New fusion reactions could lead to long-lasting superheavy nuclei with unique properties

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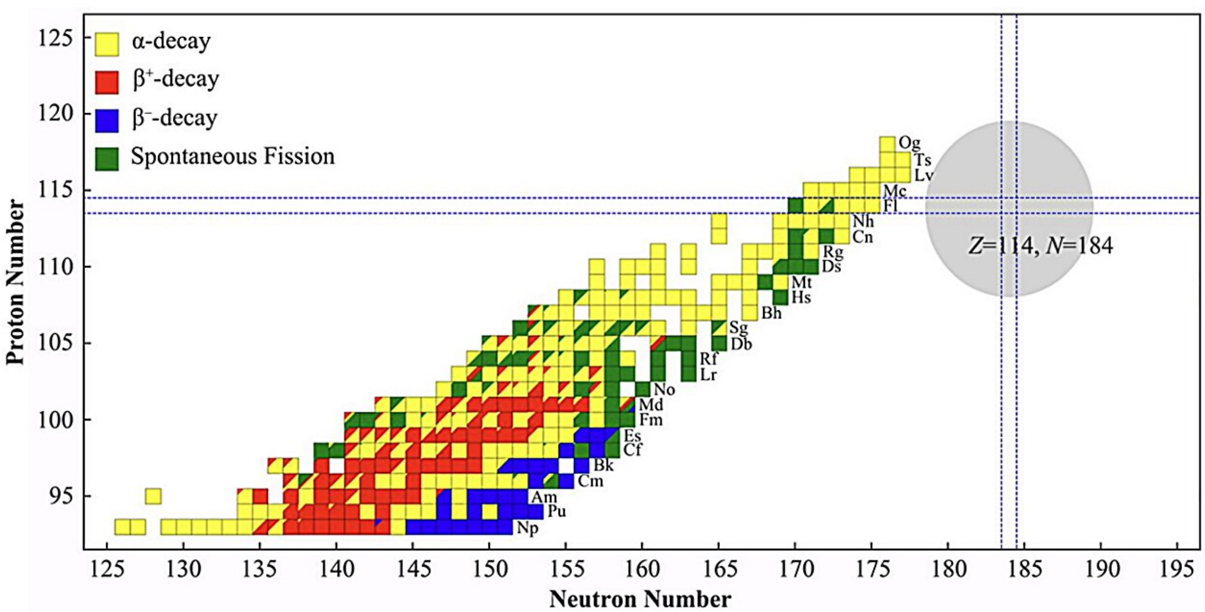


In nuclear physics, the "island of stability " refers to a hypothesized group of heavier transuranium isotopes, predicted to be significantly more stable than their neighboring isotopes, with expected half-lives ranging from minutes or days to, according to some optimists, even millions of years. Various theoretical methods have predicted the center of the "island of stability " to be at Z=114,120,124 or 126 and N=184. Credit: Minghao Zhang

A team of scientists has made significant progress in the ongoing quest to create new, long-lasting superheavy nuclei. These double magic nuclei, characterized by a precise number of protons and neutrons that form a highly stable configuration, are exceptionally resistant to decay.

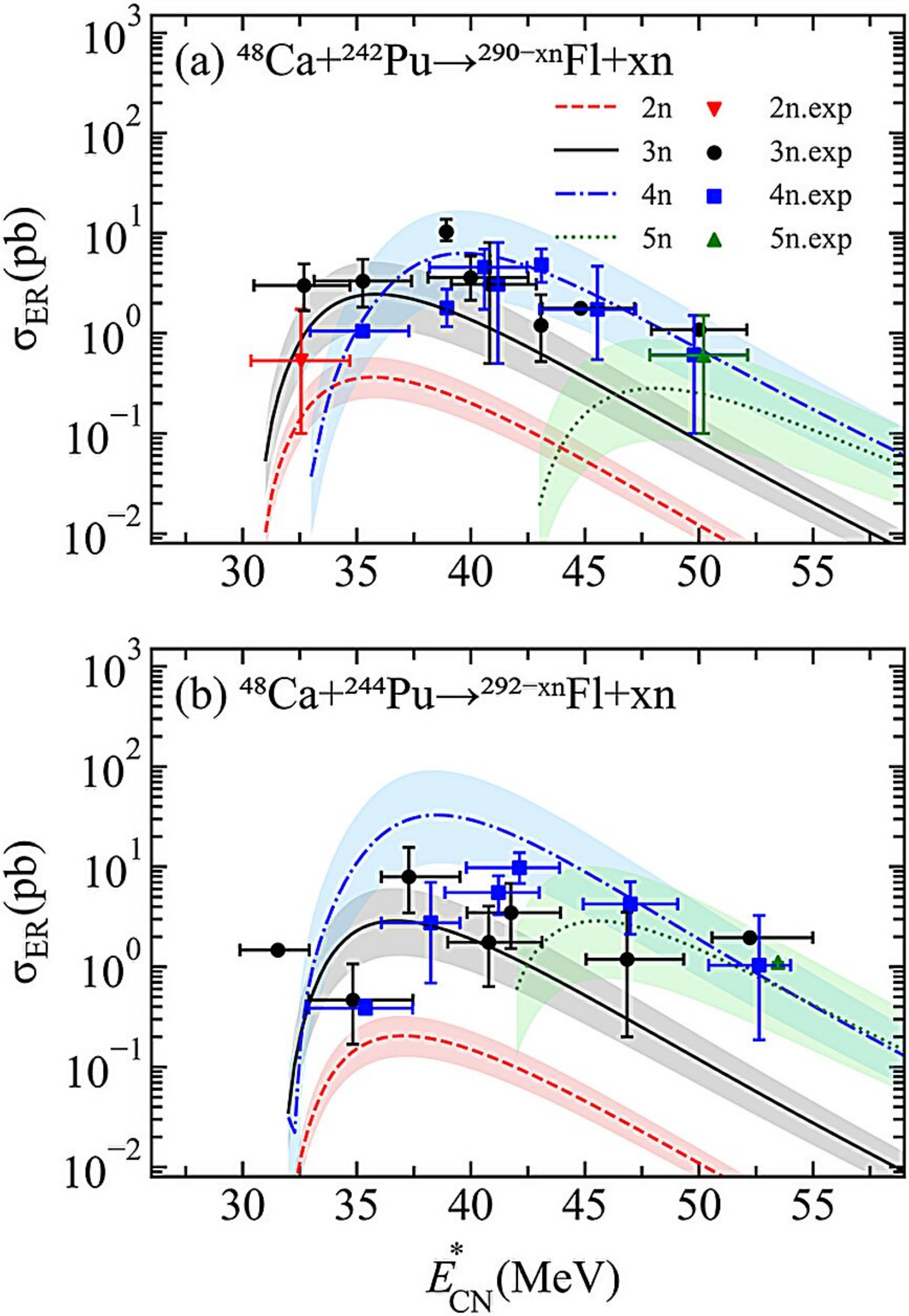
Their study could deepen our understanding of the forces that bind atoms and pave the way for the development of new materials with unique properties.

The research, published in the journal *Nuclear Science and Techniques*, is a step closer to reaching the so-called "Island of Stability," a region in the nuclei chart where it's believed some of these nuclei might exist for much longer than those created so far.

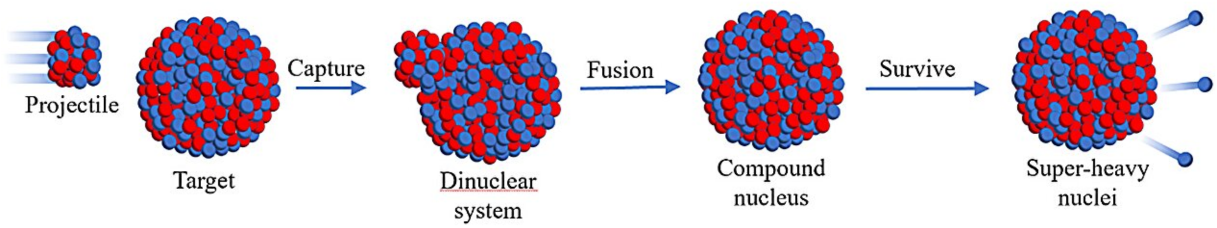
In the search for 'Island of Stability'

The research, led by Professor Feng-Shou Zhang, has predicted promising reactions between different elements that could be used in experiments to create double magic nuclei. One key discovery involves a reaction between a special type of radioactive calcium isotope and plutonium target, which could produce the predicted double magic nuclei ^{298}Fl.

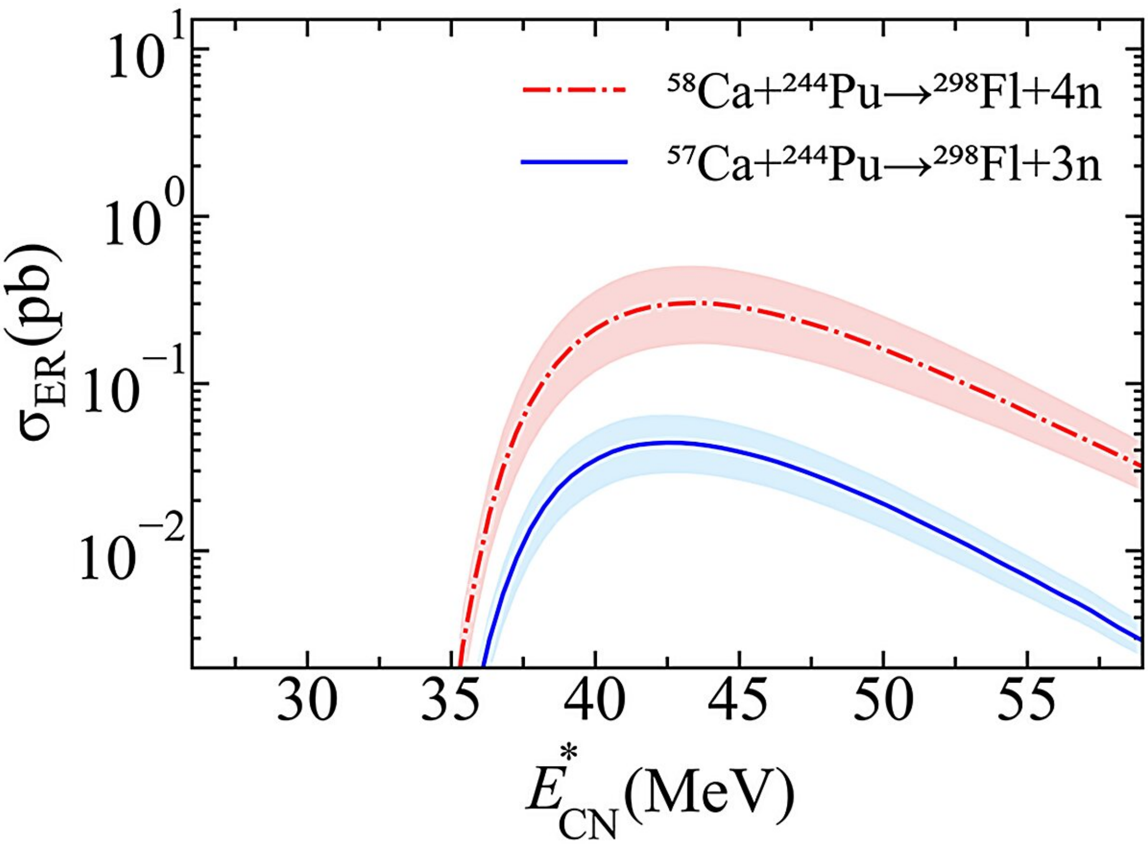
Another potential double magic nuclei, ^{304}120, could be created by combining vanadium and berkelium, although this reaction is currently less likely to succeed.


(a) $^{48}Ca+^{242}Pu \rightarrow ^{290-xn}Fl+xn$
2n
2n.exp
3n
3n.exp
4n
4n.exp
5n
5n.exp
σ_{ER}(pb)
(b) $^{48}Ca+^{244}Pu \rightarrow ^{292-xn}Fl+xn$
E^*_{CN}(MeV)

Comparison of the calculated evaporation residue cross section given by the DNS model and the experimental data. Credit: Minghao Zhang



The dinuclear system model has proven to be a reliable tool for reproducing experimental results of fusion reactions. In this model, the projectile and target nuclei must overcome the Coulomb barrier to form a dinuclear system. Subsequently, nucleons are transferred from the projectile to the target, leading to the formation of a compound nucleus. To reach its ground state, the compound nucleus must then evaporate neutrons. Credit: Minghao Zhang



Based on the dinuclear system model, the radioactive projectile ^{58}Ca and the ^{244}Pu target are predicted to be favorable for producing the predicted double-magic nucleus ^{298}Fl. Additionally, this research investigates the synthesis of another predicted double-magic nucleus, ^{304}120, with the ^{58}V +^{249}Bk reaction to be optimal. Credit: Minghao Zhang

Exploring new paths in nuclear science

The idea of creating these superheavy nuclei is exciting because they could offer new insights into atomic structure and possibly lead to the development of advanced materials. If these elements can be made and remain stable, they might have unique properties that could be useful in various scientific fields.

To make these discoveries, the research team used advanced theoretical models designed to study heavy ion collisions. By carefully choosing the right combinations of projectiles and targets, the scientists have laid out a clear path for future experiments that could bring us closer to achieving these goals.

Despite the progress, there are still challenges ahead, such as improving the efficiency of these reactions. However, this research brings us closer to understanding the "Island of Stability" and the intriguing possibilities it holds. The work not only advances the field of nuclear physics but also sets the stage for future discoveries that could have wide-ranging impacts in science and technology.

This research was conducted in collaboration with Beijing Normal University, Beijing Academy of Science and Technology, Guangxi University, and the National Laboratory of Heavy Ion Accelerator of Lanzhou.

More information: Ming-Hao Zhang et al, Possibility of reaching the predicted center of the "island of stability" via the radioactive beam-induced fusion reactions, *Nuclear Science and Techniques* (2024). DOI: 10.1007/s41365-024-01542-x

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