

chain (chain1) assigned to the new isotope  $^{207}\text{Th}$  was found. The probability of random correlations, calculated on the basis of average counting rates in the detectors, was estimated to be less than  $1.0 \times 10^{-12}$ . The  $\alpha$  decay of  $^{207}\text{Th}$ , measured with an  $\alpha$ -particle energy of 8167(21) keV and a half-life of  $9.7^{+46.6}_{-4.4}$  ms, is assigned to originate from ground state. In addition, three  $\alpha$ -decay chains of the known isotope  $^{208}\text{Th}$  were also observed in this experiment. On the basis of these events, an  $\alpha$ -particle energy of 8053(18) keV and a half-life of  $4.4^{+6.0}_{-1.6}$  ms were deduced for  $^{208}\text{Th}$ , which agree with the previously reported data of  $E_\alpha = 8044(30)$  keV and  $T_{1/2} = 1.7^{+1.7}_{-0.6}$  ms<sup>[1]</sup>.

By combining with the existing data, we find that the  $\alpha$ -decay energies of nuclei with  $Z > 82$  and  $N < 126$  show a regular and distinct odd-even staggering (OES) rather than the commonly-supposed smooth pattern. A theoretical analysis has been performed within relativistic Hartree-Fock-Bogoliubov and large-scale shell model approaches. It is found that the OES originates from both pairing correlations and blocking of particular orbitals by unpaired nucleons. Of particular importance is that pairing correlations result in the OES not only through the contribution of pairing energy to binding energy but also by configuration mixing induced by scattering nucleons to orbitals away from Fermi levels<sup>[2]</sup>.

## References

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## 3 - 3 The Reaction $^{55}\text{Mn} + ^{159}\text{Tb}$ : Preparation for the Synthesis of New Elements\*

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In recent decades, much experimental progress has been made in the synthesis of SHEs and several attempts have been made. However, none of these experiments provide evidence for the successful synthesis of the new elements. In order to produce the new elements with proton number  $Z = 119$  or  $120$ , IMP-CAS (Institute of Modern Physics, Chinese Academy of Sciences) constructed the China Accelerator Facility for superheavy Elements (CAFE2). The beams with medium mass, such as  $^{50}\text{Ti}$ ,  $^{51}\text{V}$ ,  $^{54}\text{Cr}$ ,  $^{55}\text{Mn}$ , and so on, can be used to bombard the radioactive actinide targets, producing superheavy nuclei. As above, the attempts to synthesize the elements  $Z = 119$  and  $120$  with the beams of  $^{50}\text{Ti}$  and  $^{54}\text{Cr}$  have not been successful. Considering the expansibility of experiments and the accessibility of material, the  $^{55}\text{Mn} + ^{244}\text{Pu}$  and  $^{55}\text{Mn} + ^{243}\text{Am}$  reactions might be promising for synthesizing the new elements 119 and 120. To investigate the performance of the  $^{55}\text{Mn}$  beam in synthesis experiments, the  $^{55}\text{Mn} + ^{159}\text{Tb}$  reaction was studied.

The experiment was performed on the gas-filled recoil separator, SHANS2 (Spectrometer for Heavy Atoms and Nuclear Structure-2), at CAFE2 in Lanzhou, China. The  $^{55}\text{Mn}^{18+}$  beam was accelerated to 257 MeV by a superconducting linear accelerator. The recoiled evaporation residues (ERs) were separated in-flight from the primary beam particles using the gas-filled recoil separator SHANS2, subsequently implanted into a 300- $\mu\text{m}$ -thick double-sided silicon strip detector (DSSD, model BB-17). Six 500- $\mu\text{m}$ -thick side silicon detectors (SSD, model W4) were mounted perpendicular to the face of the DSSD. Two multi-wire proportional chambers (MWPCs) mounted

upstream of the DSSD were used to distinguish  $\alpha$ -decay events from the implanted recoils. Three silicon detectors were mounted behind the DSSD and used as veto detectors, in order to minimize the interference from scattered energetic light ions in the DSSD.

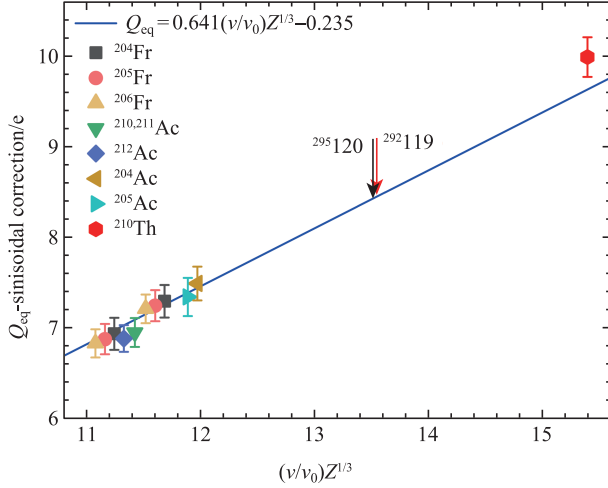


Fig. 1 (color online) Corrected equilibrium charge states plotted as a function of  $(v/v_0)Z^{1/3}$ , including the corrected one of the  $^{210}\text{Th}$  (red hexagon) and the estimated  $(v/v_0)Z^{1/3}$  of the elements 119 (red arrow) and 120 (black arrow).

actual magnetic rigidity of the ERs is first determined. With the above efforts, the equilibrium charge state of  $^{210}\text{Th}$  was determined to be 10.45 e, the corrected results are plotted as a function of  $(v/v_0)Z^{1/3}$  in Fig. 1. The estimated values  $(v/v_0)Z^{1/3}$  of the elements 119 and 120 respectively produced in the 3n channel of the  $^{55}\text{Mn} + ^{240}\text{Pu}$  and  $^{55}\text{Mn} + ^{243}\text{Am}$  reactions are also plotted in Fig. 1. Due to the lack of experimental data in  $(v/v_0)Z^{1/3}$  of 13 to 14, there is an uncertainty in the value of the equilibrium charge states. Relevant studies need to be conducted in the future.

## Reference

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In this work<sup>[1]</sup>, the identification of nuclei produced in the present experiment was performed by searching for the energy-position-time correlated  $\alpha$ -decay chains with the help of known  $\alpha$ -decay properties of its descendants. By this way, 38 decay chains were assigned to  $^{210}\text{Th}$ , of which there were 19 ER -  $\alpha_1$  -  $\alpha_2$  correlated chains, 7 chains with  $\alpha_2$  escaping and 12 chains with  $\alpha_1$  escaping. With the incident energy of 257 MeV, we also observed twelve decay chains, of which six are ER -  $\alpha_1$  -  $\alpha_2$ , were assigned to the isotope  $^{211}\text{Th}$ . The cross sections were measured to be  $0.59^{+0.25}_{-0.23}$  nb and  $0.19^{+0.12}_{-0.09}$  nb for  $^{210}\text{Th}$  and  $^{211}\text{Th}$ , respectively. The  $\alpha$ -particle energies of  $^{210}\text{Th}$  and  $^{211}\text{Th}$  are 7922(14) keV and 7788(14) keV, of which the corresponding half-lives are 14(4) ms and  $36^{+15}_{-8}$  ms.

Calculating the equilibrium charge state of the ions is crucial for the determination of the optimum magnetic rigidity for the products of interest. It is essential for the study of superheavy elements with low reaction cross sections. In the experiment, in order to obtain the equilibrium charge state of the ERs, the

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