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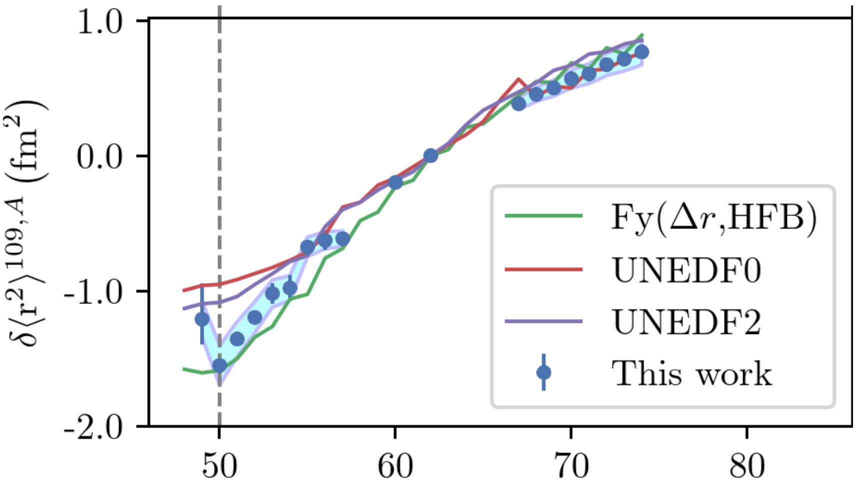
JYFL Accelerator News

– Accelerator Laboratory, Department of Physics University of Jyväskylä, Finland –

A novel set of techniques provides access to a new region of exotic atomic nuclei for optical spectroscopy and mass spectrometry



Ground-state change in mean-squared charge radii for $^{96-104}$Ag (in-source RIS) and $^{114-121}$Ag (collinear laser spectroscopy). The data are compared to theoretical calculations with Fy(Δr,Hartree-Fock-Bogoliubov(HFB)), UNEDF0 and UNEDF2 energy density functionals. The error bars indicate the statistical error. The systematic error, due to the uncertainty in the atomic parameters, is indicated by the shaded band.

The region of the nuclear chart below tin-100, the heaviest doubly-magic isotope with an equal number of protons (Z=50) and neutrons (N=50), has been of considerable interest in nuclear physics research for many years. In the region, atomic nuclei experience enhanced neutron-proton pairing, thus posing a fertile ground for testing the validity of theoretical predictions. Additionally, one finds isomers with unique features, and the astrophysical processes taking place in x-ray bursts traverses these nuclei. Despite the extensive experimental and theoretical interest, technical difficulties in producing these nuclei have, until now, hindered studies of some of the most fundamental properties, including the mass, size, and shape.

Recently, researchers at the Accelerator Laboratory of the University of Jyväskylä implemented a combination of state-of-the-art technologies, including phase-imaging ion-cyclotron resonance (PI-ICR) Penning trap mass spectrometry, an inductively-heated hot cavity catcher ion source and resonance ionization spectroscopy. These efforts are the culmination of over 10 years of developments, resulting in the first optical excursion below neutron number N=50 into the N=Z region of tin-100 with the measurement of the charge radius of silver-96, presented in the figure. The results of the research were published in Nature Communications in July 2021 [1]

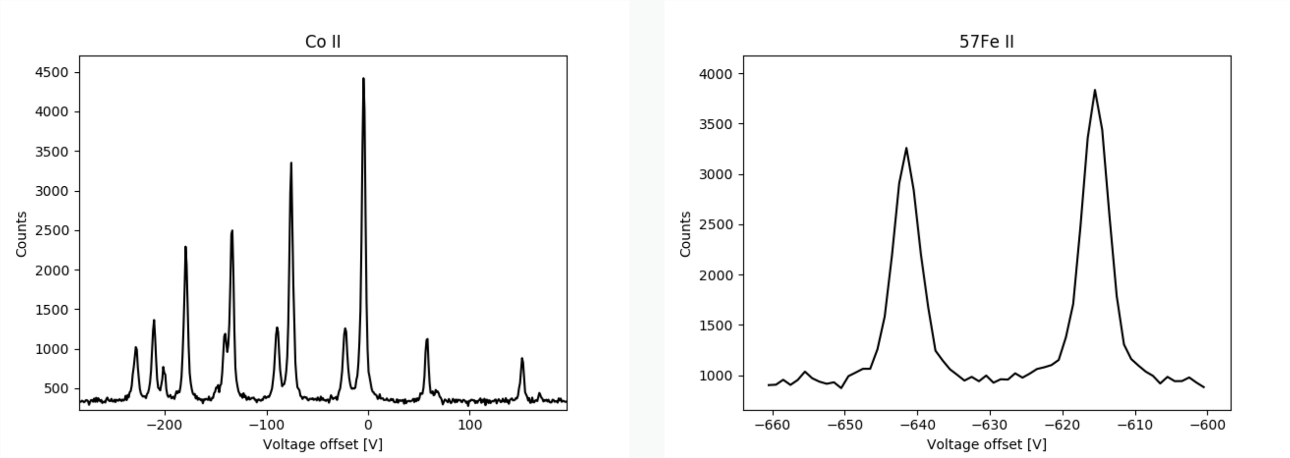
The state-of-the-art techniques were matched with the latest theoretical approaches. Nuclear theoreticians at the Department of Physics utilized a novel implementation of nuclear density functional theory. While all theoretical models provided a good reproduction of the measured charge radii in heavier silver isotopes, none of the models were able predict the sharp increase seen in silver-96 when crossing the N=50 shell closure. This result poses a challenge to present theoretical models and motivates new theoretical developments.

Most recently, in May, upgrades to the ion source as well as a different primary beam – target reaction allowed for further measurements. In addition to reducing the uncertainty of the charge radius of ^{96}Ag, the mass of both the ground and isomeric state in ^{96}Ag was measured, as well as the mass and charge radius of ^{95}Ag. The next goal will be to tackle N=Z ^{94}Ag. Moreover, a window of opportunity to extend these studies to other very proton-rich nuclei near tin-100 has been opened and will be explored.

[1] Reponen, M., de Groote, R.P., *et al.* Evidence of a sudden increase in the nuclear size of proton-rich silver-96. *Nat Commun* **12,** 4596 (2021). https://doi.org/10.1038/s41467-021-24888-x

Next Call for Proposals
Deadline: September 15, 2021

Exploring the proton-rich landscape between the doubly-magic ^{40}Ca and ^{56}Ni isotopes using collinear laser spectroscopy



Examples of the hyperfine structure of stable Co and ^{57}Fe using transitions in the 230 nm to 235 nm range.

Radioactive isotopes wedged between the magic numbers N=Z=20 and N=Z=28 have scarcely been studied with laser spectroscopy techniques. Consequently, the evolution of the nuclear charge radius is unknown in the region. The production of these isotopes at radioactive ion beam facilities is limited due to chemical properties preventing efficient extraction from thick targets. In addition, their complex atomic structure imposes a significant experimental challenge.

At IGISOL, laser spectroscopy has been previously performed on Sc (Z=21), Ti (Z=22) and Mn (Z=25). The results of the Sc experiment focusing on the investigation of the isomer shift in the self-conjugate 42Sc has been recently published in Physics Letters B [1]. Developments were initiated to expand the range of accessible elements to V (Z=23), Cr (Z=24), Fe (Z=26) and Co (Z=27). The nuclear structure of these isotopes is of particular interest to understand the phenomena emerging in proton-rich isotopes along the N=Z line as well as the evolution of collectivity between the magic nuclei bordering the proton and neutron f7/2 orbital. Most importantly, the electromagnetic properties and nuclear charge radius of the proton emitting isomer 53mCo represent a compelling case to study.

Recently, laser spectroscopy was performed on 48,49,51Cr at IGISOL, initiating this program and providing the first charge radius of a radioactive Cr isotope. Offline, the hyperfine structure and experimental efficiency of V has been investigated by performing measurements on more than 10 transitions in the blue wavelength range. To gain access to suitable transitions in Co and Fe isotopes, the spectral coverage of both the laser systems and the optical detection system were expanded into the deep-UV range. As part of these developments, a new light collection chamber was installed and equipped with photomultiplier tubes for the detection of photons between 200 nm to 300 nm.

Thanks to these developments several transitions could be measured in Fe and Co ions. Examples of the obtained hyperfine spectra are presented in the figure. The population of electrons in different ionic energy levels and their hyperfine parameters was established, and the experimental efficiency could be assessed. Collinear laser spectroscopy experiments on radioactive isotopes of these elements are therefore now feasible at IGISOL.

[1] Á. Koszorús et al. PLB 819, 10 August 2021, 13643

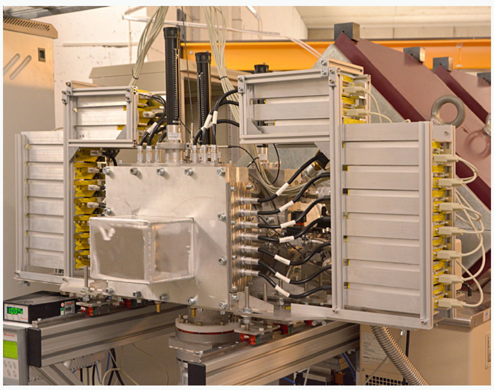
NEWS

RITU preparing for next campaigns

The RITU gas-filled separator is expected to be back in use for experimental campaigns in coming months. The focal plane has been totally reconstructed. The design is very close to that of the MARA separator. The main advantage is that the same detectors can be used in both setups. This includes 128x48 mm² DSSD detectors and a 160x60 mm² MWPC. The chamber of the focal plane is minimized in size and thickness to enhance the gamma ray efficiency. Three large Mirion 6530 BeGe detectors are available at the focal planes in all experiments.

The control of RITU magnets and vacuum system has been moved to the laboratory control system.

For example, in the future RITU will be used to perform experiments in the neutron deficient actinide region where the expected yields are rather low. This program is supported by the ongoing development work related to a new central region to be installed in K130 cyclotron to access high intensities.



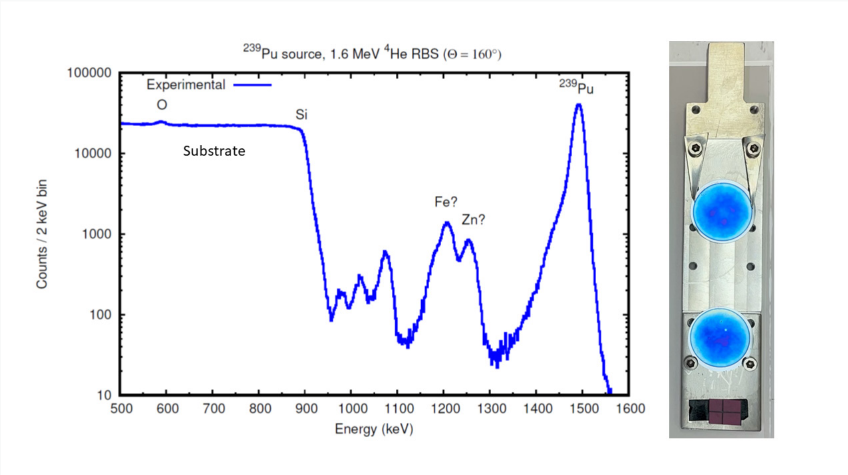
Focal plane of RITU.

Rutherford backscattering spectrometry of plutonium for the LISA Marie Curie network

LISA (Laser Ionisation and Spectroscopy of Actinides) is a European Commission funded MSCA Innovative Training Network on radioactive ion beam research and applications, laser spectroscopy, scientific laser technologies and atomic theory. As a beneficiary, JyU leads a Work Package (WP) titled "Exploring the limits of nuclear existence". One of the tasks within this WP involves actinide target development and characterization.

At the radiochemistry department of the University of Mainz, several ^{239}Pu sources have been fabricated using a molecular plating technique. With a half-life of >10^4 years, ^{239}Pu alpha decays into ^{235}U, populating the second lowest-lying isomeric state in the nuclear chart, ^{235m}U at 76 eV, with a branching ratio of almost 100%. In order to optimize the production yield of the isomer for laser spectroscopy measurements, the recoil efficiency plays a critical role. Source thickness, quality, homogeneity and substrate are all key parameters.

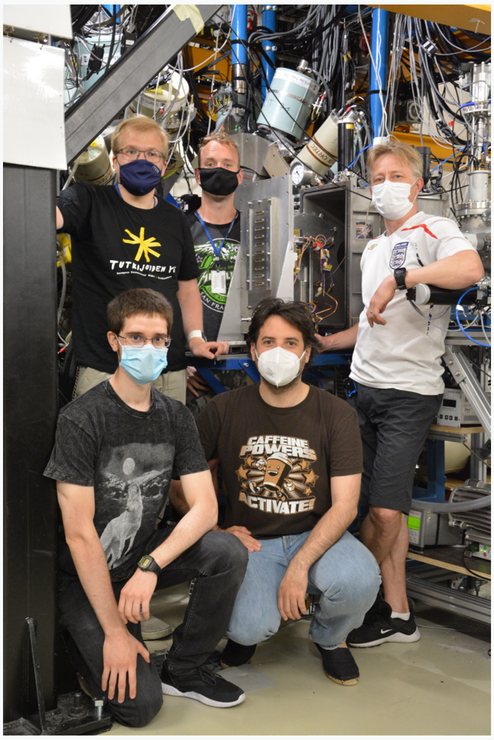
In early August, JYFL received several ^{239}Pu sources from U-Mainz, of different activity, treatment, diameter and substrate. Low-background gamma-ray spectroscopy as well as alpha decay spectroscopy was applied to determine the activity of the sources and possible contaminants. Following informal discussions between visiting Marie Curie students on secondment from U-Mainz and GSI, and members of the IGISOL and Pelletron teams, Rutherford Backscattering Spectroscopy (RBS) measurements were performed with only a few days' notice. As indicated in the figure, pairs of samples were mounted and installed in the RBS chamber. Beautiful spectra were obtained, yielding information about the substrate material, Pu thickness and other "impurity" elements, the latter likely present in the plating technique. Plutonium may well be the heaviest element studied so far using the RBS method. These multidiscliplinary characterization studies highlight the excellent collaborative atmosphere within the Accelerator Laboratory.



An RBS spectrum obtained using a ^{239}Pu source mounted on a silicon substrate. Tentative contaminants have been labelled. The sources themselves are indicated on the right, mounted on a moveable arm which inserts into the vacuum chamber.

NEWS

SAGE connected to MARA



After a few years of hibernation, the SAGE spectrometer was taken into use for its first campaign at the MARA separator. As MARA is a vacuum mode separator, this allowed for SAGE operations without the so-called carbon-foil unit that is needed at RITU to separate the 1mbar He-gas volume from the high-vacuum of the HV barrier chamber. Carbon foil removal improved the transmission efficiency and secured easier operation of SAGE, while a few other modifications were needed to adapt SAGE to operate with MARA and JUROGAM3. The campaign was very successful and produced high-quality data by affording simultaneous in-beam conversion-electron and gamma-ray spectroscopy. These data will shed light on shape coexistence in heavy nuclei in the neutron-deficient Pb region.

RADNEXT - RADiation facility Network for the EXploration of effects for indusTry and research

RADNEXT is an H2020 INFRAIA-02-2020 infrastructure project with the objective of creating a network of facilities and related irradiation methodology for responding to the emerging needs of electronics component and system irradiation; as well as combining different irradiation and simulation techniques for optimizing the radiation hardness assurance for systems, focusing on the related risk assessment.

Detailed information on the project can be found at https://radnext.web.cern.ch/

Transnational Access

Transnational Access to irradiation facilities is the cornerstone of the RADNEXT project. More than 6000 beam time hours are awarded during the four years of the project, in more than 20 different facilities in Europe and beyond. One of which is the RADEF facility at the JYFL Accelerator Laboratory.

Both academic and industrial groups are eligible for beam time as potential RADNEXT users, and in particular small and medium-sized enterprises (SMEs) are strongly encouraged to submit their proposals. Beam time awarded for RADNEXT users is free of charge, funded by EU European Union's Horizon 2020 research and innovation programme under grant agreement No 101008126.

Next quarterly call for proposals is expected to open in September 2021! More information on the Transnational Access scheme and the call for proposals can be found at https://radnext.web.cern.ch/transnational-access/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008126

NEWS

First RADMEP students have started

The first students in the Erasmus Mundus Joint Master Degree (EMJMD) programme, RADiation and its effects on MicroElectronics and Photonics technologies (RADMEP) have started their 2-year master studies in the University of Jyväskylä. In the first application round for the project there were more than 60 applications from students with nearly 30 different nationalities. From these 12 students were accepted. These students are from Bangladesh, Belgium, Brasil, Ethiopia, India, Italy, Lebanon, Mexico, Philippines.

The call for applications for RADMEP MSc studies for 2022-2024 will open later this fall. The exact date will be announced in the project webpages at https://master-radmep.org/

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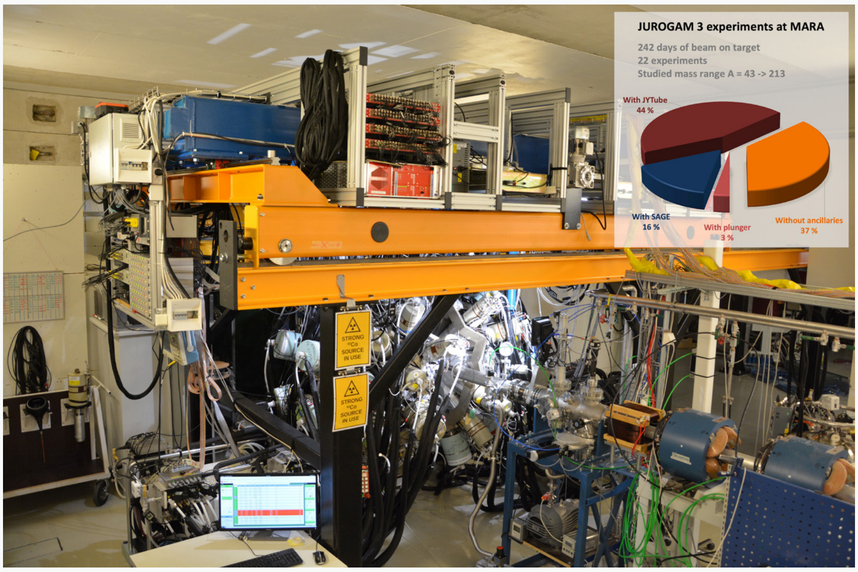
The first JUROGAM 3 campaign at MARA nearing completion

After 242 days of beam on target and 22 experiments spanning the mass range from A=43 all the way up to as heavy as A=213, the JUROGAM 3 spectrometer will have a well-deserved break. During the successful campaign at the MARA separator, JUROGAM 3 was combined with several different ancillary devices. One of them was the JYTube charged-particle detector, which was often employed in experiments investigating the isospin symmetries in N=Z nuclei. In the end of the year, the Clover detectors will be transported to the ALTO facility in Orsay, France, where they will be set-up for the second NUBALL campaign. Meanwhile, the JUROGAM 3 array will be stripped and operated with 15 Phase1 detectors in the backward angles with a main focus on plunger experiments.



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