Mean-field description of deformed states: open questions

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"Quelles sont les formes des noyaux et les symétries sous-jacentes aux frontières en spin et en masse?"

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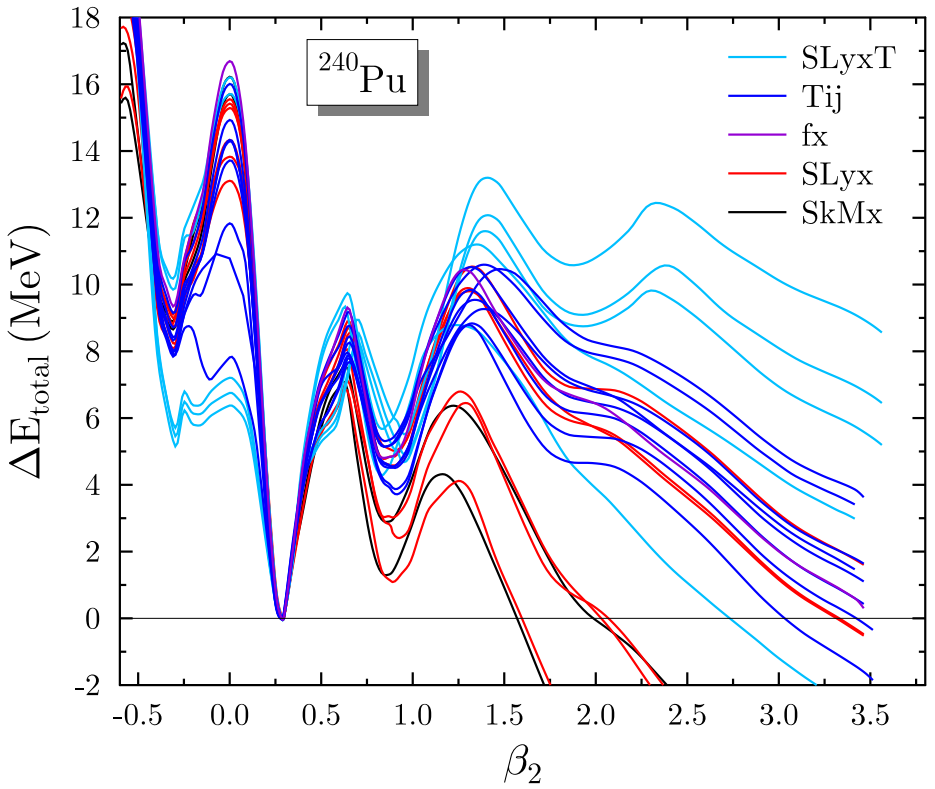
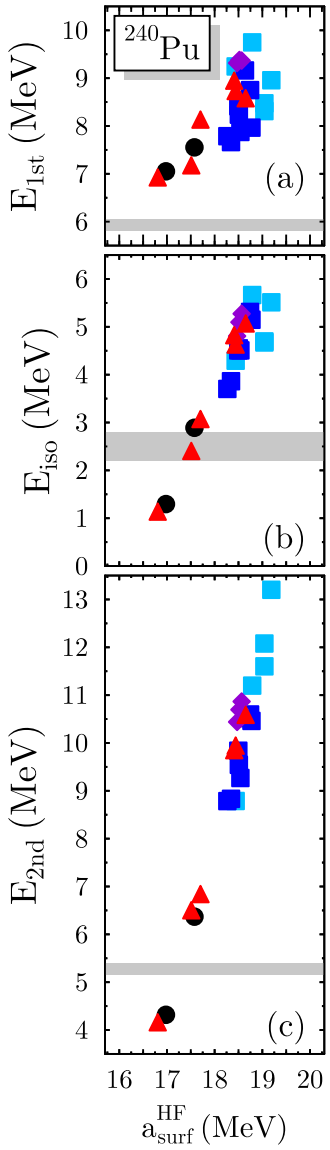
Major routes of present developments

- Improved fit protocols for parameterizations
  - more diverse observables
  - more data ("mass formulas")
  - avoiding finite-size instabilities in spin and/or isospin channels
  - better constrain deformation properties
- New and/or extended forms of effective interactions / energy density functionals
  - higher-order gradient terms [Becker, Davesne, Meyer, Navarro, Pastore, PRC 96 (2017) 044330]
  - combining finite-range and gradients [Bennaceur, Dobaczewski et al, JPG 44 (2017) 045106]
  - replacing density dependence by many-body forces [Sadoudi, Duguet, Meyer, Bender, PRC 88 (2013) 064326]
- Codes
  - Towards systematic symmetry-unrestricted calculations
  - breaking symmetries beyond triaxiality is not just "more of the same", but sometimes requires new developments for algorithms (HFB equation becoming complex, conserving number parity of configurations, tagging and following blocked states, fixing the orientation of the nucleus, ...)
  - more effcient representations are welcome (in terms of CPU and storage requirements)
  - more efficient and/or stable convergence is welcome

Relevance of surface tension



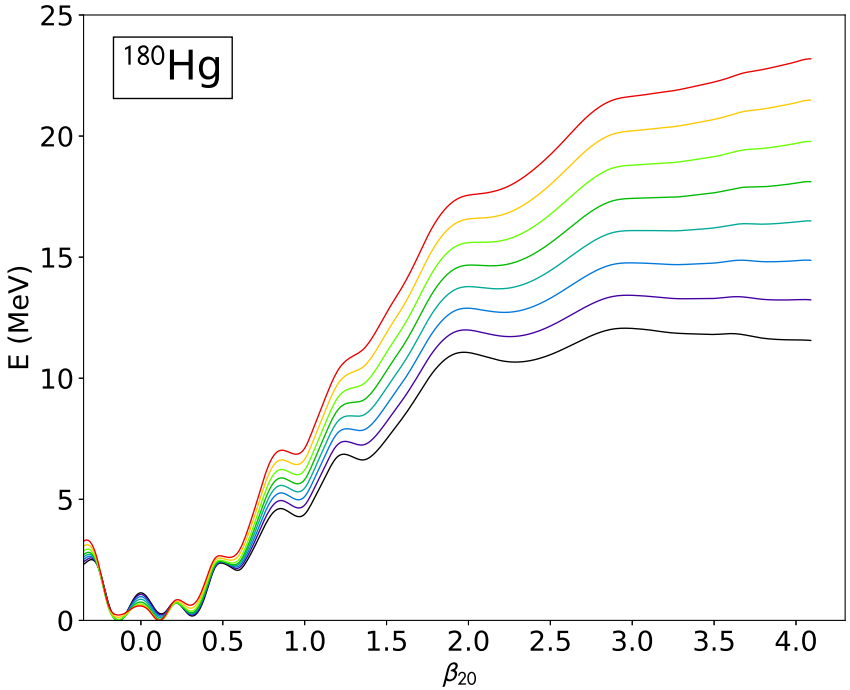


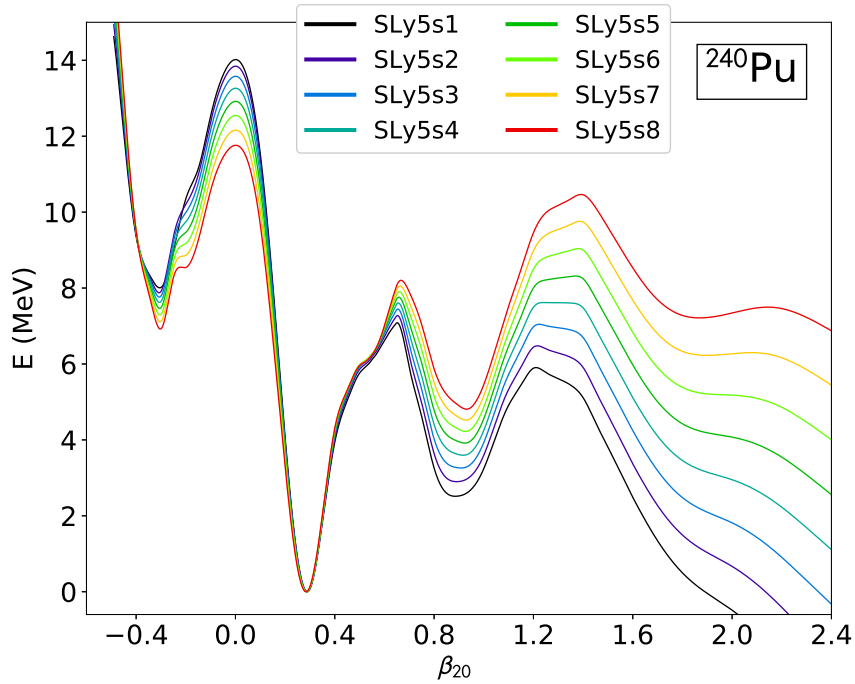
- most Skyrme parameterizations overestimate fission barriers . . .
- . . . although a few do well . . .
- and a very few even systematically underestimate them.
- Controlled fits with constraint on a_{surf} (SLy5s1)

Jodon, Bennaceur, Meyer, Bender, PRC94 (2016) 024355

Relevance of surface tension

Family of fits with systematically varied a_{surf}.





Ryssens, Bender, Bennaceur, Heenen, Meyer, arXiv:1809.04406

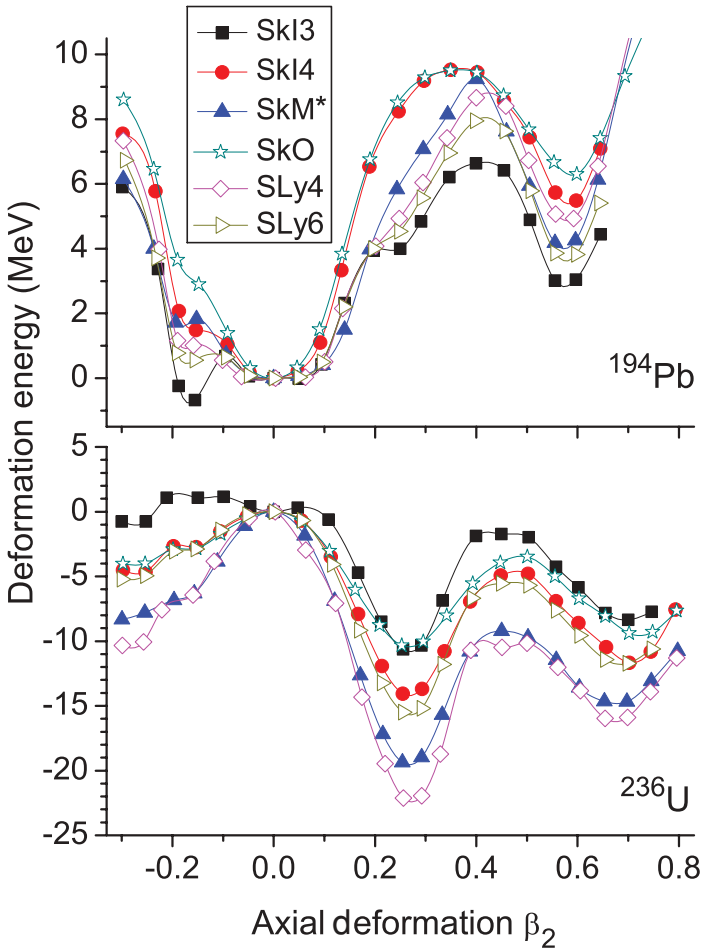


FIG. 4. (Color online) Potential energy curves for ^{194}Pb (top) and ^{236}U (bottom) versus quadrupole deformation β calculated with SkI3, SkI4, SkM*, SkO, SLy4, and SLy6 Skyrme EDFs. All curves are normalized to the spherical point. Axial symmetry is assumed.

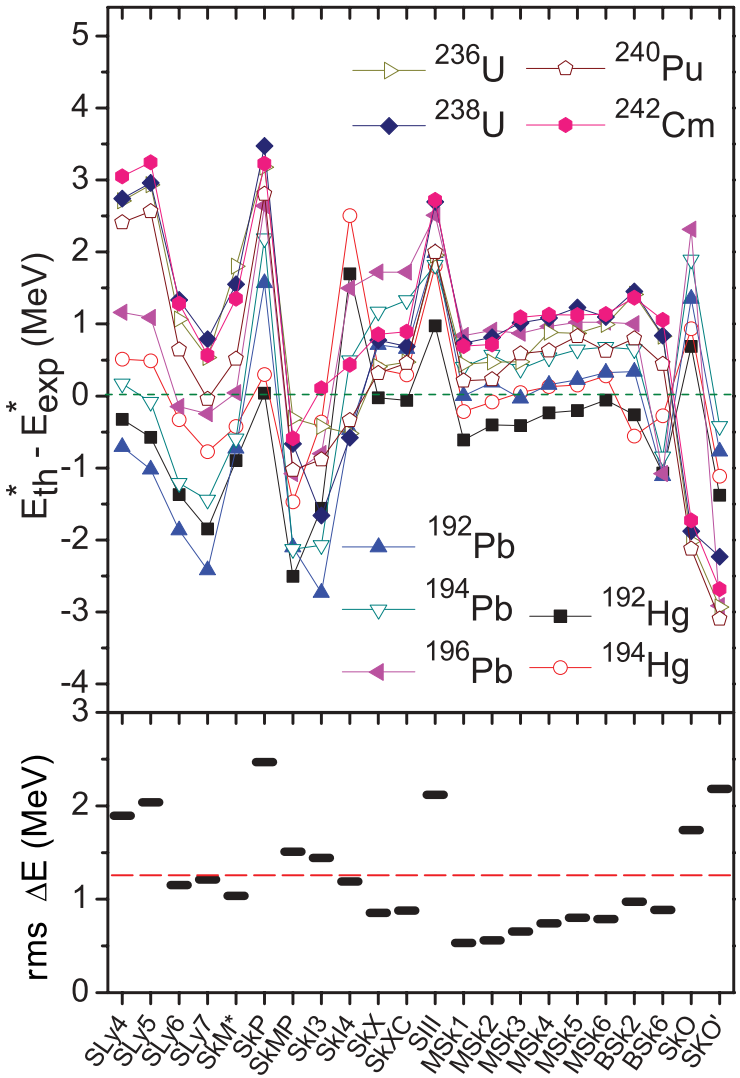
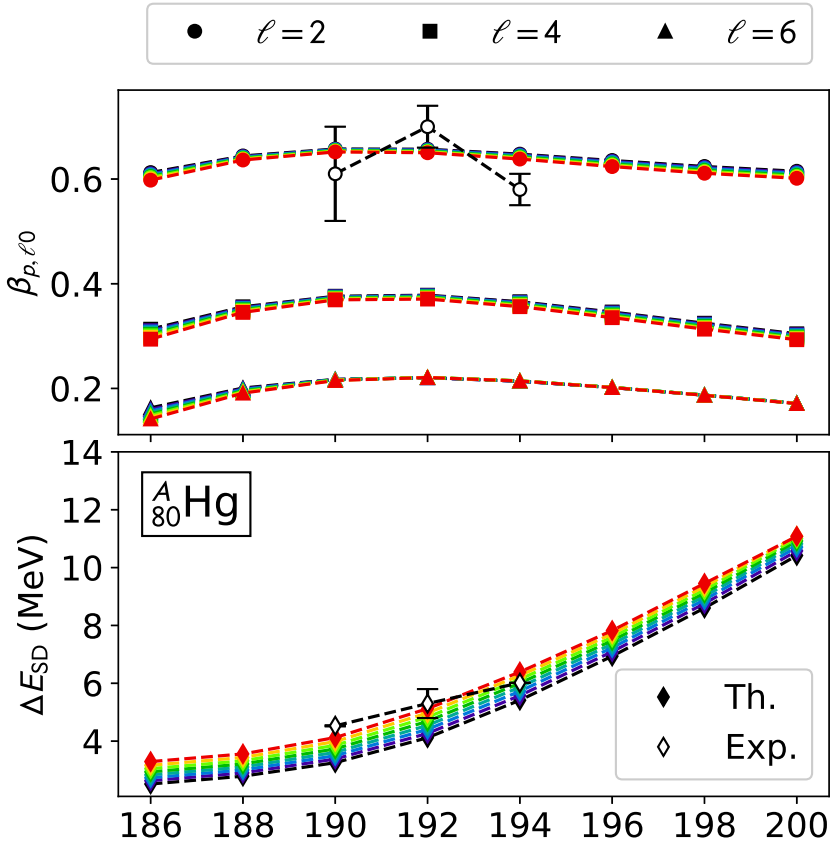
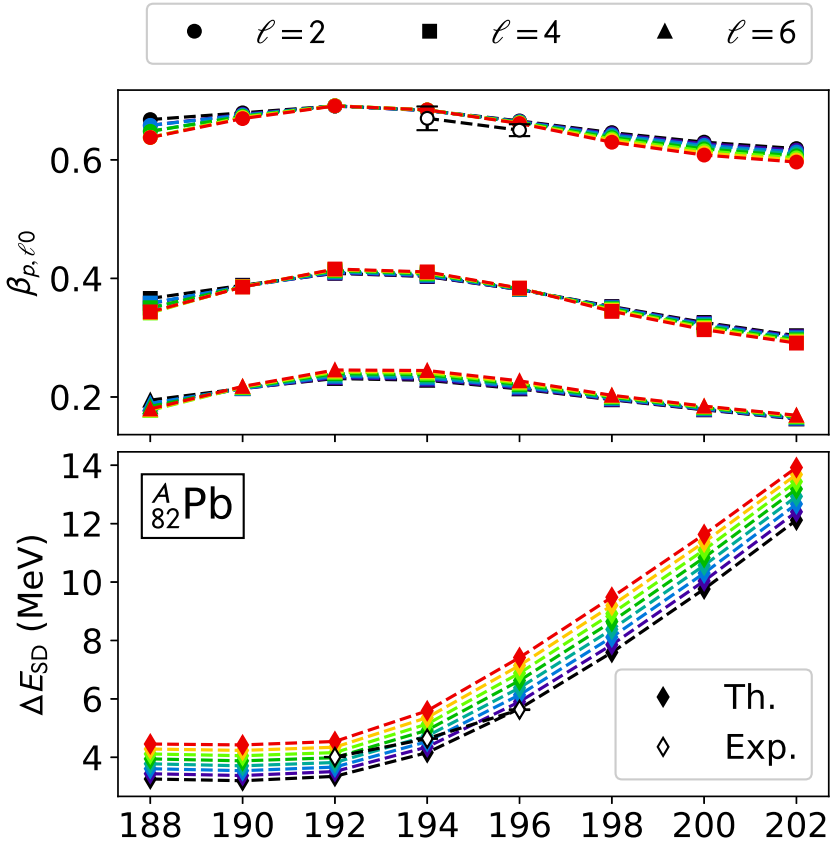


FIG. 5. (Color online) Residuals $\Delta E = E^*_{th} - E^*_{exp}$ (top) and rms deviations from experiment (bottom) for various Skyrme EDFs. Additional references for the Skyrme forces: SLy5-SLy7 [88], SkMP [126], SkX-SkXC [127], SIII [128], MSk1-MSk6 [129], BSk2 [87],

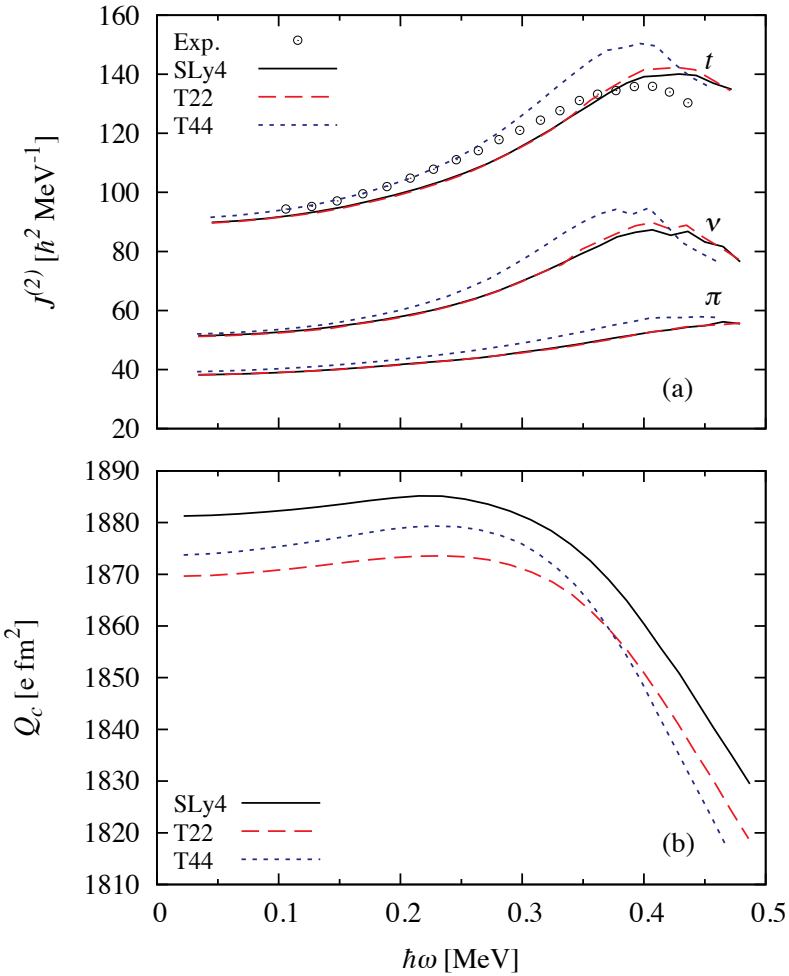
SD band heads

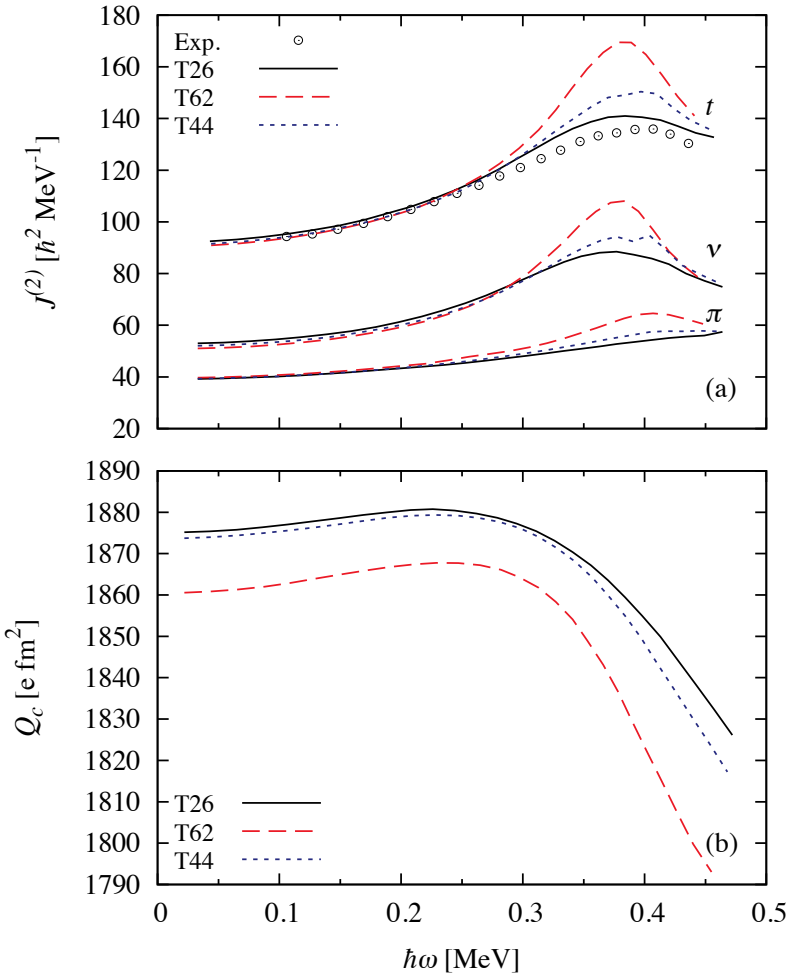




Ryssens, Bender, Bennaceur, Heenen, Meyer, arXiv:1809.04406

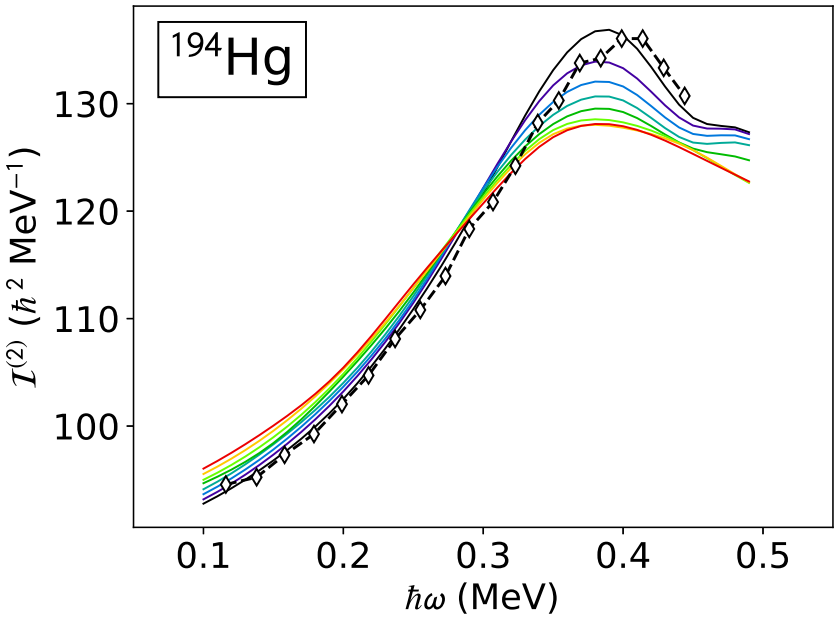
SD band impact of tensor terms





Hellemans, Heenen and Bender, PRC 85 (2012) 014326

SD band



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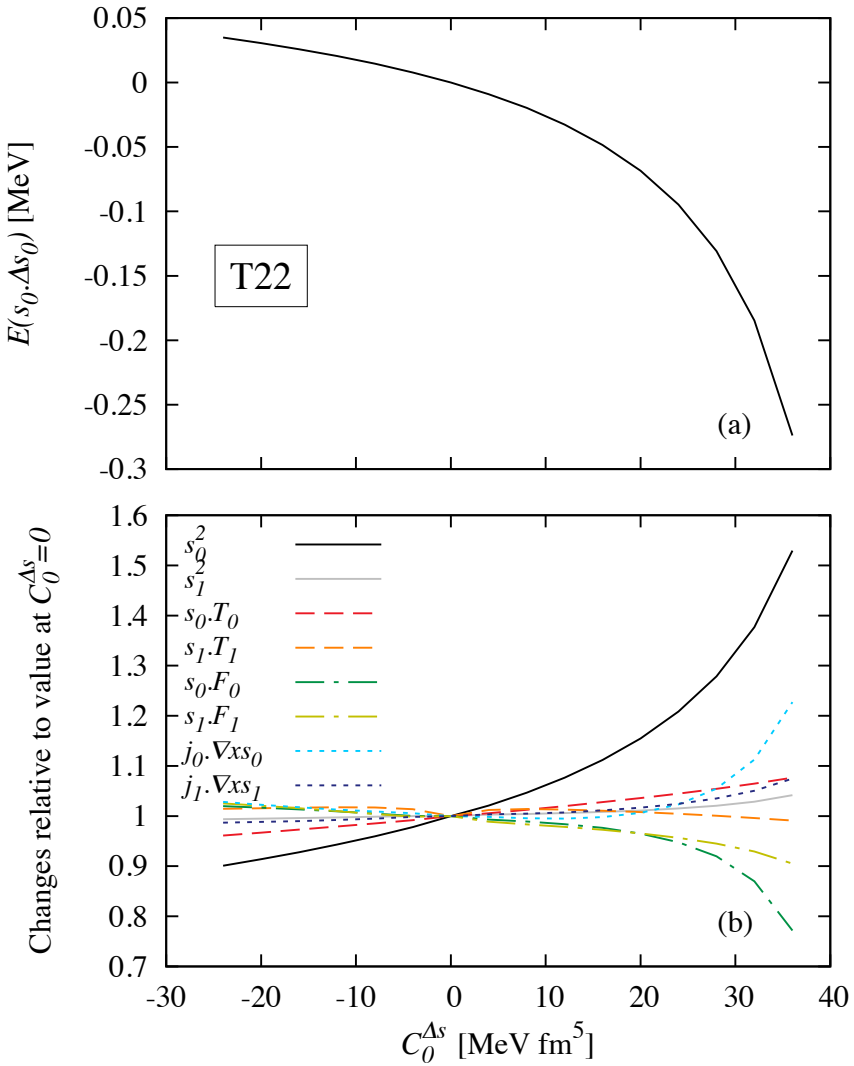
Finite-size spin instabilities



(a) Dependence of the $C_0^{\Delta s}\mathbf{s}_0 \cdot \Delta\mathbf{s}_0$ term of a variant of the T22 parameterisation on the value of $C_0^{\Delta s}$ for the $\langle \hat{J}_z \rangle = 54\hbar$ state in the yrast superdeformed rotational band of ^{194}Hg.

(b) Dependence of all other time-odd terms containing the spin density $\mathbf{s}_t$ relative to their value at $C_0^{\Delta s} = 0$ in the same calculations.

In response calculations of infinite nuclear matter, there is a pole approaching saturation density when increasing $C_0^{\Delta s}$ analogous to what has been explained the other day by Karim Bennaceur.

Hellemans, Heenen and Bender, PRC 85 (2012) 014326

Finite-size spin instabilities

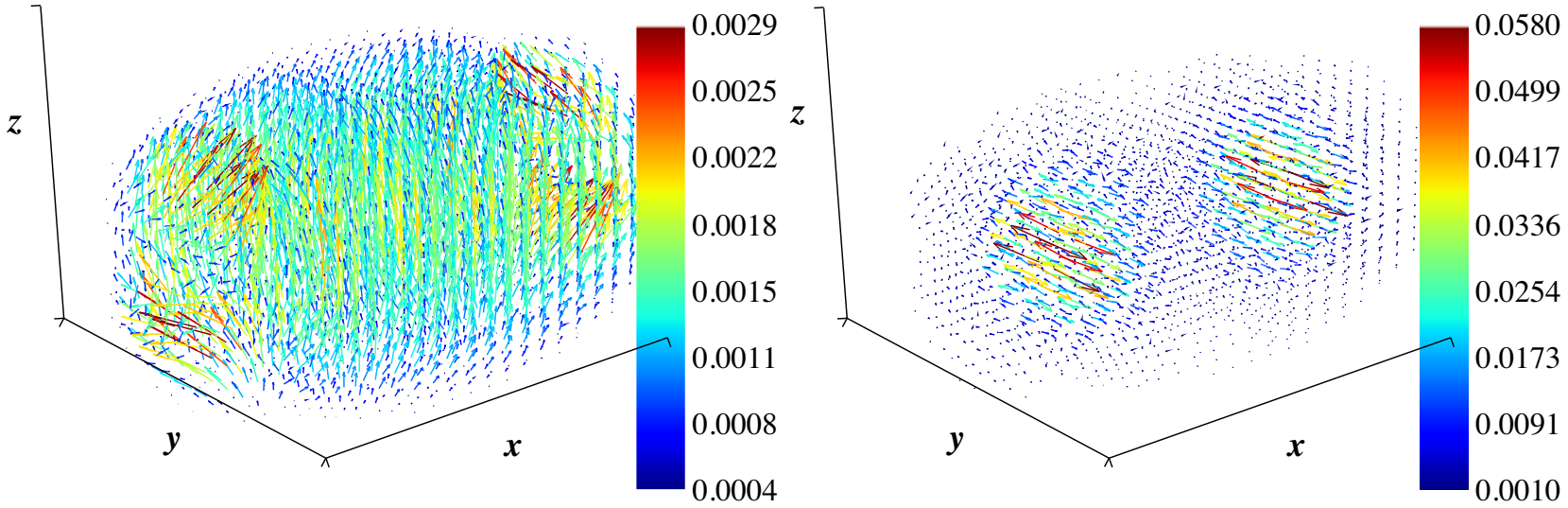
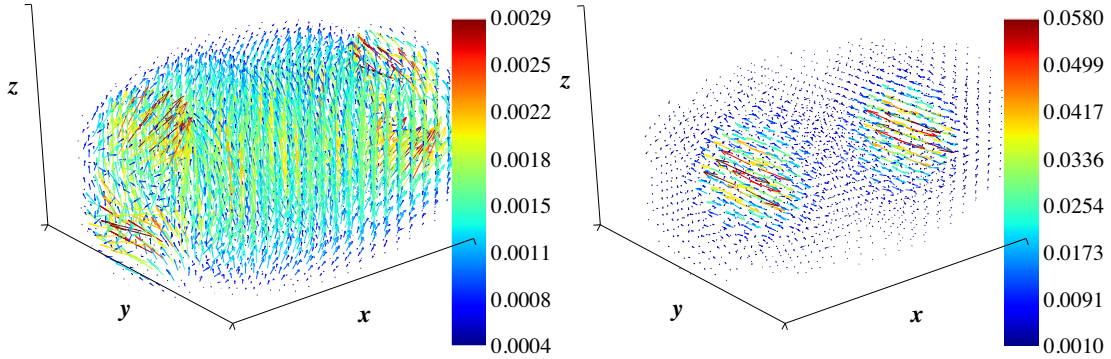


FIGURE 2. (color online) Left: The isoscalar spin density s_0 obtained with a modified T22 parameterization (see text) with $C_0^{\Delta s} = 0$ for the $J_z = 54\hbar$ state in the ground superdeformed band of ^{194}Hg at convergence. Right: Same as the panel on the left, but for $C_0^{\Delta s} = 40$ MeV fm^5 at a few iterations before the code crashes.

V. Hellemans, P.-H. Heenen and M. Bender, AIP Conf. Proc. 1491(2012) 242

Finite-size spin instabilities



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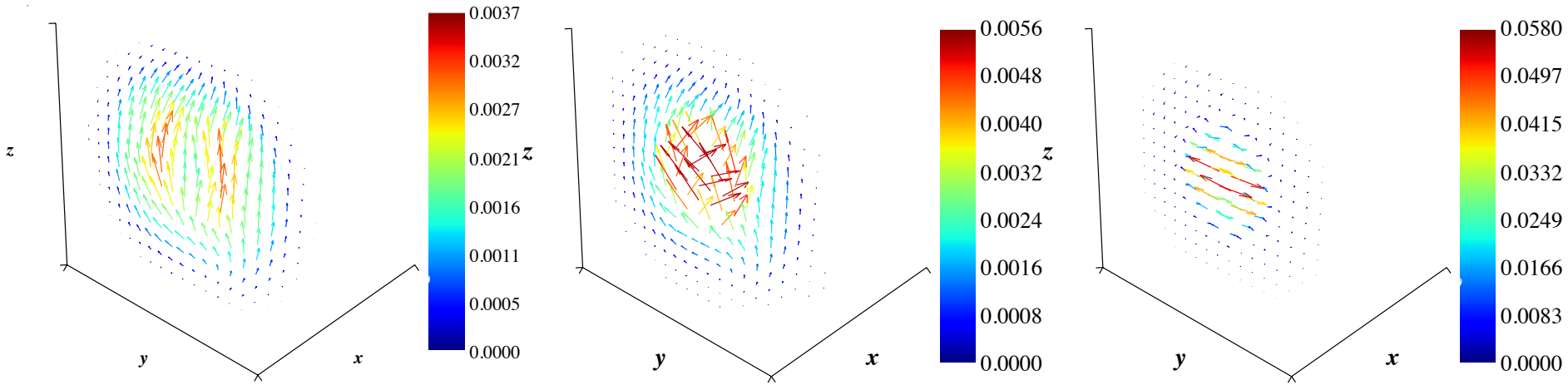
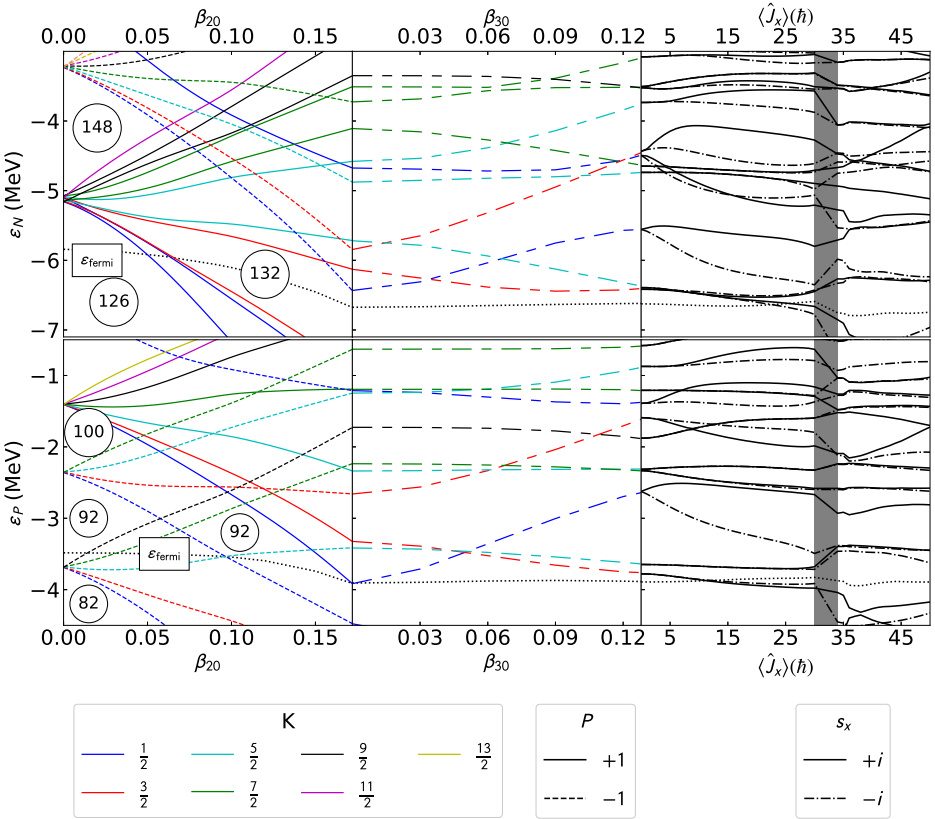


FIGURE 3. (color online) Cut through the spin density s_0 at $x = 4.4$ fm for the $J_z = 54\hbar$ state in the ground superdeformed band of ^{194}Hg as obtained with a modified T22 parameterization (see text) with $C_0^{\Delta s} = 40$ MeV fm^5 at the onset of the instability (left panel) and at few iterations before the crash of the code (right panel).

at initialisation

Hellemans, Heenen, Bender, AIP Conf. Proc. 1491(2012) 242

Towards Symmetry-unrestricted calculations: rotating pears



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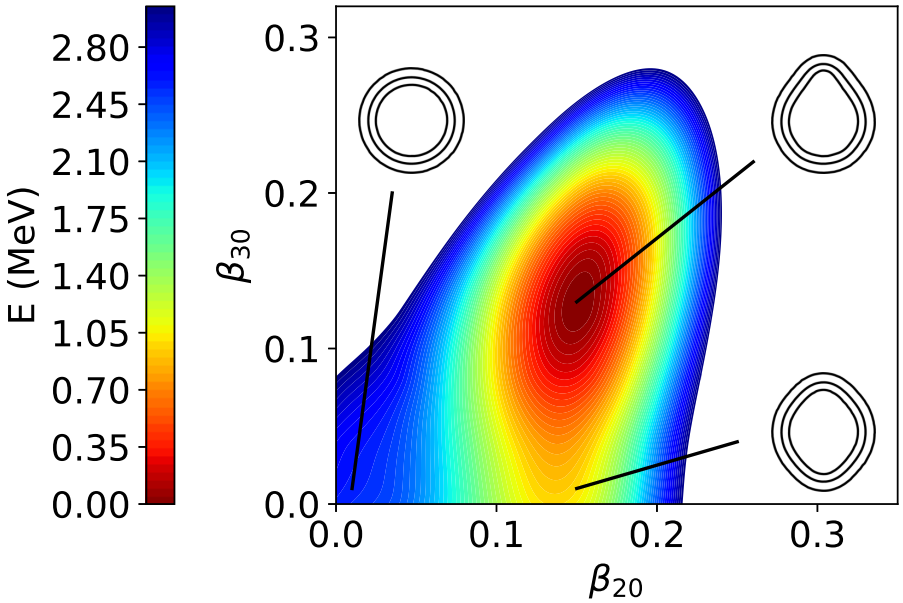

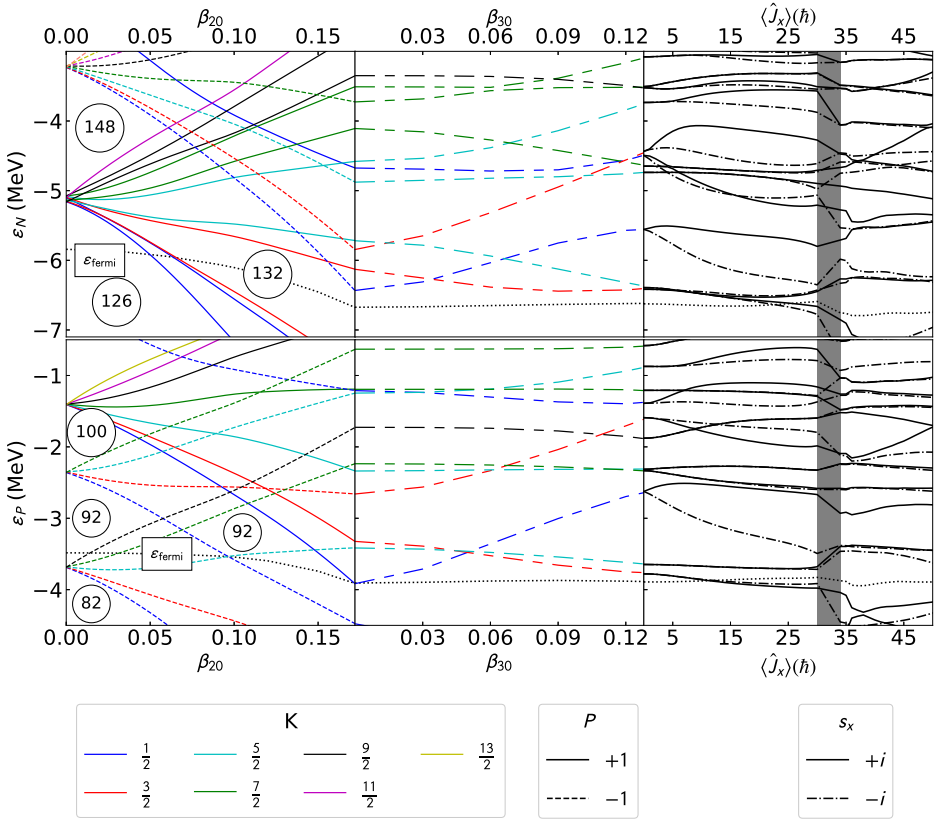

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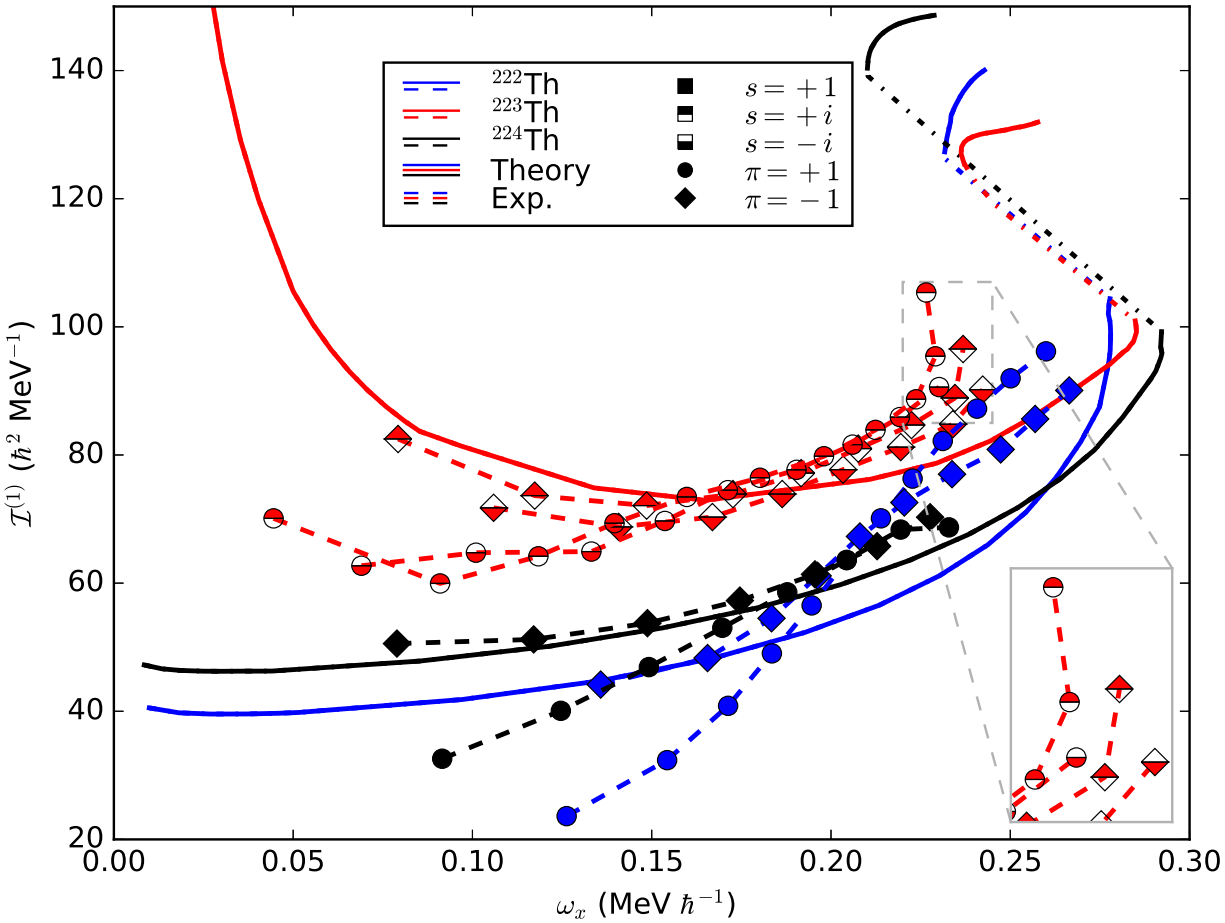

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Acknowledgements

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founding fathers

Paul Bonche	SPhT, CEA Saclay
Hubert Flocard	CSNSM Orsay
Paul-Henri Heenen	Université Libre de Bruxelles

formal aspects of the big picture

Thomas Duguet	Irfu/CEA Saclay & KU Leuven & NSCL/MSU
Denis Lacroix	IPN Orsay

design and implementation of code extensions

Benoît Avez	CEN Bordeaux Gradignan
Benjamin Bally	CEN Bordeaux Gradignan, now SPhN, CEA Saclay
Veerle Hellemans	Université Libre de Bruxelles
Jiangming Yao	Université Libre de Bruxelles
Wouter Ryssens	formerly IPN Lyon, now Yale University

development and benchmarking of new functionals

Karim Bennaceur	IPN Lyon
Dany Davesne	IPN Lyon
Robin Jodon	IPN Lyon
Jacques Meyer	IPN Lyon
Alessandro Pastore	formerly IPN Lyon, now University of York
Jeremy Sadoudi	Irfu/CEA Saclay first, then CEN Bordeaux Gradignan

color code: active (past) member of the collaboration