Scientists report remarkable enhancement of α-particle clustering in uranium isotopes

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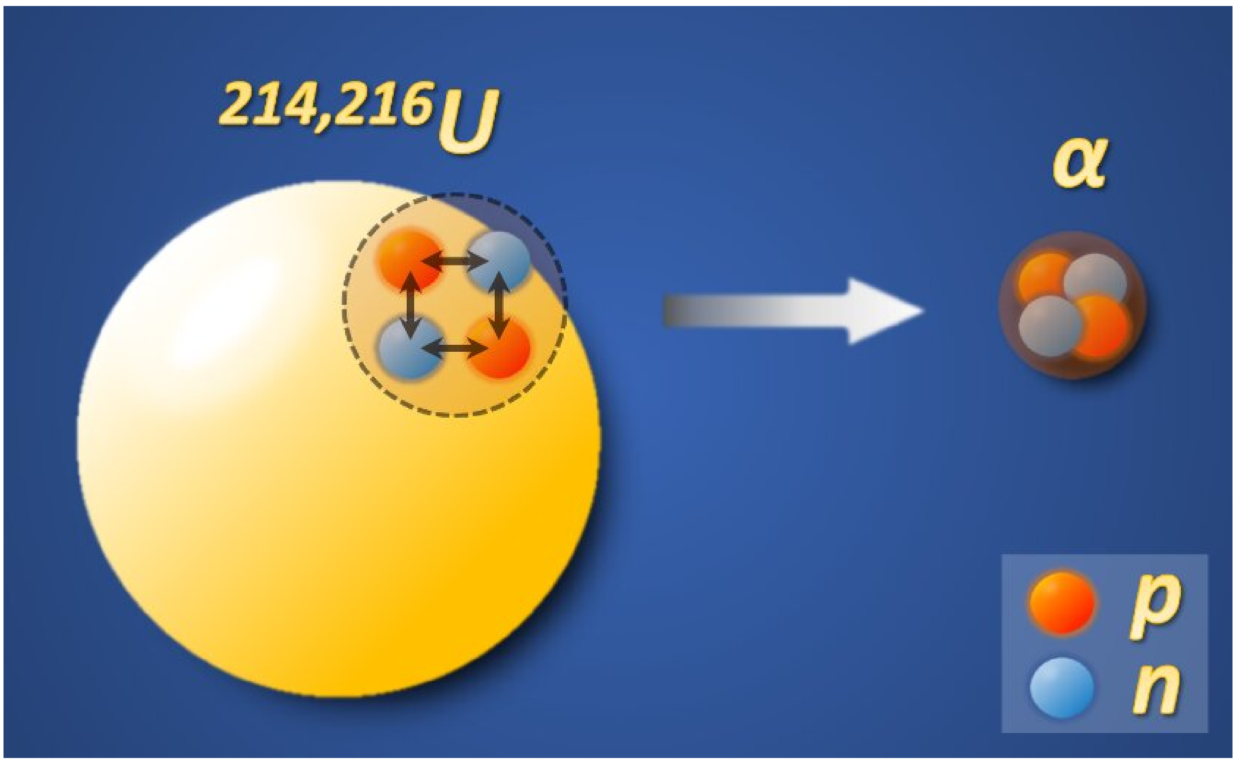


The illustration of the enhanced α-particle preformation in $^{214,216}U$ deduced by the strong proton-neutron interaction. Credit: ZHANG Zhiyuan

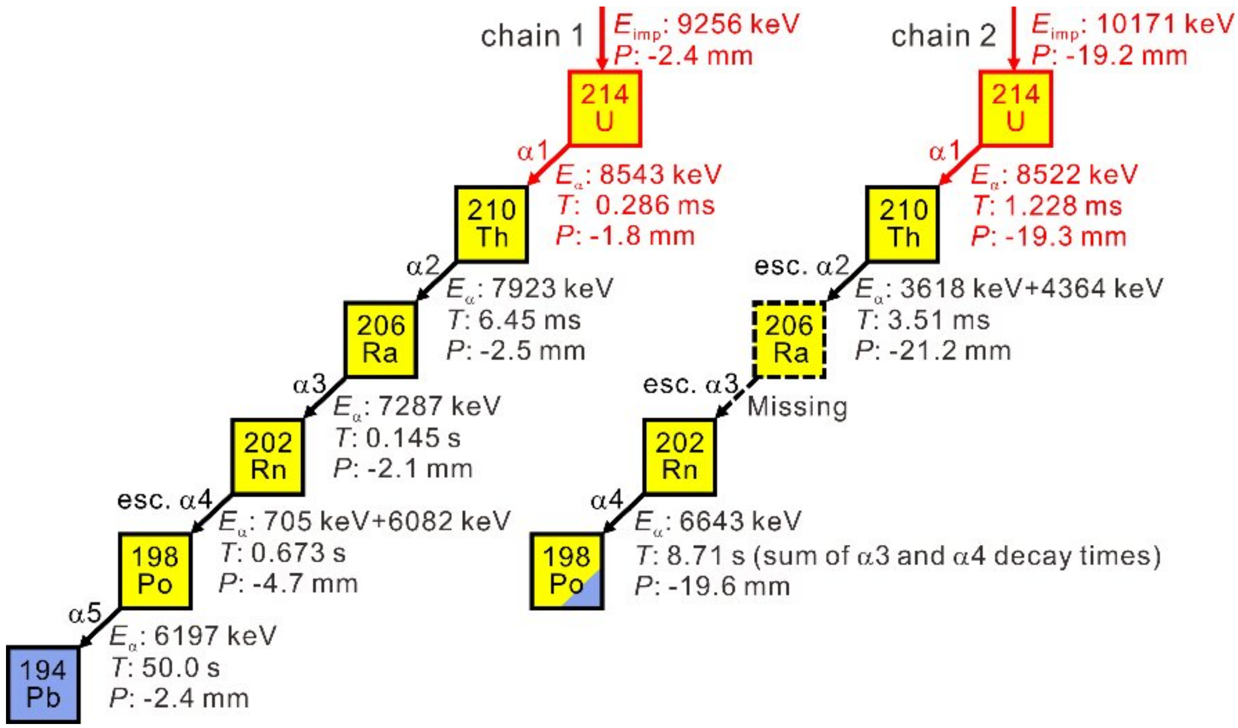
It is always exciting to find new isotopes with extreme neutron/proton numbers in nuclear physics research. In the region of heavy nuclei, α-decay is one of the pervasive decay modes and plays an essential role in searching for new isotopes. However, even after about a century of studying α-decay, scientists still cannot perfectly describe how the α-particle is formed at the surface of the nucleus before its emission.

In the α-decay process, the α-particle can be regarded not only as two protons plus two neutrons, but also as two proton-neutron pairs. Although previous studies have proved the importance of the pairing forces between the identical nucleons, it remains unclear whether the strong proton-neutron interactions have an impact on α-decay properties, especially in the heavy nuclear region.

Published in *Physical Review Letters* as an Editors' Suggestion on April 14, a study has reported the observation of ^{214}U, a new uranium (U) isotope, and has revealed for the first time the abnormal enhancement of α-particle clustering in uranium isotopes.

The study was led by scientists at the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences (CAS). Researchers carried out the experiments at the gas-filled recoil separator, Spectrometer for Heavy Atoms and Nuclear Structure (SHANS), at the Heavy Ion Research Facility in Lanzhou (HIRFL), China.

By employing the SHANS separator and the recoil-α correlation method, the researchers discovered the new isotope ^{214}U, and precisely measured the α-decay properties of $^{214,216,218}U$.



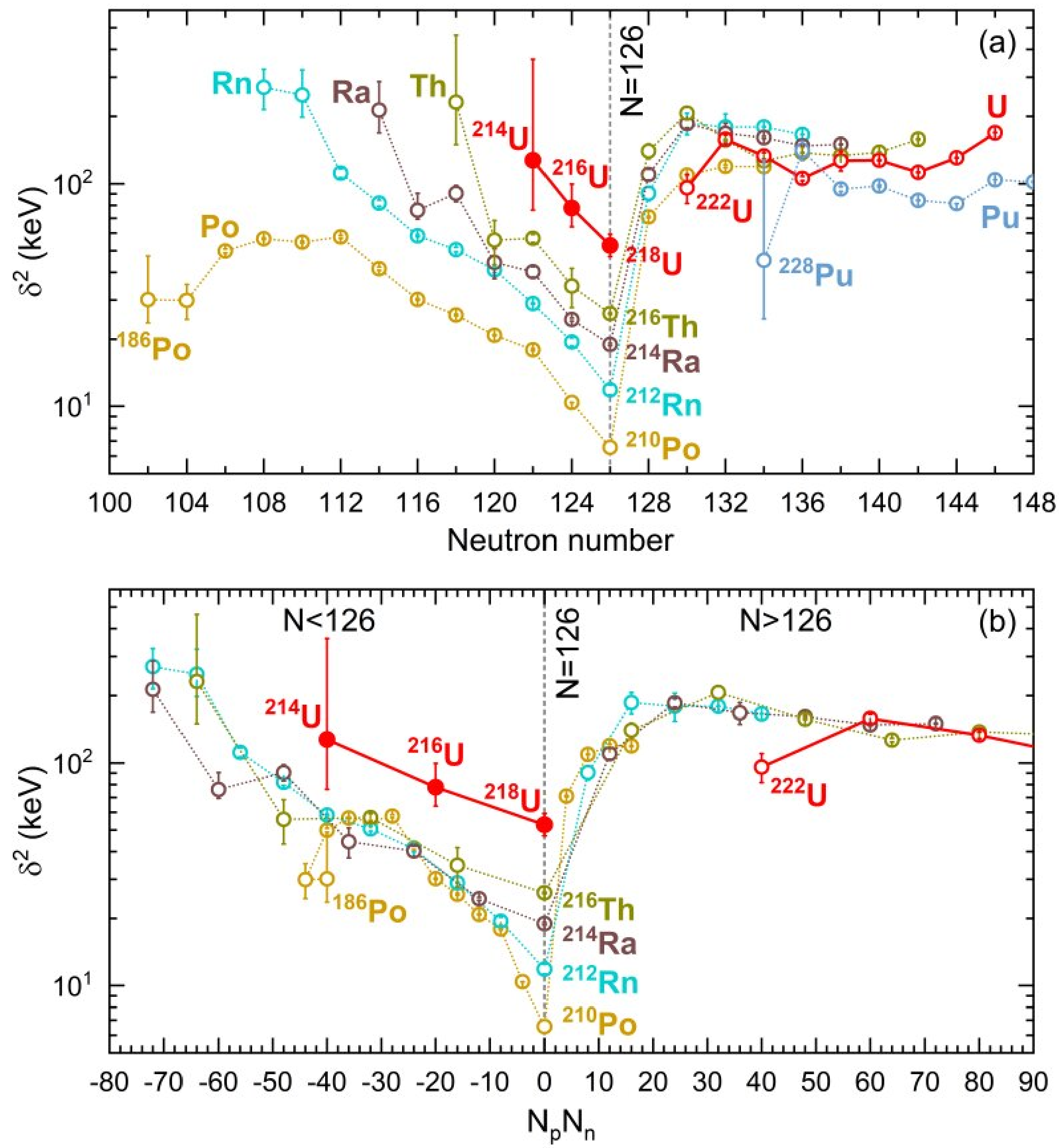
Observed α-decay chains for the new isotope ^{214}U. Credit: Physical Review Letters

It is well known that the interaction between valence protons and neutrons occupying orbits with the same number of nodes and orbital angular momenta leads to many exotic changes of closed shells. "The nuclei near the magic neutron number $N = 126$ provide an ideal place to probe how nuclear structure changes influence α-decay properties," said Zhang Zhiyuan, a researcher at IMP.

The researchers extracted the α-decay reduced widths, which are related to the α-particle formation probability, for the even-even polonium-plutonium nuclei near the $N = 126$ shell closure, and discussed their systematic trends in terms of the N_pN_n scheme.

By combining the experimental data, "the behavior in the N

Meanwhile, it is notable that the reduced widths of $^{214,216}U$ studied in this work are remarkably enhanced by a factor of two relative to the systematic trend for the N N_pN_n scheme.



Systematics of reduced widths for the α-decay of even-even 84 Z 94 nuclei as a function of neutron number (a) and NpNn value (b). Credit: Physical Review Letters

This phenomenon might be caused by the strong monopole interaction between the valence $1f_{7/2}$ protons and $1f_{5/2}$ neutrons combined with increased occupancy of the $1f_{7/2}$ proton orbit, which was confirmed by the large-scale shell model calculations.

The results break new ground in an under-explored part of the nuclide chart, where the α- particle is preformed with higher probability and emitted at a faster decay rate.

"As a possible preview of future studies in this region, it is expected that this effect might become even stronger in the plutonium isotopes. Thus, it is extremely intriguing to extend the decay-width systematics to higher-Z nuclei," the study suggests.

More information: Z. Y. Zhang et al, New α -Emitting Isotope U214 and Abnormal Enhancement of α -Particle Clustering in Lightest Uranium Isotopes, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.126.152502

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