

Pairing in fission

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- Luis Robledo

1. Motivation: Relevance of spontaneous fission

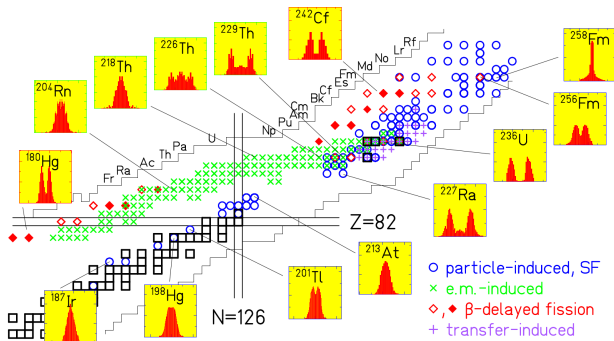
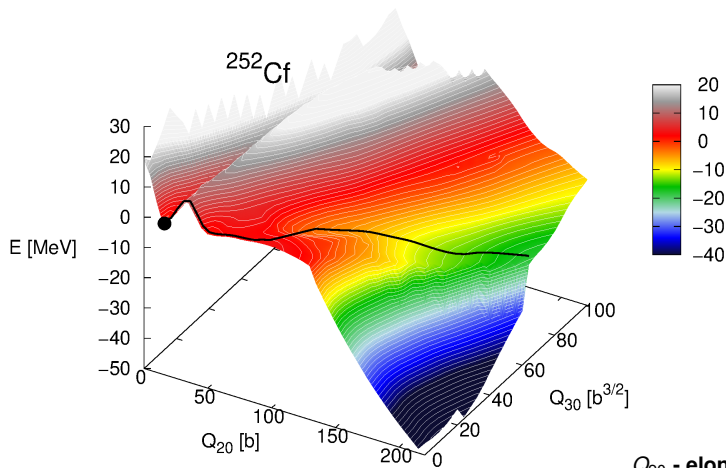


Fig. 1. K.H. Schmidt, B. Jurado *Rep. Prog. Phys.* **81** 106301 (2018).

Fission observables as a benchmark:

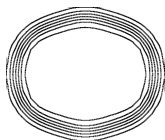
- **Half-lives:** SHE experiments' preparation & measurements analysis
- **Mass/Charge yields**
- TKE distributions
- Neutron multiplicities

1. Motivation: Choice of the relevant degrees of freedom

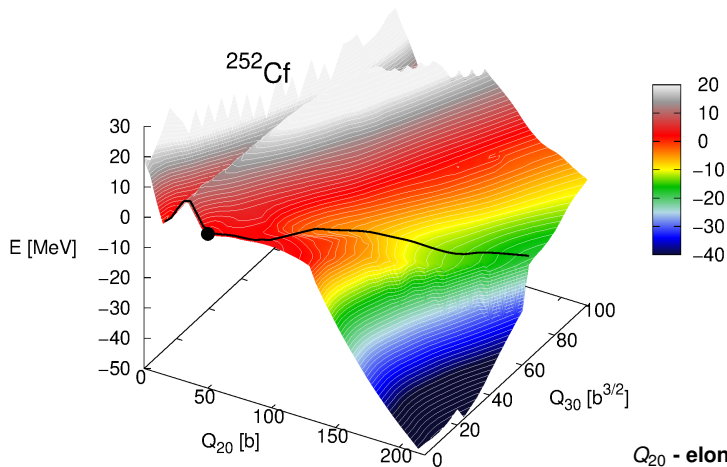


Q_{20} - elongation

Q_{30} - mass asymmetry

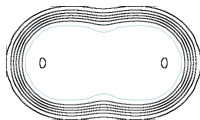


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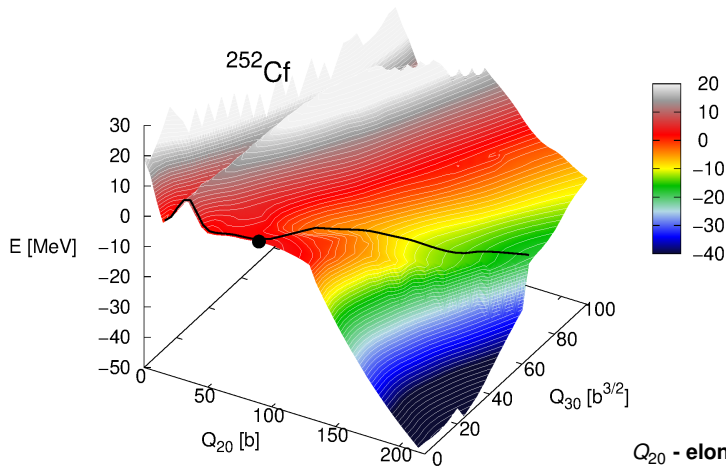


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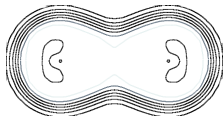


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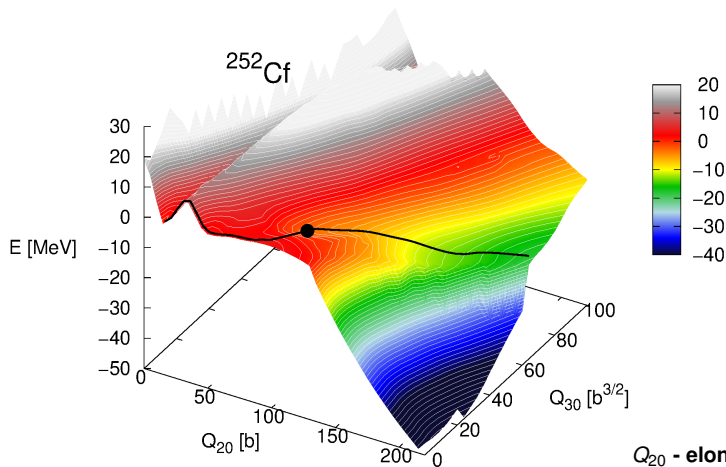


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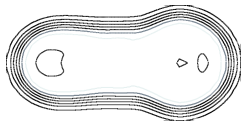


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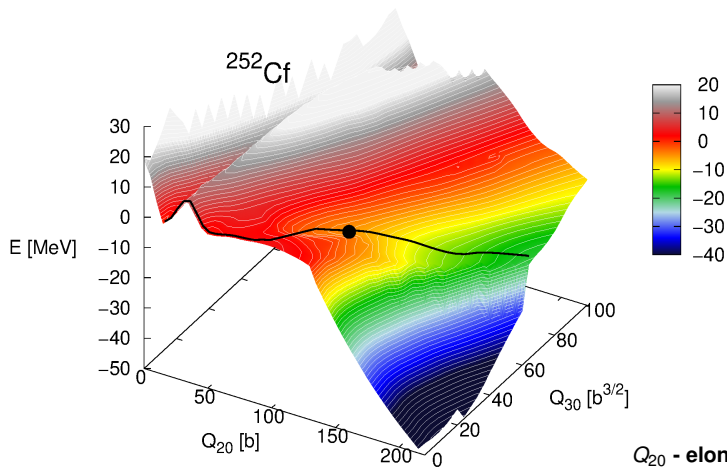


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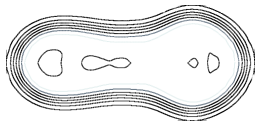


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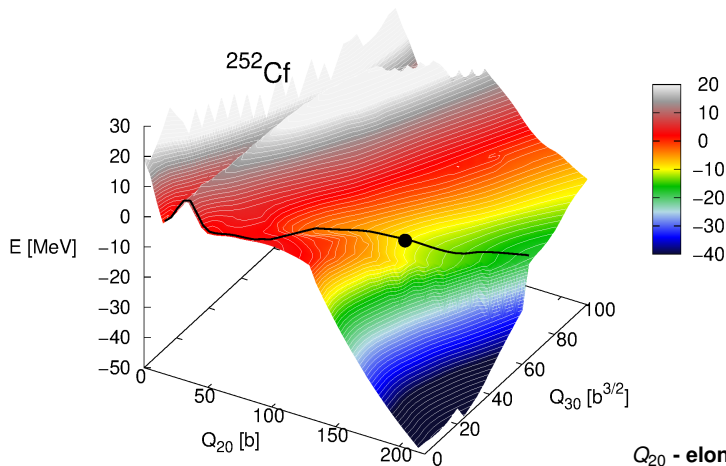


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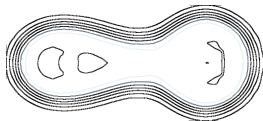


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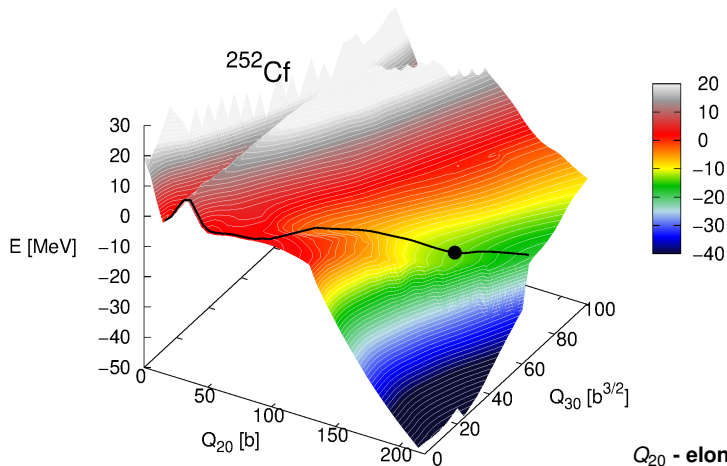


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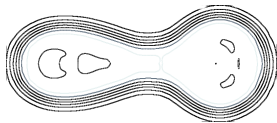


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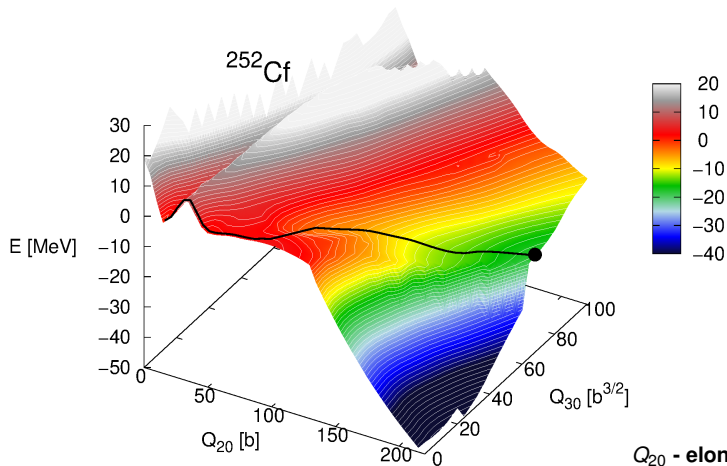


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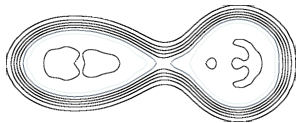


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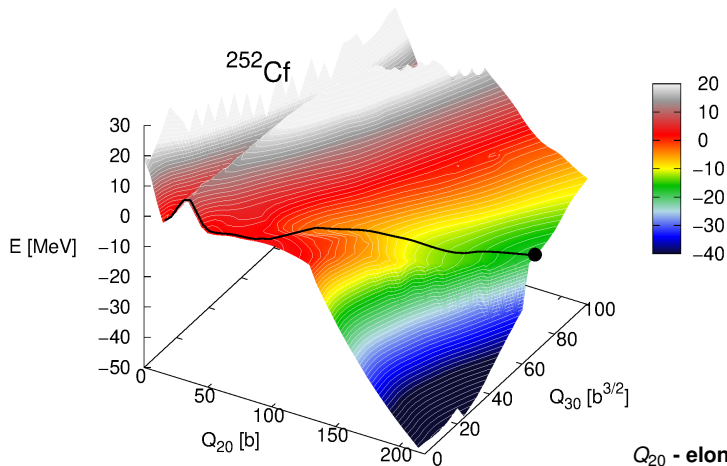


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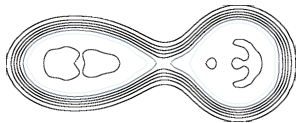


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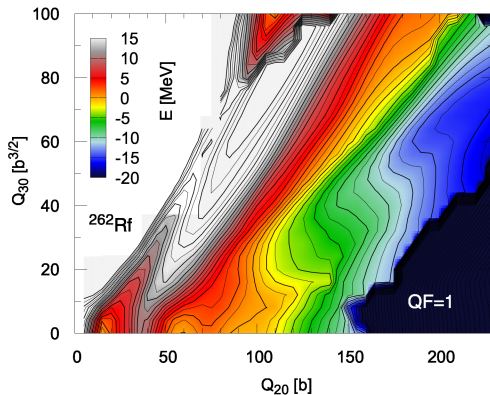


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1. Motivation: Spontaneous fission half - lives



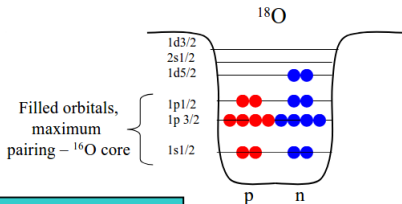
- SF half-life: $T_{1/2}^{\text{SF}} = \frac{\ln 2}{P\nu}$
- Tunelling probability: $P = [1 + e^S]^{-1}$
- Least-energy integral:

$$S = 2 \int_{s_1}^{s_2} \sqrt{\frac{2}{\hbar} (V(s) - E) B_s(s)} ds$$

1. Motivation: Role of pairing

Fission half-lives and mass distributions calculations - crucial ingredients:

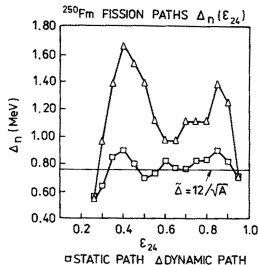
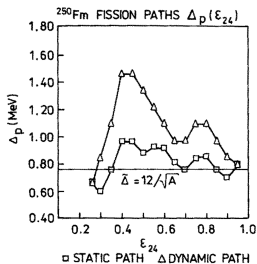
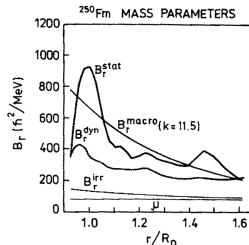
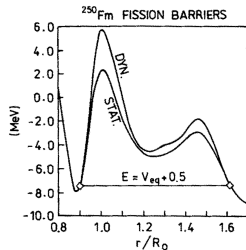
- Determination of the **least action** path. $S(L) = 2 \int_{s_1}^{s_2} \sqrt{\frac{2}{\hbar} (V(s) - E)} B_s(s) ds$
- An increase in the **pairing** gap parameter leads to an increase in the penetrability of the fission barrier \implies shorter half-lives.
- Strong interplay between the **potential energy/collective inertia** - increasing/decreasing as an inverse of the pairing gap squared.



Pairing energy refers to the additional binding that occurs for p+p and/or n+n pairs near the Fermi surface.

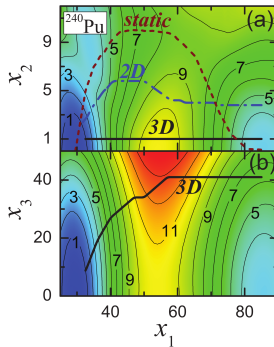
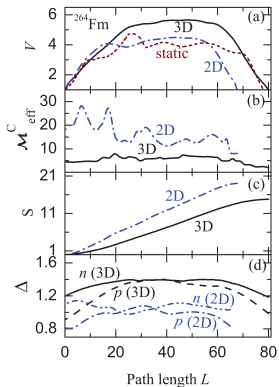
- The ground state of nuclei is very well described in terms of superfluid condensate.
- Lowering of the binding energy by joining in pairs nucleons like electrons in superconductors.
- **Pairing correlations impact fission barriers.**

1. Motivation: Some background



- GCM+GOA collective hamiltonian
- shape + pairing degrees of freedom

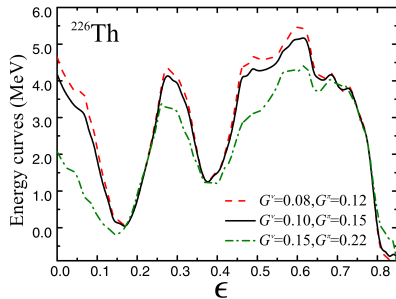
1. Motivation: Some background



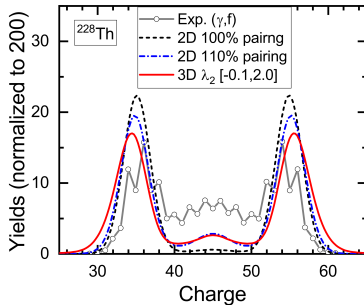
- HFB+Skyrme interaction
- Dynamic path in 3D: Q_{20} , Q_{22} , Δ
- axial symmetry restoration

J. Sadhukhan, J. Dobaczewski, W. Nazarewicz, J.A. Sheikh, A. Baran, PRC 90(2014).

1. Motivation: Some background



X. Guan, Y. Xin, Y. Chen, X. Wu, Z. Li, PRC 104 (2021).



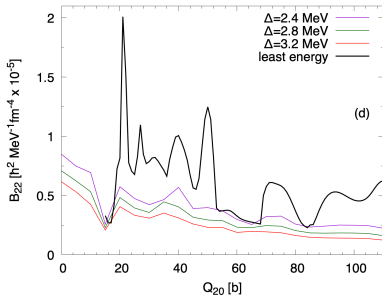
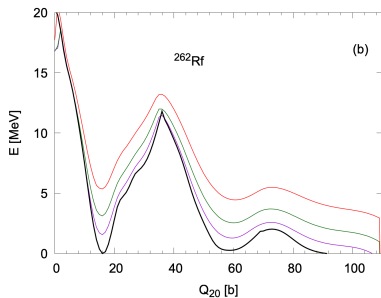
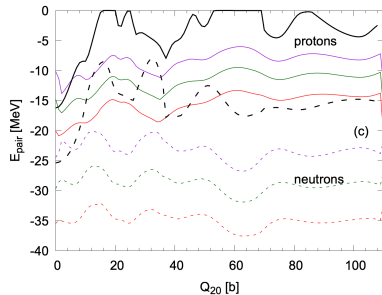
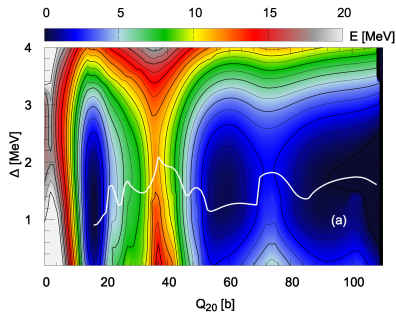
J. Zhao, T. Niksic, D. Vretenar, PRC 104 (2021).

2. Fission description: Microscopic pairing

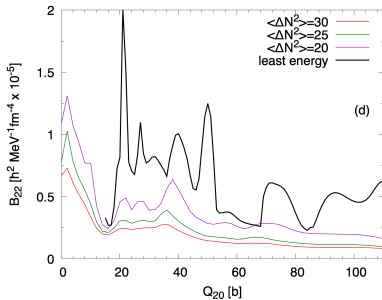
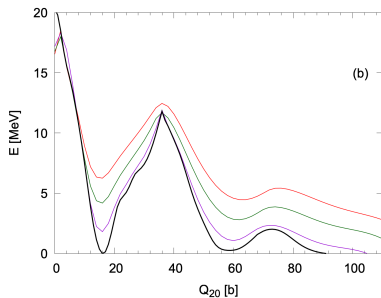
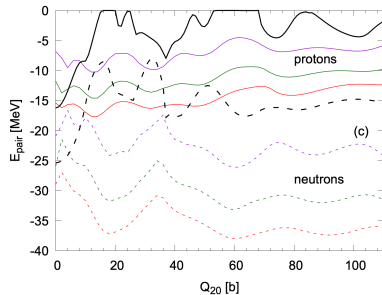
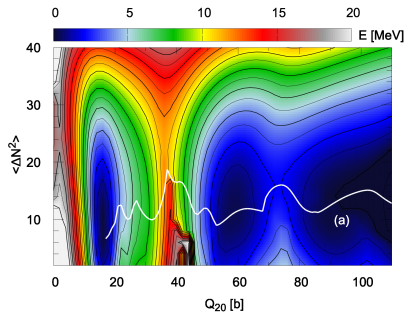
There are 3 ways of studying the effect of pairing correlations in the microscopic fission description by considering:

- the pairing gap: Δ ,
- the particle number fluctuations: $\langle \Delta N^2 \rangle$,
- the quenching factor: QF.

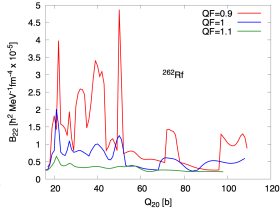
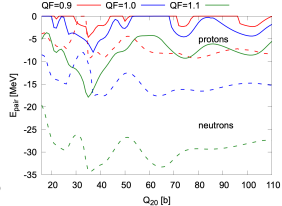
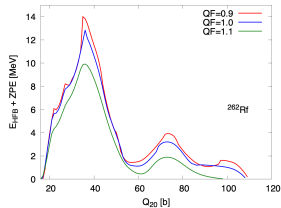
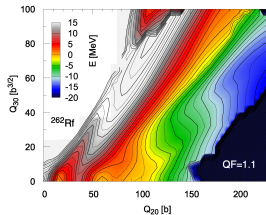
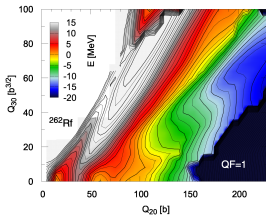
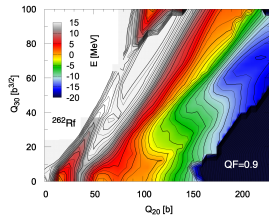
2. Fission description: Pairing gap



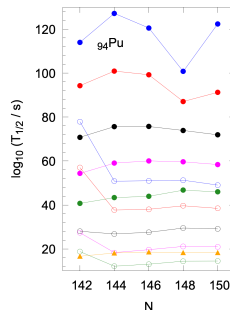
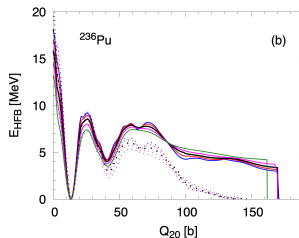
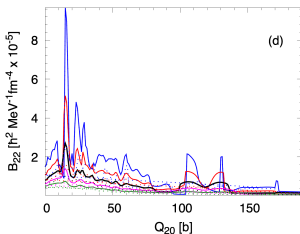
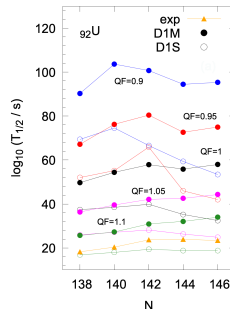
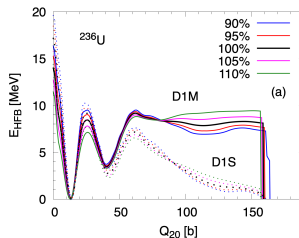
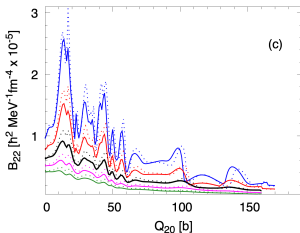
2. Fission description: Particle number fluctuations



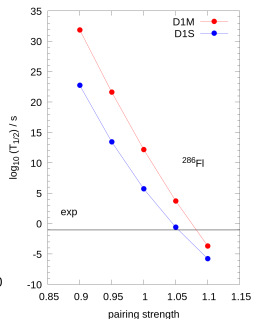
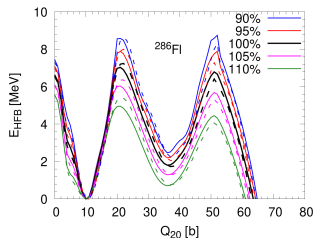
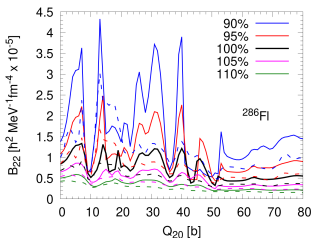
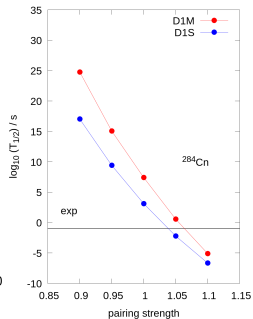
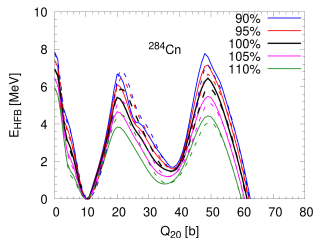
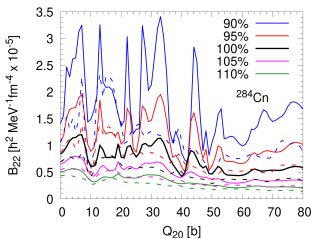
2. Fission description: Pairing strength



3. Results: Spontaneous fission half-lives - Actinides



3. Results: Spontaneous fission half-lives - SHE



4. Summary

- The increase of Δ and $\langle \Delta N^2 \rangle$ leads to an increase of the energy which is accompanied by the decrease of the collective inertias.
- The increase of Δ and $\langle \Delta N^2 \rangle$ produces wider fission barriers.
- The increase of the pairing strength leads to decrease of both: the fission barrier and the collective inertias.
- The stronger pairing the shorter path.
- The potential energy decreases monotonically with increasing pairing strength.
- It is possible to obtain a continuous transition in the saddle region when the pairing strength is increased up to 110%.

Thank you for your attention!