HK 50: Structure and Dynamics of Nuclei X

Zeit: Donnerstag 14:00–15:45 Raum: HS 16

Gruppenbericht HK 50.1 Do 14:00 HS 16

Towards a direct energy determination of the ^{229}Th nuclear isomer — •Benedict Seiferle, Ines Amersdorffer, Lars von der Wense, and Peter G. Thirolf — LMU Munich, 85748 Garching, Germany.

The nuclear first excited state in ^{229}Th (^{229m}Th) offers the unique possibility of a direct optical control of a nucleus with today's laser technology. The energy of 7.8(5) eV and it's lifetime make it a promising candidate for a nuclear optical clock. The large uncertainty of the excitation energy, however, impedes progress towards a nuclear clock. Therefore the objective of our experiment is a precise determination of the excitation energy of ^{229m}Th via the measurement of electrons emitted during the internal conversion decay of the excited state. First measured spectra will be presented.

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HK 50.2 Do 14:30 HS 16

Towards a ^{229m}Th energy determination with 40 μeV accuracy — •L. von der Wense[1], B. Seiferle[1], Ch. Schneider[2], J. Jeet[2], I. Amersdorffer[1], N. Arlt[1], F. Zacherl[1], R. Haas[3,4,5], D. Renisch[3,4], Pa. Mosel[6], Ph. Mosel[6], M. Kovacev[6], U. Morgner[6], Ch.E. Düllmann[3,4,5], E.R. Hudson[2], and P.G. Thirolf[1] — [1]Ludwig-Maximilians-Universität München — [2]University of California, Los Angeles — [3]Johannes Gutenberg-Universität Mainz — [4]Helmholtz-Institut Mainz — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [6]Leibniz Universität Hannover

The development of a nuclear clock has been a long-standing objective [1]. There is only one nuclear excitation known which could allow for the development of a nuclear clock due to its exceptionally low energy of only a few eV above the ground state. This is the metastable first excited state in ^{229}Th [1, 2]. The development of a ^{229}Th-based nuclear clock is so far hindered by an insufficient knowledge of the excited state's energy. A new scheme of experimental search will be presented, which could allow to pin down the isomeric energy value to 40 μeV accuracy, thereby paving the way to the development of a nuclear clock [3]. The concept makes use of a direct nuclear laser excitation scheme.

[1] L. v.d.Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle et al., PRL 118, 042501 (2017).
[3] L. v.d.Wense et al., PRL 119, 132503 (2017).

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HK 50.3 Do 14:45 HS 16

Magnetic dipole moment predictions for ^{229}Th — •Adriana Pálffy[1] and Nikolay Minkov[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institute of Nuclear Research and Nuclear Energy, Sofia, Bulgaria

The ^{229}Th actinide isotope has a $I = 3/2$ isomeric state lying only 7.8 eV above the ground state. This extremely small energy renders for the first time a nuclear transition accessible to vacuum ultraviolet lasers. Novel applications such as a nuclear frequency standard with unprecedented accuracy based on this transition are anticipated.

A recent laser spectroscopy experiment [1] has determined for the first time the magnetic dipole moment of the isomeric state. The measured value differs by a factor of approx. 5 from previous nuclear theory predictions based on the Nilsson model, raising questions about our understanding of the underlying nuclear structure. Here, we present a new theoretical prediction based on a nuclear model with coupled collective quadrupole-octupole and single-particle motions. Our calculations yield an isomer magnetic dipole moment of $\mu_{IS} = -0.35\mu_N$ in surprisingly good agreement with the experimentally determined value of $-0.37(6)\mu_N$, while overestimating the ground state dipole moment by a factor 1.4 [2]. The model provides further information on the states' parity mixing, the role and strength of the Coriolis mixing and the most probable value of the gyromagnetic ratio g_R and its consequences for the transition probability $B(M1)$.

[1] J. Thielking *et al.*, Nature (London) 556, 321 (2018).
[2] N. Minkov and A. Pálffy, arXiv:1812.03921 [nucl-th] (2018).

HK 50.4 Do 15:00 HS 16

Nuclear excitation by electron capture in a beam-target scenario — •Yuanbin Wu and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

A recent nuclear physics experiment [1] reports the first direct observation of nuclear excitation by electron capture (NEEC) in the depletion of the ^{93m}Mo isomer. The experiment used a beam-based setup in which Mo highly charged ions with nuclei in the isomeric state ^{93m}Mo at 2.4 MeV are slowed down in a solid-state target and electron recombination can excite the nucleus to produce isomer depletion via a triggering level lying 4.85 keV above the isomer. The reported excitation (and subsequent depletion) probability $P_{\rm exc} = 0.01$ was attributed to the so-far unobserved process of NEEC.

In this work, we investigate theoretically the beam-based setup and calculate isomer depletion rates based on state-of-the-art NEEC cross sections [2] and different ion stopping power models. For all scenarios, our calculated NEEC probability is several orders of magnitude smaller than the measured $P_{\rm exc}$. This large discrepancy suggests that the observed isomer depletion has a different underlying nuclear excitation mechanism than NEEC.

[1] C. J. Chiara, J. J. Carroll, M. P. Carpenter, *et al.*, Nature 554, 216 (2018).
[2] Y. Wu, J. Gunst, C.H. Keitel, and A. Pálffy, Phys. Rev. Lett. 120, 052504 (2018).

HK 50.5 Do 15:15 HS 16

Laser-assisted nuclear excitation by electron capture — •Pavlo Bilous and Adriana Pálffy — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, D-69117 Heidelberg, Germany

Transitions within the low-lying nuclear spectrum can often efficiently couple to the atomic shell [1]. The process of laser-assisted nuclear excitation by electron capture (LANEEC) is an excitation mechanism for low-lying nuclear levels via photoionization of the electronic shell with an X-ray photon with subsequent nuclear excitation by electron capture (NEEC). NEEC is the time-reversed process of internal conversion. The electron can recombine either into a vacancy in an open electronic shell or with a hole created prior to NEEC with another X-ray photon.

On the one hand, LANEEC may allow usage of X-ray free-electron lasers (XFEL) for nuclear excitations at energies which cannot be reached by direct photoexcitation today, for instance, the nuclear state at 29.19 keV of the ^{229}Th isotope. On the other hand, the LANEEC process could provide especially large enhancement for highly forbidden transitions, such as the excitation of the 76 eV isomer in ^{235}U proceeding via an electric octupole (E3) channel. In this work we consider the LANEEC process for nuclear excitation in several isotope species and compare the obtained rates to the ones achievable in direct one- or two-photon excitation which do not involve the electronic shell. The obtained results may be useful in the area of X-ray quantum optics with nuclei.

[1] A. Pálffy, Contemporary Phys. 51, 471 (2010).

HK 50.6 Do 15:30 HS 16

Sudden regime of laser-nucleus interaction — •Sergei Kobzak, Hans Weidenmüller, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent experimental developments in laser physics and laser-driven acceleration promise to deliver coherent photon beams with energies ranging up to several MeV. Novel experiments employing a laser beam with photon energies comparable to typical nuclear excitation energies will shed light on a number of questions and will open new unexplored avenues for nuclear physics [1,2].

In this work we investigate theoretically the interaction between coherent gamma-ray laser pulses and medium-weight or heavy nuclei. The time-dependent interplay between the average photon absorption, the compound nucleus statistical equilibration rate and the neutron evaporation rate is studied with the help of the master equation [2]. The sudden regime of laser-nucleus interaction refers to the case when photon absorption occurs faster than the nuclear equilibration of the nucleus. Consequently, nucleons are excited independently and are expelled from the common average potential. Multiple photon absorption may lead to complete evaporation of the nucleus if the duration of the laser pulse of several MeV per photon is long enough. We investigate the time scale and the characteristic parameters for the sudden regime.

[1] A. Pálffy and H. A. Weidenmüller, Phys. Rev. Lett. 112, 192502 (2014).
[2] A. Pálffy, O. Buss, A. Hoefer and H. A. Weidenmüller, Phys. Rev. C 92, 044619 (2015).