

What do we know about the ^{229}Th nuclear clock isomer?

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Abstract

Today's most precise time and frequency measurements are performed with optical atomic clocks. However, it has been proposed that they could potentially be outperformed by a nuclear clock, which employs a nuclear transition instead of an atomic shell transition. There is only one known nuclear state that could serve as a nuclear clock using currently available technology, namely, the isomeric first excited state of ^{229}Th . Since more than 40 years nuclear physicists have targeted the identification and characterization of the elusive isomeric ground state transition of ^{229m}Th . Evidence for its existence until recently could only be inferred from indirect measurements, suggesting since 2009 an excitation energy of 7.8(5) eV. Thus the first excited state in ^{229}Th represents the lowest nuclear excitation so far reported in the whole landscape of known isotopes. In 2016, the first direct detection of this nuclear state could be realized via its internal conversion decay branch, laying the foundation for precise studies of its decay parameters [1]. Subsequently, a measurement of the half-life of the neutral isomer was achieved, confirming the expected reduction of 9 orders of magnitude compared to the one of charged ^{229m}Th [2]. Recently, collinear laser spectroscopy was applied to resolve the hyperfine structure of the thorium isomer, providing information on nuclear moments and the charge radius [3]. Most recently, also the cornerstone on the road towards the nuclear clock, which is a precise and direct determination of the excitation energy of the isomer, could be achieved [4, 5]. Thus major progress on the properties of this elusive nuclear state could be achieved in the last three years, opening the door towards an all-optical control and thus the development of an ultra-precise nuclear frequency standard. Such a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time variations of fundamental constants.

References

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