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Essential steps towards a nuclear clock: half-life and decay-fraction measurements of the radiative decay of $^{229\mathrm{m}}$Th

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Due to its low excitation energy around 8.3 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 with $^{229\mathrm{m}}$Th embedded, 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, the excitation of the nuclear isomer was achieved [6] determining the energy to the 10^{-12} precision, boosting the development of a solid-state nuclear clock. A new measurement campaign in July 2023 took place at ISOLDE, aimed at testing different large-bandgap crystals and accurately determining the half-life of $^{229\mathrm{m}}$Th, embedded in different crystals. 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 isomer's time behaviour. Results of these studies will be presented, as well as the plans for future campaigns.

[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 and T. Schumm. *The nuclear excitation of Thorium-229 in the CaF2 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] C. Zhang et al. *Frequency ratio of the $^{229\mathrm{m}}$Th nuclear isomeric transition and the ^{87}Sr atomic clock.* Nature, 633(8028):63–70, 2024.

[7] S. V. Pineda, P. Chhetri, S. Bara, Y. Elskens et al. *Radiative Decay of the ^{229}Th Nuclear Clock Isomer in Different Host Materials*, 2024. Submitted to Phys. Rev. R.

Author: ELSKENS, Yens (KU Leuven (BE))

Co-authors: VANTOMME, André (KU Leuven (BE)); CLAESSENS, Arno; BERNERD, Cyril (CERN); IVANDIKOV, Fedor (KU Leuven (BE)); DE WITTE, Hilde (KU Leuven (BE)); MARTINS CORREIA, Joao (Universidade de Lisboa (PT)); CHRYSALIDIS, Katerina (CERN); DA COSTA PEREIRA, Lino Miguel (KU Leuven (BE)); AU, Mia

(CERN); ATHANASAKIS-KAKLAMANAKIS, Michail (CERN); LAATIAOUI, Mustapha; THIROLF, Peter (Ludwig-Maximilians-Universitaet Muenchen); VAN DUPPEN, Piet (KU Leuven (BE)); CHHETRI, Premaditya (KU Leuven (BE)); FERRER GARCIA, Rafael (KU Leuven (BE)); LICA, Razvan (Horia Hulubei National Institute of Physics and Nuclear Engineering (RO)); HEINKE, Reinhard (The University of Manchester (GB)); KRAEMER, Sandro Fabian (KU Leuven (BE)); RAEDER, Sebastian (GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)); ROTHE, Sebastian (CERN); TUNHUMA, Shandirai Malven (KU Leuven (BE)); BARA, Silvia (KU Leuven (BE)); Dr STEGEMANN, Simon Thomas (CERN); Mr CASCI, Simone (KU Leuven - Instituut voor Kern- en Stralingsfysica); PINEDA, Skyy Venancio (KU Leuven (BE)); Prof. COCOLIOS, Thomas Elias (KU Leuven - IKS); SCHUMM, Thorsten (T); KOESTER, Ulli (Institut Laue-Langevin (FR)); WAHL, Ulrich (Universidade de Lisboa (PT)); YUE, Zixuan (University of York (GB))

Presenter: ELSKENS, Yens (KU Leuven (BE))

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