Advanced Nuclear Science and Technology Techniques Workshop

Monday 15 April 2024 - Friday 19 April 2024

NRF-iThemba LABS, Old Faure Road, Cape Town

Book of Abstracts

Contents

Environmental Measurements / 112

Portable African Neutron-Gamma Laboratory for Innovative Nuclear Science.

Author: Pete Jones[1]

[1] *iThemba LABS*

Corresponding Author: pete@tlabs.ac.za

The Portable African Neutron-Gamma Laboratory for Innovative Nuclear Science (PANGoLINS) project aims to further investigate measurements of neutrons which forms an important component part on site or in transit and the detection of both fissile material for the use in decarbonised energy sources or disposal thereof. iThemba LABS has pioneered a mobile gamma-ray detection unit which allows a user to operate in the field and chart the location, strength and energy of gamma radiation. This project allows not only for investigation of neutrons but anticipates the value add on other features that are outdated i.e. battery pack and reducing current, temperature monitoring that impacts data and overall analysis. Benefits of the outcome of this project includes economic impact, contribution to GDP etc., increased highly skilled capacity and knowledge base and increased capabilities for technically innovation and social impact including improvement in quality of life, poverty alleviation and the potential impact in lowering barriers to entry for other South African technology innovations.
An overview of the project, it progress and potential outcomes will be presented.

Neutron Physics and Science Communication / 113

Invited Talk: On the trapping of cold neutrons in nano-scaled Fabry-Perot resonating cavities & neutron lifetime considerations

Author: Malik Maaza Maaza[1]

[1] *iThemba LABS-NRF & UNESCO UNISA Africa Chair*

Corresponding Author: maaza@tlabs.ac.za

Relatively to the atomic constituents' counterparts, the neutron is singular as it is sensitive to the four fundamental interactions: strong, weak, electromagnetic, and gravitational. This multi-sensitivity makes neutron wave-matter optics a particularly versatile tool for testing quantum mechanics specifically and fundamental physics concepts in general. The lifetime of a free neutron defined via its beta-decay ⟨τn⟩ is of a pivotal importance within the standard model & cosmology.

Indeed, the precision on the neutron lifetime is of a paramount importance as it regulates the precision of the 1st element of the Cabibbo–Kobayashi–Maskawa matrix, central to the standard model. The two major methods used to measure ⟨τn⟩ while trapping free neutrons, namely, the beam and the bottle methods give different neutron lifetime values; ⟨τn⟩Beam ~ 888.0 ± 2.0 s , that obtained by the bottle technique is smaller; of about ⟨τn⟩Bottle ~ 879.4 ± 0.6 s. In addition of the persistent difference of ~10 s persists for years, even if the two methods have been modified to enhance the experimental accuracy. This latter was shown to be enhanced if one could trap cold neutrons in nanostructured Fabry-Perot resonators.

This contribution reports on the de Broglie wave-matter quantum duality coupled to the Fermi total reflection phenomenon in addition to the tunneling & trapping of cold neutrons in such nano-resonating cavities. This quantum mechanics trapping driven phenomenon allows trapping times of cold neutrons with a precision governed by the Heisenberg uncertainty of about 10-12 s [1].

1. M. Maaza, Journal of Neutron Research -1 (2023) 1–16 1 DOI 10.3233/JNR-220015

Nuclear Structure Studies / 114

Invited Talk: Establishing the deformation characteristics of ^{66}Ge

Author: Nikita Bernier[1]

[1] *University of the Western Cape*

Corresponding Author: nbernier@uwc.ac.za

The presence of both well-deformed prolate and oblate deformations is expected in the $A \approx 70$ mass region because of the surprisingly large single-particle energy gaps at $N = 34$. Nonetheless, oblate deformations in this region have mostly been inferred from rotational bands (^{68}Se [1]) or model-dependent decay measurements (^{72}Kr [2]). Only recently, Coulomb-excitation measurements have been able to determine the sign of the quadrupole moment in a few proton-rich nuclei in this region; conclusively prolate in ^{74,76}Kr [3] and slightly oblate in ^{70}Se [4,5], although with large uncertainties. As inferred for ^{68}Se, the $N = 34$ isotone ^{66}Ge is another candidate to possess a large oblate deformation in its ground state.

The measurement of the spectroscopic quadrupole moment for the first 2_1^+ excitation, $Q_s(2_1^+)$ and shape coexistence in the neutron-deficient isotope of ^{66}Ge have been investigated using the ^{196}Pt(^{66}Ge,^{66}Ge)^{196}Pt Coulomb-excitation reaction at 4.395 MeV/u with the MINIBALL spectrometer and double-sided silicon detectors. To accurately determine the beam purity, the beam was implanted on an aluminium foil and let to decay. Here, we present results from the analysis of the Coulomb-excitation and β-decay data sets, which suggest a strong oblate collectivity with a large \textsc{E2} strength and a potentially large oblate deformation. As found in previous work [3,6], the triaxial degree of freedom seems to be relevant, as also inferred in this work from beyond mean-field calculations where the collective wave functions go from soft in the ground state to a well-defined minimum as the angular momentum increases.

[1] S. M. Fischer *et al.*, Phys. Rev. Lett. **84**, 4064 (2000).

[2] J. A. Briz *et al.*, Phys. Rev. C **92**, 054326 (2015).

[3] E. Clément *et al.*, Phys. Rev. C **75**, 054313 (2007).

[4] J. Ljungvall *et al.*, Phys. Rev. Lett. **100**, 102502 (2008).

[5] A. M. Hurst *et al.*, Phys. Rev. Lett. **98**, 072501 (2007).

[6] A. Obertelli *et al.*, Phys. Rev. C **80**, 031304(R) (2009).

115

In-source Laser Spectroscopy Studies of Neutron-rich Thallium at IDS/ RILIS-ISOLDE

Author: Zixuan Yue[1]

[1] *University of York*

Corresponding Author: zixuan.yue@york.ac.uk

Zixuan Yue - University of York, on behalf of RILIS-IDS collaboration

Laser spectroscopy is one of the most powerful tools for studying ground and isomeric state nuclear properties. By observing small changes in atomic transitions, we can deduce the nuclear spin, electromagnetic moments, and changes in mean-square charge radii across long chains of isotopes. This allows us to study how the shapes and the configurations of the nuclei vary along the chain and hence to test our models that attempt to describe how nuclear structures evolve across the chart.

In this contribution, I will present the results from hyperfine structure and isotope shift studies of neutron-rich $^{207-209}$Tl performed at the ISOLDE Decay Station (IDS), combined with the application of the Laser Ion Source and Trap (LIST) to suppress the isobaric contamination typical to this mass region. Therefore, the changes in the mean-square charge radii and magnetic dipole moments were extracted. The results display a kink [1] in the mean-square charge radii along the Tl isotopic chain when crossing the N=126 shell closure, which is the same phenomenon observed from other elements around this region [2, 3, 4]. The magnetic dipole moments for $1/2^+$ thallium ground states have a large jump at N=126. Theoretical calculations including particle-vibrational coupling with the self-consistent theory of finite Fermi systems based on energy density functional are used to model the data [5].

[1]: P. Campbell, I. D. Moore, and M. R. Pearson, Prog. Part. Nucl. Phys. 86, 127 (2016).
[2]: M. Anselment, W. Faubel, S. Göring, A. Hanser, G. Meisel, H. Rebel, and G. Schatz, The odd-even staggering of the nuclear charge radii of Pb isotopes, Nucl. Phys. A451, 471 (1986).
[3]: A. E. Barzakh, D. V. Fedorov, V. S. Ivanov, P. L. Molkanov, F. V. Moroz, S. Y. Orlov, V. N. Panteleev, M. D. Seliverstov, and Y. M. Volkov, Shell effect in the mean square charge radii and magnetic moments of bismuth isotopes near N ¼ 126, Phys. Rev. C 97, 014322 (2018).
[4]: Day Goodacre, T. et al. Laser Spectroscopy of Neutron-Rich 207,208Hg Isotopes: Illuminating the Kink and Odd-Even Staggering in Charge Radii across the N=126 Shell Closure. Physical review letters 126 3 (2021): 032502.
[5]: Z. Yue, A.N. Andreyev, A.E. Barzakh et al. Magnetic moments of thallium isotopes in the vicinity of magic = 126, Physics Letters B 849 (2024) 138452.

Environmental Measurements / 116

Development of a mobile LaBr3:Ce detector unit for in situ radionuclide analysis at TENORM contamination sites

Author: Ferdie van Niekerk[1]

Co-authors: Pete Jones [2]; Stephan Woodborne [2]; Richard Newman [3]

[1] *Tshwane University of Technology*

[2] *iThemba LABS*

[3] *Stellenbosch University*

Corresponding Authors: vanniekerkf@tut.ac.za, pete@tlabs.ac.za, swoodborne@tlabs.ac.za, rtnewman@sun.ac.za

A mobile radiation detection unit (MRDU) featuring a 2"x2" LaBr3:Ce detector was developed for real-time radiation monitoring in terrestrial environments. The detector underwent calibration for energy, resolution, and efficiency using standard point sources at iThemba LABS and standard calibration pads at NECSA. Subsequent environmental measurements were conducted at two distinct sites: The Kruger National Park (KNP) and Welverdiend AH in the West Rand, Gauteng. An effluent spill from a tailing dam at the Bosveld Phosphate mining site near Phalaborwa in the Limpopo Province resulted in chemical contamination in aquatic ecosystems within the KNP. Despite the site's rehabilitation, no previous radiation contamination studies were conducted, considering uranium is a known by-product of phosphate mining. The West Rand, renowned for gold mining, also yields uranium as a by-product. The region, characterised by numerous tailings dumps, raises concerns about potential radionuclide contamination in nearby terrestrial environments. The MRDU was deployed to conduct measurements in both areas. Results indicated the complete rehabilitation of the KNP site, with uranium activities below the minimum detectable level. However, elevated uranium levels were observed at Welverdiend AH in the West Rand. In conjunction with gamma-ray measurements, soil samples from both sites underwent chemical analyses. The results demonstrated a strong correlation between radiation measurements and chemical analyses, affirming the successful rehabilitation of the KNP site and revealing higher uranium levels at the West Rand site. The study confirmed the MRDU as a practical and effective tool for measuring radiation in terrestrial environments, producing reliable real-time data and providing precise spatial mapping that identifies hotspot sites in the measured areas.

Nuclear Structure Studies / **117**

Invited Talk: Fine structure of the IVGDR in open-shell calcium isotopes

Author: Iyabo Usman[1]

Co-author: On Behalf of K600 Collaboration

[1] *University of the Witwatersrand*

Corresponding Author: iyabo.usman@wits.ac.za

This study aims to investigate fine structure of the isovector giant dipole resonance (IVGDR) in open-shell calcium isotopes and the effect of neutron excess in the sd-shell configurations. This will allow for disentangling the origin of damping mechanisms with considerations of different theoretical model calculations beyond Random Phase Approximation (RPA). The IVGDR was excited in 42,44Ca isotopes using proton-particle inelastic scattering measurements acquired with Ep = 200 MeV beam at zero-degree scattering angle. The K600 magnetic spectrometer at iThemba LABS was used to detect and momentum analyze the inelastically scattered proton particles. An experimental energy resolution of ~35 keV (FWHM) was attained, revealing fine structure in the excitation-energy region of the IVGDR. The isovector strength distributions in these nuclei studied were obtained with equivalent photo-absorption method by considering Eikonal approximations. The theoretical comparison is based on the Relativistic Quasiparticle Time Blocking Approximation (R(Q)TBA, Relativistic Quasiparticle Random Phase Approximation (R(Q)RPA, Quasiparticle Random-Phase Approximation (QRPA) and Phonon-Phonon Couplings (PPC). Experimental cross sections as well as theoretical strength functions for 42,44Ca isotopes were extracted and compared using wavelet analysis technique. The obtained power spectra and the characteristic energy scales were found to give good agreement with the results of PPC in both nuclei, where higher contributions including 3p-3h couplings were considered.

Environmental Measurements / **118**

PALLADIUM (Pd) DECORATED ZINC OXIDE (ZnO) NANOPARTICLES FOR GAS DETECTION: MEAT SPOILAGE GASES

Author: Khulekani Bantubonke Manqele[1]

Co-authors: Ceboliyazakha Ndlangamandla [2]; Sipho Mavundla ; Thokozani Mpanza [1]

[1] *University of Zululand*

[2] *UNIVERSITY OF ZULULAND*

Corresponding Authors: mavundlas@unizulu.ac.za, mpanzat@unizulu.ac.za, ndlangamandlac@unizulu.ac.za, bantubonke393@gmail.com

The detection of odours emitted by meat products when they start to spoil remains a challenge. In response to this, materials of ZnO decorated with palladium nanoparticle was synthesised using the hydrothermal method for the purpose of testing its gas sensing properties. After the synthesis of these nanoparticles, various characterization techniques for the investigation of both physical and chemical properties were employed. Different percentages of Palladium ranges of between 0.2% and 0.7% from a PdCl2 precursor with 99.9% purity were used during the synthesis. A gas sensor was fabricated through the drop casting method on a gold grid. These gas sensor samples were exposed to both reducing and oxidizing gases. Sensing was performed at a temperature from 25℃ to 225℃. The best result was obtained at 150℃ using 0.2%Pd-ZnO sensor when sensing NO2 gas. A sensitivity of 3.8 was recorded, with both response time and recovery time of being 3.5 minutes. The 0.5%Pd-ZnO sensor performs well at room temperature for CO2, SO2, and ethanol gases.

119

Indirect experimental methods for constraining the 193,194Ir(n,γ) cross sections

Authors: SEBENZILE PRETTY ENGELINAH MAGAGULA[1]; Mathis Wiedeking[2]; Ann-Cecilie Larsen[3]

[1] *IThemba Labs and University of the Witwatersrand*

[2] *iThemba LABS & Wits*

[3] *University of Oslo*

Corresponding Authors: a.c.larsen@fys.uio.no, mwiedeking@lbl.gov, 1113601@students.wits.ac.za

As far as nucleosynthesis or element formation is concerned, almost all the nuclei heavier than iron have been made in part by the slow neutron capture and the rapid neutron capture processes (≈ 50% each), respectively known as the s- and r- processes [1].
The neutron capture reactions 192Ir(n,γ)193Ir and 193Ir(n,γ)194Ir are indirectly studied by analysing data obtained from the Oslo Cyclotron Laboratory (OCL). These data will allow for the study of 193,194 Ir iso- topes, from the 192Os(α,tγ) and 192Os(α,dγ) reactions, respectively. The 193Ir(n,γ)194Ir cross sections which our measure will constrain- ment will provide a comparison to existing (n,γ) measurement data [2].
In addition, the 192Ir(n,γ)193Ir reaction maps a branching point in the s-process making it very interesting, but it is challenging to measure the (n,γ) cross section directly since 192 Ir is unstable. Therefore the OCL data may provide very valuable information on the 192Ir(n,γ)193Ir cross section by indirectly constraining it with the experimental nuclear level density (NLD) and γ-strength function (γSF).
An array of Sodium Iodine (NaI)Tl detectors, called CACTUS, detected γ-rays and the silicon particle telescope array, called SiRi, was used to detect charged particles in coincidence. The NLDs and γSFs are extracted below the neutron separation energy, Sn, using the Oslo Method [3]. Furthermore, the NLDs and γSFs will be used as inputs in the open-source code called TALYS to calculate cross-sections of 193,194 Ir. I will provide preliminary results of the measured NLDs and γSFs from the 192Os(α,dγ)194Ir reaction which will be used as inputs in the code TALYS to calculate cross-sections of 193,194Ir.

Nuclear Structure Studies / 120

Low-Energy Nuclear Physics Beamline at the iThemba LABS' Tandetron facility

Authors: Kgashane Malatji[1]; Mathis Wiedeking[2]; Philip Adsley[3]; Armand Bahini[4]; Jacob Bekker[5]; Sifundo Binda[6]; Lindsay Donaldson[7]; Shanyn-Dee Hart[8]; Pete Jones[1]; Bonginkosi Kheswa[9]; thuthukile khumalo[1]; SEBENZILE PRETTY ENGELINAH MAGAGULA[10]; Adivhaho Netshiya[11]; Retief Neveling[1]; Luna Pellegri[12]; Lesedi Jafta[13]; Sandile Jongile[1]

[1] *iThemba LABS*

[2] *Lawrence Berkeley National Laboratory*

[3] *Texas A&M University*

[4] *University of the Witwatersrand, Johannesburg*

[5] *University of the Witwatersrand*

[6] *iThemba LABS and Wits University*

[7] *iThemba Laboratory for Accelerator Based Sciences*

[8] *University of Cape Town*

[9] *University of Johannesburg*

[10] *IThemba Labs and University of the Witwatersrand*

[11] *iThemba LABS, WITS, WSU*

[12] *University of the Witwatersrand and iThemba LABS*

[13] *University of the Western Cape*

Corresponding Authors: padsley@tamu.edu, thuthukilekhumalo87@gmail.com, mwiedeking@lbl.gov, sifundobinda1@gmail.com, pete@tlabs.ac.za, neveling@tlabs.ac.za, 1390529@students.wits.ac.za, hrtsha014@myuct.ac.za, klmalatji@tlabs.ac.za, armand.bahini@wits.ac.za, lm.donaldson@ilabs.nrf.ac.za, luna.pellegri@wits.ac.za, vincentk@uj.ac.za, adivhaho.n@gmail.com, 1113601@students.wits.ac.za

The Low-energy Nuclear Astrophysics Beamline at the Tandetron facility, iThemba LABS, is designed to study indirectly radiative capture reactions through measurements of statistical properties. These reactions involve the capture of a charged particle, either a proton or an α-particle, by the nucleus, resulting in the emission of gamma-ray photons. This process plays a pivotal role in stellar nucleosynthesis, contributing to the formation of heavier elements in the universe [1].

Extracting the photon strength function from these measurements is crucial for not only calculating nucleosynthesis reaction rates but also for studying the underlying nuclear structure. The scarcity of such data underlines the challenges in obtaining experimental results and emphasises the need to measure proton or alpha capture rates [2].

In this presentation, I will introduce the newly built experimental setup, putting emphasis on its specifications and discuss as well preliminary results on (p, γ) and (α, γ) measurements.

[1] M. Arnould and S. Goriely, Phys. Rep. **384** (2003) 1–84.
[2] S. Goriely *et al.*, Eur. Phys. J A **55**, 172, 2019

This work is based on the research supported by the National Research Foundation of South Africa Grant Number 133636 and 118846.

Opening Session / **121**

Dose Modelling and Characterization of a 6 MV Linear Accelerator Photon Beam

Author: Nhlakanipho Mdziniso[1]

[1] *University of Eswatini*

Corresponding Author: nhlakaniphom77@gmail.com

Linear accelerator (LINAC) photon beams are widely used in radiation therapy. Understanding the characteristics of a LINAC photon beam is important to ensure accurate and effective treatment delivery. Photon beams interact with matter in dierent forms (i.e photoelectric eect, compton scatter and pair production) depending on the energy of the photon beam. All these interaction mechanisms cause ionization in matter which results biological damage and death of cancerous cells in the human body. In this study, a 6 MeV together with 3 and 18 MeV linear accelerator photon beams were modelled using the Monte Carlo N-Particle eXtended code (MCNPX). The photon flux was studied at dierent source to surface distances. The attenuation of photons with source to target distance was observed to obey the
inverse square law. A theoretical study was made on depth dose characteristics. Percent depth dose characteristics change with parameters as energy,field size and source to surface (target) distance. The choice of energy used in a linear accelerator depends on the intended use on the patient. A 6 MV is considered a low energy photon beam, thus used to treat many shallow target tumors.

Environmental Measurements / **122**

Environmental Impact of Industrailization on Natural Water Quality in Matsapha; Evaluated Using Water Quality Index

Author: Nhlakanipho Mdziniso[1]

[1] *University of Eswatini*

Corresponding Author: nhlakaniphom77@gmail.com

The growing industrial hub of Matsapha, Eswatini, presents a double-edged sword. While it fuels economic progress, concerns loom regarding its impact on the precious natural water resources. This study delves into the environmental consequences of industrialization on the water quality of Matsapha's rivers and streams. Utilizing the Water Quality Index (WQI) as a comprehensive assessment tool, we analyze the presence of various pollutants and their cumulative effect on the overall health of the water bodies. Our findings reveal concerning levels of contamination, particularly from [mention specific pollutants], leading to a decline in the WQI score. This raises significant concerns about the potential risks to aquatic life and human health dependent on these water sources. The study underscores the urgent need for stricter regulations, improved waste management practices, and continuous monitoring to safeguard the vital water resources of Matsapha and ensure sustainable development in the region.

Lectures on Nuclear Data / **124**

An introductory training on the Geant4 simulation toolkit

Author: Maluba Vernon J. Chisapi[1]

[1] *iThemba LABS/Stellenbosch University*

Corresponding Author: maluba@tlabs.ac.za

Geant4 is among the most widely used toolkit today in the simulation of the interaction of radiation with matter. It uses Monte Carlo methods and its areas of application includes high energy, nuclear and accelerator physics, as well as medical and space science. It heavily relies on objected oriented C++ programming language. Because of its complex nature, this platform can be a steep learning curve especially to users who may not be familiar with object oriented C++ programming. Since simulations are in some cases unavoidable in physics and related research projects, an introduction training in Geant4 usage is usually a good idea.

Given the inclusive nature of the Advanced Nuclear Science and Technology Techniques (ANSTT5) workshop, a training of this nature will benefit a lot of attendees as it will furnish them with basic skills on how to build an experimental setup of their choice (in the various fields of research), simulate, extract and analyze the data generated. This training is tailored to be hands-on, therefore will make part of the afternoon activities at this workshop.

In this training, we will use Geant4.11.2 which is conveniently installed on the Geant4 Virtual Machine developed and maintained by CENBG and CNRS, which can be downloaded here \url{https://geant4.lp2ib.in2p3.fr/} for free. Virtual Machines hosting various older versions of Geant4 are also available here \url{https://extra.lp2ib.in2p3.fr/G4/do
Attendees should download the Virtual Machine and install it on their computers according to the instructions given here \url{https://indico.cern.ch/event/1370034/page/32238-geant4-virtual-machine}.

125

Application of dispersion models of ESTE for modelling of the radiological impact of released Cs-137 in a specific urban environment

Author: Jozef Sabol[1]

[1] *Police Academy of the Czech Republic*

Corresponding Author: sabol@polac.cz

Abstract:
The paper presents some results of modelling dispersed radionuclide Cs-137 in a specific urban area in front of one of Prague's shopping centres and the nearby university complex. The software ESTE was used to assess the activity of spreading contaminated air in terms of parameters from which radiation exposure of people affected could be calculated. The computer simulation proved a reliable tool for obtaining relevant radiation protection quantities and their dependence on such parameters as the initial source activity, its position, wind direction, and wind velocity. An inevitable condition for appropriate dispersion modelling in urban conditions is the evaluation of urban wind fields for specific urban environments and atmospheric conditions. The urban wind field is calculated in ESTE by solving Navier-Stoke equations to approximate the K-epsilon turbulence model. Dispersion modelling in urban conditions is performed by the software ESTE, applying an assimilated Lagrangian particle urban model. The location, structure and relief of building configurations have been reflected in the simulation of the behaviour and movement of radioactive air. The modelling considers external exposures expressed in ambient dose equivalent and internal exposure leading to committed effective dose. Dispersion models of ESTE proved extremely useful in obtaining essential parameters to predict the impact of the dispersed radioactivity on persons present in the investigated compounds. These data could help introduce efficient protection measures for people present in such compounds where exposure also depends on the configuration of the building structure, which can be taken into account in adopting appropriate measures to minimise the exposure of persons located on the spot or moving around.
Keywords:
ESTE software, dispersion model, Cs-137 release, radiological impact, radiation protection.

126

The significance of quantities and units in conveying CBRN risk to the public: a big difference in assessing the risk of C and B agents in comparison to R and N components

Author: Jozef Sabol[1]

[1] *Police Academy of the Czech Republic*

Corresponding Author: sabol@polac.cz

Jozef Sabol, *David Dlouhý, Jan Nejedlý*
Police Academy of the Czech Republic, P.O. Box 54, 143 00 Prague 12, Czech Republic
*(*presenter, sabol@polac.cz)
Abstract:
It is crucial to communicate clearly and understandably the information on safeguarding against potential threats posed by CBRN (chemical, biological, radiological, and nuclear) agents to the general population. This approach is vital because practical cooperation between rescue teams and the public is essential. This principle extends to various emergencies, such as accidents or terrorist attacks, where a prompt response is necessary to mitigate panic or disorder that could undermine the effectiveness of protective measures. A deliberate assault utilizing even a minimal amount of CBRN material has the potential to induce significant, unwarranted fear among the public.
Responding to a CBRN attack poses an immense challenge for emergency services, quickly drawing significant public and media attention. Meeting the need for information while prioritizing public safety and efficiently managing the incident places substantial demands on rescue personnel. Typically, during the initial stages of a CBRN emergency, the police take the lead in reaction efforts. They are responsible for ensuring the public receives timely and accurate information, safeguarding them from potential harm. Rapid and effective delivery of information is crucial to saving the lives of those impacted or at risk.
The assessment of hazards arising from chemical and biological agents differs significantly from that of radiological and nuclear agents. While numerous quantities have been introduced to evaluate the risk of stochastic and deterministic effects for nuclear and radiological constituents, there is a comprehensive system for categorizing and quantifying the level of danger for chemical and

biological materials. Typically, noteworthy incidents involving the latter are confined to specific areas, but there is potential for contamination to spread over a wide area. Traditional communication planning heavily relies on mass media, mainly broadcast media. Despite its importance, individuals vulnerable to such incidents may not have access to television and radio broadcasts. Consequently, communication advisers must explore alternative channels, including social media and direct communication methods.
The paper aims to streamline approaches to disseminating information to the public to avert chaos, panic, and misconceptions during CBRN emergencies. The presentation incorporates insights from safeguarding against ionizing radiation from radiological and nuclear materials.

Keywords:
CBRN; quantities and units; risk assessment; CBRN components.

Nuclear Physics Measurements - Home and Away / **127**

Invited Talk: Gamma-ray and Conversion Electron spectroscopy at ISAC, TRIUMF

Authors: Abraham Avaa[1]; Adam Garnsworthy[1]

[1] *TRIUMF*

Corresponding Author: aavaa@triumf.ca

The atomic nucleus represents a quantum many-body system governed by strong interaction. Understanding how the strong force binds nucleons together within nuclei is fundamental to our comprehension of the universe's existence. Nuclear physics seeks to unravel the structure and dynamics of nuclei, aiming to shed light on these fundamental questions. At TRIUMF, we employ state-of-the-art infrastructure, including Compton-suppressed high-purity germanium clover detectors complemented by a suite of ancillary detectors for precise measurements of nuclear properties. This presentation offers an overview of our advanced instrumentation and highlights recently published results, tackling questions from the origin of chemical elements in stellar explosions to the nucleus's response to varying neutron-to-proton ratios, and the fundamental interactions of matter's basic constituents.

Neutron Physics and Science Communication / **128**

Keynote Address: Magnetized dense nuclear matter...far out there

Author: Jacobus Diener[1]

Co-author: Wazha German [1]

[1] *Botswana International University of Science and Technology*

Corresponding Authors: dienerj@biust.ac.bw, wazhagerman@gmail.com

A neutron star is one of the possible end states of a massive star. It is compressed by gravity and stabilized by the nuclear degeneracy pressure. Despite its name, the composition of these objects is not exactly known. However, from the inferred densities, neutrons will most likely compose a significant fraction of the star's interior. While all neutron stars are expected to have a magnetic field, some neutron stars ("magnetars") are much more highly magnetized than others: the inferred magnetar surface magnetic field is between 10^{14} to 10^{15} gauss.

While neutron stars are macroscopic objects, due to the extreme value of the stars' energy, pressure, and magnetic field the physics of the microscopic scale can be imprinted on the star's large scale

behaviour. Thus the study of these objects are a combination of various fields of physics ranging from Quantum Mechanics to General Relativity. One of the main inputs to any calculation of neutron star properties is the equation of state of the matter that comprises the interior of the star.

This talk will focus on describing the thermodynamics of magnetized dense neutron and neutron star matter, its equation of state and composition (including exotic nuclear matter), and how the equation of state is applied to study observational consequences in neutron stars.

The MeASURe Experience - Part 2 / 129

Measuring the Relative Biological Effectiveness of High Energy Neutrons in Space

Author: Elizabeth Fairall[1]

[1] *University of Cape Town*

Corresponding Author: frleli002@myuct.ac.za

The primary radiation environment in space consists of a complex mixture of charged particles with a broad range of energies originating from our Sun and from outside of our solar system. Neutrons with energies of up to several TeV are produced through the interactions of this primary cosmic radiation with matter, such as that in spacecraft shielding, and in the atmospheres and regoliths of moons and planets. Current radiation health risk models developed within the context of future space exploration involve considerable uncertainties surrounding our knowledge of the biological effects of neutron radiation at relevant energies, doses, dose-rates, biological systems and endpoints. In particular, there is a severe lack of experimental data for neutron energies above 20 MeV. The fast neutron beam facility at iThemba LABS is capable of producing quasi-monoenergetic neutron beams in the range of 30-200 MeV. We report on a project to assess the feasibility of, and implement the preparation required for utilising this facility for the undertaking of meaningful measurements of the neutron Relative Biological Effectiveness (RBE) under conditions relevant to space travel. Such measurements require reliable neutron beam metrology and detailed computational simulations of the experimental setup for both the neutron and reference irradiations, along with appropriate radiobiological analyses.

The MeASURe Experience - Part 2 / 130

New detectors for fast neutron spectrometry using plastic scintillator and silicon photomultipliers

Authors: Miles Kidson[1]; Andy Buffler[2]; Tanya Hutton[1]

[1] *University of Cape Town*

[2] *UCT*

Corresponding Authors: tanya.hutton@uct.ac.za, kdsmil001@myuct.ac.za, andy.buffler@uct.ac.za

Fast neutron fields, such as those present in aviation, space, and nuclear research environments, pose significant biological risk. New detectors are being developed for the purpose of monitoring these fields up to 20 MeV. The detectors are made from EJ-276 plastic scintillator in novel geometries coupled to one or more silicon photomultipliers, using digital pulse acquisition and processing. The detectors have been characterised in fast neutron fields at the UCT n-lab, IRSN AMANDE, and PTB PIAF facilities. Response functions were measured using both monenergetic beams and time-of-flight with broad energy beams. GEANT4 simulations have been verified using these measurements and were used to supplement those responses. The suitability of these devices for spectrometry has been demonstrated by unfolding analyses using those response functions to produce neutron energy spectra.

The MeASURe Experience - Part 1 / **131**

Non-destructive testing of concrete using fast neutron transmission spectroscopy

Author: Nalesi Segale[1]

Co-authors: Tanya Hutton [1]; Sizwe Mhlongo [1]; Andy Buffler [2]

[1] *University of Cape Town*

[2] *UCT*

Corresponding Authors: tanya.hutton@uct.ac.za, andy.buffler@uct.ac.za, sglnxx001@myuct.ac.za, sizwesmhlongo@gmail.com

The non-destructive testing of concrete used in nuclear facilities is critical as the concrete is exposed to various unfavourable conditions such as corrosion, radiation, extremely varying temperatures, and cyclic loadings over its lifetime. Such exposure can lead to concrete deterioration and moisture loss, thus compromising the shielding and structural integrity of the concrete [1, 2]. This concern is particularly relevant as the Koeberg nuclear power plant approaches the end of its planned operational lifespan, with Eskom seeking a 20-year extension overseen by the National Nuclear Regulator (NNR) [3].

Fast neutron transmission spectroscopy involves irradiating a sample with a well-characterized beam of neutrons and analysing the transmitted neutron spectrum to infer the elemental composition using a deconvolution technique [5]. In this study, we present an experimental and simulated validation of this technique using HDPE and graphite (C) to derive energy dependent removal cross sections for hydrogen. In parallel, Si, SiO2, and H2O were used to derive energy dependent removal cross sections for oxygen. Measurements were taken at the n-lab at UCT [6], using a collimated beam of neutrons produced by an americium-beryllium (AmBe) neutron source incident on samples of HDPE, C, Si, SiO2 and H2O. Neutron energy spectra transmitted through the samples were measured using an EJ-301 organic liquid scintillator coupled with spectrum unfolding methods, enabling determination of the energy-dependent effective removal cross section for each sample. To validate the use of simulated data where physical measurements may not be possible, these results were compared with removal cross sections obtained from simulations using FLUKA.

[1] Naus, D.J., The Management of Aging in Nuclear Power Plant Concrete Structures, Materials Issues in Nuclear Reactors, 61(7), pp. 35-40 (2009).
[2] Naus, D.J. et al., Nuclear power plant concrete structures – aging consideration, Challenges of Concrete Construction: Volume 6, Concrete for Extreme Conditions, pp. 747– 764 (2002).
[3] World Nuclear News, Review of Koeberg extension plans completed by IAEA Team (2022).
[4] Hutton, T., Buffler, A. and Alexander, M. Elemental analysis of concrete via fast neutron transmission and scattering spectrometry, EPJ Web Conf., 261, 03003 (2022).
[5] Hutton, T. and Buffler, A., Characterisation of neutron fields at the n-lab, a fast neutron facility at the University of Cape Town, Appl. Rad. Iso, 206:111196 (2024).

The MeASURe Experience - Part 1 / **132**

Towards the next generation of fast neutron detectors for high-energy neutron metrology.

Authors: Kutullo Maibane[1]; Andy Buffler[2]; Tanya Hutton[1]; Zina Ndabeni[1]

[1] *University of Cape Town*

[2] *UCT*

Corresponding Authors: kutullo.maibane@uct.ac.za, andy.buffler@uct.ac.za, zina.ndabeni@uct.ac.za, tanya.hutton@uct.ac.za

Organic liquid scintillator detectors such as those based on BC-501A are widely used by metrology laboratories as the reference for measurements of fast and high-energy neutron fields, however these scintillators are composed of highly toxic, flammable, and volatile aromatics. These detectors are coupled with a high-voltage photomultiplier tube, NIM standard pulse processing modules and an analogue ADC-based multi-parameter analyser (MPA), which are not suitable for use outside of a laboratory environment and will not be sustainable for decades to come. For these reasons, a modern detector system is under development based on new organic scintillator materials capable of pulse shape discrimination, such as the high-flash point and low-toxicity liquid EJ-309, and solid plastic EJ-276. The traditional photomultiplier tube and analogue pulse processing will be replaced with silicon photomultipliers, and digital pulse processing, improving portability and flexibility. This new system forms part of the redevelopment of the fast neutron facility at iThemba LABS into an ISO accredited reference facility for neutrons up to 200 MeV. Here we present preliminary characterisations of the EJ-309 and EJ-276 scintillators and digital data acquisition system in comparison to currently adopted technologies for high-energy neutron metrology.

Opening Session / **133**

Keynote Address: The Late-Pleistocene bulk sediment geochemistry of the Rusinga and Mfangano Islands beaches, Lake Victoria, Kenya

Author: Julian Ogondo[1]

Co-authors: Boniface Oindo [1]; Daniel Olago [2]; Erick Omondi [1]; Stephan Woodborne [3]

[1] *Maseno University*

[2] *University of Nairobi*

[3] *iThemba LABS*

Corresponding Authors: sm.woodborne@ilabs.nrf.ac.za, jaogondo@gmail.com, dolago@uonbi.ac.ke, rckomondi8@gmail.com, bonifaceoindo@gmail.com

Assessing the historical water quality of the Lake Victoria Basin during the Late Pleistocene-Holocene epochs holds paramount importance in deciphering forthcoming climate changes and is crucial for accurately interpreting basin dynamics. The prehistoric lacustrine deposits in the Lake Victoria basin are invaluable as they serve as a unique repository of sedimentary records spanning across time. Particularly, the lacustrine deposits on the north-eastern shores of Lake Victoria, situated on the Rusinga-Mfangano islands, offer an optimal setting for reconstructing palaeoenvironments. These sites, concentrated in Kenya and spanning from 42,000 ka to the present, provide an optimal vantage point for studying lacustrine sediments that capture the dynamics of the last lake level fluctuations. A multi-proxy analysis was undertaken to examine the bulk sediment geochemistry of 350 lacustrine samples collected from various beach levels 3-4m, 12-14m, and 18-20m above the current lake level, on the Rusinga-Mfangano Islands of Lake Victoria, Kenya. The elemental ion analyses unveiled distinct concentrations, revealing higher levels of calcium, strontium, and potassium, and lower levels of magnesium and sodium within the 3-4m beach levels of the Rusinga-Mfangano islands. Notably, specific beaches on the Rusinga-Mfangano islands, such as Mauta, Lwanda Rombo, Nyawalongo, Kitenyi, Kamayoge, Kakrigu, Ulugi, Wayando, Nyagina, and Kolunga, exhibited elevated levels of potassium, calcium, and strontium. Conversely, Uuria, Chiro, Wakondo, Mrongo, Kitawi, Sienga, Kiwari, Wanyama, and Wakondo beaches, generally recognized as highly populated fishing sites in the area, and displayed higher levels of sodium and magnesium ions. Over the course of time, lake ion input values for sodium, potassium, calcium, magnesium, and strontium showed an upward trend from 42,228 cal. yr BP to AD 1970. A peak in sediment influx occurred between AD 1447 and AD 1551, aligning with the onset of the Little Ice Age. Analysis of mineralogy, organic content, and elemental geochemical proxies suggested a regenerating lake with heightened nutrient and sediment delivery from the gulf over the preceding millennium.

Calibrated radiocarbon dating of beach materials, conducted at the iThemba Laboratory, revealed ages spanning from the Late-Pleistocene-Holocene period (cal yr BP 42,228 to AD 1970). This groundbreaking study provides the first chronologically sequenced data of deep and high lake level stands

on the Rusinga and Mfangano Islands, derived from Late-Pleistocene biostratigraphic data and fluctuations in former low-stand and high-stand beaches. The findings shed new light on the application of bulk sediment geochemistry as proxies for palaeowater quality from ancient lake shorelines and beaches. The reactions of these proxies to intense palaeoclimatic events, poorly understood over the last 50,000 years, are now more comprehensively explored. The bulk sediment geochemistry suggests that the palaeo-Lake Victoria featured extended shorelines shaped by rivers and streams from the Rusinga and Mfangano channels, accompanied by associated flood plains. Consequently, this study asserts that palaeowater quality, geochemical influences, and productivity patterns collectively exert a significant impact on the beaches of the Rusinga-Mfangano Islands in Lake Victoria, Kenya, rendering them valuable indicator sites for further research.
Key words: Late Pleistocene, Rusinga-Mfangano Islands, bulk sediment geochemistry, Lake Victoria -Kenya

Environmental Measurements / 134

Assessing the Influence of Excavation Practices on Background Radiation Levels: A Case Study of the A-Cap Uranium Mining Lease Area in Botswana

Author: SANKWASA CHIKA[1]

Co-authors: Pete Jones [2]; Simon Mullins [3]; Gregory Hillhouse [4]

[1] *Botswana International University of Science and Technology*

[2] *iThemba LABS*

[3] *Botswana International University of Science & Technology*

[4] *BIUST*

Corresponding Authors: mullinss@biust.ac.bw, cs23017804@studentmail.biust.ac.bw, pete@tlabs.ac.za, hillhouseg@biust.ac.bw

Mining exploration usually involves drilling and sometimes excavations to visually the core. The study assessed whether excavations at the A-Cap Uranium mine lease area had the potential to cause a rise in background levels within the mining site. The Inspector 1000 digital multichannel handheld survey meter and the Mobile Radiation Detection Unit - a LaBr3(Ce) detector in a backpack geometry, developed by iThemba LABS were both used to measure radiation levels at and around previously excavated sites. The absorbed dose rates varied widely, from 34.3 nGy/h to 1171.4 nGy/h, with an average of 194.5 nGy/h, which is higher than the global average of 59 nGy/y. The Annual Effective Dose Equivalent at previously excavated sites was 2.38 ± 0.36mSv/y, while surrounding areas averaged 0.49 ± 0.13 mSv/y. The cumulative lifetime cancer risk in these areas was estimated to be 0.0083 ± 0.0055 and 0.0017 ± 0.0005 respectively. Elevated radiation levels were observed at previously excavated sites. These findings suggest that the excavation activities may have led to the observed fivefold increase in radiation pollution at excavated sites compared to the surrounding areas. The findings suggest that more radiological assessment of soil samples is required to determine radionuclide identification and concentration of the soil, with the view to assess possibilities of causing internal exposures from surface runoff and other transport mechanisms.

Poster Presentations / 135

Systematics study of ground-state bands in rotating even-even nuclei to reveal triaxial deformation at ground state.

Author: Nkonzo Xulu[1]

[1] *Masters student in Nuclear physics*

Corresponding Author: nkonzo.xulu989@gmail.com

This projects intends to provide an empirical information on all even-even rotating nuclei, in order todetermine whether they are axially symmetric or triaxil. This is a new idea which the analysis is based entirely on expirimental data and is called coriolis analysis. The coriolis analysis is based on an analysis of the plots of the gamma ray energies(of transitions that belong to a rotational band) as a function of the angular momentum I of the nuclear states. it has no input of parameters. The information that is extracted is applicable for the band of interest, thus one can extract information on the shape analysing each band independently. Our physics motivation comes from what is believed at present that the ground state band in a triaxial nucleus is very similar to that of an axially symmetric nucleus. The presence of triaxility at present is always linked to the observation and the features of the gamma band. We say okay the coriolis analysis is sensitive even to the small difference in the features of the ground state band at different gamma deformations, thus it can reavel information on the nuclear triaxiality.

The MeASURe Experience - Part 1 / **136**

Controlled density tracers for Positron Emission Particle Tracking (PEPT)

Author: Michael van Heerden[1]

Co-authors: Andy Buffler [2]; Thomas Leadbeater [1]

[1] *University of Cape Town*

[2] *UCT*

Corresponding Authors: tom.leadbeater@uct.ac.za, michael.vanheerden@uct.ac.za, andy.buffler@uct.ac.za

Positron Emission particle tracking (PEPT) is a non-invasive nuclear imaging technique used to investigate the dynamics of opaque granular and multiphase flowing systems. The basis of PEPT is to attach a sufficient positron emitting isotope to a selected particle to act as a representative of the bulk material under study for a system of interest. The resultant gamma photon pairs produced by the electron-positron annihilation within the particle are used to trace the particle's flow path within millimeter precision at millisecond intervals or better.

Novel tracer particle production techniques have been developed at PEPT Cape Town implementing a 68Ge/68Ga generator for a positron supply along-side ion exchange resins which have been manipulated to selectively absorb 68Ga. Ion exchange resins are used to fabricate tracer particle analogues of the materials used in systems of interest. It is critical that the produced radiotracer behave the same as the bulk material of interest, motivating the need for techniques that finely control both the particle size and density of the tracer to match the materials under investigation.

Application specific tracer particles are produced over a density range typically between 1.00 and 2.85 g/cm3 with final particle diameters of 350 microns and larger. These particles are representative of a range of industrially relevant materials including silica, metal ore and ceramics. We report on standardised methods for creating density-modified tracer particles to expand the range of applications feasible to research with the PEPT technique.

Nuclear Structure Studies / **137**

Understanding the Giant Dipole Resonance in Heavy Deformed Nuclei

Authors: Lindsay Donaldson[1]; Atsushi Tamii[2]; Philip Adsley[3]

[1] *iThemba Laboratory for Accelerator Based Sciences*

[2] *Research Center for Nuclear Physics, Osaka University*

[3] *Texas A&M University*

Corresponding Authors: tamii@rcnp.osaka-u.ac.jp, padsley@tamu.edu, lm.donaldson@ilabs.nrf.ac.za

The IsoVector Giant Dipole Resonance (IVGDR) has far-reaching implications in nuclear physics. Experimental GDR data have been obtained using various techniques including photo-nuclear measurements with photons from Bremsstrahlung and quasi-monoenergetic photons from positron annihilation in flight and Laser Compton Scattering, but also using proton inelastic scattering. While good agreement of (p,p′) data with (ɣ,abs) has been seen for the closed-shell nuclei 120Sn and 208Pb, unexpected differences are seen for deformed nuclei. A study on selected Nd and Sm isotopes using the K600 magnetic spectrometer at iThemba LABS found significant differences with respect to the distribution of the IVGDR strength between the extracted photo-absorption data from iThemba LABS and pre-existing (ɣ,xn) data from Saclay. Furthermore, discrepancies exist for several nuclei between photo-absorption data taken at the Saclay and Livermore laboratories. It is important for these discrepancies, as well as the IVGDR in heavy deformed nuclei in general, to be understood. To this end, a wide-ranging study of various aspects of the IVGDR will be discussed, which will include an investigation into the above-mentioned discrepancies, working as part of a larger collaboration to attempt to construct calibration standards, and investigating the effects of triaxiality and shape coexistence.

Nuclear Physics Measurements - Home and Away / 138

The spectroscopy of the low- and medium excited spin states in Samarium-148 nucleus

Author: Mfundo Zuma[1]

[1] *none*

Corresponding Author: mf04ndo@gmail.com

The low- and intermediate spin states in the ^{148}Sm nucleus have been populated using the ^{148}Nd(^{4}He, 4n)^{148}Sm fusion reaction at the iThemba Laboratory for Accelerator Based Sciences (LABS) using the AFRODITE γ-ray spectrometer comprising of 9 high-purity germanium detectors (HPGe), with detectors mounted at an angle of 90° and 4 at 135° with respect to the beam direction. The current study confirms the alternating parity structures that have been observed and reported by previous authors. weakly populated states have not been confirmed and have not been included in the deduced decay scheme. The data analysis has been done on the basis of the rad-ware γ-γ coincident data analysis technique. From the present data analysis, the level scheme has been added with approximately 15 new γ-ray transitions, and a few adjustments have been made on both low and intermediate spin states. The previously reported γ-band heads have also been further investigated, and the present analysis partially agrees with some of the proposed γ band heads; however, no new structures have been observed on top of the γ- band head. This work has further conducted a systematic comparison of the even-even isotones in the N = 86 region to further confirm the behavior of transitional nuclei. This study has observed that the ^{148}Sm and its neighboring isotones exhibit the characteristics of spherical and vibrating nuclei; such behavior gives rise to mixed nuclear excitation. An improved γ-ray spectrometer with augmented low- and high-photon detectors would provide more information about the γ- bands observed in ^{148}Sm nucleus.

Physics at iThemba LABS / 139

High-resolution 50Cr(p,t)48Cr coincidence measurements using the K600 and CAKE setup at iThemba LABS

Author: Sifundo Binda[1]

Co-authors: Philip Adsley [2]; Lindsay Donaldson [3]; Luna Pellegri [1]; and collaborators.

[1] *University of the Witwatersrand and iThemba LABS*

[2] *Department of Physics and Astronomy, and Cyclotron Institute, Texas A&M University,*

[3] *iThemba Laboratory for Accelerator Based Sciences*

Corresponding Authors: padsley@tamu.edu, luna.pellegri@wits.ac.za, lm.donaldson@ilabs.nrf.ac.za, sifundobinda1@gmail.com

The observation of γ-ray decays from the radioactive isotope ^{44}Ti makes it one of the significant isotopes in the diagnosis of core-collapse supernovae (CCSNe) explosions. The abundance of 44Ti from CCSNe explosions has been shown to be strongly dependent on the ^{44}Ti$(\alpha, p)^{47}$V reaction rate, which destroys ^{44}Ti. Direct measurements of the ^{44}Ti(α, p) 47V reaction within the Gamow window ($E_{c.m.}$ = 2 - 6 MeV) have been challenging due to the low cross sections and insufficient radioactive ion beam intensities. As a result, the reaction rate is still based on statistical models, which may not be reliable for α-induced reactions on N=Z nuclei due to the lower effective level density in the compound nucleus. To get the necessary experimental constraints of the ^{44}Ti$(\alpha, p)^{47}$V reaction such as the level density and branching ratios of the compound nucleus, ^{48}Cr, a high-resolution 0° ^{50}Cr$(p, t)^{48}$Cr coincidence measurement was performed using the K600 magnetic spectrometer and an array of five double-sided silicon detectors called CAKE. Preliminary results from the coincidence measurements will be presented.

Poster Presentations / 140

Extraction of Giant Monopole Resonance strength with Mulitipole Decomposition Analysis

Authors: Lesedi Jafta[1]; Retief Neveling[2]; Lindsay Donaldson[3]; Smarajit Triambak[4]; Armand Bahini[5]; Johann Wiggert Brummer[2]; Harshna Jivan[6]; Pete Jones[2]; Sandile Jongile[2]; Kevin Li[7]; Luna Pellegri[8]; Ricky Smit[2]; Deon Steyn[2]; Iyabo Usman[6]

[1] *University of the Western Cape*

[2] *iThemba LABS*

[3] *iThemba Laboratory for Accelerator Based Sciences*

[4] *University of Western Cape*

[5] *University of the Witwatersrand, Johannesburg*

[6] *University of the Witwatersrand*

[7] *Stellenbosch Postgraduate Student*

[8] *University of the Witwatersrand and iThemba LABS*

Corresponding Authors: jwbrummer@tlabs.ac.za, smit@tlabs.ac.za, 16252314@sun.ac.za, luna.pellegri@wits.ac.za, iyabo.usman@wits.ac.za, harshna.jivan@gmail.com, lm.donaldson@ilabs.nrf.ac.za, deon@tlabs.ac.za, neveling@tlabs.ac.za, smarajit@gmail.com, pete@tlabs.ac.za, armand.bahini@wits.ac.za

Inelastic scattering of alpha particles at ≥ 200 MeV, especially at very forward angles including 0◦, stands out as a robust technique for probing the strength distribution of the isoscalar giant monopole resonance (ISGMR) in atomic nuclei. Due to contradicting results concerning the isotopic trend of the nuclear incompressibility within the calcium isotopic chain, a dedicated study of the ISGMR in 40,42,44,48Ca was undertaken at iThemba LABS. From measurements at 0◦ and 4◦, an energy-dependent version of the difference-of-spectra (DoS) method was initially utilized. Although this method offers high energy resolution, it is dependent on the strength contributions of all L ≥ 0 multipolarity components published in literature, and this negatively impacts the independence of our results. To address this concern, we will employ a method called Multipole Decomposition Analysis (MDA) to extract E 0 strength distributions. While the limited angular range means that the MDA procedure may not yield precise strengths for higher multipolarities, it does enable the accurate extraction of the E0 component independently of other studies. Preliminary results of 40,42,44,48Ca will be presented.

This research work is supported by the National Research Foundation (ref no: PMDS22062727817).

Nuclear Safety, Security and Applications / 141

Keynote Address: The Status of Nuclear Technology Applications, Safety and Security in Tanzania

Author: Innocent Jimmy Lugendo[1]

[1] *University of Dar es Salaam*

Corresponding Author: ilugendo26@gmail.com

Nuclear technology presents both opportunities and challenges for countries seeking to meet their growing energy demands and advance scientific research. While nuclear technology offers the potential for clean, reliable, and sustainable power generation and advancements in various sectors, its deployment necessitates a robust framework for safety and security to mitigate potential risks. In Tanzania, nuclear technology is widely applied in medical, agricultural and industrial activities. Due to a rapidly expanding economy, the country aims to harness nuclear energy for electricity generation. Yet, successfully implementing nuclear technology in Tanzania requires a multi-faceted approach that integrates nuclear safety and security considerations. This entails robust design and engineering practices incorporating safety features and security measures. Equivalently, comprehensive training programs for personnel, encompassing safety and security awareness are key for developing a skilled workforce capable of safely operating and securing nuclear facilities. Furthermore, engaging in international cooperation plays a great role in fostering a safety and security culture in the country. Therefore, as the nation explores the potential of nuclear technology, it must prioritize nuclear safety and security culture amongst its people. This work highlights the applications of nuclear technology in Tanzania as well as the status of safety and security aspects of the technology.

The MeASURe Experience - Part 1 / 142

Measurement of total cross sections for fast neutron-induced fission of U-238 in the energy range 35 to 100 MeV

Authors: Dieter Geduld[1]; Andy Buffler[None]

[1] *University of Cape Town*

Corresponding Author: dieter.geduld@uct.ac.za

There has been a high level of interest across the world in the use of well-characterized neutron beams of energy 10-200 MeV for investigating physical problems connected with radiation therapy, radiation protection and intermediate-energy nuclear physics and neutron cross section measurements that span a wide range of applications. Experiments in these fields often require that the neutron fluence at the energy of interest be measured accurately. Techniques for the measurement of neutron fluence at neutron energies below about 20 MeV are relatively well established and documented. The situation is less favourable at neutron energies above about 20 MeV for several reasons, including the lack of suitable cross section standards. These have large uncertainties and the data above 30 MeV are scarce.
This work evaluates cross section standards for fast neutron-induced fission of 238U in the energy range from thermal to 200 MeV.
We have measured cross-sections at five energies between 35 MeV and 100 MeV at IThemba LABS and present preliminary results.

Nuclear Safety, Security and Applications / 143

Characterization and Performance Evaluation of SiPM-Based Gamma and Neutron Detectors for Nuclear Science Applications

Authors: Shanyn-Dee Hart[1]; Pete Jones[2]; Luna Pellegri[3]; Steve Peterson[4]

[1] *University of Cape Town and iThemba LABS*

[2] *iThemba LABS*

[3] *University of the Witwatersrand and iThemba LABS*

[4] *University of Cape Town*

Corresponding Authors: steve.peterson@uct.ac.za, luna.pellegri@wits.ac.za, hrtsha014@myuct.ac.za, pete@tlabs.ac.za

The Portable African Neutron-Gamma Laboratory for Innovative Nuclear Science project has seen the characterization of a number of new detectors using reference radioactive gamma and neutron sources. These detectors will be used for two primary projects, namely as an upgrade to the existing mobile gamma-ray and neutron detection unit and as a two-stage Compton camera prototype for a position-sensitive detection of prompt gamma rays from proton-induced nuclear reactions.

Two compact 14x14x25.4 mm $LaBr_3$(Ce) SiPM-coupled scintillation detector assemblies were investigated and benchmarked against conventional 1"x1" $LaBr_3$(Ce) photomultiplier tube detectors where they have demonstrated excellent energy resolution ($\approx$ 3% at 662 keV). Further, two epasolite Cs_2LiYCl_6 (CLYC) SiPM-coupled detector assemblies have been commissioned to maximise on their neutron detection capability using pulse shape discrimination to distinguish between neutron and gamma events for in situ neutron dose measurements.

The feasibility of building a position sensitive two-stage Compton camera using the fast-timing $LaBr_3$(Ce) crystal is investigated in terms of energy resolution, efficiency and optimum geometrical configuration to maximise on the strengths of the cutting edge SiPM technology.

Physics at iThemba LABS / 144

Keynote Address: Does Accelerator Mass Spectrometry (still) have a place in an emerging economy?

Author: Stephan Woodborne[None]

Corresponding Author: sm.woodborne@ilabs.nrf.ac.za

South Africa's science infrastructure, human capacity and budget spend must impact on wellbeing in the country. Extremely expensive science platforms, such as the Accelerator Mass Spectrometry (AMS) facility at iThemba LABS, provide a bottom-up facility for research with local benefits. In meeting the institutional mandate, the AMS facility operates in a partnership with the user base both in the provision of know-how to run analyses on science agendas set by the users, and in leading in-house research that accommodates academic partners and post-graduate student training. The AMS facility is the only one of its kind on the African continent, but despite a patent demand for an African AMS facility to serve the traditional heritage market, this can only be realised with investments in and personnel and infrastructure renewal dependent on top-down structures. AMS needs to be justified by the bottom-up contributions, but societal benefits of AMS seldom manifest in the particle physics domain. Instead, it is found in applied disciplines that make use of the systematics of rare element production, decay and distribution among different reservoirs. These include testing climate change forecasts, dating groundwater recharge, assessing global phenomenon such as magnetic field fluctuations over the last 50 000 years, and assessing the mechanisms of coastal erosion. The essence of the AMS program is to use particle physics for the benefit of the people of South Africa, and Africa, and this depends on attracting innovative young scientists into the field and supporting them within the iThemba LABS mandate.

Opening Session / 145

Invited Talk: Towards the Paarl Africa Underground Laboratory (PAUL)

Author: Richard Newman[1]

[1] *Stellenbosch University*

Corresponding Author: rtnewman@sun.ac.za

We present a rationale, including science case for the PAUL and discuss the opportunity to establish the PAUL in the Huguenot Tunnel in the Du Toitskloof Mountains, between Paarl and Worcester, Western Cape, South Africa. The PAUL concept design, proposed science programme, engineering design guidelines and timelines are presented.

The MeASURe Experience - Part 2 / 146

Measurement and simulation of secondary neutron production from a 66 MeV proton beam

Author: Josiah De Klerk[1]

Co-authors: Andy Buffler [2]; Steve Peterson [3]; Tanya Hutton [3]

[1] *University of Cape Town Physics department*

[2] *UCT*

[3] *University of Cape Town*

Corresponding Authors: tanya.hutton@uct.ac.za, andy.buffler@uct.ac.za, josiahchristiandeklerk@gmail.com, steve.peterson@uct.ac.za

Prompt gamma rays (PGs) produced by nuclear collisions during proton therapy (PT) can be used for *in vivo* proton beam range verification through a technique known as prompt gamma imaging (PGI). During PT, the production of PGs within the tissue provides a reliable location map for the proton dose deposition. The detection of these PGs using a Compton Camera (CC) can be used to construct a source image of the PGs. Since the reconstructed source image is dependent on the quality of the detection, the detection efficiency of a CC device can be negatively affected by additional secondary radiation (particularly neutrons) produced alongside the prompt gamma rays. The goal of this work is to understand the characteristics of these secondary neutrons during a proton beam irradiation and their potential impact on a CC.

The experimental setup consisted of a 66 MeV pencil beam of protons on a variety of targets (HDPE, water, graphite) with the neutron measurements made using an organic liquid scintillator detector (BC-501A) at several angles within the K600 vault (S-line) at iThemba LABS. To obtain neutron energy spectra with the BC-501A an unfolding procedure is typically used, where energy spectra are deconvolved from the measured, and calibrated, neutron light output spectra. As the quality of the unfolding is dependent on the prior knowledge of the energy spectrum, a Geant4 simulation was constructed to better understand the produced neutron field and aid the unfolding process. A comparison of the experimental and simulated results will be discussed.

The MeASURe Experience - Part 1 / 147

A multimodal radiation-based technique for characterisation of materials in bulk at the n-lab, at the University of Cape Town

Authors: Sizwe Mhlongo[1]; Andy Buffler[2]; Tanya Hutton[1]; Zina Ndabeni[1]

[1] *University of Cape Town*

[2] *UCT*

Corresponding Authors: sizwesmhlongo@gmail.com, tanya.hutton@uct.ac.za, andy.buffler@uct.ac.za, zina.ndabeni@uct.ac.za

Developing methods to non-destructively determine the elemental composition of bulk materials is important in a broad range of contexts, including food and agriculture, coal and minerals processing, contraband detection, and nuclear regulation [1,2]. Neutron-based techniques are advantageous as neutrons are highly penetrating, sensitive to low mass nuclei and produce characteristic secondary radiation for each nuclide. When a sample of unknown composition is exposed to a field of neutrons, with known intensity, energy and angular distribution, an array of radiation signatures which are characteristic of the sample composition is produced. These signatures may be in the form of prompt and delayed gamma rays, and scattered and transmitted neutrons [3,4]. Well established techniques exist to utilise each of these signatures in isolation as a means of materials analysis, and each technique will be more, or less sensitive to a different subset of elements. The combination of multiple neutron-based techniques are being explored in this work, namely fast neutron transmission analysis (FNTA) and prompt gamma-ray neutron activation analysis (PGNAA) at the fast neutron facility (n-lab) within the Metrological and Applied Sciences University Research Unit (MeASURe) in the Department of Physics at the University of Cape Town. The FNTA and PGNAA techniques exploit transmitted neutrons and de-excitation gamma rays, respectively, as elemental signatures, and ideally require fast neutrons. In this work, the FNTA and PGNAA techniques are being explored with the aim of developing a multimodal technique capable of elemental characterisation of materials in bulk using neutrons and gamma rays at the n-lab.

The n-lab [5] houses a well-characterised accelerator-based neutron source, a Thermo MP-320 deuterium-The n-lab [5] houses a well-characterised accelerator-based neutron source, a Thermo MP-320 deuterium-tritium (DT)-based sealed neutron tube generator (STNG) capable of producing 14.1 MeV neutrons at rates of up to 1 x 10^8 neutrons s^{-1} into 4⊠ steradians when operated at optimum settings. Standard samples (single and multi-elemental) have been analysed using FNTA and PGNAA techniques. The transmitted neutron energy spectra were measured utilising a 2′′ x 2′′ EJ-301 organic liquid scintillation detector while de-excitation gamma-ray energy spectra were measured utilising a pair of 3′′ x 3′′ NaI detectors. The elemental signature extracted from the FNTA measurements was the removal cross section, and for PGNAA the background subtracted gamma ray spectra normalised to density. A library of elemental responses in a form of removal cross sections and prompt gamma rays has been constructed and has been used to deconvolve mass ratios of elements [6] using an unfolding analysis software (MAXED) based on the maximum entropy principle [7]. We present in this work experimental and simulated results from the analysis of eight elements of interest, namely hydrogen, carbon, nitrogen, oxygen, aluminium, silicon, sulphur and iron, and the unfolding of elemental composition for simpler cases of multi-elemental samples.

References

[1] F. Rouessac & A. Rouessac, Chemical Analysis: Modern Instrumentation Methods and Techniques, John Wiley and Sons (2007).

[2] V. Guinn, et al., IAEA Technical Report Series No. 197 (1980).

[3] Z. Alfassi, Activation Analysis Vol.1, CRC Press (1990).

[4] F.D. Brooks, et al., Nuclear Instruments and Methods in Physics Research A 410, 319-328 (1998).

[5] T. Hutton & A. Buffler, Proceedings of SAIP2017, SA Institute of Physics (2018).

[6] T. Hutton, et al., EPJ Web of Conferences 261, 03003 (2022).

[7] M. Reginatto, P. Goldhagen, and S. Neumann, Nucl. Instr. Meth. A476 (2002) 242

Physics at iThemba LABS / 148

Invited Talk: The PANDORA project

Author: Luna Pellegri[1]

Co-author: PANDORA Collaboration

[1] *University of the Witwatersrand and iThemba LABS*

Corresponding Author: luna.pellegri@wits.ac.za

The electric-dipole (E1) strength plays a crucial role in understanding photoabsorption reactions, offering insights into nuclear structure, excitations, and responses to external fields. While extensively studied in heavy nuclei (A > 90), lighter nuclei (A < 60) present unique challenges due to factors like clustering effects, deformation, and nucleon pairing. These complexities hinder theoretical interpretations, impacting predictions and, notably, the understanding of ultra-high-energy cosmic rays (UHECRs). The PANDORA project aims to systematically measure photoabsorption cross sections and branching ratios for light elements (A<60), crucial for refining theoretical models used in UHECR propagation studies. This talk provides an overview of the PANDORA project and presents preliminary data from the first experiment performed in October 2023 at RCNP (Japan).

Nuclear Safety, Security and Applications / 149

Monte Carlo simulation of the Co-60 teletherapy unit at iThemba LABS

Author: Tarryn Bailey[1]

[1] *Student*

Corresponding Author: tarrynb8@gmail.com

TOPAS, a Monte Carlo tool that wraps Geant4, is used to simulate the cobalt-60 teletherapy unit at iThemba LABS to decrease the experimental uncertainty of the radiation dosimetry for the gamma irradiation experiments conducted in the radiation biophysics division.
The Theratron teletherapy machine utilizes a cobalt-60 source emitting gamma rays with energies of 1.173 and 1.332 MeV. The detailed treatment head simulation includes the source and source housing, the primary and secondary collimators, jaws, and phase space sources. Phase space sources are used to decrease computational time in TOPAS.
The dose to cells exposed is calculated per number of source particles and is validated by plotting percentage depth dose curves within a water phantom. The dose to voxels in the phantom is calculated along the central beam axis for various SSDs and field sizes. These curves are then compared to those obtained in comparable studies and relevant protocols.

Physics at iThemba LABS / 150

Integrating the MAGNEX Focal Plane Detector with the K600 Spectrometer at iThemba LABS for various nuclear structure studies.

Authors: Thuthukile Khumalo[1]; Luna Pellegri[2]; Retief Neveling[1]; Lindsay Donaldson[3]; Francesco Cappuzzello[4]; Manuela Cavallaro[5]; Clementina Agodi[6]; Armand Bahini[7]; Johann Wiggert Brummer[1]; Jacob Bekker[8]; Sifundo Binda[9]; Alessandro Spatafora[10]; Diana Carbone[10]; Refilwe Emil Molaeng[2]; Sandile Jongile[1]; Onoufrios Sgouros[10]

[1] *iThemba LABS*

[2] *University of the Witwatersrand and iThemba LABS*

[3] *iThemba Laboratory for Accelerator Based Sciences*

[4] *University of Catania and INFN-LNS, Italy*

[5] *INFN - LNS*

[6] *INFN.LNS*

[7] *University of the Witwatersrand, Johannesburg*

[8] *University of the Witwatersrand*

[9] *iThemba LABS and Wits University*

[10] *INFN-LNS*

Corresponding Authors: agodi@lns.infn.it, refilwemolaeng@gmail.com, 1390529@students.wits.ac.za, jwbrummer@tlabs.ac.za, carboned@lns.infn.it, armand.bahini@wits.ac.za, cappuzzello@lns.infn.it, neveling@tlabs.ac.za, manuela.cavallaro@lns.infn.it, lunapellegri@tlabs.ac.za, sifundobinda1@gmail.com, thuthukilekhumalo87@gmail.com, lm.donaldson@ilabs.nrf.ac.za, onoufrios.sgouros@lns.infn.it, alessandro.spatafora@lns.infn.it

The endeavor to expand the research capabilities of the high-resolution K600 magnetic spectrometer at iThemba LABS has been in progress for a number of years. The primary objective is to develop a novel focal-plane detector capable of detecting light ions at energies below ~30 MeV/u and heavier elements like 12C. Extensive efforts have been dedicated to the development of this envisioned detection system, and the initiation of the NUMEN project at iThemba LABS in 2019 facilitated the evaluation of utilizing the K600 with a low-pressure focal plane detector. The primary goal of the NUMEN project at iThemba LABS was to carry out double-charge exchange experiments with heavy ions (which are currently beyond our detection capability).

The project entails the integration of the MAGNEX FPD with the K600 spectrometer to enable studies on nuclear structure and reactions using heavy-ion beams and low-energy light-ion beams, thereby broadening research opportunities that were previously constrained by the characteristics of the K600-FPD system. The project involves initial testing of the MAGNEX FPD in an independent setup, followed by its integration with the K600 medium dispersion focal plane, leading to a phase of commissioning with low-energy beams and radioactive sources to assess particle identification, energy and angle resolution, and detection efficiency. Plans include the utilization of the African LaBr3:Ce array (ALBA) for particle-gamma coincidence measurements. Apart from the NUMEN project, other experiments are on the horizon with the new setup, such as the investigation of the pygmy dipole response through single-neutron transfer reactions.

In this talk, an overview of the status of both projects will be given together with an example of a study that can be conducted with this state-of-the-art setup.

The MeASURe Experience - Part 1 / 151

Digital signal processing for improved signal/noise in PET imaging.

Authors: Alice McKnight[1]; Thomas Leadbeater[1]

[1] *University of Cape Town*

Corresponding Authors: tom.leadbeater@uct.ac.za, mckali012@myuct.ac.za

Conventional positron emission tomography (PET) scanners use a front-end analogue acquisition pipeline to determine position, energy, and time of arrival for each event. The pipeline operates in real time with processing and event selection occurring at MHz rates. Although this linear approach scales well to large arrays of detectors operating in parallel, much of the available information is discarded prior to readout and the short duration for signal processing limits possibilities of algorithmic or iterative approaches to event reconstruction.

Using a digital based (listmode) data acquisition system enables increased flexibility in event processing and reconstruction. We demonstrate the use of digital data acquisition applied to different

generations of block detectors used for PET, which typically consist of a segmented scintillator crystal viewed by four photomultiplier tubes. Event parameters (position, energy, time) are resolved in the digital space and advanced processing techniques are explored. These approaches lead towards developing methods to discriminate against signal and noise events occurring within a single detector block based on their signal characteristics. To this end, an in-depth analysis of event positioning within the crystal has been employed.

Nuclear Physics Applications and Projects / 152

The Application of Convolutional Neural Networks (CNN) in the Detection and Segmentation of Brain Tumors in medical imaging

Author: Samafou Penabei[None]

Corresponding Author: pensbenj@gmail.com

Computed Tomography (SPECT), Positron Emission Tomography (PET) and Computed Tomography (CT) plays a crucial role in the non-invasive detection of brain tumors, offering detailed images that are essential for effective treatment planning. However, the interpretation of these images is traditionally time-intensive and requires significant expertise. This presentation introduces how CNNs, a subset of deep learning algorithms adept at analyzing visual data, are being leveraged to automate the detection and segmentation of brain tumors, presenting a significant advancement in diagnostic methodologies. The presentation delves into the architecture of CNNs, including their convolutional, pooling, and fully connected layers, and elucidates how these networks extract and learn from the complex patterns in medical imaging data to distinguish between healthy tissue and tumorous areas. Highlighting recent studies and advancements, the seminar demonstrates CNNs' capability to significantly improve diagnostic accuracy and speed, thereby enhancing patient outcomes. Additionally, the presentation addresses the challenges faced in applying CNNs to medical imaging, such as data limitations and computational demands, and discusses strategies like data augmentation and transfer learning to overcome these hurdles. By examining optimization techniques and the critical role of image processing methods, the presentation illustrates the ongoing progress and potential of CNNs in transforming neuro-oncology and radiology into more automated and patient-focused fields.

Mixed Topics 6 / 153

Invited Talk: Benefits of Membership and Volunteering in IEEE

Author: Udochukwu Akuru[1]

[1] *IEEE*

Corresponding Author: udochukwu.akuru@ieee.org

IEEE, the world's largest technical professional organization, offers numerous benefits to its members and encourages active participation through volunteering. With a vast global network of over 460,000 members across 190 countries, IEEE facilitates international collaboration, knowledge exchange, and continuous learning. Through conferences, a comprehensive digital library, and prestigious awards, IEEE empowers professionals to advance their careers. Its 39 technical societies, local chapters, student branches, and affinity groups provide opportunities for networking and specialized engagement. IEEE's standards work drives innovation, and its initiatives promote STEM education, humanitarian causes, and information accessibility. This talk highlights the advantages of membership and volunteering in IEEE, emphasizing how active participation can empower professionals to make a positive impact within and outside their networks.

The MeASURe Experience - Part 1 / 154

A new time interpolation algorithm to increase location rates of positron emission particle tracking measurements

Authors: Rayhaan Perin[1]; Steve Peterson[1]; Katie Cole[None]; Michael van Heerden[1]; Jonathan Shock[None]; Diego Mesa[None]; Pablo Brito-Parada[None]

[1] *University of Cape Town*

Corresponding Authors: michael.vanheerden@uct.ac.za, steve.peterson@uct.ac.za, rayhaanperin1@gmail.com

Positron emission particle tracking (PEPT) is used to track the motion of tracer particles in the mineral separation process of froth flotation. Previous measurements with PEPT were performed at a target location rate of 1.0 kHz due to the 1.0 ms precision of the timestamp recorded by the Siemens ECAT "EXACT3D" HR++ positron emission tomography (PET) scanner at the PEPT Cape Town facility in South Africa. Tracking at the 1.0 kHz location rate reduces the detail in the high frequency component of the Lagrangian path. This work introduces a new time interpolation algorithm that increases the location rate of PEPT measurements with the HR++ to 5.0 - 10.0 kHz. The algorithm also decreases the uncertainty in the time of the line-of-response (LOR) and the uncertainty in the reconstructed path, when comparing the simulation input path to the tracked output path.

The MeASURe Experience - Part 2 / 155

Towards design of beam delivery systems for the proposed Proton Therapy Centre in Cape Town

Authors: Moses Gororo[1]; Andy Buffler[2]; Steve Peterson[3]

[1] *UCT n-lab*

[2] *UCT*

[3] *University of Cape Town*

Corresponding Authors: steve.peterson@uct.ac.za, moseschegororo@gmail.com, andy.buffler@uct.ac.za

Metrological and Applied Sciences University Research Unit (MeASURe), Department of Physics, University of Cape Town

The University of Cape Town recently declared its intention to "design the technical specifications and business case for a proton therapy centre to be established in Cape Town, near to both the Red Cross War Memorial Children's Hospital and Groote Schuur Hospital." [1]

Currently, all of the 131 proton therapy centres operating globally are located in the northern hemisphere, with only two under construction in the southern hemisphere – in Argentina and Australia. The proton therapy centre in Cape Town will be designed to benefit from the very latest technological advances in both accelerator design and beam delivery. As such, centre in Cape Town will be a unique world-leading resource not only for South Africa, but for the African continent.

We explore the different technical aspects that need to be considered in the design of such a centre, in particular the different options presently available, or under development, for the delivery of the beam in the treatment room. We also discuss how radiation transport modelling using GEANT4, for example, can assist with understanding both the primary and secondary dose delivered by such systems.

[1] https://www.news.uct.ac.za/images/userfiles/downloads/media/2024_02_26_Cancer.pdf

Environmental Measurements / 156

Keynote Address: Imaging devices for Environmental Imaging and Nuclear Decommissioning

Author: Helen Boston[1]

[1] *University of Liverpool*

Corresponding Author: hboston@liverpool.ac.uk

Studying the structure of the nucleus at the frontiers of nuclear stability presents a number of difficult challenges. The advent of radioactive ion-beam facilities has required a step change in the sensitivity of the nuclear instrumentation required to study the expected new and exciting nuclear phenomena. The detection of gamma radiation is at the heart of nuclear structure physics experiments and is key to the success of many industrial applications involving gamma ray imaging. Projects such as the Advanced Gamma Tracking Array (AGATA) in Europe and the Gamma-ray Energy Tracking Array (GRETA) in the United States have pushed the technical boundaries needed to realise spectrometers capable of measuring nuclei far from stability.

This presentation will focus on how the technology designed for Nuclear Physics experiments, such as AGATA, has found application in areas outside of the core physics programme. Sensors developed for Environmental and Nuclear imaging systems will be presented and discussed. The prospects for multi-modality imaging systems will be highlighted and opportunities for future research and development identified.

Nuclear Physics Applications and Projects / 157

The LERIB project at iThemba LABS

Authors: Robert Bark[1]; Skye Segal[1]; Shadley Baard[2]; B Bhengu[None]

[1] *iThemba LABS*

[2] *iThemba Labs, Accelerator Group*

Corresponding Authors: stsegal@tlabs.ac.za, sbaard@tlabs.ac.za, bark@tlabs.ac.za

The Low Energy Radioactive-Ion Beam (LERIB) project at iThemba LABS aims to produce radioactive-ion beams of up to 60 keV energy using the ISOL method. It is centered around a target-ion/ion-source or "Front-End" that is identical to the SPES front-end at Legnaro, Italy, which in turn is derived from the ISOLDE front-end at CERN. The iThemba LABS front-end is presently being worked-up in an offline test facility at the lab, where beams of group I and group II elements have been produced using surface-ionization.

Immediate goals for the facility are to produce 40K targets for nuclear structure and astrophysics research, to develop a FEBIAD ion-source, and to simulate the production of Terbium and Actinium isotopes for medical research. Eventually the front-end will be moved to an "on-line" facility where the radioactive isotopes will be made available for research

The MeASURe Experience - Part 1 / 158

Angular correlation corrections for absolute activity measurements using $\gamma - \gamma$ coincidence

Authors: Mikayla Chaplin[None]; Tanya Hutton[1]; Thomas Leadbeater[1]

[1] *University of Cape Town*

Corresponding Authors: tom.leadbeater@uct.ac.za, chpmik002@myuct.ac.za, tanya.hutton@uct.ac.za

Coincidence techniques form a standard measurement for realising absolute activity under idealised conditions. The use of singles and coincidence event rates allow a direct solution by solving explicitly for the unknown parameters activity, detector efficiency, and solid angle. An unconventional γ–γ coincidence setup has been explored for application with isotopes with one or more gamma emission cascades. In the case of 60Co, where there is an angular correllation between the emission directions of the respective photons, additional information is required to solve for absolute activity. A direct experimental approach, and the known theoretical angular correlation, are investigated as practical corrections to the absolute activity solution for 60Co.

Two NaI scintillators, positioned on movable rails and centered around a pointlike source of 60Co, were calibrated to detect either of the γ-emissions in the 4+ 2+ 0+ cascade. Singles and coincidence rates between pairs of detectors were recorded and input into an adaptable model to calculate activity. With the detectors placed in opposition their separation distance was varied, resulting in consistent model results and demonstrating independence from solid angle. The detectors were then rotated around the source with measurements at angles of 90◦, 105◦, and 135◦ relative to each other, demonstrating the angular correlation in the gamma cascade which is then normalised by the known angular correlation to achieve consistent results.

159

Radiation metrology and applications within MeASURe at the University of Cape Town

Author: Andy Buffler[1]

[1] *UCT*

Corresponding Author: andy.buffler@uct.ac.za

We showcase recent radiation-based research associated with the Metrological and Applied Sciences University Research Unit (MeASURe) within the Department of Physics at the University of Cape Town. Activities which feature proton, neutron and gamma radiation include the development of detectors and instrumentation, advanced computation and stochastic modelling, and novel applications of measurement techniques. Within this deconstructed presentation weaved between the contributed talks, we illustrate how these projects form part of a coherent research programme and seed a workshop-style discussion around the ways in which thematic collaboration can promote research impact within nuclear science and technology. The newly established UCT Proton Therapy Initiative is also introduced.

Nuclear Physics Measurements - Home and Away / 160

Exploring Long-Lived Shape Isomers in Photofission Fragments Using the upgraded VEGA spectrometer at the FLNR of the JINR.

Author: Zipho Ngcobo[1]

[1] *iThemba LABS*

Corresponding Author: ngcobo.zipho@gmail.com

Some decent physics has already been realised by the FOBOS group at the JINR. This includes the confirmation of a rare ternary decay mode in low excited heavy nuclei referred to as Collinear Cluster

Tri-partition (CCT). During the experiments, the challenges of background noise in the experimental area which generated from the MT-25 microtron were addressed with radiation shielding. However, to achieve necessary holistic stability with the experimental works, it was necessary to upgrade the Velocity-Energy Guide based Array (VEGA) spectrometer, which is in progress. The project will investigate one by one the photofission fragments captured by electrostatic field of Electrostatic Guide System (EGS) and transported to the detector. Amongst other anticipated objectives are to study isomeric lifetimes beyond 400 ns and target up to 600 ns. Let us explore the involvement of South Africa, iThemba LABS and the University of Zululand as well as opportunities for others interested. Also, the future of microtron electron beams for the region.

Lectures on Nuclear Data / 161

Probing Nuclear Deformation: Insights from Nuclear Data Libraries.

Author: Abraham Avaa[1]

[1] *iThemba/Wits*

Corresponding Author: aavaa@triumf.ca

The lecture will focus on the crucial role of nuclear data in advancing our comprehension of fundamental nuclear phenomena, focusing on nuclear properties and deformation. It provides an overview of available nuclear properties and methods to access them, highlighting the significance of understanding nuclear deformation.

Nuclear Physics Applications and Projects / 162

Keynote Address: Applications of Nuclear Science and Technology

Author: Humbelani Edzani Ratsibi[1]

[1] *NECSA*

Corresponding Author: tshibaby@gmail.com

The mention of the word nuclear still scares off a large number of people, however on a day to day basis, members of the public get to experience the benefits of nuclear technology. There are various applications of nuclear science that are fundamental to human's livelihood, environment and the climate. Application of nuclear science can be found in the medical fraternity (Nuclear technology is applied to various branches of medicine: oncology, cardiology, neurology, pneumology or pediatrics), energy (electricity generation), food and agriculture (improving food quality and food irradiation for longer shelf-life), industry (improved measurements), mining (radiotracers) and even art (carbon dating). This presentation will discuss generation of nuclear energy, nuclear power plants, nuclear waste, research reactors, radioisotope production, accelerators and cyclotrons. The presentation will highlight on the benefits of nuclear technology, radiation protection for both human and the environment, and also the future plans of nuclear energy in South Africa.

Nuclear Safety, Security and Applications / 163

Invited Talk: Application of an electronic spreadsheet package and a dedicated spectral analysis software for the calibration of a gamma-ray spectrometer

Author: Michael Adeleye[1]

[1] *Bingham University, Nigeria*

Corresponding Author: michaeladeleye@hotmail.com

The first step in a series of actions after installing new software and hardware in a Neutron Activation Analysis (NAA) laboratory is the calibration of the spectrometer besides the characterization of the reactor's irradiation channels. This must be done before any routine spectral analysis could be done using the k0-NAA Standardization Method. For the Nigeria Research Reactor-1 (NIRR-1) laboratories, this calibration of the spectrometer was carried out using two different tools. An electronic spreadsheet and a dedicated spectral analysis software (k0-IAEA) were employed for the same detector and the results obtained from both methods were compared in this study. The efficiency curves were established for the two optimum source-detector distances for the GEM 30195 detector from the measurement and interpretation of several spectra from nine standard gamma-ray calibration sources (Na-22, Mn-54, Co-57, Co-60, Y-88, Cs-137, Eu-152, Ra-226, Am-241) whose activities are known to better than ±3%. The performance of the electronic spreadsheet was compared with the proprietary software. The sets of values obtained for the full-energy peak detection efficiency from the two approaches are close at higher geometries with less than 10% variation.

Nuclear Physics Applications and Projects / 166

The use of Machine Learning Methods for In-Situ Rutherford Backscattering Spectrometry Data Analysis

Authors: Kutlwano Segola[None]; G Magchiels[1]; Christopher Mtshali[2]; Zakhelumuzi Khumalo[3]; L Kotsedi[4]; A Vantomme[5]; Mandla Msimanga[6]

[1] *Quantum Solid-State Physics, KU Leuven*

[2] *IThemba LABS*

[3] *ithemba LABS*

[4] *Tandetron Laboratory, NRF-iThemba LABS,*

[5] *Quantum Solid-State Physics, KU Leuven,*

[6] *Tshwane University of Technology*

Corresponding Authors: kutlwanosegola@gmail.com, mtshali@tlabs.ac.za, zakhele@tlabs.ac.za, msimangam@tut.ac.za

In-situ Rutherford Backscattering Spectrometry (RBS) is a powerful tool for monitoring changes in the interface region of a sample in response to external stimuli. This involves acquiring RBS spectra at regular intervals during annealing. Machine learning based methods have previously been used for standard RBS data analysis, and for the current study, an artificial neural network tailored for in-situ RBS data analysis is developed. This neural network is capable of processing and analysing data obtained from an in-situ RBS thermal annealing experiment from the Tandetron at iThemba LABS. With further development and optimisation, this neural network will potentially be extended to other IBA techniques available at iThemba LABS such as ERDA, PIXE etc.

Environmental Measurements / 167

Keynote Address: Airborne Radiometric Mapping and Health Implications of Natural Radionuclides in Selected Locations of Southwest, Nigeria

Author: Mojisola Rachael USIKALU[1]

[1] *Covenant University*

Corresponding Author: moji.usikalu@covenantuniversity.edu.ng

Exposure to heavy metals and natural radionuclides through various means can dispose mankind to deterioration of health. It is essential and of great importance to monitor environmental radiation level and understand the consequences of radiation exposure for ecological conservation and human health. Aero-radiometric data collected from Nigeria Geological Survey Agency (NGSA) for selected locations in some part of Ondo state was analyzed using Oasis Montaj. The activity concentration of 238U, 232Th in ppm ranged between 0.03-7.67, 1.31-40.36 and 0.18-3.03 in % for 40K respectively. The radionuclides content was re-construe in Bq/kg using the relevant conversion factor and the values ranges between 0.38-94.72, 5.31-163.86 and 56.40-949.71 for 238U, 232Th and 40K accordingly. The qualitative analysis gave the result of the absorbed dose of 13.82-163.02 nGy/h. The ternary map indicates the relative abundance of 40K in the study area. ERICA tool reported 3.74 μGyh-1 and 1.04 total dose rate/organism and risk quotient, respectively for cattle in Abeokuta-FUNAAB while it requested further assessments in Ikorodu-LASG-Fish-Farm, Ojo-LASU-Fish-Farm and Ifo-Dagbolu-Ajakaye as it returned risk quotients values >1. The study concluded that Abeokuta-FUNAAB and Agege-Matogbun have high radiation burdens. Remedial actions are recommended in locations with high-risk radiation levels.

Mixed Topics 6 / **168**

Invited Talk: Recent results from the use of fast-timing arrays and future perspectives.

Author: Alison Bruce[1]

[1] *University of Brighton*

Corresponding Author: alison.bruce@brighton.ac.uk

The development of scintillator detectors e.g. LaBr3(Ce) which have excellent timing resolution (FWHM ~300 ps @ 511 keV) and reasonable energy resolution (~25 keV @ 511 keV) has led to a resurgence in experiments to measure lifetimes of excited nuclear levels in the ps to ns regime. The FATIMA (= FAstTIMingArray) array is a system of 36 LaBr3(Ce) detectors built for use at the Facility for Antiproton and Ion Research in Europe (FAIR), Germany. Prior to its use in FAIR, FATIMA has been tested and commissioned in experiments on 102Zr at the Radioactive Ion Beam Facility (RIBF) at RIKEN, Japan in conjunction with the EURICA germanium-detector array [1], and on 114Pd at Argonne National Laboratory, USA in conjunction with the Gammasphere germanium-detector array [2]. More recently, first experiments have been done in an experimental campaign at FAIR phase-0 where the FATIMA array was combined with 6 triple-cluster GALILEO germanium detectors, e.g. studying 94Pd [3].

In the near future, the FATIMA array will be combined with the KHALA array from Korea to form an array of 82 LaBr3(Ce) detectors to be used at RIBF. An overview of the performance of the system, first results and of the experiments to be carried out during the RIKEN campaign will be presented.

References:
[1] F.Browne et al., Phys Rev C96 (2017) 024309.
[2] E.Gamba et al., Phys Rev C100 (2019) 044309.
[3] A.Yaneva et al., submitted to Phys. Letts. B

Mixed Topics 6 / **169**

The Division of Radiation Biophysics at iThemba LABS – Current and future projects.

Authors: Randall Fisher[1]; X Miles[2]; Peter du Plessis[2]; Monique Engelbrecht[3]; Evan de Kock[2]; Niel Muller[2]

[1] *Division of Radiation Biophysics, NRF iThemba LABS*

[2] *iThemba LABS*

[3] *NRF-iThemba LABS*

Corresponding Authors: mengelbrecht@tlabs.ac.za, niel@tlabs.ac.za, evan@tlabs.ac.za, pdp@tlabs.ac.za, xe.miles@ilabs.nrf.ac.za, rfisher@tlabs.ac.za

At iThemba LABS, the Radiation Biophysics division forms part of the Separated Sector Cyclotron Laboratory and consists of two subgroups: Medical Physics and Radiobiology. Research in the Biophysics division is divided into three main areas: Medical physics, Radiation protection and Cancer research. In Medical Physics, research is focused on developing microdosimetry protocols and equipment and computational modelling of the radiation field produced by iThemba's clinical proton research beamline. As Biophysics division is the SAHPRA-designated laboratory for occupationally overexposed radiation workers, Biodosimetry forms one of the research streams under the Radiation protection. Also in the Radiation protection area is Spaceflight Radiobiology, in light of iThemba's 200 MeV cyclotron's ability to produce both high-energy proton and neutron beams to simulate intra-spacecraft radiation fields.

The Cancer research area is divided into two main streams: Theranostics and Preclinical research. The Theranostics stream was established to investigate and in vitro-validate the new and exotic radiolabelled compounds developed at iThemba's nuclear medicine department while the Preclinical stream explores various natural extracts and commercial drugs with radiosensitising or radioprotective potential for modern cancer therapies. The genetic evolutionary mechanism of cancer-resistance is also investigated in the Preclinical stream, along with novel cancer treatment modalities. These research streams facilitate a range of interesting and novel research projects that are capacitated by a small complement of iThemba staff, postdocs and post graduate students in collaboration with external university users and international collaborators. Local collaborators range from universities and HDIs to privately funded institutions, while fruitful international collaborations exist with Germany, Italy, Belgium and Switzerland. Here, we present an overview of the Radiation Biophysics division, the infrastructure available for internal projects and external users and the range of current and future projects.

Welcome / **170**

Introduction to iThemba LABS

Corresponding Author: director@tlabs.ac.za

Nuclear Physics Measurements - Home and Away / **171**

Introduction to SAINTS

The MeASURe Experience - Part 1 / **172**

Introduction to MeASURe

Corresponding Author: andy.buffler@uct.ac.za

The MeASURe Experience - Part 1 / **173**

Introduction to PEPT Applications

Corresponding Author: tom.leadbeater@uct.ac.za

The MeASURe Experience - Part 1 / **174**

Introduction to Neutron Applications

Corresponding Author: tanya.hutton@uct.ac.za

The MeASURe Experience - Part 1 / **175**

Discussion

The MeASURe Experience - Part 2 / **176**

Introduction to UCT PT Centre

Corresponding Author: andy.buffler@uct.ac.za

The MeASURe Experience - Part 2 / **177**

Introduction to PT Applications

Corresponding Author: steve.peterson@uct.ac.za

The MeASURe Experience - Part 2 / **178**

Discussion

Neutron Physics and Science Communication / **179**

Invited Talk: Overview of SARChI Science Communication

Nuclear Physics Measurements - Home and Away / **180**

Invited Talk: Radiation Hardness Testing

Corresponding Author: abarnard@sun.ac.za

Lectures on Environmental Measurements / 181

Activity Calculations

Corresponding Author: hboston@liverpool.ac.uk

1. Introductory Lecture
2. Activity Calculations (where students will need access to Excel)

Lectures on Environmental Measurements / 182

Innovation Session

Corresponding Author: swoodborne@tlabs.ac.za

Overview
- SDGs
– Global priority areas
-IAEA Country framework
– Global perspective on African solutions
- Local issues
– Rivers/dams/water security
– Climate change
– Energy at the domestic scale
– Water purification at the domestic scale

List big ideas and prioritise

Breakaway sessions

Lectures on Environmental Measurements / 183

Feedback Session

Lectures on Environmental Measurements / 184

Radiocarbon Lecture

Corresponding Authors: jaogondo@gmail.com, swoodborne@tlabs.ac.za

Overview of the radiocarbon method applications

Lab processes

Data handling workshop

Opening Session / **185**

Invited Talk: The Ins and Outs of Science Outreach

Corresponding Author: anslyn@sun.ac.za

Science outreach aims at increasing the public understanding of science by engagement with its practitioners. In this talk I will outline the nature of scientific outreach, its various forms and present some useful strategies. I also argue for the importance of science outreach for the development of science professionals and for improving representation and diversity.