DE LA RECHERCHE À L'INDUSTRIE

Nuclear reactions ingredients based on the Gogny interaction

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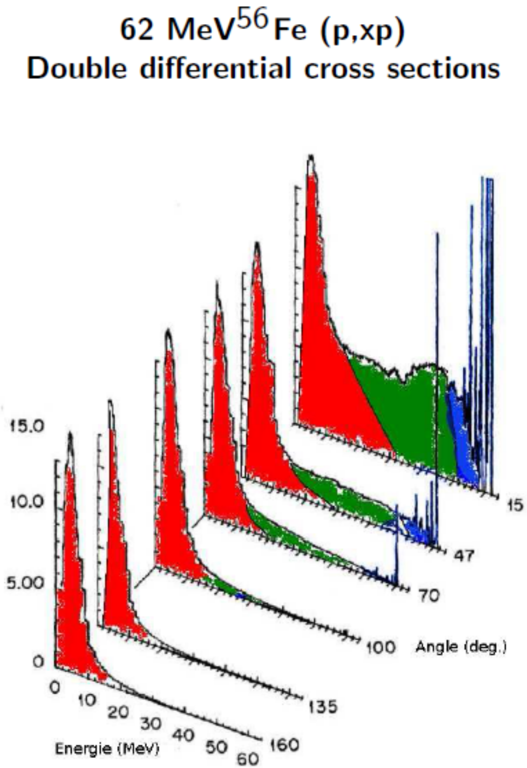
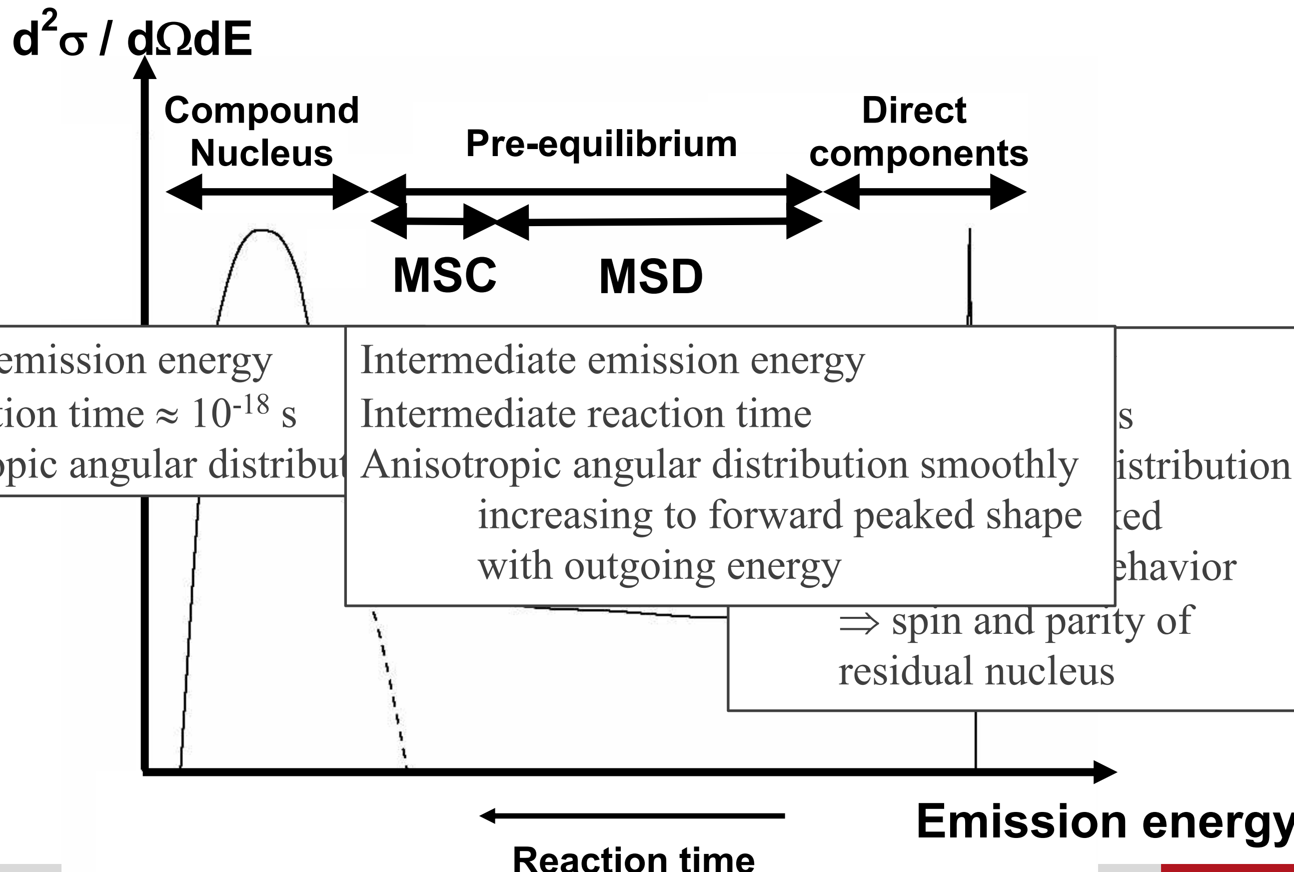
Solvay Workshop – 25-27/11/2019

Ongoing project : describe nuclear reactions **for the majority of the nuclei involved in nucleosynthesis process**

Typical spectrum shape



- Always evaporation peak
- Discrete peaks at forward angles
- Flat intermediate region



Low emission energy
Reaction time ≈ 10^{-18} s
Isotropic angular distribut

Intermediate emission energy
Intermediate reaction time
Anisotropic angular distribution smoothly increasing to forward peaked shape with outgoing energy

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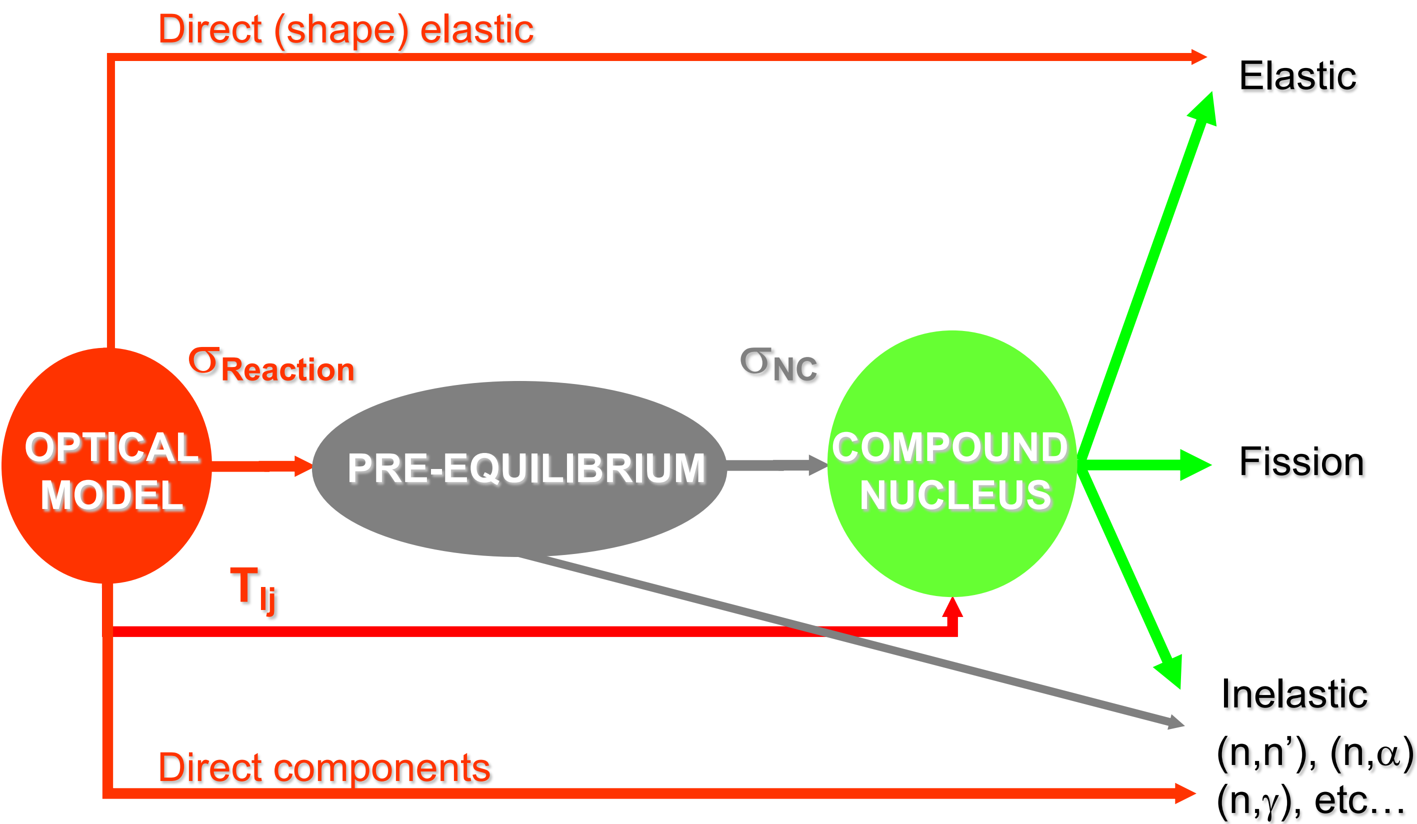
ted
ehavior
⇒ spin and parity of residual nucleus

TIME SCALES AND ASSOCIATED MODELS



Ongoing project : describe nuclear reactions **for the majority of the nuclei involved in nucleosynthesis process**

=> structure properties (masses, spectro., deformation …)

=> optical model and coupling scheme

=> nuclear level densities

=> photon strength functions

=> fission paths

Need for a reliable and universal interaction as well as robusts tools (codes)

Nuclear reaction modeling : 2 complementary paths

Empirical / Analytical approaches

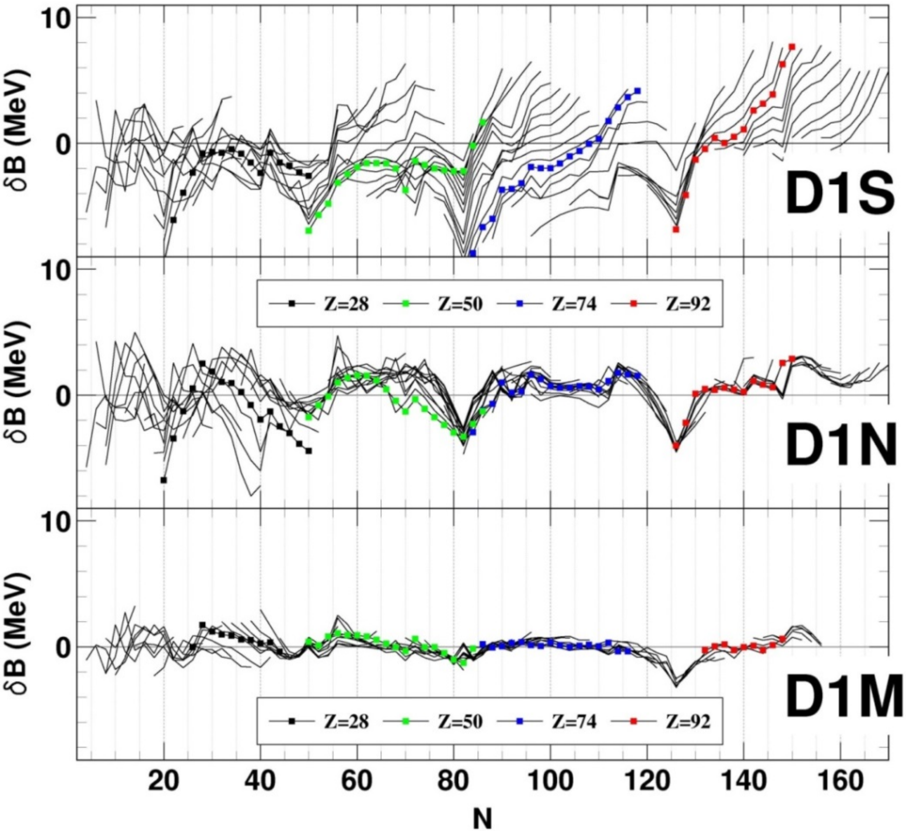
- Good (very) fitting power
- Weak (modest) computing time
- Weak predictive power
- Important human optimization

⇒ accurate evaluated files for applications (ENDF, JEFF, JENDL …)

Microscopic (semi-) approaches

- Weak fitting power
- Important computing time
- Good predictive power
- Weak human optimization

⇒ astrophysical applications
⇒ fundamental research
⇒ guide for empical approaches



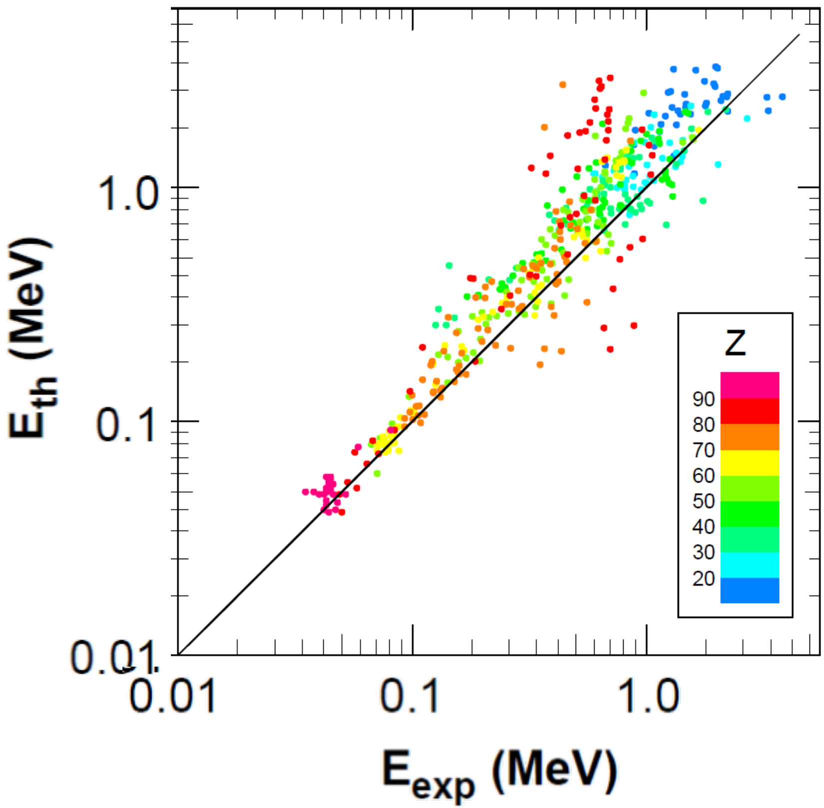
r.m.s ~ 3 MeV

r.m.s ~ 1 MeV

r.m.s = 0.798 MeV

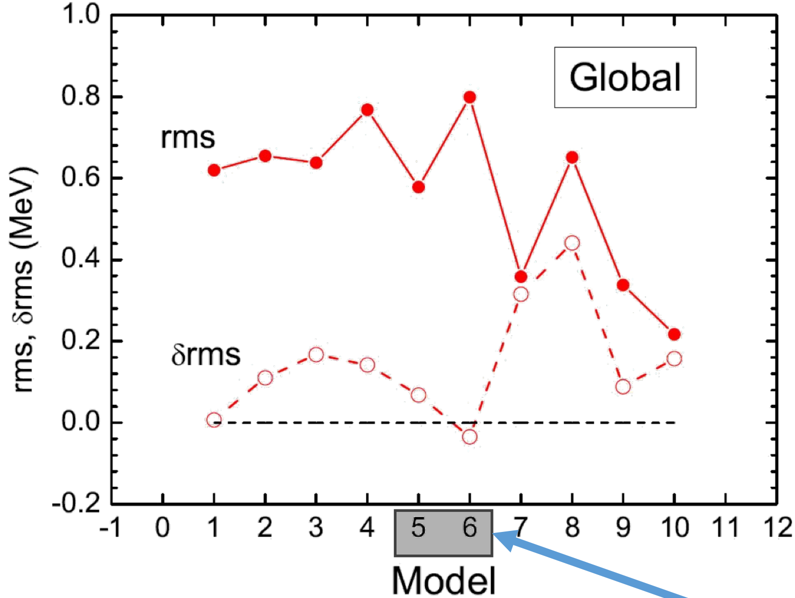
See CPC 63 (1991) 365, PLB 668 (2008) 420 & PRL 102 (2009) 242501

Excitation energies of the first 2^+ for 519 e-e nuclei



See PRL 102 (2009) 242501

Comparison between several mass models adjusted with 2003 exp and tested with 2012 exp masses



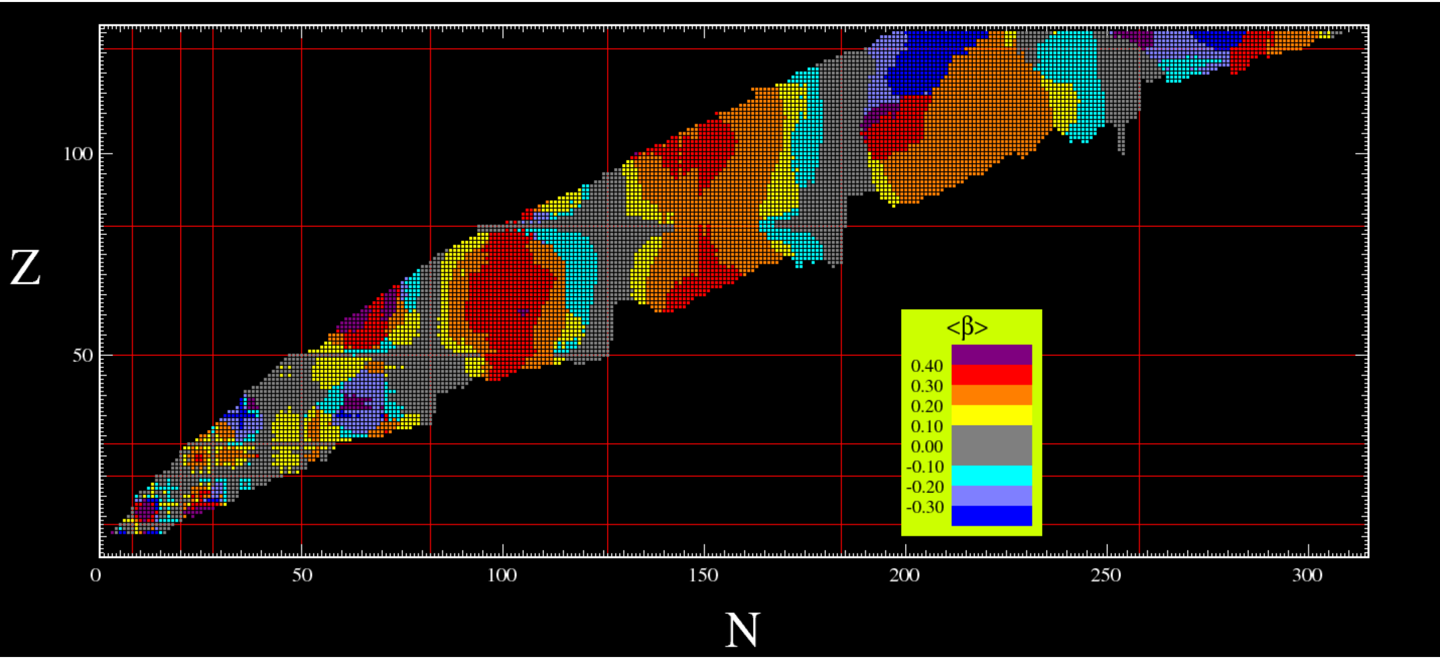
Current status

- **rms < 1 MeV (masses ≈ GeV)**
- **micro ~ macro**
- **Gogny D1M more predictive**

Microscopic models

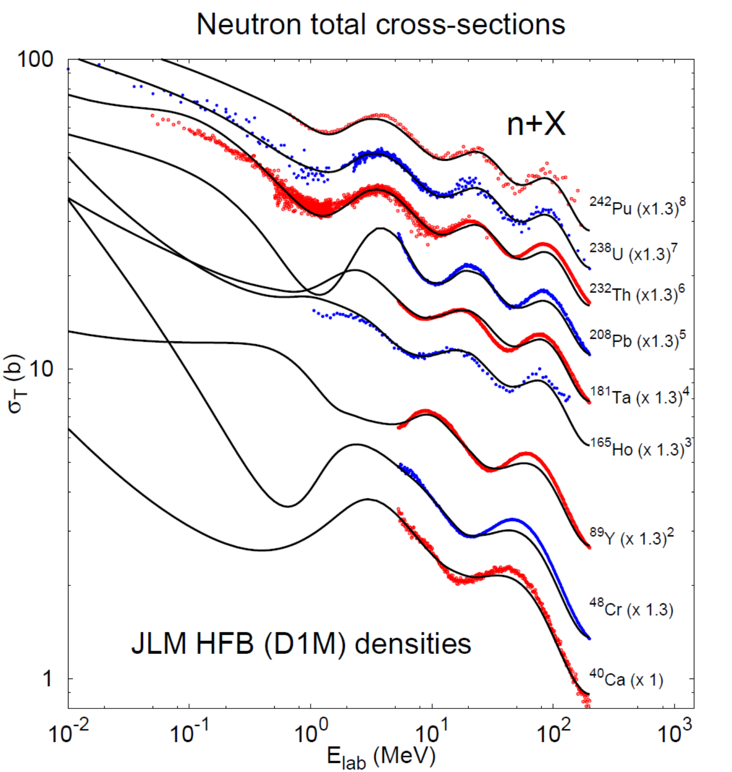
PHYSICAL REVIEW C **90**, 017302 (2014)

Model	LSD (2003) 1	FRDM (1995) 2	TF (1996) 3	FRLDM (1995) 4	HFB21 (2010) 5	GHFB (2009) 6	DZ (1995) 7	KTUY (2005) 8	WS3.6 (2011) 9	WS3.3 (2011) 10



=> Nearly 9000 nuclei up to Z=130 for D1M (500 less with D1S)

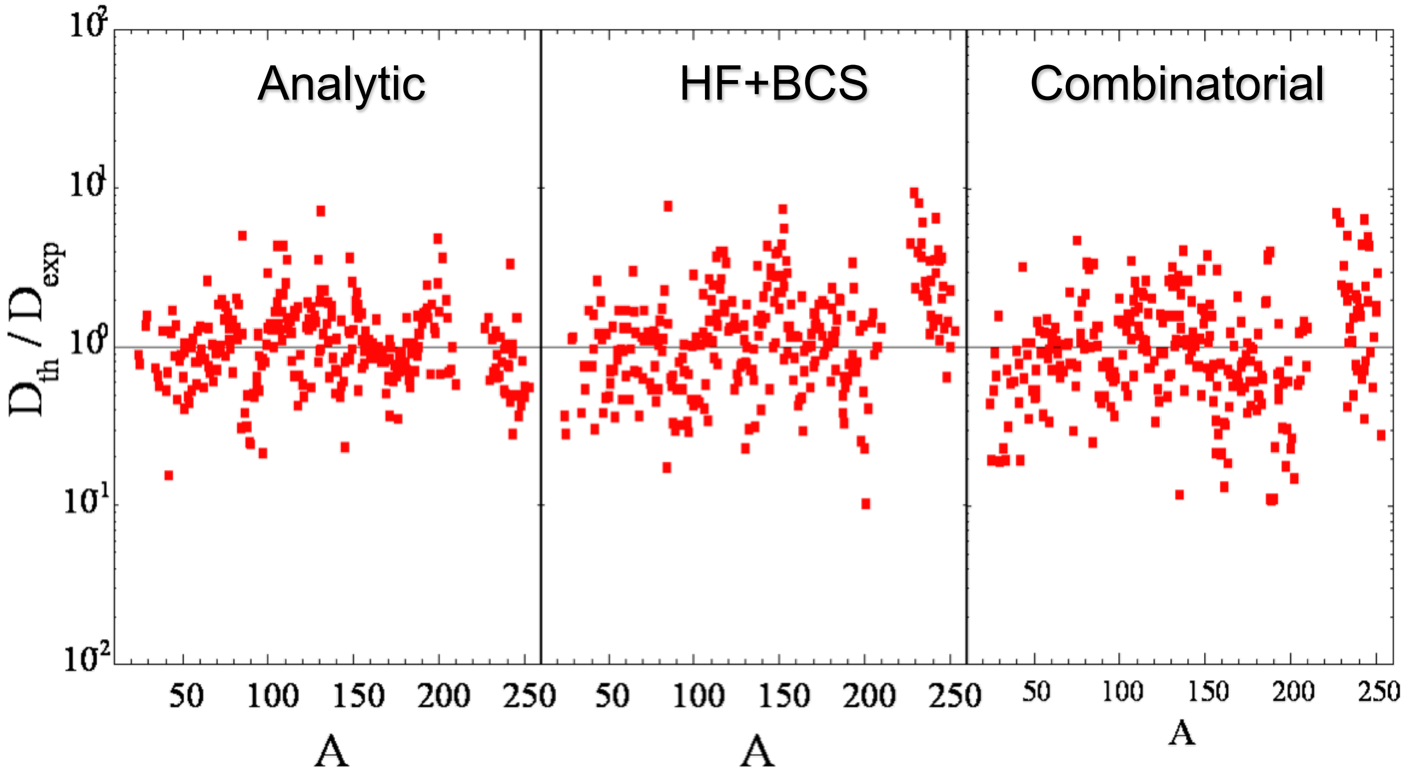
See EPJA 33 (2007) 237 + www-phynu.cea.fr

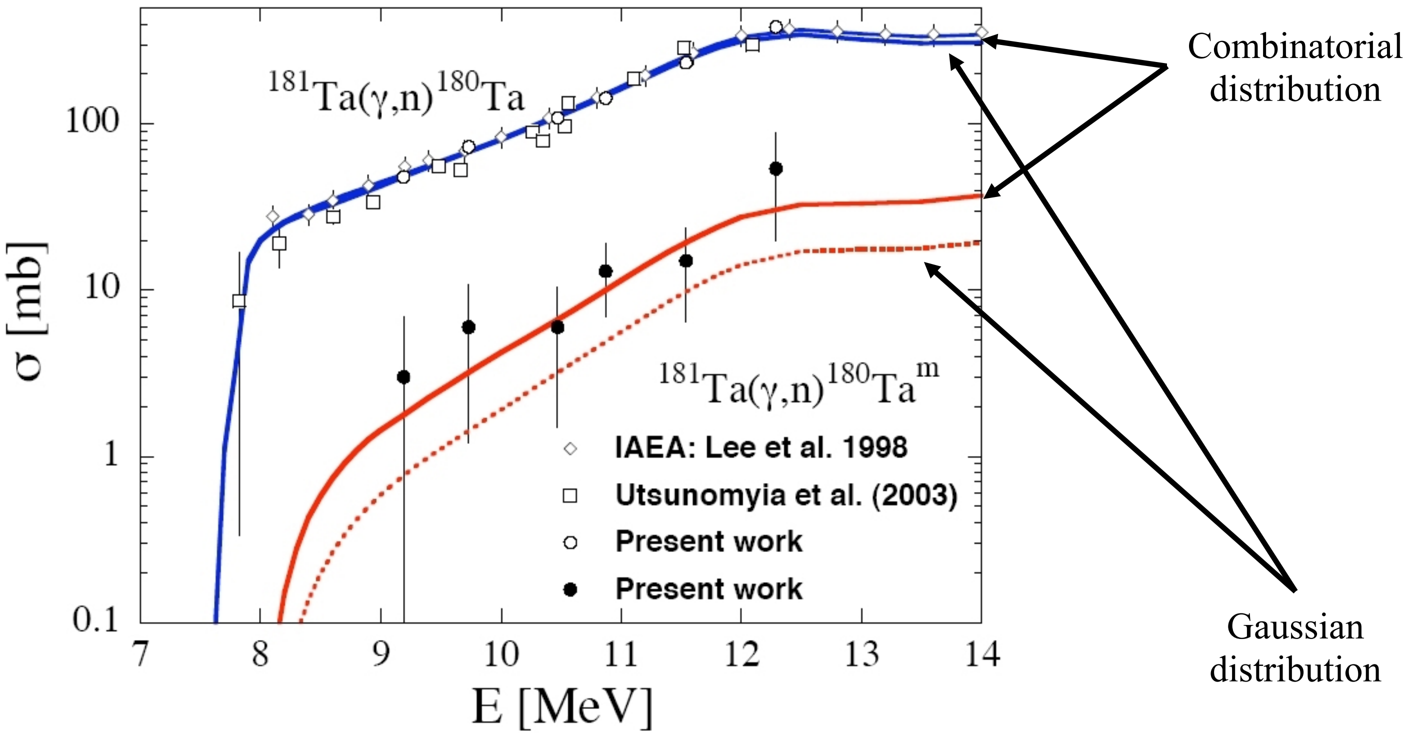


=> Obtained using D1M matter densities

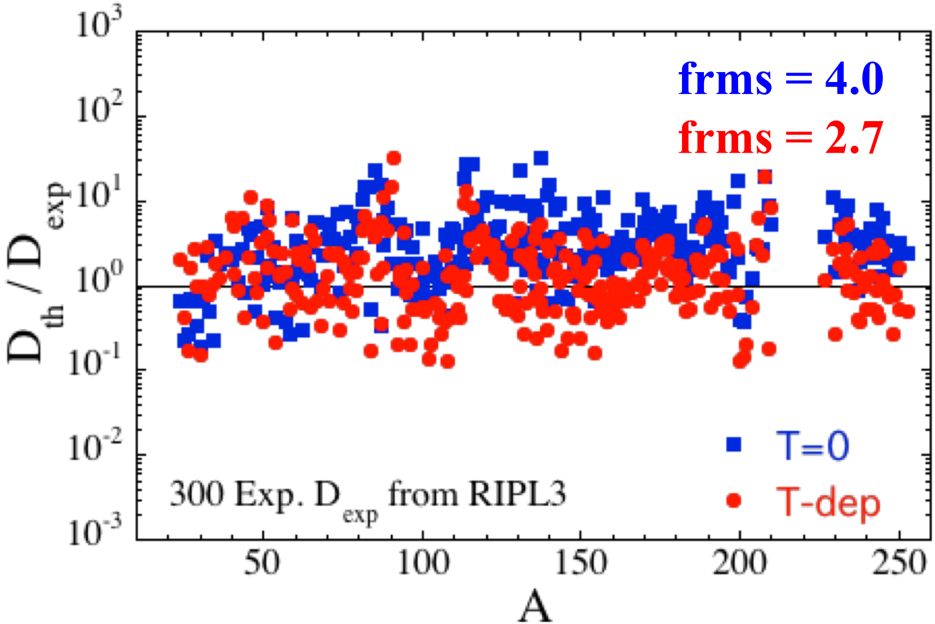
See EPJA 52 (2015) 336

NUCLEAR LEVEL DENSITIES (1/3)





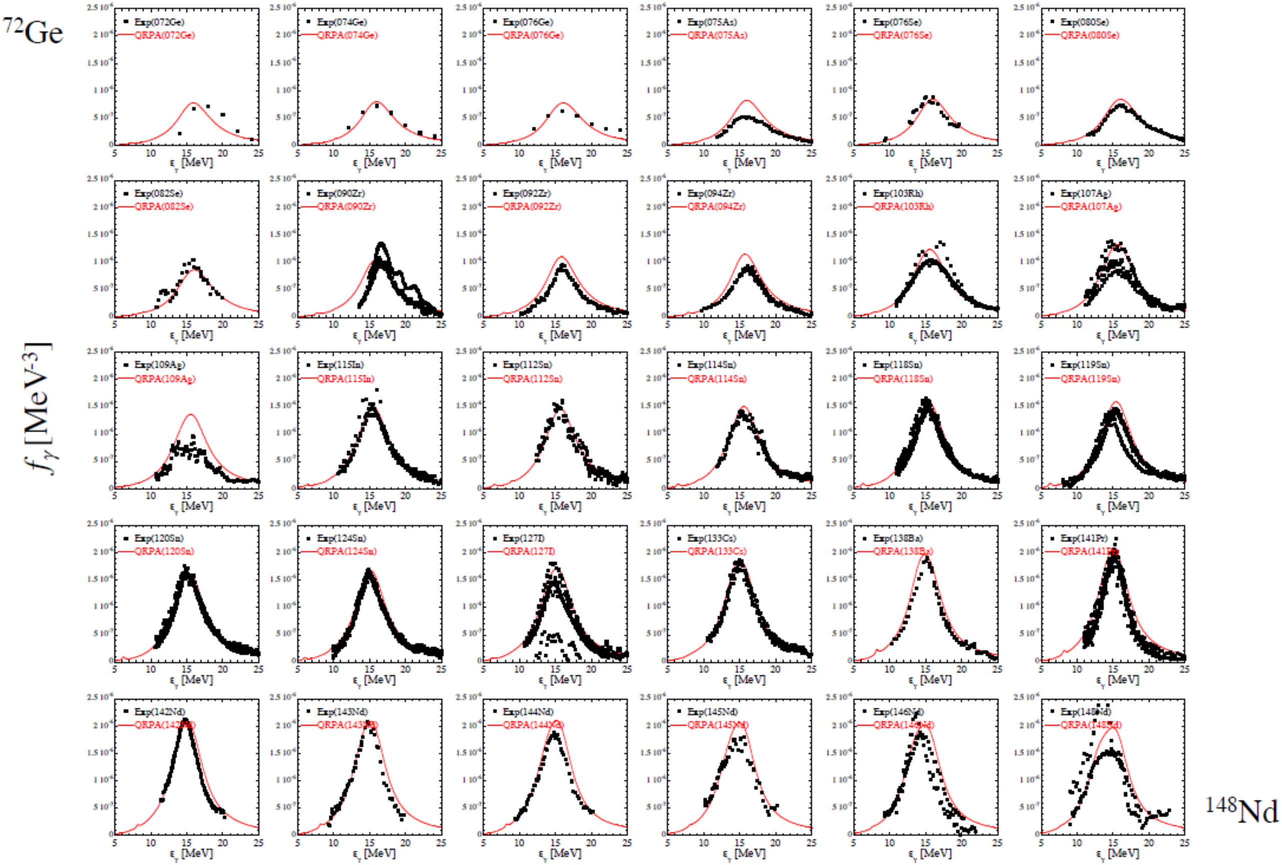
See PRL 96 (2006) 192501



$\Rightarrow$ **NLD computed for all nuclei (tables)**

See PRC 86 (2012) 064317

QRPA PHOTON STRENGTH FUNCTIONS VS IAEA RECOMMENDATIONS



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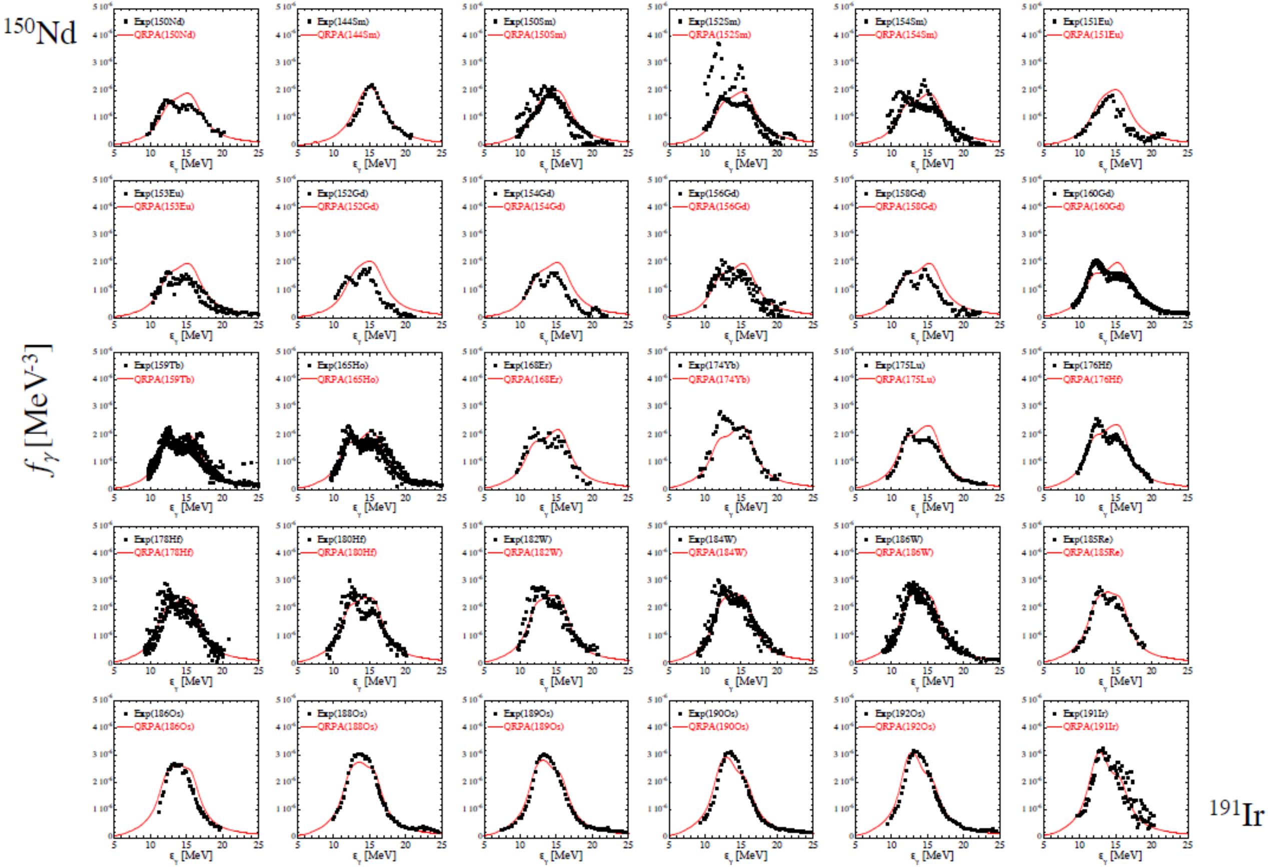
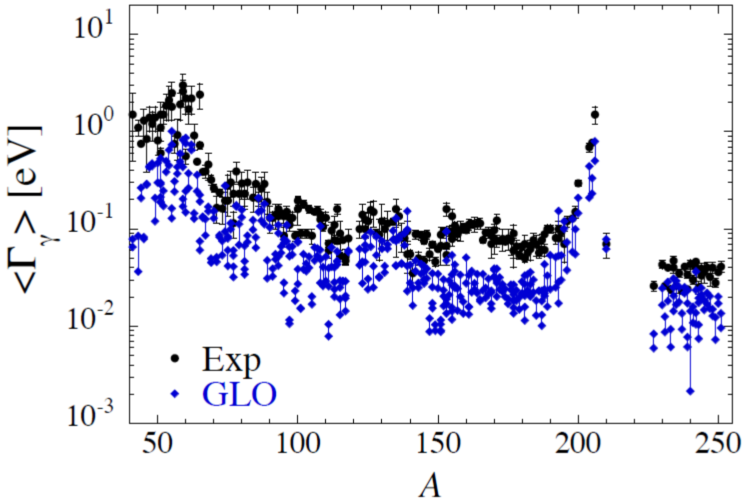
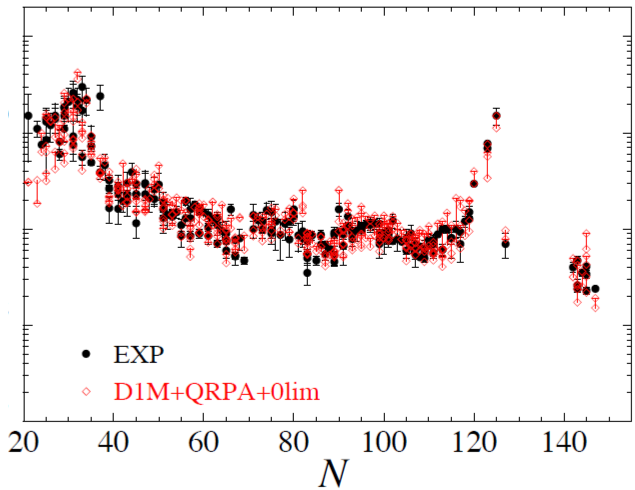


Normalisation method for thermal neutrons

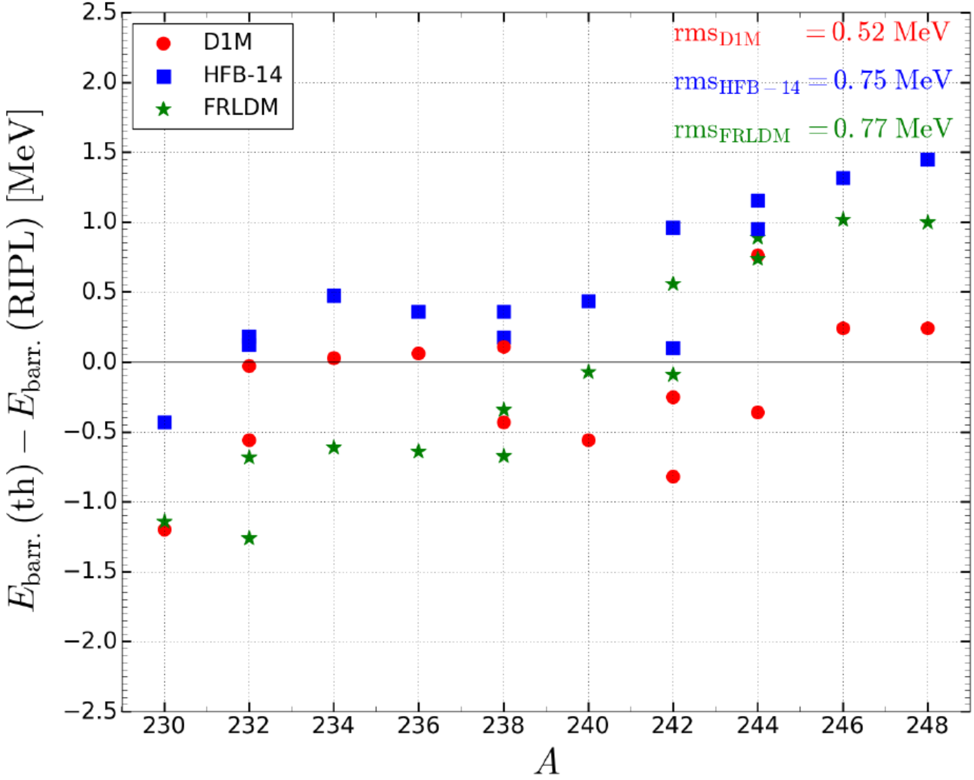
$$\langle T_\gamma \rangle = C \sum_{J_i,\pi_i} \sum_{k\lambda} \sum_{J_f,\pi_f} \int_0^{B_n} T^{k\lambda}(\varepsilon)\, \rho(B_n-\varepsilon, J_f, \pi_f)\, S(k,\lambda,J_i,\pi_i, J_f,\pi_f)\, d\varepsilon = \frac{2\pi \langle \Gamma_\gamma \rangle}{D_0}$$





See EPJA 55 (2019) 172

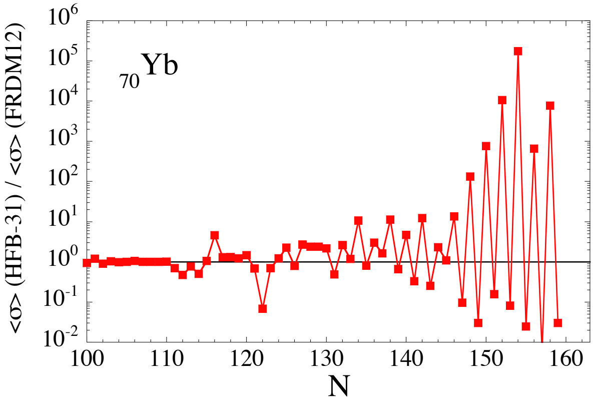
FISSION PATHS (UNDER DEVELOPMENT)



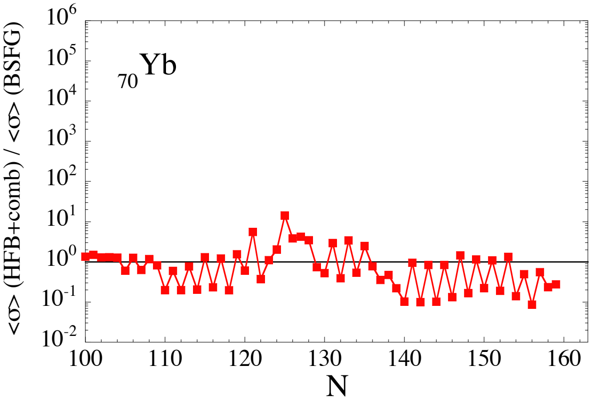
See PRC 98 (2018) 024623

IMPACT OF THE VARIOUS INGREDIENTS ON THE RADIATIVE NEUTRON CAPTURE (E_n~100KEV)

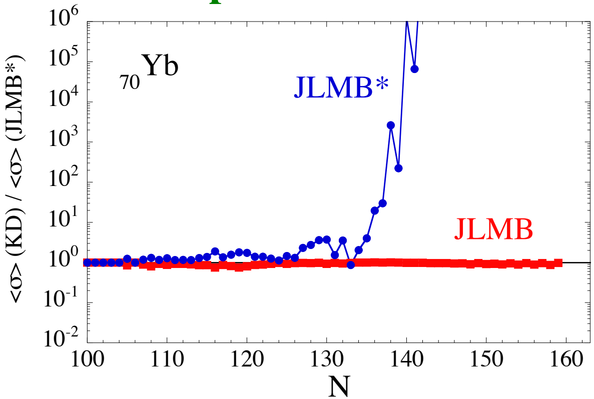
Masses



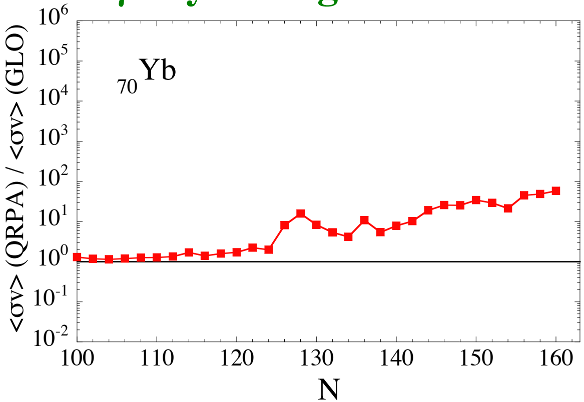
Nuclear Level Densities



Optical Potential



γ-ray Strength Function



CONCLUSIONS & PROSPECTS

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- Microscopic approaches (globally adjusted) provide results as good as historical analytical approaches

  => lower fitting power close to stability

  => better predictive power far from stability

- Encouraging fission paths

- Room for improvement for photon strength functions

- Similar work to be performed with next EDF generation (D2, DG)

- No reason to hold on using “old” approaches