100 Years of Nuclear Isomers

Book of Abstracts

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100 Years of Nuclear Isomers

Monday, May 2, 2022

Time			Duration
Opening / Welcome and Status			
08:00	Registration Open	Lea Wunderlich	
09:15	Welcome	Philip Walker	15'
Session Nuclear Structure I			
09:30	E3 Decaying Isomers and Octupole Collectivity in the Vicinity of ^{208}Pb	Zsolt Podolyak	25'+5'
10:00	In-Beam Gamma-Ray Spectroscopy and Lifetime Measurements with HiCARI	Kathrin Wimmer	25'+5'
10:30	On the Trail of Low-Lying Isomeric States by Penning-Trap Mass Spectrometry	Klaus Blaum	25'+5'
11:00	Coffee Break		30'
Session Nuclear Structure II			
11:30	From Shape Coexistence to Shape Isomers in Atomic Nuclei	Wolfram Korten	25'+5'
12:00	Structure and Energy of Isomeric States of Some Well-Deformed Even-Even Rare-Earth and Actinide Nuclei, a Microscopic Approach	Philippe Quentin	12'+3'
12:15	Decay Spectroscopy With Isomeric Beams Using the GRIFFIN Spectrometer at TRIUMF	Corina Andreoiu	12'+3'
12:30	Isomeric States at the Extremes of Proton Stability	Lidia S. Ferreira	12'+3'
12:45	Lunch		60'
14:00	Poster Session (Online)		60'
Session The Intriguing ^{229}Th Isomer			
15:00	Nuclear Metastability: From K-Isomers to the Optically Accessible ^{229m}Th	Nikolay Minkov	25'+5'
15:30	Status and Perspectives for a Nuclear Clock Based on the ^{229m}Th Isomer	Peter Thirolf	25'+5'
16:00	Continued Efforts Towards Direct Laser Spectroscopy of ^{229m}Th	Lars von der Wense	25'+5'
16:30	Coffee Break		30'
Session Evening Online Session			
17:00	Isomers in Superheavy Nuclei	Rod Clark	25'+5'
17:30	Isomer Studies by the Army Research Laboratory	Jeff Carroll	25'+5'
18:00	Transfer Reactions with Isomeric Beams for Nuclear Astrophysics	Sergio Almaraz-Calderon	12'+3'
18:15	Isomer Studies for r-Process Nucleosynthesis	Daniel Hoff	12'+3'
18:30	Studying Proton Capture on Astrophysical Isomers with SECAR	Kelly Chipps	12'+3'
18:45	Determining Cross sections for Neutron Capture Reactions Involving Isomeric States	Jutta Escher	12'+3'
19:00	Poster Session (on site)		90'

100 Years of Nuclear Isomers

Tuesday, May 3, 2022

Time			Duration
Session Isomers in Nuclear Structure and Astrophysics (Morning Online Session)			
08:30	Isomers, the Key to the Origin of Heavy Elements and Neutrino Mass Hierarchy	Taka Kajino	25'+5'
09:00	Shell Evolution Below ^{132}Sn and its Impact on Gamow-Teller beta Decay from the $(27/2^{+})$ Isomer in ^{127}Ag	Hiroshi Watanabe	25'+5'
09:30	Rotations of High-K Quasiparticle States	Furong Xu	25’+5'
10:00	Shape-Isomer-Like Excitations in 64, 66Ni Isotopes	Silvia Leoni	12'+3'
10:15	Coffee Break		30'
Session Atomic-Shell Nucleus Interface, ^{229}Th, Symmetries, etc.			
10:45	Dark Matter Searches with 229Th Isomer	Marianna Safronova	25'+5'
11:15	New Experimental Approaches to Nuclear Isomers for Nuclear Astrophysics	Iris Dillmann	25'+5'
11:45	Ultraviolet Spectroscopy of the Actinium-229 Beta Decay: On the Way to the First Observation of ^{229m}Th’s Radiative Decay?	Sandro Kraemer	12'+3'
12:00	Prospective Isomeric Studies with High-Brilliance Gamma Beams	Dimiter Balabanski	12'+3'
12:15	Proton Emission from ^{54m}Ni and Mirror Symmetry (Breaking) with ^{54m}Fe	Dirk Rudolph	12'+3'
12:30	Correlated Prompt-Delayed Gamma Spectroscopy for Nuclear Structure Studies: Isomers in the Neutron-Rich Kr Isotopes Approaching N=60	Andrey Blazhev	12'+3'
12:45	Lunch		60'
Session Precision Mass Spectrometry, Nuclear Structure			
13:45	Seniority and Isomerism in Nuclei	Bhoomika Maheshwari	25'+5'
14:15	Isomers Explored with Novel Ion-Trapping Techniques at JYFLTRAP	Anu Kankainen	25'+5'
14:45	Direct Mass-Measurements of the ^{99}In Isomeric State Provide New Experimental Input to Nuclear Theory	Lukas Nies	12'+3'
15:00	Coffee Break		30'
Session Evening Online Session			
15:30	Developments of Nuclear Structure Models for Isomers	Yang Sun	25'+5'
16:00	Highly-Converted and Low-Energy Isomer Searches and FRIB	Sean Liddick	25’+5'
16:30	Astromers: Astrophysically Metastable Isomers	G. Wendell Misch	25’+5'
17:00	Another Isomer in ^{102}Rh?	Eric Norman	12’+3’
17:15	Manifestation of the Berry Phase in the Atomic Nucleus ^{213}Pb	Jose Javier Valiente Dobon	12'+3'
17:30	A changing nuclear structure beyond N=126 from isomers in ^{211,213}Tl and ^{210}Hg	Andrea Gottardo	12'+3'
17:45	Break		15'
Evening Lecture			
18:00	Otto Hahn – His Life and His Impact on Science and Mankind	Horst Schmidt-Boecking	60'
19:30	Dinner		120'

100 Years of Nuclear Isomers

EMMI

Wednesday, May 4, 2022

Time			Duration
Session Isomers in Nuclear Structure and Astrophysics (Morning Online Session)			
08:30	From Exotic Symmetries to Exotic Isomers in Both Stable and Exotic Nuclei	Jerzy Dudek	25'+5'
09:00	^{83}Kr Isomers Induced by High Intensity Femtosecond Lasers	Changbo Fu	12’+3’
09:15	Auger and X-ray K-Shell Fluorescence Measurements for Sc-44 Isomeric Decays	Carl Wheldon	12’+3’
09:30	K Isomers in ^{248}Cf and the Z=100 Deformed Shell Gap	Riccardo Orlandi	12’+3’
09:45	Self-Consistent Mean Field Studies of Multi-Quasiparticle Excitations with the Gogny Force	Luis Miguel Robledo	12'+3'
10:00	Coffee Break		30'
Session Isomers in Heavy and Superheavy Nuclei			
10:30	Investigation of Isomers in Heavy Nuclei	Michael Block	25'+5'
11:00	Nuclear Isomers – A Probe of Nuclear Structure and Deformation for the Heaviest Nuclei	Dieter Ackermann	25’+5’
11:30	High-K isomeric States in the A~250 Region: New Isomers in ^{249,251}Md and Stability Inversion in ^{250}No	Christophe Theisen	12'+3'
11:45	Fission Hindrance of High-K Isomers in Transfermium Nuclei	Benoit Gall	12'+3'
12:00	Lunch		60'
Session Isomer Applications, Nuclear Structure			
13:00	Isomers for Medicine	Ulli Koester	25'+5'
13:30	On the Use of Nuclear Isomers in Solid State Physics	Heinz-Eberhard Mahnke	25’+5’
14:00	First Access to Isomeric Transitions in N > 126 Nuclei at RIKEN	Anabel Morales	25'+5'
14:30	Beta-Decaying Isomers in Deformed Neutron-Rich Nuclei: Nuclear Structure and Role of K Forbiddenness	Filip Kondev	25'+5'
15:00	Conclusion		10'

Type: **Talk**

Contribution ID: **1**

Prospective isomeric studies with high-brilliance gamma beams

Tuesday, May 3, 2022 12:00 PM (15 minutes)

Several aspects of the ELI-NP research program related to isomeric studies will be presented, namely, population of isomers and decay studies in γ-beam activation experiments, studies of doorway states for population or depopulation of isomers in γ-beam experiments and measure-ments of photofission product yields. he possibilities for generation of γ beams with orbital angular momentum (OAM) will be dis-cussed and the new opportunities for isomeric studies with OAM photons will be highlighted.

Primary author: BALABANSKI, Dimiter (ELI-NP / IFIN-HH)

Presenter: BALABANSKI, Dimiter (ELI-NP / IFIN-HH)

Session Classification: Atomic-Shell Nucleus Interface, 229 h, Symmetries, etc.

Contribution ID: **2** Type: **Talk**

Manifestation of the Berry phase in the atomic nucleus ^{213}Pb

Tuesday, May 3, 2022 5:15 PM (15 minutes)

We obtained some fascinating results on the ^{213}Pb neutron-rich nucleus studied using the unique availability of a primary 1 GeV A ^{238}U beam and of the FRS-RISING setup at GSI. The products of the uranium fragmentation were separated in mass and atomic number and then implanted for isomer decay γ-ray spectroscopy. A level scheme from the decay of the $21/2^+$ isomer, based on γ intensities, γ-γ coincidences and state lifetimes was built up and the $E2$ transition probabilities from the $21/2^+$ isomer to two low-lying $17/2^+$ levels were also deduced.

This experimental data has evidenced one of the best examples of a semi-magic nucleus with a half-filled isolated single-j shell where seniority selection rules are obeyed to a very good approx-imation. In the most simple shell-model approach ^{213}Pb can be described as five neutrons in the $1g_{9/2}$ orbital on top of the ^{208}Pb core. Large scale shell-model calculations in the full valence space beyond ^{208}Pb confirm that although the $1g_{9/2}$ orbital is not isolated in energy, it is found to carry the dominant component in the wave function of the low-energy states. The experimental level scheme and the reduced transition probabilities are in good agreement with the theoretical description that predicts the existence of two $17/2^+$ levels of a very different nature: one with seniority $\upsilon = 3$, while the other with $\upsilon = 5$. The absence of mixing between the two $17/2^+$ states follows from the self-conjugate character of ^{213}Pb, where the particle-hole transformation defines an observable Berry phase that leads to the conservation of seniority for most but not all states in this nucleus.

The Berry phase [1], which is a gauge-invariant geometrical phase accumulated by the wavefunc-tion along a closed path, is a class of observables that are not associated with any operator. It is a key feature in quantum-mechanical systems, that has far reaching consequences, and has been found in many fields of physics since its postulation in the eighties. In the atomic self-conjugate nucleus ^{213}Pb, the quantized Berry phase is evidenced by the conservation of seniority under the particle-hole conjugation transformation. In atomic nuclei no experimental signature of the Berry phase was reported up to now.

[1] M. V. Berry, Proc. Roy. Soc. A392, 45 (1984).

Primary authors: VALIENTE DOBON, Jose Javier (INFN-LNL); GOTTARDO, Andrea (Laboratori Nazionali di Legnaro, Istituto Nazionale di Fisica Nucleare); BENZONI, Giovanna (Instituto Nazionale di Fisica Nucleare (INFN) (INFN-Milano))

Presenter: VALIENTE DOBON, Jose Javier (INFN-LNL)

Session Classification: Evening Online Session

Contribution ID: **3** Type: **Talk**

Fission hindrance of high-K isomers in transfermium nuclei

Wednesday, May 4, 2022 11:45 AM (15 minutes)

To date, the fission branch of only a handful of identified high-K isomers has been measured or a lower limit inferred and, except in the cases of ^{250}No [1-3] and ^{254}Rf [4], all partial fission half-lives or their lower limits are reported to be shorter than the partial fission half-life of the corresponding ground state [5]. This is at odds with estimates of expected fission hindrances (defined as the ratio of the isomer and ground state partial fission half lives) due to the specialisation energy and reduced pairing fields associated with high-K states [6] and clearly calls for a revision of the available data. We report here on new measurements of the fission hindrances of high-K isomers in ^{250,252,254}No using the GABRIELA detector array [7,8] at the focal plane of the recoil separator SHELS [9].

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[1] A. Belozerov et al., Eur. Phys. J. A 16 (2003) 447

[2] D. Peterson et al., Phys. Rev. C 74 (2006) 014316

[3] J. Kallunkathariyil et al. Phys. Rev. C 101 (2020) 011301(R)

[4] H. David et al., Phys. Rev. Lett. 115 (2015) 132502}

[5] F. Kondev, G. Dracoulis and T. Kibedi, At. Dat. And Nucl. Dat. Tables 103-104 (2015) 50

[6] R.M. clark, EPJ Web of Conferences 131 (2016) 02002

[7] K. Hauschild et al., Nucl. Instr. Meth. A 560 (2006) 388-394

[8] R. Chakma et al., Eur. Phys. J. A 56 (2020) 245

[9] A. Popeko et al., Nucl. Instr. Meth. B 376 (2016) 140}

Primary authors: LOPEZ-MARTENS, Araceli (IJCLab); GALL, Benoit (IPHC CNRS) **Presenter:** GALL, Benoit (IPHC CNRS)

Session Classification: Isomers in Heavy and Superheavy Nuclei

Contribution ID: **4** Type: **Poster**

Physics of laser-assisted nuclear processes

Monday, May 2, 2022 2:00 PM + *7:00 PM*

A considerable progress during the past decades was achieved in investigation of the interrelation of the atomic structure with the nuclear processes. Nuclear isomers can be effectively triggered by making use of a resonance with the electronic transitions, which can be further tuned either through changing the electron shell, or irradiating with resonance field of a laser [1,2]. Thus, it was predicted that the decay of the 229Th isomer would be by ~700 times faster in the hydrogen-like ions. The lifetime of the nucleus in the crystal matrix also may vary.
New mode of nuclear decay: resonance conversion (RC) was predicted, suitable for the purposes of triggering. RC was discovered in fragments of prompt fission in muonic atoms [3] and 35-keV transition in 125Te [4]. The effect has to be especially strong in heavy ions, where RC can be ob-served in its undamped mode.
Moreover, experiments show influence of the electronic shells on the processes, mastered by other fundamental interactions, e.g. beta decay of isomers. Thus, effect of the electronic shake on the double e-capture diminishes the lifetimes of the parent nuclei by several times. There is a compar-ative study of α decay in H-, He-like ions on the urgent agenda, with respect to that in neutral atoms.
The resonance properties of the electron shell are of extreme importance for creation of the nu-clear clock. From the other side, it is generally accepted that the nuclear properties, specifically the radioactive decay constant, are essentially independent of the physical environment. Such stabil-ity against the environmental medium underlies the idea of the nuclear clock. This is in contrast with what is said above. In fact, in the case of the nuclear deexcitation through the resonance conversion (or electronic bridge), the decay probability turns out to be directly proportional to the atomic width. Therefore, it may be mastered by simple factors, such as ambient temperature and atmospheric pressure. This dependence may be directly related to the thorium puzzle of the short lifetime in the single ions [3]. Especial features of the electronic-nuclear resonance are discussed.

[1] B. A. Zon and F. F. Karpeshin, Sov. Phys. — JETP, 70, 224 (1990).
[2] F. F. Karpeshin, Prompt Fission in Muonic Atoms and Resonance Conversion. Saint-Petersburg: Nauka, 2006.
[3] C. Roesel, F. F. Karpeshin, P. David et al., Z. Phys. A 345, 425 (1993).
[4] F. F. Karpeshin, M.R.Harston, F. Attallah et al., Phys. Rev. {\bf C53} (1996) 1640.
[5] F. F. Karpeshin and M. B. Trzhaskovskaya, Nucl. Phys. A 1010, 122173 (2021).

Primary author: KARPESHIN, Feodor (Weizmann Institute of Science, Rehovot)

Presenter: KARPESHIN, Feodor (Weizmann Institute of Science, Rehovot)

Session Classification: Poster Session On Site

Contribution ID: **5**

Type: **Talk**

Rotations of high-K quasiparticle states

Tuesday, May 3, 2022 9:30 AM (30 minutes)

Self-consistent configuration-constrained Total Routhian Surfaces (TRS) [1,2] have been developed to treat the collective rotations of quasiparticle states built on broken-pair excited configurations. Two types of interaction have been used for the configuration-constrained TRS calculations: the deformed Woods-Saxon potential and the two-body Skyrme force within the Hartree-Fock approx-imation in the (β2, β4, γ) deformation lattice. To avoid the pairing collapse, the particle-number-conserving (PNC) pairing was employed, which takes the shell-model diagonalization technique. The rotational bands of various quasiparticle configurations from Kπ=7− to Kπ=30+ in 178W have been calculated, giving good agreements with data in the moments of inertia. The configuration-constrained TRS's show the deformation evolution with changing rotational frequency and con-figuration. The irregularities in the observed moments of inertia of the Kπ=8− bands in transfer-mium nuclei (e.g., 252No and 250Fm) were explained by the configuration mixing (band crossing) with a two-proton Kπ = 7− band [3]. Within Hartree-Fock plus PNC pairing, the configuration-constrained TRS based on the microscopic Skyrme interaction has been successfully applied to the high-K bands of Hf isotopes [2].

References:

1. X. M. Fu, F. R. Xu, J. C. Pei, C. F. Jiao, Yue Shi, Z. H. Zhang, and Y. A. Lei, Phys. Rev. C 87, 044319 (2013).
2. W. Y. Liang, C. F. Jiao, Q. Wu, X. M. Fu, and F. R. Xu, Phys. Rev. C 92, 064325 (2015).
3. X. M. Fu, F. R. Xu, C. F. Jiao, W. Y. Liang, J. C. Pei, and H. L. Liu, Phys. Rev. C 89, 054301 (2014).

Primary authors: XU, Furong (School of Physics, Peking University); Dr FU, Ximing (School of Physics, Peking University); Dr LIANG, Wuyang (School of Physics, Peking University)

Presenter: XU, Furong (School of Physics, Peking University)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **6**

Type: **Talk**

Status and Perspectives for a Nuclear Clock based on the 229mTh isomer

Monday, May 2, 2022 3:30 PM (30 minutes)

Today's most precise time and frequency measurements are performed with optical atomic clocks. However, it has been proposed that they could potentially be outper-formed by a nuclear clock, which employs a nuclear transition instead of an atomic shell transition. There is only one known nuclear state that could serve as a nuclear clock us-ing currently available technology, namely the isomeric first excited state of 229Th. Evi-dence for its existence until recently could only be inferred from indirect measurements, suggesting since 2009 an excitation energy of 7.8(5) eV, representing the lowest nuclear excitation so far reported in the whole landscape of known isotopes. In 2016, the first di-rect detection of this nuclear state could be realized via its internal conversion decay branch, laying the foundation for precise studies of its decay parameters [1]. Subse-quently, a mea-surement of the half-life of the neutral isomer was achieved, confirming the expected reduction of 9 orders of magnitude compared to the one of charged 229mTh [2]. Collinear laser spectroscopy was applied to resolve the hyperfine structure of the thorium isomer, providing information on nu-clear moments and the nuclear charge radius [3]. Most recently, also the cornerstone on the road towards the nuclear clock, which is a precise and direct determination of the excitation energy of the isomer, could be achieved by locating the isomeric excitation energy as 8.19(12) eV [4,5]. Hence major progress on the properties of this elusive nuclear state could be achieved in recent years, opening the door towards an all-optical control and thus the development of an ultra-precise nuclear frequency standard. Such a nuclear clock promises intriguing applications [6] in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of pos-sible time variations of fundamental constants and the search for Dark Matter. The collaborative project 'ThoriumNuclearClock', funded by the European Union, recently em-barked to consolidate and improve our knowledge on the thorium isomer, to realize a first pro-totype of a Nuclear Clock and apply it to fundamental physics studies [7]. The talk will review recently completed, ongoing and planned activities towards this goal.

[1] L. v.d. Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle, L. v.d. Wense, P.G. Thirolf, Phys. Rev. Lett. 118, 042501 (2017).
[3] J. Thielking et al., Nature 556, 321 (2018).
[4] B. Seiferle, L. v.d. Wense, P.G. Thirolf, Eur. Phys. Jour. A 53, 108, (2017).
[5] B. Seiferle et al., Nature 573, 243 (2019).
[6] P.G. Thirolf, B. Seiferle, L. v.d. Wense, Annalen der Physik 531, 1800391 (2019).
[7] E. Peik et al., Quantum Sci. Technol. 6, 034002 (2021).

Primary author: THIROLF, Peter (Ludwig-Maximilians-Universität München)

Presenter: THIROLF, Peter (Ludwig-Maximilians-Universität München)

Session Classification: The Intriguing 229Th Isomer

Contribution ID: **7**

Type: **Poster**

Half-life measurement of short-lived 94mRu44+ using isochronous mass spectrometry

Monday, May 2, 2022, 2 PM, Poster Session Online

Half-life of short-lived bare isomer 94m Ru44+ has been studied for the first time at the HIRFL-CSR facility in Lanzhou by employing the Isochronous Mass Spectrometry (IMS) method. It was populated in projectile fragmentation of a 112Sn beam on a 9Be target. Fragmentation products in the region of interest were passed through the radioactive ion beam line and injected into the experimental ring. Isochronous mass spectrometry was performed normally 33 microsecond after fragmentation were injected into the experimental ring by using a pulsed high-voltage power supply. The transition of 8+ isomer 94m Ru44+ via γ cascades to a final 0+ ground state was directly observed when it was being stored in the ring. The half-life of 94m Ru44+ obtained from 39 decay cases and 29 no decay cases is considerably longer than that of its neutral atom due to the hindrance of internal conversion in a bare ion. The isomeric half-life was deduced to be 102(17) μs, which agrees well with the theoretical expectation by blocking the internal conversion decay of the isomer. Our work proved the feasibility of studying decays of short-lived isomers in high atomic charge states using the isochronous mass spectrometry. In addition, 94mRu44+ represents the shortest-lived nuclear state whose mass has ever been measured directly.

Primary authors: ZENG, Qi (East China University of Technology,China); WANG, Meng (Institute of Modern Physics, Chinses Academy of Sciences)

Presenter: ZENG, Qi (East China University of Technology,China)

Contribution ID: **8**

Type: **Talk**

A changing nuclear structure beyond N=126 from isomers in ^{211,213}Tl and ^{210}Hg

Tuesday, May 3, 2022 5:30 PM (15 minutes)

Magic nuclei are the cornerstone of our understanding of the nuclear structure, and the double shell closure in ^{208}Pb (Z=82, N=126) makes no exception. The persistence of these magic number far from ^{208}Pb is a key issue for the understanding of heavy nuclei as well as for the r-process path. While the region beyond N=126 and below Z=82 is difficult to reach with multi-nucleon transfer or fusion-evaporation reactions, the exploitation of cold fragmentation reactions from ^{238}U at GSI has allowed one to perform a first spectroscopy study of these nuclei by isomer decay spectroscopy. Predicted seniority isomers were found in $^{212-216}$Pb as well as in ^{213}Pb, pointing out the role of $0\hbar\omega$ excitations across the ^{208}Pb core in determining the quadrupole polarization properties of excited states in these semi magic nuclei.

However, the combination of the high selectivity of the FRS spectrometer with the high sensi-tivity of the RISING γ-ray array at GSI, led to the population and study for the first time of the exotic nuclei ^{211,213}Tl and ^{210}Hg, three to four neutrons beyond N=126. The talk will address the deviation of the observed isomers (and their decay pattern) from shell-model predictions and seniority-scheme systematic from the neighboring lead isotopes. In particular, we will underline issues with the proton-hole space below Z=82, and compare our findings with the well understood structure of Tl and Hg isotopes with N<126.

Finally, new opportunities for studying these nuclei with in-flight as well as ISOL beams, measur-ing different variables and trying to extend the isomer spectroscopy up to ^{218,220}Pb, ^{215}Tl and ^{212}Hg will be pointed out, also in view of the FAIR facility operation.

Primary authors: GOTTARDO, Andrea (Laboratori Nazionali di Legnaro, Istituto Nazionale di Fisica Nucleare); VALIENTE DOBON, Jose Javier (INFN-LNL); BENZONI, Giovanna (Instituto Nazionale di Fisica Nucleare (INFN)(INFN-Milano))

Presenter: GOTTARDO, Andrea (Laboratori Nazionali di Legnaro, Istituto Nazionale di Fisica Nu-cleare)

Session Classification: Evening Online Session

Contribution ID: **9**

Type: **Talk**

Proton emission from 54mNi and mirror symmetry (breaking) with 54mFe

Tuesday, May 3, 2022 12:15 PM (15 minutes)

An experiment on 4D-imaging of drip-line radioactivity near doubly-magic 56Ni was conducted at GANIL. Pictured with the ACTAR TPC, proton-emission branches from the 6457-keV, 10+ iso-mer in 54mNi were established 1. These feature unusually high angular momentum, l=5 and l=7, respectively, which requires a dedicated theoretical treatment 2.

The completed proton-emission pattern of 54mNi also allows for refined studies of isospin-symmetry breaking by looking at its previously measured E2 and E4 gamma-decay paths [3]. By means of a comparison with their well-known 'mirror transitions' in 54mFe, and aided by a variety of shell-model calculations in the fp model space, effective charges for E4 transitions near N=Z 56Ni could be estimated. Mirror-energy differences were explored with various shell-model interactions and isospin-symmetry breaking terms [4].

1 J. Giovinazzo, T. Roger, B. Blank, D. Rudolph, B.A. Brown, et al., Nature Commun. 12, 4805 (2021). 2 B.A. Brown, priv. comm.

[3] D. Rudolph, R. Hoischen, M. Hellström, et al., Phys. Rev. C 78, 021301(R) (2008).
[4] D. Rudolph, B. Blank, J. Giovinazzo, T. Roger, et al., submitted to Phys. Lett. B.

Primary authors: RUDOLPH, Dirk (Lund University); Prof. BLANK, Bertram (Centre d'Etudes Nu-cléaires de Bordeaux Gradignan); Dr GIOVINAZZO, Jérome (Centre d'Etudes Nucléaires de Bordeaux Gradignan); Dr ROGER, Thomas (Grand Accélérateur National d'Ions Lourds); ON BEHALF OF THE GANIL E690 EXPERIMENT COLLABORATION

Presenter: RUDOLPH, Dirk (Lund University)

Session Classification: Atomic-Shell Nucleus Interface, 229Th, Symmetries, etc.

Contribution ID: **10**

Type: **Talk**

Transfer reactions with Isomeric beams for Nuclear Astrophysics

Monday, May 2, 2022 6:00 PM (15 minutes)

The development of high-quality isomeric beams opens the possibility to probe the influence of nuclear isomers in stellar scenarios and provide experimentally constrained parameters to astro-physical reaction rates. Such is the case of the low-lying isomers along the rp-process nucleosyn-thesis path, or on Galactic ^{26}Al.
In this talk, I'll discuss recent experimental efforts to develop high-quality radioactive isomeric beams. Specifically, a beam of ^{24m}Na with 90% of its content in its 1+ isomeric state developed and used to perform a measurement of the ^{24m}Na(d,p)^{25}Na reaction at the John D. Fox Accelerator Laboratory at Florida State University. Mirror symmetry arguments were then used to investigate the influence of the isomeric state in ^{24}Al on the ^{24}Al(p,γ)^{25}Si reaction, relevant in rp-process nucleosynthesis.

Primary author: ALMARAZ-CALDERON, Sergio (Florida State University)

Presenter: ALMARAZ-CALDERON, Sergio (Florida State University)

Session Classification: Evening Online Session

Contribution ID: **11** Type: **Talk**

On the trail of low-lying isomeric states by Penningtrap mass spectrometry

Monday, May 2, 2022 10:30 AM (30 minutes)

State-of-the-art optical clocks achieve precisions of 10−18 or better using ensembles of atoms in optical lattices or individual ions in radio-frequency traps. Promising candidates for use in atomic clocks are highly charged ions (HCIs) and nuclear transitions, which are largely insensitive to exter-nal perturbations and reach wavelengths beyond the optical range that are accessible to frequency combs. Most promising here are transitions between atomic or nuclear isomeric and ground states. However, insufficiently accurate atomic and nuclear structure calculations hinder the identifica-tion of suitable transitions in HCIs and nuclei. Here, we report on the possibility to measure the mass differences between the excited isomeric and ground states using state-of-the-art Penning-trap mass spectrometry. Relative mass uncertainties of 10-12 have been reached.

Primary author: BLAUM, Klaus (Max-Planck-Institut für Kernphysik)

Presenter: BLAUM, Klaus (Max-Planck-Institut für Kernphysik)

Session Classification: Nuclear Structure I

Contribution ID: **14** Type: **Poster**

Mass measurement and spectroscopy of 190-Re using the Q3D magnetic spectrograph

Monday, May 2, 2022, 2:00 PM + 7:00 PM

The neutron-rich isotope rhenium-190 lies in the mass ≈170-190 region of the nuclide chart; a re-gion known for the occurrence of a large number of metastable, isomeric nuclear states 1. The for-mation of these states is caused by significant quadrupole deformations and are named K- isomers, due to the large angular momentum projection, K, on the nuclear deformation axis. These K- isomers are deformation aligned states and therefore experience hindered decays into the nuclear states with significantly different K values or those which are rotationally aligned. Therefore, these high-K states commonly have long lifetimes which can form astrophysical waiting points at low energies 2.

Rhenium-190 is already known to exhibit an isomeric state, most recently observed by Reed *et al.* 2 at the Experimental Storage Ring (ESR) at GSI. This isomeric state has a half-life of $t_{1/2}$ = 3.2 ± 0.2 h, an excitation energy of 204 ± 10 keV and a spin-parity of I = (6−). As rhenium-190 lies on the decay path of nuclei populated in the astrophysical rapid neutron capture process (known as the r- process), it is possible that this state is an astrophysical waiting point. To support astrophysical network calculations, such as the Brussels Nuclear Library (BRUSLIB) [3], and to reduce decay-energy uncertainties dominating over uncertainties in the reaction rate it would be beneficial to reduce the uncertainty in the excitation energy of the isomeric state in rhenium-190. An investigation into the energy-level scheme in rhenium-190 may also lead to the discovery of further isomeric states, as currently the level scheme for this nuclei is quite poorly known, with only five states (including the ground state) currently reported.

This presentation will detail an experiment performed at the Q3D magnetic spectrograph at the Maier-Leibnitz Laboratory (MLL) in Munich. The isotopes rhenium-190 and iridium-192 were pro-duced by bombarding targets of osmium-192 and platinum-194, respectively, with an 18 MeV po-larised deuteron beam and measuring α-particle ejectiles.

An energy calibration was produced by comparing the well known energy levels in the iridium-192 spectrum to the measured peak positions. This calibration was used to obtain the difference in Q-values for the reactions 192Os(*d,α*)192Re and 194Pt(*d,α*)192Ir. As the values for the masses of platinum-194, osmium-192 and iridium-192 are well known, this difference enabled measure-ment and publication of the atomic mass of rhenium-190 to a significantly higher precision than previously published [4].

The current stage of the project involves investigating the energy, spin and parity of the observed excited states in rhenium-190. The spin and parity of the states will be investigated by comparing the intensity of the peaks in the rhenium-190 spectrum detected at a variety of angles to Distorted-Wave Born Approximation calculations of the differential cross sections for different spin/parity configurations. Through this, it is anticipated that uncertainties in the properties of the I = (6−) isomeric state can be reduced. The current state of the analysis will be presented.

1 P. M. Walker and G. D. Dracoulis. Energy traps in atomic nuclei. *Nature*, **399**, 35–40 (1999).

2 M. W. Reed et al. Long-lived isomers in neutron-rich Z=72-76 nuclides. *Phys. Rev. C*, **86**, 054321 (2012).
[3] Y. Xu et al. Databases and tools for nuclear astrophysics applications BRUSsels Nuclear LIBrary (BRUSLIB), Nuclear Astrophysics Compilation of REactions II (NACRE II) and Nuclear NETwork GENerator (NETGEN). *Astronomy and Astrophysics*, *549*, **A106** (2013).
4. M.R. Griffiths et al. Mass Measurement of Re-190. *J. Phys. G: Nucl. Part. Phys*, **47**, 0851042020

Primary author: GRIFFITHS, Mark (PhD Student - University of Birmingham)

Co-authors: Dr WHELDON, Carl (University of Birmingham); Prof. KOKALOVA WHELDON, Tzany (University of Birmingham); Dr TURNER, Anthony (University of Birmingham); Mr PIRRIE, Stuart (University of Birmingham); Dr ZIMAN, Victor (Univeristy of Birmingham); Dr ASHWOOD, Nick (Univeristy of Birmingham); Dr MALCOLM, Jonathan (University of Birmingham); Dr BARR, Matthew (University of Birmingham); Prof. FREER, Martin (University of Birmingham); Dr FAESTER-MANN, Thomas (Technische Universität München); Dr WIRTH, Hans-Friedrich (Ludwig-Maximilian-s-Universität München); Dr HERTENBERGER, Ralph (Ludwig-Maximilians-Universität München); Dr GERNHÄUSER, Roman (Technische Universität München); Prof. KRÜCKEN, Reiner (Technische Uni-versität München)'

Presenter: GRIFFITHS, Mark (PhD Student - University of Birmingham)

Session Classification: Poster Session On Site

Contribution ID: **15** Type: **Talk**

Isomer studies for r-process nucleosynthesis

Monday, May 2, 2022 6:15 PM (15 minutes)

To understand the exact path of the r-process and its link to the observed abundance pattern requires experimental discoveries combined with extensive network simulations. Structure and decay properties of thousands of neutron-rich nuclei are key determinants of the nuclear flow throughout the entire r-process. To date, multiple extensive sensitivity studies of nuclear masses, half-lives, beta-decay branching ratios, neutron captures, and neutron emission probabilities, and more recently nuclear isomers [1-4], have been performed. This recent theoretical work highlights the importance of precise information on nuclear masses and careful treatment of isomeric states in network calculations. We have performed measurements to study the energy difference between the ground state and isomeric states of some potential important to astrophysics isomers for nu-clei A ~ 120-140 with the Canadian Penning Trap (CPT) using the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique [5] at Argonne National Laboratory's CAlifornium Rare Isotope Breeder Upgrade (CARIBU) facility. Results will be presented for 128,132Sb, 131Sn, 119,122Ag and 154Pm.

1 Fujimoto S. and M. Hashimoto (2020), "The impact of isomers on a kilonova associated with neu-tron star mergers." MNRAS (493), L103-L107

2 Misch, G. W., T. M. Sprouse and M. R. Mumpower (2021), "Astromers in the radioactive decay of r -process nuclei." Astrop. Journ. Lett. (913), L2

[3] Misch, G. W., S. K. Ghorui, P. Banerjee, Y. Sun and M. R. Mumpower (2021), "Astromers: Nu-clear isomers in astrophysics" Astrophys. J. Suppl. Ser. (252), 2

[4] Misch G. W., T. M. Sprouse, M. R. Mumpower, A. Couture, C. L. Fryer, B. S. Meyer, Y. Sun (2021), "Sensitivity of neutron-rich nuclear isomer behavior to uncertainties in direct transitions" arXiv:2103.09392

[5] Eliseev, S., K. Blaum, M. Block, C. Droese, M. Goncharov, E. Minaya Ramirez, D. A. Nesterenko, Yu. N. Novikov, and L. Schweikhard (2013), "Phase-Imaging Ion-Cyclotron-Resonance measure-ments of short-lived nuclides." Phys. Rev. Lett. (110), 082501

Primary author: KOLOS, Karolina (Lawrence Livermore National Laboratory)

Co-authors: HOFF, Daniel (LLNL); MISCH, G. Wendell (LANL); SAVARD, Guy (ANL); MUMPOWER, Matthew (LANL); SCIELZO, Nicholas (LLNL); ORFORD, Rodney (LBNL); RAY, Dwaipayan (University of Manitoba); SHARMA, Kumar (University of Manitoba); CLARK, Jason (ANL); VALVERDE, Adrian (ANL); LEE, Biying (University of Notre Dame); BRODEUR, Maxime (University of Notre Dame); VAR-RIANO, Louis (University of Chicago); MORGAN, Graeme (Louisiana State University); KONDEV, Filip (ANL); CALLAHAN, Nathan (ANL); BURDETTE, Daniel (ANL)

Presenter: HOFF, Daniel (LLNL)

Session Classification: Evening Online Session

Contribution ID: **16** Type: **Talk**

Studying Proton Capture on Astrophysical Isomers with SECAR

Monday, May 2, 2022 6:30 PM (15 minutes)

Isomeric states may play an important role in the rp-process, but as of yet are not regularly included in sensitivity studies. In astrophysical environments, isomers may be populated through thermal excitation, as a beta-decay end product, or a combination of these. Significant isomeric populations can alter the effective beta decay rate of a given isotope, and proton capture on these isomers may be enhanced relative to ground state capture based on the spin differences. The SEparator for CApture Reactions, SECAR, is uniquely positioned to undertake a program of proton capture reactions on astrophysically-important isomers, or "astromers." Beam development efforts, as well as a proposed program to measure proton capture on astrophysical isomers using SECAR, will be presented.

Primary authors: CHIPPS, Kelly (Oak Ridge National Laboratory); COLLABORATION, SECAR

Presenter: CHIPPS, Kelly (Oak Ridge National Laboratory)

Session Classification: Evening Online Session

Contribution ID: **17**

Type: **Poster**

Nuclear excitation by electron capture with electron vortex beams for isomer depletion

Monday, May 2, 2022, 2:00 PM + 7:00 PM

Nuclear isomers can store a large amount of energy over long periods of time, with a very high energy-to-mass ratio. Dynamical external control of such nuclear states has proven so far very challenging, despite ground-breaking incentives for a clean and efficient energy storage solution. Here, we describe a protocol to achieve the dynamical control of the isomeric nuclear decay via the process of nuclear excitation by electron capture 1 with electron vortex beams whose wavefunction has been especially designed and reshaped on demand 2. This could lead to the controlled release of the nuclear energy. We show theoretically that the use of tailored electron vortex beams can increase the isomer depletion by 2 to 6 orders of magnitude compared to so far considered depletion mechanisms and provides a handle for manipulating the capture mechanism 2.

1 Y. Wu, C. H. Keitel, A. Pálffy, Phys. Rev. Lett. 122, 212501 (2019).

2 Y. Wu, S. Gargiulo, F. Carbone, C. H. Keitel, A. Pálffy, arXiv: 2107.12448.

Primary authors: Dr WU, Yuanbin (Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany); Prof. KEITEL, Christoph H. (Max-Planck-Institut für Kernphysik, Saupfercheck-weg 1, 69117 Heidelberg, Germany); Dr PÁLFFY, Adriana (Max-Planck-Institut für Kernphysik, Saupfercheck-weg 1, 69117 Heidelberg, Germany; Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürn-berg, D-91058 Erlangen, Germany)

Presenter: Dr PÁLFFY, Adriana (Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Hei-delberg, Germany; Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany)

Session Classification: Poster Session On Site

Contribution ID: **18** Type: **Poster**

Coherent population transfer techniques for the ^{229}Th nuclear clock candidate

Monday, May 2, 2022, 2:00 PM + 7:00 PM

The ^{229}Th nucleus posses a metastable first excited state, i.e., an isomer, at around 8.19 eV. This state should be accessible via VUV light and presents a radiative lifetime of a few hours. These unique properties make ^{229}Th a promising candidate for a nuclear clock with excellent accuracy [1]. However, due to the relatively large uncertainty on the isomeric state energy, efficient laser manipulation with VUV light has proven cumbersome so far.

Here, we investigate theoretically an alternative to populate the isomeric state by indirect excita-tion via the second excited nuclear state at 29.19 keV. We make use of quantum optics schemes to achieve the population transfer via Stimulated Raman adiabatic passage (STIRAP) or two π-pulses. The coherent x-ray pulses that we consider are generated by x-ray lasers or using UV pulses at the Gamma Factory in combination with relativistic acceleration of the nuclei in a storage ring. The two scenarios are discussed in view of experimental feasibility.

1 E. Peik *et al.*, uantum Sci. Technol. **6**, 034002 (2021).

Primary authors: KIRSCHBAUM, Tobias (Friedrich-Alexander-Universität Erlangen-Nürnberg); Dr PALFFY, Adriana (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Presenter: KIRSCHBAUM, Tobias (Friedrich-Alexander-Universität Erlangen-Nürnberg) **Session**

Classification: Poster Session On Site

Contribution ID: **19** Type: **Talk**

Ultraviolet Spectroscopy of the Actinium-229 beta decay: On the way to the first observation of 229mTh's radiative decay?

Tuesday, May 3, 2022 11:45 AM (15 minutes)

A unique feature of thorium-229 is its isomer with an exceptionally low excitation energy, pro-posed as a candidate for future optical clocks 1. The small decay width is expected to outperform the accuracy of current state-of-the-art atomic clocks by an order of magnitude 2. The current best values of the excitation energy are 8.28(17)eV and 8.10(17)eV [3,4]. These were determined us-ing two different measurement techniques whereby the isomer is populated in the alpha decay of uranium-233. The development of an optical clock requires however knowledge of the excitation energy by at least an order of magnitude more precise. Additionally, spectroscopic experiments searching for a direct signature of the radiative decay have to-date been unsuccessful, partially due to the background induced in the preceding alpha decay.

An alternative approach using the beta decay of actinium-229 is studied as a novel method to populate the isomer with high efficiency and in low background conditions [5]. Produced online at the ISOLDE facility at CERN, actinium is implanted into a large-bandgap crystal in specific lattice positions, suppressing the electron conversion decay channel of the isomer. A favorable feeding pattern significantly increases the population of the isomer compared to uranium-233 and the lower energy deposit of the beta- compared to the alpha-decay results in a reduced luminescence background.

In this contribution, a dedicated setup developed at KU Leuven for a vacuum-ultraviolet study of an actinium-229 beam implanted into a large-bandgap crystal is presented and preliminary results from a recent experimental campaign at ISOLDE showing a footprint of the radiative decay of low-energy thorium isomer are discussed.

[1] E. Peik et al., Europhys. Lett. 61, 2 (2003)
[2] C. Campbell et al., PRL 108, 120802 (2012)
[3] B. Seiferle et al., Nature 573, 243-246 (2019)
[4] T. Sikorsky et al., PRL 125, 142503 (2020)
[5] M. Verlinde et al., Physical Review C, 100 (2), 024315-024315

Primary authors: KRAEMER, Sandro (KU Leuven, Instituut voor Kern- en Stralingsfysica); ATHANASAKIS,Michail (CERN); BARA, Silvia (KU Leuven, Instituut voor Kernen Stralingsfysica); BEEKS, Kjeld (TU Wien, Atominstitut); CHHETRI, Premaditya (KU Leuven, Instituut voor Kern- en Stralingsfysica); CLAESSENS, Arno (KU Leuven, Instituut voor Kern- en Stralingsfysica); CORREIA, Guilherme (CERN); DA COSTA PEREIRA, Lino (KU Leuven, uantum Solid State Physics); DE WITTE, Hilde (KU Leuven, Instituut voor Kern- en Stralingsfysica); FERRER, Rafael (KU Leuven, Instituut voor Kern-en Stralingsfysica); GELDHOF, Sarina (KU Leuven, Instituut voor Kernen Stralingsfysica); HOSSEINI, Niyusha (TU Wien, Atominstitut); HUYSE, Mark (KU Leuven, Instituut voor Kernen Stralingsfysica); KUDRAYAVTSEV, Yuri (KU Leuven, Instituut voor Kern-en Stralingsfysica); LAATIAOUI, Mustapha (Helmholtz Inistut Mainz); LICA, Razvan (CERN); MAGHIELS, Goele (KU Leuven, uantum Solid State Physics); MOENS, Janni (KU Leuven, uantum Solid State Physics); RAEDER, Sebastian (GSI); SCHUMM, Thorsten (TU Wien, Atominstitut); SELS, Simon (KU Leuven, Instituut voor Kernen Stralingsfysica); THIROLF, Peter (Ludwigs-Maximilian Universität); TUNHUMA, Malven (KU Leuven, Quantum Solid State Physics); VAN DEN BERGH, Paul (KU Leuven, Instituut voor Kernen Stralingsfysica); VAN DUPPEN, Piet (KU Leuven, Instituut voor Kernen Stralingsfysica); VANTOMME, André (KU Leuven, Quantum Solid State Physics); VILLAREAL, Renan (KU Leuven, Quatum Solid State Physics); WAHL, Ulrich (ULisboa)

Presenter: KRAEMER, Sandro (KU Leuven, Instituut voor Kernen Stralingsfysica)

Session Classification: Atomic-Shell Nucleus Interface, 229Th, Symmetries, etc.

Contribution ID: **21**

Type: **Talk**

Shape-isomer-like excitations in 64,66Ni isotopes

Tuesday, May 3, 2022 10:00 AM (15 minutes)

The phenomenon of nuclear shape isomerism, which is an example of extreme shape coexistence in nuclei, arises from the existence of a secondary minimum in the nuclear potential energy sur-face (PES), at substantial deformation, separated from the primary energy minimum (the ground state) by a high potential energy barrier that hinders the transition between the minima. Shape isomers at spin zero have clearly been observed, so far, exclusively in actinide nuclei [1,2].

In recent years, our collaboration has identified coexistence of spherical, oblate and prolate 0+ exci-tations in the 64Ni and 66Ni isotopes, in a series of experiments with different reaction mechanisms (i.e., transfer reactions, neutron capture, Coulomb excitation, and nuclear resonance fluorescence (NRF)). In both systems, ⊠ decay from the prolate 0+ state showed significant hindrance (B(E2) < 0.08 W.u. and B(E2) = 0.2 W.u. in 64Ni and 66Ni, respectively) which, according to Monte Carlo Shell-Model calculations, arises from a prolate-to-spherical shape-changing transition through a high barrier [3,4]. These prolate 0+ states were named “shape-isomer-like” excitations. Their ap-pearance at low excitation (below 3.5 MeV) reflects the action of the monopole tensor force, and it is often referred to as Type II shell evolution [5]. It involves particle-hole excitations of neutrons to the g9/2 unique-parity orbital from the fp shell. Extra binding for such intruder states is provided largely by the monopole tensor part of the nucleon-nucleon force (the proton f5/2-f7/2 spin-orbit splitting is reduced, favoring proton excitations across the Z=28 shell gap), and stabilizes isolated, deformed local minima in the PES.

An analogous situation is expected to occur in the 112,114Sn isotopes, but with neutron excita-tions to the h11/2, unique-parity orbital playing the same role as the g9/2 neutron excitations in the Ni nuclei and inducing the reduction of the proton g7/2-g9/2 spin-orbit splitting (similarly to the proton f5/2-f7/2 one in Ni). New experiments are planned to study the properties of these systems using both two-neutron and two-proton transfer reactions and state-of-the art gamma-spectroscopy techniques.

[1] S.M. Polikanov, Sov. Phys. Uspekhi 15, 486 (1973).

[2] B. Singh, R. Zywina, and R. Firestone, Nuc. Data Sheet 97, 241 (2002).

[3] S. Leoni, B. Fornal, N. Mărginean, et al., Phys. Rev. Lett. 118, 162502 (2017).

[4] N. Mărginean, D. Litte, Y. Tsunoda, S. Leoni et al., Phys. Rev. Lett. 125, 102502 (2020).

[5] Y. Tsunoda et al., Phys. Rev. C 89, 031301R (2014).

Primary authors: LEONI, Silvia (University of Milano and INFN Milano); FORNAL, Bogdan (IFJ PAN, Krakow); MARGINEAN, Nicolae (IFIN HH, Bucharest, Romania); MICHELAGNOLI, Caterina (ILL, Grenoble, France); SFERRAZZA, Michele (Universitè libre de Bruxelles, Bruxelles, Belgium); JANSSENS, R.V.F. (North Carolina Univ., Chapel Hill & Triangle Univ. Nuclear Lab., North Carolina, USA); OT-SUKA, Takaharu (University of Tokyo); TSUNODA, Yusuke (University of Tokyo, Tokyo, Japan)

Presenter: LEONI, Silvia (University of Milano and INFN Milano)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **22**

Type: **Poster**

Nuclear isomers in neutron stars

Monday, May 2, 2022, 2 PM, Online Poster Session

In fact, nuclear isomers are studied in rapid neutron capture process so-called r - process of the nucleosynthesis in neutron stars which occurs at the energy state about several MeV (dozens of GK) causing cooling of the star matter. Thus, isomers freeze out in thermal equilibrium due to cooling the neutron star matter by the r - process, i.e. they can immediately be populated in the star medium as it is in astrophysical isomers (astromers). There are two different main states of the astromers: ground state, where the isomer transition rates characterize; and thermalization temperatures, which describes the transition rates between pairs in the nuclear states. Studying unknown behaviour of astromers in models of neutron star matter may be helpful in understanding the cooling processes, in particular, in estimations of age of radio pulsars.

Primary author: RAYIMBAEV, Javlon

Co-author: Mr AHMEDOV, Saidmuhammad (National University of Uzbekistan)

Presenters: RAYIMBAEV, Javlon; Mr AHMEDOV, Saidmuhammad (National University of Uzbekistan)

Contribution ID: **23** Type: **Poster**

Shell-model study of nuclear isomers in Sn and Pb region

Monday, May 2, 2022 , 2:00 PM + 7:00 *PM*

The neutron-rich nuclei in the vicinity of ^{132}Sn and ^{208}Pb regions exhibit an abundance of nuclear isomers. The existence of the different isomers alludes to the dominance of proton or neutron excitations for low-lying states. Thus the observed structure and transition probabilities can be easily described in terms of the seniority scheme for the low-lying structure near Sn and Pb region. In this meeting we will present our recent results of nuclear isomers for these two regions using large-scale shell model.

Primary author: Ms BHOY, Bharti (Department of Physics, Indian Institute of Technology Roor-kee)

Co-author: Prof. SRIVASTAVA, Praveen C. (Department of Physics, Indian Institute of Technology Roorkee)

Presenter: Ms BHOY, Bharti (Department of Physics, Indian Institute of Technology Roorkee)

Session Classification: Poster Session On Site

Contribution ID: **24**

Type: **Talk**

Beta-decaying Isomers in Deformed, Neutron-rich Nuclei: Nuclear Structure and Role of K Forbiddenness*

Wednesday, May 4, 2022 2:30 PM (30 minutes)

Properties of deformed, neutron-rich nuclei in the A~110 and 160 mass regions are important for achieving better understanding of the nuclear structure where little is known owing to difficul-ties in the production of these nuclei at the present RIB facilities. They are essential ingredient in the interpretation of the r-process nucleosynthesis and are needed in fission-like applications since theoretical models depend sensitively on the nuclear structure input. Predicated on these ideas, we have initiated dedicated decay spectroscopy experimental program at Argonne National Labora-tory, by combining the CARIBU radioactive beam facility with the newly developed Gammasphere decay station. The initial focus was on several deformed odd-odd nuclei, where β^- decays of both the ground state and an excited isomer were investigated. Because of the spin difference, a variety of structures in the daughter nuclei were selectively populated and characterized, which in turn provided information about the structure of the isomers. Mass measurements using the Canadian Penning Trap aimed at discovering of long-lived isomers in these regions and at determining of their excitation energies were also carried out.

Results from these experiments will be presented and compared with predictions from multi-quasiparticle blocking calculations. The effects of K-forbiddenness on the β^--decay strengths will also be discussed.

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Primary author: KONDEV, Filip (Physics Division, Argonne National Laboratory, Lemont, IL 60439, U.S.A.)

Presenter: KONDEV, Filip (Physics Division, Argonne National Laboratory, Lemont, IL 60439, U.S.A.)

Session Classification: Isomer Applications, Nuclear Structure

Contribution ID: **25**

Type: **Poster**

Analysis of high-spin isomers in A=128 hole nuclei near 132Sn

Monday, May 2, 2022, 2 PM, Online Poster Session

The neutron-rich hole nuclei of A=128 are studied by large-scale shell-model calculations employ-ing the extended pairing plus multipole-multipole force model. The high-spin energy levels of 128In and beta decay are investigated deeply between these A=128 nuclei. The excited energy and logft values of beta decay are predicted in the final states of 128Ag, 128Cd, and 128In by the cascaded decays calculated in A=128 hole nuclei. The monopole effects are investigated carefully in the beta decay process from ground state 0+ of 128Cd to the 1+ levels of 128In, and its half-life is affected by monopole corrections acting on the configuration of final states. The high-spin isomers of 128Cd are predicted as a spin-trap isomer feeding the exist high-spin 16+ of 128In by beta decay.

Primary author: WANG, Hankui
Presenter: WANG, Hankui

Contribution ID: **26** Type: **Poster**

New structure features revealed in isomeric spectroscopy in the Z ~ 82, N ~ 104 region

Monday, May 2, 2022, 2 PM, Online Poster Session

Neutron-deficient nuclei around mid-shell at $N \sim 104$ in the lead region provide many examples of shape coexistence and shape isomers. In order to study shape coexistence in this region, prompt and delayed γ-ray spectroscopy of the ^{187}Pb, ^{183}Hg and ^{188}Bi isotopes produced in the reaction ^{50}Cr+^{142}Nd→^{192}Po* has been performed at the Argonne Gas-Filled Analyzer.

In ^{187}Pb, a new 5.15(15)-μs isomeric state at 308 keV above the spherical 3/2$^-$ ground state was identified. A strongly-coupled band is observed on top of this isomer, which is nearly identical to the one built on the prolate 7/2 $^-$[514] Nilsson state in the isotone ^{185}Hg. Based on this simi-larity and on the result of the potential-energy surface calculations, the new isomer in ^{187}Pb was proposed to be prolate with J^π = 7/2$^-$ and classified as a shape isomer. The retarded character of the 308-keV (7/2$^-$)→3/2$^-$ transition with a deduced $B(E2)$ = 5.6(2) $\times 10^{-4}$ W.u. can be well explained by the significant difference between the prolate parent and spherical daughter config-urations, leading to the shape isomerism.
In ^{183}Hg, the decay of the nearly spherical 13/2$^+$isomeric state was first observed following the α decay of the 13/2$^+$ isomer in ^{187}Pb. By the α – γ correlation measurement, the half-life of this isomer was measured to be T1/2 = 290(30) μs. This isomer was proposed to deexcite by retarded $M2$ transition, which can be explained by the notable shape change between the initial and the final states.

Recently, a strong shape staggering was found in the charge radii of ^{187,188,189}Bi. To further char-acterize this phenomenon in ^{188}Bi, its in-beam and decay spectroscopy was studied in the same experiment. A new 0.25(5)-μs isomeric state decaying via a 243-keV transition to the (10$^-$) ^{188m}Bi was identified.

1 P. Möller et al., Phys. Rev. Lett. 103, 212501 (2009)
2 W. Q. Zhang et al., submitted to Physics Letters B.
[3] A. Barzakh et al., Phys. Rev. Lett. 127, 192501 (2021).
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Primary authors: ZHANG, W. Q. (Institute of Modern Physics, Chinese Academy of Sciences); AN-DREYEV, A. N.; LIU, Z.; HUANG, H.; Prof. SEWERYNIAK, D. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); LI, Z. H. (State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, China); LI, J. G. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); GUO, C. Y. (State Key Laboratory of Nu-clear Physics and Technology, School of Physics, Peking University, Beijing 100871, China); DOHERTY, D. T. (Department of Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom); BARZAKH, A. E. (Petersburg Nuclear Physics Institute, NRC Kurchatov Institute, 188300 Gatchina, Russia); DUP-PEN, P. Van. (KU Leuven, Instituut voor Kern- en Stralingsfysica, 3001 Leuven, Belgium); CUBISS, J. G.(Department of Physics, University of York, York, YO10 5DD, United Kingdom); ANDEL, B. (KU Leuven, Instituut voor Kern- en Stralingsfysica, 3001 Leuven, Belgium); ANTALIC, S. (Department of Nuclear Physics and Biophysics); BLOCK, M. (Helmholtz-Institut Mainz, Mainz, 55128, Germany); BRONIS, A. (Department of Nuclear Physics and Biophysics); CARPENTER, M. P. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); COPP, P. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); DING, B. (Institute of Modern Physics, Chinese Academy of Sciences); FAVIER, Z. (IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France); GIACOPPO, F. (Helmholtz-Institut Mainz, Mainz, 55128, Germany);

HUANG, T. H. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); KINDLER, B. (GSI Helmholtzzentrum für Schwerio-nenforschung Darmstadt, Darmstadt, 64291, Germany); KONDEV, F. G. (Physics Division, Argonne Na-tional Laboratory, Argonne, Illinois 60439, USA); LAURITSEN, T. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); LI, G. S. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); LOMMEL, B. (GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Darmstadt, 64291, Germany); LU, H. Y. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); MONTHERY, M. A. (Department of Physics, University of York, York, YO10 5DD, United Kingdom); MOˇSAˇT, P. (Department of Nuclear Physics and Biophysics); NIU, Y. F. (Lanzhou University, Lanzhou 730000, China); RAISON, C. (Department of Physics, University of York, York, YO10 5DD, United Kingdom); REVIOL, W. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); SAVARD, G. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); STOLZE, S. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); WILSON, G. (Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA); WU, H. Y. (State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, China); WANG, Z. H. (Lanzhou University, Lanzhou 730000, China); XU, F. R. (State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, China); YU, X. H. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); ZENG, Q. B. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China); ZHOU, X. H. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China)

Presenter: ZHANG, W. Q. (Institute of Modern Physics, Chinese Academy of Sciences)

Contribution ID: **27**

Type: **Talk**

Kr83 Isomers Induced by High Intensity femtosecond Lasers

Wednesday, May 4, 2022 9:00 AM (15 minutes)

A high rate of producing nuclear isomers is critical for many applications, like nuclear clocks and nuclear γ-ray lasers etc. However, due to small production cross sections and quick decays, as well as limited intensities of driving beams, it is extremely difficult to achieve a high producing rate via traditional accelerators or reactors. Here, we present a pumping of nuclear isomeric states by a femtosecond hundred-TW tabletop laser. Nuclei populated on the isomer state of 83Kr are observed with a peak efficiency of 2.34E15 particles/s for the first time. This high efficient and universal production method can be widely used for pumping isotopes with excited-state lifetimes down to picoseconds, and could be a benefit for fields like nuclear transition mechanisms and nuclear γ-ray lasers.

Primary author: FU, Changbo (Fudan University)

Presenter: FU, Changbo (Fudan University)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **28**

Type: **Poster**

Collective and intrinsic excitations in Hg and Tl isotopes explored through nanosecond to microsecond isomers

Monday, May 2, 2022, 2:00 PM + 7:00 PM

Isotopes of Hg and Tl in the $A \approx 200$ region exhibit competition between collective and intrinsic modes of angular momentum generation. The neutron number $N = 120$ appears to constitute a boundary, with lighter isotopes exhibiting collective behavior, and heavier ones displaying pri-marily single-particle excitations. Most of these isotopes lie close to the line of stability and are difficult to access through fusion-evaporation reactions involving heavy-ion beams. Therefore, multi-nucleon transfer reactions using $\approx$ 1.4 GeV ^{207}Pb and ^{209}Bi beams, with above-barrier ener-gies, incident on a ^{197}Au target, were used to populate highly-excited levels. The deexciting γ rays were recorded by the Gammasphere detector array. The beams were pulsed in different intervals ranging from < 1 μs to several seconds, to study isomers with a wide range of half-lives.

The evolution of collectivity in ^{198,200,202}Hg has been studied through a measurement of the half-lives of the 7^{-}, 9^{-} and 12^{+}states, and inferring the associated $B(E2)$ values. The half-lives of the 7^{-} and 9^{-} states in ^{202}Hg are measured to be $T_{1/2}$ = 10.4(4) ns and 1.4(3) ns, respectively, while that of the 12^{+} state in ^{200}Hg is $T_{1/2}$ = 1.0(3) ns. For even Hg isotopes, near the ground state, the extent of collective behavior is found to decrease from $N = 112$ to $N = 124$, while it increases for the $12^{+}$and 9^{-} states up to $N = 118$, and then reduces for higher neutron numbers 1. Several new isomers were identified in the isotopes ^{200,202,203}Tl. These include a six-nucleon-hole isomer with $T_{1/2} = 57(2)$ ns in ^{200}Tl 2. The level structure of ^{202}Tl has been studied up to the new I^{π}= 20^{+}state, with $T_{1/2}$ = 215(10) μs, arising from a four-nucleon-hole excitation [3]. In ^{203}Tl, isomeric states with $I^{\pi} = 15/2^{-}$, $35/2^{-}$, $39/2^{-}$ and $49/2^{+}$ have been identified, with $T_{1/2} = 7.9(5)$ ns, $4.0(5)$ ns, $1.9(2)$ ns, and $3.4(4)$ ns, respectively [4]. For the previously identified long-lived decay, the spin is reassigned as $29/2^{+}$from the earlier suggested value of $25/2^{+}$. These new isomers provide a host of nuclear structure insights, including the magnitude of residual interactions for different configurations. Shell-model calculations, using the OXBASH code and the KHH7B interaction, have been performed for these nuclei.

References

[1] Saket Suman et al., Phys. Rev. C 103, 014319 (2021).
[2] Poulomi Roy et al., Phys. Rev. C 100, 024320 (2019).
[3] S.G. Wahid et al., Phys. Rev. C 102, 024329 (2020).
[4] V. Bothe et al., to be published in Phys. Rev. C (2022).

Primary authors: Mr SUMAN, Saket (UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, India); Dr TANDEL, S.K. (UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, India)

Co-authors: Dr WAHID, S.G. (UM-DAE Centre for Excellence in Basic Sciences, University of Mum-bai, India); Ms ROY, Poulomi (UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, India); Mr BOTHE, V. (UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, In-dia); Dr SRISVASTAVA, P.C. (Indian Institute of Technology, Roorkee, India); Dr CHOWDHURY, P.(University of Massachusetts Lowell, Lowell, Massachusetts 01854, USA); Dr JANSSENS, R.V.F (Univer-sity of North Carolina at Chapel Hill, North Carolina 27599, USA); Dr KONDEV, F.G. (Argonne National Laboratory, Argonne, Illinois 60439, USA); Dr CARPENTER, M.P. (Argonne National Laboratory, Argonne, Illinois 60439, USA); Dr LAURITSEN, T. (Argonne National Laboratory, Argonne, Illinois 60439, USA); Dr SEWERYNIAK, D. (Argonne National Laboratory, Argonne, Illinois 60439, USA)

Presenter: Mr SUMAN, Saket (UM-DAE Centre for Excellence in Basic Sciences, University of Mum-bai, India)

Session Classification: Poster Session On Site

Contribution ID: **29**

Type: **Talk**

Seniority and Isomerism in Nuclei

Tuesday, May 3, 2022 1:45 PM (30 minutes)

The nuclear isomers are long-lived excited states, with half-lives ranging from nanoseconds to years. The reason behind their existence may vary from a region-to-region on the basis of hin-drance mechanisms and nucleonic surroundings. Understanding the existence of isomers can shed light on both the basic modes of nucleonic motion, single-nucleon as well as collective, and their interplay. Symmetries also play an important role in the isomeric population. In spherical, or near spherical region, symmetries due to pairing correlations exist in terms of seniority quantum number. Our recent works (as listed below) manifest the governing role of seniority and gener-alized seniority in isomers and other low-lying excitations along with their various spectroscopic properties. A few interesting and important results on the basis of generalized seniority approach, such as the discovery of a new kind of seniority isomers, resolution of double-hump B(E2) trends, existence of isomers beyond the capacity of intruder orbital etc. will be discussed in the talk.

References

1. A. K. Jain, B. Maheshwari, A. Goel, Nuclear Isomers- A Primer, Springer Nature (2021).
2. B. Maheshwari, D. Choudhury, A. K. Jain, Nuclear Physics A 1014, 122277 (2021).
3. Bhoomika Maheshwari, European Physical Journal Special Topics 229, 2485 (2020).
4. B. K. Agrawal and B. Maheshwari, European Physical Journal Special Topics 229, 2459 (2020).
5. B. Maheshwari, H. A. Kassim, N. Yusof and A. K. Jain, Nuclear Physics A 992, 121619 (2019).
6. B. Maheshwari and A. K. Jain, Nuclear Physics A 986, 232 (2019).
7. Bhoomika Maheshwari, J. Nucl. Phys. Mat. Sci. Rad. A. 6, 1 (2019).
8. B. Maheshwari, S. Garg and A. K. Jain, Pramana-Journal of Physics (Rapid Comm.) 89, 75 (2017).
9. A. K. Jain and B. Maheshwari, Physica Scripta 92, 074004 (2017).
10 . A. K. Jain and B. Maheshwari, Nuclear Physics Review 34, 73 (2017).
11. B. Maheshwari, A. K. Jain and B. Singh, Nuclear Physics A 952, 62 (2016).
12. B. Maheshwari, and A. K. Jain, Physics Letters B 753, 122 (2016).
13. A. K. Jain, B. Maheshwari, S. Garg, M. Patial and B. Singh, Nuclear Data Sheets 128, 1 (2015).
14. B. Maheshwari, A. K. Jain and P. C. Srivastava, Physical Review C 91, 024321 (2015).

Primary author: MAHESHWARI, Bhoomika (IIT Ropar, Rupnagar 140001, India)

Presenter: MAHESHWARI, Bhoomika (IIT Ropar, Rupnagar 140001, India)

Session Classification: Precision Mass Spectrometry, Nuclear Structure

Contribution ID: **30** Type: **Poster**

Study of isomer ratio in (n,2n) and (γ,n) reactions on the 198Hg nucleus

Monday, May 2, 2022, 2 PM Online Poster Session

The measurement and interpretation of isomeric ratios have provided information about the en-ergy levels structure of nuclear systems and the angular momentum and reaction mechanism ef-fects involved in the production of isomeric states in nuclei.
In the present work results of the investigation of the isomeric yield ratios Y_m/Y_g of the reaction $^{198}Hg(\gamma, n)^{197m,g}Hg$ and $^{198}Hg(n, 2n)^{197m,g}Hg$ are presented.
Samples of natural have been irradiated in the bremsstrahlung beam of the betatron SB-50 of the Institute of Applied Physics of the National University of Uzbekistan in the energy range of $12 \div 35$ MeV with an energy step of 1 MeV. For 14 MeV neutron irradiation we used the NG-150 neutron generator of the Institute of Nuclear Physics.
The gamma spectra reactions products were measured with a spectroscopic system consisting of HPGe detector CANBERRA with an energy resolution of 1.8 keV at 1332 keV gamma-ray of ^{60}Co, amplifier 2022, and multichannel analyzer 8192 connected to the computer for data processing. The results are compared with the calculations made in the statistical Fermi-gas theory. The exper-imental results are in agreement with the calculated ratios for values of the spin cut-off parameter σ between 2 and 3.

Primary authors: PALVANOV, Satimbay (National University of Uzbekistan); Ms RUSTAMOVA, Xulkar (National University of Uzbekistan); RAYIMBAEV, Javlon; TUYMURADOV, Abror (National University Of Uzbekistan); Ms PALVANOVA, Gulnoza (National University of Uzbekistan)

Presenter: Ms RUSTAMOVA, Xulkar (National University of Uzbekistan)

Contribution ID: **31** Type: **Talk**

Correlated prompt-delayed gamma spectroscopy for nuclear structure studies: isomers in the neutron-rich Kr isotopes approaching N=60

Tuesday, May 3, 2022 12:30 PM (15 minutes)

Nuclear isomers often possess a unique configuration or shape that allows testing nuclear models and advancing the understanding of nuclear structure. In addition, in many cases isomers allow for an easier experimental identification and/or correlated and background-reduced data analysis. Our recent nuclear structure studies of neutron-rich Kr isotopes using prompt and delayed gamma spectroscopy discovered new gamma-transitions feeding, depopulating and bypassing a new short-lived nanosecond isomer in ^{94}Kr1 and new transitions feeding and bypassing the known microsec-ond isomer in ^{95}Kr[2,3].

These Kr isotopes were studied during the second SEASTAR campaign [4] at the RI Beam Fac-tory[5] at the RIKEN Nishina Center and during the NuBall campaign [6] at the ALTO facility at the IPN Orsay. While the former experiment populated the isotopes of interest via nucleon knock-out reactions of a relativistic radioactive beam on a liquid-hydrogen target [7], the latter used a pulsed ^{7}Li beam together with the fast-neutron source LICORNE [8] to induce pulsed fission of a ^{238}U stacked-target. In the measurement at RIKEN, prompt gamma-rays after the knockout were detected by the DALI2 NaI array [9] and, after the subsequent flight of the exotic ions through the ZeroDegree spectrometer, delayed gamma-rays were detected by the EURICA HPGe array [10]. At the IPN Orsay, the NuBall hybrid array [11] consisting of HPGe and LaBr gamma-ray detectors surrounded the fission target and a triggerless data acquisition collected all data.

The experimental results will be presented and compared to known data in neighbouring isotones and theoretical models. Aspects of nuclear structure like single-particle and quasiparticle states, onset of deformation and shape-coexistence in the neutron-rich Kr isotopes approaching N=60 will be discussed. *Supported by the DFG under Grant No. BL 1513/1-1 .

1 R.-B. Gerst et al., Phys. Rev. C 102, 064323 (2020).

2 R.-B. Gerst et al., Phys. Rev. C 105, 024302 (2022).

[3] J. Genevey et al., Phys. Rev. C 73, 037308 (2006).

[4] P. Doornenbal et al., RIKEN Accel. Prog. Rep. 49, 35 (2016).

[5] T. Kubo et al., Prog. Theor. Exp. Phys. 2012, 03C003 (2012).

[6] N. Jovancevic et al., Acta Phys. Pol., B 50, 297 (2019).

[7] A. Obertelli et al., Eur. Phys. J. A 50, 8 (2014).

[8] M. Lebois et al., Nucl. Instrum. Methods Phys. Res. A 735, 145 (2014).

[9] S. Takeuchi et al., Nucl. Instrum. Methods Phys. Res. A 763, 596 (2014).

[10] P.-A. Söderström et al., Nucl. Instrum. Methods Phys. Res. B 317, 649 (2013).

[11] M. Lebois et al., Nucl. Instrum. Methods Phys. Res. A 960, 163580 (2020).

Primary authors: BLAZHEV, Andrey (IKP, University of Cologne); GERST, Rosa-Belle (IKP, Uni-versity of Cologne); WARR, Nigel (IKP, University of Cologne)

Co-authors: THE SEASTAR-2015 COLLABORATION; THE NUBALL COLLABORATION

Presenter: BLAZHEV, Andrey (IKP, University of Cologne)

Session Classification: Atomic-Shell Nucleus Interface, 229Th, Symmetries, etc.

Contribution ID: **32** Type: **Talk**

Self-Consistent Mean Field Studies of Multiuasiparticle Exitations With The Gogny Force

Wednesday, May 4, 2022 9:45 AM (15 minutes)

There are two fundamental kinds of excitation modes in the atomic nucleus: collective and single-particle excitations. So far, most of the theoretical effort has focused on the study of the former and the latter has been mostly treated by using the quasiparticle spectrum of neighboring nuclei 1 or the equal-filling approximation 2. However, these approaches explicitly neglect time-odd fields that can modify in a substantial way the properties of excited states. In order to take them into account, the Hartree- Fock-Bogoliubov (HFB) method with full blocking has to be introduced. The implementation has to be flexible enough as to allow for one-quasiparticle excitations (odd and odd-odd nuclei), two quasiparticle excitations (built on top of both even and odd systems), four quasiparticle excitations (as to study high K isomers), etc. Also, a careful handling of the orthogo-nality of the different states has to be made in order to obtain an excitation spectrum containing more than one state per quantum number. In order to study those multiquasiparticle excitations a computer code has been developed to solve in an efficient way the HFB equation with full block-ing in the case of the Gogny force [3]. It preserves axial symmetry so that K is a good quantum number. Parity is allowed to break but it turns out that most of the solutions only have a slight breaking of reflection symmetry and therefore the parity quantum number can also be used to characterize the states. The code includes the possibility to impose orthogonality constraints to previously computed states. The results obtained show differences with respect to simpler calculations [1,2] that can amount to a few hundred keV in excitation energy, showing the impor-tance of the time-odd fields and the self-consistency of the HFB+Blocking method. The quenching of pairing correlations is also very strong in the HFB +Blocking method. Using the HFB+Blocking method along with the finite range, density dependent Gogny force, we have carried out calcula-tions of high-K two and four- quasiparticle isomeric states in even-even and odd-A nuclei. The quite good agreement with experimental data for excitation energies shows the suitability and predictive power of the Gogny force in this kind of physics.

One of the most important consequences of blocking is the severe quenching of pairing correla-tions. This effect points to an increasing relevance of dynamics pairing in those affected excitations. To gain some understanding on this effect, we have analyzed the sensitivity of the results to the amount of pairing correlations by using larger pairing strengths. The results will also be discussed.

REFERENCES

1 T. Duguet, P. Bonche, P.-H. Heenen, and J. Meyer, Phys. Rev. C 65, 014310 (2001)

2 S. Perez-Martin and L. M. Robledo, Phys. Rev. C 78, 014304 (2008)

[3] L. M. Robledo, R. Bernard, and G. F. Bertsch, Phys. Rev. C 86, 064313 (2012)

Primary author: ROBLEDO, Luis Miguel (Universidad Autonoma de madrid) **Presenter:** ROBLEDO, Luis Miguel (Universidad Autonoma de madrid)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **34**

Type: **Talk**

Auger and X-ray K-shell fluorescence measurements for Sc-44 isomeric decays

Wednesday, May 4, 2022 9:15 AM (15 minutes)

Despite being a well-studied nucleus close to stability, the K-shell X-ray and Auger fluorescence yield for scandium-44 are not very well defined. However, the low-lying nuclear structure of 44 21SC and its population in 44Ti electron capture decay lends itself to extracting these quantities.The first two excited states in ^{44}Sc are isomeric and lie at 68 keV and 146 keV with half-lives of 154.8(8) ns and 51.0(3) μs respectively. The 146 keV level is populated by the electron capture decay of ^{44}Ti $>$99% of the time. By carefully measuring coincident K X-rays (at 4-5 keV) and γ decays over several months using an optimised ^{44}Ti source, the half-lives of the isomeric states can be fitted. This allows extraction of the fractional X-ray intensities for the initial electron capture decay as well as the subsequent internal electron conversion that competes with γ emission to de-excite the lowest two ^{44}Sc excited states. Thus, the relative X-ray-to-Auger K-shell fluorescence can be obtained for the three decay processes.

These fluorescence values are being compared to BrIccEmiss [1,2] predictions for which Monte-Carlo simulations and fits to the Evaluated Atomic Data Library (EADL) are combined. The results of this study will be reported.

1 B.Q. Lee, T. Kibedi, et al., Computational and Mathematical Methods in Medicine (2012).

2 B.Q. Lee, PhD thesis, Department of Nuclear Physics, The Australian National University (2017).

Primary authors: WHELDON, Carl (University of Birmingham); Prof. KOKALOVA, Tzany (Univer-sity of Birmingham); Mr PIRRIE, Stuart (University of Birmingham); Dr TUNGATE, Garry (University of Birmingham); Prof. KIBEDI, Tibor (ANU)

Presenter: WHELDON, Carl (University of Birmingham)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **35**

Type: **Talk**

Direct Mass-Measurements of the 99In Isomeric State Provide new Experimental Input to Nuclear Theory

Tuesday, May 3, 2022 2:45 PM (15 minutes)

Much attention has been drawn in recent years to the heaviest known self-conjugate nucleus, 100Sn, and its implications on nuclear structure models. Various decay experiments have been conducted to study the nucleus' expected doubly-magic character of the closed proton and neutron shells. Direct measurements by means of mass-spectrometry or laser-spectroscopy are challenging due to its short half-life and difficult production and have yet to be performed. One proton removed from tin, however, neutron-deficient indium isotopes play a crucial role to understand nuclear structure in the vicinity of 100Sn. Mass-measurements of 99In and 100In in combination with ab inito many-body calculations now test our understanding of nuclear forces close to the shell closure. Going one step further, the excitation energy of the (1/2)- isomeric state in 99In has been measured by means of Time-of-Flight Mass-Spectrometry at ISOLDE/CERN. In this contribution, experimental results of this experimental campaign, including the mass-spectrometry of eleven ground states and seven isomers of neutron deficient indium isotopes, are presented and compared with nuclear shell-model calculations.

Primary author: NIES, Lukas (CERN / University of Greifswald (DE))

Presenter: NIES, Lukas (CERN / University of Greifswald (DE))

Session Classification: Precision Mass Spectrometry, Nuclear Structure

Contribution ID: **36** Type: **Talk**

Isomeric states at the extremes of proton stability

Monday, May 2, 2022 12:30 PM (15 minutes)

The observation of proton radioactivity from nuclei beyond the proton drip line, provides a way to probe nuclear structure at the limits of stability. The existence of long-lived isomeric states can encourage the emission of a proton besides the ground state emission, and thus provide extra experimental information on exotic nuclei, that are difficult to produce and observe, due to the very small production cross sections, and instability.
In fact, the first time that a decay from proton emission was observed was just from an high spin isomeric state in 53Co [?, ?]. From that discovery, many proton emitters were found mapping a large portion of the proton drip line below element Z=83, and imposing constraints on the path of nucleosynthesis in explosive astrophysical scenarios. Amongst the observed decays, a few were from isomeric states.
It is the purpose of this talk to discuss some examples of isomeric states of proton drip line that decay by proton emission, and show that, from the theoretical interpretation of the decay data from these states[?, ?, ?, ?, ?], it is possible to identify nuclear structure properties of the emitter, and deduce constraints to the astrophysical processes.

1. K.P. Jackson, C.U. Cardinal, H.C. Evans, N.A. Jelley, J. Cerny Phys. Lett. B33 (1970) 281.
2. J. Cerny, J.E. Esterl, R.A. Gough, R.G. Sextro Phys. Lett. B33 (1970) 284.
3. L.S.Ferreira, E.Maglione, P.Ring, Phys. Lett. B701 (2011) 508.
4. P. Arumugam, L. S. Ferreira, E. Maglione, Phys. Lett. B680 (2009) 443.
5. M.Taylor, D. M. Cullen, M. G. Procter, A. J. Smith, et al. Phys. Rev. C 91 (2015) 044322.
6. P. Hodge, D. M. Cullen, M. J. Taylor, et al. Phys. Rev. C 94 (2016) 034321.
7. Swati Modi, M. Patial, P. Arumugam, L. S. Ferreira, and E. Maglione Phys. Rev. C 96 (2017) 064308

Primary authors: S. FERREIRA, Lidia (CeFEMA, Instituto Superior Tecnico, Univ Lisboa); Prof. MAGLIONE, Enrico (CeFEMA, Instituto Superior Tecnico)

Presenter: S. FERREIRA, Lidia (CeFEMA, Instituto Superior Tecnico, Univ Lisboa)

Session Classification: Nuclear Structure II

Contribution ID: **37**

Type: **Talk**

Determining cross sections for neutron capture reactions involving isomeric states

Monday, May 2, 2022 6:45 PM (15 minutes)

Neutron capture reactions play an important role in nuclear physics and other fields that seek to understand physical processes in which neutrons react with their environment. In particular, knowledge of capture cross sections is crucial for nuclear astrophysics applications. Many required capture cross sections are unknown and extremely difficult to determine experimentally, as their measurement involves colliding neutrons with short-lived or highly-radioactive targets. The pres-ence of isomers in the target or intermediate nuclei involved further complicate the situation. The surrogate reaction method 1, an indirect approach, has been demonstrated to provide meaningful constraints for neutron capture cross sections [2,3]. I will present an extension of the work pub-lished in Ref. 2 to determine cross sections for multiple reaction pathways that involve isomeric states in the target and/or final nucleus.

References:
1 Escher et al, RMP 84, 353 (2012)
2 Escher et al, PRL 121, 052501 (2018)
[3] Ratkiewicz et al, PRL 122, 052502 (2019)

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Primary author: ESCHER, Jutta (Lawrence Livermore National Laboratory)

Presenter: ESCHER, Jutta (Lawrence Livermore National Laboratory)

Session Classification: Evening Online Session

Contribution ID: **40**

Type: **Talk**

From shape coexistence to shape isomers in atomic nuclei

Monday, May 2, 2022 11:30 AM (30 minutes)

Shape coexistence occurs when the potential energy of the nucleus is characterized by local min-ima for different shapes. Excited states in the secondary minimum may become isomeric if the po-tential barrier separating the secondary minimum from the ground-state minimum is sufficiently pronounced. The first examples of such shape isomers were observed in the 1960s, as fission iso-mers in the actinides. They are located in a secondary minimum at very large deformation and excitation energies of several MeV. Fission is the predominant decay mode due to a strong potential barrier for gamma decay to the ground state.

In even-even nuclei, these shape isomers occur as an excited 0+ state residing in a secondary minimum as a false ground state. If located at high excitation energy (above 1-2 MeV) these states will usually not show up as long-lived states, although their reduced decay strength may still be considerably reduced. First excited 0+ states at low energy (below ~1 MeV) are very rare, and only known in a handful of stable nuclei. Research has been going on for several decades to find other examples in exotic nuclei far from nuclear stability.

In my presentation I will concentrate on the research of such low-lying shape isomers, with an emphasis on even-even mass nuclei, where the particularity of 0+ to 0+ E0 transitions to the nuclear ground state can be exploited.

Primary author: KORTEN, Wolfram (CEA Paris-Saclay)

Presenter: KORTEN, Wolfram (CEA Paris-Saclay)

Session Classification: Nuclear Structure II

Contribution ID: **41**

Type: **Poster**

Theoretical investigation of α-decay in Superheavy Isomers

Monday, May 2, 2022, 4 PM, Online Poster Session

Theoretical studies of superheavy nuclei are expected to bring in new opportunities and more ex-citing times in the arena of experimental activities eyeing on synthesis of new superheavy nuclei 1. In this particular region of periodic chart, α-decay is the dominant decay mode in which tran-sitions take place from ground-to-ground states 2 and also in or from isomeric state [3]. In the present work, inspired from recent experimental and theoretical [4, 5] studies on isomers, we have estimated α-decay half-lives from ground-to-ground states along with at least one decay from or in an isomeric state. The half-lives are calculated from few latest empirical formulas [6, 7] which are first probed on known isomers from the Atlas [8] that decay via α-emission. The QF formula [6] is found very accurate in estimating the half-lives of α-emission in isomeric state and there-fore has been applied to estimate the half-lives of α-transitions from various unknown superheavy isomers. Our calculated half-lives are found within the experimental range and also in well agree-ment with other similar formula [7]. These investigations can anticipate the future experiments towards synthesizing new superheavy elements and their isomeric states.

References: -

1. Yu. Ts. Oganessian et al., J. Phys. G 34, R165 (2007).
2. G. Saxena et al., J. Phys. G: Nucl. Part. Phys., 48, 055103 (2021).
3. J. Donget al., Nucl. Phys. A 832, 198 (2010).
4. H. Grawe et al., Phys. Lett. B 820, 136591 (2021).
5. A. K. Jain, B. Maheshwari and Alpana Goel, Nuclear Isomers: A primer, Springer Nature (2021).
6. G. Saxena et al., Phys. Scr. 96, 125304 (2021).
7. J-G Deng, H-F Zhang and G. Royer, Phys. Rev. C 101, 034307 (2020).
8. A. K. Jain, B. Maheshwari et al., “Atlas of Nuclear Isomers”, Nuclear Data Sheets 128, 1 (2015).

Primary author: Mr JAIN, A. (Department of Physics, School of Basic Sciences, Manipal University Jaipur-303007, India)

Co-authors: Dr SHARMA, P. K. (Department of Physics, Govt. Polytechnic College, Rajsamand-313324, India); Dr JAIN, S. K. (Department of Physics, School of Basic Sciences, Manipal University Jaipur-303007, India); Dr SAXENA, G. (Department of Physics (H&S), Govt. Women Engineering College, Ajmer-305002, India); Dr MAHESHWARI, B. (Department of Physics, Indian Institute of Technology Ropar, Rupna-gar-140001, India)

Presenter: Mr JAIN, A. (Department of Physics, School of Basic Sciences, Manipal University Jaipur-303007, India)

Contribution ID: **42**

Type: **Poster**

Changes in charge radius of the high-spin isomers of the proton-hole states of indium

Monday, May 2, 2022, 4 PM, Online Poster Session

One of the most basic properties of nuclear states are their size. Yet, a microscopic understanding of the size behaviour of these nuclear isomers has proved challenging as it depends strongly on the region of the nuclear chart and type of nuclear isomer.
How the change in size (quantified by their change in charge radius) of nuclear isomers varies from their ground states gives important insight into the details of the nuclear forces which enhance their stability, which is becomes especially relevant at the limits of stability.
Here we present laser spectroscopy measurements, performed at CERN-ISOLDE, of the changes in size of high-spin isomers of the proton-hole isotopes of indium, around the neutron-rich shell closure of N = 82, through their isomer shifts. The results present a particularly clean study of the effect of high-spin isomerism on nuclear size and the challenges to state-of-the-art nuclear theory in describing such systems compared to their ground states.

Primary authors: VERNON, Adam (Massachusetts Institute of Technology); THE CRIS COLLAB-ORATION

Presenter: VERNON, Adam (Massachusetts Institute of Technology)

Contribution ID: **43**

Type: **Talk**

On the use of nuclear isomers in solid state physics

Wednesday, May 4, 2022 1:30 PM (30 minutes)

With their successful application of nuclear magnetic resonance NMR to investigate the structure of atoms in liquids and solids Felix Bloch and Edward Mills Purcell (Nobel prize 1952) opened new ways to study local aspects in solids via the hyperfine interaction of a nuclear moment with extra-nuclear fields. While for roughly half the elements no appropriate nuclei are available because of either spin-zero or spin-1/2 nuclei, respectively, one finds nuclei in isomeric states with spins suitable not only for magnetic dipole but also for electric quadrupole interaction almost over the whole periodic table. The development of adequate techniques to study hyperfine interactions like Mössbauer spectroscopy, Perturbed Angular Distribution and/or Correlation, and radiation-detected-NMR adapted to the various half-lives of the isomers lead to the field of nuclear solid-state physics. Due to its very nature, the restricted range of the hyperfine interaction in combination with the high sensitivity for detecting nuclear radiation, materials studies using isomers are ideal to investigate local structures on highly isolated atoms in solids with extremely low concentrations. Among the key words for topics in solid-state physics are fullerenes (e.g. F-19), point defects in metals and insulators (e.g. Cd-111 and Sn-119), charged defect centers in semiconductors (e.g. Cd-111), local magnetic moments (e.g. Fe-54), where the study of the hyperfine interaction of isomeric nuclei greatly contributed to an improved understanding. In return, the advanced understanding of extra-nuclear fields in solids resulted in reliably determining nuclear moments by measuring the hyperfine interaction, thus contributing to key issues in nuclear structure like high-spin isomers (in e.g. Gd-147, Rn-211 and Rn-212).

Primary author: MAHNKE, Heinz-Eberhard (ÄMP, FU Berlin, HZB)

Presenter: MAHNKE, Heinz-Eberhard (ÄMP, FU Berlin, HZB)

Session Classification: Isomer Applications, Nuclear Structure

Contribution ID: **44**

Type: **Poster**

Towards the Lifetime Measurement of the ^{229m}Th^{3+}Nuclear Clock Isomer

Monday, May 2, 2022 2:00 PM + 7:00 *PM*

The elusive Thorium Isomer (^{229m}Th) with its unusually low-lying first excited state (8.19 ± 0.12 eV or $\lambda = 150.4 \pm 2.2$ 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. More-over, 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 determina-tion 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. This work was supported by the European Research Council (ERC): Grant agreement No. 856415.

Primary authors: Mr SCHARL, Kevin (LMU Munich); Dr SEIFERLE, Benedict (LMU Munich); Dr DING, Shiqian (LMU Munich and Tsinghua University Beijing, China); Mr MORITZ, Daniel (LMU Munich); Mr ZACHERL, Florian (LMU Munich); Prof. THIROLF, Peter G. (LMU Munich)

Presenter: Mr SCHARL, Kevin (LMU Munich)

Session Classification: Poster Session On Site

Contribution ID: **45** Type: **Poster**

Search of the exotic nuclear two-photon emission decay in isochronous heavy ion storage rings

Monday, May 2, 2022 2:00 PM + *7:00 PM*

The nuclear two-photon (2γ) 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, however two-photon emission may become significant when first order processes are forbid-den or strongly retarded, which can be achieved at the experimental storage ring ESR (GSI/FAIR). Within this work we will present the implemented methodology and the obtained results of two beam times performed in 2021, when for the first time the isochronous mode of ESR alongside non-destructive Schottky detectors were operated for the study of short-lived isomer production yields and lifetimes. We investigated specifically the isotope 72Ge, as it is the most easily acces-sible nucleus having a first excited 0+ state below the pair creation threshold paramount for the study of 2γ decay without competition of first order decays. In addition, the nuclei 70Se and 72Br were studied, as their isomeric states play a major role in nuclear astrophysics.

Primary author: FREIRE FERNNDEZ, David (MPIK, GSI, CEA)

Co-authors: AKINCI, Fatma Cagla; BLAUM, Klaus (Max-Planck-Institut für Kernphysik); KORTEN, Wolfram (CEA Paris-Saclay); LITVINOV, Yury (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); SANJARI, Shahab (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); COL-LABORATION, E143

Presenter: FREIRE FERNÁNDEZ, David (MPIK, GSI, CEA)

Session Classification: Poster Session On Site

Contribution ID: **46**

Type: **Talk**

Continued efforts towards direct laser spectroscopy of b229mTh

Monday, May 2, 2022 4:00 PM (30 minutes)

The first excited nuclear isomeric state of Thorium-229 exhibits a special position in the nuclear landscape as it possesses the lowest known excitation energy of all nulcear sates. With an energy of only about 8 eV it conceptually allows for nuclear laser spectroscopy and the development of a nuclear optical clock. Until the present day laser spectroscopy of Thorium-229 has not been achieved and several groups worldwide are aiming for this objective. In this presentation I will fo-cus on the efforts torwards direct frequency comb spectroscopy of Thorium-229 at JILA in Boulder, CO. I will give an update on the current status of the experiment and discuss the most recent chal-lenges and findings. In the end, I will provide a discussion about potential future investigations.

Primary author: VON DER WENSE, Lars

Co-authors: Mr ZHANG, Chuankun; Prof. YE, Jun

Presenter: VON DER WENSE, Lars

Session Classification: The Intriguing 229Th Isomer

Contribution ID: **47**

Type: **Talk**

In-beam gamma-ray spectroscopy and lifetime measurements with HiCARI

Monday, May 2, 2022 10:00 AM (30 minutes)

The coexistence of single-particle and collective degrees of freedom in atomic nuclei gives rise to various exotic phenomena. In nuclei with very asymmetric proton-to-neutron ratios, the strong nuclear interaction drives shell evolution which alters the orbital spacing, and in some cases even the ordering present in stable nuclei. Such changes in the structure can have profound conse-quences for structure and dynamics of nuclei as well as the synthesis of elements in the universe. In-beam gamma-ray spectroscopy with fast radioactive beams is an excellent tool to study the structure of the most exotic nuclei in the laboratory. High-resolution spectroscopy also allows to determine excited state lifetimes.

In this talk, I will present the HiCARI project "High-resolution Cluster Array at RIBF". This hy-brid array of segmented germanium detectors was constructed from contributions from around the world. The physics program includes a wide range of topics in nuclear structure addressing collective and single-particle structure of nuclei very far from stability. I will discuss highlights of the experimental campaign and present new ideas to further enhance the sensitivity of the exper-imental method through the use of active targets.

Primary author: WIMMER, Kathrin (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Presenter: WIMMER, Kathrin (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Session Classification: Nuclear Structure I

Contribution ID: **48**

Type: **Talk**

Another Isomer in 102Rh ?

Tuesday, May 3, 2022 5:00 PM (15 minutes)

It is well known that 102Rh has a ground state with t1/2 = 207.3 days and an isomer at an excita-tion energy of 140.7 keV with t1/2 = 3.742-years. Following the irradiation of a rhodium chloride target with 35-MeV protons from Lawrence Berkeley National Laboratory's 88-Inch Cyclotron, we chemically separated the rhodium and palladium fractions and then counted them separately us-ing high-purity Ge detectors. In the Rh fraction, we observed a growth over time in the intensities of several gamma-ray lines attributable to the decays of 102Rhg,m. One possible interpretation of these results is that there exists a previously unobserved second isomer in 102Rh. From our measurements, we deduce a half-life of this potential new isomer of approximately 46 hours. Puzzles associated with these observations will be presented.

Primary author: NORMAN, Eric (Univ. of California at Berkeley)

Presenter: NORMAN, Eric (Univ. of California at Berkeley)

Session Classification: Evening Online Session

Contribution ID: **49**

Type: **Talk**

High-K isomeric states in the A~250 region: new isomers in 249,251Md and stability inversion in 250No.

Wednesday, May 4, 2022 11:30 AM (15 minutes)

A century after its discovery, isomerism has proven to be a very fertile tool for the study of nuclear structure, with an important impact on models development. As early as 1973, isomeric states were observed in the A 250 mass region in 250 Fm and 254No by Ghiorso et al [1]. This region around Z = 100, N = 152 is characterized by prolate-deformed nuclei with the presence of several high-K orbitals, resulting in an ac-cumulation of high-K isomeric states such as in the even-even 250,256Fm, 250,252,254No, 256Rf, with 249,251Md and 255Lr being the only case in the odd-Z nuclei. These isomers together with other measurements feed and influence the interpretation of heavy nuclei in terms of shell structure.
Indeed, the presence of the isomeric state provides the opportunity to select experimentally a de-excitation path and therefore to access orbitals that would be hardly accessible otherwise. More-over, the excitation energy of such states is a good test of nuclear models since it strongly depends on the details of single-particle spectra and on generic properties such as pairing correlations and the presence or not of a shell gap.
In this presentation, we will report on recent investigations performed at the University of Jyväskylä. High-K isomers were observed for the first time in 249,251Md[2]. They are interpreted as 3-qp excitations. 250No has long been an enigmatic case with fission having two lifetimes components. This puzzle was solved thanks to digital electronics and has demonstrated that 250No is one of the rare cases with a stability inversion, i.e. an isomeric state whose lifetimes is longer than the ground state [3]. Comparisons with theoretical calculations will be presented. The systematics of high-K isomer half-lives around N=150 will also be discussed.

[1] A. Ghiorso et al., Phys. Rev. C 7 (1973) 2032
[2] T. Goigoux, Ch. Theisen, B. Sulignano et al., Eur. Phys. J. A 57 (2021) 57
[3] J. Kallunkathariyil, B. Sulignano et al., Phys. Rev. C 101 (2020) 011301(R)

Primary authors: THEISEN, Christophe (CEA Saclay); Dr SULIGNANO, Barbara (CEA/Saclay)

Presenter: THEISEN, Christophe (CEA Saclay)

Session Classification: Isomers in Heavy and Superheavy Nuclei

Contribution ID: **50**

Type: **Poster**

Global Searches and Optimisation in the Utilitarian Approach to Nuclear Excitation by Electron Capture (NEEC)

Monday, May 2, 2022 2:00 PM + *7:00 PM*

Nuclear Excitation by Electron Capture (NEEC) involves the capture of an electron into a vacant atomic orbital, with the simultaneous excitation of the nucleus, assumed due to virtual photon exchange, and is a possible mechanism that can depopulate isomers in hot-dense astrophysical plasmas. The first observation of NEEC was reported in Nature 2018 1, via the depletion of the 6.85hour $21/2^{+}$isomer of ^{93}Mo in a beam-recoil-foil setup. The depletion probability was eval-uated via a novel triple-coincidence gamma detection technique, with a resulting non-Coulomb excitation probability being attributed to the NEEC process with probability P_{exc} = 0.01. In a follow up paper 2, the theoretical calculation of the same scenario yielded an upper limit NEEC depletion probability of $P_{exc} \sim 10^{-11}$. This depletion probability has been re-examined in [3], in which including the bound ^{nat}C target electrons allows a considerable increase and broadening in the collision and momentum density of available electrons. Thus the theoretical NEEC deple-tion probability has increased by up to an order of magnitude, the process being referred to as NEEC-Resonant-Transfer. Still it seems, there is an unknown mechanism at play to account for the remaining 8 orders of magnitude in unclaimed isomer depletion probability.

Currently one cannot ascertain the reason for this disparity without repeating the experiment under similar scenarios, and designing many NEEC and non-NEEC environments that can com-plement our understanding of the interaction space. This requires a holistic approach, including all possible types of experiment.

To assist in design and enhance the extent to which theory and experiment can be compared, we have developed a systematic NEEC tool, which combines via modern data-science techniques the NIST and ENSDF databases along with the BrIcc and FLYCHK companion tools. This allows the experimenter to choose an appropriate initial species and optimise macroscopic parameters in the chosen experimental approach, with a microscopic scaling allowing NEEC resonance strengths to be accurate to within an order of magnitude or better. Concurrently, we can express how such a tool can be used to evaluate the astrophysical impact of NEEC across the entire nuclear chart.

[1] C. J. Chiara et al. "Isomer depletion as experimental evidence of nuclear excitation by electron capture". Nature Publishing Group 554.7691 (2018),pp.216–218.issn:0028-0836. doi:10.1038/nature25483.url:http://dx.doi.org/
[2] Y. Wu, C. H. Keitel, and A.Pálffy. "93mMo isomer depletion via beam-based nuclear excitation by electron capture". physical review letters(mar. 2019). doi: 10.1103/physrevlett.122.212501. url: http://arxiv.org/abs/1904.00809. url: http://dx.doi.org/10.1103/physrevlett.122.212501.
[3] J. Rzadkiewicz et al. "Novel approach to Mo93m isomer depletion: nuclear excitation by electron capture in resonant transfer process". in: physical review letters 127.4 (july 2021), p.042501. issn: 0031-9007. doi: 10.1103/physrevlett.127.042501. url: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.127.042501.

Primary author: WALLIS, Ben (University of York)

Presenter: WALLIS, Ben (University of York)

Session Classification: Poster Session On Site

Contribution ID: **51**

Type: **Poster**

Nuclear Excitation by Electron Capture in Excited Ions

Monday, May 2, 2022 2:00 PM + 7:00 PM

Nuclear excitation by electron capture (NEEC) was initially proposed in 1976 by Goldanskii and Namiot 1 as the inverse internal conversion process.

The recent observation of NEEC in the ^{93}Mo isomer depletion 2 caused a lively discussion [3, 4] and sparked new interest: the measured excitation probability P_{exc} is unexpectedly larger than what is predicted by the state-of-the-art theoretical model, differing by nine orders of magnitude [5]. A recent work [6], accounting for the difference between NEEC and NEEC-RT, where the target electrons are initially bound, slightly increased this theoretical limit. The authors showed that the depletion probability increases by several orders of magnitude in case of the L-shell. However, these L-channels do not contribute significantly to the P_{exc} because the charge state required for an L-vacancy to be present is greater than the averaged charge state (q_{mean}) at the resonance condition [5]. In fact, the evaluation of the NEEC cross section has been carried out widely using the assumption that the ion is in its electronic ground state prior to the capture (for brevity, GSA), inhibiting the capture in the innermost-shells as soon as the atomic orbitals fill up.

In our work, we studied the particular case of ^{73}Ge. If ground state assumption is used, NEEC into K-shell cannot occur: in all the cases the energy released through a K-capture exceeds the nuclear transition energy and NEEC is forbidden.
By lifting this restriction and considering NEEC in excited ions (NEEC-EXI), we show for ^{73}Ge that many more capture channels emerge [7]. These excited electronic configurations make NEEC through K-capture now possible, with new channels having resonance strengths larger than any other obtained under GSA. These considerations can be relevant in out-of-equilibrium scenarios. Here, excited electronic con-figurations might be more likely to occur and the same can hold true for the beam-based setup where ^{93}Mo depletion has been observed. Under NEEC-EXI, although the K-capture remains strictly forbidden for ^{93}Mo, the presence of vacancies in the L-shell at the resonance condition— even for lower charge states than q_{mean}— could make the contribution of L-channels no longer insignificant for the total excitation probability.

[1] Goldanskii, V. I., and V. A. Namiot. "On the excitation of isomeric nuclear levels by laser radiation through inverse internal electron conversion." Physics Letters B 62.4 (1976): 393-394.
[2] Guo, Song, et al. "Possible overestimation of isomer depletion due to contamination." Nature 594.7861 (2021): E1-E2.
[3] Chiara, C. J., et al. "Isomer depletion as experimental evidence of nuclear excitation by electron capture." Nature 554.7691 (2018): 216-218.
[4] Chiara, C. J., et al. "Reply to: Possible overestimation of isomer depletion due to contamination." Nature 594.7861 (2021): E3-E4.
[5] Wu, Yuanbin, Christoph H. Keitel, and Adriana Pálffy. "Mo 93 m Isomer Depletion via Beam-Based Nuclear Excitation by Electron Capture." Physical review letters 122.21 (2019): 212501.
[6] Rzadkiewicz, J., Polasik, M., Słabkowska, K., Syrocki, Ł., Carroll, J. J. & Chiara C. J. Novel approach to 93mMo isomer depletion: nuclear excitation by electron capture in resonant transfer process. Phys. Rev. Lett. 127, 042501.
[7] Gargiulo, S., Madan, I., & Carbone, F. (2021). Nuclear excitation by electron capture in excited ions. arXiv preprint arXiv:2102.05718.

Primary authors: GARGIULO, Simone (EPFL); Dr MADAN, Ivan (EPFL); Prof. CARBONE, Fabrizio (EPFL)

Presenter: GARGIULO, Simone (EPFL)

Session Classification: Poster Session On Site

Contribution ID: **52**

Type: **Talk**

K isomers in ^{248}Cf and the Z=100 deformed shell gap

Wednesday, May 4, 2022 9:30 AM (15 minutes)

The nuclear structure of neutron-rich actinide ^{248}Cf was investigated at the Tokai Tandem Accel-erator Laboratory of the Japan Atomic Energy Agency. This isotopes lies two neutrons and two protons below the generally accepted Z=100 and N=152 deformed shell gaps, but recently the location of these gaps has been heavily debated and Z=98 has also been suggested. ^{248}Cf was produced using the ^{249}Cf(^{18}O,^{19}O)^{248}Cf neutron-removal reaction. The γ rays emitted by ^{248}Cf were detected using a composite array of Ge detectors and $LaBr_3$ scintillators. Two isomeric states with half-lives in the nanosecond range were found among low-lying excited states. The first, with $t_{1/2}$~5 ns, is the previously known band-head of the K^π=2$^-$ octuple vibrational band at 592 keV. The second, with $t_{1/2}$~11 ns, is a new state which decays via a low-energy $E1$ transition to a much longer-lived state lying below 1 MeV of excitation. It will be shown how the observation of these low-lying isomeric states favors Z=100 over Z=98 for the location of the deformed proton shell gap also in ^{248}Cf.

Primary authors: ORLANDI, Riccardo (ASRC, Japan Atomic Energy Agency); Dr MAKII, H. (ASRC, Japan Atomic Energy Agency); Dr NISHIO, K. (ASRC, Japan Atomic Energy Agency); Dr HIROSE, K. (ASRC, Japan Atomic Energy Agency); Dr ASAI, M. (ASRC, Japan Atomic Energy Agency); Dr TSUKADA, K. (ASRC, Japan Atomic Energy Agency); Dr SATO, T. K. (ASRC, Japan Atomic Energy Agency); Dr ITO, Y. (ASRC, Japan Atomic Energy Agency); Dr SUZAKI, F. (ASRC, Japan Atomic Energy Agency); Dr NAGAME, Y. (ASRC, Japan Atomic Energy Agency); Prof. ANDREYEV, A.N. (ASRC, Japan Atomic Energy Agency); Prof. IDEGUCHI, E. (RCNP, Osaka University, Japan); Dr YAN, S. (CIAE, Beijing, China); Dr SHEN, Y. (CIAE, Beijing, China); Dr GAO, B. (IMP, CAS, Lanzhou, China); LI, G.(IMP, CAS, Lanzhou, China)

Presenter: ORLANDI, Riccardo (ASRC, Japan Atomic Energy Agency)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **53** Type: **Poster**

Lifetime measurement of first 4+ state in 102Sn via the decay from seniority isomer

Monday, May 2, 2022 2:00 PM + 7:00 PM

The long chain of Sn isotopes is a formidable testing ground for nuclear models studying the evo-lution of shell structure and interplay between pairing and quadrupole correlations. A transition from superfluid nuclei at midshell to spherical nuclei is also expected approaching the neutron shell closures at N = 50, where the seniority scheme can be adopted to describe the energy spectra. However, the corresponding $B(E2 : 0^+ \rightarrow 2^+)$ values have shown a presumed deviation from the expected parabolic behavior. From a theoretical point of view, various attempts have been done to explain the experimental results, in particular by including core-breaking excitations in the shell-model calculations by activating protons and neutrons from the $g_{\frac{9}{2}}$ orbital to the higher ones. From experimental side, limited data are available beyond ^{104}Sn on this very neutron-deficient region, leading to a difficulty in a firmly establishment of core-braking effect.

In this presentation, we will report on the first lifetime measurement for the 4_1^+ state in ^{102}Sn which is sensitive to the balance between the pairing and quadrupole terms in the nuclear inter-action. The experiment is performed at GSI based on the use of hybrid AIDA+HPGe+LaBr$_3$(Ce) array, made available by the HISPEC/DESPEC collaboration. The nuclei of interest were separated and identified through the FRS separator, following the production via fragmentation reaction of ^{124}Xe beam incident on a ^{9}Be target. The ^{102}Sn ions are stopped by AIDA array and γ rays emit-ted from the 6^+ seniority isomer are collected by FATIMA array which allows a direct lifetime measurement with a precision up to few tens of ps. The obtained experimental data would be compared with theoretical predictions, shedding light on the detailed wave function and the core breaking contribution.

Primary author: ZHANG, guangxin (Padova INFN)

Co-authors: MENGONI, Daniele (University of Padova); BENZONI, Giovanna (Instituto Nazionale di Fisica Nucleare (INFN)(INFN-Milano)); POLETTINI, Marta (University of Milan & INFN Milan); Dr RUDIGIER, Matthias (ikp.tu-darmstadt); GERL, Jürgen (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); GORSKA-OTT, Magdalena (GSI, Darmstadt); PÉREZ VIDAL, Rosa Marí a (IFIC-CSIC); VA-LIENTE DOBON, Jose Javier (INFN-LNL)

Presenter: ZHANG, guangxin (Padova INFN)

Session Classification: Poster Session On Site

Contribution ID: **55** Type: **Poster**

Isomeric states of 113,115In in radiative proton-capture reactions at energies of astrophysical interest

Monday, May 2, 2022, 2 PM, Online Poster Session

The population and decay of isomeric states in the neutron-deficient nuclei around $A \sim 100$ is important for astrophysical processes, as these states are often involved in vast reaction networks taking place at astrophysical sites. The general scarcity of cross section data for isomeric states in the *p*-process has provided the main motivation behind the present work. Experimental cross sections in $^{112,114}\mathrm{Cd}(p,\,\gamma)^{113,115}\mathrm{In}$ reactions have been measured for proton beam energies resid-ing inside the respective Gamow windows for each reaction, using isotopically enriched targets. Two different techniques, the in-beam γ-ray spectroscopy and the activation method have been applied, where the latter is considered mandatory to account for the presence of low-lying isomers in ^{113}In ($E \approx 392$ keV, $t_{1/2} \approx 100$ min), and ^{115}In ($E \approx 336$ keV, $t_{1/2} \approx 4.5$ h). Following the measurement of the cross sections, the astrophysical S factors and isomeric cross section ratios have been subsequently deduced. The experimental results provide stringent tests to theoretical models, confining the parametric space in the detailed Hauser-Feshbach calculations carried out subsequently.

Primary author: Mr VASILEIOU, Polytimos (National and Kapodistrian University of Athens)

Co-authors: Dr CHALIL, Achment (National and Kapodistrian University of Athens); Ms FAKI-OLA, Christina (National and Kapodistrian University of Athens); Mr PELONIS, Stefanos (National and Kapodisrian University of Athens); Ms ZYRILIOU, Aikaterini (National and Kapodistrian University of Athens); Prof. MERTZIMEKIS, Theo J. (National and Kapodistrian University of Athens)

Presenter: Mr VASILEIOU, Polytimos (National and Kapodistrian University of Athens)

Contribution ID: **56** Type: **Poster**

A cryogenic Paul trap setup for the determination of the ionic radiative lifetime of ^{229m}Th^{3+}

Monday, May 2, 2022 2:00 PM + 7:00 PM

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 com-peting 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).

Primary authors: MORITZ, Daniel (Ludwig-Maximilians-Universität München); SCHARL, Kevin (Ludwig-Maximilians-Universität München); SEIFERLE, Benedict (Ludwig-Maximilians-Universität München); ZACHERL, Florian (Ludwig-Maximilians-Universität München); DICKEL, Timo (Justus-Liebig-Universität Gießen; GSI Darmstadt); GREINER, Florian (Justus-Liebig-Universität Gießen; GSI Darmstadt); PLAß, Wolfgang (Justus-Liebig-Universität Gießen; GSI Darmstadt); VON DER WENSE, Lars (Ludwig-Maximilians-Universität München; JILA, University of Colorado); LEOPOLD, Tobias (Max-Planck-Institut für Kernphysik, Heidelberg; PTB Braunschweig); MICKE, Peter (Max-Planck-Institut für Kernphysik, Heidelberg; CERN, Genf); CRESPO LÓPEZ-URRUTIA, José (Max-Planck-Institut für Kernphysik, Heidelberg); SCHMIDT, Piet O. (PTB Braunschweig); THIROLF, Peter G. (Ludwig-Maximilians-Universität München)

Presenter: MORITZ, Daniel (Ludwig-Maximilians-Universität München)

Session Classification: Poster Session On Site

Contribution ID: **57**

Type: **Talk**

From Exotic Symmetries to Exotic Isomers in Both Stable and Exotic Nuclei

Wednesday, May 4, 2022 8:30 AM (30 minutes)

We discuss selected results of a large scale exotic symmetry research project addressing even-even nuclei with Z, N > 10, including exotic and super-heavy nuclei – calculations performed in multidi-mensional deformation spaces. In the presentation we focus on realistic nuclear mean-field theory results for two types of nuclear isomers: yrast-trap and K-isomers in axially symmetric nuclei, cf. recent refs. [1,2], as opposed to nuclear shape-isomers generated by exotic shape-symmetries. In the present terminology, shapes which are neither quadrupole prolate, oblate or triaxial nor pear-shape octupole deformed are referred to as exotic.

We employ our phenomenological mean field Hamiltonian with its universal parametrisation. The term 'universal' refers in the present context to the fact that the parameter set used is common for all the nuclei in the nuclear mass table. There are no further parametrisation adjustments e.g. depending on the experimental context.

Our microscopic calculations of the nuclear potential energies - in particular 2D projections usually called potential energy surfaces - involve applications of the Inverse Problem Theory to stabilise the predictive power of the new parametrisation of the Hamiltonian and of the Graph Theory to address multidimensional shape analysis. Predictive power of this new parametrisation has been tested in recent ref. [3]. Both techniques are well known in the domain of applied mathemat-ics. We employ Group Representation Theory to address point-group symmetries, in particular to construct experimental identification criteria of newly predicted, exotic symmetries.

Presentation, while focussing on new applications of the powerful mathematical tools, addresses mainly experimental nuclear-structure audiences; we use in particular selected unpublished mate-rial of our collaboration [4].

Relating specifically to exotic-shape isomers, we wish to discuss in particular the properties of the newly predicted, so-called molecular symmetries D_{3h}, D_{2v} and D_{2d} together with their experi-mental identification criteria, as well as a new mechanism referred to as 'isomer bands' – a new property of nuclei in their tetrahedral, T_d, and/or octahedral, O_h symmetry configurations, the latter recently discovered in subatomic physics, cf. ref. [5].

References:

1 C. Hornung et al., Phys. Lett. B802 (2020) 135200
2 S. Beck et al., Phys. Rev. Lett. 127 (2021) 112501
[3] A. Gaamouci, I. Dedes, J. Dudek, A. Baran, N. Benhamouda, D. Curien, H. L. Wang and J. Yang, Phys. Rev. C103 (2021) 054311
[4] J. Yang, J. Dudek, I. Dedes, A. Baran, D. Curien, A. Gaamouci, A. Gozdz, A. Pedrak, D. Rouvel,H. L. Wang and J. Burkat; submitted for publication
[5] J. Dudek et al., Phys. Rev. C97 (2018) 021302(R)

Primary author: DUDEK, Jerzy (IPHC/CNRS and Strasbourg University)

Presenter: DUDEK, Jerzy (IPHC/CNRS and Strasbourg University)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **58** Type: **Talk**

E3 decaying isomers and octupole collectivity in the vicinity of 208Pb

Monday, May 2, 2022 9:30 AM (30 minutes)

Nuclei in the vicinity of doubly-magic ones often exhibit isomeric states arisen due to the low energies and/or high multipolarities of the gamma rays depopulating them. Around ^{208}Pb these long-lived states often decay by electric octupole (E3) transitions. Their transition strength give information about their nature. In this region these can be collective, explained by the large num-ber of Δl=Δj=3 orbital pairs across Z=82 and N=126, forming a vibrational phonon with B(E3)~35 W.u. at ~2.6 MeV. Or they can be of single-particle nature, connected to the presence of a non-natural parity high j orbitals in all four shells around ^{208}Pb. Alternatively, they can be mixed. This contribution will discuss the structure of nuclei in the vicinity of ^{208}Pb, with emphasis on isomeric states and the role of octupole collectivity.

Primary author: PODOLYAK, Zsolt (U Surrey)

Presenter: PODOLYAK, Zsolt (U Surrey)

Session Classification: Nuclear Structure I

Contribution ID: **60**

Type: **Poster**

Nuclear isomers and their implications in stellar environments

Monday, May 2, 2022, 2:00 PM, Online Poster Session

Isomers are major tools for the study of nuclear structure especially high-spin spectroscopy. Nu-clear isomers occur throughout the nuclear chart, but high-K isomers are abundant in the rare-earth region. This type of isomer has an axially symmetric shape and possesses a quantum num-ber "K", corresponding to the projection of the total angular momentum onto the symmetry axis. Because of K selection rule, decay from a high-K state to low-K state can be hindered. Therefore, they have longer half-lives than usual excited states and form high-K isomers. Rotational bands based on these isomers are also possible and give unique access to the structure in exotic nuclei. From the astrophysical point of view, apart from the prominent peaks at A =130 and A =190, there is a small bump near A ~ 160. This is well-known as the rare-earth element (REE) peak. It has been suggested that deformation plays important role in the formation of the REE peak. Although the structure of neutron-rich nuclei in the rare-earth region has a broad range of interests, spectro-scopic information is very limited. We present here the nuclear structure of these nuclei, possible K-isomers and their properties. Isomers potentially have important consequences for nucleosyn-thesis. In spite of enormous progress, the treatment of isomers in stellar network simulation poses a major challenge. We demonstrate with examples of 26Al, 34Cl and 85Kr, how to treat accurately the isomers and to calculate beta-decay rates at stellar conditions. The explicit treatment of nuclear structure effects is important for calculating nuclear reaction rates in astrophysical conditions.

Primary authors: GHORUI, SURJA (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China); Dr SUN, Yang (Shanghai Jiao Tong University, Shanghai, China)

Presenter: GHORUI, SURJA (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China)

Contribution ID: **61**

Type: **Talk**

ISOMER STUDIES BY THE ARMY RESEARCH LABORATORY

Monday, May 2, 2022 5:30 PM (30 minutes)

Energy storage in chemicals, whether fuels or batteries, forms the basis for the U. S. Army's many energy and power applications. However, these materials are restricted in both energy density and longevity, motivating interest in radioisotopes and nuclear isomers as a means of pushing beyond the "chemical limit". In particular, the potential for long-lived isomers to enable production, accumulation, and storage of energy-dense materials for extended periods is attractive. The ability to utilize isomeric materials for applications will likely depend on mechanisms by which to transfer population from such isomers to shorter-lived states upon demand. This presentation will survey basic research on isomers conducted by the Army Research Laboratory.

Primary authors: CARROLL, James (DEVCOM/Army Research Laboratory); Dr CHIARA, Christopher (DEVCOM/Army Research Laboratory)

Presenter: CARROLL, James (DEVCOM/Army Research Laboratory)

Session Classification: Evening Online Session

Contribution ID: **62** Type: **Poster**

Isomers in even-Z nuclei below the N=82 shell

Monday, May 2, 2022, 2 :00 PM, Online Poster Session

Around closed shells, intruder orbitals with large angular momentum difference and opposite parity compared to the ground state orbital lead to an accumulation of isomeric states. Below the N = 82 shell, low-lying states in the even-Z, N = 81 isotones are the J_ = 1/2+; 3/2+ and 11/2 neutron-hole states, associated with the s1/2, d3/2, and h11/2 orbitals, respectively. From 13150Sn to 149 68Er, the J_ = 11/2 states are isomeric, in 129 48Cd this becomes the ground state 1. In this chain of isomers, the excitation energy remains constant at 750 keV from 139 58 Ce to 149 which is a unique feature on the nuclear chart for long-lived isomeric states. 68 Er, Recently 2, this chain was extended towards the proton drip line using TITAN's multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) at TRIUMF. MR-TOF-MS are a powerful tool to discover long-lived isomers [4, 5] and study their properties [6]. Masses of neutron-deficient Yb isotopes including the ground and isomeric state in 151 70 Yb were measured, and the excitation energy of the J_ = 11/2 isomer in 151 70 Yb was thus derived. The new value falls in line with the observed systematics. State-of-the-art mean field calculations including shape degrees of freedom were performed to unravel the constancy of the excitation energies. The measurements and the theoretical results will be presented.

1 V. Manea et al., Phys. Rev. Lett. 124, 092502 (2020)
2 S. Beck et al., Phys. Rev. Lett. 127, 112501 (2021)
[3] C. Hornung et al., Phys. Lett. B 802, 135200 (2020)
[4] C. Izzo et al., Phys. Rev. C 103, 025811 (2021)
[5] I. Miskun et al., Eur. Phys. J. A 55, 148 (2019)

Primary authors: Mr BECK, Sönke (Justus-Liebig-Universität Gießen; GSI Darmstadt); KOOTTE, Brian (TRIUMF, Vancouver, Canada; University of Manitoba, Winnipeg, Canada); DEDES, Irene (Pol-ish Academy of Sciences, Krakow, Poland); DICKEL, Timo (Justus-Liebig-Universität Gießen; GSI Darmstadt); DILLING, Jens (TRIUMF Vancouver, Canada; University of British Columbia, Vancouver, Canada); DUDEK, Jerzy (IPHC/CNRS and Strasbourg University); HORNUNG, Christine (GSI Darm-stadt); IZZO, Christopher (TRIUMF, Vancouver, Canada); KRIPKO-KONCZ, Gabriella (Justus-Liebig-U-niversität Gießen); KWIATKOWSKI, Anna A. (TRIUMF, Vancouver, Canada; University of Victoria, Victoria, Canada); LYKIARDOPOULOU, Eleni Marina (TRIUMF Vancouver, Canada; University of British Columbia, Vancouver, Canada); MINKOV, Nikolay (Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria); PLAß, Wolfgang (Justus-Liebig-Universität Gießen; GSI Darmstadt); REITER, Moritz Pascal (University of Edinburgh, Edinburgh, Scotland, UK; Justus-Liebig-Universität Gießen; TRIUMF, Vancouver, Canada); SCHEIDENBERGER, Christoph (Jus-tus-Liebig-Universität Gießen; GSI Darmstadt; Helmholtz Forschungsakademie Hessen für FAIR)

Presenter: Mr BECK, Sönke (Justus-Liebig-Universität Gießen; GSI Darmstadt)

Contribution ID: **63**   Type: **Talk**

Nuclear metastability: from K-isomers to the optically accessible ^{229m}Th

Monday, May 2, 2022 3:00 PM (30 minutes)

The common microscopic origin of nuclear metastability manifesting in the wide energy range from the mega electronvolt excitations of K-isomers in even-even nuclei to the exceptionally low-energy excitation of several electronvolts in the ^{229m}Th "clock" isomer will be discussed. It will be shown in terms of relatively simple nuclear-structure models that the very fine interplay between the intrinsic shell structure and the collective shape dynamics of the nucleus may govern the formation, energy and electromagnetic properties of the isomers throughout this vast energy scale. It will be exemplified how the reflection-asymmetric (quadrupole-octupole, QO) deformation may favour single-particle (s.p.) configurations forming K-isomers in heavy and superheavy even-even nuclei 1. For ^{229}Th it will be shown that the QO deformation may be responsible for the quasi-degeneracy of s.p. orbitals which together with the collective mode and Coriolis interaction lead to the formation of the 8 eV isomer and determine its decay characteristics 2. The later is of a great current interest in the establishing of a new frequency standard. It will be shown that the considered dynamical mechanism could govern also in other nuclei excitations close to the optical energy range which may open the door for new developments on the border between nuclear and atomic physics.

References

1 P. M. Walker and N. Minkov, Phys. Lett. B 694, 119 (2010); N. Minkov and P. M. Walker, Eur. Phys. J. A 48: 80 (2012); Phys. Scripta 89, 054021 (2014).

2 N. Minkov and A. Palffy, Phys. Rev. Lett. 118, 212501 (2017); Phys. Rev. Lett. 122, 162502 (2019); Phys. Rev. C 103, 014313 (2021).

Primary author: MINKOV, Nikolay (Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences)

Presenter: MINKOV, Nikolay (Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences)

Session Classification: The Intriguing 229Th Isomer

Contribution ID: **64**

Type: **Poster**

Lifetime of the 7(−) isomeric state of the odd-odd nucleus 68Ga

Monday, May 2, 2022, 2:00 PM, Online Poster Session

Isomeric nuclear states are nuclear states which decays with long lifetimes (T1/2 > 10 ns) and generally reveals, a big change in angular momentum in its decay, a small ma-trix element or a small transition energy. By measuring lifetimes of isomeric states it's possible to obtain information about this state wave function, being a robust test for nuclear models. There are several gamma-ray spectroscopy techniques to measure lifetimes; in this work a system de-veloped in Laboratório Aberto de Fí sica Nuclear (LAFN) of University of São Paulo called SIStema para Medida de Estados Isoméricos (SISMEI) was utilized. This system utilizes delayed coincidence between evaporated particles in a nuclear reaction and the delayed gamma-rays emitted from the isomeric state to measure lifetimes. SISMEI is composed by plastic scintillators for particle detec-tion, hiperpure germanium detectors (HPGe) and sodium iodide (NaI(Tl)) for gamma-ray detection, coupled to a coincidence electronic system, located at Pelletron (8UD) accelerator - LAFN. In the present work, an experiment to measure the $7^{(-)}$ (E = 1229.87(4) keV) isomeric state of ^{68}Ga was performed. The nuclear structure of this nucleus was calculated with the Large Scale Shell Model by using two different interactions and the results was compared with the known values. The experiment took about 80 hours with an event rate of about 8×10^4 counts per second. The obtained value was $T_{1/2}$ = 60.8 (11) ns with the HPGe detector, and $T_{1/2}$ = 60.83 (25) ns with the NaI, which are both compatible, but more accurate, with experimental results of other authors.

Primary authors: ESCUDEIRO, Rafael (University of Sao Paulo - University of Padova); Dr MEDINA, Nilberto Heder (University of Sao Paulo); Dr ALLEGRO, Paula Rangel P (University of Sao Paulo); Dr TOUFEN, Denis L (University of Sao Paulo and Instituto Federal de Educação, Ciên-cia e Tecnologia, Guarulhos,); Dr OLIVEIRA, José Roberto B (University of Sao Paulo); Dr RIBAS, Roberto V (University of Sao Paulo); Dr AGUIAR, Vitor Angelo P (University of Sao Paulo); Ms AL-BERTON, Saulo Gabriel (University of Sao Paulo); Dr ALCÁNTARA-NÚÑEZ, Juan (University of Sao Paulo); Dr ADDED, Nemitala (University of Sao Paulo); Dr MACCHIONE, Eduardo L A (University of Sao Paulo); Dr SCARDUELLI, Valdir B (University of Sao Paulo); Ms KURMAN, Valter (University of Sao Paulo); Dr GUAZZELLI, Marcilei A (Centro Universitário da FEI)

Presenter: ESCUDEIRO, Rafael (University of Sao Paulo - University of Padova)

Contribution ID: **65**

Type: **Talk**

Decay spectroscopy with isomeric beams using the GRIFFIN spectrometer at TRIUMF

Monday, May 2, 2022 12:15 PM (15 minutes)

The ISOL technique of producing radioactive beams at TRIUMF 1 is well recognized for produc-ing exotic species in both their ground- and isomeric states. The beta and beta-delayed-neutron decay of ground spin and isomeric states has been investigated with the GRIFFIN spectrometer 2, consisting of up to 16 Compton-suppressed hyper purity Germanium detectors for gamma-ray detection and augmented with a suite of ancillary detectors for beta-particle- and conversion electrons-tagging, and fast life-time measurements of nuclear states. Particular configurations of the GRIFFIN experimental setup lead to a superior gamma-ray efficiency and low peak-to-total background, and allow for determination of angular momenta and parity of states. In this talk we will present several comprehensive decay spectroscopy experiments in nuclei close to the magic proton numbers 28 and 50 and magic neutron number 82, populated by the decay of ground state and isomeric beams of 129,131,132In [3-5] and 80Ga [6,7]. Due to the high-efficiency of the exper-imental set-up we were able to improve beta-delayed neutron values for 131,132Sn and observe a new beta-decay branch in 129Sn, and we shone a light in the shape coexistence debate near the doubly magic 78Ni. Finally, by expanding the knowledge and information available near two re-gions of magicity, we provided crucial inputs to improve the nuclear shell model, especially in the case of 131Sn and 80Ge.

This work was supported, in part, by the Natural Sciences and Engineering Research Council of Canada (NSERC). The GRIFFIN spectrometer was funded by the Canadian Foundation of Inno-vation (CFI), TRIUMF, the University of Guelph and Simon Fraser University. TRIUMF receives funding from the Canadian Federal Government via a contribution agreement with the National Research Council Canada (NRC).

[1] J. Dilling et al., Hyperfine Int. 225, 1 (2014).
[2] A.B. Garnsworthy et al., NIM A 918, 9 (2019).
[3] F.H. Garcia et al., Phys. Rev. C 103, 024310 (2021).
[4] R. Dunlap et al., Phys. Rev. C 99, 045805 (2019).
[5] K. Whitmore et al., Phys. Rev. C 102, 024327 (2020).

Primary author: ANDREOIU, Corina (Simon Fraser University)

Presenter: ANDREOIU, Corina (Simon Fraser University)

Session Classification: Nuclear Structure II

Contribution ID: **66** Type: **Talk**

Structure and Energy of Isomeric States of some Well-Deformed Even-Even Rare-Earth and Actinide Nuclei, a Microscopic Approach

Monday, May 2, 2022 12:00 PM (15 minutes)

The single particle (sp) structure of isomeric states of some well-deformed even-even nuclei in the rare-earth and actinide regions is studied within a self-consistent Hartree- Fock plus BCS approach (with blocking)1. The well studied Skyrme SIII parametrisation is used for the particle-hole part of the nuclear interaction and a seniority force for its residual part. The parameters of the latter have been carefully adjusted to reproduce the moments of inertia of the first 2+ states separately in each region. The criterion to assess the relevance of our results is the fair reproduction of the isomeric energy as obtained from two independent self-consistent calculations [1,2]. The calculations will be limited to merely seniority-two states for each charge states (possibly combining them). A particular effort will be devoted to study the well-documented isomeric states around the 178Hf nucleus. The polarisation effects due to the sp excitations from what is obtained in the ground states for time-even moments of the density will be discussed.

1 P. Quentin, L. Bonneau, N. Minkov, D. Ivanova, J. Bartel, H. Molique, K. Meng-Hock, "Single-particle spectra, pairing correlations and spectroscopic properties of actinide and heavier nuclei ", Bulg. Journ. Phys. 48 (2021) 634-644.
2 N. Minkov, L. Bonneau, P. Quentin, J. Bartel, H. Molique, D. Ivanova, "Energies of K-isomeric states in well-deformed heavy even-even nuclei ", submitted for publication in Phys. Rev. C.

Primary author: QUENTIN, Philippe (CENBG)

Presenter: QUENTIN, Philippe (CENBG)

Session Classification: Nuclear Structure II

Contribution ID: **67** Type: **Poster**

B(E2) predictions within the proxy-SU(3) symmetry

Monday, May 2, 2022 2:00 PM + 7:00 PM

The proxy-SU(3)symmetry is an extention of the Elliott SU(3), applicable in medium mass and heavy nuclei. It has been succesfully used in the prediction of: a) the dominance of the prolate over the oblate nuclear shape, b) the prolate-oblate shape transition and c) the islands of shape coexistence on the nuclear chart. The quadrupole electric transition probabilities among isomeric, positive parity states shall be presented within the proxy-SU(3) symmetry.

Primary author: MARTINOU, Andriana (INPP Demokritos)

Presenter: MARTINOU, Andriana (INPP Demokritos)

Session Classification: Poster Session On Site

Contribution ID: **68** Type: **Talk**

Isomers explored with novel ion-trapping techniques at JYFLTRAP

Tuesday, May 3, 2022 2:15 PM (30 minutes)

Penning-trap mass spectrometry offers a way to determine excitation energies of isomeric states via high-precision mass measurements. The method is very useful for beta-decaying isomers with half-lives longer than around 100 ms. Excitation energies of such isomers are often challenging to unambiguously determine with other techniques. Penning-trap mass spectrometry can also reveal new isomeric states. For example, a new high-spin isomer in ^{128}In was recently discovered with the JYFLTRAP double Penning trap at the Ion Guide Isotope Separator On-Line (IGISOL) facility.

Low-lying isomeric states have been challenging for experiments and for many nuclei it has re-mained unclear which state is the ground state. The resolving power of Penning traps has increased considerably with the phase-imaging ion cyclotron resonance (PI-ICR) technique, capable of resolv-ing very low-lying isomeric states down to excitation energies of around 20 keV. A large number of low-lying isomeric states e.g. in neutron-rich Ru, Rh, Ag and In isotopes have been recently re-solved and measured using the PI-ICR technique at JYFLTRAP. In many cases, the measurements have been supported by laser or post-trap decay spectroscopy to further identify the studied states. In this contribution, I will give an overview with selected highlights of recent studies on isomers at JYFLTRAP.

Primary author: KANKAINEN, Anu (University of Jyväskylä)

Presenter: KANKAINEN, Anu (University of Jyväskylä)

Session Classification: Precision Mass Spectrometry, Nuclear Structure

Contribution ID: **69** Type: **Poster**

Significance of the 2.3 keV isomer state in 205-Lead in determining its fate in the early solar system

Monday, May 2, 2022, 2 PM, Online Poster Session

Understanding the production and survival of ^{205}Pb in stars is pivotal as ^{205}Pb is the only short-lived radionuclide that is produced exclusively by the slow neutron capture process (s-process). The ratio of radioactive ^{205}Pb to stable ^{204}Pb, when compared to the expected value from the con-tinuous galactic nucleosynthesis, helps to constrain nucleosynthesis activity just prior to the Sun's birth. Concerns were raised on the validity of ^{205}Pb as a cosmochronometer 1 as the ^{205}Pb/^{204}Pb ratio is strongly affected due to the existence of the 2.3 keV excited state in ^{205}Pb, from which the electron capture decay to ^{205}Tl is expected to be significantly faster than from the ground state ($t_{1/2}$ = 17.3(7) Myr). However, it was pointed out 2 that the bound-state beta decay [3], an exotic decay mode in which an electron is directly created in one of the empty atomic orbitals in-stead of being emitted into the continuum, of ^{205}Tl could counter-balance the reduction of ^{205}Pb.

In this talk, the authors report on the first direct measurement of the half-life of the bound-state beta decay of fully-stripped ^{205}Tl^{81+} ions to the 2.3 keV excited state of ^{205}Pb^{81+} ions [4], which was realized in the spring beamtime at the heavy-ion storage ring ESR at GSI, Darmstadt in 2020, wherein the entire accelerator chain was employed. ^{205}Tl^{81+} ions (with no electron) were pro-duced with the projectile fragmentation of ^{206}Pb primary beam on ^{9}Be target, separated in the fragment separator (FRS), accumulated, cooled, and stored for different storage times (up to 10 hours) in the experimental storage ring (ESR). The consequences of the measurement on the source of the live ^{205}Pb in the early solar system will also be stressed in the talk.

This research has been conducted in the framework of the SPARC, ILIMA, LOREX, NucAR col-laborations, experiment E121 of FAIR Phase-0 supported by GSI. The authors received support from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant Agreement No. 682841 "ASTRUm").

References:

[1] J. B. Blake *et al.,* Nature **242**, 98, (1973).
[2] K. Yokoi *et al.,* Astron. and Astrophys. **145**, 339, (1985).
[3] R. Daudel et al., J. Phys. Radium 8, 238, (1947).
[4] Ragandeep Singh Sidhu, Ph.D. Thesis, Ruprecht-Karls-Universität, (2021).

Primary authors: SIDHU, Ragandeep Singh (The University of Edinburgh, GSI Helmholtzzen-trum für Schwerionenforschung GmbH(GSI), Max-Planck-Institut für Kernphysik); CHEN, Rui Jiu (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); LITVINOV, Yury (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); AND THE E121 COLLABORATION

Presenter: SIDHU, Ragandeep Singh (The University of Edinburgh, GSI Helmholtzzentrum für Schw-erionenforschung GmbH(GSI), Max-Planck-Institut für Kernphysik)

Contribution ID: **70** Type: **Talk**

Developments of nuclear structure models for isomers

Tuesday, May 3, 2022 3:30 PM (30 minutes)

In the study of isomer excitation and deexcitation, it is important to know the structure properties of isomers, and in addition, the intermediate states with detailed internal transitions (ITs) that connect isomers and the ground state [1,2]. Theoretical study of all these requires the modern many-body technique and knowledge on nuclear interactions. We apply two different shell models, the conventional large-scale shell model for light and spherical nuclei and the Projected Shell Model (PSM) for heavy and deformed nuclei. The original version of the PSM [3] uses restricted configuration space and interactions, which limits the application in the isomer study. Inspired by the Pfaffian method introduced by Robledo [4], a numerical breakthrough has recently been made in the calculation of matrix elements [5]. The configuration space of the PSM has been aggressively expanded (up to 10-qp states) [6,7].

These developments enable us to study detailed ITs and deexcitation of high-K isomeric states. For example, with the introduction of two-body octupole and hexadecupole forces into the Hamilto-nian and a larger model space, we are able to discuss the anomalously-fast decay of the 19/2+ 3-qp isomer in 171Tm [8]. We find that only dedicate level-structure information is considered, can iso-mer deexcitation paths be accurately determined. Our theoretical methods can be applied to cases in normal laboratory environments, as well as to extraordinary cases created by strong lasers [9] and those in astrophysical conditions [10].

[1] Y. Sun, X.-R. Zhou, G.-L. Long, E.-G. Zhao, P.M. Walker, Phys. Lett. B589, 83 (2004).
[2] M. Hasegawa, Y. Sun, S. Tazaki, K. Kaneko, T. Mizusaki, Phys. Lett. B696, 197 (2011).
[3] Y. Sun, Phys. Scr. 91, 043005 (2016).
[4] L. M. Robledo, Phys. Rev. C 79, 021302(R) (2009).
[5] T. Mizusaki, M. Oi, F.-Q. Chen, Y. Sun, Phys. Lett. B 725, 175 (2013).
[6] L.-J. Wang, Y. Sun, T. Mizusaki, M. Oi, S. K. Ghorui, Phys. Rev. C 93, 034322 (2016)
[7] X.-Y. Wu, S. K. Ghorui, L.-J. Wang, Y. Sun, M. Guidry, P. M. Walker, Phys. Rev. C 95 (2017) 064314
[8] F.-Q. Chen, Y.-X. Liu, Y. Sun, P. M. Walker, G. D. Dracoulis, Phys. Rev. C 85 (2012) 024324.
[9] J. Feng et al., Phys. Rev. Lett. 128 (2022) 052501.
[10] G. W. Misch, S. K. Ghorui, P. Banerjee, Y. Sun, M. R. Mumpower, ApJ (Suppl.) 252 (2021) 2.

Primary author: SUN, Yang (Shanghai Jiao Tong University)

Presenter: SUN, Yang (Shanghai Jiao Tong University)

Session Classification: Evening Online Session

Contribution ID: **71**

Type: **Talk**

Shell evolution below ^{132}Sn and its impact on Gamow-Teller β decay from the $(27/2^{+})$ isomer in ^{127}Ag

Tuesday, May 3, 2022 9:00 AM (30 minutes)

The change of the shell structure in atomic nuclei, so-called nuclear shell evolution, occurs due to changes of major configurations through particle-hole excitations inside one nucleus, as well as due to variation of the number of constituent protons or neutrons. We have investigated how the shell evolution affects Gamow-Teller (GT) transitions, which dominate the _ decay in the region below the doubly magic nucleus 132Sn, using the newly obtained experimental data on a long-lived isomer in 127Ag. The experiment has been carried out at the RIBF facility as part of the EURICA decay spectroscopy campaign. The T1/2 = 67:5(9) ms isomer has been identified with a spin and parity of (27/2+) at an excitation energy of 1942+14 20 keV, and found to decay via an internal transition of an E3 character, which competes with the dominant _-decay branches towards the high-spin states in 127Cd. In this presentation, the underlying mechanism of a strong GT transition from the 127Ag isomer is discussed in terms of configuration-dependent optimization of the effective single-particle energies in the framework of a shell-model approach. Besides, I will introduce a new project of decay spectroscopy at RIBF with a highly efficient fast-timing LaBr3(Ce) array IDATEN.

Primary author: WATANABE, Hiroshi (RIKEN(RIKEN-Wako))

Presenter: WATANABE, Hiroshi (RIKEN(RIKEN-Wako))

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **73**

Type: **Talk**

First access to isomeric transitions in N > 126 nuclei at RIKEN

Wednesday, May 4, 2022 2:00 PM (30 minutes)

The exotic neutron-rich region around and beyond N=126 has long been pursued for investigation in many radioactive ion beam (RIB) facilities and it is still one of the major milestones of the latest generation of RIB laboratories. Because of the challenges in accessing the region due to the technical difficulties in producing, separating, and investigating neutron-rich N⊠ 126 nuclei, the experimental information available to test shell-model calculations south of 208Pb is almost non-existent at present. Such information are essential not only for our understanding of the foundations of nuclear structure –how the shell structure evolves below and beyond N=126, and if deformation or new shell gaps develop in the region–, but to calculate more complex configurations in the more exotic, inaccessible nuclei on the r-process pathway towards the trans-bismuth fissile elements [Hol19].

Until now, the most exotic nuclei in the south-east quadrant around doubly-magic 208Pb have been at the exclusive reach of GSI (Germany), the only laboratory with favourable conditions to produce and separate them through fragmentation of relativistic 238U beams with energy enough to provide a full in-flight isotopic identification. In the present contribution, we will show how the RIBF factory in RIKEN (Japan) has broken the long-term rampart of heavy-ion identification with an innovative Si telescope system used for the first time during the 2021 spring campaign of the BRIKEN collaboration [Wu17,Tol19]. We will provide evidence on how the required resolution in both A/Q and Z is currently achievable in RIBF for A~220 nuclei through the identification of the reported (8+) seniority isomer in 216Pb [Got12]. Previously observed isomeric transitions in 210Hg and 213Tl, and newly observed ones in 213Tl will be presented. Based on this information, the level schemes of these nuclei will be revisited and discussed in terms of the latest shell-model calculations in the region [Yuan21]. Future perspectives to continue with the investigation of isomerism beyond 208Pb at RIKEN [Mor21] will be discussed as well.

References

[Got12] A. Gottardo et al., Phys. Rev. Lett. 109, 162502 (2012)

[Hol19] E.M. Holmbeck et al., Ap. J. 870, 23 (2019)

[Mor21] A.I. Morales et al., Shell evolution beyond 208Pb: Isomer and β-decay spectroscopy of neutron-rich Ir to Po isotopes. RIBF NP-PAC Proposal NP2112-RIBF208

[Tol19] A. Tolosa-Delgado et al., Nucl. Instr. And Methods A, 925-133 (2019)

[Wu17] J. Wu et al., β-decay spectroscopy in the vicinity of the N=126 closed shell. RIBF NP-PAC Proposal NP1712-RIBF158

[Yuan21] Cenxi Yuan et al., arXiv:2111.04537 (2021)

Primary author: MORALES LÓPEZ, Ana isabel (Instituto de Física Corpuscular(IFIC))

Co-authors: WU, Jin (NSCL); NISHIMURA, Shunji (RIKEN); TAIN, Jose L. (Instituto de Fisica Corpuscular, CSIC-Univ. Valencia); DAVINSON, Thomas (University of Edinburgh); FUKUDA, Naoki (RIKEN Nishina Center); HALL, Oscar Benjamin (University of Edinburgh(UE-SP)); PHONG, Vi Ho (RIKEN Nishina Center); SEXTON, Lewis (University of Edimburgh); YEUNG, Marco (University of Tokyo)

Presenter: MORALES LÓPEZ, Ana isabel (Instituto de Física Corpuscular(IFIC))

Session Classification: Isomer Applications, Nuclear Structure

Contribution ID: **74**

Type: **Talk**

Isomers in Superheavy Nuclei

Monday, May 2, 2022 5:00 PM (30 minutes)

Quasi-particle structure is vital to understanding the stability of the heaviest elements. The alpha decay and fission processes ultimately determine how long a nucleus will survive. Observations in the decay chains of 270Ds suggest that high-K multi-quasiparticle isomeric states can decay via al-pha emission where the metastable state is longer lived than the ground state of the same nucleus. Results on 254Rf suggest that high-K isomeric states can have an unprecedented hindrance against fission. Low-lying one-quasiparticle isomers in odd-A superheavy nuclei can have a large influ-ence on the properties of alpha decay chains and lead to ambiguity in their interpretation. Such properties have tremendous implications for how far we may be able to push the experimental studies of the heaviest elements. In this contribution I discuss some of the examples above in more detail and then describe recent efforts to gain a better understanding of alpha decay and fission of metastable states in the heaviest nuclei.

Primary author: CLARK, Roderick (Berkeley Lab)

Presenter: CLARK, Roderick (Berkeley Lab)

Session Classification: Evening Online Session

Contribution ID: **75**

Type: **Talk**

Nuclear isomers in medicine

Wednesday, May 4, 2022 1:00 PM (30 minutes)

In terms of societal applications the nuclear isomer Tc-99m is most famous with about 30 million diagnostic procedures performed per year with Tc-99m radiopharmaceuticals. However, there are also less famous isomers with applications in nuclear medicine as well as infamous isomers that should be avoided as radionuclidic impurity. A review will be given on past, present and future of nuclear isomers used for diagnostic or therapeutic purposes in nuclear medicine.

Primary author: KÖSTER, Ulli (Institut Laue-Langevin)

Presenter: KÖSTER, Ulli (Institut Laue-Langevin)

Session Classification: Isomer Applications, Nuclear Structure

Contribution ID: **76**

Type: **Talk**

Astromers: Astrophysically Metastable Isomers

Tuesday, May 3, 2022 4:30 PM (30 minutes)

Astrophysics models usually take one of two approaches to nuclear reaction and decay rates: either they use the nuclear ground state properties, or they take a thermal equilibrium distribution of excited states. Nuclear isomers can invalidate both of these assumptions. If an isomer has a decay rate very different from the ground state rate, its inhibited transitions can cause it to fail to reach thermal equilibrium. Without thermal equilibrium or an easy path to ground, there may not be a safe assumption about the distribution of occupation probability among the nuclear levels. I will demonstrate a method to compute thermally-mediated transition rates between the ground state and long-lived isomers that allows the nucleus to be treated as two separate species: a ground state species, and an astrophysical nuclear isomer (astromer) species. I will show some examples, including the well-known astromer Al-26 (tracer of star formation), Kr-85 (s-process branch point), and likely r-process candidates.

Primary authors: MISCH, G. Wendell (Los Alamos National Laboratory); Prof. BANERJEE, Projjwal (Indian Institute of Technology, Palakkad); Dr COUTURE, Aaron (Los Alamos National Labora-tory); Dr FRYER, Chris (Los Alamos National Laboratory); Prof. GHORUI, Surja (Institute of Modern Physics, Chinese Academy of Sciences); Prof. MEYER, Bradley (Clemson University); Dr MUMPOWER, Matthew (Los Alamos National Lab); Dr SPROUSE, Trevor (Los Alamos National Laboratory); Dr SUN, Yang (Shanghai Jiao Tong University); Prof. TIMMES, Frank (Arizona State University)

Presenter: MISCH, G. Wendell (Los Alamos National Laboratory)

Session Classification: Evening Online Session

Contribution ID: **77**

Type: **Talk**

Investigation of isomers in heavy nuclei

Wednesday, May 4, 2022 10:30 AM (30 minutes)

In heavy and superheavy nuclei with Z > 100 several isomeric states are known to exist. Some of these isomers are rather long-lived and feature low excitation energies making their identifica-tion sometimes challenging. With the Penning-trap mass spectrometer SHIPTRAP at the GSI in Darmstadt, Germany, we can identify long-lived isomers and determine their excitation energy accurately. In recent experiments carried out within the FAIR phase-0 program at GSI we have studied several isomers in No, Lr, and Rf isotopes. These experiments are very challenging due to the low production rates of the nuclide of interest and the high mass resolving powers required for isomers with tens of keV excitation energy. In my contribution I will present selected recent results to illustrate the performance of the method and discuss future perspectives. Furthermore, I will address our activities to determine the configuration of the K=8- isomer in No-254 by laser spectroscopy.

Primary author: BLOCK, Michael (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Presenter: BLOCK, Michael (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)) **Session Classification:** Isomers in Heavy and Superheavy Nuclei

Contribution ID: **78**

Type: **Talk**

Otto Hahn – His Life and His Impact on Science and Mankind

Tuesday, May 3, 2022 6:00 PM (1 hour)

The lecture describes Otto Hahn's youth in Frankfurt and his growing interest in chemistry and how his teachers, professors Theodor Zincke (Marburg), Adolf von Bayer (Munich), William Ram-say (London), Ernest Rutherford (Montreal) and Emil Fischer (Berlin) paved the way for him to become one of the world's leading radiochemists. In addition to his important discoveries in the field of radionuclides (like nuclear fission), his role in World War I and during the Nazi era is pre-sented. After the Second World War, he made a decisive contribution to the reconstruction of German scientific structures.

Primary author: SCHMIDT-BÖCKING, Horst (GU Frankfurt)

Presenter: SCHMIDT-BÖCKING, Horst (GU Frankfurt)

Session Classification: Evening Lecture

Contribution ID: **79** Type: **Talk**

Nuclear isomers – a probe of nuclear structure and deformation for the heaviest nuclei

Wednesday, May 4, 2022 11:00 AM (30 minutes)

When the liquid drop fission barrier vanishes in the fermium-rutherfordium region only the stabi-lization by quantum mechanics effects allows the existence of the observed heavier species. Those are in turn providing an ideal laboratory to study the strong nuclear interaction by in-beam meth-ods as well as decay spectroscopy after separation 1.

Among the nuclear structure features to be studied nuclear deformation and exotic shapes are the most intriguing, leading also to meta-stable states. In particular interesting are K-isomers detected up the heaviest one in 270Ds 2 which is located at the edge of the onset of the decent towards sphericity [1,3], following various theory predictions which are confirmed by recent experimental findings for the synthesis of superheavy nuclei (SHN) [4,5]. Initially low statistics data had been extended in a second experiment showing increasingly complex decay spectra, despite the even-even character of the investigated nuclei.

Detailed nuclear structure studies in terms of in-beam gamma spectroscopy or decay spectroscopy after separation (DSAS) are presently still hampered by the limited efficiencies of the existing ex-perimental facilities. Detailed DSAS studies were up to now limited to deformed nuclei around the sub-shell closures in the region of Z=100-112 and N=152-162 [6]. The recently completed linear accelerator facility SPIRAL2 at GANIL in Caen, France [7], equipped with the versatile separator spectroscopy set-up S3 [8], planned to come online in 2023/2024 will address this problem with world-wide competitive beam intensities and efficient separation paired with effective mass identification.

[1] D. Ackermann and Ch. Theisen, Phys. Scripta 92, 083002 (2017).
[2] S. Hofmann et al., Eur. Phys. J. A 10, 5 (2001).
[3] D. Ackermann, Nucl. Phys. A 944, 376 (2015).
[4] Y.T. Oganessian and V.K. Utyonkov, Nucl. Phys. A 944, 62 (2015).
[5] Y.T. Oganessian, A. Sobiczewski, and G.M. Ter-Akopian, Phys. Scr. 92, 023003 (2017).
[6] M. Asai et al., Nucl. Phys. A 944, 308 (2015).
[7] E. Petit - SPIRAL2 collaboration, Proc. of NA-PAC2016, Chicago, IL, USA, TUA1IO02, 2016.
[8] F. Dechery et al., Eur. Phys. J. A 51, 66 (2015).

Primary author: ACKERMANN, Dieter (GANIL, Caen, France) **Presenter:** ACKERMANN, Dieter (GANIL, Caen, France)

Session Classification: Isomers in Heavy and Superheavy Nuclei

Contribution ID: **80** Type: **Talk**

New Experimental Approaches to Nuclear Isomers for Nuclear Astrophysics

Tuesday, May 3, 2022 11:15 AM (30 minutes)

Nuclear isomers can play a pivotal role in the nucleosynthesis of elements and can have various effects on the reaction path. Some of these "astromers" are however difficult to produce and their effects hard to study under laboratory conditions.

I will discuss two isomer-related projects that are planned at TRIUMF, utilizing the decay spec-troscopy setup at the TITAN Electron Beam Ion Trap (EBIT) and "breeding" isomeric states in a storage ring to measure direct neutron captures.

The unique setup at the TITAN-EBIT includes six access ports where HPGe's can be installed and used for decay spectroscopy of highly-charged ions (K.G. Leach et al., NIM A 780, 91 (2015); K.G. Leach, I. Dillmann et al., Atoms 5, 14 (2017)). This allows an almost background-free access to investigate rare decay modes like the non-competitive two-photon decay and "Nuclear Excitation by Electron Capture" (NEEC).

NEEC is a resonant atomic capture process that generates a nuclear excitation. A recently claimed first observation of this process in ^{93m}Mo (C.J. Chiara et al., Nature 554, 216 (2018)) is in stark contrast to more modern calculations (Y. Wu et al., PRL 122, 212501 (2019)). The new calcula-tions dispute the earlier observation since the NEEC stimulation was predicted to be 9 orders of magnitude smaller than observed.

Recent and ongoing upgrades of the TITAN-EBIT setup will allow for the first time to investigate the NEEC process in an EBIT and to challenge previous observation, hopefully solving the large discrepancy to theoretical predictions. Our experiment will involve the selective stimulation of the NEEC process in the 17.7min (19/2-) isomer ^{129m1}Sb. A successful stimulation can then be observed by deexcitation via three characteristic gamma-transitions which are not populated by the normal isomeric transition. This experiment is planned to run in late 2022.

A new project on the horizon is the TRIUMF Storage Ring (TRISR). The TRISR will be a low-energy storage ring connected to the existing ISAC radioactive beam facility and is mainly dedicated to the direct measurement of neutron capture cross section of short-lived nuclei. I will present the project and potential reach for cross sections on short-lived radionuclides. The use of a storage ring will also allow the measurement of isomerically pure samples which can be "bred" in the ring via different storage times.

Primary author: DILLMANN, Iris (Tri-University Meson Facility (TRIUMF)(TRIUMF))

Presenter: DILLMANN, Iris (Tri-University Meson Facility (TRIUMF)(TRIUMF))

Session Classification: Atomic-Shell Nucleus Interface, 229Th, Symmetries, etc.

Contribution ID: **81**

Type: **Talk**

Isomers, the key to the origin of heavy elements and neutrino mass hierarchy

Tuesday, May 3, 2022 8:30 AM (30 minutes)

Heavy nuclei are known to be produced by various nuclear processes such as r-, ν-, νp-, γ- and s-processes in massive stars as well as small-to-intermediate mass stars like AGBs. Several nuclear isomers in heavy nuclei play the critical roles in determining their final abundances. Especially, the first three r-, ν- and νp-processes among them are strongly affected by the ν-nucleus interactions which leave observational signals in nucleosynthetic products to constrain still unknown neutrino mass hierarchy. In this talk we will first show our Galactic chemical evolution studies of heavy nuclei and discuss that the supernovae (both ν-driven winds and magneto-hydrodynamic jet SNe), the collapsars (the collapse and explosion of very massive stars leaving a black hole instead of neutron star as a remnant) and the binary neutron-star mergers are the viable astrophysical sites for these explosive processes. We will then demonstrate that the nuclear isomers in ^{180}Ta, ^{92}Nb and ^{127,128}Cd play the critical roles in these processes. Combining nucleosynthesis of ^{180}Ta, ^{92}Nb, ^{138}La, ^{11}B, ^7Li, etc., we will propose how to constrain the neutrino mass hiererchy. We also suggest several isomers in the other nuclear systems which would affect explosive nucleosynthesis.

Primary author: KAJINO, Taka (Beihang University / NAOJ / University of Tokyo)

Presenter: KAJINO, Taka (Beihang University / NAOJ / University of Tokyo)

Session Classification: Isomers in Nuclear Structure and Astrophysics ONLINE

Contribution ID: **82**

Type: **Talk**

Dark matter searches with 229mTh isomer

Tuesday, May 3, 2022 10:45 AM (30 minutes)

The long-lived isomer in 229Th, first studied in the 1970s as an exotic feature in nuclear physics, is the only known candidate for the development of a nuclear clock. The transition energy between the ground and first excited states of 229Th is unusually small and amounts to only several eV, making it the only laser-accessible nuclear transition. An optical clock based on this transition is expected to be a very sensitive probe for variation of fundamental constants, searches for violations of Einstein's equivalence principle, and ultralight dark matter. I will discuss these fundamental physics opportunities with a nuclear clock on the ground and in space.

Primary author: SAFRONOVA, Marianna (University of Delaware)

Presenter: SAFRONOVA, Marianna (University of Delaware)

Session Classification: Atomic-Shell Nucleus Interface, 229Th, Symmetries, etc.

Contribution ID: **83** Type: **Talk**

Highly-converted and low-energy isomer searches and FRIB

Tuesday, May 3, 2022 4:00 PM (30 minutes)

Isomeric nuclear states provide a window into the structure of the atomic nucleus and can serve as a first indicator of change in nuclear structure as a function of neutron and proton number. However, gaps in our understanding occur when we are unable to identify and characterize certain isomeric transitions such as those where the isomeric transition is at low energy or if the transition is highly converted. This difficulty becomes increasingly important to address as a progression is made to very exotic systems which are produced at low intensities. A program of isomer searches and characterizations has been developed at MSU that deposits a rare isotope into a position sensitive solid-state detector of either HPGe or CeBr3. The ⊠ decay of the rare isotope used to populate isomeric states and their subsequent deexcitation is observed with high efficiency. Ancillary arrays of HPGe and LaBr3 are deployed around the decaying source to monitor coincident ⊠ rays. Recent applications of the technique using neutron-rich rare isotopes will be presented and including E0 transitions and newly observed isomeric states in the mass 76 system. The continuation of the program at FRIB which has the potential to produce approximately 80% of all nuclei expected to exist below Z=92 will also be discussed.

Primary author: LIDDICK, Sean (FRIB/MSU)

Presenter: LIDDICK, Sean (FRIB/MSU)

Session Classification: Evening Online Session

Contribution ID: **85**

Type: **Talk**

Welcome

Monday, May 2, 2022 9:15 AM (15 minutes)

Presenter: WALKER, Philip (UNIVERSITY OF SURREY)

Session Classification: Opening / Welcome and Status

Contribution ID: **86**

Type: **Poster**

Lattice Location of Th in CaF_2 Using Channeling Techniques: Towards a Nuclear Clock

Monday, May 2, 2022, 2:00 PM + *7:00 PM*

The extremely low-energy ^{229}Th isomeric state has two possible decay channels towards the ground state: radiative decay and internal conversion (IC). Because of a 10^9 difference in half-life, IC is the dominant channel. Blocking the IC decay channel is critical for high-precision measurements of the transition energy and for the realization of an efficient solid-state nuclear clock. According to density functional theory calculations, doping ^{229}Th atoms into a CaF_2 crystal can block the IC de-cay channel if the thorium dopant takes its ground state configuration: Th^{4+} in a substitutional Ca site accompanied by two F^- interstitials for charge compensation. In this work we experimentally assess whether Th dopants occupy this ground state configuration in CaF_2 either doped during growth or with ion implantation. Because doping during growth is an equilibrium process, it is expected for the thorium dopants to occupy the ground state configuration. In contrast, other con-figurations might be occupied after doping with ion implantation, an out-of-equilibrium process during which abundant vacancies are produced.

Lattice positions of dopants in solids can be investigated using channeling techniques. The very large difference in mass between thorium and calcium allows to measure 2D Rutherford backscat-tering image scans of CaF_2 crystals doped with 1% Th (with respect to Ca) during growth. Doping with ion implantation is performed at ISOLDE, CERN. Here, a radioactive ion beam is implanted in CaF_2 and the lattice location of ^{229}Ac and ^{231}Th is determined with the emission channeling technique by measuring the anisotropic electron emission patterns upon the beta decay of ^{229}Ac and ^{231}Th, using a position sensitive detector. Analysis of both channeling techniques, hence both doping methods, reveals that the thorium dopants primarily occupy substitutional Ca sites, in accordance with the theoretical ground state configurations. Therefore, it is possible that a significant fraction of thorium dopants is in a configuration that can block IC decay.

Primary author: MOENS, Janni (KU LEUVEN)

Co-authors: KRAEMER, Sandro (KU Leuven, Instituut voor Kern- en Stralingsfysica); CORREIA, Guilherme (CERN); WAHL, Ulrich (ULisboa); MAGHIELS, Goele (KU Leuven, uantum Solid State Physics); TUNHUMA, Malven (KU Leuven, uantum Solid State Physics); VILLAREAL, Renan (KU Leuven, uatum Solid State Physics); SCHUMM, Thorsten (TU Wien, Atominstitut); VAN DUPPEN, Piet (KU Leuven, Instituut voor Kern- en Stralingsfysica); VANTOMME, André (KU Leuven, uantum Solid State Physics); DA COSTA PEREIRA, Lino (KU Leuven, uantum Solid State Physics)

Presenter: MOENS, Janni (KU LEUVEN)

Session Classification: Poster Session On Site

Contribution ID: **87** Type: **Poster**

A VUV frequency comb for the excitation of the 229-thorium isomer

Monday, May 2, 2022, 2:00 PM + 7:00 PM

The isotope 229-thorium features a low-energy (8.28 ± 0.17 eV) nuclear-excited state, the so-called thorium isomer 1. This unique property makes it the only nuclear transition accessible with cur-rent laser technology and therefore suitable for the operation as a nuclear clock. Such a clock has applications in fundamental physics 2 and the potential to surpass the precision achieved by cur-rent atomic clocks [3]. To drive the nuclear transition, we are building a tabletop VUV frequency comb that combines a high-power frequency comb at 1050 nm, nonlinear pulse compression, and a non-collinear enhancement resonator with 10 kW circulating power to produce high power per comb mode (≥ 1 nW/mode) and a narrow comb linewidth (appr. 1 kHz) via high harmonic gen-eration (HHG). Upon completion the laser system will be combined with a 229-Thorium trap for spectroscopy at LMU Munich.

[1] Seiferle, B. et alt. Energy of the 229Th nuclear clock transition, Nature 573, 243 (2019)

[2] Safronova, M.S. et al. Search for new physics with atoms and molecules. Rev. of Mod. Phys. 90, 025008 (2018)

[3] Campbell, C.J. et al. Single-Ion nuclear clock for metrology at the 19th decimal place. Phys. Rev. Lett. 108, 120802 (2012).

Primary authors: Mr WISSENBERG, Stephan H. (Fraunhofer-Institut für Lasertechnik ILT); Dr HUSSAIN, Mahmood I. (Ludwig-Maximilians-Universität München LMU)

Co-authors: Mrs ROZIBAKIEVA, Tamila (Lehrstuhl für Lasertechnik LLT, RWTH Aachen Univer-sity); Mr GIRR, Christian (Lehrstuhl für Lasertechnik LLT, RWTH Aachen University); Mr FRH. V. STRACHWITZ, Antonius (Lehrstuhl für Lasertechnik LLT, RWTH Aachen University); Dr RUßBÜLDT, Peter (Fraunhofer-Institut für Lasertechnik ILT); Dr WEITENBERG, Johannes (Lehrstuhl für Lasertech-nik LLT, RWTH Aachen University); Mr HOFFMANN, Hans-Dieter (Fraunhofer-Institut für Lasertech-nik ILT); Prof. HÄFNER, Constantin L. (Lehrstuhl für Lasertechnik LLT, RWTH Aachen University)

Presenters: Mr WISSENBERG, Stephan H. (Fraunhofer-Institut für Lasertechnik ILT); Dr HUSSAIN, Mahmood I. (Ludwig-Maximilians-Universität München LMU)

Session Classification: Poster Session On Site