MS 3: Studies of Nuclear Metastable States

Time: Tuesday 10:30–12:05 Location: MS-H9

Invited Talk MS 3.1 Tue 10:30 MS-H9

Two-photon decay of nuclear isomers — •Wolfram Korten — IRFU, CEA, Université Paris-Saclay

The nuclear two-photon decay is a rare decay mode in atomic nuclei whereby a nucleus in an excited state emits two gamma rays simultaneously. First order processes usually dominate the decay by many orders of magnitude, but two-photon emission may become significant when first order processes are forbidden or strongly retarded. This is the case for nuclei with a first excited 0+ state, since the emission of a single gamma ray is strictly forbidden for the resulting electric monopole transition to the 0+ ground by angular momentum conservation. Such a configuration occurs when the potential energy of the nucleus is characterized by local minima for different shapes. If the potential barrier separating the secondary minimum from the ground-state minimum is sufficient strong the excited 0+ state will become a long-lived state, a so-called shape isomer.

The first successful observation of a nuclear two-photon decay was achieved in the 1980s by a direct detection of the simultaneously emitted gamma-rays. However, the very small branching ratio with respect to other decay paths, such as internal conversion, becomes minuscule when searching for low-lying 0+ states below ~1 MeV. In this talk I will present an alternative method to directly search for such isomers by using time-resolved mass spectrometry at relativistic energies, where the atomic nucleus is completely stripped of its atomic electrons and report on the first successful experiment to directly observe the decay from an isomer in 72Ge at the GSI Experimental Storage Ring (ESR).

Group Report MS 3.2 Tue 11:00 MS-H9

Towards the Lifetime Measurement of the ^{229m}Th^{3+} Nuclear Clock Isomer — •Kevin Scharl[1], Benedict Seiferle[1], Shiqian Ding[1,2], Daniel Moritz[1,2], Florian Zacherl[1], and Peter G. Thirolf[1] — [1]LMU Munich — [2]Tsinghua University Beijing, China

The elusive Thorium Isomer (^{229m}Th) with its unusually low-lying first excited state (8.19 ± 0.12 eV or λ = 150.4 ± 2.2 nm) represents the so far only candidate for the realization of an optical nuclear clock, potentially capable to outperform even state-of-the-art optical atomic clocks. Moreover, possible applications of a nuclear clock are not limited to time keeping, but reach into many other fields from geodesy to dark matter research. Considerable progress was achieved in recent years on the characterization of the thorium isomer, from its first identification, the determination of its lifetime in neutral charge state and of the isomeric hyperfine structure to recent direct decay measurements. While the identification of the nuclear resonance with laser spectroscopic precision is still awaited, a measurement of the ionic lifetime of the isomer (theory prediction: 10^3-10^4 s) is being prepared by our group. A cryogenic Paul trap is the core of this setup, providing long enough storage time for the ^{229m}Th ions. Prior to targeting the ionic lifetime by hyperfine spectroscopy, sympathetic laser cooling using ^{88}Sr$^+$ ions will be applied to the stored ions. The talk will present the status of the commissioning of the setup for ^{229m}Th^{3+} ion generation, cryogenic storage, laser cooling and spectroscopic studies.

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MS 3.3 Tue 11:20 MS-H9

Shedding light on low-lying metastable states in the heaviest elements with SHIPTRAP at GSI — •Francesca Giacoppo[1,2], Brankica Anđelić[1,2,3], Luisa Arcila Gonzalez[3], Joaquín Berrocal[4], Lennart Blaauw[3], Klaus Blaum[5], Michael Block[1,2,6], Pierre Chauveau[1,2], Stanislav Chenmarev[2,5,7], Christoph E. Düllmann[1,2,6], Julia Even[3], Manuel J. Gutiérrez[1,2,4], Fritz P. Hessberger[1,2], Nasser Kalantar-Nayestanaki[3], Oliver Kaleja[1,8], Steffen Lohse[2,6], Enrique Minaya Ramirez[9], Andrew Mistry[1], Elodie Morin[9], Yury Nechiporenko[7,10], Dennis Neidherr[1], Steven Nothhelfer[2,6], Yuri Novikov[7,10], Sebastian Raeder[1,2], Elisabeth Rickert[2,6], Daniel Rodríguez[4], Lutz Schweikhard[8], Peter G. Thirolf[11], Jessica Warbinek[1,2,6], and Alexander Yakushev[1,2] — [1]GSI Darmstadt, Germany — [2]HIM Mainz, Germany — [3]University of Groningen, the Nederlands — [4]University of Granada, Spain — [5]MPIK Heidelberg, Germany — [6]JGU Mainz, Germany — [7]PNPI Gatchina, Russia — [8]Universiy of Greifswald, Germany — [9]IJCLab Orsay, France — [10]Saint Petersburg State University, Russia — [11]LMU Munich, Germany

Probing the limit of existance at the uppermost corner of the nuclear chart requires a deep understanding of the nuclear properties of very heavy nuclides and their evolution in the superheavy region.

In the framework of the FAIR phase-0 program, the goal of directly investigating the mass of superheavy nuclei (Z⩾104) is pursued at the Penning-trap mass spectrometer SHIPTRAP at GSI. In the latest campaign the masses of the ground states as well as of low-lying metastable states of ^{257}Rf (Z=104) and ^{258}Db (Z=105) have been precisely measured. In addition, several heavy nuclides above the Z=82 magic shell closure have been investigated. Many of these nuclei display shape deformation and complex shell configurations with often more than one competing level at low energies. Such states have traditionally been studied by decay and laser spectroscopy, as for instance the ^{206}Fr-^{202}At-^{198}Bi chain. In our last campaign the excitation energies of the metastable states in some of the key nuclei in this region have been finally directly measured, allowing to benchmark the proposed level and decay schemes.

MS 3.4 Tue 11:35 MS-H9

Fission isomer studies with the FRS Ion Catcher — •Nazarena Tortorelli[1], Timo Dickel[2,3], Ilkka Pohjalainen[2,4], Peter G. Thirolf[1], Michiharu Wada[5], and Jianwei Zhao[2,6] — [1]Ludwig-Maximilian-University, Munich, Germany — [2]GSI Helmholtzentrum für Schwerionenforschung Darmstadt, Germany — [3]JLU Gießen, Germany — [4]University of Jyväskylä, Finland — [5]KEK Wako Nuclear Science Center, Japan — [6]Peking University, Beijing, China

The potential energy landscape in actinide nuclei (Z = 92-97, N = 141-151) shows a "super-deformed" second minimum. The ground state in this minimum is called a fission isomer, as it will preferably decay via isomeric (delayed) fission with known half-lives between 5 ps and 14 ms. The fragmentation mechanism (i.e. the collision of a heavy relativistic beam with a light target) offers rapid production, hence access to isomers with short half-lives, and most importantly, a clean beam and event-by-event identification.

In this contribution, we will present fission isomer studies (e.g. on ^{235}mU) with the FRS Ion Catcher at GSI where a 1 GeV/u ^{238}U beam fragments on a Be target. The projectile fragments are filtered by the FRS magnetic fragment separator and then slowed down and thermalized in the Cryogenic Stopping Cell (CSC) before being extracted into the diagnostic section for time-of-flight mass spectrometry (MR-TOF-MS).

MS 3.5 Tue 11:50 MS-H9

A cryogenic Paul trap setup for the determination of the ionic radiative lifetime of ^{229m}Th^{3+} — •Daniel Moritz[1], K. Scharl[1], B. Seiferle[1], F. Zacherl[1], T. Dickel[2,3], F. Greiner[2,3], W. Plass[2,3], L. von der Wense[1,4], T. Leopold[5,6], P. Micke[5,7], J. Crespo López-Urrutia[5], P.O. Schmidt[6], and P.G. Thirolf[1] — [1]Ludwig Maximilians Universität München — [2]Justus Liebig Universität Gießen — [3]GSI Darmstadt — [4]JILA, University of Colorado, USA — [5]Max-Planck-Institut für Kernphysik, Heidelberg — [6]PTB Braunschweig — [7]CERN, Genf, Schweiz

The exceptionally low energy of the isomeric first excited nuclear state of ^{229}Th, which has recently been constrained to 8.28±0.17 eV (i.e. λ=149.7±3.1 nm)[1], allows for direct laser excitation with current technology. This offers the unique opportunity to develop a nuclear clock capable of competing or even outperforming existing atomic clocks. One of the next steps towards the realization of such a clock is the determination of the ^{229}Th isomer's ionic lifetime (theoretically expected to range between $10^3 - 10^4$ seconds) via hyperfine spectroscopy. In order to achieve the required long ion storage time, a cryogenic Paul-trap with a corresponding mass-selective ion guide system has been set up at LMU Munich. The talk will present this new experimental platform. This work was supported by DFG (Th956/3-2) as well as by the European Union's Horizon 2020 research and innovation program under grant agreement 6674732 "nuClock" and the ERC Synergy Grant "ThoriumNuclearClock".

[1] B. Seiferle et al., Nature 573, 243 (2019).