Book of Abstracts

X^{th} Tastes of Nuclear Physics

30 Nov - 4 Dec 2020

Monday Morning November 30th

Time: 9:00 - 9:30 Morning Coffee

Speaker: **Umesh Bawa (Director of the International Office at the University of the Western Cape, South Africa)**

Title: **Welcome Speech**

Time: 9:45 - 10:00 am

Speaker: **Tyrone Pretorius (Rector and Vice-Chancellor of the University of the Western Cape, South Africa)**

Title: **Welcome Speech**

Chair: **John Simpson (KRI STFC, UK)**

Time: 10:00 - 10:45 am

Speaker: **Tibor Kibèdi (Australian National University, Australia)**

Title: **The radiative width of the Hoyle state from pair conversion and proton-γ-γ coincidence measurements**

Abstract: Stellar formation of carbon occurs when three alpha particles fuse and form the excited 7.654 MeV 0^+ Hoyle state in ^{12}C. Stable carbon is only formed if the excited nucleus decays to the ground state. The Hoyle state is located above the 3α threshold, which makes the triple alpha process very unlikely as the excited carbon nucleus decays back to three alpha particles ~99.96% of the time. The remaining 0.04% will lead the formation of stable carbon. The process is therefore a bottleneck in nuclear astrophysics, and good knowledge about the production rate is imperative for accurate modelling of carbon formation in the universe.

The internal decay of the Hoyle state occurs either by a 7.654 MeV E0 transition to the 0^+ ground state, or by a 3.215 MeV E2 transition to the first-excited 2^+ state. The current value of the radiative width, Γ_{rad}, has been determined in an indirect way, resulting in a ~12.5% uncertainty on the 3α rate.

Here we report on two experiments to improve our knowledge on rad. In both experiments the Hoyle state was excited with proton bombardment of natural carbon. In the first experiment [1], carried out at the Oslo Cyclotron Laboratory, using the CACTUS and SiRi arrays, the cascading gamma-rays of E2 multipolarity and 3.215 MeV and 4.439 MeV energy were observed. The Γ_{rad}/Γ ratio was determined from the ratio of single proton events to the number of proton-gamma-gamma triple coincidences. The new value of rad/ is about 50% larger than the currently adopted value [3].

The second experiment, carried out at the Australian National University [2], using the Super-e spectrometer [3], searched for the pair conversion of the 3.215 MeV E2 and 7.654 MeV E0 transitions, de-exciting the Hoyle state. Here we report on a new determination of the Γ_{E0}/Γ ratio from the measured 7.654 MeV E0 and 4.439 MeV E2 pair conversion ratios, as well as single proton intensities. The new recommended value of Γ_{E0}/Γ is about 11% higher and more accurate than the currently adopted one [3].

The combined effect of the two measurements is a 34% increase in the triple- reaction rate [1,4]. In this talk details of the experiments and the implications of the new rates will be discussed.

[1] T. Kibèdi *et al.*, Phys. Rev. Lett. (Accepted 22 September 2020); https://arxiv.org/abs/2009.10915

[2] T. K. Eriksen *et al.*, Phys. Rec. C **102** (2020) 024320

[3] M. Freer, H.O.U. Fynbo, Prog. Part. Nucl. Phys. **78** (2014) 1

[4] https://phys.org/news/2020-10-carbon-creation-astrophysics.html

* Project supported by the Australian Research Council - DP140102986 and DP170101673.

Time: 10:45 - 11:15 am

Speaker: **Morten Hjorth-Jensen (Michigan State University and FRIB/NSCL and University of Oslo)**

Title: **Machine Learning meets Nuclear Physics**

Abstract: The main aim is to give you a short and pedestrian introduction to how we can use Machine Learning methods to solve quantum mechanical many-body problems as well as giving an overview on how such methods can be used in nuclear physics analysis and discoveries.

Time: 11:45 am - 12:15 pm

Speaker: **Nico Orce (University of the Western Cape, South Africa)**

Title: **Is the r-process actually producing most heavy elements above iron?**

Abstract: This talk explores the mass dependency of the symmetry energy extracted from different empirical methods, namely photo-absorption cross sections, binding energies and giant dipole resonances built on ground and excited states. Results suggest the close in of the neutron drip line,

which questions the production of heavy elements via the rapid-neutron-capture or *r*-process in warm nuclei.

Time: 12:15 - 12:30 pm

Speaker: **Cebo Ngwetsheni (PhD Student, University of the Western Cape, South Africa)**

Title: **Shell effects at high-excitation energies**

Abstract: As elaborated by Migdal, the nuclear dipole polarizability is mainly governed by the dynamics of the giant dipole resonance and, assuming validity of the brink-Axel hypothesis, has been investigated along with the effects of the low-energy enhancement of the photon strength function for nuclides in medium- and heavy-mass nuclei. Cubic-polynomial fits to both data sets extrapolated down to a gamma-ray energy of 0.1 MeV show a significant reduction of the nuclear dipole polarizability for semi-magic nuclei, with magic numbers N=28, 50 and 82, which supports shell effects at high-excitation energies in the quasi-continuum region. This work assigns σ_{-2} values as sensitive measures of long-range correlations of the nuclear force and provides a new spectroscopic probe to search for ``old'' and ``new'' magic numbers at high-excitation energies [1-3].

C. Ngwetsheni and J. N. Orce, Phys. Lett. B **792** (2019) 335.
C. Ngwetsheni and J. N. Orce, Hyp. Int. **240** (2019) 94.
C. Ngwetsheni and J. N. Orce, EPJ Web of Conferences **223** (2019) 01045.

Monday Afternoon November 30th

Chair: **Mark Riley (Florida State University, USA)**

Time: 13:30 - 14:00 pm

Speaker: **Peter Butler (University of Liverpool, UK)**

Title: **Studies of Heavy Pear-Shaped Nuclei at ISOLDE**

Abstract: For certain combinations of protons and neutrons it is expected that the shape of atomic nuclei can undergo octupole deformation, which would give rise to reflection asymmetry or a "pear shape". In this talk I will describe how recent experiments using REX-ISOLDE[1] and HIE-ISOLDE[2,3,4], CERN have provided evidence that several radium and radon isotopes have either stable pear shapes or are octupole vibrational in nature. I will show that our data on transition moments in particular present challenges for theory. I will briefly talk about the relevance of our measurements for atomic EDM searches, and discuss the future prospects for this field.

1. L. P. Gaffney *et al*., Nature **497** (2013) 199
2. P. A. Butler *et al*., Phys. Rev. Lett. **124** (2020) 042503
3. P. A. Butler *et al.*, Nat. Comm. **10** (2019) 2473, Nat. Comm. **11** (2020) 3560

4. P. Spagnoletti *et al*., paper in preparation

Time: 14:00 - 14:30 pm

Speaker: **Maria José Garcia Borge (CSIC, Spain)**

Title: **The experiments to determine the electron capture and β-decay of ^{8}B into the highly excited states of ^{8}Be**

Abstract: The main goal of this work is to study the structure of the highest energy states in ^{8}Be populated following the β^{+}-decay and the electron capture (EC) of ^{8}B. With this aim, two experiments were performed at ISOLDE-CERN in 2017 and 2018. The first experiment had the aim to resolve the 2^{+} doublet at 16.6 and 16.9 MeV, in order to study their isospin mixing. The second experiment aimed to determine a value or give an experimental upper limit to the branching ratio of the exotic EC-p decay.

In this talk, we present the experimental setups and we discuss the analysis and present the results obtained so far.

Time: 14:30 - 15:00 pm

Speaker: **Magda Zielińska (Saclay, France)**

Title: **Coulomb excitation with magnetic spectrometers**

Abstract:

Time: 15:00 - 15:30 pm

Speaker: **Liam Gaffney (University of Liverpool, UK)**

Title: **Nuclear shapes of radioactive isotopes studied at HIE-ISOLDE**

Abstract: Coulomb excitation is more than 50 years old as a technique, but has never been more alive in nuclear-structure physics. That is due in a large part to the advent of high-efficiency germanium arrays for the detection of gamma-rays and the availability of post-accelerated exotic beams from ISOL facilities, such as HIE-ISOLDE at CERN [1].

The beauty of the technique lies in its sensitivity to the nuclear shape, both via the spectroscopic and intrinsic quadrupole moments extracted using the reorientation effect and the quadrupole-sum-rules method, respectively [2]. Coulex remains unique in being able to provide such observables for excited states and is now the go-to method for studying phenomena such as shape coexistence [3].

Higher-order deformations also become accessible and octupole moments can also be obtained [2]. Ground-breaking experiments were made at REX-ISOLDE, the predecessor to HIE-ISOLDE, studying the magnitude of octupole deformation in ^{224}Ra and ^{220}Rn [4]. The former was determined to have a significant

enhancement of the octupole moment and follows as only the second direct measurement of the deformation (after 226Ra) in a nucleus classified as octupole deformed in its ground state.

In this talk I will show results from a range of experiments studying nuclear shape using the Coulomb-excitation technique and the Miniball spectrometer [5]. I will focus on recent results of octupole-deformed nuclei in both the actinide [6,7] and lanthanide [8] regions of the nuclear chart. I will also discuss opportunities for the future of investigating nuclear shape at HIE-ISOLDE, taking advantage of the newly commissioned ISOLDE Solenoidal Spectrometer (ISS) [9,10].

[1] M. Lindroos, P. Butler, M. Huyse, and K. Riisager, Nucl. Instrum. Meth. B **266** (2008) 4687.
[2] M. Zielińska, L. P. Gaffney, K. Wrzosek-Lipska, E. Clément, T. Grahn, N. Kesteloot, P. Napiorkowski, J. Pakarinen, P. Van Duppen, and N. Warr, Eur. Phys. J. A **52** (2016) 99.
[3] K. Wrzosek-Lipska and L.P. Gaffney, J. Phys. G Nucl. Part. Phys. **43** (2016) 24012.
[4] L. P. Gaffney et al, Nature **497** (2013) 199.
[5] N. Warr et al., Eur. Phys. J. A **49** (2013) 40.
[6] P. A. Butler et al., Nat. Commun. **10** (2019) 2473.
[7] P. A. Butler et al., Phys. Rev. Lett. **124** (2020) 042503.
[8] L. P. Gaffney, M. Scheck, et al., (in preparation)
[9] S. J. Freeman et al., CERN-INTC 031, 099 (2010).
[10] T. L. Tang et al. Phys. Rev. Lett. **124** (2020) 062502.

15:30 - 16:00 **MANuS MatSci Celebration**

Speaker: **Nontobeko Khumalo**

Title: **Development of a MELCOR Model for the Koeberg PWR – Reactor Core and Reactor Pressure Vessel (RPV) SSC**

Abstract: The nuclear industry and its regulators have always prioritized safety and reliability in the operation of nuclear power plants. Thus the emphasis on the development, validation, and application of reliable predictive modeling capabilities for both normal and accident conditions. The Centre for Nuclear Safety and Security (CNSS) at the National Nuclear Regulatory (NNR) provides an important function in the nuclear regulatory process in South Africa. The responsibilities of the CNSS include independent research in the safety analysis and the analyses of the consequences of design basis and severe accidents at the Koeberg Nuclear Power Station (KPNS).

The objective of the present work is to develop an input model to MELCOR code for the KPNS. MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents in light water reactor nuclear power plants. This code system is developed by Sandia National Laboratories (SNL) for the US NRC. The present work focuses on developing a model for the Reactor Pressurized Vessel (RPV) and the reactor core. Input data used for developing the model are mainly obtained from the original drawings and system descriptions from the Koeberg Safety Analysis Report (KSAR). This input deck will be improved continually by the adding more sub-systems that are not included in this input deck, and the severe accident analysis of the KNPS will, thereafter, be performed.

Chair: **Corina Andreoiu (Simon Fraser University, Canada)**

Time: 16:00 - 16:30 pm

Speaker: **Azwinndini Muronga (Nelson Mandela University, South Africa)**

Title: **Relativistic Fluid Dynamics for Nuclear Matter under Extreme Conditions in Nucleus-Nucleus Collisions and Astrophysics**

Abstract: Studying nuclear matter under extreme conditions (such as those of super-high temperatures, super-high densities, and super-strong magnetic fields) not only reveals the high-energy processes that drove the evolution of the universe just after its birth, but also its very exotic nature in massively compressed stellar corpses -neutron stars. Collisions between the dense nuclei of heavy ions at high energy provide the main tool for simulating these extreme conditions in the laboratory. Astrophysical processes such as the neutron star mergers represent optimal astrophysical laboratories to investigate these extreme conditions.

Amongst the most important theoretical and computational tools and techniques that are used in the study of nucleus-nucleus collisions and astrophysical processes is the use of special and general relativistic fluids in modeling the space-time evolution of the matter produced in these collisions and processes. The relativistic fluid is a highly successful model used to describe the dynamics of many-particle, relativistic systems – from systems as small as nucleus-nucleus collisions to as large as the Universe itself, with intermediate sized objects like neutron stars being considered along the way. It takes as input, basic physics from microscopic scales, and yields as output, predictions of bulk, macroscopic motion. The detected high energy particles, electromagnetic radiation and gravitational waves probe the phase structure of the equation of state of hot and dense matter produced at the intersection of the closely related relativistic collisions of heavy ions and of the astrophysical processes such as binary neutron stars mergers.

This talk will focus on the theoretical developments of relativistic fluid dynamics in light of recent developments at the intersection of particle physics, nuclear physics, and astrophysics.

Time: 16:30 - 17:00 pm

Speaker: **Janne Pakarinen for the JYFL Nuclear Spectroscopy Group (University of Jyväskylä, Finland)**

Title: **Nuclear spectroscopy at the JYFL recoil separators**

Abstract: For more than a decade, the two incarnations of JUROGAM Ge-detector arrays have provided great wealth of in-beam spectroscopic data in recoil-decay tagging experiments at the RITU gas-filled separator [1]. In order to address our physics program for nuclei located around the N=Z line, a new vacuum mode separator MARA has been developed [2]. MARA allows for separation of recoil products from the primary beam in symmetric and inverse kinematics fusion-evaporation reactions. It has proven to be an ultimate tool for decay-spectroscopy of very proton-rich nuclei ranging from Ti-43 to Hg-170 have been successfully studied including discovery of five new isotopes.

The advent of MARA in conjunction with the JUROGAM 3 spectrometer [3] has raised sensitivity to probe the exotic nuclei around the N=Z line employing in-beam spectroscopy to a new level. The JUROGAM 3

spectrometer consists of 24 EUROGAM Clover detectors and 15 Phase1 or GASP detectors provided by the European Gamma-Ray Spectroscopy pool and it can be moved between RITU and MARA separators while keeping Ge detectors biased. Together with the JYTube charged-particle detector array, investigations of e.g. beta-decaying proton-rich nuclei can be conducted with unprecedented fashion.

The in-beam spectroscopy program at MARA addresses physics questions related to e.g. isospin symmetry breaking, neutron-proton interaction and shape coexistence. In this presentation, the first results from this program will be discussed and future prospects of the Nuclear Spectroscopy Group activities will be discussed.

[1] M. Leino et al., Nucl. Instr. and Meth. B **99** (1995) 653.

[2] J. Uusitalo et. al., Acta Phys. Pol. B **50** (2019) 319.

[3] J. Pakarinen et al., Eur. Phys. J. A **56** (2020) 149.

Time: 17:00 - 17:45 pm

Speaker: **Jens Dilling (TRIUMF and University of British Columbia, Canada)**

Title: **Precision experiments for nuclear physics using radioactive isotopes**

Abstract: Modern nuclear physics has benefited greatly from access to radioactive isotope beams (RIBs), as these allow to probe and explore behaviour at the extreme of neutron and proton numbers. To facilitate the experimental efforts, we have developed precision experimental devices: ion traps. These ion traps are originally developed for stable particles and hence over the years we have modified and adapted them to the requirements of very low isotope yields and very short nuclear half-lives. Moreover, ion traps allow to select the isotope of interest within the range of co-produced species at the RIB facility, and makes them available for experiments such as precision mass measurements. In the talk, I will introduce the various types of ion traps currently used at RIB facilities, and showcase some physics highlights achieved with them.

Tuesday Morning December 1st

Chair: **Björn Jonson (Chalmers University of Technology, Sweden)**

Time: 09:30 - 10:15 am

Speaker: **Gerda Neyens (CERN, Switzerland & Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium)**

Title: **Nuclear Physics at ISOLDE-CERN**

Abstract: The ISOLDE Facility at CERN is the world's leading facility for the production of radioactive ion beams (RIBs) using the ISOL (Isotope Separation On-Line) method. Over 1000 isotopes of more than 70 elements have been produced by the impact of a 1.4 GeV proton beam on a variety of targets and using different ion sources for providing beams at 40-50 keV energy. Purified isotope/isomer beams can be further accelerated to about 10 MeV/u using the HIE-ISOLDE post-accelerator.

The low-energy and accelerated beams are used for a wide variety of experiments in nuclear structure research, but also for studying astrophysical processes, for materials properties research, for biochemical and biomedical research and for fundamental interaction studies. This presentation will give an introduction to the ISOLDE facility and RIB production, and present some recent examples of experiments addressing open questions in nuclear physics.

Time: 10:15 - 10:45 am

Speaker: **Krish Bharuth-Ram (Durban University of Technology/University of KwaZulu-Natal, South Africa)**

Title: **Mössbauer Spectroscopy at ISOLDE/CERN: Principles, special features and applications**

Abstract: The Mössbauer effect, or nuclear resonance fluorescence, was discovered by Rudolph Mössbauer in 1958 when he was a PhD student at the University of Heidelberg, Germany. Since then the effect has developed into an extremely sensitive spectroscopy tool which has applications in various areas of Physics and Chemistry.

In this presentation, the principles of Mössbauer Spectroscopy (MS) will be presented and examples given of lab-based transmission and conversion electron MS. This will be followed by discussion of the novel approach developed at the online isotope separator ISOLDE at CERN where precursor radioactive $^{57}Mn^*$ ($t_{1/2}$= 90 s) nuclides are produced in fission in a UC_2 target induced by 1.4 GeV protons. After multistage laser ionization and mass selection, the $^{57}Mn^+$ ions are accelerated to 40-60 keV energy and implanted into substrates of interest. The Mössbauer probe isotope $^{57}Fe^*$ is populated via the $^{57}Mn \rightarrow$ $^{57}Fe^*$ β-decay.

A special feature of this approach is that low concentrations ($\leq 10^{-3}$ at. %) of the 57Fe* probe nuclei are sufficient to yield good quality data in t ≤ 10 min. This allows single ion implantation and avoids clustering, hence making the ^{5}7Fe ions more sensitive probes of their immediate environment.

Special features of eMS will be discussed, together with examples of some applications.

Time: 10:45 - 11:15 am

Speaker: **Karl Johnston (CERN, Switzerland)**

Title: **Spicing up solid state physics with radioactive isotopes: recent highlights from ISOLDE**

Abstract: The ISOLDE facility at CERN supports a lively solid state programme where radioactive isotopes are utilized as either probes or tracers to study a wide variety of materials. The advantages of using radioisotopes in materials science are many: ease of detection, sensitivity to local environment and chemical selectivity allows for experiments which can resolve outstanding issues in a variety of materials in a unique way.

This contribution to “Tastes of Nuclear Physics” will give a flavour of the scientific programme currently running at ISOLDE in solid state physics. An introduction to some of the typical techniques will be followed by recent highlights showcasing these methods. In particular, recent results on Sn centres in diamond – an important material for future quantum technologies – and in a multiferroic system where the power of radioactive probes has allowed for a characterisation of electronic phase transitions inaccessible to other experimental methods.

Time: 11:45 am - 12:15 pm

Speaker: **Nigel Warr (Universität zu Köln, Germany)**

Title: **The Comeback of Coulomb Excitation**

Abstract: Coulomb excitation was one of the earliest tools used by accelerator-based experiments to investigate nuclear structure. However, as accelerators were pushed to higher energies, this technique became somewhat neglected. At the start of the new millennium, the advent of new radioactive-beam facilities such as ISOLDE renewed the interest in Coulomb excitation, which has experienced a comeback in the last two decades.

The technique relies on our precise understanding of the Coulomb interaction, which allows us to relate the unknown nuclear structure matrix elements, to the measurable particle-gated gamma-ray yields. The relatively low beam energies required have made it ideal for use at facilities such as ISOLDE and have contributed to a revival of the technique.

This talk will look at the basics of the technique and how they are applied to obtain nuclear data from radioactive beam experiments at facilities such as ISOLDE.

Time: 12:15 - 12:30 pm

Speaker: **Kenzo Abrahams (PhD Student, University of the Western Cape, South Africa)**

Title: **Determining the collectivity of ^{66}Ge at HIE-ISOLDE**

Abstract: Neutron-deficient beams of unstable Ge ions were for the first time accelerated at safe energies, well below the Coulomb barrier. During this talk, we investigate the collectivity of the neutron-deficient ^{66}Ge nucleus, excited through safe-energy Coulomb-excitation measurements at HIE-ISOLDE. Collective properties involving the first transition in ^{66}Ge have been determined, and compared with previous work and the systematics of rapid-changing nuclear shapes found in this rich nuclear-structure region.

Tuesday Afternoon December 1st

Chair: **Marcus Scheck (University of West Scotland, UK)**

Time: 13:30 - 14:00 pm

Speaker: **Dmitry N. Voskresensky (JINR Dubna, Russia)**

Title: **A.B. Migdal, Fermi liquid description of pions in nuclear systems and beyond**

Abstract: First I'd like to review the results obtained in the Migdal's group on description of the pion degree of freedom in nuclear systems and then I focus on their subsequent development.

Time: 14:00 - 14:30 pm

Speaker: **Emanuele Vardaci (Università di Napoli "Federico II", Napoli, Italy)**

Title: **Giant dipole resonance γ-ray emission as a probe for nuclear viscosity in fission dynamics**

Abstract: It is well known that nuclear viscosity plays a fundamental role in the fission process. Experimental evidence that fission is driven by nuclear viscosity has come from the observation of prescission multiplicities of neutrons, charged particles and -rays significantly larger than those predicted by the statistical model. Much experimental and theoretical work has been devoted to this subject but

nevertheless many questions still remain open. They are mainly related to the precise determination of the fission time scale as well as to the nature of the dissipation and its dependence on the nuclear shape and temperature.

On the experimental ground it is important to stress out the importance of measuring a wide set of observables to effectively constrain the parameters of the various models.

This contribution will propose a journey within the open questions in fission dynamics and will highlight the importance of using the GDR probe along with the other probes to shed light on the dependence of the nuclear viscosity on nuclear shape and temperature.

Time: 14:30 - 15:00 pm

Speaker: **Balaram Dey (Bankura University, India)**

Title: **Jacobi shape transition and clustering effect in light nuclei**

Abstract: The study of Jacobi shape transition has become an important subject of investigation in recent times [1-7]. It is an abrupt change of shape from non-collective oblate to collective triaxial or prolate shape above a critical spin. While this was initially thought of in connection with rotating celestial objects, it is also expected to occur in an atomic nucleus due to its behavior as liquid drop at high excitation energy. The high energy gamma rays coming from the decay of giant dipole resonance (GDR) is an excellent tool to probe the nuclear shape degrees of freedom and thereby can be used to investigate the Jacobi shapes transition. The presence of a sharp low energy component around 10 MeV in the GDR spectrum, originating from the Coriolis splitting in a highly deformed rotating nucleus, can be used as a signature of the Jacobi shape transition. These type shape transitions have been observed earlier in ^{45}Sc [1], ^{46}Ti [2, 3], ^{47}V [4], etc. Very recently, we observed that ^{31}P shows the evidence of Jacobi shape transition, while the self-conjugate alpha cluster nuclei ^{32}S and ^{28}Si do not [4-6]. Based on this experimental observation, it was speculated that the nuclear orbiting phenomenon exhibited by alpha-cluster nuclei hinders the Jacobi shape transition. Furthermore, in order to understand the role of cluster structure, the extended quantum molecular dynamics (EQMD) calculation has been carried out to calculate the GDR strength functions in case of ^{32}S and ^{28}S nuclei at the similar excitation energy (beyond the decay threshold) as populated in the experiments [7]. Intriguingly, it is found that the EQMD predicts the general trend of the experimental GDR strength functions for ^{32}S and ^{28}Si by considering the exotic toroidal configuration [7], indicating the cluster formation at high temperature and angular momentum, which could be a possible reason for the absence of Jacobi shape transition in such self conjugate alpha cluster nuclei (^{32}S and ^{28}Si). The present results suggest a possibility to investigate the nuclear orbiting phenomenon using high energy GDR gamma rays as a probe and highlights the role of alpha-cluster states above the decay threshold, which is still an open field of investigation.

[1] M. Kicihska-Habior *et al*., Phys. Lett. B. **308** (1993) 225.
[2] D. R. Chakrabarty *et al*., Phys. Rev. C **85** (2012) 044619.
[3] A. Maj *et al*., Nucl. Phys. A **731** (2004) 319.
[4] Deepak Pandit *et al.*, Phys. Rev. C **81** (2010) 061302(R).
[5] Balaram dey *et al.,* Phys. Rev. C. **97**, (2018) 014317.
[6] Deepak Pandit *et al.*, Phys. Rev. C **95** (2017) 034301.
[7] Balaram Dey *et al*., Phys. Rev. C **102** (2020) 031301(R).

Time: 15:00 - 15:30 pm

Speaker: **Phil Adsley (WITS/iThemba LABS, South Africa)**

Title: **Isoscalar dipole transitions in light(ish) nuclei.**

Abstract: The most famous dipole response of nuclei is the isovector giant dipole response which has been the focus of research for a number of decades. However, other dipole transitions are available. There has been recent theoretical focus on isoscalar dipole transitions as probes of asymmetric clustering in nuclei, and on low-lying dipole states in strongly deformed nuclei as manifestations of toroidal modes. Alpha-particle inelastic scattering is a powerful tool in locating isoscalar dipole excitations. The three cases ^{24}Mg, ^{26}Mg and ^{28}Si form an interesting triplet of nuclei in which to study the isoscalar dipole response: the magnesium isotopes are both prolate but ^{24}Mg has a stiffer deformation than ^{26}Mg while ^{28}Si is oblate. In this talk I will present a brief survey of monopole and dipole transitions in ^{24,26}Mg and ^{28}Si, and discuss how these data inform theoretical models of nuclear structure.

Chair: **Zsolt Podolyak (University of Surrey, UK)**

Time: 16:00 - 16:30 pm

Speaker: **Steven W. Yates (University of Kentucky, USA)**

Title: **Examining the structure of the stable Ge nuclei with fast neutrons**

Abstract: At the University of Kentucky Accelerator Laboratory (UKAL), we have observed γ rays following inelastic scattering of fast neutrons from several candidates for neutrinoless double-beta decay (0νββ). The rate of 0νββ is approximately the product of three factors: the known phase-space factor for the emission of the two electrons, the effective Majorana mass of the electron neutrino, and a nuclear matrix element (NME) squared. The NMEs cannot be determined experimentally and, therefore, must be calculated from nuclear structure models. A focus of our recent measurements has been on providing detailed nuclear structure data to guide these model calculations.

Following our recent measurements on ^{76}Ge [1] and its double-β decay daughter, ^{76}Se [2], we have progressed to the other stable even-A Ge nuclei. From these measurements, spins and parities of low-lying excited states were characterized, level lifetimes were measured with the Doppler-shift attenuation method, multipole mixing ratios were established, and transition probabilities were determined. A new comprehensive procedure for future work, which will lead to more meaningful data for constraining calculations of NMEs, is suggested. In addition, the new information obtained from our studies permits us to examine the role of shape coexistence in the heavy stable Ge isotopes.

This material is based upon work supported by the U.S. National Science Foundation under grant no. PHY-1913028.

[1] S. Mukhopadhyay, et al., Phys. Rev. C **95** (2017) 014327.
[2] S. Mukhopadhyay, et al., Phys. Rev. C **99** (2019) 014313.

Time: 16:30 - 17:00 pm

Speaker: **Sally Hicks (University of Dallas, USA)**

Title: **^{130}Te: A Cornucopia of Nuclear Structures**

Abstract: Double-β decay of ^{130}Te was first observed by Inghram and Reynolds in 1950 [1]; today the CUORE collaboration is searching for neutrinoless double-β decay (0vββ) in this nucleus, with the rate of such events predicted to be only a few in the 5-10 years of operation of the detector. The theoretical calculation of 0vββ rates depends on nuclear matrix elements between ^{130}Te and ^{130}Xe, which makes a detailed knowledge of the level characteristics—spins, parities, lifetimes, branching and multipole mixing ratios—of these nuclei important. Additionally, with Z=52, the Te nuclei mirror the Cd nuclei with respect to the shell closure at Z=50. As such, the six stable or very long-lived even-A Te nuclei offer an excellent opportunity to explore the evolution of single-particle and collective structures across a broad isotopic chain.

As part of an effort to provide detailed nuclear structure information to guide model calculations for 0vββ candidates and to better understand the evolution of excitations in nuclei near Z=50, γ-ray spectroscopy following inelastic neutron scattering was used to probe low-lying levels in ^{130}Te at the University of Kentucky Accelerator Laboratory (UKAL). The non-selective nature of the (n,n′γ) reaction in populating nuclear levels has allowed us to identify new low-lying 0^+ levels, observe new transitions from collective levels, and assess the important role that negative-parity excitations play in this nucleus. Emphasis is placed on comparison to analogous structures of $^{122,\ 124,\ 126,\ 128}$Te, which were all investigated with the same reaction at UKAL.

This material is based upon work supported by the U.S. National Science Foundation under grants PHY-0139504 and PHY-9901508.

[1]M.G. Inghram and M.G. Reynolds, Phys. Rev. **78** (1950) 822.

[2]https://cuore.lngs.infn.it/en/about/physics (October 5, 2020).

Time: 17:00 - 17:30 pm

Speaker: **Paul Garrett (University of Guelph, Canada / UWC, SA)**

Title: **Multi-spectroscopic studies of the stable Ru isotopes; recent results plans and future plans**

Abstract: The even-even Ru isotopes, especially those with neutron number between 54 and 60, have low-lying level schemes reminiscent of that expected for a quadrupole harmonic vibrator. In a recent survey [1], it was shown that the existing data rule out such an interpretation for the Ru isotopes with A≧ 102; there is ample evidence that shape-coexistence occurs in these nuclei (see, e.g., Ref. [2,3]). For ^{98,100}Ru, however, the current state of spectroscopic data cannot exclude a harmonic vibrational interpretation. With the goal of probing the nature of the excited states in ^{98,100,102}Ru, we have launched a program of investigation using multi-spectroscopic techniques.

A very sensitive spectroscopic tool to study excited nuclear states is decay, but the parents of the neutron-deficient Ru isotopes are Rh, a refractory element from which it is difficult to produce beams at ISOL facilities. We have thus used fusion-evaporation reactions, $^{12}C+^{89}Y$ and $^{14}N+^{89}Y$, at iThemba LABS to produce activities of ^{98}Rh and ^{100}Rh, and studied their decays using the Decay Tape Station. These measurements were complemented by the two-neutron-transfer reactions $^{100,102}Ru(p; t)^{98,100}Ru$ analysed with the Q3D magnetic spectrograph of the Maier-Leibnitz Laboratorium in Garching, Germany. Additionally, we have also performed a Coulomb excitation of ^{102}Ru using ^{12}C and ^{18}O beams, also using the Q3D. The results are placed into context of the systematics of the shape-coexisting structures in the region, and comparisons with beyond-mean field calculations for the Ru isotopes are made. Finally, our immediate plans of further study will also be outlined.

[1] P.E. Garrett, S.W. Yates, and J.L. Wood, Phys. Scr. **93** (2018) 063001.
[2] W. Urban *et al*., Phys. Rev. C **87** (2013) 031304.
[3] P.E. Garrett *et al.*, Phys. Lett. B **809** (2020) 135762.

Plenary Talk

Time: 19:00 - 20:00 pm

Speaker: **John L. Wood (Georgia Institute of Technology, USA)**

Title: **How I see nuclear structure study (as presented by Nico)**

Abstract: I see the study of nuclear structure as entering a major new chapter. I have reached this view through my part in launching the IOP Series in Nuclear Spectroscopy and Nuclear Structure [1], working with Kris Heyde and David Jenkins. This view is substantially defined by my work with the late David Rowe [2], and research collaborations with many colleagues.

The major nuclear structure issues that have my attention are the following:

1) the widening manifestation of shape coexistence in nuclei [3, 4, 5];

2) the demise of quadrupole vibrational dominance of low-energy degrees of freedom in spherical nuclei [6];

3) the success of rotational models both in their description of high-precision electric quadrupole, E2 properties [7] and in their applicability to weakly deformed nuclear E2 properties, especially in the guise of a triaxial rotor model [8, 9, 10];

4) the emergence of the symplectic shell model as the dynamical symmetry of the nucleus [11].

These topics have variously featured in past TASTES presentations. In the presentation for this year, the focus is on what is emerging as a clear set of model guidelines for moving into a new chapter of nuclear structure study. Low-energy excitations of spherical nuclei exhibit seniority-dominated structure, with weak collectivity confined to the first-excited 2^+ and 3^- states. Deformed nuclei exhibit rotational behavior of axially symmetric shapes and no low-energy vibrations when the deformation is large; and axially

asymmetric shapes and no low-energy vibrations when the deformation is small. The main questions that need to be addressed are:

a) In which nuclei can we expect low-energy shape coexistence?

b) How do rotor models fail in describing E2 collectivity in weakly deformed nuclei?

c) How do nuclei rotate?

This personal view must be confronted with the design of challenging experiments and the search across the mass surface for exceptions, even new classes of behavior.

[1] "Quantum Mechanics for Nuclear Structure: a Primer", Kris Heyde and John L. Wood, IOP Publishing Ltd., Bristol, UK, 2020. "Quantum Mechanics for Nuclear Structure: an Intermediate Level View", Kris Heyde and John L. Wood, IOP Publishing Ltd., Bristol, UK, 2020. "Nuclear Data: a Primer", David G. Jenkins and John L. Wood, IOP Publishing Ltd. Bristol, UK, to be published in 2021.

[2] "Fundamentals of Nuclear Models: Foundational Models", David J. Rowe and John L. Wood, World Scientific, Singapore, 2010.

[3] "Shape coexistence in atomic nuclei", Kris Heyde and John L. Wood, Rev. Mod. Phys. 83 (2011) 1467.

[4] "A focus on shape coexistence in nuclei", ed. J.L. Wood and K. Heyde, J. Phys. G: Nucl. Part. Phys. 43 (2016) 020402.

[5] "A relationship between isobaric analog states and shape coexistence in nuclei", D.J. Rowe and J.L. Wood, J. Phys. G: Nucl. Part. Phys. 45 (2018) 06LT01.

[6] "Critical insights into nuclear collectivity from complementary nuclear spectroscopic methods", P.E. Garrett, J.L. Wood, and S.W. Yates, Phys. Scr. 93 (2018) 063001. "On the robustness of surface vibrational modes: case studies in the Cd region", P.E. Garrett and J.L. Wood, J. Phys. G: Nucl. Part. Phys. 37 (2010) 064028. "Multiple Shape Coexistence in ^{110,112}Cd", P.E. Garrett et al., Phys. Rev. Lett. 123 (2019) 142502.

[7] "Precision test of the rotor model from band mixing in ^{166}Er", W.D. Kulp et al., Phys. Rev. C73 (2006) 014308.

[8] "Triaxial rotor model description of E2 properties in ^{186,188,190,192}Os", J.M. Allmond et al., Phys. Rev. C78 (2008) 014302.

[9] "Empirical moments of inertia of axially asymmetric nuclei", J.M. Allmond and J.L. Wood, Phys. Lett. B 767 (2017) 226.

[10] "Shape coexistence and the role of axial asymmetry in ^{72}Ge", A.D. Ayangeakaa et al., Phys. Lett. B 754 (2016) 254; "Triaxiality near the ^{110}Ru ground state from Coulomb excitation", D.T. Doherty et al., Phys. Lett. B 766 (2017) 334.

[11] "Physics of Nuclei: Key Role of an Emergent Symmetry", T. Dytrych et al., Phys. Rev. Lett. 124 (2020) 042501.

Wednesday Morning December 2nd

Chair: **Pawel Napiorkowski (University of Warsaw, Poland)**

Time: 09:30 - 10:15 am

Speaker: **Vivek Datar (Ex TIFR, BARC, India)**

Title: **Electromagnetic radiation from the tiniest rotor ^{8}Be**

Abstract: I will discuss a measurement of an electromagnetic (EM) transition in the smallest rotor that we know viz. the ^{8}Be nucleus. This rare branch (~10^{-7}) from the 4^{+} resonance to the 2^{+} resonance in ^{8}Be was measured, using a ^{4}He gas target at 4 energies of a ^{4}He beam and a 38 BGO detector array, to an accuracy ~10%. The need for measuring the much weaker and more challenging $2^{+} \rightarrow 0^{+}$ transition as well as an intra-resonance EM transition strength, together with calculations that treat state-of-the-art structure models with reaction theory, will be emphasized. Possible ways of measuring this branch will be mentioned.

[1] V. M. Datar *et al.*, Phys. Rev. Lett. **111** (2013) 062502; ibid **94** (2005) 122502.

Time: 10:15 - 10:45 am

Speaker: **Song Guo (Chinese Academy of Science, Lanzhou, China)**

Title: **Towards convincing experimental evidence on low-spin wobbling motion**

Abstract: Half a century ago, wobbling motion was predicted as a unique mechanism for triaxial deformed nuclei, in analogy to precession of gyroscopes in macroscopic view. This expectation was confirmed experimentally two decades ago, by the observation of a series of wobbling bands in nuclei of the A=160 mass region. Recently, several wobbling bands in other mass regions have been reported, and new theoretical models have been proposed. In these works, large mixing ratios for the dipole linking transitions between wobbling and yrast bands are considered key experimental criteria. The mixing ratios are mainly deduced from angular distribution and linear polarization data, but reliable results depend on proper data analysis and sufficient statistics, which are not fully satisfied in these works. We therefore re-evaluated the reliability of the experimental evidence on the wobbling bands, and performed an experiment to check the case in ^{187}Au. It is found that the experimental evidence for wobbling interpretation is not sufficient for bands reported in several nuclei, and great risks of misinterpretation can be induced by careless analysis.

Time: 10:45 - 11:15 am

Speaker: **Martin Venhart (Slovak Academy of Sciences, Slovakia)**

Title: **How to establish an excellent research group in small and young country**

Abstract: Slovakia is a small country in central Europe. It has approximately 5.5 millions of citizens. It was established on January 1, 1993, by separation of Czechoslovakia. Czechoslovakia was created after the First World War in 1918. Despite the fact that for most of its existence it was not democratic state, it can be considered as a successful project in the history of Europe. This fact is well documented, e.g., with the level of the technology developed there. In 1972, Czechoslovakia started a nuclear power plant, which was completely designed by local enterprises. Later the own nuclear program was ceased and the country went to Soviet technology.

Important milestone occurred in 1989 when the so-called Velvet Revolution took place. It was the end of the era of communism. Almost immediately after the first free elections, the country abandoned its command economy and transformed to capitalism. The split of Czechoslovakia came in 1993. People of Czechoslovakia managed to separate the country in a very calm way. This was not always the case in history: we know, e.g., what happened in former Yugoslavia.

The society went through two major societal changes in a very short time. In such a situation the government had to solve a lot of problems. This caused a reduction of investments into science almost to zero. The result? Best scientists left the country. It was only in 2004 when the situation started to improve. This was the time when Slovakia joined European Union. Another important milestone was 2009, when Slovakia accepted the euro as its currency. Since this time, structural funds of European Union helped to reconstruct scientific infrastructure.

When I came back from Belgium in 2010 I found a terrible situation at the Department of Nuclear Physics. Almost no students, no post-docs, no new ideas, lack of vision… I even had to buy my own chair. Lacking big words, I started to work hard. Step-by-step, we developed our own research program at ISOLDE facility, University of Jyvaskyla and at iThemba Labs. And the situation now? The Department of Nuclear Physics in Bratislava is full of young students and post-docs. Several colleagues returned back to Slovakia from abroad. We also started to attract students from abroad. We are running our own facility based on the Tandetron accelerator. Looking back, this seems to me as a miracle. If someone told me this 10 years ago, I would think that he must be a fool. But, when you want something, all the universe conspires in helping you to achieve it.

Amen (Chair of the X Tastes of Nuclear Physics)

Time: 11:45 am - 12:15 pm

Speaker: **Costel Petrache (Université Paris-Saclay, IJCLab, CNRS-IN2P3, Orsay, France)**

Title: **Chirality and wobbling in nuclei: new achievements and perspectives**

Abstract: The breaking of symmetries in quantum systems is one of the key issues in nuclear physics. In particular, the spontaneous symmetry breaking in rotating nuclei leads to exotic collective modes, like the chiral and wobbling motions, which have been intensively studied in recent years. Chiral bands in even-even nuclei, which were taught to be unfavored energetically, unstable against 3D rotation and difficult to observe, have been instead identified very recently in ^{136}Nd. Multiple chiral bands have been also identified in the neighboring ^{135,137}Nd nuclei, and pseudospin-chiral quartet bands in the presence of octupole correlations have been identified in ^{131}Ba. These new experimental results triggered many theoretical developments and extensions of the previous models, which are now able to describe complex band structures resulting from chirality-parity violation in triaxial nuclei with reflection asymmetry. An overview of the latest experimental results and theoretical developments will be presented.

The wobbling motion is another topic related to triaxial nuclei, with new results and theoretical developments under intense current debate. The first evidence of wobbling bands built on two-quasiparticle configurations has been recently found in ^{130}Ba. Several low-spin bands in odd-even nuclei have been interpreted as wobbling bands with transverse or longitudinal coupling between the odd nucleon and the triaxial core, but the experimental evidence on the collective transitions connecting the wobbling partners is often contradictory. Recent theoretical works revealed the inadequacy of the wobbling interpretation of these low-spin bands, which in reality are tilted precession (TiP) bands. The recently published results and their interpretation will be discussed.

Time: 12:15 - 12:30 pm

Speaker: **Motswakae Sebele (MSc Student, Botswana International University of Science and Technology, Bostwana)** Supervisors: Gregory Hillhouse (BIUST) and Mikhail Sapozhnikov (JINR)

Title: **Application of tagged neutron method for detecting diamonds in kimberlite**

Abstract: Tagged neutron method is a non destructive technique of analysing the chemical composition of a material using fast neutrons. This technique can be applied in the diamond mining industry to separate diamond bearing kimberlite from the barren ores before the secondary crushing of the ore to avoid damaging diamond. It allows detecting diamond within the kimberlite without crushing the ore. The ore is irradiated with fast neutrons of energy 14.1 MeV which excites kimberlite elements. These elements de-excite through the emission of characteristic gamma rays. Diamond is mainly carbon. Carbon forms peaks at 3.9 and 4.4 MeV, therefore diamond detection is the detection of excess carbon in some regions of the ore. It can detect diamonds in an ore 10 times larger than the size of diamond. The author acknowledges support from JINR (Yury Rogov and Vladislav Kremenets).

Wednesday Afternoon December 2nd

Chair: **Shaun Wyngaardt (Stellenbosch University)**

Time: 13:30 - 14:00 pm

Speaker: **Rudrajyoti Palit (Tata Institute of Fundamental Research, India)**

Title: **Digital INGA and its Ancillary Detectors: Results and New Developments**

Abstract: The Indian National Gamma Array (INGA) campaigns at the three accelerator facilities within India have contributed significantly in recent years to studies of nuclear structure. Selected results related to the novel excitation modes of atomic nuclei from this array will be presented. Finally, we will discuss the new developments related to the ancillary detector systems of INGA.

Acknowledgement: The author would like to acknowledge the support of INGA collaboration.

Time: 14:00 - 14:30 pm

Speaker: **JJ Van Zyl (Stellenbosch University, South Africa)**

Title: **Implementation of digital DAQ system for coincidence (p,alpha) scattering experiments**

Abstract: The availability of fast, multi-channel digital data capture modules such as XIA's PIXIE16 system has greatly simplified the traditional analogue electronic coincidence setup. Constrained by aging and limited infrastructure, we attempted a traditional two-telescope scattering experiment with a digital setup to investigate the angular distributions of (p,alpha) reactions on a selection of Sn targets with a 150 MeV polarised proton beam. Customised acquisition and analysis software was adapted to replace the aged VAX-based XSYS software and investigate the feasibility of using a well-supported and user friendly system for experiments using the A-line scattering chamber and polarised ion source. We highlight some of the advantages and disadvantages of the digital setup.

Acknowledgement: The author would like to acknowledge the support of Deon Steyn, Lindsay Donaldson, Retief Neveling.

Time: 14:30 - 15:00 pm

Speaker: **Sifiso Ntshangase (University of Zululand, South Africa)**

Title: **Octupole excitation in Uranium isotopes**

Abstract: A number of interesting physics phenomena have been predicted to occur in the actinide region. These can be studied by measuring fusion-evaporation residues produced in a heavy-ion fusion reaction. However, reactions leading to this region are characterized by very low cross-sections and fission is a dominant channel. At iThemba LABS, a recoil detector which separates the fusion-evaporation residues from the fission background using the time-of-flight measurement has been developed. Here we report results obtained in studying octupole excitation in uranium isotopes.

Time: 15:00 - 15:30 pm

Speaker: **Robbie Lindsay (University of the Western Cape, South Africa)**

Title: **The highs and lows of radon concentrations**

Abstract: The Physics Department at UWC is involved in some measurements of high radon values in the South Afrcian gold mines where values of 1000 Bq/m^3 are common. On the other hand, we are also looking at materials that have as little radon as possible for use in underground laboratories where the background must be as close to zero as possible. Some of the interesting measuring techniques will be discussed in this contribution.

Chair: **Gordon Ball (TRIUMF, Canada)**

Time: 16:00 - 16:30 pm

Speaker: **Berta Rubio (IFIC / CSIC-Uni. Valencia, Spain)**

Title: **Studying Isospin symmetry with beta decay and Charge Exchange Reactions**

Abstract: Isospin Symmetry is an important concept in nuclear physics that can help us understand nuclei and their structure. It is not an exact symmetry and one has to study nuclei case by case in order to determine how reasonable the assumption of isospin symmetry is. Despite these deficiencies, isospin symmetry is often used to extrapolate the predictions of models or to estimate how nuclei far away from the line of stability will behave.

One possible way to investigate isospin symmetry is to study the beta decay of mirror nuclei. This is possible only in light nuclei. This kind of study has been carried out often in the past, and is still today the focus of intense experimental and theoretical activity. To carry out similar kinds of study in medium mass nuclei we have to draw on the comparison of beta decay and Charge Exchange reactions since under certain circumstances the latter are governed by the same operators as the beta decay. In this talk I shall concentrate on experimental examples of this type of study. I shall describe and explain the experimental techniques, the state of the art, and how far we can go by following this route.

Time: 16:30 - 17:00 pm

Speaker: **Ronald Fernando Garcia Ruiz (Massachusetts Institute of Technology, USA)**

Title: **Exotic Molecules for Fundamental Science**

Abstract: Precise knowledge of the interaction between the atomic nucleus and the surrounding electrons offers a complementary insight into the atomic nucleus and the fundamental particles and forces of nature. Exotic molecules - those containing nuclei with extreme proton-to-neutron ratios - can be tailored to investigate particular details of electron-nucleon interactions and enhanced their symmetry-violating properties. Thereby offering high sensitivity to access to unexplored nuclear phenomena, to study the violation of fundamental symmetries, and to search for new physics. In this talk, I will present recent results from laser spectroscopy experiments of these exotic species. The relevance of these results to some of the pressing questions of nuclear science and other research fields will be discussed.

Time: 17:00 - 17:45 pm

Speaker: **Eric B. Norman (University of California, Berkeley, USA)**

Title: **Stellar Alchemy - The Origin of the Chemical Elements**

Abstract: Where did all of this "stuff" come from? For as long as humans have been on Earth, we wondered about the origin of the matter we observe. Over the last century, we have learned the astonishing answer. The calcium in our bones, the iron in our blood, and almost all of the chemical elements that make up the observable universe were synthesized billions of years ago in the nuclear furnaces found at the centers of stars. While this was once only a theory, in this talk I will review the astronomical observations and laboratory nuclear physics experiments that have firmly established this concept as fact.

Thursday Morning December 3rd

Chair: **Tomas R. Rodríguez (Universidad Autónoma Madrid, Spain**

Time: 09:30 - 10:15 am

Speaker: **Jacek Dobaczewski (University of York, UK)**

Title: **Masses of masses: from Liquid Drop to nuclear DFT.**

Abstract: I will present a brief journey of modelling nuclear masses; beginning with the five-parameter Liquid Drop Model, going through modelling shell corrections, and finishing with the state-of-the-art DFT modelling. The lecture will be presented using an interactive environment of Jupyter Notebook (https://jupyter.org/), which can be downloaded from the anaconda (https://www.anaconda.com/) website along with the python interpreter. Students will have access to the Jupyter-Notebook file of the lecture, which allows for rerunning the lecture and playing with options not covered during the lecture.

Time: 10:15 - 10:45 am

Speaker: **Luis Robledo (Universidad Autónoma de Madrid, Spain)**

Title: **Octupole collectivity and reflection symmetry breaking**

Abstract: The nuclear mean field introduces the concept of spontaneous symmetry breaking in the description of atomic nuclei. Reflection symmetry (or mirror symmetry or parity) is one of the symmetries broken in the nucleus and it is associated with the multipole of order three, namely the octupole moment. It often comes intertwined with rotational symmetry breaking which is characterized by the components of the quadrupole moment. Due to the characteristic position of single particle orbitals, permanent (or static) octupole deformation is only present in a handful of nuclei concentrated in a few small islands in the nuclear chart. However, dynamical octupole correlations built around the soft response of the nucleus to the octupole field are present in most (if not all) nuclei in the nuclear chart. In this talk I will describe how to treat microscopically using beyond mean field techniques those dynamical octupole correlation, their impact in physical observables like excitation energies of collective negative parity states and their odd multipole transition strengths to positive parity states.

Time: 10:45 - 11:15 am

Speaker: **Makito Oi (Senshu University, Japan)**

Title: **Symmetries and Anti-symmetries in nuclear mean-field theory.**

Abstract: Nuclear many-body states should be constructed with the anti-symmetric nature, which originates from the fact that a nucleus consists of fermions. As a result, varieties of non-trivial mathematical structures are implemented in the many-body states, even when they are restricted to the mean-field approximation.

I would like to present some theoretical outcomes regarding the mathematical nature of the overlap functions of the many-body states, which are obtained in the mean-field framework. This theoretical investigation may be useful in attempts to go beyond the mean-field theory, such as the generator coordinate method and the quantum-number projection theory, so as to tackle the nuclear structure with a triaxial deformation.

Time: 11:45 am - 12:15 pm

Speaker: **Ramon A. Wyss (KTH Royal Institute of Technology, Sweden)**

Title: **Magic nuclei in iso-space and the concept of symmetry energy**

Abstract: In this talk, we will review the concept of symmetry energy, presenting a more general and solid framework than what is given in standard textbook descriptions. Starting from even-even N=Z nuclei, the iso cranking approach will be employed to derive the symmetry energy and its composition. Properties of even-even and odd-odd N=Z nuclei with respect to binding energy and the results of a generalized pairing interaction with T=0 and T=1 components will be presented. Results of calculations for N=Z and neighbouring nuclei will be presented.

Time: 12:15 - 12:30 pm

Speaker: **Kanting Motimele (MSc, Stellenbosch University / University of the Western Cape, South Africa)**

Title: **A relativistic analysis of proton-induced knockout reactions from oxygen isotopes with direct and inverse kinematics**

Abstract: In this study a complete set of exclusive (**p**,2**p**) polarization transfer observables of closed-shell oxygen isotopes is calculated using both direct and inverse kinematics using the relativistic plane wave impulse approximation. The interaction matrix is written in terms of the SPVAT (scalar, pseudoscalar, vector axial vector, tensor) covariants where each amplitude is obtained directly from experimental phase shifts. A relativistic mean field theory approximation is used to compute bound-state wave functions of the nucleons. We study the evolution of polarization transfer observables within oxygen isotopes and identify observables which may discriminate between these isotopes. The same kinematical conditions are considered for both direct and inverse kinematics: the incident energy is set at 504 MeV and coplanar angles are fixed at (22.12^o, -40.30^o).

Thursday Afternoon December 3rd

Chair: **Paulus Masiteng (University of Johannesburg, South Africa)**

Time: 13:30 - 14:00 pm

Speaker: **Alfredo Poves (Universidad Autónoma de Madrid, Spain)**

Title: **On the meaning of the nuclear shape**

Abstract: The concept of nuclear shape, of semi classical nature, is ubiquitous in nuclear structure studies. I will deal with the connection between the intrinsic frame and the laboratory frame description of deformation via Elliott's model and its variants, and I will discuss the limits of the applicability of the concept of shape using ^{68}Ni as a realistic example.

Time: 14:00 - 14:30 pm

Speaker: **John Sharpey-Schafer (University of Zululand, South Africa)**

Title: **Nuclear Shapes and Collective Structures**

Abstract: Recent calculations by Otsuka *et al.* [1] using the Advanced Monte Carlo Shell Model (AMCSM) show that deformed nuclei can be axially symmetric in their ground states but can become triaxial for excited intrinsic states such as the usual $K^\pi = 2^+$ “quasi-γ” band. The Triaxial Projected Shell Model

(TPSM) gets alignments right [2,3] and the Nilsson-Strutinsky Collective Model (NSCM) [4,5] has had considerable success in understanding how structures develop towards high spins. An extension of the traditional collective model to a five-dimensional collective model (5D-CM) using potentials calculated with a Covariant Density Functional Model (CDFM) [6] has been able to explain variations in signature splitting of the $K^{\pi} = 2^{+}$ “quasi-γ” bands and other features of deformed nuclei at low spins.

Experiments required to clarify the most important features that determine the details of deformed nuclear structures and the underlying Physics be discussed together with the complications due to the effects of octupole shapes. Time allowing, possible early experiments for the new South African GAMKA spectrometer, in its “Dandelion” configuration [7], will be suggested.

[1] T. Otsuka et al., Phys. Rev. Lett. **123** (2019) 222502.
[2] J. A. Sheikh et al., Phys. Rev. C **77** (2008) 034313.
[3] S. Jehangir et al., Phys. Rev. C **97** (2018) 014310.
[4] A. Kardan et al, Phys, Rev. C **86** (2012) 014309.
[5] A. Kardan, Int. J. Mod. Phys. E **26** (2017) 1750044.
[6] S. N. T. Majola *et al*., Phys. Rev. C **100** (2019) 044324.
[7] J. N. Orce, E. A. Lawrie *et al*., *private communication.*

Time: 14:30 - 15:00 pm

Speaker: **Alison Bruce (University of Brighton, UK)**

Title: **Shapes in neutron-rich A~100 nuclei obtained from lifetime measurements**

Abstract: An indirect measurement of the shape of the nucleus can be obtained from measuring level lifetimes which relate, via transition rates, to beta_2 deformation. Details of measurements of level lifetimes in the sub nanosecond range using $LaBr_3$(Ce) detectors at RIKEN ($^{104,106}Zr$) and the Argonne National Laboratory (^{114}Pd) will be presented. The construction and use of an array of 36 LaBr3(Ce) detectors at the FAIR laboratory in Darmstadt Germany will also be discussed.

Time: 15:00 - 15:30 pm

Speaker: **Daniel Doherty (University of Surrey, UK)**

Title: **Shape Evolution and Triaxiality in Hitherto Inaccessible Regions of the Nuclear Chart**

Abstract: Neutron-rich nuclei, close to mass number A ~ 100, display a variety of fascinating shape phenomena including exotic non-axial (triaxial) shapes and shape coexistence. These phenomena have been predicted by a number state-of-the-art theoretical approaches and corroborated with evidence from energy systematics. However, with the advent of new radioactive beam facilities and equipment and the renaissance of Coulomb-excitation studies, powerful new possibilities of studying these shapes directly are now available.

In this talk, I will focus on complementary Coulomb-excitation and decay studies recently performed at Argonne National Laboratory's CARIBU facility. The first results, indicated that the exotic 110Ru isotope possessed a non-axial ground state however new studies, aided by the EBIS charge breeder and a number of other experimental improvements, far more in-depth conclusions to be drawn both for 110Ru and neighbouring nuclei in this shape-shifting region. Here the new data will be presented focusing on the new information gleaned from the most recent studies and finally the possibilities for studying the most exotic, non-axial, cases in the near-future will be assessed.

Chair: **Alessandro Pastore (University of York, UK)**

Time: 16:00 - 16:30 pm

Speaker: **Alexix Diaz Torres (University of Surrey, UK)**

Title: **Role of diabaticity in reactions forming heavy elements**

Abstract: The physics of nuclear reactions is crucial for understanding element creation in the Universe, and is therefore at the core of science programmes in new generation nuclear research facilities. Understanding the formation mechanism of the heaviest nuclei is a great theoretical challenge. I will report on effects of diabaticity of the single-particle motion on the fusion of heavy nuclei at Coulomb energies. I will introduce the two-center shell model [1-3], and discuss the competition between two fusion pathways in the evolution of a heavy dinuclear system from its touching configuration to the compound nucleus [4].

[1] J.A. Maruhn and W. Greiner, Z. Phys. **251** (1972) 431.
[2] A. Diaz-Torres, Phys. Rev. Lett. **101** (2008) 122501.
[3] A. Diaz-Torres, Comp. Phys. Comm. **224** (2018) 381.
[4] A. Diaz-Torres *et al.*, Phys. Lett. B **481** (2000) 228.

Time: 16:30 - 17:00 pm

Speaker: **Petar Marevic (Lawrence Livermore National Laboratory, USA)**

Title: **Nuclear Fission Meets Symmetry Restoration**

Abstract: Eighty years after its discovery, fission remains a major puzzle for nuclear theorists. State-of-the-art fission models are based on various realizations of the density functional theory (DFT) and are only made feasible by the recent growth in supercomputing capabilities. However, in addition to a plethora of other approximations, these models are characterized by breaking of nuclear symmetries and the basic information on the number of particles, angular momentum, and parity of fissioning nucleus is consequently lost. Restoring broken symmetries, though formally and technically challenging, could be important for improving our description of different fission channels and for better estimating the properties of fission fragments. In this talk, we will first introduce the basic tenets of DFT and then proceed to discuss the very recent effort of incorporating symmetry restoration into a fission model. We will review the main conclusions of the benchmark study of ^{240}Pu and discuss future avenues in one of the most active fields of theoretical nuclear research.

Time: 17:00 - 17:30 pm

Speaker: **Jason Holt (TRIUMF, Canada)**

Title: **Atomic Nuclei For Beyond Standard Model Physics**

Abstract: As science probes ever more extreme facets of the universe, the role of nuclear theory in confronting fundamental questions of nature continues to deepen. Long considered a field of disconnected models, breakthroughs in our understanding of strong and electroweak forces in nuclei are rapidly transforming modern nuclear theory into a true first-principles, or "ab initio", discipline.

In particular, this allows us to connect directly to some of the most exciting questions in physics beyond the standard model, such as violations of fundamental symmetries, the nature of dark matter, and the nature of neutrino masses through a hypothetical process called neutrinoless double beta decay, where we must first confront a puzzle which has eluded the field for over 50 years.

Plenary Talk

Time: 19:00 - 20:00 pm

Speaker: **Dean Lee (Michigan State University, NSCL/FRIB, USA)**

Title: **Nuclear Lattice Simulations**

Abstract: I discuss simulations of nuclear structure using Monte Carlo simulations on a lattice grid. In the first half of the talk, I discuss the general formalism, how interactions are tuned to reproduce scattering data, and how the simulations are performed using auxiliary fields. In the second half, I cover some recent developments such as the calculation of the liquid-gas critical point in symmetric nuclear matter.

Friday Morning December 4th

Chair: **Nikita Bernier (University of the Western Cape / University of Zululand, South Africa)**

Time: 09:30 - 10:15 am

Speaker: **David Jenkins (University of York, UK)**

Title: **Nuclear Applications**

Abstract: Experimental nuclear physics is driven by advances in detector technology. A diversity of detectors are needed which are optimised for detecting different types of ionising radiation such as alpha particles, heavy ions, electrons/positrons, gamma rays and neutrons. We will map the basic detector concepts on to the specific detection challenges and compare and contrast the available technology. We will then see how some of this detector technology can be applied to challenges in real-word industrial settings and for medical imaging. This presentation will follow some of the examples provided in my recent book, “Radiation Detection for Nuclear Physics” published by IOP Publishing.

Time: 10:15 - 10:45 am

Speaker: **Daniel Watts (University of York, UK)**

Title: **Quantum entanglement - MeV scale opportunities**

Abstract: Entanglement is an intriguing consequence of quantum mechanics. It is well established at the optical scale (eV) where many fundamental tests of quantum theory and spin-off applications have been developed. However, advances in detector technologies and simulation methods mean that its exploitation and detailed study at the higher energy scales appropriate to nuclear physics (MeV) is becoming realisable. The talk will outline some recent results and discuss prospects in this developing area of research.

Time: 10:45 - 11:15 am

Speaker: **Simon H. Connell (University of Johannesburg, South Africa)**

Title: **Form research to innovation : PET in new applications**

Abstract: Applications of nuclear and particle physics techniques are used for innovation and commercialisation. The key innovation areas are: novel smart sensors of high granularity, high-throughput electronics, high rate and big data, high performance computing with hybrid techniques including machine learning and high fidelity physics modelling and simulation to produce digital twins. The core technologies

are related to accelerators and also positron emission tomography (PET). We have developed Intellectual Property around PET. The novel PolyPET suite of applications uses time differential PET to enable lifetime analysis, endowing PET with element sensitivity. MinPET is more similar to Medical PET, it deploys PET in a mining scenario. We have completed a full dress rehearsal of this technology in an on-line real-time diamond mining scenario showing capacity to process 1000 tons of rock per hour to discover diamonds down to 6 mm diameter locked in the host kimberlite rock with sizes up to 160 mm diameter. This provides the first ever high-throughput 3D quantitative imaging of locked diamonds within kimberlite rocks. The ore is pre-activated to produce multi-element PET isotopes by an electron accelerator which produces a high-energy photon beam of some tens of MeV via bremsstrahlung. PET isotope production is the most significant source of photons for delay times of the order of 30 minutes, with ^{11}C activity dominating. One can then form a 3D carbon density distribution map, and operate on that with an AI, to trigger the selection of the diamondiferous kimberlite. This presentation discusses the physics concepts, instrumentation and software tools that are familiar from Nuclear and Particle physics experiments, but now re-deployed in a commercial context.

Time: 11:45 am - 12:15 pm

Speaker: **Tom Leadbeater (University of Cape Town, South Africa)**

Title: **Radioisotope tracer techniques for the study of multiphase flows**

Abstract: At iThemba LABS, Positron Emission Particle Tracking (PEPT) is used to study dynamic physical processes and multiphase flow phenomena. Studies of these often turbulent systems contribute to understanding of fundamental flow behaviour and are of increasing interest in the current climate of reducing industrial wastes, improving process efficiencies, and developing design lead approaches to industrial systems. We use short lived positron emitting isotopes as tracers inside physical systems surrounded by large arrays of position sensitive gamma detectors. Coincident photons from positron-electron annihilation are used to measure the resulting dynamics.

This talk will discuss recent research produced by the PEPT Cape Town laboratory, including aspects of our four key themes: instrumentation & detector development, radioisotope tracer techniques (physical and chemical), data acquisition & processing, and the applications of such measurements.

Time: 12:15 - 12:30 pm

Speaker: **Ruth Newton (PhD Student, University of York, UK)**

Title: **Quantum entanglement in PET imaging**

Abstract: Our understanding and measurement of photon quantum entanglement at the MeV scale is currently poor compared to the optical regime. At York we have recently adopted new quantum technologies for MeV photon detection which enable entanglement measurement at a new level of precision. The first quantum-entangled simulations of MeV photon transport and detection have also been developed. This opens up a wealth of new opportunities for fundamental tests and applications of entanglement at this energy scale. Our first results on the benefits of using the (previously neglected) entanglement information in PET medical imaging will be presented.

Friday Afternoon December 4th

Chair: **Thifhelimbilu Bucher (University of the Western Cape / University of Zululand, South Africa)**

Time: 13:30 - 14:00 pm

Speaker: **David Edwin Alvarez Castillo (INP, PAS & JINR, Poland/Russia)**

Title: **Dense nuclear matter in the cores of neutron stars**

Abstract: In this talk, I will review and address the long standing problem of determination of the state of matter in the cores of neutron stars. Our understanding of the cold, dense nuclear matter in neutron star interiors has suffered a dramatic revolution during the recent years. On the one hand, laboratory experiments have been able to probe higher and higher densities that comprise the equation of state (EoS) of dense nuclear matter. On the other hand, multi-messenger astronomy observations have brought new physical constraints that narrow the parameter space of the different EoS models. There is however, certain tension between astrophysical and terrestrial measurements. One practical way to implement all the available constraints is implementing a Bayesian analysis for model comparison, which I will present.

In order address the corresponding to state-of-the-art physics, I shall introduce different approaches to the neutron star EoS: pure hadronic stars, stars with hyperonic and condensate content, and hybrid stars whose cores supports deconfined quark matter as well as strange quark stars, for the sake of comparison. Moreover, I will emphasize the role of the nuclear symmetry energy in determination of the star properties, discuss the hyperon puzzle and present a particular model of hybrid stars: mass twins.

Time: 14:00 - 14:30 pm

Speaker: **Alejandro Algora (IFIC / CSIC-Uni. Valencia, Spain) on behalf of the Valencia - Nantes - Jyväskylä Surrey *et al*. Collaboration**

Title: **Total Absorption Spectroscopy Measurements for Neutrino Physics**

Abstract: Total absorption spectroscopy is one of few methods available that provide beta decay data free from the systematic error called Pandemonium effect.

The technique is not only important for nuclear structure, but can also be relevant for practical applications, where proper beta decay data is needed, such as the determination of the reactor antineutrino spectrum in reactors and the decay heat.

In this talk, I will present the technique, and some examples of recent measurements of relevance for neutrino physics applications. The neutrino related results are of particular interest in relation to the so-called antineutrino reactor anomaly.

Time: 14:30 - 15:00 pm

Speaker: **Werner Richter**

Title: **Shell-model studies of the astrophysical rp-reactions $^{34}S(p,\gamma)^{35}Cl$ and $^{34g,m}Cl(p,\gamma)^{35}Ar$**

Abstract: The two rp-reactions $^{34}S(p,\gamma)^{35}Cl$ and $^{34g,m}Cl(p,\gamma)^{35}Ar$ were studied via a shell-model approach. At energies in the resonance region near the proton-emission threshold many negative parity states appear. We present results of calculations in a full $(0+1)\hbar\omega$ model space which addresses this problem. Energies, spectroscopic factors and proton-decay widths are calculated for input into the reaction rates as well as to assess the impact on the predicted $^{34}S/^{32}S$ isotopic ratio for pre-solar nova grains. Uncertainties were estimated using a Monte-Carlo method. Comparisons are also made with a recent experimental determination of the reaction rate for the $^{34}S(^{3}He,d)^{35}Cl$ reaction. The thermonuclear $^{34g,m}Cl(p,\gamma)^{35}Ar$ reaction rates are unknown because of a lack of experimental data. The rates for transitions from the ground state of ^{34}Cl as well as from the isomeric first excited state of ^{34}Cl are explicitly calculated taking into account the relative populations of the two states. The shell-model calculations alone are sufficient to constrain the variation of the $^{34}S/^{32}S$ ratios to within about 30%.

Time: 15:00 - 15:30 pm

Speaker: **B. Alex Brown (Michigan State University, USA)**

Title: **Hamiltonians and their applications for sd-shell nuclei**

Abstract: Low-lying states in the region of nuclei with $8 < N,Z < 20$ can be described in the nuclear shell model with protons and neutrons occupying the 0d5/2, 1s1/2 and 0d3/2 (sd) orbitals. Hamiltonians with the same set of sd-shell two-body matrix elements that have a smooth mass dependence have been extremely successful in understanding experimental properties. I will discuss the history of these universal sd-shell Hamiltonians: USD [1,2], USDcdpn [3], USDA [4], USDB [4], USDC [5] and USDI [5]. I will show a few examples for the success, and discuss the limitations.

[1] B. A. Brown and B. H. Wildenthal, Ann. Rev. of Nucl. Part. Sci. **38** (1988) 29.
[2] B. A. Brown, W. A. Richter, R. E. Julies and B. H. Wildenthal, Ann. Phys. **182** (1988) 191.
[3] W. E. Ormand and B. A. Brown, Nucl. Phys. A **491** (1989) 1.
[4] B. A. Brown and W. A. Richter, Phys. Rev. C **74** (2006) 034315.
[5] A. Magilligan and B. A. Brown, Phys. Rev. C **101** (2020) 064303.

Chair: **Xavier Roca Maza (Università degli Studi di Milano and INFN, Italy)**

Time: 16:00 - 16:30 pm

Speaker: **Jorge Piekarewicz (Florida State University, USA)**

Title: **Neutron-Rich Matter in Heaven and Earth**

Abstract: One of the overarching questions animating nuclear physics today is "How does subatomic matter organize itself". Neutron stars are cosmic laboratories uniquely poised to answer this fundamental question. The historical detection of a binary neutron star merger by the LIGO-Virgo collaboration and other critical observations since then are providing fundamental new insights into nature of neutron-rich matter and the astrophysical site for the creation of the heaviest elements through the r-process. In turn, the study of exotic nuclei at experimental facilities throughout the world will help elucidate the underlying dynamics of the r-process and the structure, dynamics, and composition of neutron stars. It is the strong synergy between heaven and earth that will be the focus of this presentation.

Time: 16:30 - 17:00 pm

Speaker: **Adriana Banu (James Madison University, USA)**

Title: **From Nuclei to Stars - A Case in Point: Photoneutron reaction cross-section measurements on ^{94}Mo and ^{90}Zr relevant to the p-process nucleosynthesis**

Abstract: The energy dependencies of the ground-state cross sections for ^{94}Mo(γ,n) and ^{90}Zr(γ,n) reactions were measured with high precision from the respective neutron emission thresholds up to 13.5 MeV. Beams of high intensity γ-rays from laser-induced Compton backscattering at the High Intensity γ-ray Source (HIγS) facility of the Triangle Universities Nuclear Laboratory (TUNL), in the USA, were used. In order to constrain the dipole γ-ray strength functions (γSFs) in the A ≃ 90 mass region, the measured cross sections were compared with predictions of Hauser-Feshbach statistical model calculations using two different dipole γSF models. Since these models are based on fundamentally different physics, they can reflect the existing uncertainties affecting the γSF, and also the impact of such uncertainties on reaction cross sections and corresponding astrophysical reaction rates.

This presentation will bring into focus key aspects of the experimental procedure, data analysis, and theoretical calculations pertaining to our final results that show how sensitive the resulting ^{94}Mo(γ,n) and ^{90}Zr(γ,n) stellar reaction rates can be to the corresponding experimental ground-state cross sections, as discussed in detail in our recent publication [1].

These measurements contribute to a broader investigation of nuclear reactions relevant to understanding the p-process nucleosynthesis [2].

[1] A. Banu, E. G. Meekins, J. A. Silano, H. J. Karwowski, and S. Goriely, Phys. Rev. C **99** (2019) 025802.

[2] M. Arnould and S. Goriely, Phys. Rep. **384** (2003) 1.

Time: 17:00 - 17:45 pm

Speaker: **Carlos Bertulani (Texas A&M University-Commerce, USA)**

Title: **Neutron skins, symmetry energy, and neutron stars.**

Abstract: In this talk, I will discuss the limitations of nuclear physics in determining the necessary conditions for the description of neutron star masses, radii, and other properties. Theoretical and experimental efforts will be reported, with emphasis on the equation of state of nuclear matter and the experimental campaigns in the U.S., Europe and Japan.

Thank you all for making the Xth Tastes of Nuclear Physics happen during these hard times. The X tastes Organizing Committee

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