α-decay chains of $^{288}115$ and $^{287}115$ in the relativistic mean field theory

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Since the prediction of the existence of superheavy islands in 1960s, the synthesis of superheavy elements has been a hot topic in nuclear physics. Following numerous ground breaking technical developments in the last three decades, the process of synthesizing superheavy elements has been sped up dramatically. From 1995–2001, five elements Z=110, 111, 112, 114, and 116 have been synthesized at GSI and Dubna respectively. In August 2003, in the reaction ^{243}Am+^{48}Ca held at Dubna [1], with a beam dose of 4.3×10^{18} 248 MeV and 253 MeV ^{48}Ca projectiles, nine new odd-Z nuclei originating from two isotopes of the new element 115, $^{288}115$ and $^{287}115$, were produced. So far, all elements with $110 \leq Z \leq 116$ have been successfully synthesized in laboratory. The experimental progress has also led to a large-scale investigation of superheavy nuclei by both refined macroscopic-microscopic (MM) models such as the finite-range droplet model with folded-Yukawa single-particle potentials (FRDM+FY) or the Yukawa-plus-exponential model with Woods-Saxon single-particle potentials (YPE+WS), and microscopic models such as the Skyme-Hartree-Fock-Bogoliubov method and the latest relativistic mean field model.

In the present work, the recently developed deformed RMF+BCS method with a zero-range δ-force in the pairing channel [2] is adopted to analyze the properties of lately synthesized superheavy nuclei $^{288}115$, $^{287}115$, and their α-decay daughter nuclei [3]. Three kinds of approaches to take into account the pairing correlations have been adopted in the present work. The first ("Const") is the usual RMF+BCS calculation with a constant pairing interaction. The inputs of pairing gaps are $\Delta_n = \Delta_p = 11.2/\sqrt{A}$ and the blocking effect is ignored. The second ("Delta1") is the RMF+BCS calculation with a density-independent δ-function interaction, $V = -V_0\delta(\vec{r}_1 - \vec{r}_2)$ [2]. Here, the blocking effect is also ignored for comparison. The third ("Delta2") is the same as the second one except that the blocking effect is taken into account by a simple blocking method [4].

Because the lifetimes of superheavy nuclei are usually very short, the most important

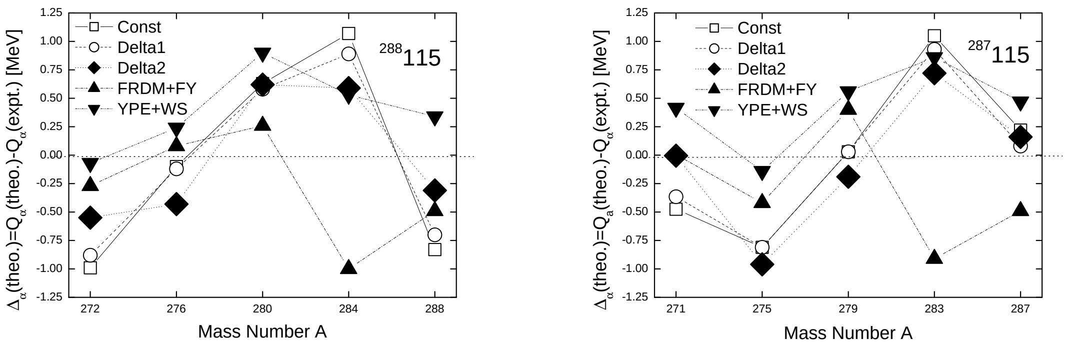

Figure 1: The difference between calculated Q_α(theor) and experimental Q_α(expt.), $\Delta_\alpha(\text{theor}) = Q_\alpha(\text{theor}) - Q_\alpha(\text{expt.})$, for the $^{288}115$ and $^{287}115$ α-decay chains as a function of mass number A.

experimentally observed properties for them are the α-decay energies. In Fig. 1 we display the differences between the theoretical predicted α-decay energies and the experimental data. It is easily seen that the results of the RMF+BCS calculations are as good as those of the macroscopic-microscopic models, FRDM+FY and YPE+WS, at the beginning of the isotopic chains or a bit better at the end of the isotopic chains. Although not significantly, the RMF+BCS calculations with the state-dependent BCS pairing and blocking are relatively better than the other two RMF+BCS calculations.

To compare in more detail the three BCS pairing treatments we have adopted in the present work, we plot the energy surfaces for all the six nuclei in the $^{288}115$ α-decay chain in Fig. 2. We note that although the three different BCS treatments give similar ground-state configurations, the potential energy surfaces are somewhat different: The fission barrier is lowered by both using the δ-force and including blocking (more details can be found in Ref. [3]).

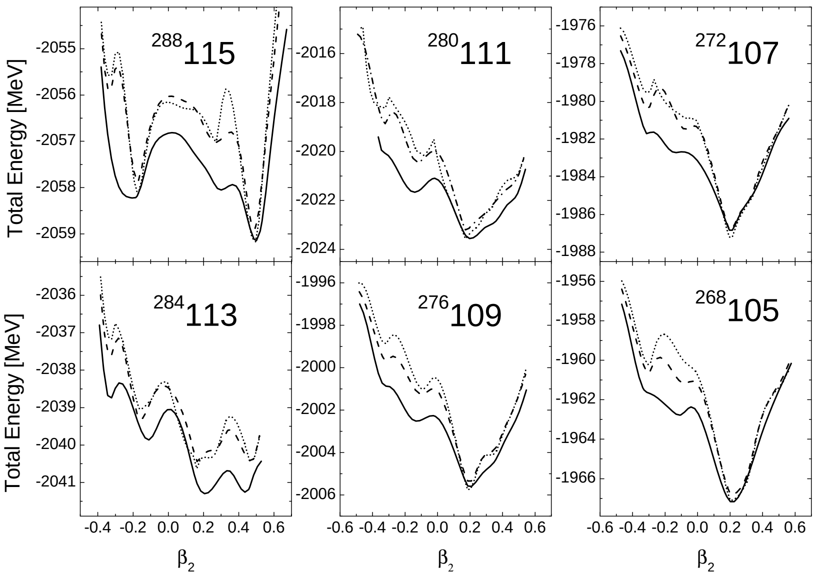

Figure 2: The energy surfaces for the $^{288}115$ α-decay chain as a function of mass quadrupole deformation β_2, obtained from three calculations: Delta2 (solid line), Delta1 (dashed line), and Const (dotted line).

To summarize, the newly synthesized superheavy nuclei in the α-decay chains starting from two *isotopes* of the element 115: $^{288}115$ and $^{287}115$, have been studied using the deformed RMF+BCS method. Good agreement with the experimental data is obtained. The influences of different pairing treatments on the ground-state properties and the energy surfaces are discussed in detail.

References

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