Reference Input Parameter Library for nuclear reaction modeling: RIPL status and outlook

Roberto Capote, Nuclear Data Section
http://www-nds.iaea.org

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

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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 108 (2007) 2655–2715

Nuclear Data Sheets

www.elsevier.com/locate/nds

EMPIRE paper

EMPIRE: Nuclear Reaction Model Code System for Data Evaluation

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RIPL contents

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

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

1.- MASSES

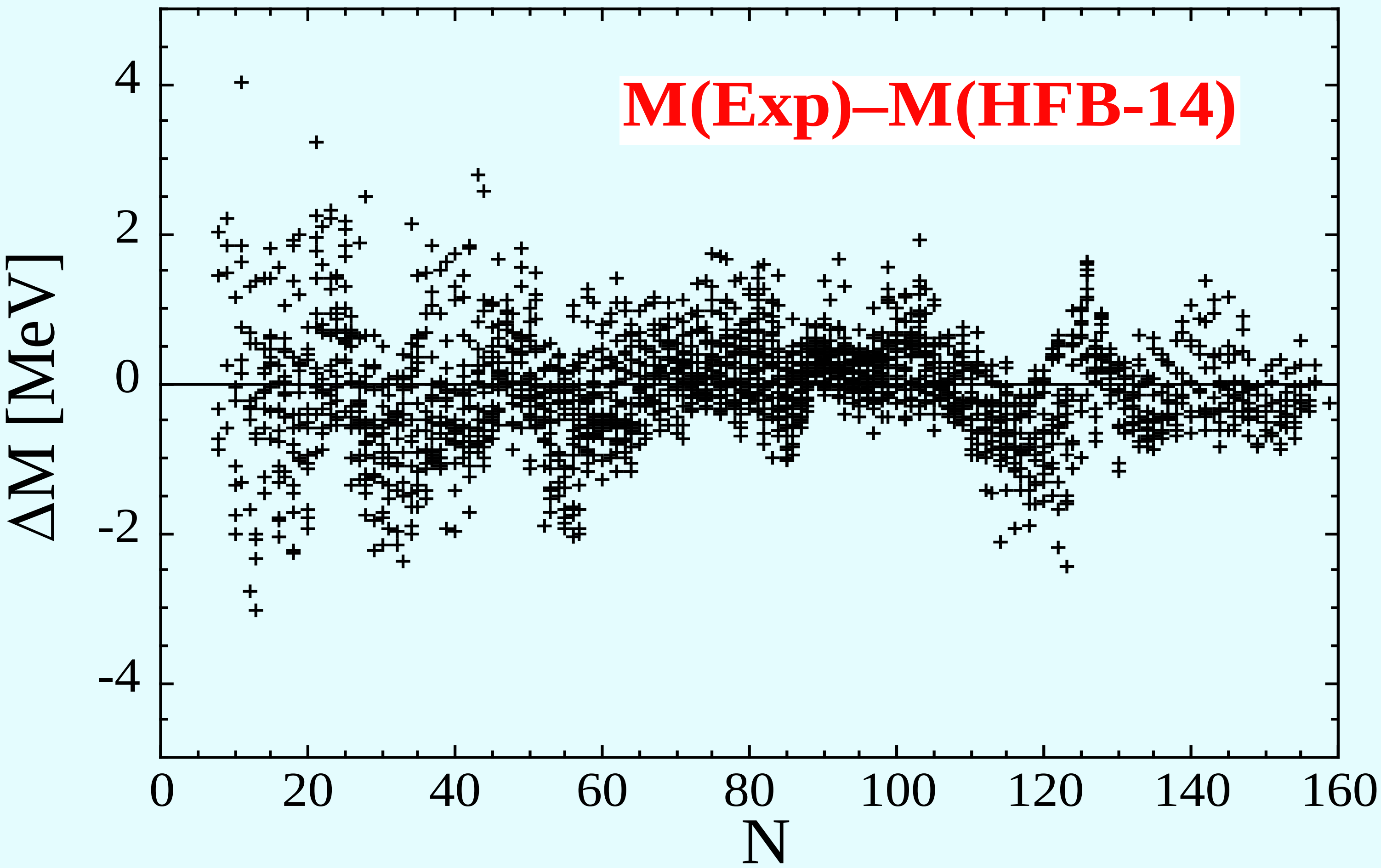
Experimental and best-recommended masses (Audi *et al*. 2003) **3179 n.**
FRDM (Moller *et al.*) **rms(M) = 656 keV on 2149 (Z ≥ 8) exp.masses**
Skyrme HFB-14 (Goriely *et al*.) **rms(M) = 729 keV**
Duflo-Zuker mass formula based on shell model **rms(M) = 564 keV**

PRL 102 (2009) 152503, S. Goriely *et al*, “Skyrme-Hartree-Fock-Bogoliubov Nuclear Mass Formulas: Crossing the 0.6 MeV Accuracy Threshold with Microscopically Deduced Pairing”, **rms(M) = 581 keV**
PRL 102, 242501 (2009) S. Hilaire *et al*, “First Gogny-Hartree-Fock-Bogoliubov Nuclear Mass Model” , **rms(M) = 728 keV**

PRC 77 (2008) 041304, J. Barea *et al*, “Garvey-Kelson Relations and the New Nuclear Mass Tables”.
NP A828 (2009) 113, Irving O. Morales *et al*, “How good are the Garvey–Kelson predictions of nuclear masses?” .
NP A843 (2010) 14, J. Mendoza-Temis, J.G. Hirsch , A. P. Zuker, “The anatomy of the simplest Duflo–Zuker mass formula”.

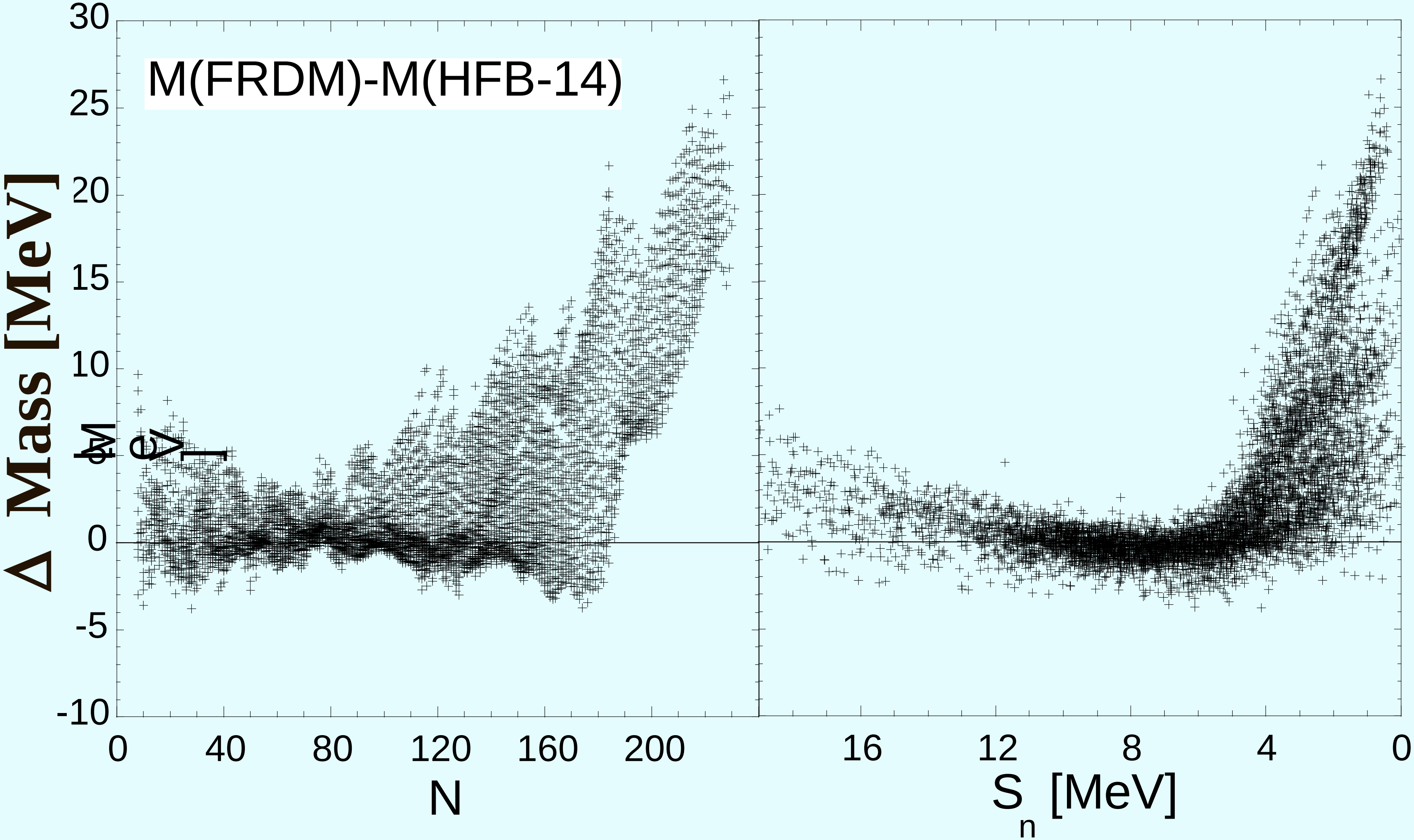
Comparison with experimental masses

(2149 nuclei: Audi, Wapstra & Thibault 2003)



HFB14 model: S. Goriely, M. Samyn, J.M. Pearson, (2007) Phys. Rev. **C75**, 064312

Uncertainties



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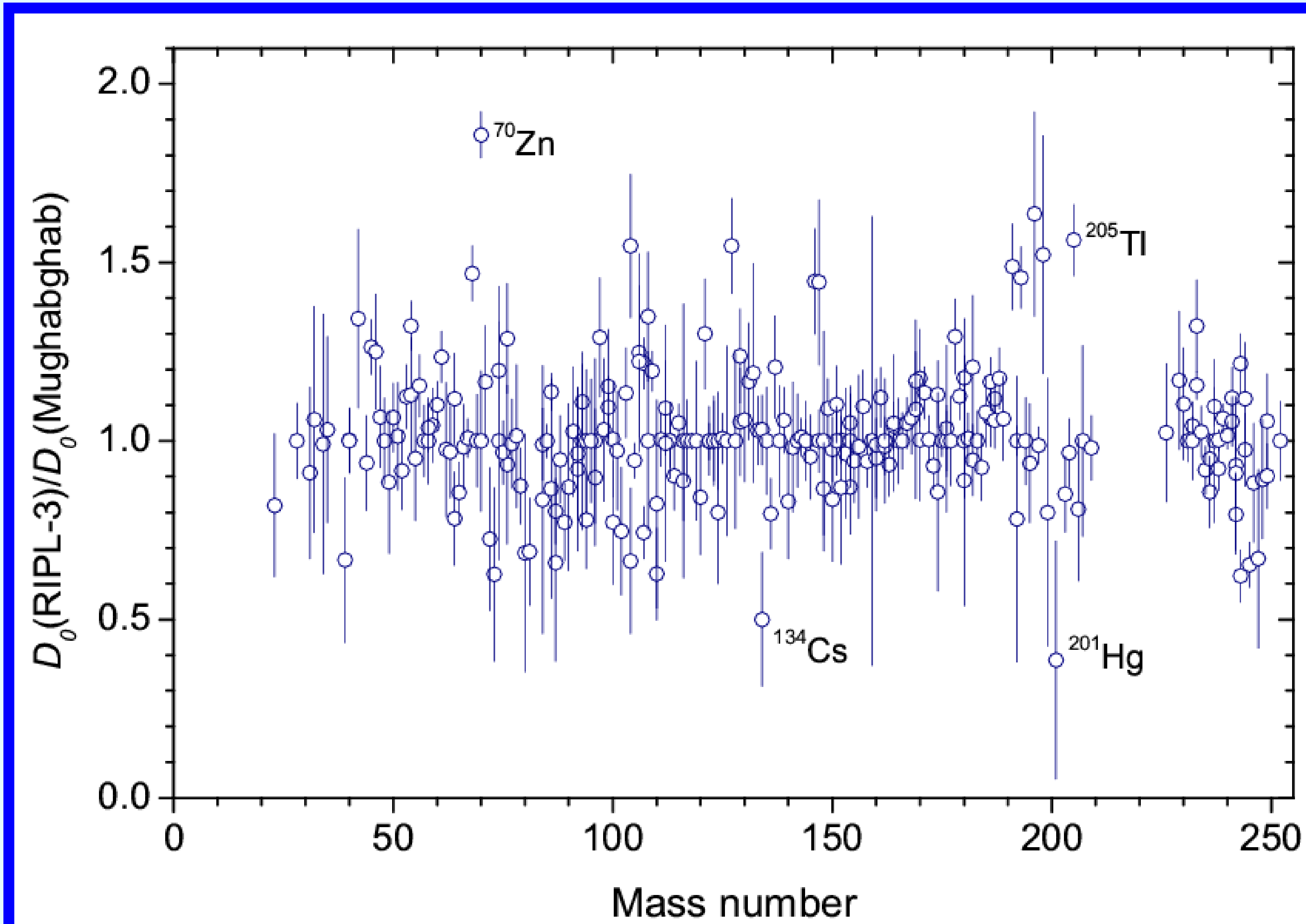
3.- NEUTRON RESONANCES



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5.- LEVEL DENSITIES

Nucl. Phys. A779 (2006) 63, "Global microscopic nuclear level densities within the HFB plus combinatorial method for practical applications"
Phys. Rev. C 78 (2008) 064307 , "Improved microscopic nuclear level densities within the HFB plus combinatorial method"

Based on OBSERVABLES: *f*rms~2.30

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.

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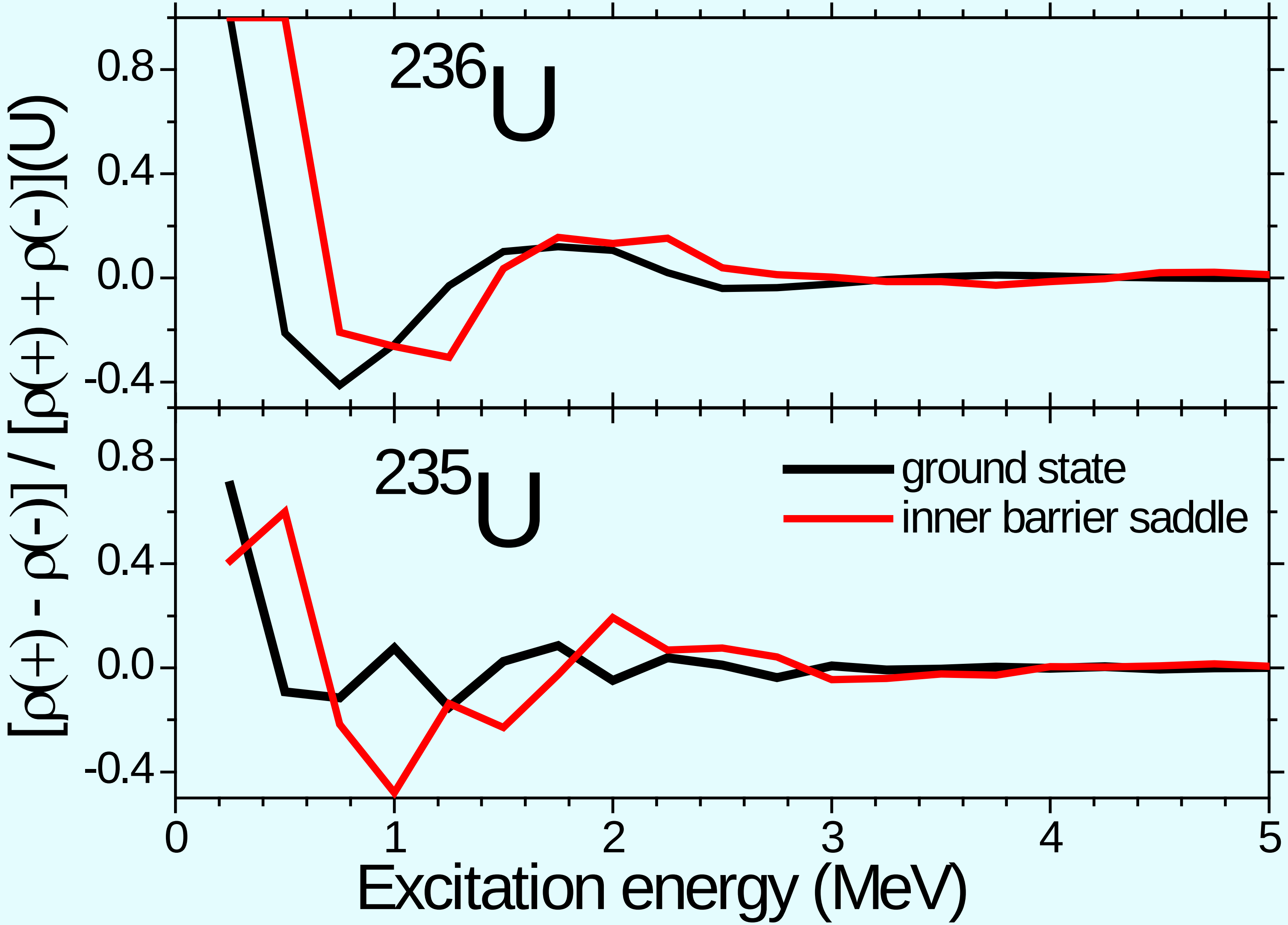
HFB LD: parity dependence



Workshop on Thermonuclear Reaction Rates for Astrophysics Applications (THERRAA), Nov 24-25, 2011, Athens, Greece
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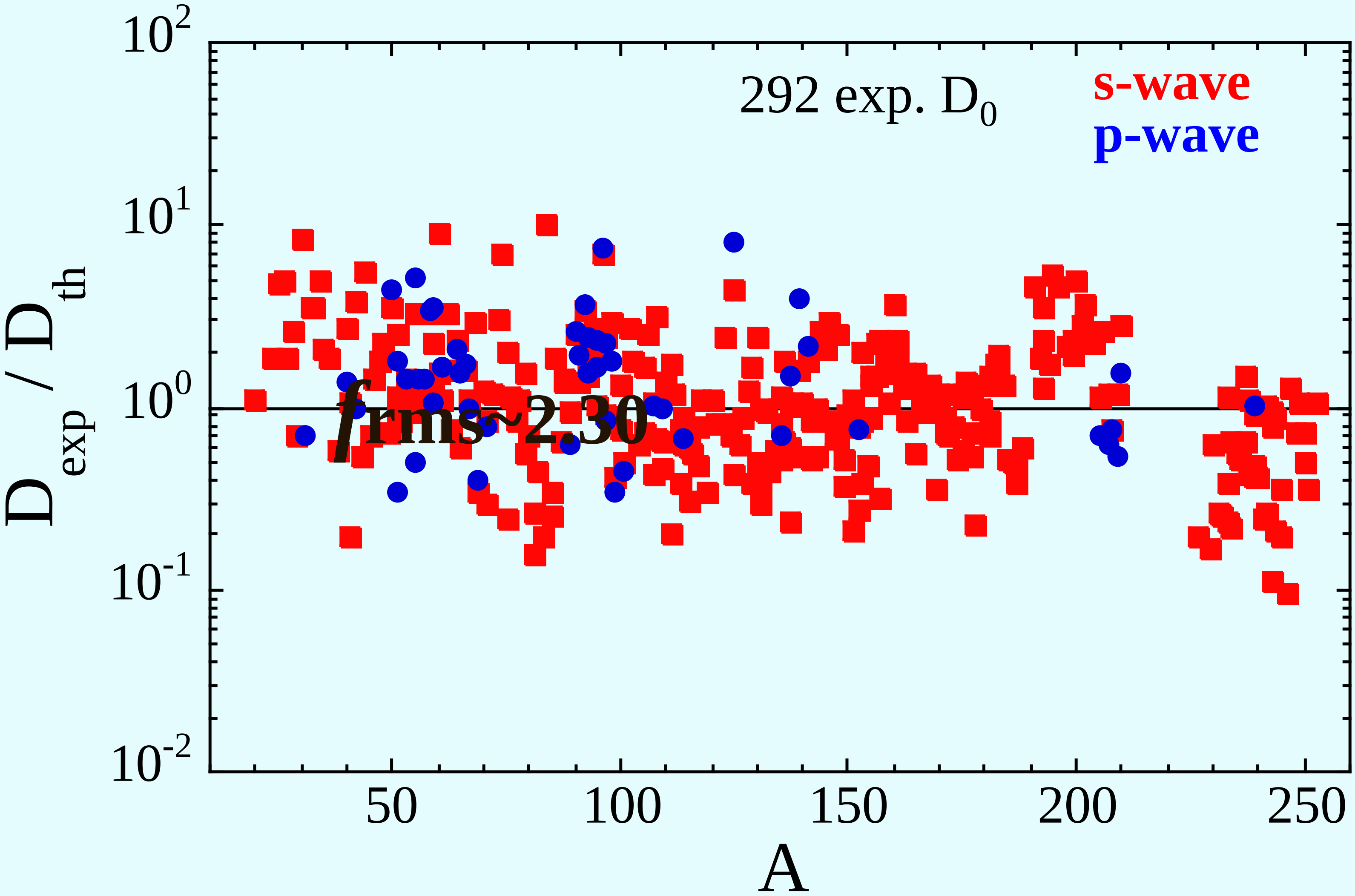
A global combinatorial NLD formula

S. Hilaire & S.Goriely & A. Koning (2006-2008)



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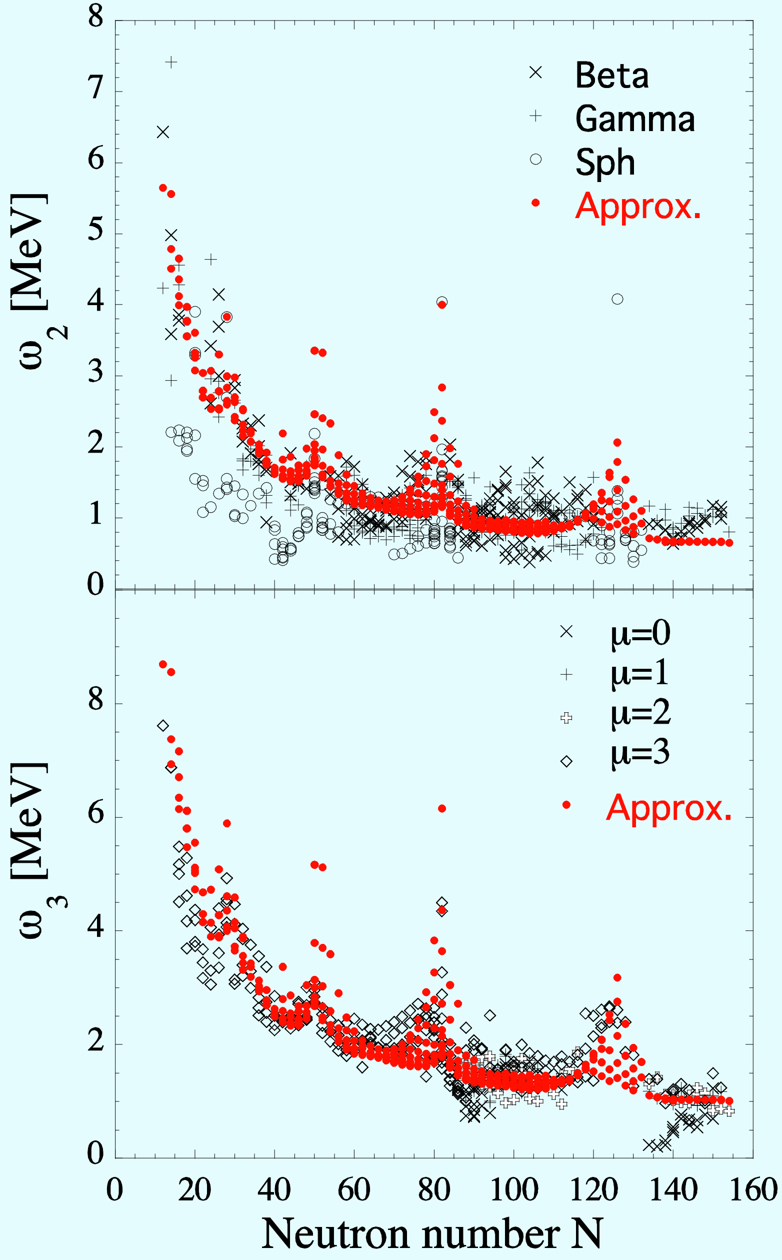

$$\omega_2[\mathrm{MeV}] = 65A^{-5/6}/(1 + 0.05E_{shell}), \tag{119}$$

for the quadrupole vibrations, and

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

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

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

Convolution of intrinsic and collective LDs

Phenomenological vibrational enhancement

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Third International Workshop on Compound Nuclear Reactions and Related Topics, Prague,Czech Republic, Sep. 19-23, 2011, “Shell Model Monte Carlo Studies”,

Cem Özen, Yoram Alhassid, and Hitoshi Nakada

The collective enhancement factors were extracted from the ratio of the SMMC to HFB level densities (~G. Hansen and A.S. Jensen, Nucl. Phys. **A406** (1983) 236) Damping of these factors seem to be associated with the pairing and shape transitions occurring in these nuclei.

Protons:
50-82 shell plus $1f_{7/2}$

Neutrons:
82-126 shell plus $0h_{11/2}$ and $1g_{9/2}$

$\approx 10^{29}$ configurations!!!

SMMC

Single-particle energies: from Woods-Saxon plus spin-orbit

Interaction: Pairing plus multipole-multipole (quadrupole, octupole, and hexadecupole) interaction.

Pairing interaction is determined from odd-even mass differences. Multipole-multipole interaction is determined self-consistently and renormalized.

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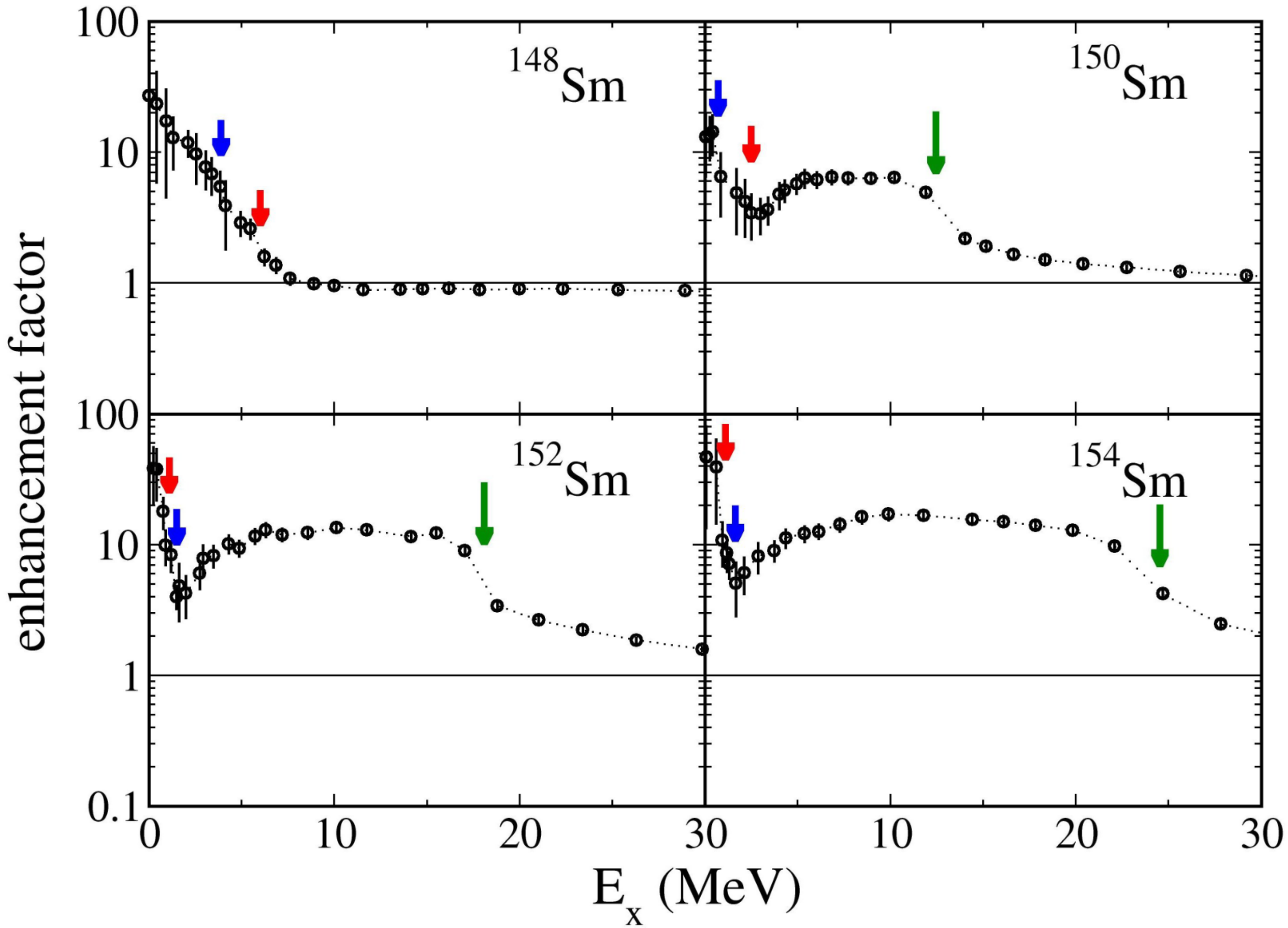

Implications of SMMC results

- Collective enhancement factors calculated.
- Vibr & Rot enhancement and damping are decoupled
- Pairing damping => damping of vibrational motion
- Shape transition => damping of rotational enhancement
- Damping temperatures much lower than usually used

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6.- GAMMA RAY STRENGTH

Next talk: A.-C. Larsen

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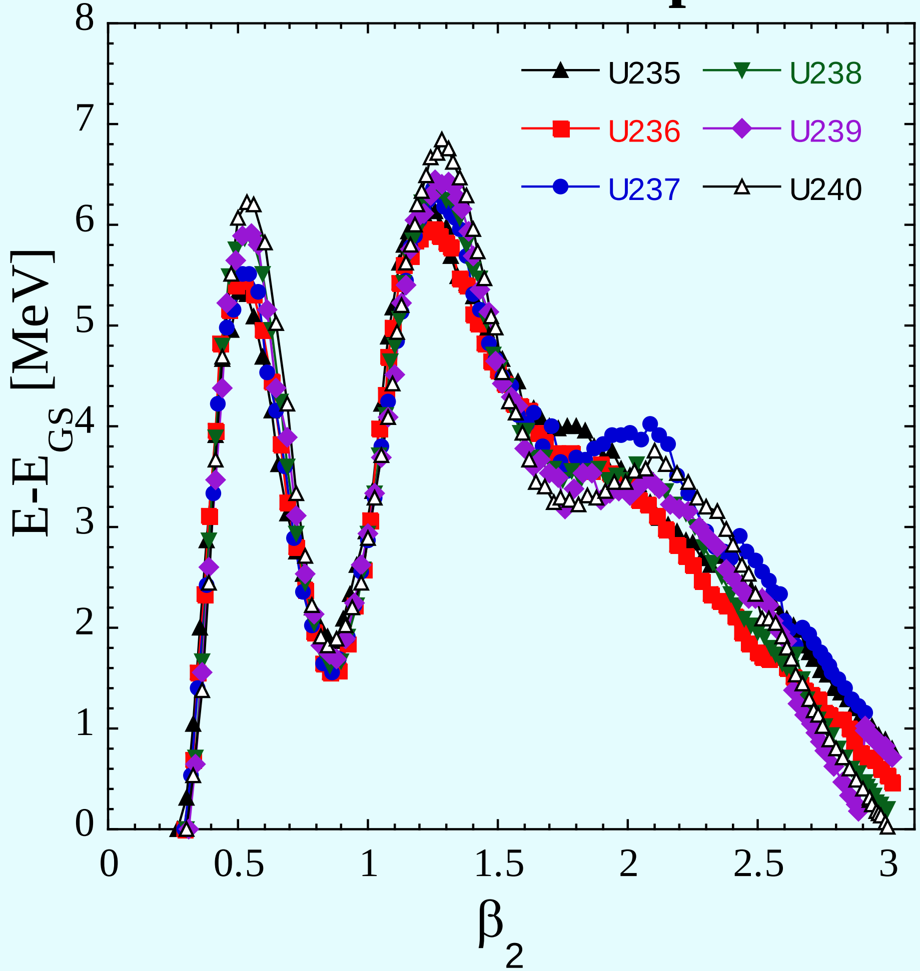
7.- FISSION

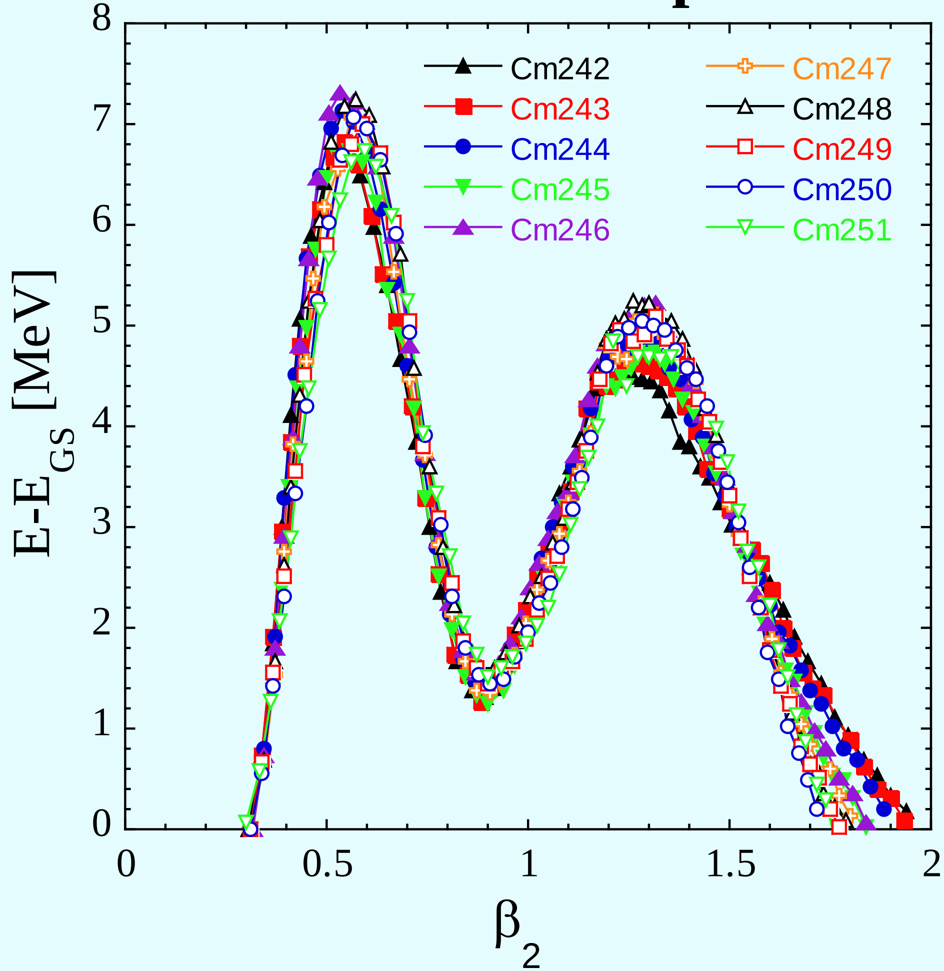
HFB14

Projection of the static path along the quadrupole deformation parameter β_2

The U isotopes



The Cm isotopes



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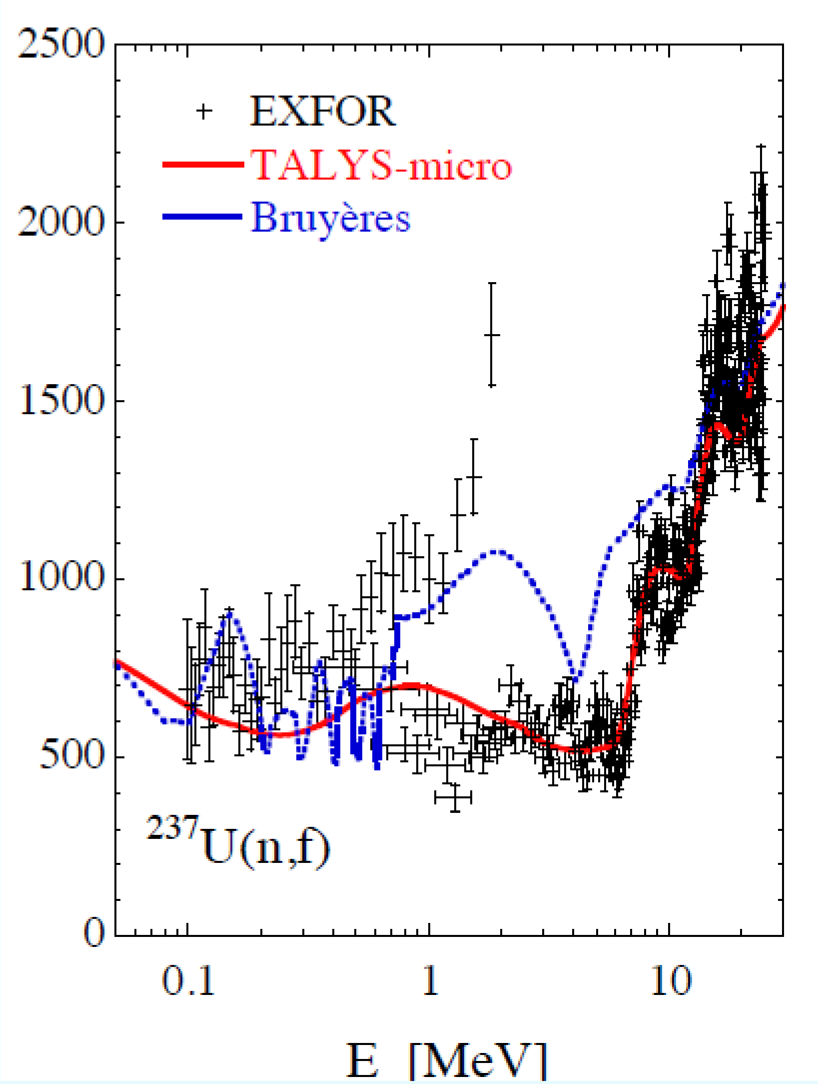
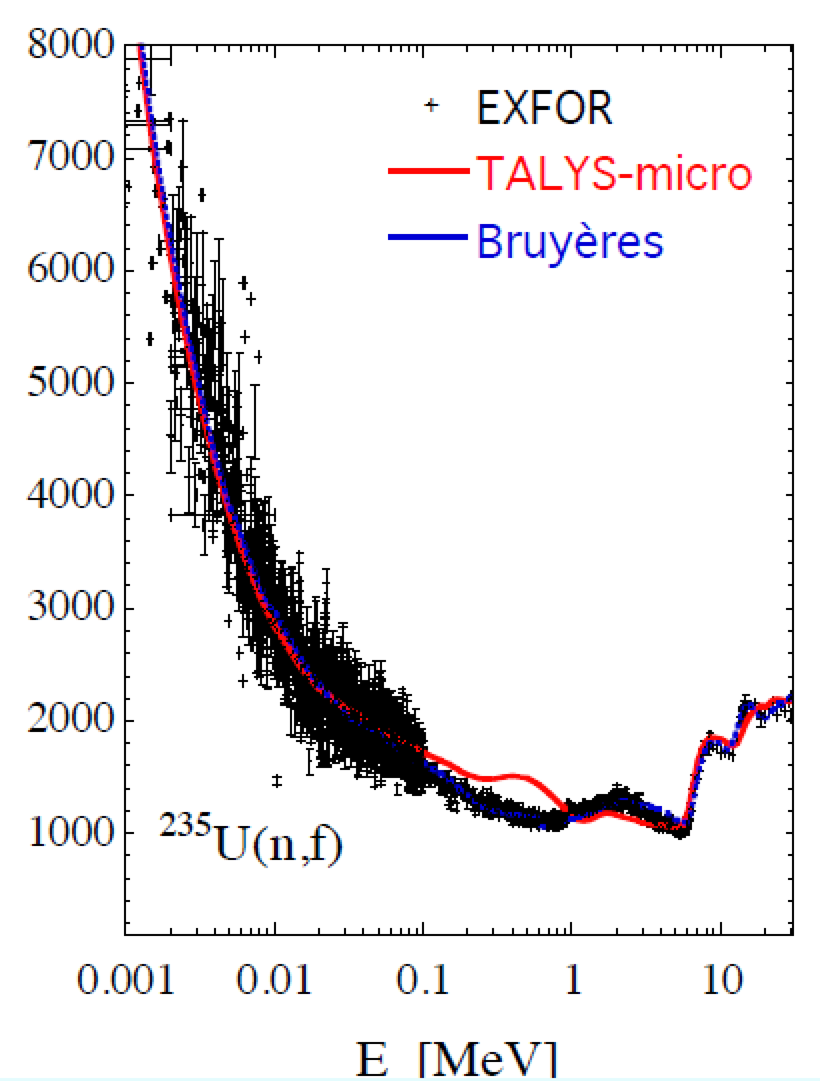
Towards an improved evaluation of neutron-induced fission cross sections on actinides

S. Goriely, S. Hilaire, A. J. Koning, and RC, Phys. Rev. C **83**, 034601 (2011)





CONCLUDING REMARKS

RIPL is a complete set of input parameters for nuclear reaction modeling. The database is maintained and regularly updated.

Mass models extended, new data being measured.
SMMC studies shed light on the damping of collective effects => new information could be used in LD models
Fission input parameters are being developed and validated

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

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