Refined analysis of the mass and charge split in asymmetric fission

Since the early 1970th it is known that the mean mass of the fragments in the heavy group of the asymmetric fission of actinides stays approximately constant at about A = 140, see e.g. [1] and also [2] for a recent compilation. This finding revealed that shell effects in the heavy fragment are essentially responsible for the preference of most actinides for splitting into fragments of different size. Experimental progress made during the last years, e.g. by observing fission of relativistic radioactive beams after electromagnetic excitation [3], has allowed to refine the knowledge on the mass and charge splits in asymmetric fission considerably. Long isotopic chains have been studied and reveal the systematic evolution of the mass respectively charge distributions over the chart of the nuclides as depicted in figure 1. The lower parts of this figure uncover that the heavy fission component moves by more than 6 units in neutron number, and thus also in mass number. In contrast, the position in atomic number is much more stable. This behaviour has been investigated in some detail in different mass regions in [5,6]. This unexpected finding has important implications for the influence of proton and neutron shells on the fission dynamics and forms a stringent test for theoretical models.

The figure also demonstrates the lack of knowledge which is still present for the nuclei beyond 238U and underlines the necessity to find experimental methods, which allow studying fission of nuclei in a larger region of the chart of the nuclides, e. g. by transfer reactions that produce nuclei around available projectiles with well defined excitation energy. A new generation of such experiments is being performed in inverse kinematics and thus provides excellent resolution in mass and atomic number [7].

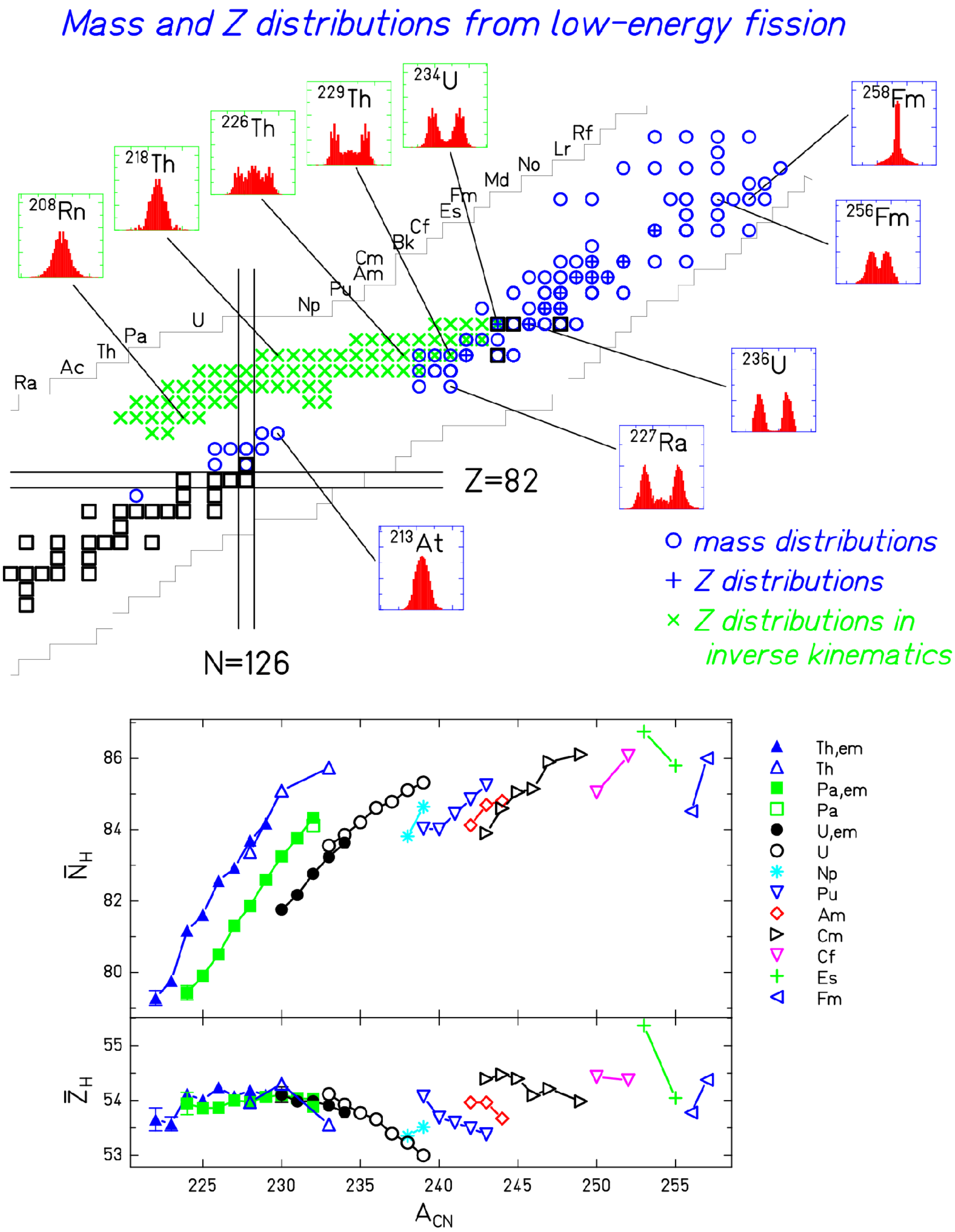

Fig. 1: The upper part shows an overview of the systems, for which mass distributions in low-energy fission have been measured on a chart of the nuclides. The nuclei studied in one experiment with secondary beams by electromagnetic excitation in inverse kinematics [2] are specifically marked. The other data are taken from one evaluation [3] and comprise data on spontaneous fission and fission induced by thermal and fast neutrons. The insets depict the systematic evolution of the mass respectively charge distributions of the fission fragments. The lower figures show the mean neutron number, respectively atomic number, of the fragments in the heavy group of asymmetric fission. The long isotopic chains of uranium, protactinium and thorium reveal that the position moves considerably in neutron number, and thus also in mass number. However the position in atomic number is astonishingly stable. (The vertical scales of the lower figures correspond to the average N/Z ratio of the fissioning systems, and thus the two figures show the same relative variation per mm.)

[1] "FRAGMENT MASS AND KINETIC ENERGY DISTRIBUTIONS FOR FISSIONING SYSTEMS RANGING FROM MASS 230 TO 256"
J. P. Unik, J. E. Gindler, L. E. Glendenin, K. F. Flynn, A. Gorski, R. K. Sjoblom
Proc. Symp. Phys. Chem. Fission, Rochester 1973, IAEA Vienna (1974), vol. 2, pp. 19.

[2] "Heaviest nuclei from 48Ca-induced reactions"
Yuri Oganessian
J. Phys. G: Nucl. Part. Phys. 34 (2007) R165-R242.

[3] "Relativistic radioactive beams: A new access to nuclear-fission studies"
K.-H. Schmidt, S. Steinhaeuser, C. Boeckstiegel, A. Grewe, A. Heinz, A. R. Junghans, J. Benlliure, H.-G. Clerc, M. de Jong, J. Mueller, M. Pfuetzner, B. Voss
Nucl. Phys. A 665 (2000) 221-267.

[4] "Evaluation and Compilation of Fission Product Yields"
T. R. England, B. F. Rider, ENDF349, 1994.

[5] "Nuclear-fission studies with relativistic secondary beams: analysis of fission channels"
C. Boeckstiegel, S. Steinhaeuser, K.-H. Schmidt, H.-G. Clerc, A. Grewe, A. Heinz, M. de Jong, A. R. Junghans, J. Mueller, B. Voss
Nucl. Phys. A 802 (2008) 12-25 / arXiv nucl-ex/0712.3808.

[6] "Modal approach to the description of fragment mass yields in neutron and proton induced fission of actinides at incident particle energies from 5 to 200 MeV"
D. M. Gorodisskiy, S. I. Mulgin, A. Ya. Rusanov, S. V. Zhdanov
in IAEA report STI/PUB/1286, IAEA, Vienna, 2008, pp. 183.

[7] "Isotopic resolution of fission fragments from 238U + 12C transfer and fusion reactions"
M. Caamano, F. Rejmund et al.
4th Int. Workshop on Nuclear Fission and Fission-Product Spectroscopy, Cadarache, France, May 2009, AIP