(E,Z,A) = \tilde{a}(A)\left\{1 + \frac{\delta W(Z,A)}{U}\left[1 - \exp(-\gamma U)\right]\right\},$$

$$\tilde{a} = \alpha A + \beta A^{2/3},$$

$$\gamma = \frac{\gamma_0}{A^{\frac{1}{3}}}.$$

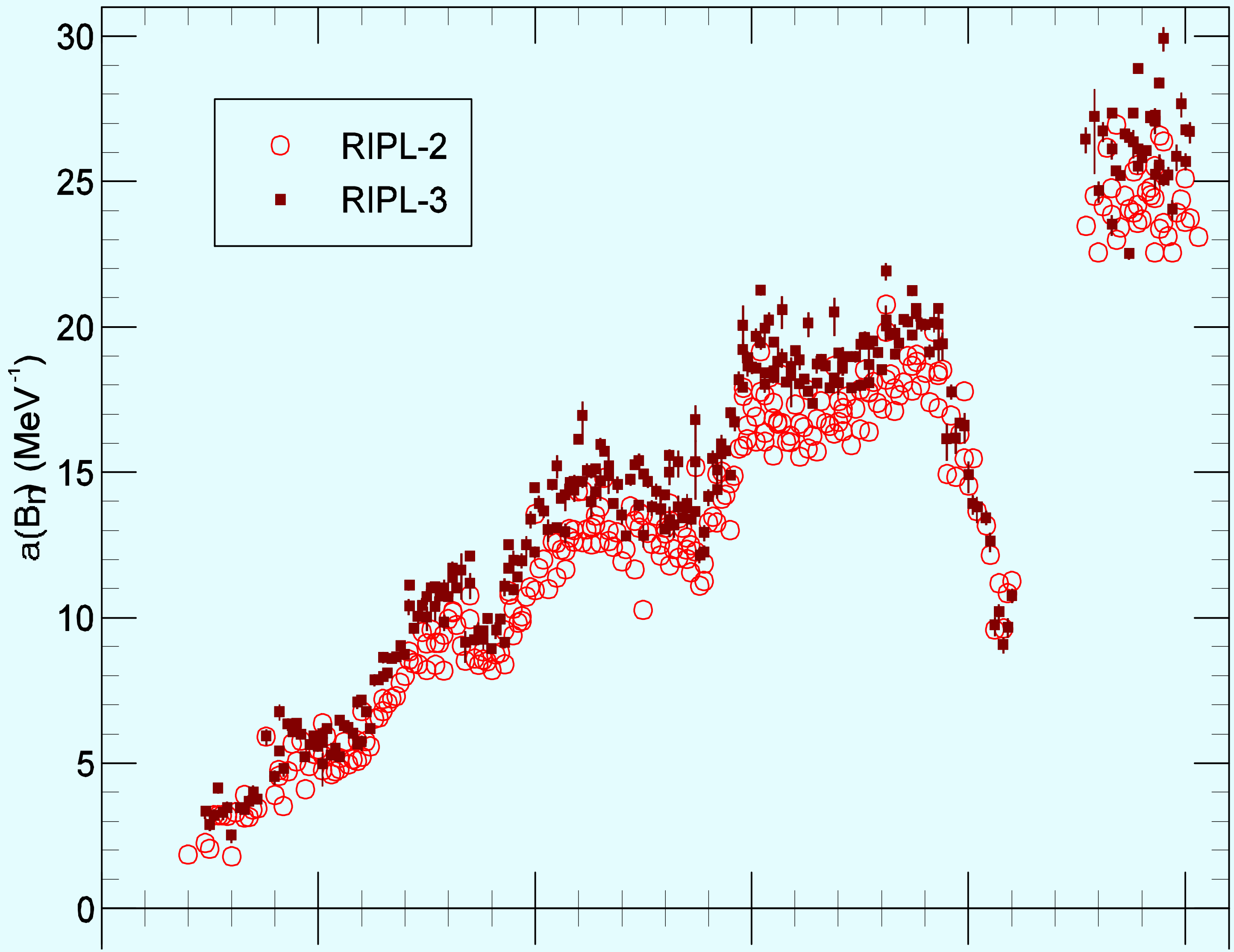
**Statistical treatment, parity=1/2**

# CTM (1)

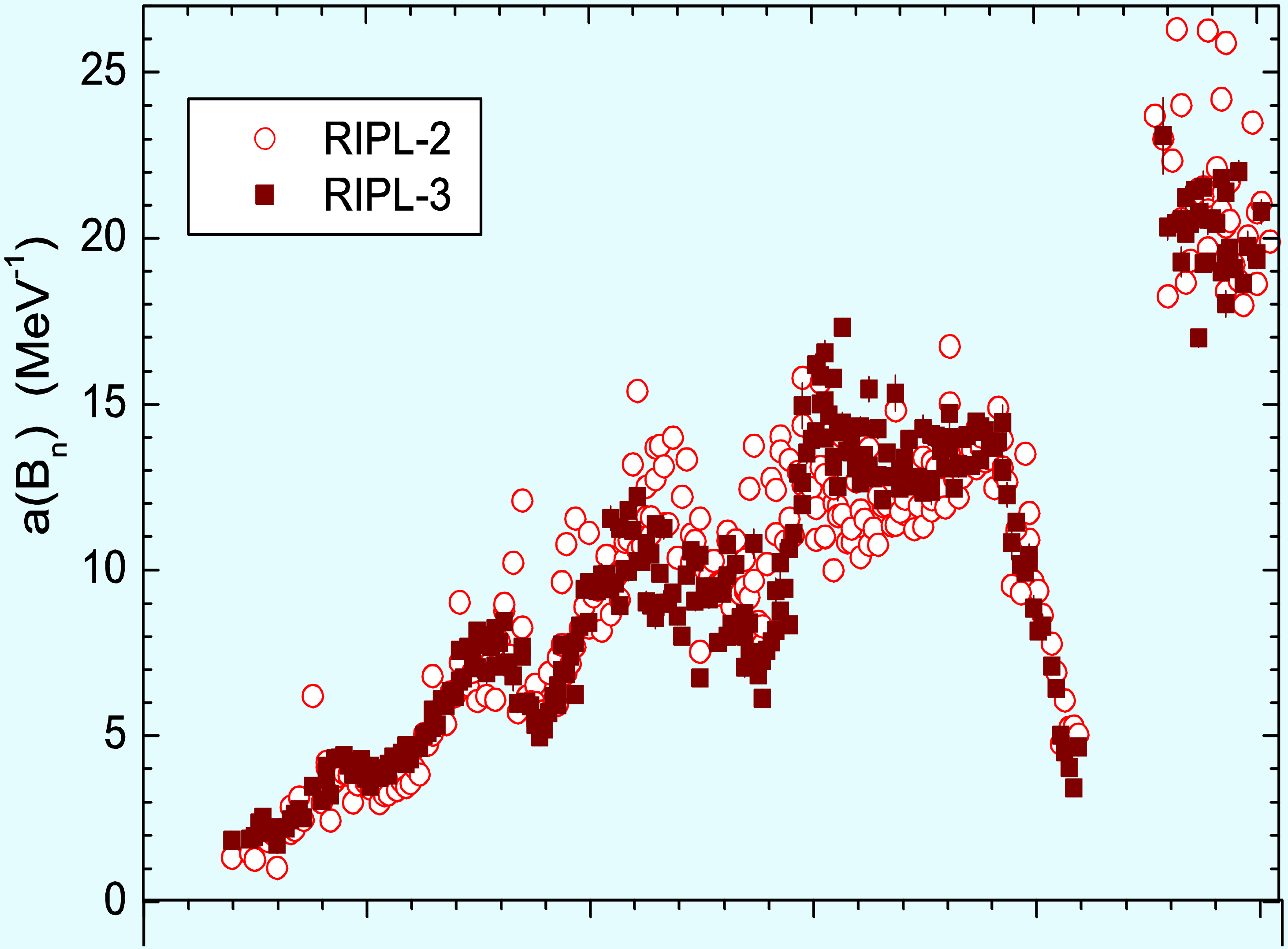


RIPL-2
RIPL-3
a(B$_n$) (MeV$^{-1}$)
Mass number
0
5
10
15
20
25
30
35
0
50
100
150
200
250

# BFM (1)



# GSM (1)

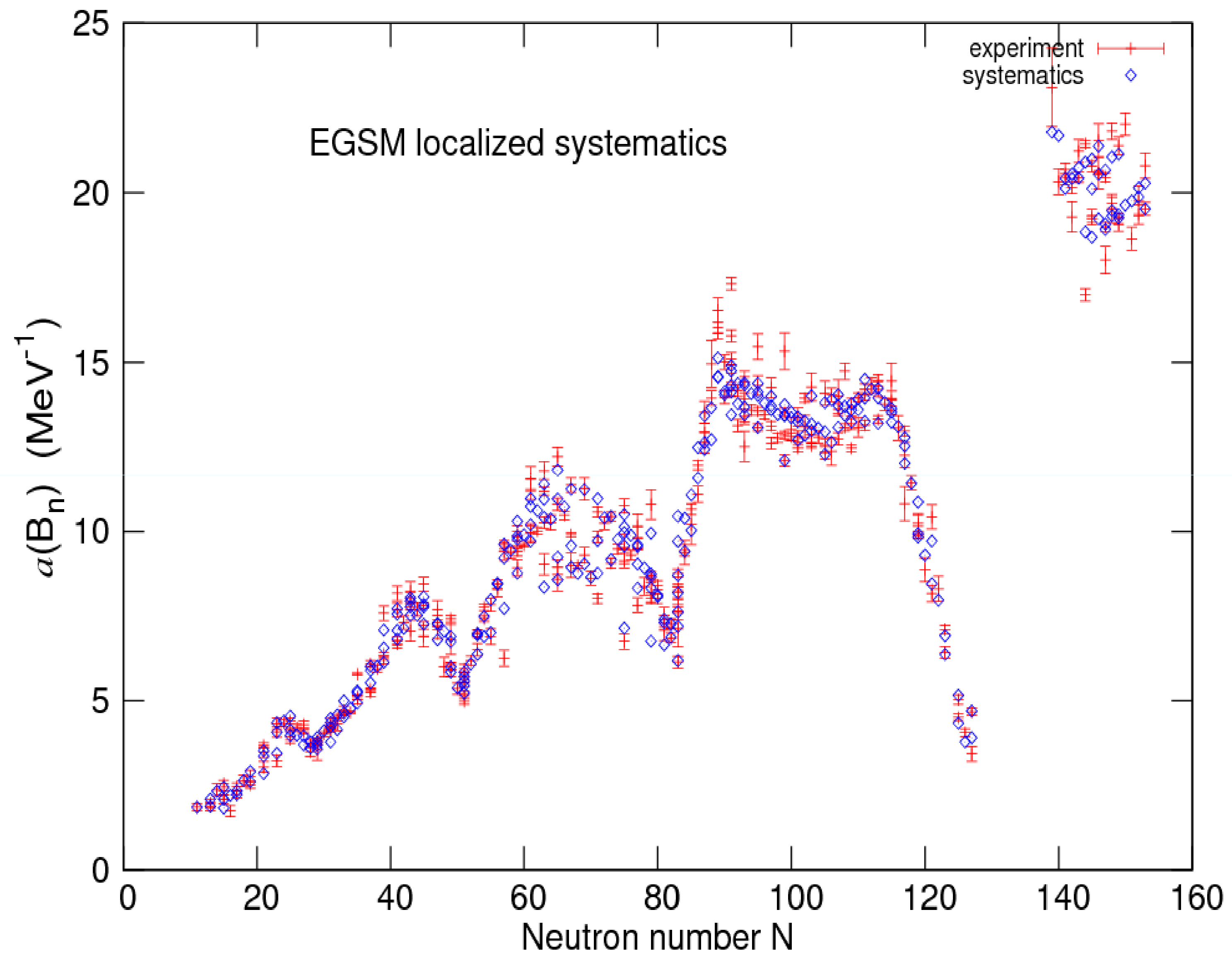





**RIPL database**

Roberto Capote, r.capotenoy@iaea.org

# EGSM (1)



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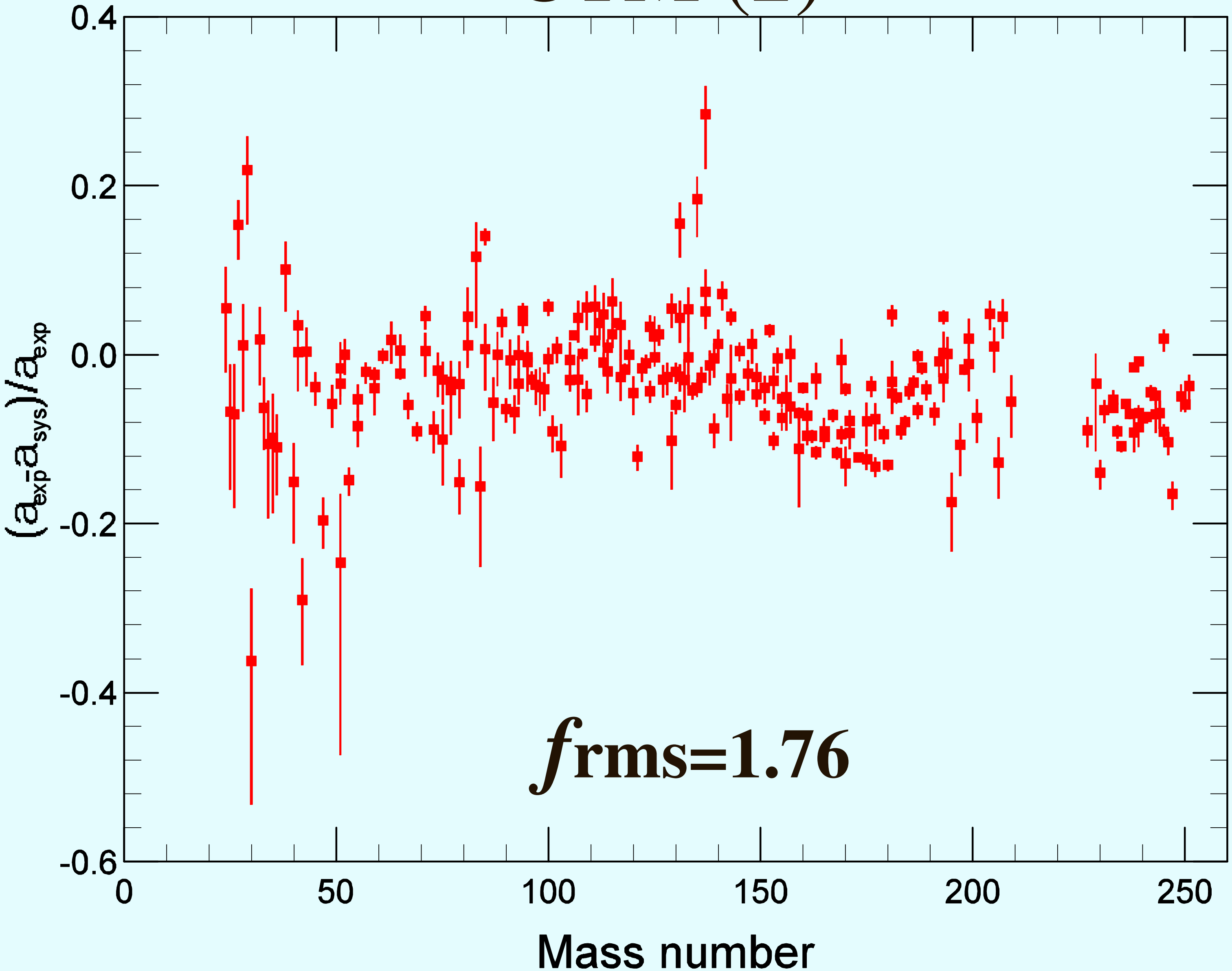
Roberto Capote, r.capotenoy@iaea.org

# CTM (2)



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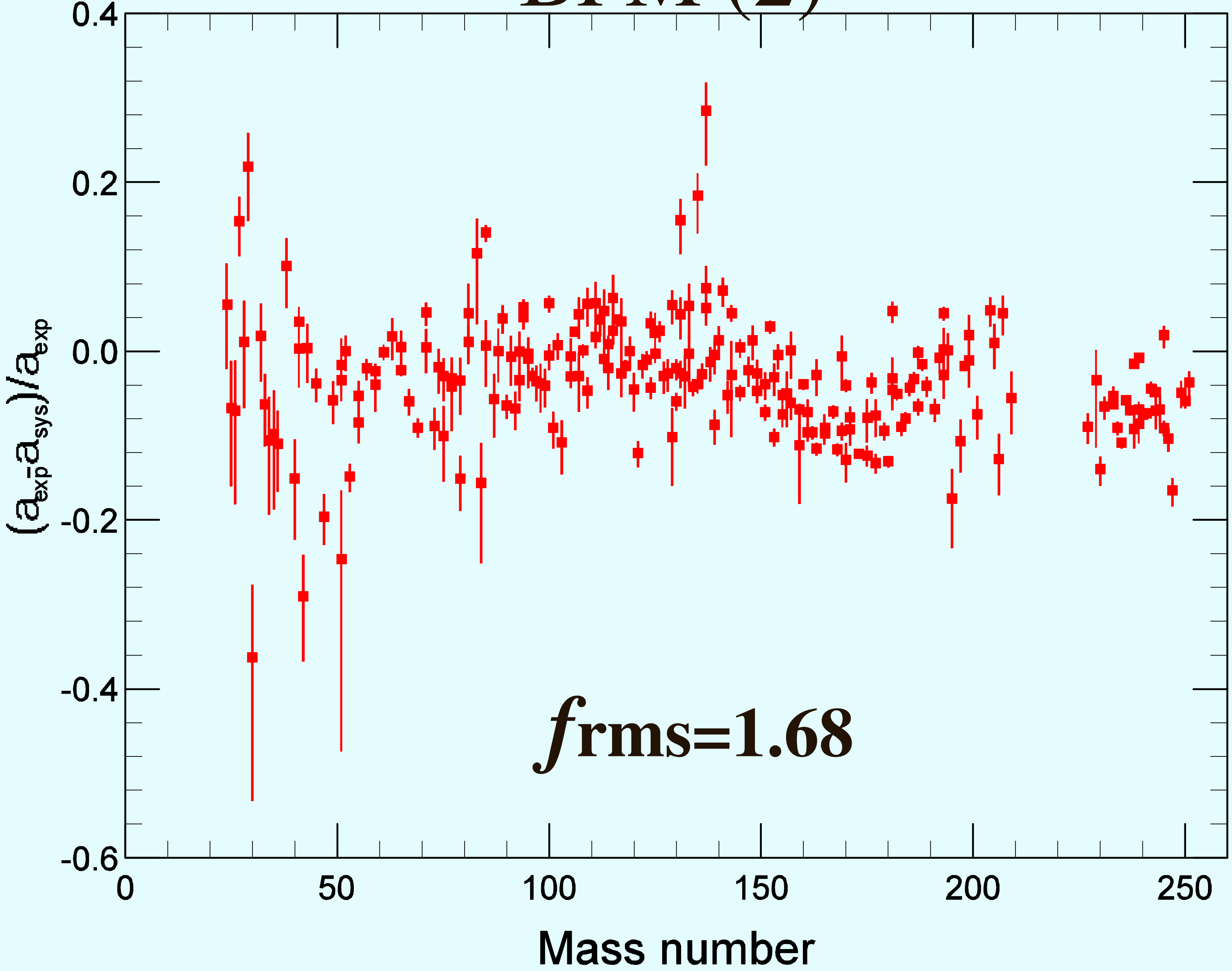
Roberto Capote, r.capotenoy@iaea.org

# BFM (2)



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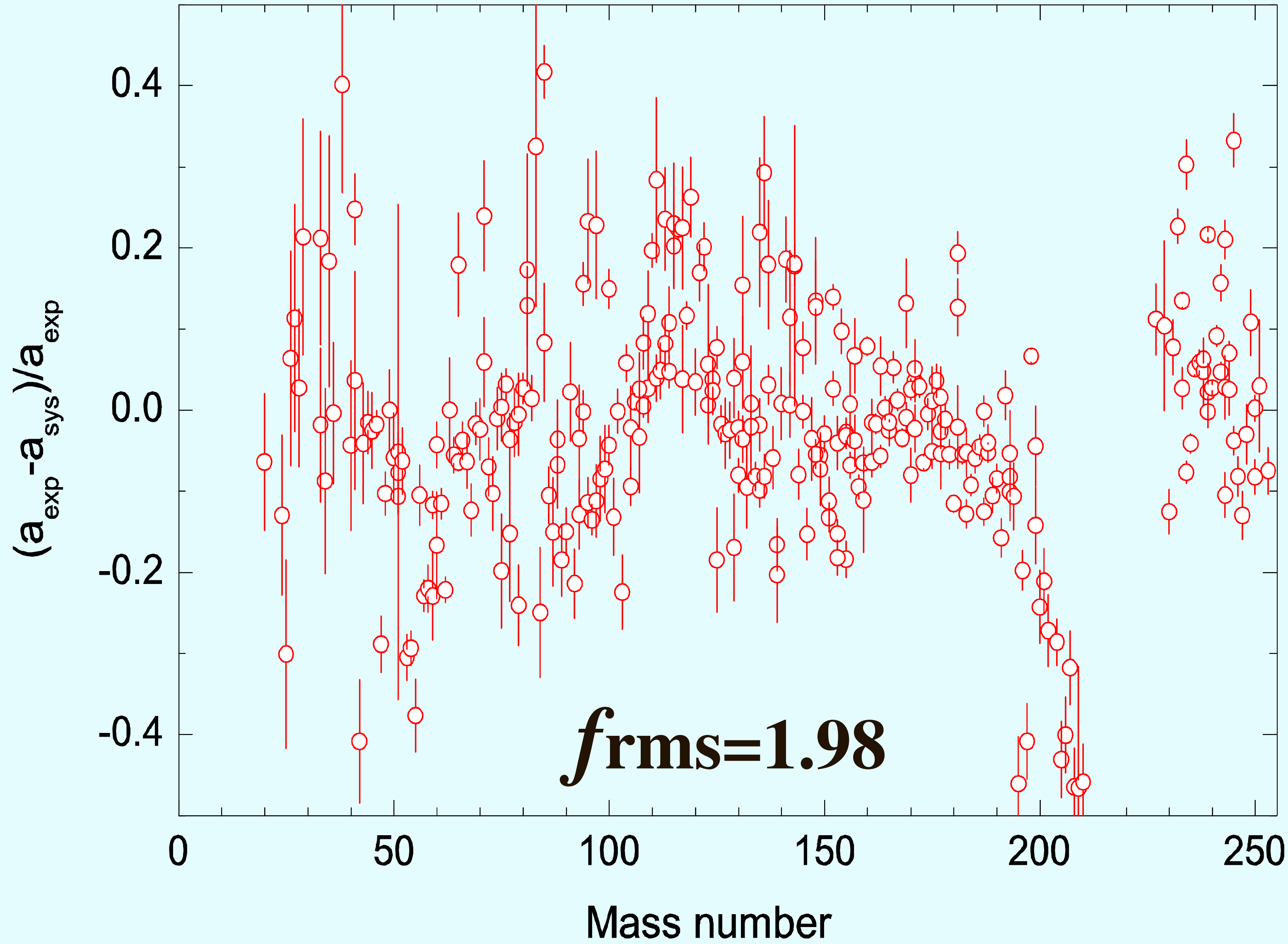
# GSM (2)



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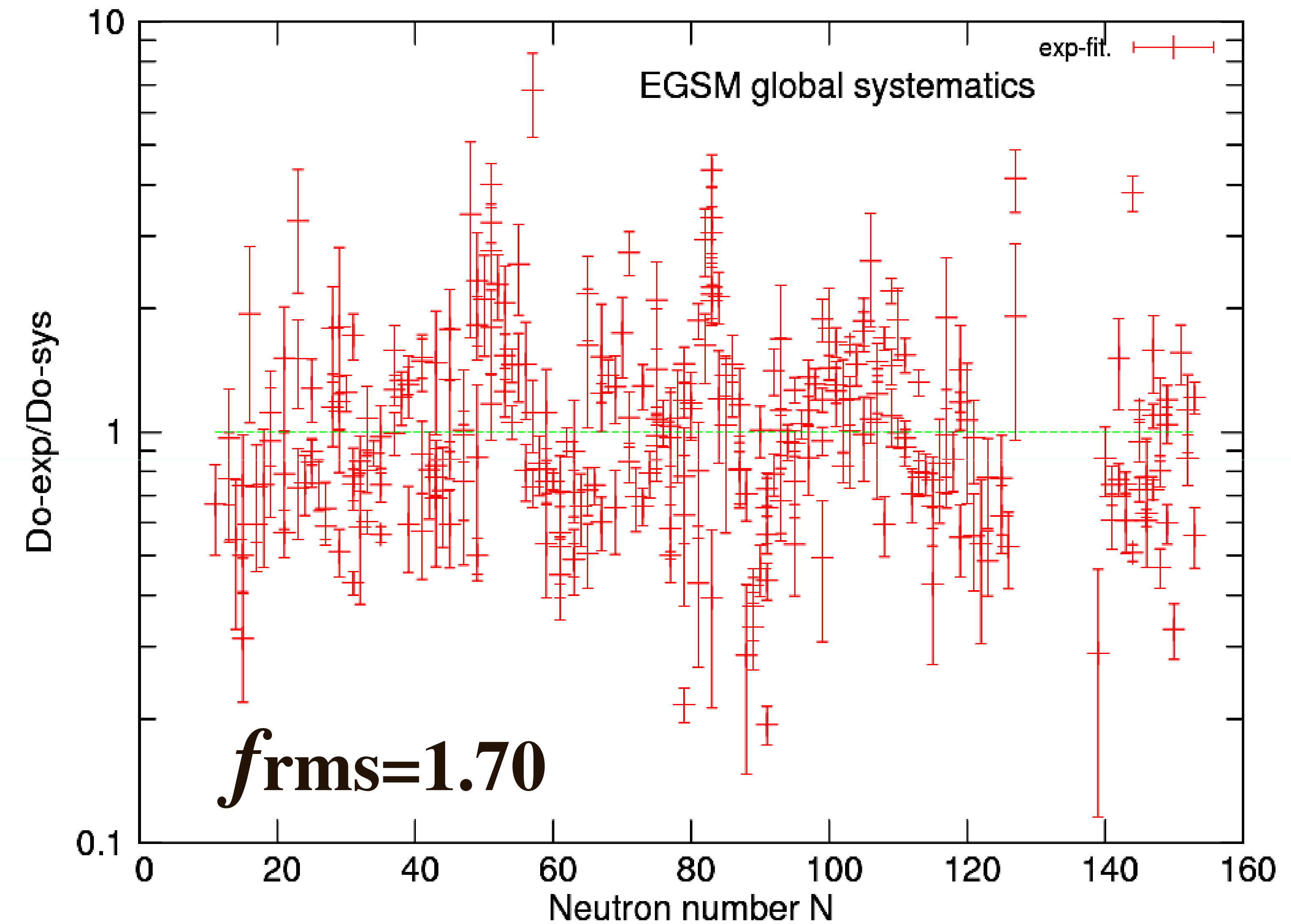
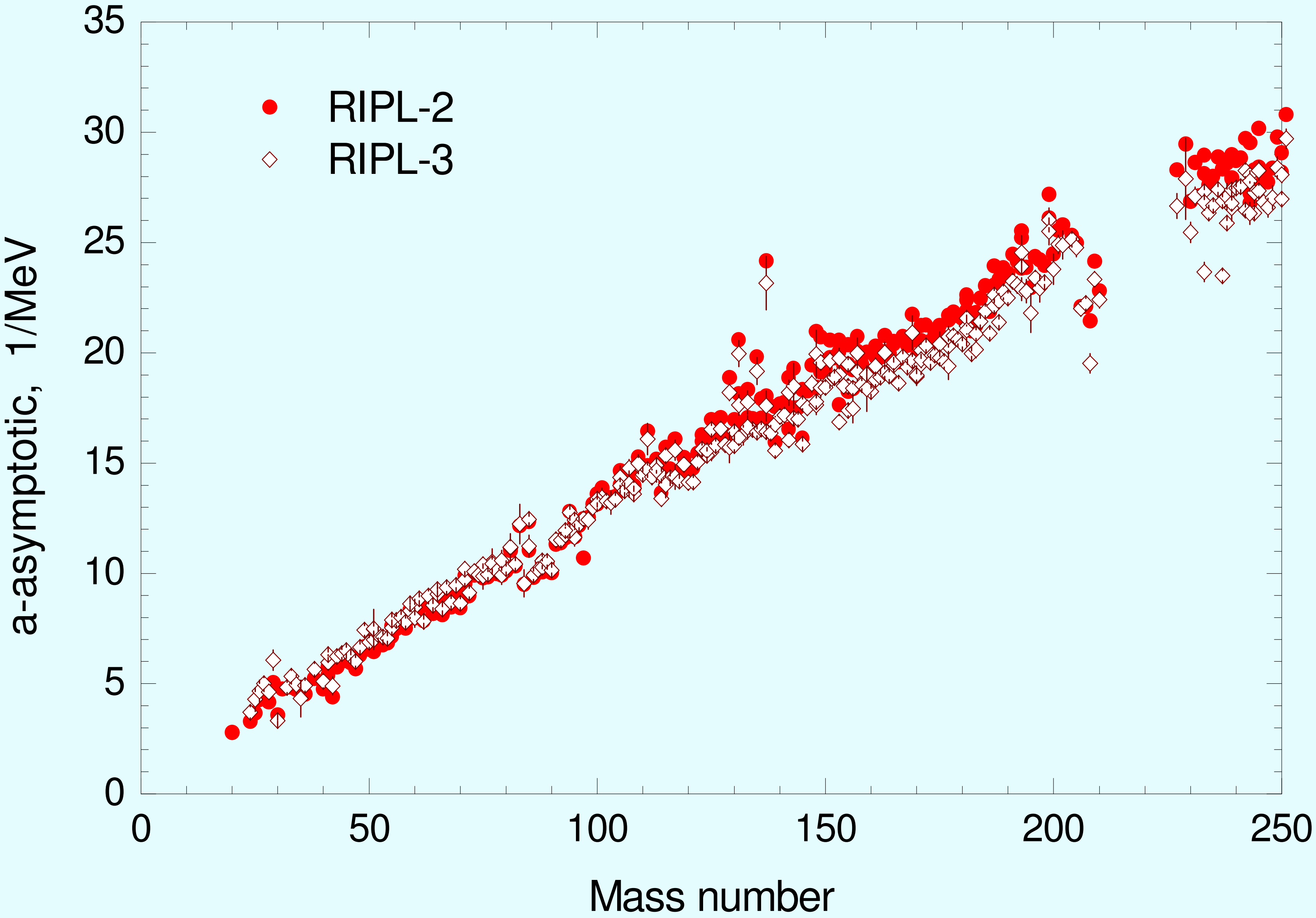
Roberto Capote, r.capotenoy@iaea.org

# EGSM (2)



exp-fit.
EGSM global systematics
Do-exp/Do-sys
Neutron number N
10
1
0.1
0
20
40
60
80
100
120
140
160
*f*rms=1.70

# CTM (G&C)



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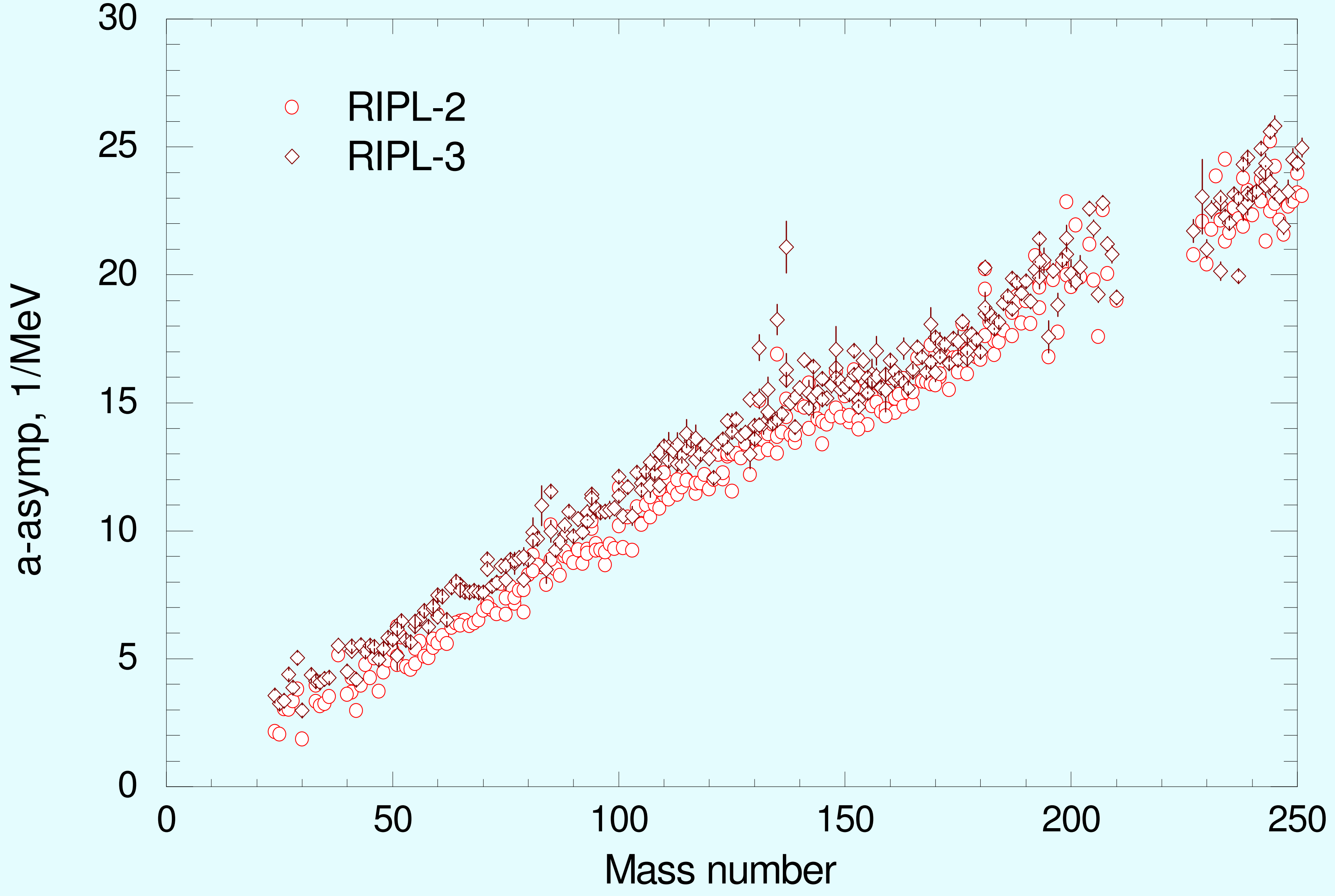
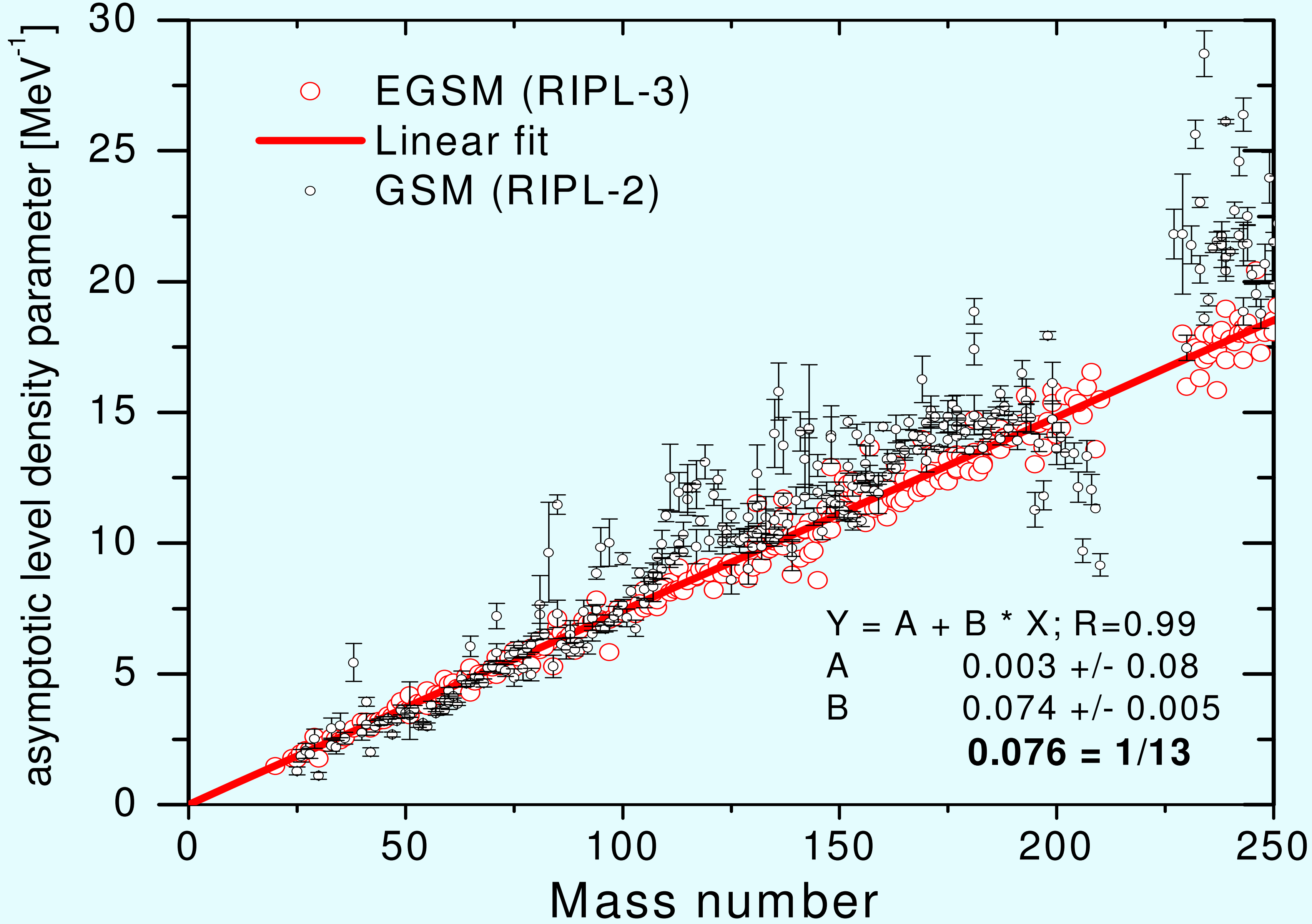
Roberto Capote, r.capotenoy@iaea.org

# BSFGM

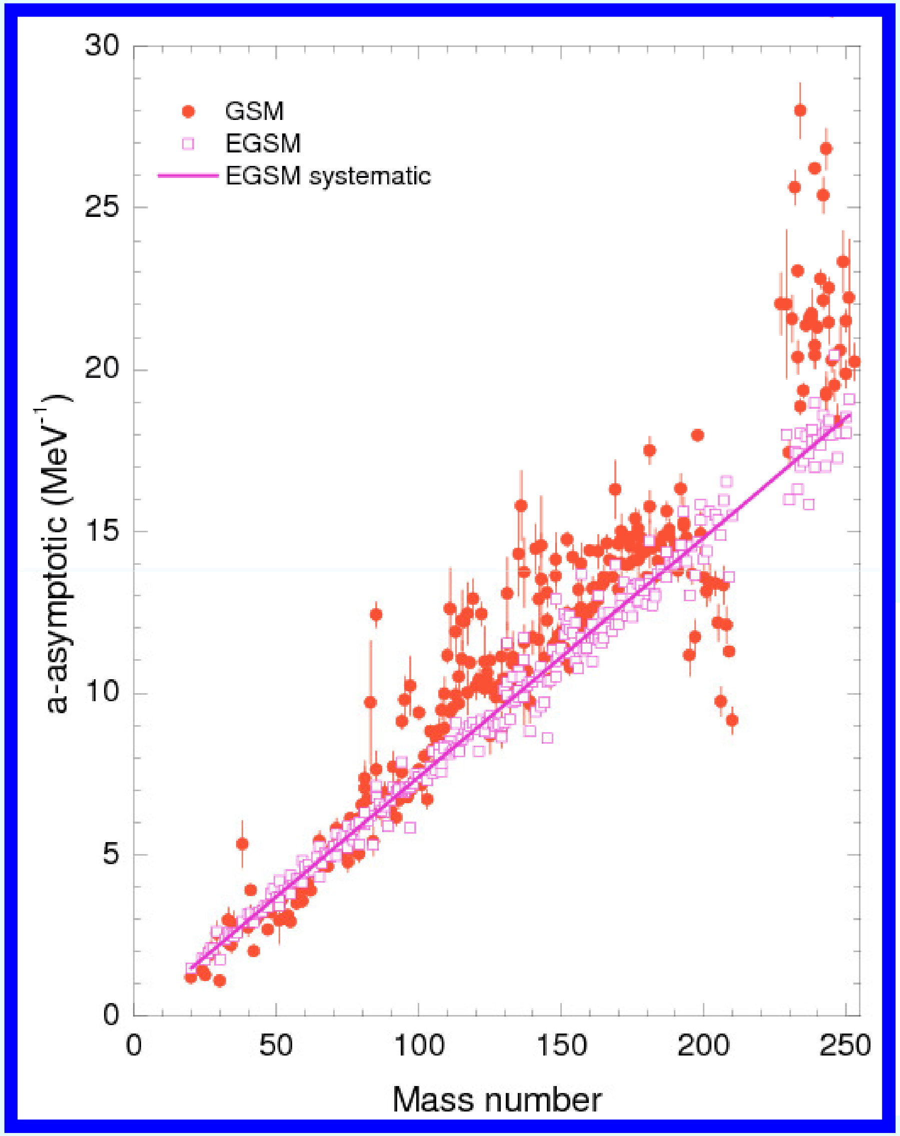


RIPL-2
RIPL-3
a-asymp, 1/MeV
Mass number
0
5
10
15
20
25
30
0
50
100
150
200
250

# EGSM vs GSM


EGSM (RIPL-3)
Linear fit
GSM (RIPL-2)
Y = A + B * X; R=0.99
A 0.003 +/- 0.08
B 0.074 +/- 0.005
0.076 = 1/13
asymptotic level density parameter [MeV-1]
Mass number
0
5
10
15
20
25
30
0
50
100
150
200
250

# EGSM level density model




$$\tilde{a} = \alpha A + \beta A^{2/3},$$

$$\alpha = 0.0741, \quad \beta = 0.0003, \quad \gamma_0 = 0.5725.$$

**$f_{rms}$=1.70**

Notable features of the EGSM parameterization are the vanishing role of the nuclear surface term ($\beta$ parameter is negligible compared to $\alpha$ in Eq. (52)), and the linear dependence of "experimental" asymptotic $\tilde{a}$ values on mass number $A$ ($\tilde{a} \approx 0.0741A = A/13.5$). The derived asymptotic value of the level density parameter is very close to the theoretical value of the Fermi gas model of Eq. (44); the complete absence of the shell effects in the mass dependence of $\tilde{a}$ is a strong argument in favor of the collective enhancements and shell corrections adopted in the EGSM.




Roberto Capote, r.capotenoy@iaea.org

# 5.- LEVEL DENSITIES

**Based on OBSERVABLES:**

RIPL-3 discrete levels (2) and Neutron resonances (3)

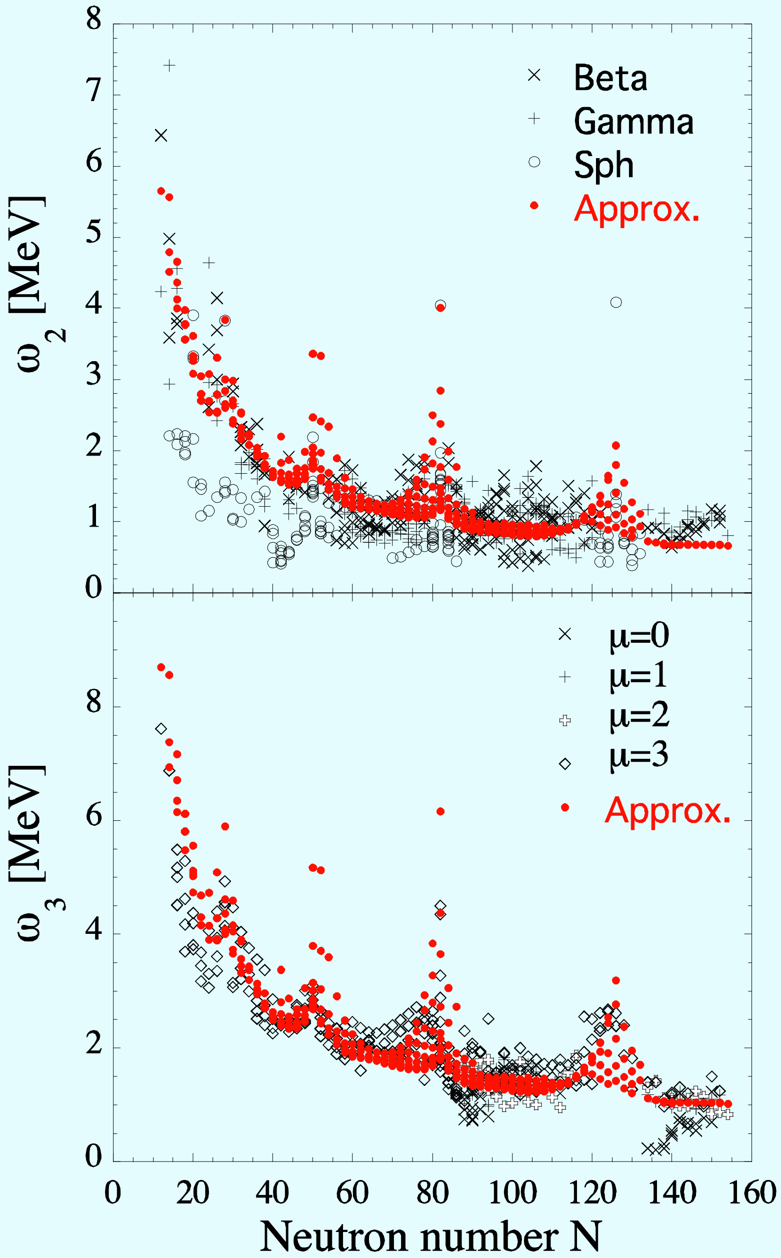
Provide **SEMI-MICROSCOPIC** level density parameters for :

HFB combinatorial LD: (TALYS & EMPIRE)

Micro-canonical treatment : A truly combinatorial method can provide NLDs as a function of the excitation energy, spin and parity without any a-priori assumption on the spin and parity distributions for all the nuclei of the periodic table.

**Convolution of intrinsic and collective LDs**

**Phenomenological vibrational enhancement,** $\Im = \Im_{rig}$




$$\omega_2[\mathrm{MeV}] = 65A^{-5/6}/(1 + 0.05E_{shell}), \quad (119)$$

for the quadrupole vibrations, and

$$\omega_3[\mathrm{MeV}] = 100A^{-5/6}/(1 + 0.05E_{shell}), \quad (120)$$

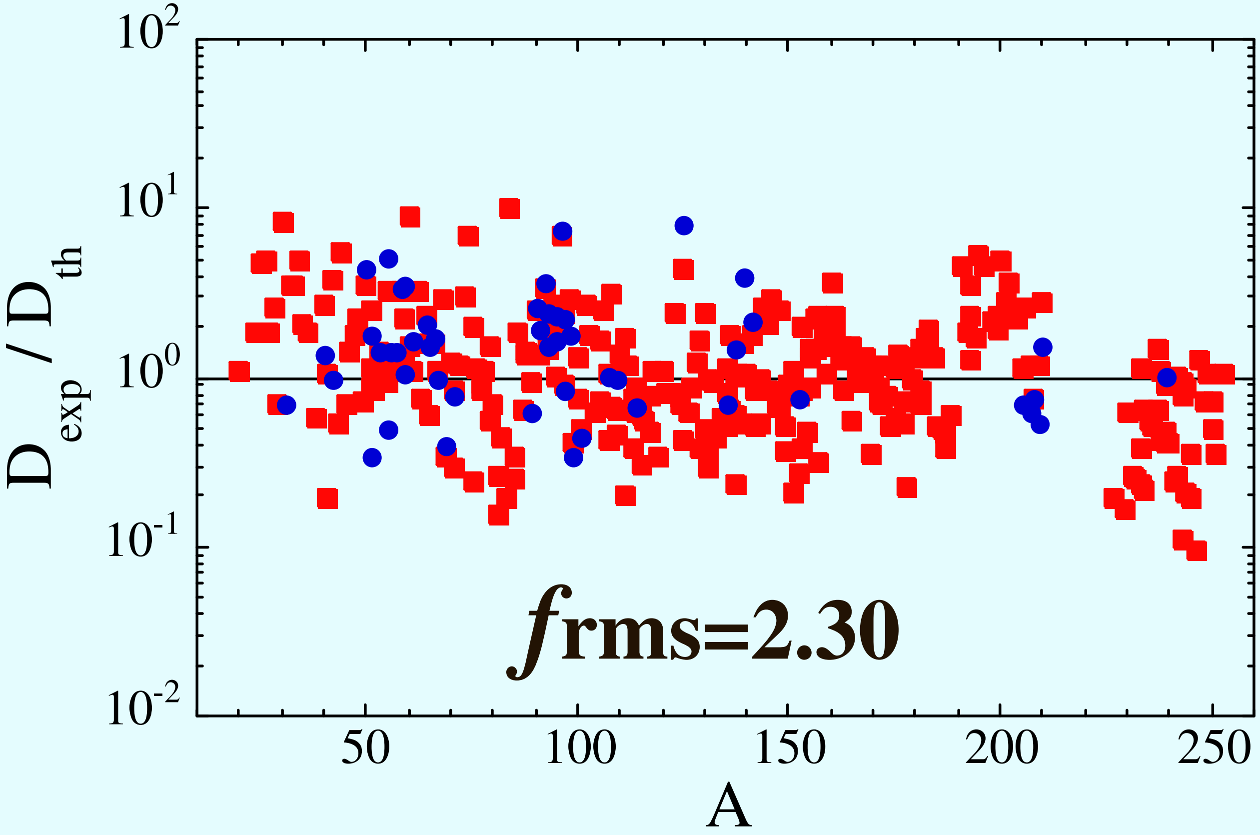
for the octupole excitations. The hexadecapole mode can be expressed relative to the quadrupole mode [210], leading to a similar expression:

$$\omega_4[\mathrm{MeV}] = 160A^{-5/6}/(1 + 0.05E_{shell}). \quad (121)$$

# A NEW global combinatorial NLD formula

**S. Hilaire & S.Goriely (2007)**

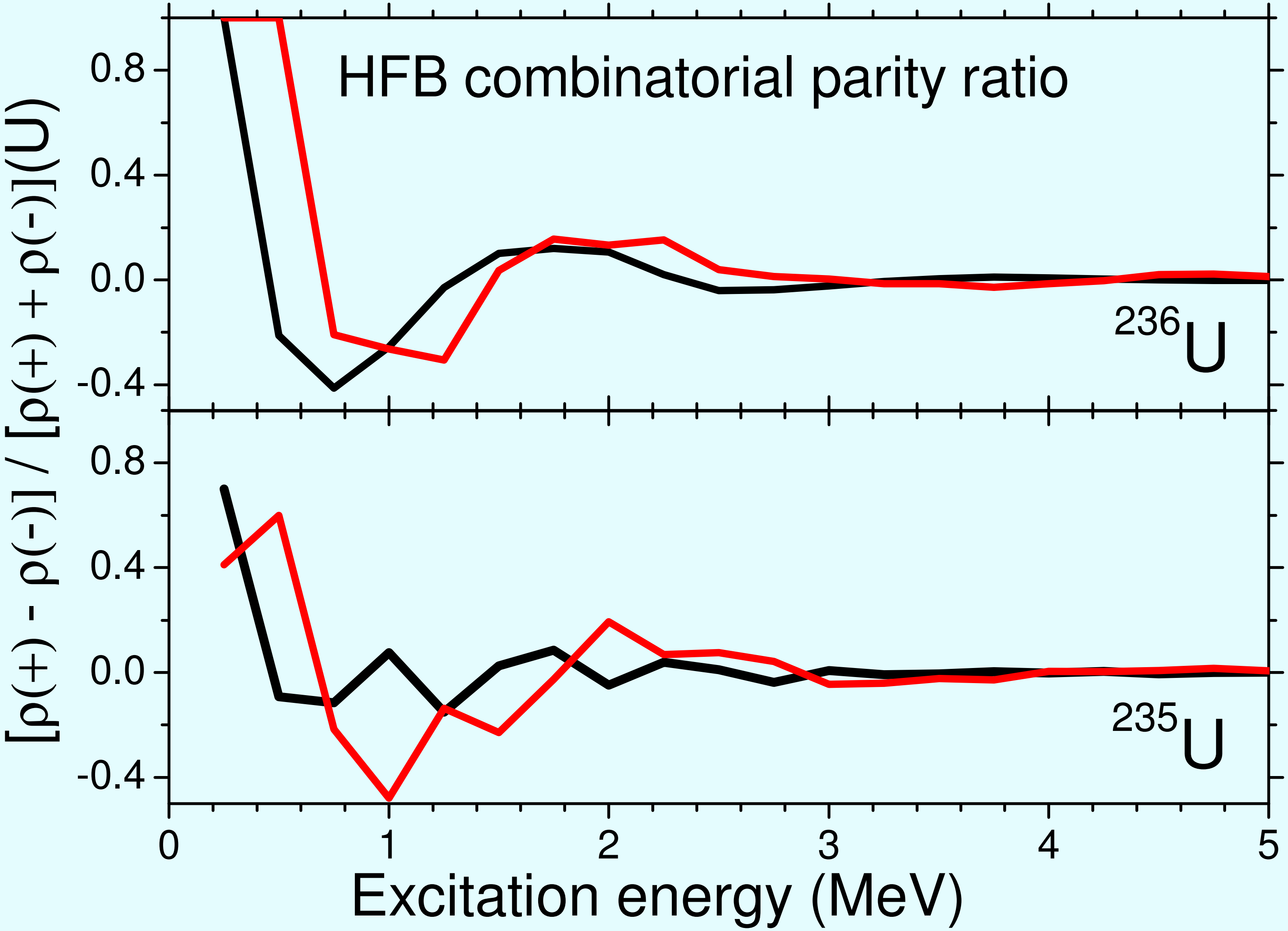
- Particle-hole as well as total parity-, spin- and E-dependent NLD
- Deviation from the statistical limit at low energies (discrete counting)




**s-wave**
**p-wave**

292 exp. $D_0$

# RIPL-3 HFB LD: parity dependence



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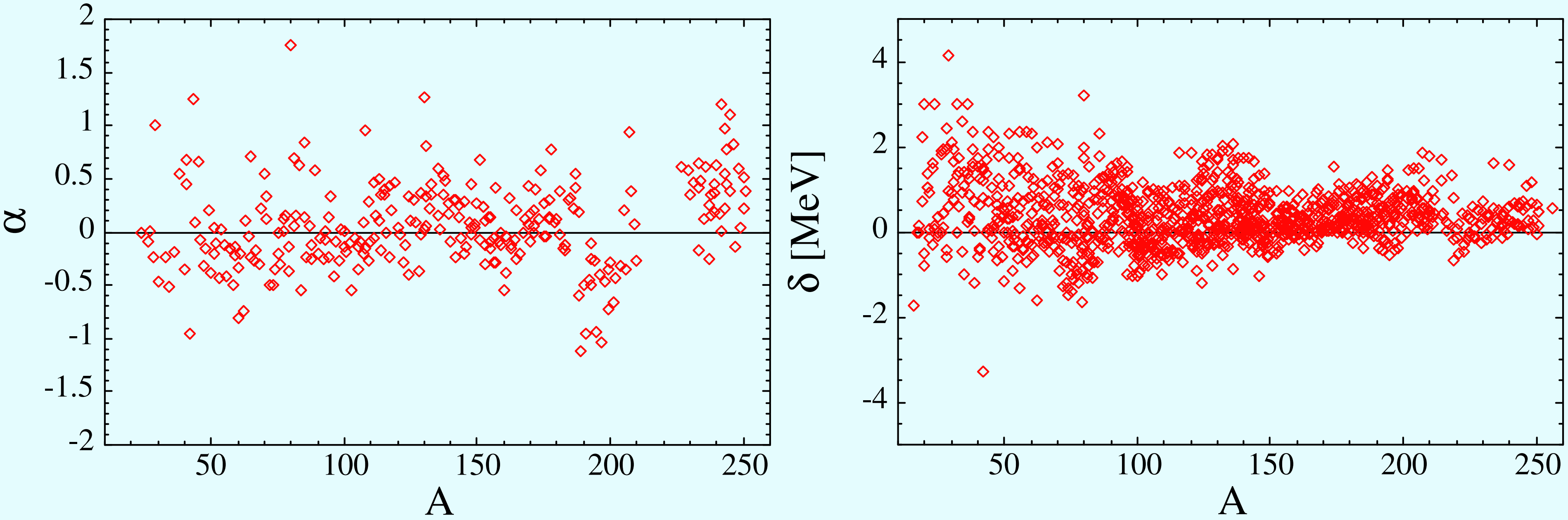
Roberto Capote, r.capotenoy@iaea.org

# Renormalization factors to reproduce $D_0$ and cumulative levels

$$\rho_{\text{renorm}}(U) = e^{\alpha\sqrt{U-\delta}}\,\rho_{\text{HFB}}(U-\delta)$$



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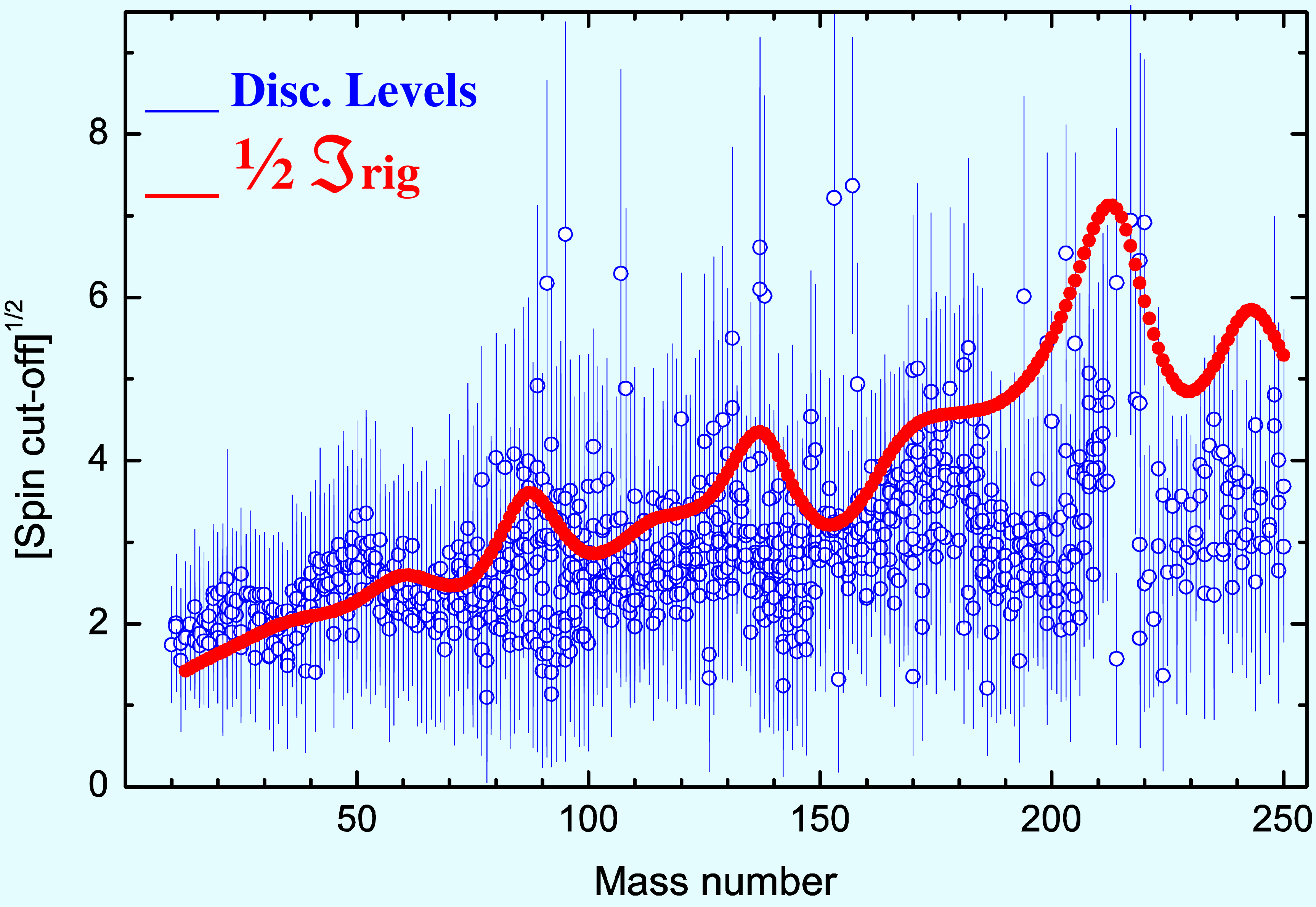
Roberto Capote, r.capotenoy@iaea.org



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Roberto Capote, r.capotenoy@iaea.org

# CONCLUDING REMARKS

**RIPL database development has involved important advances in the evolution of a complete and consistent set of input parameters for the calculation of a wide range of nuclear reactions.**

**Both phenomenological and semi-microscopic LDs were fitted to the latest discrete level and resonance spacing data.**

**Efforts will continue to develop this database further, and monitor all studies that impact and could possibly improve their contents.**

**http://www-nds.iaea.org/RIPL-3/**

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Roberto Capote, r.capotenoy@iaea.org