Nuclear clocks and search for new physics

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The isomeric transition in ^{229}Th - recently laser-excited by multiple groups - opens a path to a nuclear clock with accuracy competitive with, and potentially exceeding, the best optical atomic clocks. The nuclear clock can be realised using different charge states - Th^{+}, Th$^{2+,}$ Th$^{3+,}$ and Th^{4+} - each exhibiting distinct frequency shifts due to electron-nucleus interactions [1]. In effect, these represent different clocks, each with unique properties and precision limits.

The surrounding electrons strongly mediate excitation and decay via the electronic-bridge mechanism and can modify both transition probability and lifetime by orders of magnitude [2]. The clock performance is influenced by external perturbations, such as ion-trapping fields and blackbody radiation [3]. A "stretched-state" scheme suppresses leading-order electron-nucleus entanglement and mitigates key systematic effects [4].

The ^{229}Th transition is exceptionally sensitive to physics beyond the Standard Model: spatial/temporal variation of fundamental constants (α, quark masses, Λ_{QCD}) [5], ultralight dark-matter couplings to gluons and nucleons [6], and violations of Lorentz invariance and Einstein's equivalence principle [7]. For orders enhancement factors relative to electronic transitions, together with frequency-ratio networks linking nuclear and atomic references, enable stringent, model-aware constraints.

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