Mean field and beyond in α-decay chains of superheavy elements[B+G]

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Recent experiments at GSI [1] and JINIR Dubna [2] brought evidence for the synthesis of new superheavy elements. One of the key observable in these experiments is the Q_α value along the α-decay chains. In this contribution, we want to investigate this observable within self-consistent mean-field models.

We consider two different models, the Skyrme-Hartree-Fock approach (SHF) and the relativistic mean-field model (RMF), for a most recent review see [3]. From the world of different parametrisations we confine the discussion to a few well adjusted, typical and recent sets. For SHF we consider the parametrisations SkP, SkI3, SkI4, and SLy6. The force SkP uses effective mass $m^*/m = 1$ and is designed to allow a self-consistent treatment of pairing. The other forces all have smaller effective masses around $m^*/m = 0.7-0.8$. The force SLy6 stem from an attempt to cover properties of pure neutron matter together with normal nuclear ground-state properties. The forces SkI3/4 employ a spin-orbit force with isovector freedom to simulate the relativistic spin-orbit structure. SkI3 contains a fixed isovector part exactly analogous to the RMF, whereas SkI4 is adjusted allowing free variation of the isovector spin-orbit force. The modified spin-orbit force has a strong effect on the spectral distribution in heavy nuclei and thus for the predictions of superheavy elements. For the RMF we consider the parametrisations NL-Z2 and NL3. The force NL-Z2 comes from fits much similar to those of SkI3 and SkI4. NL3 is fitted without looking at the electron-scattering formfactor but with taking more care about the isovector trends. We ought to remind here that these different parametrisations produce much different predictions for the magic shell closure in SHE [4, 5].

Fig. 1 compares calculated and experimental α energies for the new isotopes. Most models make similar predictions at the lower end of the chains and these agree very nicely with the available new data for both chains. Larger differences among the forces show up when going to heavier systems. This is mainly due to differently pronounced shell closures which produce these curious kinks. Having a closer look on the deformation energies shows that one comes into a regime of very soft nuclei with pronounced shape isomerism. The mean-field state represents the one configuration at the absolute minimum of energy. But many other configurations are energetically competitive in soft nuclei. Thus one needs to consider a correlated ground state built from an appropriate coherent mixture of configurations. In practice, we superpose the states along the quadrupole deformation path using the generator-coordinate method [6]. The effect of such correlations is shown in Fig. 2. They wipe out the kinks and produce a smooth trend throughout. There is little correlation effect at the lower end of the chain such that the orginally given good agreement with data is maintained. Moreover, correlations bring the predictions from the the various forces closer together again. The then remaining difference is a clear signal of different bulk properties deep within the models, yet to be worked out in detail.

To conclude, mean-field models provide a pertinent description for the Q_α values along the recently measured decay chains of superheavy elements. Correlations effects beyond mean field need to be taken into account for the heavier isotopes.

References

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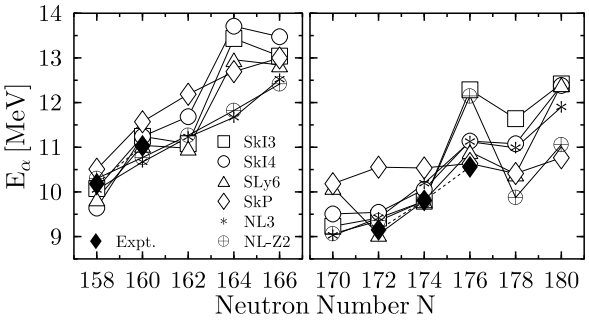

Figure 1: Ground-state-to-ground-state α energies for the α-decay chains containing $^{270}_{160}110$ (left panel) and $^{282}_{176}116$ (right panel) from mean-field calculations with the forces as indicated. Filled diamonds denote the experimental values.

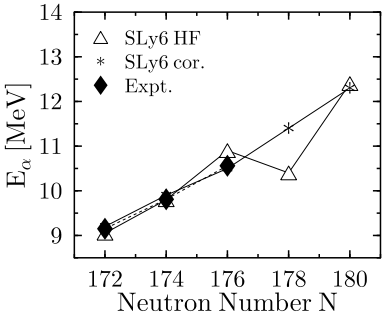

Figure 2: Ground-state-to-ground-state α energies for the decay chain containing $^{282}_{176}116$ computed with the force SLy6. Compared are calculations with and without taking ground-state correlations into account.