Energy dependence of fission yields - challenge for evaluation and application

Karl-Heinz Schmidt
Christelle Schmitt
Andreas Heinz

Contribution to the
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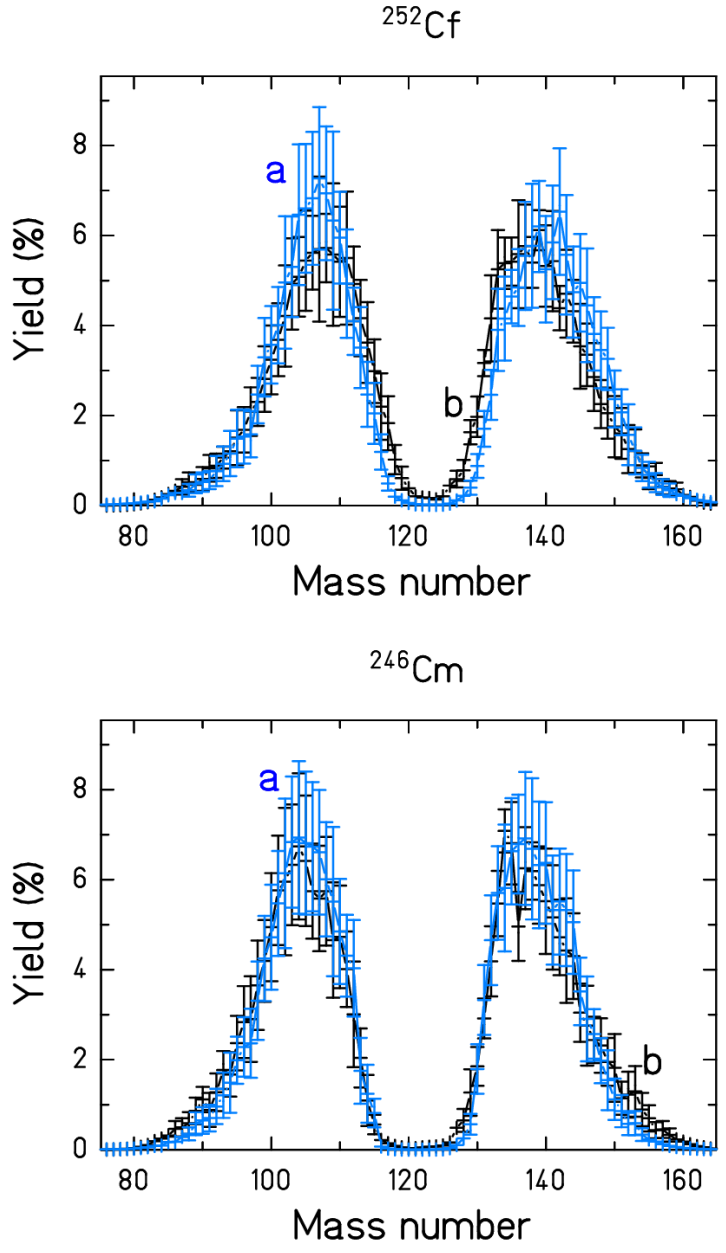
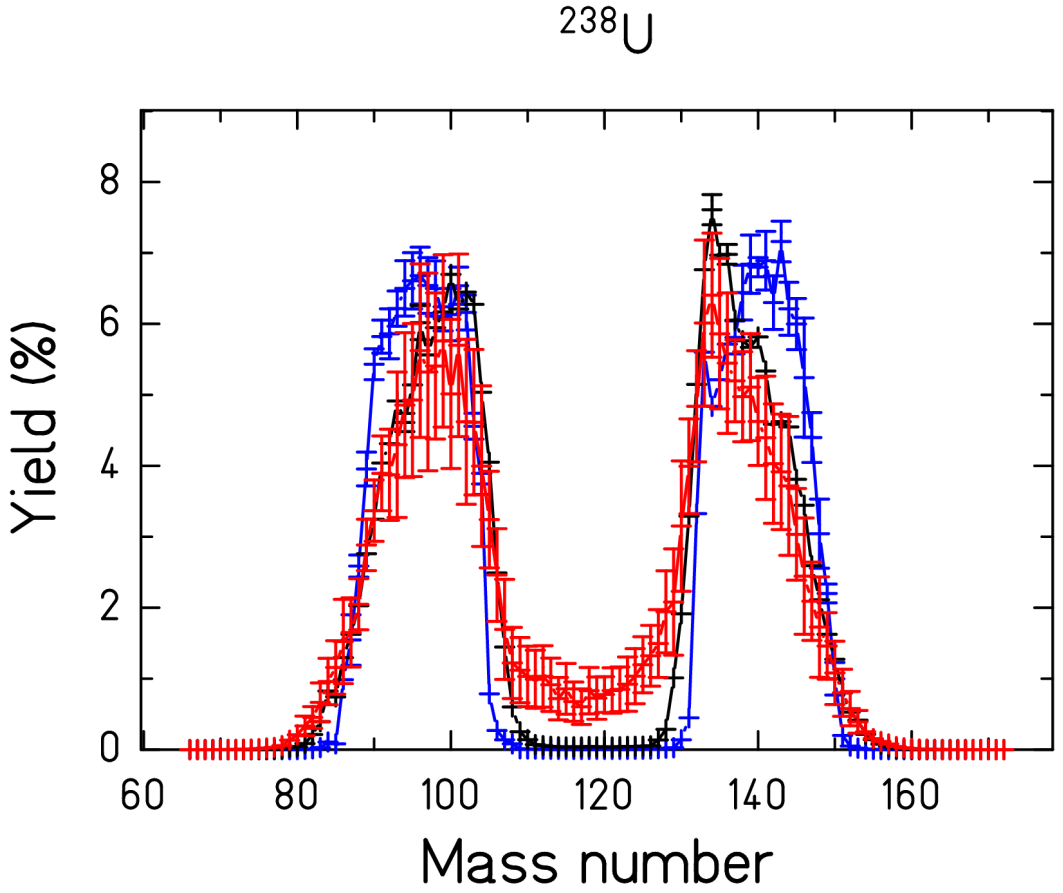
252Cf and 246Cm



- **Post-neutron mass yields from England and Rider (1995).**
- **(a) Spontaneous fission and (b) (n_{th},f)**
- **Heavy actinides 252Cf and 246Cm: no E* dependence found.**

U238: anomaly in spont. fission



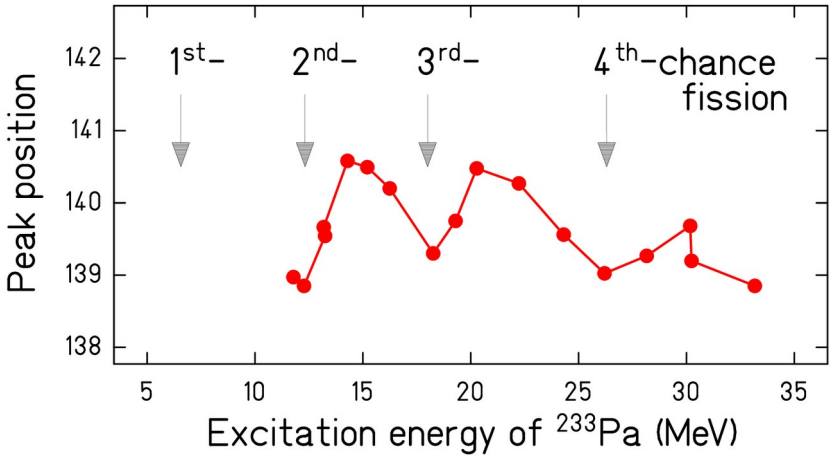
238U(sf)
E* = 0 MeV

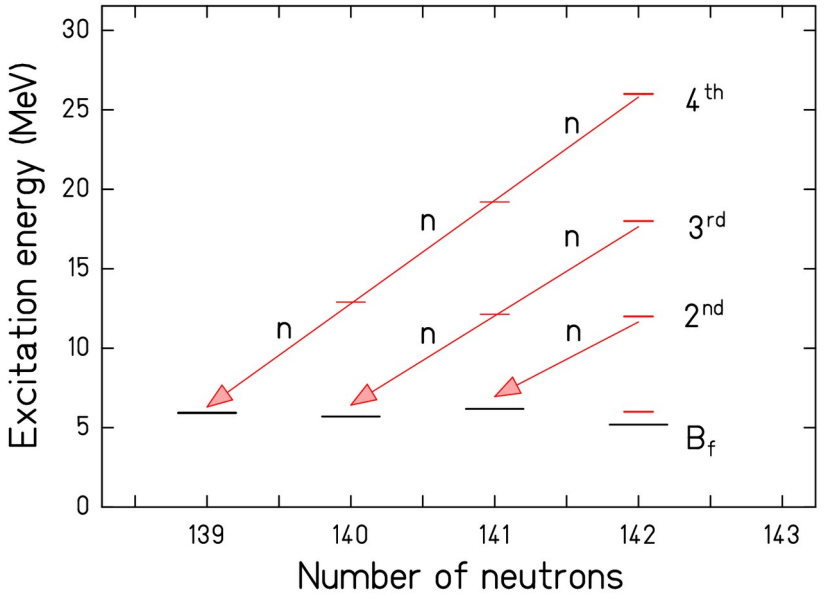
238U(n_{fast},f)
E* ≈ 6 MeV

238U(n,f),
E_n=14 MeV
E* ≈ 20 MeV

- **Drastic change of yields in 238U(sf).**
- **Model-independent signature.**

Anomaly in multi-chance fission





232Th(p,f)
Berriman et al.
Phys. Rev. C 105 (2022) 064614

- **Regular appearance of the anomaly just above the threshold of the next-chance fission.**
- **Anomaly appears also at higher initial excitation energies.**

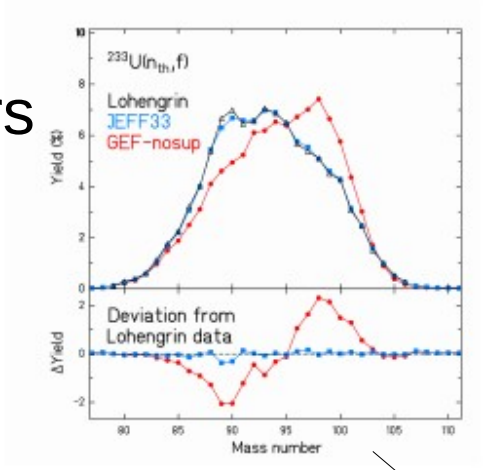
Comparison exp. - GEF (until 2024/1.1)

Light fragments shown. Clear deviations for light CN!

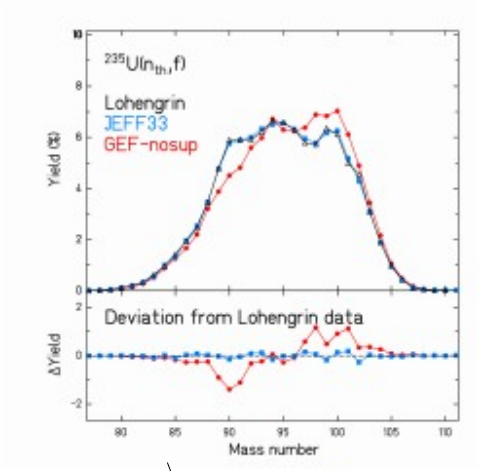
Unique parameters (4 shells in GEF).

All nth,f.

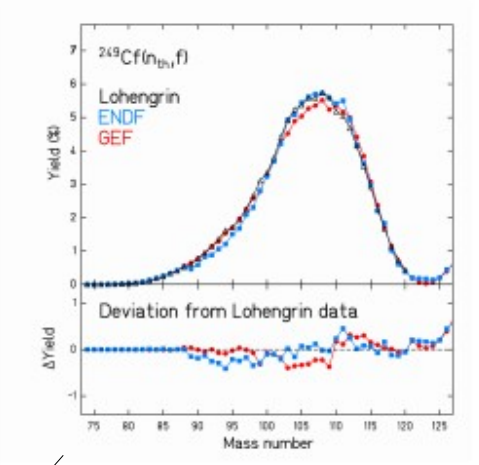
234U



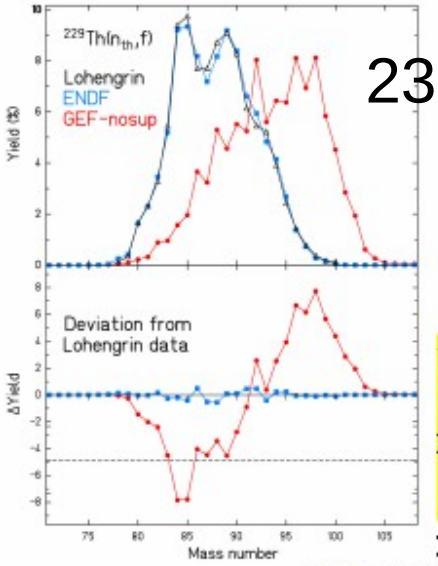
236U

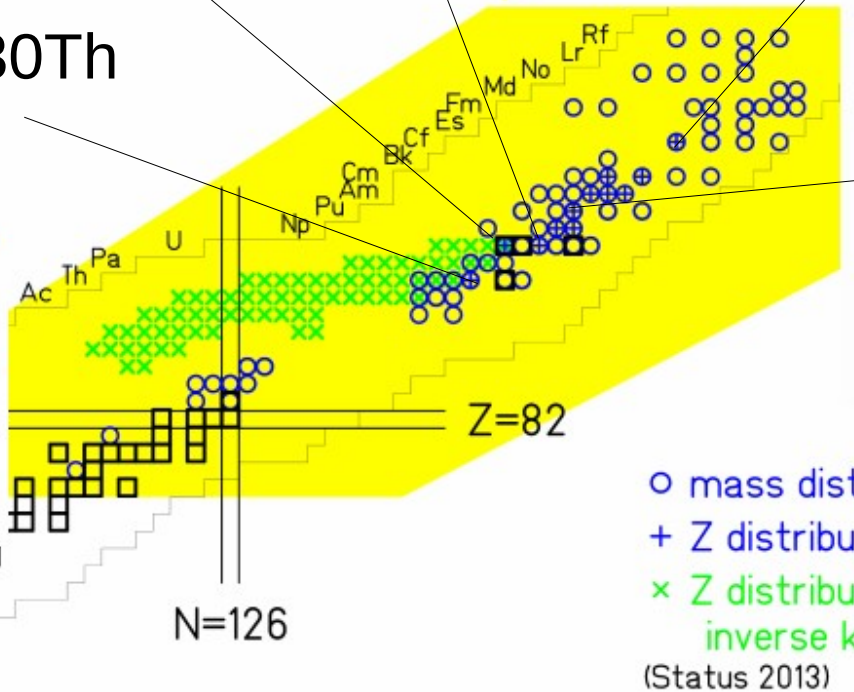


250Cf

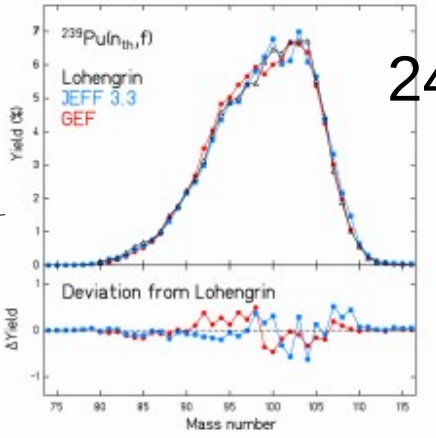


230Th

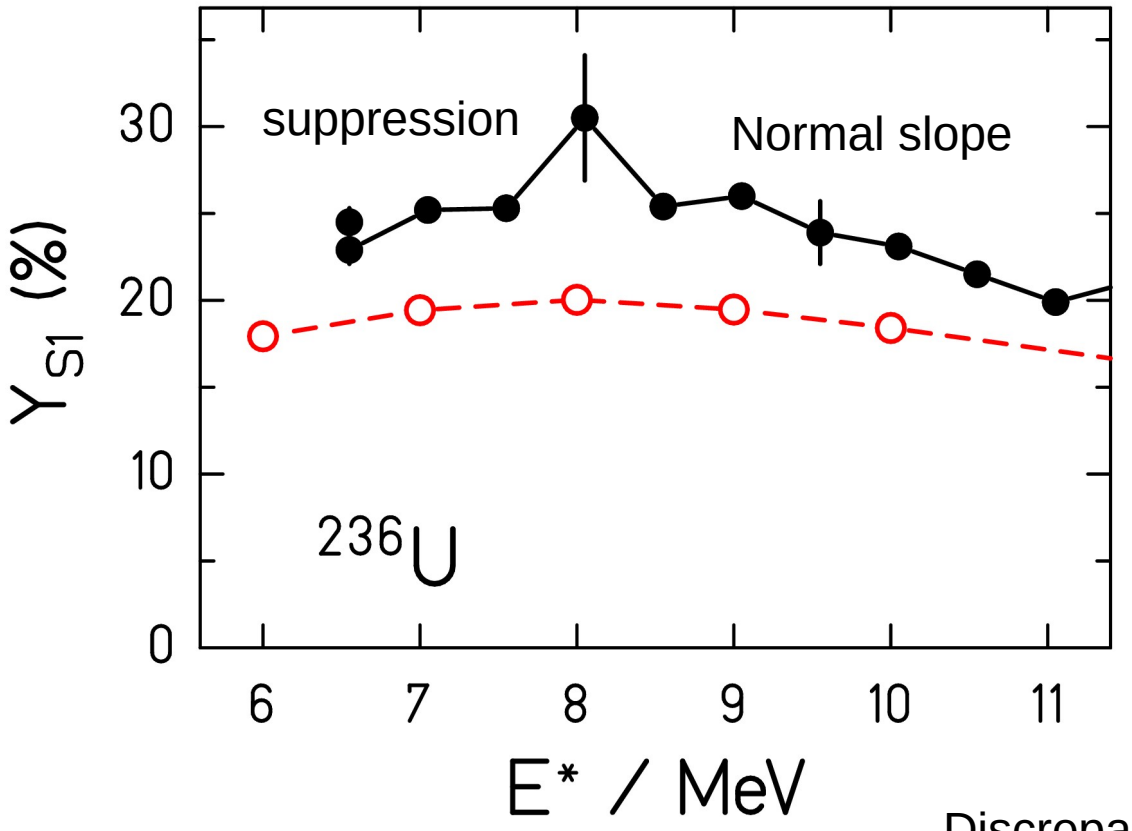




240Pu



Brosa‘s analysis (1999)



Brosa‘s analysis from data with low resolution and low statistics (kinematical method).

● Brosa

○ GEF

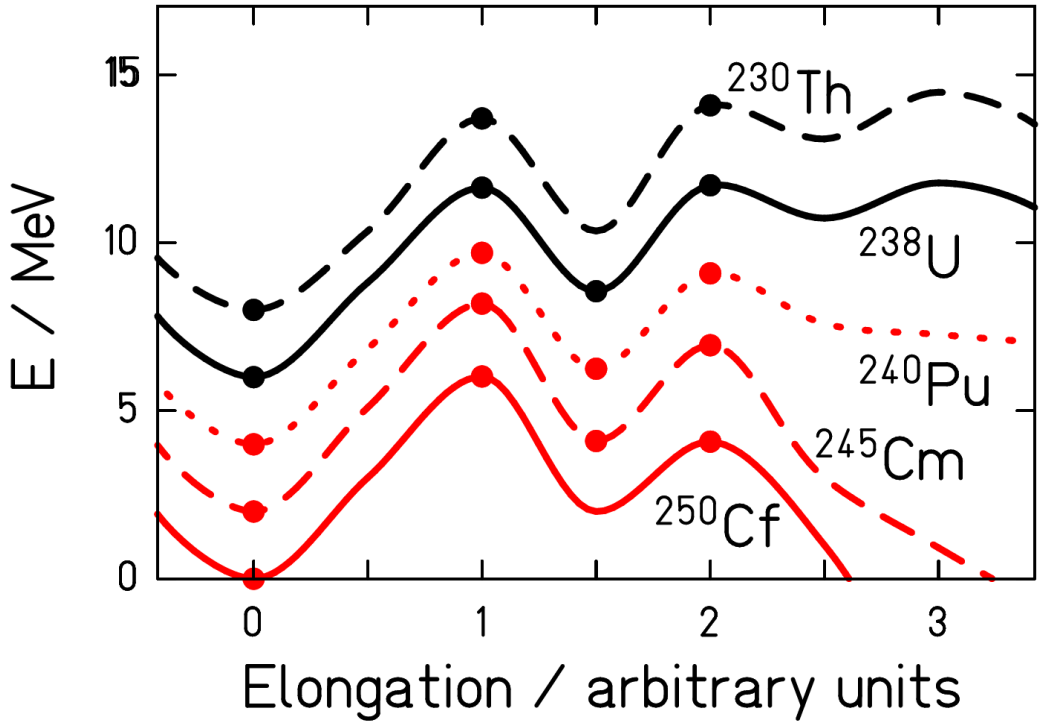
New GEF, considering the suppression of events with high TKE by the 3rd barrier with an empirical profile.

Discrepancy explained by different properties of the fission channels.

U. Brosa et al., Phys. Rev. C 59 (1999) 767

- **Inversion of S1-yield slope at the threshold of the anomaly**

Our hypothesis: Suppression by 3rd barrier



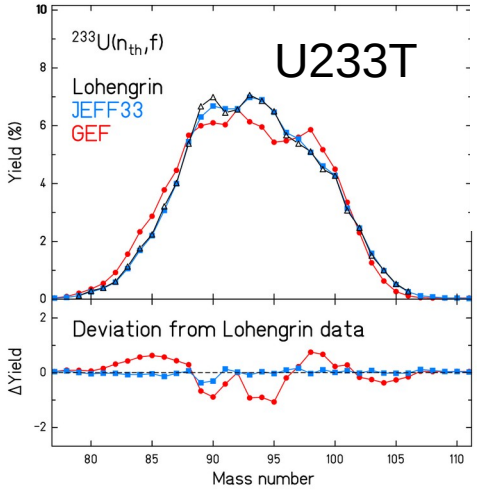
- ← Schematic drawing.
- Third barrier is high for light actinides.
- Discussed since the 1970th as the „thorium anomaly“ in fission probabilities and angular distributions.

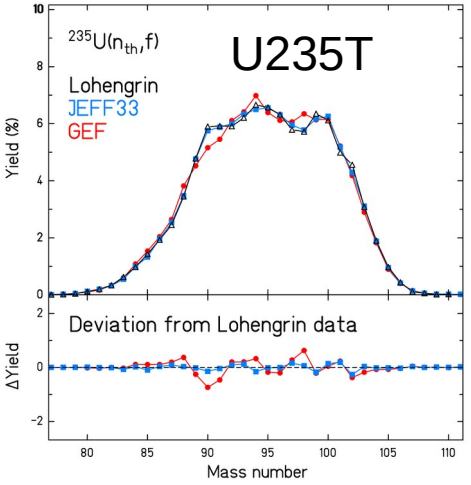
Our hypothesis (2024): Suppression of fission events with compact shapes (high TKE) by the third fission barrier with empirical profile.

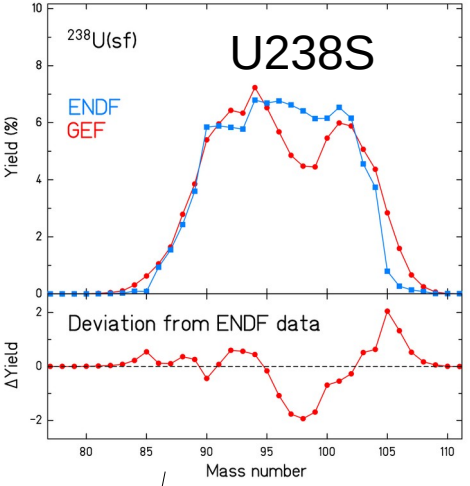
K.-H. Schmidt et al., Annals of Nuclear Energy 208 (2024) 110784
K.-H. Schmidt et al., https://arxiv.org/abs/2509.24590

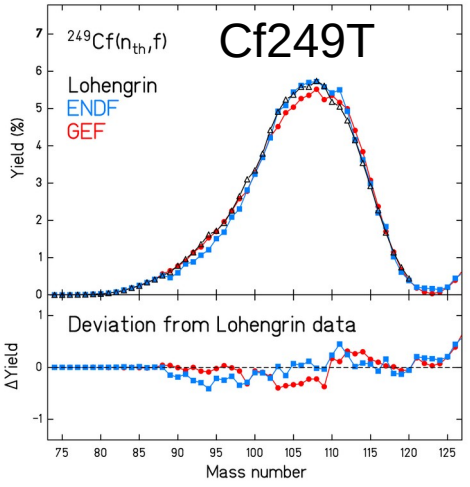
Exp. - GEF(GEF-2025/1.3)

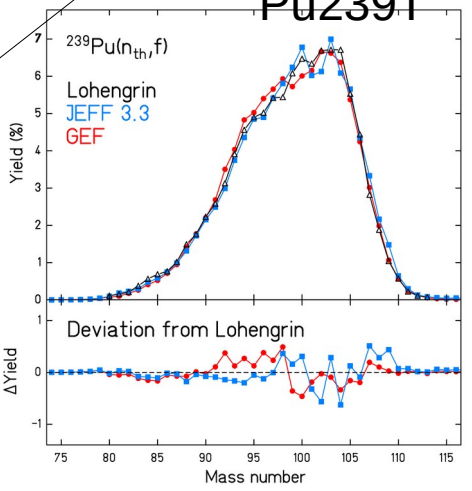
T = (nth,f)
S = (sf)
Light fragments

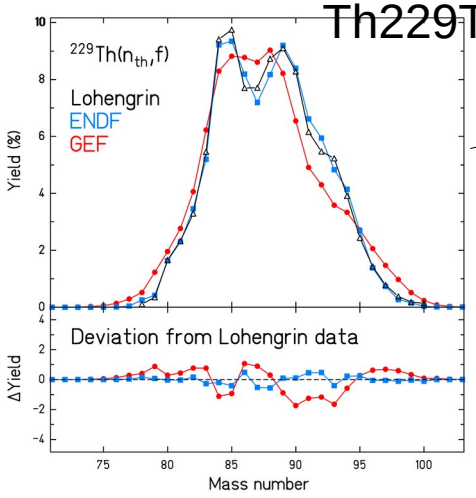


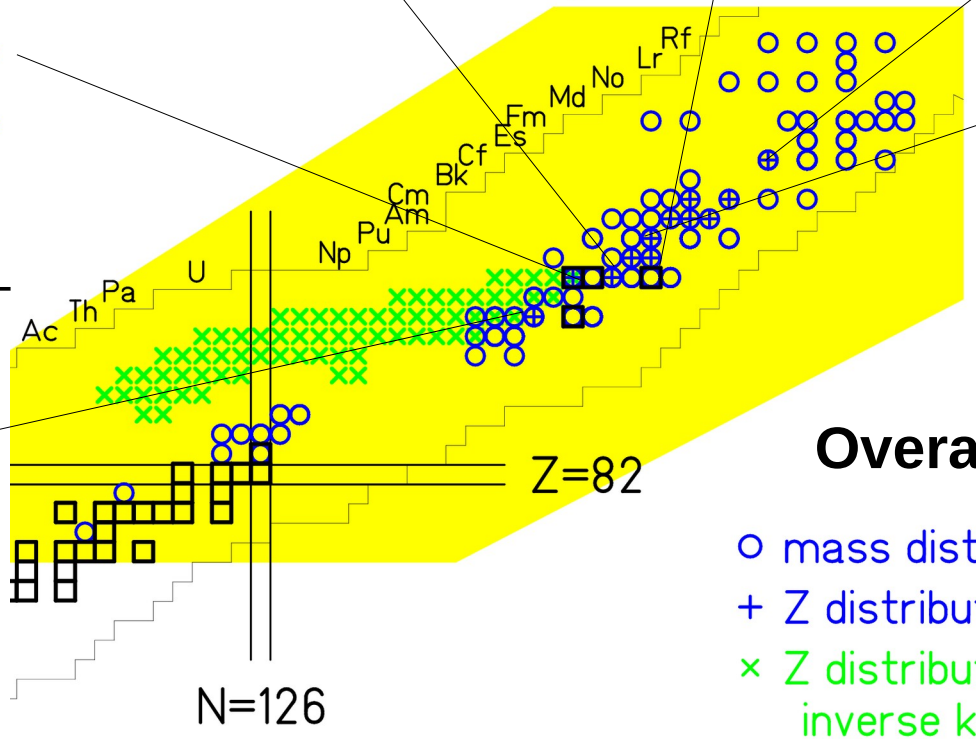












Overall good agreement.

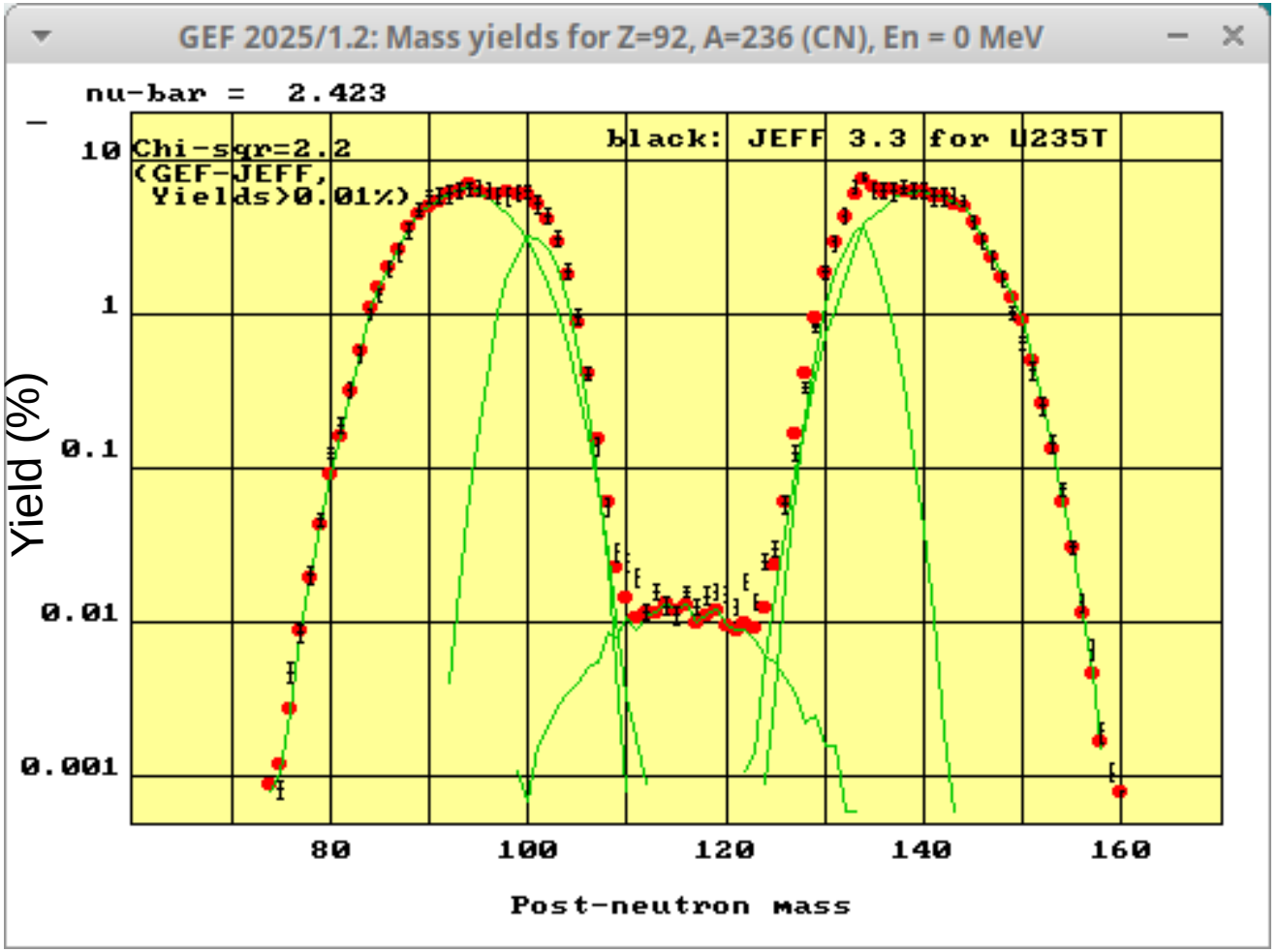
- mass distributions
+ Z distributions
× Z distributions in inverse kinematics

(Status 2013)

Conclusion

- **Important steps in the general understanding of nuclear fission by unexpected observations:**
  - **Discovery of fission (Hahn, Strassman, Meitner 1939)**
  - **Shell effects in mass asymmetry (Goeppert-Mayer 1948)**
  - **Discovery of shape isomers (Polikanov 1964)**
  - **„Thorium anomaly“: 3rd minimum (Back et al. 1972)**
  - **Fission channels (Brosa 1986-1990)**
  - **Universal shells of fragments (Schmidt et al. 2016)**
    - **GEF: FY for all systems with 4 universal fragment shells**
  - **Revival of the thorium anomaly: (Schmidt et al. 2024)**
    - **Evidence for influence of 3rd barrier on fission dynamis.**
    - **First in-depth analysis of E*-dependent FY in low-energy fission.**
    - **Implemented in GEF.**

Accuracy $^{235}U(n_{th},f)$



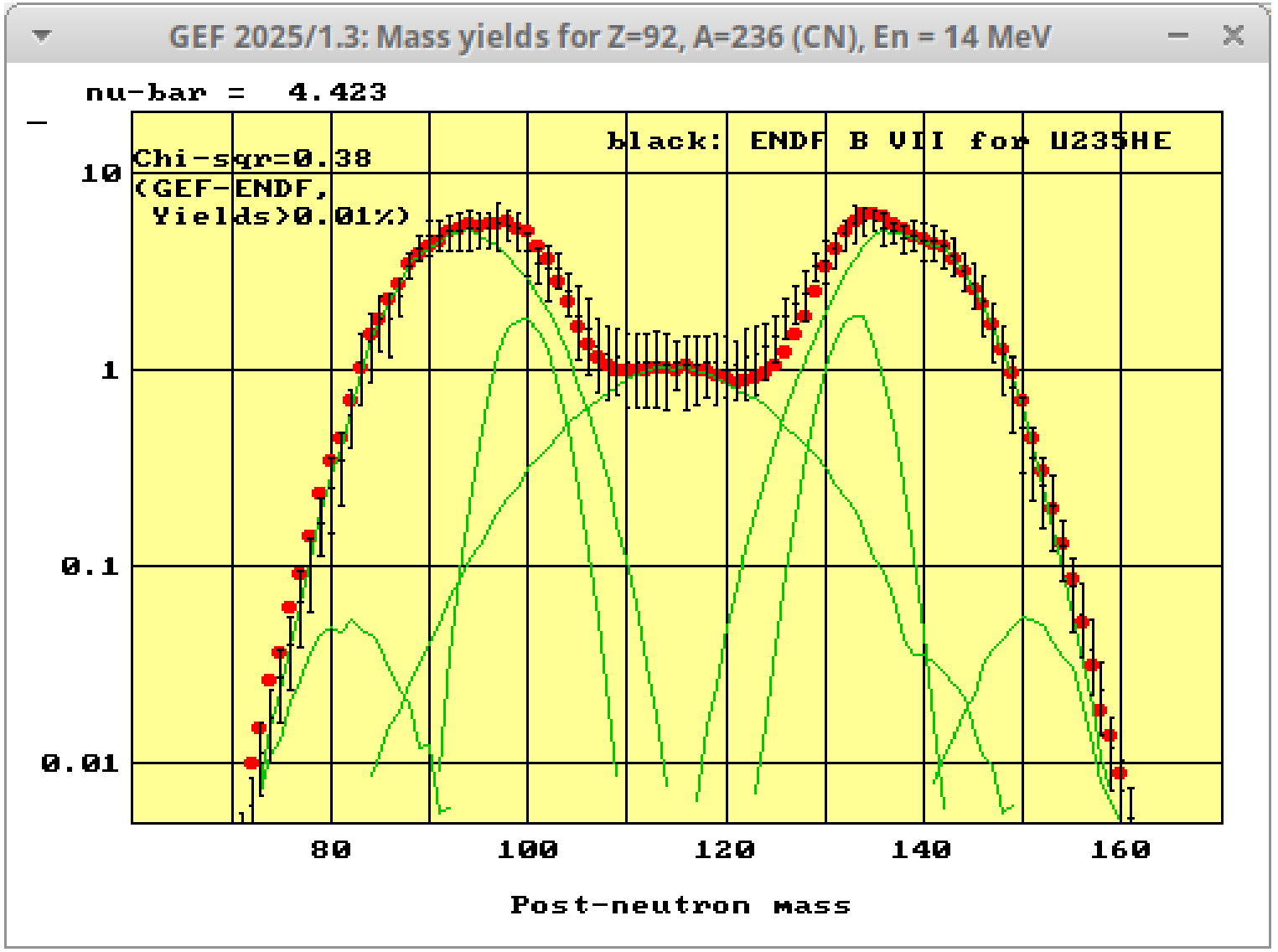
┼ JEFF 3.3

● GEF

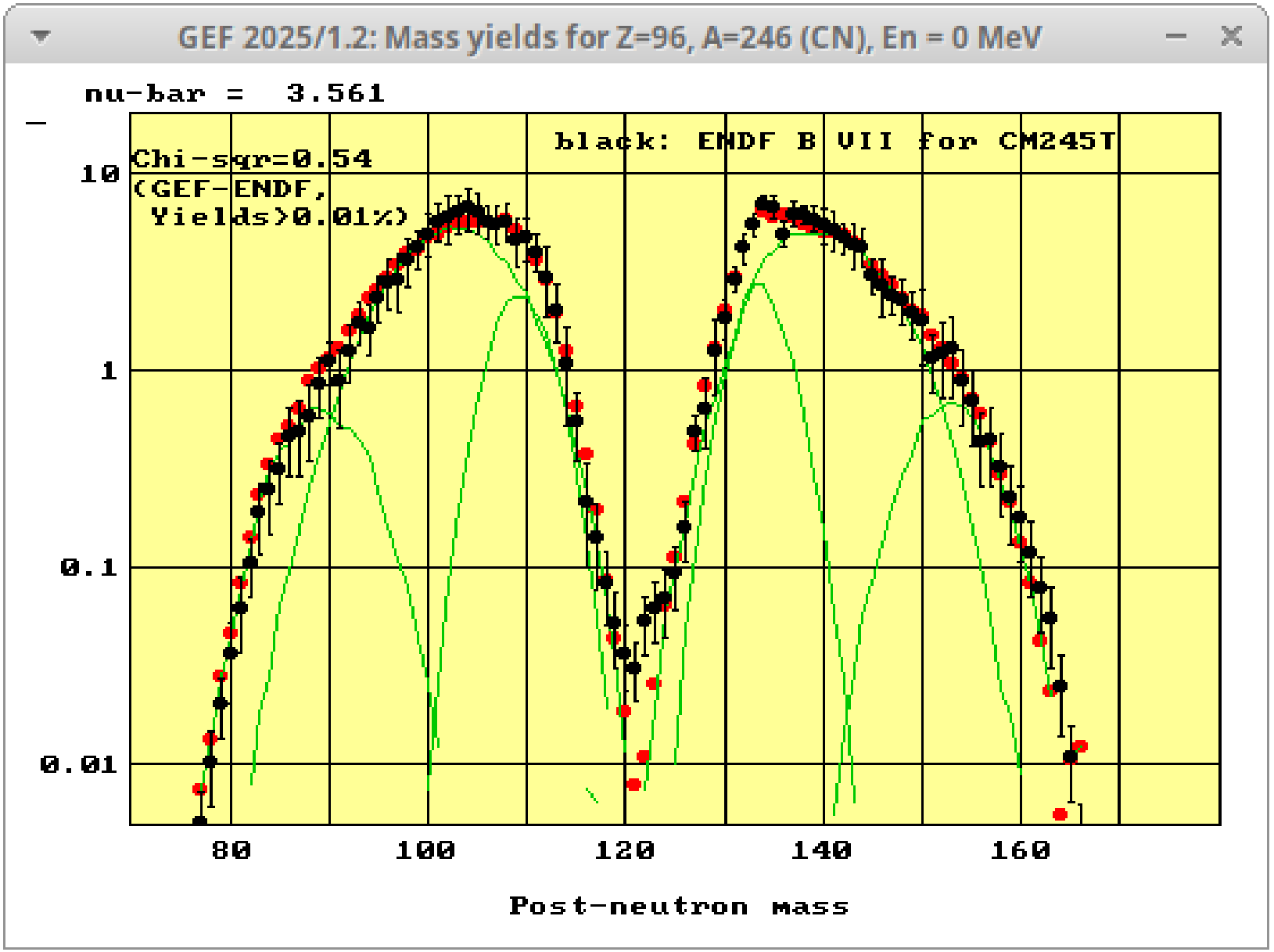
__ Fission modes

- Mass yields and ν-bar well reproduced.

Accuracy $^{235}U(n,f)$, E_n = 14 MeV



Accuracy $^{245}Cm(n_{th},f)$



Accuracy ^{252}Cf(sf)