Shell stabilization in superheavy elements^{B+G}

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Superheavy elements (SHE) are by definition those very heavy nuclei which have a negligible liquid-drop fission barrier. Quantum mechanical shell effects create one or several minima in the potential energy surface which stabilize the nucleus against fission. This additional binding from shell effects is quantified by the shell correction energy which is thus a first hint on the fission stability.

The shell correction energy can be computed by comparing the actual discrete distribution of single-particle energies with a smoothened level density. The weakly–bound SHE require a careful treatment of the continuum which we perform according to the recipe of [1]. Fig. 1 shows the shell correction energies from fully self-consistent calculations with the Skyrme interactions SkI3 and SLy6 and the relativistic mean-field interactions NL3 and NL–Z2. Remind that the shell correction is always sharply peaked at shell closures for nuclei up to Pb. This changes when going to SHE. There emerges a broad island of shell stabilization which spreads around the shell closures predicted by the various forces. Similar pattern are found in macroscopic-microscopic models. As a consequence, the significant differences seen in the prediction of magic numbers when looking at the δ_{2q} [2] are much mellowed by the generally softer pattern of the shell energy which looks similar for all models investigated in [3]. The reason for this behaviour is an accumulation of states with low angular momentum at the Fermi surface for these SHE. On one hand, this causes the fast changes of the various shell closures by small shifts of individual levels [4]. On the other hand, this turns the shell effect of individual levels into the shell effect of a bunch of levels more independent on the subtle details of actual shell closures.

Spherical shell corrections are, of course, a first indicator only for the stability of SHE. What finally counts is the fission barrier. And fission can go unusual paths in SHE.

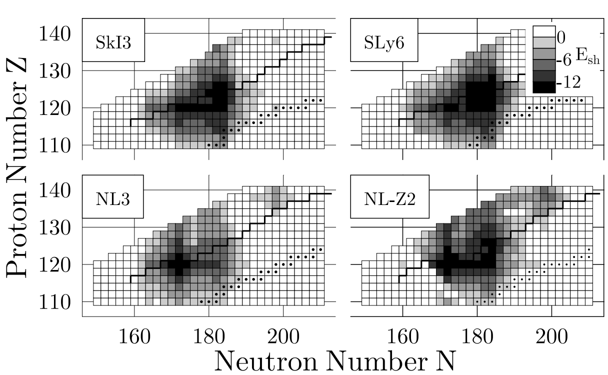

Figure 1: Total shell correction for spherical configurations of superheavy nuclei extracted from self–consistent calculations with the effective interactions as indicated. The (calculated) two–proton drip line and the valley of stability are emphasized. Data taken from [3].

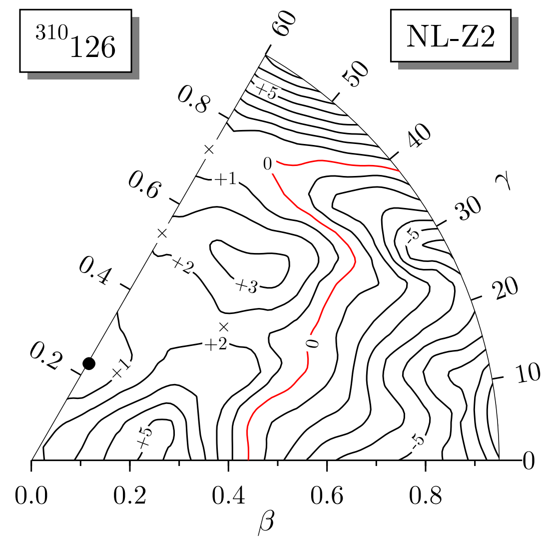

Figure 2: Potential energy surface of $^{310}_{184}126$ in the β–γ plane calculated with the relativistic mean-field interaction NL–Z2. The filled circle denotes the oblate minimum, while crosses denote the various saddle points. Deformation energies in MeV are with respect to the oblate ground state.

Fig. 2 shows as an example the potential energy landscape of $^{310}_{184}126$ in the full triaxial plane. In spite of the huge shell correction of more than −12 MeV at spherical shape the actual ground state of $^{310}_{184}126$ is oblate when calculated with NL–Z2. Triaxial configurations reduce the axial prolate barrier of more than 5 MeV to 1.8 MeV. The result has to be taken with precaution because these detailed fission pattern seem to depend sensitively on the actual nucleus and force used. $^{292}_{172}120$ has spherical shape and a triaxial barrier of nearly 6 MeV when calculated with the same force. Skyrme interactions give a similar potential landscape in $^{310}_{184}126$ but with a spherical ground state and substantially higher barriers around 9 MeV, see [5]. This systematic difference in fission barrier heights when comparing Skyrme interactions and relativistic mean field has already been seen in [6] and still needs to be understood. Fig. 2 demonstrates, however, that one has to be aware of surprises in this region of nuclei and that there is still a bulk of work ahead to uncover all these features.

References

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