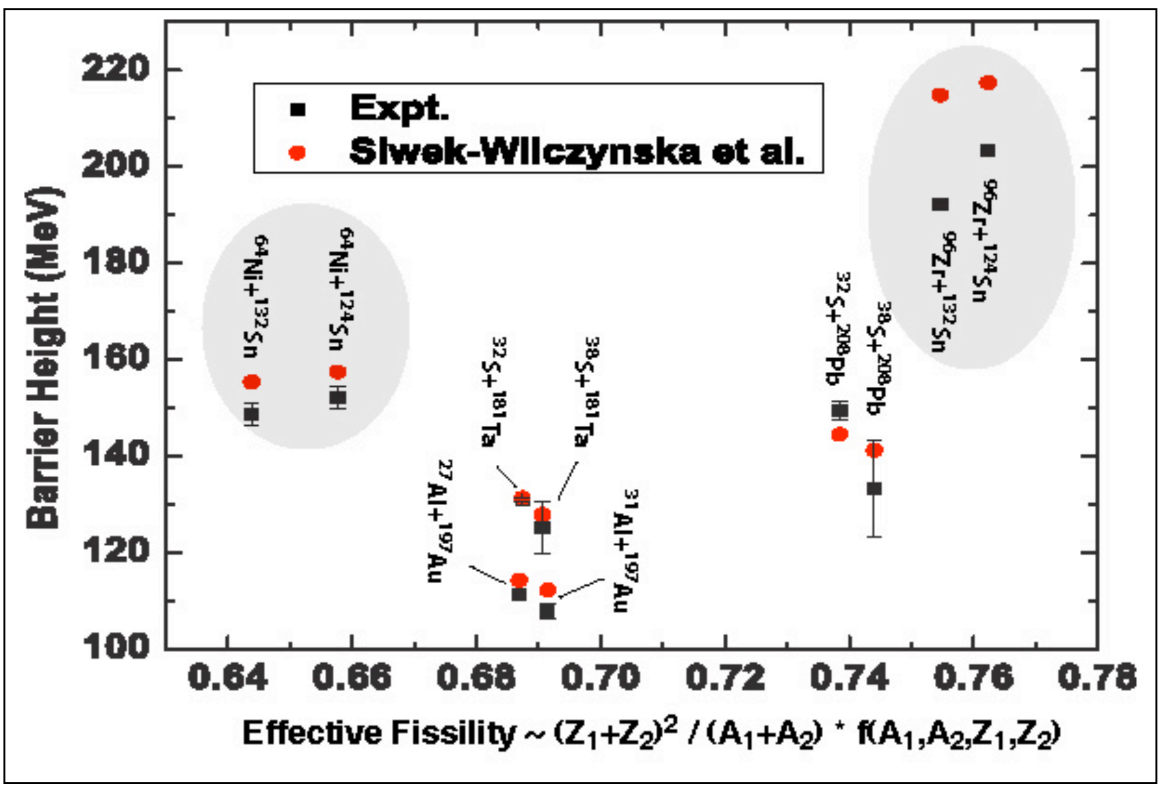
Attempting to understand the synthesis of heavy nuclei

Superheavy elements are synthesized in nuclear reactions where two separate nuclei are forced to fuse together to form an excited "compound" system. There are several known hurdles the colliding nuclei have to pass in order to become a single new nucleus. First, the electrostatic repulsion of the nuclear charges has to be overcome. At this stage, a di-nuclear complex is formed, much like a weightlifter's dumbbells. In the next step, a transformation from the di-nuclear shape to a single nucleus is taking place. Finally, if the energy and makeup of the fused system is right, the compound nucleus will resist the temptation to fission into smaller fragments.

There is evidence that using neutron-rich nuclei in the reaction increases the probability of the system surmounting the hurdles listed above. Indeed, neutrons are sometimes referred to as "nuclear glue" as they add the attractive nuclear force and, unlike protons, they do not produce electrostatic repulsion. We seized on the availability of accelerated neutron-rich beams at the Holifield Radioactive Ion Beam Facility to study how changing the neutron excess of the colliding nuclei will further affect our ability to synthesize yet-unexplored superheavy elements. The intensity of the nuclear beams available is generally low but we developed special tools that allow us to study specific reactions between heavy nuclei with sufficient accuracy to test nuclear reaction models. The figure below displays the energy barriers that inhibit two heavy nuclei from being captured into a di-nuclear state. The red dots are predictions made with the currently best semi-empirical model and the black ones are barriers deduced from experiment. The barriers based on data measured at HRIBF (ref. 1,2,3) are encircled by ellipses and show that in all cases involving neutron-rich nuclei, the measured barrier is significantly lower than the predicted one. Such barriers enhance the fusion probability, especially at the lower energies required to synthesize a compound nucleus that is not highly excited.



Ref. 1 J.F. Liang et al. PRC 75, 054607 (2007). Ref. 2 A.M. Vinodkumar et al. PRC 74, 064612 (2006). Ref. 3 A.M. Vinodkumar et al. PRC 78, 054608 (2007).