

Shape-shifting experiment challenges interpretation of how cadmium nuclei move

February 27 2023



A new experiment probed the shape and motion of cadmium-106 and found more support for rotational motion than the textbook interpretation of vibrational motion. Color indicates radial distance to give an indication of the nuclear shape. Credit: T. J. Gray, Oak Ridge National Laboratory

Atomic nuclei take a range of shapes, from spherical (like a basketball) to deformed (like an American football). Spherical nuclei are often described by the motion of a small fraction of the protons and neutrons,



while deformed nuclei tend to rotate as a collective whole.

A third kind of motion has been proposed since the 1950s. In this motion, known as nuclear vibration, <u>atomic nuclei</u> fluctuate about an average shape. Scientists recently investigated cadmium-106 using a technique called Coulomb excitation to probe its <u>nuclear shape</u>. They found clear experimental evidence that the vibrational description fails for this isotope's nucleus. This finding is counter to the expected results.

Research published in *Physics Letters B* builds on a long quest to understand the transition between spherical and deformed <u>nuclei</u>. This transition often includes vibrational motion as an intermediate step. The new result suggests that <u>nuclear physicists</u> may need to revise the long-standing paradigm describing how this transition occurs.

Scientists have not yet answered the question of what behavior takes place during this transition, but new evidence points to a description based on rotational motion of a nucleus together with a reorganization of its outermost protons and neutrons. The results make clear that scientists need more data to shed light on nuclei they have traditionally thought to be vibrational.

A multinational team of nuclear physicists used the <u>Argonne Tandem</u> <u>Linac Accelerator System</u> (ATLAS), a DOE Office of Science user facility at Argonne National Laboratory, to accelerate a beam of cadmium-106 nuclei to 9% of the speed of light and direct it onto a 1-micron thick lead-208 target foil.

During the collision, gamma rays from the cadmium-106 nuclei were emitted and detected by the Gamma-Ray Energy Tracking In-beam Nuclear Array (GRETINA), and the recoiling lead and cadmium nuclei were detected by the Compact Heavy Ion Counter 2 (CHICO2). The intensities of the gamma rays provided a measure of the probability of



exciting cadmium-106 nuclei via the electromagnetic interaction, from which the electromagnetic properties of cadmium-106 were established.

The researchers integrated these properties into a model-independent measure of the nuclear shape and compared the result to expectations from several leading nuclear theories. The results indicate that at low-energies, cadmium-106 is not vibrational but instead more in line with the rotation of a slightly deformed triaxial rotor—a shape akin to a deflated American football.

More information: T.J. Gray et al, E2 rotational invariants of 01+ and 21+ states for 106Cd: The emergence of collective rotation, *Physics Letters B* (2022). DOI: 10.1016/j.physletb.2022.137446

Provided by US Department of Energy

Citation: Shape-shifting experiment challenges interpretation of how cadmium nuclei move (2023, February 27) retrieved 12 September 2024 from <u>https://phys.org/news/2023-02-shape-shifting-cadmium-nuclei.html</u>

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