Modeling complex features in the fission of light actinides with GEF

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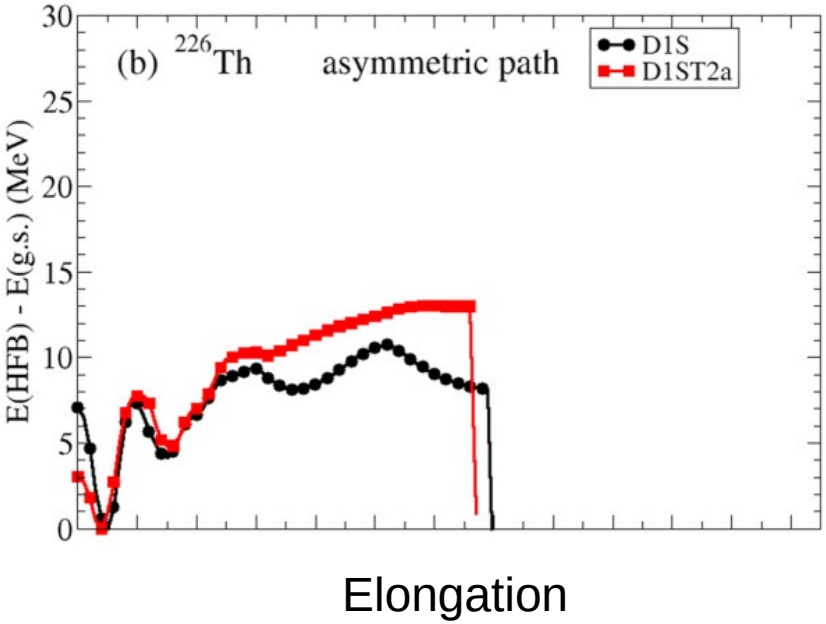
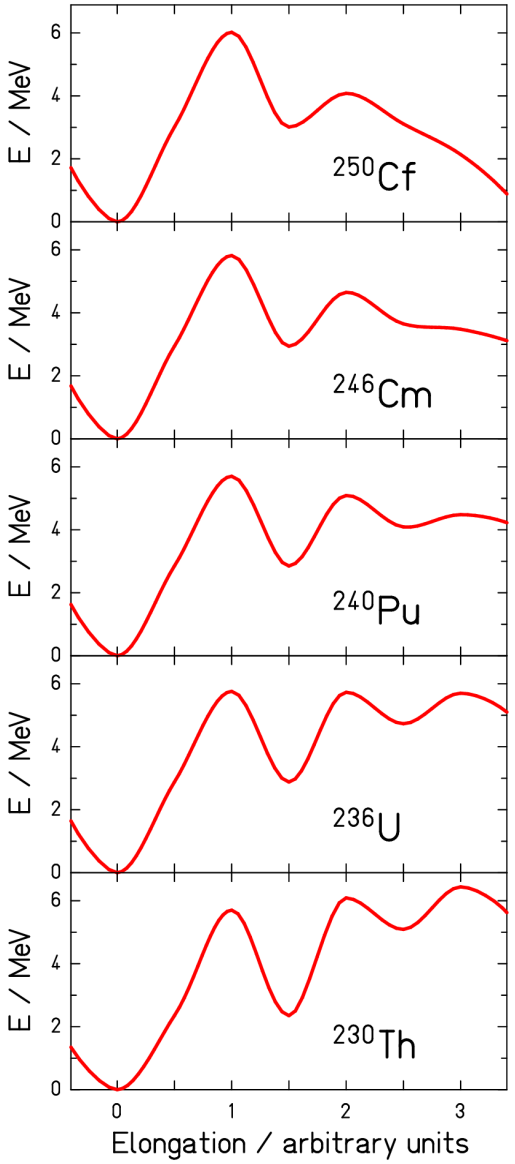
Triple-humped barrier

- Established: Triple-humped fission barrier in the light actinides.
- Effect investigated since the 1970th on
  - Fission probability
  - FF angular distribution
- No investigation yet on
  - FF yields

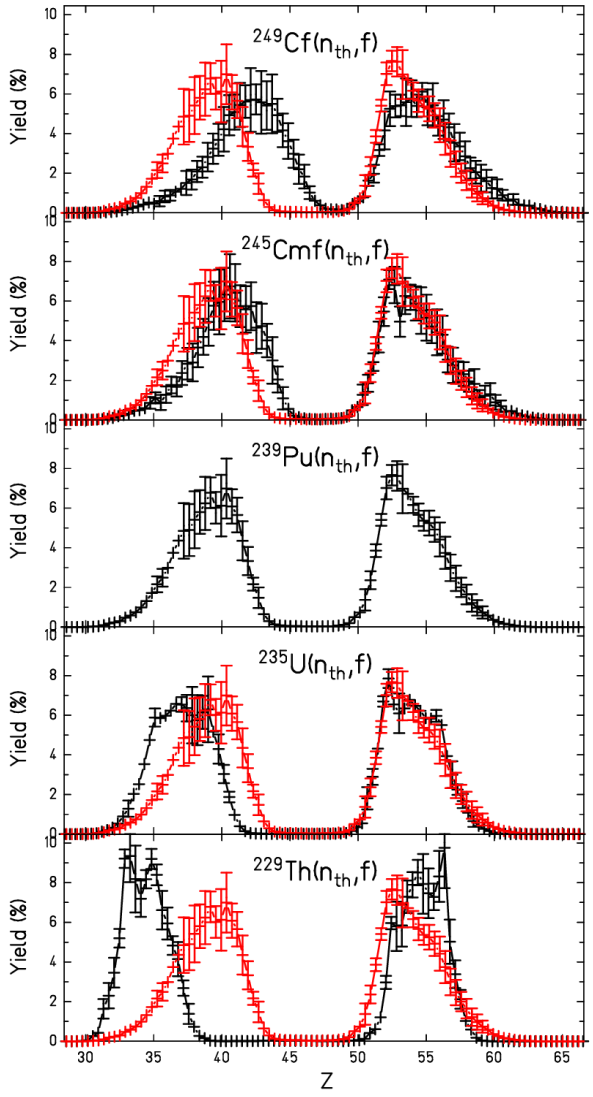


HFB calculation
R. N. Bernard et al.,
Phys. Rev. C 101 (2020) 044615



Estimated barrier profile

- Educated guess
  - E_A and E_B from experiment (used in GEF)
  - E_C from extrapolation
  - Lines „to guide the eye“ (smooth lines)
- E_c becomes highest barrier in the light actinides (e.g. ^{230}Th)

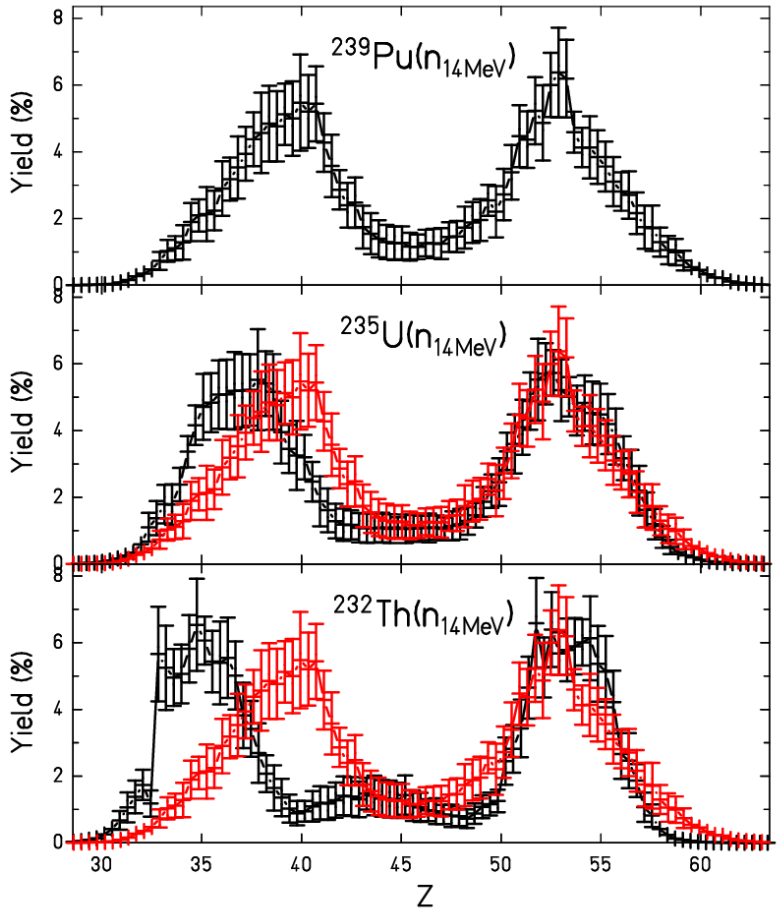


Systematics of Z yields (n_{th},f)

- Z yields derived from mass yields with UCD assumption
- Anomaly: Heavy peak shifted towards asymmetry for ^{229}Th(n_{th},f)

Data from ENDF-B/VII
Red: data from ^{239}Pu(n_{th},f) for comparison

Systematics of Z yields (E_n=14 MeV)

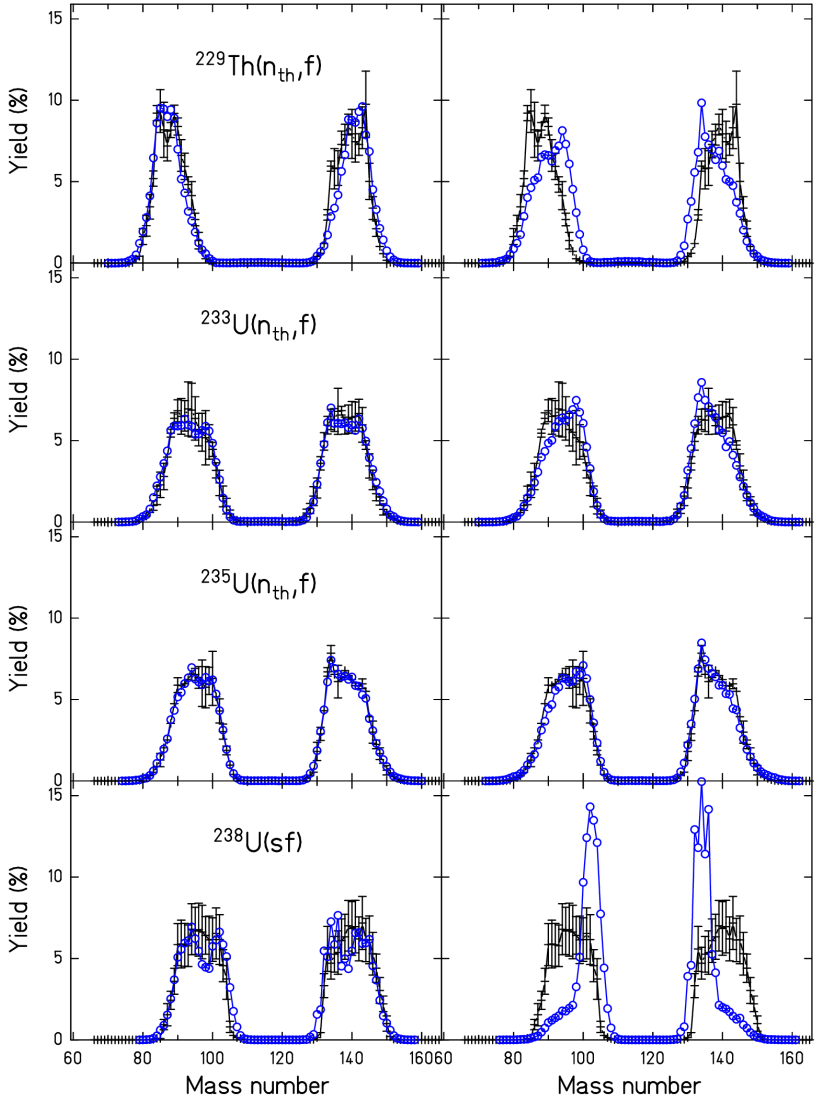


- Anomaly disappeared !

Data from ENDF-B/VII
Red: data from ^{239}Pu(n,f) for comparison

Interpretation

- Anomaly is caused by the third barrier.
- Anomaly disappears at higher E*.
- Effect of nuclear dynamics
  - Influence of inertia and dissipation
  - Memory on E_B preserved at high E*
  - Memory on E_B erased by tunneling through E_C
- Model developed and implemented in GEF

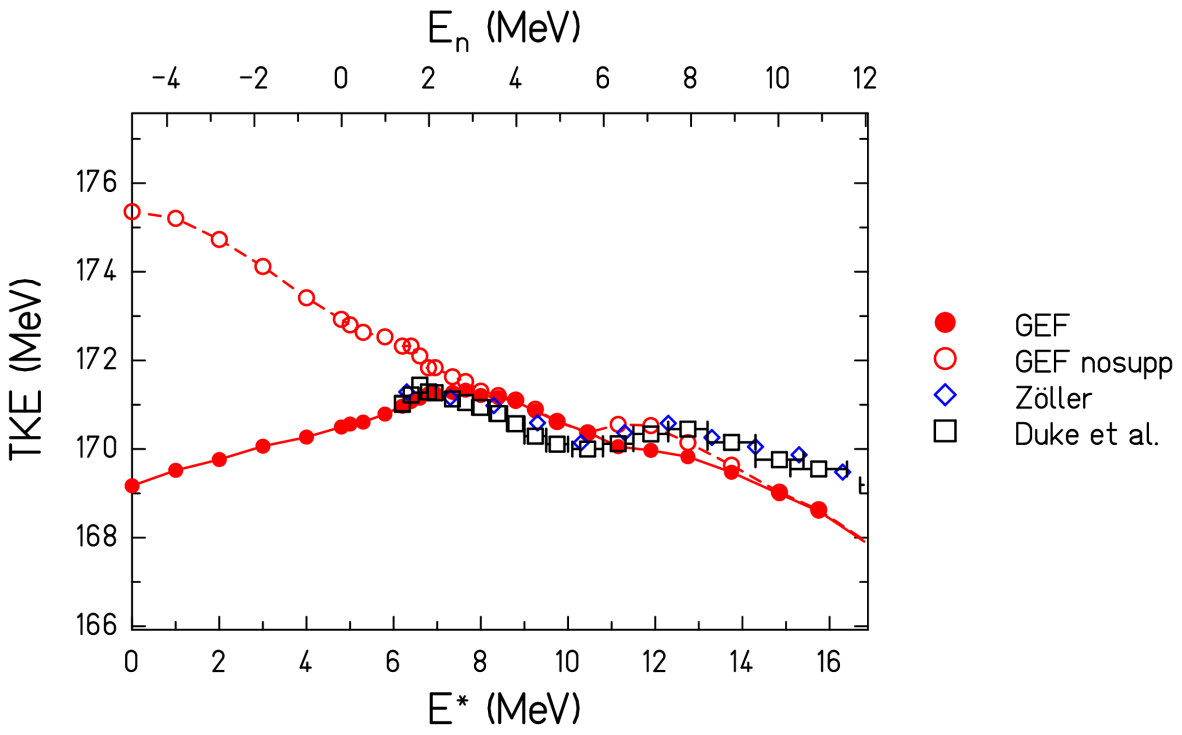


Effect of third barrier

- Compact shapes suppressed for Z_{CN} <= 92!
- Drastic effect for spont. fission of ^{238}U.

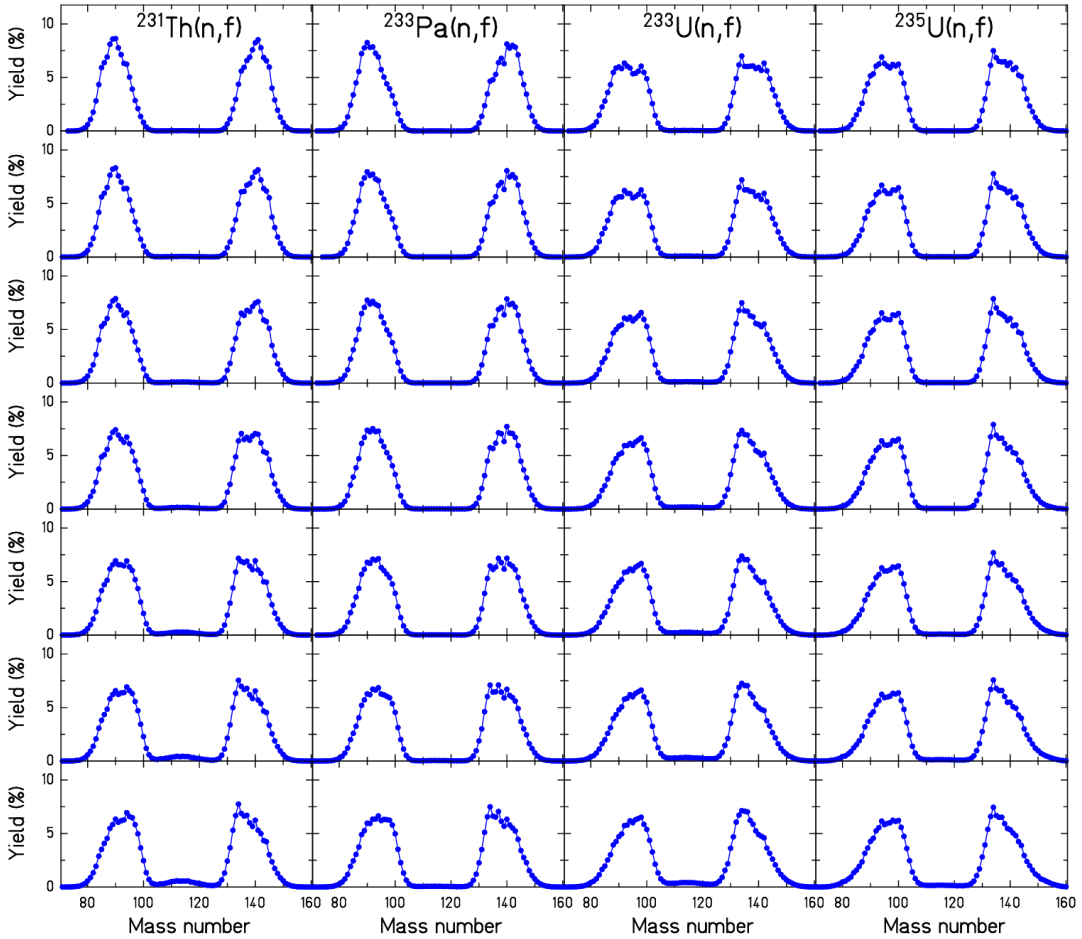
Left: with suppression effect
Right: without suppression effect
Black: ENDF-B/VII
Blue: GEF

Effect on TKE



- Effect of third barrier disappears a few MeV above the barrier
- Strong variation of fission yields as f(E*)!

Systematics of yields from GEF



E_n = 3 MeV

E_n = 2.5 MeV

E_n = 2 MeV

E_n = 1.5 MeV

E_n = 1 MeV

E_n = 0.5 MeV

E_n = thermal

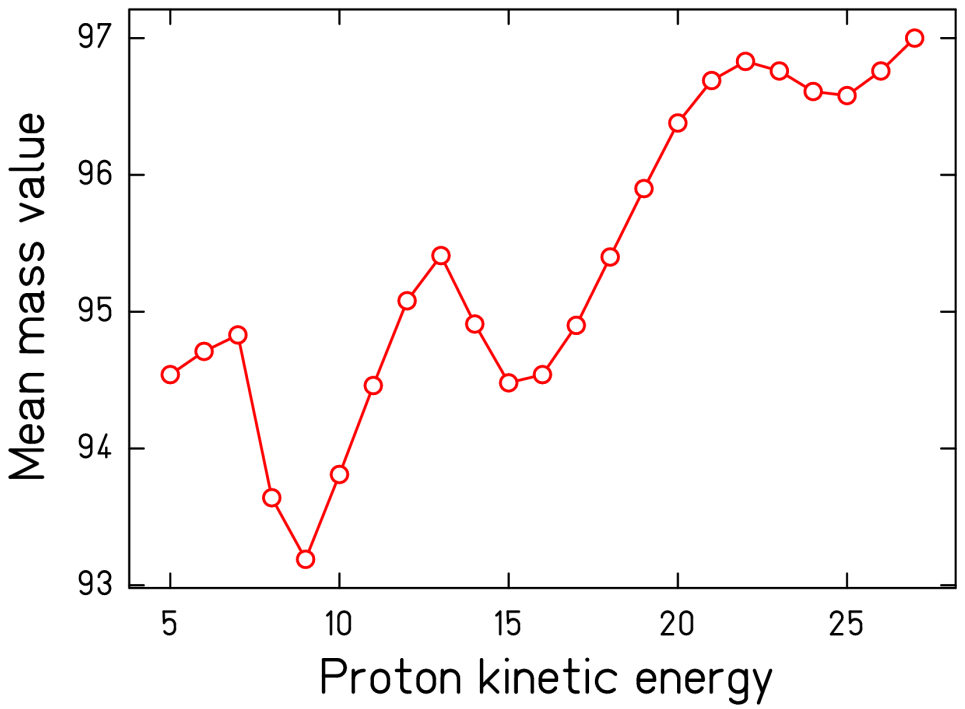
Conclusion

- Influence of triple-humped barrier in the light actinides.
- Strong variation of FF yields as f(E*).
- No clear direct experimental data available on this effect.
- Data from (n_{th},f) cannot be used at higher E*!
- Already ^{235}U(n,f) is affected!
- Critical for fast reactors!
- GEF *) code and GEFY 9.1 **) tables include this effect.
  - Reference: https://hal.in2p3.fr/in2p3-04489502
  - Code and tables: www.khschmidts-nuclear-web.eu

*) Also available from the NEA Data Bank, **) Also available in Janis.

Supplement: Multi-chance fission

Mean A of light fragment (GEF)



- Oscillations by low-E* fission at onset of higher-chances
- Experimental: "Energy dependence of p + 232Th fission mass distributions: Mass-asymmetric standard I and standard II modes, and multichance fission", A. C. Berriman, D. J. Hinde et al., Phys. Rev. C 105 (2022) 064614