DE LA RECHERCHE À L'INDUSTRIE

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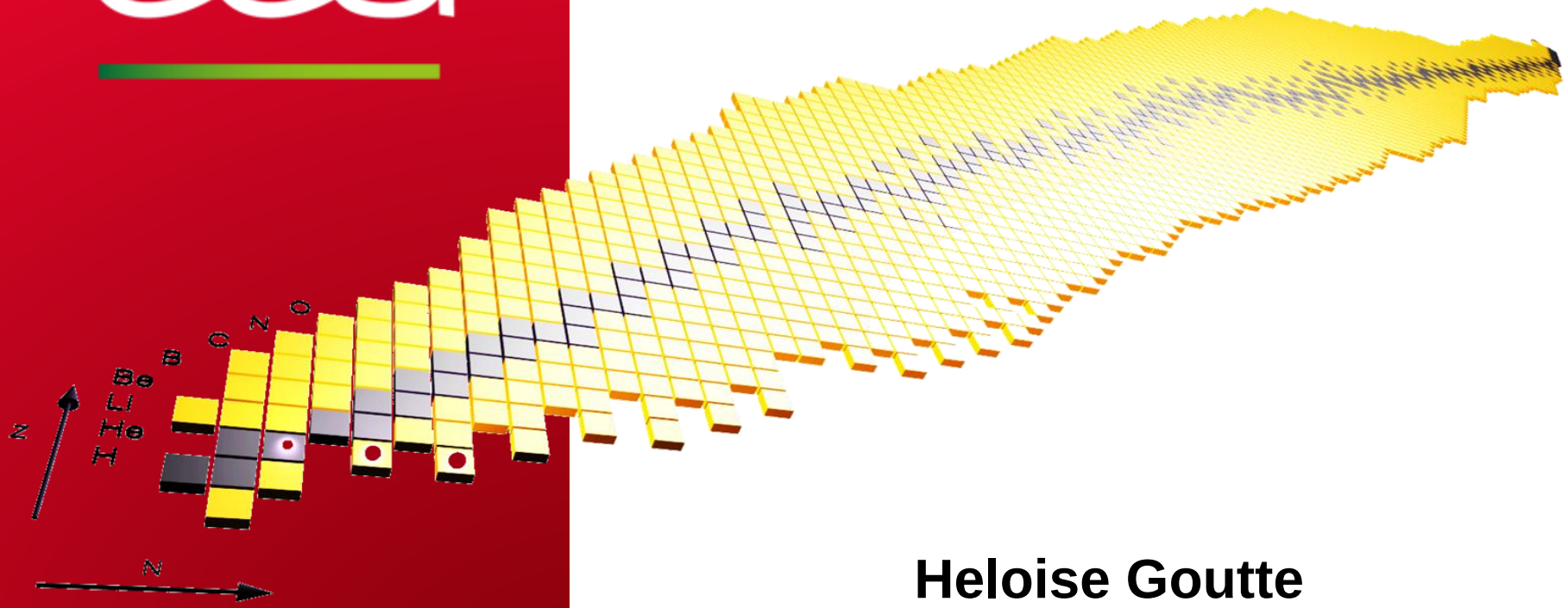
Fission studies with DANIEL GOGNY



Heloise Goutte
SPhN division
CEA Saclay

My Interaction with Daniel Gogny… beyond the D1S Gogny force

Formal side:

- jury member of my PhD (1997-2000) and HdR (2008)
- co-authors of 2 papers on fission (+proceedings)

Unformal side:

Sharp physics discussions evolving into endless calculations which took the dimension of epic poetry
… in Bruyères … on the Golf terrace…
at home with colleagues

Extracts of email correspondence

Object: HELOISE HAIDER and **THIS POOR GOGNY**

God knows how **beautiful and powerful this formali** me go to the most crucial part and introduce the mandatory noti erstand that **nice paper**.

As we have seen together, th moments properties are of paramount importance co r model. Therefore let's dedicate ourselves to the analy diagonal and non diagonal moments
I am using the i=0 the zero q.p () q state
I do hope tha drunk when you extracted that file from page 9

Let's start again :@#$% !**

The guideline of fission studies with Daniel Gogny

Towards a description :

• as « *fundamental* » as possible (no adjustable parameters)

• able to give quantitative results, which can be directly compared to experimental data.

• able to describe on the same footing structure properties of the fissioning system and fission fragment and the fission dynamics.

May the force be with you

A pioneering work by J.-F. Berger and D. Gogny in 1984

Nuclear Physics A428 (1984) 23c-36c
North-Holland, Amsterdam

From fission to fusion valleys

MICROSCOPIC ANALYSIS OF COLLECTIVE DYNAMICS IN LOW ENERGY FISSION

J.F. BERGER, M. GIROD, D. GOGNY.

Service de Physique Neutronique et Nucléaire, Centre d'Etudes de Bruyères le-Châtel, BP n° 12 91680 Bruyères-le-Châtel - France

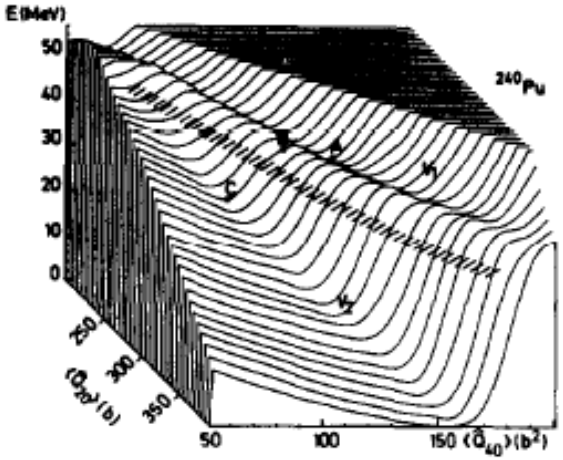


FIGURE 3
Potential energy surface of ^{240}Pu as a function of the elongation $\langle Q_{20} \rangle$ and necking-in $\langle Q_{40} \rangle$

Scission configurations

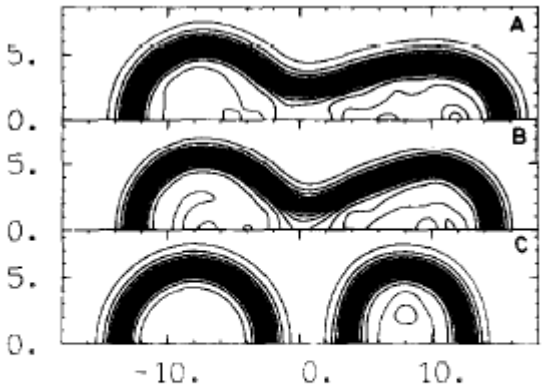


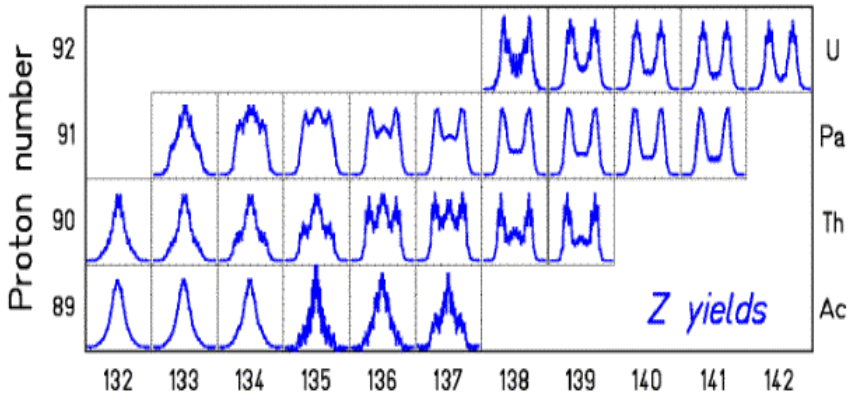
FIGURE 4
Nucleon density distributions found at the points A, B and C defined in fig 3. Lengths are in fermis.

Why this revival of fission studies in 2000s ?

Introduction of
H. Goutte, J.-F. Berger, P. Casoli and D. Gogny PRC71, 024316 (2005)

Interest in fission has recently increased since it is proposed to be used in new applications such as accelerator-driven systems, new electro-nuclear cycles such as a thorium-based fuel cycle, and the next generation of exotic beam facilities. For these applications, there is an important need for fission cross sections in a large range of excitation energies and for mass-charge fission fragment distributions. [] It is important to test the accuracy of a theoretical prediction …

At the crossroads between application and fundamental research

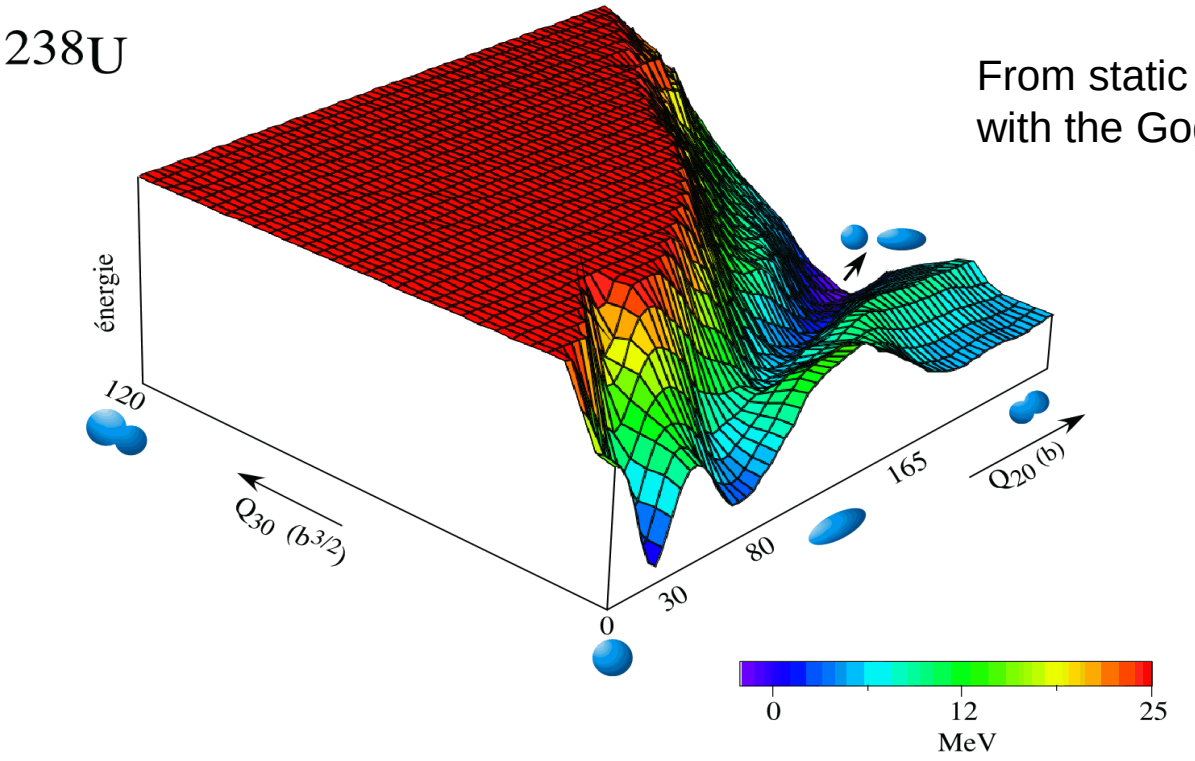


K-H Schmidt et al., NPA 665 (2000) 221

Illustration of our work on fission

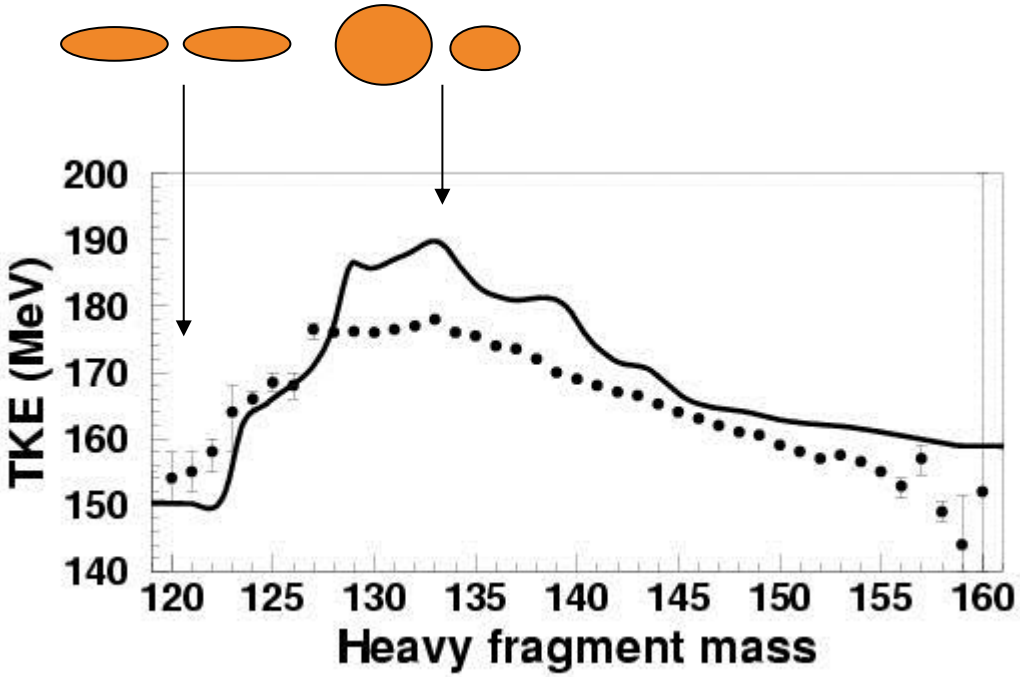
H. Goutte, J.-F. Berger, P. Casoli and D. Gogny PRC71, 024316 (2005)

Potential energy surface

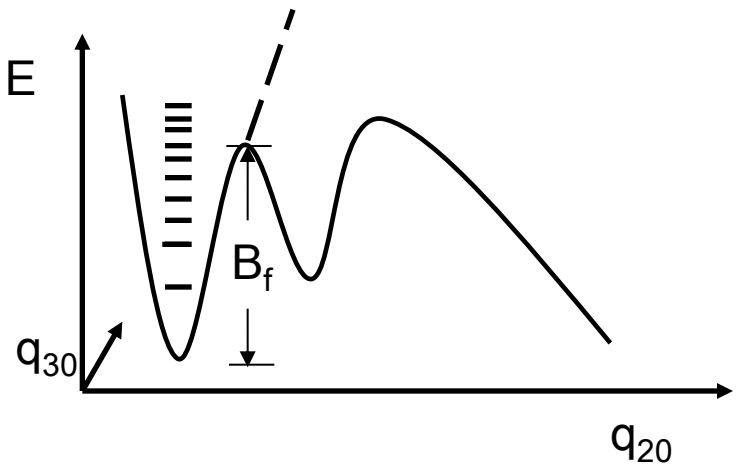


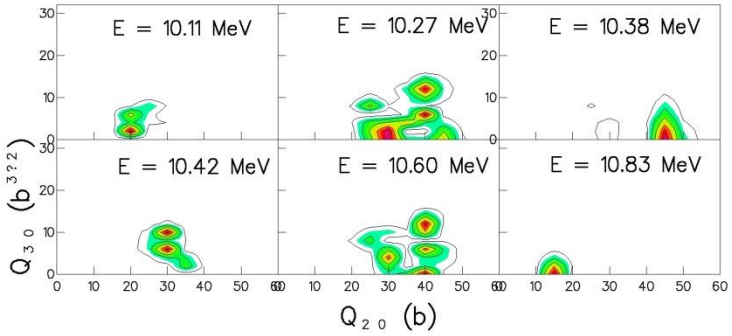
From static HFB calculations with the Gogny force

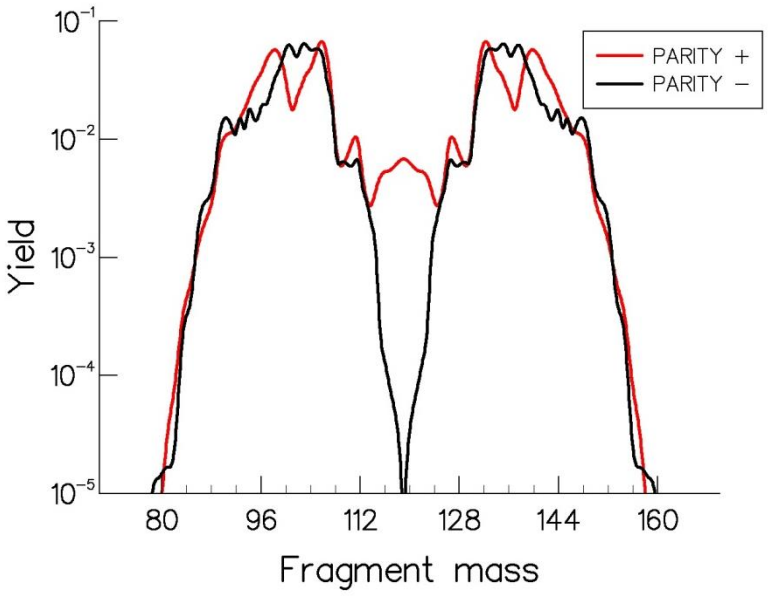
Total kinetic energy



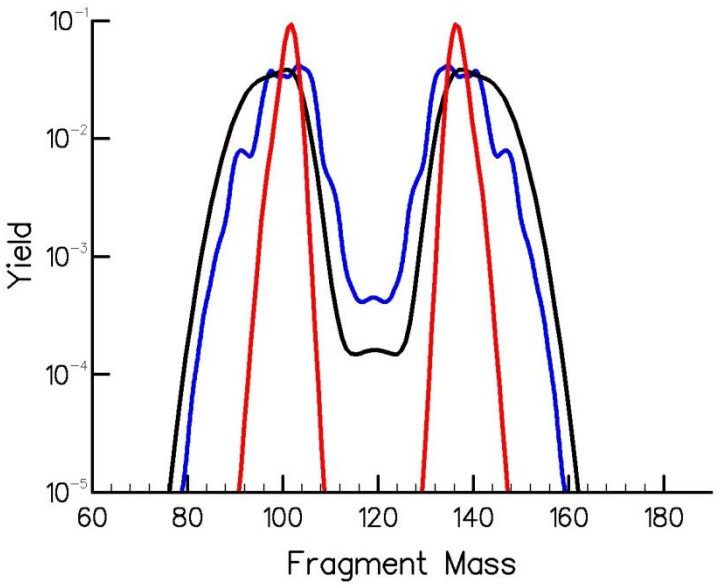
Influence of the initial state







Dynamical effects



Wahl evaluation

Static calculations

Present dynamical calculations

“Very large microscopic effects”

^{257}**Fm** : α decay
$T_{1/2\alpha}$ = 8.7 10^{6} s

^{258}**Fm** : spontaneous fission
$T_{1/2sf}$ = 3.8 10^{-4} s

PhD thesis of R. Bernard
and
R. Bernard, H. Goutte, D. Gogny and W. Younes PRC 84, 044308 (2011)

Microscopic and nonadiabatic Schrodinger equation derived from the generator coordinate method ¨ based on zero- and two-quasiparticle states

(talk from R. Bernard on Wednesday)

What is needed then ? (Personal view 1/2)

Systematics:

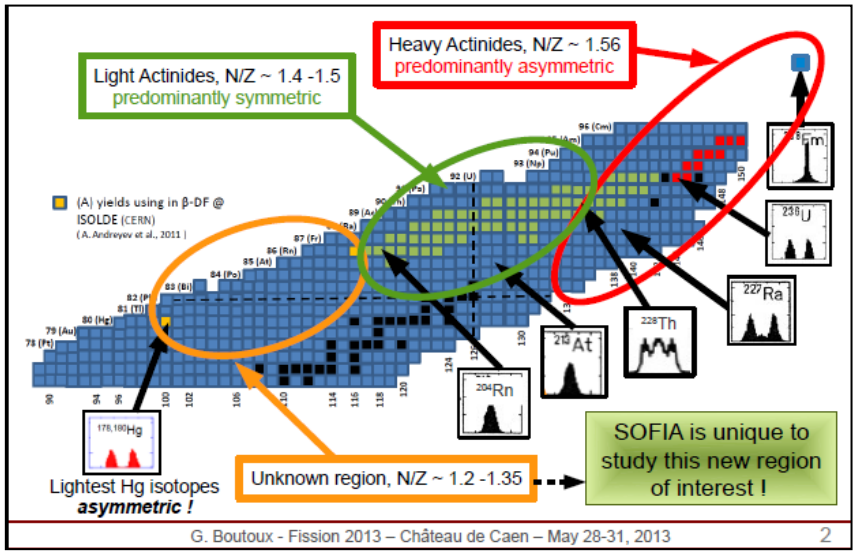
- To look at global evolutions

(as functions of E*, N, Z …)

Correlated observables:

- To have access to several observables during the same experiment

(e.g. prompt neutrons, gammas, mass – charge distributions …)



Almost 70 nuclei studied in SOFIA

SOFIA
Studies On FIssion with ALADIN

Pellereau et al. EPJ Web of conf 62 06005(2013)

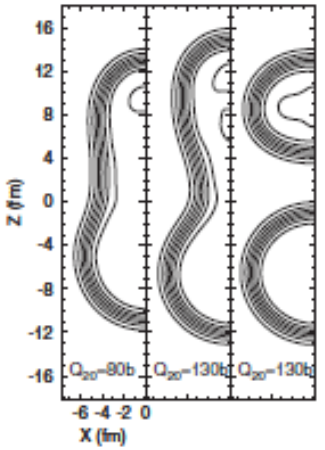
What is needed then ? (Personal view 2/2)

Theoretical improvements :

→ Better define the fission fragments at scission

W. Younes, D. Gogny, PRL 107, 132501 (2011). Quantum localization

S.A. Giuliani and L.M. Robledo, PRC88, 054325 (2013).



→ Introduce finite temperature effects

N. Schunck et al., PRC 91, 034327 (2015).

→ Quality inputs of the functionals:

S.A. Giuliani et al., PRC 90, 054311 (2014). Gogny D1M, BCPM

→ Enrich the dynamical approaches

N. Dubray, D. Regnier at al., CPC (2015) N dim. calculations on a non regular grid

R. Bernard et al. PRC84, 044308 (2011) TDGCM (+GOA) based HFB + qp

C. Simenel, A.S. Umar, PRC89, 031601(R)(2014), TDHF for quasi-fission

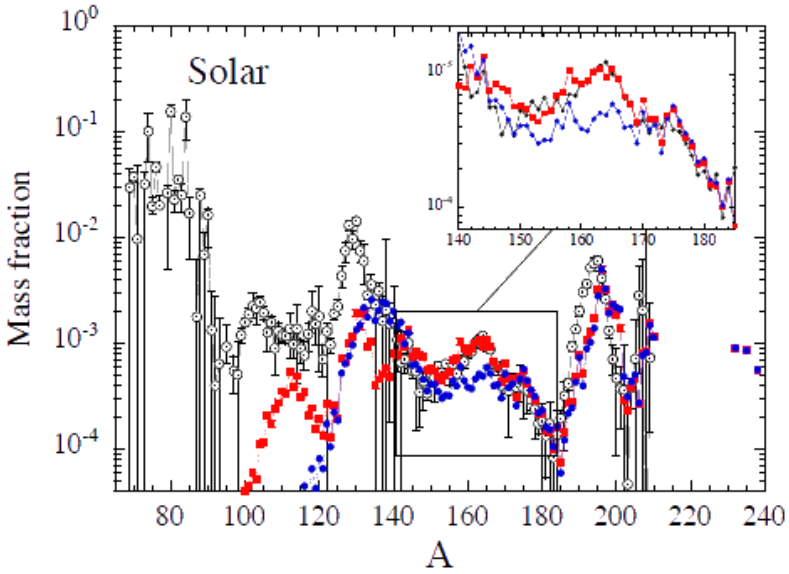
G. Scamps et al., PRC 91, 044606 (2015) Time-dep. Schrödinger equation for spontaneous fission

G. Scamps, C. Simenel, D. Lacroix, PRC 92, 011602(R) (2015) TDHF+BCS for s.f.

Fission in the heart of the nucleosynthesis

None of the existing model of nucleosynthesis is able to explain the abundances of rare earth nuclei. Are the neutron stars good sites for the formation of these heavy elements ?

→ Need of the modelisation of the fission of a huge number of nuclei (2000), including drip-line nuclei



S. Goriely, et al., PRL 111, 242502 (2013)

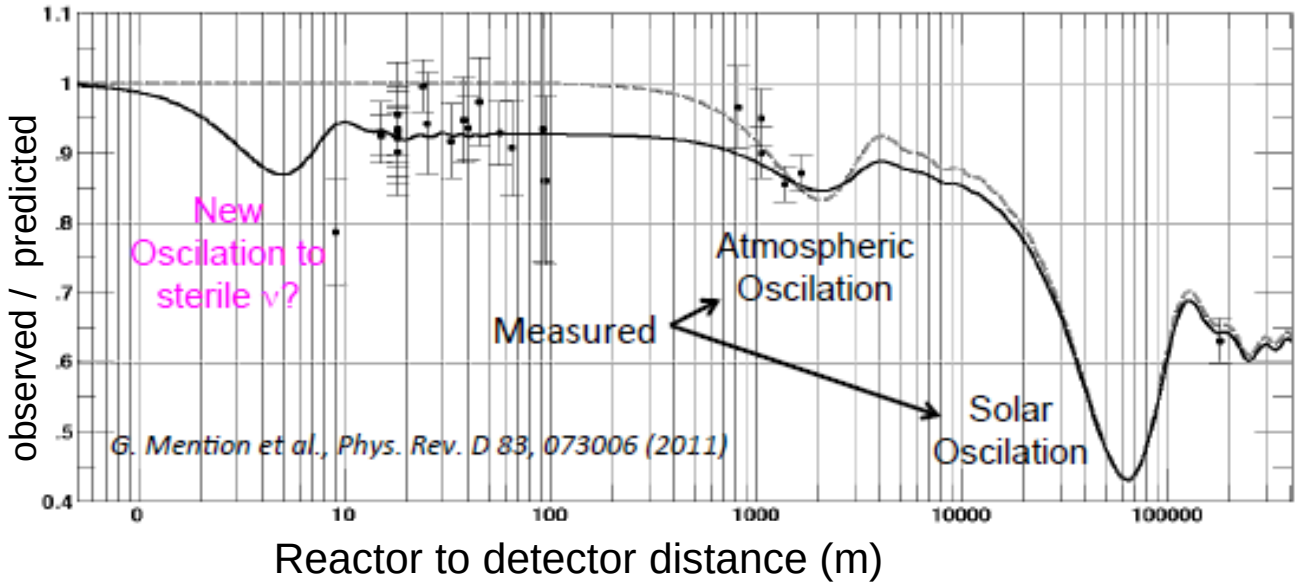
White : Solar r-abundance distribution
Red : fission yields from SPY
Blue : fission yields from phenomenological fission model (GEF)

Fission : a source of antineutrinos

Most of fission products are neutron rich nuclei undergoing β-decay.

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-} + \overline{\nu}_e $$

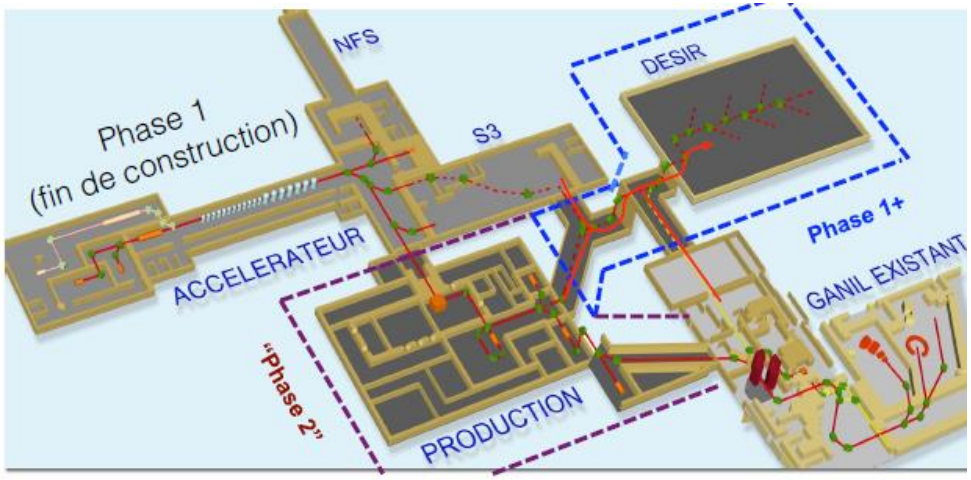
The reevaluation of the anti-neutrino spectrum associated to fission fragments has recently shown a significant deviation that could sign the existence of sterile neutrinos.



Conclusion

→ Very active field

Start of NFS soon @ SPIRAL2



Thanks to you, Daniel Gogny and to all of you in Bruyères