Separability of compound-nucleus and fragment properties in fission

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Nuclear fission is a prominent example for the decay of a meta-stable state, in which many properties of the decay process are determined on the out-of-equilibrium descent outside the meta-stable state beyond the barrier. Out-of-equilibrium processes still pose a severe challenge to their theoretical description; thus, the realistic modelling of the fission process is far from being achieved at present times. This is in particular problem at low excitation energies, where the influence of nuclear structure is responsible for individual features, which are specific for each fissionning system. Thus, it is important to study a great variety of systems and to measure as many quantities as possible in order to gain a complete overview on the underlying physics. We have analyzed the large body of experimental data on nuclear fission with a semiempirical ordering scheme based on the macroscopic-microscopic approach and the separability of compound-nucleus (CN) and fragment properties on the fission path [1]. Using this approach we analyse [1] the microscopic corrections to the macroscopic potential from the appearance of fission channels. We applied this procedure for ^{226}Th, ^{239}U, ^{252}Cf and ^{260}Md as shown in Fig. 1. According to the separability principle [1] it should be possible to trace the microscopic structures deduced in Fig. 1 back to shells in the fragments, which should be the same for all systems. The success of this approach is illustrated in Fig. 1–third raw in a schematic way. Obviously, the complex behaviour of shell structure as a function of mass asymmetry of the four systems shown in Fig. 1 can be reproduced already rather well as a superposition of only two shells at N=82 and N=92. Thus, the separability of CN and fragment properties of the system on the fission path seems to be realized to a good approximation and makes the macro-microscopic approach particularly strong in its application to nuclear fission. By deducing the shell effects from the measured fission-fragment nuclide distributions and attributing those to two major shells in the nascent fragments, we arrived at a remarkably realistic reproduction of the microscopic features of fission over the whole range covered by experiment. This approach is also suited for robust extrapolations, e.g. it has already been used to predict nuclide distributions from the fission of neutron-rich nuclei on the astrophysical r-process path [2].

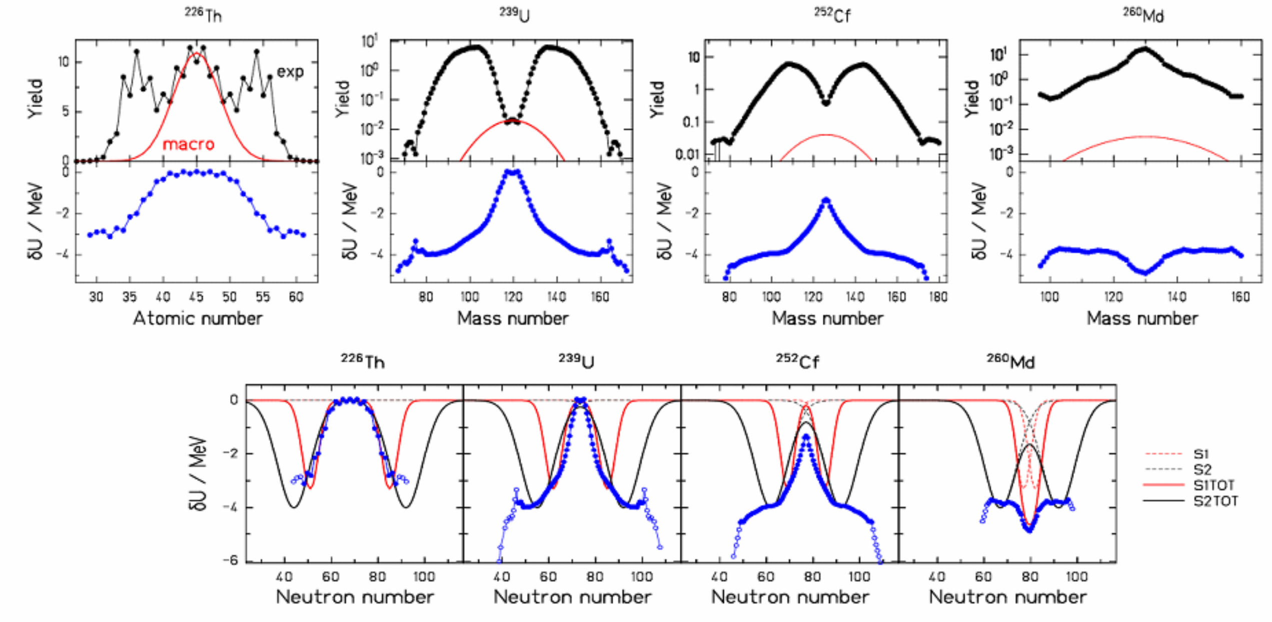

Figure 1: Extraction of the microscopic potential responsible for the nuclear-charge or mass split in fission: The amount the measured yields (data points in upper row) exceed the macroscopic prediction (red lines in upper row) is attributed to the shell-correction energy at saddle. The shell correction energies are displayed as a function of atomic number and mass number, respectively, (second row) and in a projection on neutron number (third row). In the third raw, also the comparison of the empirical shell corrections (points) and the shell correction energies constructed from two neutron shells at N=82 (S1, light lines) and N=92 (S2, dark lines) is shown. For more details and references to the data, see [1].

References

[1] K.-H. Schmidt, A. Kelić and M.V. Ricciardi, arXiv nucl-ex/0711.3967v1.

[2] A. Kelić, N. Zinner , et al., Phys. Lett. B616 (2005) 48