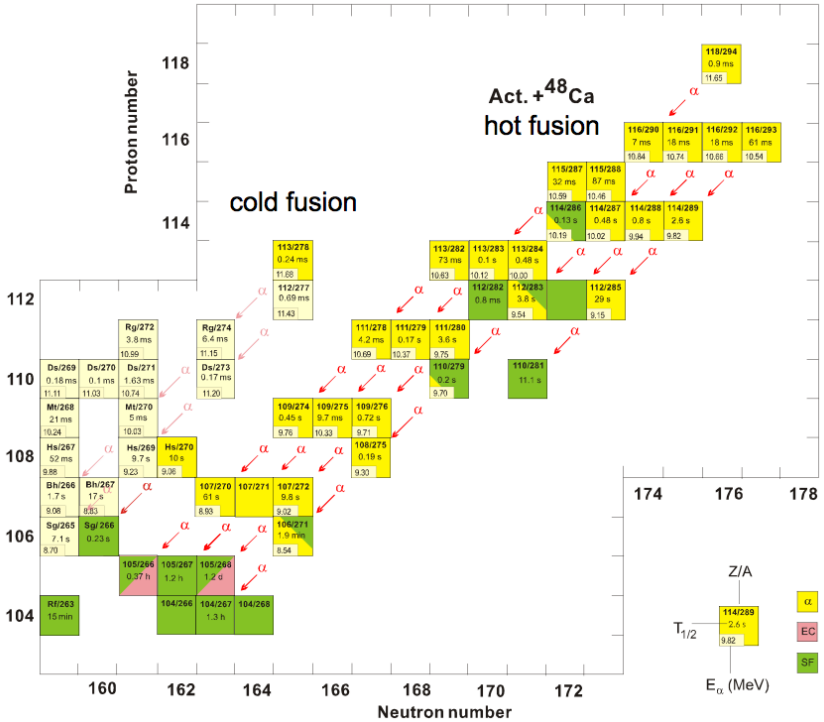
Even Superheavies Need a Little Protection

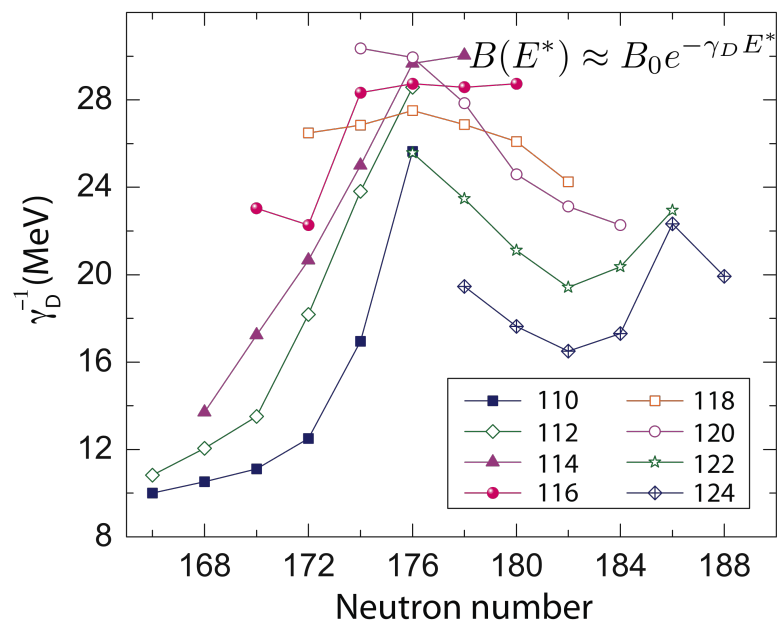
How heavy can the periodic table go? Scientists have long had the capability to create new, “superheavy” elements by fusing lighter nuclei. The existence of a system formed in a heavy-ion fusion reaction is often brief, however, because the nucleus heats up in the process and must find a way to shed energy and cool back down to a more stable state. Often this is accomplished through fission, where the nucleus simply breaks apart. While much progress has been made in recent years, it’s still a challenge to find the optimal combination of beam and target—as well as the kinematic conditions—to maintain the structural integrity of the superheavies and lead to the formation, at reasonable rates, of new elements. This is due in part to the relationship between fission barriers and excitation energy—the energy difference between the ground and excited state. The conventional wisdom has been that fission barriers, which stabilize the nucleus, tend to disappear at higher excitation energies.

Using microscopic density functional theory, nuclear theorists from UT/ORNL carried out calculations [1,2] showing that fission barriers of excited superheavy nuclei vary rapidly with particle number, pointing to the importance of shell effects even at large excitation energies. The results are consistent with recent experiments where superheavy elements were created by bombarding an actinide target with 48-calcium; yet even at high excitation energies, sizable fission barriers remained. Not only does this reveal clues about the conditions for creating new elements, it also provides a wider context for understanding other types of fission, such as that used in reactors to provide energy

Superheavy elements synthesized in cold- and hot fusion reactions



Calculated inverse barrier damping parameter for even-even superheavy nuclei. The fastest decrease of fission barriers with excitation energy is predicted for deformed nuclei around N =164 and spherical nuclei around N =184 that are strongly stabilized by shell effects. On the other hand, for the transitional nuclei around N=176, synthesized in hot fusion reactions, the barrier damping is relatively weak.



[1] “Fission barriers of compound superheavy nuclei”,J.C.Pei, W.Nazarewicz, J.A. Sheikh, and A.K. Kerman, Phys. Rev. Lett. **102**, 192501 (2009).

[2] “Systematic study of fission barriers of excited superheavy nuclei”, J.A. Sheikh, W. Nazarewicz, and J.C. Pei, Phys. Rev. C **80**, 011302(R) (2009).