Contribution ID: **322** Type: **Oral Presentation**

Essential steps towards a nuclear clock: decay-fraction measurements of the radiative decay of 229mTh in solid-state hosts

Due to its low excitation energy around 8.4 eV, the unique ^{229}Th isomer is the ideal candidate for developing a nuclear clock [1]. Such a clock would be particularly suited for fundamental physics studies [1]. In the past, measuring the isomer's radiative decay from a large-bandgap crystal doped with ^{229m}Th, has proven difficult: the commonly used population of the isomer via the ^{233}U α-decay has a limited branching ratio towards the isomer and creates a high-radioluminescence background [2, 3]. However, recently, a new approach to populate the isomer through the β-decay of ^{229}Ac was proposed [2]. This approach made it possible to observe, for the first time, the radiative decay of the ^{229}Th isomer with vacuum-ultraviolet (VUV) spectroscopy, which allowed to successfully determine the resulting photon's wavelength at a value of $\lambda = 148.7 \pm 0.4$ nm ($E = 8.338 \pm 0.024$ eV) and the isomer's radiative half-life in a MgF_2 crystal at a value of $t_{1/2} = 670 \pm 102$ s [4, 5]. Based on this work, narrow-band laser excitation of the nuclear isomer was achieved [6] with a frequency comb, determining the energy to 10^{-12} precision, boosting the development of a solid-state nuclear clock. A new measurement campaign in July 2023 took place at CERN-ISOLDE, aimed at investigating different large-bandgap crystals and accurately determining the time behaviour of the radiative decay of ^{229m}Th, embedded in different crystal materials. This allowed to (1) observe, for the first time, the radiative decay in a $LiSrAlF_6$ crystal, (2) determine the radiative decay fraction of the isomer in different crystals [7], and (3) study the time behaviour of an ensemble of ^{229}Th isomers. These studies revealed the presence of a crystal-material-dependent quenching mechanism induced by the β-decay of the precursor isotopes. Results will be presented, as well as the scope of a new measurement campaign which is expected to take place in May 2025. This campaign aims to extend the earlier radiative-decay fraction measurements with new crystalline materials, and investigate the β-decay-induced quenching mechanism in order to link it to laser- and X-ray-induced quenching as reported in [8, 9].

References

[1] E. Peik et al. Nuclear clocks for testing fundamental physics. Quantum Science and Technology, 6(3):034002, apr 2021.

[2] M. Verlinde et al. Alternative approach to populate and study the ^{229}Th nuclear clock isomer. Phys. Rev. C100, page 024315, 2019.

[3] K. Beeks. The nuclear excitation of Thorium-229 in the CaF_2 environment. eng. PhD thesis. Wien: TU Wien, 2022.

[4] S. Kraemer et al. Observation of the radiative decay of the ^{229}Th nuclear clock isomer. Nature, 617(7962):706–710, 2023.

[5] S. Kraemer. Vacuum-ultraviolet spectroscopy of the radiative decay of the low-energy isomer in ^{229}Th. PhD thesis, KU Leuven - Instituut voor Kern- en Stralingsfysica, 2022.

[6] Chuankun Zhang et al. Frequency ratio of the ^{229m}Th nuclear isomeric transition and the ^{87}Sr atomic clock. Nature, 633(8028):63–70, 2024.

[7] S. V. Pineda et al. Radiative decay of the ^{229m}Th nuclear clock isomer in different host materials. Phys. Rev. Res., 7:013052, Jan 2025.

[8] F. Schaden et al. Laser-induced quenching of the Th-229 nuclear clock isomer in calcium fluoride. arXiv preprint arXiv:2412.12339, 2024.

[9] J. E. S. Terhune et al. Photo-induced quenching of the ^{229}Th isomer in a solid-state host. arXiv preprint arXiv:2412.08998, 2024.

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Session Classification: Parallel session

Track Classification: Nuclear Structure, Spectroscopy and Dynamics