Considerations on the validity of GEF in an extended region

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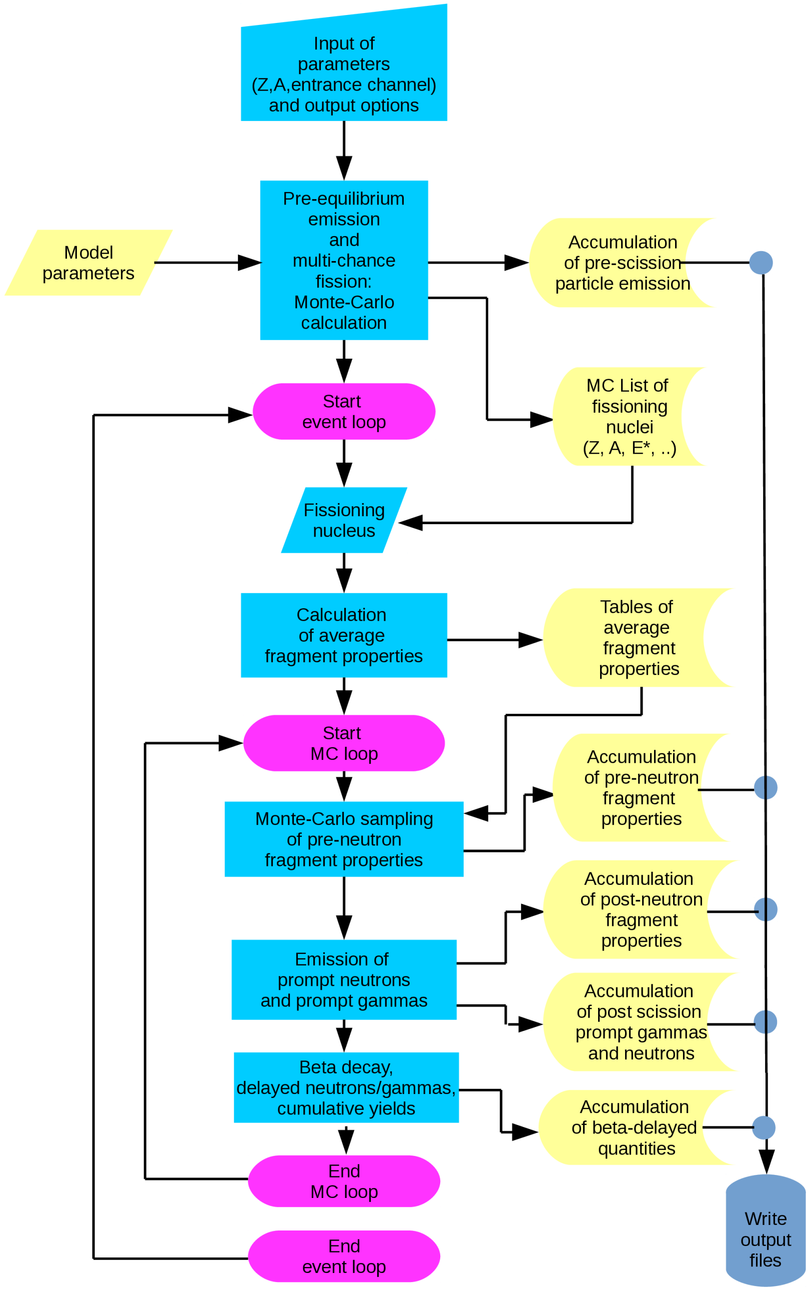
TASCA Workshop, 25.-27. April 2023

Flow diagram of GEF



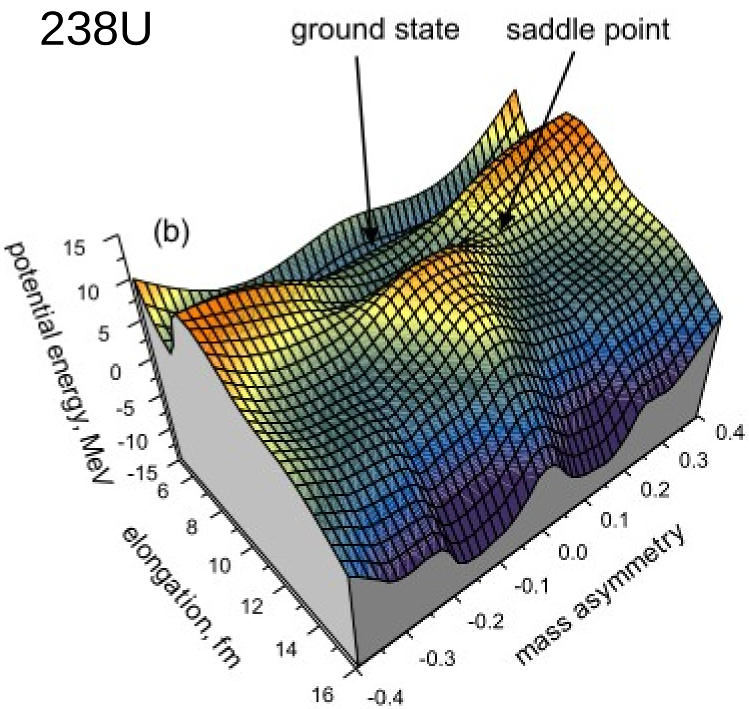
- GEF is a semi-empirical model of nuclear fission
  - Consistent description of the whole fission process with practically all fission quantities
- Calculated quantities:
  - Fission probabilities
  - Multichance fission
  - Fission yields, TKE
  - Prompt gammas/neutrons
  - Radioactive decay
  - Cumulative yields
  - Delayed neutrons
  - Anti-neutrinos

Fomr Nucl. Data Sheets 173 (2021) 54

The physics of GEF

Consistent combination of several powerful theoretical models and ideas.

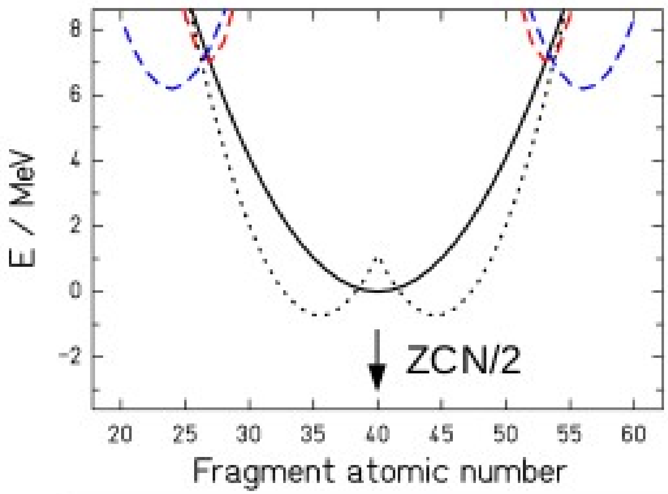
238U

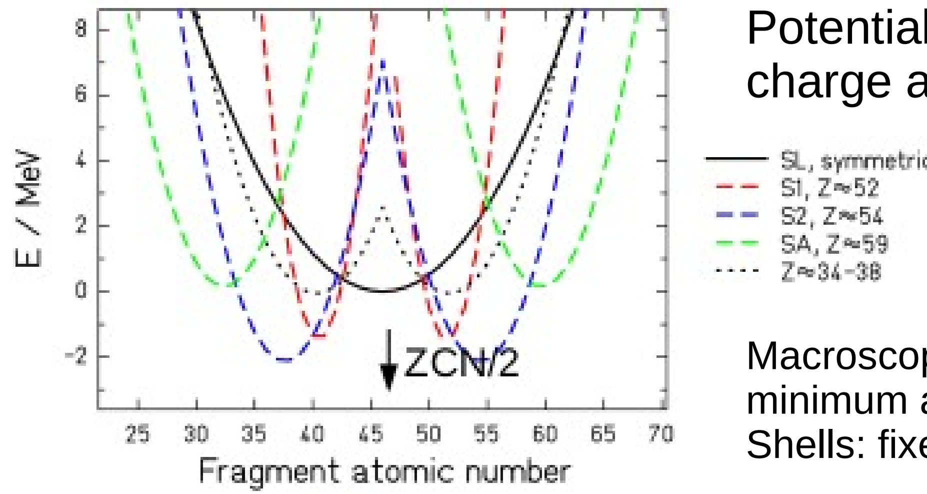


Potential-energy surface, calculation from Karpov et al., J. Phys. G: Nucl. Part. Phys. 35 (2008) 035104]

- Fission barriers from the topographic theorem (Myers & Swiatecki, 1996)
- Fission yields from statistical population of fission valleys („Pre-scission-point“ model, **new**)
- Early appearance of fragment shells (Greiner, Mosel, Schmitt, et al., 1971)
- Fragment shells deduced from unfolding measured yields **(new)** (using the mic-mac approach)
- Scission configuration from prompt-neutron yields (deform.-dependent shells)
- Energy sorting before scission **(new)**
- Statistical decay code (standard)
- Radioactive decay (standard)

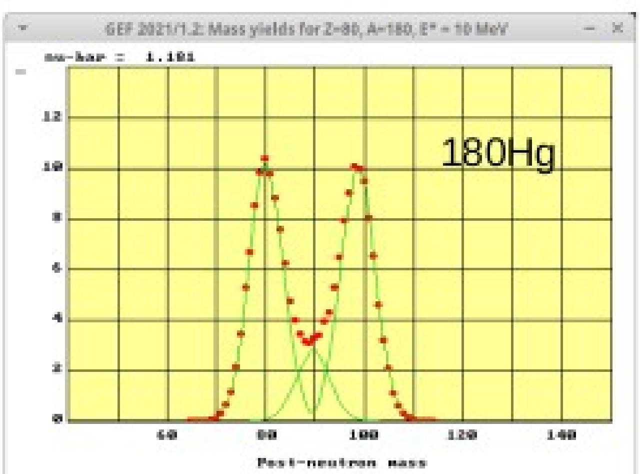
Yields of fission modes

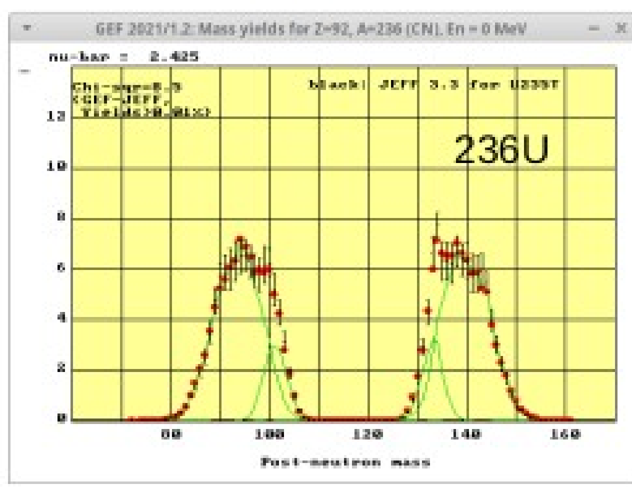




Potential valleys in charge asymmetry

Macroscopic: minimum at symmetry
Shells: fixed in Z





Fission-fragment mass distributions

Black. Experimental
Red: GEF yields
Green: Fission modes

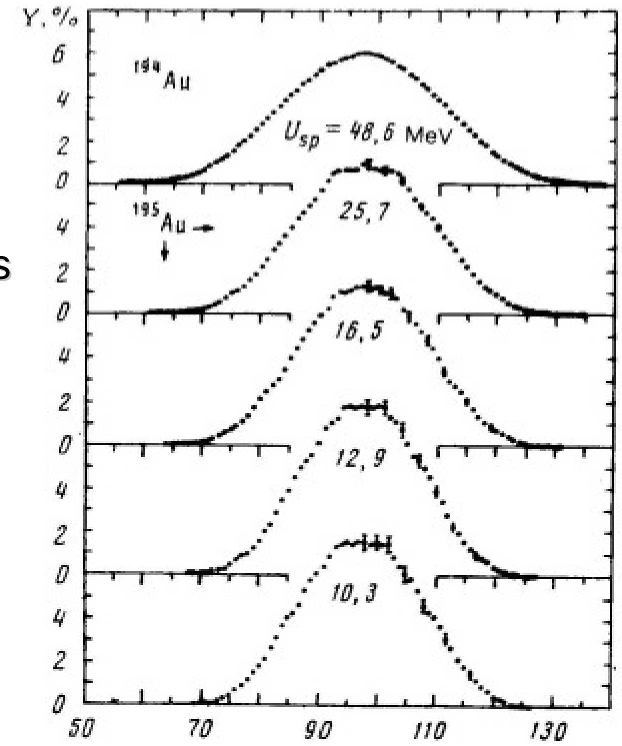
Yields are determined by fission valleys formed by macroscopic potential + 4 proton shells

Empirical mac. potential

Curvature of the macroscopic potential vs. mass asymmetry between saddle and scission as a function of Z^2/A:

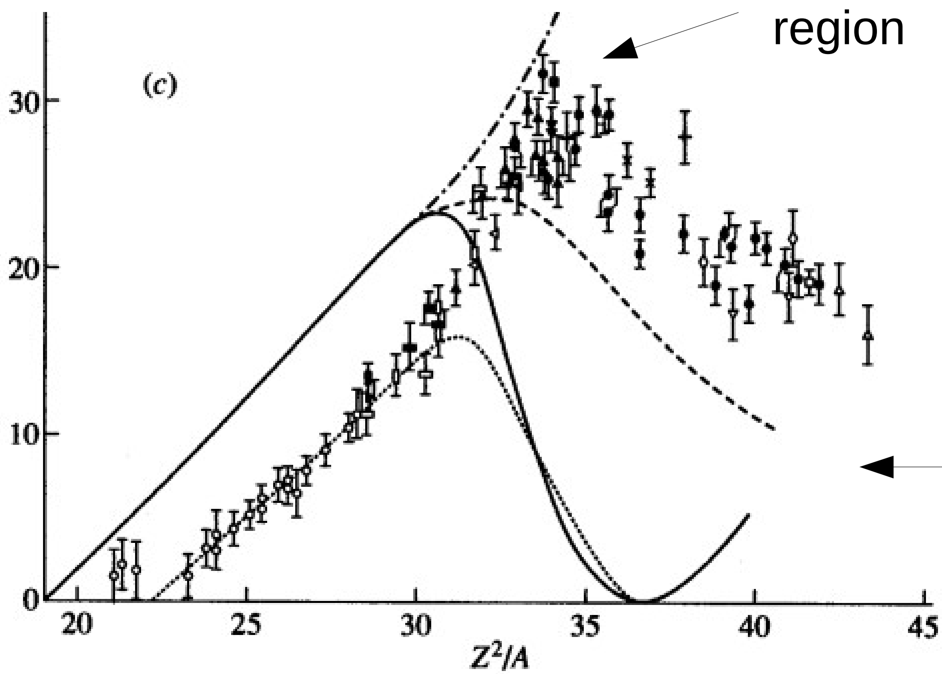
Growing mass width due to increasing nuclear temperature:

$$\sigma_q^2 = \frac{T}{d^2U/dq^2}$$



Itkis et al.,Yad. Fys. 53 (1991) 1225

Critical region



Deduced from the width of the FF mass distributions at high E*, where shell effects are washed out.

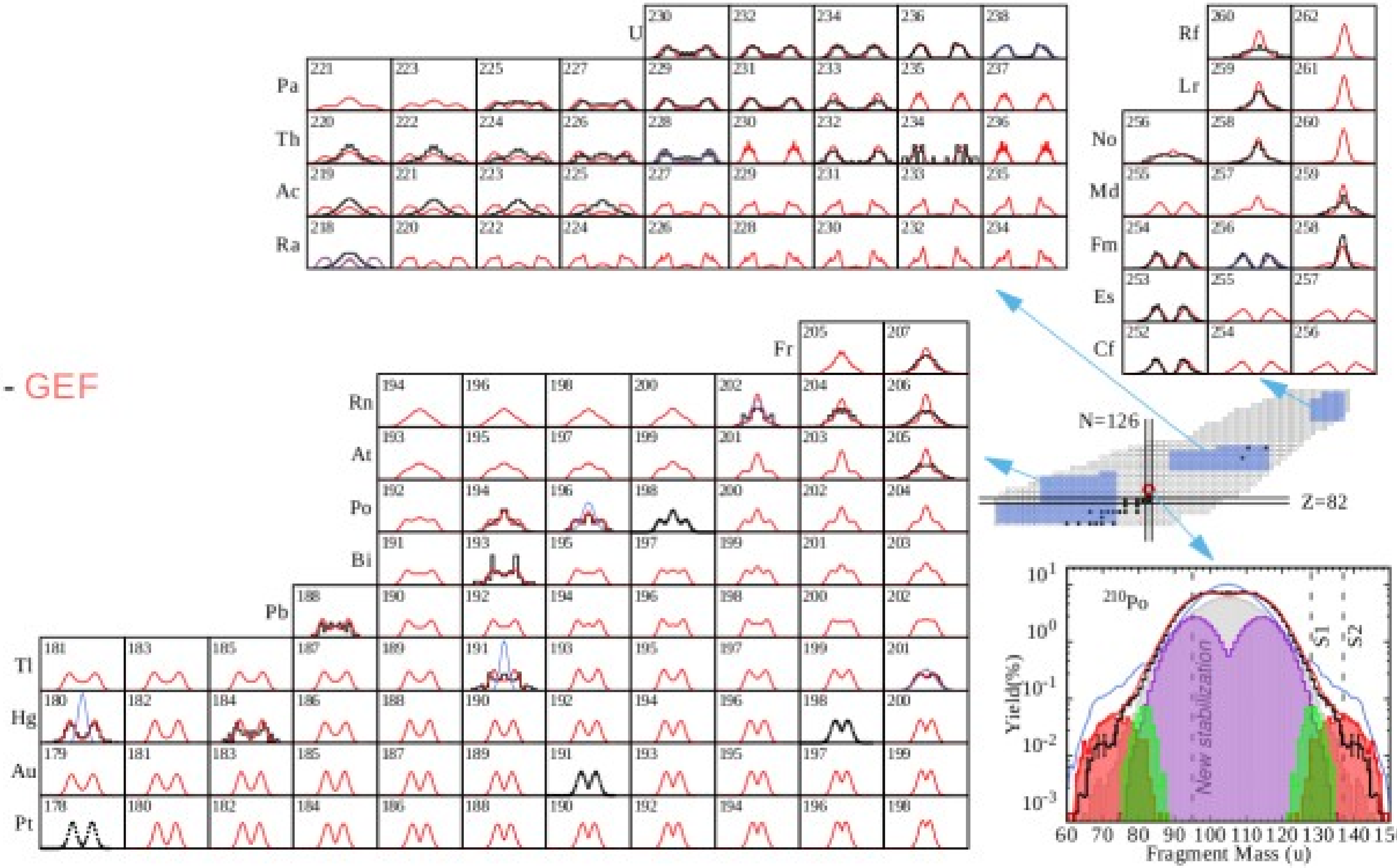
Symbols and error bars: Experimental results

Lines: Different theoretical approaches.

[Itkis, Rusanov, Phys. Part. Nuclei 29 (1998) 160]

Mass yields in know region

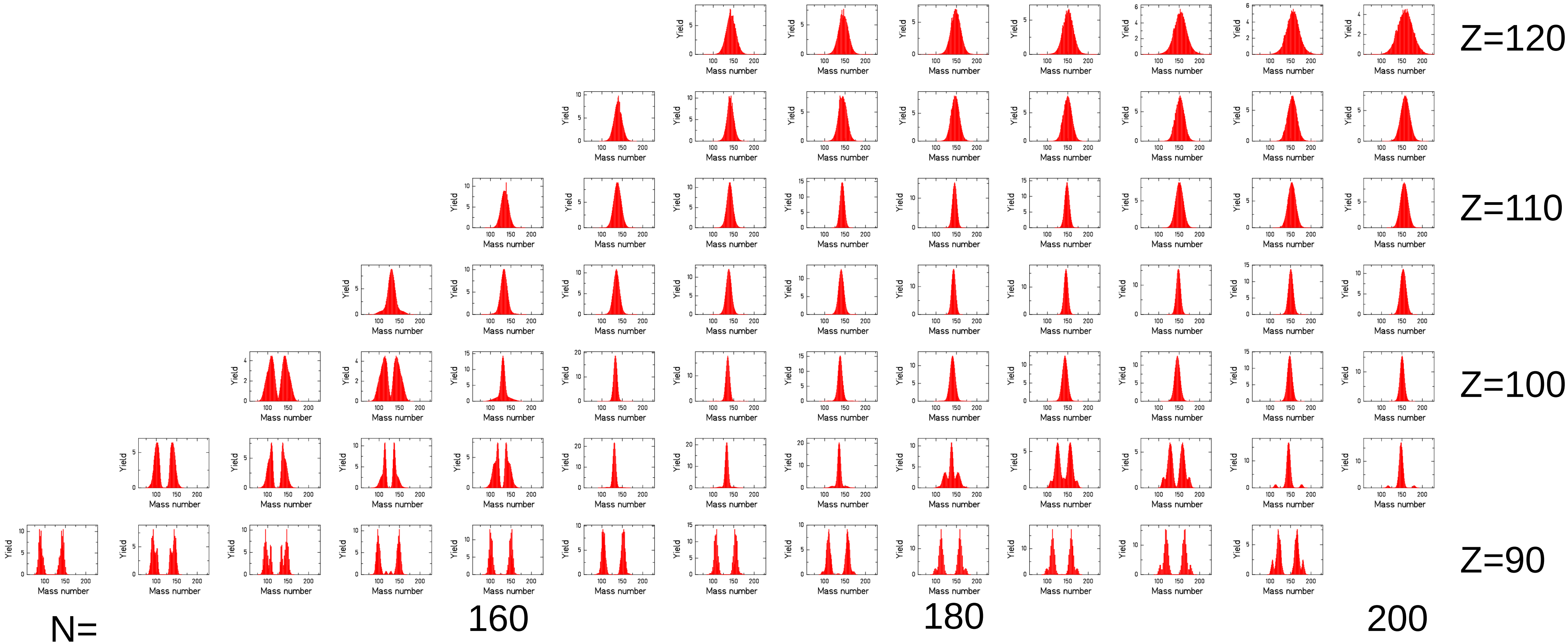
exp - GEF



From Phys. Lett. B 825 (2022) 136859

Pretty good reproduction of all measured mass distributions. Problem around 226Th solved,

Extrapolation



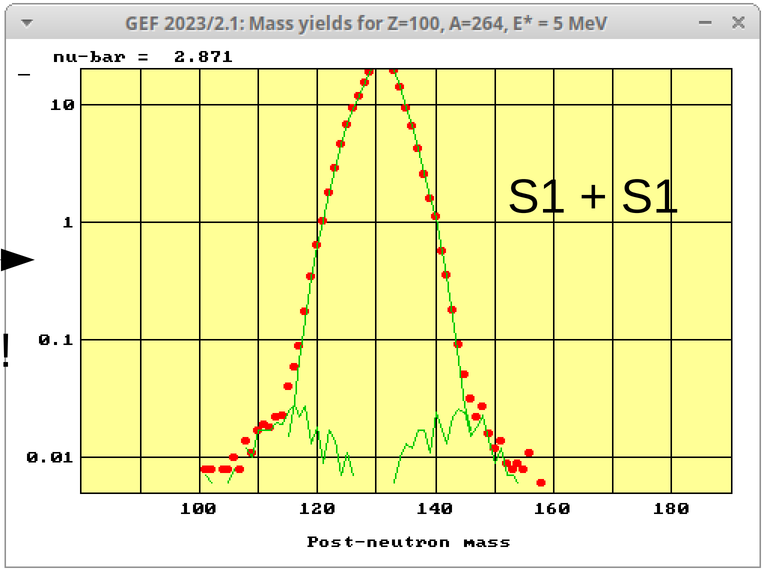
Dominant shells:

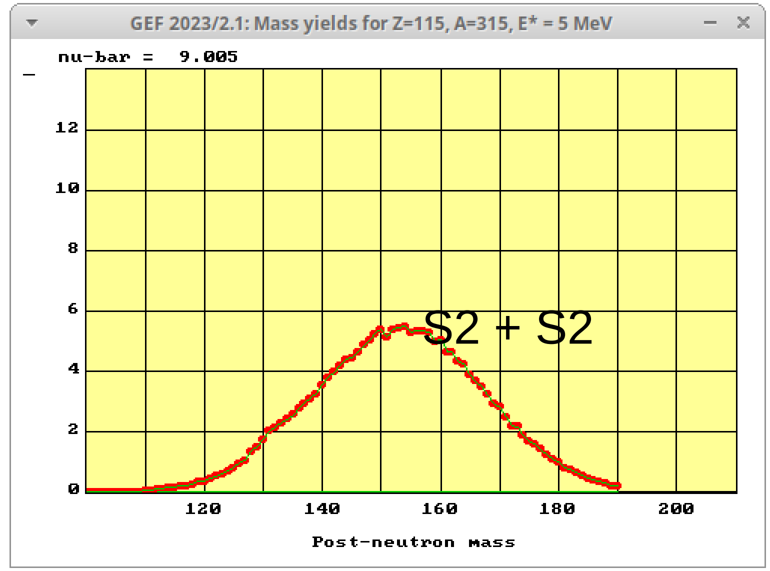
- Standard 2 (Z around 54)
- Standard 1 (Z around 52, near 132Sn, 2 protons from the neck!)
- Super-asymmetric (Z around 59)

No signature of Z=82 shell

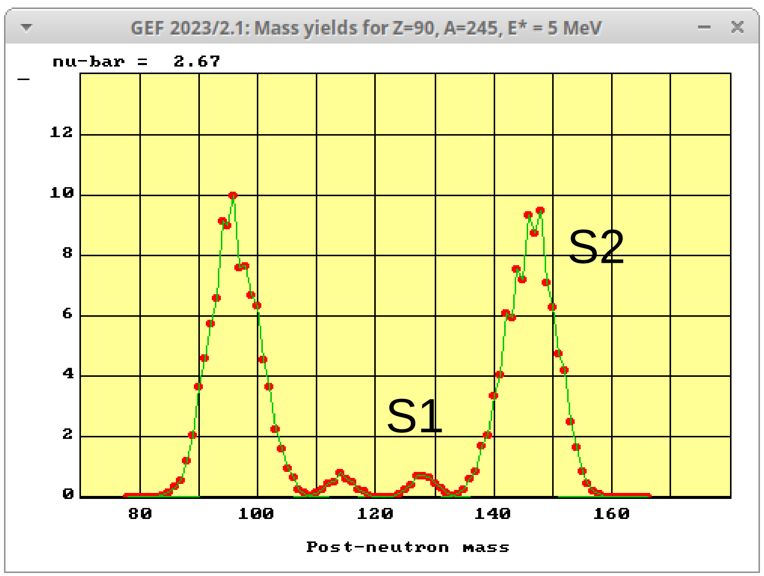
Shells in both fragments may join!

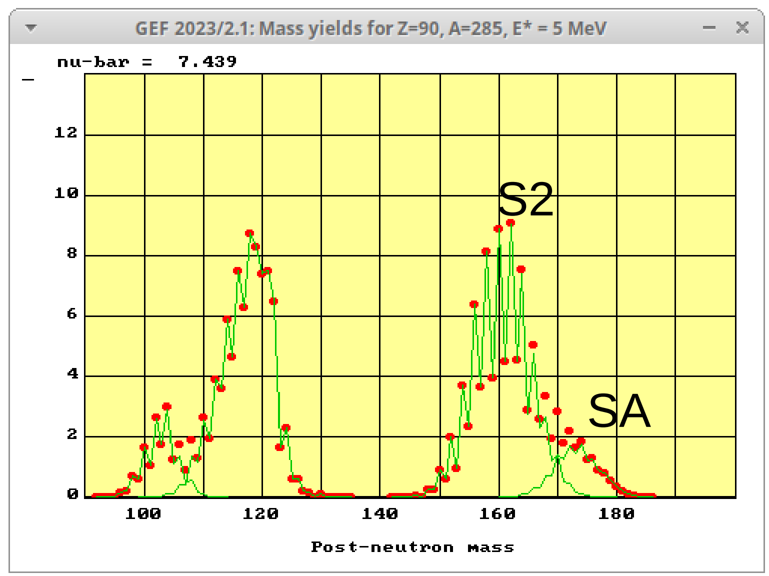
Variety of mass distributions





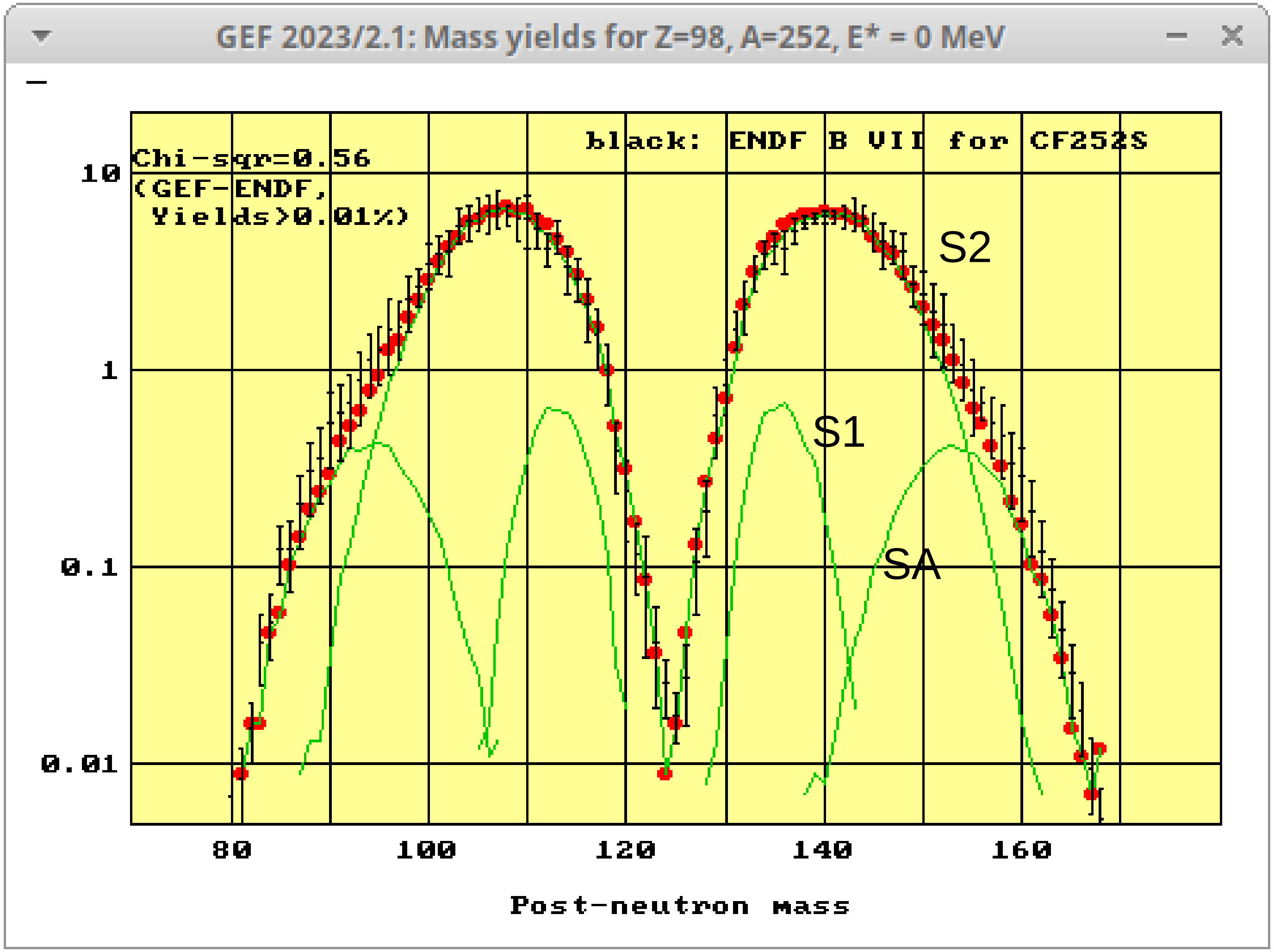
log. scale!





5 different fission channels appearing

$^{252}Cf(sf)$



- Best experimental data on the super-asymmetric mode, will become more important for heavier systems.

Conclusion

- In view of the good reproduction of the fission yields in the known region between Z=78 and Z=104 with only 4 proton shells, the extension of GEF towards more neutron-rich and super-heavy nuclei can be considered with some confidence as a reasonable guess.
- In the SHE region the FF mass distributions are complex due to several fragment shells and their overlap in the two fragments.
- The next shell, expected at Z=82 (in analogy to Z=50), does not yet appear with sizeable yield in the range Z<=120 and N <= 200.
- The GEF code is available from www.khschmidts-nuclear-web.eu and http://www.cenbg.in2p3.fr/GEF .

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