STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

BOOK OF ABSTRACTS
SCK•CEN-BA-46

International Workshop on

Detailed decay spectroscopy at ISOL@MYRRHA

SCK•CEN Club-House, Mol, Belgium, April 23-25, 2012

SCK•CEN
Boeretang 200
BE-2400 MOL
Belgium
http://www.sckcen.be

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Status: Unclassified

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Introduction

The MYRRHA project at SCK•CEN aims to realize an accelerator-driven system consisting of a nuclear-reactor core coupled to a high-power proton Linac. The ISOL@MYRRHA facility will use a part of the proton beam of the MYRRHA accelerator to produce intense high-purity radioactive ion beams. These will allow fundamental and applied research in various fields of science including nuclear, atomic and solid-state physics, fundamental interactions and medical physics.

ISOL@MYRRHA will focus on precision experiments needing high statistics and accurate calibration and on experiments that hunt for very rare phenomena. These studies can be uniquely addressed at ISOL@MYRRHA, because of the availability of long uninterrupted beam times and the high reliability of the MYRRHA Linac. To achieve this, ISOL@MYRRHA will use ruggedized target ion sources, a cooler and buncher system and a high resolution on-line mass-separator complex.

In April 2008, a first ISOL@MYRRHA workshop was held at SCK•CEN, bringing together physicists from different research fields to discuss the physics opportunities of the ISOL@MYRRHA facility. Thereafter, the scientific as well as the technical aspects of the project were further investigated and the feasibility of a number of possible experiments was looked into. This resulted in the report "*ISOL@MYRRHA, an On-Line Isotope Separator coupled to the MYRHHA proton accelerator*" which can be found at http://isolmyrrha.sckcen.be/en/Documents. At the end of 2010, ISOL@MYRRHA was included in the NuPECC long-range plan.

In order to further detail the needs for the development of the ISOL@MYRRHA facility, a series of follow-up topical workshops is being organized gathering experts from the different disciplines that ISOL@MYRRHA is addressing. The aim is to investigate the particular opportunities for each field at ISOL@MYRRHA. These include fundamental-interactions physics, low-energy nuclear physics, radioactive-ion-beam production, laser spectroscopy and atomic physics, radiobiology and nuclear solid-state physics.

Within the present workshop, we intend to establish the physics cases for ISOL@MYRRHA in the field of detailed decay spectroscopy and to collect information on the instrumentation and requirements for the design study of the facility.

The workshop is organized in the framework of the WOG project “Exotische kernen als laboratorium voor de fundamentele interacties” 2011 funded by FWO, and the **Interuniversity Attraction Poles (IAP) Programme of the Belgian Science Policy Office (P7/22).**

Programme

	Monday, April 23, 2012		
12.30 h	Welcome lunch		
14.00 h	Opening Address	(10 min)	Eric Van Walle, SCK•CEN
	Outline of the workshop	(10 min)	Riccardo Raabe, KU Leuven
14.20 h	**Session 1 | Chair: Mark Huyse, KU Leuven**		
	MYRRHA: project status	(25+5 min)	Hamid Aït Abderrahim, SCK•CEN
	ISOL@MYRRHA project - status and perspectives	(20+5 min)	Lucia Popescu, SCK•CEN
	The Garden of Eden: ^{60}Fe; enter the snake: ^{66}Fe; detailed spectroscopy near ^{68}Ni	(30+5 min)	William Walters (Univ. of Maryland)
	Exotic Nuclei and Explosive Nucleosynthesis of Heavy Elements	(30+5 min)	Gabriel Martinez-Pinedo (TU Darmstadt)
16.25 h	Coffee break		
17.00 h	**Session 2 | Chair: Berta Rubio, CSIC-Valencia**		
	Fast timing measurements off-stability: examples and prospects at ISOL@MYRRHA	(30+5 min)	Luis Mario Fraile (UCM, Madrid)
	Ultra High Resolution Gamma Spectroscopy with Crystal Spectrometers	(30+5 min)	Michael Jentschel (ILL)
	Ideas for beta-decay spectroscopy inspired by ISOLDE and LISOL experiments in the ^{68}Ni region	(30+5 min)	Dieter Pauwels (SCK•CEN)
19.00 h	Dinner		

	Tuesday, April 24, 2012		
09.00 h	**Session 3 | Chair: William Walters, University of Maryland**		
	The need for ultra-high statistics, (ultra-) high precision spectroscopy in nuclear structure studies	(30+5 min)	John Wood (School of Physics, Georgia Institute of Technology)
	Pushing back the sensitivity frontier; high-statistics β -decay for nuclear structure studies	(30+5 min)	Paul Garrett (University of Guelph)
	The spectroscopy of ^{179}Au: the shape coexistence in odd-mass Au isotopes	(30+5 min)	Martin Venhart (Institute of Physics, Slovak Academy of Sciences)
10.45 h	Coffee break		

11.15 h	**Session 4 | Chair: Riccardo Raabe, KU Leuven**		
	Exotic beta decays of ^{11}Li	(30+5 min)	Pierre Descouvemont (ULB)
	Beta-delayed particle emission studies and its future @ MYRRHA	(30+5 min)	Maria J. G. Borge (IEM-CSIC)
12.40 h	Walking lunch		
14.00 h	**Session 5 | Chair: Lucia Popescu, SCK•CEN**		
	Beta decay experiments with the Total Absorption Technique (TAS), overview and new opportunities	(30+5 min)	Berta Rubio (CSIC-Valencia)
	Access to Highly Excited States by Gamow-Teller Transitions (in the β decay and charge-exchange reactions)	(30+5 min)	Yoshitaka Fujita (Osaka University)
	Richardson-Gaudin description of pairing in atomic nuclei	(30+5 min)	Stijn De Baerdemacker (Ghent University)
15.45h	Coffee break		
16.15 h	**Session 6 | Chair: Maria J. G. Borge, IEM-CSIC**		
	Decay spectroscopy as a probe of exotic proton-rich nuclei	(30+5 min)	David Jenkins (University of York)
	Recent results from the campaign of the AGATA Demonstrator Array at LNL	(30+5 min)	Enrico Farnea (INFN)
	Low-energy fission of proton-rich nuclei in the lead region	(30+5 min)	Andrei Andreyev (UWS)
18.00 h	Reception		
19.00 h	Dinner		

Wednesday, April 25, 2012

09.00 h	**Session 7 | Chair: Piet Van Duppen, KU Leuven**		
	Conversion electron spectroscopy, the rarely used but vital probe of nuclear structure; and the innovative development of one-of-a-kind spectroscopic equipment	(30+5 min)	Edward Zganjar (Louisiana State University)
	Trap-assisted decay spectroscopy	(30+5 min)	Sami Rinta-Antila (University of Jyväskylä)
10.10 h	Coffee break		
10.45 h	**Round-up and discussion**		**Moderator: Riccardo Raabe (KU Leuven)**
12.15 h	Walking lunch		
14.00 h	End of workshop		

Abstracts

The Garden of Eden: ^{60}Fe; enter the snake: ^{66}Fe; detailed spectroscopy near ^{68}Ni

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Abstract session 1|

New data from several recent nuclear structure experiments for nuclei near ^{68}Ni will be presented and discussed in the context of where details are important and why. The nuclei of interest will be ^{65,67}Cu, ^{62,64,66}Ni, ^{60,62}Fe, and ^{72,74}Zn.

Exotic Nuclei and Explosive Nucleosynthesis of Heavy Elements

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Abstract session 1 |

The properties of exotic nuclei play an important role in understanding the nucleosynthesis of heavy elements. Current observations of metal-poor stars show that elements with Z < 52 and those with Z > 52 are produced in different astrophysical environments. The first are most likely produced in core-collapse supernova while the astrophysical environment for the production of the heavier elements is currently unknown. In this talk, I will discuss how future experiments can help to constrain the dynamics of the astrophysical environment.

Fast timing measurements off-stability: examples and prospects at ISOL@MYRRHA

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Abstract session 2 |
The measurement of absolute nuclear transition probabilities is a very sensitive tool to study the structure of the atomic nucleus. Direct access to transition rates can be achieved via the lifetime of the nuclear levels de-populated in radioactive decay. The Advanced Time-Delayed (ATD) method, or Fast Timing, is a well-established technique to measure lifetimes down to a few ps. The development of the technique was based on the use of BaF_2 detectors, but a recent major breakthrough occurred with the introduction of $LaBr_3$(Ce) detectors, uniting excellent time response with much superior energy resolution than BaF_2 crystals.

The presentation will discuss some of the latest developments in detector and photosensor technologies, in order design and build the ultimate fast timing array. Recent experimental examples will be shown, with emphasis on decay experiments at ISOL type facilities. The opportunities at ISOL@MYRRHA will be explored.

Ultra High Resolution Gamma Spectroscopy with Crystal Spectrometers

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Abstract session 2 |

Gamma ray spectroscopy via crystal diffraction allows to achieve outstanding resolution and dynamic range when compared to absorption based detectors. The talk summarizes the main physical principles of gamma ray diffraction at crystals. Two schemes of crystal spectrometers will be discussed in detail: Single curved crystal spectrometers and double flat crystal spectrometers. Examples of experiments using a curved crystal spectrometer for the investigation of very complex spectra or the search for weak transitions will be given. Double flat crystal spectrometers allow to obtain a relative energy resolution of 10^{-6}. This allows measuring the Doppler-broadening of gamma rays from which nuclear state lifetimes can be measured via the GRID technique. Finally a outlook on an eventual combination of crystal spectrometer with refractive optics to improve luminosity and resolution will be given.

Ideas for beta-decay spectroscopy inspired by ISOLDE and LISOL experiments in the ^{68}Ni region

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Abstract session 2 |

The ^{68}Ni (Z=28, N=40) region has drawn a lot of experimental and theoretical attention in a quest to understand the subtle stabilizing effects of the N=40 gap. The region south of ^{68}Ni is of particular interest because of the observed rapid onset of deformation from the Co isotopes onwards. Based on the Co, Fe, and Mn beta-decay studies which were carried out at LISOL (Louvain-La-Neuve, Belgium) and ISOLDE (CERN), ideas will be presented for future beta-decay spectroscopy at ISOL@MYRRHA.

The high purity of the respective Co, Fe, and Mn RIBs using resonant laser-ionization schemes was crucial and, in general, also sufficient to disentangle the decay chains towards the Ni isotopes. In the ^{67}Fe decay study, however, this was not the case due to the presence of a long-lived isomer in the decay chain. The isomer could only be unambiguously placed and its half-life of 0.5 s could be determined using a slow correlation technique. Such slow correlations could be successfully applied though thanks to a combination of high RIB purity and a sufficiently low production yield, in this case of several ions/s. Since the production rate should be limited for a successful application of slow correlations, long beam times may be required to obtain the desired statistics.

The Mn-decay data, which were obtained at ISOLDE, contain a wealth of information: the Mn half-lives, gamma intensities and direct beta feedings, beta-delayed neutron probabilities, and often still additional information for the Fe and Co decays. Based on these beta-decay feeding patterns, spin assignments could be obtained. One piece of information, which could not be extracted though, is the full Mn decay-strength distribution as the beta-delayed neutron energies are not known. A possibility would be to measure the Doppler broadening of gammas emitted after neutron recoil. With the availability of intense and pure Mn beams and long beam times, this could become possible at ISOL@MYRRHA.

The need for ultra-high statistics, (ultra-) high precision spectroscopy in nuclear structure studies

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Abstract session 3 |

The presentation will emphasize the power of nuclear decay spectroscopy in answering questions that effectively advance our understanding of nuclear structure. The techniques emphasized will cover ultra-high statistics coincidence gamma-ray spectroscopy with large detector arrays and conversion electron spectroscopy. Illustrative examples will be taken from where decay scheme spectroscopy is uniquely suited to solving the specific structure problem.

Pushing back the sensitivity frontier; high-statistics β -decay for nuclear structure studies

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Abstract session 3 |

Modern radioactive-beam facilities are capable of producing intense sources that are ideal for β -decay studies that push the frontier of nuclear structure in the highly-non-yrast regime. The low-spin states away from the yrast line are often far more sensitive to details of structure than the yrast-line states, yet are difficult to probe in most reaction studies. As we move away from stable nuclei, the reaction tools at our disposal for nuclear structure become more limited in their capacity for detailed study, and β –decay becomes *the* tool of choice.

At the TRIUMF-ISAC facility, a substantial part of our nuclear structure studies have concentrated on very-high-statistics measurements of β -decay using the 8π spectrometer. With 20 Compton-suppressed HPGe detectors, an array of 20 plastic scintillators for β -particle tagging, 5 Si(Li) detectors for conversion electrons, a fast-plastic scintillator and 10 BaF_2 or $LaBr_3$ detectors for lifetime measurements, a moving-tape collector, all coupled to a high-precision and high-throughput data acquisition system, the 8π spectrometer is currently the world's most sensitive array dedicated to β -decay studies.

Our measurements aim to collect sufficient statistics for the construction of $\gamma-\gamma$ matrices with 10^8-10^9 events, allowing us to observe γ -transition branching ratios from individual states at the 10^{-4} level. Coupled with complementary information for other reactions, such as Coulomb excitation or the (*n,n'*γ) reaction, unprecedented views of the electromagnetic decay strength can be obtained.

We are beginning construction of the GRIFFIN array to replace the current 8π spectrometer.

GRIFFIN, an array of 16 large-volume unsegmented clover detectors, will deliver a factor of 300 increase in $\gamma-\gamma$ coincidence efficiency at 1.3 MeV, and will begin operation in late 2014. GRIFFIN will also be coupled to the new DESCANT neutron detector array to enable studies of β -delayed neutron emitters.

This presentation will focus on our β -decay programme with the 8π spectrometer, highlight some of the physics and lessons learned, and areas of complementarity between TRIUMF-ISAC and ISOL@MYRRHA.

The spectroscopy of ^{179}Au: the shape coexistence in odd-mass Au isotopes

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Abstract session 3 |

Neutron-deficient isotopes in the vicinity of Z = 82 and N = 104 have become the most extensively characterized region of low-energy shape coexistence. In the past, odd-Au (Z = 79) isotopes in this region, in particular, have been the subject of many experiments of different types, including decay studies, in-beam γ-ray studies and laser spectroscopy.

Phenomenon of the shape coexistence has been investigated in ^{179}Au. This very neutron-deficient isotope, 18 neutrons away from the stable gold isotope ^{197}Au, was studied by a combination of α-decay and isomer-decay spectroscopy employing the RITU gas-filled separator and the great focal-plane spectrometer at the University of Jyväskylä and CERN-ISOLDE facility. A new isomer with $T_{1/2}$=328(2) ns was observed and states associated with $s_{1/2}$ and $d_{3/2}$ proton-hole and $h_{9/2}$ and $f_{7/2}$ proton-particle structures were revealed. The implications of these results on the systematics of and intruder structures in the odd-mass gold isotopes will be discussed. The minimum of the parabolic trend is at N=104, i.e. exactly at the mid-shell point.

The structural feature behind the low-energy shape coexistence is the appearance of intruder states. These are states that intrude across closed shells because their energies are dictated not only by shell gaps but also by correlation energies resulting from changing shell occupancies. A very rich spectrum of coexisting intruder structures remains to be discovered in odd-Au isotopes and further systematic spectroscopic elucidation of these states is highly demanding. The quantification of the properties of intruder configurations, e.g. excitation energies and spectroscopic purities, particularly their nucleon number dependence, will demand that theory moves beyond mean-field descriptions to quantify the specific nucleon number dependence. Only in this way will we have a reliable framework within which structural questions like e.g. the appearance and disappearance of closed shells can be addressed.

Such experiments have to involve unambiguous identification of the electric monopole transitions ("*E0*"), which occur between states with the same spin and parity and are rare in odd-mass nuclei. Electric monopole transition strengths reflect the matrix elements of the *E0* operator, T(E0). The diagonal matrix elements of T(*E0*) are directly related to the change in mean-square charge radii, δr of the initial and final state. The mean-square charge radii are well known to reveal shape changes in nuclei and thus the presence of *E0* transition can be associated with shape coexistence phenomenon.

This requires quantifying the *E0* components in *E0+M1+E2* transitions if states with spin other than zero are involved. Essentially, this requires quantifying the K conversion line intensity with sufficient precision so that one can subtract off the contribution from the *M1+E2* part (via knowing the *E2/M1* mixing ratio and using the theoretical conversion coefficient value). The challenge comes if the amount of *E0* admixture is small. Although this admixture may be small, the monopole transition strength may not be small. In that case, the tiny effects, which are often neglected, like e.g. true coincidence summing, have to be investigated thoroughly. The power of Monte Carlo simulations based on the GEANT4 package will presented on the example of ^{114}Ag $\rightarrow$ ^{114}Cd beta decay.

Exotic beta decays of ^{11}Li

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Abstract session 4 |

Owing to its low binding energy, the ^{11}Li nucleus presents unusual beta-decay channels. In addition to the decay to ^{11}Be, it can also decay to the two-body ^{9}Li+d channel, and even to the three-body ^{9}Li+n+p channel. These beta decays to continuum states have been investigated by describing the ^{11}Li ground state as a ^{9}Li+n+n system in hyperspherical coordinates. Our recent work on beta decay to the three-body channel suggests that the branching ratio is of the order of 10^{-10}.

Beta-delayed particle emission studies and its future @ MYRRHA

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Abstract session 4 |

The beta decay process allows for understanding the interaction and behavior of the nucleons inside the nucleus. This process is well understood and the interpretation of the data yields a wide variety of spectroscopic information: level energies, spins, parities, widths and level densities.

Far from stability the difference in isobaric masses are large and the binding energy of the last nucleon small, so the beta-decay feed both bound and unbound excited states allowing for a good mapping of the distribution of the low spin states in the daughter in a large energy window. Particle emission becomes dominant near the drip lines and, in many cases, both particle and multi-particle emission are energetically possible.

The high efficiency for charged particle detection makes the study of the beta delayed particles a unique tool to study and understand the nuclear structure of very rare species through very exotic decay modes. Correlations between the emitted particles can shed light to both the decay mechanism and the spin of the states involved.

Recent achievements in beta delayed particle studies will be presented in this contribution. The different techniques developed to do high quality spectroscopy of exotic nuclei will be revised. Emphasis will be given to the description of unique effects that can give rise to very interesting physics but whose measurement requires relatively high intensity and long beam times.

Beta decay experiments with the Total Absorption Technique (TAS), overview and new opportunities

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Abstract session 5|

Total absorption spectroscopy has shown to be the best experimental technique to measure beta strength functions or beta feeding to highly excited states in decay cases where the emitted gamma radiation is very fragmented or/and where gamma rays of very high-energy occur. An intense activity in this field has been carried out in recent years at facilities such as Isolde or Jyväskylä. However there are still many decays reported in the literature which might be affect by the so called "Pandemonuium Effect" and where the "apparent" log ft might be wrong. The ISOL@MYRRHA facility can be an ideal place to revise some of these cases.

Access to Highly Excited States by Gamow-Teller Transitions
- in the β decay and charge-exchange reactions -

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Abstract session 5 |

Gamow-Teller (GT) transitions are caused by the most common weak interaction of spin-isospin ($\sigma\tau$) type with L = 0. Since spin and isospin are unique quantum numbers in nuclei, GT transitions represent important nuclear response.

GT transitions are studied by the β decay and charge-exchange (CE) reactions. The β decay has a direct access to the absolute GT transition strengths B(GT), but it can access excited states lower than the decay Q-value. In contrast, the CE reactions, such as the (p, n) or (^{3}He,t) reactions at intermediate beam energies and 0^o, can selectively excite GT states up to high excitation energies in the final nucleus.

Although the study of GT strength in the β decay is restricted by the decay Q-value, exotic unstable nuclei can have the Q-value of 12 MeV or larger, which, in principle, allows the study of the central part of the GT resonance (GTR) where the GT strength is concentrated. Since the β decay study does not suffer from the reaction mechanism and the mixture of L = 1 or 2 strengths associated with CE reactions, a pure GT response, i.e., the spin-isospin response of nuclei can be investigated. A precise comparison with the isospin mirror GT transitions studied in CE reactions, especially with the high-resolution (^{3}He,t) reactions that can be performed in Osaka, will give us further knowledge on the long standing quenching problem of the spin-isospin excitations in nuclear physics.

Richardson-Gaudin description of pairing in atomic nuclei

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Abstract session 5 |

The exponential size-explosion of the Hilbert space will be a major challenge for theoretical nuclear structure physics away from stability. Therefore, it will be quintessential to capture the dominant quantum correlations in the system while selecting convenient many-body techniques to accommodate these correlations. Richardson and Gaudin have shown that the reduced BCS Hamiltonian, modeling the pairing interaction in atomic nuclei, is Bethe integrable. The integrability of the system ensures that the system is exactly solvable with a numerical effort scaling linear with the system size, in contrast to the exponential size of the Hilbert space. In this contribution, I will discuss recent developments in the numerics of integrability that will allow us to go to large systems beyond the reach of more conventional approaches.

Decay spectroscopy as a probe of exotic proton-rich nuclei

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Abstract session 6 |

This talk will focus on two regions of the nuclear chart for proton-rich nuclei: the N=Z nuclei, and heavy nuclei around Z=82. The N=Z nuclei are a fascinating laboratory for study where nuclear structure effects are amplified through the occupation of the same orbitals for protons and neutrons. There is a wide range of Physics which can be investigated here and in even more exotic nuclei going towards the proton drip line. This ranges from shape coexistence in the mid-shell region, and interplay between states with different isospin, to fundamental physics (CVC hypothesis) and nuclear astrophysics (the rp-process). In practice, all of these different aspects are intertwined and very detailed decay spectroscopy may be an additional means to unpick them. Some specific examples will be given both for revisiting previous studies with higher sensitivity and for measurements at the limits.

In the heavy nuclei around Z=82, shape coexistence is again a topic of strong interest. Historically, this region has been well explored via decay spectroscopy but I foresee potential to revisit some of this work with very high statistics experiments to search for weakly-populated states and to perform detailed alpha-gamma and alpha-electron studies with the aim to investigate angular correlations. These could be used to fix mean field models in this region. This would be complementary to ongoing studies of these nuclei via Coulomb excitation and in-beam studies at other facilities.

Recent results from the campaign of the AGATA Demonstrator Array at LNL

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Abstract session 6 |

The expected experimental conditions at the planned future facilities for radioactive ion beams and for high-intensity stable beams are extremely challenging, requiring unprecedented levels of efficiency and sensitivity, which cannot be reached with the conventional 4π arrays of Compton-suppressed high-purity germanium detectors.

The approach pursued in the past few years implies covering the full 4π solid angle with germanium detectors only, and maximizing the photopeak efficiency and the peak-to-total ratio through the identification of the interaction points of the photons within the germanium crystals (pulse shape analysis) and a software reconstruction of the trajectories of the individual photons (γ-ray tracking). The major advantage with respect to the present generation arrays is arguably the excellent spectra quality provided up to relativistic beam velocities, where the Doppler broadening correction is dominated by the position resolution within the individual crystals rather than by the finite opening angle of the detectors.

Presently, two projects aim to build an array based on the concepts of pulse shape analysis and γ-ray tracking: AGATA in Europe and GRETA in the United States. Both instruments are expected to play a major role in the future nuclear structure studies at the very limits of nuclear stability.

This contribution will focus on the AGATA project. A subset of the whole array, known as the AGATA Demonstrator Array, has operated since 2009 until the end of 2011 at the Laboratori Nazionali di Legnaro, where it was installed at the target position of the magnetic spectrometer PRISMA. The device was commissioned during the year 2009 and its performance were found to be in agreement with the expectations from Monte Carlo simulations. It should be mentioned here that thanks to the state-of-the-art digital electronics and processing algorithms it was possible to measure up to a rate of 50 kHz per crystal with reasonably good efficiency and energy resolution. The AGATA Demonstrator was subsequently exploited in a two-years experimental campaign. A total of 20 PAC-approved measurements were performed, plus 3 in-beam tests, for a grand total of 148 days of beam time. Given the possibilities offered by the coupling with the PRISMA magnetic spectrometer, the campaign has focused mainly on the study of moderately neutron-rich nuclei populated via multinucleon transfer or deep inelastic reactions. However, the proton-rich side of the nuclides chart has been explored as well by coupling AGATA with other complementary devices such as the TRACE silicon detectors or the scintillators of HELENA and HECTOR. The analysis of all of the performed experiments is still in progress and the preliminary results of a few selected of them will be presented.

Low-energy fission of proton-rich nuclei in the lead region

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On behalf of Paisley-Leuven- Bratislava-Darmstadt-Geneva-Gent-Grenoble-Liverpool-Manchester-Mol-Tokai collaboration

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Abstract session 6 |

In the last decade, through technological, experimental and theoretical advances, the situation in experimental low-energy fission studies has changed dramatically. With the use of advanced production and detection techniques, much more detailed fission information can be obtained for traditional regions of fission research and, very importantly, ***new regions of nuclei*** have become accessible for fission studies.

The talk will give a review of recent low-energy fission experiments in very proton-rich nuclei in the lead region. Results of experiments at ISOLDE (CERN) on the very exotic process of low-energy beta-delayed fission of neutron-deficient Tl, At and Fr nuclei will be presented. Beta-delayed fission is a rare nuclear decay process in which beta-decay of a parent nuclide populates excited states of the daughter, which may then fission. As an example, a beta-delayed fission study of ^{180}Tl at ISOLDE will be discussed in details [1]. Recent identification of beta-delayed fission of ^{202}Fr, ^{194,196}At and ^{178}Tl at ISOLDE will also be presented. The studies of At and Tl isotopes were facilitated by the use of the highly-selective Resonance Ionization Laser Ion Source of ISOLDE.

As a result of these experiments, a new region of asymmetric fission was established, which includes isotopes ^{178,180}Hg (N/Z=1.22-1.25), in addition to the previously known broad area of asymmetric fission in the heavy actinides with N/Z~1.55-1.6. Possible ideas for long experiments at ISOL@MYRRHA for detailed fission studies in this region of nuclei will be discussed.

1. A. Andreyev et al., “New type of asymmetric fission in proton-rich nuclei”, Phys. Rev. Lett. 105, 252502 (2010)

Conversion electron spectroscopy, the rarely used but vital probe of nuclear structure; and the innovative development of *one-of-a-kind* spectroscopic equipment

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Abstract session 7 |

The presentation will describe the utility of conversion electron spectroscopy in nuclear decay experiments to greatly enhance our ability to quantify a number of important quantities in the energy level schemes of nuclei. These include, for example, electromagnetic multipoles, and multipole mixing of transitions, observation and quantification of electric monopole transitions where no gamma-ray is present, and measurement of the electric monopole component in mixed multipole transitions (e.g. E0+M1+E2). In contrast to angular correlation measurements with gamma rays, which can predict energy level spins, conversion electron measurements can predict both the spin and the parity of the interconnected levels. In addition, a case for internal pair formation spectroscopy (for unique situations) will be presented since the segmented detector systems developed for conversion electron spectroscopy are ideal for internal pair spectroscopy. A review of the *one-of-a-kind* spectroscopic equipment developed over the past few decades to facilitate our nuclear decay spectroscopy, as well as an important future innovation, will be presented.

Trap-assisted decay spectroscopy

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Abstract session 7 |

In trap-assisted decay spectroscopy ion trapping techniques are used to manipulate low-energy radioactive ion beams in order to improve the experimental conditions for decay spectroscopy. The technique is commonly divided in two categories, in-trap decay spectroscopy and post-trap decay spectroscopy. In the former the detection system is build in such a way that it can detect radiation from the decay of the studied radioactive ion while it is being held trapped in an ion trap and in the latter ion traps are typically used as a high-resolution mass separators to provide isotopic or even isomeric beam for the decay spectroscopy set-up down stream from the trap.

At the IGISOL facility in the accelerator laboratory of University of Jyväskylä a double Penning trap system JYFLTRAP has been routinely utilized in a post-trap decay spectroscopy as a high-resolving power mass separator. The physics motivation for the post-trap decay spectroscopy ranges from fundamental CKM matrix unitarity testing to Gamow-Teller strength determination and used spectroscopic tools from germanium detectors and plastic scintillator to total absorption spectrometer and neutron long counters. In all of these experiments the common motivation for the trap usage is to get clean isotopic beam to the detector set-up. One of the main virtues of the IGISOL technique is its universality, ion beams of all elements, even refractory, are produce equally. On the other hand there was a need for further high-resolution mass separation that Penning trap could provide. The need for the additional cleaning is more pronounced in less selective production method, as in the case of fission, because the yields of most abundantly produced isotopes are very high and the production yields can go down by order of magnitude when moving one step more exotic in the isobaric chain. The overwhelming background from the less exotic species can easily swamp the faint signal one is looking for. In other cases the detection technique itself and the following data analysis relies heavily on the assumption that only ions of investigated isotope are implanted into the detector as is the case in the total absorption gamma ray spectrometer TAGS.

This presentation will cover different beam cleaning techniques that are used at JYFLTRAP and what can be achieved with them. To illustrate the performance some trap-assisted decay spectroscopy results from JYFLTRAP are shown. Finally an outlook to future prospects of trap-assisted decay spectroscopy at JYFLTRAP and complementarily at ISOL@MYRRHA is given.

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