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Book of Abstracts

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Coulomb Excitation of 66Ge

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This work pertains to determining the spectroscopic quadrupole moment for the first 2+ state in 66Ge using "safe" Coulomb excitation measurements. Motivation to study 66Ge arises from the anomalous rotational behaviour of the high-lying first 2+ state observed in even-even isotopes in the A ~ 70 region [1]. Low-lying 0+ excited states have been suggested for even-even neutron-deficient nuclei Se [2] and Kr [3] which may be an indication of shape coexistence [4]. The same trend was observed in 198Pt and is interpreted as the result of the presence of an intruder state [4]. The A ~ 70 region near the N = Z line is a region of rapidly changing nuclear shapes due to the shell gaps at proton and neutron number 34 and 36, making this region an excellent testing ground to study the phenomenom of shape coexistence. In addition, macroscopic-microscopic models suggest gamma-softness for 64Ge through oblate-prolate shape coexistence in 68Se and 72Kr to some of the most deformed nuclei at 76Sr and 80Zr.

Our experiment was performed at HIE-ISOLDE during July 2017. A 4 mg/cm2 target of 196Pt was bombarded with 66Ge beams at 4.395 MeV/u. This was the first experiment carried out using accelerated unstable Ge beams. The initial aim was to study 70Se, but the beam was contaminated with 66Ge. At first it was thought not to be a problem, but it became clear that the ratio between 70Se and 66Ge grew in favour of 66Ge. The beam was then tuned to run 66Ge for the rest of the experiement. The gamma rays were detected using the MINIBALL array containing 8 cluster of HPGe detectors. Scattered particles were detected using an annular CD detector placed a distance of 25.74 mm, covering scattering angles from 21 to 57 degrees. Studying the shape of 66Ge may shed light on some of the systematics in this rapidly changing region of nuclear shapes.

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

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ASSESSMENT OF RADIOACTIVITY LEVEL IN WATER USED FOR IRRIGATION IN VEGETABLE FARMS IN LAGOS, NIGERIA.

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ABSTRACT
Levels of naturally occurring radionuclides in waters used in irrigation of cultivated vegetables farms in Lagos metropolis have been investigated. The activity concentrations were determined by gamma spectrometry measurements using NaI(Tl) detector. The activity concentrations for 238U, 232Th and 40K ranged from 1.95 to 5.66Bq/l with mean values of 4.14± 0.16 Bq/l, from 0.74 to 4.38 Bq/l

with mean values of 2.68 ±0.05Bq/l and from 1.61 to 14.93 Bq/l with mean values of 9.10±0.15 Bq/l respectively. The mean value obtained for 238U was below the WHO reference value of 10 Bq/l for drinking water but the mean value obtained for 232Th was greater than the WHO safe limit of 1Bq/l . To evaluate the radiological risk, absorbed dose, annual effective dose and external hazard index were evaluated from the activity concentrations. The mean values obtained were 3.92±1.72 nGy/hr, 0.005±0.002 mSv/yr, and 0.023±0.10 respectively. The absorbed dose value obtained was much lower than the world average terrestrial dose rate of 57 nGy/hr and the external hazard index was much less than unity. The annual effective dose obtained from this study was 5% of the UNSCEAR individual dose recommended for drinking water (0.1 mSv/yr) and 30% of the estimated average for Nigeria by Farai and Jibiri 2000 about 1% of the world average of 460μSv/yr) recommended by WHO. From the obtained results of radiological indices, the use of these waters for cultivating vegetables does not pose significant radiological risks to consumers of the vegetables. However, routine investigation should be carried out to certify safety in the use of these waters as the activity concentration of 232Th obtained was higher than the WHO reference level. Also, because prolong industrial activities have the potential to increase the radioactivity level of the environment.

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Gamma-ray measurement of TENORMs in the environment and the use of simulations codes to benchmark the data.

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Human beings are exposed to ionising radiation from natural sources throughout their lifetime, and sometime from man-made sources, therefore the knowledge of radionuclide distribution and radiation levels in the environment are very important for assessing the effects of radiation exposure due to primordial radionuclide, cosmogenic radionuclide and anthropogenic radionuclide.
The study seeks to assess the concentration of natural and man-made radionuclides in environmental samples. The samples will be taken from Uranium mining, heavy mineral and gold mining in Witwatersrand Basin area. These samples will be analysed in a low-background high resolution gamma-ray spectroscopy system using a Hyper Pure Germanium detector (HPGe) system available at the Environmental Radioactivity Laboratory (ERL) of iThemba LABS, Cape Town. The activity concentration of 238U, 232Th and 40K will be determined and the growth curves of activity in the uranium and thorium chain will be examine to assess if the decay products are in equilibrium. The gamma dose rate to an individual living in the region will be determined from the derived specific activity obtained during experiment. The main task is to establish the use of simulations for different parameters such as volume, coincidence summing and density on how it affects the absolute photopeak efficiency of the ERL's HPGe in a close geometry (Marinelli beaker) for different samples. The advantage of the simulation codes is that they can generate and simulate multiple particles in a single event; therefore primary and secondary particles can be corrected. This feature is very important for problems that include multiple gamma-ray emitting radionuclides.

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CHARACTERISATION OF ELECTRON SPECTROMETER AT iThemba LABS

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The refurbishment of the Siegbahn-Kleinheinz dual lens spectrometer previously used at Orsay, France for the study of excited 0+ states has reached an advanced stage at iThemba LABS, South Africa. The spectrometer is made up of a Si(Li) detector for measurements of internal conversion electrons and pair production, it is also surrounded with an array of LaBr3 for the detection of coincident decays and lifetime measurements of states which provide value-added information on the branches.
Moreover, the monopole transition strength parameter of the excited 0+ states extracted from experimental data of intermediate energies will further enhance our understanding of shape-coexistence and phase transition in nuclei. To this end, characterization measurements of parameters that are useful in describing the performance of electron spectrometer such as magnetic field, efficiency, energy resolution and transmission are carried out.

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Latest Developments of the South African Isotope Facility

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The latest developments with the Radioactive-Ion Beam project of iThemba LABS, the South African Isotope Facility, SAIF, will be reported [1]. SAIF has two phases, the first of which comprises the Low-Energy Radioactive-Ion Beam (LERIB) project together with the ACE Isotopes (Accelerator Centre for Exotic Isotopes) project. ACE isotopes calls for the installation of a commercial, off-the-shelf 70 MeV cyclotron for radionuclide production. It will remove radionuclide production from the existing Separated Sector Cyclotron (SSC) accelerator, allowing it to be dedicated to research. The partially-funded LERIB project, is an ISOL project that will be capable of producing neutron-rich beams of high-intensity, by using 66 MeV protons from the SSC to fission natural uranium at an initial rate of up to 6 x 1012 f/s. The target/ion-source at the heart of LERIB is a copy of the SPES [2] front-end, in a collaboration between iThemba LABS and INFN-Legnaro, Italy. In future, the power of the primary beam can be increased to give a fission yield of up to 2 x 1013 f/s. The beams from LERIB will be of low-energy, 60 keV - suitable for decay studies and implantation in materials as radioactive probes. Phase 2 of the SAIF project is the Accelerator Centre for Exotic Beams (ACE Beams). It will eventually see the addition of a post-accelerator, likely a LINAC, to take beams from the LERIB to high-energies for research into sub-atomic physics.

[1] R.A. Bark PoS(INPC2016)100
[2] http://www.scholarpedia.org/article/The_LNL_radioactive_beam_facility

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Environmental sample measurement using two cerium doped lanthanum bromide scintillator detectors.

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Two $LaBr_3$:Ce scintillator detectors linked to a XIA PIXIE-16 Digital Signal Processing data-acquisition were used to measure reference soil samples. The samples were placed $8 \cdot 55$ cm from each detector, each sample was measured for 2 hours. The absolute full-energy peak gamma-ray detection efficiency at 1461 keV (^{40}K), 1765 keV (^{238}U) and 2614 keV (^{232}Th) are $8 \cdot 2 \times 10^{-2} \pm 2 \cdot 5 \times 10^{-3}$ %, $5 \cdot 6 \times 10^{-2} \pm 2 \cdot 4 \times 10^{-3}$ % and $4 \cdot 7 \times 10^{-2} \pm 1 \cdot 1 \times 10^{-3}$ % respectively. The minimum detectable activity (MDA) of the measurement for the peak of interest were determined. The activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the sample were determined and the results were consistent within measurement uncertainty when compared with certified values.

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ASSESSMENT OF NATURAL RADIOACTIVITY LEVELS AND THE ASSOCIATED RADIOLOGICAL HAZARDS IN SOME BUILDING MATERIALS OF THE MAYO-KEBBI REGION, CHAD.

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In order to assess the levels of natural radioactivity and the associated radiological hazards in some building materials of the Mayo-Kebbi region (Chad), a total of nineteen samples were collected on the field. Using a high resolution ⊠-ray spectrometry system, the activity concentrations of radium (226Ra), thorium (232Th) and potassium (40K) in these samples have been determined. The measured average activity concentrations range from 0.56±0.37 Bq kg-1 to 434.88±7.11 Bq kg-1, 1.30±0.60 Bq kg-1 to 50.61±1.12 Bq kg-1 and 4.28±1.96 Bq kg-1 to 839.54±8.98 Bq kg-1, for 226Ra, 232Th and 40K, respectively. The highest 226Ra average activities is found in soil bricks of Zabili. The highest mean value of 232Th and 40K concentrations is found in soil bricks of Madajang. The activity concentration and the radium equivalent activity (Raeq) have been compared to other studies done elsewhere in the world. Their average values are lower than most of those of countries with which the comparison has been made. Were also evaluated, the external radiation hazard index, the internal radiation hazard index, the indoor air absorbed dose rate, the outdoor air absorbed dose rate, the activity utilization index, the annual effective dose, the annual gonadal dose equivalent, the alpha index, the gamma index, the representative level index, as well as, the excess lifetime cancer risk. In accordance with the criterion of the Organization for Economic Cooperation and Development, our results show that soil bricks of Zabili and Madajang could lead to radiation hazards, and the risk of developing cancer by people living in this environment is very high. Thus, except these materials, all the others should be used for construction purposes.

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Detecting and Quantifying Uranium-Series Disequilibrium in Natural Samples for Dosimetric Dating Applications

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In natural aquatic environments, the process of isotopic fractionation may occur. Radioisotopes with activity ratios between daughter and mother nuclides not at equilibrium may be found in such open-system environments. Small deviations from unity may have negligible effect in terms of dosimetric dating but over longer time scales the mobility of 226Ra and 234U may affect the accuracy of the dating result.
The Canberra LabSOCS software in association with a standard 60 mm diameter BEGe detector were employed to carry out gamma-ray spectroscopy on the 238U decay series in a number of environmental samples from locations including Namibia. These samples were characterised in terms of density, filling height and chemical composition.
LabSOCS will be shown to be in good agreement in terms of experimental transmission measurements taken with point sources, with results from standard IAEA materials and in comparison with ICP-MS measurements.
The results show excellent agreement between outputs from model and independent control measurements. This suggests that the method to be presented is robust and allows quantifying and correcting isotopic fractionation using readily available gamma spectrometric setup and software.

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Fast beta-gamma timing measurements conducted at the RIBF

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Precise knowledge of the shape evolution of neutron-rich Zr isotopes provides vital insight into the mechanism by which the sudden deformation manifests in the neutron-rich A>100 region. To extend our knowledge of this evolution to 106Zr, a decay spectroscopy experiment was carried out at the Radioactive Isotope Beam Factory, RIKEN Nishina Center. Additionally, a search for isomerism in the lighter isotopes showed the presence of a 9.5(7) ns K-isomer in 102Zr.

Nuclei of interest were selected and identified with the BigRIPS spectrometer from a cocktail beam produced from the in-flight abrasion-fission of 238U. The selected nuclei were implanted into the WAS3ABi silicon stack and gamma rays emitted following beta decay, or decay of isomeric states were detected in an array of 12 cluster HPGe detectors augmented with 18 LaBr(Ce) detectors. The latter providing access to the lifetimes of excited states in the nanosecond regime.

During the talk, the experimental set-up, as well as results obtained from it, shall be discussed. In addition, results from tests of a new scintillation material, GAGG(Ce), shall be briefly presented.

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Characterisation of the iThemba LABS segmented clover detector.

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The iThemba LABS segmented clover detector manufactured by Canberra France is made up of four front tapered n-type HPGe crystals packed closely together in the same cryostat. Each crystal has 60 mm diameter and is 90 mm long before shaping. The crystals have segmentation in depth at 35 mm. The outer contact of each crystal is electrically segmented into 8 contacts. This results in a total of 36 electronic channels of which 32 are associated with the outer contacts and 4 with the inner core contacts of the detector.

iThemba LABS acquired a Multi Geometry Simulation (MGS) and AGATA Detector Library (ADL) codes to simulate the pulse shapes for the iThemba LABS segmented clover detector. These codes are capable of simulating the pulse shapes for an arbitrary gamma-ray interaction position within the germanium. With these codes, the sensitivity of the iThemba LABS segmented clover detector to the exact position of the gamma-ray interaction was tested. The characterisation of the detector in order to obtain realistic simulations of the pulse shapes is advancing well. The biased voltage and the impurity profiles for each crystal as given by the manufacturer are implemented into the codes. The orientation of the crystal lattice of one of the germanium crystal is measured and the results show that the fast <100> axis is at an angle of 47 degree. The measurements of the preamplifier response is performed and implemented into the ADL code. The analysis showed that the preamplifier response function of the core is different from that of the segments. A modified response function was used for the segments. The drift velocity of electrons is been measured and implemented into the ADL code. After including these properties of the germanium crystal into the ADL code, we found excellent agreement between the shapes of the simulated and measured charge collecting pulses.

In addition, the proportional cross-talk as a function of the deposited gamma-ray energy was determined. In some cases propositional cross-talk as large as 50keV was observed. The correction for the proportional cross–talk was successfully implemented and the full gamma-ray energies were recovered. In this presentation the results from the proportional crosstalk correction for the iThemba LABS segmented clover will be discussed.

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A new compact neutron spectrometer

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There is an ongoing need to develop compact neutron spectrometers, particularly for deployment in aircraft and spacecraft, for minerals exploration, personal and workplace dosimetry and in security, particularly for the detection of special nuclear materials. Furthermore, for dosimetry in the upper atmosphere and in space, neutrons in the energy range 1-100 MeV need to be measured.

Neutrons and gamma-rays nearly always co-exist in the same radiation field, therefore any useful detector will need to discriminate between the two radiation types. Three recent technological developments have assisted with the development of detectors requiring pulse shape discrimination (PSD) for the separation of neutron and gamma-ray signals for use in non-laboratory environments. The invention of solid ("plastic") scintillator which exhibits PSD capability, such as the EJ299-33 scintillator used in the present work, removes the toxic and fire hazards associated with most liquid scintillators. Furthermore, plastic scintillators have no need for an optical window when coupled to a photodetector, and may be fairly easily produced in any geometrical form. Secondly, the development of efficient and very compact silicon photomultipliers (SiPMs) offers compact and robust alternative to traditional photomultiplier tubes and removes the requirement of high voltage. Finally, the emergence of digital data acquisition and processing systems allows pulse shape discrimination to be implemented and dynamically optimized in software form across a wide energy range, or implemented on specialized hardware, such as field programmable gate arrays (FPGAs) or digital signal processors (DSPs).

We are well advanced in developing a compact neutron spectrometer, suitable for measurements between 1 and 100 MeV, based on EJ299-33 scintillator, SiPMs and an FPGA-based acquisition system. We present measurements of the response of the detector to neutrons and gamma-rays from an AmBe source, a DT sealed tube neutron generator, and from cyclotron beams, and illustrate the use of a small EJ299-33-based detector for spectrometry by unfolding measured pulse height spectra using a response matrix calculated via a GEANT4-based simulation.

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Efficiency calibration of the laboratory based gamma-ray detector for various sample geometries

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Radioactivity has been present on earth since its formation and is part of the environment we live in. Humans are exposed every day to radioactivity through the radioactive elements that occur naturally in the environment. Radionuclides are found naturally in air, water, soil, plants and inside our bodies. The radionuclides we encounter in the environment can be classified into the following three categories; primordial, cosmogenic and anthropogenic [Kno10]. In the study radiometric measurements using various sample containers/holders are performed. Available sample holders under study are Marinelli beaker, cylinder (pill bottle) and point source. The gamma-ray spectrometry method is the tool used to analyse samples. For absolute photo peak efficiency measurements IAEA reference material RGU-1, RGTh-1 and potassium chloride powder were prepared for 100 ml pill bottles and the Marinelli beakers (1L) then each measured in HPGe detector for a day. Additionally, certified reference point sources bought from NMISA were also measured. From the known activities of the point sources and the prepared volume sources, photo peak efficiency was calculated and efficiency parameters for these geometries were obtained. The experimentally determined efficiency parameter of various geometries, will therefore be compared with simulated results of similar setups. For this contribution, the efficiency of the detector as function of gamma-ray energy in various measuring geometries will be discussed.

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Lifetime Studies of 166Dy Using the NuBALL Array

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This work presents the initial analysis from the first in-beam experiment using the NuBALL hybrid HPGe-LaBr3 coincident gamma-ray spectrometer at IPN, Orsay in November 2017. In this configuration NuBALL comprised 24 Compton suppressed four-element HPGe Clover detectors, 10 coaxial HPGe Compton suppressed spectrometers, and 20 single-element LaBr3 detectors from the FATIMA collaboration. These were operated using a fully digitized data acquisition system. The excited states in 166Dy were populated using the 164Dy(18O,16O)166Dy two-neutron transfer reaction using a pulsed 18O beam at energies of 71, 76 and 80 MeV. The aim of this work is to determine excited state lifetimes in the vicinity of the valence maximum nucleus 170Dy with high precision. We will report on the array performance during the experiment and the current progress on analysis of these data to extract B(E2) values of low-lying transitions in 166Dy and also the 164Dy target material. In particular, the effects of fold-sum energy, prompt-delayed coincidence timing and high-resolution energy coincidence gating will be presented.

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Developing Cs2LiYCl6 (CLYC) Scintillators for Fast Neutron Spectroscopy*

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Cs_2LiYCl_6 (CLYC) scintillators detect both gammas and neutrons with excellent pulse shape discrimination. Originally designed to detect thermal neutrons via the ^{6}Li(n,α)t reaction, our surprising discovery of its fast neutron response via the ^{35}Cl(n,p)^{35}S reaction led us to develop a 16-element 1" x 1" array with ^{7}Li-enriched C^{7}LYC, where the thermal neutron response from ^{6}Li is virtually eliminated [1]. The scintillator shows great promise for low energy nuclear science and applications, with its unprecedented spectroscopic properties (~10% pulse height resolution for fast neutrons in the < 8 MeV range). Our test experiments to date include elastic and inelastic neutron scattering cross-sections on ^{56}Fe at Los Alamos with a pulsed white neutron source, as well as (p,n) and (d,n) reactions on low-Z targets using mono-energetic proton and deuteron beams from the 5.5 MV Van de Graaff accelerator at the UMass Lowell Radiation Laboratory. The array is also being tested at the CARIBU facility at Argonne for measuring beta-delayed neutrons. Larger CLYC crystals are also now a reality and measurements with the first 3" x 3" C^{7}LYC crystal are in progress. A key goal is to evaluate whether the low intrinsic efficiency of C^{7}LYC for fast neutrons (<1$\%$) can be effectively offset by the significant gain in solid angle obtained by positioning the detectors much closer to the target, since the typical need for long time-of-flight arms to achiev good neutron energy resolution is eliminated. Overall, this is an exciting candidate to consider for auxiliary scintillator arrays for stopped-beam measurements in next generation rare isotope accelerator facilities.

*Supported by the NNSA Stewardship Science Academic Alliance Program under Grant DE-NA0002932 and the DOE Office of Science under Grant DE-FG02-94ER40848.

1. N. D'Olympia et al., Nucl. Inst. Meth. A694, 140 (2012), and A763, 433 (2014).

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Fast-Timing measurements of prompt states fed by isomeric decays at the focal plane of a recoil separator - including a new timing correction for the differing spatial recoil-implant locations.

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Over the past few years at University of Jyvaskyla, Finland, the lifetimes of several nuclear states near to and beyond the proton dip line have been determined for the first time [1-3]. New information on nuclear matrix elements and effective charges has been obtained. These experiments were only possible with the development of differential-plunger experiments in conjunction with isomer-, proton-, and alpha-tagging techniques using the GREAT and RITU spectrometers. The focus of that work was to measure the lifetimes of promptly fed states in fusion-evaporation reactions. The interpretation of these experiments has and continues to prove a challenge for nuclear theory [1-3].
In order to complement these existing approaches, a new array of 30 LaBr3detectors has been designed to be placed at the focal plane of the gas-filled RITU spectrometer. A test experiment was performed with an array of 8 detectors at the focal plane of RITU on the ground-state bands in 136Sm and 138Gd which were fed by K=8 isomeric state decays. Each fast-timing event had to be corrected for the position at which the implant occurred across the double-sided silicon-strip detectors. Left uncorrected, these differing positions are expected to smear out the timing resolution of the array and in some cases even dominate the lifetime being measured. The results of this experiment will be discussed along with the prospects for future experiments at Jyvaskyla and other facilities.

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[2] M.G. Procter et al., Phys. Lett. B 704 (2011) 118.
[3] M.G. Procter et al., Phys. Lett. B 725 (2013) 79–84

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Binding Blocks - Inspiring Future Physicists

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"Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mine worker can become the head of the mine, that a child of farmworkers can become the president of a great nation." (N. Mandela, Long Walk to Freedom, 1994).

The Binding Blocks programme is focussed on developing and supporting high-quality engagement with nuclear science in secondary schools. This is a challenge faced not only across Southern Africa, but around the world, and it can be hard to grasp the challenging concepts in nuclear physics, or the excitement nuclear physics in the world around us, in stars, on Earth, and in society.

However, through workshops for schools and teachers we give participating students a hands-on experience in actually building a nuclear chart and couple this with key areas of modern nuclear science, as well as secondary school (and undergraduate) learning outcomes. With Binding Blocks as an educational focal point, we have developed a range of activities, including in nuclear astrophysics, around which nuclear science can be engaged with in an interactive manner. The first stage of educational material has recently been published by the Binding Blocks team (see [1] and citations thereof).

Implementation across Southern Africa could be facilitated through training of undergraduate and graduate students, empowering these to deliver engaging teaching on fundamental and applied nuclear physics in schools as part of their training, most effectively through university-based regional centres. The present workshop and presentation therefore aims to introduce the core learning and training methodology of the Binding Blocks programme with an aim to assess its potential for implementation across Southern Africa.

[1] C.Aa. Diget; Binding blocks: building the Universe one nucleus at a time; Physics Education, 52(2017)024001. [Article available free of charge from IoP Phys.Ed.]

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Novel method to make a calibrated thoron source

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Thoron (220Rn) is the radioactive isotope of radon that occurs naturally as a result of the decay series of 232Th. 220Rn has a short half-life (55.8s), but recent work has shown that it does have possible serious health dangers just like the isotope radon (222Rn) which is the second most important cause of lung cancer. 220Rn is a radiation protection issue at mines with a high thorium concentration and in the heavy mineral sands industry. In this work we describe a simple, cheap method that can provide a reasonably accurate flow of 220Rn for checking the feasibility of measuring 220Rn with detectors such as RAD7.

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Fast-timing measurements in neutron-rich zirconium isotopes using LaBr3(Ce) detectors coupled with Gammasphere

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A fast-timing experiment was performed at the Argonne National Laboratory, with the purpose of measuring the lifetimes of the lowest lying states of nuclei belonging to the deformed regions around A≈110 and A≈150. The lifetimes of the first excited states give a measure of the nuclear quadrupole moment, which gives information about the structural evolution that occurs in the deformed areas of the nuclear chart. The nuclei of interest were produced in the spontaneous fission of ^{252}Cf and the gamma rays emitted from the fission fragments were collected using 51 HPGe detectors from Gammasphere (GS) coupled to 25 $LaBr_3$(Ce) scintillator detectors. Triple events (one gamma ray from Gammasphere and two from the $LaBr_3$(Ce) array) were collected for a period of 30 days. This was the first time that the GS array was successfully coupled with an array containing such a large number of $LaBr_3$(Ce) detectors, using a fully digital acquisition system. The level of interest is isolated by gating on the HPGe detector and its lifetime is measured using the scintillator array,

capable to access the sub-nanosecond range. The lifetime measurement of the 2^+ level in ^{110}Ru will be presented as a test case and details on the analysis will be given, focusing in particular on the background subtraction and the GS-gating procedure. The cases of some lifetime measurements in low lying states in $^{100-104}$Zr will also be presented.

38

Neutron spectrometer for the experiments with radioactive beams on the ACCULINNA-2 fragment separator

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The stilbene crystals based neutron spectrometer built in the Flerov Labvoratory of Nuclear Reactions (FLNR JINR, Dubna, Russia) is described in the presentation. Time resolution as a function of
the signal amplitude and the energy resolution are derived for the detection of gamma-quanta. At the amplitude of 1MeV in electron equivalent (e.e.) dT = 0.18 ns, dE/E = 4,5%. The quality of the neutron-gamma discrimination is studied. Assured separation is possible for energy losses exceeding 100 keV e.e. Such a value corresponds to the recoil proton kinetic energy of 700 keV. The neutron spectrometer significantly extends experimental capability of the facility and allows to perform correlation experiments with radioactive beams at the fragment-separator ACCULINNA-2 at a much higher level.

25

Improved Digital Pulse Timing Using Lower Speed ADCs

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It is becoming increasingly desirable in a number of fields, including nuclear physics, nuclear medicine and photon ranging applications, to measure the time of arrival of pulses, for example from photon detectors such as photo multiplier tubes and silicon photo multipliers, with time resolutions in the picosecond range, often approaching 100 ps or below. Achieving such results has, in turn, generally required very fast analog to digital converters (ADCs), typically with sampling rates of 1 – 5 GS/s. These devices are expensive and do not interface well with digital logic implemented in field programmable gate arrays (FPGAs), which, while capable of capturing GHz input streams, are limited to approximately 250 MHz processing clock speeds. In this work we present two methods for achieving similar time resolutions using ADCs operating from 250 – 500 MS/s. The first, a double interpolation method, first interpolates the pulse's maximum M and then interpolates the constant fraction f*M as the pulse's arrival time. The second, a ratio measurement method, measures two values in a rapidly changing region of the pulse and uses their ratio with a preconstructed lookup table to provide the arrival time. As examples, the interpolation method is shown to achieve better than 50 ps resolution between two PMTs excited by a short laser pulse and digitized at 500 MS/s, while the ratio method achieves 150 ps resolution between two LaBr3 detectors excited by 60Co and digitized at 250 MS/s.

32

Negative Parity Bands in the Light Translead Nuclei

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Low-lying negative parity bands with bandheads at excitation energies of approximately 1 MeV occur in several isotopes of heavy nuclei and are usually associated with nuclear octupole deformation. These bands have recently been described within a binary cluster-core model employing the coupled channel formalism. We use this technique to investigate the structure of the negative parity states of some light translead nuclei. A description of this formalism and the results of preliminary investigation on a representative nucleus indicating the need for new measurements will be presented.

9

Developing the Oslo SCintillator ARray (OSCAR)

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A new high efficiency scintillator array consisting of 30 large volume $LaBr_3$(Ce) detectors are currently being developed at the Oslo Cyclotron Laboratory (OCL), University of Oslo. The first commissioning experiments was performed in December 2017 with 15 of the detectors installed. The array has been characterized and response functions have been extracted from in-beam particle-γ coincidences. The experimental response functions have been reproduced by Geant4 simulations modeling the full setup. The data acquisition system at OCL will be replaced by modern electronics from XIA in mid February, 2018.

19

Towards a Standard Digital Data Format for Nuclear Instrumentation: IEC 63047

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A New Work Item Proposal for an international standard data format related to digital instrumentation used for the detection and measurement of radiation was developed by the EURAMET EMPIR 14SIP07 project consortium, submitted to (and subsequently approved by) IEC TC/45 WG9. This addresses the lack of an internationally recognised standard data format for the data presented by such systems (time-stamped list-mode), which hinders the interoperability between hardware for data acquisition and software for data analysis.
This standard data format relies on the well-known and widely-used ASN.1 notation, incorporating the possibility of collecting data from multiple detector systems simultaneously. When synchronised to a common clock of adequate precision and frequency, the data sets may be analysed to perform coincidence counting as used in nuclear structure measurements, as well as for primary standards of radioactivity (coincidence counting, TDCR etc). This is turn opens up new possibilities in the operation an validation of radioactivity International Comparisons exercises under the auspices of the BIPM CCRI(II), where not only an activity concentration is reported, but the entire data sets themselves may be submitted for scrutiny by the relevant Key Comparison Working Group.
Furthermore, the format incorporates the possibility to couple time-stamped list-mode data to geolocation data facilitating new measurement regimes:

• The use of unmanned robotic or remote controlled ground and aerial vehicle systems in an emergency scenario, enabling radiation detection following radiological incidents based on state-of-the-art digital sampling.

• Non-expert field officers may send the data to off-site analysis centre, where the experts can follow in real-time the measurements and provide advice accordingly to the operational response users: e.g. law enforcement, response teams, operation centres. The use of this standard will facilitate a new approach which provides a faster and more reliable response and requires less human resources. Real-time transmission of data to experts enables a focus on the core activity of the field mission: to provide accurate analysis and enable informed decision-making.

The IEC 63047 standard is nearing completion, currently at the Committee Draft for Vote stage. The final standard is due to be published in the first quarter of 2019.

13

Cross section measurements of light ion production using (p,xp) and (p,xn) reactions

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Neutron rich beams are being developed at iThemba LABS to study nuclear structure away from the stability. The primary beam is expected to be an intense 70 MeV proton beam. Several techniques using proton induced reactions have been developed to produce exotic nuclei. The interest of using (p,xp) and (p,xn) reactions lies in the fact that proton beams have a large penetrating power and can be produced with high intensity. Some preliminary measurements were performed at iThemba LABS using, 7Li, 9Be and natB targets with protons projectiles of energy 66 MeV. The nuclides of interest 6He, 8Li and 9Li were identified. Further cross section measurements are planned using a beam chopper being installed at iThemba LABS. The detection setup includes two electron spectrometers composed of a 5mm thick plastic scintillator, for energy loss measurement, and a thin window Germanium detector (LEPS) for residual energy measurement. The E-ΔE technique with this combination of detectors allows particle identification and high resolution measurement simultaneously. The results of this investigation will be used to evaluate the feasibility of light neutron rich beams at iThemba LABS using ISOL technique.

39

The radiative width of the Hoyle state from pair conversion and proton-gamma-gamma measurements

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Stellar formation of carbon occurs when three alpha particles fuse and form the so-called Hoyle state in 12C at 7.654 MeV. Stable carbon is only formed if the Hoyle states decays to the ground state. The Hoyle state is located above the 3 threshold, which makes the triple alpha process very unlikely as the excited carbon nucleus decays back to three alpha particles 99.96% of the time. The process is therefore a bottleneck in nuclear astrophysics, and good knowledge about the production rate is imperative for carbon formation in the universe. Since the formation of stable carbon depends on the electromagnetic decays from the Hoyle state, the 3 rate is directly related to its radiative transition probabilities. The internal decay of the J =0+ Hoyle state occurs either by a 7.654 MeV E0 transition to the 0+ ground state, or by a 3.215 MeV E2 transition to the first excited 2+ state. The current value of the radiative width, rad, has been determined in an indirect way, resulting in a 10-12% uncertainty on the 3 rate.

Here we report on two new experiments to improve our knowledge on rad. In both experiments the Hoyle state was excited with proton bombardment of natural carbon. In the first experiment, carried out at the Oslo Cyclotron Laboratory, using the CACTUS and SiRi arrays the cascading gamma-rays of E2 multipolarity and 3.215 MeV and 4.439 MeV energy were observed. The rad / ratio was determined from the ratio of singles proton events to number of proton- triple coincidences. In the second experiment, carried out at the ANU, using the Super-e spectrometer, the pair conversion of the 3.215 MeV E2 and 7.654 MeV E0 transitions, de-exciting the Hoyle state, was observed in a single experiment for the first time since the state was observed in the laboratory more than sixty years ago. This method eliminates most of the difficulties of attributed to limited knowledge of proton and gamma angular distributions of the 4.4 MeV intermediate state.

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Applied Nuclear and Radiation Physics research at BIUST

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The Botswana International University of Science and Technology (BIUST) is a young institution, having opened its doors to the first cohort of students in year 2012. Nuclear and Radiation Physics research at BIUST is at its infancy. Naturally, we have an ambitious target to develop human resources capacity through postgraduate research. We, therefore, are always eager to partner and collaborate with Nuclear and Radiation researchers from anywhere across the globe. In this presentation I will give an overview of the research currently ongoing or envisaged in our research group.

14

Lifetime measurement simulations with the AGATA-FATIMA array at GANIL.

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The simulated response of multi-detector systems can be useful to strengthen experiment proposals, optimise experimental setups, assist in the data analysis and confront theoretical predictions or interpretations. Prior to the recent AGATA-FATIMA-VAMOS experimental campaign at GANIL, a series of simulations have been performed for both the AGATA and FATIMA subsystems. The results of this work will be presented within the frame of the lifetime measurement experiment of neutron-rich A~100 nuclei. The tools/frameworks developed for this kind of simulations will also be described and the benefits of sharing these tools to a larger community will be highlighted.

6

Advancing nuclear technology through Positron Emission Particle Tracking

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The Department of Physics at the University of Cape Town runs a dedicated facility for Positron Emission Particle Tracking (PEPT) at iThemba LABS, South Africa. Pioneered by our long term collaborators at the University of Birmingham UK, PEPT is a powerful measurement and characterisation tool for studying a wide range of dynamic physical processes, granular systems, and multiphase flows.

The PEPT technique uses high speed, large area, position sensitive arrays to detect the annihilation photons produced by a positron emitting tracer particle which is representative of the bulk material under study. Reconstructing the photon path allows the instantaneous position of the tracer particle to be determined by triangulation. At Birmingham raw data acquisition rates up to 100 kHz are routinely measured. With post-processing of event data an optimum PEPT performance is given: a particle moving at 1 m/s can be located to within 1 mm in 3 dimensions at a rate of 1 kHz. Recently, at iThemba LABS, using state of the art detectors and data acquisition electronics, a greatly increased performance has been measured. Raw data rates in the MHz range allow particle location rates approaching 100 kHz with otherwise similar performance metrics as above.

The increased performance for PEPT offers the unprecedented tracking of low activity tracer particles, small tracers which are inherently difficult to label with sufficiently high radioactivity, or tracer particles moving in fast flowing systems. For traditional applications which have been successfully studied using this technique our system offers a step change performance for equivalent conditions. Such improvements come at a cost and there are increased complexity overheads of high speed data acquisition, data handling and storage, and data processing.

Looking to the future we are developing the next generation data acquisition architecture, based around optical fibre Ethernet allowing acquisition of event data up to 10 Gbps. Routing data in this manner will enable hard storage of the data stream, real-time on-line diagnostics, preliminary data analysis, and display, to be shared between multiple nodes on different network sockets. We will be investigating parallel computation techniques using multiple CPU cores and GPU devices to improve data acquisition and processing, and will investigate genetic algorithms and machine learning technologies to aid in data analysis and processing. We actively encourage and invite collaboration within all stages of our multidisciplinary enterprise.

45

Applied Nuclear Research at the University of the Western Cape

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The Department of Physics and Astronomy at UWC has developed expertise in environmental radioactivity for applications especially in the South African context. We have studied:

1. Radioactivity in mine dumps and radon escape from the dumps.
2. Radon measurement techniques in the mines, radon as an indicator of pollution, Radon as a tracer of Fresh water in the sea and radon in bore hole water in the Karoo as a natural tracer.
3. Thoron measurement techniques.
4. Accurate, long term gamma measurements as a start to a long term project to look at neutrino measurements and low activity measurements in the Hugenot tunnel.

11

iThemba LABS low-radiation level counting facility

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Radiation levels in areas suspected to be higher than normal, such as those near large granite deposits, some mining activities and/or there are natural hot springs, and where there are man-made sources of radiation such as nuclear power plants, must be monitored for radiation safety of human, animals and plants. These monitoring is best done by independent environmental radiation laboratories. These laboratories are either located at research institutions, metrology facilities, or universities. Environmental radiation laboratories can work with the country's nuclear regulators and/or radiation safety bodies and international organisations such as the IAEA to provide routine radioactivity information. The environmental laboratories working with the nuclear regulators can also conduct routine radiation level measurements at the designated areas to confirm compliance.

The Environmental Radioactivity Laboratory of iThemba LABS, in the department of Subatomic Physics has been using radiation detectors for measurements of anthropogenic ('man-made') and natural radionuclides present in our environment. The radiation detectors consist of a laboratory-based HPGe detector, field-based MEDUSA detector systems and a flexible radon monitor, RAD7. To assist in the testing and calibrations of the detectors, the Monte Carlo (MC) methods are also being used to benchmark the experimental data with the calculations. For this contribution, the capabilities and the future plans of the facility will be discussed.

41

Zig-zag Shapes

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Spear's 1981 evaluation of spectroscopic quadrupole moments for the first 2^+ states, $Q_S(2_1^+)$, in 2s-1d shell nuclei still have many of the accepted
values in the NNDC, even when most reorientation-effect measurements were done at unsafe energies, e.g. ^{22}Ne, ^{28}Si,
^{32}S and ^{36,40}Ar~\cite{Spear}.
The adopted experimental $Q_S(2_1^+)$ values show that $A = 20 - 26$ nuclei present a decreasing prolate
deformation as A increases. The next nucleus ^{28}Si has a large oblate deformation with $Q_s(2^+)$= +16$\pm$3 $e\,fm^2$ followed
by ^{30}Si with a prolate $Q_s(2^+)$= -5$\pm$6 $e\,fm^2$. This confusing zig-zag of shapes continues through to the end of the 2s-1d shell.
It was advised by Spear to carry out safe reorientation-effect measurements at distances between nuclear surfaces of at least 6.5 fm
in order to avoid nuclear interference and pursue a compelling explanation. A new pipe line for Coulomb-excitation measurements at iThemba LABS
has been developed with double-sided silicon detectors coupled to the AFRODITE array. Our first campaign of Coulomb -excitation reorientation-effect
measurements of 20Ne, ^{36,40}Ar and 32S beams onto heavy targets were successful and new results will be presented.

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Determing the shape of the Nucleus, 20Ne

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The shape of ^{20}Ne is relevant to understand the mixing between mean field and cluster states [1]. This work aims at determining the spectroscopic quadrupole moment of the first excited 2_1^+ state, $Q_s(2_1^+)$ in ^{20}Ne at safe energies. At present the current nuclear collective and mean field models overestimate the $Q_s(2_1^+)$ value in ^{20}Ne [2] by about 30%. Two of the previous RE measurements [4,5,6] regards the separation between nuclear surfaces of about 4 fm [2]. The third RE measurement was done by Schwalm et al. [5] and has a rather large uncertainty associated with the gas ^{20}Ne target that was utilized to make the measurement. In fact, the RE is enhanced for light beams onto heavy targets.
\\
\\
The measurement of the $\langle 2_1^+||E2||2_1^+\rangle$ diagonal matrix element in ^{20}Ne was carried out at iThemba LABS over the course of three days. The safe Coulomb excitation of $^{20}Ne^{3+}$ beams at 73 MeV was undertaken with a ^{194}Pt target having a thickness of 1.2 mg·cm^{-2}. The detection of γ rays was done using the AFRODITE HPGe detector array, which consisted of 8 clover detectors, of which 4 were positioned at 90° and 4 at 135° in coincidence with the ^{20}Ne particles detected with an annular S3 silicon detector at backward angles. The $Q_s(2_1^+)$ value in ^{20}Ne, has been determined using the Gosia Coulomb excitation code [7] and will be presented during the conference.
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20

Investigating the Feasibility of using the Neutron Activation Analysis (NAA) Technique to Measure Industrial Pollution in Sedi-

ment and Water in the Richards Bay Area

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The area of Richards Bay is one of the industrialized areas in South Africa, as a result it is prone to industrial pollution which negatively affect the environment. Various studies have been conducted to investigate the presence of heavy metals and other trace elements in the environment using various analysis methods. A recent study was conducted using ICP-MS and it was found that heavy metals such as Arsenic (As), Manganese (Mn) and Cadmium (Cd) were the main contaminants, with Mn being above the target water quality range (TWQR). In this study the aim is to investigate the feasibility of employing the Neutron Activation Analysis Technique to measure industrial pollution in the area of Richards Bay. The technique has been found to be sensitive to about 78 elements in the periodic table when activation is done using thermal neutrons, however the sensitivity declines with an increase in neutron energy, and thus a poor spectrum is obtained for analysis. Monte Carlo simulations of the activation process will be done using the FLUKA package in this study, with the focus being on the energies of the resulting photons, which will be used as indicators of successful activation. The trial runs that have been done using 14 MeV neutrons on FLUKA show that some elements are activated, although they yield low energy densities compared to when thermal neutrons are used. Thus the sub-objective is to optimize the activation using 14 MeV neutrons since a 14 MeV neutron generator will be used for the experiment.

Keywords:
Neutron Activation Analysis, Heavy metals, Monte Carlo simulations

3

ASSESSMENT OF NATURAL RADIOACTIVITY IN SOIL AND THE ASSOCIATED EXPOSURE RISK IN VICINITY OF THE MKUJU RIVER URANIUM PROJECT IN TANZANIA

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The need of baseline data to ensure effective environmental assessment, mitigation, radiation protection and control of related waste in a proposed large scale uranium mine in Tanzania is particularly high. In order to establish representative data for a vast area (about 1,300 km2) around the Mkuju river uranium project, a gamma ray survey was conducted using inspector 1000. Based on the dose rate measurements the study area was divided into blocks with similar dose rate. For the sake of reproducibility sampling was made in selected reference points with GPS in the blocks. Results of activity obtained using HPGe for 226Ra, 232Th and 40K activity (Bqkg-1) in soils onsite the project ranged higher from 2430 to 4200 (3263), 100.00 to 220.00 (156.80) and 1293.3 to 1466.1(1415.93), respectively compared to values recorded offsite ranging from 28.84 to 53.5 (38.13). 20.86 to 47.14(34.3) and 344.50 to 672.80 (554.68), respectively. The spatial activity distributions offsite the project were comparable to the global ranges in normal soils (UNSCEAR 2000). However soils obtained onsite the project indicated higher activities above normal ranges. The associated activity ratios for Th/Ra, K/Ra and K/Th for soils offsite the project were higher than was onsite. Implicit is that soils onsite the project is enriched with radium and thorium daughter progenies. As expected the estimated dose rate and external effective dose onsite were higher than from offsite the project. Both external and internal hazards indices estimated for all locations onsite were higher than locations offsite the

project. The internal hazards index in particular was about twice the external index. These findings suggest that movement of the radionuclides pollutants offsite the project would cause noticeable change on the recorded values at reference points. Therefore data established in the vicinity of the proposed project can be used as baseline reference for monitoring the radiological impact related to the uranium mining at MRP.

18

Lifetime measurements using a fast timing array of LaBr₃ detectors

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Characteristic decay properties of radionuclides are essential in the study of nuclear spectroscopy. Lifetime measurements and transition moments for excited nuclear levels form
part of this extensive study that seeks to unveil properties of nuclear structure. Scintillation detectors prove to be formidable in gamma ray detection and lifetime measurements. With advent of LaBr3 detectors it is now possible to have both excellent timing properties, (around 300ps) and energy resolution (approximately 3.0% at 1332keV). Recently a fast timing
array has been commissioned at iThemba LABS, Cape Town consisting of eight 2" by 2" LaBr₃(Ce) detectors. Several experiments been performed with short-lived radioactive
sources showing impressive lifetime measurements. Furthermore, the detectors were used for in-beam measurements at iThemba LABS in order measure the nuclear lifetimes of ⁴²Ca and Sc. Results will be presented of the measurements undertaken for radioactive sources.

7

Cosine Similarity Measure for Pulse-Shape Discrimination of Radiation Detectors

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Cosine Similarity Measure for Pulse-Shape Discrimination of Radiation Detectors

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In computer science, a similarity measure is a function that quantifies the similarity between two objects, represented by vectors. Various similarity measure techniques are used in different areas of science and technology among which the cosine similarity is the most widely used one due to its simplicity and effectiveness. In this work, we have employed the cosine similarity measure for pulse-shape discrimination (PSD) of radiation detectors. Our approach is based on the measurement of the similarity of sampled detectors' pulses from a synthetic pulse. The method is tested with different detectors including a BF3 proportional counter, a coplanar CZT detector, a liquid scintillator detector and a closed-end coaxial germanium detector. It is shown that very useful and highly accurate PSD

information on the background events (BF3 detector), charge-trapping effect (CZT detector), particle types (liquid scintillator detector) and multi-cite events (germanium detector) can be extracted and some novel features and unique advantages of this PSD approach such as its applicability to various types of detectors, simple operation and independence from an adjustment parameter are discussed. Our results demonstrate the suitability of the method for building general purpose digital pulse-shape discrimination modules.

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Evidence of enhanced nuclear polarizability and shell effects in the quasi-continuum

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The impact of the low-energy enhancement (LEE) of the photon strength function on nuclear polarizability in the quasi-continuum has been investigated. The enhancement of the photon strength function is observed as a dipole up-bend in the low energy tail of the photon strength function. It is found that the low-energy dipole up-bend in the photon-strength function gives rise to an enhancement of the polarizability in the quasi-continuum of nuclei with mass number A ~ 50, under the assumption that Brink-Axel hypothesis is valid. The enhancement is observed in isotopes 45-Sc, 51-V and 56-Fe evaluated in the current work. This enhancement of polarizability may be stronger for lighter nuclei, yet to be tested due to unavailability of data. For heavy nuclei the enhancement is negligible due to dominance of the collective quadrupole degree of freedom excitation. Evidence of the N=28 shell closure in the quasi-continuum is noted by the sudden drop of 51-V photo-absorption cross-section, however, this remains to be validated by photo-nuclear cross-sections calculations of close-neighbouring nuclei.

The data analysed in this work was obtained from nuclear databases EXFOR and ENDF and photo-nuclear cross sections were computed using an interpolation method.

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Lifetime measurement station at iThemba labs

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Development and implementation of digital data acquisition and associated hardware for lifetime measurement station to come online in 2018 at iThemba labs.

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RADIATION DOSES IN SELECTED AQUATIC LIFE, FISHING WATER AND COAST SOIL IN MAINLAND LOCALITY OF LAGOS STATERADIATION DOSES IN SELECTED AQUATIC LIFE, FISHING WATER AND COAST SOIL IN MAINLAND LOCALITY OF LAGOS STATE

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Fish and other aquatic life consumption is very high in densely populated Lagos Coastline of Nigeria. The essence of this study is to investigate the radionuclide concentrations in soils and waters of the Coastline and also in some selected aquatic that are commonly consumed in this Coastline. Radioactivity levels were evaluated in their natural occurrences in Water, Soil and selected Aquatic life from three different locations in Mainland locality part of Lagos State (Makoko, University of Lagos waterfront and Bariga) which is linked to the Atlantic Ocean. Canberra High Purity Germanium Gamma spectrometer was used to detect the types of radionuclides present and determine activity. The activity concentrations of Pb-214, Pb-212, Cs-134, and K-40 in the Soil samples of Makoko was found to be 7.89±0.51, 10.20±1.21, 0.69±0.10 and 67.37±2.52 Bq/kg, respectively. While, in Bariga, the activity concentration was found to be 7.89±0.51 Bq/kg for Pb-214, 15.37±1.43 Bq/kg for Pb-212, 1.02±0.12 Bq/kg for Cs-134 and 163.85±4.43 Bq/kg for K-40. From the University of Lagos water front the activity concentration of the Soil samples was found to be 8.22±0.51 Bq/kg for Pb-214, 10.54±1.1851 Bq/kg for Pb-212, 0.57±0.15 for Cs-134, and 161.78±4.38 Bq/kg for K-40. Using the atomic absorption spectrophotometer (AAS) to analyze the radionuclides in some of the selected Aquatic life (Tilapia Fish, Cat Fish and Crab) from the three locations of interest. The activity concentrations of K-40 ; Pb-214;Pb-212 Cd-113; Cr-51; Ni-59 in Tilapia fish from Makoko water body were found to be 24.630 Bq\Kg; 0.568 Bq\Kg; 0.073 Bq\Kg, BDL; 0.156 Bq\Kg;1.652 Bq\Kg , respectively. While the Makoko Catfish has activity Concentrations of K-40; Pb-214; Pb-212; Cd-113; Cr-51; Ni-59 activity were found to be 11.750 Bq\Kg; 0.201Bq\Kg; 0.035Bq\Kg; BDL; 0.129 Bq\Kg and 1.052 Bq\Kg , respectively, Activity Concentrations for Ni-59 and K-40; Pb-214; Pb-212 Cr-51 in Makoko Crab were detected to be 0.880 Bq\Kg; and 3.000 Bq\Kg;0.475Bq\Kg;0.079Bq\Kg and 0.139Bq\Kg respectively while Cs-134 Cd-113 were not detected. The activity concentration show insignificant values in the three locations based on Nigerian Basic Ionizing Radiation Regulation 2003, UNSCEAR 2008, ICRP 1983, and IAEA 2011 standards.

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Tapered plastic scintillator array

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A new neutron wall for (3He,n) studies is highly desirable. Previous work conducted with 100x100x600 rectangular bars is found to be limited in terms of position measurement and acceptance. Funds are being secured for further deployment of plastic scintillators. It is thought that a spherical geometry could potentially be superior than the current stacking of square detectors.
In this talk it is proposed to use a tapered plastic scintillator of 500mm long fitted with only one PM tube. The coating of the side of the pastic bar facing the target is reflective. The flash of light produced by an energetic neutron is therefore expected to produce two distinct components in the pulse. The prompt and strong flash from direct photons to the PM tube, a second weaker component from the reflected light on the reflective material. The pulse height of the ctwo omponents together with timing information using 500 MHz digital electronics are thought to be sufficient to recover the position along side the bar with a position resolution under 100 mm. The net advantage of this

detector geometry is a better spatial resolution (theta, phi) together with a sufficient timing resolution for neutron time of flight discrimination over a relatively short distance from target to detector. This also allows multi hit identification and increased efficiency for multiple scatters accross detector units.

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Development of a Digital Data Acquisition and Analysis System

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Nuclear science has worked with digital data acquisition systems for decades. The cost of these systems is rapidly decreasing. Software development costs are becoming the dominant factor in adopting digital systems. Graduate students and post-docs often develop scientific software. Their primary focus is data collection and analysis. This transient workforce leads to amazing scientific breakthroughs and unmanageable code bases. The flexibility of digital systems creates a situation where software used in one experiment may be antiquated in just a few months.

The experimental nuclear structure group at the University of Tennessee (UTK-LENS), through collaboration with ORNL, has a long history of data acquisition and analysis software development. The Digital Gamma Finder (DGF) electronics produced by XIA, LLC provide a stable hardware base. XIA worked intimately with the UTK-LENS development team to ensure that changes in the electronics worked in tandem with the scientific software. This collaboration produced software that can handle a variety of experimental campaigns with little modification.

The author will present algorithms and software features of interest for for digital systems. In particular, we will discuss details of timing algorithms capable of achieving time resolutions on the order of 700 ps for a digital system with 250 MS/s (see Ref 1).

References

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The African LaBr Array - ALBA

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A project to increase the γ-ray detection efficiency of the iThemba LABS setup was recently funded by the South African National Research Foundation (NRF). This project will result in the acquisition and installation of the γ-ray detector array ALBA (African LaBr Array), composed of 23 large volume LaBr3:Ce. This array could be used as a stand-alone gamma-ray spectrometer as well as coupled to the K600 spectrometer or to silicon-detector arrays for the particle identification.

This unique experimental setup would allow for new generation of studies where the γ-decay probability has been too low to be investigated with the arrays currently available worldwide. The study of the giant and pygmy resonances as well as the investigation of the nuclear level density and gamma strength function are of particular interest.

The first five detectors of ALBA arrived in December 2018 and they are now being characterised in term of energy/time resolution and efficiency. The project and the preliminary results will be presented.

2

The NUSTAR (and DESPEC) experimental programme(s) at GSI/FAIR

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NuSTAR (Nuclear Structure, Astrophysics and Reactions) is an "umbrella" collaboration focussing on experiments using radioactive beams at the GSI/ FAIR facility. NuSTAR will provide data on nuclear many-body systems under extreme conditions. The common aim is to exploit the beams of short-lived radioactive species to study how the properties of nuclei and nuclear matter vary over a wide range of isospin, angular momentum, temperature and density. NuSTAR comprises several different collaborations based around state-of-the art detector systems. The first experiments, involving the DESPEC, R3B, ILIMA, SuperFRS sub-collaborations will be performed in 2018.

The Decay Spectroscopy (DESPEC) collaboration will focus on the study of isomeric internal-decay and charged-particle decays of the very short-lived radioactive species. These experiments can provide information on exotic nuclei produced with extremely low yields. The nuclei of interest will be implanted in the AIDA implantation and decay detector. Their decay will be studied with a range of gamma-ray, charged particle and neutron detectors. For example, the FATIMA fast-timing array based on LaBr3(Ce) detectors will provide lifetime information for excited states, following both internal and beta decays.

The presentation will introduce the NUSTAR experimental programme, focussing on the DESPEC sub-project. DESPEC, with its flexible modular geometry, presents a good opportunity for collaboration with the South African nuclear physics community.

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Investigation of γ-γ coincidence counting using the National Nuclear Array (NANA) as a Primary Standard.

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The UK National Physical Laboratory has commissioned a multi-detector γ-ray array - the National Nuclear Array (NANA). In this study we have sought to exploit the NANA and the excellent timing characteristics of its intrinsic LaBr3(Ce) scintillation detectors for use as a primary standardisation system. For
this initial investigation, the absolute standardisation of 60Co has been performed by the γ-γ coincidence technique using NANA and the result compared to the established 4π(LS)-γ Digital Coincidence Counting (DCC) system. The effect of the angular correlation of the stretched E2 transitions emitted from the 4+ ⟶ 2+ ⟶ 0 states of 60Ni on the activity determined by NANA was observed between the pairs of detectors. Corrections for these angular correlations were derived through Monte Carlo simulations. An activity per unit mass by NANA of 330.8(10) kBq.g−1 for the 60Co solution was determined. There was no significant statistical difference between the results of NANA and the 4π(LS)-γ DCC, with a relative difference of 0.04% observed. This study shows that NANA can be used as a primary standard.

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Digital fast timing with large LaBr_3 scintillator detector arrays

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Electronic gamma-gamma timing using fast LaBr_3 scintillator detectors is
a well established method for measuring half lives of excited states
of atomic nuclei
for many years. Progress in digitiser design achieved in recent years makes
it now possible to use such detector systems with fully digital data
acquisition systems with digital constant fraction discrimination.
This talk deals with the basics of fast timing
with large arrays of fast scintillator detectors using digitisers.
Recent experiments performed at the IPN Orsay using “faster”-digitisers

developed at LPC Caen, as well as plans for possible future measuring campaigns will be discussed.

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Angular correlation measurements with the iThemba LABS segmented clover detector

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iThemba LABS has purchased a segmented clover detector, a detector that uses the latest achievements in the Ge detectors technology. Contrary to the standard Ge detectors the new detector is segmented on the outer contact, resulting in 8 segments per crystals, or 32 segments for the whole detector. The segments can be run as individual detectors, allowing considerably higher event rates to be handled successfully. In addition, utilising segments allows improved accuracy for all direction-sensitive measurements, such as Doppler correction, angular distributions and correlations, g-factor measurements based on recoil in vacuum technique, linear polarization, lifetime measurements based on Doppler effects, etc. The impact of this improvements increases dramatically with the increase of the opening angle of the detector, i.e. at small detector-to-target distances.

In close geometry the face of the detector covers a large opening angle, for instance at 4 cm from the radioactive target the detector subtends a solid angle of approximately 1/8 of 4π. Therefore, it covers the whole range of angles needed for precise angular correlation measurements. Such full coverage in addition to the excellent position sensitivity of the detector (due to its segmentation and its tracking ability) allows very precise spin and parity measurements to be carried out. It should be noted that measurements with such precision cannot be performed at present with the current much larger AFRODITE array. In particular, one would be able to measure (i) high-order multipolarities such as E3, M4, E4, M5, E5, etc, (ii) mixing ratios of M1+E2, M2+E3, etc, (iii) distinguish unstretched dipole from a stretched quadrupole transition, etc. Furthermore, due to the segmentation and the tracking capability, the detector will produce more precise linear polarization results too.

We collected data with several gamma-ray sources to evaluate the performance of the detector in close geometry for angular correlations measurements. A few targets were also irradiated with neutrons in the neutron therapy vault to test the activity that can be produced and the performance of the detector. The data are being analysed, but preliminary results look very promising. The results will be presented and discussed.

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The AGATA Spectrometer

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The Advanced GAmma Tracking Array (AGATA) is a European project to develop and operate the next generation gamma-ray spectrometer. AGATA is based on the technique of gamma-ray energy tracking in electrically segmented high-purity germanium crystals. The spectrometer will have an unparalleled level of detection power for electromagnetic nuclear radiation. The tracking technique requires the accurate determination of the energy, time and position of every interaction as a gamma ray deposits its energy within the detector volume. Reconstruction of the full interaction path results in a detector with very high efficiency and excellent spectral response. The realisation of gamma-ray tracking and AGATA is a result of many technical advances and the spectrometer is now operational. AGATA has been operated in a series of scientific campaigns at Legnaro National Laboratory in Italy, GSI in Germany and is currently operating at GANIL in France. The status of the project will be reviewed.

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Studies of octupole correlations in heavy nuclei and prospects for experiments at iThemba

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Nuclei in the light-actinide region, close to $Z = 90$ and $N = 134$ are known to possess large reflection-asymmetric octupole deformations due to the presence of octupole-driving orbitals with $\Delta\ell = \Delta j = 3$, specifically the $f_{7/2} \otimes i_{13/2}$ orbitals for protons and $g_{9/2} \otimes j_{15/2}$ orbitals for neutrons. The characteristic features of octupole deformation have been observed in around 20 nuclei 1 in this region using γ-ray spectroscopy techniques. Recently, the subject of octupole correlations was reinvigorated by the measurement of the electric octupole moment of ^{224}Ra using radioactive-beams at ISOLDE [2]. Renewed theoretical interest has ensued such as a recent systematic study of ground-state octupole deformations using covariant density-functional theory [3]. Despite the reasonably large amount of experimental data and the interest in these nuclei, some questions remain. For example, the location of the upper-N boundary of the octupole region is not well established. Also, there is very little information beyond the ground-state bands for any of the nuclei in this region.

Gamma-ray spectroscopy studies of actinide nuclei are challenging due to low cross sections, overwhelming competition from fission, low gamma-ray transition energies, and large internal-conversion coefficients. In order to extract information from experiments, experimental techniques must be developed that can circumvent these issues. To this end, we are carrying out a programme of experiments using a number of different techniques including recoil detection for fission suppression using HERCULES with Gammasphere at Argonne National Laboratory, recoil-decay tagging using Jurogam, RITU and GREAT at Jyvaskyla, gamma-electron coincidence spectroscopy using Sage at Jyvaskyla, and fission suppression by detection of evaporated particles using Galileo and Euclides at Legnaro National Laboratory. Results from this programme of work will be presented, and prospects for future experiments at iThemba will be put forward.

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Comparison of Digital Pulse Processors and Analogue Nuclear Spectrometry System: Applications in Environmental Measurements, Nuclear Safety and Security Systems in CARST

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Almost all nuclear faci lities and institutions includ ing Centre for Applied Radiation Science and Technology (CARST) utilize rad iation detectors as part of their operations, be it for research, monitoring or analytical purposes. Every rad iation detector have compati ble nuclear electronics build to characteri zed and achieve best possible system performance. In many cases, improvements in the system performance are made possible by significant advances in digital electronics enabling new and enhanced methods to acquire and process signals from radiation detectors. This is because the digital pulse processors (OPP) is rapid ly replacing the analog pulse processing systems (APPS) in many nuclear spectrometry systems. The d igital electronics and digital pulse processing methods have shown that the rad iation spectrometry systems is capable of accepting higher throughputs when compared with analog electronics. This has opened up new oppmtunities in high resol ution spectrometry at high count rates, an area of great interest to researchers in CARST who have been in collaboration with iThemba LABS and the South African Nuclear Energy Corporation SOC Limited (Necsa) using high intensity neutron beam and X ray beam faci lities. This presentation reviews the status, developments, and approaches in digital pulse processing in nuclear spectrometry, providing useful information and the need for CARST to collaborate with nuclear physicists to develop the d igital data acquisition and pulse shape analysis techniques.

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Evaluation of Radiation Dose of Soil from Ijero Ekiti, Nigeria

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The activity concentration of the natural occurring radionuclides (238U, 232Th and 40K) in the soils of mining and living areas of Ijero Ekiti were determined using hyper pure germanium gamma ray spectrometer. The mean concentrations of 238U, 232Th and 40K was found to be 128.05 Bqkg-1, 24.8 Bqkg-1 and 455.05 Bqkg-1 respectively for mining areas, while for it was found to be 42.02 Bqkg-1, 43.27 Bqkg-1 and 635.41 Bqkg-1 respectively for the living areas. The mean absorbed dose rate, annual effective dose equivalent, gamma index and the excess lifetime cancer risk evaluated for the locations were 89.70 nGyh-1, 0.11 mSvy-1 and 1.4 for mining areas, and 72.22 nGyh-1, 0.089 mSvy-1 and 1.14 for living areas respectively. The mean excess lifetime cancer risk estimated for the mining areas and living areas were higher than the recommended limit of 0.29×10-3 for background radiation. All the mean radiological parameters estimated for both locations were higher than the

recommended permissible limit of natural background radiation. It is therefore necessary for government to barn illegal mining activities going on in the town so as to reduce natural radiation burden from the mining in the town.

4

Primary and secondary radioactivity capabilities at NMISA

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The Radioactivity Standards (RS) section of the National Metrology Institute of South Africa (NMISA) maintains the measurement standard for radioactivity in South Africa. Radioactivity standards are established through absolute activity measurements (also known as primary standardizations) of various radionuclides. Radioactivity standards and calibrations are mainly disseminated to the South African industry through secondary services.

Primary measurements via coincidence counting are made with a NaI detector and three phototubes connected to NIM electronics. Support for NIM electronics is decreasing, prompting an investigation into more modern technology such as digital coincidence counting. As such, a PIXIE 4e digital counting system has been procured and testing and verification is underway. Switching to digital coincidence counting also allows data acquisition in list mode, allowing data sharing between institutes for independent analyses.

Primary standardizations are maintained through the calibration of secondary standard instrumentation. This traceability chain of activity measurements is disseminated to the user community via three instruments; an ionization chamber (IC), a high-purity germanium detector (HPGe) and a commercial liquid scintillation counter.

The IC is most commonly used to measure the activity of nuclear medicine in various geometries.

Where environmental radioactivity and radioactivity in consumer products are a concern, NMISA can carry out low level gamma-ray spectroscopy measurements on the samples and products, using a HPGe detector and Genie 2000 software, to ensure that they are safe and below the legally acceptable radioactivity limits. Samples are most commonly analysed for the following radionuclides: Cs-134, Cs-137 (in milk, water, black mussels/ fish, green leafy vegetables, grass, soil, sediment and sewage) and I-131 in milk.

A commercial liquid scintillation counter is available for detecting small amounts of beta radioactivity. This computer-controlled benchtop analyser is used to measure primarily pure beta-emitters such as H-3 (tritium) in fresh surface water, C-14 and Sr-90 in milk.