Searching for the first excited nuclear state of ^{229}Th

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The first excited nuclear state of ^{229}Th (Thorium) possesses the lowest excitation energy among the known nuclear levels. The excitation energy of this nuclear state is only 7.8 ± 0.5 eV and can be excited directly using lasers. Which makes the design of a nuclear clock based on the first excited nuclear state of ^{229}Th becomes possible.

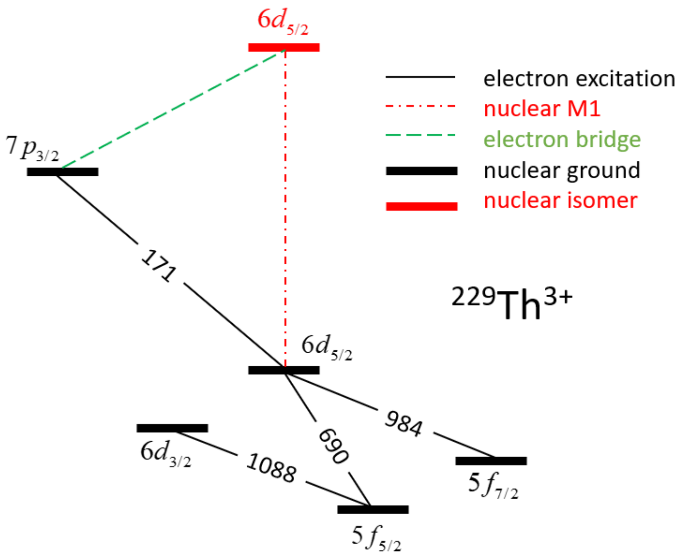

Figure 1: Electron excitation, nuclear M1 and electron bridge existed in $^{229}Th^{3+}$

Kroger and Reich figure out the existence of this low energy nuclear level in 1976 [1]. In 2016, Lars von der Wense and colleagues observe the internal conversion electrons produced due to this nuclear level, which proves again the existence of this excited nuclear state [2].

We are proposed to measure the energy of this first excited nuclear state of ^{229}Th based on $^{229}Th^{3+}$ coulomb crystals in vacuum chamber. The procedure includes 1) Preparation of $^{229}Th^{3+}$; 2) Confinement of $^{229}Th^{3+}$ using radio frequency quadrupole ion trap, together with Doppler laser cooling and high vacuum technology. Obtaining long lifetime and stabilized confined $^{229}Th^{3+}$ coulomb crystals; 3) Illuminating the $^{229}Th^{3+}$ Coulomb crystal with tunable lasers. Determing the energy range and lifetime of the first excited nuclear state of ^{229}Th.

The probability of first excited nuclear state of ^{229}Th (red in Figure 1) is small, makes it difficult to observe and measure directly. Alternate method is to measure the electron bridge (green in Figure 1) to obtain information of the first excited nuclear state of ^{229}Th indirectly.

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[1] L. A. Kroger and C.W. Reich, Nuclear Physics A **259** (1976) 29-60.
[2] L. von der Wense, *et al.*, Nature **533** (2016) 47-63.